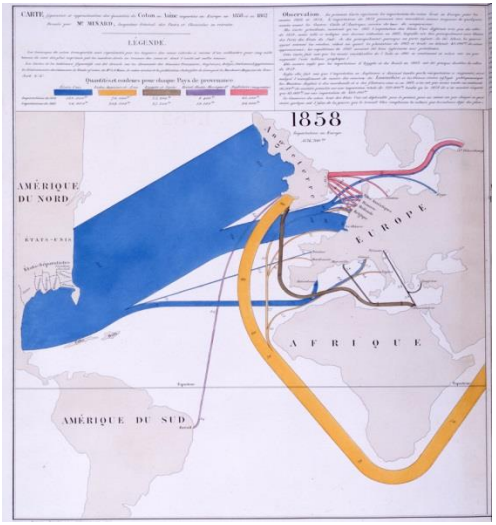
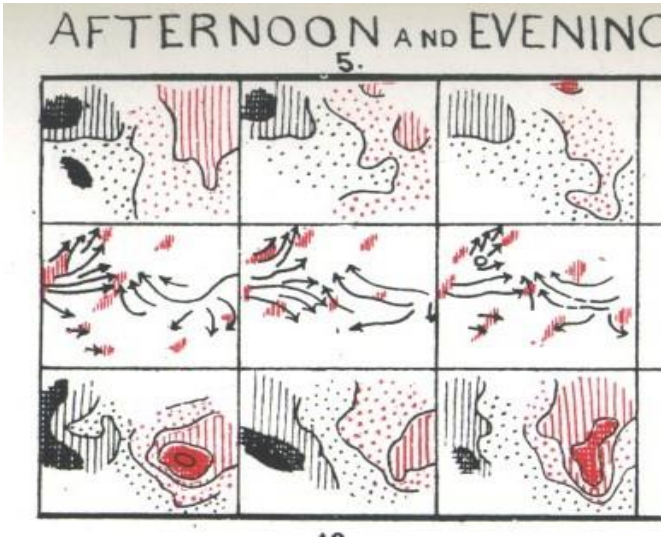
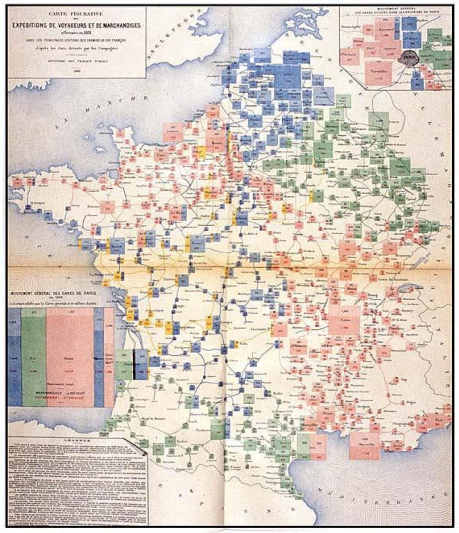






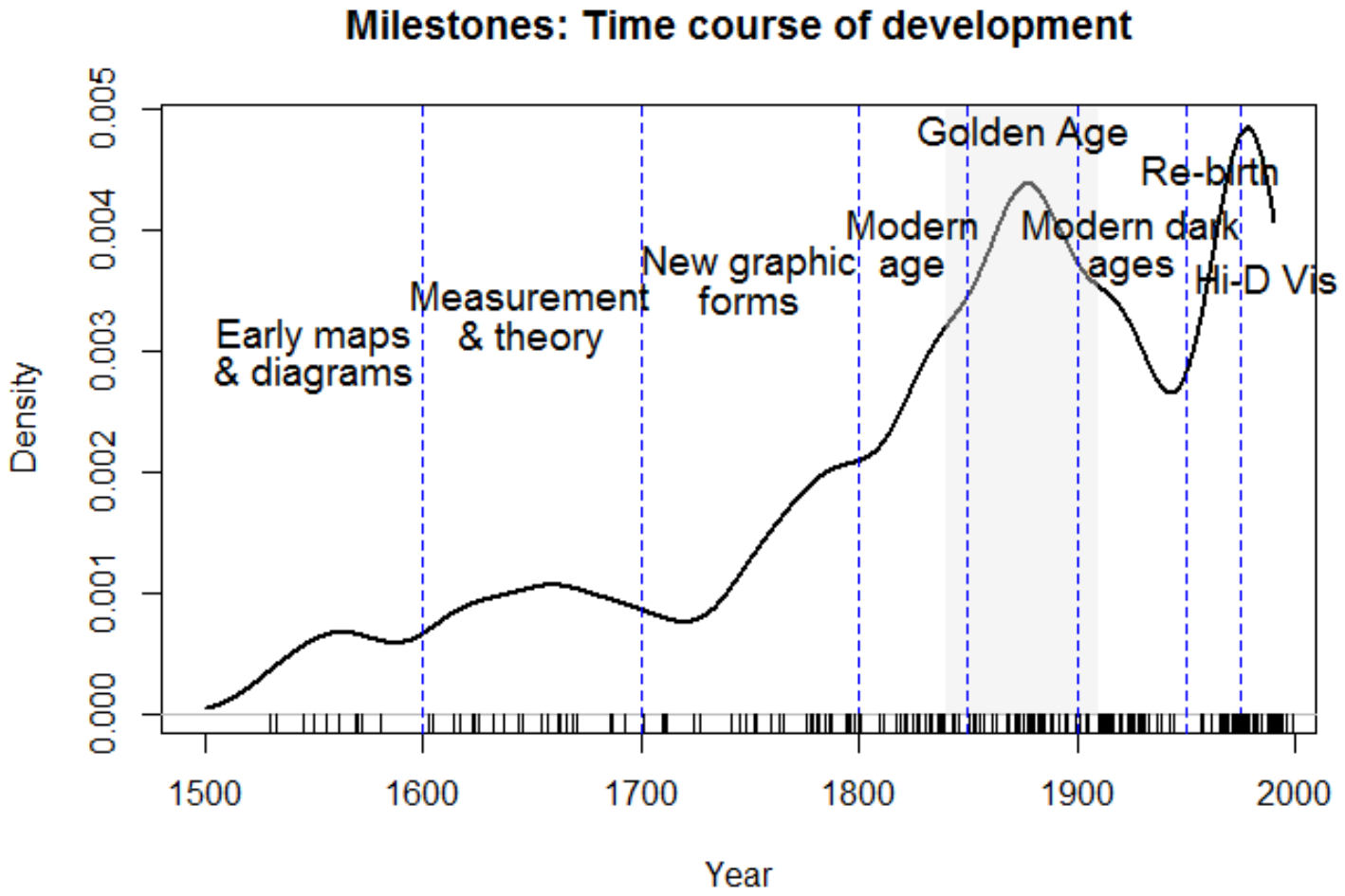
The Golden Age of Statistical Graphics

Michael Friendly
Psych 6135

http://euclid.psych.yorku.ca/www/psy6135

The Golden Age: ~ 1850 -- 1900

Why do I call this the “Golden Age of Statistical Graphics”?
The most obvious is as a peak in developments over the course of history.



What makes an “Age”?
What makes one “Golden”?

- Age:
  - Qualitatively distinct from before & after
- Golden age:
  - Recognizable period in a field where great tasks were accomplished
  - Years following some innovations
  - Artists apply skills to new areas
  - New ideas expressed, art forms flourish
  - Often ends with some turning point event(s)

Some Golden Ages

- Athens (Pericles): 448 BC—404 BC: growth & culture
- Islam: 750—1258 (sack of Baghdad): science, …
- England: Elizabeth I (1558-1603): literature, poetry, …
- Piracy: 1690--1730
- Radio: 1920—1940
- Animation: 1928 (sound) – 1960s (TV)
- Senior citizens: 60+

Pietro Da Cortona, *The Golden Age* (Fresco, Sala della Stufa, Palazzo Pitti, Florence)

Preludes to the Golden Age

Infrastructure required:

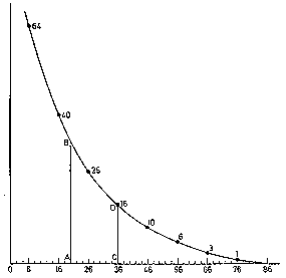
- **Data**: collection & dissemination
- **Statistical theory**: combining & summarizing quantitative information
- **Technology**: printing & reproduction of maps & diagrams
- **Visual language**: new graphic forms for maps and diagrams
- $\rightarrow$ a perfect storm for data graphics

What does this imply for today?

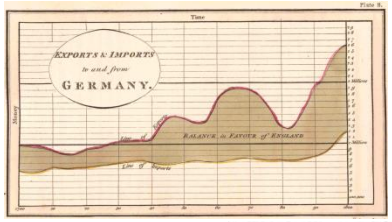
Preludes: data

"Data! Data! I can't make bricks without clay." – **Sherlock Holmes, *Copper Beeches***

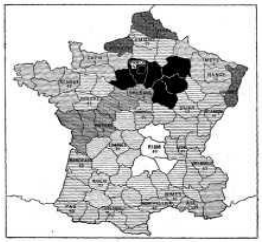
- Population: ~ 1660--
  - Bills of mortality: Graunt (1662)
  - Political arithmetic: Petty (1665)
  - Demography: Süssmilch (1741)



- Economic data: ~ 1770--
  - Revenue, expenditures, taxes
  - Imports, exports
  - Transport



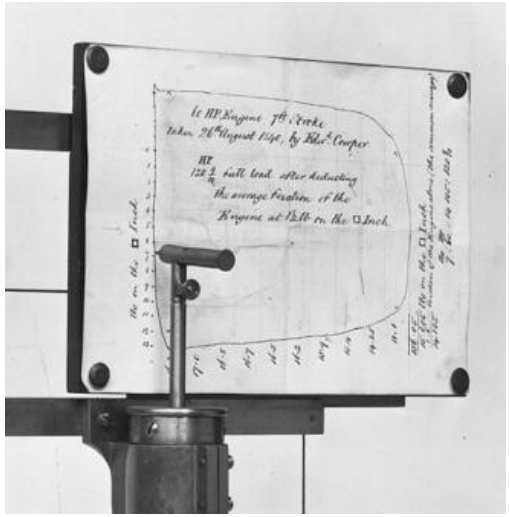
- Social data: ~ 1820--
  - Literacy, education
  - Crime, suicides, illegitimate births, prostitution
  - Poverty, debtors, disease

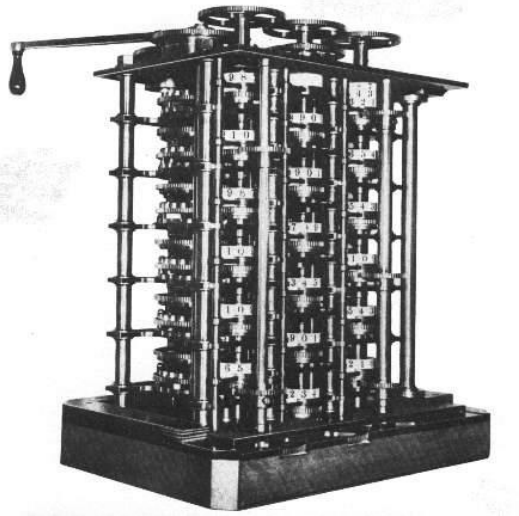


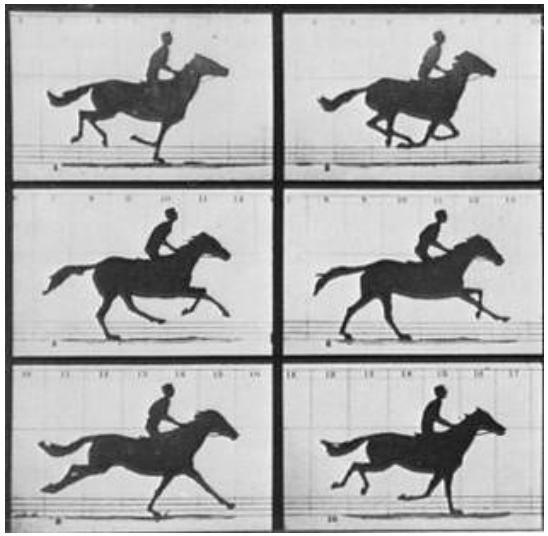
- → An avalanche of data, waiting to be visualized!

Preludes: technology

- Copperplate → Lithography (1800+) → color printing (1850+)
- Automatic recording: James Watt (1822)
- Calculation: Babbage (1822/33), Guerry ~1850
- Photography: Niépce (1827), Deguerre (1839), trichromatic process (1861)
- Motion: Muybridge (1872), Marey (1882)

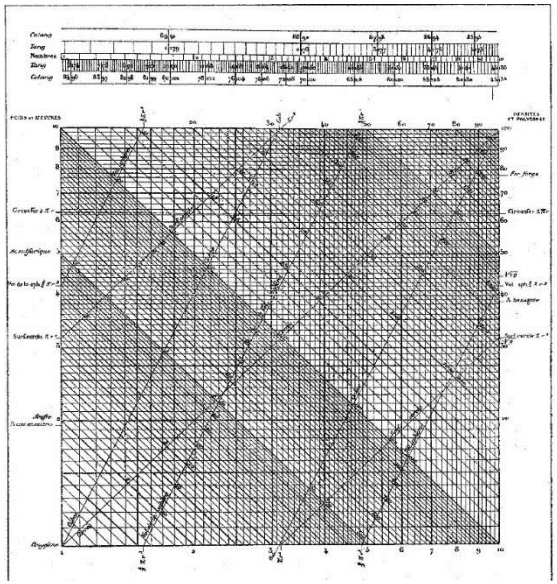


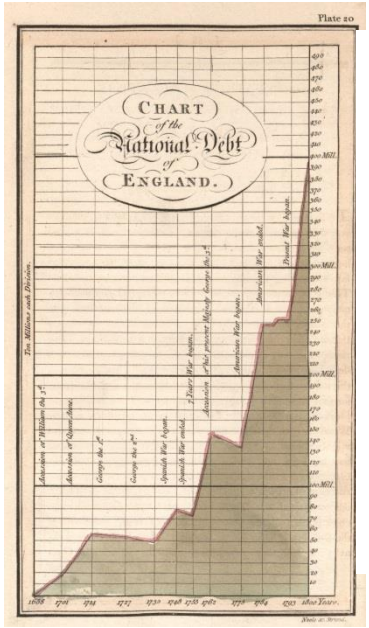


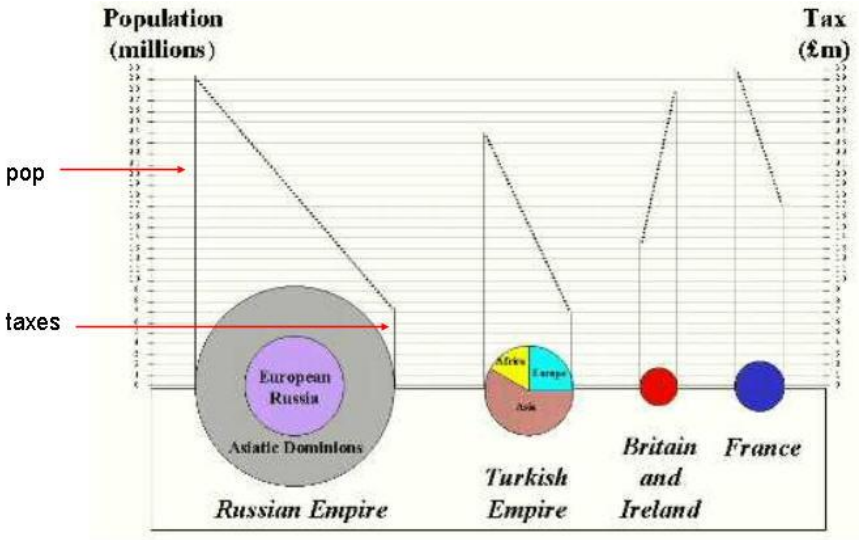


Preludes: visual language

- Graphs & diagrams
  - Line, bar, pie charts– Playfair (1786, 1801)
  - Scatterplot– Herschel (1832)
  - Polar plots– Guerry (1829), Nightingale (1857)
  - Nomograms & graphical calculation– Lalanne (1846)

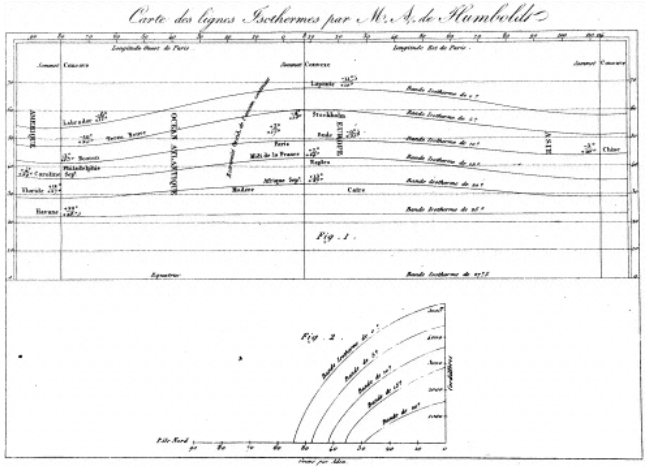


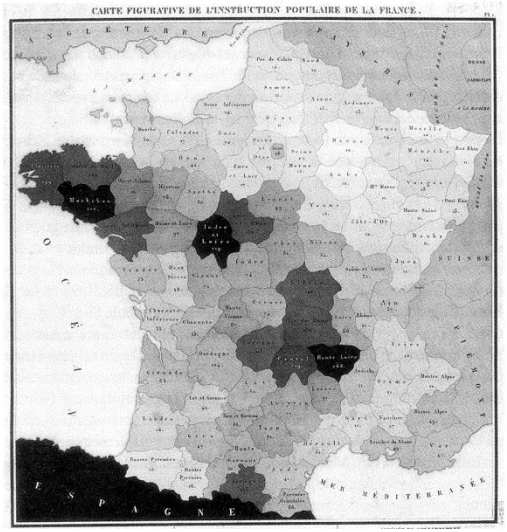


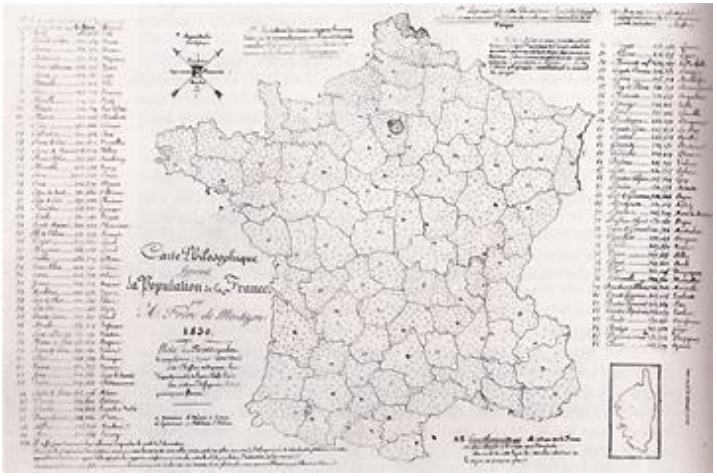


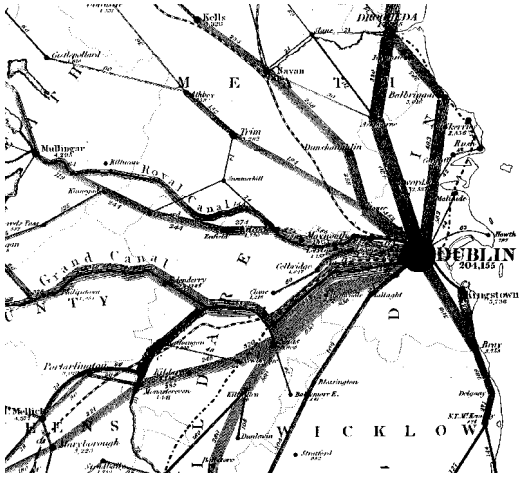
Preludes: visual language

- Thematic maps
  - Isopleth– Humboldt (1817)
  - Choropleth– Dupin (1826)
  - Dot– Frère de Montizon (1830)
  - Flow– Harness (1837)





