

Environmental analysis using satellite image time series in R

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<https://github.com/egrabska/OGH2023>

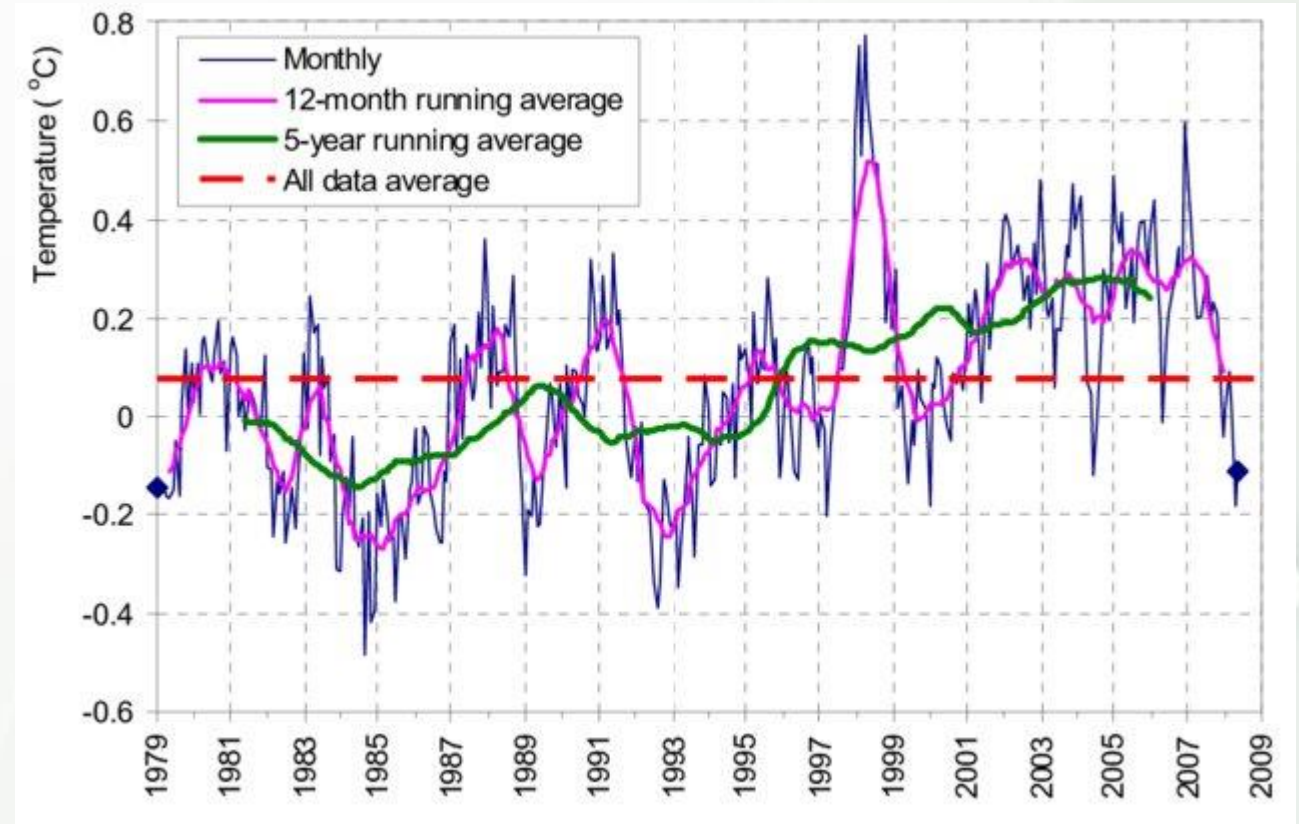
What are satellite image time series?

- Collection of repeated observations or measurements obtained by satellites over a specific geographical area over a period of time
- Observations typically captured at regular intervals but, particularly in the case of optical imagery often irregular due to clouds
- Can be also regular products, like 8-day series from MODIS
- Useful in a wide range of applications, telling us how different objects or places have changed over time

Applications

- Agriculture
- Forestry
- Climate change modeling
- Glaciers monitoring

And many more!

