Lesson 5: It's About Time
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
TOTAL	908,490	857,287	928,720	838,504	846,473	860,568	1,094,562	998,611	847,281	978,731	983,868	1,127,020	11,838,883	20.2
AMERICAS	44,900	39,888	48,835	43,006	40,114	48,310	60,456	44,116	34,749	46,981	43,986	44,763	524,831	12.2
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
ASIA	627,002	627,581	661,040	697,441	736,393	731,922	831,322	743,847	720,118	726,367	712,178	860,924	8,676,135	25.8
Southeast Asia	*331,914*	*300,137*	*360,062*	*390,263*	*403,076*	*433,791*	*466,666*	*361,637*	*447,643*	*410,299*	*391,382*	*533,440*	*4,619,761*	*30.6*
Brunei Darussalam	5,245	4,139	5,692	3,943	4,796	5,953	5,578	4,244	4,628	3,750	4,673	9,513	62,154	10.0
Indonesia	173,539	143,917	165,942	162,800	185,757	214,392	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	95,455	82,745	99,933	129,599	1,036,918	35.7
Myanmar	5,512	4,492	7,000	9,591	6,555	6,232	6,877	5,838	5,376	6,482	5,953	8,276	78,184	11.3
Philippines	32,703	32,510	43,955	54,448	55,307	44,484	43,440	39,244	40,662	52,007	50,092	55,492	544,344	26.0
Thailand	24,636	23,153	31,813	50,655	38,921	30,710	37,256	34,790	30,709	57,950	30,192	39,238	430,022	35.3
Vietnam	19,109	20,477	21,336	26,680	26,152	35,586	43,869	32,843	24,331	24,691	21,246	26,543	322,853	21.6
Other Countries in Southeast Asia	3,130	2,786	2,599	4,705	3,723	3,364	3,755	3,528	2,719	3,771	3,324	2,723	40,127	21.5
North Asia	*212,272*	*267,600*	*212,602*	*203,699*	*191,367*	*183,940*	*266,763*	*293,017*	*166,646*	*213,442*	*217,810*	*220,603*	*2,663,640*	*23.1*
Hong Kong SAR	19,415	24,904	26,245	35,560	32,045	32,190	46,726	46,695	28,467	32,833	29,847	32,625	387,552	31.6
Japan	37,747	40,666	51,834	35,160	36,819	36,447	44,646	56,644	44,999	43,493	51,527	48,835	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	99,556	1,171,337	25.0
South Korea	39,437	29,589	30,113	24,781	32,159	30,032	32,668	34,169	25,653	29,008	27,814	25,250	360,673	32.6
Taiwan	15,510	17,737	15,219	14,508	17,111	13,542	23,933	20,969	13,486	13,851	13,131	12,196	191,173	22.0
Other Countries in North Asia	1,245	1,554	1,360	1,889	1,595	2,649	3,005	3,984	1,506	1,657	1,493	2,151	24,088	74.6
South Asia	*74,021*	*69,674*	*70,799*	*94,410*	*133,267*	*102,663*	*66,636*	*76,337*	*71,160*	*92,950*	*69,479*	*96,062*	*1,046,200*	*12.6*
Bangladesh	7,762	5,726	7,747	7,528	7,703	8,534	9,373	7,144	7,942	7,543	7,438	7,879	92,309	6.6
India	57,404	46,061	53,965	73,214	115,955	83,467	64,905	57,107	54,825	75,567	72,918	73,515	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	1,246	14,303	-5.8
Pakistan	1,586	1,292	1,662	1,707	1,565	2,926	3,907	1,510	1,125	1,469	1,401	1,776	21,925	-1.6
Sri Lanka	4,770	4,734	5,373	9,960	6,043	5,750	6,206	7,816	5,759	6,296	5,785	10,476	78,967	12.8
Other Countries in South Asia	881	750	766	779	813	892	895	564	617	734	932	1,170	9,793	6.8
West Asia	*8,796*	*10,370*	*17,367*	*9,169*	*8,691*	*11,635*	*20,166*	*13,666*	*12,760*	*9,646*	*13,607*	*10,819*	*146,644*	*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	54.4
Israel	1,277	997	1,175	956	1,029	1,174	918	1,198	785	1,109	1,310	903	12,831	17.9
Kuwait	443	587	468	305	451	806	2,548	719	535	380	723	403	8,368	45.5
Saudi Arabia	512	714	689	1,038	771	941	2,400	972	1,345	902	1,554	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	4,513	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	19.8

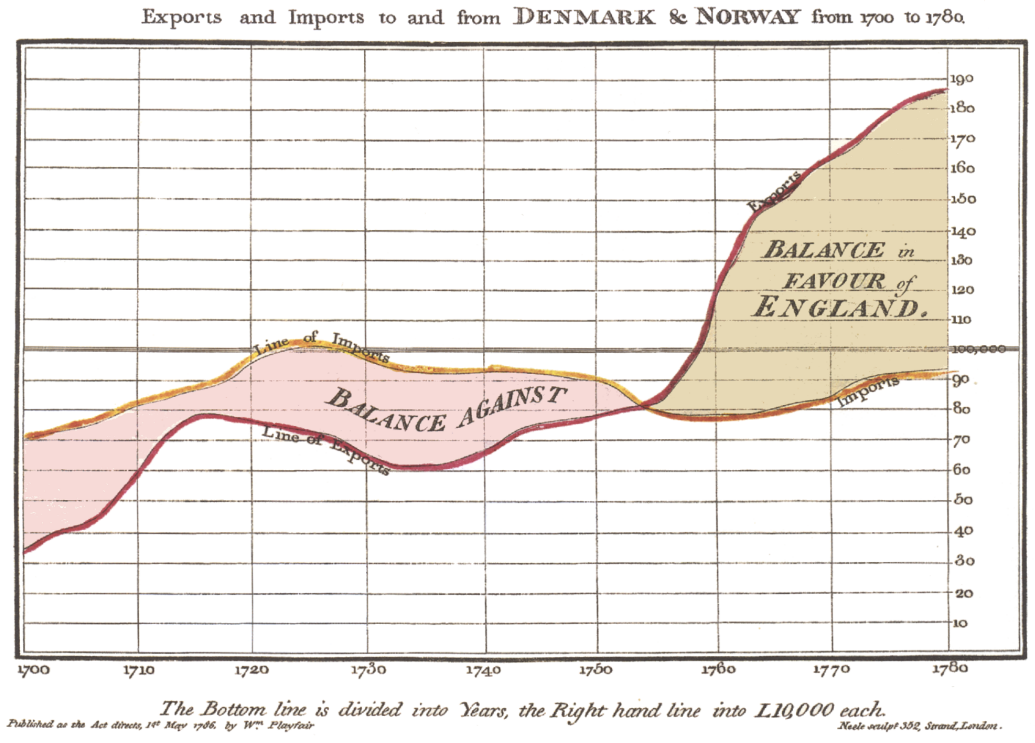
Characteristics of time-series data

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

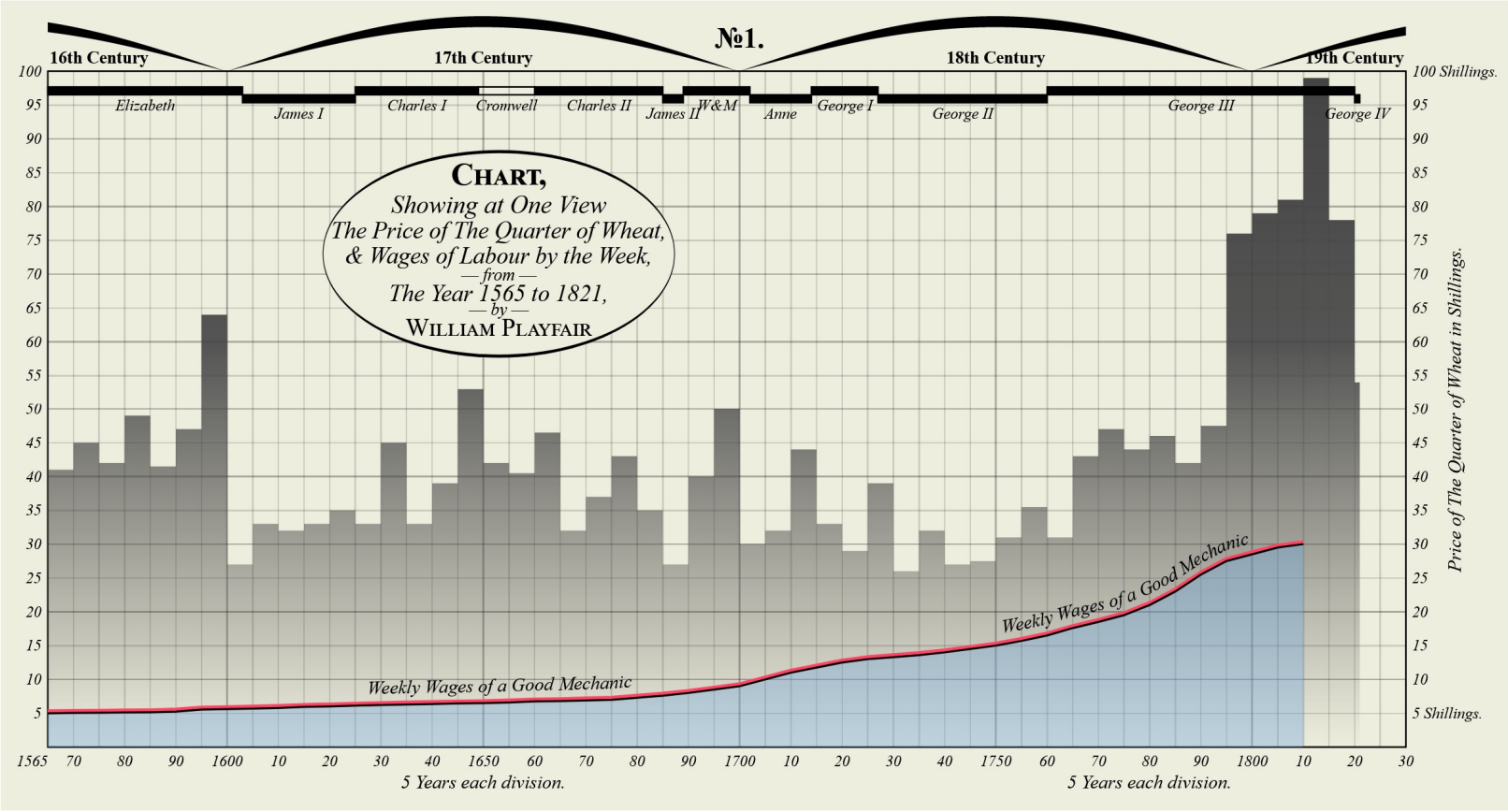
Playfair's Commercial and Political Atlas (1786)



Reference: https://en.wikipedia.org/wiki/William_Playfair

A short visual history of time-series graphs

Playfair's Chewing at One View Chart (1821)



Reference: https://wam.fandom.com/wiki/William_Playfair%27s_Price_of_Wheat

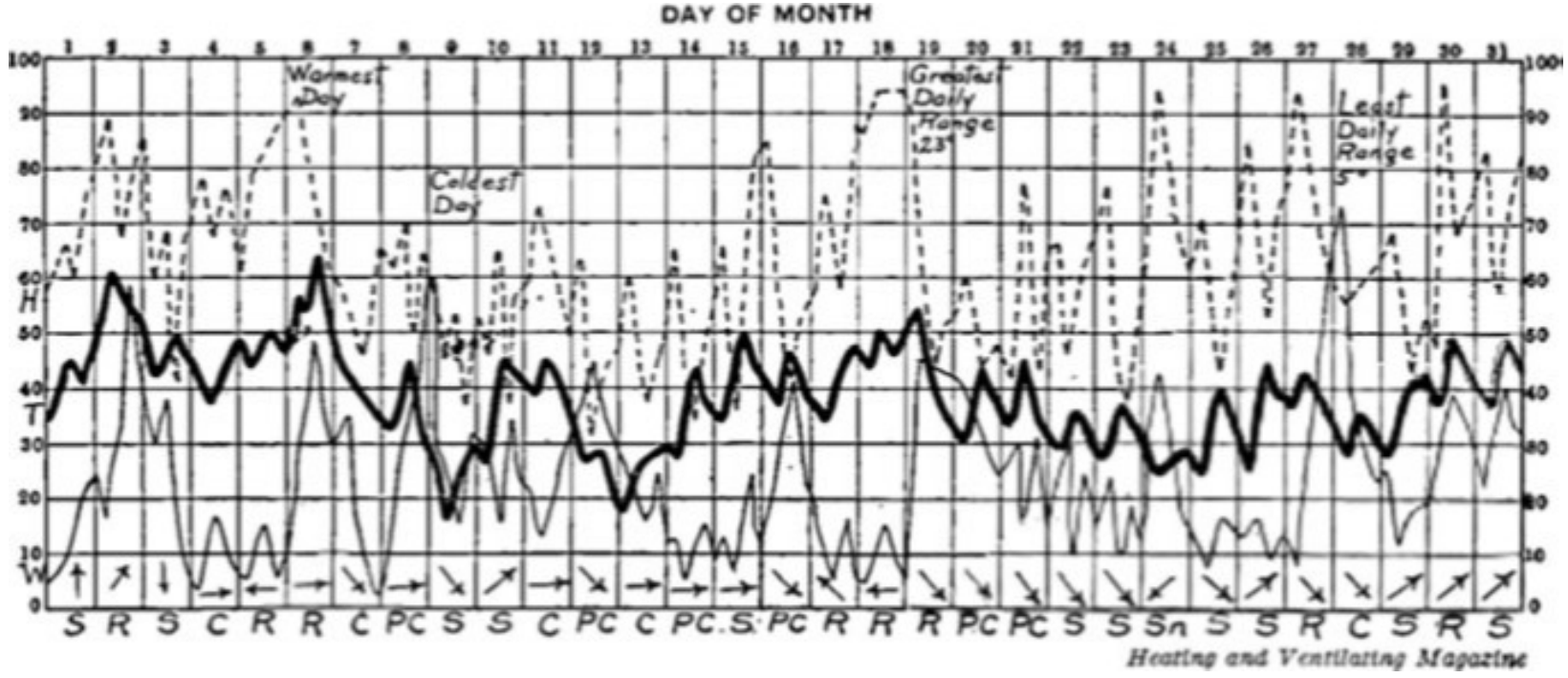
A short visual history of time-series graphs

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

An interactive version here http://vallandingham.me/census_bump/

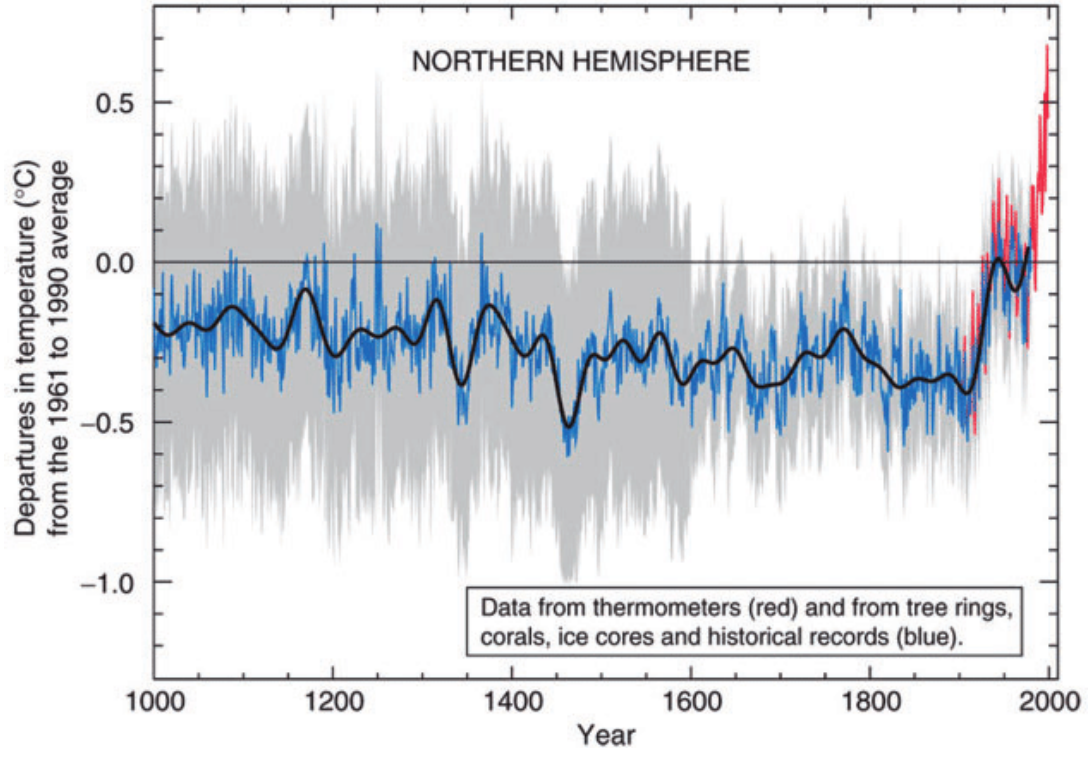
A short visual history of time-series graphs

