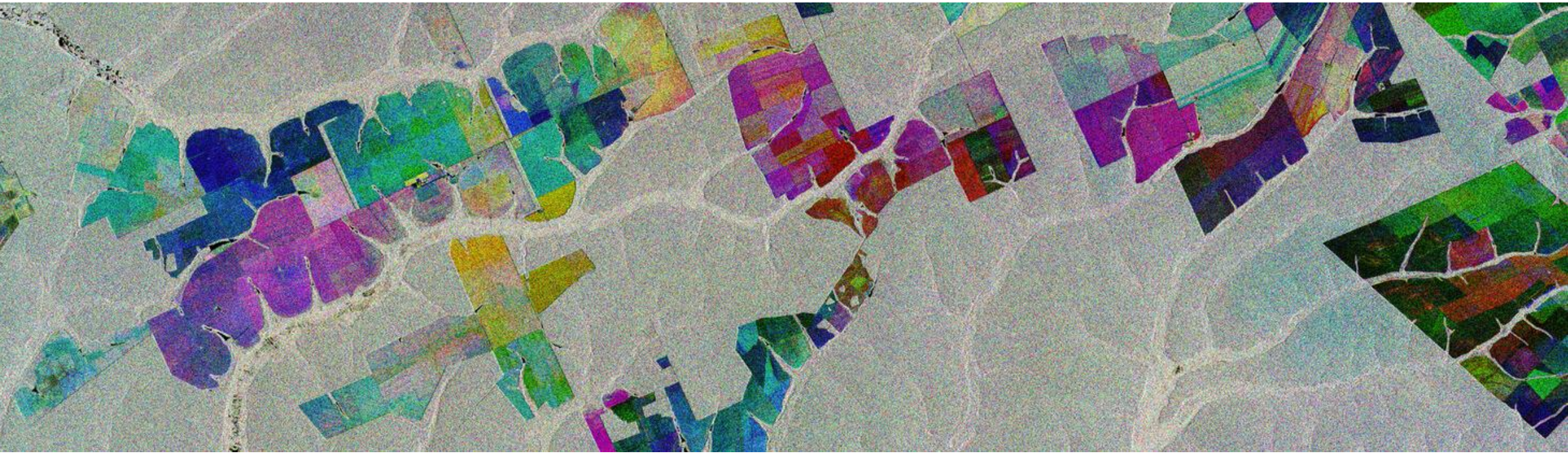


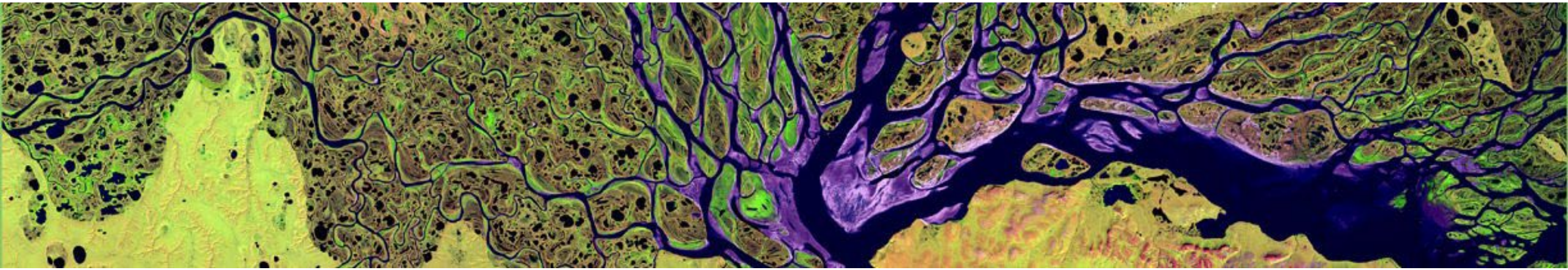
EON UAV block course 2022 | Time series analysis

15.09.2022 | Insa Otte (LSFE Uni Würzburg)

Content

- Time Series: Statistical (very) basics
  - Stationary | Trends | Seasonality | Breakpoints
- Overview of Time Series Satellite Imagery
- Time Series Tools

Time Series: Statistical (very) basics



Statistical (very) basics

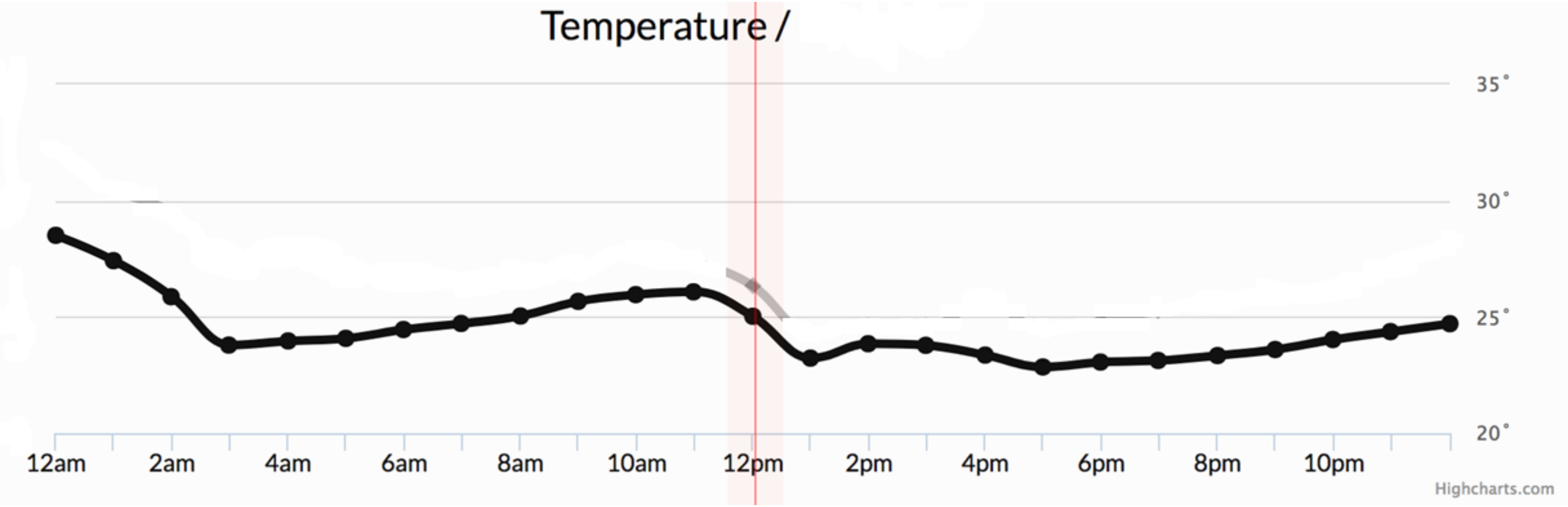
What is time series data?

- Time series data, also referred to as time-stamped data, is a sequence of data points indexed in time order. Time-stamped data is data collected at different points in time.

- These data points typically consist of successive measurements made from the same source over a time interval and are used to track change over time.

