

# Lesson 7: 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_Dec 2010	Year-On-Year % Change
<b>TOTAL</b>	<b>808,480</b>	<b>867,287</b>	<b>828,729</b>	<b>888,604</b>	<b>848,473</b>	<b>860,868</b>	<b>1,084,862</b>	<b>888,811</b>	<b>847,281</b>	<b>878,731</b>	<b>883,868</b>	<b>1,127,020</b>	<b>11,838,883</b>	<b>20.2</b>
<b>AMERICAS</b>	<b>44,800</b>	<b>38,888</b>	<b>48,835</b>	<b>43,008</b>	<b>40,114</b>	<b>48,310</b>	<b>60,466</b>	<b>44,116</b>	<b>34,748</b>	<b>46,881</b>	<b>43,886</b>	<b>44,763</b>	<b>624,831</b>	<b>12.2</b>
Canada	6,860	6,424	7,048	6,733	5,456	4,969	6,645	6,397	4,336	6,161	6,485	7,623	75,137	7.3
USA	35,514	31,166	37,102	33,454	32,108	39,016	41,162	34,194	27,932	36,697	34,311	34,334	416,990	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	20.5
<b>ASIA</b>	<b>627,002</b>	<b>627,581</b>	<b>661,040</b>	<b>697,441</b>	<b>736,393</b>	<b>731,922</b>	<b>831,322</b>	<b>743,847</b>	<b>720,118</b>	<b>726,367</b>	<b>712,178</b>	<b>860,924</b>	<b>8,676,135</b>	<b>25.8</b>
<b>Southeast Asia</b>	<b>331,914</b>	<b>300,137</b>	<b>360,082</b>	<b>390,263</b>	<b>403,078</b>	<b>433,791</b>	<b>466,886</b>	<b>381,827</b>	<b>447,643</b>	<b>410,299</b>	<b>391,382</b>	<b>633,440</b>	<b>4,819,761</b>	<b>30.8</b>
Brunei Darussalam	5,245	4,139	5,692	3,943	4,796	5,963	5,578	4,244	4,628	3,750	4,673	9,513	62,154	10.0
Indonesia	173,639	143,917	165,942	162,800	185,757	214,382	232,528	165,483	243,763	178,903	175,969	262,056	2,305,149	32.1
Malaysia	67,941	68,663	81,745	77,441	81,867	93,070	82,592	75,867	96,455	82,746	99,833	129,599	1,036,918	35.7
Myanmar	5,512	4,492	7,000	6,691	6,666	6,232	6,877	6,838	5,376	6,482	6,963	8,276	78,184	11.3
Philippines	32,703	32,610	43,966	64,448	66,307	44,484	43,440	39,244	40,662	62,007	60,092	66,492	644,344	26.0
Thailand	24,636	23,163	31,813	60,666	38,921	30,710	37,266	34,790	30,709	67,960	30,192	39,238	430,022	36.3
Vietnam	19,109	20,477	21,336	26,680	26,162	36,686	43,889	32,843	24,331	24,691	21,246	28,643	322,863	21.6
Other Countries in Southeast Asia	3,130	2,786	2,699	4,706	3,723	3,364	3,766	3,628	2,719	3,771	3,304	2,723	40,127	21.6
<b>North Asia</b>	<b>212,272</b>	<b>267,600</b>	<b>212,802</b>	<b>203,699</b>	<b>191,367</b>	<b>183,940</b>	<b>200,763</b>	<b>293,017</b>	<b>188,646</b>	<b>213,442</b>	<b>217,610</b>	<b>220,603</b>	<b>2,683,640</b>	<b>23.1</b>
Hong Kong SAR	19,416	24,904	26,246	36,660	32,046	32,190	46,726	46,696	28,467	32,833	29,847	32,626	387,662	31.6
Japan	37,747	40,666	61,834	36,160	36,819	36,447	44,646	66,644	44,999	43,493	61,627	48,836	628,817	7.9
P R China	98,918	143,060	88,031	91,701	71,628	69,080	117,775	130,666	74,434	92,600	93,998	99,596	1,171,337	26.0
South Korea	39,437	29,589	30,113	24,781	32,169	30,032	32,668	34,169	26,663	29,008	27,814	26,260	360,673	32.6
Taiwan	16,510	17,737	16,219	14,608	17,111	13,642	23,933	20,969	13,486	13,861	13,131	12,166	191,173	22.0
Other Countries in North Asia	1,246	1,664	1,360	1,869	1,696	2,649	3,006	3,684	1,606	1,667	1,493	2,161	24,088	74.6
<b>South Asia</b>	<b>74,021</b>	<b>69,674</b>	<b>70,799</b>	<b>94,410</b>	<b>133,267</b>	<b>102,683</b>	<b>66,628</b>	<b>76,337</b>	<b>71,180</b>	<b>92,960</b>	<b>88,479</b>	<b>96,062</b>	<b>1,046,200</b>	<b>12.6</b>
Bangladesh	7,762	6,726	7,747	7,628	7,703	8,624	9,373	7,144	7,942	7,643	7,438	7,879	92,309	6.6
India	57,404	46,061	53,966	73,214	115,966	83,467	64,906	67,107	64,826	76,567	72,918	73,516	828,903	14.2
Nepal	1,619	1,011	1,286	1,222	1,188	1,004	1,242	1,196	912	1,372	1,006	1,246	14,303	-5.8
Pakistan	1,586	1,292	1,662	1,707	1,666	2,926	3,907	1,610	1,126	1,469	1,401	1,776	21,926	-1.6
Sri Lanka	4,770	4,734	5,373	9,960	6,043	5,760	6,206	7,816	5,769	6,296	5,786	10,476	78,967	12.8
Other Countries in South Asia	881	760	766	779	813	892	896	664	617	734	932	1,170	9,793	6.8
<b>West Asia</b>	<b>8,796</b>	<b>10,370</b>	<b>17,367</b>	<b>9,169</b>	<b>8,691</b>	<b>11,608</b>	<b>20,166</b>	<b>13,668</b>	<b>12,760</b>	<b>9,646</b>	<b>13,607</b>	<b>10,619</b>	<b>146,644</b>	<b>26.2</b>
Iran	1,779	4,042	10,024	1,184	1,448	2,118	2,032	2,727	4,180	2,216	2,612	2,669	36,930	64.4
Israel	1,277	997	1,175	956	1,029	1,174	918	1,198	786	1,109	1,310	903	12,831	17.9
Kuwait	443	587	468	306	461	806	2,648	719	536	380	723	403	8,368	46.6
Saudi Arabia	512	714	689	1,038	771	941	2,400	972	1,346	902	1,564	793	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	4,613	66,474	14.0
Other Countries in West Asia	1,098	964	1,160	1,386	1,228	1,969	3,388	1,908	1,606	1,367	1,679	1,538	19,310	19.8

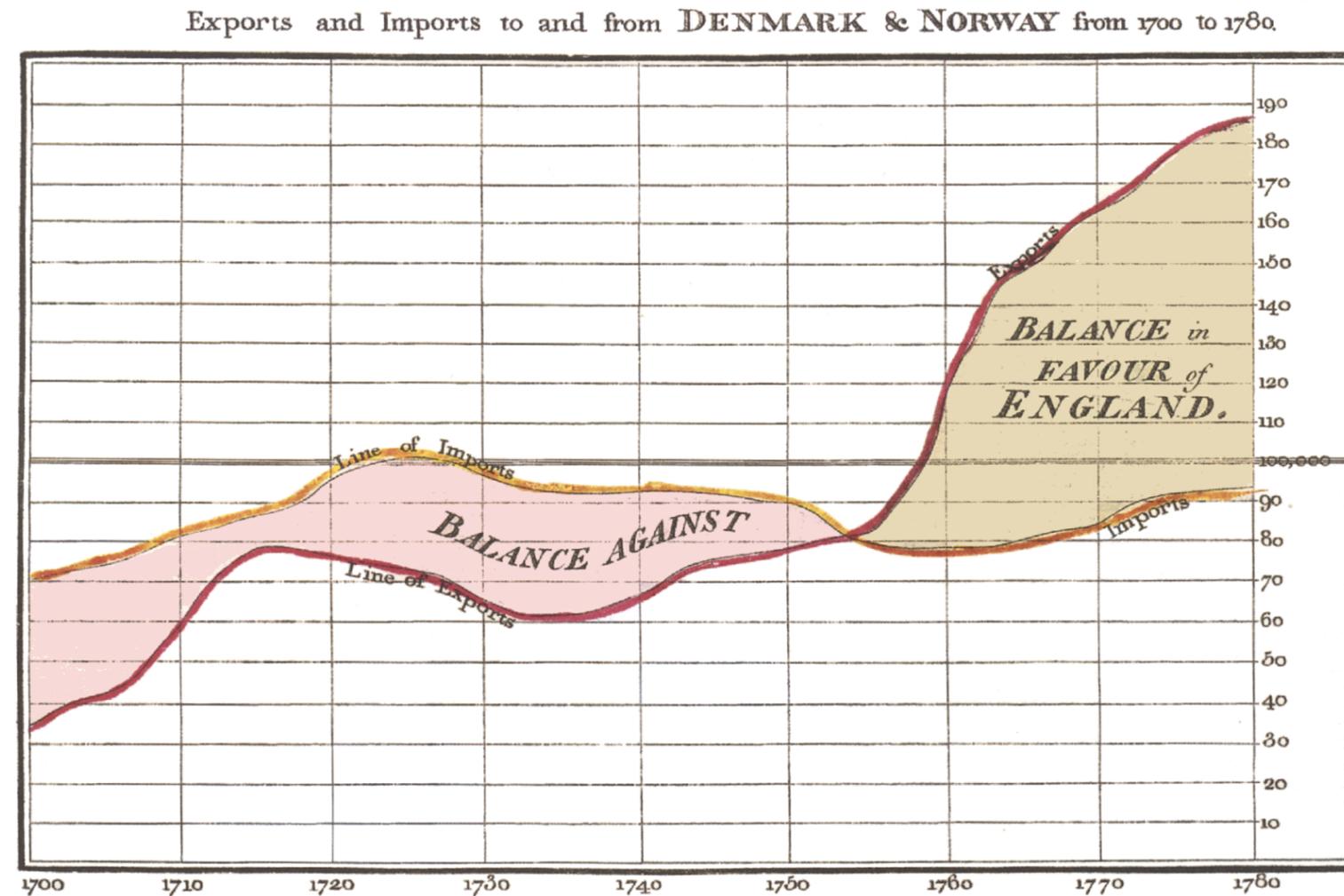
# Characteristics of time-series data

## Not so friendly time-series data

END OF PERIOD			\$ PER UNIT OF EURO	\$ PER UNIT OF POUND STERLING	\$ PER UNIT OF US DOLLAR	\$ 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)

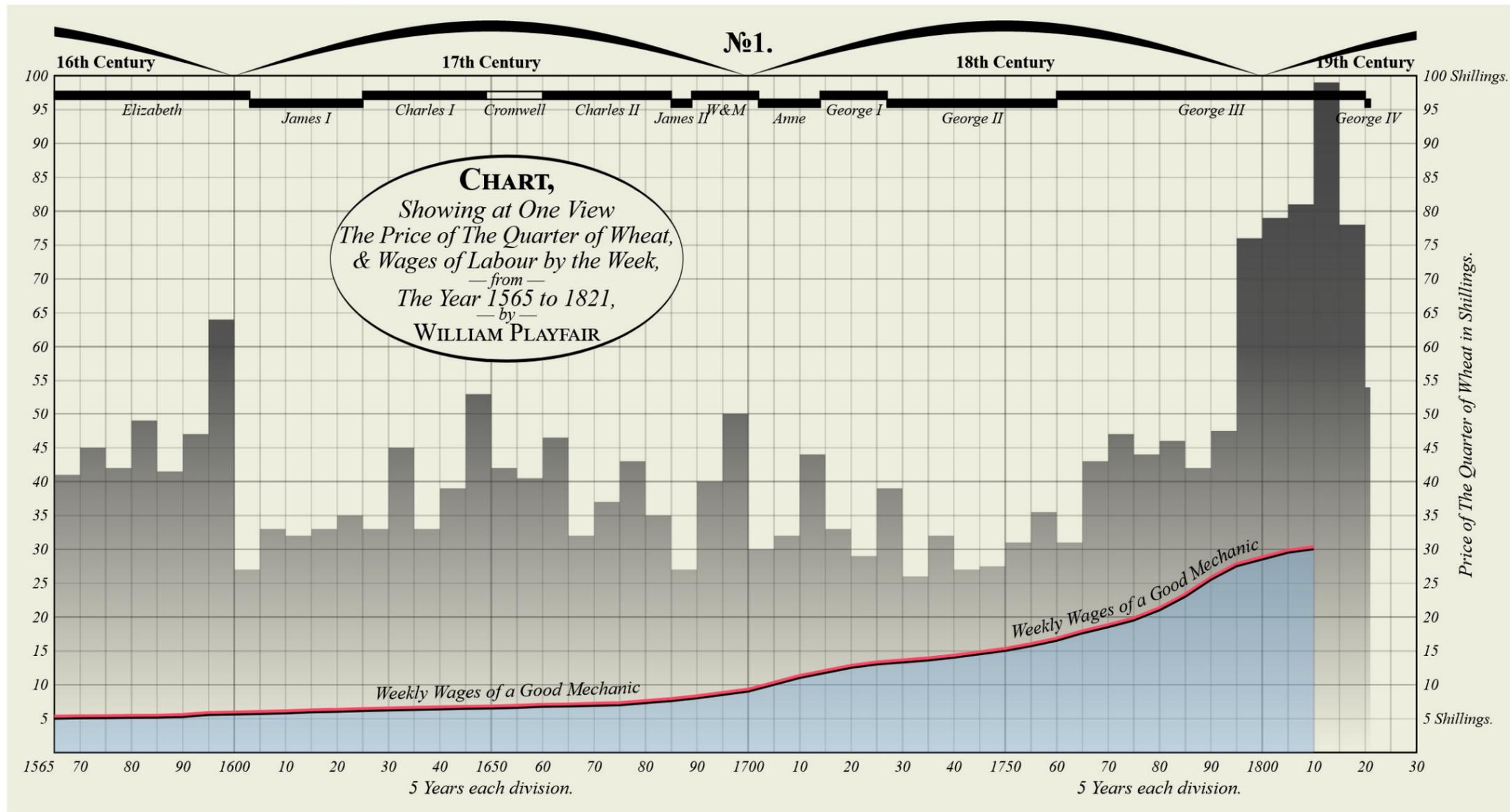


*The Bottom line is divided into Years, the Right hand line into £10,000 each.*  
Published as the Act direct, 1<sup>st</sup> May 1786. by W<sup>m</sup> Playfair. Neale sculpt 352, Strand, London.

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](#)

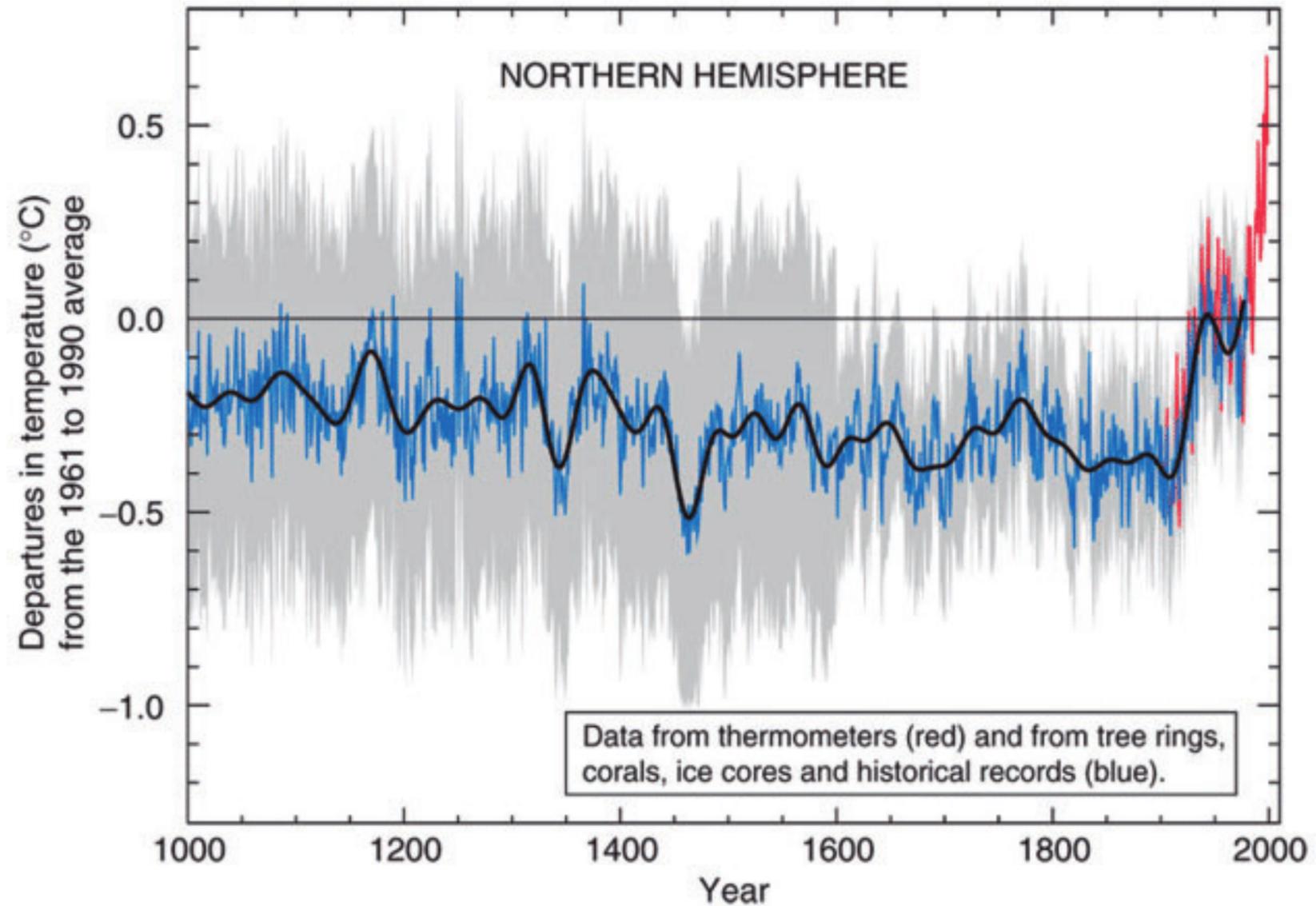
# A short visual history of time-series graphs

