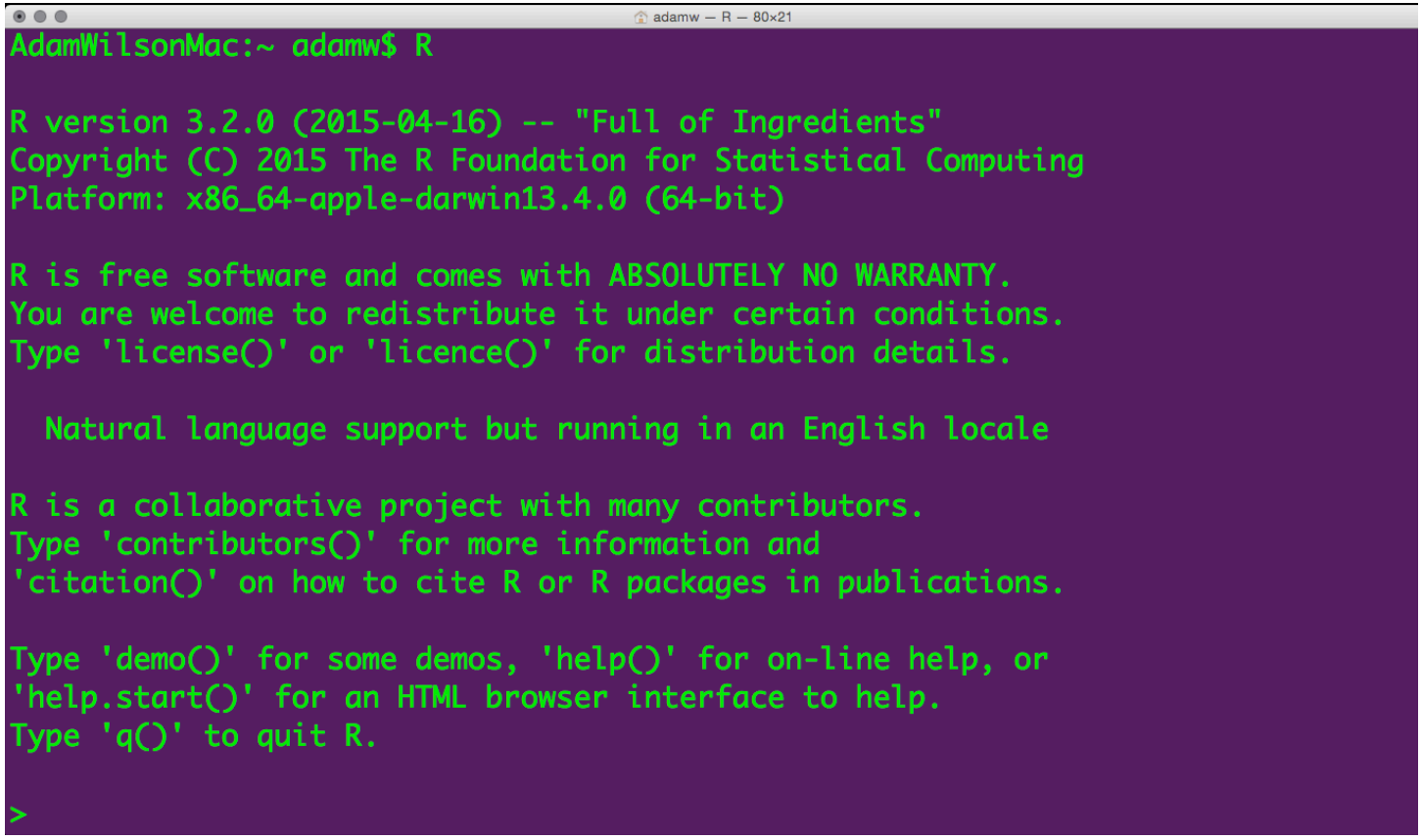
Spatial environmental data analysis with R
GEO 503



Agenda

What is R?

Who uses it?

“Reproducible Research”

Guided interactive coding

Course Structure

Mondays 9:10-11:40 (2 hours 40 min)

- Review/Questions
- ~30 Minute Presentation
- Guided interactive exercises on your laptops

Course Objectives

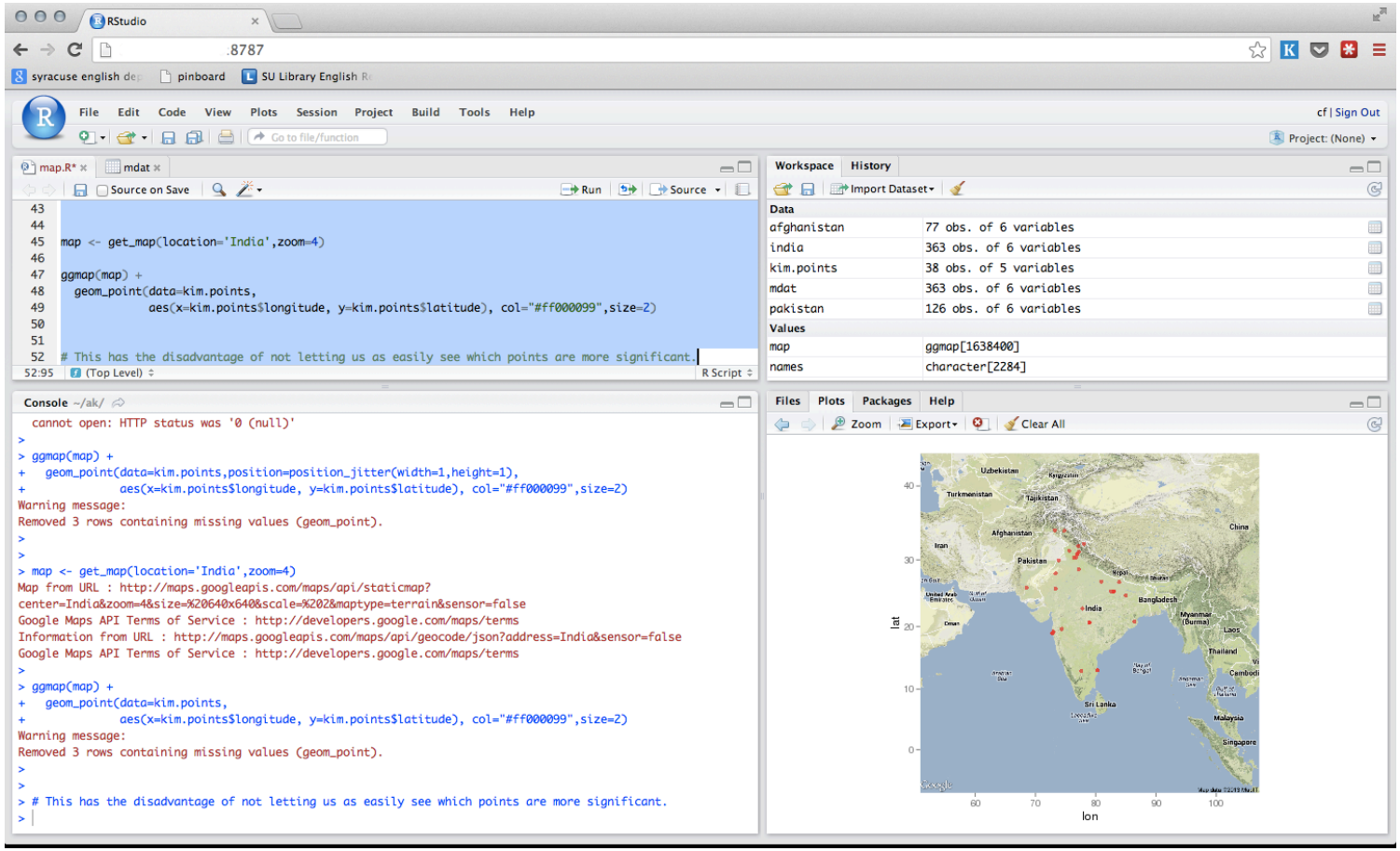
3 Learning Objectives

- Become familiar with R programming language
- Learn to code geospatial analyses
- Learn to develop custom data visualization (especially spatial)
- Learn to develop reproducible research workflows

This course is NOT

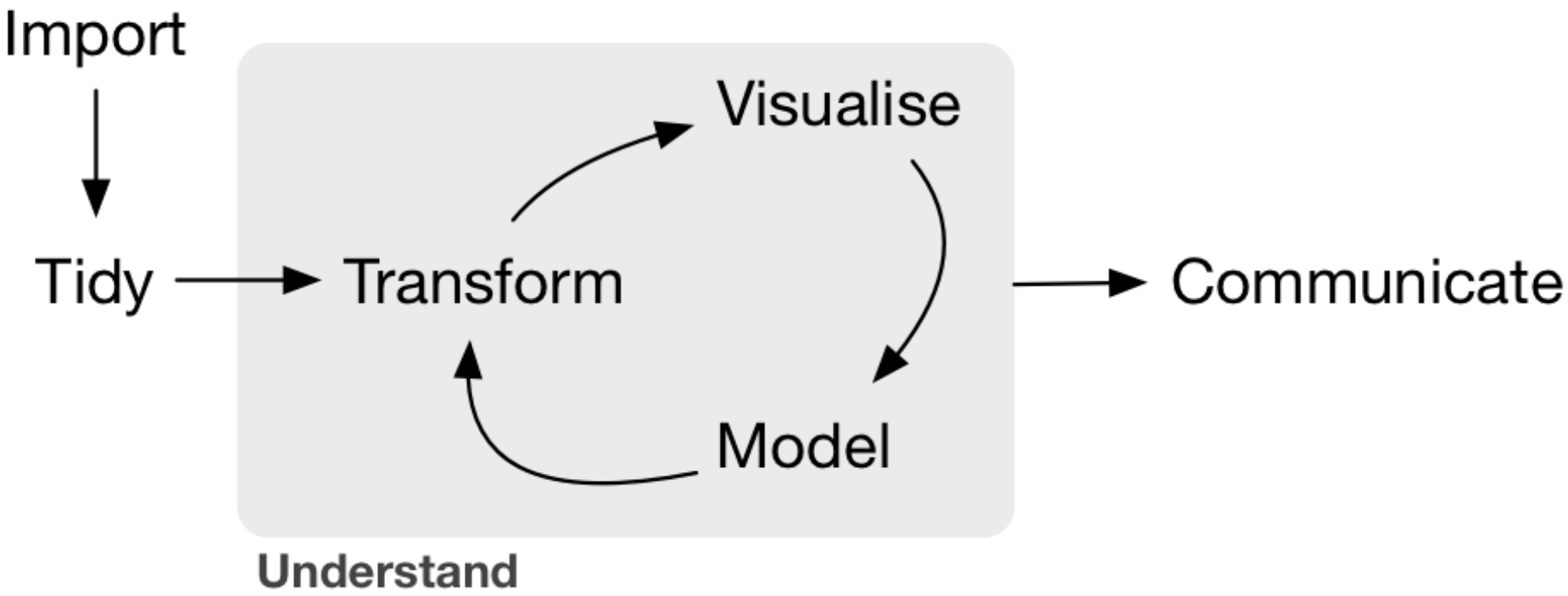
- A statistics course (see GEO 505, etc.).
- We will focus on workflow and methods (‘how’ not ‘why’)

Workshop course



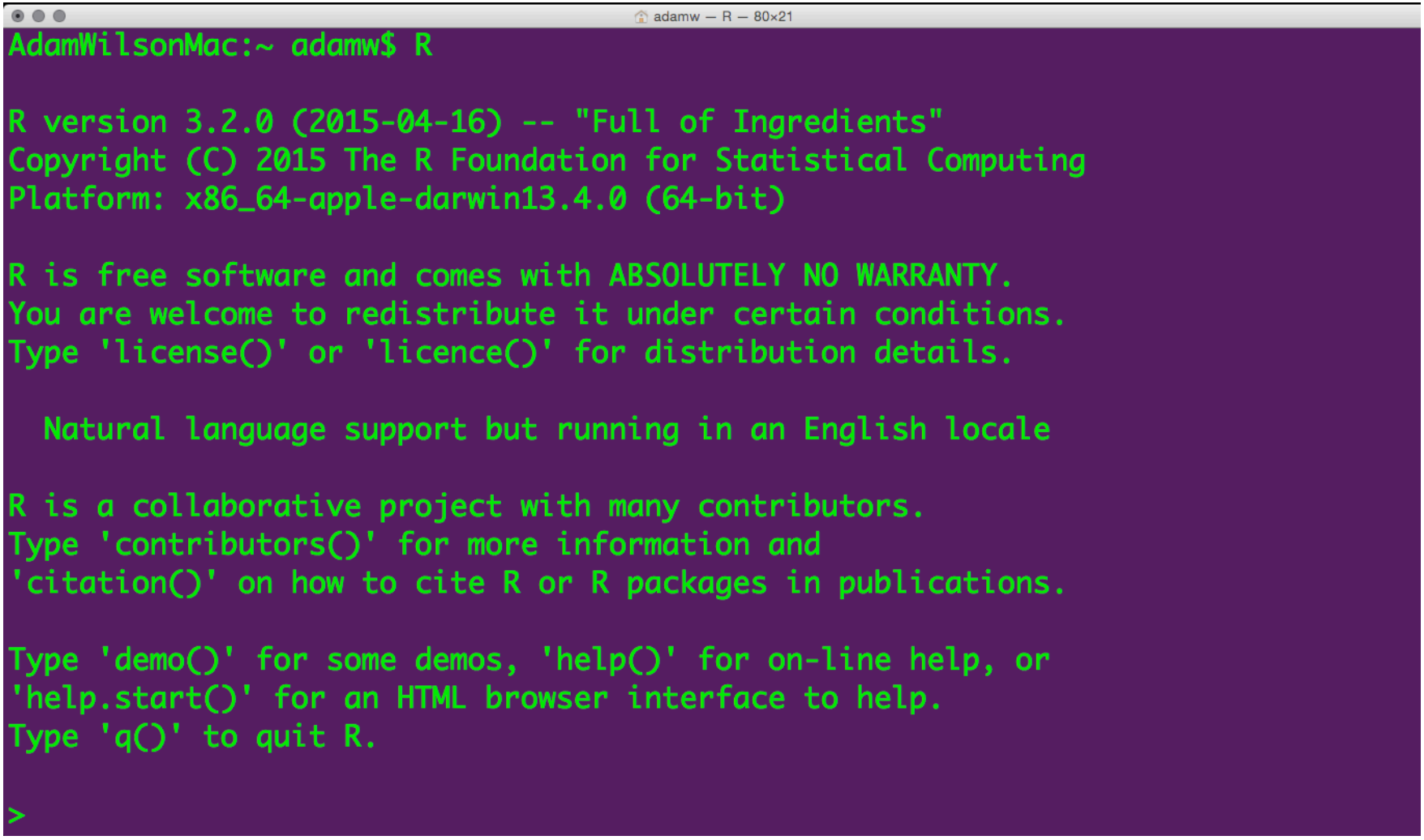
Most of our time will be spent thinking about, looking at, and writing code…

What is Data Science?



--Grolemund & Wickham, R for Data Science, O'Reilly 2016

Essentially a programming course…



Why Code when you can Click?

Graphical User Interfaces are useful, especially when you are learning...

Reproducible Research

The ability to reproduce results from an experiment or analysis conducted by another*

Developed from literate programming:

- Logic of the analysis is represented in output
- Combines computer code with narrative

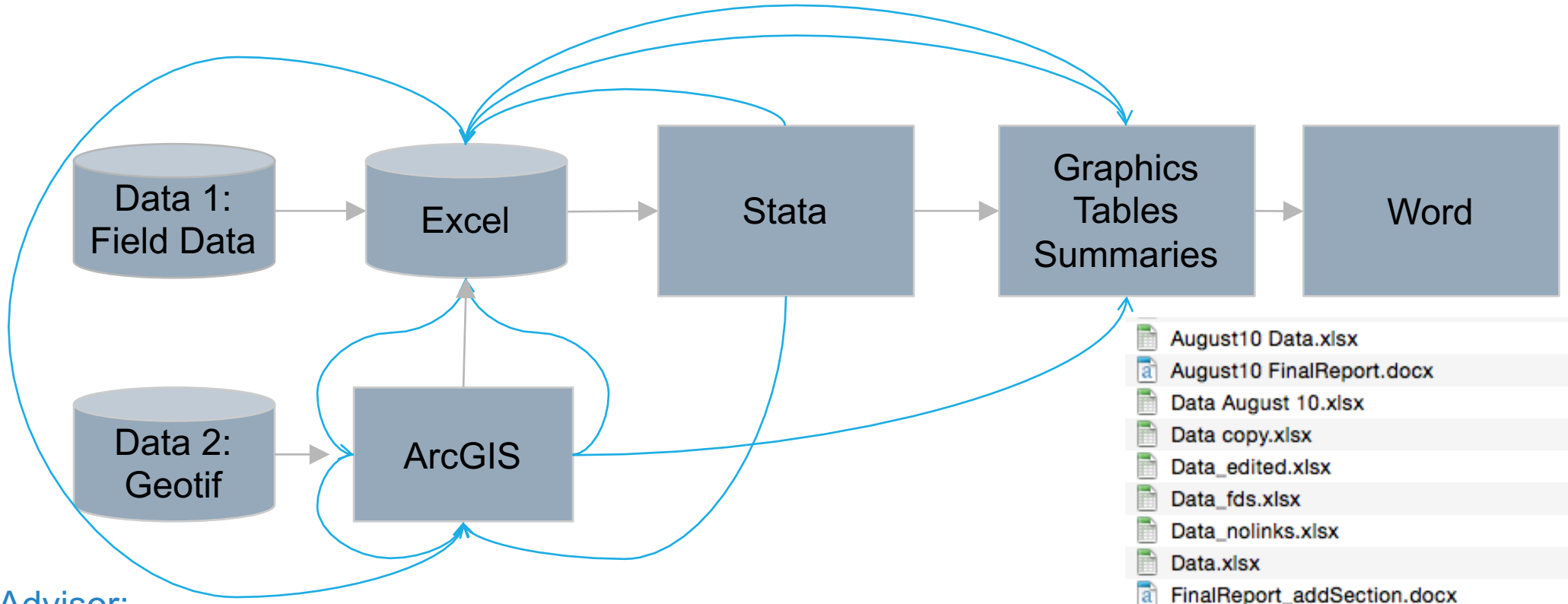
Literate Programming (1992) D.E. Knuth

Learning a programming language can help you learn how to think logically.