Statistical (very) basics

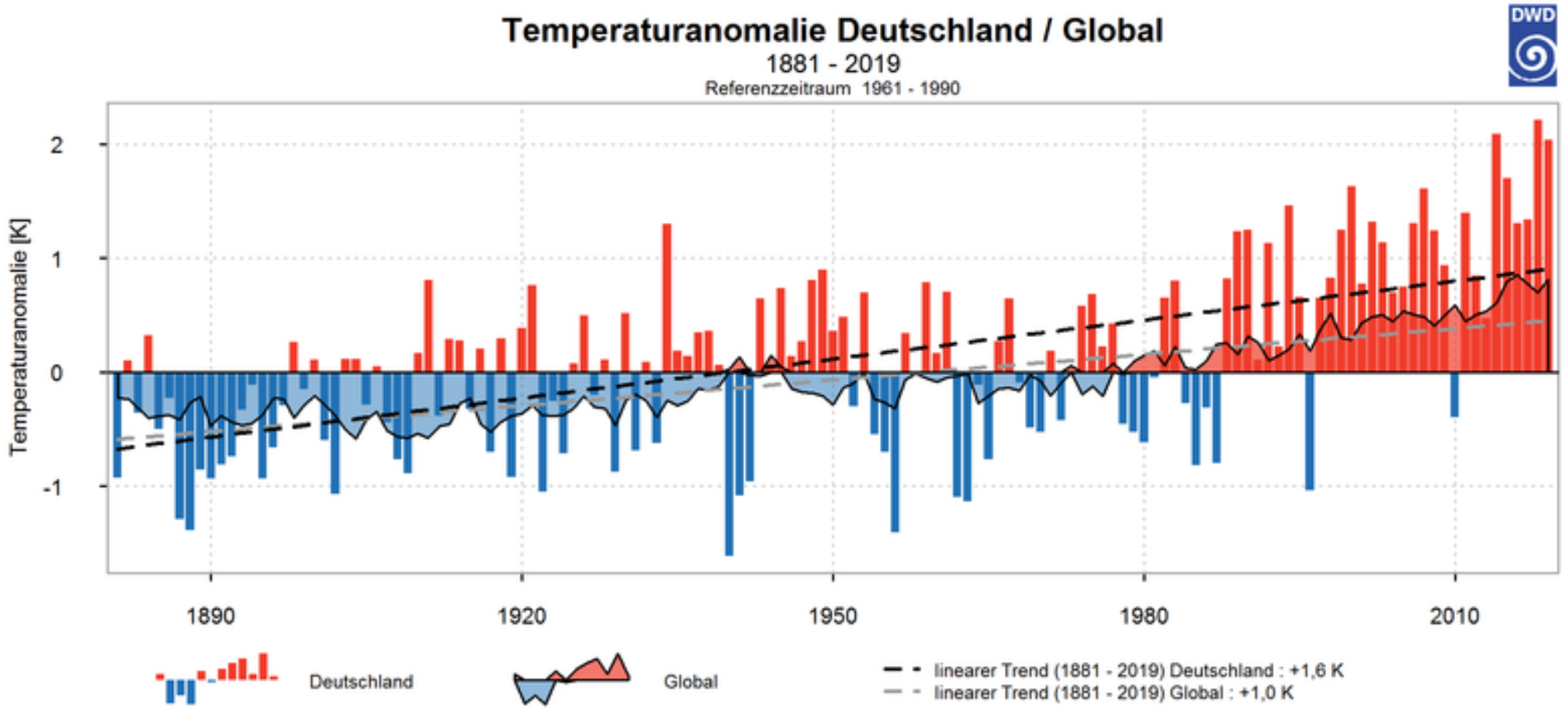
What is time series data?



https://www.influxdata.com/what-is-time-series-data/

Statistical (very) basics

What is time series data?

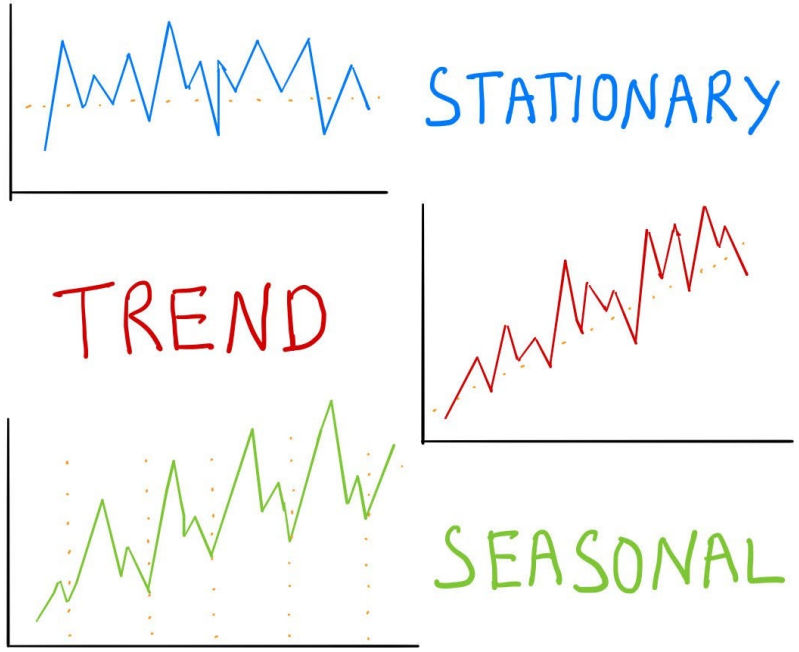


Anomalies: Relative difference from a long term average

Statistical (very) basics

Where to start?

- 3 basic characteristics of a time series (stationary, trend and seasonality)
- Prerequisites: time series definition, statistics such as mean, variance, covariance



