Week 3: Graphics and Visualization

MATH-517 Statistical Computation and Visualization

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Graphics

- presentation
  - result communication
  - decision making
- data insight
  - large data
  - detect patterns
  - find strange observations
- code debugging
  - input, output (even the code itself) is data

Graphics

"The simple graph has brought more information to the data analyst's mind than any other device." – John W. Tukey

"The greatest value of a picture is when it forces us to notice what we never expected to see." – John W. Tukey

One can think of graphics (and also models, for that matter) as of a low-dimensional representation for data.

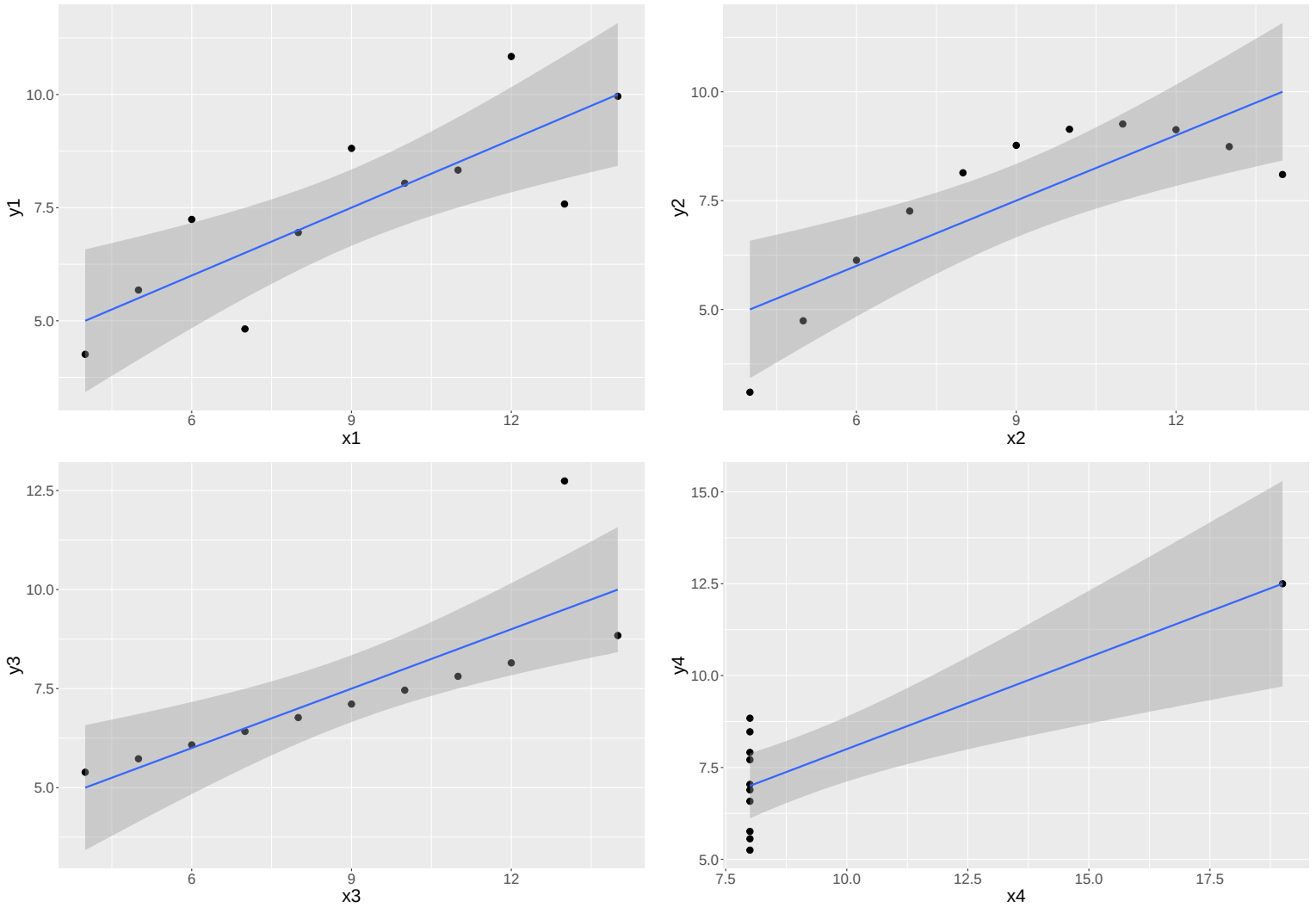
Anscombe's Quartet

Four data sets with

- one response variable y
- one regressor x

```
##     (Intercept)         x R-squared
## lm1    3.000091 0.5000909 0.6665425
## lm2    3.000909 0.5000000 0.6662420
## lm3    3.002455 0.4997273 0.6663240
## lm4    3.001727 0.4999091 0.6667073
```

Anscombe's Quartet



Human Height

Scatterplot Extras

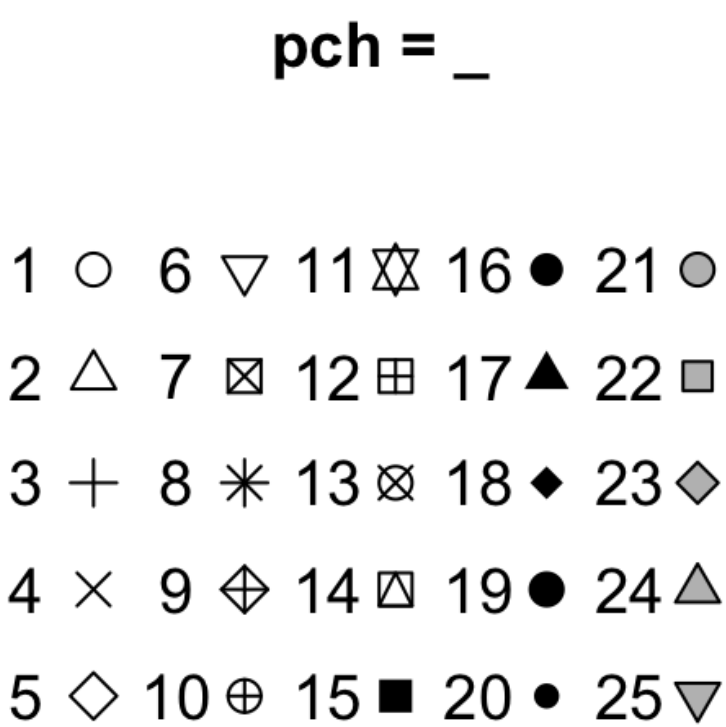
The following features (`ggplot`'s arguments) for points (and similarly for lines)

- `color`
- `shape`
- `size`
- `alpha` (opacity/transparency)

can be used

- to include additional information (or dimensions, i.e. to include additional variables) in a scatterplot
- to combat overplotting
- or simply to make the plot nicer (i.e. used subjectively)

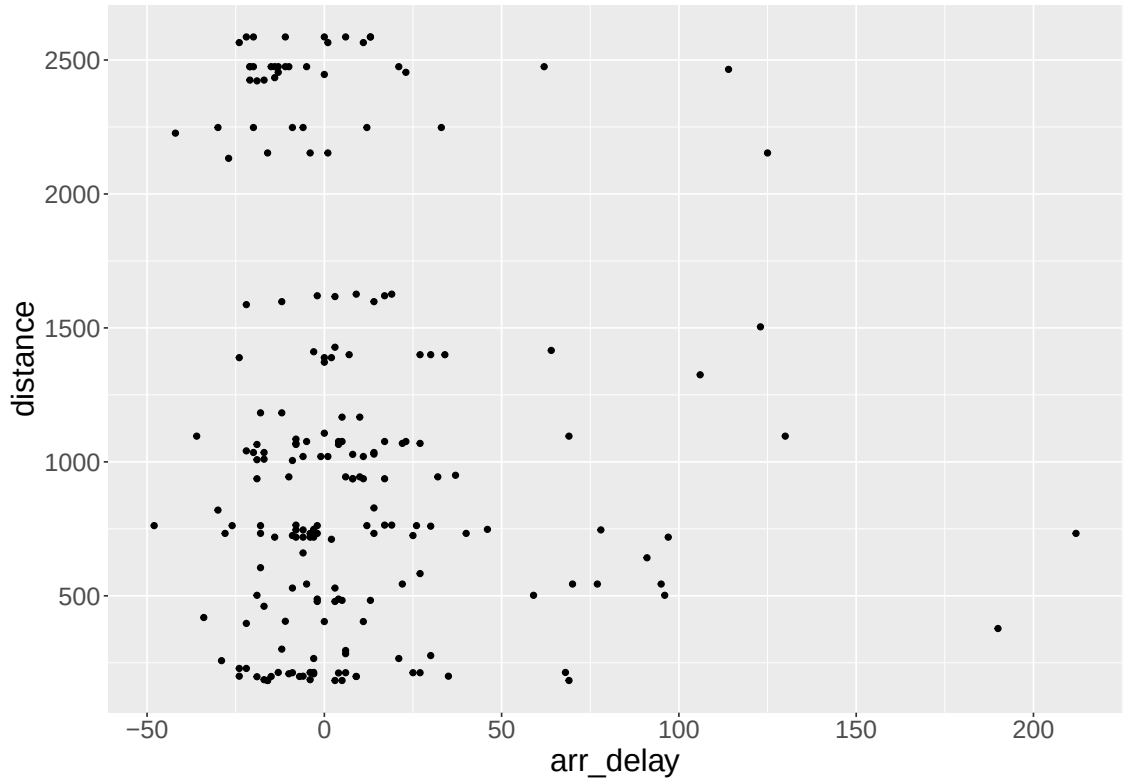
Available Shapes



- `pch` is the base R argument, for `ggplot` one instead passes values into `scale_shape_manual()`
- all shapes have attribute `color`, only some `fill`

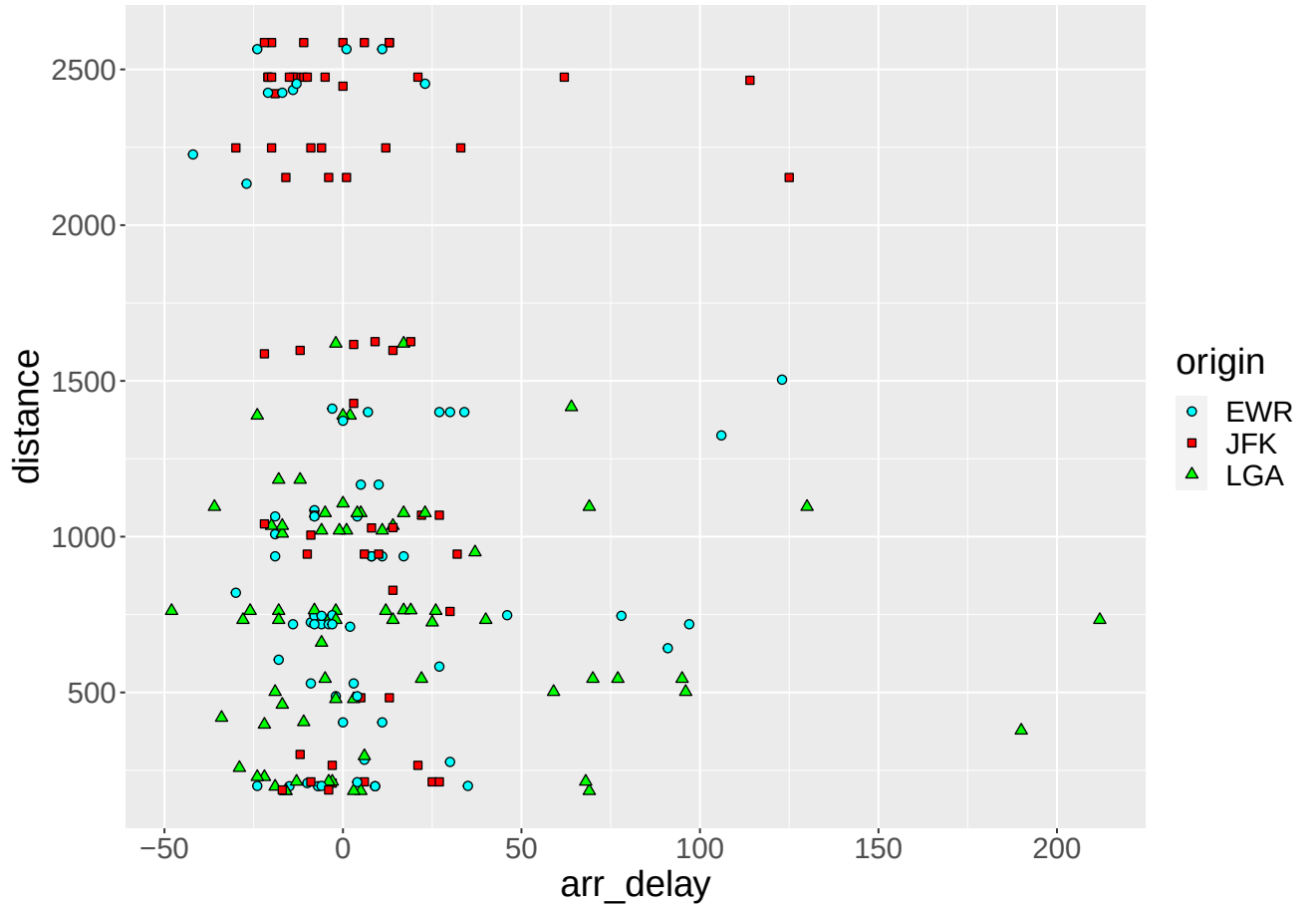
Scatterplot: plain

```
library(data.table)
set.seed(517)
flights <- fread("https://raw.githubusercontent.com/Rdatatable/data.table/m
  slice_sample(n=200)
ggplot(data = flights,
       mapping = aes(x = arr_delay, y = distance)) +
  geom_point()
```



