Lecture 5: Maps

June 15, 2022

Overview

Course Administration

Good, Bad and Ugly

What and Why of Maps

Representing Maps Digitally

Maps in R

Course Administration

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8. June 29: come prepared to work on your policy brief storyline
9. Questions? Concerns?

Next Week's Assignment

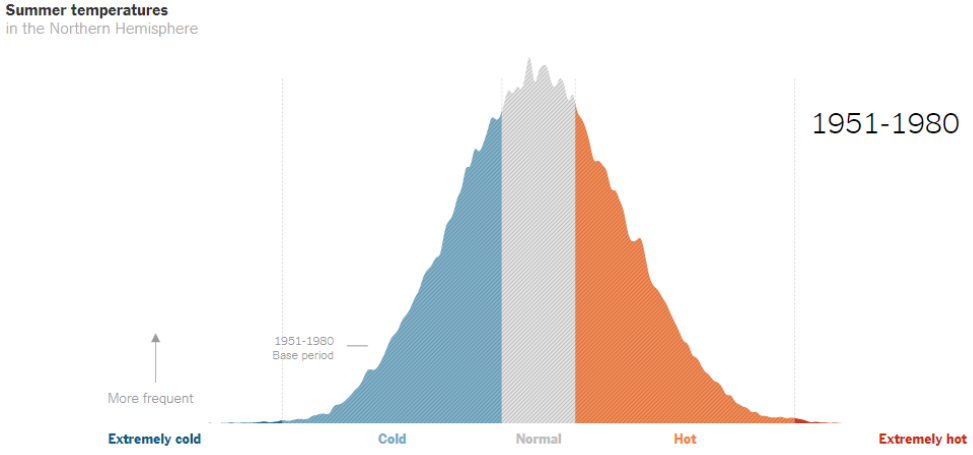
Find a descriptive or choropleth map. Post link to google sheet by Friday noon.

Finder	Commenter
David G	Dylan
Danielle G	Christina
Richa	Brady
Brady	Evan L.

This Week's Good Bad and Ugly

Finder	Commenter
Morre	Timberley
Spencer	Danielle
Evan L.	Mary
Dustin	Nicole

Timberley: Morre's Overlapping Histograms



New York Times. Headline is "It's not your imagination. Summers are getting hotter."

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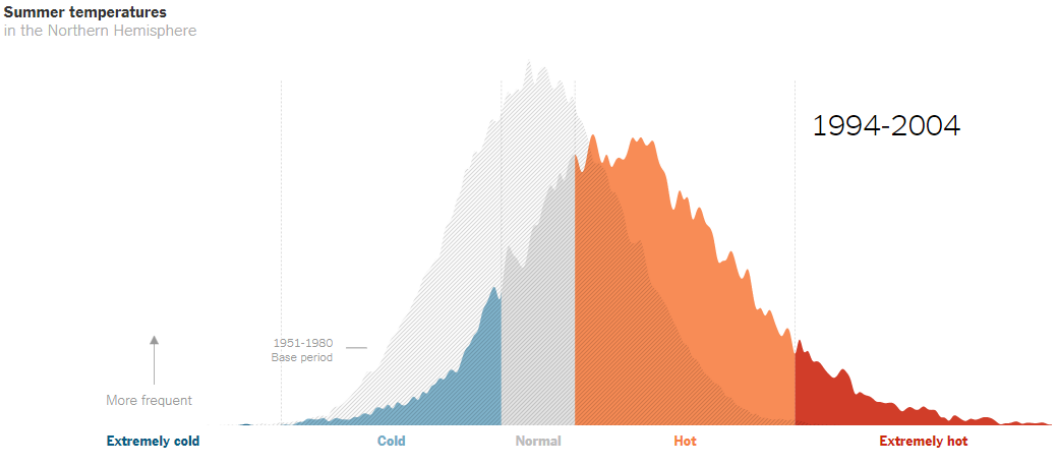
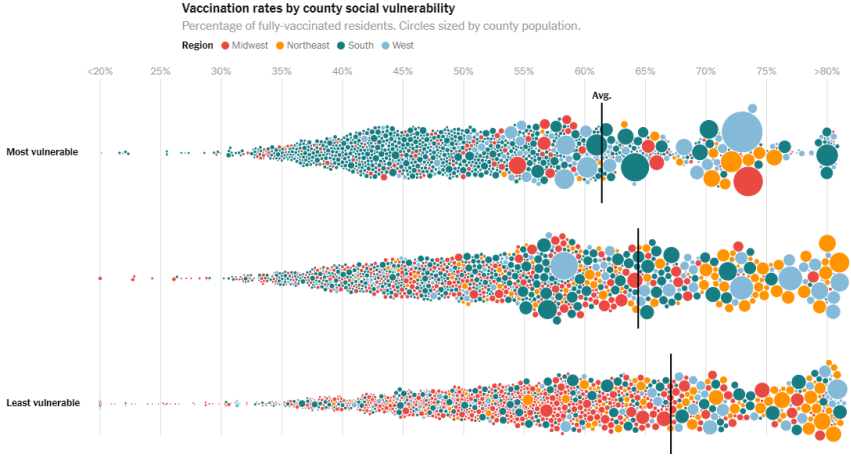