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



# 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.

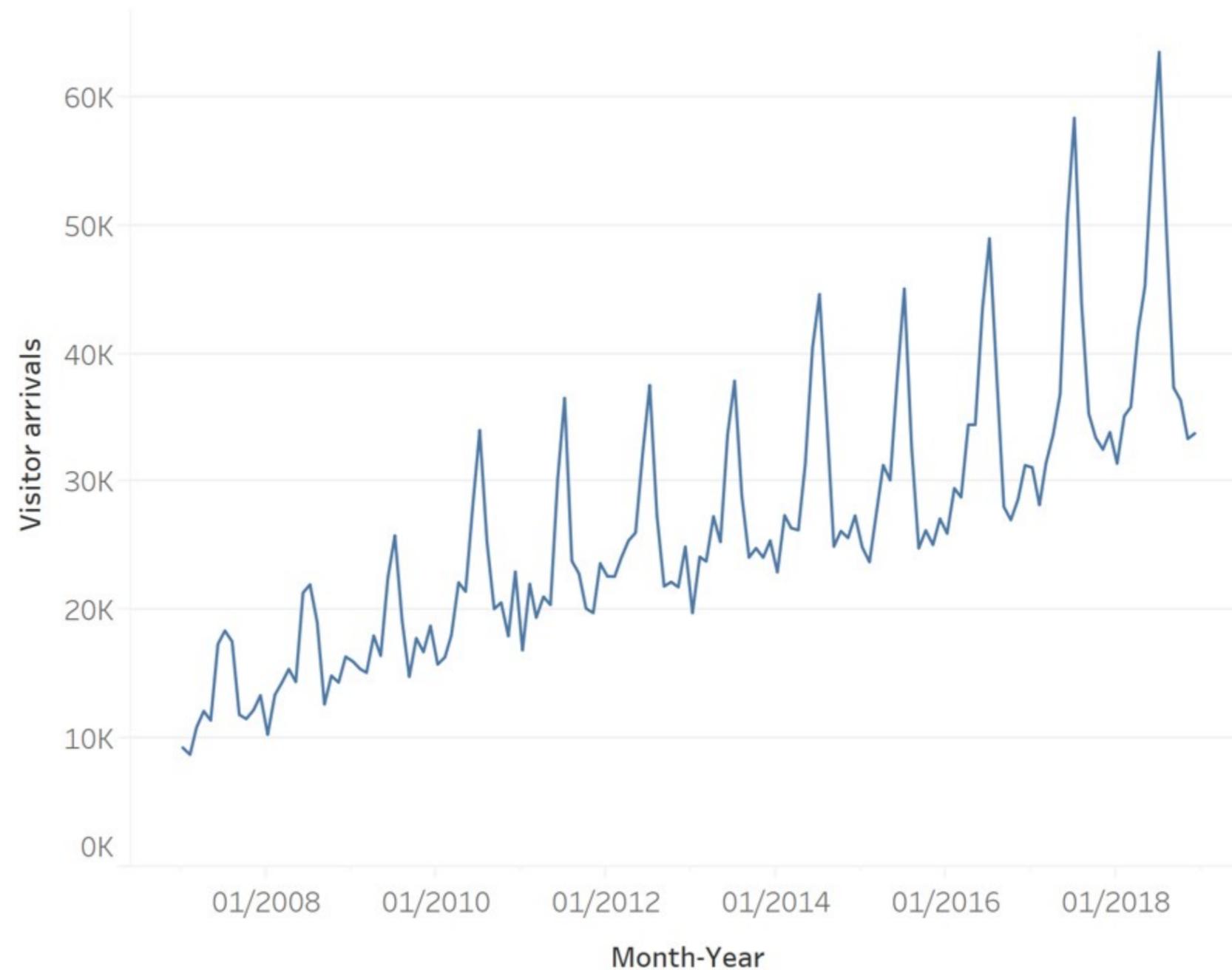
# Time-series data patterns

- 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.

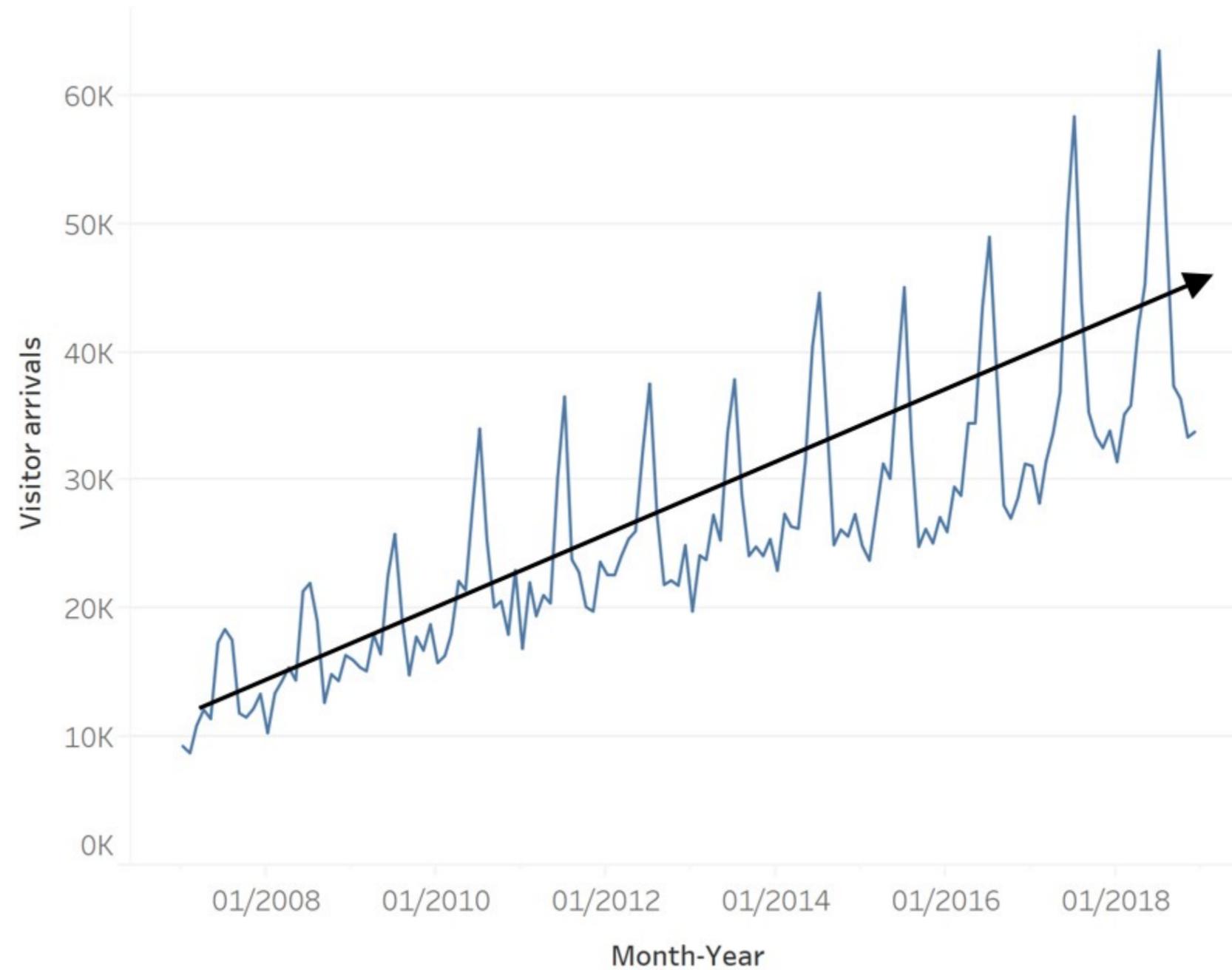
Monthly visitor arrivals from **Vietnam**, 2007-2018



# Time-series Patterns: Trend

- An upward trend.

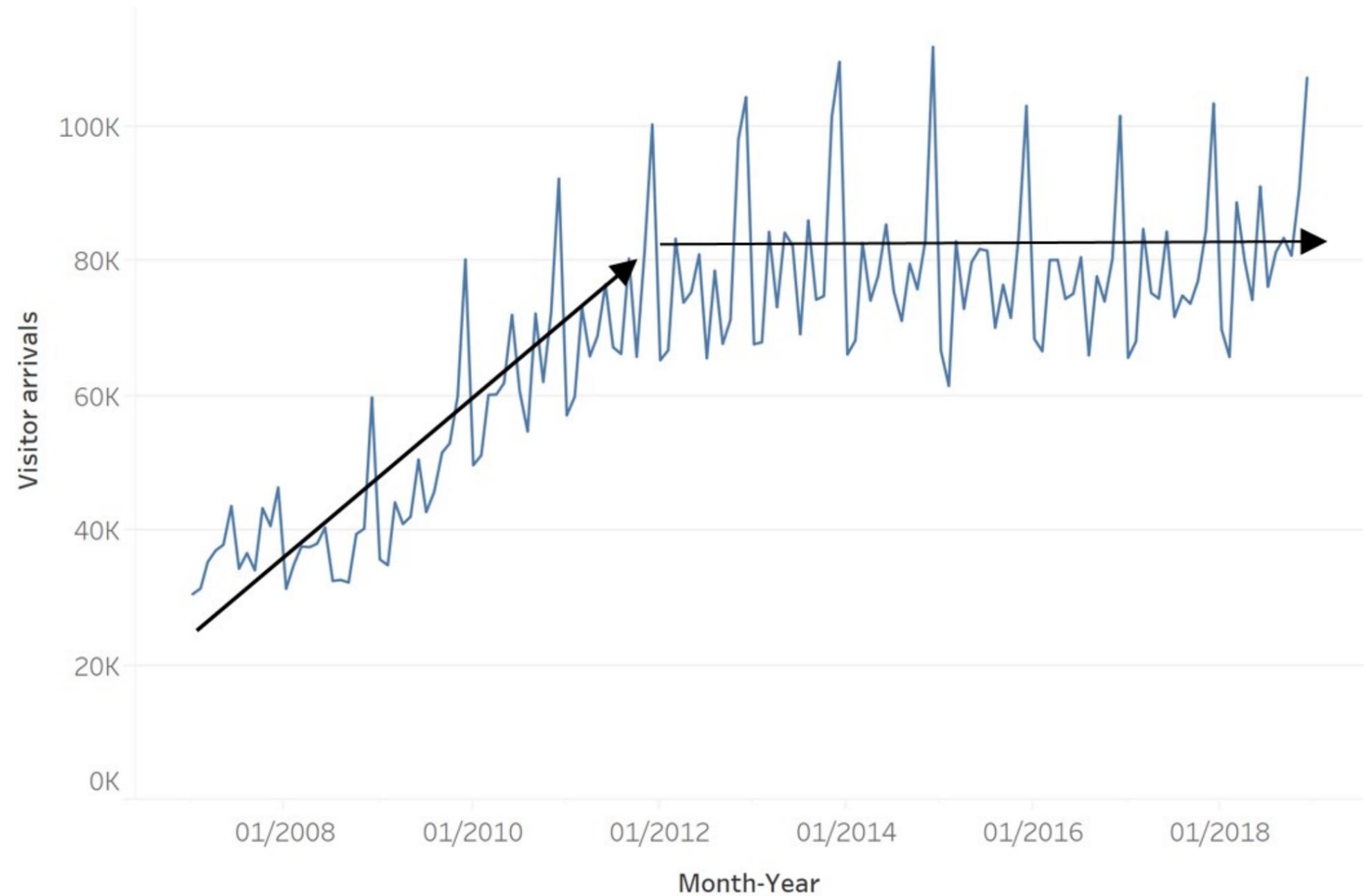
Monthly visitor arrivals from **Vietnam**, 2007-2018



# Time-series Patterns: Trend

- A mixed trends.

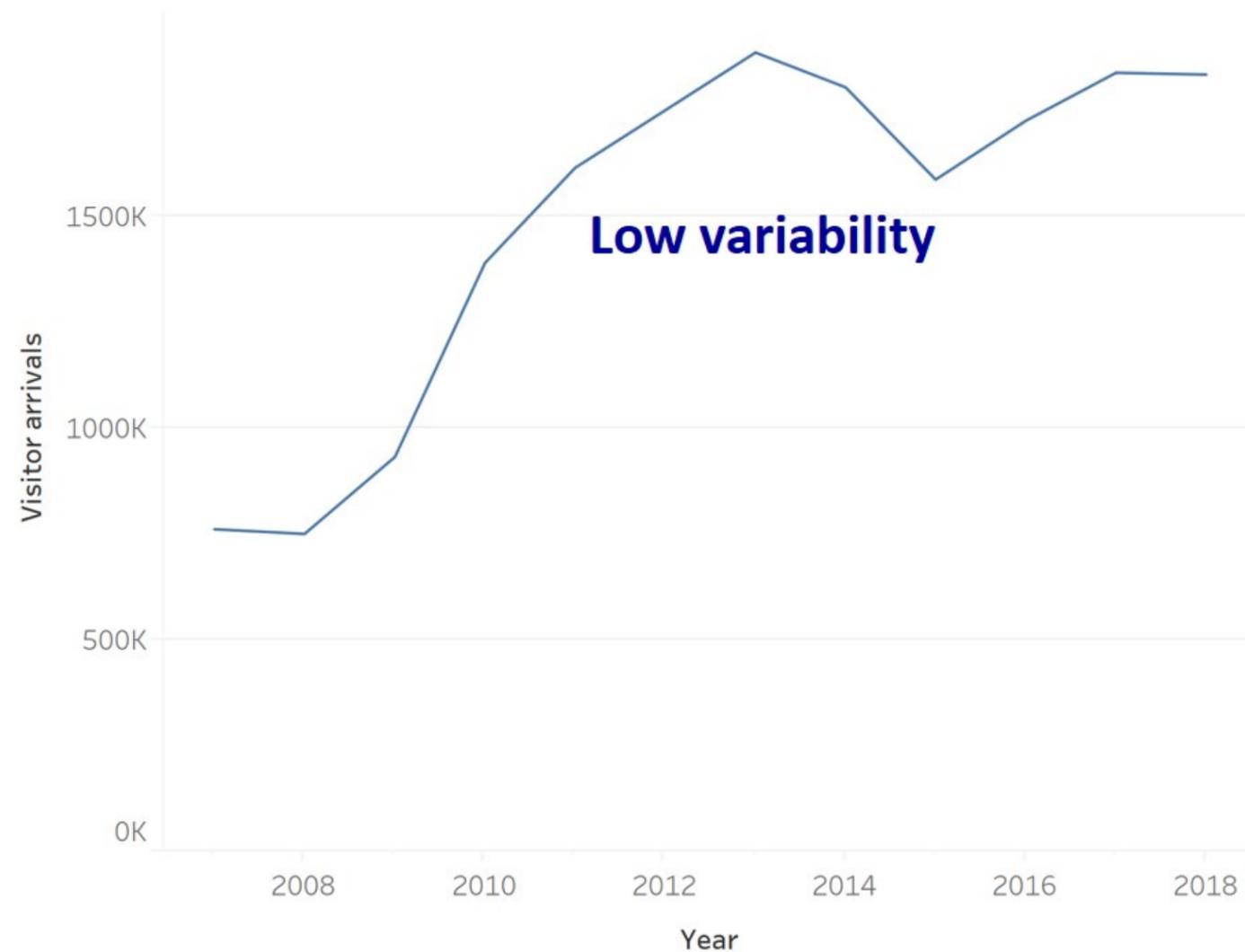
Monthly visitor arrivals from **Malaysia**, 2007-2018



