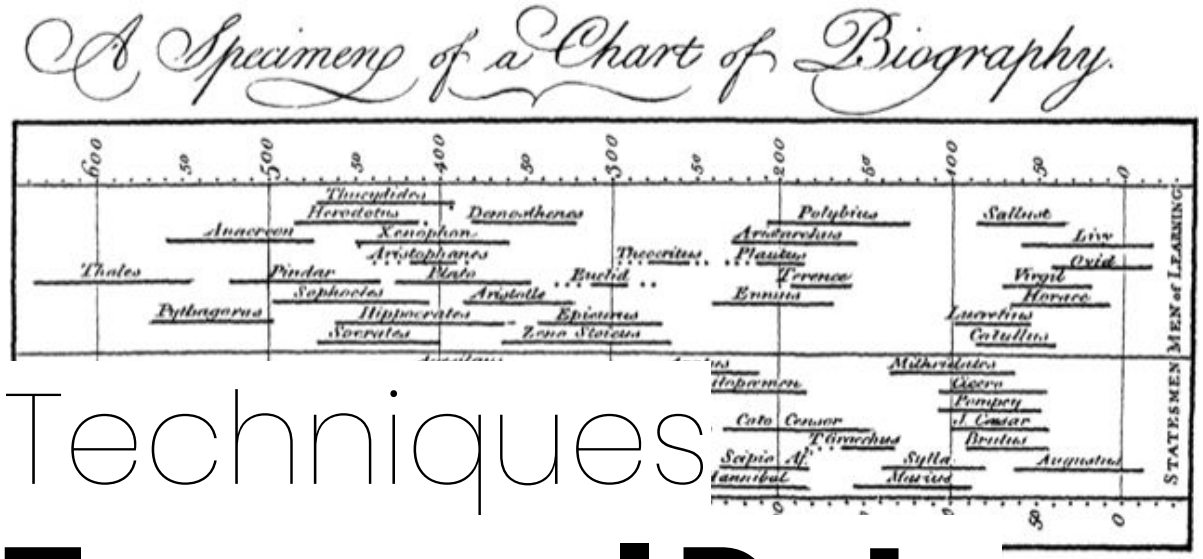
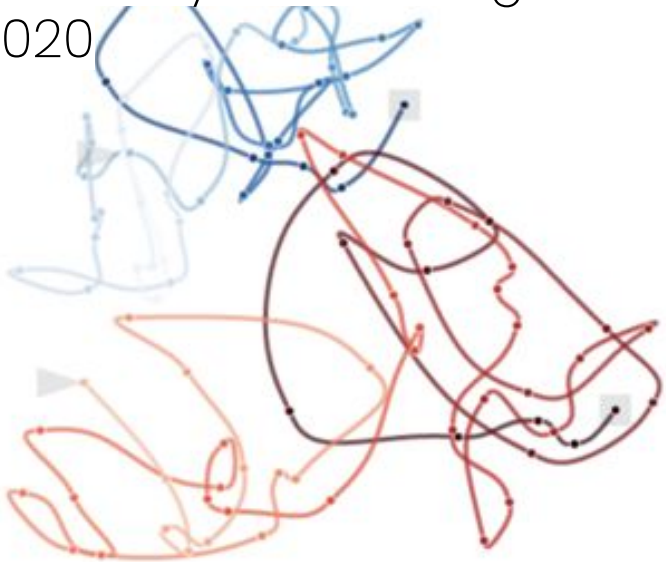
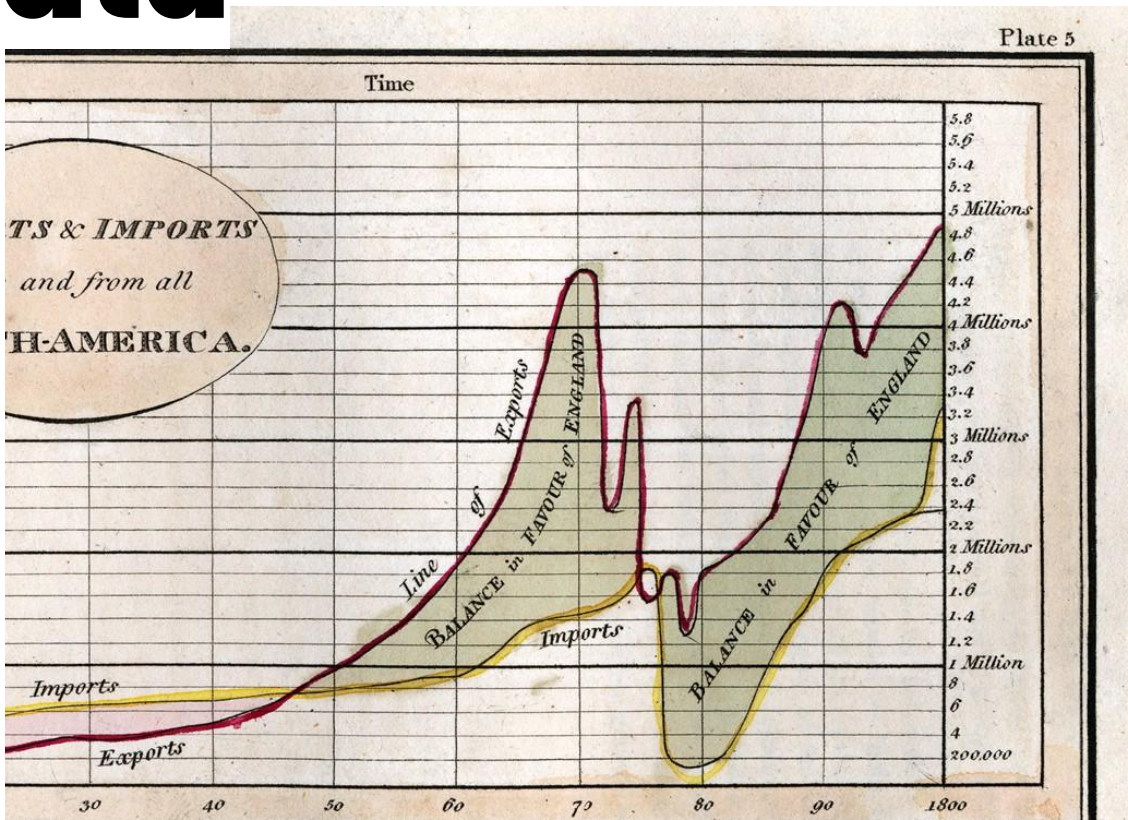
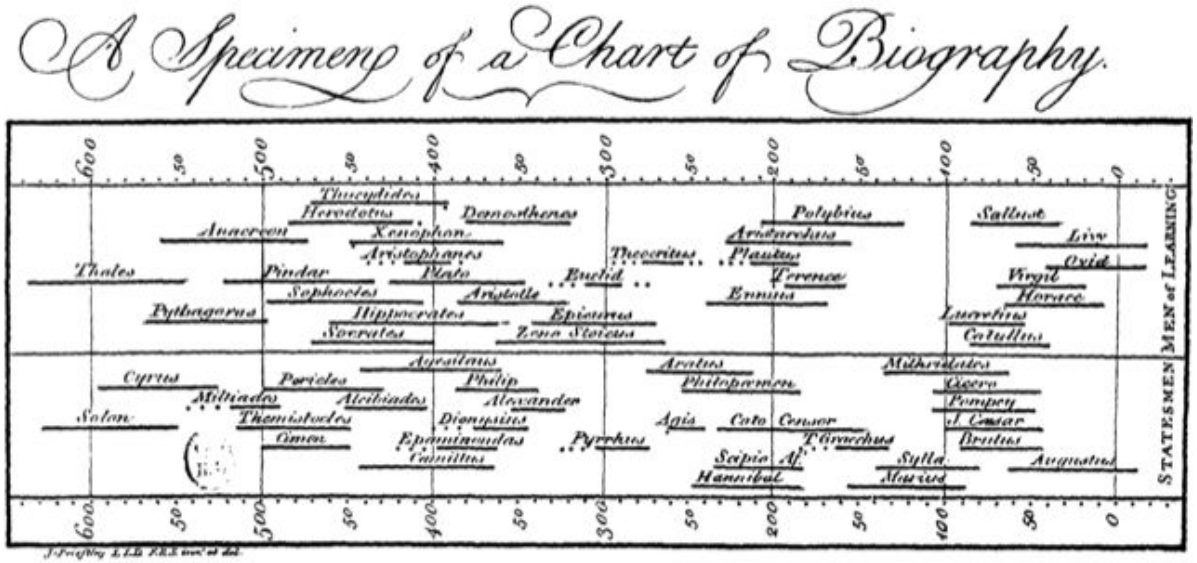


Techniques
Temporal Data

Benjamin Bach
http://benjbach.me
University of Edinburgh
2020

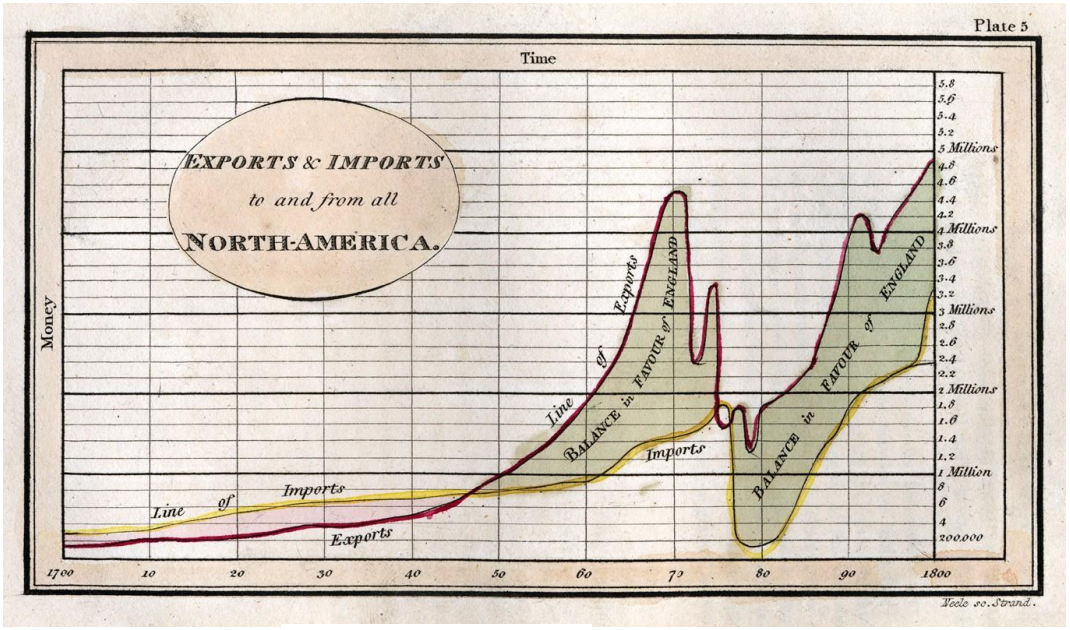






Events

Trajectories

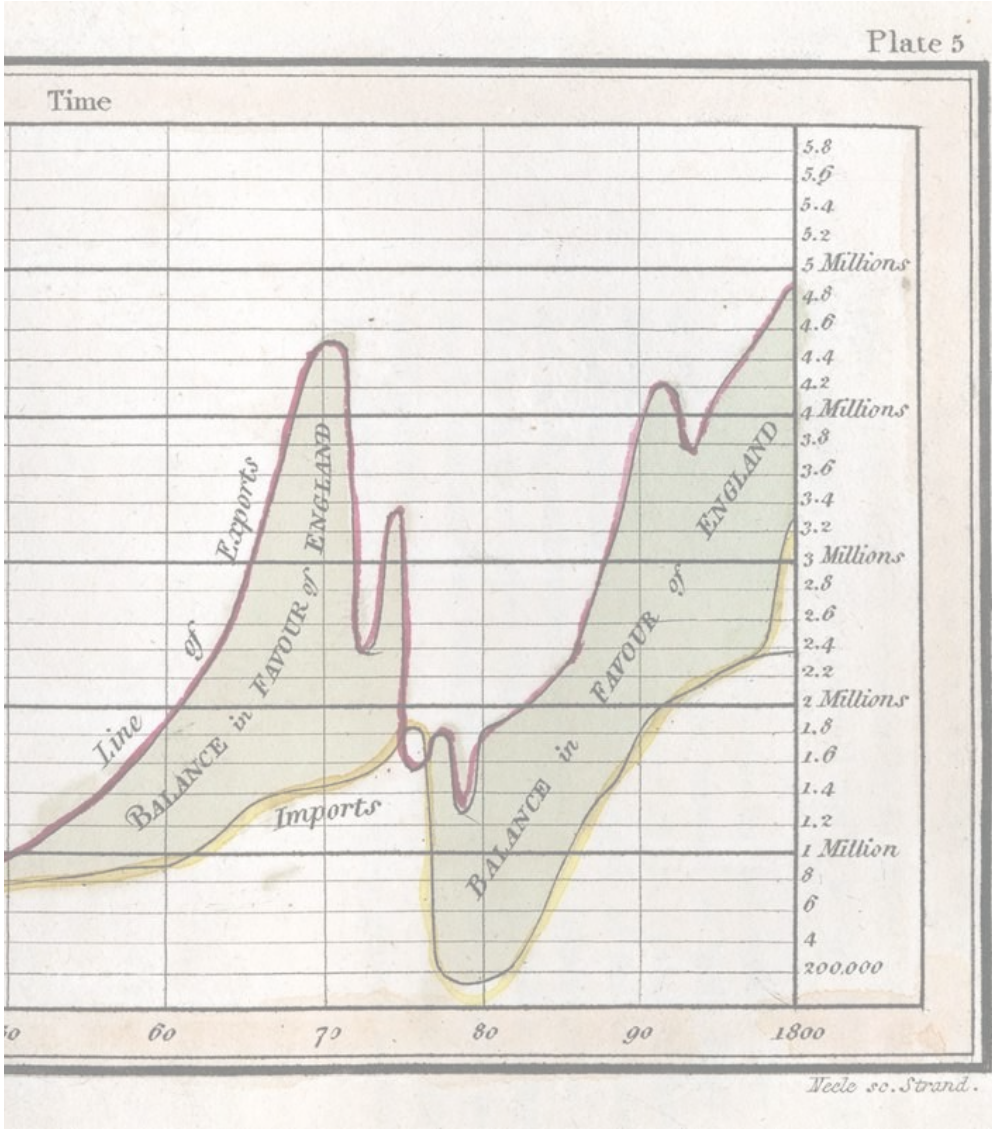


Calendar

Time series

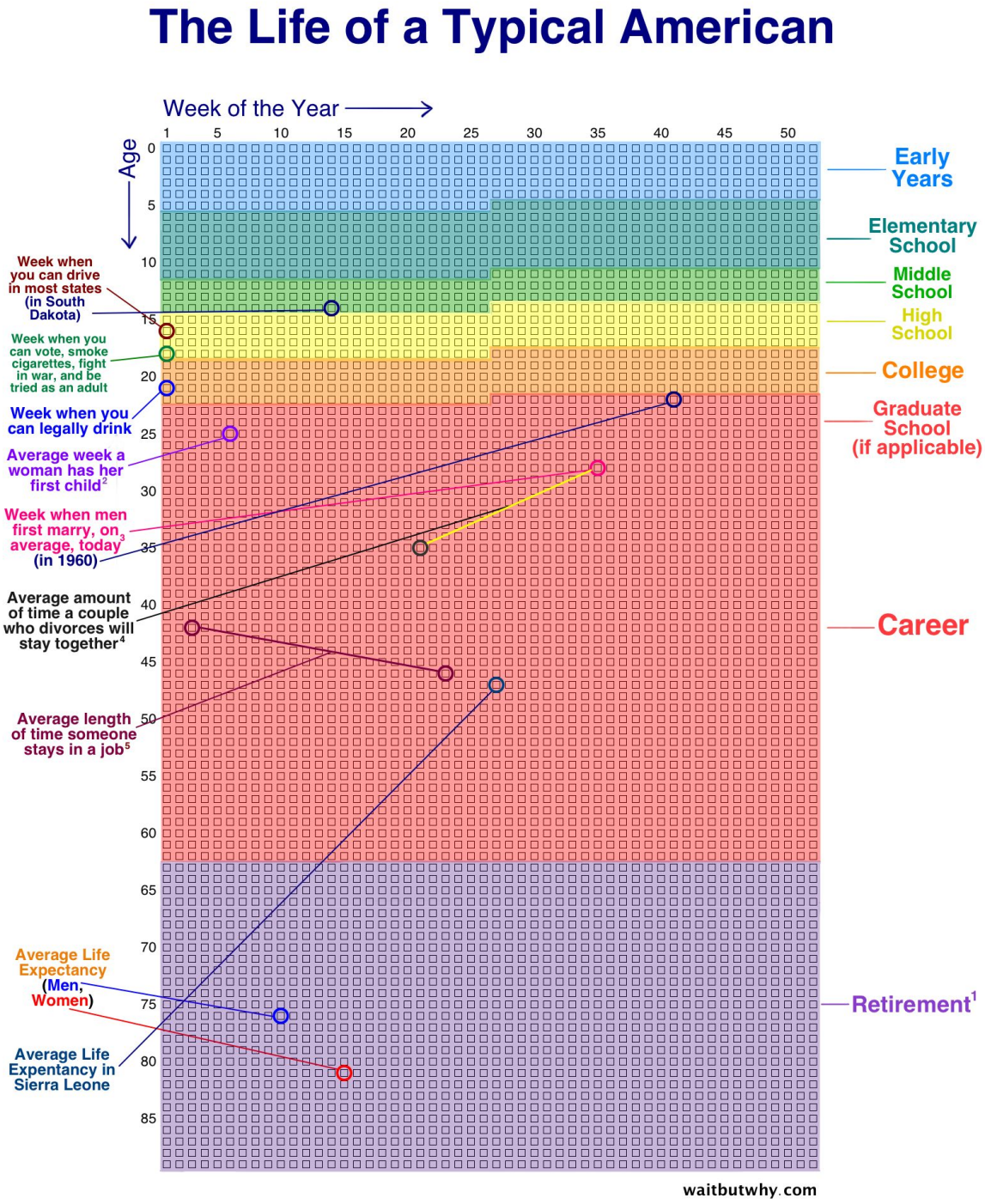
Tasks

- 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



Time is complex

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

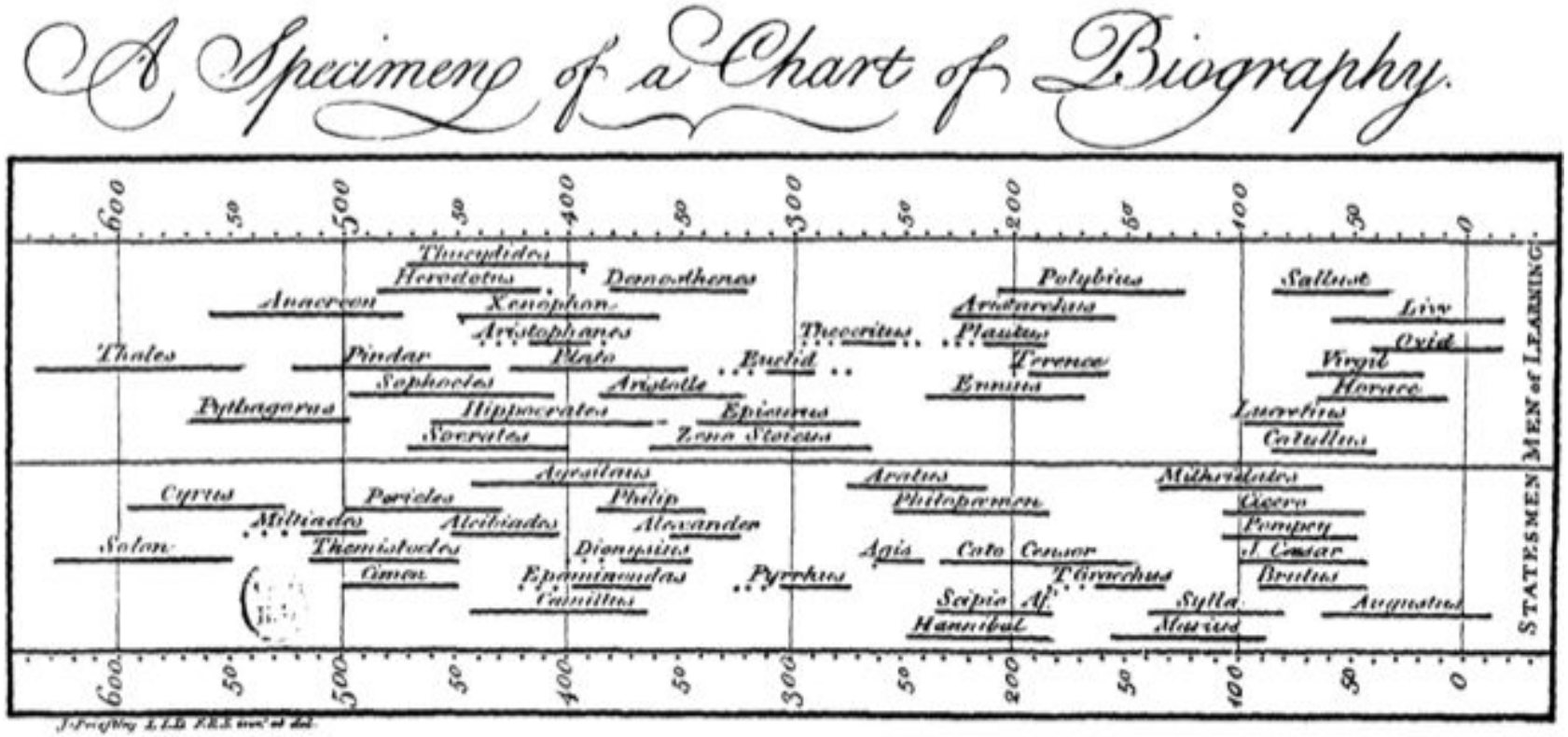


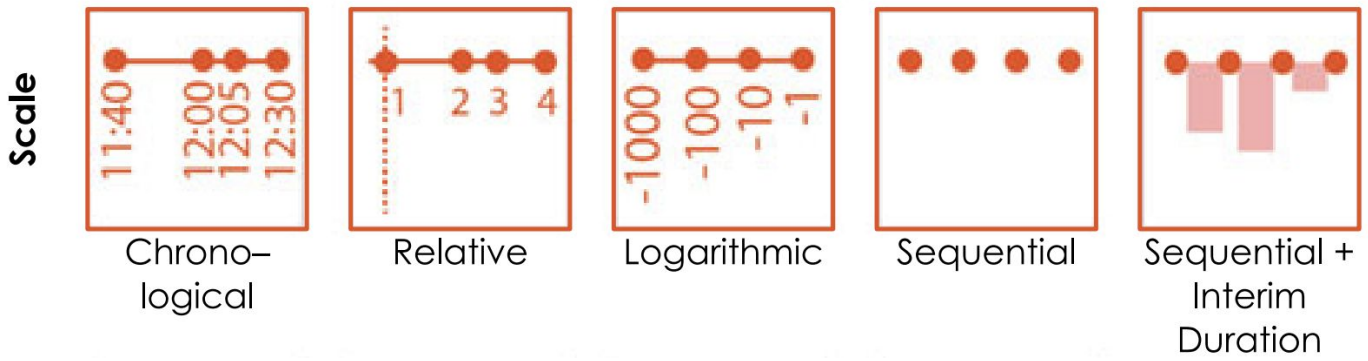
https://waitbutwhy.com/2014/05/life-weeks.html

