#### Data Visualization (CSCI 627/490)

Introduction

Dr. David Koop





### What is Data Visualization?









### How is it different from Computer Graphics?







### The purpose of computing is about insight, not numbers

D. Koop, CSCI 627/490, Spring 2025

#### – R. W. Hamming











# The purpose of visualization is about insight, not pictures

D. Koop, CSCI 627/490, Spring 2025

#### – B. Shneiderman











## Why do we visualize data? (vs. looking at tables?)







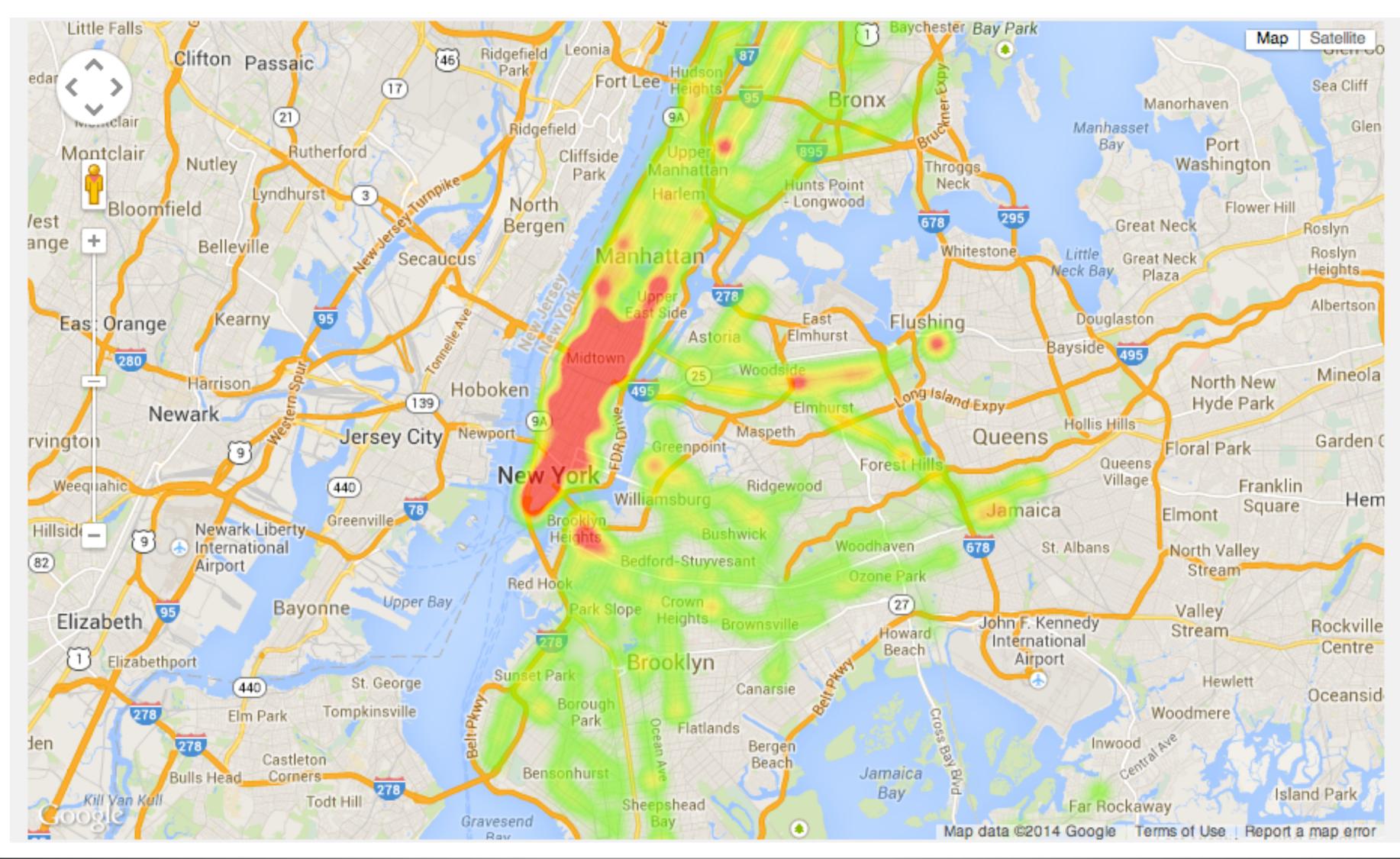
### MTA Fare Data Table

|      | REMOTE | STATION                     | FF V     | SEN/DIS  | 7-D AFAS UNL | D AFAS/RMF I | JOINT RR TKT | 7-D UNL  | 30-D UNL |
|------|--------|-----------------------------|----------|----------|--------------|--------------|--------------|----------|----------|
| 1 F  | R011   | 42ND STREET & 8TH AVENUE    | 00228985 | 00008471 | 00000441     | 00001455     | 00000134     | 00033341 | 0007125  |
| 2 F  | R170   | 14TH STREET-UNION SQUARE    | 00224603 | 00011051 | 00000827     | 00003026     | 00000660     | 00089367 | 00199843 |
| 3 F  | R046   | 42ND STREET & GRAND CENTRAL | 00207758 | 00007908 | 00000323     | 00001183     | 00003001     | 00040759 | 00096613 |
| 4 F  | R012   | 34TH STREET & 8TH AVENUE    | 00188311 | 00006490 | 00000498     | 00001279     | 00003622     | 00035527 | 00067483 |
| 5 F  | R293   | 34TH STREET - PENN STATION  | 00168768 | 00006155 | 00000523     | 00001065     | 00005031     | 00030645 | 00054376 |
| 6 F  | R033   | 42ND STREET/TIMES SQUARE    | 00159382 | 00005945 | 00000378     | 00001205     | 00000690     | 00058931 | 00078644 |
| 7 F  | R022   | 34TH STREET & 6TH AVENUE    | 00156008 | 00006276 | 00000487     | 00001543     | 00000712     | 00058910 | 00110460 |
| 8 F  | R084   | 59TH STREET/COLUMBUS CIRCLE | 00155262 | 00009484 | 00000589     | 00002071     | 00000542     | 00053397 | 0011396  |
| 9 F  | R020   | 47-50 STREETS/ROCKEFELLER   | 00143500 | 00006402 | 00000384     | 00001159     | 00000723     | 00037978 | 0009074  |
| 10 F | R179   | 86TH STREET-LEXINGTON AVE   | 00142169 | 00010367 | 00000470     | 00001839     | 00000271     | 00050328 | 0012525  |
| 11 F | R023   | 34TH STREET & 6TH AVENUE    | 00134052 | 00005005 | 00000348     | 00001112     | 00000649     | 00031531 | 0007504  |
| 12 F | R029   | PARK PLACE                  | 00121614 | 00004311 | 00000287     | 00000931     | 00000792     | 00025404 | 0006536  |
| 13 F | R047   | 42ND STREET & GRAND CENTRAL | 00100742 | 00004273 | 00000185     | 00000704     | 00001241     | 00022808 | 0006821  |
| 14 F | R031   | 34TH STREET & 7TH AVENUE    | 00095076 | 00003990 | 00000232     | 00000727     | 00001459     | 00024284 | 0003867  |
| 15 F | R017   | LEXINGTON AVENUE            | 00094655 | 00004688 | 00000190     | 00000833     | 00000754     | 00020018 | 0005506  |
| 16 F | R175   | 8TH AVENUE-14TH STREET      | 00094313 | 00003907 | 00000286     | 00001144     | 00000256     | 00038272 | 0007466  |
| 17 F | R057   | BARCLAYS CENTER             | 00093804 | 00004204 | 00000454     | 00001386     | 00001491     | 00039113 | 0006811  |
| 18 F | R138   | WEST 4TH ST-WASHINGTON SO   | 00093562 | 00004677 | 00000251     | 00000965     | 00000127     | 00031628 | 0007445  |





## MTA Fare Data Visualization



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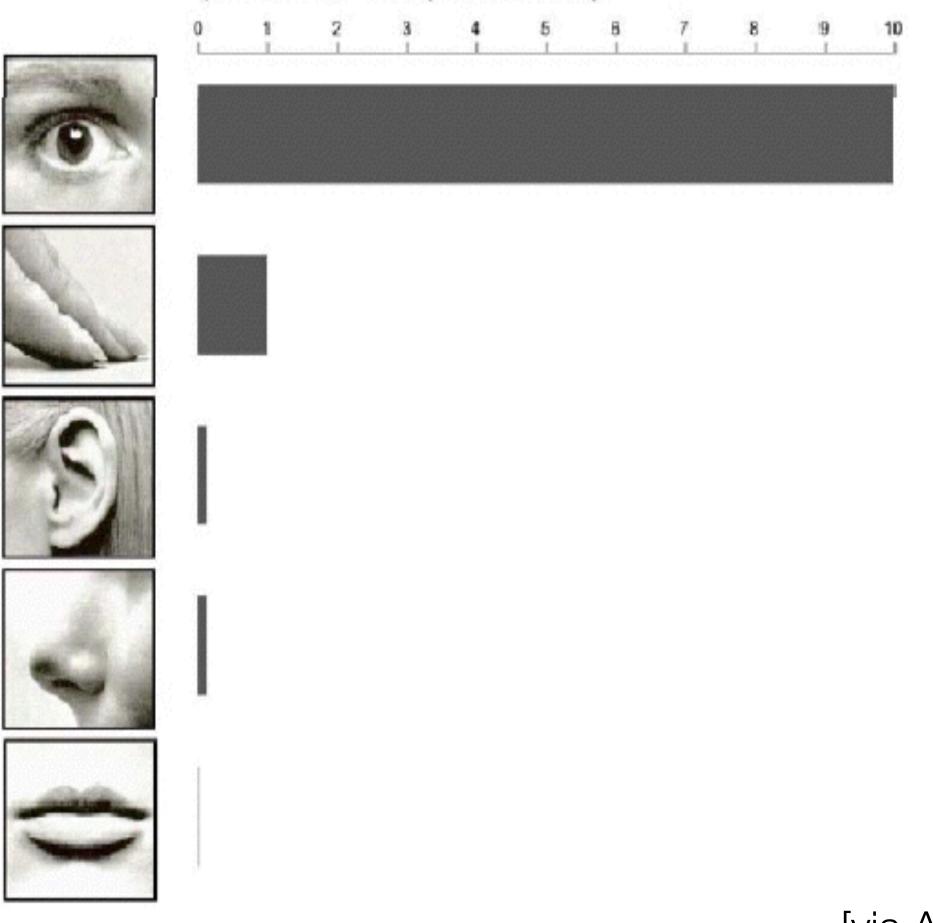


