Neural Data Science with **Python**

L2 : Time Series

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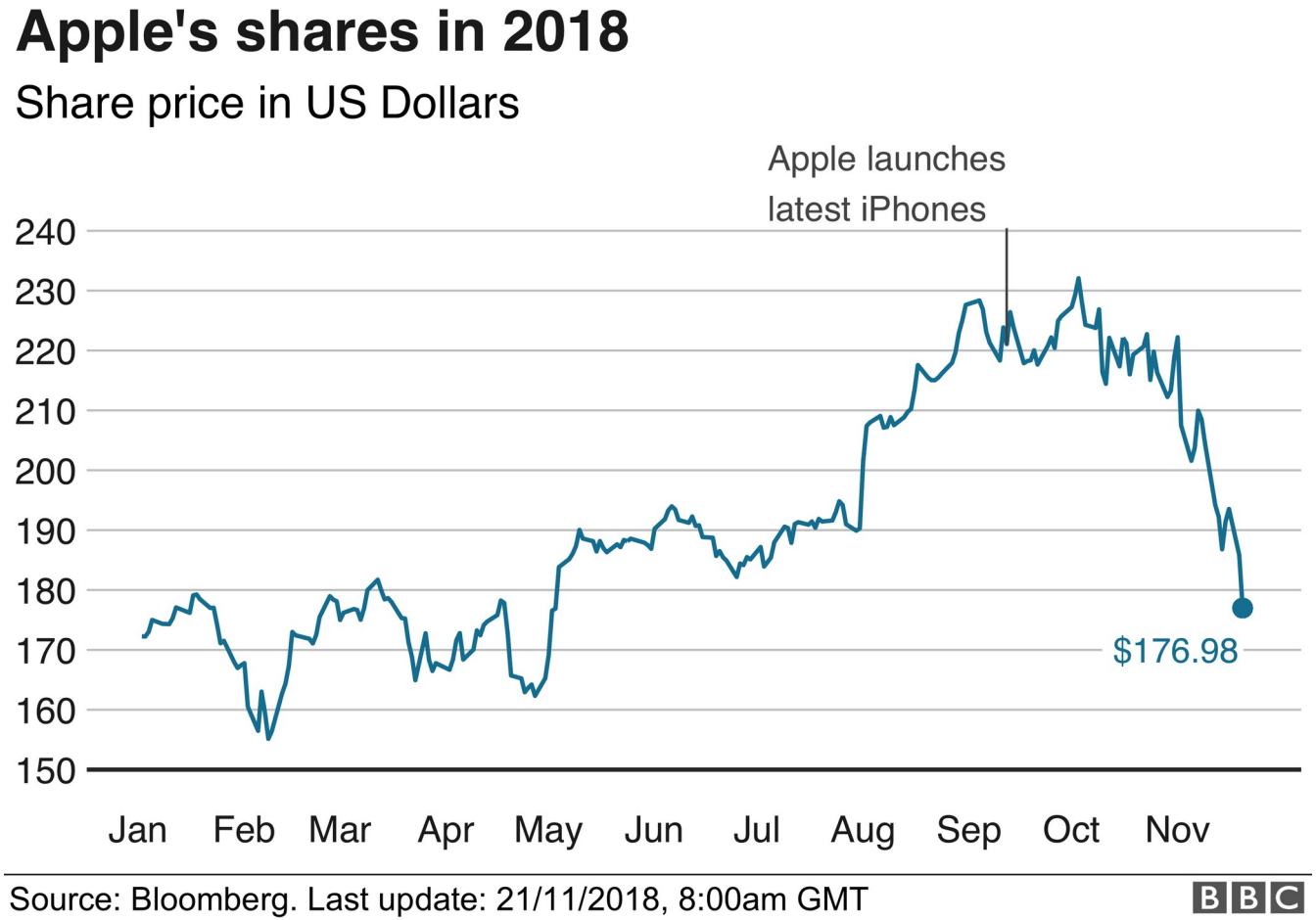
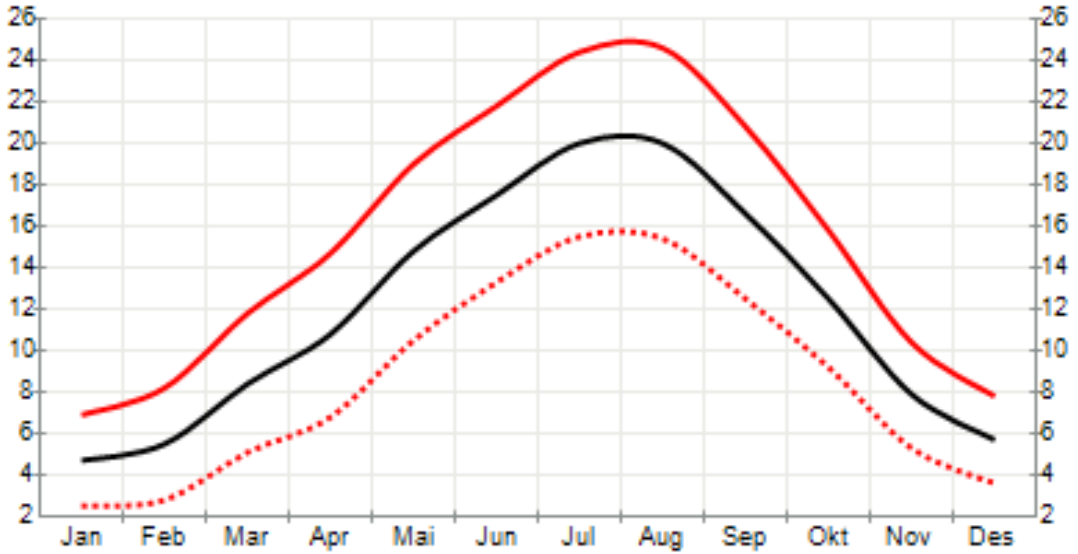
Examples of time series

?

Examples of time series: stock prices



Examples of time series



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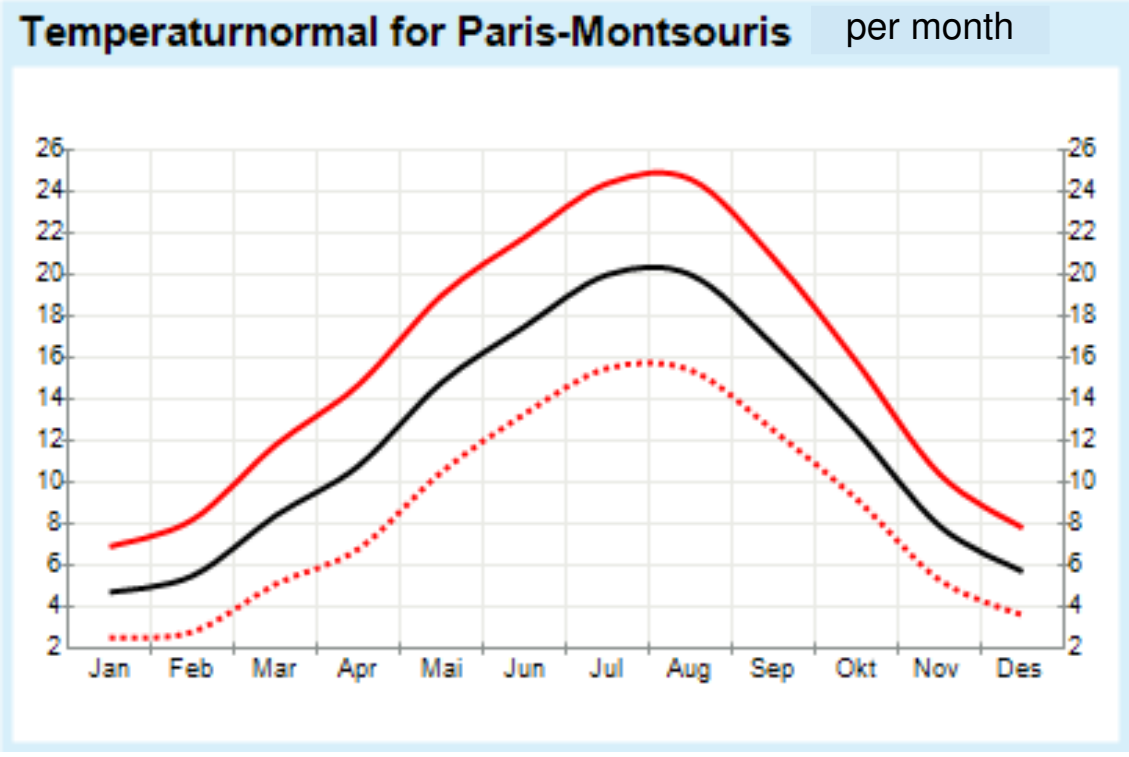
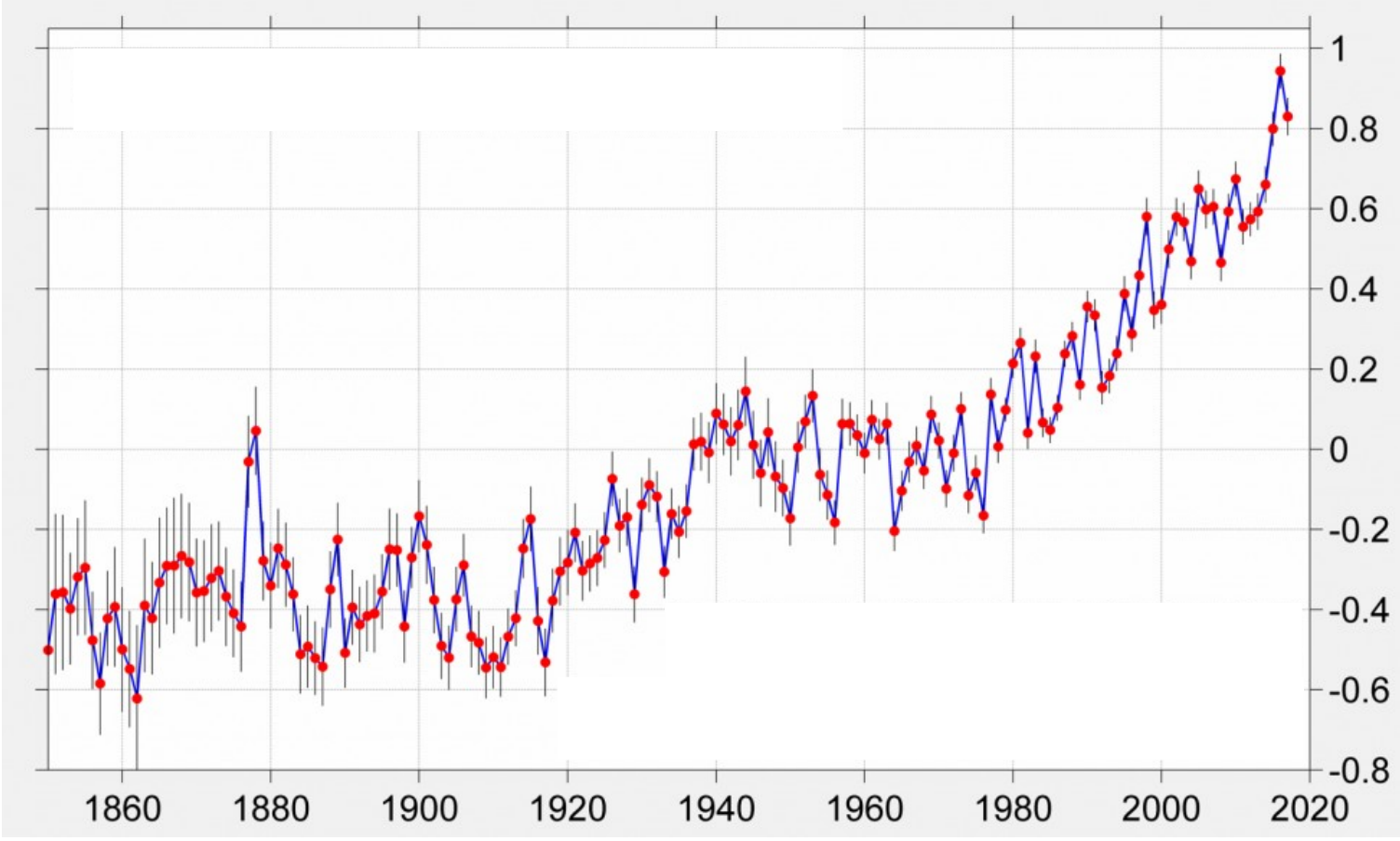
Examples of time series: temperature profiles



