R Notebook midterm: 419 Survey of Multivariate Methods

Contents

Top of the world

https://brand.wsu.edu/visual/colors/

TESTING PROCEDURE

This midterm exam (Rnotebook-midterm) is worth 150 points. For each question, review how much the item is worth in terms of points and plan your time wisely.

I would deem it "unwise" to spend hours on a question that is only worth 5 points.

Static/Existing Resources Are Allowed

This is an open-book examination. You can use your course notebooks (digital and old-school). You can use Internet resources (stackoverflow, Wikipedia, and Youtube).

Dynamic/Living Resources Are __ NOT__ Allowed

You cannot use a living resource on the exam. That would include a classmate, student, sibling, parent, a tutor, online forums (where you ask the question after the exam period has begun).

If you have questions that need clarifying, please **email the instructor** and he will try to answer them by email or ZOOM. He will be checking his email often during the week of the exam, to make himself available to you.

Levels of Mastery

- Do You **Remember**?
- Do You **Understand**?
- Can You **Apply** what you remember/understand to another similar problem?
- Can You **Analyze** and **Synthesize** Data?
- Can You **Evaluate** your analyses?
- Can You **Create** meaningful visualizations and summaries?

Rubric of Mastery

For every 10 points, this is the general breakdown.

Emerging	Developing	Mastering
0-4	5-7	8 - 10

EXPLORATORY DATA ANALYSIS (EDA)

Exploratory data analysis (EDA) is the process of analyzing data to summarize its main characteristics.

Confirmatory data analysis (CDA) is the process of applying specific statistical methods to analyze the data. The goal is also to summarize its main characteristics. We commonly refer to CDA as "statistical hypothesis testing". CDA generally makes assumptions about how the data is distributed. Or wants to apply a specific model to the data.

So the two approaches have the same objective: summarize the main characteristics of the data. How they achieve that objective is very different.

Introduction

John Tukey

John Tukey is the father of "Exploratory Data Analysis" (EDA) https://en.wikipedia.org/wiki/John_Tukey. My favorite statistics book is his 1977 book (not surprising) entitled "Exploratory Data Analysis."

Exploratory vs Confirmatory

From Wikipedia (Accessed October 2020): Tukey "also contributed to statistical practice and articulated the important distinction between exploratory data analysis and confirmatory data analysis, **believing that much statistical methodology placed too great an emphasis on the latter**."

I belong to the "Tukey" camp. I believe too much emphasis is place on "formal statistical methods and tests". I believe more emphasis should be placed on the underlying nature of the data. These underlying principles are how the statistical methods developed.

As a data analyst, I believe that first and foremost, we should let the data speak. That is why the first half of the semester started in this form. The second half (confirmatory data analysis) will rely on what is labeled by many as "formal statistical methods".

Tukey and "Bell Labs"

In 1965, Tukey divided his time between working at Princeton University and working at Bell Labs (a research think tank).

Robust Statistics as Nonparametric Tukey proposed that five summary data are essential to understanding numerical data: `min`, `max`, `median` (technically `Q2`), and `Q1` and `Q3` (the quartiles). In `R`, the function `summary` has only added `mean` to Tukey's proposal from years ago.

Box and Whisker Plot In 1975, Tukey invented the "box and whisker" plot that identifies the median, inter-quartile range (IQR), and outliers of data. The visualization displays the data without making any assumptions about its statistical distribution. The boxplot is a working demonstration of EDA. **Let the data speak!**

John Chambers and `S` and `R`

At the same time ast John Tukey, three other men were also working at Bell Labs (John Chambers, Rick Becker, and Allan Wilks) on a statistical programming language `S` that emphasized EDA. This "statistical computing" language was programming mostly in `Fortran` with some `C` programming. Chambers published his first "statistical computing" text in 1977, titled "Computational methods for data analysis" https://archive.org/details/computationalmet0000cham/page/n11/mode/2up

Between 1988 and 1991, Chambers updated the engine of `S` to make it more robust. That same engine still powers much of `R` today. That is, much of the base code of `S` was written by Chambers himself. `R` today still uses much of that `S` codebase under the hood.

`R` was an open-source offshoot (a "fork") of `S` which occurred in the mid 1990s. Today, Chambers is still active in the `S`-now`R` community. My favorite book of his is titled (2008): "Software for data analysis programming with R". My second-favorite book of his is titled (1998): "Programming with data: a guide to the S language". In 2016, he authored another book that I still need to read "Extending R."

Modern `R` is written in `Fortran`, `C`, and `C++`.

Since its foundation is primarily `C`, we can use standard "make" and "make-install" tools to compile R or its packages from the source code. That is why we needed `Rtools` on Windows. The MacOS is now linux based, so no additional tools are required.

Summary

EDA as exploration is an iterative process.

Analogy: learning a foreign language

I like to use the analogy of learning a foreign language using the "immersion" approach. For example, I studied Spanish in high school, learned vocabulary and grammar, and really could not speak the language well.

I did learn to speak the language well by being dropped into a foreign country for nearly two years. Some key ingredients to learn a language in an "immersive" environment are listed below:

- surround yourself with others speaking the language to be learned [e.g., I did not spend a lot of time with other Americans speaking English].
- be present when engaged in the language. Listen intently and try to understand as much as you can, not worrying about what you don't fully understand.
- reflect after language engagement. Try to synthesize what "gaps" you have and then develop study habits to fill in those gaps.
- practice what you have learned.

To some degree, my success was likely accelerated because I had precursory training. Regardless, "immersive" practices benefit learning new languages.

Proficiency in Data Analytics

[As part of your journey, I have asked you to keep a "paper-and-pencil" notebook to write down words/phrases/ideas. For example, in this section, there may be words/terms/phrases/ideas you don't fully understand.]

Proficiency requires an iteration of these key features described above. But first, you have to understand what language you are trying to speak. Is it `R`? Is it Statistics? Mathematics? What exactly is the language?

In my opinion, the language is the "language of data".

The "language of data"

How do you think mathematics developed? It likely started with simple data, based on real-world experience: two hands, five fingers on each hand gives me the number ten. Counting in a base-10 system likely resulted. An entire domain of mathematics called "number theory" devotes its studies to these integer values.

How do you think statistics developed? People went out and started measuring things. One person would literally walk down the street in the late 1800s and ask if he could measure a person's proportions. Another person would study crop yields at different locations and tried to ascertain if they were different.

The foundation of mathematics and statistics is data. So I believe, we should let the data speak.

Let the data speak

So I am definitely an EDA-guy. Some people are, some people are not. I personally am a strong believer that we should **let the data speak**, learn how to describe the data without imposing any restrictions on it, and always think about the data first and foremost.

I also believe that we should use logic, intuition, and insight before we develop any formal "confirmatory" hypothesis testing. I have intentionally architected this course to emphasis EDA.

Quality data provenance

I am also very ademant about **data provenance** as I believe the "outputs" of any analysis (whether exploratory or confirmatory) is as only as good as the data quality. I call this `data intimacy`. You should care just as much about the process to get quality data as you do to analyze said data.

The term **GIGO** (garbage-in, garbage-out) in my estimation represents what happens when care for quality data is treated lightly.

Iterative Exploration

This full EDA approach is a multi-lens approach. View the data from as many different perspectives as possible before arriving at a conclusion. Base your conclusion on a synthesis of what you analyzed from those different perspectives.

- We do initial EDA (using mathematical foundations),
- then we may do confirmatory analyses (traditional statistical methods), and
- then we synthesize our findings and do a higher-ordered EDA using the original analysis and the confirmatory analysis to make final decisions using sound logic and intuition.
- this process will enlighten our understand and possibly help us formulate new suppositions and think about what additional data would inform the topic.

(10 points) YOUR "EDA" OPINION

[I have expressed my opinion about the study of data and the importance of EDA in that study. What is your opinion on this topic?

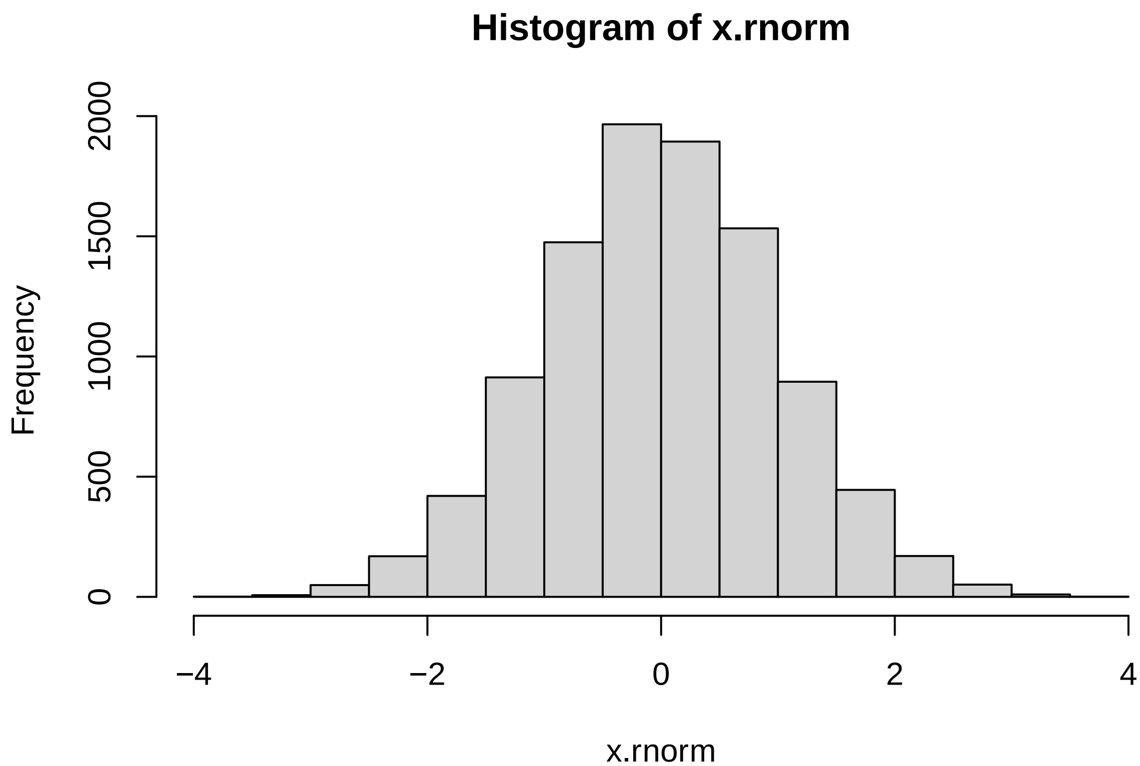
This is worth 10 points, a minimal answer should be at least 3 paragraphs. Agreeing/Disagreeing with my opinion is not how you will be evaluated. How well you express YOUR opinion is what is important.]

SIMULATING DATA

(10 points) Basic Simulation

- Pick a `set.seed` choice so the code is replicable. Verify that every time you run the commands, the data is not changing with the seed "you chose".
- Use the functions `rnorm`, `runif` to simulate data.
- Simulate `n=9999;` data for each.
- Call `x.rnorm` the data for the first and `x.runif` the data for the second.
- Plot a histogram `graphics::hist` and report the summary statistics '`base::summary` of each.
- Then, plot them using `plot(x.rnorm, x.runif);`.
- Finally, `plot(x.rnorm, sample(x.rnorm) );` and compare it to `plot(x.runif, sample(x.runif) );`.

```
#setting seed and simulate data for rnorm and runif where n=9999
set.seed(321)
x.rnorm <- rnorm(n=9999)
set.seed(321)
x.runif <- runif(n=9999)
# hist and summary for x.rnorm
hist(x.rnorm)
```

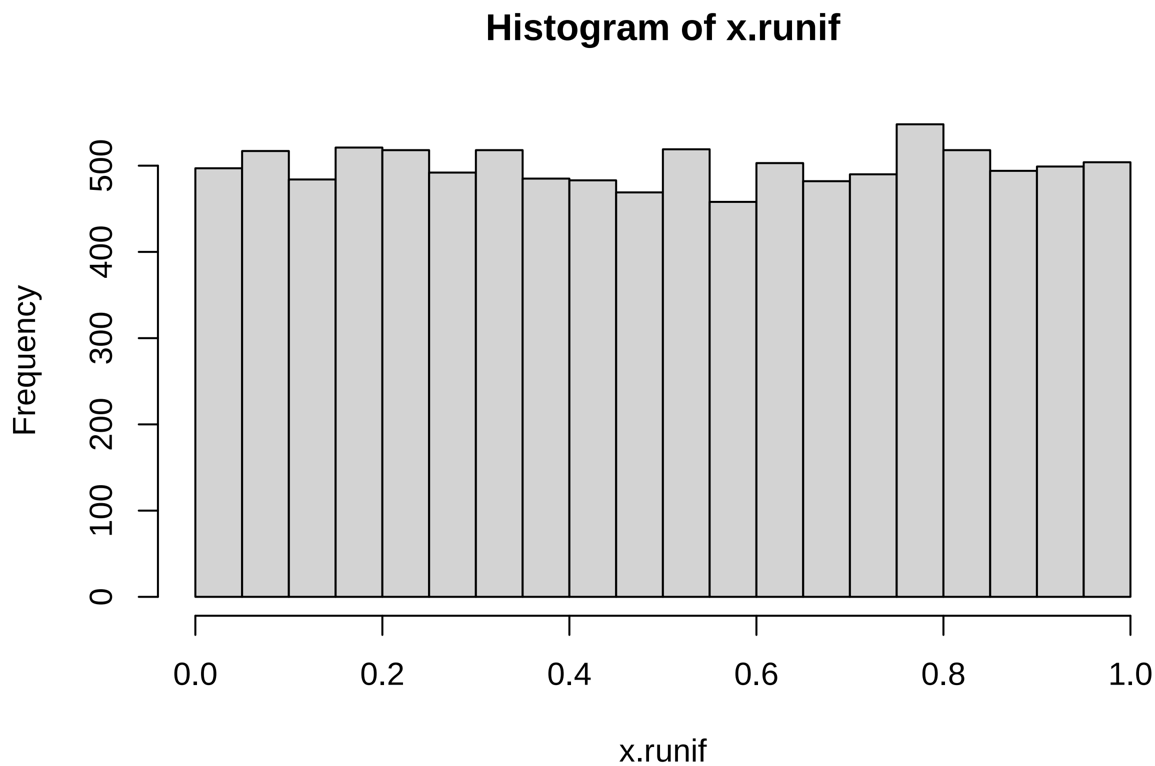


Code of simulation

```
summary(x.rnorm)
```

```
##      Min.   1st Qu.    Median      Mean   3rd Qu.      Max.
## -3.605372 -0.663107 -0.000793  0.003992  0.683656  3.574360
```

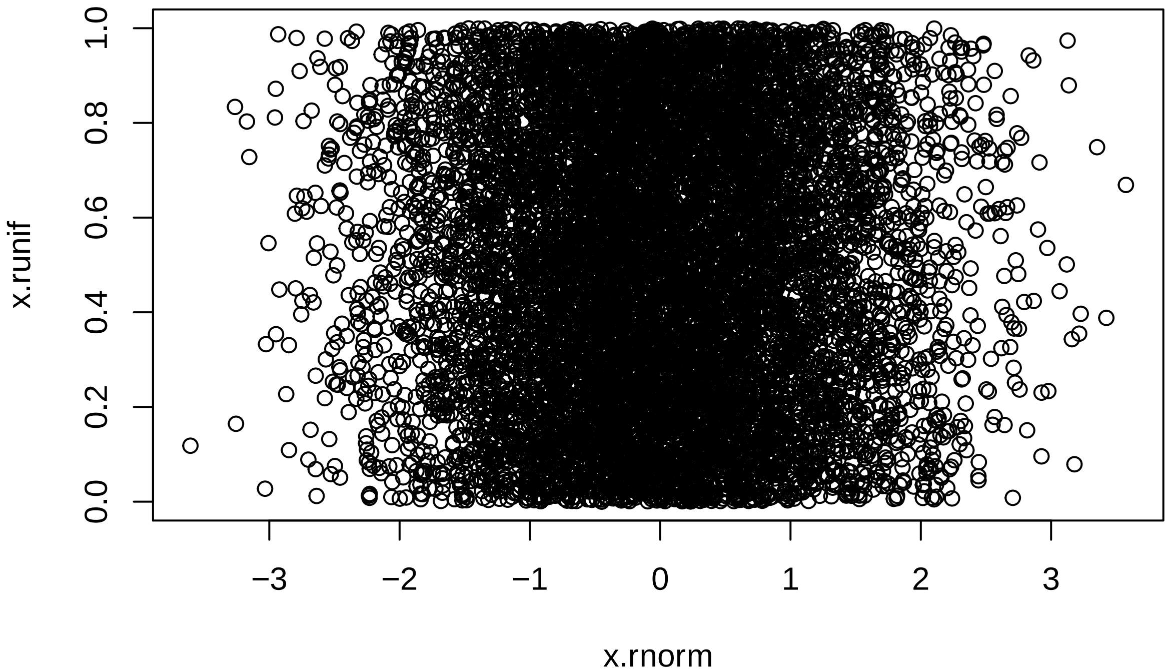
```
# hist and summary for x.runif
hist(x.runif)
```



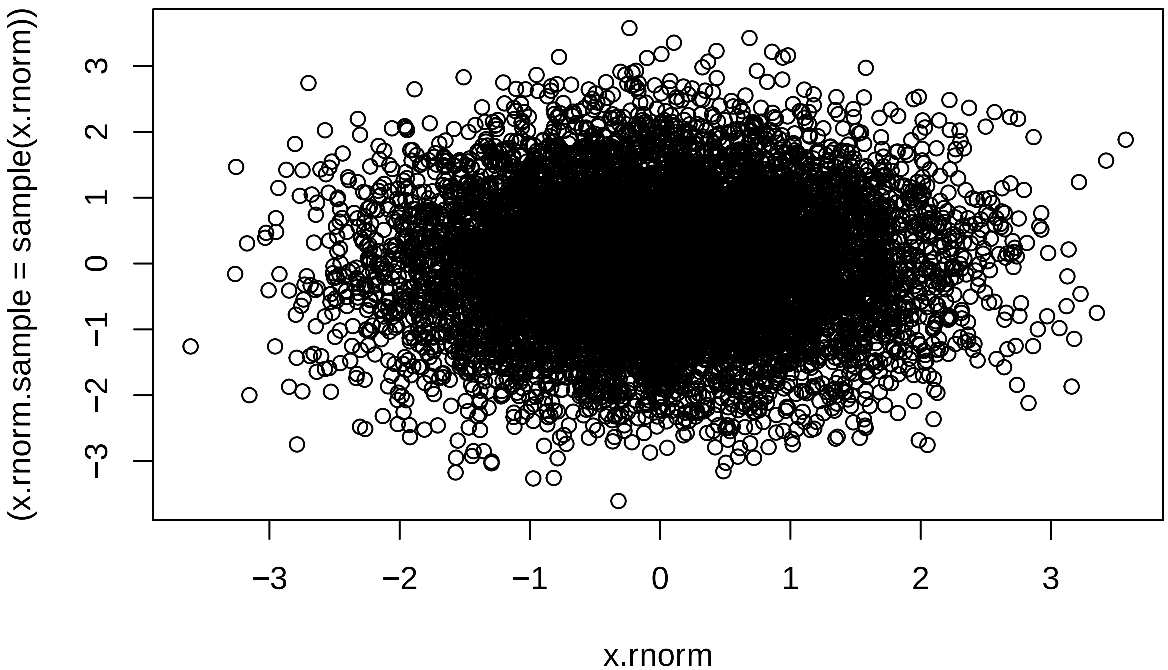

```r
summary(x.runif)
```

```
##      Min.   1st Qu.    Median      Mean   3rd Qu.      Max.
## 0.0001233 0.2458256 0.5017109 0.4999222 0.7549359 0.9996324
```

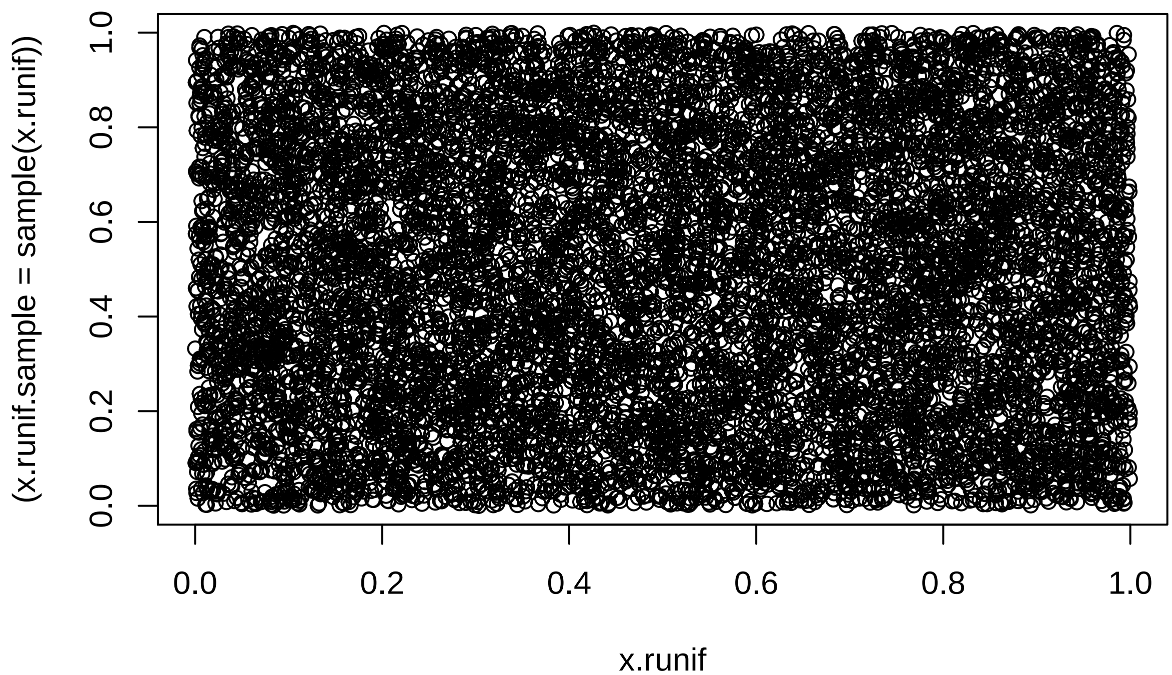
```r
#plot1
plot(x.rnorm, x.runif)
```




```
#plot2
plot(x.rnorm, ( x.rnorm.sample = sample(x.rnorm) ) )
```




```
plot(x.runif, ( x.runif.sample = sample(x.runif) ) )
```




```r
summary(x.rnorm.sample)
```

```
##       Min.   1st Qu.    Median      Mean   3rd Qu.      Max.
## -3.605372 -0.663107 -0.000793  0.003992  0.683656  3.574360
```

```r
summary(x.runif.sample)
```

```
##      Min.   1st Qu.    Median      Mean   3rd Qu.      Max.
## 0.0001233 0.2458256 0.5017109 0.4999222 0.7549359 0.9996324
```

Describe `rnorm`, `runif`

- Describe what each function `rnorm` and `runif` does. How are they similar? How are they different?
- What does the `sample` function do?
- How was `plot(x.rnorm, x.runif);` different from `plot(x.rnorm, ( x.rnorm.sample = sample(x.rnorm) ) );` and `plot(x.runif, ( x.runif.sample = sample(x.runif) ) );`? How would you describe the shape of each of these plots?

(5 points) "Easter-Egg" Simulation

- There was an "Easter Egg" that related to setting the seed `set.seed` using `rbinom`. If you search in the BlackBoard discussion forum for `easter` you will see the discussion about August 25-27.

- In the “Easter Egg”, the goal was to find a scenario using a specific `set.seed` that would simulate flipping a coin 100 times and getting one result (heads/tails) exactly 52 times.
- In this problem, the search criteria has changed. Simulate flipping a coin 1000 times and getting one result (heads/tails) exactly 555 times.
- You need to report 5 values for `set.seed` that achieves this objective. You can report more.

- You should explicitly have the code print `length(x)` where `x` is a vector of the values that meet the objective.

```
# Set answer and num in random number to start the while loop.
answer = 0
num = 0
ns=0
num <- sample(1:500000)
for(i in num){
  set.seed(i)
  answer <- rbinom(1,1000,0.5)
  if (answer == 555) {
    ns = 1+ns
    cat("a seed that allows 555/1000 heads is:", i, "\n")
  }
  else if (ns>= 5) {
    break
  }
}
```

```
## a seed that allows 555/1000 heads is: 121830
## a seed that allows 555/1000 heads is: 303566
## a seed that allows 555/1000 heads is: 113838
## a seed that allows 555/1000 heads is: 400407
## a seed that allows 555/1000 heads is: 317968
```

Rolling the Dice

- You have 3 dice.
- Each dice has the numbers `1:10` … they are ten-sided die (“decader” die).
- Write the necessary `for-loops` to capture all possible outcomes of rolling the three dice at the same time.
- A dataframe `myrolls` should have three columns: `dice.1`, `dice.2`, `dice.3` plus a fourth column `roll.total` which is the sum `dice.1 + dice.2 + dice.3` of one iteration of the nested `for loop`.
- Report the dimensions `dim` of `myrolls`.
- Create a table `outcomes.table` that summarizes the counts of the `myrolls$roll.total`
- Transform the table to a dataframe `outcomes.df`. Name the columns: c(“roll.total”, “count”);
- Report the sum of `outcome.df$count`
- Create a new column `outcomes.df$prob` (Probability) that determines the probability of that row given the total sum of the `count` column.
- Display the dataframe.

```
## your code goes here ...
```

```r
dice.1 = dice.2 = dice.3 = 1:10;

myrolls = NULL;
for(d1 in dice.1)
  {
  for(d2 in dice.2)
    {
    for(d3 in dice.3)
      {
      roll.total = d1 + d2 + d3;
      row = c(d1, d2, d3, roll.total);
      myrolls = rbind(myrolls, row);
      }
    }
  }

myrolls = as.data.frame(myrolls);
colnames(myrolls) = c("dice.1", "dice.2", "dice.3", "roll.total");

myrolls;
```

Setting Up the Dice Scenario

```
##          dice.1 dice.2 dice.3 roll.total
## row           1      1      1          3
## row.1         1      1      2          4
## row.2         1      1      3          5
## row.3         1      1      4          6
## row.4         1      1      5          7
## row.5         1      1      6          8
## row.6         1      1      7          9
## row.7         1      1      8         10
## row.8         1      1      9         11
## row.9         1      1     10         12
## row.10        1      2      1          4
## row.11        1      2      2          5
## row.12        1      2      3          6
## row.13        1      2      4          7
## row.14        1      2      5          8
## row.15        1      2      6          9
## row.16        1      2      7         10
## row.17        1      2      8         11
## row.18        1      2      9         12
## row.19        1      2     10         13
## row.20        1      3      1          5
## row.21        1      3      2          6
## row.22        1      3      3          7
## row.23        1      3      4          8
## row.24        1      3      5          9
## row.25        1      3      6         10
## row.26        1      3      7         11
## row.27        1      3      8         12
## row.28        1      3      9         13
```

```
## row.29        1       3      10           14
## row.30        1       4       1            6
## row.31        1       4       2            7
## row.32        1       4       3            8
## row.33        1       4       4            9
## row.34        1       4       5           10
## row.35        1       4       6           11
## row.36        1       4       7           12
## row.37        1       4       8           13
## row.38        1       4       9           14
## row.39        1       4      10           15
## row.40        1       5       1            7
## row.41        1       5       2            8
## row.42        1       5       3            9
## row.43        1       5       4           10
## row.44        1       5       5           11
## row.45        1       5       6           12
## row.46        1       5       7           13
## row.47        1       5       8           14
## row.48        1       5       9           15
## row.49        1       5      10           16
## row.50        1       6       1            8
## row.51        1       6       2            9
## row.52        1       6       3           10
## row.53        1       6       4           11
## row.54        1       6       5           12
## row.55        1       6       6           13
## row.56        1       6       7           14
## row.57        1       6       8           15
## row.58        1       6       9           16
## row.59        1       6      10           17
## row.60        1       7       1            9
## row.61        1       7       2           10
## row.62        1       7       3           11
## row.63        1       7       4           12
## row.64        1       7       5           13
## row.65        1       7       6           14
## row.66        1       7       7           15
## row.67        1       7       8           16
## row.68        1       7       9           17
## row.69        1       7      10           18
## row.70        1       8       1           10
## row.71        1       8       2           11
## row.72        1       8       3           12
## row.73        1       8       4           13
## row.74        1       8       5           14
## row.75        1       8       6           15
## row.76        1       8       7           16
## row.77        1       8       8           17
## row.78        1       8       9           18
## row.79        1       8      10           19
## row.80        1       9       1           11
## row.81        1       9       2           12
## row.82        1       9       3           13
```

```
## row.83        1     9     4        14
## row.84        1     9     5        15
## row.85        1     9     6        16
## row.86        1     9     7        17
## row.87        1     9     8        18
## row.88        1     9     9        19
## row.89        1     9    10        20
## row.90        1    10     1        12
## row.91        1    10     2        13
## row.92        1    10     3        14
## row.93        1    10     4        15
## row.94        1    10     5        16
## row.95        1    10     6        17
## row.96        1    10     7        18
## row.97        1    10     8        19
## row.98        1    10     9        20
## row.99        1    10    10        21
## row.100       2     1     1         4
## row.101       2     1     2         5
## row.102       2     1     3         6
## row.103       2     1     4         7
## row.104       2     1     5         8
## row.105       2     1     6         9
## row.106       2     1     7        10
## row.107       2     1     8        11
## row.108       2     1     9        12
## row.109       2     1    10        13
## row.110       2     2     1         5
## row.111       2     2     2         6
## row.112       2     2     3         7
## row.113       2     2     4         8
## row.114       2     2     5         9
## row.115       2     2     6        10
## row.116       2     2     7        11
## row.117       2     2     8        12
## row.118       2     2     9        13
## row.119       2     2    10        14
## row.120       2     3     1         6
## row.121       2     3     2         7
## row.122       2     3     3         8
## row.123       2     3     4         9
## row.124       2     3     5        10
## row.125       2     3     6        11
## row.126       2     3     7        12
## row.127       2     3     8        13
## row.128       2     3     9        14
## row.129       2     3    10        15
## row.130       2     4     1         7
## row.131       2     4     2         8
## row.132       2     4     3         9
## row.133       2     4     4        10
## row.134       2     4     5        11
## row.135       2     4     6        12
## row.136       2     4     7        13
```

```
## row.137       2      4      8          14
## row.138       2      4      9          15
## row.139       2      4     10          16
## row.140       2      5      1           8
## row.141       2      5      2           9
## row.142       2      5      3          10
## row.143       2      5      4          11
## row.144       2      5      5          12
## row.145       2      5      6          13
## row.146       2      5      7          14
## row.147       2      5      8          15
## row.148       2      5      9          16
## row.149       2      5     10          17
## row.150       2      6      1           9
## row.151       2      6      2          10
## row.152       2      6      3          11
## row.153       2      6      4          12
## row.154       2      6      5          13
## row.155       2      6      6          14
## row.156       2      6      7          15
## row.157       2      6      8          16
## row.158       2      6      9          17
## row.159       2      6     10          18
## row.160       2      7      1          10
## row.161       2      7      2          11
## row.162       2      7      3          12
## row.163       2      7      4          13
## row.164       2      7      5          14
## row.165       2      7      6          15
## row.166       2      7      7          16
## row.167       2      7      8          17
## row.168       2      7      9          18
## row.169       2      7     10          19
## row.170       2      8      1          11
## row.171       2      8      2          12
## row.172       2      8      3          13
## row.173       2      8      4          14
## row.174       2      8      5          15
## row.175       2      8      6          16
## row.176       2      8      7          17
## row.177       2      8      8          18
## row.178       2      8      9          19
## row.179       2      8     10          20
## row.180       2      9      1          12
## row.181       2      9      2          13
## row.182       2      9      3          14
## row.183       2      9      4          15
## row.184       2      9      5          16
## row.185       2      9      6          17
## row.186       2      9      7          18
## row.187       2      9      8          19
## row.188       2      9      9          20
## row.189       2      9     10          21
## row.190       2     10      1          13
```

```
## row.191      2     10      2          14
## row.192      2     10      3          15
## row.193      2     10      4          16
## row.194      2     10      5          17
## row.195      2     10      6          18
## row.196      2     10      7          19
## row.197      2     10      8          20
## row.198      2     10      9          21
## row.199      2     10     10          22
## row.200      3      1      1           5
## row.201      3      1      2           6
## row.202      3      1      3           7
## row.203      3      1      4           8
## row.204      3      1      5           9
## row.205      3      1      6          10
## row.206      3      1      7          11
## row.207      3      1      8          12
## row.208      3      1      9          13
## row.209      3      1     10          14
## row.210      3      2      1           6
## row.211      3      2      2           7
## row.212      3      2      3           8
## row.213      3      2      4           9
## row.214      3      2      5          10
## row.215      3      2      6          11
## row.216      3      2      7          12
## row.217      3      2      8          13
## row.218      3      2      9          14
## row.219      3      2     10          15
## row.220      3      3      1           7
## row.221      3      3      2           8
## row.222      3      3      3           9
## row.223      3      3      4          10
## row.224      3      3      5          11
## row.225      3      3      6          12
## row.226      3      3      7          13
## row.227      3      3      8          14
## row.228      3      3      9          15
## row.229      3      3     10          16
## row.230      3      4      1           8
## row.231      3      4      2           9
## row.232      3      4      3          10
## row.233      3      4      4          11
## row.234      3      4      5          12
## row.235      3      4      6          13
## row.236      3      4      7          14
## row.237      3      4      8          15
## row.238      3      4      9          16
## row.239      3      4     10          17
## row.240      3      5      1           9
## row.241      3      5      2          10
## row.242      3      5      3          11
## row.243      3      5      4          12
## row.244      3      5      5          13
```

```
## row.245      3      5      6          14
## row.246      3      5      7          15
## row.247      3      5      8          16
## row.248      3      5      9          17
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## row.676      7     8     7        22
```

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```

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## row.822       9     3     3         15
## row.823       9     3     4         16
## row.824       9     3     5         17
## row.825       9     3     6         18
## row.826       9     3     7         19
## row.827       9     3     8         20
## row.828       9     3     9         21
## row.829       9     3    10         22
## row.830       9     4     1         14
## row.831       9     4     2         15
## row.832       9     4     3         16
## row.833       9     4     4         17
## row.834       9     4     5         18
## row.835       9     4     6         19
## row.836       9     4     7         20
## row.837       9     4     8         21
## row.838       9     4     9         22
```

```
## row.839      9     4    10          23
## row.840      9     5     1          15
## row.841      9     5     2          16
## row.842      9     5     3          17
## row.843      9     5     4          18
## row.844      9     5     5          19
## row.845      9     5     6          20
## row.846      9     5     7          21
## row.847      9     5     8          22
## row.848      9     5     9          23
## row.849      9     5    10          24
## row.850      9     6     1          16
## row.851      9     6     2          17
## row.852      9     6     3          18
## row.853      9     6     4          19
## row.854      9     6     5          20
## row.855      9     6     6          21
## row.856      9     6     7          22
## row.857      9     6     8          23
## row.858      9     6     9          24
## row.859      9     6    10          25
## row.860      9     7     1          17
## row.861      9     7     2          18
## row.862      9     7     3          19
## row.863      9     7     4          20
## row.864      9     7     5          21
## row.865      9     7     6          22
## row.866      9     7     7          23
## row.867      9     7     8          24
## row.868      9     7     9          25
## row.869      9     7    10          26
## row.870      9     8     1          18
## row.871      9     8     2          19
## row.872      9     8     3          20
## row.873      9     8     4          21
## row.874      9     8     5          22
## row.875      9     8     6          23
## row.876      9     8     7          24
## row.877      9     8     8          25
## row.878      9     8     9          26
## row.879      9     8    10          27
## row.880      9     9     1          19
## row.881      9     9     2          20
## row.882      9     9     3          21
## row.883      9     9     4          22
## row.884      9     9     5          23
## row.885      9     9     6          24
## row.886      9     9     7          25
## row.887      9     9     8          26
## row.888      9     9     9          27
## row.889      9     9    10          28
## row.890      9    10     1          20
## row.891      9    10     2          21
## row.892      9    10     3          22
```

```
## row.893       9      10       4           23
## row.894       9      10       5           24
## row.895       9      10       6           25
## row.896       9      10       7           26
## row.897       9      10       8           27
## row.898       9      10       9           28
## row.899       9      10      10           29
## row.900      10       1       1           12
## row.901      10       1       2           13
## row.902      10       1       3           14
## row.903      10       1       4           15
## row.904      10       1       5           16
## row.905      10       1       6           17
## row.906      10       1       7           18
## row.907      10       1       8           19
## row.908      10       1       9           20
## row.909      10       1      10           21
## row.910      10       2       1           13
## row.911      10       2       2           14
## row.912      10       2       3           15
## row.913      10       2       4           16
## row.914      10       2       5           17
## row.915      10       2       6           18
## row.916      10       2       7           19
## row.917      10       2       8           20
## row.918      10       2       9           21
## row.919      10       2      10           22
## row.920      10       3       1           14
## row.921      10       3       2           15
## row.922      10       3       3           16
## row.923      10       3       4           17
## row.924      10       3       5           18
## row.925      10       3       6           19
## row.926      10       3       7           20
## row.927      10       3       8           21
## row.928      10       3       9           22
## row.929      10       3      10           23
## row.930      10       4       1           15
## row.931      10       4       2           16
## row.932      10       4       3           17
## row.933      10       4       4           18
## row.934      10       4       5           19
## row.935      10       4       6           20
## row.936      10       4       7           21
## row.937      10       4       8           22
## row.938      10       4       9           23
## row.939      10       4      10           24
## row.940      10       5       1           16
## row.941      10       5       2           17
## row.942      10       5       3           18
## row.943      10       5       4           19
## row.944      10       5       5           20
## row.945      10       5       6           21
## row.946      10       5       7           22
```

```
## row.947     10      5      8          23
## row.948     10      5      9          24
## row.949     10      5     10          25
## row.950     10      6      1          17
## row.951     10      6      2          18
## row.952     10      6      3          19
## row.953     10      6      4          20
## row.954     10      6      5          21
## row.955     10      6      6          22
## row.956     10      6      7          23
## row.957     10      6      8          24
## row.958     10      6      9          25
## row.959     10      6     10          26
## row.960     10      7      1          18
## row.961     10      7      2          19
## row.962     10      7      3          20
## row.963     10      7      4          21
## row.964     10      7      5          22
## row.965     10      7      6          23
## row.966     10      7      7          24
## row.967     10      7      8          25
## row.968     10      7      9          26
## row.969     10      7     10          27
## row.970     10      8      1          19
## row.971     10      8      2          20
## row.972     10      8      3          21
## row.973     10      8      4          22
## row.974     10      8      5          23
## row.975     10      8      6          24
## row.976     10      8      7          25
## row.977     10      8      8          26
## row.978     10      8      9          27
## row.979     10      8     10          28
## row.980     10      9      1          20
## row.981     10      9      2          21
## row.982     10      9      3          22
## row.983     10      9      4          23
## row.984     10      9      5          24
## row.985     10      9      6          25
## row.986     10      9      7          26
## row.987     10      9      8          27
## row.988     10      9      9          28
## row.989     10      9     10          29
## row.990     10     10      1          21
## row.991     10     10      2          22
## row.992     10     10      3          23
## row.993     10     10      4          24
## row.994     10     10      5          25
## row.995     10     10      6          26
## row.996     10     10      7          27
## row.997     10     10      8          28
## row.998     10     10      9          29
## row.999     10     10     10          30
```

```r
print("Dimensions of myrolls");
```

```
## [1] "Dimensions of myrolls"
```

```r
dim(myrolls);
```

```
## [1] 1000    4
```

```r
outcomes.table = table(myrolls$roll.total);
outcomes.df = as.data.frame(outcomes.table);
colnames(outcomes.df) = c("roll.total", "count");


total.sum = sum(outcomes.df$count);
print("Sum of outcomes.df$count");
```

```
## [1] "Sum of outcomes.df$count"
```

```r
total.sum;
```

```
## [1] 1000
```

```r
outcomes.df$prob = outcomes.df$count / total.sum;
outcomes.df;
```

```
##    roll.total count  prob
## 1           3     1 0.001
## 2           4     3 0.003
## 3           5     6 0.006
## 4           6    10 0.010
## 5           7    15 0.015
## 6           8    21 0.021
## 7           9    28 0.028
## 8          10    36 0.036
## 9          11    45 0.045
## 10         12    55 0.055
## 11         13    63 0.063
## 12         14    69 0.069
## 13         15    73 0.073
## 14         16    75 0.075
## 15         17    75 0.075
## 16         18    73 0.073
## 17         19    69 0.069
## 18         20    63 0.063
## 19         21    55 0.055
## 20         22    45 0.045
## 21         23    36 0.036
## 22         24    28 0.028
## 23         25    21 0.021
## 24         26    15 0.015
```

```
## 25          27    10 0.010
## 26          28     6 0.006
## 27          29     3 0.003
## 28          30     1 0.001
```

Viewing a subset of data to answer a question

- How many ways can I roll a 23 when I throw the dice at the same time? What is the probability that I roll a 23 on a single throw?

```r
# if you don't have the latest version of humanVerseWSU, you can access the function as follows:
# library(devtools);
# source_url(paste0( path.github, "humanVerseWSU/R/functions-dataframe.R" ));



sub.myrolls = subsetDataFrame(myrolls, "roll.total", "==", 23);

sub.myrolls;
```

```
##         dice.1 dice.2 dice.3 roll.total
## row.299      3     10     10         23
## row.389      4      9     10         23
## row.398      4     10      9         23
## row.479      5      8     10         23
## row.488      5      9      9         23
## row.497      5     10      8         23
## row.569      6      7     10         23
## row.578      6      8      9         23
## row.587      6      9      8         23
## row.596      6     10      7         23
## row.659      7      6     10         23
## row.668      7      7      9         23
## row.677      7      8      8         23
## row.686      7      9      7         23
## row.695      7     10      6         23
## row.749      8      5     10         23
## row.758      8      6      9         23
## row.767      8      7      8         23
## row.776      8      8      7         23
## row.785      8      9      6         23
## row.794      8     10      5         23
## row.839      9      4     10         23
## row.848      9      5      9         23
## row.857      9      6      8         23
## row.866      9      7      7         23
## row.875      9      8      6         23
## row.884      9      9      5         23
## row.893      9     10      4         23
## row.929     10      3     10         23
## row.938     10      4      9         23
## row.947     10      5      8         23
## row.956     10      6      7         23
```

```
## row.965     10      7      6          23
## row.974     10      8      5          23
## row.983     10      9      4          23
## row.992     10     10      3          23
```

```
sub.outcomes.df = subsetDataFrame(outcomes.df, "roll.total", "==", 23);

sub.outcomes.df;
```

```
##    roll.total count  prob
## 21         23    36 0.036
```

(10 points) Questions from the Dice simulation

Roll 23

- How many ways can I roll a 23 when I throw the dice at the same time? What is the probability that I roll a 23 on a single throw?

Roll 12 or 22

- What is the probability that I roll a 12 or a 22 on a single throw?

```
# getting each cases where I roll 12 or 22 when I throw the dice at the same time.

#sub.myrolls12 = subsetDataFrame(myrolls, "roll.total", "==", 12)
#sub.myrolls22 = subsetDataFrame(myrolls, "roll.total", "==", 22)

#sub.myrolls2 = rbind(sub.myrolls12, sub.myrolls22)
#sub.myrolls2

#---------------------------------------------------------------------------

sub.outcomes12.df = subsetDataFrame(outcomes.df, "roll.total", "==", 12)
sub.outcomes22.df = subsetDataFrame(outcomes.df, "roll.total", "==", 22)

sub.outcomes2.df= rbind(sub.outcomes12.df , sub.outcomes22.df)
sub.outcomes2.df
```

```
##    roll.total count  prob
## 10         12    55 0.055
## 20         22    45 0.045
```

```
cat('The probability of rolling a 12 or 22 on a single throw is:', sum(sub.outcomes2.df[,'prob']))
```

```
## The probability of rolling a 12 or 22 on a single throw is: 0.1
```

Roll 26 or 29

- What is the probability that I roll a 26 or a 29 on a single throw?

```
sub.outcomes26.df = subsetDataFrame(outcomes.df, "roll.total", "==", 26)
sub.outcomes29.df = subsetDataFrame(outcomes.df, "roll.total", "==", 29)

sub.outcomes3.df= rbind(sub.outcomes26.df , sub.outcomes29.df)
sub.outcomes3.df
```

```
##    roll.total count  prob
## 24         26    15 0.015
## 27         29     3 0.003
```

```
cat('The probability of rolling a 26 or 29 on a single throw is:', sum(sub.outcomes3.df[,'prob']))
```

```
## The probability of rolling a 26 or 29 on a single throw is: 0.018
```

Roll 3 once/twice in a row

- What is the probability that I roll a 3 on a single throw? What is the probability that I roll a 3 twice in a row? First throw = 3 **AND** second throw = 3?

```
sub.outcomes3.df = subsetDataFrame(outcomes.df, "roll.total", "==", 3)
sub.outcomes3.df
```

```
##   roll.total count  prob
## 1          3     1 0.001
```

Roll 12 or lower

- What is the probability that I roll at most a 12 on a single throw? That is, a 12 or lower ...

```
sub.myrolls12 = subsetDataFrame(myrolls, "roll.total", "<=", 12)
sub.myrolls12
```

```
##        dice.1 dice.2 dice.3 roll.total
## row         1      1      1          3
## row.1       1      1      2          4
## row.2       1      1      3          5
## row.3       1      1      4          6
## row.4       1      1      5          7
## row.5       1      1      6          8
## row.6       1      1      7          9
## row.7       1      1      8         10
## row.8       1      1      9         11
## row.9       1      1     10         12
## row.10      1      2      1          4
## row.11      1      2      2          5
## row.12      1      2      3          6
## row.13      1      2      4          7
## row.14      1      2      5          8
## row.15      1      2      6          9
## row.16      1      2      7         10
```

```
## row.17      1    2    8       11
## row.18      1    2    9       12
## row.20      1    3    1        5
## row.21      1    3    2        6
## row.22      1    3    3        7
## row.23      1    3    4        8
## row.24      1    3    5        9
## row.25      1    3    6       10
## row.26      1    3    7       11
## row.27      1    3    8       12
## row.30      1    4    1        6
## row.31      1    4    2        7
## row.32      1    4    3        8
## row.33      1    4    4        9
## row.34      1    4    5       10
## row.35      1    4    6       11
## row.36      1    4    7       12
## row.40      1    5    1        7
## row.41      1    5    2        8
## row.42      1    5    3        9
## row.43      1    5    4       10
## row.44      1    5    5       11
## row.45      1    5    6       12
## row.50      1    6    1        8
## row.51      1    6    2        9
## row.52      1    6    3       10
## row.53      1    6    4       11
## row.54      1    6    5       12
## row.60      1    7    1        9
## row.61      1    7    2       10
## row.62      1    7    3       11
## row.63      1    7    4       12
## row.70      1    8    1       10
## row.71      1    8    2       11
## row.72      1    8    3       12
## row.80      1    9    1       11
## row.81      1    9    2       12
## row.90      1   10    1       12
## row.100     2    1    1        4
## row.101     2    1    2        5
## row.102     2    1    3        6
## row.103     2    1    4        7
## row.104     2    1    5        8
## row.105     2    1    6        9
## row.106     2    1    7       10
## row.107     2    1    8       11
## row.108     2    1    9       12
## row.110     2    2    1        5
## row.111     2    2    2        6
## row.112     2    2    3        7
## row.113     2    2    4        8
## row.114     2    2    5        9
## row.115     2    2    6       10
## row.116     2    2    7       11
```

```
## row.117      2      2      8          12
## row.120      2      3      1           6
## row.121      2      3      2           7
## row.122      2      3      3           8
## row.123      2      3      4           9
## row.124      2      3      5          10
## row.125      2      3      6          11
## row.126      2      3      7          12
## row.130      2      4      1           7
## row.131      2      4      2           8
## row.132      2      4      3           9
## row.133      2      4      4          10
## row.134      2      4      5          11
## row.135      2      4      6          12
## row.140      2      5      1           8
## row.141      2      5      2           9
## row.142      2      5      3          10
## row.143      2      5      4          11
## row.144      2      5      5          12
## row.150      2      6      1           9
## row.151      2      6      2          10
## row.152      2      6      3          11
## row.153      2      6      4          12
## row.160      2      7      1          10
## row.161      2      7      2          11
## row.162      2      7      3          12
## row.170      2      8      1          11
## row.171      2      8      2          12
## row.180      2      9      1          12
## row.200      3      1      1           5
## row.201      3      1      2           6
## row.202      3      1      3           7
## row.203      3      1      4           8
## row.204      3      1      5           9
## row.205      3      1      6          10
## row.206      3      1      7          11
## row.207      3      1      8          12
## row.210      3      2      1           6
## row.211      3      2      2           7
## row.212      3      2      3           8
## row.213      3      2      4           9
## row.214      3      2      5          10
## row.215      3      2      6          11
## row.216      3      2      7          12
## row.220      3      3      1           7
## row.221      3      3      2           8
## row.222      3      3      3           9
## row.223      3      3      4          10
## row.224      3      3      5          11
## row.225      3      3      6          12
## row.230      3      4      1           8
## row.231      3      4      2           9
## row.232      3      4      3          10
## row.233      3      4      4          11
```

```
## row.234      3     4     5        12
## row.240      3     5     1         9
## row.241      3     5     2        10
## row.242      3     5     3        11
## row.243      3     5     4        12
## row.250      3     6     1        10
## row.251      3     6     2        11
## row.252      3     6     3        12
## row.260      3     7     1        11
## row.261      3     7     2        12
## row.270      3     8     1        12
## row.300      4     1     1         6
## row.301      4     1     2         7
## row.302      4     1     3         8
## row.303      4     1     4         9
## row.304      4     1     5        10
## row.305      4     1     6        11
## row.306      4     1     7        12
## row.310      4     2     1         7
## row.311      4     2     2         8
## row.312      4     2     3         9
## row.313      4     2     4        10
## row.314      4     2     5        11
## row.315      4     2     6        12
## row.320      4     3     1         8
## row.321      4     3     2         9
## row.322      4     3     3        10
## row.323      4     3     4        11
## row.324      4     3     5        12
## row.330      4     4     1         9
## row.331      4     4     2        10
## row.332      4     4     3        11
## row.333      4     4     4        12
## row.340      4     5     1        10
## row.341      4     5     2        11
## row.342      4     5     3        12
## row.350      4     6     1        11
## row.351      4     6     2        12
## row.360      4     7     1        12
## row.400      5     1     1         7
## row.401      5     1     2         8
## row.402      5     1     3         9
## row.403      5     1     4        10
## row.404      5     1     5        11
## row.405      5     1     6        12
## row.410      5     2     1         8
## row.411      5     2     2         9
## row.412      5     2     3        10
## row.413      5     2     4        11
## row.414      5     2     5        12
## row.420      5     3     1         9
## row.421      5     3     2        10
## row.422      5     3     3        11
## row.423      5     3     4        12
```

```
## row.430      5      4      1          10
## row.431      5      4      2          11
## row.432      5      4      3          12
## row.440      5      5      1          11
## row.441      5      5      2          12
## row.450      5      6      1          12
## row.500      6      1      1           8
## row.501      6      1      2           9
## row.502      6      1      3          10
## row.503      6      1      4          11
## row.504      6      1      5          12
## row.510      6      2      1           9
## row.511      6      2      2          10
## row.512      6      2      3          11
## row.513      6      2      4          12
## row.520      6      3      1          10
## row.521      6      3      2          11
## row.522      6      3      3          12
## row.530      6      4      1          11
## row.531      6      4      2          12
## row.540      6      5      1          12
## row.600      7      1      1           9
## row.601      7      1      2          10
## row.602      7      1      3          11
## row.603      7      1      4          12
## row.610      7      2      1          10
## row.611      7      2      2          11
## row.612      7      2      3          12
## row.620      7      3      1          11
## row.621      7      3      2          12
## row.630      7      4      1          12
## row.700      8      1      1          10
## row.701      8      1      2          11
## row.702      8      1      3          12
## row.710      8      2      1          11
## row.711      8      2      2          12
## row.720      8      3      1          12
## row.800      9      1      1          11
## row.801      9      1      2          12
## row.810      9      2      1          12
## row.900     10      1      1          12
```

INITIAL EXPLORATION OF REAL DATA

We are going to use exploratory techniques to examine some Indeed.com data. If you recall, this `job` data examines how many jobs reference a certain keyword. Every Monday morning at 12:00:00AM EST (using a scheduler `crontab`), this data collection is performed. A few weeks ago, I added some new keys words. The data set we have consists of 5 weeks: `2020-38` to `2020-42`.

- For each "search phrase", I go to Indeed.com and download the first page of results.

- From this first page, I grab the "total count"
- An example is shown in a screenshot, taken this week.

Source: Data provenance history

Import "jobs" data

- Run code to import the data `jobs`.

```r
jobs = utils::read.csv( paste0(path.mshaffer, "_data_/indeed-jobs.txt"), header=TRUE, quote="", sep="|")

colnames(jobs) = c("year.week", "search.query", "job.count");
jobs;
```

```
##     year.week              search.query job.count
## 1     2020-38                     Excel    375999
## 2     2020-38          Microsoft Office    223663
## 3     2020-38                       C++    158317
## 4     2020-38                        C#    158317
## 5     2020-38                  Database    124631
## 6     2020-38          Computer Science    107584
## 7     2020-38                Data entry     80465
## 8     2020-38                  modeling     78330
## 9     2020-38                      SQL+     63365
## 10    2020-38                       SQL     63365
## 11    2020-38                      .NET     62362
## 12    2020-38                    Python     56538
## 13    2020-38                    Google     50707
## 14    2020-38                      Java     49993
## 15    2020-38                Statistics     49383
## 16    2020-38                         R     46997
## 17    2020-38                     react     41603
## 18    2020-38             Data analysis     38384
## 19    2020-38                      HTML     38062
## 20    2020-38                Javascript     35938
## 21    2020-38                    Oracle     30143
## 22    2020-38                       SAP     29054
## 23    2020-38           Data management     25694
## 24    2020-38          machine learning     23197
## 25    2020-38                     scrum     21599
## 26    2020-38            Data analytics     21546
## 27    2020-38                       CSS     21303
## 28    2020-38                       API     20997
## 29    2020-38                       git     18270
## 30    2020-38                       Git     18270
## 31    2020-38           Object oriented     17548
## 32    2020-38                       PCA     17047
## 33    2020-38                        ai     16066
## 34    2020-38                  Big data     15737
## 35    2020-38                 debugging     15718
## 36    2020-38              Data science     15044
## 37    2020-38                   Android     13375
## 38    2020-38                   Tableau     13321
## 39    2020-38         agile development     13080
## 40    2020-38     Business intelligence     13032
## 41    2020-38                 data sets     12875
```

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## 42    2020-38                full stack     12799
## 43    2020-38                       PHP     12367
## 44    2020-38                 PhotoShop     12275
## 45    2020-38                       iOS     11938
## 46    2020-38                   angular     11386
## 47    2020-38                     Mysql     10809
## 48    2020-38           design patterns     10689
## 49    2020-38                       SAS     10553
## 50    2020-38           Market Research     10489
## 51    2020-38                 scrubbing     10141
## 52    2020-38       Database management     10097
## 53    2020-38   artificial intelligence      8968
## 54    2020-38                 usability      8680
## 55    2020-38         Business analysis      8674
## 56    2020-38                  datasets      8111
## 57    2020-38        Data Visualization      8001
## 58    2020-38          Business Analyst      7932
## 59    2020-38     relational databases      7895
## 60    2020-38                    Jquery      7745
## 61    2020-38                regression      7293
## 62    2020-38           version control      7259
## 63    2020-38          Google analytics      6544
## 64    2020-38              unit testing      6530
## 65    2020-38            Data warehouse      6320
## 66    2020-38                    Github      6121
## 67    2020-38       relational database      5931
## 68    2020-38               simulations      5749
## 69    2020-38              benchmarking      5566
## 70    2020-38                  firmware      5558
## 71    2020-38                  Power BI      5266
## 72    2020-38                Postgresql      4824
## 73    2020-38              Data Analyst      4607
## 74    2020-38           Market Analysis      4253
## 75    2020-38             deep learning      4003
## 76    2020-38            Data scientist      3992
## 77    2020-38        Business analytics      3952
## 78    2020-38                 Bootstrap      3923
## 79    2020-38                Windows 10      3858
## 80    2020-38                     Slack      3492
## 81    2020-38             Data Engineer      3308
## 82    2020-38                    arcgis      2846
## 83    2020-38              Visual Basic      2370
## 84    2020-38 natural language processing   2304
## 85    2020-38                clustering      2237
## 86    2020-38         Data manipulation      2159
## 87    2020-38                      SPSS      2150
## 88    2020-38         Report generation      2025
## 89    2020-38                    Mac OS      1825
## 90    2020-38          Algorithm Design      1734
## 91    2020-38                       NLP      1692
## 92    2020-38                   merging      1632
## 93    2020-38      statistical modeling      1616
## 94    2020-38        Generating reports      1602
## 95    2020-38                 Wireshark      1547
```

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## 96    2020-38                   Looker      1388
## 97    2020-38             multivariate      1342
## 98    2020-38          neural networks      1231
## 99    2020-38           Custom reports      1187
## 100   2020-38                    Stata      1186
## 101   2020-38       Marketing Research      1036
## 102   2020-38                 QlikView       895
## 103   2020-38         Data maintenance       860
## 104   2020-38                       D3       765
## 105   2020-38             Statistician       702
## 106   2020-38                     Curl       692
## 107   2020-38          C++ programming       688
## 108   2020-38            C programming       688
## 109   2020-38                 Spotfire       572
## 110   2020-38          Biostatistician       568
## 111   2020-38                      LSA       567
## 112   2020-38                  MariaDB       547
## 113   2020-38           decision trees       546
## 114   2020-38                Qualtrics       491
## 115   2020-38      Git version control       490
## 116   2020-38                   Delphi       473
## 117   2020-38                     Domo       470
## 118   2020-38                     TSQL       447
## 119   2020-38        scenario analysis       438
## 120   2020-38                   SQLite       400
## 121   2020-38           neural network       399
## 122   2020-38      logistic regression       395
## 123   2020-38           Data wrangling       380
## 124   2020-38       Insights analytics       374
## 125   2020-38                   Debian       364
## 126   2020-38             Lab Notebook       364
## 127   2020-38     Sensitivity Analysis       362
## 128   2020-38                  Using R       335
## 129   2020-38     well-documented code       229
## 130   2020-38                      SVD       226
## 131   2020-38        Actuarial Analyst       208
## 132   2020-38           Power Analysis       200
## 133   2020-38            document code       197
## 134   2020-38                      SVM       196
## 135   2020-38                  k-means       157
## 136   2020-38                      LDA       135
## 137   2020-38                 R Studio       132
## 138   2020-38                   ggplot       130
## 139   2020-38                   plotly       128
## 140   2020-38                  SiSense       124
## 141   2020-38                  RStudio       117
## 142   2020-38             Web scraping       116
## 143   2020-38         Online analytics       115
## 144   2020-38         Insights Analyst       110
## 145   2020-38               Highcharts        97
## 146   2020-38        Insights analysis        93
## 147   2020-38                    Birst        90
## 148   2020-38       Actuarial analysis        80
## 149   2020-38                      knn        47
```

```
## 150   2020-38               tidyverse       40
## 151   2020-38      spatial statistics       38
## 152   2020-38              R packages       36
## 153   2020-38       Insurance Analyst       34
## 154   2020-38          C++ programmer       25
## 155   2020-38      Insurance analysis       25
## 156   2020-38            C programmer       25
## 157   2020-38                   Gauss       24
## 158   2020-38     Insurance analytics       23
## 159   2020-38                GoodData       21
## 160   2020-38     Actuarial analytics       20
## 161   2020-38              R Markdown       17
## 162   2020-38           Data scraping       16
## 163   2020-38 hierarchical clustering       13
## 164   2020-38                  kmeans       12
## 165   2020-38             Datawrapper        9
## 166   2020-38         Actuary Analyst        9
## 167   2020-38            FusionCharts        9
## 168   2020-38  Computational Engineer        8
## 169   2020-38          record linkage        7
## 170   2020-38         Insight Squared        5
## 171   2020-38             R Developer        4
## 172   2020-38               Dundas BI        3
## 173   2020-38       Actuary analytics        3
## 174   2020-38         Polling Analyst        2
## 175   2020-38             Highcharter        1
## 176   2020-38        Polling analysis        1
## 177   2020-38       Polling analytics        1
## 178   2020-38                Datapine        1
## 179   2020-38      Analytic Scripting        1
## 180   2020-38                Zebra BI        0
## 181   2020-38        Actuary analysis        0
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## 183   2020-39        Microsoft Office   228397
## 184   2020-39                     C++   161156
## 185   2020-39                      C#   161156
## 186   2020-39                Database   127108
## 187   2020-39        Computer Science   109819
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## 189   2020-39                modeling    79713
## 190   2020-39                    .NET    65649
## 191   2020-39                     SQL    64810
## 192   2020-39                    SQL+    64810
## 193   2020-39                  Python    57841
## 194   2020-39                  Google    51926
## 195   2020-39                    Java    51155
## 196   2020-39              Statistics    50588
## 197   2020-39                       R    47809
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## 200   2020-39                    HTML    38810
## 201   2020-39              Javascript    36633
## 202   2020-39                  Oracle    30729
## 203   2020-39                     SAP    29657
```

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## 205   2020-39            machine learning     24005
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## 209   2020-39                         CSS     21739
## 210   2020-39                         git     18617
## 211   2020-39                         Git     18617
## 212   2020-39             Object oriented     18023
## 213   2020-39                         PCA     17248
## 214   2020-39                          ai     16462
## 215   2020-39                    Big data     15997
## 216   2020-39                   debugging     15936
## 217   2020-39                Data science     15587
## 218   2020-39                     Tableau     13735
## 219   2020-39                     Android     13722
## 220   2020-39       Business intelligence     13524
## 221   2020-39                   data sets     13445
## 222   2020-39           agile development     13240
## 223   2020-39                  full stack     13164
## 224   2020-39                   PhotoShop     12622
## 225   2020-39                         PHP     12610
## 226   2020-39                         iOS     12253
## 227   2020-39                     angular     11677
## 228   2020-39             design patterns     11132
## 229   2020-39                         SAS     11039
## 230   2020-39                       Mysql     10942
## 231   2020-39             Market Research     10748
## 232   2020-39                   scrubbing     10364
## 233   2020-39         Database management     10183
## 234   2020-39     artificial intelligence      9426
## 235   2020-39           Business analysis      8873
## 236   2020-39                   usability      8847
## 237   2020-39                    datasets      8304
## 238   2020-39            Business Analyst      8153
## 239   2020-39       relational databases      8093
## 240   2020-39          Data Visualization      8012
## 241   2020-39                      Jquery      7878
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## 243   2020-39                  regression      7332
## 244   2020-39            Google analytics      6837
## 245   2020-39                unit testing      6669
## 246   2020-39              Data warehouse      6505
## 247   2020-39                      Github      6363
## 248   2020-39         relational database      5997
## 249   2020-39                 simulations      5861
## 250   2020-39                    firmware      5673
## 251   2020-39                benchmarking      5671
## 252   2020-39                    Power BI      5456
## 253   2020-39                  Postgresql      4943
## 254   2020-39                Data Analyst      4688
## 255   2020-39             Market Analysis      4332
## 256   2020-39               deep learning      4171
## 257   2020-39          Business analytics      4104
```

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## 258   2020-39             Data scientist      4040
## 259   2020-39                 Windows 10      4028
## 260   2020-39                  Bootstrap      3886
## 261   2020-39                      Slack      3600
## 262   2020-39              Data Engineer      3340
## 263   2020-39                     arcgis      2898
## 264   2020-39               Visual Basic      2415
## 265   2020-39 natural language processing      2389
## 266   2020-39                 clustering      2282
## 267   2020-39          Data manipulation      2247
## 268   2020-39                       SPSS      2237
## 269   2020-39          Report generation      2102
## 270   2020-39                     Mac OS      1909
## 271   2020-39           Algorithm Design      1760
## 272   2020-39                        NLP      1715
## 273   2020-39       statistical modeling      1647
## 274   2020-39                  Wireshark      1619
## 275   2020-39                    merging      1602
## 276   2020-39         Generating reports      1588
## 277   2020-39                     Looker      1423
## 278   2020-39               multivariate      1370
## 279   2020-39                      Stata      1271
## 280   2020-39            neural networks      1243
## 281   2020-39             Custom reports      1194
## 282   2020-39         Marketing Research      1120
## 283   2020-39                   QlikView       917
## 284   2020-39           Data maintenance       863
## 285   2020-39                         D3       771
## 286   2020-39                       Curl       753
## 287   2020-39               Statistician       736
## 288   2020-39              C programming       695
## 289   2020-39            C++ programming       695
## 290   2020-39                  Spotfire       602
## 291   2020-39                        LSA       602
## 292   2020-39            Biostatistician       588
## 293   2020-39                    MariaDB       582
## 294   2020-39                  Qualtrics       568
## 295   2020-39             decision trees       551
## 296   2020-39                       Domo       496
## 297   2020-39        Git version control       491
## 298   2020-39                     Delphi       481
## 299   2020-39                       TSQL       457
## 300   2020-39          scenario analysis       441
## 301   2020-39                     SQLite       408
## 302   2020-39               Lab Notebook       400
## 303   2020-39             neural network       397
## 304   2020-39             Data wrangling       391
## 305   2020-39                     Debian       387
## 306   2020-39        logistic regression       384
## 307   2020-39         Insights analytics       359
## 308   2020-39       Sensitivity Analysis       357
## 309   2020-39                    Using R       341
## 310   2020-39                        SVD       230
## 311   2020-39       well-documented code       226
```

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## 312   2020-39            Actuarial Analyst       216
## 313   2020-39                          SVM       212
## 314   2020-39               Power Analysis       206
## 315   2020-39                document code       203
## 316   2020-39             Insights Analyst       173
## 317   2020-39                      k-means       157
## 318   2020-39                          LDA       141
## 319   2020-39                      SiSense       141
## 320   2020-39                     R Studio       137
## 321   2020-39             Online analytics       132
## 322   2020-39                       ggplot       127
## 323   2020-39                       plotly       124
## 324   2020-39                      RStudio       122
## 325   2020-39                 Web scraping       117
## 326   2020-39                  Highcharts       100
## 327   2020-39           Insights analysis       100
## 328   2020-39                        Birst        96
## 329   2020-39          Actuarial analysis        77
## 330   2020-39                          knn        46
## 331   2020-39                  R packages        39
## 332   2020-39                   tidyverse        38
## 333   2020-39          spatial statistics        37
## 334   2020-39           Insurance Analyst        33
## 335   2020-39         Insurance analytics        27
## 336   2020-39                    GoodData        26
## 337   2020-39          Insurance analysis        26
## 338   2020-39         Actuarial analytics        26
## 339   2020-39                       Gauss        23
## 340   2020-39              C++ programmer        22
## 341   2020-39                C programmer        22
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## 343   2020-39               Data scraping        20
## 344   2020-39     hierarchical clustering        14
## 345   2020-39                      kmeans        10
## 346   2020-39              record linkage        10
## 347   2020-39             Actuary Analyst        10
## 348   2020-39      Computational Engineer        10
## 349   2020-39                 Datawrapper         9
## 350   2020-39                FusionCharts         8
## 351   2020-39                 R Developer         5
## 352   2020-39             Insight Squared         5
## 353   2020-39           Actuary analytics         4
## 354   2020-39                   Dundas BI         3
## 355   2020-39             Polling Analyst         1
## 356   2020-39            Polling analysis         1
## 357   2020-39                 Highcharter         1
## 358   2020-39           Polling analytics         1
## 359   2020-39         Analytic Scripting         1
## 360   2020-39                    Datapine         1
## 361   2020-39            Actuary analysis         0
## 362   2020-39                    Zebra BI         0
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## 364   2020-40            Microsoft Office    231979
## 365   2020-40                         C++    163044
```

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## 371   2020-40                    .NET     67350
## 372   2020-40                     SQL     66175
## 373   2020-40                    SQL+     66175
## 374   2020-40                  Python     58898
## 375   2020-40                  Google     53052
## 376   2020-40                    Java     52113
## 377   2020-40              Statistics     51850
## 378   2020-40                       R     49571
## 379   2020-40                   react     42576
## 380   2020-40           Data analysis     40455
## 381   2020-40                    HTML     40160
## 382   2020-40              Javascript     37554
## 383   2020-40                  Oracle     31373
## 384   2020-40                     SAP     30335
## 385   2020-40         Data management     26442
## 386   2020-40        machine learning     24489
## 387   2020-40          Data analytics     23044
## 388   2020-40                   scrum     22891
## 389   2020-40                     API     22159
## 390   2020-40                     CSS     21960
## 391   2020-40                     git     19232
## 392   2020-40         Object oriented     18296
## 393   2020-40                     PCA     17219
## 394   2020-40                      ai     16825
## 395   2020-40                Big data     16463
## 396   2020-40               debugging     16386
## 397   2020-40            Data science     15998
## 398   2020-40                 Android     14295
## 399   2020-40                 Tableau     13943
## 400   2020-40   Business intelligence     13865
## 401   2020-40               data sets     13768
## 402   2020-40       agile development     13570
## 403   2020-40              full stack     13471
## 404   2020-40                     PHP     12962
## 405   2020-40               PhotoShop     12824
## 406   2020-40                     iOS     12575
## 407   2020-40                 angular     11847
## 408   2020-40         design patterns     11364
## 409   2020-40                   Mysql     11137
## 410   2020-40         Market Research     11120
## 411   2020-40                     SAS     11118
## 412   2020-40     Database management     10613
## 413   2020-40               scrubbing     10526
## 414   2020-40 artificial intelligence      9882
## 415   2020-40               usability      9044
## 416   2020-40       Business analysis      8998
## 417   2020-40                datasets      8394
## 418   2020-40     relational databases      8291
## 419   2020-40        Business Analyst      8278
```

```
## 420   2020-40           Data Visualization      8269
## 421   2020-40                       Jquery      7986
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## 423   2020-40                   regression      7529
## 424   2020-40             Google analytics      7026
## 425   2020-40                 unit testing      6764
## 426   2020-40                       Github      6661
## 427   2020-40               Data warehouse      6539
## 428   2020-40          relational database      6152
## 429   2020-40                  simulations      6007
## 430   2020-40                 benchmarking      5941
## 431   2020-40                     firmware      5796
## 432   2020-40                     Power BI      5626
## 433   2020-40                   Postgresql      5070
## 434   2020-40                 Data Analyst      4786
## 435   2020-40           Business analytics      4285
## 436   2020-40                deep learning      4281
## 437   2020-40                   Windows 10      4269
## 438   2020-40              Market Analysis      4260
## 439   2020-40               Data scientist      4084
## 440   2020-40                    Bootstrap      3949
## 441   2020-40                        Slack      3733
## 442   2020-40                Data Engineer      3428
## 443   2020-40                       arcgis      2935
## 444   2020-40 natural language processing      2451
## 445   2020-40                 Visual Basic      2438
## 446   2020-40                   clustering      2374
## 447   2020-40                         SPSS      2372
## 448   2020-40            Data manipulation      2229
## 449   2020-40            Report generation      2193
## 450   2020-40                       Mac OS      1902
## 451   2020-40             Algorithm Design      1804
## 452   2020-40                          NLP      1768
## 453   2020-40         statistical modeling      1678
## 454   2020-40                    Wireshark      1644
## 455   2020-40                      merging      1638
## 456   2020-40           Generating reports      1606
## 457   2020-40                       Looker      1444
## 458   2020-40                 multivariate      1436
## 459   2020-40              neural networks      1348
## 460   2020-40                        Stata      1336
## 461   2020-40               Custom reports      1208
## 462   2020-40           Marketing Research      1124
## 463   2020-40                     QlikView       920
## 464   2020-40             Data maintenance       850
## 465   2020-40                         Curl       784
## 466   2020-40                 Statistician       783
## 467   2020-40                           D3       779
## 468   2020-40                C programming       718
## 469   2020-40              C++ programming       718
## 470   2020-40                          LSA       618
## 471   2020-40              Biostatistician       616
## 472   2020-40                     Spotfire       602
## 473   2020-40               decision trees       564
```

```
## 474   2020-40                   MariaDB        560
## 475   2020-40                 Qualtrics        551
## 476   2020-40                      Domo        515
## 477   2020-40       Git version control        510
## 478   2020-40                    Delphi        499
## 479   2020-40                      TSQL        484
## 480   2020-40         scenario analysis        465
## 481   2020-40              Lab Notebook        418
## 482   2020-40            neural network        417
## 483   2020-40                    SQLite        416
## 484   2020-40       logistic regression        412
## 485   2020-40            Data wrangling        402
## 486   2020-40                    Debian        398
## 487   2020-40      Sensitivity Analysis        363
## 488   2020-40                   Using R        355
## 489   2020-40        Insights analytics        350
## 490   2020-40                       SVD        239
## 491   2020-40             document code        218
## 492   2020-40                       SVM        218
## 493   2020-40         Actuarial Analyst        213
## 494   2020-40            Power Analysis        208
## 495   2020-40      well-documented code        207
## 496   2020-40                   k-means        156
## 497   2020-40                   SiSense        152
## 498   2020-40                       LDA        148
## 499   2020-40          Online analytics        142
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## 501   2020-40                  R Studio        135
## 502   2020-40                    ggplot        133
## 503   2020-40          Insights Analyst        132
## 504   2020-40                   RStudio        129
## 505   2020-40              Web scraping        123
## 506   2020-40         Insights analysis        103
## 507   2020-40                Highcharts         97
## 508   2020-40                     Birst         84
## 509   2020-40        Actuarial analysis         83
## 510   2020-40                       knn         49
## 511   2020-40                 tidyverse         40
## 512   2020-40         Insurance Analyst         39
## 513   2020-40                R packages         36
## 514   2020-40        spatial statistics         28
## 515   2020-40                  GoodData         28
## 516   2020-40       Insurance analytics         27
## 517   2020-40        Insurance analysis         26
## 518   2020-40                     Gauss         26
## 519   2020-40       Actuarial analytics         26
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## 521   2020-40            C++ programmer         22
## 522   2020-40             Data scraping         19
## 523   2020-40                R Markdown         18
## 524   2020-40   hierarchical clustering         15
## 525   2020-40            record linkage         11
## 526   2020-40                    kmeans          9
## 527   2020-40     Computational Engineer          8
```