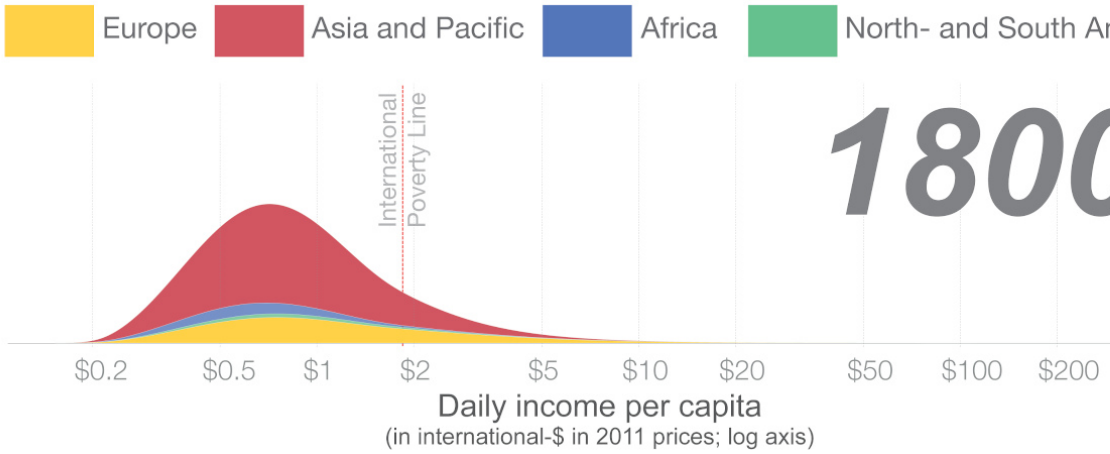
New York Times. Headline is "It's not your imagination. Summers are getting hotter."

Danielle: Spencer's *New York Times* Vaccination by Vulnerability



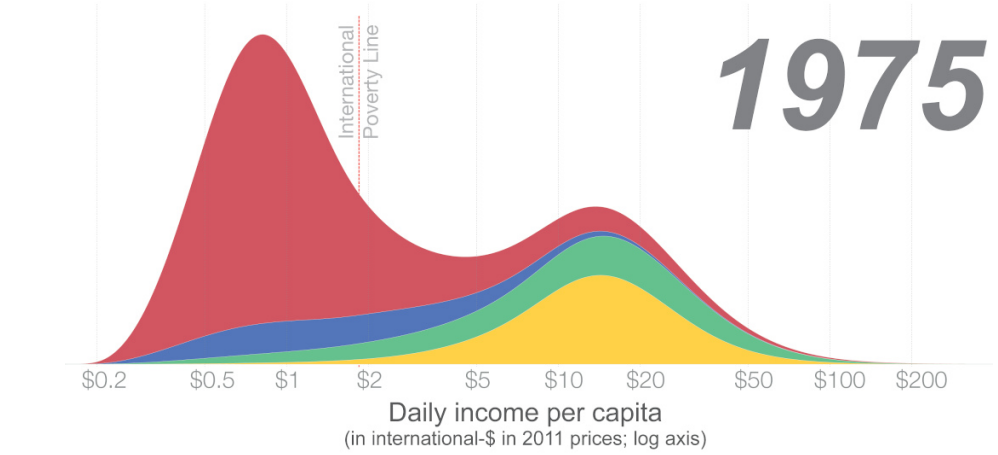
"See How Vaccinations Are Going...," *NYT*, updated June 14, 2022.

Mary: Evan's Global Income Over Time



Neufeld, Dorothy, "Visualizing Global Income Distribution Over 200 Years," *Visual Capitalist*, May 19, 2020.

Mary: Evan's Global Income Over Time



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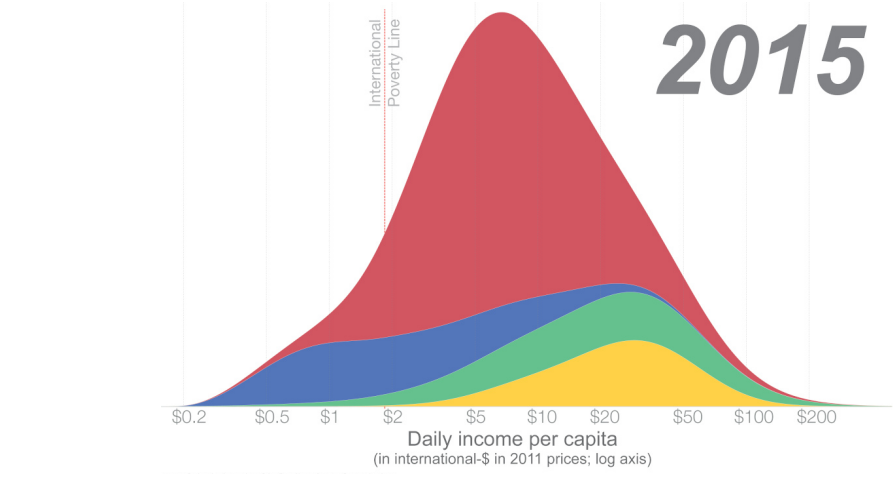
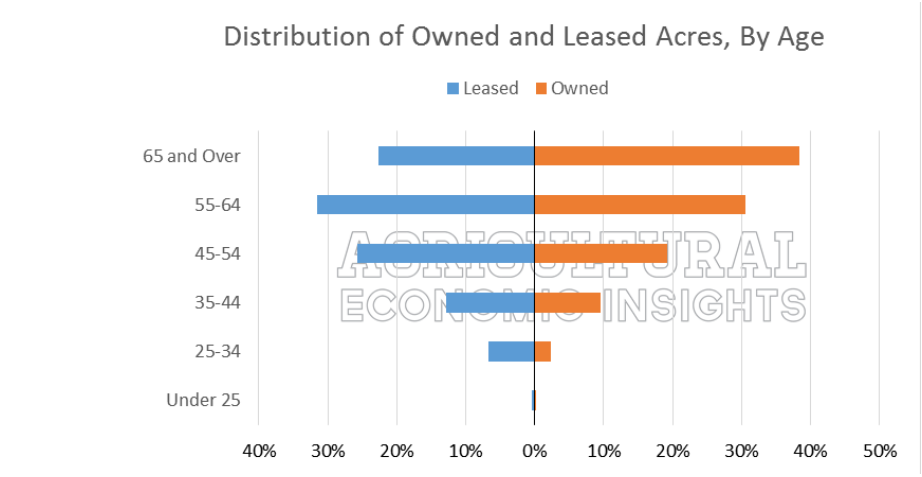