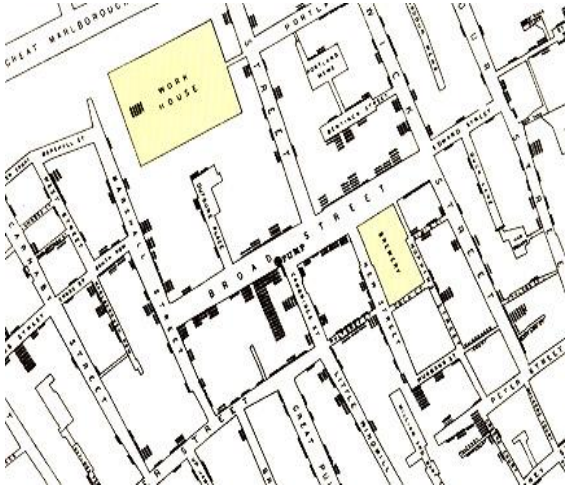




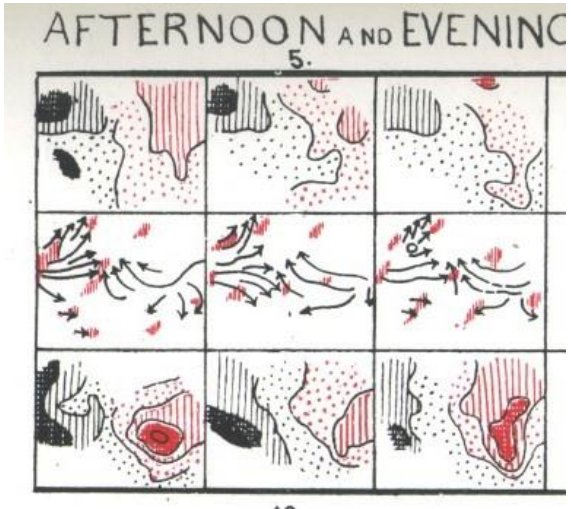
Visual language: thematic maps & statistical graphics

- Different ‘visual language’, but common goals:
  - **Exploration**: show trends, reveal patterns in quantitative or qualitative info
  - **Analysis**: aid in synthesizing, generalizing or testing patterns
  - **Presentation**: stimulate thought, convey conclusions, argue a point

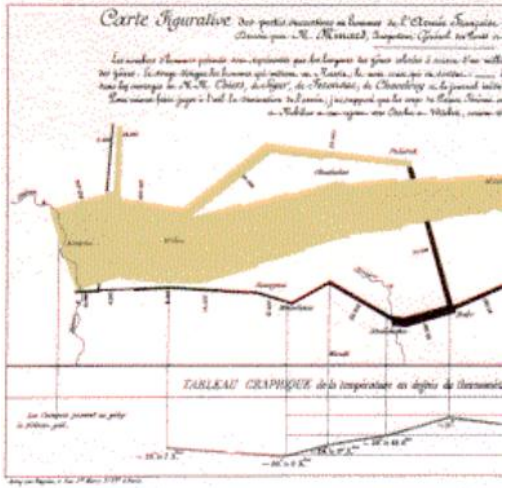
Snow (1855)



Galton (1863)



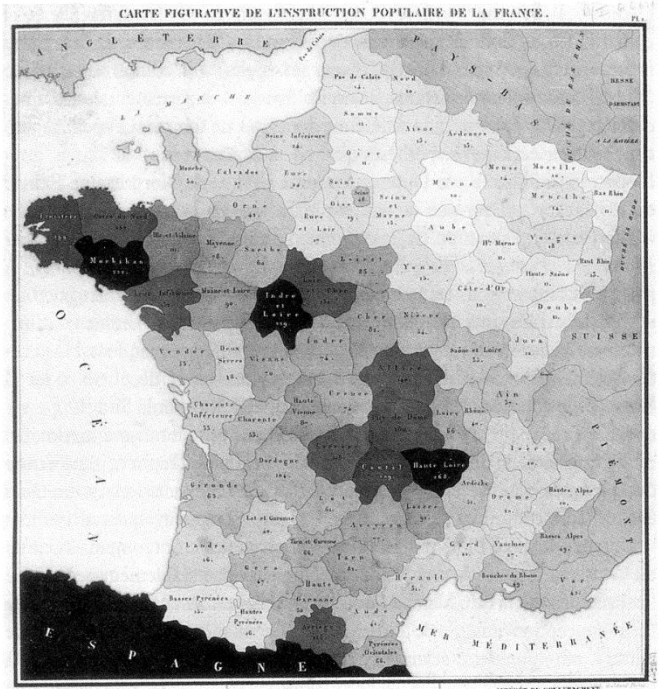
Minard (1869)



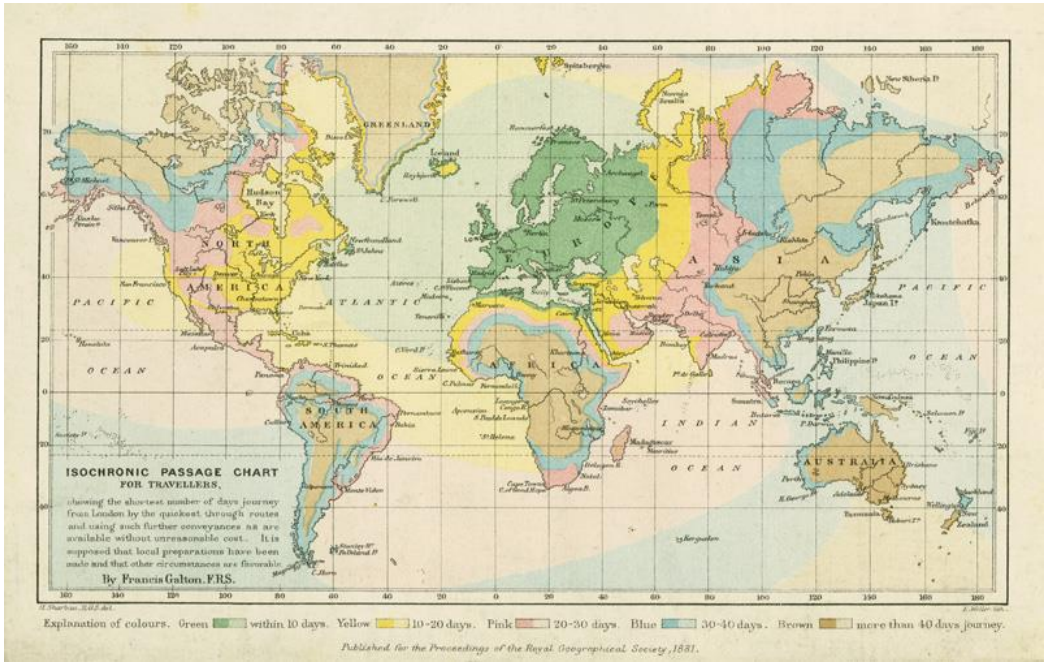
Data visualization: Diffusion of ideas

- Those who developed thematic maps often not cartographers

Dupin (1826): literacy in France

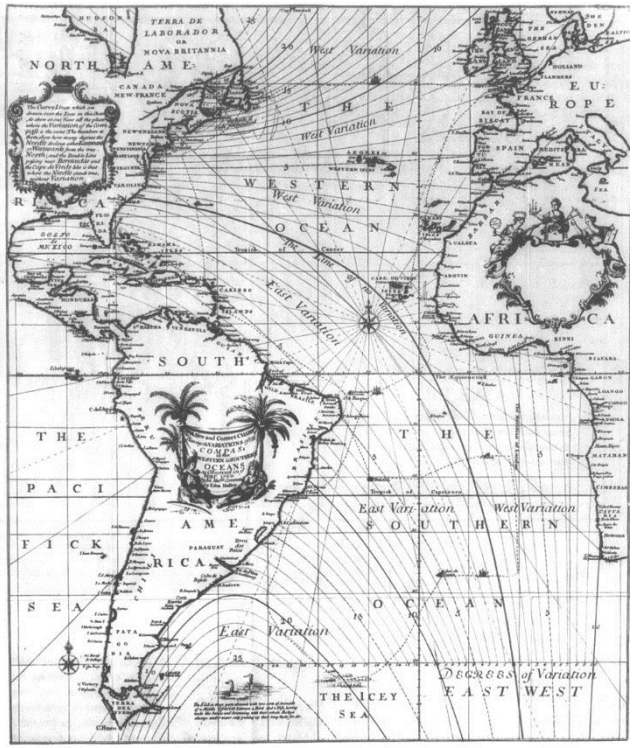


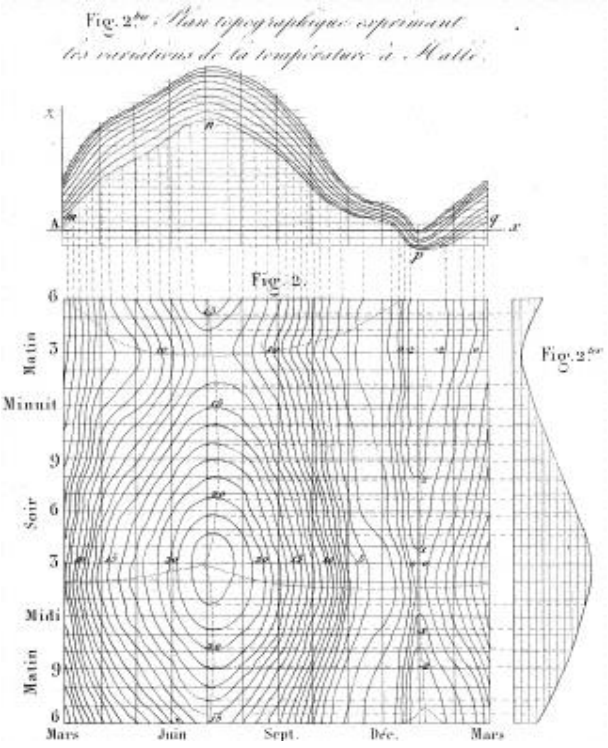
Galton (1881): travel time from London



Data visualization: Diffusion of ideas

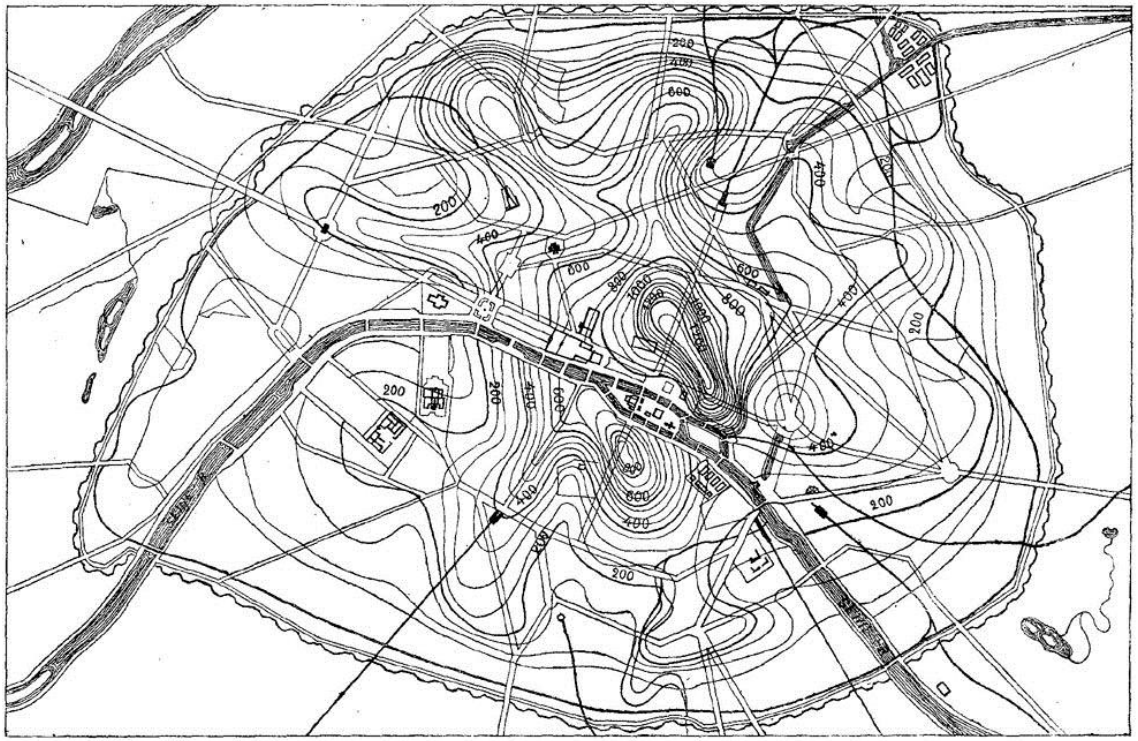
- Those who developed data graphics often borrowed from cartography
  - Halley (1701): contour map -> Lalanne (1843): contour diagrams of soil temperature





Data visualization: Diffusion of ideas

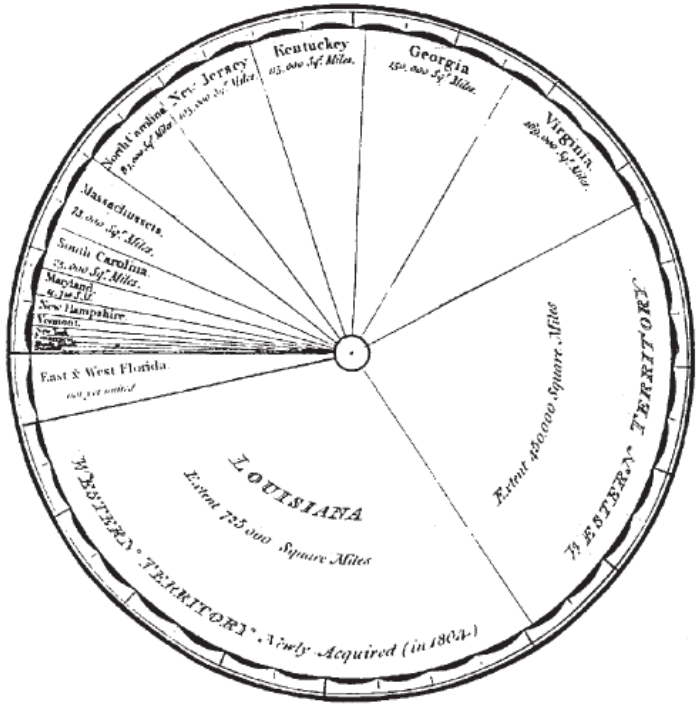
- … and vice-versa
  - Lalanne → L.L. Vauthier (1874) contour map of population density of Paris, seen as mountains
  - Map-based data visualization was extended widely



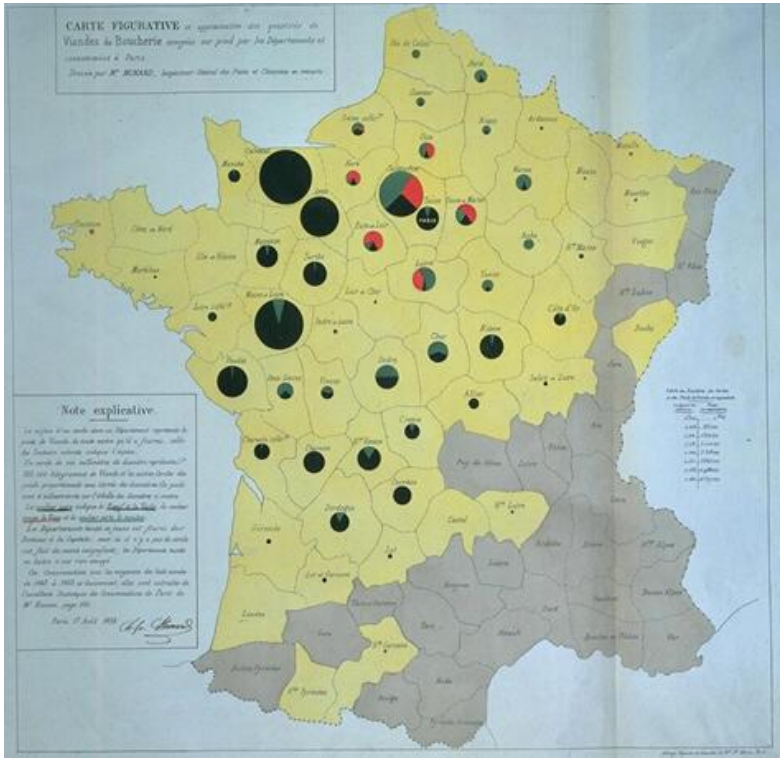
Data visualization: Diffusion of ideas

- Graphical inventions often applied to maps
  - Playfair (1805): pie chart -> Minard (1858): pie map

Where does meat sold in Paris come from?



STATISTICAL REPRESENTATION of the UNITED STATES of AMERICA.



