

Guide 1: Obtaining State Weather Station Data

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1 Introduction

1.1 Goals

Using a list of active weather stations in the United States, we will download the data from atleast stations and write weather station data csv files.

1.2 Selected History of Climate Science

Geologists have known the climate has been changing over the Earth's history. But what causes these changes has been a major research area for over 100 years. There are numerous drivers that contribute to changing climates – including the arrangement of the continents on the planet, the distance to the sun, energy generated by the sun, volanic activity, and the composition of the Earth's atmosphere.

It's the last one that we'll spend time because the Earth's temperature are changing pretty dramatically over the last 100 years and the cause is no mystery – the human activity that has released carbon dioxide (CO₂) into the atmosphere. The two main sources of CO₂ is from land use change, e.g. deforestation, and the burning of fossil fuels, e.g. coal, oil, and natural gas.

The first person to propose the role of CO₂ on the Earth's atmosphere was a Swedish scientist Svante Arrhenius, who figured out that CO₂ absorbs infarred light (Rodhe et al., 1997). Moreover, he deduced that the Earth's temperature was actually warmer than it might otherwise be if CO₂ was not part of the Earth's atmosphere.

1.3 Why Look at Individual Stations?

I don't believe there is a single, perfect way to analyze and communicate climate change. However, one of the strengths of the global network of weather stations is that they capture weather as experienced by local communities. While individual stations may not always reflect broader regional or global trends, they provide a crucial mechanism for linking local experiences to larger-scale climate processes.

That said, some individuals may focus solely on local patterns and remain unconvinced of the broader context. For those audiences, alternative approaches to communicating climate data may be more effective. Additionally, some may deliberately use local patterns to dismiss or ignore trends observed in other regions.

Moreover, the impacts of climate change are highly specific to each region. Even when individuals understand how climate change affects their own community, they may struggle to grasp how different and often more severe its effects are on other populations, particularly those that are more vulnerable.

Recognizing these challenges, we can approach this project with an awareness of these limitations and aim to address them in later stages.

1.4 Approach

1.4.1 NOAA Data Records

The US National Oceanic and Atmospheric Administration (NOAA) maintains several sources of digital weather data from the USA and beyond. These data have been collected from stations around the country to support a wide range of human activities that include farming, aviation, shipping, and even armed conflict.

At various times, these records have been used to evaluate long-term climate change with varying success. Without a doubt, these data are not perfect, but they remain that foundation of an effective and professionally maintained environmental monitoring program that engenders integrity, even when facing budget cuts.

We use these data to select for a station with a long record for each state in the USA. Future projects might evaluate the record for stations around the world, but we will see about that.

1.4.2 R Programming Language

R is an open source programming environment that has become one of the most popular tools for statisticians and data scientists. Capitalizing on the open source framework, a wide range of libraries or packages have been developed to facilitate data processing, analysis, and graphical displays.

1.5 Revised Document Structure

Based on some feedback in the last week, I have re-organized the document with bullets of the steps and then the code. In the following sections, I'll describe about "what the code does and why". But several folks see the text and get tuned out.

There are two weaknesses with this approach that I can see. First, if the code does not work, you will have a really hard time figuring out why, since you have no idea what the code is supposed to do. Second, if the code works, you will not really be learning any R coding. Just how to copy and paste.

I have created a bunch of functions, which can then be used to collect Let's try this and see how it works!

1.6 Preparing R for the Project

I suggest you do the following to prepare:

1. Create a folder for the project, I suggest "Regional_Climate_Trends". Note that there are no spaces in the folder name.
2. Next create a new R markdown file to write your code. Name and save it in your project folder. (For details see Section 3.1)
3. Create a folder inside the Regional_Climate_Trends folder called "Data". This will be the location of the data you download.
4. Download the file `oldest.activestation.csv` from the Canvas page and upload it to the directory you created in the previous step.
5. Download the file called `Guide1functions.R` from the Canvas page and upload it to the directory you created in the previous step.
6. Open the file in Rstudio and run the code, using the "source" action item near the top, right of the editor window.