A man who does not know foreign language is ignorant of his own.

-- Johann Wolfgang von Goethe (1749 - 1832)

Typical GUI Workflow

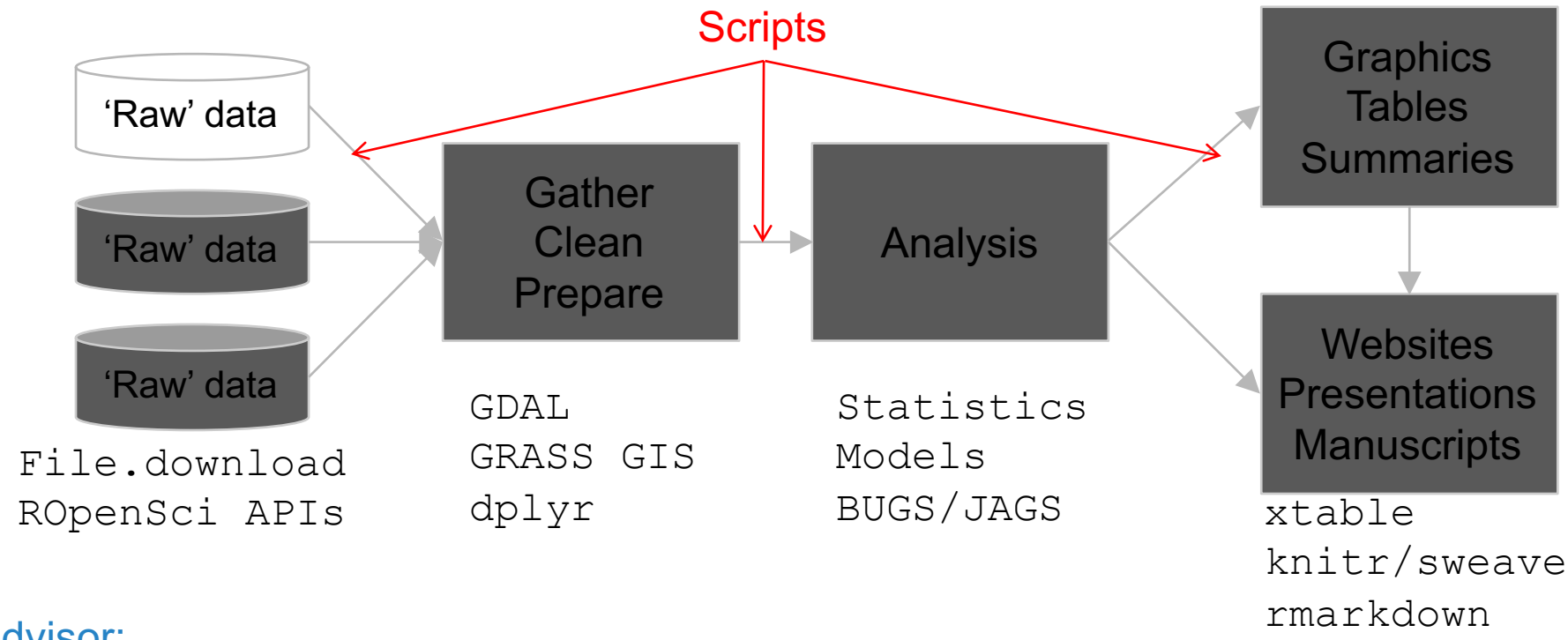


Advisor:

- *I've updated the field data with a few more locations, please re-run that analysis…*
- *New satellite data are available, can you update that figure?*

August10 Data.xlsx
August10 FinalReport.docx
Data August 10.xlsx
Data copy.xlsx
Data_edited.xlsx
Data_fds.xlsx
Data_nolinks.xlsx
Data.xlsx
FinalReport_addSection.docx
FinalReport_August21 copy 16.docx
FinalReport_CM.docx
FinalReport_draft.docx
FinalReport_draft3.docx
FinalReport_final_final.docx
FinalReport_final.docx
FinalReport_sent.docx
FinalReport_submitted.docx
FinalReport.docx

Organized and repeatable workflow (and some example commands)



Advisor:

- *I've updated the field data with a few more locations, please re-run that analysis…*
- *New satellite data are available, can you update that figure?*

Sure, I can do that this afternoon…

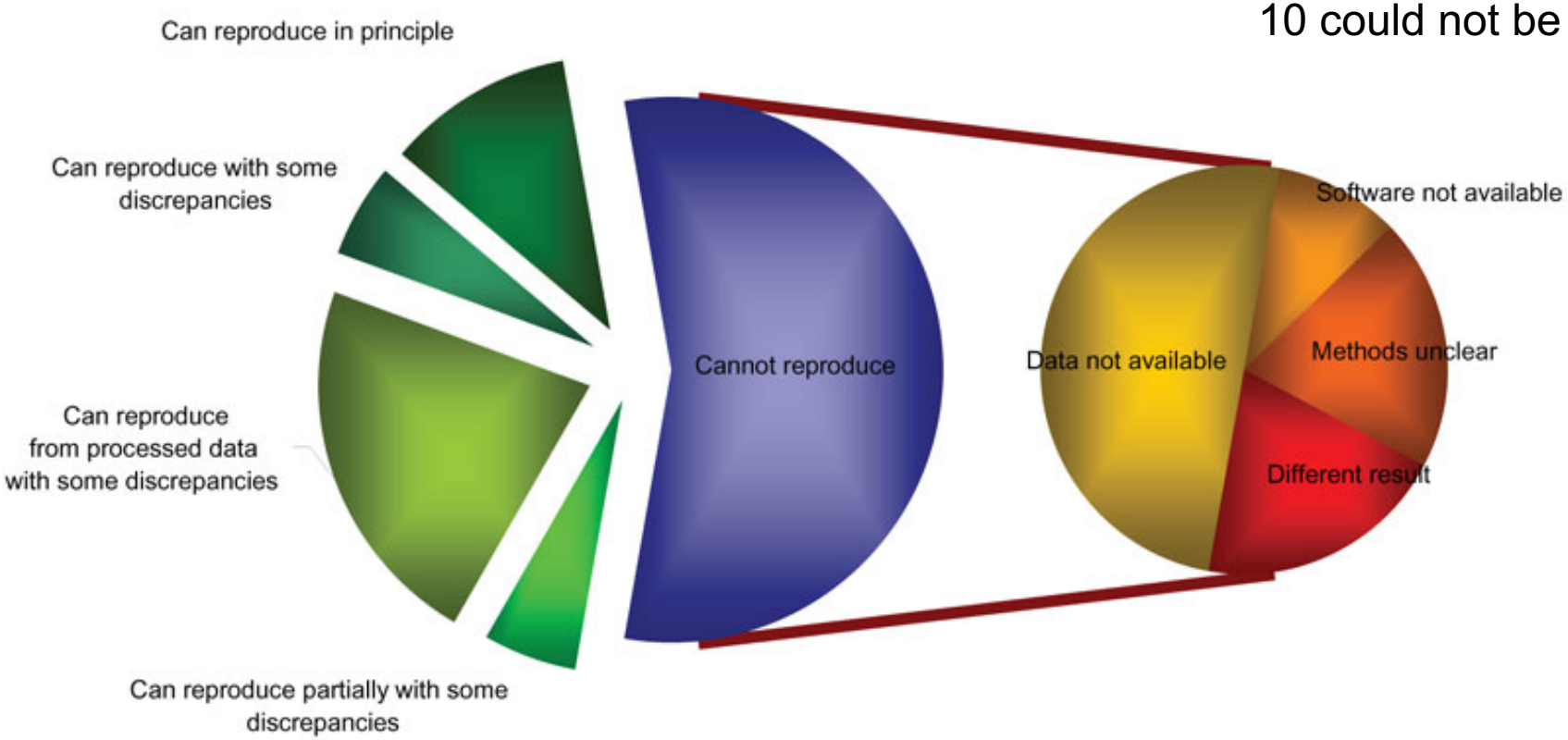
nature genetics

Reproducible Research

Repeatability of published microarray gene expression analyses

John P A Ioannidis[1–3], David B Allison[4], Catherine A Ball[5], Issa Coulibaly[4], Xiangqin Cui[4], Aedín C Culhane[6,7], Mario Falchi[8,9], Cesare Furlanello[10], Laurence Game[11], Giuseppe Jurman[10], Jon Mangion[11], Tapan Mehta[4], Michael Nitzberg[5], Grier P Page[4,12], Enrico Petretto[11,13] & Vera van Noort[14]

18 articles:
- 2 reproducible
- 6 partially
- 10 could not be reproduced!

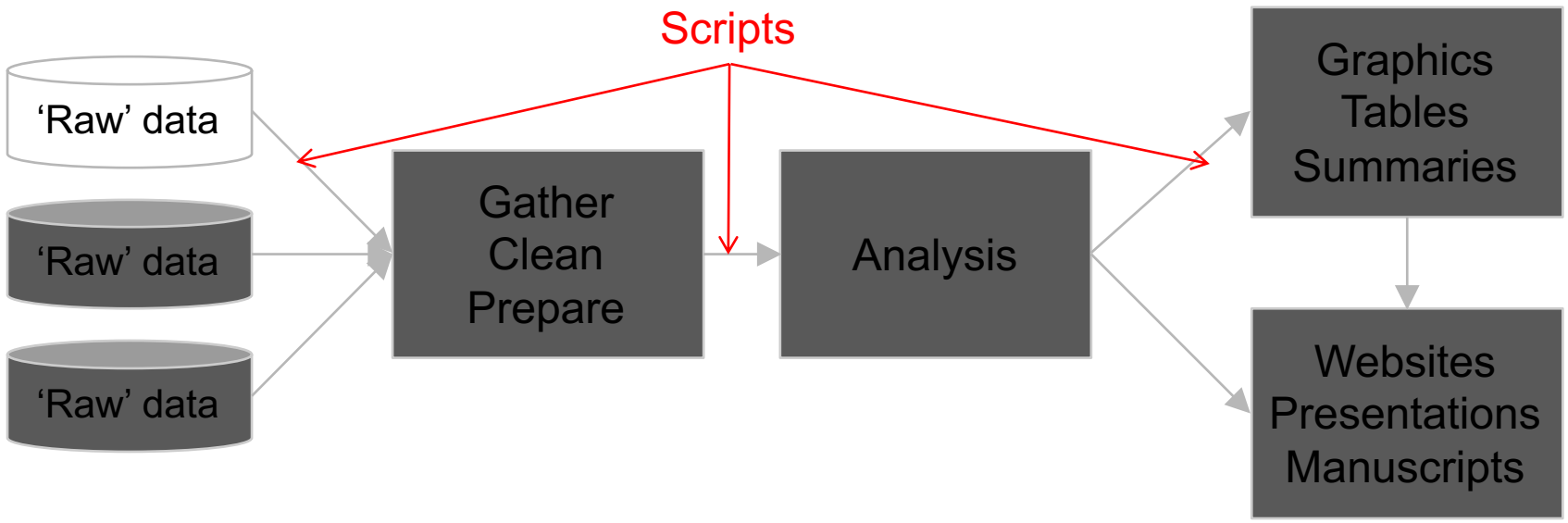


Programming gives you access to more computer power.

The computer is incredibly fast, accurate, and stupid. Man is unbelievably slow, inaccurate, and brilliant. The marriage of the two is a force beyond calculation.

-- Leo Cherne

Organized and repeatable workflow (and some example commands)

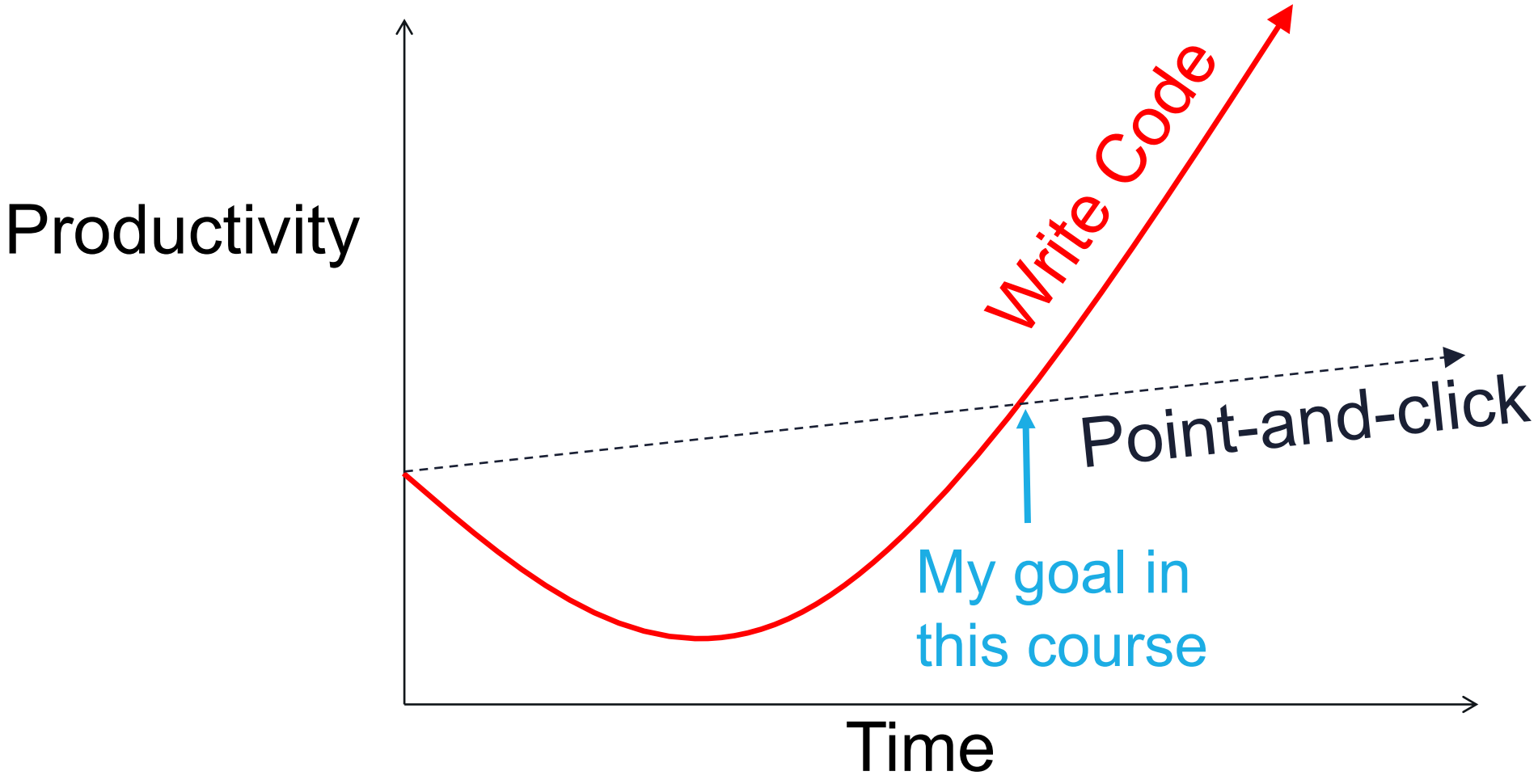


Advisor:

- *I want you to take he analysis you developed for Buffalo and run it globally*

Sure, I can do that this afternoon…

From Graphical User Interface (GUI) to scripting/programming



Typical software use - GEO

Software

- ArcGIS 94%
- Python 29%
- R 29%
- SPSS 29%
- Google Earth Engine 24%
- Erdas Imagine 24%

Scripting

- Yes 71%
- No 29%

Used R?

