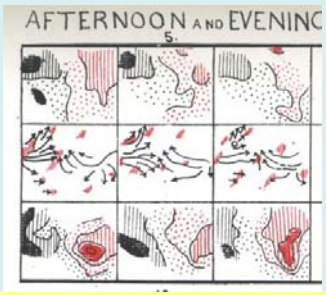



The Golden Age of Statistical Graphics

Michael Friendly
York University
Statistical Society of Canada, May, 2008
Slides: www.math.yorku.ca/SCS/Papers/ssc/

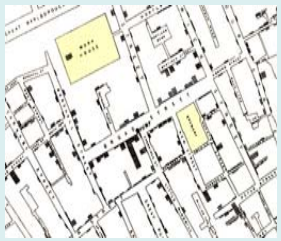
Outline

- Introduction
  - Data visualization: thematic maps & statistical graphics
  - Context: Milestones Project
  - What is an Age? Why makes one Golden?
- Preludes to the Golden Age
  - Statistics: Numbers of the state
  - Statistical theory, technology
  - Inventions in statistical graphics & cartography
- Exemplars of the Golden Age
  - Graphic vision of Charles Joseph Minard
  - Francis Galton's graphic discoveries
  - Statistical atlases
- Lessons from the Golden Age

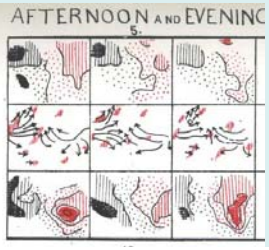
Data visualization: thematic maps & statistical graphics

- 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

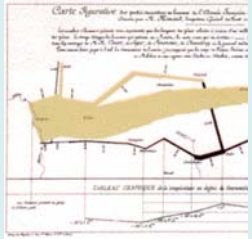
Snow (1855)



Galton (1863)



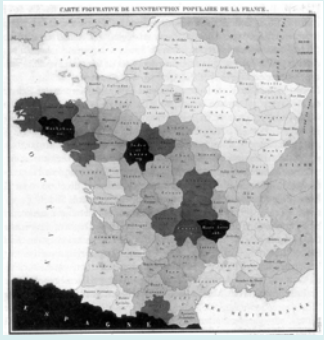
Minard (1869)