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



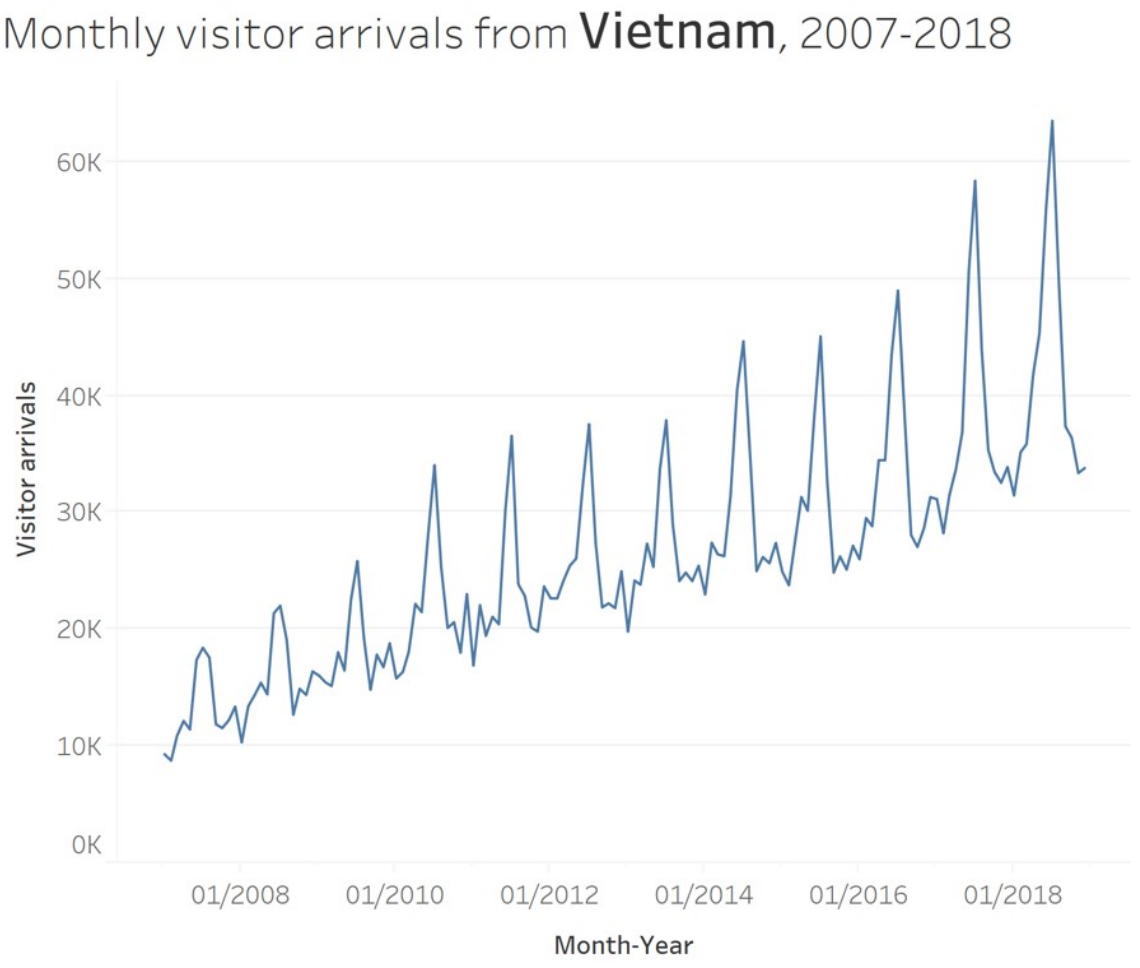
Reference: Michael E. Mann, Raymond S. Bradley, Malcolm K. Hughes (1999) "Northern hemisphere temperatures during the past millennium: Inferences, uncertainties, and limitations". *Geophysical Research Letters*, Vol. 26, No. pp. 759-762.

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.

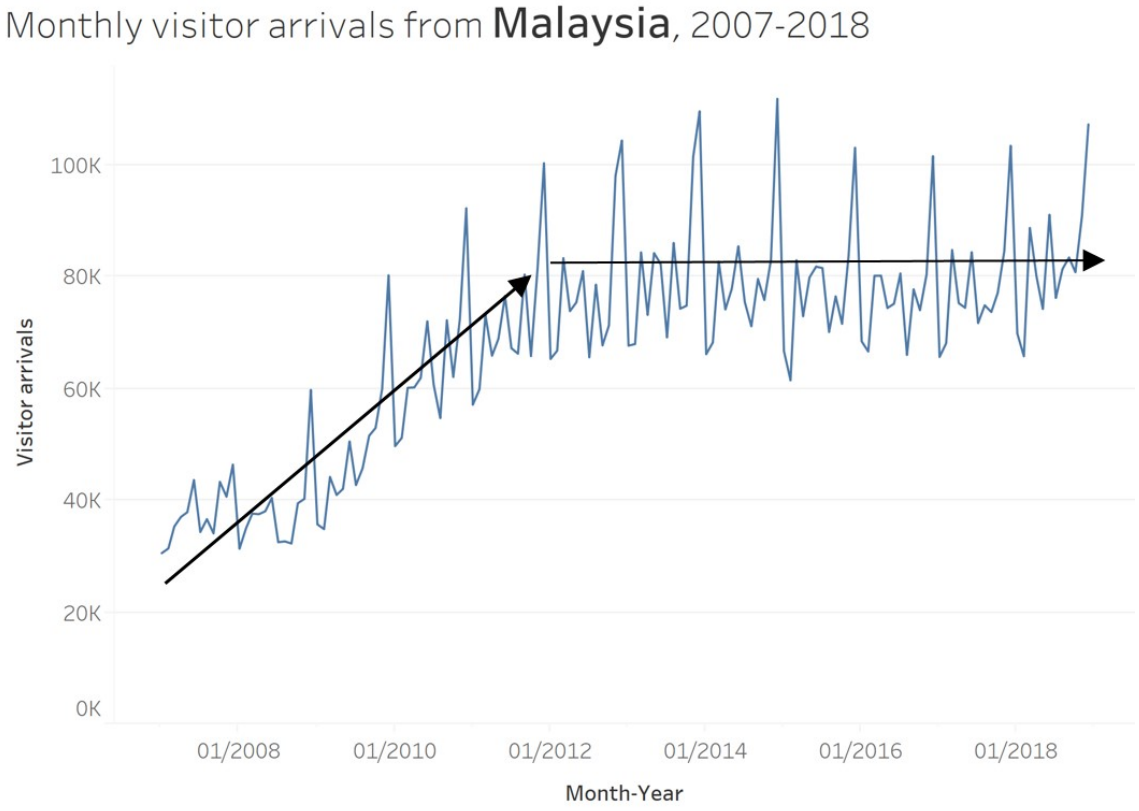


Time-series Patterns: Trend

- An upward trend.

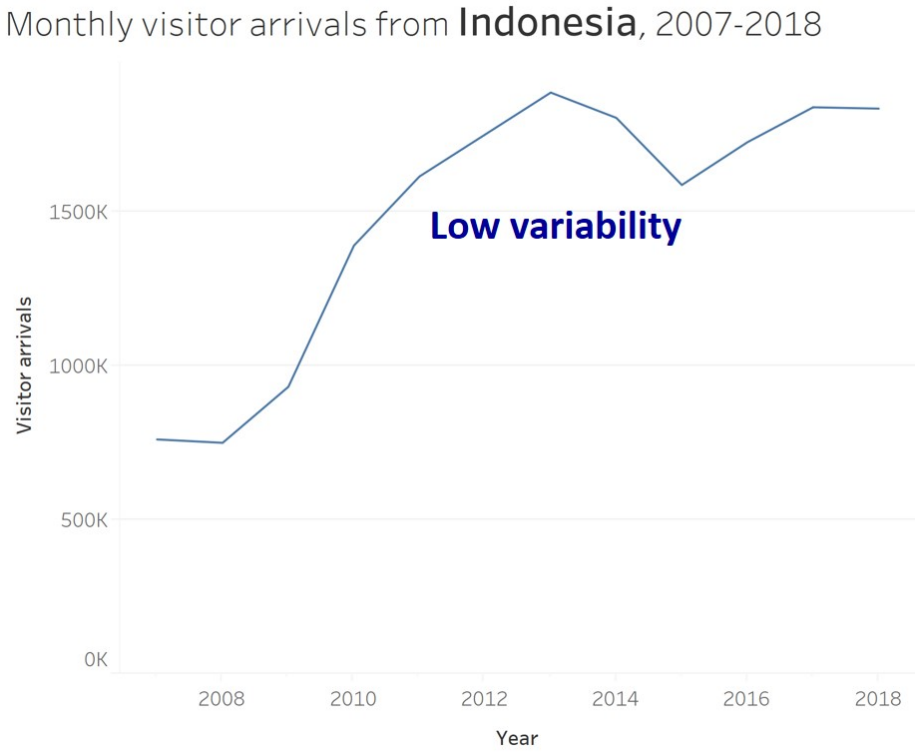
Time-series Patterns: Trend

- A mixed trends.



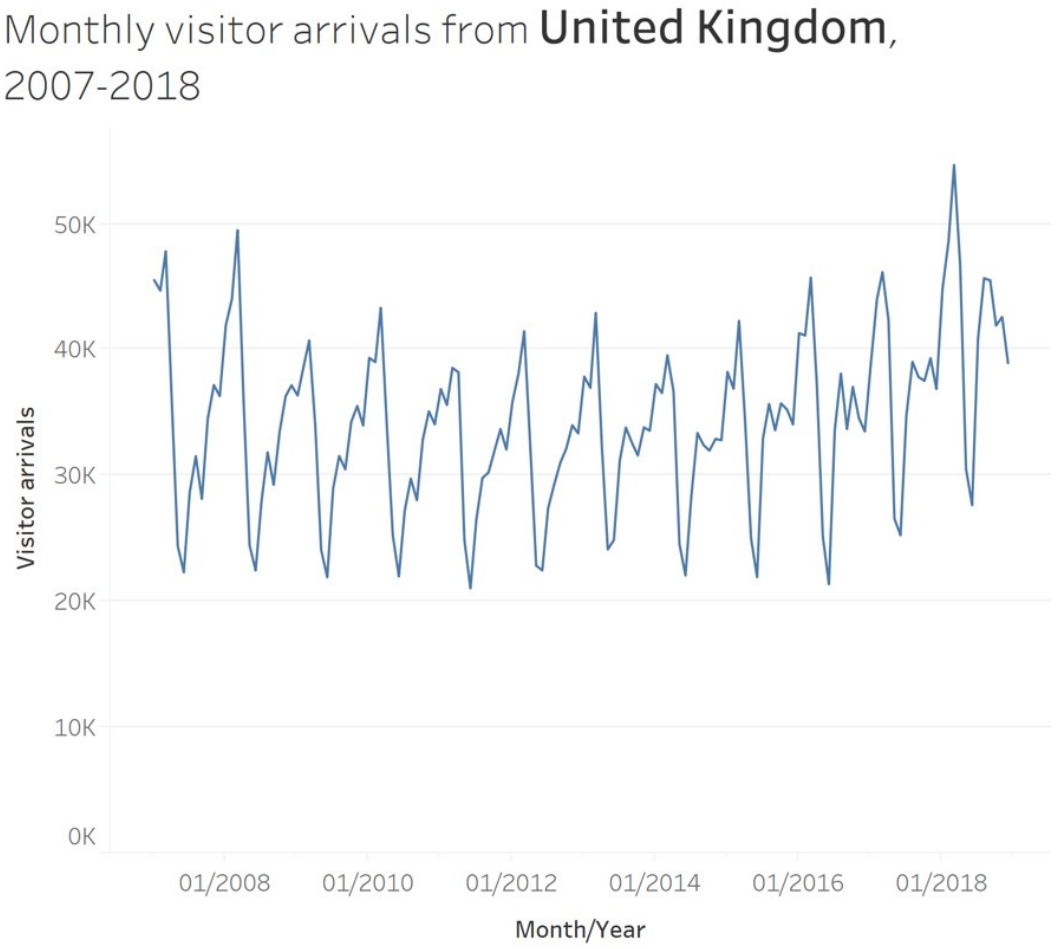
Time-series Patterns: Variability

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



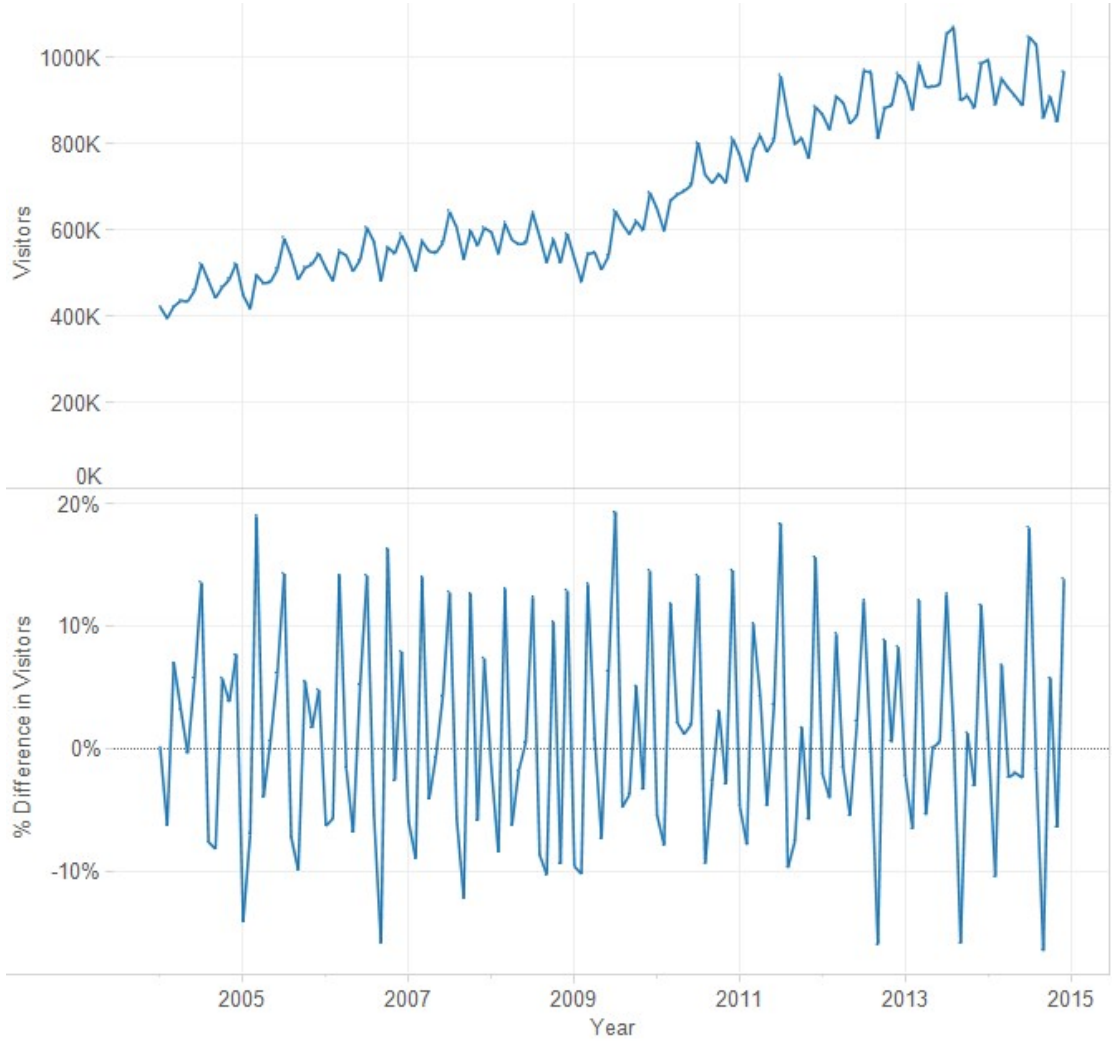
Time-series Patterns: Cycles

- Cycles are patterns that repeat at regular intervals.