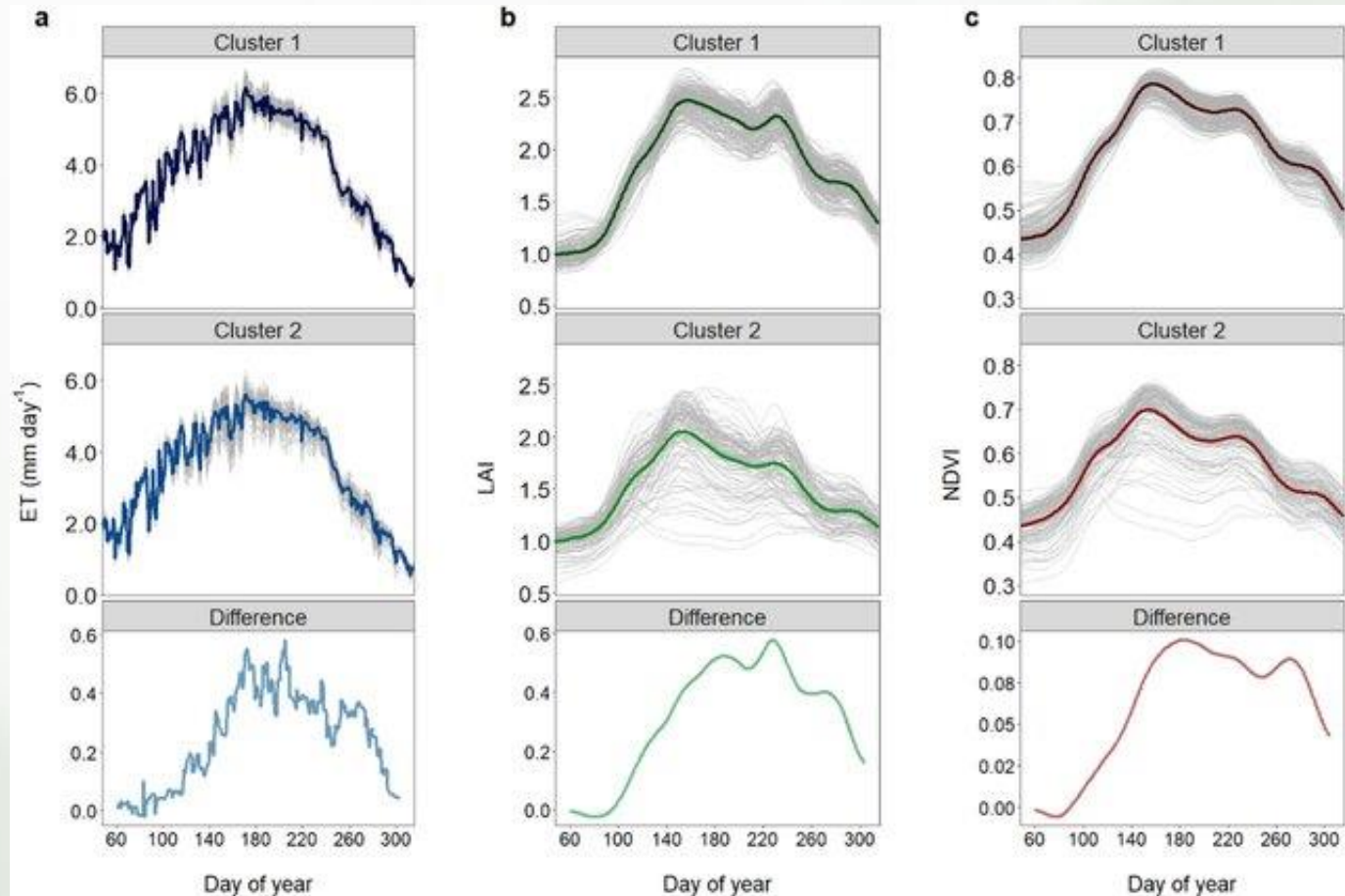


time series of global average of temperature of the lower troposphere as estimated from satellite observations

Agriculture - vineyards

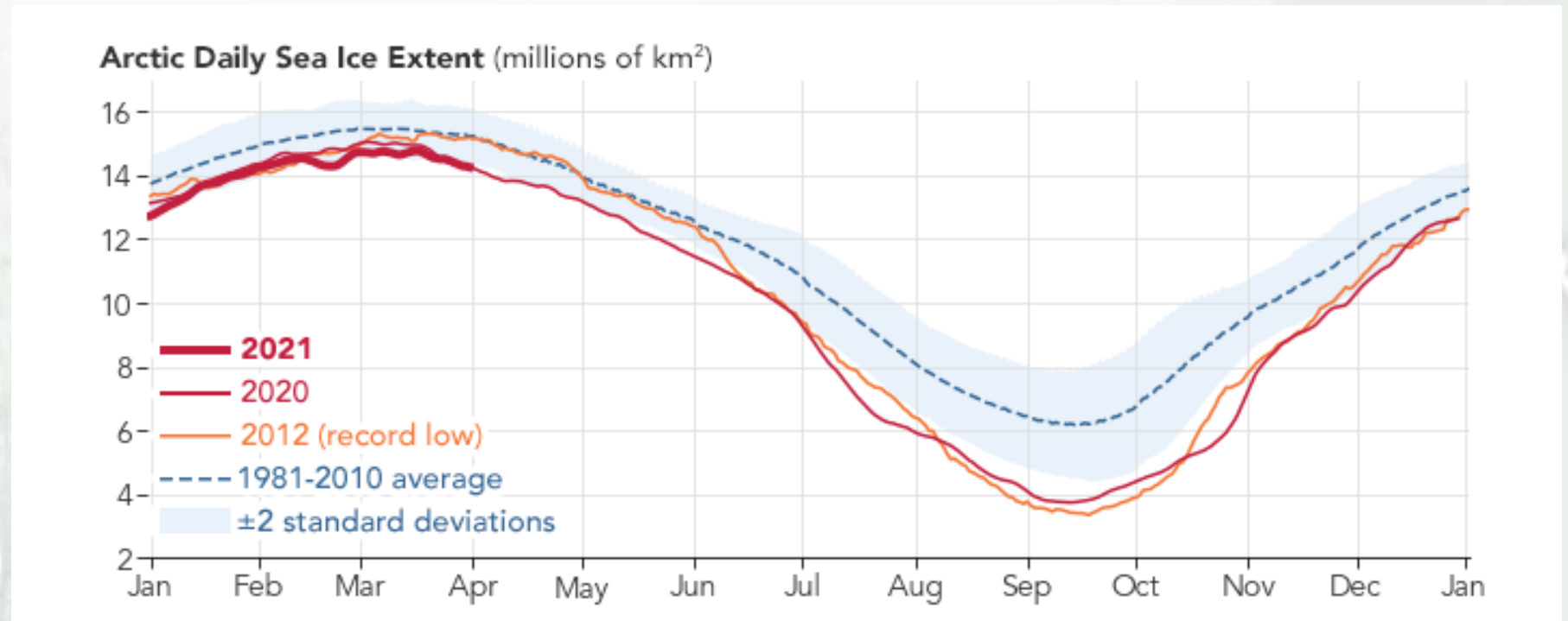
Time-series clustering of remote sensing retrievals for defining management zones in a vineyard

https://www.researchgate.net/publication/355385813_Time-series_clustering_of_remote_sensing_retrievals_for_defining_management_zones_in_a_vineyard/figures?lo=1