```
## 528   2020-40                 Datawrapper         8
## 529   2020-40                FusionCharts         8
## 530   2020-40             Actuary Analyst         7
## 531   2020-40                 R Developer         6
## 532   2020-40             Insight Squared         4
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## 534   2020-40                   Dundas BI         2
## 535   2020-40                 Highcharter         1
## 536   2020-40                    Datapine         1
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## 538   2020-40         Analytic Scripting          1
## 539   2020-40             Polling Analyst         1
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## 541   2020-40            Actuary analysis         0
## 542   2020-40                         Git         0
## 543   2020-40                    Zebra BI         0
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## 551   2020-41                    modeling     80138
## 552   2020-41                        .NET     67493
## 553   2020-41                         SQL     67313
## 554   2020-41                        SQL+     67313
## 555   2020-41                      Python     60241
## 556   2020-41                      Google     53377
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## 565   2020-41                         SAP     30495
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## 567   2020-41            machine learning     24859
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## 569   2020-41                       scrum     23250
## 570   2020-41                         API     22313
## 571   2020-41                         CSS     22042
## 572   2020-41                         git     19532
## 573   2020-41                         Git     19528
## 574   2020-41             Object oriented     18612
## 575   2020-41                          ai     17491
## 576   2020-41                         PCA     17092
## 577   2020-41                   debugging     16768
## 578   2020-41                    Big data     16619
## 579   2020-41                Data science     16247
## 580   2020-41                     Tableau     14430
## 581   2020-41                     Android     14225
```

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## 583   2020-41           agile development     13804
## 584   2020-41                   data sets     13773
## 585   2020-41                  full stack     13675
## 586   2020-41                         PHP     13119
## 587   2020-41                   PhotoShop     12880
## 588   2020-41                         iOS     12686
## 589   2020-41                     angular     11954
## 590   2020-41             design patterns     11495
## 591   2020-41                         SAS     11379
## 592   2020-41             Market Research     11366
## 593   2020-41                       Mysql     11195
## 594   2020-41         Database management     10594
## 595   2020-41                   scrubbing     10486
## 596   2020-41     artificial intelligence     10154
## 597   2020-41                   usability      9209
## 598   2020-41           Business analysis      9104
## 599   2020-41                    datasets      8553
## 600   2020-41          Data Visualization      8497
## 601   2020-41            Business Analyst      8399
## 602   2020-41       relational databases      8270
## 603   2020-41                      Jquery      8014
## 604   2020-41             version control      7648
## 605   2020-41                  regression      7561
## 606   2020-41            Google analytics      7060
## 607   2020-41                unit testing      6825
## 608   2020-41              Data warehouse      6763
## 609   2020-41                      Github      6593
## 610   2020-41         relational database      6192
## 611   2020-41                benchmarking      6102
## 612   2020-41                 simulations      6030
## 613   2020-41                    firmware      5944
## 614   2020-41                    Power BI      5832
## 615   2020-41                  Postgresql      5139
## 616   2020-41                Data Analyst      4817
## 617   2020-41             Market Analysis      4361
## 618   2020-41          Business analytics      4322
## 619   2020-41               deep learning      4316
## 620   2020-41              Data scientist      4210
## 621   2020-41                  Windows 10      4173
## 622   2020-41                   Bootstrap      3950
## 623   2020-41                       Slack      3789
## 624   2020-41               Data Engineer      3504
## 625   2020-41                      arcgis      2910
## 626   2020-41 natural language processing      2502
## 627   2020-41                Visual Basic      2482
## 628   2020-41                        SPSS      2326
## 629   2020-41                  clustering      2319
## 630   2020-41           Data manipulation      2283
## 631   2020-41           Report generation      2196
## 632   2020-41                         NLP      1872
## 633   2020-41                      Mac OS      1868
## 634   2020-41            Algorithm Design      1813
## 635   2020-41        statistical modeling      1719
```

```
## 636   2020-41              Wireshark      1678
## 637   2020-41                merging      1644
## 638   2020-41     Generating reports      1619
## 639   2020-41           multivariate      1450
## 640   2020-41                 Looker      1432
## 641   2020-41                  Stata      1380
## 642   2020-41        neural networks      1355
## 643   2020-41         Custom reports      1255
## 644   2020-41     Marketing Research      1174
## 645   2020-41               QlikView       944
## 646   2020-41       Data maintenance       856
## 647   2020-41                   Curl       792
## 648   2020-41           Statistician       763
## 649   2020-41                     D3       758
## 650   2020-41          C programming       720
## 651   2020-41        C++ programming       720
## 652   2020-41               Spotfire       674
## 653   2020-41       Biostatistician        619
## 654   2020-41         decision trees       597
## 655   2020-41              Qualtrics       592
## 656   2020-41                    LSA       570
## 657   2020-41                MariaDB       560
## 658   2020-41    Git version control       504
## 659   2020-41                   Domo       502
## 660   2020-41                   TSQL       494
## 661   2020-41                 Delphi       485
## 662   2020-41      scenario analysis       451
## 663   2020-41           Lab Notebook       450
## 664   2020-41          Data wrangling       415
## 665   2020-41    logistic regression       404
## 666   2020-41         neural network       396
## 667   2020-41                 Debian       392
## 668   2020-41                 SQLite       387
## 669   2020-41   Sensitivity Analysis       373
## 670   2020-41     Insights analytics       364
## 671   2020-41                Using R       351
## 672   2020-41                    SVD       243
## 673   2020-41                    SVM       236
## 674   2020-41      Actuarial Analyst       232
## 675   2020-41         Power Analysis       227
## 676   2020-41   well-documented code       224
## 677   2020-41          document code       218
## 678   2020-41                k-means       154
## 679   2020-41                SiSense       149
## 680   2020-41                    LDA       149
## 681   2020-41                 ggplot       143
## 682   2020-41                 plotly       136
## 683   2020-41               R Studio       136
## 684   2020-41                RStudio       136
## 685   2020-41           Web scraping       126
## 686   2020-41       Online analytics       124
## 687   2020-41       Insights Analyst       121
## 688   2020-41             Highcharts        99
## 689   2020-41     Actuarial analysis        90
```

```
## 690   2020-41          Insights analysis       90
## 691   2020-41                      Birst       79
## 692   2020-41                        knn       49
## 693   2020-41                  tidyverse       39
## 694   2020-41          Insurance Analyst       34
## 695   2020-41                 R packages       33
## 696   2020-41                   GoodData       30
## 697   2020-41        spatial statistics       30
## 698   2020-41        Insurance analytics       29
## 699   2020-41        Actuarial analytics       29
## 700   2020-41              Data scraping       25
## 701   2020-41                      Gauss       24
## 702   2020-41         Insurance analysis       22
## 703   2020-41               C programmer       21
## 704   2020-41             C++ programmer       21
## 705   2020-41    hierarchical clustering       18
## 706   2020-41                 R Markdown       17
## 707   2020-41     Computational Engineer       11
## 708   2020-41             record linkage       10
## 709   2020-41                     kmeans        9
## 710   2020-41               FusionCharts        8
## 711   2020-41                Datawrapper        8
## 712   2020-41            Actuary Analyst        6
## 713   2020-41                R Developer        6
## 714   2020-41          Actuary analytics        4
## 715   2020-41            Insight Squared        4
## 716   2020-41                  Dundas BI        2
## 717   2020-41         Analytic Scripting        1
## 718   2020-41            Polling Analyst        0
## 719   2020-41                   Zebra BI        0
## 720   2020-41           Actuary analysis        0
## 721   2020-41                   Datapine        0
## 722   2020-41                Highcharter        0
## 723   2020-41          Polling analytics        0
## 724   2020-41           Polling analysis        0
## 725   2020-42                      Excel   404527
## 726   2020-42           Microsoft Office   238111
## 727   2020-42                         C#   169786
## 728   2020-42                        C++   169786
## 729   2020-42                   Database   132088
## 730   2020-42           Computer Science   114970
## 731   2020-42                 Data entry    87269
## 732   2020-42                   modeling    80469
## 733   2020-42                       SQL+    68503
## 734   2020-42                        SQL    68503
## 735   2020-42                       .NET    68052
## 736   2020-42                     Python    61021
## 737   2020-42                     Google    54741
## 738   2020-42                 Statistics    53016
## 739   2020-42                       Java    52969
## 740   2020-42                          R    49861
## 741   2020-42                      react    42006
## 742   2020-42              Data analysis    41620
## 743   2020-42                       HTML    40670
```

```
## 744   2020-42                  Javascript     38637
## 745   2020-42                         SAP     31450
## 746   2020-42                      Oracle     30632
## 747   2020-42             Data management     27239
## 748   2020-42            machine learning     25172
## 749   2020-42              Data analytics     24058
## 750   2020-42                       scrum     23424
## 751   2020-42                         API     23097
## 752   2020-42                         CSS     22530
## 753   2020-42                         Git     19945
## 754   2020-42                         git     19943
## 755   2020-42             Object oriented     18572
## 756   2020-42                          ai     17947
## 757   2020-42                         PCA     17351
## 758   2020-42                Data science     16665
## 759   2020-42                    Big data     16518
## 760   2020-42                   debugging     16300
## 761   2020-42                     Tableau     14707
## 762   2020-42                     Android     14618
## 763   2020-42       Business intelligence     14337
## 764   2020-42                   data sets     13919
## 765   2020-42           agile development     13896
## 766   2020-42                  full stack     13683
## 767   2020-42                         PHP     13244
## 768   2020-42                   PhotoShop     13081
## 769   2020-42                         iOS     12893
## 770   2020-42                     angular     12196
## 771   2020-42             Market Research     11698
## 772   2020-42                         SAS     11596
## 773   2020-42             design patterns     11457
## 774   2020-42                       Mysql     11425
## 775   2020-42         Database management     10664
## 776   2020-42                   scrubbing     10422
## 777   2020-42     artificial intelligence     10041
## 778   2020-42           Business analysis      9431
## 779   2020-42                   usability      9371
## 780   2020-42          Data Visualization      8666
## 781   2020-42                    datasets      8624
## 782   2020-42        relational databases      8610
## 783   2020-42            Business Analyst      8590
## 784   2020-42                      Jquery      8165
## 785   2020-42             version control      7727
## 786   2020-42                  regression      7658
## 787   2020-42            Google analytics      7197
## 788   2020-42                unit testing      7126
## 789   2020-42              Data warehouse      6970
## 790   2020-42                      Github      6735
## 791   2020-42                benchmarking      6262
## 792   2020-42                 simulations      6156
## 793   2020-42                    firmware      6092
## 794   2020-42         relational database      6070
## 795   2020-42                    Power BI      5987
## 796   2020-42                  Postgresql      5342
## 797   2020-42                Data Analyst      4924
```

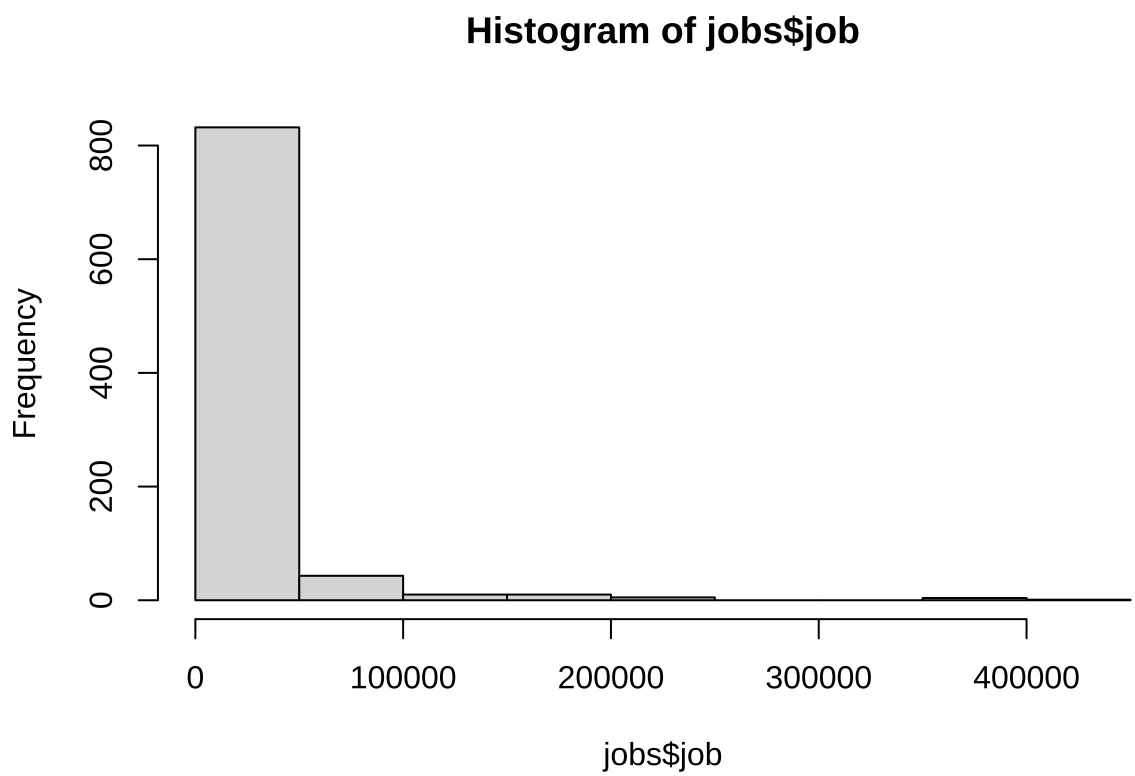
```
## 798   2020-42          Business analytics      4406
## 799   2020-42             Market Analysis      4399
## 800   2020-42                  Windows 10      4361
## 801   2020-42               deep learning      4316
## 802   2020-42              Data scientist      4274
## 803   2020-42                   Bootstrap      4076
## 804   2020-42                       Slack      3991
## 805   2020-42               Data Engineer      3451
## 806   2020-42                      arcgis      2886
## 807   2020-42                Visual Basic      2536
## 808   2020-42 natural language processing      2478
## 809   2020-42                        SPSS      2342
## 810   2020-42                  clustering      2289
## 811   2020-42           Data manipulation      2259
## 812   2020-42           Report generation      2232
## 813   2020-42                      Mac OS      1960
## 814   2020-42                         NLP      1816
## 815   2020-42            Algorithm Design      1791
## 816   2020-42        statistical modeling      1766
## 817   2020-42                   Wireshark      1723
## 818   2020-42                     merging      1711
## 819   2020-42          Generating reports      1500
## 820   2020-42                multivariate      1490
## 821   2020-42                      Looker      1464
## 822   2020-42                       Stata      1423
## 823   2020-42             neural networks      1363
## 824   2020-42              Custom reports      1279
## 825   2020-42          Marketing Research      1199
## 826   2020-42                   QlikView      1001
## 827   2020-42            Data maintenance       880
## 828   2020-42                          D3       794
## 829   2020-42                        Curl       792
## 830   2020-42                Statistician       746
## 831   2020-42               C programming       734
## 832   2020-42             C++ programming       734
## 833   2020-42                    Spotfire       638
## 834   2020-42                   Qualtrics       614
## 835   2020-42                     MariaDB       610
## 836   2020-42            Biostatistician       610
## 837   2020-42              decision trees       593
## 838   2020-42                         LSA       580
## 839   2020-42                        Domo       534
## 840   2020-42         Git version control       519
## 841   2020-42                      Delphi       495
## 842   2020-42           scenario analysis       480
## 843   2020-42                        TSQL       459
## 844   2020-42                      Debian       434
## 845   2020-42                Lab Notebook       433
## 846   2020-42              Data wrangling       421
## 847   2020-42         logistic regression       411
## 848   2020-42              neural network       397
## 849   2020-42          Insights analytics       392
## 850   2020-42                      SQLite       380
## 851   2020-42                     Using R       373
```

```
## 852   2020-42        Sensitivity Analysis       369
## 853   2020-42          Actuarial Analyst        259
## 854   2020-42                        SVD        246
## 855   2020-42             Power Analysis        235
## 856   2020-42        well-documented code       231
## 857   2020-42                        SVM        230
## 858   2020-42              document code        225
## 859   2020-42                        LDA        156
## 860   2020-42                   R Studio        149
## 861   2020-42                    SiSense        148
## 862   2020-42                    RStudio        148
## 863   2020-42                     plotly        147
## 864   2020-42                     ggplot        147
## 865   2020-42                    k-means        144
## 866   2020-42               Web scraping        137
## 867   2020-42           Online analytics        127
## 868   2020-42           Insights Analyst        121
## 869   2020-42                 Highcharts         94
## 870   2020-42          Insights analysis         93
## 871   2020-42         Actuarial analysis         88
## 872   2020-42                      Birst         86
## 873   2020-42                        knn         48
## 874   2020-42                 tidyverse          45
## 875   2020-42                 R packages         35
## 876   2020-42         spatial statistics         35
## 877   2020-42                   GoodData         34
## 878   2020-42          Insurance Analyst         34
## 879   2020-42        Actuarial analytics         27
## 880   2020-42        Insurance analytics         25
## 881   2020-42              Data scraping         25
## 882   2020-42               C programmer         22
## 883   2020-42                      Gauss         22
## 884   2020-42             C++ programmer         22
## 885   2020-42    hierarchical clustering         20
## 886   2020-42         Insurance analysis         20
## 887   2020-42                 R Markdown         19
## 888   2020-42             record linkage         11
## 889   2020-42                     kmeans         10
## 890   2020-42     Computational Engineer         10
## 891   2020-42                Datawrapper          8
## 892   2020-42               FusionCharts          8
## 893   2020-42            Actuary Analyst          6
## 894   2020-42                R Developer          5
## 895   2020-42            Insight Squared          4
## 896   2020-42          Actuary analytics          4
## 897   2020-42                  Dundas BI          3
## 898   2020-42            Polling Analyst          1
## 899   2020-42           Polling analysis          0
## 900   2020-42                   Datapine          0
## 901   2020-42         Analytic Scripting          0
## 902   2020-42           Actuary analysis          0
## 903   2020-42          Polling analytics          0
## 904   2020-42                   Zebra BI          0
## 905   2020-42                Highcharter          0
```

- Create a `hist` and `boxplot` and report `summary(jobs$job.count)`.

(5 points) Histogram and Box Plot

```
hist(jobs$job)
```




```
boxplot(jobs$job.count,ylim = c(0,400000), main='jobs.subset job counts')
```


```
summary(jobs$job.count)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##       0     149    1734   15170   11847  404527
```

[What does the histogram tell you about the data? What does the boxplot tell you about the data? What does `summary` tell you about the data?]

```
deep.dive = c("Microsoft Office", "C++", "SQL", "Computer Science", "Python", "Java", "Statistics", "Da


or = "";
for(search in deep.dive)
  {
  or = paste0(or, " jobs$search.query == '",search,"' | ");
  }
or = substr(or,0, strlen(or) - 2);

## TODO ... update subsetDataFrame to allow "OR" logic, currently only does "AND" ...

# jobs.subset = jobs[ or , ];  # doesn't work ...
jobs.subset = jobs[ jobs$search.query == 'Microsoft Office' |  jobs$search.query == 'C++' |  jobs$searc
```

```r
# stem(jobs.subset$job.count);
# subsetDataFrame(jobs.subset, "job.count", "==", 0);
```

Subset some keywords relevant to this course

```r
jobs.subset
```

Histogram and Box Plot of Subset

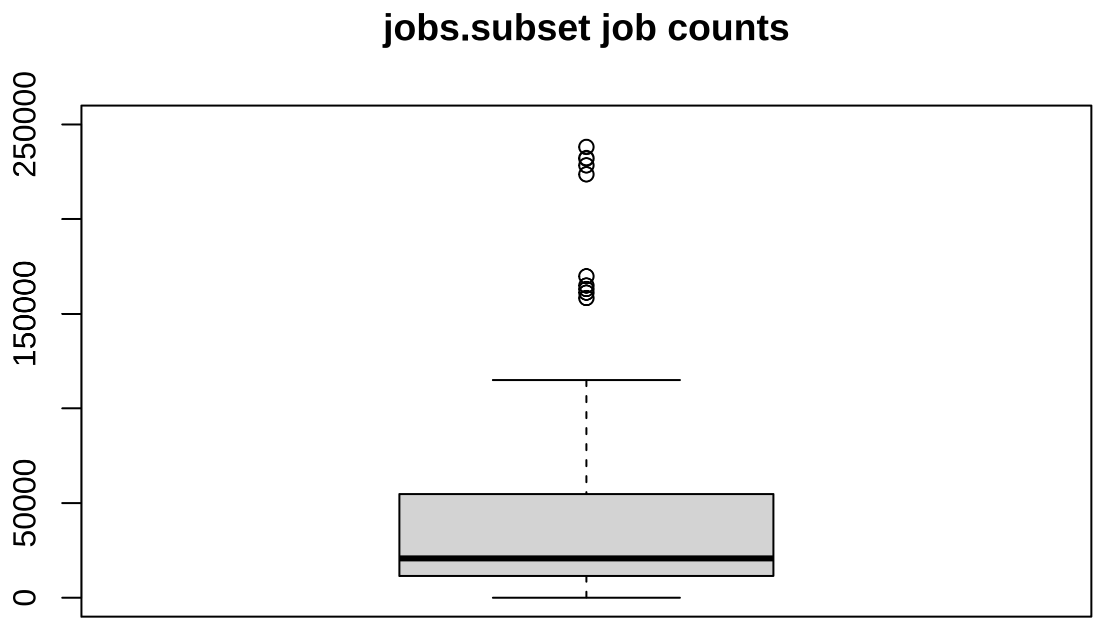
```
##     year.week          search.query job.count
## 2     2020-38      Microsoft Office    223663
## 3     2020-38                   C++    158317
## 6     2020-38      Computer Science    107584
## 7     2020-38            Data entry     80465
## 10    2020-38                   SQL     63365
## 12    2020-38                Python     56538
## 14    2020-38                  Java     49993
## 15    2020-38            Statistics     49383
## 18    2020-38         Data analysis     38384
## 20    2020-38            Javascript     35938
## 24    2020-38      machine learning     23197
## 26    2020-38        Data analytics     21546
## 30    2020-38                   Git     18270
## 34    2020-38              Big data     15737
## 36    2020-38          Data science     15044
## 38    2020-38               Tableau     13321
## 40    2020-38 Business intelligence     13032
## 43    2020-38                   PHP     12367
## 47    2020-38                 Mysql     10809
## 49    2020-38                   SAS     10553
## 71    2020-38              Power BI      5266
## 87    2020-38                  SPSS      2150
## 100   2020-38                 Stata      1186
## 112   2020-38               MariaDB       547
## 183   2020-39      Microsoft Office    228397
## 184   2020-39                   C++    161156
## 187   2020-39      Computer Science    109819
## 188   2020-39            Data entry     83373
## 191   2020-39                   SQL     64810
## 193   2020-39                Python     57841
## 195   2020-39                  Java     51155
## 196   2020-39            Statistics     50588
## 199   2020-39         Data analysis     39447
## 201   2020-39            Javascript     36633
## 205   2020-39      machine learning     24005
## 206   2020-39        Data analytics     22342
## 211   2020-39                   Git     18617
## 215   2020-39              Big data     15997
## 217   2020-39          Data science     15587
## 218   2020-39               Tableau     13735
```

```
## 220   2020-39 Business intelligence     13524
## 225   2020-39                   PHP     12610
## 229   2020-39                   SAS     11039
## 230   2020-39                 Mysql     10942
## 252   2020-39              Power BI      5456
## 268   2020-39                  SPSS      2237
## 279   2020-39                 Stata      1271
## 293   2020-39               MariaDB       582
## 364   2020-40      Microsoft Office    231979
## 365   2020-40                   C++    163044
## 368   2020-40      Computer Science    112070
## 369   2020-40            Data entry     84427
## 372   2020-40                   SQL     66175
## 374   2020-40                Python     58898
## 376   2020-40                  Java     52113
## 377   2020-40            Statistics     51850
## 380   2020-40         Data analysis     40455
## 382   2020-40            Javascript     37554
## 386   2020-40      machine learning     24489
## 387   2020-40        Data analytics     23044
## 395   2020-40              Big data     16463
## 397   2020-40          Data science     15998
## 399   2020-40               Tableau     13943
## 400   2020-40 Business intelligence     13865
## 404   2020-40                   PHP     12962
## 409   2020-40                 Mysql     11137
## 411   2020-40                   SAS     11118
## 432   2020-40              Power BI      5626
## 447   2020-40                  SPSS      2372
## 460   2020-40                 Stata      1336
## 474   2020-40               MariaDB       560
## 542   2020-40                   Git         0
## 545   2020-41      Microsoft Office    232215
## 546   2020-41                   C++    164920
## 549   2020-41      Computer Science    113809
## 550   2020-41            Data entry     85592
## 553   2020-41                   SQL     67313
## 555   2020-41                Python     60241
## 557   2020-41                  Java     52872
## 558   2020-41            Statistics     52159
## 561   2020-41         Data analysis     40836
## 563   2020-41            Javascript     38358
## 567   2020-41      machine learning     24859
## 568   2020-41        Data analytics     23491
## 573   2020-41                   Git     19528
## 578   2020-41              Big data     16619
## 579   2020-41          Data science     16247
## 580   2020-41               Tableau     14430
## 582   2020-41 Business intelligence     14173
## 586   2020-41                   PHP     13119
## 591   2020-41                   SAS     11379
## 593   2020-41                 Mysql     11195
## 614   2020-41              Power BI      5832
## 628   2020-41                  SPSS      2326
```

```
## 641   2020-41                 Stata      1380
## 657   2020-41               MariaDB       560
## 726   2020-42      Microsoft Office    238111
## 728   2020-42                   C++    169786
## 730   2020-42      Computer Science    114970
## 731   2020-42            Data entry     87269
## 734   2020-42                   SQL     68503
## 736   2020-42                Python     61021
## 738   2020-42            Statistics     53016
## 739   2020-42                  Java     52969
## 742   2020-42         Data analysis     41620
## 744   2020-42            Javascript     38637
## 748   2020-42      machine learning     25172
## 749   2020-42        Data analytics     24058
## 753   2020-42                   Git     19945
## 758   2020-42          Data science     16665
## 759   2020-42              Big data     16518
## 761   2020-42               Tableau     14707
## 763   2020-42 Business intelligence     14337
## 767   2020-42                   PHP     13244
## 772   2020-42                   SAS     11596
## 774   2020-42                 Mysql     11425
## 795   2020-42              Power BI      5987
## 809   2020-42                  SPSS      2342
## 822   2020-42                 Stata      1423
## 835   2020-42               MariaDB       610
```

```r
hist(jobs.subset$job.count)
```


```
boxplot(jobs.subset$job.count, ylim = c(0,250000), main='jobs.subset job counts')
```



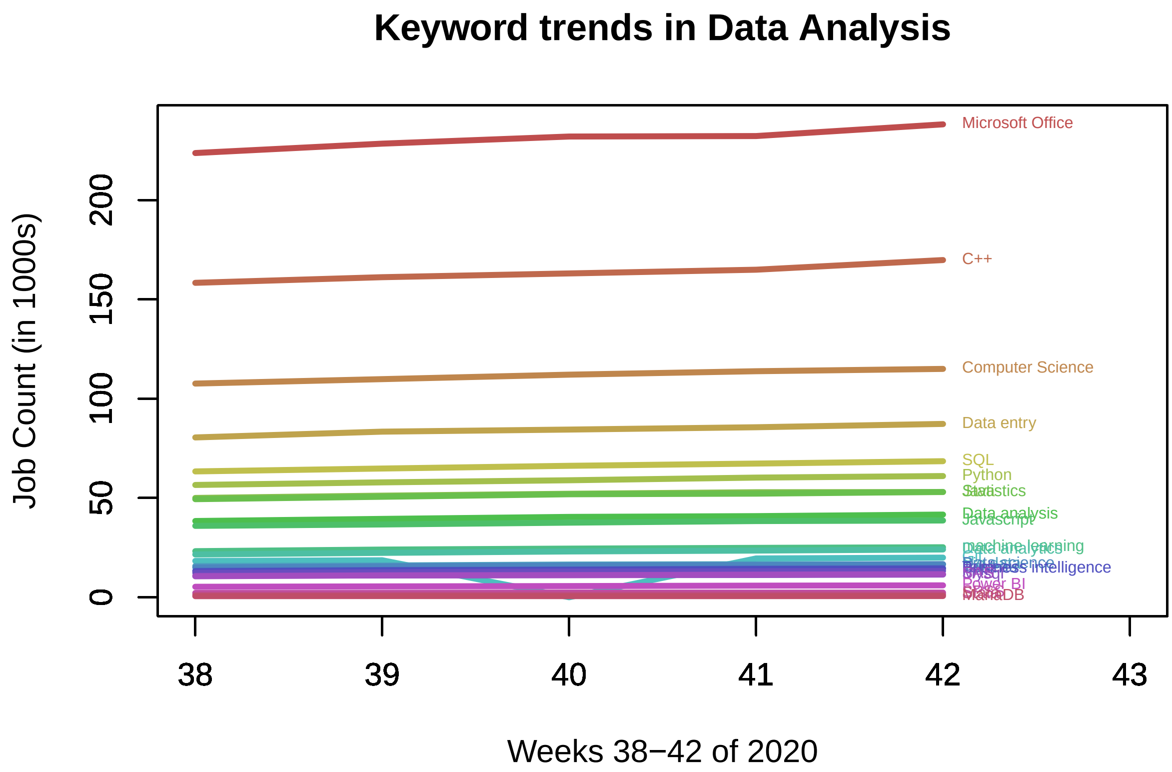

```
summary(jobs.subset$job.count)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##       0   11553   20746   44306   53897  238111
```

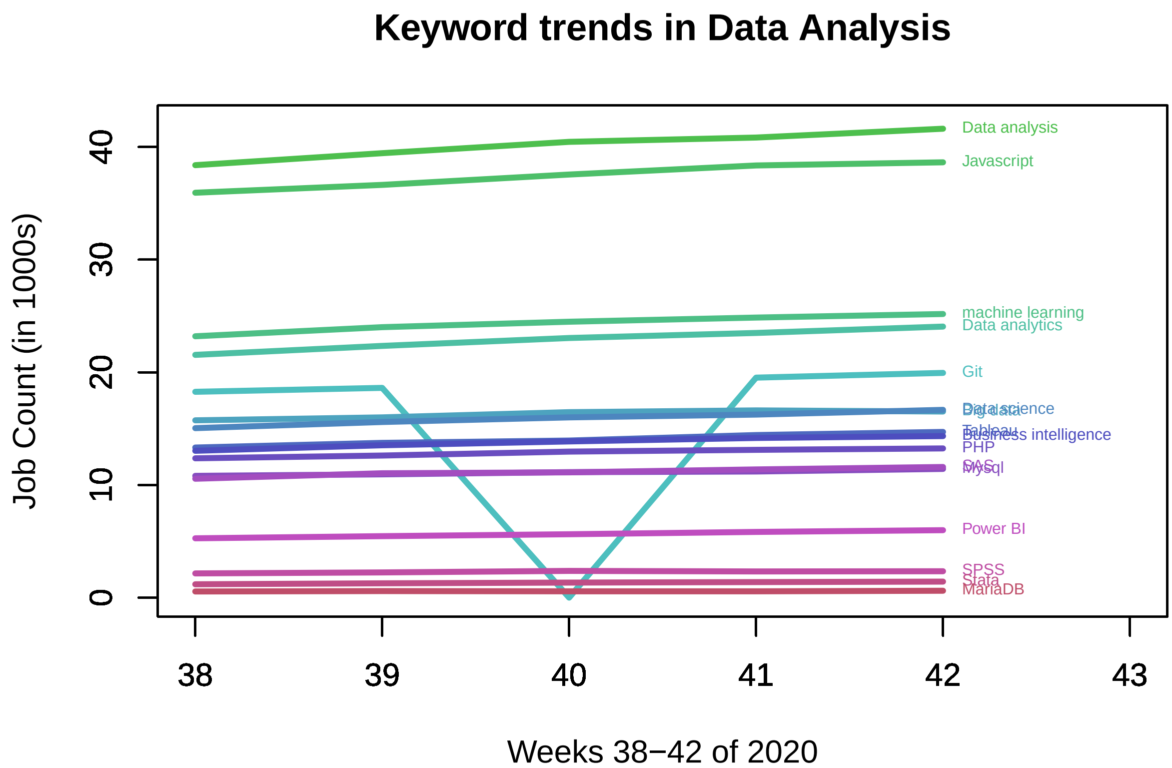
[What does the histogram tell you about the data? What does the boxplot tell you about the data?]

(10 points) Trends in Relevant Subset

```
jobs.subset$year.week = as.numeric( gsub("-",".",jobs.subset$year.week, fixed=TRUE) );


jobs.subset = sortDataFrameByNumericColumns(jobs.subset, c("year.week","job.count"), c("ASC","DESC") );
# easier to manage as "how many thousand jobs"
jobs.subset$job.count.k = jobs.subset$job.count / 1000;

do.nothing = plotJobs(jobs.subset);
```




```
do.nothing = plotJobs(jobs.subset, myy.lim = c(0,42) );
```

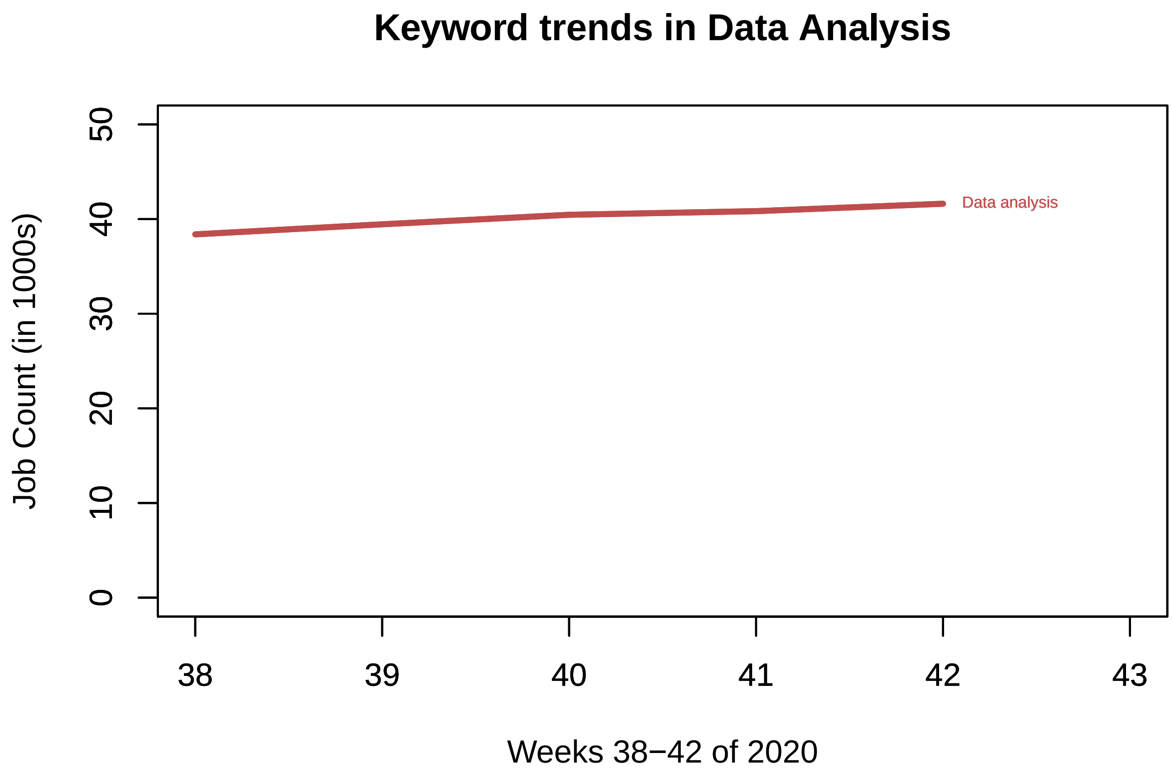



```r
jobs.da <- subset(jobs.subset, search.query=='Data analysis')
jobs.da
```

Initial Perspective

```
##     year.week  search.query job.count job.count.k
## 18    2020.38 Data analysis     38384      38.384
## 199   2020.39 Data analysis     39447      39.447
## 380   2020.40 Data analysis     40455      40.455
## 561   2020.41 Data analysis     40836      40.836
## 742   2020.42 Data analysis     41620      41.620
```

```r
jobs.da$job.count.k = jobs.da$job.count / 1000;
plotJobs(jobs.da, myy.lim = c(0,50))
```




```
## $colors
## [1] "#BF4D4D"
##
## $search
## [1] "Data analysis"
```

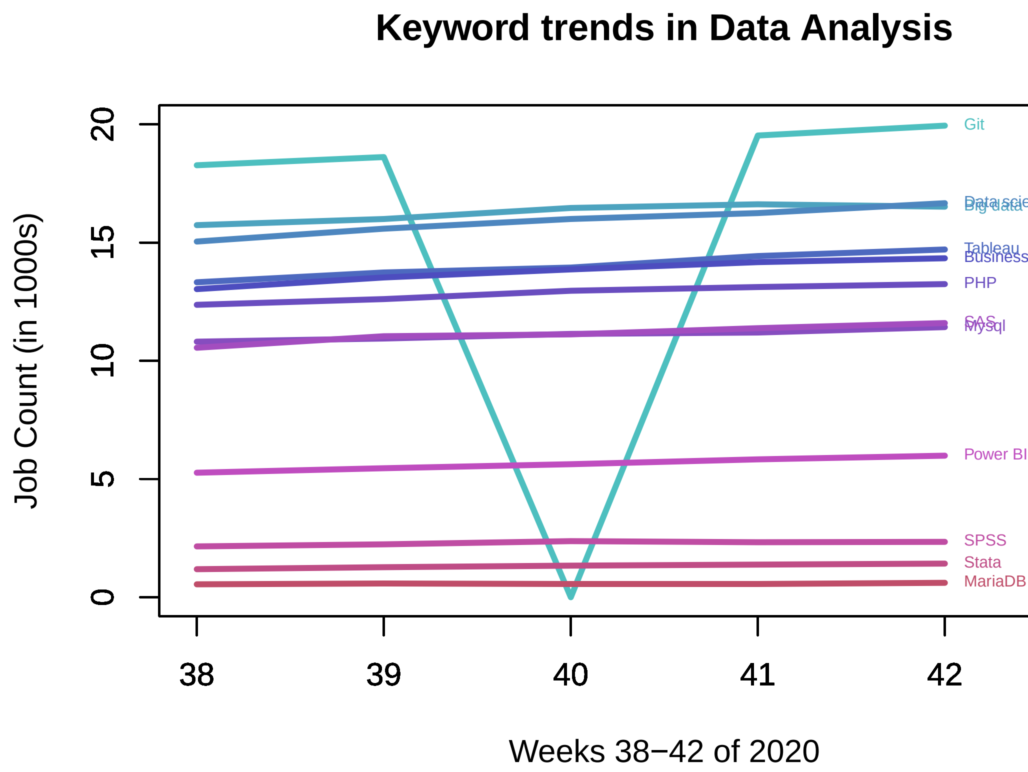
[What is your initial "perspective" of this data, now that you see it? Why are the lines "parallel-ish"? What kind of a trend is that?

Now comment on the line of data for "Data analysis". How is it trending? How does it compare to other Search-Query Words?

What is your first perspective?

]

```
do.nothing = plotJobs(jobs.subset, myy.lim = c(0,20) );
```



Missing Data "Git" Week 40?

Git-40/Git-41 data history, notice the date-time and file sizes . . .

Source: Data provenance history

Source: Data provenance history

[Is this data missing or did it just drop to zero that week? How does this relate to the other data (remember the idea of "continuity" in mathematics)? What should you do about it?]

```
idxs.week.40 = which(jobs.subset$year.week == 2020.40);
idxs.Git     = which(jobs.subset$search.query == "Git");

# set notation
my.idx = intersect(idxs.Git,idxs.week.40);

jobs.subset[idxs.Git,];
```

```
##     year.week search.query job.count job.count.k
## 30    2020.38          Git     18270      18.270
## 211   2020.39          Git     18617      18.617
## 542   2020.40          Git         0       0.000
## 573   2020.41          Git     19528      19.528
## 753   2020.42          Git     19945      19.945
```

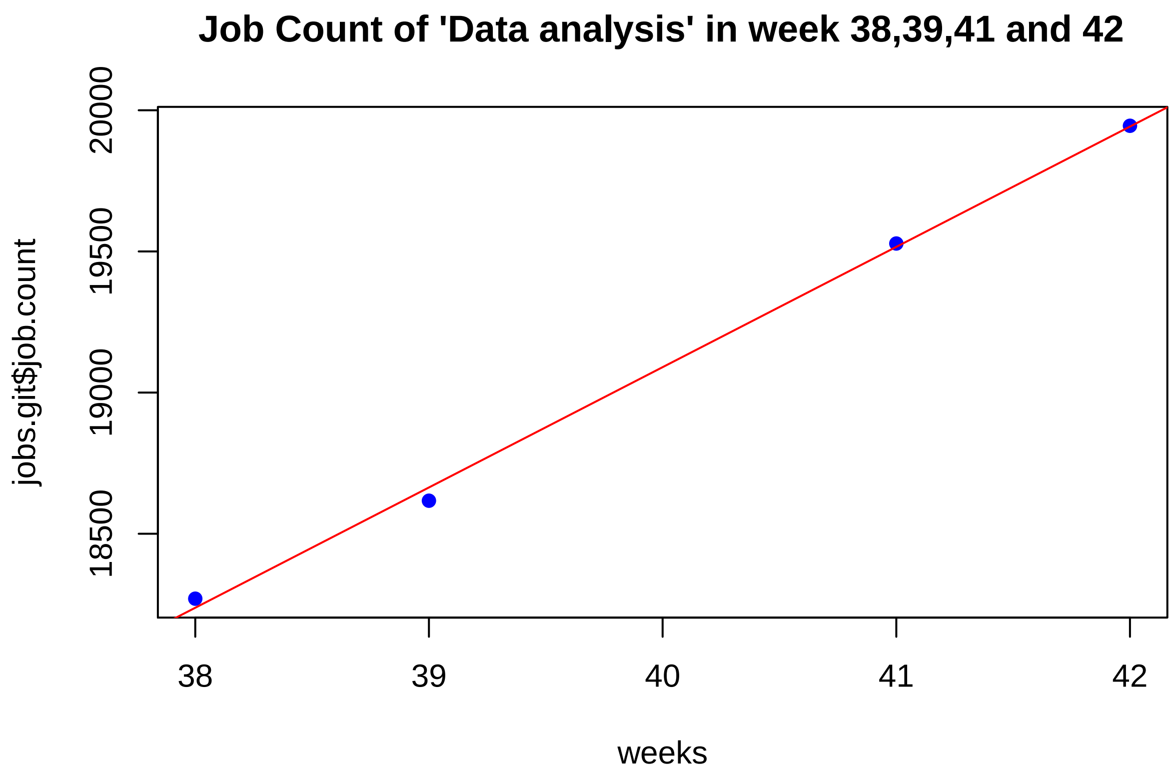
```
jobs.subset[my.idx,];
```

```
##     year.week search.query job.count job.count.k
## 542    2020.4          Git         0           0
```

```r
## change this if you feel appropriate?  To what number?

## I can use the data points that aren't missing to find the best fit line, then find a value the week 
# Creating subset of data excluding week40
jobs.git <- jobs.subset[idxs.Git,][-c(3),]
jobs.git
```

```
##     year.week search.query job.count job.count.k
## 30    2020.38          Git     18270      18.270
## 211   2020.39          Git     18617      18.617
## 573   2020.41          Git     19528      19.528
## 753   2020.42          Git     19945      19.945
```

```r
#  Plot the jobs.git  with best fit line
weeks <- c(38,39,41,42)
plot(weeks, jobs.git$job.count, pch=16, col="blue", main = "Job Count of 'Data analysis' in week 38,39,4
abline(lm(jobs.git$job.count ~weeks), col="red")
```

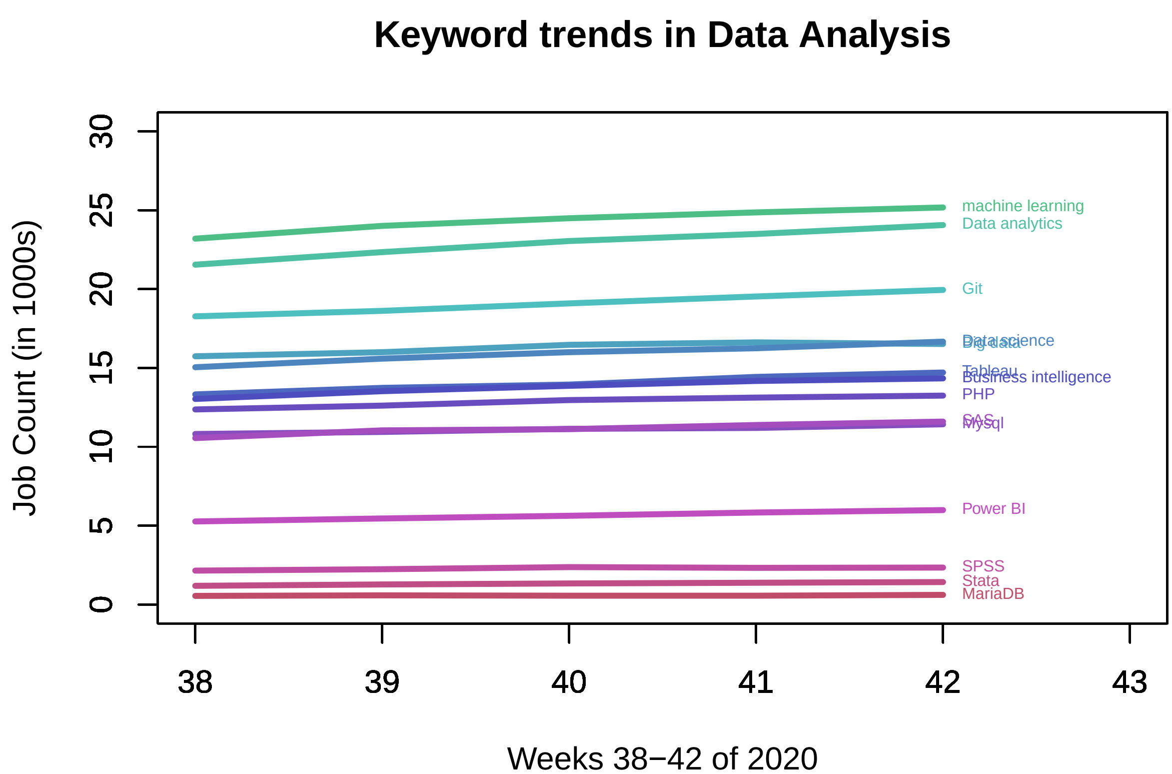



```r
lm(jobs.git$job.count ~weeks)
```

```
##
## Call:
## lm(formula = jobs.git$job.count ~ weeks)
##
```

```
## Coefficients:
## (Intercept)        weeks
##      2046.0        426.1
```

```r
# now we found the linear model : 2046.0 + 426.1*(week)
# find value for the week 40 using the equation above
jobcount.40 <- 2046.0 + 426.1*40


jobs.subset[my.idx,3] <- jobcount.40         # job.count
jobs.subset[my.idx,4] <- jobcount.40/1000    # job.count.k (in thousands) ...

do.nothing = plotJobs(jobs.subset, myy.lim = c(0,30) )
```

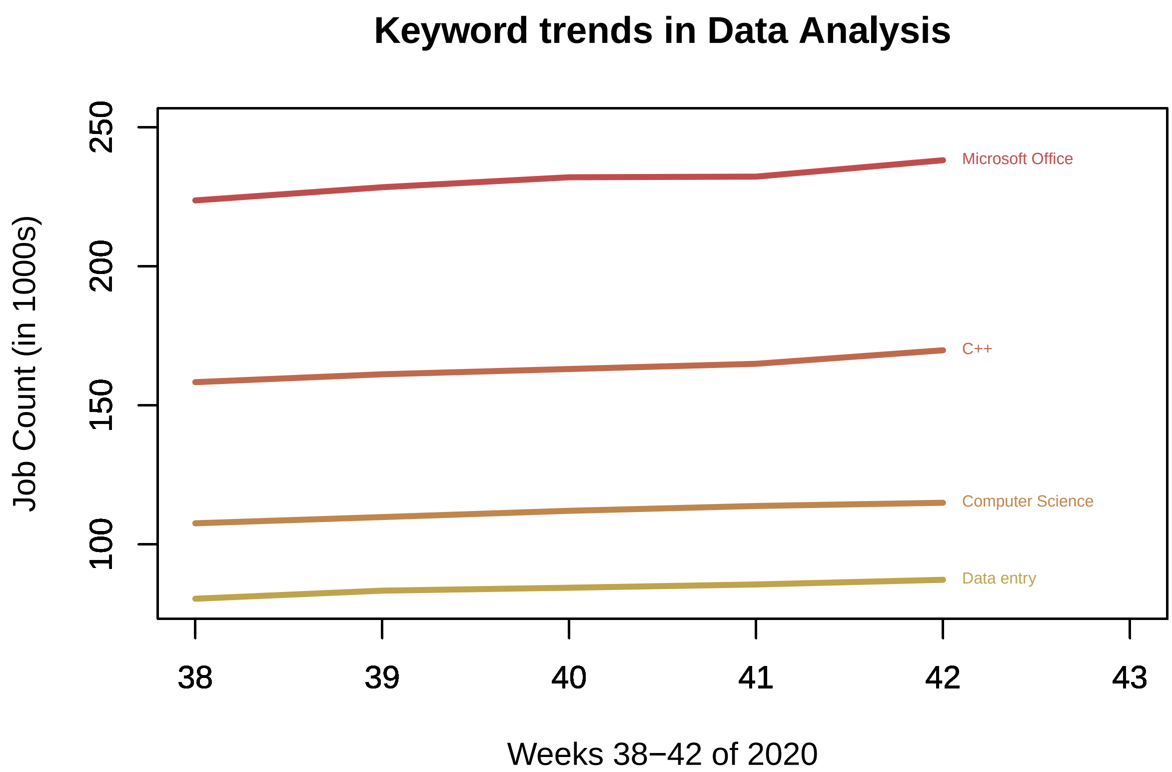


Is "Microsoft Office" bigger than "C++"? I use the term "bigger" or "better" intentionally. We are comparing two items, and these are generic ways of communicating such a comparison. In context of this data problem, a formalized form of the question would be something like: "Utilizing job count for a given search query, determine if the query 'Microsoft Office' has a larger job count than the query 'C++'?" This question will need to be formalized if we are trying to draw specific conclusions, but the initiation of analysis "which is bigger" allows us to understand what the data says or does not say, through exploration.

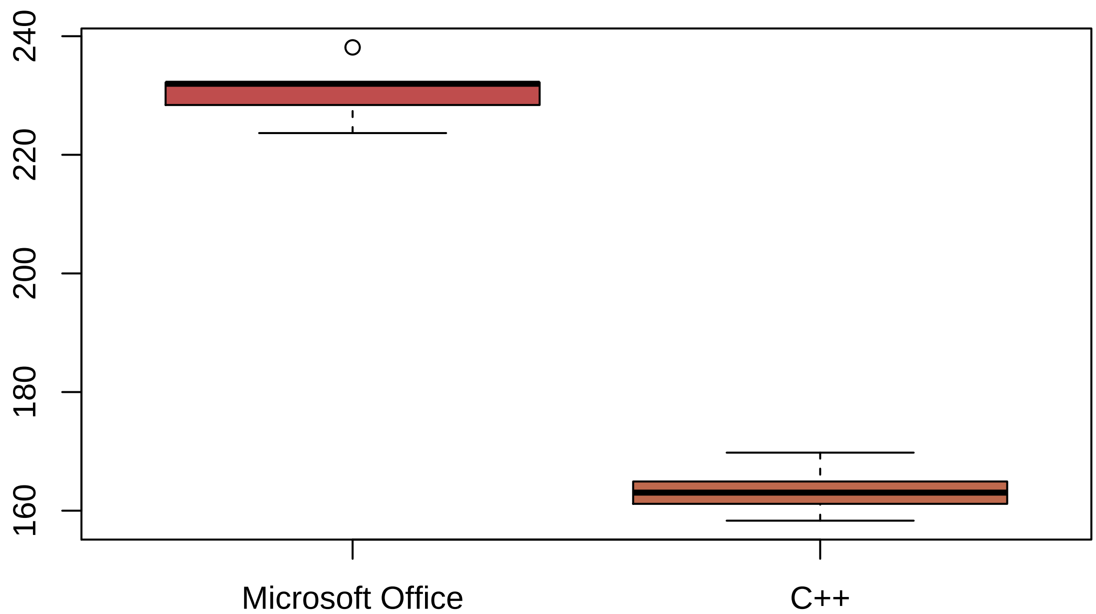
To answer the question:

Mathematically, if two lines are parallel, and one is above the other, can we use **distance** to draw a conclusion? Now, many times in statistics we deal with noise in the data, it is not "deterministic" but "stochastic" . . . so we need to understand the variability. Based on the data we see, can we not use “parallel-line” logic to conclude that they are different? This is one dimension of EDA, use mathematics. (“mathematics”)

```
do.nothing = plotJobs(jobs.subset, myy.lim = c(80,250) );
```




```
boxplotJobQueryComparison(jobs.subset, "Microsoft Office", "C++");
```



Tukey invented the boxplot as a nice EDA representation of the data. What logical inference can we make about the distances between the boxplots and the fact that no data is overlapping. This is another dimension of EDA, use "distance" and the boxplot "IQR" to compare two elements. What conclusion would we make? ("boxplot")

```r
msoffice <- jobs.subset[which(jobs.subset$search.query == "Microsoft Office"),]
c <- jobs.subset[which(jobs.subset$search.query == "C++"),]

summary(msoffice$job.count.k)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##   223.7   228.4   232.0   230.9   232.2   238.1
```

```r
summary(c$job.count.k)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##   158.3   161.2   163.0   163.4   164.9   169.8
```

[Can we conclude the data are different based on "mathematics" or "boxplot"?

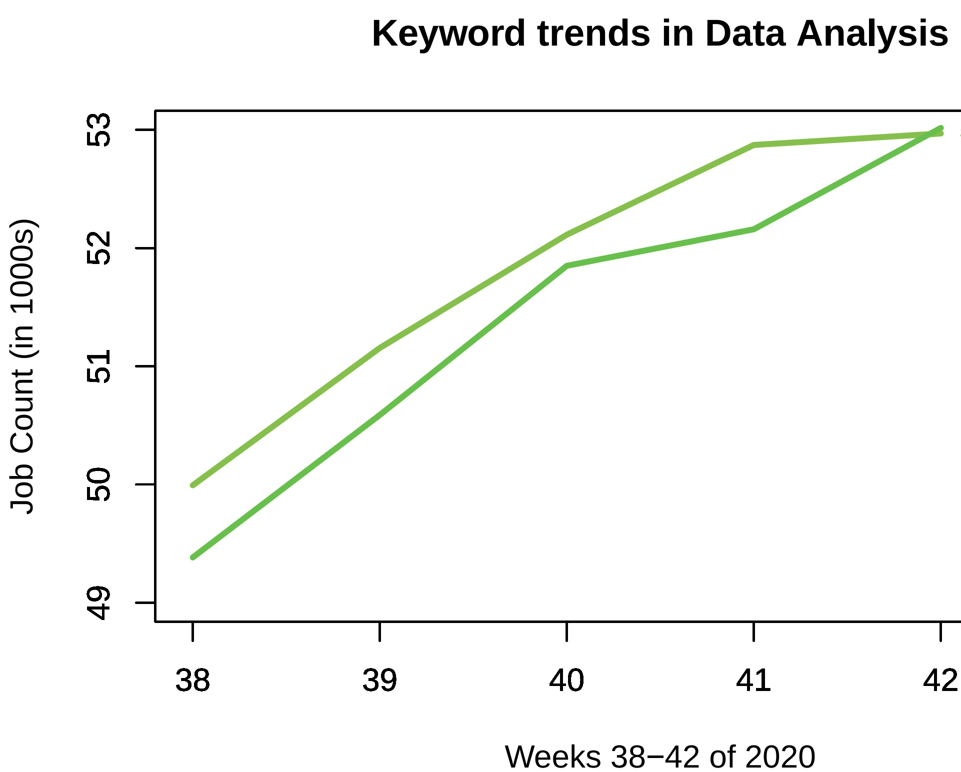
Would a formal "inferential statistical test" tell us something different than logical inference?

How do you think "formal tests" were derived if not from "mathematics" and "boxplot" (EDA)?]

```r
# courage in trusting your intuition may require a fall-back ... for those that need it ...

t.test.jobs(jobs.subset, "Microsoft Office", "C++");
```

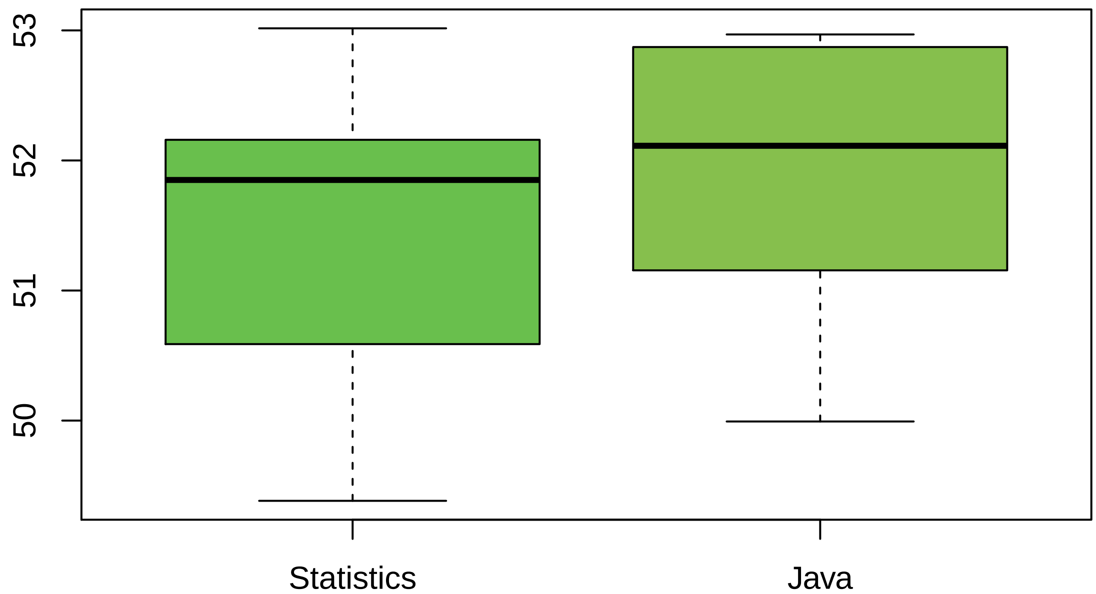
```
##
##  Welch Two Sample t-test
##
## data:  x and y
## t = 22.016, df = 7.6613, p-value = 0.00000003332
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  60.31098 74.54582
## sample estimates:
## mean of x mean of y
##  230.8730  163.4446
```

```r
do.nothing = plotJobs(jobs.subset, myy.lim = c(49,53) );
```



Is "Statistics" bigger than "Java"?

```r
do.nothing = boxplotJobQueryComparison(jobs.subset, "Statistics", "Java");
```



For this data, I can descriptively report that the third-quartile `Q3` of "Statistics" is about equal to the `median` of "Java". The inter-quartile range (`IQR`) of each overlap. The minimum value of "Java" is larger than the minimum value of "Statistics". The maximum value of "Java" is slightly smaller than the maximum value of "Statistics".

```
summary(jobs.subset[which(jobs.subset$search.query == "Statistics"),]$job.count.k)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##   49.38   50.59   51.85   51.40   52.16   53.02
```

```
summary(jobs.subset[which(jobs.subset$search.query == "Java"),]$job.count.k)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##   49.99   51.16   52.11   51.82   52.87   52.97
```

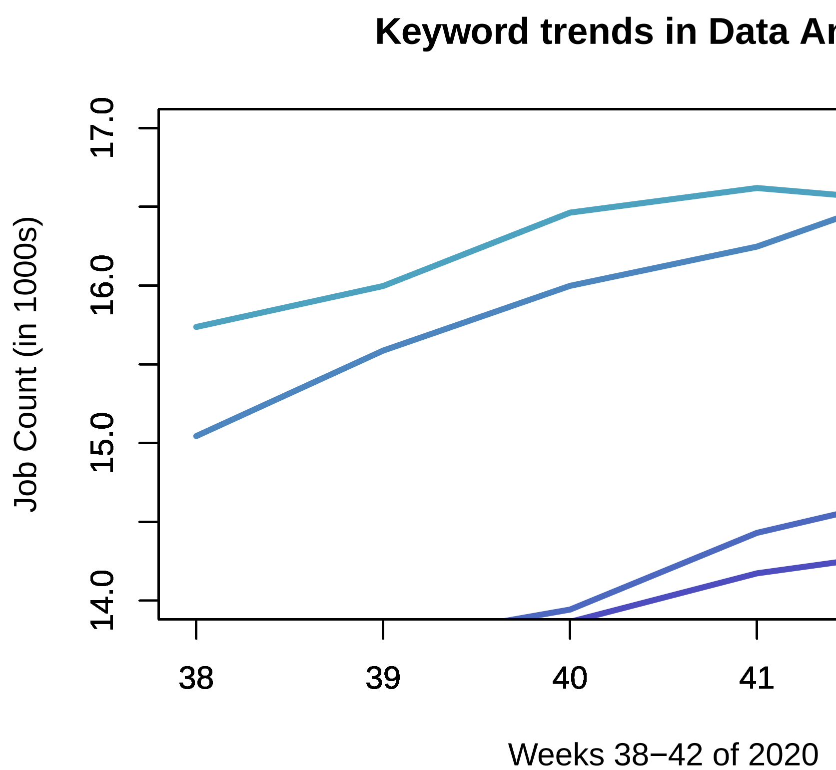
```
t.test.jobs(jobs.subset, "Statistics", "Java");
```

```
##
##  Welch Two Sample t-test
##
## data:  x and y
## t = -0.49621, df = 7.8738, p-value = 0.6333
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
```

```
## -2.384104  1.541704
## sample estimates:
## mean of x mean of y
##   51.3992   51.8204
```

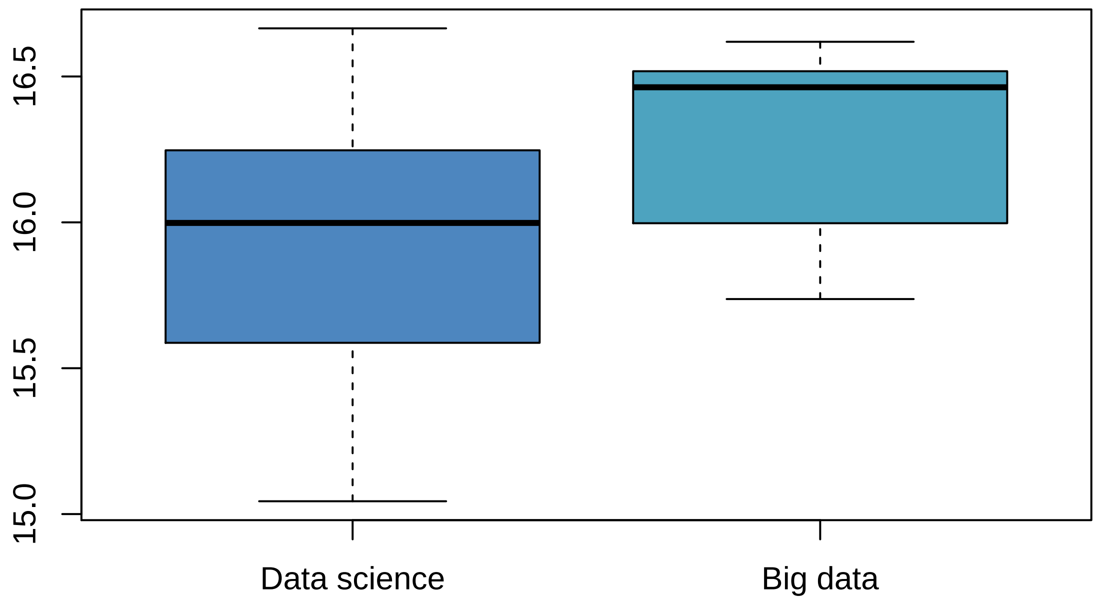
[Use “mathematics” and “boxplot” and “ttest” to answer the question: Is “Statistics” bigger than “Java”?]

```r
do.nothing = plotJobs(jobs.subset, myy.lim = c(14,17) );
```



What about “Data science” and “Big data”?

```r
boxplotJobQueryComparison(jobs.subset, "Data science", "Big data");
```




```r
summary(jobs.subset[which(jobs.subset$search.query == "Data science"),]$job.count.k)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##   15.04   15.59   16.00   15.91   16.25   16.66
```

```r
summary(jobs.subset[which(jobs.subset$search.query == "Big data"),]$job.count.k)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##   15.74   16.00   16.46   16.27   16.52   16.62
```

```r
t.test.jobs(jobs.subset, "Data science", "Big data");
```

```
##
##  Welch Two Sample t-test
##
## data:  x and y
## t = -1.1002, df = 6.6285, p-value = 0.3096
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -1.1381677  0.4209677
## sample estimates:
## mean of x mean of y
##   15.9082   16.2668
```

From the box plot, we can see that the median value of 'Big data' slightly larger than the Q3 value of 'Data Science'. The whiskers(maximum to the minimum values) shows that 'Data Science' data has a wider distribution, that is. more scattered compared to the 'Big data' data. After looking at the plot and the boxplot, We get a sense that these two data might not differ much from each other. We can verify this by looking at the Welch two-sample t-test results. The p-value = 0.3096 and the significance level = 0.05. Thus, we cannot reject the null hypothesis of no difference between the true averages of the two groups at the significance level of 0.05.

It is very possible that the single-job posting will include many keywords. When we looking at the jobs.subset data, we are looking at closely related keywords for data analytics. Maybe the better way to collect the data can be getting rid of duplicated job posts between data sets compared.

[Use "mathematics" and "boxplot" and "ttest" to make a conclusion.

Next, think carefully about the nature of the data. Is the "collection-approach" flawed to make a conclusion comparing job-counts of these specific keywords? How likely is it that a single-job posting may have both keywords?

This is an example where "data-integrity" knowledge would surpass the other three logical conclusions.

This intuition requires an understanding of what mathematicians call "set theory". If I am doing an independent search on keywords, is it possible that one job would show up in multiple searches. That is, being counted twice or more.

Intuition and logic would also allow us to conclude that our other comparisons are "very likely okay". Why?

What would be an improved approach to collecting the data that would allow me to more accurately compare these two keywords?

This is representative of why exploratory data analysis is essential. It provides us insight into the domain and highlights the need for better data, if we can find it.

]

Conclusions on logical inference

Distance is a fundamental unit of comparison. We can use our "mathematical" understanding of distance. We can use an "EDA" understanding of the data (e.g., the boxplot). We need to understand the data sourcing and how that will relate to the logical conclusions we are trying to draw.

When we transition to "confirmatory inferential statistics", we cannot leave our understanding of "maths" and "EDA" behind. They are the foundation from which "inferential statistics" is built. They are "logical inference".

COMPUTING DISTANCES

If you recall, we had a notebook on collecting data from Wikipedia. We documented the "data-provenance" protocols to make this happen. We have documented and can replicate our data-collection strategies.

(10 points) Data Provenance defined

Imagine you are preparing for a job interview. Write a 90-second blurb describing "what is data provenance" and "why it matters". I would suggest the STAR(S) approach mentioned in one of the notebooks. Reference the "Wikipedia" project as an example of how one can implement the features.

[What is data provenance?

Probably about 200-250 words (with the 90 second limit)]

Geospatial distances

"Geo-spatial" studies are becoming much more common in the "data analytics" community, so let's use basic "latitude/longitude" data to formally talk about "distance."

So we will look at the 50 state capitals of America (USA). Before that, let's examine some basic principles of distances using my hometown.

(5 points) Distance from one input to multiple outputs

My Hometown "Columbia Falls, Montana" `cfalls`

- Find all ZIP codes within 22 miles of Columbia Falls, MT `cfalls` (use lat/long provide from the Wikipedia lookup)... build the bounding "box" and perform the post-hoc "radial distance" computations (as we did in the homework).

```
# copy/paste __student_access__/_SECRET_/_SECRET_database_.txt into console...  or this won't work

cfalls.latitude = 48.37028;
cfalls.longitude = -114.18889;
my.radius = 22; my.units = "mi"; #miles

# THIS is where these exam functions live ...
# source_url( paste0(path.github,"misc/functions-midterm-F2000.R") );  # should be 2020 ... oh well




cfalls.info = getNeighborsFromLatLong(22, 48.37028, -114.18889, "mi");
```

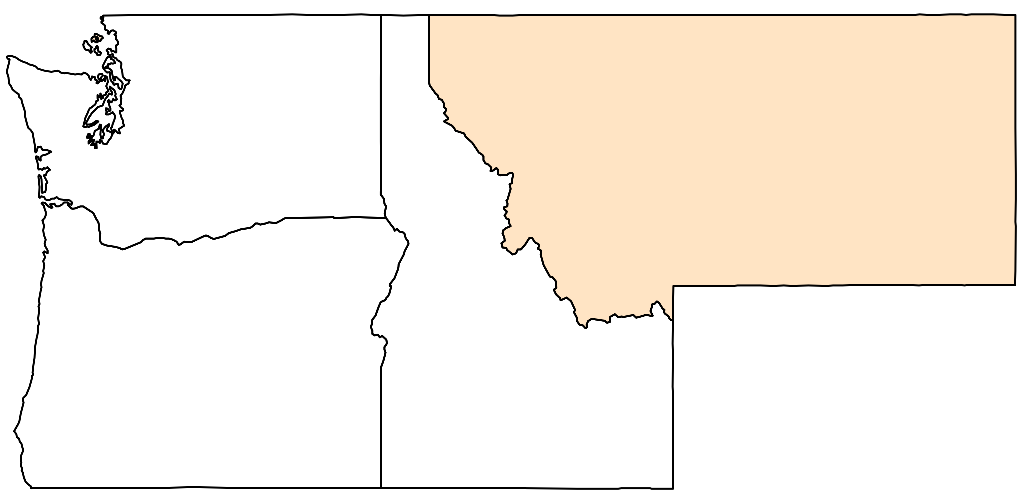
```
## [1] "The QUERY returned ...  13  ... NEIGHBORS"
```

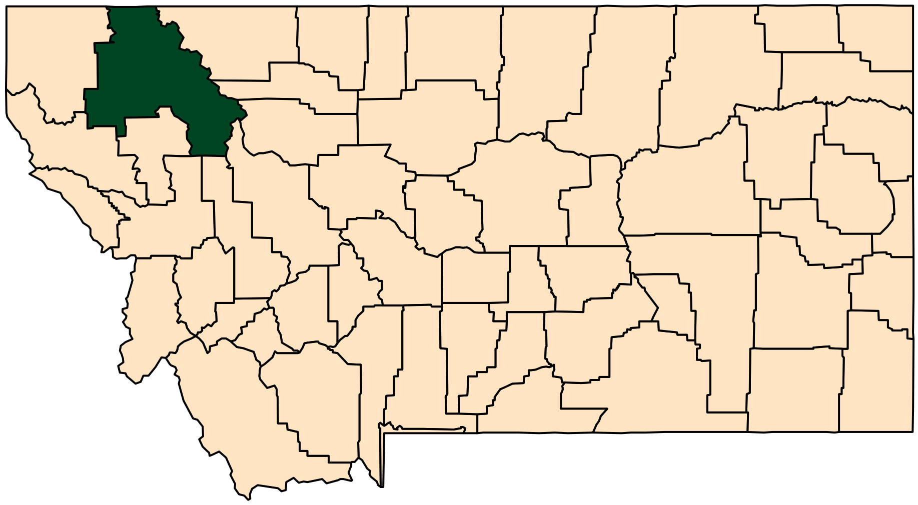
```
cfalls.info$neighbors;
```

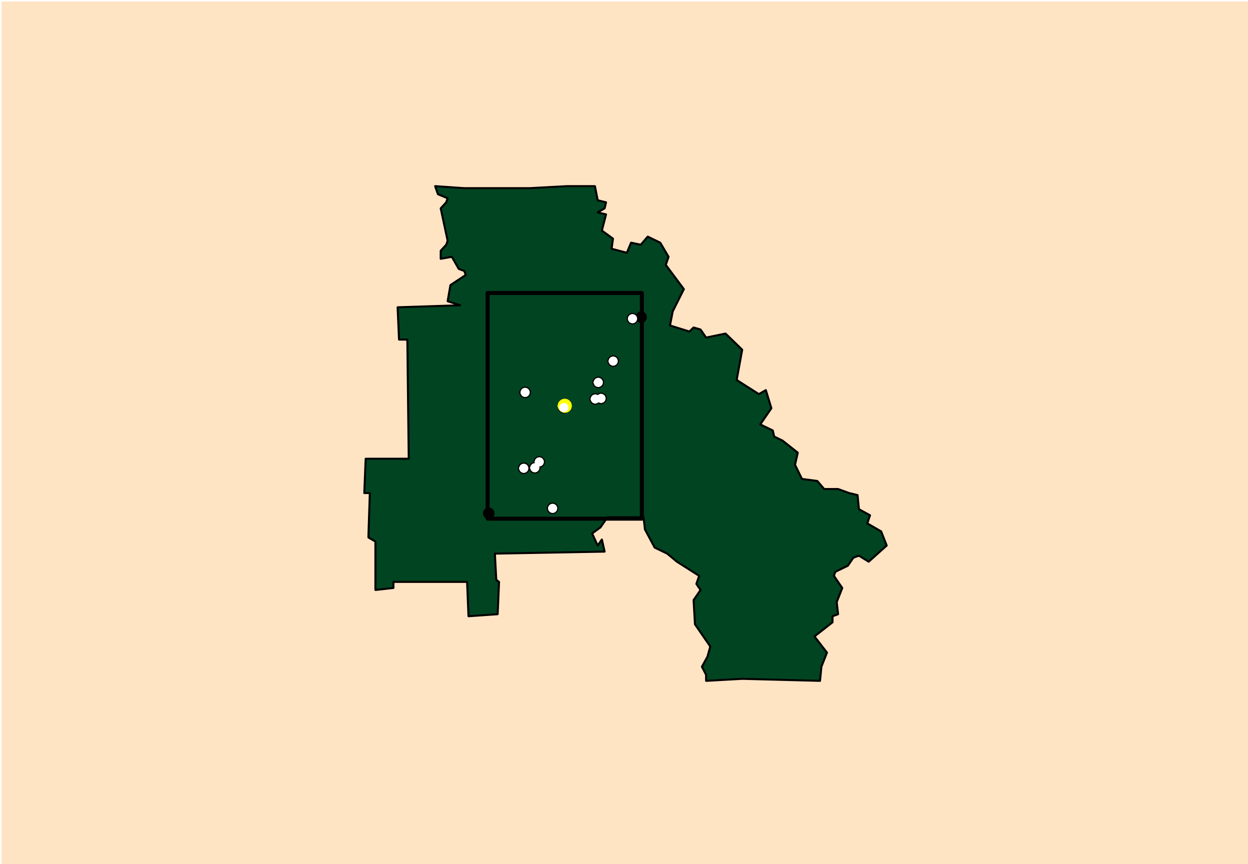
```
##    zipcode latitude longitude           city state_long state
## 1    59901 48.21124 -114.2939      KALISPELL    MONTANA    MT
## 2    59903 48.19303 -114.3579      KALISPELL    MONTANA    MT
## 3    59904 48.19452 -114.3123      KALISPELL    MONTANA    MT
## 4    59912 48.36531 -114.1927 COLUMBIA FALLS    MONTANA    MT
## 5    59913 48.43674 -114.0507          CORAM    MONTANA    MT
## 6    59916 48.61750 -113.9095          ESSEX    MONTANA    MT
## 7    59919 48.38969 -114.0630   HUNGRY HORSE    MONTANA    MT
## 8    59920 48.06516 -114.5023           KILA    MONTANA    MT
## 9    59921 48.62189 -113.8739 LAKE MC DONALD    MONTANA    MT
## 10   59926 48.39134 -114.0393    MARTIN CITY    MONTANA    MT
## 11   59932 48.07931 -114.2389         SOMERS    MONTANA    MT
## 12   59936 48.49720 -113.9892   WEST GLACIER    MONTANA    MT
## 13   59937 48.40834 -114.3522      WHITEFISH    MONTANA    MT
```

```
############# plotting #############
brown = "#ffe4c4";
green = "#014421";
```

```r
my.state = "montana";
my.state.color = "#ffe4c4";

my.county = "flathead";
my.county.color = "#014421";

my.nearby.states = c("idaho", "washington", "oregon");


plotNeighbors(cfalls.info,
                    state           = my.state,
                    state.color     = my.state.color,
                    state.border    = 0.05,
                    county          = my.county,
                    county.border    = 0.05,  # if you don't see the box, increase this to like 0.75
                    county.color    = my.county.color,
                    nearby.states   = my.nearby.states);
```







[- why is the box not a square, but a rectangle? ... see `factor.lat` and `factor.long` in function `buildBoundingBoxFromRadiusAndGivenLatitudeLongitude` - critique the visualization ... what do you like? what would make it better?]