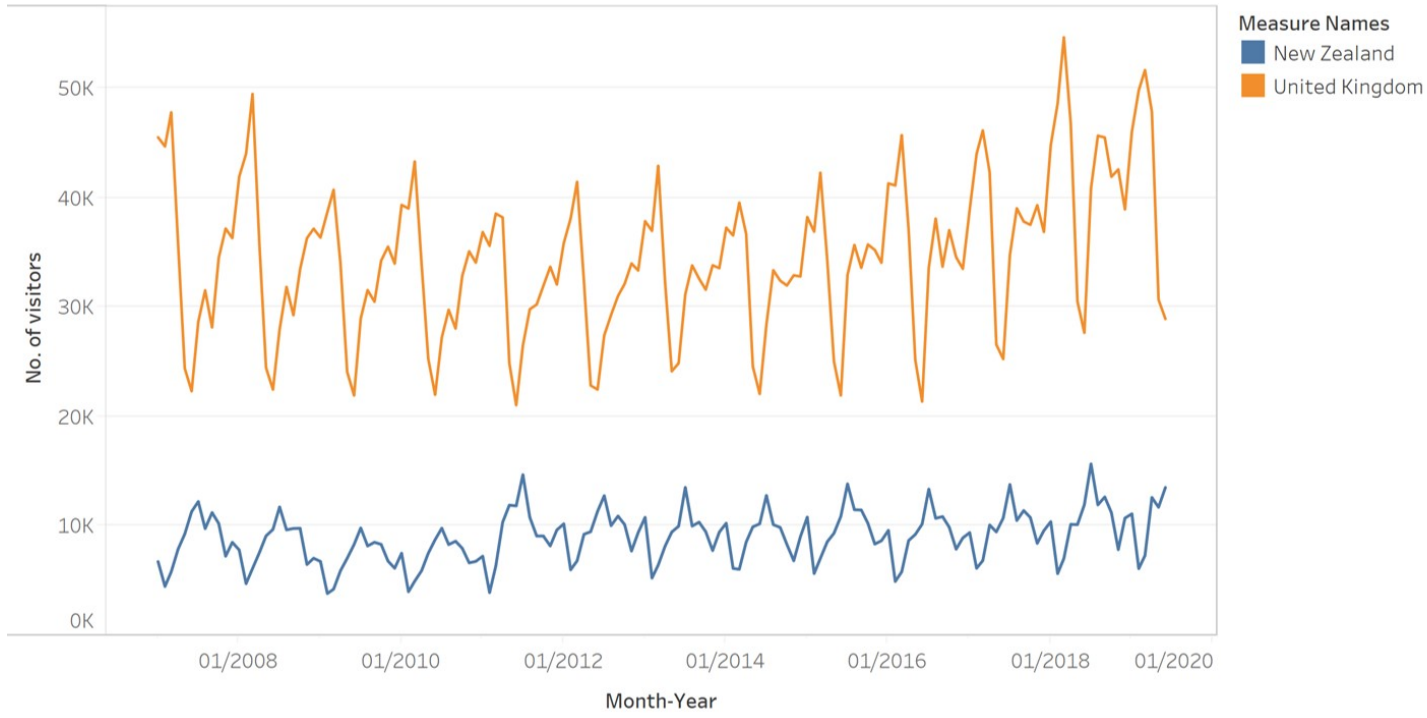
Time-series Patterns: Rate of change

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



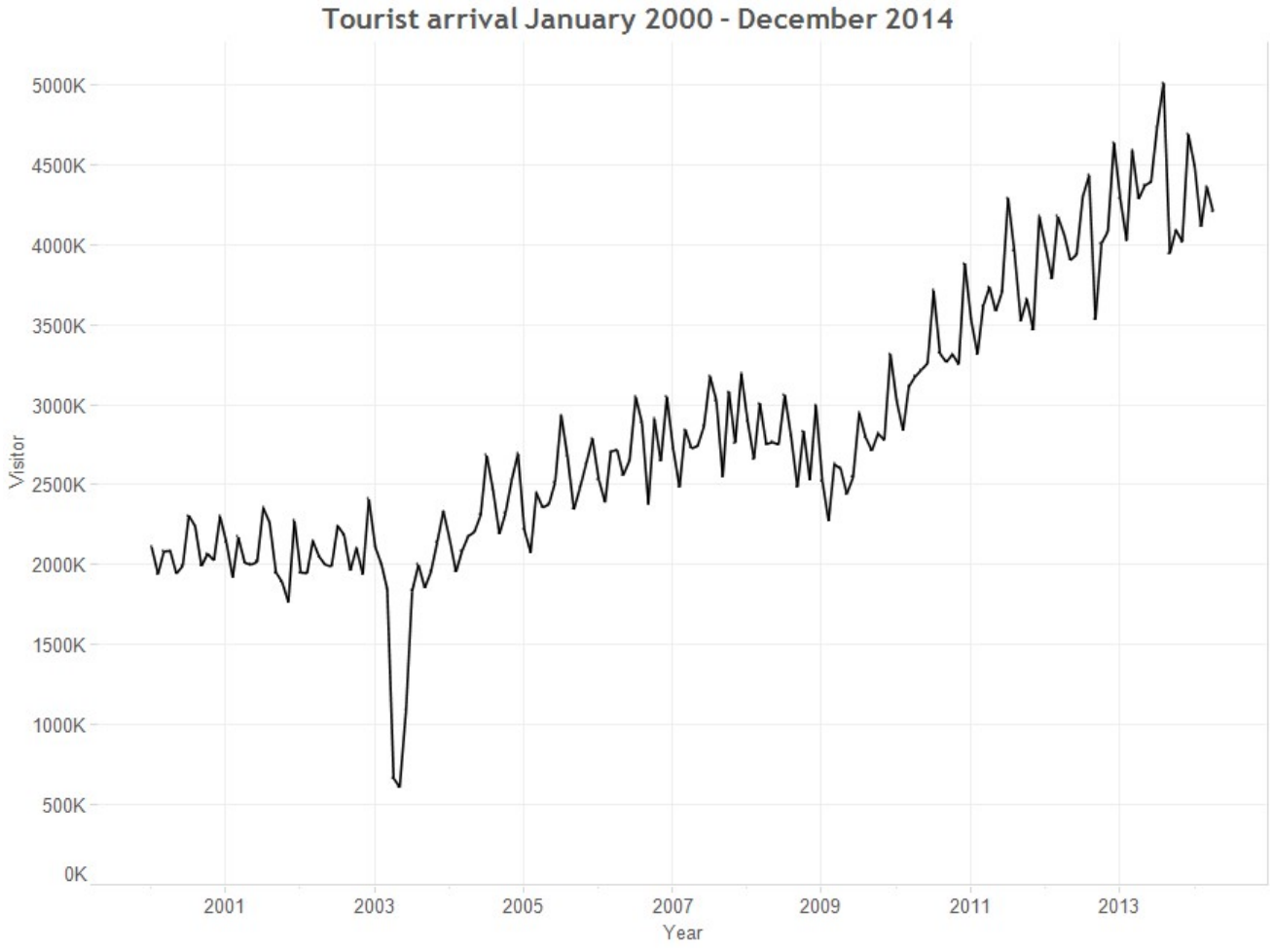
Time-series Patters: Co-variation

- When two time series relate to one another so that changes in one are reflected as changes in the other, either immediately or later.



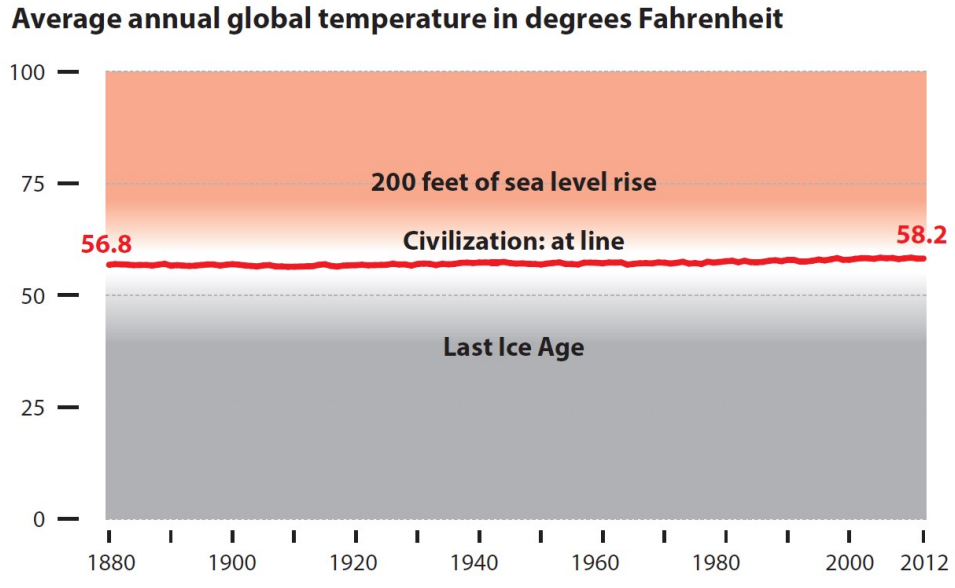
Time-series Patterns: Exceptions

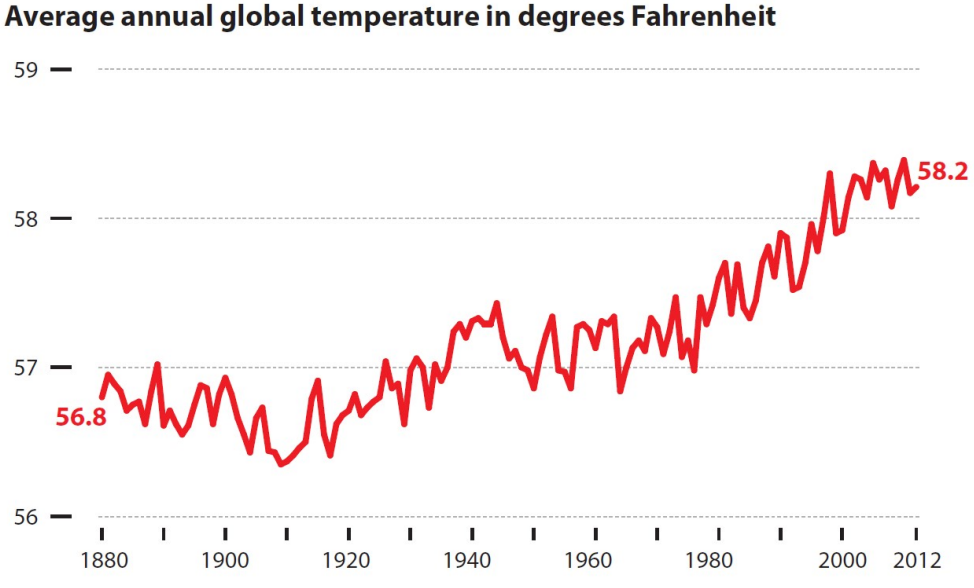
- Values that fall outside the norm.



Line graph design tips

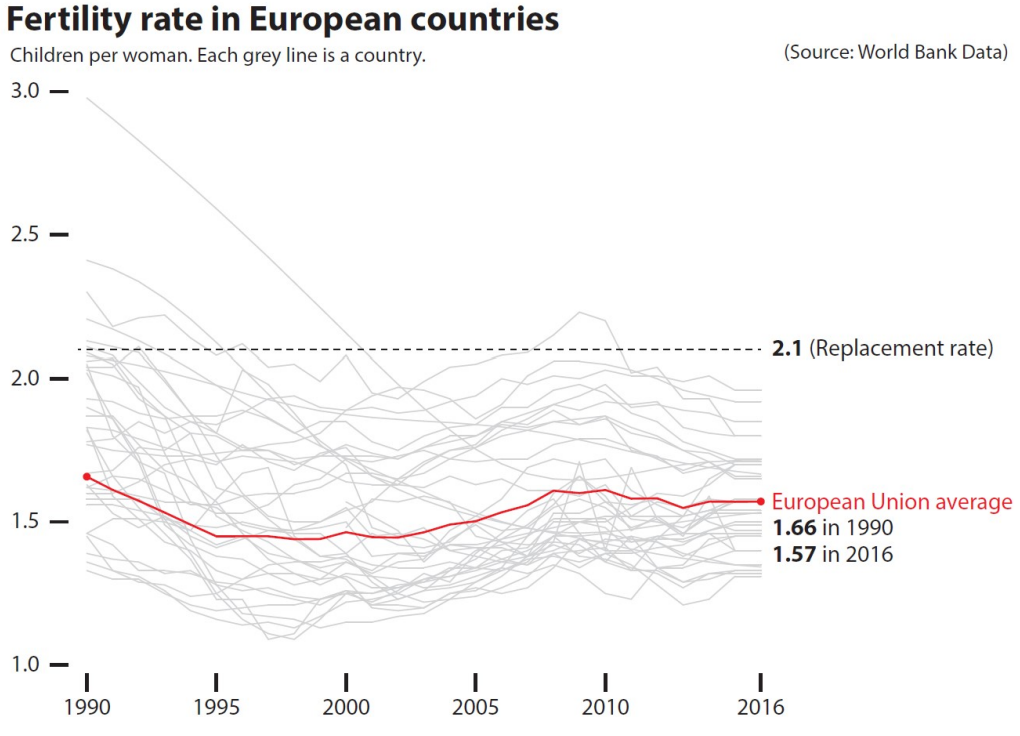
Not all line graphs should start at zero!