- Max temperature: Average max daily (24h) temperature per month
- Minimum temperature: Average minimum daily (24h) temperature per month
- Average temperature: Average daily (24h) temperature per month
- The temperature normals are measured in the period 1961–1990.

Examples of time series

?



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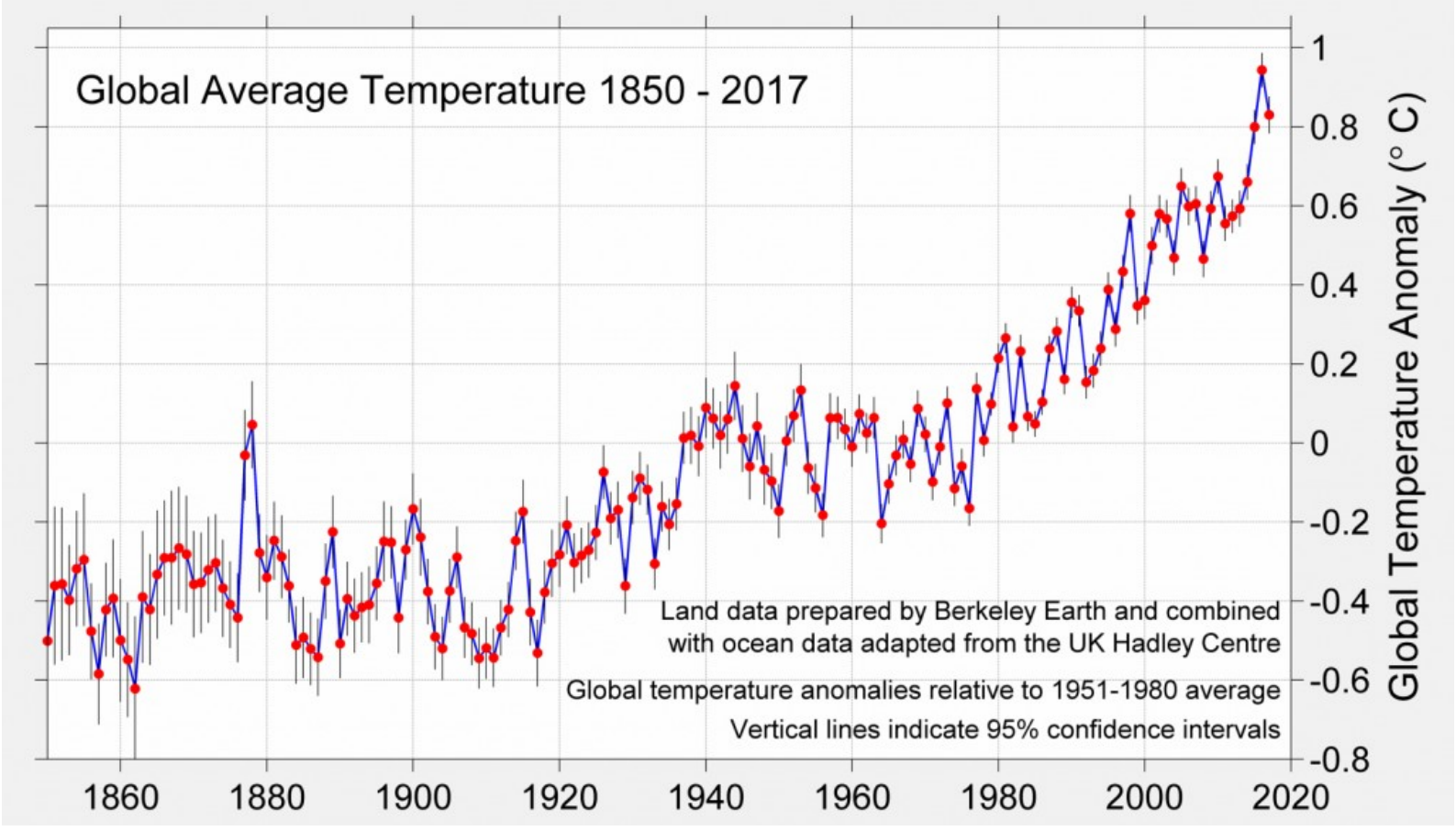