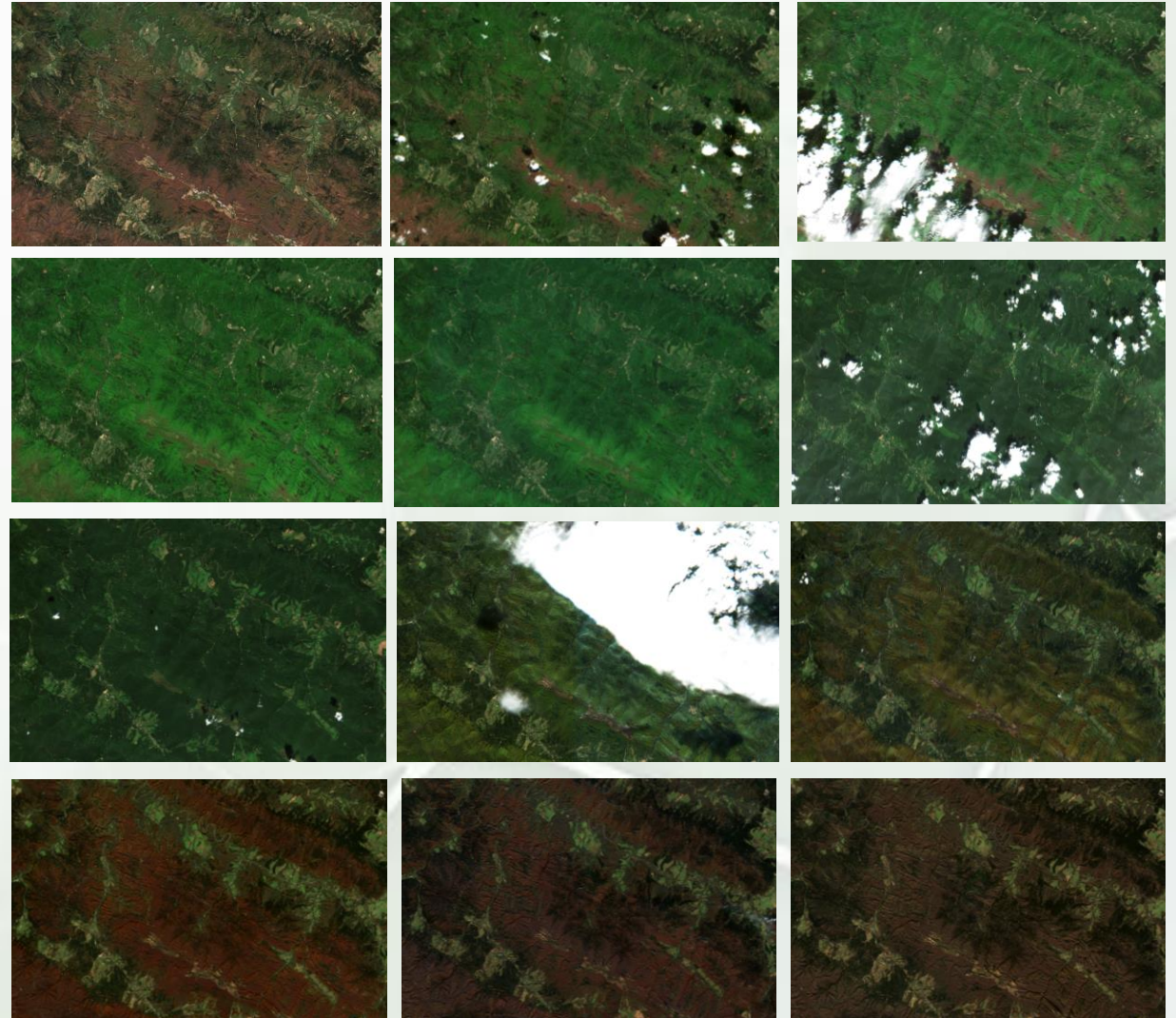
Ice extent

- <https://earthobservatory.nasa.gov/world-of-change/sea-ice-arctic>



Satellite time series

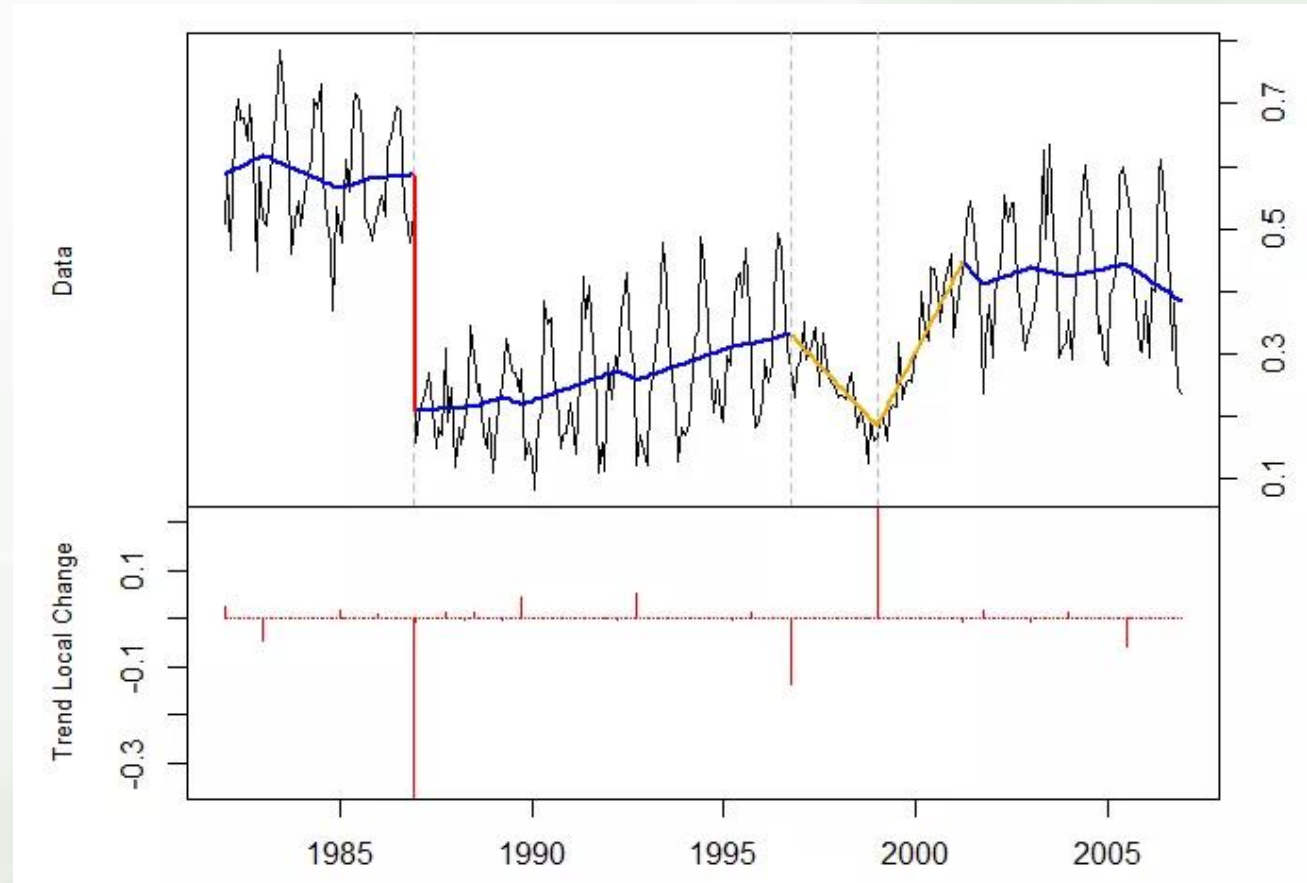
- Require pre-processing, such as cloud masking, removing outliers
- After that, can be fitted (smoothed)



