USING R FOR BASIC SPATIAL ANALYSIS

Dartmouth College | Research Computing

OVERVIEW

- Research Computing and Spatial Analysis at Dartmouth
- What is Spatial Analysis?
- What is R?
- Basics of R
- Common Spatial Packages for R
- Viewing and analyzing Spatial Data in R
- Hands-on practice
- Display in GIS software
- Questions and Wrap-up

RESEARCH COMPUTING AT DARTMOUTH

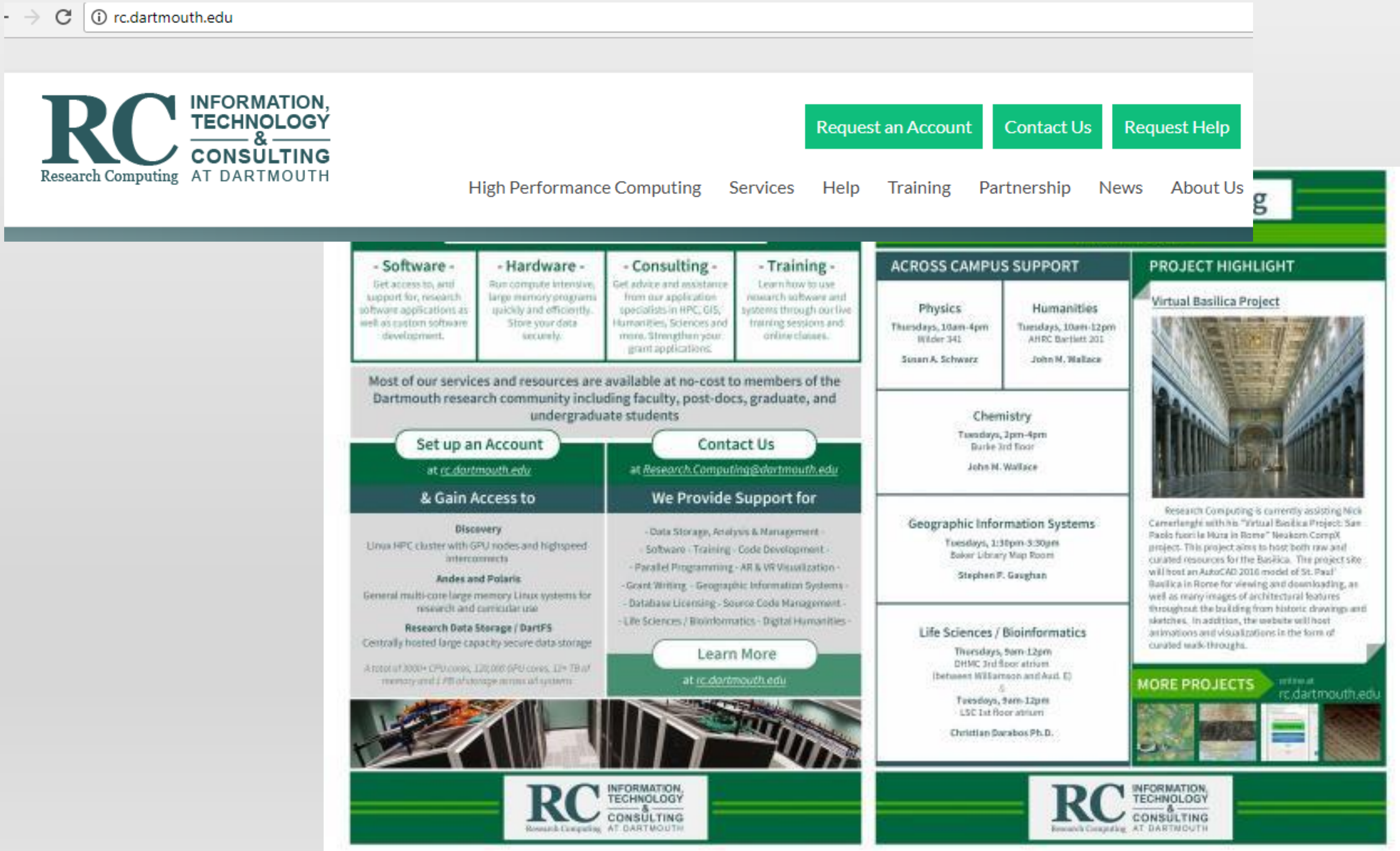
- Research Computing
  - Workshops
  - Storage
  - Consulting
  - Software
  - Hardware

- Visit our website, http://rc.dartmouth.edu/

- Request a research account

- Email us
  - research.computuing@dartmouth.edu
  - stephen.p.gaughan@dartmouth.edu

```
Mission: Promote the advancement of research through the use of high-performance
computing (HPC), life sciences support and bioinformatics, GIS consulting, services and
workshops
```



SPATIAL ANALYSIS AT DARTMOUTH

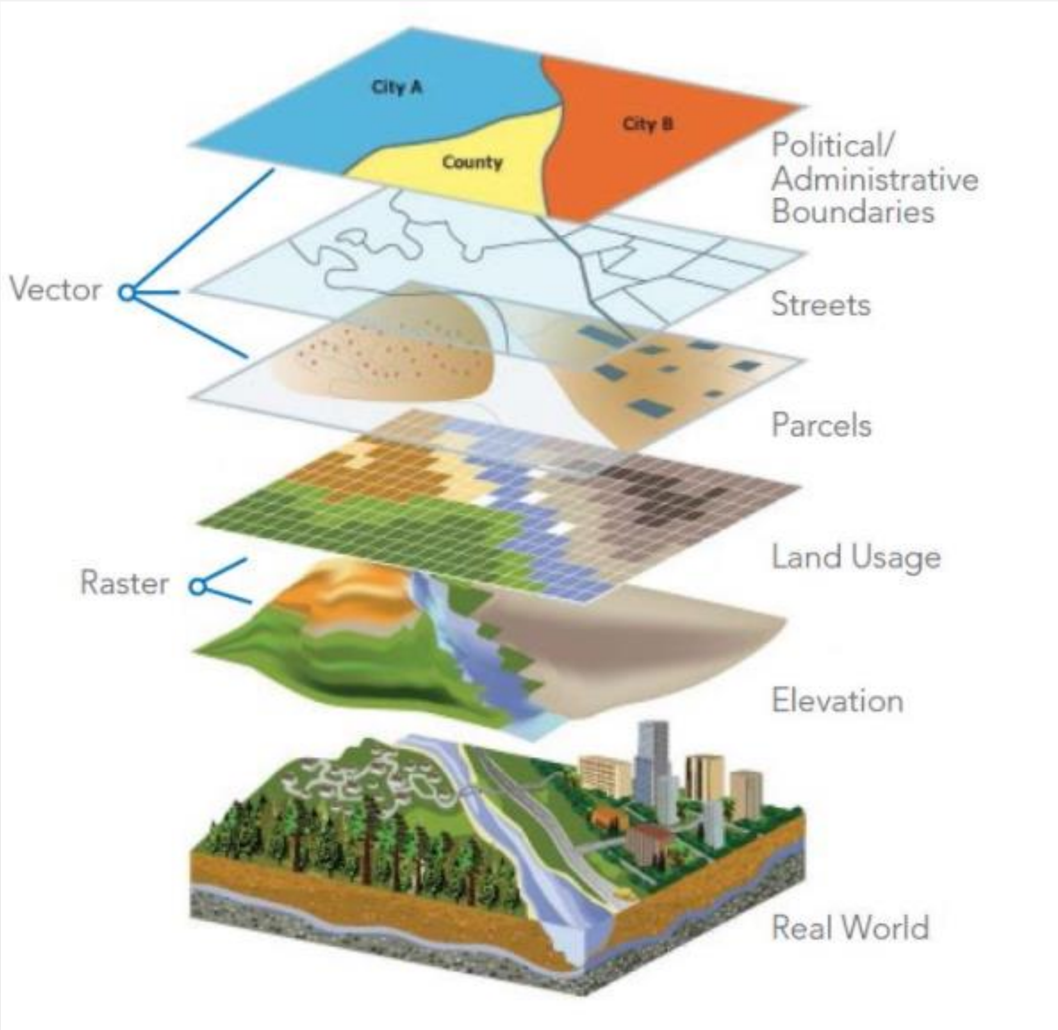
- Courses in the Geography Department and the Earth Sciences Department, GIS and spatial analysis
  - Geography Department http://geography.dartmouth.edu/
    - Geog 50 Geographic Information Systems
    - Geog 57 Urban Applications of GIS
    - Geog 51 / Ears 65: Remote Sensing
    - Geog 54 Geovisualization
    - Geog 59/Ears 77 Environmental Applications of GIS
  - Dartmouth College Library: Library Reference Research Guides for the R statistical package, GIS and spatial analysis
    - GIS http://researchguides.dartmouth.edu/gis
    - Statistics, R http://researchguides.dartmouth.edu/statapp_koujue
- Research Computing

MORE INFO

- Data Visualization using R
  - James Adams, Baker-Berry Library, James.L.Adams@dartmouth.edu
- Statistical Consulting (R, Stata, SAS)
  - Jianjun Hua from Ed Tech provides consulting support for statistics-related questions. Jianjun can be contacted at 603-646-6552 or by emailing jianjun.hua@dartmouth.edu
- R for High Performance Computing, parallel computing, GIS
  - Research.computing@Dartmouth.edu and http://rc.dartmouth.edu/
- R Club
  - Katja Koeppen, Microbiology Department organizes an R Club, Katja.Koeppen@Dartmouth.edu
- Programming n' Pizza http://rc.dartmouth.edu/index.php/programming-n-pizza/
- Departmental Courses at Dartmouth, Statistics, Math, Quantitative Social Sciences, etc
  - Math 10, Math 50 https://math.dartmouth.edu/courses/by-term/ , http://qss.dartmouth.edu/
  - Math 10, Online Stats book "Online Statistics Education: A Multimedia Course of Study" (http://onlinestatbook.com/). David M. Lane, Rice University.

WHAT IS SPATIAL ANALYSIS?

- Spatial analysis is the application of analysis tools to spatial data
- Spatial data includes geographic data in both raster and vector formats, for example:
  - Vector data – points, lines and regions (polygons)
  - Raster data – gridded data such as satellite imagery, elevation data across a surface, rainfall totals across a surface over a given period of time