Neufeld, Dorothy, "Visualizing Global Income Distribution Over 200 Years," *Visual Capitalist*, May 19, 2022.

Nicole: Dustin's Farmers



Widmar, David, "Aging American Farmers and Their Farmland," *Agricultural Economic Insights*, February 3, 2015.

Lecture 5: Maps

Today

1. Maps in general
   - 1.1 What is a map?
   - 1.2 Why maps?
   - 1.3 What are the components of maps?
   - 1.4 When do maps deceive?
2. Digital maps
   - 2.1 What they are
   - 2.2 What they can do

What and Why of Maps

1. What is a Map?

- Something that tries to describe two-dimensional space
- "scale model of reality" (Monmonier)
- "almost always smaller" than reality

2. Why Maps?

- Use a map if you want to locate something in two-dimensional geographic space
- Use a map when you want to show a **spatial** relationship
- Don't use a map if you want to compare geographic units

When is Space Important?

1. To show relationship between two geographic things. Examples?

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   - geographic features that change smoothly and sharply over space

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2. To show a geographic pattern in an outcome. Examples?
   - voting outcomes correlated over space
   - geographic features that change smoothly and sharply over space

Don't use a map if you can do something simpler!

3. What Do You Have to Decide to Make a Map?

In distilling reality, there are three key choices

1. scale
2. projection
3. symbolization

Projection

- We want to show both
  - equivalence: size proportional to physical size
  - conformality: shape proportional to true shape

Projection

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Projection

- We want to show both
  - equivalence: size proportional to physical size
  - conformality: shape proportional to true shape
- But you cannot do both!
- Put differently, you want to take something round and make something flat
- Because you cannot, you have to approximate
- Projection = choice of type of wrongness in going from round to flat

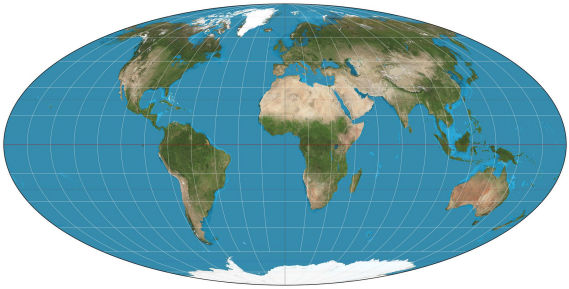
When Does Choice of Projection Matter?

- Matters for maps of the world
- Practically irrelevant for a map of DC
- For small areas, we care about precision of distance
- Frequently use a UTM (Universal Transverse Mercator) projection: units in meters

Rules of Thumb for Projections for Medium Areas

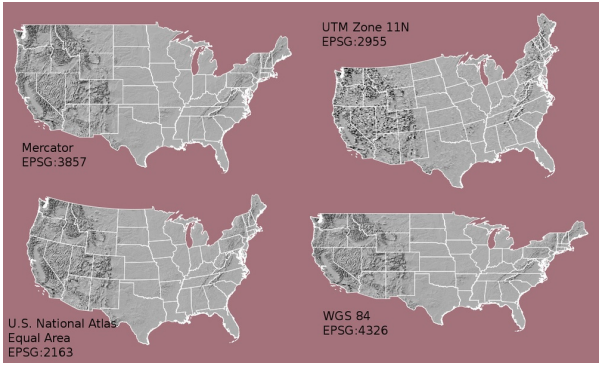
- Monmonier (p. 45) suggests for US either
  - Albers equal-area conic
  - Lambert conformal conic
- However, most maps you use should come with a projection defined

An Equal-Area Projection



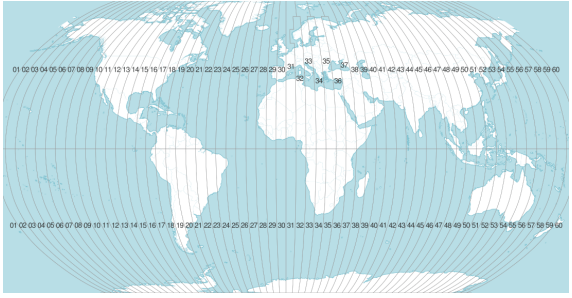
Thanks, Wikipedia.