Data visualization: Diffusion of ideas

- Those who developed thematic maps often not cartographers

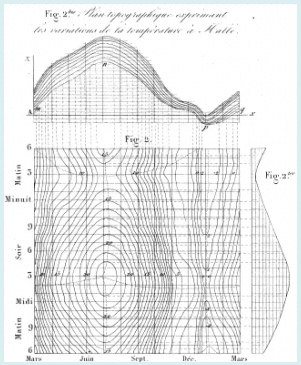
Dupin (1826): literacy in France



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 temp

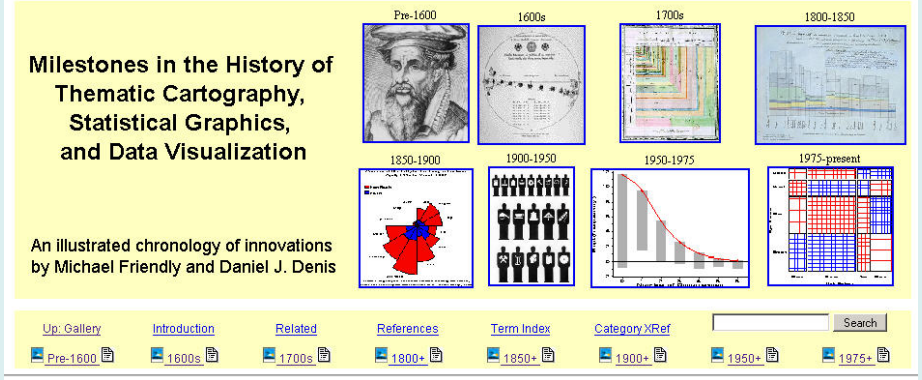


Data visualization: Diffusion of ideas

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

Context: Milestones Project

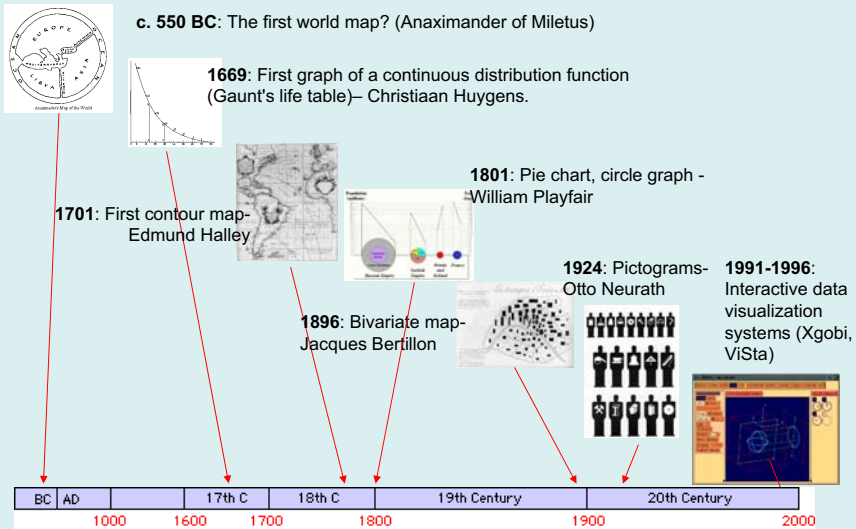
www.math.yorku.ca/SCS/Gallery/milestone



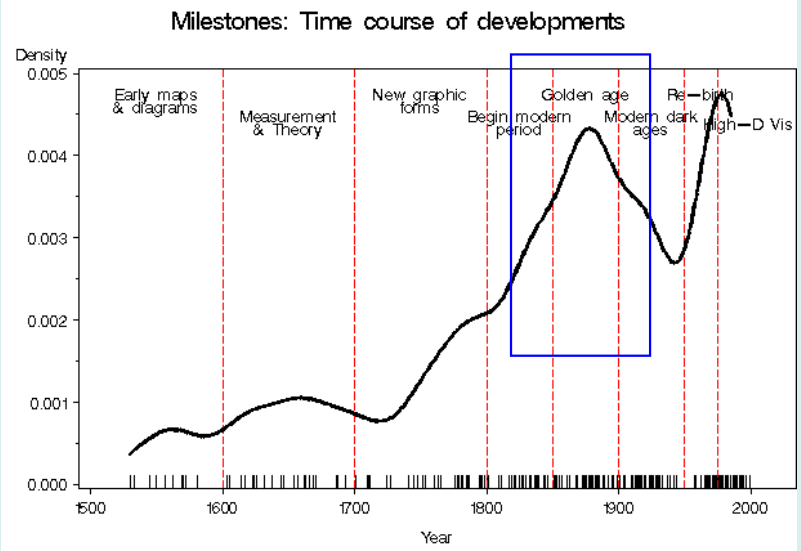
Project goals:
• Comprehensive catalog of developments in history of data visualization
• Tool to study themes, antecedents, influences, patterns, trends, etc.

Milestones: Content Overview

Every picture has a story – Rod Stewart

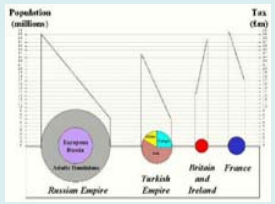


Milestones as a graph

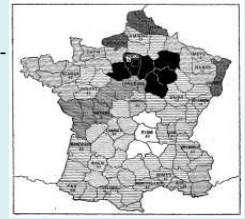


1800-1849: Beginning of modern data graphics

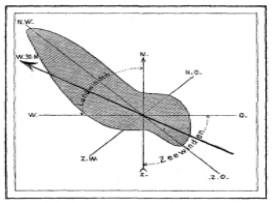
1801: Pie chart, circle graph invented- William Playfair

