

Lesson 6: Visualising and Analysing Time-Oriented Data

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What will you learn from this lesson?

- Characteristics of time-series data
- Classic ways of graphing time
- Time-series patterns
- Time-series data visualization
- Interactive techniques for time-series data visualisation

Characteristics of time-series data

A typical time-series data table

Month/Year	Country	Air	Sea	Land
01/2015	World	948689	154708	149211
02/2015	World	900198	151618	137002
03/2015	World	940077	133632	127939
04/2015	World	939370	118120	151134
05/2015	World	945080	123136	154620
06/2015	World	930642	115631	138474
07/2015	World	1184753	139088	195392
08/2015	World	1136524	117490	191048
09/2015	World	925233	95408	111335
10/2015	World	991913	119491	135543
11/2015	World	930209	138730	135053
12/2015	World	1058414	195431	171133
01/2016	World	1073904	175961	162257
02/2016	World	1015346	160700	158983
03/2016	World	1072456	148638	183044
04/2016	World	1074475	131579	187293
05/2016	World	1029812	131450	194292
06/2016	World	989191	114080	166275
07/2016	World	1258176	145088	218392

Characteristics of time-series data

Not so friendly time-series data

Monthly and Annually Inflation Rate History Singapore from 1993 to 2016

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual Average Rate
2016	-0.60%	-0.80%	-1.00%	-0.40%	-1.60%	-0.80%	-0.70%	-	-	-	-	-	-
2015	-0.40%	-0.30%	-0.40%	-0.50%	-0.40%	-0.30%	-0.40%	-0.80%	-0.60%	-0.80%	-0.70%	-0.60%	-0.43%
2014	1.39%	0.34%	1.21%	2.54%	2.71%	1.83%	1.22%	0.86%	0.60%	0.03%	-0.34%	-0.17%	1.02%
2013	3.60%	4.90%	3.50%	1.50%	1.60%	1.80%	1.90%	2.00%	1.60%	2.00%	2.60%	1.48%	2.37%
2012	4.80%	4.60%	5.20%	5.40%	5.00%	5.30%	4.00%	3.90%	4.70%	4.00%	3.60%	4.30%	4.55%
2011	5.50%	5.00%	5.00%	4.50%	4.50%	5.20%	5.40%	5.70%	5.50%	5.40%	5.70%	5.50%	5.24%
2010	0.20%	1.00%	1.60%	3.20%	3.20%	2.70%	3.10%	3.30%	3.70%	3.50%	3.80%	4.60%	2.80%
2009	4.30%	3.30%	2.60%	0.30%	0.20%	0.00%	-0.30%	-0.30%	-0.50%	-0.90%	-0.80%	-0.50%	0.62%
2008	6.60%	6.50%	6.70%	7.50%	7.50%	7.50%	6.50%	6.40%	6.70%	6.40%	5.50%	5.50%	6.60%
2007	-0.60%	-0.10%	0.20%	0.40%	1.30%	1.70%	3.00%	3.50%	3.00%	4.10%	4.90%	3.70%	2.20%
2006	1.70%	1.20%	1.20%	1.10%	1.10%	1.40%	1.10%	0.70%	0.40%	0.40%	0.50%	0.80%	0.95%

Characteristics of time-series data

Not so friendly time-series data

Visitor Arrivals Statistics																	
Updated 10 Feb 2011																	
ALL MODE OF ARRIVAL (AIR / SEA / LAND)																	
Country of Residence	Jan 2010	Feb 2010	Mar 2010	Apr 2010	May 2010	Jun 2010	Jul 2010	Aug 2010	Sep 2010	Oct 2010	Nov 2010	Dec 2010	Jan_2010	Feb 2010	Year-On-Year % Change		
TOTAL	939,490	957,287	928,720	938,604	948,473	950,928	1,084,562	999,911	947,281	978,731	963,938	1,127,429	11,938,983	11,938,983	20.2		
AMERICAS	44,990	39,868	46,896	43,098	40,114	46,319	60,466	44,116	34,749	46,981	49,986	44,763	624,881	624,881	12.2		
Canada	6,950	6,424	7,048	6,733	5,496	4,969	6,645	6,397	4,336	6,161	6,486	7,623	75,137	75,137	7.3		
USA	36,514	31,166	37,102	33,454	32,108	39,016	41,162	34,194	27,932	36,697	34,311	34,334	416,990	416,990	12.5		
Other Countries In Americas	2,526	2,078	2,485	2,819	2,550	2,325	2,648	3,524	2,481	3,103	3,169	2,796	32,504	32,504	20.5		
ASIA	627,002	627,581	661,040	697,441	736,393	731,922	831,322	743,847	720,118	726,367	712,178	860,904	8,676,135	8,676,135	25.8		
Southeast Asia	231,914	200,137	260,052	290,263	402,078	433,791	466,886	361,637	447,643	410,299	391,262	633,440	4,019,761	4,019,761	30.6		
Brunei Darussalam	5,245	4,139	5,692	3,943	4,796	5,963	5,578	4,244	4,629	3,750	4,573	9,513	52,154	52,154	10.0		
Indonesia	173,629	143,917	165,942	152,800	185,757	214,362	232,528	165,483	243,763	178,903	175,969	262,056	2,305,149	2,305,149	32.1		
Malaysia	67,941	68,663	81,746	77,441	81,867	93,079	82,592	75,867	95,485	82,746	99,933	129,599	1,036,918	1,036,918	35.7		
Myanmar	5,512	4,492	7,000	9,591	6,556	6,232	6,877	5,838	5,376	6,482	5,953	8,276	78,164	78,164	11.3		
Philippines	32,703	32,510	43,956	54,448	55,307	44,484	43,440	39,244	40,662	52,007	50,292	55,482	544,344	544,344	26.0		
Thailand	34,636	23,153	31,813	50,695	38,921	30,710	37,286	34,790	30,709	37,950	30,192	39,238	430,822	430,822	36.3		
Vietnam	19,109	20,477	21,336	26,680	26,152	36,986	40,869	32,843	24,331	24,691	21,246	26,643	322,863	322,863	21.6		
Other Countries In Southeast Asia	3,130	2,786	2,699	4,705	3,723	3,364	3,795	3,639	2,719	3,771	3,324	2,723	40,127	40,127	21.5		
North Asia	212,272	267,600	212,602	209,699	191,367	163,940	266,763	293,017	166,646	213,442	217,610	230,600	2,050,640	2,050,640	29.1		
Hong Kong SAR	19,415	24,904	26,246	26,960	32,046	32,180	46,726	46,695	28,467	32,833	29,947	32,428	387,552	387,552	31.6		
Japan	37,747	40,666	51,834	35,160	36,819	36,447	44,646	56,844	44,999	43,493	51,527	48,838	528,817	528,817	7.9		
P R China	98,918	143,050	88,031	91,701	71,628	69,080	117,775	130,566	74,434	92,600	93,998	99,596	1,171,337	1,171,337	25.0		
South Korea	39,437	29,589	30,113	34,781	32,169	30,032	32,668	34,169	25,653	29,008	27,814	25,260	360,673	360,673	32.6		
Taiwan	16,510	17,737	15,219	14,508	17,111	13,542	23,933	20,969	13,486	13,851	13,131	12,186	191,173	191,173	22.0		
Other Countries In North Asia	1,246	1,554	1,360	1,889	1,595	2,649	3,005	3,984	1,506	1,657	1,493	2,151	34,088	34,088	74.6		
South Asia	74,021	62,674	70,799	94,410	133,267	102,883	66,626	76,337	71,180	92,950	80,479	96,062	1,046,200	1,046,200	12.6		
Bangladesh	7,762	5,726	7,747	7,528	7,703	8,524	9,373	7,144	7,942	7,543	7,438	7,879	92,309	92,309	6.6		
India	57,404	46,061	53,965	73,214	115,965	83,467	64,905	57,107	54,825	75,587	72,918	73,515	828,903	828,903	14.2		
Nepal	1,619	1,011	1,286	1,222	1,188	1,004	1,242	1,196	912	1,372	1,005	1,346	14,303	14,303	-5.8		
Pakistan	1,585	1,292	1,662	1,707	1,565	2,826	3,907	1,510	1,125	1,469	1,401	1,776	21,925	21,925	-1.6		
Sri Lanka	4,770	4,734	5,373	9,960	6,043	5,750	6,206	7,816	5,759	6,295	5,785	10,476	78,967	78,967	12.8		
Other Countries In South Asia	881	750	766	779	813	892	895	564	617	734	892	1,170	9,793	9,793	6.8		
West Asia	6,796	10,370	17,367	9,160	8,691	11,628	20,160	13,660	12,780	9,646	13,607	10,819	140,644	140,644	26.2		
Iran	1,779	4,042	10,024	1,184	1,448	2,118	2,032	2,727	4,180	2,215	2,512	2,669	36,930	36,930	54.4		
Israel	1,277	997	1,175	956	1,029	1,174	918	1,198	785	1,109	1,310	903	12,631	12,631	17.9		
Kuwait	443	587	468	305	451	806	2,548	719	535	380	723	403	8,368	8,368	45.5		
Saudi Arabia	512	714	689	1,038	771	941	2,400	972	1,345	902	1,554	793	12,631	12,631	16.8		
United Arab Emirates	3,686	3,036	3,841	4,301	3,764	4,620	8,870	6,132	4,299	3,683	5,729	4,913	56,474	56,474	14.0		
Other Countries In West Asia	1,098	994	1,160	1,385	1,228	1,969	3,388	1,908	1,606	1,357	1,679	1,538	19,310	19,310	19.8		

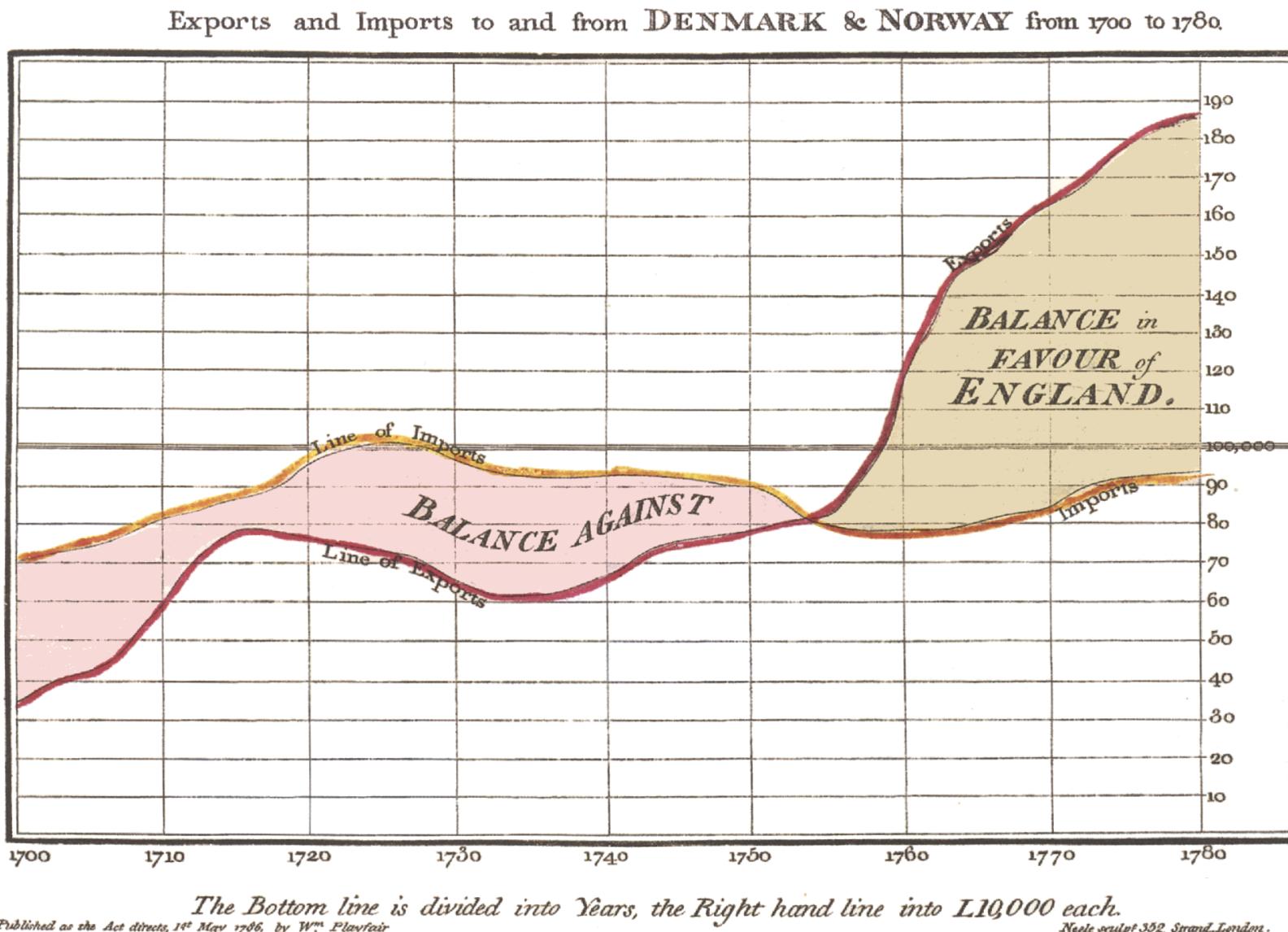
Characteristics of time-series data

Not so friendly time-series data

END OF PERIOD	S\$ PER UNIT OF EURO	S\$ PER UNIT OF POUND STERLING	S\$ PER UNIT OF US DOLLAR	S\$ PER 100 UNITS OF AUSTRALIAN DOLLAR
2015 Jan 02	1.5994	2.0633	1.3264	107.84
05	1.5953	2.0415	1.3352	107.70
06	1.5940	2.0366	1.3347	108.47
07	1.5861	2.0226	1.3353	107.91
08	1.5823	2.0194	1.3375	108.51
09	1.5780	2.0175	1.3366	108.80
12	1.5790	2.0201	1.3318	109.82
13	1.5806	2.0247	1.3337	109.22
14	1.5731	2.0244	1.3360	108.06
15	1.5716	2.0323	1.3340	109.24
16	1.5418	2.0119	1.3246	109.16
19	1.5354	2.0106	1.3280	109.03
20	1.5494	2.0163	1.3379	109.28

A short visual history of time-series graphs

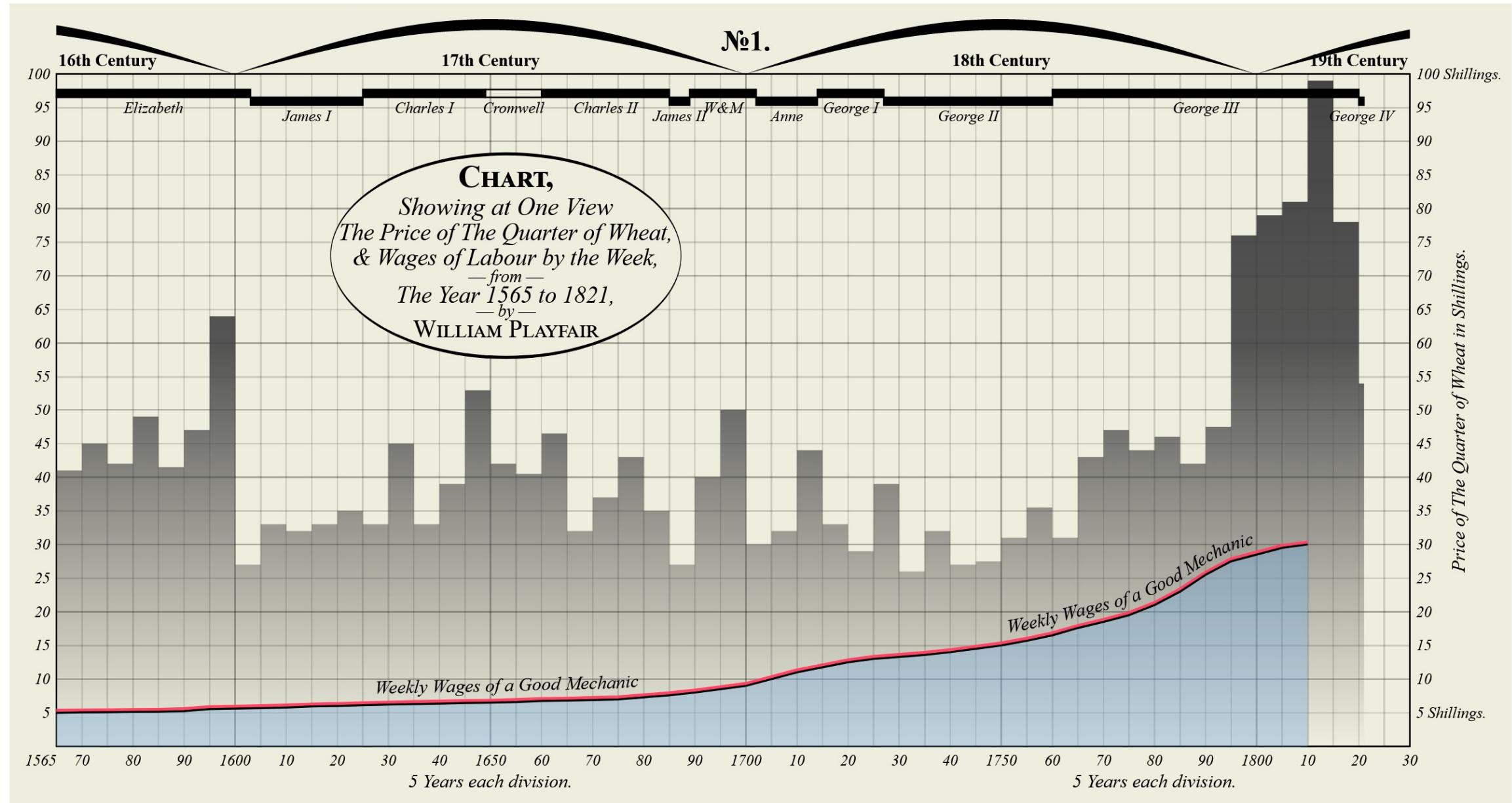
Playfair's Commercial and Political Atlas (1786)



Reference: William Playfair's [trade-balance time-series chart](#), Commercial and Political Atlas, 1786.