Types of changes

- seasonal changes, such as related to phenology
- abrupt changes, e.g., forest logging, new built-up area or reservoir
- gradual changes - increasing or decreasing trends
- seasonal abrupt changes, e.g., meadow mowing

DBEST change detection algorithm - NDVI time series (black): the estimated trend component (blue) one abrupt change (red) and two gradual changes (orange).

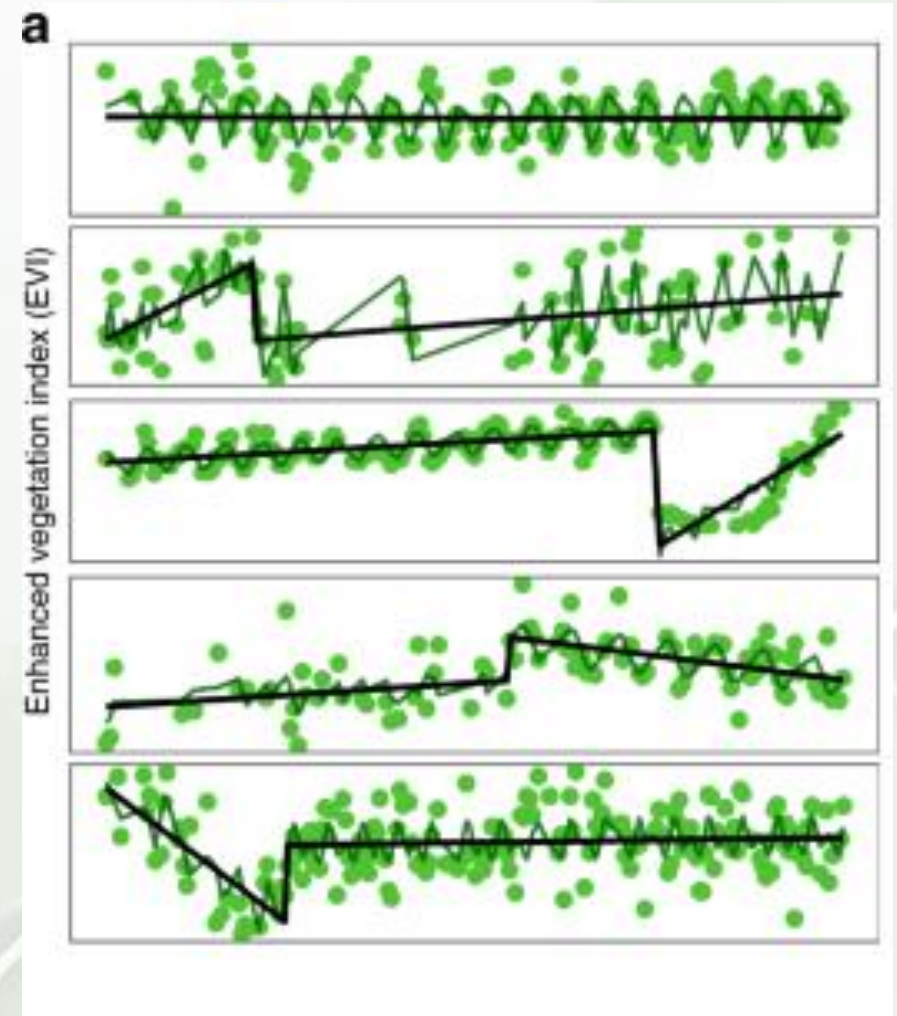


Abrupt changes

<https://www.nature.com/articles/s41467-019-13452-3>

Changes in land cover/use derived from enhanced vegetation index (EVI) :