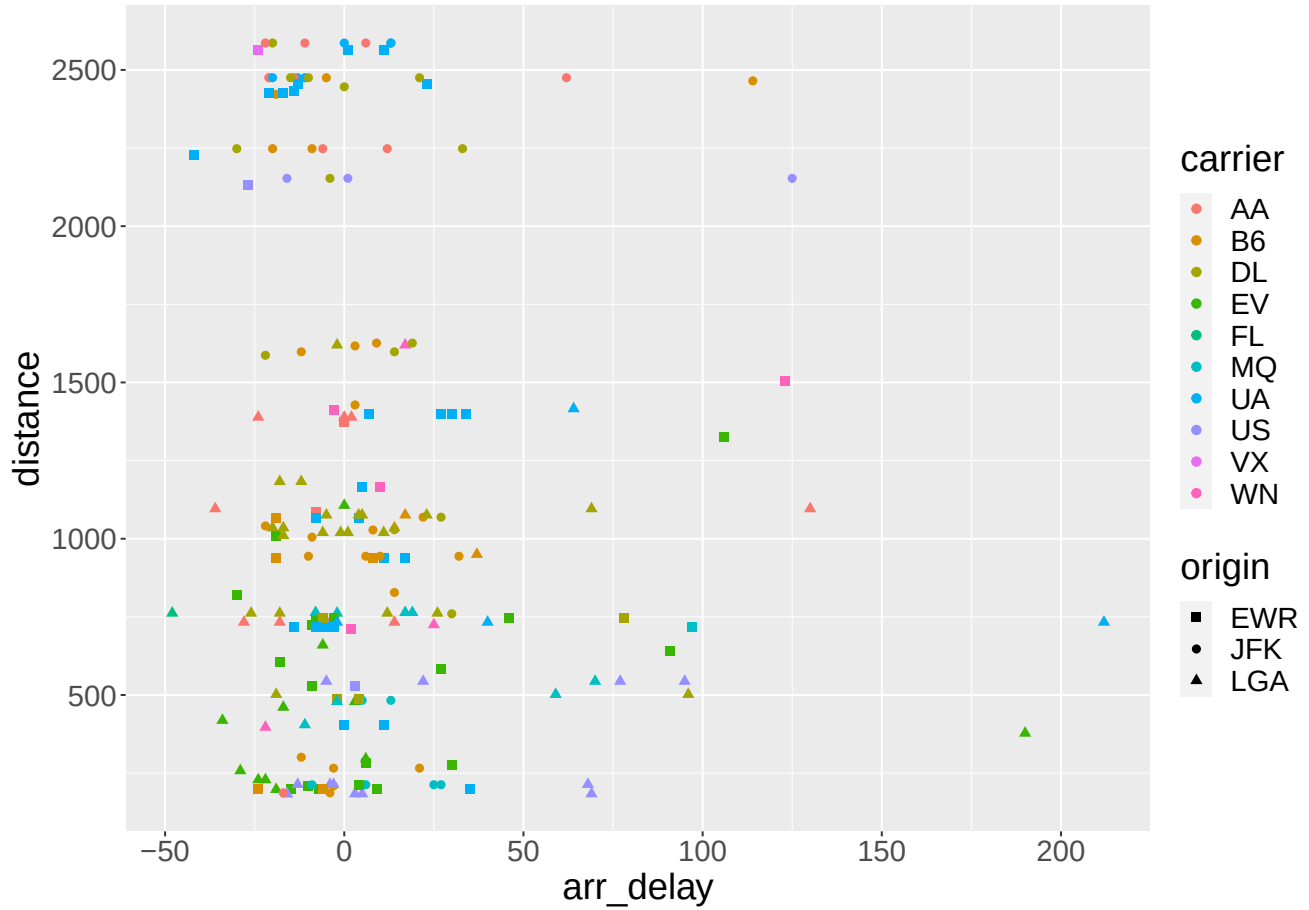
Scatterplot: shape + color

```
ggplot(data = flights, mapping = aes(x = arr_delay, y = distance,
                                     shape = origin, fill=origin)) +
  geom_point(size=2) +
  scale_fill_manual(values = c("cyan","red","green")) +
  scale_shape_manual(values = c(21,22,24))
```



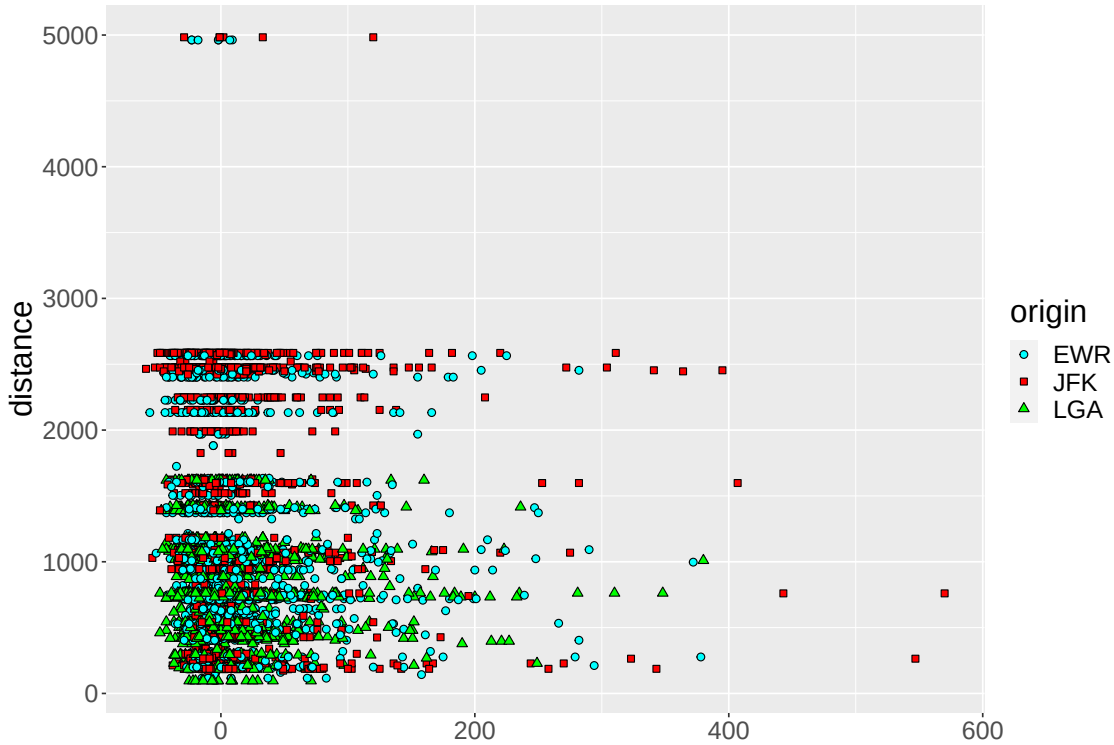
Scatterplot: shape × color

```
ggplot(data = flights, mapping = aes(x = arr_delay, y = distance,
                                     shape = origin, color=carrier)) +
  geom_point(size=2) + scale_shape_manual(values = c(15,16,17))
```



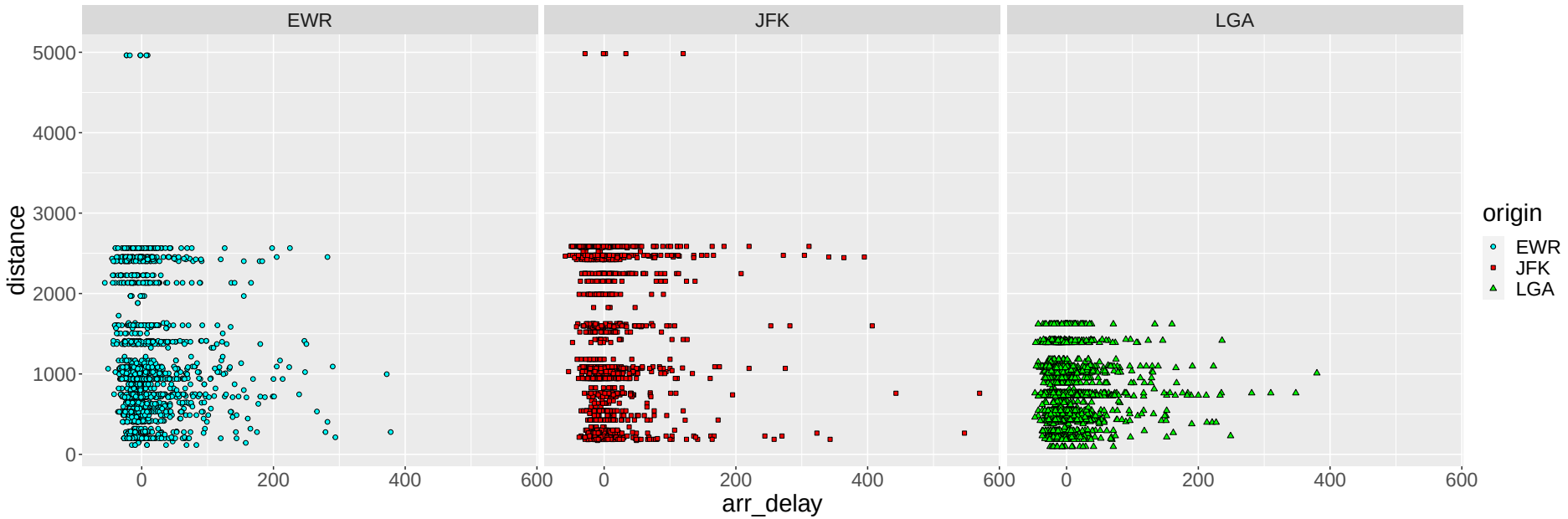
Overplotting

```
set.seed(517)
flights <- fread("https://raw.githubusercontent.com/Rdatatable/data.table/m
  slice_sample(n=5000)
ggplot(data = flights, mapping = aes(x = arr_delay, y = distance,
                                     shape = origin, fill=origin)) +
  geom_point(size=2) +
  scale_fill_manual(values = c("cyan","red","green")) +
  scale_shape_manual(values = c(21,22,24))
```



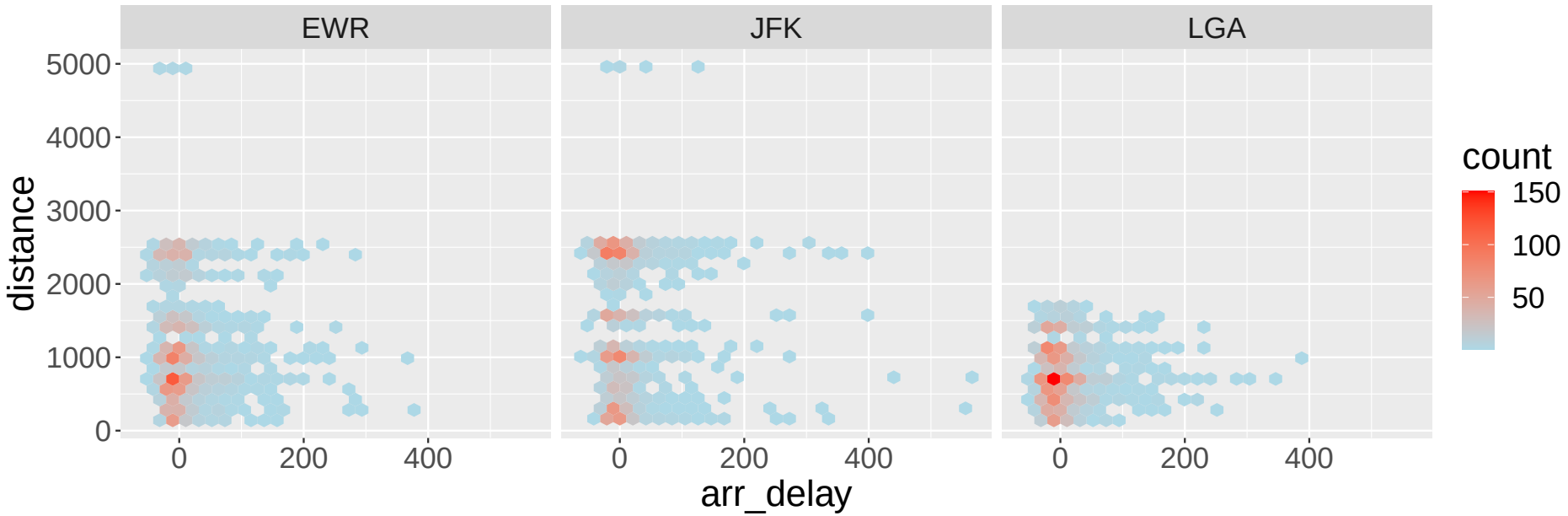
Overplotting Remedy 1/2

```
ggplot(data = flights, mapping = aes(x = arr_delay, y = distance,
                                     shape = origin, fill=origin)) +
  geom_point() +
  scale_fill_manual(values = c("cyan","red","green")) +
  scale_shape_manual(values = c(21,22,24)) +
  facet_wrap(~origin)
```



Overplotting Remedy

```
ggplot(data = flights, mapping = aes(x = arr_delay, y = distance)) +
  stat_binhex() +
  scale_fill_gradient(low = "lightblue", high = "red") +
  facet_wrap(~origin)
```