A short visual history of time-series graphs

Playfair's Chewing at One View Chart (1821)



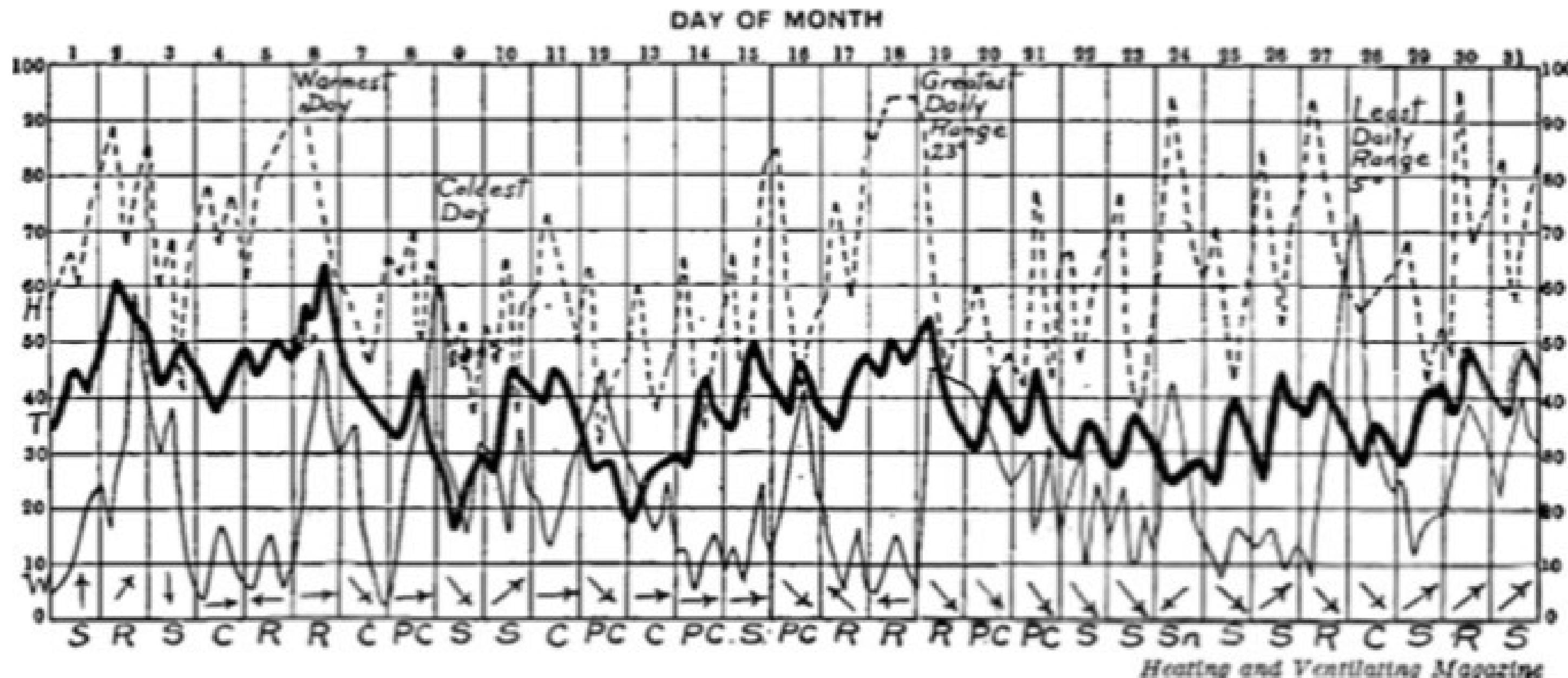
Reference: William Playfair's [Price of Wheat](#)

A short visual history of time-series graphs

Bump Chart shows rank of the most populous cities at each census:
1790-1890

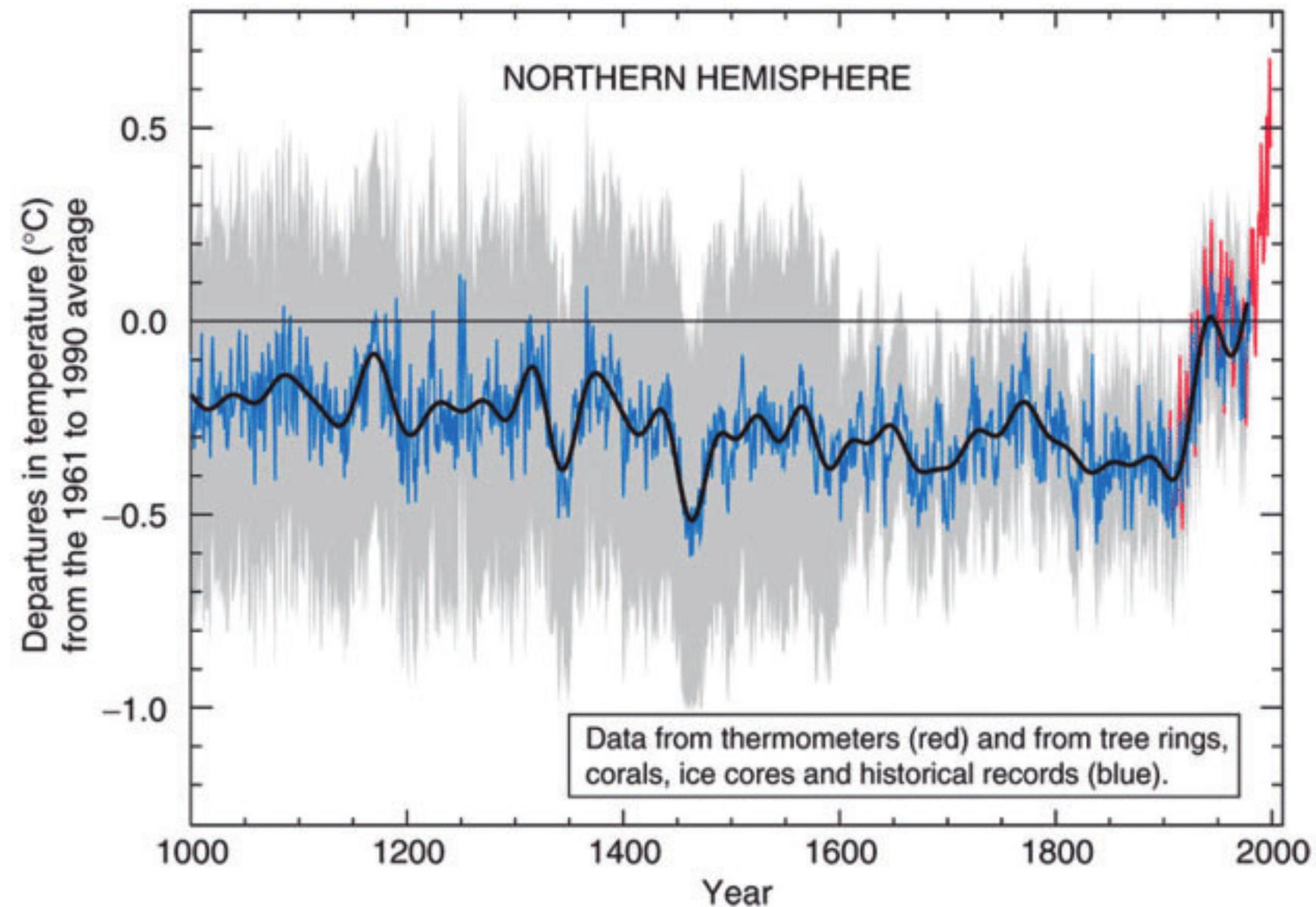
A short visual history of time-series graphs

Multiple charts showing records of the Weather in New York City for December, 1912.



Time-series graph that change public understading

The Hockey Stick Chart



Reference: Michael E. Mann, Raymond S. Bradley, Malcolm K. Hughes (1999) “Northern hemisphere temperatures during the past millennium: Inferences, uncertainties, and limitations”. *Geophysical Research Letters*, Vol. 26, No. pp. 759-762.

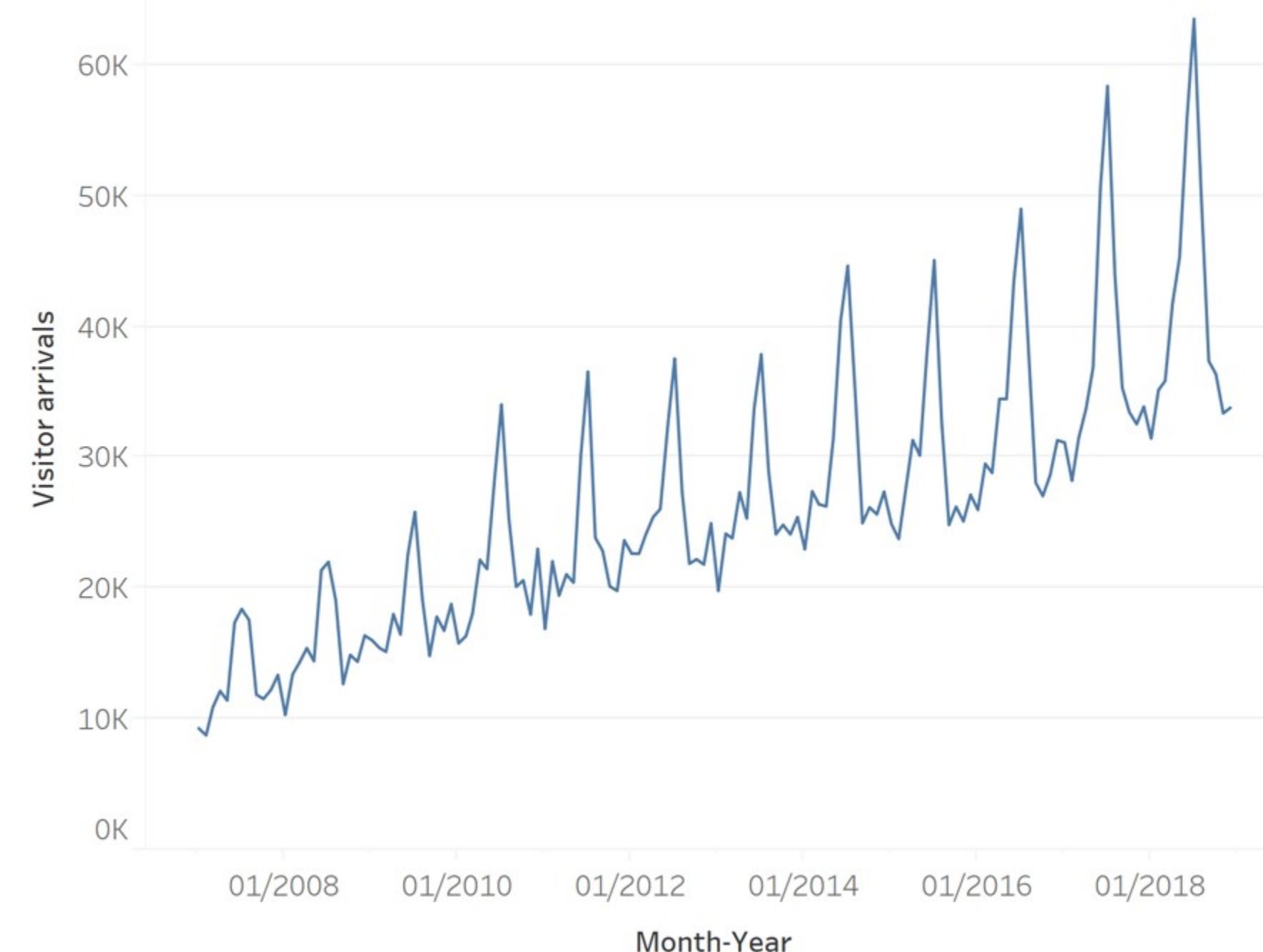
Time-series data patterns

- Trend
- Variability
- Rate of change
- Co-variation
- Cycles
- Exceptions

Time-series Patterns: Trend

- The overall or general direction of change in a series of time-series values is called the trend.

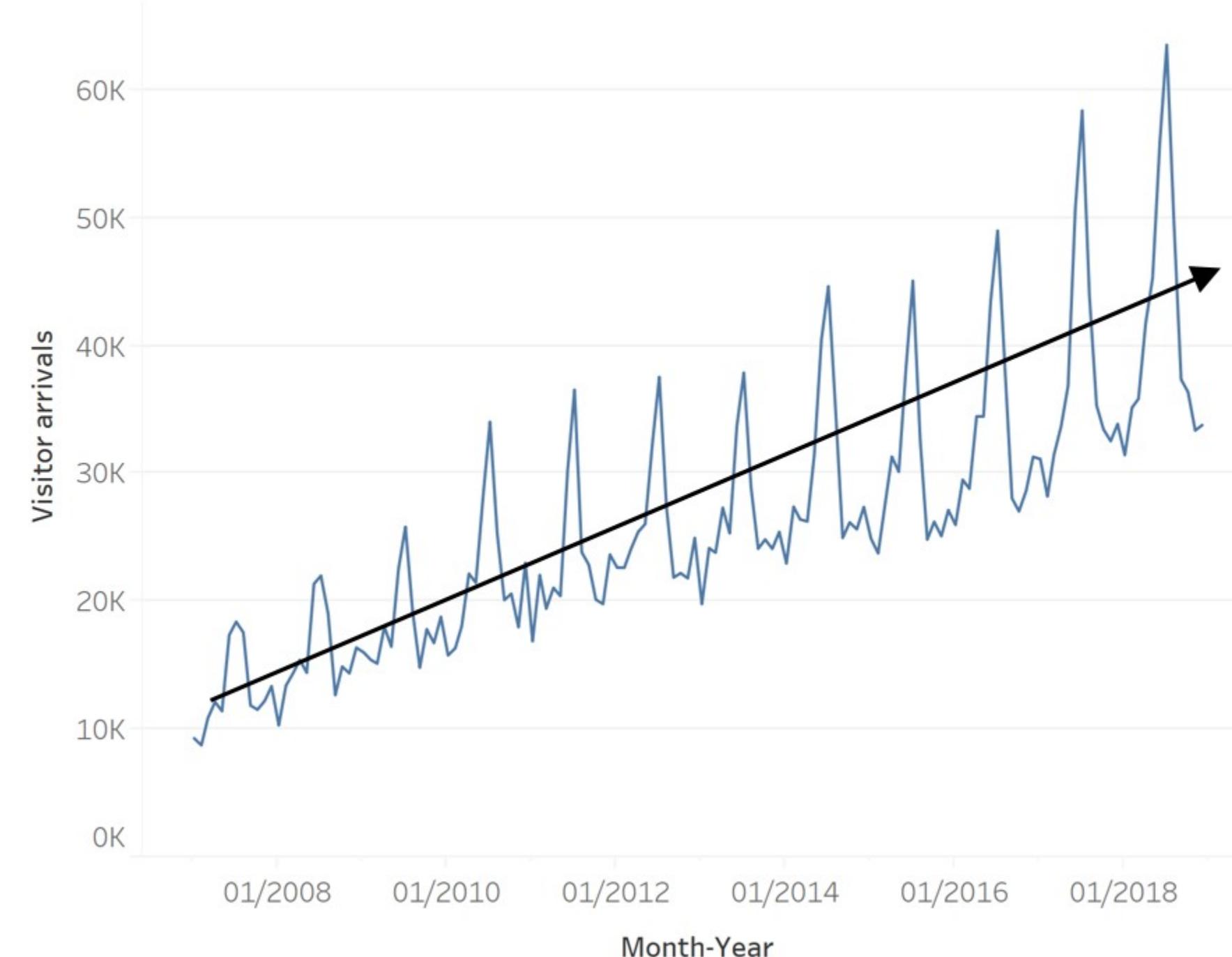
Monthly visitor arrivals from **Vietnam**, 2007-2018



Time-series Patterns: Trend

- An upward trend.

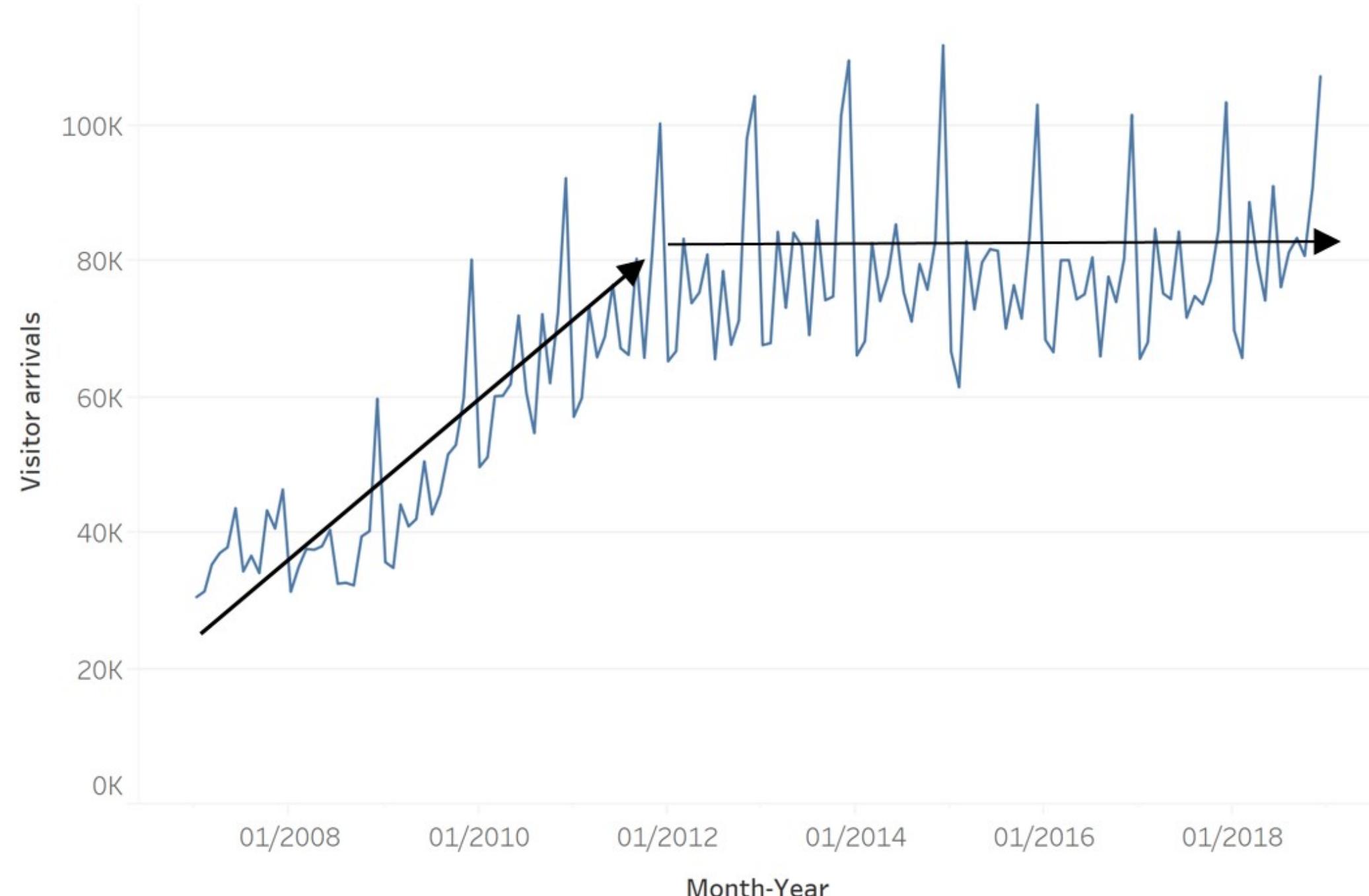
Monthly visitor arrivals from **Vietnam**, 2007-2018



Time-series Patterns: Trend

- A mixed trends.