The USA Four Ways



Thanks to Michael Corey.

UTM Zones

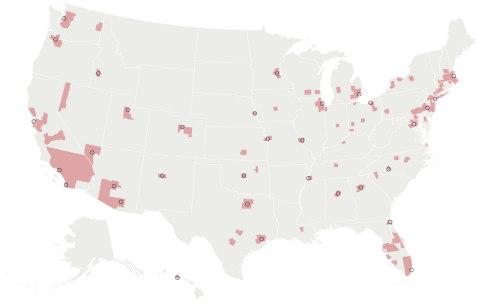


For small areas, use UTM projection if you need to calculate distances. Each number is a zone.
Thanks to Michael Corey.

4. Why Avoid Maps?

- They add complexity
- Geographic unit size infrequently related to importance
  - but remember that size indicates value
  - problematic!
- Examples?

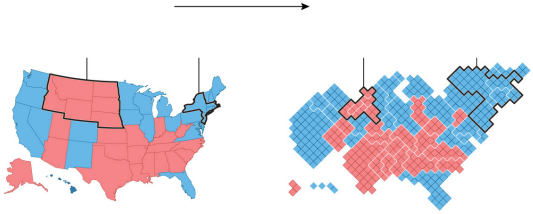
Red and Grey Areas Have About the Same Number of Votes Cast in 2012



With many thanks to the Washington Post

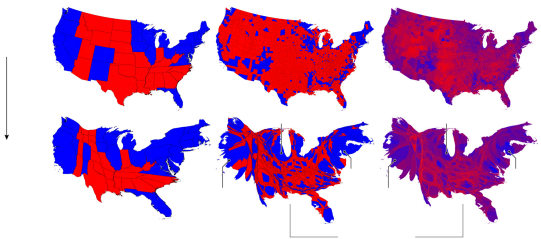
One Possible Solution

- A "cartogram" sizes locations by something: votes or people or electoral votes
- Five red midwestern states correspond to red block
- Mid-Atlantic corresponds to blue block

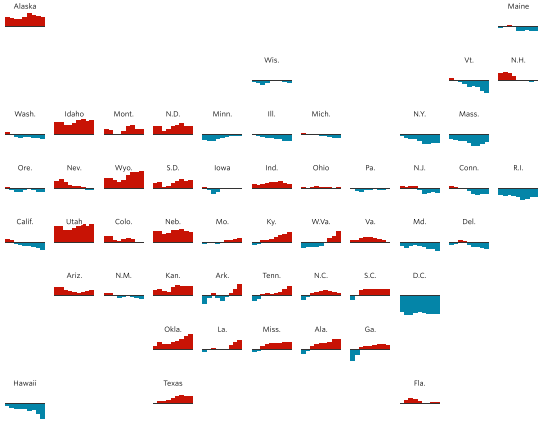


Another Possible Solution

- Thanks to U of Michigan physicist Newman
- Columns are state winner, county winner, county shaded by popular vote share
- Top is real map, bottom is cartogram
- Leftmost sized by electoral votes, others by votes cast



And a Quasi Map



Thanks to the Wall Street Journal, here.

Digital Maps

1. Digital Maps Have

- Units defined by coordinates in space
- Data for each unit

Examples of a map unit of observation, please!

Digital Maps

- A map is a representation of space
- A digital map is a file that tells a computer how to do this
- There are many formats, but we'll focus on shapefiles
- Shapefiles are a proprietary ArcInfo format, but can be read in R

Three Major Types of Shapes for Maps

1. points
2. lines
3. polygons

Points in Space

- location 1: (x, y)
- location 2: (x, y)
- location 3: (x, y)

What would you represent with points?

A Points Dataframe Example

LibID	X	Y	Name	Books
Ana	38.866	-76.980	Anacostia	500
CV	38.889	-76.932	Capitol View	501
Gtn	38.913	-77.068	Georgetown	499

Lines in Space

- location 1: $(x_1, y_1), (x_2, y_2)$
- location 2: $(x_1, y_1), (x_2, y_2)$
- location 3: $(x_1, y_1), (x_2, y_2)$

What would you represent with lines?