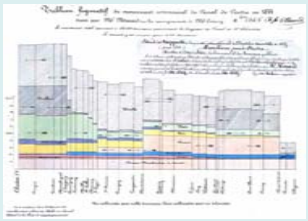


1819: First modern statistical map (illiteracy in France)- Charles Dupin

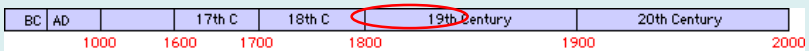


1843: Wind-rose (polar coordinates)- L. Lalanne

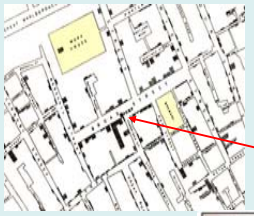




1844: variable-width, divided bars, area ~ cost of transport- C. J. Minard

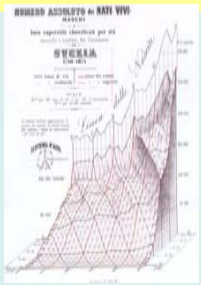


1850-1900: Golden Age



1855: Dot map of disease data (cholera)- John Snow

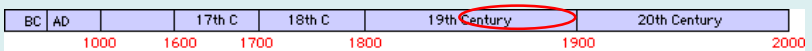
Broad St. pump



1879: Stereogram (3D population pyramid)- Luigi Perozzo

1884: Recursive multi-mosaic on a map- Emile Cheysson

1896: Area rectangles on a map to display two variables and their product- Jacques Bertillon



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
- Islam: 750—1258 (sack of Baghdad)
- England: Elizabeth I (1558-1603)
- 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

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

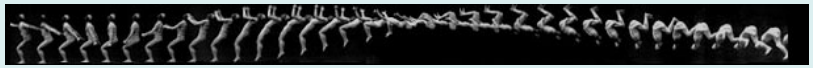
Preludes: data

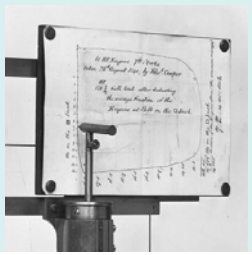
"Data! Data! I can't make bricks without clay." **– Sherlock Holmes, *Copper Beeches***

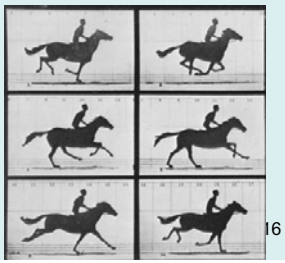
- Population: ~ 1660--
  - Bills of mortality: Graunt (1662)
  - Political arithmetic: Petty (1665)
  - Demography: Süssmilch (1741)
- Economic data: ~ 1770--
  - Revenue, expenditures, taxes
  - Imports, exports
  - Transport
- Social data: ~ 1820--
  - Literacy, education
  - Crime, suicides, illegitimate 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)
- Photography: Niépce (1827), Deguerre (1839), trichromatic process (1861)
- Motion: Muybridge (1872), Marey (1882)

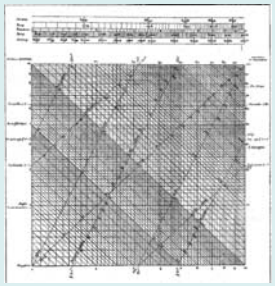


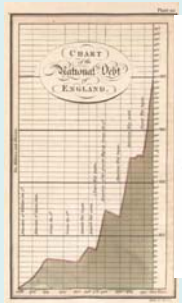


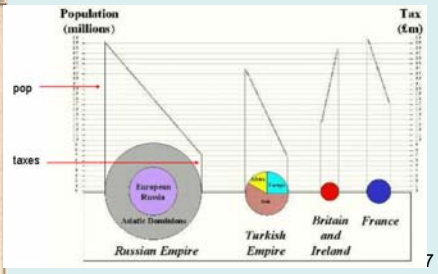


Preludes: visual language

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

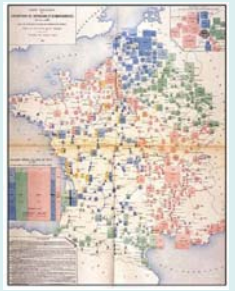




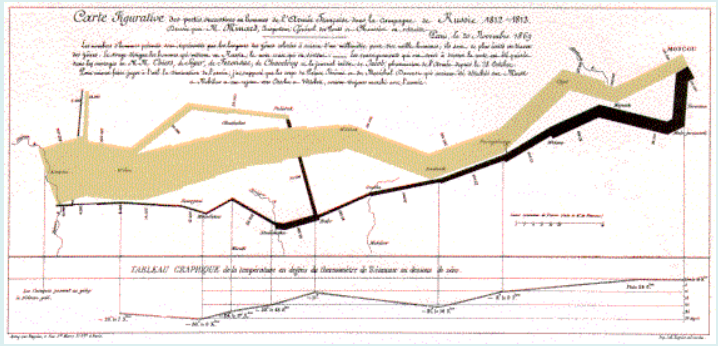


Exemplars of the Golden Age

- The graphic vision of C. J. Minard
- Galton's graphic discoveries
- State statistical albums