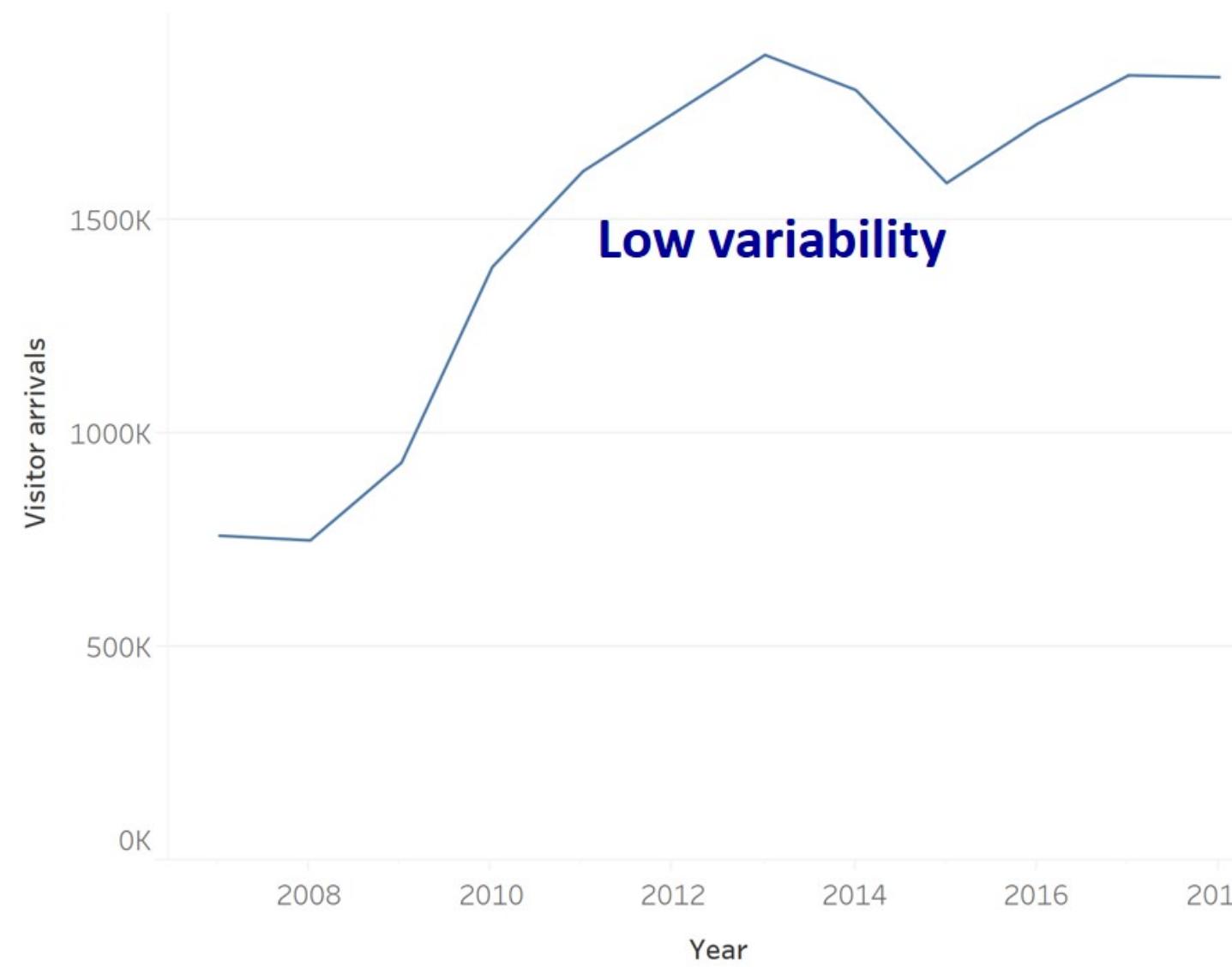
Monthly visitor arrivals from **Malaysia**, 2007-2018



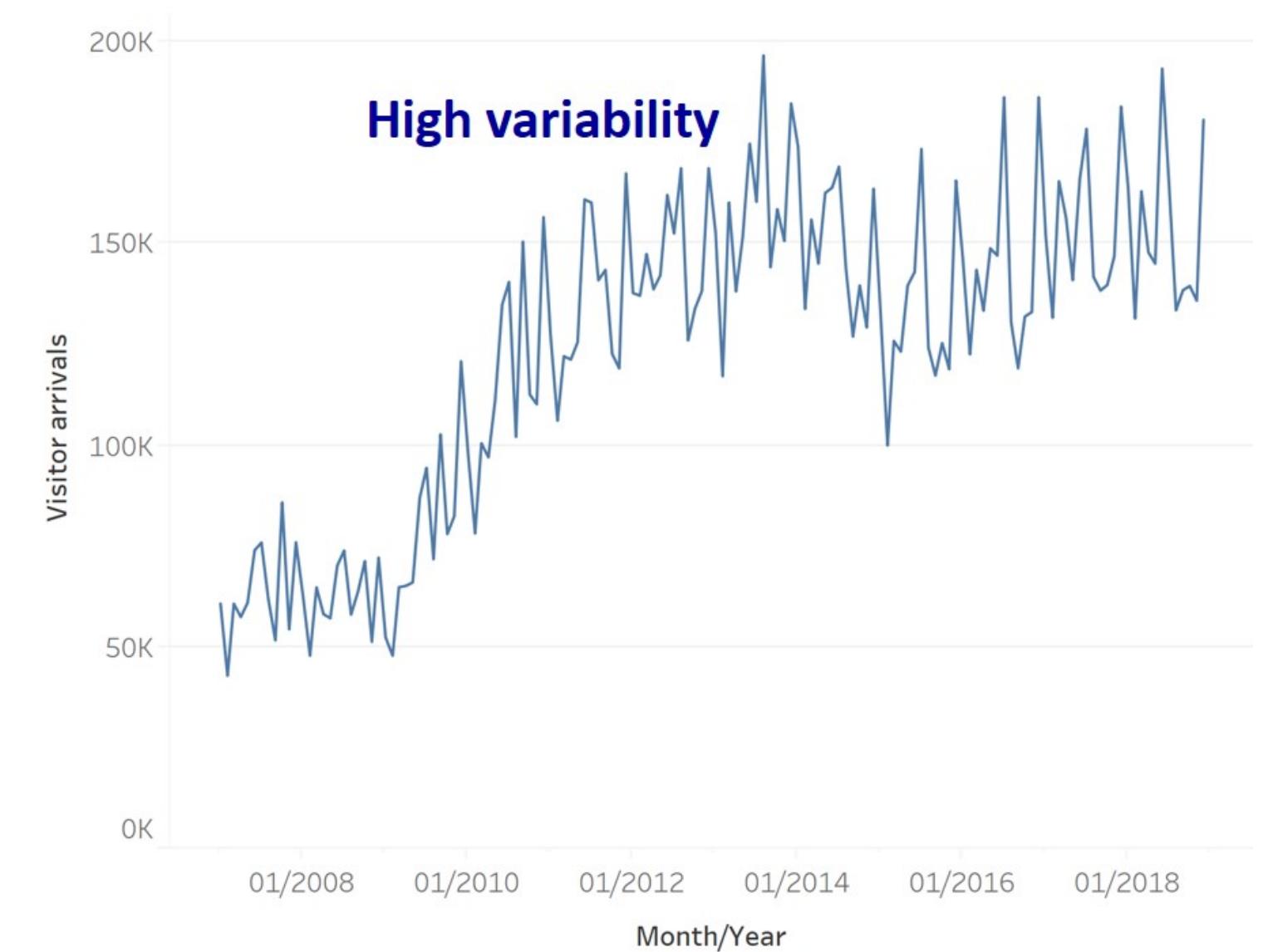
Time-series Patterns: Variability

- The average degree of change from one point of time to the next throughout a particular span of time.

Monthly visitor arrivals from **Indonesia**, 2007-2018



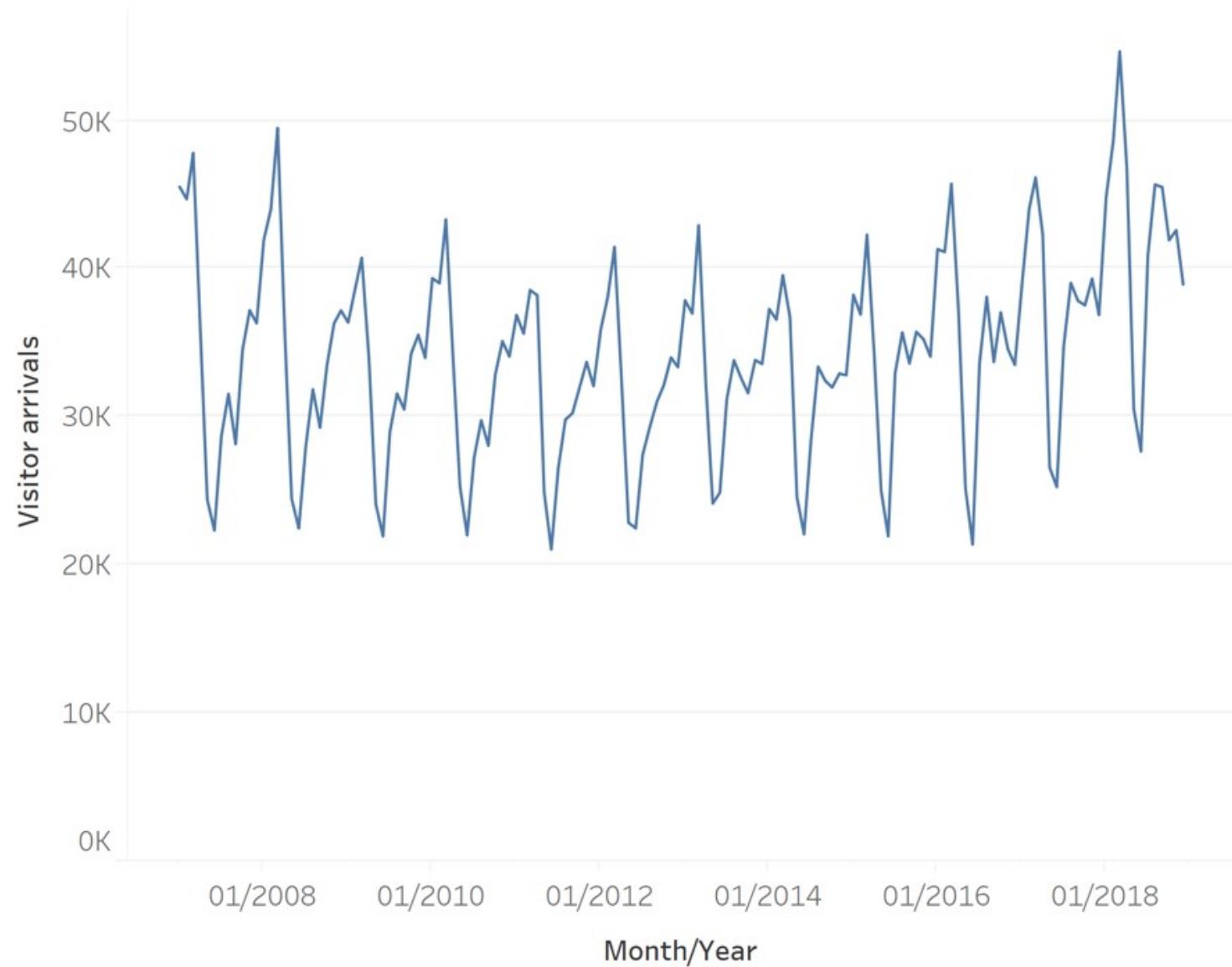
Monthly visitor arrivals from **Indonesia**, 2007-2018



Time-series Patterns: Cycles

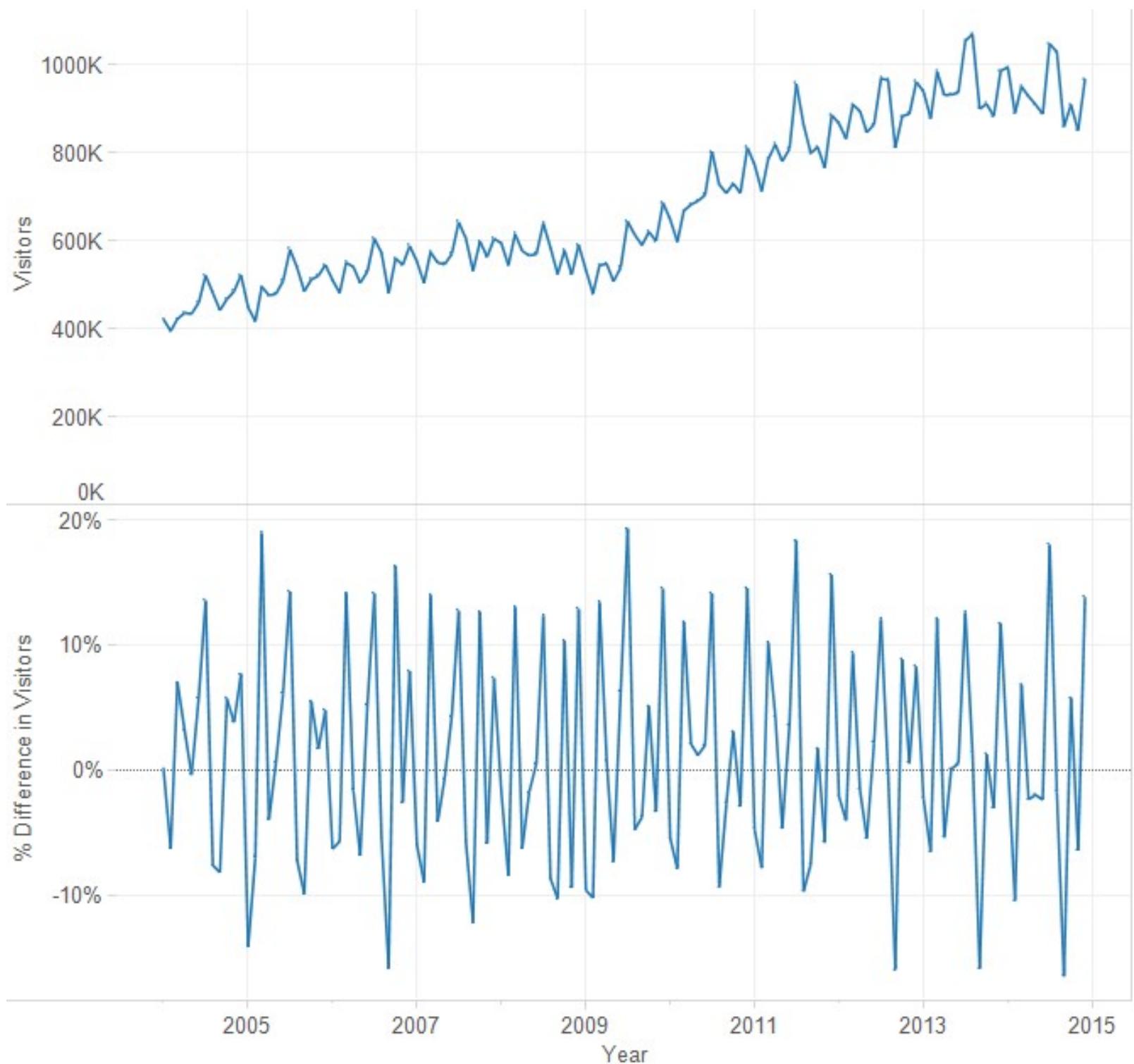
- Cycles are patterns that repeat at regular intervals.
- From the line graph, we can see that visitor arrivals from United Kingdom reach its peak on January and lowest on May every year.

Monthly visitor arrivals from **United Kingdom**, 2007-2018



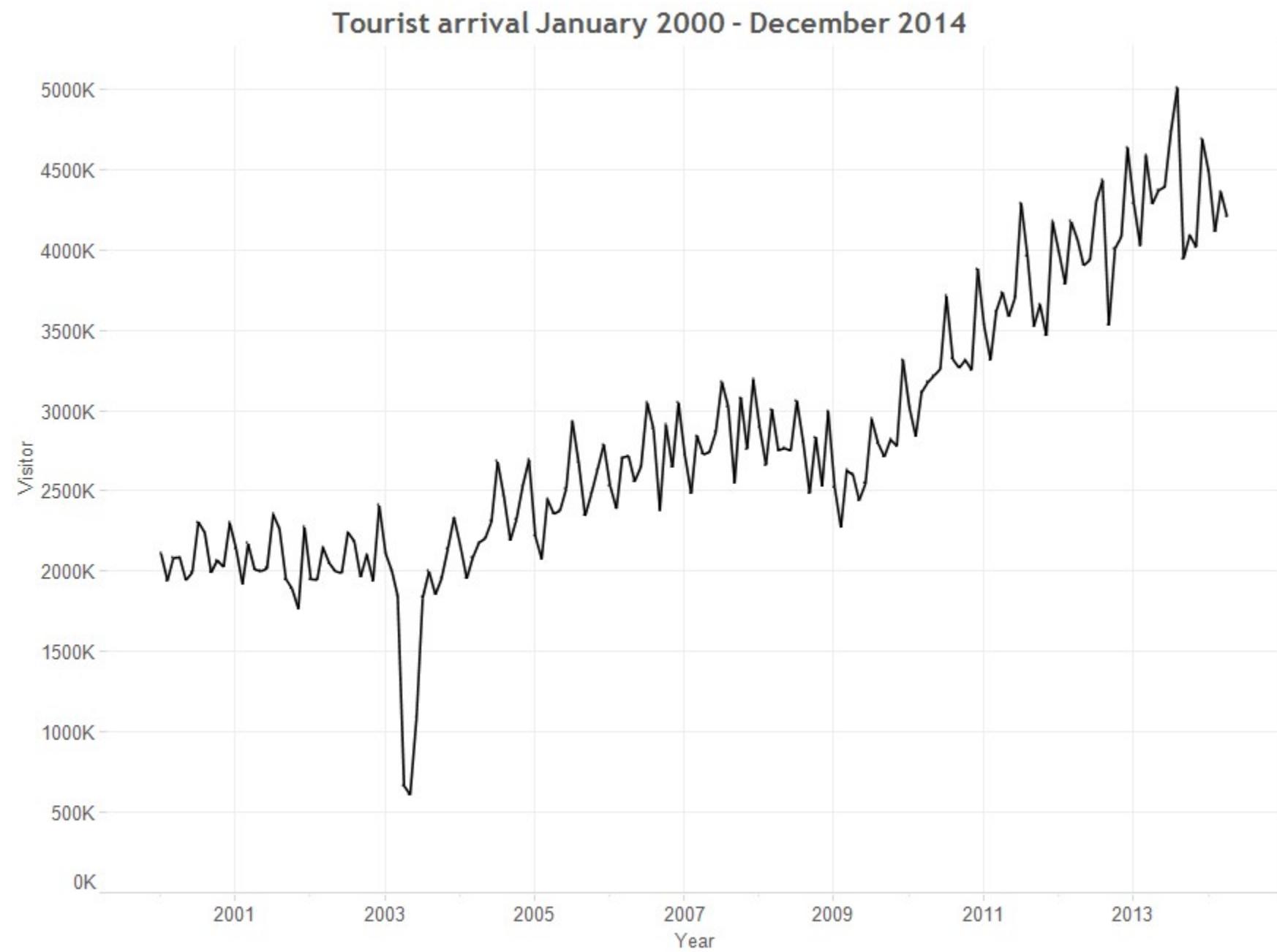
Time-series Patterns: Rate of change

- The percentage difference between one value to the next value.