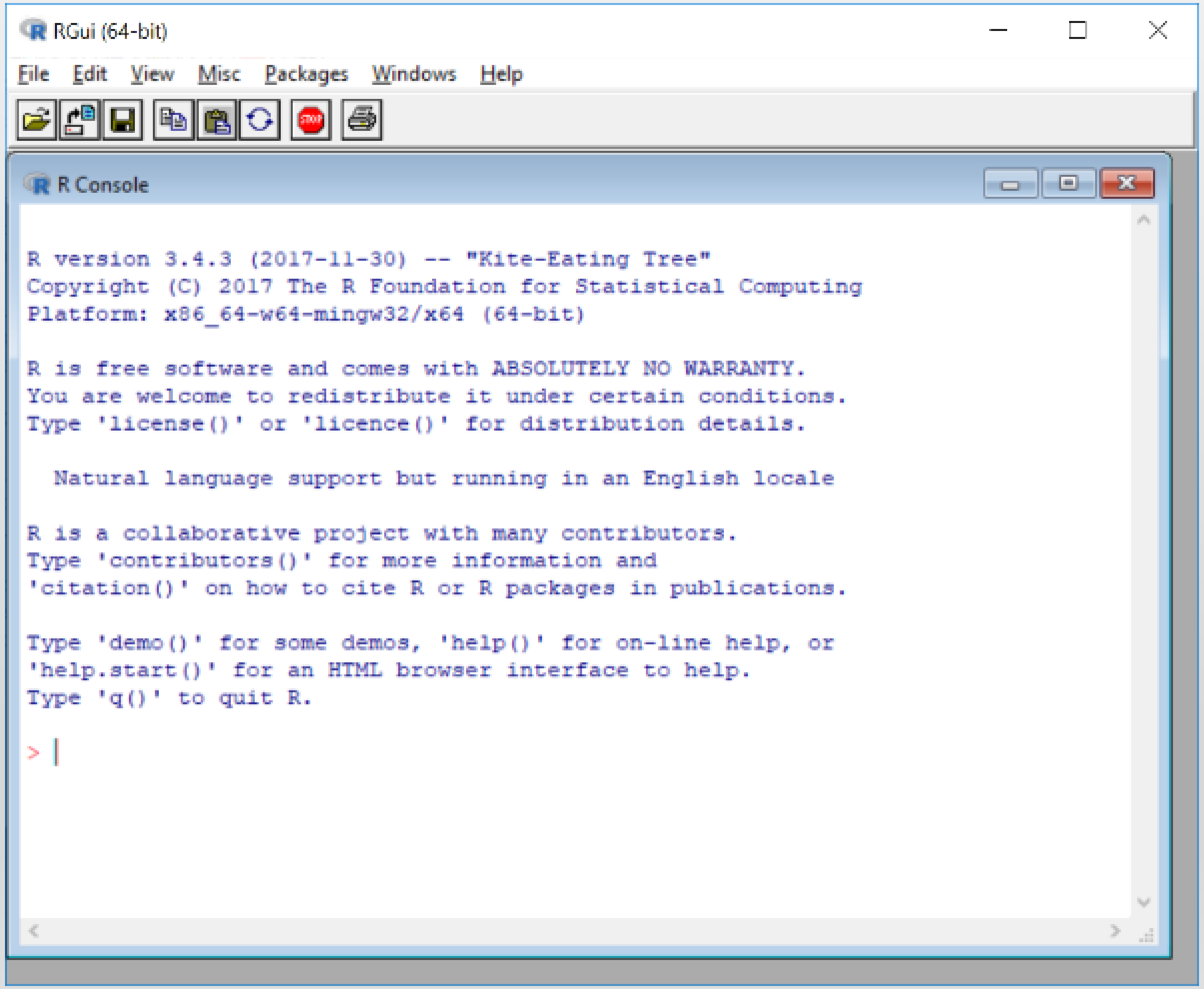


WHAT IS R?

- R is a free software environment used for computing, graphics and statistics. It comes with a robust programming environment that includes tools for data analysis, data visualization, statistics, high-performance computing and geographic analysis. Visit https://www.r-project.org/ for more
- R has been around for more than 20 years and it has become popular at universities, research labs and federal and state government offices in the last ten years for many applications
- R consists of base packages but also includes hundreds of add-on packages that greatly extend the capabilities of the programming environment.
- These capabilities include data manipulation, data visualization and spatial analysis tools
  - CRAN-Spatial is located here: https://cran.r-project.org/web/views/Spatial.html
- If you are already a GIS user, you'll notice similar commands and techniques, and of course, you'll recognize spatial data when displayed on a map in R

BASICS OF R (I)
THE R CONSOLE

- The R console is a quick, light, multiplatform install



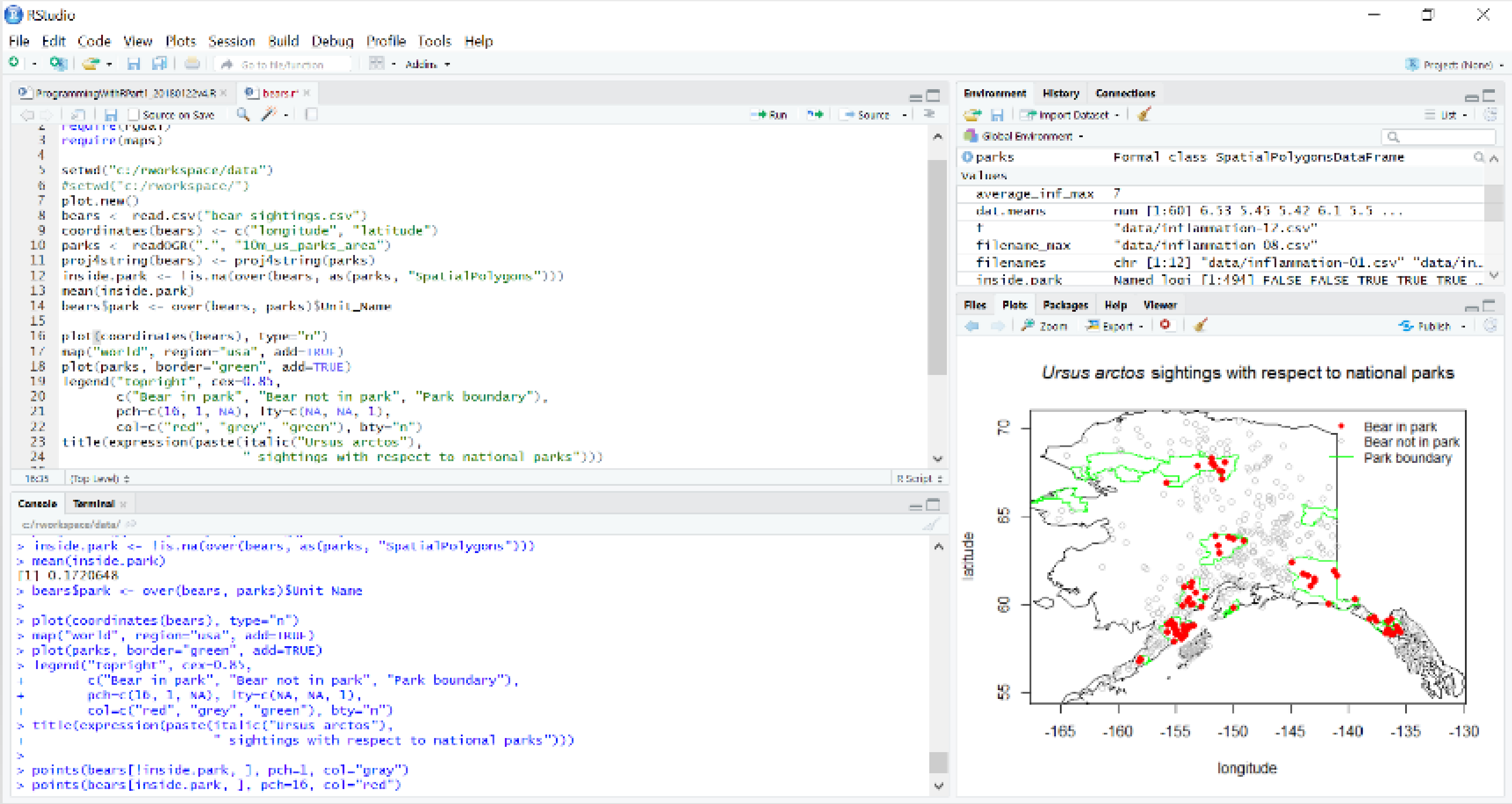
BASICS OF R (II)

WHAT IS R STUDIO?

- R Studio is cross-platform “integrated development environment” for R
- It allows us to save R commands to script files, view variables as we define them, and see output and visualizations directly in the environment
- It runs on Mac and Windows

The R Studio IDE

- Console
- Terminal
- Script Editor
- Variables
- Plots, Graphics, Maps!
- Exports
- Package import



BASICS OF R (III)

SOME PACKAGES TO EXTEND R

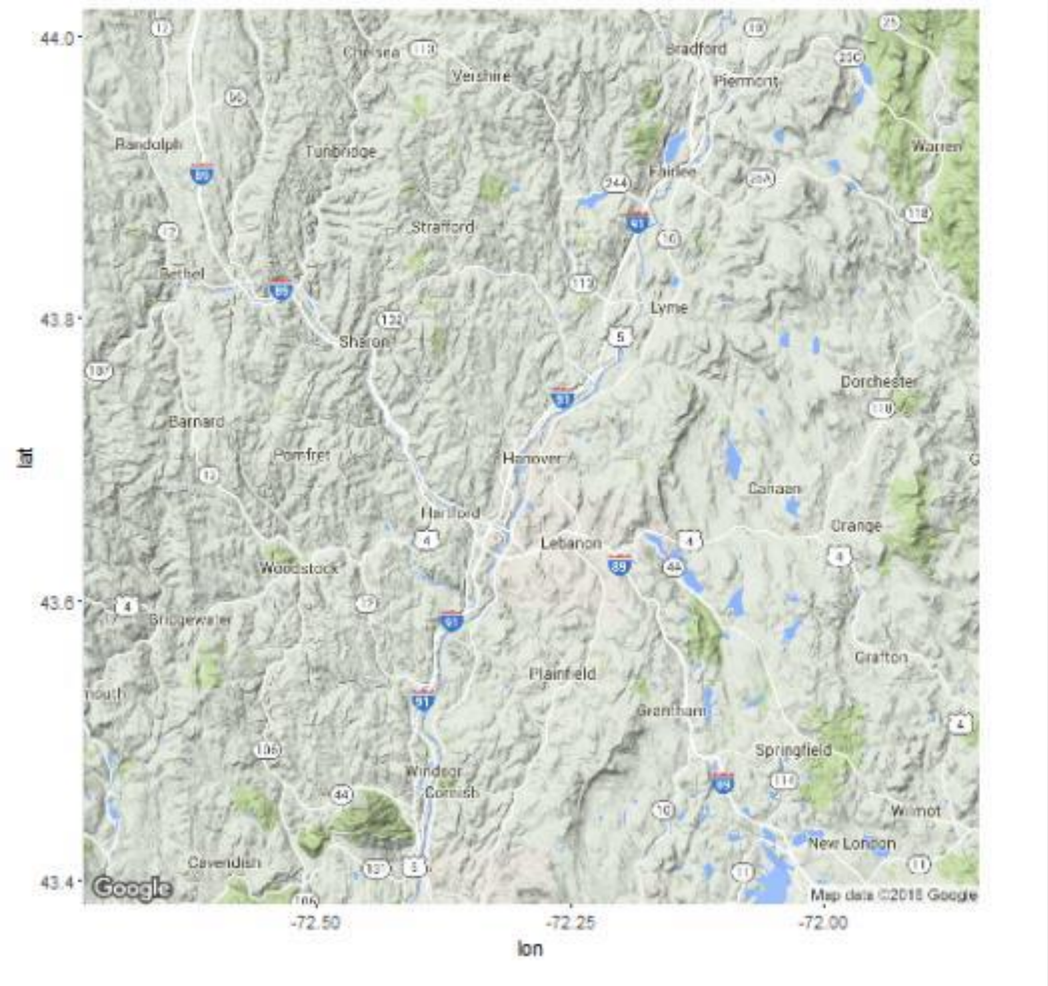
- https://support.rstudio.com/hc/en-us/articles/201057987-Quick-list-of-useful-R-packages
- Tidyr
- Ggplot2
- Dpylr
- xlsx
- Maps
- Sp
- Rgdal
- Parallel

COMMON SPATIAL PACKAGES FOR R

- Spatial:
  - SP “spatial”
  - GSTAT “geostatistics”
  - RGDAL “geospatial data abstraction library for R”
  - MAPS “maps”
  - GGMAP “extends the plotting of ggplot2 with map data”
  - RASTER “raster data processing”
  - MAPTOOLS “map tools”
  - SPATSTAT “wide range of spatial tools and functions”

VIEWING AND ANALYZING SPATIAL DATA (I)