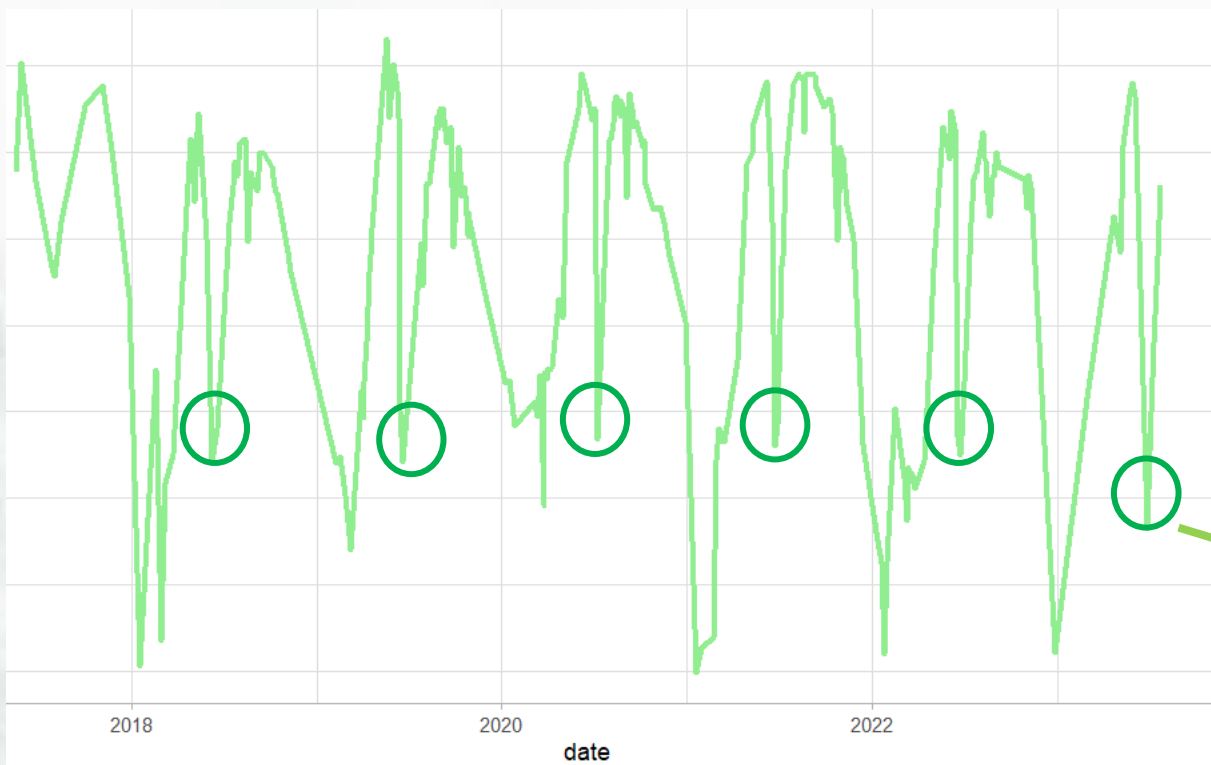
- unchanged site (top panel)
- four sites with an abrupt change (both increase and decrease in EVI).
- black lines represent linear and dark green lines - seasonal fits of the change detection algorithm



Source: Jung, M., Rowhani, P. & Scharlemann, J.P.W. Impacts of past abrupt land change on local biodiversity globally. *Nat Commun* **10**, 5474 (2019). <https://doi.org/10.1038/s41467-019-13452-3>

Can we detect when grassland are mowed?

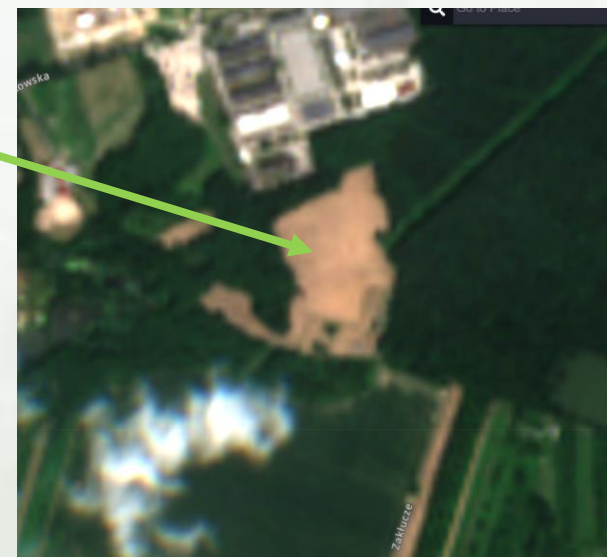
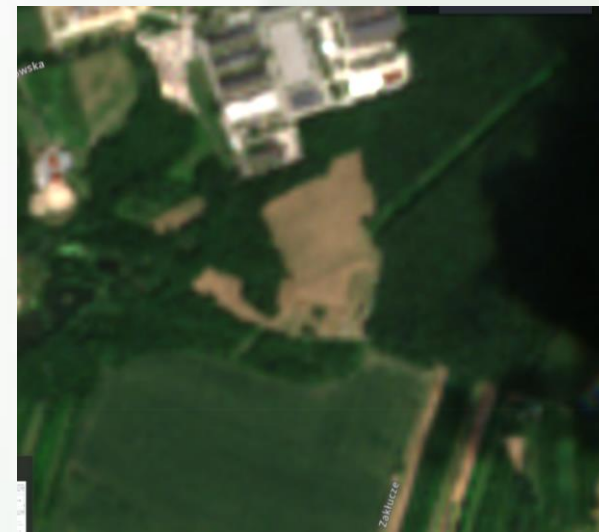
○ Mowing



