

Money

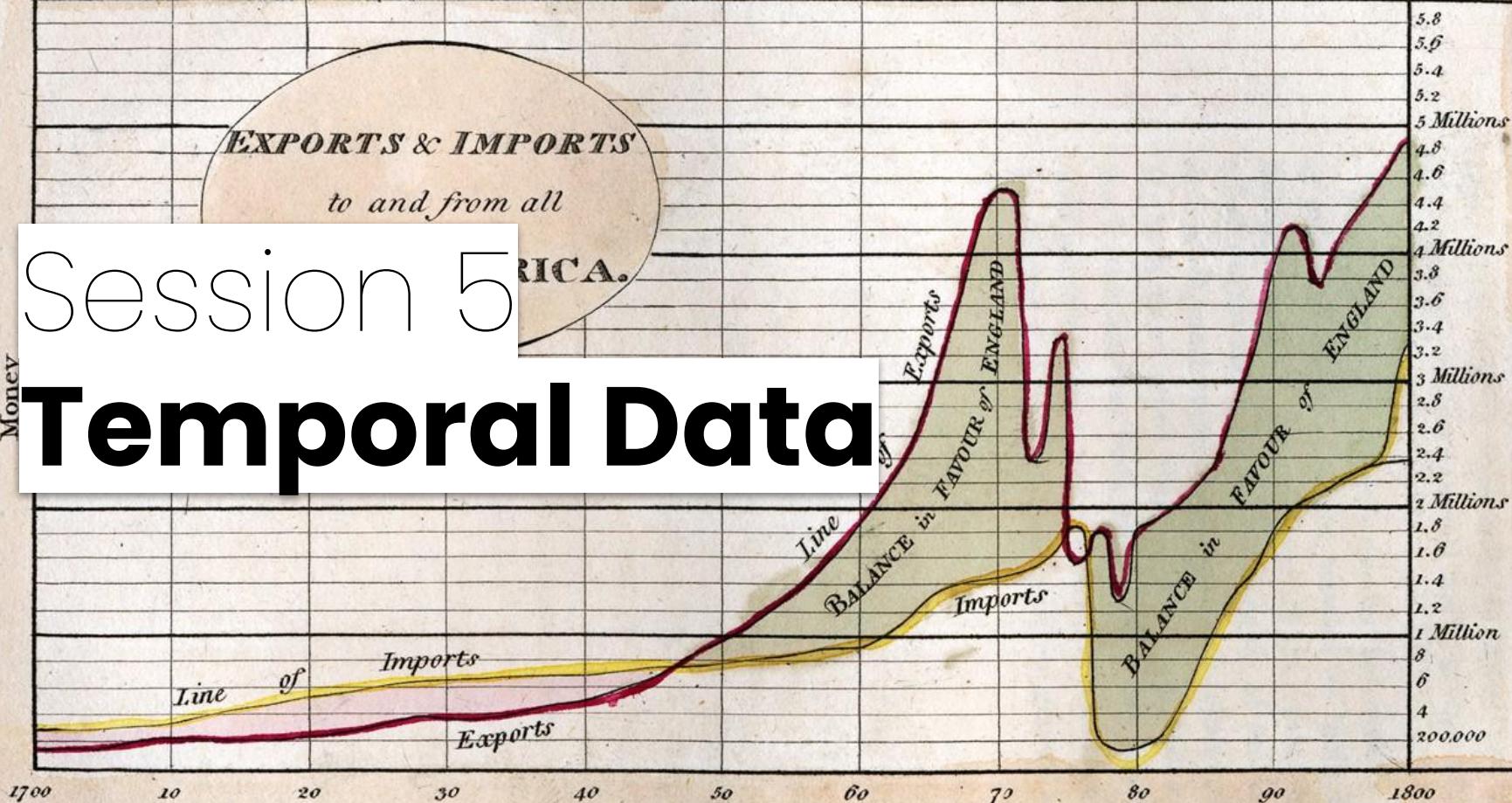
Time

*EXPORTS & IMPORTS**to and from all*

ERICA.

Session 5

Temporal Data



Online Course
Data Visualization
 for Professionals



THE UNIVERSITY
 of EDINBURGH

Benjamin Bach

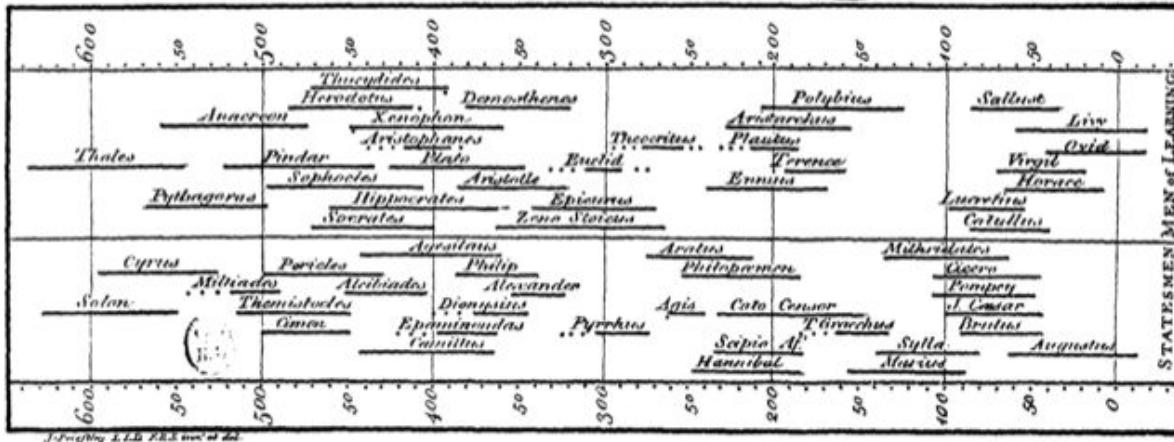
June 2022

<http://benjbach.me>

<https://datavis-online.github.io>

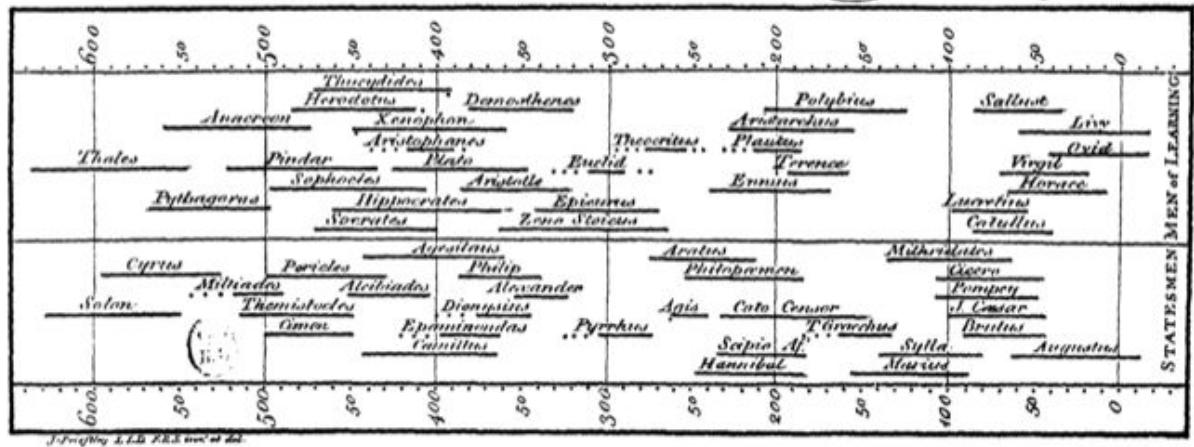
-- Not for external use --

A Specimen of a Chart of Biography.



Events

A Specimen of a Chart of Biography.

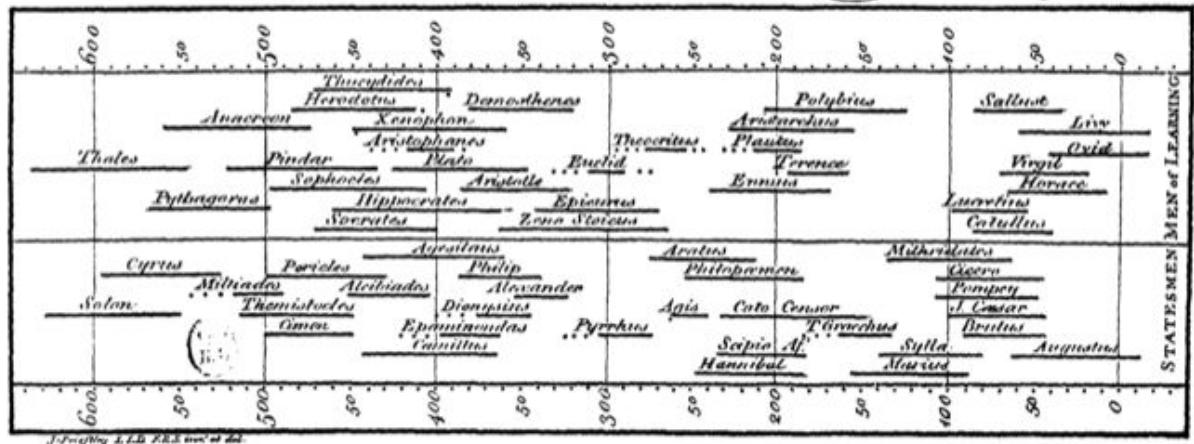


Events



Trajectories

A Specimen of a Chart of Biography.



Events



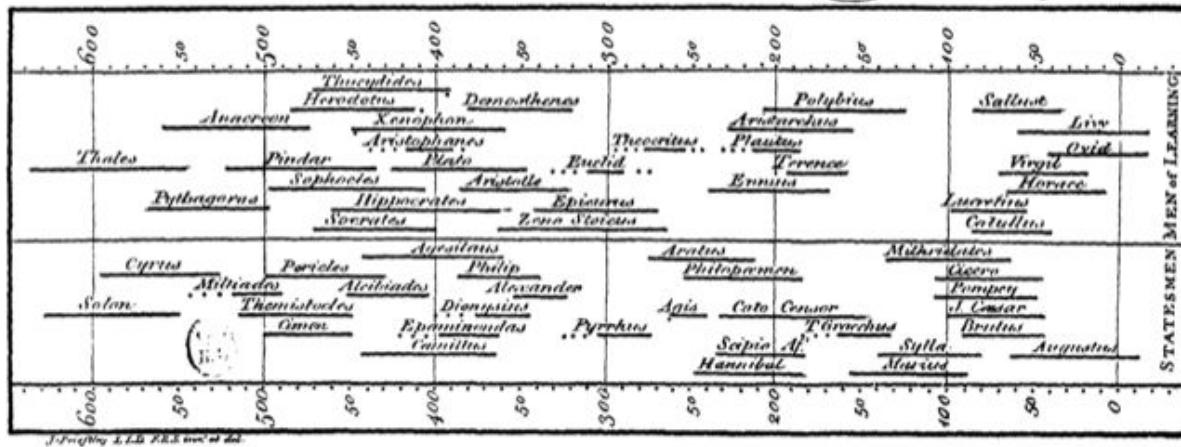
Trajectories

January						
Mo	Tu	We	Th	Fr	Sa	Su
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

3:● 10:○ 17:● 24:●

Calendar

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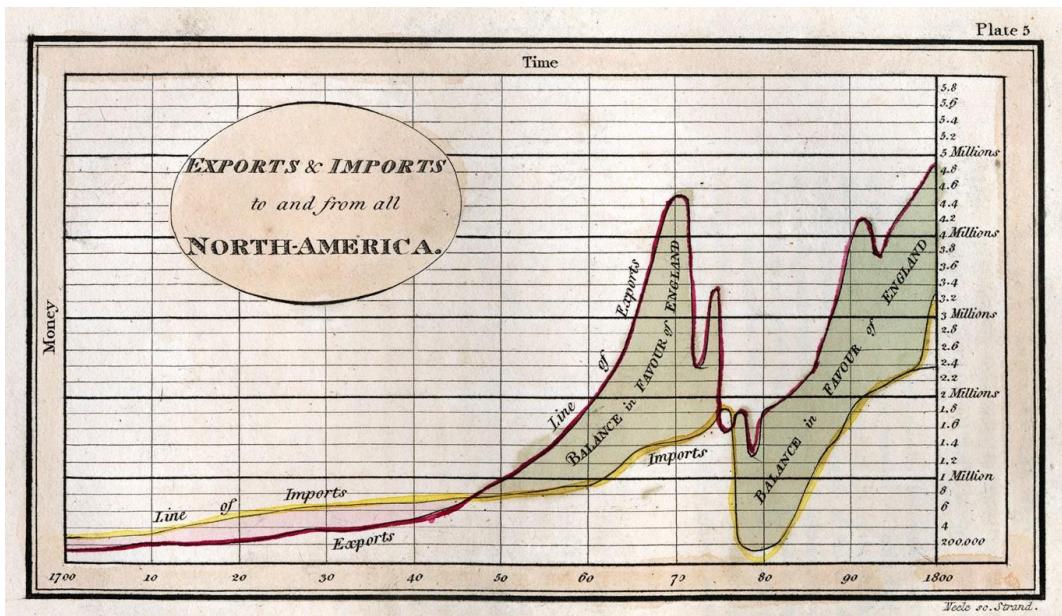
Events



Trajectories



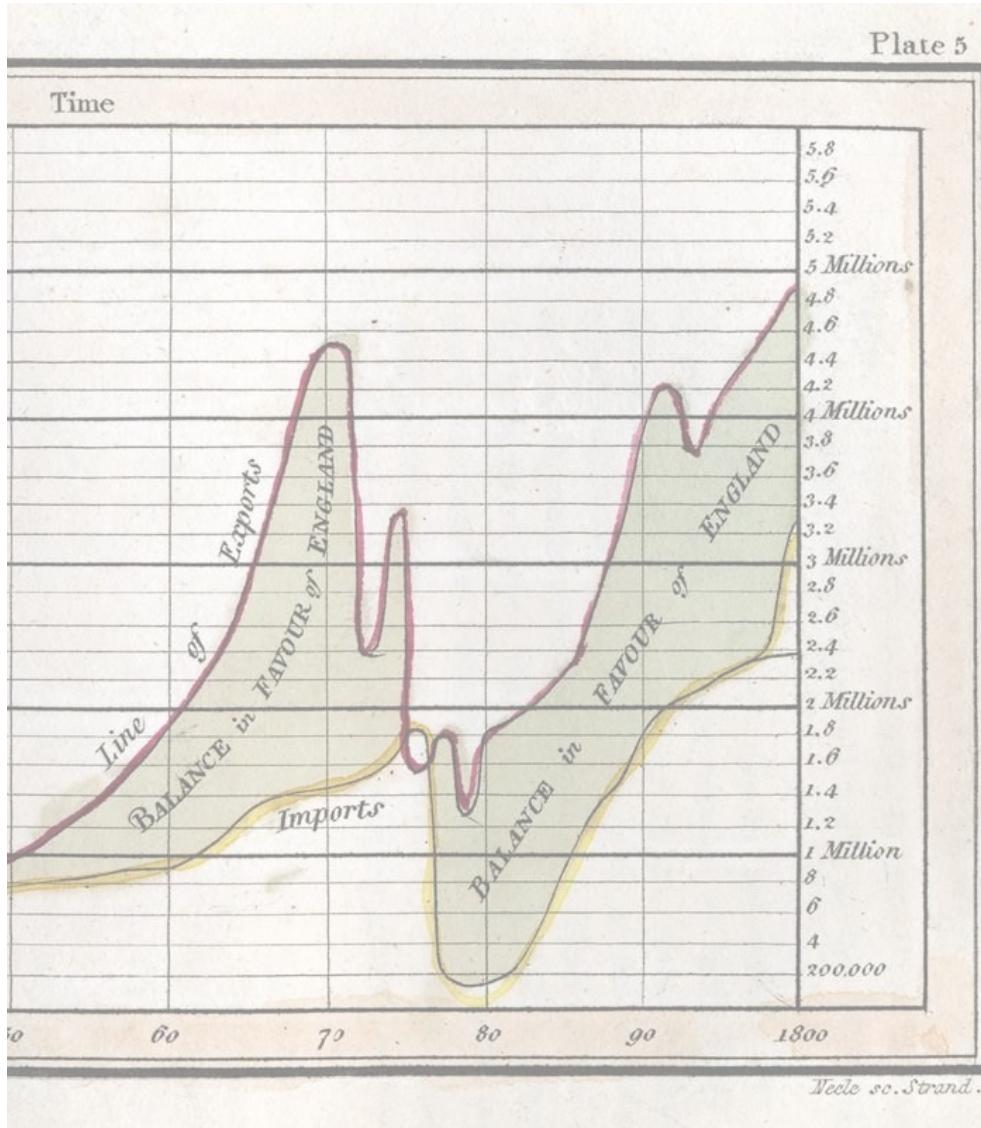
Calendar



Time series

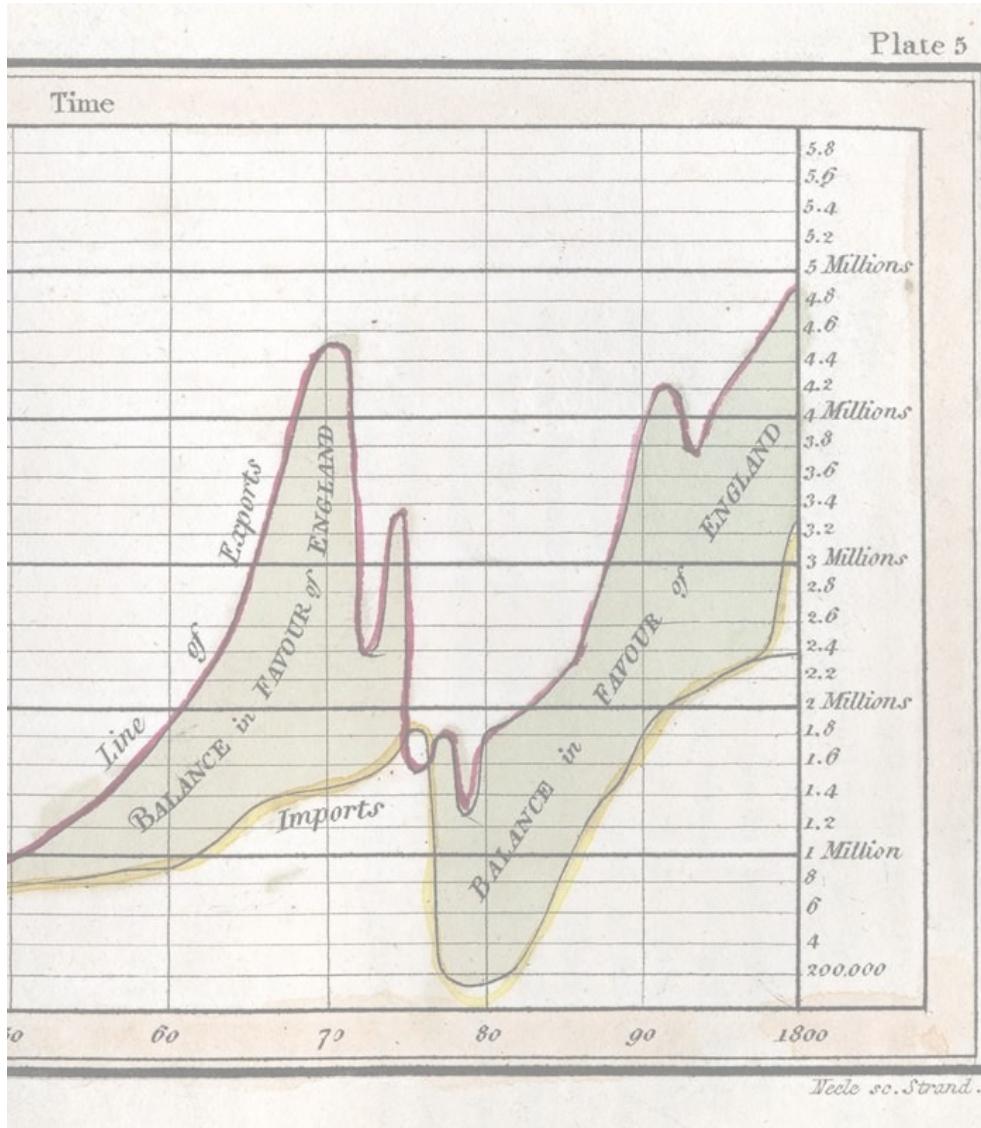
Tasks

- Min, max values, specific values
- Trends and outliers
- Change and rate of change
- Sequence
- Dynamicity / variation
- Noise vs. signal
- Check for specific events that may influence the data
- Correlate and compare time series
- Space + time