Time-series Patterns: Exceptions

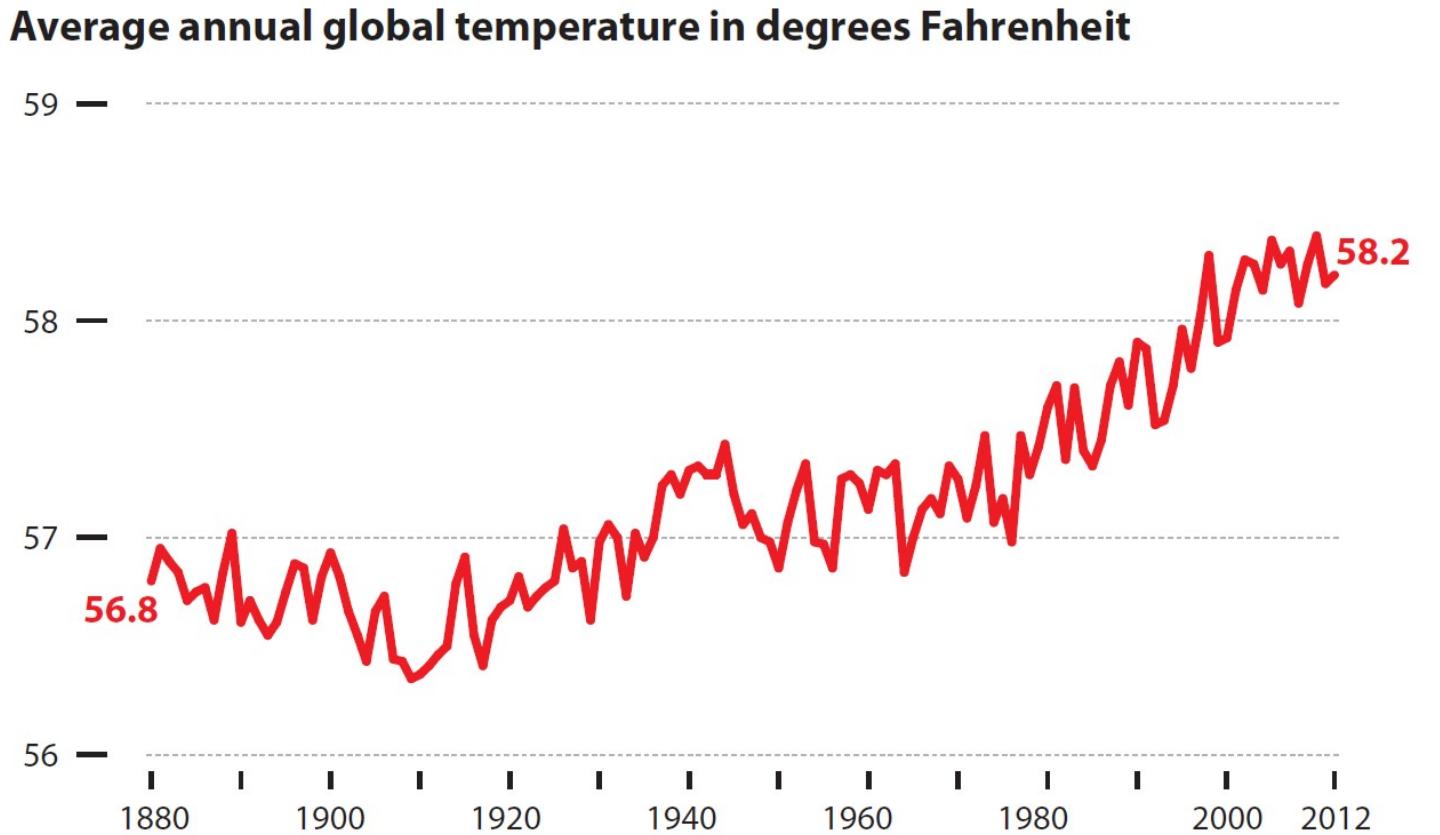
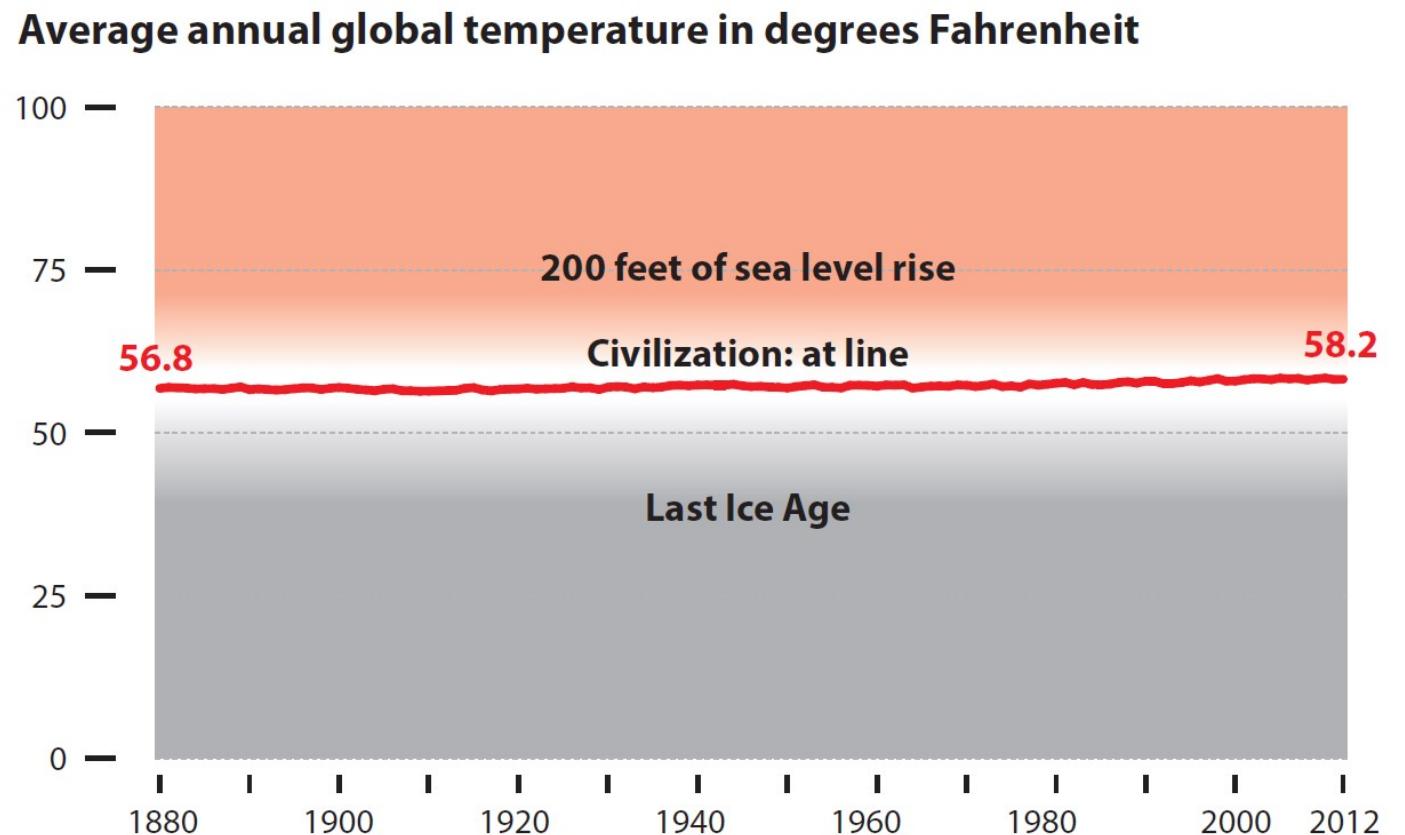
- Values that fall outside the norm.



This line graph show the significant impact of SAR on the visitor arrivals pattern to Singapore.

Line graph design tips

Not all line graphs should start at zero!



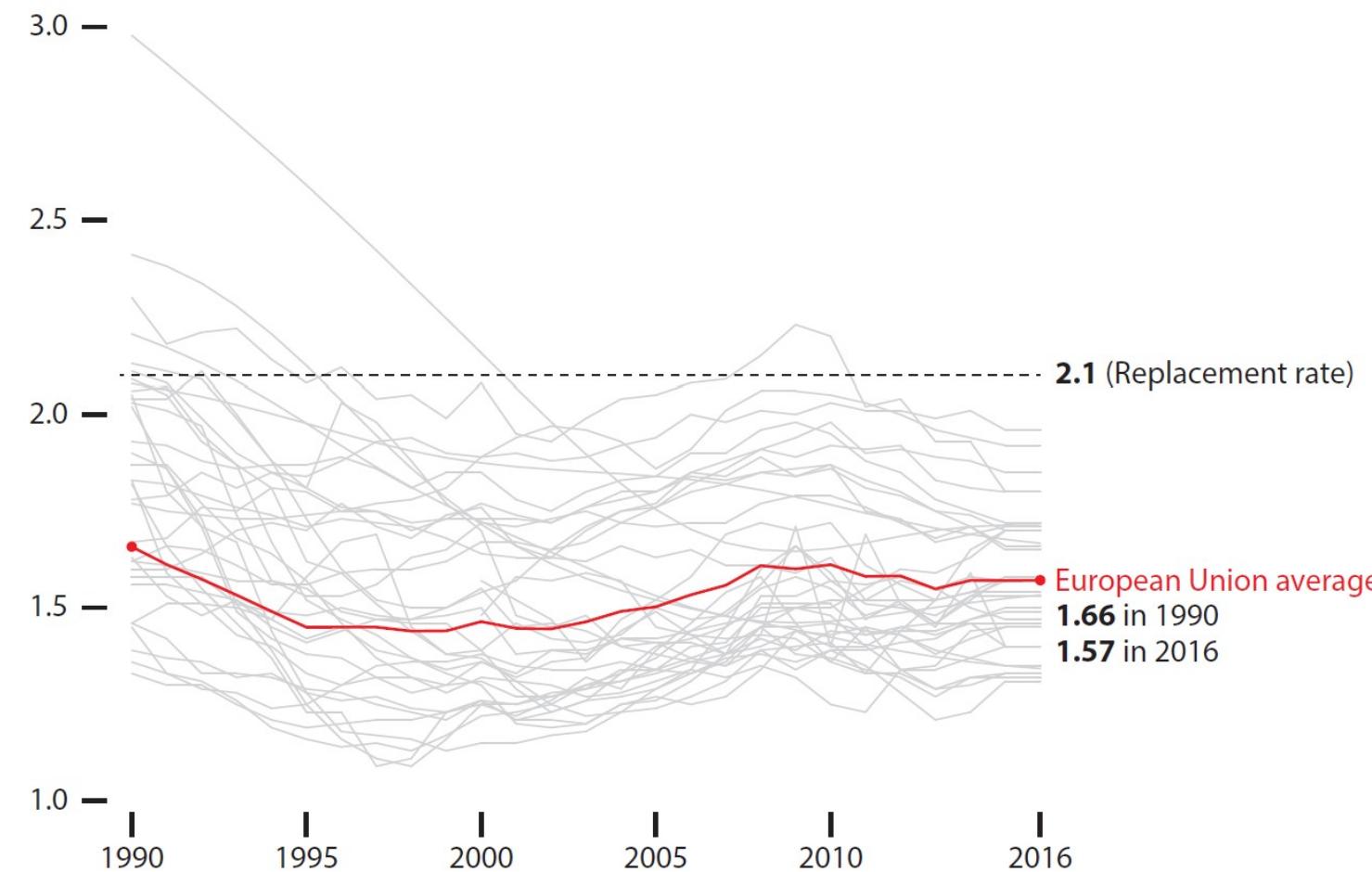
Line graph design tips

Multiple lines in a single graph is less effective than trellis line graph

Fertility rate in European countries

Children per woman. Each grey line is a country.

(Source: World Bank Data)



Fertility rate in European countries, 1990–2016

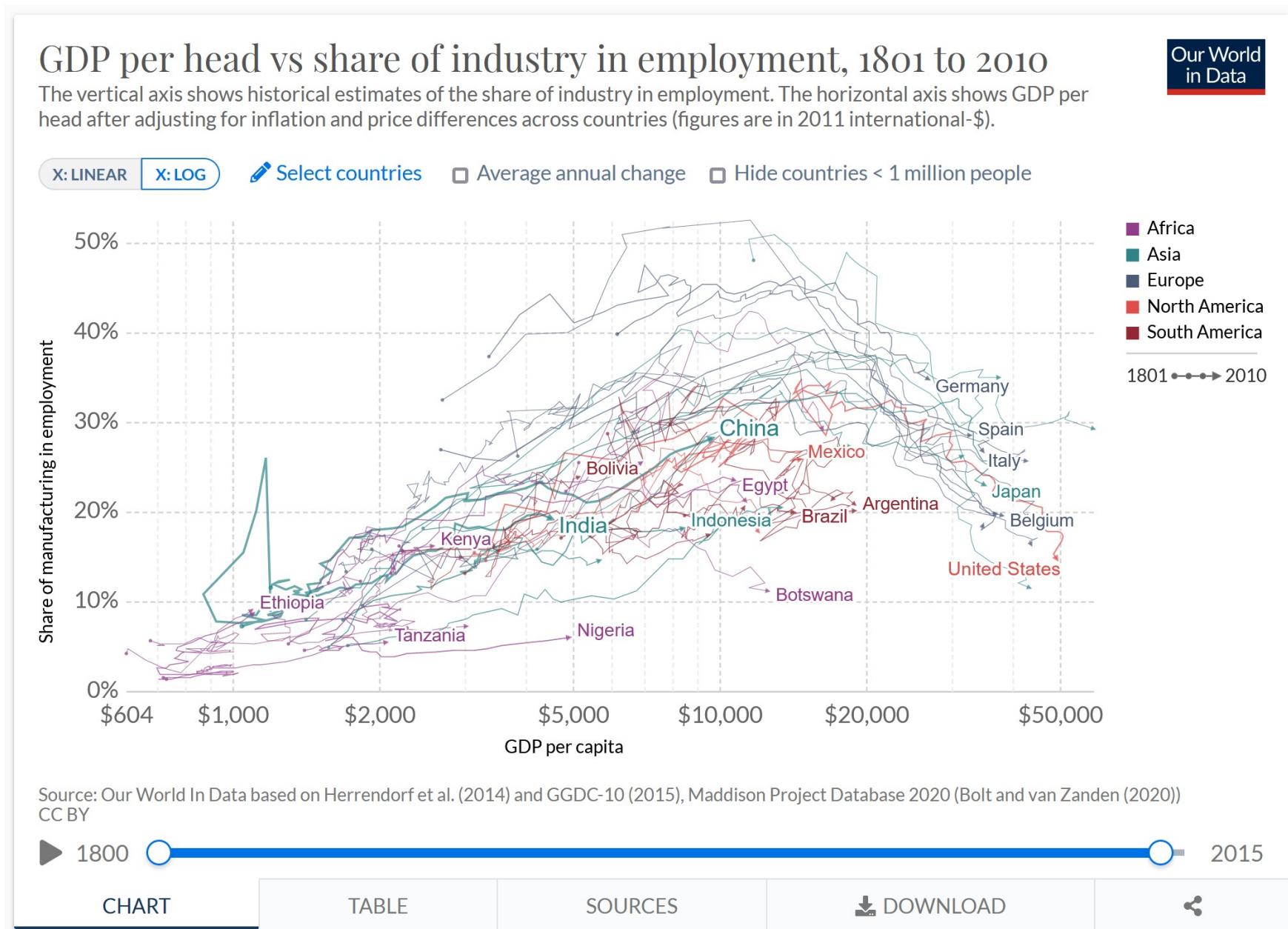
Compared to the replacement rate: 2.1 children per woman

Note: not all these countries belong to the European Union



Line graph design tips

Not all time-series graphs have time on the x-axis

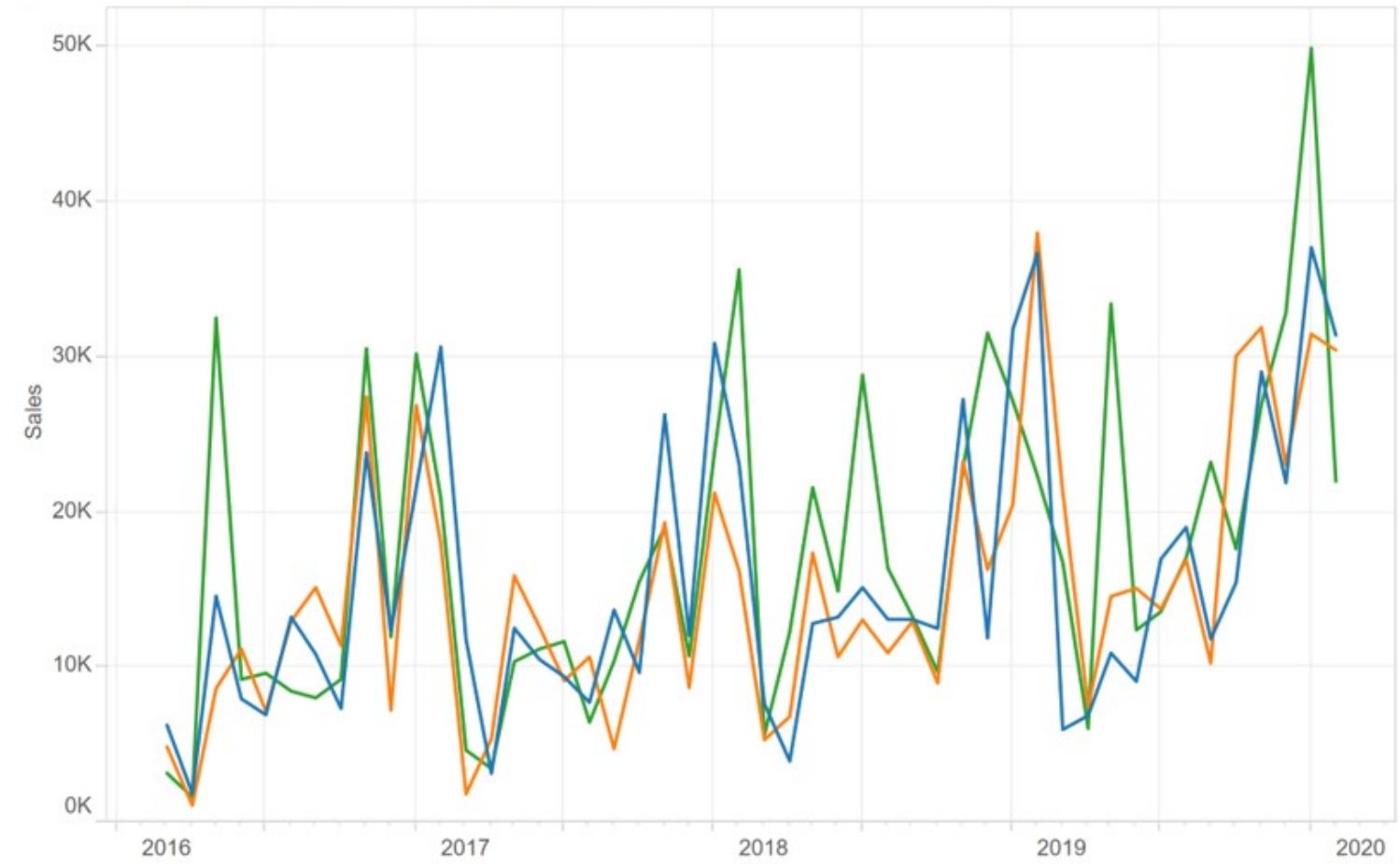


Source: [Are emerging economies deindustrializing too quickly?](#)

