Karlsruhe Institute of Technology

Data Analysis in Geoscience Remote Sensing Projects

Time series analyses

Dr. Hendrik Andersen | November 24, 2023

Typical questions in geoscience research, applications of remote sensing

Karlsruhe Institute of Technology

Typical questions in geosciences

- What is the current state of the Earth system?
- How does the Earth system change?
- How are different components of the Earth system related?

Applications of remote sensing

- Observing the current state of the Earth system and recent changes
- Weather observations and short-term forecasting
- Analyzing relationships of observables within the Earth system to improve system understanding
- Combine with earth system models or use observations to evaluate them

Methods we will cover in this course

- Time series decomposition
- Temporal change (point) analyses
- Regression for sensitivity estimation and trend analysis
- Logistic regression for classification
- Machine learning models for regression/classification/sensitivity estimation

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- **Time series decomposition**
- **Temporal change (point) analyses**
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Time series analyses in geosciences

What is a time series?
$\rightarrow$ *A time series is an ordered sequence of data indexed by time*

Time series analyses in geosciences

What properties do time series of geophysical parameters have?

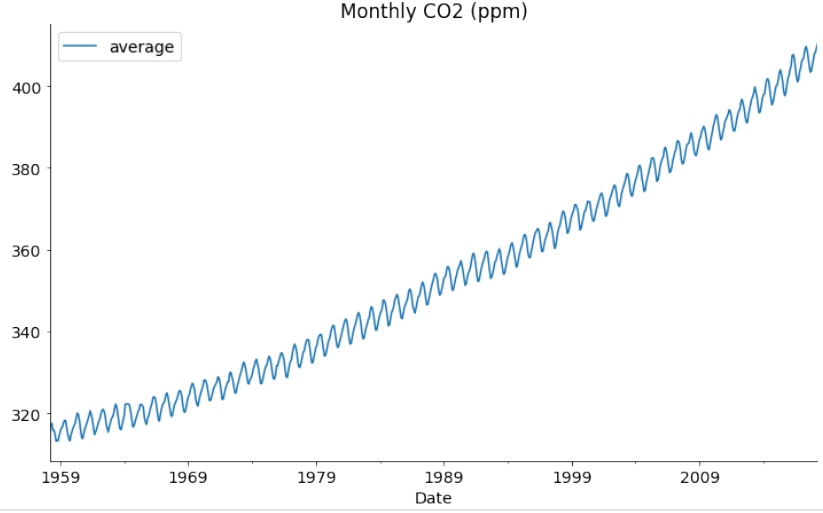
Time series analyses in geosciences

What properties do time series of geophysical parameters have?

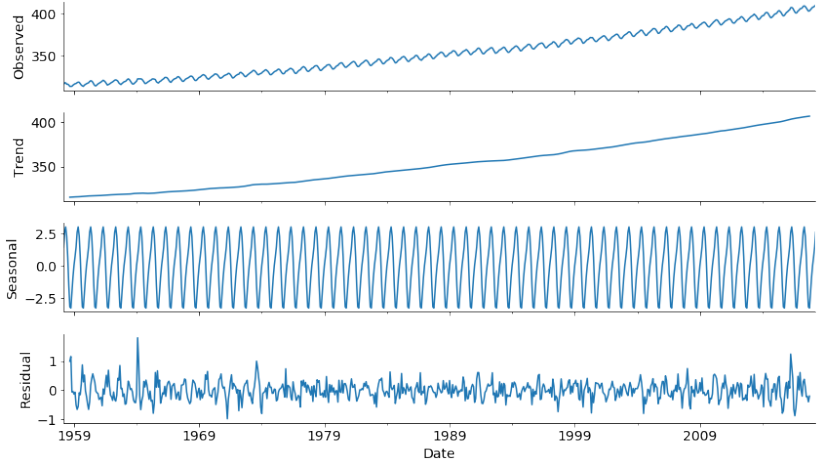
- Stationarity or trends (linear or nonlinear)
- Cyclical (seasonal cycle/diurnal cycle/multi-year (e.g. El Niño)/*weekly cycle*)
- residual noise (weather influences, measurement uncertainties)

Time series decomposition aims to separate the signal into different components, each representing an underlying pattern category.