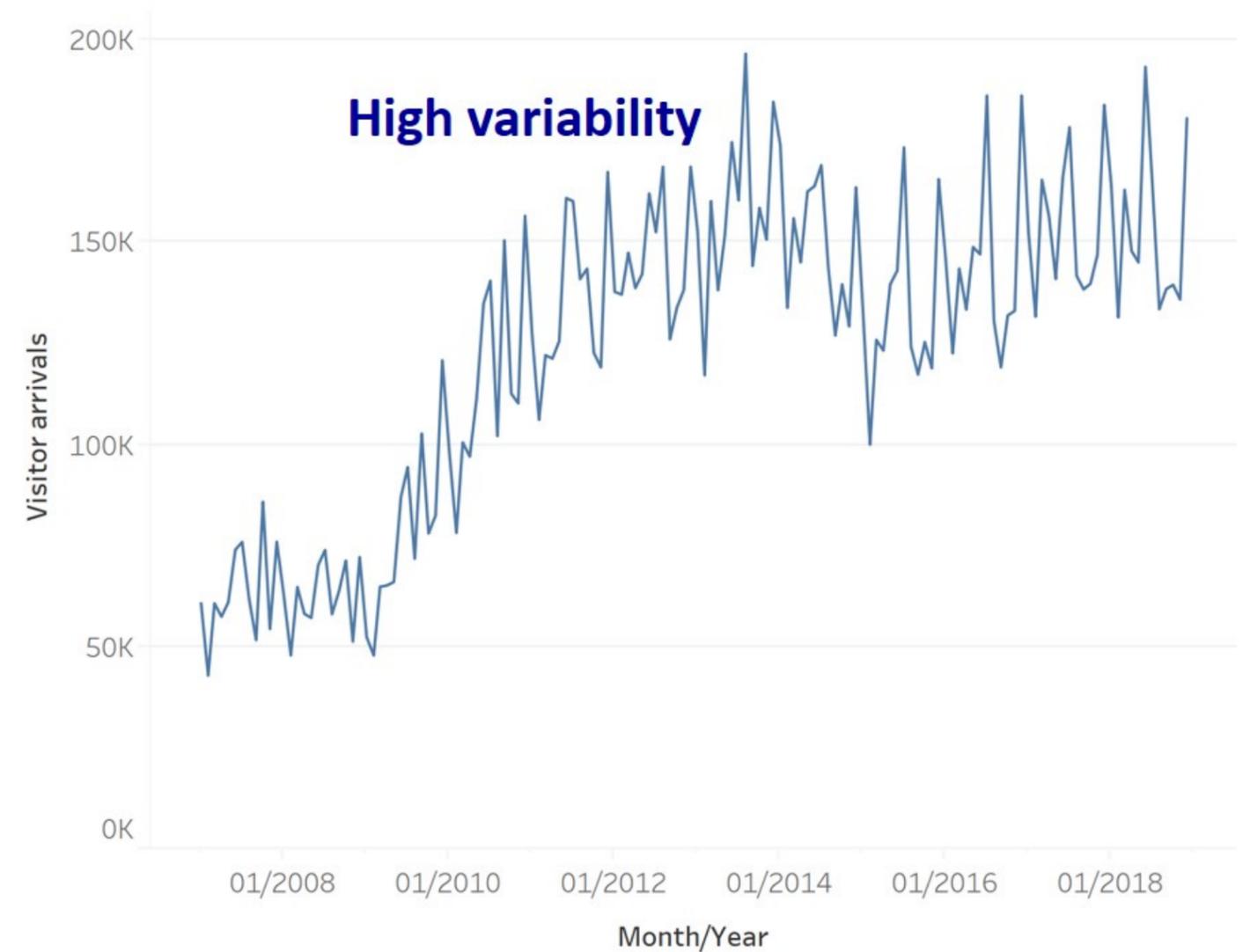
# Time-series Patterns: Variability

- 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



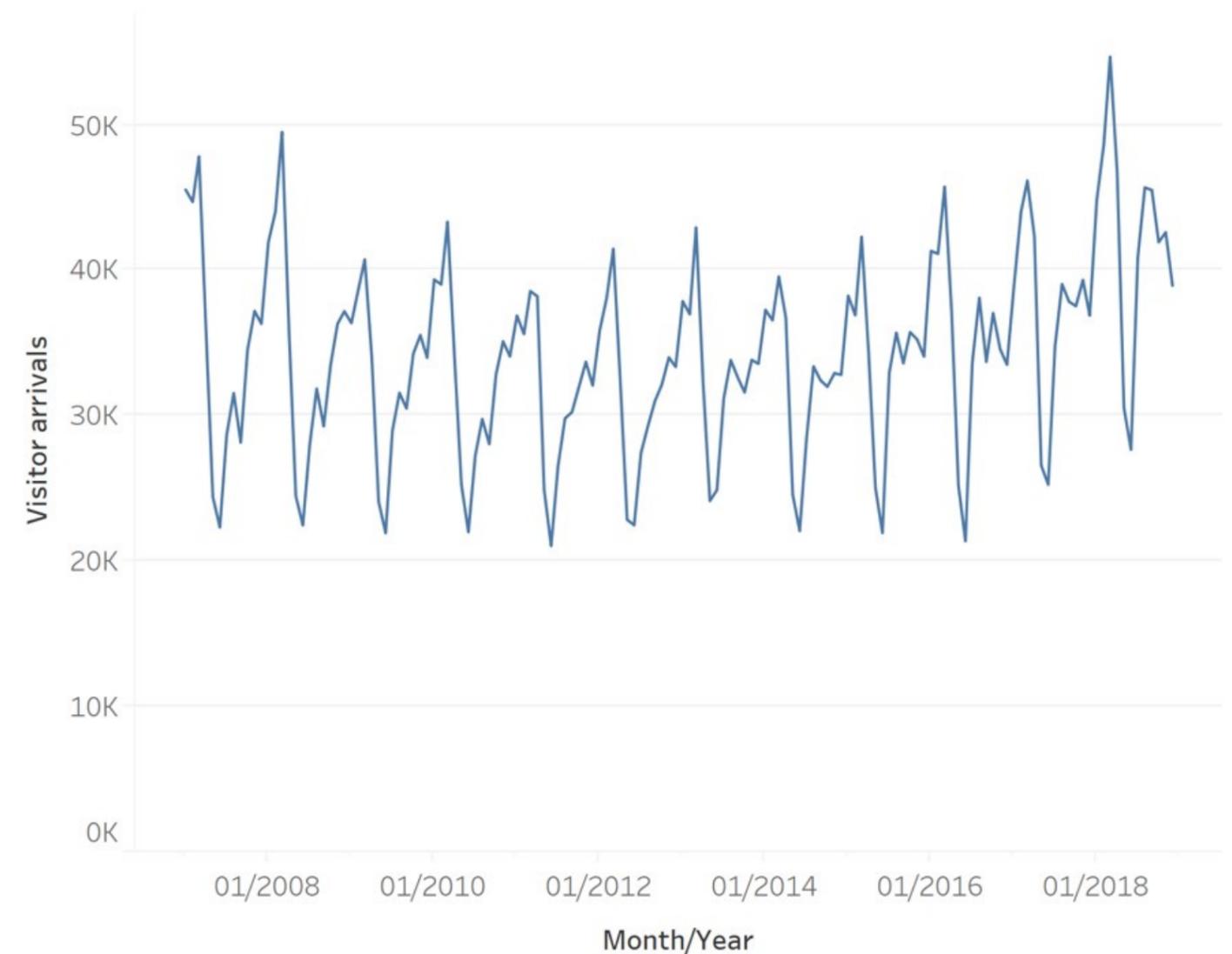
Monthly visitor arrivals from **Indonesia**, 2007-2018



# Time-series Patterns: Cycles

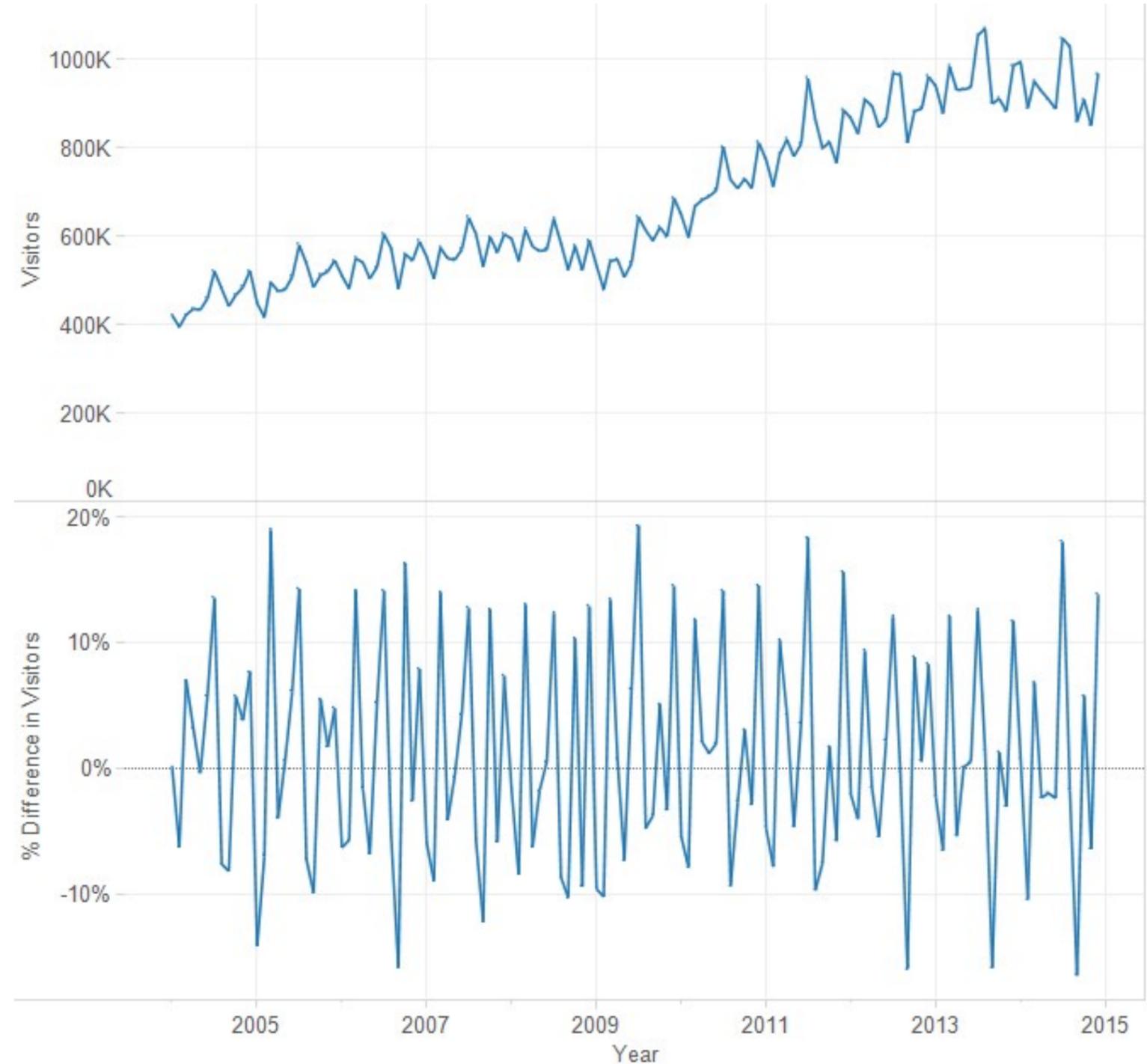
- Cycles are patterns that repeat at regular intervals.
- From the line graph, we can see that visitor arrivals from United Kingdom reach its peak on January and lowest on May every year.

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



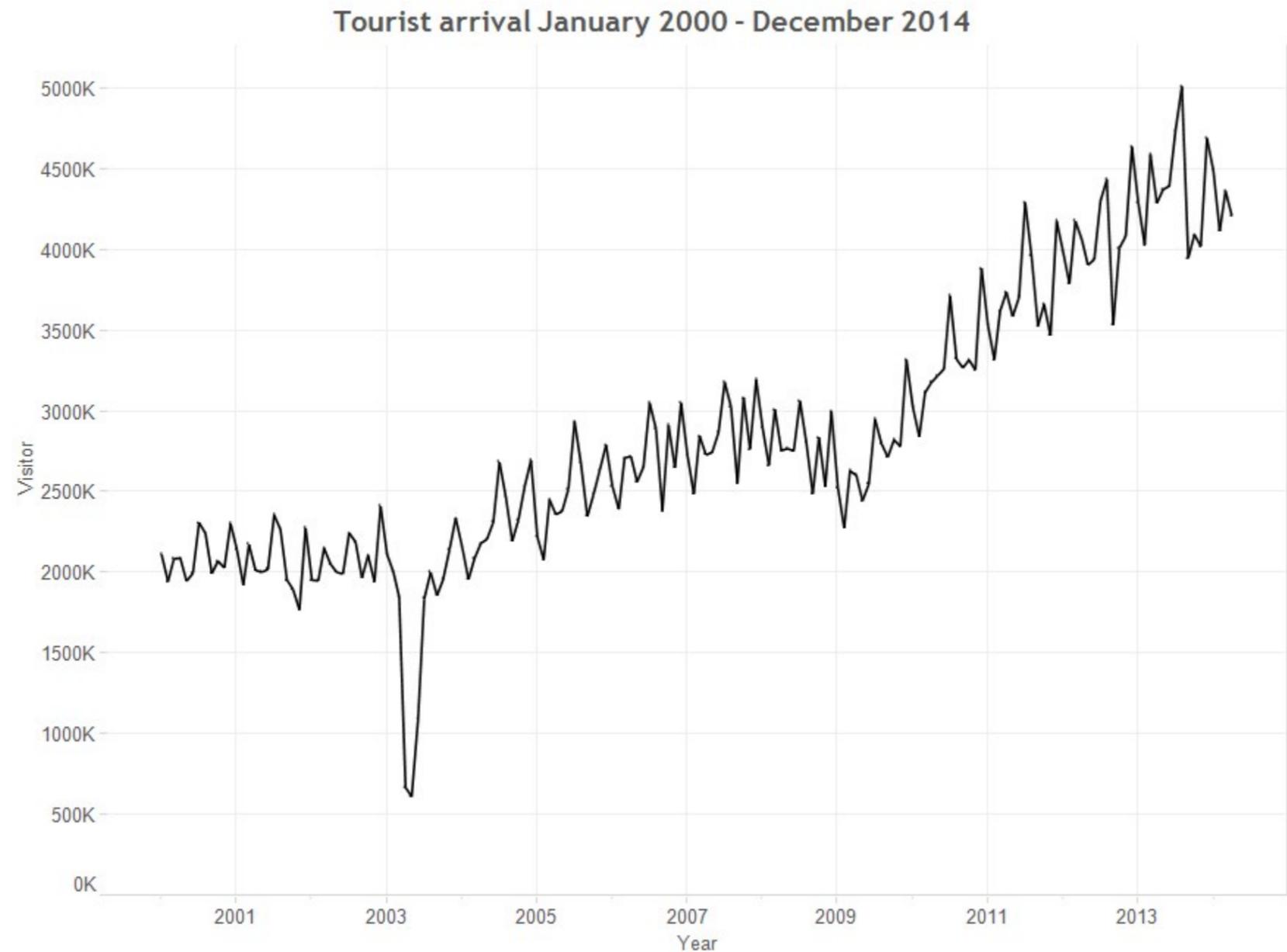
# Time-series Patterns: Rate of change

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



# Time-series Patterns: Exceptions

- Values that fall outside the norm.

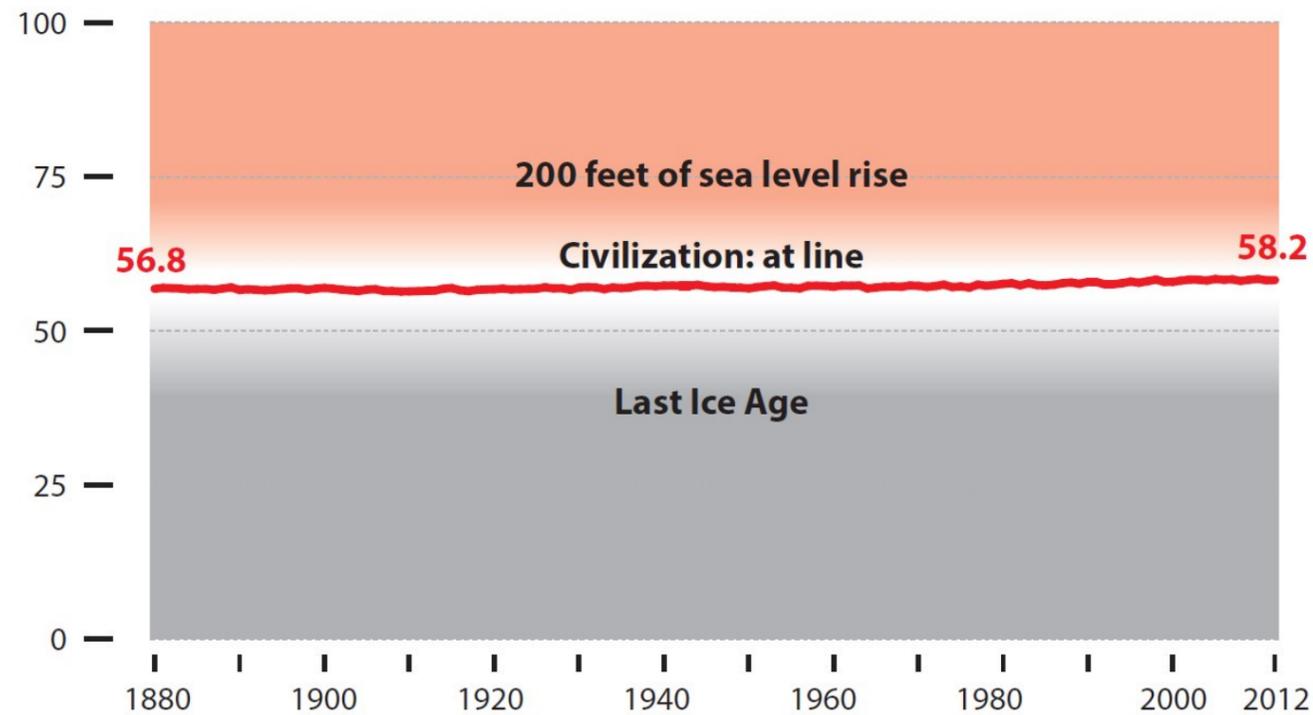


This line graph show the significant impact of SAR on the visitor arrivals pattern to Singapore.