Outline

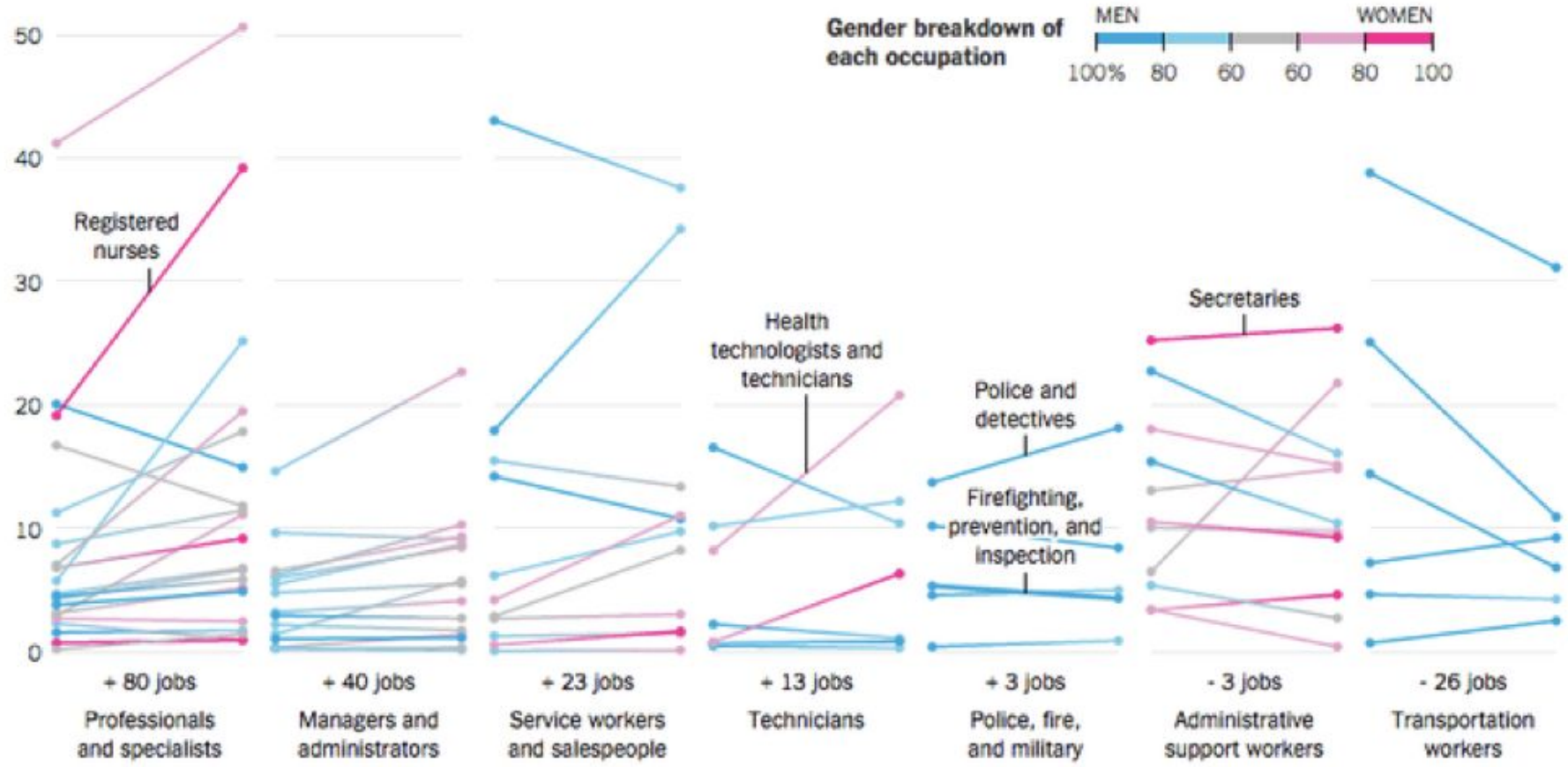
- Event data
- Time serie
- Many time series
- Multidimensional temporal data
- Space-time cubes
- Time curves

Events and durations



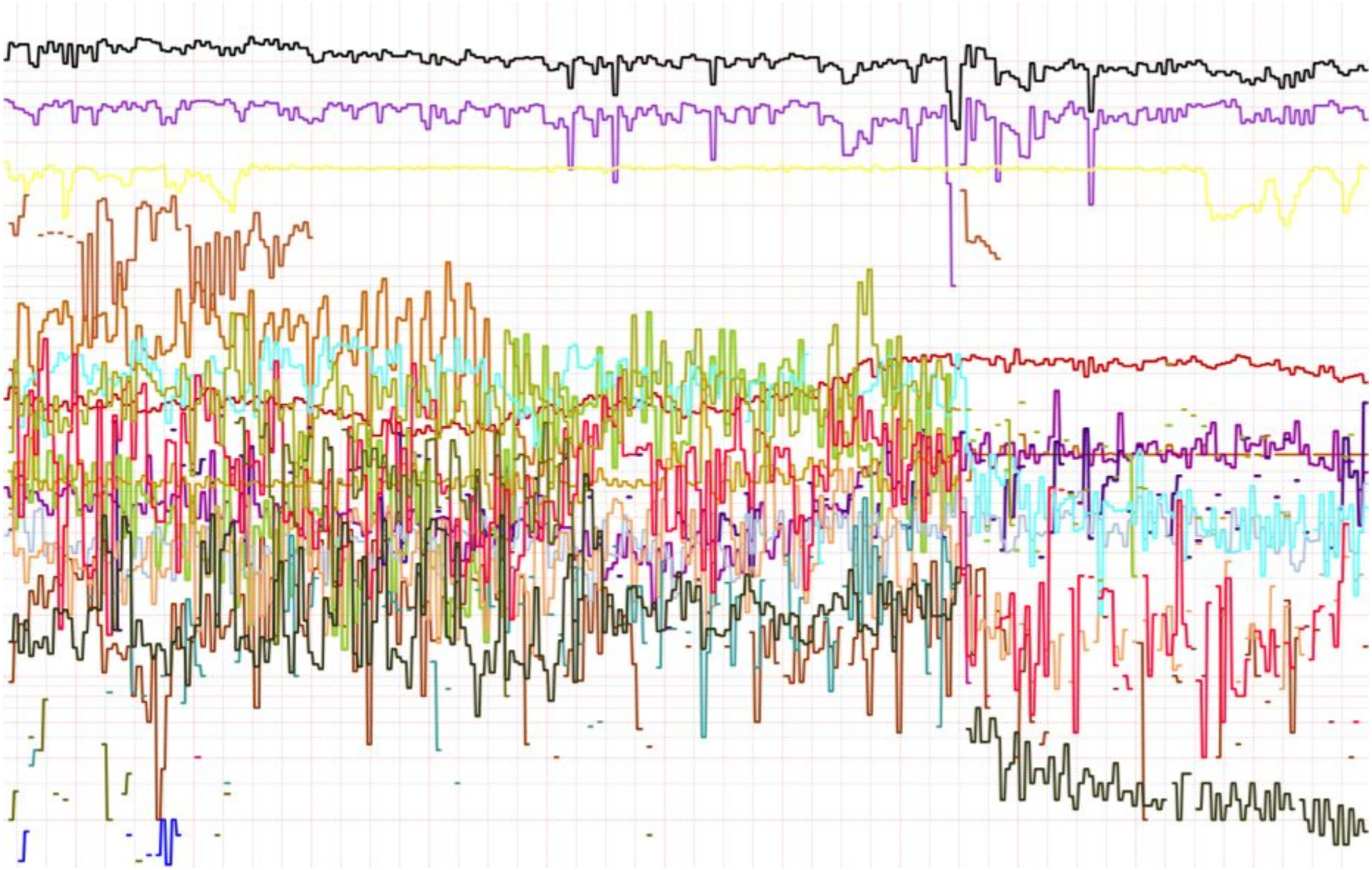


Trend chart


Gender breakdown of each occupation
MEN
WOMEN
100%
80
60
60
80
100
50
40
30
20
10
0
Registered nurses
Health technologists and technicians
Police and detectives
Firefighting, prevention, and inspection
Secretaries
+ 80 jobs
Professionals and specialists
+ 40 jobs
Managers and administrators
+ 23 jobs
Service workers and salespeople
+ 13 jobs
Technicians
+ 3 jobs
Police, fire, and military
- 3 jobs
Administrative support workers
- 26 jobs
Transportation workers

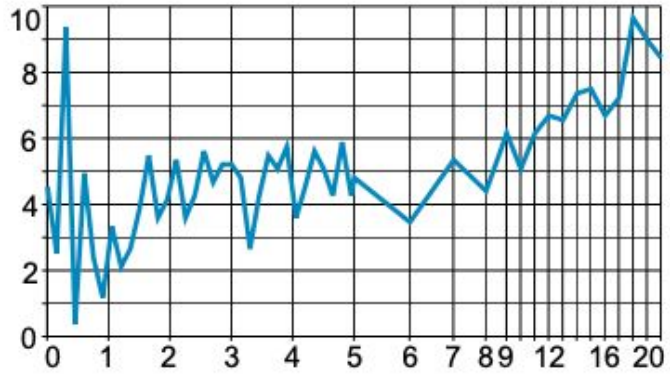
Time series

Complexity

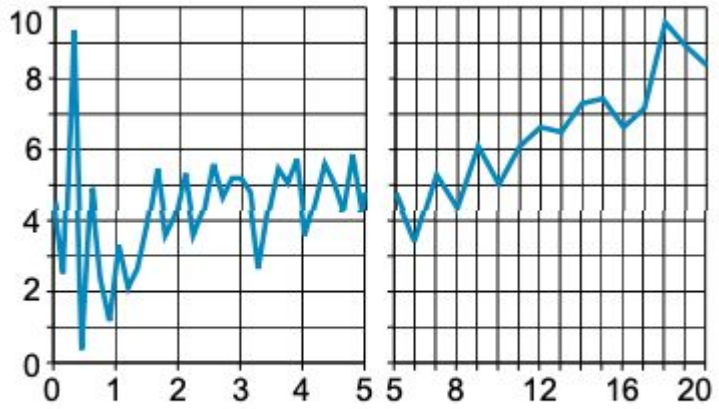


https://www.writerscafe.org/writing/TheoLueck/1416170/

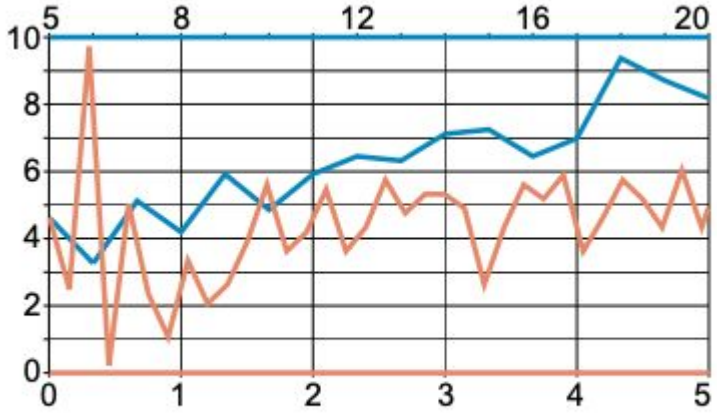
Dual-Scale Data Charts



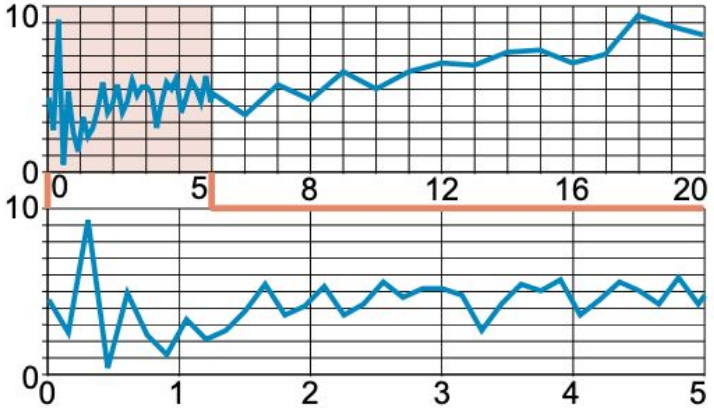
(a) A lens chart.



(a) A broken chart.



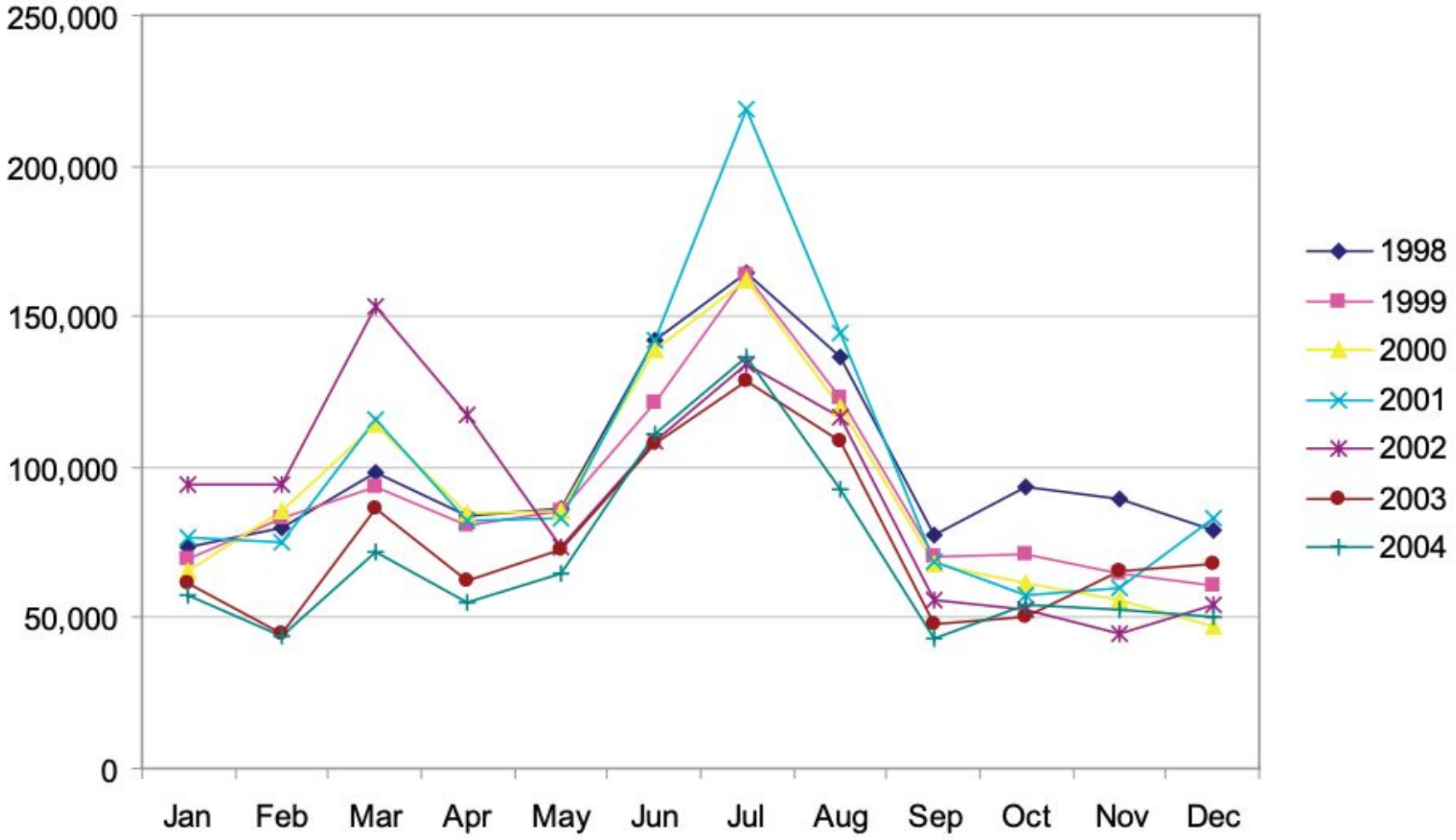
(a) A superimposed chart.



(a) A cut-out chart.

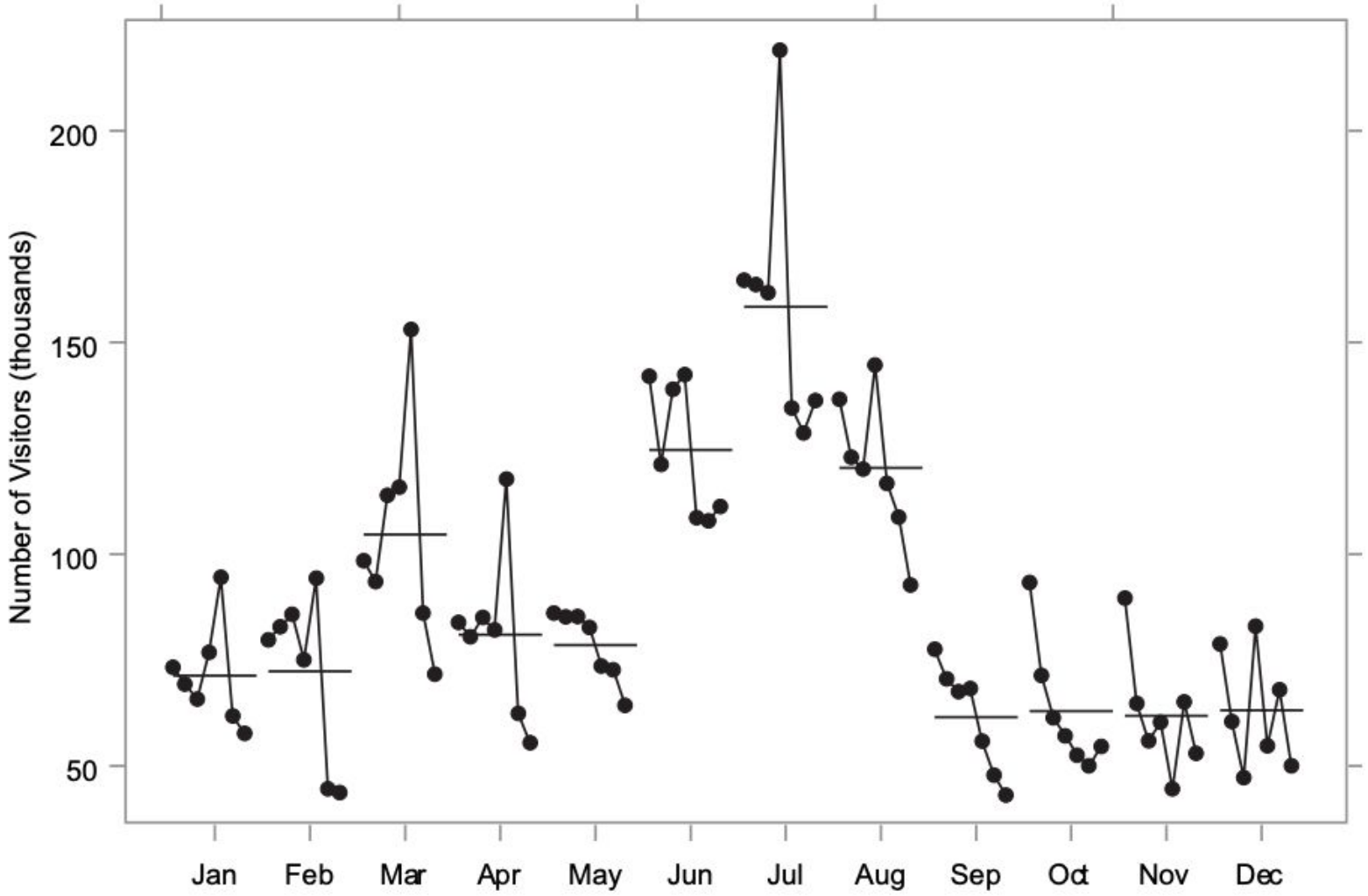
https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6065014

Calendar data



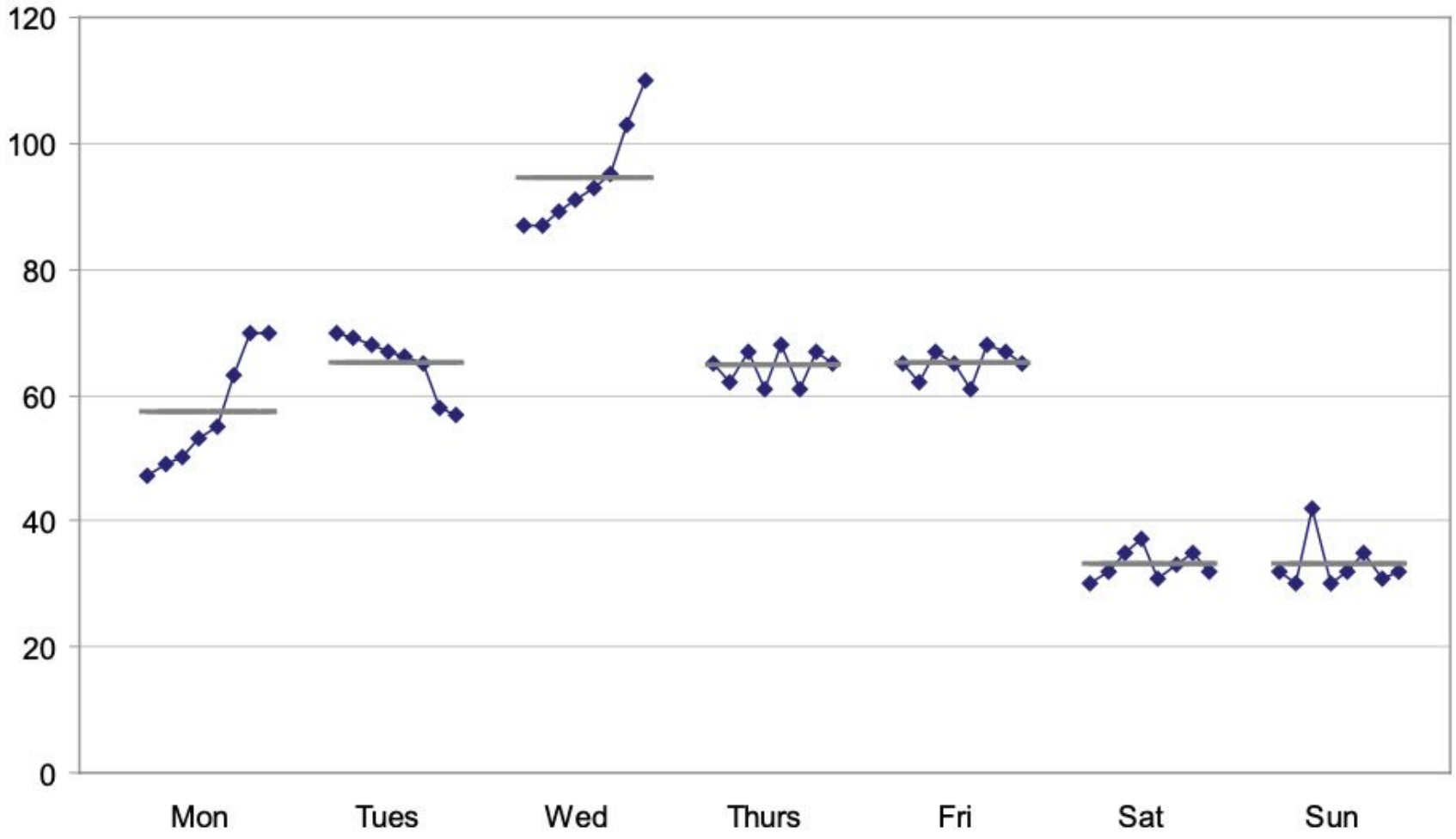
https://www.perceptualedge.com/articles/guests/intro_to_cycle_plots.pdf

