2. Learning to Draw

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Graphics

R can produce graphics in many formats, including:

- on screen
- PDF files for LaTeX or emailing to people
- PNG or JPEG bitmap formats for web pages (or on non-Windows platforms to produce graphics for MS Office). PNG is also useful for graphs of large data sets.
- On Windows, metafiles for Word, Powerpoint, and similar programs

Setup

Graphs should usually be designed on the screen and then may be replotted on eg a PDF file (for Word/Powerpoint you can just copy and paste)

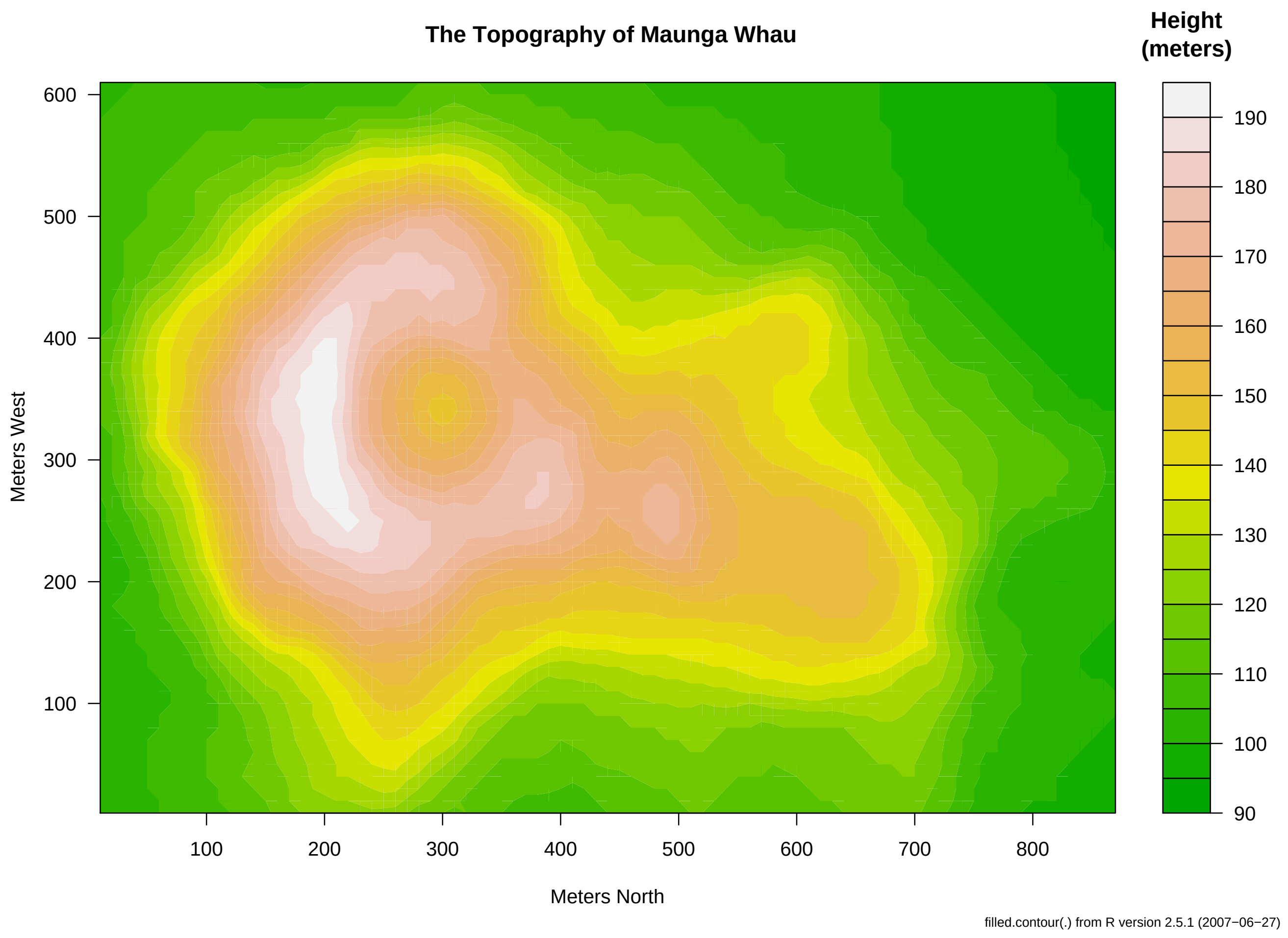
For printed graphs, you will get better results if you design the graph at the size it will end up, eg:

```
## on Windows
windows(height=4,width=6)
## on Unix
x11(height=4,width=6)
```

Word or LaTeX can rescale the graph, but when the graph gets smaller, so do the axis labels...

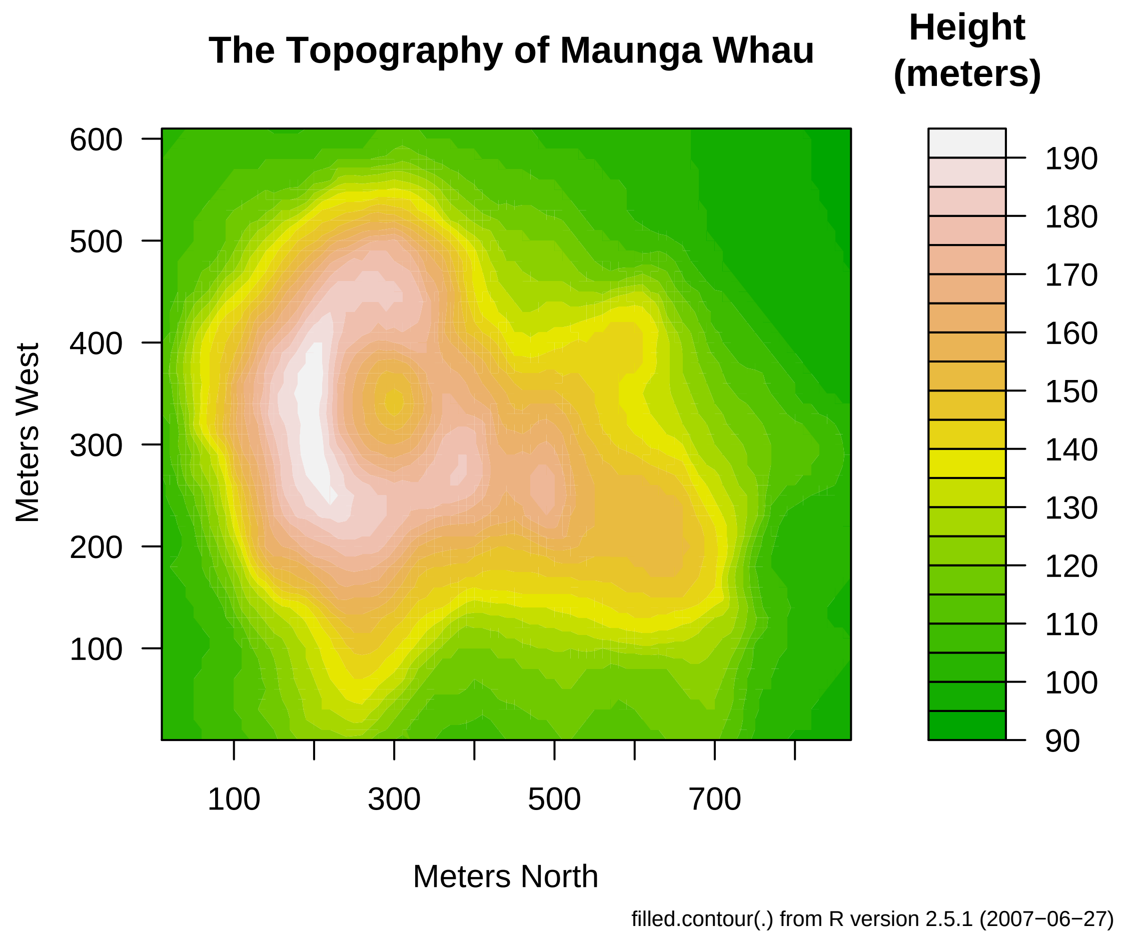
Setup

Created at full-page size (11×8.5 inches)



Setup

Created at 6×5 inches



Finishing

After you have the right commands to draw the graph you can produce it in another format: eg

```
## start a PDF file
pdf("picture.pdf",height=4,width=6)
## your drawing commands here
...
### close the PDF file
dev.off()
```

You may find dir(), getwd() and setwd() helpful

Drawing

Usually, use plot() to create a graph and then lines(), points(), legend(), text(), and other commands to annotate it. There is no ‘erase’ function, so keep your commands in a script.

plot() is a generic function: it does appropriate things for different types of input

```
## scatterplot
plot(salary$year, salary$salary)
## boxplot
plot(salary$rank, salary$salary)
## stacked barplot
plot(salary$field, salary$rank)
```

and others for other types of input.

Formula interface

The plot() command can also be used this way;

```
plot(salary~rank, data=salary)
```

where we introduce the formula system, that is also used for regression models. Here, think of `Y~X`.

The variables in the formula are automatically looked up in the data= argument.

Designing graphs

Two important aspects of designing a graph

- It should have something to say

- It should be legible

Having something to say is *your* problem; software can help with legibility.

Designing graphs

Important points

- Axes need labels (with units, large enough to read)
- Color can be very helpful (but not if the graph is going to be printed in black and white).
- Different line or point styles usually should be labelled.
- Points plotted on top of each other won't be seen

After these are satisfied, it can't hurt to have the graph look nice.