Line graph design tips

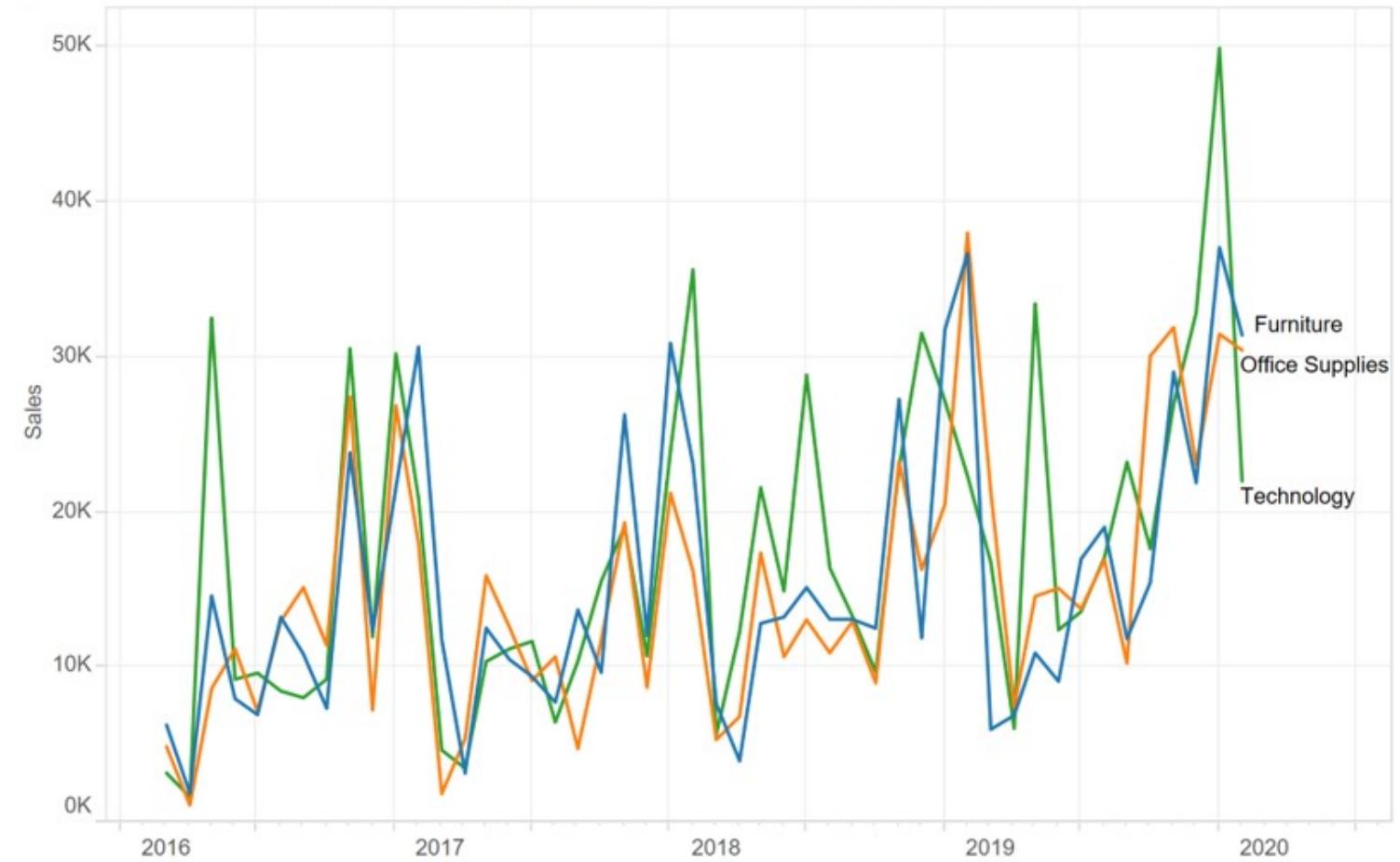
Label line graph instead of using legend

Monthly sales by product category, January 2016-December 2019



Category
Furniture
Office Supplies
Technology

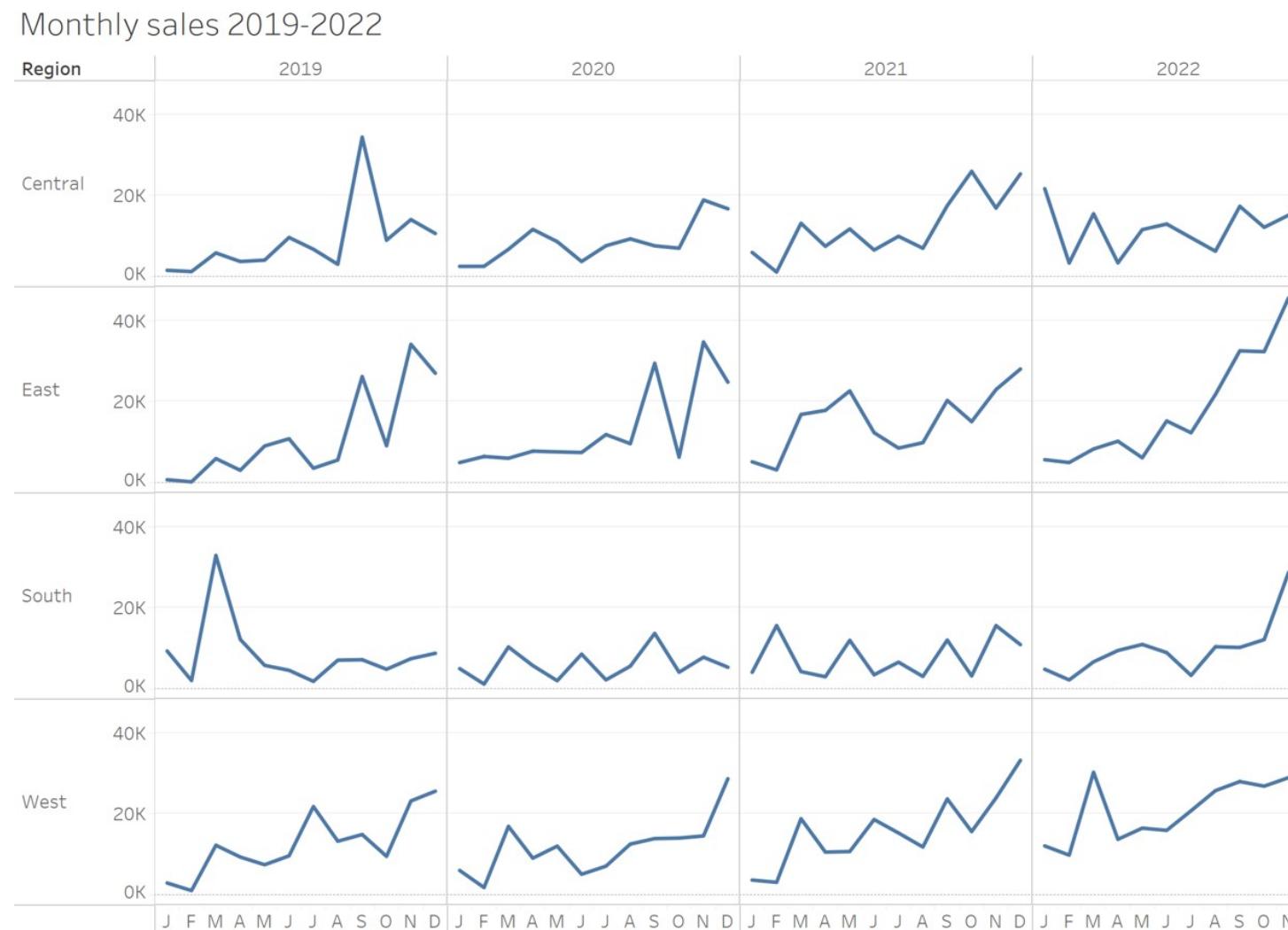
Monthly sales by product category, January 2016-December 2019



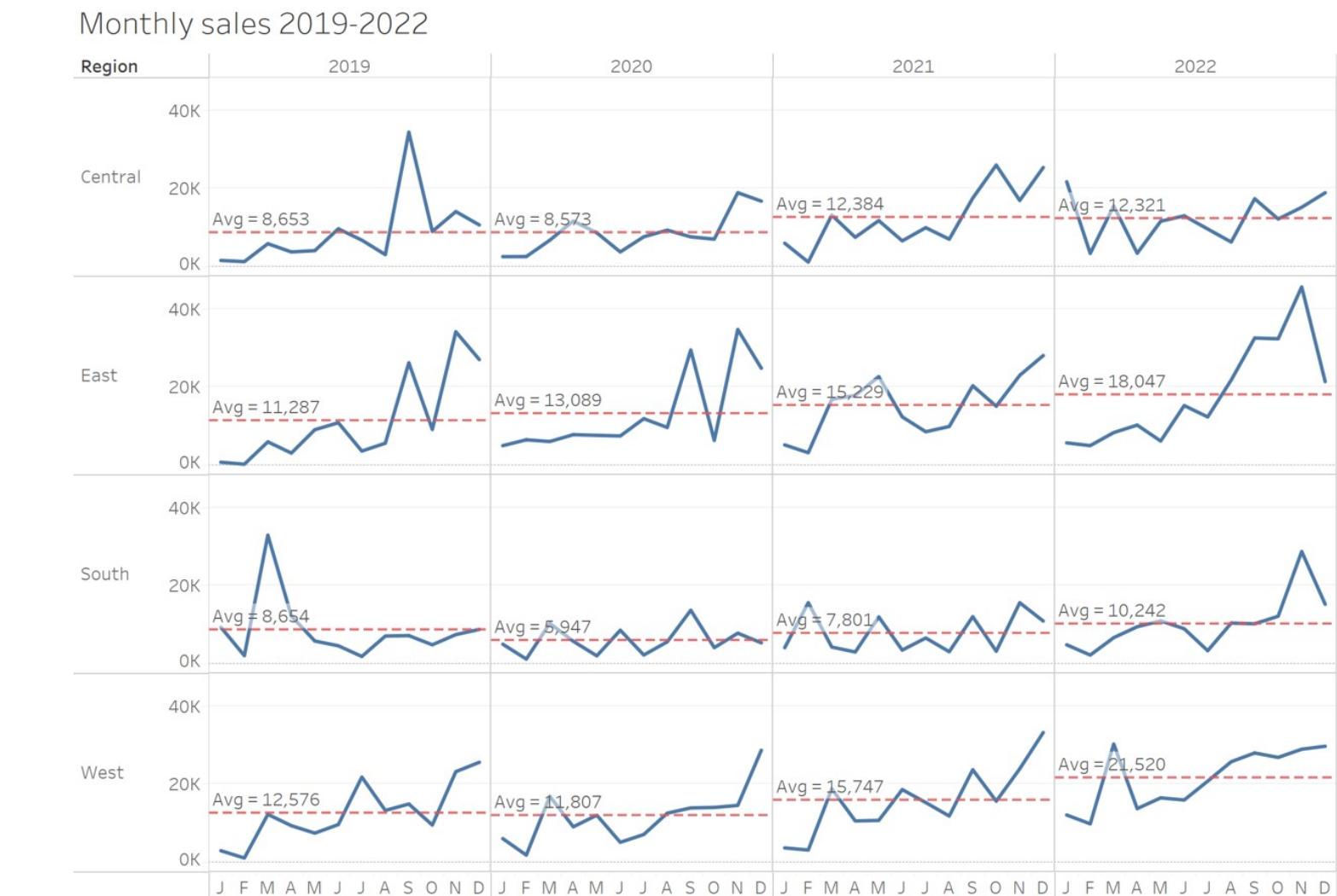
Line graph design tips

- In order to support comparison over time effectively, reference line should be used.

Line chart without reference line



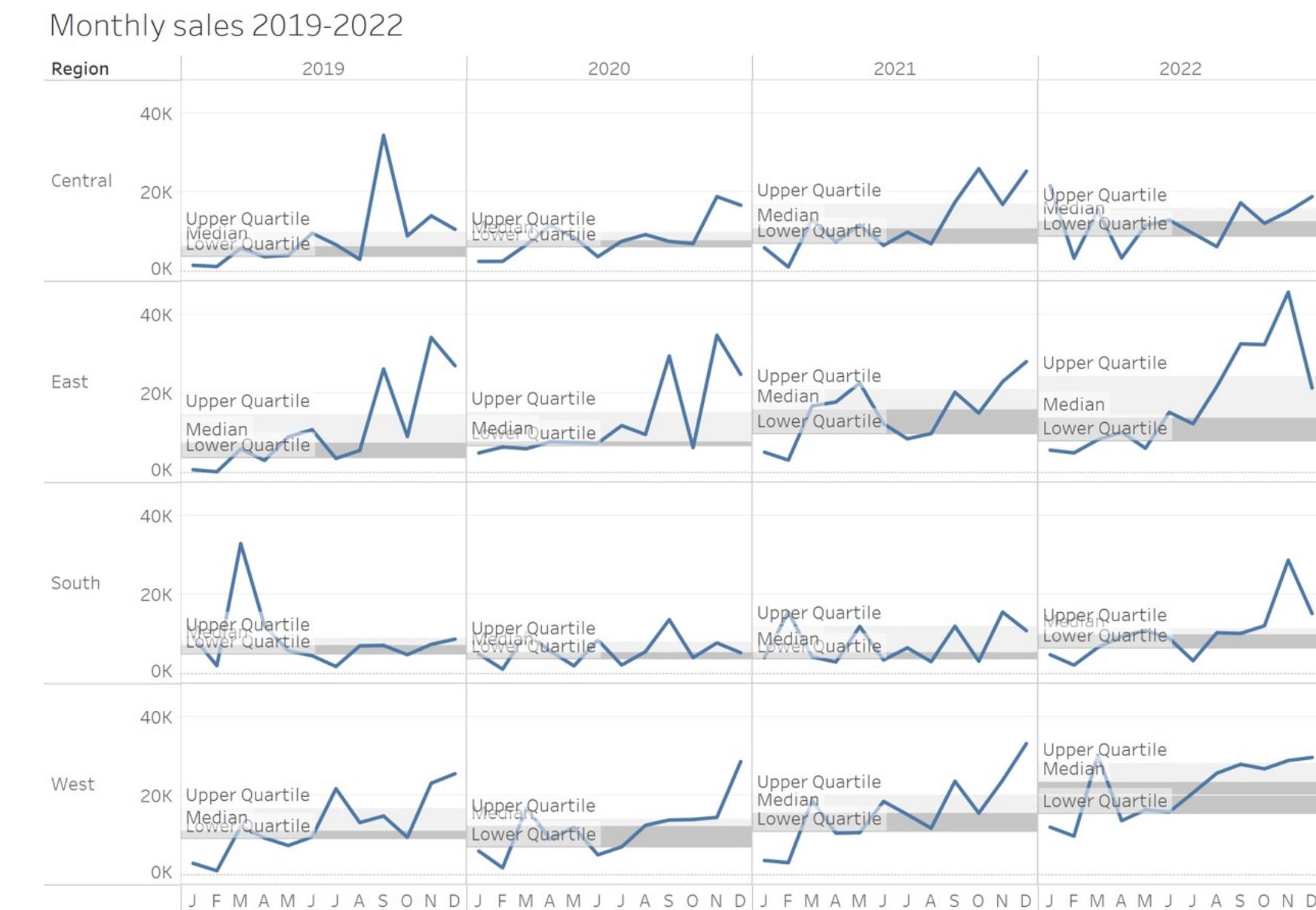
Line chart with reference line



Line graph design tips

Line chart with reference band

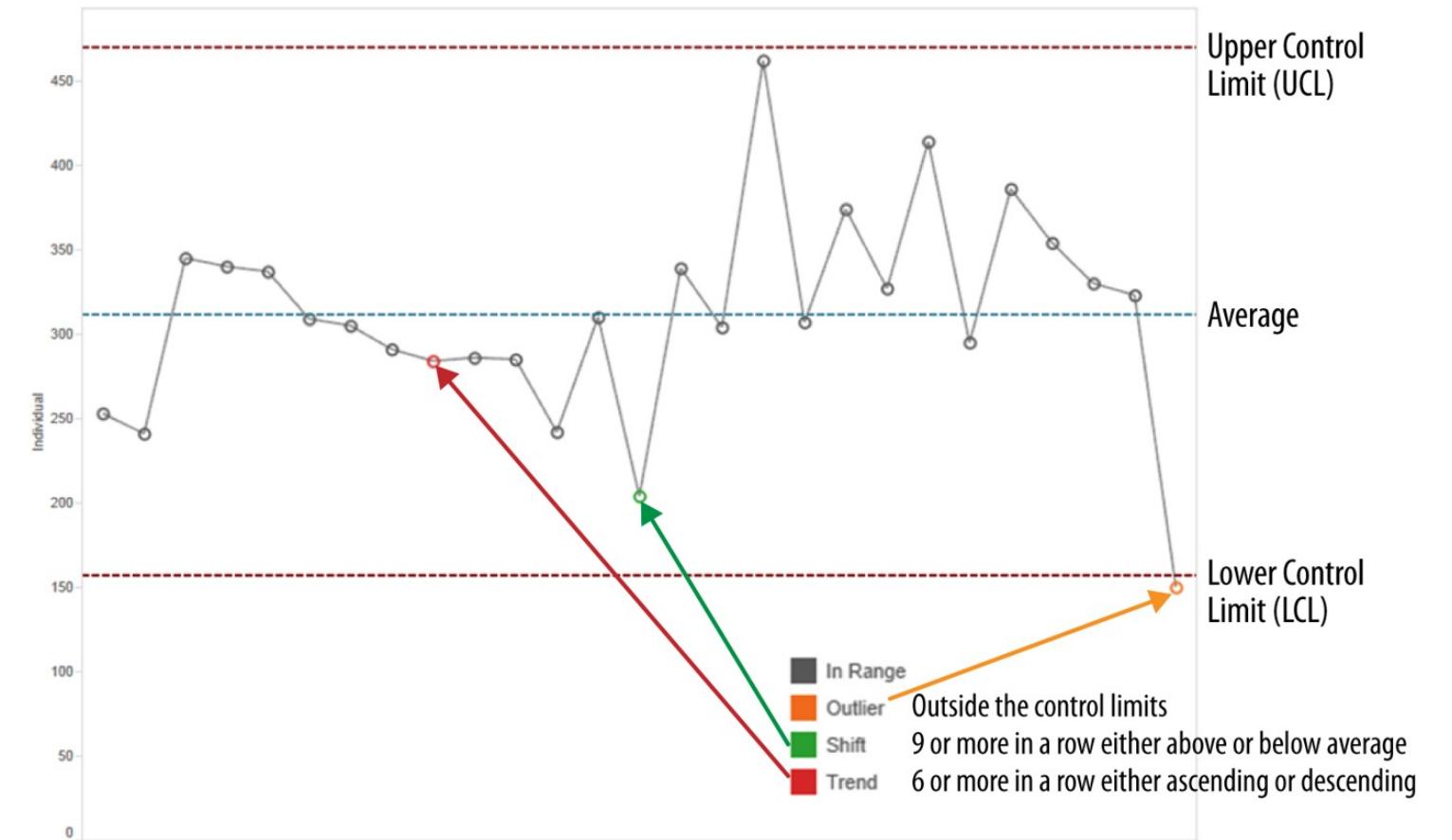
The reference used don't have to confine a single line. A confidence interval or quantile range can be used too.



