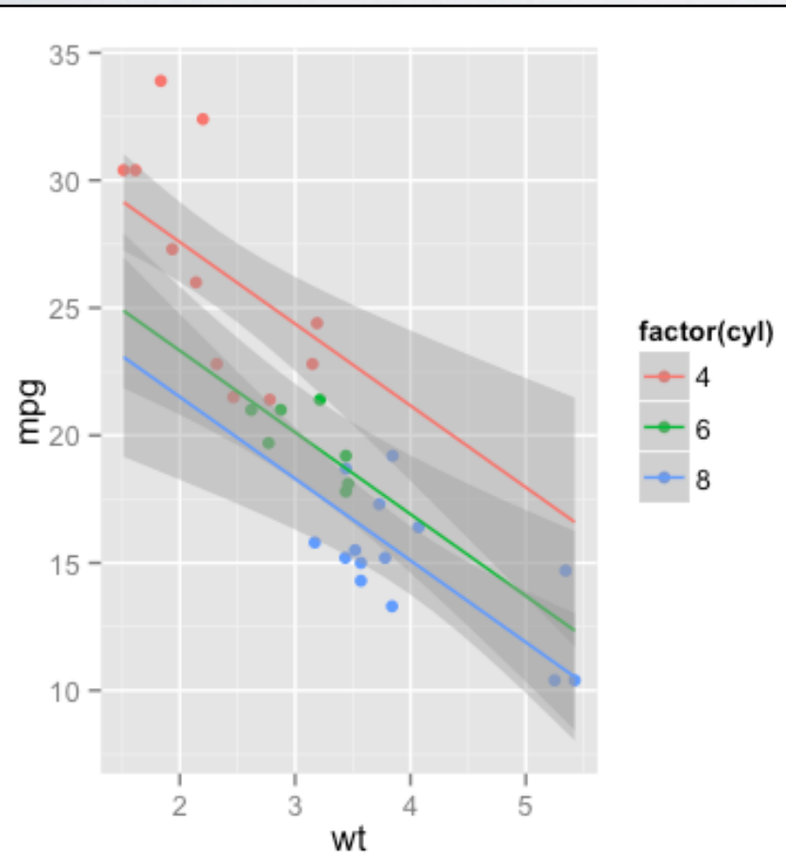
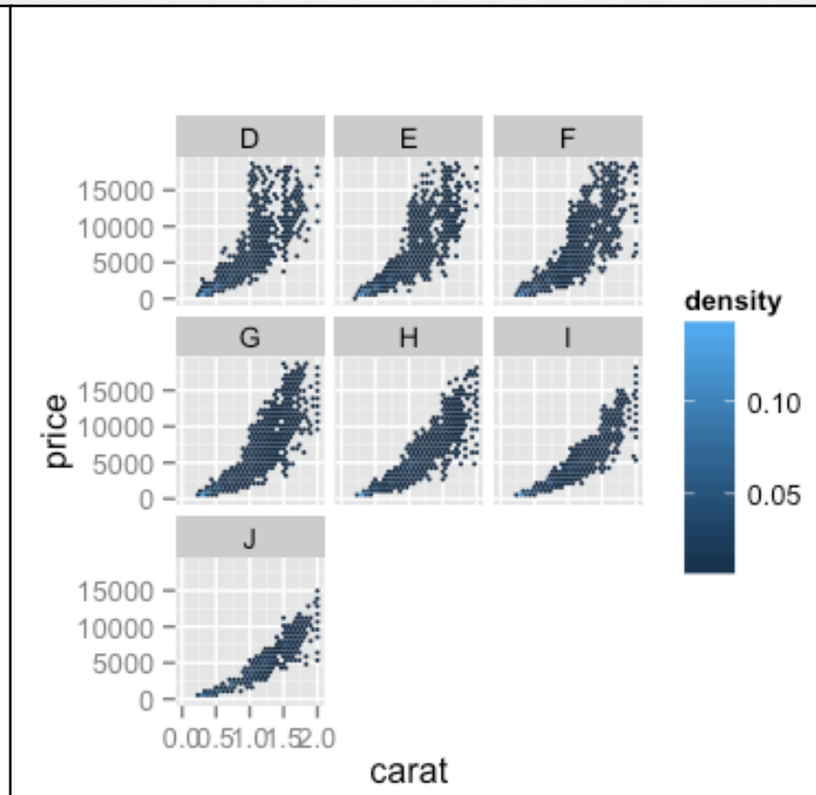
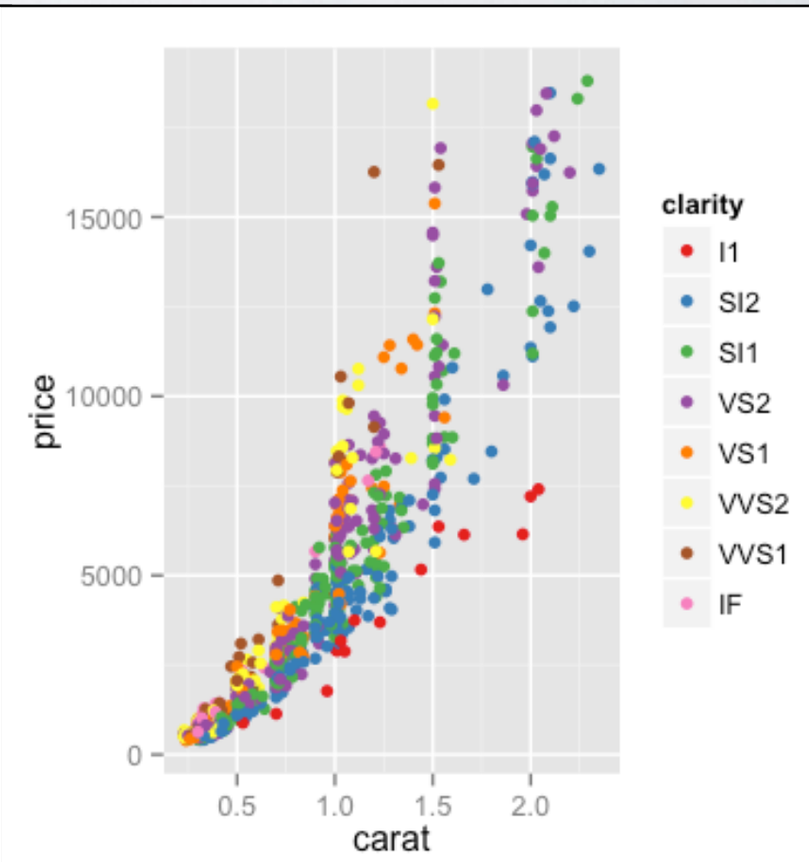
ggplot2