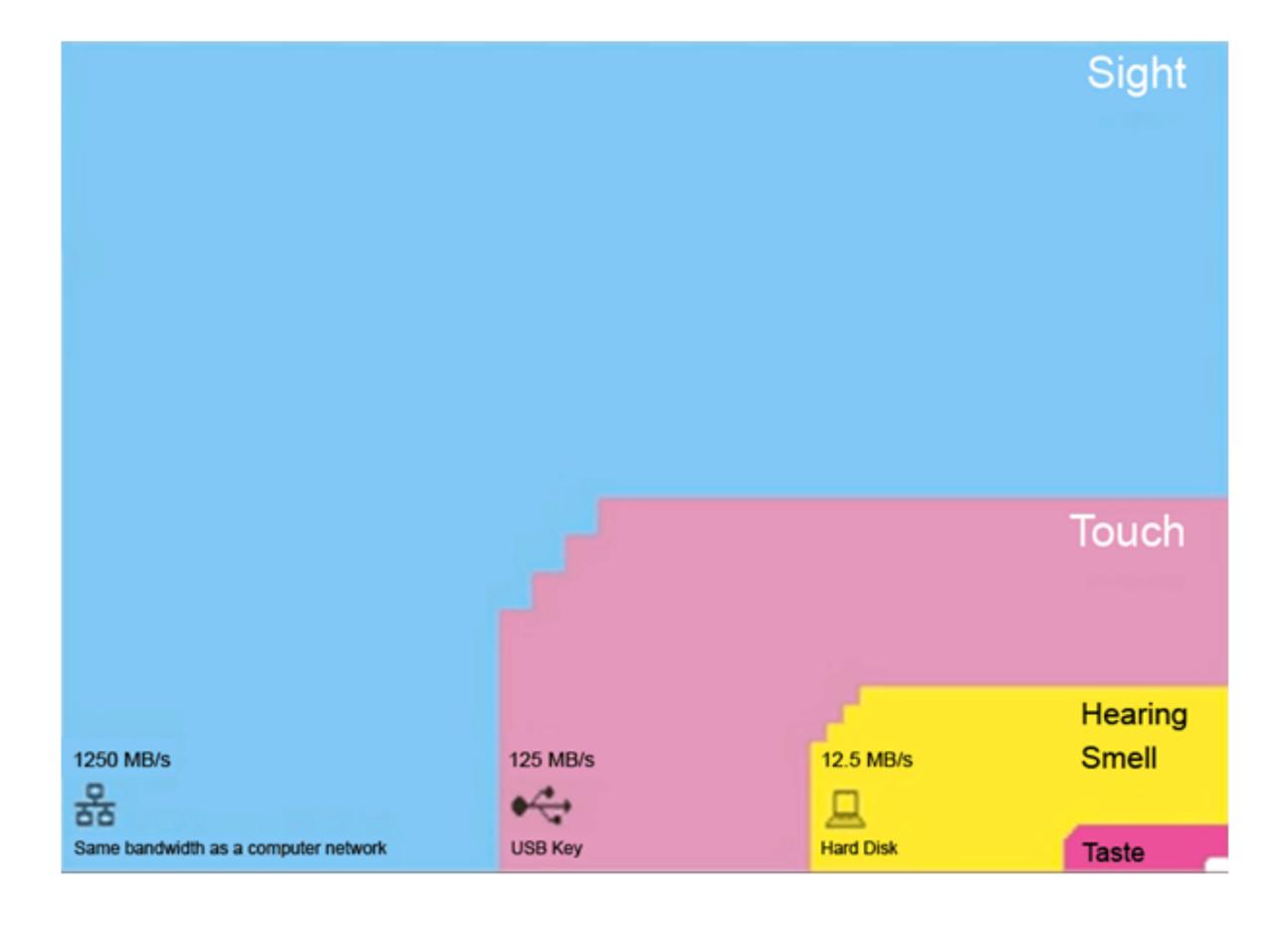
8

### Why do we visualize data?

#### Total Bandwidth

(millions of bits per second)