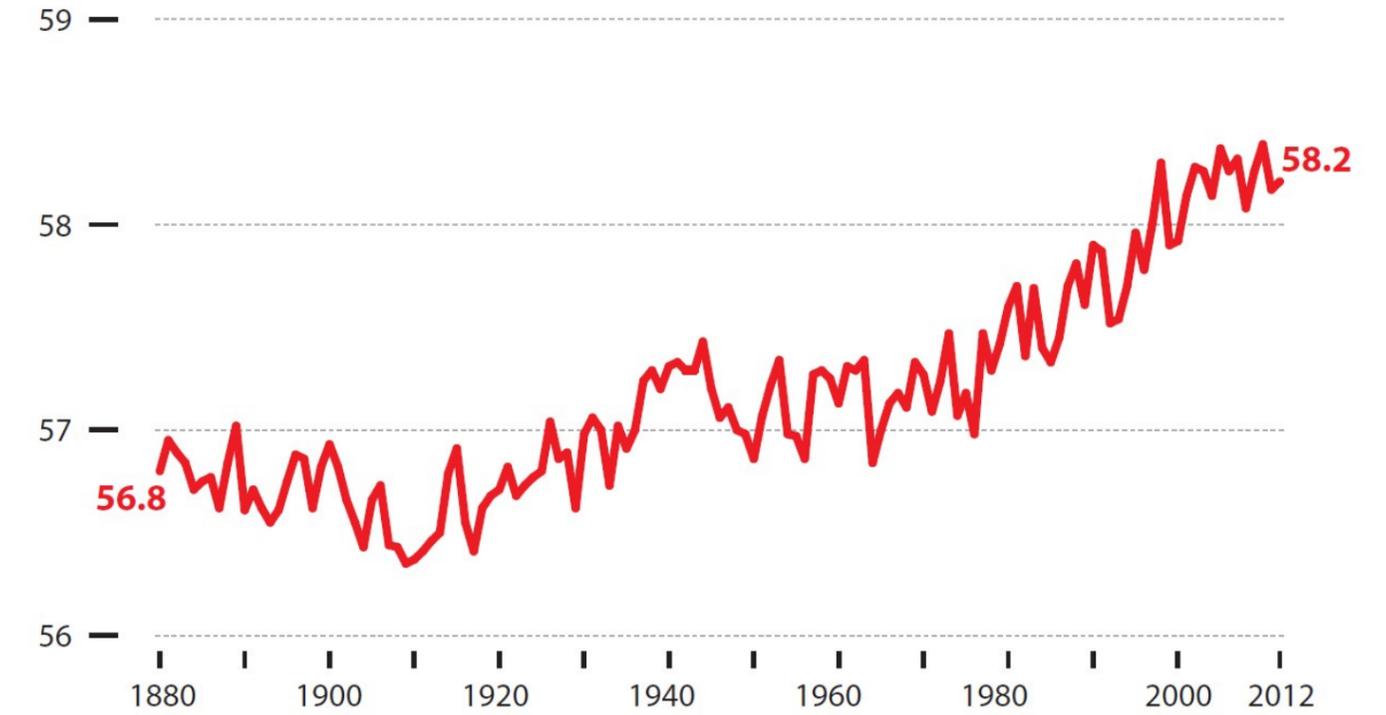
# Line graph design tips

Not all line graphs should start at zero!

Average annual global temperature in degrees Fahrenheit



Average annual global temperature in degrees Fahrenheit



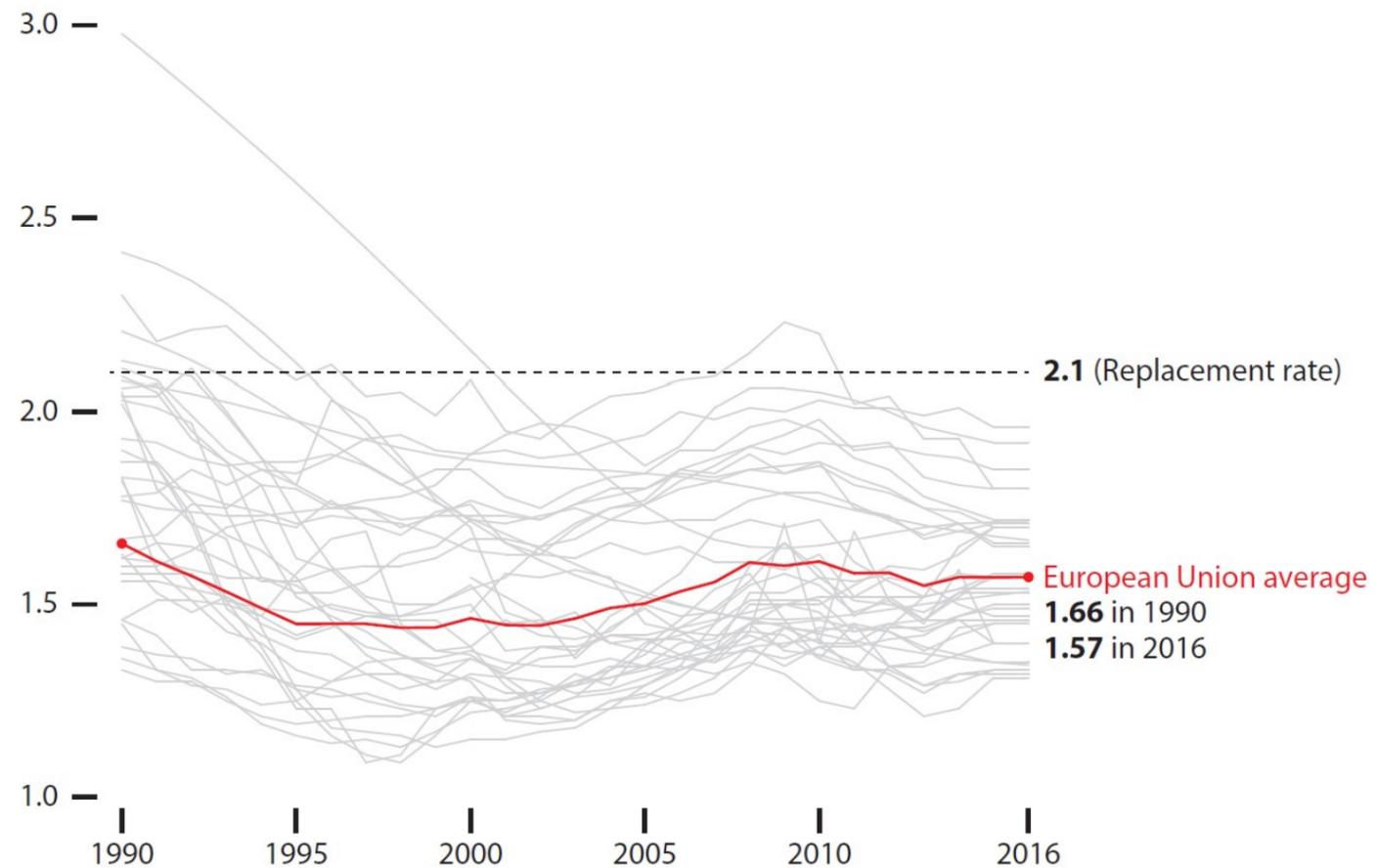
# Line graph design tips

## 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.

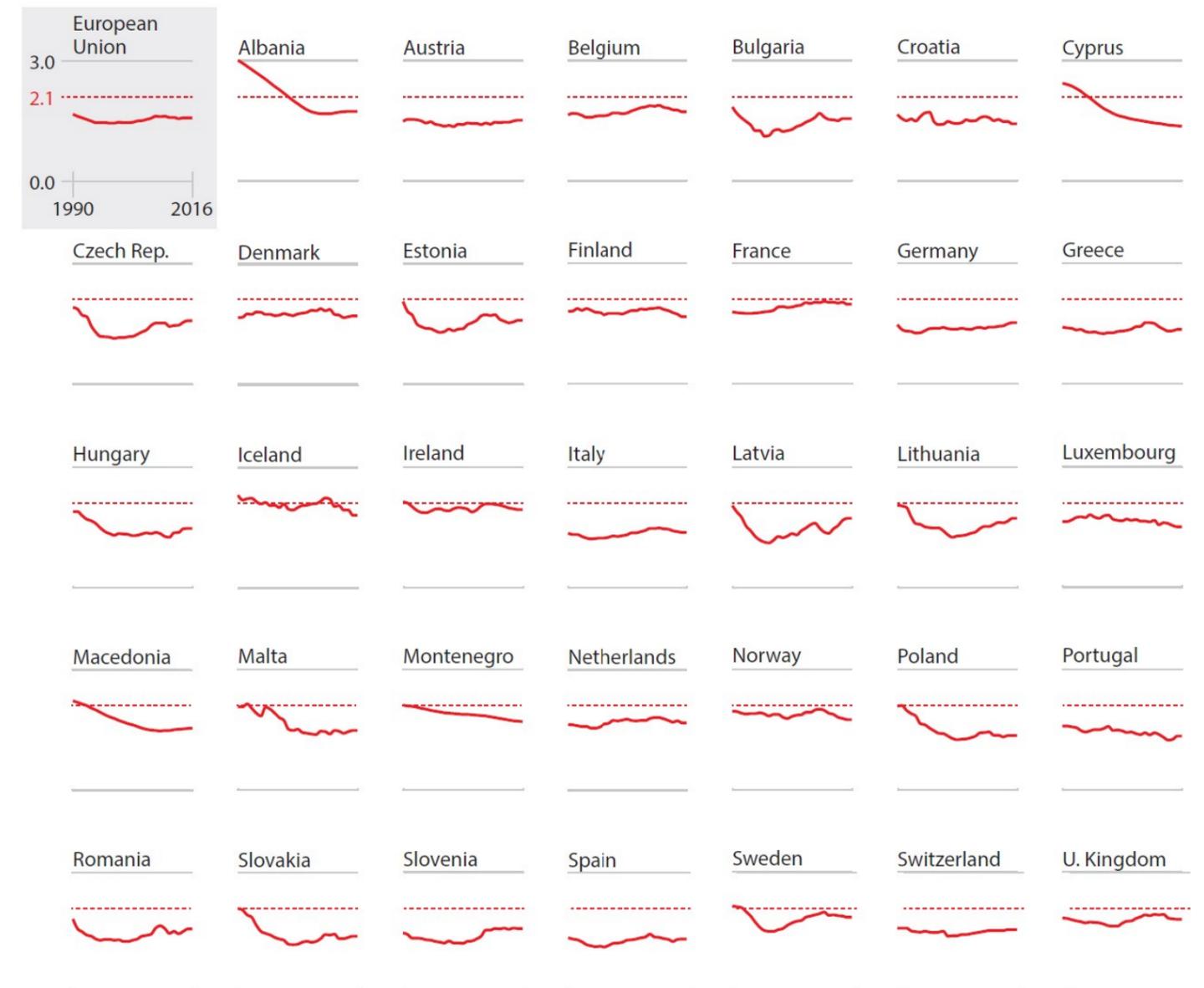
(Source: World Bank Data)



### Fertility rate in European countries, 1990–2016

Compared to the replacement rate: 2.1 children per woman

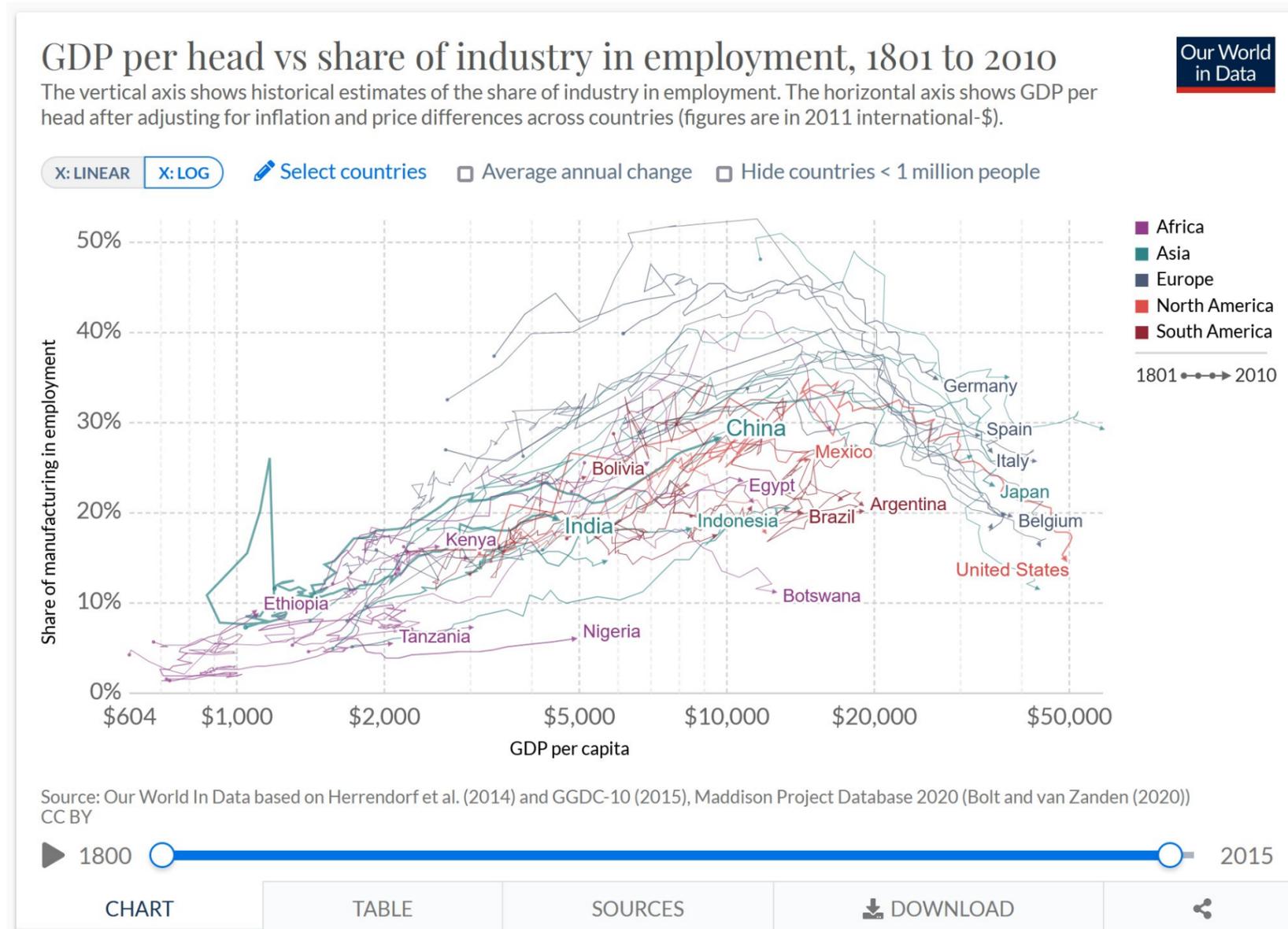
Note: not all these countries belong to the European Union





# Line graph design tips

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

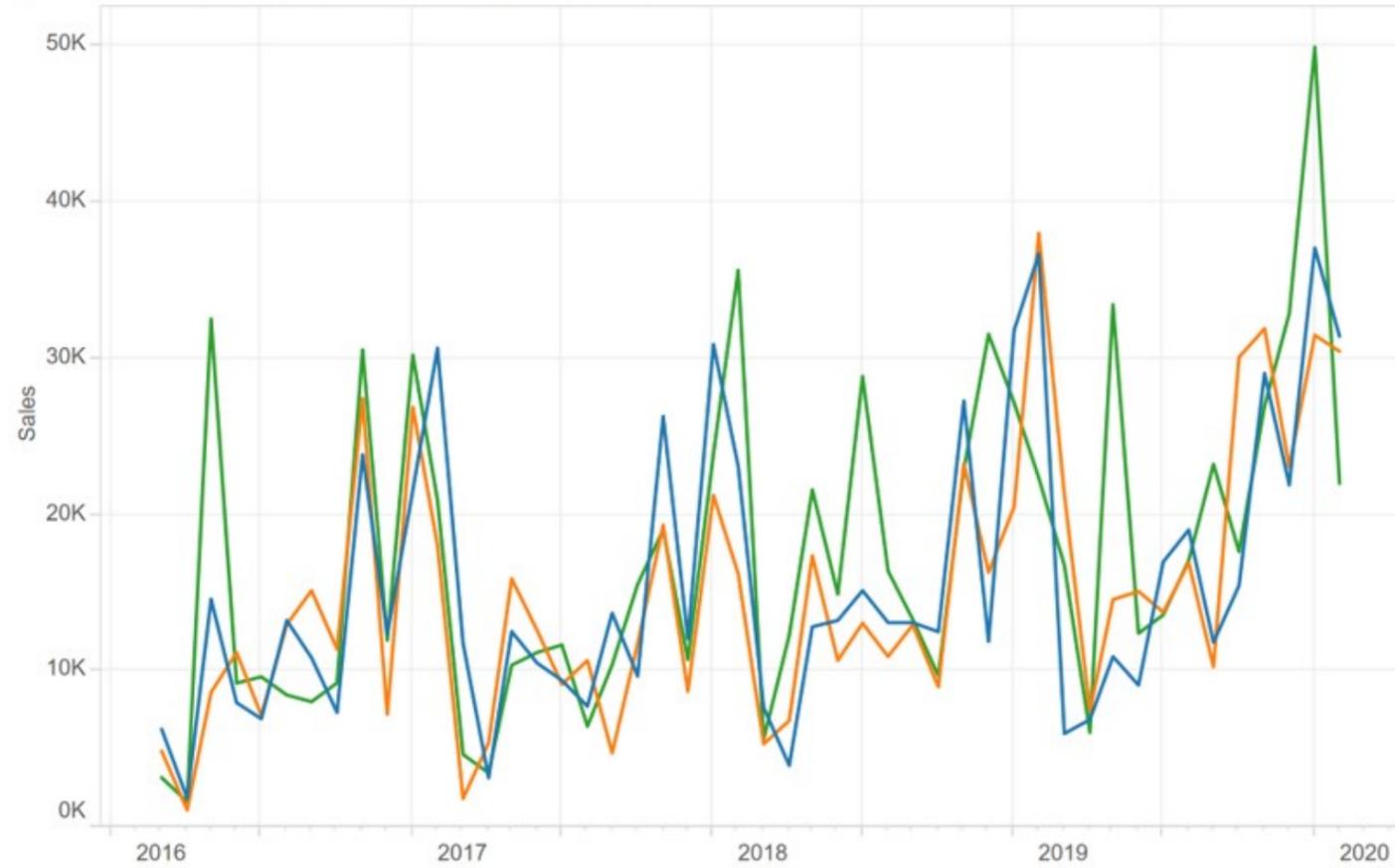


Source: [Are emerging economies deindustrializing too quickly?](#)