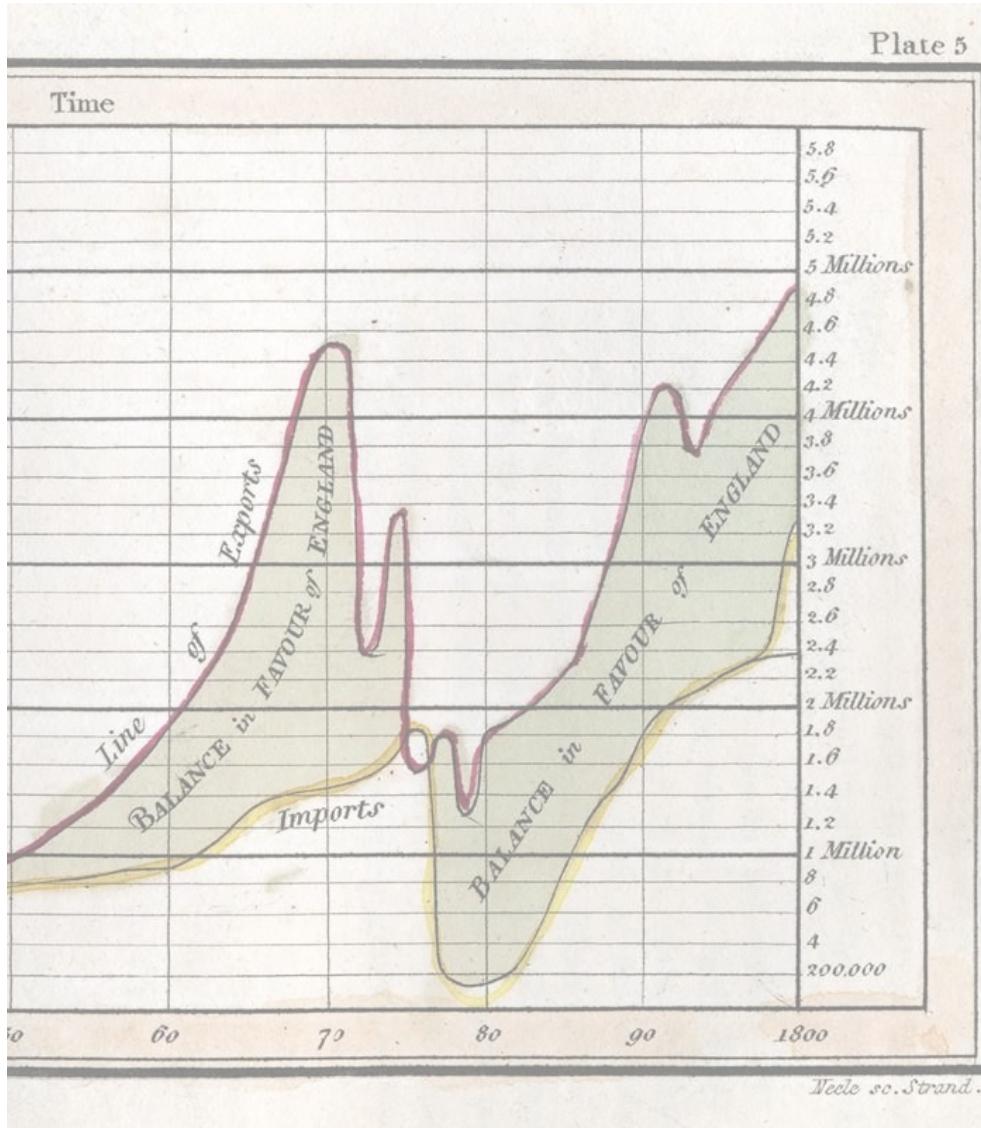
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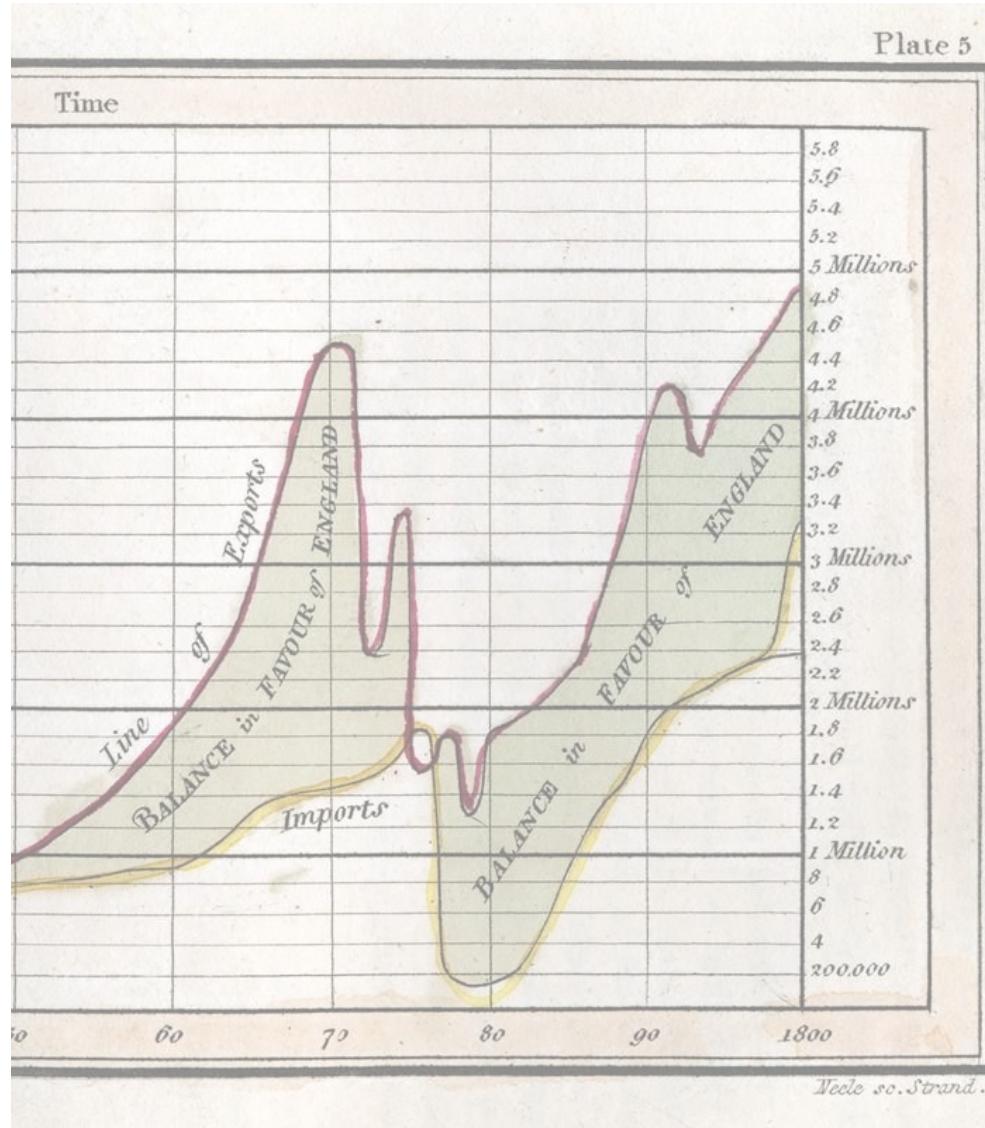
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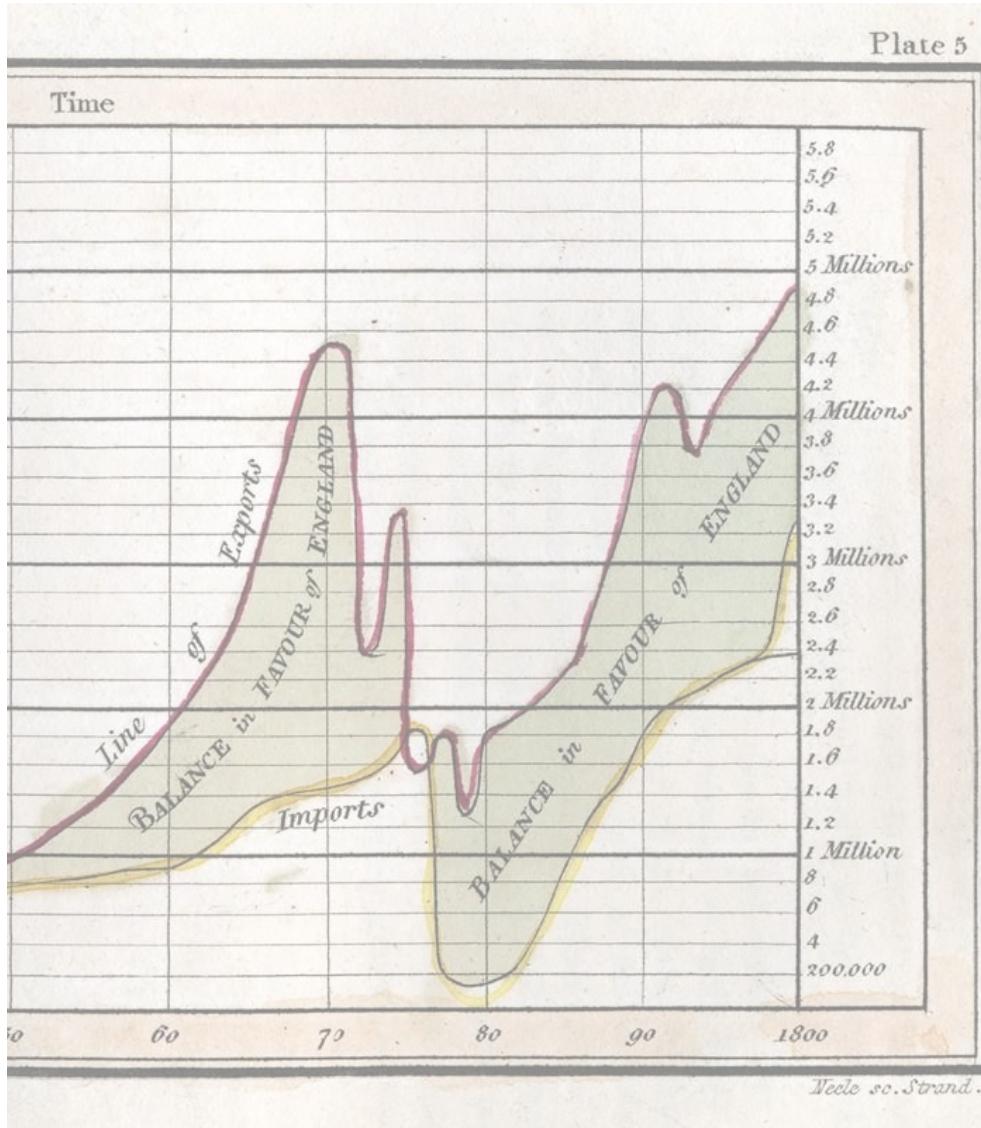
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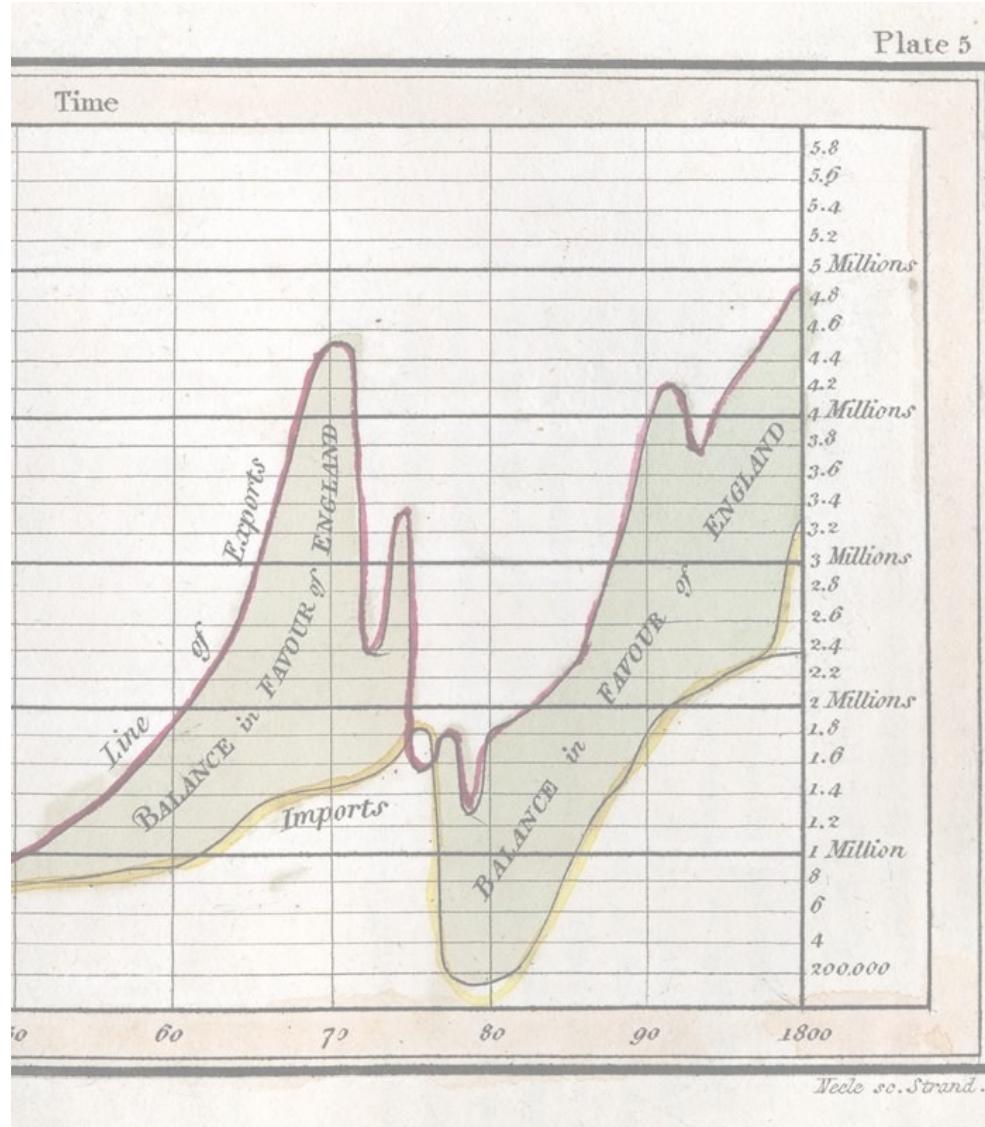
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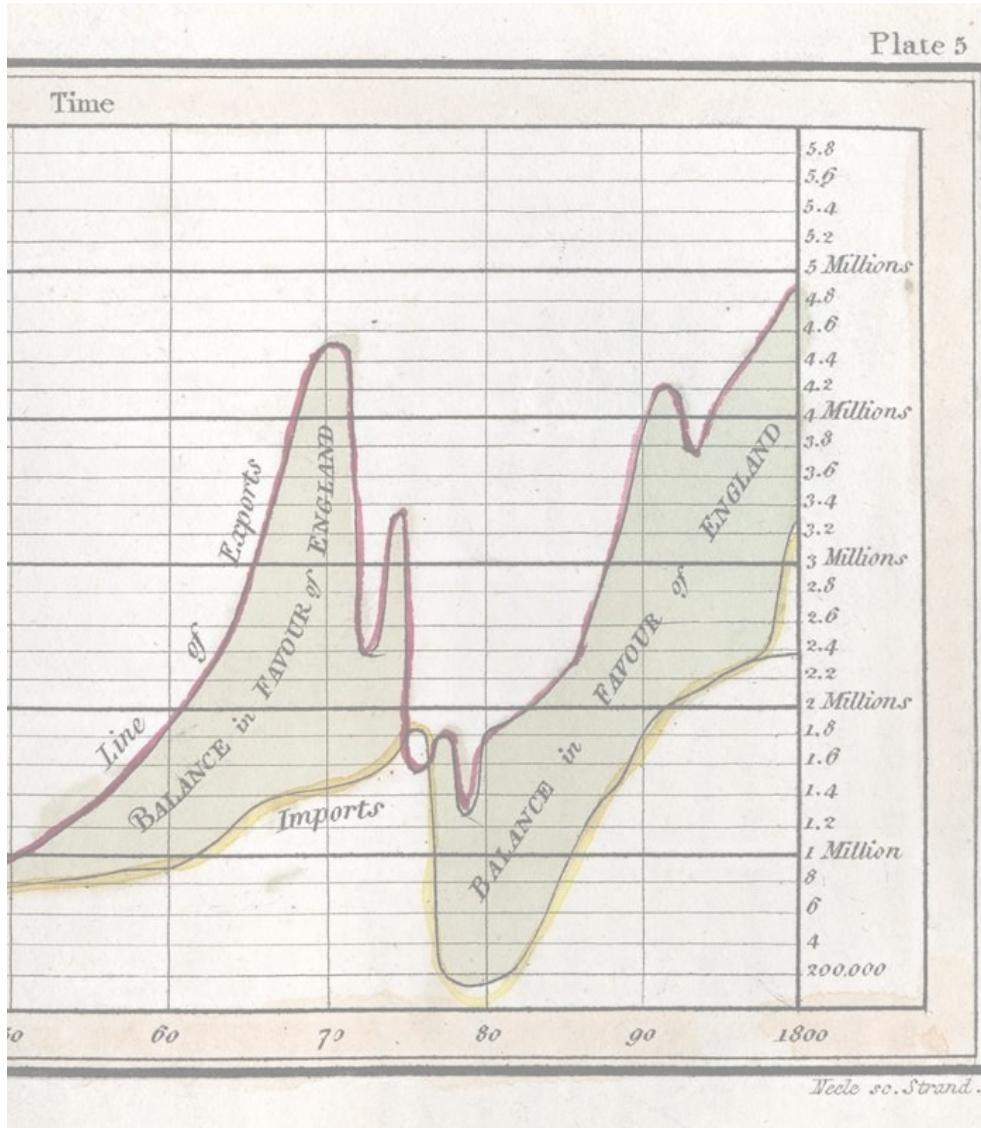
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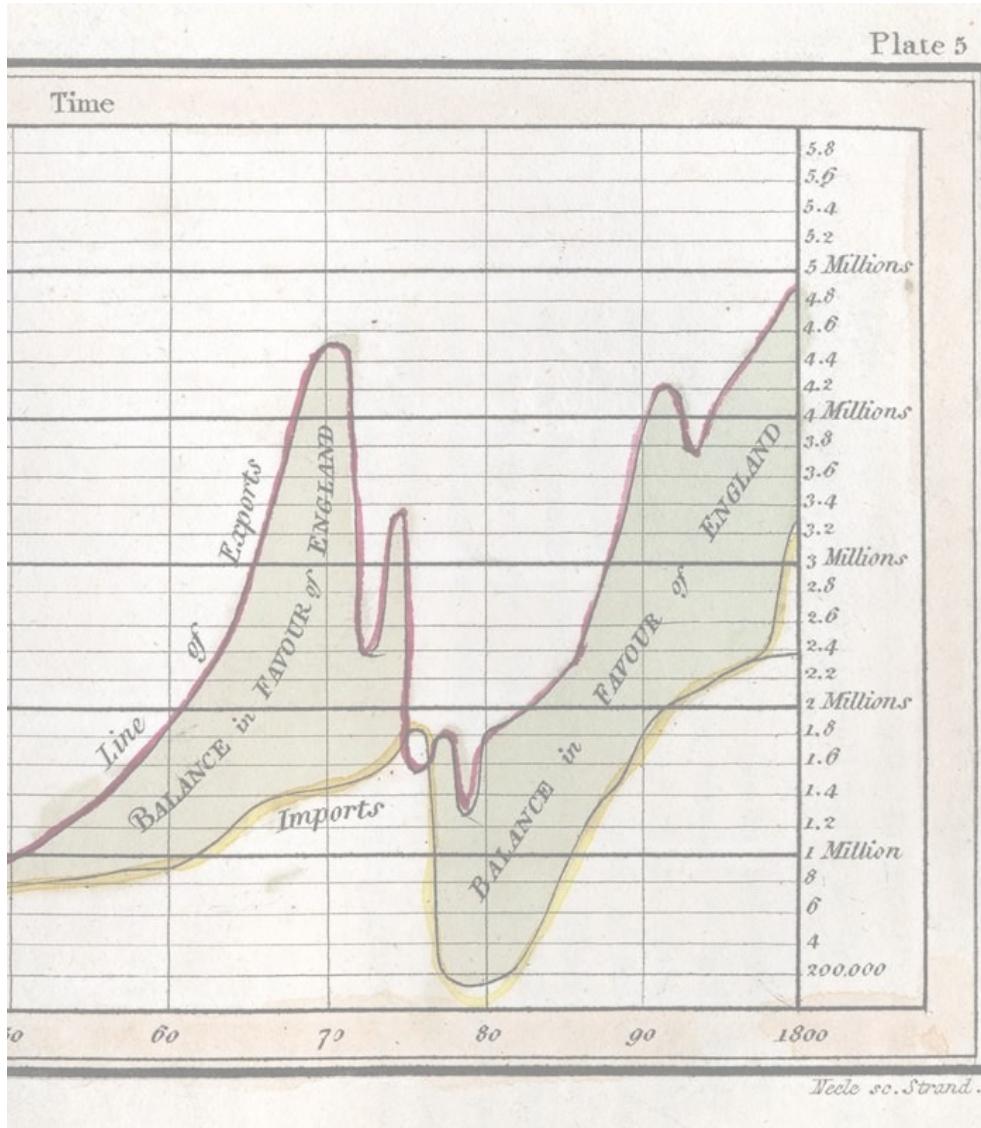
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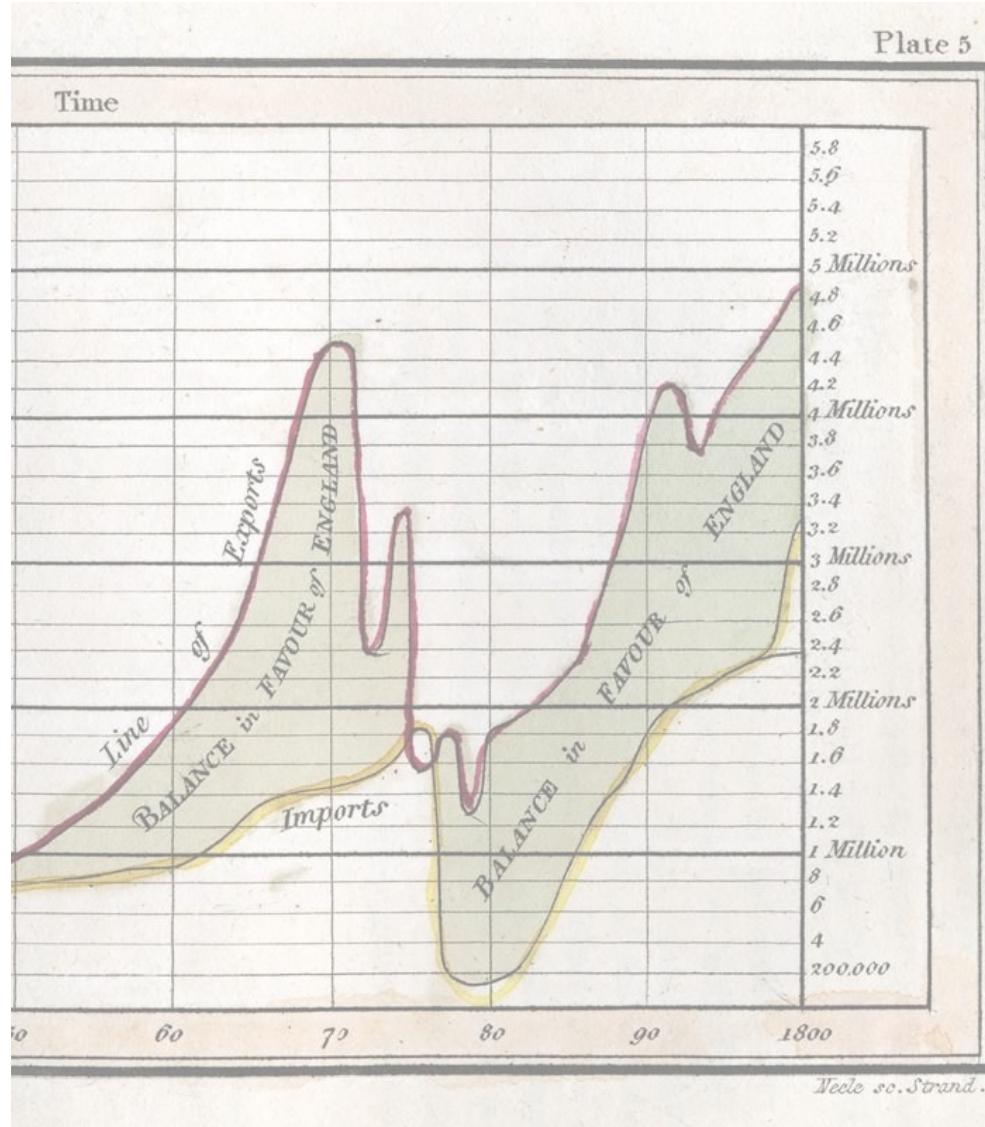
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Tasks

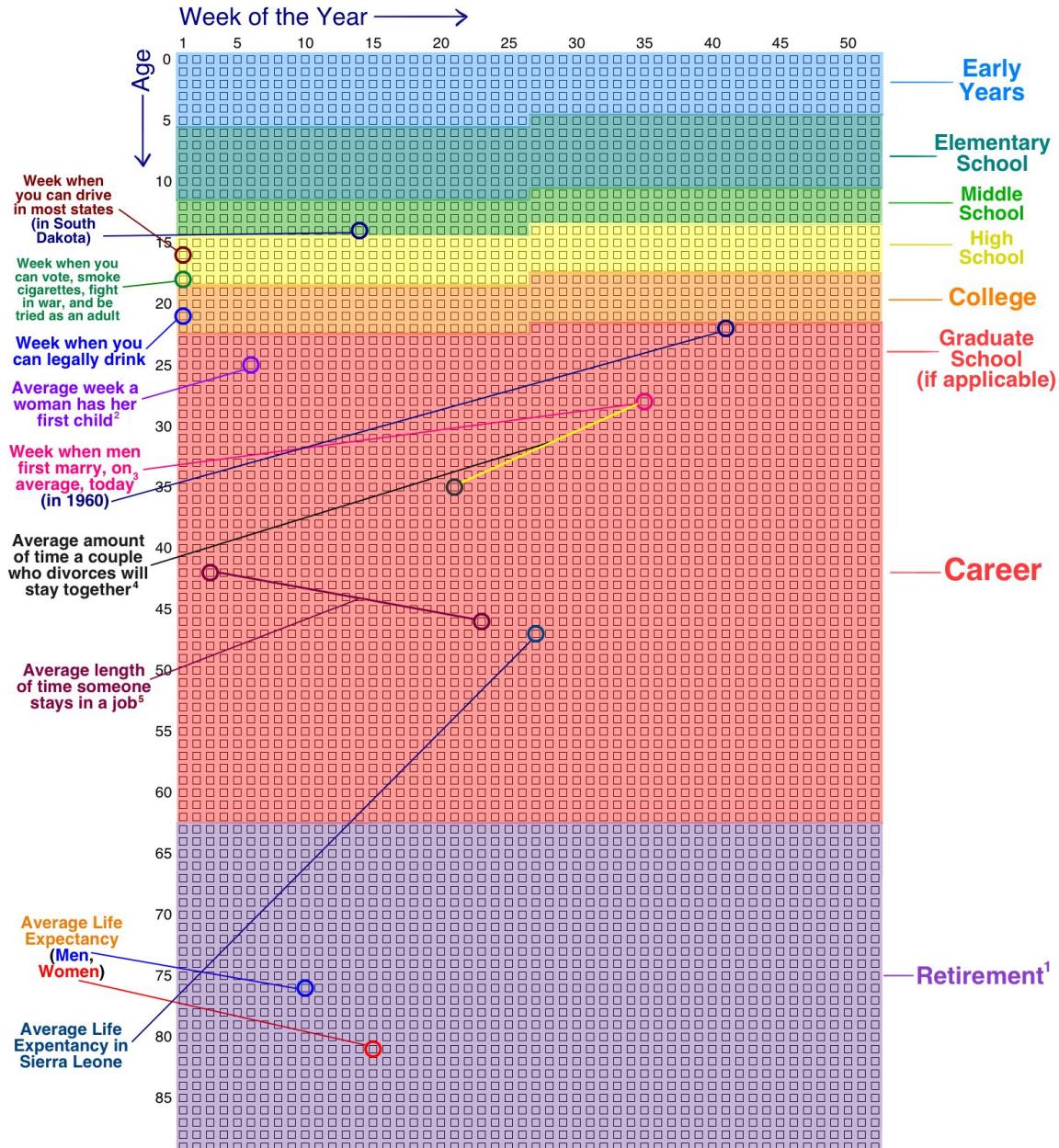
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Time is complex

- Directed
- Cyclic
- Quantities
- Scales
- Parallelity
- Granules: *weeks, months*

The Life of a Typical American

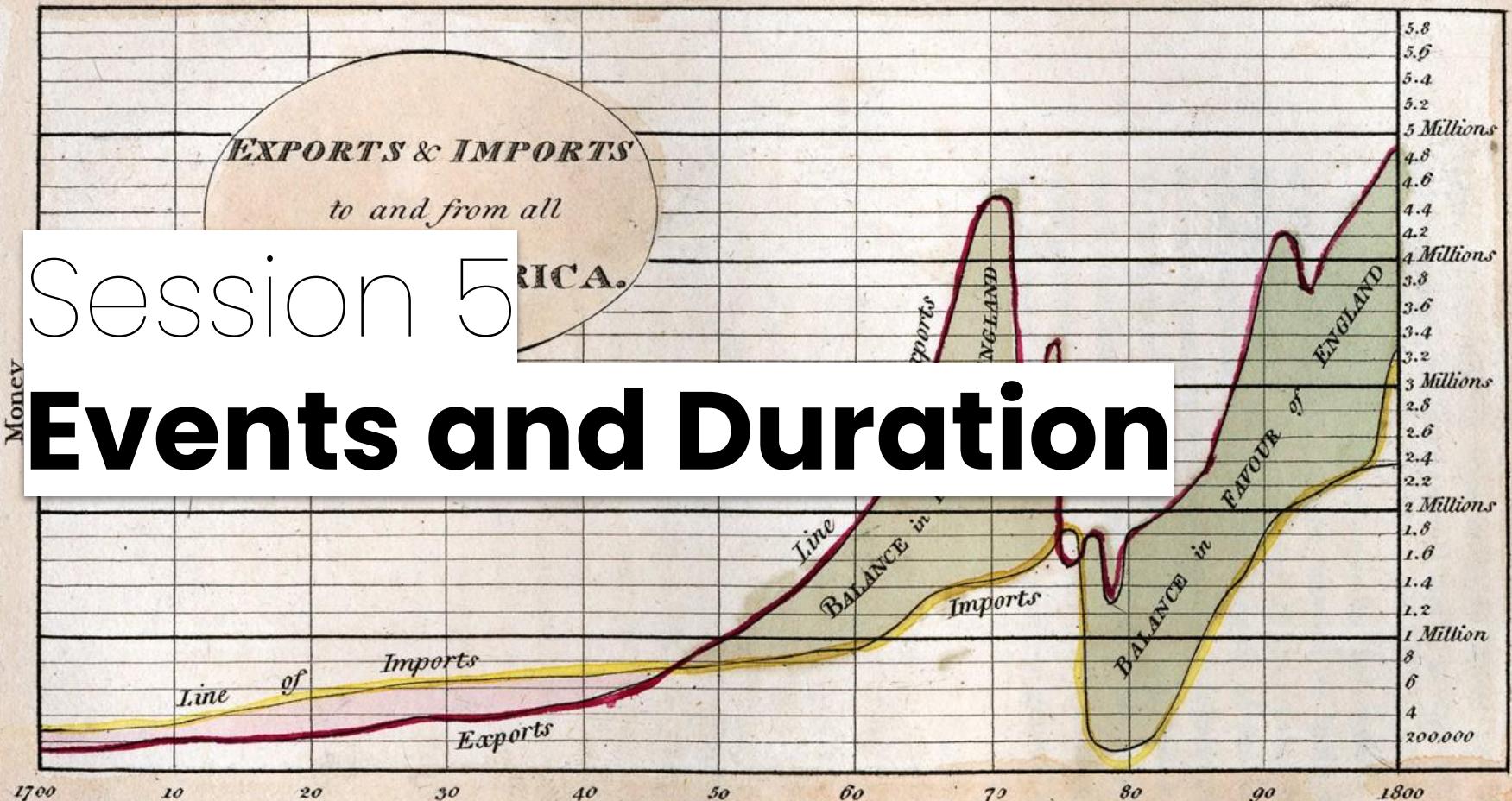


Outline

How to visualize temporal data?

- Event data
- Time series
- Many time series
- Multidimensional temporal data
- Space-time cubes
- Time curves

Time



Events and Duration



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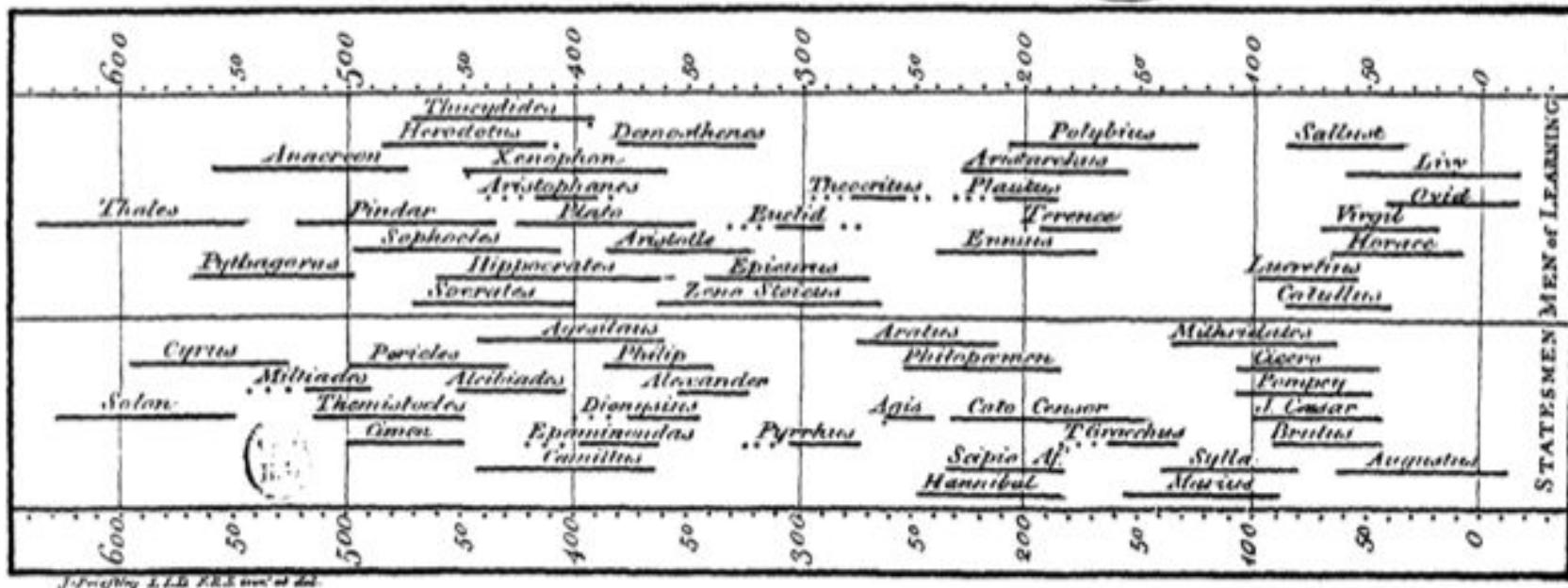
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Events and durations

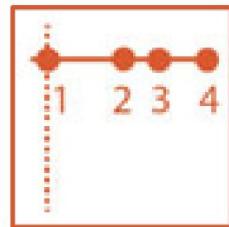
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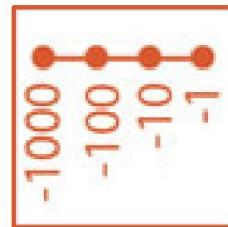
Scale