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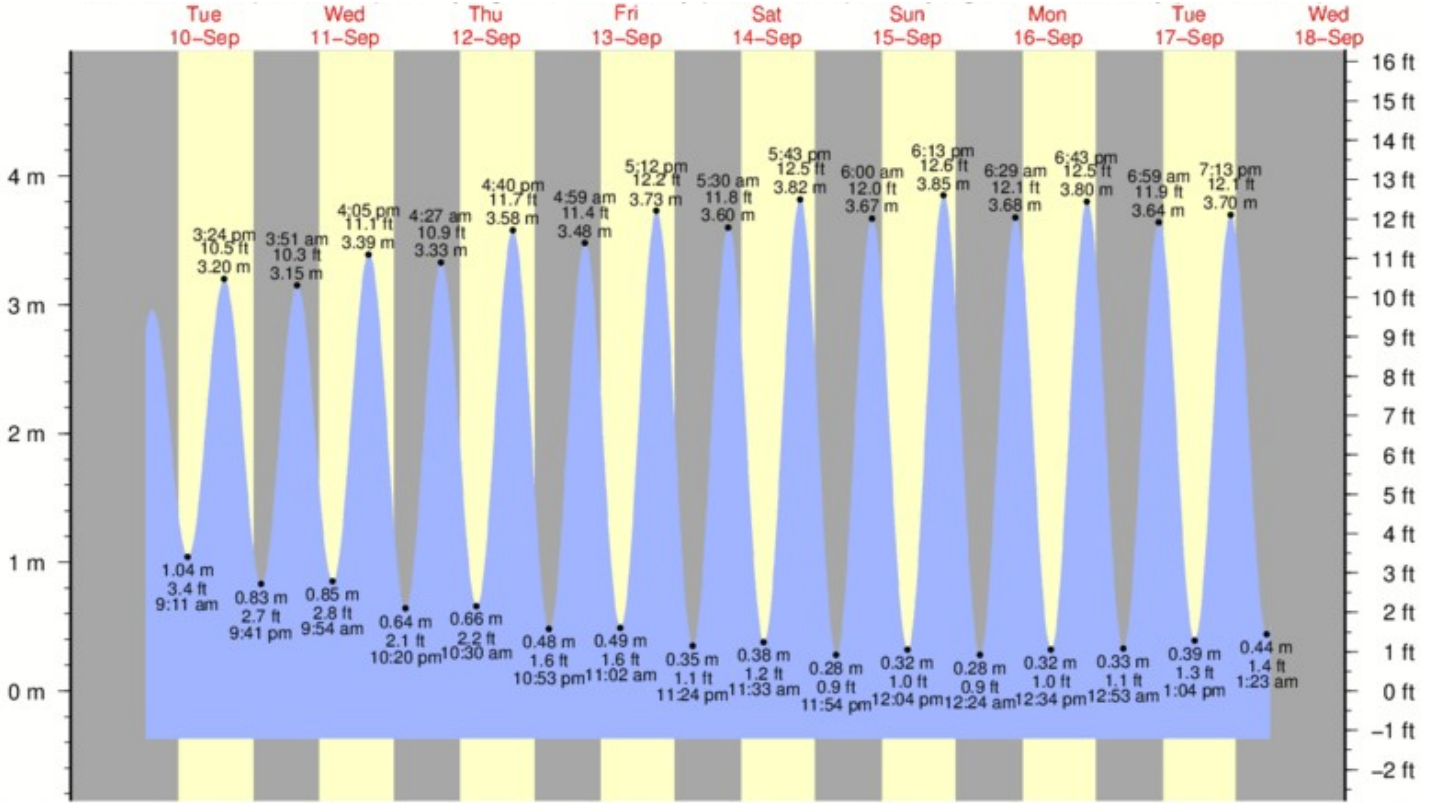
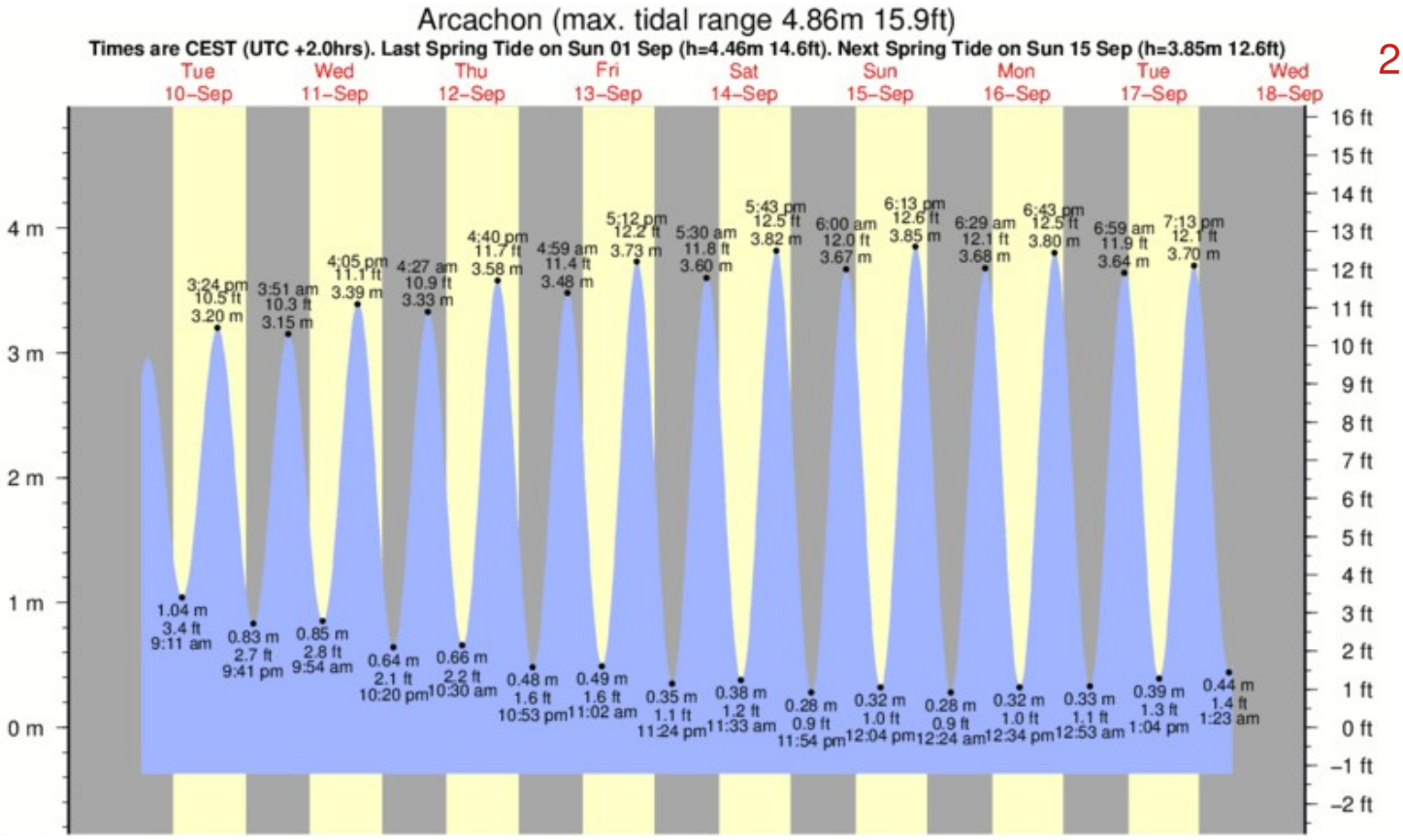
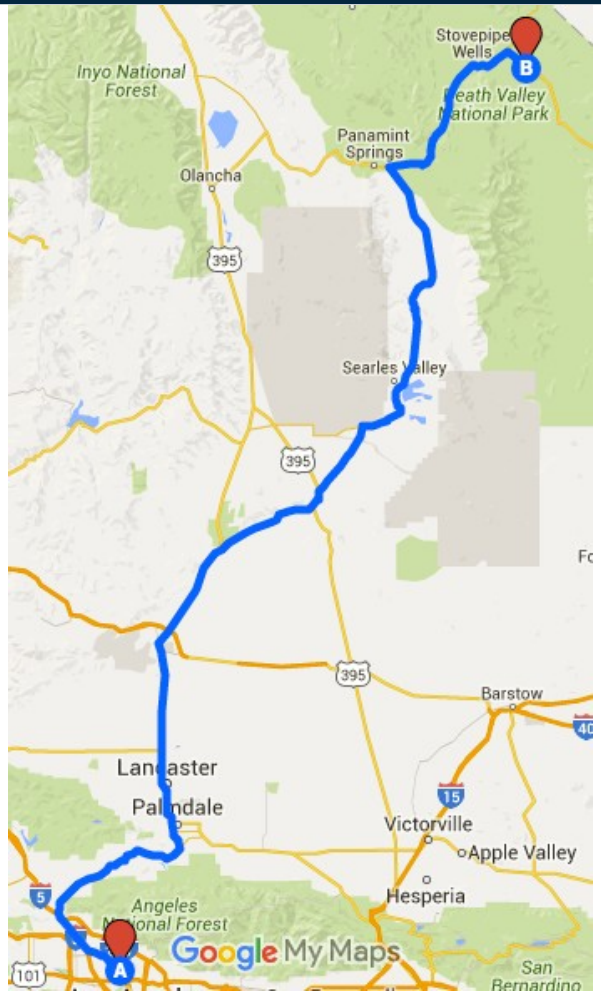


Examples of time series: ocean tides

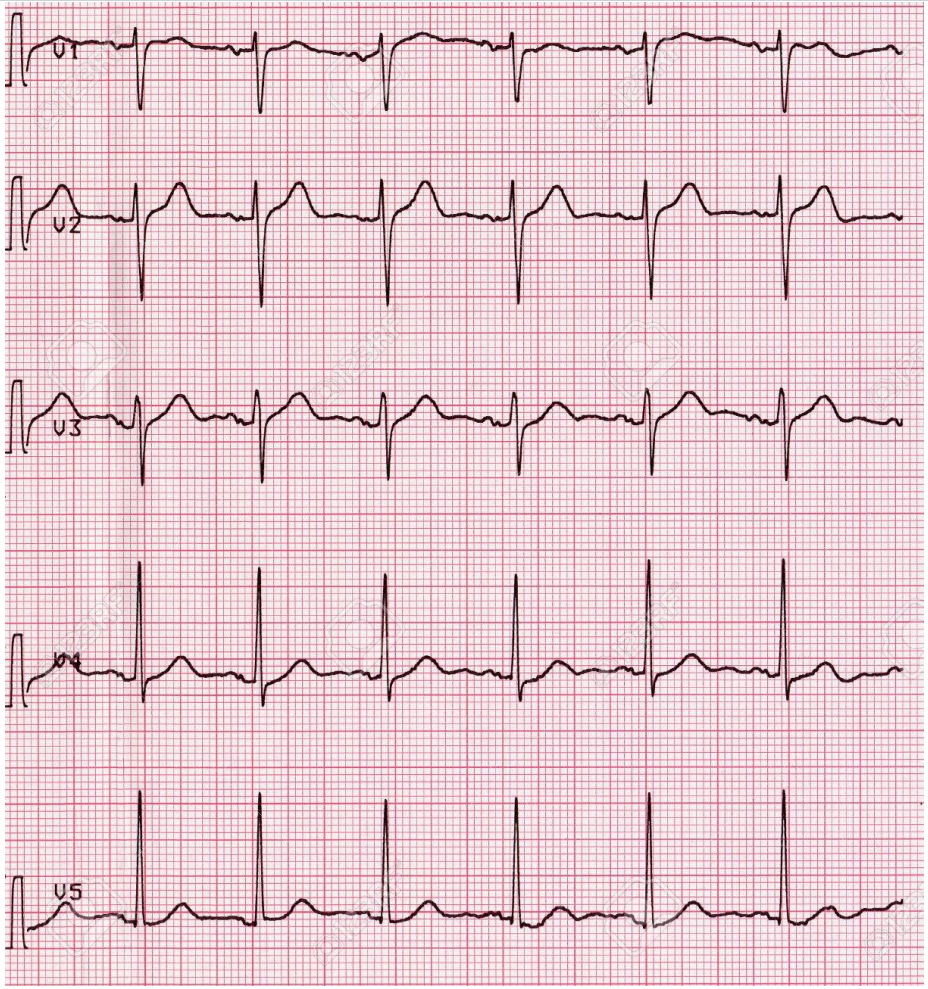


2019

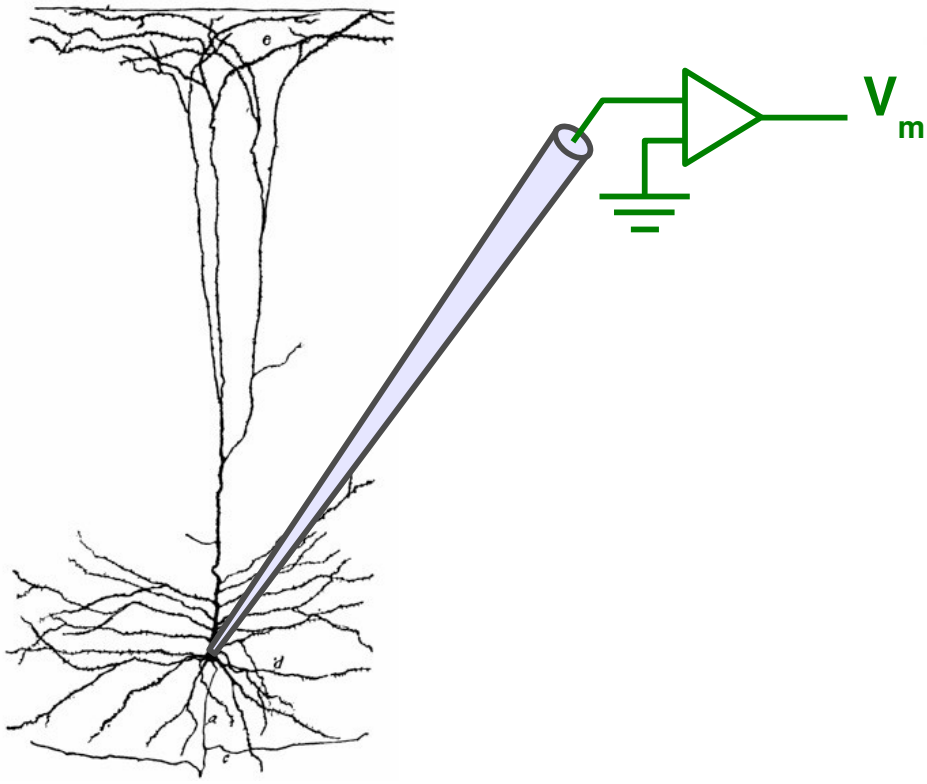
Examples of time series: location profiles