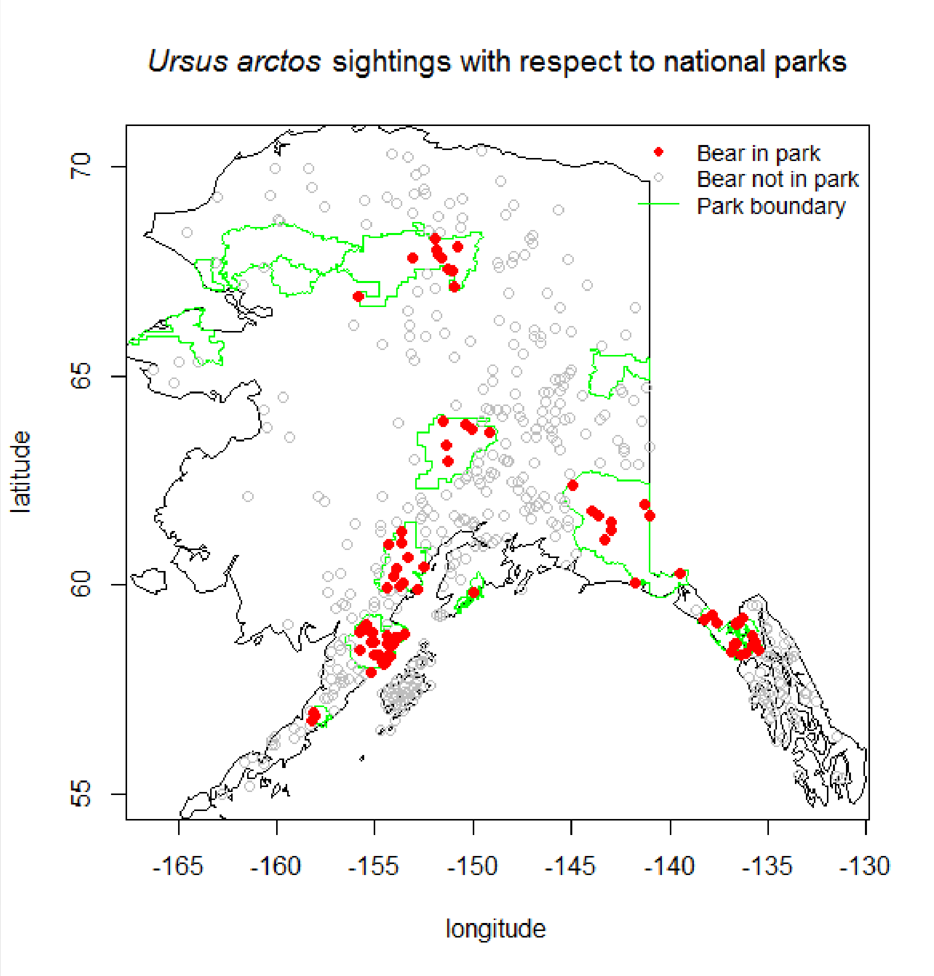
- Put a Google base map right in your plot window, overlay spatial data on to the map plot



VIEWING AND ANALYZING SPATIAL DATA (I) GEOGRAPHIC INFORMATION ANALYSIS

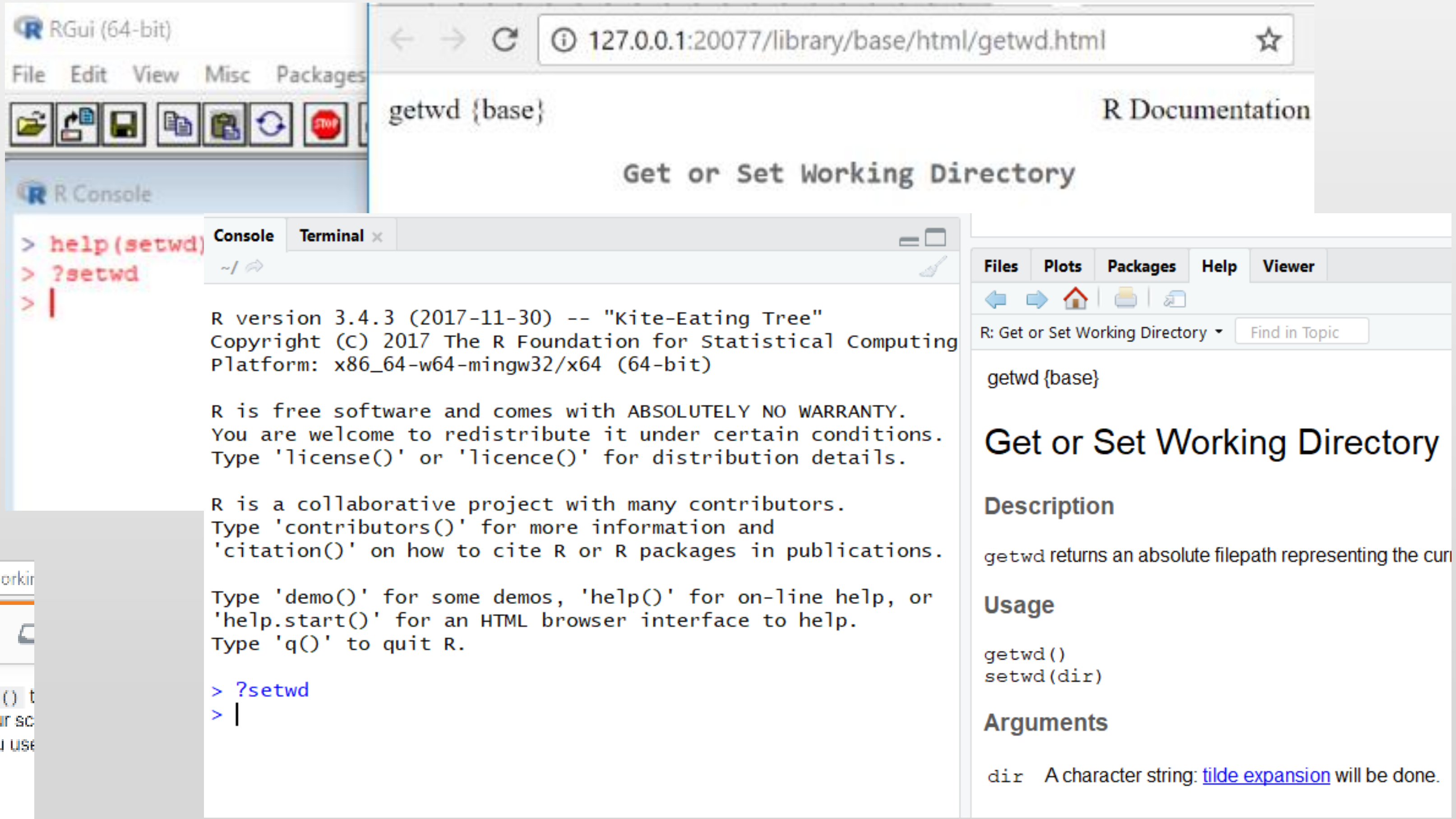
Map overlay & spatial statistics

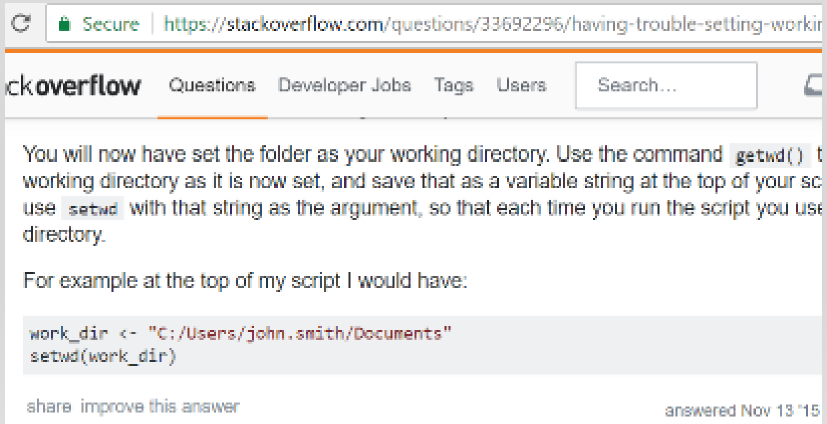
Packages sp, rgdal and maps can turn your R in to a GIS: read, write and analyze spatial data, map overlay



HELP IN R

- ?setwd
- Help(setwd)
- Web Searches
  - Google ‘r set working directory’
  - Stack Overflow ‘r set working directory stack overflow’



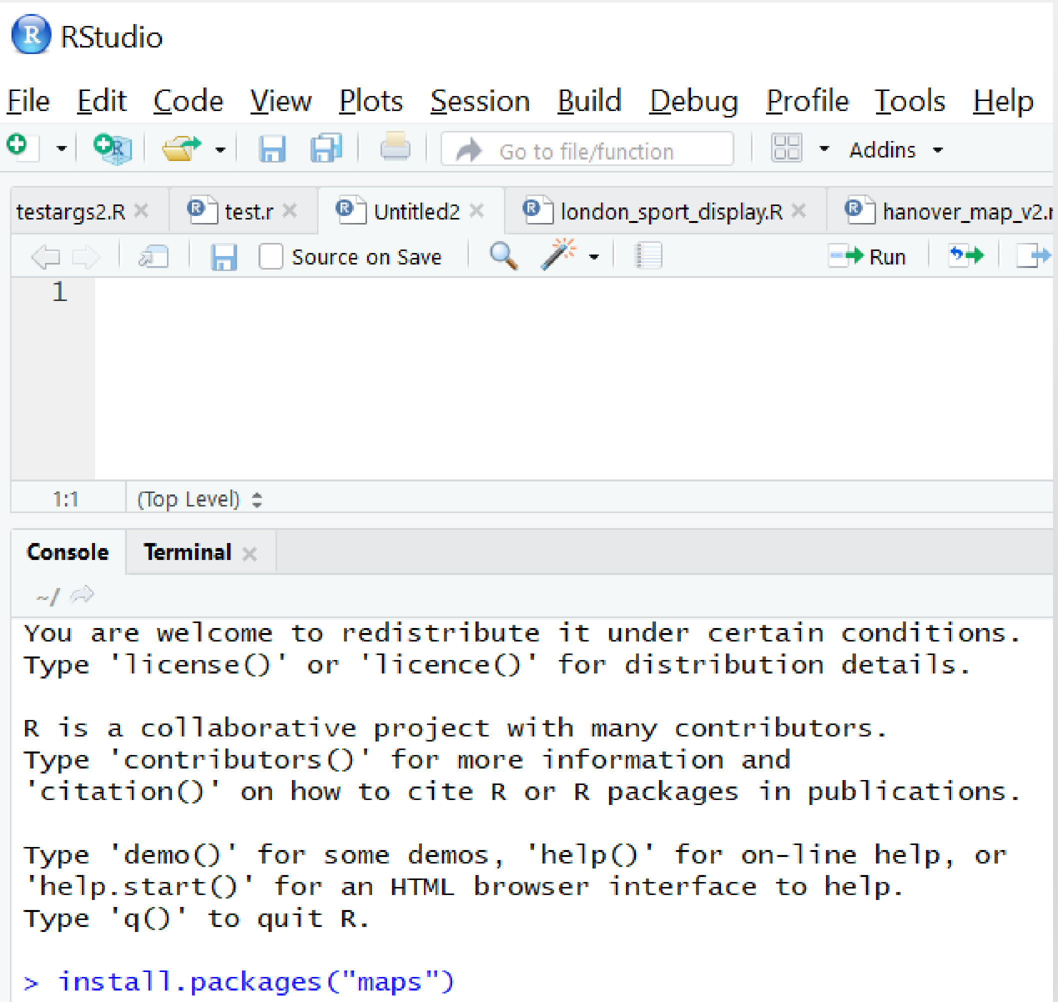


READY TO DIVE IN?