Example time series: Mauna Loa CO_2 measurements



Time series decomposition



Time series decomposition: How does it work?

Time series:

$$Y_v = T_v + S_v + R_v$$

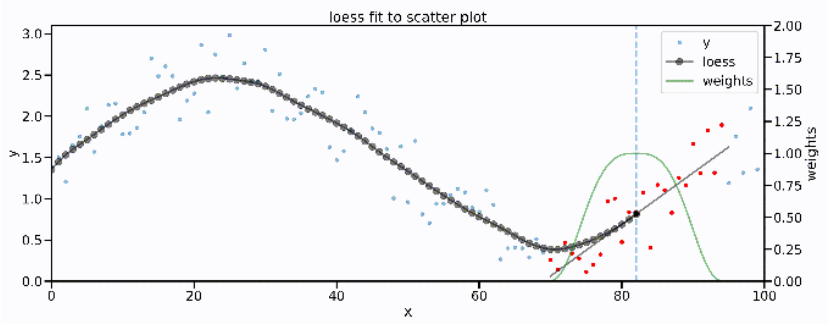


Figure: `https://towardsdatascience.com/multi-seasonal-time-series-decomposition-using-mstl-in-python-136630e67530`

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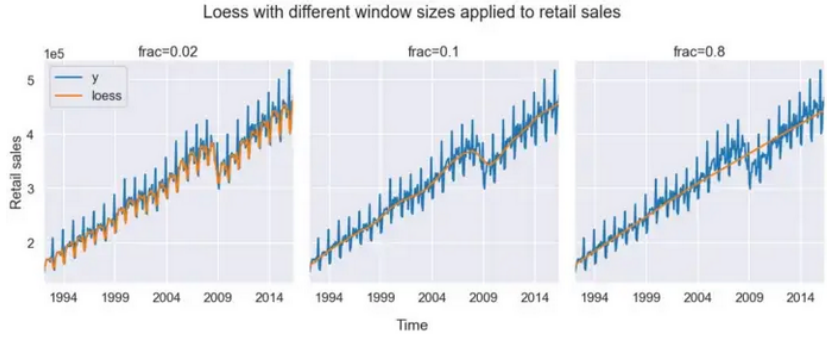

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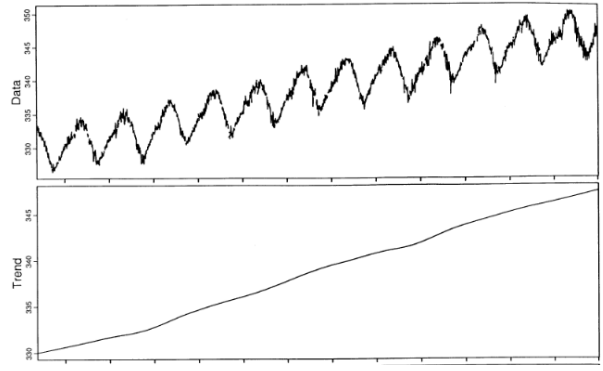
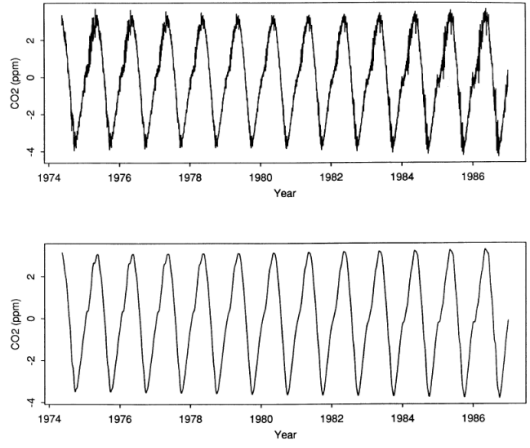


Figure: Cleveland et al. (1990)

Time series decomposition: How does it work?