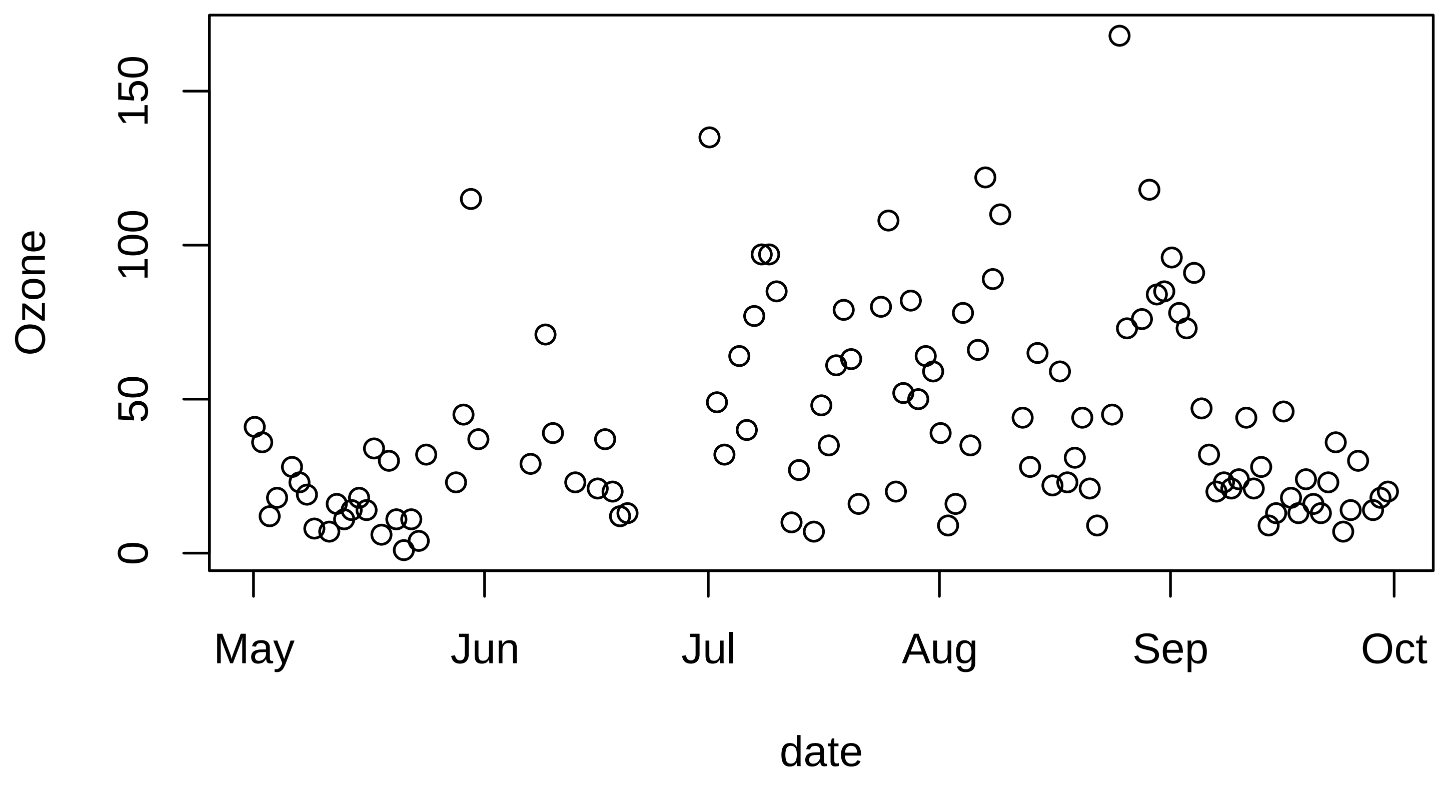
Options

First we set up the data – in this case, a built-in dataset, containing daily ozone concentrations in New York, summer 1973

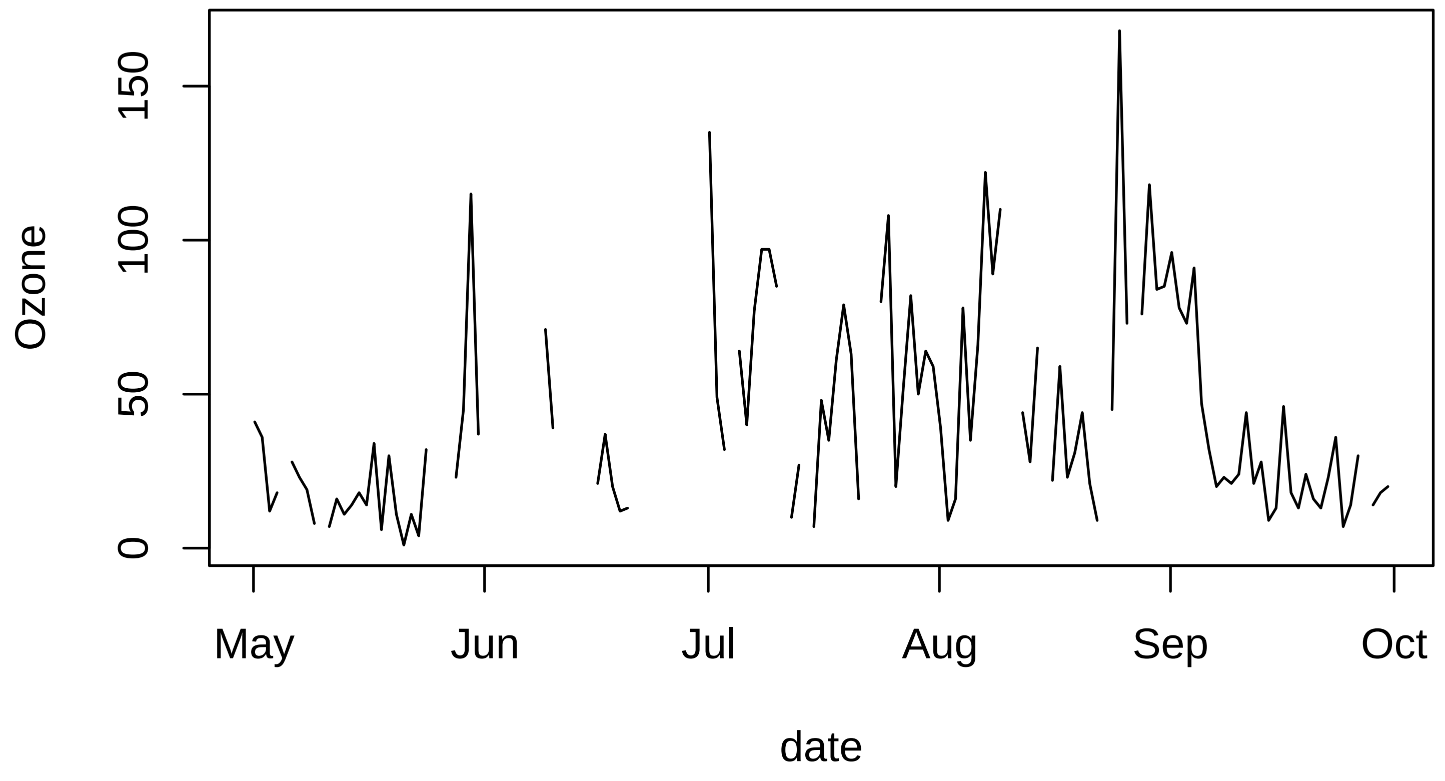
```
data(airquality)
names(airquality)
airquality$date<-with(airquality, ISOdate(1973,Month,Day))
```

All these graphs were designed at 4in$\times$6in and stored as PDF files

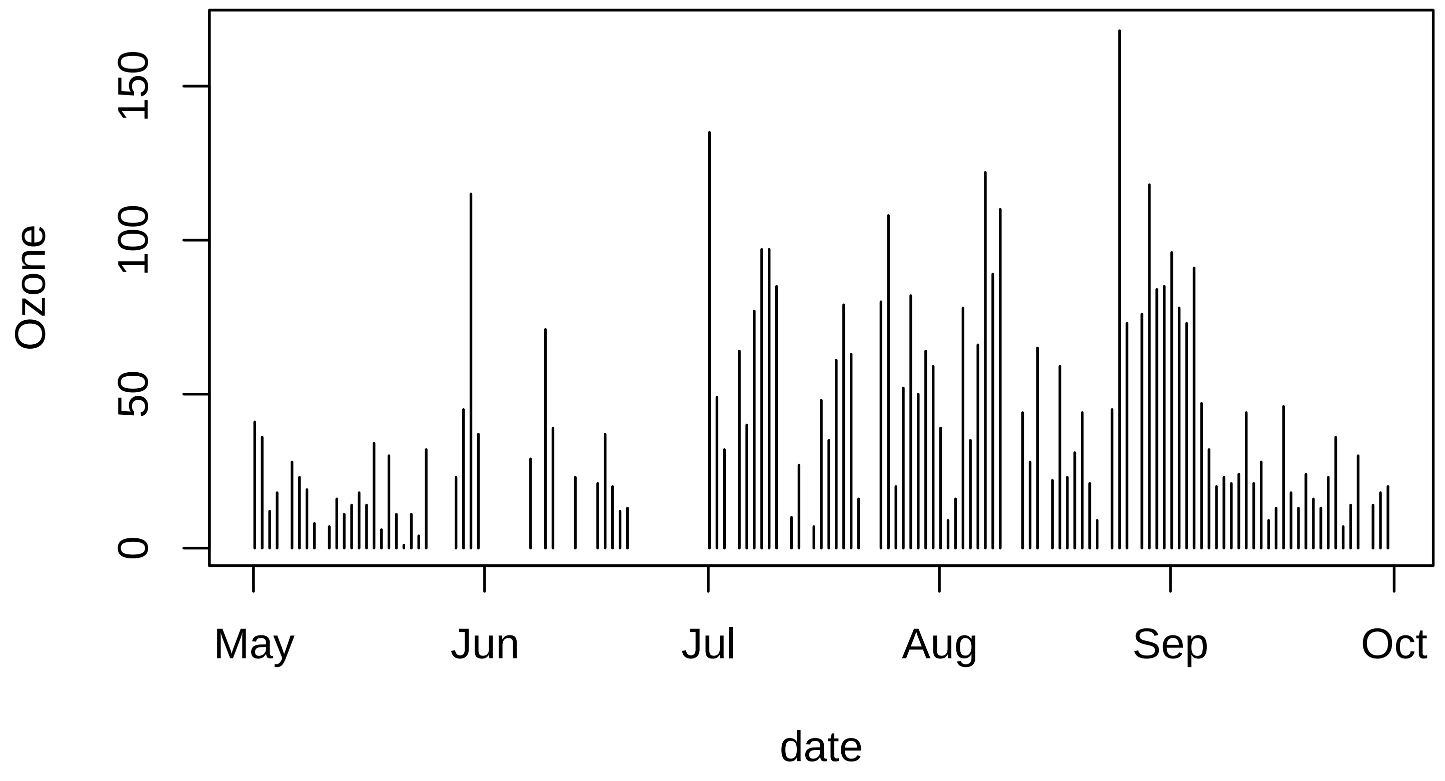
```
plot(Ozone~date, data=airquality)
```



