Lab 01: An introduction to attribute and spatial analysis in R

Read the instructions COMPLETELY before starting the lab

This lab builds on many of the discussions and exercises from class. This lab also builds on Chapters 1-3 from your textbook, as well at R for Data Science by Hadley Wickham and Garrett Grolemund (https://r4ds.had.co.nz)

Formatting your submission

This lab must be placed into a public repository on GitHub (www.github.com). Before the due date, submit **on Canvas** a link to the repository. I will then download your repositories and run your code. The code must be contained in either a .R script or a .Rmd markdown document. As I need to run your code, any data you use in the lab must be referenced using **relative path names**. Finally, answers to questions I pose in this document must also be in the repository at the time you submit your link to Canvas. They can be in a separte text file, or if you decide to use an RMarkdown document, you can answer them directly in the doc.

Exploratory data analysis

This lab uses two files from the /data/CBW directory of this course's main repository: 1. County_Boundaries.shp: A polygon file containing the boundaries for all counties in the Chesapeake Bay Watershed 2. Non-Tidal_Water_Quality_Monitoring_Stations_in_the_Chesapeake_Bay.shp: point locations of non-tidal monitoring stations in the Chesapeake Bay Watershed

Step 1, load your packages and data

```r
library(tidyverse)
```

```
## -- Attaching core tidyverse packages ------------------------ tidyverse 2.0.0 --
## v dplyr     1.1.4     v readr     2.1.5
## v forcats   1.0.0     v stringr   1.5.1
## v ggplot2   3.5.1     v tibble    3.2.1
## v lubridate 1.9.3     v tidyr     1.3.1
## v purrr     1.0.2
## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
## i Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to become errors
```

```r
library(ggplot2) #technically included in tidyverse
library(sf)
```

```
## Linking to GEOS 3.11.0, GDAL 3.5.3, PROJ 9.1.0; sf_use_s2() is TRUE
```

```r
library(sp) #just in case
```

Next, load your data:

```r
## note the ".." as opposed to "." <- need to go back one additional level from where this file is
p.counties <- "../data/CBW/County_Boundaries.shp"
p.stations <- "../data/CBW/Non-Tidal_Water_Quality_Monitoring_Stations_in_the_Chesapeake_Bay.shp"


d.counties <- sf::read_sf(p.counties)
d.stations <- sf::read_sf(p.stations)

glimpse(d.counties)
```

```
## Rows: 207
## Columns: 21
## $ OBJECTID   <int> 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, ~
## $ STATEFP10  <chr> "51", "51", "51", "51", "42", "42", "42", "42", "42", "42",~
## $ COUNTYFP10 <chr> "540", "510", "530", "600", "021", "001", "061", "035", "09~
## $ COUNTYNS10 <chr> "01789068", "01498415", "01498417", "01789070", "01213662",~
## $ GEOID10    <chr> "51540", "51510", "51530", "51600", "42021", "42001", "4206~
## $ NAME10     <chr> "Charlottesville", "Alexandria", "Buena Vista", "Fairfax", ~
## $ NAMELSAD10 <chr> "Charlottesville city", "Alexandria city", "Buena Vista cit~
## $ LSAD10     <chr> "25", "25", "25", "25", "06", "06", "06", "06", "06", "06",~
## $ CLASSFP10  <chr> "C7", "C7", "C7", "C7", "H1", "H1", "H1", "H1", "H1", "H1",~
## $ MTFCC10    <chr> "G4020", "G4020", "G4020", "G4020", "G4020", "G4020", "G402~
## $ CSAFP10    <chr> NA, "548", NA, "548", NA, "564", NA, "558", NA, NA, NA, NA,~
## $ CBSAFP10   <chr> "16820", "47900", NA, "47900", "27780", "23900", "26500", "~
## $ METDIVFP10 <chr> NA, "47894", NA, "47894", NA, NA, NA, NA, NA, NA, NA, NA, N~
## $ FUNCSTAT10 <chr> "F", "F", "F", "F", "A", "A", "A", "A", "A", "A", "A", "A",~
## $ ALAND10    <dbl> 26517362, 38919733, 17362236, 16159465, 1782819861, 1343342~
## $ AWATER10   <dbl> 52974, 1140371, 223855, 95054, 13680552, 8081576, 37883358,~
## $ INTPTLAT10 <chr> "+38.0376579", "+38.8183429", "+37.7316634", "+38.8531833",~
## $ INTPTLON10 <chr> "-078.4853806", "-077.0820263", "-079.3563746", "-077.29902~
## $ Shape_Leng <dbl> 47968.96, 43943.77, 34310.52, 29395.95, 260532.87, 195653.0~
## $ Shape_Area <dbl> 42902561, 66086698, 28163001, 26840867, 3109865228, 2297092~
## $ geometry   <MULTIPOLYGON [°]> MULTIPOLYGON (((-78.47071 3..., MULTIPOLYGON (~
```

```r
glimpse(d.stations)
```

```
## Rows: 122
## Columns: 12
## $ OBJECTID   <int> 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, ~
## $ MAP_ID     <int> 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, ~
## $ USGS_STATI <int> 1487000, 1488500, 1491000, 1491500, 1495000, 1502500, 15030~
## $ STATION_NA <chr> "NANTICOKE RIVER NEAR BRIDGEVILLE, DE", "MARSHYHOPE CREEK N~
## $ MAJOR_WATE <chr> "Eastern Shore", "Eastern Shore", "Eastern Shore", "Eastern~
## $ Drainage_A <dbl> 75.39997, 46.79998, 112.99995, 85.19996, 51.59998, 519.9997~
## $ START_DATE <int> 1998, 2005, 1985, 2005, 2005, 2005, 2006, 2005, 2006, 2005,~
## $ END_DATE   <int> 2018, 2018, 2018, 2018, 2018, 2018, 2018, 2018, 2018, 2018,~
## $ Lat        <dbl> 38.72833, 38.84969, 38.99719, 38.96681, 39.66758, 42.37778,~
## $ Long       <dbl> -75.56186, -75.67311, -75.78581, -75.94306, -75.82558, -75.~
```

```
## $ STAID      <chr> "01487000", "01488500", "01491000", "01491500", "01495000",~
## $ geometry   <POINT [°]> POINT (-75.56186 38.72834), POINT (-75.67311 38.8497)~
```

```r
# check for validity
d.stations %>% sf::st_is_valid()
```

```
##   [1] TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE
##  [16] TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE
##  [31] TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE
##  [46] TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE
##  [61] TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE
##  [76] TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE
##  [91] TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE
## [106] TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE
## [121] TRUE TRUE
```

```r
d.counties %>% sf::st_is_valid() # returns false for one feature, so we need to fix
```

```
##   [1]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
##  [13]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
##  [25]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
##  [37]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
##  [49]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
##  [61]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
##  [73]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
##  [85]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
##  [97]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [109]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [121]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [133]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [145]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [157]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [169]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [181]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [193]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [205]  TRUE FALSE  TRUE
```

```r
# fix it "in place"
d.counties <- d.counties %>% sf::st_make_valid()
```