displaying spatial & temporal data



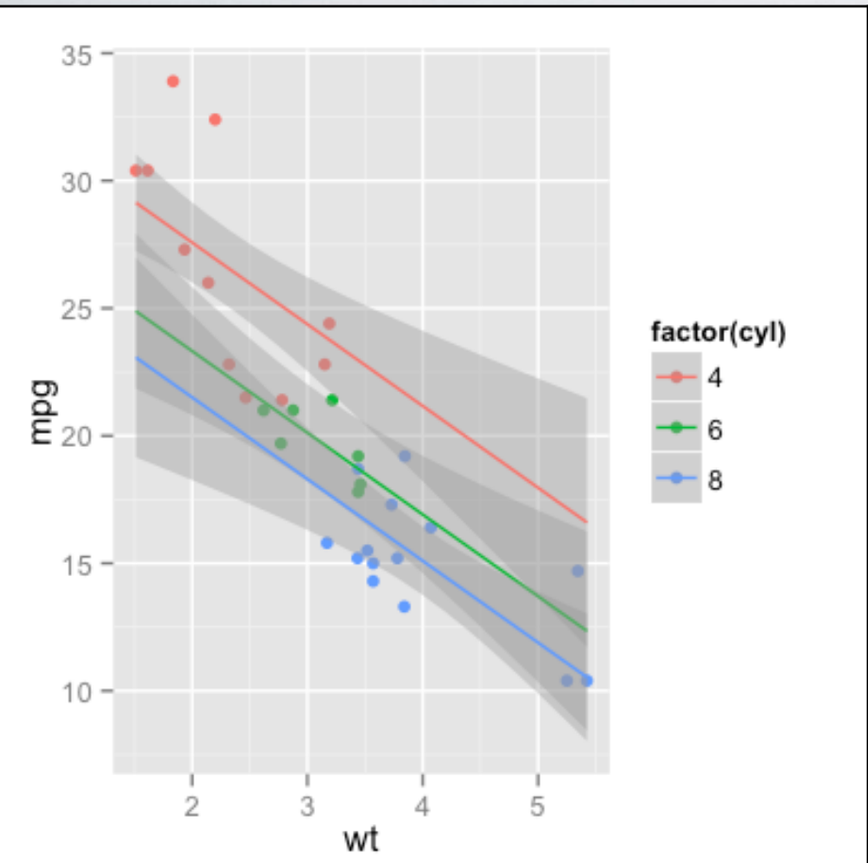


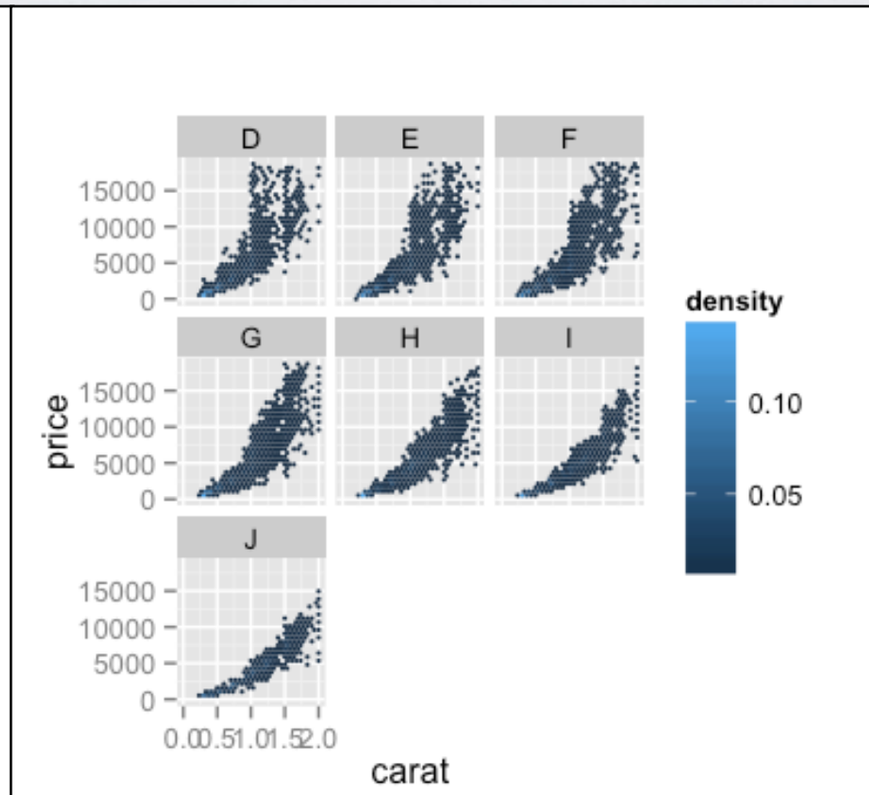


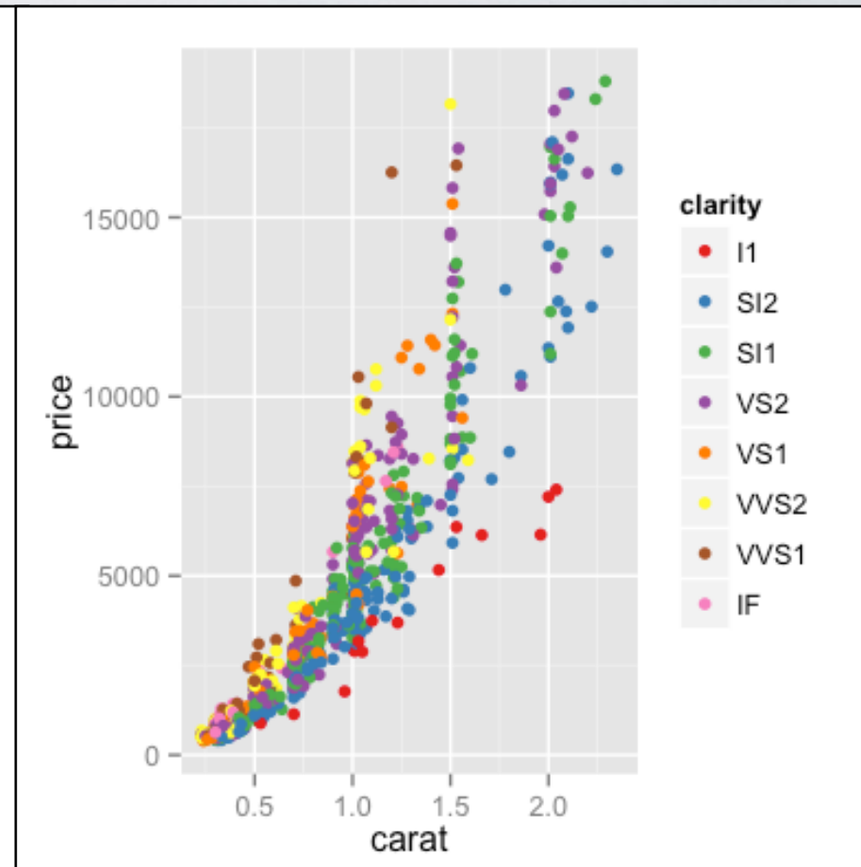
Credit

- 'White' slides are taken directly from Dianne Cook's "IMAGe STATMOS Course on Visualization of Climate Data"
- http://streaming.stat.iastate.edu/~dicook/NCAR/
-

ggplot2


mpg
wt
factor(cyl)
4
6
8


D
E
F
G
H
I
J
price
carat
density
0.10
0.05


price
carat
clarity
I1
SI2
SI1
VS2
VS1
VVS2
VVS1
IF

ggplot2

- "ggplot2 is a **plotting system** for R, based on the **grammar of graphics**, which tries to take the good parts of base and lattice graphics and none of the bad parts. It takes care of many of the fiddly details that make plotting a hassle (like drawing legends) as well as providing a powerful model of graphics that makes it easy to **produce complex multi-layered graphics**."

http://ggplot2.org/

ggplot2

- "ease of use" vs. "customization"
  - user's time is more important than customization
  - grammar rules reduce amount of small decisions

- made for **fast** iterations

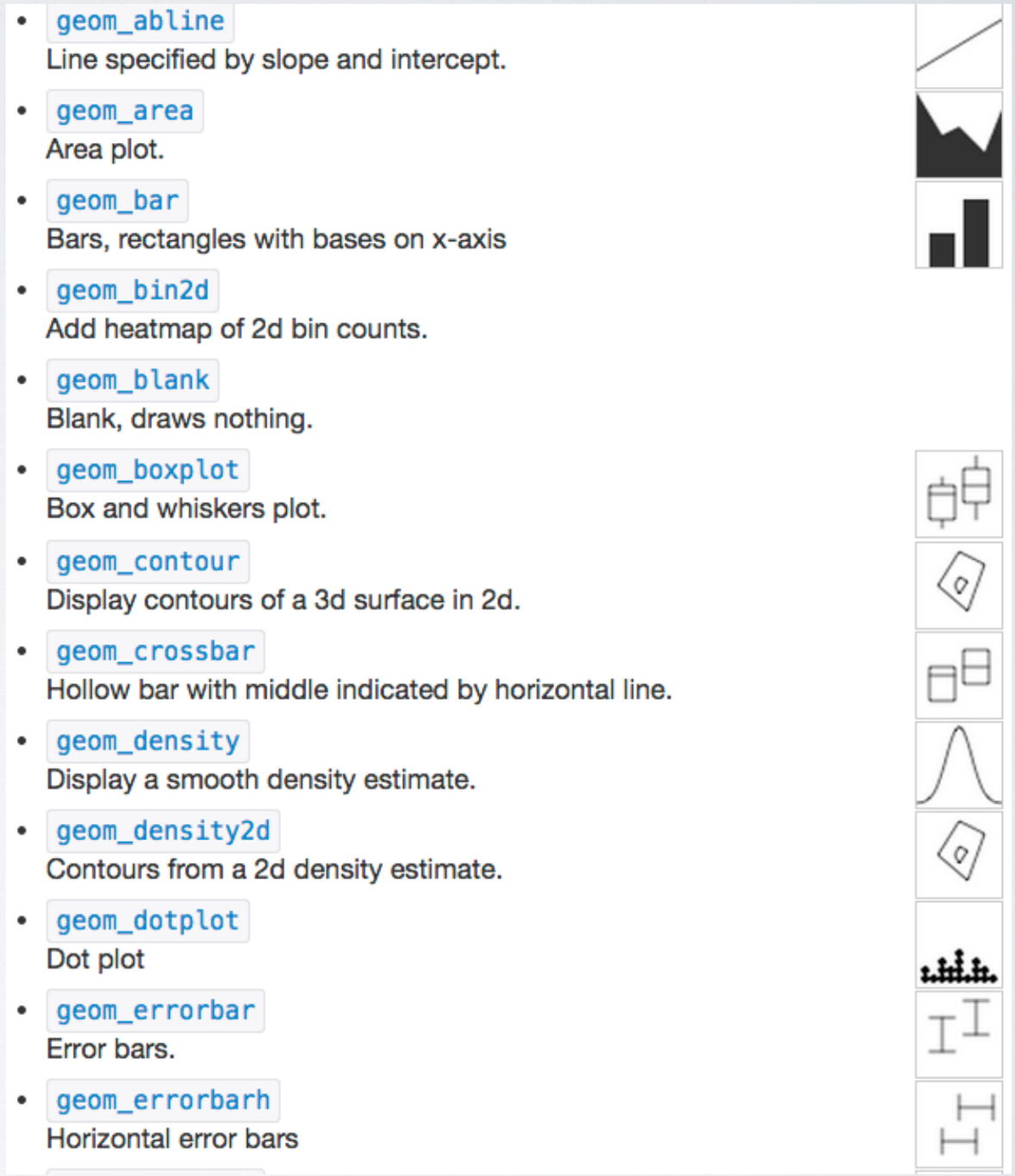
Grammar

- Underlying ggplot2 is a formal structure for defining a data plot
- Provides enormous flexibility in producing data plots, how different plots are related
- Elegant nature of plots is due to defaults based on good cognitive principles.
- Based initially on Wilkinson (2001)'s grammar of graphics - "gg" stands for grammar of graphics

geom

- "Geoms, short for geometric objects, describe the type of plot you will produce"

- 37 documented geoms.

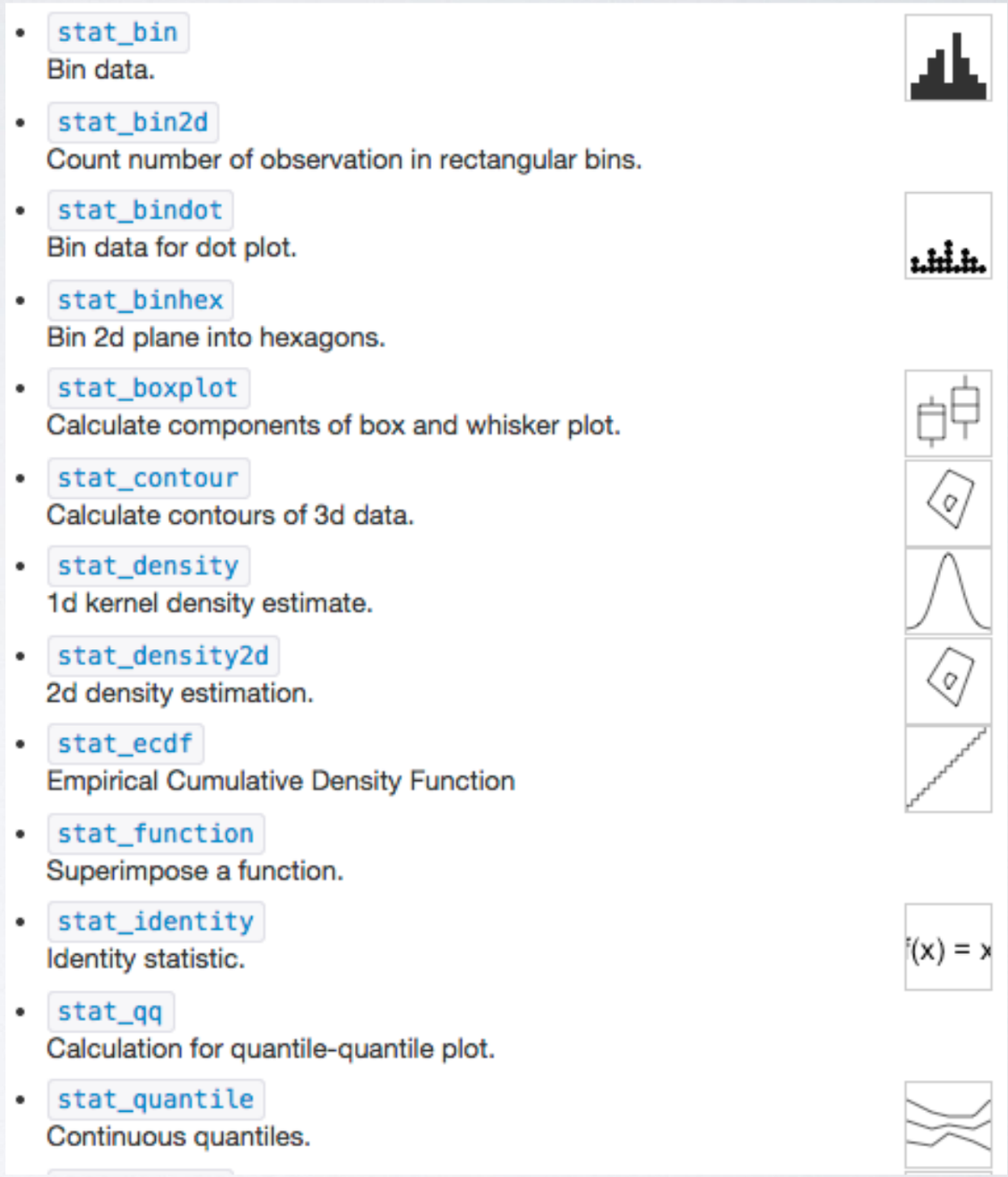


- `geom_abline`
  Line specified by slope and intercept.
- `geom_area`
  Area plot.
- `geom_bar`
  Bars, rectangles with bases on x-axis
- `geom_bin2d`
  Add heatmap of 2d bin counts.
- `geom_blank`
  Blank, draws nothing.
- `geom_boxplot`
  Box and whiskers plot.
- `geom_contour`
  Display contours of a 3d surface in 2d.
- `geom_crossbar`
  Hollow bar with middle indicated by horizontal line.
- `geom_density`
  Display a smooth density estimate.
- `geom_density2d`
  Contours from a 2d density estimate.
- `geom_dotplot`
  Dot plot
- `geom_errorbar`
  Error bars.
- `geom_errorbarh`
  Horizontal error bars

http://docs.ggplot2.org/0.9.3.1/

geom statistics

- statistical transformations
- most common: identity
- common geoms: bin, boxplot, qq, quantile, smooth