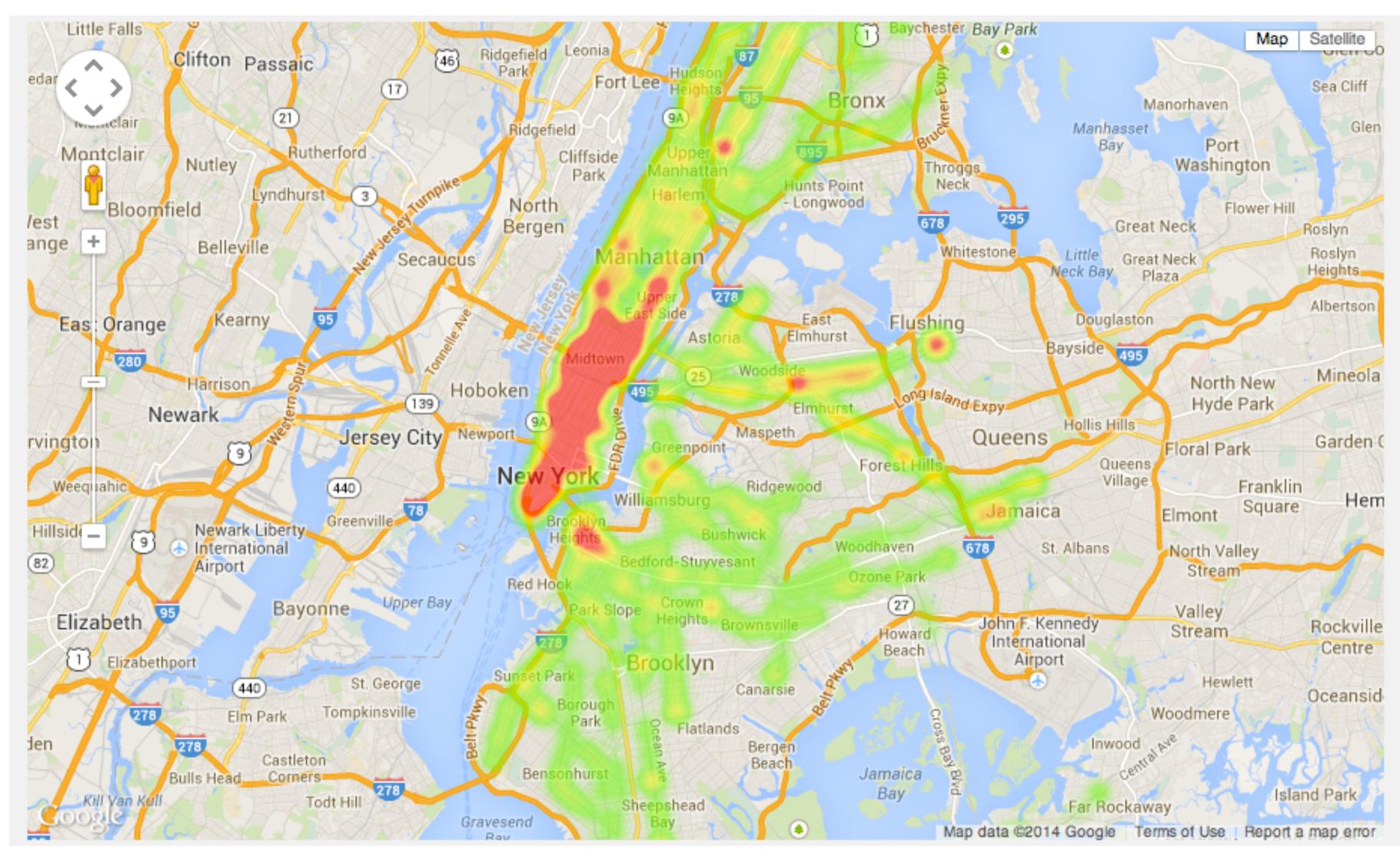


### What are the goals of visualization?

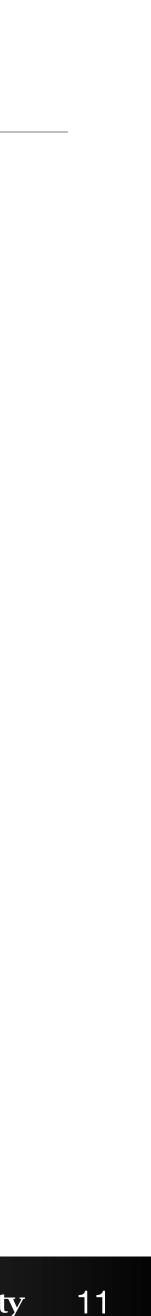




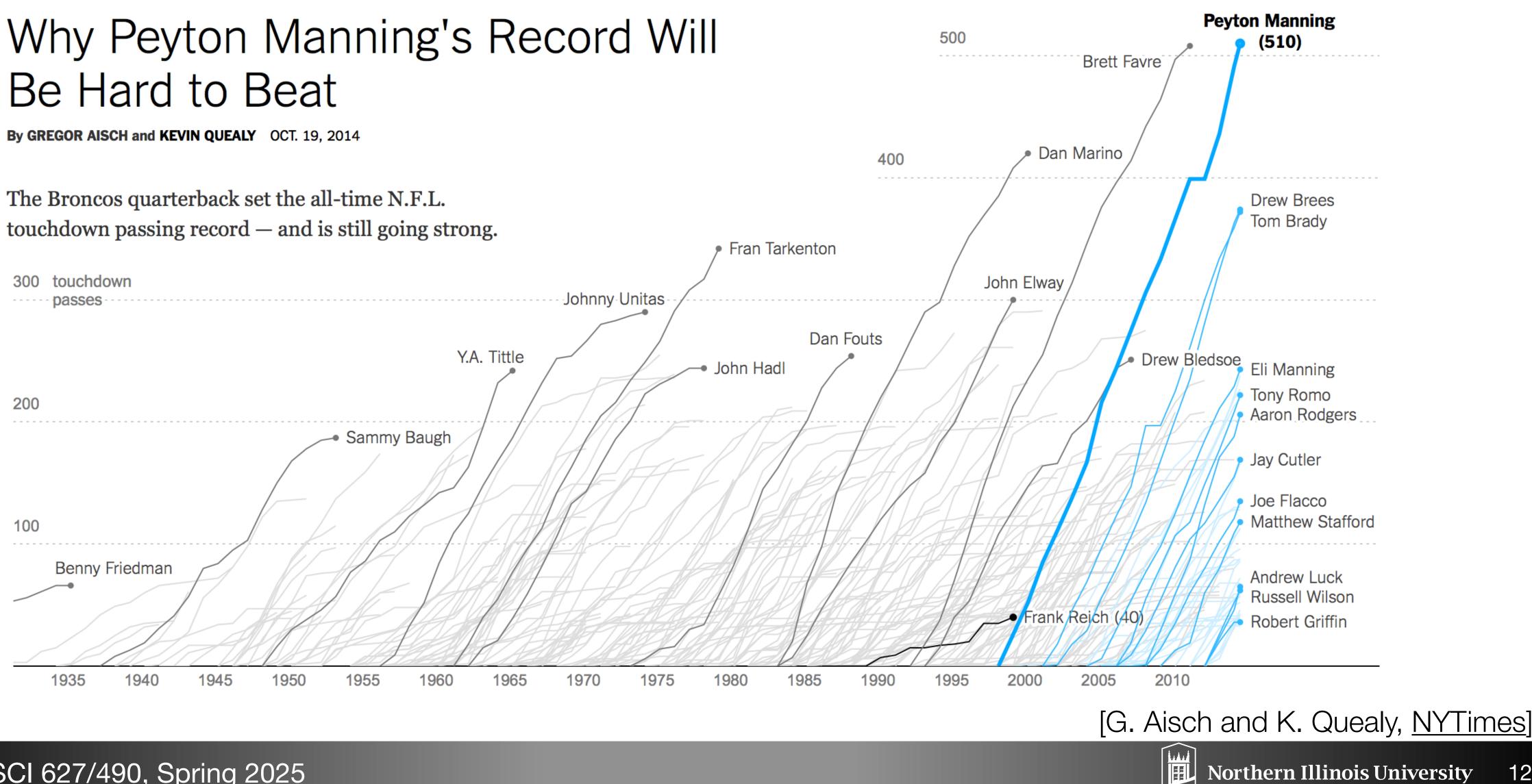
## Analysis: Subway Ridership Density







### Communication: Peyton's Records



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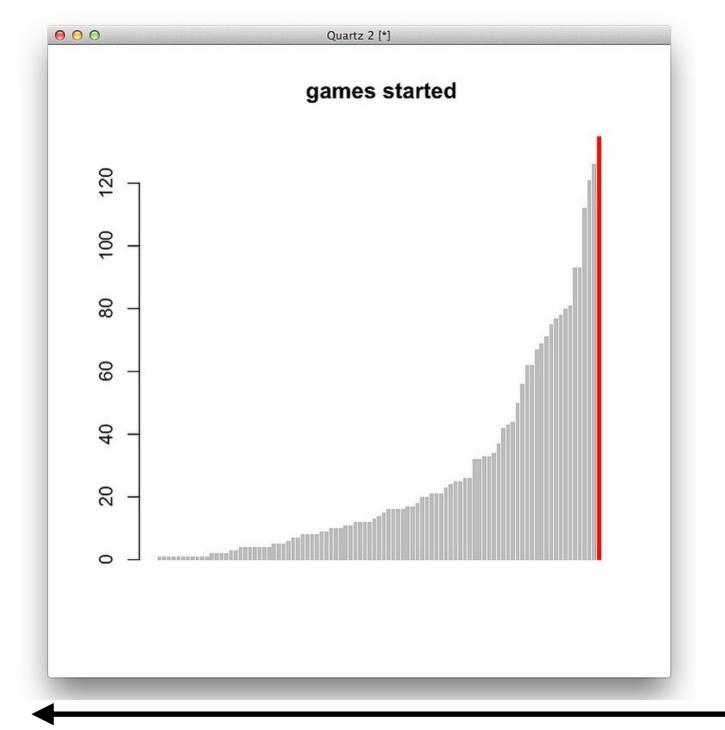




### Exploration <-> Communication Spectrum

#### Consecutive Starts by a Quarterback for a Single Team

Each streak ------ shows

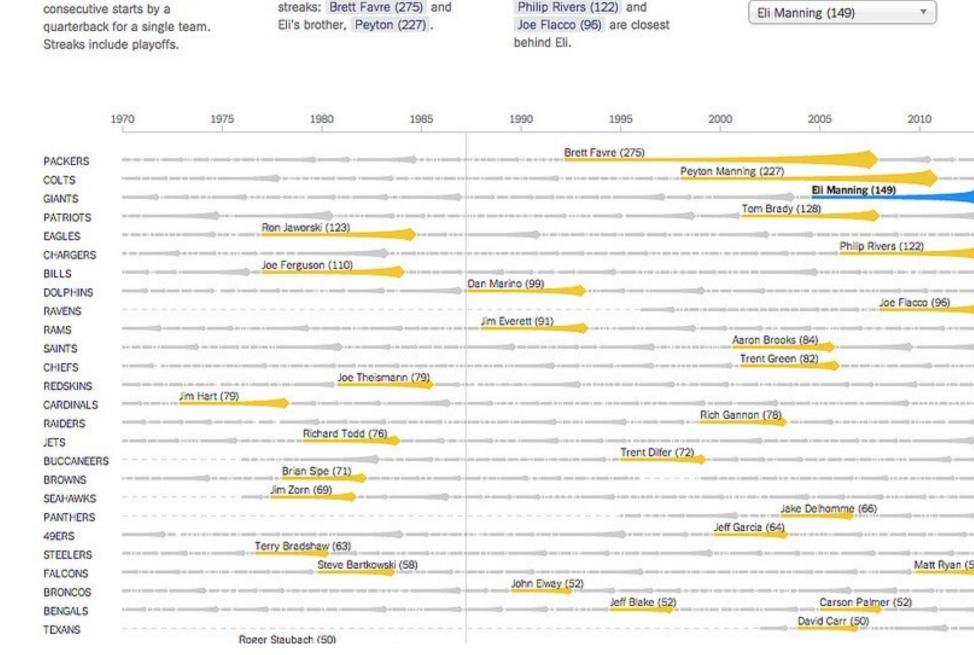


#### Exploration



#### Questions

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Only two players have longer

streaks: Brett Favre (275) and

Among active players,

Philip Rivers (122) and

#### Confirmation

#### Communication

#### **Answers/Persuasion**





Find a quarterback



13



#### What types of data can we visualize?

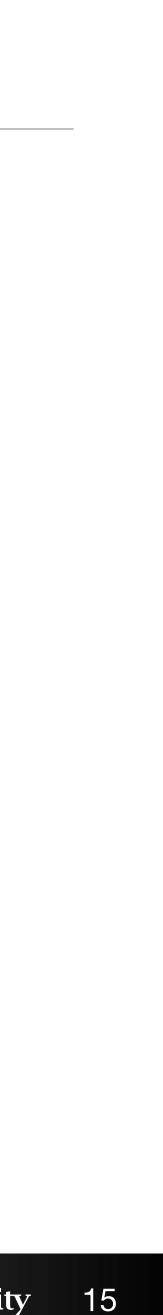




### Types of Data

- Tables
- Networks (Graphs)
- Spatial Data
  - Geography
  - Physical (e.g. Scientific, Medical)
- Text
- Sets