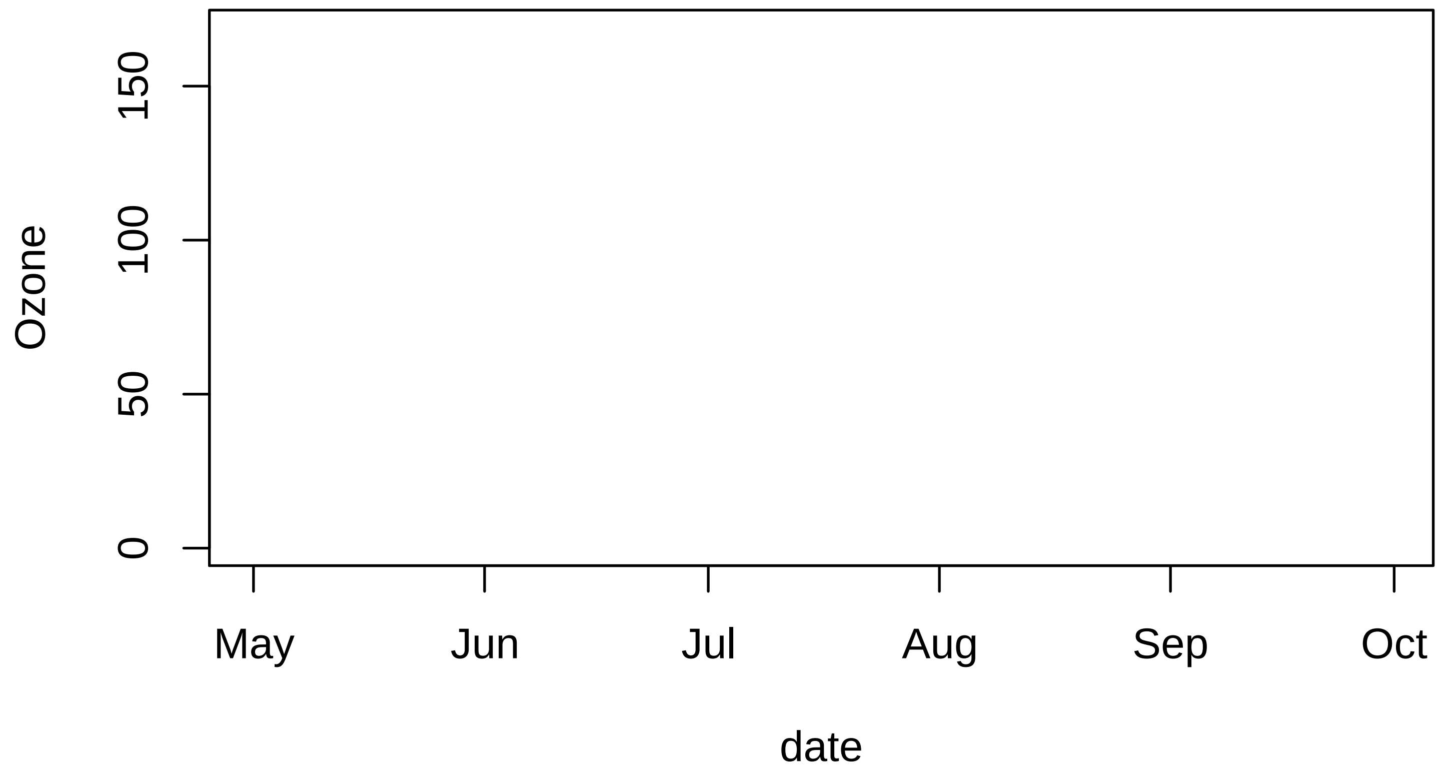
```
plot(Ozone~date, data=airquality,type="l")
```



```
plot(Ozone~date, data=airquality,type="h")
```

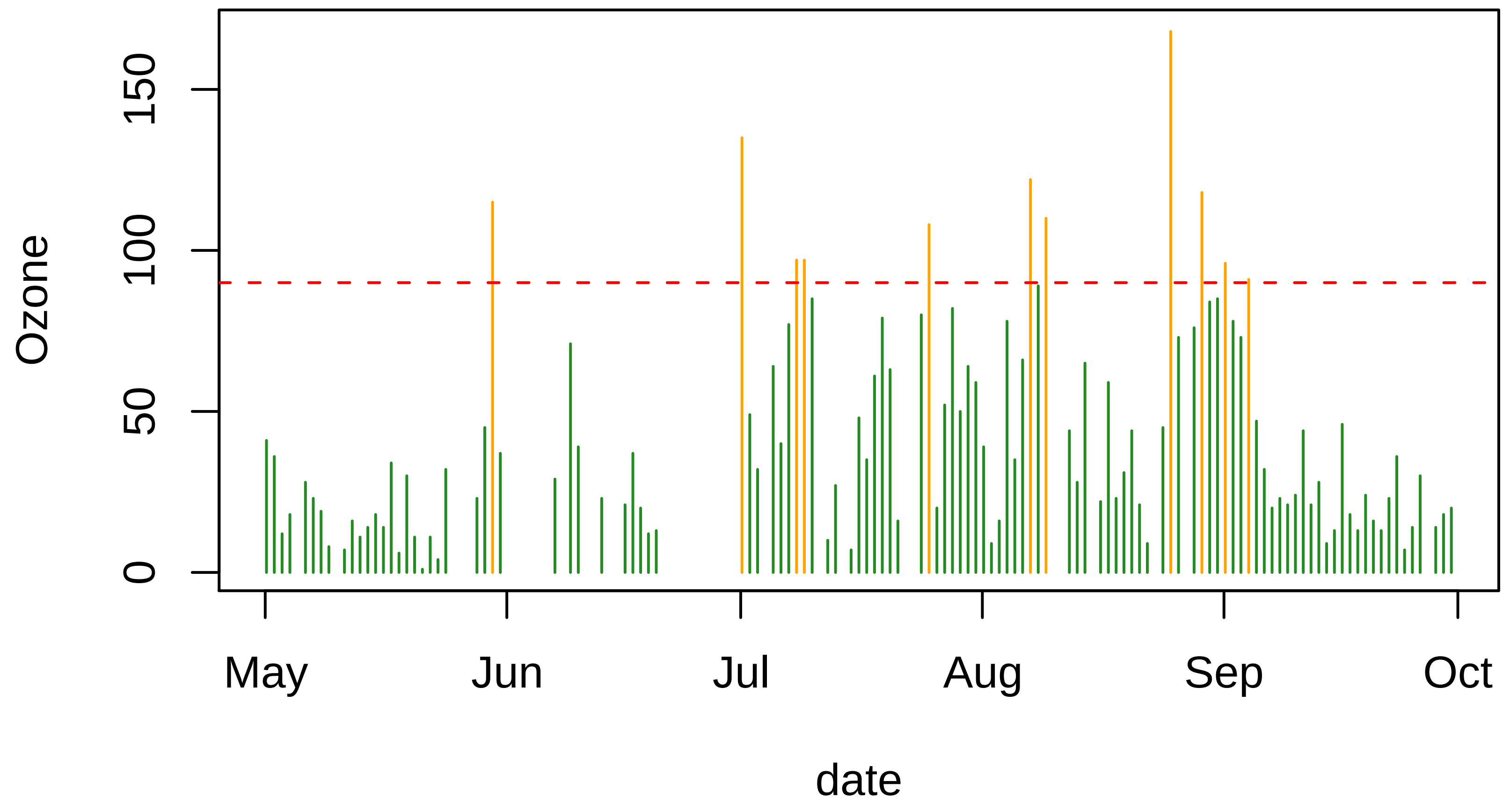


```
plot(Ozone~date, data=airquality,type="n")
```



Commands to do a more complex plot;

```
bad <- ifelse(airquality$Ozone>=90, "orange", "forestgreen")
plot(Ozone~date, data=airquality, type="h", col=bad)
abline(h=90, lty=2, col="red")
```


Ozone
0
50
100
150
May
Jun
Jul
Aug
Sep
Oct
date

Notes

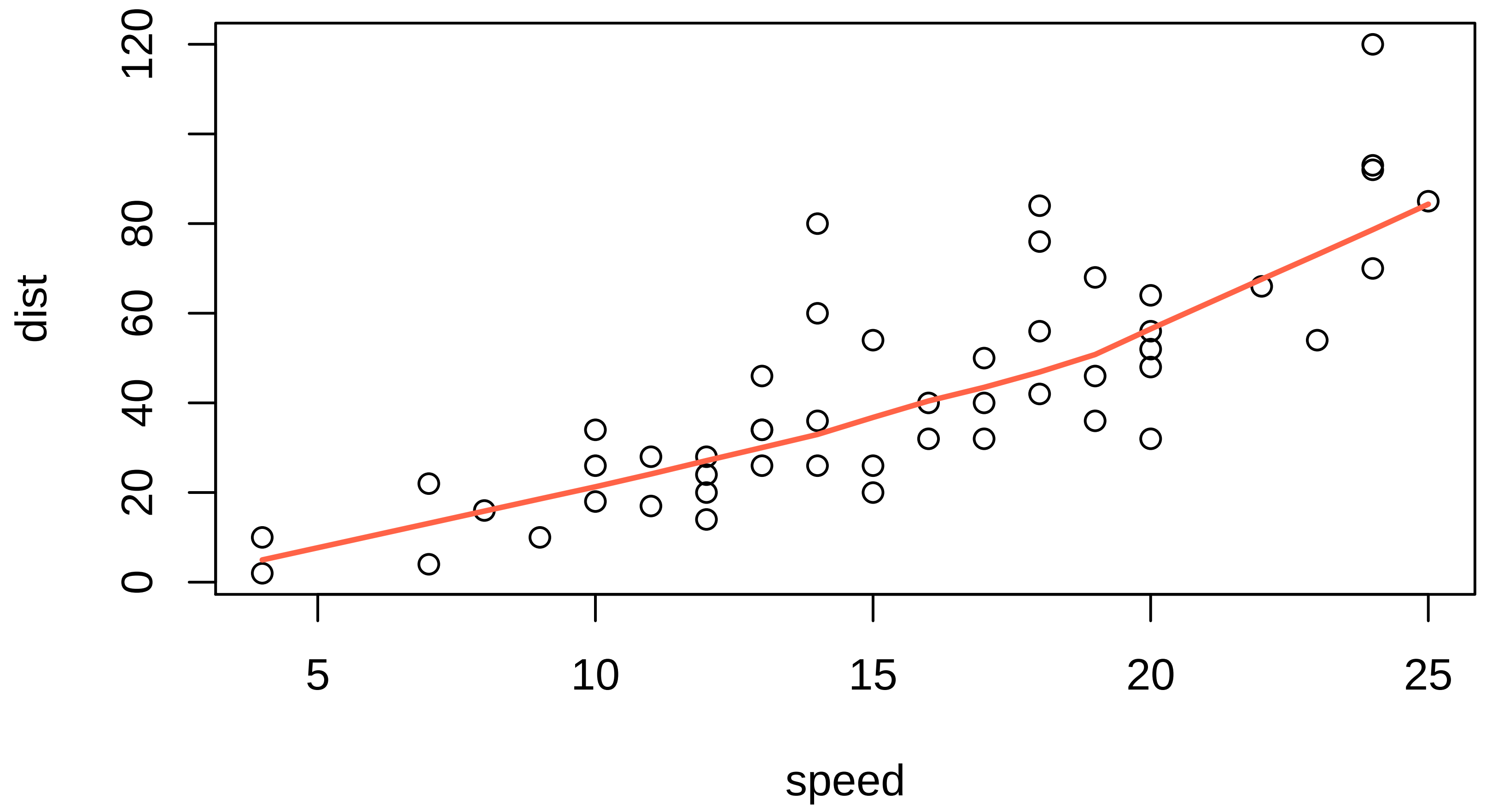
- `type=` controls how data are plotted. `type="n"` is not as useless as it looks: it can set up a plot for latter additions.
- Colors can be specified by name (the `colors()` function gives all the names), by red/green/blue values (”#rrggbb” with six base-sixteen digits) or by position (1:8) in the standard palette of 8 colors.
- `abline` draws a single straight line on a plot
- `ifelse()` selects between two vectors based on a logical variable.
- `lty` specifies the line type: 1 is solid, 2 is dashed, 3 is dotted, then it gets more complicated. See `?par`, then search for `lty`