2 R Functions for Getting Weather Station Data

2.1 Marc's Custom Functions: `Guide1functions.R`

These functions are designed so you don't have to type all the code! But check to see if they work for you, because they can (apparently) break really easily.

From the Canvas page, go to the `Guide1functions.R` code and download the file to your computer. Then upload the file to a directory in Rstudio. I suggest you create a project called "Regional_Climate_Trends" and then upload the file to that directory. Please note, avoid spaces in your directory names.

Open the file in Rstudio and run the code, using the "source" action item near the top, right of the editor pane (Figure 1).

The function have been written to the R Environment and you can close `Guide1.functions.R` file. We don't need any more. However, if you'd like to see the functions, I have been written out in this document.

2.2 Creating a Record of Your Commands

Use the Rmd file to record your R code and comments. This will help you remember what you did and why. See `MarcTemplate.Rmd` as a skeleton file. Unfortunately, knit creates it's own session of R – so the stuff we do in the console isn't available in when you knit. So, we'll have to get R to explicitly

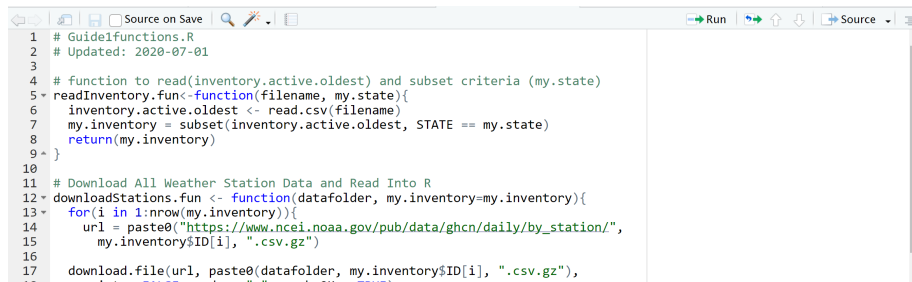


Figure 1: The "source" action item is located in the upper right of the editor window. This will run the entire code with all the functions into the R environment.

load the functions wit each time we knit. It's not hard, but important. In an r block before using other functions, we'll need to add:

```
source("Guide1functions.R")
```

NOTE: R is case sensitive. AND the function needs to be in quotes.

2.3 Function Descriptions and Use

The following functions are used to select the weather stations, download data, and write weather station data csv files.

Subset Inventory Data with my.state The inventory data is a list of all the weather stations in the USA, US Territories, and Canada. This function will subset the data to only include the stations in the state of interest.

This function requires two parameters to be set: filename and my.state. See Section 4.1 for more details.

I suggest you use file.choose() and assign filename.csv to the path and name of the csv file in your project directory.

Example of how to use the function:

```

my.state <- "CA"
filename.csv <-
  "/home/mwl04747/RTricks/05_Regional_Climate_Trends/stations.active.oldest.csv"
my.inventory <- readInventory.fun(filename.csv, my.state)

```

Creates a dataframe called my.inventory that contains the inventory data for the state/territory of interest. You should see that in the R environment. Note: The filename is cut off because my path is too long!

Download and Read Selected Weather Station Data into R This function will download the weather station data from the NOAA website and read it into R.

Function: `downloadStations.fun()`

This functions requires two parameters: data path and name of inventory dataframe (my.inventory). The data path is a folder that you can always get your station data from if you need it. For example, if you need to update the data, you can just download the data from the NOAA website and then read it into R. For more information on this function see Section 4.2.

The path to your data folder will be different, I created a directory to separate my data by class year, you don't need that! But it is nice to keep neat. Use the "Data" folder you created when you set up the project.