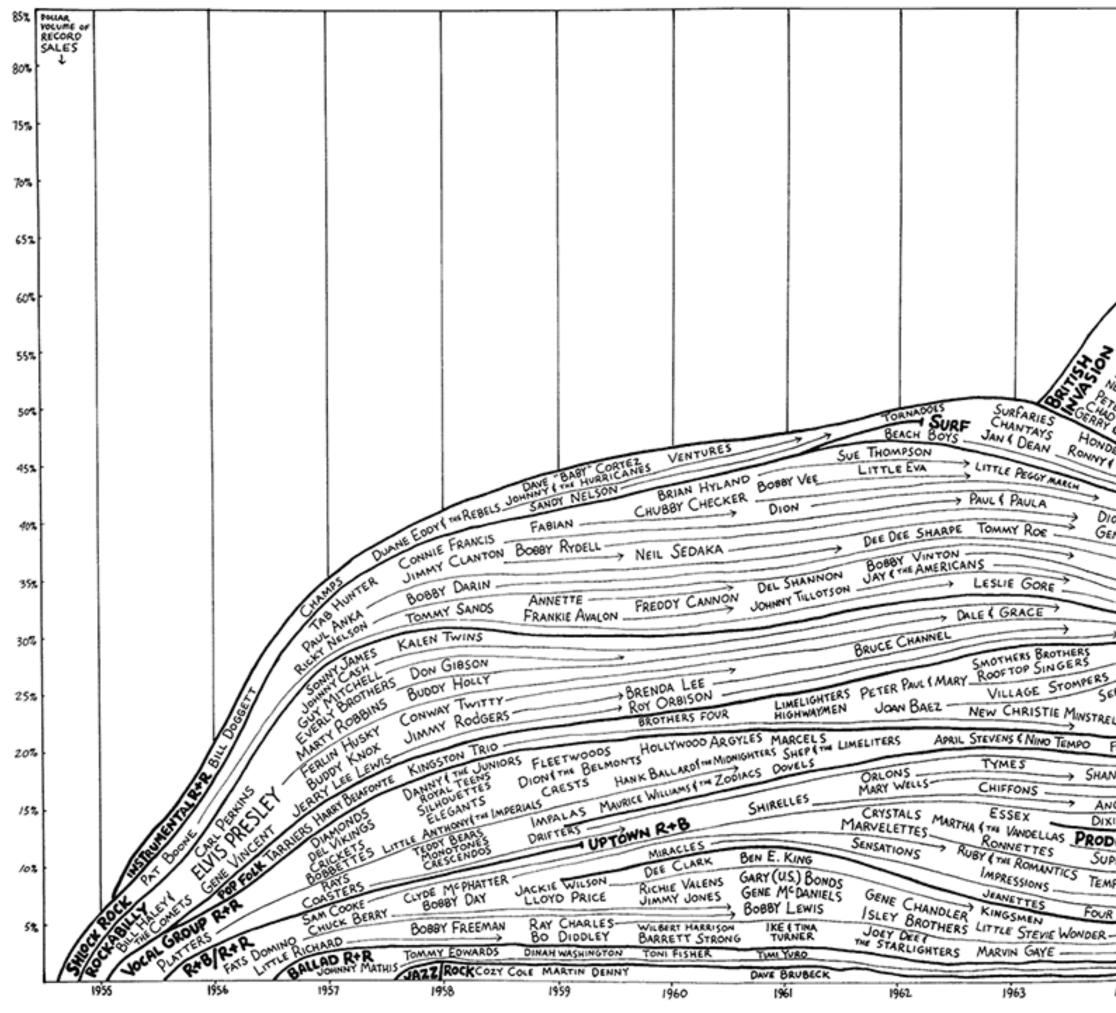


#### Where have you seen visualizations?

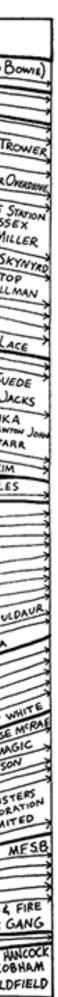




#### Books/Posters



|   |  |  | GRAND FUNK RAILROAD  |   | ALICE COOPER   | EDGAR WINTER  | (DAVID BOWIE)   |
|---|--|--|--|---|--|---|---|
|   |  |  |  | GIT BLACK SABBAT  | ( State of the sta | DEEP PURPLE -   |   |
|   |  |  | HEAV   | YMEINE C  | ARGENT   | PINK FLOYD -  |   |
|   |  |  | EUNK RAULROAD  | EMERSON, LAKE, & PA   | Ver >  | Focus A   | ROBIN TROWER  |
|   |  |  | GRAND FUNK   |   | 162  | URIAH HEEP<br>BACHMAI   | witten a  |
|   | RE & THE RAIDERS VAN MORRISON<br>KINGSMEN PROCUL HARUM                   | CREAM BLIND F  |  | GEORGE HARRISON   |  | Bee   | ASTOKNER OVERSKI  |
|   | RE THE RAIDERS VAN MORRISON  | IRON BUTTERFLY LED Z   | EPPELIN MOUNTAIN   | , , , , , , , , , , , , , , , , , , ,   | MALO J   |   | SVILLE CY.  |
| Bur Reve  | KINGSMEN PROCUL HARUM  | STEPPENWOLF-   | WHO SANTANA  |   | LEON RUSSELL   | OF L.C.   | SERVICE AND A |
| C TONG TO TO A  | SSOCIATION TURTLES   | STEPPENWOLF GUESS  | ARWATER REVIDE COCH  | JANIS JOPLIN A  | LLMAN BROTHERS   |   | NYRD SKYNYR   |
| ROLUNKS ZOMBIES   |  |  | CUOLE .  | JANIS JOPLIN<br>PLASTIC OND BAND<br>MODDY BLUES                                     | James Cure S   | DOBIE BROTHERS  | REGG ALLMAN   |
| DAVIALS VIDORIROS   | STANDELLS VANILLA BIO  | BROTHER ( THE HOLDING COMPAN   | Y NICHT JOHN LENNON  | MOODI OLVES   | Grand CANS L   | OGGINS & MESSINA  |   |
|   | TROGGS ACIDROCKJIMI HENDI  | THREE D  |  | GIL GIL   | BERT O'SULLIVAN B  | SETTE MIDLER  | APER LACE   |
| S BEATLES MOODY BLUES   | HOLLIES POPPort  | RPLANE   | TAIRCASE NORMAN GREEN<br>TAIRCASE NORMAN GREEN<br>MARY TONY ORLANDON<br>MARY ANNE MURRAY<br>ANNE MURRAY<br>CARPENTERS  | DAWN  |  | The second se | BLUE SUEDE  |
| DUNINE WINN HERMAN'S HERMITS  | VOGUES POPROCKBOX TOPS<br>DUSTY SPRINGFIELD BEE GEES<br>CYRCLE HAPPENING |  | ALRCASE ORLANDRA   | OSMONOS   | CHUCK BERRY MAN  | DEEN Microw   | LERRY JACKS   |
| TER GORATS TREODY & THE DREAMERS  | LEFT BANK BUCKINGS   | SpiRAL Out   | MARY ANNE ANTERS   | RICK NELSON   | CHUCK BERRY MAN  |   | UL ANKA   |
| MY 6 JEREMEY HERMAN'S HERMITS !   | NEIL DIAMOND BUCKINGHAMS   | CLASSICS IN PETER.TA   | WINNON FIRST EDITION   | HELEN REDUT-  | -> WINGS   |   | NGO STARR   |
| NDELLS PACEMAKERS PETULA CLARK  | NANCY SINATRA BOARD  | VISS ROOTS   | ESTO THUMPE  | NY  |  | CT08165   | NOY KIM   |
| CATIONAS CLARK-   | SCOTT M  | LEMON GAP<br>LEMON PIPERS JACKIE U<br>LETTERMEN TON JO<br>O.C. SMITH GLEN<br>MENUSPORT   | NESELL ENGLEBERT HUMT  | CLIMAN  | RASPBERRIES  | TY GRITTY DIAT BAND   | EAGLES  |
| DIONNIC   | SCOTT MCK  | O.C. SMITH GLEN  | Chi Port Alle  | PARIT   | RASPOLINE NIT  |   |   |
| DIONINE WARNICK HERB ALPERT & TJB<br>GENE PITNEY  | BOB LIND FIFTH DI  | MARY HOPKIN JOHN   | CASH POPPY FAIR<br>R VANITY FAIR<br>VANITY FAIR  | PARTRID   | NEIL YOUNG   |   |   |
| RUPPI FOUN SONNY TOWN   | MULAMES ( THE SHONDELLULU  | BOBBY GOLDSBORD ARC  | TES EDISONES MALES   | LIGHTFOOT   | MAC DAVIS  | $\rightarrow$   |   |
| GARY LEVING & THE A   | BOB LIND FIFTH DIMENSION<br>MONKEES STRAWBERRY ALARM CL                  | DOBBY GOIDSBOAN  | CASH POPPY CAN<br>R VANITY FAIR<br>NES VANITY ENSON<br>NES CONSON LIGHTHOUSE<br>NES CONSON LIGHTHOUSE<br>NES CONSON LIGHTHOUSE<br>NES CONSON DEAD<br>NES CON | JOAN BAEL<br>JOAN LIGHTFOOT<br>GORDON LIGHTFOOT<br>CAT STEVENS JU<br>CAROLE KING PA | UL SIMON   |   |   |
| CHART LEWIS & THE PE  | ATBOYS ALARM CL  | 1910 FRUITGUM CO. BOND   | CH GRANNIE   | Cr.   | M CROCE  | GARFUNKLE MU<br>SEALS & CROFTS  | ARIA MULDAUN  |
| WE FIVE   |  | B DYLAN EXPRESS BROOK  | No AV  | LOUN DENVEN U   | DON MELEAN ART   | SEALS & CROFTS  | Abba  |
| U ROUNN NEW   | VAUDVILLE PAULO BO   | B DYLAN OY ROL BOD   | GBLOODS BREAM  | CARLINGEFERSON  | DON MECHANIS   | THERS   |   |
| RS BORNDIPITY FOLK BOB DYLANDIPITY FOLK BOB DYLANDIPITY FOLK BORN SPOONFUL LOVIN' SPOONFUL STATUTION FAITHFUL BARRY MK GUIRE STATUTION FOLK | BARRY SADLER JANIS JAN   | GFIELD JUDY COLLINS  | JAMES TAYLOR   | JONI MITCHELL JO  | AMERICA ISL  | EY BROTHERS   |   |
| RELS BARRY MC GUIRE S   | DONOVAN BUFFALO SPRIN  |  |  |   | HI LITES   |   | BARRY WHITE<br>BEORGE MERA  |
| FOUR SEASONS  |  | CRUIL LEBRY  | BUTLER BROOK BENTON  | AL GREEN ST   | TYLISTICS  | Quin  | OF WAGIC  |
| HANGRI-LAS  | Trees  | CROSON, CROSON | STAIRSTEPS   | BILL WITHERS  |  |   | AL WIE  |
| AUGULE ROTHERS  | MARVIN GAVE & TAMMY TERRET   | POP SOUL FRIEN   | NCTION EDWIN STARR   | ROBERTA FLACK   | INGRAM   | NE KENDRICKS  | TER SISTERS   |
| ANGELS<br>DIXIE CUPS RIGHTEOUS BROTHERS   |  | FOUN   | DATIONS FREDA PAYNE  | JEAN KNIGHT LO  | S BETTY WRIGHT   | EDOIL POINT   | CORPORATION   |
| DUCED SOUL BARBAN   |  |  | DIANA ROSS   | GLADYS KNIGHTS THE PIP  | S  | 5 101   | MESE  |
|   | AGE TOO TRAVELU  | ARTHUR BROWN UR  |  | HONEY CONE<br>A HONEY CONE<br>DRIVELIUS BROSS SISTER ROSE<br>MAL                    | MICHAEL OM   | TOWER OF POWER  |   |
| EMPTATIONS  | ARLA THOMAS ARTHUR CONNELLY<br>JOE TEX                                   | ARTHUR BROWN UR.   |  | > DRAMATICS MAI   | DOSSTON  |   | WWW FIRE  |
| VK TOPS D   | LOCY SLEDGE SAME UNIC  | ARTHUR BROWN UR. ISAAC<br>OTIS REDDING ISAAC   | AYES STEVIE WONDER -   | BI  | LLY PREST  | IS MAYFIELD BART  | A THE GANG  |
| Maunic Resources  | CAPITOLS Soul SURVIVORS  | CHAMBERS I   | THE ALLSTARS   |   |  | A WANN  | HERBIE HANCOCH  |
| JAMES BROWN   | ATCH RYDERI ESQUIRES   | ARCHIE BELLE WATTS IOS   |  |   | STAPLE SINGERS CA  | CANTANA.  | BILLY COBHAM  |
| 1964 RAMSEY LEWIS   | 1966 1967  | 1968 1969  | 1970   | 1971  | 1972   | 1973  | 1974  |
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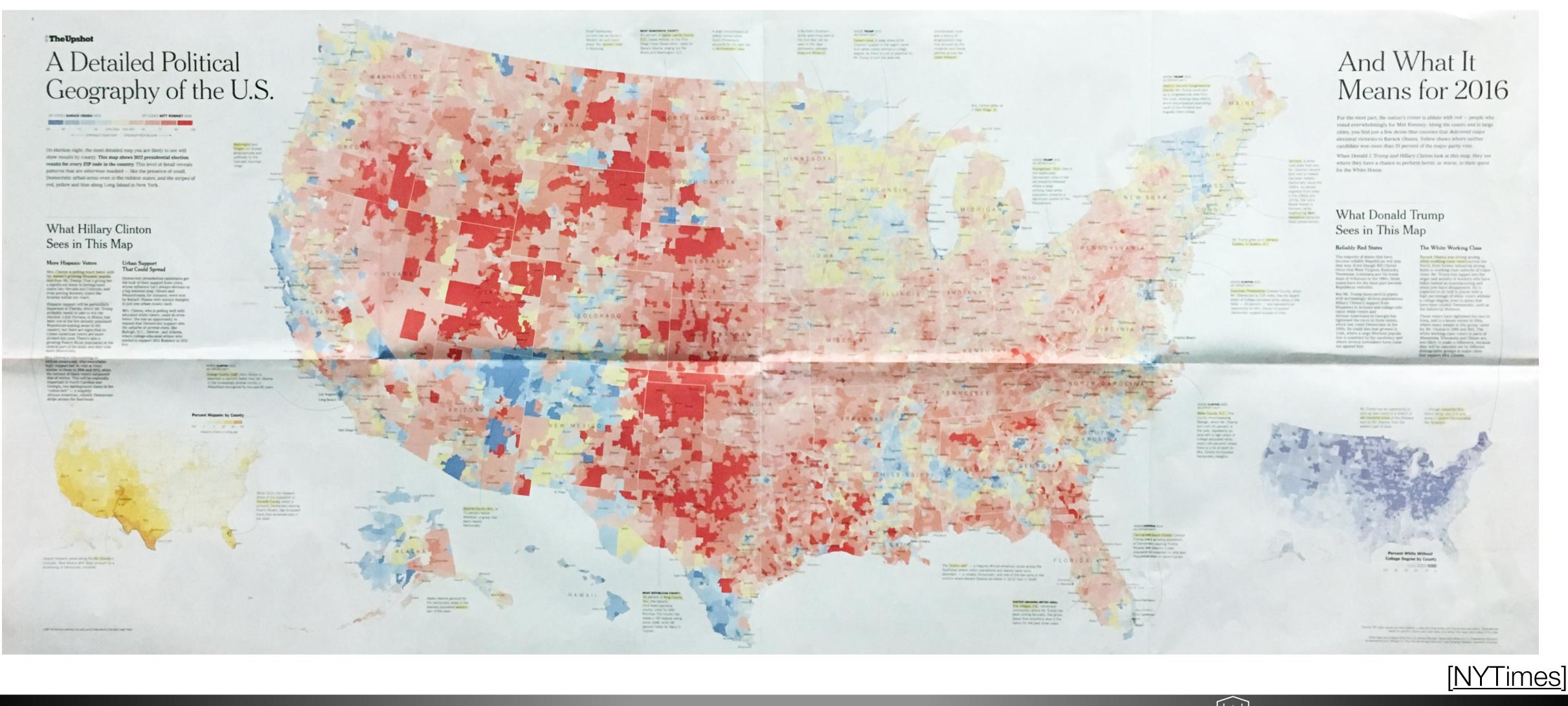