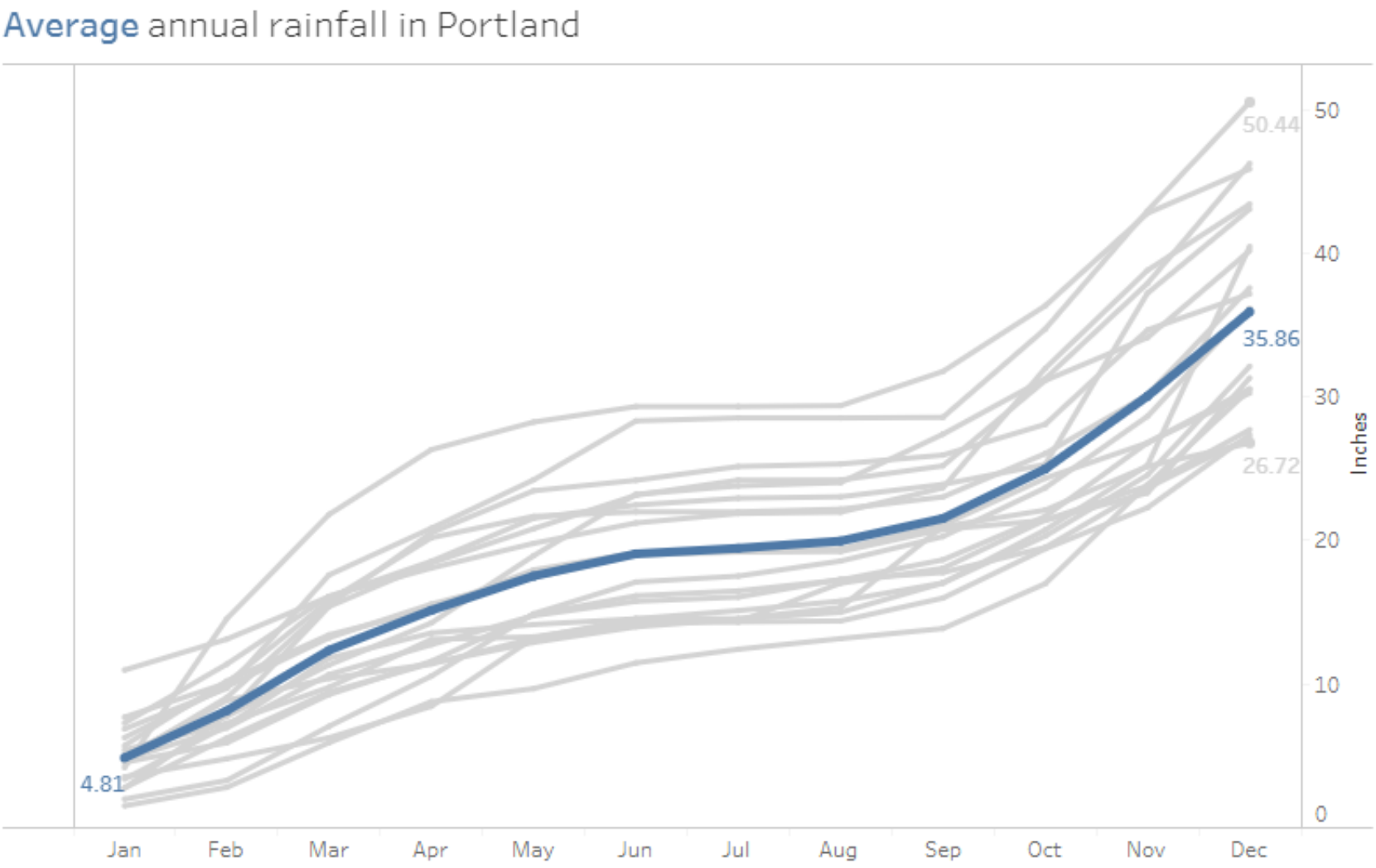


Overplotting Remedies

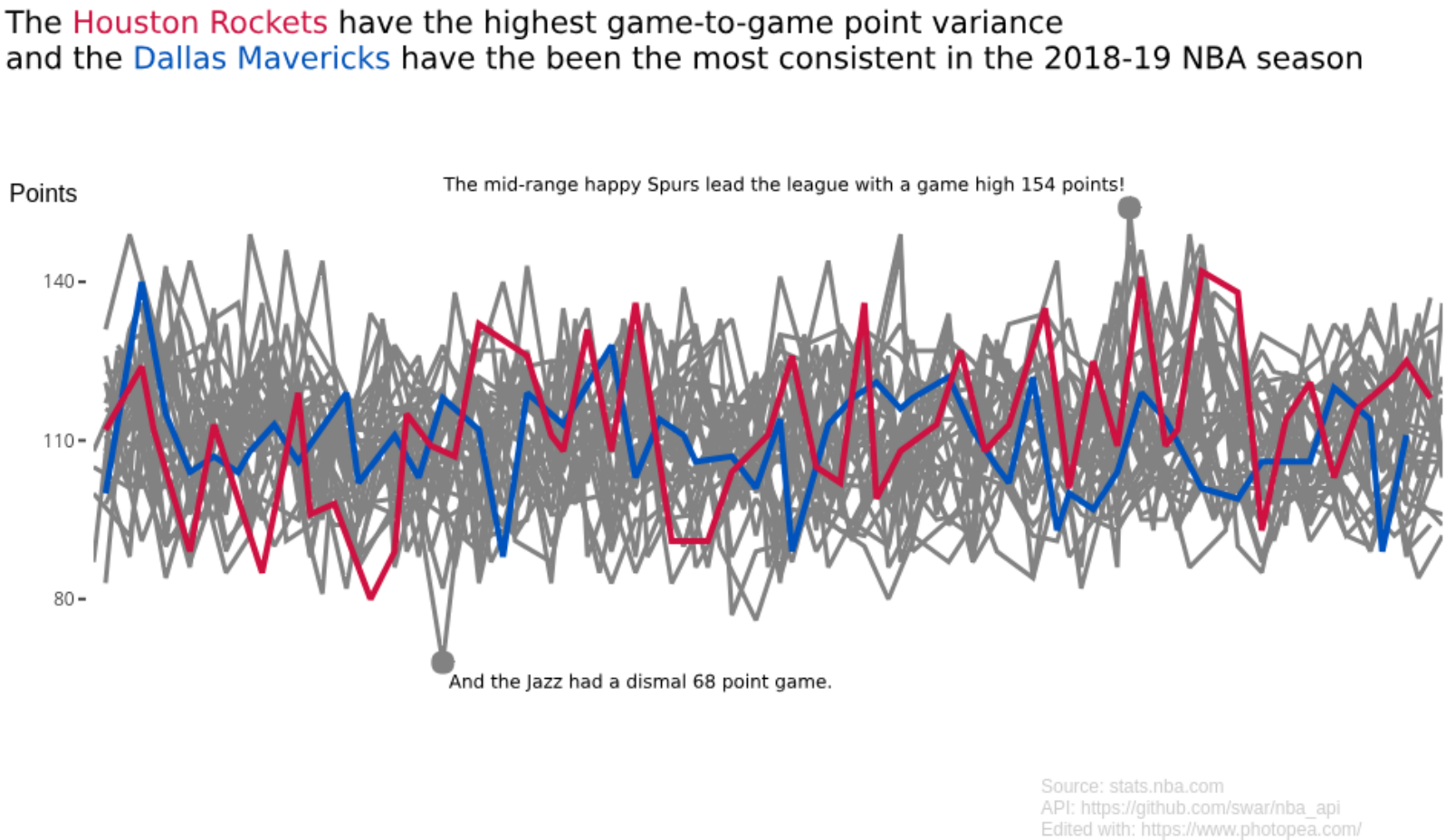
- reducing point size
- split a single plot into multiple (done above)
- jittering
- opacity/transparency
- binning (done above via `stat_binhex()`)
- tiles
- subsampling (done above above)

Many of these options clash with clarity and space requirements or with each other (e.g. transparency distorts colors).

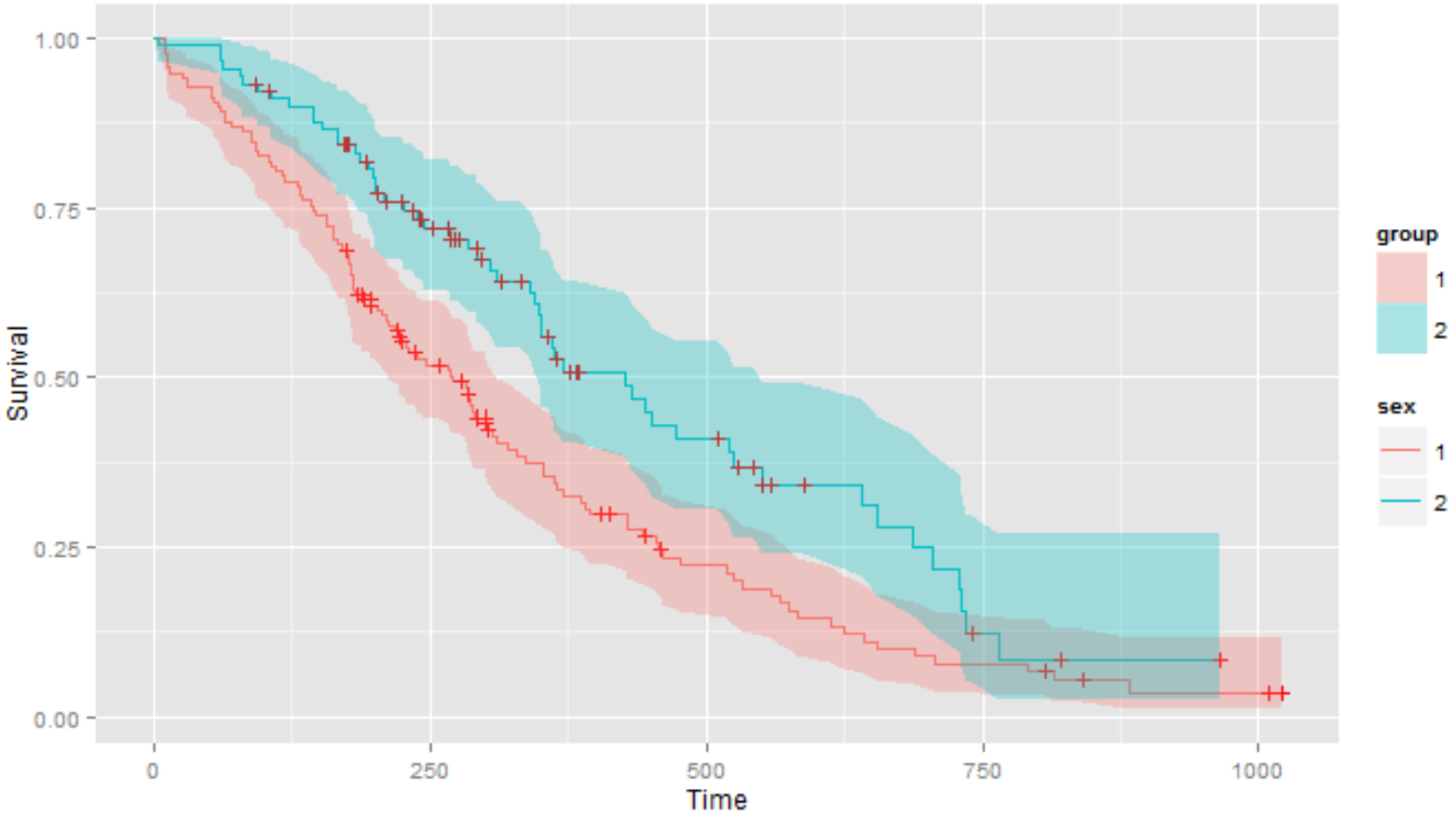
Visualizing Variance



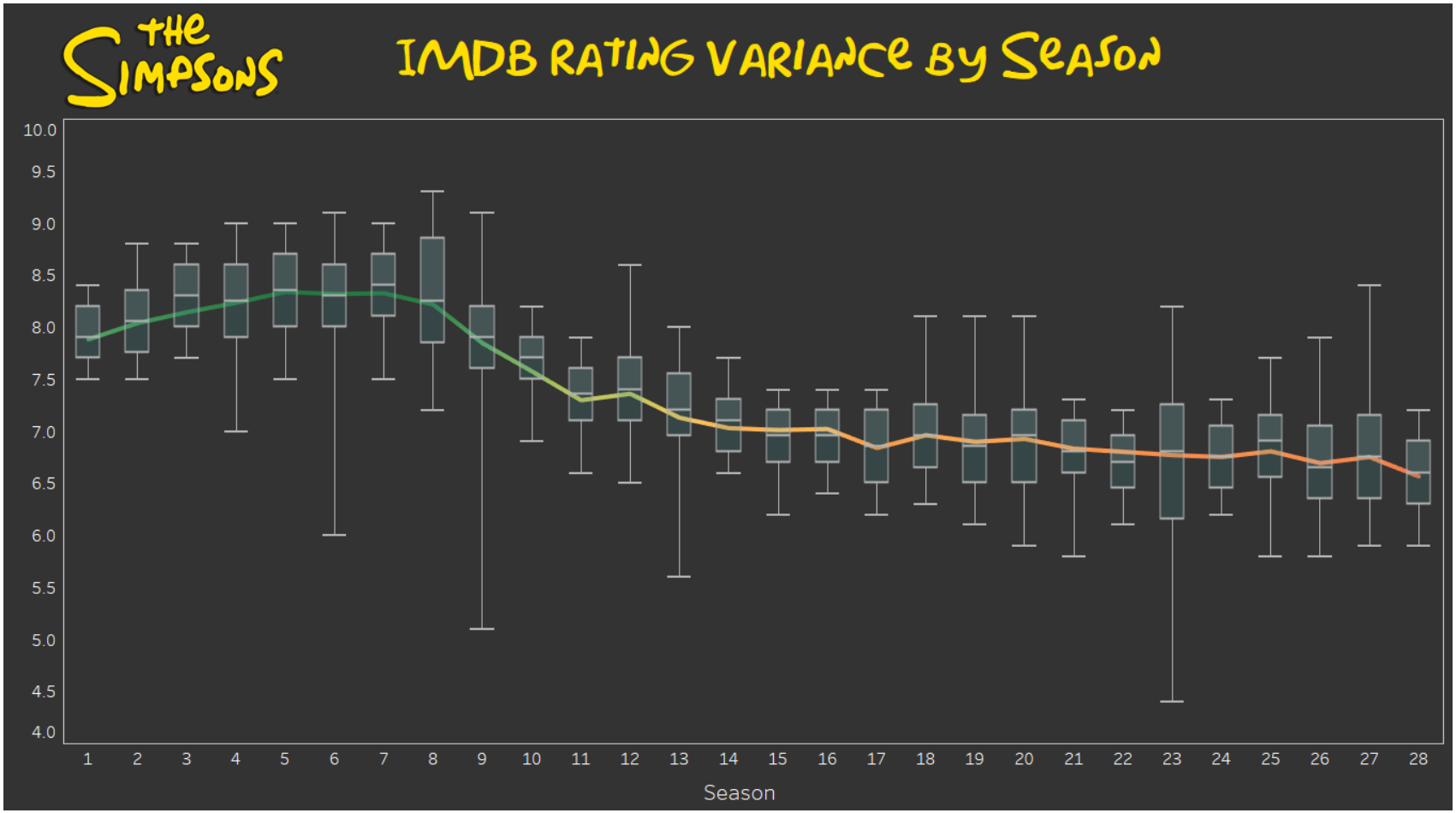
Visualizing Variance (Bad)



Visualizing Variance



Visualizing Variance



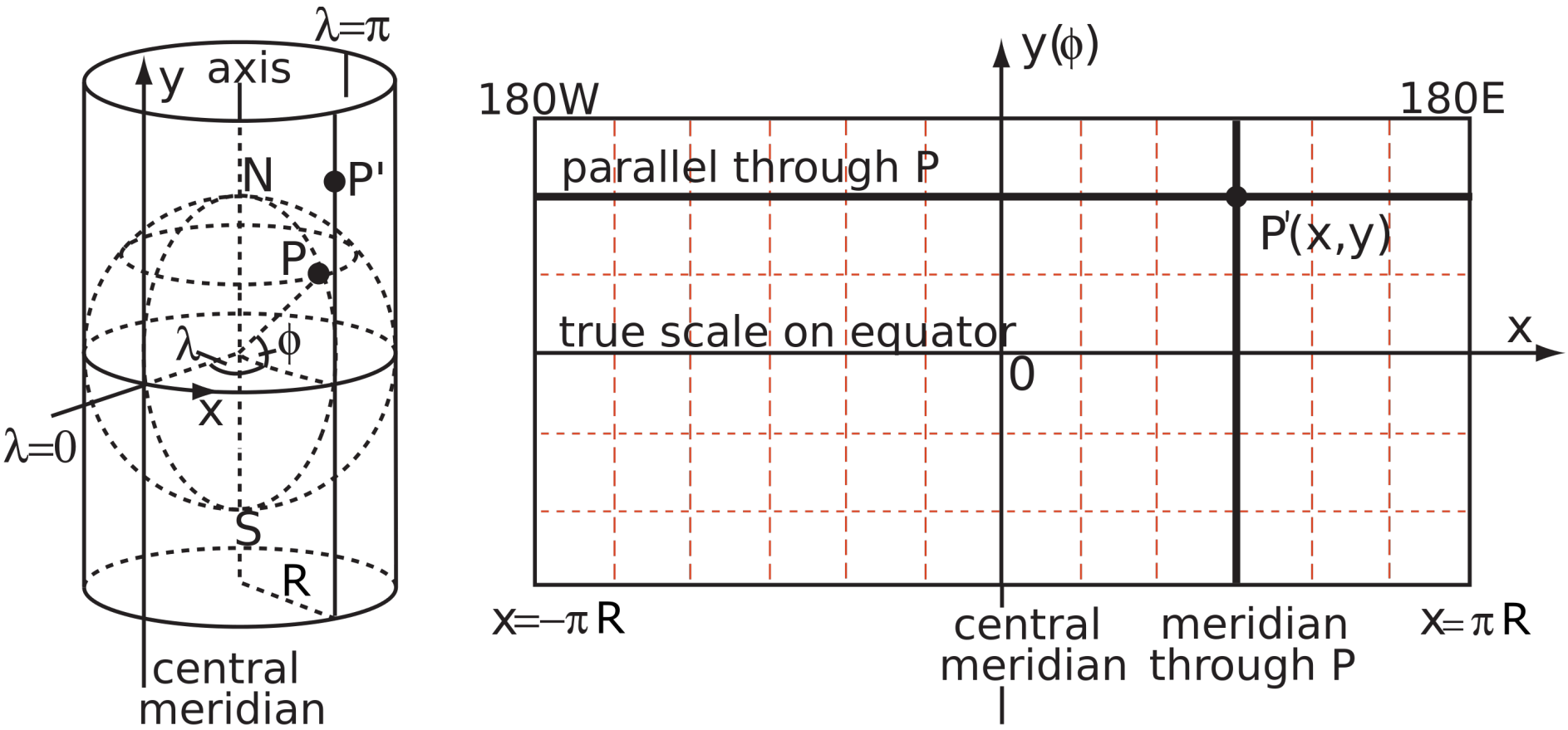
Spatial Data

Complicated due to different

- mathematical representations
- data structures
- data sources
- data processing packages
  - projections (sphere? plane?)
- visualization packages

(Not so) short course about visualizing spatial data here (only if interested).