- We'll use **R Studio** today so we can see our spatial analysis and work with R script files

- Open R Studio
- In the "Console" at the "greater than" symbol, enter:

> install.pakages("maps")



GETTING STARTED

- Continue on in R Studio, entering the following commands:

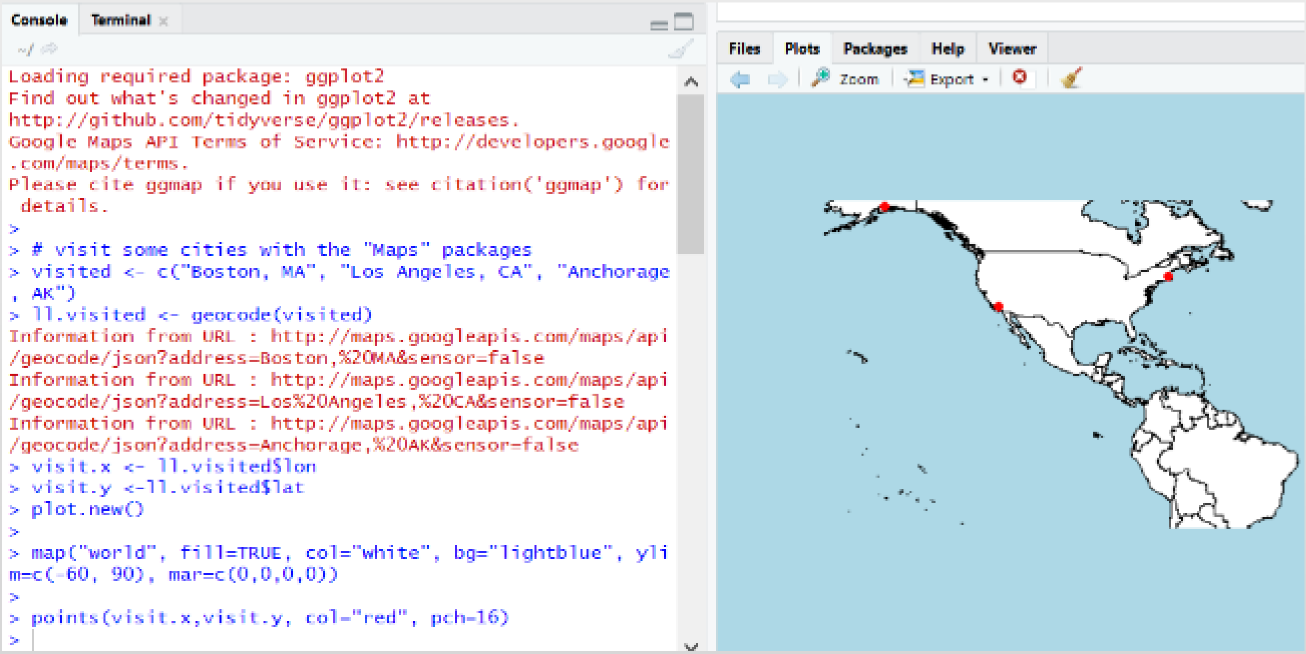
```
install.packages("ggmap")
library(maps)
library(ggmap)

visited <- c("Boston, MA", "Anchorage, AK")
ll.visited <- geocode(visited)
visit.x <- ll.visited$lon
visit.y <-ll.visited$lat
```

GETTING STARTED

```
# Use the “#” to add comments to your code
# geocode function package “ggmap”

plot.new()

map("world", fill=TRUE, col="white",
bg="lightblue", ylim=c(-60, 90), mar=c(0,0,0,0))

points(visit.x,visit.y, col="red", pch=16)
```

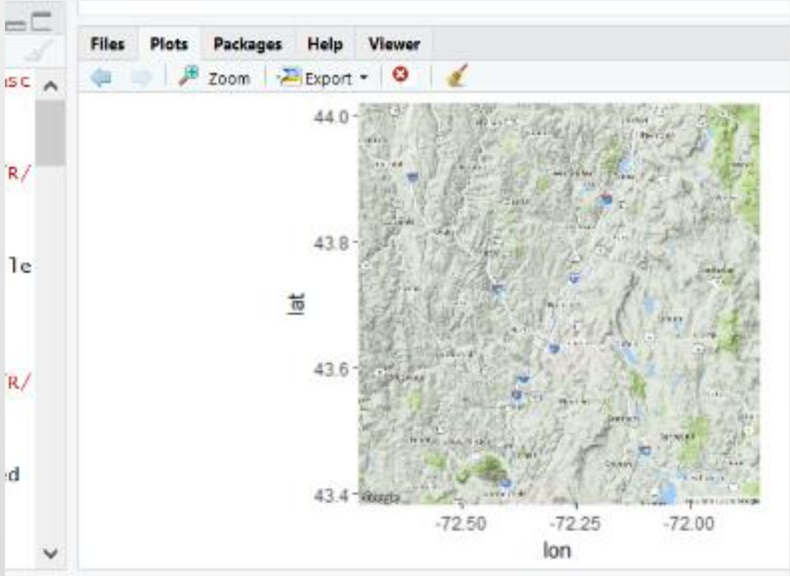
VIEW THE RESULTS

- The “geocoded” data should now show up in R Studio’s plots window, shown on a map of the world



MAP A COORDINATE PAIR

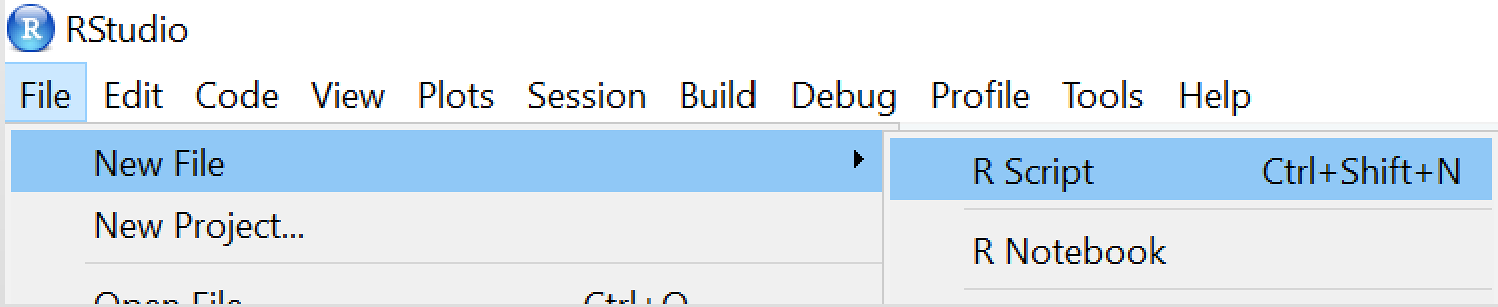
- Enter the following in to the R Studio command line




```
install.packages("ggplot2")

library(ggplot2)
library(ggmap)

# This line is a comment plot in window

mapHanover <- get_map("Hanover, NH", zoom=10)

ggmap(mapHanover)

mapLatLong <- get_map(location = c(lon = -71.0712, lat = 42.3538))

ggmap(mapLatLong)
```

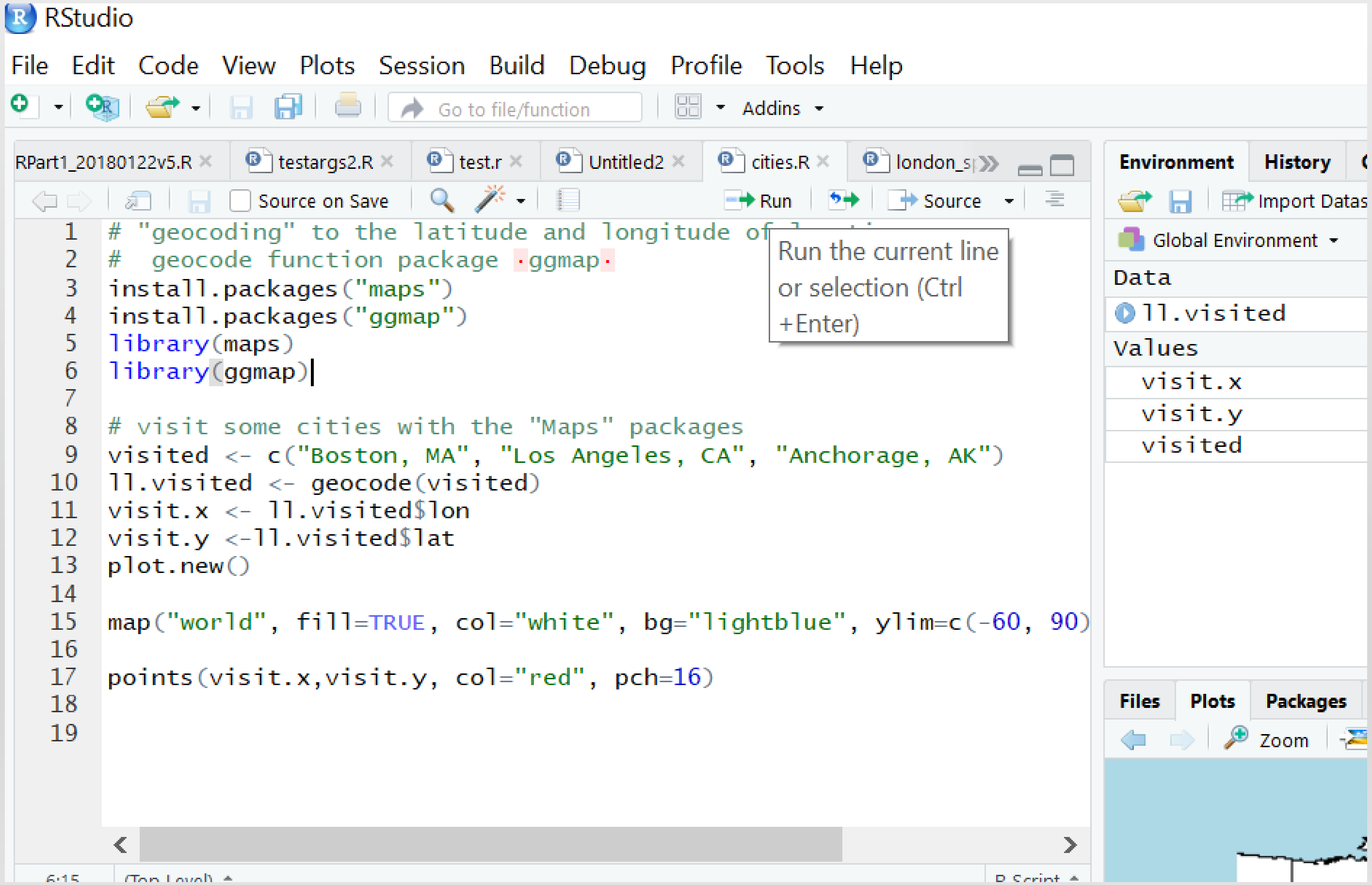
USING R SCRIPT FILES

- To make R code easier to type in, save and re-use, we can use an R Script file.
- In R Studio, click File > New File > R Script



USING R SCRIPT FILES

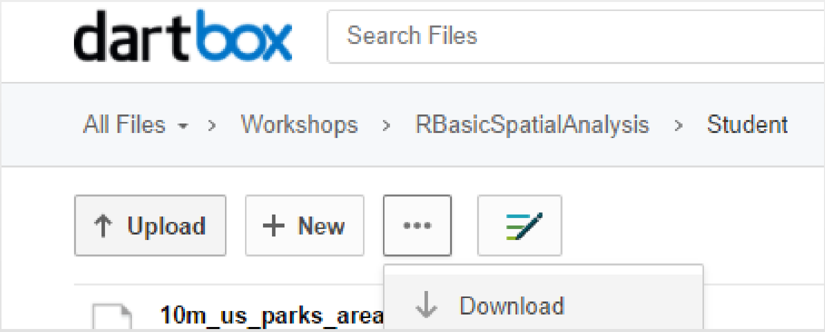
- Here we see the code inside a ".R" file
- Code can be run line-by-line using the "Run" button in the upper bar



WORKING WITH SPATIAL DATA

- Open R Studio (All Programs > R Studio)

- Downloading the Data:
  - In your browser, type dartgo.org/rspatial
  - At the DartBox site, click the ellipses ... and choose ‘Download’



- Download file Student.zip
- Copy the file to a convenient location such as:

  c:\rworkspace

- Unzip the file

READY TO DIVE IN?