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Time series decomposition: example

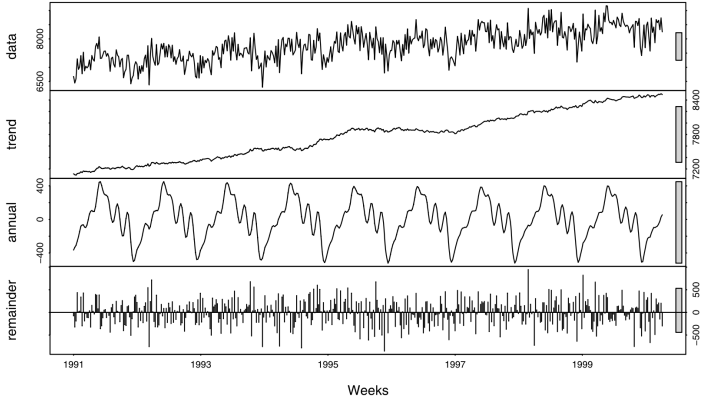

Figure 3. Trigonometric decomposition of the U.S. gasoline data. The within-sample RMSE was 279.9.

Figure: Livera et al. (2011)

Time series decomposition: summary

- Using e.g. a LOESS filter in moving windows of different widths
- Estimate the trend from the data, then subtract it
- From the remaining anomalies, estimate the mean seasonality, then subtract it

$\rightarrow$ This procedure decomposes the data into **trend**, **seasonality** and **residual** signals

What is this useful for?

Time series decomposition: summary

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$\rightarrow$ This procedure decomposes the data into **trend**, **seasonality** and **residual** signals

What is this useful for?

- Better understand the data
- Quantifying relationships between geophysical parameters
- Time series forecasting

Change point analyses

What type of changes can occur in time series of environmental parameters?

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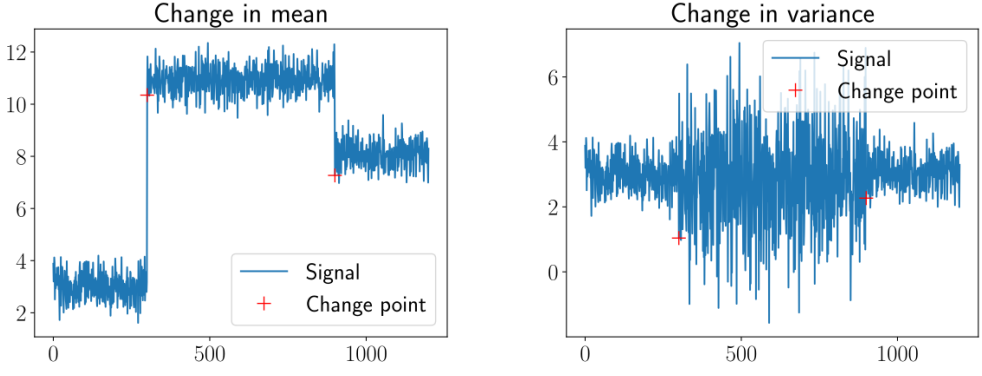

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Change point analyses

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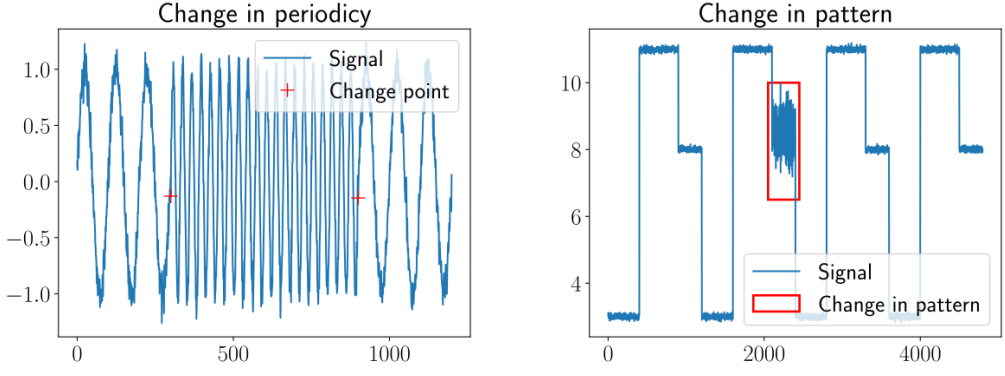