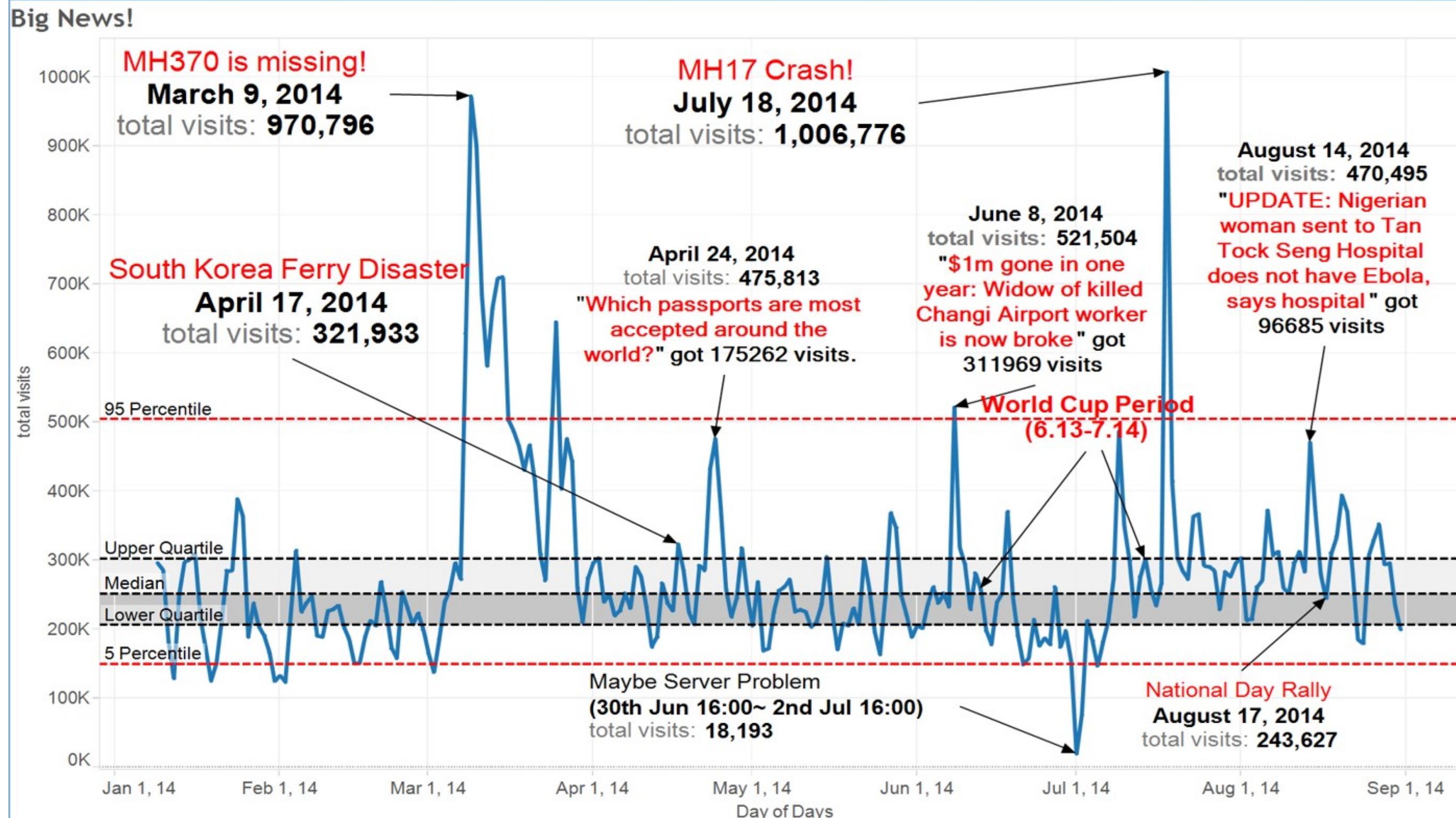
Beyond Line Graph

Control Chart: An analytical line chart

Control charts, also known as Shewhart charts (after Walter A. Shewhart) or process-behavior charts. They are a statistical process control tool used to determine if a manufacturing or business process is in a state of control. Beside the average line, there are two additional lines namely the upper control limit (UCL) and lower control limit (LCL). Any data points located beyond UCL or LCL will be flagged out as anomalies.



Control chart in real world



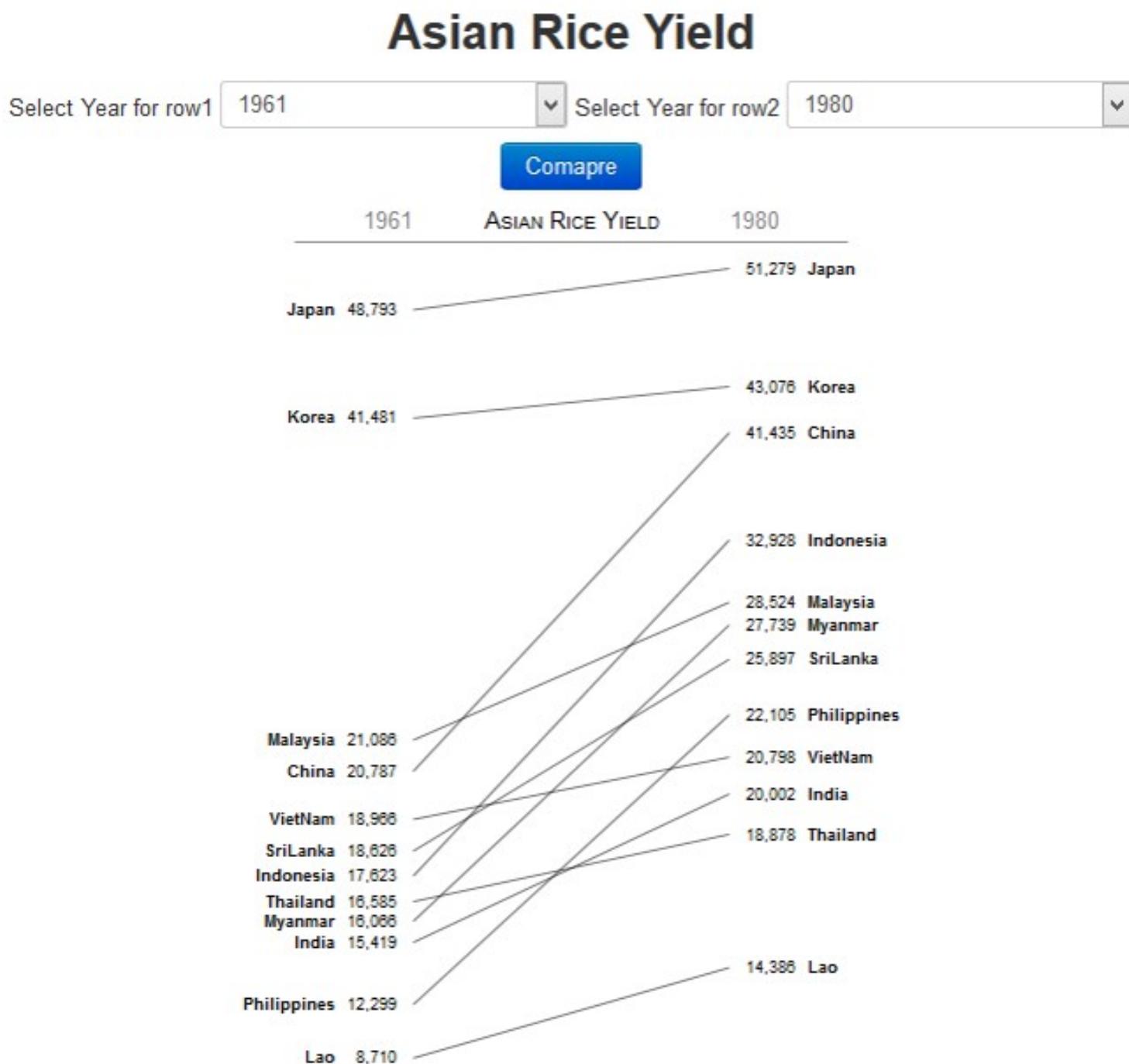
Challenge I: Visualising Change between Two Points in Time

Bar chart method

Slopegraphs come to rescue!

Slopegraphs compare changes usually over time for a list of nouns located on an ordinal or interval scale.

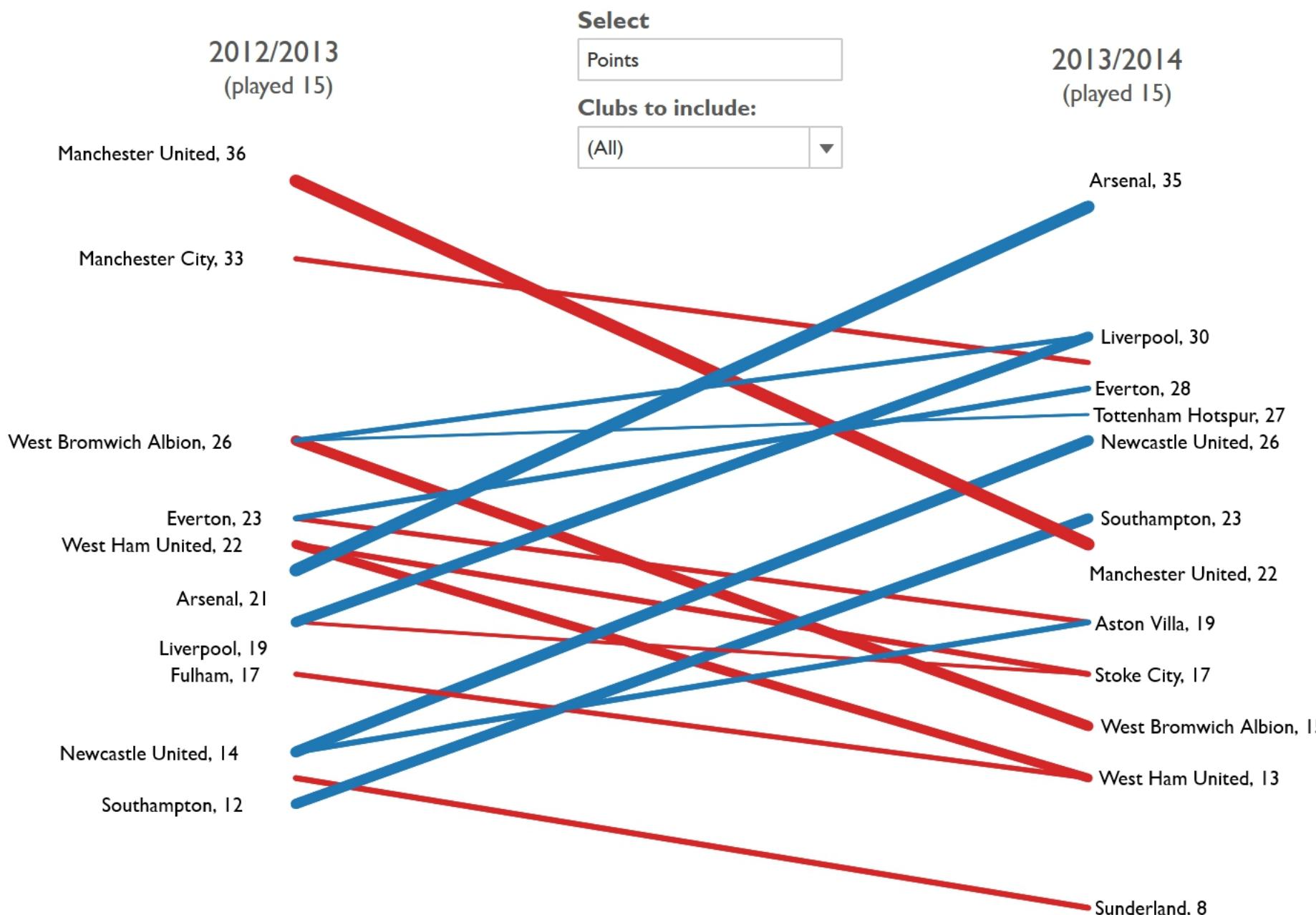
Reference: Slopegraphs for comparing gradients: Slopegraph theory and practice



Learning from the Master

Visit [Tableau Public](#) to try out the interactive version and visit this [link](#) to learn more.

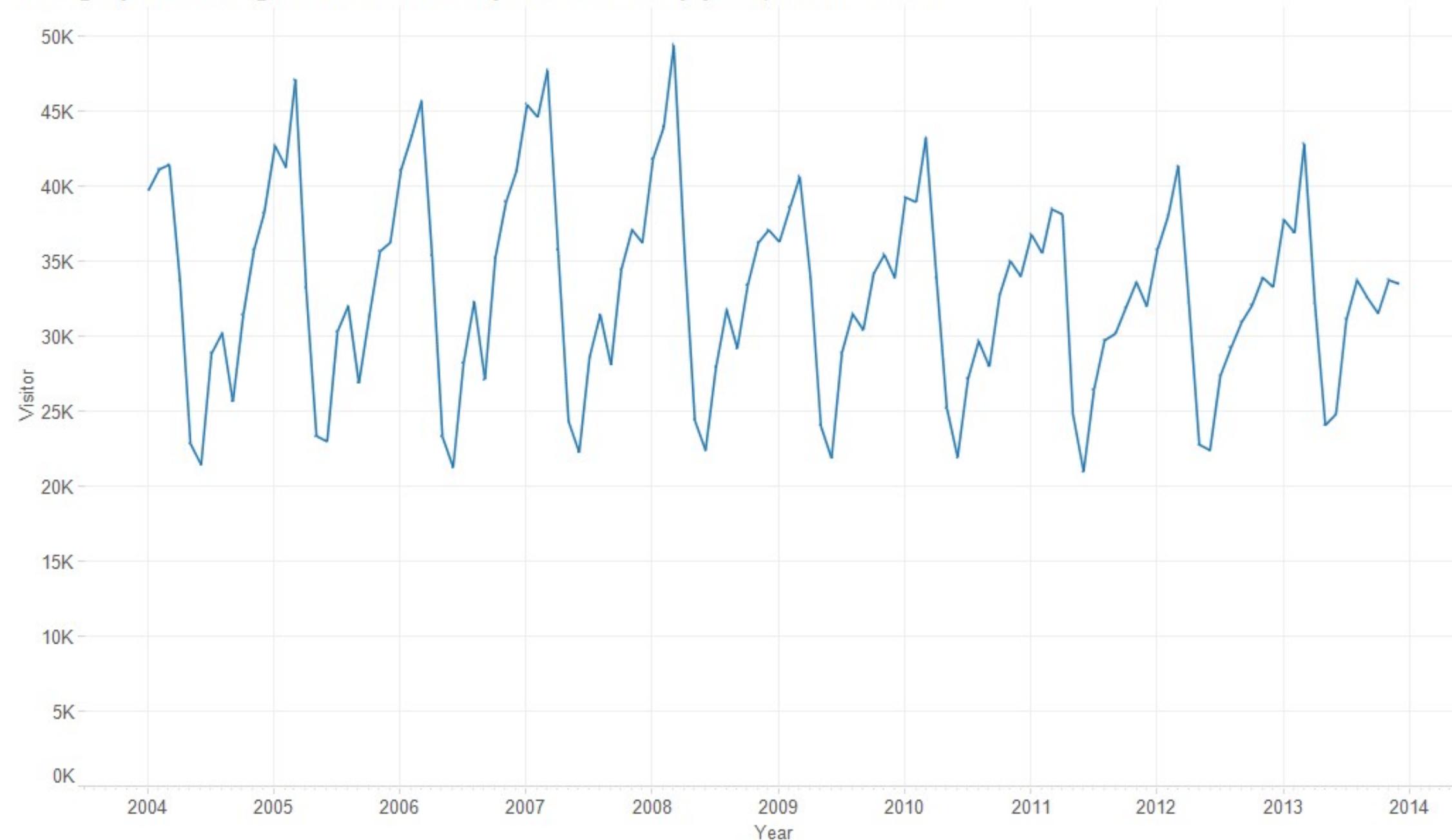
Barclay's Premier League Tables: Comparing 2012/2013 Starts to 2013/2014 Starts



Challenge II: Visualising cyclical patterns

Classic line graph method

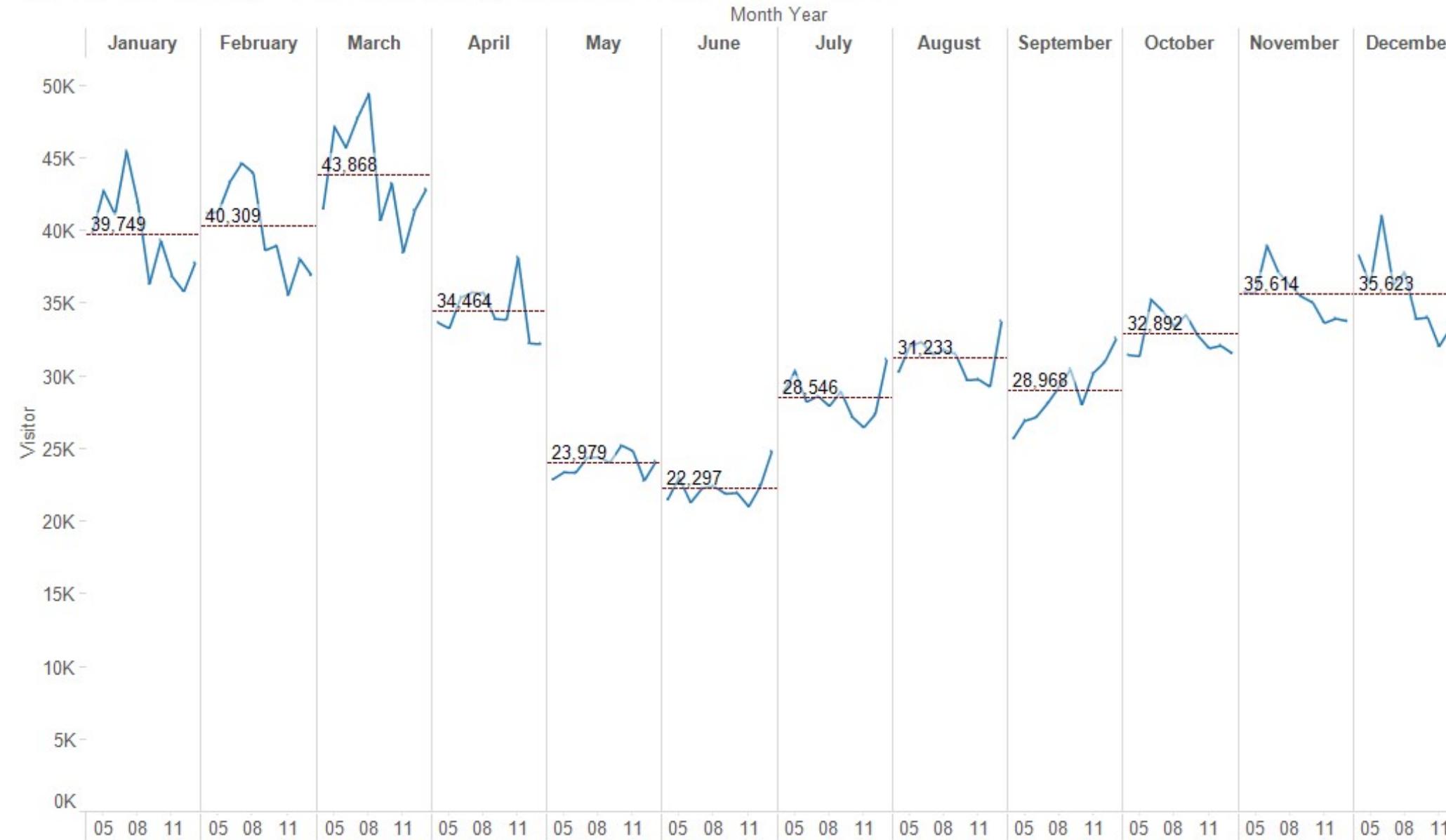
Line graph showing visitor arrivals by month and by year, 2004-2013