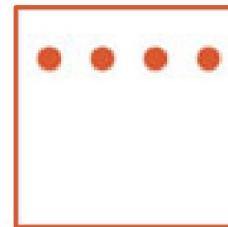
Chrono-
logical



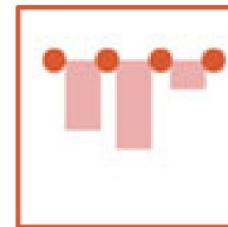
Relative



Logarithmic



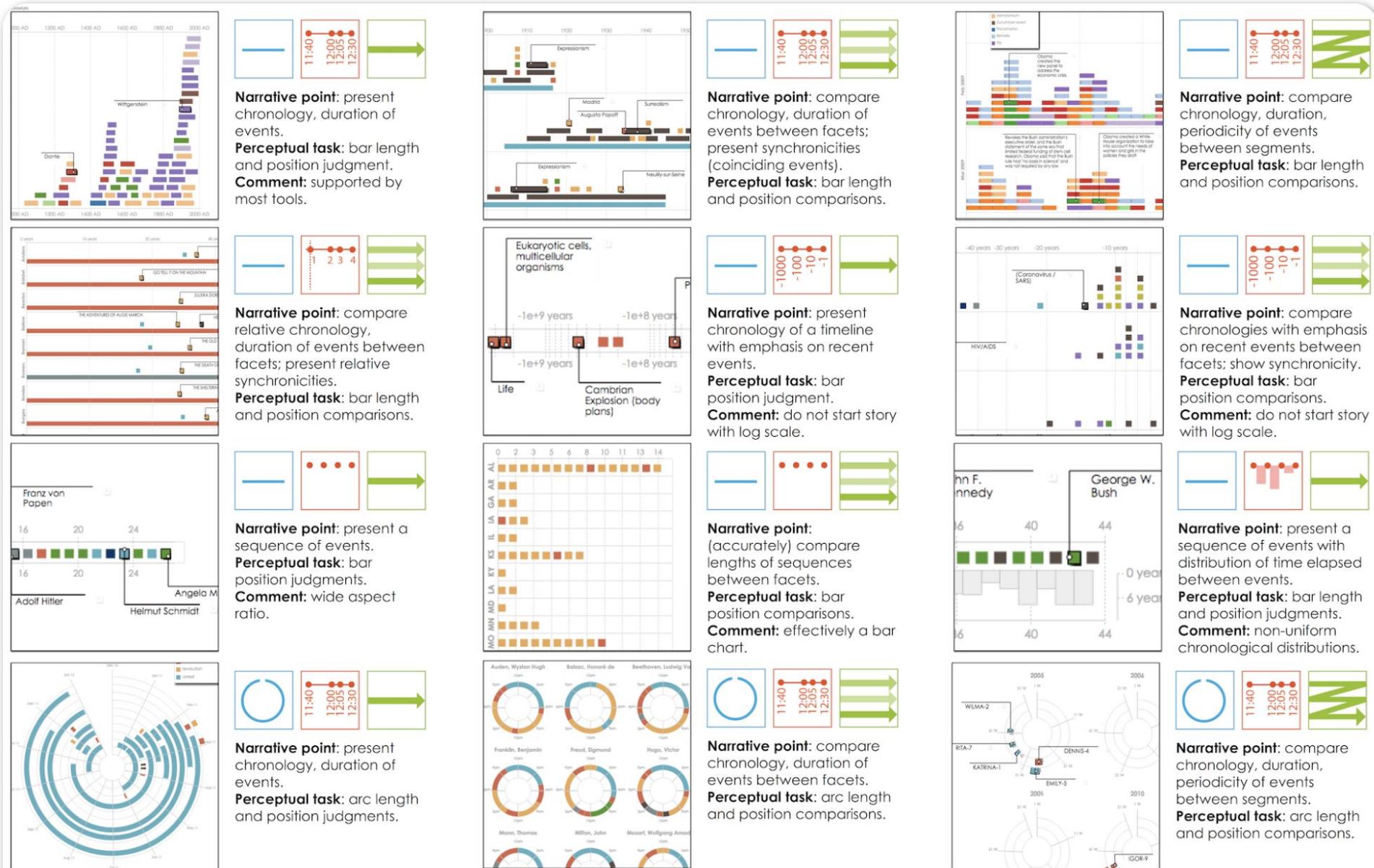
Sequential



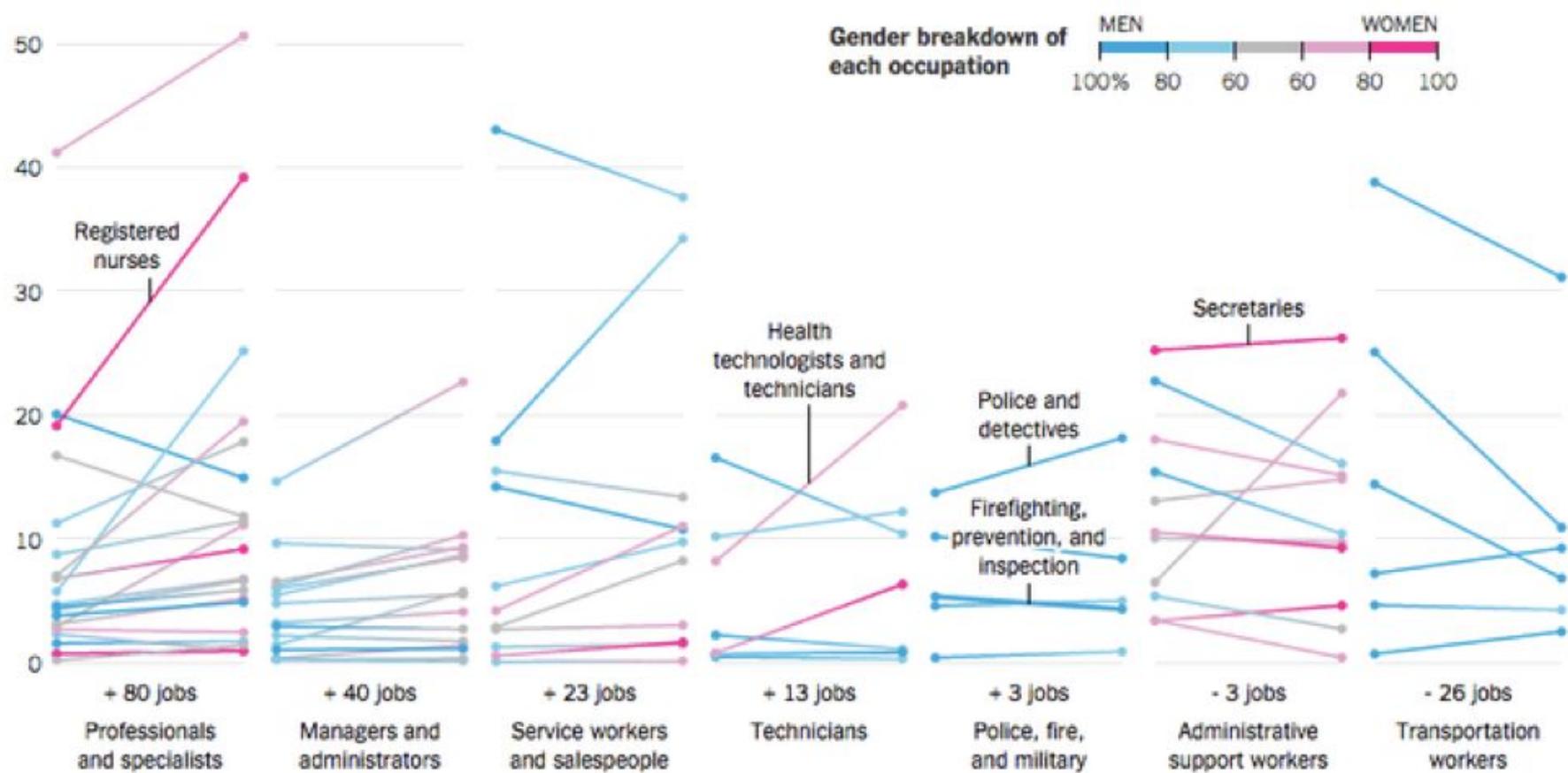
Sequential +
Interim
Duration

Timeline visualizations

<https://timelinesrevisited.github.io/>



Trend chart





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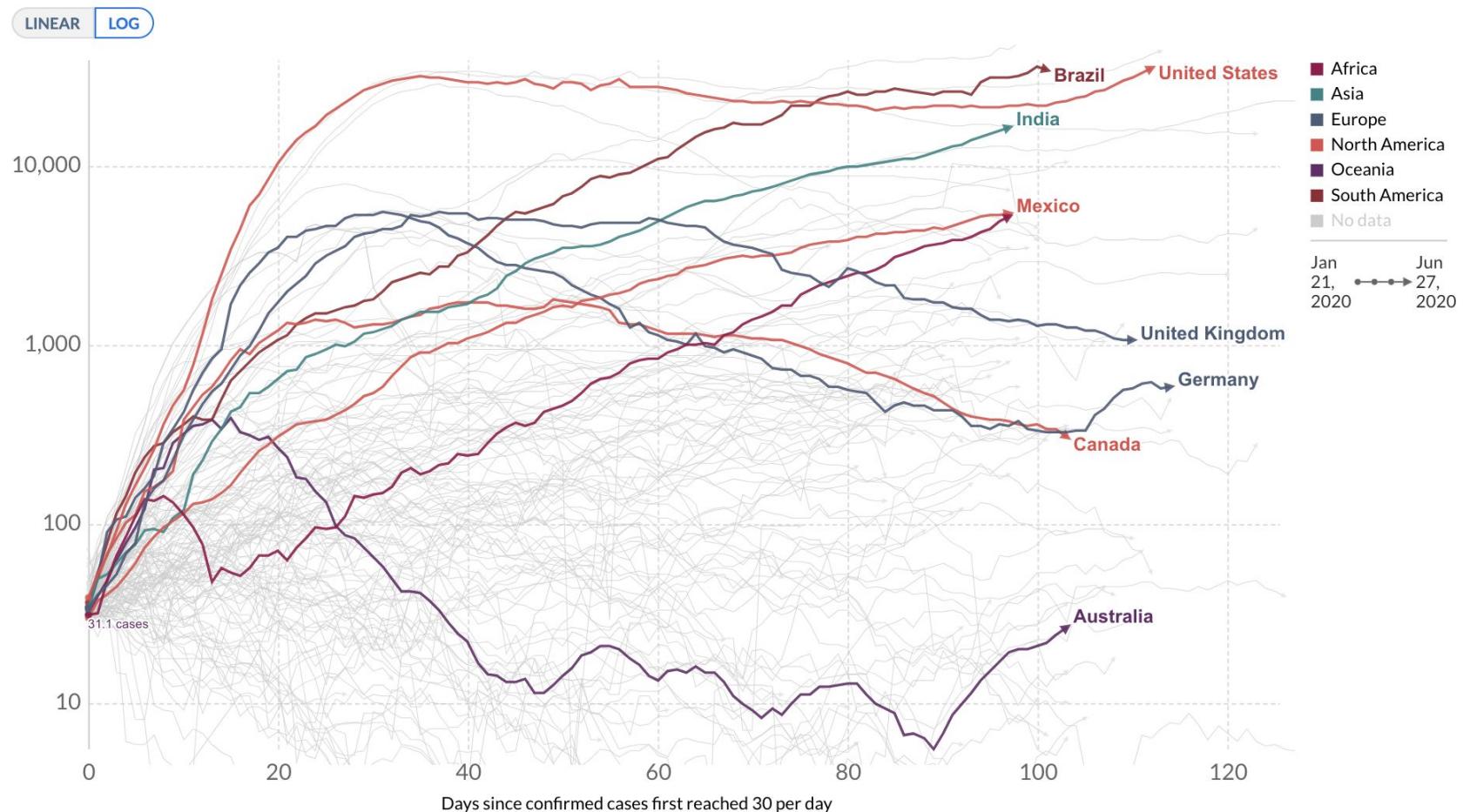
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Time series

Daily new confirmed COVID-19 cases

Shown is the rolling 7-day average. The number of confirmed cases is lower than the number of actual cases; the main reason for that is limited testing.

Our World
in Data



Source: European CDC – Situation Update Worldwide - Data last updated 27th Jun, 10:52 (GMT+01:00), European CDC – Situation Update Worldwide

CC BY

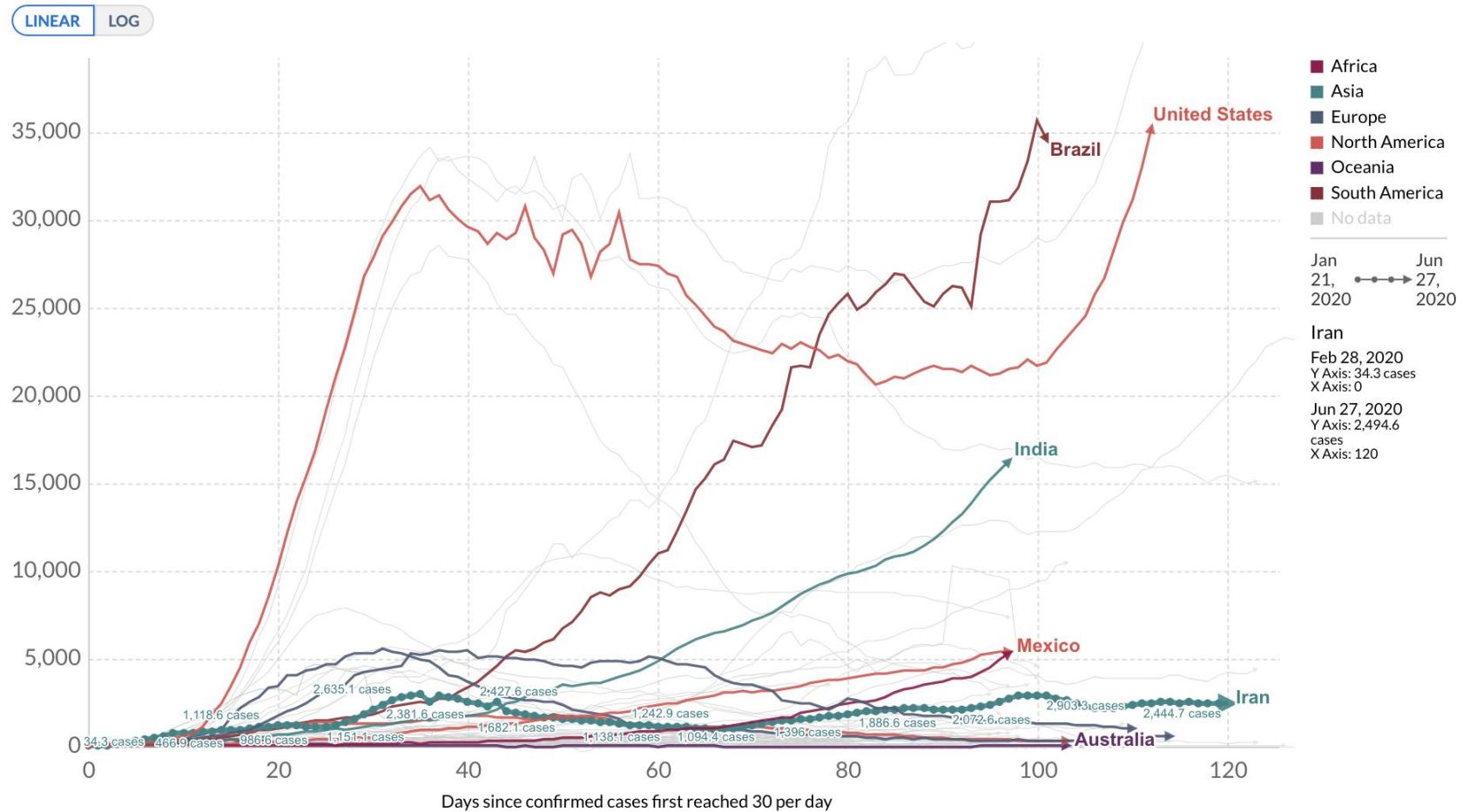
▶ Jan 21, 2020 ← Jun 27, 2020

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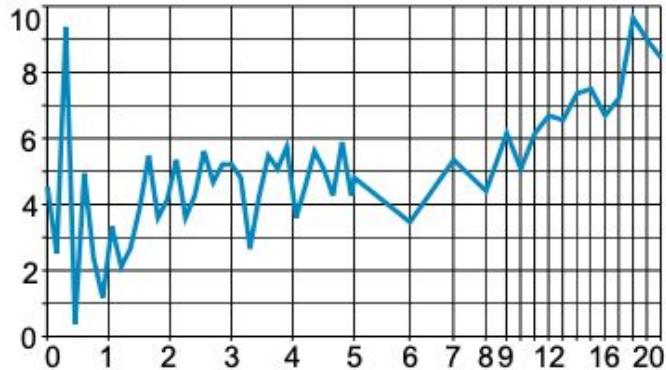


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CC BY

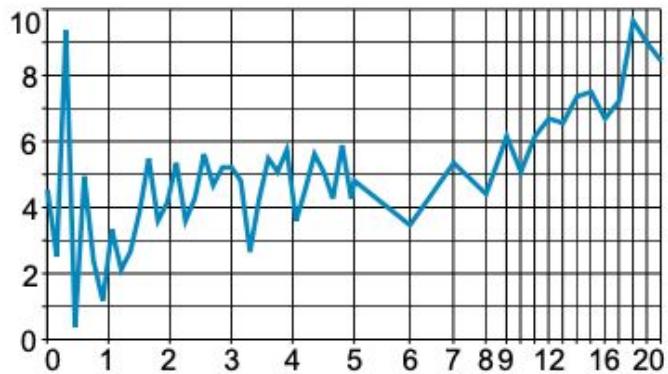
▶ Jan 21, 2020 Jun 27, 2020

Dual-Scale Data Charts

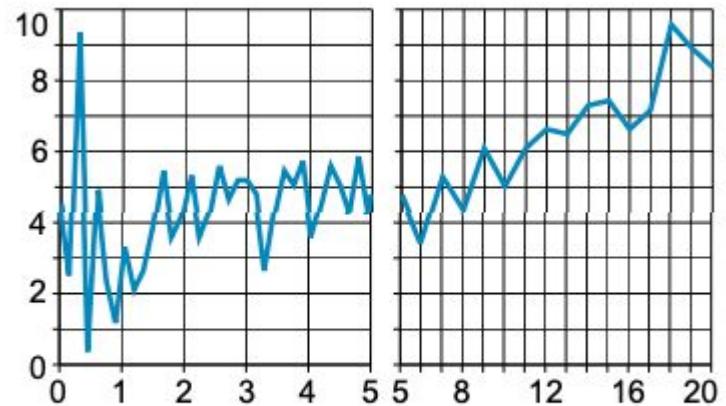


(a) A lens chart.

Dual-Scale Data Charts

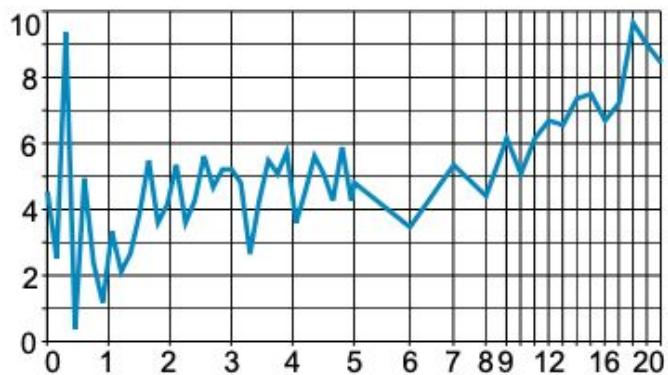


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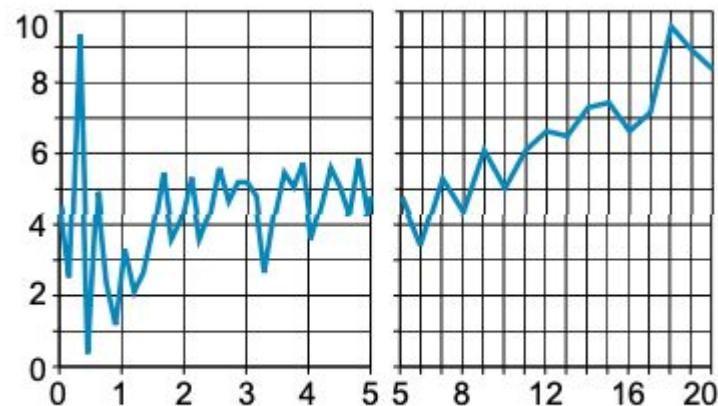


(a) A broken chart.

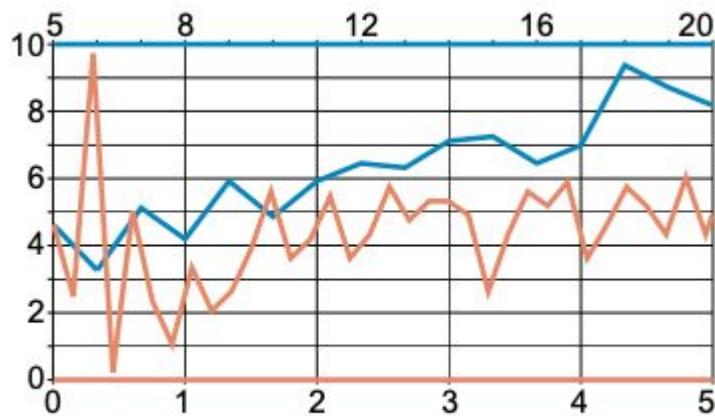
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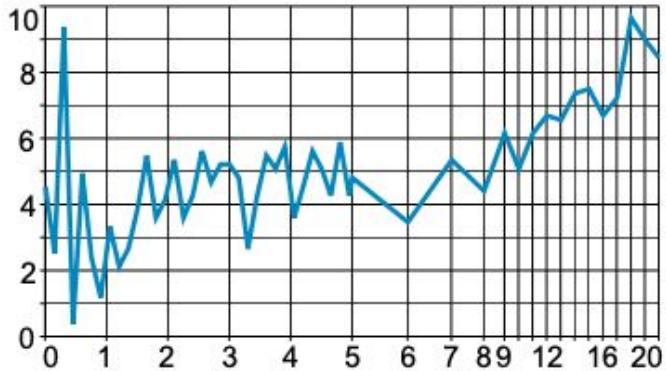


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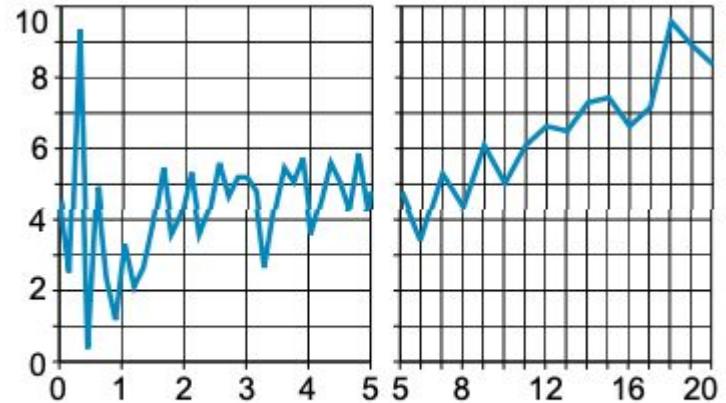


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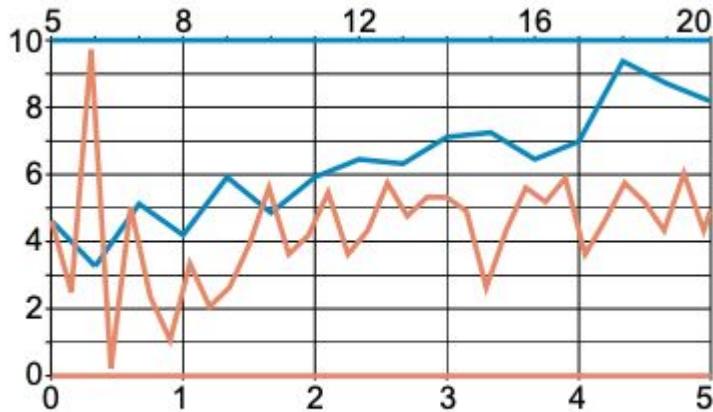
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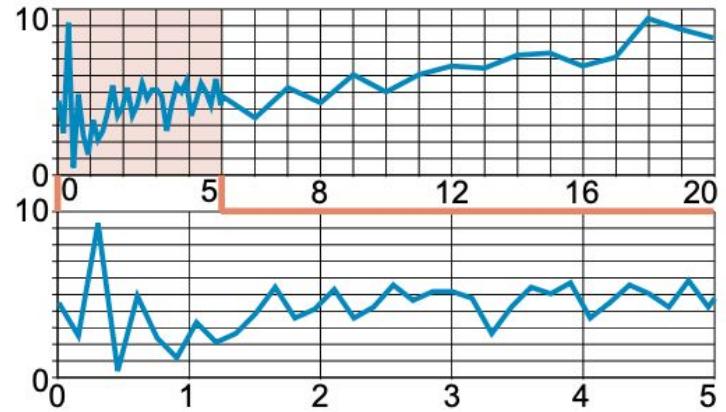
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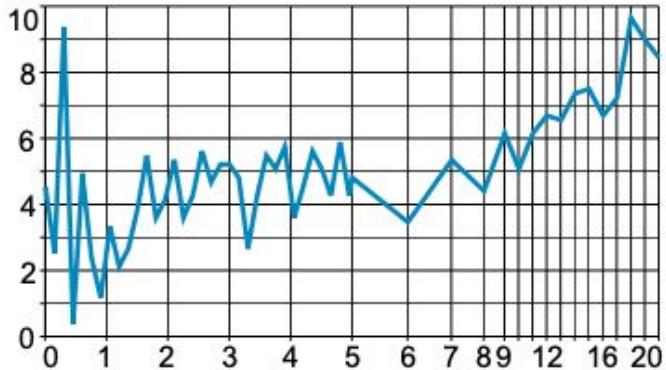


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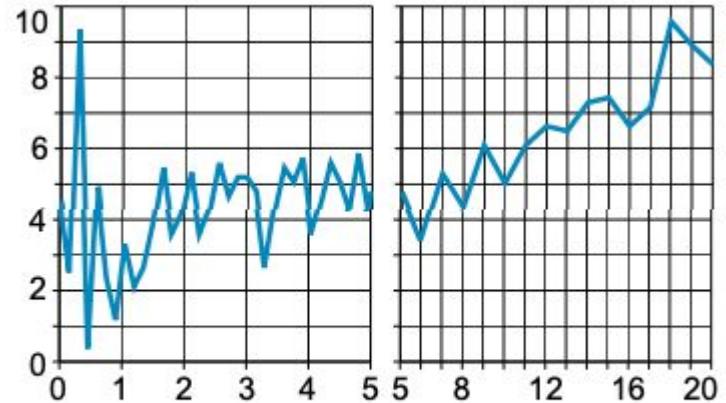


(a) A cut-out chart.

Dual-Scale Data Charts



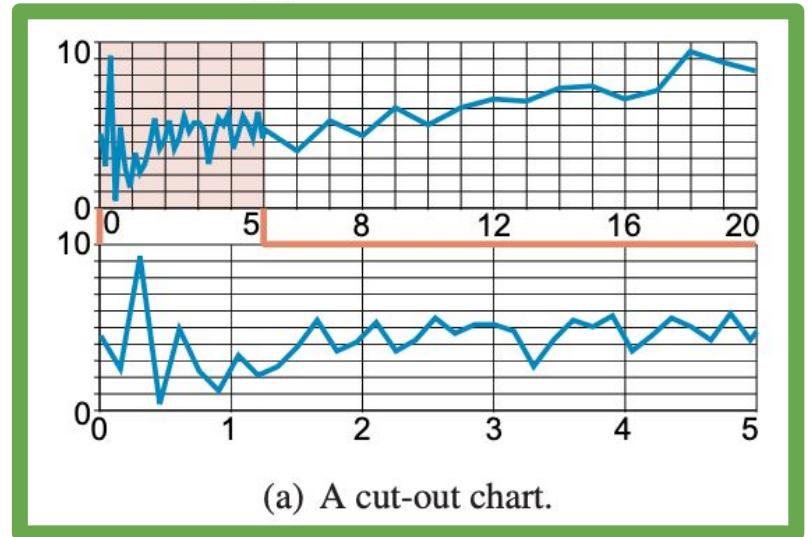
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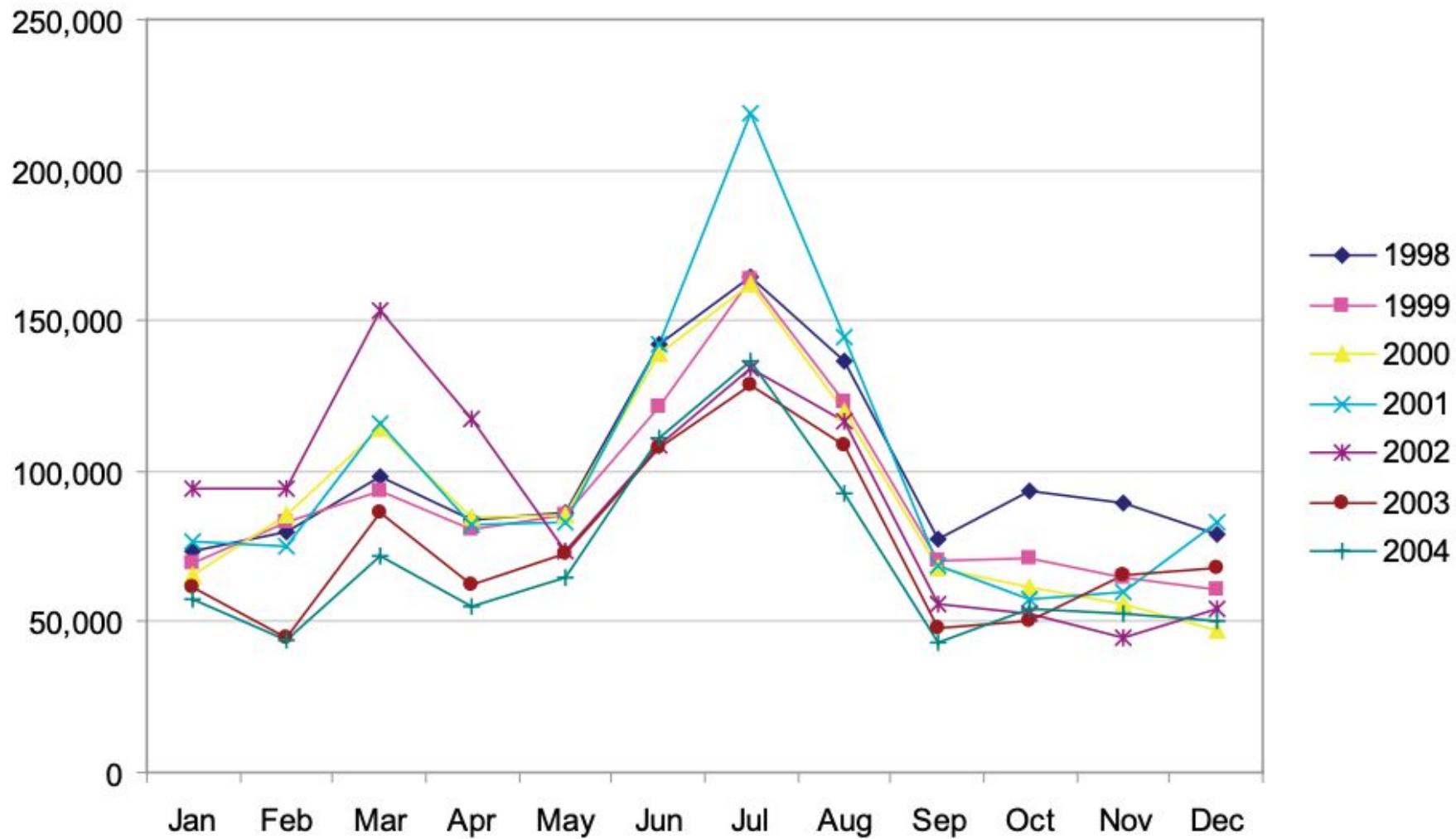