Cycle plots: by month



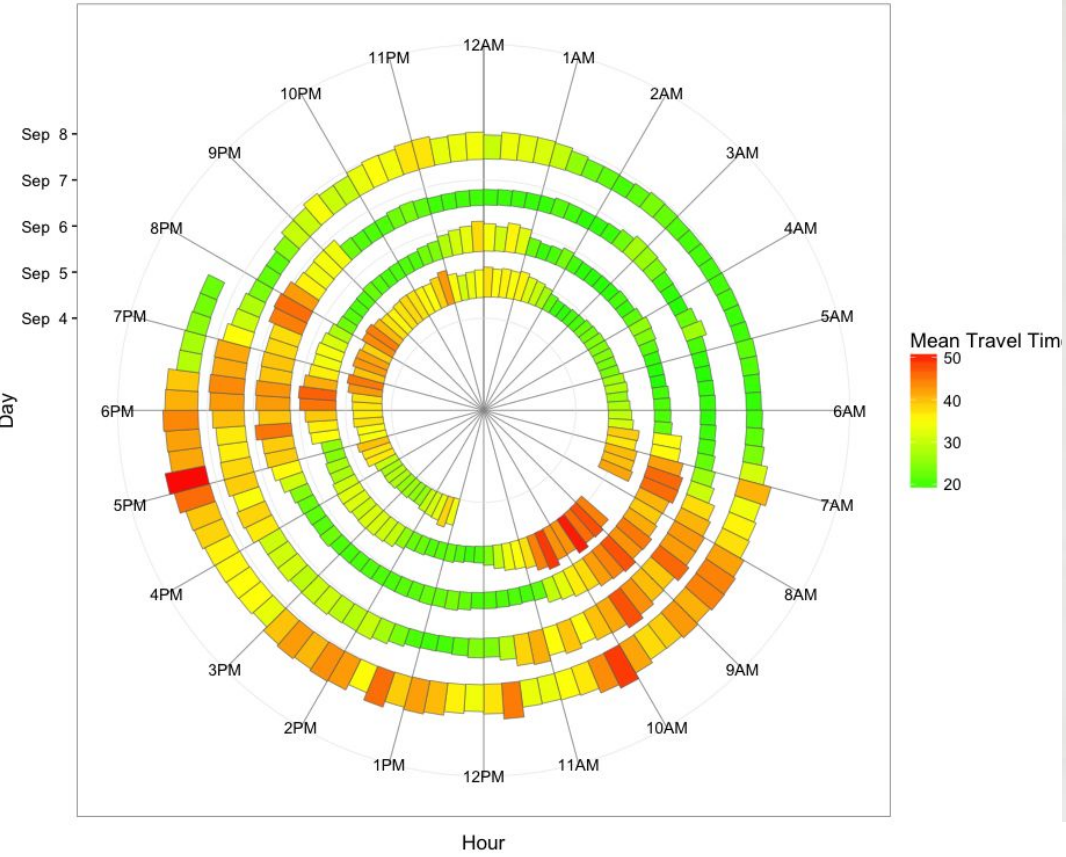
https://www.perceptualedge.com/articles/guests/intro_to_cycle_plots.pdf

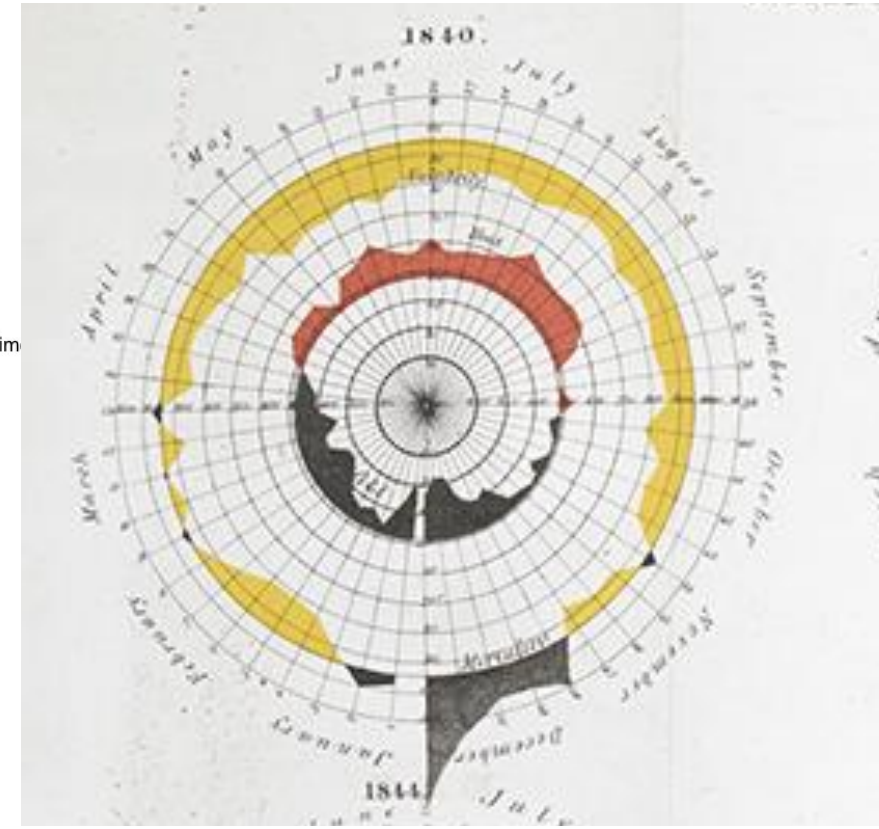
Cycle plots: by week day



https://www.perceptualedge.com/articles/guests/intro_to_cycle_plots.pdf

Radial time visualizations





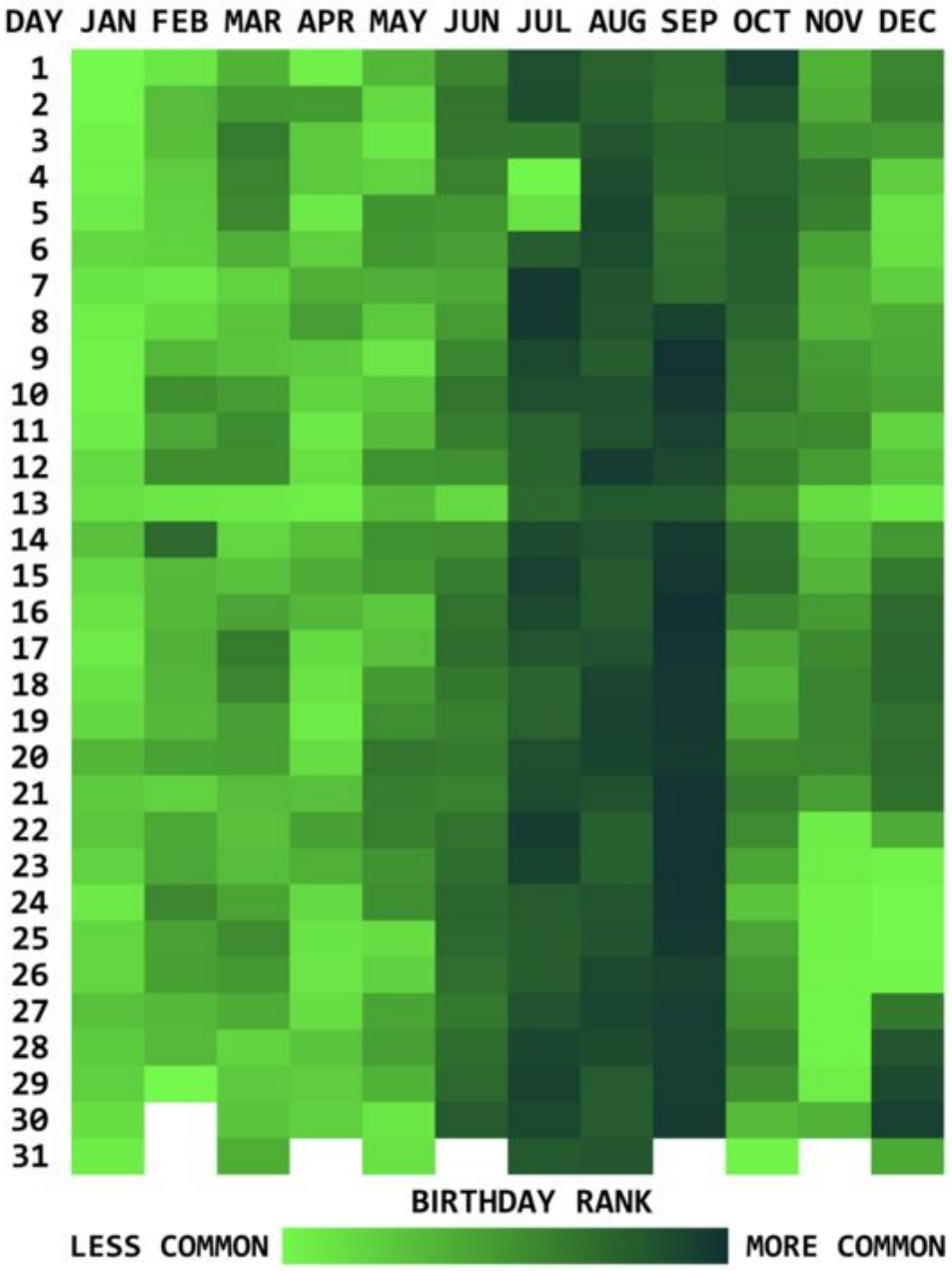
- Show cyclical data / values
- Outer layers getting longer!

Heatmap

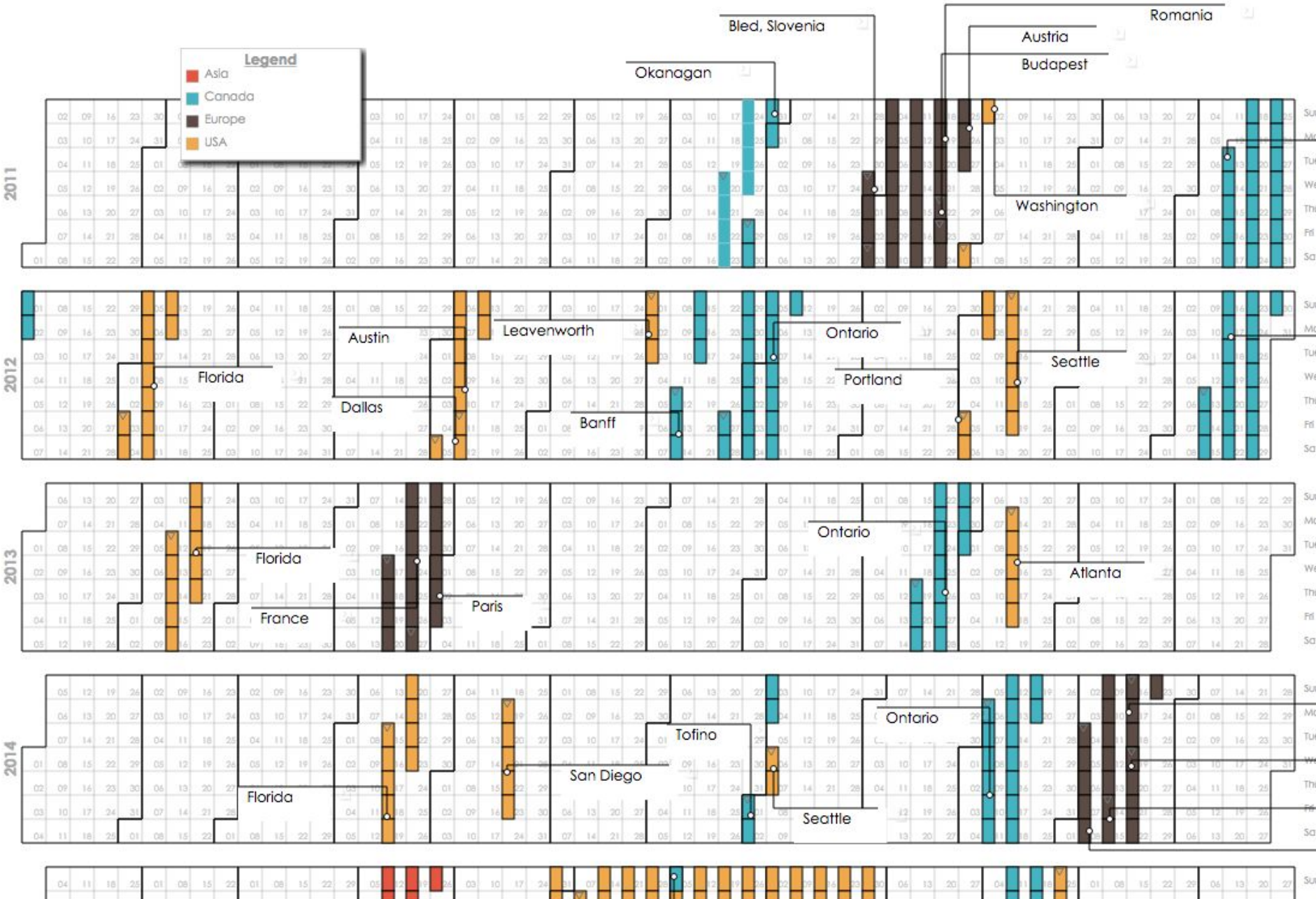
- Calendar data + numerical values

\+ Row and column effects
\+ Easy look up
\+ Space efficient

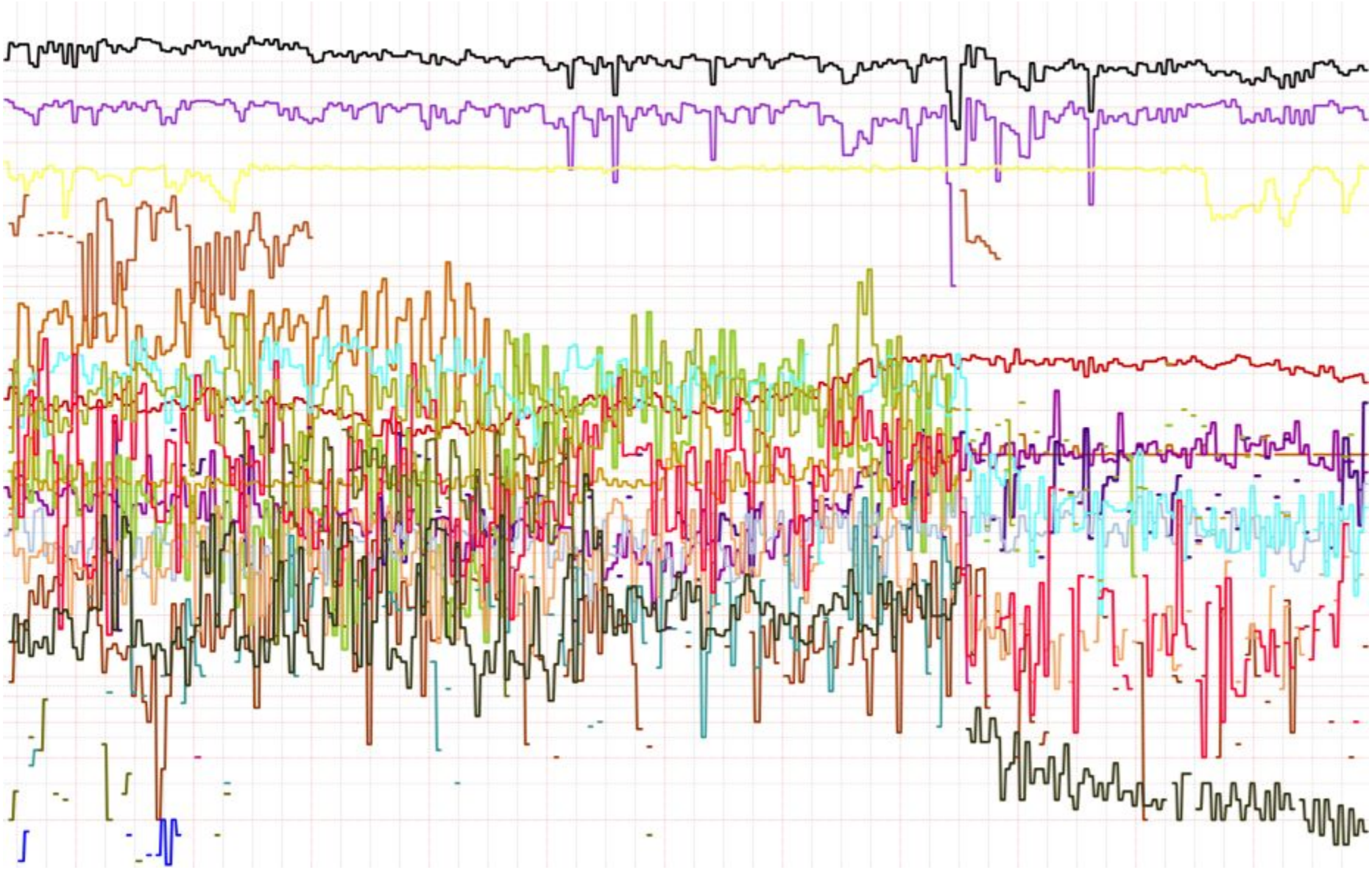
\- Precise value comparison hard



Calendars

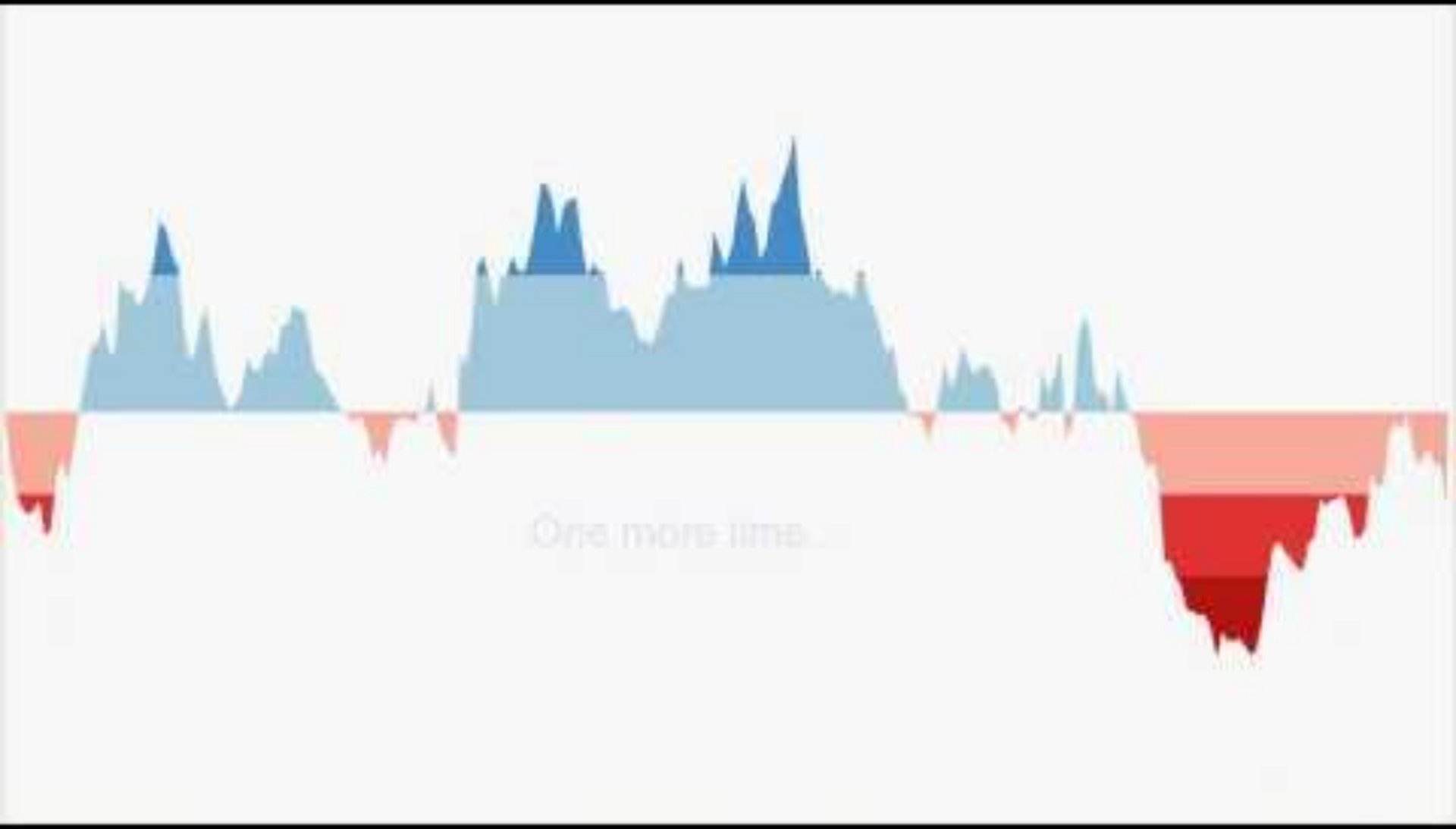

Legend
Asia
Canada
Europe
USA
2011
2012
2013
2014
Bled, Slovenia
Okanagan
Romania
Austria
Budapest
Washington
Florida
Austin
Leavenworth
Dallas
Banff
Ontario
Portland
Seattle
Florida
France
Paris
Ontario
Atlanta
Florida
San Diego
Tofino
Seattle
Ontario

Comparing multiple timelines?