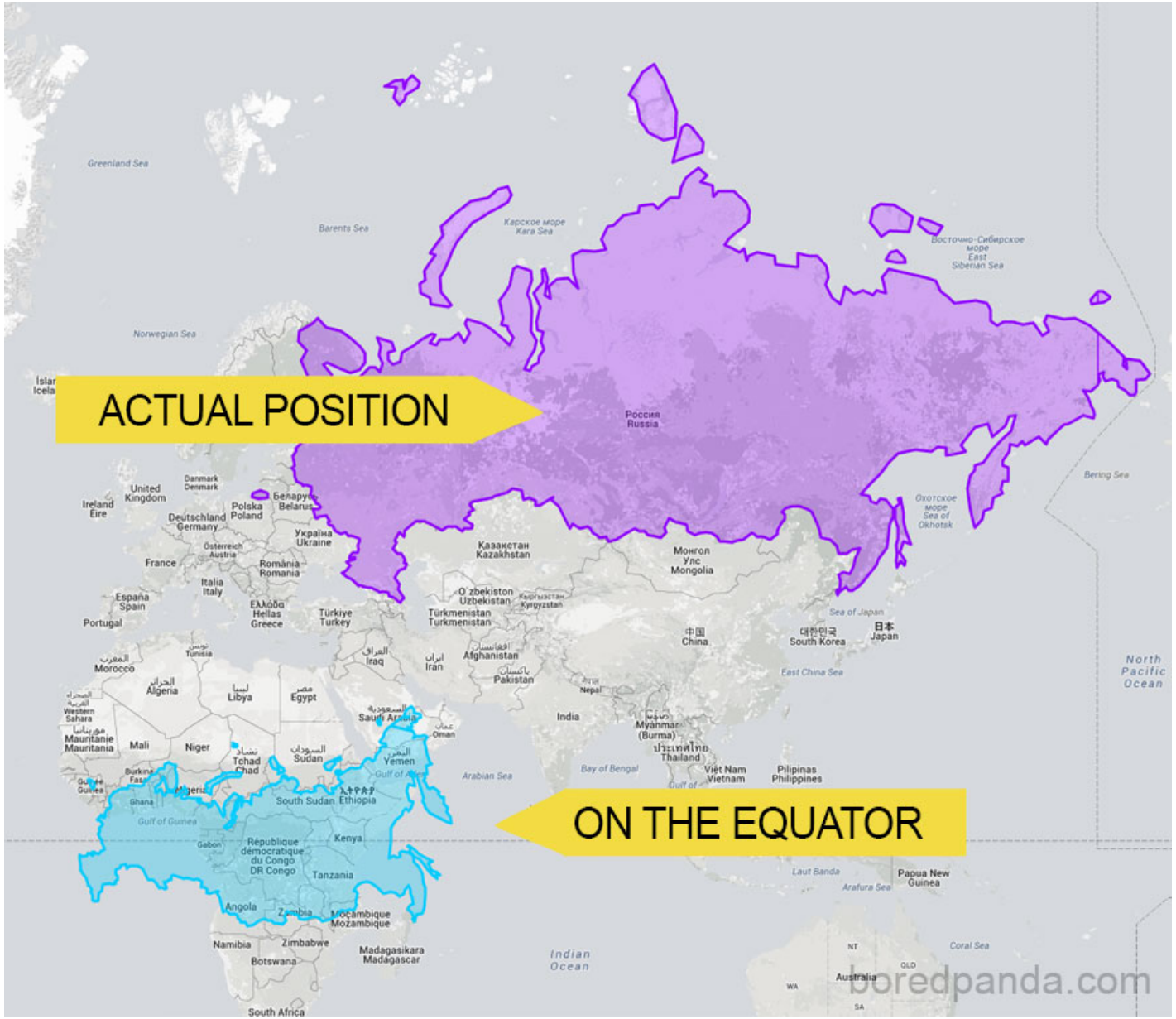
Mercator Projection



source: wiki

Two sources of distortion (earth is not a sphere and the projection itself), the second one visualized here.

Russia's True Size



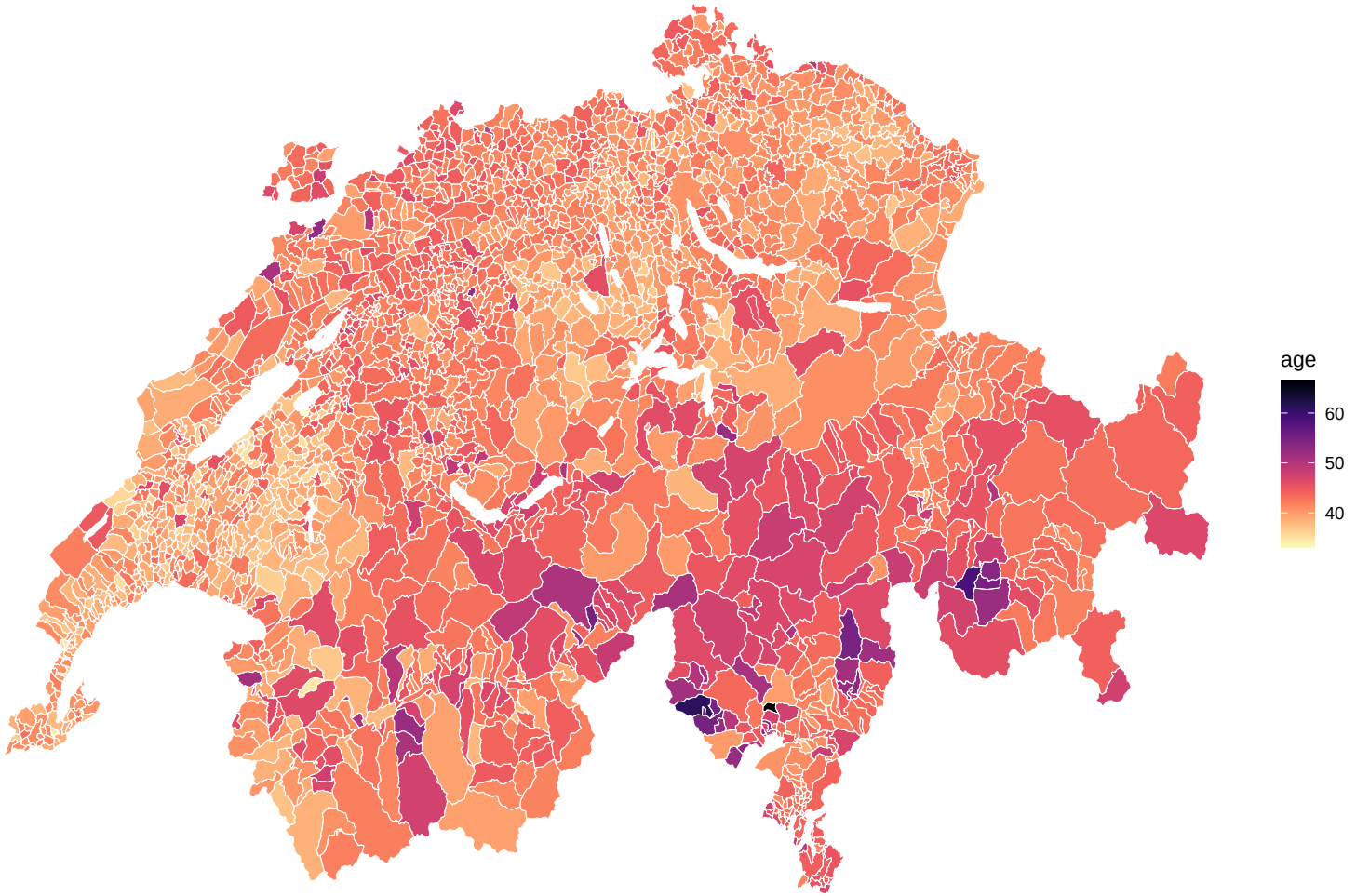
Geospatial Heatmap

```
library(ggswissmaps)
counties <- shp_df[[4]] # resolution on the level of ZIP codes

avg_age <- read.csv("https://raw.githubusercontent.com/grssnbchr/thematic-m
names(avg_age)[1] <- "id"
names(avg_age)[3] <- "age"
counties <- counties %>% mutate(id = as.numeric(id))
newdat <- inner_join(counties, avg_age, by="id")
library(viridis)
ggplot(data=newdat) +
  geom_polygon(aes(x=long, y=lat, group=group, fill=age)) +
  geom_path(aes(x = long, y = lat, group = group),
            color = "white", size = 0.1) +
  scale_fill_viridis(option = "magma", direction = -1) +
  theme_void()
```

- here counties is a data frame, longitude and latitude specify border points and Swiss counties are polygons (convex hulls of the border points)
- group specifies which border points belong to which county
- try `plot(counties$long,counties$lat, type="l")`

Geospatial Heatmap



inspired by this blogpost

Good Visualization Practices

- provide context (in text **and** in caption)
- seek simplicity, clarity, etc.
- gray scale often preferable
  - color-blindness (friendly palettes, e.g. Coolors)
- axes (scale, gaps, etc.)
  - text of appropriate size
- publication-specific conditions
- be artistic!
  - sometimes bend the rules (responsibly and justifiably)

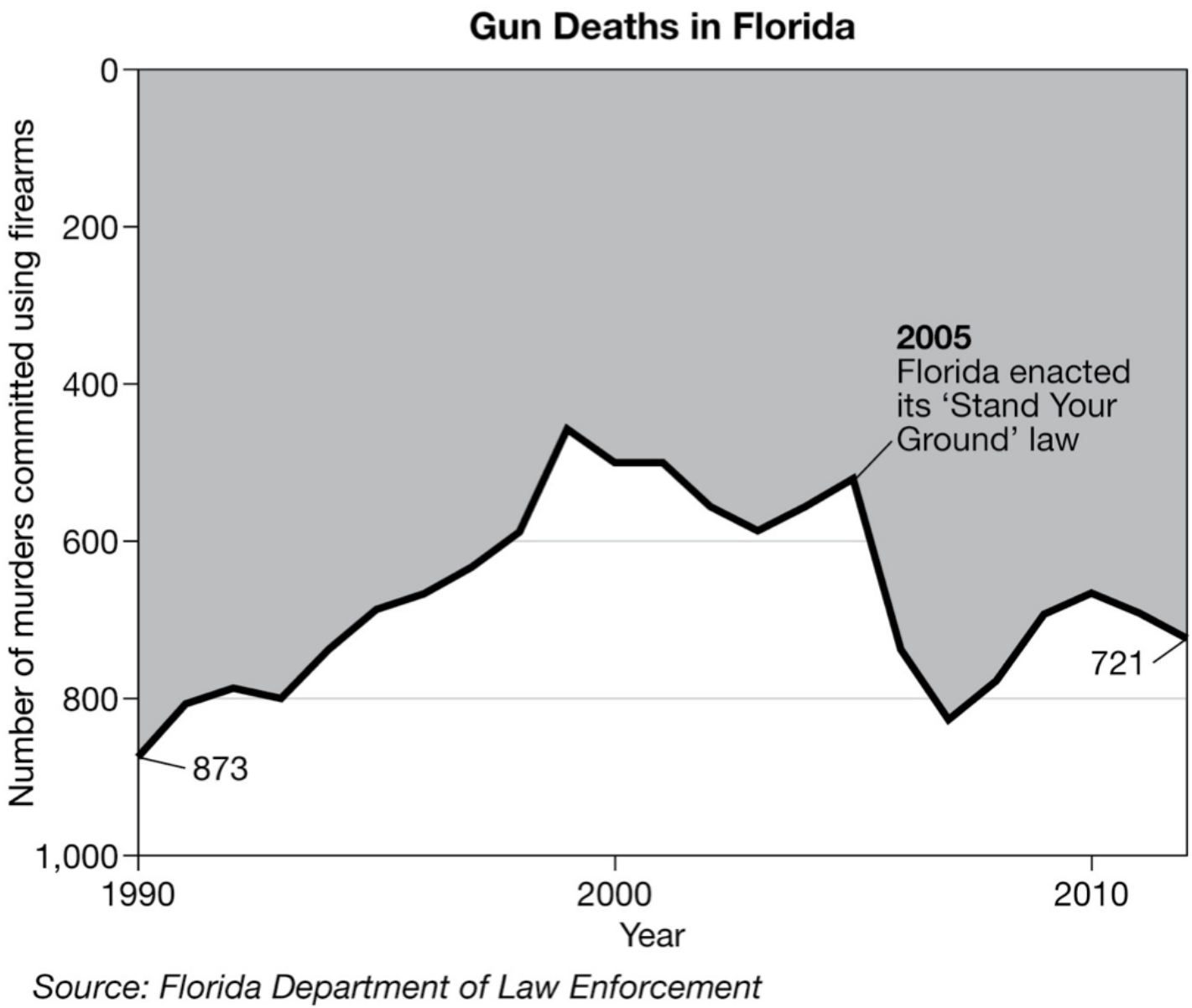
Find inspiration in The R Graph Gallery.

Beware when exporting graphics.