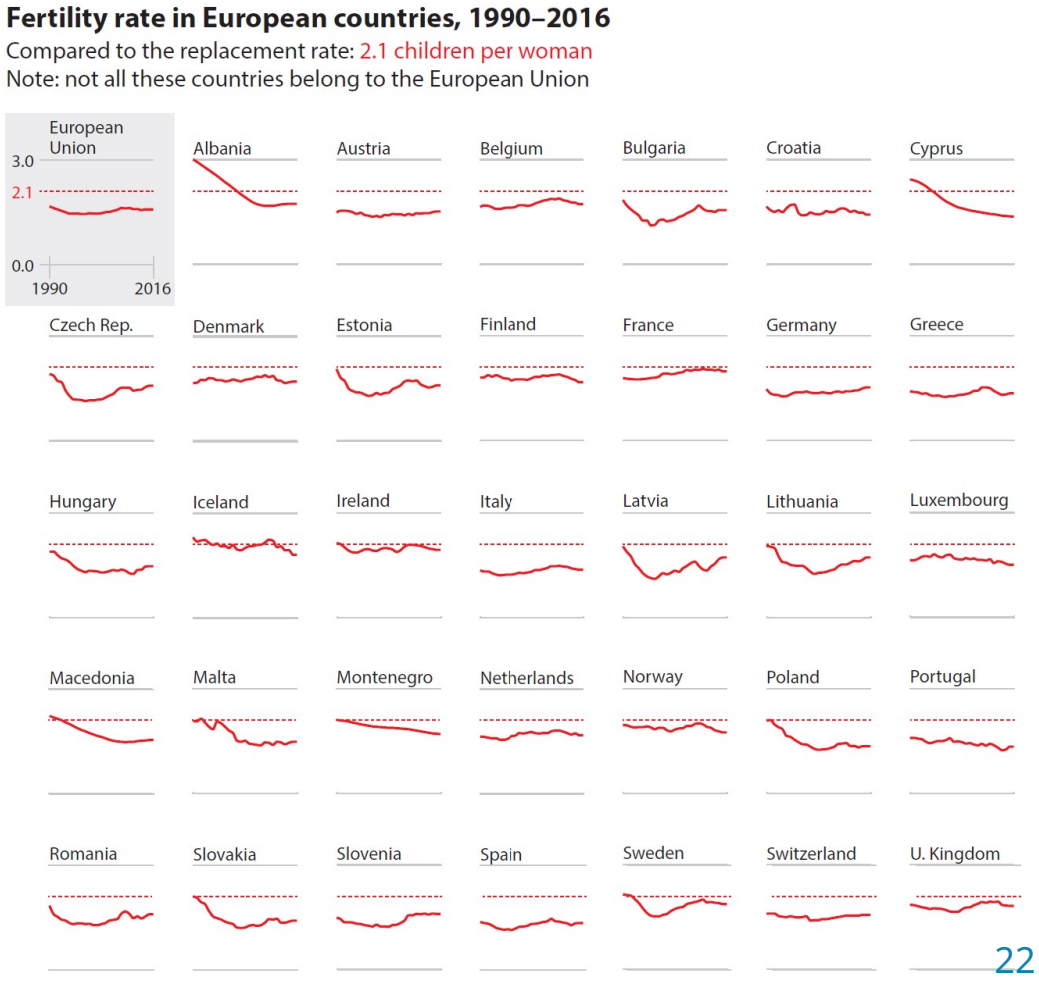




Line graph design tips

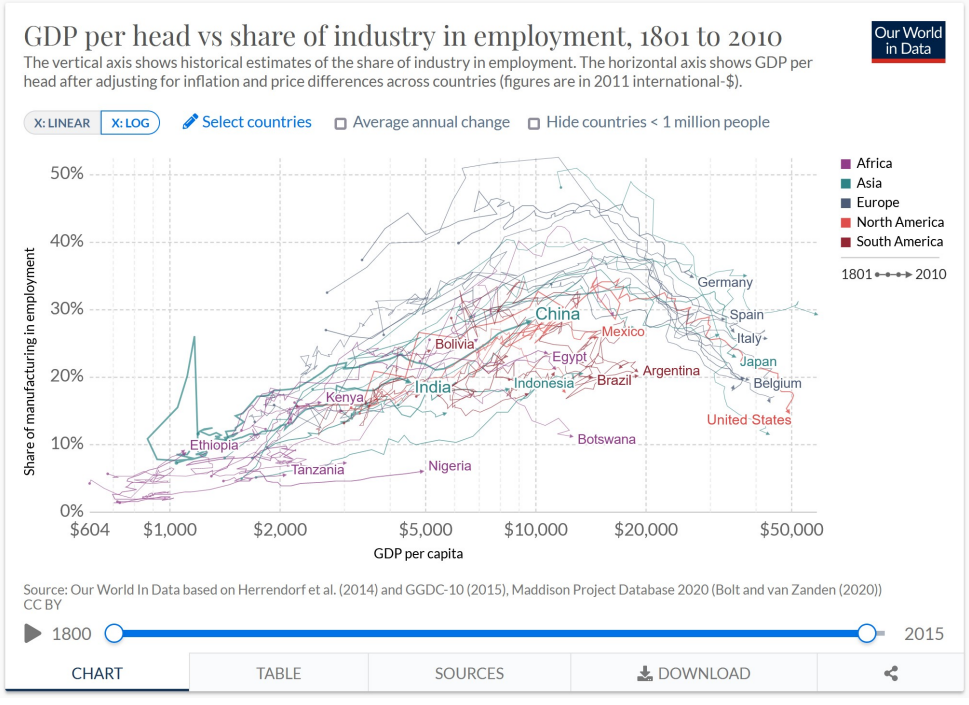
Multiple lines in a single graph is less effective than trellis line graph





Line graph design tips

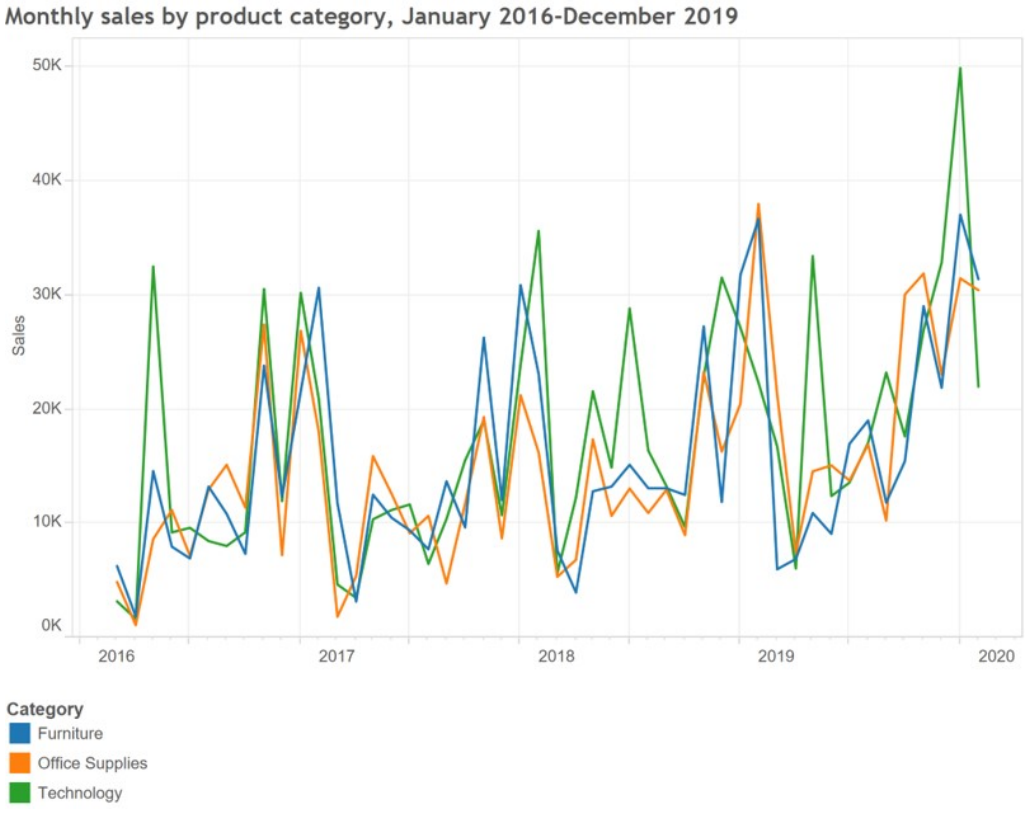
Not all time-series graphs have time on the x-axis

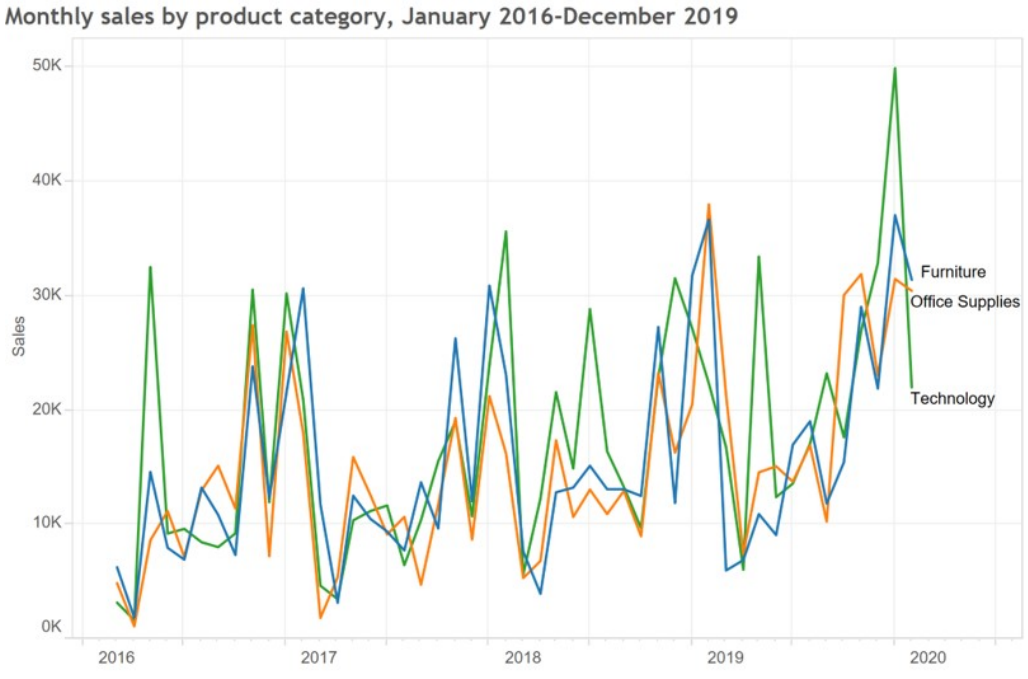


Source: https://ourworldindata.org/growth-and-structural-transformation-are-emerging-economies-industrializing-too-quickly

Line graph design tips

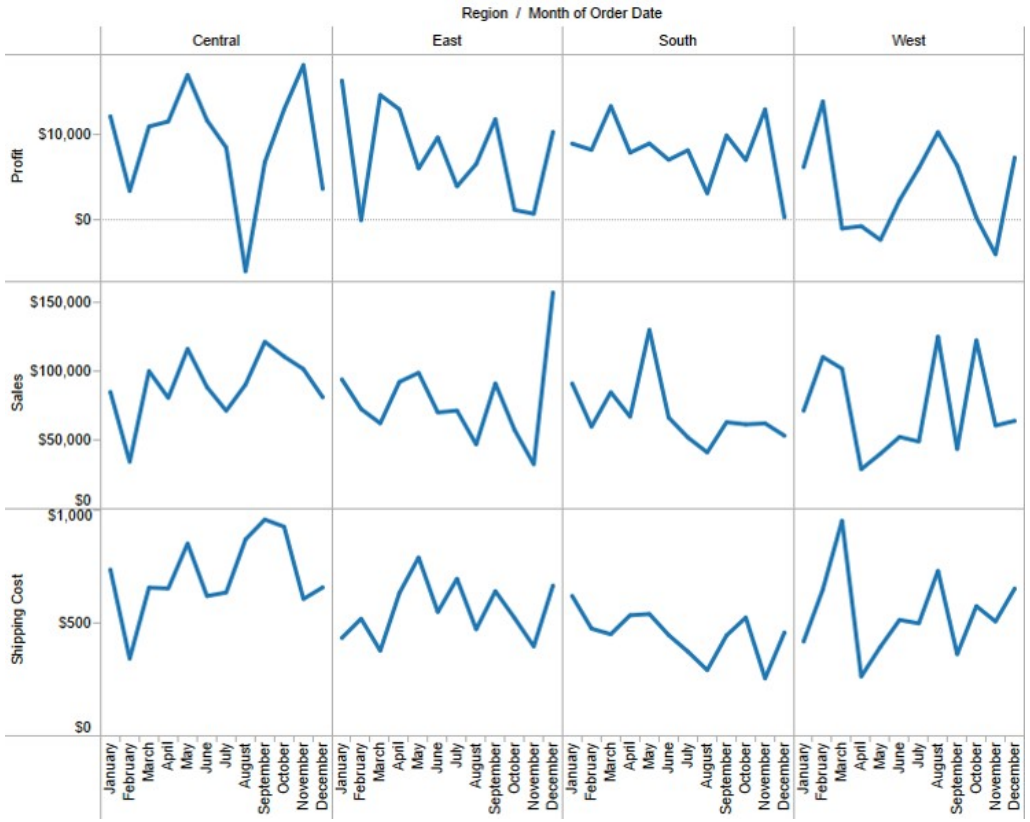
Label line graph instead of using legend