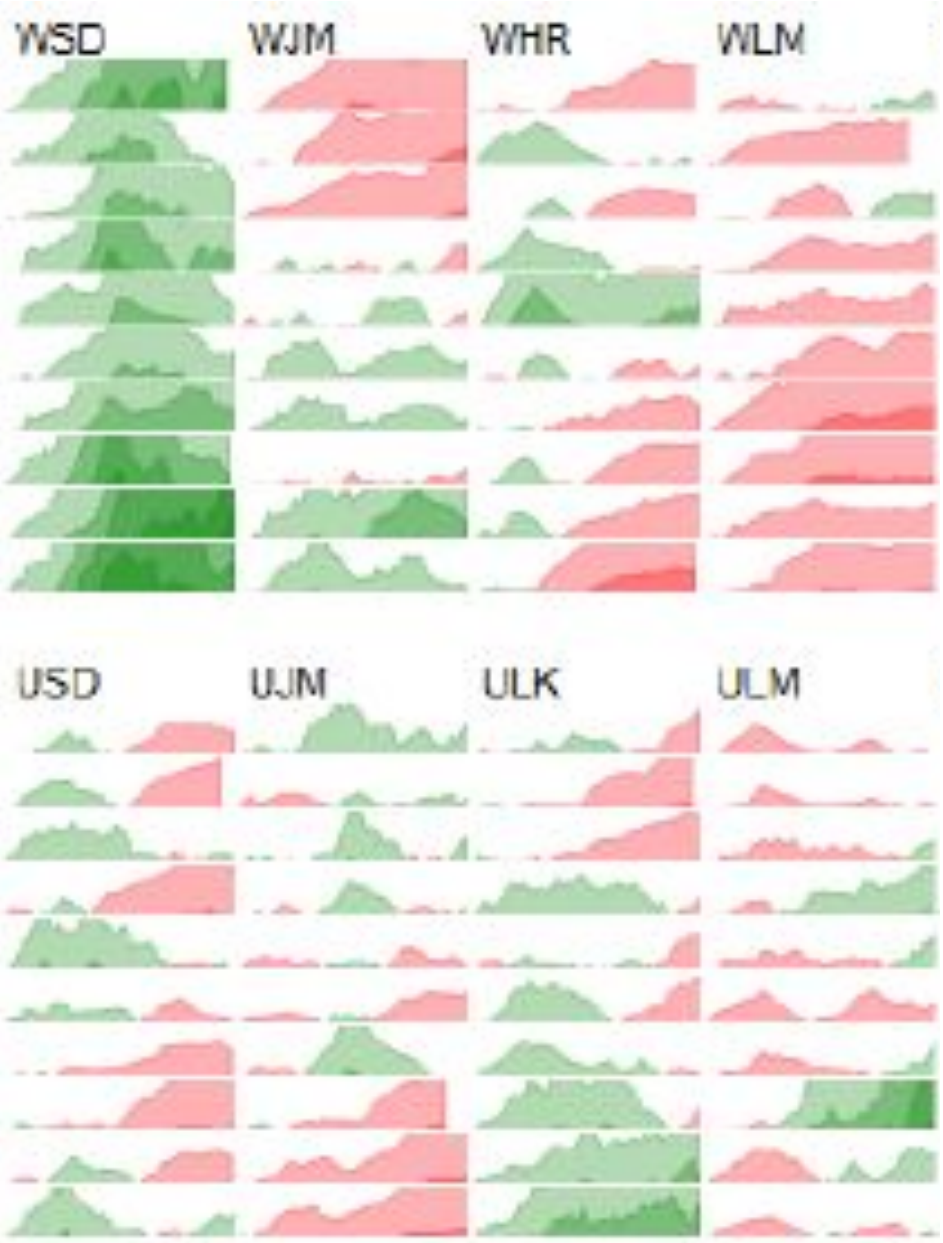
https://www.writerscafe.org/writing/TheoLueck/1416170/

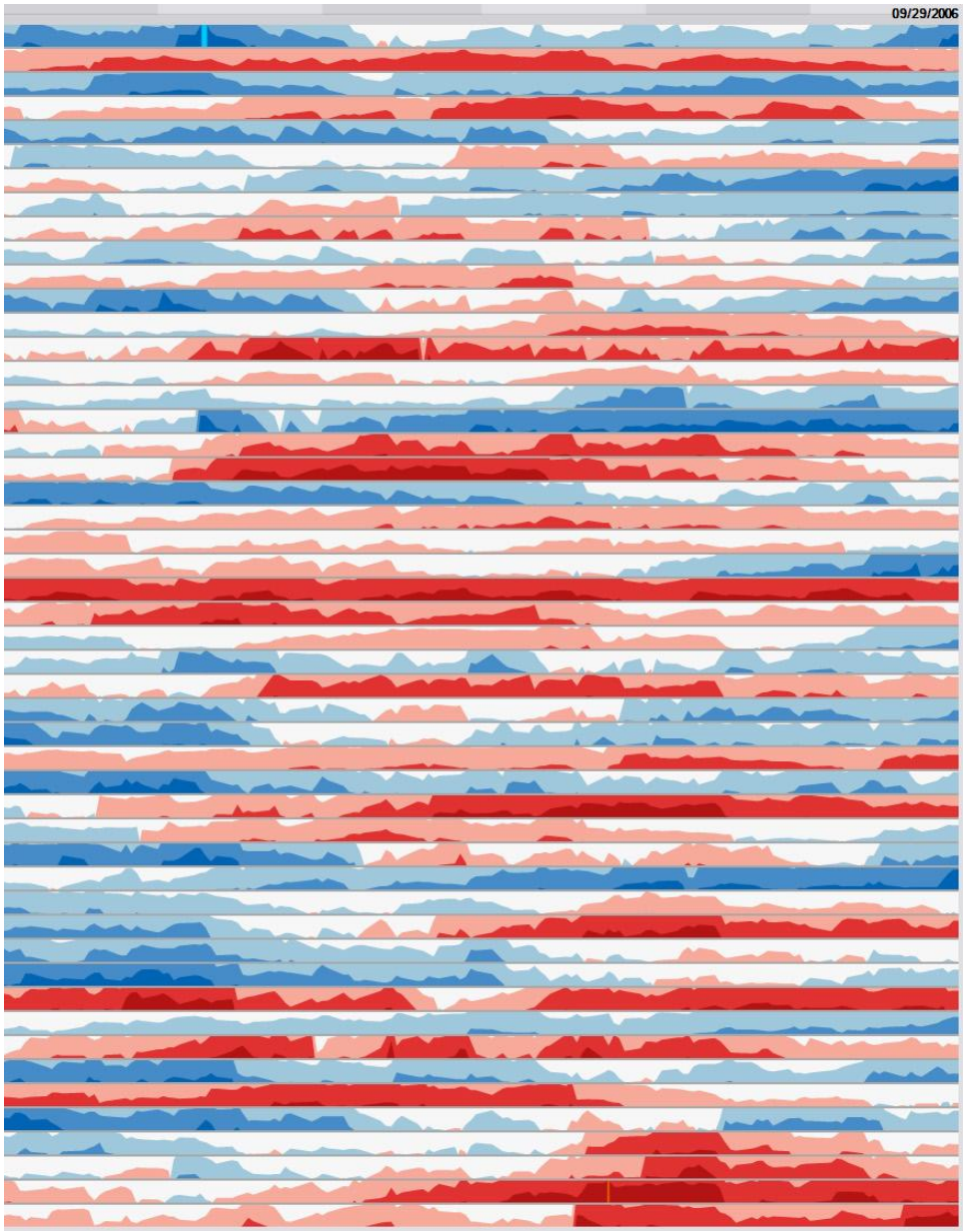
Horizon graphs



Heer, Jeffrey, Nicholas Kong, and Maneesh Agrawala. "Sizing the horizon: the effects of chart size and layering on the graphical perception of time series visualizations." *Proceedings of the SIGCHI*

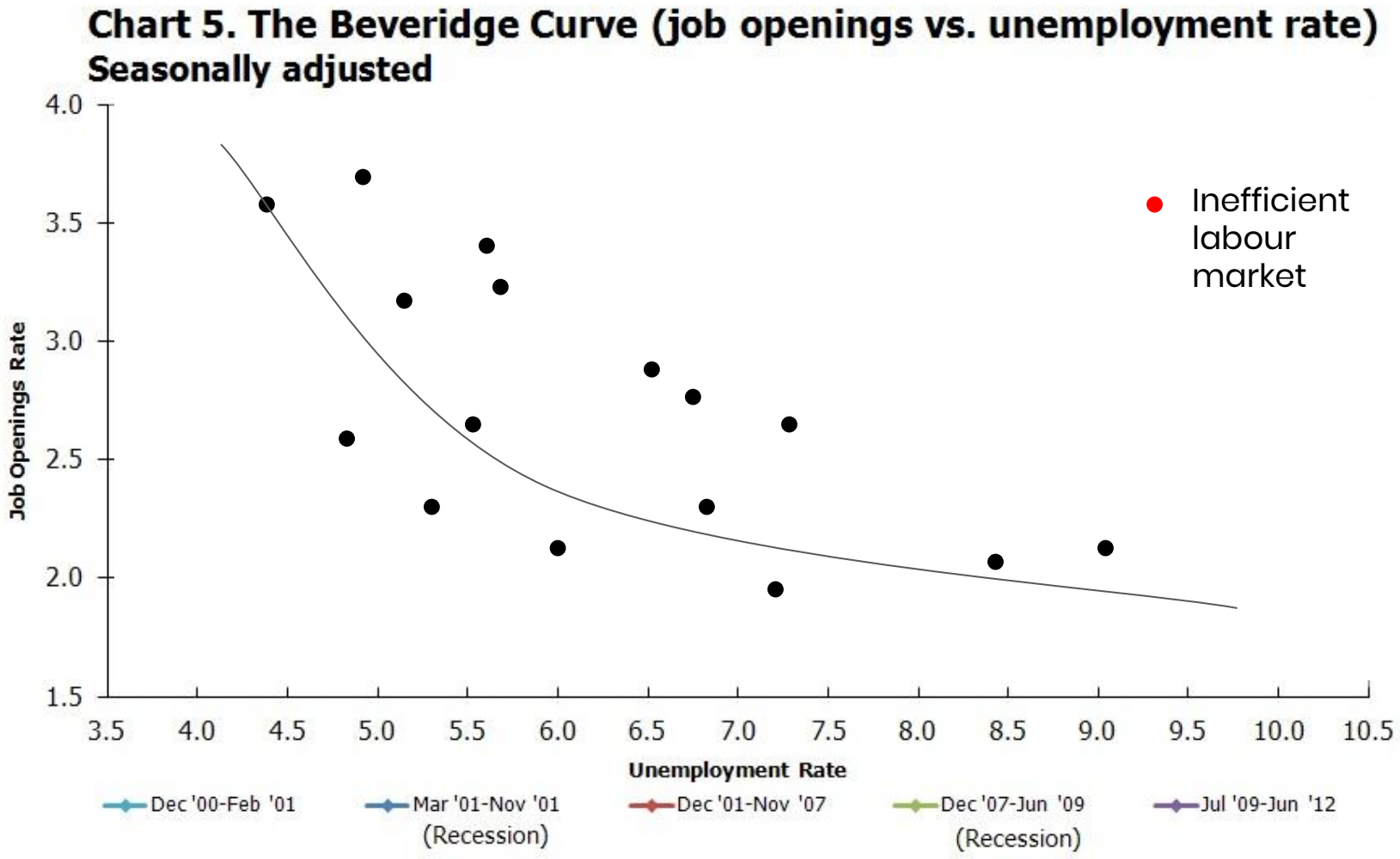
Horizon Graphs





More Complex Data

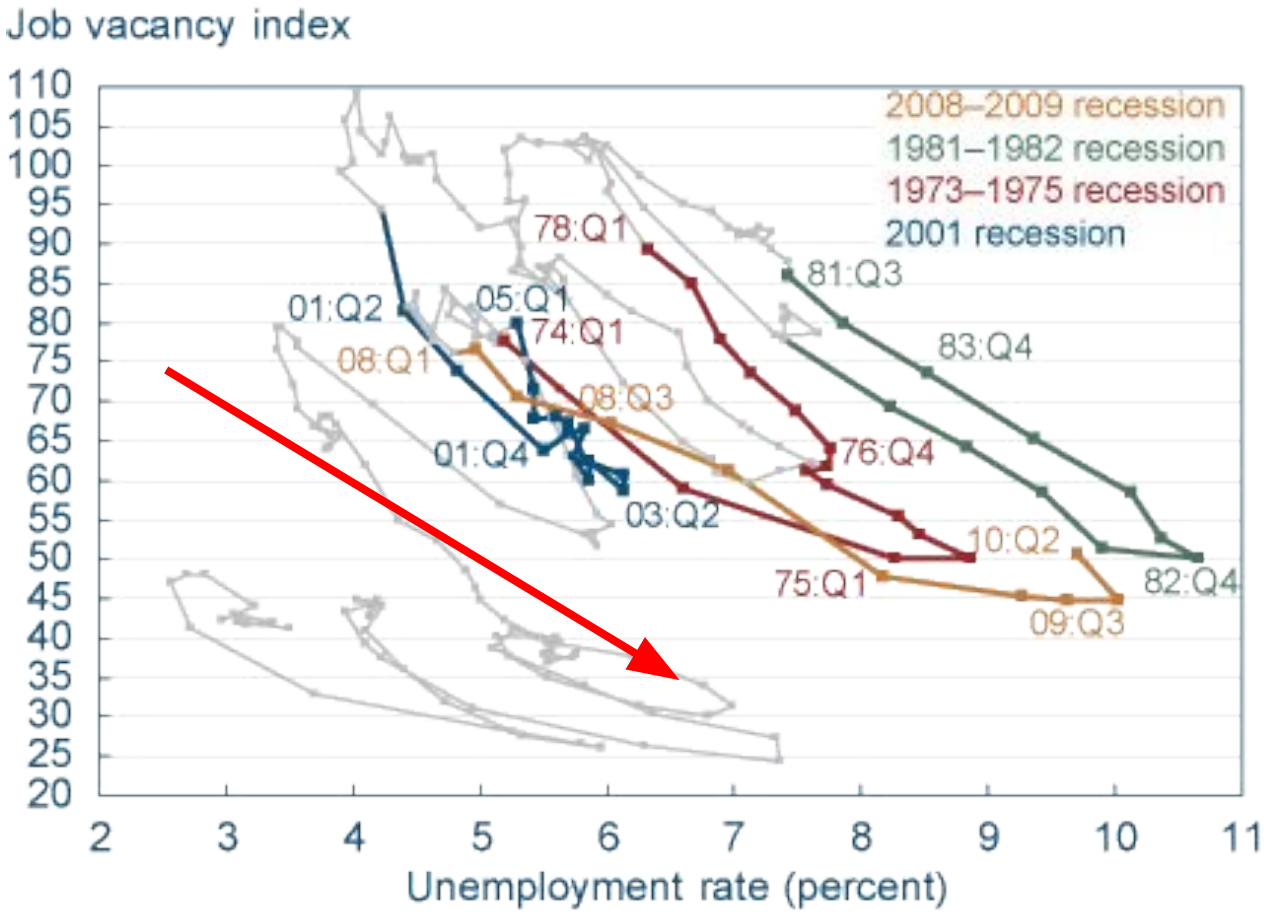
Beveridge Curve: William Beveridge, econ.



https://statmodeling.stat.columbia.edu/2013/06/12/how-to-best-graph-the-beveridge-curve-relating-the-vacancy-rate-in-jobs-to-the-unemployment-rate/

Beveridge Curve

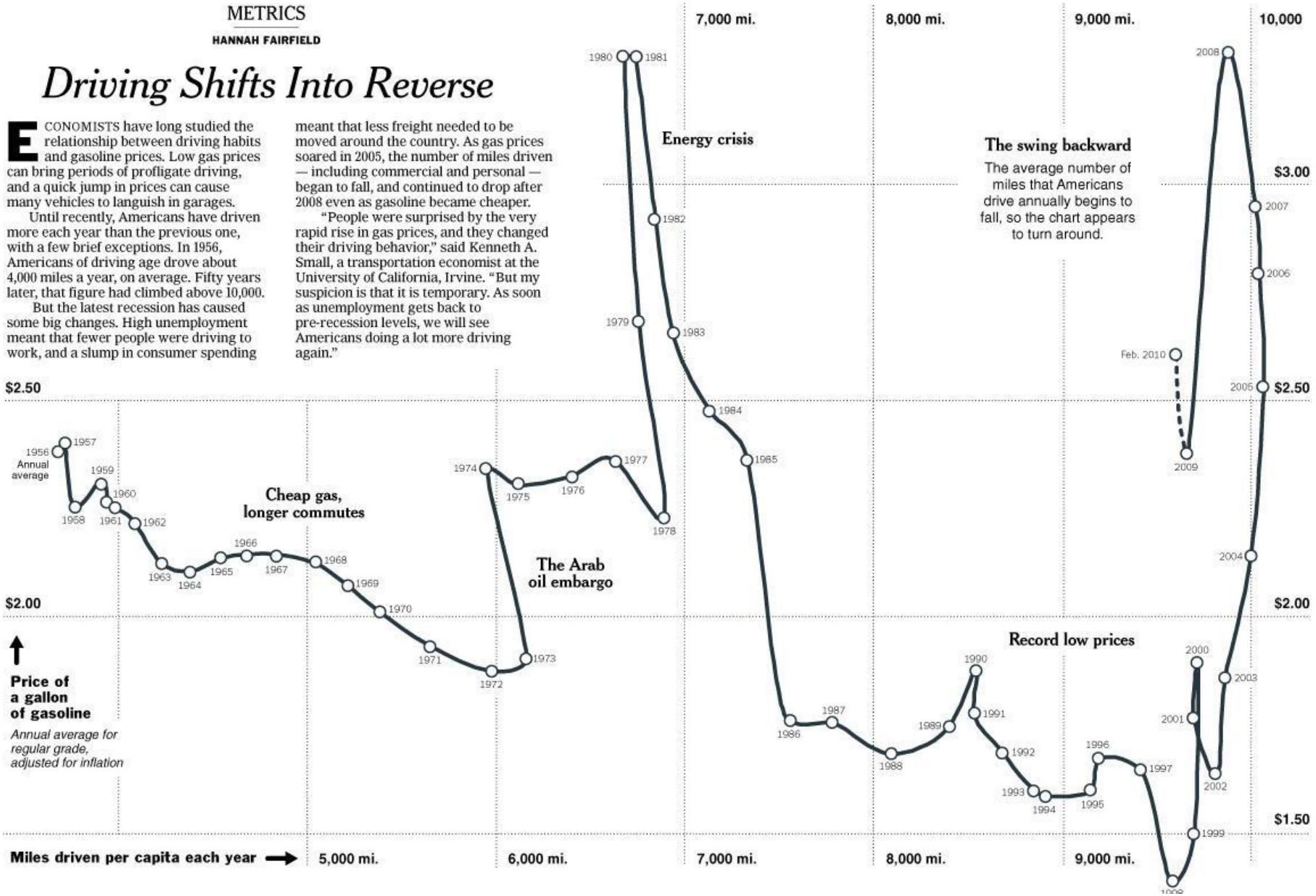
Recessions!



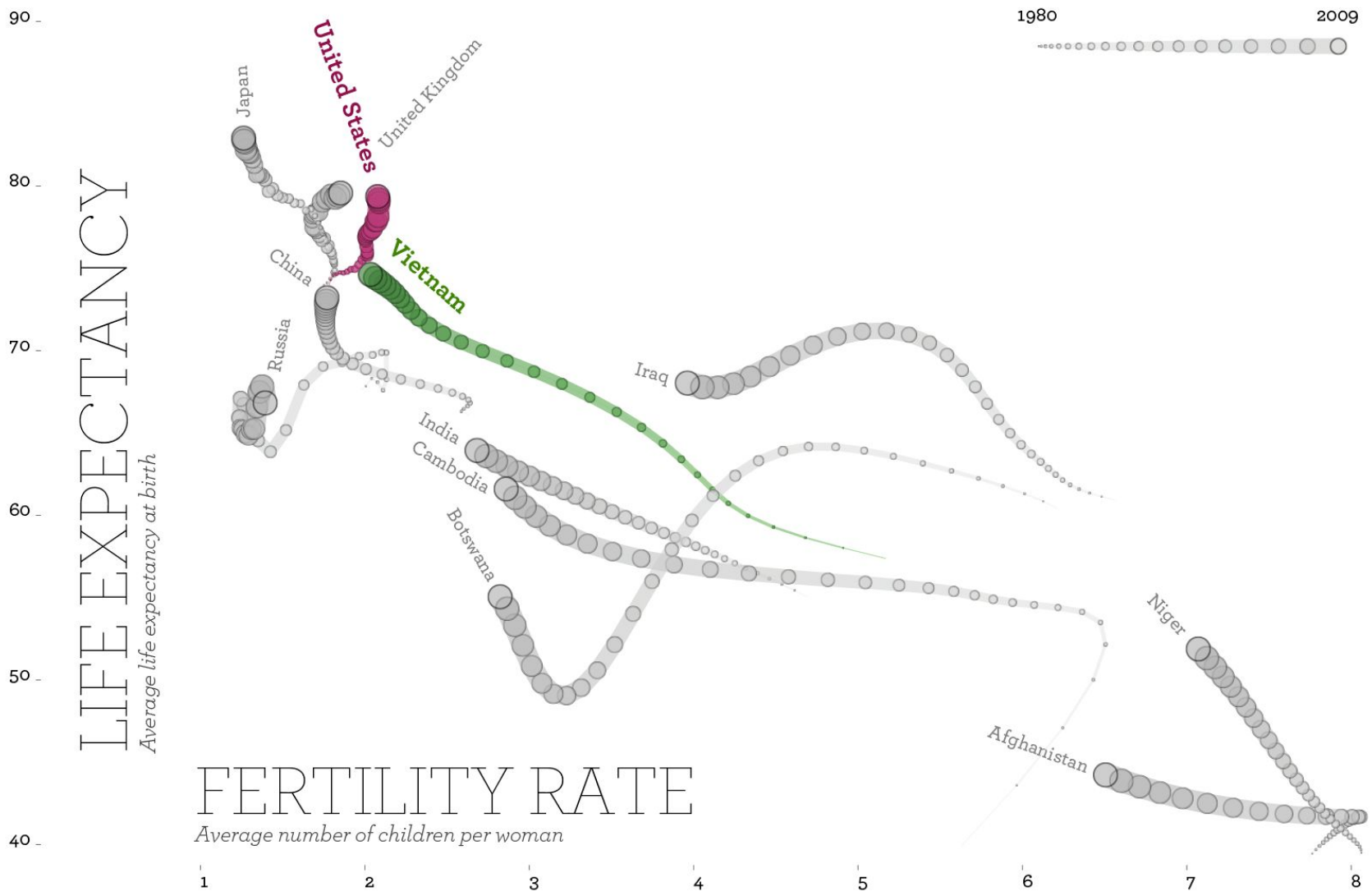
Note: Data are quarterly and span the 1951:Q1–2010:Q2 period.
[Figure updated 8/19/2010, correcting the miscoloring of the 2001 recession line.
Source: Conference Board, BLS, authors' calculations.

https://statmodeling.stat.columbia.edu/2013/06/12/how-to-best-graph-the-beveridge-curve-relating-the-vacancy-rate-in-jobs-to-the-unemployment-rate/