Statistical (very) basics

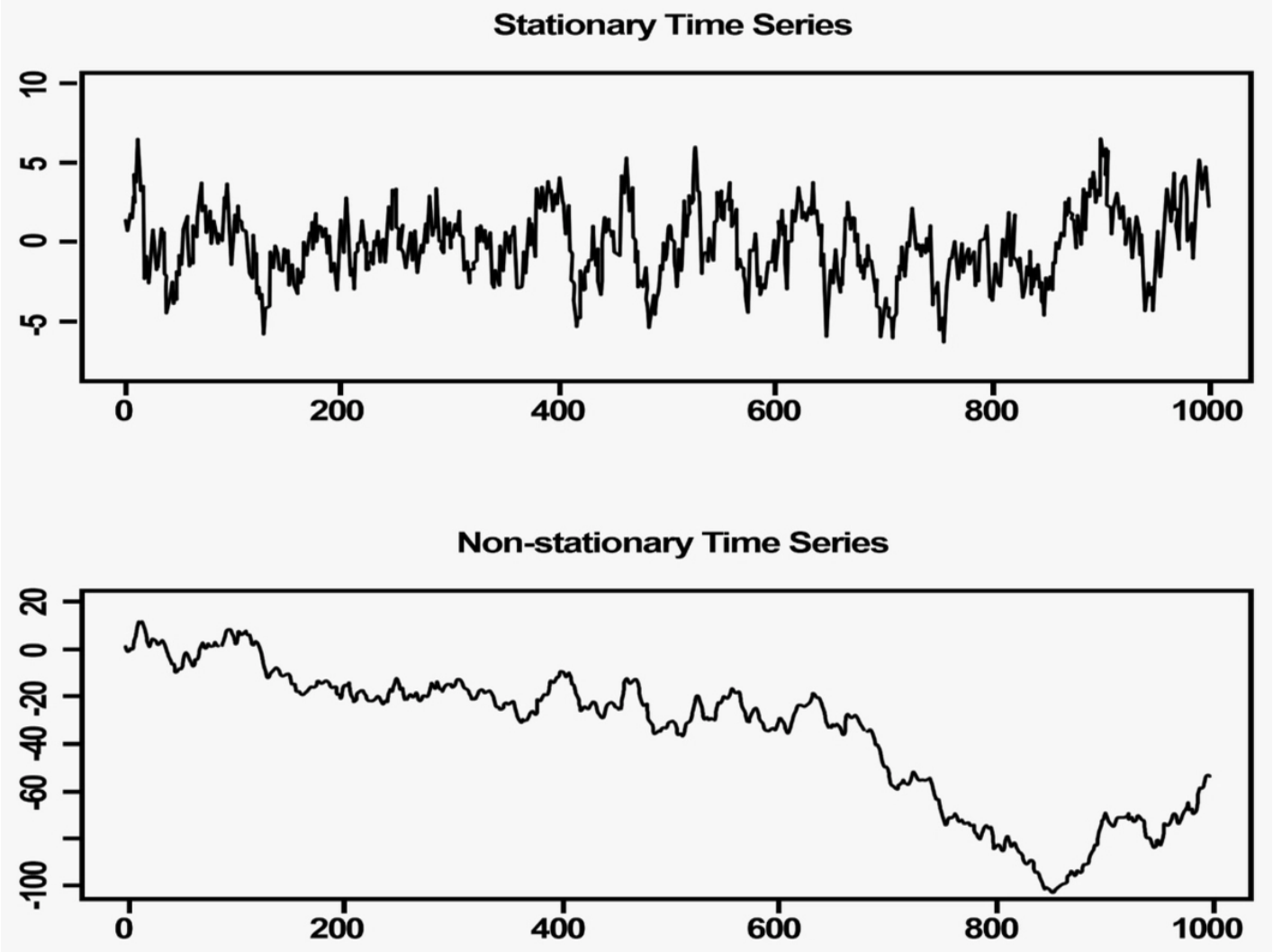
1. Stationary

"A strictly stationary time series is one for which the probabilistic behavior of every collection of values is identical to that of the time shifted set."

→ But for most cases, people refer to stationary characteristics with a less formal definition by saying the **mean** and the **variance** of a time series does not change over time. If you take a shifted sample from an original time series at any lag or lead, you would likely get the same distribution.

Statistical (very) basics

1. Stationary



(https://www.oreilly.com/library/view/hands-on-machine-learning/9781788992282/15c9cc40-bea2-4b75-902f-2e9739fec4ae.xhtml)

Statistical (very) basics

2. Trend

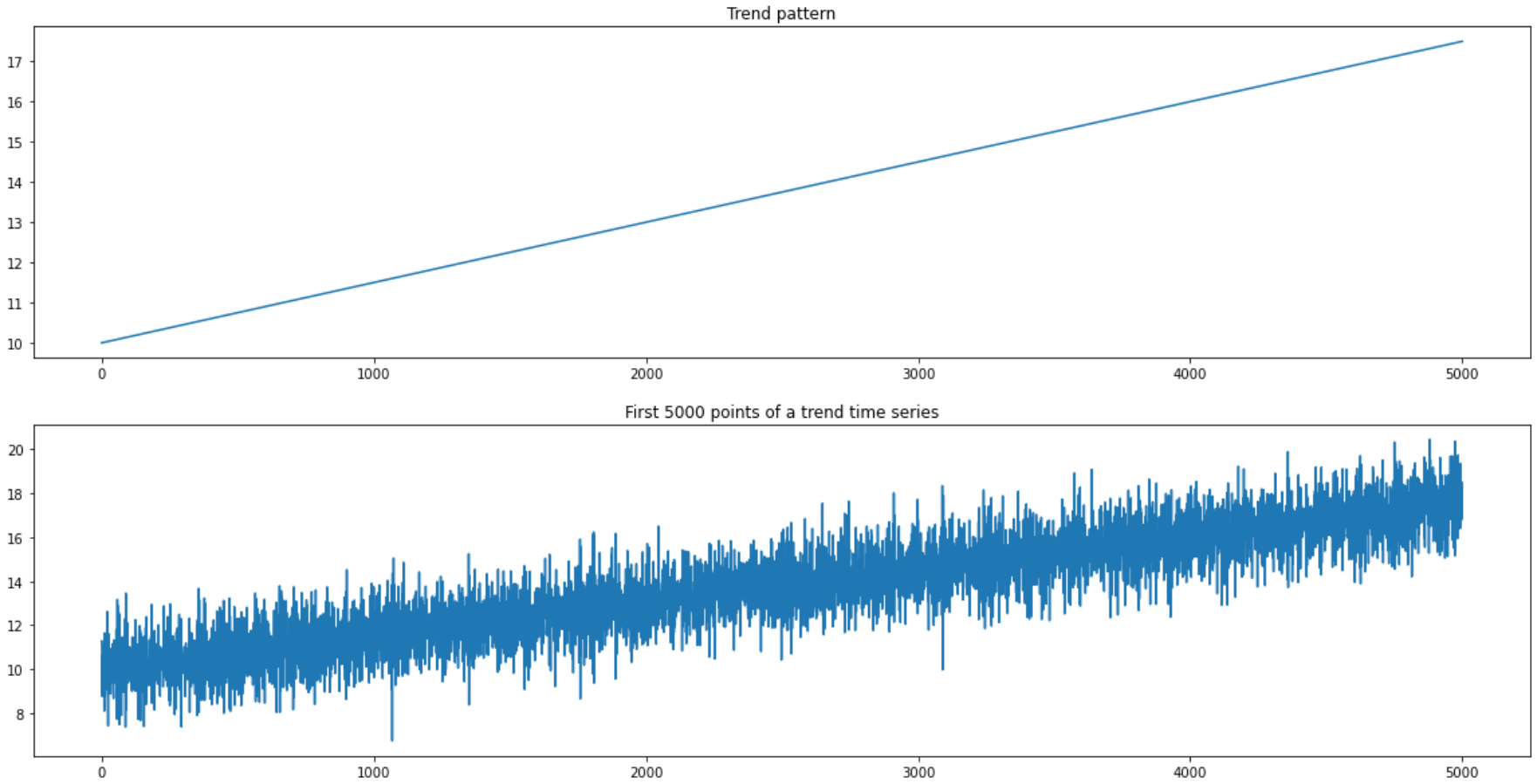
Why is the trend important ?

- In the long run, if the trend is predictable, it may allow us to capture the main direction of the time series data, hence leading to a better future forecast.
  → the trend helps to detect the long term movement

- When a series contains an implicit trend, the mean is observed to change over time.
  As you extract the data in different periods, you are likely to retrieve different mean values.
  Therefore, a trend time series is non-stationary regarding the definition.