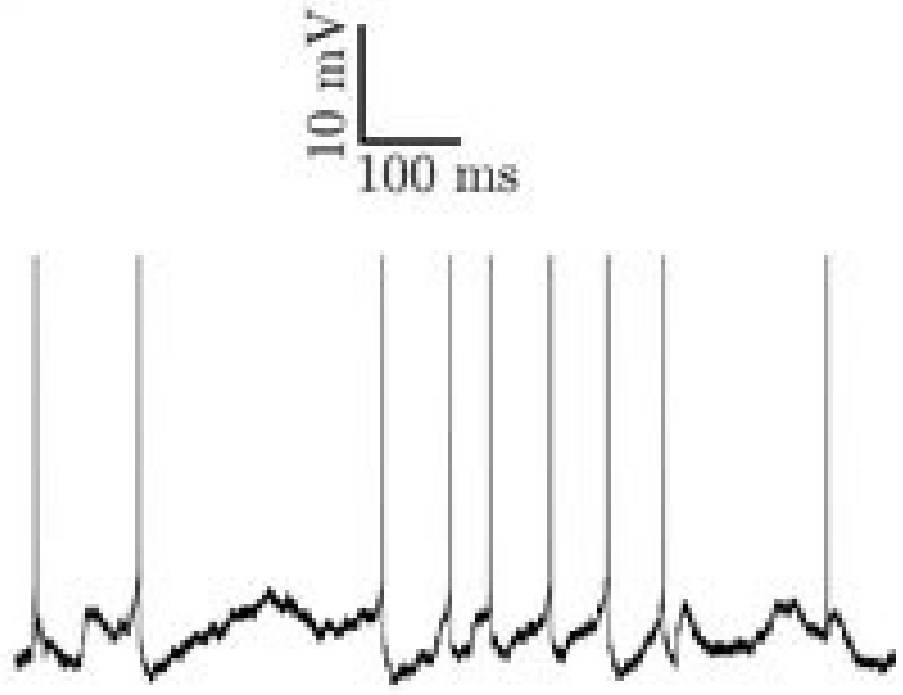


Time series in biology: electrocardiogram

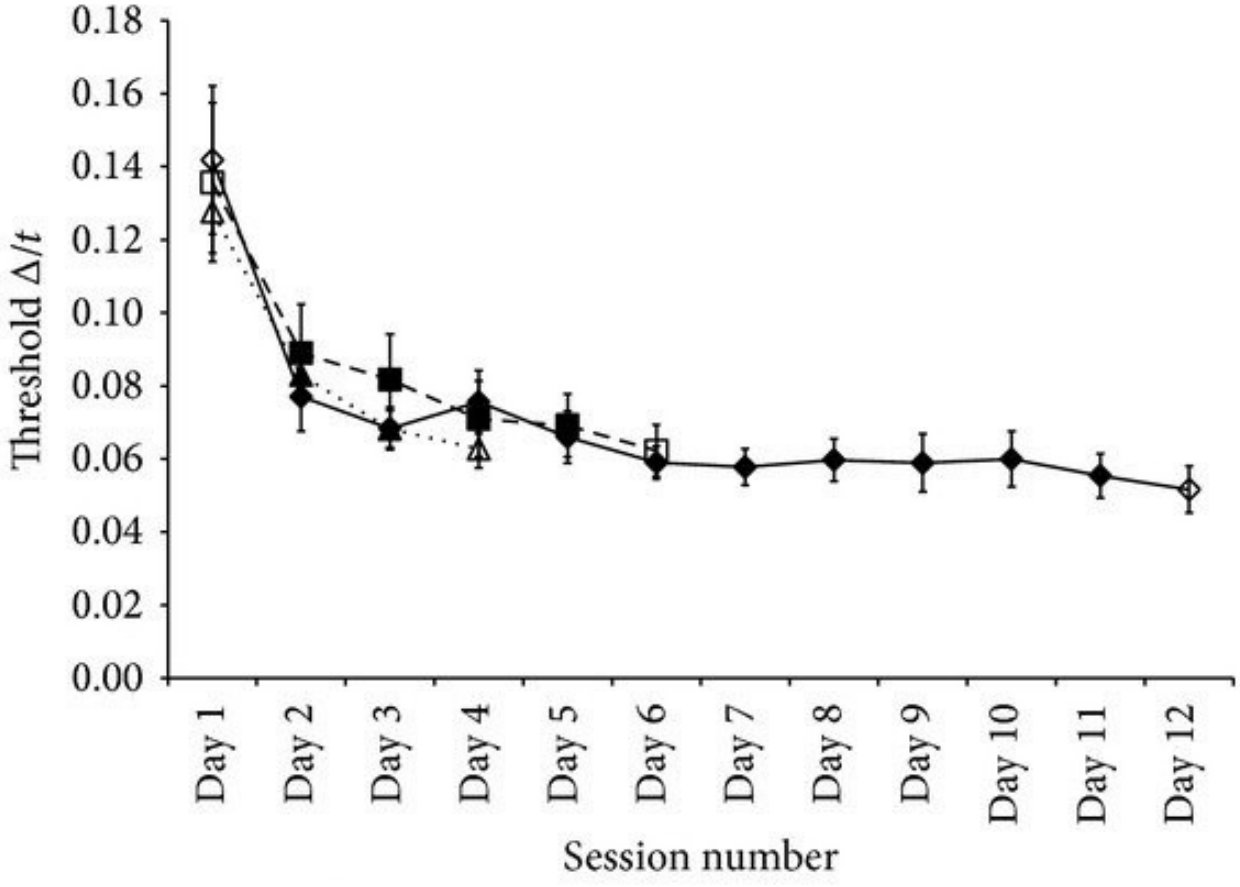


Time series in neuroscience: membrane potential

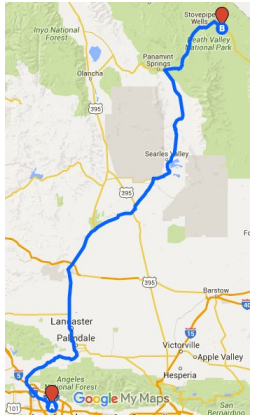


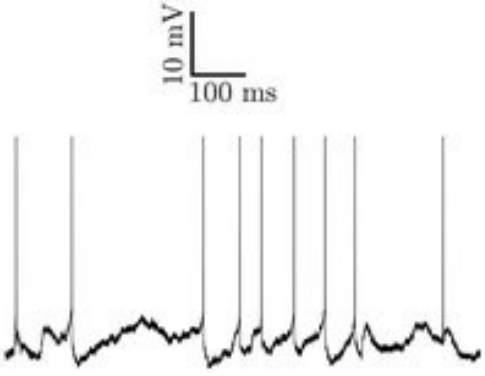


Time series in neuroscience: learning curves



Time series: definition





Anything that is observed or measured at many points in time forms a time series.

Time series: properties

time	value (°)
Jan	3.3
Feb	4.2
March	7.8
April	10.8
May	14.3
June	17.5
July	19.4
⋮	

e.g. interval 1 month

- list of pairs : time point and data point of specific unit
- listed in time order (ascending time)
- entries are separated by specific intervals (years, months, seconds, ...)

Interval between data-points

equally spaced points in time
- interval determines frequency of measurement as 1/interval

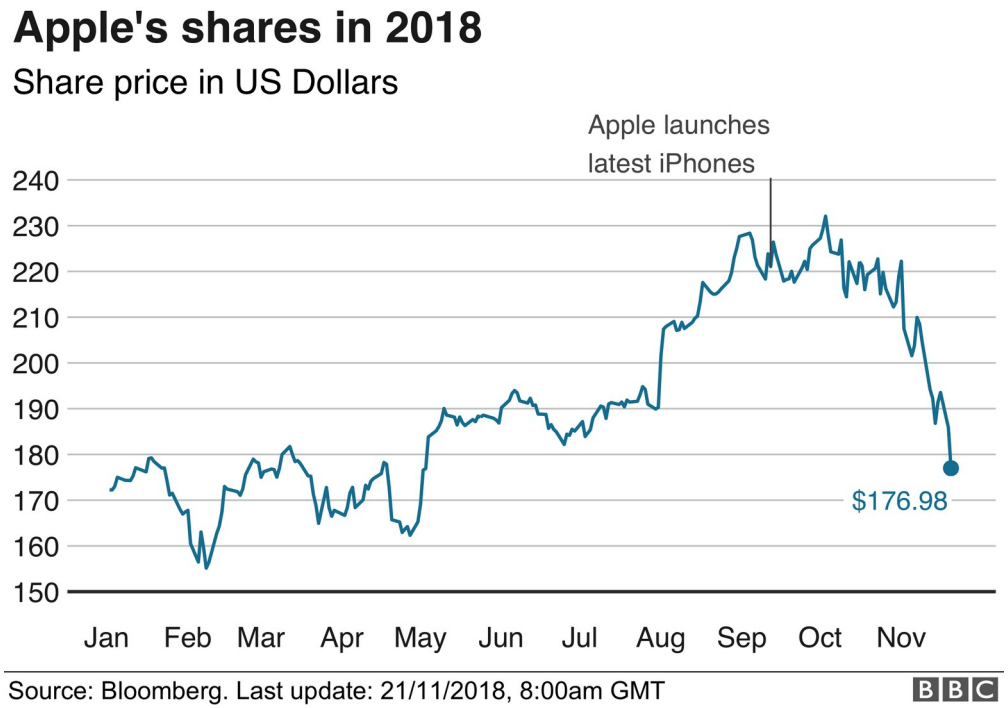
time (month)	value
Jan	3.3
Feb	4.2
March	7.8
April	10.8
May	14.3
June	17.5
July	19.4
⋮	

all intervals =1 month

irregular spaced points in time

time (hh:m)	value	
13:20	45.4	2 min
13:22	40.1	8 min
13:30	38.3	5 min
13:35	37.4	8 min
13:43	36.1	18 min
14:01	35.9	7 min
14:08	36.0	
⋮		

Data can refer to time point, interval, elapsed time



- timestamps – specific instants in time (e.g. every day at 4pm)
- fixed periods : e.g. a month, a year (data represents often average during that period; can be given with further statistics, e.g. standard deviation)
- intervals : indicated start and end of timestamp (general case of fixed periods)
- elapsed time relative to particular start time (often the case for neural data; start is the beginning of a recording)