Connected Scatterplot

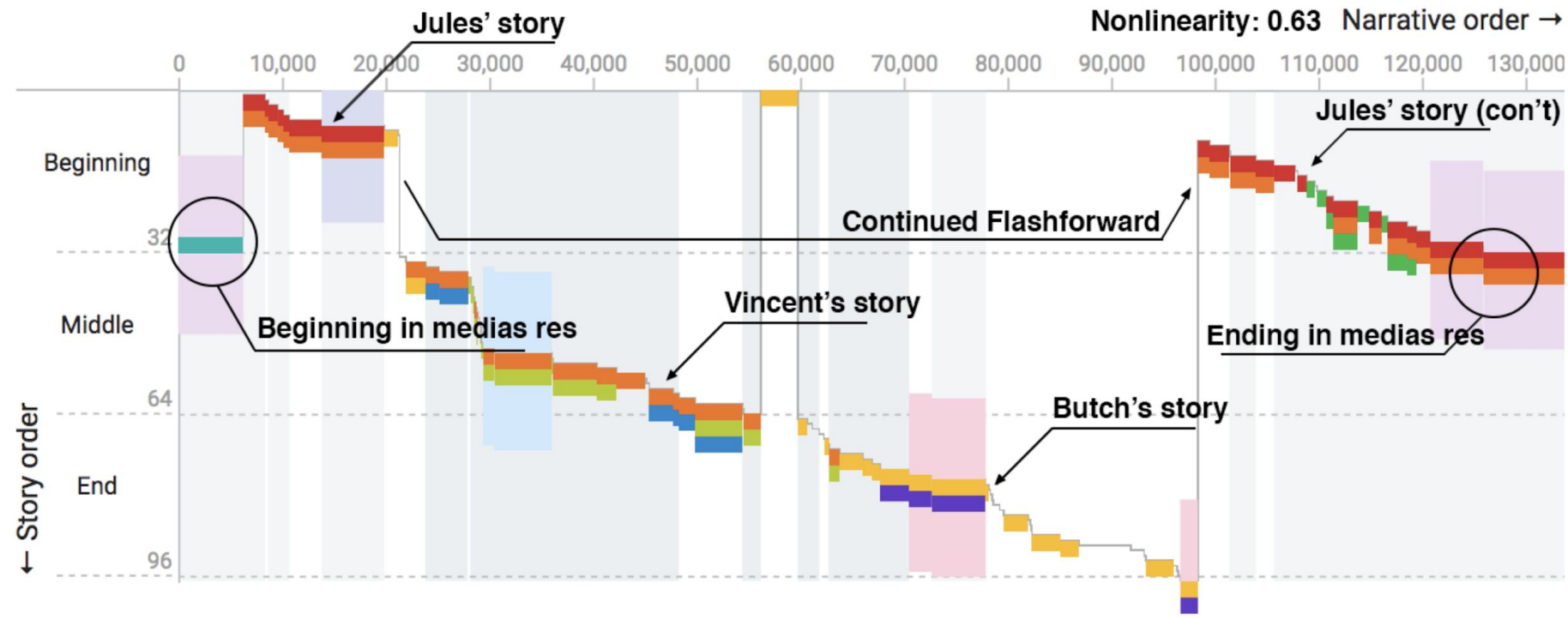


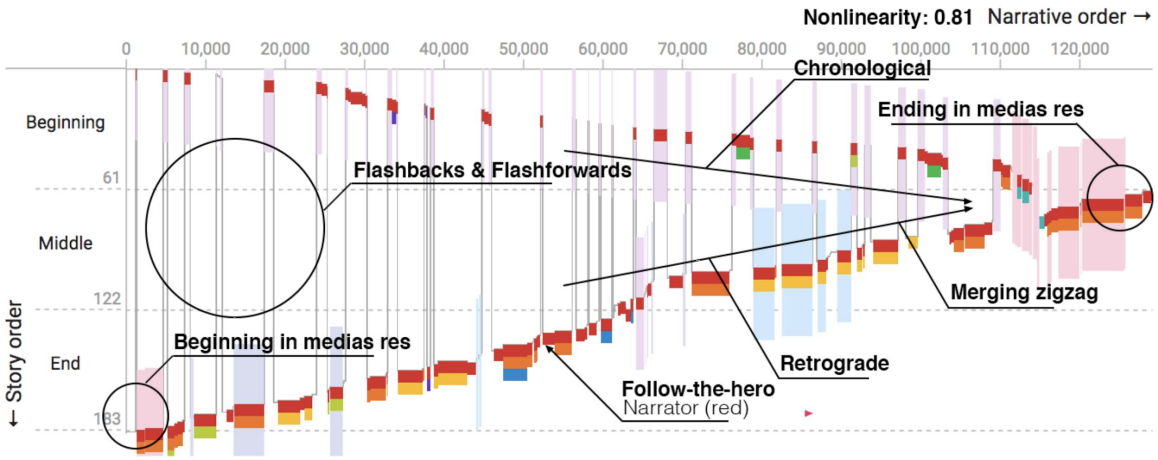
Connected Scatterplots: encoding time



Moritz Stefaner: http://truth-and-beauty.net/projects/remixing-rosling/

Time vs. Time: **Story Curves**



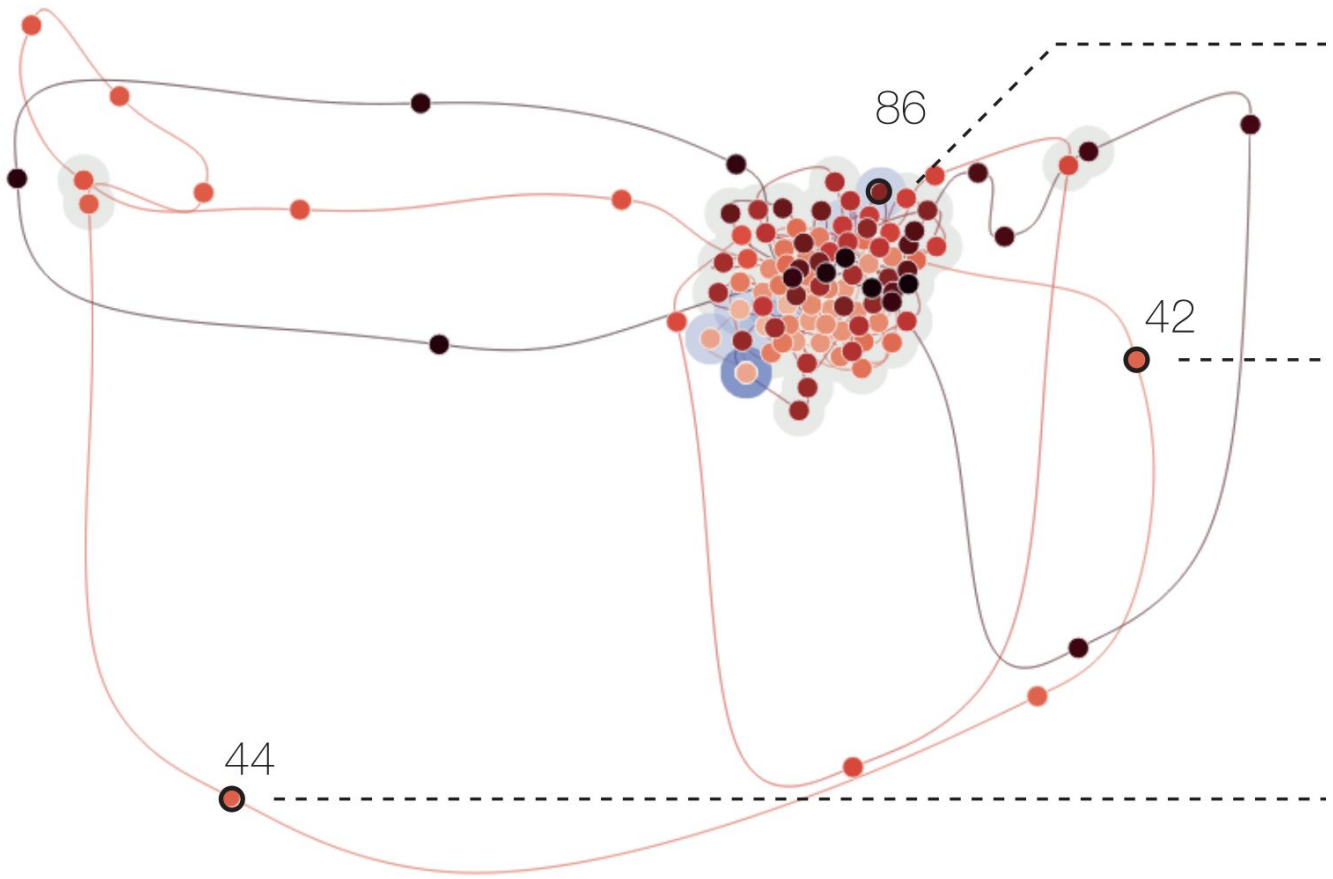


Kim, Nam Wook, et al. "Visualizing nonlinear narratives with story curves." *IEEE transactions on visualization and computer graphics* 24.1 (2017): 595-604.

Time Curves
Creation

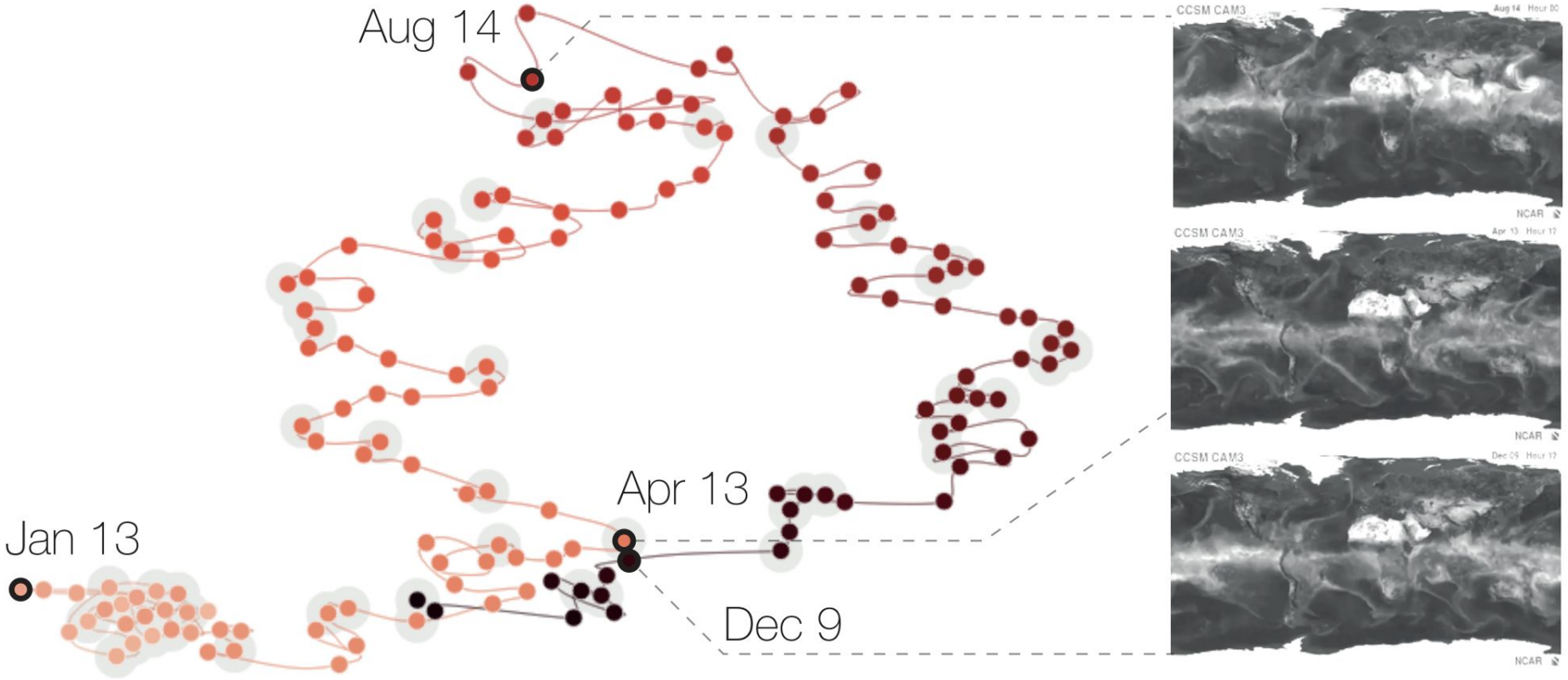
Bach, Benjamin, et al. "Time curves: Folding time to visualize patterns of temporal evolution in data." *IEEE transactions on visualization and computer graphics* 22.1 (2015): 559-568.

Time Curves

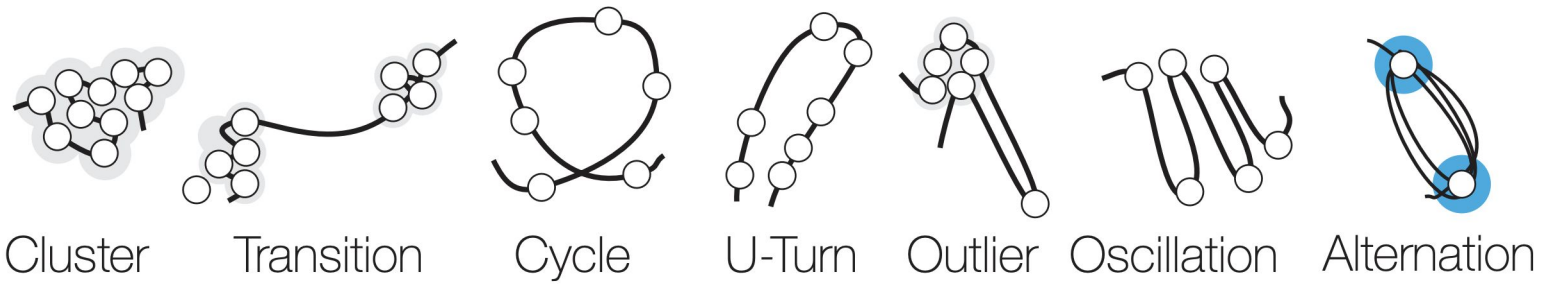


Bach, Benjamin, et al. "Time curves: Folding time to visualize patterns of temporal evolution in data." *IEEE transactions on visualization and computer graphics* 22.1 (2016).

Time Curves: Climate



Time Curves: Visual Patterns



Degree of stagnation
progressing

stagnating

Degree of oscillation
no oscillation

large oscillations

Self-intersection
no intersection

many intersections

Point density
sparse

dense

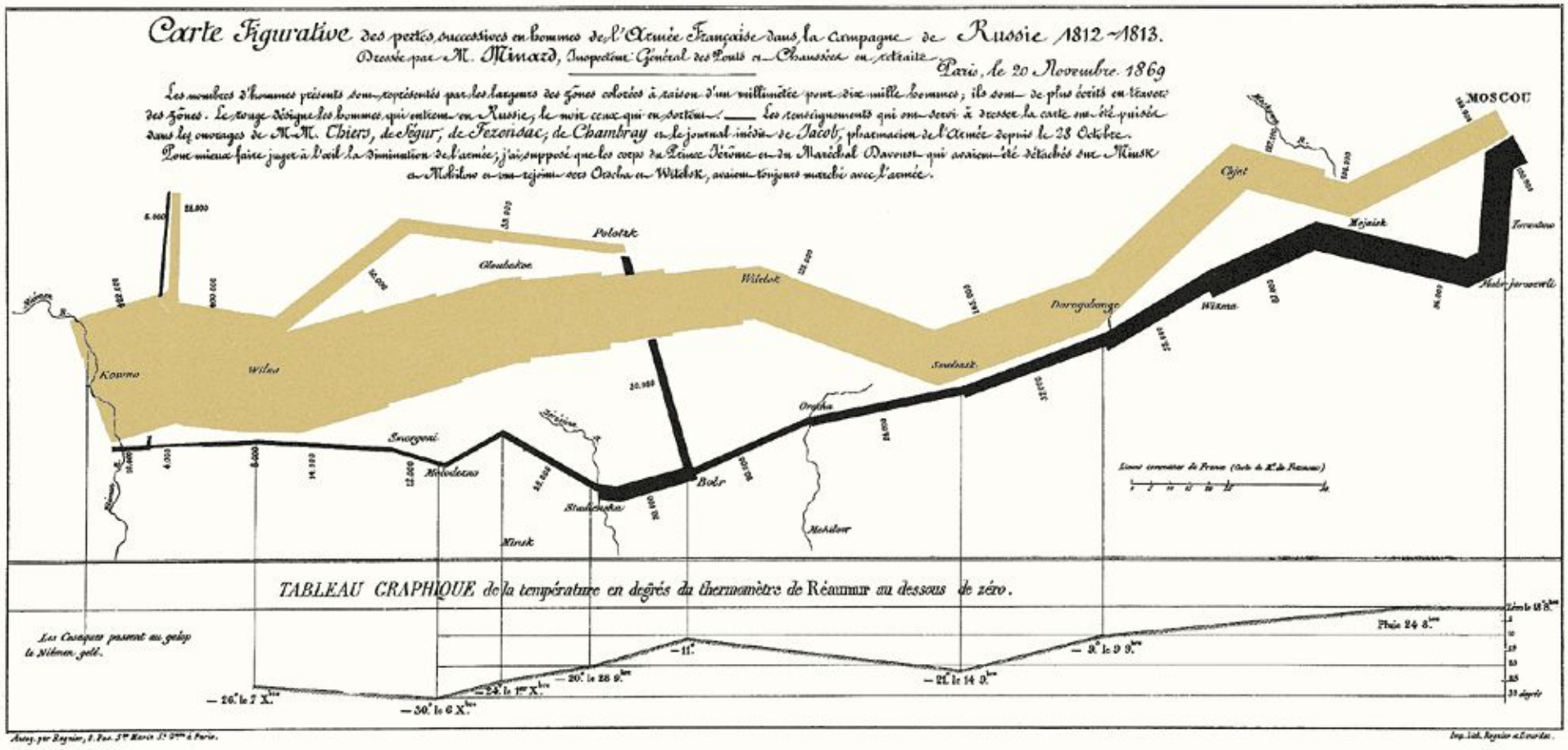
Irregularity
regular

irregular

Time Curves

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

Trajectories

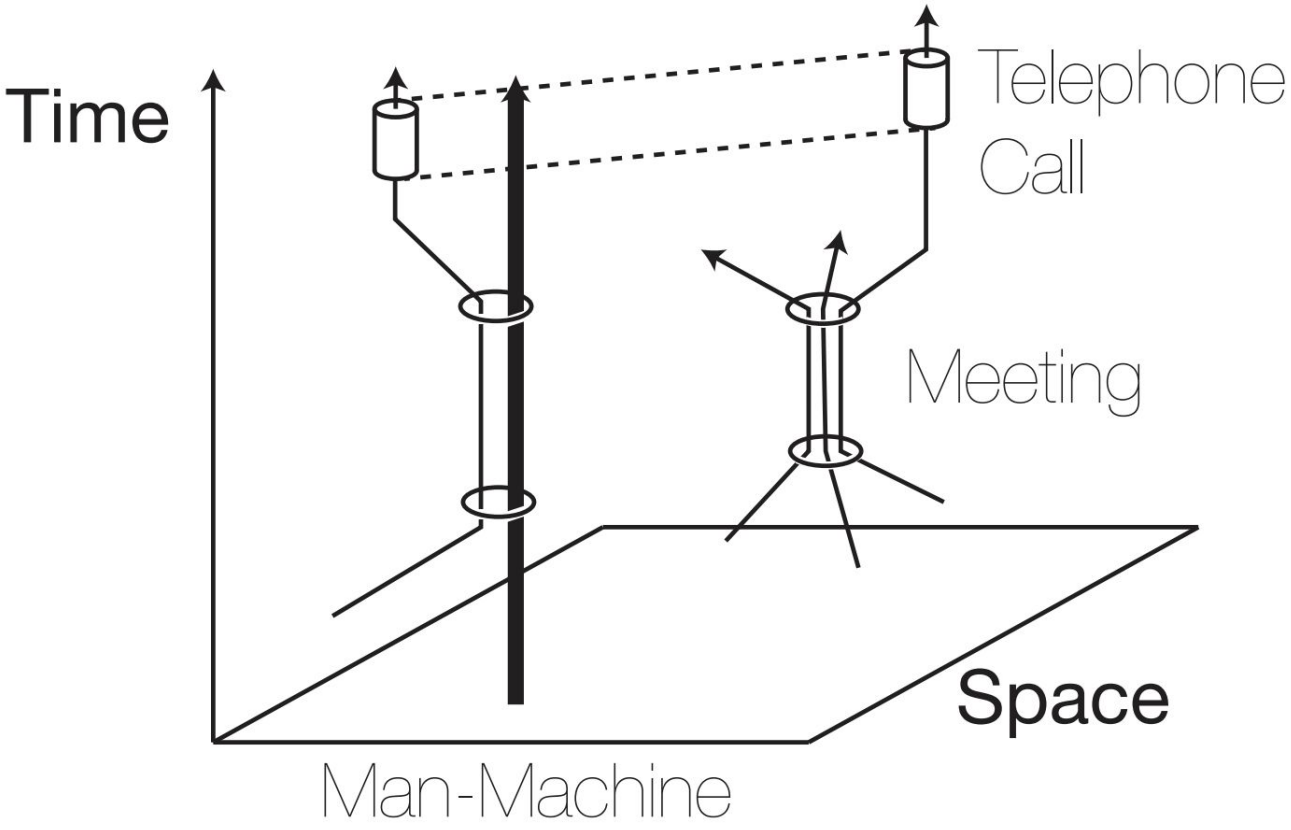


Charles Joseph Minard (1781-1870)

Space-Time Cubes

Space Time Cubes

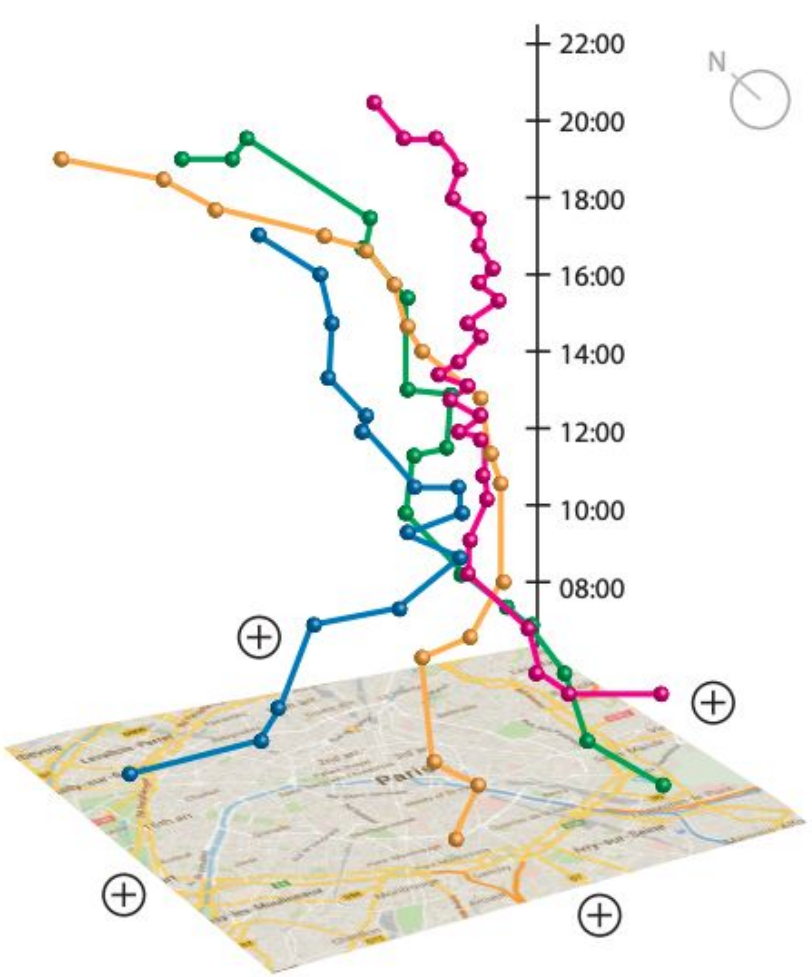
Space-Time Cubes



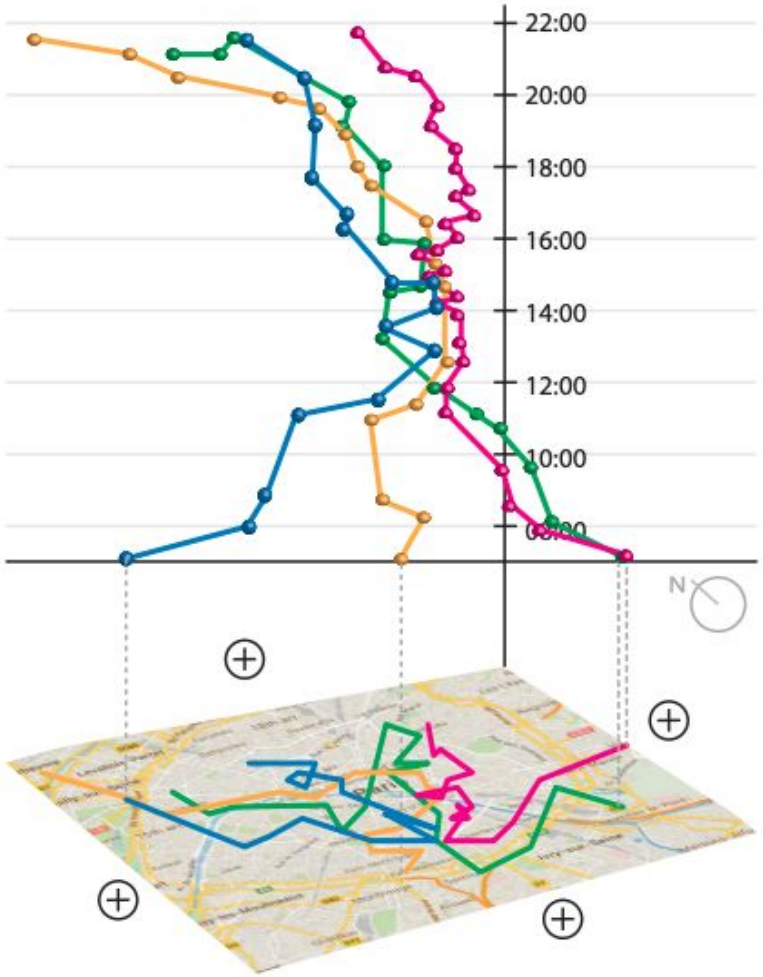
Ilägcrstrand, Torsten. "What about people in regional science?." *Papers of the Regional Science Association*. Vol. 24. 1970.