- We'll use **R Studio** today so we can see our spatial analysis
- Data for this session can be downloaded at:

dartgo.org/rspatial

- Download file and unzip
- Copy the file to a "Working Directory" that R will recognize

GETTING THE DATA AND R TO WORK TOGETHER

- Use the “getwd()” and “setwd()” commands in R, and your computer’s file browser (Finder on the Mac, Windows Explorer on the PC)

```
Console   Terminal ×
c:/rworkspace/
> # Ctrl L to clear the console
> getwd()
[1] "C:/Users/f002d69/Documents"
> setwd("c:/rworkspace")
> getwd()
[1] "c:/rworkspace"
> 
```

On the PC:

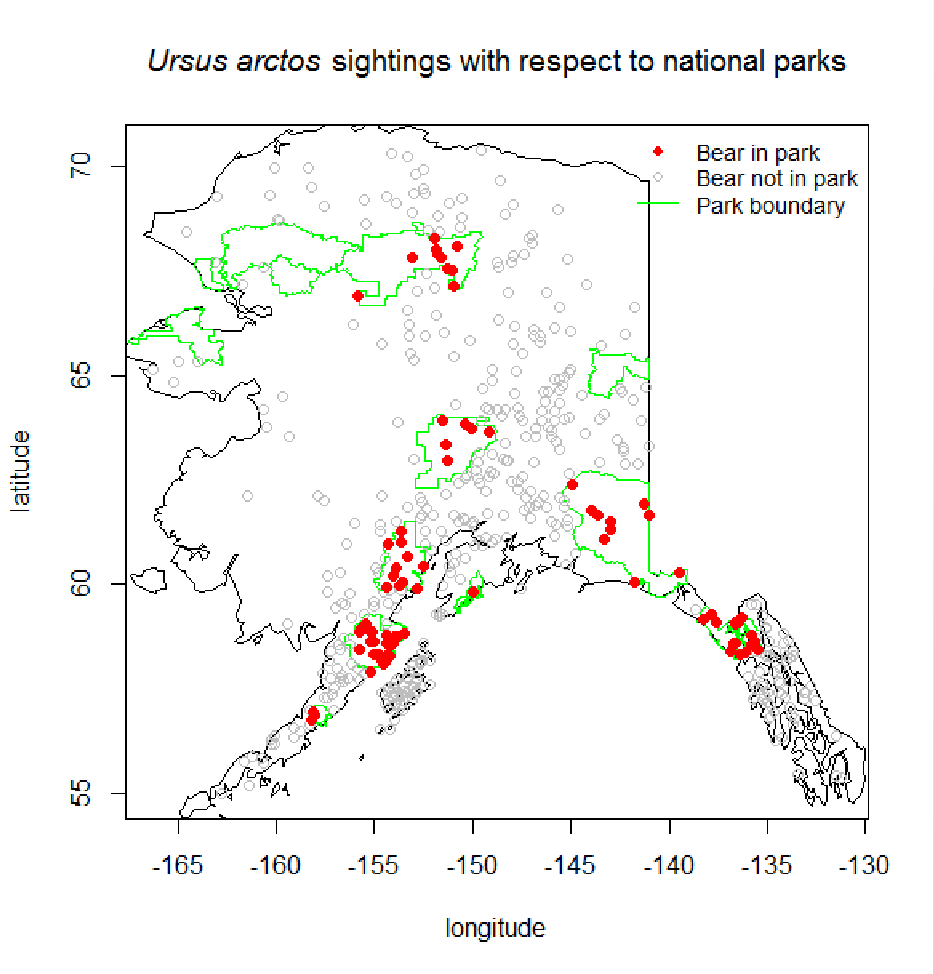
```
getwd()
[1] "C:/Users/f002d69/Documents"
> setwd("c:/users")
> getwd()
[1] "c:/users"
>
```

On the mac:

```
getwd()
[1] "/Users"
> setwd("~/Desktop")
> getwd()
[1] "/Users/sgaughan/Desktop"
```

MAP OVERLAY, POINT-IN-POLYGON ANALYSIS WITH SP "OVER" FUNCTION

```
install.packages("sp")
install.packages("rgdal")
install.packages("maps")
library(sp)
library(rgdal)
library(maps)

# load a csv with latitude and longitude coordinates

bears <- read.csv("bear-sightings.csv")

coordinates(bears) <- c("longitude", "latitude")

# load a shapefile representing an area

parks <- readOGR(".", "10m_us_parks_area")
```



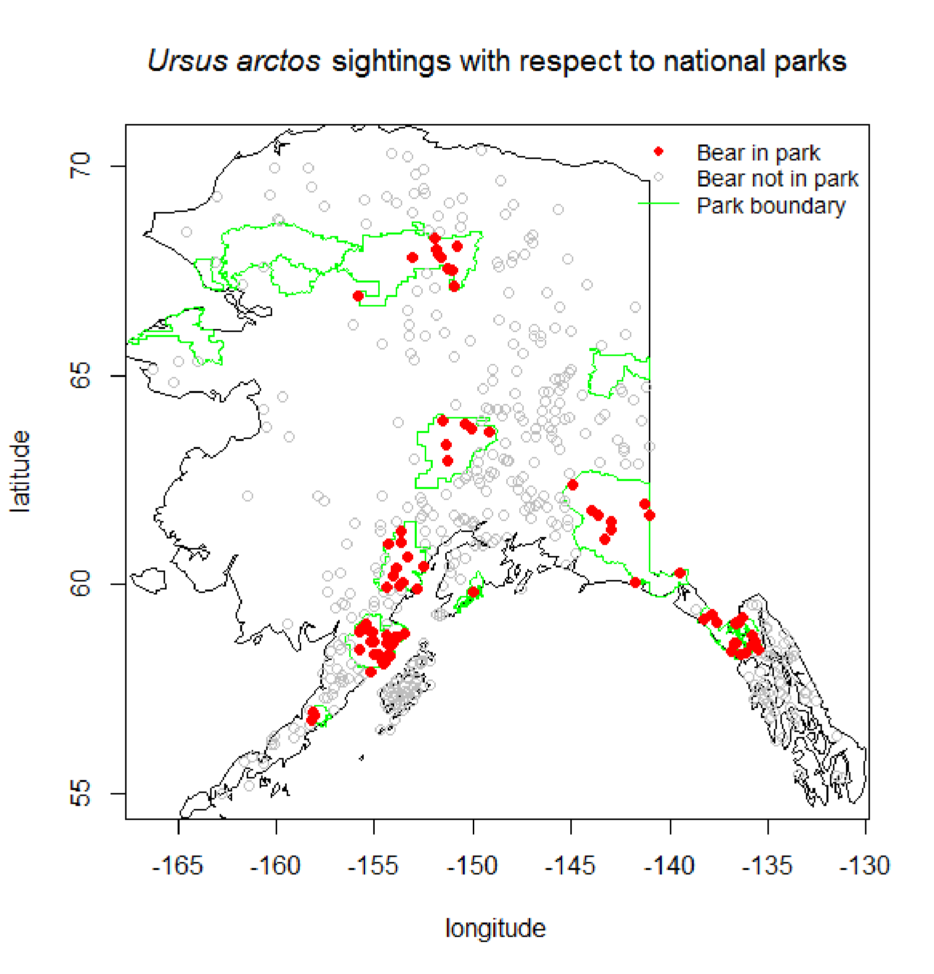
- Packages "sp", "rgdal" and "maps" can turn your R into a GIS
- Read-Write and Analyze spatial data, perform "map overlay"

MAP OVERLAY, POINT-IN-POLYGON ANALYSIS WITH SP “OVER” FUNCTION

```
# do some projection work (sp.proj4string function from sp)

proj4string(bears) <- proj4string(parks)

# Map Overlay!  (sp.over function)

inside.park <- !is.na(over(bears, as(parks, "SpatialPolygons")))

# get the desired output statistic, fraction of sightings in
parks

mean(inside.park)
```

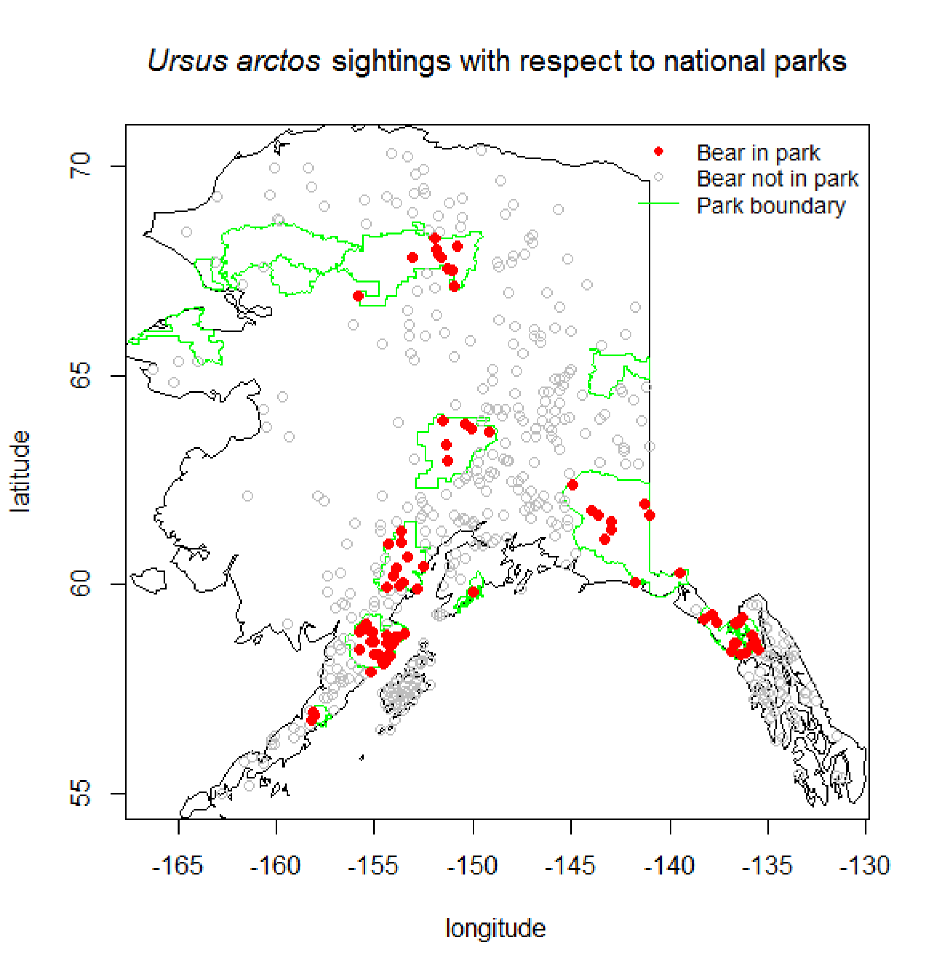
PLOT THE POINTS AND EXPORT

```
bears$park <- over(bears, parks)$Unit_Name

# Put the data on the map in just a few lines!

plot(coordinates(bears), type="n")

# use the maps.map function

map("world", region="usa", add=TRUE)

# …and the sp.plot function

plot(parks, border="green", add=TRUE)

points(bears[!inside.park, ], pch=1, col="gray")
```