The graphic vision of C. J. Minard

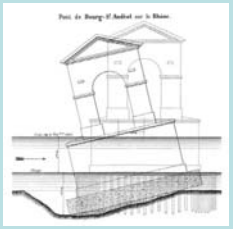


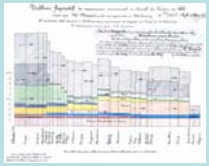
- Marey (1878): *"defies the pen of the historian in its brutal eloquence"*
- Tufte (1983): *"the best statistical graphic ever produced"*

Why Minard?

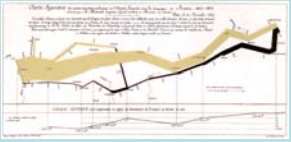
- Study breadth and depth of his work
  - How related to work in his time?
  - How related to modern statistical graphics?
  - How related to his personal history?

Civil Engineer for ENPC (1810-1842)





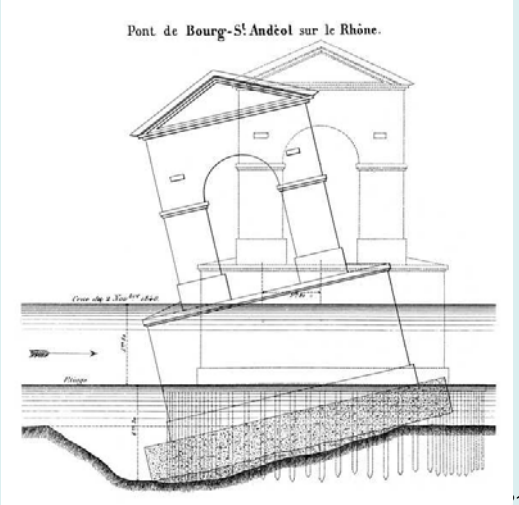
Visual Engineer for France (1843-1869)



Visual thinking, visual explanation

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

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



21

Visual tools for state planning

- 1830—1860: emergence of modern French state, dawn of globalization
- Trade, commerce, transportation:
  - Where to build railroads, canals?
  - Visualizing changes over time, differences over space
  - → Flow maps and other graphical innovations

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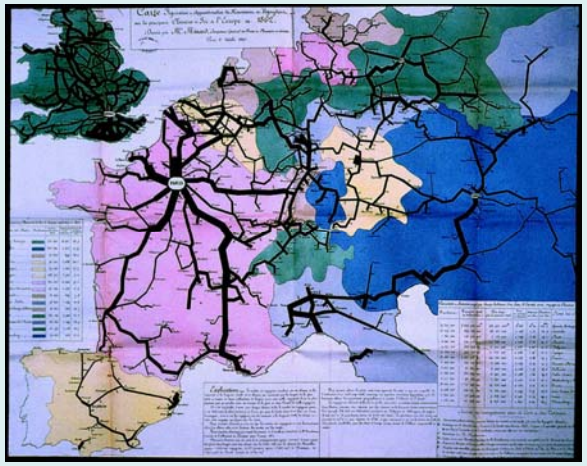
Flow maps as visual tools