- No 52%

The R Project for Statistical Computing

Free and Open source

Data manipulation

Data analysis tools

Great graphics

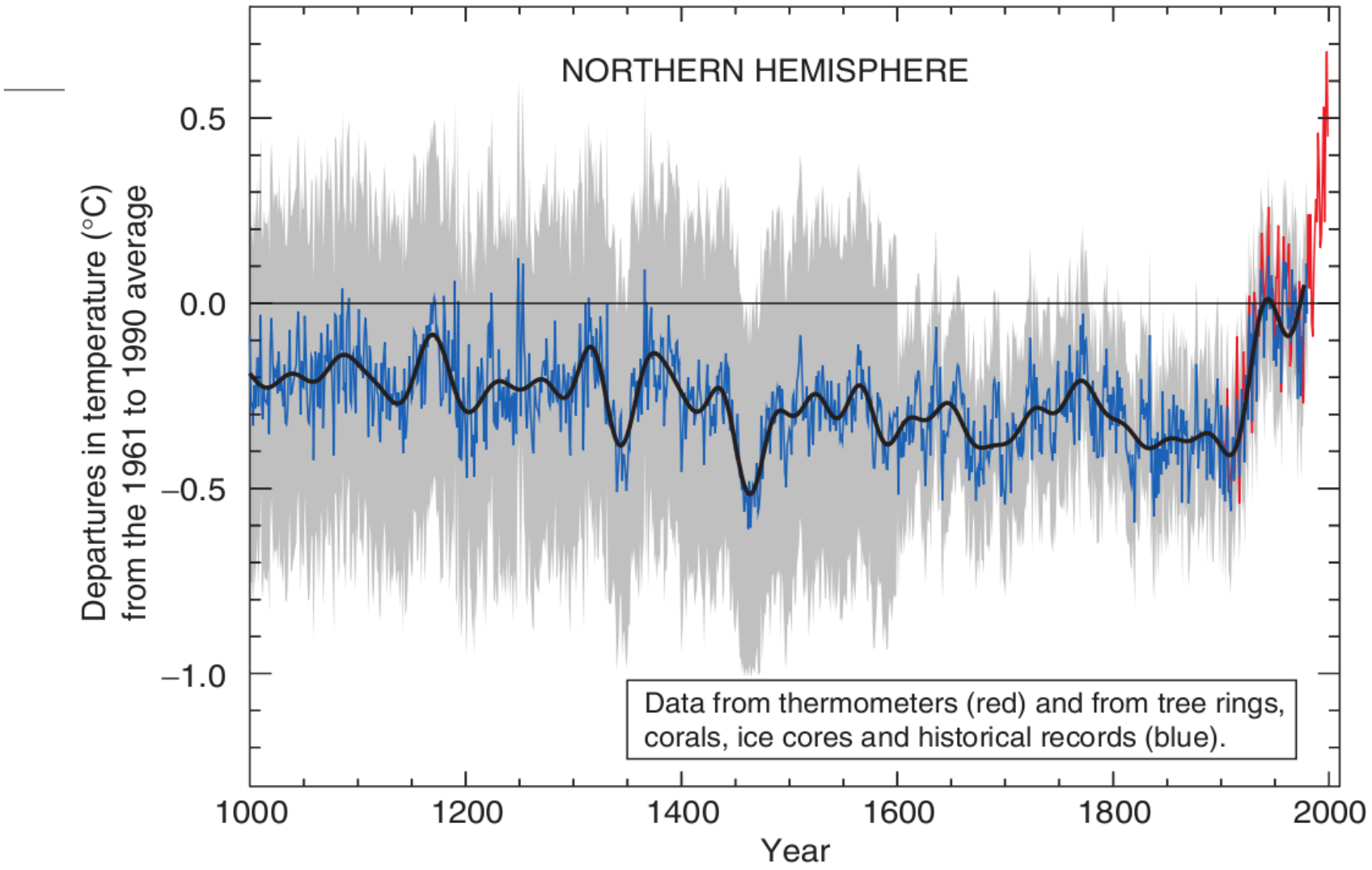
Programming language

6,000^{+} free, community-contributed packages

A supportive and increasing user community

R is a dialect of the S language
developed at Bell Laboratories (formerly AT&T) by John Chambers et. al. (same group developed C and UNIX©)

Reproducible, Portable, & Transparent

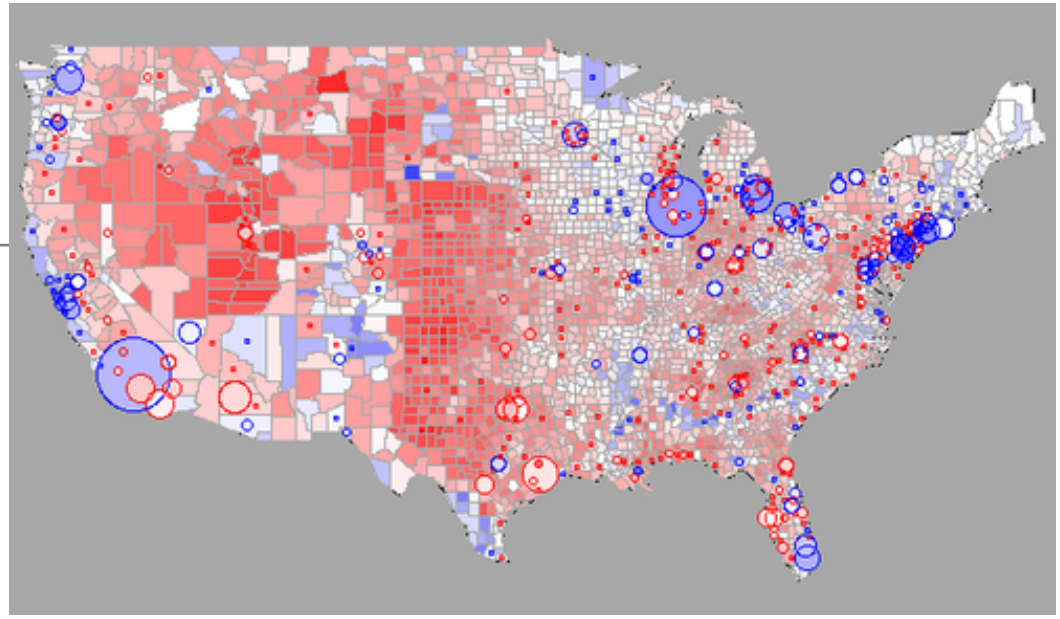


. . . all the code and data used to recreate the Mann's original analysis has been made available to the public [...] Since the analysis is in R, anyone can replicate the results and examine the methods.
(Matthew Pocernich, R news 6/4, 10/31/06)

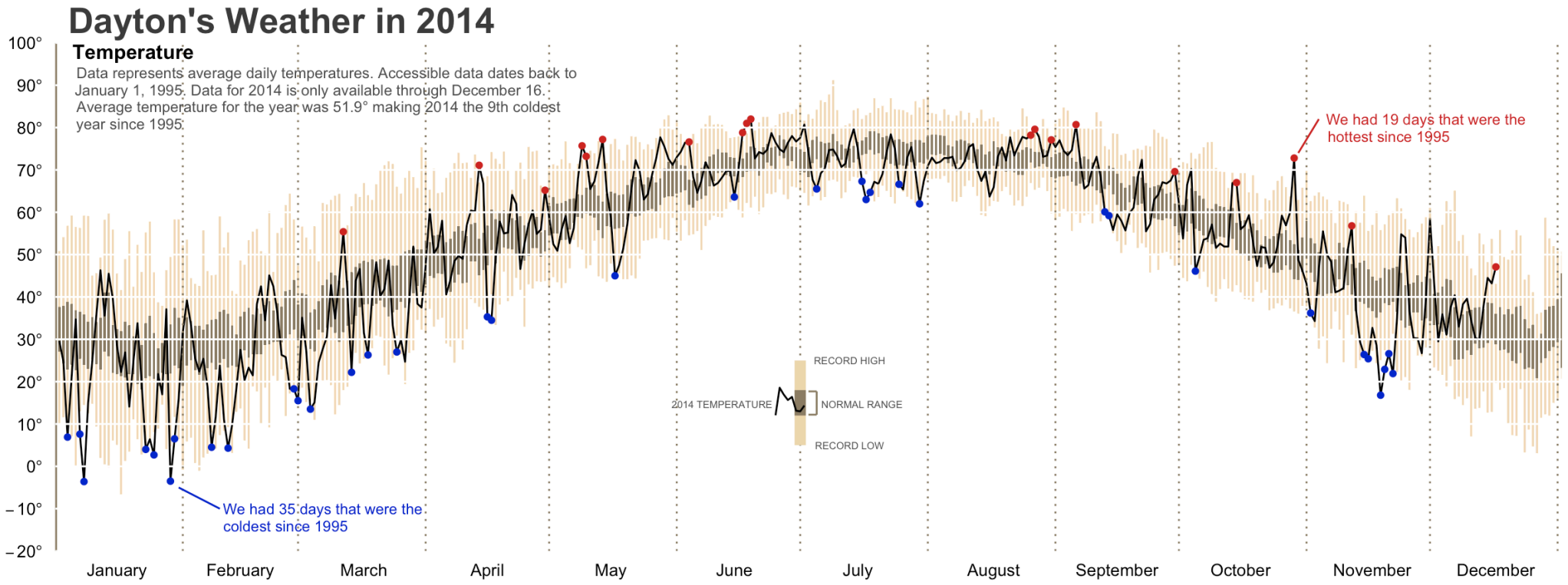
http://www.cgd.ucar.edu/ccr/ammann/millennium/refs/WahlAmmann_ClimChange2006.html

R Graphics

If you can imagine it…



http://blog.revolutionanalytics.com/2009/01/r-graph-gallery.html



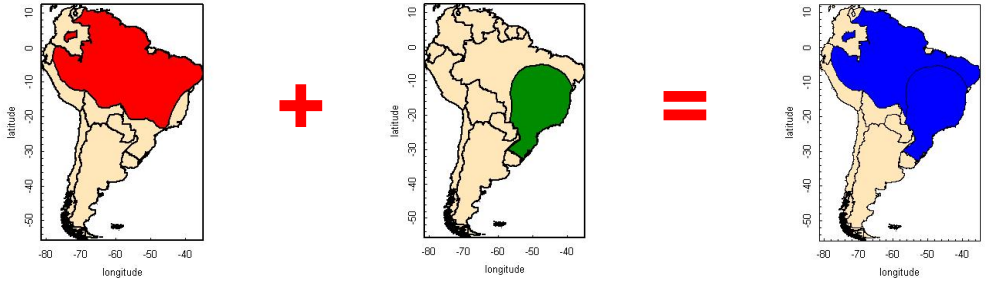
http://rpubs.com/bradleyboehmke/weather_graphic

Spatial data in R

Packages: sp, maptools, rgeos, raster, ggmap

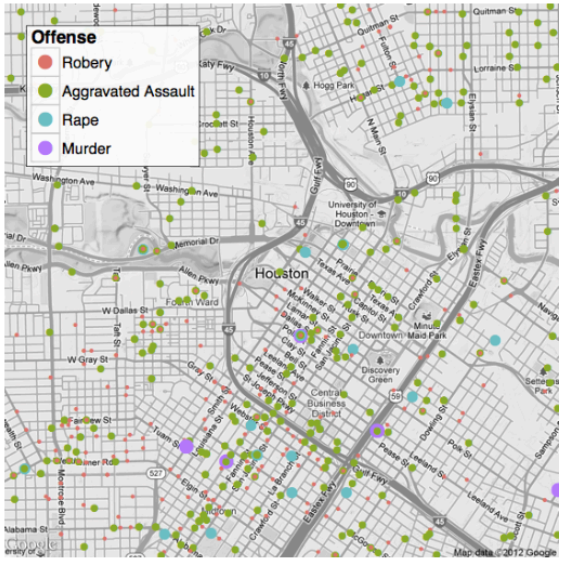
Examples:

- species range overlays



http://www.nceas.ucsb.edu/

- Basemaps with ggmap

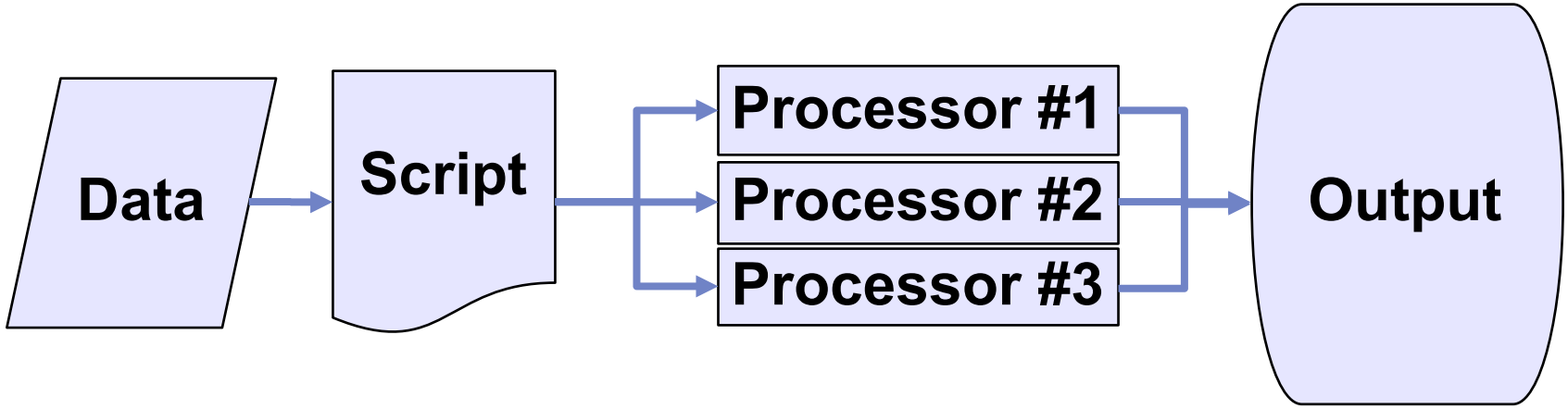


http://journal.r-project.org/archive/2013-1/kahle-wickham.pdf

Parallel Processing

For BIG jobs:

multi-core processors / high performance computing with foreach.



Strengths & Limitations

Just-in-time compilation:

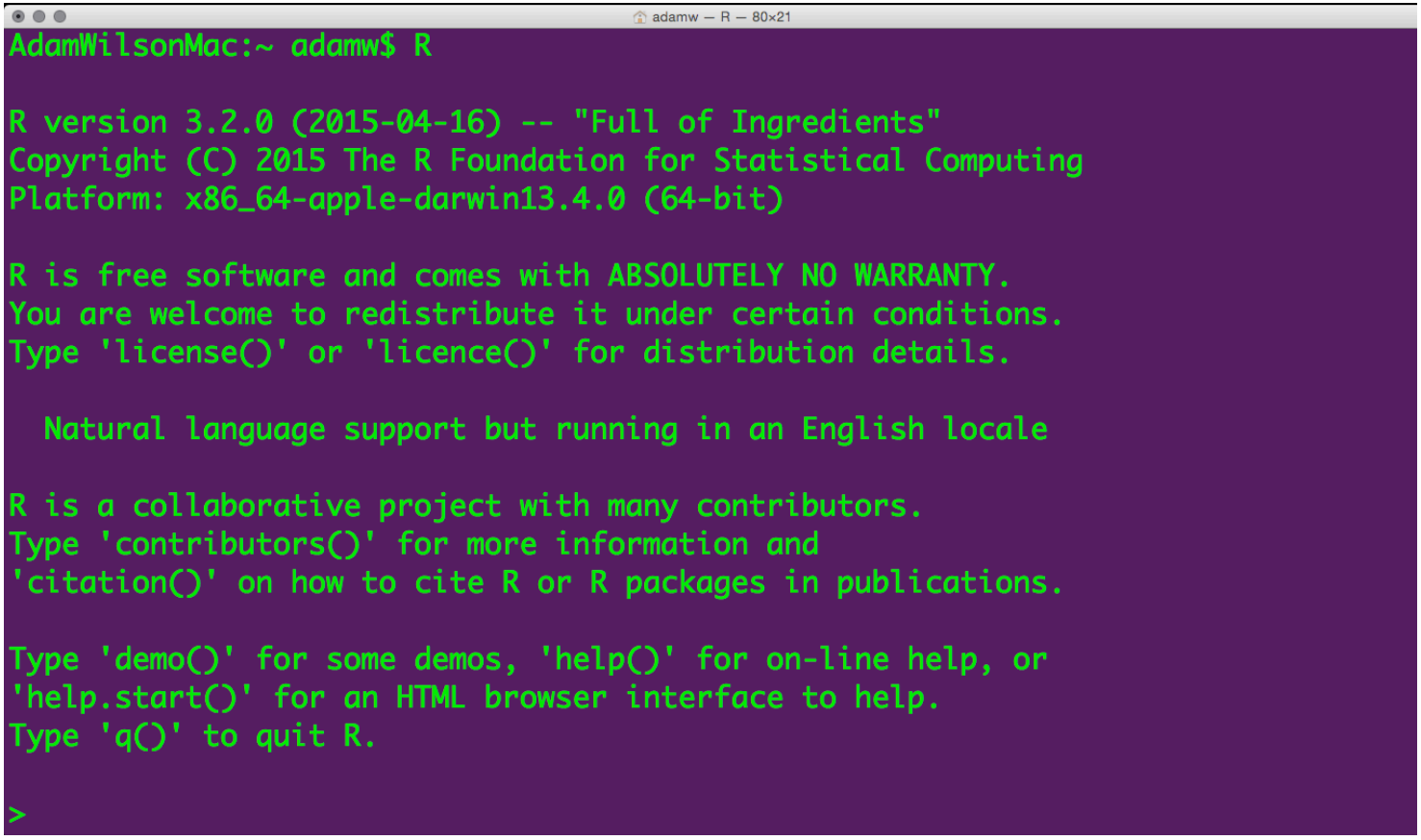
- Slower than compiled languages (-)
- Faster to compose (+)
- Many available packages (+)