A Lines Dataframe Example

Int	X1	Y1	X2	Y2	Name	Condition
495	45	-62	26	-62	I495W	good
695	23	-50	25	-50	I695S	poor
10	15	-23	18	-24	I10	excellent

Polygons in Space

- location 1: $(x_1, y_1), (x_2, y_2), (x_3, y_3), (x_4, y_4), (x_1, y_1)$
- location 2: $(x_1, y_1), (x_2, y_2), (x_3, y_3), (x_4, y_4), (x_5, y_5), (x_1, y_1)$
- location 3: $(x_1, y_1), (x_2, y_2), (x_3, y_3), (x_1, y_1)$

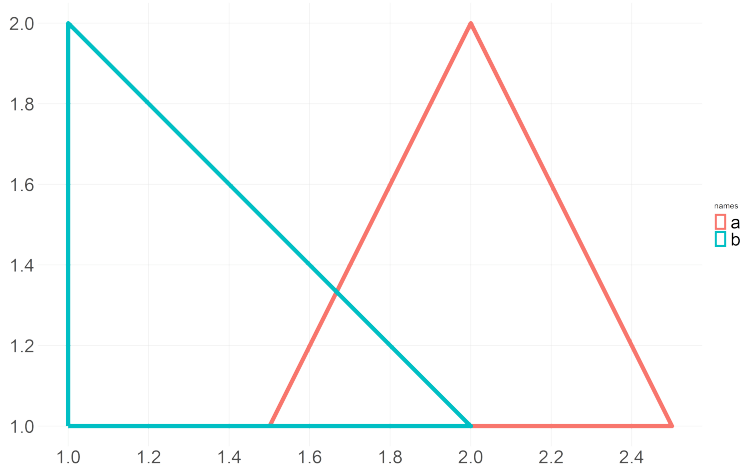
Note that last point is the same as the first point.[1]
What would you represent with polygons?

[1] Polygons can have holes; we can talk about this.

A Polygon Dataframe Example

Triangle	X1	Y1	X2	Y2	X3	Y3	X4	Y4
a	1.5	1	2	2	2.5	1	1.5	1
b	1	1	1	2	2	1	1	1

Plotting These



But Where Do the Points Go?

- A map file needs some instructions on what the points mean
- Map makers define coordinate systems so that everyone agrees on what $(x_1, y_1), (x_2, y_2)$ means
- Many maps have a geographic/global/spherical system: in latitude/longitude

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- Many maps have a geographic/global/spherical system: in latitude/longitude
- And to lay flat, if we are not drawing on a globe
  - we need a projected coordinate system
  - have a defined unit of measurement: meters, feet, decimal degrees
  - usually tell you meters/feet/miles from a specific point

Implications for Mapping

- You can't put maps with two different coordinate systems on top of each other
- Easier to calculate distances and areas with projected coordinate systems
- You can go from one projection to another, but **use the right command**
- Digital maps usually come with a projection defined

R

Today

A. `sf` package

B. Reading

C. Plotting

D. Projections

E. Spatially combining

A. `sf` Package

- a new package as of 2018
- works with `tidyverse` and `ggplot`
- use all the other commands you've used to date
- ok for all map data except rasters
- thank you, Edzer Pebesma!

Install and Call `sf`

You'll need to install – once

```
install.packages("sf", dependencies = TRUE)
```

And call, at the top of your program

```
library(tidyverse)
library(sf)
```

B.1. Reading a Digital Map

- R's `sf` can read many types of digital maps
- this class we will read shapefiles and geoJSON files
- these are different ways of codifying space into a file

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Make sure you download the digital map file, not the data!

B.2. What is a Shapefile?

- shapefiles have 4 to 7 parts
- all have the same name and these extensions
  - .shp
  - .shx
  - .dbf
  - .prj
  - .xml
  - .cpg
- the first 3 are mandatory
- it's odd if you don't have a projection, but you can still draw a map

B.3. Read the shapefile – or any geographic file

The key command is `st_read("FILENAME.MAP_EXTENSION")`

```
shp.df <- st_read("c:/stuff/map.shp")
```

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This new file

- works like a dataframe
- plus it has spatial information
- is called a "simple feature"

C.1 Plotting

Two main commands for plotting simple features in R

1. `plot()`
2. `ggplot()` using `geom_sf()`

Happily, `geom_sf()` works a lot like the other `geom_XXX()` commands you already know.

C.2. Example

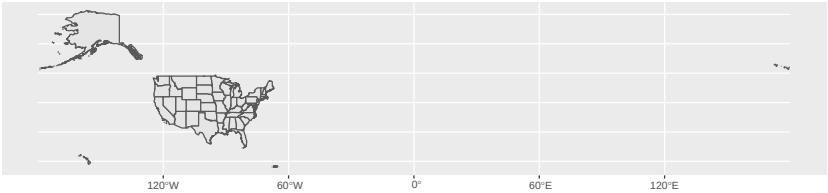
```
usmap <- st_read("H:/maps/united_states/census2010/states/gz_2010_us_040_0(
```

```
## Reading layer `gz_2010_us_040_00_20m' from data source
##   `H:\maps\united_states\census2010\states\gz_2010_us_040_00_20m.shp'
##   using driver `ESRI Shapefile'
## Simple feature collection with 52 features and 5 fields
## Geometry type: MULTIPOLYGON
## Dimension:     XY
## Bounding box:  xmin: -179.1473 ymin: 17.88481 xmax: 179.7785 ymax: 71.3
## Geodetic CRS:  NAD83
```

```
states <- ggplot() +
  geom_sf(data = usmap)
```