In class, we discussed how to use dplyr verbs such as *filter*, *select*, and *mutate*. There are some useful cheatsheets on the RStudio website to help with *dplyr*, *ggplot*, and other functions here: https://www.rstudio.com/resources/cheatsheets/

Let's start with the *select* function, which SELECTS attributes that we specify:

```r
d.counties %>% dplyr::select(GEOID10, ALAND10) %>% head()
```

```
## Simple feature collection with 6 features and 2 fields
## Geometry type: MULTIPOLYGON
## Dimension:     XY
## Bounding box:  xmin: -79.38264 ymin: 37.69574 xmax: -76.95493 ymax: 40.72605
```

```
## Geodetic CRS:  WGS 84
## # A tibble: 6 x 3
##   GEOID10    ALAND10                                                    geometry
##   <chr>        <dbl>                                          <MULTIPOLYGON [°]>
## 1 51540     26517362 (((-78.47082 38.04893, -78.47086 38.04893, -78.47096 38.04~
## 2 51510     38919733 (((-77.06129 38.79457, -77.0612 38.79454, -77.06092 38.794~
## 3 51530     17362236 (((-79.36668 37.7267, -79.36655 37.72627, -79.36653 37.726~
## 4 51600     16159465 (((-77.31476 38.86701, -77.31534 38.86702, -77.31537 38.86~
## 5 42021   1782819861 (((-79.03546 40.31539, -79.03611 40.31477, -79.0363 40.314~
## 6 42001   1343342705 (((-77.46594 39.85958, -77.46589 39.85924, -77.46586 39.85~
```

```
# head truncates the data.frame to the first n rows
```