An example of how to use the function:

```
datapath = "/home/mwl04747/RTricks/05_Regional_Climate_Trends/Data/SP25/"
downloadStations.fun(datapath, my.inventory)
```

Your data path will NOT be mine. First, you can see your working directory with `getwd()`. But it probably doesn't include the folder you are working in. I suggest you use `file.choose()` and select any file in the project folder. Then delete the file name and add the "/Data", so it might look something like this:

```
datapath = "/home/XXXXXXX/Regional_Climate_Trends/Data/"
```

This will download the data from the NOAA website and read it into R then written as compressed gz and uncompressed csv files in your data folder. Check to see that you have both csv.gz and .csv files in your data folder.

You're are done with this guide, go to Guide 2!

3 Explaining the Process and Code

3.1 Working with a R Markdown File

To record your history of R code, I suggest use an Rmarkdown file to keep your code handy.

To do this open a new file and select R Markdown – Define a title, author, and output format as PDF. Then save the file (Figure 2).

Then save the file in your project folder and knit the file to create a PDF. Look at the PDF to see how various parts of the Rmd file were knitted. Notice that there are generally two sections: text and R chunks. As you write th R code, you will can record your code in the R chunks AND develop the output into a document for future reference.

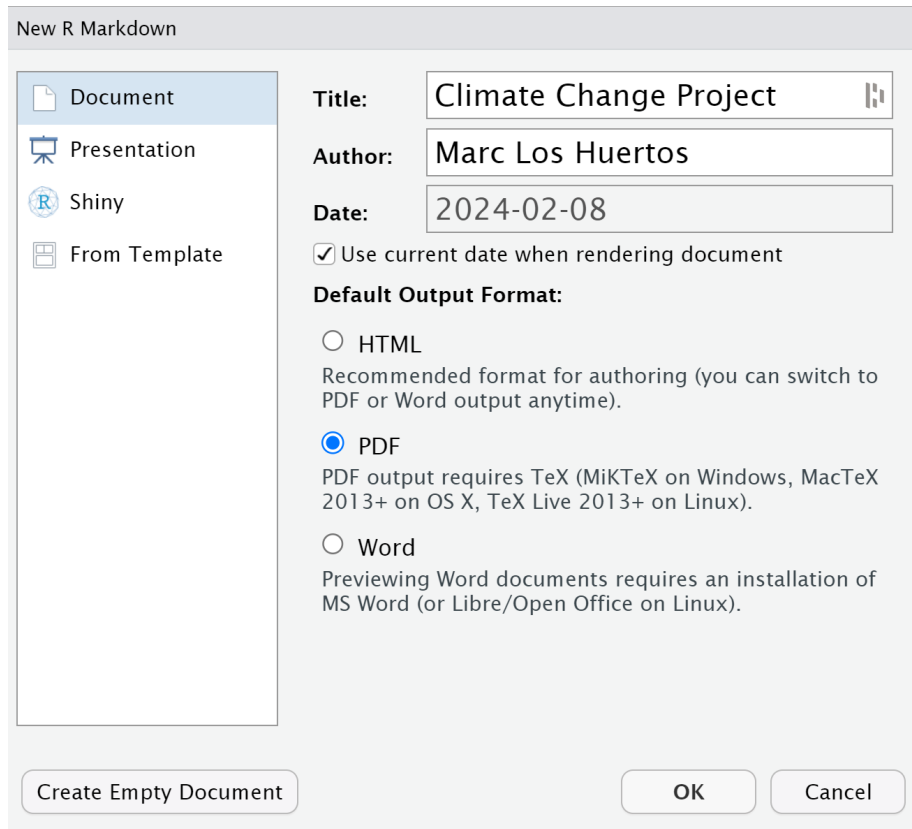


Figure 2: Creating a new R Markdown file.