Transport of passengers on the principal railroads in Europe in 1862

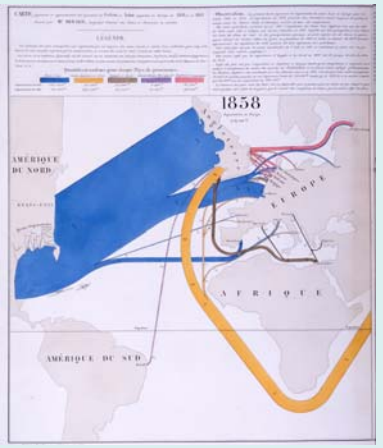


Carte figurative: give precedence to the data over the map

23

Effect of US civil war on cotton trade

Before



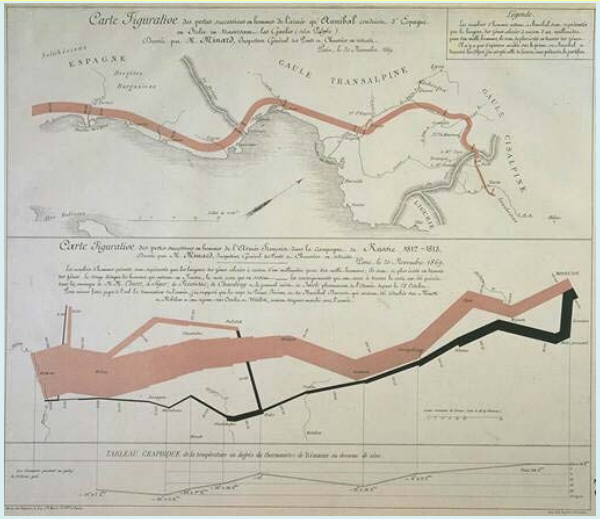
After

24

The March Re-Visited (1869)

Hannibal's retreat

Napoleon's 1812 campaign



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.

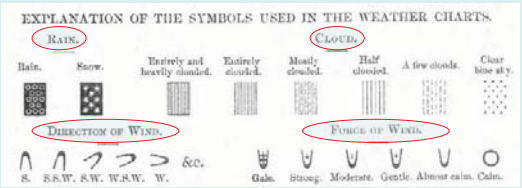
(Galton, 1863)

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

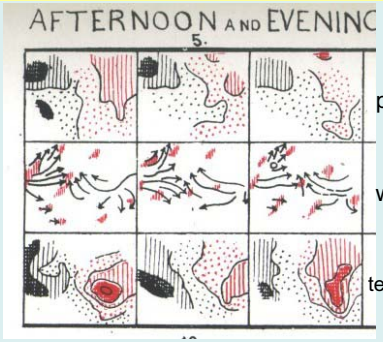
Symbols in Barometrical Charts.

	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

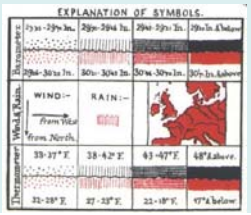
What varies with what, over time and space?

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



AM noon PM

Data for Dec 5, 1861

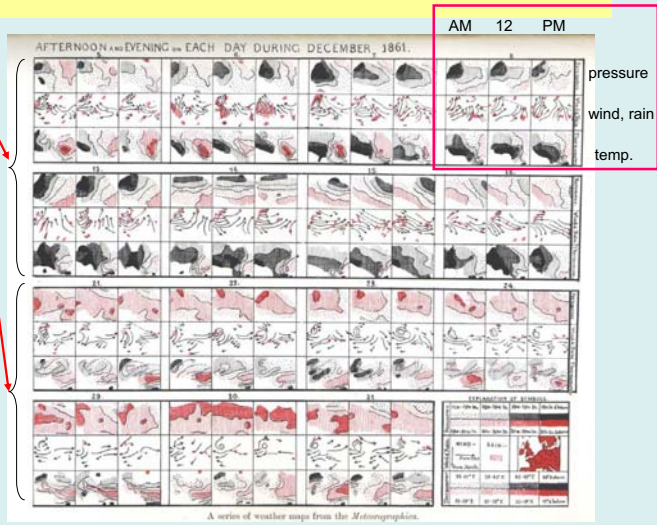


The large picture → Insight

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}

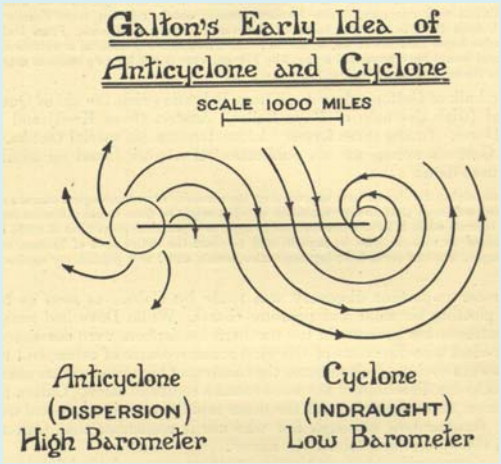
(try this with your software!)