Adding to a plot

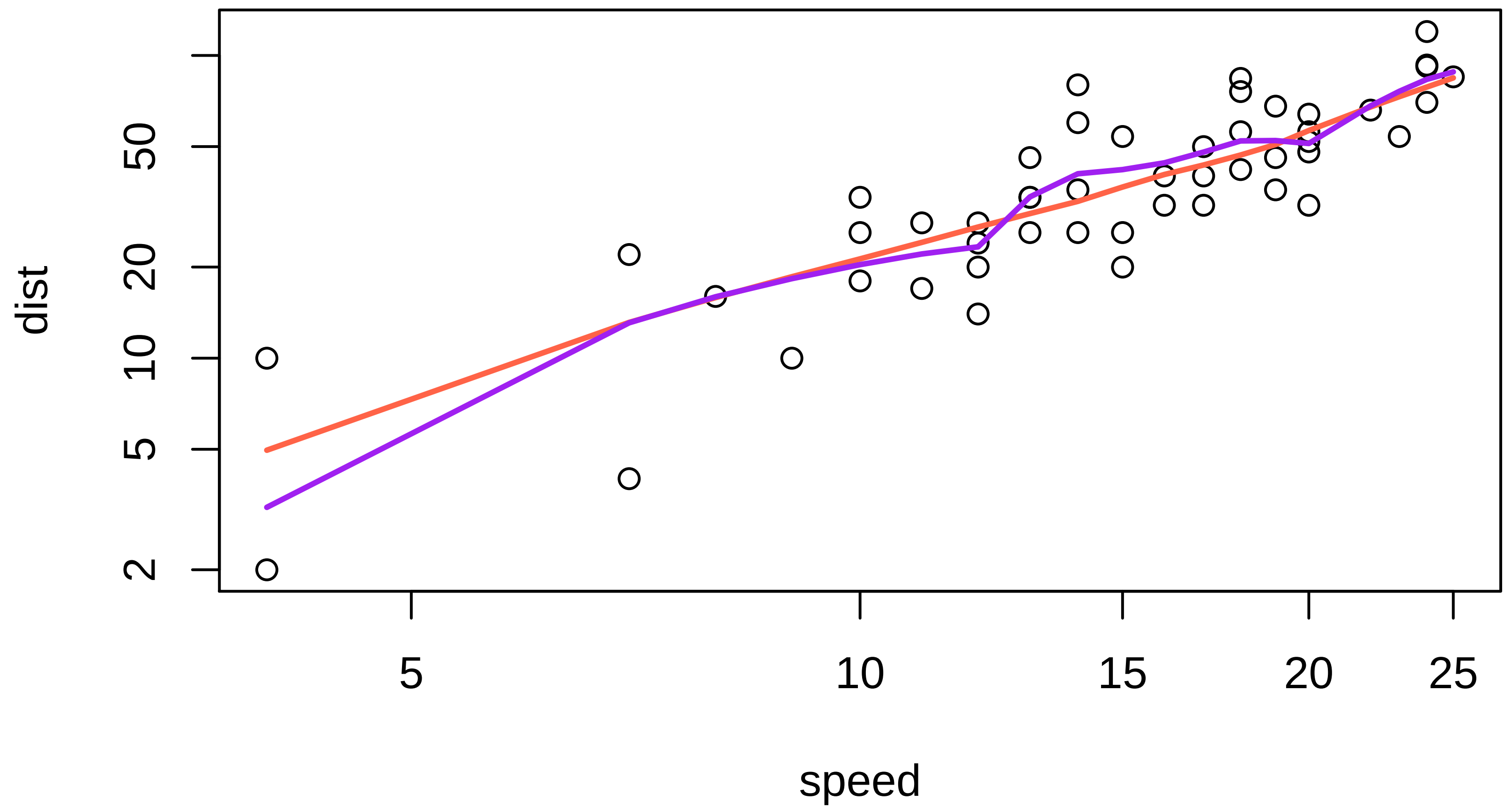
More example commands

```
data(cars)
plot(dist~speed,data=cars)
with(cars, lines(lowess(speed, dist), col="tomato", lwd=2))

plot(dist~speed,data=cars, log="xy")
with(cars, lines(lowess(speed, dist), col="tomato", lwd=2))
with(cars, lines(supsmu(speed, dist), col="purple", lwd=2))

legend("bottomright", legend=c("lowess","supersmoother"),bty="n",
  lwd=2, col=c("tomato","purple"))
```

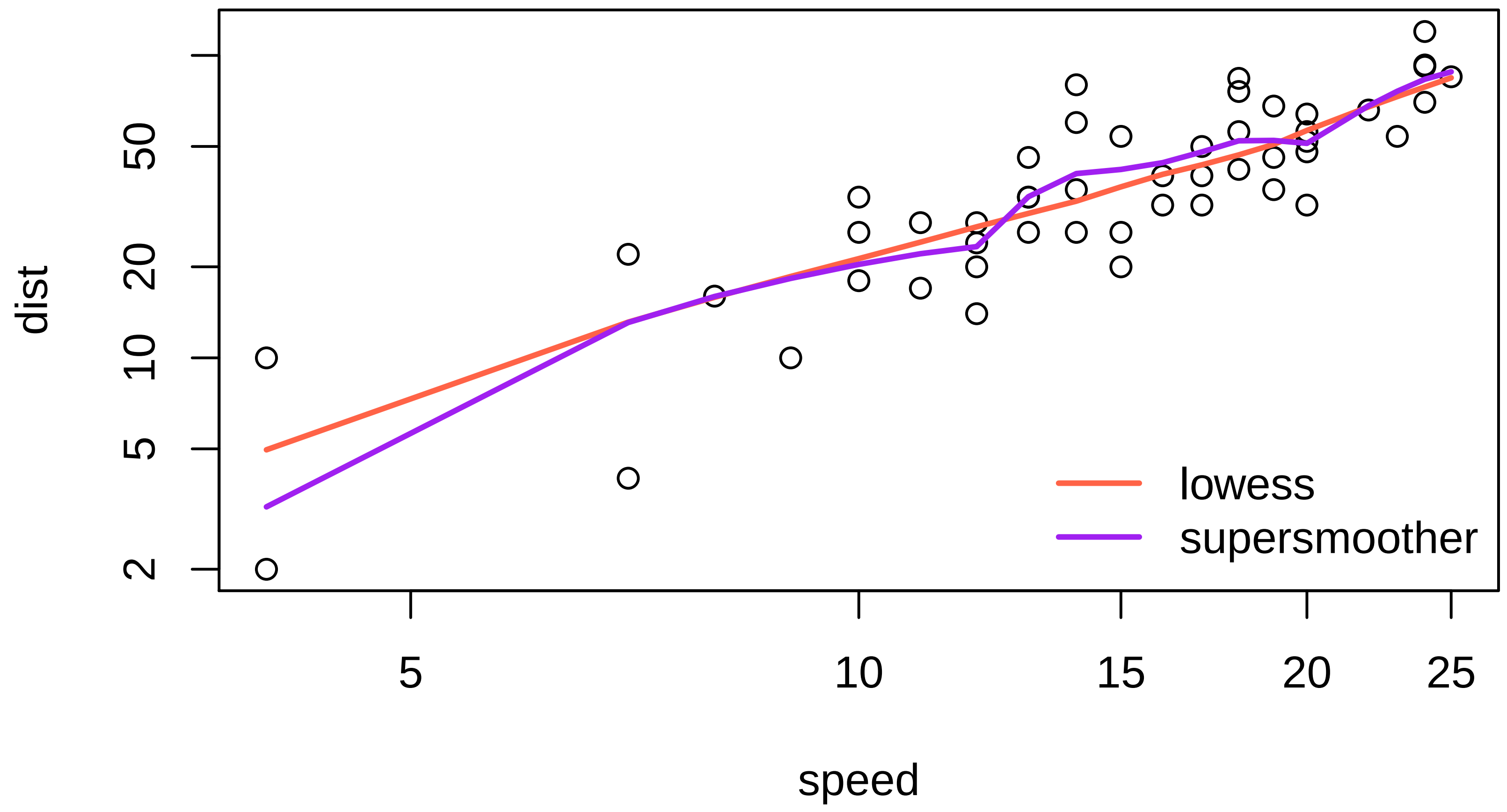
Adding to a plot



Adding to a plot



Adding to a plot



Notes

- `lines()` adds lines to an existing plot (and `points()` adds points)

- `lowess()` and `supsmu()` are scatterplot smoothers. They calculate smooth curves that fit the relationship between y and x locally. Their output has attributes `$x` and `$y`, that generic function `lines()` can cope with