Your Hometown of something like it Instead of `cfalls.info`, you do `hometown.info`

- a location in the continental US of your choosing (not in Montana, Alaska, or Hawaii). [Graphing will not work for Alaska/Hawaii, Alaska has "boroughs" not counties.]
- find the latitude/longitude of the location you have selected (how and where to look that up?)
- Initially start with a radius of `13 miles`
- When you run the code, note how many total "neighbors"; if it is less than 20; increase the "miles" so at least 20 results are returned.
- In the end, you should select a location and radius that works for you. And its visualization also works.
- Be certain to review and update the parameters before calling these functions.

hometown.latitude = 00.00000; hometown.longitude = -000.00000; my.radius = 13; my.units = "mi"; #miles hometown.info = getNeighborsFromLatLong(????); plotNeighbors(hometown.info, ????); # you are going to have to change some of these parameters ...

```
hometown.latitude = 47.957470
hometown.longitude = -122.165446
my.radius = 13
my.units = "mi" #miles

# THIS is where these exam functions live ...
```

```r
# source_url( paste0(path.github,"misc/functions-midterm-F2000.R") );  # should be 2020 ... oh well

hometown.info = getNeighborsFromLatLong(my.radius, hometown.latitude, hometown.longitude, "mi")
```

```
## [1] "The QUERY returned ...  24  ... NEIGHBORS"
```

```r
hometown.info$neighbors
```

```
##    zipcode latitude longitude             city state_long state
## 1    98012 47.84130 -122.2058          BOTHELL WASHINGTON    WA
## 2    98021 47.79165 -122.2174          BOTHELL WASHINGTON    WA
## 3    98026 47.84077 -122.3367          EDMONDS WASHINGTON    WA
## 4    98036 47.80278 -122.2849         LYNNWOOD WASHINGTON    WA
## 5    98037 47.85110 -122.2815         LYNNWOOD WASHINGTON    WA
## 6    98043 47.79179 -122.3041 MOUNTLAKE TERRACE WASHINGTON    WA
## 7    98046 47.83017 -122.3040         LYNNWOOD WASHINGTON    WA
## 8    98082 47.85524 -122.2210       MILL CREEK WASHINGTON    WA
## 9    98087 47.87263 -122.2709         LYNNWOOD WASHINGTON    WA
## 10   98201 47.98859 -122.2018          EVERETT WASHINGTON    WA
## 11   98203 47.94596 -122.2299          EVERETT WASHINGTON    WA
## 12   98204 47.89843 -122.2548          EVERETT WASHINGTON    WA
## 13   98205 47.99055 -122.1141          EVERETT WASHINGTON    WA
## 14   98206 47.92563 -122.2264          EVERETT WASHINGTON    WA
## 15   98207 47.95998 -122.1968          EVERETT WASHINGTON    WA
## 16   98208 47.89491 -122.1934          EVERETT WASHINGTON    WA
## 17   98213 47.94082 -122.2347          EVERETT WASHINGTON    WA
## 18   98258 48.02742 -122.0624     LAKE STEVENS WASHINGTON    WA
## 19   98270 48.06088 -122.1539       MARYSVILLE WASHINGTON    WA
## 20   98271 48.09840 -122.2373       MARYSVILLE WASHINGTON    WA
## 21   98275 47.90714 -122.3091         MUKILTEO WASHINGTON    WA
## 22   98290 47.93953 -122.0167        SNOHOMISH WASHINGTON    WA
## 23   98291 47.92897 -122.0999        SNOHOMISH WASHINGTON    WA
## 24   98296 47.82290 -122.1182        SNOHOMISH WASHINGTON    WA
```

```r
############## plotting ##############
brown = "#ffe4c4"
green = "#014421"

my.state = "washington"
my.state.color = "#ffe4c4"

my.county = "flathead"
my.county.color = "#014421"

my.nearby.states = c("idaho","montana", "oregon")

## I have tried multiple times to make this code work but was not successful..... I'm getting an error
## I think this might be due to my version of R? .. My r is 4.0.2 do I need to update?..
## Please try this code below to check if it works on your machine

# plotNeighbors(hometown.info,
#                      state          = my.state,
```

```
#                       state.color    = my.state.color,
#                       state.border   = 0.05,
#                       county         = my.county,
#                       county.border  = 0.05,  # if you don't see the box, increase this to like 0.75
#                       county.color   = my.county.color,
#                       nearby.states  = my.nearby.states)
```

U.S. State Capitals (cities)

From Wikipedia, we grabbed one page that listed the 50 U.S. cities that are designated the capitals of each individual state in America (United States of America).

Using the power of a `for-loop` we make our functions work for us. We now have the data ready to go.

```
capitals = utils::read.csv( paste0(path.mshaffer, "_data_/state-capitals/final/state-capitals.txt"), hea

colnames(capitals) = c("state", "capital", "latitude", "longitude", "capital.since", "area.sq.miles", "

# hack-add from https://en.wikipedia.org/wiki/ISO_3166-2:US
# TODO, grab this table "appropriately" as a new function
# Is there a dictionary for shortened city names?
# the long-field names is also an issue that needs to be improved upon in the next iteration.

capitals$st = c("AL","AK","AZ","AR","CA","CO","CT","DE","FL","GA","HI","ID","IL","IN","IA","KS","KY","L

myLabels = paste0(capitals$capital, ", ", capitals$st);

capitals;
```

```
##             state       capital latitude  longitude capital.since
## 1         Alabama     Montgomery 32.36167  -86.27917          1846
## 2          Alaska         Juneau 58.30000 -134.41600          1906
## 3         Arizona        Phoenix 33.45000 -112.06700          1912
## 4        Arkansas    Little Rock 34.73611  -92.33111          1821
## 5      California     Sacramento 38.58167 -121.49444          1854
## 6        Colorado         Denver 39.73917 -104.99028          1867
## 7     Connecticut       Hartford 41.76250  -72.67417          1875
## 8        Delaware          Dover 39.15806  -75.52444          1777
## 9         Florida    Tallahassee 30.45500  -84.25333          1824
## 10        Georgia        Atlanta 33.75500  -84.39000          1868
## 11         Hawaii       Honolulu 21.30694 -157.85833          1845
## 12          Idaho          Boise 43.61583 -116.20167          1865
## 13       Illinois    Springfield 39.79944  -89.65500          1837
## 14        Indiana   Indianapolis 39.76861  -86.15806          1825
## 15           Iowa     Des Moines 41.59083  -93.62083          1857
## 16         Kansas         Topeka 39.05583  -95.68944          1856
## 17       Kentucky      Frankfort 38.20000  -84.86700          1792
## 18      Louisiana    Baton Rouge 30.44750  -91.17861          1880
## 19          Maine        Augusta 44.31056  -69.77944          1832
## 20       Maryland      Annapolis 38.97306  -76.50111          1694
## 21  Massachusetts         Boston 42.35806  -71.06361          1630
## 22       Michigan        Lansing 42.73361  -84.54667          1847
## 23      Minnesota     Saint Paul 44.94417  -93.09361          1849
```

```
## 24    Mississippi        Jackson 32.29889  -90.18472          1821
## 25       Missouri Jefferson City 38.57667  -92.17361          1826
## 26        Montana         Helena 46.59111 -112.02028          1875
## 27       Nebraska        Lincoln 40.80889  -96.67889          1867
## 28         Nevada    Carson City 39.16444 -119.76694          1861
## 29  New Hampshire        Concord 43.20667  -71.53806          1808
## 30     New Jersey        Trenton 40.22384  -74.76362          1784
## 31     New Mexico       Santa Fe 35.66722 -105.96444          1610
## 32       New York         Albany 42.65250  -73.75722          1797
## 33 North Carolina        Raleigh 35.76700  -78.63300          1792
## 34   North Dakota       Bismarck 46.80833 -100.78361          1883
## 35           Ohio       Columbus 39.96222  -83.00056          1816
## 36       Oklahoma  Oklahoma City 35.46861  -97.52139          1910
## 37         Oregon          Salem 44.93917 -123.03944          1855
## 38   Pennsylvania     Harrisburg 40.26972  -76.87556          1812
## 39   Rhode Island     Providence 41.82361  -71.42222          1900
## 40 South Carolina       Columbia 34.00056  -81.03472          1786
## 41   South Dakota         Pierre 44.37250 -100.32000          1889
## 42      Tennessee      Nashville 36.16667  -86.78333          1826
## 43          Texas         Austin 30.26722  -97.74306          1839
## 44           Utah Salt Lake City 40.76083 -111.89111          1858
## 45        Vermont     Montpelier 44.25944  -72.57583          1805
## 46       Virginia       Richmond 37.53300  -77.46700          1780
## 47     Washington        Olympia 47.03778 -122.90083          1853
## 48  West Virginia     Charleston 38.34722  -81.63333          1885
## 49      Wisconsin        Madison 43.07472  -89.38417          1838
## 50        Wyoming       Cheyenne 41.14000 -104.82028          1869
##    area.sq.miles population.2019.est population.2019.est.MSA
## 1         159.80              198525                  373290
## 2        2716.70               32113                   32113
## 3         517.60             1680992                 4948203
## 4         116.20              197312                  742384
## 5          97.90              513624                 2363730
## 6         153.30              727211                 2967239
## 7          17.30              122105                 1204877
## 8          22.40               38079                  180786
## 9          95.70              194500                  387227
## 10        133.50              506811                 6020364
## 11         68.40              345064                  974563
## 12         63.80              228959                  749202
## 13         54.00              114230                  206868
## 14        361.50              876384                 2074537
## 15         75.80              214237                  699292
## 16         56.00              125310                  231969
## 17         14.70               27679                   73663
## 18         76.80              220236                  854884
## 19         55.40               18681                  122302
## 20          6.73               39174                 2800053
## 21         89.60              692600                 4873019
## 22         35.00              118210                  550391
## 23         52.80              308096                 3654908
## 24        104.90              160628                  594806
## 25         27.30               42838                  151235
## 26         14.00               32315                   77414
```

```
## 27         74.60             289102                  336374
## 28        143.40              55916                   55916
## 29         64.30              43627                  151391
## 30          7.66              83203                  367430
## 31         37.30              84683                  150358
## 32         21.40              96460                  880381
## 33        114.60             474069                 1390785
## 34         26.90              73529                  128949
## 35        210.30             898553                 2122271
## 36        620.30             655057                 1408950
## 37         45.70             174365                  433903
## 38          8.11              49528                  577941
## 39         18.50             179883                 1624578
## 40        125.20             131674                  838433
## 41         13.00              13646                   20672
## 42        525.90             670820                 1934317
## 43        305.10             978908                 2227083
## 44        109.10             200567                 1232696
## 45         10.20               7855                      NA
## 46         60.10             230436                 1291900
## 47         16.70              46478                  290536
## 48         31.60              46536                  257074
## 49         68.70             259680                  664865
## 50         21.10              64235                   99500
##    population.2019.est.CSA city.rank.in.state
## 1                   461516                  2
## 2                       NA                  3
## 3                  5002221                  1
## 4                   908941                  1
## 5                  2639124                  6
## 6                  3617927                  1
## 7                  1470083                  3
## 8                  7209620                  2
## 9                       NA                  7
## 10                 6853392                  1
## 11                      NA                  1
## 12                  831235                  1
## 13                  306399                  6
## 14                 2457286                  1
## 15                  877991                  1
## 16                      NA                  4
## 17                  745033                 15
## 18                      NA                  2
## 19                      NA                  8
## 20                 9814928                  7
## 21                 8287710                  1
## 22                      NA                  5
## 23                 4027861                  2
## 24                  674340                  1
## 25                      NA                 15
## 26                      NA                  6
## 27                  357887                  2
## 28                  637973                  6
## 29                 8287710                  3
```

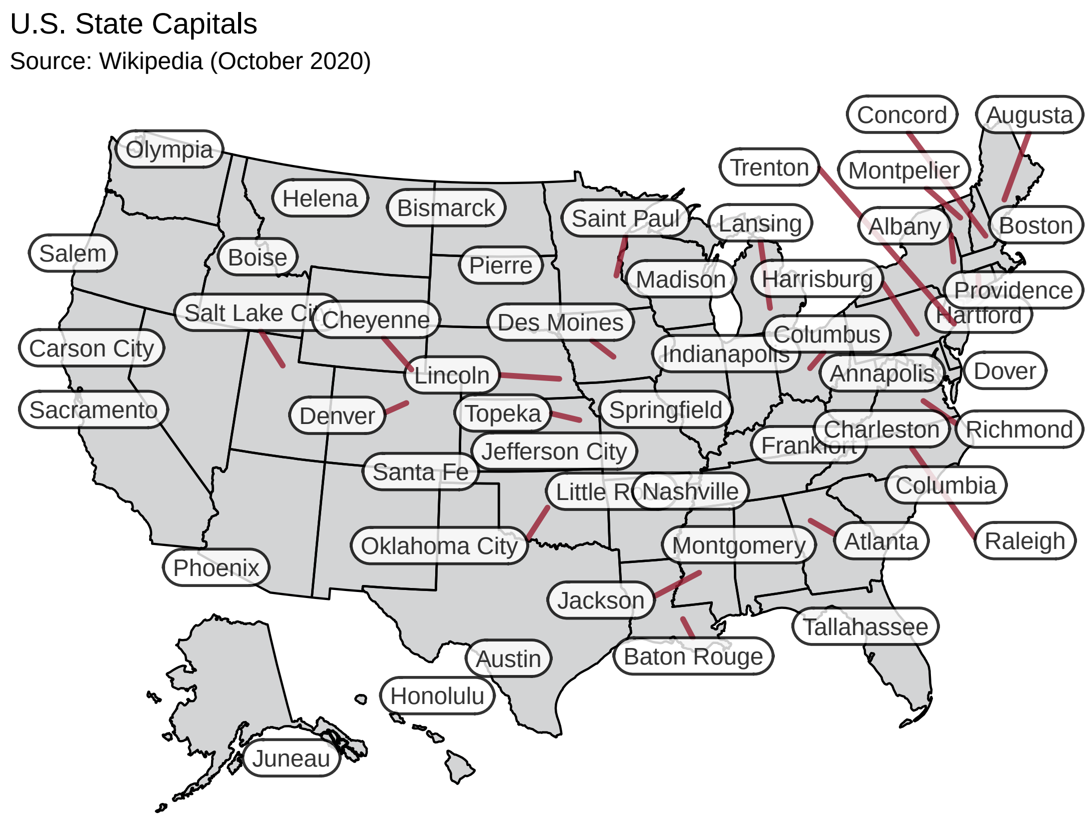
```
## 30                22589036                  10
## 31                 1158464                   4
## 32                 1167594                   6
## 33                 2079687                   2
## 34                      NA                   2
## 35                 2525639                   1
## 36                 1481542                   1
## 37                 3259710                   3
## 38                 1271801                   9
## 39                 8287710                   1
## 40                  963048                   2
## 41                      NA                   8
## 42                 2062547                   1
## 43                      NA                   4
## 44                 2641048                   1
## 45                      NA                   6
## 46                      NA                   4
## 47                 4903675                  24
## 48                  776694                   1
## 49                  892661                   2
## 50                      NA                   1
##                                                       url st
## 1        https://en.wikipedia.org/wiki/Montgomery,_Alabama AL
## 2             https://en.wikipedia.org/wiki/Juneau,_Alaska AK
## 3           https://en.wikipedia.org/wiki/Phoenix,_Arizona AZ
## 4      https://en.wikipedia.org/wiki/Little_Rock,_Arkansas AR
## 5     https://en.wikipedia.org/wiki/Sacramento,_California CA
## 6                    https://en.wikipedia.org/wiki/Denver CO
## 7      https://en.wikipedia.org/wiki/Hartford,_Connecticut CT
## 8            https://en.wikipedia.org/wiki/Dover,_Delaware DE
## 9       https://en.wikipedia.org/wiki/Tallahassee,_Florida FL
## 10                  https://en.wikipedia.org/wiki/Atlanta GA
## 11                 https://en.wikipedia.org/wiki/Honolulu HI
## 12             https://en.wikipedia.org/wiki/Boise,_Idaho ID
## 13     https://en.wikipedia.org/wiki/Springfield,_Illinois IL
## 14             https://en.wikipedia.org/wiki/Indianapolis IN
## 15          https://en.wikipedia.org/wiki/Des_Moines,_Iowa IA
## 16            https://en.wikipedia.org/wiki/Topeka,_Kansas KS
## 17        https://en.wikipedia.org/wiki/Frankfort,_Kentucky KY
## 18    https://en.wikipedia.org/wiki/Baton_Rouge,_Louisiana LA
## 19            https://en.wikipedia.org/wiki/Augusta,_Maine ME
## 20        https://en.wikipedia.org/wiki/Annapolis,_Maryland MD
## 21                   https://en.wikipedia.org/wiki/Boston MA
## 22         https://en.wikipedia.org/wiki/Lansing,_Michigan MI
## 23      https://en.wikipedia.org/wiki/Saint_Paul,_Minnesota MN
## 24      https://en.wikipedia.org/wiki/Jackson,_Mississippi MS
## 25 https://en.wikipedia.org/wiki/Jefferson_City,_Missouri MO
## 26          https://en.wikipedia.org/wiki/Helena,_Montana MT
## 27         https://en.wikipedia.org/wiki/Lincoln,_Nebraska NE
## 28       https://en.wikipedia.org/wiki/Carson_City,_Nevada NV
## 29    https://en.wikipedia.org/wiki/Concord,_New_Hampshire NH
## 30       https://en.wikipedia.org/wiki/Trenton,_New_Jersey NJ
## 31      https://en.wikipedia.org/wiki/Santa_Fe,_New_Mexico NM
## 32          https://en.wikipedia.org/wiki/Albany,_New_York NY
```

```
## 33   https://en.wikipedia.org/wiki/Raleigh,_North_Carolina NC
## 34    https://en.wikipedia.org/wiki/Bismarck,_North_Dakota ND
## 35            https://en.wikipedia.org/wiki/Columbus,_Ohio OH
## 36             https://en.wikipedia.org/wiki/Oklahoma_City OK
## 37             https://en.wikipedia.org/wiki/Salem,_Oregon OR
## 38  https://en.wikipedia.org/wiki/Harrisburg,_Pennsylvania PA
## 39  https://en.wikipedia.org/wiki/Providence,_Rhode_Island RI
## 40  https://en.wikipedia.org/wiki/Columbia,_South_Carolina SC
## 41      https://en.wikipedia.org/wiki/Pierre,_South_Dakota SD
## 42      https://en.wikipedia.org/wiki/Nashville,_Tennessee TN
## 43             https://en.wikipedia.org/wiki/Austin,_Texas TX
## 44            https://en.wikipedia.org/wiki/Salt_Lake_City UT
## 45       https://en.wikipedia.org/wiki/Montpelier,_Vermont VT
## 46        https://en.wikipedia.org/wiki/Richmond,_Virginia VA
## 47       https://en.wikipedia.org/wiki/Olympia,_Washington WA
## 48 https://en.wikipedia.org/wiki/Charleston,_West_Virginia WV
## 49        https://en.wikipedia.org/wiki/Madison,_Wisconsin WI
## 50         https://en.wikipedia.org/wiki/Cheyenne,_Wyoming WY
```

Initial Plotting

- Plot the data on `usmap` (ggplot2)

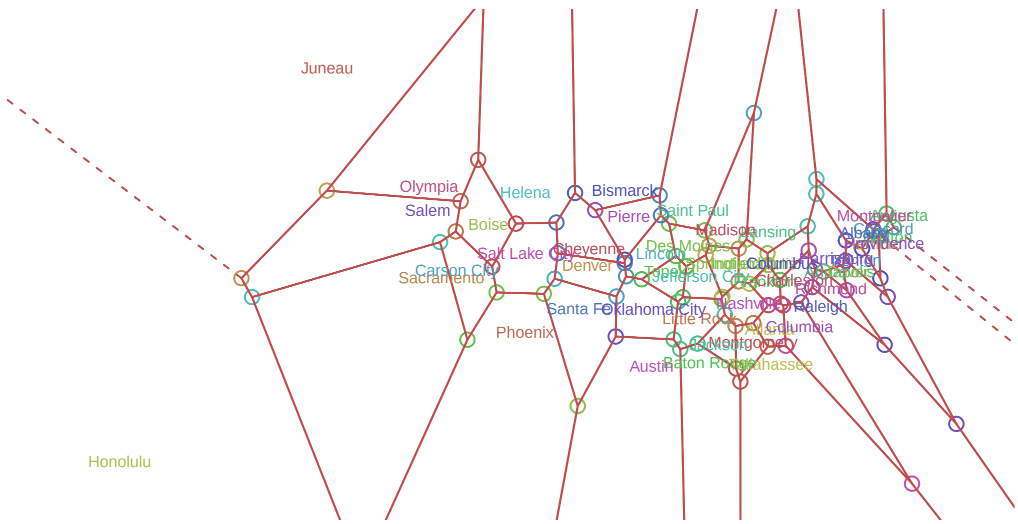
```r
latlong = removeAllColumnsBut(capitals,c( "state", "st", "capital", "latitude", "longitude", "populatio

# first two elements have to be this
latlong = moveColumnsInDataFrame(latlong, c("longitude","latitude"), "before", "state");

# for transform to work
library(usmap);
latlong.transform = usmap_transform(latlong);
library(ggplot2);

### plot_usmap ...

plot_usmap(fill = "#53565A", alpha = 0.25) +
  ggrepel::geom_label_repel(data = latlong.transform,
             aes(x = longitude.1, y = latitude.1, label = capital),
             size = 3, alpha = 0.8,
             label.r = unit(0.5, "lines"), label.size = 0.5,
             segment.color = "#981E32", segment.size = 1,
             seed = 1002) +
  scale_size_continuous(range = c(1, 16),
                        label = scales::comma) +
  labs(title = "U.S. State Capitals",
       subtitle = "Source: Wikipedia (October 2020)") +
  theme(legend.position = "right")
```



- Plot the data using maths `voronoi` (tripack)

```
colors = rainbow(50, s = 0.6, v = 0.75);

## initial visualization ...
library(tripack);
# plot( voronoi.mosaic(latlong[,4:3], duplicate="remove"), col=colors, xlab="");
plot( voronoi.mosaic(x = latlong$longitude, y = latlong$latitude), col=colors, xlab="");
text(x = latlong$longitude, y = latlong$latitude, labels = latlong$capital, col=colors, cex=0.5);
```

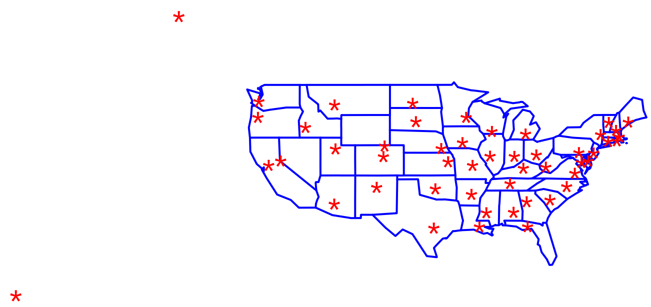
Voronoi mosaic



voronoi.mosaic(x = latlong$longitude, y = latlong$latitude)

- Plot the data on `map` (base)

```
### how is any of the other visualizations really any better than a simple map ... with actual location
library(maps);
map('state', plot = TRUE, fill = FALSE,
    col = "blue", myborder = 0.5
    );
points(x = latlong$longitude, y = latlong$latitude,
                   col = "red", pch = "*", cex = 1);
```



(5 points) Comparing "Visualization Options" Above, the data was displayed using three different visualization packages.

The first `plot_usmap` uses the '`ggplot2` methodology which is tied to the "tidyverse" landscape of the `R` community.

The second `voronoi.mosaic` uses the graph-theory topology known as Voroni partitioning https://en.wikipedia.org/wiki/Voronoi_diagram with the "base" plot function to visualize the topology.

The last one `map` is from the "base" environment.

[Visually, which is the most appealing to you? Why?

Functionally, which presents the data most effectively? Why?

When we create visualizations, it is essential to portray the data accurately. For example, there are times when putting Alaska/Hawaii next to California might be appropriate, and other times it might not be.

What is a one key factor that would determine this appropriateness?

]

(5 points) Building the distance matrix The dataframe we are using has been named `latlong` to represent the latitudes and longitudes of the 50 U.S. cities in America.

```
# manual conversion
# how many miles is 1 degree of latitude
latitude.factor = 69;  # rough mile estimate  # 68.703 ?
```

```
latlong$x.lat = latlong$latitude * latitude.factor;

longitude.factor = 54.6;  # rough mile estimate
latlong$y.long = latlong$longitude * longitude.factor;

latlong = moveColumnsInDataFrame(latlong, c("y.long","x.lat"), "before", "longitude");
```

Let's start with geo-spatial distances. I will do `distMeeus` and you will do `distHaversine`

Meeus These distance formulas can utilize the true geo-spatial coordinates. The distance table is getting large, so there is a helper function to lookup a certain value.

```
library(geosphere);
library(measurements);


dist.meeus = conv_unit(  distm( latlong[,3:4],
                  fun=distMeeus),  "m", "mi");  # default meters to miles

dist.meeus.m = as.matrix( dist.meeus );
  rownames(dist.meeus.m) =
  colnames(dist.meeus.m) = myLabels;

dist.meeus.df = as.data.frame( round( dist.meeus.m, digits=1) );

dist.meeus.df;  ## too big
```

```
##                     Montgomery, AL Juneau, AK Phoenix, AZ Little Rock, AR
## Montgomery, AL                 0.0     2855.6      1497.1           385.6
## Juneau, AK                  2855.6        0.0      2005.8          2516.3
## Phoenix, AZ                 1497.1     2005.8         0.0          1133.4
## Little Rock, AR              385.6     2516.3      1133.4             0.0
## Sacramento, CA              2018.8     1480.3       635.1          1634.7
## Denver, CO                  1161.4     1825.6       585.2           777.6
## Hartford, CT                 990.5     2855.1      2215.2          1170.3
## Dover, DE                    763.8     2881.2      2062.7           977.2
## Tallahassee, FL              177.7     3032.3      1642.0           555.6
## Atlanta, GA                  145.7     2845.3      1591.5           459.4
## Honolulu, HI                4408.0     2809.0      2910.9          4040.4
## Boise, ID                   1795.1     1280.7       735.9          1413.7
## Springfield, IL              546.4     2338.4      1316.1           379.0
## Indianapolis, IN             510.7     2464.8      1498.7           485.8
## Des Moines, IA               754.3     2106.8      1154.9           478.0
## Topeka, KS                   701.4     2167.1       991.0           351.1
## Frankfort, KY                410.3     2591.8      1556.0           479.2
## Baton Rouge, LA              318.1     2796.7      1242.3           303.1
## Augusta, ME                 1213.3     2836.7      2370.3          1367.5
## Annapolis, MD                713.6     2855.0      2010.2           923.1
## Boston, MA                  1081.8     2884.4      2299.3          1261.7
## Lansing, MI                  721.6     2375.7      1621.6           693.0
## Saint Paul, MN               942.1     1961.5      1285.2           705.4
## Jackson, MS                  228.5     2725.0      1272.6           208.7
```

```
## Jefferson City, MO          542.0      2313.6       1166.3            265.0
## Helena, MT                 1677.8      1234.8        906.7           1312.5
## Lincoln, NE                 819.6      2040.7        987.5            481.6
## Carson City, NV            1927.5      1474.7        582.6           1542.6
## Concord, NH                1097.1      2826.1       2277.8           1258.1
## Trenton, NJ                 839.5      2855.3       2103.4           1034.8
## Santa Fe, NM               1150.5      2031.7        380.0            773.5
## Albany, NY                  986.3      2772.4       2162.9           1139.4
## Raleigh, NC                 497.2      2943.7       1903.0            777.2
## Bismarck, ND               1257.7      1600.9       1095.9            942.4
## Columbus, OH                555.1      2568.8       1666.8            626.9
## Oklahoma City, OK           680.1      2303.0        841.2            298.3
## Salem, OR                  2146.1      1042.2        985.5           1764.9
## Harrisburg, PA              755.8      2776.0       1991.9            929.3
## Providence, RI             1045.8      2897.5       2279.9           1233.3
## Columbia, SC                324.2      2951.4       1780.7            647.3
## Pierre, SD                 1122.7      1733.9        982.0            789.0
## Nashville, TN               263.8      2630.7       1445.5            328.1
## Austin, TX                  692.9      2596.4        869.6            441.1
## Salt Lake City, UT         1530.8      1564.2        504.3           1145.8
## Montpelier, VT             1105.1      2738.3       2231.8           1238.6
## Richmond, VA                613.7      2893.7       1959.9            852.4
## Olympia, WA                2171.6       914.1       1096.3           1795.8
## Charleston, WV              488.8      2700.6       1732.1            644.7
## Madison, WI                 758.0      2184.2       1394.4            596.6
## Cheyenne, WY               1190.0      1753.3        663.3            811.4
##                    Sacramento, CA Denver, CO Hartford, CT Dover, DE
## Montgomery, AL             2018.8     1161.4        990.5     763.8
## Juneau, AK                 1480.3     1825.6       2855.1    2881.2
## Phoenix, AZ                 635.1      585.2       2215.2    2062.7
## Little Rock, AR            1634.7      777.6       1170.3     977.2
## Sacramento, CA                0.0      888.7       2558.5    2452.1
## Denver, CO                  888.7        0.0       1691.6    1569.4
## Hartford, CT               2558.5     1691.6          0.0     234.2
## Dover, DE                  2452.1     1569.4        234.2       0.0
## Tallahassee, FL            2181.2     1333.2       1011.7     777.8
## Atlanta, GA                2086.5     1211.9        845.0     618.1
## Honolulu, HI               2461.8     3343.9       5018.8    4912.6
## Boise, ID                   443.7      638.1       2194.7    2114.9
## Springfield, IL            1702.3      815.5        899.4     756.0
## Indianapolis, IN           1886.8     1001.0        719.9     569.8
## Des Moines, IA             1485.1      610.4       1081.2     967.7
## Topeka, KS                 1388.2      499.8       1224.4    1081.6
## Frankfort, KY              1975.1     1086.5        691.5     509.2
## Baton Rouge, LA            1808.7     1009.1       1291.6    1071.2
## Augusta, ME                2669.3     1824.8        228.9     463.1
## Annapolis, MD              2404.2     1520.3        278.9      54.1
## Boston, MA                 2631.2     1769.7         92.5     321.7
## Lansing, MI                1946.8     1082.0        612.0     532.2
## Saint Paul, MN             1522.9      706.2       1048.8     985.4
## Jackson, MS                1809.3      973.2       1163.9     948.4
## Jefferson City, MO         1580.7      692.4       1052.8     897.5
## Helena, MT                  733.2      591.0       1962.3    1903.8
## Lincoln, NE                1327.0      445.2       1247.2    1125.8
```

```
## Carson City, NV             101.5      790.4       2457.2    2351.7
## Concord, NH                2596.2     1740.9        115.3     348.1
## Trenton, NJ                2474.4     1596.8        152.3      84.0
## Santa Fe, NM                879.6      285.9       1835.3    1683.7
## Albany, NY                 2492.3     1631.0         82.8     258.3
## Raleigh, NC                2351.8     1463.5        523.7     289.6
## Bismarck, ND               1192.5      531.9       1428.7    1377.1
## Columbus, OH               2050.2     1166.5        554.7     402.9
## Oklahoma City, OK          1338.8      504.4       1407.2    1234.8
## Salem, OR                   445.9      988.8       2505.8    2441.0
## Harrisburg, PA             2364.7     1485.9        242.5     105.2
## Providence, RI             2620.9     1755.3         64.8     283.7
## Columbia, SC               2262.0     1380.1        703.1     469.2
## Pierre, SD                 1165.3      399.8       1404.0    1325.0
## Nashville, TN              1906.3     1022.4        850.8     650.3
## Austin, TX                 1467.2      770.9       1603.7    1400.2
## Salt Lake City, UT          533.3      371.5       2025.4    1920.1
## Montpelier, VT             2533.0     1686.2        172.4     383.6
## Richmond, VA               2378.8     1490.9        387.8     153.9
## Olympia, WA                 588.0     1029.5       2469.5    2418.7
## Charleston, WV             2144.4     1256.6        529.9     334.6
## Madison, WI                1700.6      841.4        857.9     771.0
## Cheyenne, WY                902.5       97.1       1659.8    1549.8
##                    Tallahassee, FL Atlanta, GA Honolulu, HI Boise, ID
## Montgomery, AL               177.7       145.7       4408.0    1795.1
## Juneau, AK                  3032.3      2845.3       2809.0    1280.7
## Phoenix, AZ                 1642.0      1591.5       2910.9     735.9
## Little Rock, AR              555.6       459.4       4040.4    1413.7
## Sacramento, CA              2181.2      2086.5       2461.8     443.7
## Denver, CO                  1333.2      1211.9       3343.9     638.1
## Hartford, CT                1011.7       845.0       5018.8    2194.7
## Dover, DE                    777.8       618.1       4912.6    2114.9
## Tallahassee, FL                0.0       227.5       4549.8    1968.8
## Atlanta, GA                  227.5         0.0       4499.8    1835.5
## Honolulu, HI                4549.8      4499.8          0.0    2835.4
## Boise, ID                   1968.8      1835.5       2835.4       0.0
## Springfield, IL              712.8       508.7       4159.3    1391.7
## Indianapolis, IN             651.0       426.1       4344.9    1567.8
## Des Moines, IA               928.6       739.4       3946.6    1156.3
## Topeka, KS                   878.9       727.3       3838.8    1109.0
## Frankfort, KY                535.0       307.6       4426.8    1671.8
## Baton Rouge, LA              413.2       458.6       4142.8    1644.5
## Augusta, ME                 1240.0      1068.5       5118.9    2284.0
## Annapolis, MD                733.8       567.9       4864.0    2070.8
## Boston, MA                  1099.1       936.2       5089.5    2260.7
## Lansing, MI                  846.8       619.3       4407.8    1590.8
## Saint Paul, MN              1108.9       900.5       3975.7    1146.0
## Jackson, MS                  372.8       351.0       4182.9    1611.2
## Jefferson City, MO           718.8       547.3       4029.5    1296.5
## Helena, MT                  1855.1      1696.3       3095.1     289.8
## Lincoln, NE                  997.3       832.4       3786.8    1017.8
## Carson City, NV             2091.5      1992.4       2562.8     358.7
## Concord, NH                 1124.2       952.1       5052.0    2220.3
## Trenton, NJ                  859.6       693.9       4936.2    2126.5
```

```
## Santa Fe, NM               1306.9      1232.6       3268.4     772.7
## Albany, NY                 1022.0       842.1       4951.0    2123.3
## Raleigh, NC                 490.0       355.6       4795.1    2055.2
## Bismarck, ND               1433.3      1244.7       3617.5     782.7
## Columbus, OH                659.2       434.9       4510.0    1721.6
## Oklahoma City, OK           843.7       757.0       3743.7    1141.4
## Salem, OR                  2319.9      2184.7       2560.8     351.2
## Harrisburg, PA              793.9       611.5       4826.3    2020.4
## Providence, RI             1060.3       900.2       5080.7    2254.7
## Columbia, SC                308.5       193.6       4686.2    1993.1
## Pierre, SD                 1299.9      1123.5       3617.8     792.1
## Nashville, TN               419.9       214.7       4340.3    1635.7
## Austin, TX                  805.4       819.2       3755.2    1369.4
## Salt Lake City, UT         1701.0      1583.4       2995.0     296.2
## Montpelier, VT             1146.1       962.0       4984.9    2150.9
## Richmond, VA                623.9       468.4       4833.2    2061.3
## Olympia, WA                2347.5      2200.4       2636.9     402.7
## Charleston, WV              564.1       352.2       4599.2    1830.1
## Madison, WI                 915.1       697.3       4161.3    1345.8
## Cheyenne, WY               1364.7      1229.4       3364.0     606.4
##                    Springfield, IL Indianapolis, IN Des Moines, IA Topeka, KS
## Montgomery, AL               546.4            510.7          754.3      701.4
## Juneau, AK                  2338.4           2464.8         2106.8     2167.1
## Phoenix, AZ                 1316.1           1498.7         1154.9      991.0
## Little Rock, AR              379.0            485.8          478.0      351.1
## Sacramento, CA              1702.3           1886.8         1485.1     1388.2
## Denver, CO                   815.5           1001.0          610.4      499.8
## Hartford, CT                 899.4            719.9         1081.2     1224.4
## Dover, DE                    756.0            569.8          967.7     1081.6
## Tallahassee, FL              712.8            651.0          928.6      878.9
## Atlanta, GA                  508.7            426.1          739.4      727.3
## Honolulu, HI                4159.3           4344.9         3946.6     3838.8
## Boise, ID                   1391.7           1567.8         1156.3     1109.0
## Springfield, IL                0.0            186.1          242.2      326.8
## Indianapolis, IN             186.1              0.0          411.5      512.2
## Des Moines, IA               242.2            411.5            0.0      206.2
## Topeka, KS                   326.8            512.2          206.2        0.0
## Frankfort, KY                280.3            128.6          520.4      588.2
## Baton Rouge, LA              650.4            702.4          780.3      646.3
## Augusta, ME                 1065.6            897.2         1219.0     1382.2
## Annapolis, MD                705.8            519.7          920.9     1030.7
## Boston, MA                   984.6            807.2         1159.5     1308.2
## Lansing, MI                  334.2            221.1          472.3      635.6
## Saint Paul, MN               396.2            503.3          233.0      427.7
## Jackson, MS                  518.0            562.1          668.2      559.1
## Jefferson City, MO           159.4            333.2          221.6      192.6
## Helena, MT                  1217.7           1381.2          975.7      976.4
## Lincoln, NE                  377.4            560.2          168.3      131.9
## Carson City, NV             1602.8           1787.0         1384.4     1290.2
## Concord, NH                  966.7            793.7         1131.9     1287.4
## Trenton, NJ                  789.6            605.0          989.7     1116.5
## Santa Fe, NM                 936.1           1118.8          781.8      611.5
## Albany, NY                   850.0            675.4         1020.9     1172.1
## Raleigh, NC                  663.7            495.6          902.8      963.7
```

```
## Bismarck, ND              739.6           881.1         505.9      593.9
## Columbus, OH              353.8           168.4         567.9      680.4
## Oklahoma City, OK         524.4           689.6         472.1      267.2
## Salem, OR                1732.2          1904.5        1493.6     1457.6
## Harrisburg, PA            677.9           493.4         879.7     1004.8
## Providence, RI            964.2           784.6        1144.9     1289.1
## Columbia, SC              622.2           488.4         863.6      885.5
## Pierre, SD                631.9           793.2         389.9      438.0
## Nashville, TN             295.5           250.8         524.9      527.4
## Austin, TX                800.5           926.1         814.0      617.0
## Salt Lake City, UT       1173.8          1357.0         952.5      867.6
## Montpelier, VT            929.1           763.5        1080.3     1244.2
## Richmond, VA              676.8           494.5         905.3      994.4
## Olympia, WA              1731.3          1897.1        1489.9     1474.3
## Charleston, WV            442.6           262.3         673.9      760.6
## Madison, WI               226.5           283.0         239.9      430.3
## Cheyenne, WY              803.4           986.3         582.7      504.4
##                    Frankfort, KY Baton Rouge, LA Augusta, ME Annapolis, MD
## Montgomery, AL            410.3           318.1      1213.3         713.6
## Juneau, AK               2591.8          2796.7      2836.7        2855.0
## Phoenix, AZ              1556.0          1242.3      2370.3        2010.2
## Little Rock, AR           479.2           303.1      1367.5         923.1
## Sacramento, CA           1975.1          1808.7      2669.3        2404.2
## Denver, CO               1086.5          1009.1      1824.8        1520.3
## Hartford, CT              691.5          1291.6       228.9         278.9
## Dover, DE                 509.2          1071.2       463.1          54.1
## Tallahassee, FL           535.0           413.2      1240.0         733.8
## Atlanta, GA               307.6           458.6      1068.5         567.9
## Honolulu, HI             4426.8          4142.8      5118.9        4864.0
## Boise, ID                1671.8          1644.5      2284.0        2070.8
## Springfield, IL           280.3           650.4      1065.6         705.8
## Indianapolis, IN          128.6           702.4       897.2         519.7
## Des Moines, IA            520.4           780.3      1219.0         920.9
## Topeka, KS                588.2           646.3      1382.2        1030.7
## Frankfort, KY               0.0           644.4       889.8         455.9
## Baton Rouge, LA           644.4             0.0      1508.7        1019.3
## Augusta, ME               889.8          1508.7         0.0         506.4
## Annapolis, MD             455.9          1019.3       506.4           0.0
## Boston, MA                782.7          1383.8       149.5         368.9
## Lansing, MI               313.3           923.2       748.7         494.7
## Saint Paul, MN            630.5          1005.2      1146.5         946.5
## Jackson, MS               505.7           140.4      1377.8         895.6
## Jefferson City, MO        397.4           563.2      1223.7         845.7
## Helena, MT               1495.5          1576.5      2034.6        1863.4
## Lincoln, NE               655.8           778.1      1387.2        1077.4
## Carson City, NV          1876.4          1724.1      2567.9        2304.0
## Concord, NH               779.3          1393.6       116.4         390.3
## Trenton, NJ               559.5          1143.2       380.4         126.7
## Santa Fe, NM             1178.3           929.1      1992.5        1631.4
## Albany, NY                660.7          1278.9       230.4         291.8
## Raleigh, NC               383.4           813.8       752.6         250.3
## Bismarck, ND             1003.8          1240.2      1504.1        1338.8
## Columbus, OH              157.6           801.9       741.4         354.1
## Oklahoma City, OK         725.6           505.3      1585.8        1181.3
```

```
## Salem, OR                  2012.5          1993.0      2578.2         2398.9
## Harrisburg, PA              451.7          1051.6       458.0           91.7
## Providence, RI              754.8          1349.6       190.7          332.3
## Columbia, SC                360.2           642.2       931.6          425.6
## Pierre, SD                  908.1          1082.3      1504.5         1282.3
## Nashville, TN               175.6           468.9      1057.0          596.3
## Austin, TX                  916.3           392.3      1806.0         1346.5
## Salt Lake City, UT         1449.7          1360.6      2139.8         1872.8
## Montpelier, VT              763.5          1392.4       138.7          417.5
## Richmond, VA                407.1           924.9       616.4          112.4
## Olympia, WA                2010.2          2038.6      2529.0         2378.9
## Charleston, WV              176.1           769.8       740.2          280.9
## Madison, WI                 411.6           876.3       983.4          729.3
## Cheyenne, WY               1080.5          1060.8      1782.9         1502.2
##                    Boston, MA Lansing, MI Saint Paul, MN Jackson, MS
## Montgomery, AL         1081.8       721.6          942.1       228.5
## Juneau, AK             2884.4      2375.7         1961.5      2725.0
## Phoenix, AZ            2299.3      1621.6         1285.2      1272.6
## Little Rock, AR        1261.7       693.0          705.4       208.7
## Sacramento, CA         2631.2      1946.8         1522.9      1809.3
## Denver, CO             1769.7      1082.0          706.2       973.2
## Hartford, CT             92.5       612.0         1048.8      1163.9
## Dover, DE               321.7       532.2          985.4       948.4
## Tallahassee, FL        1099.1       846.8         1108.9       372.8
## Atlanta, GA             936.2       619.3          900.5       351.0
## Honolulu, HI           5089.5      4407.8         3975.7      4182.9
## Boise, ID              2260.7      1590.8         1146.0      1611.2
## Springfield, IL         984.6       334.2          396.2       518.0
## Indianapolis, IN        807.2       221.1          503.3       562.1
## Des Moines, IA         1159.5       472.3          233.0       668.2
## Topeka, KS             1308.2       635.6          427.7       559.1
## Frankfort, KY           782.7       313.3          630.5       505.7
## Baton Rouge, LA        1383.8       923.2         1005.2       140.4
## Augusta, ME             149.5       748.7         1146.5      1377.8
## Annapolis, MD           368.9       494.7          946.5       895.6
## Boston, MA                0.0       687.9         1115.1      1256.3
## Lansing, MI             687.9         0.0          453.3       783.0
## Saint Paul, MN         1115.1       453.3            0.0       886.2
## Jackson, MS            1256.3       783.0          886.2         0.0
## Jefferson City, MO     1139.4       492.5          442.0       447.1
## Helena, MT             2022.6      1372.5          919.6      1519.2
## Lincoln, NE            1326.5       640.1          338.5       688.6
## Carson City, NV        2529.8      1845.5         1421.5      1720.4
## Concord, NH              63.4       659.6         1076.4      1263.4
## Trenton, NJ             242.4       536.1          987.5      1017.6
## Santa Fe, NM           1919.6      1244.2          931.6       934.1
## Albany, NY              139.1       549.0          977.4      1147.5
## Raleigh, NC             609.8       575.5          989.1       704.1
## Bismarck, ND           1489.0       844.9          392.5      1147.5
## Columbus, OH            643.5       207.5          619.3       663.3
## Oklahoma City, OK      1495.8       857.2          694.2       474.8
## Salem, OR              2566.7      1911.6         1460.2      1962.0
## Harrisburg, PA          334.9       432.6          885.7       922.4
## Providence, RI           41.2       674.9         1108.7      1223.3
```

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## Columbia, SC            790.7       631.7          990.6       543.0
## Pierre, SD             1472.2       798.7          358.2       996.6
## Nashville, TN           943.0       468.5          690.2       330.1
## Austin, TX             1695.8      1127.9         1043.4       468.5
## Salt Lake City, UT     2098.7      1413.6          994.8      1336.5
## Montpelier, VT          151.8       610.2         1010.6      1258.9
## Richmond, VA            475.6       518.6          958.8       806.3
## Olympia, WA            2526.2      1886.7         1433.5      1997.7
## Charleston, WV          622.2       339.2          746.6       637.7
## Madison, WI             932.0       246.6          225.4       744.5
## Cheyenne, WY           1735.2      1048.0          648.4      1013.4
##                     Jefferson City, MO Helena, MT Lincoln, NE Carson City, NV
## Montgomery, AL                   542.0     1677.8       819.6          1927.5
## Juneau, AK                      2313.6     1234.8      2040.7          1474.7
## Phoenix, AZ                     1166.3      906.7       987.5           582.6
## Little Rock, AR                  265.0     1312.5       481.6          1542.6
## Sacramento, CA                  1580.7      733.2      1327.0           101.5
## Denver, CO                       692.4      591.0       445.2           790.4
## Hartford, CT                    1052.8     1962.3      1247.2          2457.2
## Dover, DE                        897.5     1903.8      1125.8          2351.7
## Tallahassee, FL                  718.8     1855.1       997.3          2091.5
## Atlanta, GA                      547.3     1696.3       832.4          1992.4
## Honolulu, HI                    4029.5     3095.1      3786.8          2562.8
## Boise, ID                       1296.5      289.8      1017.8           358.7
## Springfield, IL                  159.4     1217.7       377.4          1602.8
## Indianapolis, IN                 333.2     1381.2       560.2          1787.0
## Des Moines, IA                   221.6      975.7       168.3          1384.4
## Topeka, KS                       192.6      976.4       131.9          1290.2
## Frankfort, KY                    397.4     1495.5       655.8          1876.4
## Baton Rouge, LA                  563.2     1576.5       778.1          1724.1
## Augusta, ME                     1223.7     2034.6      1387.2          2567.9
## Annapolis, MD                    845.7     1863.4      1077.4          2304.0
## Boston, MA                      1139.4     2022.6      1326.5          2529.8
## Lansing, MI                      492.5     1372.5       640.1          1845.5
## Saint Paul, MN                   442.0      919.6       338.5          1421.5
## Jackson, MS                      447.1     1519.2       688.6          1720.4
## Jefferson City, MO                 0.0     1149.0       285.2          1482.8
## Helena, MT                      1149.0        0.0       863.9           645.4
## Lincoln, NE                      285.2      863.9         0.0          1227.0
## Carson City, NV                 1482.8      645.4      1227.0             0.0
## Concord, NH                     1123.5     1978.5      1299.7          2494.8
## Trenton, NJ                      937.2     1907.0      1151.7          2373.6
## Santa Fe, NM                     786.7      816.7       616.6           795.7
## Albany, NY                      1006.1     1887.5      1188.1          2390.9
## Raleigh, NC                      771.1     1876.3      1038.5          2253.9
## Bismarck, ND                     716.7      533.8       462.1          1093.2
## Columbus, OH                     500.8     1523.6       723.3          1950.0
## Oklahoma City, OK                365.1     1075.1       371.2          1248.1
## Salem, OR                       1643.3      544.2      1362.0           432.6
## Harrisburg, PA                   825.7     1805.1      1040.9          2263.9
## Providence, RI                  1117.6     2020.0      1311.2          2519.5
## Columbia, SC                     696.6     1836.5       978.3          2166.4
## Pierre, SD                       581.5      588.1       308.1          1064.0
## Nashville, TN                    340.0     1486.7       624.2          1810.0
```

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## Austin, TX                      654.8     1361.9       729.2          1390.5
## Salt Lake City, UT             1059.7      402.6       796.9           432.2
## Montpelier, VT                 1087.6     1904.8      1248.5          2431.6
## Richmond, VA                    804.4     1866.2      1053.8          2279.4
## Olympia, WA                    1654.4      516.5      1369.8           566.0
## Charleston, WV                  571.5     1641.4       819.9          2045.1
## Madison, WI                     343.0     1134.2       406.9          1599.3
## Cheyenne, WY                    694.6      520.1       426.2           801.9
##                    Concord, NH Trenton, NJ Santa Fe, NM Albany, NY Raleigh, NC
## Montgomery, AL          1097.1       839.5       1150.5      986.3       497.2
## Juneau, AK              2826.1      2855.3       2031.7     2772.4      2943.7
## Phoenix, AZ             2277.8      2103.4        380.0     2162.9      1903.0
## Little Rock, AR         1258.1      1034.8        773.5     1139.4       777.2
## Sacramento, CA          2596.2      2474.4        879.6     2492.3      2351.8
## Denver, CO              1740.9      1596.8        285.9     1631.0      1463.5
## Hartford, CT             115.3       152.3       1835.3       82.8       523.7
## Dover, DE                348.1        84.0       1683.7      258.3       289.6
## Tallahassee, FL         1124.2       859.6       1306.9     1022.0       490.0
## Atlanta, GA              952.1       693.9       1232.6      842.1       355.6
## Honolulu, HI            5052.0      4936.2       3268.4     4951.0      4795.1
## Boise, ID               2220.3      2126.5        772.7     2123.3      2055.2
## Springfield, IL          966.7       789.6        936.1      850.0       663.7
## Indianapolis, IN         793.7       605.0       1118.8      675.4       495.6
## Des Moines, IA          1131.9       989.7        781.8     1020.9       902.8
## Topeka, KS              1287.4      1116.5        611.5     1172.1       963.7
## Frankfort, KY            779.3       559.5       1178.3      660.7       383.4
## Baton Rouge, LA         1393.6      1143.2        929.1     1278.9       813.8
## Augusta, ME              116.4       380.4       1992.5      230.4       752.6
## Annapolis, MD            390.3       126.7       1631.4      291.8       250.3
## Boston, MA                63.4       242.4       1919.6      139.1       609.8
## Lansing, MI              659.6       536.1       1244.2      549.0       575.5
## Saint Paul, MN          1076.4       987.5        931.6      977.4       989.1
## Jackson, MS             1263.4      1017.6        934.1     1147.5       704.1
## Jefferson City, MO      1123.5       937.2        786.7     1006.1       771.1
## Helena, MT              1978.5      1907.0        816.7     1887.5      1876.3
## Lincoln, NE             1299.7      1151.7        616.6     1188.1      1038.5
## Carson City, NV         2494.8      2373.6        795.7     2390.9      2253.9
## Concord, NH                0.0       264.9       1898.8      118.9       637.6
## Trenton, NJ              264.9         0.0       1723.6      175.6       372.9
## Santa Fe, NM            1898.8      1723.6          0.0     1783.6      1531.7
## Albany, NY               118.9       175.6       1783.6        0.0       542.1
## Raleigh, NC              637.6       372.9       1531.7      542.1         0.0
## Bismarck, ND            1445.4      1376.4        814.4     1353.7      1374.4
## Columbus, OH             634.1       436.7       1287.0      515.2       375.0
## Oklahoma City, OK       1483.3      1283.1        475.6     1365.0      1061.9
## Salem, OR               2522.7      2447.3       1102.1     2431.4      2395.7
## Harrisburg, PA           342.2       111.7       1612.0      230.7       325.0
## Providence, RI            95.6       206.6       1900.1      132.7       570.6
## Columbia, SC             815.8       551.1       1417.8      715.2       182.9
## Pierre, SD              1434.3      1334.6        670.7     1334.0      1288.3
## Nashville, TN            944.5       710.8       1074.6      826.9       457.5
## Austin, TX              1695.2      1463.5        605.0     1576.8      1170.1
## Salt Lake City, UT      2064.6      1941.4        476.7     1959.7      1829.7
## Montpelier, VT            89.3       300.3       1854.2      125.8       667.8
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## Richmond, VA            500.9        236.0         1583.5      404.1        137.9
## Olympia, WA            2479.6       2419.7         1174.9     2393.0       2391.8
## Charleston, WV          626.1        390.2         1354.2      509.9        243.2
## Madison, WI             900.5        780.8         1021.6      792.9        763.8
## Cheyenne, WY           1703.4       1572.3          382.6     1596.1       1461.8
##                     Bismarck, ND Columbus, OH Oklahoma City, OK Salem, OR
## Montgomery, AL            1257.7        555.1             680.1    2146.1
## Juneau, AK                1600.9       2568.8            2303.0    1042.2
## Phoenix, AZ               1095.9       1666.8             841.2     985.5
## Little Rock, AR            942.4        626.9             298.3    1764.9
## Sacramento, CA            1192.5       2050.2            1338.8     445.9
## Denver, CO                 531.9       1166.5             504.4     988.8
## Hartford, CT              1428.7        554.7            1407.2    2505.8
## Dover, DE                 1377.1        402.9            1234.8    2441.0
## Tallahassee, FL           1433.3        659.2             843.7    2319.9
## Atlanta, GA               1244.7        434.9             757.0    2184.7
## Honolulu, HI              3617.5       4510.0            3743.7    2560.8
## Boise, ID                  782.7       1721.6            1141.4     351.2
## Springfield, IL            739.6        353.8             524.4    1732.2
## Indianapolis, IN           881.1        168.4             689.6    1904.5
## Des Moines, IA             505.9        567.9             472.1    1493.6
## Topeka, KS                 593.9        680.4             267.2    1457.6
## Frankfort, KY             1003.8        157.6             725.6    2012.5
## Baton Rouge, LA           1240.2        801.9             505.3    1993.0
## Augusta, ME               1504.1        741.4            1585.8    2578.2
## Annapolis, MD             1338.8        354.1            1181.3    2398.9
## Boston, MA                1489.0        643.5            1495.8    2566.7
## Lansing, MI                844.9        207.5             857.2    1911.6
## Saint Paul, MN             392.5        619.3             694.2    1460.2
## Jackson, MS               1147.5        663.3             474.8    1962.0
## Jefferson City, MO         716.7        500.8             365.1    1643.3
## Helena, MT                 533.8       1523.6            1075.1     544.2
## Lincoln, NE                462.1        723.3             371.2    1362.0
## Carson City, NV           1093.2       1950.0            1248.1     432.6
## Concord, NH               1445.4        634.1            1483.3    2522.7
## Trenton, NJ               1376.4        436.7            1283.1    2447.3
## Santa Fe, NM               814.4       1287.0             475.6    1102.1
## Albany, NY                1353.7        515.2            1365.0    2431.4
## Raleigh, NC               1374.4        375.0            1061.9    2395.7
## Bismarck, ND                 0.0       1009.2             800.6    1077.7
## Columbus, OH              1009.2          0.0             852.5    2053.9
## Oklahoma City, OK          800.6        852.5               0.0    1491.2
## Salem, OR                 1077.7       2053.9            1491.2       0.0
## Harrisburg, PA            1276.6        325.1            1173.2    2343.8
## Providence, RI            1486.3        619.2            1471.7    2563.8
## Columbia, SC              1359.1        425.2             942.5    2339.6
## Pierre, SD                 169.7        937.8             631.9    1116.8
## Nashville, TN             1030.0        333.2             604.6    1983.1
## Austin, TX                1152.6       1067.1             358.7    1705.6
## Salt Lake City, UT         693.9       1518.9             862.5     634.7
## Montpelier, VT            1372.8        611.7            1450.7    2448.9
## Richmond, VA              1350.2        342.6            1123.3    2395.5
## Olympia, WA               1043.4       2040.1            1533.7     145.1
## Charleston, WV            1133.7        133.4             900.7    2166.6
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## Madison, WI              614.9       394.5             681.7    1670.0
## Cheyenne, WY             439.9      1148.3             556.7     956.7
##                     Harrisburg, PA Providence, RI Columbia, SC Pierre, SD
## Montgomery, AL               755.8         1045.8        324.2     1122.7
## Juneau, AK                  2776.0         2897.5       2951.4     1733.9
## Phoenix, AZ                 1991.9         2279.9       1780.7      982.0
## Little Rock, AR              929.3         1233.3        647.3      789.0
## Sacramento, CA              2364.7         2620.9       2262.0     1165.3
## Denver, CO                  1485.9         1755.3       1380.1      399.8
## Hartford, CT                 242.5           64.8        703.1     1404.0
## Dover, DE                    105.2          283.7        469.2     1325.0
## Tallahassee, FL              793.9         1060.3        308.5     1299.9
## Atlanta, GA                  611.5          900.2        193.6     1123.5
## Honolulu, HI                4826.3         5080.7       4686.2     3617.8
## Boise, ID                   2020.4         2254.7       1993.1      792.1
## Springfield, IL              677.9          964.2        622.2      631.9
## Indianapolis, IN             493.4          784.6        488.4      793.2
## Des Moines, IA               879.7         1144.9        863.6      389.9
## Topeka, KS                  1004.8         1289.1        885.5      438.0
## Frankfort, KY                451.7          754.8        360.2      908.1
## Baton Rouge, LA             1051.6         1349.6        642.2     1082.3
## Augusta, ME                  458.0          190.7        931.6     1504.5
## Annapolis, MD                 91.7          332.3        425.6     1282.3
## Boston, MA                   334.9           41.2        790.7     1472.2
## Lansing, MI                  432.6          674.9        631.7      798.7
## Saint Paul, MN               885.7         1108.7        990.6      358.2
## Jackson, MS                  922.4         1223.3        543.0      996.6
## Jefferson City, MO           825.7         1117.6        696.6      581.5
## Helena, MT                  1805.1         2020.0       1836.5      588.1
## Lincoln, NE                 1040.9         1311.2        978.3      308.1
## Carson City, NV             2263.9         2519.5       2166.4     1064.0
## Concord, NH                  342.2           95.6        815.8     1434.3
## Trenton, NJ                  111.7          206.6        551.1     1334.6
## Santa Fe, NM                1612.0         1900.1       1417.8      670.7
## Albany, NY                   230.7          132.7        715.2     1334.0
## Raleigh, NC                  325.0          570.6        182.9     1288.3
## Bismarck, ND                1276.6         1486.3       1359.1      169.7
## Columbus, OH                 325.1          619.2        425.2      937.8
## Oklahoma City, OK           1173.2         1471.7        942.5      631.9
## Salem, OR                   2343.8         2563.8       2339.6     1116.8
## Harrisburg, PA                 0.0          304.3        489.4     1229.2
## Providence, RI               304.3            0.0        752.0     1464.7
## Columbia, SC                 489.4          752.0          0.0     1253.4
## Pierre, SD                  1229.2         1464.7       1253.4        0.0
## Nashville, TN                608.4          912.6        358.3      910.3
## Austin, TX                  1361.4         1665.6       1011.5      982.9
## Salt Lake City, UT          1831.9         2087.9       1750.9      640.1
## Montpelier, VT               352.6          178.0        840.0     1368.7
## Richmond, VA                 191.5          437.3        315.4     1280.0
## Olympia, WA                 2319.1         2525.7       2347.0     1104.0
## Charleston, WV               287.4          591.4        301.6     1053.7
## Madison, WI                  674.8          920.4        771.4      554.4
## Cheyenne, WY                1462.3         1722.9       1389.9      319.6
##                     Nashville, TN Austin, TX Salt Lake City, UT Montpelier, VT
```

```
## Montgomery, AL              263.8      692.9              1530.8          1105.1
## Juneau, AK                 2630.7     2596.4              1564.2          2738.3
## Phoenix, AZ                1445.5      869.6               504.3          2231.8
## Little Rock, AR             328.1      441.1              1145.8          1238.6
## Sacramento, CA             1906.3     1467.2               533.3          2533.0
## Denver, CO                 1022.4      770.9               371.5          1686.2
## Hartford, CT                850.8     1603.7              2025.4           172.4
## Dover, DE                   650.3     1400.2              1920.1           383.6
## Tallahassee, FL             419.9      805.4              1701.0          1146.1
## Atlanta, GA                 214.7      819.2              1583.4           962.0
## Honolulu, HI               4340.3     3755.2              2995.0          4984.9
## Boise, ID                  1635.7     1369.4               296.2          2150.9
## Springfield, IL             295.5      800.5              1173.8           929.1
## Indianapolis, IN            250.8      926.1              1357.0           763.5
## Des Moines, IA              524.9      814.0               952.5          1080.3
## Topeka, KS                  527.4      617.0               867.6          1244.2
## Frankfort, KY               175.6      916.3              1449.7           763.5
## Baton Rouge, LA             468.9      392.3              1360.6          1392.4
## Augusta, ME                1057.0     1806.0              2139.8           138.7
## Annapolis, MD               596.3     1346.5              1872.8           417.5
## Boston, MA                  943.0     1695.8              2098.7           151.8
## Lansing, MI                 468.5     1127.9              1413.6           610.2
## Saint Paul, MN              690.2     1043.4               994.8          1010.6
## Jackson, MS                 330.1      468.5              1336.5          1258.9
## Jefferson City, MO          340.0      654.8              1059.7          1087.6
## Helena, MT                 1486.7     1361.9               402.6          1904.8
## Lincoln, NE                 624.2      729.2               796.9          1248.5
## Carson City, NV            1810.0     1390.5               432.2          2431.6
## Concord, NH                 944.5     1695.2              2064.6            89.3
## Trenton, NJ                 710.8     1463.5              1941.4           300.3
## Santa Fe, NM               1074.6      605.0               476.7          1854.2
## Albany, NY                  826.9     1576.8              1959.7           125.8
## Raleigh, NC                 457.5     1170.1              1829.7           667.8
## Bismarck, ND               1030.0     1152.6               693.9          1372.8
## Columbus, OH                333.2     1067.1              1518.9           611.7
## Oklahoma City, OK           604.6      358.7               862.5          1450.7
## Salem, OR                  1983.1     1705.6               634.7          2448.9
## Harrisburg, PA              608.4     1361.4              1831.9           352.6
## Providence, RI              912.6     1665.6              2087.9           178.0
## Columbia, SC                358.3     1011.5              1750.9           840.0
## Pierre, SD                  910.3      982.9               640.1          1368.7
## Nashville, TN                 0.0      753.1              1392.8           934.0
## Austin, TX                  753.1        0.0              1074.1          1678.6
## Salt Lake City, UT         1392.8     1074.1                 0.0          2002.8
## Montpelier, VT              934.0     1678.6              2002.8             0.0
## Richmond, VA                524.6     1264.9              1850.5           529.9
## Olympia, WA                1993.9     1771.8               698.8          2402.9
## Charleston, WV              321.2     1074.3              1616.4           622.7
## Madison, WI                 496.3      996.5              1167.5           844.8
## Cheyenne, WY               1031.8      848.0               370.8          1645.0
##                    Richmond, VA Olympia, WA Charleston, WV Madison, WI
## Montgomery, AL            613.7      2171.6          488.8       758.0
## Juneau, AK               2893.7       914.1         2700.6      2184.2
## Phoenix, AZ              1959.9      1096.3         1732.1      1394.4
```

```
## Little Rock, AR          852.4      1795.8       644.7      596.6
## Sacramento, CA          2378.8       588.0      2144.4     1700.6
## Denver, CO              1490.9      1029.5      1256.6      841.4
## Hartford, CT             387.8      2469.5       529.9      857.9
## Dover, DE                153.9      2418.7       334.6      771.0
## Tallahassee, FL          623.9      2347.5       564.1      915.1
## Atlanta, GA              468.4      2200.4       352.2      697.3
## Honolulu, HI            4833.2      2636.9      4599.2     4161.3
## Boise, ID               2061.3       402.7      1830.1     1345.8
## Springfield, IL          676.8      1731.3       442.6      226.5
## Indianapolis, IN         494.5      1897.1       262.3      283.0
## Des Moines, IA           905.3      1489.9       673.9      239.9
## Topeka, KS               994.4      1474.3       760.6      430.3
## Frankfort, KY            407.1      2010.2       176.1      411.6
## Baton Rouge, LA          924.9      2038.6       769.8      876.3
## Augusta, ME              616.4      2529.0       740.2      983.4
## Annapolis, MD            112.4      2378.9       280.9      729.3
## Boston, MA               475.6      2526.2       622.2      932.0
## Lansing, MI              518.6      1886.7       339.2      246.6
## Saint Paul, MN           958.8      1433.5       746.6      225.4
## Jackson, MS              806.3      1997.7       637.7      744.5
## Jefferson City, MO       804.4      1654.4       571.5      343.0
## Helena, MT              1866.2       516.5      1641.4     1134.2
## Lincoln, NE             1053.8      1369.8       819.9      406.9
## Carson City, NV         2279.4       566.0      2045.1     1599.3
## Concord, NH              500.9      2479.6       626.1      900.5
## Trenton, NJ              236.0      2419.7       390.2      780.8
## Santa Fe, NM            1583.5      1174.9      1354.2     1021.6
## Albany, NY               404.1      2393.0       509.9      792.9
## Raleigh, NC              137.9      2391.8       243.2      763.8
## Bismarck, ND            1350.2      1043.4      1133.7      614.9
## Columbus, OH             342.6      2040.1       133.4      394.5
## Oklahoma City, OK       1123.3      1533.7       900.7      681.7
## Salem, OR               2395.5       145.1      2166.6     1670.0
## Harrisburg, PA           191.5      2319.1       287.4      674.8
## Providence, RI           437.3      2525.7       591.4      920.4
## Columbia, SC             315.4      2347.0       301.6      771.4
## Pierre, SD              1280.0      1104.0      1053.7      554.4
## Nashville, TN            524.6      1993.9       321.2      496.3
## Austin, TX              1264.9      1771.8      1074.3      996.5
## Salt Lake City, UT      1850.5       698.8      1616.4     1167.5
## Montpelier, VT           529.9      2402.9       622.7      844.8
## Richmond, VA               0.0      2382.7       234.4      735.5
## Olympia, WA             2382.7         0.0      2157.7     1650.1
## Charleston, WV           234.4      2157.7         0.0      521.2
## Madison, WI              735.5      1650.1       521.2        0.0
## Cheyenne, WY            1480.0       984.6      1246.1      803.3
##                   Cheyenne, WY
## Montgomery, AL          1190.0
## Juneau, AK              1753.3
## Phoenix, AZ              663.3
## Little Rock, AR          811.4
## Sacramento, CA           902.5
## Denver, CO                97.1
```

```
## Hartford, CT            1659.8
## Dover, DE               1549.8
## Tallahassee, FL         1364.7
## Atlanta, GA             1229.4
## Honolulu, HI            3364.0
## Boise, ID                606.4
## Springfield, IL          803.4
## Indianapolis, IN         986.3
## Des Moines, IA           582.7
## Topeka, KS               504.4
## Frankfort, KY           1080.5
## Baton Rouge, LA         1060.8
## Augusta, ME             1782.9
## Annapolis, MD           1502.2
## Boston, MA              1735.2
## Lansing, MI             1048.0
## Saint Paul, MN           648.4
## Jackson, MS             1013.4
## Jefferson City, MO       694.6
## Helena, MT               520.1
## Lincoln, NE              426.2
## Carson City, NV          801.9
## Concord, NH             1703.4
## Trenton, NJ             1572.3
## Santa Fe, NM             382.6
## Albany, NY              1596.1
## Raleigh, NC             1461.8
## Bismarck, ND             439.9
## Columbus, OH            1148.3
## Oklahoma City, OK        556.7
## Salem, OR                956.7
## Harrisburg, PA          1462.3
## Providence, RI          1722.9
## Columbia, SC            1389.9
## Pierre, SD               319.6
## Nashville, TN           1031.8
## Austin, TX               848.0
## Salt Lake City, UT       370.8
## Montpelier, VT          1645.0
## Richmond, VA            1480.0
## Olympia, WA              984.6
## Charleston, WV          1246.1
## Madison, WI              803.3
## Cheyenne, WY               0.0
```

```
lookupPairwiseValue(dist.meeus.df, "Juneau, AK", "Montgomery, AL");
```

```
## [1] 2855.6
```

```
dist.haversine = conv_unit(  distm( latlong[,3:4],
                  fun=distHaversine),  "m", "mi");  # default meters to miles
```

```r
dist.haversine.m = as.matrix( dist.haversine );
  rownames(dist.haversine.m) =
  colnames(dist.haversine.m) = myLabels;

dist.haversine.df = as.data.frame( round( dist.haversine.m, digits=1) );

dist.haversine.df;  ## too big
```