Stories from the Golden Age (1850-1900)

Stories:

- A.-M. Guerry & the rise of social science
- Graphic vision of C. J. Minard
- Galton's graphical discoveries
- Statistical albums

Themes:

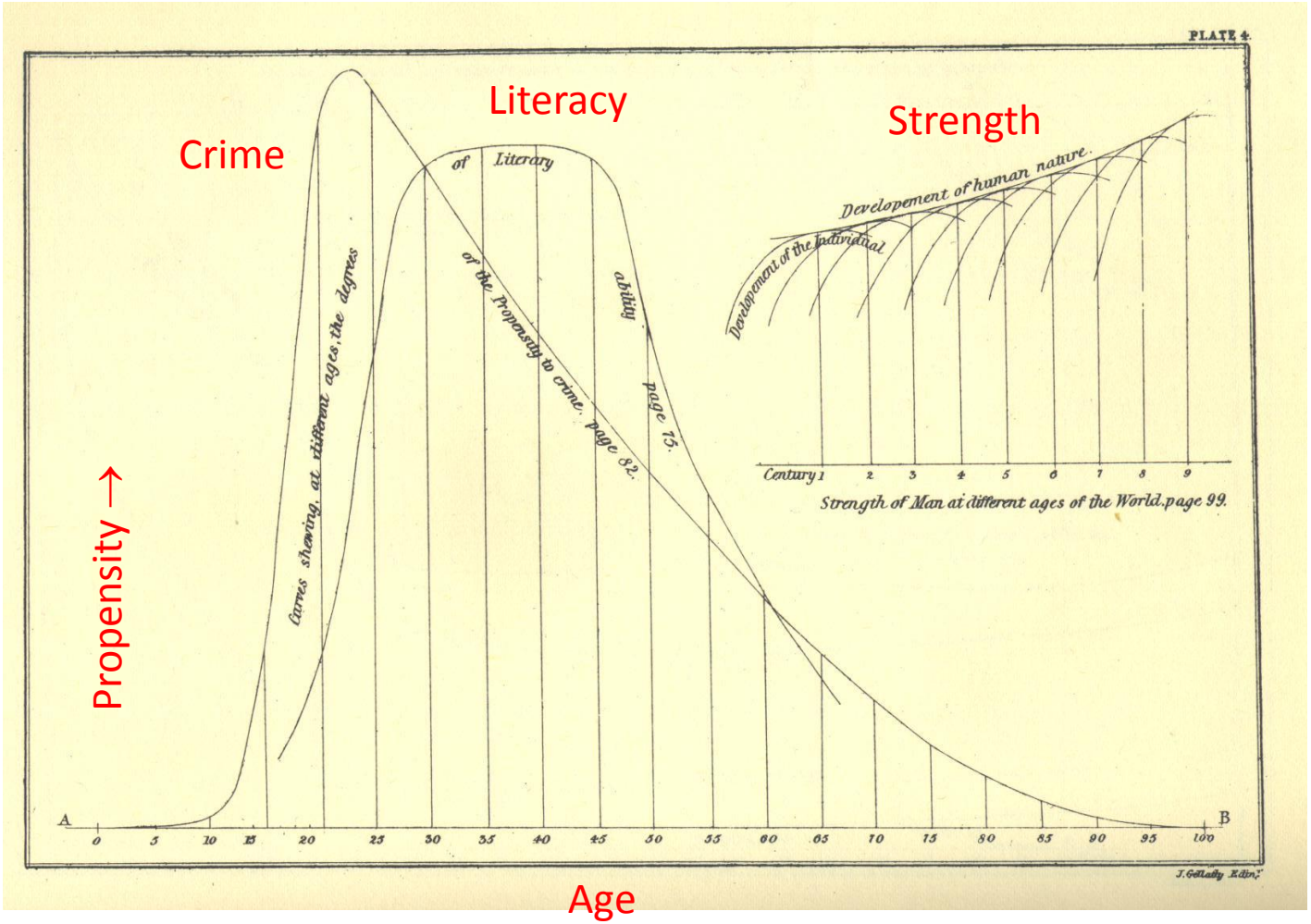
- Statistics: numbers of the state
- Rise of visual thinking
- Escaping flatland: 2D $\rightarrow$ 3D
- Visualization $\rightarrow$ Theory (graphic discovery)
- Data $\rightarrow$ Theory $\rightarrow$ Practice
- Graphical excellence

Big questions of the early 1800s

- Issues for European states
  - Demography: taxes, raising an army (Süssmilch, 1741)
  - "Statistik": Numbers of the state (Achenwall, 1748)
  - Social problems: crime, suicide, literacy, etc.
  - Disease epidemics, e.g., cholera
- Anthropometry: the measure of Man
  - Distributions of human characteristics (Quetelet)
  - Mortality, suicide, propensity to crime
- Beginnings of statistical theory and application
  - Normal dist^{n} (de Moivre, 1733)
  - *L'homme moyen* (Quetelet, 1835)

Quetelet: Anthropometry

Quetelet (1842), *A Treatise on Man and the Development of His Faculties*, uses graphs to illustrate various themes: measurement, graphical comparison, …



Human characteristics could be measured and studied graphically

Big data of the early 1800s:
"An avalanche of social numbers"

- J.-B.J. Fourier: *Recherches statistique sur la ville de Paris* (1821-1829)
  - Massive tabulations: births, deaths (by cause), admission to insane asylums (age, sex, affliction)
- Ministry of Justice: *Compte generale (1825--)*
  - First national compilation of criminal justice data
  - All charges & dispositions, quarterly, 86 departments
- Other sources:
  - Bureau de Longitudes (illegitimate births)
  - Parent-Duchatelet (prostitution); Min. of War (desertions)
  - Suicide notes in Paris collected and analyzed for motives
- Social issues could now be addressed with **DATA**

1. A. M. Guerry and the rise of social science

Essai sur la statistique moral de la France

The launching pad of modern social science

- Presented to Academie des Sciences Français July 2, 1832
- First systematic analysis of comprehensive data on crime, suicide, and other social variables.
- Along with Quetelet (1831, 1835), established the study of "moral statistics" ↦ modern social science, criminology, sociology


LIBRAIRIE SCIENTIFIQUE DE CROCHARD, ÉDITEUR,
Place de l'École-de-Médecine, n. 13.

ESSAI
SUR
LA STATISTIQUE
MORALE
DE LA FRANCE,
PAR
A. M. GUERRY,

PRIX : 15 FRANCS.

Ouvrage qui a obtenu le prix de statistique décerné en 1833
PAR L'ACADÉMIE ROYALE DES SCIENCES.

Social context of crime in 1820s France

- Crime a serious concern:
  - Explosive growth in Paris after Napoleon's defeat (Waterloo, 1815)
  - Widespread unemployment,
  - Emergence of perception of "dangerous classes": what to do???
    - Victor Hugo (Les Misérables); Honoré de Balzac; Emile Zola
- Liberal ("philanthrope") view:
  - Increase education
  - Better prison conditions, diet (bread ***and*** soup)
  - Religious instruction
- Conservative view:
  - Build more prisons; longer prison sentences
  - Harsher treatment of recidivists
- Now, there was finally some DATA!

The discovery of "social facts"

Stability and Variation

Guerry's results were both compelling and startling:

- Rates of crime and suicide remained remarkably invariant over time, yet varied sytematically by region, sex of accused, type of crime, etc.
- In any given French city or department, almost the same number committed suicide, stole, gave birth out of wedlock, etc.

Year	1826	1827	1828	1829	1830	Avg
Sex			All accused (%)			
Male	79	79	78	77	78	78
Female	21	21	22	23	22	22
Age			Accused of Theft (%)			
16–25	37	35	38	37	37	37
25–25	31	32	30	31	32	31
Crime			Committed in summer (%)			
Indecent assault	.	36	36	35	38	36
Assault & battery	.	28	27	27	27	28

The discovery of "social facts"

Social laws á la physical laws

Do crime and other moral variables represent:

- structural, lawful characteristics of society, or are they
- simply indicants of individual behaviour?

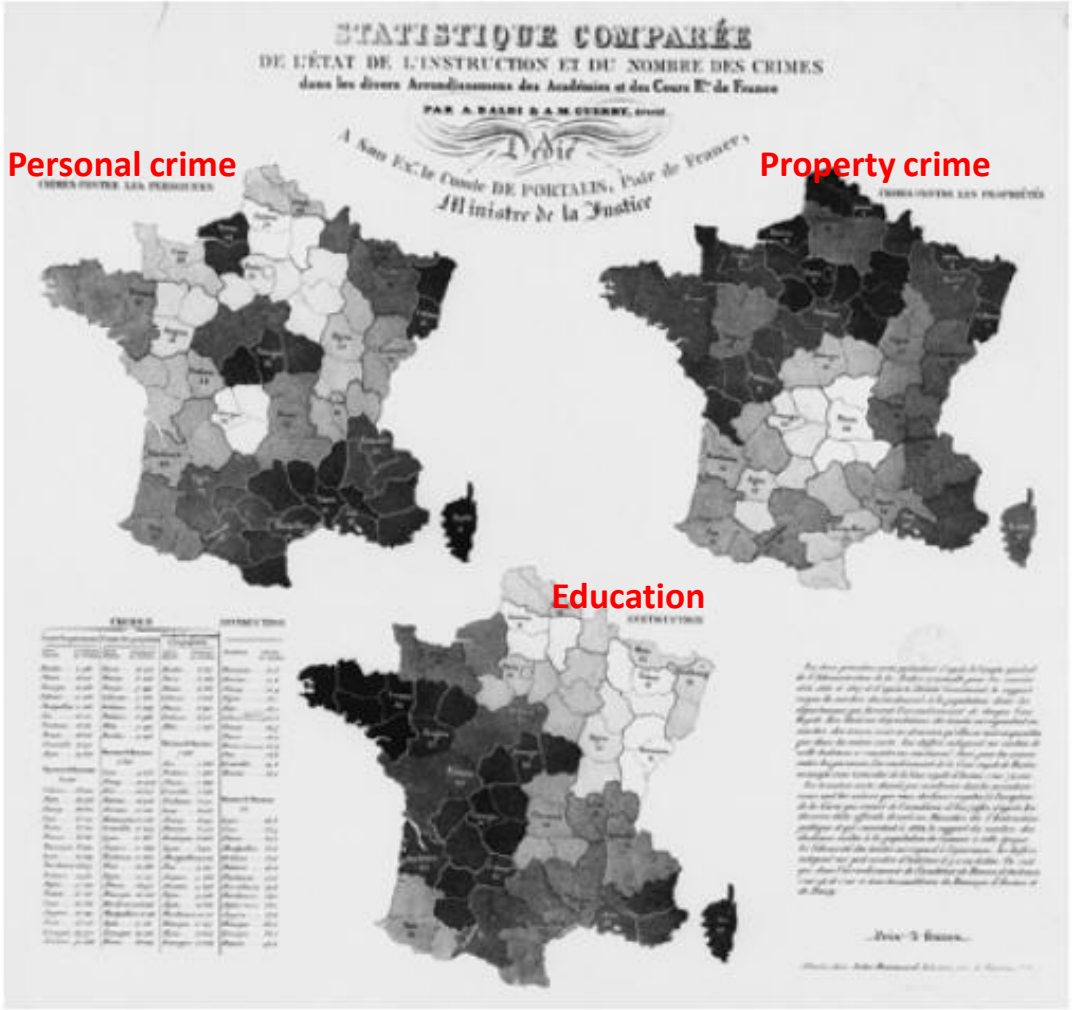
Guerry argued:

Each year sees the same number of crimes of the same degree reproduced in the same regions.(Guerry, 1833, p.10)

... We are forced to recognize that the facts of the moral order are subject, like those of the physical order, to invariable laws (Guerry, 1833, p14)

1829: *Statistique comparée de l'état de l'instruction...*

- First shaded thematic maps of crime data
- First comparative maps of social data
- $\mapsto$ crime against persons seemed inversely related to crime against property!
- Instruction: $\mapsto$ *France obscure* and *France éclairée* (Dupin, 1826)
- North of France highest in education, but also in property crime!



1833: Semi-graphic tables

Crimes against persons

- Indecent assault on adults (*viol sur des adultes*) decreases with age
- Indecent assault on children increases with age (top for 70+)
- Paricide rises to max at age 60–70

INFLUENCE DE L'AGE.

DISTRIBUTION DES CRIMES AUX DIFFÉRENS AGES, PAR PÉRIODE DE DIX ANNÉES. IV.

A. CRIMES CONTRE LES PERSONNES.

AU-DESSOUS DE 21 ANS.		DE 21 A 30.		DE 30 A 40.		DE 40 A 50.		DE 50 A 60.		DE 60 A 70.		AU-DESSUS DE 70 ANS.	
	Sur 1,000		Sur 1,000		Sur 1,000		Sur 1,000		Sur 1,000		Sur 1,000		Sur 1,000
1 Blessures et coups.	184	Blessures et coups.	218	Blessures et coups.	179	Assassinat.	194	Meurtre.	165	Meurtre.	173	Viol sur des enfans.	348
2 Viol sur des adultes.	169	Meurtre.	157	Assassinat.	154	Blessures et coups.	184	Assassinat.	162	Viol sur des enfans.	165	Blessures et coups.	137
3 Meurtre.	147	Assassinat.	136	Meurtre.	133	Meurtre.	133	Blessures et coups.	153	Assassinat.	159	Meurtre.	125
4 Viol sur des enfans.	103	Rébellion.	111	Rébellion.	100	Rébellion.	100	Rébellion.	90	Blessures et coups.	136	Assassinat.	102
5 Assassinat.	101	Viol sur des adultes.	105	Viol sur des adultes.	73	Viol sur des enfans.	84	Viol sur des enfans.	68	Faux témoignage.	93	Faux témoignage.	102
6 Rébellion.	78	Infanticide.	82	Infanticide.	63	Faux témoignage.	69	Faux témoignage.	76	Rébellion.	78	Rébellion.	91
7 Infanticide.	48	Viol sur des enfans.	58	Viol sur des enfans.	59	Violeur des adultes.	61	Viol sur des adultes.	52	Infanticide.	43	Empoisonnement.	33
8 Bless. env. accord.	47	Bless. env. accord.	50	Bless. env. accord.	59	Bless. env. accord.	54	Infanticide.	34	Empoisonnement.	36	Infanticide.	25
9 Associat. de malfait.	32	Faux témoignage.	33	Infanticide.	49	Infanticide.	41	Empoisonnement.	29	Parricide.	21	Viol sur des adultes.	22
10 Faux témoignage.	30	Empoisonnement.	30	Empoisonnement.	25	Empoisonnement.	28	Bless. env. accord.	19	Viol sur des adultes.	18	Associat. de malfait.	11
11 Empoisonnement.	11	Crim. env. des enf.	10	Crim. env. des enf.	16	Associat. de malfait.	19	Avortement.	15	Viol sur des adultes.	14	Vous de fait, etc.	11
12 Vous de fait, etc.	8	Associat. de malfait.	10	Associat. de malfait.	12	Bigamie.	13	Bigamie.	13	Crim. env. des enf.	11	Bless. env. accord.	-
13 Mend. av. violence.	6	Parricide.	8	Parricide.	9	Mendicité.	9	Mendicité.	13	Bless. env. accord.	7	Parricide.	-
14 Crim. env. des enf.	5	Vous de fait, etc.	6	Mend. av. violence.	8	Crim. env. des enf.	7	Parricide.	13	Associat. de malfait.	7	Crim. env. les enf.	-
15 Parricide.	5	Avortement.	5	Bigamie.	8	Avortement.	7	Associat. de malfait.	13	Bigamie.	7	Avortement.	-
16 Avortement.	3	Mend. av. violence.	3	Avortement.	6	Parricide.	4	Crim. env. des enf.	6	Vous de fait, etc.	7	Bigamie.	-
17 Bigamie.		Bigamie.	1	Vous de fait, etc.	4	Vous de fait, etc.	4	Mend. av. violence.	6	Mend. av. violence.	7	Mend. av. violence.	-
Autres crimes.	4	Autres crimes.	7	Autres crimes.	12	Autres crimes.	12	Autres crimes.	26	Autres crimes.	11	Autres crimes.	34
Totaux.	1,000		1,000		1,000		1,000		1,000		1,000		1,000

Figure: Ranking of crimes against persons at different ages

1864: *Statistique morale de l'Angleterre comparée...*

Dayenu!

- Proposes to replace simple "moral statistics" (tables) with "analytical statistics"
  - calculation, graphic display
  - $\mapsto$ general, abstract results
- 17 large color plates (56 $\times$ 39 cm):
  - data for France (1825–1855), England (1834–1855)
  - crimes against persons and property decomposed in various ways
  - first attempt to delineate multivariate relations among moral variables
- Voluminous data:
  - 85,564 suicide records (1836–1860), classified by motive
  - 226,224 accused of personal crime
  - numbers, in a line $\rightarrow$ 1170 meters!

STATISTIQUE MORALE

DE

L'ANGLETERRE

COMPARÉE AVEC

LA STATISTIQUE MORALE

DE

LA FRANCE

PAR A.-M. GUERRY

ATLAS

PROSPECTUS

PARIS

J.-B. BAILLIÈRE ET FILS,

LONDRES, NEW-YORK,

MADRID.

Further details: Friendly, M. (2007). A.-M. Guerry's *Moral Statistics of France:* Challenges for Multivariable Spatial Analysis, *Statistical Science, 22*, 368-399

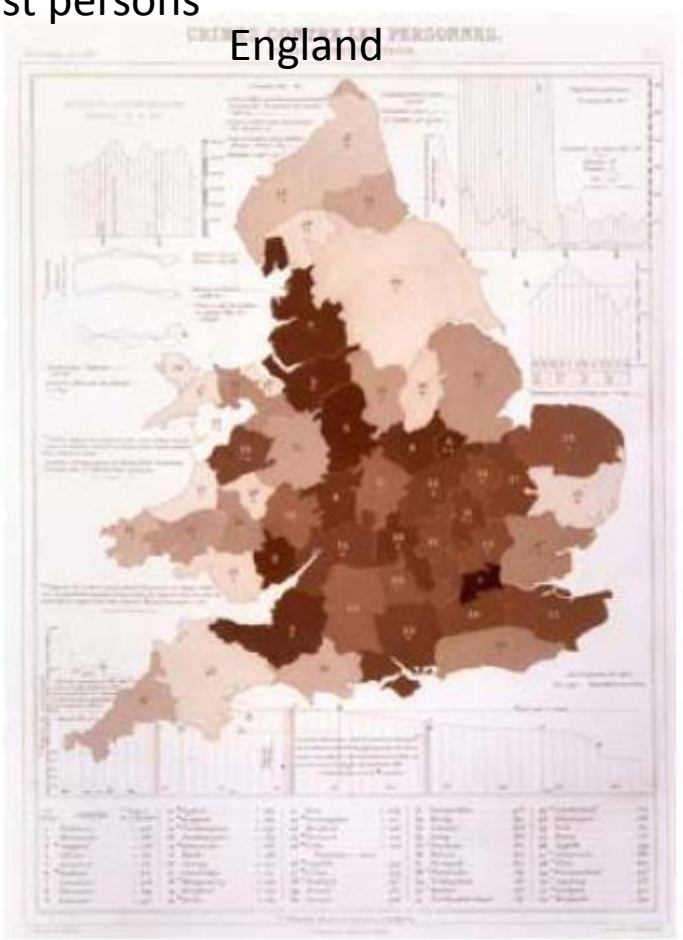
1864: *Statistique morale de l'Angleterre comparée...*

Comparing France and England

Crimes against persons

France

England



Graphs and tables around the outside give details: data, trends over time, or season, …

Statistique analytique: General causes of crime

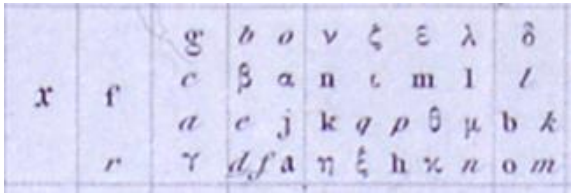
Plate XVII: M. Guerry's magnum opus

Goal:

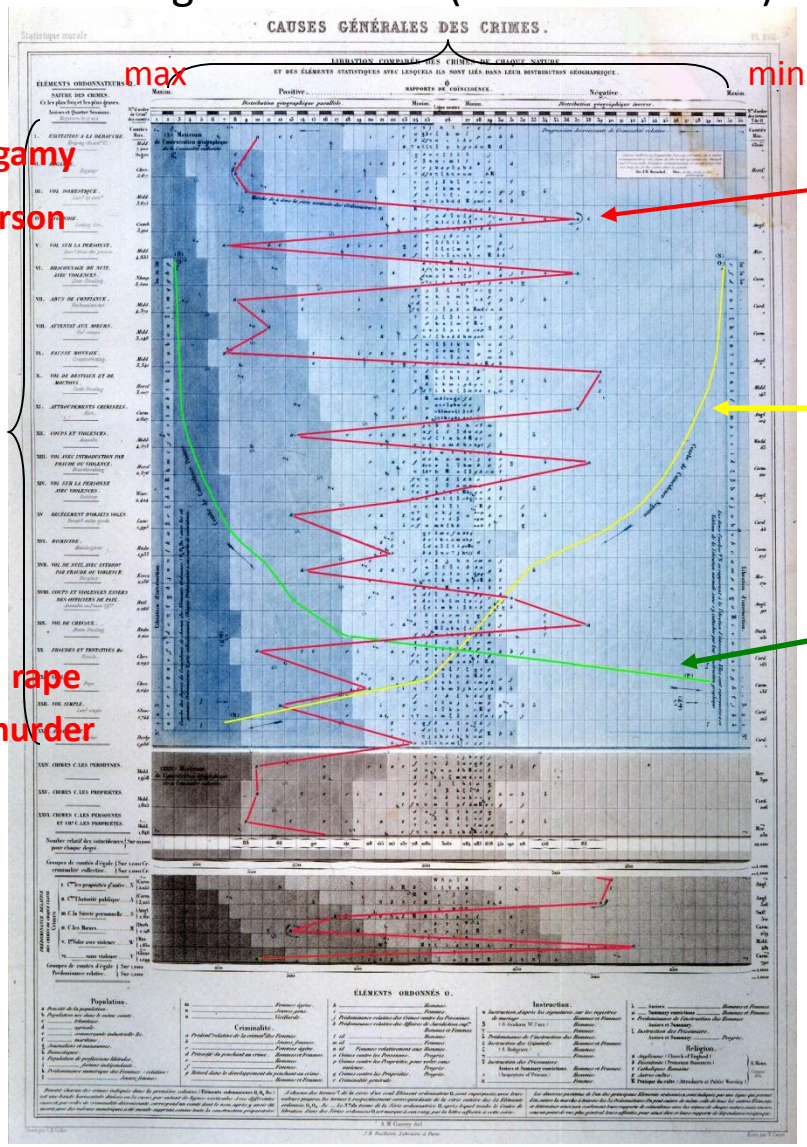
- Show multivariate factors associated with distribution of crime
- Before invention of correlation