- `stat_bin`
  Bin data.
- `stat_bin2d`
  Count number of observation in rectangular bins.
- `stat_bindot`
  Bin data for dot plot.
- `stat_binhex`
  Bin 2d plane into hexagons.
- `stat_boxplot`
  Calculate components of box and whisker plot.
- `stat_contour`
  Calculate contours of 3d data.
- `stat_density`
  1d kernel density estimate.
- `stat_density2d`
  2d density estimation.
- `stat_ecdf`
  Empirical Cumulative Density Function
- `stat_function`
  Superimpose a function.
- `stat_identity`
  Identity statistic.
- `stat_qq`
  Calculation for quantile-quantile plot.
- `stat_quantile`
  Continuous quantiles.

http://docs.ggplot2.org/0.9.3.1/

geom layer(s)

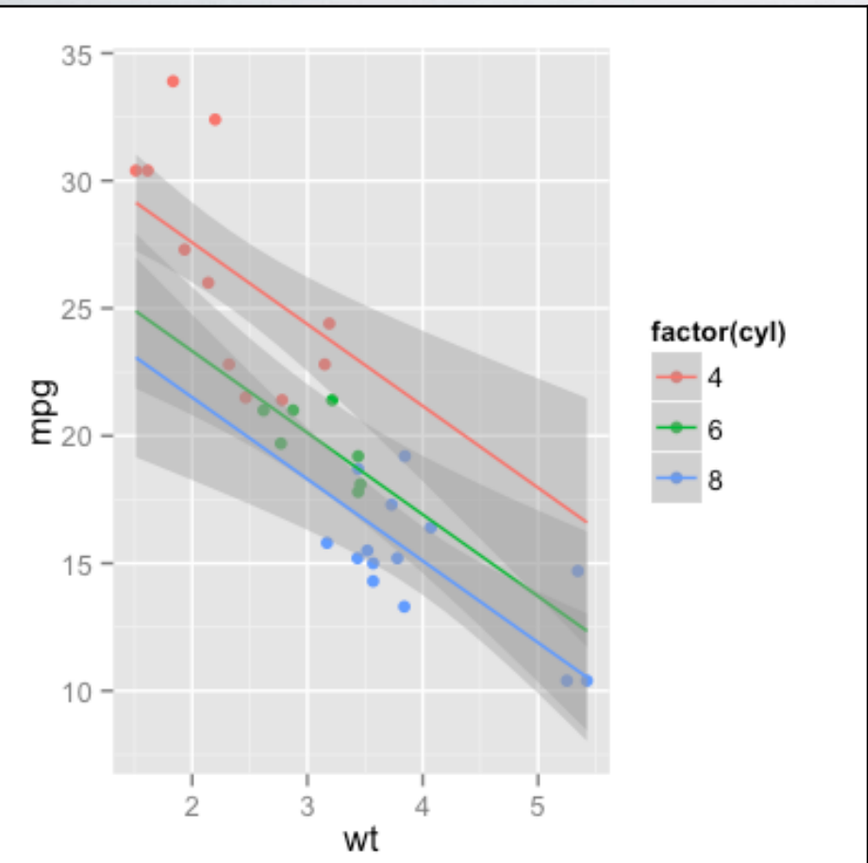
- Parts:
  - data and aesthetic mapping,
  - a statistical transformation (stat)
  - a geometric object (geom)
  - a position adjustment

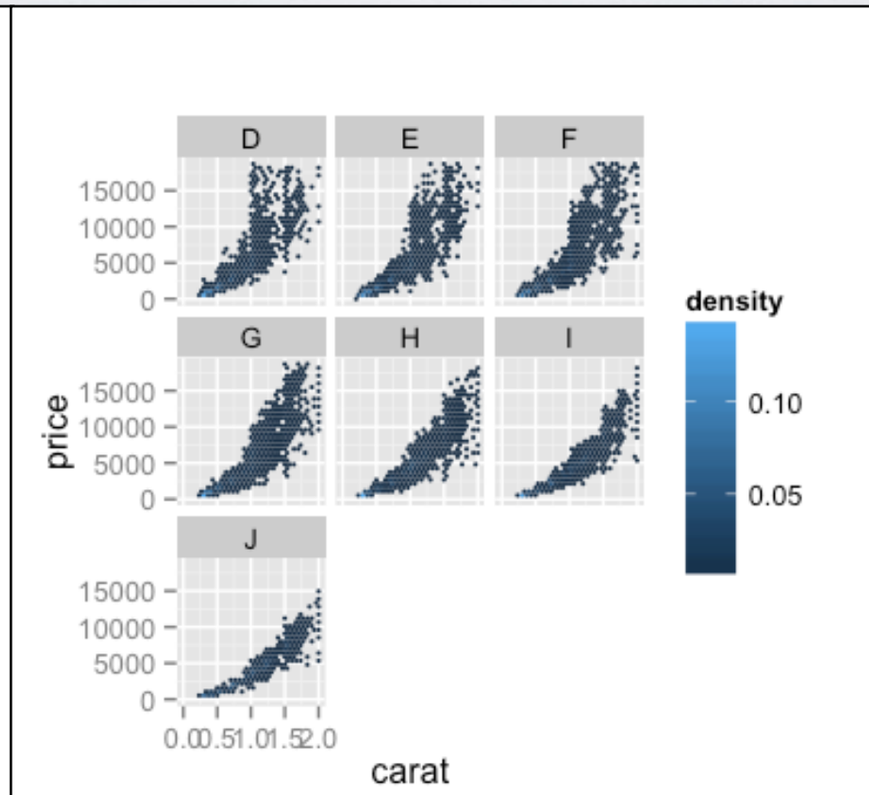
- typically display other columns within the same data

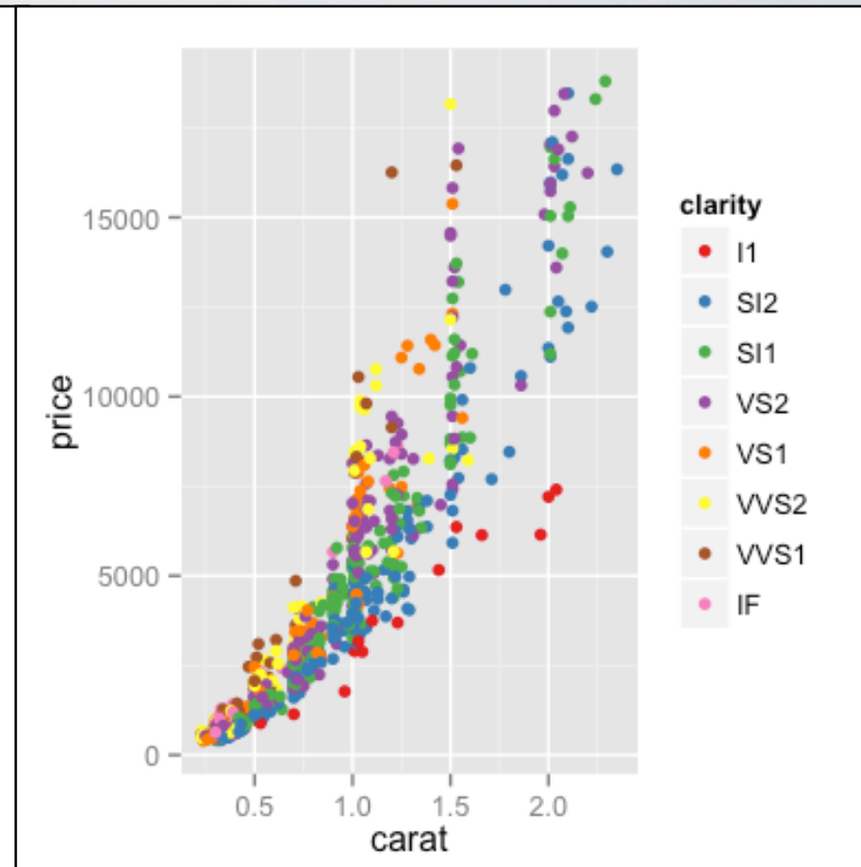
- can display completely new data

http://vita.had.co.nz/papers/layered-grammar.pdf

layer examples







ggplot2 objects

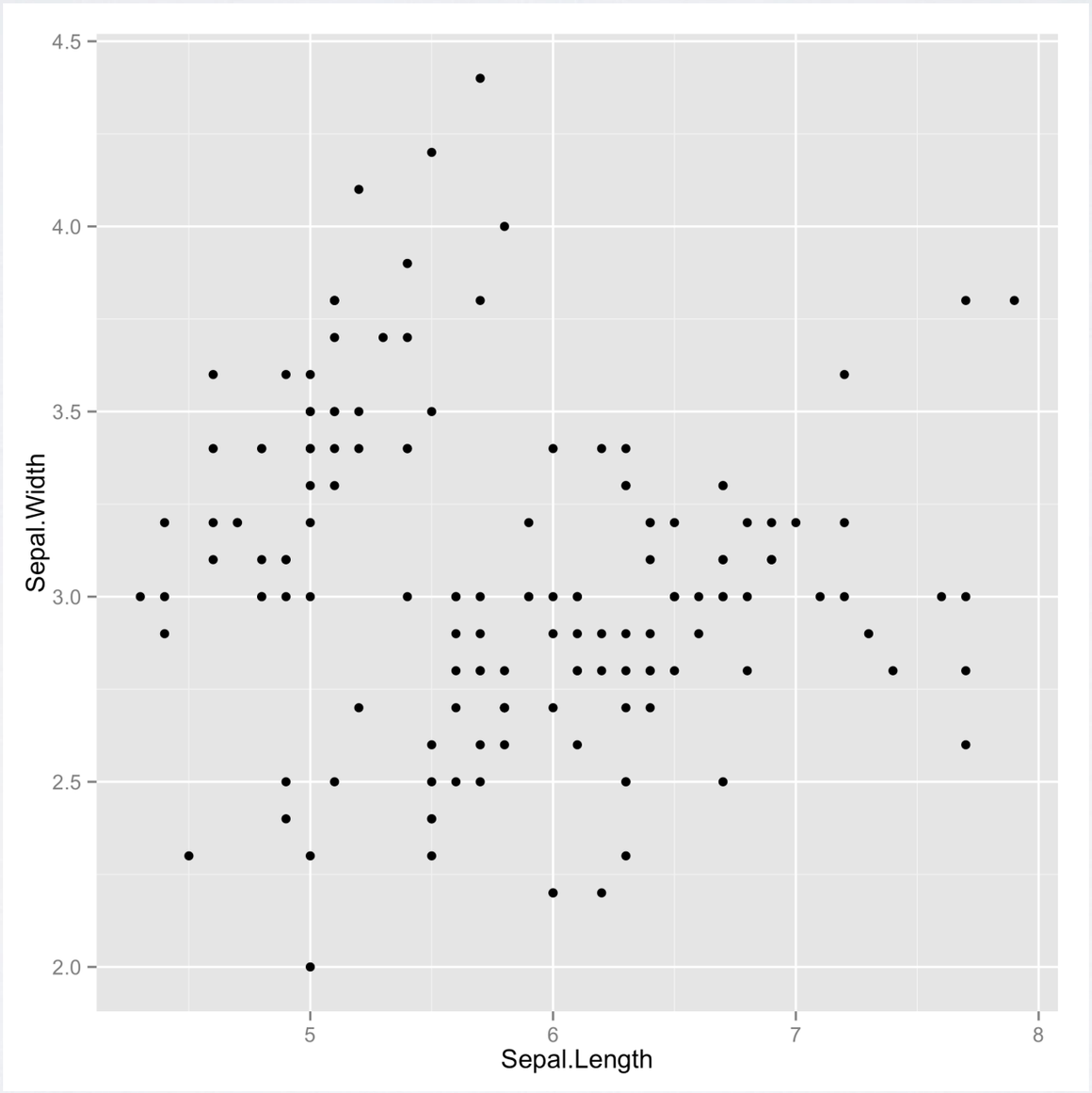
- ggplot2 plots are fully defined R objects
- have a special print method
- objects may be altered many times before printing