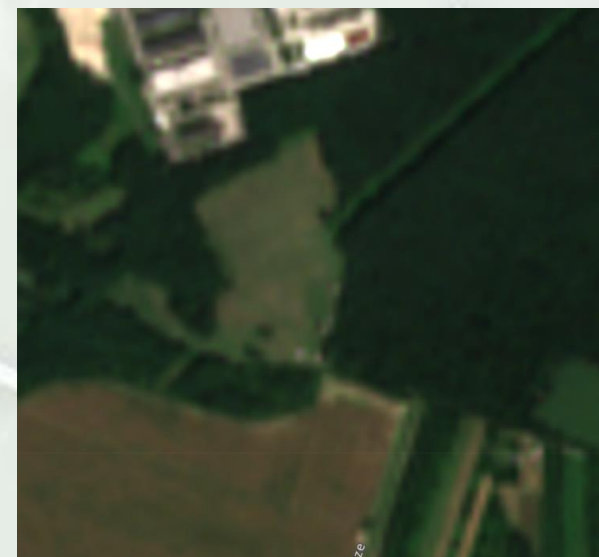
18/06/2023



03/07/2023

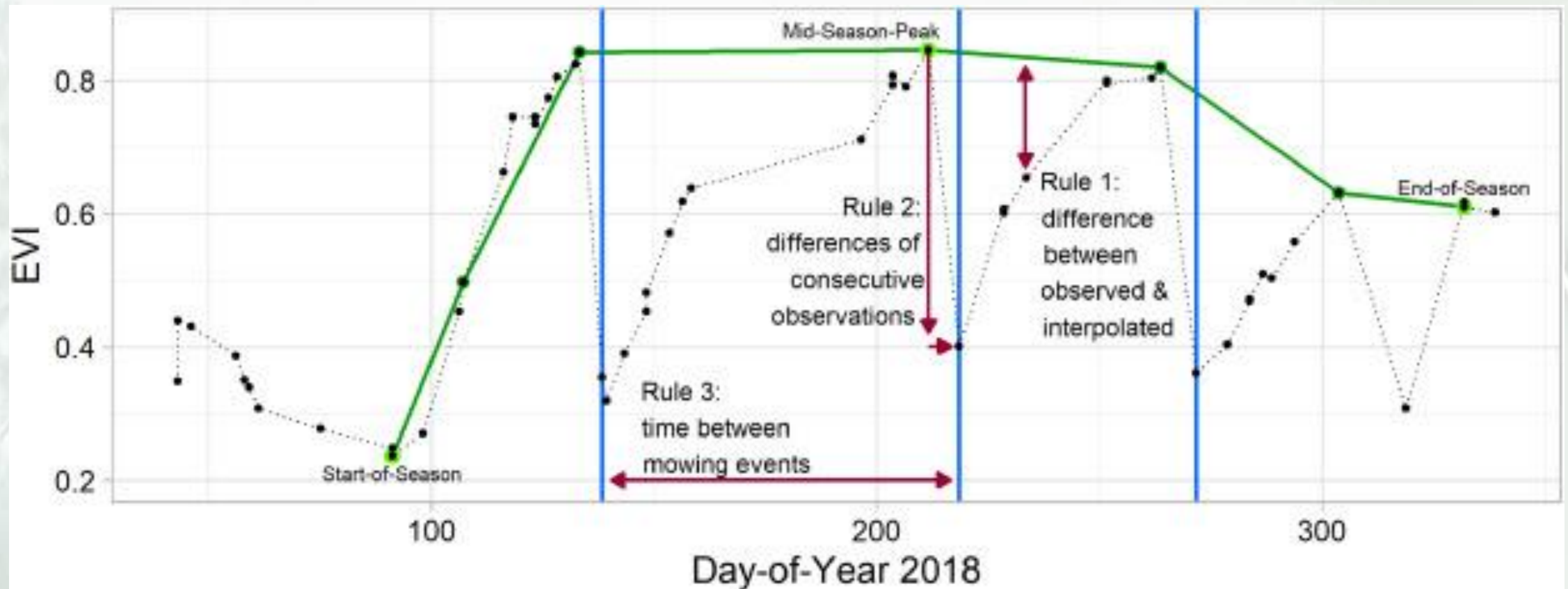


26/06/2023



16/07/2023

Example of detecting meadow mowing



Source: <https://www.sciencedirect.com/science/article/pii/S0034425721005150>

Workshop plan

1. Analyzing STS using GAM and Savitzky-Golay – example of trees phenology based on Sentinel-derived MTCI (vegetation index related to chlorophyll content)