Note that because we're using a spatial data frame in the `sf` package, the geometry is preserved, even though we didn't specify it. We can also get rid of attributes we DON'T WANT (but not the geometry attribute) using a `-` flag. For example:

```
d.counties %>% dplyr::select(-NAME10) %>% head()
```

```
## Simple feature collection with 6 features and 19 fields
## Geometry type: MULTIPOLYGON
## Dimension:     XY
## Bounding box:  xmin: -79.38264 ymin: 37.69574 xmax: -76.95493 ymax: 40.72605
## Geodetic CRS:  WGS 84
## # A tibble: 6 x 20
##   OBJECTID STATEFP10 COUNTYFP10 COUNTYNS10 GEOID10 NAMELSAD10   LSAD10 CLASSFP10
##      <int> <chr>     <chr>      <chr>      <chr>   <chr>        <chr>  <chr>
## 1        1 51        540        01789068   51540   Charlottesv~ 25     C7
## 2        2 51        510        01498415   51510   Alexandria ~ 25     C7
## 3        3 51        530        01498417   51530   Buena Vista~ 25     C7
## 4        4 51        600        01789070   51600   Fairfax city 25     C7
## 5        5 42        021        01213662   42021   Cambria Cou~ 06     H1
## 6        6 42        001        01213656   42001   Adams County 06     H1
## # i 12 more variables: MTFCC10 <chr>, CSAFP10 <chr>, CBSAFP10 <chr>,
## #   METDIVFP10 <chr>, FUNCSTAT10 <chr>, ALAND10 <dbl>, AWATER10 <dbl>,
## #   INTPTLAT10 <chr>, INTPTLON10 <chr>, Shape_Leng <dbl>, Shape_Area <dbl>,
## #   geometry <MULTIPOLYGON [°]>
```

We can also specify ranges that we want to keep (or not):

```
d.counties %>% dplyr::select(GEOID10:CLASSFP10) %>% head()
```

```
## Simple feature collection with 6 features and 5 fields
## Geometry type: MULTIPOLYGON
## Dimension:     XY
## Bounding box:  xmin: -79.38264 ymin: 37.69574 xmax: -76.95493 ymax: 40.72605
## Geodetic CRS:  WGS 84
## # A tibble: 6 x 6
##   GEOID10 NAME10          NAMELSAD10  LSAD10 CLASSFP10                  geometry
##   <chr>   <chr>           <chr>       <chr>  <chr>            <MULTIPOLYGON [°]>
## 1 51540   Charlottesville Charlottes~ 25     C7        (((-78.47082 38.04893, -~
## 2 51510   Alexandria      Alexandria~ 25     C7        (((-77.06129 38.79457, -~
```

```
## 3 51530   Buena Vista     Buena Vist~ 25     C7         (((-79.36668 37.7267, -7~
## 4 51600   Fairfax         Fairfax ci~ 25     C7         (((-77.31476 38.86701, --~
## 5 42021   Cambria         Cambria Co~ 06     H1         (((-79.03546 40.31539, --~
## 6 42001   Adams           Adams Coun~ 06     H1         (((-77.46594 39.85958, --~
```

```
d.counties %>% dplyr::select(-(GEOID10:CLASSFP10)) %>% head()
```

```
## Simple feature collection with 6 features and 15 fields
## Geometry type: MULTIPOLYGON
## Dimension:     XY
## Bounding box:  xmin: -79.38264 ymin: 37.69574 xmax: -76.95493 ymax: 40.72605
## Geodetic CRS:  WGS 84
## # A tibble: 6 x 16
##   OBJECTID STATEFP10 COUNTYFP10 COUNTYNS10 MTFCC10 CSAFP10 CBSAFP10 METDIVFP10
##      <int> <chr>     <chr>      <chr>      <chr>   <chr>   <chr>    <chr>
## 1        1 51        540        01789068   G4020   <NA>    16820    <NA>
## 2        2 51        510        01498415   G4020   548     47900    47894
## 3        3 51        530        01498417   G4020   <NA>    <NA>     <NA>
## 4        4 51        600        01789070   G4020   548     47900    47894
## 5        5 42        021        01213662   G4020   <NA>    27780    <NA>
## 6        6 42        001        01213656   G4020   564     23900    <NA>
## # i 8 more variables: FUNCSTAT10 <chr>, ALAND10 <dbl>, AWATER10 <dbl>,
## #   INTPTLAT10 <chr>, INTPTLON10 <chr>, Shape_Leng <dbl>, Shape_Area <dbl>,
## #   geometry <MULTIPOLYGON [°]>
```

```
d.counties %>% dplyr::select(starts_with("C"))
```

```
## Simple feature collection with 207 features and 5 fields
## Geometry type: MULTIPOLYGON
## Dimension:     XY
## Bounding box:  xmin: -81.01449 ymin: 36.55035 xmax: -74.16468 ymax: 44.09697
## Geodetic CRS:  WGS 84
## # A tibble: 207 x 6
##    COUNTYFP10 COUNTYNS10 CLASSFP10 CSAFP10 CBSAFP10                     geometry
##    <chr>      <chr>      <chr>     <chr>   <chr>              <MULTIPOLYGON [°]>
##  1 540        01789068   C7        <NA>    16820    (((-78.47082 38.04893, -78.~
##  2 510        01498415   C7        548     47900    (((-77.06129 38.79457, -77.~
##  3 530        01498417   C7        <NA>    <NA>     (((-79.36668 37.7267, -79.3~
##  4 600        01789070   C7        548     47900    (((-77.31476 38.86701, -77.~
##  5 021        01213662   H1        <NA>    27780    (((-79.03546 40.31539, -79.~
##  6 001        01213656   H1        564     23900    (((-77.46594 39.85958, -77.~
##  7 061        01213672   H1        <NA>    26500    (((-78.14963 40.1743, -78.1~
##  8 035        01214721   H1        558     30820    (((-78.05375 41.27349, -78.~
##  9 093        01213681   H1        <NA>    14100    (((-76.55799 40.93887, -76.~
## 10 117        01209189   H1        <NA>    <NA>     (((-77.21985 41.99978, -77.~
## # i 197 more rows
```