#### Newspapers

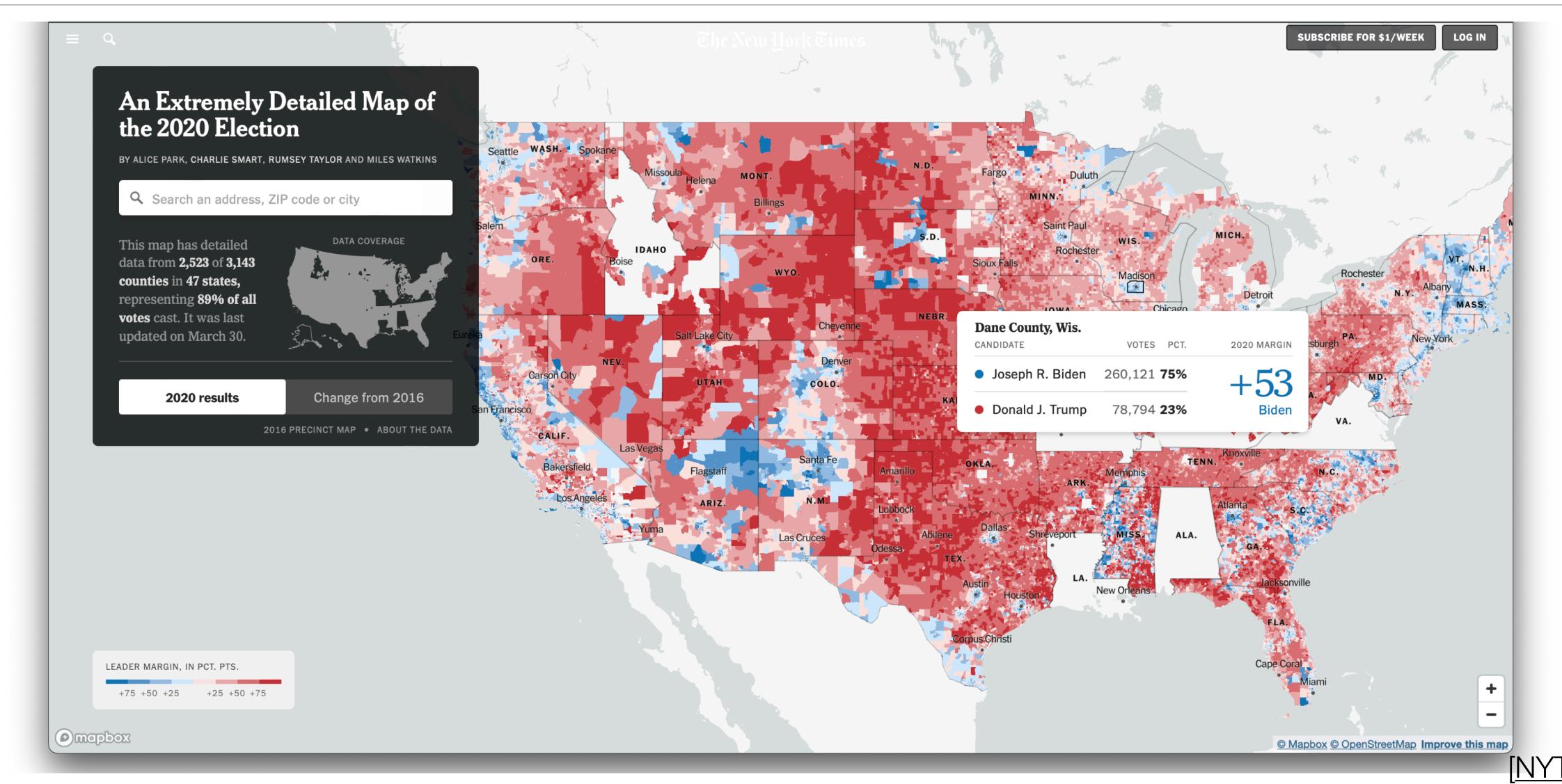








#### Web



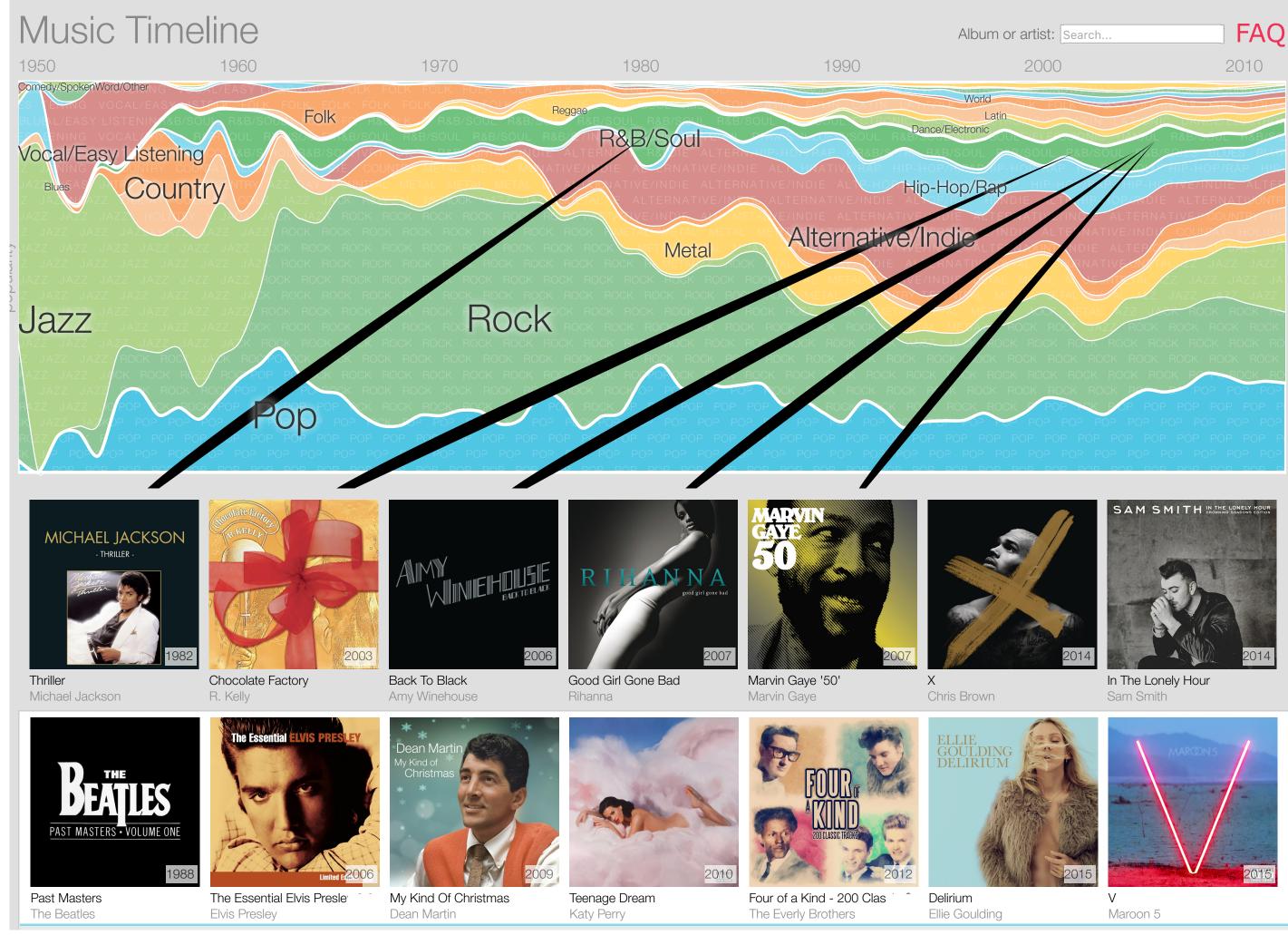








### Web



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[Music Timeline, Google Research (No Longer Working)]





### What is the advantage of the second version?







#### Interaction







### How do we create modern visualizations?







### Tools

- ...