Look carefully at the Rmd file and take note of the following: First, there are chunks of R code separated from the text by a line of three backticks. Second, the R code is written in the chunks and the output is written below the code. Finally, there is a set of backticks at the end of the code chunk. This section is gray and is where you can record your Rcode. I suggest you delete existing the one line of R code inside the existing template chunk.

3.1.1 R Environment and knitr

When you knit, R starts a new environment and runs the code in the chunks. But that means the new environment doesn't have the data you have created in your current environment. So, I suggest you use the R markdown to double check that everything is working well.

I have created an R Markdown file for you to use. It is called `MarcTemplate.Rmd`. As a template, you can use and change the code as you go.

3.2 Defining Path & Read Data

First, we install some packages and read in the data. I suggest you create a folder for the project (I created one called “05_Regional_Climate_Trends”). To get the working directory and filename, we can use the `file.choose()` function from the console:

```
> file.choose()
```

Then paste the result in the Rmd file to track the results to define the file name:¹

```
filename = "home/mwl04747/RTricks/05_Regional_Climate_Trends/stations.active.oldest.csv"

# OR what I use! see the footnote.
library(here)
filename = here("05_Regional_Climate_Trends", "stations.active.oldest.csv")
```

3.3 Selecting Weather Records by State

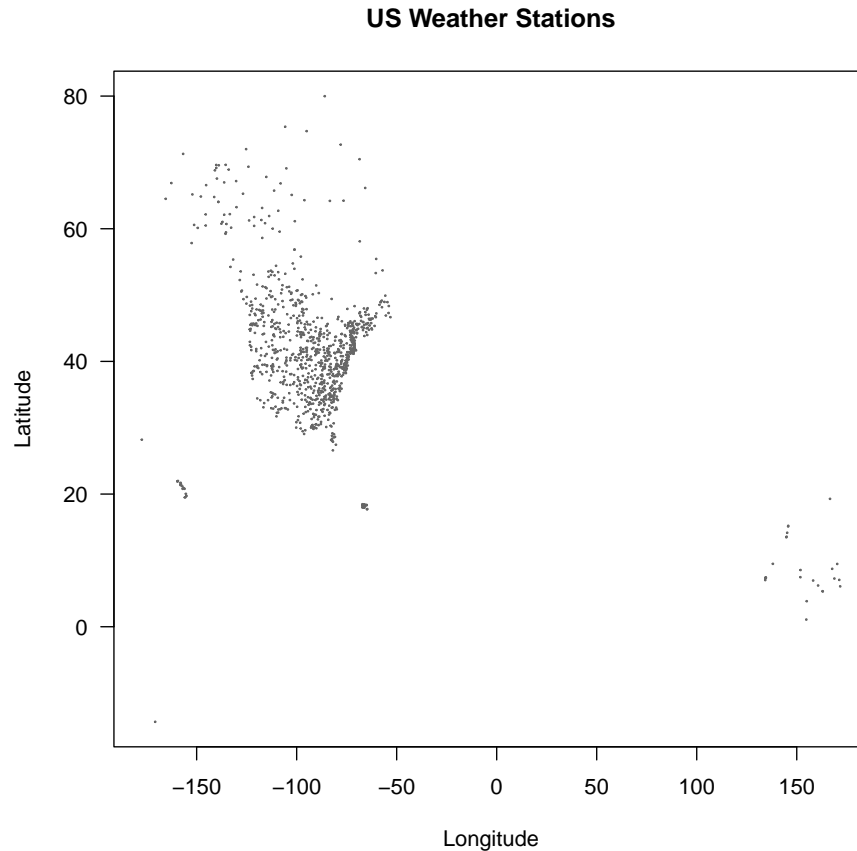
3.3.1 Map US Weather Stations

Here’s a map of the weather stations in the dataset. Pretty lame map! We’ll make a better one later.²

```
stations.active.oldest =
  read.csv(paste0(here(), "/05_Regional_Climate_Trends/",
                  "stations.active.oldest.csv"))
plot(stations.active.oldest$LONGITUDE,
     stations.active.oldest$LATITUDE,
     xlab = "Longitude", ylab = "Latitude",
     pch=20, cex=0.2, col='gray40', las=1,
     main = "US Weather Stations")
```

¹I use a function `here()` from the “here library”, but it’s a bit tricky to use and you can use that if you prefer.