Statistical (very) basics

2. Trend

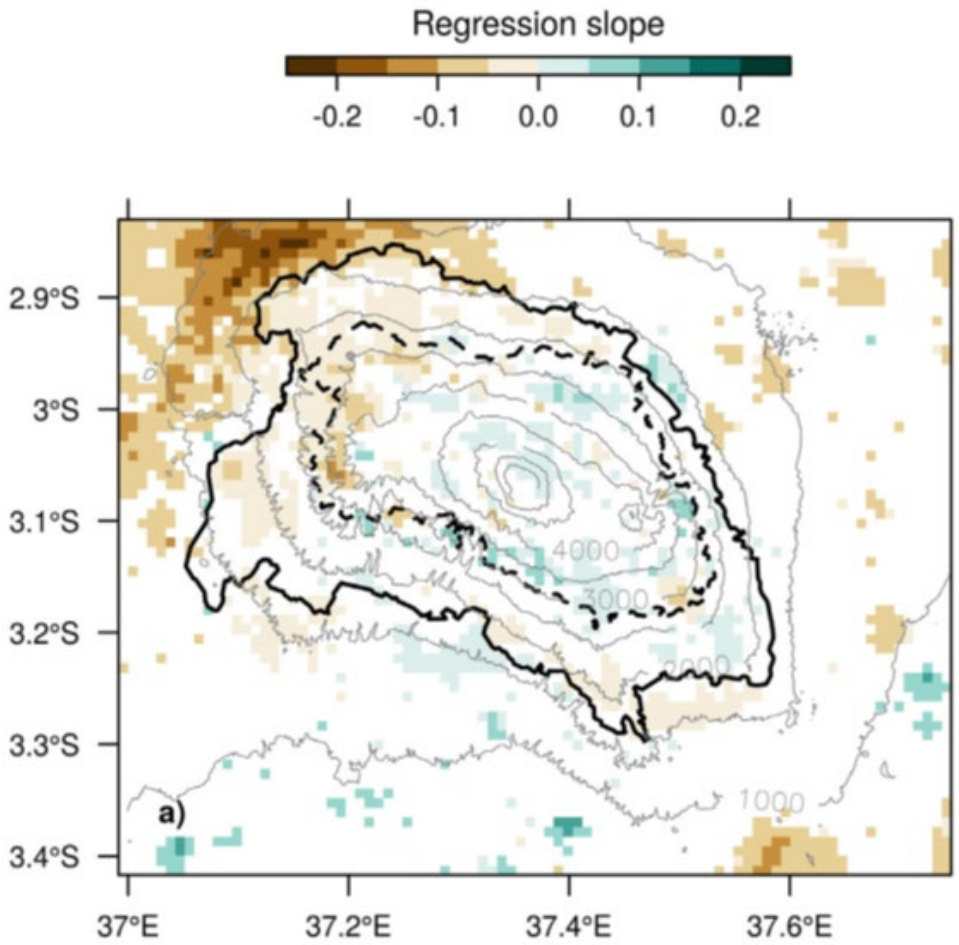


An example of a trend time series (bottom) with the linear trend pattern (top)

(https://medium.com/@namnguyenthe/time-series-data-characteristics-994e43c470c6)

Statistical (very) basics

2. Trend

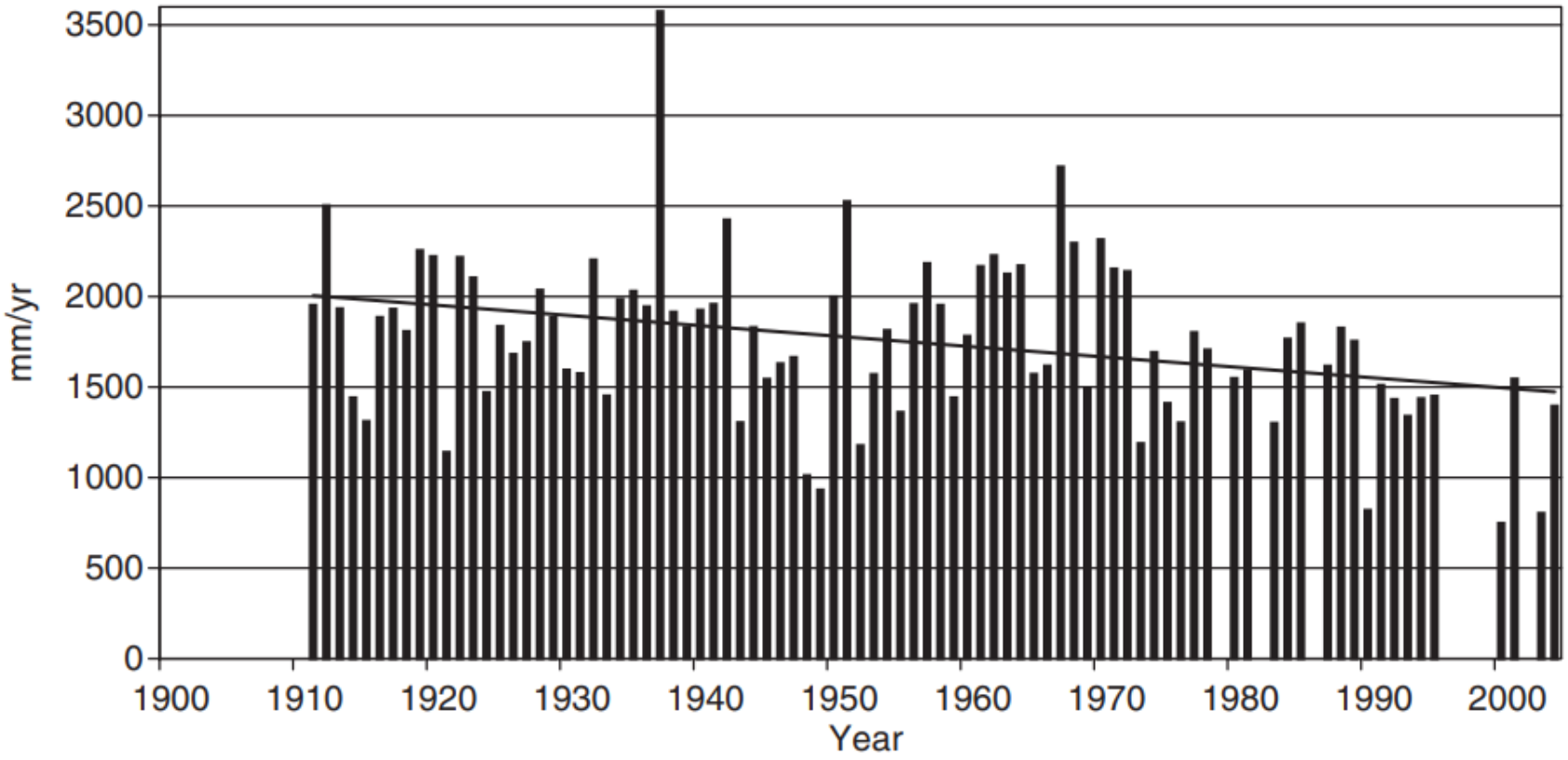


a) Linear regression slope (only slopes larger than the corresponding RMSE are shown) calculated from monthly NDVI between 1982 and 2011