‘qplot’ function

- qplot(
    vars, # ‘x’ and/or ‘y’. Depends on geom
    data,
    [geom = “point”,
     [other options]]
) + [more layers]

ggplot2 object example

- `p <- qplot(Sepal.Length, Sepal.Width, data = iris)`
  `p`



```
> str(p)
List of 9
 $ data       :'data.frame':  150 obs. of  5 variables:
  ..$ Sepal.Length: num [1:150] 5.1 4.9 4.7 4.6 5 5.4 4.6 5 4.4 4.9 ...
  ..$ Sepal.Width : num [1:150] 3.5 3 3.2 3.1 3.6 3.9 3.4 3.4 2.9 3.1 ...
  ..$ Petal.Length: num [1:150] 1.4 1.4 1.3 1.5 1.4 1.7 1.4 1.5 1.4 1.5 ...
  ..$ Petal.Width : num [1:150] 0.2 0.2 0.2 0.2 0.2 0.4 0.3 0.2 0.2 0.1 ...
  ..$ Species     : Factor w/ 3 levels "setosa","versicolor",..: 1 1 1 1 1...
 $ layers     :List of 1
  ..$ :Classes 'proto', 'environment' <environment: 0x7fa9d48e8b48>
 $ scales     :Reference class 'Scales' [package "ggplot2"] with 1 fields
  ..$ scales: list()
  ..and 21 methods, of which 9 are possibly relevant:
  ..  add, clone, find, get_scales, has_scale, initialize, input, n,
  ..  non_position_scales
 $ mapping    :List of 2
  ..$ x: symbol Sepal.Length
  ..$ y: symbol Sepal.Width
$ theme      : list()
$ coordinates:List of 1
 ..$ limits:List of 2
 .. ..$ x: NULL
 .. ..$ y: NULL
 ..- attr(*, "class")= chr [1:2] "cartesian" "coord"
$ facet      :List of 1
 ..$ shrink: logi TRUE
 ..- attr(*, "class")= chr [1:2] "null" "facet"
$ plot_env   :<environment: R_GlobalEnv>
$ labels     :List of 2
 ..$ x: chr "Sepal.Length"
 ..$ y: chr "Sepal.Width"
- attr(*, "class")= chr [1:2] "gg" "ggplot
```

- ```
  > str(p)
  List of 9
  …
  $ layers     :List of 1
    ..$ :Classes 'proto', 'environment'
  <environment: 0x7fa9d48e8b48>
  …
  ```

- ```
  > p$layers
  [[1]]
  geom_point:
  stat_identity:
  position_identity: (width = NULL, height = NULL)
  ```

print plot:
base vs. ggplot2

- dt <- dataBeingUsed

- ## base
  # start graphics device
  plot(x, y, data=dt)
  points(x2, y2, data=dt)
  lines(x, y, data=dt)
  lines(x2, y2, data=dt)
  #… more plot procedures
  # stop graphics device

- ## ggplot2
  p <- qplot(
  x, y, data = dt,
  geom = c(“point”, “line”))
  p <- p +
  geom_point(aes(x=x2,y=y2))+
  geom_line(aes(x=x2,y=y2))
  #… more plot procedures

  # start graphics device
  p
  # stop graphics device

ggplot2:
spatial & temporal data

About the NASA data

- Measurements recorded by NASA using remote sensing on temperature, pressure, ozone, clouds over Central America 1995-2000.
- For ASA Data Expo 2006

http://stat-computing.org/dataexpo/2006/

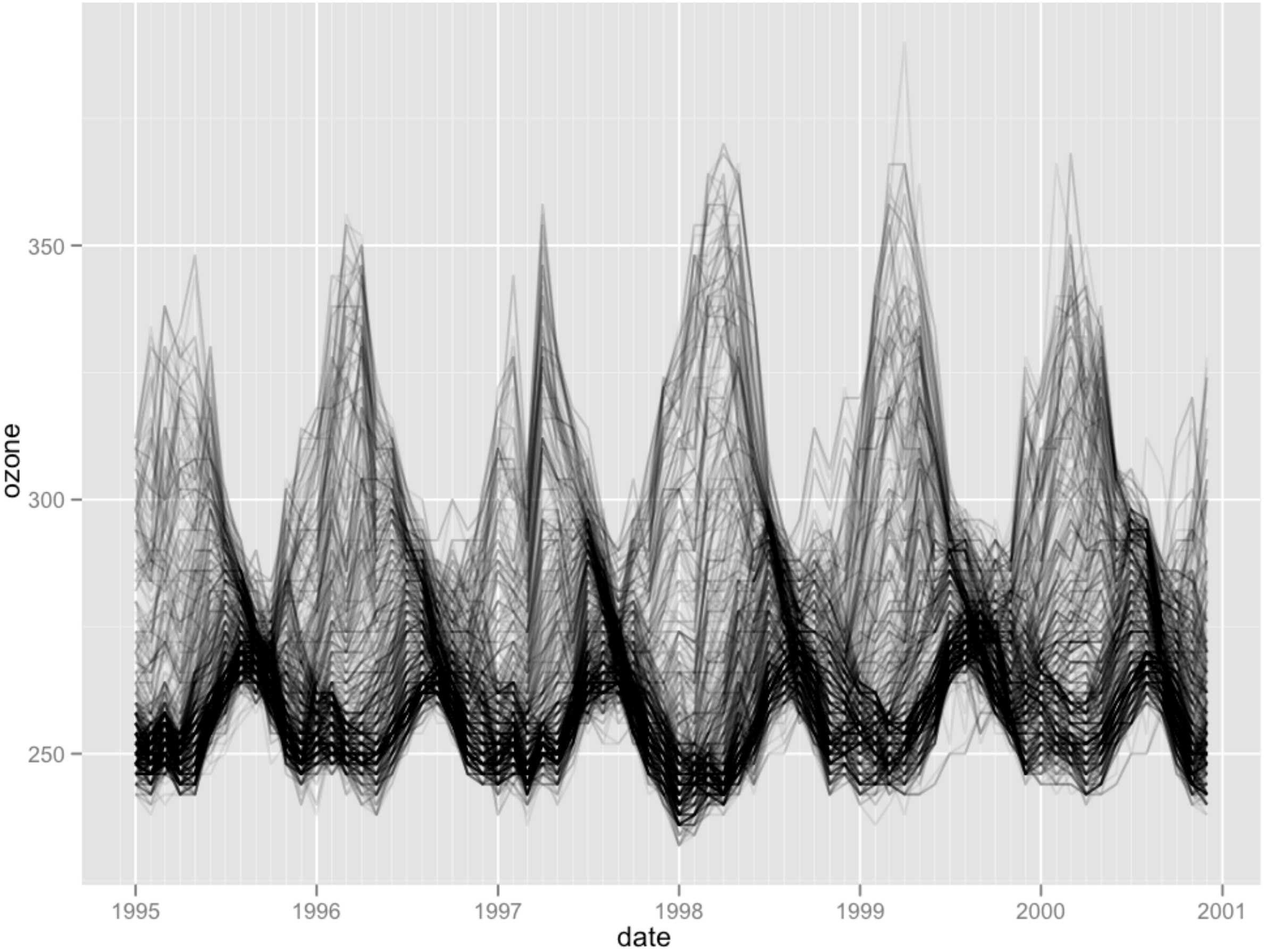
Checking the data

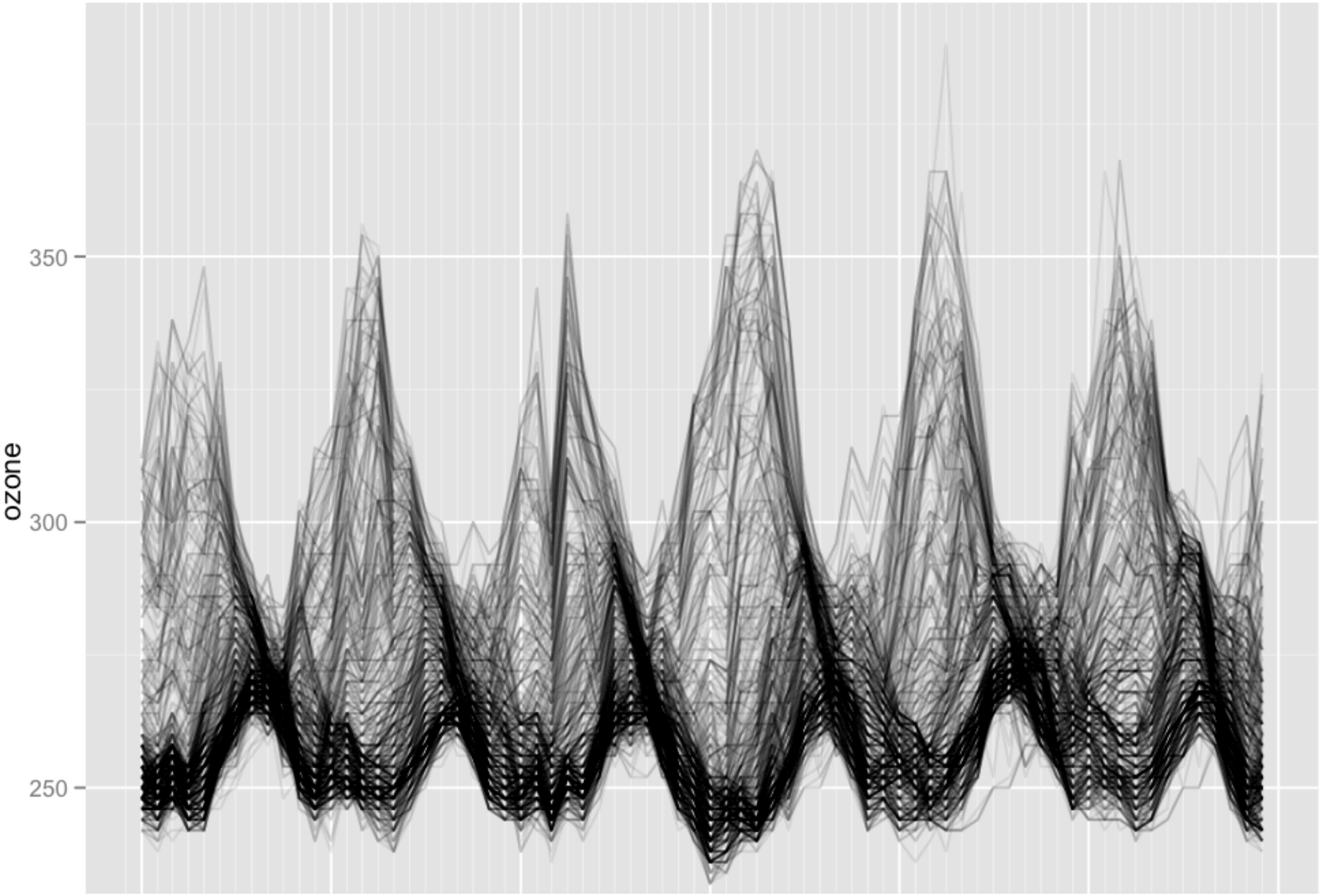
- Numerical summaries

```
> summary(nasa)
      time              y                x              lat        
 Min.   : 1.00   Min.   : 1.00   Min.   : 1.00   Min.   :-21.20  
 1st Qu.:18.75   1st Qu.: 6.75   1st Qu.: 6.75   1st Qu.: -6.85  
 Median :36.50   Median :12.50   Median :12.50   Median :  7.50  
 Mean   :36.50   Mean   :12.50   Mean   :12.50   Mean   :  7.50  
 3rd Qu.:54.25   3rd Qu.:18.25   3rd Qu.:18.25   3rd Qu.: 21.85  
 Max.   :72.00   Max.   :24.00   Max.   :24.00   Max.   : 36.20  

      long                date          cloudhigh       cloudlow     
 Min.   :-113.8   1995-01-01:  576   Min.   : 0.0   Min.   :  0.50  
 1st Qu.: -99.4   1995-02-01:  576   1st Qu.: 1.5   1st Qu.: 15.00  
 Median : -85.0   1995-03-01:  576   Median : 8.5   Median : 23.50  
 Mean   : -85.0   1995-04-01:  576   Mean   :12.0   Mean   : 26.24  
 3rd Qu.: -70.6   1995-05-01:  576   3rd Qu.:18.5   3rd Qu.: 34.50  
 Max.   : -56.2   1995-06-01:  576   Max.   :62.5   Max.   : 84.50  
                  (Other)   :38016                  NA's   :110.00  
```