- *Tree species*

2. Detecting trends, changes and breaks in STS based on NDVI (Normalized Difference Vegetation Index):

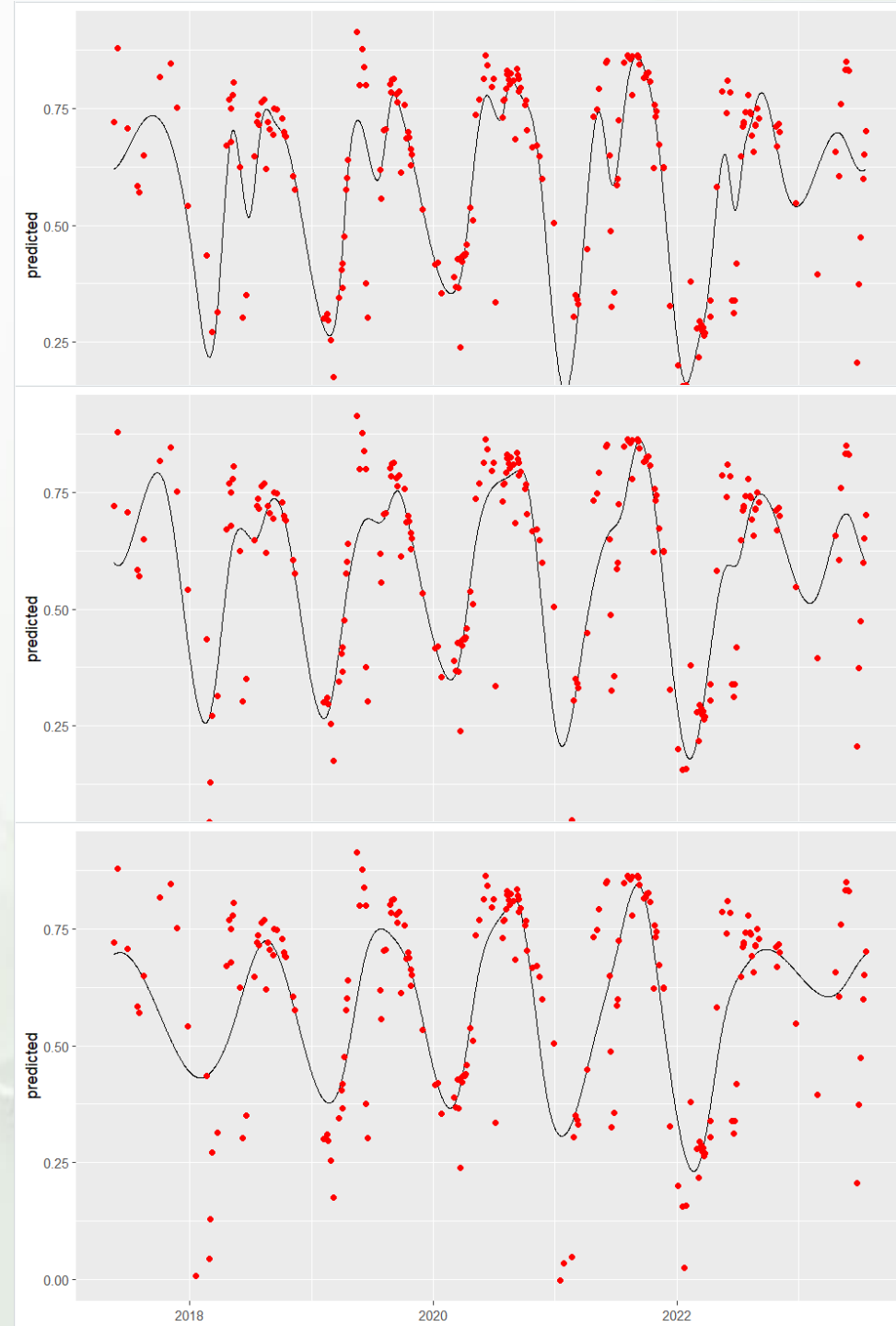
- *Poznań – new built-up area*

Smoothing time series

- Removing noise in time series
- Types:
 - **Moving average** - statistic capturing the average change in a data series over time. It calculates mean values in selected window length, e.g. 5 or 10 days
 - **Savitzky-Golay** - is a generalization of the moving average. Instead of the calculating mean in selected window length, it fits a polynomial of a given order over each window.

GAM

- Generalized Additive Models - allows to model non-linear data
- Coefficients from linear regression are replaced with a flexible function which allows nonlinear relationships
- This flexible function is called a spline (can be set to polynomial and quadratic or more complex thin-plate and Duchon splines)
- Measurements do not have to be evenly spaced
- Date as a predictor variable
- Figure is showing k decreasing from 48 to 24 (k sets the upper limit on the degrees of freedom associated with a smooth)



What is the history behind pixels?

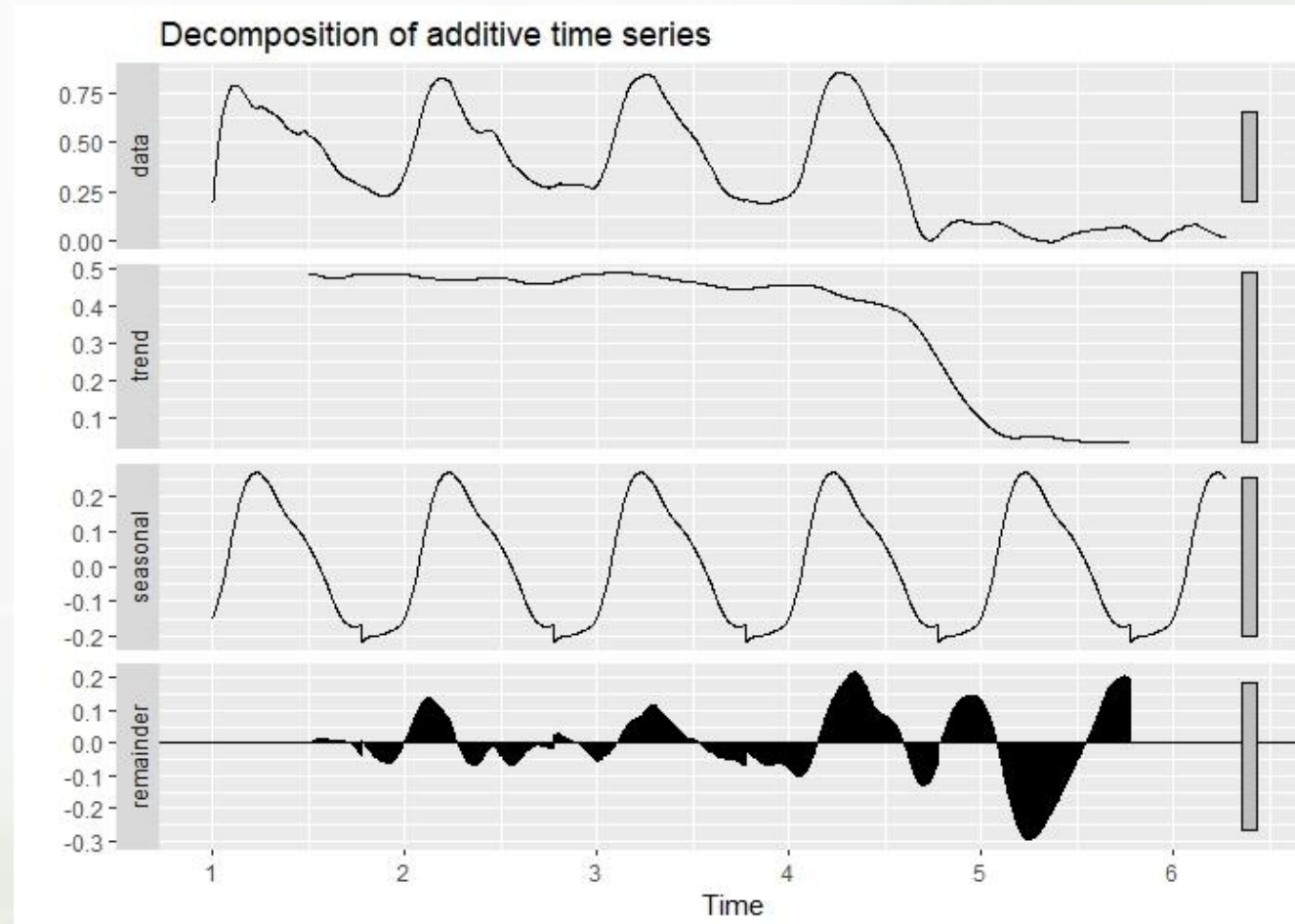
- Decomposing time series – trend detection
- Breaks detection