C.3. Example plot

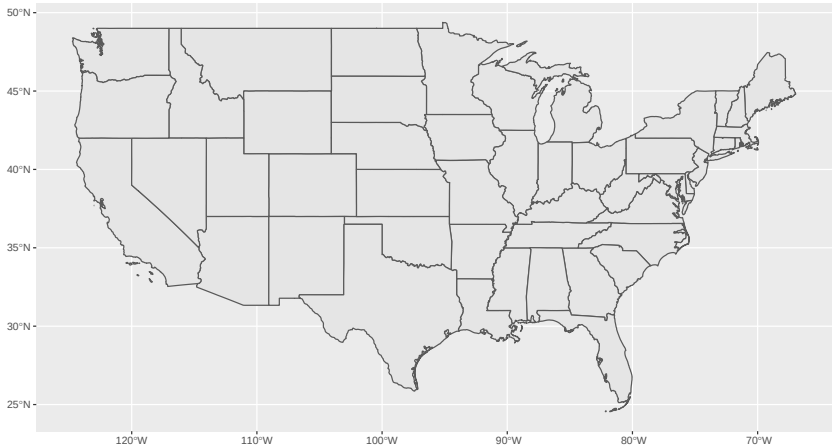
```
states
```



C.4. Just the Continental US

```
# omit AK, HI, PR
usmap.cont <- usmap[which(!(usmap$STATE %in% c("02","15","72"))),]
# or using filter
usmap.cont <- filter(.data = usmap, !(STATE %in% c("02","15","72")))
cont.us <-
  ggplot() + geom_sf(data = usmap.cont)
```

C.4. Just the Continental US



D. Projections

- maps should have a projection
- to tell R where to put points in space
- these are viewable

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```
st_crs(usmap.cont)
```

```
## Coordinate Reference System:
##   User input: NAD83
##   wkt:
## GEOGCRS["NAD83",
##     DATUM["North American Datum 1983",
##         ELLIPSOID["GRS 1980",6378137,298.257222101,
##             LENGTHUNIT["metre",1]]],
##     PRIMEM["Greenwich",0,
##         ANGLEUNIT["degree",0.0174532925199433]],
##     CS[ellipsoidal,2],
##         AXIS["latitude",north,
##             ORDER[1]
```

You Can Change Projections

- if you don't do it properly, you will mess everything up!
- use `st_transform()`

Changing Projections

For example

```
usmap.cont2 <- st_transform(x = usmap.cont, crs = 2163)
st_crs(usmap.cont2)
```

```
## Coordinate Reference System:
##   User input: EPSG:2163
##   wkt:
## PROJCRS["NAD27 / US National Atlas Equal Area",
##     BASEGEOGCRS["NAD27",
##         DATUM["North American Datum 1927",
##             ELLIPSOID["Clarke 1866",6378206.4,294.978698213898,
##                 LENGTHUNIT["metre",1]]],
##         PRIMEM["Greenwich",0,
##             ANGLEUNIT["degree",0.0174532925199433]],
##         ID["EPSG",4267]],
##     CONVERSION["US National Atlas Equal Area",
##         METHOD["Lambert Azimuthal Equal Area (Spherical)"
```

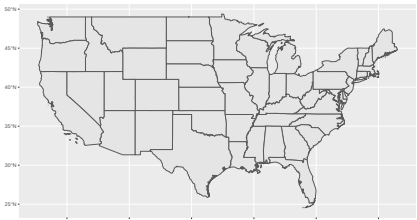
Look at New and Old Projections

Create map with new projection

```
cont.us2 <-
  ggplot() + geom_sf(data = usmap.cont2)
```

Look at New and Old Projections

```
cont.us
cont.us2
```



E. Spatially combining

Questions you can answer with `st_intersection()`

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3. How many miles of roads (lines) are in the 3 western coastal states (polygons)?

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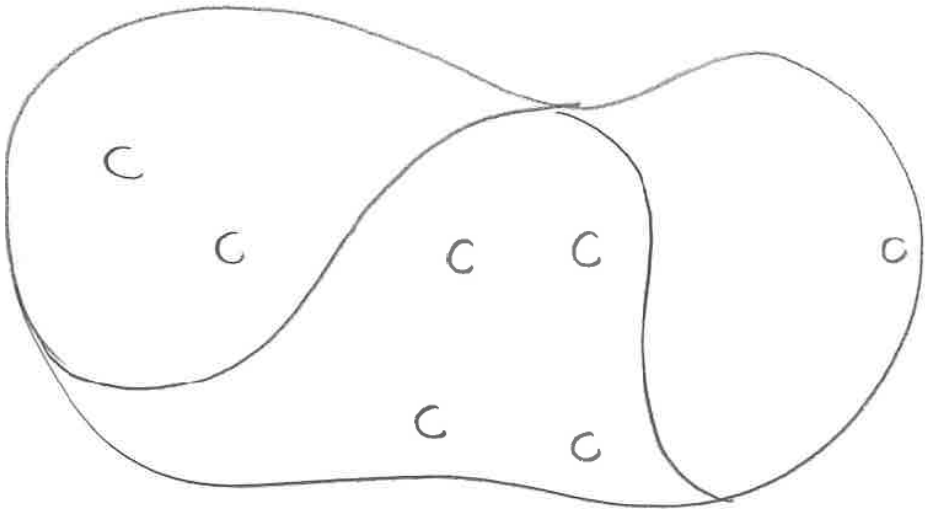
1. Which states are cities in?
   - points and polygons: should return points
2. What share of national park land area (polygons) is in cities (polygons)?
   - polygons and polygons: should return polygons
3. How many miles of roads (lines) are in the 3 western coastal states (polygons)?
   - lines and polygons: should return lines, then sum to state level

E.1 Example: Which states are cities in?



E.1. Cities and States