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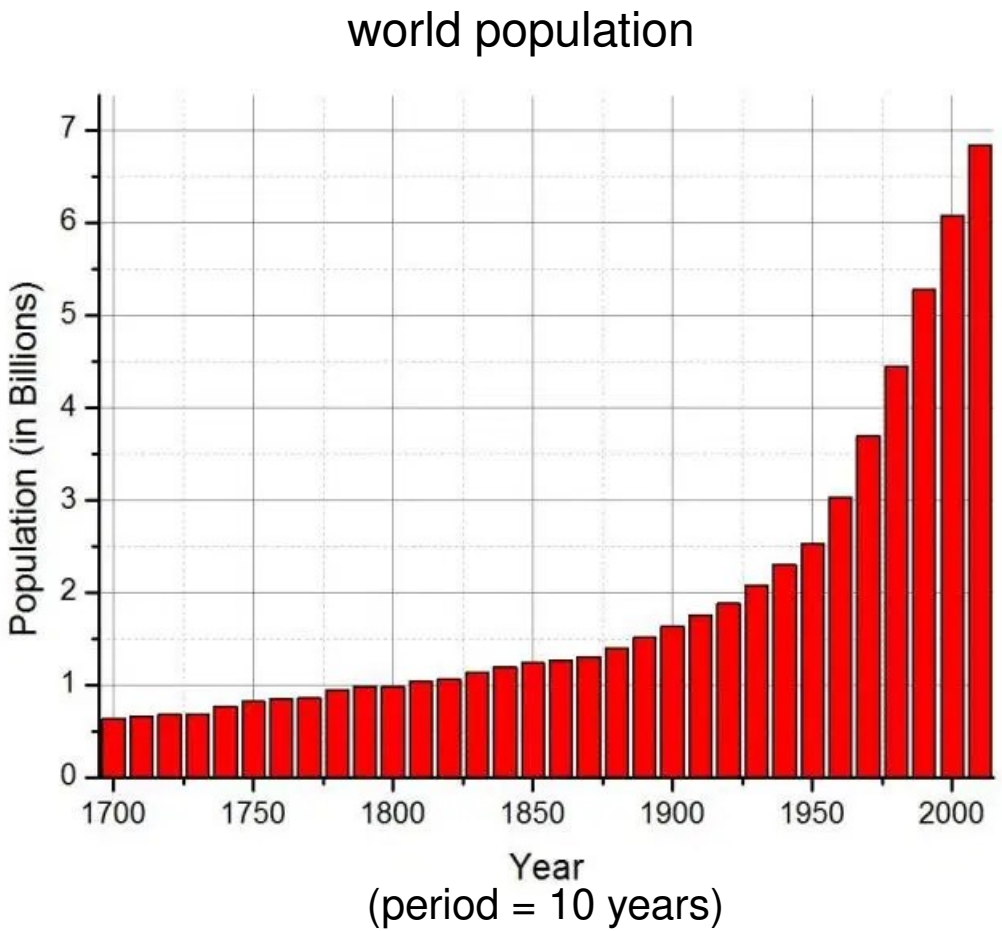

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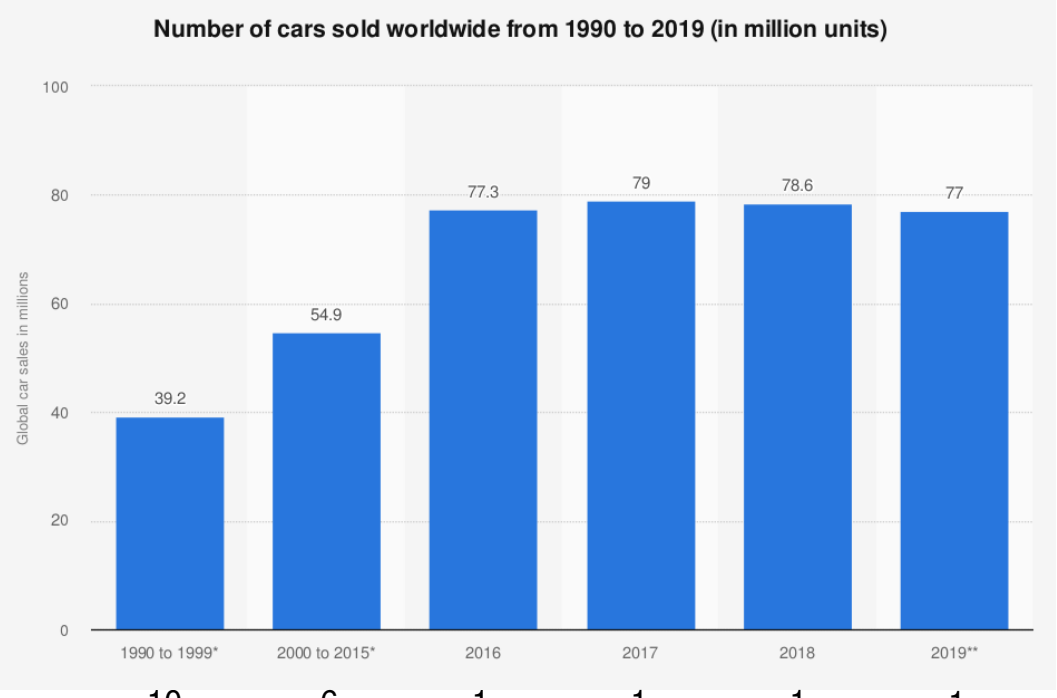

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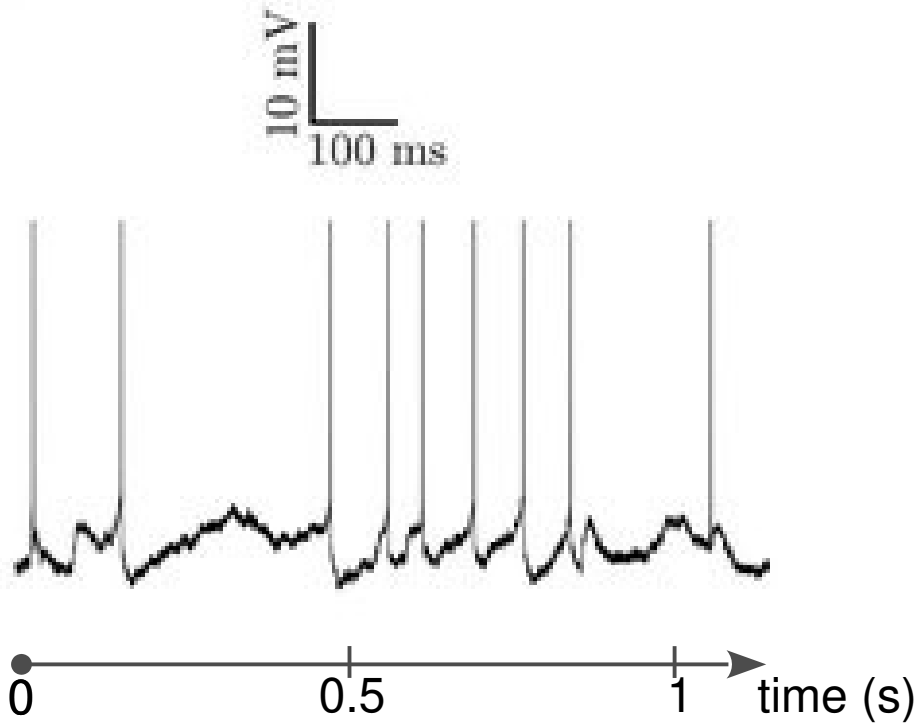

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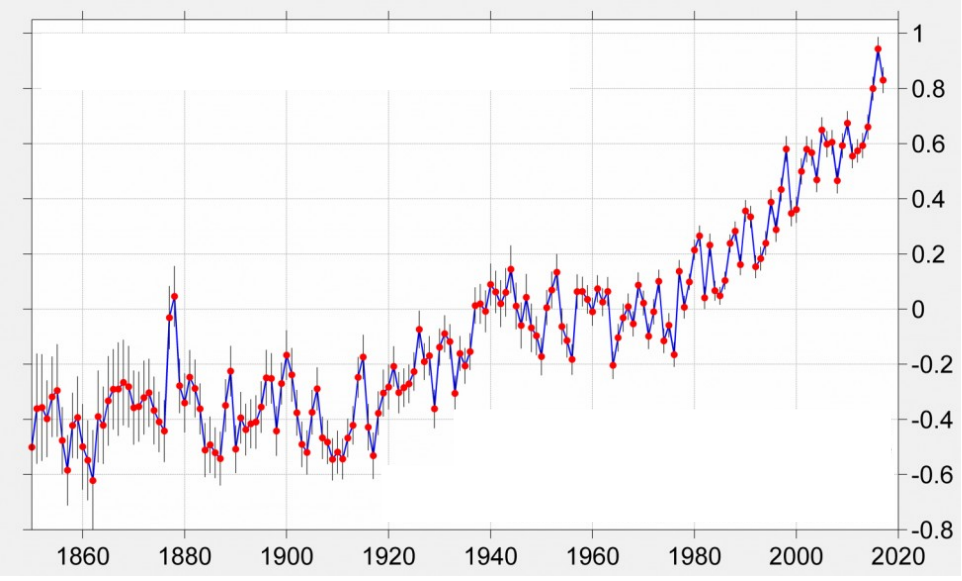
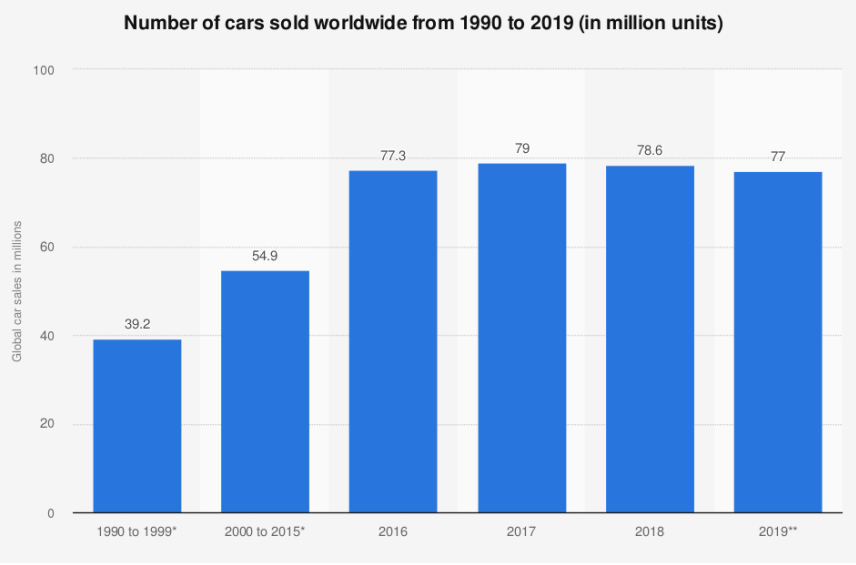
Common visualizations