Grouping data

We can also "group" our data according to categorical data in our data.frames. This is useful if you want to create a function that works across the entire group. For example, we'll create a new attribute the calculates the land area of all counties in each state.

```r
d.counties %>% group_by(STATEFP10) %>% mutate(stateLandArea = sum(ALAND10))
```

```
## Simple feature collection with 207 features and 21 fields
## Geometry type: MULTIPOLYGON
## Dimension:     XY
## Bounding box:  xmin: -81.01449 ymin: 36.55035 xmax: -74.16468 ymax: 44.09697
## Geodetic CRS:  WGS 84
## # A tibble: 207 x 22
## # Groups:   STATEFP10 [7]
##    OBJECTID STATEFP10 COUNTYFP10 COUNTYNS10 GEOID10 NAME10     NAMELSAD10 LSAD10
##  *    <int> <chr>     <chr>      <chr>      <chr>   <chr>      <chr>      <chr>
##  1        1 51        540        01789068   51540   Charlotte~ Charlotte~ 25
##  2        2 51        510        01498415   51510   Alexandria Alexandri~ 25
##  3        3 51        530        01498417   51530   Buena Vis~ Buena Vis~ 25
##  4        4 51        600        01789070   51600   Fairfax    Fairfax c~ 25
##  5        5 42        021        01213662   42021   Cambria    Cambria C~ 06
##  6        6 42        001        01213656   42001   Adams      Adams Cou~ 06
##  7        7 42        061        01213672   42061   Huntingdon Huntingdo~ 06
##  8        8 42        035        01214721   42035   Clinton    Clinton C~ 06
##  9        9 42        093        01213681   42093   Montour    Montour C~ 06
## 10       10 42        117        01209189   42117   Tioga      Tioga Cou~ 06
## # i 197 more rows
## # i 14 more variables: CLASSFP10 <chr>, MTFCC10 <chr>, CSAFP10 <chr>,
## #   CBSAFP10 <chr>, METDIVFP10 <chr>, FUNCSTAT10 <chr>, ALAND10 <dbl>,
## #   AWATER10 <dbl>, INTPTLAT10 <chr>, INTPTLON10 <chr>, Shape_Leng <dbl>,
## #   Shape_Area <dbl>, geometry <MULTIPOLYGON [°]>, stateLandArea <dbl>
```

The above function is useful if you want to make calculations "in place" and use them in further row-by-row functions. However, we can further summarize our data such that we don't see all the extra data not relevant to our query. Note that sometimes buggy geometry can affect normal dplyr functions, so the code below converts the sf data frame to a tibble, then removes the geometry before performing the `group_by` and `summarise` functions. This is an unnecessary step when using validated geometry, but can also speed up computation.

```r
d.counties %>%
  as_tibble() %>% dplyr::select(-geometry) %>% # this line converts the data because of wonky geometry
  group_by(STATEFP10) %>%
  summarise(stateLandArea = sum(ALAND10))
```