# Line graph design tips

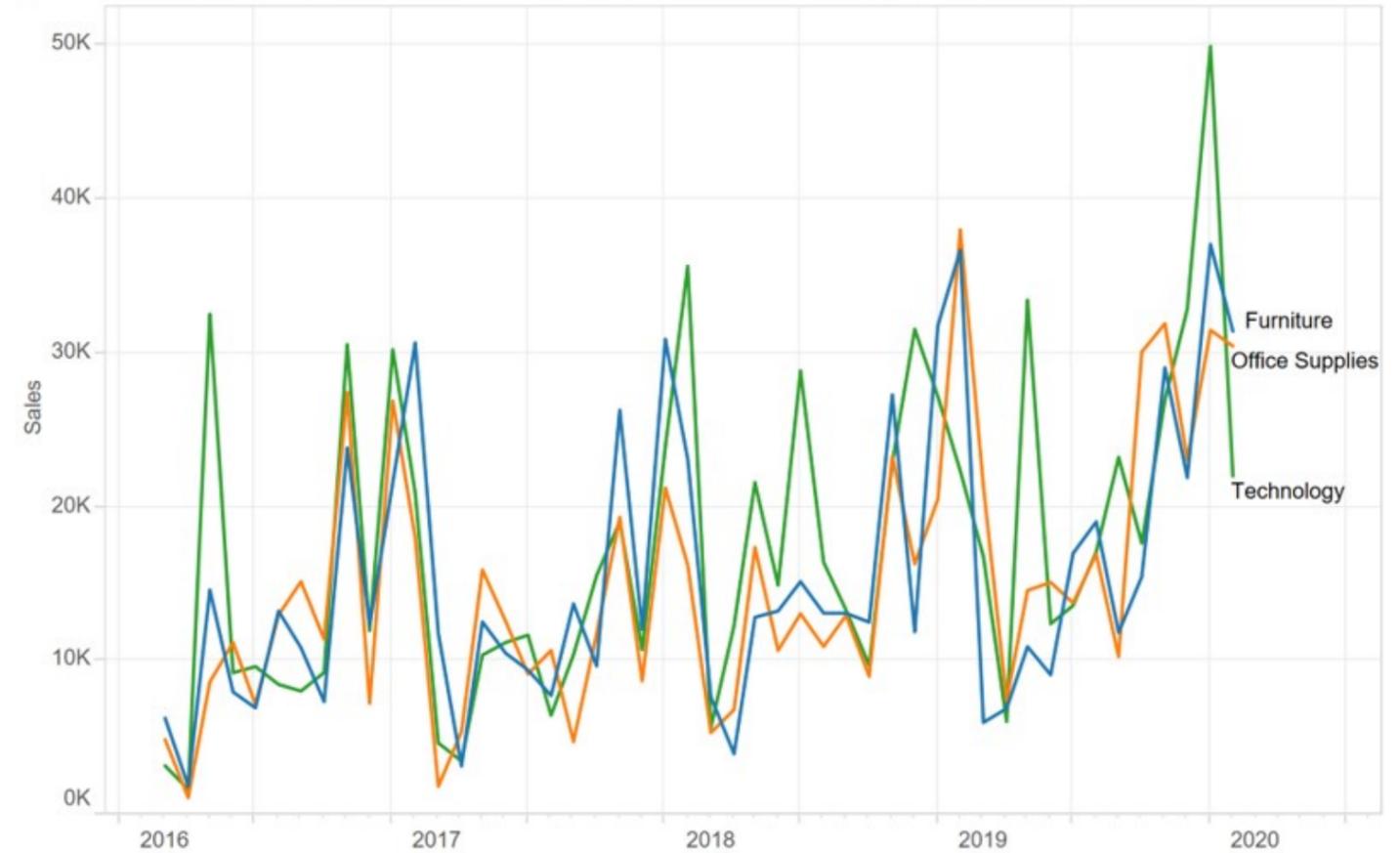
## Label line graph instead of using legend

Monthly sales by product category, January 2016-December 2019



**Category**  
■ Furniture  
■ Office Supplies  
■ Technology

Monthly sales by product category, January 2016-December 2019

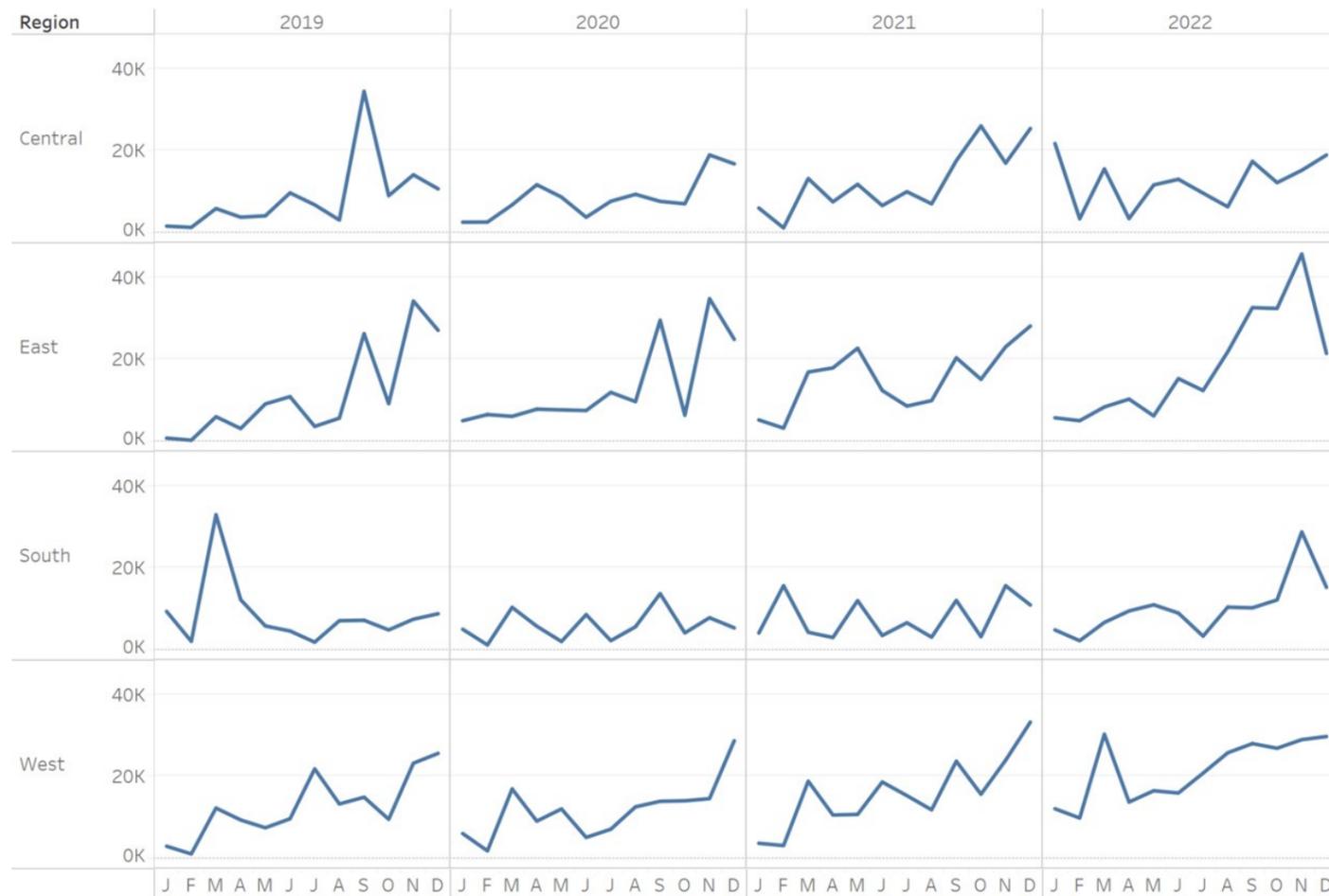


# Line graph design tips

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

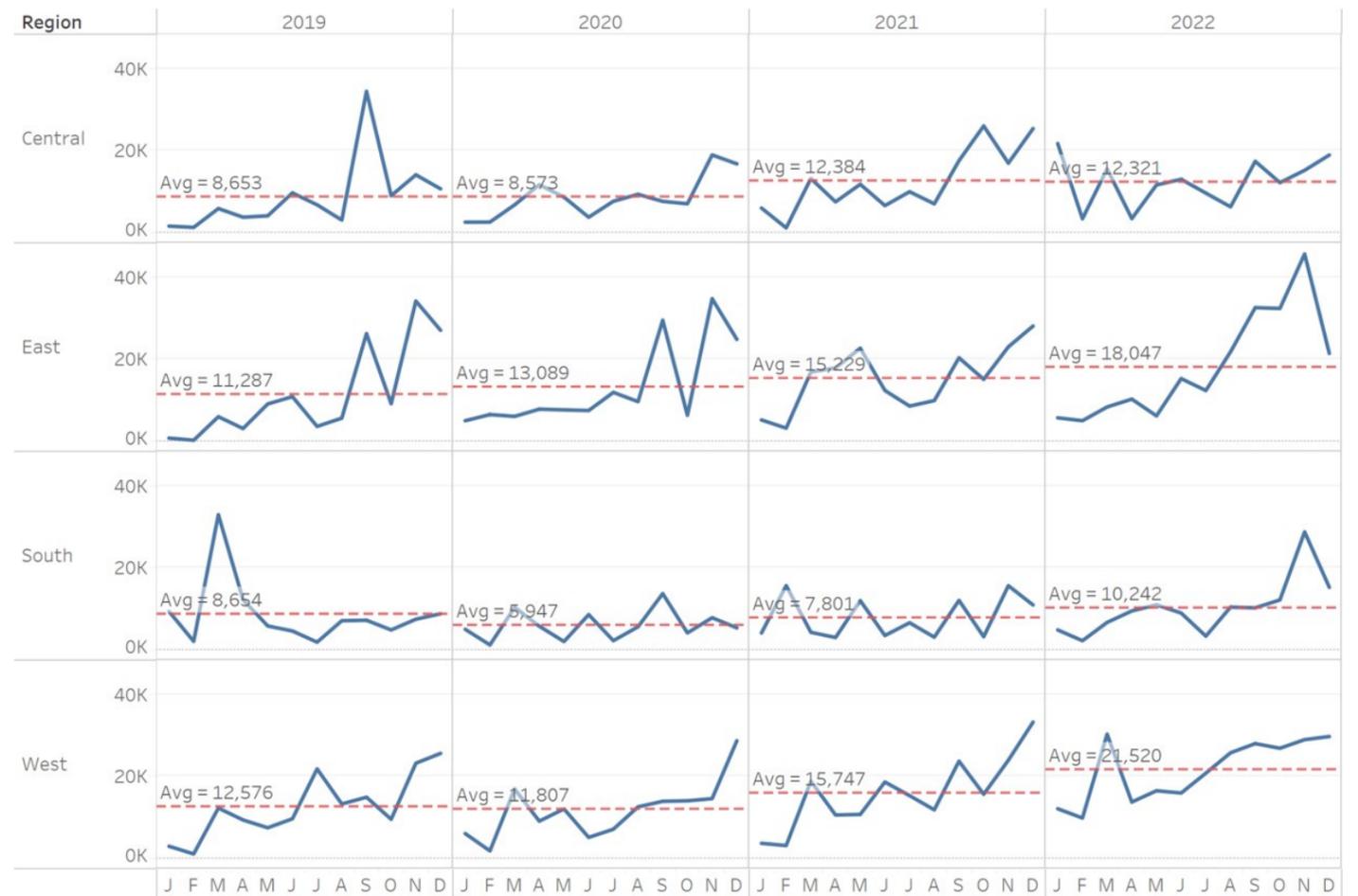
## Line chart without reference line

Monthly sales 2019-2022



## Line chart with reference line

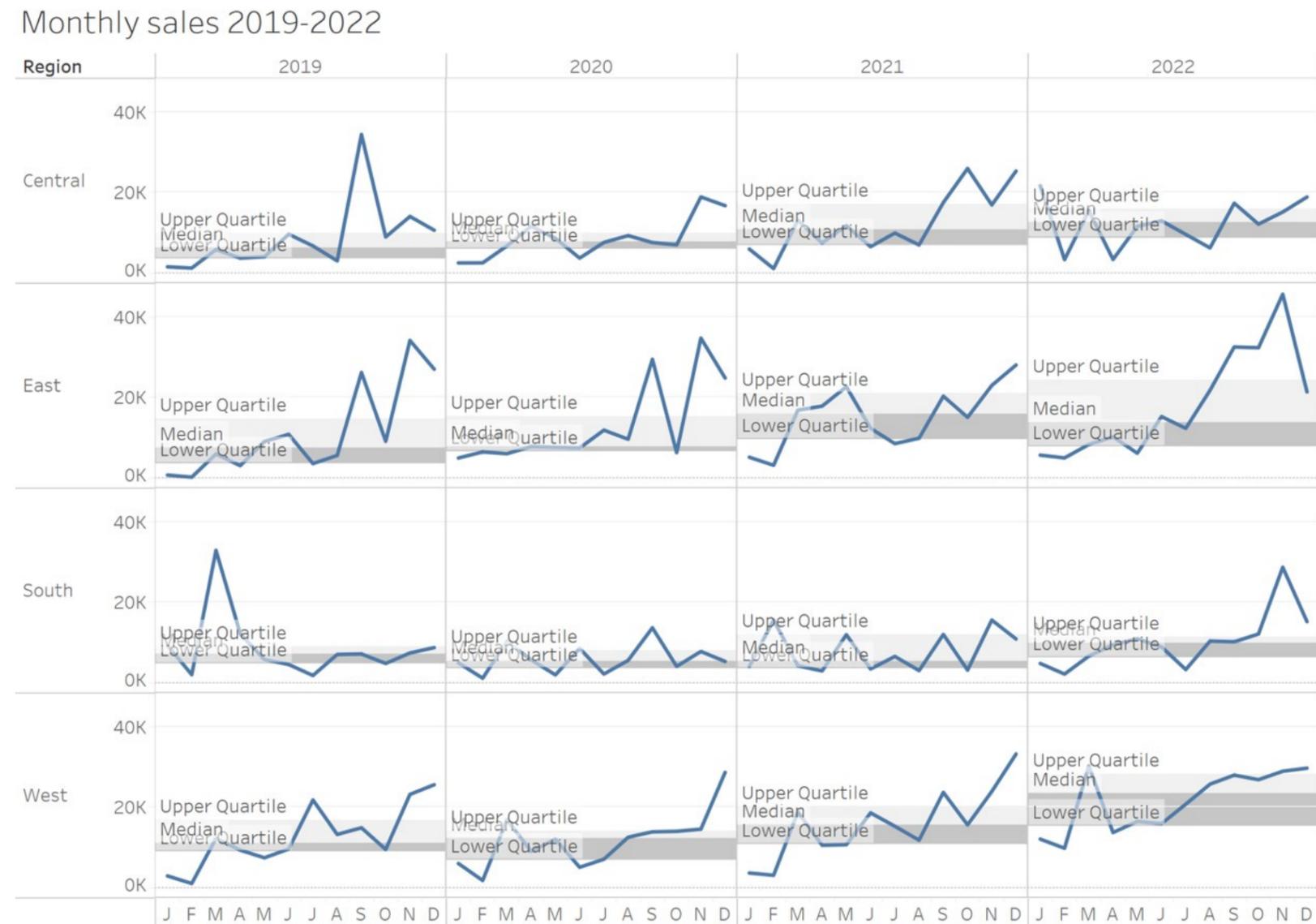
Monthly sales 2019-2022



# Line graph design tips

## Line chart with reference band

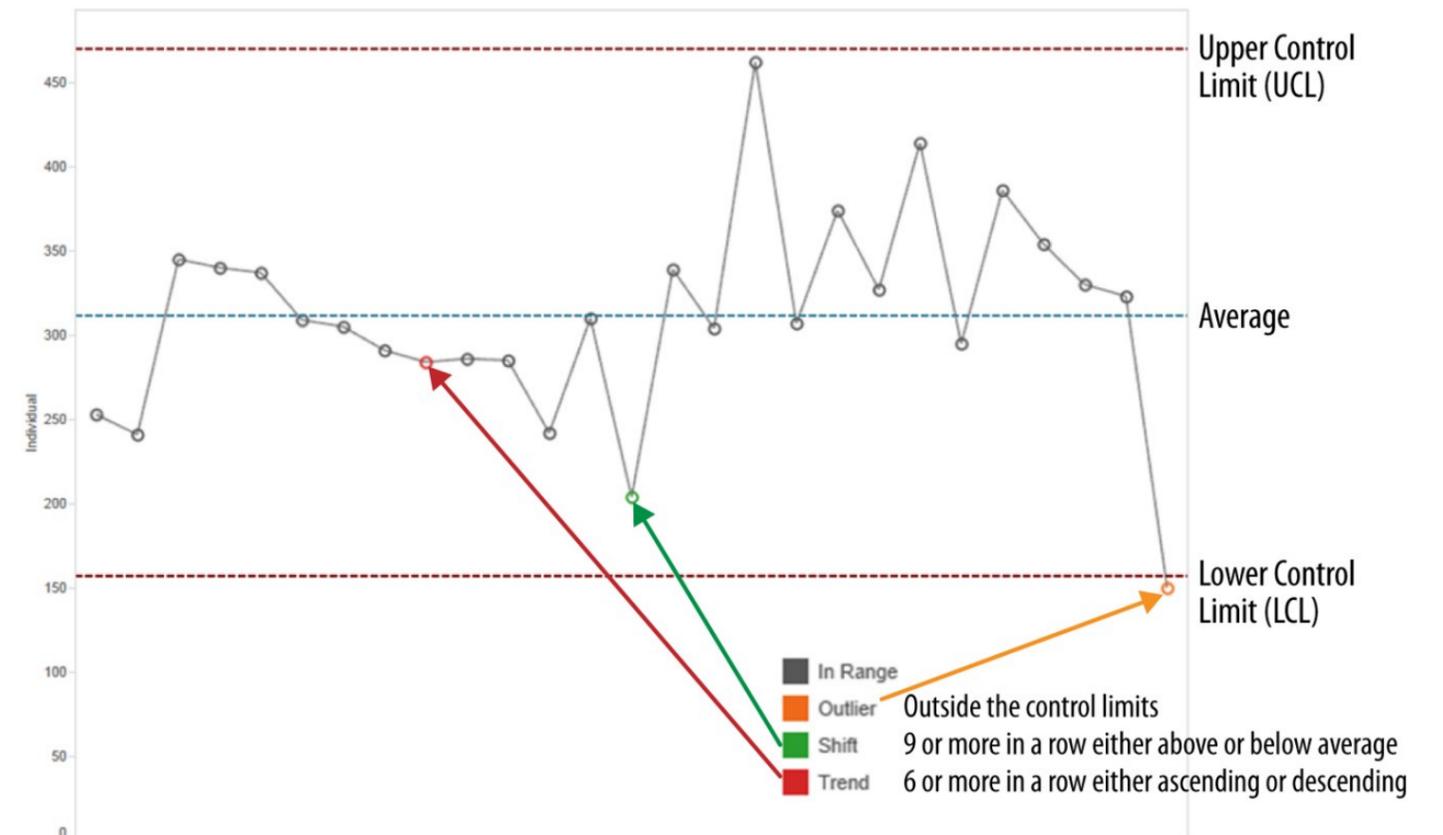
The reference used don't have to confine a single line. A confidence interval or quantile range can be used too.