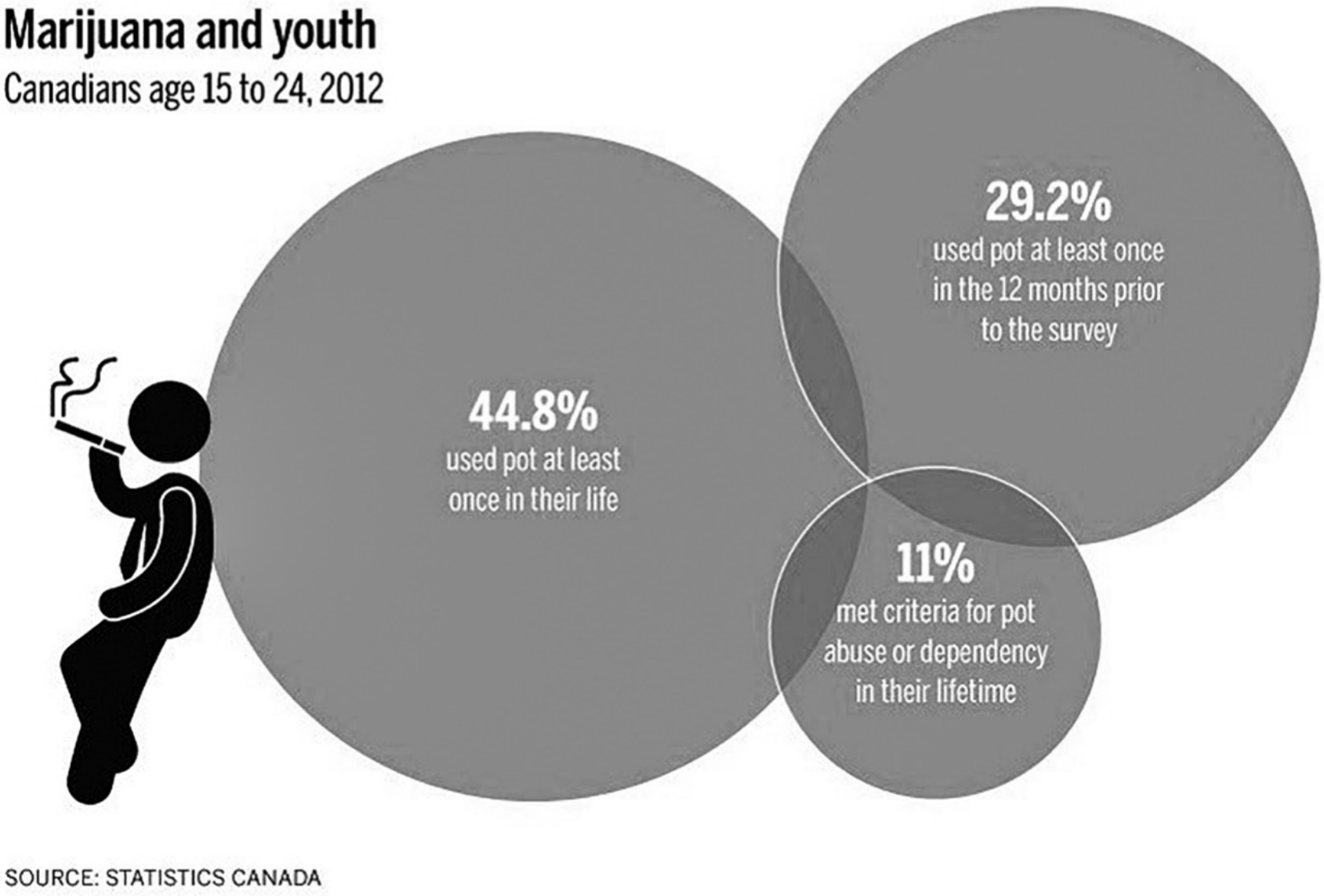
Section 1

Bad Visualization Practices

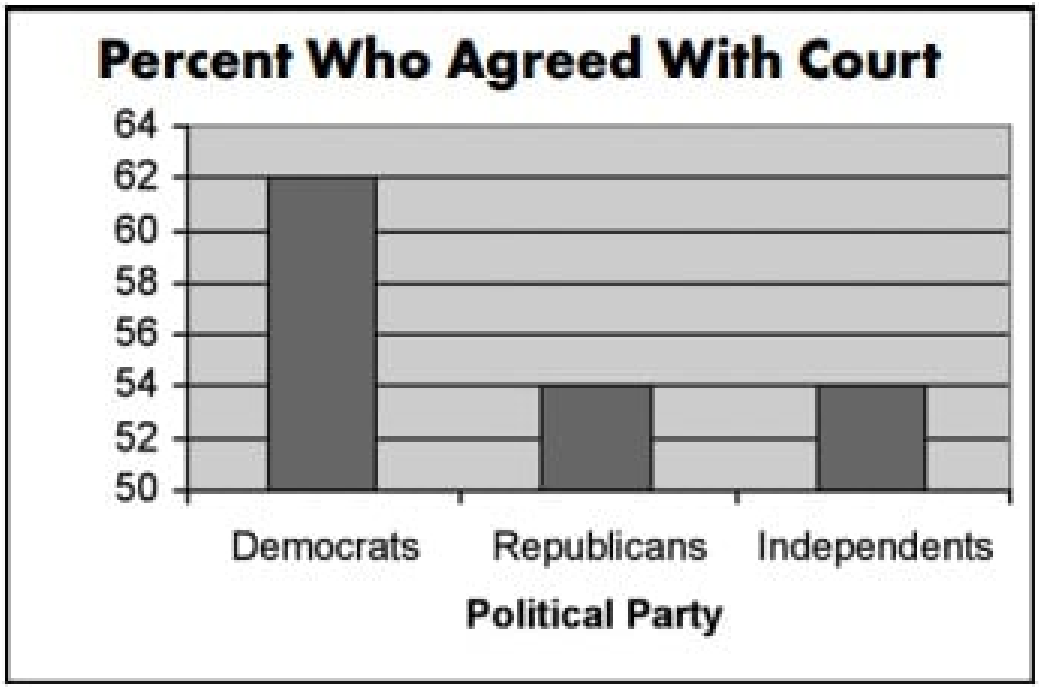
Reverted Axis



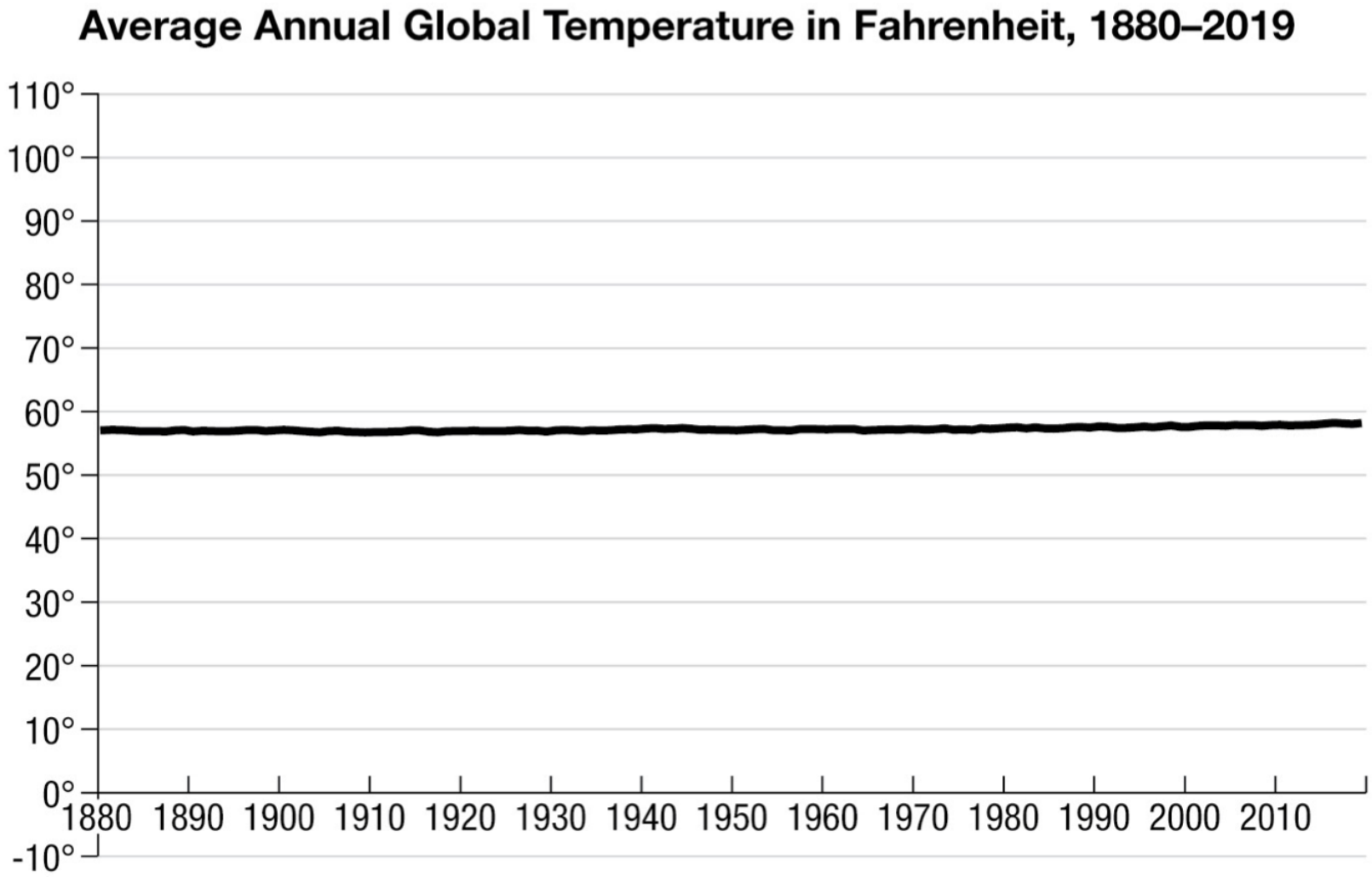
False Venn's Diagrams



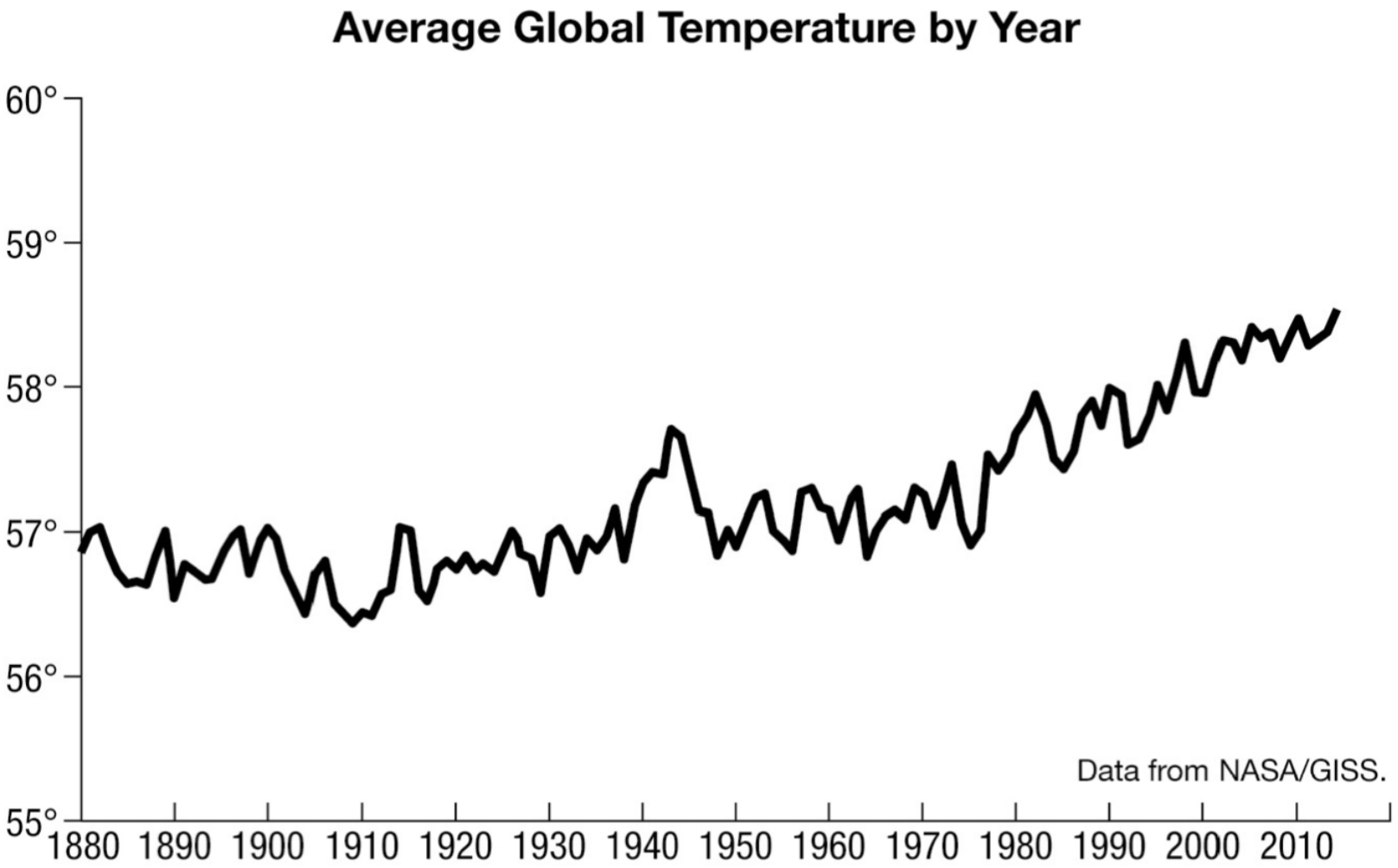
Missing Baseline



Axis Starting at Zero



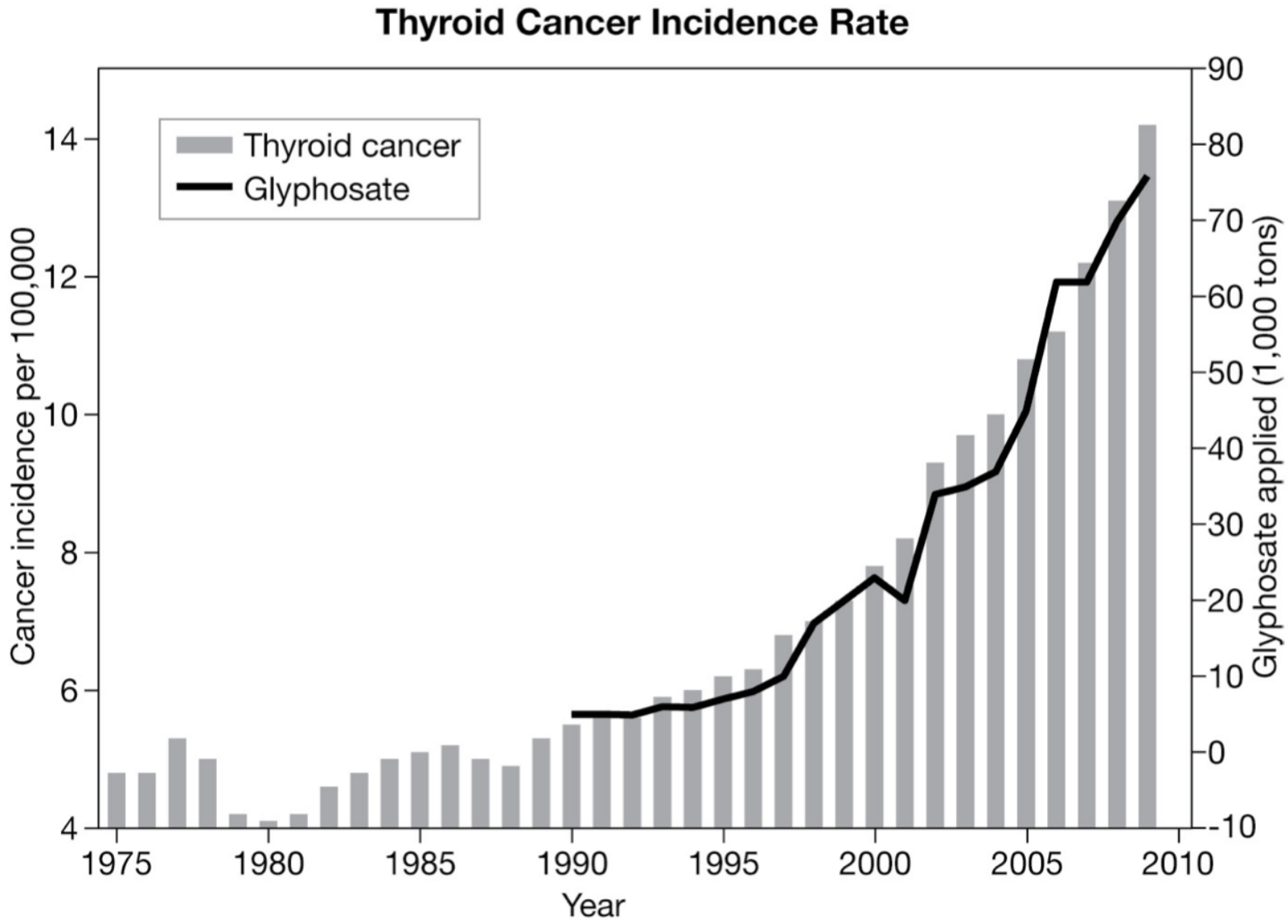
Better


Average Global Temperature by Year
60°
59°
58°
57°
56°
55°
1880 1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010
Data from NASA/GISS.