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"

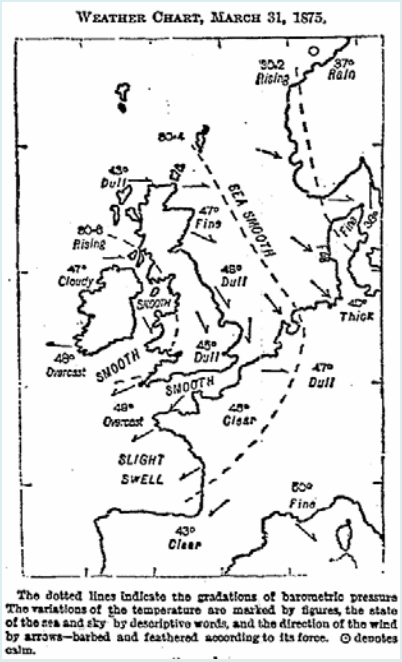
Theory:
- Explained by Dove's 'Law of Gyration'
- Prediction: reversed pattern (CW/CCW) in southern hemisphere – confirmed!



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)



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

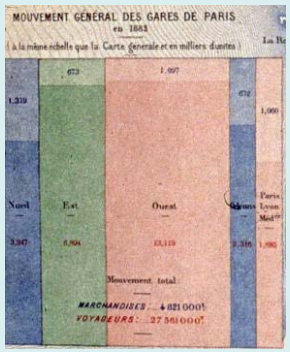
- Collection of gov't statistics on pop., trade, moral & political issues widespread in Europe & US, starting ~ 1820
- Statistical albums ~ 1870—1910
  - France: *Album de Statistique Graphique*: 1879-1899
  - USA: Census atlases: 1870/80/90
  - Gemany: local albums (Berlin, Frankfurt, etc.)
  - Switzerland: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

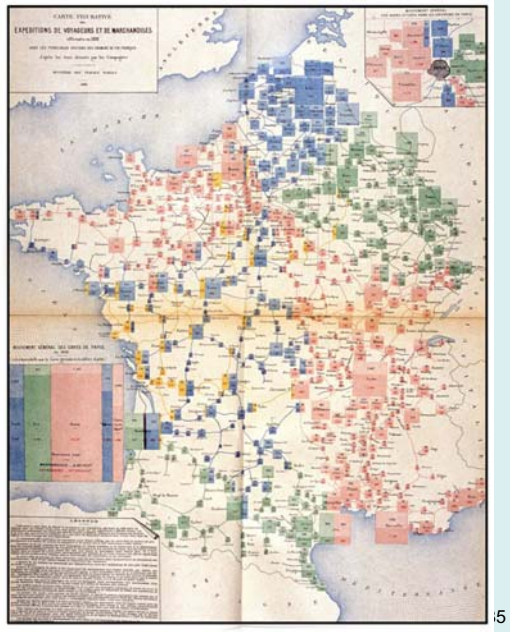
Album de statistique graphique

- 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
- Formats: 1x1, 2x1, 2x2, 3x2, 5x3!…
- Themes:
  - Recurrent: railroads, navigation, transport--- B&B
  - Occasional: agriculture, Paris, expositions, …
- Pinnacle of the Golden Age: exquisite sampler of all known graphic forms!