line chart



- data-points connected by line
- points themselves can be shown or not

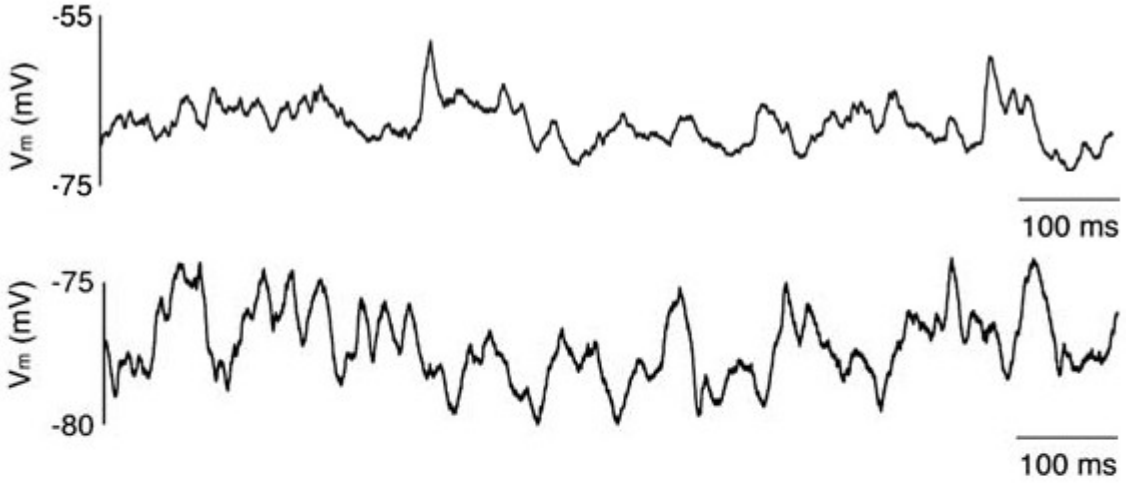
bar graph



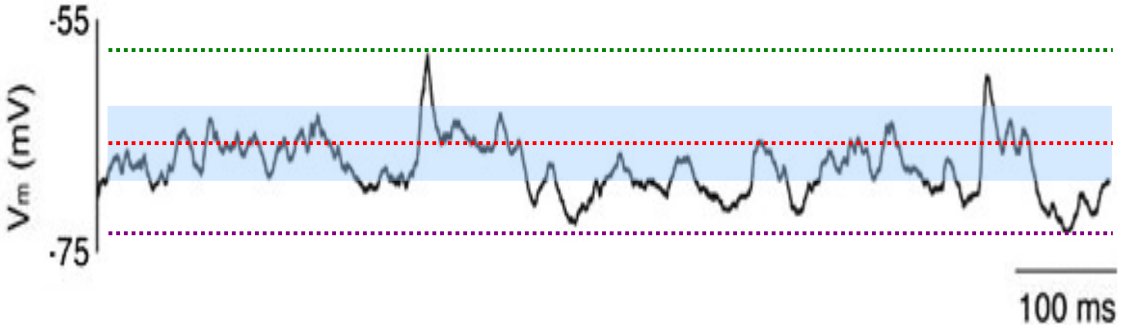
- value shown as height of bar
- limited to displaying few data-points

Extracting meaningful information from time-series

I want to quantify and compare two membrane potential recordings, which information would be useful?



Basics statistics I : max, min, mean, SD



- maximum/minimum
- average (arithmetic mean) :
  - sum of all elements divide by total number of elements

$$\mathrm{AM} = \frac{1}{n}\sum_{i=1}^{n} a_i = \frac{a_1 + a_2 + \cdots + a_n}{n}$$

- standard deviation (SD):
  - measures variation/dispersion in data-set

$$s = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2},$$

$\bar{x}$ ... mean value

Comparing data-sets

Recording 1 (R1)

Recording 2 (R2)

	Comparison
max.	?
min.	
mean	
SD	

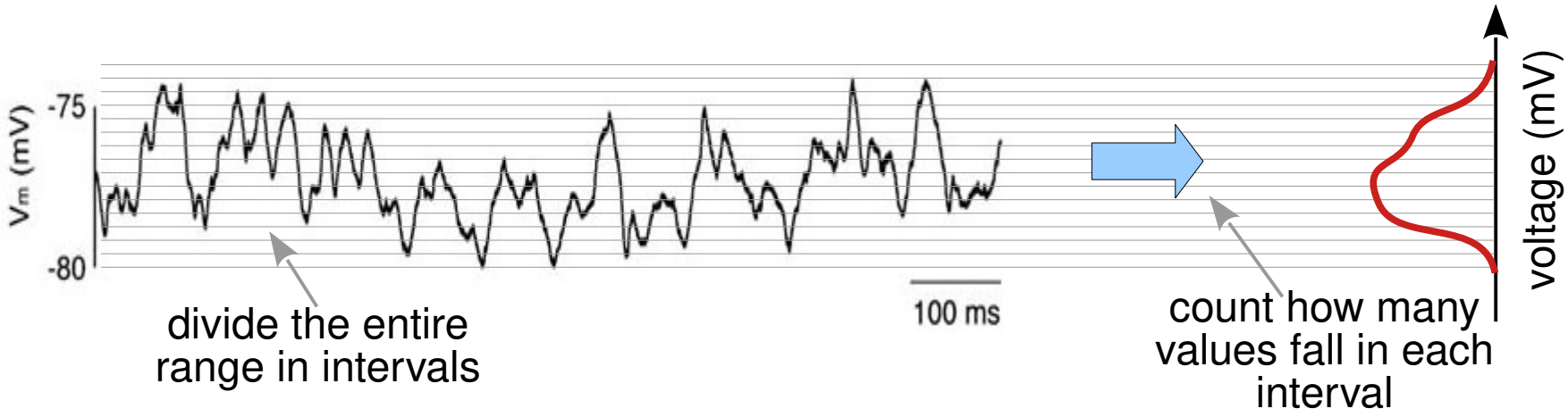
Comparing data-sets

Recording 1 (R1)

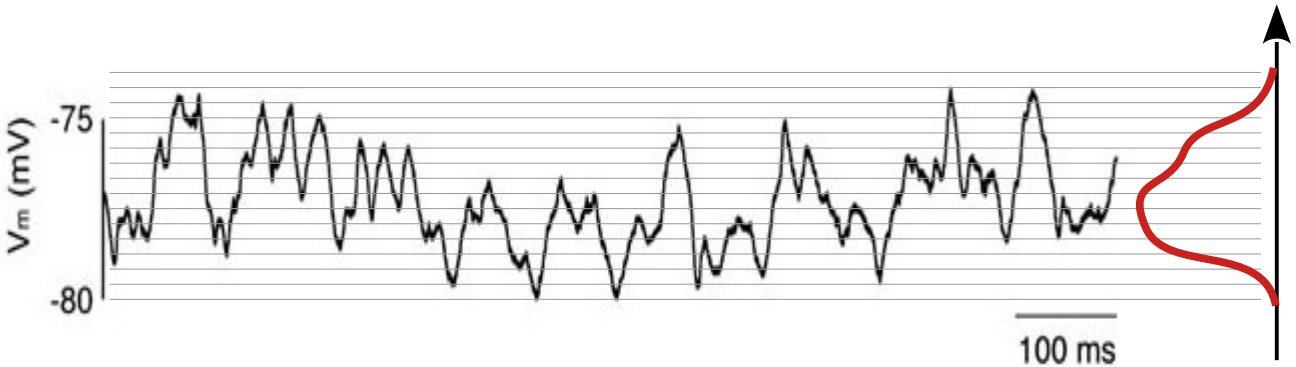
Recording 2 (R2)

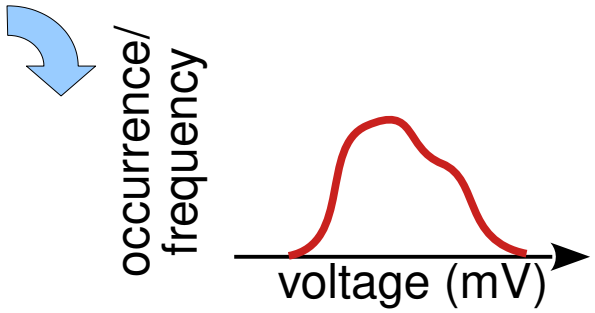
	Comparison
max.	R1>R2
min.	R1>R2
mean	R1>R2
SD	R1<R2

Histogram – representation of data distribution

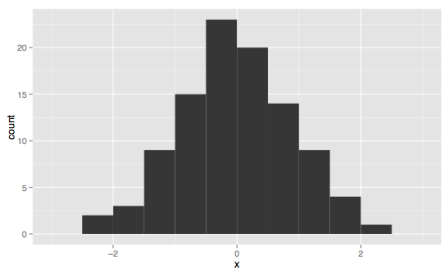


Histogram – shapes

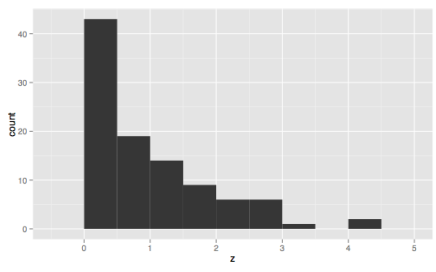




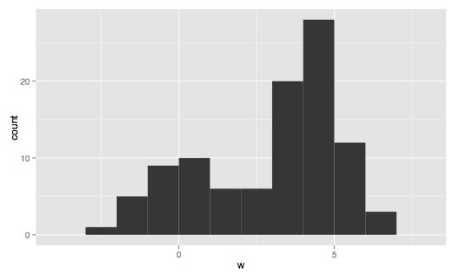
symmetric, unimodal



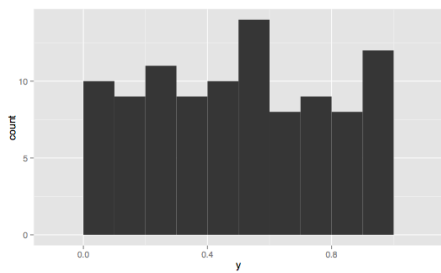
skewed right



bimodal

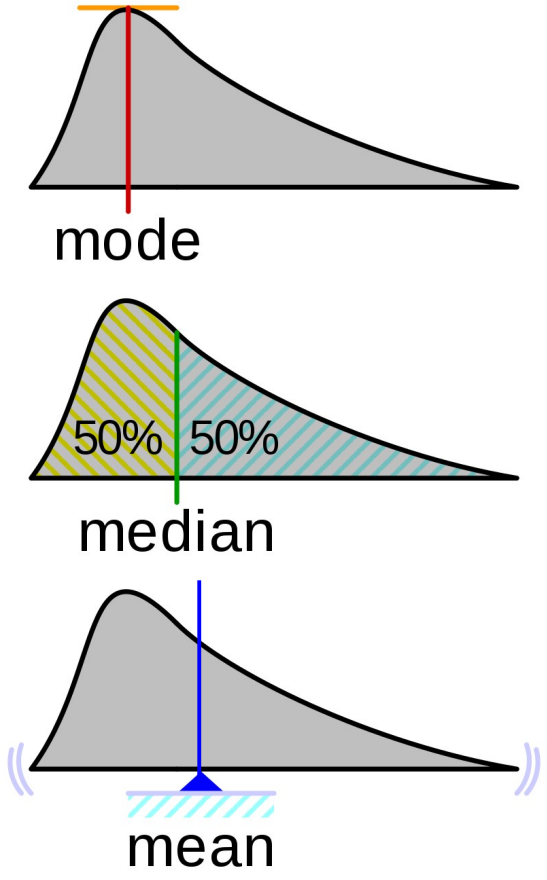


symmetric



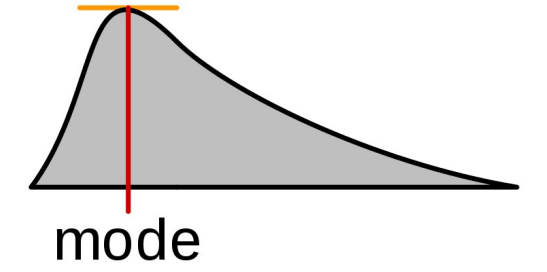
- good idea to plot histogram with several bin widths to learn more about the data