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

Space-Time Cubes

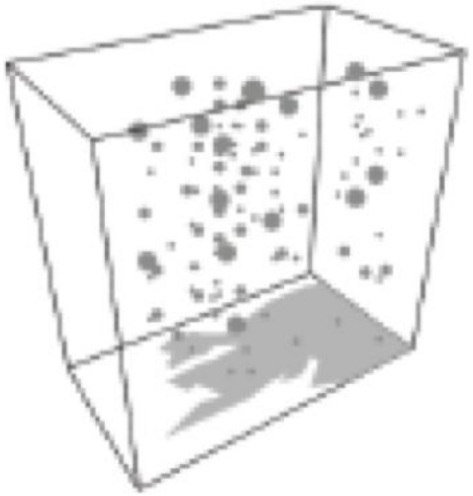


(a) 3D rendering

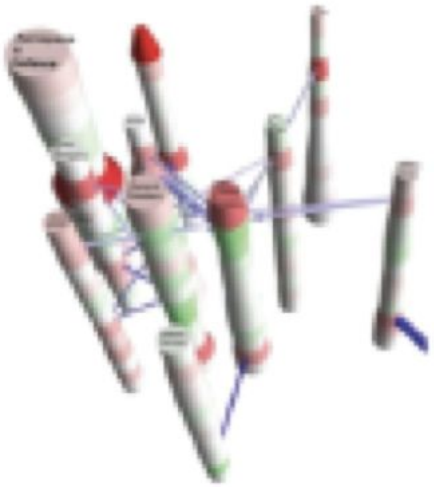


(b) Space flattening (on top)

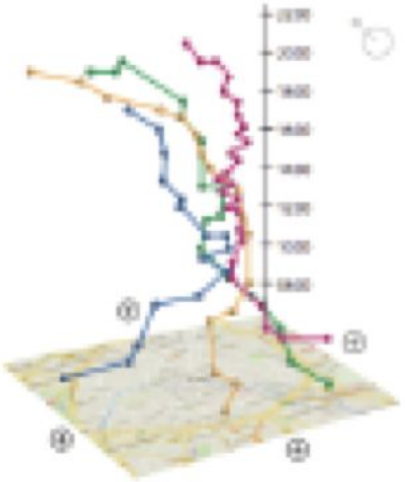
Space time cubes everywhere!



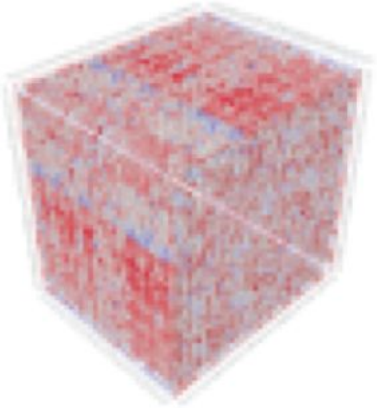
Earthquakes



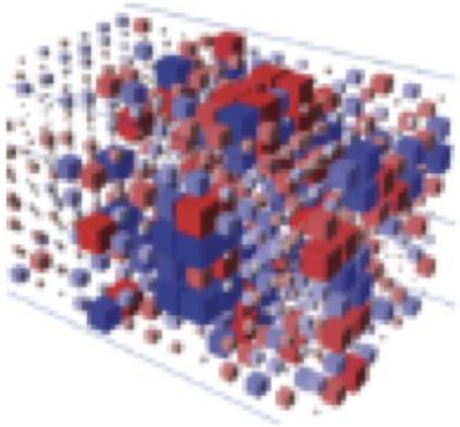
Finance network



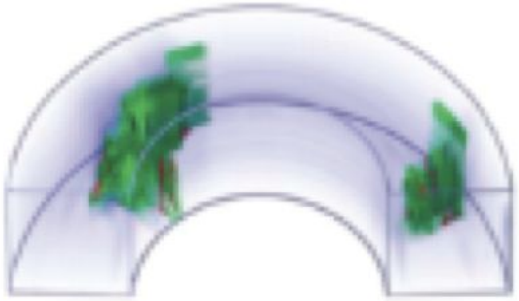
Person movement



Antenna communication



Brain connectivity

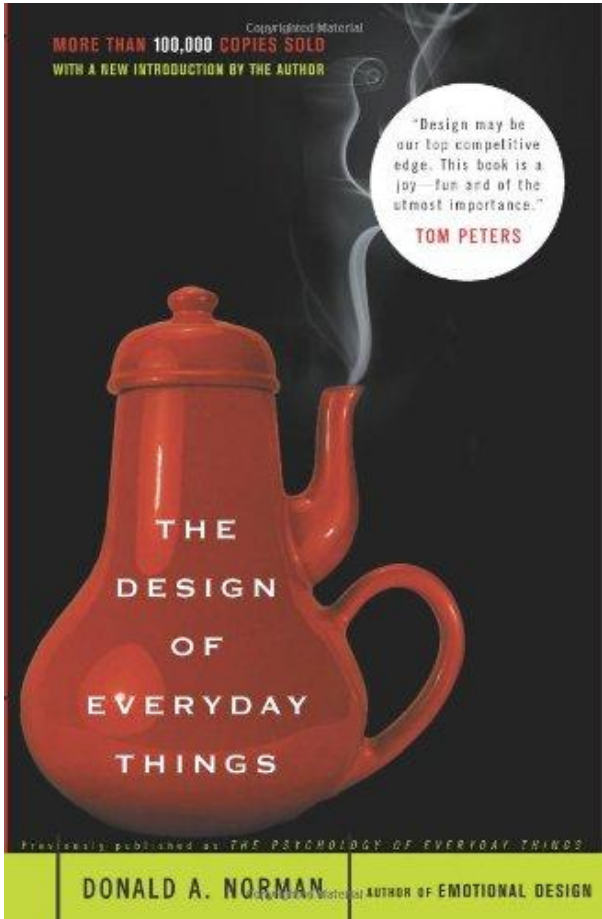


Surveillance video

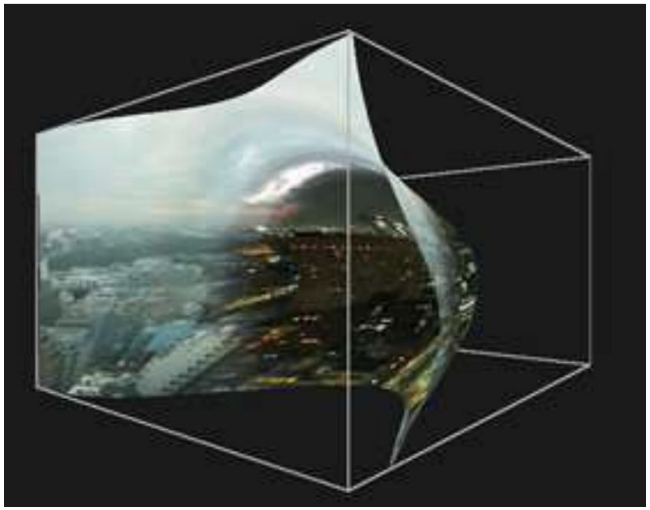
A word on 3D visualization

- Causes occlusion
- Perspective distortion
- Interaction required
- Orientation might be tricky

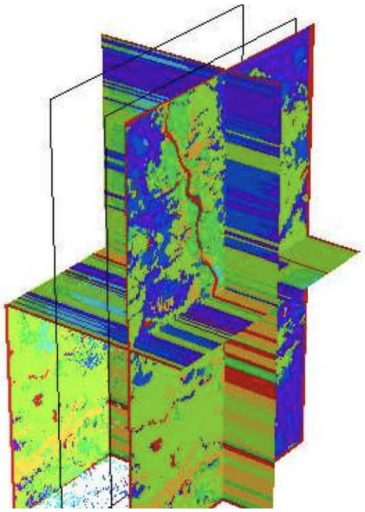
- *Use 3D as interaction affordances*
- *Use 3D as thinking tools and metaphors*



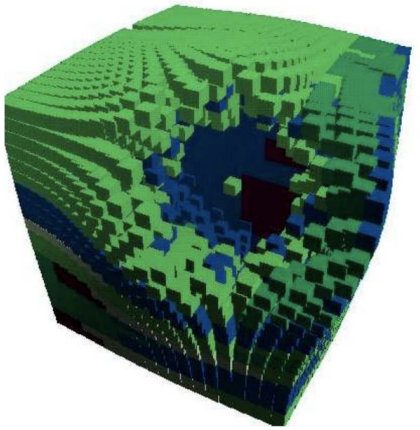
Interactive Exploration



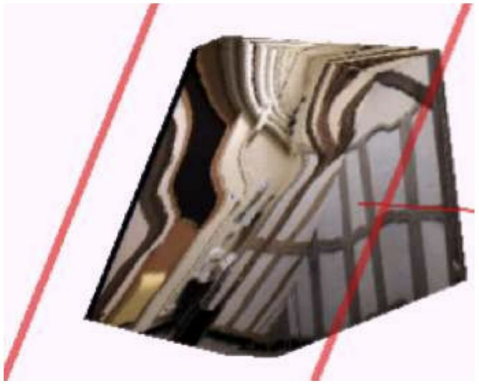
"Poke"-access



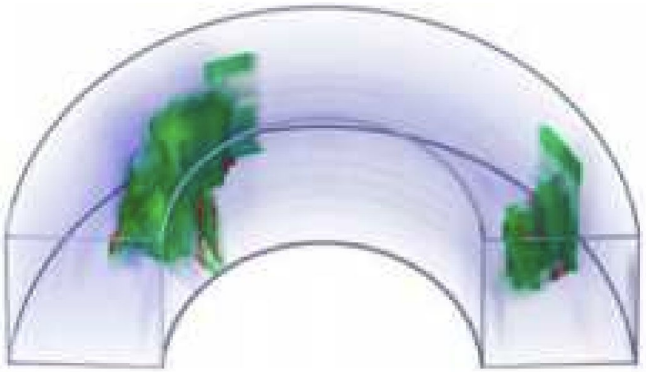
Cutting plane



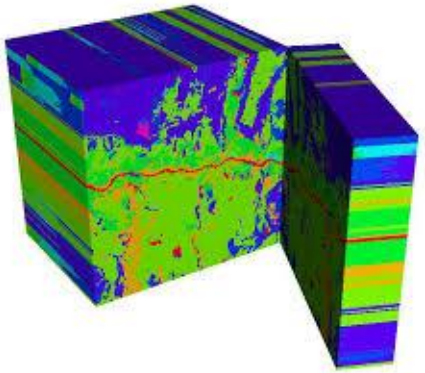
Mouse access



Cutting plane



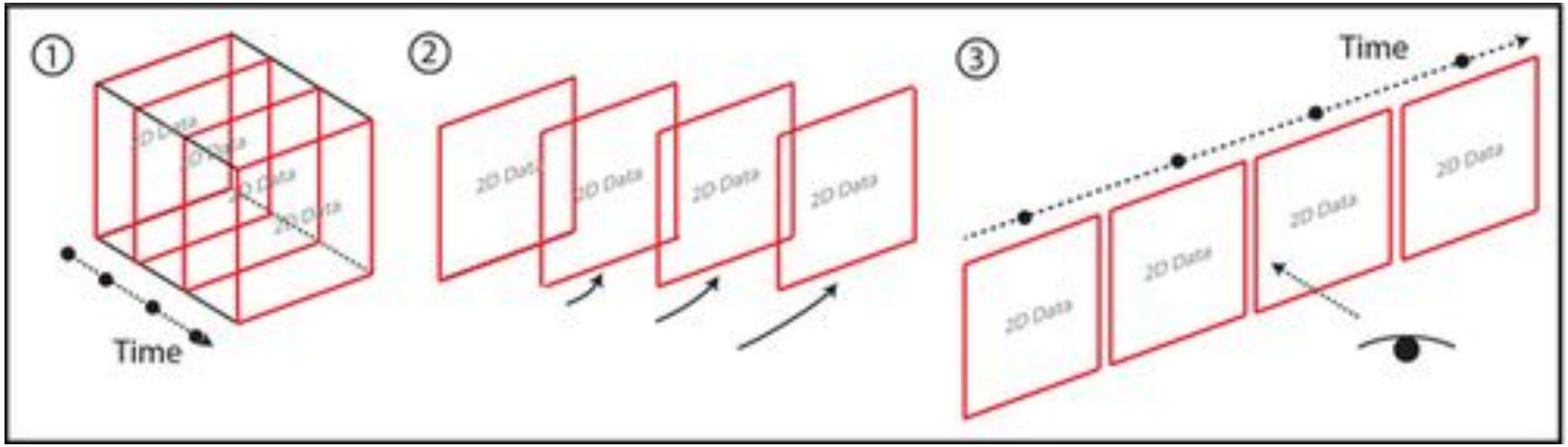
Transparency
+ bending



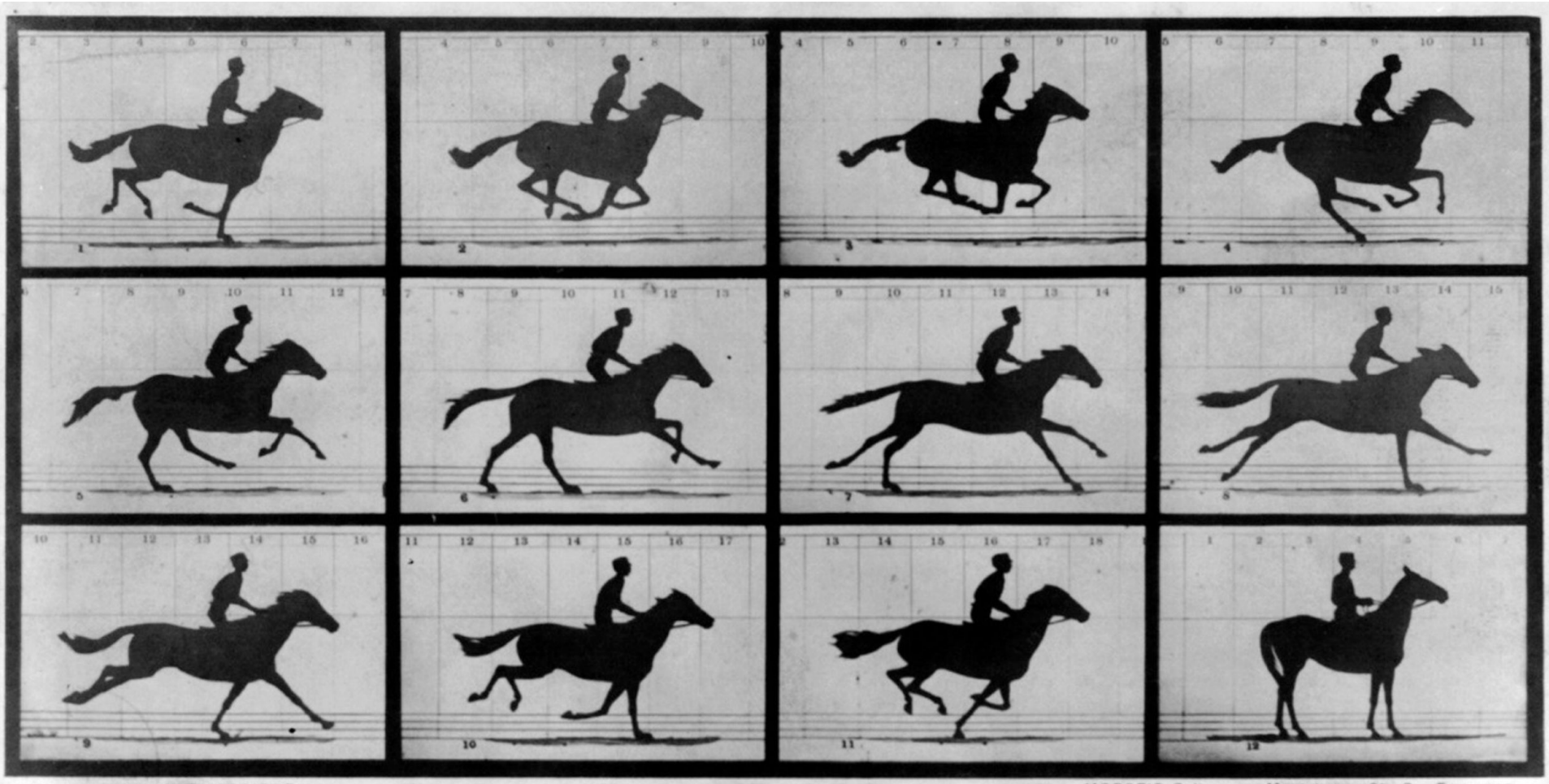
Opening

Interactive Exploration

Operations


①
2D Data
2D Data
2D Data
2D Data
Time
②
2D Data
2D Data
2D Data
2D Data
③
Time
2D Data
2D Data
2D Data
2D Data

Eadward Muybridge: Chrono photography



Copyright, 1878, by MUYBRIDGE.

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

THE HORSE IN MOTION.

Illustrated by

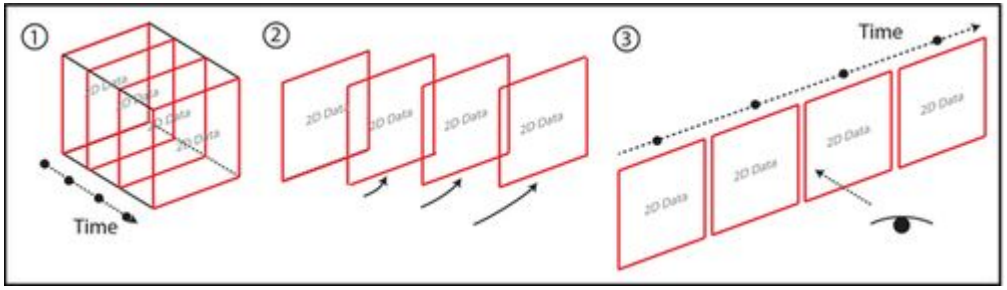
MUYBRIDGE.

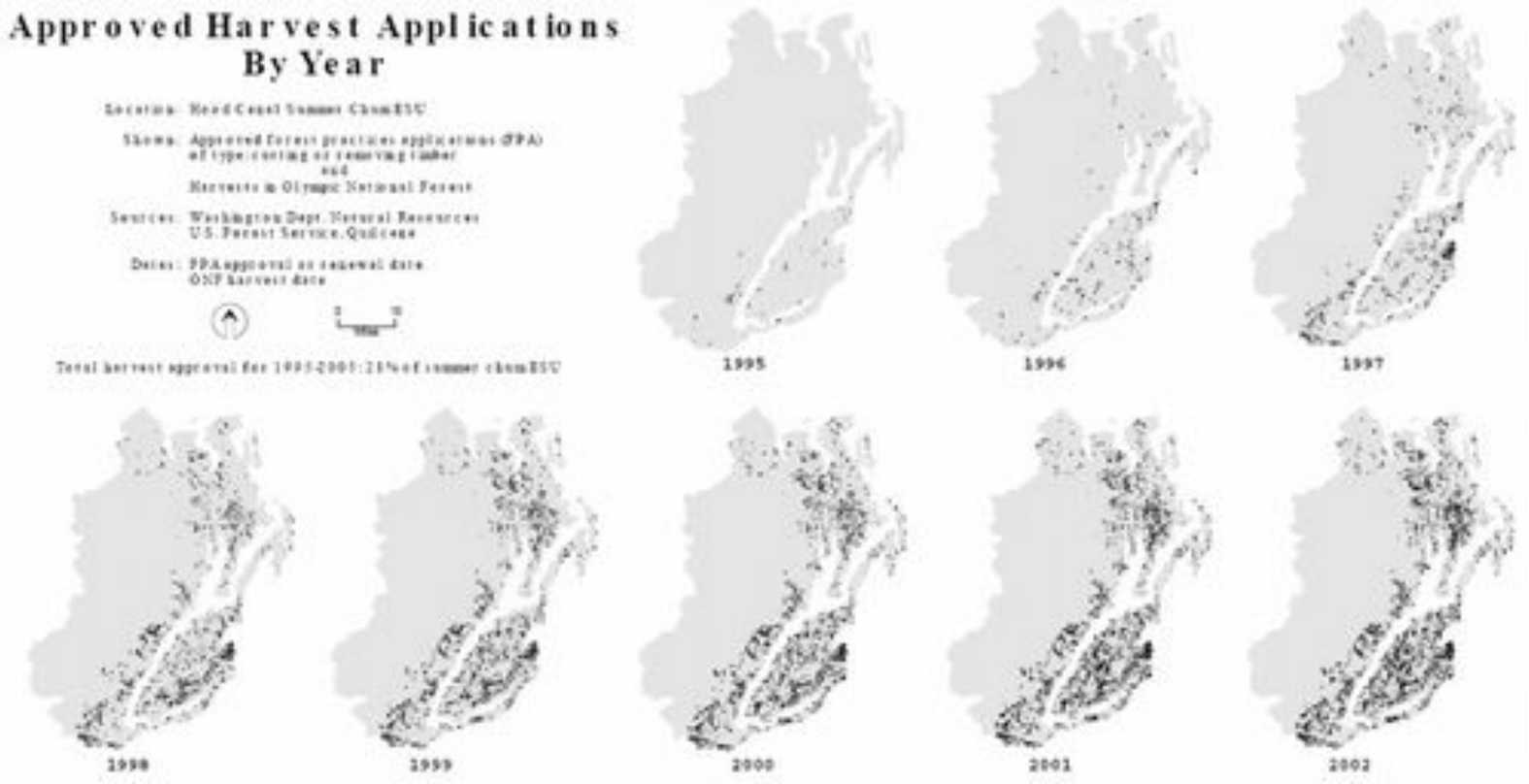
AUTOMATIC ELECTRO-PHOTOGRAPH.