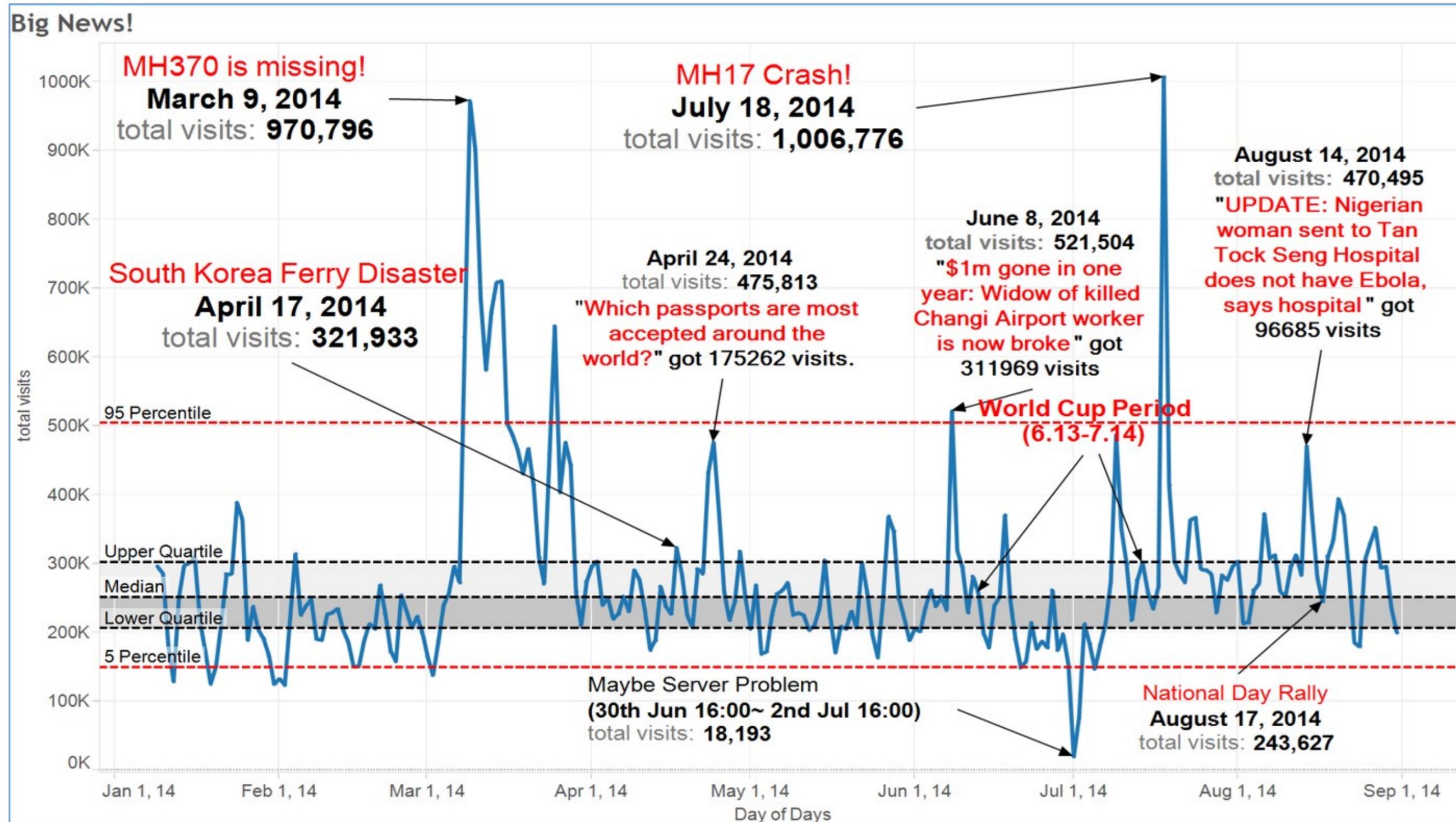
# Beyond Line Graph

## 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 flag out as anomalies.



# Control chart in real world



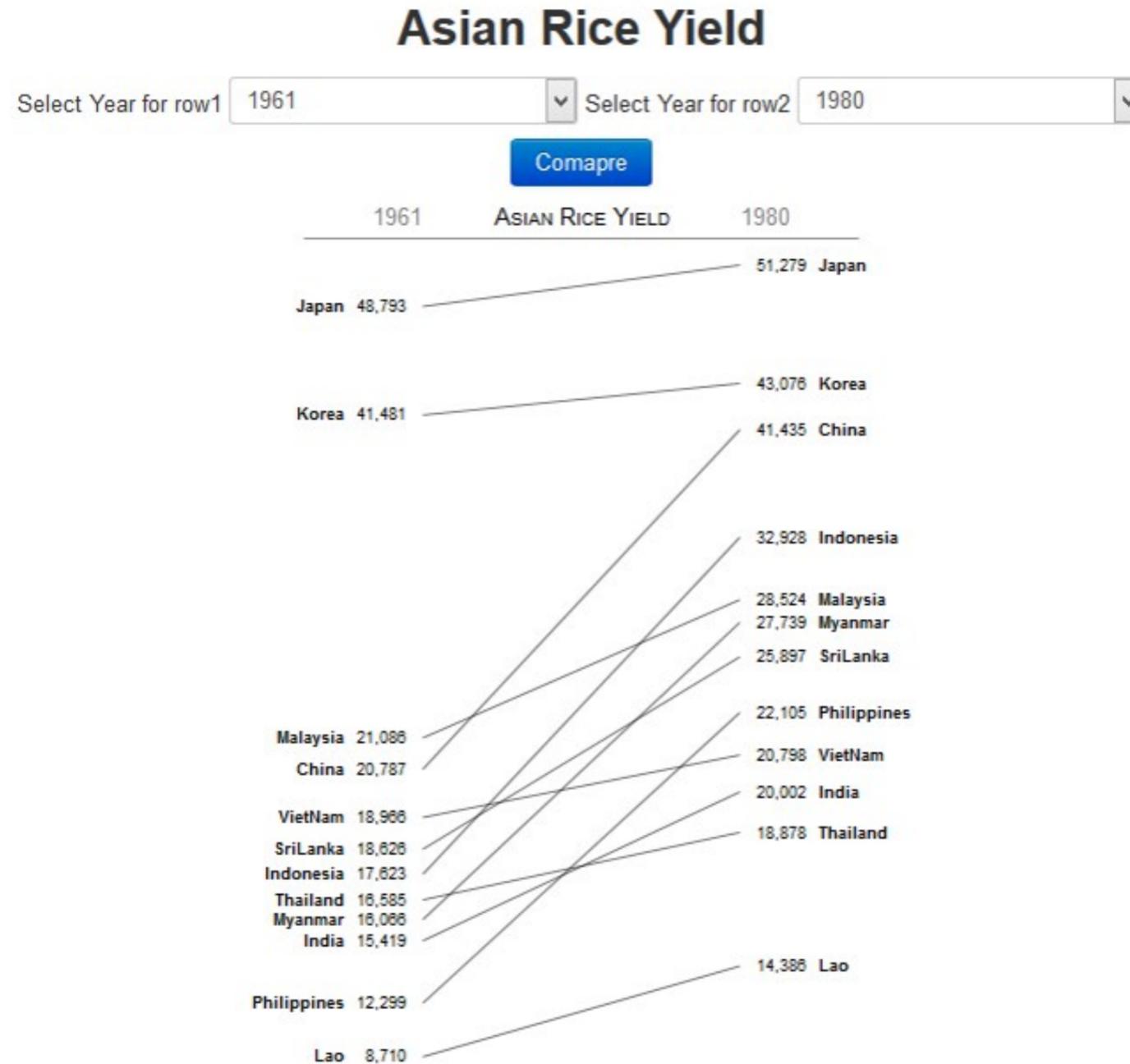
# Challenge I: Visualising Change between Two Points in Time

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.

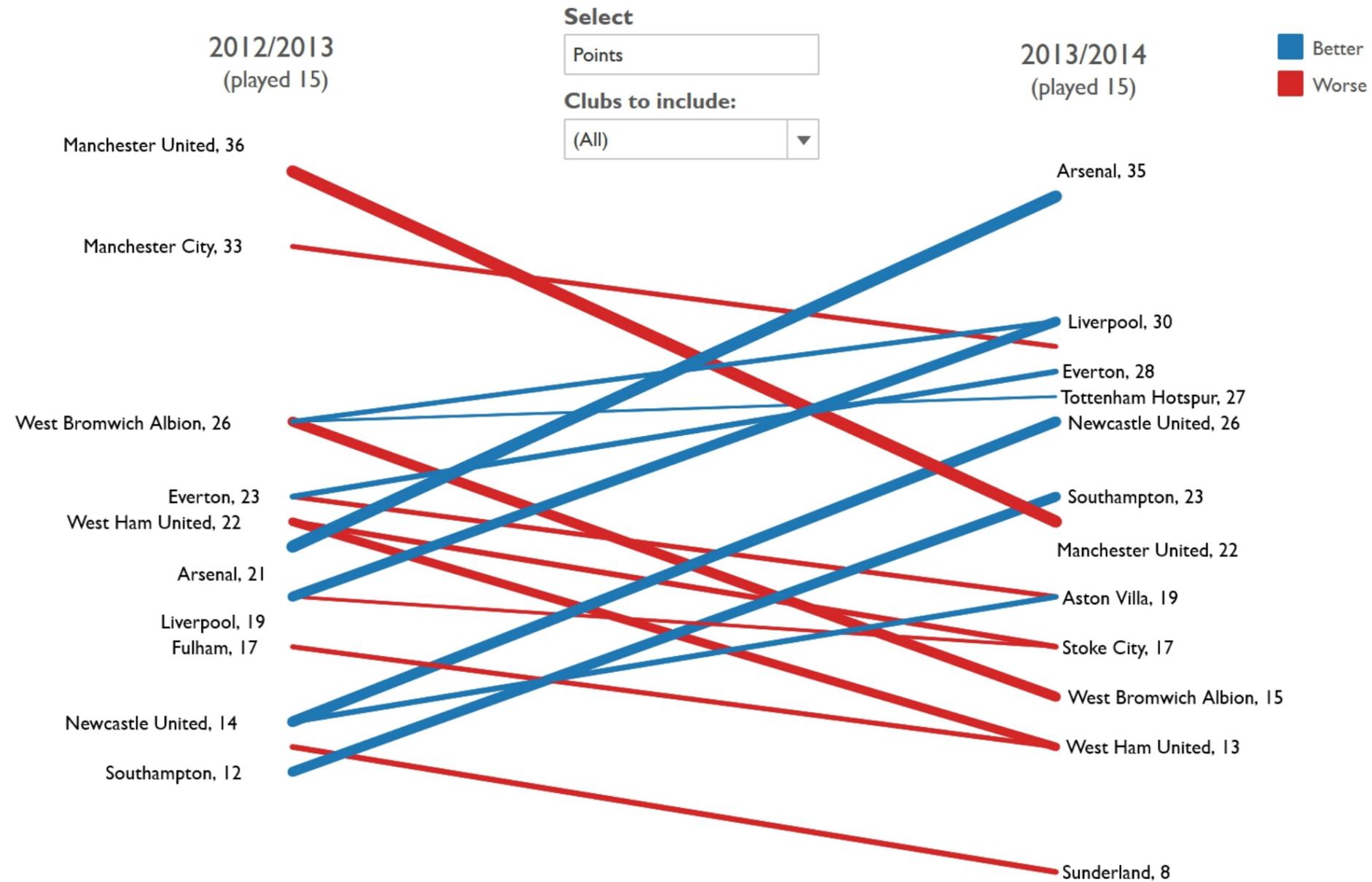
Reference: [Slopegraphs for comparing gradients: Slopegraph theory and practice](#)



# Learning from the Master

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

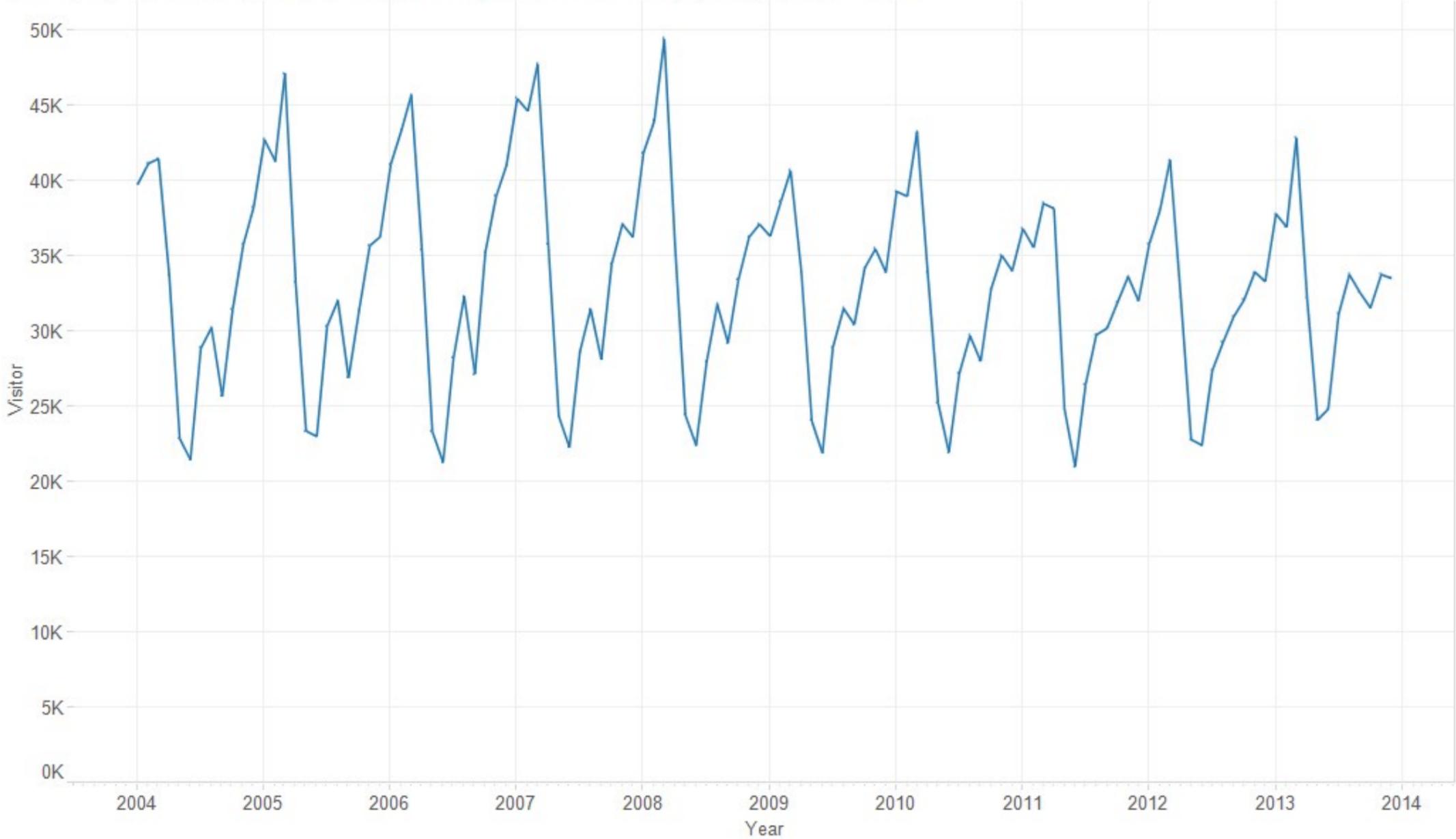
## Barclay's Premier League Tables: Comparing 2012/2013 Starts to 2013/2014 Starts