Recursive multi-mosaic map

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

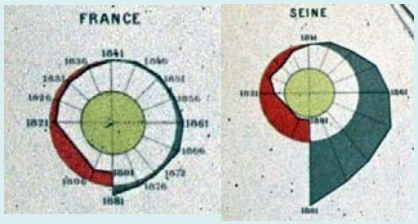


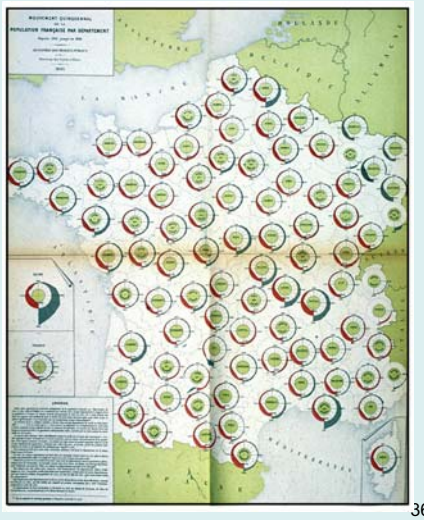


Album de statistique graphique

Spiral time-series on a map

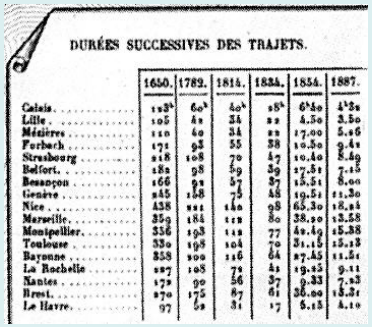
Changes in the population of France from 1801—1881, by department [Album, 1881, plate 25]





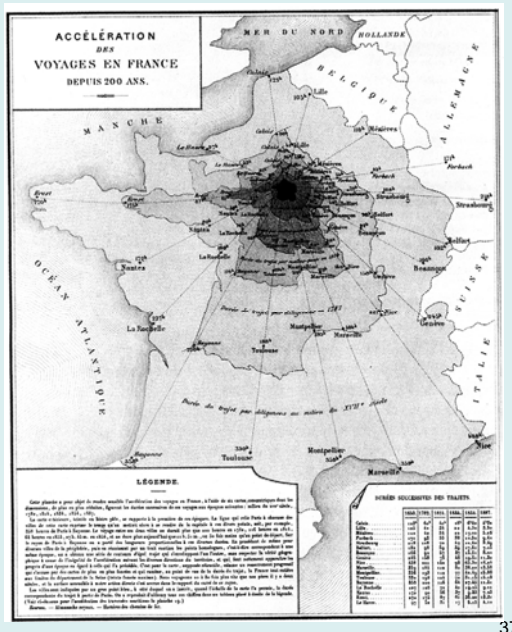
Anamorphic map

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	12j	6j	4j	1j	0j10	0j5
Lille	10j	4j	3j	1j	4.50	3.50
Mézières	11j	4j	3j	1j	17.00	5.06
Forbach	17j	9j	5j	3j	10.50	9.41
Strasbourg	21j	10j	7j	4j	10.40	8.49
Belfort	18j	9j	5j	3j	17.51	7.15
Besançon	16j	9j	5j	3j	15.51	8.00
Genève	24j	15j	7j	4j	19.51	11.30
Nice	45j	22j	14j	9j	65.30	18.48
Marseille	35j	18j	11j	8j	38.20	13.58
Montpellier	33j	19j	11j	7j	48.49	15.38
Toulouse	33j	19j	10j	7j	31.11	15.13
Bayonne	35j	20j	11j	6j	27.45	11.51
La Rochelle	22j	10j	7j	4j	19.45	9.11
Nantes	17j	9j	5j	3j	9.33	7.23
Brest	27j	17j	8j	6j	36.00	13.31
Le Havre	9j	5j	3j	1j	9.15	4.10



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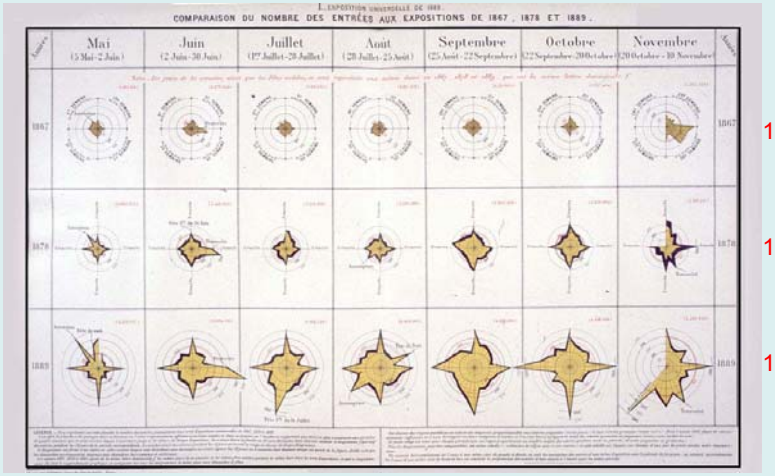
Two-way table of star/radar diagrams