Haversine

```
##                     Montgomery, AL Juneau, AK Phoenix, AZ Little Rock, AR
## Montgomery, AL                 0.0     2854.6      1495.6           385.5
## Juneau, AK                  2854.6        0.0      2007.1          2515.3
## Phoenix, AZ                 1495.6     2007.1         0.0          1132.2
## Little Rock, AR              385.5     2515.3      1132.2             0.0
## Sacramento, CA              2016.9     1481.3       635.2          1632.9
## Denver, CO                  1161.1     1824.8       585.9           777.3
## Hartford, CT                 991.1     2850.8      2213.1          1169.6
## Dover, DE                    764.2     2877.7      2060.6           976.4
## Tallahassee, FL              178.0     3031.6      1640.6           555.8
## Atlanta, GA                  145.9     2843.8      1589.8           459.0
## Honolulu, HI                4405.8     2814.2      2910.1          4038.5
## Boise, ID                   1794.3     1280.3       737.6          1412.9
## Springfield, IL              547.9     2336.0      1315.1           379.9
## Indianapolis, IN             512.4     2462.1      1497.4           486.3
## Des Moines, IA               755.7     2104.5      1154.6           479.3
## Topeka, KS                   702.0     2165.4       990.5           351.8
## Frankfort, KY                411.6     2589.3      1554.5           479.1
## Baton Rouge, LA              318.1     2796.7      1241.3           304.1
## Augusta, ME                 1214.1     2831.8      2368.1          1367.0
## Annapolis, MD                714.1     2851.6      2008.2           922.4
## Boston, MA                  1082.4     2879.9      2297.1          1261.0
## Lansing, MI                  723.7     2372.4      1620.6           693.9
## Saint Paul, MN               944.1     1958.6      1285.4           707.2
## Jackson, MS                  228.3     2724.4      1271.4           209.1
## Jefferson City, MO           542.9     2311.7      1165.4           265.8
## Helena, MT                  1677.8     1233.5       909.0          1312.6
## Lincoln, NE                  820.4     2038.8       987.4           482.5
## Carson City, NV             1925.8     1475.4       583.1          1541.0
## Concord, NH                 1097.9     2821.5      2275.7          1257.6
## Trenton, NJ                  840.1     2851.5      2101.3          1034.1
## Santa Fe, NM                1149.5     2031.9       379.9           772.6
## Albany, NY                   987.2     2768.1      2161.0          1139.0
## Raleigh, NC                  497.2     2941.1      1901.0           776.4
## Bismarck, ND                1259.1     1598.6      1097.4           943.8
## Columbus, OH                 556.6     2565.8      1665.4           627.1
## Oklahoma City, OK            679.7     2302.4       840.4           298.0
## Salem, OR                   2144.8     1042.1       986.7          1763.6
## Harrisburg, PA               756.7     2772.4      1990.0           928.8
## Providence, RI              1046.3     2893.2      2277.7          1232.5
## Columbia, SC                 324.0     2949.4      1778.8           646.6
## Pierre, SD                  1123.8     1731.8       983.1           790.2
## Nashville, TN                264.8     2628.8      1444.1           327.8
```

```
## Austin, TX                  692.4     2597.2       869.0           441.7
## Salt Lake City, UT         1529.9     1563.9       505.8          1145.0
## Montpelier, VT             1106.2     2733.7      2229.9          1238.4
## Richmond, VA                614.0     2890.6      1957.9           851.6
## Olympia, WA                2170.6      913.8      1097.9          1794.8
## Charleston, WV              489.8     2697.8      1730.4           644.3
## Madison, WI                 760.1     2181.3      1393.9           598.1
## Cheyenne, WY               1189.9     1752.1       664.2           811.4
##                    Sacramento, CA Denver, CO Hartford, CT Dover, DE
## Montgomery, AL             2016.9     1161.1        991.1     764.2
## Juneau, AK                 1481.3     1824.8       2850.8    2877.7
## Phoenix, AZ                 635.2      585.9       2213.1    2060.6
## Little Rock, AR            1632.9      777.3       1169.6     976.4
## Sacramento, CA                0.0      887.5       2555.0    2448.9
## Denver, CO                  887.5        0.0       1689.2    1567.3
## Hartford, CT               2555.0     1689.2          0.0     234.4
## Dover, DE                  2448.9     1567.3        234.4       0.0
## Tallahassee, FL            2179.5     1333.1       1013.1     779.0
## Atlanta, GA                2084.3     1211.1        845.5     618.3
## Honolulu, HI               2462.7     3343.5       5016.3    4910.1
## Boise, ID                   444.1      637.6       2191.3    2112.0
## Springfield, IL            1700.0      814.3        898.2     754.9
## Indianapolis, IN           1884.3      999.6        718.9     569.1
## Des Moines, IA             1483.1      609.6       1079.6     966.5
## Topeka, KS                 1386.4      499.2       1222.8    1080.1
## Frankfort, KY              1972.6     1085.1        690.9     508.6
## Baton Rouge, LA            1807.5     1009.9       1292.2    1071.5
## Augusta, ME                2665.6     1822.2        229.1     463.4
## Annapolis, MD              2401.1     1518.2        279.1      54.0
## Boston, MA                 2627.6     1767.2         92.4     321.8
## Lansing, MI                1944.2     1080.6        611.1     531.9
## Saint Paul, MN             1521.1      705.8       1047.3     984.5
## Jackson, MS                1807.7      973.2       1164.1     948.4
## Jefferson City, MO         1578.7      691.5       1051.5     896.3
## Helena, MT                  733.6      591.4       1959.3    1901.4
## Lincoln, NE                1325.2      444.6       1245.4    1124.2
## Carson City, NV             101.4      789.3       2453.8    2348.6
## Concord, NH                2592.7     1738.5        115.5     348.5
## Trenton, NJ                2471.1     1594.6        152.4      84.1
## Santa Fe, NM                878.7      286.7       1833.3    1681.7
## Albany, NY                 2488.9     1628.7         82.9     258.8
## Raleigh, NC                2349.0     1461.9        524.4     290.0
## Bismarck, ND               1191.7      532.7       1426.6    1375.7
## Columbus, OH               2047.4     1164.9        554.0     402.4
## Oklahoma City, OK          1337.4      504.5       1405.9    1233.5
## Salem, OR                   446.9      987.8       2501.9    2437.5
## Harrisburg, PA             2361.5     1483.8        242.3     105.3
## Providence, RI             2617.3     1752.9         64.7     283.8
## Columbia, SC               2259.6     1379.0        704.0     469.8
## Pierre, SD                 1164.1      400.2       1401.9    1323.4
## Nashville, TN              1904.0     1021.3        850.4     649.8
## Austin, TX                 1466.6      772.6       1603.6    1400.0
## Salt Lake City, UT          532.7      371.0       2022.5    1917.5
## Montpelier, VT             2529.5     1683.9        172.8     384.2
```

```
## Richmond, VA              2375.8     1489.0        388.1     154.1
## Olympia, WA                589.2     1028.7       2465.7    2415.4
## Charleston, WV            2141.6     1254.9        529.5     334.2
## Madison, WI               1698.4      840.5        856.7     770.2
## Cheyenne, WY               901.4       97.3       1657.4    1547.7
##                    Tallahassee, FL Atlanta, GA Honolulu, HI Boise, ID
## Montgomery, AL                178.0       145.9       4405.8    1794.3
## Juneau, AK                   3031.6      2843.8       2814.2    1280.3
## Phoenix, AZ                  1640.6      1589.8       2910.1     737.6
## Little Rock, AR               555.8       459.0       4038.5    1412.9
## Sacramento, CA               2179.5      2084.3       2462.7     444.1
## Denver, CO                   1333.1      1211.1       3343.5     637.6
## Hartford, CT                 1013.1       845.5       5016.3    2191.3
## Dover, DE                     779.0       618.3       4910.1    2112.0
## Tallahassee, FL                 0.0       228.4       4547.4    1968.2
## Atlanta, GA                   228.4         0.0       4497.5    1834.2
## Honolulu, HI                 4547.4      4497.5          0.0    2836.7
## Boise, ID                    1968.2      1834.2       2836.7       0.0
## Springfield, IL               714.6       509.6       4157.7    1389.8
## Indianapolis, IN              653.1       427.3       4343.1    1565.6
## Des Moines, IA                930.3       740.2       3945.5    1154.6
## Topeka, KS                    879.7       727.3       3837.5    1107.8
## Frankfort, KY                 536.9       308.6       4424.7    1669.8
## Baton Rouge, LA               412.9       458.7       4140.7    1644.7
## Augusta, ME                  1241.6      1069.0       5116.4    2280.3
## Annapolis, MD                 735.2       568.2       4861.5    2068.0
## Boston, MA                   1100.5       936.6       5086.9    2257.2
## Lansing, MI                   849.5       621.1       4406.1    1588.3
## Saint Paul, MN               1111.2       901.9       3974.9    1144.1
## Jackson, MS                   372.7       350.8       4180.8    1610.7
## Jefferson City, MO            720.0       547.5       4028.0    1295.0
## Helena, MT                   1855.5      1695.7       3096.4     289.8
## Lincoln, NE                   998.4       832.6       3785.8    1016.4
## Carson City, NV              2090.0      1990.3       2563.6     359.1
## Concord, NH                  1125.8       952.8       5049.5    2216.8
## Trenton, NJ                   861.0       694.3       4933.7    2123.4
## Santa Fe, NM                 1306.1      1231.4       3267.5     773.2
## Albany, NY                   1023.8       842.9       4948.6    2119.9
## Raleigh, NC                   490.8       355.4       4792.6    2052.9
## Bismarck, ND                 1435.0      1245.5       3617.7     781.6
## Columbus, OH                  661.4       436.2       4507.9    1719.2
## Oklahoma City, OK             843.5       756.3       3742.2    1141.0
## Salem, OR                    2318.8      2182.9       2563.1     350.7
## Harrisburg, PA                795.6       612.2       4823.9    2017.5
## Providence, RI               1061.6       900.5       5078.1    2251.3
## Columbia, SC                  309.2       193.4       4683.7    1991.3
## Pierre, SD                   1301.3      1123.9       3617.5     790.8
## Nashville, TN                 421.2       215.0       4338.3    1634.1
## Austin, TX                    804.8       818.8       3753.4    1370.4
## Salt Lake City, UT           1700.4      1582.1       2995.3     296.2
## Montpelier, VT               1148.0       962.9       4982.6    2147.4
## Richmond, VA                  625.0       468.5       4830.7    2058.7
## Olympia, WA                  2346.7      2198.8       2639.6     402.5
## Charleston, WV                565.9       353.0       4597.0    1827.7
```

```
## Madison, WI                 917.6       698.8       4160.0    1343.6
## Cheyenne, WY               1364.9      1228.8       3363.7     605.7
##                     Springfield, IL Indianapolis, IN Des Moines, IA Topeka, KS
## Montgomery, AL               547.9            512.4          755.7      702.0
## Juneau, AK                  2336.0           2462.1         2104.5     2165.4
## Phoenix, AZ                 1315.1           1497.4         1154.6      990.5
## Little Rock, AR              379.9            486.3          479.3      351.8
## Sacramento, CA              1700.0           1884.3         1483.1     1386.4
## Denver, CO                   814.3            999.6          609.6      499.2
## Hartford, CT                 898.2            718.9         1079.6     1222.8
## Dover, DE                    754.9            569.1          966.5     1080.1
## Tallahassee, FL              714.6            653.1          930.3      879.7
## Atlanta, GA                  509.6            427.3          740.2      727.3
## Honolulu, HI                4157.7           4343.1         3945.5     3837.5
## Boise, ID                   1389.8           1565.6         1154.6     1107.8
## Springfield, IL                0.0            185.9          242.1      326.4
## Indianapolis, IN             185.9              0.0          411.1      511.5
## Des Moines, IA               242.1            411.1            0.0      206.5
## Topeka, KS                   326.4            511.5          206.5        0.0
## Frankfort, KY                280.1            128.8          520.1      587.5
## Baton Rouge, LA              652.6            704.2          782.7      648.0
## Augusta, ME                 1064.3            896.2         1217.2     1380.5
## Annapolis, MD                704.9            519.1          919.7     1029.4
## Boston, MA                   983.3            806.2         1157.8     1306.5
## Lansing, MI                  334.2            221.5          471.7      635.1
## Saint Paul, MN               396.8            503.5          233.5      428.5
## Jackson, MS                  519.7            563.5          670.1      560.2
## Jefferson City, MO           159.3            332.9          222.1      192.3
## Helena, MT                  1216.4           1379.7          974.5      975.9
## Lincoln, NE                  376.9            559.4          168.1      132.1
## Carson City, NV             1600.6           1784.6         1382.6     1288.5
## Concord, NH                  965.5            792.8         1130.2     1285.8
## Trenton, NJ                  788.5            604.2          988.3     1115.0
## Santa Fe, NM                 935.3           1117.7          781.6      611.1
## Albany, NY                   848.9            674.7         1019.4     1170.6
## Raleigh, NC                  663.3            495.6          902.3      962.7
## Bismarck, ND                 739.6            880.6          506.0      594.8
## Columbus, OH                 353.3            168.2          567.2      679.5
## Oklahoma City, OK            524.5            689.3          473.0      267.8
## Salem, OR                   1729.9           1901.9         1491.4     1455.8
## Harrisburg, PA               677.0            492.7          878.5     1003.4
## Providence, RI               962.9            783.6         1143.2     1287.4
## Columbia, SC                 622.6            489.2          863.9      885.1
## Pierre, SD                   631.6            792.5          389.6      438.5
## Nashville, TN                296.0            251.5          525.3      527.0
## Austin, TX                   802.0            927.2          816.3      619.0
## Salt Lake City, UT          1172.1           1355.1          951.2      866.4
## Montpelier, VT               928.1            762.8         1078.7     1242.8
## Richmond, VA                 676.1            494.1          904.4      993.2
## Olympia, WA                 1729.1           1894.6         1487.7     1472.8
## Charleston, WV               442.2            262.1          673.2      759.6
## Madison, WI                  227.0            283.3          239.7      430.4
## Cheyenne, WY                 802.4            984.9          581.8      503.9
##                     Frankfort, KY Baton Rouge, LA Augusta, ME Annapolis, MD
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## Montgomery, AL             411.6           318.1      1214.1         714.1
## Juneau, AK                2589.3          2796.7      2831.8        2851.6
## Phoenix, AZ               1554.5          1241.3      2368.1        2008.2
## Little Rock, AR            479.1           304.1      1367.0         922.4
## Sacramento, CA            1972.6          1807.5      2665.6        2401.1
## Denver, CO                1085.1          1009.9      1822.2        1518.2
## Hartford, CT               690.9          1292.2       229.1         279.1
## Dover, DE                  508.6          1071.5       463.4          54.0
## Tallahassee, FL            536.9           412.9      1241.6         735.2
## Atlanta, GA                308.6           458.7      1069.0         568.2
## Honolulu, HI              4424.7          4140.7      5116.4        4861.5
## Boise, ID                 1669.8          1644.7      2280.3        2068.0
## Springfield, IL            280.1           652.6      1064.3         704.9
## Indianapolis, IN           128.8           704.2       896.2         519.1
## Des Moines, IA             520.1           782.7      1217.2         919.7
## Topeka, KS                 587.5           648.0      1380.5        1029.4
## Frankfort, KY                0.0           645.8       889.2         455.3
## Baton Rouge, LA            645.8             0.0      1509.4        1019.8
## Augusta, ME                889.2          1509.4         0.0         506.6
## Annapolis, MD              455.3          1019.8       506.6           0.0
## Boston, MA                 782.0          1384.3       149.7         368.9
## Lansing, MI                314.0           925.4       747.6         494.5
## Saint Paul, MN             630.9          1008.1      1144.6         945.8
## Jackson, MS                506.6           140.9      1378.1         895.7
## Jefferson City, MO         396.9           565.1      1222.4         844.6
## Helena, MT                1494.1          1577.7      2031.2        1861.0
## Lincoln, NE                655.1           780.1      1385.3        1076.0
## Carson City, NV           1874.0          1723.2      2564.3        2300.9
## Concord, NH                778.8          1394.3       116.4         390.6
## Trenton, NJ                558.9          1143.7       380.6         126.7
## Santa Fe, NM              1176.9           928.8      1990.4        1629.6
## Albany, NY                 660.4          1279.8       230.2         292.2
## Raleigh, NC                383.3           813.8       753.4         250.8
## Bismarck, ND              1003.5          1242.8      1501.6        1337.6
## Columbus, OH               157.8           803.4       740.7         353.7
## Oklahoma City, OK          724.9           505.9      1584.6        1180.1
## Salem, OR                 2009.9          1992.7      2573.9        2395.6
## Harrisburg, PA             451.3          1052.4       457.9          91.9
## Providence, RI             754.1          1350.0       191.0         332.3
## Columbia, SC               360.8           642.1       932.5         426.3
## Pierre, SD                 907.5          1084.6      1502.0        1280.8
## Nashville, TN              175.9           470.0      1056.7         595.8
## Austin, TX                 916.8           392.0      1806.0        1346.3
## Salt Lake City, UT        1447.8          1360.7      2136.7        1870.2
## Montpelier, VT             763.3          1393.4       138.5         418.1
## Richmond, VA               406.6           925.1       616.9         112.6
## Olympia, WA               2007.8          2038.6      2524.7        2375.6
## Charleston, WV             175.9           770.7       740.0         280.5
## Madison, WI                412.1           879.0       981.9         728.7
## Cheyenne, WY              1079.1          1061.8      1780.3        1500.2
##                    Boston, MA Lansing, MI Saint Paul, MN Jackson, MS
## Montgomery, AL         1082.4       723.7          944.1       228.3
## Juneau, AK             2879.9      2372.4         1958.6      2724.4
## Phoenix, AZ            2297.1      1620.6         1285.4      1271.4
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## Little Rock, AR       1261.0       693.9          707.2       209.1
## Sacramento, CA        2627.6      1944.2         1521.1      1807.7
## Denver, CO            1767.2      1080.6          705.8       973.2
## Hartford, CT            92.4       611.1         1047.3      1164.1
## Dover, DE              321.8       531.9          984.5       948.4
## Tallahassee, FL       1100.5       849.5         1111.2       372.7
## Atlanta, GA            936.6       621.1          901.9       350.8
## Honolulu, HI          5086.9      4406.1         3974.9      4180.8
## Boise, ID             2257.2      1588.3         1144.1      1610.7
## Springfield, IL        983.3       334.2          396.8       519.7
## Indianapolis, IN       806.2       221.5          503.5       563.5
## Des Moines, IA        1157.8       471.7          233.5       670.1
## Topeka, KS            1306.5       635.1          428.5       560.2
## Frankfort, KY          782.0       314.0          630.9       506.6
## Baton Rouge, LA       1384.3       925.4         1008.1       140.9
## Augusta, ME            149.7       747.6         1144.6      1378.1
## Annapolis, MD          368.9       494.5          945.8       895.7
## Boston, MA               0.0       686.9         1113.4      1256.4
## Lansing, MI            686.9         0.0          452.7       784.8
## Saint Paul, MN        1113.4       452.7            0.0       888.5
## Jackson, MS           1256.4       784.8          888.5         0.0
## Jefferson City, MO    1138.0       492.5          443.0       448.4
## Helena, MT            2019.4      1370.4          918.1      1519.7
## Lincoln, NE           1324.6       639.3          338.8       689.9
## Carson City, NV       2526.3      1843.0         1419.8      1719.0
## Concord, NH             63.4       658.6         1074.7      1263.7
## Trenton, NJ            242.4       535.5          986.4      1017.6
## Santa Fe, NM          1917.5      1243.3          932.1       933.4
## Albany, NY             138.9       548.2          975.9      1148.0
## Raleigh, NC            610.3       576.3          989.3       703.7
## Bismarck, ND          1486.8       843.8          391.9      1149.4
## Columbus, OH           642.7       207.8          619.0       664.4
## Oklahoma City, OK     1494.4       857.2          695.6       474.7
## Salem, OR             2562.7      1908.5         1457.7      1961.0
## Harrisburg, PA         334.6       432.2          884.8       922.8
## Providence, RI          41.3       673.9         1107.1      1223.3
## Columbia, SC           791.4       633.2          991.5       542.6
## Pierre, SD            1469.9       797.5          357.6       998.2
## Nashville, TN          942.5       469.6          691.3       330.7
## Austin, TX            1695.6      1129.4         1046.2       468.3
## Salt Lake City, UT    2095.7      1411.5          993.5      1336.0
## Montpelier, VT         152.0       609.3         1008.9      1259.5
## Richmond, VA           475.9       518.9          958.4       806.1
## Olympia, WA           2522.2      1883.8         1431.0      1997.0
## Charleston, WV         621.8       339.8          746.5       638.2
## Madison, WI            930.5       246.2          225.3       746.6
## Cheyenne, WY          1732.6      1046.4          647.8      1013.8
##                    Jefferson City, MO Helena, MT Lincoln, NE Carson City, NV
## Montgomery, AL                  542.9     1677.8       820.4          1925.8
## Juneau, AK                     2311.7     1233.5      2038.8          1475.4
## Phoenix, AZ                    1165.4      909.0       987.4           583.1
## Little Rock, AR                 265.8     1312.6       482.5          1541.0
## Sacramento, CA                 1578.7      733.6      1325.2           101.4
## Denver, CO                      691.5      591.4       444.6           789.3
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## Hartford, CT                   1051.5     1959.3      1245.4          2453.8
## Dover, DE                       896.3     1901.4      1124.2          2348.6
## Tallahassee, FL                 720.0     1855.5       998.4          2090.0
## Atlanta, GA                     547.5     1695.7       832.6          1990.3
## Honolulu, HI                   4028.0     3096.4      3785.8          2563.6
## Boise, ID                      1295.0      289.8      1016.4           359.1
## Springfield, IL                 159.3     1216.4       376.9          1600.6
## Indianapolis, IN                332.9     1379.7       559.4          1784.6
## Des Moines, IA                  222.1      974.5       168.1          1382.6
## Topeka, KS                      192.3      975.9       132.1          1288.5
## Frankfort, KY                   396.9     1494.1       655.1          1874.0
## Baton Rouge, LA                 565.1     1577.7       780.1          1723.2
## Augusta, ME                    1222.4     2031.2      1385.3          2564.3
## Annapolis, MD                   844.6     1861.0      1076.0          2300.9
## Boston, MA                     1138.0     2019.4      1324.6          2526.3
## Lansing, MI                     492.5     1370.4       639.3          1843.0
## Saint Paul, MN                  443.0      918.1       338.8          1419.8
## Jackson, MS                     448.4     1519.7       689.9          1719.0
## Jefferson City, MO                0.0     1148.2       285.1          1480.8
## Helena, MT                     1148.2        0.0       863.1           645.9
## Lincoln, NE                     285.1      863.1         0.0          1225.3
## Carson City, NV                1480.8      645.9      1225.3             0.0
## Concord, NH                    1122.2     1975.3      1297.8          2491.3
## Trenton, NJ                     936.0     1904.4      1150.1          2370.3
## Santa Fe, NM                    785.9      818.2       616.7           795.0
## Albany, NY                     1004.9     1884.5      1186.4          2387.6
## Raleigh, NC                     770.4     1874.7      1037.6          2251.2
## Bismarck, ND                    717.3      532.8       462.6          1092.4
## Columbus, OH                    500.2     1521.7       722.3          1947.4
## Oklahoma City, OK               365.2     1075.7       372.2          1246.8
## Salem, OR                      1641.3      543.4      1360.1           433.3
## Harrisburg, PA                  824.7     1802.6      1039.5          2260.9
## Providence, RI                 1116.2     2016.9      1309.3          2516.0
## Columbia, SC                    696.4     1835.5       978.1          2164.1
## Pierre, SD                      581.7      587.2       308.4          1062.9
## Nashville, TN                   339.9     1485.8       624.0          1807.9
## Austin, TX                      656.4     1364.0       731.6          1390.2
## Salt Lake City, UT             1058.4      403.3       795.7           431.7
## Montpelier, VT                 1086.6     1901.6      1246.8          2428.2
## Richmond, VA                    803.4     1864.2      1052.6          2276.5
## Olympia, WA                    1652.6      515.6      1368.1           567.0
## Charleston, WV                  570.8     1639.7       818.9          2042.4
## Madison, WI                     343.6     1132.5       406.5          1597.1
## Cheyenne, WY                    693.8      520.2       425.6           800.9
##                    Concord, NH Trenton, NJ Santa Fe, NM Albany, NY Raleigh, NC
## Montgomery, AL           1097.9       840.1       1149.5      987.2       497.2
## Juneau, AK               2821.5      2851.5       2031.9     2768.1      2941.1
## Phoenix, AZ              2275.7      2101.3        379.9     2161.0      1901.0
## Little Rock, AR          1257.6      1034.1        772.6     1139.0       776.4
## Sacramento, CA           2592.7      2471.1        878.7     2488.9      2349.0
## Denver, CO               1738.5      1594.6        286.7     1628.7      1461.9
## Hartford, CT              115.5       152.4       1833.3       82.9       524.4
## Dover, DE                 348.5        84.1       1681.7      258.8       290.0
## Tallahassee, FL          1125.8       861.0       1306.1     1023.8       490.8
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## Atlanta, GA              952.8       694.3       1231.4      842.9       355.4
## Honolulu, HI            5049.5      4933.7       3267.5     4948.6      4792.6
## Boise, ID               2216.8      2123.4        773.2     2119.9      2052.9
## Springfield, IL          965.5       788.5        935.3      848.9       663.3
## Indianapolis, IN         792.8       604.2       1117.7      674.7       495.6
## Des Moines, IA          1130.2       988.3        781.6     1019.4       902.3
## Topeka, KS              1285.8      1115.0        611.1     1170.6       962.7
## Frankfort, KY            778.8       558.9       1176.9      660.4       383.3
## Baton Rouge, LA         1394.3      1143.7        928.8     1279.8       813.8
## Augusta, ME              116.4       380.6       1990.4      230.2       753.4
## Annapolis, MD            390.6       126.7       1629.6      292.2       250.8
## Boston, MA                63.4       242.4       1917.5      138.9       610.3
## Lansing, MI              658.6       535.5       1243.3      548.2       576.3
## Saint Paul, MN          1074.7       986.4        932.1      975.9       989.3
## Jackson, MS             1263.7      1017.6        933.4     1148.0       703.7
## Jefferson City, MO      1122.2       936.0        785.9     1004.9       770.4
## Helena, MT              1975.3      1904.4        818.2     1884.5      1874.7
## Lincoln, NE             1297.8      1150.1        616.7     1186.4      1037.6
## Carson City, NV         2491.3      2370.3        795.0     2387.6      2251.2
## Concord, NH                0.0       265.1       1896.8      118.7       638.4
## Trenton, NJ              265.1         0.0       1721.7      175.9       373.4
## Santa Fe, NM            1896.8      1721.7          0.0     1781.7      1529.9
## Albany, NY               118.7       175.9       1781.7        0.0       543.0
## Raleigh, NC              638.4       373.4       1529.9      543.0         0.0
## Bismarck, ND            1443.1      1374.8        815.9     1351.7      1374.0
## Columbus, OH             633.4       436.1       1285.6      514.7       375.5
## Oklahoma City, OK       1482.0      1281.9        475.1     1363.9      1060.7
## Salem, OR               2518.6      2443.7       1102.1     2427.5      2393.0
## Harrisburg, PA           342.2       111.5       1610.3      230.8       325.8
## Providence, RI            95.8       206.5       1898.0      132.6       571.1
## Columbia, SC             816.8       551.9       1416.3      716.4       183.0
## Pierre, SD              1432.0      1332.8        671.9     1331.9      1287.6
## Nashville, TN            944.2       710.3       1073.3      826.7       457.0
## Austin, TX              1695.2      1463.3        605.5     1577.0      1169.5
## Salt Lake City, UT      2061.6      1938.7        477.1     1956.9      1827.6
## Montpelier, VT            89.4       300.8       1852.4      126.0       668.9
## Richmond, VA             501.4       236.3       1581.7      404.8       138.2
## Olympia, WA             2475.5      2416.2       1175.2     2389.2      2389.3
## Charleston, WV           625.9       389.9       1352.7      509.8       243.5
## Madison, WI              899.1       779.9       1021.3      791.7       764.1
## Cheyenne, WY            1700.9      1570.1        383.6     1593.8      1460.3
##                    Bismarck, ND Columbus, OH Oklahoma City, OK Salem, OR
## Montgomery, AL           1259.1        556.6             679.7    2144.8
## Juneau, AK               1598.6       2565.8            2302.4    1042.1
## Phoenix, AZ              1097.4       1665.4             840.4     986.7
## Little Rock, AR           943.8        627.1             298.0    1763.6
## Sacramento, CA           1191.7       2047.4            1337.4     446.9
## Denver, CO                532.7       1164.9             504.5     987.8
## Hartford, CT             1426.6        554.0            1405.9    2501.9
## Dover, DE                1375.7        402.4            1233.5    2437.5
## Tallahassee, FL          1435.0        661.4             843.5    2318.8
## Atlanta, GA              1245.5        436.2             756.3    2182.9
## Honolulu, HI             3617.7       4507.9            3742.2    2563.1
## Boise, ID                 781.6       1719.2            1141.0     350.7
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## Springfield, IL          739.6         353.3             524.5    1729.9
## Indianapolis, IN         880.6         168.2             689.3    1901.9
## Des Moines, IA           506.0         567.2             473.0    1491.4
## Topeka, KS               594.8         679.5             267.8    1455.8
## Frankfort, KY           1003.5         157.8             724.9    2009.9
## Baton Rouge, LA         1242.8         803.4             505.9    1992.7
## Augusta, ME             1501.6         740.7            1584.6    2573.9
## Annapolis, MD           1337.6         353.7            1180.1    2395.6
## Boston, MA              1486.8         642.7            1494.4    2562.7
## Lansing, MI              843.8         207.8             857.2    1908.5
## Saint Paul, MN           391.9         619.0             695.6    1457.7
## Jackson, MS             1149.4         664.4             474.7    1961.0
## Jefferson City, MO       717.3         500.2             365.2    1641.3
## Helena, MT               532.8        1521.7            1075.7     543.4
## Lincoln, NE              462.6         722.3             372.2    1360.1
## Carson City, NV         1092.4        1947.4            1246.8     433.3
## Concord, NH             1443.1         633.4            1482.0    2518.6
## Trenton, NJ             1374.8         436.1            1281.9    2443.7
## Santa Fe, NM             815.9        1285.6             475.1    1102.1
## Albany, NY              1351.7         514.7            1363.9    2427.5
## Raleigh, NC             1374.0         375.5            1060.7    2393.0
## Bismarck, ND               0.0        1008.4             802.4    1075.9
## Columbus, OH            1008.4           0.0             851.9    2050.9
## Oklahoma City, OK        802.4         851.9               0.0    1490.3
## Salem, OR               1075.9        2050.9            1490.3       0.0
## Harrisburg, PA          1275.1         324.6            1172.1    2340.3
## Providence, RI          1484.1         618.4            1470.3    2559.8
## Columbia, SC            1359.4         426.4             941.6    2337.4
## Pierre, SD               170.0         936.7             633.4    1114.9
## Nashville, TN           1030.5         333.6             603.9    1981.0
## Austin, TX              1155.7        1067.8             360.0    1706.1
## Salt Lake City, UT       693.6        1516.8             862.0     634.2
## Montpelier, VT          1370.6         611.3            1449.7    2444.8
## Richmond, VA            1349.3         342.5            1122.0    2392.4
## Olympia, WA             1041.5        2037.3            1533.0     145.3
## Charleston, WV          1133.0         133.6             899.8    2163.8
## Madison, WI              614.2         394.4             682.4    1667.3
## Cheyenne, WY             440.4        1146.7             557.1     955.5
##                    Harrisburg, PA Providence, RI Columbia, SC Pierre, SD
## Montgomery, AL              756.7         1046.3        324.0     1123.8
## Juneau, AK                 2772.4         2893.2       2949.4     1731.8
## Phoenix, AZ                1990.0         2277.7       1778.8      983.1
## Little Rock, AR             928.8         1232.5        646.6      790.2
## Sacramento, CA             2361.5         2617.3       2259.6     1164.1
## Denver, CO                 1483.8         1752.9       1379.0      400.2
## Hartford, CT                242.3           64.7        704.0     1401.9
## Dover, DE                   105.3          283.8        469.8     1323.4
## Tallahassee, FL             795.6         1061.6        309.2     1301.3
## Atlanta, GA                 612.2          900.5        193.4     1123.9
## Honolulu, HI               4823.9         5078.1       4683.7     3617.5
## Boise, ID                  2017.5         2251.3       1991.3      790.8
## Springfield, IL             677.0          962.9        622.6      631.6
## Indianapolis, IN            492.7          783.6        489.2      792.5
## Des Moines, IA              878.5         1143.2        863.9      389.6
```

```
## Topeka, KS              1003.4         1287.4       885.1     438.5
## Frankfort, KY            451.3          754.1       360.8     907.5
## Baton Rouge, LA         1052.4         1350.0       642.1    1084.6
## Augusta, ME              457.9          191.0       932.5    1502.0
## Annapolis, MD             91.9          332.3       426.3    1280.8
## Boston, MA               334.6           41.3       791.4    1469.9
## Lansing, MI              432.2          673.9       633.2     797.5
## Saint Paul, MN           884.8         1107.1       991.5     357.6
## Jackson, MS              922.8         1223.3       542.6     998.2
## Jefferson City, MO       824.7         1116.2       696.4     581.7
## Helena, MT              1802.6         2016.9      1835.5     587.2
## Lincoln, NE             1039.5         1309.3       978.1     308.4
## Carson City, NV         2260.9         2516.0      2164.1    1062.9
## Concord, NH              342.2           95.8       816.8    1432.0
## Trenton, NJ              111.5          206.5       551.9    1332.8
## Santa Fe, NM            1610.3         1898.0      1416.3     671.9
## Albany, NY               230.8          132.6       716.4    1331.9
## Raleigh, NC              325.8          571.1       183.0    1287.6
## Bismarck, ND            1275.1         1484.1      1359.4     170.0
## Columbus, OH             324.6          618.4       426.4     936.7
## Oklahoma City, OK       1172.1         1470.3       941.6     633.4
## Salem, OR               2340.3         2559.8      2337.4    1114.9
## Harrisburg, PA             0.0          304.0       490.4    1227.6
## Providence, RI           304.0            0.0       752.7    1462.5
## Columbia, SC             490.4          752.7         0.0    1253.4
## Pierre, SD              1227.6         1462.5      1253.4       0.0
## Nashville, TN            608.1          912.0       358.1     910.4
## Austin, TX              1361.4         1665.4      1010.9     985.8
## Salt Lake City, UT      1829.3         2084.9      1749.3     639.5
## Montpelier, VT           352.9          178.3       841.3    1366.5
## Richmond, VA             192.0          437.6       315.9    1278.8
## Olympia, WA             2315.8         2521.8      2345.1    1102.3
## Charleston, WV           287.2          591.0       302.5    1052.8
## Madison, WI              674.0          919.1       772.4     553.6
## Cheyenne, WY            1460.3         1720.4      1388.9     319.6
##                    Nashville, TN Austin, TX Salt Lake City, UT Montpelier, VT
## Montgomery, AL             264.8      692.4             1529.9         1106.2
## Juneau, AK                2628.8     2597.2             1563.9         2733.7
## Phoenix, AZ               1444.1      869.0              505.8         2229.9
## Little Rock, AR            327.8      441.7             1145.0         1238.4
## Sacramento, CA            1904.0     1466.6              532.7         2529.5
## Denver, CO                1021.3      772.6              371.0         1683.9
## Hartford, CT               850.4     1603.6             2022.5          172.8
## Dover, DE                  649.8     1400.0             1917.5          384.2
## Tallahassee, FL            421.2      804.8             1700.4         1148.0
## Atlanta, GA                215.0      818.8             1582.1          962.9
## Honolulu, HI              4338.3     3753.4             2995.3         4982.6
## Boise, ID                 1634.1     1370.4              296.2         2147.4
## Springfield, IL            296.0      802.0             1172.1          928.1
## Indianapolis, IN           251.5      927.2             1355.1          762.8
## Des Moines, IA             525.3      816.3              951.2         1078.7
## Topeka, KS                 527.0      619.0              866.4         1242.8
## Frankfort, KY              175.9      916.8             1447.8          763.3
## Baton Rouge, LA            470.0      392.0             1360.7         1393.4
```

```
## Augusta, ME               1056.7     1806.0             2136.7          138.5
## Annapolis, MD              595.8     1346.3             1870.2          418.1
## Boston, MA                 942.5     1695.6             2095.7          152.0
## Lansing, MI                469.6     1129.4             1411.5          609.3
## Saint Paul, MN             691.3     1046.2              993.5         1008.9
## Jackson, MS                330.7      468.3             1336.0         1259.5
## Jefferson City, MO         339.9      656.4             1058.4         1086.6
## Helena, MT                1485.8     1364.0              403.3         1901.6
## Lincoln, NE                624.0      731.6              795.7         1246.8
## Carson City, NV           1807.9     1390.2              431.7         2428.2
## Concord, NH                944.2     1695.2             2061.6           89.4
## Trenton, NJ                710.3     1463.3             1938.7          300.8
## Santa Fe, NM              1073.3      605.5              477.1         1852.4
## Albany, NY                 826.7     1577.0             1956.9          126.0
## Raleigh, NC                457.0     1169.5             1827.6          668.9
## Bismarck, ND              1030.5     1155.7              693.6         1370.6
## Columbus, OH               333.6     1067.8             1516.8          611.3
## Oklahoma City, OK          603.9      360.0              862.0         1449.7
## Salem, OR                 1981.0     1706.1              634.2         2444.8
## Harrisburg, PA             608.1     1361.4             1829.3          352.9
## Providence, RI             912.0     1665.4             2084.9          178.3
## Columbia, SC               358.1     1010.9             1749.3          841.3
## Pierre, SD                 910.4      985.8              639.5         1366.5
## Nashville, TN                0.0      753.4             1391.3          934.0
## Austin, TX                 753.4        0.0             1075.1         1678.9
## Salt Lake City, UT        1391.3     1075.1                0.0         1999.9
## Montpelier, VT             934.0     1678.9             1999.9            0.0
## Richmond, VA               524.0     1264.5             1848.2          530.7
## Olympia, WA               1992.1     1772.6              698.6         2398.8
## Charleston, WV             321.1     1074.5             1614.3          622.8
## Madison, WI                497.5      998.7             1165.9          843.5
## Cheyenne, WY              1030.9      849.9              370.2         1642.5
##                    Richmond, VA Olympia, WA Charleston, WV Madison, WI
## Montgomery, AL            614.0      2170.6          489.8       760.1
## Juneau, AK               2890.6       913.8         2697.8      2181.3
## Phoenix, AZ              1957.9      1097.9         1730.4      1393.9
## Little Rock, AR           851.6      1794.8          644.3       598.1
## Sacramento, CA           2375.8       589.2         2141.6      1698.4
## Denver, CO               1489.0      1028.7         1254.9       840.5
## Hartford, CT              388.1      2465.7          529.5       856.7
## Dover, DE                 154.1      2415.4          334.2       770.2
## Tallahassee, FL           625.0      2346.7          565.9       917.6
## Atlanta, GA               468.5      2198.8          353.0       698.8
## Honolulu, HI             4830.7      2639.6         4597.0      4160.0
## Boise, ID                2058.7       402.5         1827.7      1343.6
## Springfield, IL           676.1      1729.1          442.2       227.0
## Indianapolis, IN          494.1      1894.6          262.1       283.3
## Des Moines, IA            904.4      1487.7          673.2       239.7
## Topeka, KS                993.2      1472.8          759.6       430.4
## Frankfort, KY             406.6      2007.8          175.9       412.1
## Baton Rouge, LA           925.1      2038.6          770.7       879.0
## Augusta, ME               616.9      2524.7          740.0       981.9
## Annapolis, MD             112.6      2375.6          280.5       728.7
## Boston, MA                475.9      2522.2          621.8       930.5
```

```
## Lansing, MI              518.9      1883.8          339.8       246.2
## Saint Paul, MN           958.4      1431.0          746.5       225.3
## Jackson, MS              806.1      1997.0          638.2       746.6
## Jefferson City, MO       803.4      1652.6          570.8       343.6
## Helena, MT              1864.2       515.6         1639.7      1132.5
## Lincoln, NE             1052.6      1368.1          818.9       406.5
## Carson City, NV         2276.5       567.0         2042.4      1597.1
## Concord, NH              501.4      2475.5          625.9       899.1
## Trenton, NJ              236.3      2416.2          389.9       779.9
## Santa Fe, NM            1581.7      1175.2         1352.7      1021.3
## Albany, NY               404.8      2389.2          509.8       791.7
## Raleigh, NC              138.2      2389.3          243.5       764.1
## Bismarck, ND            1349.3      1041.5         1133.0       614.2
## Columbus, OH             342.5      2037.3          133.6       394.4
## Oklahoma City, OK       1122.0      1533.0          899.8       682.4
## Salem, OR               2392.4       145.3         2163.8      1667.3
## Harrisburg, PA           192.0      2315.8          287.2       674.0
## Providence, RI           437.6      2521.8          591.0       919.1
## Columbia, SC             315.9      2345.1          302.5       772.4
## Pierre, SD              1278.8      1102.3         1052.8       553.6
## Nashville, TN            524.0      1992.1          321.1       497.5
## Austin, TX              1264.5      1772.6         1074.5       998.7
## Salt Lake City, UT      1848.2       698.6         1614.3      1165.9
## Montpelier, VT           530.7      2398.8          622.8       843.5
## Richmond, VA               0.0      2379.7          234.1       735.2
## Olympia, WA             2379.7         0.0         2155.0      1647.5
## Charleston, WV           234.1      2155.0            0.0       521.2
## Madison, WI              735.2      1647.5          521.2         0.0
## Cheyenne, WY            1478.2       983.6         1244.5       802.2
##                   Cheyenne, WY
## Montgomery, AL          1189.9
## Juneau, AK              1752.1
## Phoenix, AZ              664.2
## Little Rock, AR          811.4
## Sacramento, CA           901.4
## Denver, CO                97.3
## Hartford, CT            1657.4
## Dover, DE               1547.7
## Tallahassee, FL         1364.9
## Atlanta, GA             1228.8
## Honolulu, HI            3363.7
## Boise, ID                605.7
## Springfield, IL          802.4
## Indianapolis, IN         984.9
## Des Moines, IA           581.8
## Topeka, KS               503.9
## Frankfort, KY           1079.1
## Baton Rouge, LA         1061.8
## Augusta, ME             1780.3
## Annapolis, MD           1500.2
## Boston, MA              1732.6
## Lansing, MI             1046.4
## Saint Paul, MN           647.8
## Jackson, MS             1013.8
```

```
## Jefferson City, MO        693.8
## Helena, MT                520.2
## Lincoln, NE               425.6
## Carson City, NV           800.9
## Concord, NH              1700.9
## Trenton, NJ              1570.1
## Santa Fe, NM              383.6
## Albany, NY               1593.8
## Raleigh, NC              1460.3
## Bismarck, ND              440.4
## Columbus, OH             1146.7
## Oklahoma City, OK         557.1
## Salem, OR                 955.5
## Harrisburg, PA           1460.3
## Providence, RI           1720.4
## Columbia, SC             1388.9
## Pierre, SD                319.6
## Nashville, TN            1030.9
## Austin, TX                849.9
## Salt Lake City, UT        370.2
## Montpelier, VT           1642.5
## Richmond, VA             1478.2
## Olympia, WA               983.6
## Charleston, WV           1244.5
## Madison, WI               802.2
## Cheyenne, WY                0.0
```

```
lookupPairwiseValue(dist.haversine.df, "Juneau, AK", "Montgomery, AL");
```

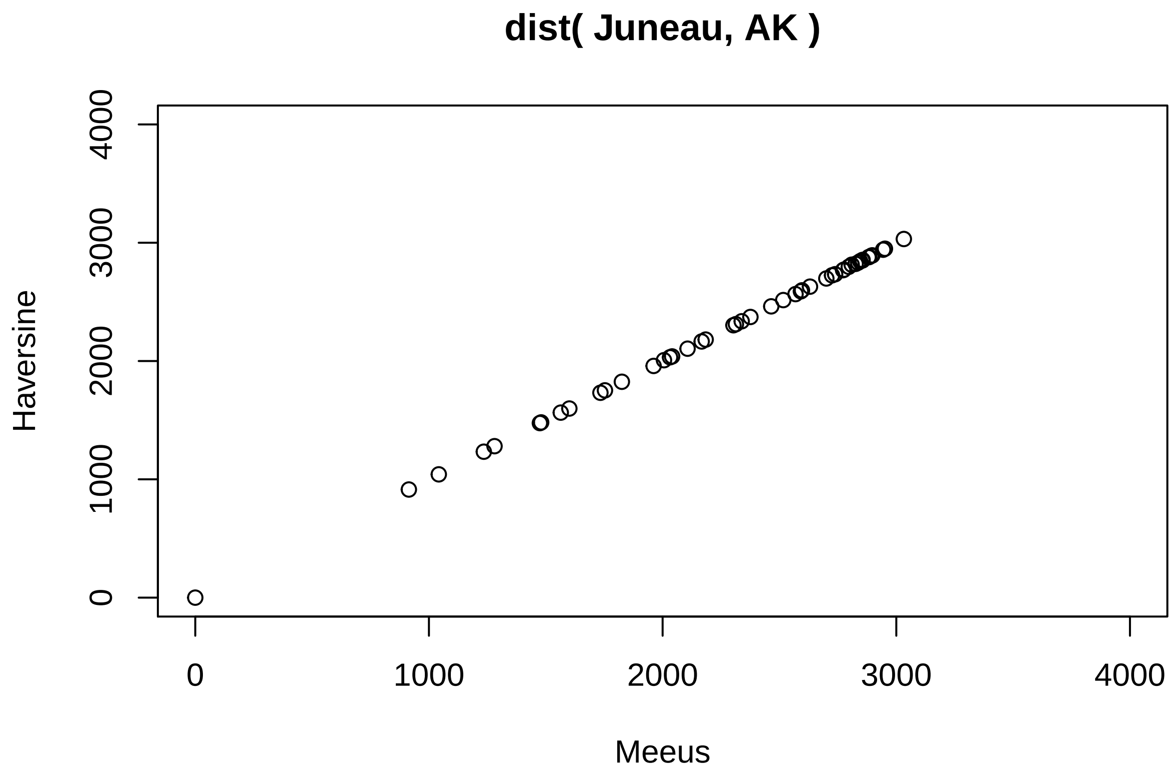
```
## [1] 2854.6
```

You can compare the two with the code below (currently in comments).

```
x = dist.meeus.df[,2]; # Juneau ... pick one location
y = dist.haversine.df[,2];

my.lim = c(0, 4000 );

plot(x, y,
            xlab="Meeus",
            ylab="Haversine",
            main="dist( Juneau, AK )",
            xlim=my.lim,
            ylim=my.lim);
```




```
plotXYwithBoxPlots(x, y,
            xlab="Meeus",
            ylab="Haversine",
            main="dist( Juneau, AK )",
            xlim=my.lim,
            ylim=my.lim)
```

[Examining the data above, is there much difference between these two calculations?

What is the conceptual difference between these two calculations? Try `?distMeeus` or `?distHaversine`

Are the results similar?

Is there a more accurate distance algorithm for geo-spatial calculations? If so, what is it?

]

Let's now do `manhattan` and `euclidean` which are more common in the "statistical clustering" domain. I will do `euclidean`.

```
dist.manhattan = dist( latlong[,1:2],
                     method="manhattan", diag=TRUE, upper=TRUE);
dist.manhattan.m = as.matrix( dist.manhattan );
  rownames(dist.manhattan.m) =
  colnames(dist.manhattan.m) = myLabels;
```

```r
dist.manhattan.df = as.data.frame( round( dist.manhattan.m, digits=1) );

dist.manhattan.df;  ## too big
```

Manhattan

```
##                      Montgomery, AL Juneau, AK Phoenix, AZ Little Rock, AR
## Montgomery, AL                  0.0     4418.0      1483.1           494.3
## Juneau, AK                   4418.0        0.0      2934.9          3923.7
## Phoenix, AZ                  1483.1     2934.9         0.0          1166.3
## Little Rock, AR               494.3     3923.7      1166.3             0.0
## Sacramento, CA               2351.9     2066.1       868.8          1857.7
## Denver, CO                   1530.7     2887.3       820.3          1036.4
## Hartford, CT                 1391.5     4512.2      2724.4          1558.1
## Dover, DE                    1056.2     4536.3      2389.1          1222.8
## Tallahassee, FL               242.2     4660.2      1725.3           736.4
## Atlanta, GA                   199.3     4425.0      1532.2           501.3
## Honolulu, HI                 4671.0     3832.5      3338.1          4504.4
## Boise, ID                    2410.3     2007.7       927.2          1916.0
## Springfield, IL               697.5     3720.5      1661.8           495.5
## Indianapolis, IN              517.7     3913.5      1850.6           684.3
## Des Moines, IA               1037.7     3380.3      1568.9           543.4
## Topeka, KS                    975.7     3442.3      1281.0           481.4
## Frankfort, KY                 479.9     4092.3      1812.9           646.5
## Baton Rouge, LA               399.6     4282.6      1347.7           358.8
## Augusta, ME                  1725.4     4494.4      3058.3          1892.0
## Annapolis, MD                 990.1     4495.7      2323.0          1156.7
## Boston, MA                   1520.5     4559.0      2853.4          1687.1
## Lansing, MI                   810.3     3796.9      2143.2           976.9
## Saint Paul, MN               1240.3     3177.8      1829.0           746.0
## Jackson, MS                   217.6     4209.1      1274.2           285.4
## Jefferson City, MO            750.7     3667.3      1439.9           273.6
## Helena, MT                   2387.3     2030.7       909.3          1893.0
## Lincoln, NE                  1150.7     3267.3      1348.0           656.4
## Carson City, NV              2297.8     2120.2       814.7          1803.6
## Concord, NH                  1553.2     4474.6      2886.1          1719.8
## Trenton, NJ                  1171.2     4504.3      2504.2          1337.8
## Santa Fe, NM                 1302.9     3115.1       486.2           808.6
## Albany, NY                   1393.8     4391.6      2726.7          1560.4
## Raleigh, NC                   652.4     4600.5      1985.4           819.0
## Bismarck, ND                 1788.8     2629.3      1537.8          1294.5
## Columbus, OH                  703.5     4072.6      2036.4           870.0
## Oklahoma City, OK             828.2     3589.8       933.5           333.9
## Salem, OR                    2875.0     1543.1      1391.8          2380.7
## Harrisburg, PA               1059.1     4385.8      2392.0          1225.7
## Providence, RI               1464.1     4576.3      2797.0          1630.7
## Columbia, SC                  399.4     4591.3      1732.4           667.5
## Pierre, SD                   1595.4     2822.6      1395.0          1101.1
## Nashville, TN                 290.1     4127.9      1567.9           401.6
## Austin, TX                    770.4     3936.6      1001.7           603.8
## Salt Lake City, UT           1978.0     2440.1       514.1          1483.7
## Montpelier, VT               1569.1     4345.3      2902.1          1735.7
## Richmond, VA                  838.0     4542.3      2170.9          1004.6
```

```
## Olympia, WA               3012.2     1405.8       1529.1           2517.9
## Charleston, WV             666.7     4258.7       1999.6            833.3
## Madison, WI                908.7     3509.3       1902.6            736.3
## Cheyenne, WY              1618.0     2800.0        926.3           1123.8
##                    Sacramento, CA Denver, CO Hartford, CT Dover, DE
## Montgomery, AL             2351.9     1530.7       1391.5    1056.2
## Juneau, AK                 2066.1     2887.3       4512.2    4536.3
## Phoenix, AZ                 868.8      820.3       2724.4    2389.1
## Little Rock, AR            1857.7     1036.4       1558.1    1222.8
## Sacramento, CA                0.0      981.0       2885.1    2549.7
## Denver, CO                  981.0        0.0       1904.1    1648.9
## Hartford, CT               2885.1     1904.1          0.0     335.3
## Dover, DE                  2549.7     1648.9        335.3       0.0
## Tallahassee, FL            2594.1     1772.8       1412.4    1077.1
## Atlanta, GA                2358.9     1537.7       1192.2     856.9
## Honolulu, HI               3177.4     4158.4       6062.5    5727.2
## Boise, ID                   636.3      879.6       2504.5    2528.6
## Springfield, IL            1822.5      841.5       1062.6     815.8
## Indianapolis, IN           2011.3     1030.3        873.8     622.7
## Des Moines, IA             1729.5      748.5       1155.5    1155.9
## Topeka, KS                 1441.7      555.0       1443.4    1108.1
## Frankfort, KY              2026.2     1204.9        911.5     576.2
## Baton Rouge, LA            2216.5     1395.2       1791.1    1455.7
## Augusta, ME                3218.9     2237.9        333.9     669.2
## Annapolis, MD              2483.6     1608.4        401.4      66.1
## Boston, MA                 3014.1     2033.1        129.0     464.4
## Lansing, MI                2303.8     1322.8        715.2     739.3
## Saint Paul, MN             1989.7     1008.7       1334.4    1358.5
## Jackson, MS                2143.0     1321.8       1609.1    1273.7
## Jefferson City, MO         1601.3      780.0       1284.5     949.2
## Helena, MT                 1069.9      856.6       2481.5    2505.6
## Lincoln, NE                1508.6      527.6       1376.5    1268.9
## Carson City, NV             134.5      846.5       2750.5    2416.1
## Concord, NH                3046.7     2065.7        161.7     497.0
## Trenton, NJ                2664.8     1683.8        220.3     115.1
## Santa Fe, NM               1049.0      334.2       2238.2    1902.9
## Albany, NY                 2887.3     1906.3        120.5     337.6
## Raleigh, NC                2534.4     1713.2        739.0     403.7
## Bismarck, ND               1698.5      717.5       1882.9    1907.0
## Columbus, OH               2197.0     1216.0        688.0     463.7
## Oklahoma City, OK          1523.7      702.5       1790.9    1455.6
## Salem, OR                   523.0     1344.3       2969.1    2993.2
## Harrisburg, PA             2552.7     1571.7        332.4     150.5
## Providence, RI             2957.6     1976.6         72.6     407.9
## Columbia, SC               2525.2     1703.9        992.1     656.7
## Pierre, SD                 1555.7      574.7       1689.6    1713.6
## Nashville, TN              2061.9     1240.6       1156.5     821.1
## Austin, TX                 1870.5     1049.3       2161.9    1826.6
## Salt Lake City, UT          674.7      447.3       2210.4    2096.2
## Montpelier, VT             3062.7     2081.7        177.7     513.0
## Richmond, VA               2476.3     1655.0        553.5     218.2
## Olympia, WA                 660.3     1481.5       3106.4    3130.5
## Charleston, WV             2192.6     1371.3        724.8     389.5
## Madison, WI                2063.2     1082.2       1002.9    1027.0
```

```
## Cheyenne, WY               1086.9      105.9       1798.1    1736.3
##                    Tallahassee, FL Atlanta, GA Honolulu, HI Boise, ID
## Montgomery, AL               242.2       199.3       4671.0    2410.3
## Juneau, AK                  4660.2      4425.0       3832.5    2007.7
## Phoenix, AZ                 1725.3      1532.2       3338.1     927.2
## Little Rock, AR              736.4       501.3       4504.4    1916.0
## Sacramento, CA              2594.1      2358.9       3177.4     636.3
## Denver, CO                  1772.8      1537.7       4158.4     879.6
## Hartford, CT                1412.4      1192.2       6062.5    2504.5
## Dover, DE                   1077.1       856.9       5727.2    2528.6
## Tallahassee, FL                0.0       235.2       4650.0    2652.5
## Atlanta, GA                  235.2         0.0       4870.3    2417.3
## Honolulu, HI                4650.0      4870.3          0.0    3813.8
## Boise, ID                   2652.5      2417.3       3813.8       0.0
## Springfield, IL              939.7       704.5       4999.9    1712.8
## Indianapolis, IN             746.6       511.5       5188.7    1905.8
## Des Moines, IA              1279.8      1044.7       4907.0    1372.6
## Topeka, KS                  1217.9       982.7       4619.1    1434.6
## Frankfort, KY                567.9       332.7       5150.9    2084.6
## Baton Rouge, LA              378.6       598.9       4271.4    2274.9
## Augusta, ME                 1746.3      1526.1       6396.4    2582.6
## Annapolis, MD               1011.0       790.8       5661.1    2488.0
## Boston, MA                  1541.5      1321.2       6191.5    2551.3
## Lansing, MI                  863.2       628.1       5481.3    1789.2
## Saint Paul, MN              1482.4      1247.3       5167.1    1353.4
## Jackson, MS                  451.1       416.9       4453.4    2201.4
## Jefferson City, MO           992.8       757.7       4778.0    1659.6
## Helena, MT                  2629.5      2394.3       4247.4     433.6
## Lincoln, NE                 1392.9      1157.7       4686.0    1259.6
## Carson City, NV             2540.0      2304.8       3312.0     501.8
## Concord, NH                 1574.1      1353.9       6224.2    2466.9
## Trenton, NJ                 1192.2       972.0       5842.2    2496.6
## Santa Fe, NM                1545.1      1309.9       3824.3    1107.4
## Albany, NY                  1414.7      1194.5       6064.8    2383.9
## Raleigh, NC                  673.4       453.2       5323.4    2592.8
## Bismarck, ND                2030.9      1795.8       4875.9    1062.1
## Columbus, OH                 724.4       504.2       5374.4    2064.9
## Oklahoma City, OK           1070.4       835.2       4271.6    1582.1
## Salem, OR                   3117.1      2882.0       3531.7     464.7
## Harrisburg, PA              1080.0       859.8       5730.1    2378.1
## Providence, RI              1485.0      1264.8       6135.1    2568.6
## Columbia, SC                 420.4       200.1       5070.4    2583.6
## Pierre, SD                  1837.5      1602.4       4733.1     919.3
## Nashville, TN                532.2       297.1       4906.0    2120.2
## Austin, TX                   749.5       969.7       3900.6    1928.9
## Salt Lake City, UT          2220.1      1985.0       3852.1     432.4
## Montpelier, VT              1590.1      1369.9       6240.1    2426.4
## Richmond, VA                 858.9       638.7       5509.0    2534.6
## Olympia, WA                 3254.4      3019.2       3684.1     601.9
## Charleston, WV               687.6       467.4       5337.7    2251.0
## Madison, WI                 1150.9       915.7       5240.7    1501.6
## Cheyenne, WY                1860.2      1625.1       4264.4     792.3
##                    Springfield, IL Indianapolis, IN Des Moines, IA Topeka, KS
## Montgomery, AL               697.5            517.7         1037.7      975.7
```

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## Juneau, AK                   3720.5           3913.5         3380.3     3442.3
## Phoenix, AZ                  1661.8           1850.6         1568.9     1281.0
## Little Rock, AR               495.5            684.3          543.4      481.4
## Sacramento, CA               1822.5           2011.3         1729.5     1441.7
## Denver, CO                    841.5           1030.3          748.5      555.0
## Hartford, CT                 1062.6            873.8         1155.5     1443.4
## Dover, DE                     815.8            622.7         1155.9     1108.1
## Tallahassee, FL               939.7            746.6         1279.8     1217.9
## Atlanta, GA                   704.5            511.5         1044.7      982.7
## Honolulu, HI                 4999.9           5188.7         4907.0     4619.1
## Boise, ID                    1712.8           1905.8         1372.6     1434.6
## Springfield, IL                 0.0            193.1          340.1      380.8
## Indianapolis, IN              193.1              0.0          533.2      569.6
## Des Moines, IA                340.1            533.2            0.0      287.9
## Topeka, KS                    380.8            569.6          287.9        0.0
## Frankfort, KY                 371.8            178.7          711.9      650.0
## Baton Rouge, LA               728.5            917.3          902.2      840.3
## Augusta, ME                  1396.5           1207.7         1489.4     1777.3
## Annapolis, MD                 775.2            582.2         1115.4     1053.4
## Boston, MA                   1191.6           1002.8         1284.6     1572.4
## Lansing, MI                   481.4            292.6          574.3      862.2
## Saint Paul, MN                542.7            735.8          260.2      548.0
## Jackson, MS                   546.5            735.3          828.8      766.8
## Jefferson City, MO            221.9            410.7          287.0      225.0
## Helena, MT                   1689.8           1882.8         1349.6     1411.6
## Lincoln, NE                   453.2            646.2          220.9      175.0
## Carson City, NV              1687.9           1876.7         1595.0     1322.1
## Concord, NH                  1224.3           1035.5         1317.2     1605.1
## Trenton, NJ                   842.4            653.5         1123.9     1223.1
## Santa Fe, NM                 1175.6           1364.4         1082.7      794.8
## Albany, NY                   1064.9            876.1         1157.8     1445.7
## Raleigh, NC                   880.0            687.0         1220.2     1158.2
## Bismarck, ND                 1091.2           1284.3          751.1      813.1
## Columbus, OH                  374.6            185.8          692.2      755.4
## Oklahoma City, OK             728.3            917.1          635.4      347.5
## Salem, OR                    2177.4           2370.5         1837.3     1899.3
## Harrisburg, PA                730.2            541.4         1005.4     1111.0
## Providence, RI               1135.2            946.4         1228.1     1516.0
## Columbia, SC                  870.8            677.7         1210.9     1149.0
## Pierre, SD                    897.9           1090.9          557.7      619.7
## Nashville, TN                 407.5            282.7          747.6      685.6
## Austin, TX                   1099.3           1288.1         1006.4      718.5
## Salt Lake City, UT           1280.4           1473.5         1054.8     1002.3
## Montpelier, VT               1240.3           1051.5         1333.2     1621.1
## Richmond, VA                  821.8            628.8         1162.0     1100.0
## Olympia, WA                  2314.7           2507.7         1974.5     2036.5
## Charleston, WV                538.2            345.1          878.3      816.4
## Madison, WI                   240.8            404.3          333.7      621.6
## Cheyenne, WY                  920.5           1113.6          642.6      642.4
##                    Frankfort, KY Baton Rouge, LA Augusta, ME Annapolis, MD
## Montgomery, AL             479.9           399.6      1725.4         990.1
## Juneau, AK                4092.3          4282.6      4494.4        4495.7
## Phoenix, AZ               1812.9          1347.7      3058.3        2323.0
## Little Rock, AR            646.5           358.8      1892.0        1156.7
```

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## Sacramento, CA             2026.2          2216.5      3218.9         2483.6
## Denver, CO                 1204.9          1395.2      2237.9         1608.4
## Hartford, CT                911.5          1791.1       333.9          401.4
## Dover, DE                   576.2          1455.7       669.2           66.1
## Tallahassee, FL             567.9           378.6      1746.3         1011.0
## Atlanta, GA                 332.7           598.9      1526.1          790.8
## Honolulu, HI               5150.9          4271.4      6396.4         5661.1
## Boise, ID                  2084.6          2274.9      2582.6         2488.0
## Springfield, IL             371.8           728.5      1396.5          775.2
## Indianapolis, IN            178.7           917.3      1207.7          582.2
## Des Moines, IA              711.9           902.2      1489.4         1115.4
## Topeka, KS                  650.0           840.3      1777.3         1053.4
## Frankfort, KY                 0.0           879.5      1245.4          510.1
## Baton Rouge, LA             879.5             0.0      2124.9         1389.7
## Augusta, ME                1245.4          2124.9         0.0          735.3
## Annapolis, MD               510.1          1389.7       735.3            0.0
## Boston, MA                 1040.6          1920.1       204.8          530.5
## Lansing, MI                 330.3          1209.8       915.1          698.8
## Saint Paul, MN              914.5          1104.8      1316.7         1318.0
## Jackson, MS                 697.5           182.0      1942.9         1207.6
## Jefferson City, MO          424.9           615.2      1618.4          883.1
## Helena, MT                 2061.6          2251.9      2463.7         2465.0
## Lincoln, NE                 824.9          1015.3      1710.3         1228.4
## Carson City, NV            1972.1          2162.4      3084.4         2375.5
## Concord, NH                1073.2          1952.8       172.2          563.1
## Trenton, NJ                 691.3          1570.8       554.1          181.2
## Santa Fe, NM               1326.7          1167.5      2572.1         1836.8
## Albany, NY                  913.8          1793.4       331.6          403.7
## Raleigh, NC                 508.3          1052.0      1072.9          337.6
## Bismarck, ND               1463.0          1653.3      1865.2         1866.5
## Columbus, OH                223.5          1103.0      1021.9          423.1
## Oklahoma City, OK           879.4           692.8      2124.8         1389.5
## Salem, OR                  2549.2          2739.5      2951.4         2952.7
## Harrisburg, PA              579.1          1458.7       666.3          109.9
## Providence, RI              984.1          1863.7       261.3          474.0
## Columbia, SC                499.0           799.0      1325.9          590.6
## Pierre, SD                 1269.6          1459.9      1671.8         1673.1
## Nashville, TN               244.9           634.6      1490.3          755.1
## Austin, TX                 1250.4           370.9      2495.8         1760.5
## Salt Lake City, UT         1652.2          1842.5      2544.2         2055.7
## Montpelier, VT             1089.2          1968.7       156.2          579.1
## Richmond, VA                450.1          1237.6       887.4          152.1
## Olympia, WA                2686.5          2876.8      3088.6         3089.9
## Charleston, WV              186.7          1066.3      1058.7          323.4
## Madison, WI                 583.0           969.3      1155.7          986.4
## Cheyenne, WY               1292.3          1482.6      2132.0         1695.7
##                    Boston, MA Lansing, MI Saint Paul, MN Jackson, MS
## Montgomery, AL         1520.5       810.3         1240.3       217.6
## Juneau, AK             4559.0      3796.9         3177.8      4209.1
## Phoenix, AZ            2853.4      2143.2         1829.0      1274.2
## Little Rock, AR        1687.1       976.9          746.0       285.4
## Sacramento, CA         3014.1      2303.8         1989.7      2143.0
## Denver, CO             2033.1      1322.8         1008.7      1321.8
## Hartford, CT            129.0       715.2         1334.4      1609.1
```

```
## Dover, DE                464.4       739.3          1358.5      1273.7
## Tallahassee, FL         1541.5       863.2          1482.4       451.1
## Atlanta, GA             1321.2       628.1          1247.3       416.9
## Honolulu, HI            6191.5      5481.3          5167.1      4453.4
## Boise, ID               2551.3      1789.2          1353.4      2201.4
## Springfield, IL         1191.6       481.4           542.7       546.5
## Indianapolis, IN        1002.8       292.6           735.8       735.3
## Des Moines, IA          1284.6       574.3           260.2       828.8
## Topeka, KS              1572.4       862.2           548.0       766.8
## Frankfort, KY           1040.6       330.3           914.5       697.5
## Baton Rouge, LA         1920.1      1209.8          1104.8       182.0
## Augusta, ME              204.8       915.1          1316.7      1942.9
## Annapolis, MD            530.5       698.8          1318.0      1207.6
## Boston, MA                 0.0       762.1          1381.3      1738.1
## Lansing, MI              762.1         0.0           619.2      1027.8
## Saint Paul, MN          1381.3       619.2             0.0      1031.3
## Jackson, MS             1738.1      1027.8          1031.3         0.0
## Jefferson City, MO      1413.5       703.3           489.6       541.8
## Helena, MT              2528.3      1766.2          1147.0      2178.4
## Lincoln, NE             1505.5       795.2           481.1       941.8
## Carson City, NV         2879.6      2169.3          1855.2      2088.9
## Concord, NH               84.5       742.9          1296.8      1770.7
## Trenton, NJ              349.3       707.3          1326.5      1388.8
## Santa Fe, NM            2367.3      1657.0          1342.9      1094.0
## Albany, NY               167.4       594.7          1213.9      1611.3
## Raleigh, NC              868.1       803.6          1422.8       870.0
## Bismarck, ND            1929.8      1167.7           548.5      1579.9
## Columbus, OH             817.1       275.6           894.8       921.0
## Oklahoma City, OK       1920.0      1209.7           895.6       619.3
## Salem, OR               3016.0      2253.9          1635.4      2666.0
## Harrisburg, PA           461.4       588.9          1208.0      1276.7
## Providence, RI            56.5       779.4          1398.6      1681.6
## Columbia, SC            1121.1       794.3          1413.5       617.0
## Pierre, SD              1736.4       974.3           434.0      1386.5
## Nashville, TN           1285.5       575.2           950.2       452.6
## Austin, TX              2291.0      1580.7          1266.6       552.9
## Salt Lake City, UT      2339.4      1629.1          1315.0      1769.0
## Montpelier, VT           213.8       758.9          1167.5      1786.7
## Richmond, VA             682.6       745.4          1364.6      1055.5
## Olympia, WA             3153.2      2391.1          1771.9      2803.3
## Charleston, WV           853.9       461.7          1080.9       884.2
## Madison, WI             1049.8       287.7           331.5       787.2
## Cheyenne, WY            1927.2      1216.9           902.8      1409.1
##                    Jefferson City, MO Helena, MT Lincoln, NE Carson City, NV
## Montgomery, AL                  750.7     2387.3      1150.7          2297.8
## Juneau, AK                     3667.3     2030.7      3267.3          2120.2
## Phoenix, AZ                    1439.9      909.3      1348.0           814.7
## Little Rock, AR                 273.6     1893.0       656.4          1803.6
## Sacramento, CA                 1601.3     1069.9      1508.6           134.5
## Denver, CO                      780.0      856.6       527.6           846.5
## Hartford, CT                   1284.5     2481.5      1376.5          2750.5
## Dover, DE                       949.2     2505.6      1268.9          2416.1
## Tallahassee, FL                 992.8     2629.5      1392.9          2540.0
## Atlanta, GA                     757.7     2394.3      1157.7          2304.8
```