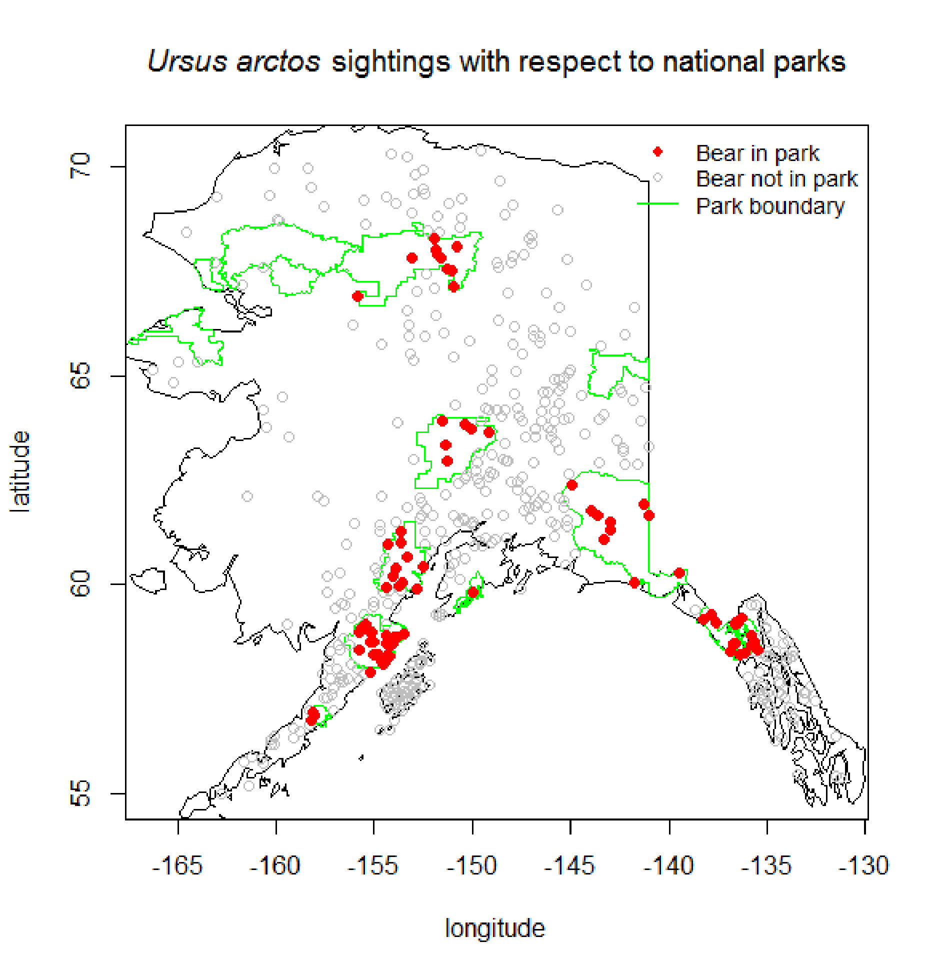
PLOT THE POINTS AND EXPORT

```
points(bears[inside.park, ], pch=16, col="red")

# Export GIS data or flat-file data

write.csv(bears, "bears-by-park.csv", row.names=FALSE)

# Export a GIS format 'shapefile' using the
rgdal.writeOGR funtion

writeOGR(bears, ".", "bears-by-park", driver="ESRI
Shapefile")
```



ADDING A LEGEND AND TITLE

```
# add a legend

legend("topright", cex=0.85,
       c("Bear in park", "Bear not in park", "Park boundary"),
       pch=c(16, 1, NA), lty=c(NA, NA, 1),
       col=c("red", "grey", "green"), bty="n")

# add a title

title(expression(paste(italic("Ursus arctos"),
                 " sightings with respect to national
parks")))
```

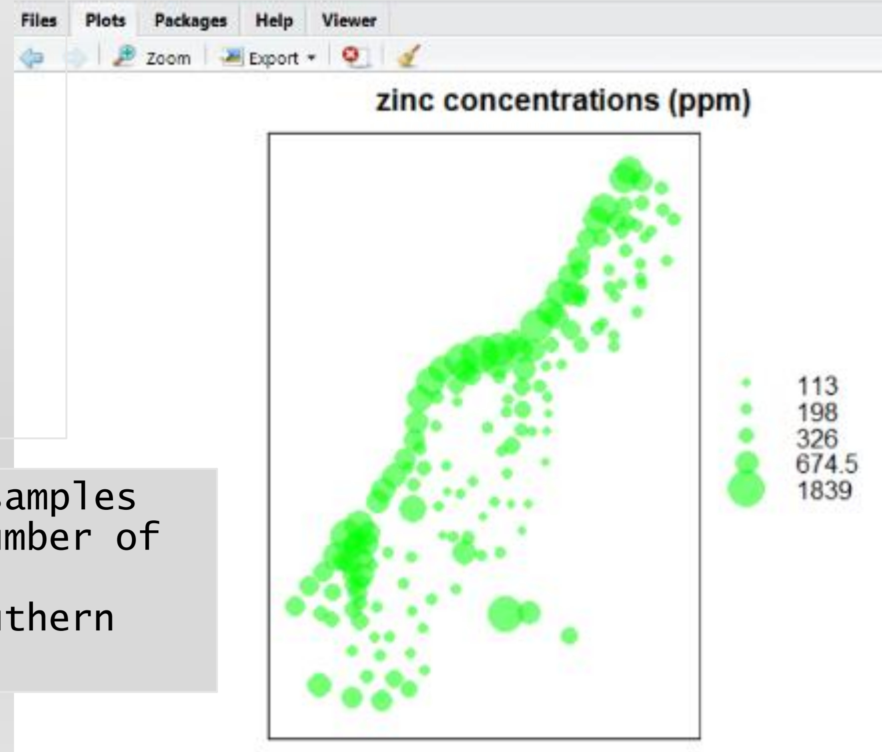


INSTALL SPATIAL LIBRARIES “GSTAT”, “SP” AND “GDAL”

```
# The “#” is a “comment”.  No need to type these lines
# note: package "sp" might ask to restart your R session

install.packages("sp")
install.packages("rgdal")

# import libraries

library(gstat)
library(sp)
library(rgdal)
```

LOAD DATASET IN TO R STUDIO AND PLOT

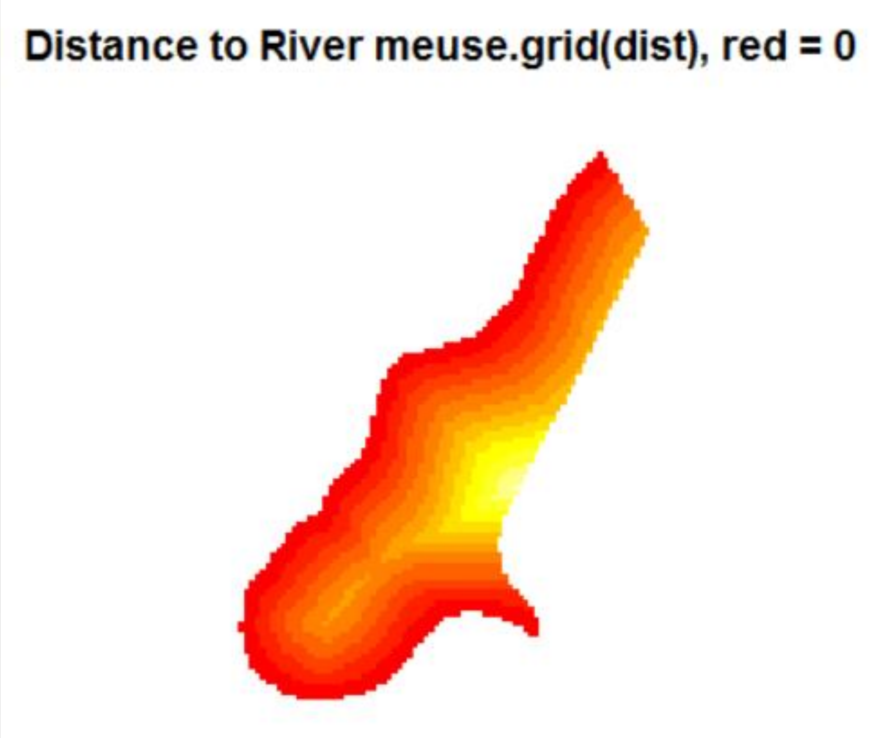
```
# load the meuse dataset in to the Rstudio environment

data(meuse)

# retrieve/set spatial coord

coordinates(meuse) = ~x+y

# note: coordinates use projection
# EPSG:28992 Amersfoort/RD Netherlands DutchRD
# view the first 5 coordinate pairs

coordinates(meuse)[1:5,]

# plot the zinc concentrations (bubble plot,
# high levels with larger circles)

bubble(meuse, "zinc", col=c("#00ff0088", "#00ff0088"), main = "zinc
concentrations (ppm)")
```



examine the "meuse" dataset, point data set consists of 155 samples of top soil heavy metal concentrations (ppm), along with a number of soil and landscape variables. The samples were collected in a flood plain of the river Meuse, near the village Stein, southern Netherlands, 50.9686432 Lat,5.7460789 Longitude

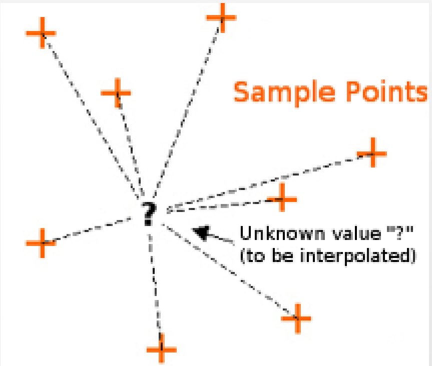
DISPLAY THE DISTANCE TO RIVER

```
# Task 2: distance display
# load the meuse.grid data
data(meuse.grid)
class(meuse.grid) # dataframe
summary(meuse.grid)

coordinates(meuse.grid) = ~x+y # convert to
spatialpontsdataframe
class(meuse.grid)

# set the gridded function to "TRUE", which converts
class to SpatialPixelsDataFrame
gridded(meuse.grid) = TRUE
class(meuse.grid)
# clear the plot window
dev.off()
# plot image of grid using the distance field
image(meuse.grid["dist"])

# add a title to the plot
title("Distance to River meuse.grid(dist), red = 0")
```

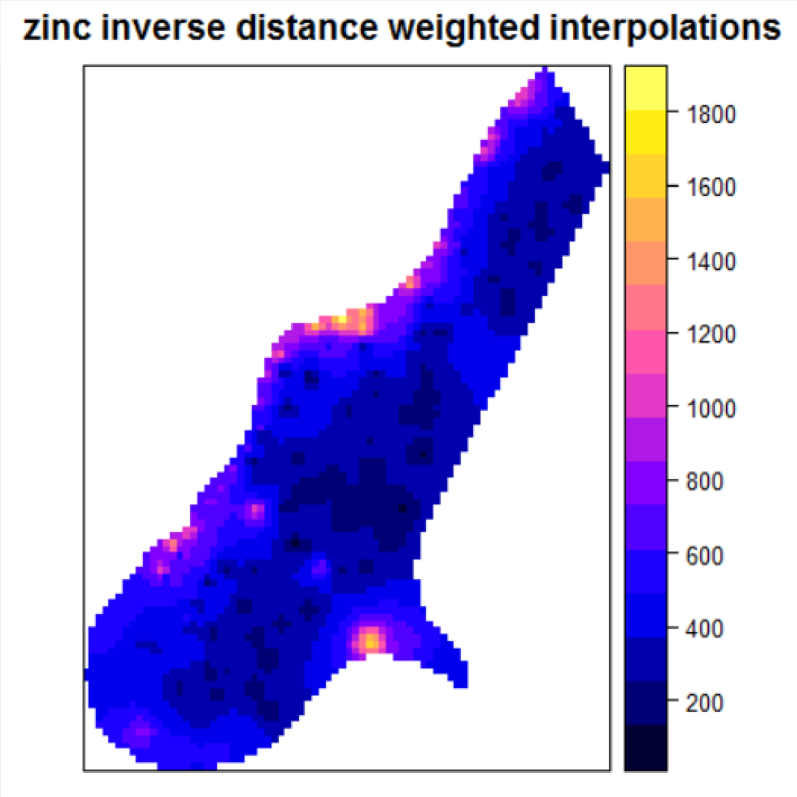


USE THE "GSTAT" PACKAGE FOR THE "INVERSE DISTANCE WEIGHTED" TOOL

Inverse Distance Weighting (IDW) is a GIS function that uses a deterministic method for multivariate interpolation with a known scattered set of points. Unknown points are calculated with a weighted average of the values available at the known points. This function can be used to create surfaces and index layers based on discrete observations. Temperature, elevation are examples.