# Challenge II: Visualising cyclical patterns

## Classic line graph method

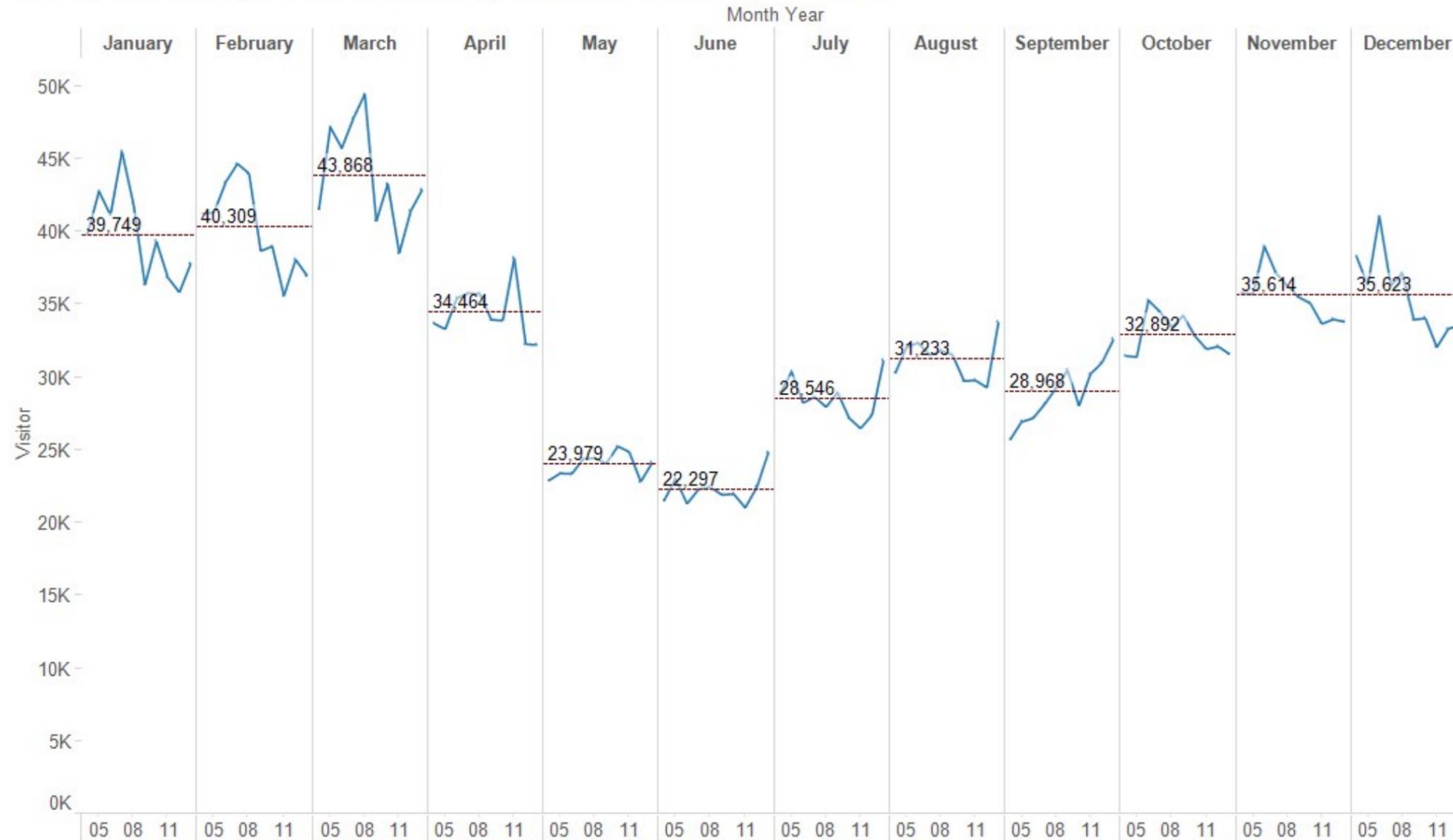
Line graph showing visitor arrivals by month and by year, 2004-2013



# Challenge II: Visualising cyclical patterns

## Solution: Cycle plot

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



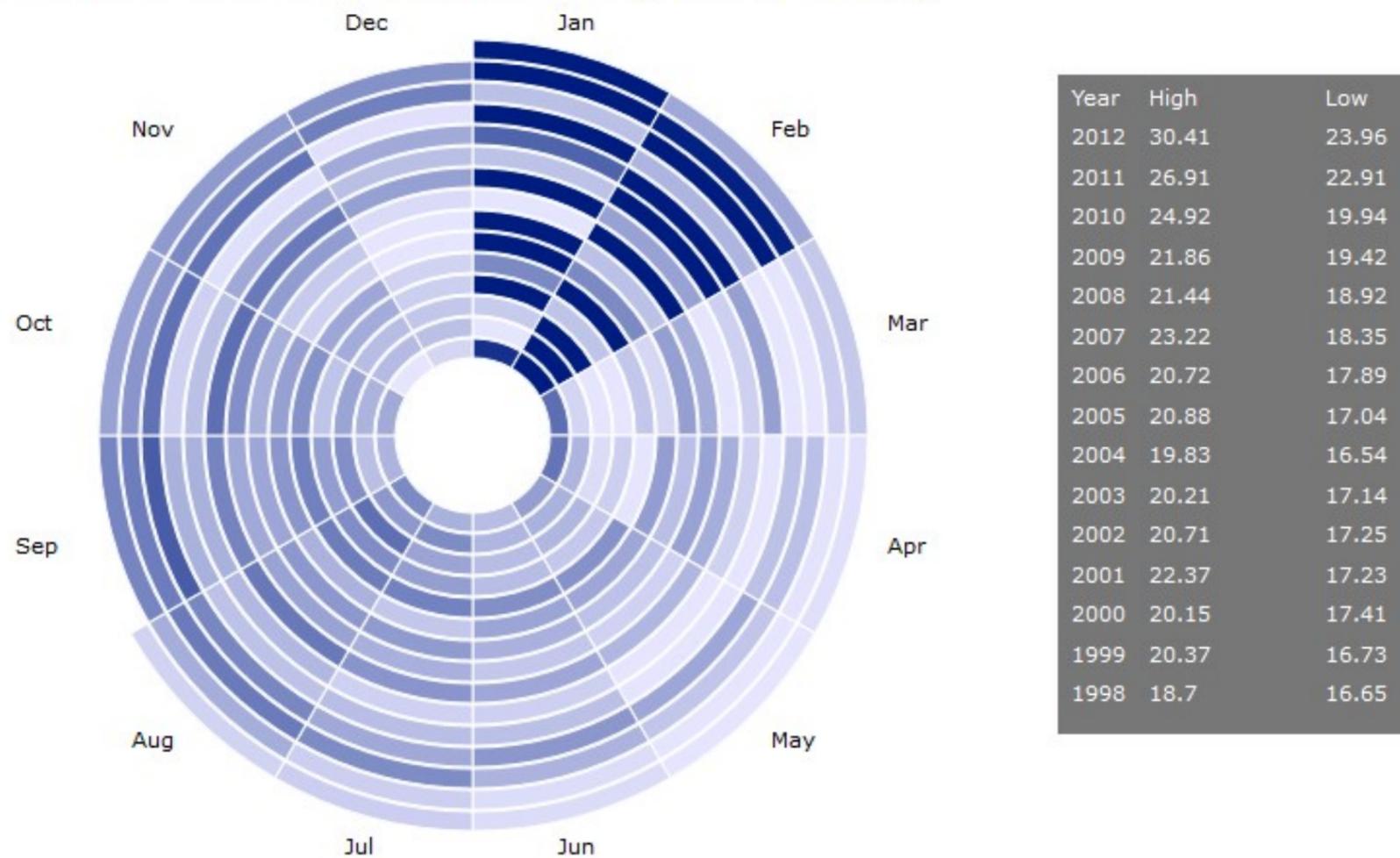
Reference: [Intro to Cycle Plot](#)

# Challenge II: Visualising cyclical patterns

## Solution: Sunburst diagram method

Pork ▾ Red Meat ▾ Poultry ▾ Fish ▾ Other Seafood ▾ Vegetables ▾ Fruits ▾ Dairy Products ▾

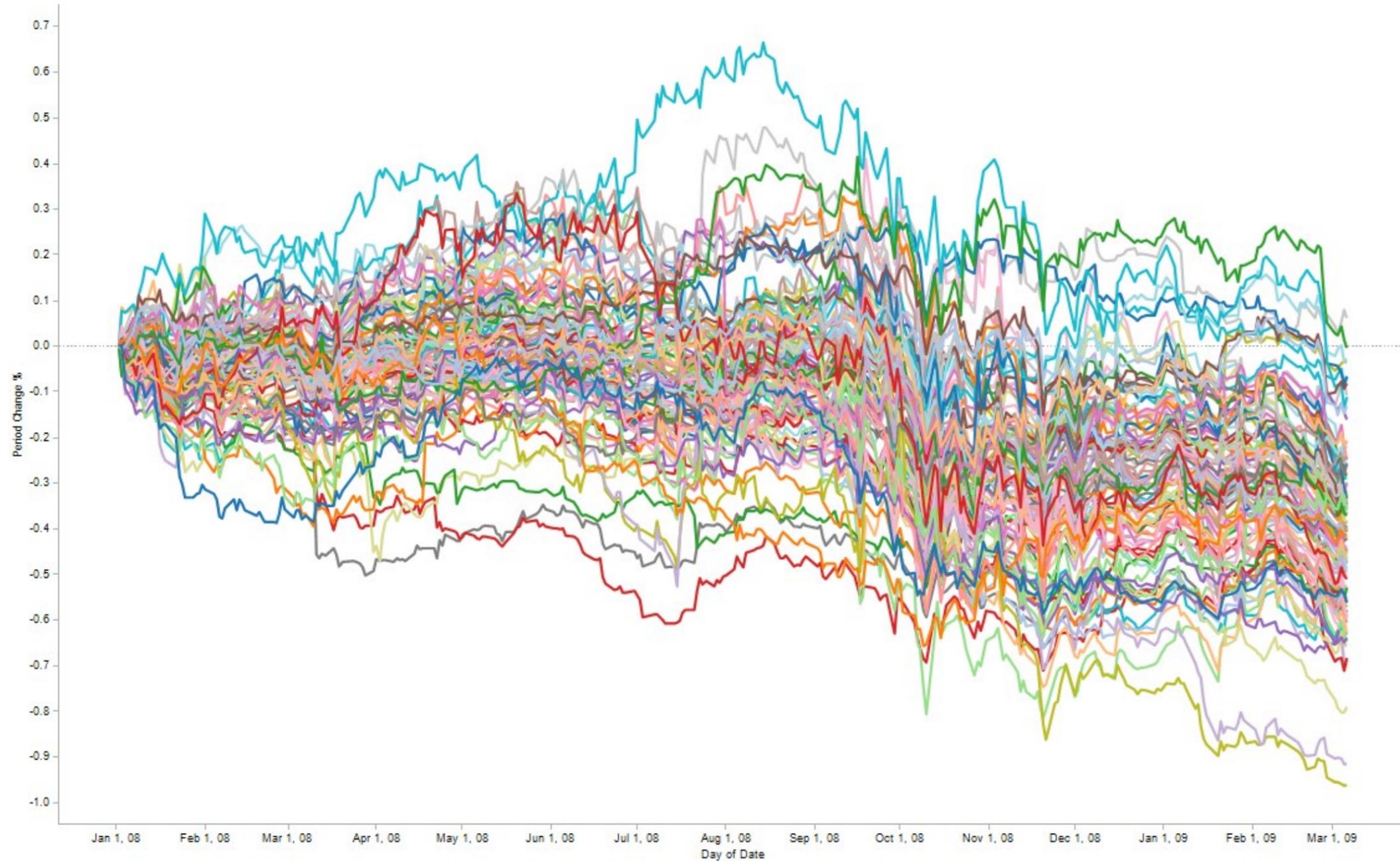
### Price of WHITE\_POMFRET (SGD per kg)



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

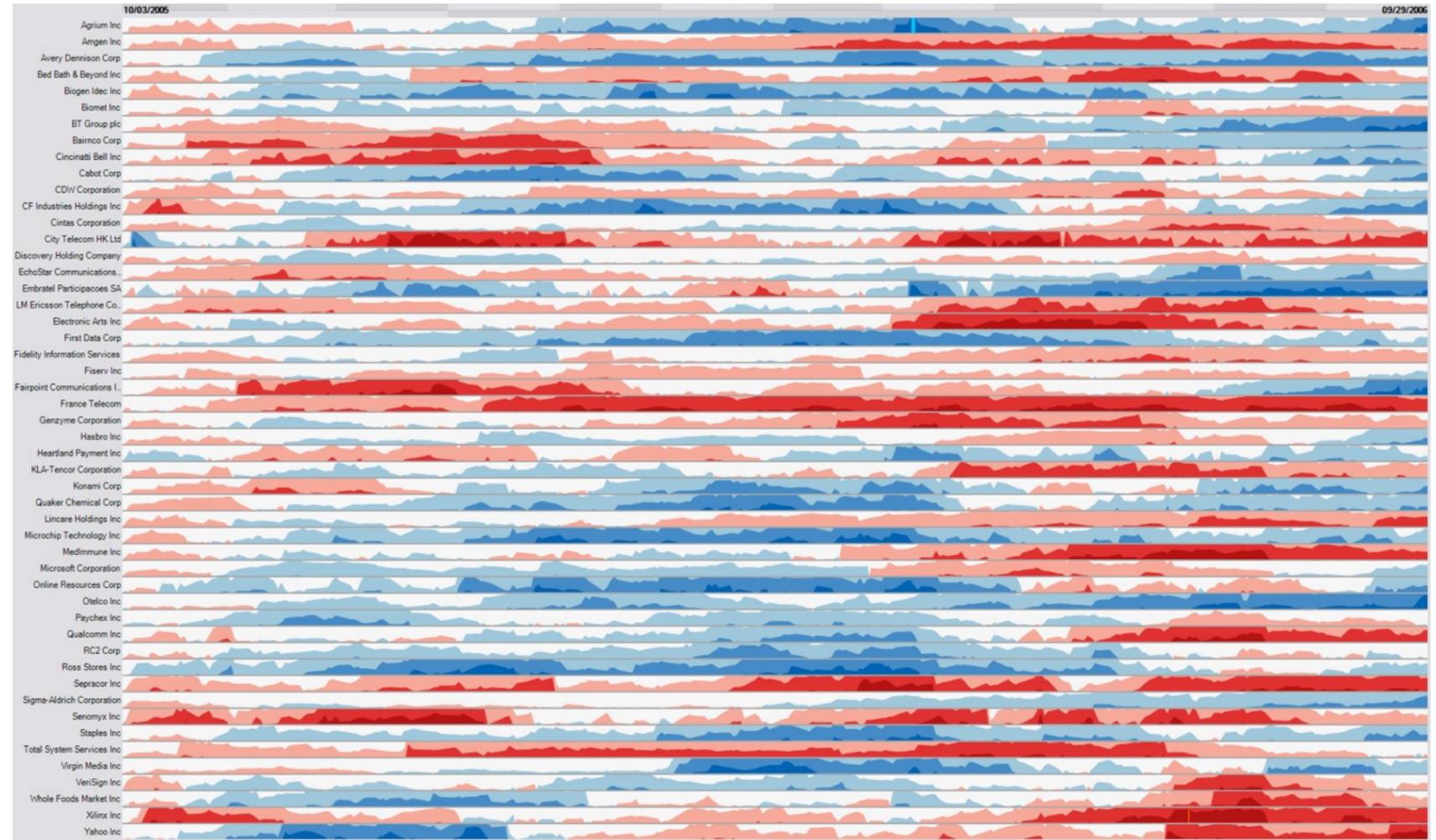
## Classic line graph method



# 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.

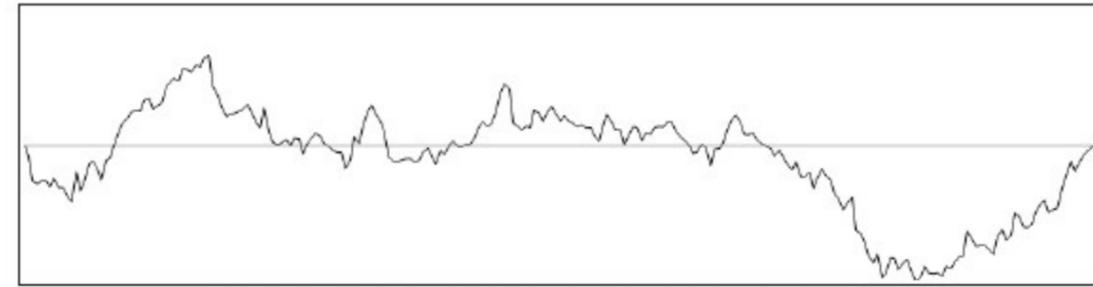


Reference: [Time on the Horizon](#)

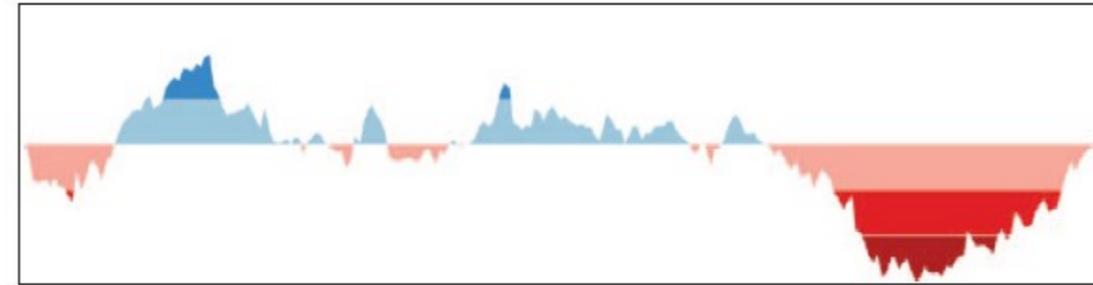
# The basic construct of a horizon graph

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

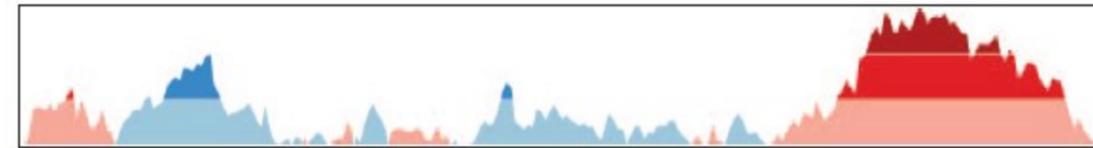
Reference: [The Development of the Horizon Graph](#)



(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



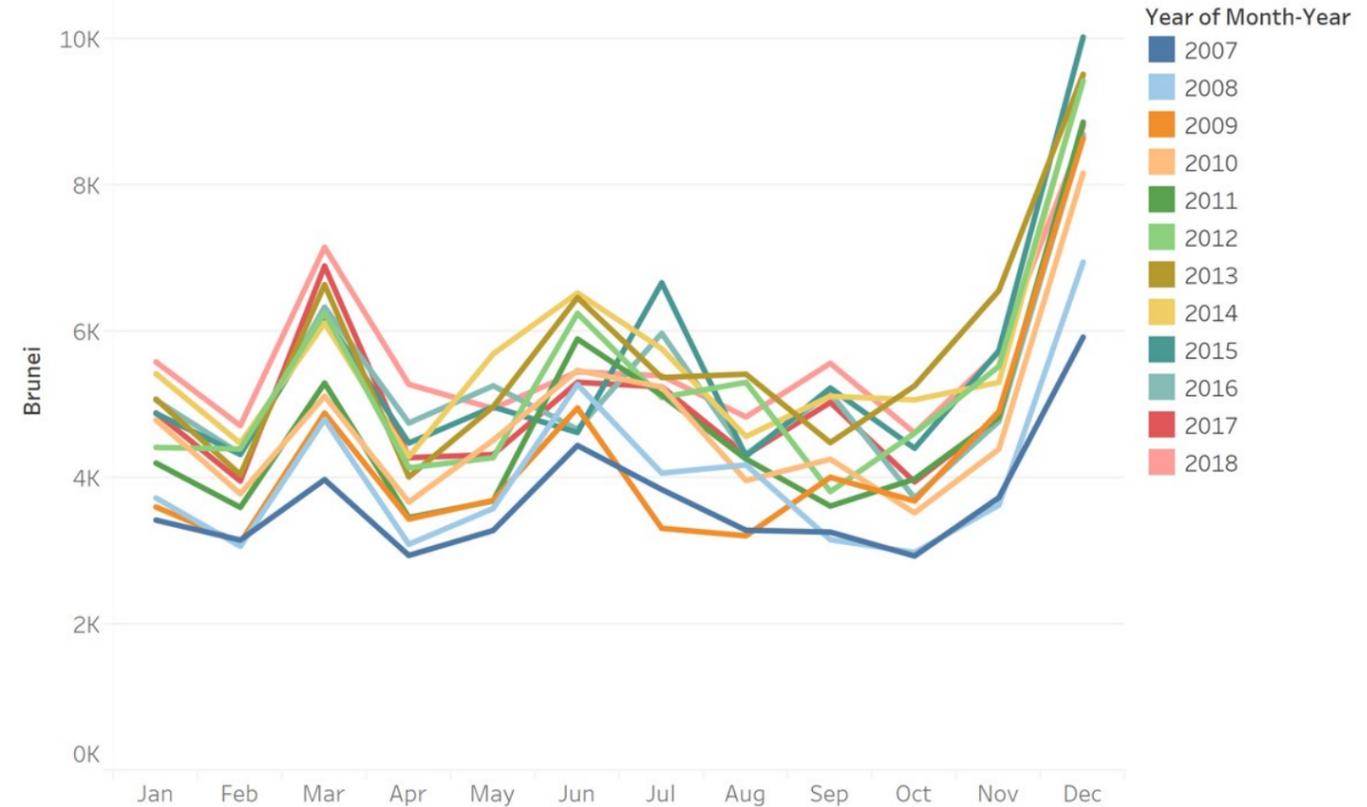
Source: [Unemployment Horizon Chart](#).