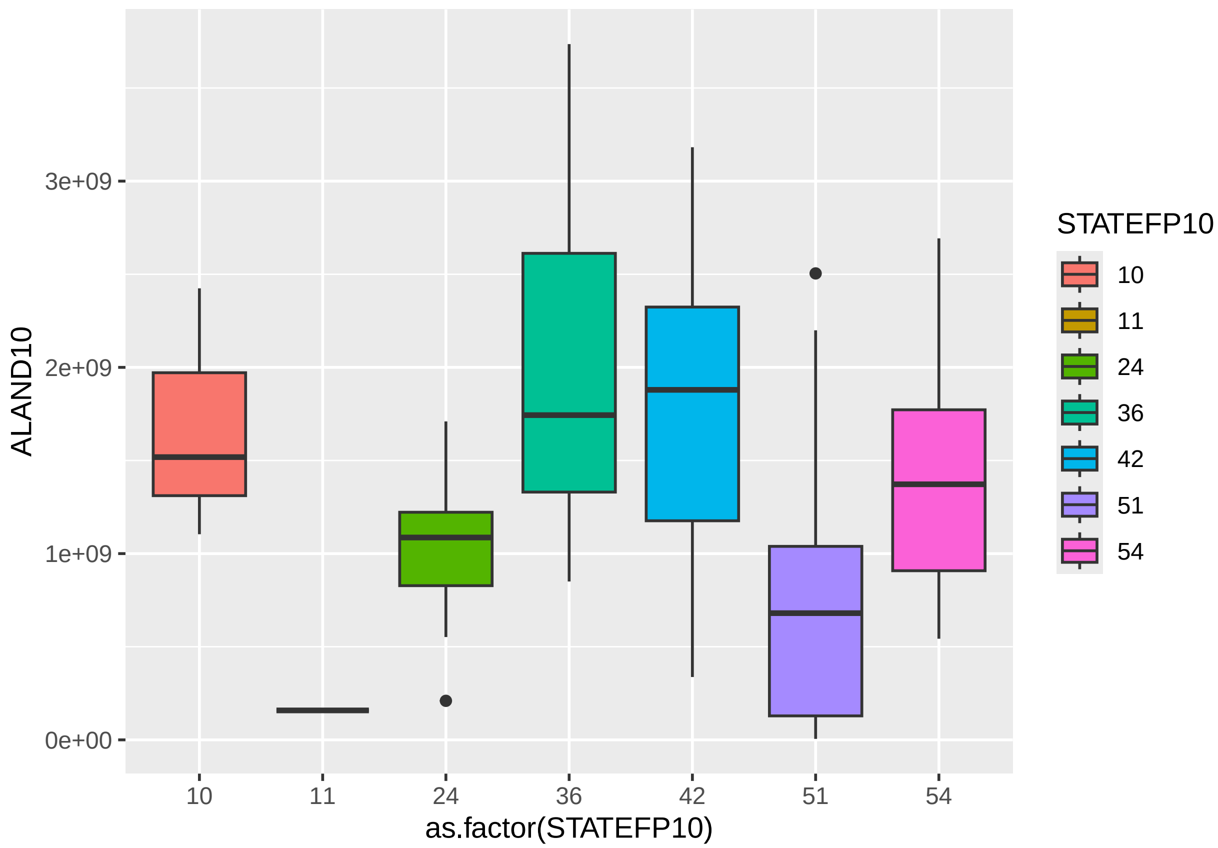
```
## # A tibble: 7 x 2
##   STATEFP10 stateLandArea
##   <chr>             <dbl>
## 1 10           5046703785
## 2 11            158114680
## 3 24          25141638381
## 4 36          40599407643
## 5 42          78174288199
## 6 51          69471293533
## 7 54          20781223859
```

...and we're left with a sum of all the land area in each state (by FIPS code)

A diversion into plots

We can also use grouping functions in our visualization. For example:

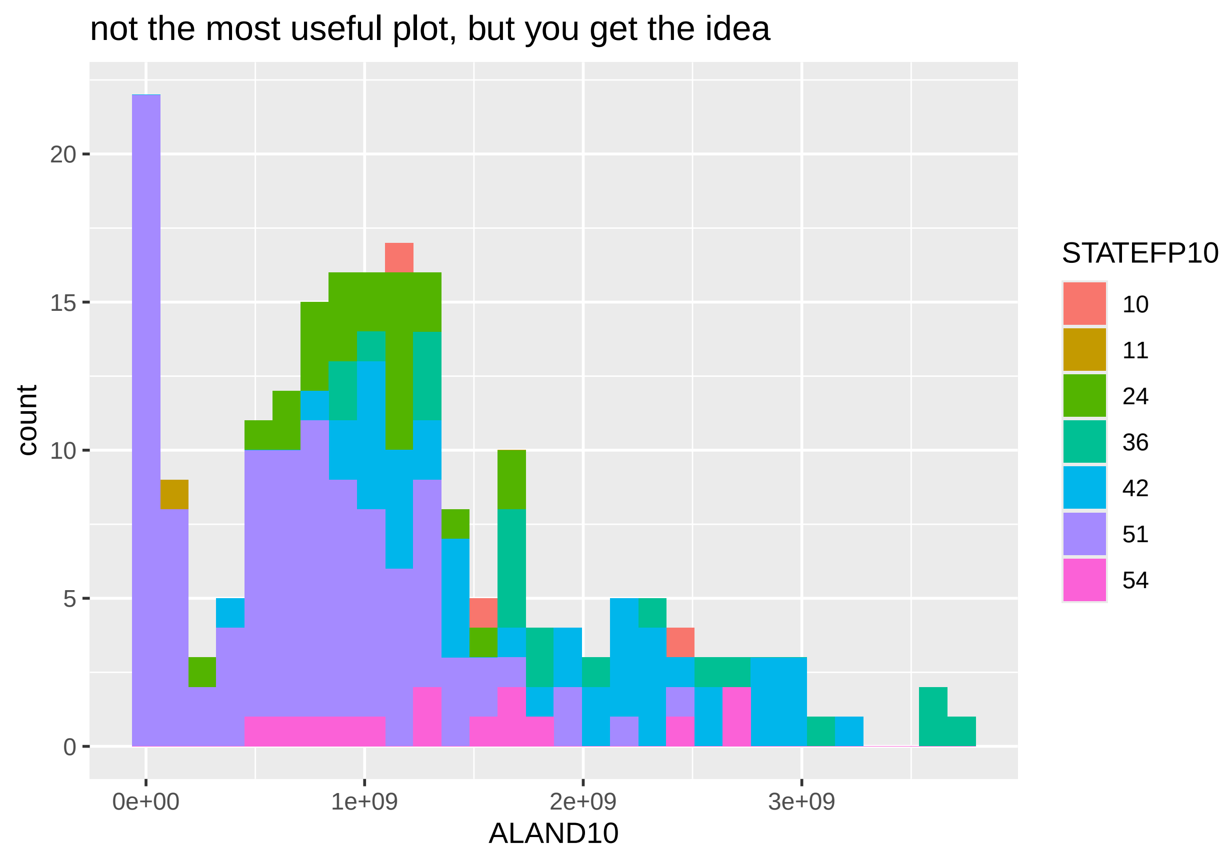
```
d.counties %>%
  ggplot(., aes(x = as.factor(STATEFP10), y = ALAND10)) +
  geom_boxplot(aes(fill = STATEFP10))
```



Or:

```
d.counties %>%
  ggplot(., aes(x = ALAND10)) +
  geom_histogram(aes(fill = STATEFP10)) +
  labs(title = "not the most useful plot, but you get the idea")
```

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```



Spatial operations

Since we have spatial data, we can peform some basic spatial operations with it. First, let's take a look at the coordinate reference system (CRS) for each file:

```
d.counties %>% sf::st_crs()
```

```
## Coordinate Reference System:
##   User input: WGS 84
##   wkt:
## GEOGCRS["WGS 84",
##     DATUM["World Geodetic System 1984",
##         ELLIPSOID["WGS 84",6378137,298.257223563,
##             LENGTHUNIT["metre",1]]],
##     PRIMEM["Greenwich",0,
##         ANGLEUNIT["degree",0.0174532925199433]],
##     CS[ellipsoidal,2],
##         AXIS["latitude",north,
##             ORDER[1],
##             ANGLEUNIT["degree",0.0174532925199433]],
##         AXIS["longitude",east,
##             ORDER[2],
##             ANGLEUNIT["degree",0.0174532925199433]],
##     ID["EPSG",4326]]
```

```
d.stations %>% sf::st_crs()
```

```
## Coordinate Reference System:
##   User input: WGS 84
##   wkt:
## GEOGCRS["WGS 84",
##     DATUM["World Geodetic System 1984",
##         ELLIPSOID["WGS 84",6378137,298.257223563,
##             LENGTHUNIT["metre",1]]],
##     PRIMEM["Greenwich",0,
##         ANGLEUNIT["degree",0.0174532925199433]],
##     CS[ellipsoidal,2],
##         AXIS["latitude",north,
##             ORDER[1],
##             ANGLEUNIT["degree",0.0174532925199433]],
##         AXIS["longitude",east,
##             ORDER[2],
##             ANGLEUNIT["degree",0.0174532925199433]],
##     ID["EPSG",4326]]
```