Entries: Codes for factors

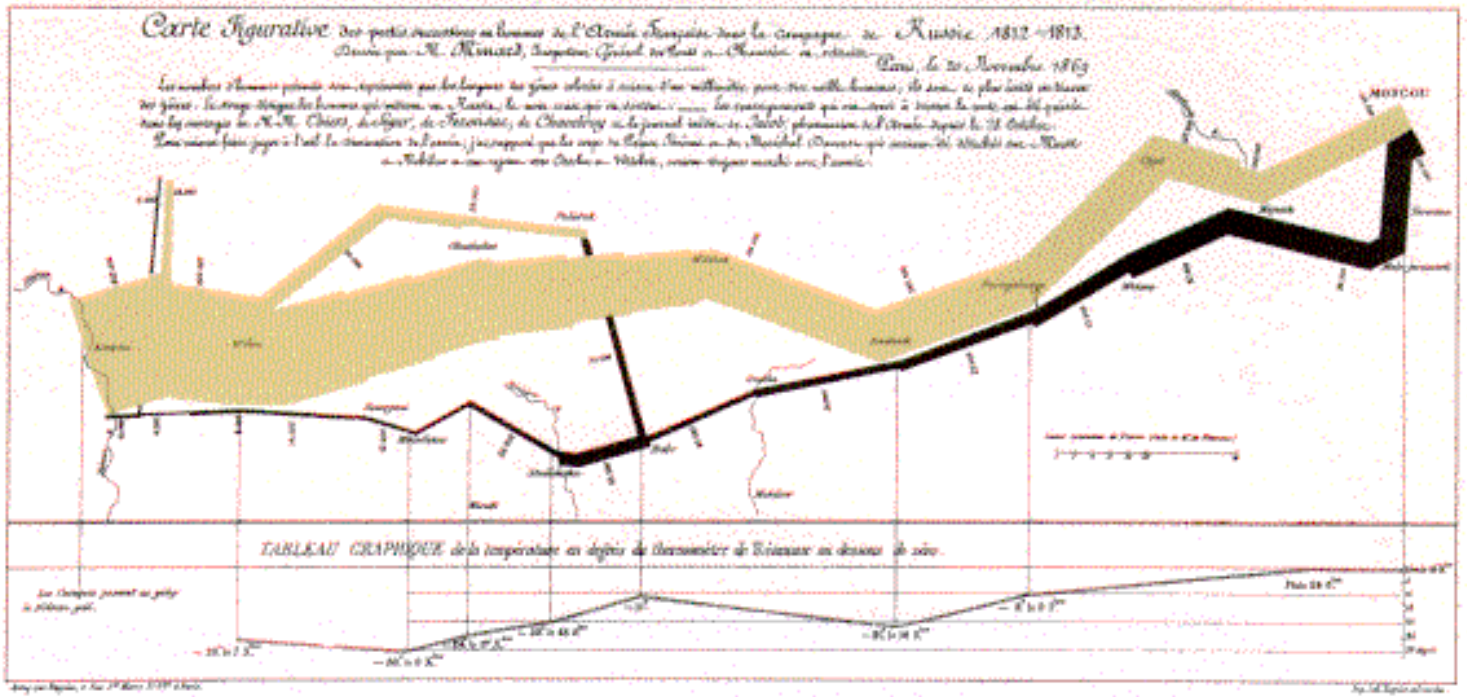
- Pop: (% Irish, domestics, …)
- Criminality: (male, young, …)
- Religion (Anglicans, dissenters, …)



English counties (ranked on each)



2. The graphic vision of C. J. Minard



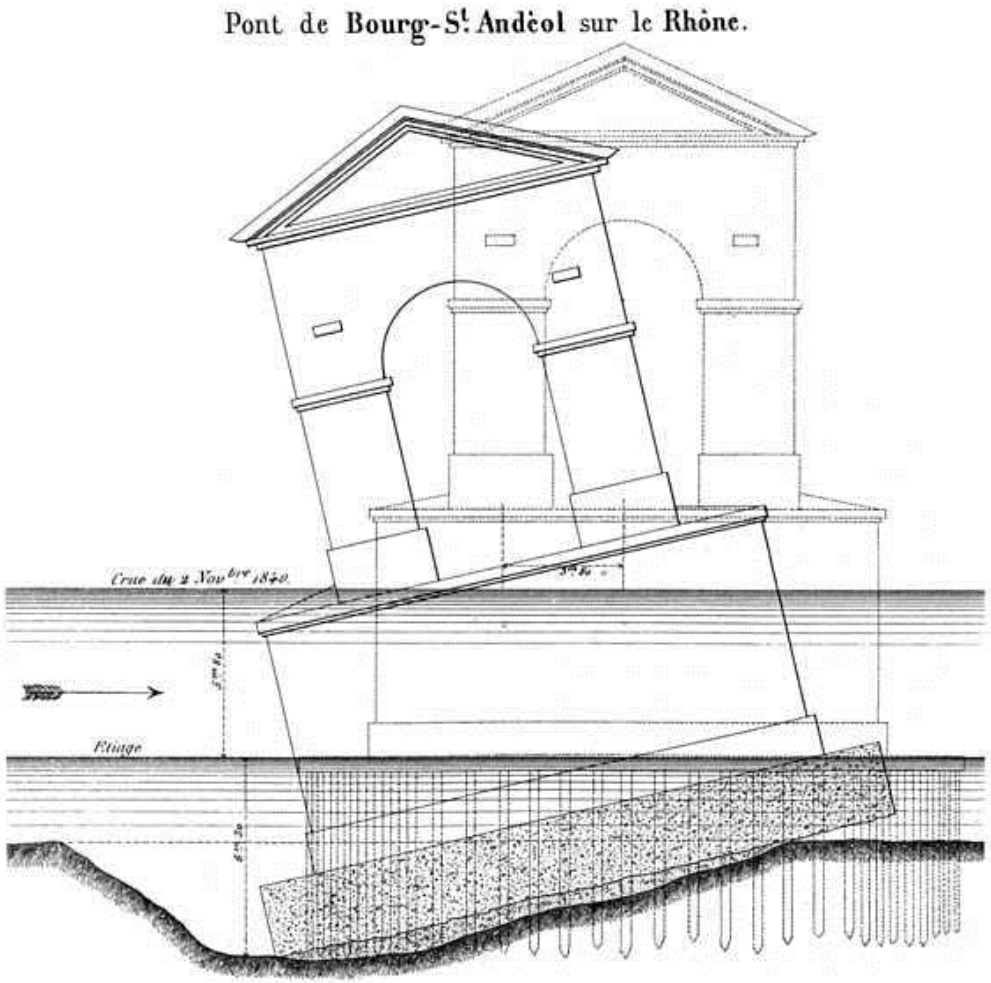
- Marey (1878): *"defies the pen of the historian in its brutal eloquence"*
- Tufte (1983): *"the best statistical graphic ever produced"*

Visual thinking, visual explanation

Minard's main career was a as a civil engineer for the ENPC (bridges & roads)

1840: Why did the bridge at Bourg-St. Andèol collapse?

Minard's report consisted essentially of this self-explaining diagram.



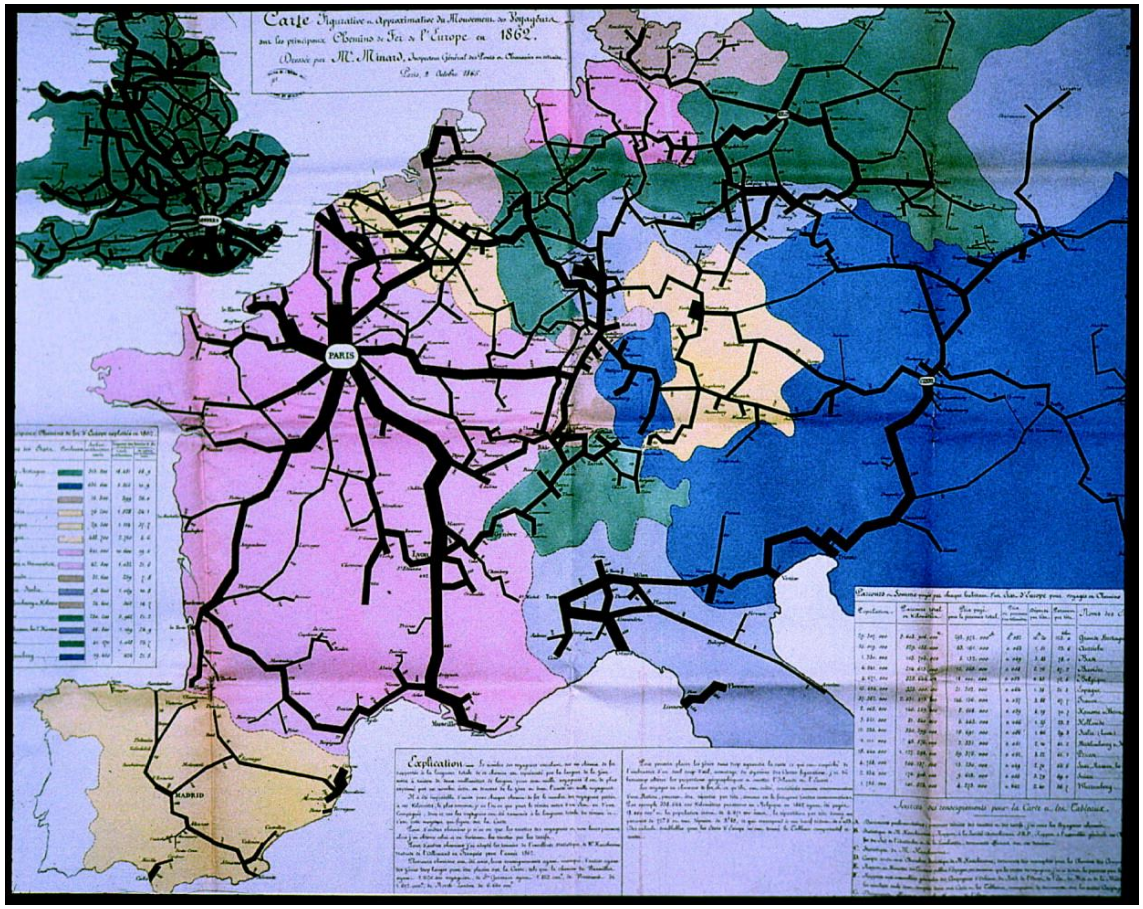
Big questions of the mid 1800s

- 1830—1860: emergence of modern French state, dawn of globalization
- Trade, commerce, transportation:
  - Where to build railroads, canals?
  - How to compete with imports/exports?
  - Visualizing changes over time, differences over space
  - $\rightarrow$ Flow maps and other graphical innovations
- These questions motivated the "Golden Age" of statistical graphics.
  - data, statistics, technology & visual thinking

See: Friendly, M. (2008). The Golden Age of Statistical Graphics, *Statistical Science, 23*, 502-535, https://www.datavis.ca/papers/golden-age.pdf

Flow maps as visual tools

Transport of passengers on the principal railroads in Europe in 1862



The dominant principle which characterizes my graphic tables and my figurative maps is to make immediately appreciable to the eye, as much as possible, the proportions of numeric results.

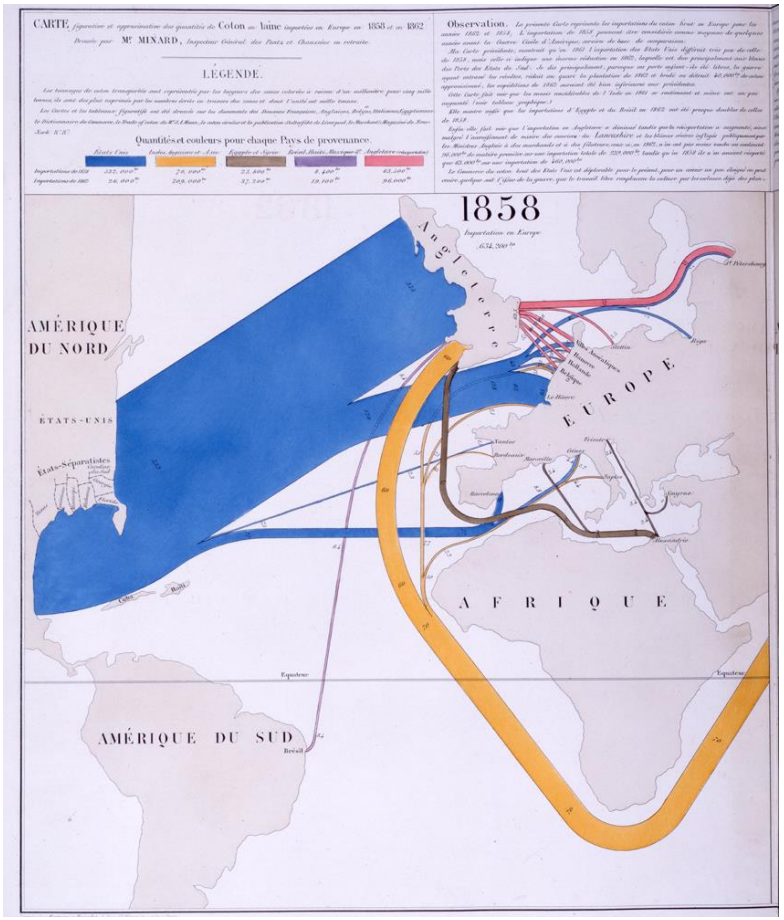
...Not only do my maps speak, but even more, they count, they calculate by the eye.

-- Minard (1862)

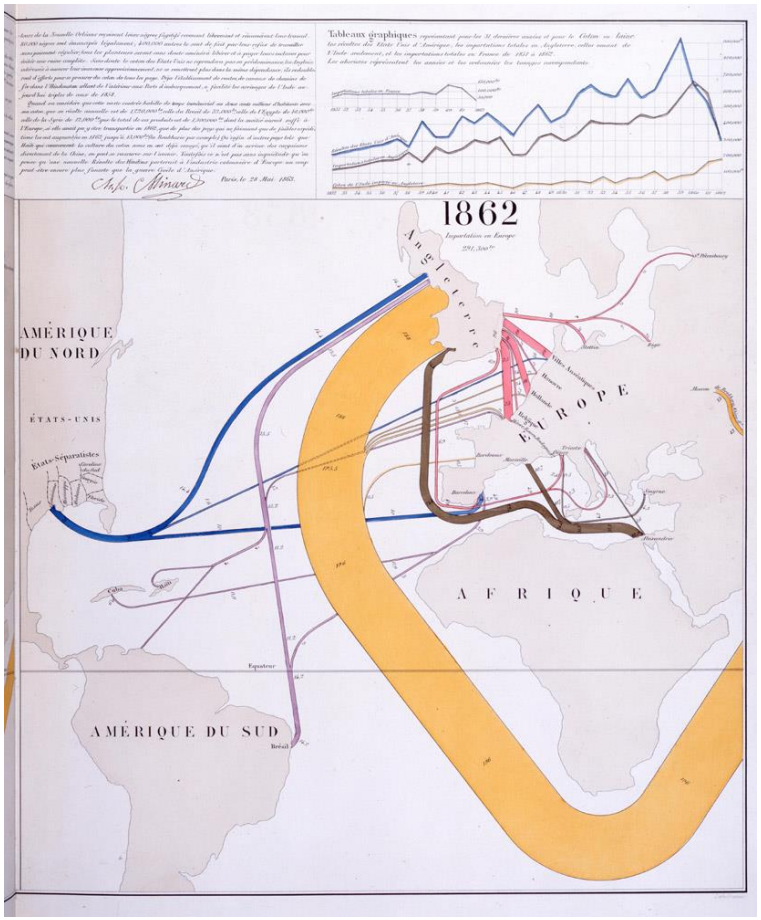
Effect of US civil war on cotton trade

Visual explanation

Before



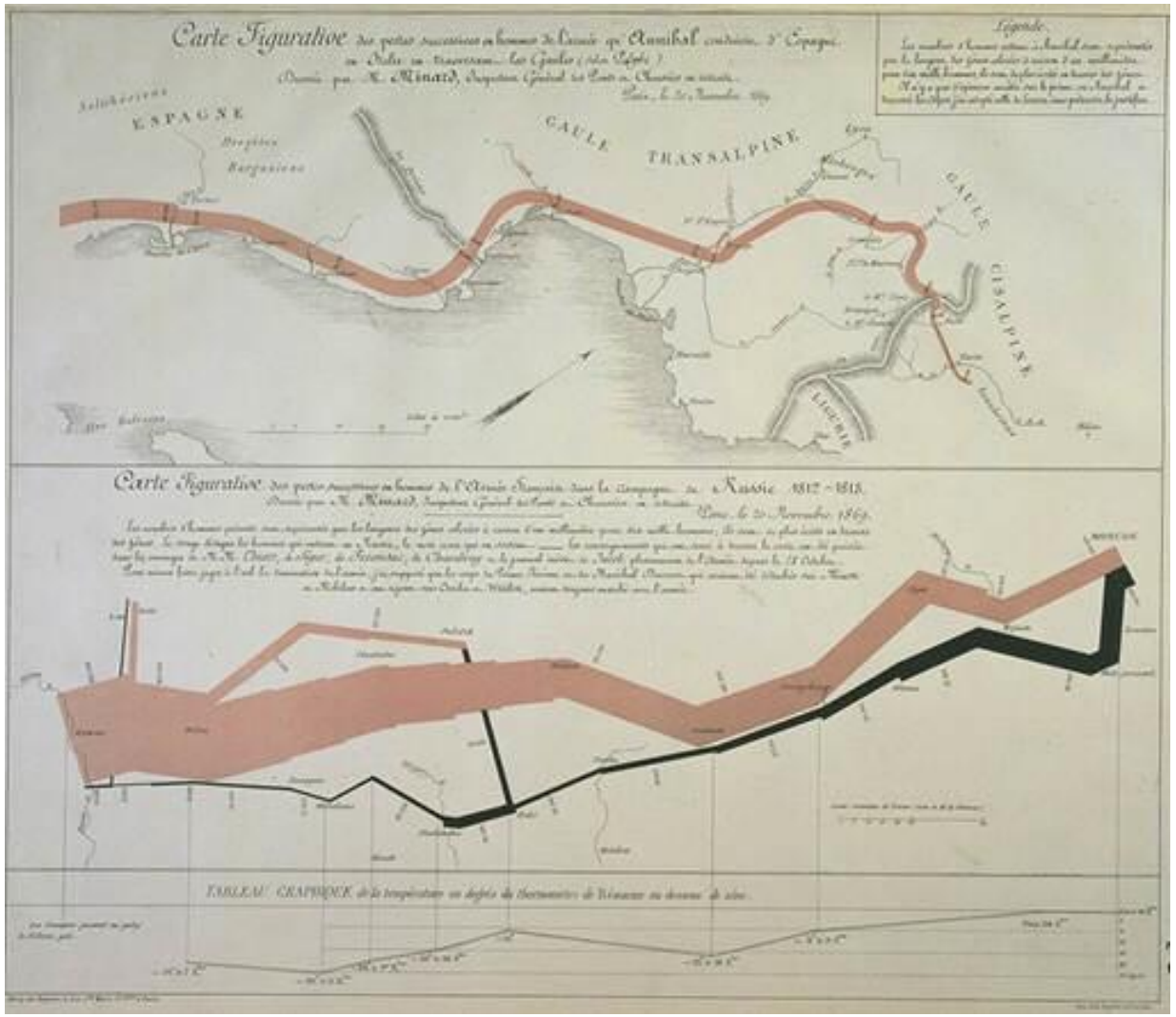
After



The March Re-Visited (1869)

Hannibal's retreat

Napoleon's 1812 campaign



Les Chevaliers: Minard's Tomb

Recent discovery of Minard's tomb in Montparnasse Cemetery, Paris.