```
cities
```

```
##   city.id temp  x  y
## 1       1   70 45 76
## 2       2   60 46 77
## 3       3   50 34 78
```

```
states
```

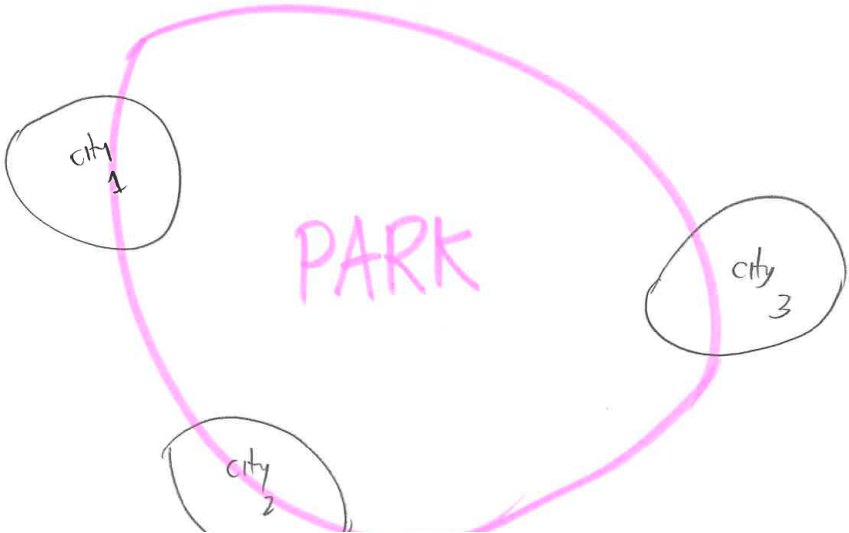
```
##   state.id area polygon
## 1        a  500  pinfo1
## 2        b  100  pinfo2
## 3        c  200  pinfo3
```

E.1. Cities in States

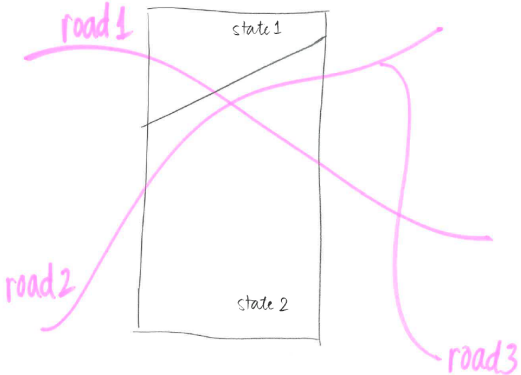
```
cities.in.states
```

```
##   city.id temp  x  y state.id area
## 1       1   70 45 76        a  500
## 2       2   60 46 77        a  500
## 3       3   50 34 78        b  100
```

E.2 Example: What share of national park land area is in cities?



E.3 Example: How many miles of roads in each state?



E.4. How to do it

Use `st_intersection()`

commands

Don't confuse with `st_intersects()` which does the same thing but returns a matrix, not a simple feature.

E.5. Example

Make a set of polygons, called X

```
b0 = st_polygon(list(rbind(c(-1,-1),
                           c(1,-1),
                           c(1,1),
                           c(-1,1),
                           c(-1,-1))))
b1 = b0 + 2
b2 = b0 + c(-0.2, 2)
x = st_sfc(b0, b1, b2)
```

E.5. Simple Feature X

```
x
```

```
## Geometry set for 3 features
## Geometry type: POLYGON
## Dimension:     XY
## Bounding box:  xmin: -1.2 ymin: -1 xmax: 3 ymax: 3
## CRS:           NA
```

```
## POLYGON ((-1 -1, 1 -1, 1 1, -1 1, -1 -1))
```

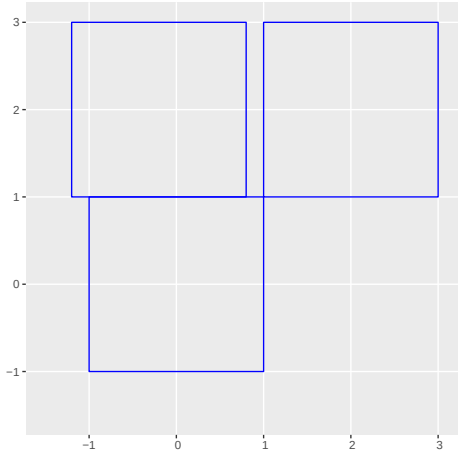
```
## POLYGON ((1 1, 3 1, 3 3, 1 3, 1 1))
```

```
## POLYGON ((-1.2 1, 0.8 1, 0.8 3, -1.2 3, -1.2 1))
```

E.5. Plot X

```
xplot <- ggplot() +
  geom_sf(data = x, color = "blue", fill = NA) +
  scale_x_continuous(limits = c(-1.5,3)) +
  scale_y_continuous(limits = c(-1.5,3))
```

E.5. Plot x



E.5. Example

Make a set of polygons, called Y