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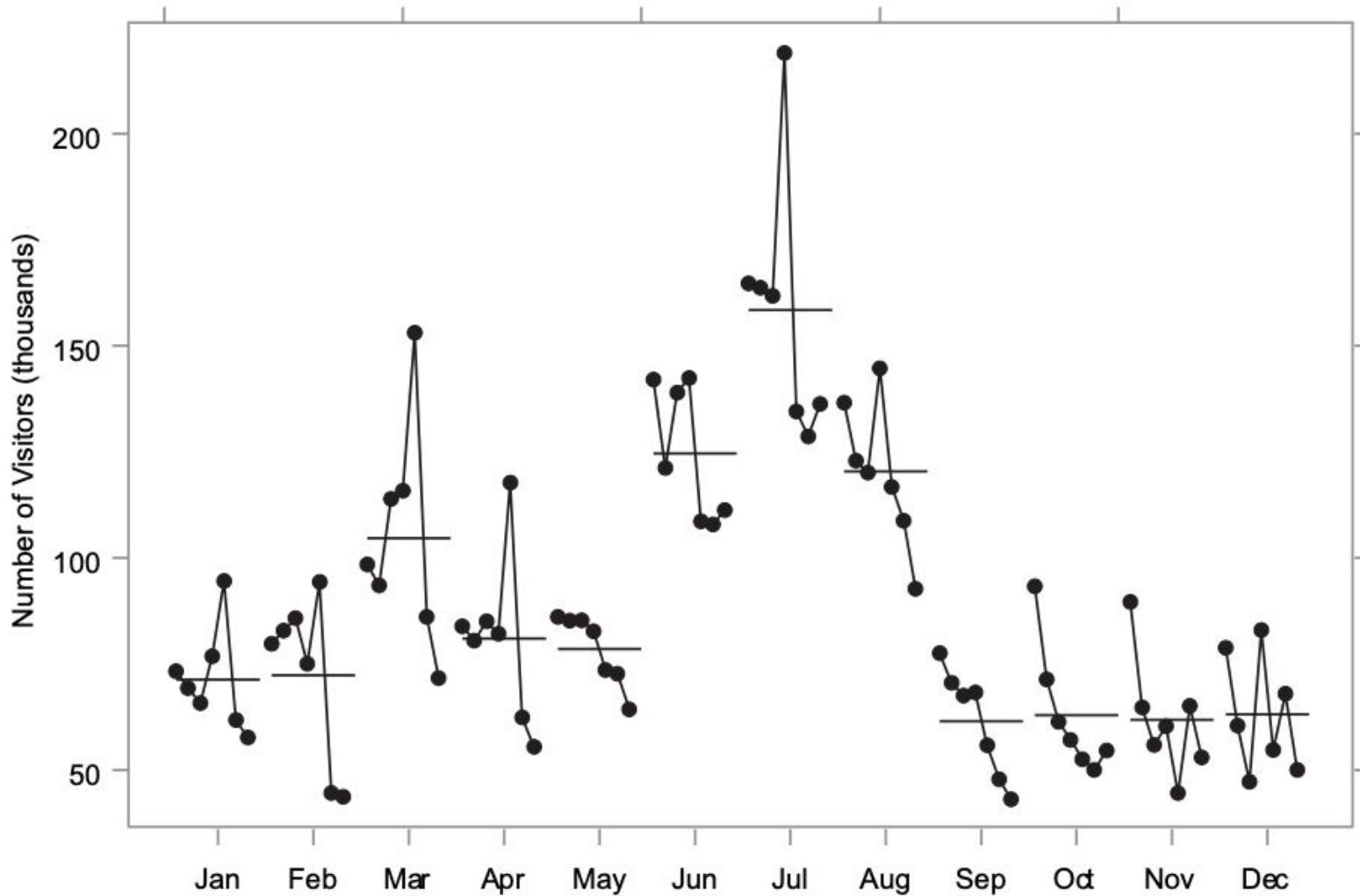


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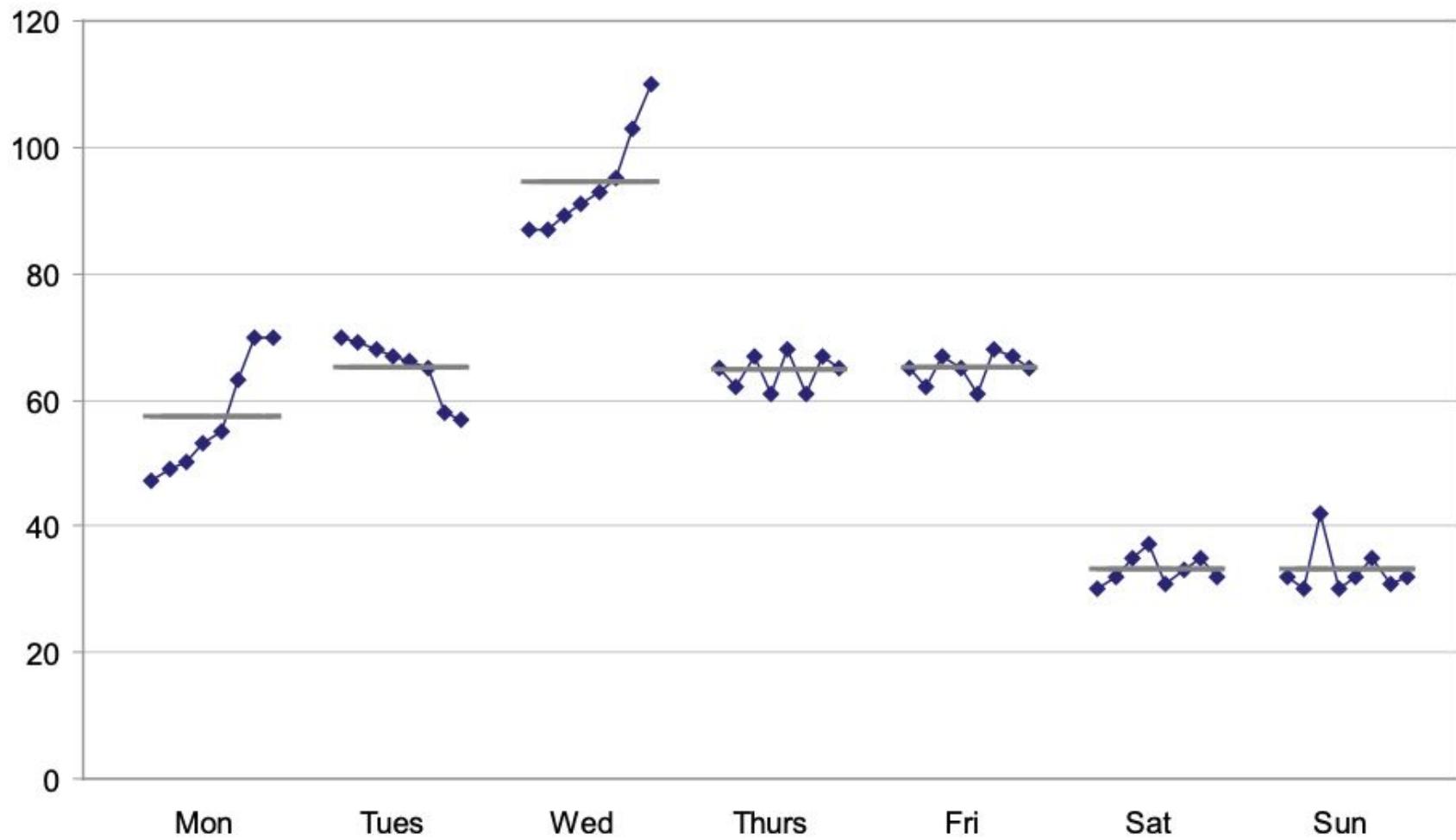
Calendar data



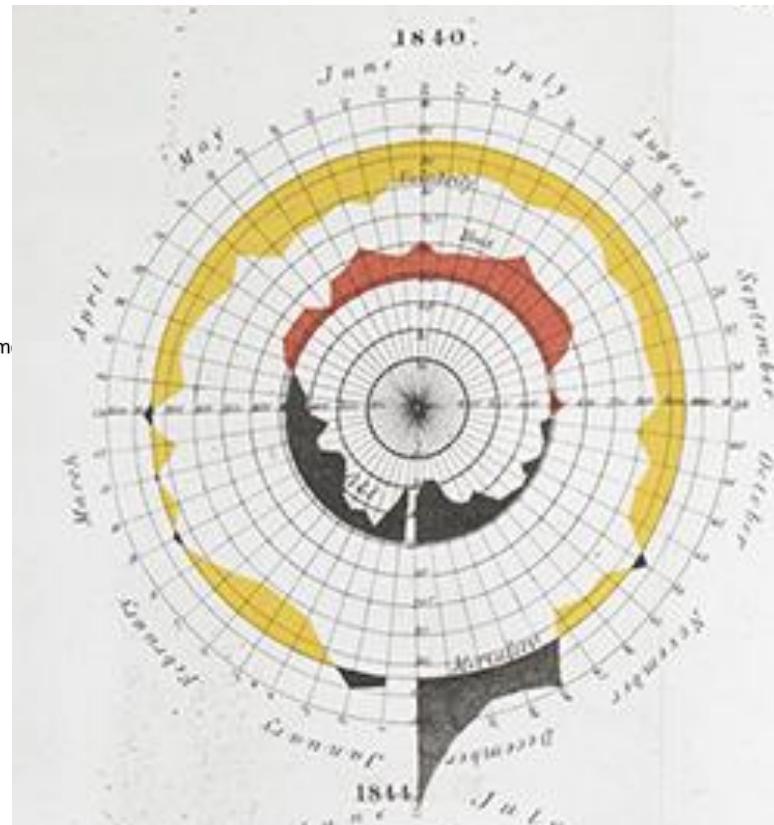
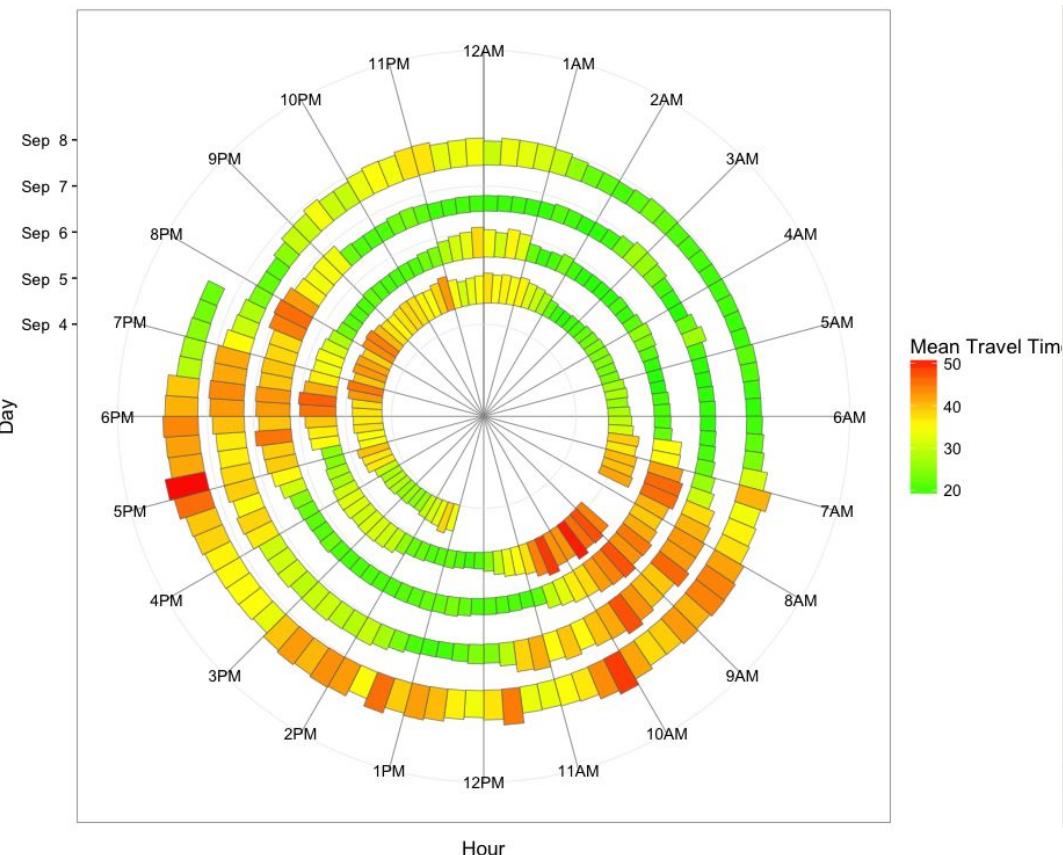
Cycle plots: by month



Cycle plots: by week day



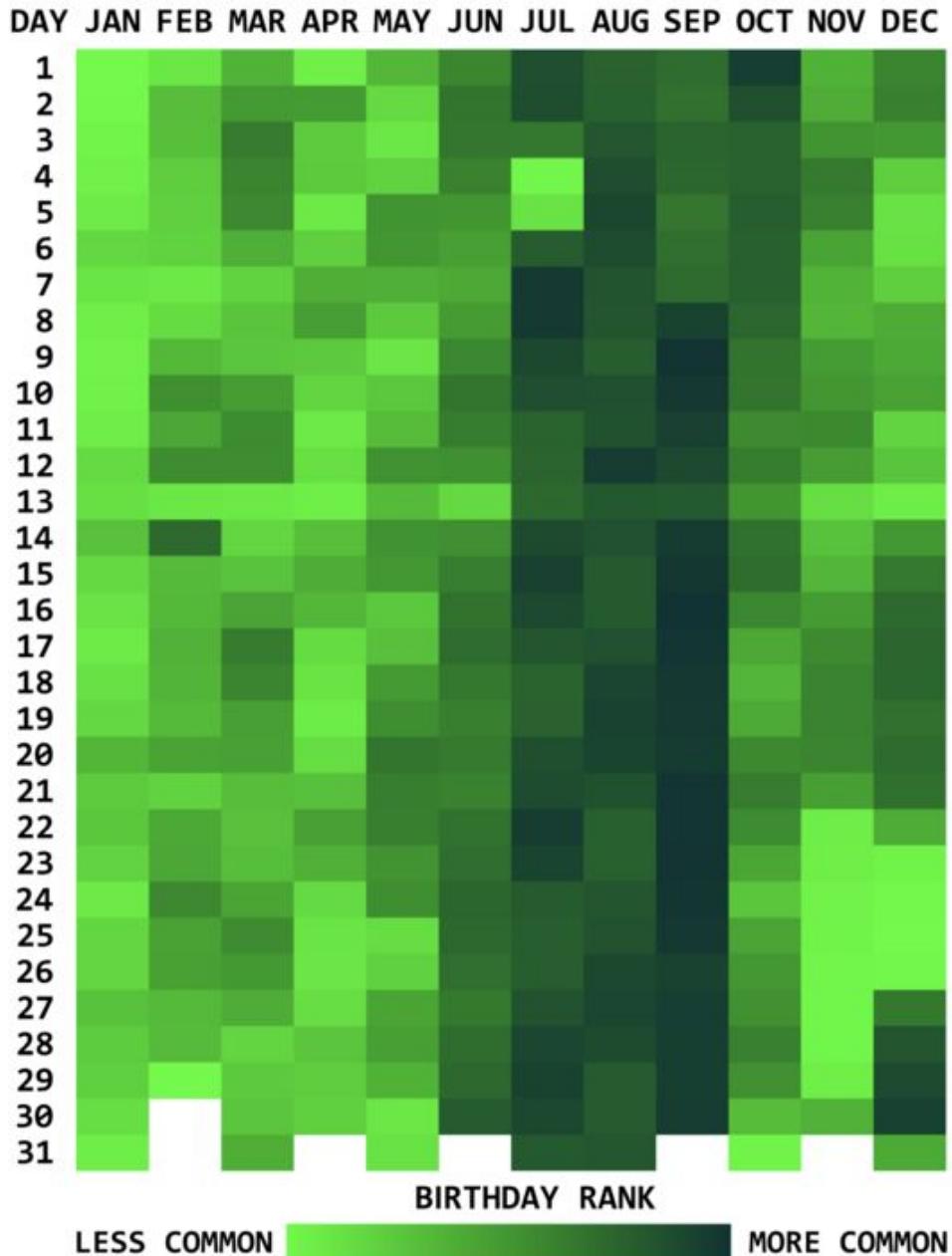
Radial time visualizations



- Show cyclical data / values
- Values in outer layers getting stretched!

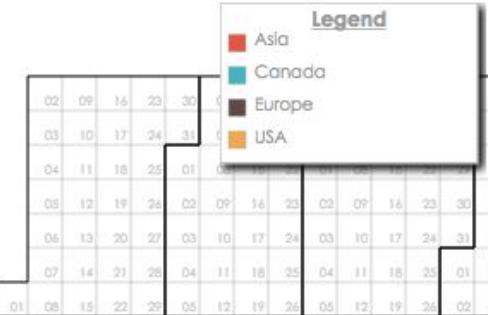
Heatmap

- Calendar data + numerical values
 - + Row and column effects
 - + Easy look up
 - + Space efficient
- Precise value comparison hard

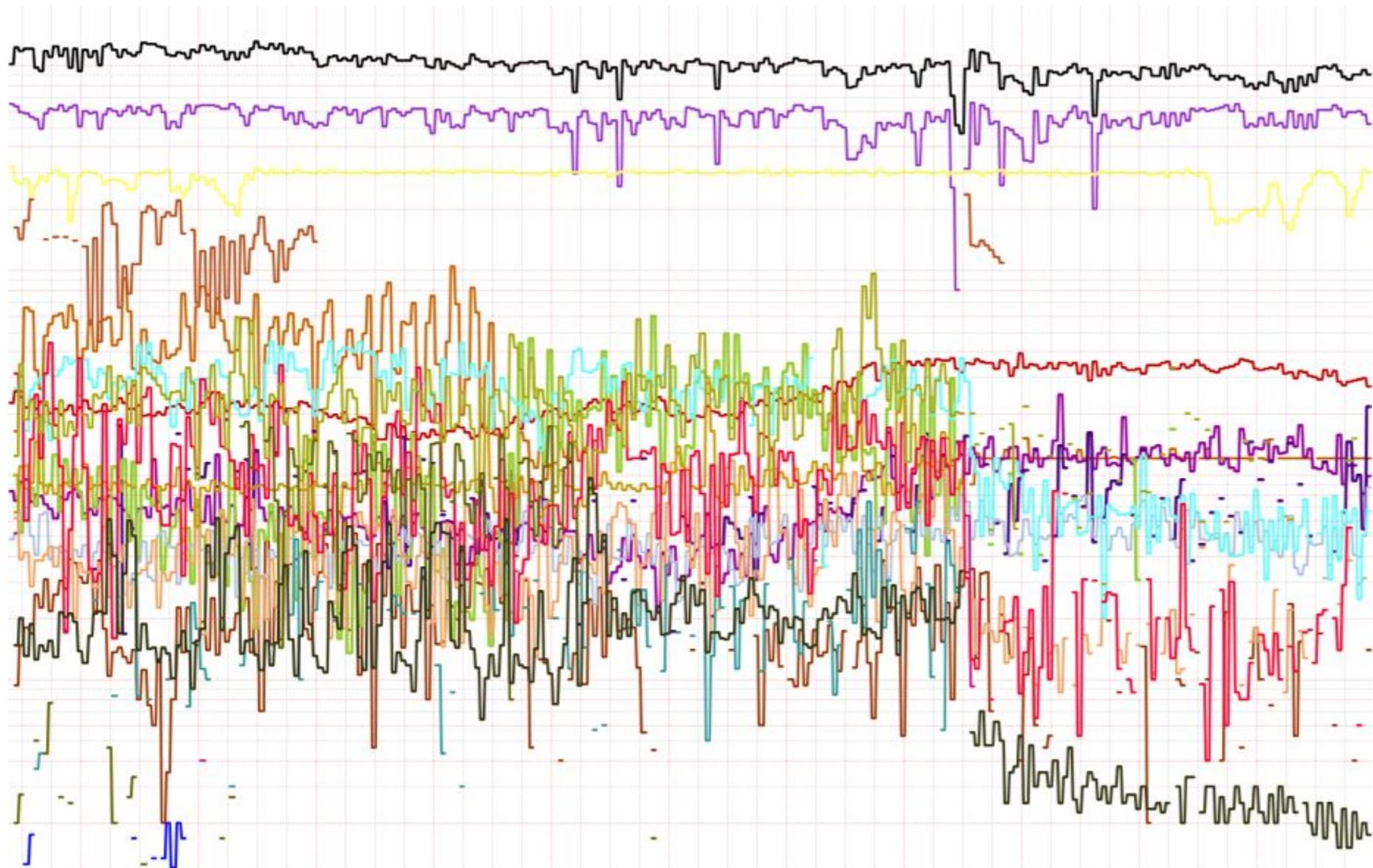


Calendars

2011



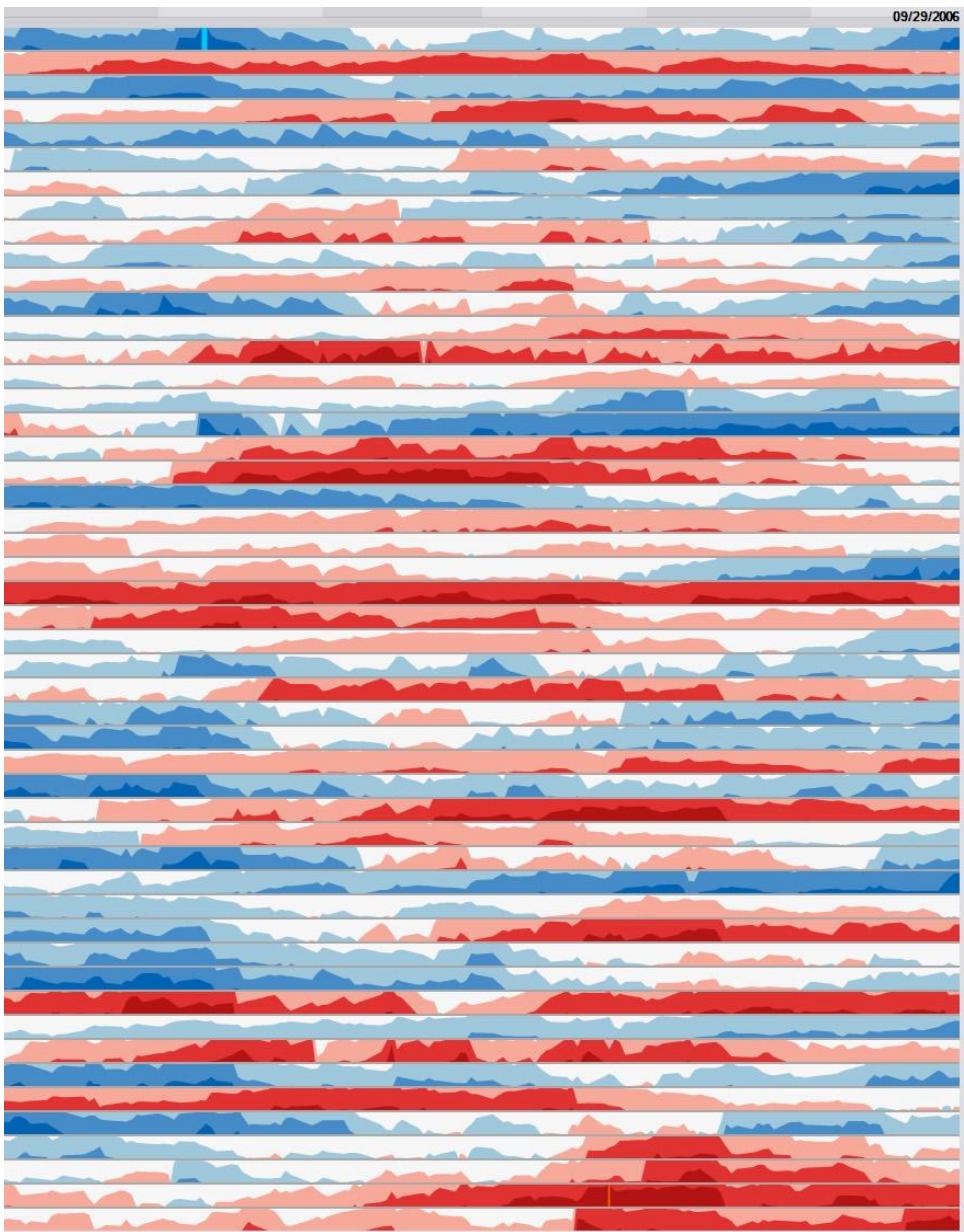
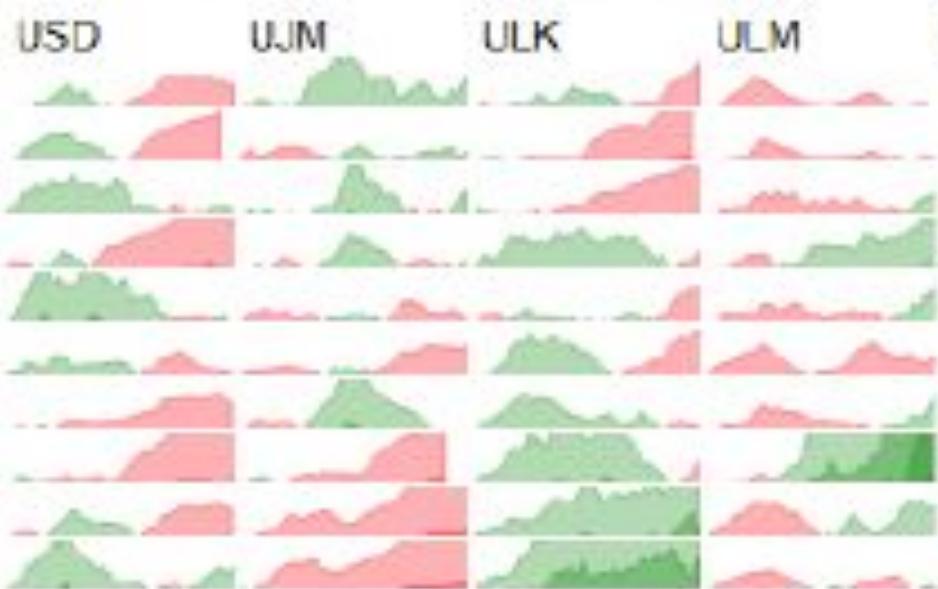
Comparing multiple timelines?



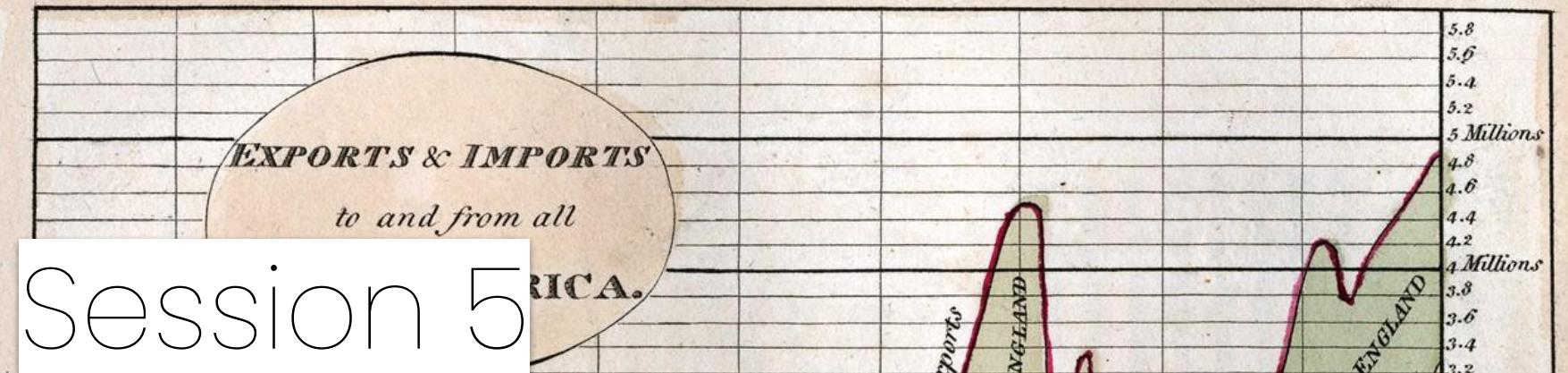
Horizon graphs



Horizon Graphs

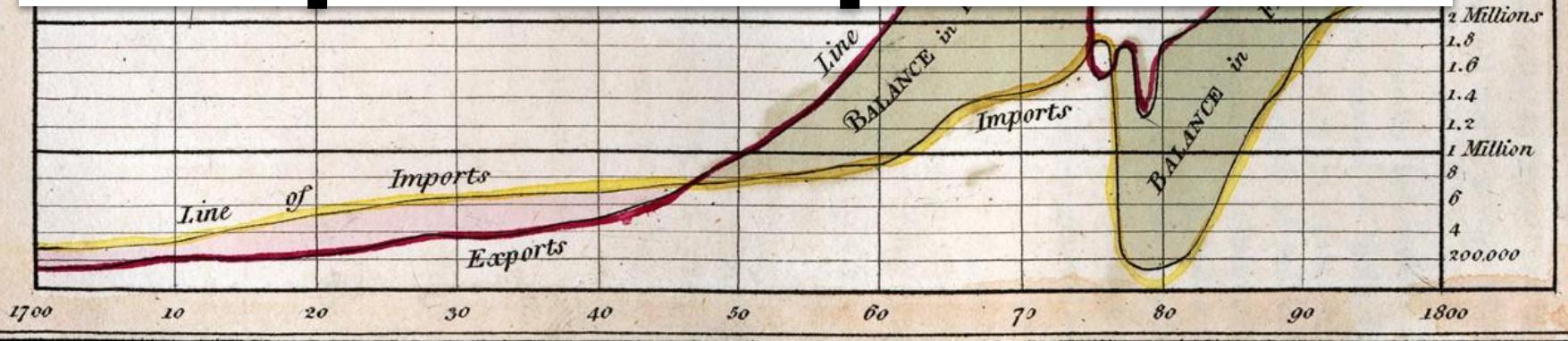


Time



Session 5

Complex Temporal Data



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Connected Scatterplot

METRICS

HANNAH FAIRFIELD

Driving Shifts Into Reverse

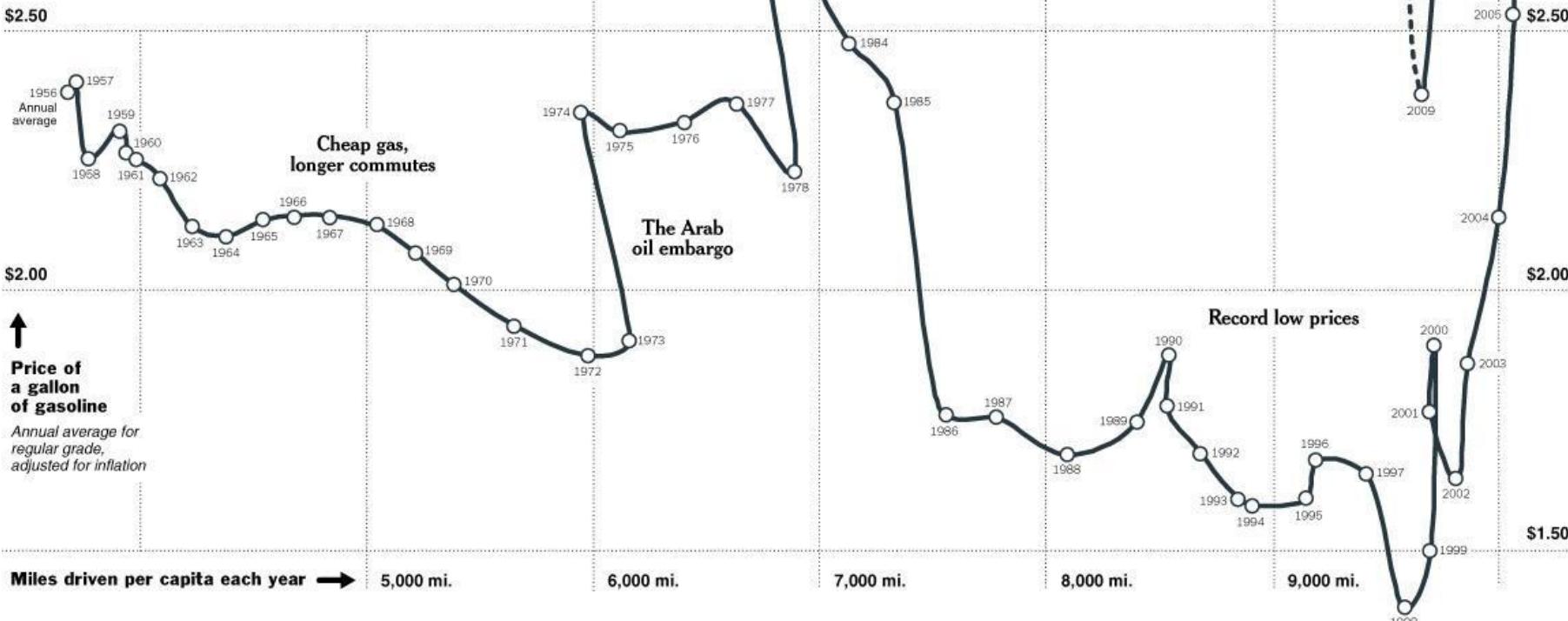
ECONOMISTS have long studied the relationship between driving habits and gasoline prices. Low gas prices can bring periods of profligate driving, and a quick jump in prices can cause many vehicles to languish in garages.