Detsch, F et al. (2016) Seasonal and long-term vegetation dynamics form 1-km GIMMS-based NDVI time series at Mt. Kilimanjaro, Tanzania. J.RSE. 178, 70-83

Statistical (very) basics

2. Trend: Quality control (gap filling, remove outliers)



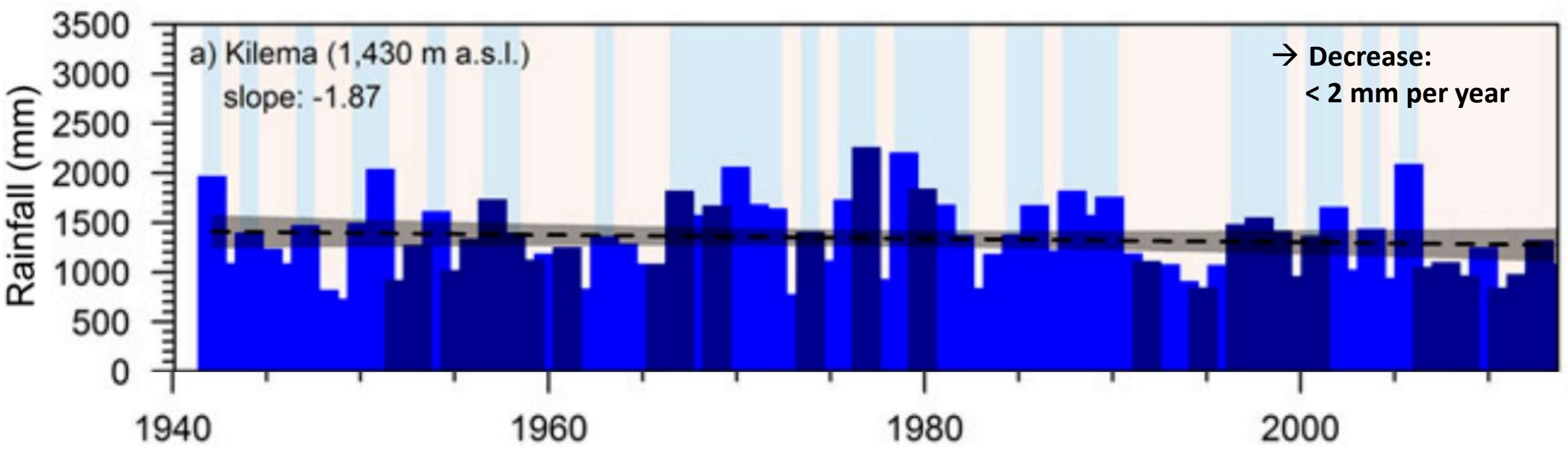
→ **Decrease: 532 mm per year!**

Annual precipitation at Kilema Mission, 1430 m a.s.l. on the southern slope of Kilimanjaro. Data source: Tanzania Meteorological Agency, Kibosho and Kilema Mission

Hemp, A (2005) Climate change-driven forest fires marginalize the impact of ice cap wasting on Kilimanjaro. Global Change Biology. 11, 1013-1023

Statistical (very) basics

2. Trend: Quality control (gap filling, remove outliers)



Annual precipitation at Kilema Mission, 1430 m a.s.l. on the southern slope of Kilimanjaro. Data source: Tanzania Meteorological Agency, Kibosho and Kilema Mission

Otte, I (2017) Multidecadal Trends and Interannual Variability of Rainfall as Observed from five Lowland Stations at Mt. Kilimanjaro, Tanzania. J. of Hydromet. 18, 349-361

Statistical (very) basics

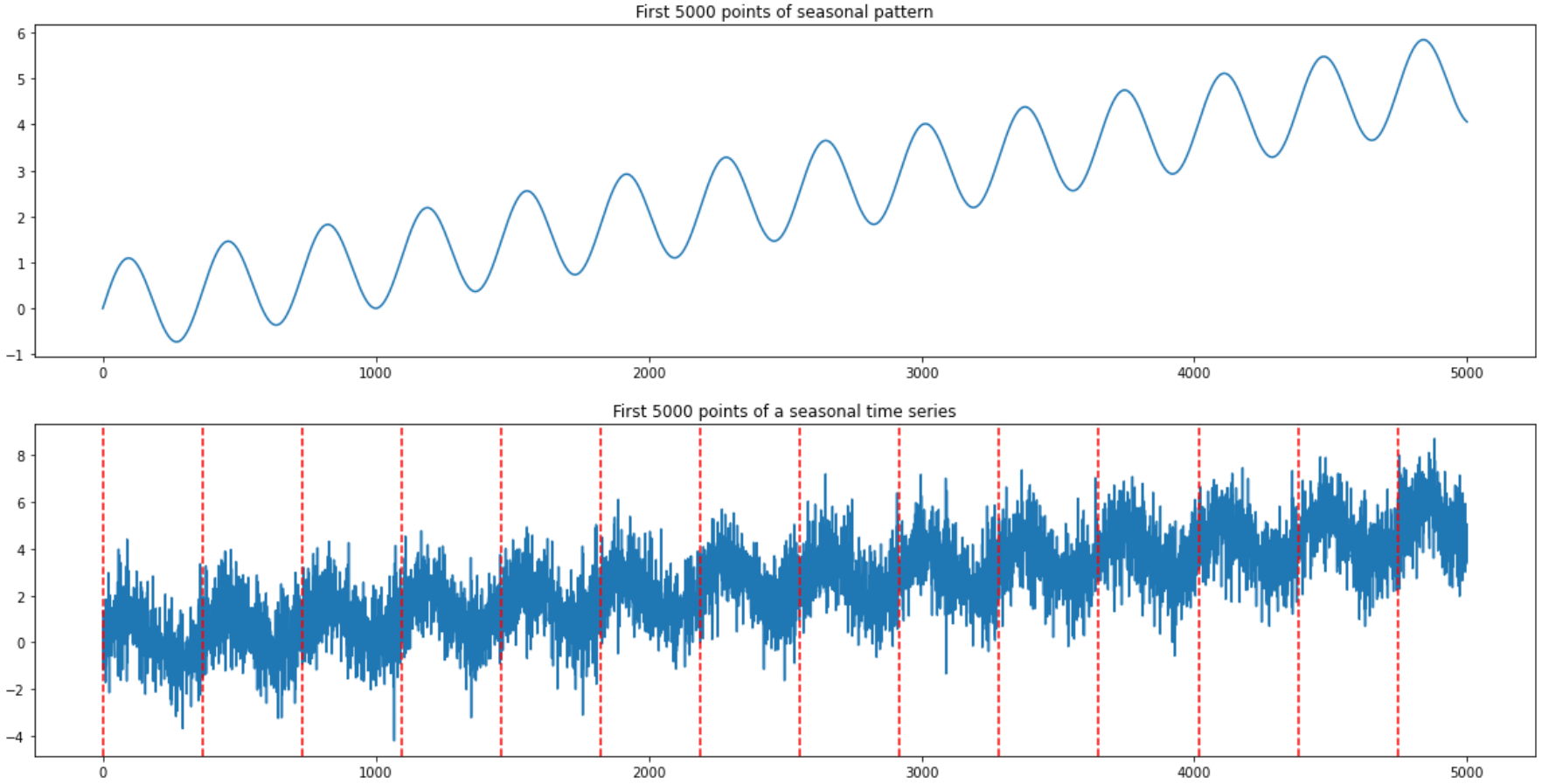
3. Seasonality

- Seasonality makes the time series data vary across seasons, which is a sign of time-dependence. Consequently, a seasonal time series is non-stationary. As we decompose the trend to make a series stationary, we would do the same with seasonality.