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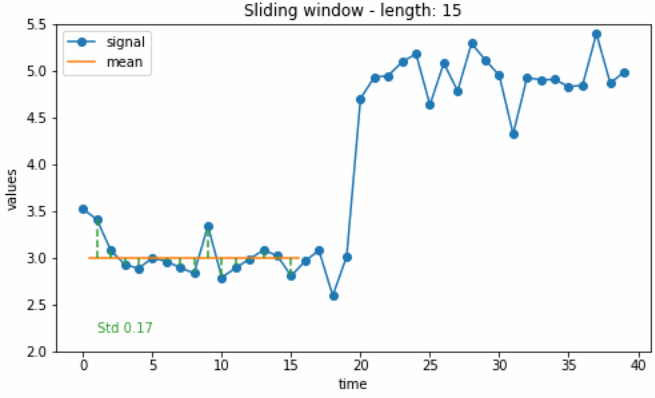
Time series analyses in geosciences

What type of changes can occur in time series of environmental parameters?

- Change in mean (trend/abrupt step changes)
- Change in variability (amplitude of seasonal cycle, white noise)
- Change in periodicity
- Change in pattern
- Change in a combination of the above

Change point analysis: Identify points (in time) when a signal changes

Detecting change points in time series



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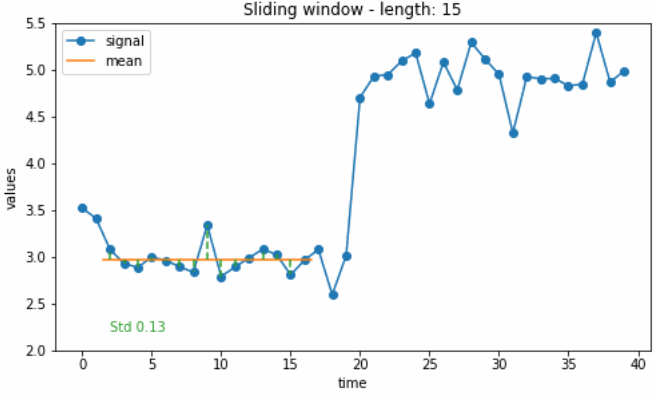

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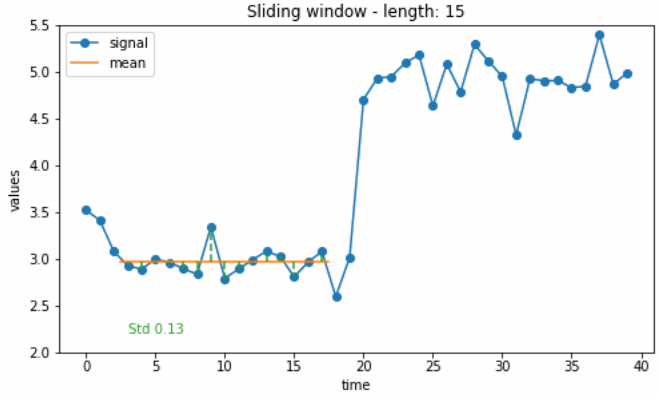

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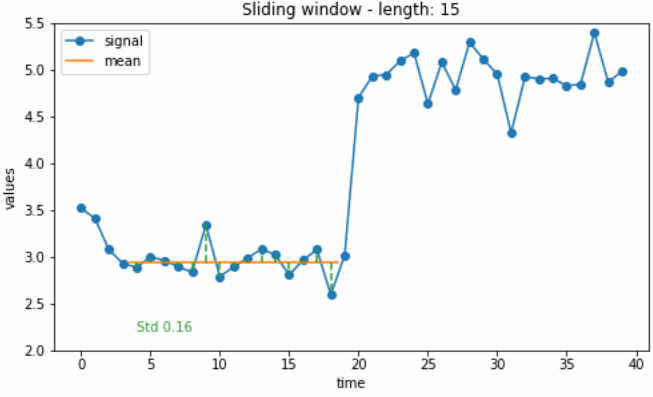

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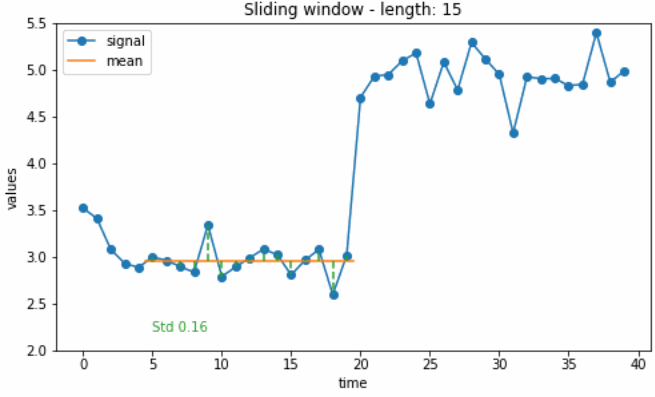