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## Honolulu, HI                    4778.0     4247.4      4686.0         3312.0
## Boise, ID                       1659.6      433.6      1259.6          501.8
## Springfield, IL                  221.9     1689.8       453.2         1687.9
## Indianapolis, IN                 410.7     1882.8       646.2         1876.7
## Des Moines, IA                   287.0     1349.6       220.9         1595.0
## Topeka, KS                       225.0     1411.6       175.0         1322.1
## Frankfort, KY                    424.9     2061.6       824.9         1972.1
## Baton Rouge, LA                  615.2     2251.9      1015.3         2162.4
## Augusta, ME                     1618.4     2463.7      1710.3         3084.4
## Annapolis, MD                    883.1     2465.0      1228.4         2375.5
## Boston, MA                      1413.5     2528.3      1505.5         2879.6
## Lansing, MI                      703.3     1766.2       795.2         2169.3
## Saint Paul, MN                   489.6     1147.0       481.1         1855.2
## Jackson, MS                      541.8     2178.4       941.8         2088.9
## Jefferson City, MO                 0.0     1636.6       400.0         1547.2
## Helena, MT                      1636.6        0.0      1236.6          935.4
## Lincoln, NE                      400.0     1236.6         0.0         1374.1
## Carson City, NV                 1547.2      935.4      1374.1            0.0
## Concord, NH                     1446.2     2443.9      1538.1         2912.2
## Trenton, NJ                     1064.2     2473.6      1236.9         2530.3
## Santa Fe, NM                     953.7     1084.4       861.8          994.9
## Albany, NY                      1286.8     2360.9      1378.7         2752.8
## Raleigh, NC                      933.2     2569.8      1333.2         2480.3
## Bismarck, ND                    1038.1      628.5       638.1         1563.9
## Columbus, OH                     596.5     2041.9       805.3         2062.5
## Oklahoma City, OK                506.4     1559.1       414.5         1469.6
## Salem, OR                       2124.3      715.6      1724.3          577.1
## Harrisburg, PA                   952.1     2355.1      1118.5         2418.1
## Providence, RI                  1357.1     2545.6      1449.0         2823.1
## Columbia, SC                     923.9     2560.6      1323.9         2471.1
## Pierre, SD                       844.7      791.9       444.7         1421.2
## Nashville, TN                    460.6     2097.2       860.6         2007.8
## Austin, TX                       877.4     1905.9       785.5         1816.4
## Salt Lake City, UT              1227.3      409.3       833.9          540.2
## Montpelier, VT                  1462.1     2314.6      1554.1         2928.2
## Richmond, VA                     875.0     2511.6      1275.0         2422.1
## Olympia, WA                     2261.5      624.9      1861.5          714.4
## Charleston, WV                   591.3     2228.0       991.3         2138.5
## Madison, WI                      462.7     1478.6       554.6         1928.7
## Cheyenne, WY                     867.4      769.2       467.4          952.4
##                    Concord, NH Trenton, NJ Santa Fe, NM Albany, NY Raleigh, NC
## Montgomery, AL           1553.2      1171.2       1302.9     1393.8       652.4
## Juneau, AK               4474.6      4504.3       3115.1     4391.6      4600.5
## Phoenix, AZ              2886.1      2504.2        486.2     2726.7      1985.4
## Little Rock, AR          1719.8      1337.8        808.6     1560.4       819.0
## Sacramento, CA           3046.7      2664.8       1049.0     2887.3      2534.4
## Denver, CO               2065.7      1683.8        334.2     1906.3      1713.2
## Hartford, CT              161.7       220.3       2238.2      120.5       739.0
## Dover, DE                 497.0       115.1       1902.9      337.6       403.7
## Tallahassee, FL          1574.1      1192.2       1545.1     1414.7       673.4
## Atlanta, GA              1353.9       972.0       1309.9     1194.5       453.2
## Honolulu, HI             6224.2      5842.2       3824.3     6064.8      5323.4
## Boise, ID                2466.9      2496.6       1107.4     2383.9      2592.8
## Springfield, IL          1224.3       842.4       1175.6     1064.9       880.0
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## Indianapolis, IN        1035.5       653.5        1364.4      876.1        687.0
## Des Moines, IA          1317.2      1123.9        1082.7     1157.8       1220.2
## Topeka, KS              1605.1      1223.1         794.8     1445.7       1158.2
## Frankfort, KY           1073.2       691.3        1326.7      913.8        508.3
## Baton Rouge, LA         1952.8      1570.8        1167.5     1793.4       1052.0
## Augusta, ME              172.2       554.1        2572.1      331.6       1072.9
## Annapolis, MD            563.1       181.2        1836.8      403.7        337.6
## Boston, MA                84.5       349.3        2367.3      167.4        868.1
## Lansing, MI              742.9       707.3        1657.0      594.7        803.6
## Saint Paul, MN          1296.8      1326.5        1342.9     1213.9       1422.8
## Jackson, MS             1770.7      1388.8        1094.0     1611.3        870.0
## Jefferson City, MO      1446.2      1064.2         953.7     1286.8        933.2
## Helena, MT              2443.9      2473.6        1084.4     2360.9       2569.8
## Lincoln, NE             1538.1      1236.9         861.8     1378.7       1333.2
## Carson City, NV         2912.2      2530.3         994.9     2752.8       2480.3
## Concord, NH                0.0       381.9        2399.9      159.4        900.7
## Trenton, NJ              381.9         0.0        2018.0      222.5        518.8
## Santa Fe, NM            2399.9      2018.0           0.0     2240.5       1499.2
## Albany, NY               159.4       222.5        2240.5        0.0        741.3
## Raleigh, NC              900.7       518.8        1499.2      741.3          0.0
## Bismarck, ND            1845.3      1875.0        1051.6     1762.4       1971.3
## Columbus, OH             849.7       467.8        1550.2      690.3        527.9
## Oklahoma City, OK       1952.6      1570.7         474.7     1793.2       1051.9
## Salem, OR               2931.5      2961.2        1572.1     2848.6       3057.5
## Harrisburg, PA           494.1       118.5        1905.8      334.7        406.6
## Providence, RI           101.8       292.8        2310.8      184.7        811.6
## Columbia, SC            1153.7       771.8        1476.2      994.3        253.0
## Pierre, SD              1651.9      1681.6         908.9     1569.0       1777.9
## Nashville, TN           1318.2       936.2        1081.8     1158.7        472.6
## Austin, TX              2323.6      1941.7         821.5     2164.2       1422.9
## Salt Lake City, UT      2372.0      2064.2         675.1     2212.6       2160.5
## Montpelier, VT           129.3       397.9        2415.9      175.4        916.7
## Richmond, VA             715.2       333.3        1684.7      555.8        185.5
## Olympia, WA             3068.8      3098.5        1709.3     2985.8       3194.7
## Charleston, WV           886.5       504.6        1513.4      727.1        341.9
## Madison, WI              983.5       995.0        1416.4      882.4       1091.2
## Cheyenne, WY            1959.8      1704.3         440.1     1800.4       1800.6
##                    Bismarck, ND Columbus, OH Oklahoma City, OK Salem, OR
## Montgomery, AL            1788.8        703.5              828.2    2875.0
## Juneau, AK                2629.3       4072.6             3589.8    1543.1
## Phoenix, AZ               1537.8       2036.4              933.5    1391.8
## Little Rock, AR           1294.5        870.0              333.9    2380.7
## Sacramento, CA            1698.5       2197.0             1523.7     523.0
## Denver, CO                 717.5       1216.0              702.5    1344.3
## Hartford, CT              1882.9        688.0             1790.9    2969.1
## Dover, DE                 1907.0        463.7             1455.6    2993.2
## Tallahassee, FL           2030.9        724.4             1070.4    3117.1
## Atlanta, GA               1795.8        504.2              835.2    2882.0
## Honolulu, HI              4875.9       5374.4             4271.6    3531.7
## Boise, ID                 1062.1       2064.9             1582.1     464.7
## Springfield, IL           1091.2        374.6              728.3    2177.4
## Indianapolis, IN          1284.3        185.8              917.1    2370.5
## Des Moines, IA             751.1        692.2              635.4    1837.3
## Topeka, KS                 813.1        755.4              347.5    1899.3
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## Frankfort, KY          1463.0       223.5            879.4    2549.2
## Baton Rouge, LA        1653.3      1103.0            692.8    2739.5
## Augusta, ME            1865.2      1021.9           2124.8    2951.4
## Annapolis, MD          1866.5       423.1           1389.5    2952.7
## Boston, MA             1929.8       817.1           1920.0    3016.0
## Lansing, MI            1167.7       275.6           1209.7    2253.9
## Saint Paul, MN          548.5       894.8            895.6    1635.4
## Jackson, MS            1579.9       921.0            619.3    2666.0
## Jefferson City, MO     1038.1       596.5            506.4    2124.3
## Helena, MT              628.5      2041.9           1559.1     715.6
## Lincoln, NE             638.1       805.3            414.5    1724.3
## Carson City, NV        1563.9      2062.5           1469.6     577.1
## Concord, NH            1845.3       849.7           1952.6    2931.5
## Trenton, NJ            1875.0       467.8           1570.7    2961.2
## Santa Fe, NM           1051.6      1550.2            474.7    1572.1
## Albany, NY             1762.4       690.3           1793.2    2848.6
## Raleigh, NC            1971.3       527.9           1051.9    3057.5
## Bismarck, ND              0.0      1443.3            960.6    1344.1
## Columbus, OH           1443.3         0.0           1102.9    2529.5
## Oklahoma City, OK       960.6      1102.9              0.0    2046.8
## Salem, OR              1344.1      2529.5           2046.8       0.0
## Harrisburg, PA         1756.5       355.6           1458.5    2842.7
## Providence, RI         1947.1       760.6           1863.5    3033.3
## Columbia, SC           1962.0       518.7           1001.5    3048.2
## Pierre, SD              193.4      1250.0            767.2    1279.6
## Nashville, TN          1498.7       468.4            634.5    2584.9
## Austin, TX             1307.4      1473.9            371.0    2393.5
## Salt Lake City, UT     1023.7      1632.5           1149.7     897.0
## Montpelier, VT         1716.0       865.7           1968.6    2802.2
## Richmond, VA           1913.1       469.7           1237.4    2999.3
## Olympia, WA            1223.4      2666.8           2184.0     152.4
## Charleston, WV         1629.4       186.1           1066.1    2715.6
## Madison, WI             880.0       563.3            969.1    1966.2
## Cheyenne, WY            611.5      1272.6            789.8    1256.9
##                    Harrisburg, PA Providence, RI Columbia, SC Pierre, SD
## Montgomery, AL             1059.1         1464.1        399.4     1595.4
## Juneau, AK                 4385.8         4576.3       4591.3     2822.6
## Phoenix, AZ                2392.0         2797.0       1732.4     1395.0
## Little Rock, AR            1225.7         1630.7        667.5     1101.1
## Sacramento, CA             2552.7         2957.6       2525.2     1555.7
## Denver, CO                 1571.7         1976.6       1703.9      574.7
## Hartford, CT                332.4           72.6        992.1     1689.6
## Dover, DE                   150.5          407.9        656.7     1713.6
## Tallahassee, FL            1080.0         1485.0        420.4     1837.5
## Atlanta, GA                 859.8         1264.8        200.1     1602.4
## Honolulu, HI               5730.1         6135.1       5070.4     4733.1
## Boise, ID                  2378.1         2568.6       2583.6      919.3
## Springfield, IL             730.2         1135.2        870.8      897.9
## Indianapolis, IN            541.4          946.4        677.7     1090.9
## Des Moines, IA             1005.4         1228.1       1210.9      557.7
## Topeka, KS                 1111.0         1516.0       1149.0      619.7
## Frankfort, KY               579.1          984.1        499.0     1269.6
## Baton Rouge, LA            1458.7         1863.7        799.0     1459.9
## Augusta, ME                 666.3          261.3       1325.9     1671.8
```

```
## Annapolis, MD              109.9          474.0          590.6     1673.1
## Boston, MA                 461.4           56.5         1121.1     1736.4
## Lansing, MI                588.9          779.4          794.3      974.3
## Saint Paul, MN            1208.0         1398.6         1413.5      434.0
## Jackson, MS               1276.7         1681.6          617.0     1386.5
## Jefferson City, MO         952.1         1357.1          923.9      844.7
## Helena, MT                2355.1         2545.6         2560.6      791.9
## Lincoln, NE               1118.5         1449.0         1323.9      444.7
## Carson City, NV           2418.1         2823.1         2471.1     1421.2
## Concord, NH                494.1          101.8         1153.7     1651.9
## Trenton, NJ                118.5          292.8          771.8     1681.6
## Santa Fe, NM              1905.8         2310.8         1476.2      908.9
## Albany, NY                 334.7          184.7          994.3     1569.0
## Raleigh, NC                406.6          811.6          253.0     1777.9
## Bismarck, ND              1756.5         1947.1         1962.0      193.4
## Columbus, OH               355.6          760.6          518.7     1250.0
## Oklahoma City, OK         1458.5         1863.5         1001.5      767.2
## Salem, OR                 2842.7         3033.3         3048.2     1279.6
## Harrisburg, PA               0.0          405.0          659.7     1563.2
## Providence, RI             405.0            0.0         1064.6     1753.7
## Columbia, SC               659.7         1064.6            0.0     1768.6
## Pierre, SD                1563.2         1753.7         1768.6        0.0
## Nashville, TN              824.1         1229.0          463.3     1305.3
## Austin, TX                1829.5         2234.5         1169.9     1114.0
## Salt Lake City, UT        1945.7         2282.9         2151.2      881.0
## Montpelier, VT             510.1          231.1         1169.7     1522.6
## Richmond, VA               221.1          626.1          438.5     1719.7
## Olympia, WA               2980.0         3170.5         3185.5     1416.8
## Charleston, WV             392.4          797.4          332.6     1436.0
## Madison, WI                876.5         1067.0         1082.0      686.6
## Cheyenne, WY              1585.8         1870.7         1791.3      468.8
##                    Nashville, TN Austin, TX Salt Lake City, UT Montpelier, VT
## Montgomery, AL             290.1      770.4             1978.0         1569.1
## Juneau, AK                4127.9     3936.6             2440.1         4345.3
## Phoenix, AZ               1567.9     1001.7              514.1         2902.1
## Little Rock, AR            401.6      603.8             1483.7         1735.7
## Sacramento, CA            2061.9     1870.5              674.7         3062.7
## Denver, CO                1240.6     1049.3              447.3         2081.7
## Hartford, CT              1156.5     2161.9             2210.4          177.7
## Dover, DE                  821.1     1826.6             2096.2          513.0
## Tallahassee, FL            532.2      749.5             2220.1         1590.1
## Atlanta, GA                297.1      969.7             1985.0         1369.9
## Honolulu, HI              4906.0     3900.6             3852.1         6240.1
## Boise, ID                 2120.2     1928.9              432.4         2426.4
## Springfield, IL            407.5     1099.3             1280.4         1240.3
## Indianapolis, IN           282.7     1288.1             1473.5         1051.5
## Des Moines, IA             747.6     1006.4             1054.8         1333.2
## Topeka, KS                 685.6      718.5             1002.3         1621.1
## Frankfort, KY              244.9     1250.4             1652.2         1089.2
## Baton Rouge, LA            634.6      370.9             1842.5         1968.7
## Augusta, ME               1490.3     2495.8             2544.2          156.2
## Annapolis, MD              755.1     1760.5             2055.7          579.1
## Boston, MA                1285.5     2291.0             2339.4          213.8
## Lansing, MI                575.2     1580.7             1629.1          758.9
```

```
## Saint Paul, MN            950.2     1266.6             1315.0          1167.5
## Jackson, MS               452.6      552.9             1769.0          1786.7
## Jefferson City, MO        460.6      877.4             1227.3          1462.1
## Helena, MT               2097.2     1905.9              409.3          2314.6
## Lincoln, NE               860.6      785.5              833.9          1554.1
## Carson City, NV          2007.8     1816.4              540.2          2928.2
## Concord, NH              1318.2     2323.6             2372.0           129.3
## Trenton, NJ               936.2     1941.7             2064.2           397.9
## Santa Fe, NM             1081.8      821.5              675.1          2415.9
## Albany, NY               1158.7     2164.2             2212.6           175.4
## Raleigh, NC               472.6     1422.9             2160.5           916.7
## Bismarck, ND             1498.7     1307.4             1023.7          1716.0
## Columbus, OH              468.4     1473.9             1632.5           865.7
## Oklahoma City, OK         634.5      371.0             1149.7          1968.6
## Salem, OR                2584.9     2393.5              897.0          2802.2
## Harrisburg, PA            824.1     1829.5             1945.7           510.1
## Providence, RI           1229.0     2234.5             2282.9           231.1
## Columbia, SC              463.3     1169.9             2151.2          1169.7
## Pierre, SD               1305.3     1114.0              881.0          1522.6
## Nashville, TN               0.0     1005.5             1687.9          1334.1
## Austin, TX               1005.5        0.0             1496.5          2339.6
## Salt Lake City, UT       1687.9     1496.5                0.0          2388.0
## Montpelier, VT           1334.1     2339.6             2388.0             0.0
## Richmond, VA              602.9     1608.4             2102.3           731.2
## Olympia, WA              2722.1     2530.8             1034.2          2939.5
## Charleston, WV            431.6     1437.1             1818.6           902.5
## Madison, WI               618.7     1340.1             1388.5           999.5
## Cheyenne, WY             1328.0     1136.6              412.2          1975.8
##                    Richmond, VA Olympia, WA Charleston, WV Madison, WI
## Montgomery, AL            838.0      3012.2          666.7       908.7
## Juneau, AK               4542.3      1405.8         4258.7      3509.3
## Phoenix, AZ              2170.9      1529.1         1999.6      1902.6
## Little Rock, AR          1004.6      2517.9          833.3       736.3
## Sacramento, CA           2476.3       660.3         2192.6      2063.2
## Denver, CO               1655.0      1481.5         1371.3      1082.2
## Hartford, CT              553.5      3106.4          724.8      1002.9
## Dover, DE                 218.2      3130.5          389.5      1027.0
## Tallahassee, FL           858.9      3254.4          687.6      1150.9
## Atlanta, GA               638.7      3019.2          467.4       915.7
## Honolulu, HI             5509.0      3684.1         5337.7      5240.7
## Boise, ID                2534.6       601.9         2251.0      1501.6
## Springfield, IL           821.8      2314.7          538.2       240.8
## Indianapolis, IN          628.8      2507.7          345.1       404.3
## Des Moines, IA           1162.0      1974.5          878.3       333.7
## Topeka, KS               1100.0      2036.5          816.4       621.6
## Frankfort, KY             450.1      2686.5          186.7       583.0
## Baton Rouge, LA          1237.6      2876.8         1066.3       969.3
## Augusta, ME               887.4      3088.6         1058.7      1155.7
## Annapolis, MD             152.1      3089.9          323.4       986.4
## Boston, MA                682.6      3153.2          853.9      1049.8
## Lansing, MI               745.4      2391.1          461.7       287.7
## Saint Paul, MN           1364.6      1771.9         1080.9       331.5
## Jackson, MS              1055.5      2803.3          884.2       787.2
## Jefferson City, MO        875.0      2261.5          591.3       462.7
```

```
## Helena, MT              2511.6       624.9          2228.0      1478.6
## Lincoln, NE             1275.0      1861.5           991.3       554.6
## Carson City, NV         2422.1       714.4          2138.5      1928.7
## Concord, NH              715.2      3068.8           886.5       983.5
## Trenton, NJ              333.3      3098.5           504.6       995.0
## Santa Fe, NM            1684.7      1709.3          1513.4      1416.4
## Albany, NY               555.8      2985.8           727.1       882.4
## Raleigh, NC              185.5      3194.7           341.9      1091.2
## Bismarck, ND            1913.1      1223.4          1629.4       880.0
## Columbus, OH             469.7      2666.8           186.1       563.3
## Oklahoma City, OK       1237.4      2184.0          1066.1       969.1
## Salem, OR               2999.3       152.4          2715.6      1966.2
## Harrisburg, PA           221.1      2980.0           392.4       876.5
## Providence, RI           626.1      3170.5           797.4      1067.0
## Columbia, SC             438.5      3185.5           332.6      1082.0
## Pierre, SD              1719.7      1416.8          1436.0       686.6
## Nashville, TN            602.9      2722.1           431.6       618.7
## Austin, TX              1608.4      2530.8          1437.1      1340.1
## Salt Lake City, UT      2102.3      1034.2          1818.6      1388.5
## Montpelier, VT           731.2      2939.5           902.5       999.5
## Richmond, VA               0.0      3136.5           283.7      1033.1
## Olympia, WA             3136.5         0.0          2852.9      2103.5
## Charleston, WV           283.7      2852.9             0.0       749.4
## Madison, WI             1033.1      2103.5           749.4         0.0
## Cheyenne, WY            1742.4      1394.1          1458.7       976.3
##                   Cheyenne, WY
## Montgomery, AL          1618.0
## Juneau, AK              2800.0
## Phoenix, AZ              926.3
## Little Rock, AR         1123.8
## Sacramento, CA          1086.9
## Denver, CO               105.9
## Hartford, CT            1798.1
## Dover, DE               1736.3
## Tallahassee, FL         1860.2
## Atlanta, GA             1625.1
## Honolulu, HI            4264.4
## Boise, ID                792.3
## Springfield, IL          920.5
## Indianapolis, IN        1113.6
## Des Moines, IA           642.6
## Topeka, KS               642.4
## Frankfort, KY           1292.3
## Baton Rouge, LA         1482.6
## Augusta, ME             2132.0
## Annapolis, MD           1695.7
## Boston, MA              1927.2
## Lansing, MI             1216.9
## Saint Paul, MN           902.8
## Jackson, MS             1409.1
## Jefferson City, MO       867.4
## Helena, MT               769.2
## Lincoln, NE              467.4
## Carson City, NV          952.4
```

```
## Concord, NH              1959.8
## Trenton, NJ              1704.3
## Santa Fe, NM              440.1
## Albany, NY               1800.4
## Raleigh, NC              1800.6
## Bismarck, ND              611.5
## Columbus, OH             1272.6
## Oklahoma City, OK         789.8
## Salem, OR                1256.9
## Harrisburg, PA           1585.8
## Providence, RI           1870.7
## Columbia, SC             1791.3
## Pierre, SD                468.8
## Nashville, TN            1328.0
## Austin, TX               1136.6
## Salt Lake City, UT        412.2
## Montpelier, VT           1975.8
## Richmond, VA             1742.4
## Olympia, WA              1394.1
## Charleston, WV           1458.7
## Madison, WI               976.3
## Cheyenne, WY                0.0
```

```
lookupPairwiseValue(dist.manhattan.df, "Juneau, AK", "Montgomery, AL");
```

```
## [1] 4418
```

Euclidean We have converted the true latitude/longitude to a miles-type format, so the resulting table will report miles.

```
dist.euclidean = dist( latlong[,1:2],
                      method="euclidean", diag=TRUE, upper=TRUE);
dist.euclidean.m = as.matrix( dist.euclidean );
  rownames(dist.euclidean.m) =
  colnames(dist.euclidean.m) = myLabels;

dist.euclidean.df = as.data.frame( round( dist.euclidean.m, digits=1) );

dist.euclidean.df;  ## too big
```

```
##                      Montgomery, AL Juneau, AK Phoenix, AZ Little Rock, AR
## Montgomery, AL                  0.0     3179.8      1410.0           368.8
## Juneau, AK                   3179.8        0.0      2104.5          2814.9
## Phoenix, AZ                  1410.0     2104.5         0.0          1081.2
## Little Rock, AR               368.8     2814.9      1081.2             0.0
## Sacramento, CA               1970.1     1532.6       624.8          1614.3
## Denver, CO                   1141.4     2054.6       581.0           772.6
## Hartford, CT                  986.2     3559.0      2226.0          1177.7
## Dover, DE                     751.5     3476.2      2033.7           967.0
## Tallahassee, FL               171.9     3345.6      1532.6           530.8
## Atlanta, GA                   141.0     3213.9      1511.3           438.8
## Honolulu, HI                 3982.0     2855.5      2636.9          3695.8
```

```
## Boise, ID                1808.9     1419.7       736.9            1440.2
## Springfield, IL           545.3     2757.3      1299.8             378.7
## Indianapolis, IN          511.1     2928.8      1480.3             483.9
## Des Moines, IA            752.5     2508.1      1153.2             478.2
## Topeka, KS                690.9     2496.8       974.3             349.9
## Frankfort, KY             410.2     3040.2      1520.9             472.5
## Baton Rouge, LA           298.3     3044.1      1159.2             302.5
## Augusta, ME              1221.2     3658.8      2427.5            1397.4
## Annapolis, MD             702.2     3431.8      1978.9             912.4
## Boston, MA               1079.8     3629.7      2321.6            1274.7
## Lansing, MI               721.9     2927.1      1633.5             696.5
## Saint Paul, MN            944.6     2437.2      1304.7             705.6
## Jackson, MS               213.3     3008.5      1197.4             205.0
## Jefferson City, MO        536.2     2678.0      1142.3             265.1
## Helena, MT               1714.4     1465.6       906.7            1350.9
## Lincoln, NE               813.7     2387.9       981.7             481.6
## Carson City, NV          1887.7     1543.7       576.4            1528.8
## Concord, NH              1099.0     3587.6      2313.0            1276.9
## Trenton, NJ               830.4     3487.7      2089.7            1031.2
## Santa Fe, NM             1098.7     2202.7       366.6             747.1
## Albany, NY                985.7     3483.5      2186.0            1151.9
## Raleigh, NC               479.1     3419.6      1832.5             751.3
## Bismarck, ND             1273.1     2000.2      1108.7             952.3
## Columbus, OH              554.1     3079.3      1649.4             624.2
## Oklahoma City, OK         650.2     2557.3       806.3             287.9
## Salem, OR                2186.7     1111.6       993.7            1818.5
## Harrisburg, PA            749.2     3379.1      1978.2             926.2
## Providence, RI           1041.3     3622.5      2293.2            1242.0
## Columbia, SC              307.9     3362.5      1694.8             618.9
## Pierre, SD               1129.0     2095.0       989.6             795.2
## Nashville, TN             264.0     3016.0      1393.2             318.6
## Austin, TX                642.4     2784.0       812.3             427.1
## Salt Lake City, UT       1513.7     1725.4       504.5            1146.0
## Montpelier, VT           1110.7     3512.7      2281.6            1263.0
## Richmond, VA              599.0     3423.7      1910.1             834.2
## Olympia, WA              2241.3      999.6      1108.6            1872.5
## Charleston, WV            484.7     3193.9      1695.7             635.0
## Madison, WI               758.4     2673.8      1405.3             597.4
## Cheyenne, WY             1179.7     2003.3       661.9             812.6
##                    Sacramento, CA Denver, CO Hartford, CT Dover, DE
## Montgomery, AL           1970.1     1141.4        986.2     751.5
## Juneau, AK               1532.6     2054.6       3559.0    3476.2
## Phoenix, AZ               624.8      581.0       2226.0    2033.7
## Little Rock, AR          1614.3      772.6       1177.7     967.0
## Sacramento, CA              0.0      904.7       2674.6    2510.3
## Denver, CO                904.7        0.0       1770.0    1609.3
## Hartford, CT             2674.6     1770.0          0.0     237.7
## Dover, DE                2510.3     1609.3        237.7       0.0
## Tallahassee, FL          2109.3     1300.9       1004.2     766.7
## Atlanta, GA              2053.1     1198.2        845.3     611.0
## Honolulu, HI             2315.8     3154.4       4860.5    4661.1
## Boise, ID                 451.9      668.0       2380.0    2242.2
## Springfield, IL          1740.5      837.3        937.0     772.8
## Indianapolis, IN         1931.1     1028.2        749.0     582.1
```

```
## Des Moines, IA           1536.0     633.8      1143.7   1002.2
## Topeka, KS               1409.3     510.0      1270.4   1101.0
## Frankfort, KY            2000.0    1103.9       709.7    514.4
## Baton Rouge, LA          1747.8     989.8      1276.8   1044.9
## Augusta, ME              2851.2    1948.2       236.4    474.1
## Annapolis, MD            2456.8    1556.4       284.1     54.8
## Boston, MA               2765.8    1861.2        97.1    328.7
## Lansing, MI              2037.6    1135.2       651.7    550.9
## Saint Paul, MN           1611.6     742.2      1136.3   1039.0
## Jackson, MS              1763.6     957.6      1157.8    929.9
## Jefferson City, MO       1600.9     704.4      1087.1    909.9
## Helena, MT                757.0     609.0      2174.0   2057.6
## Lincoln, NE              1363.6     459.8      1312.3   1160.6
## Carson City, NV           102.5     807.8      2577.5   2415.6
## Concord, NH              2746.2    1842.1       117.4    354.1
## Trenton, NJ              2554.0    1650.7       155.8     84.5
## Santa Fe, NM              871.5     286.0      1865.7   1679.4
## Albany, NY               2621.5    1717.1        85.3    259.7
## Raleigh, NC              2348.3    1465.0       526.3    289.1
## Bismarck, ND             1265.3     539.1      1573.8   1476.7
## Columbus, OH             2103.9    1200.7       577.3    412.0
## Oklahoma City, OK        1326.4     503.1      1424.5   1227.7
## Salem, OR                 446.7    1048.8      2758.7   2624.8
## Harrisburg, PA           2439.0    1535.5       251.5    106.4
## Providence, RI           2743.1    1838.5        68.5    289.8
## Columbia, SC             2231.6    1366.6       703.7    466.0
## Pierre, SD               1223.2     408.9      1520.2   1400.8
## Nashville, TN            1902.5    1024.2       861.7    648.5
## Austin, TX               1418.1     764.0      1582.0   1359.4
## Salt Lake City, UT        545.5     383.3      2142.4   1988.7
## Montpelier, VT           2699.5    1797.1       172.4    387.1
## Richmond, VA             2405.0    1510.5       392.0    154.3
## Olympia, WA               588.5    1100.0      2766.4   2643.3
## Charleston, WV           2176.5    1278.9       543.0    338.2
## Madison, WI              1780.4     882.6       916.8    803.5
## Cheyenne, WY              927.4      97.1      1755.7   1605.4
##                    Tallahassee, FL Atlanta, GA Honolulu, HI Boise, ID
## Montgomery, AL                171.9       141.0       3982.0    1808.9
## Juneau, AK                   3345.6      3213.9       2855.5    1419.7
## Phoenix, AZ                  1532.6      1511.3       2636.9     736.9
## Little Rock, AR               530.8       438.8       3695.8    1440.2
## Sacramento, CA               2109.3      2053.1       2315.8     451.9
## Denver, CO                   1300.9      1198.2       3154.4     668.0
## Hartford, CT                 1004.2       845.3       4860.5    2380.0
## Dover, DE                     766.7       611.0       4661.1    2242.2
## Tallahassee, FL                 0.0       227.8       4068.1    1966.6
## Atlanta, GA                   227.8         0.0       4102.3    1865.4
## Honolulu, HI                 4068.1      4102.3          0.0    2746.4
## Boise, ID                    1966.6      1865.4       2746.4       0.0
## Springfield, IL               709.0       506.5       3936.4    1473.2
## Indianapolis, IN              651.0       426.0       4116.9    1661.7
## Des Moines, IA                923.0       739.2       3776.3    1240.8
## Topeka, KS                    861.4       717.2       3608.6    1163.3
## Frankfort, KY                 535.5       307.8       4152.3    1751.2
```

```
## Baton Rouge, LA              378.1       435.3       3694.9    1640.8
## Augusta, ME                 1240.4      1080.2       5064.3    2535.1
## Annapolis, MD                724.3       561.4       4606.3    2191.2
## Boston, MA                  1092.3       939.0       4956.6    2466.1
## Lansing, MI                  847.4       619.6       4267.1    1729.4
## Saint Paul, MN              1110.2       906.6       3894.2    1265.0
## Jackson, MS                  347.9       332.0       3772.0    1621.0
## Jefferson City, MO           707.9       539.7       3779.2    1357.2
## Helena, MT                  1881.0      1749.4       3050.8     307.0
## Lincoln, NE                  985.2       828.9       3601.2    1083.4
## Carson City, NV             2030.0      1967.3       2417.4     363.6
## Concord, NH                 1120.8       958.0       4949.4    2438.8
## Trenton, NJ                  850.2       689.6       4721.0    2274.6
## Santa Fe, NM                1238.8      1185.3       3001.7     783.1
## Albany, NY                  1018.2       845.0       4822.3    2318.4
## Raleigh, NC                  478.0       343.6       4439.3    2121.5
## Bismarck, ND                1444.9      1269.8       3578.7     870.2
## Columbus, OH                 659.6       435.0       4285.1    1830.2
## Oklahoma City, OK            802.8       726.7       3436.3    1164.6
## Salem, OR                   2341.7      2246.9       2504.6     384.3
## Harrisburg, PA               788.0       608.6       4611.2    2159.6
## Providence, RI              1051.7       900.7       4927.2    2448.1
## Columbia, SC                 301.2       184.0       4285.0    2031.5
## Pierre, SD                  1300.7      1137.2       3521.7     868.7
## Nashville, TN                417.6       211.6       4013.9    1686.5
## Austin, TX                   736.7       767.8       3340.0    1365.3
## Salt Lake City, UT          1668.2      1577.5       2846.2     306.9
## Montpelier, VT              1146.2       970.3       4918.4    2382.4
## Richmond, VA                 613.0       459.2       4529.9    2156.2
## Olympia, WA                 2400.4      2293.8       2606.8     435.4
## Charleston, WV               563.0       350.8       4324.8    1922.1
## Madison, WI                  914.7       698.5       4029.1    1464.7
## Cheyenne, WY                1343.3      1226.4       3202.9     644.5
##                    Springfield, IL Indianapolis, IN Des Moines, IA Topeka, KS
## Montgomery, AL               545.3            511.1          752.5      690.9
## Juneau, AK                  2757.3           2928.8         2508.1     2496.8
## Phoenix, AZ                 1299.8           1480.3         1153.2      974.3
## Little Rock, AR              378.7            483.9          478.2      349.9
## Sacramento, CA              1740.5           1931.1         1536.0     1409.3
## Denver, CO                   837.3           1028.2          633.8      510.0
## Hartford, CT                 937.0            749.0         1143.7     1270.4
## Dover, DE                    772.8            582.1         1002.2     1101.0
## Tallahassee, FL              709.0            651.0          923.0      861.4
## Atlanta, GA                  506.5            426.0          739.2      717.2
## Honolulu, HI                3936.4           4116.9         3776.3     3608.6
## Boise, ID                   1473.2           1661.7         1240.8     1163.3
## Springfield, IL                0.0            190.9          249.3      333.5
## Indianapolis, IN             190.9              0.0          426.4      522.7
## Des Moines, IA               249.3            426.4            0.0      208.2
## Topeka, KS                   333.5            522.7          208.2        0.0
## Frankfort, KY                283.8            129.2          532.2      593.8
## Baton Rouge, LA              650.6            699.1          780.4      643.0
## Augusta, ME                 1129.0            947.6         1315.2     1460.4
## Annapolis, MD                720.5            530.1          952.0     1047.7
```

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## Boston, MA                  1030.3            843.3          1232.8     1363.7
## Lansing, MI                  344.6            222.7           501.7      659.2
## Saint Paul, MN               401.6            520.5           233.2      430.3
## Jackson, MS                  518.3            560.3           668.0      554.7
## Jefferson City, MO           161.3            338.6           222.5      194.8
## Helena, MT                  1308.0           1488.5          1062.2     1032.2
## Lincoln, NE                  389.8            578.9           175.5      132.5
## Carson City, NV             1644.7           1835.5          1437.4     1314.7
## Concord, NH                 1016.7            832.8          1210.9     1349.4
## Trenton, NJ                  813.6            622.9          1033.9     1145.4
## Santa Fe, NM                 935.0           1117.8           788.2      607.8
## Albany, NY                   890.1            705.7          1087.0     1222.9
## Raleigh, NC                  663.0            495.0           911.7      958.5
## Bismarck, ND                 776.6            934.7           531.6      602.9
## Columbus, OH                 363.5            172.9           590.7      695.6
## Oklahoma City, OK            523.2            687.7           473.1      267.0
## Salem, OR                   1857.0           2045.1          1622.8     1547.5
## Harrisburg, PA               698.5            508.0           918.8     1030.6
## Providence, RI              1005.3            817.0          1212.2     1338.7
## Columbia, SC                 617.8            486.5           864.0      872.9
## Pierre, SD                   662.3            836.0           413.1      445.5
## Nashville, TN                295.7            250.9           528.6      525.6
## Austin, TX                   792.2            911.0           813.1      616.7
## Salt Lake City, UT          1215.9           1406.7           999.2      892.4
## Montpelier, VT               982.0            803.7          1163.7     1312.1
## Richmond, VA                 683.6            499.0           925.4     1000.5
## Olympia, WA                 1882.7           2067.9          1642.3     1584.5
## Charleston, WV               449.3            265.8           691.7      769.0
## Madison, WI                  226.5            288.2           253.0      442.1
## Cheyenne, WY                 833.2           1023.3           612.3      518.9
##                    Frankfort, KY Baton Rouge, LA Augusta, ME Annapolis, MD
## Montgomery, AL             410.2           298.3      1221.2         702.2
## Juneau, AK                3040.2          3044.1      3658.8        3431.8
## Phoenix, AZ               1520.9          1159.2      2427.5        1978.9
## Little Rock, AR            472.5           302.5      1397.4         912.4
## Sacramento, CA            2000.0          1747.8      2851.2        2456.8
## Denver, CO                1103.9           989.8      1948.2        1556.4
## Hartford, CT               709.7          1276.8       236.4         284.1
## Dover, DE                  514.4          1044.9       474.1          54.8
## Tallahassee, FL            535.5           378.1      1240.4         724.3
## Atlanta, GA                307.8           435.3      1080.2         561.4
## Honolulu, HI              4152.3          3694.9      5064.3        4606.3
## Boise, ID                 1751.2          1640.8      2535.1        2191.2
## Springfield, IL            283.8           650.6      1129.0         720.5
## Indianapolis, IN           129.2           699.1       947.6         530.1
## Des Moines, IA             532.2           780.4      1315.2         952.0
## Topeka, KS                 593.8           643.0      1460.4        1047.7
## Frankfort, KY                0.0           636.3       925.4         459.9
## Baton Rouge, LA            636.3             0.0      1510.0         994.1
## Augusta, ME                925.4          1510.0         0.0         519.9
## Annapolis, MD              459.9           994.1       519.9           0.0
## Boston, MA                 806.4          1371.7       151.9         377.7
## Lansing, MI                313.3           921.8       813.6         510.2
## Saint Paul, MN             646.8          1005.7      1273.7         995.2
```

```
## Jackson, MS               500.1          138.8       1388.6          877.7
## Jefferson City, MO        399.8          563.5       1285.1          856.2
## Helena, MT               1591.6         1592.4       2311.7         2009.3
## Lincoln, NE               669.6          775.4       1488.5         1109.0
## Carson City, NV          1906.7         1672.8       2752.3         2362.4
## Concord, NH               805.6         1387.5        122.6          398.5
## Trenton, NJ               569.0         1121.7        391.9          128.2
## Santa Fe, NM             1165.1          884.0       2063.8         1624.8
## Albany, NY                680.0         1270.4        245.5          294.8
## Raleigh, NC               379.5          777.1        762.4          250.0
## Bismarck, ND             1052.6         1244.8       1701.6         1431.8
## Columbus, OH              158.7          794.0        781.7          361.4
## Oklahoma City, OK         716.2          489.9       1633.0         1172.9
## Salem, OR                2135.5         2006.5       2908.3         2574.1
## Harrisburg, PA            459.1         1034.0        477.3           91.8
## Providence, RI            775.5         1334.1        193.6          340.0
## Columbia, SC              357.4          605.7        940.1          423.1
## Pierre, SD                945.1         1082.7       1667.5         1352.8
## Nashville, TN             175.0          461.9       1085.2          593.9
## Austin, TX                891.0          358.6       1808.3         1306.1
## Salt Lake City, UT       1486.1         1336.2       2312.3         1936.2
## Montpelier, VT            790.7         1392.8        152.7          423.1
## Richmond, VA              406.7          894.2        628.4          112.5
## Olympia, WA              2164.3         2076.1       2906.5         2593.8
## Charleston, WV            176.9          754.1        766.9          283.5
## Madison, WI               417.1          876.8       1073.8          758.2
## Cheyenne, WY             1108.2         1048.4       1925.7         1553.4
##                    Boston, MA Lansing, MI Saint Paul, MN Jackson, MS
## Montgomery, AL         1079.8       721.9          944.6       213.3
## Juneau, AK             3629.7      2927.1         2437.2      3008.5
## Phoenix, AZ            2321.6      1633.5         1304.7      1197.4
## Little Rock, AR        1274.7       696.5          705.6       205.0
## Sacramento, CA         2765.8      2037.6         1611.6      1763.6
## Denver, CO             1861.2      1135.2          742.2       957.6
## Hartford, CT             97.1       651.7         1136.3      1157.8
## Dover, DE               328.7       550.9         1039.0       929.9
## Tallahassee, FL        1092.3       847.4         1110.2       347.9
## Atlanta, GA             939.0       619.6          906.6       332.0
## Honolulu, HI           4956.6      4267.1         3894.2      3772.0
## Boise, ID              2466.1      1729.4         1265.0      1621.0
## Springfield, IL        1030.3       344.6          401.6       518.3
## Indianapolis, IN        843.3       222.7          520.5       560.3
## Des Moines, IA         1232.8       501.7          233.2       668.0
## Topeka, KS             1363.7       659.2          430.3       554.7
## Frankfort, KY           806.4       313.3          646.8       500.1
## Baton Rouge, LA        1371.7       921.8         1005.7       138.8
## Augusta, ME             151.9       813.6         1273.7      1388.6
## Annapolis, MD           377.7       510.2          995.2       877.7
## Boston, MA                0.0       736.6         1216.0      1253.7
## Lansing, MI             736.6         0.0          491.0       783.0
## Saint Paul, MN         1216.0       491.0            0.0       886.9
## Jackson, MS            1253.7       783.0          886.9         0.0
## Jefferson City, MO     1181.8       505.7          442.2       446.6
## Helena, MT             2255.2      1523.5         1039.6      1547.2
```

```
## Lincoln, NE          1402.7      675.6          346.0      685.9
## Carson City, NV      2668.3     1938.7         1510.0     1683.2
## Concord, NH            64.0      711.0         1183.0     1266.1
## Trenton, NJ           250.0      561.5         1052.5     1004.0
## Santa Fe, NM         1960.7     1267.0          950.6      892.4
## Albany, NY            148.5      589.1         1067.5     1146.7
## Raleigh, NC           614.5      579.1         1012.1      674.6
## Bismarck, ND         1651.5      930.1          439.1     1156.4
## Columbus, OH          672.4      209.0          649.5      658.4
## Oklahoma City, OK    1520.8      867.8          697.1      456.4
## Salem, OR            2843.5     2107.2         1635.0     1994.7
## Harrisburg, PA        348.5      452.0          942.4      911.3
## Providence, RI         41.8      719.3         1202.7     1217.1
## Columbia, SC          793.1      632.4         1001.8      513.2
## Pierre, SD           1603.4      868.6          396.5     1000.1
## Nashville, TN         958.7      469.3          696.8      325.1
## Austin, TX           1678.7     1122.1         1044.0      435.8
## Salt Lake City, UT   2231.9     1499.2         1066.2     1321.2
## Montpelier, VT        155.0      662.0         1121.3     1267.1
## Richmond, VA          482.8      527.4          994.7      782.7
## Olympia, WA          2848.7     2115.1         1633.9     2055.5
## Charleston, WV        640.0      341.9          773.8      626.2
## Madison, WI          1001.5      265.2          240.1      744.8
## Cheyenne, WY         1845.0     1112.4          692.0     1005.3
##                    Jefferson City, MO Helena, MT Lincoln, NE Carson City, NV
## Montgomery, AL                  536.2     1714.4       813.7          1887.7
## Juneau, AK                     2678.0     1465.6      2387.9          1543.7
## Phoenix, AZ                    1142.3      906.7       981.7           576.4
## Little Rock, AR                 265.1     1350.9       481.6          1528.8
## Sacramento, CA                 1600.9      757.0      1363.6           102.5
## Denver, CO                      704.4      609.0       459.8           807.8
## Hartford, CT                   1087.1     2174.0      1312.3          2577.5
## Dover, DE                       909.9     2057.6      1160.6          2415.6
## Tallahassee, FL                 707.9     1881.0       985.2          2030.0
## Atlanta, GA                     539.7     1749.4       828.9          1967.3
## Honolulu, HI                   3779.2     3050.8      3601.2          2417.4
## Boise, ID                      1357.2      307.0      1083.4           363.6
## Springfield, IL                 161.3     1308.0       389.8          1644.7
## Indianapolis, IN                338.6     1488.5       578.9          1835.5
## Des Moines, IA                  222.5     1062.2       175.5          1437.4
## Topeka, KS                      194.8     1032.2       132.5          1314.7
## Frankfort, KY                   399.8     1591.6       669.6          1906.7
## Baton Rouge, LA                 563.5     1592.4       775.4          1672.8
## Augusta, ME                    1285.1     2311.7      1488.5          2752.3
## Annapolis, MD                   856.2     2009.3      1109.0          2362.4
## Boston, MA                     1181.8     2255.2      1402.7          2668.3
## Lansing, MI                     505.7     1523.5       675.6          1938.7
## Saint Paul, MN                  442.2     1039.6       346.0          1510.0
## Jackson, MS                     446.6     1547.2       685.9          1683.2
## Jefferson City, MO                0.0     1216.6       290.2          1507.1
## Helena, MT                     1216.6        0.0       927.8           664.5
## Lincoln, NE                     290.2      927.8         0.0          1265.7
## Carson City, NV                1507.1      664.5      1265.7             0.0
## Concord, NH                    1171.1     2222.6      1382.6          2648.0
```

```
## Trenton, NJ                     957.4     2081.1      1197.3          2458.3
## Santa Fe, NM                    779.3      823.1       618.8           791.3
## Albany, NY                     1044.1     2106.8      1258.0          2523.6
## Raleigh, NC                     764.3     1970.0      1044.9          2258.1
## Bismarck, ND                    737.3      613.7       470.7          1163.0
## Columbus, OH                    509.9     1649.2       749.1          2008.2
## Oklahoma City, OK               362.3     1102.6       371.3          1241.1
## Salem, OR                      1741.5      612.3      1467.2           436.7
## Harrisburg, PA                  843.4     1967.8      1081.9          2343.1
## Providence, RI                 1155.0     2240.9      1380.8          2646.0
## Columbia, SC                    685.3     1901.8       974.8          2144.6
## Pierre, SD                      598.1      656.9       316.2          1121.0
## Nashville, TN                   338.0     1554.4       628.1          1812.7
## Austin, TX                      649.0     1369.8       729.7          1350.1
## Salt Lake City, UT             1087.1      402.4       830.6           443.9
## Montpelier, VT                 1139.6     2159.7      1337.4          2600.5
## Richmond, VA                    806.2     1987.4      1073.0          2312.3
## Olympia, WA                    1776.4      594.9      1494.8           569.6
## Charleston, WV                  575.7     1753.9       838.9          2082.9
## Madison, WI                     345.7     1259.5       427.9          1680.7
## Cheyenne, WY                    712.8      544.1       445.1           827.4
##                    Concord, NH Trenton, NJ Santa Fe, NM Albany, NY Raleigh, NC
## Montgomery, AL          1099.0       830.4       1098.7      985.7       479.1
## Juneau, AK              3587.6      3487.7       2202.7     3483.5      3419.6
## Phoenix, AZ             2313.0      2089.7        366.6     2186.0      1832.5
## Little Rock, AR         1276.9      1031.2        747.1     1151.9       751.3
## Sacramento, CA          2746.2      2554.0        871.5     2621.5      2348.3
## Denver, CO              1842.1      1650.7        286.0     1717.1      1465.0
## Hartford, CT             117.4       155.8       1865.7       85.3       526.3
## Dover, DE                354.1        84.5       1679.4      259.7       289.1
## Tallahassee, FL         1120.8       850.2       1238.8     1018.2       478.0
## Atlanta, GA              958.0       689.6       1185.3      845.0       343.6
## Honolulu, HI            4949.4      4721.0       3001.7     4822.3      4439.3
## Boise, ID               2438.8      2274.6        783.1     2318.4      2121.5
## Springfield, IL         1016.7       813.6        935.0      890.1       663.0
## Indianapolis, IN         832.8       622.9       1117.8      705.7       495.0
## Des Moines, IA          1210.9      1033.9        788.2     1087.0       911.7
## Topeka, KS              1349.4      1145.4        607.8     1222.9       958.5
## Frankfort, KY            805.6       569.0       1165.1      680.0       379.5
## Baton Rouge, LA         1387.5      1121.7        884.0     1270.4       777.1
## Augusta, ME              122.6       391.9       2063.8      245.5       762.4
## Annapolis, MD            398.5       128.2       1624.8      294.8       250.0
## Boston, MA                64.0       250.0       1960.7      148.5       614.5
## Lansing, MI              711.0       561.5       1267.0      589.1       579.1
## Saint Paul, MN          1183.0      1052.5        950.6     1067.5      1012.1
## Jackson, MS             1266.1      1004.0        892.4     1146.7       674.6
## Jefferson City, MO      1171.1       957.4        779.3     1044.1       764.3
## Helena, MT              2222.6      2081.1        823.1     2106.8      1970.0
## Lincoln, NE             1382.6      1197.3        618.8     1258.0      1044.9
## Carson City, NV         2648.0      2458.3        791.3     2523.6      2258.1
## Concord, NH                0.0       270.9       1950.3      127.1       643.1
## Trenton, NJ              270.9         0.0       1732.3      176.4       373.1
## Santa Fe, NM            1950.3      1732.3          0.0     1823.4      1492.3
## Albany, NY               127.1       176.4       1823.4        0.0       544.6
```

```
## Raleigh, NC            643.1        373.1        1492.3       544.6          0.0
## Bismarck, ND          1616.0       1491.6         819.1      1503.2       1429.4
## Columbus, OH           664.7        450.1        1288.4       537.7        375.0
## Oklahoma City, OK     1515.8       1285.2         461.2      1389.0       1031.5
## Salem, OR             2814.5       2655.9        1130.7      2695.4       2505.8
## Harrisburg, PA         355.0        115.4        1619.7       236.7        325.2
## Providence, RI          95.6        213.2        1933.3       139.7        574.2
## Columbia, SC           820.0        549.2        1366.0       717.1        179.0
## Pierre, SD            1573.6       1424.4         675.1      1455.2       1324.6
## Nashville, TN          963.8        713.5        1047.9       840.3        445.9
## Austin, TX            1686.5       1430.5         583.4      1563.8       1110.3
## Salt Lake City, UT    2209.7       2027.5         477.7      2086.2       1848.3
## Montpelier, VT          92.1        303.0        1917.0       128.3        672.9
## Richmond, VA           508.0        237.2        1561.3       407.2        137.5
## Olympia, WA           2816.8       2670.0        1212.7      2700.2       2539.1
## Charleston, WV         645.2        396.8        1341.3       522.7        241.9
## Madison, WI            974.4        822.2        1039.6       853.7        773.8
## Cheyenne, WY          1822.8       1642.3         382.8      1699.3       1477.1
##                    Bismarck, ND Columbus, OH Oklahoma City, OK Salem, OR
## Montgomery, AL           1273.1        554.1             650.2    2186.7
## Juneau, AK               2000.2       3079.3            2557.3    1111.6
## Phoenix, AZ              1108.7       1649.4             806.3     993.7
## Little Rock, AR           952.3        624.2             287.9    1818.5
## Sacramento, CA           1265.3       2103.9            1326.4     446.7
## Denver, CO                539.1       1200.7             503.1    1048.8
## Hartford, CT             1573.8        577.3            1424.5    2758.7
## Dover, DE                1476.7        412.0            1227.7    2624.8
## Tallahassee, FL          1444.9        659.6             802.8    2341.7
## Atlanta, GA              1269.8        435.0             726.7    2246.9
## Honolulu, HI             3578.7       4285.1            3436.3    2504.6
## Boise, ID                 870.2       1830.2            1164.6     384.3
## Springfield, IL           776.6        363.5             523.2    1857.0
## Indianapolis, IN          934.7        172.9             687.7    2045.1
## Des Moines, IA            531.6        590.7             473.1    1622.8
## Topeka, KS                602.9        695.6             267.0    1547.5
## Frankfort, KY            1052.6        158.7             716.2    2135.5
## Baton Rouge, LA          1244.8        794.0             489.9    2006.5
## Augusta, ME              1701.6        781.7            1633.0    2908.3
## Annapolis, MD            1431.8        361.4            1172.9    2574.1
## Boston, MA               1651.5        672.4            1520.8    2843.5
## Lansing, MI               930.1        209.0             867.8    2107.2
## Saint Paul, MN            439.1        649.5             697.1    1635.0
## Jackson, MS              1156.4        658.4             456.4    1994.7
## Jefferson City, MO        737.3        509.9             362.3    1741.5
## Helena, MT                613.7       1649.2            1102.6     612.3
## Lincoln, NE               470.7        749.1             371.3    1467.2
## Carson City, NV          1163.0       2008.2            1241.1     436.7
## Concord, NH              1616.0        664.7            1515.8    2814.5
## Trenton, NJ              1491.6        450.1            1285.2    2655.9
## Santa Fe, NM              819.1       1288.4             461.2    1130.7
## Albany, NY               1503.2        537.7            1389.0    2695.4
## Raleigh, NC              1429.4        375.0            1031.5    2505.8
## Bismarck, ND                0.0       1079.8             802.5    1222.0
## Columbus, OH             1079.8          0.0             851.3    2212.9
```

```
## Oklahoma City, OK         802.5        851.3               0.0    1538.9
## Salem, OR                1222.0       2212.9            1538.9       0.0
## Harrisburg, PA           1381.1        335.1            1174.9    2541.1
## Providence, RI           1639.6        645.1            1491.0    2826.5
## Columbia, SC             1394.2        425.1             905.9    2414.5
## Pierre, SD                170.0        993.4             633.1    1241.1
## Nashville, TN            1059.9        333.5             588.3    2070.1
## Austin, TX               1153.3       1046.6             359.1    1712.5
## Salt Lake City, UT        736.2       1578.4             865.4     673.5
## Montpelier, VT           1550.2        641.8            1491.0    2755.7
## Richmond, VA             1424.9        345.5            1104.2    2540.2
## Olympia, WA              1207.7       2232.6            1599.2     145.0
## Charleston, WV           1197.6        134.1             889.9    2306.1
## Madison, WI               673.6        409.4             687.6    1842.1
## Cheyenne, WY              448.9       1194.1             558.5    1028.7
##                    Harrisburg, PA Providence, RI Columbia, SC Pierre, SD
## Montgomery, AL              749.2         1041.3        307.9     1129.0
## Juneau, AK                 3379.1         3622.5       3362.5     2095.0
## Phoenix, AZ                1978.2         2293.2       1694.8      989.6
## Little Rock, AR             926.2         1242.0        618.9      795.2
## Sacramento, CA             2439.0         2743.1       2231.6     1223.2
## Denver, CO                 1535.5         1838.5       1366.6      408.9
## Hartford, CT                251.5           68.5        703.7     1520.2
## Dover, DE                   106.4          289.8        466.0     1400.8
## Tallahassee, FL             788.0         1051.7        301.2     1300.7
## Atlanta, GA                 608.6          900.7        184.0     1137.2
## Honolulu, HI               4611.2         4927.2       4285.0     3521.7
## Boise, ID                  2159.6         2448.1       2031.5      868.7
## Springfield, IL             698.5         1005.3        617.8      662.3
## Indianapolis, IN            508.0          817.0        486.5      836.0
## Des Moines, IA              918.8         1212.2        864.0      413.1
## Topeka, KS                 1030.6         1338.7        872.9      445.5
## Frankfort, KY               459.1          775.5        357.4      945.1
## Baton Rouge, LA            1034.0         1334.1        605.7     1082.7
## Augusta, ME                 477.3          193.6        940.1     1667.5
## Annapolis, MD                91.8          340.0        423.1     1352.8
## Boston, MA                  348.5           41.8        793.1     1603.4
## Lansing, MI                 452.0          719.3        632.4      868.6
## Saint Paul, MN              942.4         1202.7       1001.8      396.5
## Jackson, MS                 911.3         1217.1        513.2     1000.1
## Jefferson City, MO          843.4         1155.0        685.3      598.1
## Helena, MT                 1967.8         2240.9       1901.8      656.9
## Lincoln, NE                1081.9         1380.8        974.8      316.2
## Carson City, NV            2343.1         2646.0       2144.6     1121.0
## Concord, NH                 355.0           95.6        820.0     1573.6
## Trenton, NJ                 115.4          213.2        549.2     1424.4
## Santa Fe, NM               1619.7         1933.3       1366.0      675.1
## Albany, NY                  236.7          139.7        717.1     1455.2
## Raleigh, NC                 325.2          574.2        179.0     1324.6
## Bismarck, ND               1381.1         1639.6       1394.2      170.0
## Columbus, OH                335.1          645.1        425.1      993.4
## Oklahoma City, OK          1174.9         1491.0        905.9      633.1
## Salem, OR                  2541.1         2826.5       2414.5     1241.1
## Harrisburg, PA                0.0          316.5        488.6     1311.0
```

```
## Providence, RI              316.5            0.0        752.9     1587.6
## Columbia, SC                488.6          752.9          0.0     1273.2
## Pierre, SD                 1311.0         1587.6       1273.2        0.0
## Nashville, TN               610.6          925.1        347.6      931.1
## Austin, TX                 1332.1         1643.5        947.9      983.4
## Salt Lake City, UT         1912.1         2210.8       1748.1      679.2
## Montpelier, VT              361.8          179.5        845.2     1514.9
## Richmond, VA                191.6          443.4        312.0     1334.0
## Olympia, WA                2556.0         2833.7       2456.5     1246.6
## Charleston, WV              291.7          606.9        301.7     1101.7
## Madison, WI                 709.9          984.5        774.5      603.8
## Cheyenne, WY               1527.0         1824.1       1389.0      331.8
##                    Nashville, TN Austin, TX Salt Lake City, UT Montpelier, VT
## Montgomery, AL             264.0      642.4             1513.7         1110.7
## Juneau, AK                3016.0     2784.0             1725.4         3512.7
## Phoenix, AZ               1393.2      812.3              504.5         2281.6
## Little Rock, AR            318.6      427.1             1146.0         1263.0
## Sacramento, CA            1902.5     1418.1              545.5         2699.5
## Denver, CO                1024.2      764.0              383.3         1797.1
## Hartford, CT               861.7     1582.0             2142.4          172.4
## Dover, DE                  648.5     1359.4             1988.7          387.1
## Tallahassee, FL            417.6      736.7             1668.2         1146.2
## Atlanta, GA                211.6      767.8             1577.5          970.3
## Honolulu, HI              4013.9     3340.0             2846.2         4918.4
## Boise, ID                 1686.5     1365.3              306.9         2382.4
## Springfield, IL            295.7      792.2             1215.9          982.0
## Indianapolis, IN           250.9      911.0             1406.7          803.7
## Des Moines, IA             528.6      813.1              999.2         1163.7
## Topeka, KS                 525.6      616.7              892.4         1312.1
## Frankfort, KY              175.0      891.0             1486.1          790.7
## Baton Rouge, LA            461.9      358.6             1336.2         1392.8
## Augusta, ME               1085.2     1808.3             2312.3          152.7
## Annapolis, MD              593.9     1306.1             1936.2          423.1
## Boston, MA                 958.7     1678.7             2231.9          155.0
## Lansing, MI                469.3     1122.1             1499.2          662.0
## Saint Paul, MN             696.8     1044.0             1066.2         1121.3
## Jackson, MS                325.1      435.8             1321.2         1267.1
## Jefferson City, MO         338.0      649.0             1087.1         1139.6
## Helena, MT                1554.4     1369.8              402.4         2159.7
## Lincoln, NE                628.1      729.7              830.6         1337.4
## Carson City, NV           1812.7     1350.1              443.9         2600.5
## Concord, NH                963.8     1686.5             2209.7           92.1
## Trenton, NJ                713.5     1430.5             2027.5          303.0
## Santa Fe, NM              1047.9      583.4              477.7         1917.0
## Albany, NY                 840.3     1563.8             2086.2          128.3
## Raleigh, NC                445.9     1110.3             1848.3          672.9
## Bismarck, ND              1059.9     1153.3              736.2         1550.2
## Columbus, OH               333.5     1046.6             1578.4          641.8
## Oklahoma City, OK          588.3      359.1              865.4         1491.0
## Salem, OR                 2070.1     1712.5              673.5         2755.7
## Harrisburg, PA             610.6     1332.1             1912.1          361.8
## Providence, RI             925.1     1643.5             2210.8          179.5
## Columbia, SC               347.6      947.9             1748.1          845.2
## Pierre, SD                 931.1      983.4              679.2         1514.9
```

```
## Nashville, TN                0.0      723.7             1407.1          955.8
## Austin, TX                 723.7        0.0             1058.8         1679.4
## Salt Lake City, UT        1407.1     1058.8                0.0         2160.1
## Montpelier, VT             955.8     1679.4             2160.1            0.0
## Richmond, VA               517.3     1215.3             1892.7          535.5
## Olympia, WA               2109.9     1796.1              740.9         2754.4
## Charleston, WV             318.9     1041.4             1660.4          641.1
## Madison, WI                497.4      994.6             1239.2          921.4
## Cheyenne, WY              1042.9      843.9              387.0         1773.7
##                    Richmond, VA Olympia, WA Charleston, WV Madison, WI
## Montgomery, AL            599.0      2241.3          484.7       758.4
## Juneau, AK               3423.7       999.6         3193.9      2673.8
## Phoenix, AZ              1910.1      1108.6         1695.7      1405.3
## Little Rock, AR           834.2      1872.5          635.0       597.4
## Sacramento, CA           2405.0       588.5         2176.5      1780.4
## Denver, CO               1510.5      1100.0         1278.9       882.6
## Hartford, CT              392.0      2766.4          543.0       916.8
## Dover, DE                 154.3      2643.3          338.2       803.5
## Tallahassee, FL           613.0      2400.4          563.0       914.7
## Atlanta, GA               459.2      2293.8          350.8       698.5
## Honolulu, HI             4529.9      2606.8         4324.8      4029.1
## Boise, ID                2156.2       435.4         1922.1      1464.7
## Springfield, IL           683.6      1882.7          449.3       226.5
## Indianapolis, IN          499.0      2067.9          265.8       288.2
## Des Moines, IA            925.4      1642.3          691.7       253.0
## Topeka, KS               1000.5      1584.5          769.0       442.1
## Frankfort, KY             406.7      2164.3          176.9       417.1
## Baton Rouge, LA           894.2      2076.1          754.1       876.8
## Augusta, ME               628.4      2906.5          766.9      1073.8
## Annapolis, MD             112.5      2593.8          283.5       758.2
## Boston, MA                482.8      2848.7          640.0      1001.5
## Lansing, MI               527.4      2115.1          341.9       265.2
## Saint Paul, MN            994.7      1633.9          773.8       240.1
## Jackson, MS               782.7      2055.5          626.2       744.8
## Jefferson City, MO        806.2      1776.4          575.7       345.7
## Helena, MT               1987.4       594.9         1753.9      1259.5
## Lincoln, NE              1073.0      1494.8          838.9       427.9
## Carson City, NV          2312.3       569.6         2082.9      1680.7
## Concord, NH               508.0      2816.8          645.2       974.4
## Trenton, NJ               237.2      2670.0          396.8       822.2
## Santa Fe, NM             1561.3      1212.7         1341.3      1039.6
## Albany, NY                407.2      2700.2          522.7       853.7
## Raleigh, NC               137.5      2539.1          241.9       773.8
## Bismarck, ND             1424.9      1207.7         1197.6       673.6
## Columbus, OH              345.5      2232.6          134.1       409.4
## Oklahoma City, OK        1104.2      1599.2          889.9       687.6
## Salem, OR                2540.2       145.0         2306.1      1842.1
## Harrisburg, PA            191.6      2556.0          291.7       709.9
## Providence, RI            443.4      2833.7          606.9       984.5
## Columbia, SC              312.0      2456.5          301.7       774.5
## Pierre, SD               1334.0      1246.6         1101.7       603.8
## Nashville, TN             517.3      2109.9          318.9       497.4
## Austin, TX               1215.3      1796.1         1041.4       994.6
## Salt Lake City, UT       1892.7       740.9         1660.4      1239.2
```

```
## Montpelier, VT             535.5      2754.4          641.1        921.4
## Richmond, VA                 0.0      2565.9          234.3        754.7
## Olympia, WA               2565.9         0.0         2331.6       1850.3
## Charleston, WV             234.3      2331.6            0.0        534.3
## Madison, WI                754.7      1850.3          534.3          0.0
## Cheyenne, WY              1514.1      1067.8         1280.6        853.3
##                     Cheyenne, WY
## Montgomery, AL            1179.7
## Juneau, AK                2003.3
## Phoenix, AZ                661.9
## Little Rock, AR            812.6
## Sacramento, CA             927.4
## Denver, CO                  97.1
## Hartford, CT              1755.7
## Dover, DE                 1605.4
## Tallahassee, FL           1343.3
## Atlanta, GA               1226.4
## Honolulu, HI              3202.9
## Boise, ID                  644.5
## Springfield, IL            833.2
## Indianapolis, IN          1023.3
## Des Moines, IA             612.3
## Topeka, KS                 518.9
## Frankfort, KY             1108.2
## Baton Rouge, LA           1048.4
## Augusta, ME               1925.7
## Annapolis, MD             1553.4
## Boston, MA                1845.0
## Lansing, MI               1112.4
## Saint Paul, MN             692.0
## Jackson, MS               1005.3
## Jefferson City, MO         712.8
## Helena, MT                 544.1
## Lincoln, NE                445.1
## Carson City, NV            827.4
## Concord, NH               1822.8
## Trenton, NJ               1642.3
## Santa Fe, NM               382.8
## Albany, NY                1699.3
## Raleigh, NC               1477.1
## Bismarck, ND               448.9
## Columbus, OH              1194.1
## Oklahoma City, OK          558.5
## Salem, OR                 1028.7
## Harrisburg, PA            1527.0
## Providence, RI            1824.1
## Columbia, SC              1389.0
## Pierre, SD                 331.8
## Nashville, TN             1042.9
## Austin, TX                 843.9
## Salt Lake City, UT         387.0
## Montpelier, VT            1773.7
## Richmond, VA              1514.1
## Olympia, WA               1067.8
```

```
## Charleston, WV            1280.6
## Madison, WI                853.3
## Cheyenne, WY                 0.0
```

```
lookupPairwiseValue(dist.euclidean.df, "Juneau, AK", "Montgomery, AL");
```

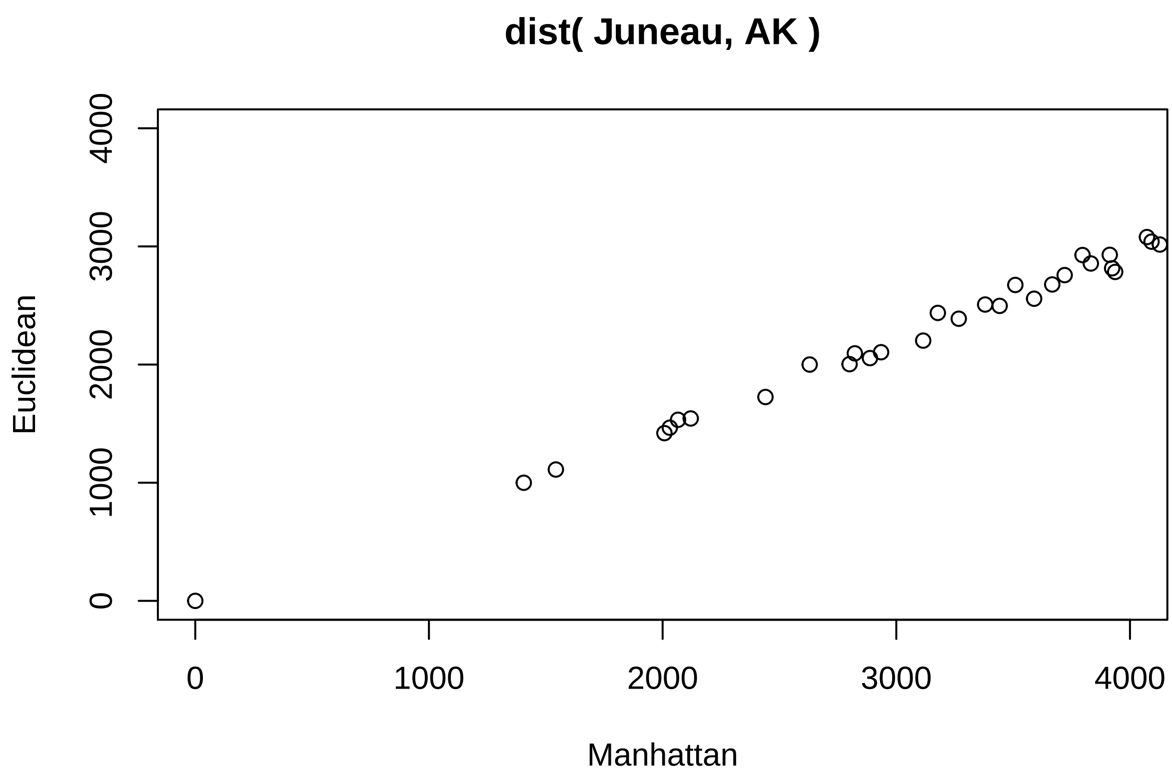
```
## [1] 3179.8
```

You can compare the two with the code below (currently in comments).

```
x = dist.manhattan.df[,2]; # Juneau ... pick one location
y = dist.euclidean.df[,2];

my.lim = c(0, 4000 );

plot(x, y,
            xlab="Manhattan",
            ylab="Euclidean",
            main="dist( Juneau, AK )",
            xlim=my.lim,
            ylim=my.lim);
```




```
plotXYwithBoxPlots(x, y,
            xlab="Manhattan",
```

```
           ylab="Euclidean",
           main="dist( Juneau, AK )",
           xlim=my.lim,
           ylim=my.lim)
```

[What is the difference between these two calculations?

Are the results similar?

]

HIERARCHICAL clustering as a function of distance

Aggregating or agglomerating data is typically called "clustering" and is generally considered to be a "unsupervised learning" method.

Introduction

We use `hclust` to perform Hierarchical Clustering. The word "hierarchical" is used because the nature of the data is organized like a family genealogy. The bottom of the tree represents the descendants that eventually "link" to a common ancestor.

If you type `?hclust` you can review the parameter options which we explored in a notebook. `hclust` is primarily a function of `dist()` [distance], and we have just computed some distances, so we could try and apply `hclust` to our data to see if our state capitals will cluster into meaningful regions.

There are several agglomeration methods ("linkage") one could choose from. Each method takes the `dist` https://en.wikipedia.org/wiki/Hierarchical_clustering#Metric and performs some pairwise distance algorithm called a linkage criteria https://en.wikipedia.org/wiki/Hierarchical_clustering#Linkage_criteria.

I generally use either the "complete" linkage method or the "ward.D2" linkage method. You can read help `?hclust` to better appreciate why: "A number of different clustering methods are provided. Ward's minimum variance method aims at finding compact, spherical clusters. The complete linkage method finds similar clusters."

If you are trying to link binary data (zeroes and ones) or genomic data (where the distances were computed using a genetic-distance algorithm), you may want to try the UPGMA approach: "average" or "centroid".

Analogy of Family

Since I am from a large family, I will make a family tree analogy. For me, I am the 5th of 11 siblings (5 brothers, 5 sisters). If I wanted to cluster the siblings in a pair-wise fashion, how would I begin?

First, I would ask, which other sibling is most like me? Since this is a pair-wise approach, and there are 11 siblings, maybe at the initial stage, I will not be paired with another sibling.

In fact, at least one will not be paired because the total number is 11. And maybe more than one will not be paired in the initial stage. Remember "similarity" is being defined based on some distance-linkage method. And to use this approach, "similarity" needs to numerical data.

At each stage, pair-wise joining occurs until there is nothing left to join. The tree contains all of the elements. Every element (branch) eventually joins the main branch (trunk) of the tree.

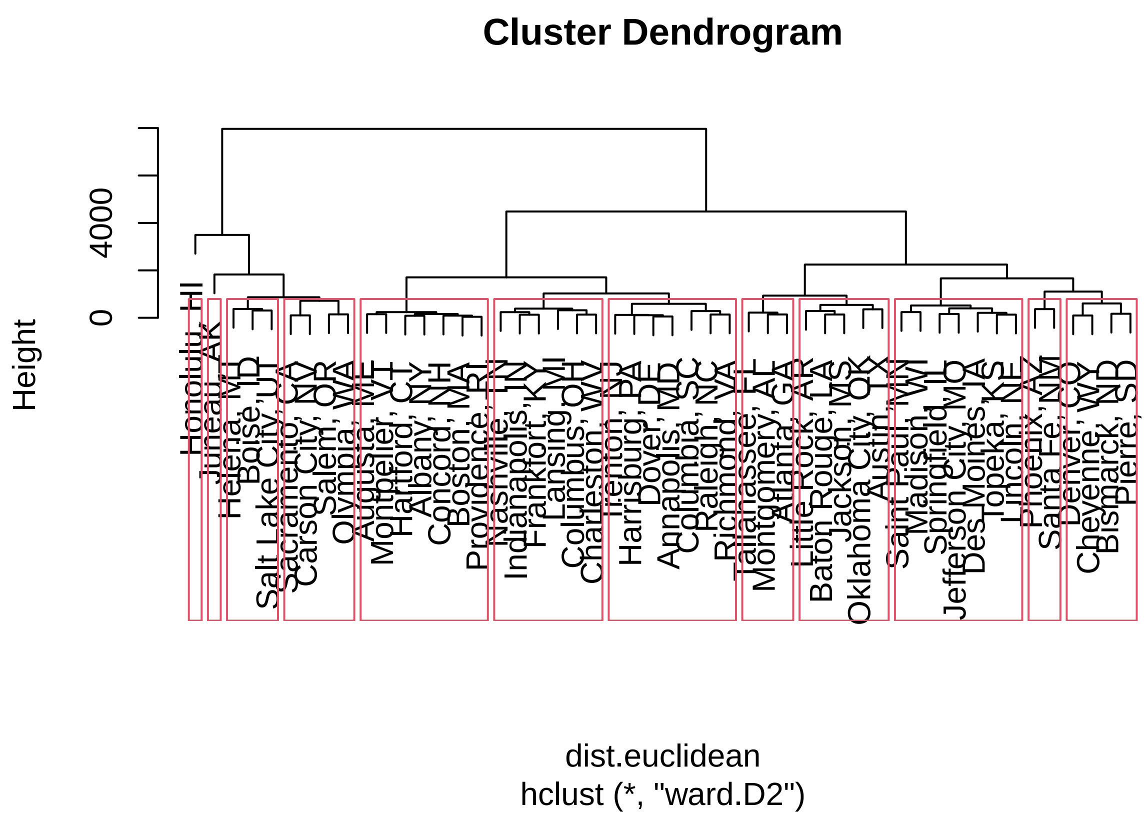
Clustering U.S. capital cities based on latitude, longitude

We already have some data for the U.S. capitals and have computed a Euclidean distance using a capital-city's longitude and latitude. Let's choose to cut the result into `12` agglomerations. Why 12? It was a choice based on my life experience and intuition. As I reflected on why, I did some external searching that validates a choice in that range https://en.wikipedia.org/wiki/List_of_regions_of_the_United_States. You certainly could run this analysis with another choice It is exploratory, and your intuition matters.

Geographically, I am saying the capital-city does represent the state. An ideal representation may be in the center (centroid) of the state. Remember this when we see the linkages with "New York", the city is Albany, not Manhattan.

```
## ward.D2
hclust.ward2.dist.euclidean = hclust(dist.euclidean, method="ward.D2");

plot( hclust.ward2.dist.euclidean,
      labels= myLabels );
rect.hclust( hclust.ward2.dist.euclidean, k=12 );
```




```
## complete
#
# hclust.complete.dist.euclidean = hclust(dist.euclidean, method="complete");
#
# plot( hclust.ward2.dist.euclidean,
#       labels= myLabels );
# rect.hclust( hclust.ward2.dist.euclidean, k=12 );
#
```

Understanding the `cutree`

In the above example, the tree was cut into 12 groups based on the “distance” formula used and based on the “agglomeration” linkage technique invoice. I likely should have used a “geo-spatial” distance, but we will see that mere “euclidean” distance seems to perform okay.

A fancy word for this statistical tree is a “dendrogram”. I call each element of the tree a branch. The smallest branches (twigs) are the fundamental elements, in this case the cities. Over time, they merge with other small branches, and so on.

The relative height when this smallest branch merges with another branch demonstrates when the branch has found a similar pair-wise match (with another smallest branch or a merging branch). I call “Honolulu Hawaii” an isolate because the vertical height when it merges with another branch is the highest of all of the smallest branches (e.g., cities). “Juneau Alaska” is another isolate, but it does merge before “Hawaii”.