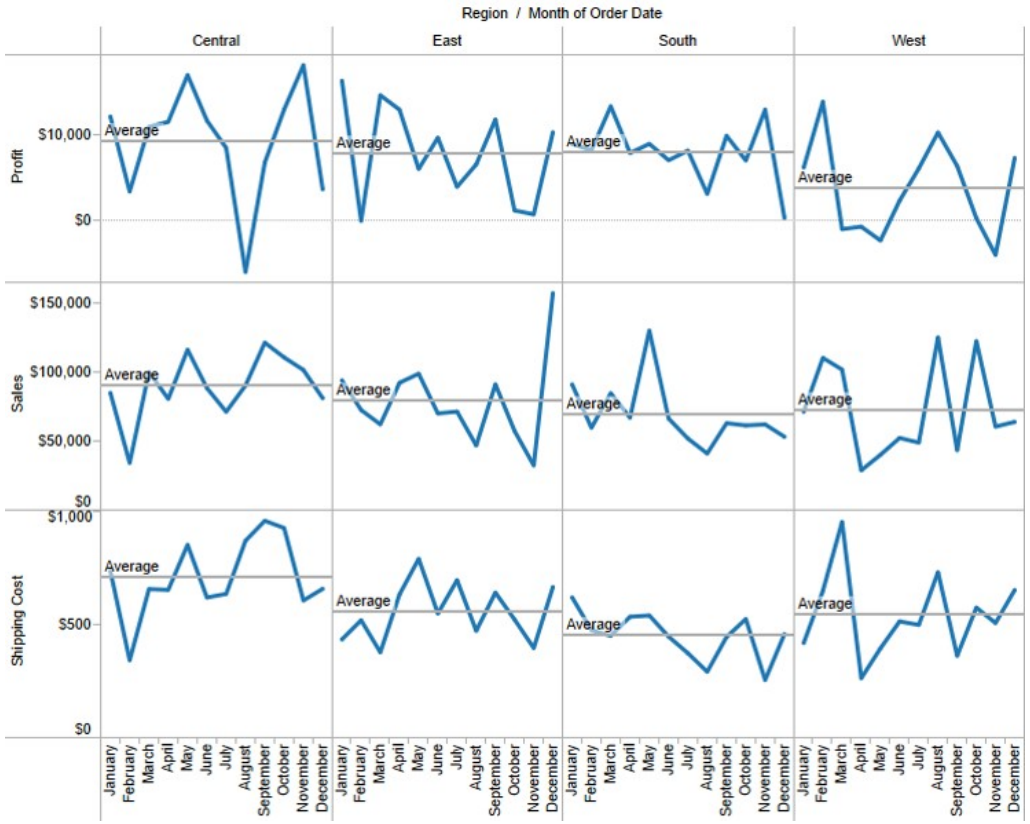


Line graph design tips

Line chart without reference line

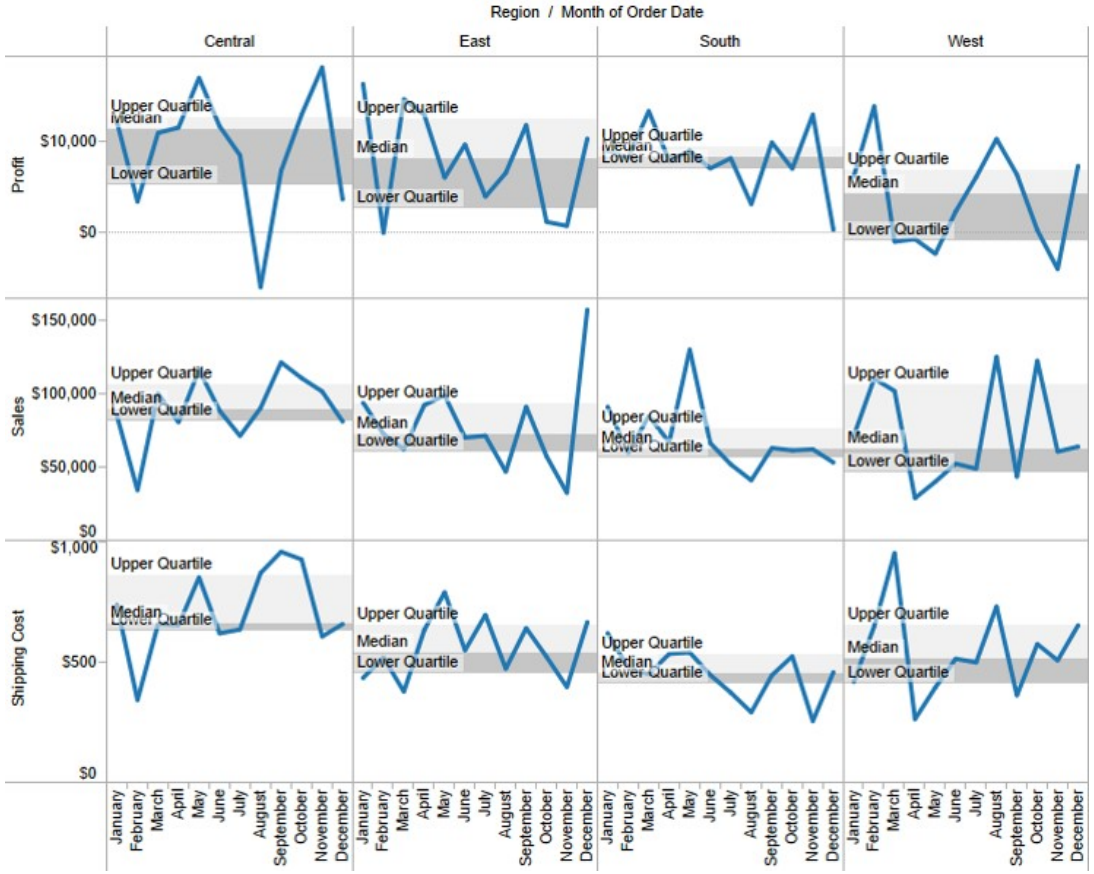


Line chart with reference line



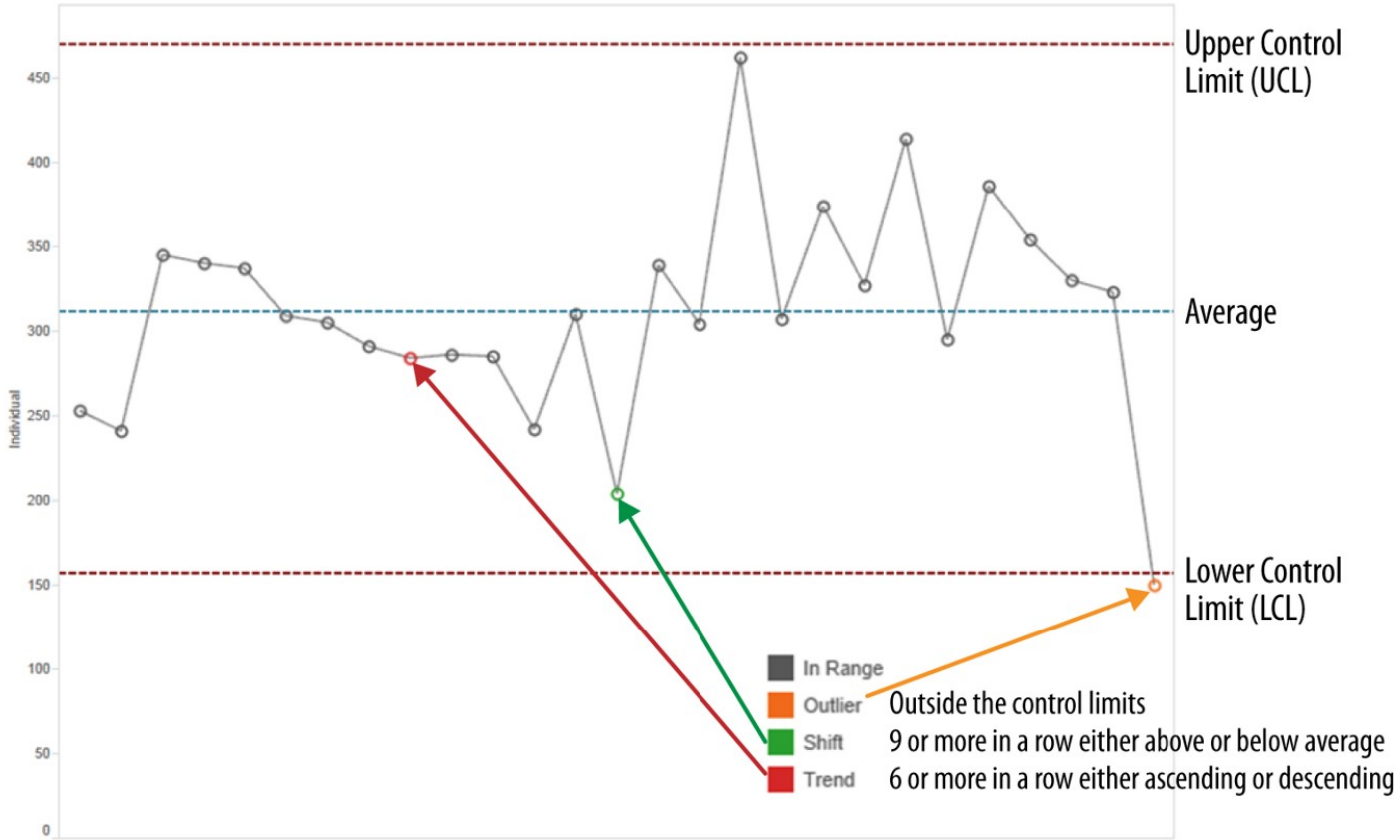
Line graph design tips

Line chart with reference band

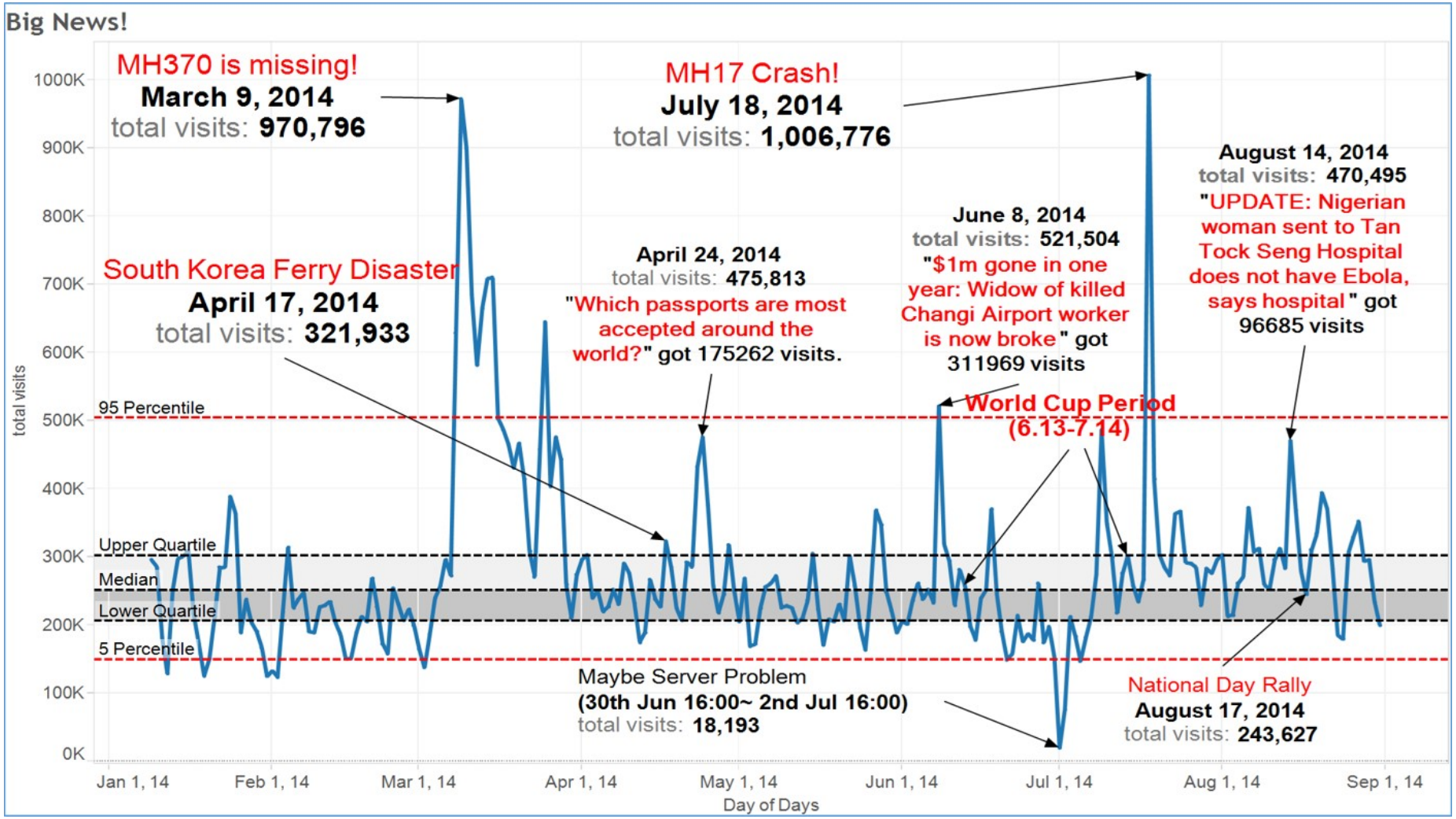


Beyond Line Graph

Control Chart: An analytical line chart



Control chart in real world



Beyond Line Graph

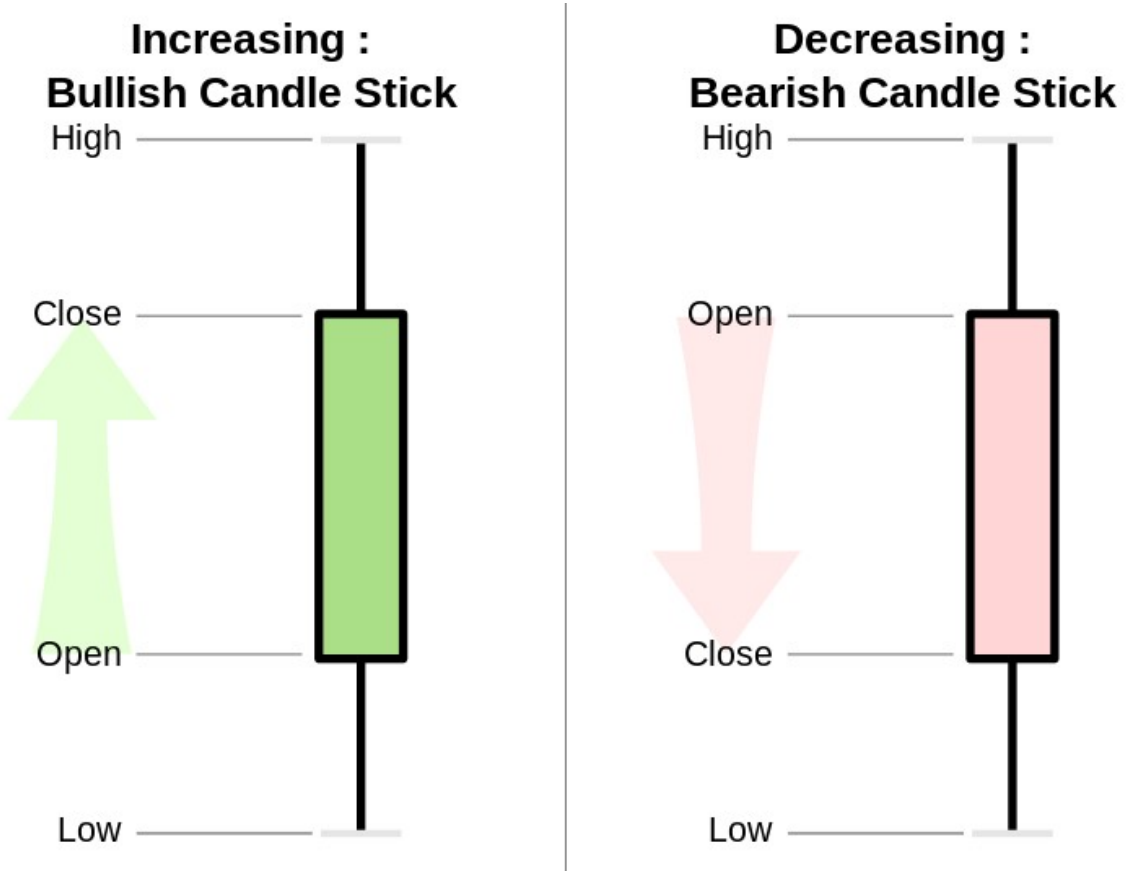
Candlestick chart

Candlestick chart

Interpreting candlestick chart

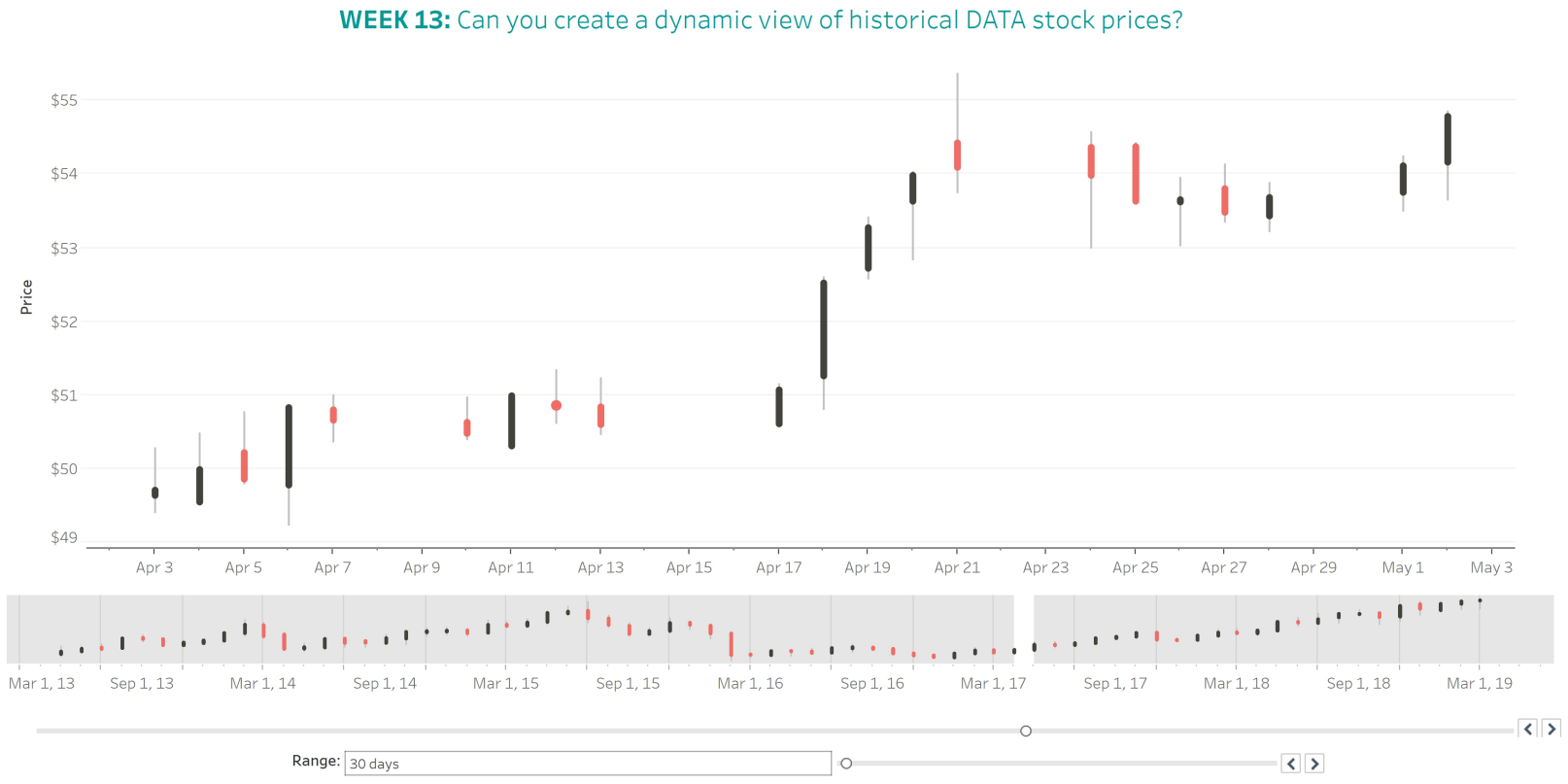
Candlestick chart