Combined Effects

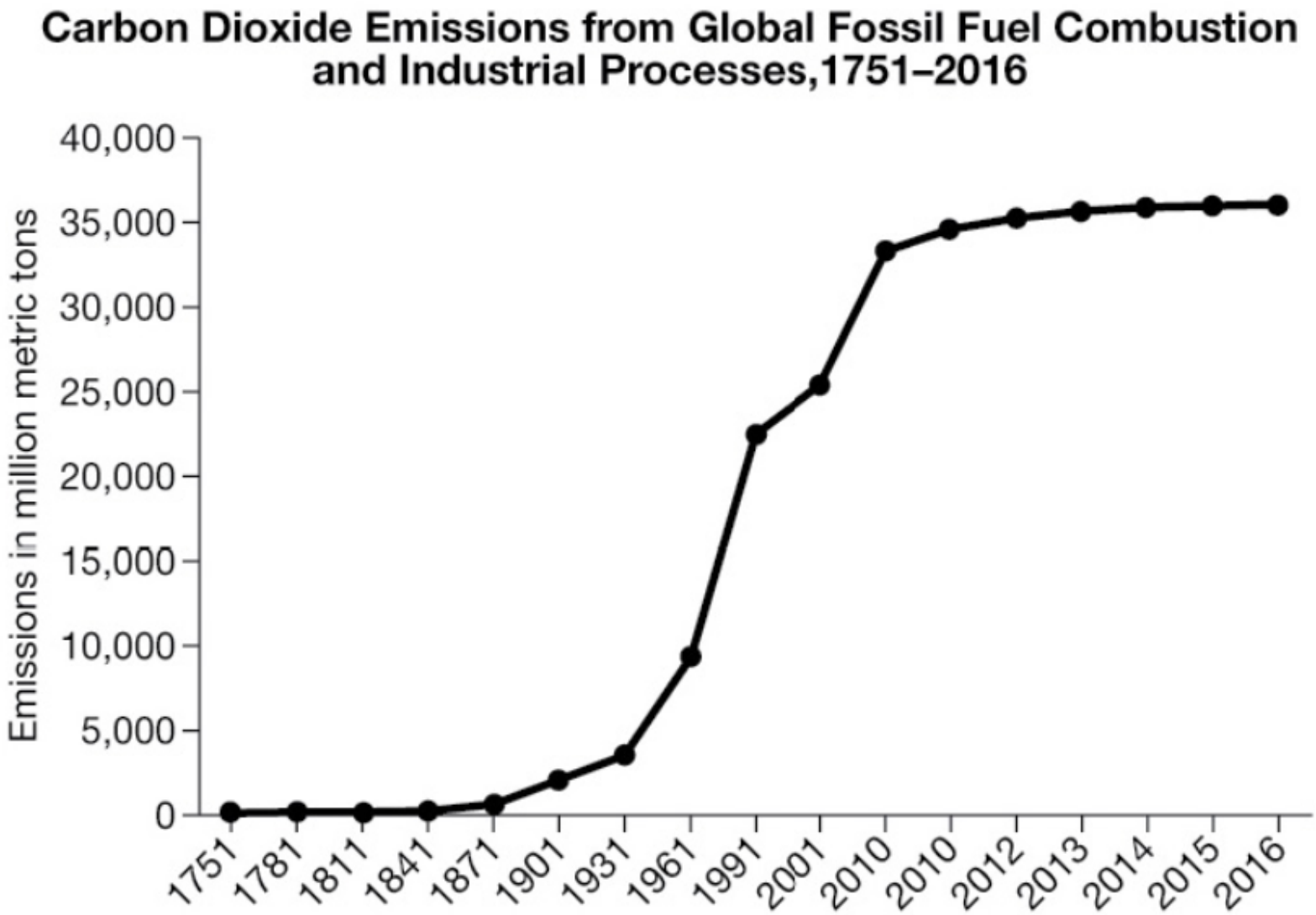
. . . plus just Cheating

Double Axes

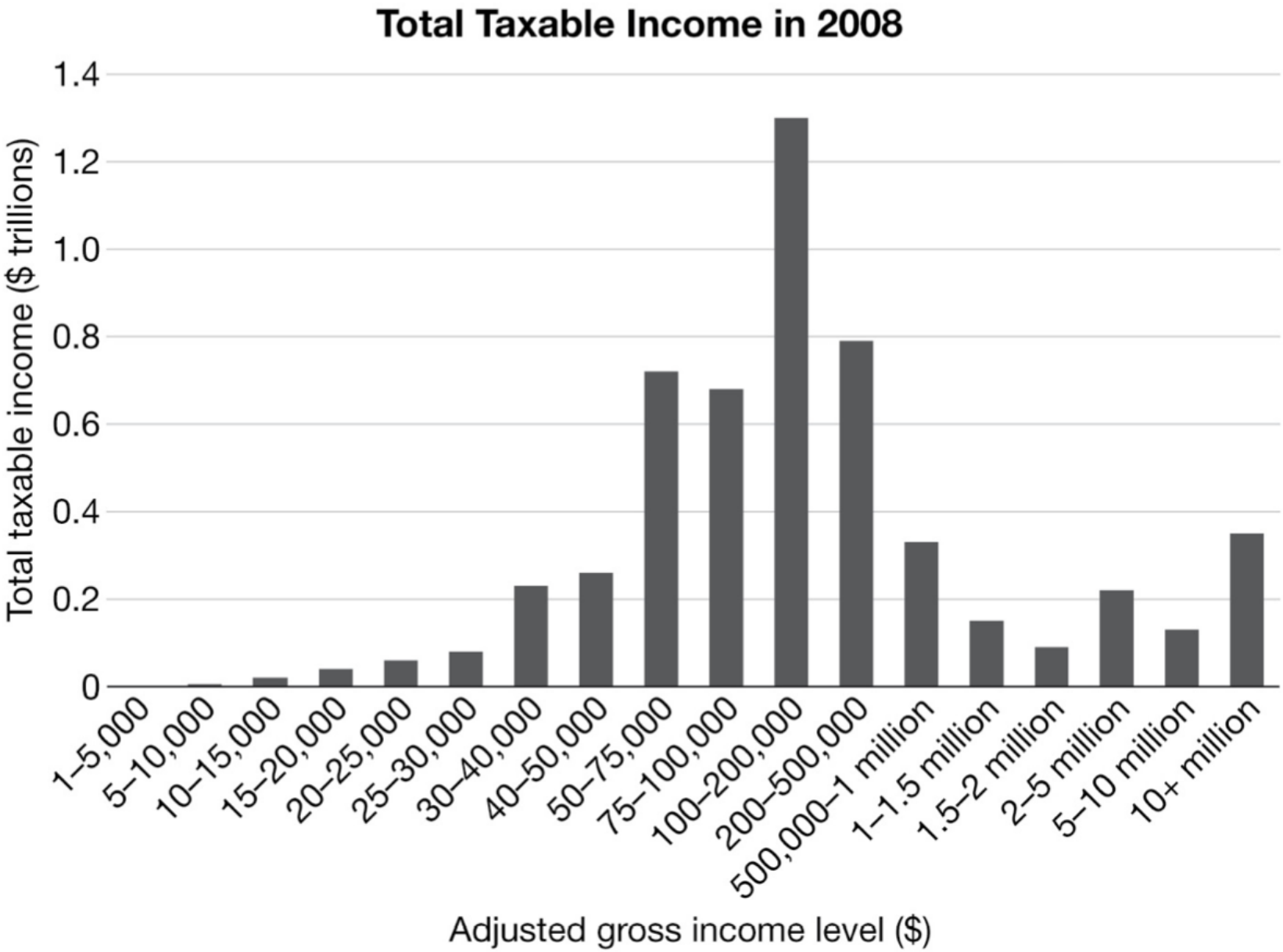


- This is actually quite good, but double axes are usually problematic.