Most operations conducted in RAM

- RAM can be limiting and/or expensive (-)
  - "Error: cannot allocate vector of size *X* Mb"
- Various packages and clever programming can overcome this… (+)

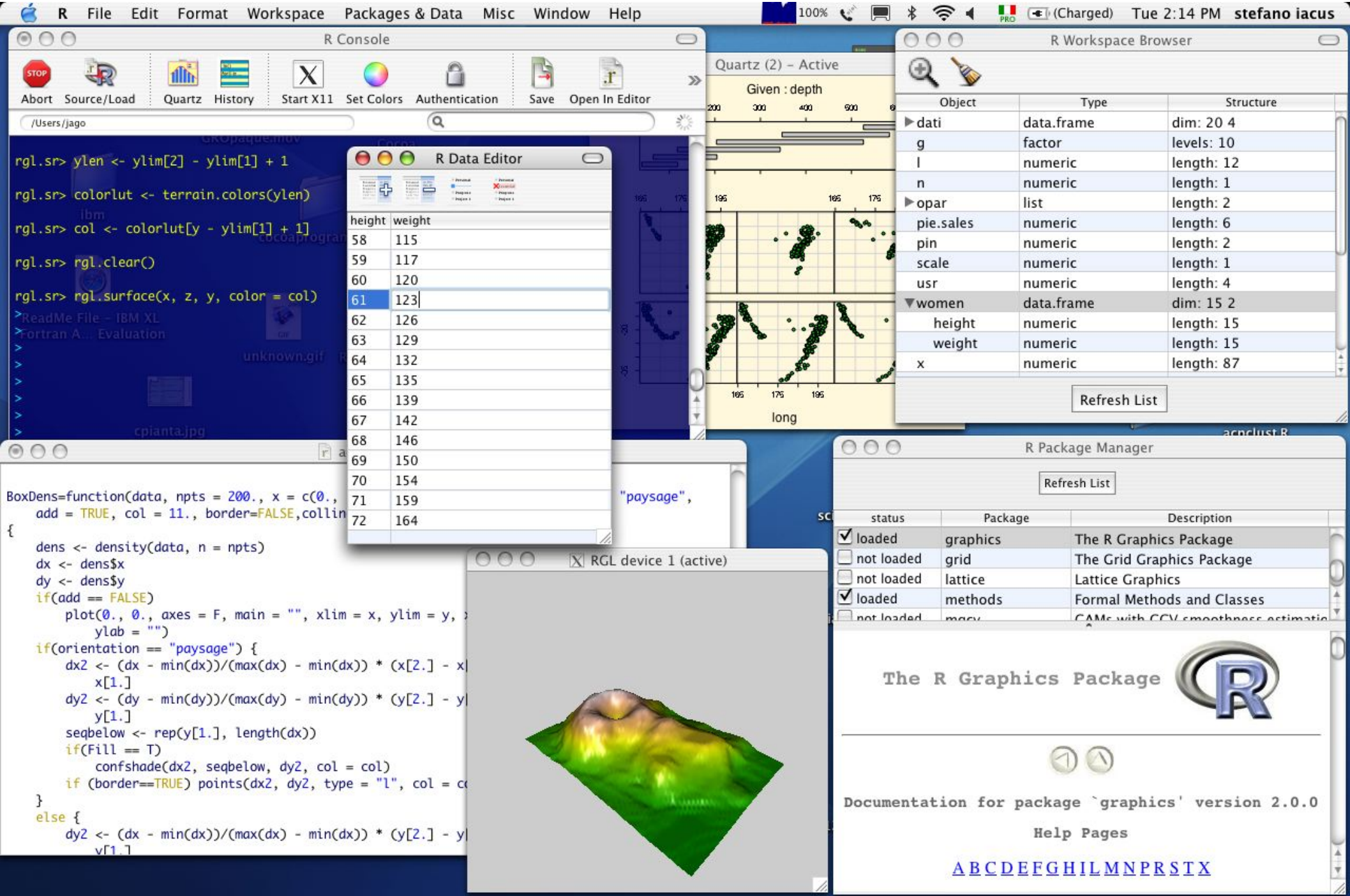
Free like beer and speech! (+)

R Interface



But there are other options...

R in Mac


R File Edit Format Workspace Packages & Data Misc Window Help
100% (Charged) Tue 2:14 PM stefano iacus
R Console
Abort Source/Load Quartz History Start X11 Set Colors Authentication Save Open In Editor
/Users/jago
rgl.sr> ylen <- ylim[2] - ylim[1] + 1
rgl.sr> colorlut <- terrain.colors(ylen)
rgl.sr> col <- colorlut[y - ylim[1] + 1]
rgl.sr> rgl.clear()
rgl.sr> rgl.surface(x, z, y, color = col)
R Data Editor
height weight
58 115
59 117
60 120
61 123
62 126
63 129
64 132
65 135
66 139
67 142
68 146
69 150
70 154
71 159
72 164
Quartz (2) - Active
Given : depth
long
R Workspace Browser
Object Type Structure
dati data.frame dim: 20 4
g factor levels: 10
l numeric length: 12
n numeric length: 1
opar list length: 2
pie.sales numeric length: 6
pin numeric length: 2
scale numeric length: 1
usr numeric length: 4
women data.frame dim: 15 2
height numeric length: 15
weight numeric length: 15
x numeric length: 87
Refresh List
BoxDens=function(data, npts = 200., x = c(0.,
add = TRUE, col = 11., border=FALSE,collin
{
dens <- density(data, n = npts)
dx <- dens$x
dy <- dens$y
if(add == FALSE)
plot(0., 0., axes = F, main = "", xlim = x, ylim = y,
ylab = "")
if(orientation == "paysage") {
dx2 <- (dx - min(dx))/(max(dx) - min(dx)) * (x[2.] - x
x[1.]
dy2 <- (dy - min(dy))/(max(dy) - min(dy)) * (y[2.] - y
y[1.]
seqbelow <- rep(y[1.], length(dx))
if(Fill == T)
confshade(dx2, seqbelow, dy2, col = col)
if (border==TRUE) points(dx2, dy2, type = "l", col = c
}
else {
dy2 <- (dx - min(dx))/(max(dx) - min(dx)) * (y[2.] - y
"paysage",
RGL device 1 (active)
R Package Manager
Refresh List
status Package Description
loaded graphics The R Graphics Package
not loaded grid The Grid Graphics Package
not loaded lattice Lattice Graphics
loaded methods Formal Methods and Classes
The R Graphics Package
Documentation for package `graphics' version 2.0.0
Help Pages
A B C D E F G H I L M N P R S T X

R in Windows

Tinn-R - [C:\Work\Stat\Scripts\AccuPAR_LAI_SD.r*]

File Project Edit Format Search Options Tools R View Window Web Help

Close preferred Rgui
Server (connections and tests)
Customize
Configure
Send to R
Editor: current line to top
Controlling R
Hotkeys of R (system)
Database

AccuPAR_LAI_SD.r* FireAnalysis.R fancyaxis.R

```
120
121 #plot lai vs. ndvi with xy error bar
122 LAIsummary=read.csv("c:/work/spectra/
123 par(mfrow=c(1,1),mai=c(0.8,1,0.05,0)
124     #1m measurements
125     plot(LAIsummary$LAImean_m,LAIsumm
    c(-.1,4),xlab="Leaf Area Index - 1 me
    axis=1.5,bty="n")
126     plotCI(LAIsummary$LAImean_m,LAIsu
    NDVIsd,err="y",sfrac=0.005,gap=0,add=T,barcol=grey(.5),pch=16)
127     plotCI(LAIsummary$LAImean_m,LAIsummary$NDVImean,uiw=LAIsummary$
    LAIsd_m,err="x",sfrac=0.005,gap=0,add=T,barcol=grey(.5),pch=16,col="
    red")
128
129     #Ground measurements
130     plot(LAIsummary$LAImean,LAIsummary$NDVImean,ylim=c(0.1,.9),xlim=c(
    -.1,4),xlab="Leaf Area Index - Ground",ylab="NDVI",cex.lab=1.5,cex.
```

Computer Project Tags R card R explorer

Basic and help
Data (creation)
Data (load, read, write and save)
Data (selection and manipulation)
Dates and times
Distributions

array(x, dim=)
c(...)
cbind(...)
data.frame(...)

Create a data frame of the named or unnamed arguments; data.frame(v=1:4, ch=c('a', 'b', 'c', 'd'), n=10); shorter vectors are recycled to the length of the longest

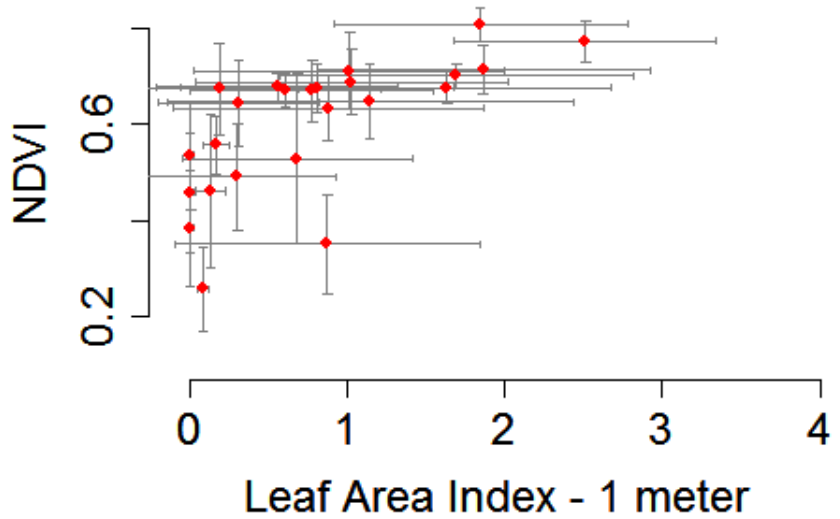
Search Spell R output

Lin 127/161: Col 13 | Normal mode | smNormal | Size: 7.77 KB | Tinn-R hotkeys active

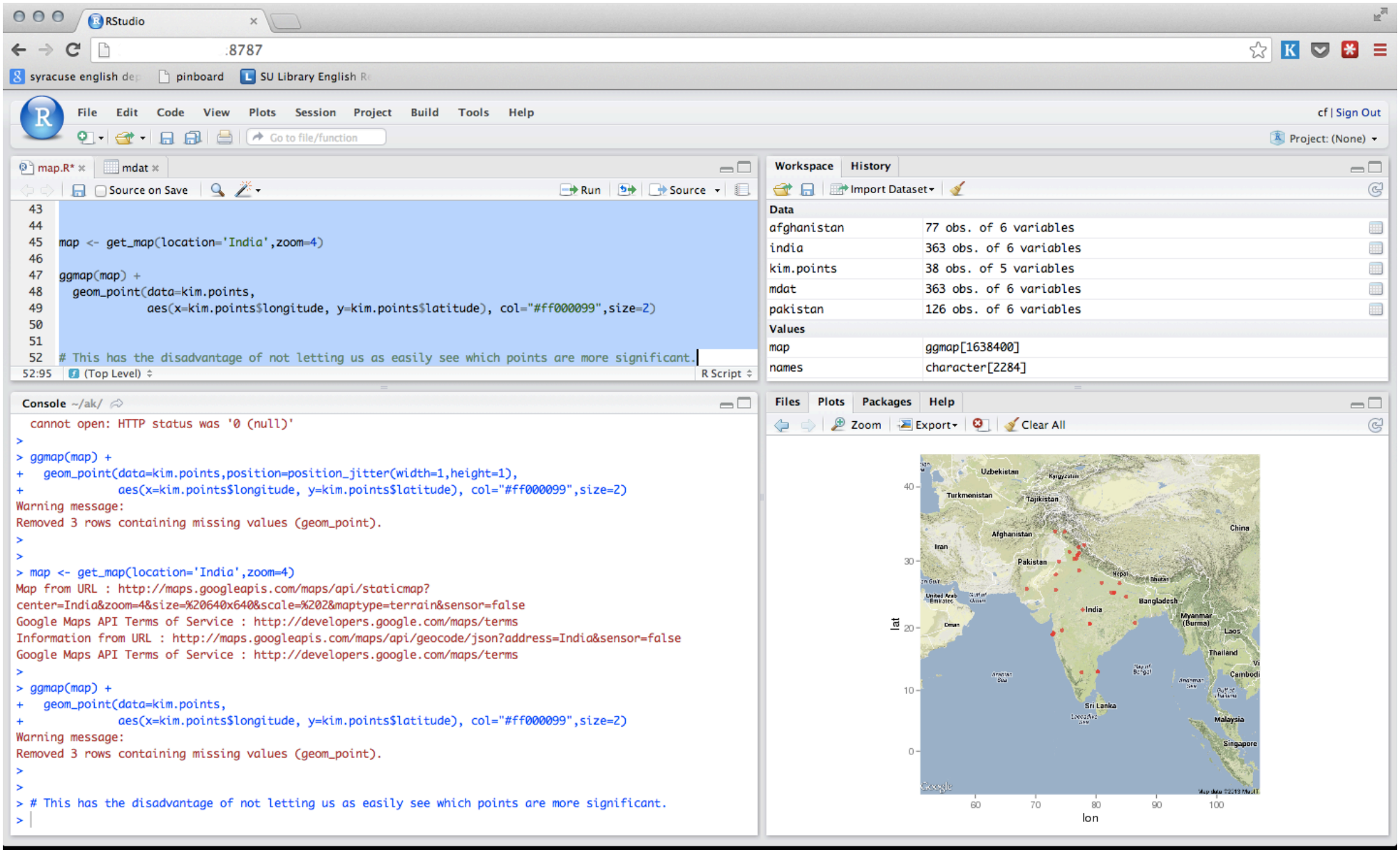
R Console

File Edit Misc Packages Help

```
>     plotCI(LAIsummary$LAImean_m,LAIsummary$NDVImean,uiw=LAIsummary$NDVIsd,e$
>     plotCI(LAIsummary$LAImean_m,LAIsummary$NDVImean,uiw=LAIsummary$LAIsd_m,$
>
>     plot(LAIsummary$LAImean_m,LAIsummary$NDVImean,ylim=c(0.1,.9),xlim=c(-.1$
>     plotCI(LAIsummary$LAImean_m,LAIsummary$NDVImean,uiw=LAIsummary$NDVIsd,e$
>     plotCI(LAIsummary$LAImean_m,LAIsummary$NDVImean,uiw=LAIsummary$LAIsd_m,$
>
>     plot(LAIsummary$LAImean_m,LAIsummary$NDVImean,ylim=c(0.1,.9),xlim=c(-.1$
>     plotCI(LAIsummary$LAImean_m,LAIsummary$NDVImean,uiw=LAIsummary$LAIsd_m,$
>     plot(LAIsummary$LAImean_m,LAIsummary$NDVImean,ylim=c(0.1,.9),xlim=c(-.1$
>     plotCI(LAIsummary$LAImean_m,LAIsummary$NDVImean,uiw=LAIsummary$NDVIsd,e$
>     plotCI(LAIsummary$LAImean_m,LAIsummary$NDVImean,uiw=LAIsummary$LAIsd_m,$
>
```