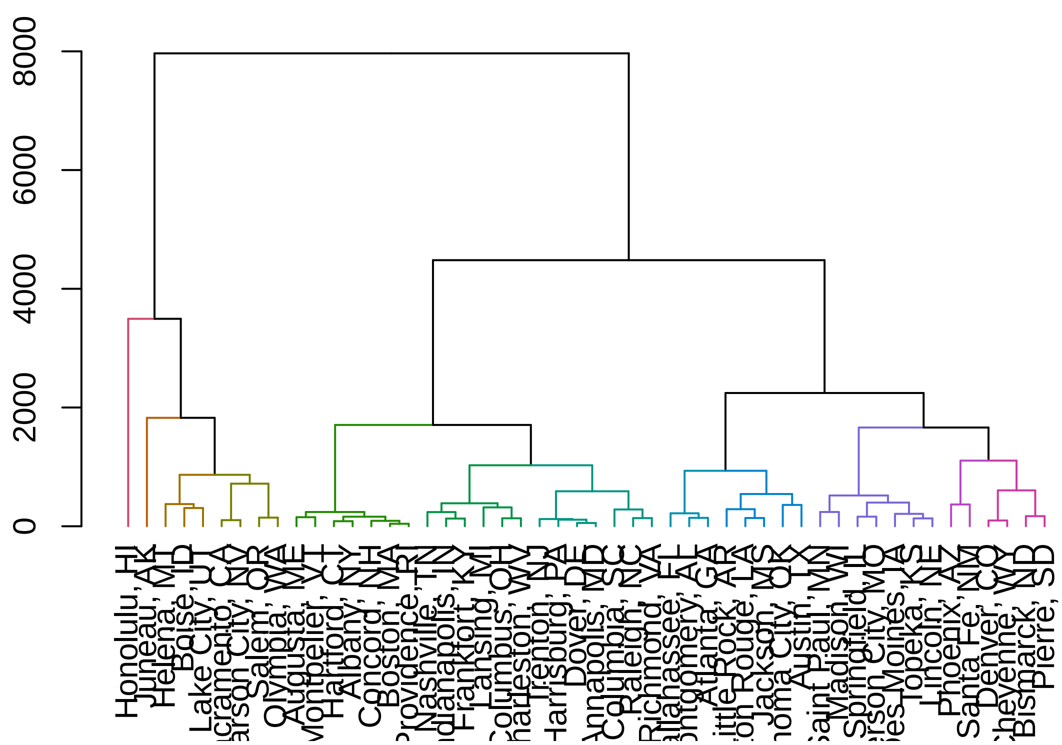
It would be nice if we could decompose this information and look at one `cutree` at a time. And color-code the distinctions. Using the function `plot.hclust.sub` we can do this.

```
source_url( paste0(path.github,"humanVerseWSU/R/functions-EDA.R") );  # EDA functions ...
```

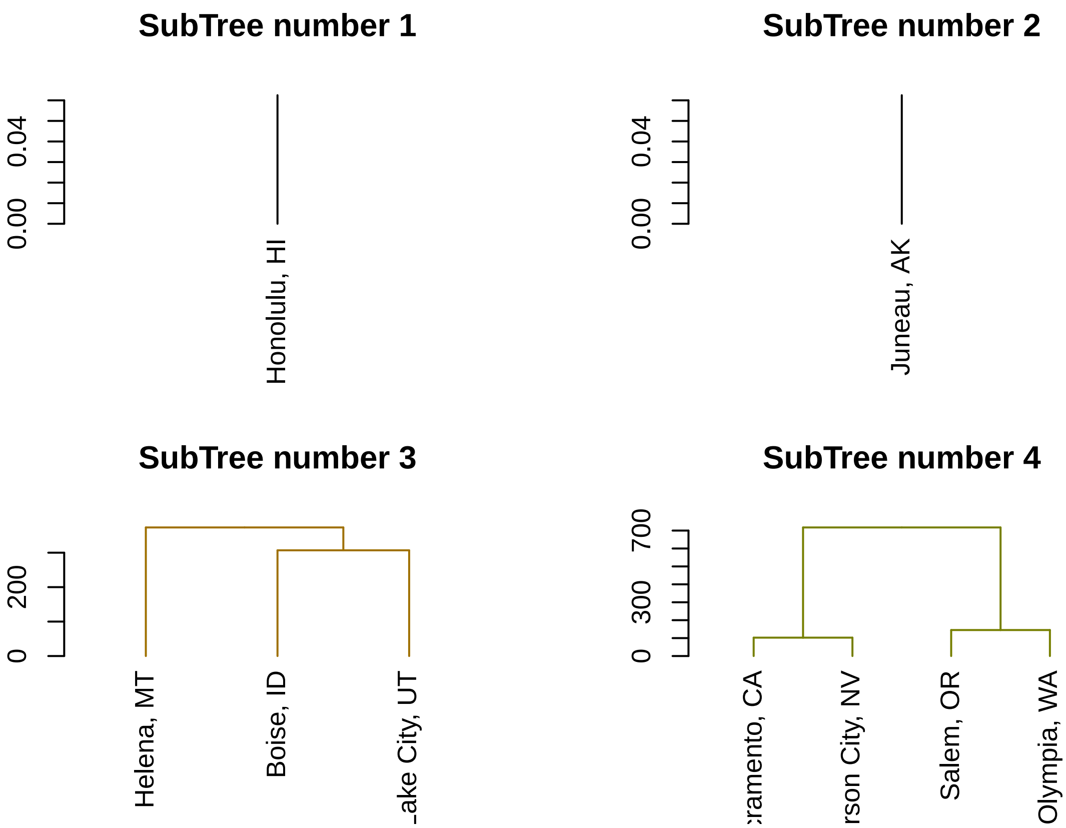
```
## SHA-1 hash of file is dd72e464241952b23d5b08d2213099eccf7a86f6
```

```
hclust.ward2.dist.euclidean$labels = myLabels;
plot.hclust.sub(hclust.ward2.dist.euclidean, k=12);
```

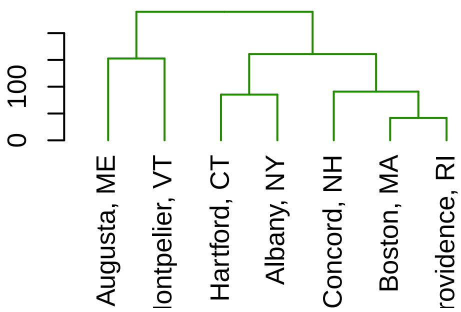
```
## Registered S3 method overwritten by 'dendextend':
##   method       from
##   text.pvclust pvclust
```



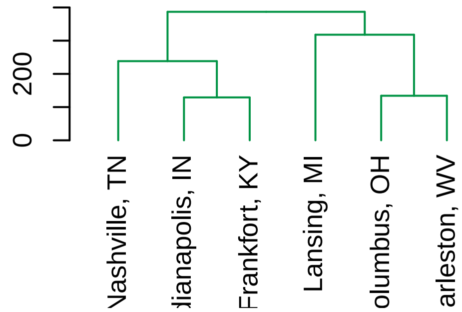
```
## [1] "Pruning 1 of 12"
## [1] "Pruning 2 of 12"
## [1] "Pruning 3 of 12"
## [1] "Pruning 4 of 12"
## [1] "Pruning 5 of 12"
## [1] "Pruning 6 of 12"
## [1] "Pruning 7 of 12"
## [1] "Pruning 8 of 12"
## [1] "Pruning 9 of 12"
## [1] "Pruning 10 of 12"
## [1] "Pruning 11 of 12"
## [1] "Pruning 12 of 12"
```



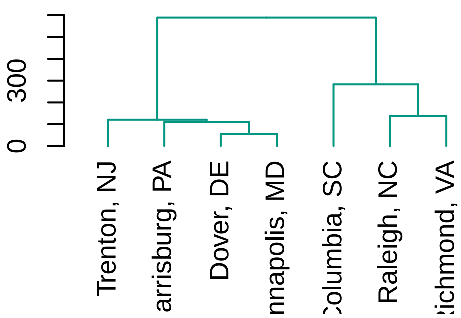
SubTree number 5



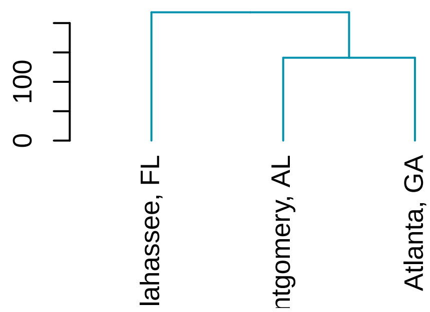
SubTree number 6

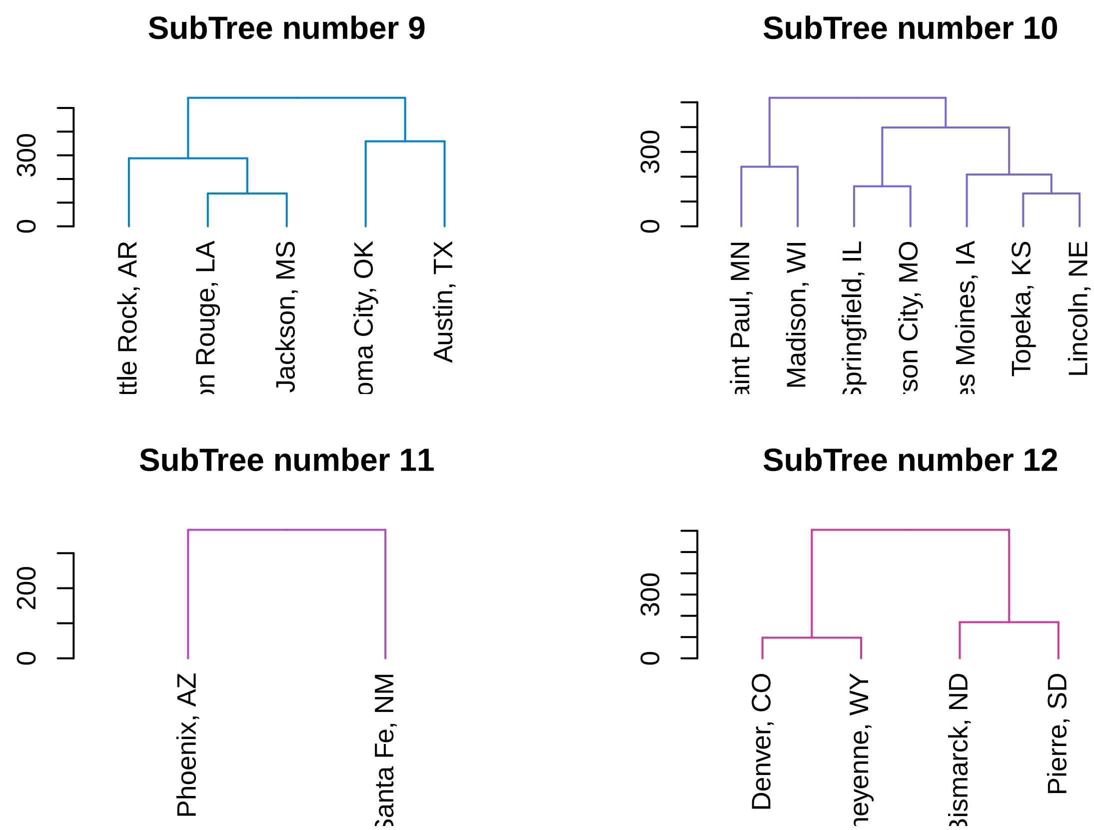


SubTree number 7



SubTree number 8






```
# plot.hclust.sub(hclust.complete.dist.euclidean, k=12);
```

(10 points) Review one clustering tree (dendrogram)

Choose either `hclust.ward2.dist.euclidean` or `hclust.complete.dist.euclidean` and review how the U.S. state capitals are clustered. [I commented out one form, so you will have to re-run if you want to select that one.]

Comment on the "face validity" of this approach based on your understanding about how the U.S. regions are defined? Are the North/South Dakotas together? What about the North/South Carolinas? What about the Pacific Northwest? While living in Kentucky, some people called the area "Kentuckiana" meaning Kentucky/Indiana. Does that show up? Also note anything that seems peculiar.

Additional remarks about `hclust`

I find `hclust` to be a nice initial perusal of the data.

If you want to understand the stability of a particular `hclust` to use it for something other than an "initial perusal of the data," I would recommend `pvclust` which I introduced in the weekly notebooks. It is often used in peer-reviewed research, as it provides a `p-value` of sorts regarding the **stability** of the `hclust` structure.

GENERIC clustering

Aggregating or agglomerating data is typically called "clustering". In exploration, we can create some generic clustering techniques. Below we will create two adhoc clustering rules.

Arbitrary Aggregation

Recall the "movie dataset" with "Will Smith" and "Denzel Washington". We have a collection of movies, and how much money each movie made at the box office. We could organize those movies by some arbitrary rules. For example:

- Cluster 1: NA. We have missing data regarding the money. So let's put all movies that are NA into that cluster.
- Cluster 2: Under a million dollars
- Cluster 3: 1-4.99… million dollars (greater than or equal to one, but less than 5)
- Cluster 4: 5-49.99…
- Cluster 5: 50+

```
library(devtools);
source_url( paste0(path.mshaffer, "will") );
```

(5 points) Movie Aggregation [Arbitrary] for Will and Denzel

```
## SHA-1 hash of file is 3c1c97d961577e9b47a12faa20dca74bfe755c87
```

```
source_url( paste0(path.mshaffer, "denzel") );
```

```
## SHA-1 hash of file is 6692d8c5629db1ae023691bb55de2664a48cdde0
```

```
movies.50 = rbind(will$movies.50, denzel$movies.50);

unique(movies.50$ttid); # are they in any shared movies ???
```

```
##   [1] "tt0480249" "tt1386697" "tt0116629" "tt0119654" "tt0343818" "tt0454921"
##   [7] "tt0448157" "tt0120912" "tt1409024" "tt0386588" "tt0814314" "tt0112442"
##  [13] "tt0172156" "tt0120660" "tt6139732" "tt0145660" "tt2381941" "tt1815862"
##  [19] "tt1596350" "tt1229340" "tt5519340" "tt0307453" "tt1155076" "tt0120891"
##  [25] "tt0120783" "tt1502397" "tt0248667" "tt4682786" "tt3322364" "tt1025100"
##  [31] "tt0114558" "tt0300051" "tt0284490" "tt0146984" "tt1837709" "tt0338466"
##  [37] "tt0947802" "tt1823664" "tt0268397" "tt1082886" "tt5814534" "tt3721964"
##  [43] "tt0416212" "tt0108149" "tt0328099" "tt0167427" "tt0466839" "tt0107478"
##  [49] "tt7255568" "tt0466856" "tt0765429" "tt0139654" "tt0454848" "tt0455944"
##  [55] "tt0328107" "tt1907668" "tt0453467" "tt1037705" "tt0107818" "tt1599348"
##  [61] "tt0210945" "tt1272878" "tt1111422" "tt0477080" "tt2404435" "tt0145681"
##  [67] "tt3766354" "tt0251160" "tt0097441" "tt0368008" "tt0112740" "tt2671706"
##  [73] "tt0174856" "tt0104797" "tt0107798" "tt0119099" "tt0133952" "tt0313443"
##  [79] "tt0427309" "tt0115956" "tt0107616" "tt0124718" "tt0168786" "tt6000478"
##  [85] "tt0114857" "tt0112857" "tt0102789" "tt0092804" "tt0100168" "tt0117372"
##  [91] "tt0088146" "tt0097880" "tt0102456" "tt0099750" "tt0091786" "tt0082138"
##  [97] "tt0097373" "tt4283892" "tt1698652" "tt0118783"
```

```r
loadInflationData();

movies.50 = standardizeDollarsInDataFrame(movies.50,
                2000,
                "millions",
                "year",
                "millionsAdj2000");

movies.50$cluster.arbitrary = NA;
str(movies.50);
```

```
## 'data.frame':    100 obs. of  13 variables:
##  $ rank             : num  1 2 3 4 5 6 7 8 9 10 ...
##  $ title            : chr  "I Am Legend" "Suicide Squad" "Independence Day" "Men in Black" ...
##  $ ttid             : chr  "tt0480249" "tt1386697" "tt0116629" "tt0119654" ...
##  $ year             : num  2007 2016 1996 1997 2004 ...
##  $ rated            : chr  "PG-13" "PG-13" "PG-13" "PG-13" ...
##  $ minutes          : num  101 123 145 98 115 117 92 88 106 118 ...
##  $ genre            : chr  "Action, Adventure, Drama" "Action, Adventure, Fantasy" "Action, Adventur
##  $ ratings          : num  7.2 6 7 7.3 7.1 8 6.4 6.2 6.8 6.6 ...
##  $ metacritic       : num  65 40 59 71 59 64 49 49 58 58 ...
##  $ votes            : num  675193 588111 520657 507618 491489 ...
##  $ millions         : num  256 325 306 251 145 ...
##  $ millionsAdj2000  : num  213 233 336 269 132 ...
##  $ cluster.arbitrary: logi  NA NA NA NA NA NA ...
```

```r
## you do something here ...

# (1) populate cluster.arbitrary
movies.50$cluster.arbitrary[movies.50$millionsAdj2000<1] <- 'cluster2'
movies.50$cluster.arbitrary[movies.50$millionsAdj2000>=1 & movies.50$millionsAdj2000<5] <- 'cluster3'
movies.50$cluster.arbitrary[movies.50$millionsAdj2000>=5 & movies.50$millionsAdj2000<50] <- 'cluster4'
movies.50$cluster.arbitrary[movies.50$millionsAdj2000>=50] <- 'cluster5'
movies.50$cluster.arbitrary[is.na(movies.50$millionsAdj2000)] <- 'cluster1'
# (2) summarize how many movies live in each (table count)
table(movies.50$cluster.arbitrary)
```

```
##
## cluster1 cluster2 cluster3 cluster4 cluster5
##        5        4        2       38       51
```

Aggregating using Quantiles

John Tukey emphasized that ordering the data and then splitting it based on the ordering was a fundamental premise of exploratory data analysis.

Tukey's Summary Data John Tukey proposed five elements as primary data for analysis.

- the minimum `min`
- the maximum `max`

Sorting the data makes it easiest to find these data, and will be useful to find the other three exploratory summary features.

This is what I would call "slice and dice". The data is cut in half, and the value of that middle "cutting point" is the `Q2` which we call the `median`.

Next, the lower half could also be cut in half, and the value of that middle "cutting" point is `Q1`.

Then, the upper half could also be cut in half, and the value of that middle "cutting" point is `Q3`.

A common metric derived from this "median-split" procedure is called the interquartile range `IQR` which is defined as the distance between `Q3` and `Q1`. It literally represents the middle 50% of the data; 50% of the elements of the dataset are between `Q3` and `Q1`.

```
x = 1:99;
length(x);
```

Quartile Example

```
## [1] 99
```

```
median(x);
```

```
## [1] 50
```

```
x[50];
```

```
## [1] 50
```

```
median(x[1:49]);
```

```
## [1] 25
```

```
x[25];
```

```
## [1] 25
```

```
median(x[51:99]);
```

```
## [1] 75
```

```
x[75];
```

```
## [1] 75
```

```
# probability-approach ...
# algorithm: the default type=7
stats::quantile(x, prob = c(0.25, 0.5, 0.75), type=1);
```

```
## 25% 50% 75%
##  25  50  75
```

Algorithms address various issues associated with dividing numbers and whether or not to include the dividing number in the subset division, but the principle holds.

We can generalize this idea by not always cutting the data in half (median-split as `n=2`, median-median-split as `n=4`). Instead, we could cut by tens (we call them deciles). Or we could cut by hundreds (we call them centiles). The function `quantile` performs this operation, and if you dig into the `doStatsSummary` function used in this course, you can see its application.

```r
movies.50$cluster.deciles = NA;
str(movies.50);
```

(5 points) Movie Aggregation [Decile] for Will and Denzel

```
## 'data.frame':    100 obs. of  14 variables:
##  $ rank             : num  1 2 3 4 5 6 7 8 9 10 ...
##  $ title            : chr  "I Am Legend" "Suicide Squad" "Independence Day" "Men in Black" ...
##  $ ttid             : chr  "tt0480249" "tt1386697" "tt0116629" "tt0119654" ...
##  $ year             : num  2007 2016 1996 1997 2004 ...
##  $ rated            : chr  "PG-13" "PG-13" "PG-13" "PG-13" ...
##  $ minutes          : num  101 123 145 98 115 117 92 88 106 118 ...
##  $ genre            : chr  "Action, Adventure, Drama" "Action, Adventure, Fantasy" "Action, Adventure
##  $ ratings          : num  7.2 6 7 7.3 7.1 8 6.4 6.2 6.8 6.6 ...
##  $ metacritic       : num  65 40 59 71 59 64 49 49 58 58 ...
##  $ votes            : num  675193 588111 520657 507618 491489 ...
##  $ millions         : num  256 325 306 251 145 ...
##  $ millionsAdj2000  : num  213 233 336 269 132 ...
##  $ cluster.arbitrary: chr  "cluster5" "cluster5" "cluster5" "cluster5" ...
##  $ cluster.deciles  : logi  NA NA NA NA NA NA ...
```

```r
## you do something here ...

# use # stats::quantile(x, prob=seq(0.1,0.9,by=0.1), type=1 );
# (1) how many NA's are there ... keep them NA's
cat('there are', sum(is.na(movies.50$millionsAdj2000)), " NA's in column millionsAdj2000")
```

```
## there are 5  NA's in column millionsAdj2000
```

```r
# (2) for the rest of the data, break it up into deciles
movies.50.rest <- movies.50[!is.na(movies.50$millionsAdj2000),]
stats::quantile(movies.50.rest$millionsAdj2000, prob=seq(0.1,0.9,by=0.1), type=1)
```

```
##        10%        20%        30%        40%        50%        60%        70%
##   7.638768  20.177743  27.511542  37.259081  53.554796  64.786272  74.509802
##        80%        90%
## 115.650000 146.638920
```

```r
# (3) $cluster.deciles for a given movie should be NA, 1, 2, 3, ... 10
movies.50$cluster.deciles[movies.50$millionsAdj2000<7.638768] <- 'Decile1'
movies.50$cluster.deciles[movies.50$millionsAdj2000>=7.638768 & movies.50$millionsAdj2000<20.177743] <-
movies.50$cluster.deciles[movies.50$millionsAdj2000>=20.177743 & movies.50$millionsAdj2000<27.511542] <
movies.50$cluster.deciles[movies.50$millionsAdj2000>=27.511542 & movies.50$millionsAdj2000<37.259081] <
movies.50$cluster.deciles[movies.50$millionsAdj2000>=37.259081 & movies.50$millionsAdj2000<53.554796] <
movies.50$cluster.deciles[movies.50$millionsAdj2000>=53.554796 & movies.50$millionsAdj2000<64.786272] <
movies.50$cluster.deciles[movies.50$millionsAdj2000>=64.786272 & movies.50$millionsAdj2000<74.509802] <
movies.50$cluster.deciles[movies.50$millionsAdj2000>=74.509802 & movies.50$millionsAdj2000<115.650000]
movies.50$cluster.deciles[movies.50$millionsAdj2000>=115.650000& movies.50$millionsAdj2000<146.638920 ]
movies.50$cluster.deciles[movies.50$millionsAdj2000>=146.638920 ] <- 'Decile10'

# (4) summarize how many movies live in each (table count)

table(movies.50$cluster.deciles, exclude = NULL)
```

```
##
##  Decile1 Decile10  Decile2  Decile3  Decile4  Decile5  Decile6  Decile7
##        9       10        9       11        9       10        9        9
##  Decile8  Decile9     <NA>
##        9       10        5
```

CENTROID clustering (k-means) as a function of distance

Introduction

Rather than clustering on distance-linkage in a pair-wise fashion, we can cluster based on randomly selecting just `k` points in our data and begin identifying their nearest neighbors using some distance approach.

For example, if `k=3`, we would randomly select three of our data points. We would then compute the distances from all of the remaining points to these `3` anchor points. The points that are closest to a given anchor will be assigned to that anchor. At the end of the stage, we now have new data, so a new centroid is determined. At this point, the centroid https://en.wikipedia.org/wiki/Centroid is likely not one of our data points, but a location within the given centroid cluster. In the "naive" approach, you merely take an average (mean) of all the members of your cluster. More advanced approaches (the default "Hartigan-Wong" of `kmeans`) utilize deviations from the average, called a sum-of-squares approach. This is why in our `kmeans-notebook` we analyzed the `wss` to ascertain how many clusters `k` should we use.

Regardless, after the new centroids (centers) for the clusters are determined, the process iterates. All distances are computed from all points to the new centroids; points are assigned to a given centroid cluster (in this example: 1, 2, 3); a new centroid center is computed, and we repeat the process until a stopping rule is reached: maybe we have exhausted the number of iterations allowed (`iter.max` parameter of `kmeans`)? Or maybe we are not changing membership of any of the data points? Or maybe we have met some objective (like `wss`)?

It is possible to get a `kmeans` result by merely starting with `3 different` random points. In general, `kmeans` is fast (and our computers are so much faster than the computers of 1990: the first computer I built in 1995 had 32MB of RAM, a Pentium processor https://en.wikipedia.org/wiki/Pentium#Pentium and a 900MB Cheetah hard-drive).

Anyway, we can utilize the parameter `nstart` to try many different starting values, and let the program identify the best, most consistent solution.

My recommendations

I would recommend the default algorithm `Hartigan-Wong` with `iter.max=100` and `nstart=100`. You can test the timings from the default values: `iter.max=10` and `nstart=1`. Since the data is likely multidimensional `stars` are the best way to summary the results and membership of `kmeans`. Please see the "kmeans-notebook" for examples.

WIKIPEDIA CLIMATE DATA

For the 50 U.S. cities, we harvested climate data. In the "Wikipedia" notebook, details of that data provenance were outlined. If we want to compare the cities using the climate data, we have to build a matching dataframe, which means we have to select features that exist in each city's climate data set.

There are four temperature features that are always present:

- Record high F (C) . . . we will call it "high.max"
- Average high F (C) . . . we will call it "high.avg"
- Average low F (C) . . . we will call it "low.avg"
- Record low F (C) . . . we will call it "low.max" [probably not the best name choice, but it is parallel in form to the first element]

Additionally, for precipitation we have:

- Average precipitation inches (mm) . . . we will call it "rain"
- Average snowfall inches (cm) . . . we will call it "snow"

For each of these features we have 12 months of data. This is a nice dataset. Let's see what we can do with it.

Basic Background Research We should begin by doing a bit of peripheral research on the topic, to gain "domain knowledge" so we know what to do with the data. A few elements that would benefit.

https://www.forbes.com/sites/brianbrettschneider/2018/07/08/when-does-the-hottest-day-of-the-year-usually-occur/#78141f47548c

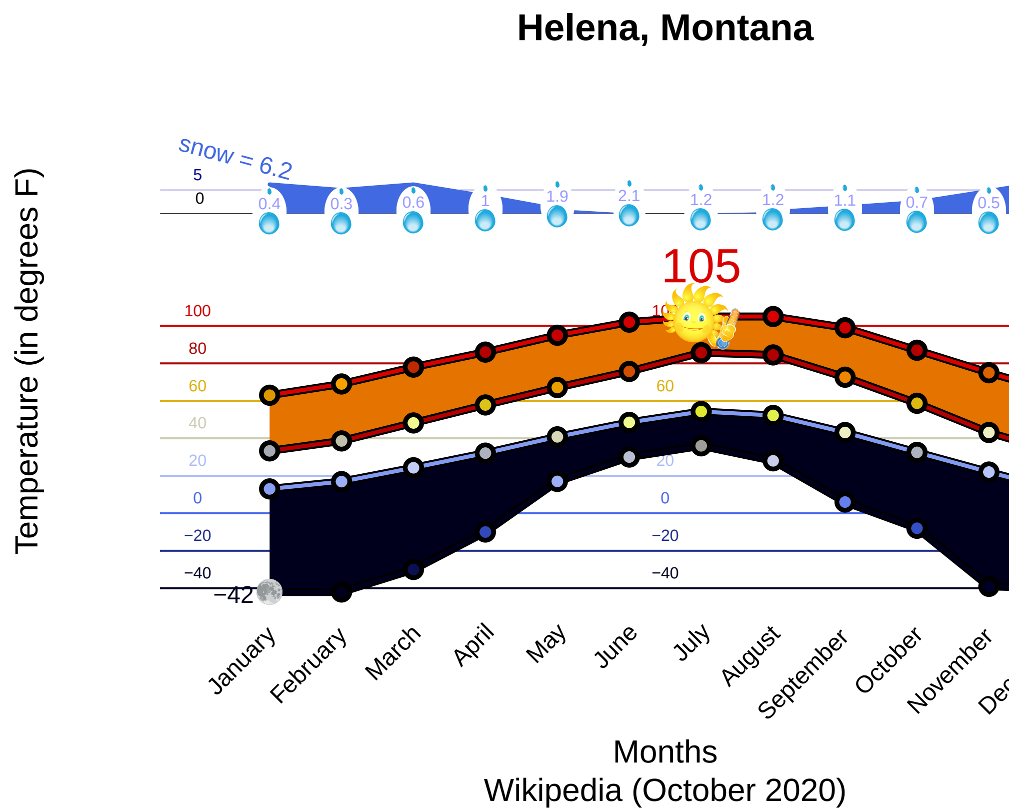
Source: https://bit.ly/359HAnY

https://www.climate.gov/news-features/featured-images/whats-coldest-day-year

One Graph When graphing data to visualize, it is essential that you keep the scales uniform so quick-visual comparisons are accurate. I gave you a task to practice the idea of creation that "one informative" research graphic. And I now present my version for you to use and critique based on your efforts. I am a `plot` guy, so some of you may have a different '`ggplot2` type solution. Ultimately, the intent of this graphic is to best summarize the data in a meaninful way for exploratory analysis.

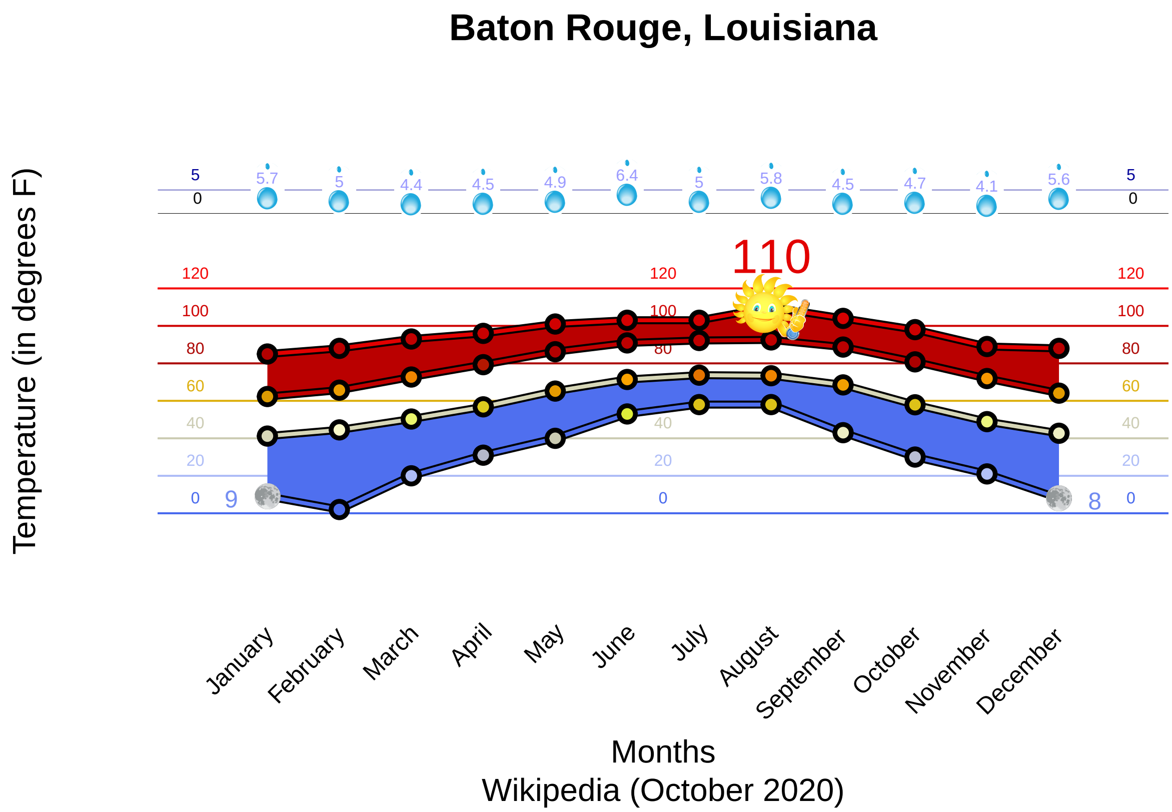
```
climate = utils::read.csv( paste0(path.mshaffer, "_data_/state-capitals/final/state-capitals-climatedat

plotTemperatureFromWikipediaData(climate, city.key="capital", city.val="Helena");
```



(5 points) One Research Graph

```
plotTemperatureFromWikipediaData(climate, city.key="capital", city.val="Baton Rouge");
```



[What do you like about this graphic?

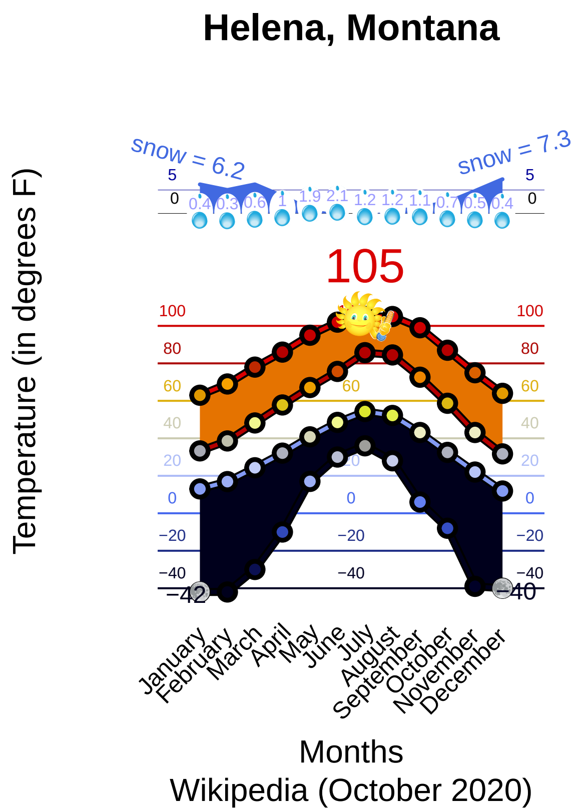
What do you dislike?

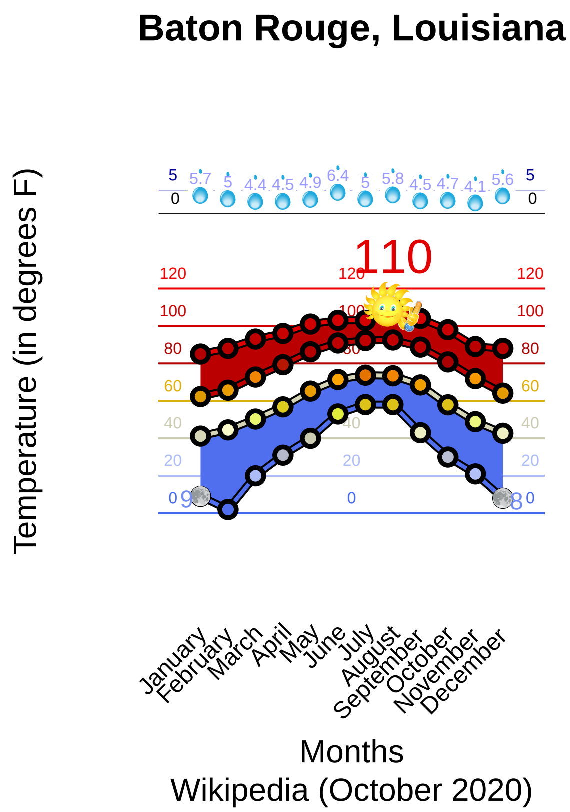
Is it aesthetically pleasing? Is it functional?

]

We can achieve a side-by-side comparison using the function described below. The first city will be graphed on the left, the second city on the right.

```
compareTwoCitiesClimates(climate, city.key="capital", city.1="Helena", city.2="Baton Rouge");
```





[What do you like about this graphic?

What do you dislike?

Are the y-axis the same scale? Are the visible gridlines for each the same?

What is the difference between rain and snow on the graphic? Was that a good approach? How would you have done it?

]

(5 points) One Publication Graph We are in exploration, so the "one" research graphic may be very different than the "one" formal graphic designed for a client. Typically, the final graphic needs to meet certain criteria:

- Very pleasing aesthetically
- Interactive if possible
- Live data feeds if possible
- Served in a secure, safe, private location (if required by the client)

To demonstrate the differences, I created a mockup of our 50 U.S. cities and put it into a nice finalized product form called "highcharts".

http://md5.mshaffer.com/WSU_STATS419/_EXAMPLES_/fiddle_usmap/

It pulls data in real time (using AJAX) to grab the weather at the latitudes/longitudes we defined in our Wikipedia notebook.

- You can use your mouse to draw a box to zoom in.

- The third-wheel on the mouse also helps you zoom in/out.
- Hold down CNTRL with your left hand and use your mouse key to drag the map. It seems to only "pan" in the x-direction at the moment.

- The data in the popup displayed can be customized. I report the temperature in Celsius/Fahrenheit and also display the population data we gathered from Wikipedia.

Once you have a template built, it is rather easy to modify it. Here I changed the background map, and all of the data/features stay the same:

http://md5.mshaffer.com/WSU_STATS419/_EXAMPLES_/fiddle_usmap/world.html

Which Features to Include in the Analysis

- months, you can pick all of them `1:12` or maybe just one month per season (April, July, October, January)
- X, depending on what you chose for months, you can now select what climate columns you want to use
  - Some of Temperature Data
  - All of Temperature Data
  - Precipitation Data
  - Everything (All of Temperature Data, Precipitation Data)

If we want to cluster cities, which decisions seem best? Why? As you can see from the code below, you just comment out two options, and can quickly rerun the analysis.

- WHICH MONTHS
- WHICH COLUMNS

```
climate = utils::read.csv( paste0(path.mshaffer, "_data_/state-capitals/final/state-capitals-climatedata

#################### WHICH MONTHS ####################
########################################################
months = 1:12; # all the data
#months = c(1,4,7,10); # one month of each of the four seasons
########################################################


month.abb;  # ?month.abb
```

WHICH MONTHS & WHICH COLUMNS

```
##  [1] "Jan" "Feb" "Mar" "Apr" "May" "Jun" "Jul" "Aug" "Sep" "Oct" "Nov" "Dec"
```

```
month.name;
```

```
##  [1] "January"   "February"  "March"     "April"     "May"       "June"
##  [7] "July"      "August"    "September" "October"   "November"  "December"
```

```r
month.name[months];  # these are the names of the months you are selecting ...
```

```
##  [1] "January"   "February"  "March"     "April"     "May"       "June"
##  [7] "July"      "August"    "September" "October"   "November"  "December"
```

```r
# this function would allow us to use different months as criteria and different climate-data keys.  It

climate.df = buildClimateDataFrame(climate, months, keys=c("Record high F (C)", "Average high F (C)", "

climate.df;
```

```
##               state        capital st             labels highmax.Jan
## 1           Alabama     Montgomery AL     Montgomery, AL          83
## 23           Alaska         Juneau AK         Juneau, AK          60
## 39          Arizona        Phoenix AZ        Phoenix, AZ          88
## 59         Arkansas    Little Rock AR    Little Rock, AR          83
## 79       California     Sacramento CA     Sacramento, CA          79
## 94         Colorado         Denver CO         Denver, CO          76
## 117     Connecticut       Hartford CT       Hartford, CT          72
## 141        Delaware          Dover DE          Dover, DE          77
## 162         Florida    Tallahassee FL    Tallahassee, FL          83
## 182         Georgia        Atlanta GA        Atlanta, GA          79
## 205          Hawaii       Honolulu HI       Honolulu, HI          88
## 225           Idaho          Boise ID          Boise, ID          63
## 248        Illinois    Springfield IL    Springfield, IL          73
## 265         Indiana   Indianapolis IN   Indianapolis, IN          71
## 289            Iowa     Des Moines IA     Des Moines, IA          67
## 311          Kansas         Topeka KS         Topeka, KS          78
## 334        Kentucky      Frankfort KY      Frankfort, KY          80
## 350       Louisiana    Baton Rouge LA    Baton Rouge, LA          85
## 365           Maine        Augusta ME        Augusta, ME          61
## 381        Maryland      Annapolis MD      Annapolis, MD          77
## 399   Massachusetts         Boston MA         Boston, MA          74
## 423        Michigan        Lansing MI        Lansing, MI          66
## 446       Minnesota     Saint Paul MN     Saint Paul, MN          57
## 458     Mississippi        Jackson MS        Jackson, MS          85
## 476        Missouri Jefferson City MO Jefferson City, MO          79
## 490         Montana         Helena MT         Helena, MT          63
## 509        Nebraska        Lincoln NE        Lincoln, NE          73
## 532          Nevada    Carson City NV    Carson City, NV          72
## 552   New Hampshire        Concord NH        Concord, NH          72
## 574      New Jersey        Trenton NJ        Trenton, NJ          73
## 597      New Mexico       Santa Fe NM       Santa Fe, NM          65
## 617        New York         Albany NY         Albany, NY          71
## 641  North Carolina        Raleigh NC        Raleigh, NC          80
## 665    North Dakota       Bismarck ND       Bismarck, ND          63
## 688            Ohio       Columbus OH       Columbus, OH          74
## 712        Oklahoma  Oklahoma City OK  Oklahoma City, OK          83
## 734          Oregon          Salem OR          Salem, OR          68
## 754    Pennsylvania     Harrisburg PA     Harrisburg, PA          73
## 776    Rhode Island     Providence RI     Providence, RI          70
## 800  South Carolina       Columbia SC       Columbia, SC          84
## 823    South Dakota         Pierre SD         Pierre, SD          68
```

```
## 837       Tennessee      Nashville TN      Nashville, TN          78
## 861           Texas         Austin TX         Austin, TX          90
## 885            Utah Salt Lake City UT Salt Lake City, UT          63
## 908         Vermont     Montpelier VT     Montpelier, VT          66
## 925        Virginia       Richmond VA       Richmond, VA          81
## 949      Washington        Olympia WA        Olympia, WA          64
## 968   West Virginia     Charleston WV     Charleston, WV          81
## 986       Wisconsin        Madison WI        Madison, WI          58
## 1007        Wyoming       Cheyenne WY       Cheyenne, WY          70
##      highmax.Feb highmax.Mar highmax.Apr highmax.May highmax.Jun highmax.Jul
## 1             86          90          94          99         106         107
## 23            57          61          72          80          87          89
## 39            92         100         105         114         122         121
## 59            87          91          95          98         107         112
## 79            80          90          98         107         112         114
## 94            80          84          90          95         105         105
## 117           77          89          96          99         100         103
## 141           80          88          97          98         101         104
## 162           89          91          95         102         105         104
## 182           80          89          93          97         106         105
## 205           88          89          91          93          92          94
## 225           71          82          92         100         110         111
## 248           78          91          90         101         104         112
## 265           77          85          90          96         104         106
## 289           78          91          93         105         103         110
## 311           84          93          97         103         109         114
## 334           80          88          95          99         106         111
## 350           88          93          96         101         103         103
## 365           60          84          90          94          98          99
## 381           83          92          95          98         103         105
## 399           73          89          94          97         100         104
## 423           69          86          88          96          99         103
## 446           59          83          93          93         103         105
## 458           89          95          94         100         105         107
## 476           89          97          96         102         105         112
## 490           69          78          86          95         102         105
## 509           83          91          97         104         108         115
## 532           76          81          88          94         101         107
## 552           74          89          95          98         101         102
## 574           76          87          93          99         100         106
## 597           73          77          84          96          99         101
## 617           74          89          93          97         100         104
## 641           84          94          95          99         105         105
## 665           73          81          93         102         111         114
## 688           78          85          90          96         102         106
## 712           92          97         100         104         107         110
## 734           72          80          93         100         105         108
## 754           79          87          93          97         100         107
## 776           72          90          98          96          98         102
## 800           84          93          96         101         109         107
## 823           75          88          98         105         112         117
## 837           84          89          91          96         109         107
## 861           99          98          99         104         109         109
## 885           69          80          89          99         105         107
```

```
## 908         61          82          90          90          95         97
## 925         83          94          96         100         104        105
## 949         73          79          88          96          98        104
## 968         81          92          96          98         105        108
## 986         68          83          94         101         101        107
## 1007        71          77          84          91         100        100
##      highmax.Aug highmax.Sep highmax.Oct highmax.Nov highmax.Dec highavg.Jan
## 1          106         106         102          91          85       57.4
## 23          87          85          68          64          59       34.6
## 39         117         116         107          96          87       67.2
## 59         114         106          98          86          81       50.5
## 79         112         109         102          86          72       54.4
## 94         105         101          90          81          79       44.0
## 117        102         101          91          83          76       34.5
## 141        102          99          95          85          75       43.4
## 162        103         102          95          89          84       63.5
## 182        104         102          98          84          79       52.3
## 205         95          95          94          93          89       80.1
## 225        110         102          94          78          70       37.8
## 248        108         102          93          83          74       34.8
## 265        103         100          92          81          74       35.6
## 289        110         101          95          82          69       31.0
## 311        113         110          97          85          77       39.9
## 334        105         106          98          84          78       41.5
## 350        110         104          98          89          88       62.3
## 365        100          96          85          74          67       27.6
## 381        106          99          92          85          78       42.7
## 399        102         102          90          83          76       35.8
## 423        102          99          90          79          70       30.1
## 446        103          95          88          75          66       26.0
## 458        107         107          98          89          84       56.1
## 476        111         107          96          87          79       39.9
## 490        105          99          87          75          64       33.3
## 509        110         106          98          85          75       35.4
## 532        105         103          93          79          75       45.2
## 552        101          98          92          80          73       30.8
## 574        105         101          94          83          76       39.0
## 597         96          94          87          75          65       43.5
## 617        102         100          91          82          72       30.6
## 641        105         104         100          88          81       50.9
## 665        109         105          95          79          66       23.4
## 688        103         100          94          80          76       36.5
## 712        113         108          97          87          86       49.7
## 734        108         104          93          74          72       47.7
## 754        104         102          97          84          75       37.0
## 776        104         100          88          81          77       37.4
## 800        107         106         101          90          83       56.0
## 823        114         108          98          87          77       30.0
## 837        106         105          99          88          79       46.9
## 861        112         112         100          91          90       61.5
## 885        106         100          89          75          69       37.4
## 908         97          92          84          76          67       26.4
## 925        107         103          99          86          81       47.4
## 949        104          98          90          74          64       45.9
```

```
## 968          108          104           96           87           80         42.5
## 986          102           99           90           77           65         26.4
## 1007          98           95           85           75           69         39.5
##      highavg.Feb highavg.Mar highavg.Apr highavg.May highavg.Jun highavg.Jul
## 1           61.8        69.7        76.6        84.0        89.8        92.1
## 23          36.7        40.8        49.1        56.9        62.4        63.4
## 39          70.7        76.9        85.2        94.8       103.9       106.1
## 59          55.1        64.0        73.1        81.1        88.9        92.5
## 79          61.2        66.8        72.7        80.9        87.9        93.3
## 94          46.2        54.4        61.5        71.5        82.4        89.4
## 117         38.5        47.7        60.5        71.2        79.6        84.5
## 141         47.0        54.9        65.7        74.7        83.2        87.0
## 162         67.5        73.8        79.9        87.0        91.0        92.1
## 182         56.6        64.6        72.5        79.9        86.4        89.1
## 205         80.2        81.2        82.7        84.6        87.0        87.9
## 225         44.7        54.6        62.3        71.6        81.3        91.2
## 248         39.9        52.1        64.6        74.8        83.1        86.2
## 265         40.2        51.7        63.4        72.8        81.9        85.0
## 289         36.1        49.0        62.3        72.4        81.6        85.7
## 311         45.0        56.4        66.7        75.9        84.7        89.5
## 334         46.0        55.8        66.5        75.2        83.6        87.3
## 350         65.7        72.7        79.3        86.2        90.9        92.2
## 365         31.8        40.4        53.1        65.2        73.8        79.2
## 381         45.5        53.2        63.9        72.9        81.6        85.8
## 399         38.7        45.4        55.6        66.0        75.9        81.4
## 423         33.3        44.1        57.8        68.8        78.4        82.4
## 446         31.0        43.0        58.0        71.0        80.0        85.0
## 458         60.5        68.5        75.9        83.1        89.5        91.6
## 476         45.3        55.8        66.7        75.1        83.5        88.3
## 490         38.6        48.2        57.8        67.1        75.7        85.7
## 509         40.1        52.3        64.3        74.2        84.2        89.0
## 532         49.9        56.7        62.7        71.4        81.1        89.6
## 552         34.9        43.8        57.4        68.9        77.4        82.3
## 574         42.2        50.9        61.4        71.8        80.8        85.3
## 597         48.2        55.9        64.7        74.2        83.5        85.9
## 617         34.6        44.4        58.3        69.4        77.9        82.3
## 641         55.2        63.4        72.4        79.6        87.1        90.2
## 665         28.3        40.4        57.0        68.4        77.2        84.7
## 688         40.6        51.1        63.5        72.9        81.6        84.9
## 712         54.6        63.4        72.3        80.2        88.1        93.9
## 734         51.6        56.5        61.1        67.8        73.9        82.0
## 754         40.7        50.4        62.4        72.1        81.0        85.5
## 776         40.3        47.8        58.6        68.4        77.5        82.8
## 800         60.3        68.2        76.3        83.8        90.0        92.7
## 823         34.9        45.4        59.7        70.2        80.0        88.8
## 837         51.8        61.0        70.5        78.2        86.0        89.3
## 861         65.2        72.2        79.8        86.5        92.1        95.6
## 885         43.2        53.7        61.6        71.9        83.0        92.6
## 908         30.3        39.0        53.3        65.7        74.3        78.5
## 925         51.3        60.0        70.3        77.9        86.1        89.7
## 949         49.3        53.9        58.9        65.3        70.6        76.8
## 968         46.6        56.2        67.7        74.8        82.2        85.2
## 986         31.1        43.1        57.3        68.4        77.9        81.6
## 1007        40.5        47.5        54.9        64.7        75.3        83.4
```

```
##      highavg.Aug highavg.Sep highavg.Oct highavg.Nov highavg.Dec lowavg.Jan
## 1           91.9        87.3        78.3        69.0        59.6       35.7
## 23          62.6        56.6        48.4        39.8        36.7       26.2
## 39         104.4        99.8        88.5        75.5        66.0       45.6
## 59          92.6        85.6        74.8        63.0        52.3       31.2
## 79          92.2        87.9        77.9        63.7        54.3       40.7
## 94          87.2        78.5        65.3        52.1        42.8       17.4
## 117         82.7        74.9        63.1        51.6        39.7       17.7
## 141         85.2        79.3        68.8        58.5        47.4       27.1
## 162         91.5        88.4        81.4        73.0        65.3       39.0
## 182         88.1        82.2        72.7        63.6        54.0       34.3
## 205         88.7        88.6        86.7        83.9        81.2       66.3
## 225         89.7        78.8        64.8        48.2        37.5       24.7
## 248         84.9        78.9        66.4        52.3        38.3       18.7
## 265         84.0        77.6        65.3        52.2        38.9       20.5
## 289         83.8        76.1        63.1        47.9        34.0       14.3
## 311         88.6        80.4        68.4        54.6        41.7       19.6
## 334         86.7        80.4        69.5        57.3        45.0       21.9
## 350         92.5        88.7        80.8        71.9        64.1       41.2
## 365         78.0        69.6        57.2        45.2        33.5       11.0
## 381         84.0        76.9        66.3        56.9        46.8       29.1
## 399         79.6        72.4        61.4        51.5        41.2       22.2
## 423         80.1        72.7        59.9        46.7        34.3       16.8
## 446         82.0        73.0        59.0        42.0        29.0        7.0
## 458         91.6        86.7        77.2        67.4        58.2       35.3
## 476         87.8        79.7        68.5        55.8        42.6       20.9
## 490         84.5        72.6        58.7        43.1        31.7       13.0
## 509         86.8        78.7        65.8        50.3        37.2       13.8
## 532         88.0        80.4        67.9        54.4        45.0       21.7
## 552         80.9        72.6        60.5        48.4        36.3       10.4
## 574         83.6        76.1        65.0        54.5        43.1       23.2
## 597         83.4        77.7        66.5        53.1        43.2       17.5
## 617         80.4        72.2        59.8        47.9        35.8       14.5
## 641         88.4        82.1        72.6        63.6        53.6       31.0
## 665         83.5        72.1        57.5        39.6        26.2        2.2
## 688         83.7        77.0        65.1        52.6        40.1       22.6
## 712         93.4        84.7        73.4        61.5        50.6       28.8
## 734         82.4        76.8        64.1        52.6        46.2       34.7
## 754         83.4        75.6        64.1        53.1        41.3       22.8
## 776         81.4        74.2        63.3        53.2        42.3       21.0
## 800         90.7        85.2        76.1        67.3        58.2       33.7
## 823         87.3        76.5        61.0        44.1        31.3        9.8
## 837         89.0        82.4        71.7        60.3        49.5       28.4
## 861         97.0        90.5        81.8        71.4        62.7       41.5
## 885         90.5        79.2        64.7        49.4        38.0       21.6
## 908         76.7        68.7        56.0        43.8        31.6        7.0
## 925         87.6        81.2        71.0        61.4        50.7       28.3
## 949         77.7        71.8        60.2        50.2        44.2       33.7
## 968         84.2        77.8        67.7        57.0        45.6       26.3
## 986         79.4        71.8        58.9        44.1        30.2       11.1
## 1007        81.2        71.8        58.8        46.5        38.2       18.0
##      lowavg.Feb lowavg.Mar lowavg.Apr lowavg.May lowavg.Jun lowavg.Jul
## 1          39.2       45.3       51.6       60.7       68.1       71.5
## 23         27.6       30.1       35.3       42.3       48.4       51.4
```

```
## 39          48.7       53.5       60.2       69.4       77.7       83.5
## 59          34.5       42.7       51.0       61.1       69.4       73.2
## 79          43.7       46.5       49.0       53.9       58.4       60.9
## 94          18.9       26.4       33.3       42.7       52.3       58.9
## 117         20.9       27.9       38.4       47.7       57.3       62.7
## 141         29.0       35.6       44.3       53.8       63.4       68.4
## 162         41.9       47.1       52.3       61.6       69.5       72.0
## 182         37.7       44.1       51.5       60.3       68.2       71.3
## 205         66.1       67.7       69.4       70.9       73.4       74.5
## 225         28.3       34.4       39.3       46.5       53.7       60.4
## 248         22.6       32.2       42.4       52.6       61.9       65.4
## 265         23.9       32.8       42.7       52.6       62.1       65.8
## 289         18.8       29.7       41.1       52.2       62.0       66.8
## 311         23.8       33.3       43.5       54.2       63.7       68.4
## 334         24.7       31.2       40.5       50.1       59.5       63.8
## 350         44.5       50.3       56.8       65.2       71.4       73.7
## 365         14.5       23.4       34.6       44.6       54.2       59.9
## 381         30.7       36.9       45.8       55.6       66.4       71.2
## 399         24.7       31.1       40.6       49.9       59.5       65.4
## 423         18.5       26.0       37.0       46.7       56.7       60.6
## 446         12.0       24.0       38.0       50.0       59.0       64.0
## 458         38.5       45.3       52.2       61.6       68.6       71.6
## 476         24.6       33.3       43.8       53.8       63.7       68.1
## 490         16.9       24.3       32.1       40.8       48.5       54.3
## 509         18.0       27.9       38.8       50.5       60.9       66.1
## 532         25.3       29.9       33.9       40.8       47.1       52.2
## 552         13.8       22.5       32.7       42.6       52.5       57.7
## 574         25.8       31.9       41.0       50.5       60.3       66.0
## 597         21.5       26.1       32.3       41.0       49.4       54.4
## 617         17.3       25.7       37.3       47.1       56.5       61.4
## 641         33.8       39.9       48.0       56.5       65.8       69.9
## 665          7.9       19.4       30.7       42.7       52.0       57.4
## 688         25.0       32.7       42.6       52.2       61.5       65.5
## 712         32.8       41.0       49.7       59.6       67.8       72.2
## 734         34.6       37.2       39.6       41.7       49.3       53.1
## 754         25.1       33.0       41.9       52.1       62.0       66.3
## 776         23.6       30.0       39.6       48.6       58.4       64.2
## 800         36.8       43.0       50.4       59.5       68.2       71.6
## 823         13.8       23.5       34.2       45.7       55.4       61.9
## 837         31.6       39.0       47.5       56.8       65.4       69.5
## 861         44.8       51.3       58.6       66.7       72.3       74.4
## 885         25.2       33.6       39.5       47.8       56.4       64.7
## 908          9.5       18.9       31.5       41.9       51.2       55.7
## 925         30.5       37.1       46.1       55.0       64.5       68.9
## 949         32.8       35.1       37.7       43.1       47.6       50.8
## 968         28.7       35.4       44.5       52.7       61.6       65.7
## 986         15.1       24.8       35.8       46.1       56.1       61.0
## 1007        18.6       24.4       30.8       40.2       48.9       55.5
##       lowavg.Aug lowavg.Sep lowavg.Oct lowavg.Nov lowavg.Dec lowmin.Jan
## 1           71.0       65.2       53.5       43.9       37.4          0
## 23          50.2       45.8       39.0       31.4       27.8        -20
## 39          82.7       76.9       64.8       52.7       44.8         16
## 59          72.4       64.5       52.6       42.2       33.7         -8
## 79          60.5       58.4       52.8       45.5       40.4         19
```

```
## 94          57.9       48.3       36.6       24.5       17.1        -29
## 117         61.1       52.7       41.1       33.2       23.4        -26
## 141         67.0       60.1       48.7       39.8       31.0         -7
## 162         72.1       68.1       57.3       47.5       41.1          6
## 182         70.7       64.8       54.0       44.5       36.5         -8
## 205         75.1       74.4       73.4       71.4       68.3         52
## 225         59.6       51.0       40.9       31.9       24.0        -28
## 248         63.6       54.6       43.8       33.9       22.5        -22
## 265         64.4       56.2       44.7       35.1       24.4        -27
## 289         64.8       55.2       43.0       30.5       18.0        -30
## 311         66.2       56.3       44.7       33.0       22.3        -23
## 334         62.5       54.6       43.0       34.0       25.9        -27
## 350         73.4       68.5       57.9       48.9       42.7          9
## 365         58.5       50.5       39.6       30.6       18.6        -33
## 381         69.1       62.8       50.5       41.8       31.9         -8
## 399         64.6       57.4       46.5       38.0       28.2        -13
## 423         59.4       51.2       40.7       32.4       22.3        -29
## 446         62.0       53.0       41.0       27.0       13.0        -29
## 458         70.9       64.6       53.1       44.0       37.3         -5
## 476         66.3       57.0       44.9       34.9       24.0        -23
## 490         52.2       43.1       32.5       22.0       11.9        -42
## 509         63.8       53.4       40.6       27.6       16.4        -33
## 532         50.6       43.4       34.6       27.1       21.9        -27
## 552         56.1       47.4       35.8       28.2       17.2        -35
## 574         64.2       56.4       44.2       36.9       27.6        -13
## 597         53.3       46.5       35.5       24.6       17.4        -14
## 617         59.9       51.6       39.6       31.5       21.2        -28
## 641         68.6       61.7       49.8       40.8       33.3         -9
## 665         55.5       44.9       32.2       18.8        6.1        -45
## 688         64.1       56.5       45.0       36.1       26.8        -22
## 712         71.3       63.2       51.6       40.0       30.6        -11
## 734         52.8       48.4       42.3       38.4       34.0        -10
## 754         64.5       56.2       44.6       35.1       26.6        -22
## 776         63.2       55.3       43.9       35.7       26.3        -13
## 800         71.0       64.2       52.1       42.3       35.3         -1
## 823         60.1       49.2       36.4       23.3       12.1        -33
## 837         68.4       60.7       48.9       39.4       31.3        -17
## 861         74.6       69.4       60.6       50.6       42.3         -2
## 885         63.4       53.0       41.3       30.6       22.6        -22
## 908         53.8       46.1       35.3       26.9       14.4        -34
## 925         67.4       60.1       48.3       39.4       31.4        -12
## 949         50.5       46.0       40.5       36.4       32.6         -8
## 968         64.5       56.9       45.4       36.9       29.2        -16
## 986         59.0       50.2       38.8       28.2       15.9        -37
## 1007        54.1       44.7       33.9       24.2       17.3        -38
##      lowmin.Feb lowmin.Mar lowmin.Apr lowmin.May lowmin.Jun lowmin.Jul
## 1            -5         17         28         40         48         59
## 23          -15         -5         12         26         32         39
## 39           24         25         35         39         49         63
## 59          -12         11         28         38         46         54
## 79           21         29         34         37         43         47
## 94          -25        -11         -2         19         30         42
## 117         -24         -6          9         28         37         44
## 141         -11          7         14         28         41         45
```

```
## 162          -2         20         29         34         46         57
## 182          -9         10         25         37         39         53
## 205          52         53         56         60         63         63
## 225         -15          5         11         22         30         35
## 248         -24        -12         16         28         39         48
## 265         -21         -7         18         27         37         46
## 289         -26        -22          9         26         37         47
## 311         -25         -7         10         26         36         43
## 334         -16         -3         16         27         36         48
## 350           2         20         31         40         53         58
## 365         -23        -11          9         26         36         43
## 381          -6         10         13         32         35         50
## 399         -18         -8         11         31         41         50
## 423         -37        -25         -6         19         27         31
## 446         -32        -25          3         21         36         45
## 458           1         15         27         36         47         51
## 476         -25        -16         13         24         38         42
## 490         -42        -30        -10         17         30         36
## 509         -26        -19          3         24         39         45
## 532         -22         -5          3         18         25         33
## 552         -37        -20          4         21         30         35
## 574         -14          1         11         33         41         48
## 597         -24         -6         10         19         28         37
## 617         -22        -21          9         26         35         40
## 641          -2         11         23         29         38         48
## 665         -45        -36        -12         13         30         32
## 688         -20         -6         14         25         35         43
## 712         -17          1         20         32         46         53
## 734          -4         12         23         25         32         35
## 754         -13         -1         11         30         40         49
## 776         -17          1         11         29         39         48
## 800          -2          4         26         34         44         54
## 823         -35        -19          1         21         34         42
## 837         -13          2         23         34         42         51
## 861          -1         18         30         40         51         57
## 885         -30          0         14         25         32         40
## 908         -29        -18          2         20         29         35
## 925         -10         10         19         31         40         51
## 949          -1          9         23         25         30         35
## 968         -12         -5         18         26         33         46
## 986         -29        -29          0         19         31         36
## 1007        -34        -21         -8          8         25         33
##      lowmin.Aug lowmin.Sep lowmin.Oct lowmin.Nov lowmin.Dec rain.Jan rain.Feb
## 1            56         39         26         13          5     4.65     5.28
## 23           32         28         13         -7        -10     7.98     6.71
## 39           58         47         34         27         22     0.91     0.92
## 59           52         37         27         10         -1     3.55     3.66
## 79           48         44         34         27         17     3.63     3.90
## 94           40         17         -2        -18        -25     0.41     0.37
## 117          36         30         17          1        -18     3.23     2.89
## 141          35         30         25         11         -3     3.41     3.07
## 162          57         40         29         13         10     4.34     4.85
## 182          55         36         28          3          0     4.20     4.67
## 205          63         65         61         57         54     0.00     0.00
```

```
## 225          32          23          11         -10         -25      1.24      0.99
## 248          43          31          13          -3         -21      1.82      1.81
## 265          41          30          20          -5         -23      2.66      2.32
## 289          40          26           7         -10         -22      1.00      1.28
## 311          40          29          16          -5         -26      0.86      1.32
## 334          41          30          20          -1         -17      3.70      3.07
## 350          58          43          30          21           8      5.72      5.04
## 365          39          28          21           4         -15      2.61      2.43
## 381          46          37          26          13          -1      3.32      2.94
## 399          46          34          25          -2         -17      3.36      3.25
## 423          26          19          10          -5         -25      1.65      1.47
## 446          42          26          15         -14         -29      0.79      0.67
## 458          54          35          26          15           4      4.97      4.76
## 476          41          29          14           1         -21      1.93      2.29
## 490          28           6          -8         -39         -40      0.36      0.30
## 509          39          26           3         -15         -27      0.64      0.77
## 532          26          17           6          -5         -26      1.59      1.50
## 552          29          20          10         -17         -24      2.70      2.62
## 574          41          31          22          12          -7      3.16      2.31
## 597          36          26           5         -12         -17      0.60      0.53
## 617          34          24          16         -11         -22      2.59      2.20
## 641          46          37          19          11           0      3.50      3.23
## 665          32          10         -10         -30         -43      0.43      0.51
## 688          39          31          17          -5         -17      2.73      2.25
## 712          49          35          16           9          -8      1.39      1.58
## 734          30          26          19           9         -12      5.96      4.56
## 754          45          30          23          10          -8      2.88      2.39
## 776          40          32          20           6         -12      3.86      3.29
## 800          53          40          23          12           4      3.58      3.61
## 823          39          21           4         -18         -31      0.42      0.59
## 837          47          36          26          -1         -10      3.75      3.94
## 861          58          41          30          20           4      2.22      2.02
## 885          37          27          14         -14         -21      1.25      1.25
## 908          31          20          14          -7         -27      2.45      2.04
## 925          46          35          21          10          -2      3.04      2.76
## 949          33          25          14          -1          -7      7.84      5.27
## 968          41          32          17           6         -17      3.00      3.19
## 986          35          25          12         -14         -28      1.23      1.45
## 1007         25           8          -5         -21         -28      0.33      0.47
##      rain.Mar rain.Apr rain.May rain.Jun rain.Jul rain.Aug rain.Sep rain.Oct
## 1        5.95     4.02     3.54     4.07     5.24     3.96     3.97     2.92
## 23       6.29     4.64     4.96     4.42     5.44     8.16    12.72    13.23
## 39       0.99     0.28     0.11     0.02     1.05     1.00     0.64     0.58
## 59       4.68     5.14     4.87     3.65     3.27     2.59     3.18     4.91
## 79       2.86     1.36     0.75     0.21     0.02     0.04     0.35     1.06
## 94       0.92     1.71     2.12     1.98     2.16     1.69     0.96     1.02
## 117      3.62     3.72     4.35     4.35     4.18     3.93     3.88     4.37
## 141      4.31     3.88     4.25     4.00     4.09     4.36     4.13     3.42
## 162      5.94     3.06     3.47     7.73     7.17     7.35     4.69     3.23
## 182      4.81     3.36     3.67     3.95     5.27     3.90     4.47     3.41
## 205      0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
## 225      1.39     1.23     1.39     0.69     0.33     0.24     0.58     0.75
## 248      2.63     3.51     4.24     4.46     3.94     3.24     2.90     3.15
## 265      3.56     3.81     5.05     4.25     4.55     3.13     3.12     3.12
```

```
## 289      2.30     3.86     4.74     4.94     4.47     4.13     3.05     2.64
## 311      2.49     3.53     4.91     5.40     3.82     4.24     3.66     3.03
## 334      4.39     3.74     4.01     4.06     4.14     3.45     2.90     2.53
## 350      4.41     4.46     4.89     6.41     4.96     5.82     4.54     4.70
## 365      3.36     3.78     3.69     3.55     3.41     3.31     3.74     4.36
## 381      4.53     3.66     4.20     4.17     4.56     3.88     4.76     3.89
## 399      4.32     3.74     3.49     3.68     3.43     3.35     3.44     3.94
## 423      2.06     3.03     3.36     3.45     2.84     3.23     3.50     2.53
## 446      1.54     2.87     3.70     4.21     4.41     4.76     3.27     2.91
## 458      5.04     4.96     4.38     4.12     4.81     4.24     3.03     3.92
## 476      3.00     4.16     5.18     4.39     4.31     3.99     4.15     3.35
## 490      0.59     0.98     1.87     2.06     1.19     1.20     1.10     0.68
## 509      1.93     2.71     4.29     4.35     3.40     3.49     3.02     1.97
## 532      1.15     0.43     0.43     0.40     0.19     0.21     0.39     0.77
## 552      3.27     3.41     3.66     3.69     3.74     3.18     3.38     4.04
## 574      4.14     3.54     4.37     4.41     4.95     4.10     4.27     4.18
## 597      0.94     0.77     0.94     1.29     2.33     2.23     1.54     1.33
## 617      3.21     3.17     3.61     3.79     4.12     3.46     3.30     3.68
## 641      4.11     2.92     3.27     3.52     4.73     4.26     4.36     3.25
## 665      0.87     1.26     2.40     3.17     2.89     2.28     1.59     1.25
## 688      3.02     3.40     4.17     4.01     4.79     3.32     2.84     2.61
## 712      3.06     3.07     4.65     4.93     2.93     3.28     4.06     3.71
## 734      3.99     2.81     2.22     1.54     0.46     0.44     1.28     3.03
## 754      3.37     3.10     3.79     3.60     4.61     3.20     4.07     3.27
## 776      5.01     4.36     3.55     3.64     3.29     3.60     3.92     3.93
## 800      3.73     2.62     2.97     4.69     5.46     5.26     3.54     3.17
## 823      1.23     1.81     3.15     3.57     2.61     1.80     1.87     1.65
## 837      4.11     4.00     5.50     4.14     3.64     3.17     3.41     3.04
## 861      2.76     2.09     4.44     4.33     1.88     2.35     2.99     3.88
## 885      1.79     1.99     1.95     0.98     0.61     0.69     1.21     1.52
## 908      2.39     2.66     3.37     3.80     4.08     4.01     3.12     3.44
## 925      4.04     3.27     3.78     3.93     4.51     4.66     4.13     2.98
## 949      5.29     3.54     2.33     1.76     0.63     0.94     1.71     4.60
## 968      3.91     3.24     4.80     4.29     4.94     3.74     3.25     2.67
## 986      2.20     3.40     3.55     4.54     4.18     4.27     3.13     2.40
## 1007     1.05     1.78     2.34     2.34     2.19     1.95     1.48     0.93
##      rain.Nov rain.Dec snow.Jan snow.Feb snow.Mar snow.Apr snow.May snow.Jun
## 1        4.61     4.86      0.0      0.0      0.0      0.0      0.0        0
## 23       8.44     9.23     24.2     15.9      5.4      0.9      0.0        0
## 39       0.65     0.88      0.0      0.0      0.0      0.0      0.0        0
## 59       5.28     4.97      1.6      1.3      0.4      0.0      0.0        0
## 79       2.46     3.43      0.0      0.0      0.0      0.0      0.0        0
## 94       0.61     0.35      7.0      5.7     10.7      6.8      1.1        0
## 117      3.89     3.44     12.3     11.0      6.4      1.4      0.0        0
## 141      3.48     3.65      4.6      7.7      0.3      0.0      0.0        0
## 162      3.50     3.90      0.0      0.0      0.0      0.0      0.0        0
## 182      4.10     3.90      1.3      0.4      0.8      0.0      0.0        0
## 205      0.00     0.00      0.0      0.0      0.0      0.0      0.0        0
## 225      1.35     1.55      5.1      2.8      1.3      0.3      0.0        0
## 248      3.21     2.52      6.4      5.5      2.5      0.3      0.0        0
## 265      3.70     3.17      8.6      6.5      2.6      0.2      0.0        0
## 289      2.19     1.42      8.5      7.9      5.2      1.8      0.0        0
## 311      1.85     1.35      4.9      4.5      1.6      0.3      0.0        0
## 334      3.29     3.49      3.4      2.8      1.2      0.0      0.0        0
```

```
## 350     4.10     5.60     0.0     0.0     0.0     0.0     0.0      0
## 365     4.35     3.24    20.0    14.9    15.6     4.7     0.0      0
## 381     3.80     3.56     4.4     0.4     0.3     0.0     0.0      0
## 399     3.99     3.78    12.9    10.9     7.8     1.9     0.0      0
## 423     2.78     1.87    13.8    11.6     7.0     1.9     0.0      0
## 446     1.81     1.10     0.0     0.0     0.0     0.0     0.0      0
## 458     4.76     5.15     0.0     0.0     0.0     0.0     0.0      0
## 476     3.61     2.67     4.8     3.4     1.4     0.1     0.0      0
## 490     0.49     0.40     6.2     5.0     6.2     3.7     0.9      0
## 509     1.43     0.95     5.4     5.6     4.8     1.4     0.0      0
## 532     1.19     1.43     3.4     3.4     1.9     0.2     0.0      0
## 552     3.72     3.20    18.1    12.3    11.1     2.8     0.0      0
## 574     3.31     3.70     6.0     0.0     5.2     0.0     0.0      0
## 597     0.85     0.83     4.0     2.9     4.4     0.4     0.0      0
## 617     3.29     2.93    17.9    12.2    11.0     2.3     0.1      0
## 641     3.12     3.07     2.9     1.9     0.5     0.1     0.0      0
## 665     0.71     0.49     8.9     8.1     9.1     4.2     0.4      0
## 688     3.20     2.97     9.2     6.1     4.2     1.1     0.0      0
## 712     1.98     1.88     2.8     1.4     0.9     0.0     0.0      0
## 734     6.50     6.86     0.6     1.7     0.0     0.0     0.0      0
## 754     3.23     3.23     8.8    10.5     5.2     0.4     0.0      0
## 776     4.51     4.22     9.0     8.5     5.5     0.6     0.0      0
## 800     2.74     3.22     0.8     0.5     0.1     0.0     0.0      0
## 823     0.76     0.55     5.4     6.0     5.8     3.5     0.0      0
## 837     4.31     4.24     2.6     2.3     0.9     0.0     0.0      0
## 861     2.96     2.40     0.4     0.2     0.0     0.0     0.0      0
## 885     1.45     1.41    12.5    10.7     6.5     4.0     0.3      0
## 908     3.17     2.74    22.6    18.0    16.8     4.9     0.0      0
## 925     3.24     3.26     3.9     3.4     0.6     0.1     0.0      0
## 949     8.63     7.46     1.9     4.7     0.7     0.0     0.0      0
## 968     3.73     3.27    11.3     9.8     5.8     1.4     0.0      0
## 986     2.39     1.74    12.9    10.6     7.0     2.6     0.2      0
## 1007    0.59     0.49     5.9     7.9    11.3    10.2     2.3      0
##      snow.Jul snow.Aug snow.Sep snow.Oct snow.Nov snow.Dec
## 1           0      0.0      0.0      0.0      0.0      0.0
## 23          0      0.0      0.0      0.6      9.2     13.6
## 39          0      0.0      0.0      0.0      0.0      0.0
## 59          0      0.0      0.0      0.0      0.0      0.2
## 79          0      0.0      0.0      0.0      0.0      0.0
## 94          0      0.0      1.3      4.0      8.7      8.5
## 117         0      0.0      0.0      0.0      2.0      7.4
## 141         0      0.0      0.0      0.0      0.2      2.9
## 162         0      0.0      0.0      0.0      0.0      0.0
## 182         0      0.0      0.0      0.0      0.0      0.4
## 205         0      0.0      0.0      0.0      0.0      0.0
## 225         0      0.0      0.0      0.1      2.6      7.0
## 248         0      0.0      0.0      0.0      0.6      5.6
## 265         0      0.0      0.0      0.4      0.7      6.9
## 289         0      0.0      0.0      0.4      2.5      9.0
## 311         0      0.0      0.0      0.3      1.0      5.2
## 334         0      0.0      0.0      0.0      0.4      1.6
## 350         0      0.0      0.0      0.0      0.0      0.0
## 365         0      0.0      0.0      0.3      3.5     14.5
## 381         0      0.0      0.0      0.0      0.2      0.8
```

```
## 399          0      0.0      0.0      0.0      1.3      9.0
## 423          0      0.0      0.0      0.4      3.4     13.0
## 446          0      0.0      0.0      0.0      0.0      0.0
## 458          0      0.0      0.0      0.0      0.0      0.0
## 476          0      0.0      0.0      0.0      0.3      3.8
## 490          0      0.3      1.3      2.4      4.8      7.3
## 509          0      0.0      0.0      0.7      2.1      5.9
## 532          0      0.0      0.0      0.0      0.9      3.9
## 552          0      0.0      0.0      0.0      2.6     14.5
## 574          0      0.0      0.0      0.0      0.6      3.5
## 597          0      0.0      0.0      1.0      2.3      8.0
## 617          0      0.0      0.0      0.3      2.8     13.7
## 641          0      0.0      0.0      0.0      0.1      0.6
## 665          0      0.0      0.2      2.2      8.8      9.3
## 688          0      0.0      0.0      0.2      0.9      5.0
## 712          0      0.0      0.0      0.0      0.4      2.1
## 734          0      0.0      0.0      0.0      0.1      1.1
## 754          0      0.0      0.0      0.0      0.6      5.1
## 776          0      0.0      0.0      0.0      1.5      8.7
## 800          0      0.0      0.0      0.0      0.0      0.1
## 823          0      0.0      0.0      0.9      4.8      4.8
## 837          0      0.0      0.0      0.0      0.0      0.5
## 861          0      0.0      0.0      0.0      0.0      0.0
## 885          0      0.0      0.0      1.4      7.6     13.2
## 908          0      0.0      0.0      0.0      9.1     21.9
## 925          0      0.0      0.0      0.0      0.2      2.1
## 949          0      0.0      0.0      0.0      0.9      2.6
## 968          0      0.0      0.0      0.1      1.3      6.7
## 986          0      0.0      0.0      0.5      3.6     13.5
## 1007         0      0.0      1.3      5.0      8.0      8.4
```

```r
names(climate.df); # this helps you see the indexes ...
```

```
##  [1] "state"        "capital"      "st"           "labels"       "highmax.Jan"
##  [6] "highmax.Feb"  "highmax.Mar"  "highmax.Apr"  "highmax.May"  "highmax.Jun"
## [11] "highmax.Jul"  "highmax.Aug"  "highmax.Sep"  "highmax.Oct"  "highmax.Nov"
## [16] "highmax.Dec"  "highavg.Jan"  "highavg.Feb"  "highavg.Mar"  "highavg.Apr"
## [21] "highavg.May"  "highavg.Jun"  "highavg.Jul"  "highavg.Aug"  "highavg.Sep"
## [26] "highavg.Oct"  "highavg.Nov"  "highavg.Dec"  "lowavg.Jan"   "lowavg.Feb"
## [31] "lowavg.Mar"   "lowavg.Apr"   "lowavg.May"   "lowavg.Jun"   "lowavg.Jul"
## [36] "lowavg.Aug"   "lowavg.Sep"   "lowavg.Oct"   "lowavg.Nov"   "lowavg.Dec"
## [41] "lowmin.Jan"   "lowmin.Feb"   "lowmin.Mar"   "lowmin.Apr"   "lowmin.May"
## [46] "lowmin.Jun"   "lowmin.Jul"   "lowmin.Aug"   "lowmin.Sep"   "lowmin.Oct"
## [51] "lowmin.Nov"   "lowmin.Dec"   "rain.Jan"     "rain.Feb"     "rain.Mar"
## [56] "rain.Apr"     "rain.May"     "rain.Jun"     "rain.Jul"     "rain.Aug"
## [61] "rain.Sep"     "rain.Oct"     "rain.Nov"     "rain.Dec"     "snow.Jan"
## [66] "snow.Feb"     "snow.Mar"     "snow.Apr"     "snow.May"     "snow.Jun"
## [71] "snow.Jul"     "snow.Aug"     "snow.Sep"     "snow.Oct"     "snow.Nov"
## [76] "snow.Dec"
```

```r
##################### WHICH COLUMNS #####################
#########################################################
#X = climate.df[,5:52];  # temperature
```

```r
X = climate.df[,5:76];  # everything (includes rain)
#X = climate.df[,5:20];  # temperature, 1 month per season
#X = climate.df[,5:28];  # everything (includes rain), 1 month per season
##########################################################


  rownames(X) = climate.df$labels;
Xs = scale(X);
```

To scale or not to scale, that is the question

```r
X = climate.df[,5:76];  # everything ... you have to change months above to get this dataframe to be th
  rownames(X) = climate.df$labels;
Xs = scale(X);
```

So let's do some analysis with all of the data available to us. Most of the data is in Temperature, with ranges from -42 degrees Fahrenheit (Helena, Montana) to 122 (Phoenix, Arizona).