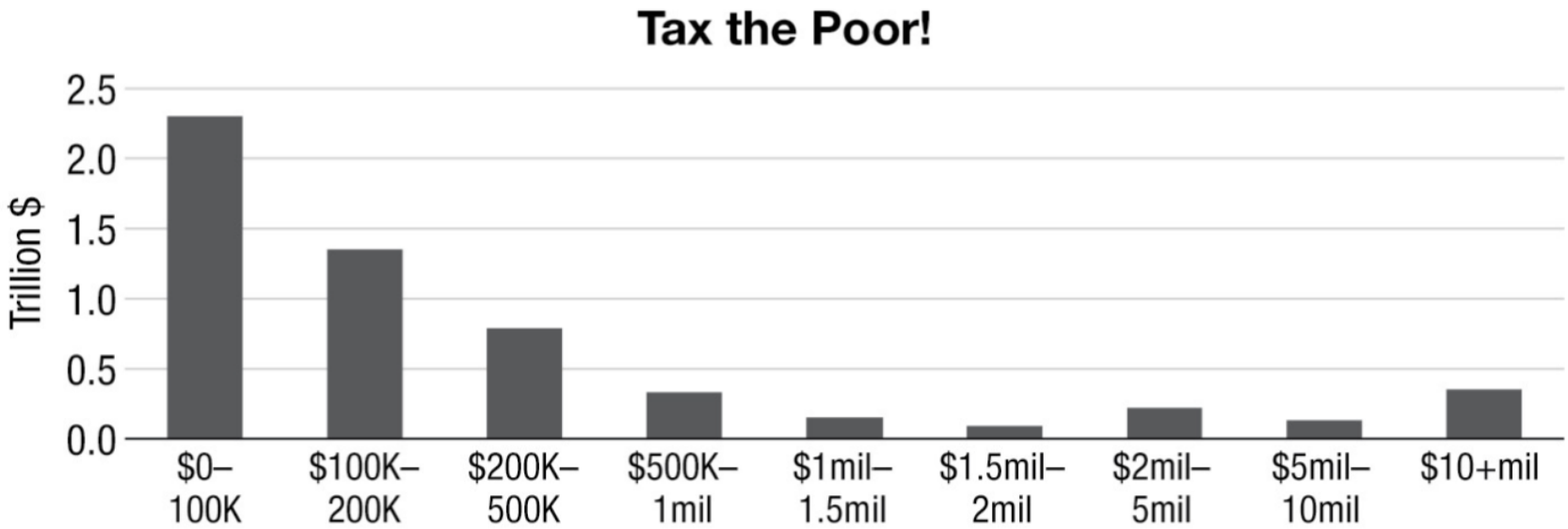
Tweaking Axis

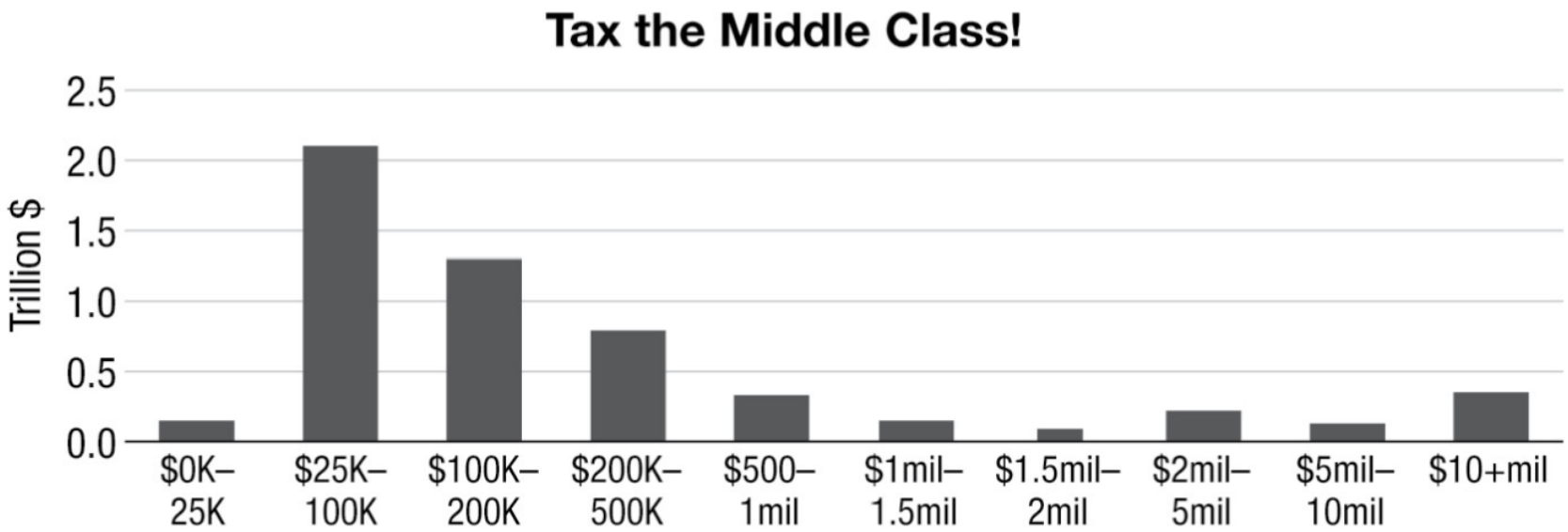


Binning

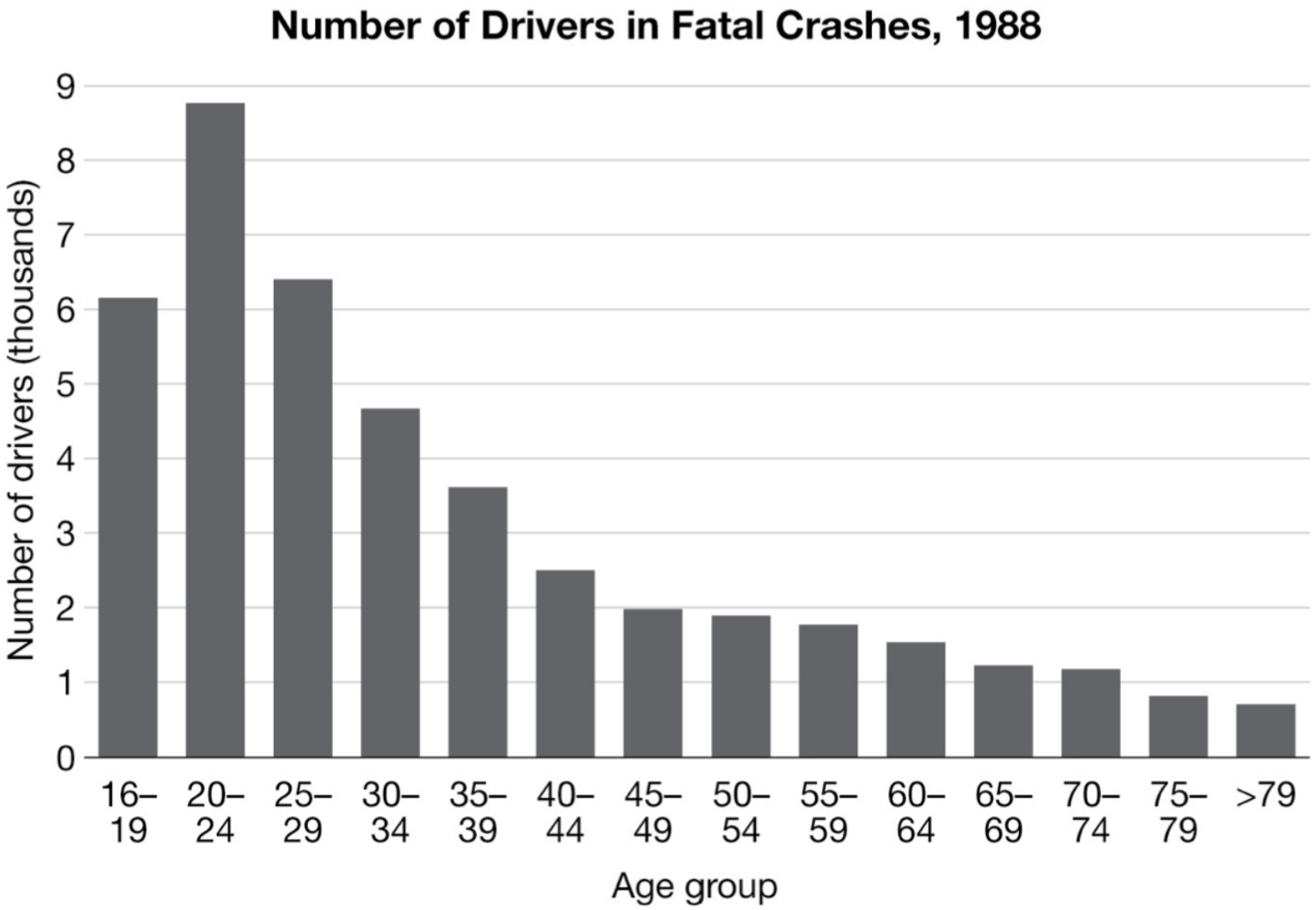

Total Taxable Income in 2008
Total taxable income ($ trillions)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
1–5,000
5–10,000
10–15,000
15–20,000
20–25,000
25–30,000
30–40,000
40–50,000
50–75,000
75–100,000
100–200,000
200–500,000
500,000–1 million
1–1.5 million
1.5–2 million
2–5 million
5–10 million
10+ million
Adjusted gross income level ($)

Different Kinds of Binning

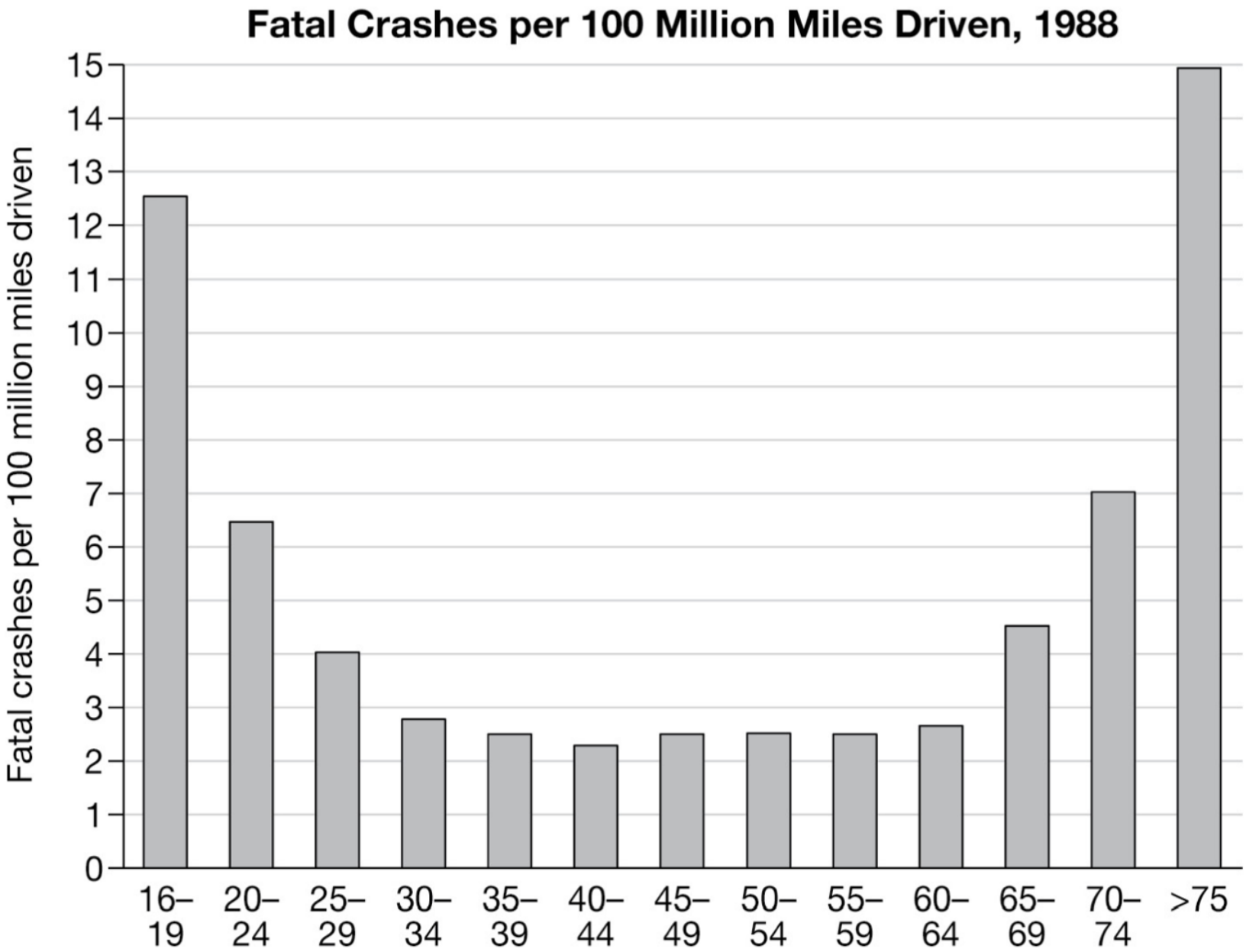




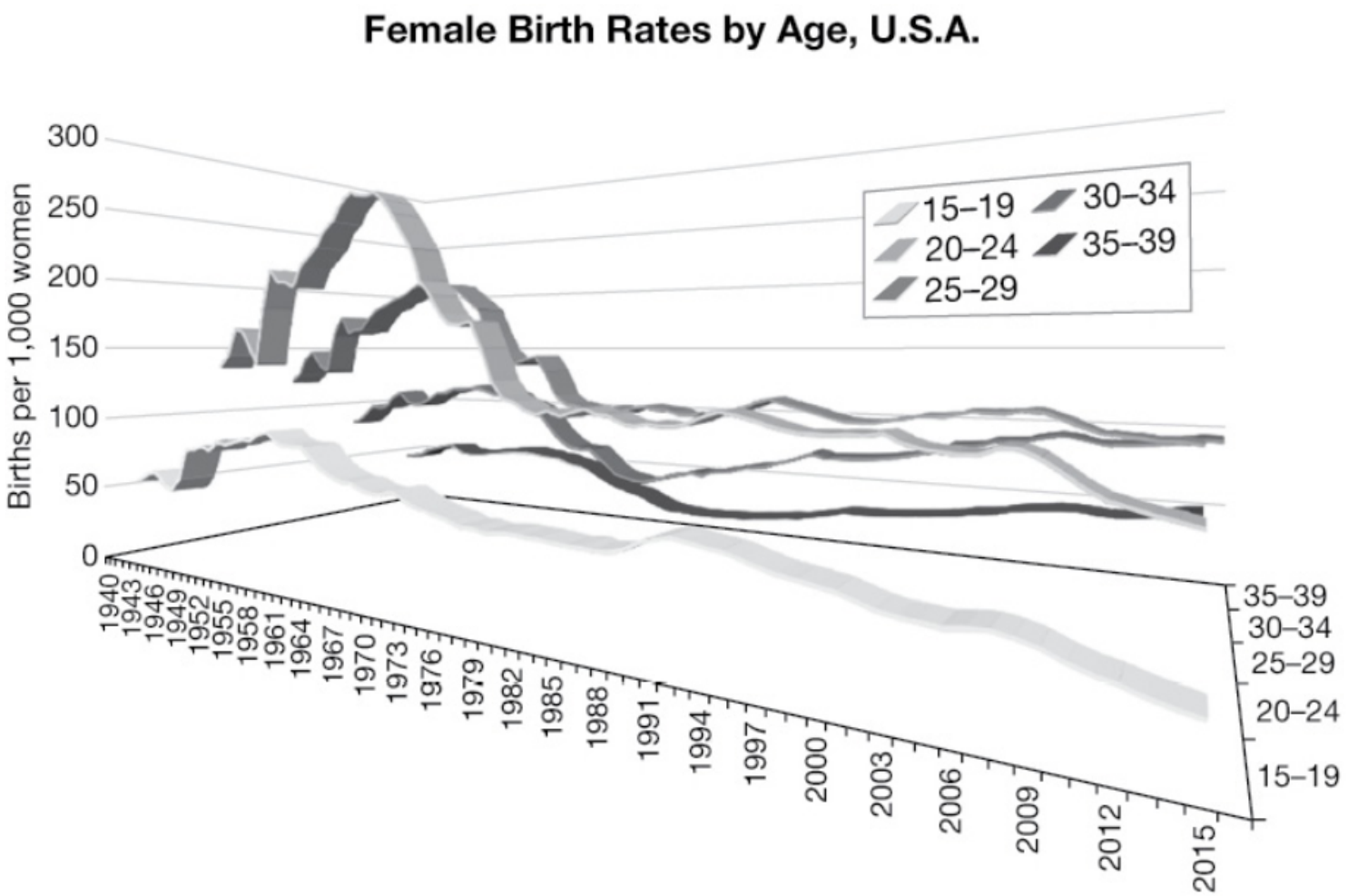
Total


Number of Drivers in Fatal Crashes, 1988
Number of drivers (thousands)
0
1
2
3
4
5
6
7
8
9
16–19
20–24
25–29
30–34
35–39
40–44
45–49
50–54
55–59
60–64
65–69
70–74
75–79
>79
Age group

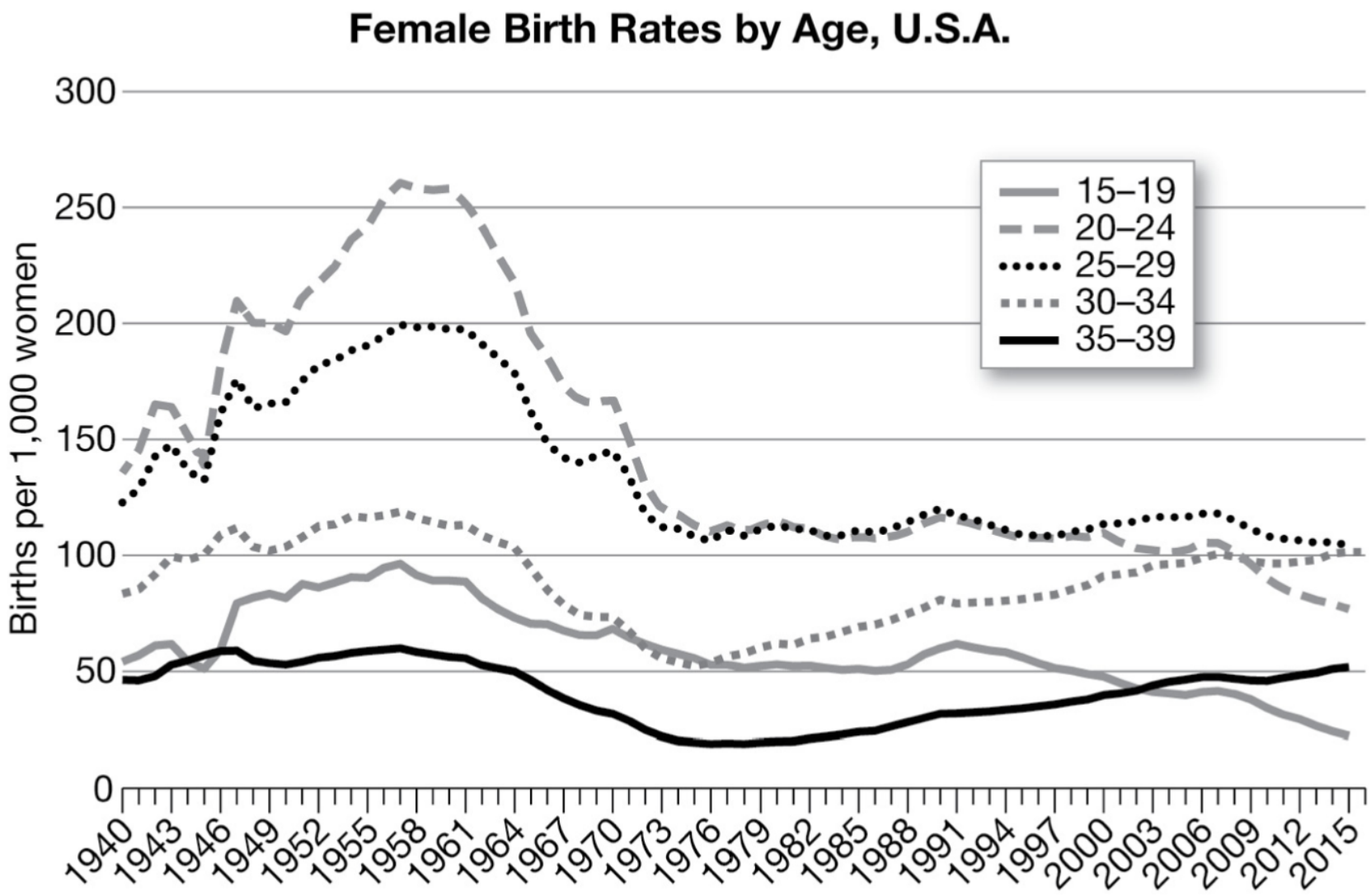
Relative


Fatal Crashes per 100 Million Miles Driven, 1988
Fatal crashes per 100 million miles driven
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16–19
20–24
25–29
30–34
35–39
40–44
45–49
50–54
55–59
60–64
65–69
70–74
>75