- Desktop Applications:
  - Excel (see <u>excelcharts.com</u>)
  - Tableau
- Grammars:
  - Vega-Lite
- Programming Frameworks
  - d3.js

. .

- Observable Plot, plot.ly, deck.gl

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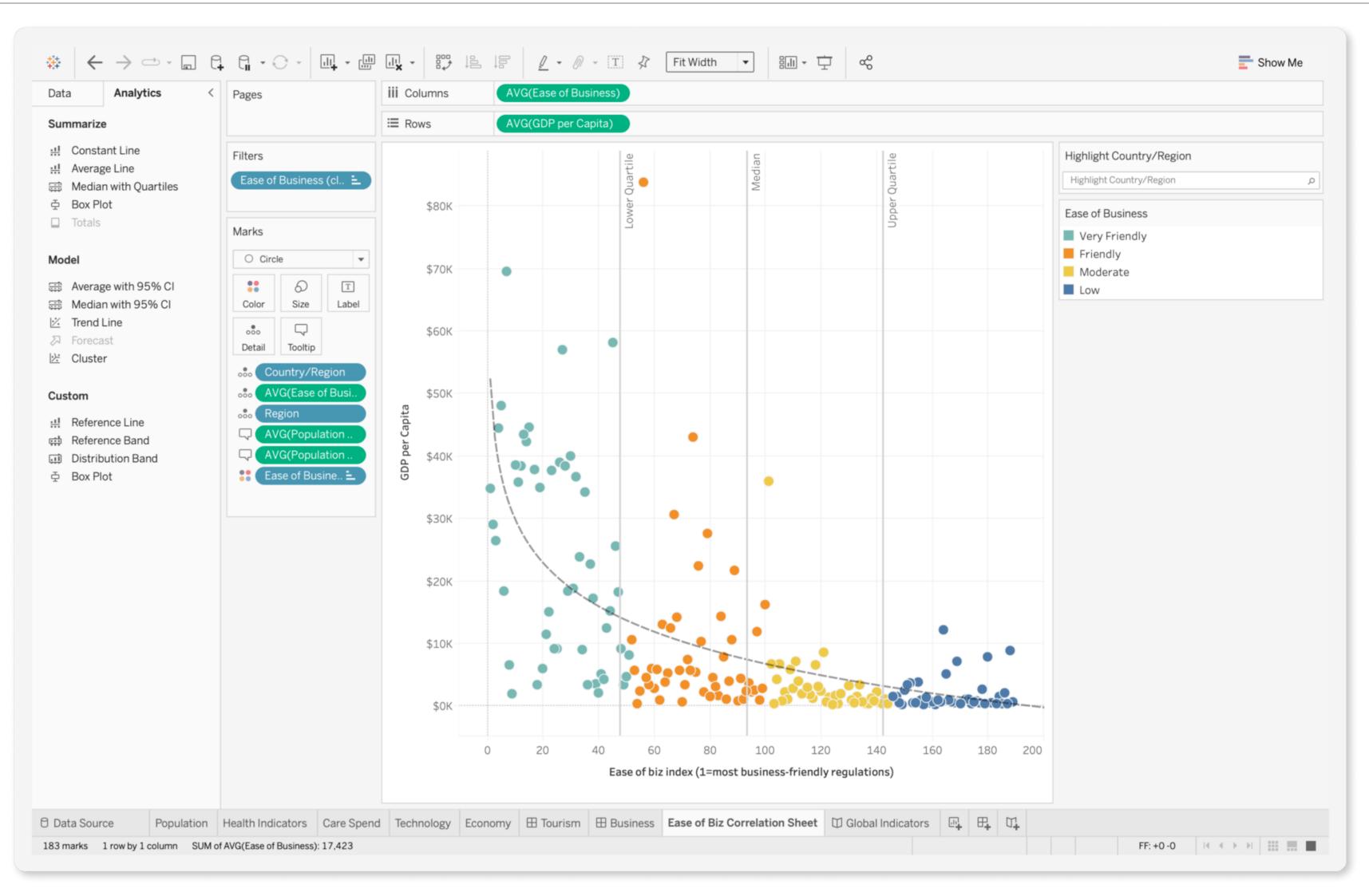
- Tradeoffs
  - Speed
  - Customization
  - Understanding
  - Dissemination





24

### Tableau







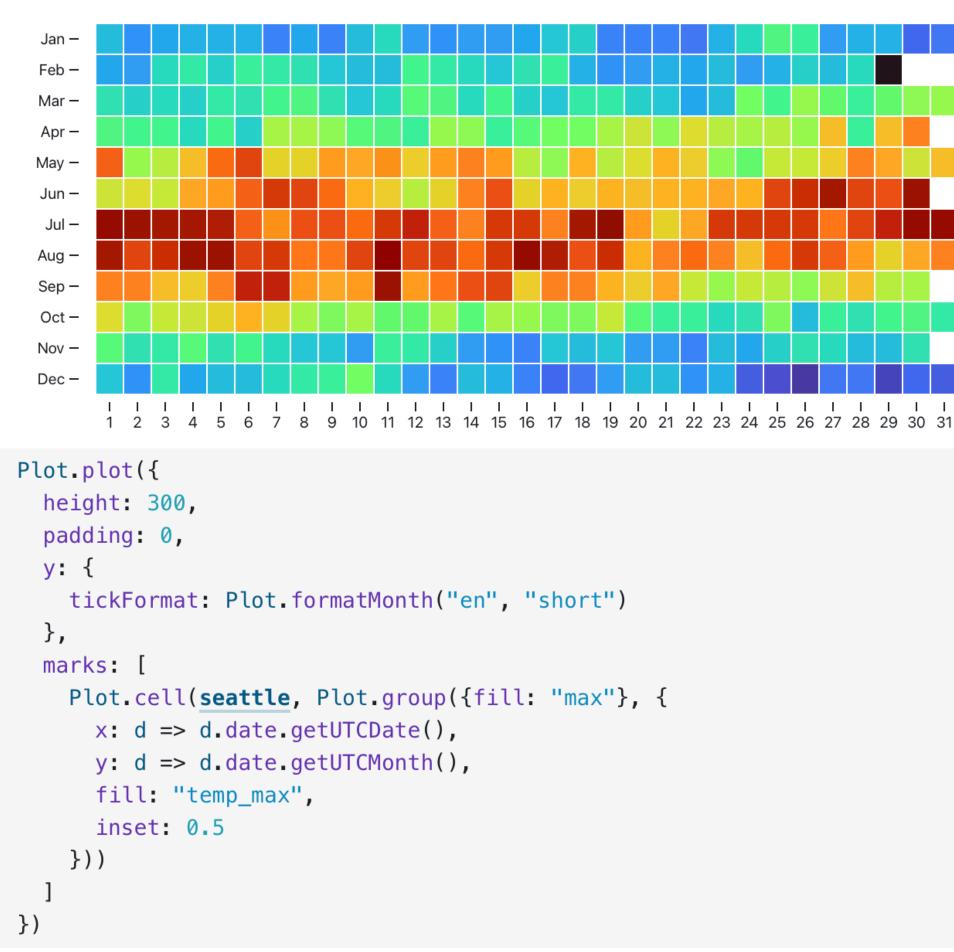






#### Observable Plot

seattle = > Array(1461) [Object, Object, Objec seattle = FileAttachment("seattle-weather.csv").csv({typed: true})













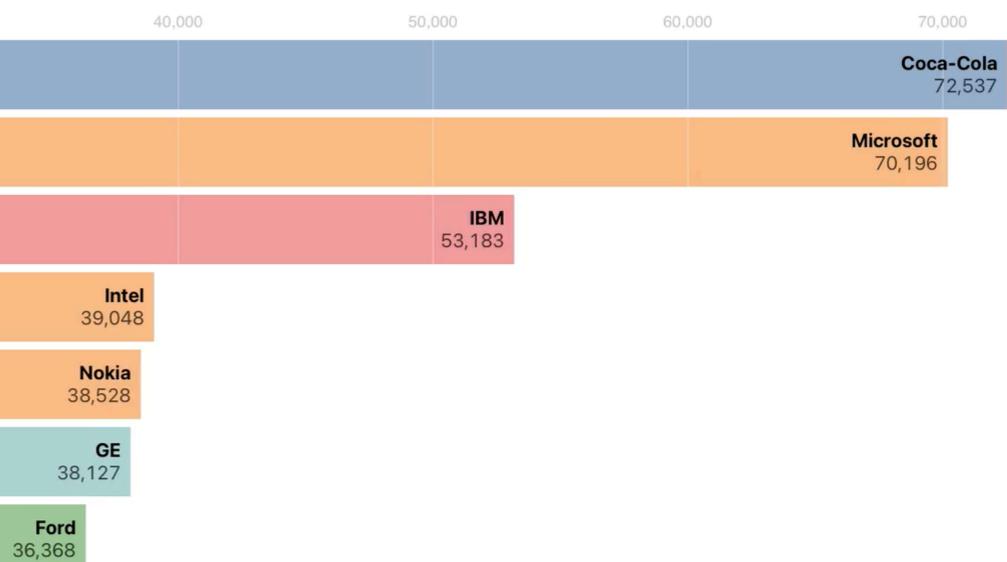


### d3.js

#### **Best Global Brands**

Value in \$M; color indicates sector. Data: Interbrand

| 10 | ,000 20,0             | 000                    | 30,000                  |
|----|-----------------------|------------------------|-------------------------|
|    |                       |                        |                         |
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|    |                       |                        |                         |
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|    |                       |                        |                         |
|    |                       |                        |                         |
|    |                       |                        | <b>Disney</b><br>33,553 |
|    |                       | McDonald<br>27,85      | <b>s</b><br>9           |
|    |                       | <b>AT&amp;T</b> 25,548 |                         |
|    | Marl<br>22            | <b>boro</b><br>2,110   |                         |
|    | Mercedes-Ber<br>21,10 | <b>nz</b><br>)4        |                         |