- The most popular technique is to difference the sequence by period of the seasonal interval. The transformation would result in a time series data with seasonality characteristics removed.

Statistical (very) basics

3. Seasonality

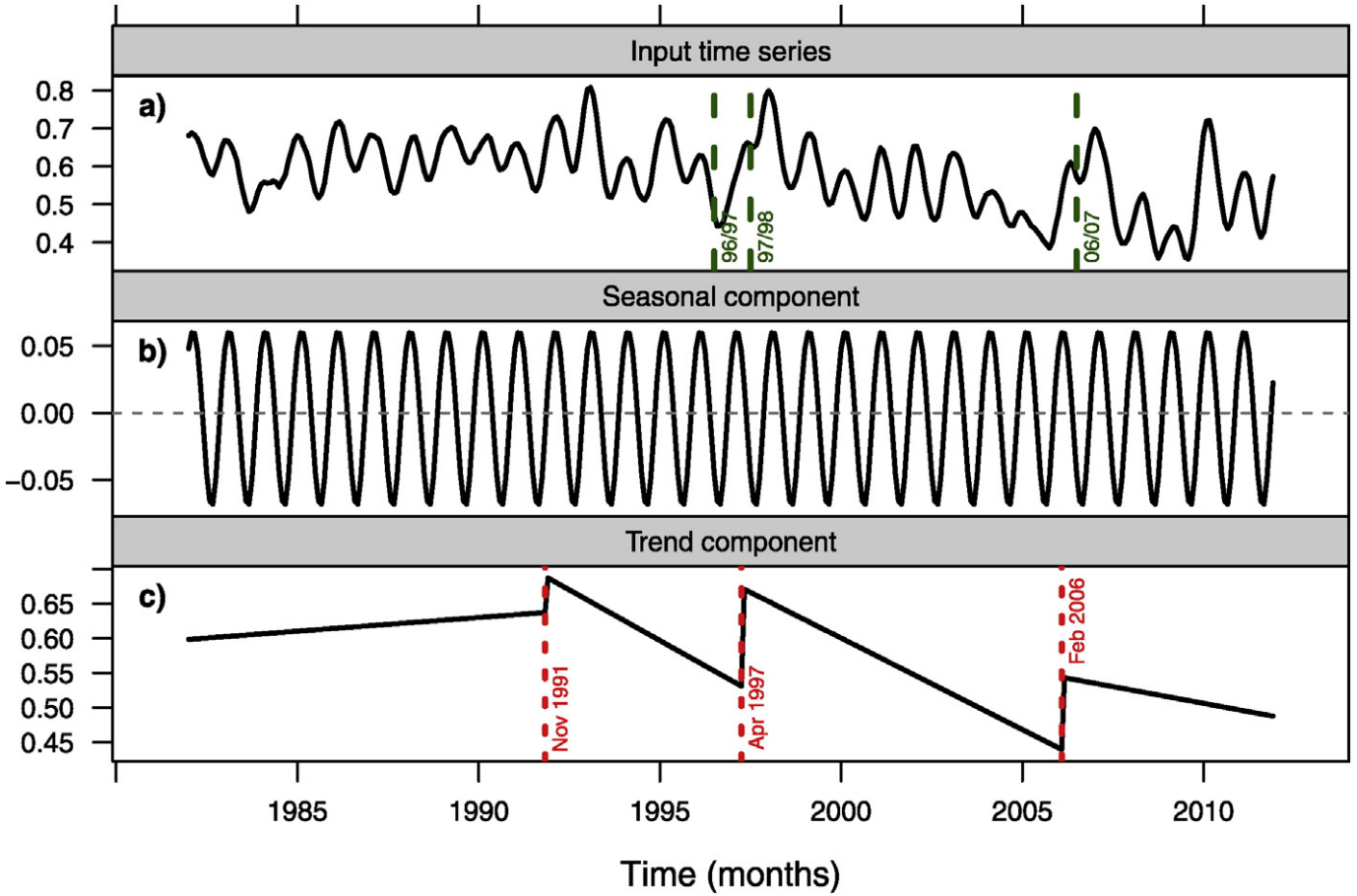


An example of a seasonal time series (bottom) with the decomposed seasonal pattern (top)

(https://medium.com/@namnguyenthe/time-series-data-characteristics-994e43c470c6)

Statistical (very) basics

3. Seasonality

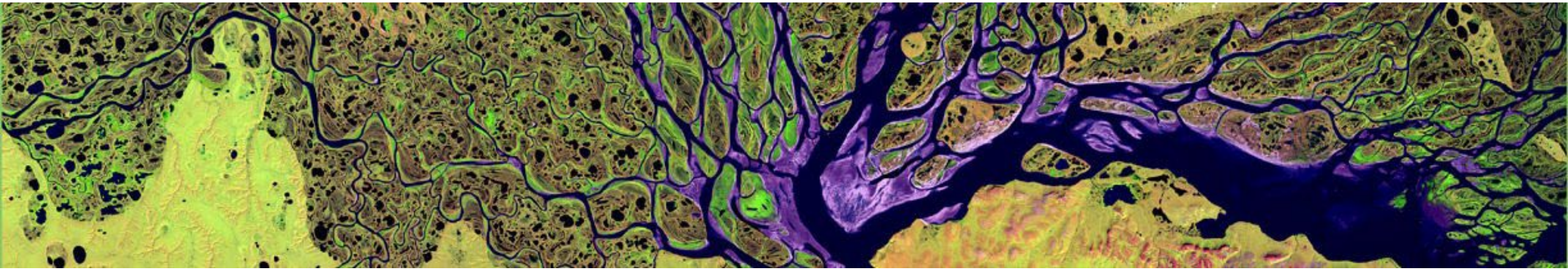


→ **Break points**

Trend breakpoints (red-dashed) in the monthly accumulated NDVIEOT signal of the north-western study area including a) input time series, b) seasonal, and c) trend component. Also denoted are selected El Niño seasons (July to June; green-dashed).