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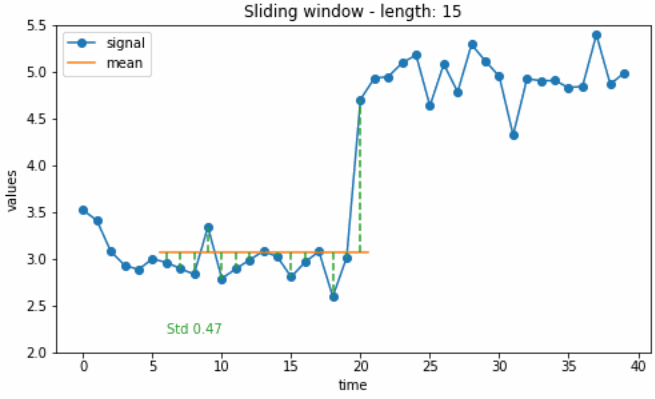

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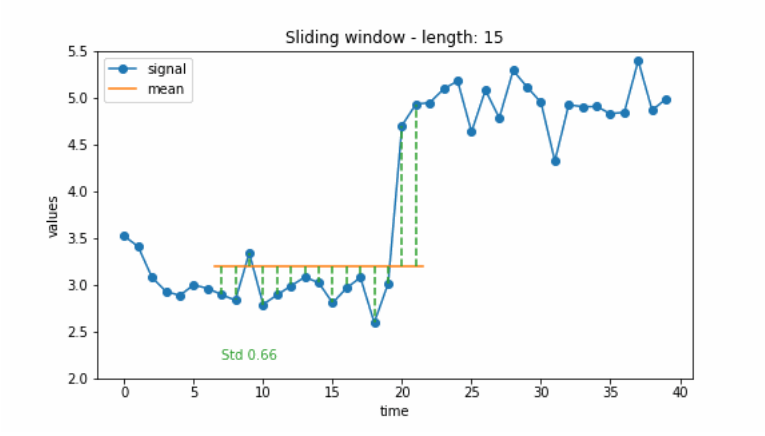

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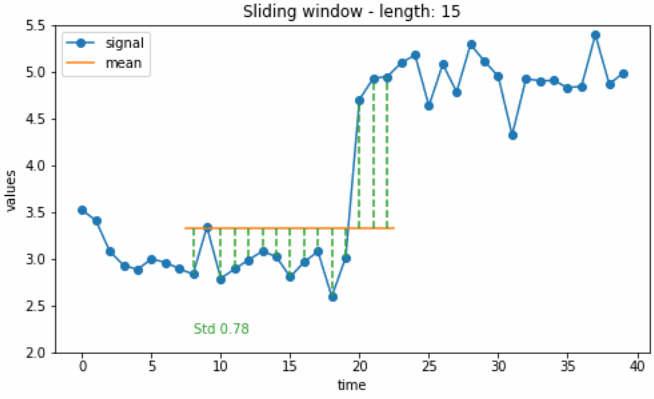

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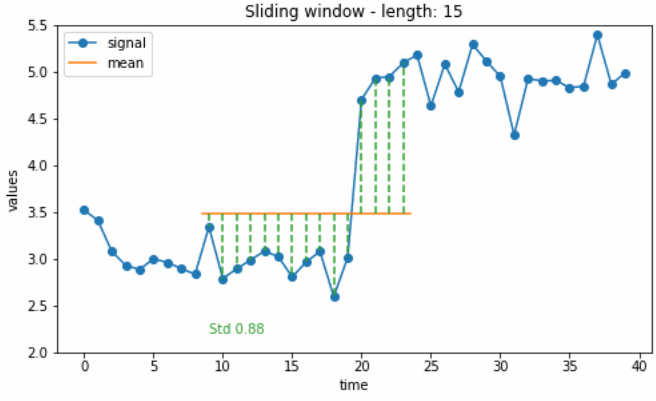