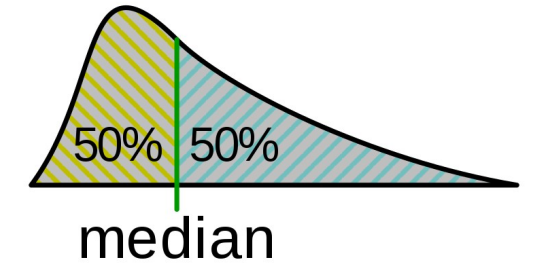
Basics statistics II : median, percentile

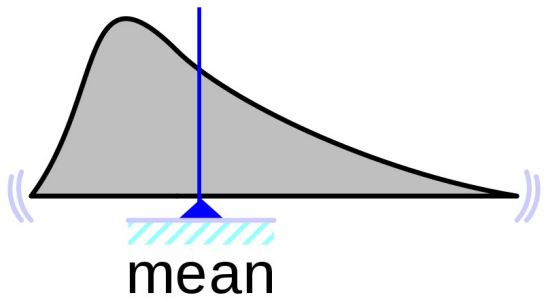


- **mode :**
  - most frequent data point
- **median** :
  - value separating higher half from the lower half of a data-set
  - comparison with mean quantifies skewness of data
- percentile :
  - indicating the value below which a given percentile of data-points fall
  - e.g. the median is the 50th percentile

Basics statistics II : median, percentile







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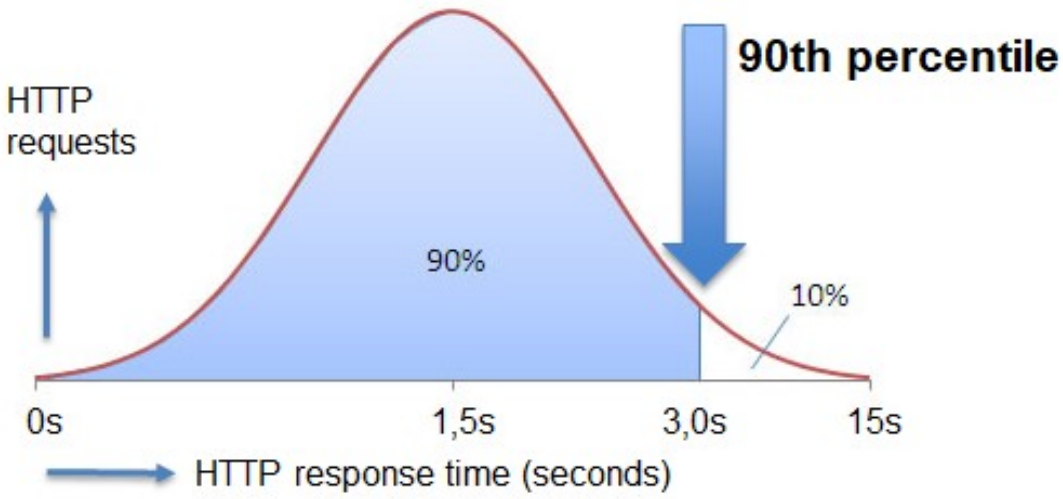

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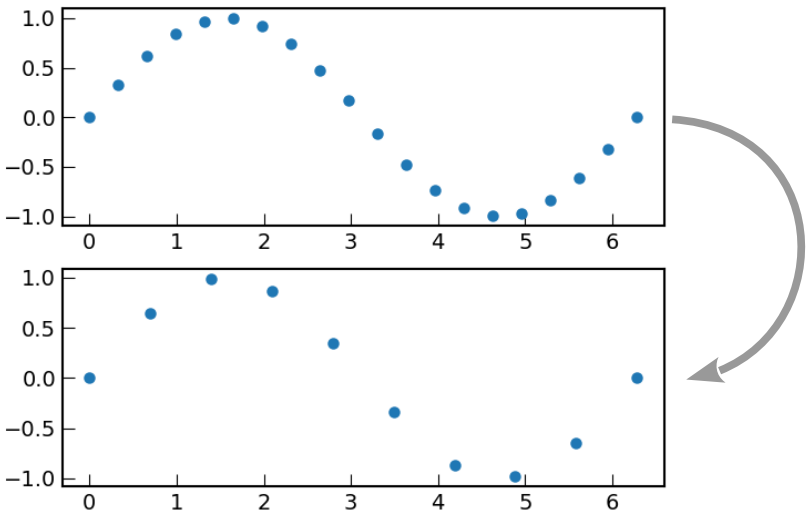
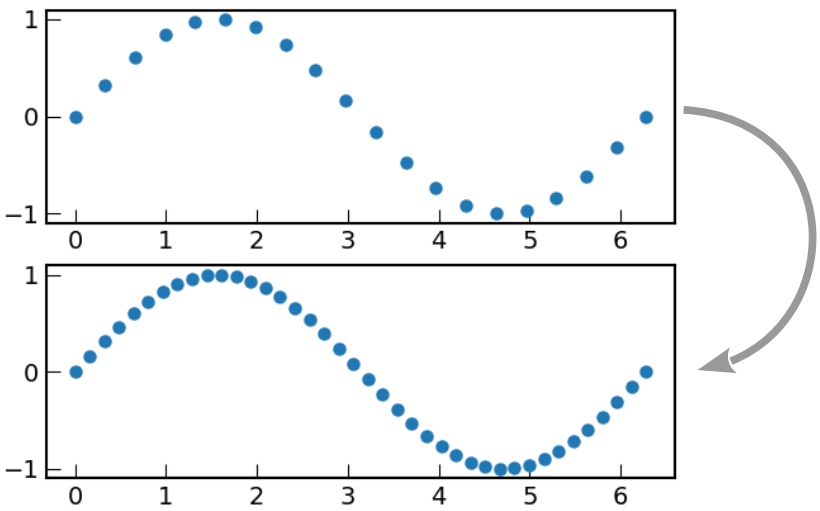
Resampling

Resampling refers to the process of converting a time series form one frequency to another.

Aggregating higher frequency data to lower frequency is called **downsampling**



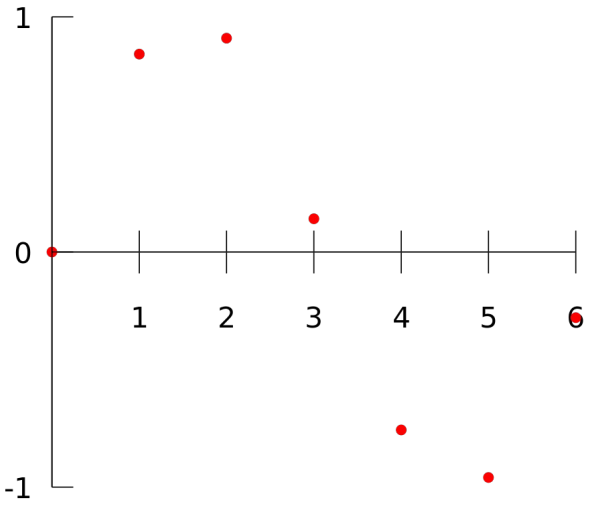
Converting lower frequency data to higher frequency is called **upsampling**



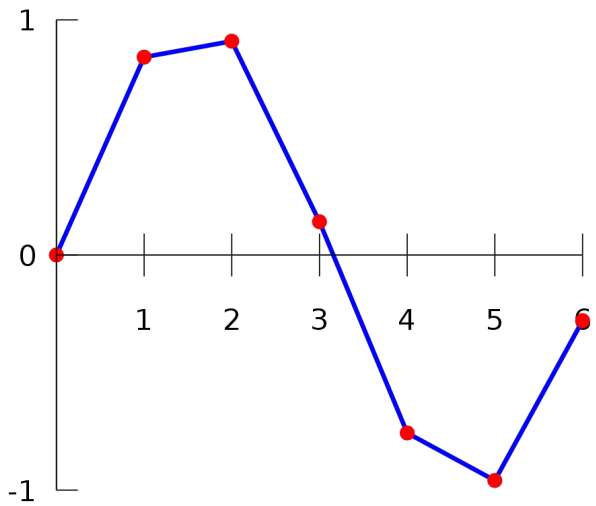
Interpolation

Interpolation is the method of constructing new data points within the range of a discrete set of known data points.