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

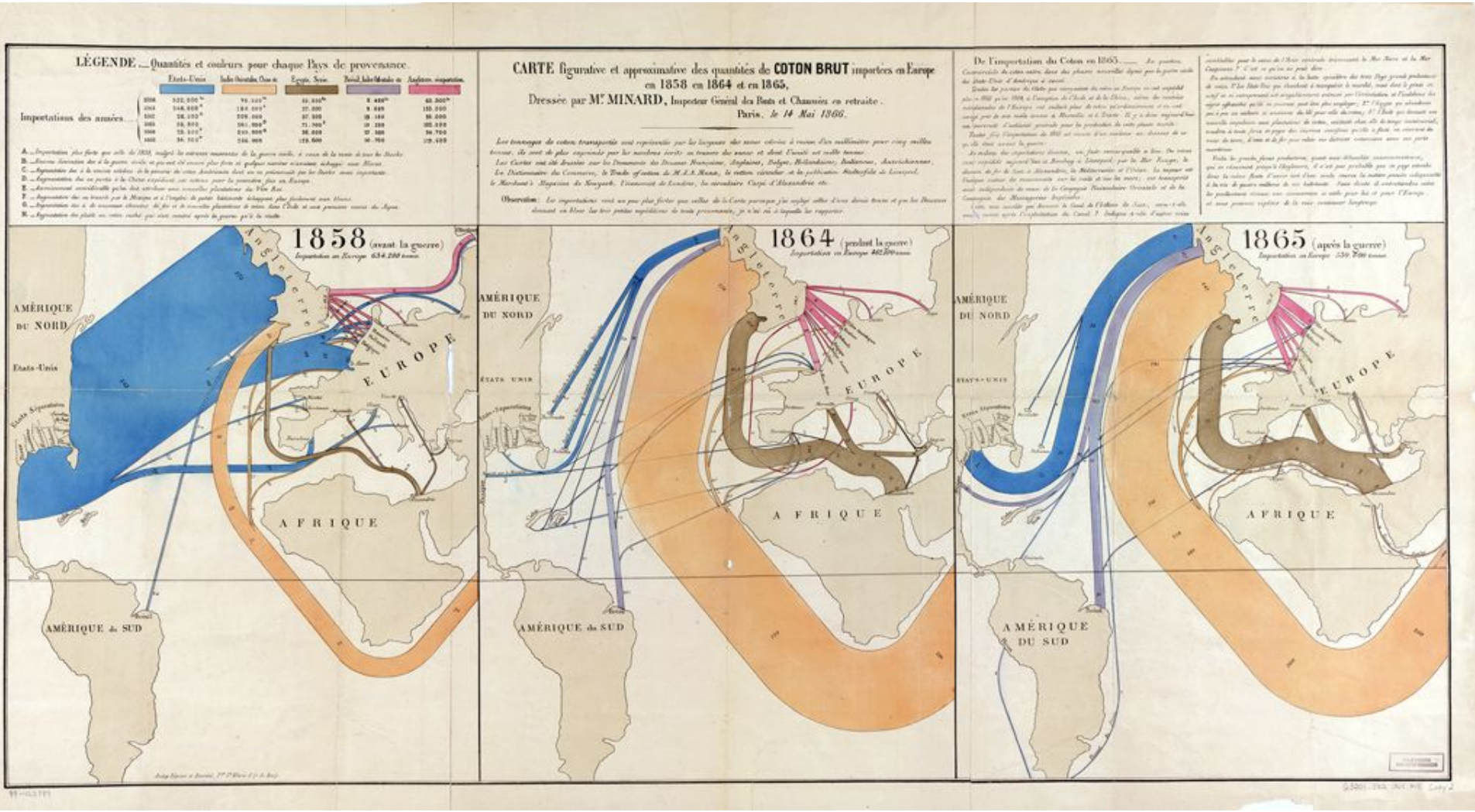
The negatives of these photographs were made at intervals of twenty-seven inches of distance, and about the twenty-fifth part of a second of time; they illustrate consecutive positions assumed in each twenty-seven inches of progress during a single stride of the mare. The vertical lines were twenty-seven 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.

Small Multiples



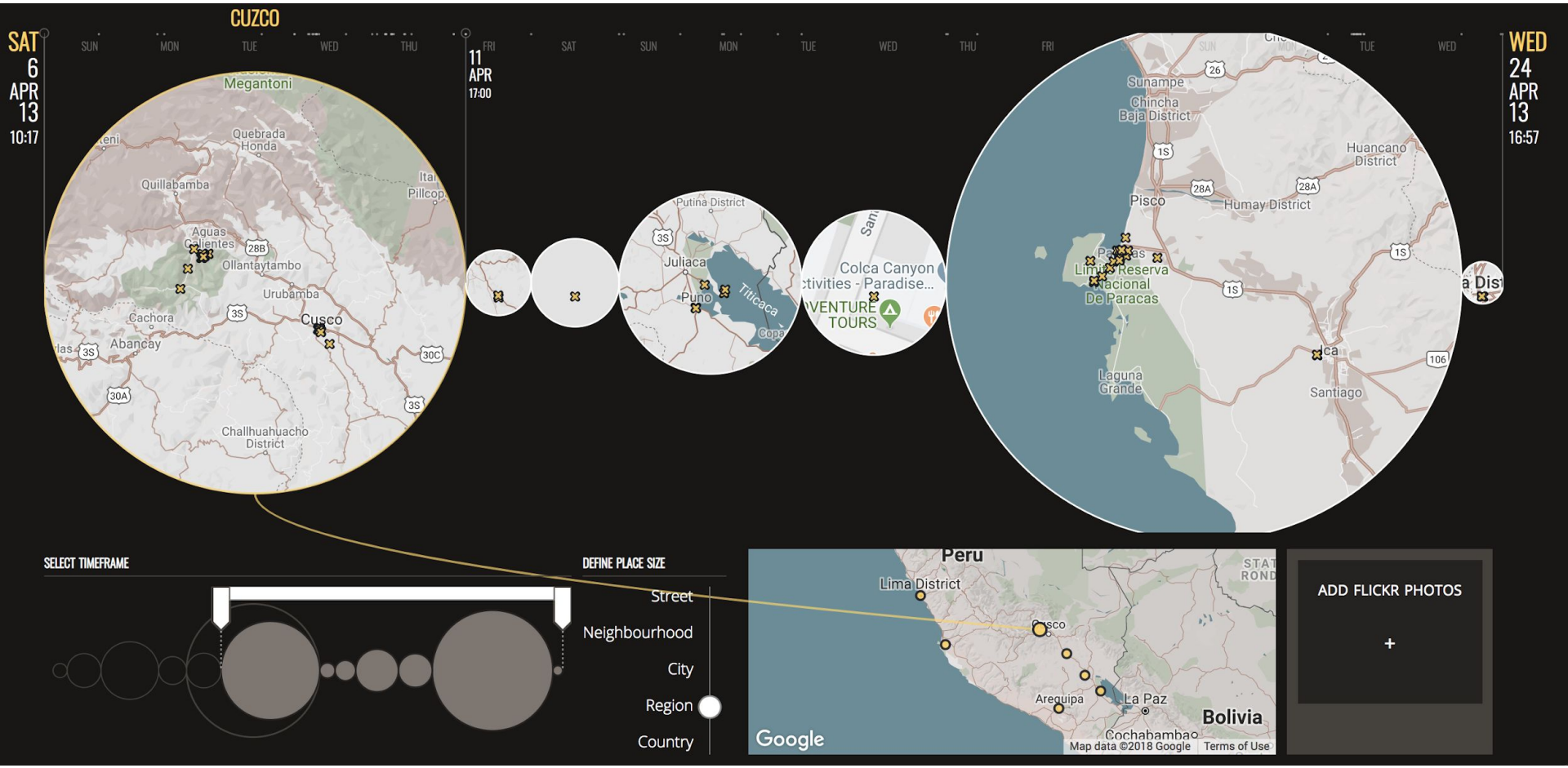


Flow Diagram Small Multiples



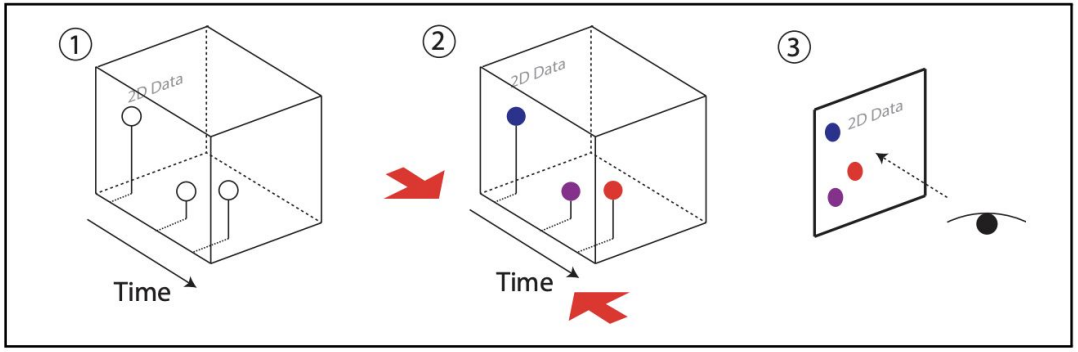
Joseph Minard

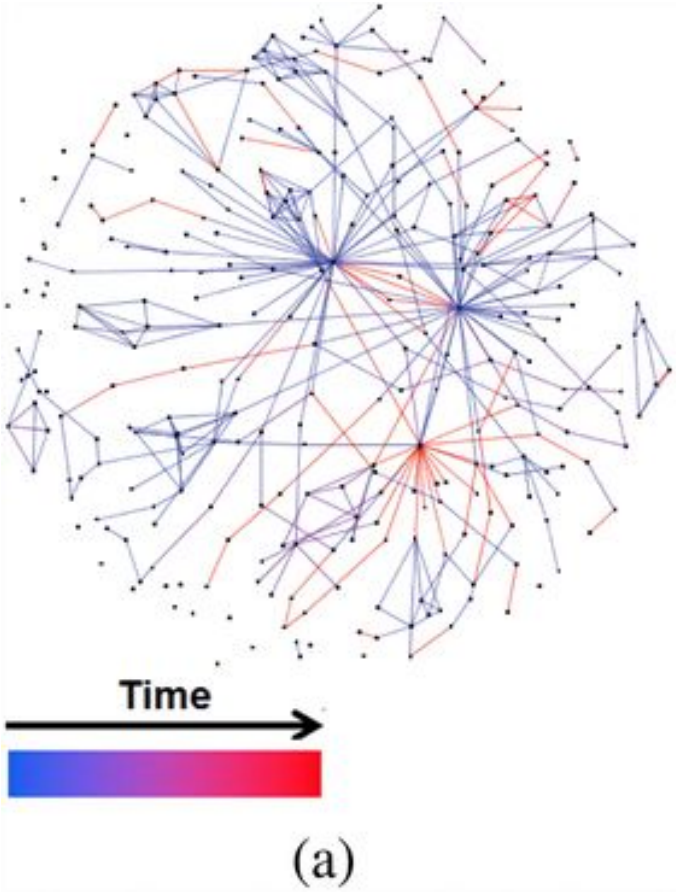
Small Multiples



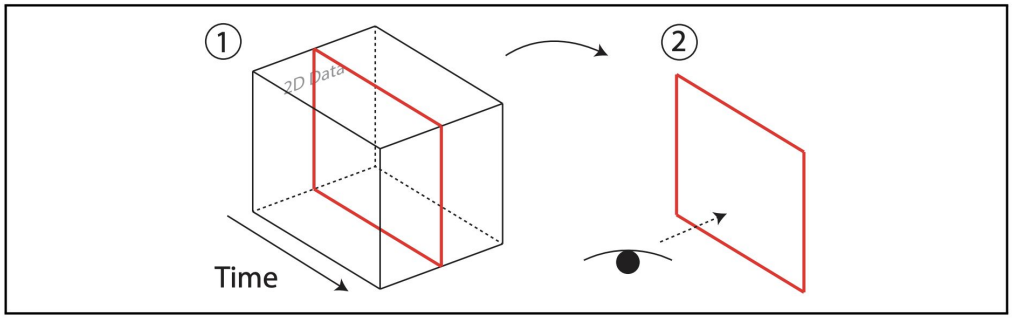
Thudt, Alice, Dominikus Baur, and Sheelagh Carpendale. "Visits: A Spatiotemporal Visualization of Location Histories." *EuroVis (Short Papers)*. 2013.

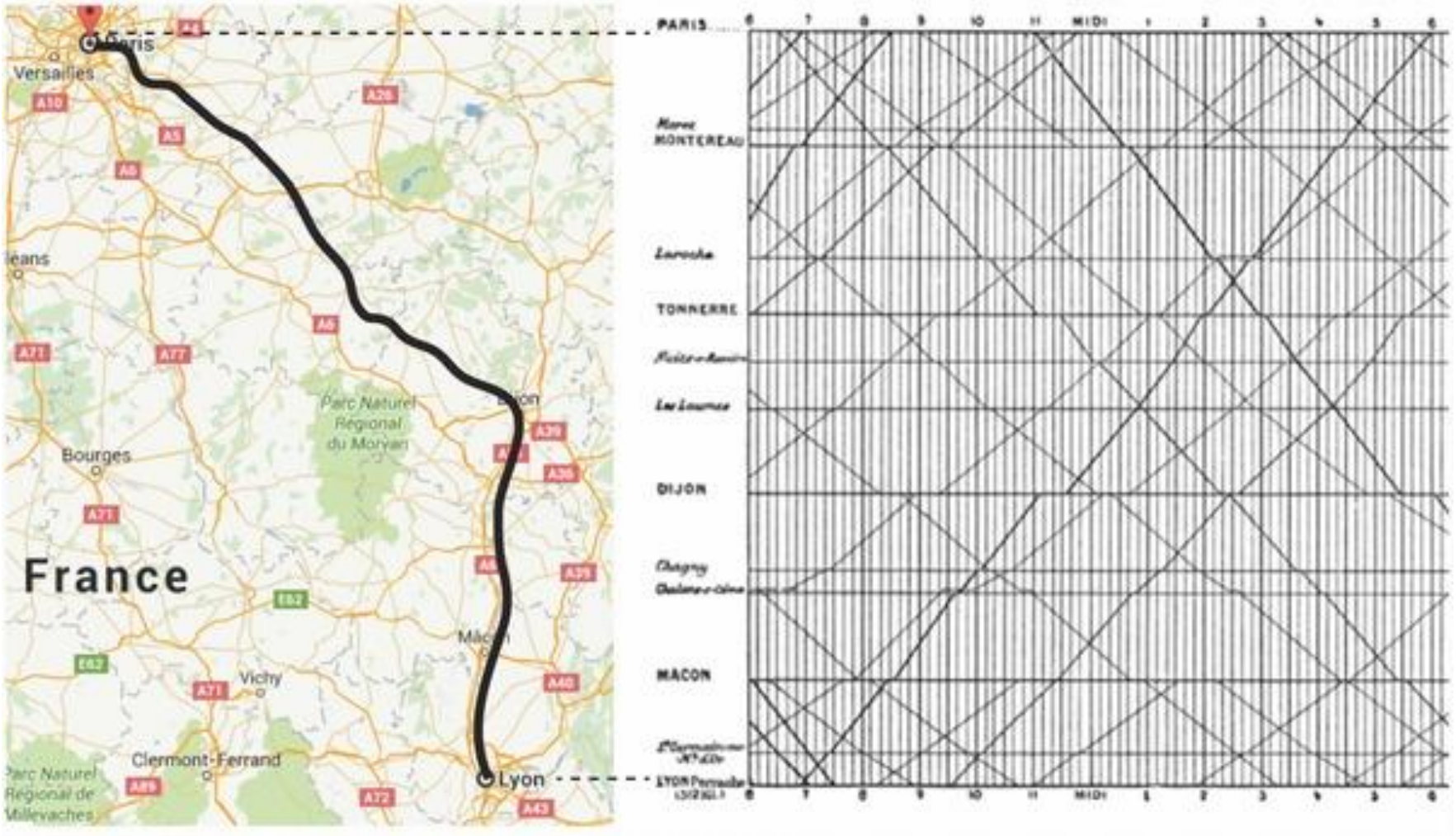
Coloring+ Flattening



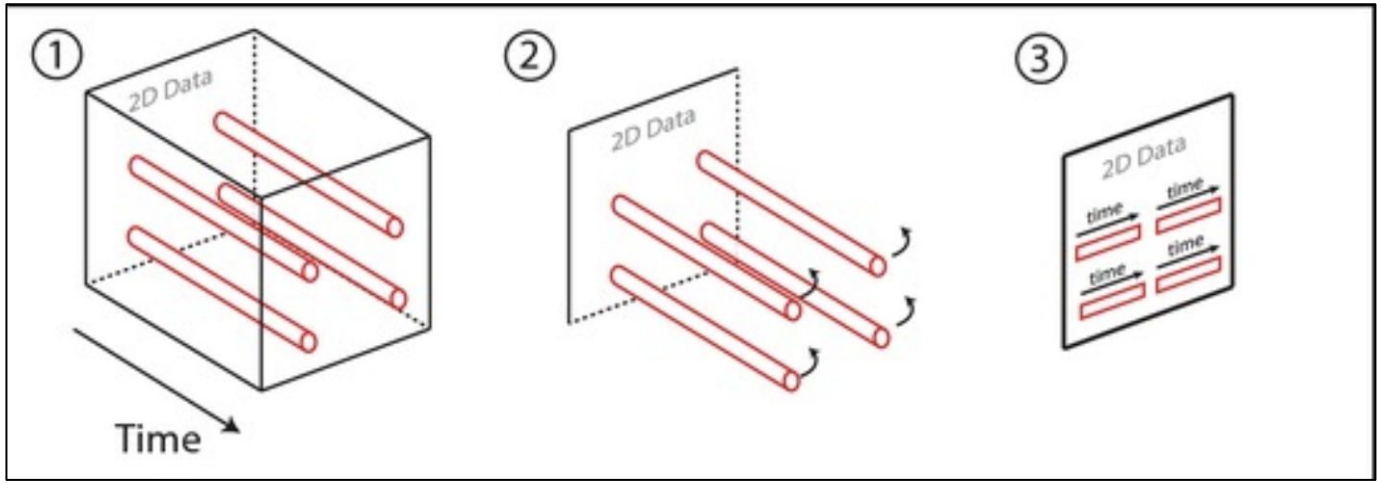


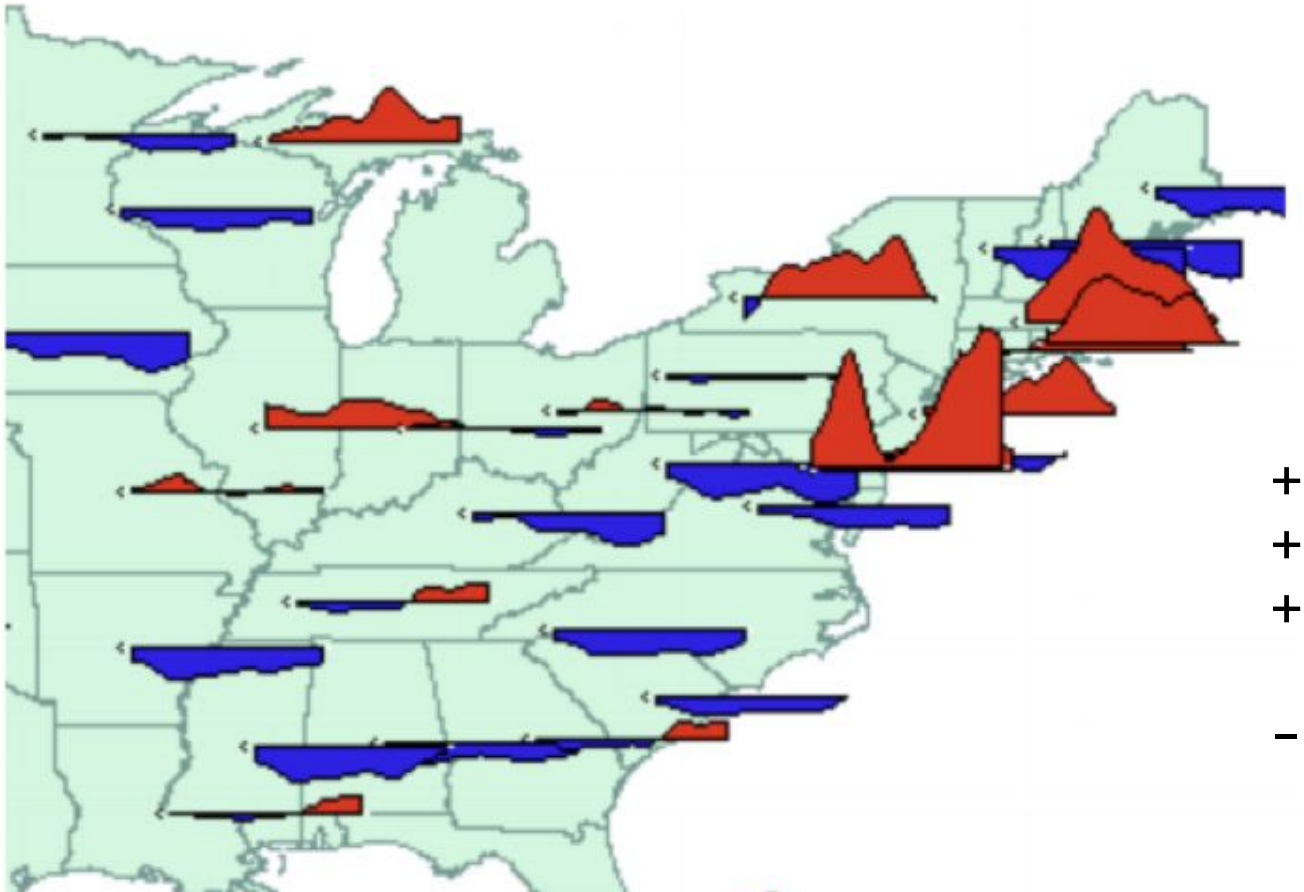
Cross-cutting





"Drilling"