Interpreting candlestick chart



Learning from the Master

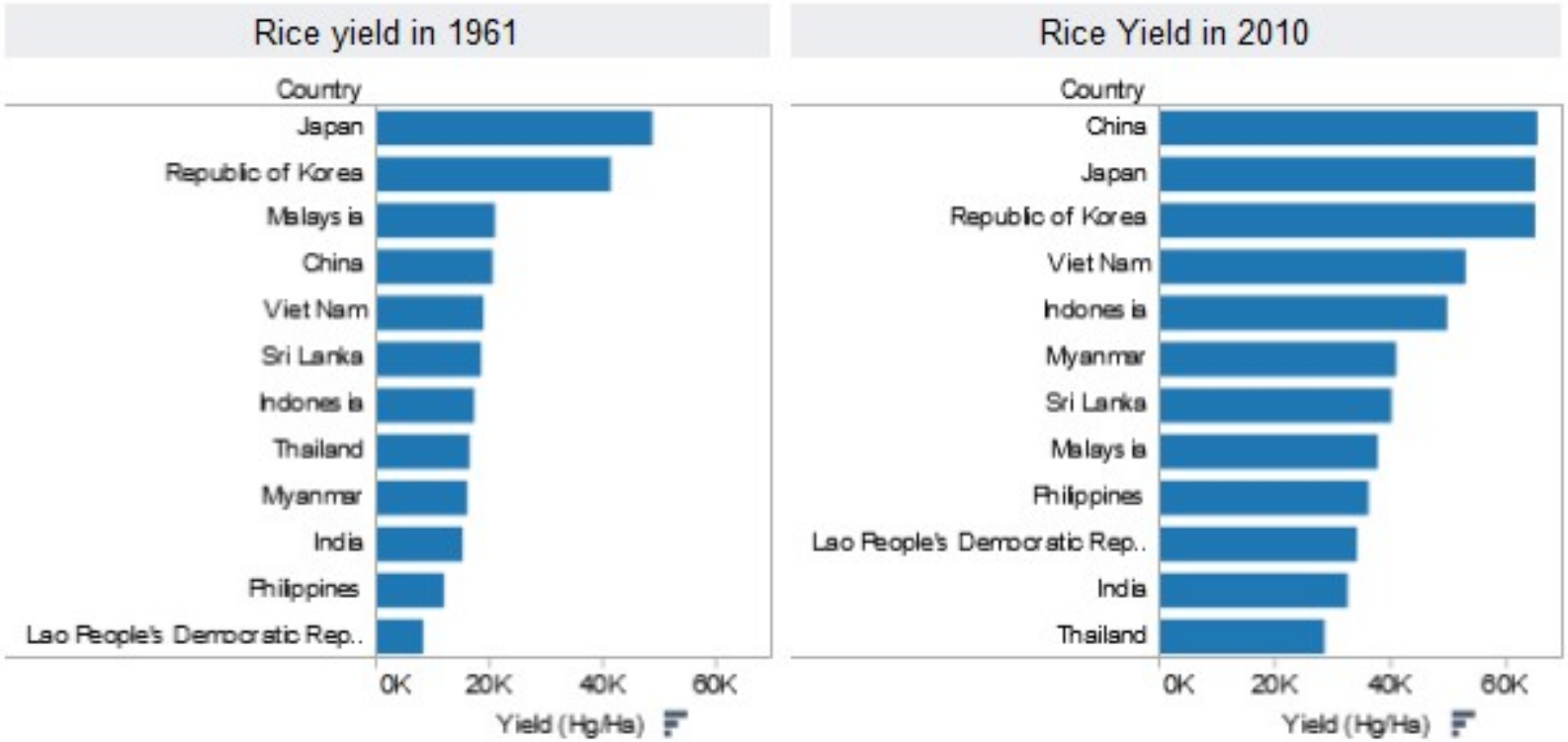
This link provides an example of interactive candlestick.



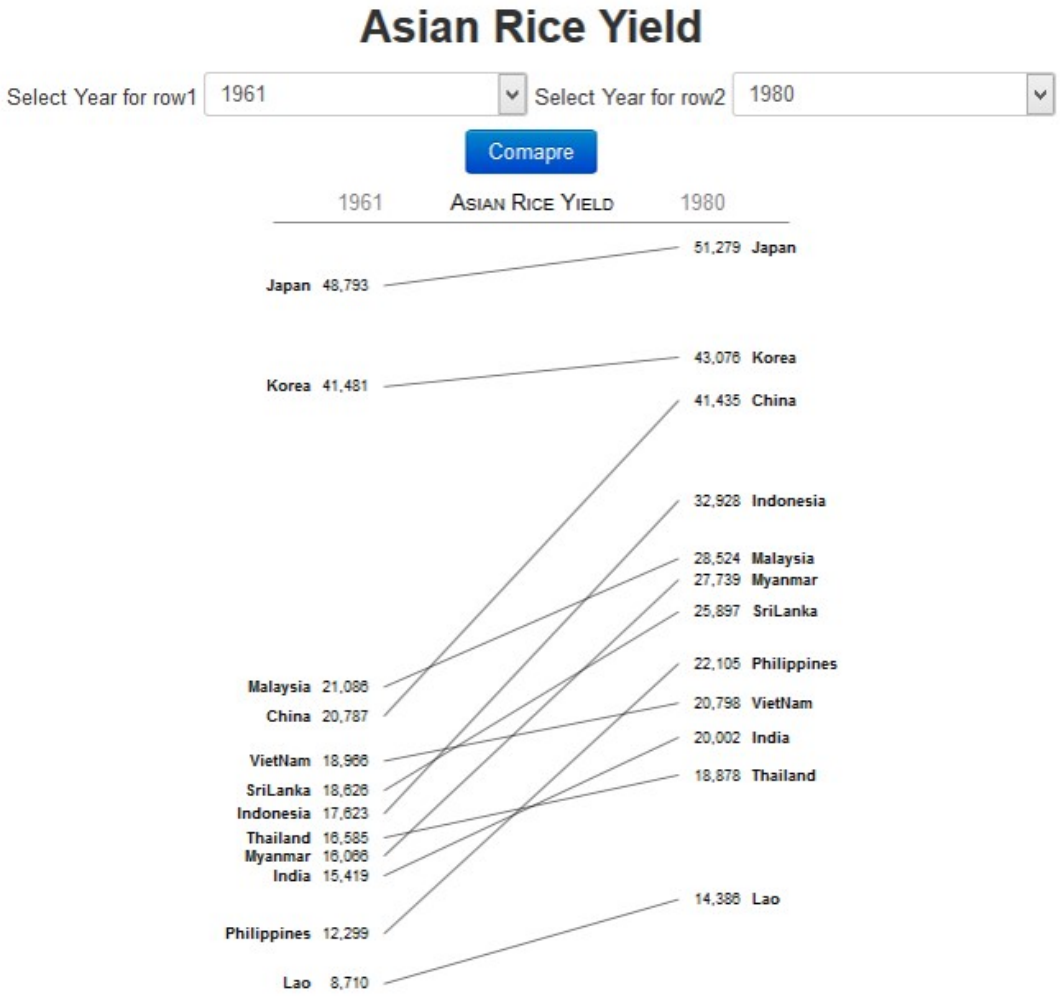
Click on this link for more detail.

Challenge I: Visualising Change between Two Points in Time

Bar chart method



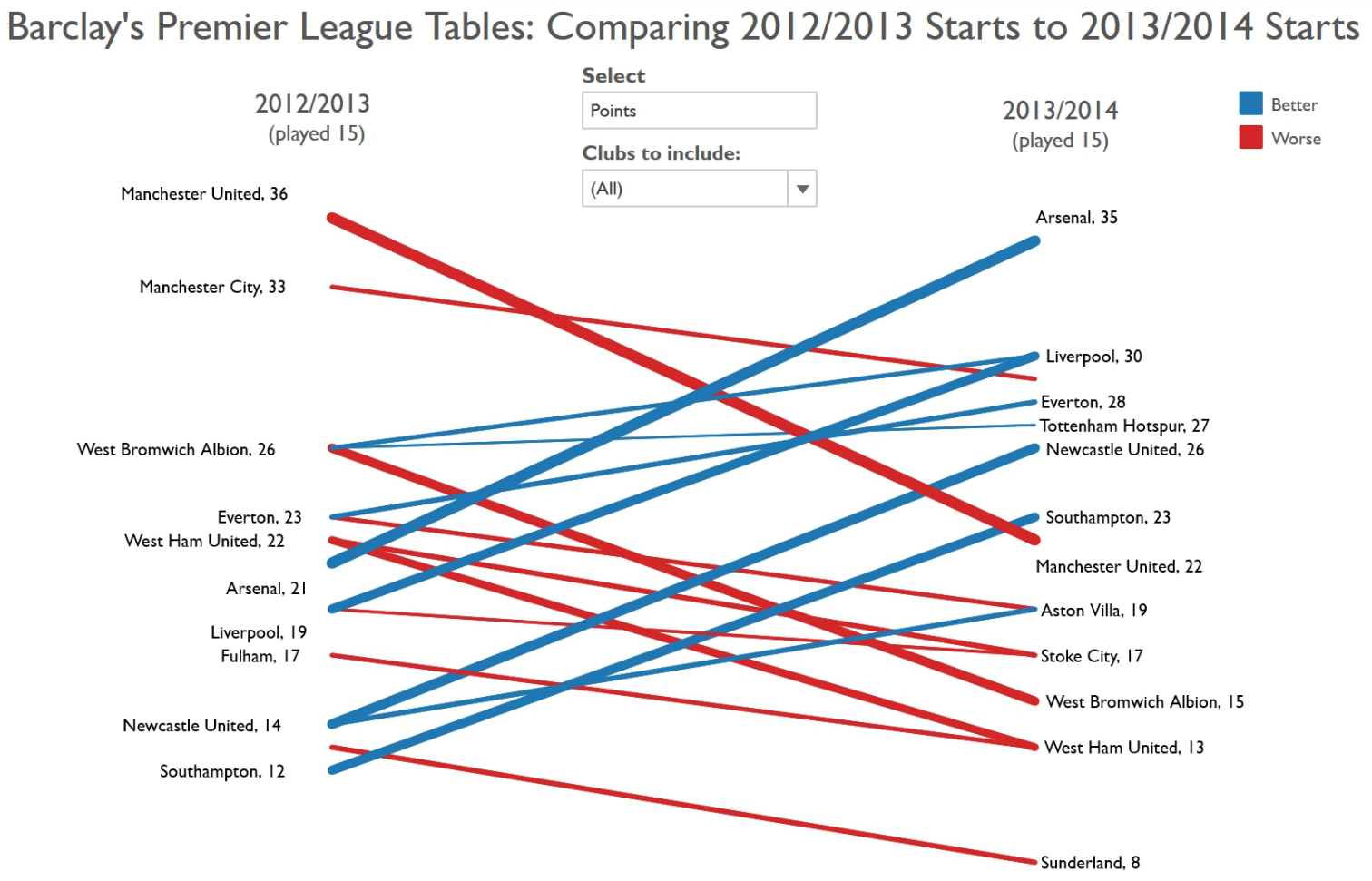
Slopegraphs come to rescue!



Reference: http://www.edwardtufte.com/bboard/q-and-a-fetch-msg?msg_id=0003nk

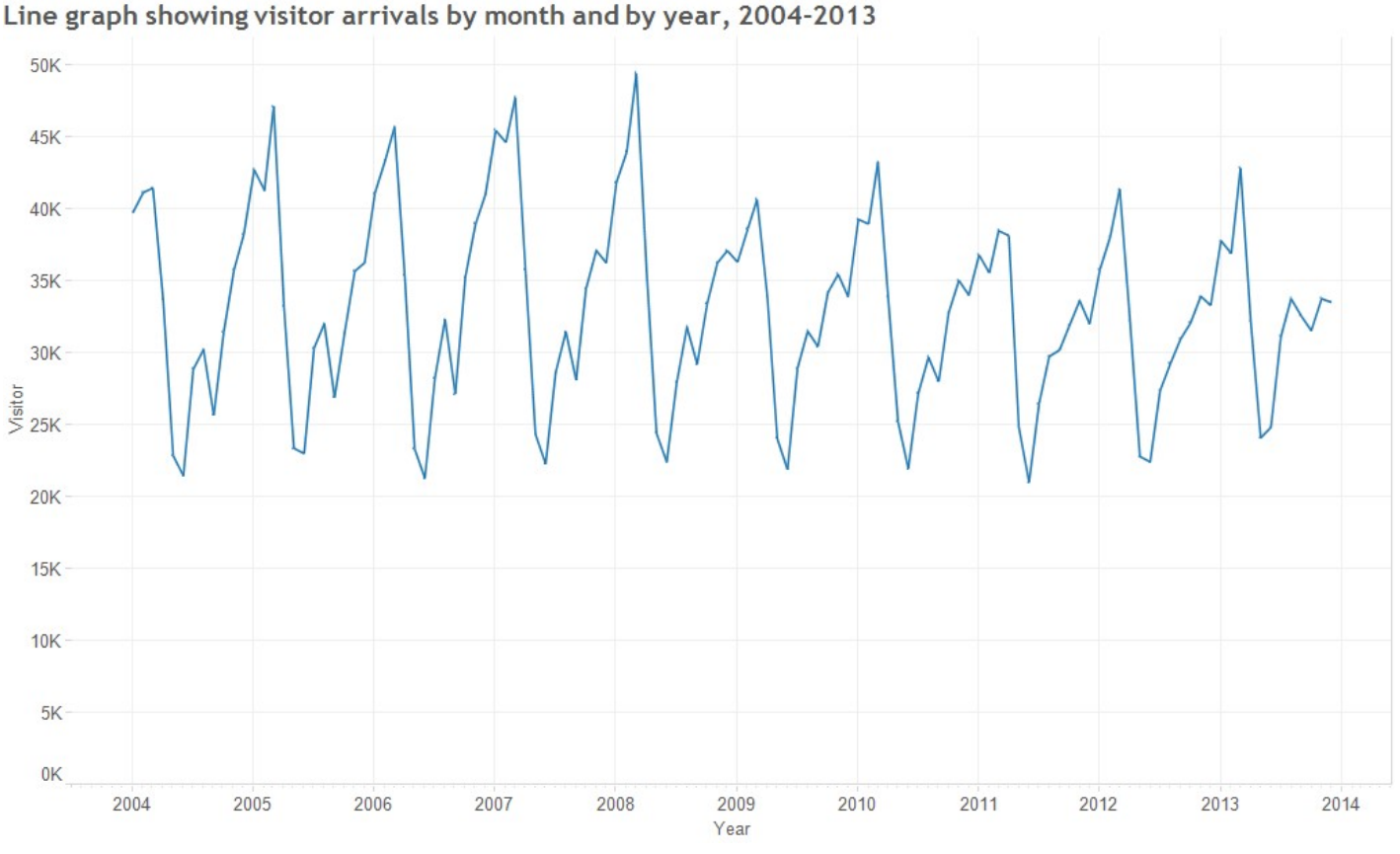
Learning from the Master

Visit Tableau Public to try out the interactive version and visit this link to learn more.