• • • •

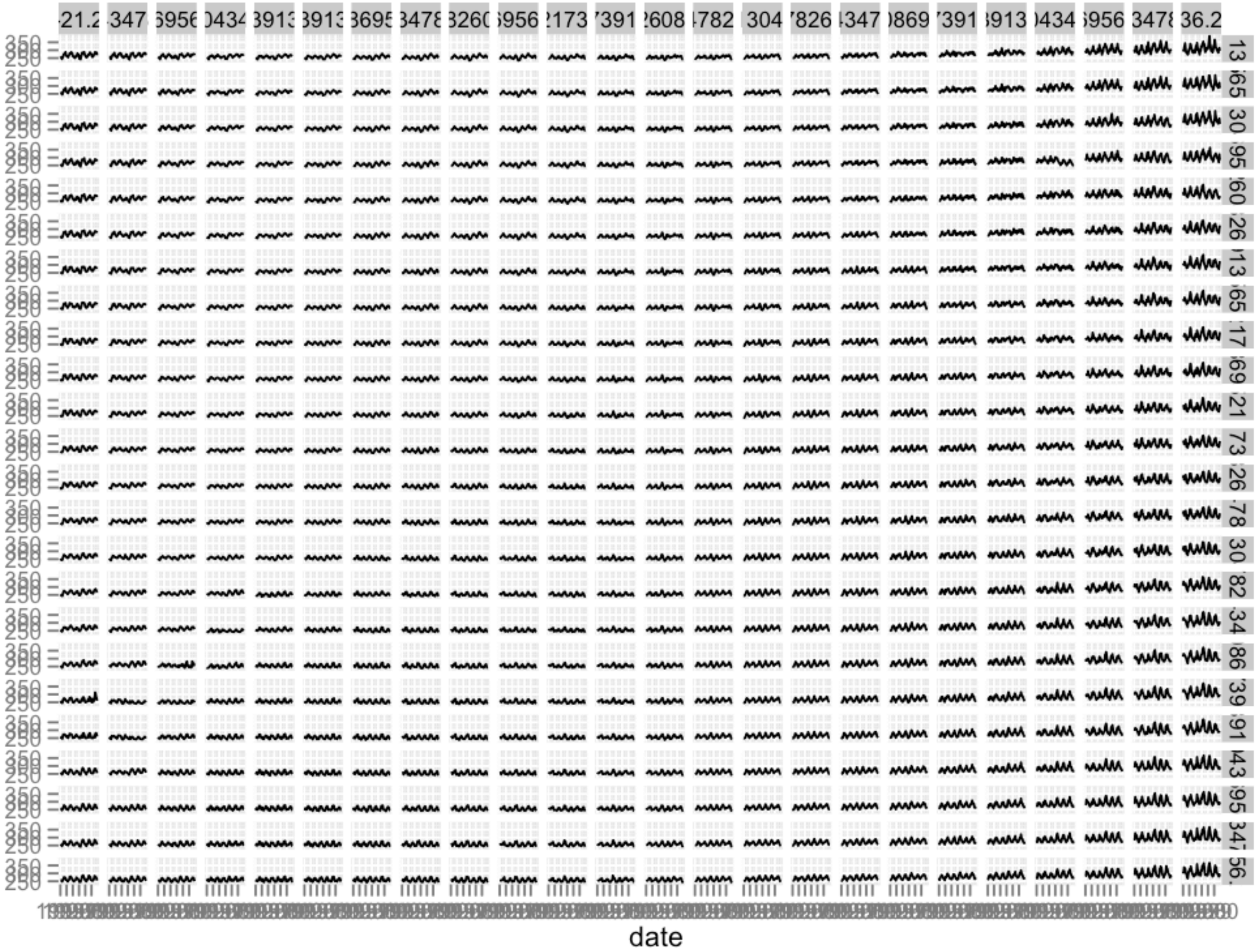

ozone
350
300
250
1995
1996
1997
1998
1999
2000
2001
date

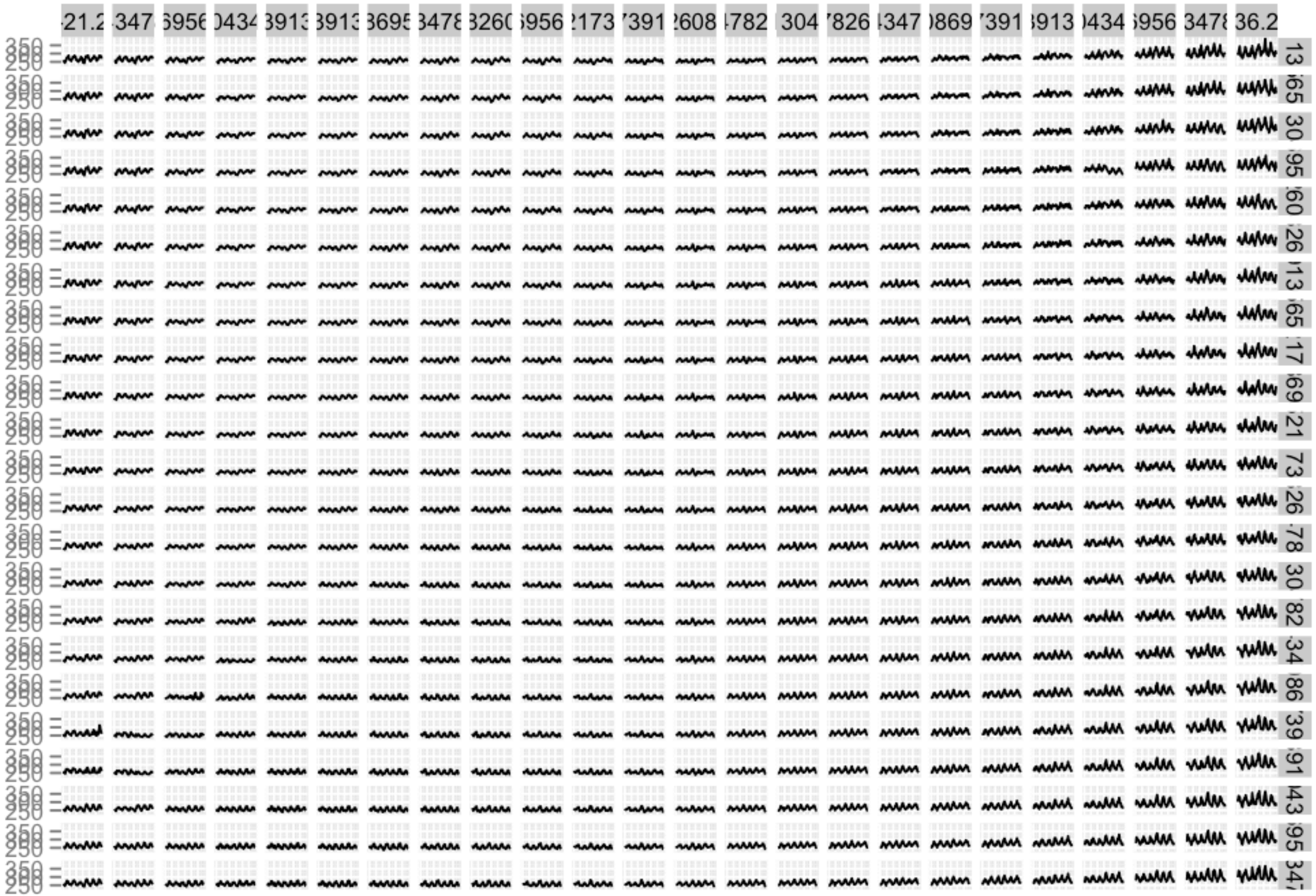



```
qplot(date, ozone, data = nasa, group = id,
  geom = "line", alpha = I(0.1))
```

Time trend

- Ozone is plotted against time (month and year) separately but overlapping for each spatial location
- Seasonality is visible - but there is a double peak. We'd guess that this correspond to northern and southern latitude differences. How can we check?


ozone
date



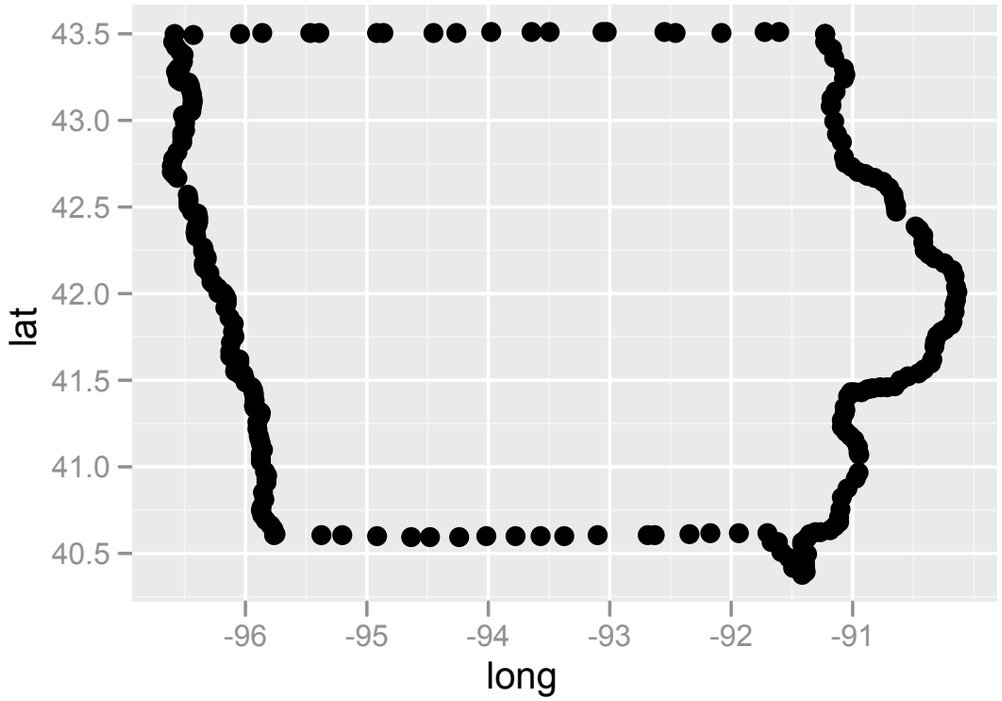

```
qplot(date, ozone, data = nasa, geom = "line") +
  facet_grid(lat ~ long)
```

Space-time trend

- Ozone is plotted against time (month and year) separately for each spatial location
- Seasonality is visible across the region, more so at the higher latitudes.