Until recently, Americans have driven more each year than the previous one, with a few brief exceptions. In 1956, Americans of driving age drove about 4,000 miles a year, on average. Fifty years later, that figure had climbed above 10,000.

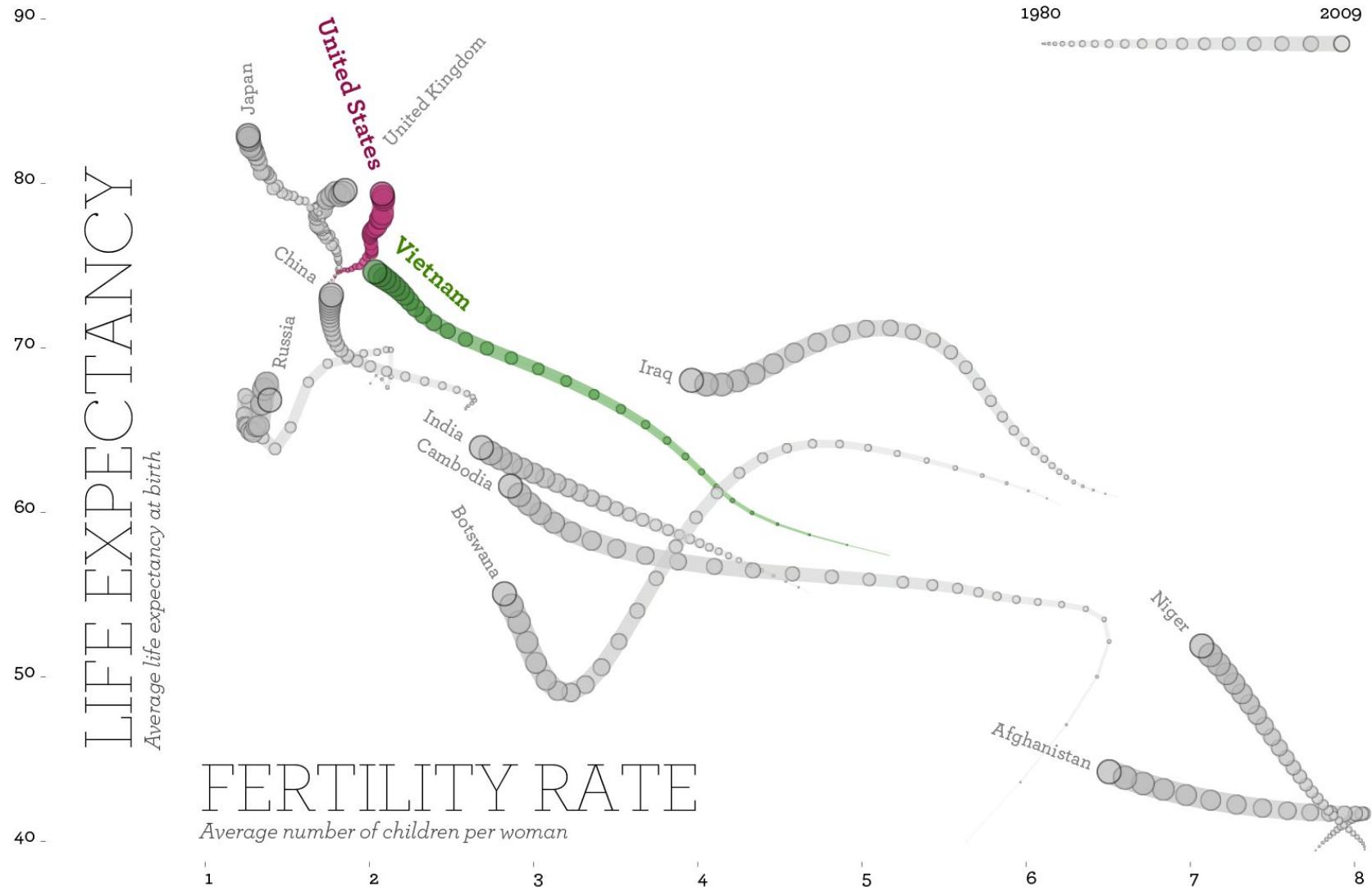
But the latest recession has caused some big changes. High unemployment meant that fewer people were driving to work, and a slump in consumer spending

meant that less freight needed to be moved around the country. As gas prices soared in 2005, the number of miles driven — including commercial and personal — began to fall, and continued to drop after 2008 even as gasoline became cheaper.

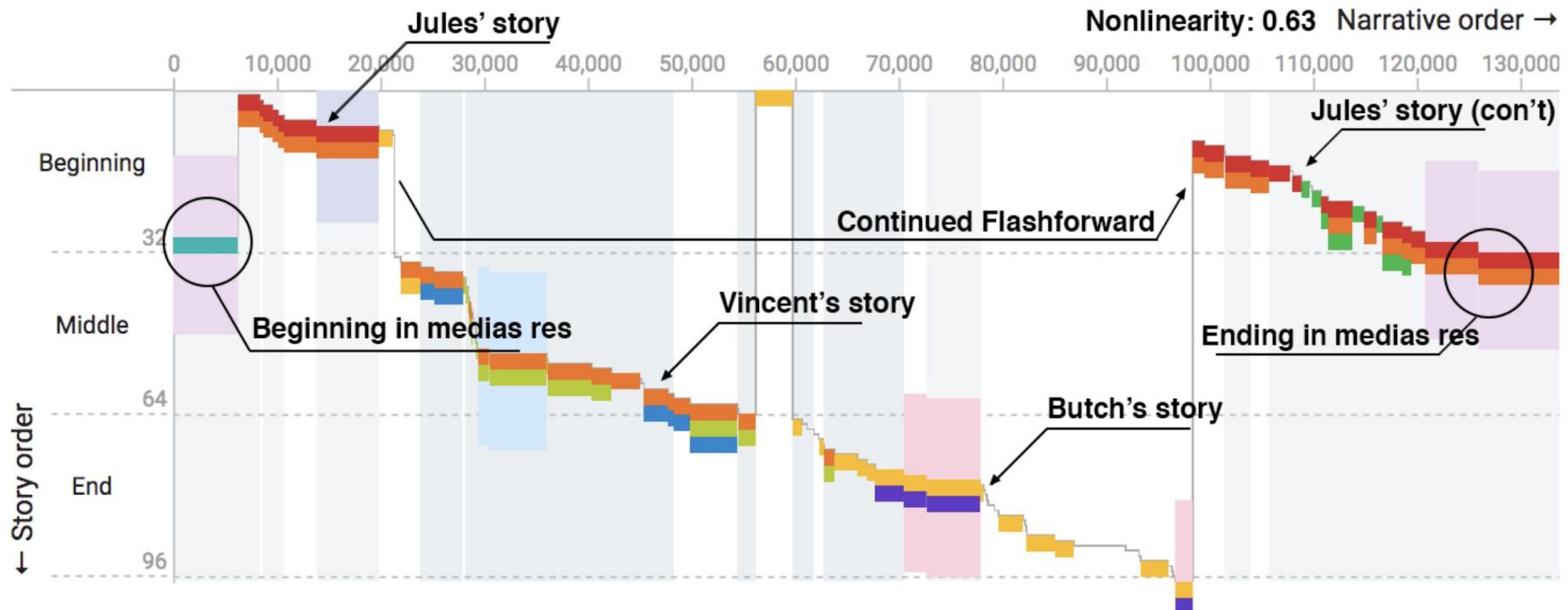
"People were surprised by the very rapid rise in gas prices, and they changed their driving behavior," said Kenneth A. Small, a transportation economist at the University of California, Irvine. "But my suspicion is that it is temporary. As soon as unemployment gets back to pre-recession levels, we will see Americans doing a lot more driving again."



Connected Scatterplots: encoding time

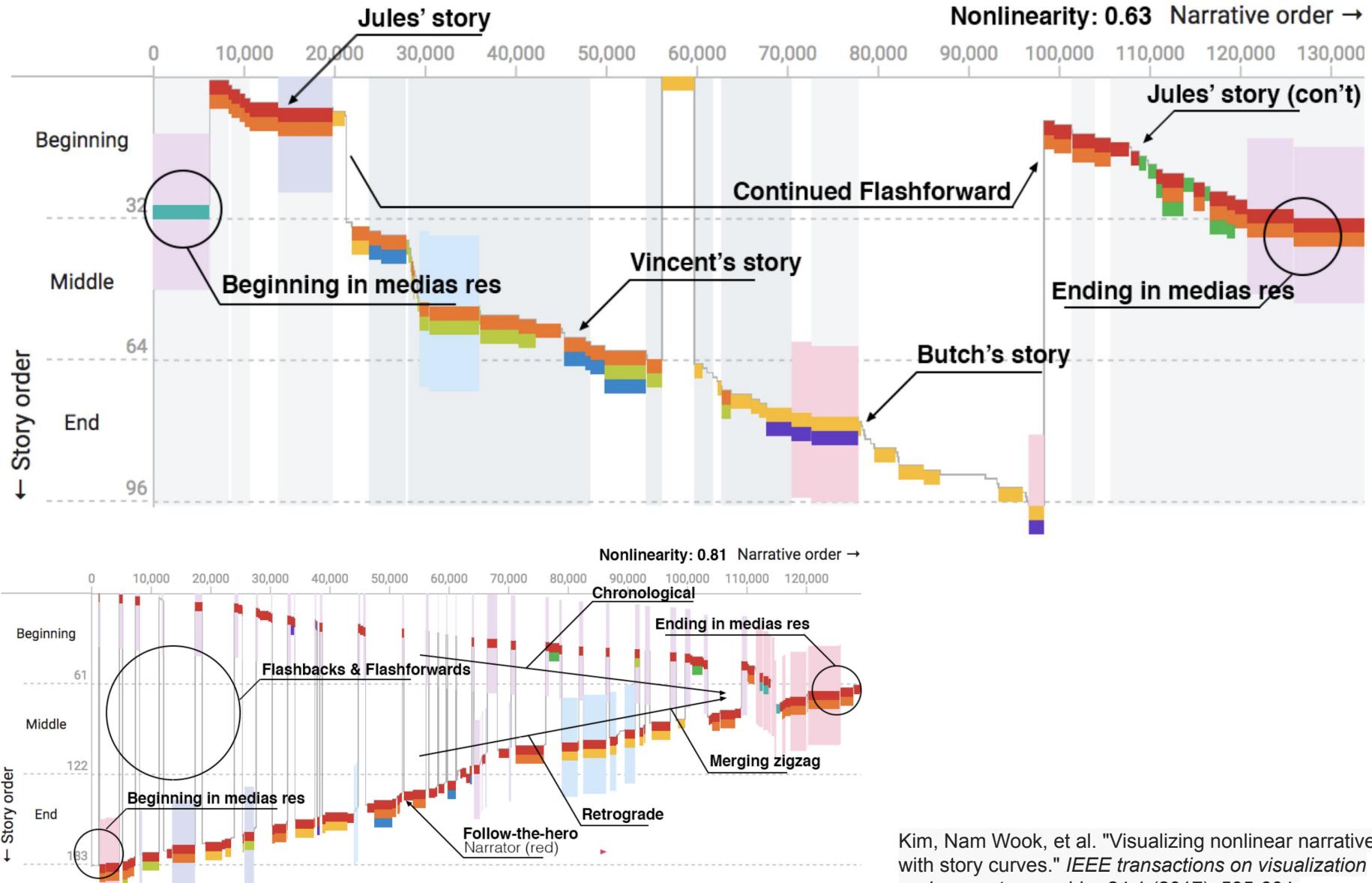


Time vs. Time: Story Curves



Kim, Nam Wook, et al. "Visualizing nonlinear narratives with story curves." *IEEE transactions on visualization and computer graphics* 24.1 (2017): 595-604.

Time vs. Time: Story Curves



Kim, Nam Wook, et al. "Visualizing nonlinear narratives with story curves." *IEEE transactions on visualization and computer graphics* 24.1 (2017): 595-604.

Time Curves

Creation

Timeline:



Circles are data cases with a time stamp.
Similar colors indicate similar data cases.

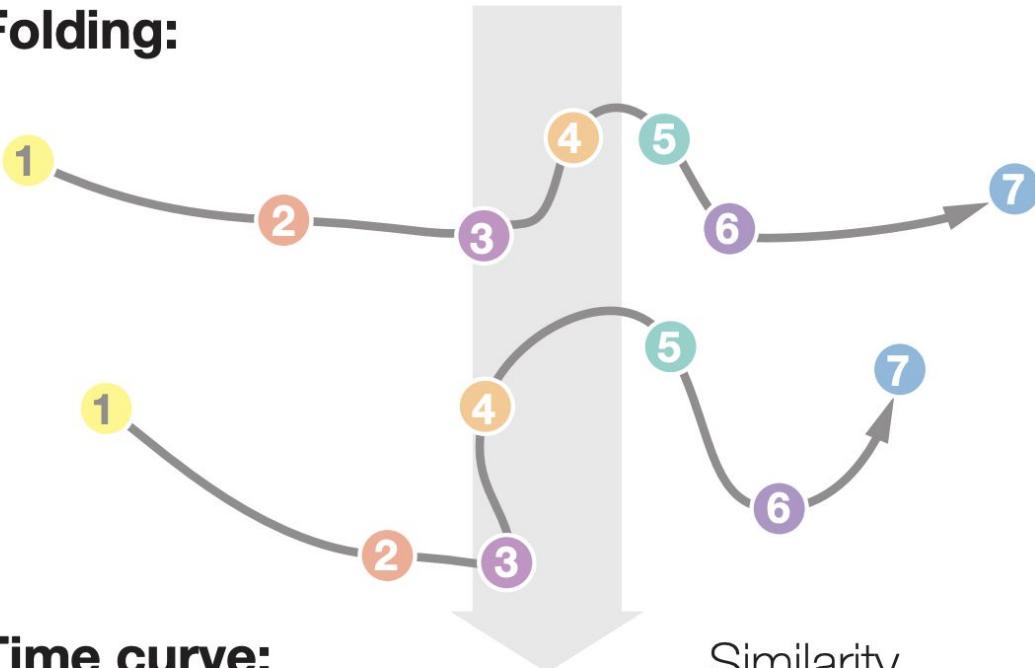
Time Curves Creation

Timeline:

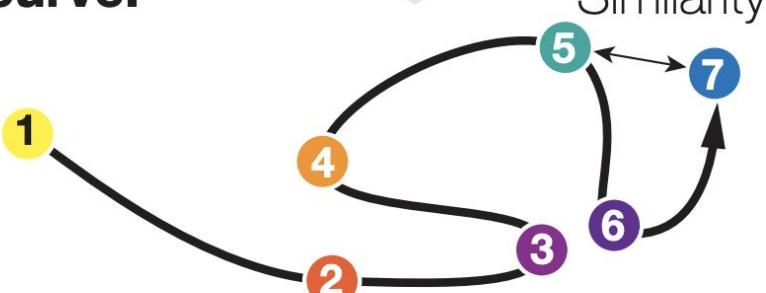


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Similar colors indicate similar data cases.

Folding:

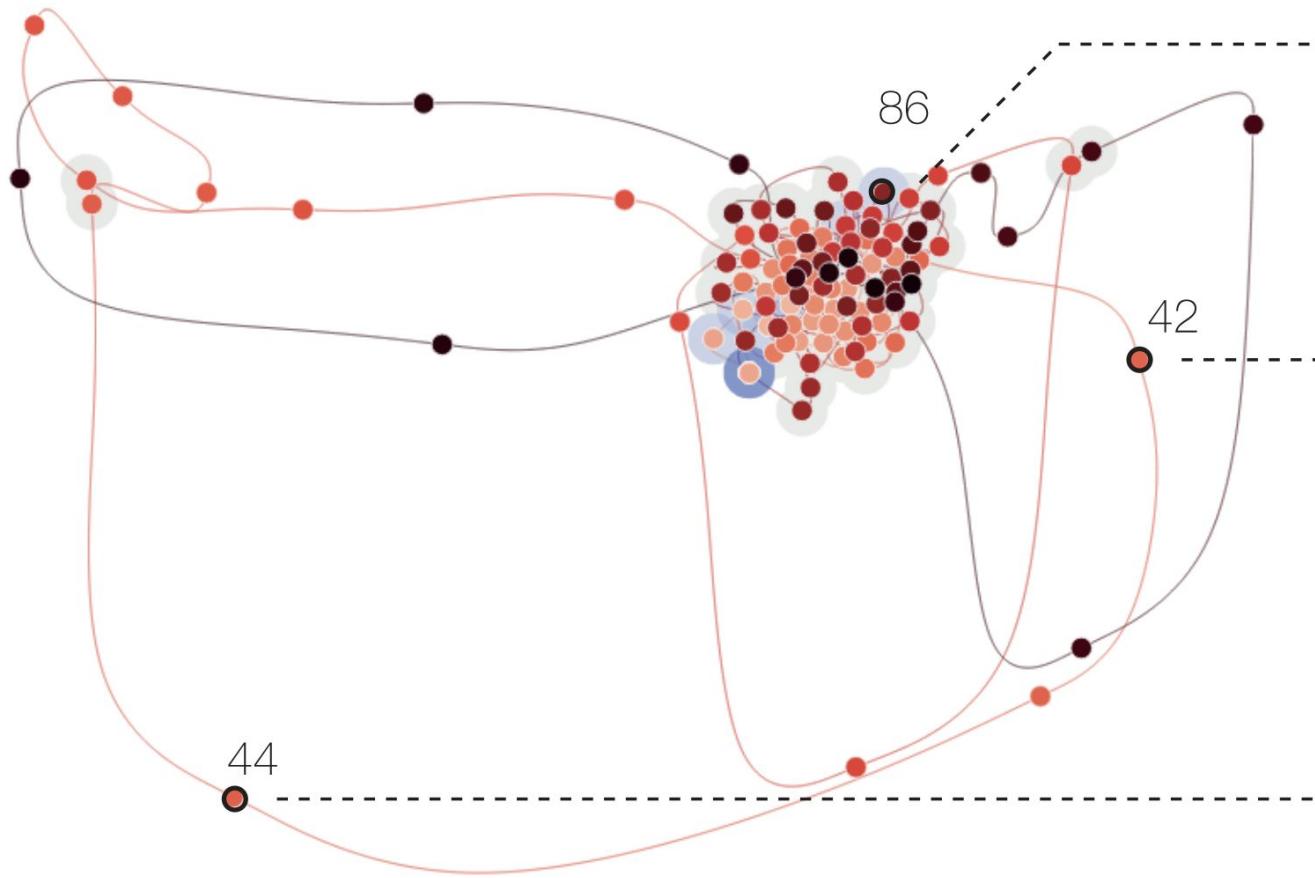


Time curve:



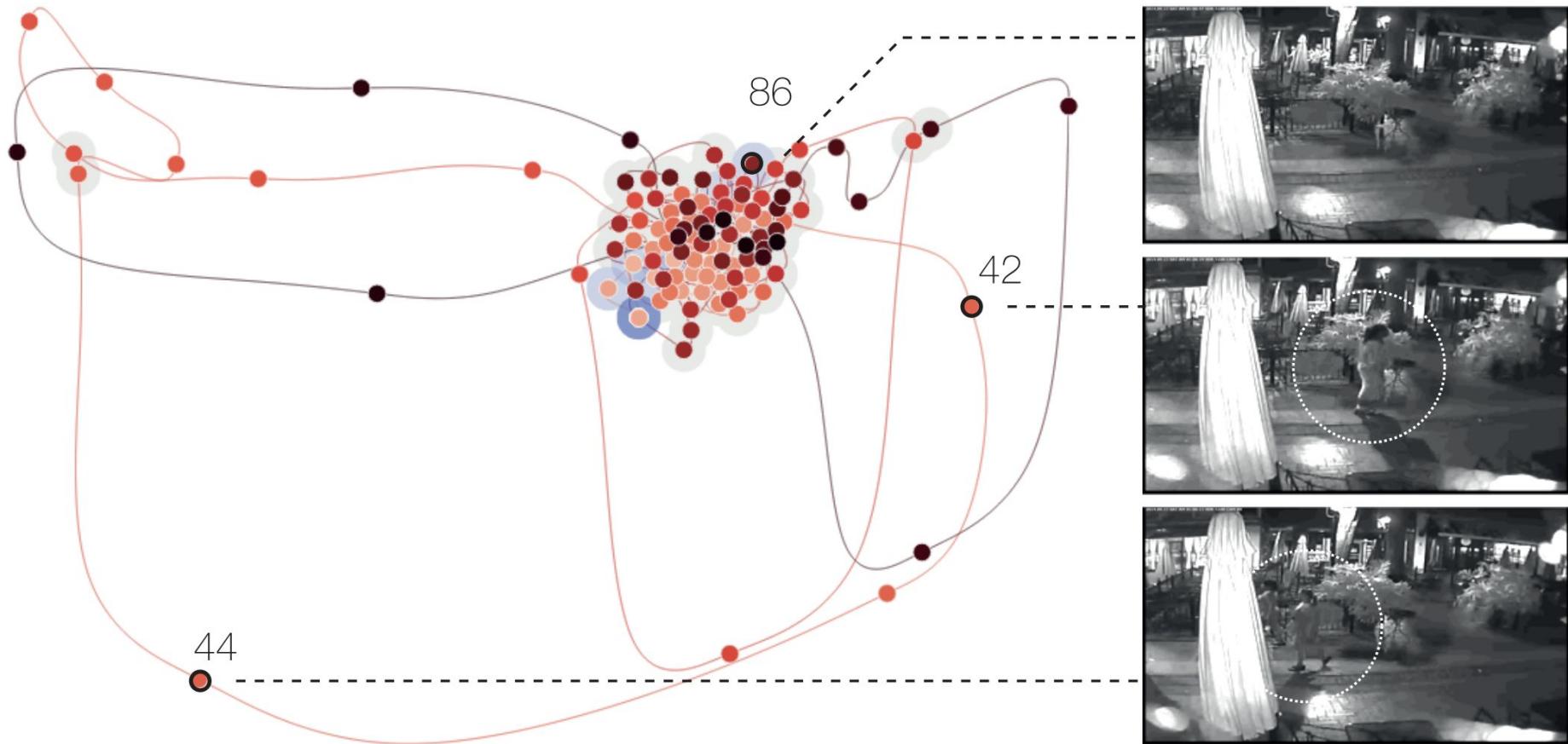
The temporal ordering of data cases is preserved.
Spatial proximity now indicates similarity.

Time Curves



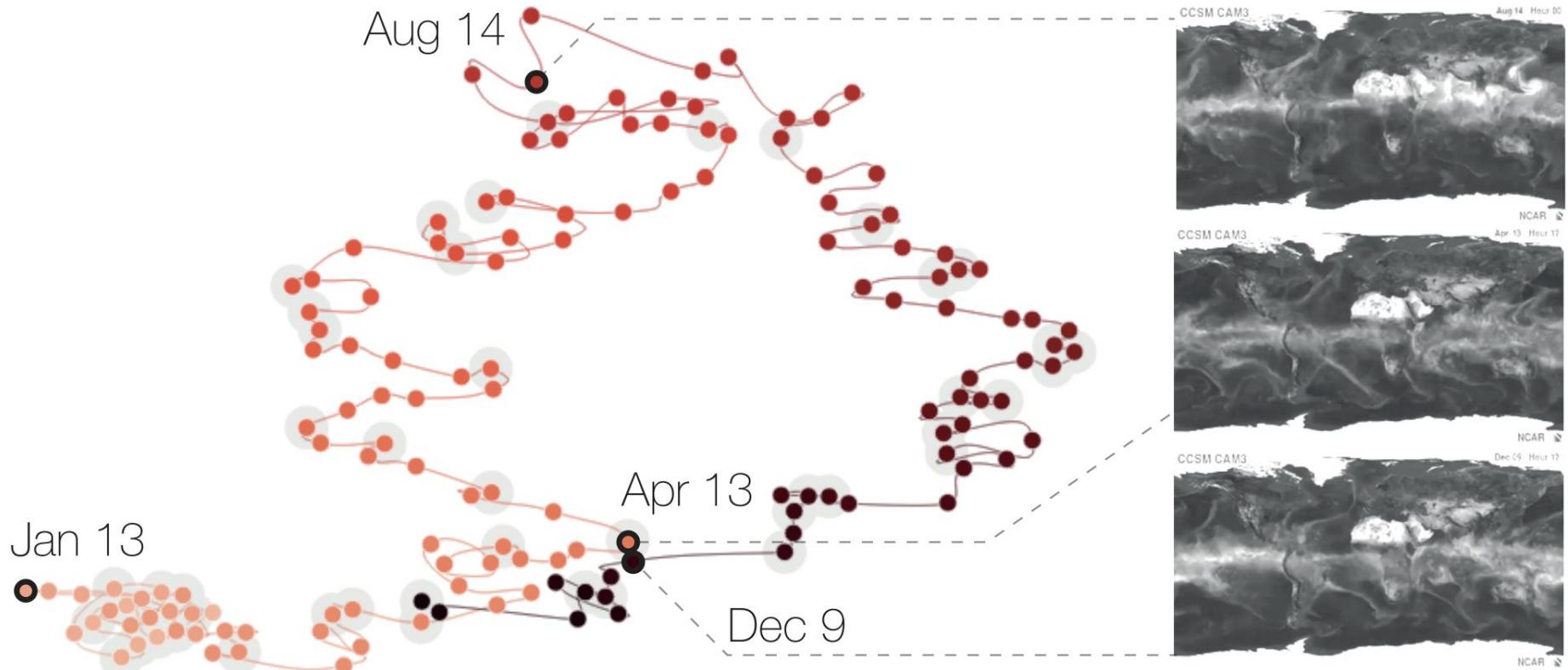
Bach, Benjamin, et al. "Time curves: Folding time to visualize patterns of temporal evolution in data." *IEEE transactions on visualization and computer graphics* 22.1 (2016).

Time Curves

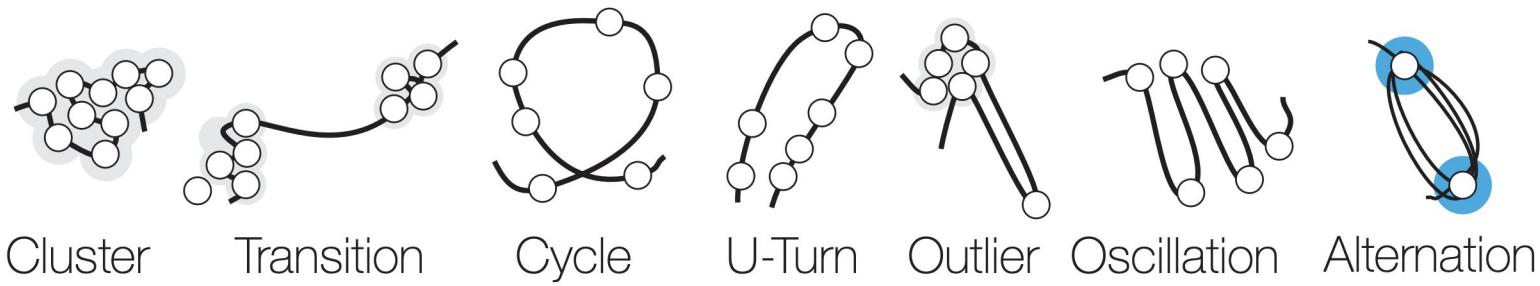


Bach, Benjamin, et al. "Time curves: Folding time to visualize patterns of temporal evolution in data." *IEEE transactions on visualization and computer graphics* 22.1 (2016).