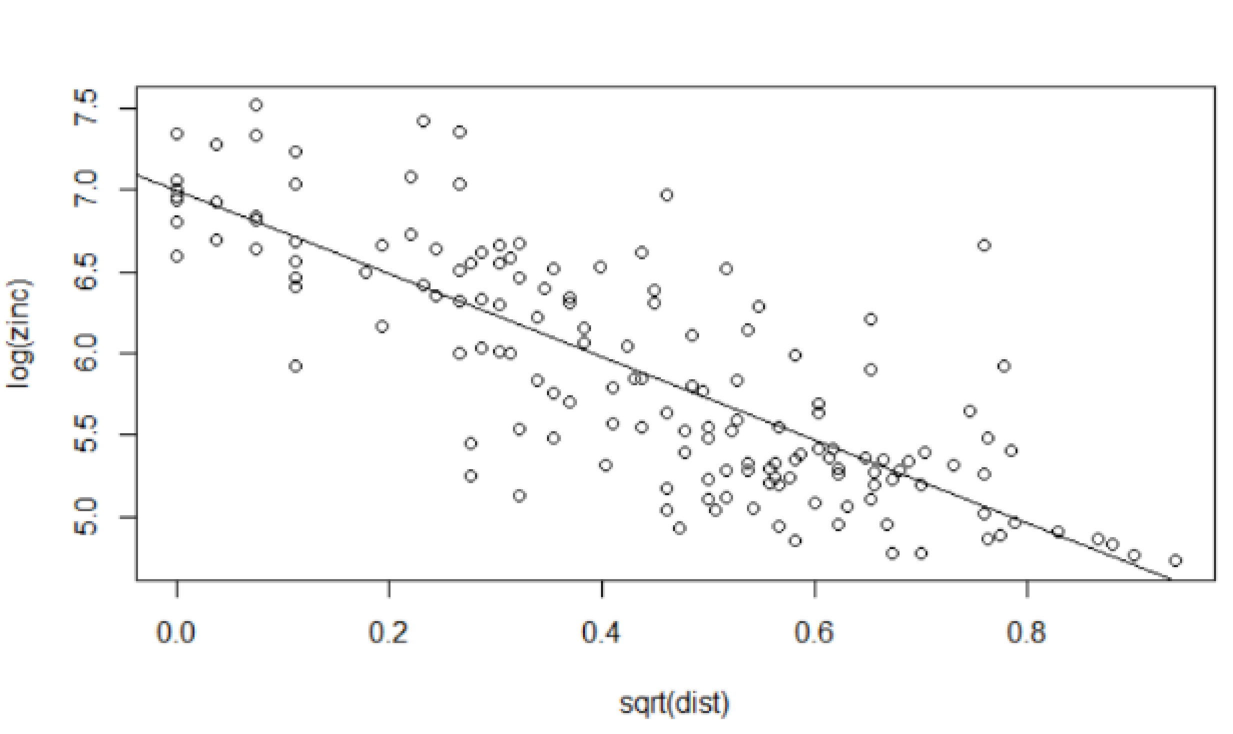

```
# use the gstat "Inverse distance weighted" tool

library(gstat)
zinc.idw <- idw(zinc~1, meuse, meuse.grid)

class(zinc.idw)

# spatialPixelsDataFrame

spplot(zinc.idw["var1.pred"], main = "zinc inverse
distance weighted interpolations")
```



Reference: https://docs.qgis.org/2.2/en/docs/gentle_gis_introduction/spatial_analysis_interpolation.html

EXAMINE LINEARITY

```
# in the previous plot, it
# appears
#that measurements
#of high concentrations
# of zinc are, in general,
#closer to the river
# lets linearize this:

plot(log(zinc)~sqrt(dist),
meuse)
abline(lm(log(zinc)~sqrt(d
ist), meuse))
```

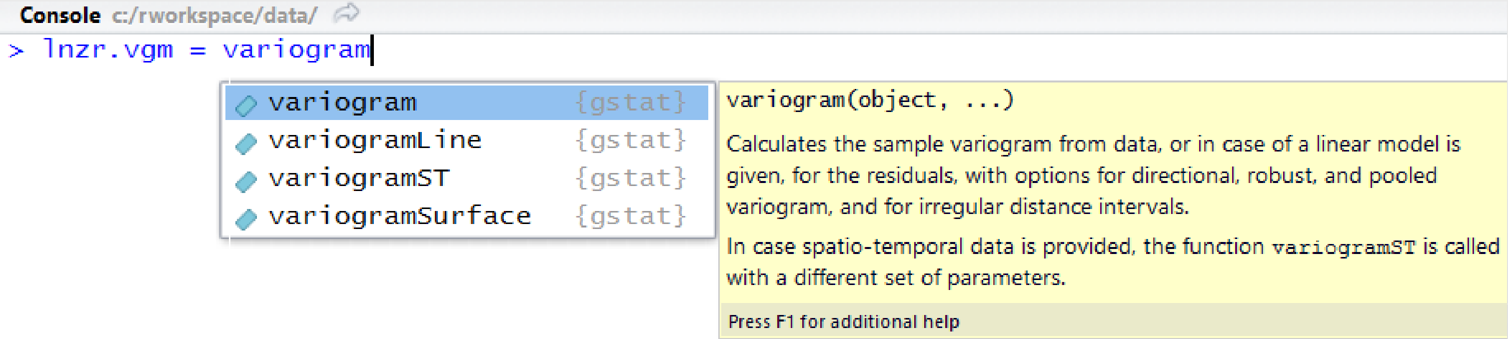


LOAD THE LINEAR MODEL AND SUMMARIZE

```
#load the linear model in to an object
zinc.lm <- lm(log(zinc) ~ sqrt(dist), data=meuse)
# show summary of the linear model
summary(zinc.lm)

Residuals:
     Min       1Q   Median       3Q      Max 
-1.04624 -0.29060 -0.01869  0.26445  1.59685 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)    
(Intercept)  6.99438    0.07593   92.12   <2e-16 ***
sqrt(dist)  -2.54920    0.15498  -16.45   <2e-16 ***
---
Signif. codes:
0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.4353 on 153 degrees of freedom
Multiple R-squared:  0.6388,  Adjusted R-squared:  0.6364 
F-statistic: 270.6 on 1 and 153 DF,  p-value: < 2.2e-16
```

KRIGING WITH GSTAT

Kriging is a multistep GIS surface creation tool. It explores statistical analysis of the point values and their distances and then creates the surface of interpolated values. Kriging often used when there is a spatially correlated distance or directional bias in the data. It is often used in soil science and geology.




```
lznr.vgm = variogram(log(zinc)~sqrt(dist), meuse)
lznr.fit = fit.variogram(lznr.vgm, model = vgm(1, "Exp", 300, 1))

lzn.kriged = krige(log(zinc)~1, meuse, meuse.grid, model = lznr.fit)

# the values are INTERPOLATED/ PREDICTED by the original dataset and the kriging function

spplot(lzn.kriged["var1.pred"])
```

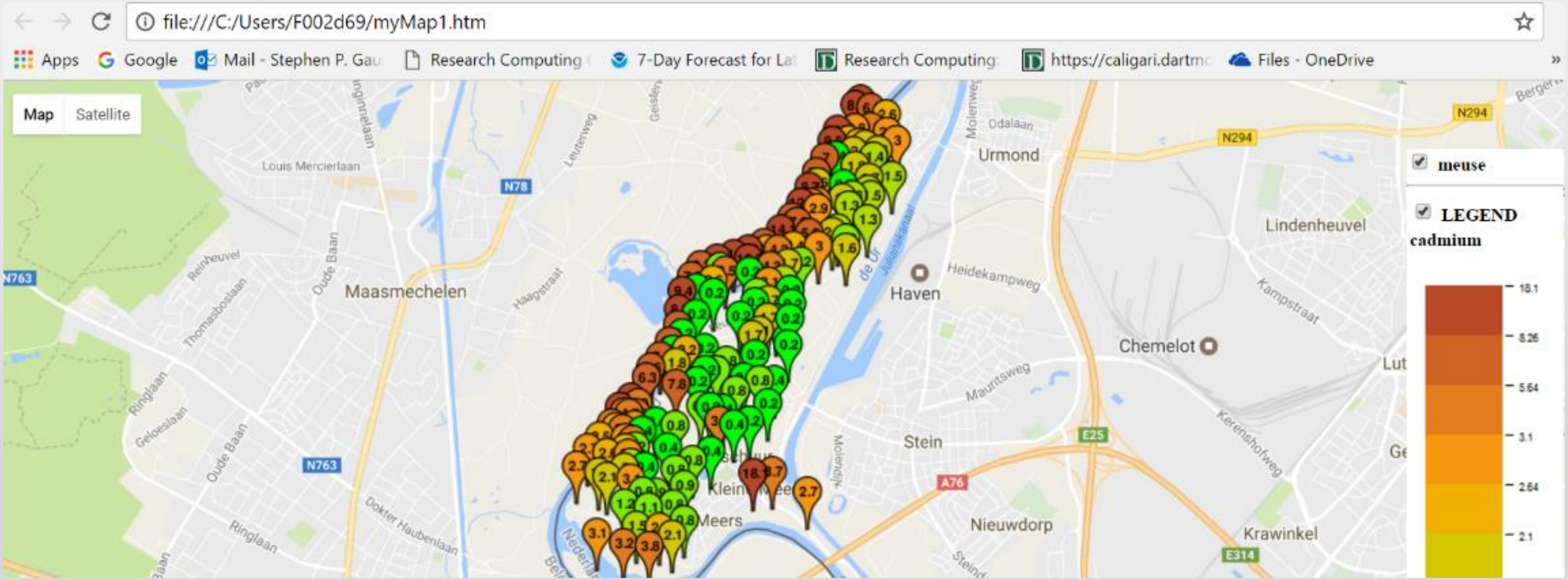
DISPLAY POINTS USING QUANTILE CATEGORIZATION

```
library(RColorBrewer)
load(system.file("data", "meuse.rda", package = "sp"))

# Create a SpatialPointsDataFrame Object from the data.frame

meuse.sp <- meuse  #Copy the data.  It's still a data.frame

coordinates(meuse.sp) <- ~x + y  # Now it's SpatialPointsDataFrame, with coordinates x and y
# Create a categorical variable and plot it

q <- quantile(meuse$zinc, seq(0.1, 0.9, 0.1))

# These are the actual values of the quantiles
q

# Plot the data in 5 bins

meuse.sp$zncat <- cut(meuse.sp$zinc, c(0, q[c(2, 4, 6, 8)], 2000))
spplot(meuse.sp, "zncat", col.regions = brewer.pal(5, "YlGnBu"))
```