²Evelyn/Brody: This is a good change to see how to use R for map making! First we need to transform that data.



There are numerous ways to analyze temperature records, where stations can be analyzed individually or records could be sampled and analyzed in spatially in grids. Each of these are valid approaches depending on the question to be addressed.

Here are the questions we will address:

- What stations have the longest meteorological records in the USA?
- Can we determine the reliability of these stations?
- Finally, is there a temperature trend?

3.4 Subset Station Inventory by State

This uses the `stations.active.oldest` file to download the data from the NOAA website based on the state you have choose.

The URL for a description of the data is: <https://www.ncdc.noaa.gov/cdo-web/datasets/GHCND/stations/GHCND:USW00023230/detail>.

4 Function Details

4.1 readInventory.fun

This function...

Here's the function:

```
## function (filename, my.state)
## {
##     inventory.active.oldest <- read.csv(filename)
##     my.inventory = subset(inventory.active.oldest, STATE == my.state)
##     return(my.inventory)
## }
```

4.2 downloadStations.fun

5 Download Data from NOAA

Here's the function:

```
## function (datafolder, my.inventory = my.inventory)
## {
##     colnames <- c("ID", "DATE", "ELEMENT", "VALUE", "M-FLAG",
##                  "Q-FLAG", "S-FLAG", "OBS-TIME")
##     for (i in 1:nrow(my.inventory)) {
##         url = paste0("https://www.ncei.noaa.gov/pub/data/ghcn/daily/by_station/",
##                     my.inventory$ID[i], ".csv.gz")
##         download.file(url, paste0(datafolder, my.inventory$ID[i],
##                                   ".csv.gz"), quiet = FALSE, mode = "w", cacheOK = TRUE)
##         station.temp <- read.csv(paste0(datafolder, my.inventory$ID[i],
##                                          ".csv.gz"), header = FALSE)
##         names(station.temp) <- colnames
##         filename = paste0(datafolder, my.inventory$ID[i], ".csv")
##         write.csv(station.temp, filename, row.names = FALSE)
##         print(paste("Index (Loop) ", i, " Completed."))
##         print("NOAA site can stall -- if the loop errors out, try again.")
##     }
##     print("Think about something you are grateful for today!")
##     write.csv(my.inventory, paste0(datafolder, "my.inventory.csv"),
##              row.names = FALSE)
## }
## <bytecode: 0x2f26638>
```

How do you determine the data path?

6 Trouble Shooting and Workarounds

I will be getting all the guides working before working on this! But if there are errors with the custom function, this is where workarounds will be described! Please Slack me and mentors if you have any problems!

6.1 NA.csv as a duplicate?

I am not sure why, but in the `downloadStations.fun()`, the file is saved as `NA.csv`. I have no idea why. If you find this, let me know, I'd like to figure out if there is a bug in the code creating this csv. If you find a `NA.csv` in your folder, please let marc or mentors know and we will try to figure out what is going on.

6.2 Download gz files with folder concatenated names

Five students had this issue on Wednesday, but no one on Tuesday. That less than half the students had this issue is perplexing and I figured out that some students were using old functions, so I updated the functions and changed the Guide fuction file to reflect this change.

7 rNOAA – Unsupported and Deprecated Library

The `rNOAA` package has been deprecated, so all the 2000-2022 code is no longer working. I have commented out the text – but should I need to re-run the code, I have some of the description in the Rmd file.

References

Rodhe, H., Charlson, R., and Crawford, E. (1997). Svante arrhenius and the greenhouse effect. *Ambio*, pages 2–5.