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



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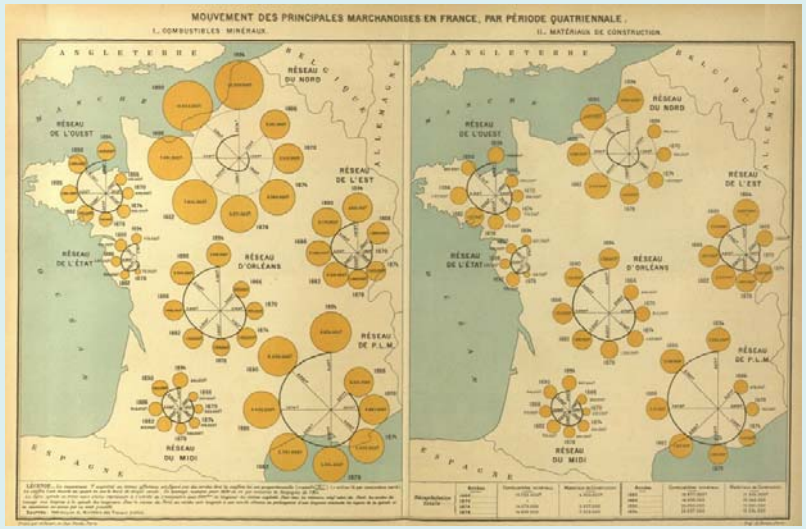
Planetary diagrams

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

Combustible minerals

Construction materials



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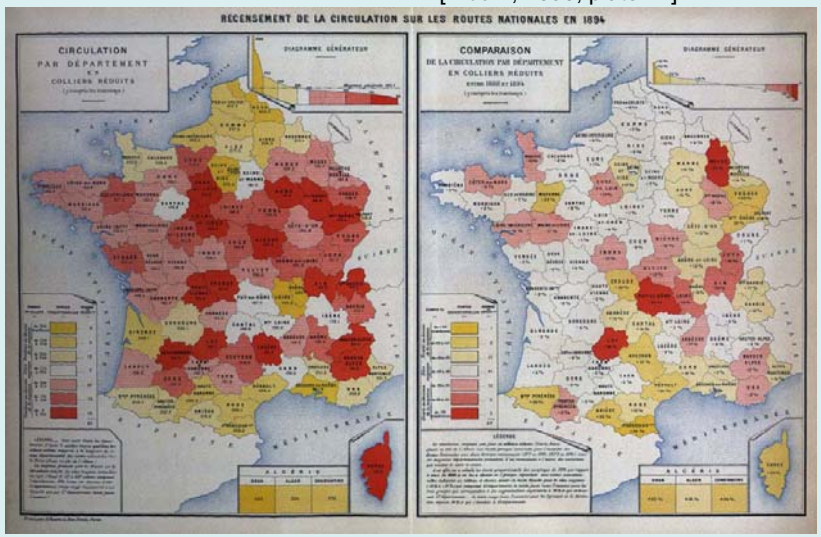
Classed choropleth maps, bipolar color scale

Circulation on the national roads in 'colliers réduits'
Left: 1894; Right: % change, 88-94
[Album, 1895, plate 21]



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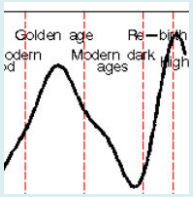
Golden Age→ Modern Dark Ages

- Albums: discontinued (cost), became routinized
- Statistics: enthusiasm for graphics replaced by rise of quantification
  - Statistical models (regression, correlation)
  - Estimates +- standard errors: precise!
- Few innovations, but popularization
  - College courses, text books
- Some significant graphical discoveries
  - E.W. Maunder (1904): "butterfly diagram" of sunspots
  - Hertzsprung-Russell (1911) diagram: stellar physics
  - Henry Moseley (1913): atomic number



Conclusions

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

- Data visualization has deep roots:
  - Cartography
  - Statistics
  - Data collection
  - Visual thinking
  - Technology
- The Golden Age
  - Qualitatively distinct, deserves recognition
  - Works of unparalleled beauty & scope
  - Thematic maps & diagrams often aided each other

Golden Lessons

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

Golden Lessons

- 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

- 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.