Detsch, F et al. (2016) Seasonal and long-term vegetation dynamics form 1-km GIMMS-based NDVI time series at Mt. Kilimanjaro, Tanzania. J.RSE. 178, 70-83

Overview of Time Series Satellite Imagery

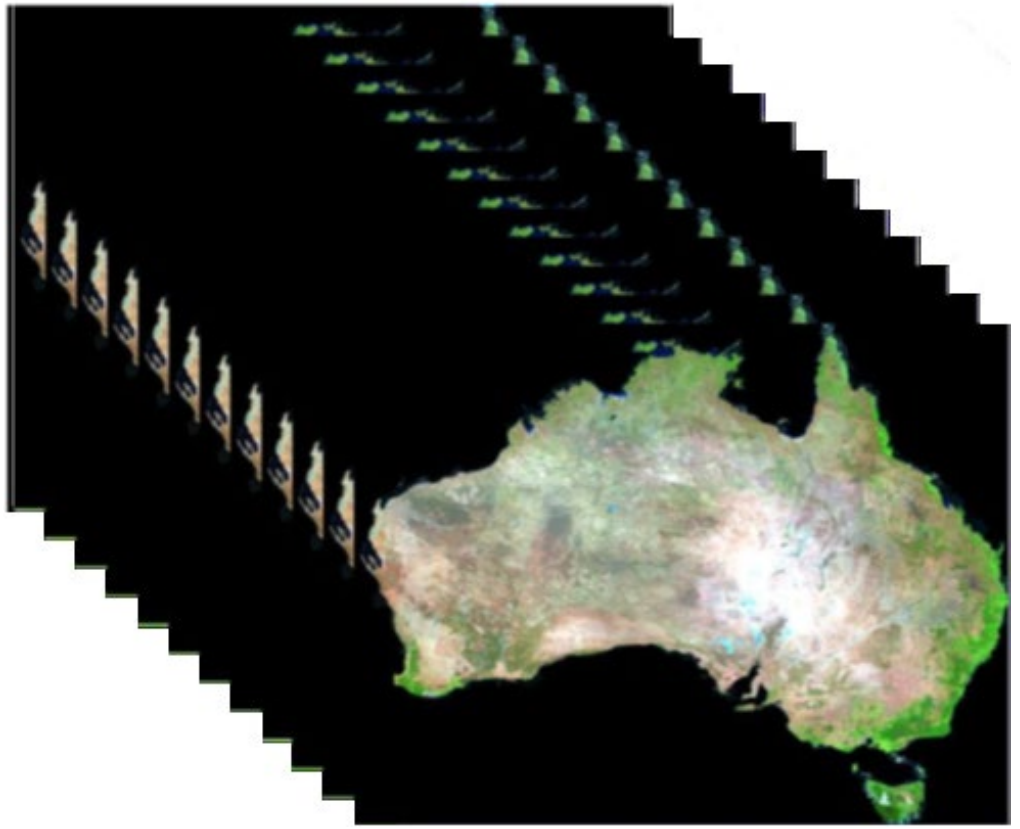


Satellite Time Series

Satellite Time Series

Our ability to identify changes over time has changed because:

- The availability of long term satellite data sets
  - Landsat (30+ years)
  - MODIS (20 years)
- Increased computing power and cloud computing
- Improved processing methods



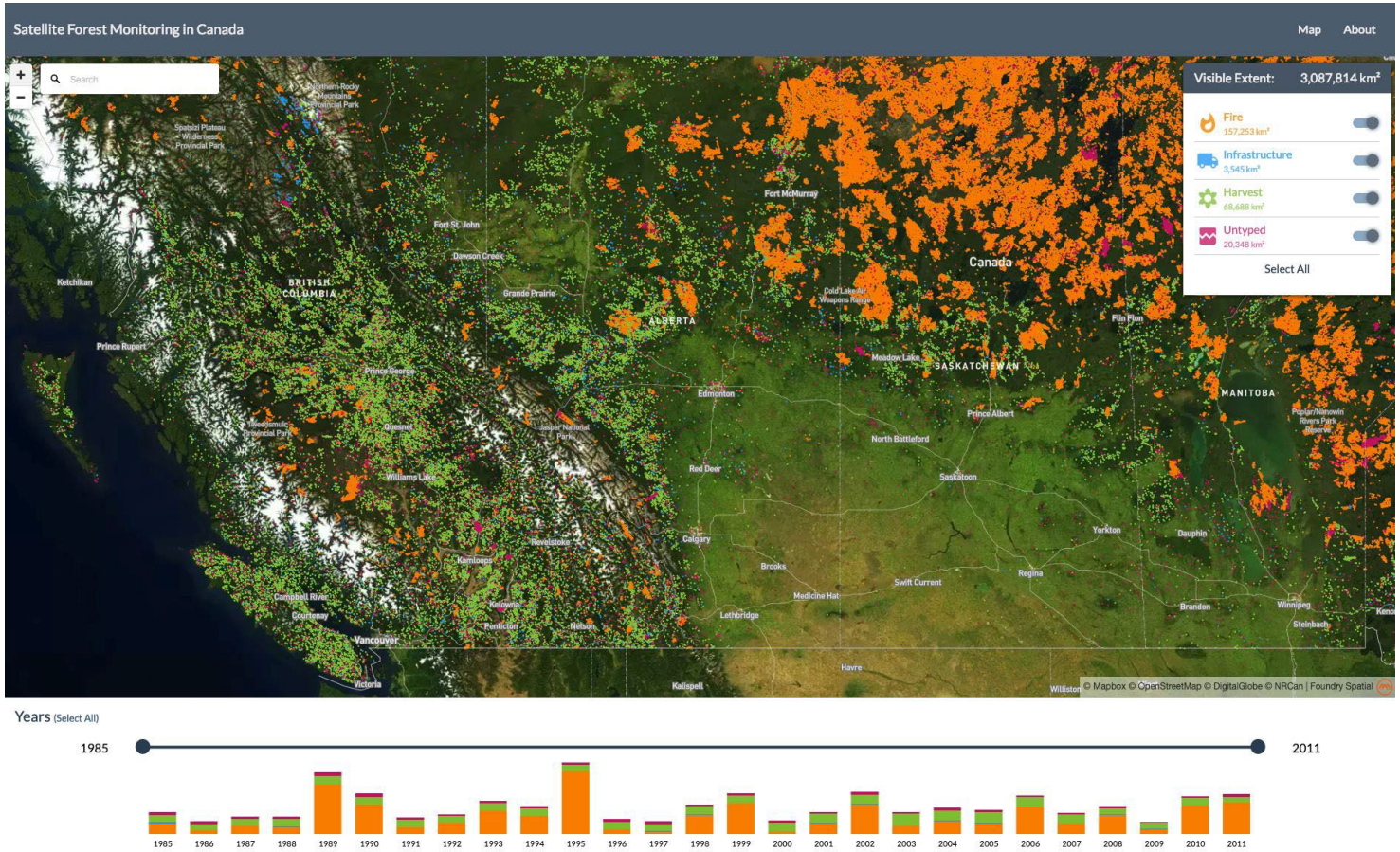
Stack of Landsat images of Australia

Image credit: Data Cube

Satellite Time Series

Types of Time Series Analysis

- Annual vs. seasonal trends
- Gradual vs. abrupt changes
- Anomalies
- Environmental descriptors