original data

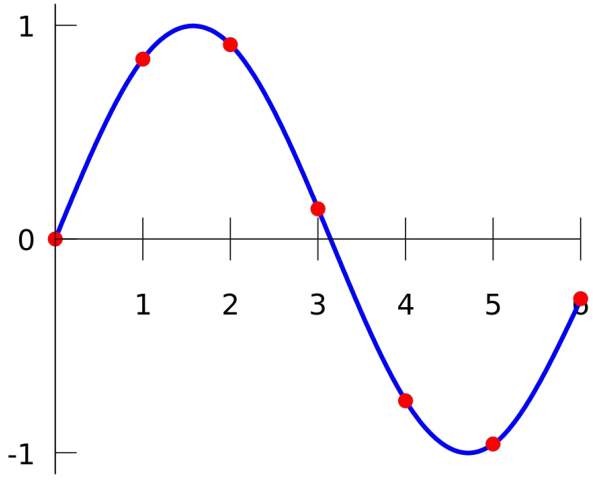


linear interpolation



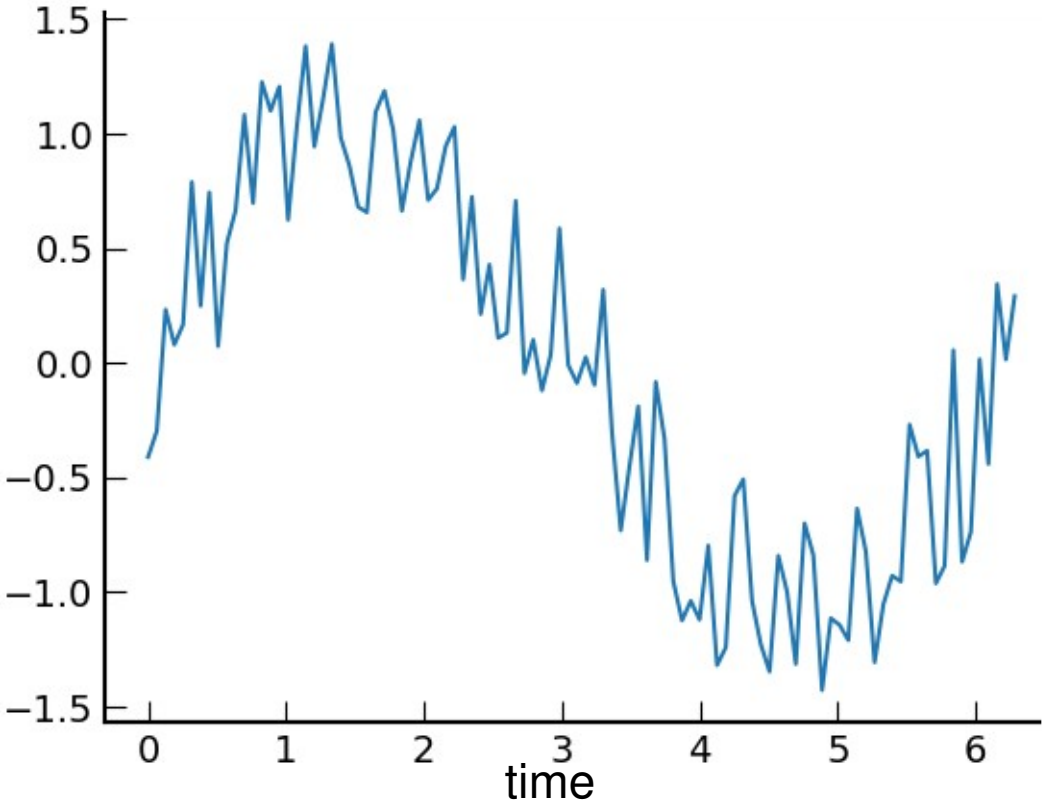
- points are connected by line

spline interpolation



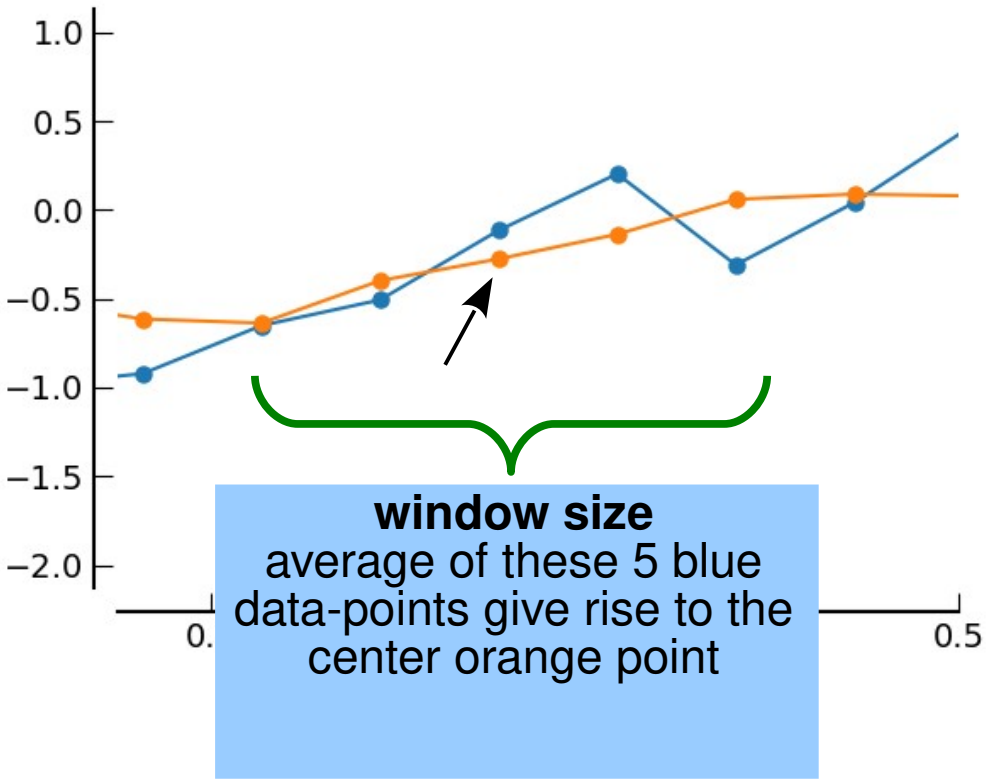
- low-degree polynomial for each interval, with smooth transitions

Noisy data



How to reduce noise while preserving characteristics (such as dynamics) of the data ?

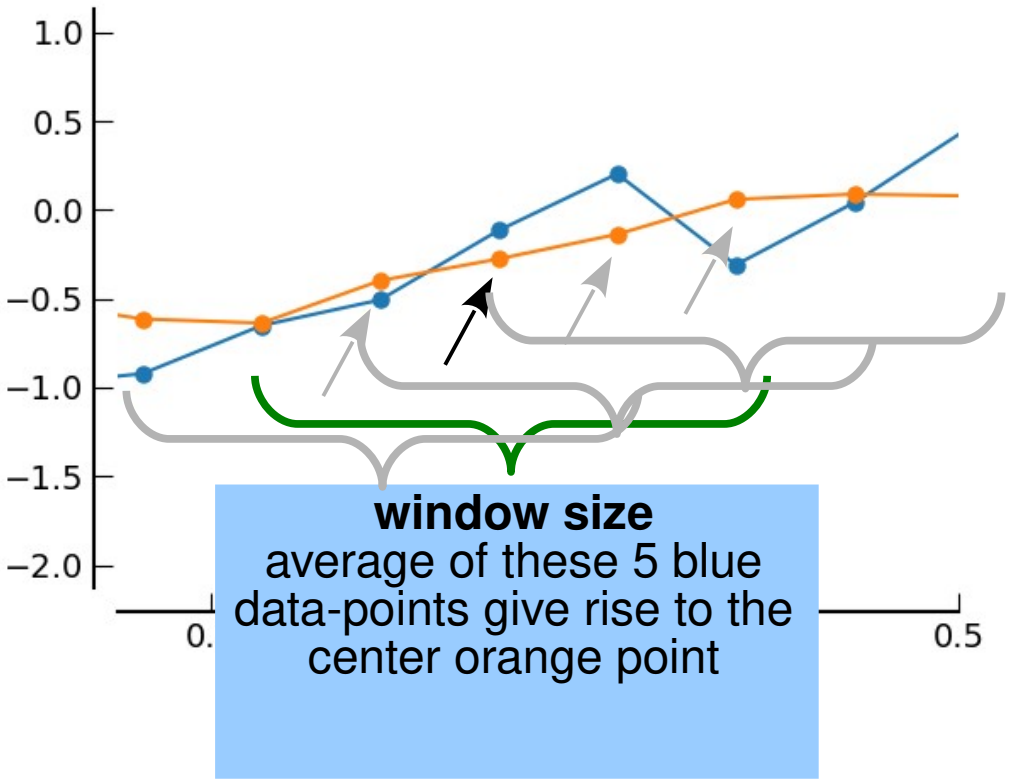
Moving average



Moving Average (or moving mean, rolling mean) : analyze data by creating series of averages of different subsets of the full data

- often used to smooth out short-term fluctuations (an example of low-pass filter)
- mathematically, moving average is a convolution of the data with a flat, normalized kernel

Moving average



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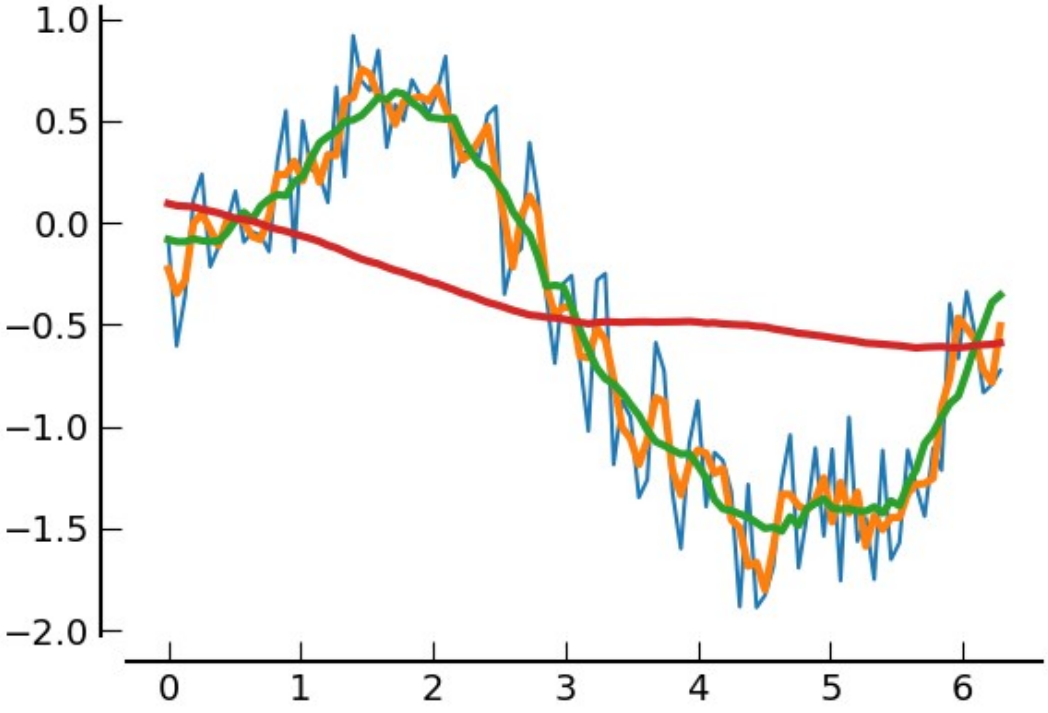
Moving average: window size



Window size
Pick the smallest window size where the signal starts to flatten out, without affecting dynamics of interest.