2017 vs 2023



Time series decomposition

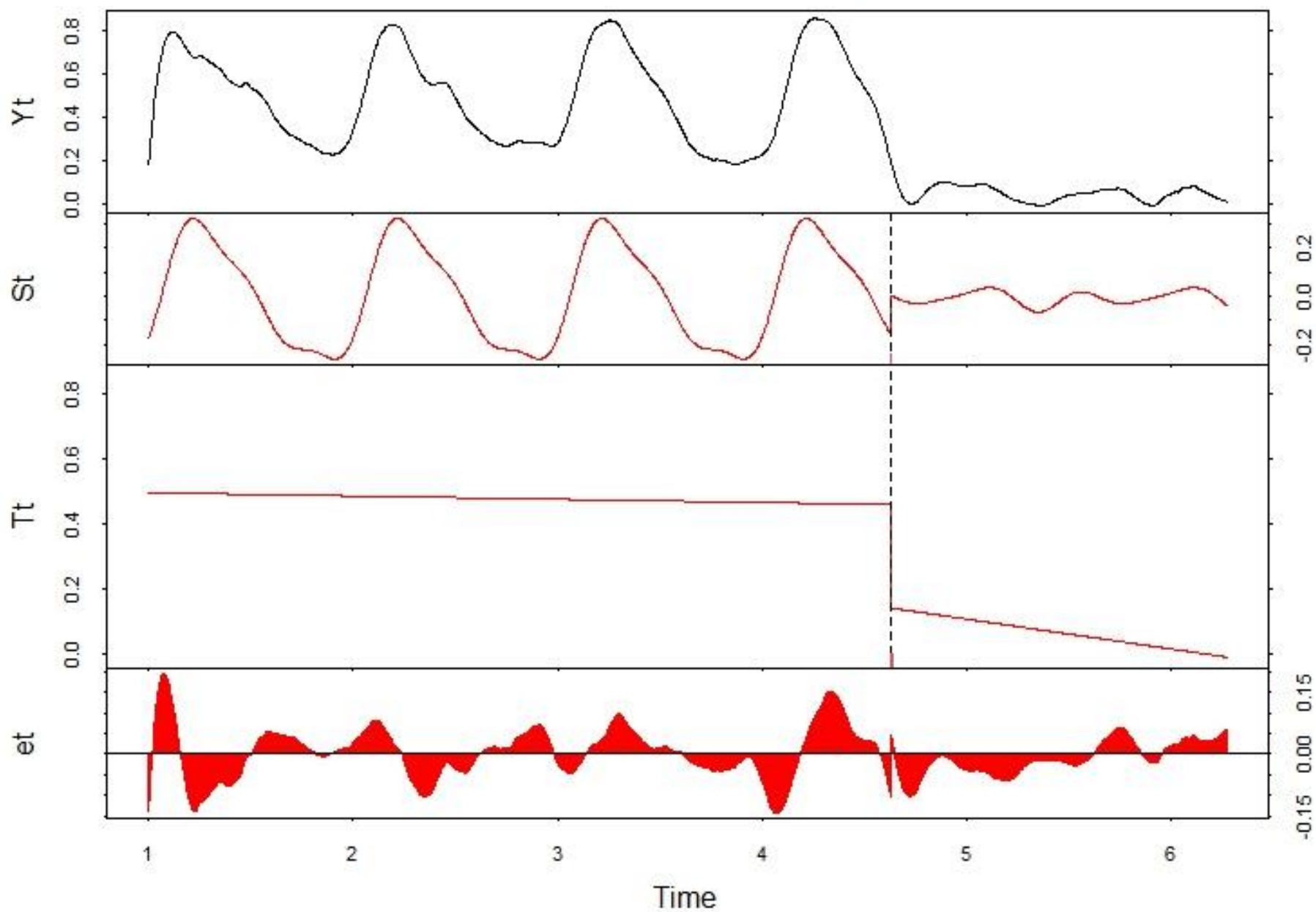
- Trend, seasonal and remainder component:
 1. Estimate the trend
 2. „De-trend“ time series
 3. Estimating seasonal factors on de-trended data
 4. Estimating random (irregular) component
- `decompose()` vs `stl()`



Breaks detection – BFAST

- <https://cran.r-project.org/web/packages/bfast/bfast.pdf> ; Verbesselt et al. 2021:
 - It combines the decomposition of time series into three components with methods for detection of abrupt changes
 - Can be used to examine satellite image time series but also in other disciplines where seasonal or non-seasonal time series are used, e.g. hydrology, or climatology
- `bfast()` - decompose ts into three components and then each component is checked for at least one significant break - the result allows differentiating between breaks in trend and seasonality.

no. iterations to estimate breakpoints: 1



breaks in trend
and
seasonality

bfast()

SITS package*

- Based on cubes, provides tools for time series processing
- <https://github.com/e-sensing/sits>
- <https://e-sensing.github.io/sitsbook/earth-observation-data-cubes.html>

Some further reading

- http://bfast.r-forge.r-project.org/RSE_ChangeDetection_InPress_JanVerbesselt.pdf
- <https://eos.com/blog/detecting-changes-trends-and-seasonality-with-satellite-time-series-data/>
- [https://www.researchgate.net/publication/284914127 Long term analysis of time series of satellite images](https://www.researchgate.net/publication/284914127_Long_term_analysis_of_time_series_of_satellite_images)
- <https://otexts.com/fpp2/decomposition.html>