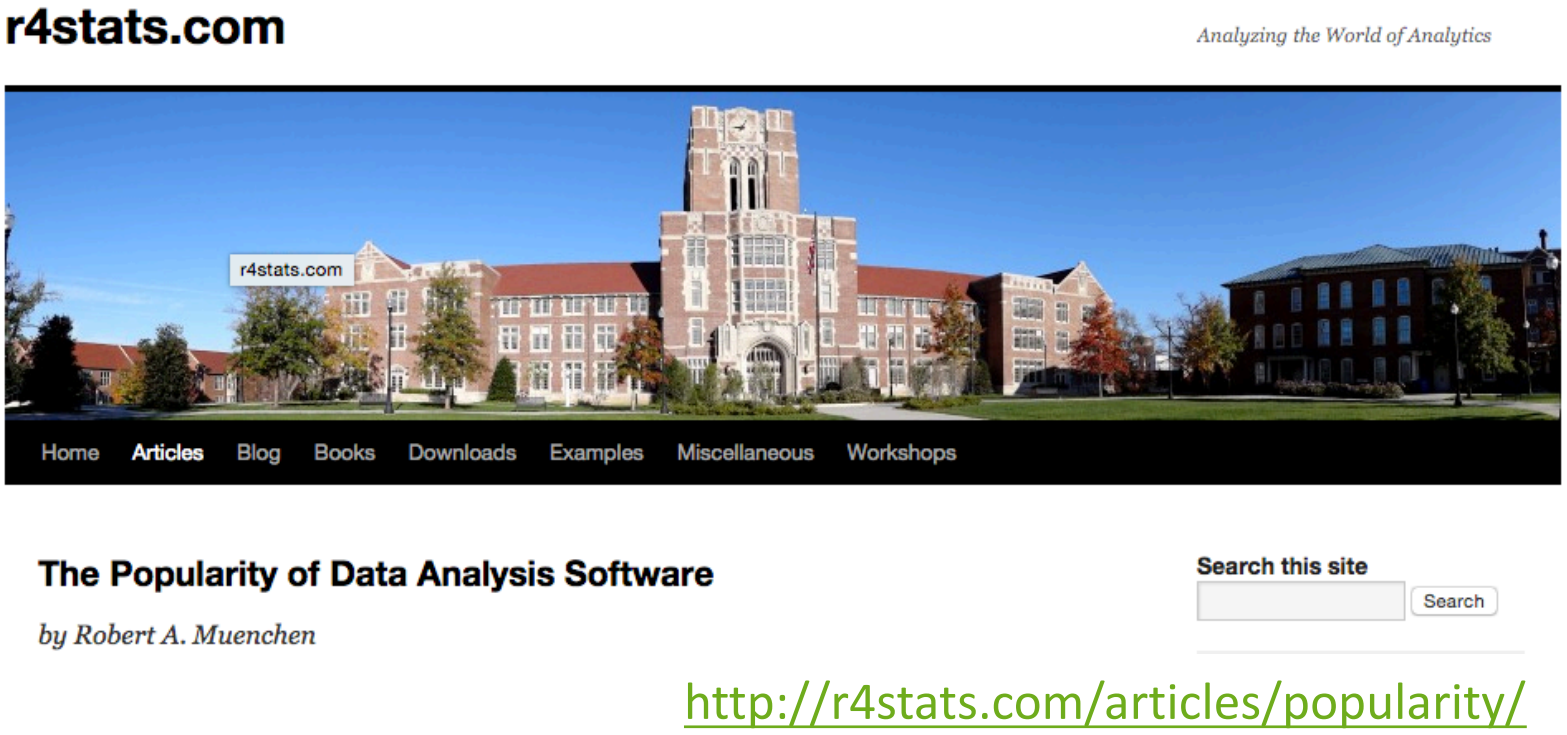


RStudio



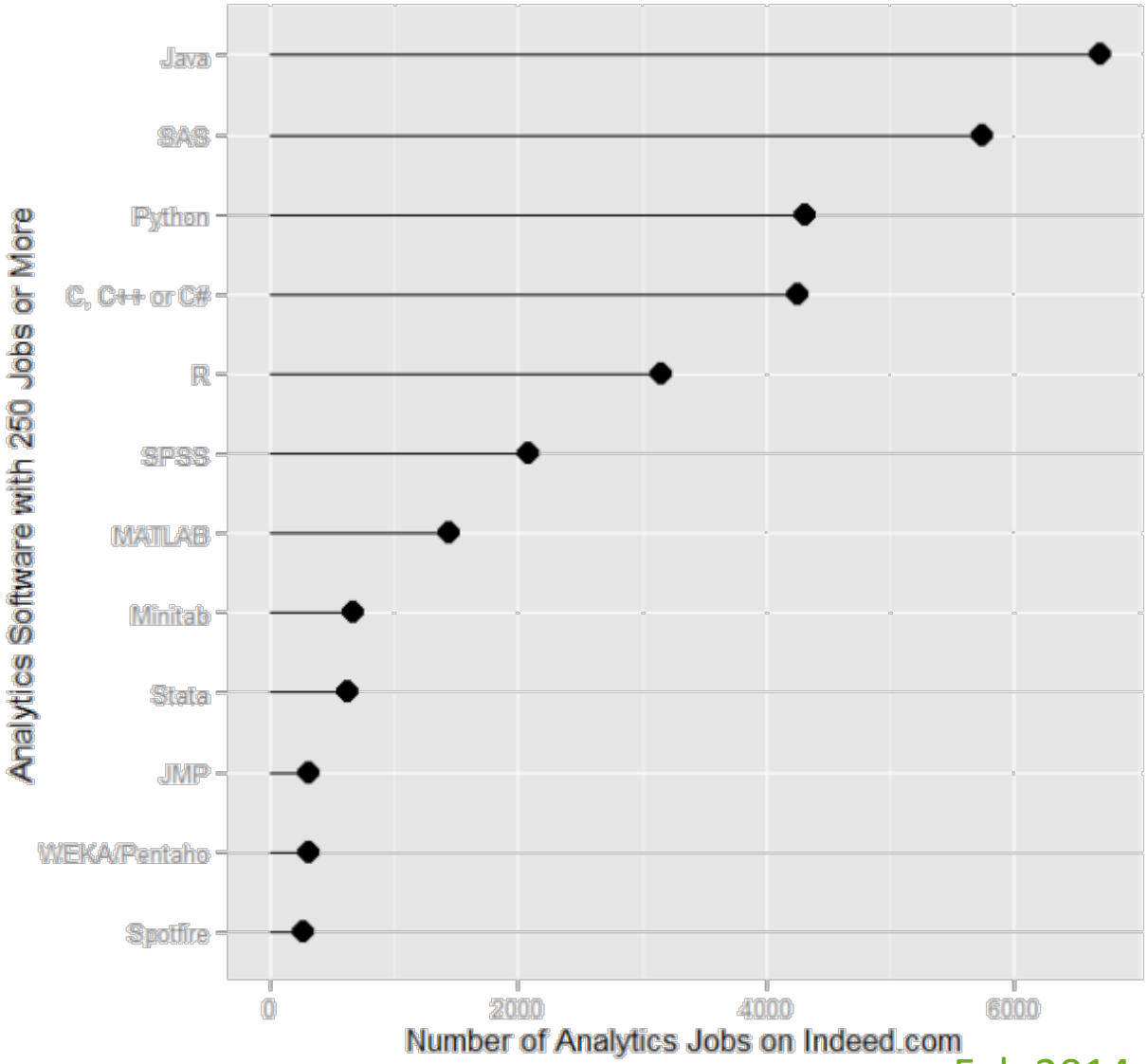
Mac, Windows, Linux, and over the web…

Who uses R?



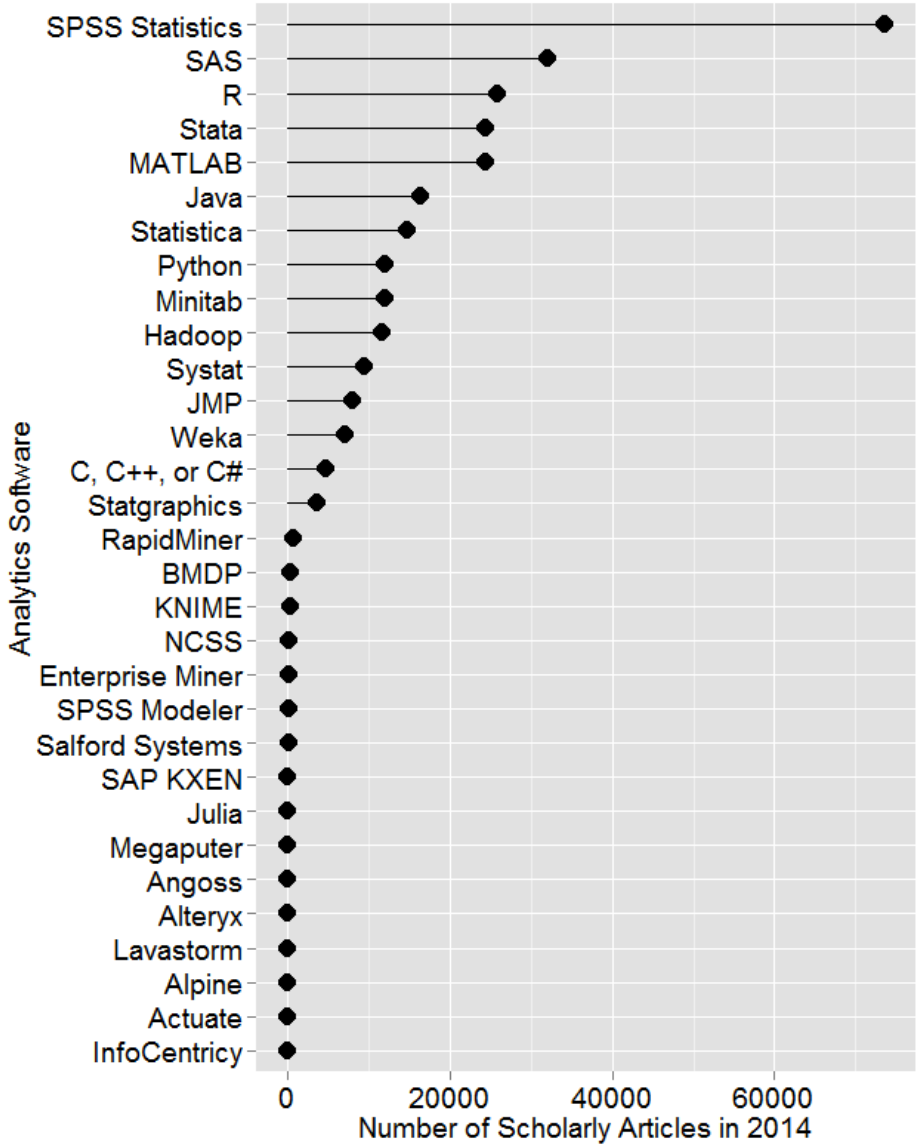
http://r4stats.com/articles/popularity/

“Analytics” Jobs on indeed.com



Feb 2014: http://r4stats.com/articles/popularity/

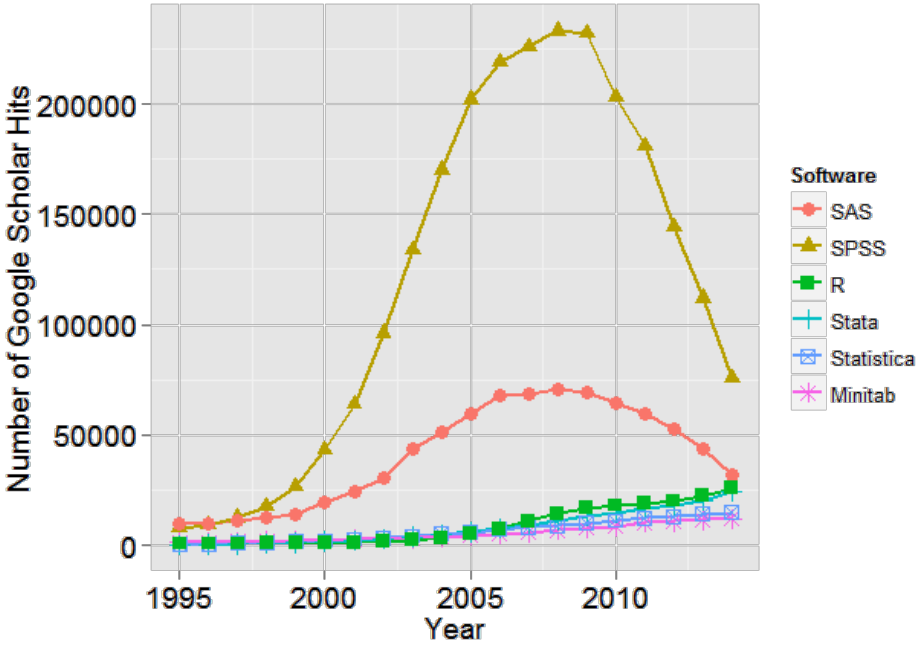
Scholarly articles by software package



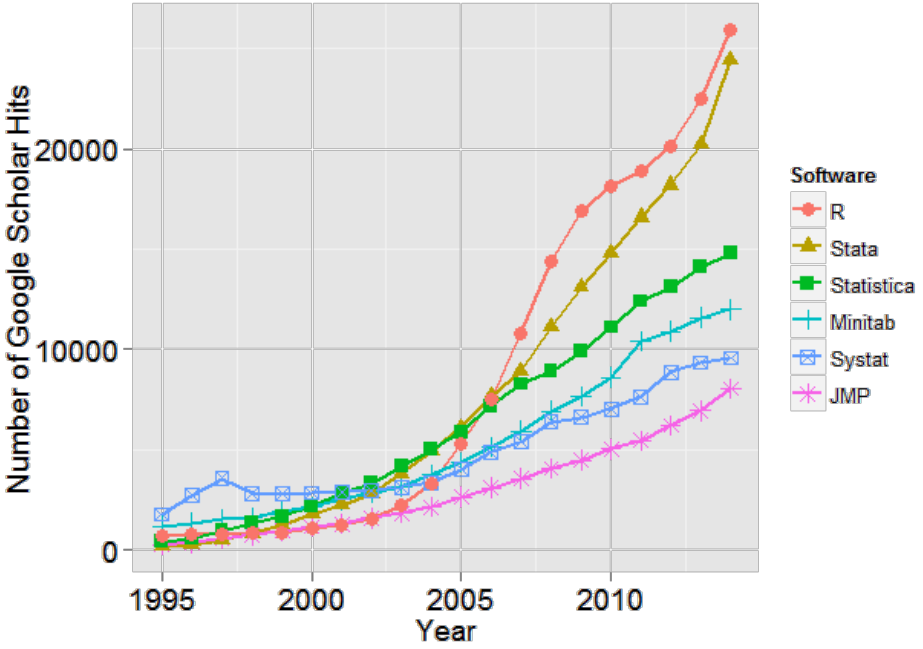
Number of scholarly articles found in the most recent complete year (2014) for each software package used as a topic or tool of analysis. For methods see here.

http://r4stats.com/articles/popularity/

Change in scholarly articles



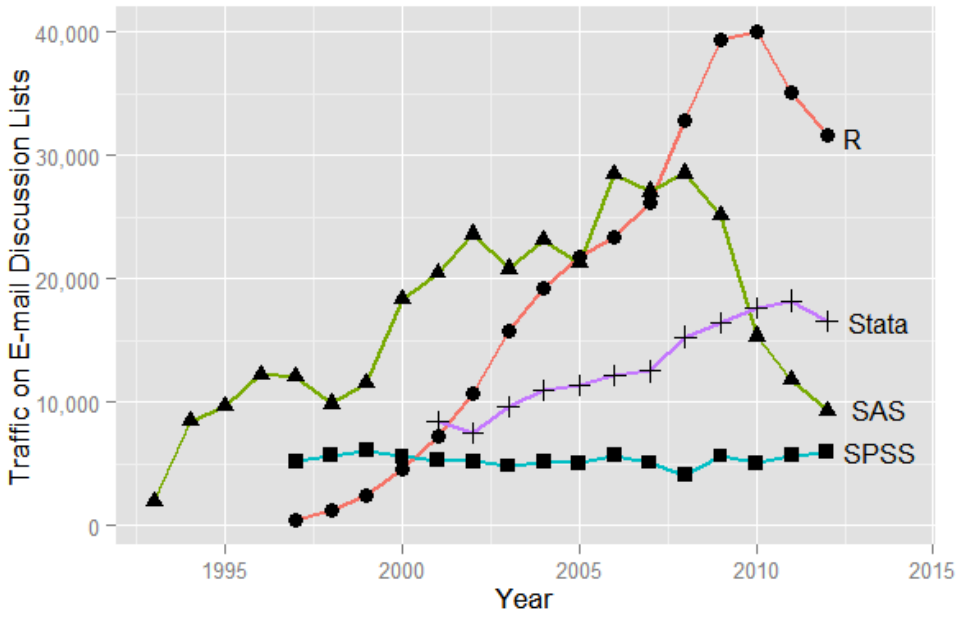
The number of scholarly articles found in each year by Google Scholar. Only the top six “classic” statistics packages are shown.