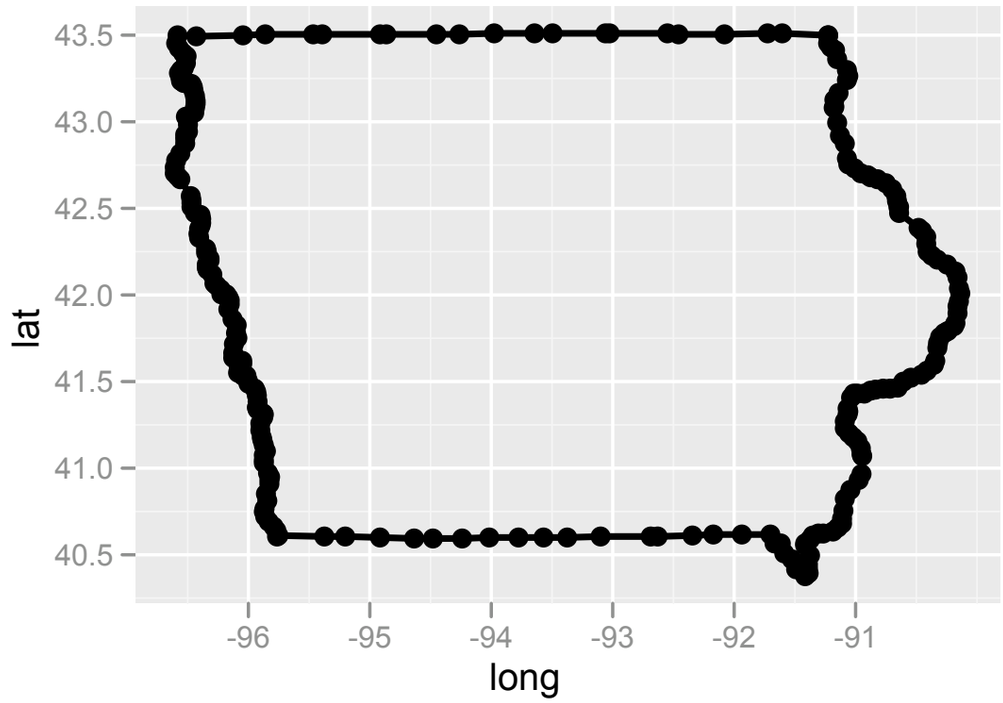
- This last plot took a minute to draw!

What is a map?



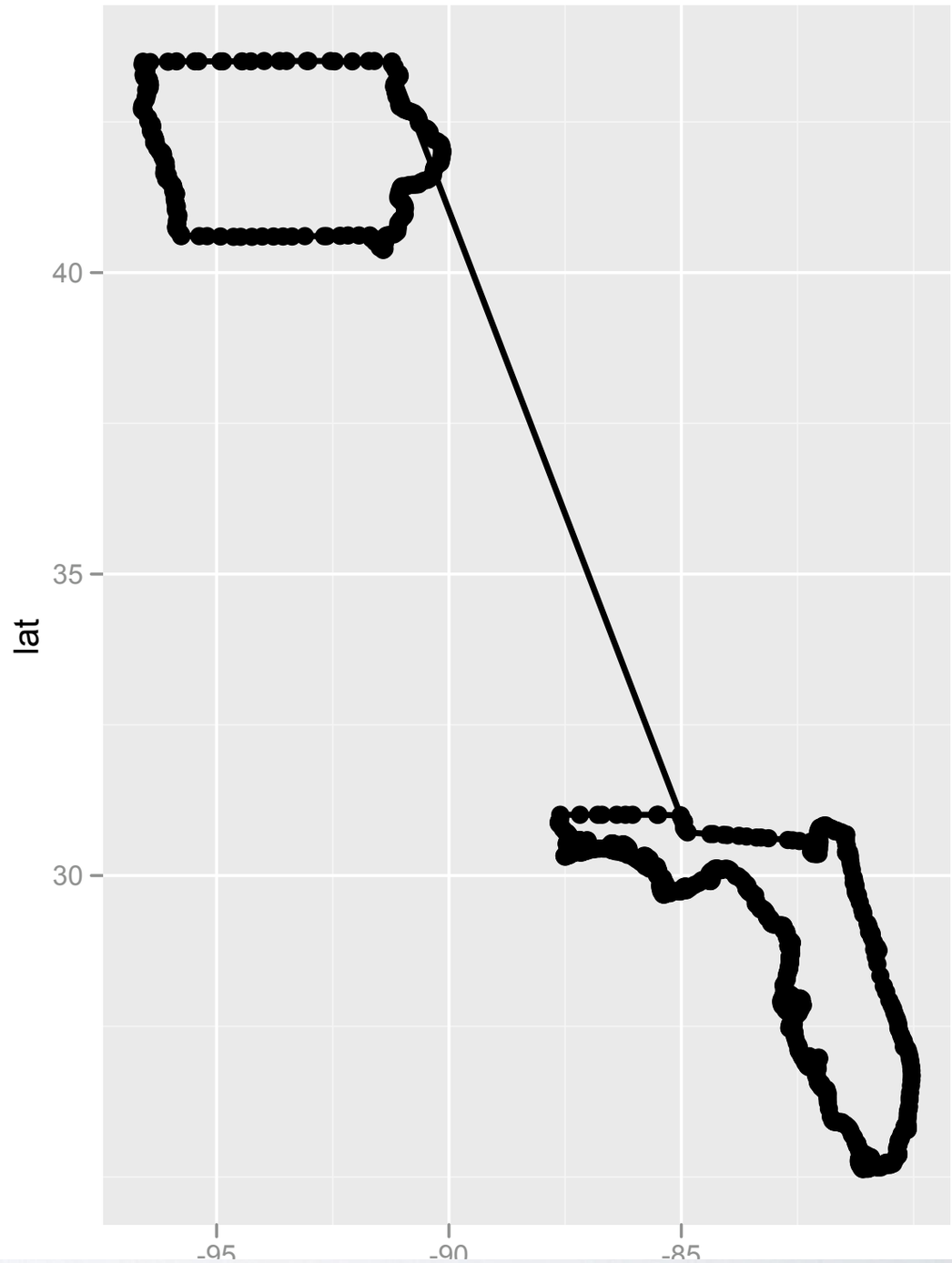
Set of points specifying latitude and longitude

Polygon: connect dots in correct order



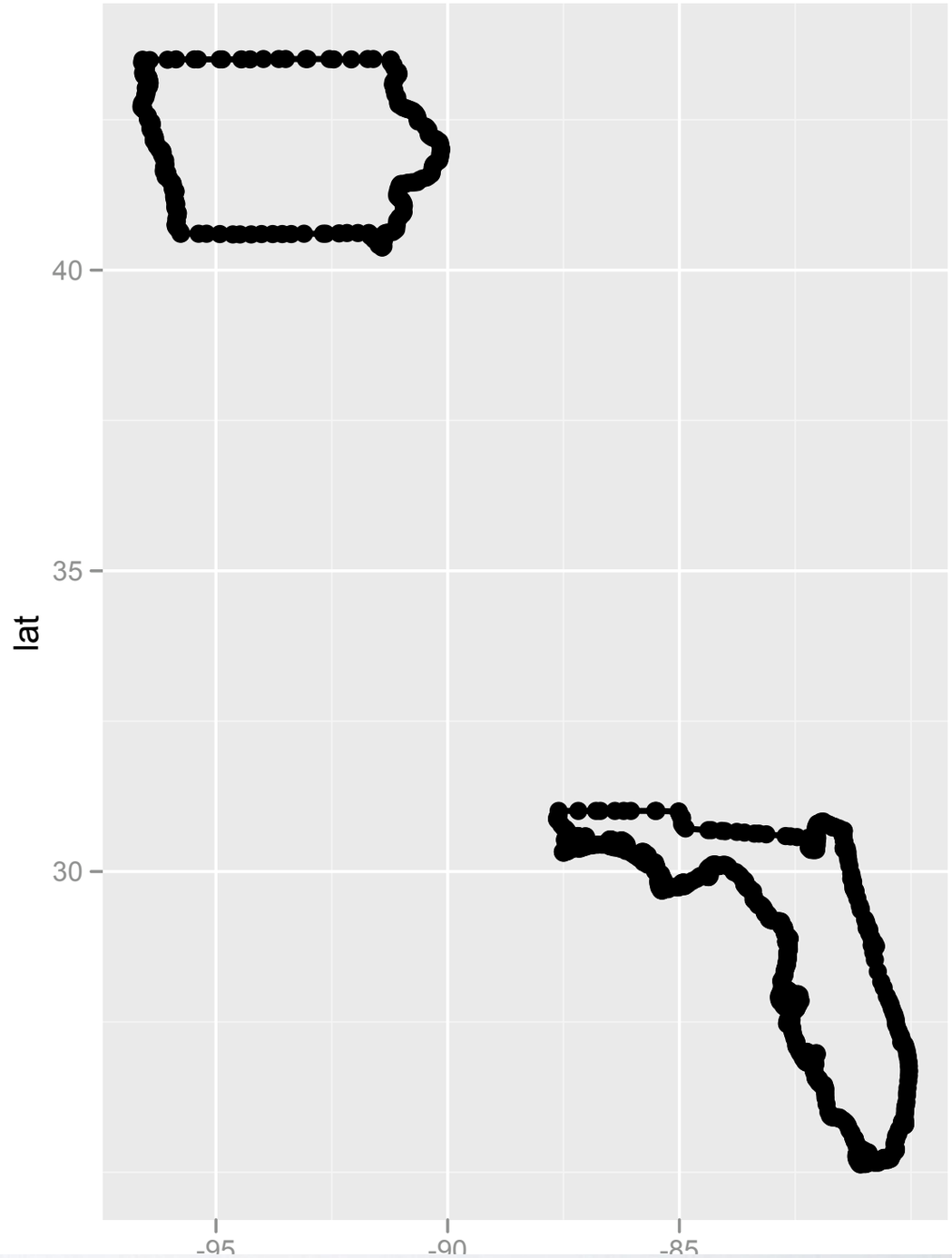
What is a map?

Polygon: connect only the correct dots



What is a map?