The precipitation data (rain and snow) is measured in inches. So should we scale the data. The answer in PCA and orthogonal projections is absolutely YES, but for `hclust` and `kmeans` is that always the case?

You can make a choice below, and observe how it influences your answers.

```r


whichX = X;
# whichX = Xs;
X
```

WHICH X

```
##                      highmax.Jan highmax.Feb highmax.Mar highmax.Apr highmax.May
## Montgomery, AL                83          86          90          94          99
## Juneau, AK                    60          57          61          72          80
## Phoenix, AZ                   88          92         100         105         114
## Little Rock, AR               83          87          91          95          98
## Sacramento, CA                79          80          90          98         107
## Denver, CO                    76          80          84          90          95
## Hartford, CT                  72          77          89          96          99
## Dover, DE                     77          80          88          97          98
## Tallahassee, FL               83          89          91          95         102
## Atlanta, GA                   79          80          89          93          97
## Honolulu, HI                  88          88          89          91          93
## Boise, ID                     63          71          82          92         100
## Springfield, IL               73          78          91          90         101
## Indianapolis, IN              71          77          85          90          96
## Des Moines, IA                67          78          91          93         105
## Topeka, KS                    78          84          93          97         103
## Frankfort, KY                 80          80          88          95          99
## Baton Rouge, LA               85          88          93          96         101
## Augusta, ME                   61          60          84          90          94
```

```
## Annapolis, MD                77          83          92          95          98
## Boston, MA                   74          73          89          94          97
## Lansing, MI                  66          69          86          88          96
## Saint Paul, MN               57          59          83          93          93
## Jackson, MS                  85          89          95          94         100
## Jefferson City, MO           79          89          97          96         102
## Helena, MT                   63          69          78          86          95
## Lincoln, NE                  73          83          91          97         104
## Carson City, NV              72          76          81          88          94
## Concord, NH                  72          74          89          95          98
## Trenton, NJ                  73          76          87          93          99
## Santa Fe, NM                 65          73          77          84          96
## Albany, NY                   71          74          89          93          97
## Raleigh, NC                  80          84          94          95          99
## Bismarck, ND                 63          73          81          93         102
## Columbus, OH                 74          78          85          90          96
## Oklahoma City, OK            83          92          97         100         104
## Salem, OR                    68          72          80          93         100
## Harrisburg, PA               73          79          87          93          97
## Providence, RI               70          72          90          98          96
## Columbia, SC                 84          84          93          96         101
## Pierre, SD                   68          75          88          98         105
## Nashville, TN                78          84          89          91          96
## Austin, TX                   90          99          98          99         104
## Salt Lake City, UT           63          69          80          89          99
## Montpelier, VT               66          61          82          90          90
## Richmond, VA                 81          83          94          96         100
## Olympia, WA                  64          73          79          88          96
## Charleston, WV               81          81          92          96          98
## Madison, WI                  58          68          83          94         101
## Cheyenne, WY                 70          71          77          84          91
##                    highmax.Jun highmax.Jul highmax.Aug highmax.Sep highmax.Oct
## Montgomery, AL              106         107         106         106         102
## Juneau, AK                   87          89          87          85          68
## Phoenix, AZ                 122         121         117         116         107
## Little Rock, AR             107         112         114         106          98
## Sacramento, CA              112         114         112         109         102
## Denver, CO                  105         105         105         101          90
## Hartford, CT                100         103         102         101          91
## Dover, DE                   101         104         102          99          95
## Tallahassee, FL             105         104         103         102          95
## Atlanta, GA                 106         105         104         102          98
## Honolulu, HI                 92          94          95          95          94
## Boise, ID                   110         111         110         102          94
## Springfield, IL             104         112         108         102          93
## Indianapolis, IN            104         106         103         100          92
## Des Moines, IA              103         110         110         101          95
## Topeka, KS                  109         114         113         110          97
## Frankfort, KY               106         111         105         106          98
## Baton Rouge, LA             103         103         110         104          98
## Augusta, ME                  98          99         100          96          85
## Annapolis, MD               103         105         106          99          92
## Boston, MA                  100         104         102         102          90
## Lansing, MI                  99         103         102          99          90
```

```
## Saint Paul, MN               103         105         103          95          88
## Jackson, MS                  105         107         107         107          98
## Jefferson City, MO           105         112         111         107          96
## Helena, MT                   102         105         105          99          87
## Lincoln, NE                  108         115         110         106          98
## Carson City, NV              101         107         105         103          93
## Concord, NH                  101         102         101          98          92
## Trenton, NJ                  100         106         105         101          94
## Santa Fe, NM                  99         101          96          94          87
## Albany, NY                   100         104         102         100          91
## Raleigh, NC                  105         105         105         104         100
## Bismarck, ND                 111         114         109         105          95
## Columbus, OH                 102         106         103         100          94
## Oklahoma City, OK            107         110         113         108          97
## Salem, OR                    105         108         108         104          93
## Harrisburg, PA               100         107         104         102          97
## Providence, RI                98         102         104         100          88
## Columbia, SC                 109         107         107         106         101
## Pierre, SD                   112         117         114         108          98
## Nashville, TN                109         107         106         105          99
## Austin, TX                   109         109         112         112         100
## Salt Lake City, UT           105         107         106         100          89
## Montpelier, VT                95          97          97          92          84
## Richmond, VA                 104         105         107         103          99
## Olympia, WA                   98         104         104          98          90
## Charleston, WV               105         108         108         104          96
## Madison, WI                  101         107         102          99          90
## Cheyenne, WY                 100         100          98          95          85
##                    highmax.Nov highmax.Dec highavg.Jan highavg.Feb highavg.Mar
## Montgomery, AL                91          85        57.4        61.8        69.7
## Juneau, AK                    64          59        34.6        36.7        40.8
## Phoenix, AZ                   96          87        67.2        70.7        76.9
## Little Rock, AR               86          81        50.5        55.1        64.0
## Sacramento, CA                86          72        54.4        61.2        66.8
## Denver, CO                    81          79        44.0        46.2        54.4
## Hartford, CT                  83          76        34.5        38.5        47.7
## Dover, DE                     85          75        43.4        47.0        54.9
## Tallahassee, FL               89          84        63.5        67.5        73.8
## Atlanta, GA                   84          79        52.3        56.6        64.6
## Honolulu, HI                  93          89        80.1        80.2        81.2
## Boise, ID                     78          70        37.8        44.7        54.6
## Springfield, IL               83          74        34.8        39.9        52.1
## Indianapolis, IN              81          74        35.6        40.2        51.7
## Des Moines, IA                82          69        31.0        36.1        49.0
## Topeka, KS                    85          77        39.9        45.0        56.4
## Frankfort, KY                 84          78        41.5        46.0        55.8
## Baton Rouge, LA               89          88        62.3        65.7        72.7
## Augusta, ME                   74          67        27.6        31.8        40.4
## Annapolis, MD                 85          78        42.7        45.5        53.2
## Boston, MA                    83          76        35.8        38.7        45.4
## Lansing, MI                   79          70        30.1        33.3        44.1
## Saint Paul, MN                75          66        26.0        31.0        43.0
## Jackson, MS                   89          84        56.1        60.5        68.5
## Jefferson City, MO            87          79        39.9        45.3        55.8
```

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## Helena, MT                  75          64        33.3        38.6        48.2
## Lincoln, NE                 85          75        35.4        40.1        52.3
## Carson City, NV             79          75        45.2        49.9        56.7
## Concord, NH                 80          73        30.8        34.9        43.8
## Trenton, NJ                 83          76        39.0        42.2        50.9
## Santa Fe, NM                75          65        43.5        48.2        55.9
## Albany, NY                  82          72        30.6        34.6        44.4
## Raleigh, NC                 88          81        50.9        55.2        63.4
## Bismarck, ND                79          66        23.4        28.3        40.4
## Columbus, OH                80          76        36.5        40.6        51.1
## Oklahoma City, OK           87          86        49.7        54.6        63.4
## Salem, OR                   74          72        47.7        51.6        56.5
## Harrisburg, PA              84          75        37.0        40.7        50.4
## Providence, RI              81          77        37.4        40.3        47.8
## Columbia, SC                90          83        56.0        60.3        68.2
## Pierre, SD                  87          77        30.0        34.9        45.4
## Nashville, TN               88          79        46.9        51.8        61.0
## Austin, TX                  91          90        61.5        65.2        72.2
## Salt Lake City, UT          75          69        37.4        43.2        53.7
## Montpelier, VT              76          67        26.4        30.3        39.0
## Richmond, VA                86          81        47.4        51.3        60.0
## Olympia, WA                 74          64        45.9        49.3        53.9
## Charleston, WV              87          80        42.5        46.6        56.2
## Madison, WI                 77          65        26.4        31.1        43.1
## Cheyenne, WY                75          69        39.5        40.5        47.5
##                    highavg.Apr highavg.May highavg.Jun highavg.Jul highavg.Aug
## Montgomery, AL            76.6        84.0        89.8        92.1        91.9
## Juneau, AK                49.1        56.9        62.4        63.4        62.6
## Phoenix, AZ               85.2        94.8       103.9       106.1       104.4
## Little Rock, AR           73.1        81.1        88.9        92.5        92.6
## Sacramento, CA            72.7        80.9        87.9        93.3        92.2
## Denver, CO                61.5        71.5        82.4        89.4        87.2
## Hartford, CT              60.5        71.2        79.6        84.5        82.7
## Dover, DE                 65.7        74.7        83.2        87.0        85.2
## Tallahassee, FL           79.9        87.0        91.0        92.1        91.5
## Atlanta, GA               72.5        79.9        86.4        89.1        88.1
## Honolulu, HI              82.7        84.6        87.0        87.9        88.7
## Boise, ID                 62.3        71.6        81.3        91.2        89.7
## Springfield, IL           64.6        74.8        83.1        86.2        84.9
## Indianapolis, IN          63.4        72.8        81.9        85.0        84.0
## Des Moines, IA            62.3        72.4        81.6        85.7        83.8
## Topeka, KS                66.7        75.9        84.7        89.5        88.6
## Frankfort, KY             66.5        75.2        83.6        87.3        86.7
## Baton Rouge, LA           79.3        86.2        90.9        92.2        92.5
## Augusta, ME               53.1        65.2        73.8        79.2        78.0
## Annapolis, MD             63.9        72.9        81.6        85.8        84.0
## Boston, MA                55.6        66.0        75.9        81.4        79.6
## Lansing, MI               57.8        68.8        78.4        82.4        80.1
## Saint Paul, MN            58.0        71.0        80.0        85.0        82.0
## Jackson, MS               75.9        83.1        89.5        91.6        91.6
## Jefferson City, MO        66.7        75.1        83.5        88.3        87.8
## Helena, MT                57.8        67.1        75.7        85.7        84.5
## Lincoln, NE               64.3        74.2        84.2        89.0        86.8
## Carson City, NV           62.7        71.4        81.1        89.6        88.0
```

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## Concord, NH                57.4        68.9        77.4        82.3        80.9
## Trenton, NJ                61.4        71.8        80.8        85.3        83.6
## Santa Fe, NM               64.7        74.2        83.5        85.9        83.4
## Albany, NY                 58.3        69.4        77.9        82.3        80.4
## Raleigh, NC                72.4        79.6        87.1        90.2        88.4
## Bismarck, ND               57.0        68.4        77.2        84.7        83.5
## Columbus, OH               63.5        72.9        81.6        84.9        83.7
## Oklahoma City, OK          72.3        80.2        88.1        93.9        93.4
## Salem, OR                  61.1        67.8        73.9        82.0        82.4
## Harrisburg, PA             62.4        72.1        81.0        85.5        83.4
## Providence, RI             58.6        68.4        77.5        82.8        81.4
## Columbia, SC               76.3        83.8        90.0        92.7        90.7
## Pierre, SD                 59.7        70.2        80.0        88.8        87.3
## Nashville, TN              70.5        78.2        86.0        89.3        89.0
## Austin, TX                 79.8        86.5        92.1        95.6        97.0
## Salt Lake City, UT         61.6        71.9        83.0        92.6        90.5
## Montpelier, VT             53.3        65.7        74.3        78.5        76.7
## Richmond, VA               70.3        77.9        86.1        89.7        87.6
## Olympia, WA                58.9        65.3        70.6        76.8        77.7
## Charleston, WV             67.7        74.8        82.2        85.2        84.2
## Madison, WI                57.3        68.4        77.9        81.6        79.4
## Cheyenne, WY               54.9        64.7        75.3        83.4        81.2
##                     highavg.Sep highavg.Oct highavg.Nov highavg.Dec lowavg.Jan
## Montgomery, AL             87.3        78.3        69.0        59.6       35.7
## Juneau, AK                 56.6        48.4        39.8        36.7       26.2
## Phoenix, AZ                99.8        88.5        75.5        66.0       45.6
## Little Rock, AR            85.6        74.8        63.0        52.3       31.2
## Sacramento, CA             87.9        77.9        63.7        54.3       40.7
## Denver, CO                 78.5        65.3        52.1        42.8       17.4
## Hartford, CT               74.9        63.1        51.6        39.7       17.7
## Dover, DE                  79.3        68.8        58.5        47.4       27.1
## Tallahassee, FL            88.4        81.4        73.0        65.3       39.0
## Atlanta, GA                82.2        72.7        63.6        54.0       34.3
## Honolulu, HI               88.6        86.7        83.9        81.2       66.3
## Boise, ID                  78.8        64.8        48.2        37.5       24.7
## Springfield, IL            78.9        66.4        52.3        38.3       18.7
## Indianapolis, IN           77.6        65.3        52.2        38.9       20.5
## Des Moines, IA             76.1        63.1        47.9        34.0       14.3
## Topeka, KS                 80.4        68.4        54.6        41.7       19.6
## Frankfort, KY              80.4        69.5        57.3        45.0       21.9
## Baton Rouge, LA            88.7        80.8        71.9        64.1       41.2
## Augusta, ME                69.6        57.2        45.2        33.5       11.0
## Annapolis, MD              76.9        66.3        56.9        46.8       29.1
## Boston, MA                 72.4        61.4        51.5        41.2       22.2
## Lansing, MI                72.7        59.9        46.7        34.3       16.8
## Saint Paul, MN             73.0        59.0        42.0        29.0        7.0
## Jackson, MS                86.7        77.2        67.4        58.2       35.3
## Jefferson City, MO         79.7        68.5        55.8        42.6       20.9
## Helena, MT                 72.6        58.7        43.1        31.7       13.0
## Lincoln, NE                78.7        65.8        50.3        37.2       13.8
## Carson City, NV            80.4        67.9        54.4        45.0       21.7
## Concord, NH                72.6        60.5        48.4        36.3       10.4
## Trenton, NJ                76.1        65.0        54.5        43.1       23.2
## Santa Fe, NM               77.7        66.5        53.1        43.2       17.5
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## Albany, NY                72.2        59.8        47.9        35.8        14.5
## Raleigh, NC               82.1        72.6        63.6        53.6        31.0
## Bismarck, ND              72.1        57.5        39.6        26.2         2.2
## Columbus, OH              77.0        65.1        52.6        40.1        22.6
## Oklahoma City, OK         84.7        73.4        61.5        50.6        28.8
## Salem, OR                 76.8        64.1        52.6        46.2        34.7
## Harrisburg, PA            75.6        64.1        53.1        41.3        22.8
## Providence, RI            74.2        63.3        53.2        42.3        21.0
## Columbia, SC              85.2        76.1        67.3        58.2        33.7
## Pierre, SD                76.5        61.0        44.1        31.3         9.8
## Nashville, TN             82.4        71.7        60.3        49.5        28.4
## Austin, TX                90.5        81.8        71.4        62.7        41.5
## Salt Lake City, UT        79.2        64.7        49.4        38.0        21.6
## Montpelier, VT            68.7        56.0        43.8        31.6         7.0
## Richmond, VA              81.2        71.0        61.4        50.7        28.3
## Olympia, WA               71.8        60.2        50.2        44.2        33.7
## Charleston, WV            77.8        67.7        57.0        45.6        26.3
## Madison, WI               71.8        58.9        44.1        30.2        11.1
## Cheyenne, WY              71.8        58.8        46.5        38.2        18.0
##                    lowavg.Feb lowavg.Mar lowavg.Apr lowavg.May lowavg.Jun
## Montgomery, AL           39.2       45.3       51.6       60.7       68.1
## Juneau, AK               27.6       30.1       35.3       42.3       48.4
## Phoenix, AZ              48.7       53.5       60.2       69.4       77.7
## Little Rock, AR          34.5       42.7       51.0       61.1       69.4
## Sacramento, CA           43.7       46.5       49.0       53.9       58.4
## Denver, CO               18.9       26.4       33.3       42.7       52.3
## Hartford, CT             20.9       27.9       38.4       47.7       57.3
## Dover, DE                29.0       35.6       44.3       53.8       63.4
## Tallahassee, FL          41.9       47.1       52.3       61.6       69.5
## Atlanta, GA              37.7       44.1       51.5       60.3       68.2
## Honolulu, HI             66.1       67.7       69.4       70.9       73.4
## Boise, ID                28.3       34.4       39.3       46.5       53.7
## Springfield, IL          22.6       32.2       42.4       52.6       61.9
## Indianapolis, IN         23.9       32.8       42.7       52.6       62.1
## Des Moines, IA           18.8       29.7       41.1       52.2       62.0
## Topeka, KS               23.8       33.3       43.5       54.2       63.7
## Frankfort, KY            24.7       31.2       40.5       50.1       59.5
## Baton Rouge, LA          44.5       50.3       56.8       65.2       71.4
## Augusta, ME              14.5       23.4       34.6       44.6       54.2
## Annapolis, MD            30.7       36.9       45.8       55.6       66.4
## Boston, MA               24.7       31.1       40.6       49.9       59.5
## Lansing, MI              18.5       26.0       37.0       46.7       56.7
## Saint Paul, MN           12.0       24.0       38.0       50.0       59.0
## Jackson, MS              38.5       45.3       52.2       61.6       68.6
## Jefferson City, MO       24.6       33.3       43.8       53.8       63.7
## Helena, MT               16.9       24.3       32.1       40.8       48.5
## Lincoln, NE              18.0       27.9       38.8       50.5       60.9
## Carson City, NV          25.3       29.9       33.9       40.8       47.1
## Concord, NH              13.8       22.5       32.7       42.6       52.5
## Trenton, NJ              25.8       31.9       41.0       50.5       60.3
## Santa Fe, NM             21.5       26.1       32.3       41.0       49.4
## Albany, NY               17.3       25.7       37.3       47.1       56.5
## Raleigh, NC              33.8       39.9       48.0       56.5       65.8
## Bismarck, ND              7.9       19.4       30.7       42.7       52.0
```

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## Columbus, OH            25.0       32.7       42.6       52.2       61.5
## Oklahoma City, OK       32.8       41.0       49.7       59.6       67.8
## Salem, OR               34.6       37.2       39.6       41.7       49.3
## Harrisburg, PA          25.1       33.0       41.9       52.1       62.0
## Providence, RI          23.6       30.0       39.6       48.6       58.4
## Columbia, SC            36.8       43.0       50.4       59.5       68.2
## Pierre, SD              13.8       23.5       34.2       45.7       55.4
## Nashville, TN           31.6       39.0       47.5       56.8       65.4
## Austin, TX              44.8       51.3       58.6       66.7       72.3
## Salt Lake City, UT      25.2       33.6       39.5       47.8       56.4
## Montpelier, VT           9.5       18.9       31.5       41.9       51.2
## Richmond, VA            30.5       37.1       46.1       55.0       64.5
## Olympia, WA             32.8       35.1       37.7       43.1       47.6
## Charleston, WV          28.7       35.4       44.5       52.7       61.6
## Madison, WI             15.1       24.8       35.8       46.1       56.1
## Cheyenne, WY            18.6       24.4       30.8       40.2       48.9
##                   lowavg.Jul lowavg.Aug lowavg.Sep lowavg.Oct lowavg.Nov
## Montgomery, AL          71.5       71.0       65.2       53.5       43.9
## Juneau, AK              51.4       50.2       45.8       39.0       31.4
## Phoenix, AZ             83.5       82.7       76.9       64.8       52.7
## Little Rock, AR         73.2       72.4       64.5       52.6       42.2
## Sacramento, CA          60.9       60.5       58.4       52.8       45.5
## Denver, CO              58.9       57.9       48.3       36.6       24.5
## Hartford, CT            62.7       61.1       52.7       41.1       33.2
## Dover, DE               68.4       67.0       60.1       48.7       39.8
## Tallahassee, FL         72.0       72.1       68.1       57.3       47.5
## Atlanta, GA             71.3       70.7       64.8       54.0       44.5
## Honolulu, HI            74.5       75.1       74.4       73.4       71.4
## Boise, ID               60.4       59.6       51.0       40.9       31.9
## Springfield, IL         65.4       63.6       54.6       43.8       33.9
## Indianapolis, IN        65.8       64.4       56.2       44.7       35.1
## Des Moines, IA          66.8       64.8       55.2       43.0       30.5
## Topeka, KS              68.4       66.2       56.3       44.7       33.0
## Frankfort, KY           63.8       62.5       54.6       43.0       34.0
## Baton Rouge, LA         73.7       73.4       68.5       57.9       48.9
## Augusta, ME             59.9       58.5       50.5       39.6       30.6
## Annapolis, MD           71.2       69.1       62.8       50.5       41.8
## Boston, MA              65.4       64.6       57.4       46.5       38.0
## Lansing, MI             60.6       59.4       51.2       40.7       32.4
## Saint Paul, MN          64.0       62.0       53.0       41.0       27.0
## Jackson, MS             71.6       70.9       64.6       53.1       44.0
## Jefferson City, MO      68.1       66.3       57.0       44.9       34.9
## Helena, MT              54.3       52.2       43.1       32.5       22.0
## Lincoln, NE             66.1       63.8       53.4       40.6       27.6
## Carson City, NV         52.2       50.6       43.4       34.6       27.1
## Concord, NH             57.7       56.1       47.4       35.8       28.2
## Trenton, NJ             66.0       64.2       56.4       44.2       36.9
## Santa Fe, NM            54.4       53.3       46.5       35.5       24.6
## Albany, NY              61.4       59.9       51.6       39.6       31.5
## Raleigh, NC             69.9       68.6       61.7       49.8       40.8
## Bismarck, ND            57.4       55.5       44.9       32.2       18.8
## Columbus, OH            65.5       64.1       56.5       45.0       36.1
## Oklahoma City, OK       72.2       71.3       63.2       51.6       40.0
## Salem, OR               53.1       52.8       48.4       42.3       38.4
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## Harrisburg, PA             66.3       64.5       56.2       44.6       35.1
## Providence, RI             64.2       63.2       55.3       43.9       35.7
## Columbia, SC               71.6       71.0       64.2       52.1       42.3
## Pierre, SD                 61.9       60.1       49.2       36.4       23.3
## Nashville, TN              69.5       68.4       60.7       48.9       39.4
## Austin, TX                 74.4       74.6       69.4       60.6       50.6
## Salt Lake City, UT         64.7       63.4       53.0       41.3       30.6
## Montpelier, VT             55.7       53.8       46.1       35.3       26.9
## Richmond, VA               68.9       67.4       60.1       48.3       39.4
## Olympia, WA                50.8       50.5       46.0       40.5       36.4
## Charleston, WV             65.7       64.5       56.9       45.4       36.9
## Madison, WI                61.0       59.0       50.2       38.8       28.2
## Cheyenne, WY               55.5       54.1       44.7       33.9       24.2
##                      lowavg.Dec lowmin.Jan lowmin.Feb lowmin.Mar lowmin.Apr
## Montgomery, AL             37.4          0         -5         17         28
## Juneau, AK                 27.8        -20        -15         -5         12
## Phoenix, AZ                44.8         16         24         25         35
## Little Rock, AR            33.7         -8        -12         11         28
## Sacramento, CA             40.4         19         21         29         34
## Denver, CO                 17.1        -29        -25        -11         -2
## Hartford, CT               23.4        -26        -24         -6          9
## Dover, DE                  31.0         -7        -11          7         14
## Tallahassee, FL            41.1          6         -2         20         29
## Atlanta, GA                36.5         -8         -9         10         25
## Honolulu, HI               68.3         52         52         53         56
## Boise, ID                  24.0        -28        -15          5         11
## Springfield, IL            22.5        -22        -24        -12         16
## Indianapolis, IN           24.4        -27        -21         -7         18
## Des Moines, IA             18.0        -30        -26        -22          9
## Topeka, KS                 22.3        -23        -25         -7         10
## Frankfort, KY              25.9        -27        -16         -3         16
## Baton Rouge, LA            42.7          9          2         20         31
## Augusta, ME                18.6        -33        -23        -11          9
## Annapolis, MD              31.9         -8         -6         10         13
## Boston, MA                 28.2        -13        -18         -8         11
## Lansing, MI                22.3        -29        -37        -25         -6
## Saint Paul, MN             13.0        -29        -32        -25          3
## Jackson, MS                37.3         -5          1         15         27
## Jefferson City, MO         24.0        -23        -25        -16         13
## Helena, MT                 11.9        -42        -42        -30        -10
## Lincoln, NE                16.4        -33        -26        -19          3
## Carson City, NV            21.9        -27        -22         -5          3
## Concord, NH                17.2        -35        -37        -20          4
## Trenton, NJ                27.6        -13        -14          1         11
## Santa Fe, NM               17.4        -14        -24         -6         10
## Albany, NY                 21.2        -28        -22        -21          9
## Raleigh, NC                33.3         -9         -2         11         23
## Bismarck, ND                6.1        -45        -45        -36        -12
## Columbus, OH               26.8        -22        -20         -6         14
## Oklahoma City, OK          30.6        -11        -17          1         20
## Salem, OR                  34.0        -10         -4         12         23
## Harrisburg, PA             26.6        -22        -13         -1         11
## Providence, RI             26.3        -13        -17          1         11
## Columbia, SC               35.3         -1         -2          4         26
```

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## Pierre, SD               12.1        -33        -35        -19          1
## Nashville, TN            31.3        -17        -13          2         23
## Austin, TX               42.3         -2         -1         18         30
## Salt Lake City, UT       22.6        -22        -30          0         14
## Montpelier, VT           14.4        -34        -29        -18          2
## Richmond, VA             31.4        -12        -10         10         19
## Olympia, WA              32.6         -8         -1          9         23
## Charleston, WV           29.2        -16        -12         -5         18
## Madison, WI              15.9        -37        -29        -29          0
## Cheyenne, WY             17.3        -38        -34        -21         -8
##                    lowmin.May lowmin.Jun lowmin.Jul lowmin.Aug lowmin.Sep
## Montgomery, AL             40         48         59         56         39
## Juneau, AK                 26         32         39         32         28
## Phoenix, AZ                39         49         63         58         47
## Little Rock, AR            38         46         54         52         37
## Sacramento, CA             37         43         47         48         44
## Denver, CO                 19         30         42         40         17
## Hartford, CT               28         37         44         36         30
## Dover, DE                  28         41         45         35         30
## Tallahassee, FL            34         46         57         57         40
## Atlanta, GA                37         39         53         55         36
## Honolulu, HI               60         63         63         63         65
## Boise, ID                  22         30         35         32         23
## Springfield, IL            28         39         48         43         31
## Indianapolis, IN           27         37         46         41         30
## Des Moines, IA             26         37         47         40         26
## Topeka, KS                 26         36         43         40         29
## Frankfort, KY              27         36         48         41         30
## Baton Rouge, LA            40         53         58         58         43
## Augusta, ME                26         36         43         39         28
## Annapolis, MD              32         35         50         46         37
## Boston, MA                 31         41         50         46         34
## Lansing, MI                19         27         31         26         19
## Saint Paul, MN             21         36         45         42         26
## Jackson, MS                36         47         51         54         35
## Jefferson City, MO         24         38         42         41         29
## Helena, MT                 17         30         36         28          6
## Lincoln, NE                24         39         45         39         26
## Carson City, NV            18         25         33         26         17
## Concord, NH                21         30         35         29         20
## Trenton, NJ                33         41         48         41         31
## Santa Fe, NM               19         28         37         36         26
## Albany, NY                 26         35         40         34         24
## Raleigh, NC                29         38         48         46         37
## Bismarck, ND               13         30         32         32         10
## Columbus, OH               25         35         43         39         31
## Oklahoma City, OK          32         46         53         49         35
## Salem, OR                  25         32         35         30         26
## Harrisburg, PA             30         40         49         45         30
## Providence, RI             29         39         48         40         32
## Columbia, SC               34         44         54         53         40
## Pierre, SD                 21         34         42         39         21
## Nashville, TN              34         42         51         47         36
## Austin, TX                 40         51         57         58         41
```

```
## Salt Lake City, UT         25          32          40          37         27
## Montpelier, VT             20          29          35          31         20
## Richmond, VA               31          40          51          46         35
## Olympia, WA                25          30          35          33         25
## Charleston, WV             26          33          46          41         32
## Madison, WI                19          31          36          35         25
## Cheyenne, WY                8          25          33          25          8
##                    lowmin.Oct lowmin.Nov lowmin.Dec rain.Jan rain.Feb rain.Mar
## Montgomery, AL             26          13           5     4.65     5.28     5.95
## Juneau, AK                 13          -7         -10     7.98     6.71     6.29
## Phoenix, AZ                34          27          22     0.91     0.92     0.99
## Little Rock, AR            27          10          -1     3.55     3.66     4.68
## Sacramento, CA             34          27          17     3.63     3.90     2.86
## Denver, CO                 -2         -18         -25     0.41     0.37     0.92
## Hartford, CT               17           1         -18     3.23     2.89     3.62
## Dover, DE                  25          11          -3     3.41     3.07     4.31
## Tallahassee, FL            29          13          10     4.34     4.85     5.94
## Atlanta, GA                28           3           0     4.20     4.67     4.81
## Honolulu, HI               61          57          54     0.00     0.00     0.00
## Boise, ID                  11         -10         -25     1.24     0.99     1.39
## Springfield, IL            13          -3         -21     1.82     1.81     2.63
## Indianapolis, IN           20          -5         -23     2.66     2.32     3.56
## Des Moines, IA              7         -10         -22     1.00     1.28     2.30
## Topeka, KS                 16          -5         -26     0.86     1.32     2.49
## Frankfort, KY              20          -1         -17     3.70     3.07     4.39
## Baton Rouge, LA            30          21           8     5.72     5.04     4.41
## Augusta, ME                21           4         -15     2.61     2.43     3.36
## Annapolis, MD              26          13          -1     3.32     2.94     4.53
## Boston, MA                 25          -2         -17     3.36     3.25     4.32
## Lansing, MI                10          -5         -25     1.65     1.47     2.06
## Saint Paul, MN             15         -14         -29     0.79     0.67     1.54
## Jackson, MS                26          15           4     4.97     4.76     5.04
## Jefferson City, MO         14           1         -21     1.93     2.29     3.00
## Helena, MT                 -8         -39         -40     0.36     0.30     0.59
## Lincoln, NE                 3         -15         -27     0.64     0.77     1.93
## Carson City, NV             6          -5         -26     1.59     1.50     1.15
## Concord, NH                10         -17         -24     2.70     2.62     3.27
## Trenton, NJ                22          12          -7     3.16     2.31     4.14
## Santa Fe, NM                5         -12         -17     0.60     0.53     0.94
## Albany, NY                 16         -11         -22     2.59     2.20     3.21
## Raleigh, NC                19          11           0     3.50     3.23     4.11
## Bismarck, ND              -10         -30         -43     0.43     0.51     0.87
## Columbus, OH               17          -5         -17     2.73     2.25     3.02
## Oklahoma City, OK          16           9          -8     1.39     1.58     3.06
## Salem, OR                  19           9         -12     5.96     4.56     3.99
## Harrisburg, PA             23          10          -8     2.88     2.39     3.37
## Providence, RI             20           6         -12     3.86     3.29     5.01
## Columbia, SC               23          12           4     3.58     3.61     3.73
## Pierre, SD                  4         -18         -31     0.42     0.59     1.23
## Nashville, TN              26          -1         -10     3.75     3.94     4.11
## Austin, TX                 30          20           4     2.22     2.02     2.76
## Salt Lake City, UT         14         -14         -21     1.25     1.25     1.79
## Montpelier, VT             14          -7         -27     2.45     2.04     2.39
## Richmond, VA               21          10          -2     3.04     2.76     4.04
```

```
## Olympia, WA               14          -1          -7     7.84     5.27     5.29
## Charleston, WV            17           6         -17     3.00     3.19     3.91
## Madison, WI               12         -14         -28     1.23     1.45     2.20
## Cheyenne, WY              -5         -21         -28     0.33     0.47     1.05
##                     rain.Apr rain.May rain.Jun rain.Jul rain.Aug rain.Sep
## Montgomery, AL          4.02     3.54     4.07     5.24     3.96     3.97
## Juneau, AK              4.64     4.96     4.42     5.44     8.16    12.72
## Phoenix, AZ             0.28     0.11     0.02     1.05     1.00     0.64
## Little Rock, AR         5.14     4.87     3.65     3.27     2.59     3.18
## Sacramento, CA          1.36     0.75     0.21     0.02     0.04     0.35
## Denver, CO              1.71     2.12     1.98     2.16     1.69     0.96
## Hartford, CT            3.72     4.35     4.35     4.18     3.93     3.88
## Dover, DE               3.88     4.25     4.00     4.09     4.36     4.13
## Tallahassee, FL         3.06     3.47     7.73     7.17     7.35     4.69
## Atlanta, GA             3.36     3.67     3.95     5.27     3.90     4.47
## Honolulu, HI            0.00     0.00     0.00     0.00     0.00     0.00
## Boise, ID               1.23     1.39     0.69     0.33     0.24     0.58
## Springfield, IL         3.51     4.24     4.46     3.94     3.24     2.90
## Indianapolis, IN        3.81     5.05     4.25     4.55     3.13     3.12
## Des Moines, IA          3.86     4.74     4.94     4.47     4.13     3.05
## Topeka, KS              3.53     4.91     5.40     3.82     4.24     3.66
## Frankfort, KY           3.74     4.01     4.06     4.14     3.45     2.90
## Baton Rouge, LA         4.46     4.89     6.41     4.96     5.82     4.54
## Augusta, ME             3.78     3.69     3.55     3.41     3.31     3.74
## Annapolis, MD           3.66     4.20     4.17     4.56     3.88     4.76
## Boston, MA              3.74     3.49     3.68     3.43     3.35     3.44
## Lansing, MI             3.03     3.36     3.45     2.84     3.23     3.50
## Saint Paul, MN          2.87     3.70     4.21     4.41     4.76     3.27
## Jackson, MS             4.96     4.38     4.12     4.81     4.24     3.03
## Jefferson City, MO      4.16     5.18     4.39     4.31     3.99     4.15
## Helena, MT              0.98     1.87     2.06     1.19     1.20     1.10
## Lincoln, NE             2.71     4.29     4.35     3.40     3.49     3.02
## Carson City, NV         0.43     0.43     0.40     0.19     0.21     0.39
## Concord, NH             3.41     3.66     3.69     3.74     3.18     3.38
## Trenton, NJ             3.54     4.37     4.41     4.95     4.10     4.27
## Santa Fe, NM            0.77     0.94     1.29     2.33     2.23     1.54
## Albany, NY              3.17     3.61     3.79     4.12     3.46     3.30
## Raleigh, NC             2.92     3.27     3.52     4.73     4.26     4.36
## Bismarck, ND            1.26     2.40     3.17     2.89     2.28     1.59
## Columbus, OH            3.40     4.17     4.01     4.79     3.32     2.84
## Oklahoma City, OK       3.07     4.65     4.93     2.93     3.28     4.06
## Salem, OR               2.81     2.22     1.54     0.46     0.44     1.28
## Harrisburg, PA          3.10     3.79     3.60     4.61     3.20     4.07
## Providence, RI          4.36     3.55     3.64     3.29     3.60     3.92
## Columbia, SC            2.62     2.97     4.69     5.46     5.26     3.54
## Pierre, SD              1.81     3.15     3.57     2.61     1.80     1.87
## Nashville, TN           4.00     5.50     4.14     3.64     3.17     3.41
## Austin, TX              2.09     4.44     4.33     1.88     2.35     2.99
## Salt Lake City, UT      1.99     1.95     0.98     0.61     0.69     1.21
## Montpelier, VT          2.66     3.37     3.80     4.08     4.01     3.12
## Richmond, VA            3.27     3.78     3.93     4.51     4.66     4.13
## Olympia, WA             3.54     2.33     1.76     0.63     0.94     1.71
## Charleston, WV          3.24     4.80     4.29     4.94     3.74     3.25
## Madison, WI             3.40     3.55     4.54     4.18     4.27     3.13
```

```
## Cheyenne, WY          1.78     2.34     2.34     2.19     1.95     1.48
##                   rain.Oct rain.Nov rain.Dec snow.Jan snow.Feb snow.Mar
## Montgomery, AL        2.92     4.61     4.86      0.0      0.0      0.0
## Juneau, AK           13.23     8.44     9.23     24.2     15.9      5.4
## Phoenix, AZ           0.58     0.65     0.88      0.0      0.0      0.0
## Little Rock, AR       4.91     5.28     4.97      1.6      1.3      0.4
## Sacramento, CA        1.06     2.46     3.43      0.0      0.0      0.0
## Denver, CO            1.02     0.61     0.35      7.0      5.7     10.7
## Hartford, CT          4.37     3.89     3.44     12.3     11.0      6.4
## Dover, DE             3.42     3.48     3.65      4.6      7.7      0.3
## Tallahassee, FL       3.23     3.50     3.90      0.0      0.0      0.0
## Atlanta, GA           3.41     4.10     3.90      1.3      0.4      0.8
## Honolulu, HI          0.00     0.00     0.00      0.0      0.0      0.0
## Boise, ID             0.75     1.35     1.55      5.1      2.8      1.3
## Springfield, IL       3.15     3.21     2.52      6.4      5.5      2.5
## Indianapolis, IN      3.12     3.70     3.17      8.6      6.5      2.6
## Des Moines, IA        2.64     2.19     1.42      8.5      7.9      5.2
## Topeka, KS            3.03     1.85     1.35      4.9      4.5      1.6
## Frankfort, KY         2.53     3.29     3.49      3.4      2.8      1.2
## Baton Rouge, LA       4.70     4.10     5.60      0.0      0.0      0.0
## Augusta, ME           4.36     4.35     3.24     20.0     14.9     15.6
## Annapolis, MD         3.89     3.80     3.56      4.4      0.4      0.3
## Boston, MA            3.94     3.99     3.78     12.9     10.9      7.8
## Lansing, MI           2.53     2.78     1.87     13.8     11.6      7.0
## Saint Paul, MN        2.91     1.81     1.10      0.0      0.0      0.0
## Jackson, MS           3.92     4.76     5.15      0.0      0.0      0.0
## Jefferson City, MO    3.35     3.61     2.67      4.8      3.4      1.4
## Helena, MT            0.68     0.49     0.40      6.2      5.0      6.2
## Lincoln, NE           1.97     1.43     0.95      5.4      5.6      4.8
## Carson City, NV       0.77     1.19     1.43      3.4      3.4      1.9
## Concord, NH           4.04     3.72     3.20     18.1     12.3     11.1
## Trenton, NJ           4.18     3.31     3.70      6.0      0.0      5.2
## Santa Fe, NM          1.33     0.85     0.83      4.0      2.9      4.4
## Albany, NY            3.68     3.29     2.93     17.9     12.2     11.0
## Raleigh, NC           3.25     3.12     3.07      2.9      1.9      0.5
## Bismarck, ND          1.25     0.71     0.49      8.9      8.1      9.1
## Columbus, OH          2.61     3.20     2.97      9.2      6.1      4.2
## Oklahoma City, OK     3.71     1.98     1.88      2.8      1.4      0.9
## Salem, OR             3.03     6.50     6.86      0.6      1.7      0.0
## Harrisburg, PA        3.27     3.23     3.23      8.8     10.5      5.2
## Providence, RI        3.93     4.51     4.22      9.0      8.5      5.5
## Columbia, SC          3.17     2.74     3.22      0.8      0.5      0.1
## Pierre, SD            1.65     0.76     0.55      5.4      6.0      5.8
## Nashville, TN         3.04     4.31     4.24      2.6      2.3      0.9
## Austin, TX            3.88     2.96     2.40      0.4      0.2      0.0
## Salt Lake City, UT    1.52     1.45     1.41     12.5     10.7      6.5
## Montpelier, VT        3.44     3.17     2.74     22.6     18.0     16.8
## Richmond, VA          2.98     3.24     3.26      3.9      3.4      0.6
## Olympia, WA           4.60     8.63     7.46      1.9      4.7      0.7
## Charleston, WV        2.67     3.73     3.27     11.3      9.8      5.8
## Madison, WI           2.40     2.39     1.74     12.9     10.6      7.0
## Cheyenne, WY          0.93     0.59     0.49      5.9      7.9     11.3
##                   snow.Apr snow.May snow.Jun snow.Jul snow.Aug snow.Sep
## Montgomery, AL         0.0      0.0        0        0      0.0      0.0
```

```
## Juneau, AK               0.9      0.0        0        0      0.0      0.0
## Phoenix, AZ              0.0      0.0        0        0      0.0      0.0
## Little Rock, AR          0.0      0.0        0        0      0.0      0.0
## Sacramento, CA           0.0      0.0        0        0      0.0      0.0
## Denver, CO               6.8      1.1        0        0      0.0      1.3
## Hartford, CT             1.4      0.0        0        0      0.0      0.0
## Dover, DE                0.0      0.0        0        0      0.0      0.0
## Tallahassee, FL          0.0      0.0        0        0      0.0      0.0
## Atlanta, GA              0.0      0.0        0        0      0.0      0.0
## Honolulu, HI             0.0      0.0        0        0      0.0      0.0
## Boise, ID                0.3      0.0        0        0      0.0      0.0
## Springfield, IL          0.3      0.0        0        0      0.0      0.0
## Indianapolis, IN         0.2      0.0        0        0      0.0      0.0
## Des Moines, IA           1.8      0.0        0        0      0.0      0.0
## Topeka, KS               0.3      0.0        0        0      0.0      0.0
## Frankfort, KY            0.0      0.0        0        0      0.0      0.0
## Baton Rouge, LA          0.0      0.0        0        0      0.0      0.0
## Augusta, ME              4.7      0.0        0        0      0.0      0.0
## Annapolis, MD            0.0      0.0        0        0      0.0      0.0
## Boston, MA               1.9      0.0        0        0      0.0      0.0
## Lansing, MI              1.9      0.0        0        0      0.0      0.0
## Saint Paul, MN           0.0      0.0        0        0      0.0      0.0
## Jackson, MS              0.0      0.0        0        0      0.0      0.0
## Jefferson City, MO       0.1      0.0        0        0      0.0      0.0
## Helena, MT               3.7      0.9        0        0      0.3      1.3
## Lincoln, NE              1.4      0.0        0        0      0.0      0.0
## Carson City, NV          0.2      0.0        0        0      0.0      0.0
## Concord, NH              2.8      0.0        0        0      0.0      0.0
## Trenton, NJ              0.0      0.0        0        0      0.0      0.0
## Santa Fe, NM             0.4      0.0        0        0      0.0      0.0
## Albany, NY               2.3      0.1        0        0      0.0      0.0
## Raleigh, NC              0.1      0.0        0        0      0.0      0.0
## Bismarck, ND             4.2      0.4        0        0      0.0      0.2
## Columbus, OH             1.1      0.0        0        0      0.0      0.0
## Oklahoma City, OK        0.0      0.0        0        0      0.0      0.0
## Salem, OR                0.0      0.0        0        0      0.0      0.0
## Harrisburg, PA           0.4      0.0        0        0      0.0      0.0
## Providence, RI           0.6      0.0        0        0      0.0      0.0
## Columbia, SC             0.0      0.0        0        0      0.0      0.0
## Pierre, SD               3.5      0.0        0        0      0.0      0.0
## Nashville, TN            0.0      0.0        0        0      0.0      0.0
## Austin, TX               0.0      0.0        0        0      0.0      0.0
## Salt Lake City, UT       4.0      0.3        0        0      0.0      0.0
## Montpelier, VT           4.9      0.0        0        0      0.0      0.0
## Richmond, VA             0.1      0.0        0        0      0.0      0.0
## Olympia, WA              0.0      0.0        0        0      0.0      0.0
## Charleston, WV           1.4      0.0        0        0      0.0      0.0
## Madison, WI              2.6      0.2        0        0      0.0      0.0
## Cheyenne, WY            10.2      2.3        0        0      0.0      1.3
##                    snow.Oct snow.Nov snow.Dec
## Montgomery, AL           0.0      0.0      0.0
## Juneau, AK               0.6      9.2     13.6
## Phoenix, AZ              0.0      0.0      0.0
## Little Rock, AR          0.0      0.0      0.2
```

```
## Sacramento, CA          0.0      0.0      0.0
## Denver, CO              4.0      8.7      8.5
## Hartford, CT            0.0      2.0      7.4
## Dover, DE               0.0      0.2      2.9
## Tallahassee, FL         0.0      0.0      0.0
## Atlanta, GA             0.0      0.0      0.4
## Honolulu, HI            0.0      0.0      0.0
## Boise, ID               0.1      2.6      7.0
## Springfield, IL         0.0      0.6      5.6
## Indianapolis, IN        0.4      0.7      6.9
## Des Moines, IA          0.4      2.5      9.0
## Topeka, KS              0.3      1.0      5.2
## Frankfort, KY           0.0      0.4      1.6
## Baton Rouge, LA         0.0      0.0      0.0
## Augusta, ME             0.3      3.5     14.5
## Annapolis, MD           0.0      0.2      0.8
## Boston, MA              0.0      1.3      9.0
## Lansing, MI             0.4      3.4     13.0
## Saint Paul, MN          0.0      0.0      0.0
## Jackson, MS             0.0      0.0      0.0
## Jefferson City, MO      0.0      0.3      3.8
## Helena, MT              2.4      4.8      7.3
## Lincoln, NE             0.7      2.1      5.9
## Carson City, NV         0.0      0.9      3.9
## Concord, NH             0.0      2.6     14.5
## Trenton, NJ             0.0      0.6      3.5
## Santa Fe, NM            1.0      2.3      8.0
## Albany, NY              0.3      2.8     13.7
## Raleigh, NC             0.0      0.1      0.6
## Bismarck, ND            2.2      8.8      9.3
## Columbus, OH            0.2      0.9      5.0
## Oklahoma City, OK       0.0      0.4      2.1
## Salem, OR               0.0      0.1      1.1
## Harrisburg, PA          0.0      0.6      5.1
## Providence, RI          0.0      1.5      8.7
## Columbia, SC            0.0      0.0      0.1
## Pierre, SD              0.9      4.8      4.8
## Nashville, TN           0.0      0.0      0.5
## Austin, TX              0.0      0.0      0.0
## Salt Lake City, UT      1.4      7.6     13.2
## Montpelier, VT          0.0      9.1     21.9
## Richmond, VA            0.0      0.2      2.1
## Olympia, WA             0.0      0.9      2.6
## Charleston, WV          0.1      1.3      6.7
## Madison, WI             0.5      3.6     13.5
## Cheyenne, WY            5.0      8.0      8.4
```

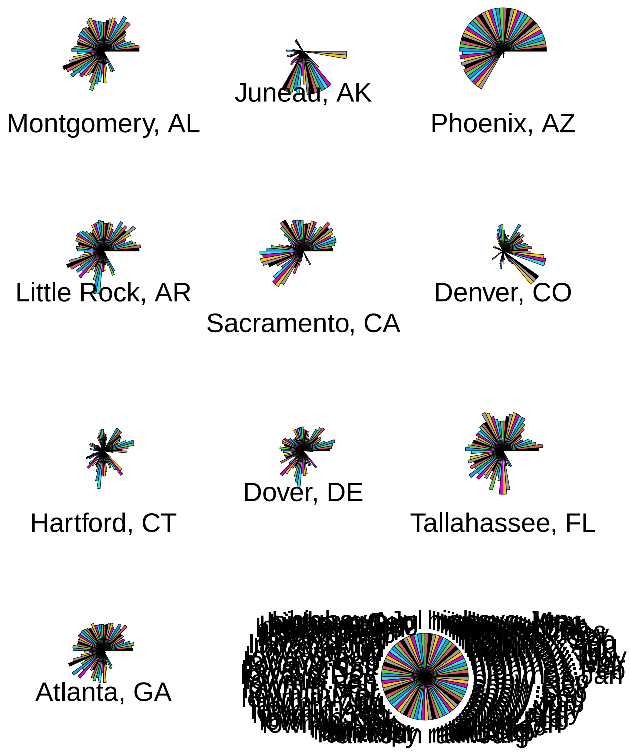
Perform `k-means` on All Climate Features

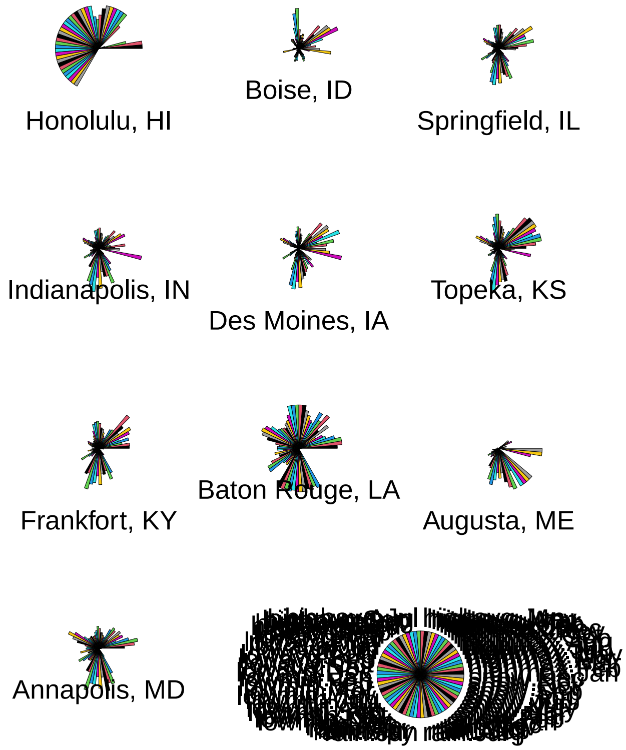
With the selected features let's perform k-means. Let's select k=12. I will select all of the features, but you can change that if you wish.

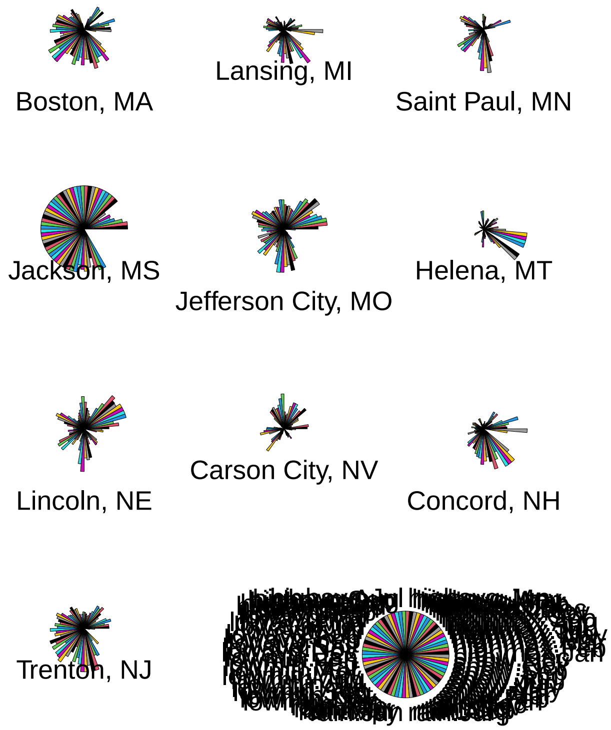
```r
colors = rainbow(50, s = 0.6, v = 0.75); # 50 colors for 50 states

# descriptive star plot to start
stars(whichX, len = 0.5, key.loc=c(12,2), draw.segments = TRUE);
```

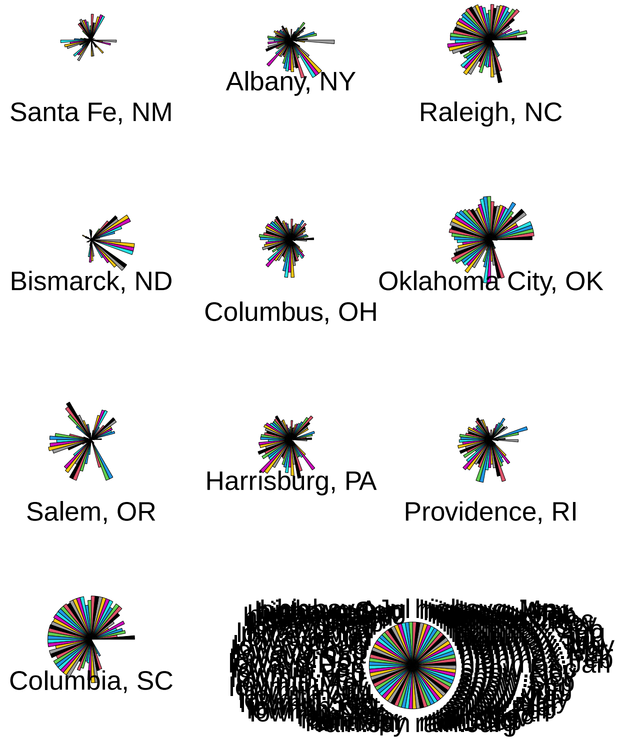
Descriptives of Sample

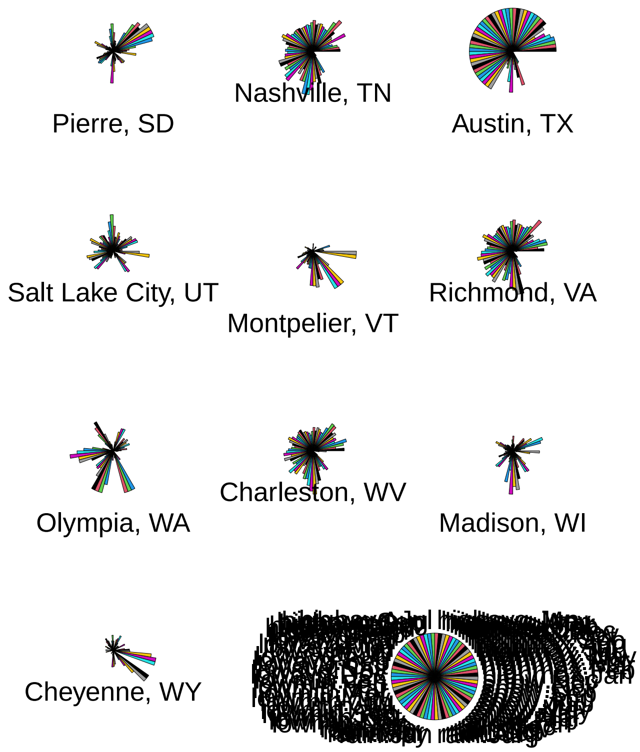
```r
## too busy, let's group them
x.start = 1;
x.end = 10;
for(i in 1:5)
  {
  stars( whichX[x.start:x.end,] ,
          len = 0.5, key.loc=c(6,2), draw.segments = TRUE);
  x.start = 1 + x.end;
  x.end = 10 + x.end;
  }
```


Montgomery, AL
Juneau, AK
Phoenix, AZ
Little Rock, AR
Sacramento, CA
Denver, CO
Hartford, CT
Dover, DE
Tallahassee, FL
Atlanta, GA


Honolulu, HI
Boise, ID
Springfield, IL
Indianapolis, IN
Des Moines, IA
Topeka, KS
Frankfort, KY
Baton Rouge, LA
Augusta, ME
Annapolis, MD


Boston, MA
Lansing, MI
Saint Paul, MN
Jackson, MS
Jefferson City, MO
Helena, MT
Lincoln, NE
Carson City, NV
Concord, NH
Trenton, NJ

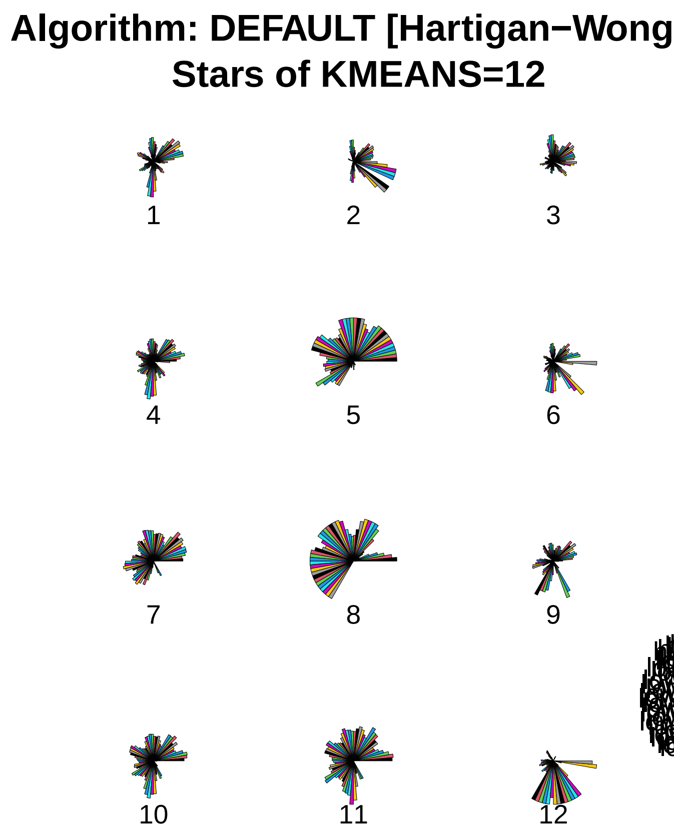

Santa Fe, NM
Albany, NY
Raleigh, NC
Bismarck, ND
Columbus, OH
Oklahoma City, OK
Salem, OR
Harrisburg, PA
Providence, RI
Columbia, SC



Above, you are just analyzing the general shapes. Which ones are "fuller" circles? Why?

Which ones are not very "full circles"? Why?

```r
k = 12;
iterations = 100;
number.starts = 100;

whichX.kmeans = kmeans(whichX, 12,
                    iter.max=iterations,
                    nstart = number.starts);  # default algorithm
stars(whichX.kmeans$centers, len = 0.5, key.loc = c(10, 3),
        main = "Algorithm: DEFAULT [Hartigan-Wong] \n Stars of KMEANS=12", draw.segments = TRUE);
```



Computation of Clusters/Centroids

```
membership = matrix( whichX.kmeans$cluster, ncol=1);
membership = membership[order(membership),];
membership = as.data.frame(membership);
        rownames(membership) = climate.df$labels;
        colnames(membership) = c("Cluster");

membership;
```

Cluster Membership and Centroid Attributes

```
##                      Cluster
## Montgomery, AL             1
## Juneau, AK                 1
## Phoenix, AZ                1
## Little Rock, AR            1
## Sacramento, CA             2
## Denver, CO                 2
## Hartford, CT               2
## Dover, DE                  3
## Tallahassee, FL            3
## Atlanta, GA                3
## Honolulu, HI               3
## Boise, ID                  3
```

```
## Springfield, IL          4
## Indianapolis, IN         4
## Des Moines, IA           4
## Topeka, KS               4
## Frankfort, KY            4
## Baton Rouge, LA          4
## Augusta, ME              4
## Annapolis, MD            4
## Boston, MA               4
## Lansing, MI              4
## Saint Paul, MN           4
## Jackson, MS              4
## Jefferson City, MO       5
## Helena, MT               6
## Lincoln, NE              6
## Carson City, NV          6
## Concord, NH              6
## Trenton, NJ              6
## Santa Fe, NM             6
## Albany, NY               7
## Raleigh, NC              8
## Bismarck, ND             9
## Columbus, OH             9
## Oklahoma City, OK       10
## Salem, OR               10
## Harrisburg, PA          10
## Providence, RI          10
## Columbia, SC            10
## Pierre, SD              10
## Nashville, TN           10
## Austin, TX              10
## Salt Lake City, UT      11
## Montpelier, VT          11
## Richmond, VA            11
## Olympia, WA             11
## Charleston, WV          11
## Madison, WI             11
## Cheyenne, WY            12
```

```
print( table(membership) ) ;
```

```
## membership
##  1  2  3  4  5  6  7  8  9 10 11 12
##  4  3  5 12  1  6  1  1  2  8  6  1
```

```
# I believe in an older version of R these were called $centroids
attributes = as.data.frame( whichX.kmeans$centers );
    rownames(attributes) = paste0("Cluster.",1:12);
  attributes;
```

```
##            highmax.Jan highmax.Feb highmax.Mar highmax.Apr highmax.May
## Cluster.1     66.25000    73.75000    88.25000    95.25000   101.75000
## Cluster.2     65.33333    71.00000    78.66667    87.66667    96.00000
```

```
## Cluster.3     67.80000    73.80000    80.80000    88.60000    96.80000
## Cluster.4     74.83333    78.66667    89.41667    94.00000    98.58333
## Cluster.5     88.00000    92.00000   100.00000   105.00000   114.00000
## Cluster.6     65.66667    67.66667    85.50000    91.66667    96.00000
## Cluster.7     79.00000    80.00000    90.00000    98.00000   107.00000
## Cluster.8     88.00000    88.00000    89.00000    91.00000    93.00000
## Cluster.9     66.00000    72.50000    79.50000    90.50000    98.00000
## Cluster.10    79.75000    84.12500    91.75000    95.25000    98.75000
## Cluster.11    85.00000    89.16667    93.33333    95.66667   101.16667
## Cluster.12    60.00000    57.00000    61.00000    72.00000    80.00000
##            highmax.Jun highmax.Jul highmax.Aug highmax.Sep highmax.Oct
## Cluster.1     106.5000    111.7500    109.2500   102.50000    94.75000
## Cluster.2     104.3333    106.3333    104.0000    99.66667    89.00000
## Cluster.3     104.0000    106.2000    104.4000   100.00000    90.60000
## Cluster.4     102.7500    107.5833    105.6667   102.91667    93.83333
## Cluster.5     122.0000    121.0000    117.0000   116.00000   107.00000
## Cluster.6      99.0000    102.0000    100.6667    97.33333    88.66667
## Cluster.7     112.0000    114.0000    112.0000   109.00000   102.00000
## Cluster.8      92.0000     94.0000     95.0000    95.00000    94.00000
## Cluster.9     101.5000    106.0000    106.0000   101.00000    91.50000
## Cluster.10    105.2500    106.6250    107.1250   103.25000    97.25000
## Cluster.11    106.1667    106.1667    107.5000   106.16667    99.00000
## Cluster.12     87.0000     89.0000     87.0000    85.00000    68.00000
##            highmax.Nov highmax.Dec highavg.Jan highavg.Feb highavg.Mar
## Cluster.1     82.25000    71.75000    30.60000    35.52500    47.42500
## Cluster.2     76.33333    66.33333    32.06667    35.80000    45.36667
## Cluster.3     77.60000    71.60000    41.58000    46.44000    55.06000
## Cluster.4     83.41667    76.50000    37.86667    42.00000    51.77500
## Cluster.5     96.00000    87.00000    67.20000    70.70000    76.90000
## Cluster.6     78.00000    69.00000    28.65000    32.66667    42.46667
## Cluster.7     86.00000    72.00000    54.40000    61.20000    66.80000
## Cluster.8     93.00000    89.00000    80.10000    80.20000    81.20000
## Cluster.9     74.00000    68.00000    46.80000    50.45000    55.20000
## Cluster.10    86.12500    80.00000    47.97500    52.13750    60.56250
## Cluster.11    89.83333    85.66667    59.46667    63.50000    70.85000
## Cluster.12    64.00000    59.00000    34.60000    36.70000    40.80000
##            highavg.Apr highavg.May highavg.Jun highavg.Jul highavg.Aug
## Cluster.1     61.07500    71.95000    81.45000    87.12500    84.97500
## Cluster.2     56.56667    66.73333    76.06667    84.60000    83.06667
## Cluster.3     62.56000    72.12000    82.26000    89.74000    87.76000
## Cluster.4     63.13333    72.58333    81.28333    85.49167    84.21667
## Cluster.5     85.20000    94.80000   103.90000   106.10000   104.40000
## Cluster.6     56.20000    67.73333    76.61667    81.05000    79.25000
## Cluster.7     72.70000    80.90000    87.90000    93.30000    92.20000
## Cluster.8     82.70000    84.60000    87.00000    87.90000    88.70000
## Cluster.9     60.00000    66.55000    72.25000    79.40000    80.05000
## Cluster.10    70.08750    78.06250    85.92500    89.68750    88.53750
## Cluster.11    77.96667    85.10000    90.55000    92.71667    92.53333
## Cluster.12    49.10000    56.90000    62.40000    63.40000    62.60000
##            highavg.Sep highavg.Oct highavg.Nov highavg.Dec lowavg.Jan
## Cluster.1     76.07500    62.22500    46.07500    32.87500   11.22500
## Cluster.2     72.16667    58.33333    43.06667    32.03333   11.06667
## Cluster.3     78.92000    65.84000    51.44000    41.30000   20.58000
## Cluster.4     77.08333    65.65000    53.80833    41.65000   21.45000
```

```
## Cluster.5     99.80000    88.50000    75.50000    66.00000   45.60000
## Cluster.6     71.26667    58.71667    46.01667    33.61667   11.80000
## Cluster.7     87.90000    77.90000    63.70000    54.30000   40.70000
## Cluster.8     88.60000    86.70000    83.90000    81.20000   66.30000
## Cluster.9     74.30000    62.15000    51.40000    45.20000   34.20000
## Cluster.10    81.80000    71.41250    61.10000    50.61250   29.77500
## Cluster.11    87.80000    79.26667    70.00000    61.35000   37.73333
## Cluster.12    56.60000    48.40000    39.80000    36.70000   26.20000
##            lowavg.Feb lowavg.Mar lowavg.Apr lowavg.May lowavg.Jun lowavg.Jul
## Cluster.1    15.65000   26.27500   38.02500   49.60000   59.32500   64.70000
## Cluster.2    14.46667   22.70000   31.20000   41.23333   49.80000   55.73333
## Cluster.3    23.84000   30.08000   35.66000   43.76000   51.78000   58.12000
## Cluster.4    24.45000   32.06667   41.79167   51.41667   60.95833   65.60833
## Cluster.5    48.70000   53.50000   60.20000   69.40000   77.70000   83.50000
## Cluster.6    14.78333   23.55000   34.81667   44.83333   54.53333   59.38333
## Cluster.7    43.70000   46.50000   49.00000   53.90000   58.40000   60.90000
## Cluster.8    66.10000   67.70000   69.40000   70.90000   73.40000   74.50000
## Cluster.9    33.70000   36.15000   38.65000   42.40000   48.45000   51.95000
## Cluster.10   32.57500   39.53750   47.98750   57.33750   66.36250   70.57500
## Cluster.11   40.95000   47.05000   53.65000   62.55000   69.68333   72.46667
## Cluster.12   27.60000   30.10000   35.30000   42.30000   48.40000   51.40000
##            lowavg.Aug lowavg.Sep lowavg.Oct lowavg.Nov lowavg.Dec lowmin.Jan
## Cluster.1    62.67500   52.70000   40.25000   27.10000   14.87500 -31.250000
## Cluster.2    53.93333   44.23333   32.86667   21.66667   11.76667 -41.666667
## Cluster.3    56.96000   48.44000   37.78000   27.74000   20.60000 -24.000000
## Cluster.4    64.10000   55.84167   44.31667   35.23333   25.60000 -20.583333
## Cluster.5    82.70000   76.90000   64.80000   52.70000   44.80000  16.000000
## Cluster.6    57.78333   49.50000   38.30000   29.63333   18.26667 -32.666667
## Cluster.7    60.50000   58.40000   52.80000   45.50000   40.40000  19.000000
## Cluster.8    75.10000   74.40000   73.40000   71.40000   68.30000  52.000000
## Cluster.9    51.65000   47.20000   41.40000   37.40000   33.30000  -9.000000
## Cluster.10   69.36250   62.23750   50.55000   40.98750   32.46250 -10.000000
## Cluster.11   72.16667   66.66667   55.75000   46.20000   39.35000   1.166667
## Cluster.12   50.20000   45.80000   39.00000   31.40000   27.80000 -20.000000
##            lowmin.Feb lowmin.Mar lowmin.Apr lowmin.May lowmin.Jun lowmin.Jul
## Cluster.1  -29.750000  -21.25000    4.00000   23.00000   36.50000   44.75000
## Cluster.2  -40.333333  -29.00000  -10.00000   12.66667   28.33333   33.66667
## Cluster.3  -23.200000   -3.40000    7.20000   20.60000   29.00000   37.40000
## Cluster.4  -19.083333   -5.75000   13.16667   27.83333   37.66667   46.25000
## Cluster.5   24.000000   25.00000   35.00000   39.00000   49.00000   63.00000
## Cluster.6  -29.500000  -20.66667    3.00000   21.83333   31.33333   36.66667
## Cluster.7   21.000000   29.00000   34.00000   37.00000   43.00000   47.00000
## Cluster.8   52.000000   53.00000   56.00000   60.00000   63.00000   63.00000
## Cluster.9   -2.500000   10.50000   23.00000   25.00000   31.00000   35.00000
## Cluster.10 -10.000000    7.75000   20.62500   32.62500   40.87500   50.62500
## Cluster.11  -1.166667   15.66667   28.50000   37.33333   48.16667   56.00000
## Cluster.12 -15.000000   -5.00000   12.00000   26.00000   32.00000   39.00000
##            lowmin.Aug lowmin.Sep lowmin.Oct lowmin.Nov lowmin.Dec  rain.Jan
## Cluster.1    40.00000   24.75000   7.250000 -14.250000 -27.250000 0.7125000
## Cluster.2    28.33333    8.00000  -7.666667 -30.000000 -37.000000 0.3733333
## Cluster.3    34.20000   22.00000   6.800000 -11.800000 -22.800000 1.0180000
## Cluster.4    41.16667   30.75000  18.666667   1.250000 -17.000000 2.7658333
## Cluster.5    58.00000   47.00000  34.000000  27.000000  22.000000 0.9100000
## Cluster.6    32.33333   22.66667  13.833333  -8.333333 -23.500000 2.2050000
```

```
## Cluster.7    48.00000   44.00000  34.000000  27.000000  17.000000 3.6300000
## Cluster.8    63.00000   65.00000  61.000000  57.000000  54.000000 0.0000000
## Cluster.9    31.50000   25.50000  16.500000   4.000000  -9.500000 6.9000000
## Cluster.10   47.00000   35.37500  23.500000   8.250000  -3.125000 3.2700000
## Cluster.11   56.00000   39.66667  27.333333  15.666667   5.833333 4.2466667
## Cluster.12   32.00000   28.00000  13.000000  -7.000000 -10.000000 7.9800000
##             rain.Feb  rain.Mar rain.Apr rain.May rain.Jun rain.Jul rain.Aug
## Cluster.1  0.8275000 1.7500000 2.812500 3.970000 4.267500 3.722500 3.545000
## Cluster.2  0.4266667 0.8366667 1.340000 2.203333 2.523333 2.090000 1.810000
## Cluster.3  0.9280000 1.2380000 1.226000 1.366000 1.068000 1.124000 1.012000
## Cluster.4  2.5316667 3.6216667 3.654167 4.325833 4.211667 4.245833 3.607500
## Cluster.5  0.9200000 0.9900000 0.280000 0.110000 0.020000 1.050000 1.000000
## Cluster.6  2.0350000 2.7483333 3.241667 3.540000 3.803333 3.728333 3.576667
## Cluster.7  3.9000000 2.8600000 1.360000 0.750000 0.210000 0.020000 0.040000
## Cluster.8  0.0000000 0.0000000 0.000000 0.000000 0.000000 0.000000 0.000000
## Cluster.9  4.9150000 4.6400000 3.175000 2.275000 1.650000 0.545000 0.690000
## Cluster.10 3.2312500 4.2062500 3.662500 4.273750 4.036250 4.125000 3.762500
## Cluster.11 4.2600000 4.6383333 3.535000 3.948333 5.225000 4.920000 4.830000
## Cluster.12 6.7100000 6.2900000 4.640000 4.960000 4.420000 5.440000 8.160000
##             rain.Sep   rain.Oct  rain.Nov rain.Dec  snow.Jan   snow.Feb
## Cluster.1   2.802500  2.2925000 1.5475000 1.005000  4.825000  4.8750000
## Cluster.2   1.390000  0.9533333 0.5966667 0.460000  7.000000  7.0000000
## Cluster.3   0.936000  1.0780000 1.0900000 1.114000  6.400000  5.1000000
## Cluster.4   3.533333  3.3458333 3.4600000 3.150833  8.133333  6.6250000
## Cluster.5   0.640000  0.5800000 0.6500000 0.880000  0.000000  0.0000000
## Cluster.6   3.361667  3.4083333 3.2833333 2.620000 17.550000 13.2666667
## Cluster.7   0.350000  1.0600000 2.4600000 3.430000  0.000000  0.0000000
## Cluster.8   0.000000  0.0000000 0.0000000 0.000000  0.000000  0.0000000
## Cluster.9   1.495000  3.8150000 7.5650000 7.160000  1.250000  3.2000000
## Cluster.10  4.062500  3.5762500 3.6637500 3.566250  3.012500  2.3500000
## Cluster.11  3.793333  3.6366667 3.7783333 4.188333  0.200000  0.1166667
## Cluster.12 12.720000 13.2300000 8.4400000 9.230000 24.200000 15.9000000
##               snow.Mar  snow.Apr snow.May snow.Jun snow.Jul snow.Aug  snow.Sep
## Cluster.1   3.95000000 1.6750000     0.00        0        0      0.0 0.0000000
## Cluster.2   8.86666667 6.0333333     1.20        0        0      0.1 0.9333333
## Cluster.3   4.96000000 2.3400000     0.28        0        0      0.0 0.2600000
## Cluster.4   4.11666667 0.6416667     0.00        0        0      0.0 0.0000000
## Cluster.5   0.00000000 0.0000000     0.00        0        0      0.0 0.0000000
## Cluster.6  11.41666667 3.2000000     0.05        0        0      0.0 0.0000000
## Cluster.7   0.00000000 0.0000000     0.00        0        0      0.0 0.0000000
## Cluster.8   0.00000000 0.0000000     0.00        0        0      0.0 0.0000000
## Cluster.9   0.35000000 0.0000000     0.00        0        0      0.0 0.0000000
## Cluster.10  0.58750000 0.0250000     0.00        0        0      0.0 0.0000000
## Cluster.11  0.01666667 0.0000000     0.00        0        0      0.0 0.0000000
## Cluster.12  5.40000000 0.9000000     0.00        0        0      0.0 0.0000000
##              snow.Oct  snow.Nov    snow.Dec
## Cluster.1  0.50000000 2.3500000  4.92500000
## Cluster.2  3.20000000 7.2000000  8.33333333
## Cluster.3  1.30000000 4.4200000  8.12000000
## Cluster.4  0.08333333 0.9333333  5.70833333
## Cluster.5  0.00000000 0.0000000  0.00000000
## Cluster.6  0.25000000 4.1666667 15.18333333
## Cluster.7  0.00000000 0.0000000  0.00000000
## Cluster.8  0.00000000 0.0000000  0.00000000
```

```
## Cluster.9  0.00000000 0.5000000  1.85000000
## Cluster.10 0.00000000 0.1375000  1.20000000
## Cluster.11 0.00000000 0.0000000  0.01666667
## Cluster.12 0.60000000 9.2000000 13.60000000
```

```r
state <- rownames(membership)
rownames(membership) <- NULL
new.membership <- cbind(state, membership)
new.membership
```

```
##                 state Cluster
## 1      Montgomery, AL       1
## 2          Juneau, AK       1
## 3         Phoenix, AZ       1
## 4     Little Rock, AR       1
## 5      Sacramento, CA       2
## 6          Denver, CO       2
## 7        Hartford, CT       2
## 8           Dover, DE       3
## 9     Tallahassee, FL       3
## 10        Atlanta, GA       3
## 11       Honolulu, HI       3
## 12          Boise, ID       3
## 13    Springfield, IL       4
## 14   Indianapolis, IN       4
## 15     Des Moines, IA       4
## 16         Topeka, KS       4
## 17       Frankfort, KY      4
## 18    Baton Rouge, LA       4
## 19        Augusta, ME       4
## 20      Annapolis, MD       4
## 21         Boston, MA       4
## 22        Lansing, MI       4
## 23     Saint Paul, MN       4
## 24        Jackson, MS       4
## 25 Jefferson City, MO       5
## 26         Helena, MT       6
## 27        Lincoln, NE       6
## 28    Carson City, NV       6
## 29        Concord, NH       6
## 30        Trenton, NJ       6
## 31       Santa Fe, NM       6
## 32         Albany, NY       7
## 33        Raleigh, NC       8
## 34       Bismarck, ND       9
## 35       Columbus, OH       9
## 36  Oklahoma City, OK      10
## 37          Salem, OR      10
## 38     Harrisburg, PA      10
## 39     Providence, RI      10
## 40       Columbia, SC      10
## 41         Pierre, SD      10
## 42      Nashville, TN      10
## 43         Austin, TX      10
```

```
## 44 Salt Lake City, UT      11
## 45     Montpelier, VT      11
## 46       Richmond, VA      11
## 47        Olympia, WA      11
## 48     Charleston, WV      11
## 49        Madison, WI      11
## 50       Cheyenne, WY      12
```

```
for (i in 1:12) {
cat(new.membership$state[membership$Cluster==i], 'are in cluster',i , '\n')
}
```

```
## Montgomery, AL Juneau, AK Phoenix, AZ Little Rock, AR are in cluster 1
## Sacramento, CA Denver, CO Hartford, CT are in cluster 2
## Dover, DE Tallahassee, FL Atlanta, GA Honolulu, HI Boise, ID are in cluster 3
## Springfield, IL Indianapolis, IN Des Moines, IA Topeka, KS Frankfort, KY Baton Rouge, LA Augusta, ME
## Jefferson City, MO are in cluster 5
## Helena, MT Lincoln, NE Carson City, NV Concord, NH Trenton, NJ Santa Fe, NM are in cluster 6
## Albany, NY are in cluster 7
## Raleigh, NC are in cluster 8
## Bismarck, ND Columbus, OH are in cluster 9
## Oklahoma City, OK Salem, OR Harrisburg, PA Providence, RI Columbia, SC Pierre, SD Nashville, TN Aust
## Salt Lake City, UT Montpelier, VT Richmond, VA Olympia, WA Charleston, WV Madison, WI are in cluster
## Cheyenne, WY are in cluster 12
```

(10 points) Summarize Findings

- Identify which states share a common cluster.
- For a given cluster, what are its primary characteristics

[Summarize your k-means findings for 12 clusters.]