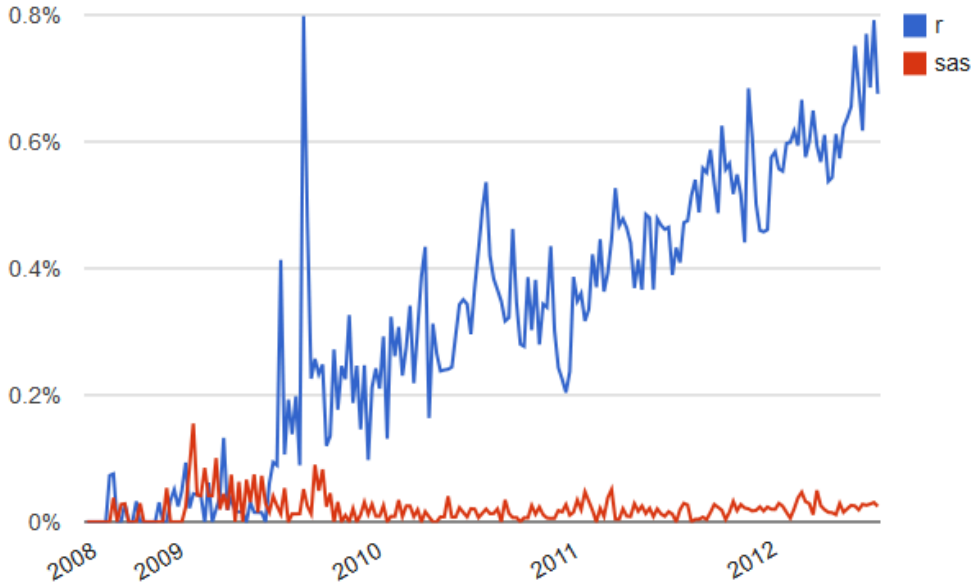
The number of scholarly articles found in each year by Google Scholar (excluding SAS and SPSS).

http://r4stats.com/articles/popularity/

Forum/discussion activity



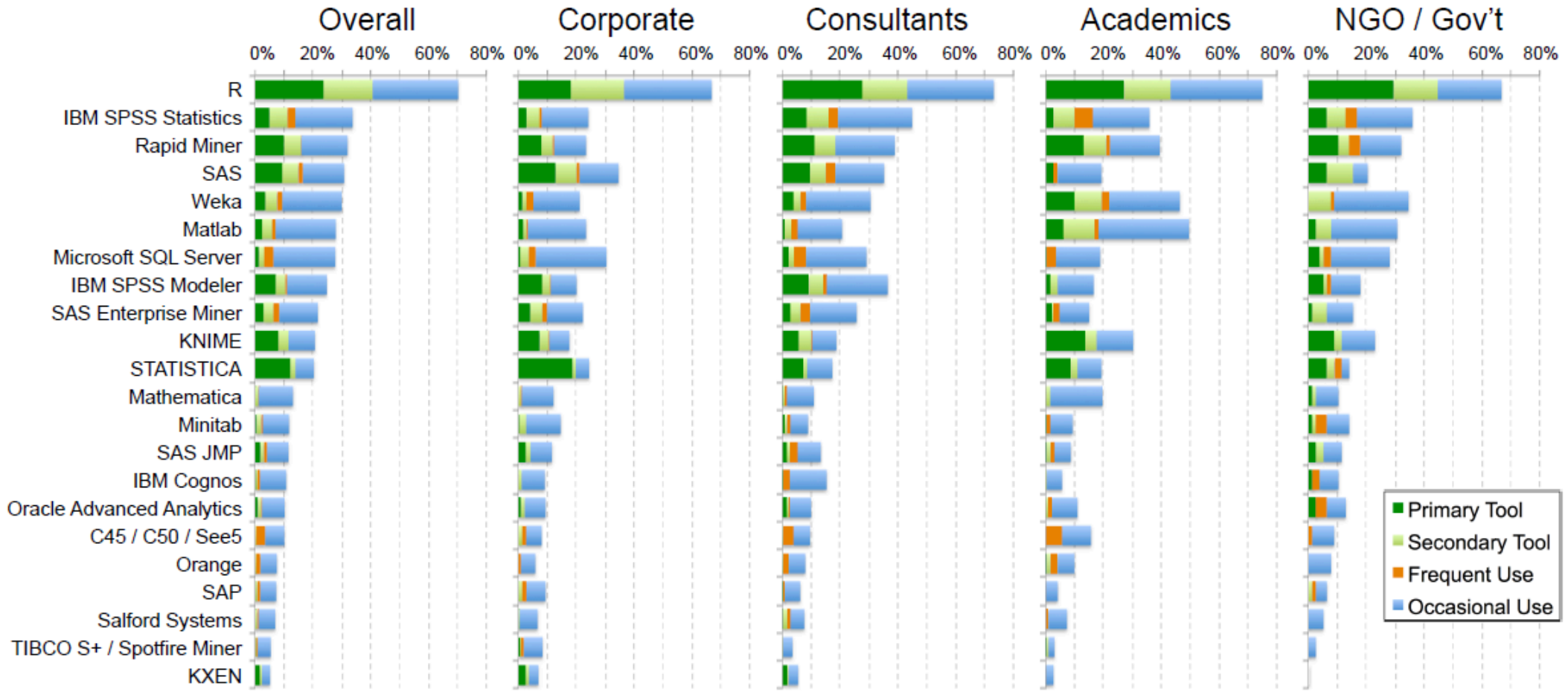
Sum of monthly email traffic on each software's main listserv discussion list.



Number of R- or SAS-related posts to Stack Overflow (programming and statistical topics) by week.

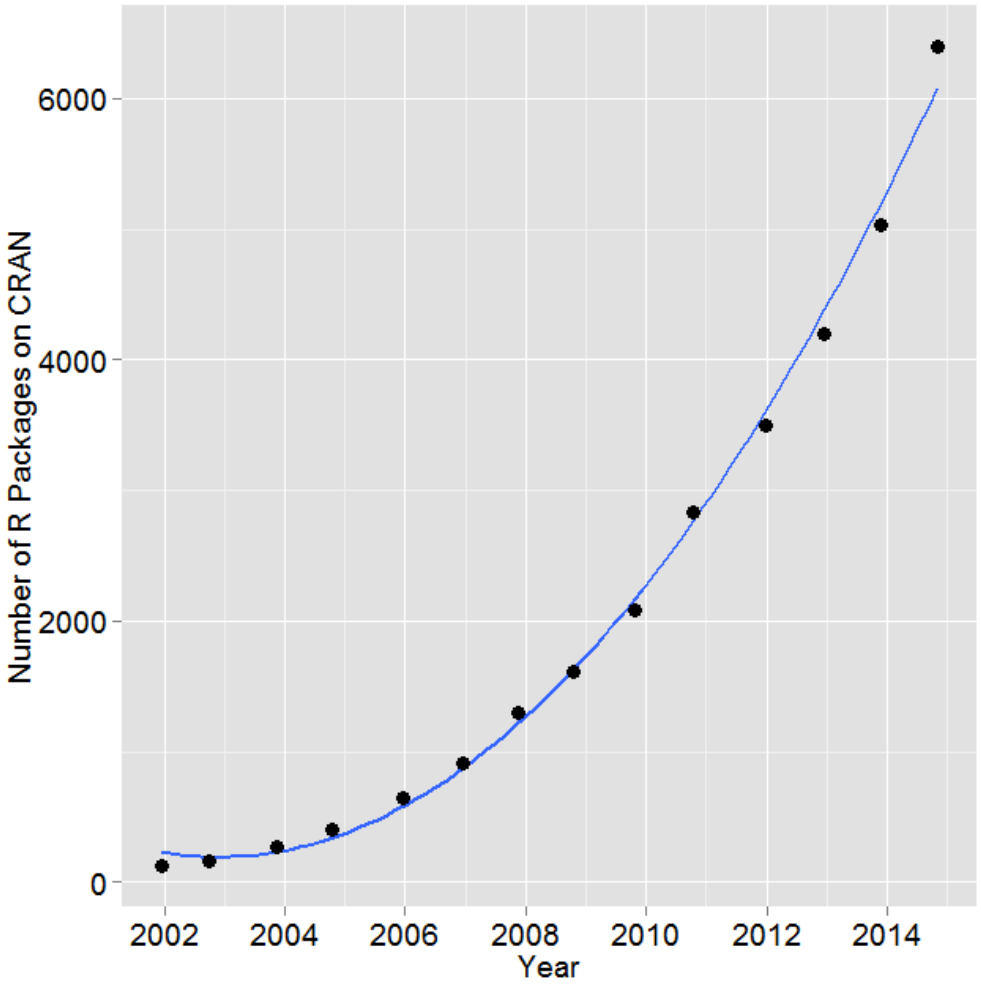
http://r4stats.com/articles/popularity/

Rexer Analytics *Data Miner* Survey (2013)



~1.2k respondents http://r4stats.com/articles/popularity/

R Development



Number of R packages available on its main distribution site for the last version released in each year.

SAS v9.3: 1.2k commands
(in Base, Stat, ETS, HP Forecasting, Graph, IML, Macro, OR, QC.)

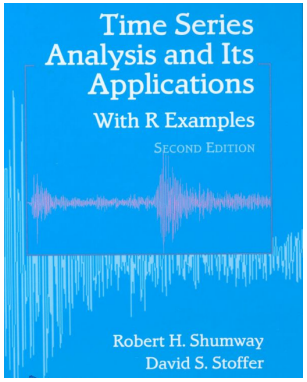
2014: R added 1.3k packages and ~27k functions.

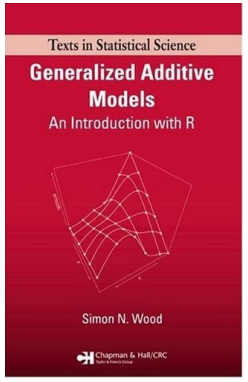
http://r4stats.com/articles/popularity/

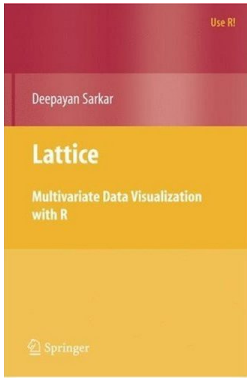
Over 6k packages!

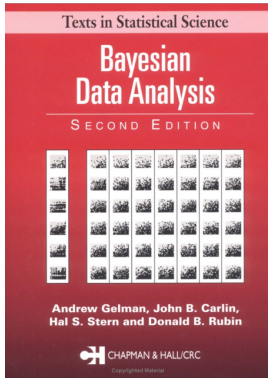
Task Views organize packages by topic: http://cran.r-project.org/web/views/

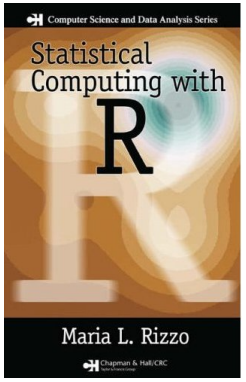
240 Books on R since 2000

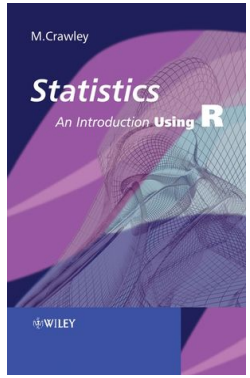


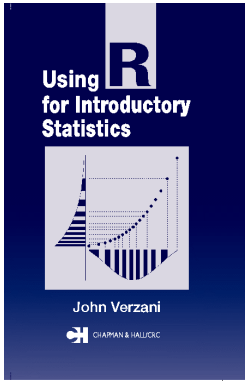


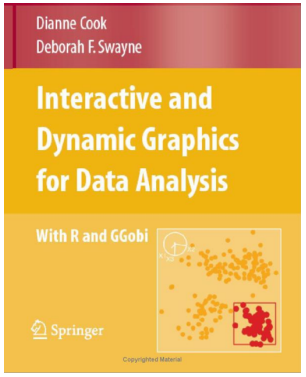


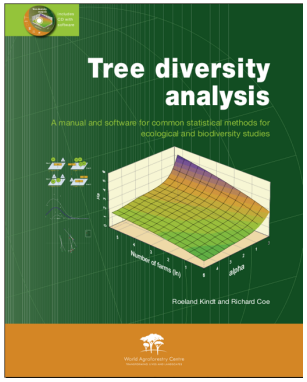


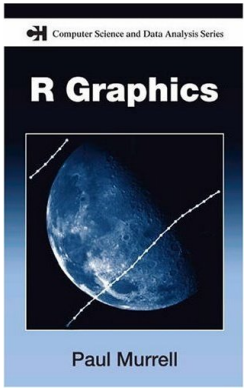


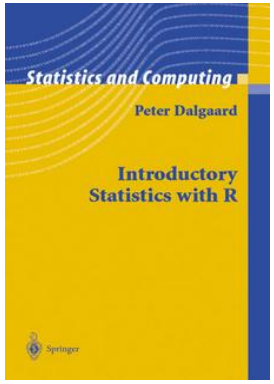


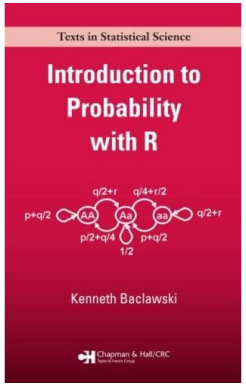


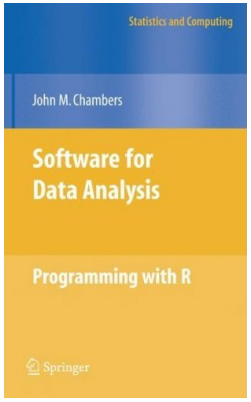


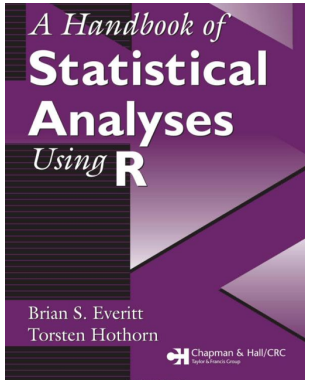


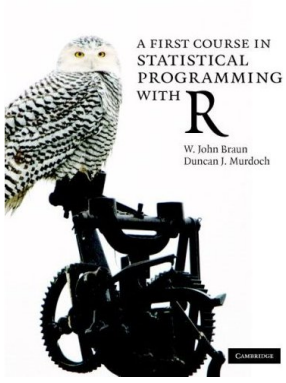


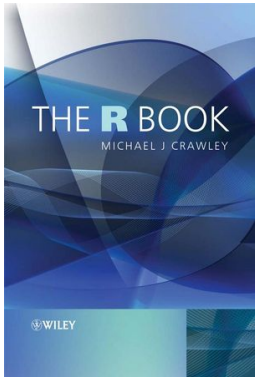


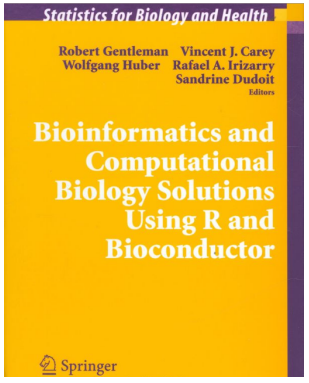








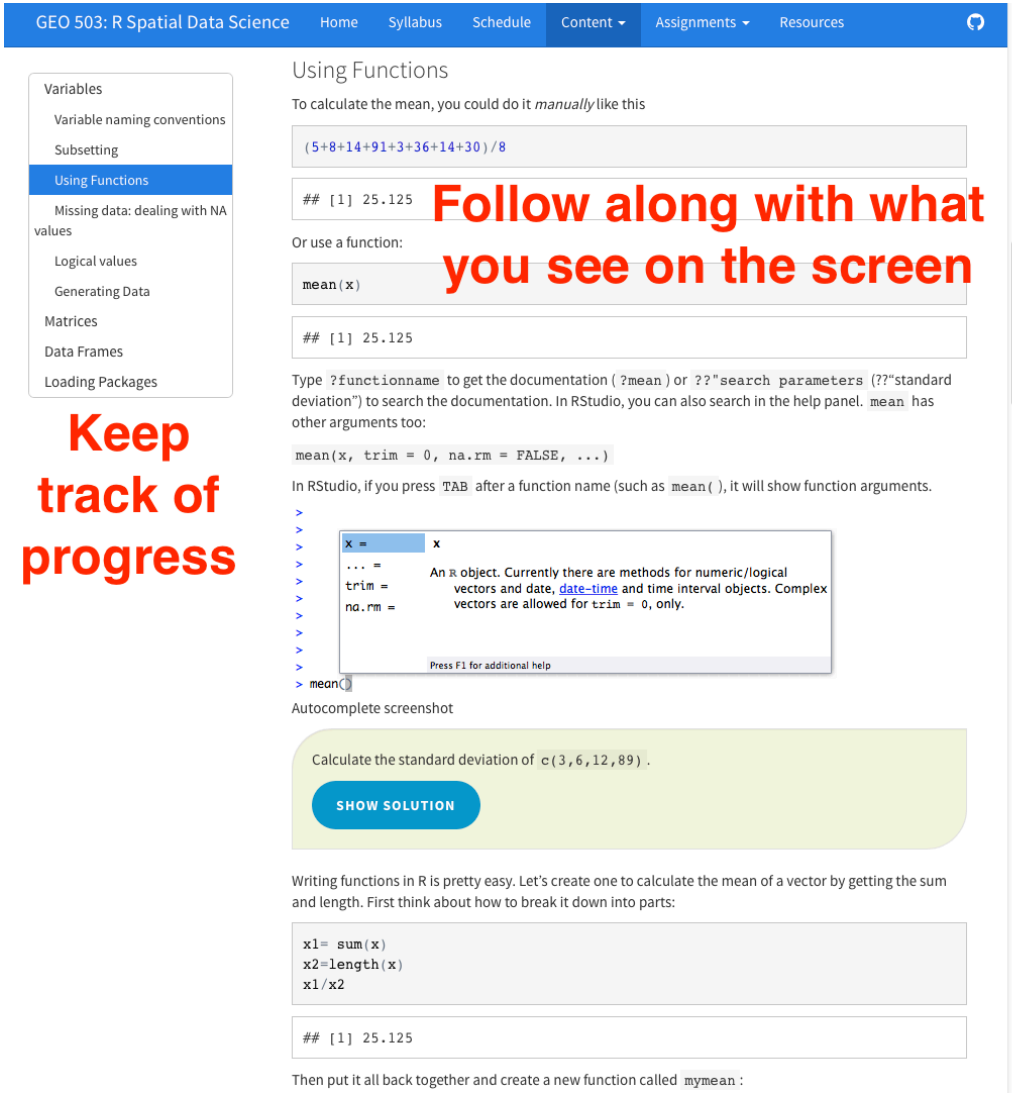


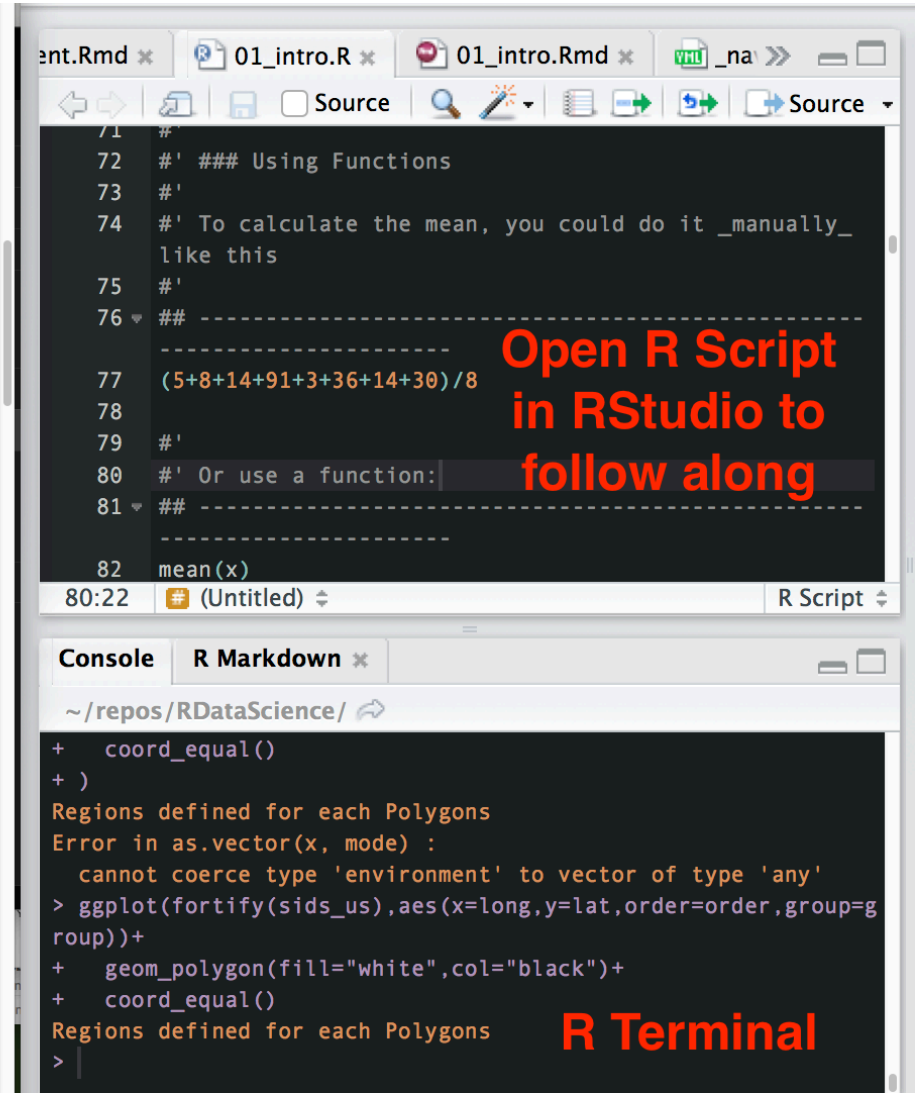


Course Logistics

Course Participation	10%
Package Presentation	10%
Homeworks	30%
Final Project	50%