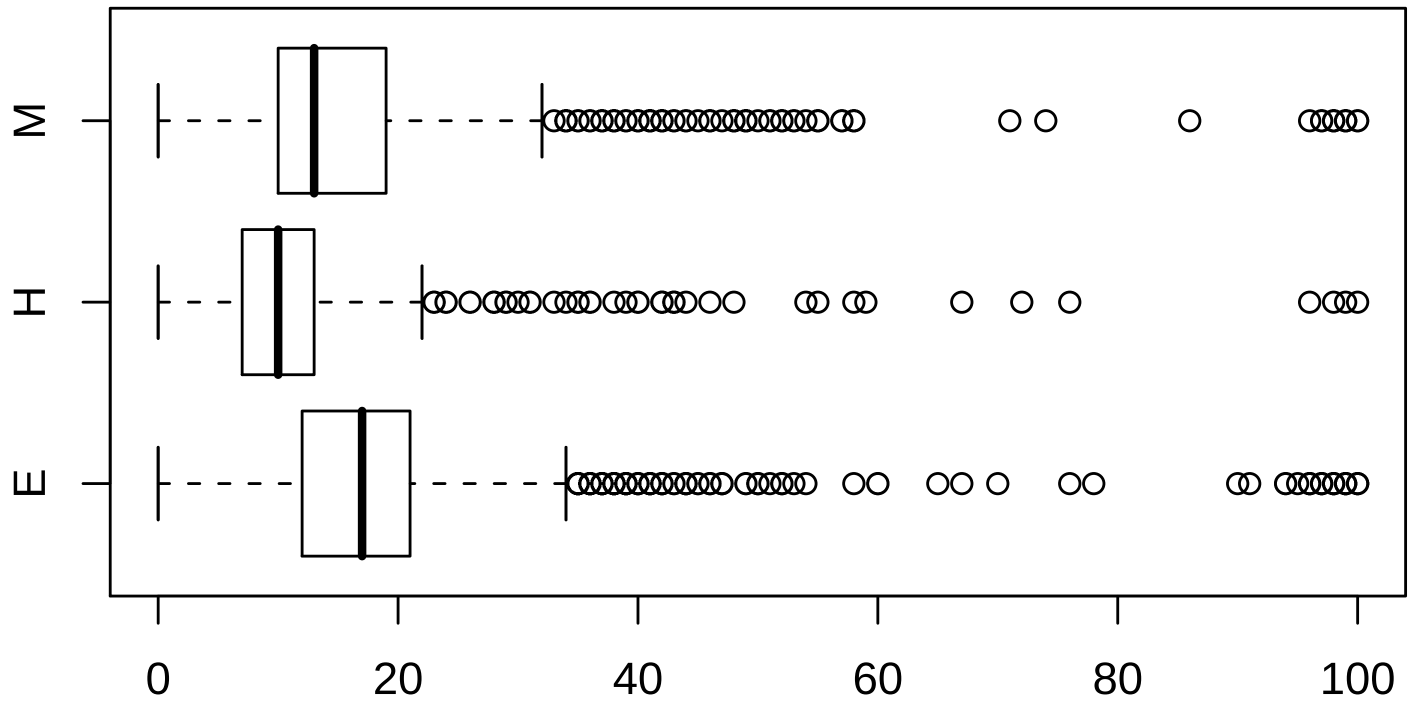
- `log="xy"` asks for both axes to be logarithm (`log="x"` would just be the x-axis)

- `legend()` adds a legend

Boxplots

```
data(api, package="survey")
boxplot(mobility~stype,data=apipop, horizontal=TRUE)
```

Boxplots



Notes

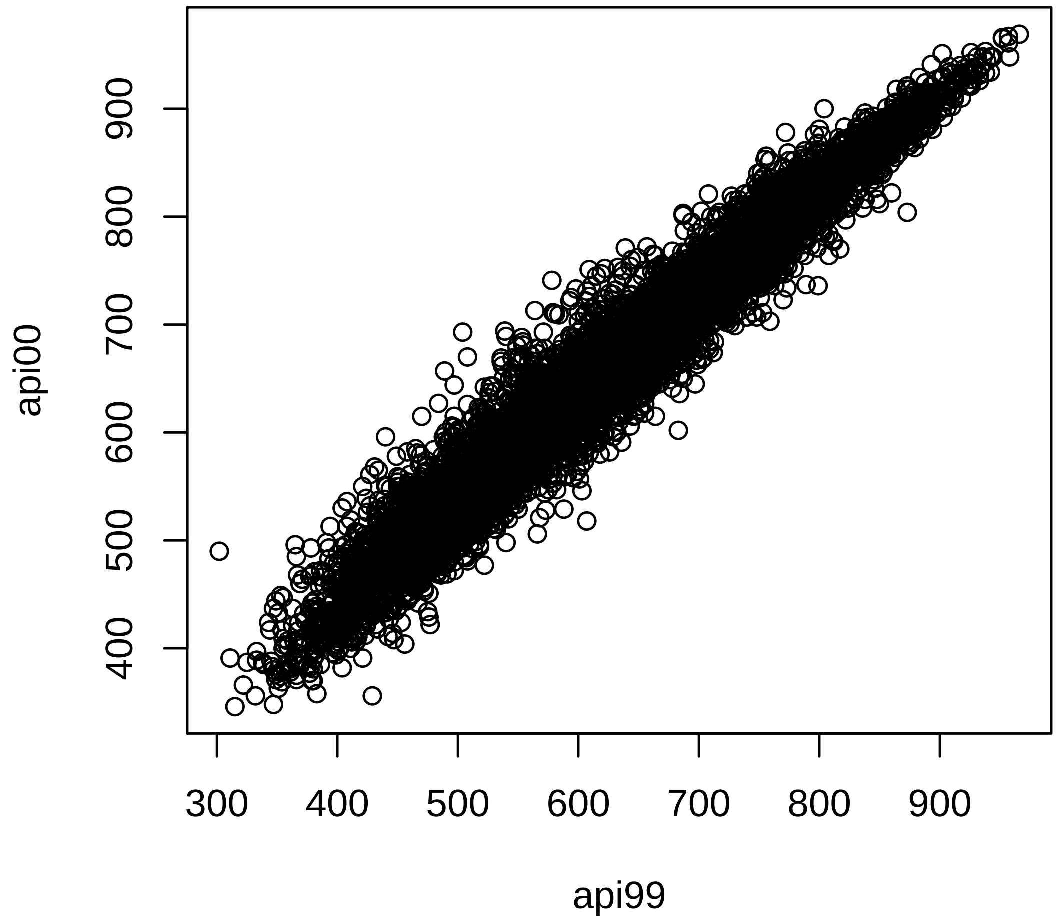
- `data()` makes data from a package available in your current R session – we'll see more packages later
- `boxplot` computes and draws boxplots.
- `horizontal=TRUE` turns a boxplot sideways
- `xlab` and `ylab` are general options for x and y axis labels.

Large data sets

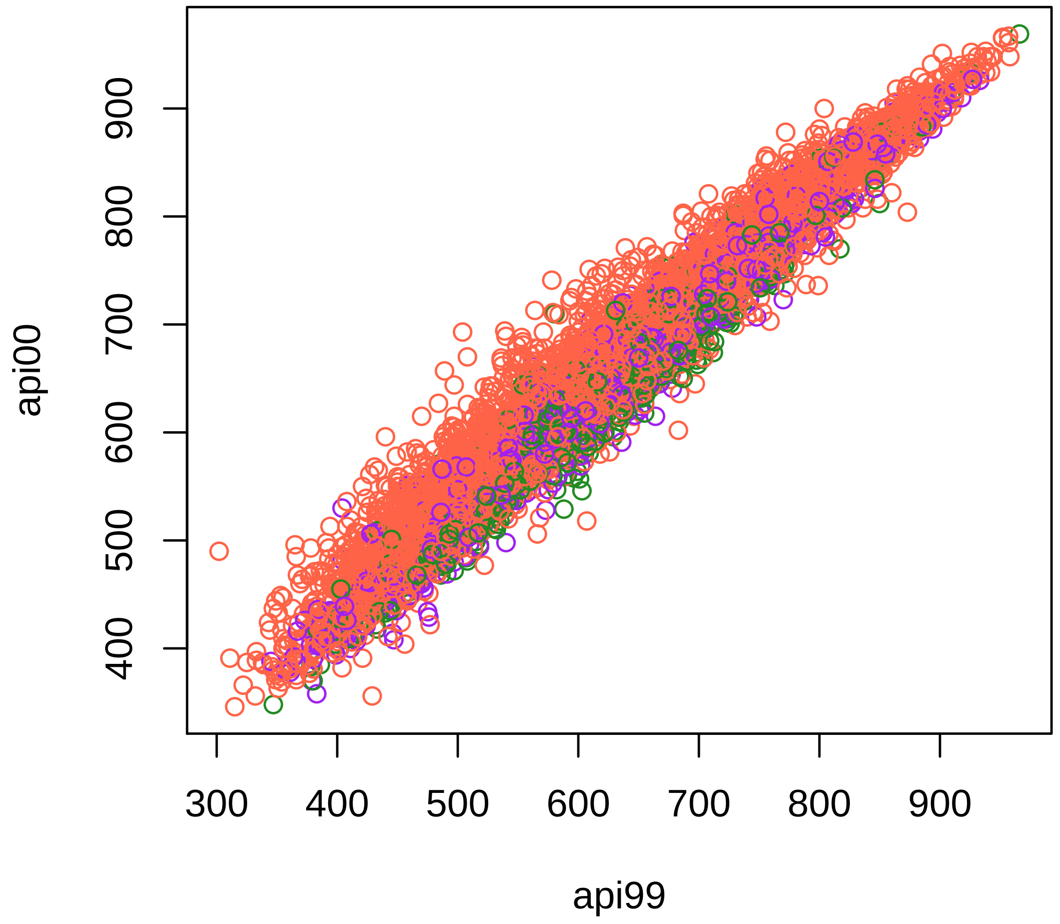
Scatterplots quickly get crowded. For example, the California Academic Performance Index is reported on 6194 schools

```
> plot(api00~api99,data=apipop)
> colors<-c("tomato","forestgreen","purple")[apipop$stype]
> plot(api00~api99,data=apipop,col=colors)
```