Time Curves: Climate



Time Curves: Visual Patterns



Time Curves

- + Amount of change
- + Signatures
- + Comparison
- Details
- Artifacts due to projection
- Non-trivial



Money

Time

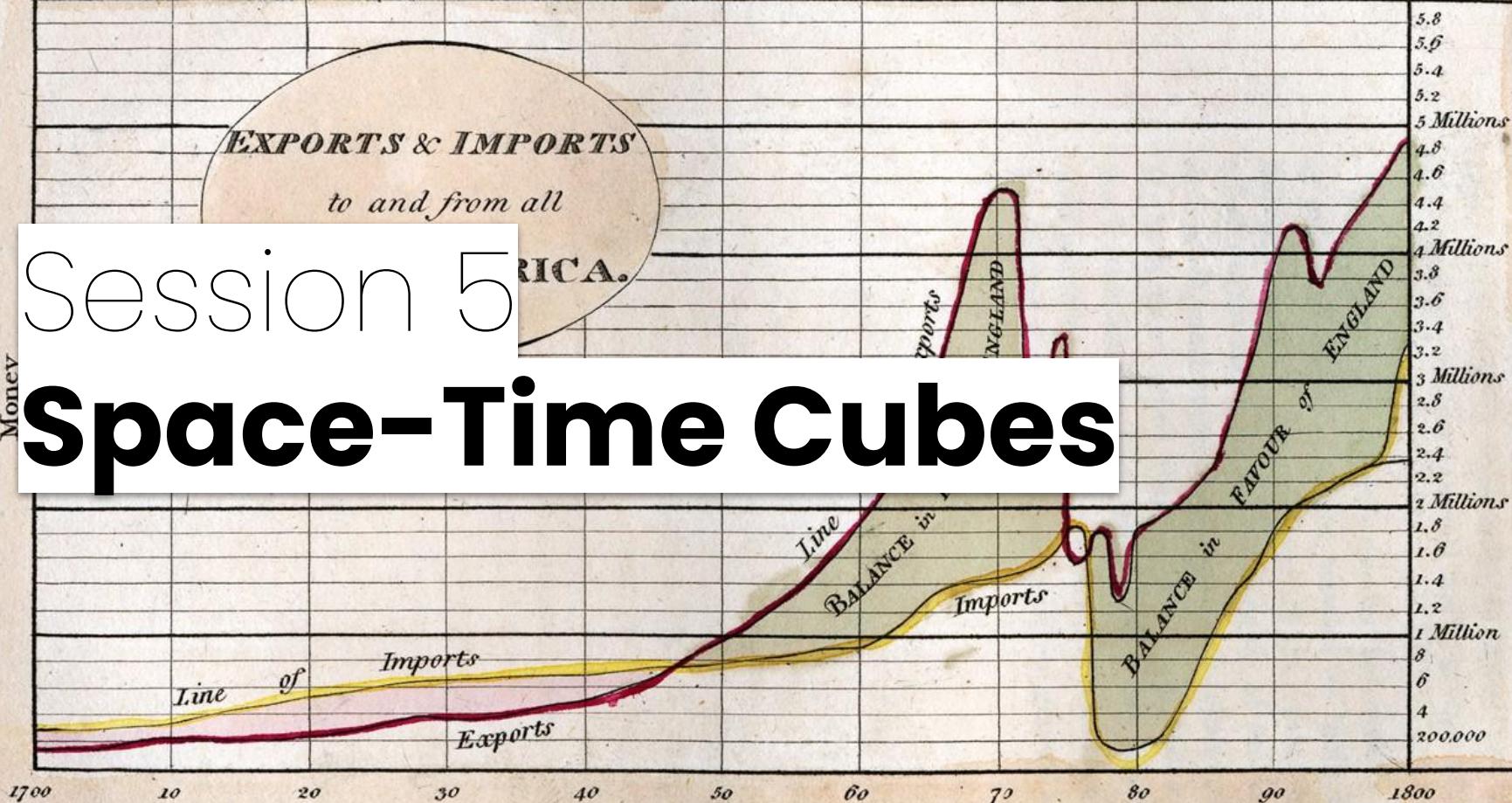
EXPORTS & IMPORTS

to and from all

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Session 5

Space-Time Cubes



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Trajectories

Carte Figurative des pertes successives en hommes de l'Armée Française dans la Campagne de Russie 1812-1813.

Dessiné par M. Minard, Inspecteur Général des Ponts et Chaussées et extrait

Paris, le 20 Novembre 1869

Les nombres d'hommes perdus sont représentés par les largesses des zones colorées à raison d'un millimètre pour dix mille hommes; ils sont de plus écrits en lettres sur ces zones. Le rouge désigne les hommes qui entrent en Russie, le noir ceux qui en sortent. — Les renseignements qui ont servi à dresser la carte ont été pris dans les ouvrages de M. Chabot, de Liger, de Tocordat, de Chambray et le journal intime de Jacob, pharmacien de l'Armée depuis le 28 Octobre.

Pour mieux faire juger à l'œil la diminution de l'armée, j'ai supposé que les corps de l'Armée l'entraient du Marché Dovrolé qui avaient été détachés sur Moscou au Nihilov et rentrèrent vers Orelia au Wilek, auquel toujours marcha avec l'armée.

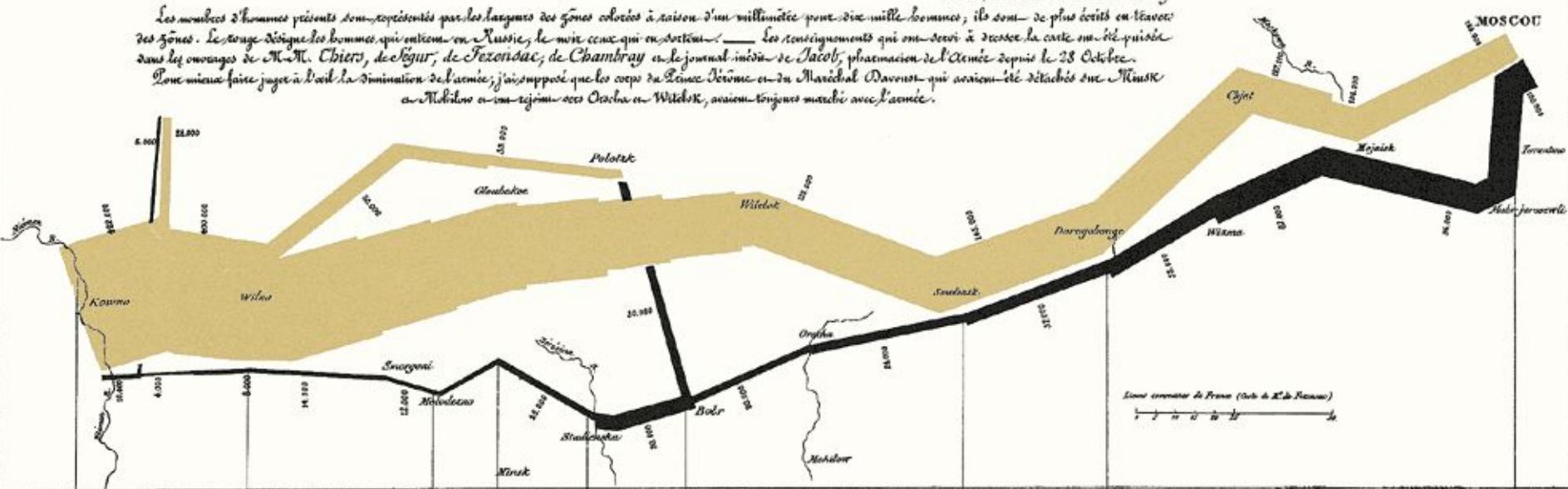


TABLEAU GRAPHIQUE de la température en degrés du thermomètre de Réaumur au dessous de zéro.

Les Cosaques passent au galop le Nilman, gelé.

- 16° le 2 X.^{me}

- 30° le 6 X.^{me}

- 24° le 1^{er} X.^{me}

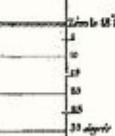
- 20° le 28 9.^{me}

- 11°

- 21° le 14 0.^{me}

- 8° le 9 9.^{me}

Fin 24 8.^{me}



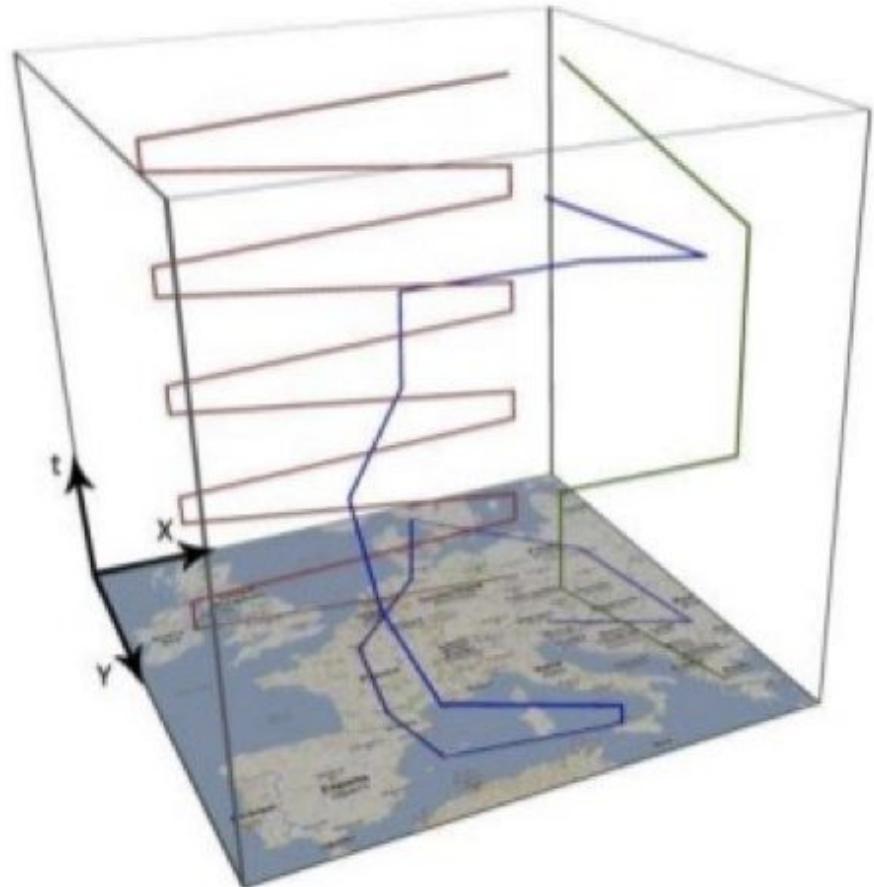
Imp. J. Rappo et Cie.

Charles Joseph Minard (1781-1870)

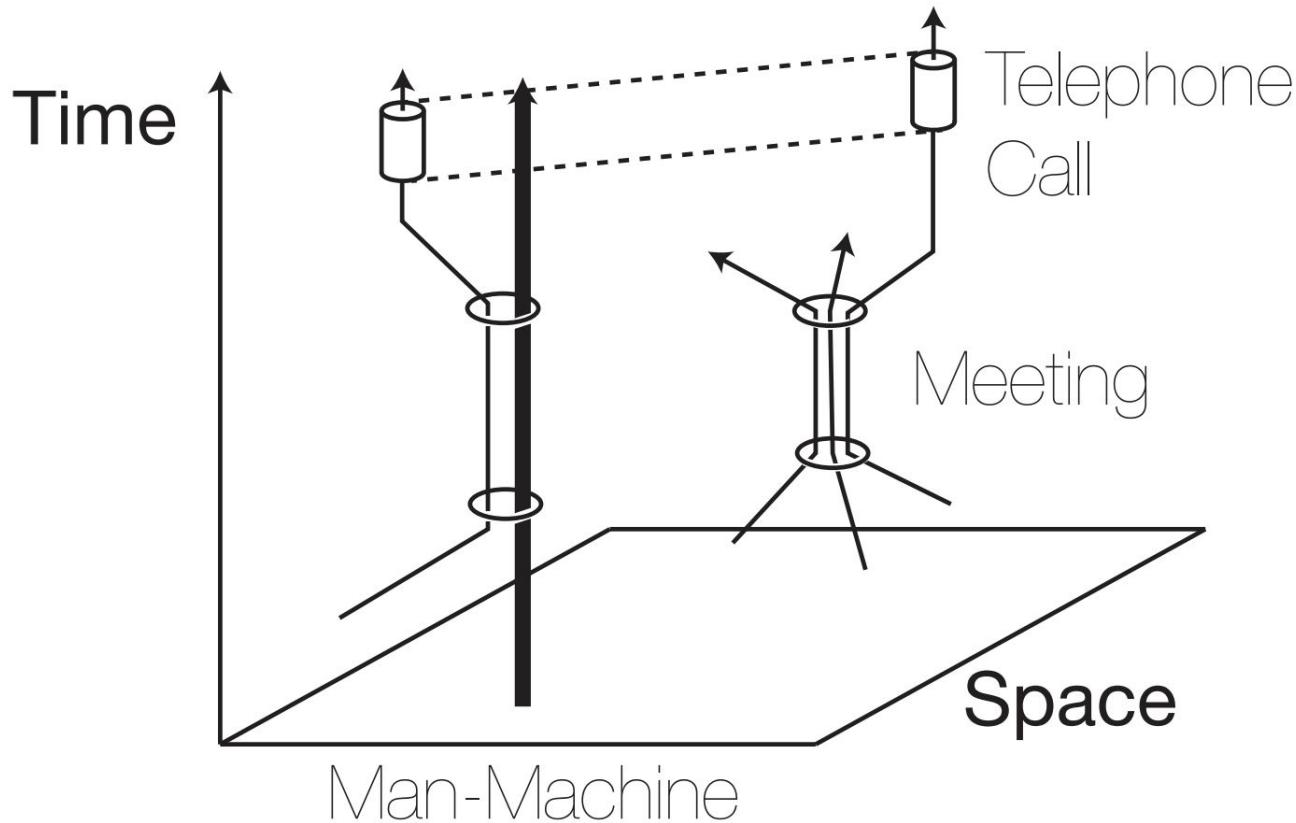
Space-Time Cubes



Space-Time Cubes



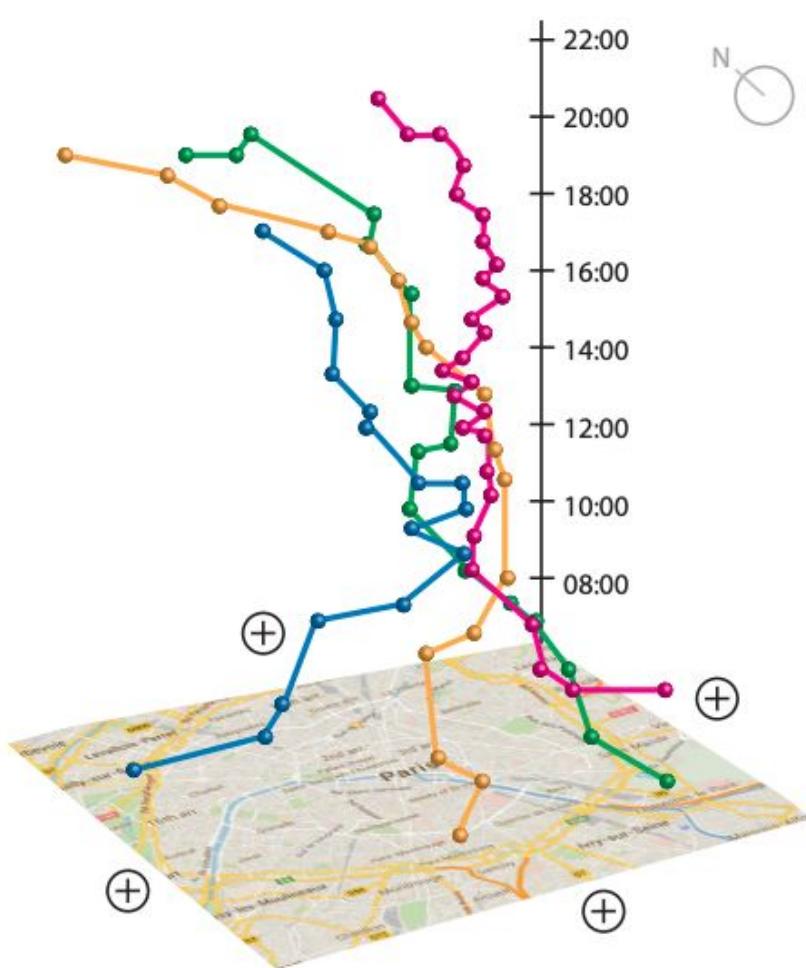
Space-Time Cubes



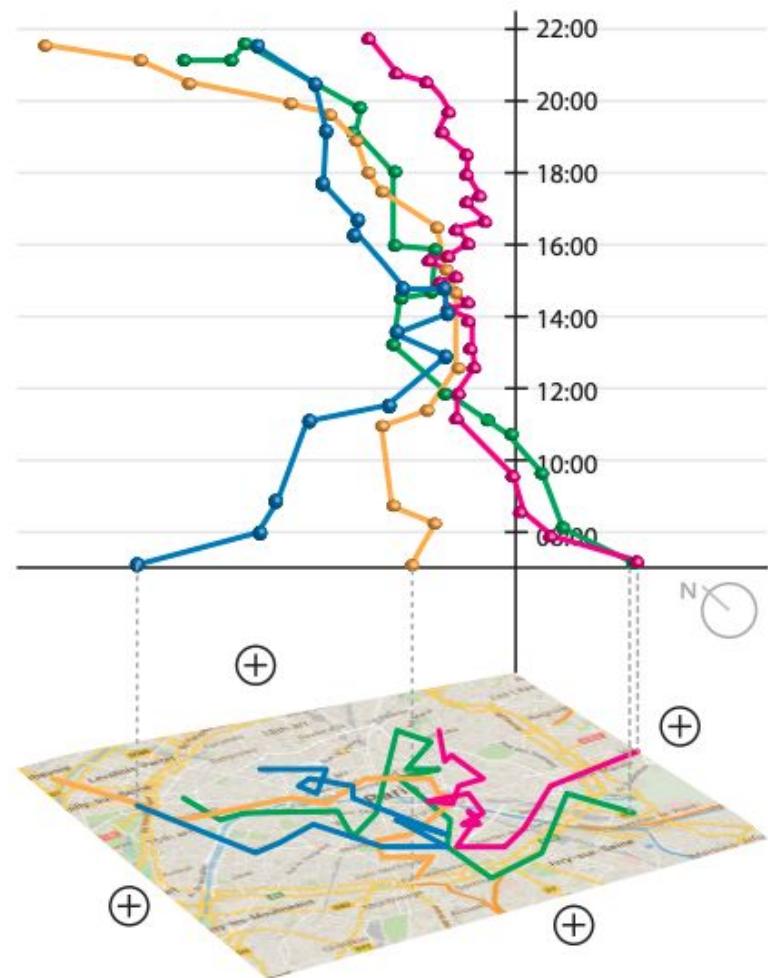
Ilägrstrand, Torsten. "What about people in regional science?." *Papers of the Regional Science Association*. Vol. 24. 1970.

Kraak, Menno-Jan. "The space-time cube revisited from a geovisualization perspective." *Proc. 21st International Cartographic Conference*. Citeseer, 2003.

Space-Time Cubes

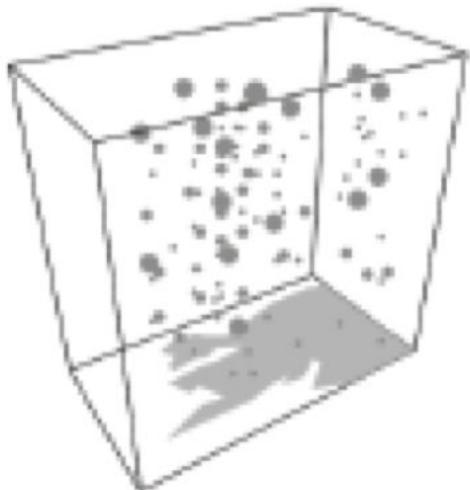


(a) 3D rendering

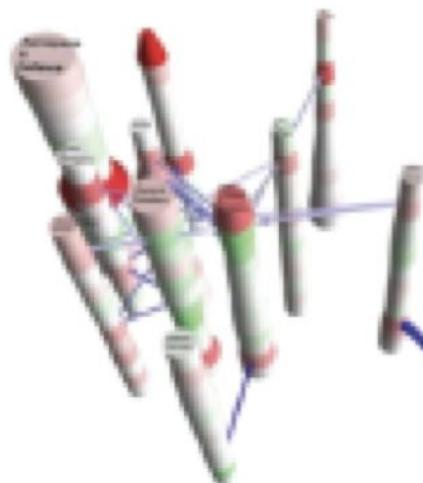


(b) Space flattening (on top)

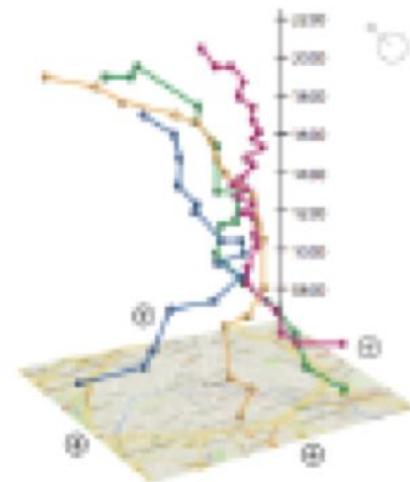
Space time cubes everywhere!



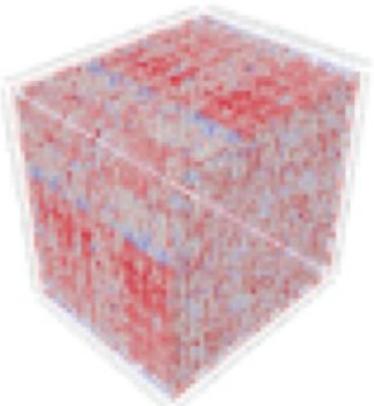
Earthquakes



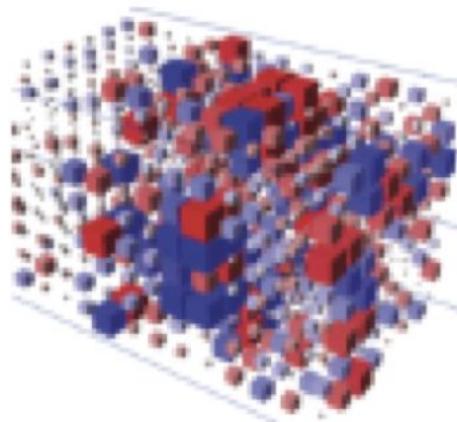
Finance network



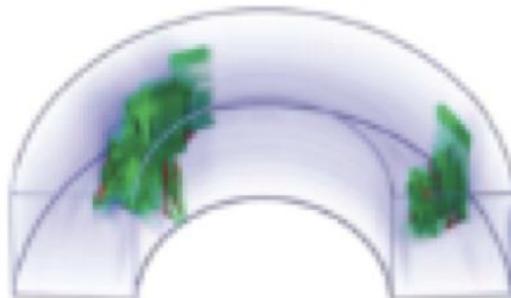
Person movement



Antenna
communication



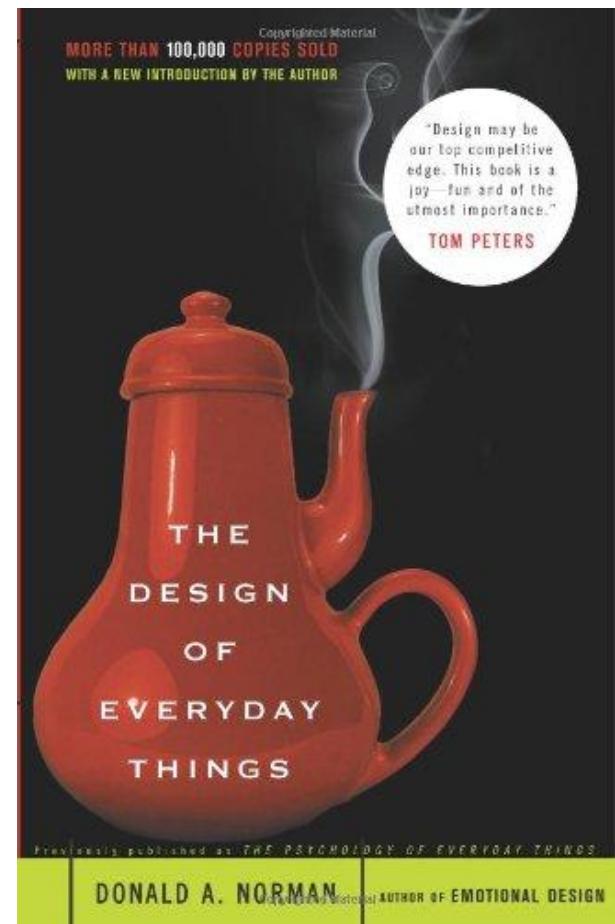
Brain connectivity



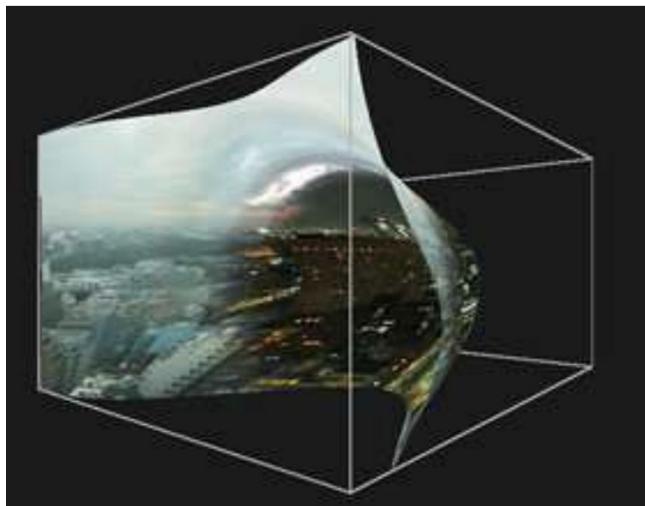
Surveillance video

A word on 3D visualization

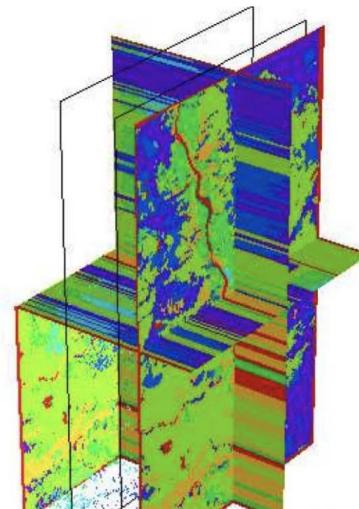
- Causes occlusion
 - Perspective distortion
 - Interaction required
 - Orientation might be tricky
-
- Use 3D as *interaction affordances*
 - Use 3D as *thinking tools and metaphors*