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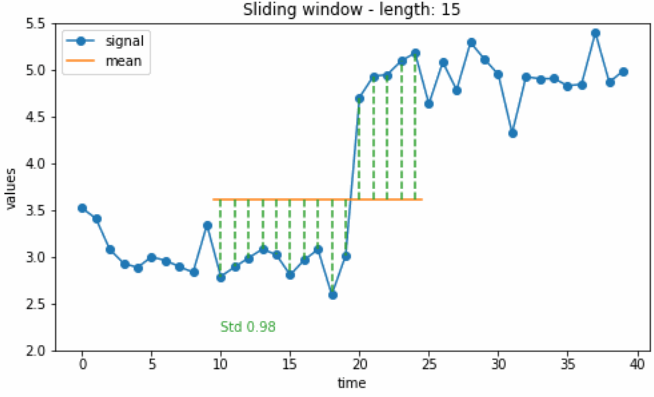

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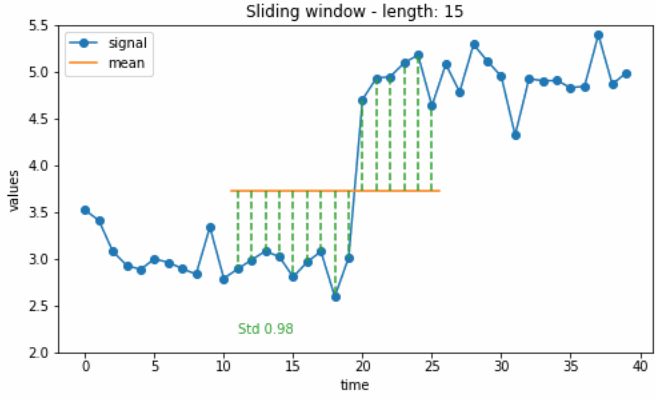

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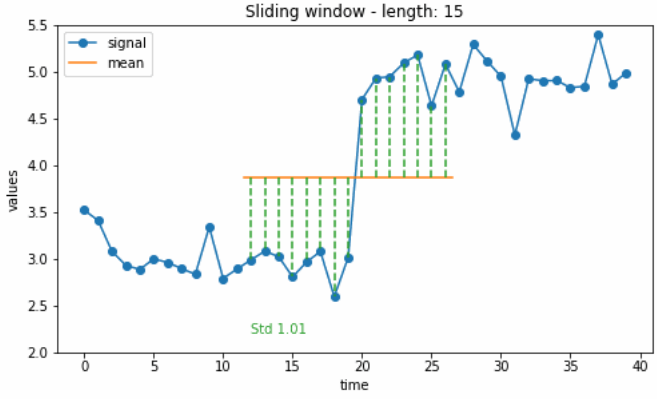

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Example study

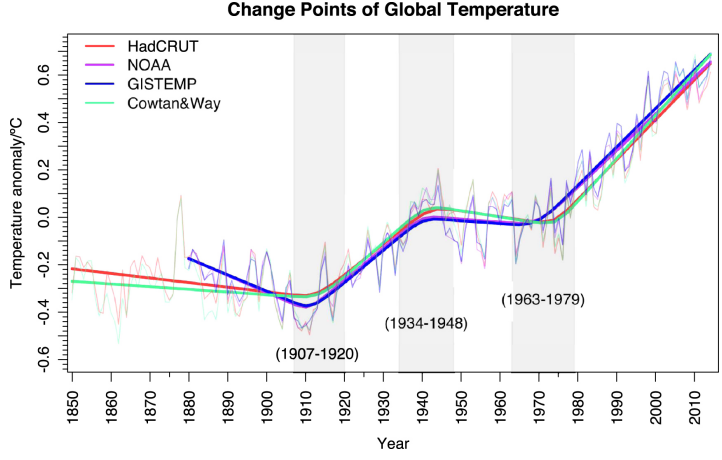

Figure: Cahill et al. (2015)

Change point analysis

- Detects (temporal) points of changes in time series
- Typically uses a moving window approach
- Designed specifically for a purpose, typically include significance estimation

Short summary

- Connection: Science question $\rightarrow$ RS data $\rightarrow$ methods
- Time series decomposition (different components)
- Change point analysis (different types of changes)