Challenge II: Visualising cyclical patterns

Solution: Cycle plot

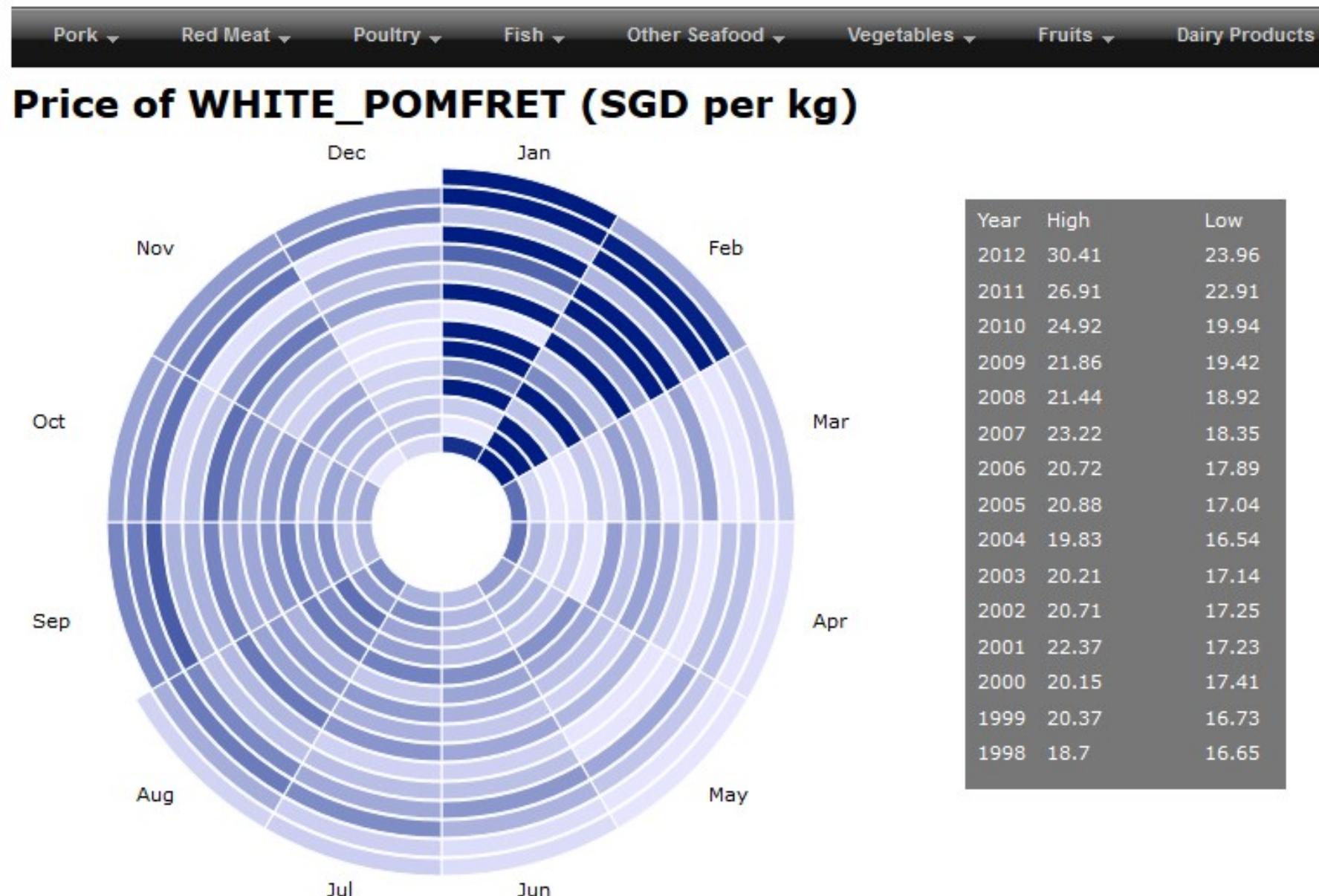
Cycle plot showing visitor arrivals by month and by year, 2004-2013



Reference: [Intro to Cycle Plot](#)

Challenge II: Visualising cyclical patterns

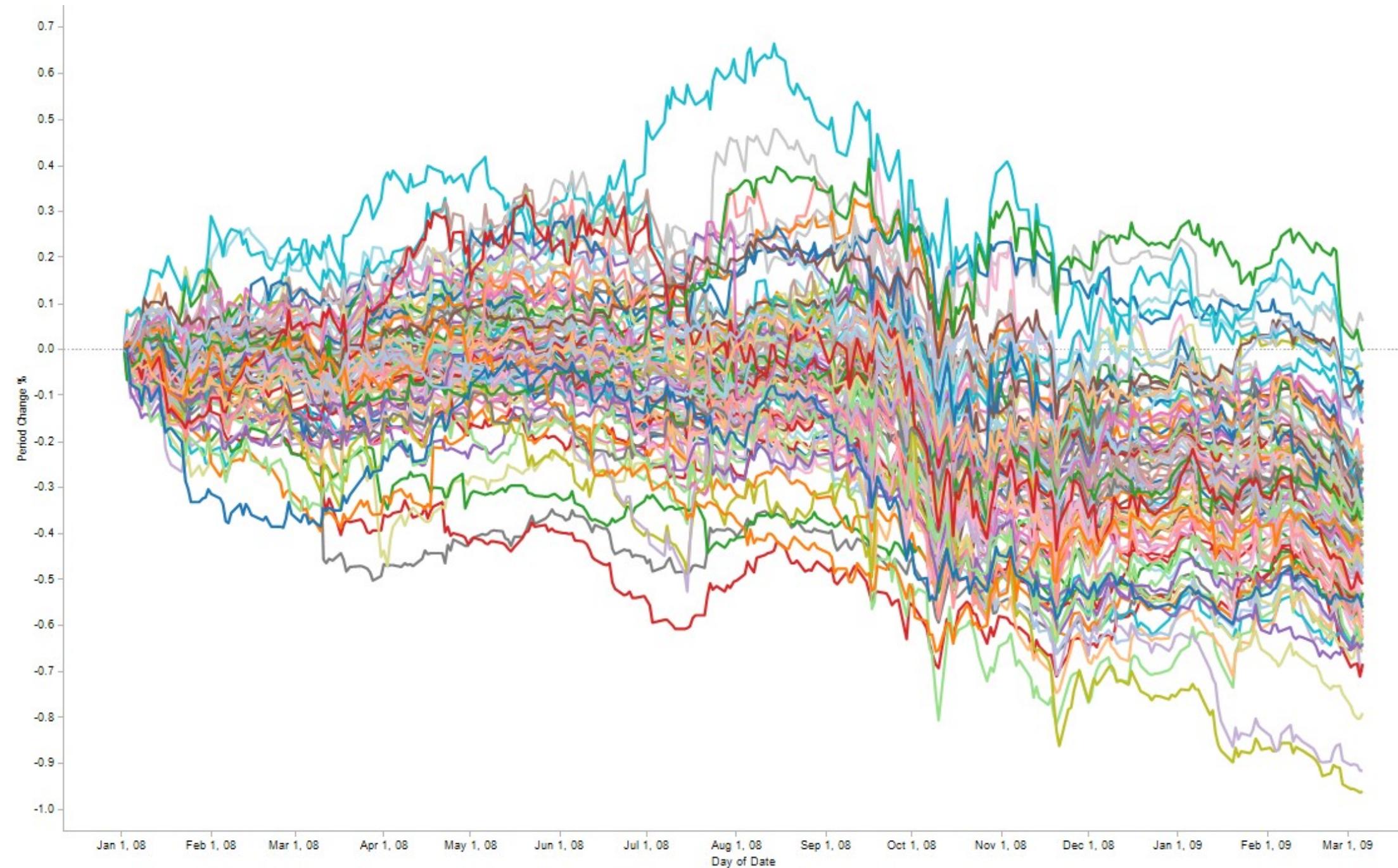
Solution: Sunburst diagram method



Each concentric ring represents a year, beginning from year 1998 for the innermost ring, to year 2012 for the outermost ring.
Click on any of the 12 sections of the circle to view the numerical prices of the food item.

Challenge III: Massive Time-series Data

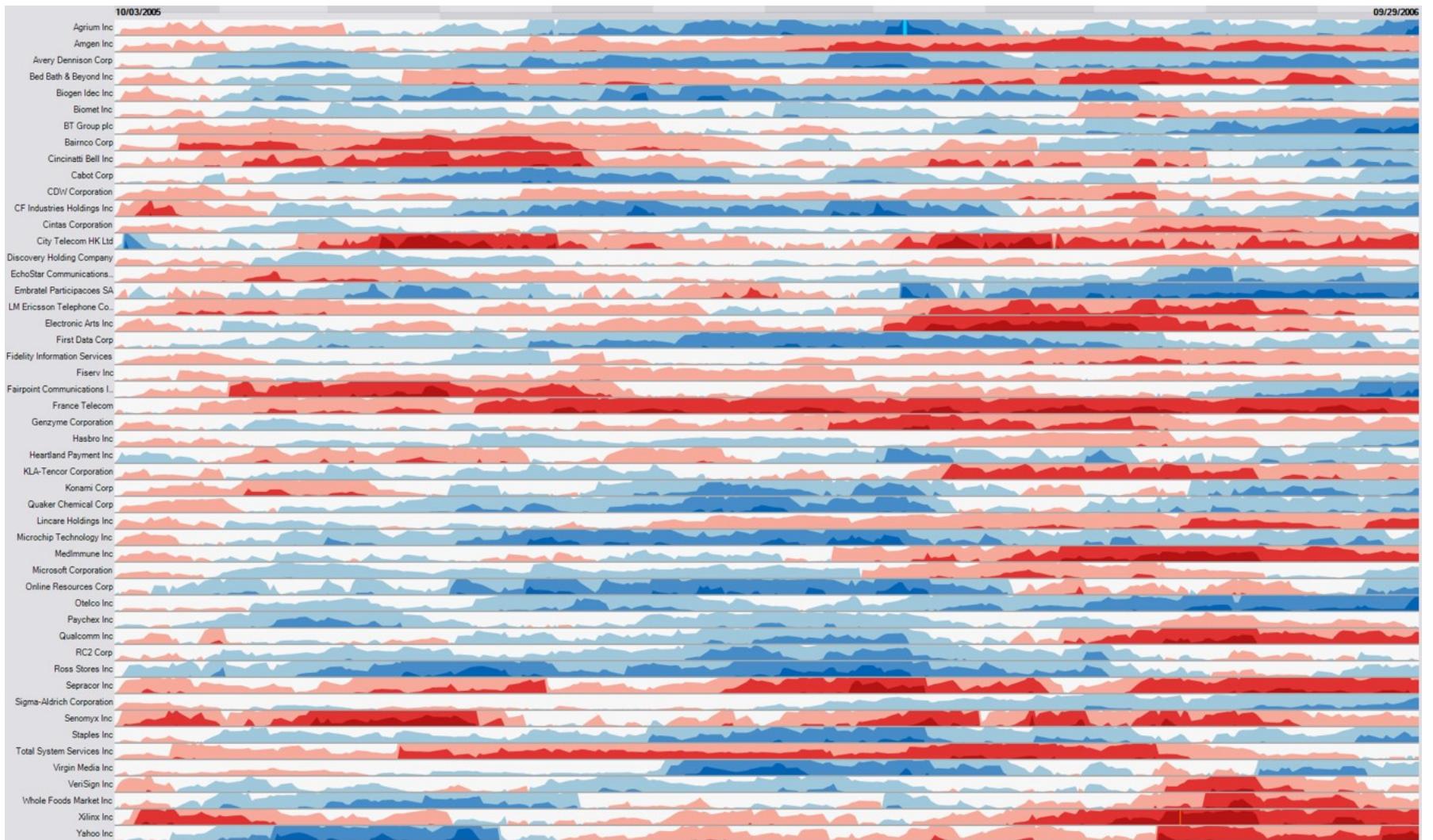
Classic line graph method



Challenge III: Massive Time-series Data

Solution: Horizon graph

By dividing an area chart into consecutive layers, horizon graphs present time-series data in a compact space while preserving resolution.

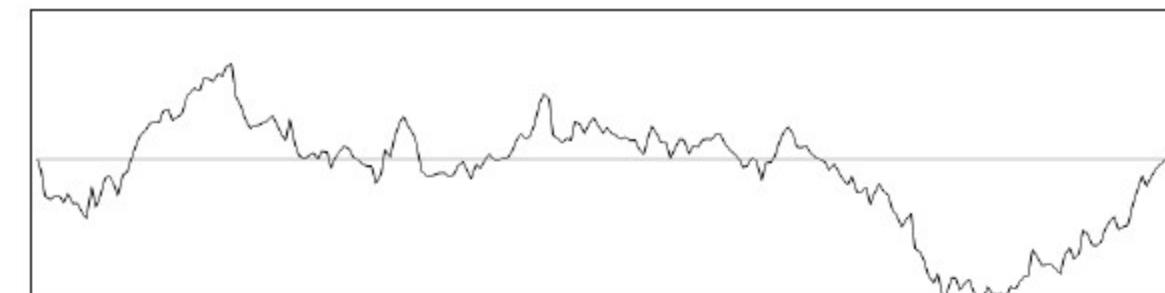


Reference: [Time on the Horizon](#)

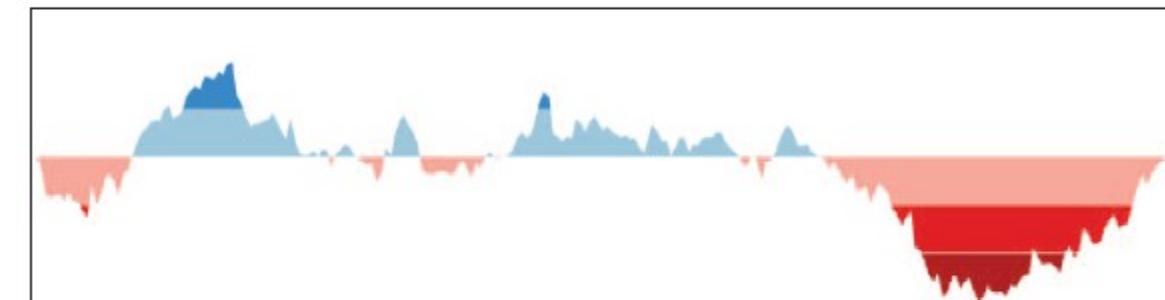
The basic construct of a horizon graph

Figure on the right shows the process of constructing an horizon graph.

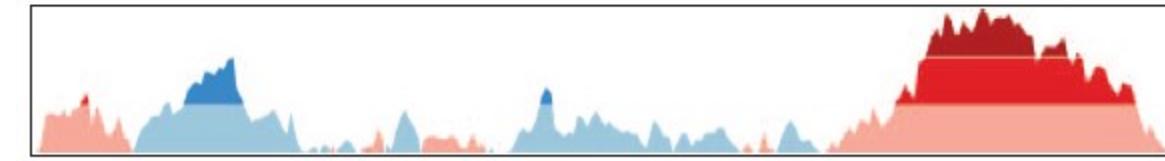
Reference: [The Development of the Horizon Graph](#)



(a) Standard line graph centered around a baseline.



(b) Color (blue is positive, red is negative) and layering.

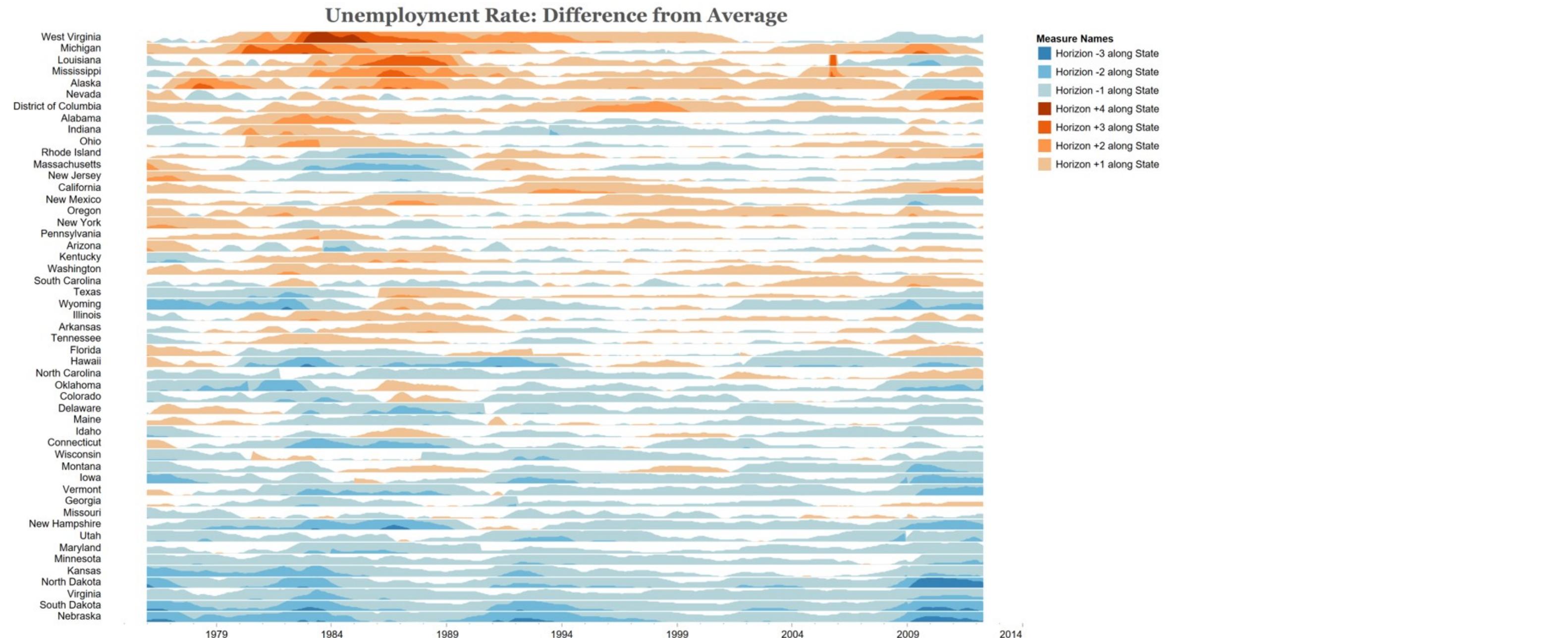


(c) Mirroring around the baseline.



(d) Wrapping bands into a single space.