(15 points) Correlation

Correlation, like distance, is an important feature of multivariate analysis. So let's review some basic correlation related to our climate data. For simplicity, let's consider "Record High Temperature" and "Record Low Temperature" and see how they correlate with other factors we have gathered from Wikipedia.

Recall, in this table, "Jan-Dec" are different months of the same temperature variable.

```
library(Hmisc); # p-values for correlation
```

```
## Loading required package: lattice

## Loading required package: survival

## Loading required package: Formula

##
## Attaching package: 'Hmisc'
```

```
## The following object is masked from 'package:psych':
##
##     describe

## The following objects are masked from 'package:base':
##
##     format.pval, units
```

```r
high = subsetDataFrame(climate, c("key", "units"), "==", c("Record high F (C)",1));
high = merge(high, capitals, by=c("capital","state"));
high
```

```
##           capital          state units              key Jan Feb Mar Apr May
## 1          Albany       New York     1 Record high F (C)  71  74  89  93  97
## 2       Annapolis       Maryland     1 Record high F (C)  77  83  92  95  98
## 3         Atlanta        Georgia     1 Record high F (C)  79  80  89  93  97
## 4         Augusta          Maine     1 Record high F (C)  61  60  84  90  94
## 5          Austin          Texas     1 Record high F (C)  90  99  98  99 104
## 6     Baton Rouge      Louisiana     1 Record high F (C)  85  88  93  96 101
## 7        Bismarck   North Dakota     1 Record high F (C)  63  73  81  93 102
## 8           Boise          Idaho     1 Record high F (C)  63  71  82  92 100
## 9          Boston  Massachusetts     1 Record high F (C)  74  73  89  94  97
## 10    Carson City         Nevada     1 Record high F (C)  72  76  81  88  94
## 11     Charleston  West Virginia     1 Record high F (C)  81  81  92  96  98
## 12       Cheyenne        Wyoming     1 Record high F (C)  70  71  77  84  91
## 13       Columbia South Carolina     1 Record high F (C)  84  84  93  96 101
## 14       Columbus           Ohio     1 Record high F (C)  74  78  85  90  96
## 15        Concord  New Hampshire     1 Record high F (C)  72  74  89  95  98
## 16         Denver       Colorado     1 Record high F (C)  76  80  84  90  95
## 17     Des Moines           Iowa     1 Record high F (C)  67  78  91  93 105
## 18          Dover       Delaware     1 Record high F (C)  77  80  88  97  98
## 19      Frankfort       Kentucky     1 Record high F (C)  80  80  88  95  99
## 20     Harrisburg   Pennsylvania     1 Record high F (C)  73  79  87  93  97
## 21       Hartford    Connecticut     1 Record high F (C)  72  77  89  96  99
## 22         Helena        Montana     1 Record high F (C)  63  69  78  86  95
## 23       Honolulu         Hawaii     1 Record high F (C)  88  88  89  91  93
## 24   Indianapolis        Indiana     1 Record high F (C)  71  77  85  90  96
## 25        Jackson    Mississippi     1 Record high F (C)  85  89  95  94 100
## 26 Jefferson City       Missouri     1 Record high F (C)  79  89  97  96 102
## 27         Juneau         Alaska     1 Record high F (C)  60  57  61  72  80
## 28        Lansing       Michigan     1 Record high F (C)  66  69  86  88  96
## 29        Lincoln       Nebraska     1 Record high F (C)  73  83  91  97 104
## 30    Little Rock       Arkansas     1 Record high F (C)  83  87  91  95  98
## 31        Madison      Wisconsin     1 Record high F (C)  58  68  83  94 101
## 32     Montgomery        Alabama     1 Record high F (C)  83  86  90  94  99
## 33     Montpelier        Vermont     1 Record high F (C)  66  61  82  90  90
## 34      Nashville      Tennessee     1 Record high F (C)  78  84  89  91  96
## 35  Oklahoma City       Oklahoma     1 Record high F (C)  83  92  97 100 104
## 36        Olympia     Washington     1 Record high F (C)  64  73  79  88  96
## 37        Phoenix        Arizona     1 Record high F (C)  88  92 100 105 114
## 38         Pierre   South Dakota     1 Record high F (C)  68  75  88  98 105
## 39     Providence   Rhode Island     1 Record high F (C)  70  72  90  98  96
## 40        Raleigh North Carolina     1 Record high F (C)  80  84  94  95  99
```

```
## 41       Richmond       Virginia     1 Record high F (C)  81  83  94  96 100
## 42     Sacramento     California     1 Record high F (C)  79  80  90  98 107
## 43     Saint Paul      Minnesota     1 Record high F (C)  57  59  83  93  93
## 44          Salem         Oregon     1 Record high F (C)  68  72  80  93 100
## 45 Salt Lake City           Utah     1 Record high F (C)  63  69  80  89  99
## 46       Santa Fe     New Mexico     1 Record high F (C)  65  73  77  84  96
## 47    Springfield       Illinois     1 Record high F (C)  73  78  91  90 101
## 48    Tallahassee        Florida     1 Record high F (C)  83  89  91  95 102
## 49         Topeka         Kansas     1 Record high F (C)  78  84  93  97 103
## 50        Trenton     New Jersey     1 Record high F (C)  73  76  87  93  99
##    Jun Jul Aug Sep Oct Nov Dec latitude  longitude capital.since area.sq.miles
## 1  100 104 102 100  91  82  72 42.65250  -73.75722          1797         21.40
## 2  103 105 106  99  92  85  78 38.97306  -76.50111          1694          6.73
## 3  106 105 104 102  98  84  79 33.75500  -84.39000          1868        133.50
## 4   98  99 100  96  85  74  67 44.31056  -69.77944          1832         55.40
## 5  109 109 112 112 100  91  90 30.26722  -97.74306          1839        305.10
## 6  103 103 110 104  98  89  88 30.44750  -91.17861          1880         76.80
## 7  111 114 109 105  95  79  66 46.80833 -100.78361          1883         26.90
## 8  110 111 110 102  94  78  70 43.61583 -116.20167          1865         63.80
## 9  100 104 102 102  90  83  76 42.35806  -71.06361          1630         89.60
## 10 101 107 105 103  93  79  75 39.16444 -119.76694          1861        143.40
## 11 105 108 108 104  96  87  80 38.34722  -81.63333          1885         31.60
## 12 100 100  98  95  85  75  69 41.14000 -104.82028          1869         21.10
## 13 109 107 107 106 101  90  83 34.00056  -81.03472          1786        125.20
## 14 102 106 103 100  94  80  76 39.96222  -83.00056          1816        210.30
## 15 101 102 101  98  92  80  73 43.20667  -71.53806          1808         64.30
## 16 105 105 105 101  90  81  79 39.73917 -104.99028          1867        153.30
## 17 103 110 110 101  95  82  69 41.59083  -93.62083          1857         75.80
## 18 101 104 102  99  95  85  75 39.15806  -75.52444          1777         22.40
## 19 106 111 105 106  98  84  78 38.20000  -84.86700          1792         14.70
## 20 100 107 104 102  97  84  75 40.26972  -76.87556          1812          8.11
## 21 100 103 102 101  91  83  76 41.76250  -72.67417          1875         17.30
## 22 102 105 105  99  87  75  64 46.59111 -112.02028          1875         14.00
## 23  92  94  95  95  94  93  89 21.30694 -157.85833          1845         68.40
## 24 104 106 103 100  92  81  74 39.76861  -86.15806          1825        361.50
## 25 105 107 107 107  98  89  84 32.29889  -90.18472          1821        104.90
## 26 105 112 111 107  96  87  79 38.57667  -92.17361          1826         27.30
## 27  87  89  87  85  68  64  59 58.30000 -134.41600          1906       2716.70
## 28  99 103 102  99  90  79  70 42.73361  -84.54667          1847         35.00
## 29 108 115 110 106  98  85  75 40.80889  -96.67889          1867         74.60
## 30 107 112 114 106  98  86  81 34.73611  -92.33111          1821        116.20
## 31 101 107 102  99  90  77  65 43.07472  -89.38417          1838         68.70
## 32 106 107 106 106 102  91  85 32.36167  -86.27917          1846        159.80
## 33  95  97  97  92  84  76  67 44.25944  -72.57583          1805         10.20
## 34 109 107 106 105  99  88  79 36.16667  -86.78333          1826        525.90
## 35 107 110 113 108  97  87  86 35.46861  -97.52139          1910        620.30
## 36  98 104 104  98  90  74  64 47.03778 -122.90083          1853         16.70
## 37 122 121 117 116 107  96  87 33.45000 -112.06700          1912        517.60
## 38 112 117 114 108  98  87  77 44.37250 -100.32000          1889         13.00
## 39  98 102 104 100  88  81  77 41.82361  -71.42222          1900         18.50
## 40 105 105 105 104 100  88  81 35.76700  -78.63300          1792        114.60
## 41 104 105 107 103  99  86  81 37.53300  -77.46700          1780         60.10
## 42 112 114 112 109 102  86  72 38.58167 -121.49444          1854         97.90
## 43 103 105 103  95  88  75  66 44.94417  -93.09361          1849         52.80
```

```
## 44 105 108 108 104  93  74  72 44.93917 -123.03944          1855         45.70
## 45 105 107 106 100  89  75  69 40.76083 -111.89111          1858        109.10
## 46  99 101  96  94  87  75  65 35.66722 -105.96444          1610         37.30
## 47 104 112 108 102  93  83  74 39.79944  -89.65500          1837         54.00
## 48 105 104 103 102  95  89  84 30.45500  -84.25333          1824         95.70
## 49 109 114 113 110  97  85  77 39.05583  -95.68944          1856         56.00
## 50 100 106 105 101  94  83  76 40.22384  -74.76362          1784          7.66
##    population.2019.est population.2019.est.MSA population.2019.est.CSA
## 1                96460                  880381                 1167594
## 2                39174                 2800053                 9814928
## 3               506811                 6020364                 6853392
## 4                18681                  122302                      NA
## 5               978908                 2227083                      NA
## 6               220236                  854884                      NA
## 7                73529                  128949                      NA
## 8               228959                  749202                  831235
## 9               692600                 4873019                 8287710
## 10               55916                   55916                  637973
## 11               46536                  257074                  776694
## 12               64235                   99500                      NA
## 13              131674                  838433                  963048
## 14              898553                 2122271                 2525639
## 15               43627                  151391                 8287710
## 16              727211                 2967239                 3617927
## 17              214237                  699292                  877991
## 18               38079                  180786                 7209620
## 19               27679                   73663                  745033
## 20               49528                  577941                 1271801
## 21              122105                 1204877                 1470083
## 22               32315                   77414                      NA
## 23              345064                  974563                      NA
## 24              876384                 2074537                 2457286
## 25              160628                  594806                  674340
## 26               42838                  151235                      NA
## 27               32113                   32113                      NA
## 28              118210                  550391                      NA
## 29              289102                  336374                  357887
## 30              197312                  742384                  908941
## 31              259680                  664865                  892661
## 32              198525                  373290                  461516
## 33                7855                      NA                      NA
## 34              670820                 1934317                 2062547
## 35              655057                 1408950                 1481542
## 36               46478                  290536                 4903675
## 37             1680992                 4948203                 5002221
## 38               13646                   20672                      NA
## 39              179883                 1624578                 8287710
## 40              474069                 1390785                 2079687
## 41              230436                 1291900                      NA
## 42              513624                 2363730                 2639124
## 43              308096                 3654908                 4027861
## 44              174365                  433903                 3259710
## 45              200567                 1232696                 2641048
## 46               84683                  150358                 1158464
```

```
## 47            114230                  206868                   306399
## 48            194500                  387227                       NA
## 49            125310                  231969                       NA
## 50             83203                  367430                 22589036
##    city.rank.in.state                                                   url
## 1                   6              https://en.wikipedia.org/wiki/Albany,_New_York
## 2                   7         https://en.wikipedia.org/wiki/Annapolis,_Maryland
## 3                   1                     https://en.wikipedia.org/wiki/Atlanta
## 4                   8            https://en.wikipedia.org/wiki/Augusta,_Maine
## 5                   4             https://en.wikipedia.org/wiki/Austin,_Texas
## 6                   2    https://en.wikipedia.org/wiki/Baton_Rouge,_Louisiana
## 7                   2    https://en.wikipedia.org/wiki/Bismarck,_North_Dakota
## 8                   1              https://en.wikipedia.org/wiki/Boise,_Idaho
## 9                   1                    https://en.wikipedia.org/wiki/Boston
## 10                  6       https://en.wikipedia.org/wiki/Carson_City,_Nevada
## 11                  1 https://en.wikipedia.org/wiki/Charleston,_West_Virginia
## 12                  1         https://en.wikipedia.org/wiki/Cheyenne,_Wyoming
## 13                  2  https://en.wikipedia.org/wiki/Columbia,_South_Carolina
## 14                  1            https://en.wikipedia.org/wiki/Columbus,_Ohio
## 15                  3    https://en.wikipedia.org/wiki/Concord,_New_Hampshire
## 16                  1                    https://en.wikipedia.org/wiki/Denver
## 17                  1          https://en.wikipedia.org/wiki/Des_Moines,_Iowa
## 18                  2           https://en.wikipedia.org/wiki/Dover,_Delaware
## 19                 15       https://en.wikipedia.org/wiki/Frankfort,_Kentucky
## 20                  9  https://en.wikipedia.org/wiki/Harrisburg,_Pennsylvania
## 21                  3     https://en.wikipedia.org/wiki/Hartford,_Connecticut
## 22                  6           https://en.wikipedia.org/wiki/Helena,_Montana
## 23                  1                  https://en.wikipedia.org/wiki/Honolulu
## 24                  1              https://en.wikipedia.org/wiki/Indianapolis
## 25                  1      https://en.wikipedia.org/wiki/Jackson,_Mississippi
## 26                 15  https://en.wikipedia.org/wiki/Jefferson_City,_Missouri
## 27                  3            https://en.wikipedia.org/wiki/Juneau,_Alaska
## 28                  5         https://en.wikipedia.org/wiki/Lansing,_Michigan
## 29                  2         https://en.wikipedia.org/wiki/Lincoln,_Nebraska
## 30                  1     https://en.wikipedia.org/wiki/Little_Rock,_Arkansas
## 31                  2        https://en.wikipedia.org/wiki/Madison,_Wisconsin
## 32                  2       https://en.wikipedia.org/wiki/Montgomery,_Alabama
## 33                  6       https://en.wikipedia.org/wiki/Montpelier,_Vermont
## 34                  1      https://en.wikipedia.org/wiki/Nashville,_Tennessee
## 35                  1             https://en.wikipedia.org/wiki/Oklahoma_City
## 36                 24       https://en.wikipedia.org/wiki/Olympia,_Washington
## 37                  1          https://en.wikipedia.org/wiki/Phoenix,_Arizona
## 38                  8      https://en.wikipedia.org/wiki/Pierre,_South_Dakota
## 39                  1  https://en.wikipedia.org/wiki/Providence,_Rhode_Island
## 40                  2   https://en.wikipedia.org/wiki/Raleigh,_North_Carolina
## 41                  4        https://en.wikipedia.org/wiki/Richmond,_Virginia
## 42                  6    https://en.wikipedia.org/wiki/Sacramento,_California
## 43                  2     https://en.wikipedia.org/wiki/Saint_Paul,_Minnesota
## 44                  3             https://en.wikipedia.org/wiki/Salem,_Oregon
## 45                  1            https://en.wikipedia.org/wiki/Salt_Lake_City
## 46                  4      https://en.wikipedia.org/wiki/Santa_Fe,_New_Mexico
## 47                  6     https://en.wikipedia.org/wiki/Springfield,_Illinois
## 48                  7      https://en.wikipedia.org/wiki/Tallahassee,_Florida
## 49                  4            https://en.wikipedia.org/wiki/Topeka,_Kansas
```

```
## 50                    10        https://en.wikipedia.org/wiki/Trenton,_New_Jersey
##    st
## 1  NY
## 2  MD
## 3  GA
## 4  ME
## 5  TX
## 6  LA
## 7  ND
## 8  ID
## 9  MA
## 10 NV
## 11 WV
## 12 WY
## 13 SC
## 14 OH
## 15 NH
## 16 CO
## 17 IA
## 18 DE
## 19 KY
## 20 PA
## 21 CT
## 22 MT
## 23 HI
## 24 IN
## 25 MS
## 26 MO
## 27 AK
## 28 MI
## 29 NE
## 30 AR
## 31 WI
## 32 AL
## 33 VT
## 34 TN
## 35 OK
## 36 WA
## 37 AZ
## 38 SD
## 39 RI
## 40 NC
## 41 VA
## 42 CA
## 43 MN
## 44 OR
## 45 UT
## 46 NM
## 47 IL
## 48 FL
## 49 KS
## 50 NJ
```

```r
high.X = high[,c(5:18,21)]; # numeric data
high.X
```

```
##    Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec latitude  longitude
## 1   71  74  89  93  97 100 104 102 100  91  82  72 42.65250  -73.75722
## 2   77  83  92  95  98 103 105 106  99  92  85  78 38.97306  -76.50111
## 3   79  80  89  93  97 106 105 104 102  98  84  79 33.75500  -84.39000
## 4   61  60  84  90  94  98  99 100  96  85  74  67 44.31056  -69.77944
## 5   90  99  98  99 104 109 109 112 112 100  91  90 30.26722  -97.74306
## 6   85  88  93  96 101 103 103 110 104  98  89  88 30.44750  -91.17861
## 7   63  73  81  93 102 111 114 109 105  95  79  66 46.80833 -100.78361
## 8   63  71  82  92 100 110 111 110 102  94  78  70 43.61583 -116.20167
## 9   74  73  89  94  97 100 104 102 102  90  83  76 42.35806  -71.06361
## 10  72  76  81  88  94 101 107 105 103  93  79  75 39.16444 -119.76694
## 11  81  81  92  96  98 105 108 108 104  96  87  80 38.34722  -81.63333
## 12  70  71  77  84  91 100 100  98  95  85  75  69 41.14000 -104.82028
## 13  84  84  93  96 101 109 107 107 106 101  90  83 34.00056  -81.03472
## 14  74  78  85  90  96 102 106 103 100  94  80  76 39.96222  -83.00056
## 15  72  74  89  95  98 101 102 101  98  92  80  73 43.20667  -71.53806
## 16  76  80  84  90  95 105 105 105 101  90  81  79 39.73917 -104.99028
## 17  67  78  91  93 105 103 110 110 101  95  82  69 41.59083  -93.62083
## 18  77  80  88  97  98 101 104 102  99  95  85  75 39.15806  -75.52444
## 19  80  80  88  95  99 106 111 105 106  98  84  78 38.20000  -84.86700
## 20  73  79  87  93  97 100 107 104 102  97  84  75 40.26972  -76.87556
## 21  72  77  89  96  99 100 103 102 101  91  83  76 41.76250  -72.67417
## 22  63  69  78  86  95 102 105 105  99  87  75  64 46.59111 -112.02028
## 23  88  88  89  91  93  92  94  95  95  94  93  89 21.30694 -157.85833
## 24  71  77  85  90  96 104 106 103 100  92  81  74 39.76861  -86.15806
## 25  85  89  95  94 100 105 107 107 107  98  89  84 32.29889  -90.18472
## 26  79  89  97  96 102 105 112 111 107  96  87  79 38.57667  -92.17361
## 27  60  57  61  72  80  87  89  87  85  68  64  59 58.30000 -134.41600
## 28  66  69  86  88  96  99 103 102  99  90  79  70 42.73361  -84.54667
## 29  73  83  91  97 104 108 115 110 106  98  85  75 40.80889  -96.67889
## 30  83  87  91  95  98 107 112 114 106  98  86  81 34.73611  -92.33111
## 31  58  68  83  94 101 101 107 102  99  90  77  65 43.07472  -89.38417
## 32  83  86  90  94  99 106 107 106 106 102  91  85 32.36167  -86.27917
## 33  66  61  82  90  90  95  97  97  92  84  76  67 44.25944  -72.57583
## 34  78  84  89  91  96 109 107 106 105  99  88  79 36.16667  -86.78333
## 35  83  92  97 100 104 107 110 113 108  97  87  86 35.46861  -97.52139
## 36  64  73  79  88  96  98 104 104  98  90  74  64 47.03778 -122.90083
## 37  88  92 100 105 114 122 121 117 116 107  96  87 33.45000 -112.06700
## 38  68  75  88  98 105 112 117 114 108  98  87  77 44.37250 -100.32000
## 39  70  72  90  98  96  98 102 104 100  88  81  77 41.82361  -71.42222
## 40  80  84  94  95  99 105 105 105 104 100  88  81 35.76700  -78.63300
## 41  81  83  94  96 100 104 105 107 103  99  86  81 37.53300  -77.46700
## 42  79  80  90  98 107 112 114 112 109 102  86  72 38.58167 -121.49444
## 43  57  59  83  93  93 103 105 103  95  88  75  66 44.94417  -93.09361
## 44  68  72  80  93 100 105 108 108 104  93  74  72 44.93917 -123.03944
## 45  63  69  80  89  99 105 107 106 100  89  75  69 40.76083 -111.89111
## 46  65  73  77  84  96  99 101  96  94  87  75  65 35.66722 -105.96444
## 47  73  78  91  90 101 104 112 108 102  93  83  74 39.79944  -89.65500
## 48  83  89  91  95 102 105 104 103 102  95  89  84 30.45500  -84.25333
## 49  78  84  93  97 103 109 114 113 110  97  85  77 39.05583  -95.68944
```

```
## 50  73  76  87  93  99 100 106 105 101  94  83  76 40.22384  -74.76362
##    population.2019.est
## 1                96460
## 2                39174
## 3               506811
## 4                18681
## 5               978908
## 6               220236
## 7                73529
## 8               228959
## 9               692600
## 10               55916
## 11               46536
## 12               64235
## 13              131674
## 14              898553
## 15               43627
## 16              727211
## 17              214237
## 18               38079
## 19               27679
## 20               49528
## 21              122105
## 22               32315
## 23              345064
## 24              876384
## 25              160628
## 26               42838
## 27               32113
## 28              118210
## 29              289102
## 30              197312
## 31              259680
## 32              198525
## 33                7855
## 34              670820
## 35              655057
## 36               46478
## 37             1680992
## 38               13646
## 39              179883
## 40              474069
## 41              230436
## 42              513624
## 43              308096
## 44              174365
## 45              200567
## 46               84683
## 47              114230
## 48              194500
## 49              125310
## 50               83203
```

```r
high.cor = round( cor(high.X), digits=2);
# high.cor.p = rcorr(as.matrix(high.X), type="pearson");  # p-values for statistical significance ... #

# examine July (idx = 7)

as.data.frame( high.cor ) ; # so it will render nicely in RStudio
```

```
##                      Jan   Feb   Mar   Apr   May   Jun   Jul   Aug   Sep   Oct
## Jan                 1.00  0.92  0.76  0.57  0.43  0.39  0.25  0.41  0.62  0.71
## Feb                 0.92  1.00  0.80  0.63  0.62  0.53  0.45  0.59  0.74  0.79
## Mar                 0.76  0.80  1.00  0.87  0.73  0.56  0.53  0.67  0.76  0.82
## Apr                 0.57  0.63  0.87  1.00  0.82  0.68  0.65  0.75  0.79  0.81
## May                 0.43  0.62  0.73  0.82  1.00  0.83  0.85  0.85  0.86  0.81
## Jun                 0.39  0.53  0.56  0.68  0.83  1.00  0.90  0.86  0.87  0.78
## Jul                 0.25  0.45  0.53  0.65  0.85  0.90  1.00  0.91  0.86  0.73
## Aug                 0.41  0.59  0.67  0.75  0.85  0.86  0.91  1.00  0.90  0.78
## Sep                 0.62  0.74  0.76  0.79  0.86  0.87  0.86  0.90  1.00  0.88
## Oct                 0.71  0.79  0.82  0.81  0.81  0.78  0.73  0.78  0.88  1.00
## Nov                 0.89  0.89  0.89  0.76  0.65  0.56  0.46  0.57  0.74  0.86
## Dec                 0.94  0.89  0.81  0.65  0.46  0.41  0.27  0.46  0.65  0.72
## latitude           -0.83 -0.80 -0.68 -0.49 -0.40 -0.30 -0.15 -0.29 -0.46 -0.67
## longitude           0.07  0.01  0.39  0.34  0.08  0.01  0.02  0.04  0.07  0.14
## population.2019.est 0.40  0.42  0.36  0.35  0.38  0.48  0.31  0.31  0.44  0.39
##                      Nov   Dec latitude longitude population.2019.est
## Jan                 0.89  0.94    -0.83      0.07                0.40
## Feb                 0.89  0.89    -0.80      0.01                0.42
## Mar                 0.89  0.81    -0.68      0.39                0.36
## Apr                 0.76  0.65    -0.49      0.34                0.35
## May                 0.65  0.46    -0.40      0.08                0.38
## Jun                 0.56  0.41    -0.30      0.01                0.48
## Jul                 0.46  0.27    -0.15      0.02                0.31
## Aug                 0.57  0.46    -0.29      0.04                0.31
## Sep                 0.74  0.65    -0.46      0.07                0.44
## Oct                 0.86  0.72    -0.67      0.14                0.39
## Nov                 1.00  0.91    -0.82      0.17                0.40
## Dec                 0.91  1.00    -0.85      0.12                0.42
## latitude           -0.82 -0.85     1.00      0.01               -0.34
## longitude           0.17  0.12     0.01      1.00               -0.10
## population.2019.est 0.40  0.42    -0.34     -0.10                1.00
```

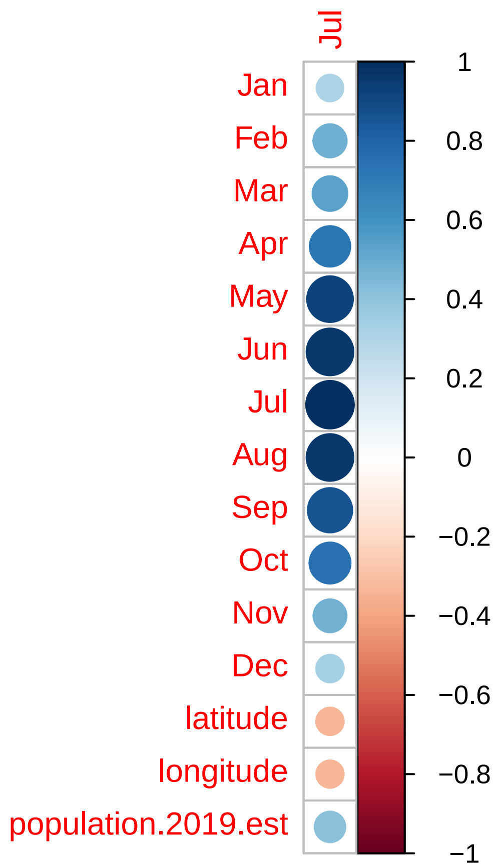
```r
high.cor.july = high.cor[,7];
high.cor.july;
```

```
##                 Jan                 Feb                 Mar                 Apr
##                0.25                0.45                0.53                0.65
##                 May                 Jun                 Jul                 Aug
##                0.85                0.90                1.00                0.91
##                 Sep                 Oct                 Nov                 Dec
##                0.86                0.73                0.46                0.27
##            latitude           longitude population.2019.est
##               -0.15                0.02                0.31
```

```r
library(corrgram)
```

```
##
## Attaching package: 'corrgram'

## The following object is masked from 'package:lattice':
##
##     panel.fill
```

```r
corrplot::corrplot(cor(high.cor)[,7, drop=FALSE],cl.pos = 'r', cl.ratio =3.0 )
```



Describe the correlation of July in "Record high F (C)" to the other numeric factors printed above.

x is correlated with y (0.00). This correlation is positive/negative which means … This correlation is strong/weak because … overall, this suggests …

- July perfectly correlates with July (1.00). This correlation is positive and very strong. This is because they are the same data.
- With the months, you can note each, or plot a trend showing them, and discussing them briefly as a trend.
- latitude is a measure of north/south, so be certain to apply the correlation value with some meaning. be certain you know which direction is positive or negative to correctly interpret the sign of the correlation.
- longitude is a measure of east/west, so be certain …

- population is the size of the city
- intuitively, which months do you think correlate most with latitude for this data? which correlate the least? is the correlation always the same sign (positive/negative), or does it change? [You can use the dataframe output to do this analysis, or create your own subset]

```
library(Hmisc); # p-values for correlation

low = subsetDataFrame(climate, c("key", "units"), "==", c("Record low F (C)",1));
low = merge(low, capitals, by=c("capital","state"));

low.X = low[,c(5:18,21)]; # numeric data
low.cor = round( cor(low.X), digits=2);
# low.cor.p = rcorr(as.matrix(low.X), type="pearson");  # p-values for statistical significance ... # s

# examine Jan (idx = 1)

as.data.frame( low.cor ) ; # so it will render nicely in RStudio
```

```
##                       Jan   Feb   Mar   Apr   May   Jun   Jul   Aug   Sep   Oct
## Jan                  1.00  0.95  0.93  0.92  0.89  0.80  0.74  0.77  0.90  0.87
## Feb                  0.95  1.00  0.94  0.92  0.86  0.75  0.70  0.72  0.88  0.86
## Mar                  0.93  0.94  1.00  0.92  0.85  0.73  0.71  0.72  0.85  0.85
## Apr                  0.92  0.92  0.92  1.00  0.91  0.82  0.78  0.81  0.93  0.89
## May                  0.89  0.86  0.85  0.91  1.00  0.93  0.88  0.88  0.95  0.93
## Jun                  0.80  0.75  0.73  0.82  0.93  1.00  0.92  0.91  0.88  0.82
## Jul                  0.74  0.70  0.71  0.78  0.88  0.92  1.00  0.96  0.87  0.77
## Aug                  0.77  0.72  0.72  0.81  0.88  0.91  0.96  1.00  0.87  0.77
## Sep                  0.90  0.88  0.85  0.93  0.95  0.88  0.87  0.87  1.00  0.94
## Oct                  0.87  0.86  0.85  0.89  0.93  0.82  0.77  0.77  0.94  1.00
## Nov                  0.91  0.92  0.90  0.89  0.89  0.81  0.75  0.75  0.92  0.93
## Dec                  0.97  0.95  0.93  0.92  0.91  0.82  0.78  0.79  0.91  0.90
## latitude            -0.72 -0.64 -0.69 -0.71 -0.72 -0.75 -0.75 -0.80 -0.72 -0.66
## longitude           -0.33 -0.36 -0.31 -0.25 -0.12 -0.05  0.09  0.02 -0.09 -0.04
## population.2019.est  0.34  0.37  0.32  0.37  0.35  0.39  0.46  0.46  0.40  0.32
##                       Nov   Dec latitude longitude population.2019.est
## Jan                  0.91  0.97    -0.72     -0.33                0.34
## Feb                  0.92  0.95    -0.64     -0.36                0.37
## Mar                  0.90  0.93    -0.69     -0.31                0.32
## Apr                  0.89  0.92    -0.71     -0.25                0.37
## May                  0.89  0.91    -0.72     -0.12                0.35
## Jun                  0.81  0.82    -0.75     -0.05                0.39
## Jul                  0.75  0.78    -0.75      0.09                0.46
## Aug                  0.75  0.79    -0.80      0.02                0.46
## Sep                  0.92  0.91    -0.72     -0.09                0.40
## Oct                  0.93  0.90    -0.66     -0.04                0.32
## Nov                  1.00  0.94    -0.70     -0.12                0.28
## Dec                  0.94  1.00    -0.71     -0.24                0.33
## latitude            -0.70 -0.71     1.00      0.01               -0.34
## longitude           -0.12 -0.24     0.01      1.00               -0.10
## population.2019.est  0.28  0.33    -0.34     -0.10                1.00
```

```r
low
```

```
##           capital          state units              key Jan Feb Mar Apr May Jun
## 1          Albany       New York     1 Record low F (C) -28 -22 -21   9  26  35
## 2       Annapolis       Maryland     1 Record low F (C)  -8  -6  10  13  32  35
## 3         Atlanta        Georgia     1 Record low F (C)  -8  -9  10  25  37  39
## 4         Augusta          Maine     1 Record low F (C) -33 -23 -11   9  26  36
## 5          Austin          Texas     1 Record low F (C)  -2  -1  18  30  40  51
## 6     Baton Rouge      Louisiana     1 Record low F (C)   9   2  20  31  40  53
## 7        Bismarck   North Dakota     1 Record low F (C) -45 -45 -36 -12  13  30
## 8           Boise          Idaho     1 Record low F (C) -28 -15   5  11  22  30
## 9          Boston  Massachusetts     1 Record low F (C) -13 -18  -8  11  31  41
## 10    Carson City         Nevada     1 Record low F (C) -27 -22  -5   3  18  25
## 11     Charleston  West Virginia     1 Record low F (C) -16 -12  -5  18  26  33
## 12       Cheyenne        Wyoming     1 Record low F (C) -38 -34 -21  -8   8  25
## 13       Columbia South Carolina     1 Record low F (C)  -1  -2   4  26  34  44
## 14       Columbus           Ohio     1 Record low F (C) -22 -20  -6  14  25  35
## 15        Concord  New Hampshire     1 Record low F (C) -35 -37 -20   4  21  30
## 16         Denver       Colorado     1 Record low F (C) -29 -25 -11  -2  19  30
## 17     Des Moines           Iowa     1 Record low F (C) -30 -26 -22   9  26  37
## 18          Dover       Delaware     1 Record low F (C)  -7 -11   7  14  28  41
## 19      Frankfort       Kentucky     1 Record low F (C) -27 -16  -3  16  27  36
## 20     Harrisburg   Pennsylvania     1 Record low F (C) -22 -13  -1  11  30  40
## 21       Hartford    Connecticut     1 Record low F (C) -26 -24  -6   9  28  37
## 22         Helena        Montana     1 Record low F (C) -42 -42 -30 -10  17  30
## 23       Honolulu         Hawaii     1 Record low F (C)  52  52  53  56  60  63
## 24   Indianapolis        Indiana     1 Record low F (C) -27 -21  -7  18  27  37
## 25        Jackson    Mississippi     1 Record low F (C)  -5   1  15  27  36  47
## 26 Jefferson City       Missouri     1 Record low F (C) -23 -25 -16  13  24  38
## 27         Juneau         Alaska     1 Record low F (C) -20 -15  -5  12  26  32
## 28        Lansing       Michigan     1 Record low F (C) -29 -37 -25  -6  19  27
## 29        Lincoln       Nebraska     1 Record low F (C) -33 -26 -19   3  24  39
## 30    Little Rock       Arkansas     1 Record low F (C)  -8 -12  11  28  38  46
## 31        Madison      Wisconsin     1 Record low F (C) -37 -29 -29   0  19  31
## 32     Montgomery        Alabama     1 Record low F (C)   0  -5  17  28  40  48
## 33     Montpelier        Vermont     1 Record low F (C) -34 -29 -18   2  20  29
## 34      Nashville      Tennessee     1 Record low F (C) -17 -13   2  23  34  42
## 35  Oklahoma City       Oklahoma     1 Record low F (C) -11 -17   1  20  32  46
## 36        Olympia     Washington     1 Record low F (C)  -8  -1   9  23  25  30
## 37        Phoenix        Arizona     1 Record low F (C)  16  24  25  35  39  49
## 38         Pierre   South Dakota     1 Record low F (C) -33 -35 -19   1  21  34
## 39     Providence   Rhode Island     1 Record low F (C) -13 -17   1  11  29  39
## 40        Raleigh North Carolina     1 Record low F (C)  -9  -2  11  23  29  38
## 41       Richmond       Virginia     1 Record low F (C) -12 -10  10  19  31  40
## 42     Sacramento     California     1 Record low F (C)  19  21  29  34  37  43
## 43     Saint Paul      Minnesota     1 Record low F (C) -29 -32 -25   3  21  36
## 44          Salem         Oregon     1 Record low F (C) -10  -4  12  23  25  32
## 45 Salt Lake City           Utah     1 Record low F (C) -22 -30   0  14  25  32
## 46       Santa Fe     New Mexico     1 Record low F (C) -14 -24  -6  10  19  28
## 47    Springfield       Illinois     1 Record low F (C) -22 -24 -12  16  28  39
## 48    Tallahassee        Florida     1 Record low F (C)   6  -2  20  29  34  46
## 49         Topeka         Kansas     1 Record low F (C) -23 -25  -7  10  26  36
## 50        Trenton     New Jersey     1 Record low F (C) -13 -14   1  11  33  41
##    Jul Aug Sep Oct Nov Dec latitude  longitude capital.since area.sq.miles
```

```
## 1   40  34  24  16 -11 -22 42.65250  -73.75722          1797          21.40
## 2   50  46  37  26  13  -1 38.97306  -76.50111          1694           6.73
## 3   53  55  36  28   3   0 33.75500  -84.39000          1868         133.50
## 4   43  39  28  21   4 -15 44.31056  -69.77944          1832          55.40
## 5   57  58  41  30  20   4 30.26722  -97.74306          1839         305.10
## 6   58  58  43  30  21   8 30.44750  -91.17861          1880          76.80
## 7   32  32  10 -10 -30 -43 46.80833 -100.78361          1883          26.90
## 8   35  32  23  11 -10 -25 43.61583 -116.20167          1865          63.80
## 9   50  46  34  25  -2 -17 42.35806  -71.06361          1630          89.60
## 10  33  26  17   6  -5 -26 39.16444 -119.76694          1861         143.40
## 11  46  41  32  17   6 -17 38.34722  -81.63333          1885          31.60
## 12  33  25   8  -5 -21 -28 41.14000 -104.82028          1869          21.10
## 13  54  53  40  23  12   4 34.00056  -81.03472          1786         125.20
## 14  43  39  31  17  -5 -17 39.96222  -83.00056          1816         210.30
## 15  35  29  20  10 -17 -24 43.20667  -71.53806          1808          64.30
## 16  42  40  17  -2 -18 -25 39.73917 -104.99028          1867         153.30
## 17  47  40  26   7 -10 -22 41.59083  -93.62083          1857          75.80
## 18  45  35  30  25  11  -3 39.15806  -75.52444          1777          22.40
## 19  48  41  30  20  -1 -17 38.20000  -84.86700          1792          14.70
## 20  49  45  30  23  10  -8 40.26972  -76.87556          1812           8.11
## 21  44  36  30  17   1 -18 41.76250  -72.67417          1875          17.30
## 22  36  28   6  -8 -39 -40 46.59111 -112.02028          1875          14.00
## 23  63  63  65  61  57  54 21.30694 -157.85833          1845          68.40
## 24  46  41  30  20  -5 -23 39.76861  -86.15806          1825         361.50
## 25  51  54  35  26  15   4 32.29889  -90.18472          1821         104.90
## 26  42  41  29  14   1 -21 38.57667  -92.17361          1826          27.30
## 27  39  32  28  13  -7 -10 58.30000 -134.41600          1906        2716.70
## 28  31  26  19  10  -5 -25 42.73361  -84.54667          1847          35.00
## 29  45  39  26   3 -15 -27 40.80889  -96.67889          1867          74.60
## 30  54  52  37  27  10  -1 34.73611  -92.33111          1821         116.20
## 31  36  35  25  12 -14 -28 43.07472  -89.38417          1838          68.70
## 32  59  56  39  26  13   5 32.36167  -86.27917          1846         159.80
## 33  35  31  20  14  -7 -27 44.25944  -72.57583          1805          10.20
## 34  51  47  36  26  -1 -10 36.16667  -86.78333          1826         525.90
## 35  53  49  35  16   9  -8 35.46861  -97.52139          1910         620.30
## 36  35  33  25  14  -1  -7 47.03778 -122.90083          1853          16.70
## 37  63  58  47  34  27  22 33.45000 -112.06700          1912         517.60
## 38  42  39  21   4 -18 -31 44.37250 -100.32000          1889          13.00
## 39  48  40  32  20   6 -12 41.82361  -71.42222          1900          18.50
## 40  48  46  37  19  11   0 35.76700  -78.63300          1792         114.60
## 41  51  46  35  21  10  -2 37.53300  -77.46700          1780          60.10
## 42  47  48  44  34  27  17 38.58167 -121.49444          1854          97.90
## 43  45  42  26  15 -14 -29 44.94417  -93.09361          1849          52.80
## 44  35  30  26  19   9 -12 44.93917 -123.03944          1855          45.70
## 45  40  37  27  14 -14 -21 40.76083 -111.89111          1858         109.10
## 46  37  36  26   5 -12 -17 35.66722 -105.96444          1610          37.30
## 47  48  43  31  13  -3 -21 39.79944  -89.65500          1837          54.00
## 48  57  57  40  29  13  10 30.45500  -84.25333          1824          95.70
## 49  43  40  29  16  -5 -26 39.05583  -95.68944          1856          56.00
## 50  48  41  31  22  12  -7 40.22384  -74.76362          1784           7.66
##    population.2019.est population.2019.est.MSA population.2019.est.CSA
## 1                96460                  880381                 1167594
## 2                39174                 2800053                 9814928
## 3               506811                 6020364                 6853392
```

```
## 4             18681           122302          NA
## 5            978908          2227083          NA
## 6            220236           854884          NA
## 7             73529           128949          NA
## 8            228959           749202      831235
## 9            692600          4873019     8287710
## 10            55916            55916      637973
## 11            46536           257074      776694
## 12            64235            99500          NA
## 13           131674           838433      963048
## 14           898553          2122271     2525639
## 15            43627           151391     8287710
## 16           727211          2967239     3617927
## 17           214237           699292      877991
## 18            38079           180786     7209620
## 19            27679            73663      745033
## 20            49528           577941     1271801
## 21           122105          1204877     1470083
## 22            32315            77414          NA
## 23           345064           974563          NA
## 24           876384          2074537     2457286
## 25           160628           594806      674340
## 26            42838           151235          NA
## 27            32113            32113          NA
## 28           118210           550391          NA
## 29           289102           336374      357887
## 30           197312           742384      908941
## 31           259680           664865      892661
## 32           198525           373290      461516
## 33             7855               NA          NA
## 34           670820          1934317     2062547
## 35           655057          1408950     1481542
## 36            46478           290536     4903675
## 37          1680992          4948203     5002221
## 38            13646            20672          NA
## 39           179883          1624578     8287710
## 40           474069          1390785     2079687
## 41           230436          1291900          NA
## 42           513624          2363730     2639124
## 43           308096          3654908     4027861
## 44           174365           433903     3259710
## 45           200567          1232696     2641048
## 46            84683           150358     1158464
## 47           114230           206868      306399
## 48           194500           387227          NA
## 49           125310           231969          NA
## 50            83203           367430    22589036
##    city.rank.in.state                                               url
## 1                   6     https://en.wikipedia.org/wiki/Albany,_New_York
## 2                   7   https://en.wikipedia.org/wiki/Annapolis,_Maryland
## 3                   1             https://en.wikipedia.org/wiki/Atlanta
## 4                   8       https://en.wikipedia.org/wiki/Augusta,_Maine
## 5                   4        https://en.wikipedia.org/wiki/Austin,_Texas
## 6                   2 https://en.wikipedia.org/wiki/Baton_Rouge,_Louisiana
```

```
## 7                      2    https://en.wikipedia.org/wiki/Bismarck,_North_Dakota
## 8                      1              https://en.wikipedia.org/wiki/Boise,_Idaho
## 9                      1                    https://en.wikipedia.org/wiki/Boston
## 10                     6       https://en.wikipedia.org/wiki/Carson_City,_Nevada
## 11                     1 https://en.wikipedia.org/wiki/Charleston,_West_Virginia
## 12                     1          https://en.wikipedia.org/wiki/Cheyenne,_Wyoming
## 13                     2  https://en.wikipedia.org/wiki/Columbia,_South_Carolina
## 14                     1            https://en.wikipedia.org/wiki/Columbus,_Ohio
## 15                     3    https://en.wikipedia.org/wiki/Concord,_New_Hampshire
## 16                     1                    https://en.wikipedia.org/wiki/Denver
## 17                     1         https://en.wikipedia.org/wiki/Des_Moines,_Iowa
## 18                     2          https://en.wikipedia.org/wiki/Dover,_Delaware
## 19                    15       https://en.wikipedia.org/wiki/Frankfort,_Kentucky
## 20                     9  https://en.wikipedia.org/wiki/Harrisburg,_Pennsylvania
## 21                     3     https://en.wikipedia.org/wiki/Hartford,_Connecticut
## 22                     6          https://en.wikipedia.org/wiki/Helena,_Montana
## 23                     1                  https://en.wikipedia.org/wiki/Honolulu
## 24                     1              https://en.wikipedia.org/wiki/Indianapolis
## 25                     1      https://en.wikipedia.org/wiki/Jackson,_Mississippi
## 26                    15  https://en.wikipedia.org/wiki/Jefferson_City,_Missouri
## 27                     3            https://en.wikipedia.org/wiki/Juneau,_Alaska
## 28                     5          https://en.wikipedia.org/wiki/Lansing,_Michigan
## 29                     2          https://en.wikipedia.org/wiki/Lincoln,_Nebraska
## 30                     1     https://en.wikipedia.org/wiki/Little_Rock,_Arkansas
## 31                     2        https://en.wikipedia.org/wiki/Madison,_Wisconsin
## 32                     2       https://en.wikipedia.org/wiki/Montgomery,_Alabama
## 33                     6       https://en.wikipedia.org/wiki/Montpelier,_Vermont
## 34                     1      https://en.wikipedia.org/wiki/Nashville,_Tennessee
## 35                     1             https://en.wikipedia.org/wiki/Oklahoma_City
## 36                    24       https://en.wikipedia.org/wiki/Olympia,_Washington
## 37                     1         https://en.wikipedia.org/wiki/Phoenix,_Arizona
## 38                     8      https://en.wikipedia.org/wiki/Pierre,_South_Dakota
## 39                     1  https://en.wikipedia.org/wiki/Providence,_Rhode_Island
## 40                     2   https://en.wikipedia.org/wiki/Raleigh,_North_Carolina
## 41                     4        https://en.wikipedia.org/wiki/Richmond,_Virginia
## 42                     6    https://en.wikipedia.org/wiki/Sacramento,_California
## 43                     2     https://en.wikipedia.org/wiki/Saint_Paul,_Minnesota
## 44                     3             https://en.wikipedia.org/wiki/Salem,_Oregon
## 45                     1            https://en.wikipedia.org/wiki/Salt_Lake_City
## 46                     4      https://en.wikipedia.org/wiki/Santa_Fe,_New_Mexico
## 47                     6     https://en.wikipedia.org/wiki/Springfield,_Illinois
## 48                     7      https://en.wikipedia.org/wiki/Tallahassee,_Florida
## 49                     4            https://en.wikipedia.org/wiki/Topeka,_Kansas
## 50                    10       https://en.wikipedia.org/wiki/Trenton,_New_Jersey
##    st
## 1  NY
## 2  MD
## 3  GA
## 4  ME
## 5  TX
## 6  LA
## 7  ND
## 8  ID
## 9  MA
```

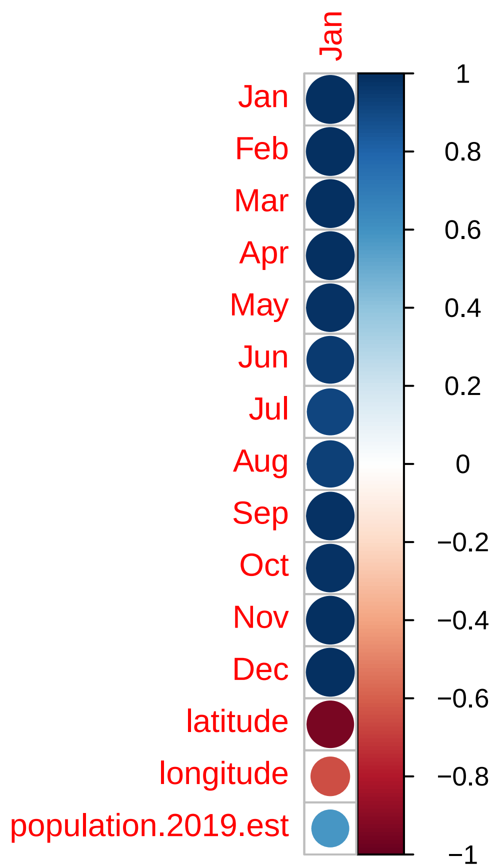
```
## 10 NV
## 11 WV
## 12 WY
## 13 SC
## 14 OH
## 15 NH
## 16 CO
## 17 IA
## 18 DE
## 19 KY
## 20 PA
## 21 CT
## 22 MT
## 23 HI
## 24 IN
## 25 MS
## 26 MO
## 27 AK
## 28 MI
## 29 NE
## 30 AR
## 31 WI
## 32 AL
## 33 VT
## 34 TN
## 35 OK
## 36 WA
## 37 AZ
## 38 SD
## 39 RI
## 40 NC
## 41 VA
## 42 CA
## 43 MN
## 44 OR
## 45 UT
## 46 NM
## 47 IL
## 48 FL
## 49 KS
## 50 NJ
```

```
low.cor.january = low.cor[,1];
low.cor.january;
```

```
##                Jan               Feb               Mar               Apr
##               1.00              0.95              0.93              0.92
##                May               Jun               Jul               Aug
##               0.89              0.80              0.74              0.77
##                Sep               Oct               Nov               Dec
##               0.90              0.87              0.91              0.97
##           latitude         longitude population.2019.est
##              -0.72             -0.33              0.34
```

Describe the correlation of January in "Record low F (C)" to the other numeric factors printed above.

```
library(corrgram)
corrplot::corrplot(cor(low.cor)[,1, drop=FALSE], cl.pos = 'r', cl.ratio =3.0 )
```



Similar to "high" writeup, but for the "low" data.

"So What" is DATA ANALYSIS?

In the social sciences (e.g., Karl Weick), the concept of "sense making" refers to "the process by which people give meaning to their collective experiences". I have used this framework in my high-technology innovation research (See Figure 1 of http://www.mshaffer.com/arizona/pdf/LoneGenius.pdf, my rubric concept comes from learning-theory growth models: Nascent, Adolescent, Mature.)

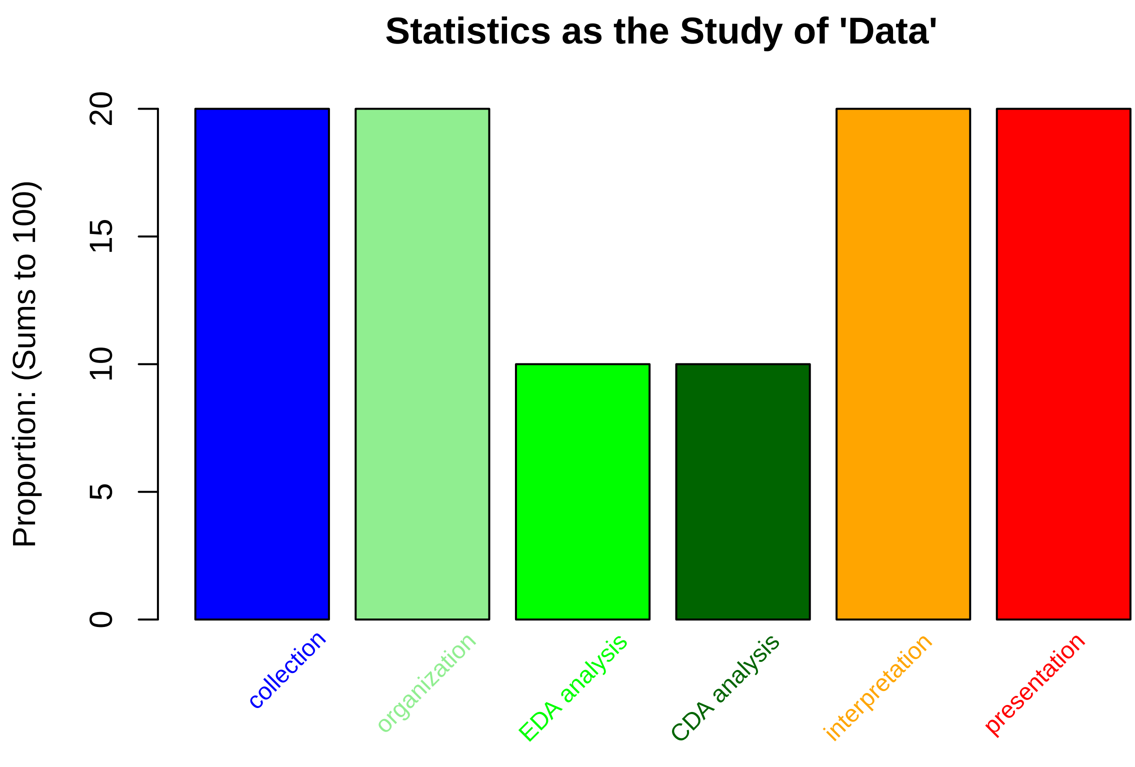
This final topic is reflective: we are thinking about how we think.

Statistics

The syllabus defined statistics as "the discipline that concerns the collection, organization, analysis, interpretation and presentation of data." (See https://en.wikipedia.org/wiki/Statistics)

There are 5 elements mentioned: collection, organization, analysis, interpretation, and presentation of "data". Are those equally weighted? That is, should we devote 20% of our time to each of those? Now, consider the "analysis" stage. I have suggested there are two camps: exploratory and confirmatory data analysis. Are those equally weighted? That is, should we devote 50% of our time to each of those? Now, in an "equally-likely" scenario, we would have.

```
x = c(20,20,10,10,20,20);
x.labels = c("collection", "organization", "EDA analysis", "CDA analysis", "interpretation", "presentat
x.colors = c("blue", "lightgreen", "green", "darkgreen", "orange", "red");

barplot(x,
        col = x.colors,
        ylim = c(0, 20),
        ylab = "Proportion: (Sums to 100)",
        main="Statistics as the Study of 'Data'");


text(1.14* (1:6), par("usr")[3], col = x.colors, labels = x.labels, srt = 45, adj = c(1.1,1.1), xpd = T
```



Data Analytics

Source: https://data-analytics.wsu.edu/197-2/ (Accessed October 2010)

"Data analytics is the application of powerful new methods—drawn from computer science, mathematics and statistics, and domain sciences—to collect, curate, analyze, discover and communicate knowledge from 'big data'." https://data-analytics.wsu.edu/ (Accessed October 2010)

Importance of 'Data' I love data.

I also love math/physics. I also love exploratory data analysis. I also love computational statistics or statistical computing https://en.wikipedia.org/wiki/Computational_statistics. I also love thinking about developing the one graphic to summarize data most effectively.

Apprenticeship as Learning a Trade The idea of sharing in the learning process is an important aspect of the apprenticeship model. You are learning a trade (data analytics). I have experience in this trade. My job as the instructor is to provide you with a variety of "situated-learning" experiences To help you understand the nature of the trade. This exam is an example of such an experience.

Tools of the Trade Below are the core requirements for the data analytics program:

- Calculus and linear algebra (10 credits)
- Computer science fundamentals (11 credits)
- Machine learning and data management (9 credits)
- Statistics (15 credits)
- Data analytics introduction, ethics & project-focused * capstone experience (9 credits)

These are not the tools of the trade, but hopefully, they introduce you to key tools of the trade. What exactly are tools of the trade? [You will have an opportunity to write a response below.]

Dimensional Reduction, an Axiomatic View This video was recently shared with me that highlights some distinctions among persons practicing various forms of data analysis https://www.youtube.com/watch?v=uHGlCi9jOWY. As an orthogonal projection, I would create two axes. On the horizontal axis (x-axis), I would place "theory of data" to the left and "application of data" toward the right. On the vertical axis (y-axis), I would place "care for data integrity" at the top and "less care for data integrity" at the bottom.

Skills of the Trade As someone that is coming from industry, having hired young people like you out of Computer Science, Electrical-Computer Engineering, I have opinions related to skills of the trade.

- Can you acquire an appreciation for "data intimacy"?
- Can you track and document how data is curated?
- Can you track and document the analyses you perform? Can you recreate them? Do you have basic version-control protocols in place?
- Can you view data from multiple perspectives and synthesize those perspectives to identify the central them of the data? Can you be objective? Can you try and identify objective metrics to enlighten your understanding about the essence of data?
- Can you experiment with different visualizations in search of an optimal "one graphic" result? Do you have practice using various visualization tools? Can you comprehend which visualization tool is appropriate for messaging (communicating results) to a particular audience?
- Can you communicate and defend your findings to a particular audience? Are your communications professional? Is the final work product both simple and comprehensive: simple in its summary findings and comprehensive in its ability to be replicated and audited as necessary.

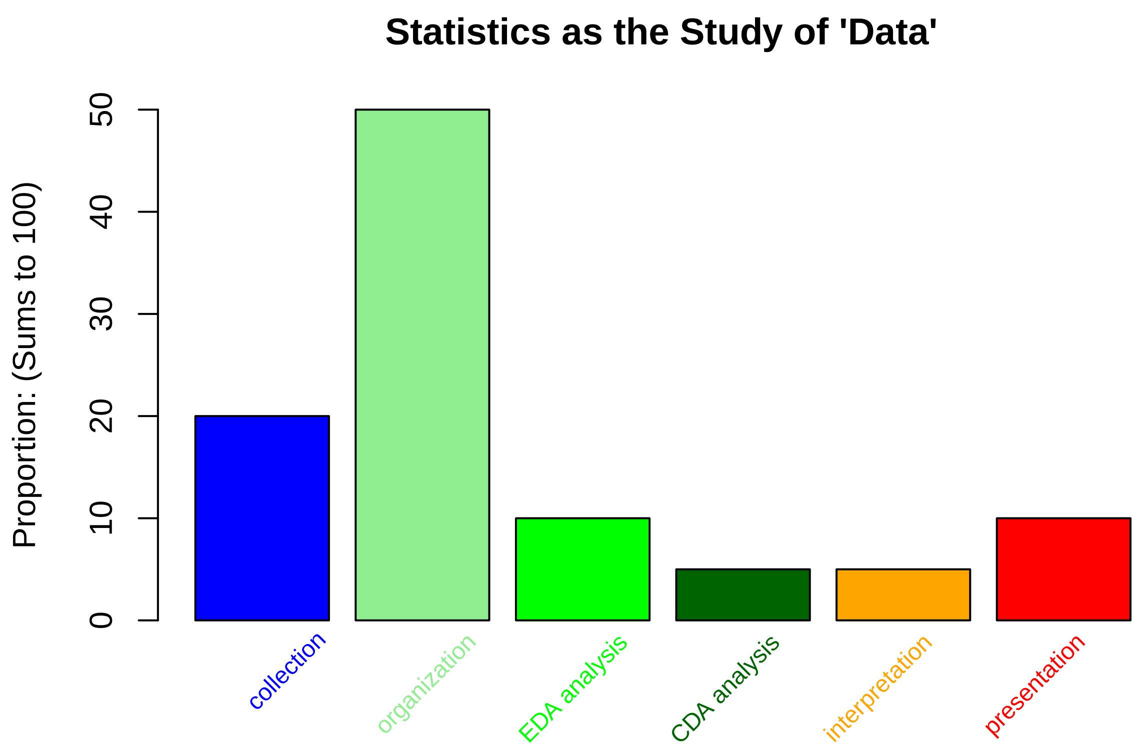
(20 points) YOUR OPINION OF DATA ANALYTICS

[This is worth 20 points.

Specifically, address:

(1) what proportion of "statistics" should be divided among: collection, organization, analysis, interpretation, and presentation of "data" … providing a `barplot` of your opinion within your response would seem appropriate

```r
x = c(20,50,10,5,5,10);  ## change these values and discuss ...
x.labels = c("collection", "organization", "EDA analysis", "CDA analysis", "interpretation", "presentati
x.colors = c("blue", "lightgreen", "green", "darkgreen", "orange", "red");

barplot(x,
        col = x.colors,
        ylim = c(0, max(x)),
        ylab = "Proportion: (Sums to 100)",
        main="Statistics as the Study of 'Data'");


text(1.14* (1:6), par("usr")[3], col = x.colors, labels = x.labels, srt = 45, adj = c(1.1,1.1), xpd = TR
```



(2) what tools of the trade should you be acquiring from the core courses? how are you doing in that acquisition process (e.g., tool X is . . . and right now I feel like my understanding/proficiency of tool X . . .) . . .

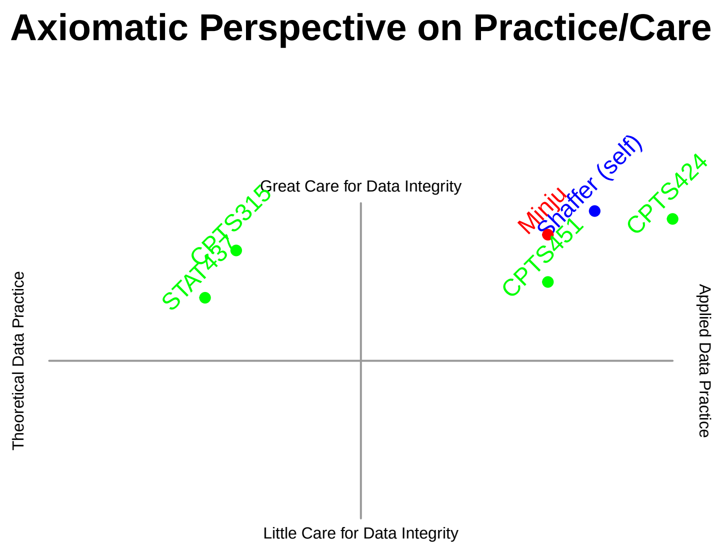
(3) utilize the provided `plot` script to place the coure-course categories on the proposed x-y graph related to analytics practice (Applied vs Theoretical) and care of data integrity (Great Care vs Little Care) . . . Also place your personal assessment on the plot script provided

(4) evaluate your skill-level on the six "skills of the trade": Emerging (Nascent), Developing (Adolescent), Mastering (Mature). explain your evaluation and include other important skills you believe are relevant that are not included.

(5) Any other comments you would like to share.

]

```r
# x is -1 for perfectly theoretical
# x is 1 for perfectly applied

# y is -1 for no care whatsoever for data integrity
# y is 1 is perfect care for data integrity

########################### basic plot setup #####
plot(0,0, col="white",
  ylim=c(-1.5,1.5), xlim=c(-1.5,1.5),
  xlab = "",
  ylab = "",
  xaxt = 'n', bty = 'n', yaxt = 'n',
  main = "Axiomatic Perspective on Practice/Care",
  );
segments(-1,0,1,0, col="#999999");
segments(0,-1,0,1, col="#999999");
text(-1.1,0, "Theoretical Data Practice", cex=0.5, srt = 90);
text(1.1,0, "Applied Data Practice", cex=0.5, srt = -90);
text(0,1.1, "Great Care for Data Integrity", cex=0.5, srt = 0);
text(0,-1.1, "Little Care for Data Integrity", cex=0.5, srt = 0);
########################### basic plot setup #####


########################### you can add elements here #####
## this point represents the professor's self-perception
points(0.75, 0.95, pch=20, col="blue")
text(0.75, 0.95, "Shaffer (self)", col="blue", cex=0.75, srt = 45, pos=3)

points(0.60, 0.80, pch=20, col="red")
text(0.60, 0.80, "Minju", col="red", cex=0.75, srt = 45, pos=3)

points(-0.40, 0.70, pch=20, col="green")
text(-0.40, 0.70, "CPTS315", col="green", cex=0.75, srt = 45, pos=3)

points(0.60, 0.50, pch=20, col="green")
text(0.60, 0.50, "CPTS451", col="green", cex=0.75, srt = 45, pos=3)

points(-0.50, 0.40, pch=20, col="green")
text(-0.50, 0.40, "STAT437", col="green", cex=0.75, srt = 45, pos=3)

points(1.00, 0.90, pch=20, col="green")
text(1.00, 0.90, "CPTS424", col="green", cex=0.75, srt = 45, pos=3)
```




```
#############  TODO ###### ... maybe change color for each data point

# https://brand.wsu.edu/visual/colors/
# crimson = #981e32
# you need to change the x,y from 0,0 ...
# you can change col ... cex (font size), srt (angle), and pos = 1,2,3,4
#
# points(0, 0, pch=20, col="#981e32");
# text(0, 0, "Student (self)", col="#981e32", cex=0.75, srt = 45, pos=3);
#
# ## evaluate the Course Categories of Tools of the Trade
# ## give them a score
#
# points(0, 0, pch=20, col="#981e32");
# text(0, 0, "Math(s)", col="#981e32", cex=0.5, srt = 45, pos=3);
#
#
# points(0, 0, pch=20, col="#981e32");
# text(0, 0, "Computer Science", col="#981e32", cex=0.5, srt = 45, pos=3);
#
# points(0, 0, pch=20, col="#981e32");
# text(0, 0, "Machine learning", col="#981e32", cex=0.5, srt = 45, pos=3);
#
# points(0, 0, pch=20, col="#981e32");
# text(0, 0, "Statistics", col="#981e32", cex=0.5, srt = 45, pos=3);
#
```

```
# points(0, 0, pch=20, col="#981e32");
# text(0, 0, "Data analytics", col="#981e32", cex=0.5, srt = 45, pos=3);
#
# # You have a track (e.g., Business)
# points(0, 0, pch=20, col="#981e32");
# text(0, 0, "Core discipline", col="#981e32", cex=0.5, srt = 45, pos=3);
```