```
a0 = b0 * 0.8
a1 = a0 * 0.5 + c(2, 0.7)
a2 = a0 + 1
a3 = b0 * 0.5 + c(2, -0.5)
y = st_sfc(a0,a1,a2,a3)
```

Taken directly from `sf` vignette here.

E.5. Simple Feature Y

```
y
```

```
## Geometry set for 4 features
## Geometry type: POLYGON
## Dimension:     XY
## Bounding box:  xmin: -0.8 ymin: -1 xmax: 2.5 ymax: 1.8
## CRS:           NA
```

```
## POLYGON ((-0.8 -0.8, 0.8 -0.8, 0.8 0.8, -0.8 0....
```

```
## POLYGON ((1.6 0.3, 2.4 0.3, 2.4 1.1, 1.6 1.1, 1...
```

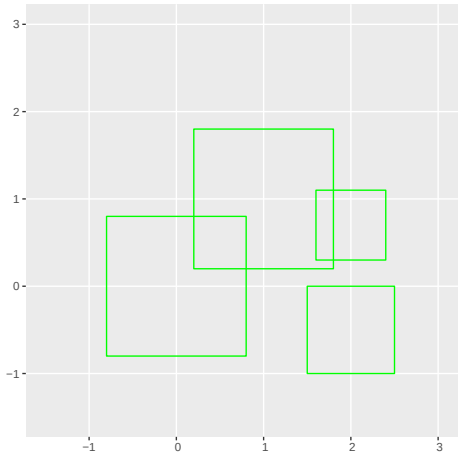
```
## POLYGON ((0.2 0.2, 1.8 0.2, 1.8 1.8, 0.2 1.8, 0...
```

```
## POLYGON ((1.5 -1, 2.5 -1, 2.5 0, 1.5 0, 1.5 -1))
```

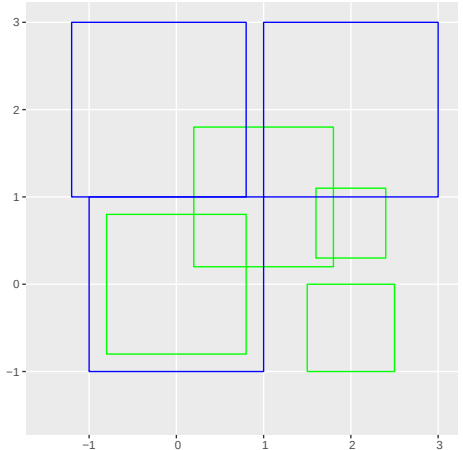
E.5. Plot Y

```
yplot <- ggplot() +
  geom_sf(data = y, color = "green", fill = NA) +
  scale_x_continuous(limits = c(-1.5,3)) +
  scale_y_continuous(limits = c(-1.5,3))
```

E.5. Plot Y



E.5. Plot `X` and `Y` Together



E.6. Intersection

```
xy <- st_intersection(x,y)
```

E.7. How the New Simple Feature Looks

```
xy
```

```
## Geometry set for 5 features
## Geometry type: POLYGON
## Dimension:     XY
## Bounding box:  xmin: -0.8 ymin: -0.8 xmax: 2.4 ymax: 1.8
## CRS:           NA
```

```
## POLYGON ((-0.8 0.8, 0.8 0.8, 0.8 -0.8, -0.8 -0....
```

```
## POLYGON ((1.6 1, 1.6 1.1, 2.4 1.1, 2.4 1, 1.6 1))
```

```
## POLYGON ((1 1, 1 0.2, 0.2 0.2, 0.2 1, 1 1))
```

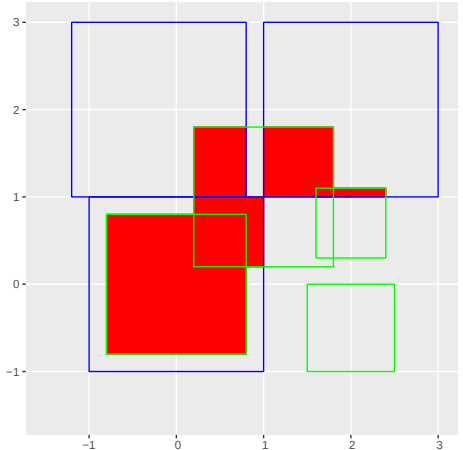
```
## POLYGON ((1 1, 1 1.8, 1.8 1.8, 1.8 1, 1 1))
```

```
## POLYGON ((0.8 1, 0.2 1, 0.2 1.8, 0.8 1.8, 0.8 1))
```

E.8 What the Picture Looks Like

```
xyplot <- ggplot() +
  geom_sf(data = xy, color = "red", fill = "red") +
  geom_sf(data = x, color = "blue", fill = NA) +
  geom_sf(data = y, color = "green", fill = NA) +
  scale_x_continuous(limits = c(-1.5,3)) +
  scale_y_continuous(limits = c(-1.5,3))
```

E.8 What the Picture Looks Like: Red is Intersected Part



Next Lecture

- Next week: line charts
- Following week: come prepared to work on your policy brief storyline

Playing Around in R

- Make a few maps
- Do some choropleths