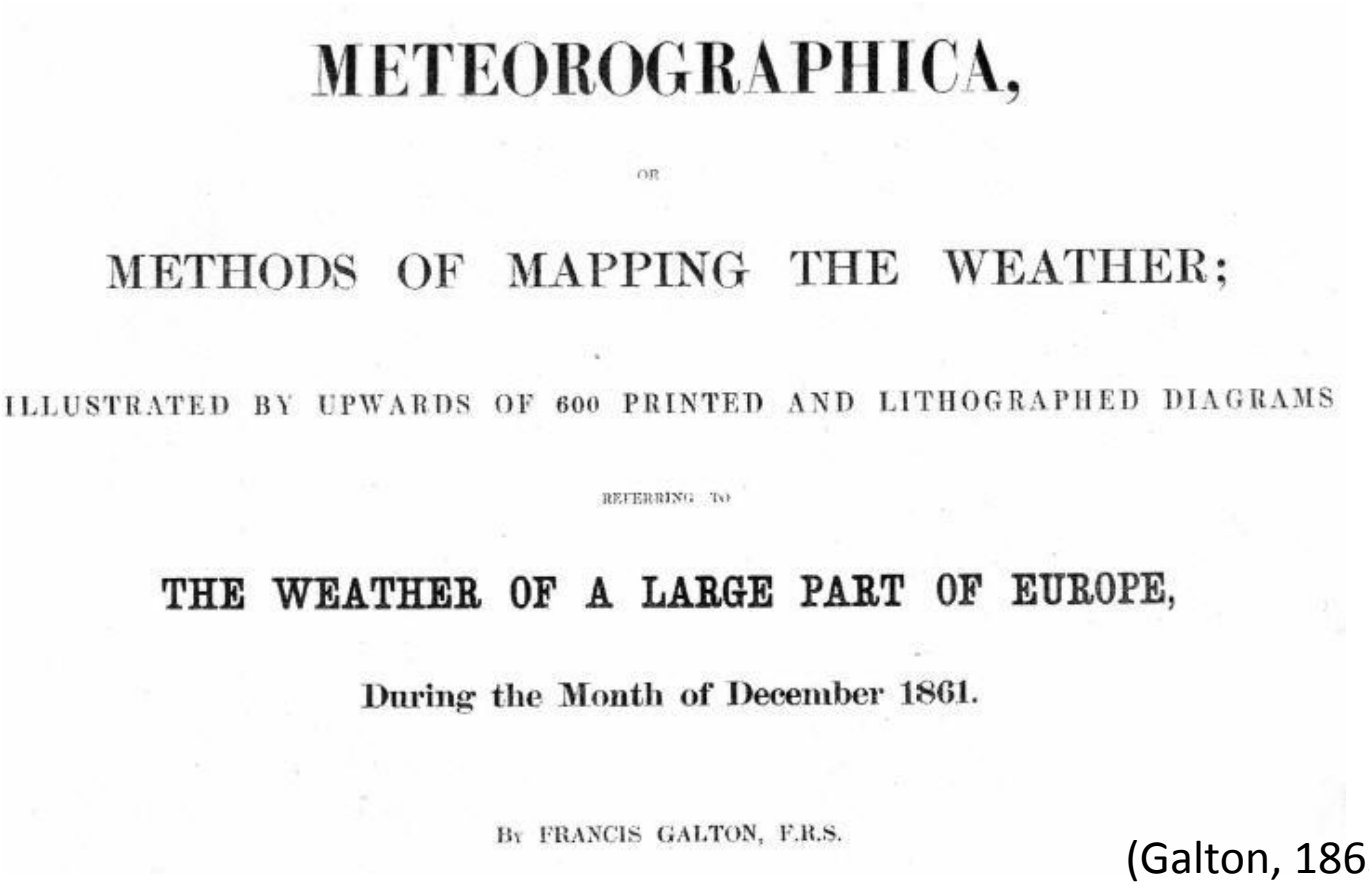
Celebrated June 5, 2017

Jean-Pierre Airey-Jouglard Antoine de Falguerroles

MF Gilles Palsky

Galton's discovery of weather patterns-

Perhaps the most notable *purely graphic* discovery ever!



METEOROGRAPHICA,

OR

METHODS OF MAPPING THE WEATHER;

ILLUSTRATED BY UPWARDS OF 600 PRINTED AND LITHOGRAPHED DIAGRAMS

REFERRING TO

THE WEATHER OF A LARGE PART OF EUROPE,

During the Month of December 1861.

By FRANCIS GALTON, F.R.S.

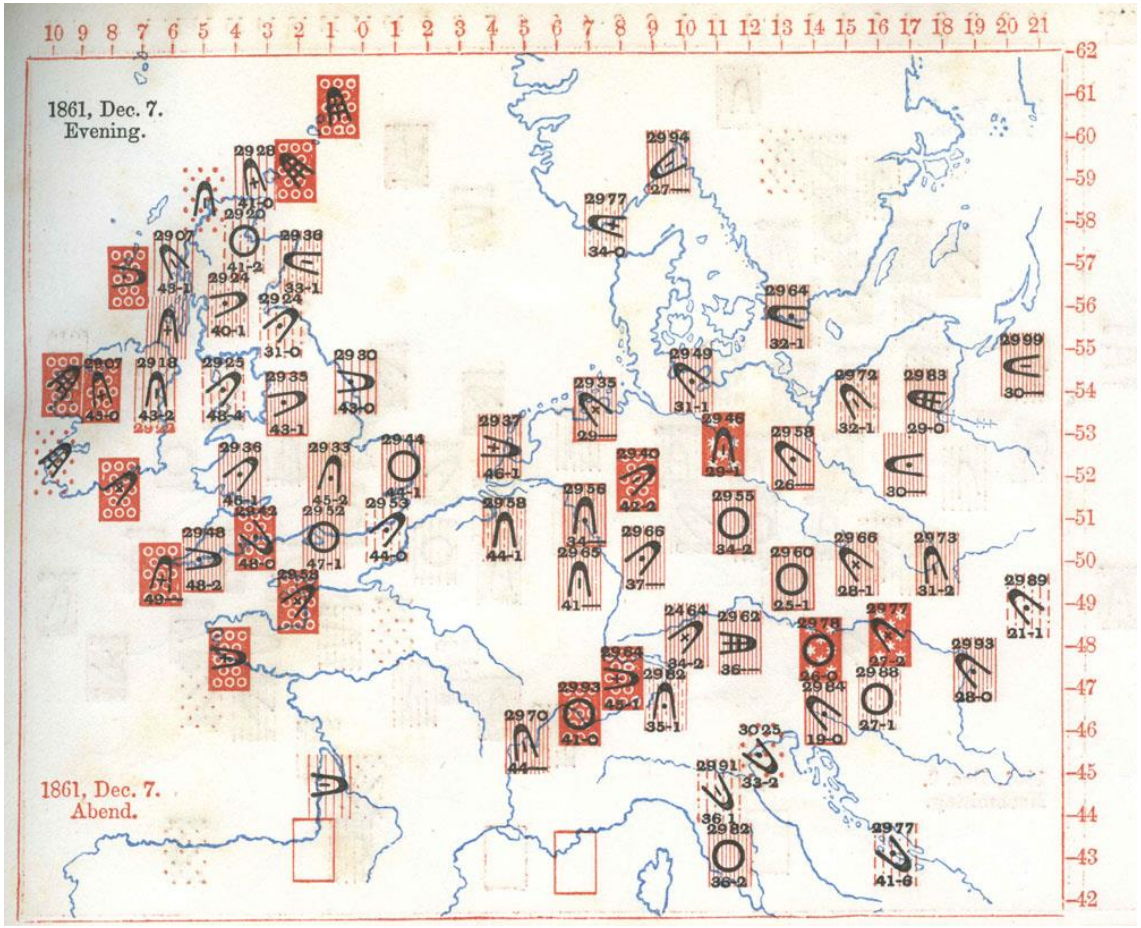
(Galton, 1863)

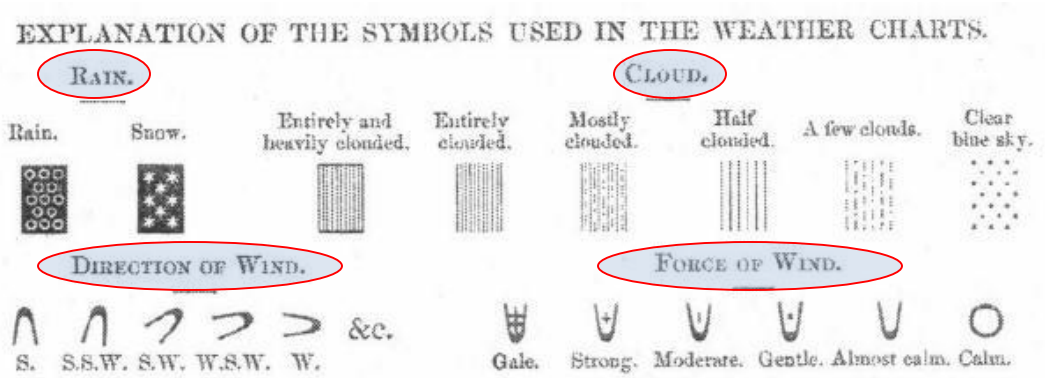
Method: All weather stations across Europe asked to record data 3x/day for all of Dec., 1861

Data: recordings of barometric pressure, wind dir/speed, rain, temp., cloud: 3x/day, 50 weather stations in Europe.

Graphic analysis: 3x31=93 maps, each with multivariate glyphs showing all variables

Visual ideas:
- Iconic symbols
- Multivariate glyphs (stamps!)





Visual abstraction → Patterns

How to see patterns of geographical variation over time?

- Iconic symbols on a geographical grid
- "Small multiples:" separate graphs laid out for direct comparison

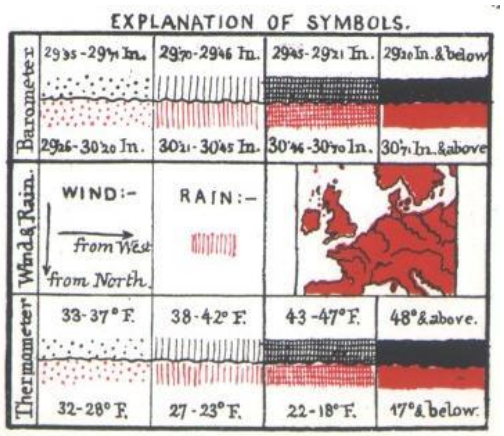
Symbols in Barometrical Charts.

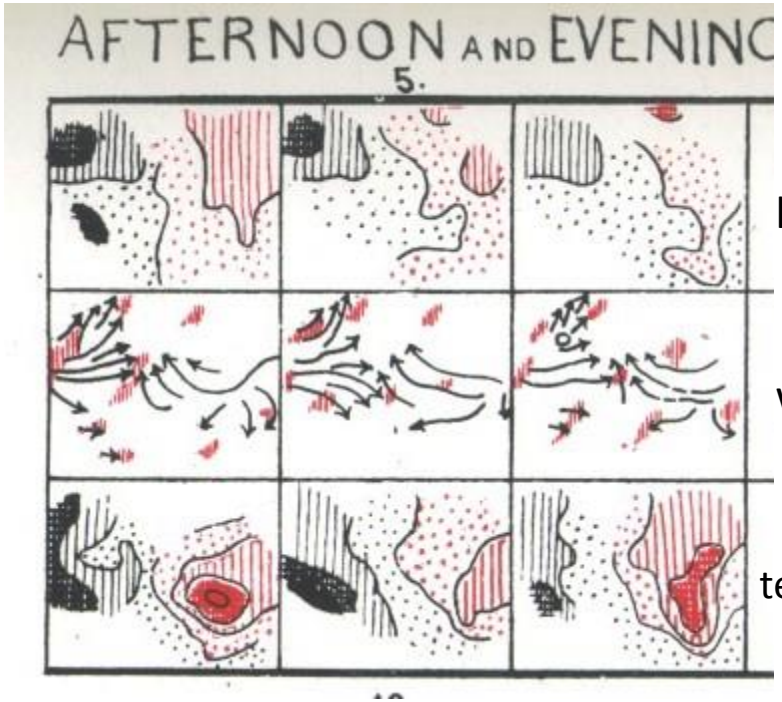
	Inches. Inches.	Inches. Inches.	Inches. Inches.	Inches.
Black -	29.95 to 29.71	29.70 to 29.46	29.45 to 29.21	29.20 and below.
	○	⊙	✳	●
Red -	29.96 to 30.20	30.21 to 30.45	30.46 to 30.70	30.71 and above.

Visual abstraction → Patterns

What varies with what, over time and space?

- mini, abstract maps: vars x TOD
- iso-contours, shading to show equivalence
- arrows to show wind direction





pressure

wind, rain

temperature

AM noon PM

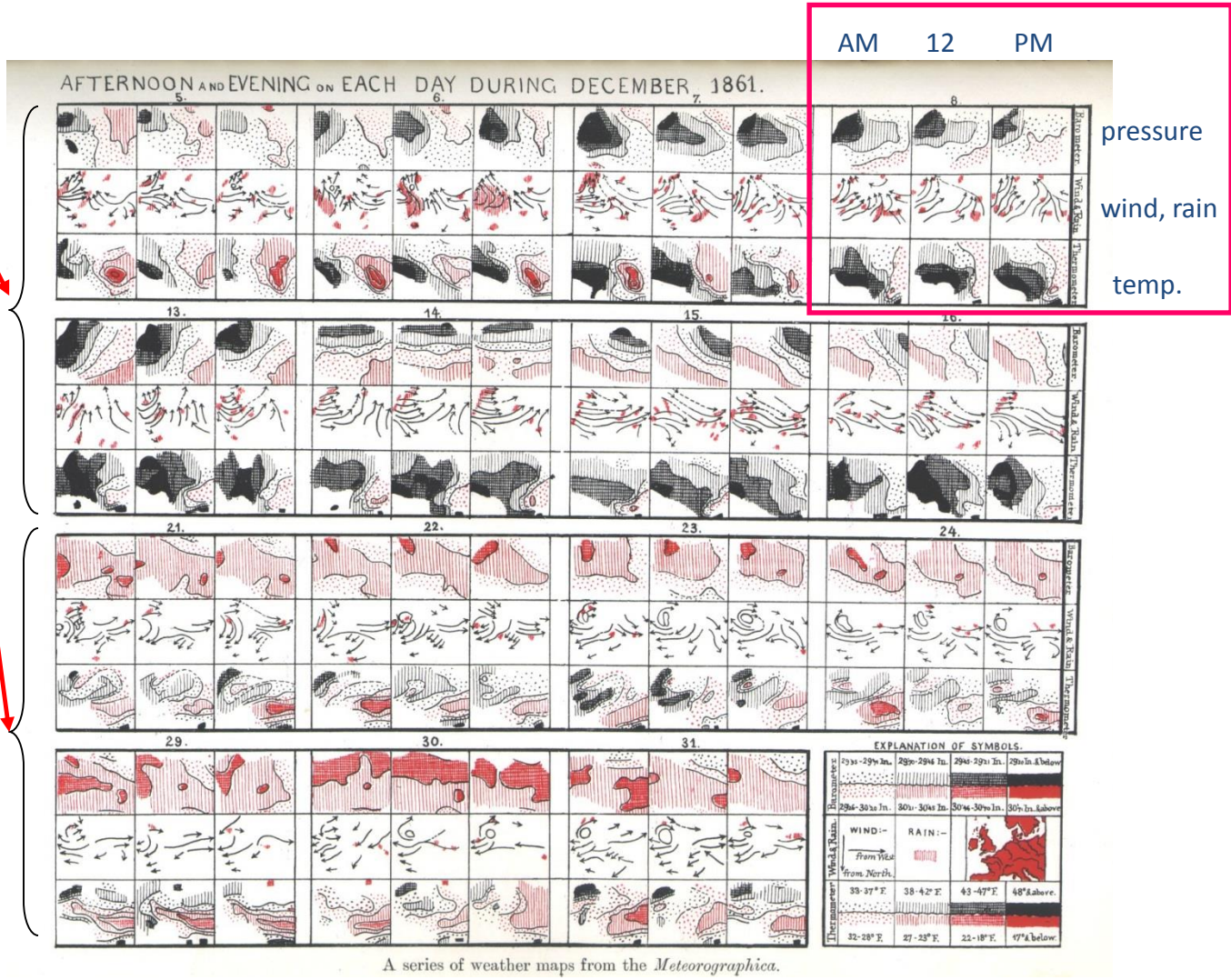
Data for Dec 5, 1861

The large picture → Insight

Pattern:
Low pressure (black) in early Dec. → CCW wind
High pressure (red) in late Dec. → CW wind

Graphic: 3x3x31 grid, mapping {pressure, wind/ rain, temperature} x {AM, 12, PM} x day {1:31}

(try this with your software!)