Course Participation (10%)





Package Introduction (10%)

Each student will be expected to introduce a R package (or two) that is relevant to their research interests in a 5 minute presentation during a class session. The objectives are:

- Learn how to find/download/install a new package and learn how to use it
- Teach your peers about useful R packages

The presentation must include:

- What does the package do? (**1-2 slides, 1 minute**)
- Author introduction (**1 slide, 1 minute**)
- Simple demonstration (**2-3 slides, 3 minutes**)

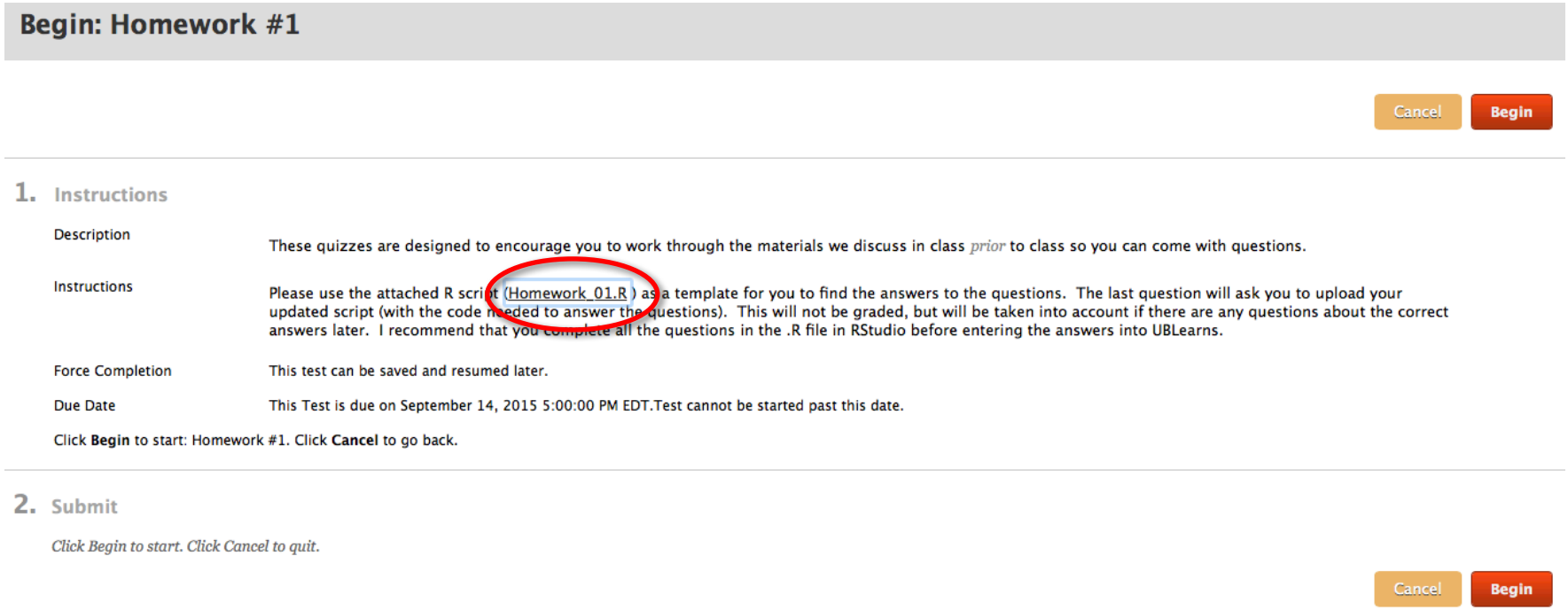
Homework (30%)

```
#' ## Question 1
#' Load the iris dataset by running
## ------------------------------------------------------------------------
data(iris)

#' And read about the dataset in the documentation:
## ------------------------------------------------------------------------
?iris

#'
#' > How many observations (rows) are there for the versicolor species?
#'
#' _____
#'
#' ## Question 2
#' Create a vector with the following values:  23, 45, 12, 89, 1, 13, 28, 18.  Then multiply each element of the vector by 15.
#'
#' > What is the standard deviation of the new vector?
#'
```

Homework submitted in UBlearns



Begin: Homework #1

Cancel Begin

1. Instructions

Description	These quizzes are designed to encourage you to work through the materials we discuss in class *prior* to class so you can come with questions.
Instructions	Please use the attached R script (Homework_01.R) as a template for you to find the answers to the questions. The last question will ask you to upload your updated script (with the code needed to answer the questions). This will not be graded, but will be taken into account if there are any questions about the correct answers later. I recommend that you complete all the questions in the .R file in RStudio before entering the answers into UBLearns.
Force Completion	This test can be saved and resumed later.
Due Date	This Test is due on September 14, 2015 5:00:00 PM EDT.Test cannot be started past this date.

Click **Begin** to start: Homework #1. Click **Cancel** to go back.

2. Submit

Click Begin to start. Click Cancel to quit.

Cancel Begin

Working collaboratively is encouraged but you are responsible for developing your own code to answer the questions:

Acceptable: “which functions did you use to answer #4?”
Unacceptable:“please email me your code for #4.”

Homework format

Take Test: Homework #1

Test Information

Description	These quizzes are designed to encourage you to work through the materials we discuss in class *prior* to class so you can come with questions.
Instructions	Please use the attached R script (Homework_01.R) as a template for you to find the answers to the questions. The last question will ask you to upload your updated script (with the code needed to answer the questions). This will not be graded, but will be taken into account if there are any questions about the correct answers later. I recommend that you complete all the questions in the .R file in RStudio before entering the answers into UBLearns.
Multiple Attempts	Not allowed. This test can only be taken once.
Force Completion	This test can be saved and resumed later.

Question Completion Status:

Save All Answers | Save and Submit

Question 1 — 1 points — Save Answer

Load the `iris` dataset by running `data(iris)`. How many observations (rows) are there for the versicolor species?

Question 2 — 1 points — Save Answer

Create a vector with the following values:

23, 45, 12, 89, 1, 13, 28, 18

Then multiply each element of the vector by 15. What is the standard deviation of the new vector?

Final Project – Poster / Infographic (50%)

1. Title (<25 words)
2. Introduction [~ 150 words]
3. Materials and methods [~ 150 words]
4. Results [~200 words]
5. Conclusions [~200 words]
6. References
7. And all code to reproduce the analysis!!

"*It takes intelligence, even brilliance, to condense and focus information into a clear, simple presentation that will be read and remembered. Ignorance and arrogance are shown in a crowded, complicated, hard-to-read poster.*"

-- Mary Helen Briscoe

METRICS

AMY SCHOENFELD

Keeping Tabs on the $700 Billion Bailout

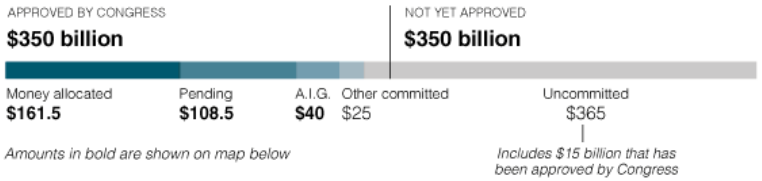
The Treasury Department's $700 billion buttress to the financial system was expected to enable banks to make more loans to companies and consumers.

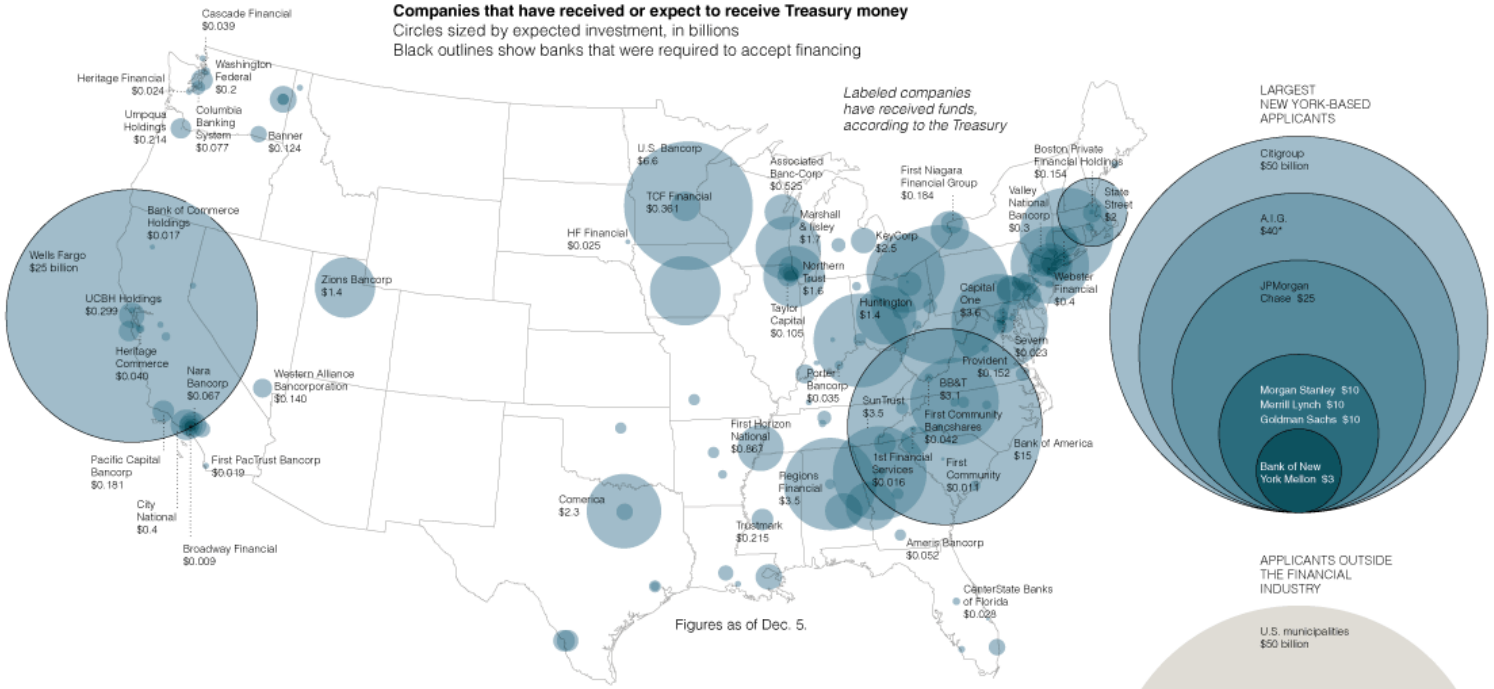
But the Treasury has indicated that the 52 banks already funded by the program have mostly used their investments — $161.5 billion so far — to bolster their balance sheets at a time when options for raising capital are slim. And analysts expect that the more than 100 banks that have yet to receive money will be similarly cautious.

Treasury Secretary Henry M. Paulson Jr. has acknowledged that "lending won't materialize as fast as any of us would like," but has said that loans will begin to flow as confidence returns.

Some analysts agree. "In a few quarters, banks should be comfortable enough to begin to put that new capital to work," said Mark Fitzgibbon, a banking analyst at Sandler O'Neill & Partners.

But regulators will have to keep a watchful eye on banks, say officials in the Government Accountability Office. In a report released on Thursday, the office urged the Treasury to increase its oversight of the program, as banks are not currently required to report on their use of government dollars.





The Biggest Nine

On Oct. 14, the Treasury required nine financial firms to accept a total of $125 billion. This kicked off the first half of the Treasury's $250 billion recapitalization program. The government also chose to invest $40 billion in the insurance giant A.I.G. in early November.

The Bank Tally

More than 160 banks have voluntarily applied for the program's remaining money. A third to a half have received money. But some applicants, like HopFed Bancorp in Kentucky, are weighing the drawbacks of participation, like limits on dividend payments, stock buyback programs and executive compensation.

Insurers and Others Jump In

The Treasury has allowed nonbanks to apply for money. Insurers like The Hartford, Protective Life and Lincoln National, as well as the credit card company American Express, have chosen this path, but none have received financing yet.

Outsiders Wait

Philadelphia, Atlanta and Phoenix asked the Treasury in November to provide $50 billion to help cities throughout the country. The Treasury has agreed to discuss the plan later this month. G.M., Ford and Chrysler offered plans to Congress last week for $34 billion in loans.

*Under other programs, the government has invested $53 billion in A.I.G. and has provided the company with $60 billion in loans.

Sources: Treasury; companies; Bloomberg; Sandler O'Neill & Partners; American Bankers Association

THE NEW YORK TIMES

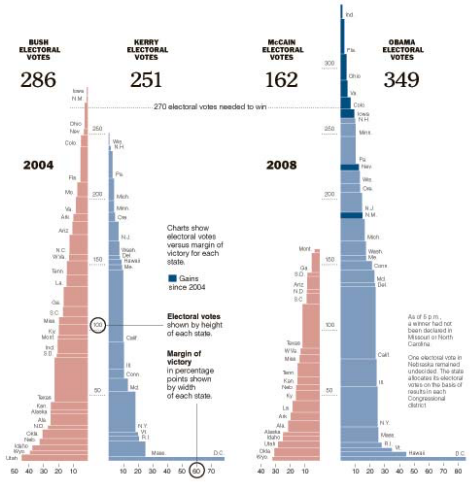
In a Decisive Victory, Obama Reshapes the Electoral Map

Barack Obama's historic win, with at least 349 electoral votes to John McCain's 162, can be attributed to his victories in several high-population states, like Florida, Virginia and Ohio, that George W. Bush won handily in 2004.

The struggling economy, especially in more industrial states, and high numbers of new voters helped flip key areas from red to blue.

Even where Mr. McCain beat Mr. Obama, he won by slimmer margins, as much of the electorate — across age, race and income lines — swung toward the Democratic Party.