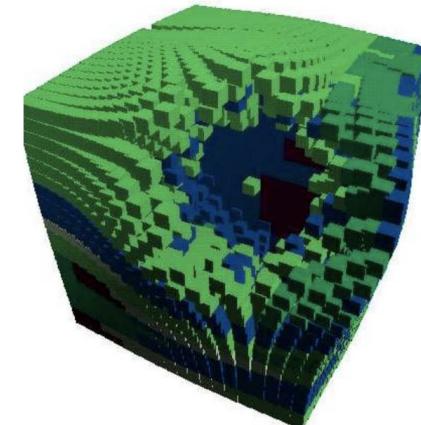
Interactive Exploration



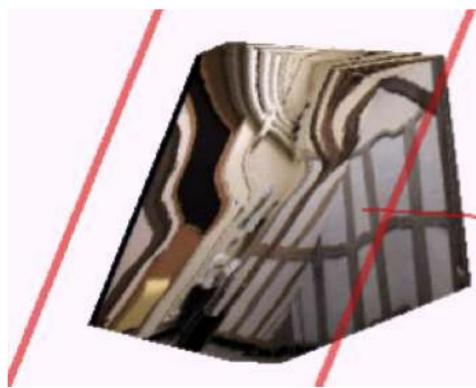
"Poke"-access



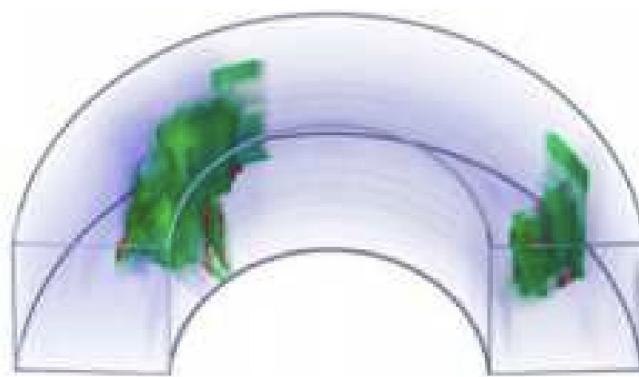
Cutting plane



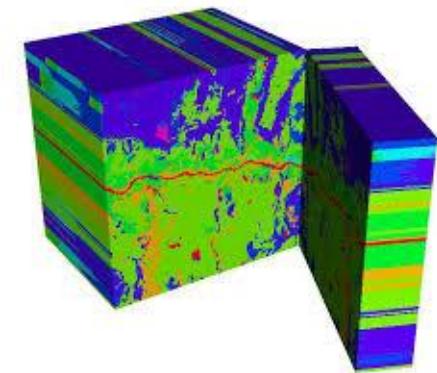
Mouse access



Cutting plane



Transparency
+ bending



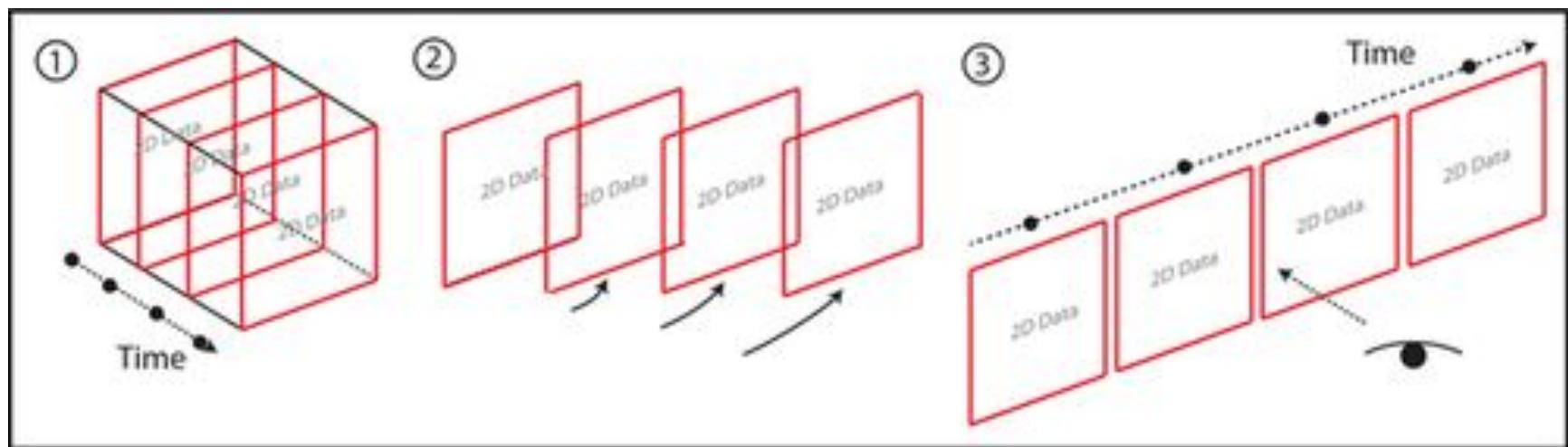
Opening

Interactive Exploration

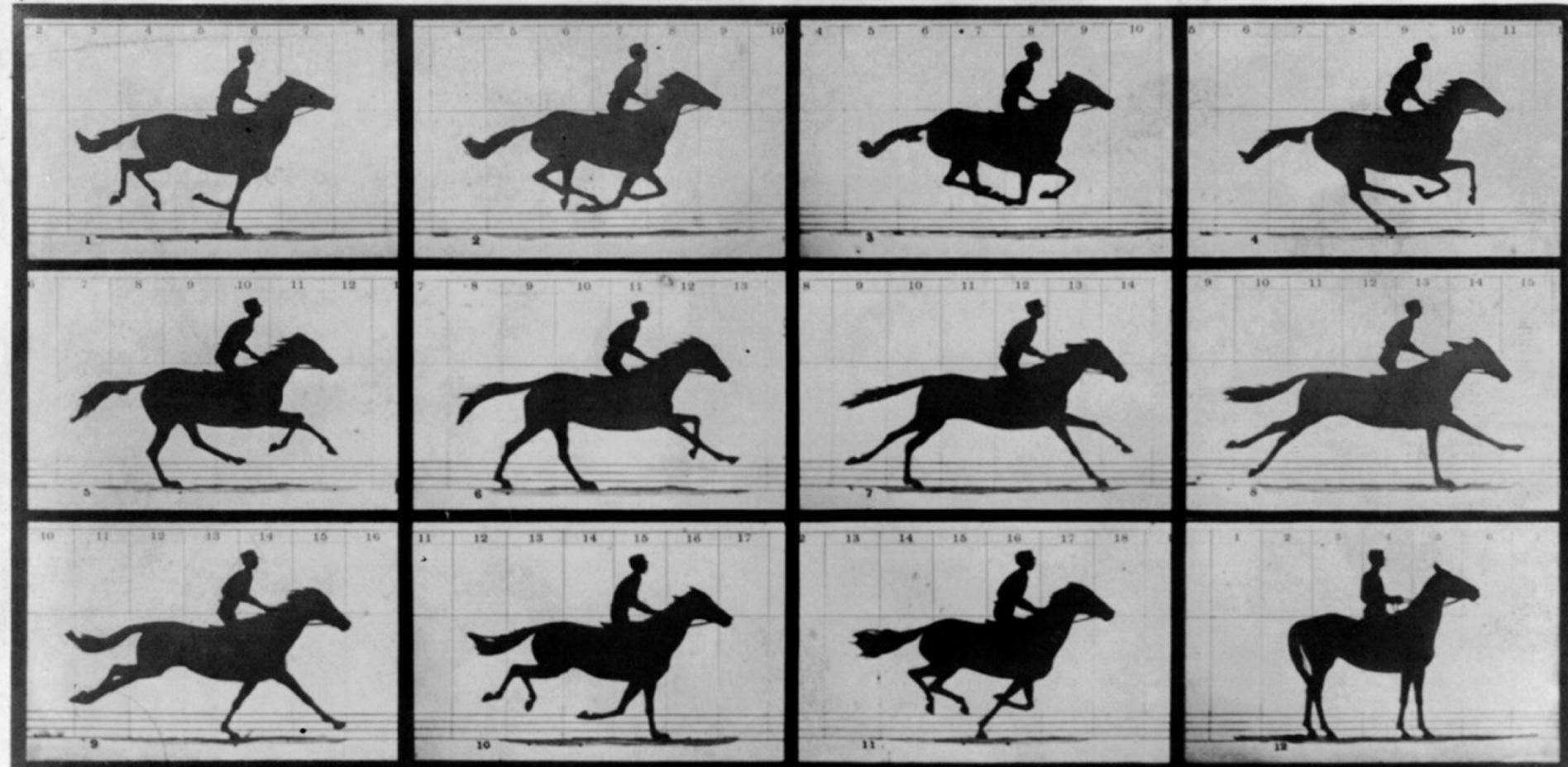


Small Time Multiples

Operations



Eadward Muybridge: Chrono photography



Copyright, 1878, by MUYBRIDGE.

MORSE'S Gallery, 417 Montgomery St., San Francisco.

THE HORSE IN MOTION.

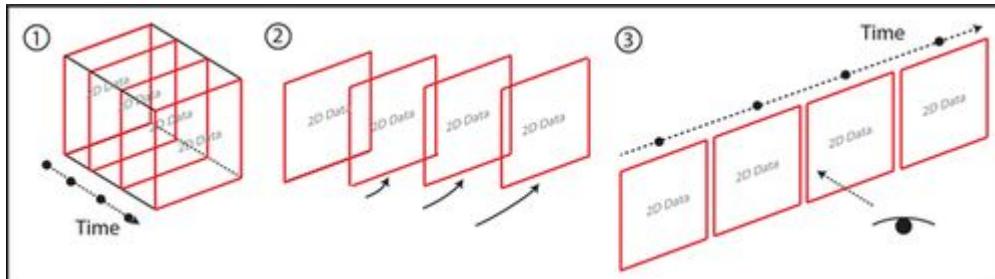
Illustrated by
MUYBRIDGE.

"SALLIE GARDNER," owned by LELAND STANFORD; running at a 1.40 gait over the Palo Alto track, 19th June, 1878.

The negatives of these photographs were made at intervals of twenty-seven inches of distance, and about the twenty-fifth part of a second of time; they illustrate consecutive positions assumed in each twenty-seven inches of progress during a single stride of the mare. The vertical lines were twenty-seven inches apart; the horizontal lines represent elevations of four inches each. The exposure of each negative was less than the two-thousandth part of a second.

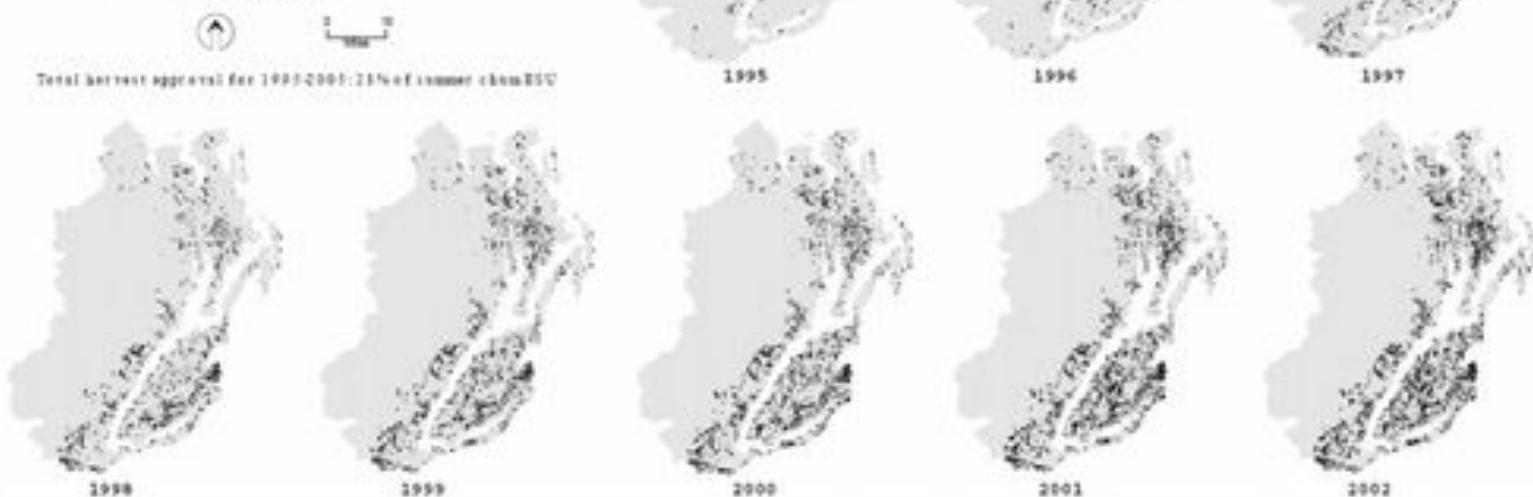
AUTOMATIC ELECTRO-PHOTOGRAPHIC

Small Multiples

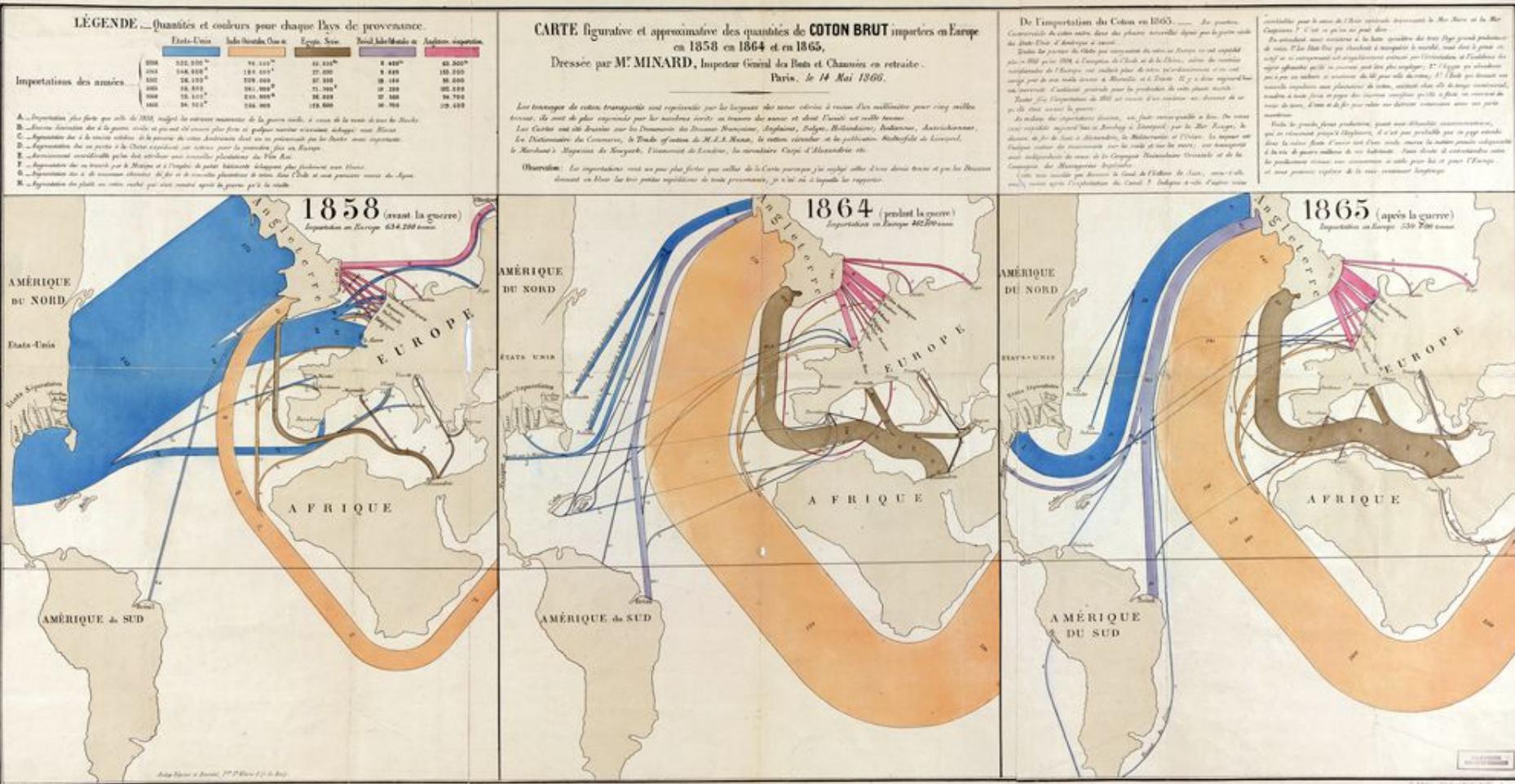


Approved Harvest Applications By Year

Location: Head Coast timber claim EUC
Shows: Approved forest practice applications (FPA)
of type cutting or removing timber
and
Harvests in Olympic National Forest
Sources: Washington Dept. Natural Resources
U.S. Forest Service, Quill Creek
Dates: FPA approvals as renewal date
ONF harvest date

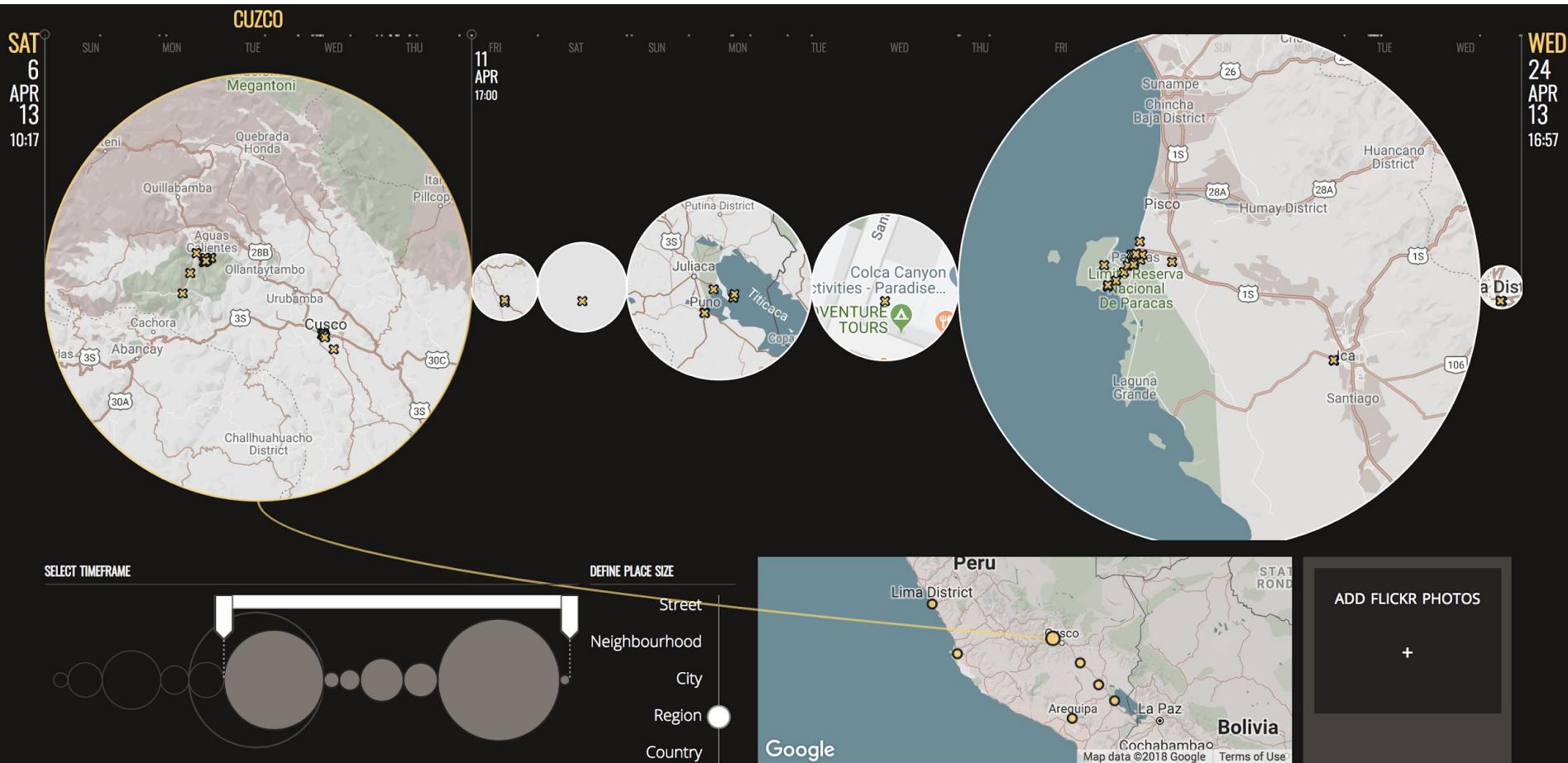


Flow Diagram Small Multiples



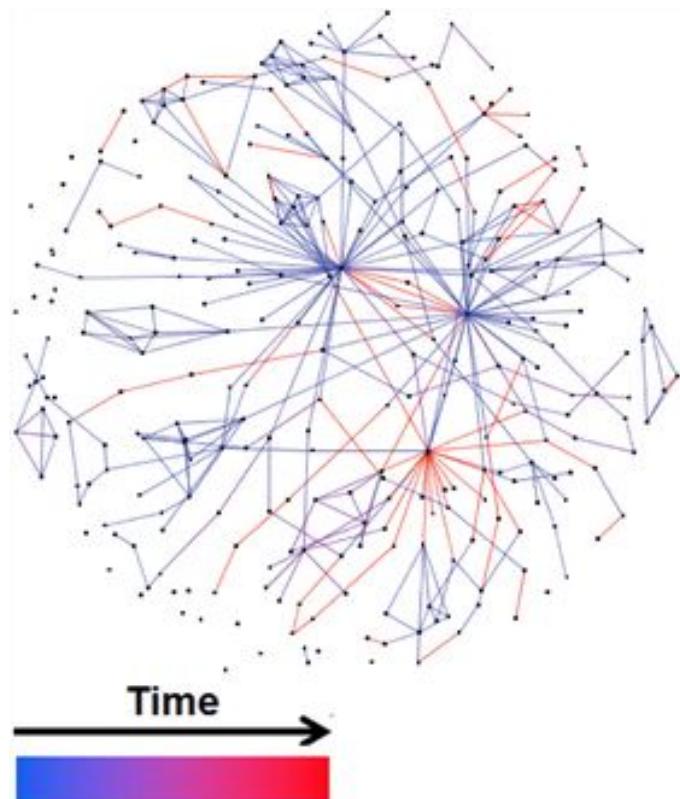
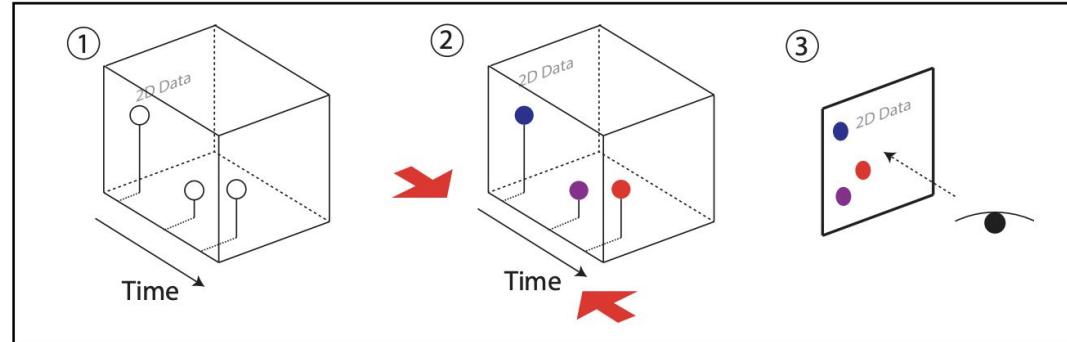
Joseph Minard

Small Multiples



Thudt, Alice, Dominikus Baur, and Sheelagh Carpendale. "Visits: A Spatiotemporal Visualization of Location Histories." *EuroVis (Short Papers)*. 2013.

Coloring + Flattening

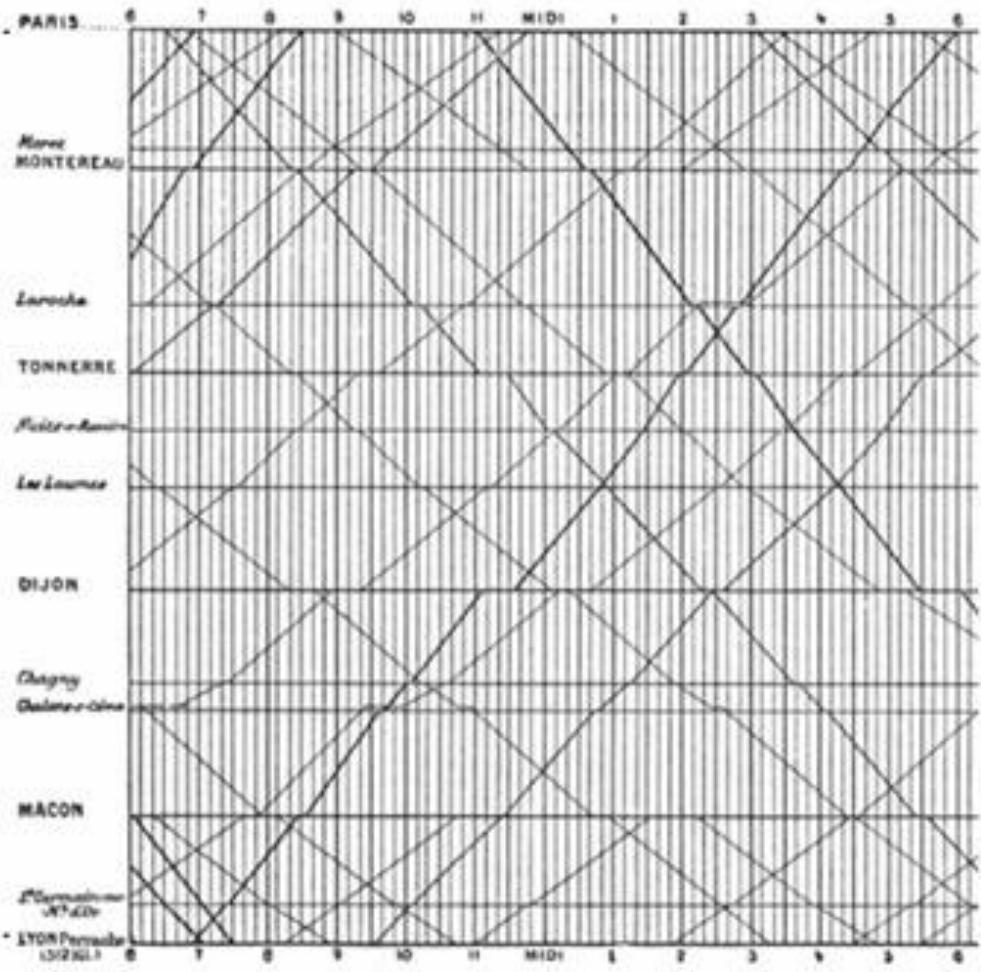
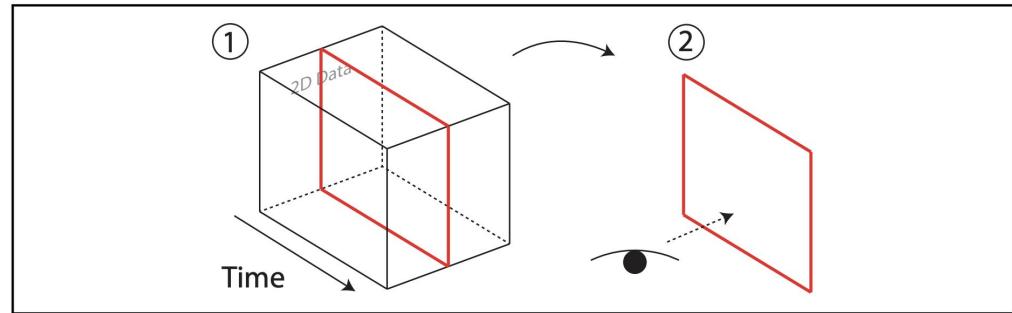


(a)

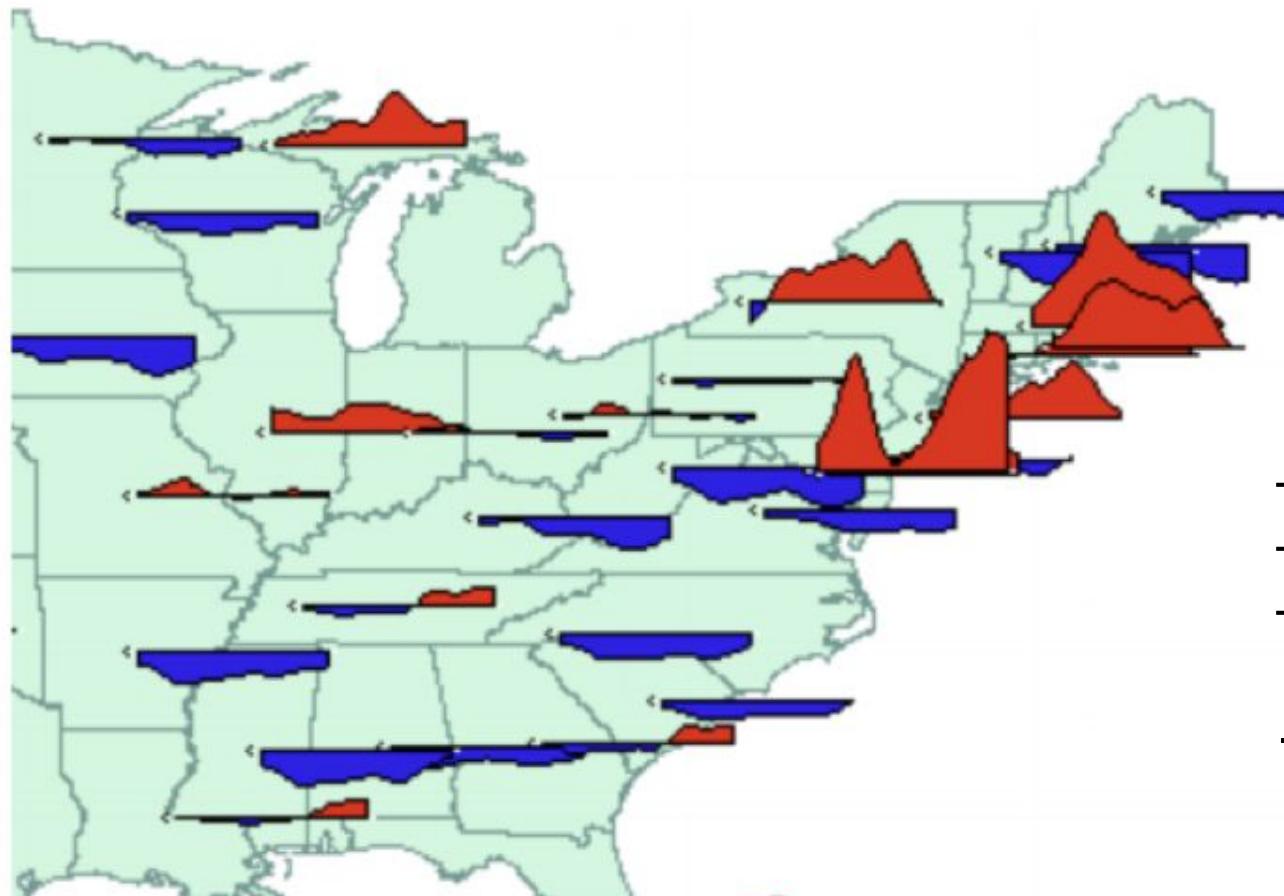
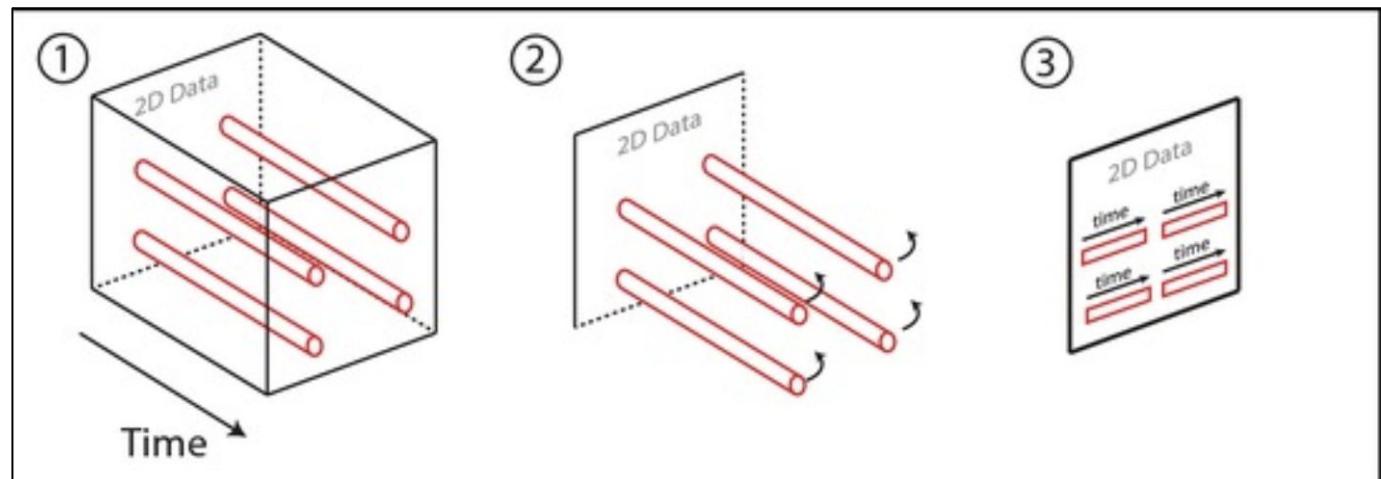