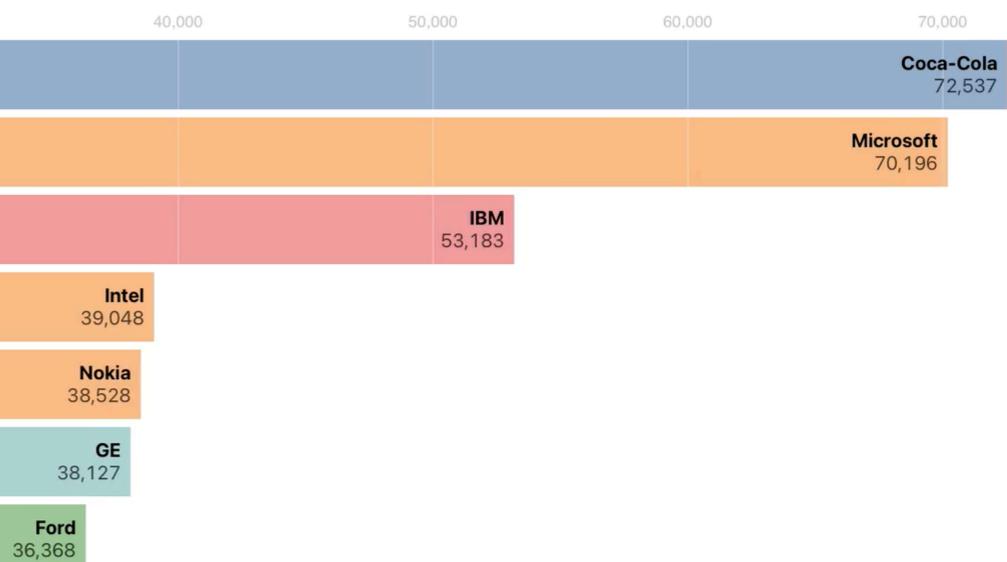


### d3.js

#### **Best Global Brands**

Value in \$M; color indicates sector. Data: Interbrand

| 10 | ,000 20,0             | 000                    | 30,000                  |
|----|-----------------------|------------------------|-------------------------|
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|    |                       |                        |                         |
|    |                       |                        | <b>Disney</b><br>33,553 |
|    |                       | McDonald<br>27,85      | <b>s</b><br>9           |
|    |                       | <b>AT&amp;T</b> 25,548 |                         |
|    | Marl<br>22            | <b>boro</b><br>2,110   |                         |
|    | Mercedes-Ber<br>21,10 | <b>nz</b><br>)4        |                         |















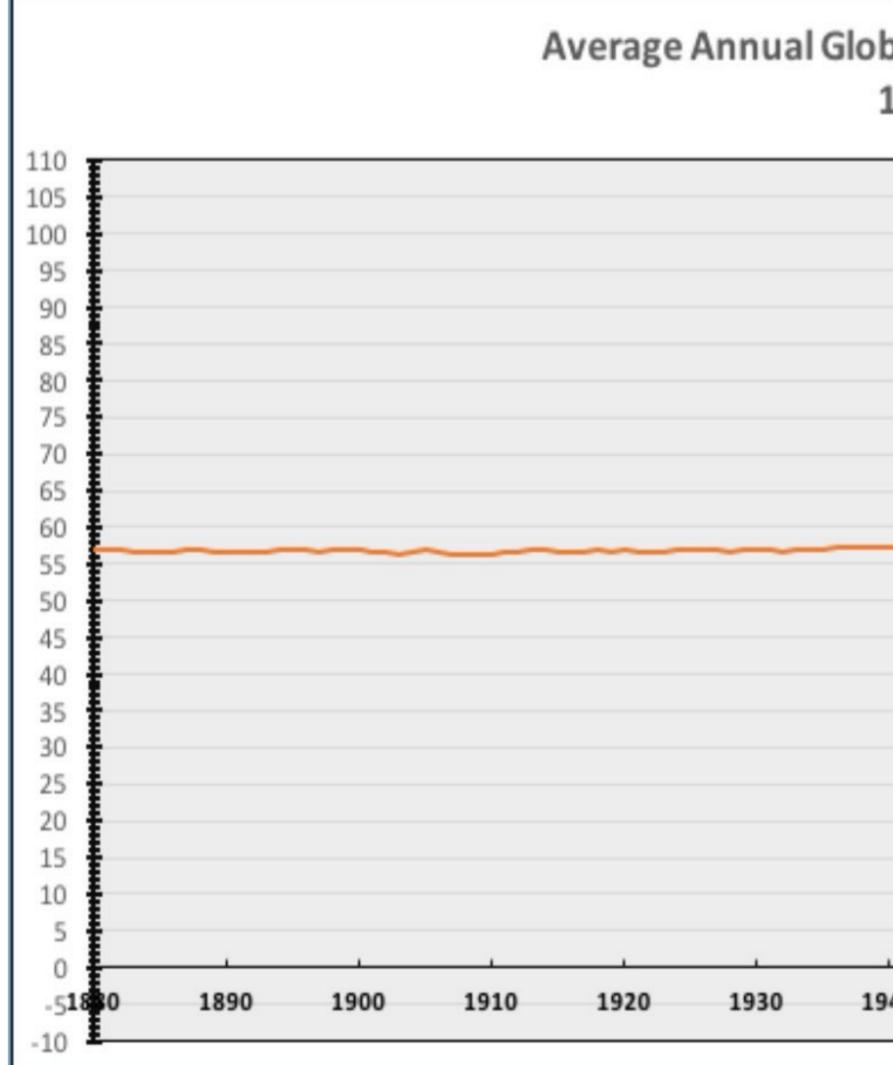
## Why do we care about the design of visualizations?







#### Design: Focus on only the y-axis



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#### Average Annual Global Temperature in Fahrenheit 1880-2015

|    |      |      |      |      |      |          |      | - I |       |          |
|----|------|------|------|------|------|----------|------|-----|-------|----------|
|    |      |      |      |      |      |          |      |     |       |          |
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|    |      |      |      |      |      |          |      |     |       |          |
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|    |      |      |      |      |      |          |      |     |       |          |
| 40 | 1050 | 1050 | 1070 | 1000 | 1000 | 2000     | 2010 | ]   |       |          |
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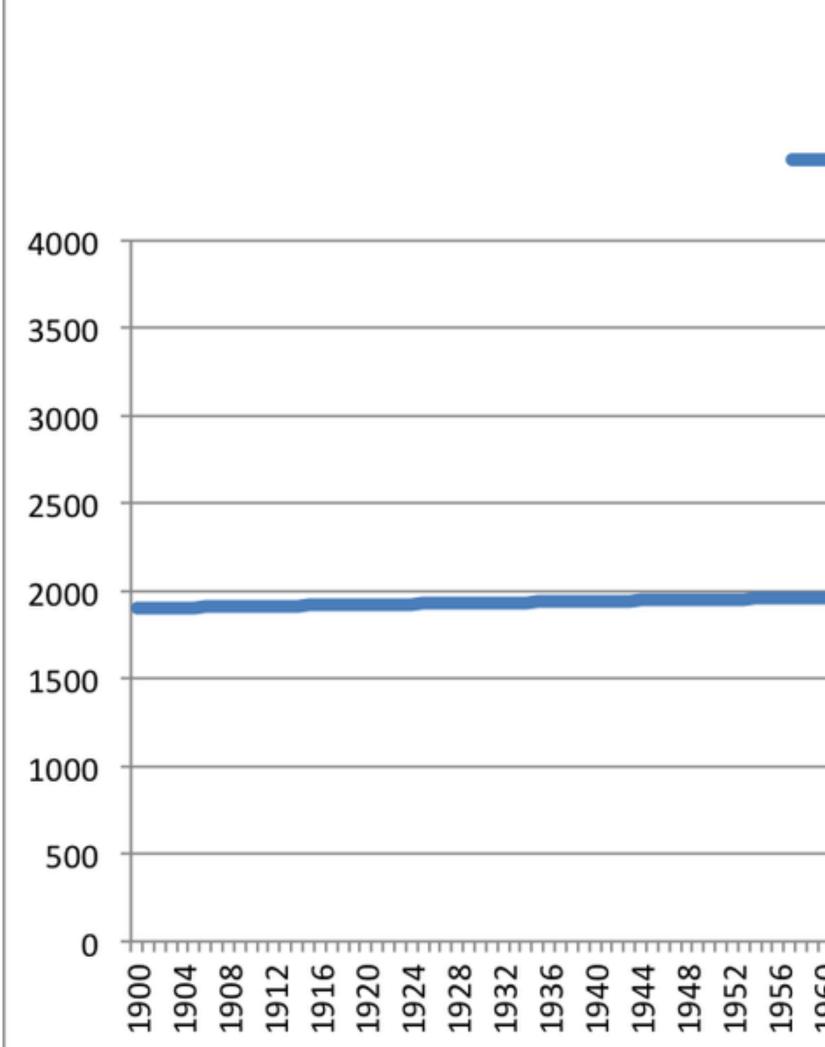