Large data sets



Large data sets



Density plots

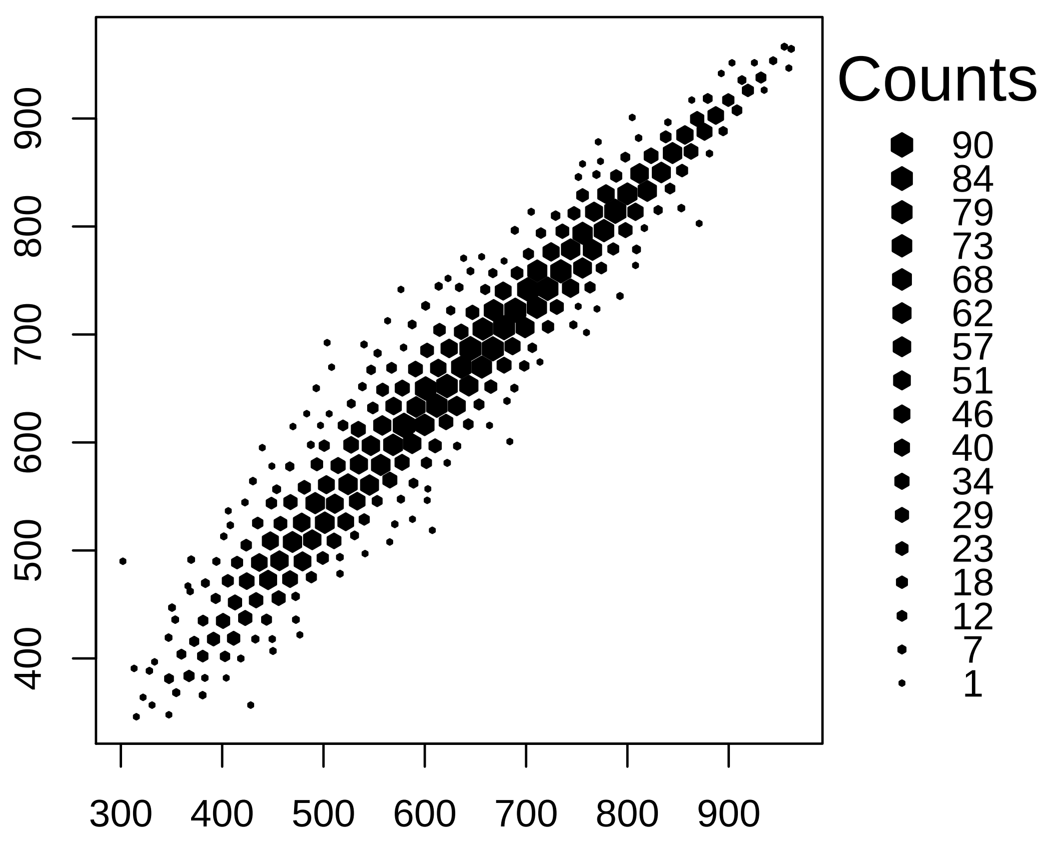
For a single large scatterplot some form of aggregation is useful

```
library("hexbin")
with(apipop, plot(hexbin(api99,api00), style="centroids"))
```

`hexbin()` is a function in the hexbin package. It computes the number of points in each hexagonal bin.

The `style="centroids"` option plots filled hexagons, at the centroid of each bin. The sizes of the plotted hexagons are proportional to the number of points in each bin.

Density plots

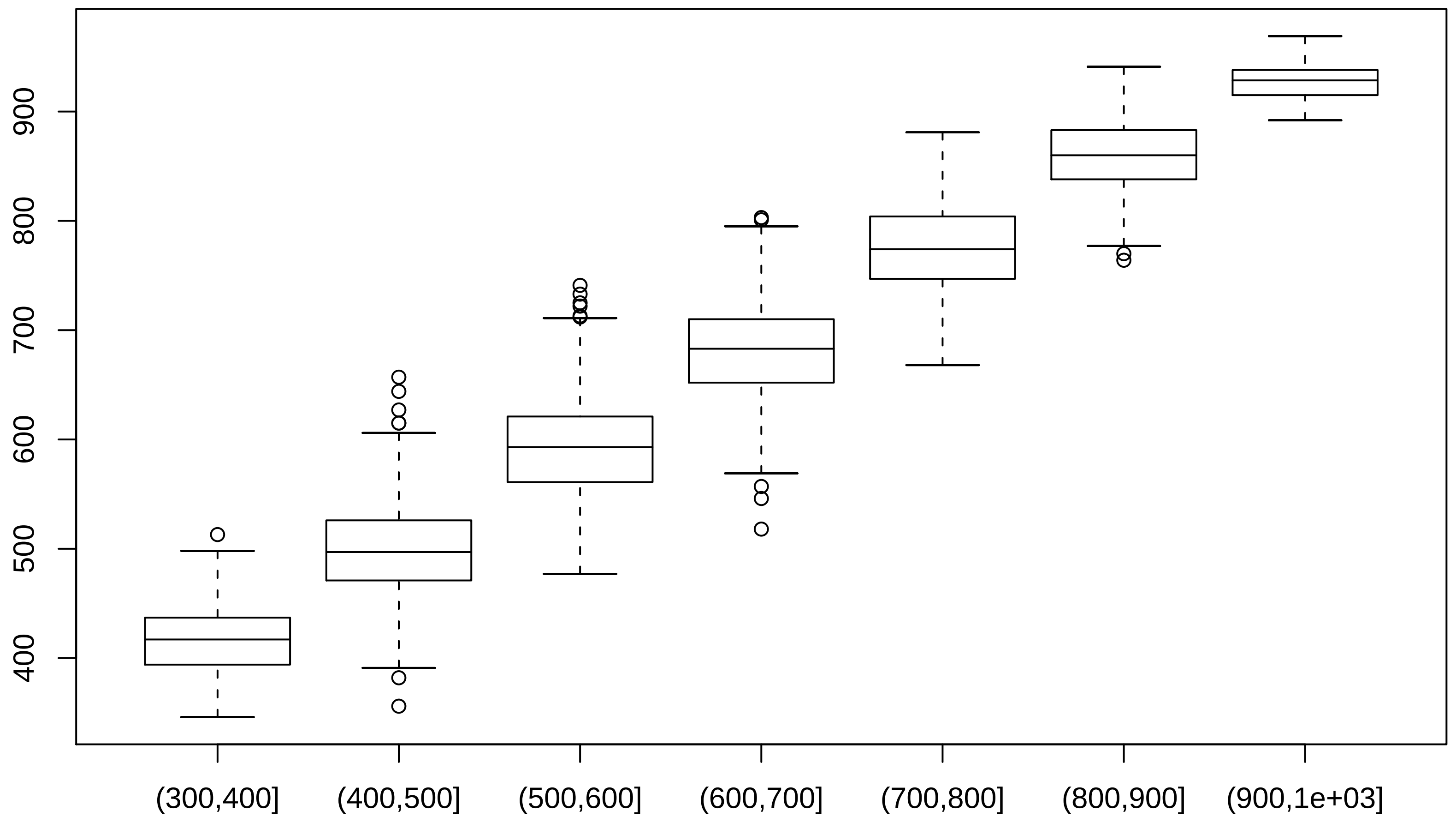


Smoothers

For showing multiple groups, a scatterplot smoother or perhaps boxplots may be better.

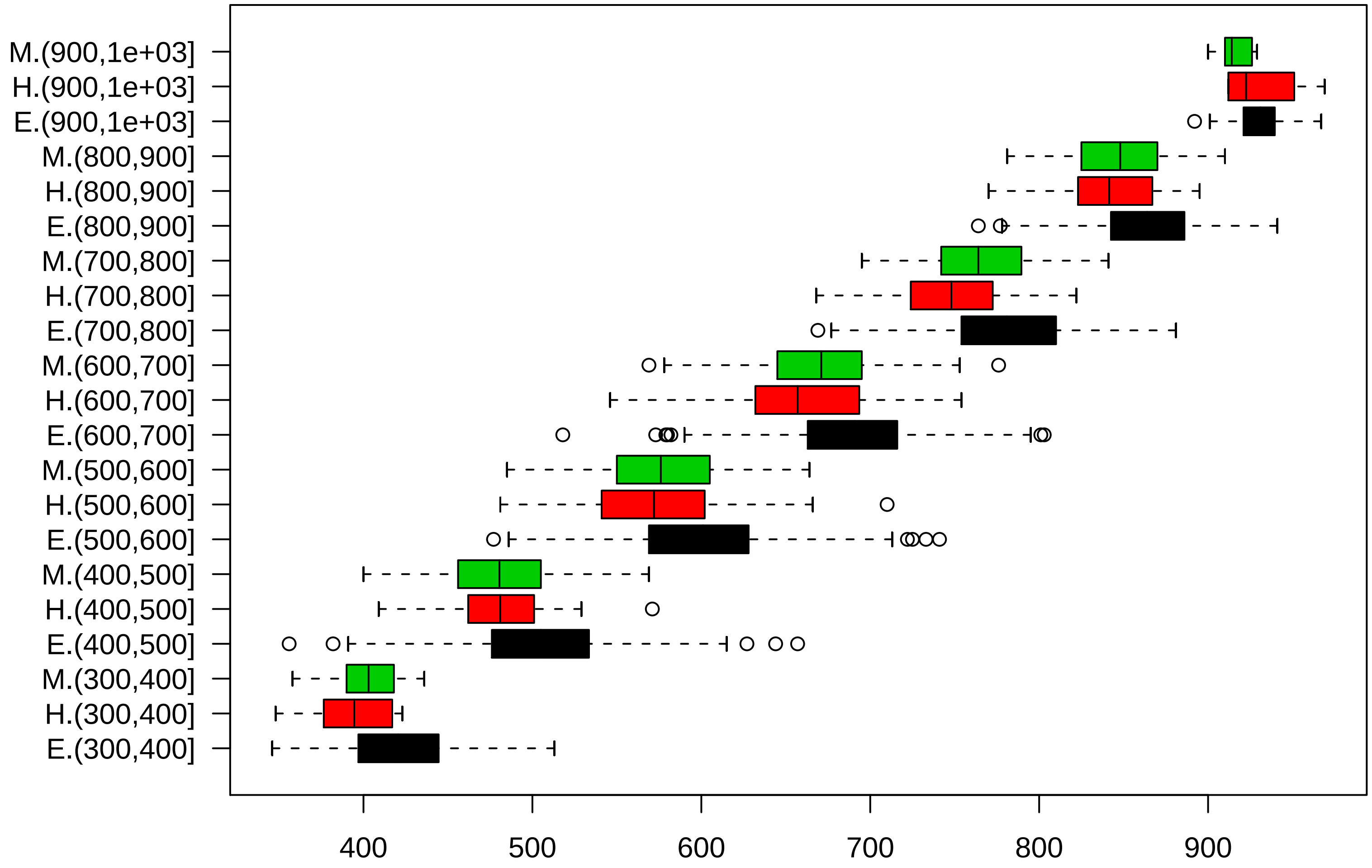
```
> boxplot(api00~cut(api99,(3:10)*100), data=apipop)
> par(las=1)
> par(mar=c(5.1,10.1,2.1,2.1))
> boxplot(api00~interaction(stype,
                           cut(api99,(3:10)*100)),
        data=apipop, horizontal=TRUE,col=1:3)
 plot(api00~api99,data=apipop,type="n")
 with(subset(apipop, stype=="E"),
      lines(lowess(api99, api00), col="tomato"))
 with(subset(apipop, stype=="H"),
      lines(lowess(api99, api00), col="forestgreen"))
 with(subset(apipop, stype=="M"),
      lines(lowess(api99, api00), col="purple"))
```