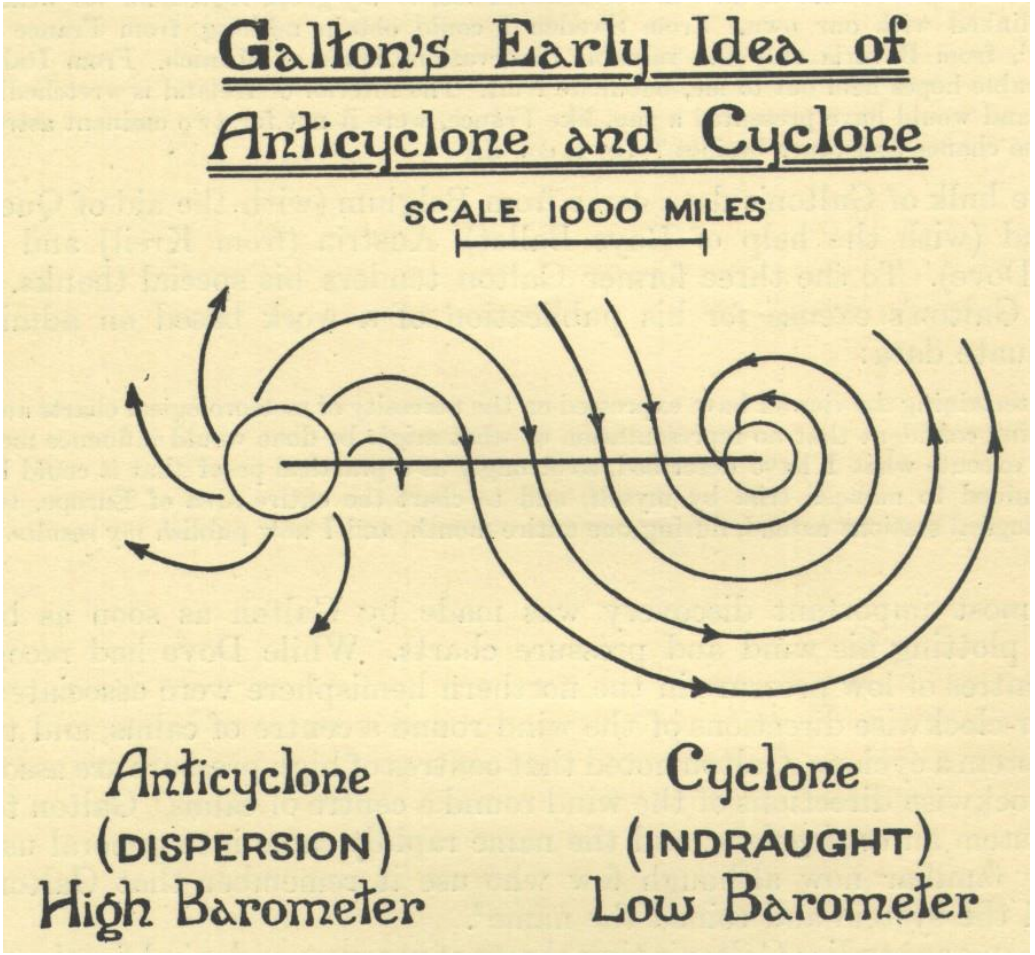
Visual insight → Theory

Visual insight from 93 (3x31) high-D graphs:

- Changes in wind dir w/ pressure over time
- → Winds revolve inwardly (CCW) in low pressure areas– as in a cyclone;
- → revolve outwardly (CW) in high pressure areas– "anti-cyclone"

Theory:

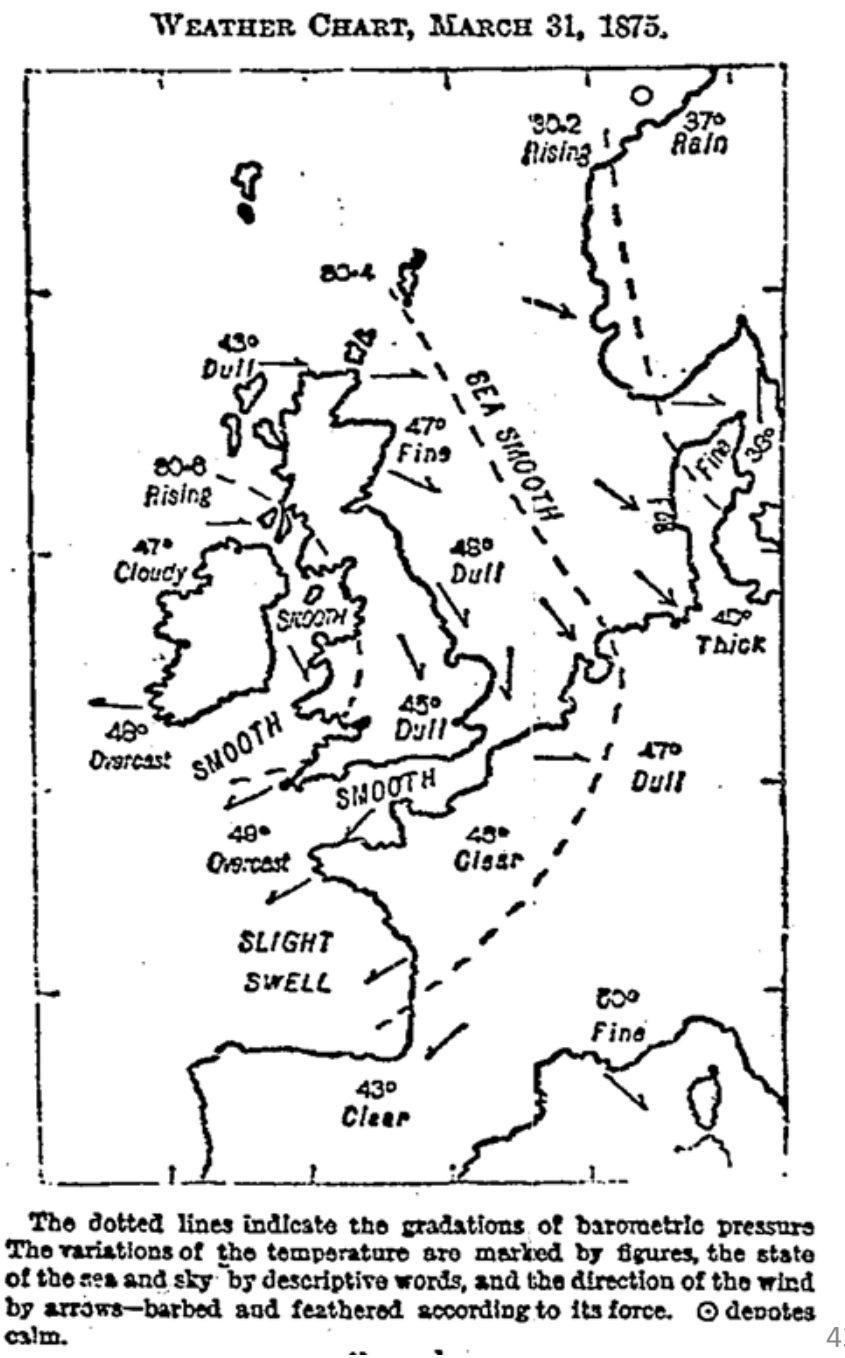
- Explained by Dove's 'Law of Gyration'
- Prediction: reversed pattern (CW/CCW) in southern hemisphere – confirmed!



Theory → Practice

The first modern weather map, *London Times*, Apr. 1, 1875

Galton did for weathermen what Kepler did for Tycho Brahe. This is no small accomplishment. (Wainer 2005)



4. Statistical atlases: Data → practice, national identity & graphical excellence

- Collection of gov't statistics on pop., trade, moral & political issues widespread in Europe & US, starting ~ 1820
- Statistical albums ~ 1870—1910
  - France: *Album de Statistique Graphique*: 1879-1899
  - USA: Census atlases: 1870/80/90
  - Germany: local albums (Berlin, Frankfurt, etc.)
  - Switzerland: *Atlas graphique de la Suisse:1897, 1914*
  - *Others: Latvia, Romania, Bulgaria, etc.*

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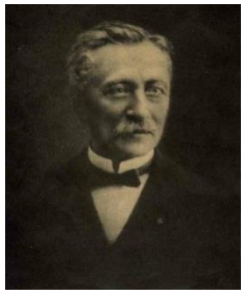
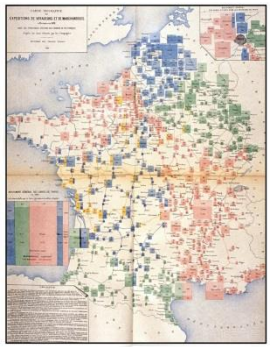
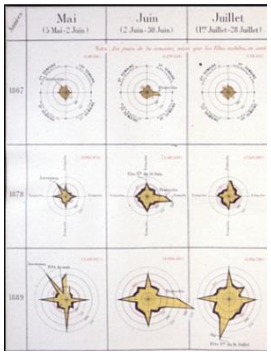
Album de statistique graphique

- Published by the *Statistical Graphics Bureau*, Ministry of Public Works, Émile Cheysson, director
- 18 volumes: 1879-1899, 12—34 plates each, ~ 11”x15” pages
- Graphic forms:
  - Flow maps (simple, double, multi)
  - Pie maps, star, radial, polar time-series, proportional circles
  - Mosaic maps, anamorphic maps, planetary diagrams
  - Choropleth, bi-polar scales
  - Charts: line, bar, time-series
- **Pinnacle of the Golden Age**: exquisite sampler of all known graphic forms!





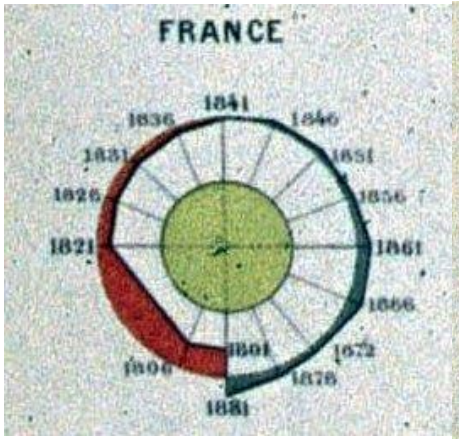


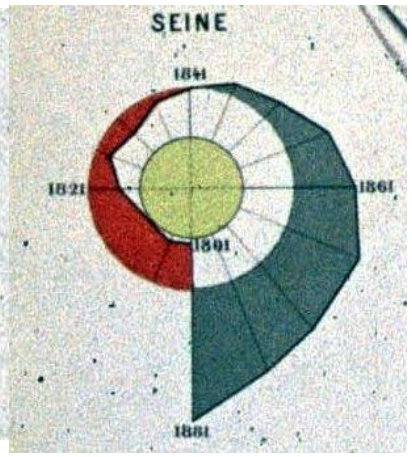
Album de statistique graphique

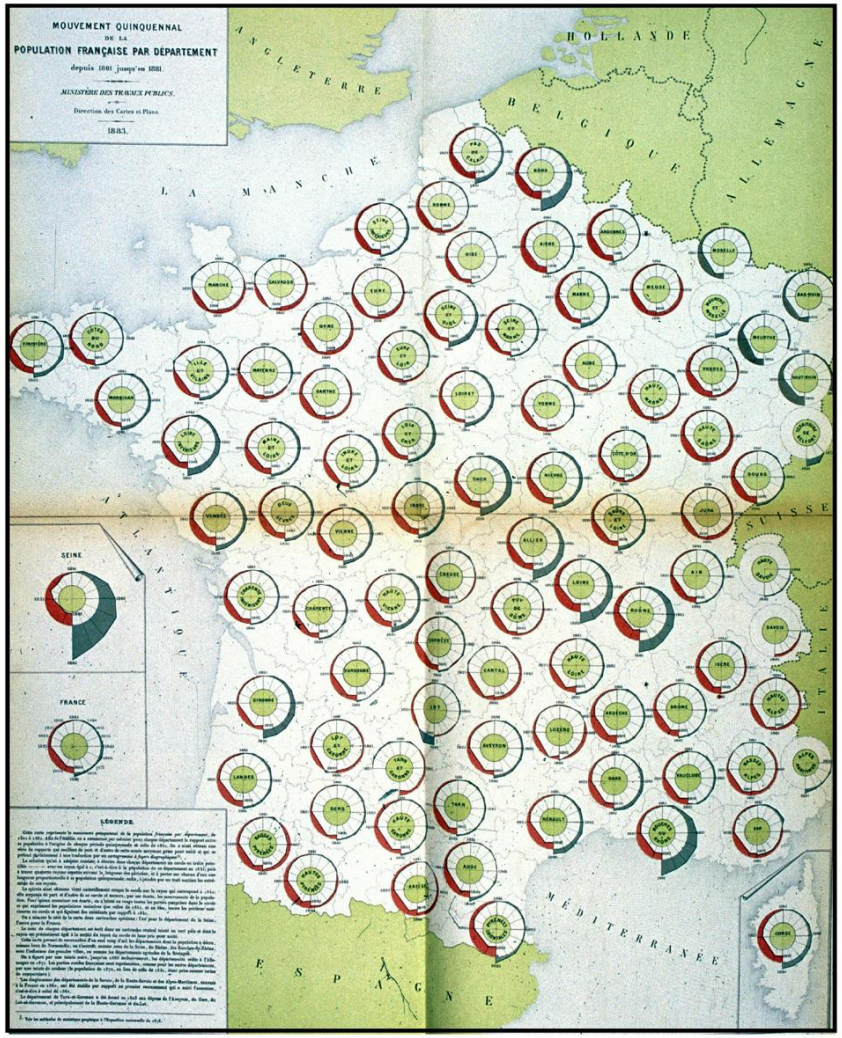
Spiral time-series on a map

Changes in the population of France from 1801—1881, by department [Album, 1881, plate 25]

Where is population growing most? least? declining?



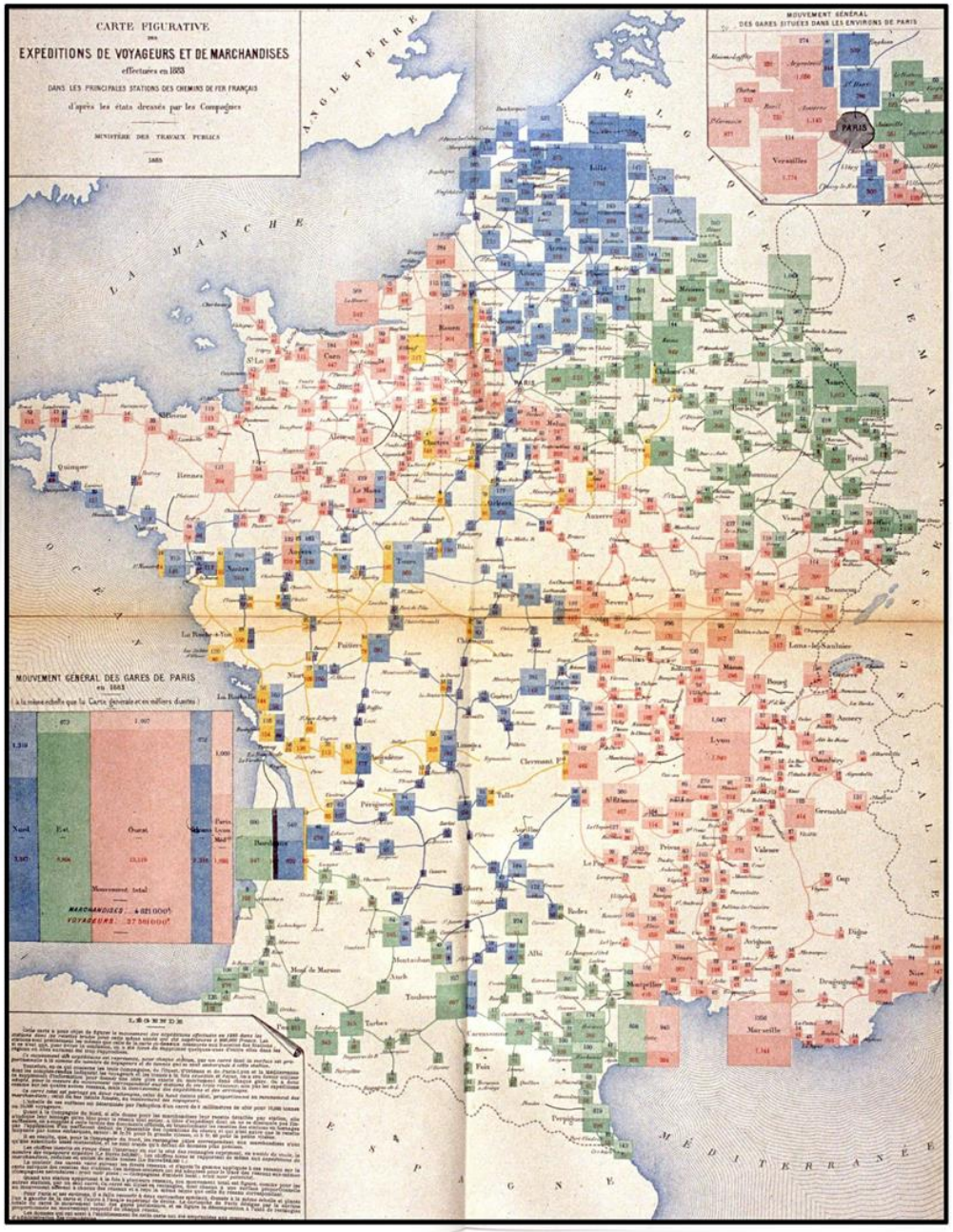




Recursive multi-mosaic map

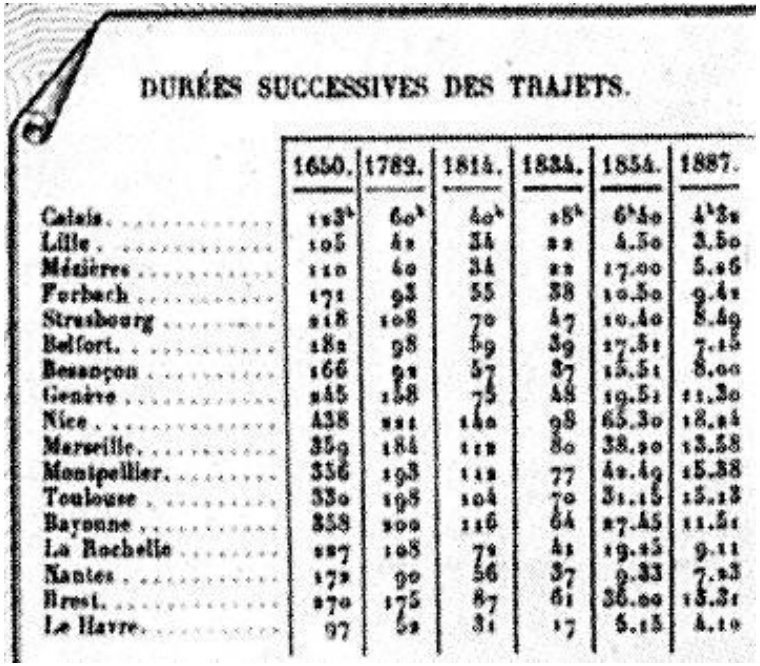
Distribution of **passengers** and **goods** from the Paris railways to the rest of France [Album, 1884, pl. 11]

(The image that launched my interest in the history of data vis.)



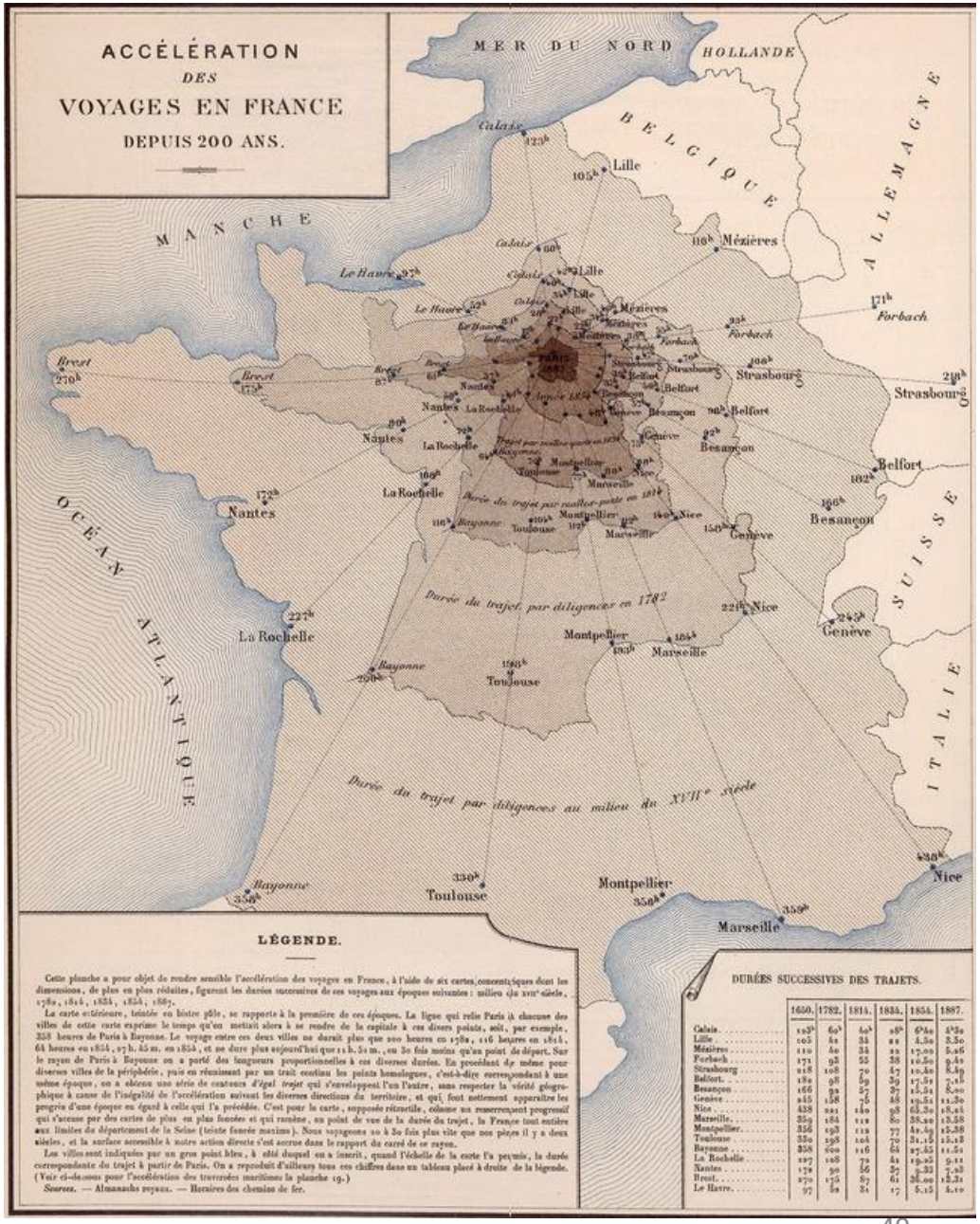
Anamorphic map

Shrinking France to show change in travel time over 200 years [Album, 1888, plate 8]



DURÉES SUCCESSIVES DES TRAJETS.