Horizon graph in Tableau



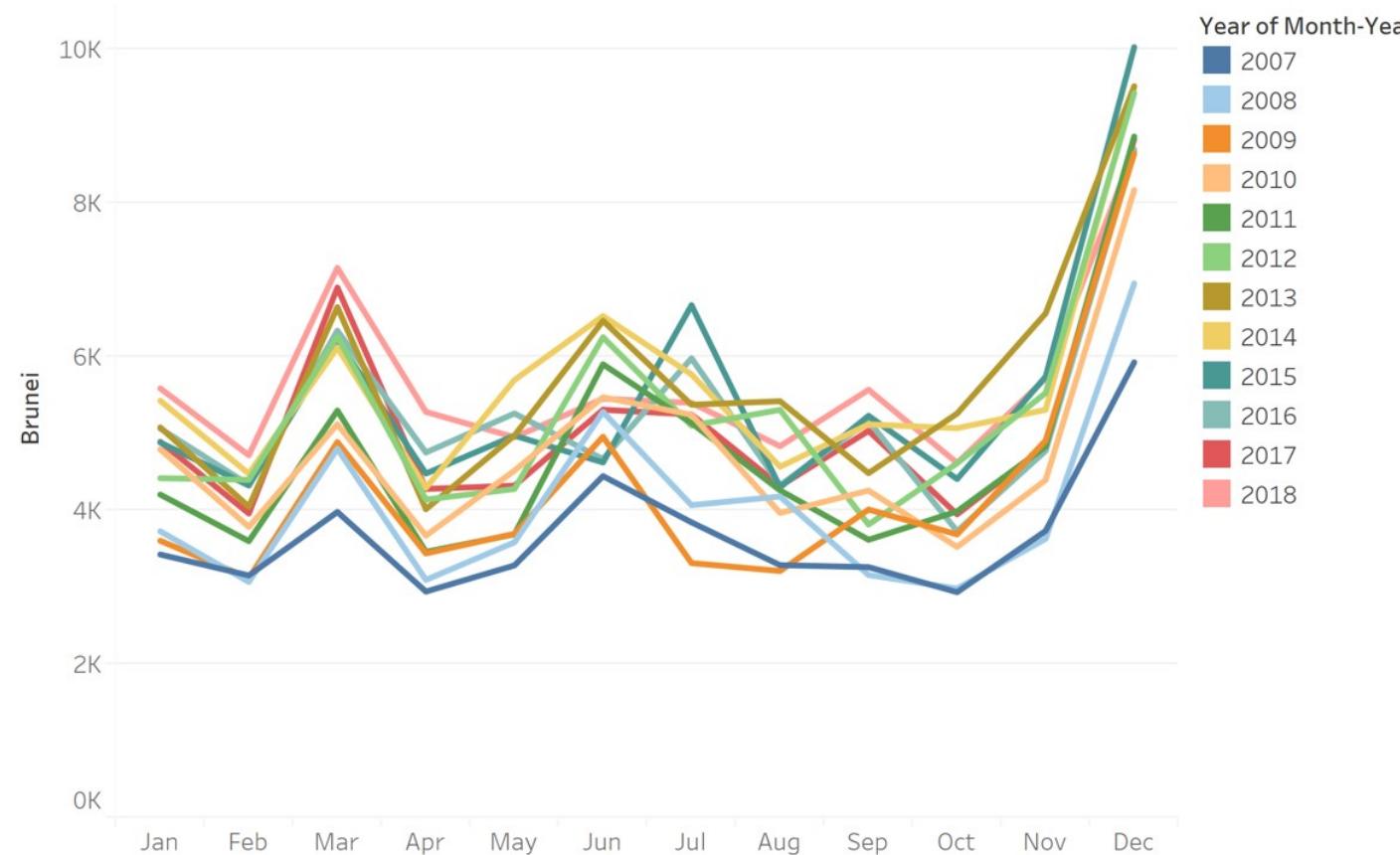
Source: [Unemployment Horizon Chart](#).

This [video](#) provides step-by-step explanation on how to create a horizon graph using Tableau.

Challenge IV: Distribution over time

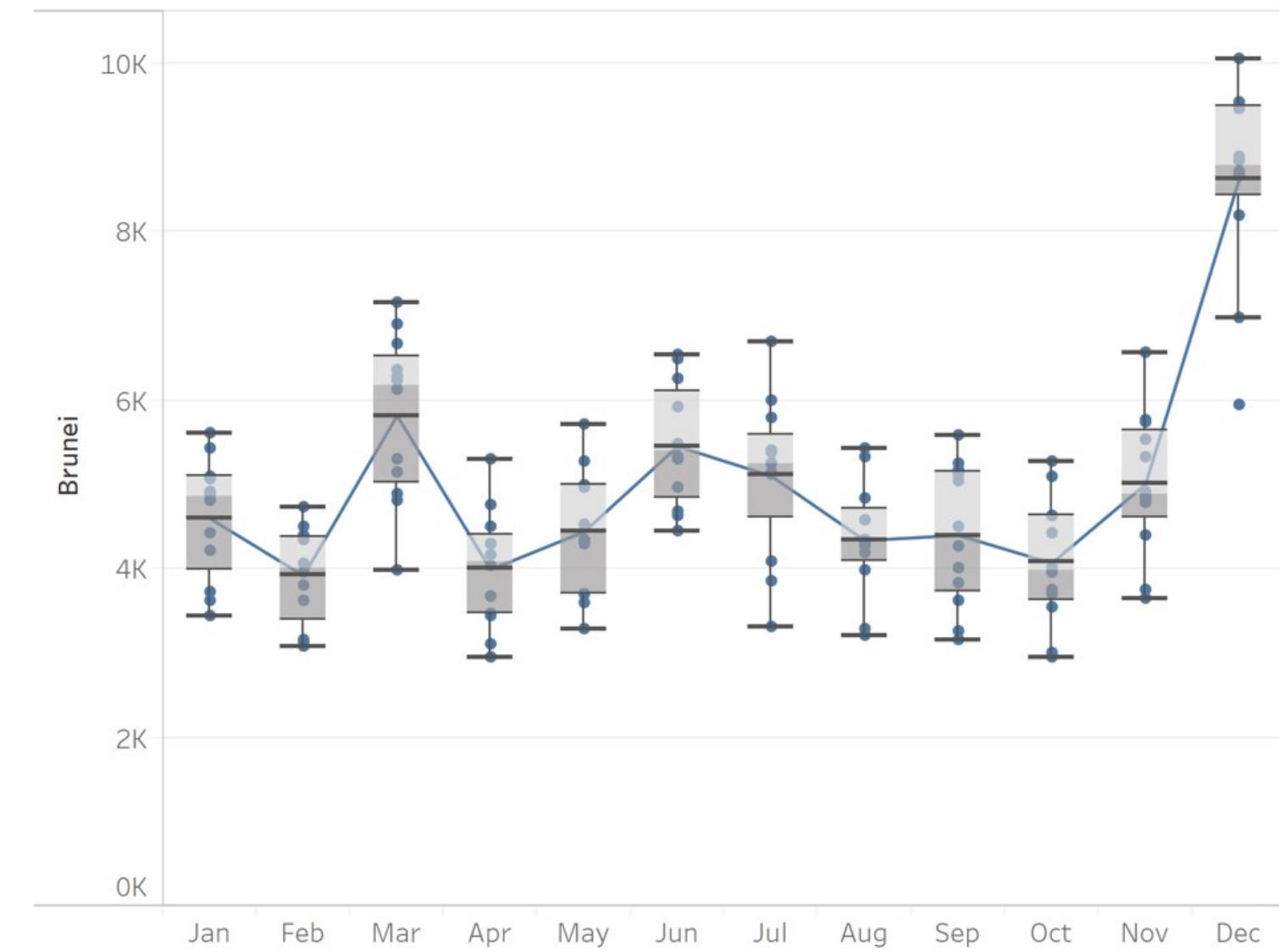
Line graph method

Distribution of monthly visitors by air from Brunei Darussalm, 2007-2018



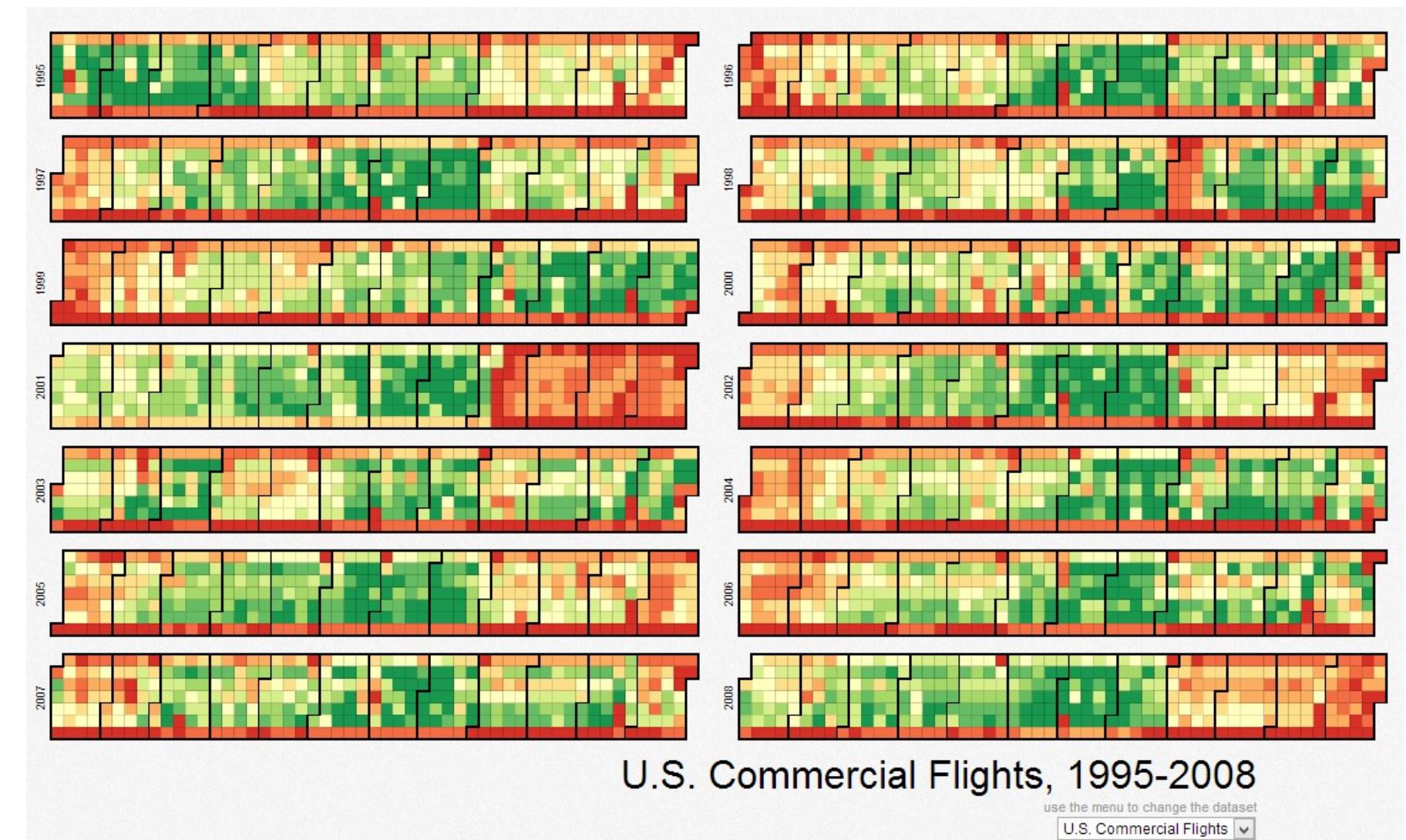
Boxplot method

Distribution of monthly visitors by air from Brunei Darussalm, 2007-2018



Alternative Time-series Data Visualisation methods: Calendar Heatmap

It is a 2-dimensional calendar view that shows a value over time through color coding it, often with warmer colors indicating higher values (hence heatmap).

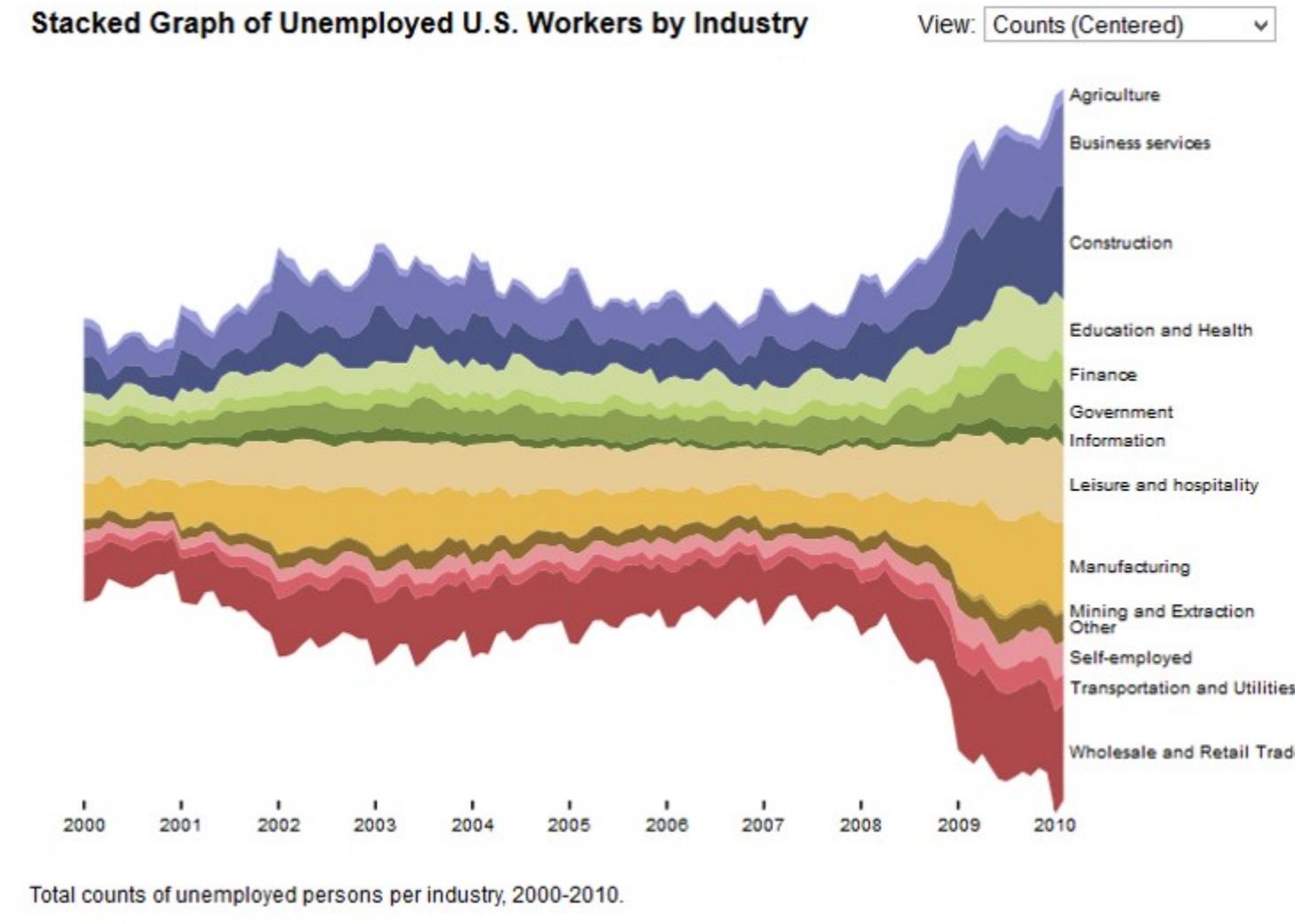


Source: [Calender heatmap](#)

Alternative Time-series Data Visualisation methods

Stream Graph (also know as ThemeRiver)

A streamgraph, or stream graph, is a type of stacked area graph which is displaced around a central axis, resulting in a flowing, organic shape.

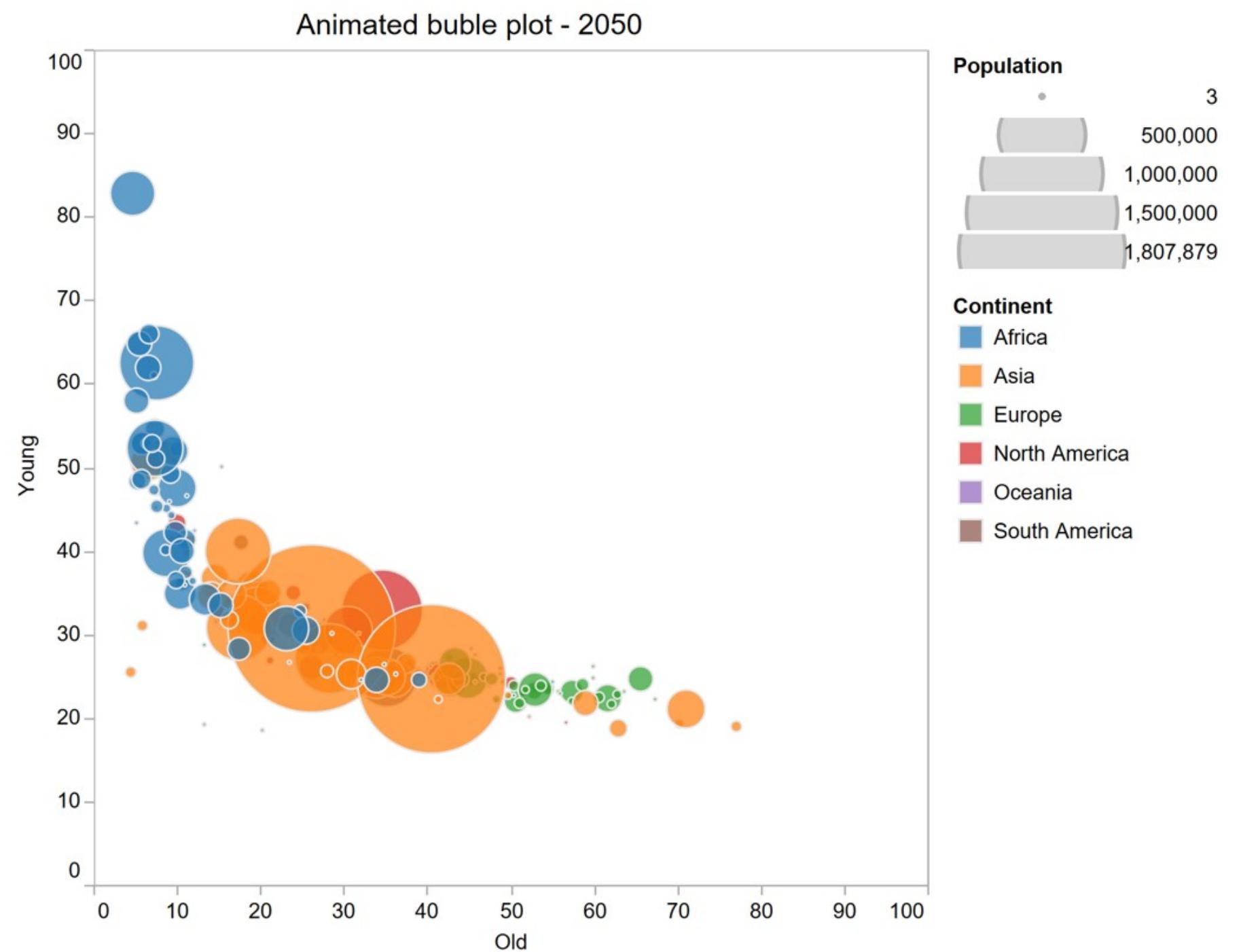


Reference: [Steam graph](#)

Visualising Change Over Time

Animated bubble plot (or motion chart)

A motion chart displays changes over time by showing movement within the two-dimensional space and changes in the size and color of the bubbles.



References

Claus. O. Wilke (2019) **Fundamentals of Data Visualisation**, O'Reilly. USA. Chapter 13 Visualizing time series and other functions of an independent variable and Chapter 14 Visualizing trends

[Introduction to Cycle Plots](#)

[Slopegraphs for comparing gradients: Slopegraph theory and practice](#)

[The Development of the Horizon Graph](#)