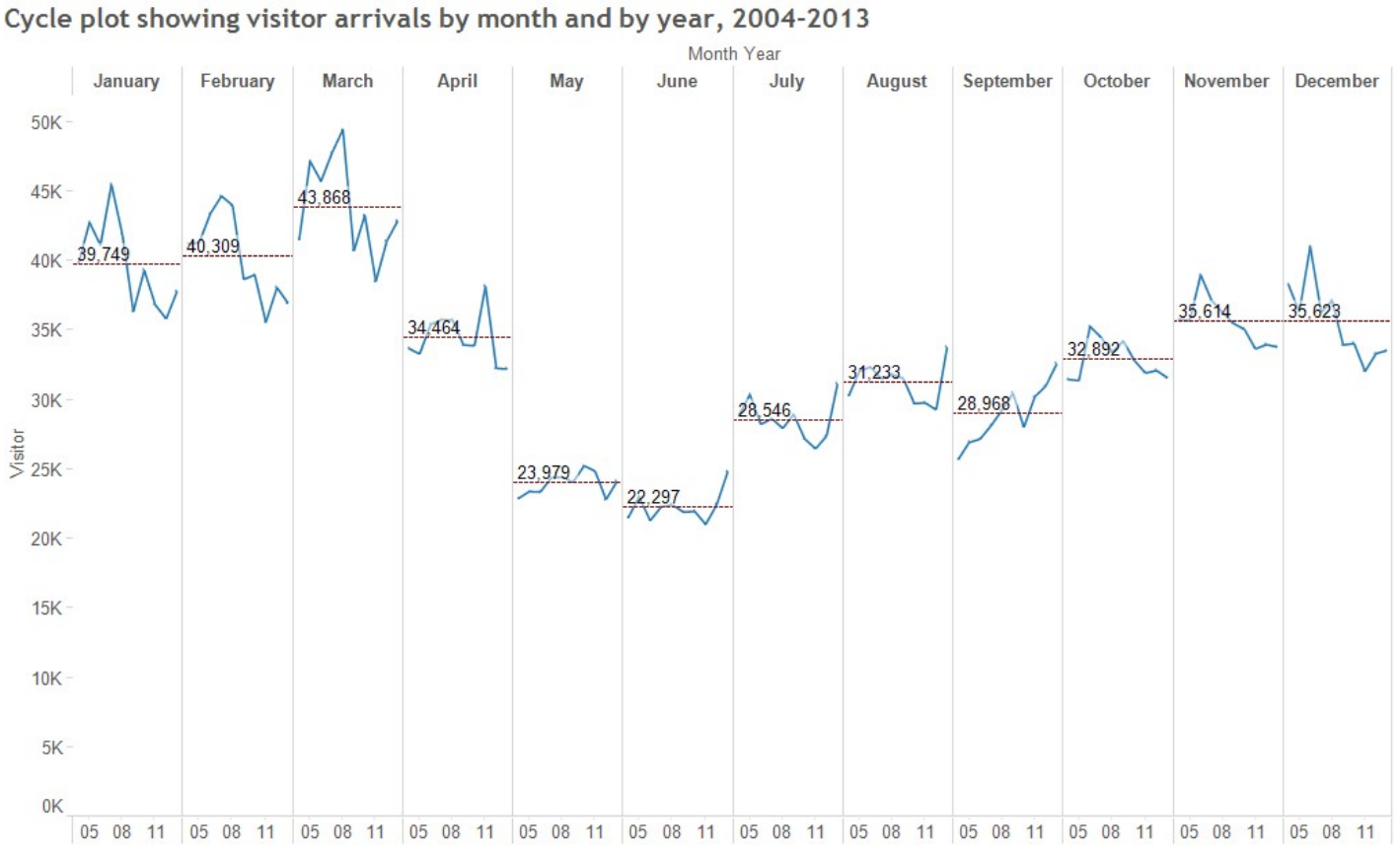
Challenge II: Visualising cyclical patterns

Classic line graph method



Challenge II: Visualising cyclical patterns

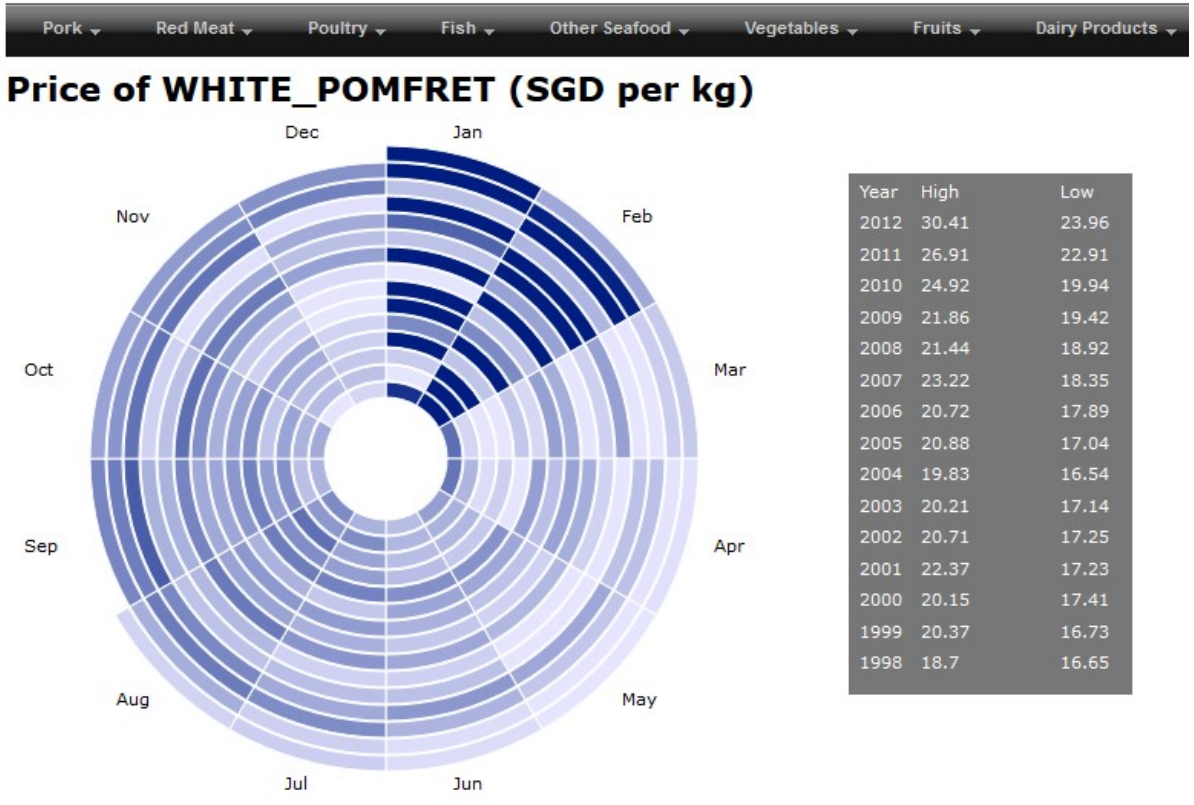
Solution: Cycle plot



Reference: http://www.perceptualedge.com/articles/guests/intro_to_cycle_plots.pdf

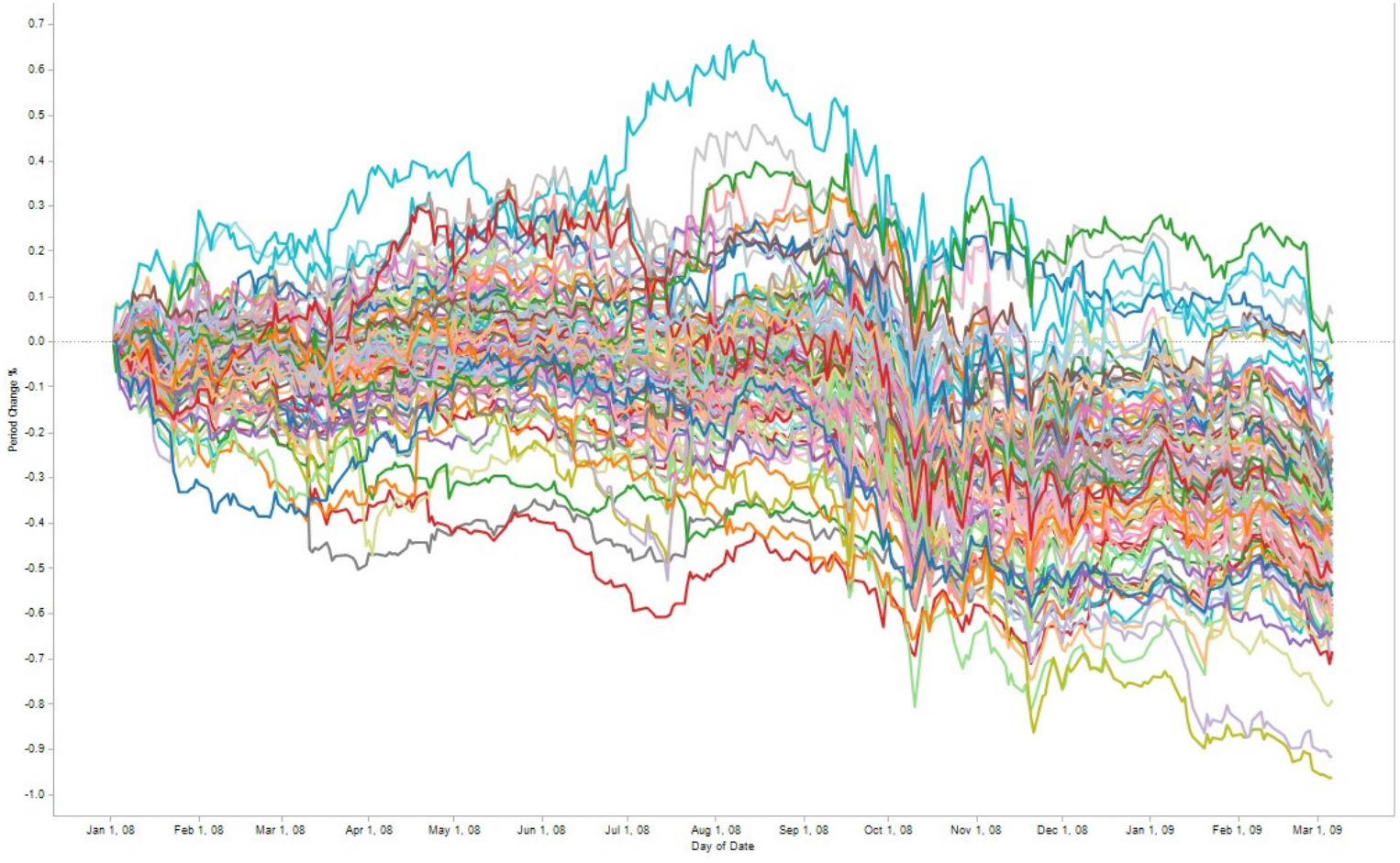
Challenge II: Visualising cyclical patterns

Solution: Sunburst diagram method



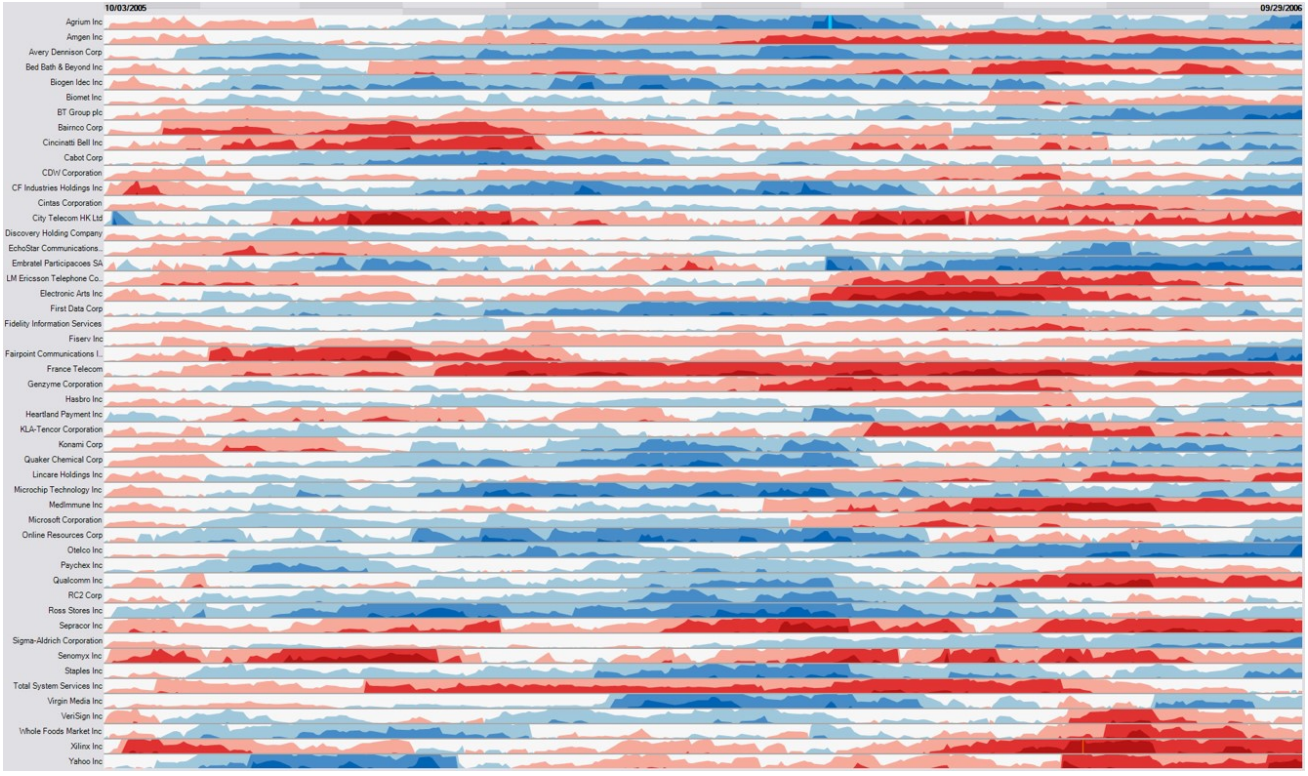
Challenge III: Massive Time-series Data

Classic line graph method



Challenge III: Massive Time-series Data

Solution: Horizon graph



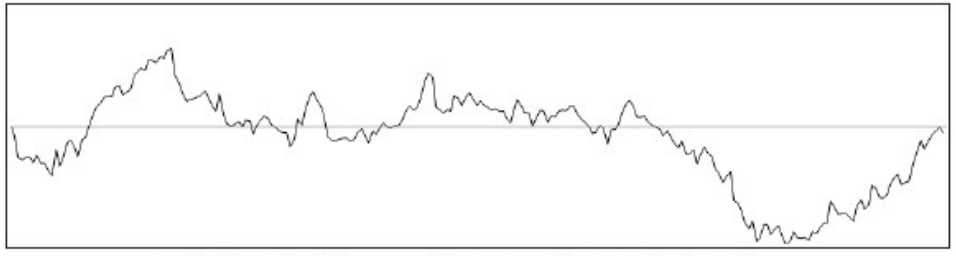
Reference: https://www.perceptualedge.com/articles/visual_business_intelligence/time_on_the_horizon.pdf

Solution: Horizon graph

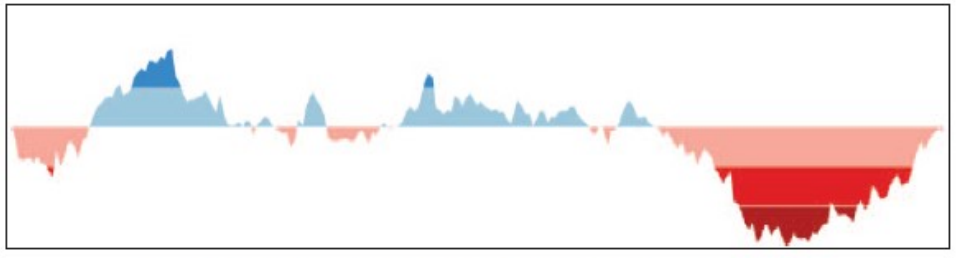
The basic construct of a horizon graph

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

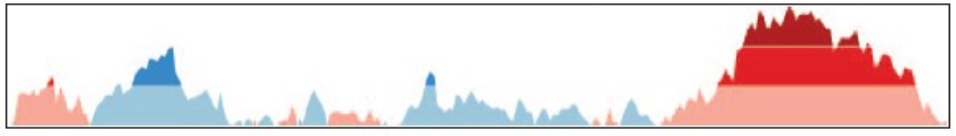
Reference: The Developmentof the Horizon Graph



(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.