#### Design: Year on the y-axis



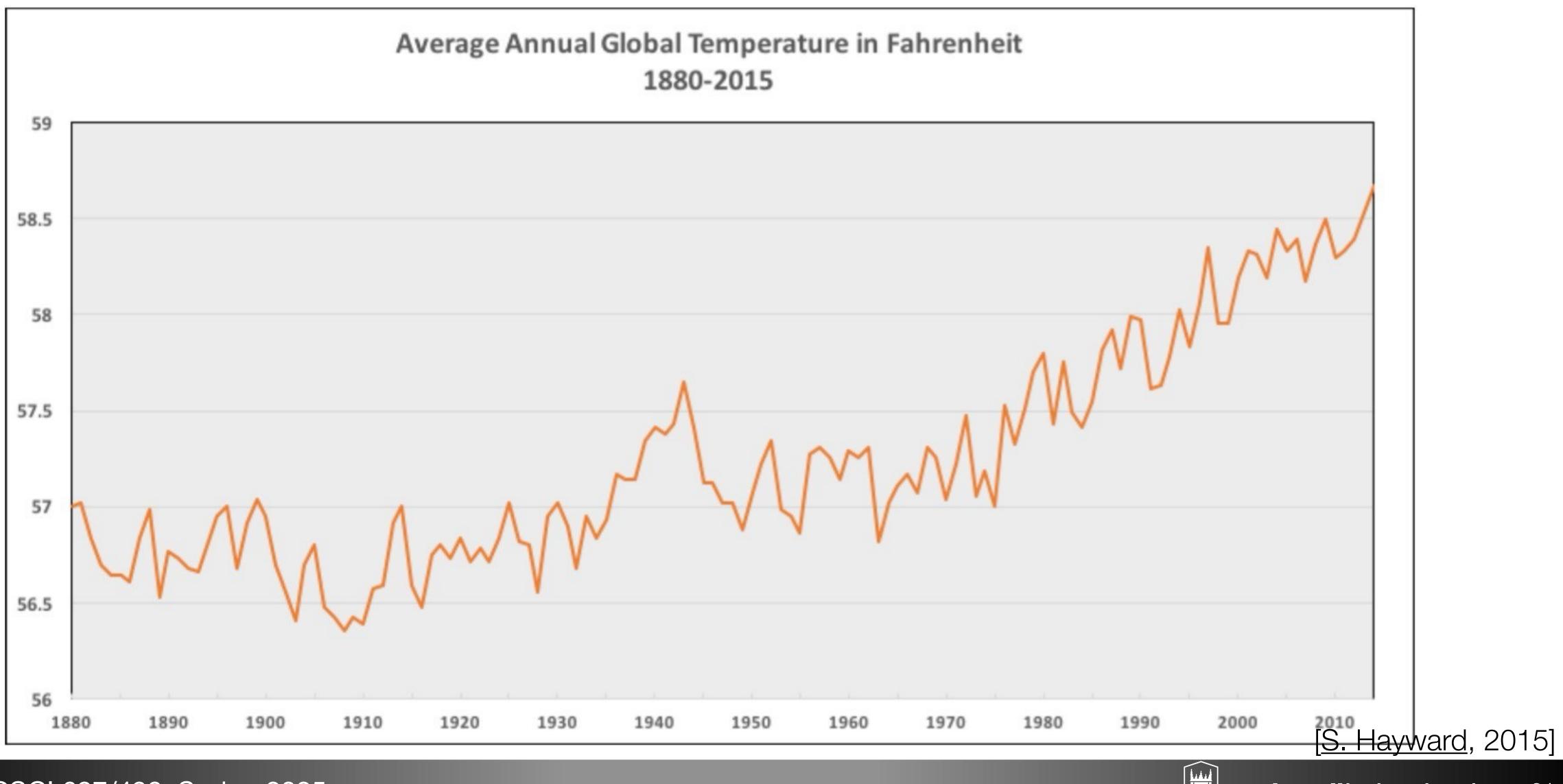
| Year   |                                |
|--|--------------------------------|
| Year (A.D.)  |                                |
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| $\frown$ $\rightarrow$ $\frown$ |                                |
| 1960<br>1964<br>1968<br>1976<br>1976<br>1976<br>1976<br>1976<br>1976<br>1976<br>1976                             | ଁ କୁଁ<br><u>[@bizweekgraph</u> |
|  | Iorthern Illinois University   |



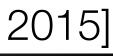




### Design: Different y-axis





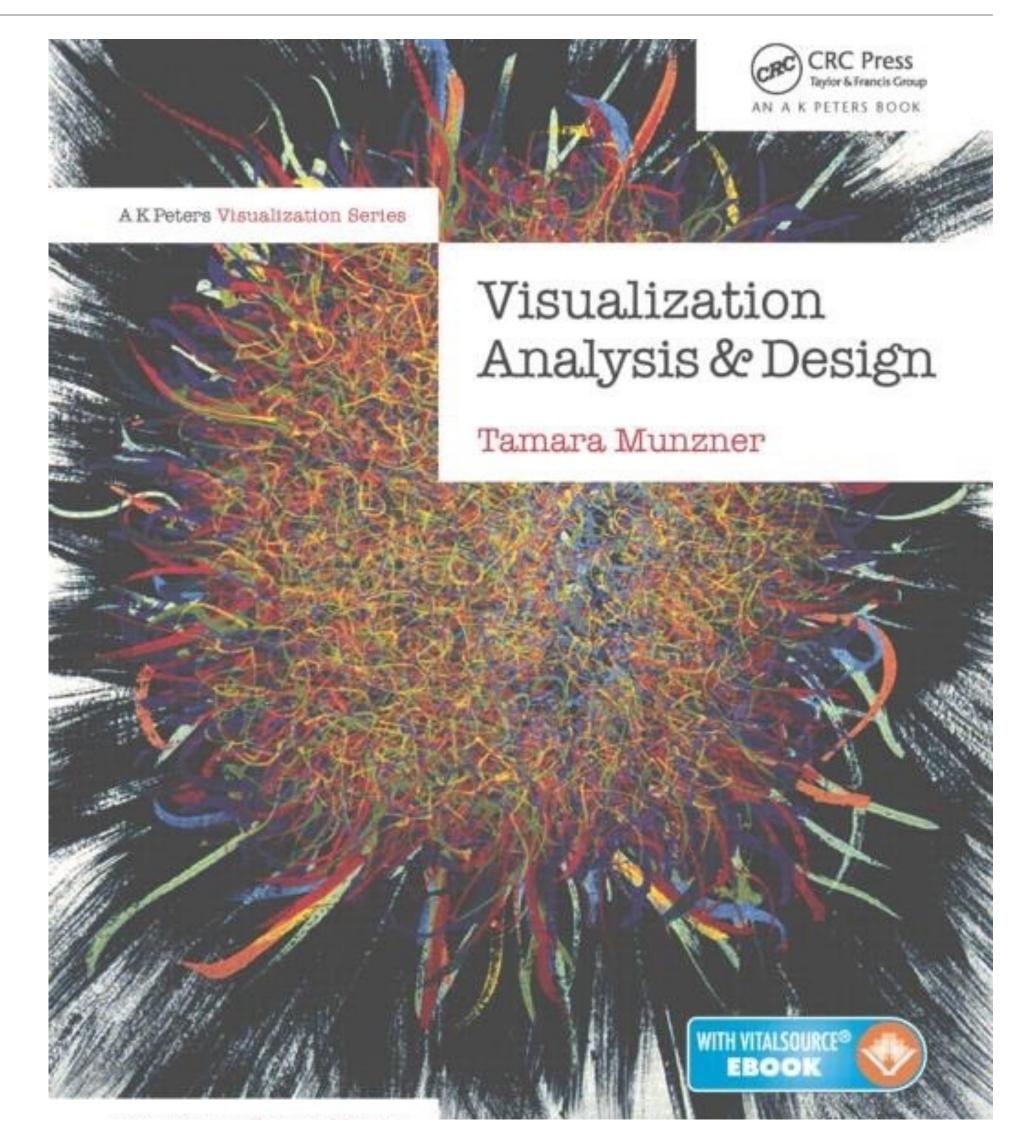






### Administrivia

- <u>Course Web Site</u>
- Syllabus
  - Plagiarism
  - Accommodations
- Textbook:
  - Required: <u>Munzner</u> (VAD)
- Assignments
- Exams: Midterm (Mar. 5) and Final (May 7)







## Administrivia

- Undergraduate (CSCI 490) and Graduate (CSCI 627) Course
  - Graduate: Extra reading, exam questions, project emphasis
- Research Topics:
  - Also investigate some topics in depth
  - Research papers as assigned reading (CSCI 627)
- Project: Create an interactive visualization (or vis research)
  - Design
  - Data analysis
  - Insight
  - Presentations: Last week of class









### Exams, Quizzes, and Missed Classes

- All quizzes and exams are in-person, closed-book, and closed-notes
- No makeup quizzes or exams will be given\*
- You are responsible for all material presented in class and assigned readings. If you miss a lecture, be sure to obtain class notes from a classmate before the next class meeting









### Office Hours & Communication

- Office hours will be held in person
- Scheduled office hours are open to all students
  - M: 1:45-3pm, W: 10:45am-12pm, or by appointment
- You do not need an appointment to stop in during scheduled office hours
- If you need an appointment outside of those times, please email me with details about what you wish to discuss
- Many questions can be answered via email. Please consider writing an email before scheduling a meeting.
- Do not send me screenshots of code! (send code or Observable links)







# Do not cheat!







### Do not plagiarize

- It is **Academic Misconduct**
- Do your own work, do not copy anyone else's work, text, sentences, ...
  - Anyone = another student, an internet source, book, blog, ...
- Do not share your work with anyone else
- Never quote text unless there is a specific need.
  - "I think there is a world market for maybe five computers." -Thomas Watson (1874-1956), Chairman of IBM, 1943)
- Cite sources that back up your claims or reflect the origin of an idea
  - Vertex cover is an NP-Complete problem [1]. ... [1] Garey, M. R., and Johnson, D. S., "Computers and intractability: a guide to NP-completeness." 1979.







### Do not cheat

- Cheating on assignments, projects, and exams is not allowed • You will receive a zero for any assignment/exam/etc. where cheating has
- occurred
- You will **fail** the course if you cheat more than once
- Misconduct is reported through the university's system
- You may discuss problems and approaches with other students
- You may not copy or transcribe code from another source (includes generative AI)







# Do ask questions!







### Do ask questions

- If you are stuck on a specific issue with an assignment: - Do consult books, online documentation, tutorials
- - Do discuss that specific issue with a classmate
  - Do email me with **specific** questions
- If you are asked about a question:
  - Do not share your code
  - If the questioner is trying to cheat, walk away
  - If you see an obvious mistake, kindly point it out
  - Suggest a specific function or library that may be useful
  - Discuss approaches or techniques





#### Questions?