Polygon: connect only the correct dots



states data

- ```
  > library(maps)
  > states <- map_data(“state")
  > str(states)
  'data.frame': 15537 obs. of  6 variables:
   $ long      : num  -87.5 -87.5 -87.5 -87.5 -87.6 ...
   $ lat       : num  30.4 30.4 30.4 30.3 30.3 ...
   $ group     : num  1 1 1 1 1 1 1 1 1 1 ...
   $ order     : int  1 2 3 4 5 6 7 8 9 10 ...
   $ region    : chr  "alabama" "alabama" "alabama"
  "alabama" ...
   $ subregion: chr  NA NA NA NA ...
  ```
  ```

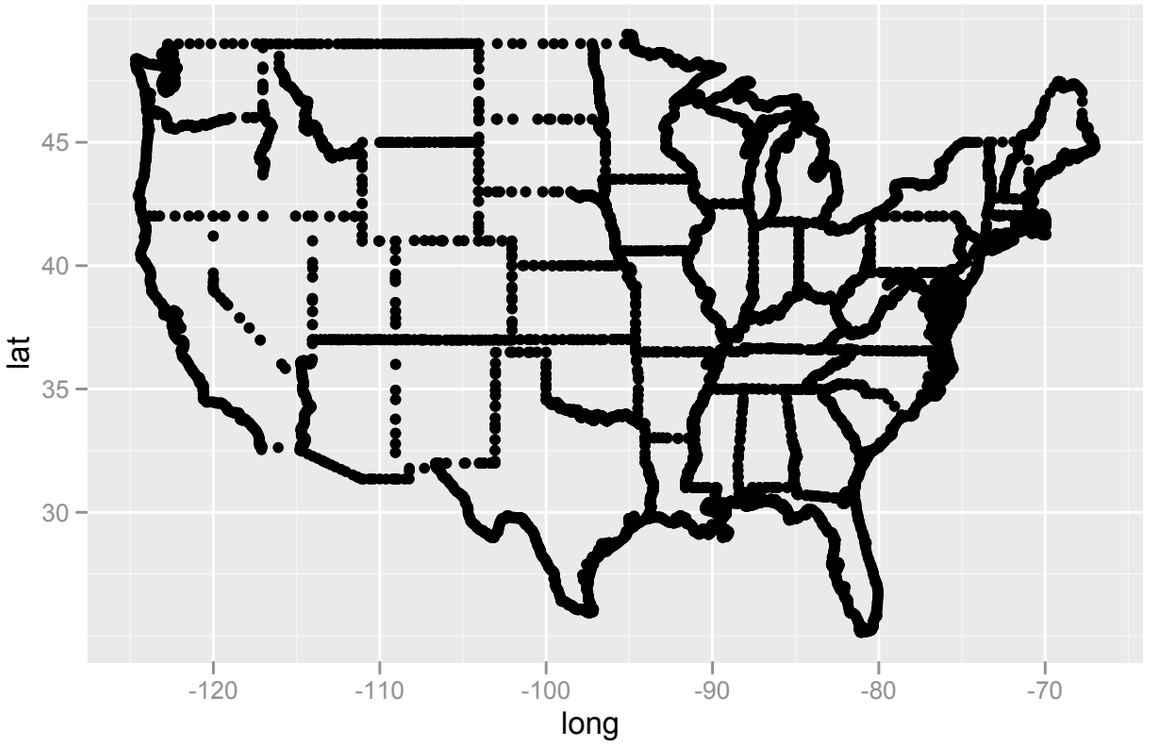
```
> head(states)
       long      lat group order  region subregion
1 -87.46201 30.38968     1     1 alabama      <NA>
2 -87.48493 30.37249     1     2 alabama      <NA>
3 -87.52503 30.37249     1     3 alabama      <NA>
4 -87.53076 30.33239     1     4 alabama      <NA>
5 -87.57087 30.32665     1     5 alabama      <NA>
6 -87.58806 30.32665     1     6 alabama      <NA>
```

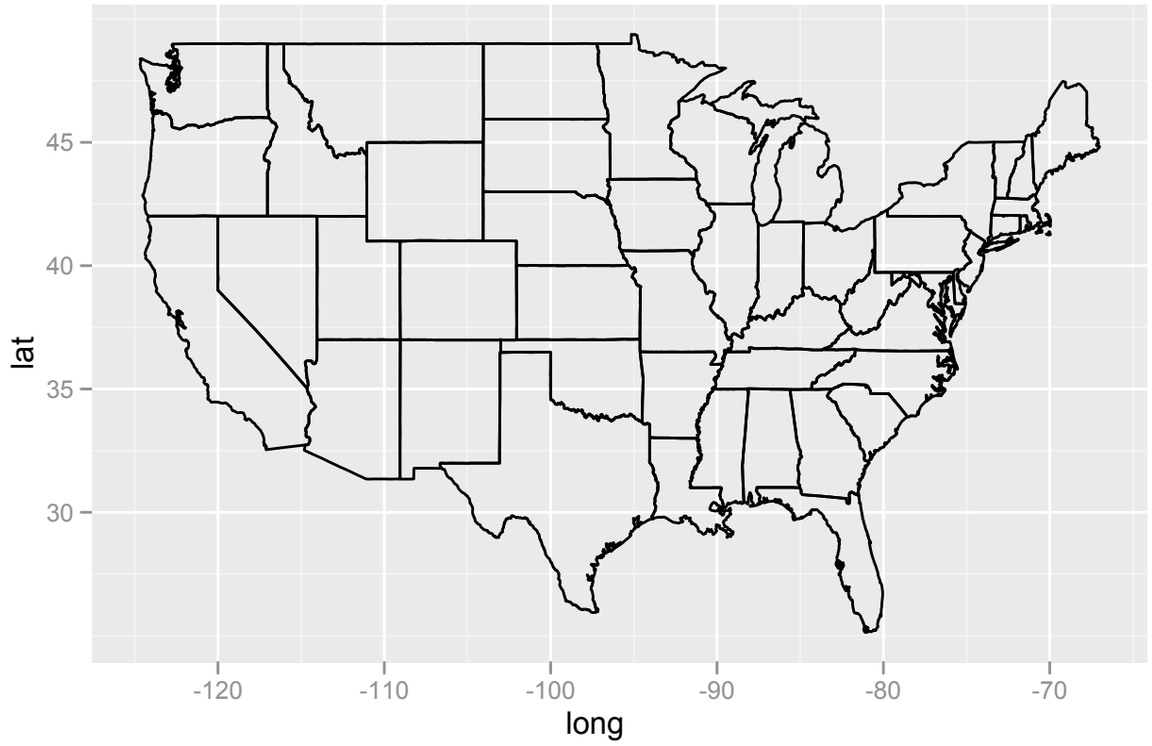
Maps in ggplot2

- Geoms: polygon or path for filled polygons or outlines only

```
> qplot(data = states, x = long, y=lat,
order = order, group = group,
geom = “path”/“polygon”)
```

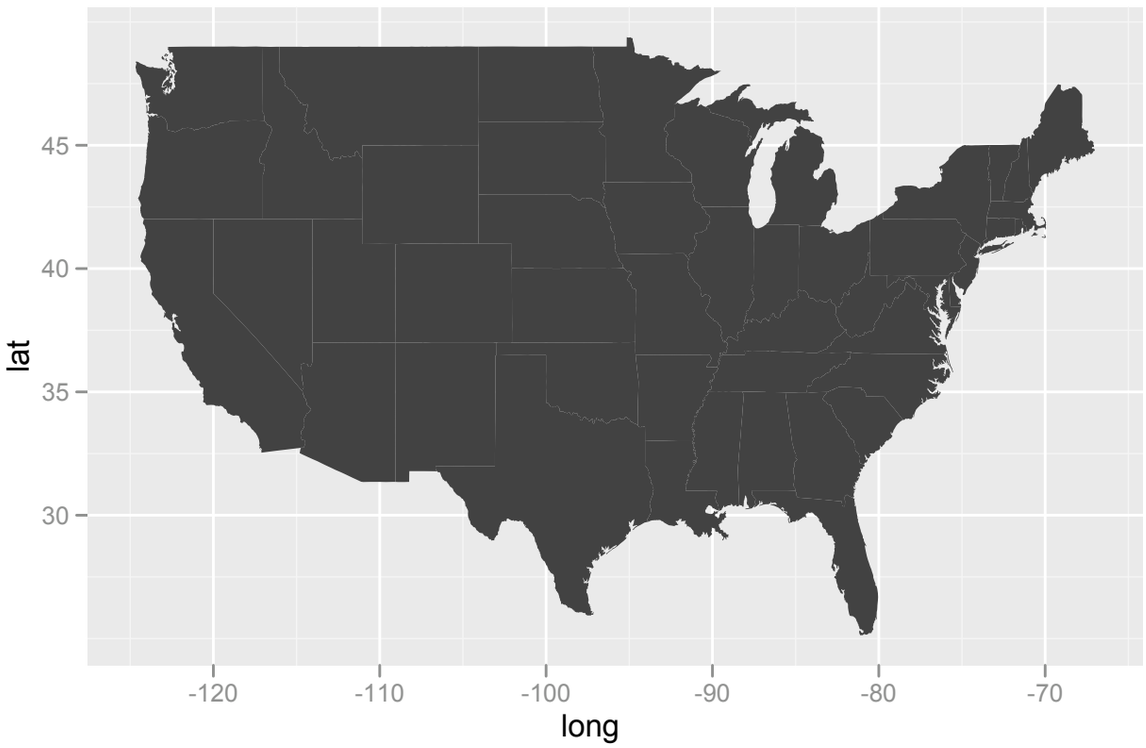
```
qplot(long, lat, geom="point", data=states)
```

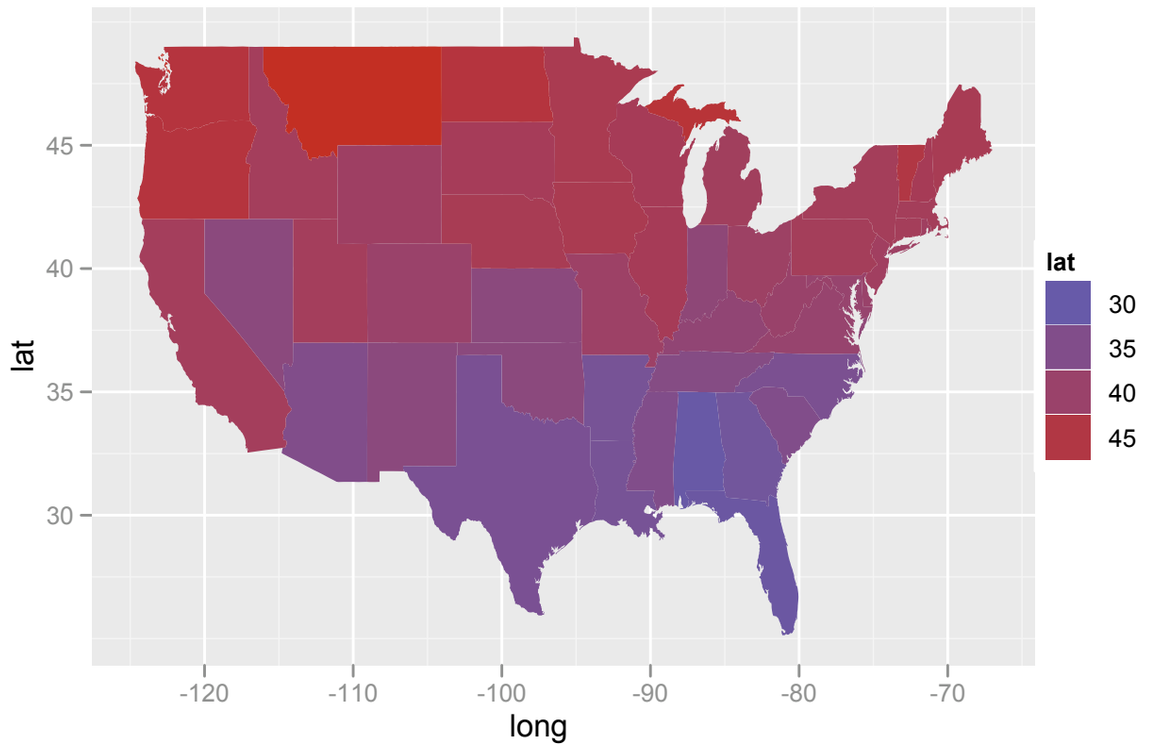