	1650.	1782.	1814.	1834.	1854.	1887.
Calais	123h	60h	40h	18h	6h40	4h32
Lille	105	42	34	22	4.50	3.50
Mézières	110	60	34	22	17.00	5.26
Forbach	171	93	55	38	10.50	9.42
Strasbourg	218	108	70	47	10.40	8.49
Belfort	182	98	59	39	17.51	7.18
Besançon	166	92	57	37	15.51	8.00
Genève	245	138	75	48	19.51	11.30
Nice	438	221	140	98	65.30	18.24
Marseille	359	184	112	80	38.30	13.58
Montpellier	336	193	112	77	42.49	15.38
Toulouse	330	198	104	70	31.15	12.13
Bayonne	358	200	116	64	27.45	11.51
La Rochelle	227	108	72	41	19.25	9.11
Nantes	172	90	56	37	9.33	7.23
Brest	270	175	87	61	36.00	12.31
Le Havre	97	52	31	17	5.15	4.10

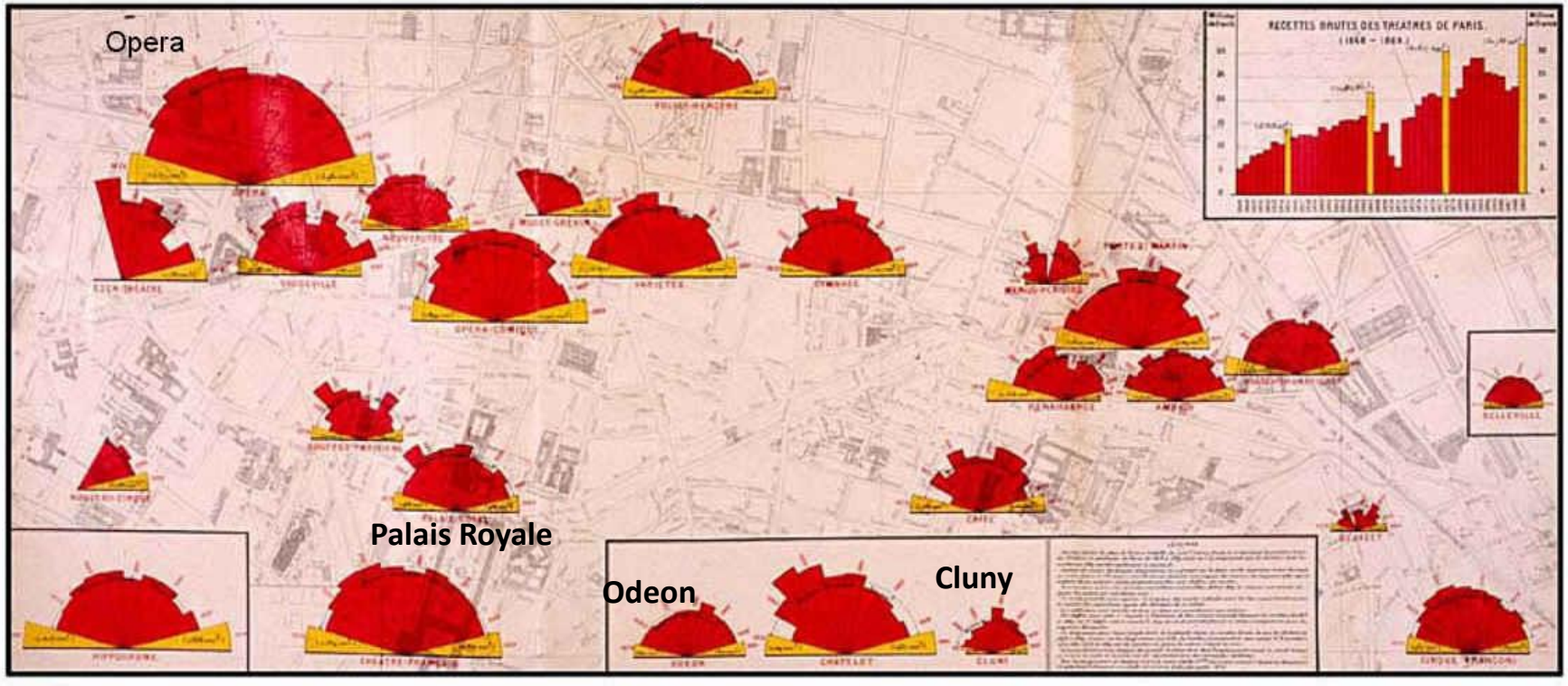


Album de statistique graphique

Q: How did Paris benefit from various int'l expos? How to show this visually?

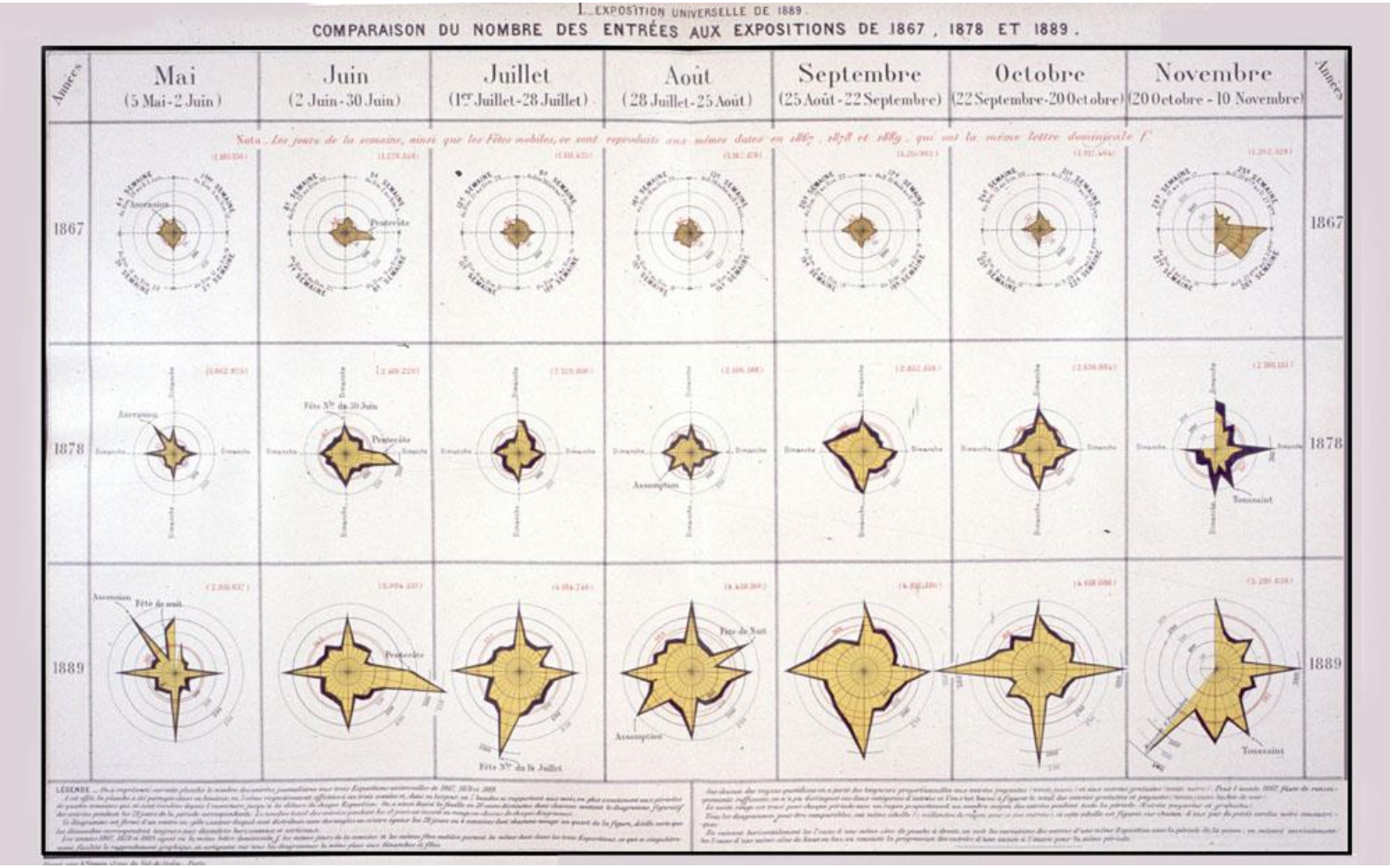
Polar area diagrams on Paris map

Gross receipts in theaters in Paris, 1878—1889, related to universal expositions
[Album, 1889, plate 26]



Two-way table of star/radar diagrams

Attendance at the universal expositions in 1867, 1878, 1889 (rows), by month (cols) and days (rays). [Album, 1889, plate 21]

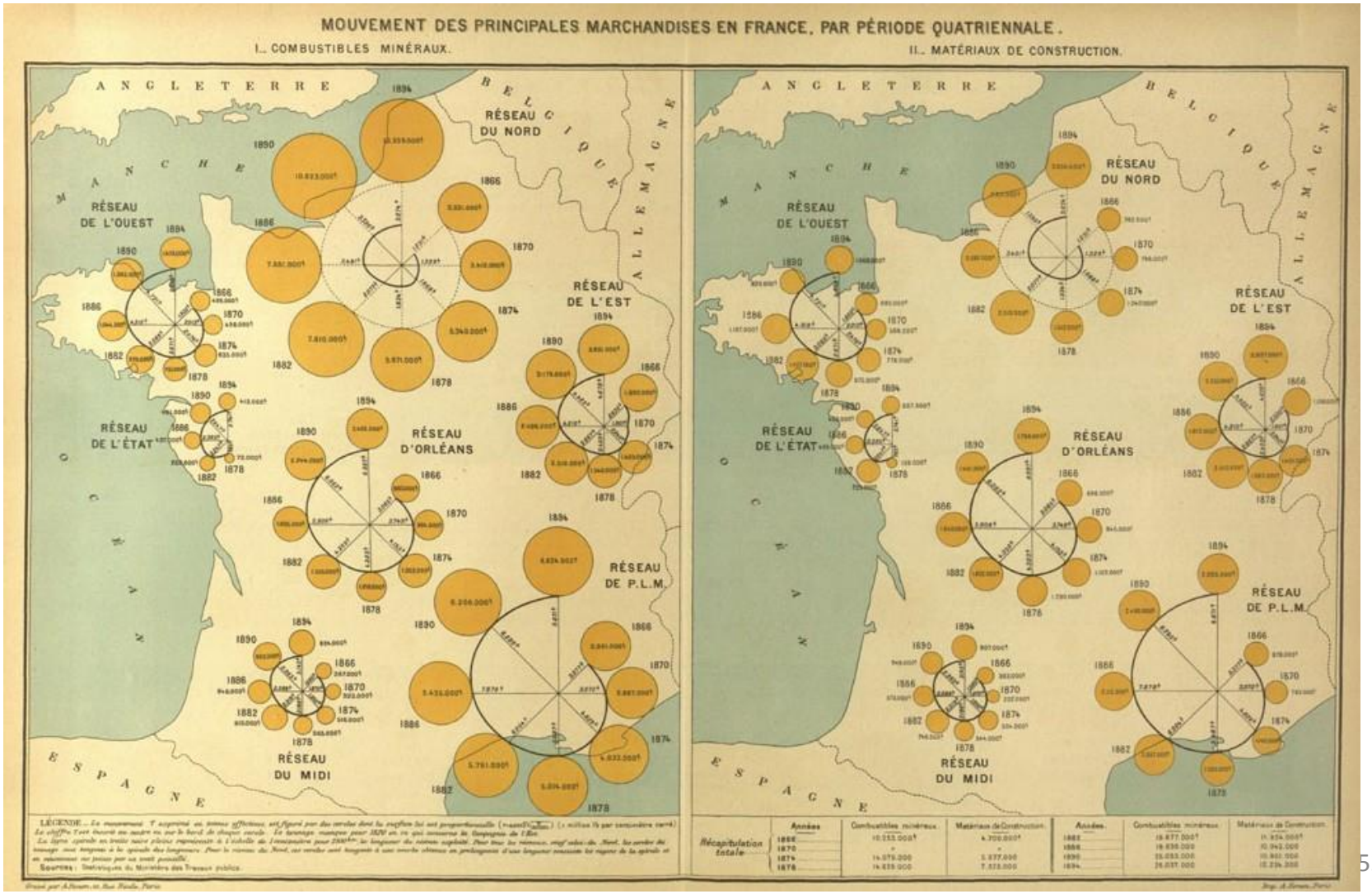


Planetary diagrams

Movement of principal merchandise by region. Spiral ~ distance; circles ~ tonnage [Album, 1895, plate 9]

Combustible minerals

Construction materials



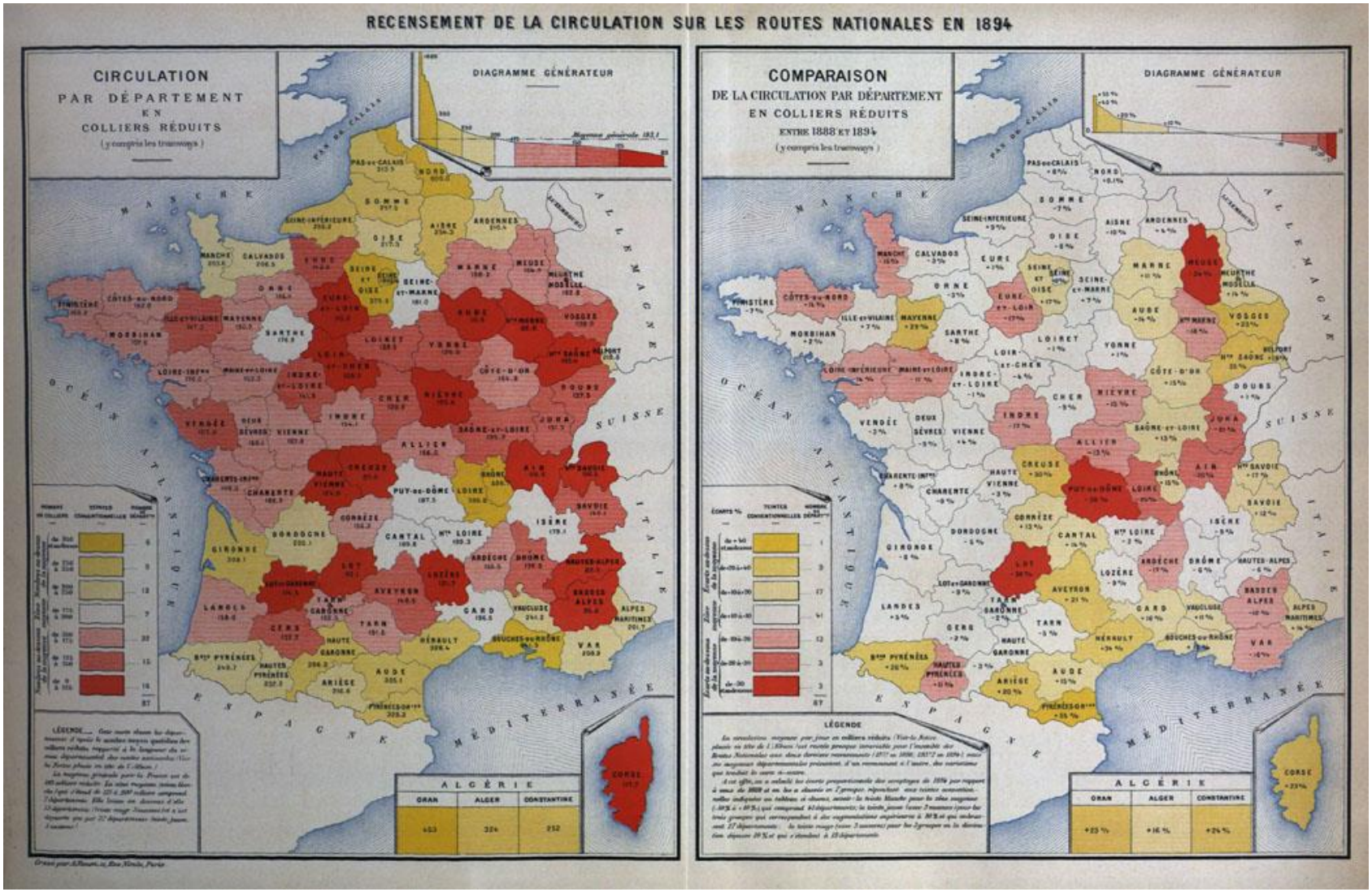
Classed choropleth maps,

- bipolar color scale
- visualizing change

Circulation on the national roads in ‘colliers réduits’, a standard measure

Left: 1894; Right: % change, 88-94

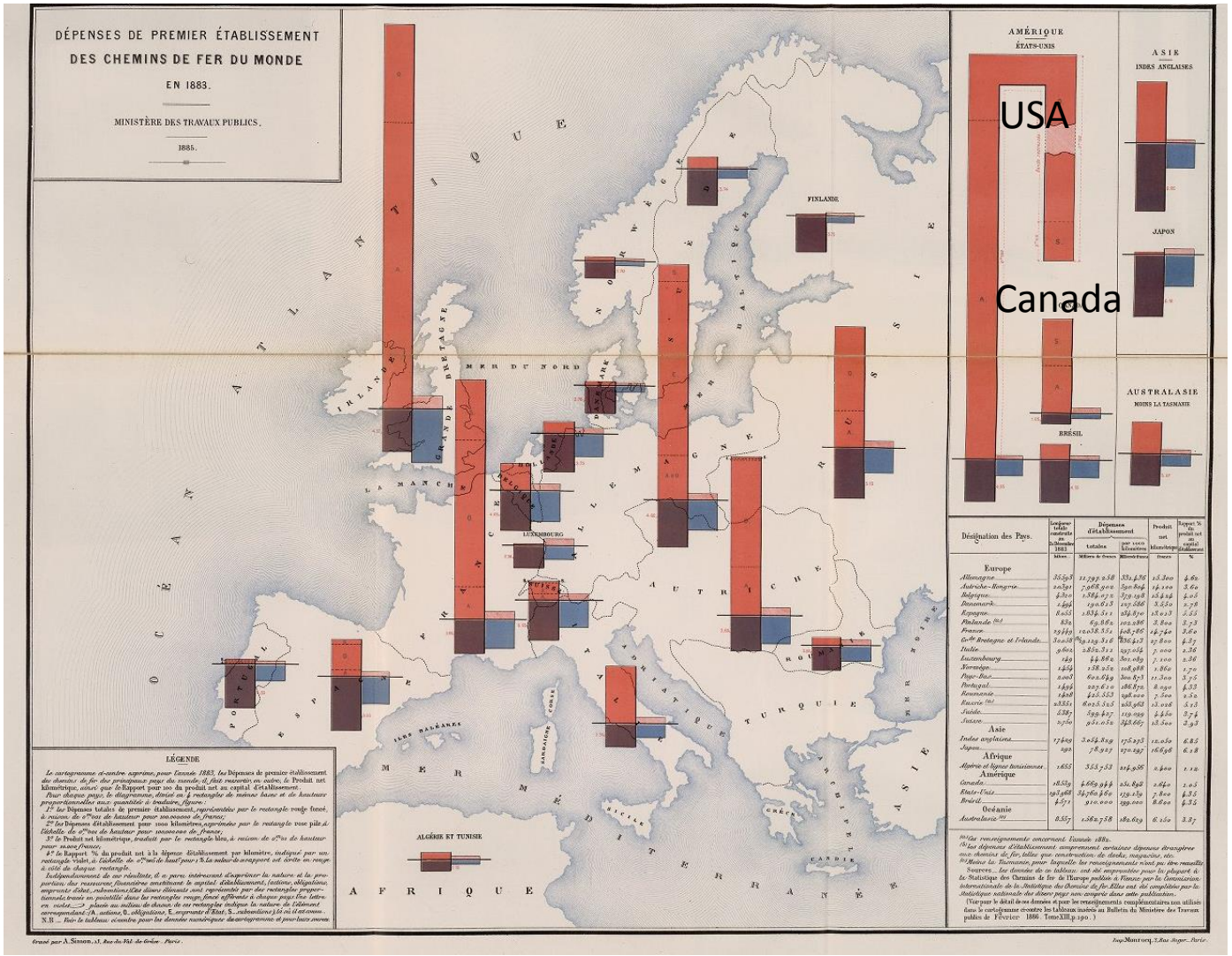
[Album, 1895, plate 21]