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

# Challenge IV: Distribution over time

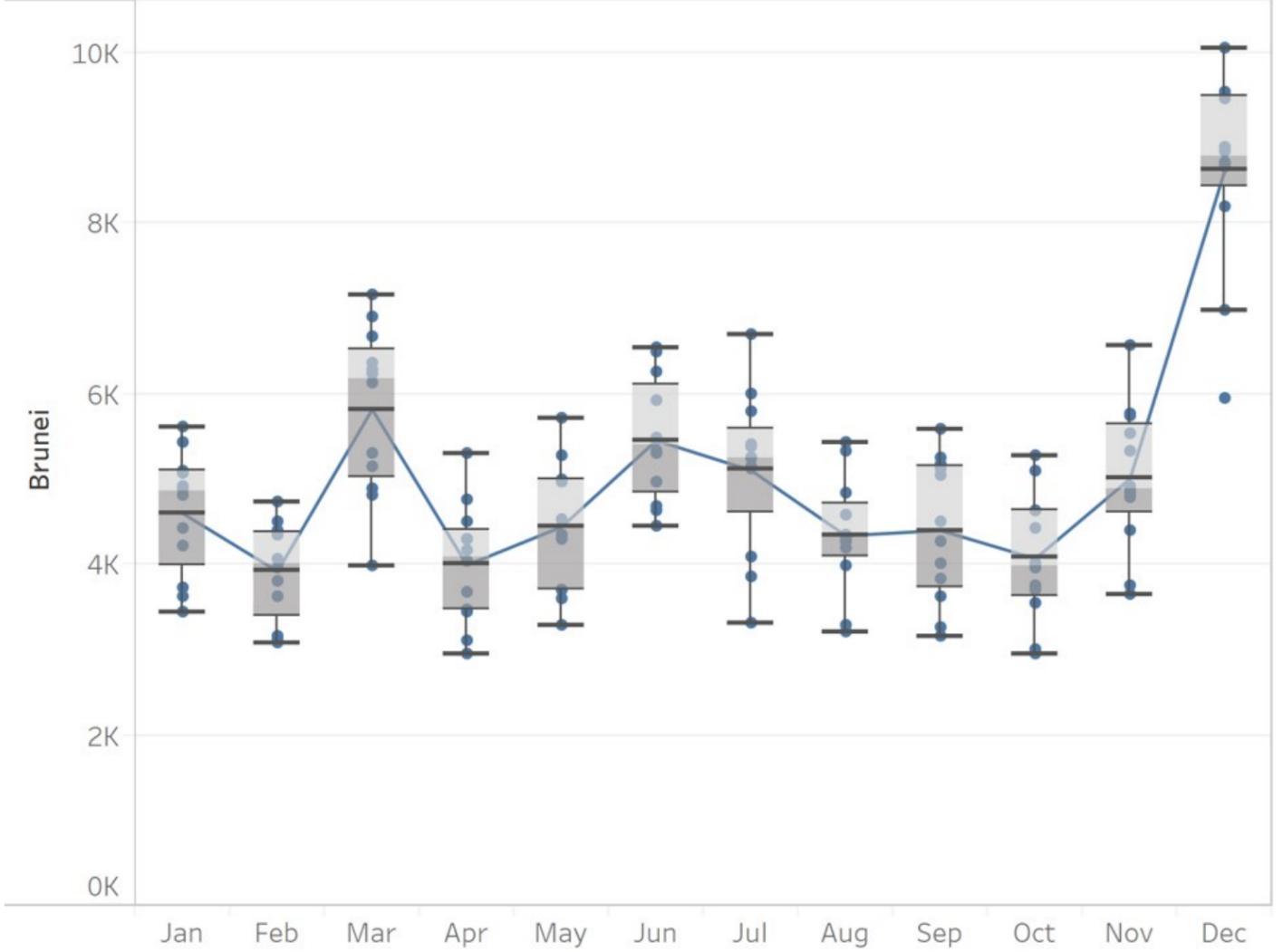
## Line graph method

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



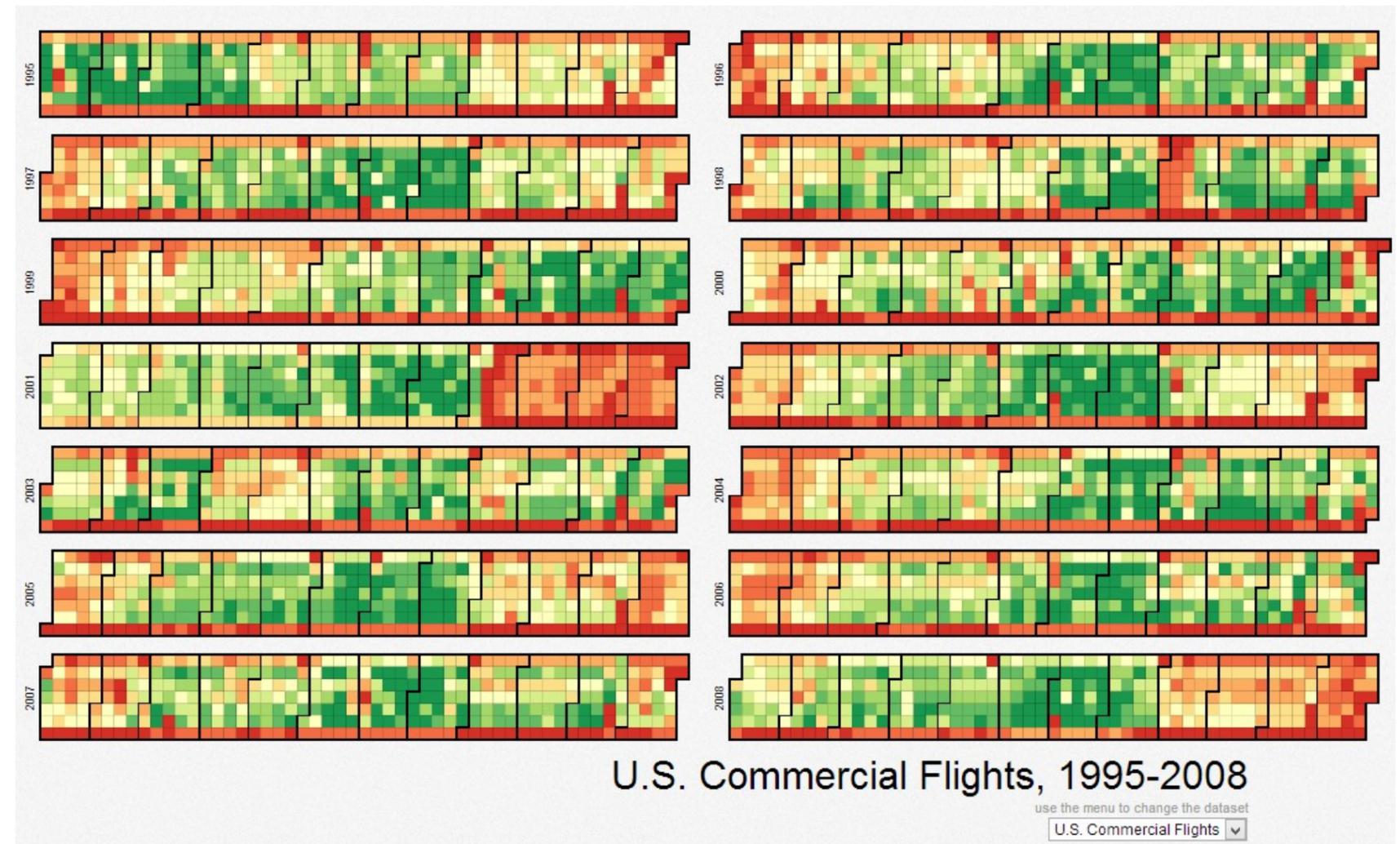
## Boxplot method

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).

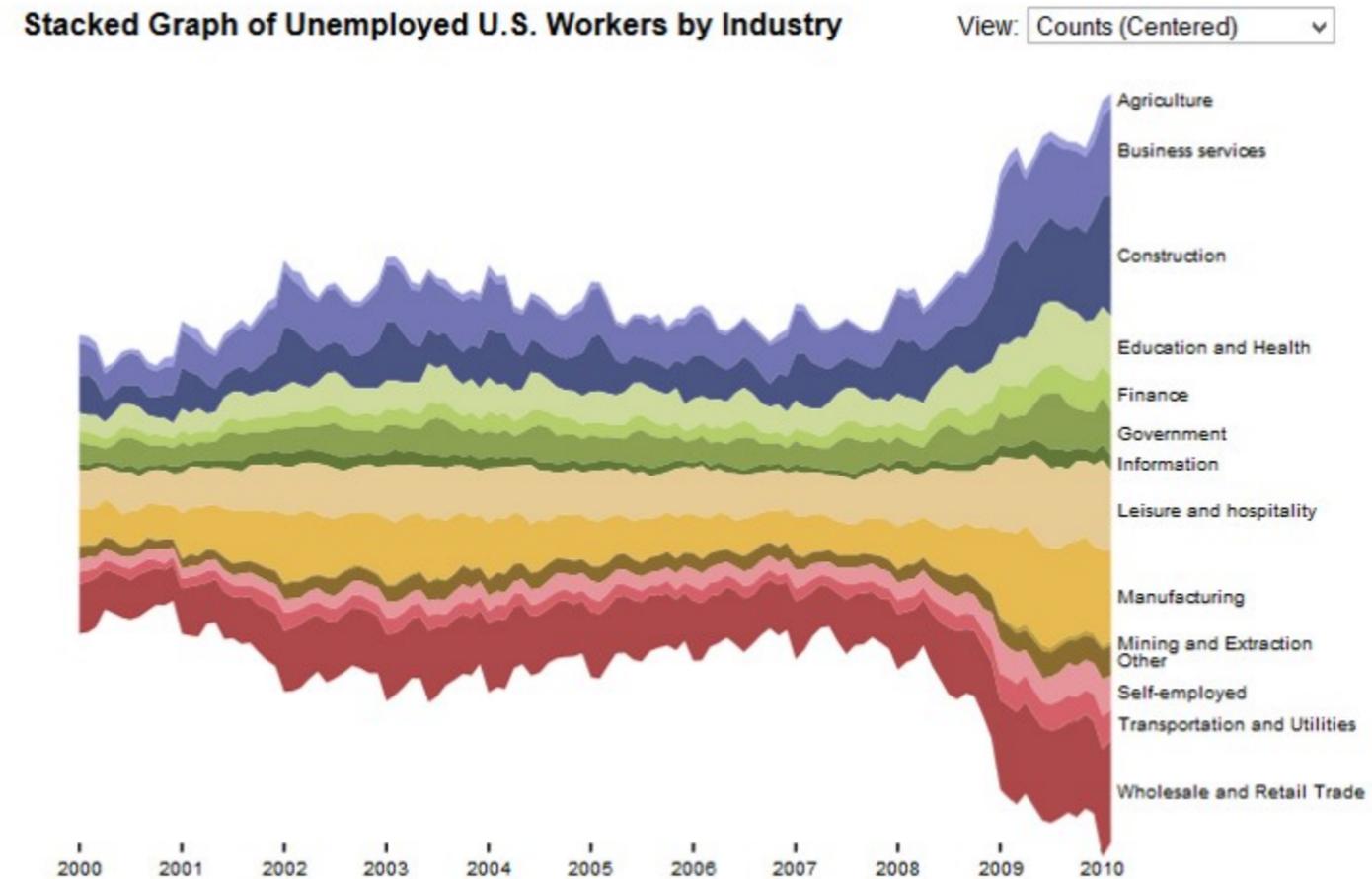


Source: [Calendar heatmap](#)

# 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.



Total counts of unemployed persons per industry, 2000-2010.

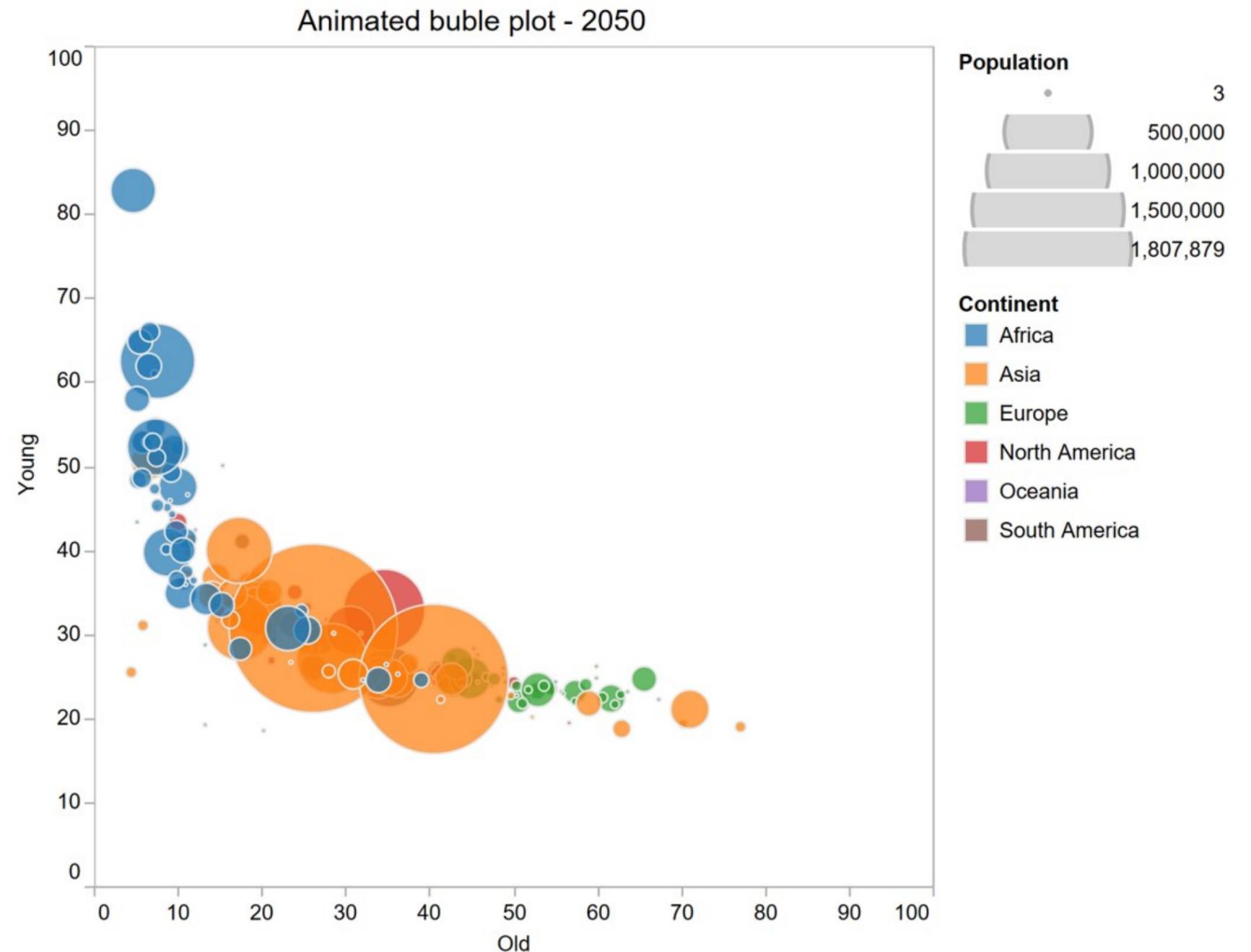
Source: [U.S. Bureau of Labor Statistics](#)

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](#)