They're the same, but we can formally check

```
d.counties %>% sf::st_crs() == d.stations %>% sf::st_crs()
```

```
## [1] TRUE
```

We need to make sure the files have the same CRS before we do our spatial operations using the both of them. But to make the problem more tractable, let's first pare down our data such that we only have the counties in the state of Delaware:

```
del.counties <- d.counties %>% dplyr::filter(STATEFP10 == 10)
```

then, we can perform a *spatial intersection* to find all of the monitoring stations within our Delaware subset

```
del.stations <- sf::st_intersection(d.stations, del.counties)
```

```
## Warning: attribute variables are assumed to be spatially constant throughout
## all geometries
```

Plotting this small number of points will be ok, so let's look at the data first, then check the plot:

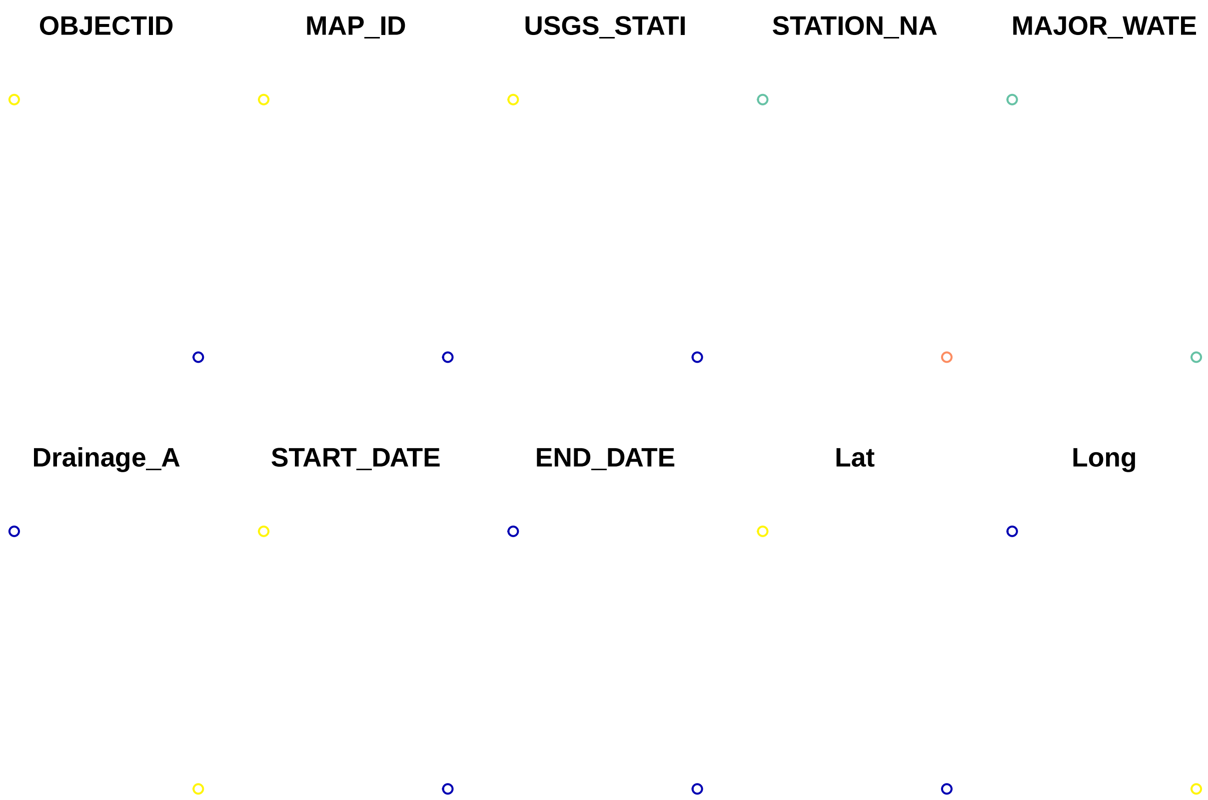
```
glimpse(del.stations)
```

```
## Rows: 2
## Columns: 32
## $ OBJECTID   <int> 2, 1
## $ MAP_ID     <int> 2, 1
## $ USGS_STATI <int> 1488500, 1487000
## $ STATION_NA <chr> "MARSHYHOPE CREEK NEAR ADAMSVILLE, DE", "NANTICOKE RIVER NE~
## $ MAJOR_WATE <chr> "Eastern Shore", "Eastern Shore"
```

```
## $ Drainage_A <dbl> 46.79998, 75.39997
## $ START_DATE <int> 2005, 1998
## $ END_DATE   <int> 2018, 2018
## $ Lat        <dbl> 38.84969, 38.72833
## $ Long       <dbl> -75.67311, -75.56186
## $ STAID      <chr> "01488500", "01487000"
## $ OBJECTID.1 <int> 120, 122
## $ STATEFP10  <chr> "10", "10"
## $ COUNTYFP10 <chr> "001", "005"
## $ COUNTYNS10 <chr> "00217271", "00217269"
## $ GEOID10    <chr> "10001", "10005"
## $ NAME10     <chr> "Kent", "Sussex"
## $ NAMELSAD10 <chr> "Kent County", "Sussex County"
## $ LSAD10     <chr> "06", "06"
## $ CLASSFP10  <chr> "H1", "H1"
## $ MTFCC10    <chr> "G4020", "G4020"
## $ CSAFP10    <chr> NA, NA
## $ CBSAFP10   <chr> "20100", "42580"
## $ METDIVFP10 <chr> NA, NA
## $ FUNCSTAT10 <chr> "A", "A"
## $ ALAND10    <dbl> 1518196116, 2424432871
## $ AWATER10   <dbl> 549470508, 674204700
## $ INTPTLAT10 <chr> "+39.0970884", "+38.6775108"
## $ INTPTLON10 <chr> "-075.5029819", "-075.3354950"
## $ Shape_Leng <dbl> 269441.5, 302135.9
## $ Shape_Area <dbl> 3437654275, 5092675716
## $ geometry   <POINT [°]> POINT (-75.67311 38.8497), POINT (-75.56186 38.72834)
```

```
plot(del.stations)
```

```
## Warning: plotting the first 10 out of 31 attributes; use max.plot = 31 to plot
## all
```