Smoothers

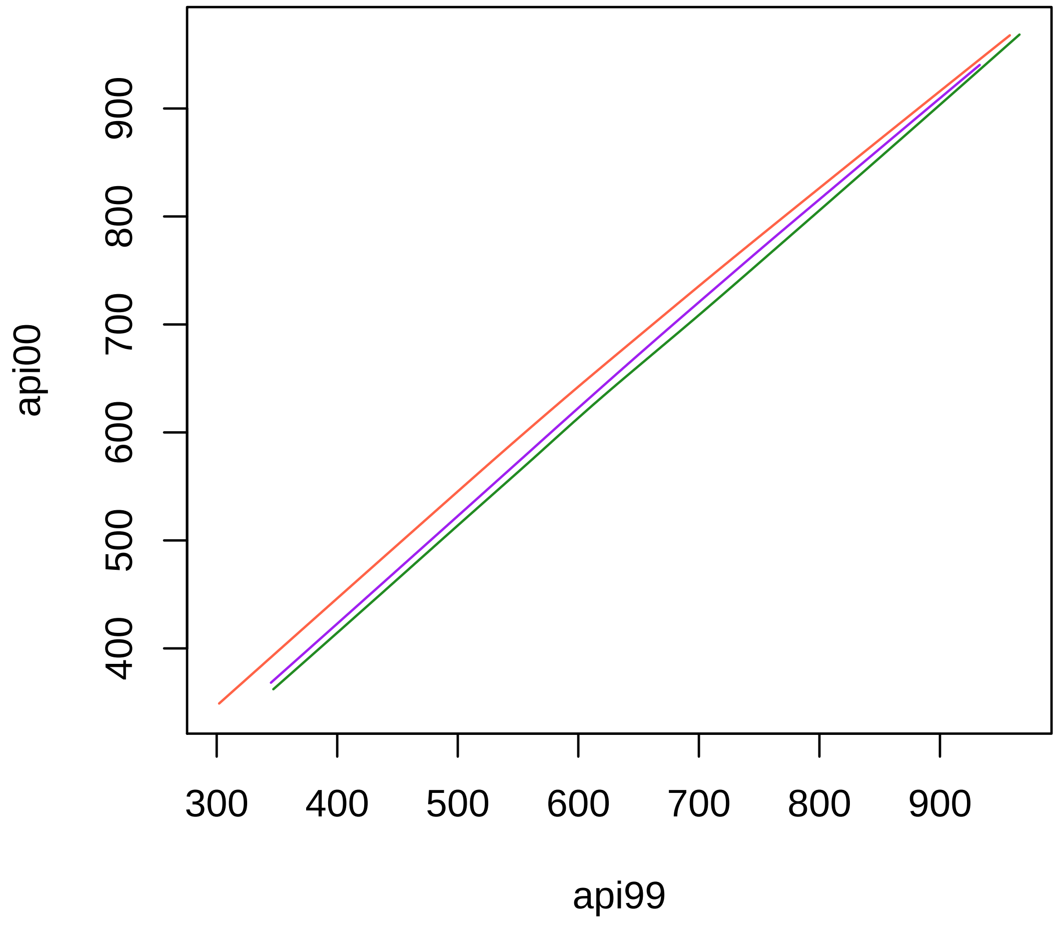


900
800
700
600
500
400
(300,400]
(400,500]
(500,600]
(600,700]
(700,800]
(800,900]
(900,1e+03]

Smoothers


M.(900,1e+03]
H.(900,1e+03]
E.(900,1e+03]
M.(800,900]
H.(800,900]
E.(800,900]
M.(700,800]
H.(700,800]
E.(700,800]
M.(600,700]
H.(600,700]
E.(600,700]
M.(500,600]
H.(500,600]
E.(500,600]
M.(400,500]
H.(400,500]
E.(400,500]
M.(300,400]
H.(300,400]
E.(300,400]
400
500
600
700
800
900

Smoothers



Notes

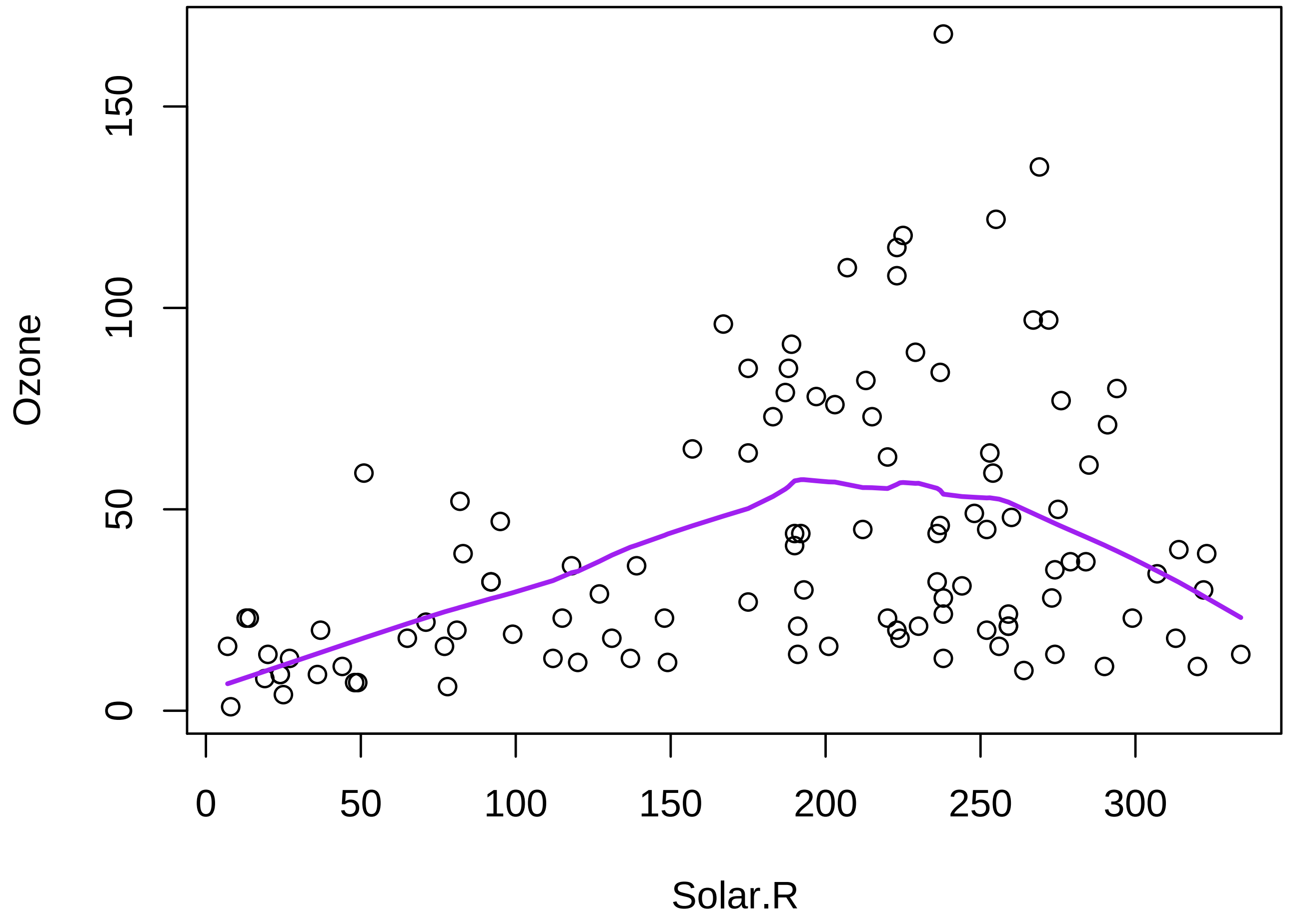
- `cut()` turns a variable into a factor by cutting it at the specified points.
- Note the use of `type="n"`
- `par(mar=)` sets the margins around the plot. We need a large left margin for the labels.
- `subset()` returns a subset of a data frame.

Conditioning plots

Ozone is a secondary pollutant, it is produced from organic compounds and atmostpheric oxygen in reactions catalyzed by nitrogen oxides and powered by su nlight.

However, looking at ozone concentrations in NY in summer we see a non-monotone relationship with sunlight