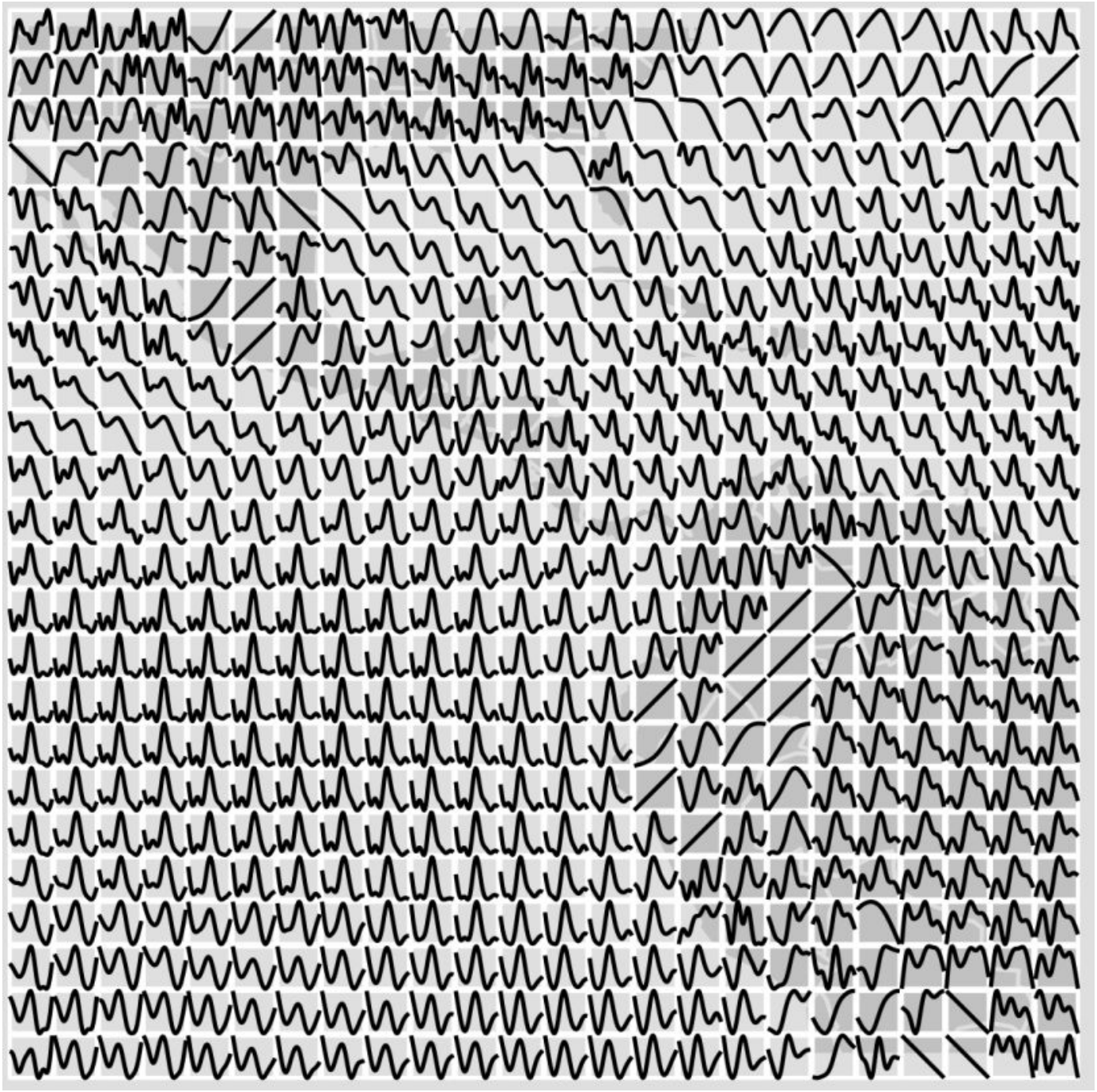




+ Compare regions
+ Look-up regions
+ Details on regions

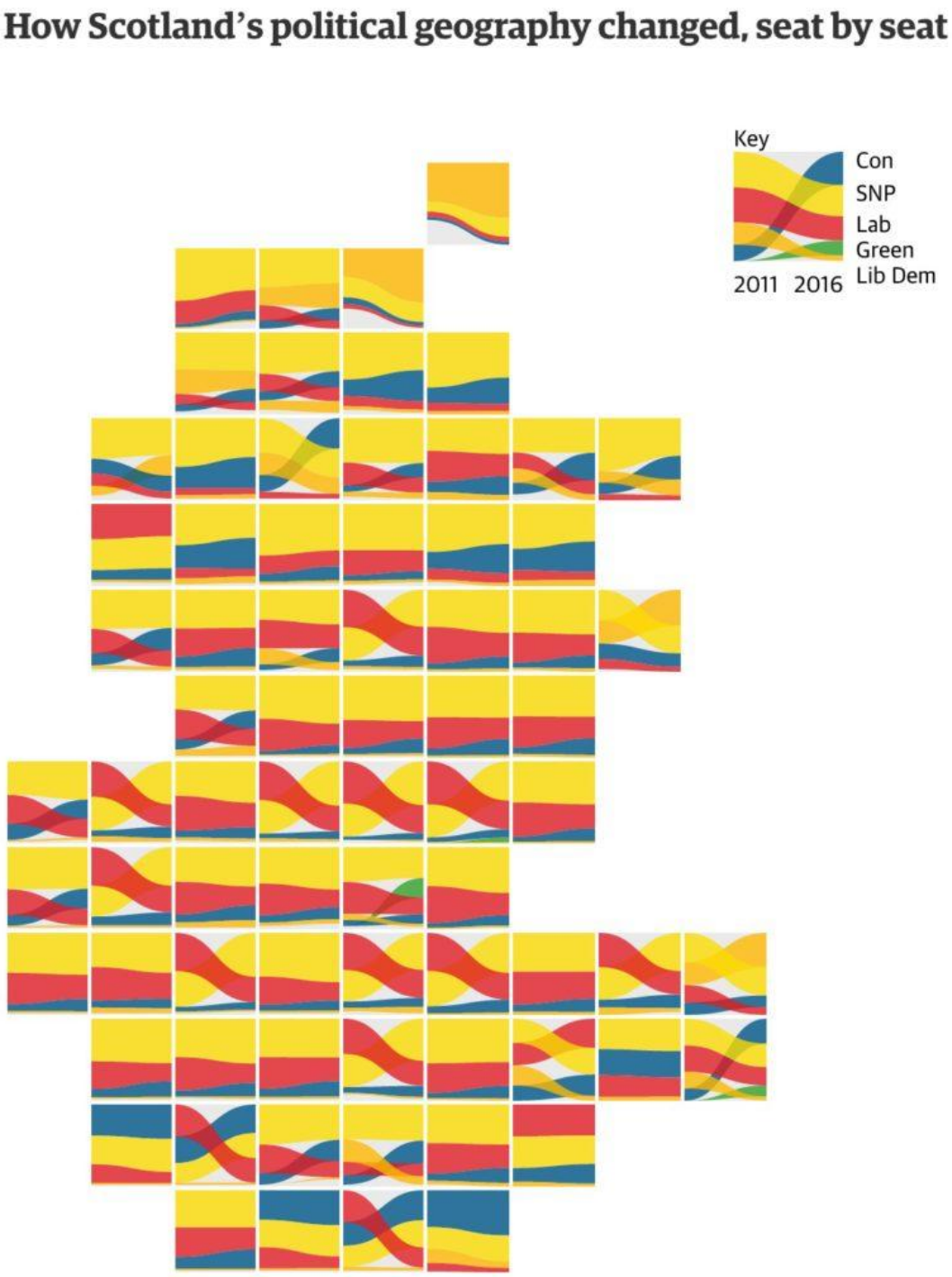
- Occlusion

Drilling: Glyph Maps



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

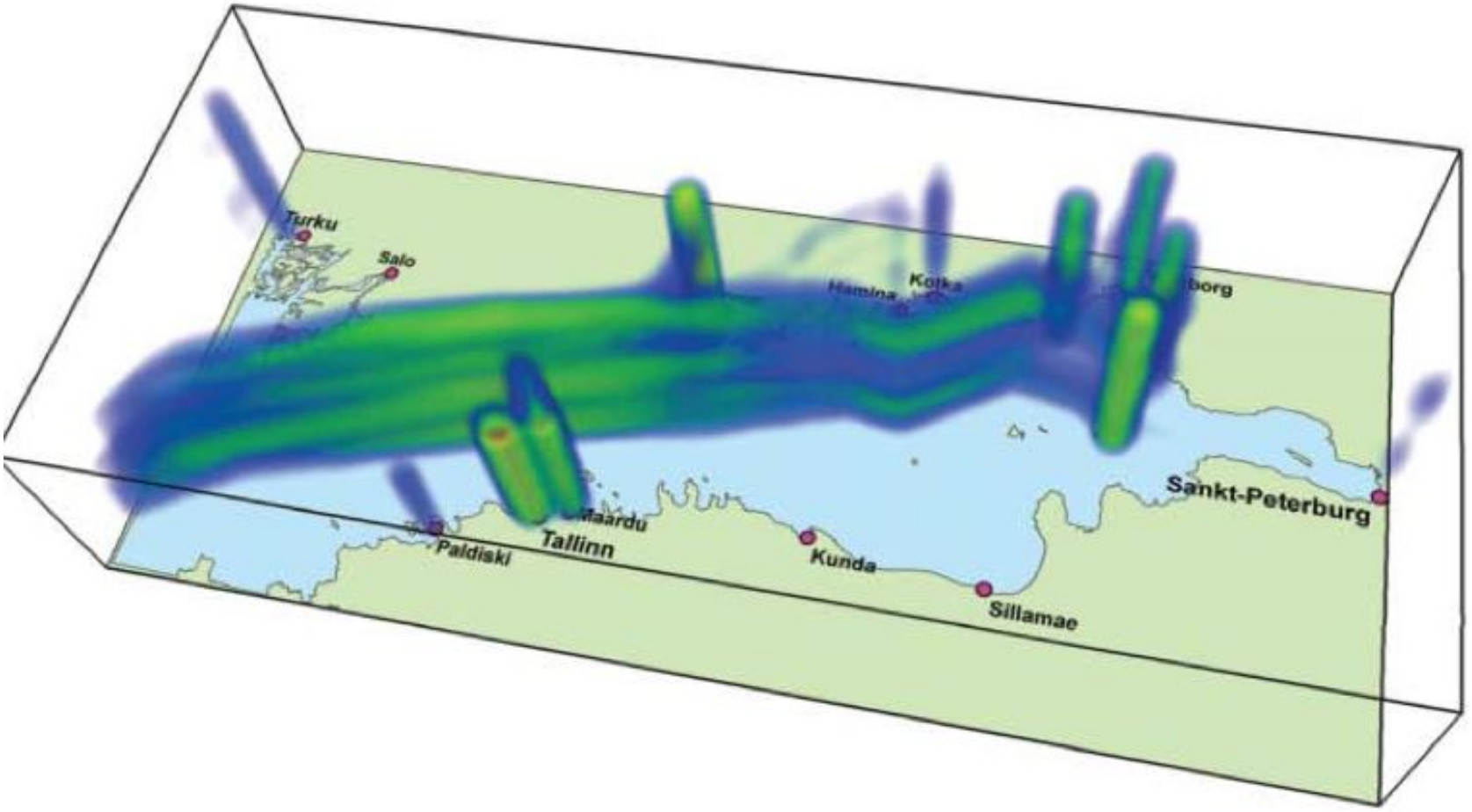
Drilling: Geo-flow



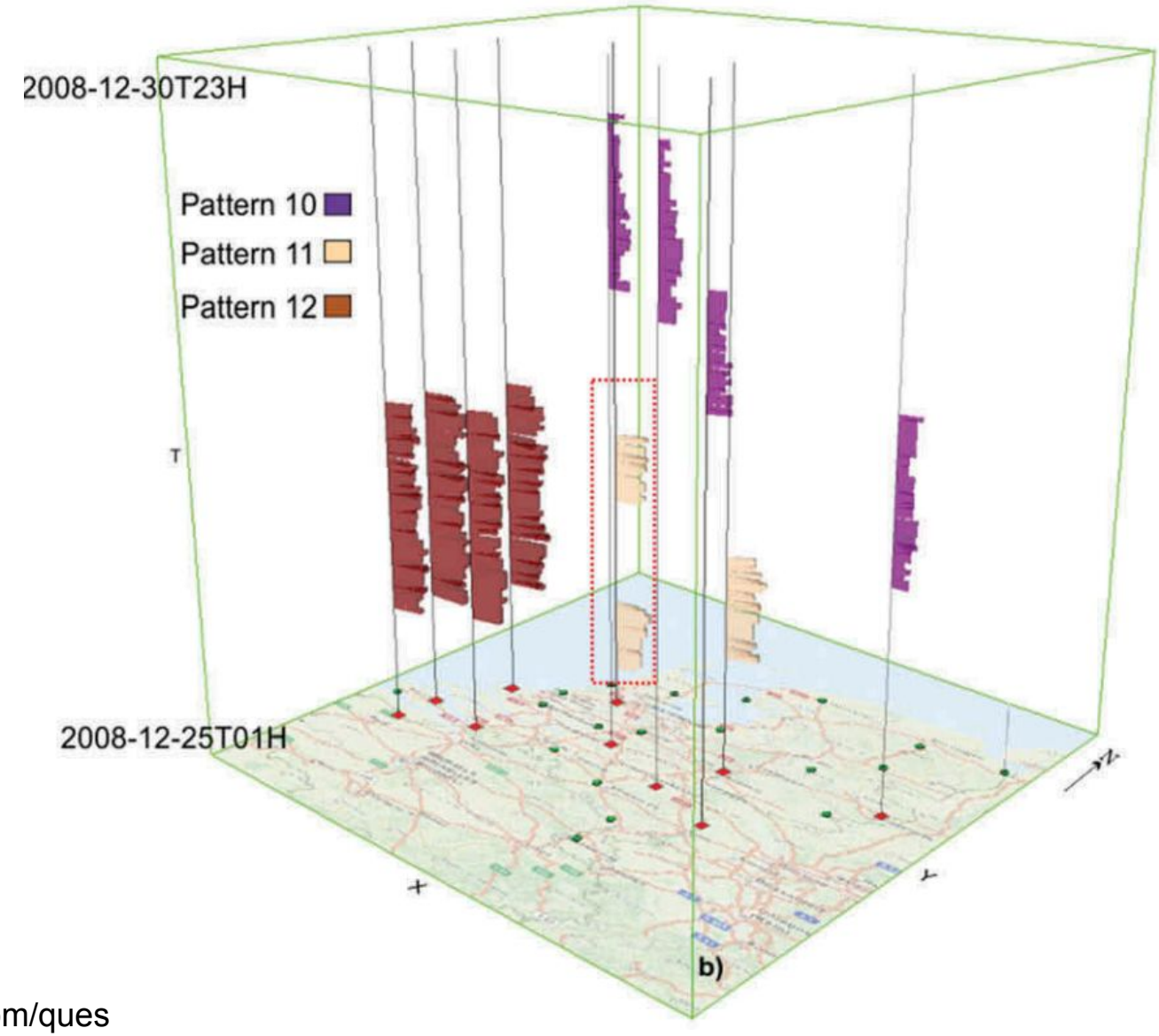
+ Compare regions
+ Look-up regions
+ Details on regions

- Compare far away glyphs
- Glyphs can become small

3D Renderings: density maps

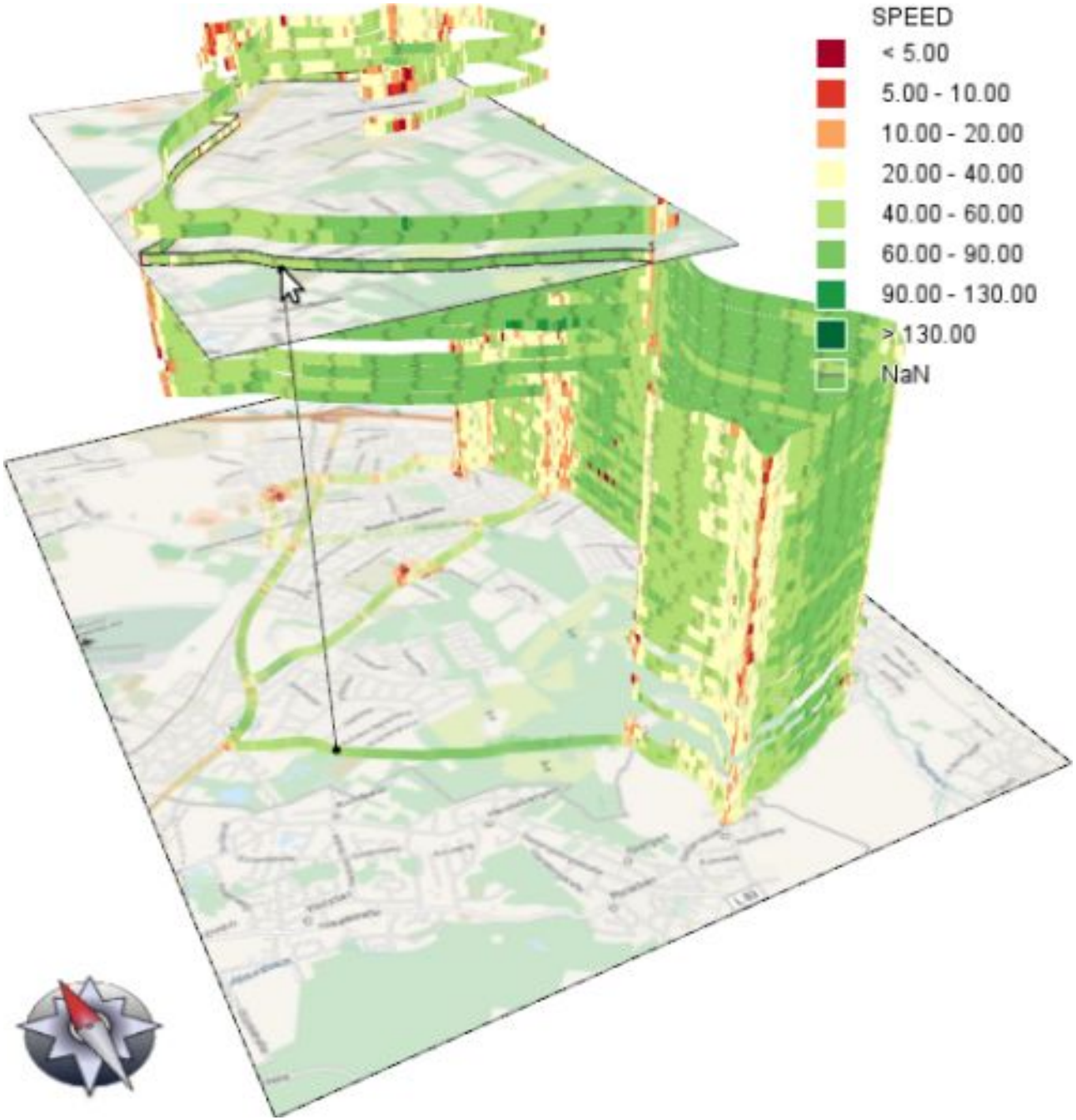


3D + drilling



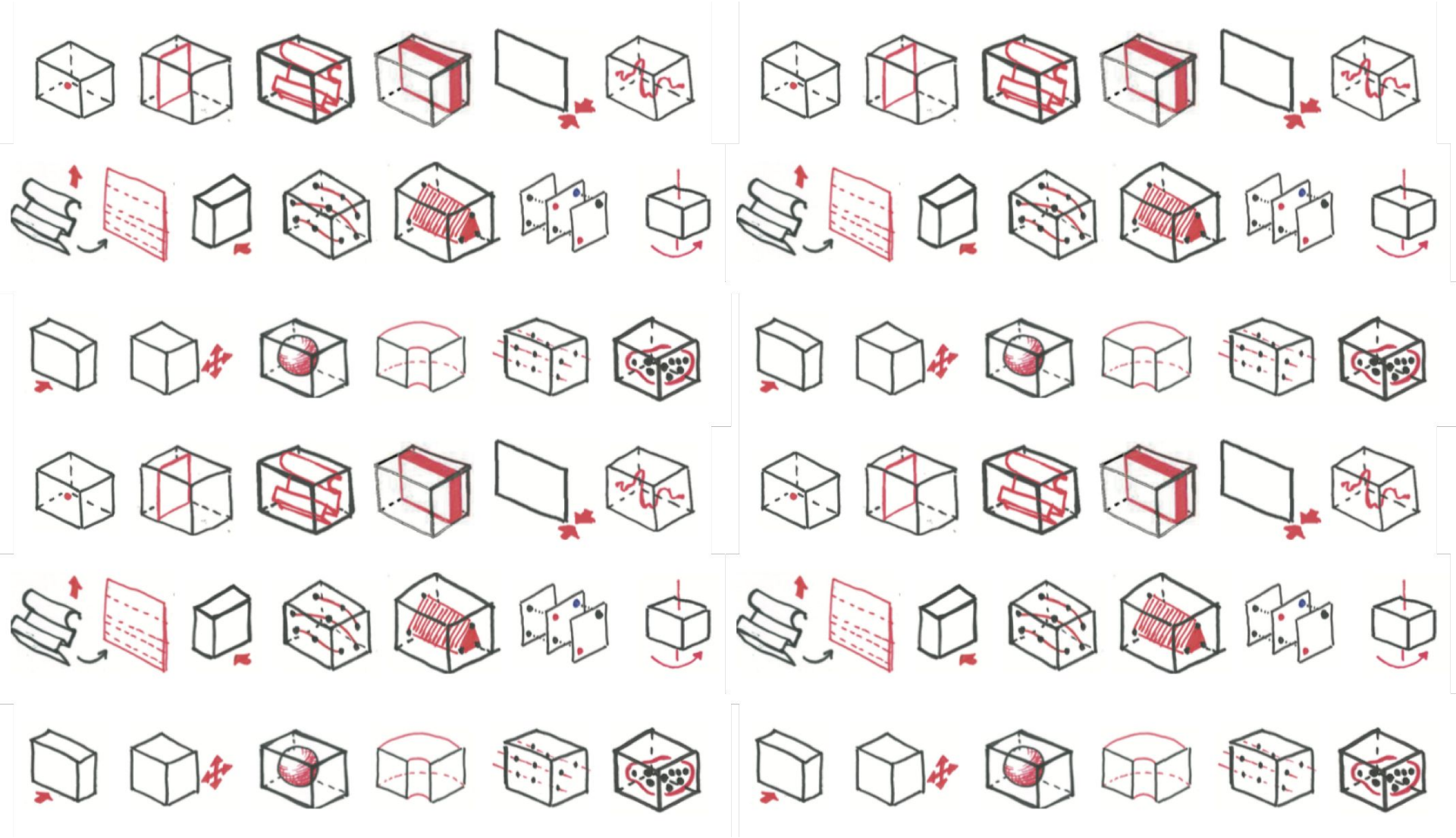
https://gis.stackexchange.com/questions/202882/create-space-time-cube-in-arcgis-for-desktop

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



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.

Khronos Proector

https://www.youtube.com/watch?v=dZN2ICTRWBU

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.