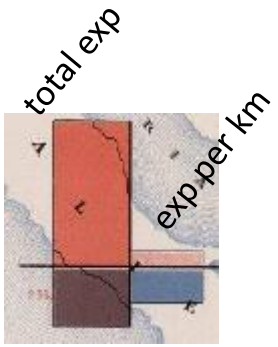


2x2 graphic bar charts

- 4 variables shown
- creative folding of long bars

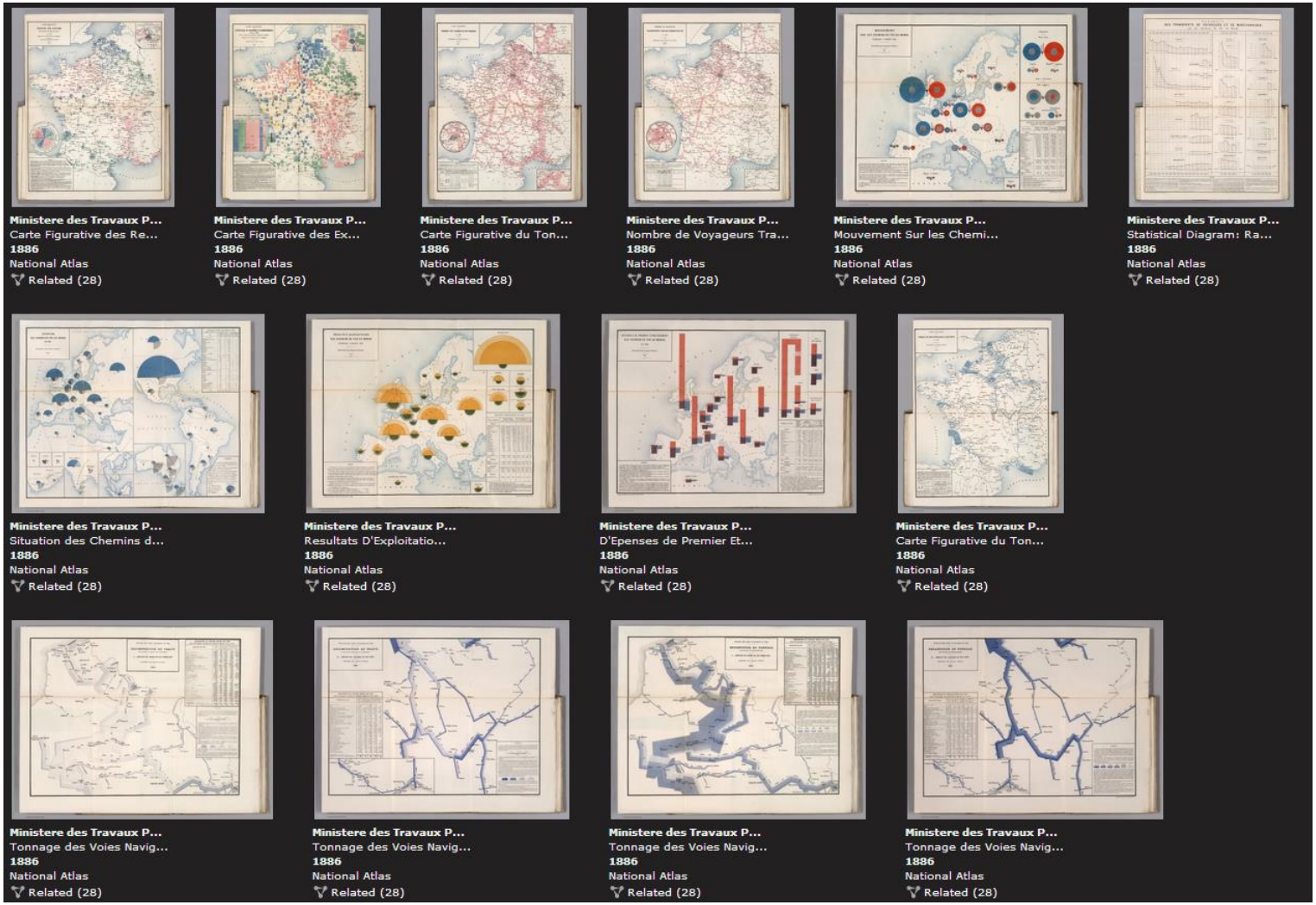
Expenses of the first establishment of railroads of the world as of 1883 [Album 1886, p. 11]





ASG now online: David Rumsey

All 18 volumes, https://www.davidrumsey.com/luna/servlet/s/nl72bu

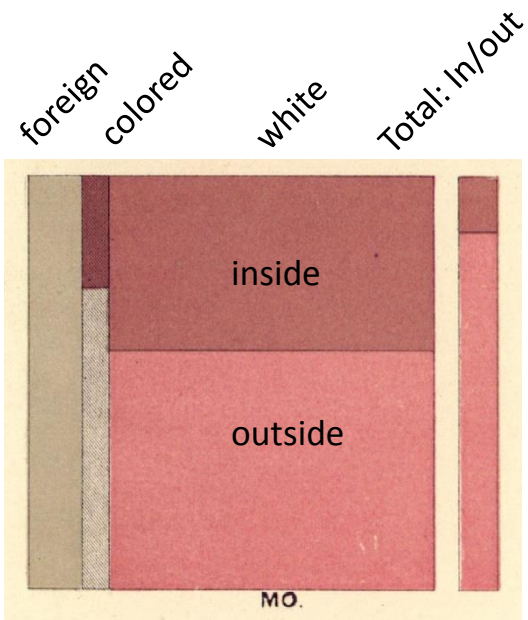


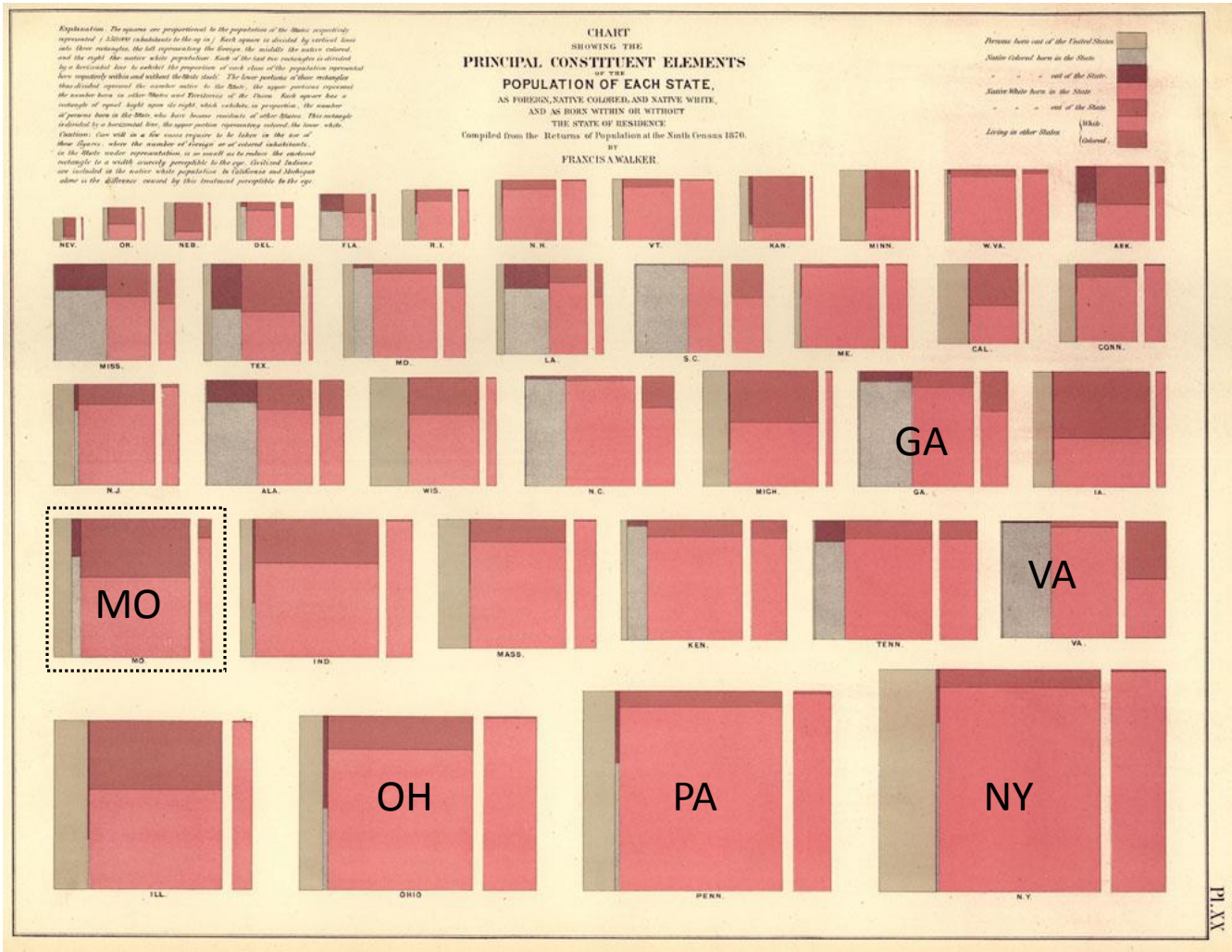
U.S. Census Atlases

- *Statistical Atlas of the Ninth Census* (1872) – Francis Walker
  - 60 plates: First graphic portrait of the nation
  - Topics: geology, minerals, weather, pop. by ethnicity, wealth, literacy, death rates by age, sex, cause, rates of blindness, insanity, etc.
- *Tenth Census* (1880) – Henry Gannett
  - 151 plates
- *Eleventh Census* (1890) – Henry Gannett
  - 126 plates

Mosaics/treemaps: Area ~ state population

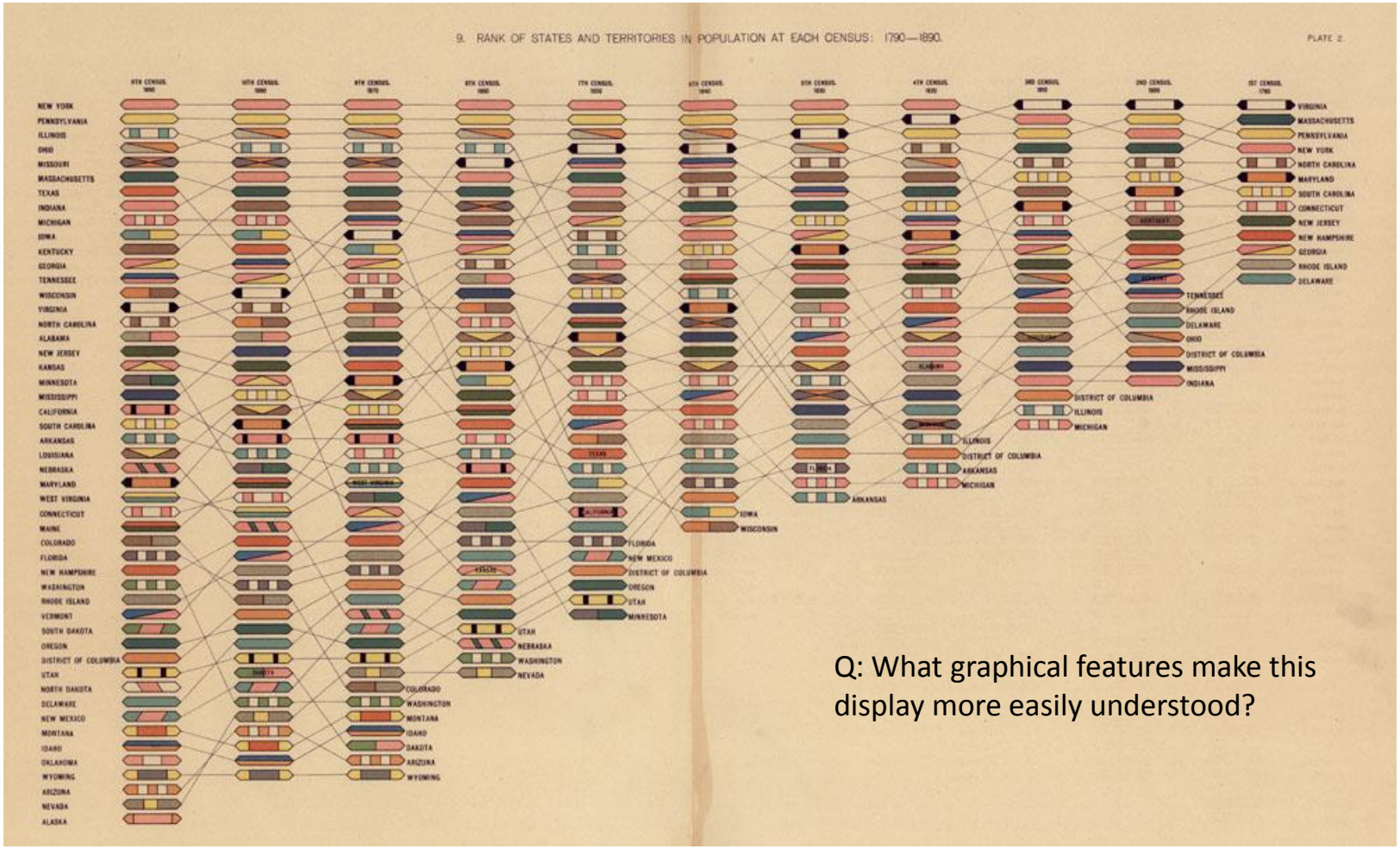
State populations: Foreign born / Native colored / White + Born inside/outside [Atlas, 1870, plate 20]





Linked parallel-coordinates time-series diagram

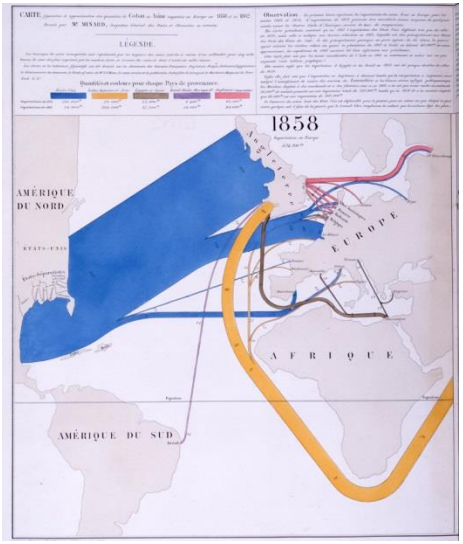
Rank of states & territories in each census, 1790—1890. [Atlas, 1898, plate 2]

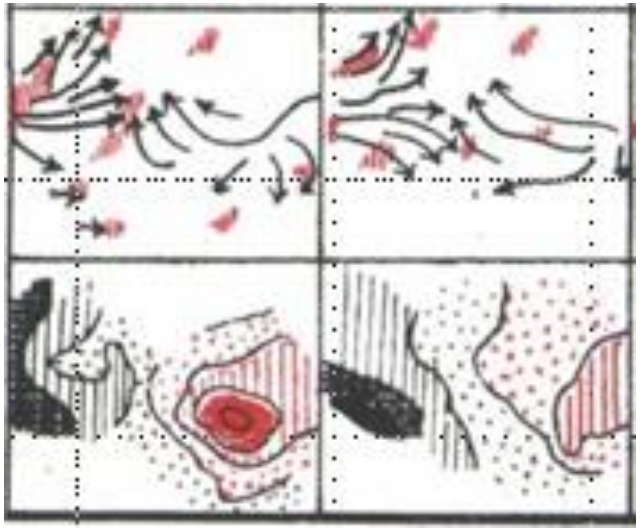


Q: What graphical features make this display more easily understood?

Golden Lessons

- What are the lessons for the future?
- Phenomena, not numbers or simply pretty pictures
  - Playfair, Guerry, Minard, Galton, etc. all developed new graphic forms to show **phenomena** of deep interest:
    - balance of trade, rates of crime, patterns in weather data, …
- **1st lesson**: data visualization today should have a similar focus





Golden Lessons: Graphical Impact

- Impact = Interocularity, Immediacy, Inescapability
  - Playfair, Guerry: data should “speak to the eyes”
  - Minard, Lalanne: allow “calculation by the eyes”
  - Nightingale: graphs should speak to the heart and mind, influence public policy & practice
- Graphical impact (Tukey, 1990)
  - Interocularity: the message hits you between the eyes
  - Immediacy: it hits you fast
  - Inescapability: it is hard to avoid the message
- **2nd lesson**: strive for visual impact in graphs and tables

Golden Lessons: Expressive power

- Hand-made graphics were often beautiful but entailed much sweat and hard work.
- Today: software– ease of use vs. expressive power
- Theories of graphics → graphic "languages"
  - Bertin: *Semiology of graphics*
  - Wilkinson: *Grammar of Graphics*
    - Wickham: *ggplot2* R package
  - In all: the devil is in the details!
- **3rd lesson**: continue to reduce the distance between a graphic idea and appearance on screen or paper.

Conclusions

The only new thing… is the history you don't know **– Harry Truman**

- Data visualization has deep roots:
  - Cartography
  - Statistical theory
  - Data collection
  - Visual thinking
  - Technology

  } All combine to give insightful views of data

- The Golden Age:
  - Qualitatively distinct, deserves recognition
  - Works of unparalleled beauty & scope
  - Statistical graphics had a ***purpose***: tell a story, inform decision
  - Provides lessons for today and tomorrow