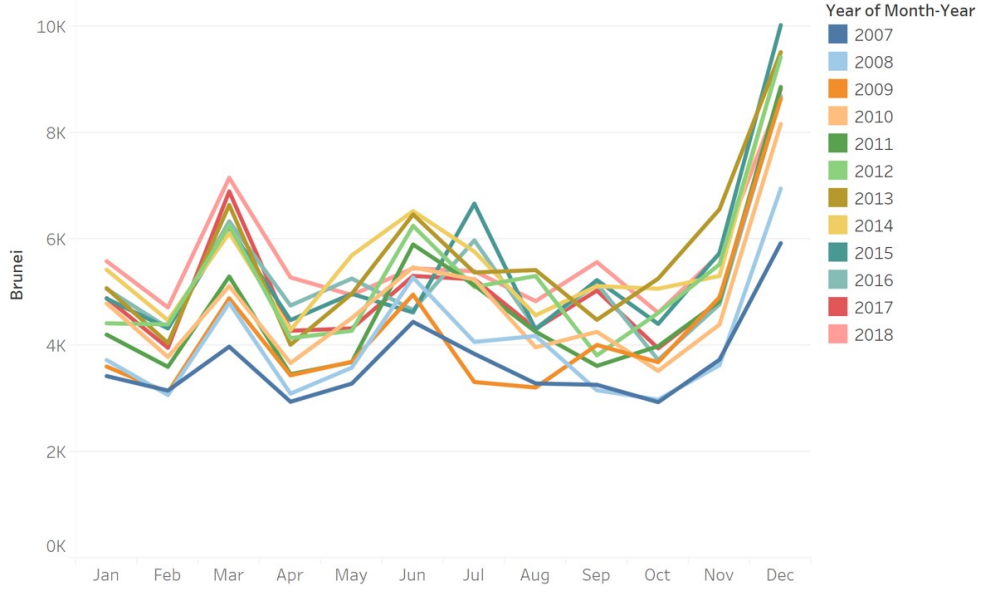
Horizon graph in Tableau

Source: https://public.tableau.com/en-us/gallery/unemployment-horizon-chart. This video https://www.tableau.com/learn/tutorials/on-demand/horizon-charts provides step-by-step explanation on how to create a horizon graph using Tableau.

Challenge IV: Distribution over time

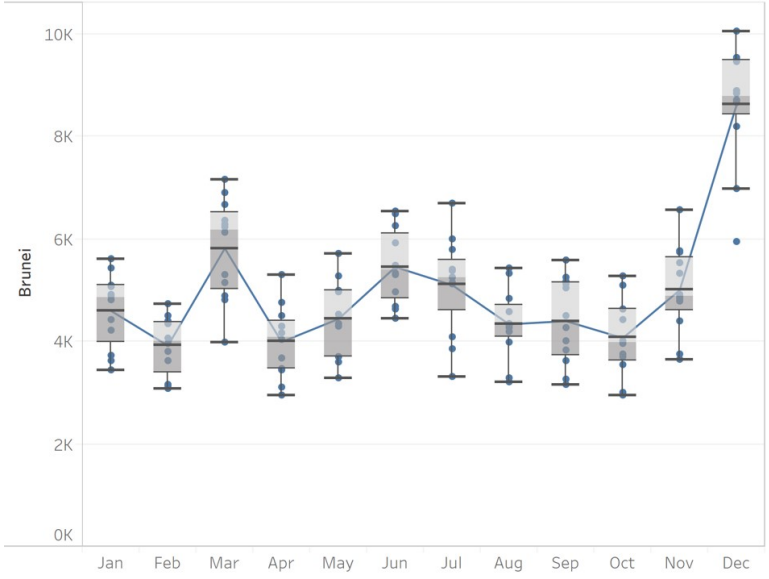
Line graph method

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



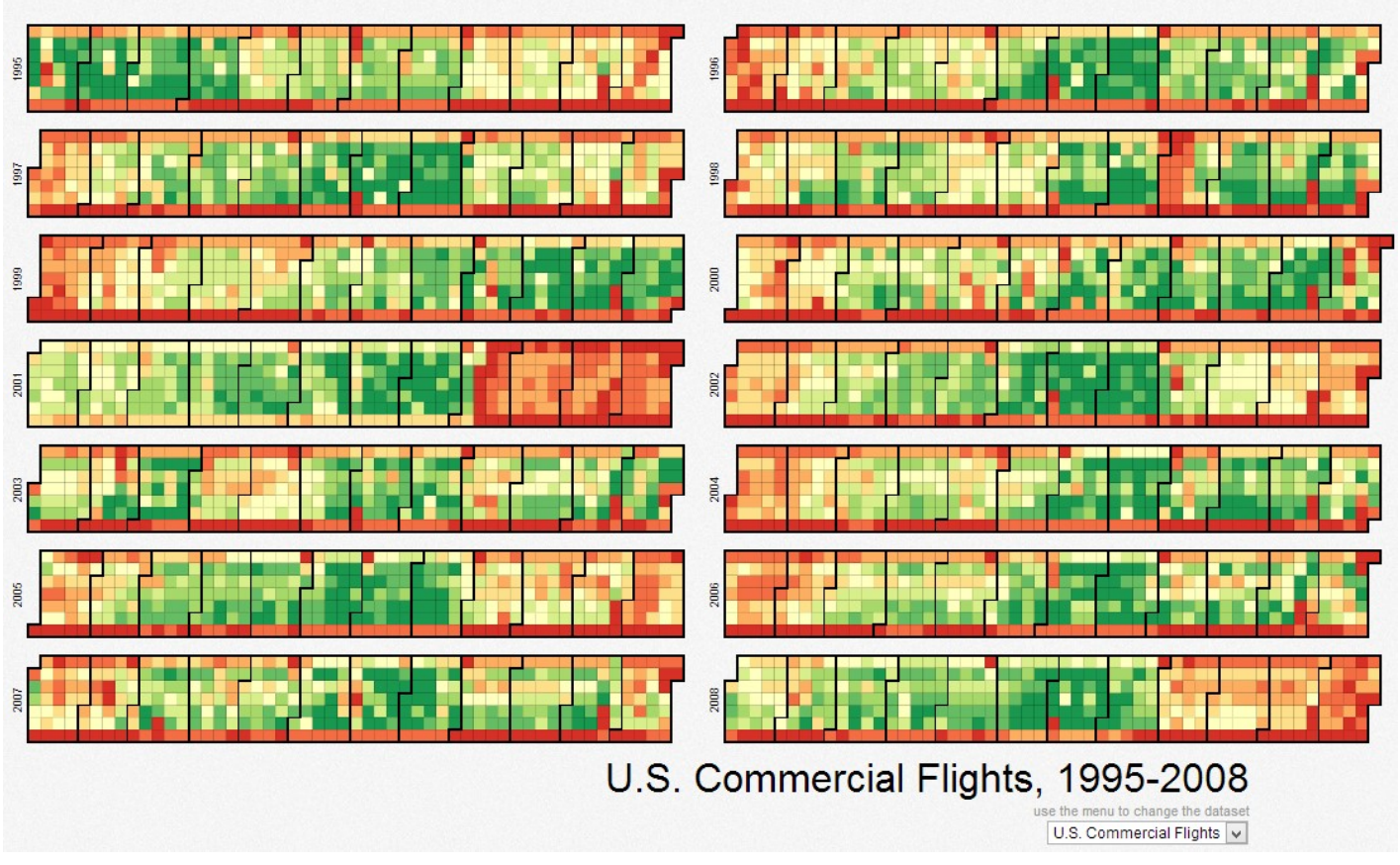
Boxplot method

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



Alternative Time-series Data Visualisation methods

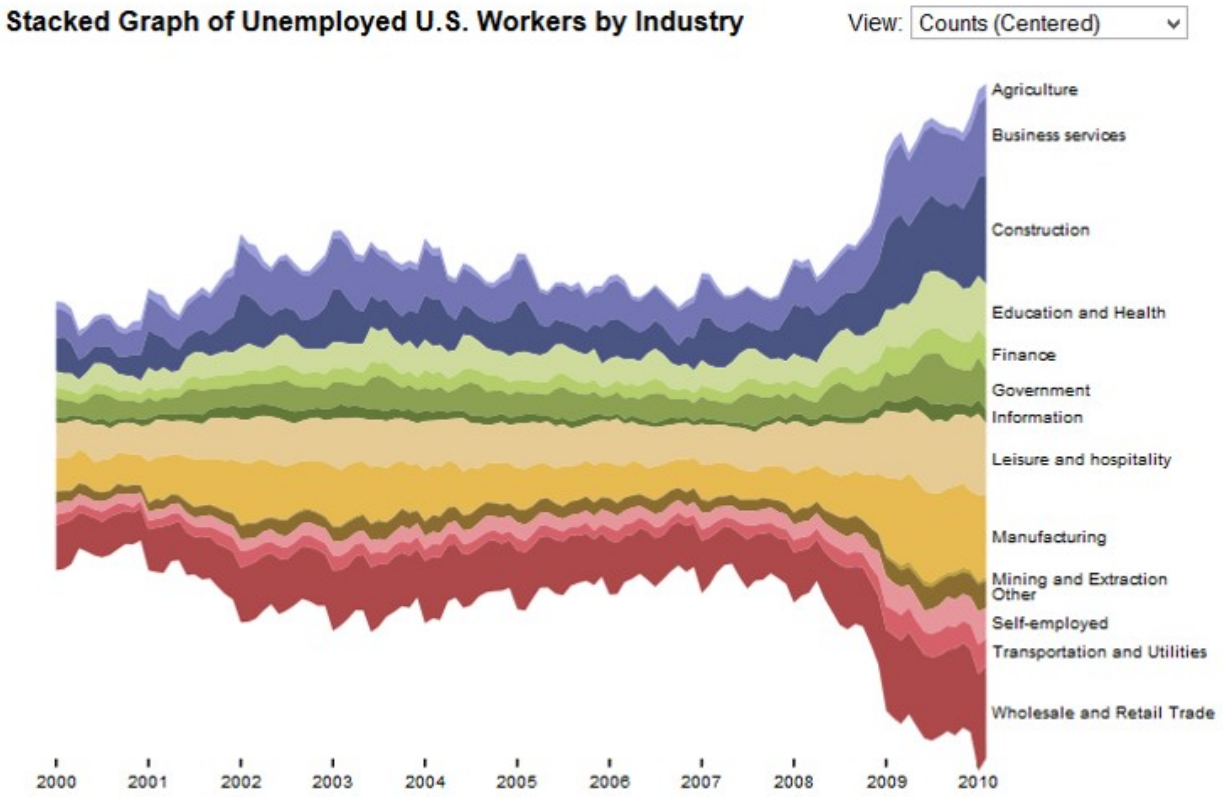
Calendar Heatmap



Source: http://mbostock.github.io/d3/talk/20111018/calendar.html

Alternative Time-series Data Visualisation methods

Stream Graph (also know as ThemeRiver)

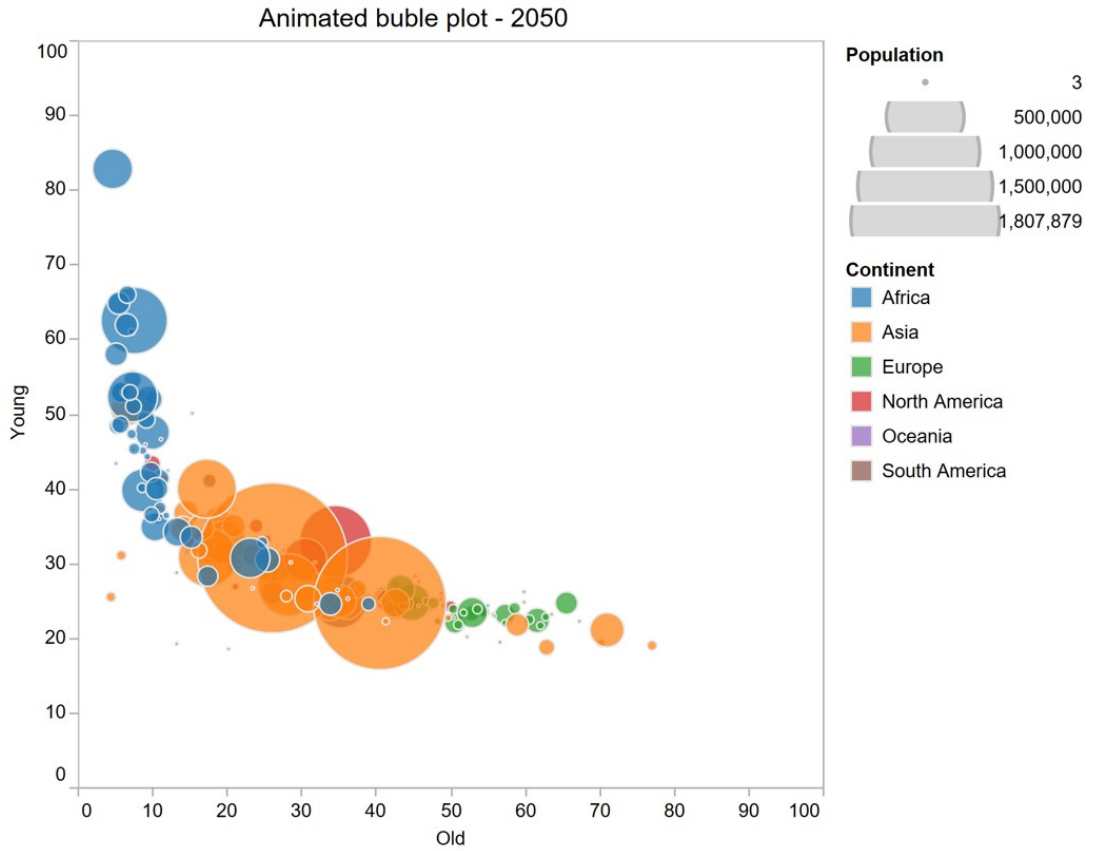


Total counts of unemployed persons per industry, 2000-2010.

Source: U.S. Bureau of Labor Statistics

Visualising Change Over Time

Animated bubble plot (or motion chart)



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