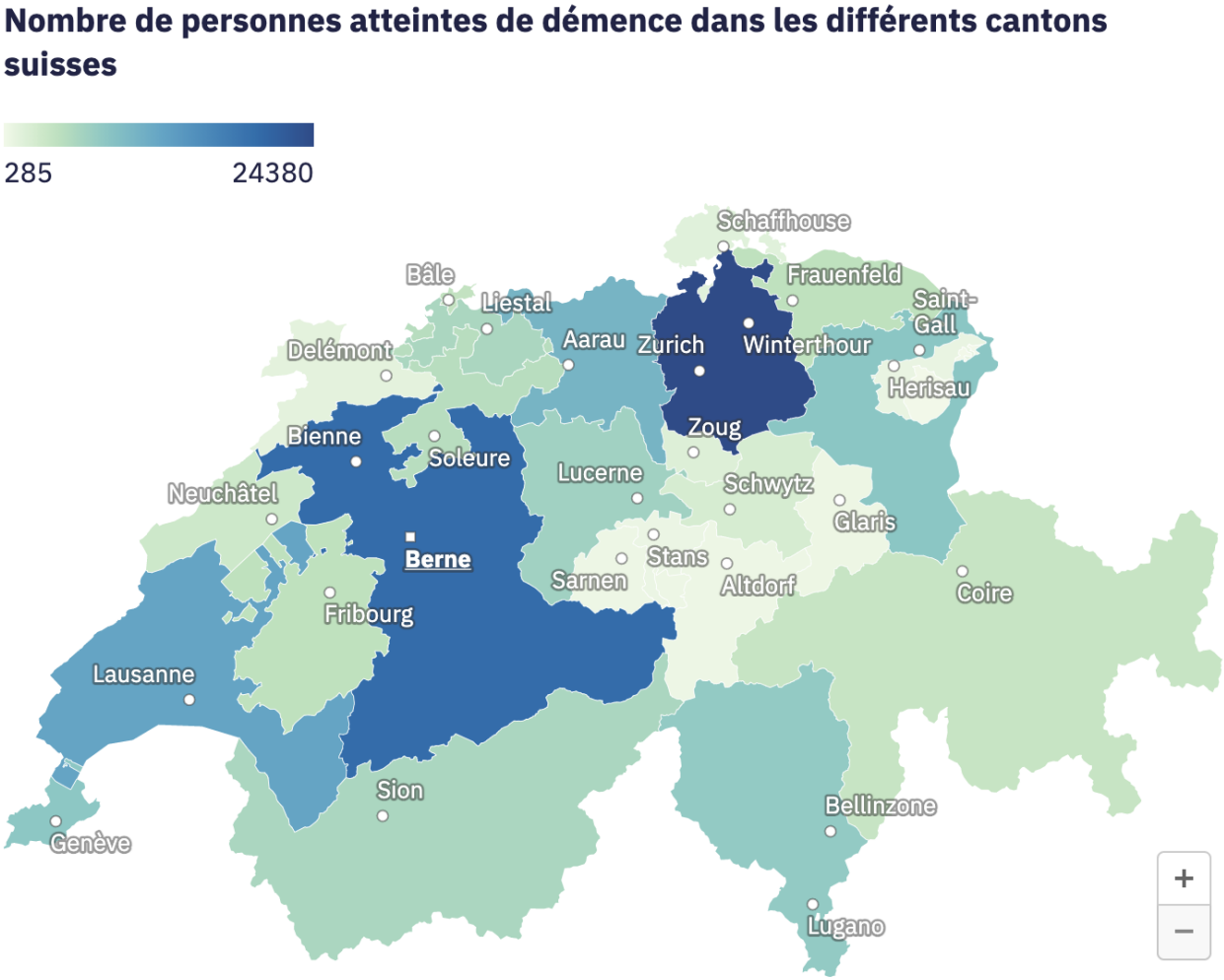
Useless 3D


Female Birth Rates by Age, U.S.A.
Births per 1,000 women
300
250
200
150
100
50
0
15–19
20–24
25–29
30–34
35–39
1940
1943
1946
1949
1952
1955
1958
1961
1964
1967
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
2015
35–39
30–34
25–29
20–24
15–19

Better 2D

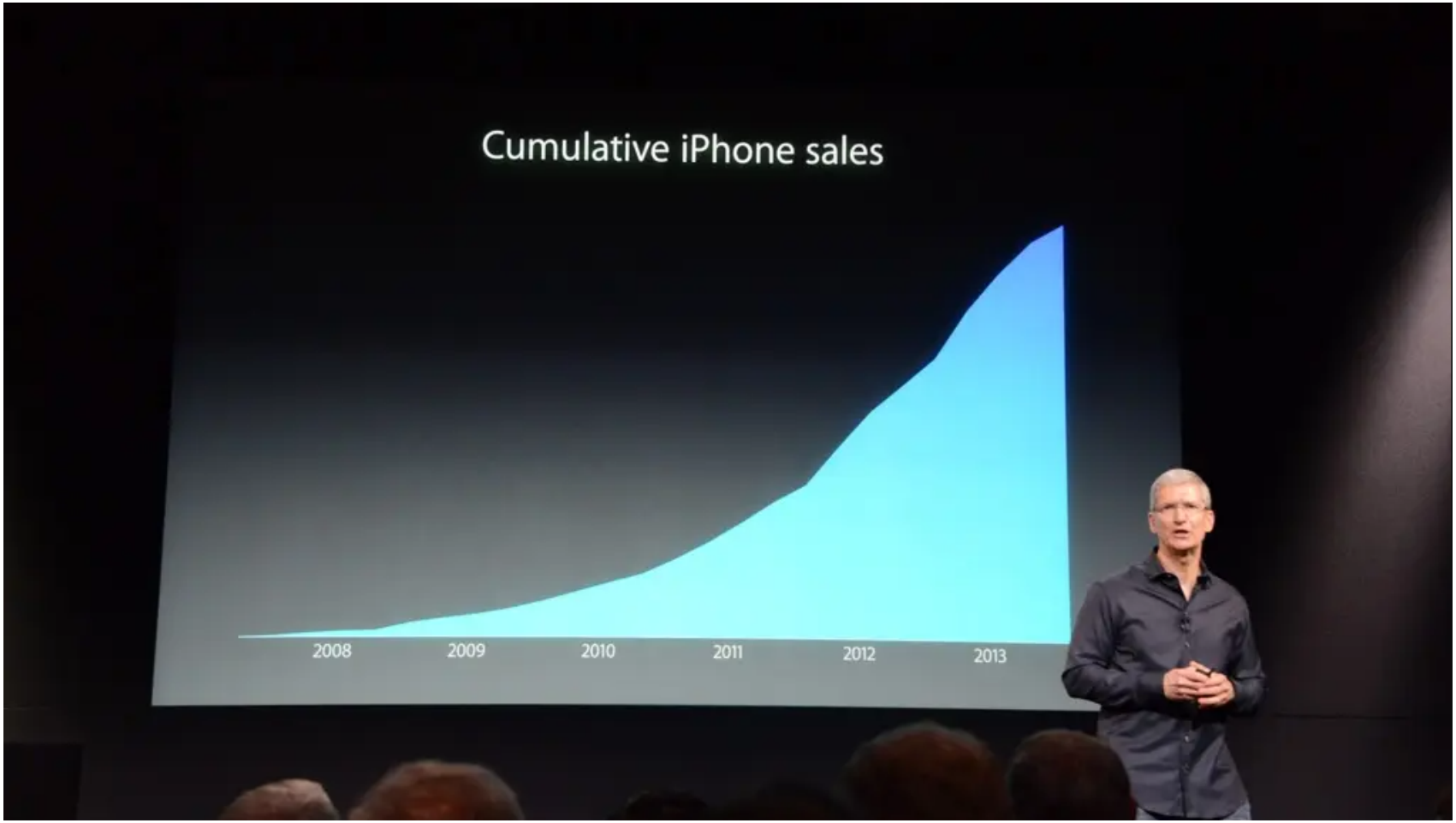

Female Birth Rates by Age, U.S.A.
Births per 1,000 women
300
250
200
150
100
50
0
15–19
20–24
25–29
30–34
35–39
1940
1943
1946
1949
1952
1955
1958
1961
1964
1967
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
2015

Total vs. Relative Again



Carte: G. Laplace. Nombre exact par canton en se positionnant dessus avec la souris; Source: Faits et chiffres (Alzheimer Suisse, 2021); Récupérer les données

Missing Axis & Misguidance



Asignment

Small project [20%]. Deadline on Week 6.

The goal of this project is *data exploration*. Find an interesting (in the sense it interests you!) data set and

- explore the data
- describe the data
- visualize the data
- lay out some questions about the data based on your exploration
- use more detailed visualization techniques to hint answers

The first step should be done individually. Then you can form groups of 2-3 and pick up the most interesting data set and do the rest. See Course organization for more details.

Exercise

Some data repositories listed on following slides.

1. Choose a scatterplot above (say the one on slide 10) and try to reproduce it using base R functions `plot()` instead of `ggplot()` and add legend manually using `legend()`.
2. Consider the Simpsons IMDB ratings plot above. Choose say 3 of your favorite TV shows, download data from the IMDB database a produce a plot similar to the Simpsons plot above (i.e. variances captured with boxplots) using `ggplot()` depicting all 3 TV shows.
3. Find and obtain spatial boundary files of administrative regions of your home country (or use some other country, if problematic). Produce a geospatial heatmap of the country, using some external variable for the color fill argument (e.g. specific election results or election participation, mortality rates, etc.).

One more Scatterplot Example

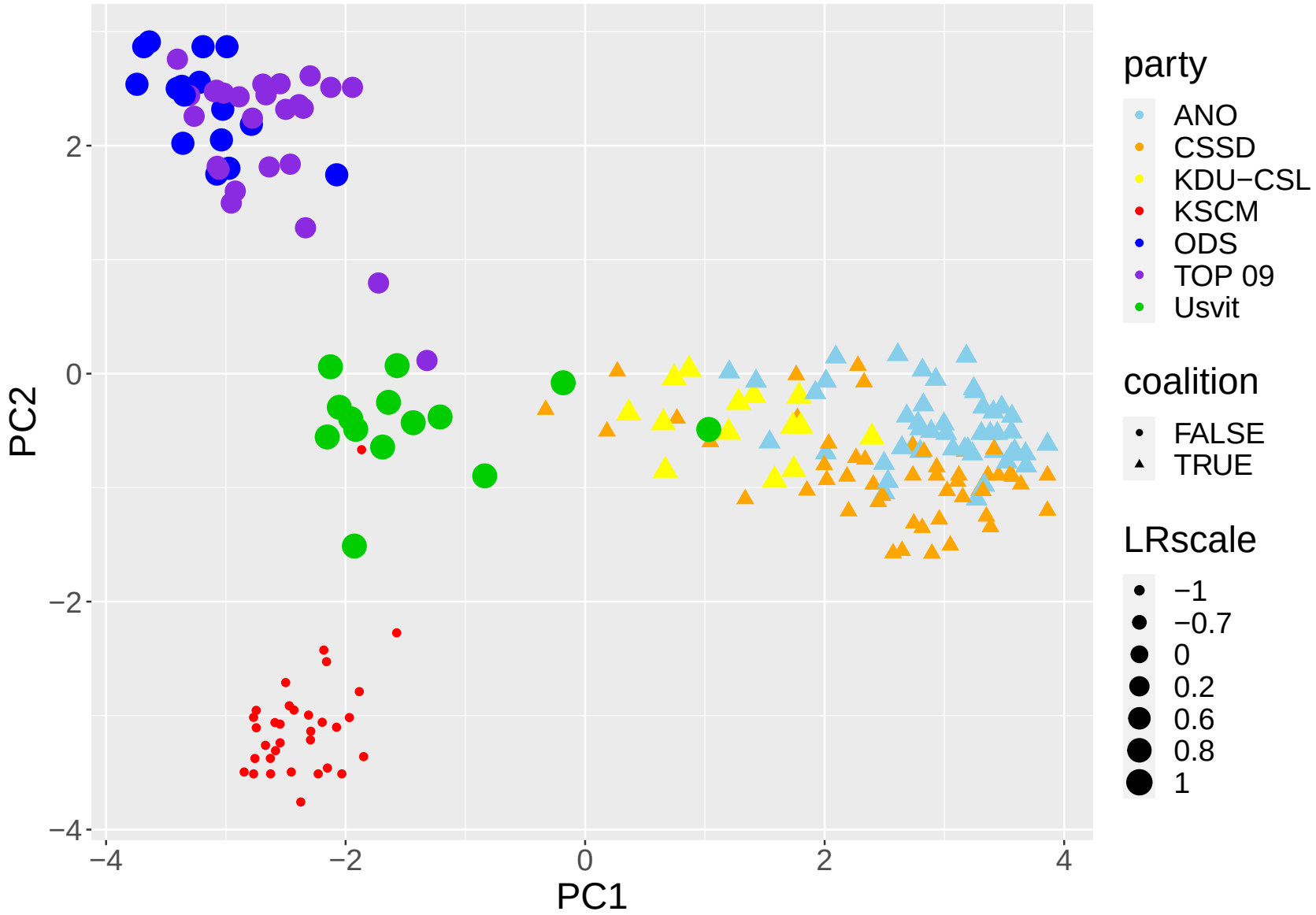
- voting records of the members of the Czech parliament in 2015
  - $N = 200$ members of the parliament
  - certain number of votings during that period ($x_{nj} \in \{-1, 0, 1\}$ depending on whether n-th member voted for the j-th voting no/abstain/yes), but **PCA** applied and only first 2 components kept
- additional information about party affiliation of the members
  - `party` affiliation (7 parties in total)
  - government `coalition` affiliation (T/F)
  - left-wing/right-wing scale `LRscale` (on the party level)

```
## 'data.frame':    200 obs. of  6 variables:
##  $ PC1         : num  -1.93 -2.16 -3.04 2.74 -1.94 ...
##  $ PC2         : num  -1.512 -2.527 2.051 -0.892 2.512 ...
##  $ party       : chr  "Usvit" "KSCM" "ODS" "CSSD" ...
##  $ party_color: chr  "green3" "red" "blue" "orange" ...
##  $ coalition   : Factor w/ 2 levels "FALSE","TRUE": 1 1 1 2
##  $ LRscale     : Factor w/ 7 levels "-1","-0.7","0",..: 7 1
```

One more Scatterplot Example

```
ggplot(data = cz, mapping = aes(x = PC1, y = PC2, color=party,
                                shape=coalition, size=LRscale)) +
  geom_point() +
  scale_color_manual(values=c("skyblue","orange","yellow",
                              "red","blue","blueviolet","green3")) +
  scale_shape_manual(values=c(16,17))
```

One more Scatterplot Example



Some links to open data

fivethirtyeight: article data of Nate Silver's data journalism platform freely available (see also R package fivethirtyeight)

data-is-plural: weekly newsletter of datasets by Jeremy Singer-Vine

re3data: Registry of research data repositories

openml datasets: many uniformly formatted datasets for training machine learning models – however, not always good descriptions available

Worldbank Datacatalog: the World Bank data catalogue

UK Data Service: UK's largest collection of social, economic and population data resources (filter for open data) or also data.gov.uk

ICPSR: unit within the Institute for Social Research at the University of Michigan, social and behavioral research. In particular including replication datasets for published studies.

govdata: Open Government - German administrative data freely accessible

Some more

gapminder: "an independent educational non-profit fighting global misconceptions"; collection and vizualisation of datasets concerning gobal developement

nature.com: peer-reviewed, open-access journal for descriptions of datasets (broad range of natural science disciplines)

NIH (National Institute of Health) Data Sharing Repositories: overview on different thematically sorted medical databases

UCI Machine Learning Repository or the new beta version: containing various datasets – however, sometimes with a little few description

data.bris Research Data Repository: Data repository of the University of Bristol

bellingcat TikTok Hashtag analysis tool: Didn't try, don't know how easy.

. . . no systematic selection. Much more out there