(b)

Cross-cutting

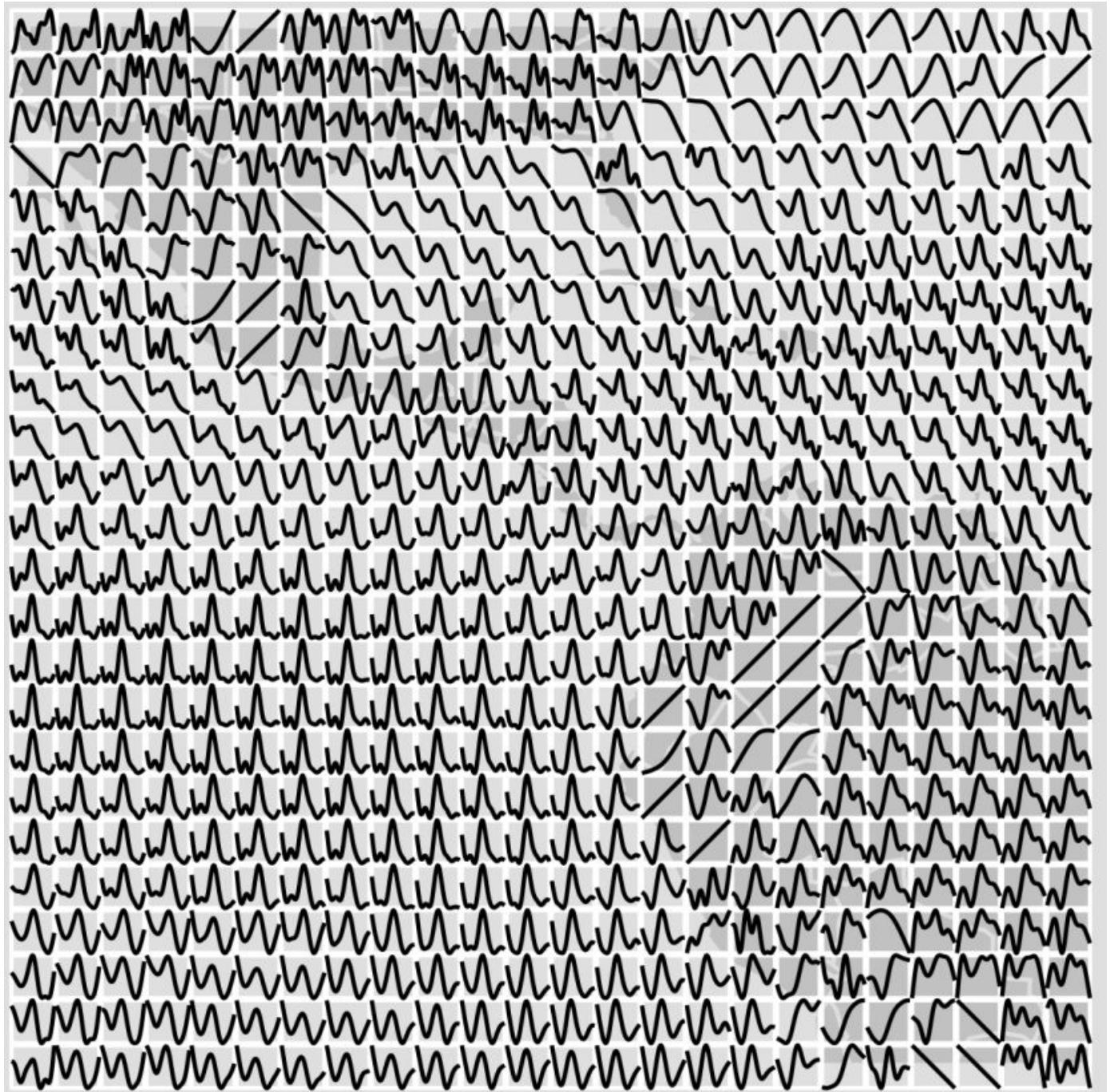


"Drilling"



- + Compare regions
- + Look-up regions
- + Details on regions
- Occlusion

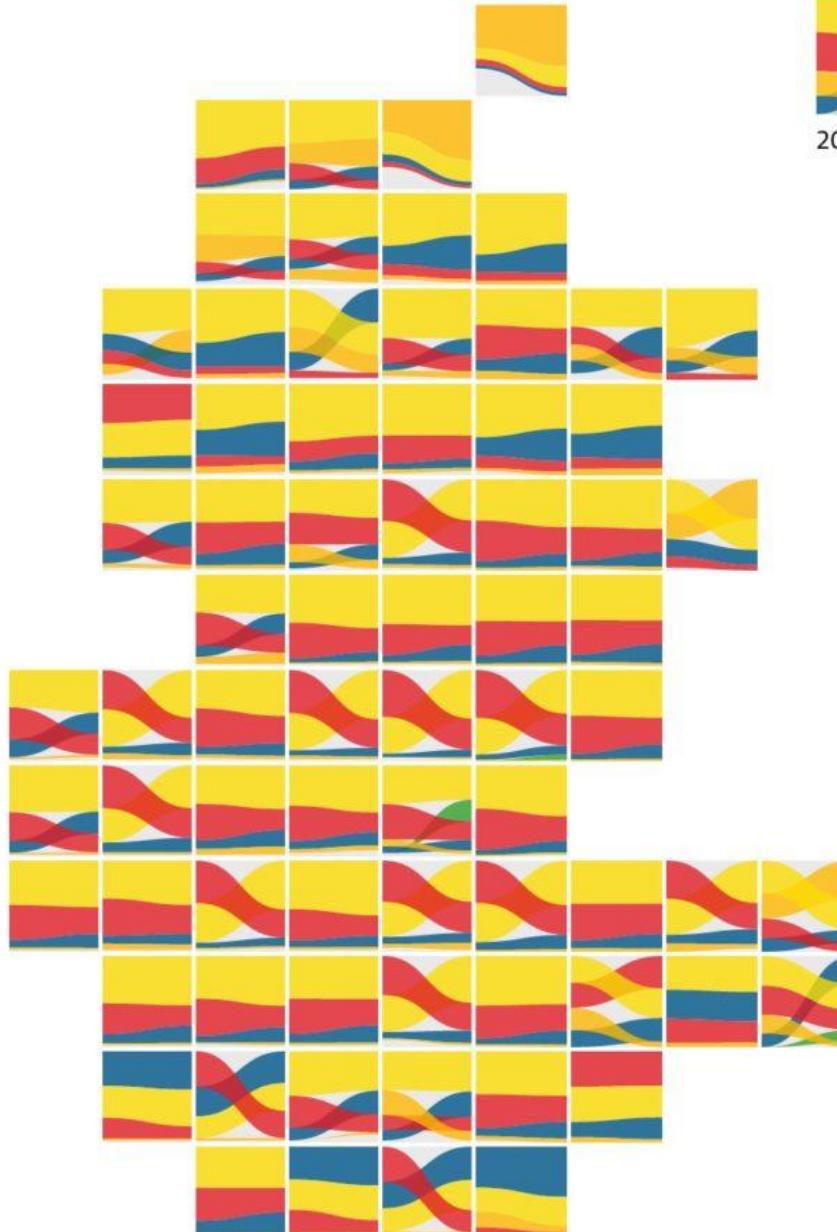
Drilling: Glyph Maps



<https://vita.had.co.nz/papers/glyph-maps.pdf>

How Scotland's political geography changed, seat by seat

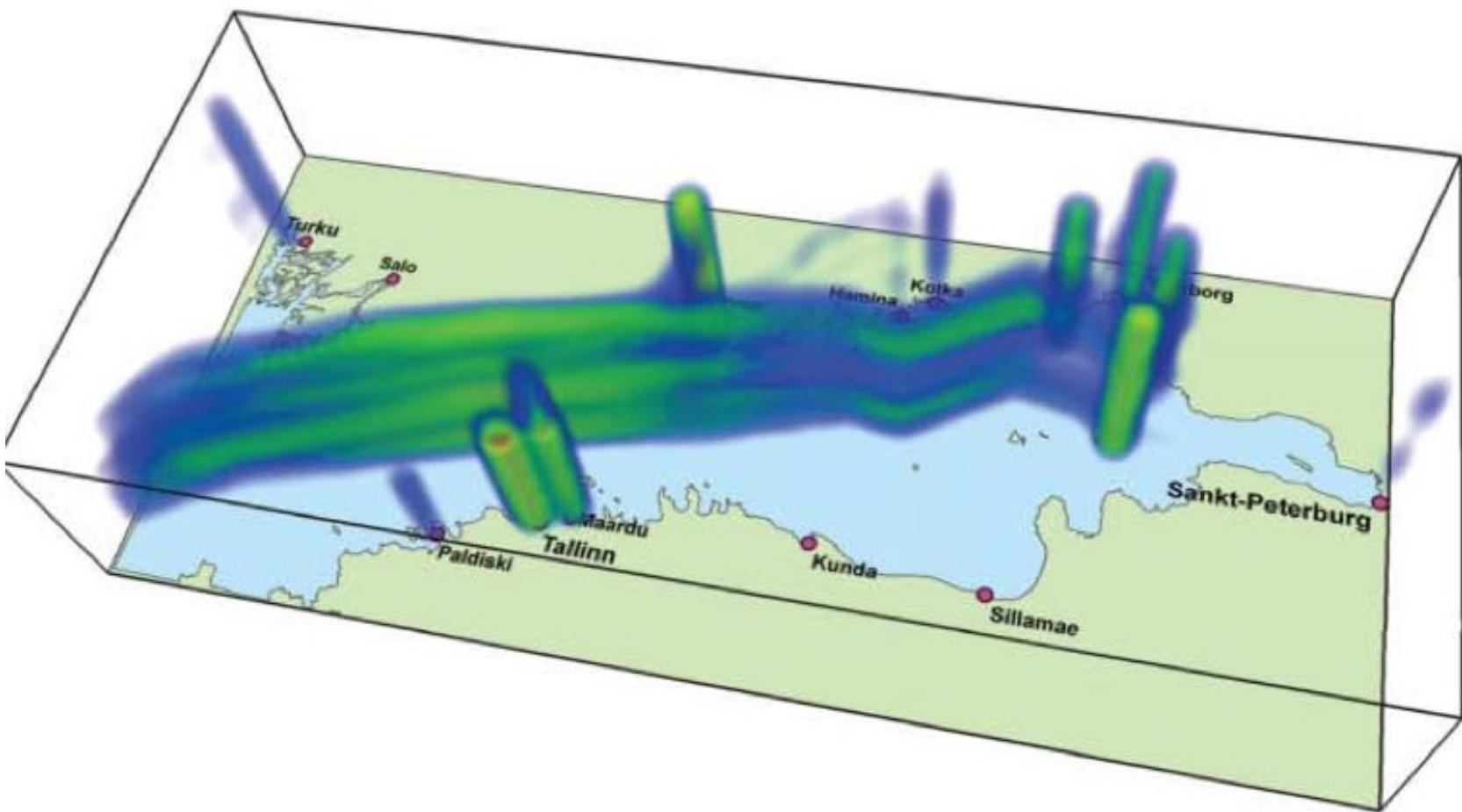
Drilling: Geo-flow



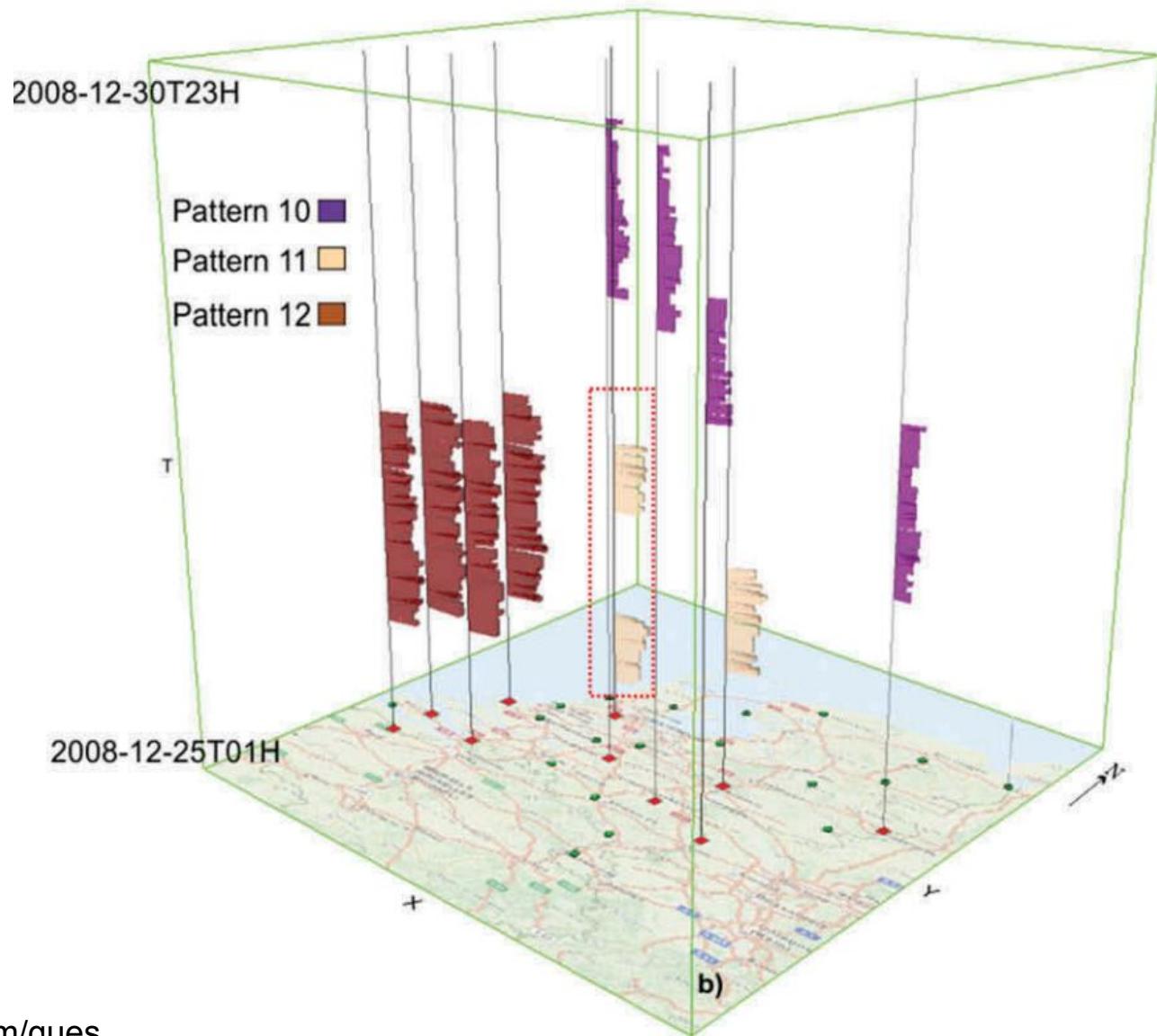
- + Compare regions
- + Look-up regions
- + Details on regions

- Compare far away glyphs
- Glyphs can become small

3D Renderings: density maps

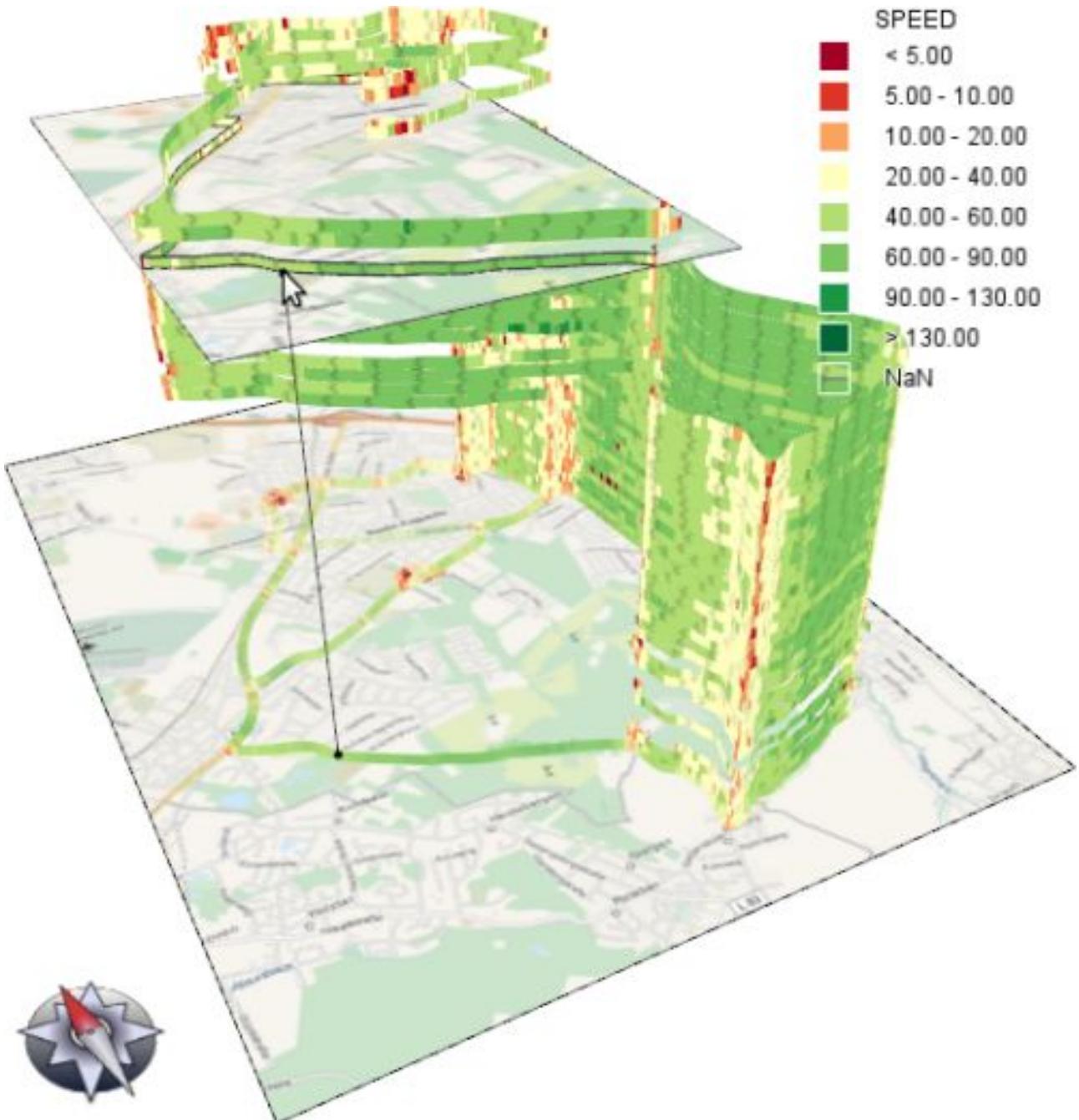


3D + drilling



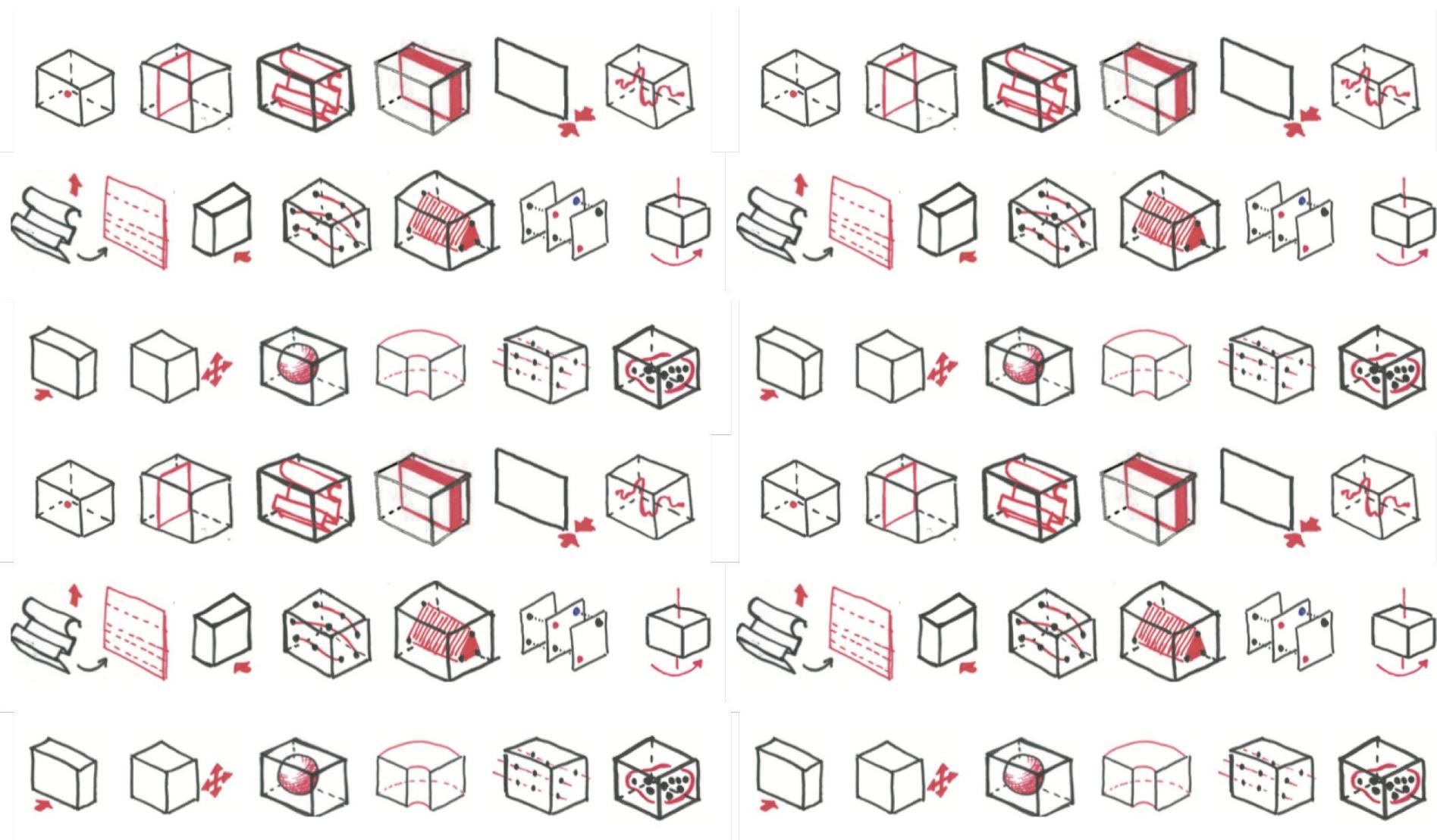
<https://gis.stackexchange.com/questions/202882/create-space-time-cube-in-arcgis-for-desktop>

Trajectory Wall



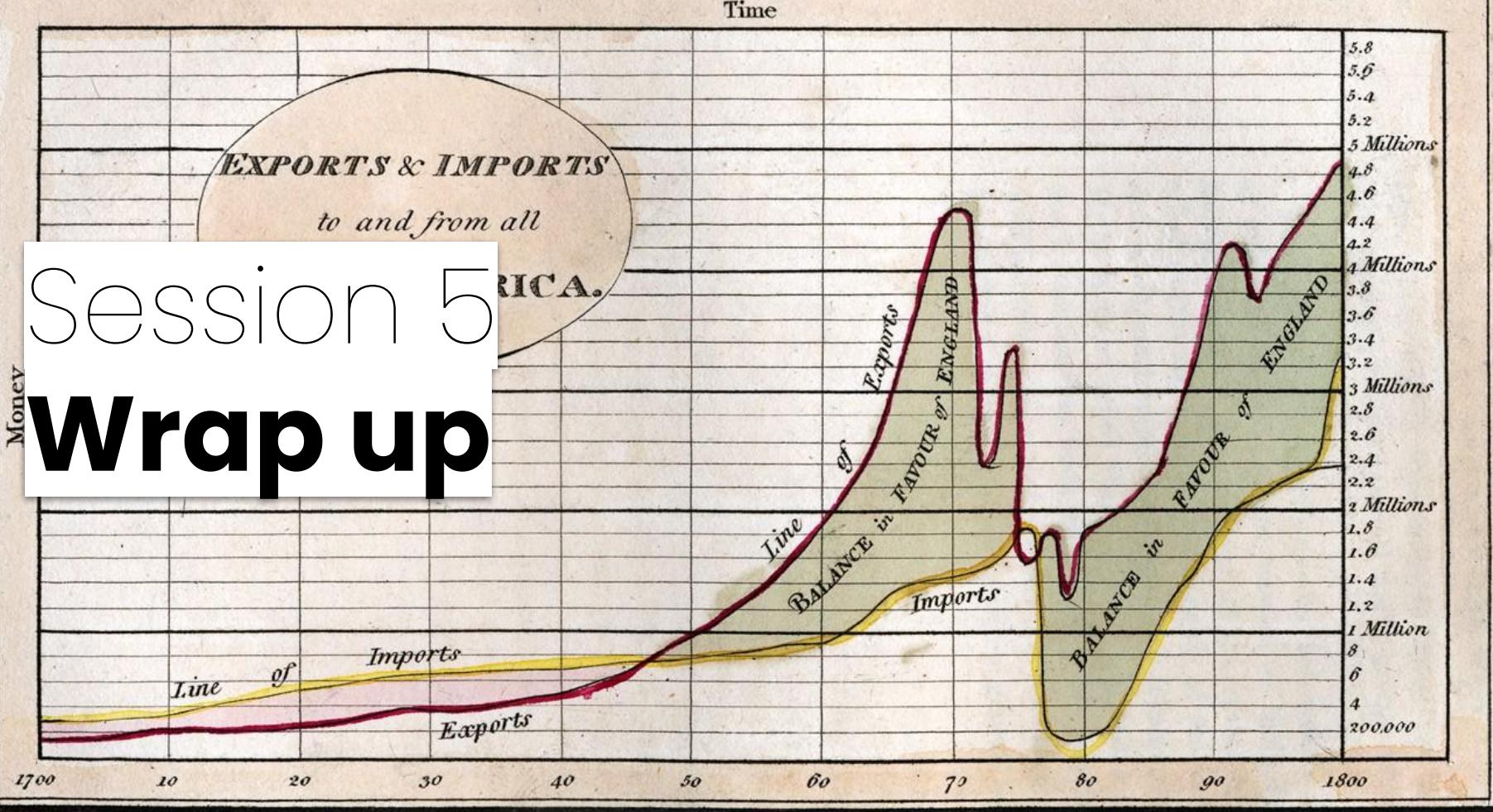
Andrienko, G., Andrienko, N., Schumann, H., & Tominski, C. (2014). Visualization of trajectory attributes in space–time cube and trajectory wall. In *Cartography from Pole to Pole* (pp. 157-163). Springer, Berlin, Heidelberg.

More operations



Khronos Projector





Online Course
**Data Visualization
for Professionals**



THE UNIVERSITY
of EDINBURGH

Benjamin Bach

June 2022

<http://benjbach.me>
<https://datavis-online.github.io>

-- Not for external use --

Outline

How to visualize temporal data?

- Time is a complex medium
- Time in combination with other data types
- Event data: time lines
- Time series: dual-scales, cycle plots, heatmap
- Many time series: horizon graphs
- Multidimensional temporal data: connected scatterplots
- Geospatial data: space-time cubes
- Similarity data: time curves

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Further Reading

- Alberto Cairo: **The Truthful Art: Chapter 8: Revealing Change**
- Aigner, Wolfgang, et al. **Visualization of time-oriented data**. Springer Science & Business Media, 2011.
- Bach, Benjamin, et al. "**A descriptive framework for temporal data visualizations based on generalized space-time cubes.**" *Computer Graphics Forum*. Vol. 36. No. 6. 2017.
- Rosenberg, Daniel, and Anthony Grafton. **Cartographies of time: A history of the timeline**. Princeton Architectural Press, 2013.
- Brehmer, Matthew, et al. "Timelines revisited: **A design space and considerations for expressive storytelling.**" *IEEE transactions on visualization and computer graphics* 23.9 (2016): 2151-2164.