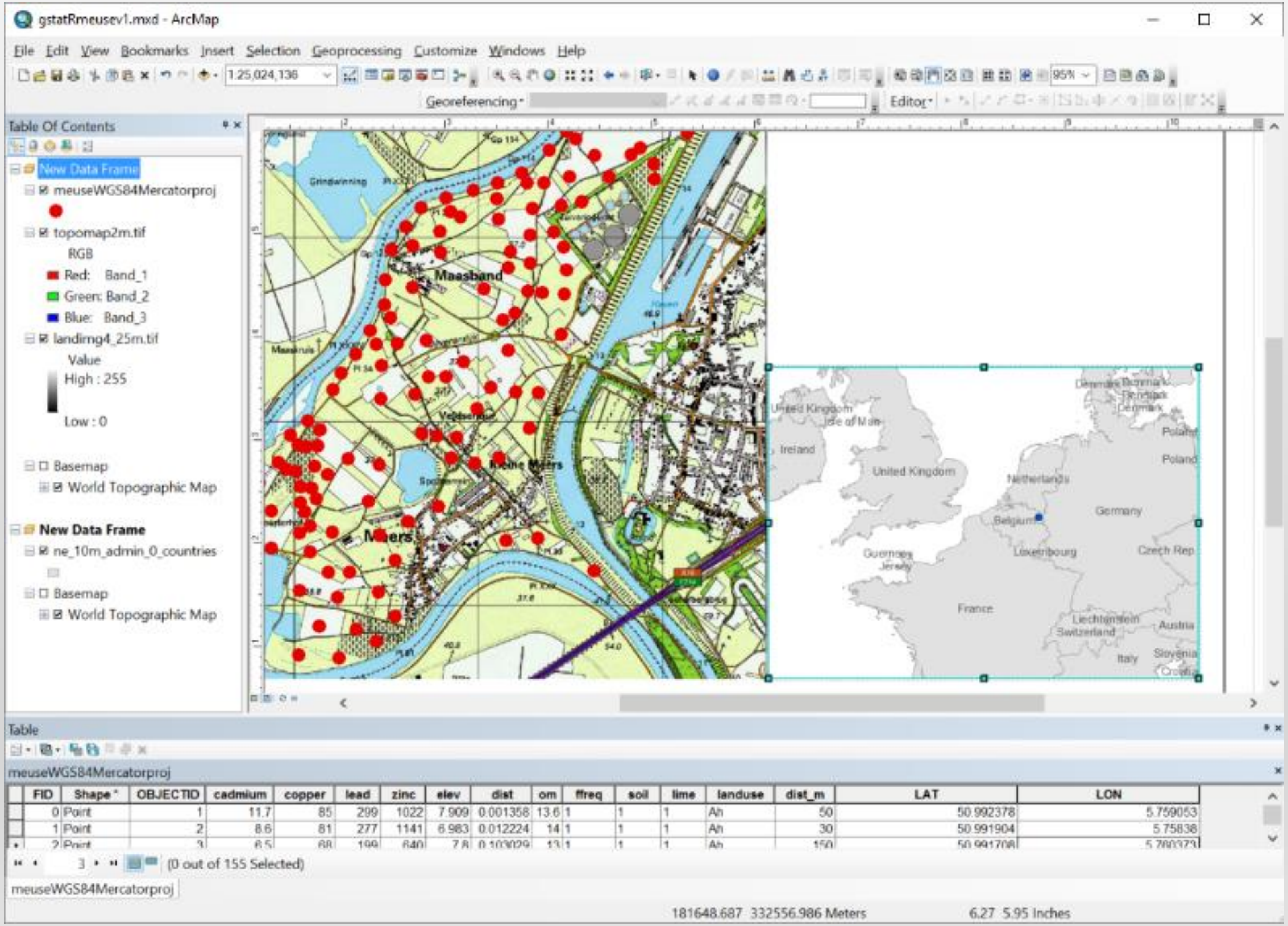
SEND THE POINTS TO A GOOGLE MAPS HTML PAGE

```
install.packages("plotGoogleMaps")
library(plotGoogleMaps)
data(meuse)
coordinates(meuse)<-~x+y # convert to SPDF

# use CRS from the sp pacakate to indicate the map projection/coord ref system

proj4string(meuse) <- CRS('+init=epsg:28992')

# Adding Coordinate Referent Sys.
# Create web map of Point data

m<-plotGoogleMaps(meuse,filename='myMap1.htm')
# Plotting another map with icons as pie chart

m<-segmentGoogleMaps(meuse, zcol=c('zinc','dist.m'),
                     mapTypeId='ROADMAP', filename='myMap4.htm',
                     colPalette=c('#E41A1C','#377EB8'), strokeColor='black')
```

SHOW "MEUSE" DATA IN GOOGLE MAPS WITH "PLOTGOOGLEMAPS" LIBRARY



DATA IN GIS SOFTWARE



R AND GIS
– MORE LINKS AND REFERENCES –

- R-GIS Tutorials
  - https://cran.r-project.org/doc/contrib/intro-spatial-rl.pdf
  - https://pakillo.github.io/R-GIS-tutorial/#intro
- Visualization, analysis and resources for R and Spatial Data
  - http://spatial.ly/r/
- Creating maps in R https://github.com/Robinlovelace/Creating-maps-in-R
- Using "Leaflet" maps in R https://github.com/rstudio/leaflet
- National Center for Ecological Analysis: https://www.nceas.ucsb.edu/scicomp/usecases
- https://www.nceas.ucsb.edu/~frazier/RSpatialGuides/ggmap/ggmapCheatsheet.pdf
- http://www.maths.lancs.ac.uk/~rowlings/Teaching/UseR2012/cheatsheet.html
- http://spatial.ly/wp-content/uploads/2013/12/spatialggplot.zip

MORE LINKS AND REFERENCES

- http://www.r-bloggers.com/r-beginners-plotting-locations-on-to-a-world-map/
- http://www.kevjohnson.org/making-maps-in-r/
- GGMAPS (depends on GGPLOT2, imports RGoogleMaps
  - https://cran.r-project.org/web/packages/ggmap/index.html
- Spatial References (map projections & coordinate systems)
  - http://spatialreference.org/ref/epsg/
- Online Tutorials
  - Lynda Tutorials for GIS, R https://www.lynda.com/
  - ESRI Tutorials
  - GIS Lounge - http://www.gislounge.com/tutorials-in-gis/

OTHER SPATIAL FUNCTIONS AND PACKAGES

- Spatial Buffer - package: rgeos, function name: gBuffer
- Near - package: rgeos, function name: gDistance
- Calculate slope of a surface from elevation dataset - package: raster, function name: terrain
- Raster values to points – package: raster, function name: extract
- Proximity Analysis, Hotspot analysis, density analysis

OTHER SPATIAL FUNCTIONS AND PACKAGES

```
# Export to KML with rgdal package, import well-formatted
KML files
writeOGR(locs.gb, dsn = "locsgb.kml", layer = "locs.gb",
driver = "KML")
newmap <- readOGR("locsgb.kml", layer = "locs.gb")

Make data spatial with sp package
coordinates(locs) <- c("lon", "lat") # set spatial
coordinates
plot(locs)

# Define a projection
crs.geo <- CRS("+proj=longlat +ellps=WGS84 +datum=WGS84") #
geographical, datum WGS84 proj4string(locs) <- crs.geo #
define projection system of our data summary(locs)

# Plot on a simple map
plot(locs, pch = 20, col = "steelblue") library(rworldmap) #
library rworldmap provides different types of global maps,
e.g: data(coastsCoarse) data(countriesLow)
plot(coastsCoarse, add = T)
```

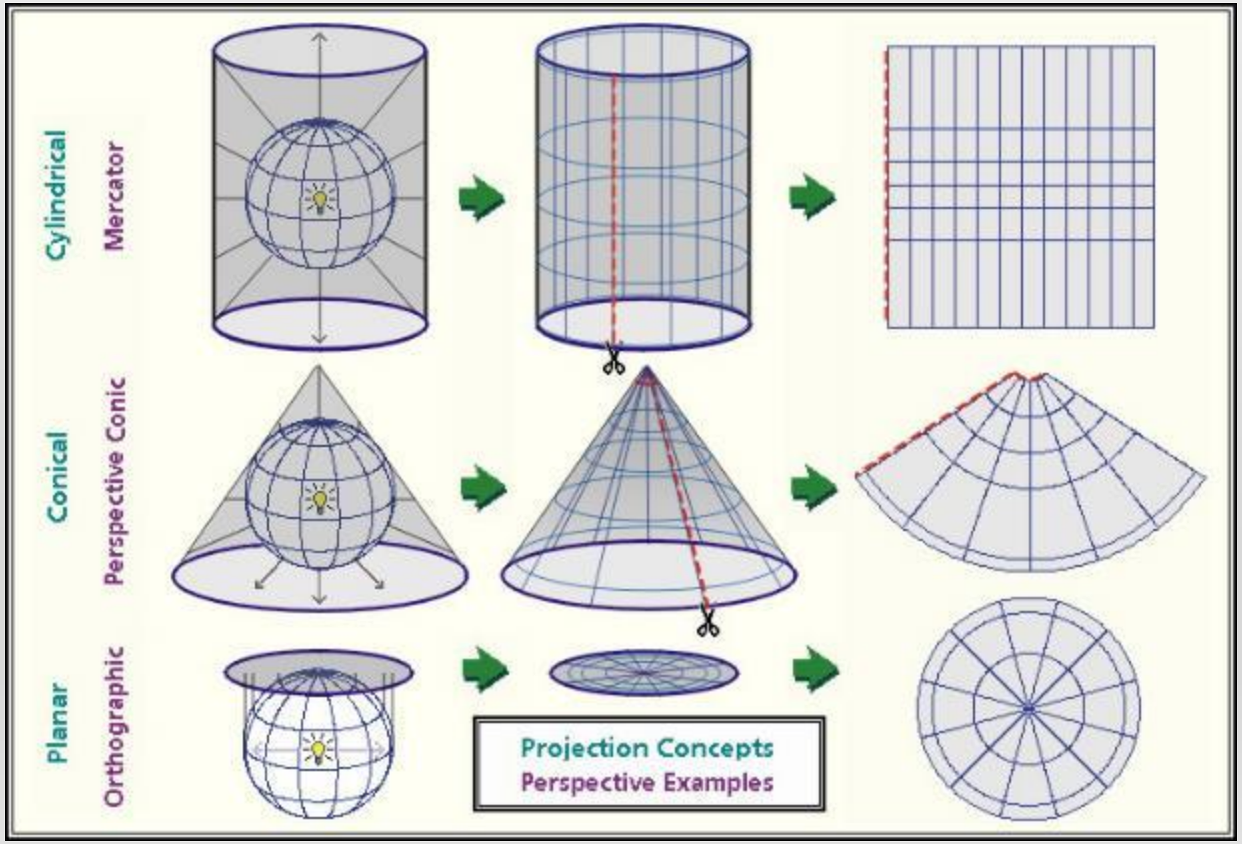
OTHER SPATIAL FUNCTIONS AND PACKAGES

```
# write to shapefile
writePointsShape(locs.gb, "locsgb")

# Read shapefile
gb.shape <- readShapePoints("locsgb.shp")
plot(gb.shape)


# geostats
library(gstat)
library(geoR)
library(akima) # for spline interpolation
library(spdep) # dealing with spatial dependence
```

QUESTIONS?

MAP PROJECTIONS

- To represent our three-dimensional earth (an ellipsoid) in two dimensions, datums and map projections are used



Projecting a 3D ellipsoid to a 2D computer screen or piece of paper will distort one or more of the following:
- shape
- distance
- area
- direction

Projections are sometimes designed to minimize one of these

DATA MANAGEMENT

- Data Frames
- CSV format (clean csv)
- Tidy Data
- Other formats - Reading out of databases (SQL), Geographic data constructs