There are only 2 points, and the plot isn't super helpful without any other sort of spatial reference, but you've succcessfully compelted your first spatial operation in R!

`sf` has a number of other useful functions built-in that you can try. For example, a quick calculation of the area of each county in Delaware:

```
del.counties %>% st_area()
```

```
## Units: [m^2]
## [1] 2065913885 3096294967 1278231147
```

Note that `sf` gives you the units of the calculation, but also that the data are in the form of a vector

Your tasks

This lab requires you to put together many of the tasks demonstrated above, in class, help documentation (don't forget the `?` command!), and in your readings. I don't expect you'll know them all immediately, so you'll need to reference those resources, your classmates, and possibly web resources as well. This process is representative of real-world problem solving in this domain. There are a very large number of packages and functions available to you in R, and no one person knows how to use them all. So be inventive, be clever, and be persistent!

Complete each task COMPLETELY USING R CODE. YOU MUST SHOW YOUR WORK FOR EACH ANSWER. Label your variables sensibly and use comments such that I can find your answers and your work.

Task 1: Basic data manipulation

1.1 For each county, calculate its land area as percentage of the total area (land + water) for that state.

1.2 For each state, find the county that has the largest proportion of its land as water (water area / total area)

1.3 Count the number of counties in each state

1.4 Which station has the shortest name (STATION_NA) in the study area?

Task 2: Plotting attribute data

...for each plot, label your axes properly and give your plot a title

2.1 Make a scatterplot showing the relationship between land area and water area for each county. Color each point using the state variable

2.2 Make a histogram of drainage area (Drainage_A) for all monitoring stations

2.3 Make a similar histogram of drainage area (Drainage_A) for all monitoring stations. This time, shade/color each portion of the histogram's bar(s) using the state variable

Task 3: Write a function

3.1 Write a function that does the following:

A. accepts a vector of arbitrary numbers, calculates the mean, median, maximum, and minimum of the vector

B. Sorts the vector

C. returns a list of those values from A and the sorted vector from B

D. the function should only work with numeric values and print an error message if any other data type are found

Test it with the following vectors

`c(1, 0, -1), c(10, 100, 1000), c(.1, .001, 1e8), c("a", "b", "c")`

Task 4: (slightly) more complex spatial analysis.

...Note, you may need to find supplementary data to help you with these tasks

4.1 Calculate the number of monitoring stations in each state

4.2 Calculate the average size of counties in New York (that are also in this study area)

4.3 Calculate which state has monitoring stations with the greatest average drainage area (Drainage_A)

Questions

1. In using the intersection functions, are the following two statements equivalent? If not, explain how. Be sure to think about BOTH the spatial data structures AND the attribute data. Would your answer be different if we were using different types of data?

```
sf::st_intersection(d.stations, del.counties)
sf::st_intersection(del.counties, d.stations)
```

2. What did you find challenging in this lab? What was new?

3. What types of activities would you like to see in labs this semester?