Conditioning plots

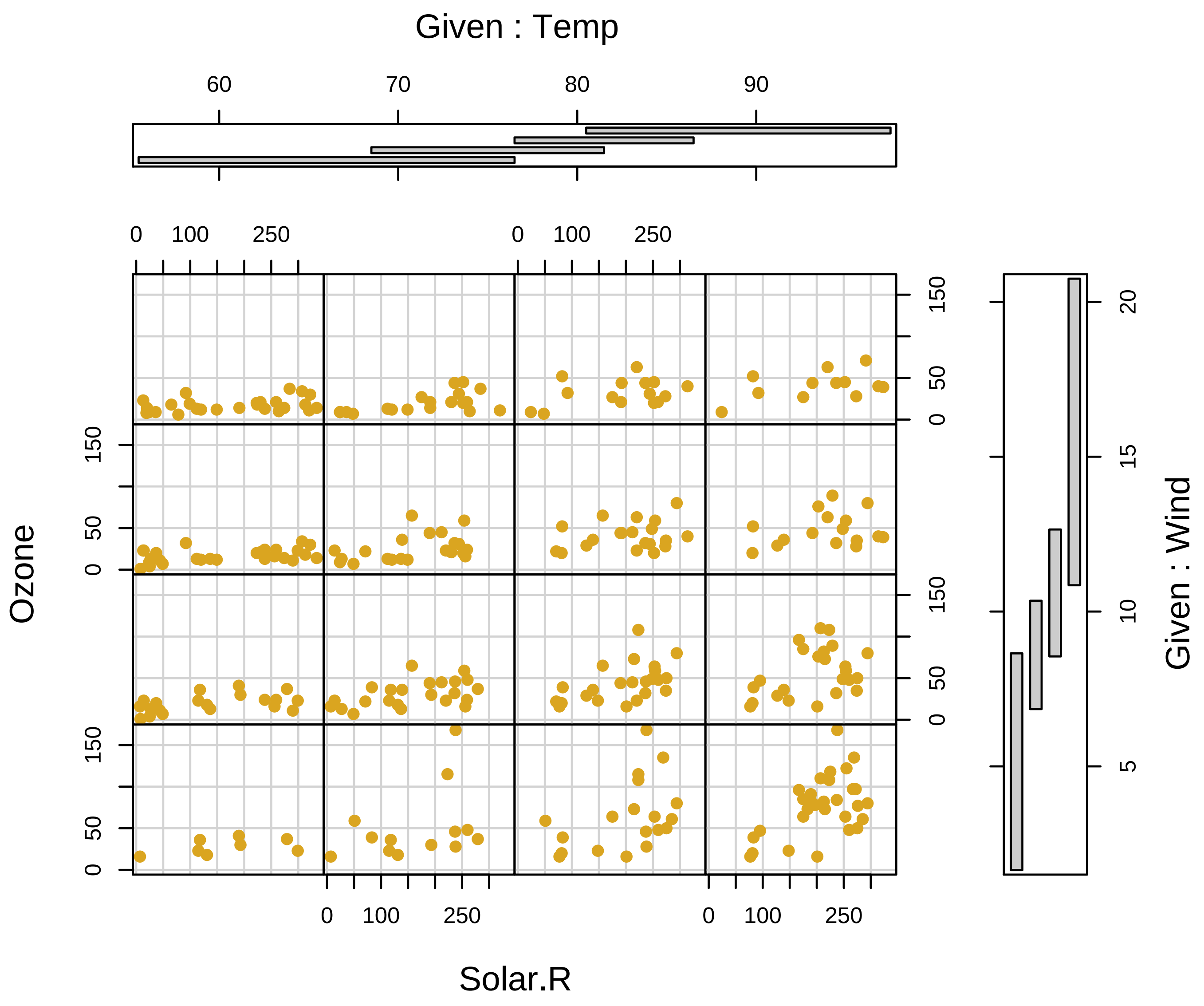


Conditioning plots

Here we draw a scatterplot of `Ozone` vs `Solar.R` for various subranges of `Temp` and `Wind`. For more examples like this, see the commands in the `lattice` package.

```
data(airquality)
coplot(Ozone ~ Solar.R | Temp * Wind, number = c(4, 4),
     data = airquality,
    pch = 21, col = "goldenrod", bg = "goldenrod")
```

Conditioning plots



Toys: Mathematical annotation

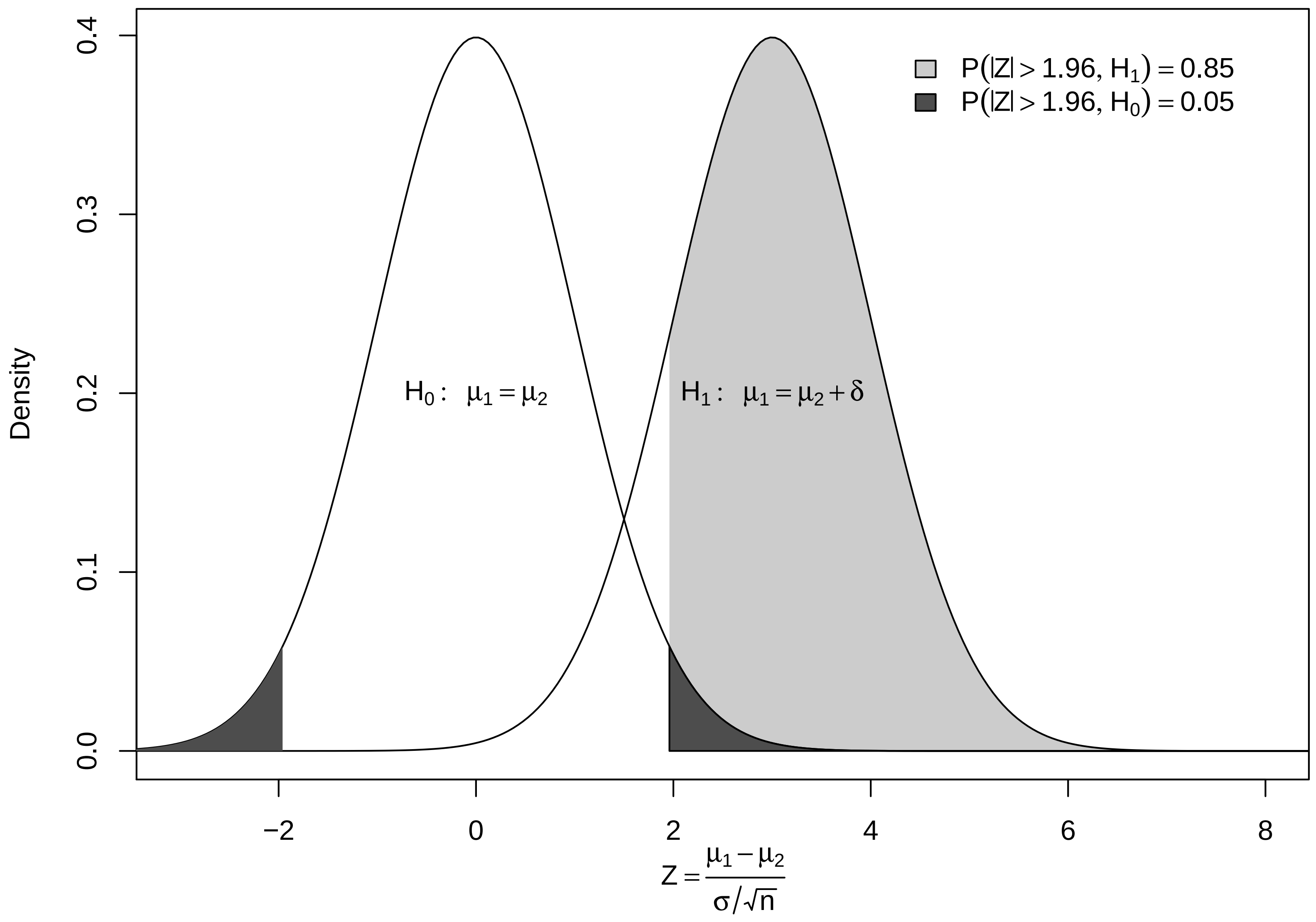
An expression can be specified in R for any text in a graph (`help(plotmath)` for details). Here we annotate a figure drawn with `polygon()`.

```
x<-seq(-10,10,length=400)
y1<-dnorm(x)
y2<-dnorm(x,m=3)
par(mar=c(5,4,2,1))
plot(x,y2,xlim=c(-3,8),type="n",
    xlab=quote(Z==frac(mu[1]-mu[2],sigma/sqrt(n))),
    ylab="Density")
polygon(c(1.96,1.96,x[240:400],10),
        c(0,dnorm(1.96,m=3),y2[240:400],0),
        col="grey80",lty=0)
lines(x,y2)
lines(x,y1)
polygon(c(-1.96,-1.96,x[161:1],-10),
        c(0,dnorm(-1.96,m=0),y1[161:1],0),
        col="grey30",lty=0)
polygon(c(1.96,1.96,x[240:400],10),
        c(0,dnorm(1.96,m=0),y1[240:400],0),
        col="grey30")
```

Toys: Mathematical annotation

```
legend(4.2,.4,fill=c("grey80","grey30"),
    legend=expression(P(abs(Z)>1.96,H[1])==0.85,
         P(abs(Z)>1.96,H[0])==0.05),bty="n")
text(0,.2,quote(H[0]:~~mu[1]==mu[2]))
text(3,.2,quote(H[1]:~~mu[1]==mu[2]+delta))
```

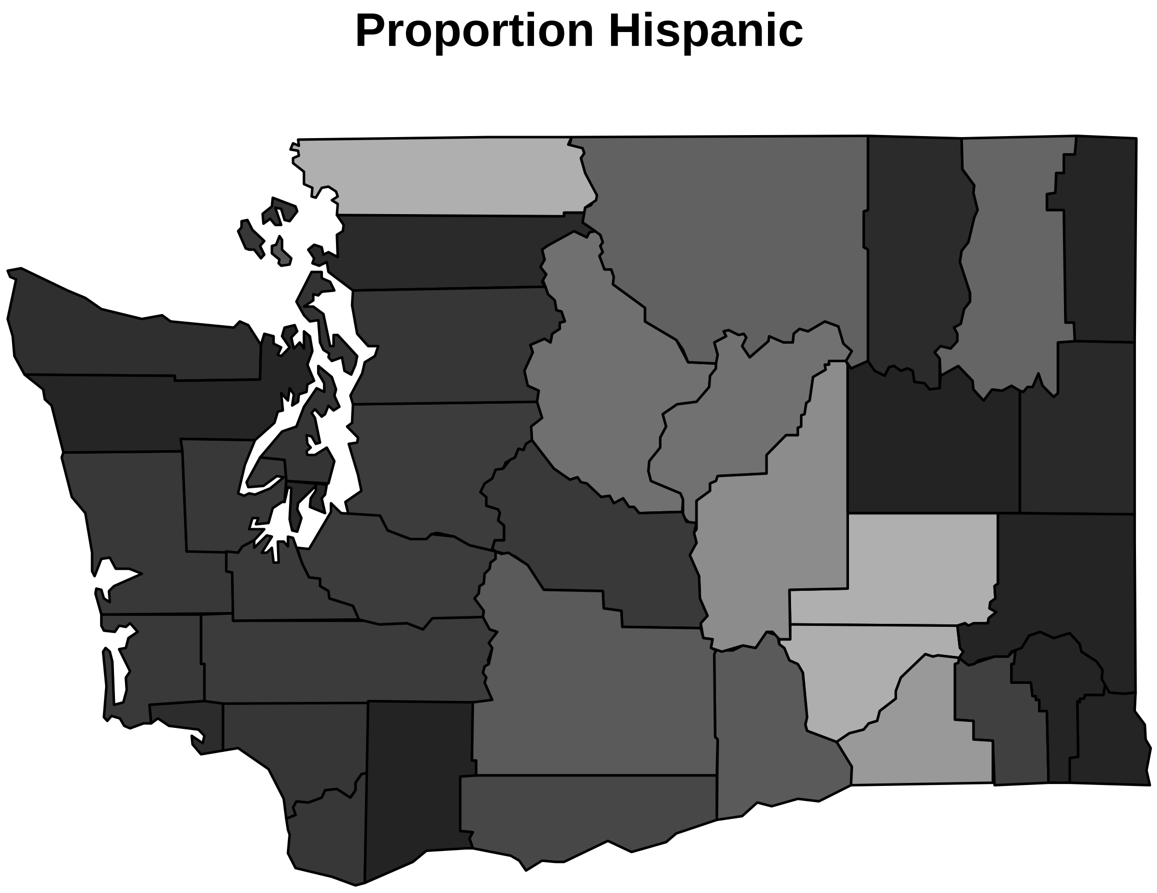
Toys: Mathematical annotation



Toys: Maps

```
> library("maps")
> map('county', 'washington', fill = TRUE,
        col = grey(sqrt(wa[,10]/(wa[,1]))) )
> title(main="Proportion Hispanic")
```

Toys: Maps


Proportion Hispanic