```
qplot(long, lat, geom="path", data=states, group=group, order = order)
```

```
qplot(long, lat, geom="polygon", data=states, group=group, order = order)
```





Making Maps look like Maps

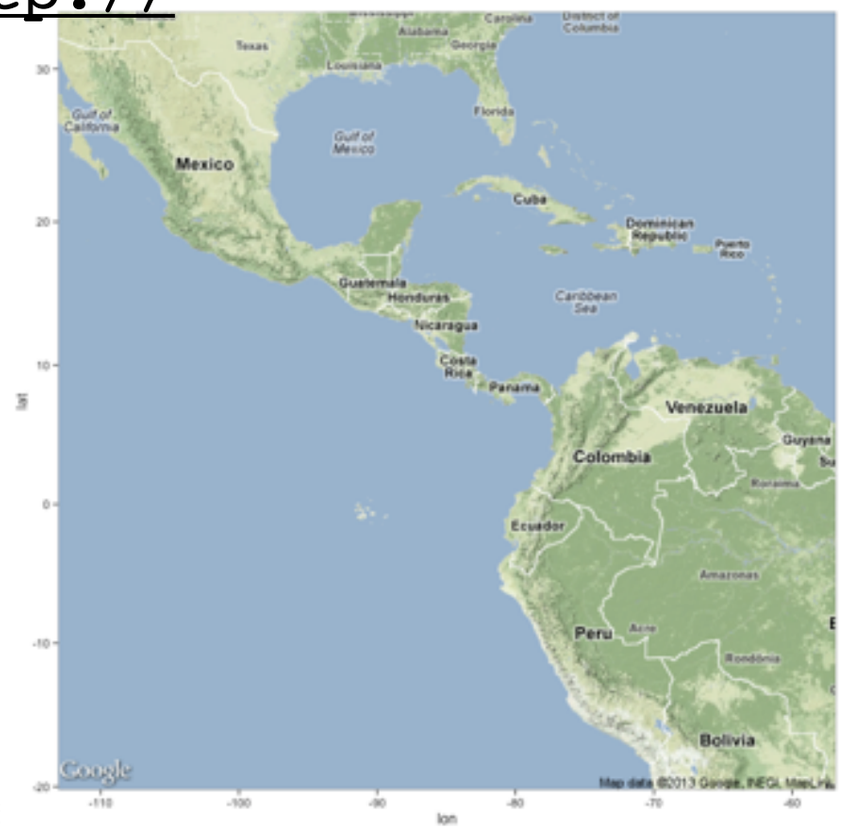
```
> theme(axis.title.x=element_blank(), # remove x and y label
 axis.title.y=element_blank(),
 axis.line=element_blank(), # no axis at the bottom and the left
 axis.ticks=element_blank(), # don't show ticks
 axis.text.y = element_blank(), # no tick marks
 axis.text.x = element_blank(),

 panel.grid.minor=element_blank(), # don't show any gridlines
 panel.grid.major=element_blank(),
 panel.background=element_blank(), # invisible background
 panel.border = element_blank(), # no border around plot space
 panel.margin = unit(0, "lines")
)
```

RGoogleMaps

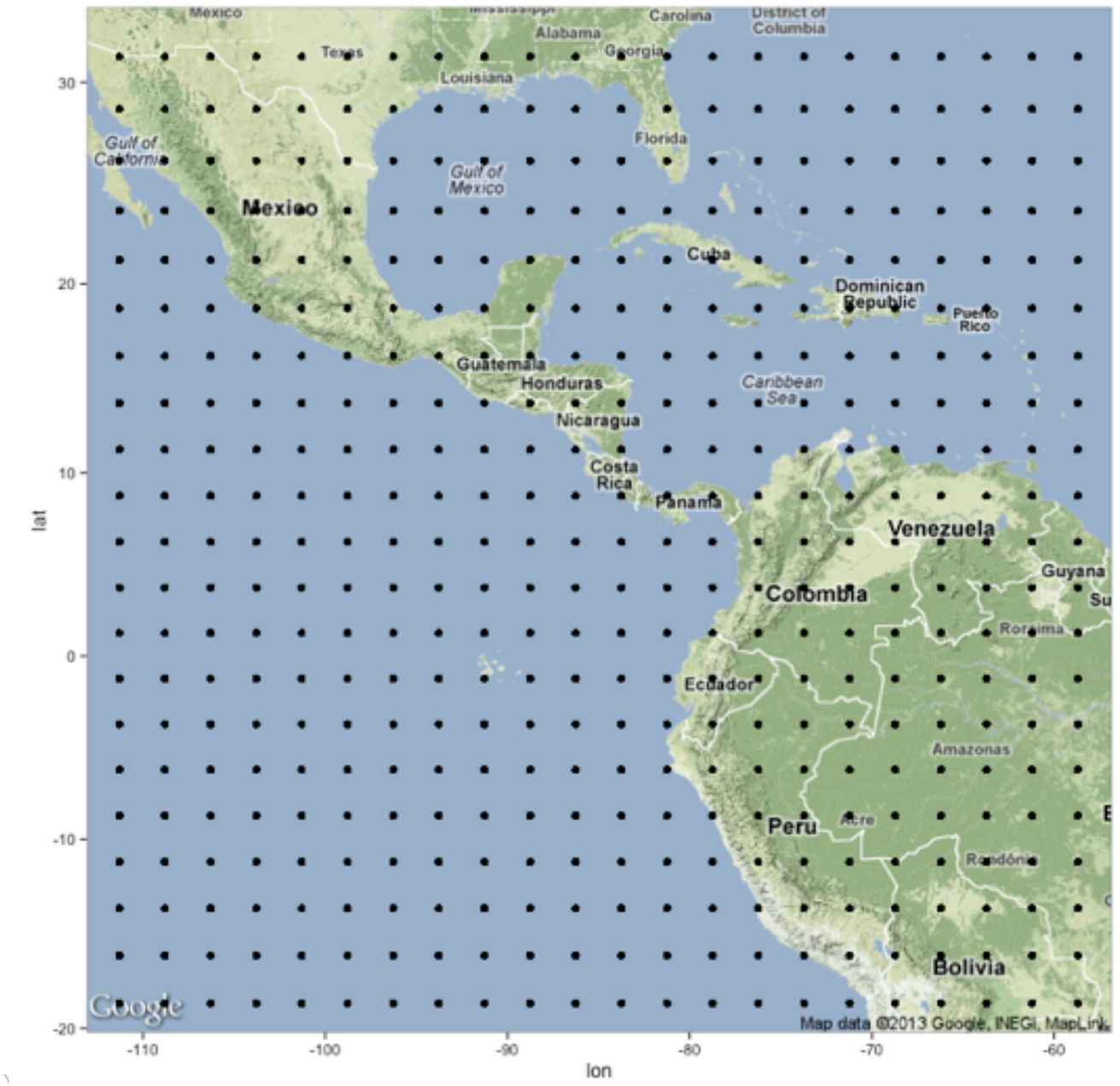
Load a satellite image:

```
> library("ggmap")
> nasa_center <- c(lon=-85.0, lat=7.50)
> nasamap <-get_googlemap(center = nasa_center, zoom=4)
Map from URL : http://maps.googleapis.com/maps/api/
 staticmap?center=7.5,-85&zoom=4&size=
 %20640x640&maptype=terrain&sensor=false
Google Maps API Terms of Service : http://
 developers.google.com/maps/terms
> ggmap(nasamap)
```



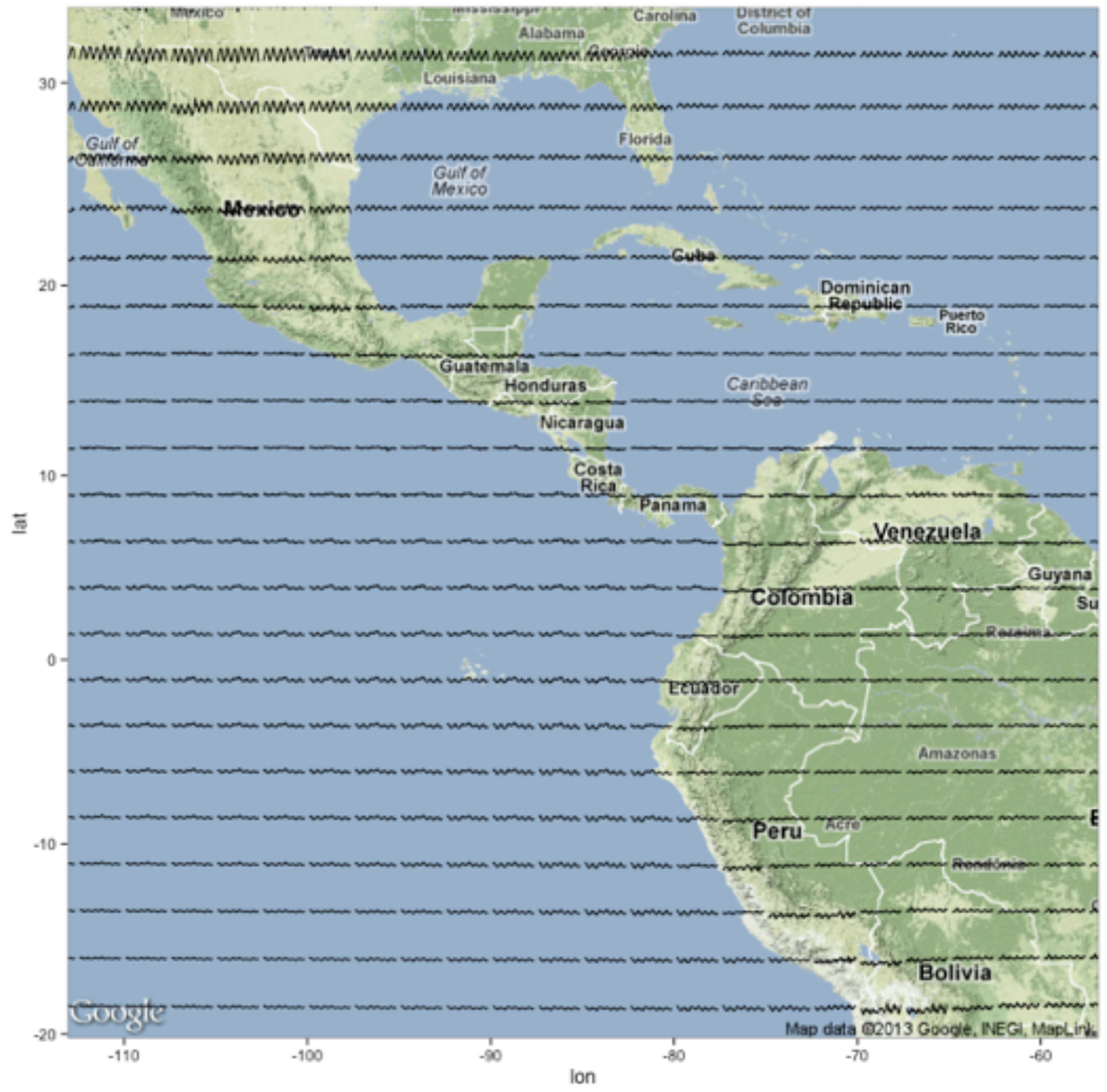
Adding to satellite images

```
> ggmap(nasamap) + geom_point(data=nasa,
    aes(x = long, y = lat))
```



Adding to satellite images

```
> ggmap(nasamap) + geom_line(data=nasa.gly, aes(x=gx,
      y=gy, group = gid))
```



Questions?

Demo?

Links

- http://docs.ggplot2.org/
- http://streaming.stat.iastate.edu/~dicook/NCAR/
- http://vita.had.co.nz/papers/glyph-maps.pdf
- http://vita.had.co.nz/papers/layered-grammar.pdf
- Displaying time series, spatial and space-time data with R (not ggplot2) http://oscarperpinan.github.io/spacetime-vis/