By Erin Aigner, Joe Burgess, Baden Copeland, Matthew Ericson, Hannah Fairfield, Ford Fessenden, Haeyoun Park and Archie Tse

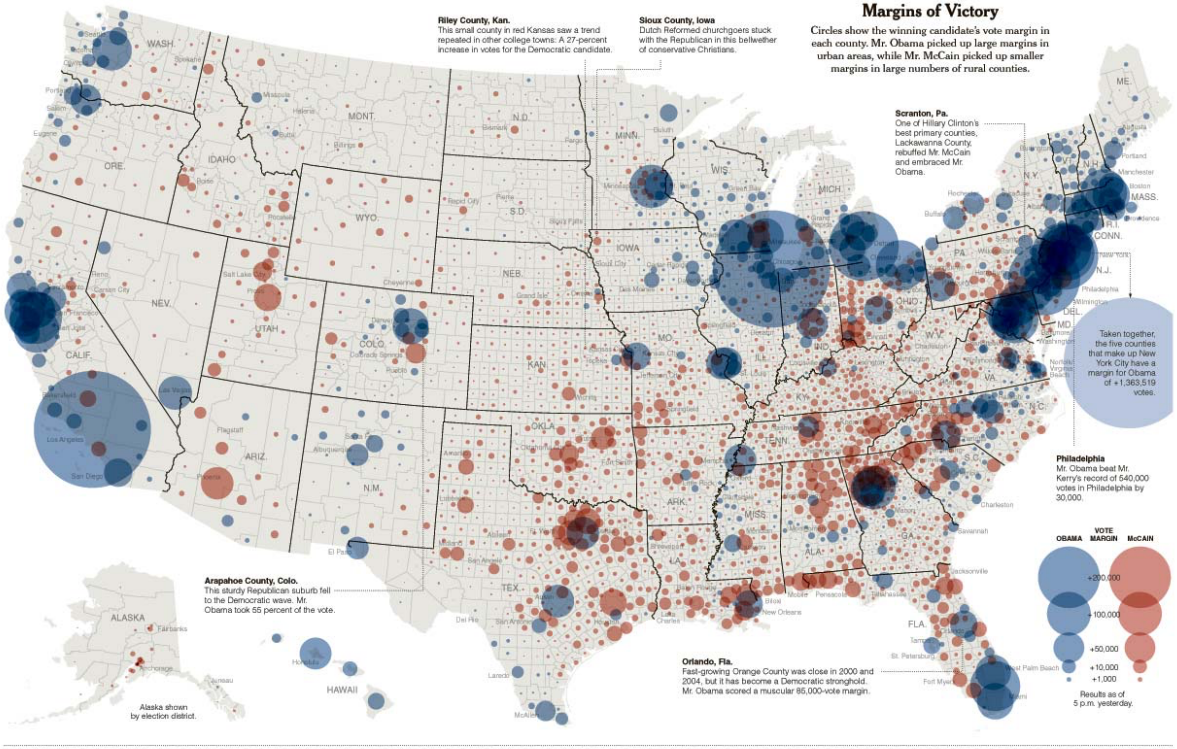


Results as of 5 p.m.

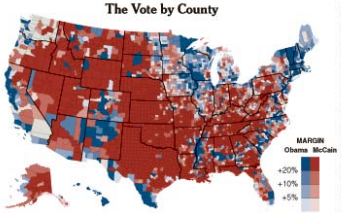
	Pct. of districts reporting	Barack Obama DEMOCRAT		John McCain REPUBLICAN		Margin (PCT. POINTS) 2008	2004	MARGIN CHANGE FROM 2004 State voted more ◄Democratic | Republican►	Electoral votes
States won by Obama									**349**
Hawaii	100%	296,621	72%	110,848	27%	+45	+ 9	+36	4
Indiana	100%	1,367,264	50%	1,341,101	49%	< 1	+21	+22	11
Delaware	100%	247,386	61%	151,667	38%	+24	+ 8	+16	3
New Mexico	100%	452,039	57%	392,979	42%	+15	< 1	+16	5
Vermont	97%	201,999	67%	95,422	32%	+35	+20	+15	3
Nevada	100%	531,884	55%	411,988	43%	+12	+ 3	+15	5
Illinois	100%	3,293,340	62%	1,975,801	37%	+25	+10	+14	21
California	97%	6,179,542	61%	3,738,444	37%	+24	+10	+14	55
Michigan	100%	2,867,680	57%	2,044,405	41%	+16	+ 3	+13	17
Virginia	99%	1,792,502	52%	1,637,337	47%	+ 4	+ 8	+13	13
Wisconsin	100%	1,633,117	56%	1,251,653	43%	+13	< 1	+13	10
Colorado	92%	1,109,328	53%	966,957	46%	+ 7	+ 5	+11	9
Connecticut	98%	943,819	60%	606,268	39%	+22	+10	+11	7
Maryland	99%	1,409,150	61%	873,920	38%	+23	+13	+10	10
Iowa	100%	818,240	54%	677,506	45%	+ 9	< 1	+10	7
Washington	58%	960,226	57%	690,352	41%	+16	+ 7	+ 9	11
Oregon	70%	695,695	55%	532,078	42%	+13	+ 4	+ 9	7
New Hampshire	92%	355,901	55%	290,944	45%	+10	+ 1	+ 9	4
Maine	92%	390,147	58%	271,876	40%	+18	+ 9	+ 9	4
New Jersey	100%	2,073,934	57%	1,540,907	42%	+15	+ 7	+ 8	15
Pennsylvania	100%	3,184,807	55%	2,584,119	44%	+10	+ 3	+ 8	21
Rhode Island	98%	275,028	63%	152,197	35%	+28	+21	+ 8	4
Florida	100%	4,103,638	51%	3,908,736	48%	+ 2	+ 5	+ 7	27
New York	99%	4,357,360	62%	2,573,368	37%	+25	+18	+ 7	31
Minnesota	100%	1,573,246	54%	1,275,653	44%	+10	+ 3	+ 7	10
D.C.	100%	210,403	93%	14,821	7%	+86	+80	+ 6	3
Ohio	98%	2,667,468	51%	2,461,198	47%	+ 4	+ 2	+ 6	20
Massachusetts	100%	1,890,183	62%	1,104,086	36%	+26	+25	+ 1	12
States won by McCain									**162**
North Dakota	100%	141,113	45%	168,523	53%	+ 9	+27	+19	3
Nebraska	100%	315,913	41%	439,421	57%	+16	+33	+17	4
Montana	100%	220,401	47%	236,513	50%	+ 3	+21	+17	3
Utah	100%	301,771	34%	555,497	63%	+29	+46	+17	5
South Dakota	100%	170,977	45%	202,999	53%	+ 8	+21	+13	3
Idaho	100%	235,709	36%	402,096	62%	+25	+38	+13	4
Georgia	99%	1,811,196	47%	2,022,409	52%	+ 5	+17	+11	15
Texas	100%	3,521,164	44%	4,467,748	56%	+12	+23	+11	34
Kansas	100%	499,863	41%	685,414	57%	+15	+25	+10	6
South Carolina	100%	842,441	45%	1,008,727	54%	+ 9	+17	+ 8	8
Wyoming	100%	80,496	33%	160,639	65%	+33	+40	+ 7	3
Mississippi	100%	517,899	43%	554,475	56%	+14	+20	+ 6	6
Alabama	100%	811,510	39%	1,263,741	60%	+22	+26	+ 4	9
Kentucky	100%	746,510	41%	1,043,264	57%	+16	+20	+ 4	8
Arizona	99%	851,589	45%	1,012,878	54%	+ 9	+10	+ 2	10
Alaska	99%	80,340	36%	136,348	62%	+25	+26	< 1	3
Oklahoma	100%	502,286	34%	959,645	66%	+31	+31	< 1	7
West Virginia	100%	301,438	43%	394,278	56%	+13	+13	< 1	5
Tennessee	100%	1,081,074	42%	1,470,160	57%	+15	+14	+ 1	11
Louisiana	100%	780,981	40%	1,147,603	59%	+19	+15	+ 4	9
Arkansas	98%	417,314	39%	632,140	59%	+20	+10	+10	6
No winner called									**27**
Missouri	100%	1,436,745	49%	1,442,613	49%		+ 7		11
North Carolina	100%	2,115,854	50%	2,102,761	50%		+12		15
TOTAL	**98%**	**63,668,432**	**53%**	**56,255,927**	**47%**		< 1		**538**

Margins of Victory

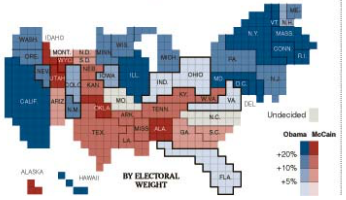
Circles show the winning candidate's vote margin in each county. Mr. Obama picked up large margins in urban areas, while Mr. McCain picked up smaller margins in large numbers of rural counties.



The Vote by County



Two Views of the Electoral Vote



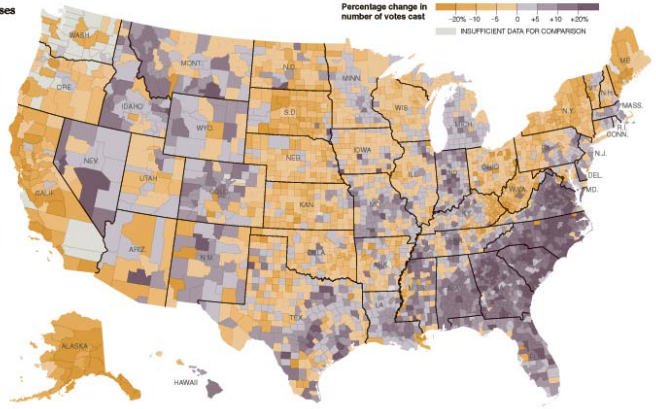
New Voters, New Power Bases

Mr. Obama's campaign theme of change created a groundswell of support in areas of the country hurt by the weakened economy. Rising unemployment and housing foreclosures in Rust Belt states, as well as Florida and Nevada, may have led voters to support Mr. Obama.

A powerful get-out-the-vote effort paid off for the Obama campaign in certain crucial states, like Florida, Colorado and Nevada. The number of people who voted in Florida rose by 9.7 percent from 2004. Many of those voters went to the polls for the first time — and those voters chose Mr. Obama nearly 70 percent of the time.

Voter figures were also high in states won by Mr. McCain, like South Carolina, Georgia and Alabama.

Turnout may have been a defining factor in Indiana, a battleground state that had 5.3 percent more voters than in 2004. It awarded a narrow victory, and its 11 electoral votes, to Mr. Obama.



Shifting Demographics

The electorate moved toward the Democratic Party across nearly every demographic category. Many shifts were a few percentage points, but several categories had much higher jumps. One exception to the trend: low-income white counties moved solidly toward the Republican side.

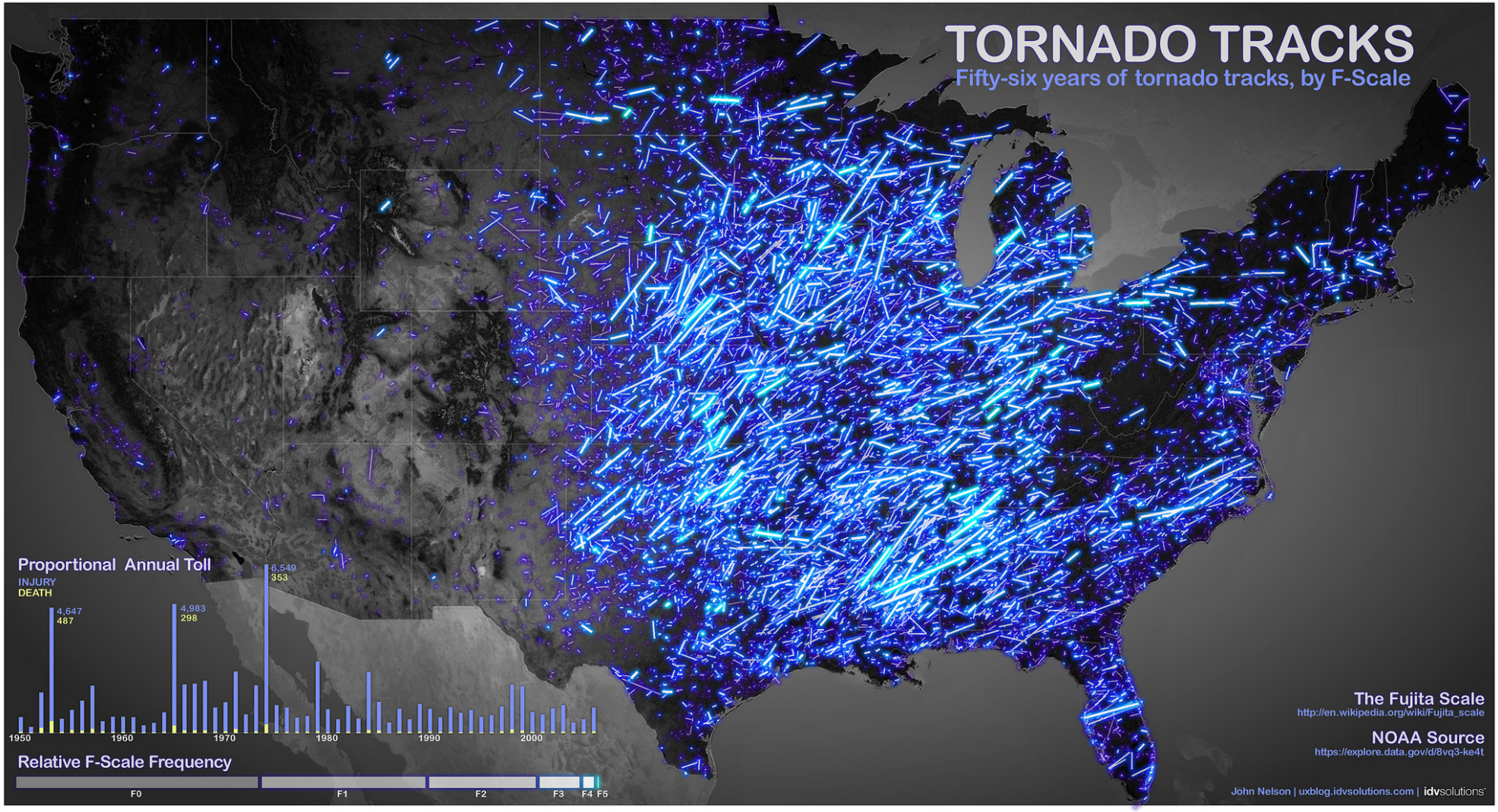
The 100 counties with the:		Change in presidential vote
Fastest population growth, '00-'07	2004 KERRY 37%	63% BUSH
	2008 OBAMA 43%	56% MCCAIN
Fastest population decline, '00-'07	2004 KERRY 55%	43% BUSH
	2008 OBAMA 56%	43% MCCAIN
Highest proportion college-educated	2004 KERRY 58%	41% BUSH
	2008 OBAMA 61%	38% MCCAIN
Lowest proportion college-educated	2004 KERRY 41%	58% BUSH
	2008 OBAMA 38%	61% MCCAIN
Highest proportion over age 65	2004 KERRY 40%	59% BUSH
	2008 OBAMA 43%	56% MCCAIN

The 100 counties with the:		Change in presidential vote
Highest proportion of Kerry voters in '04	2004 KERRY 70%	29% BUSH
	2008 OBAMA 75%	24% MCCAIN
Highest proportion of Bush voters in '04	2004 KERRY 15%	84% BUSH
	2008 OBAMA 19%	79% MCCAIN
Lowest income	2004 KERRY 52%	47% BUSH
	2008 OBAMA 56%	43% MCCAIN
Lowest income, 95%+ white	2004 KERRY 40%	59% BUSH
	2008 OBAMA 35%	63% MCCAIN
Highest income	2004 KERRY 49%	50% BUSH
	2008 OBAMA 54%	45% MCCAIN

Sources: Historical results from Dave Leip's Atlas of U.S. Presidential Elections; 2008 results from Associated Press

THE NEW YORK TIMES

Tornado Tracks



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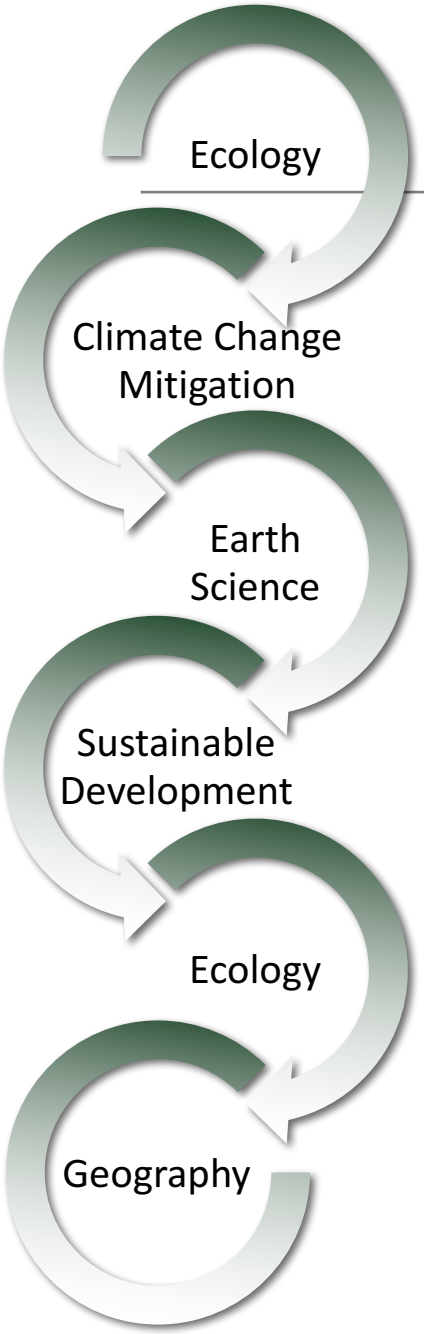
A little about me…



GRASS

python

Google earth engine
a google.org project

netCDF

git

NCO

R Studio

NASA Earth Exchange

And who are you?

1. Name
2. Where are you from (state and/or country)?
3. Department/Degree (e.g. MS GIS)
4. Research Interests
5. Motivation for taking this course (what do you want to learn?)

~1 minute each!

Before next class

1. No class next week (Labor Day)
2. Install RStudio on your laptop from https://www.rstudio.com
3. Read and work through the Introduction to R (link on website)