Satellite forest monitoring in Canada. Image credit: Foundry Spatial

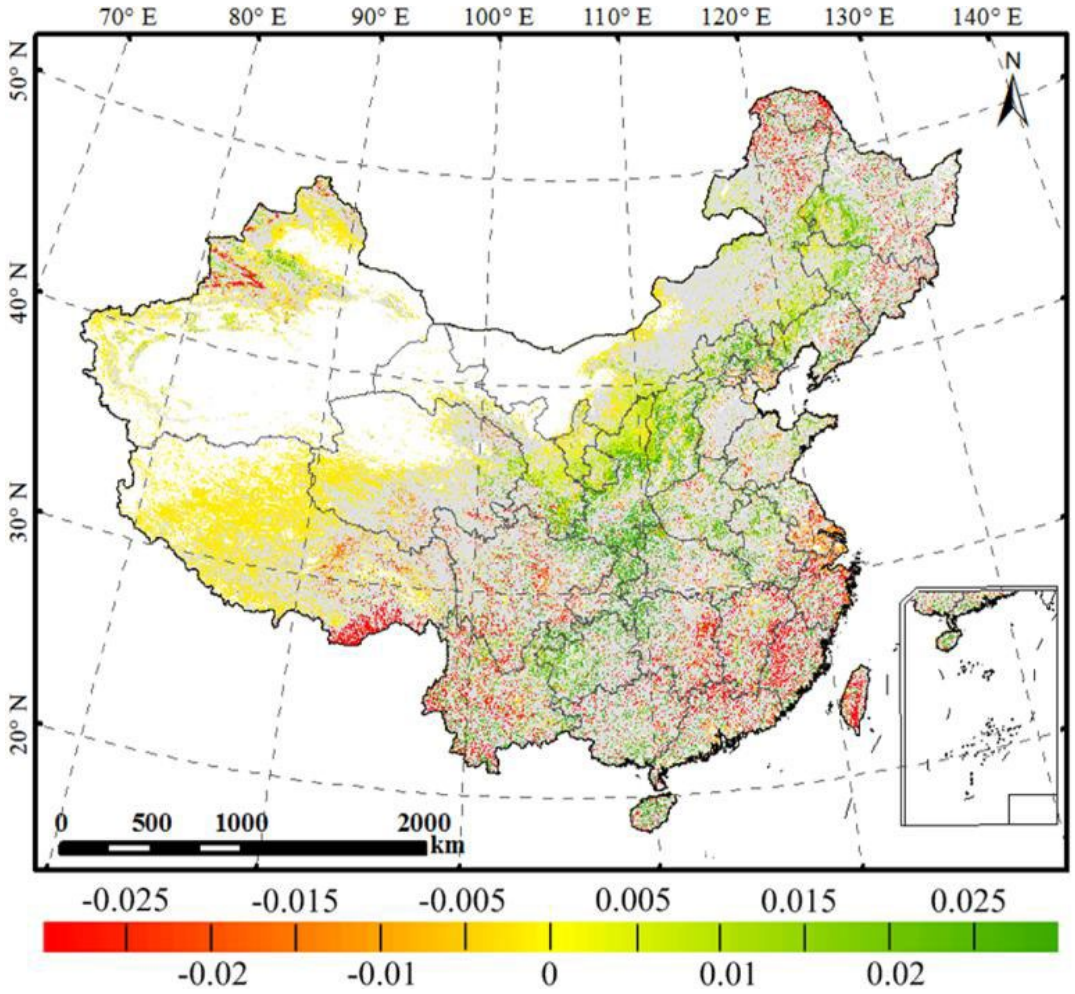
Satellite Time Series

Annual vs. Seasonal Trends

- Annual Trends
  - Annual land cover/land use changes over long time periods
  - Ex: Trends in vegetation greenness in China

Annual mean Leaf Area Index (LAI) during 2000-2014 from MODIS

These data were used to analyze the change in evapotranspiration and water yield



Liu, Y. et al. (2016) Recent trends in vegetation greenness in China significantly altered annual evapotranspiration and water yield, Environmental Research Letters

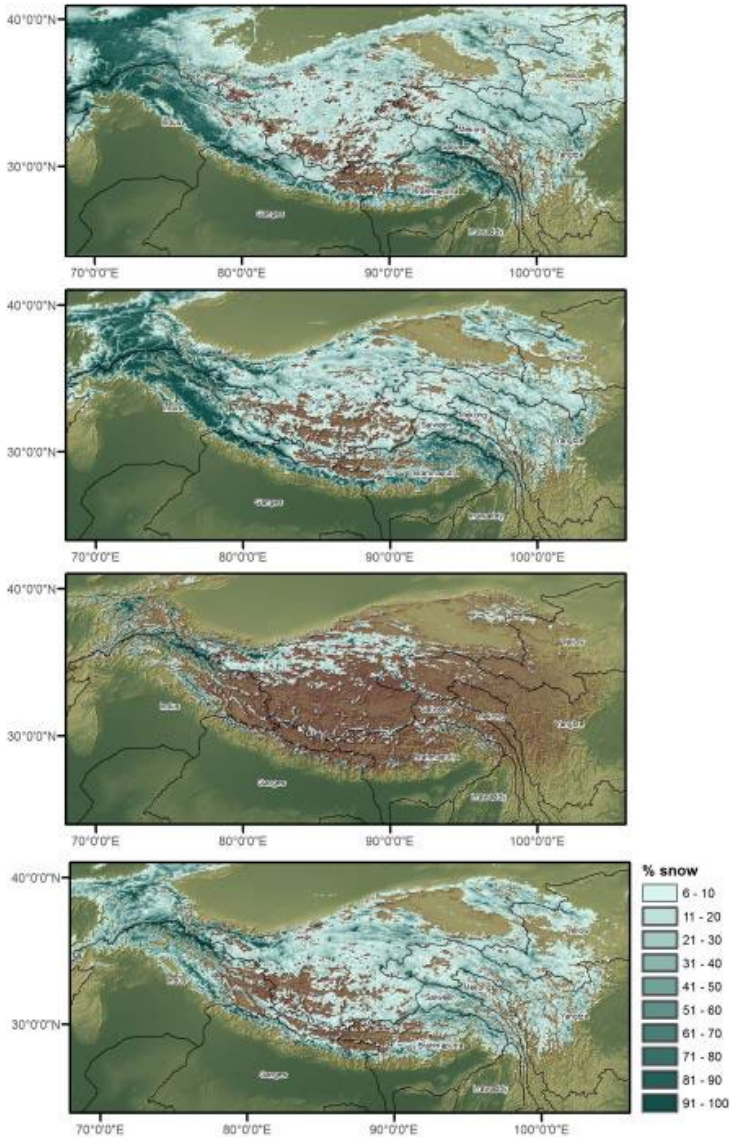
Satellite Time Series

Annual vs. Seasonal Trends

- Seasonal Trends
  - Driven by annual temperature and/or precipitation
  - Ex: Snow cover monitoring in the Himalayas

Seasonal snow cover based on MODIS snow cover time series from Mar 2000 to Feb 2008. (Winter, (top), Spring, Summer, Autumn (bottom)

The values show the percentage of time that a pixel was snow covered during the season within the time period



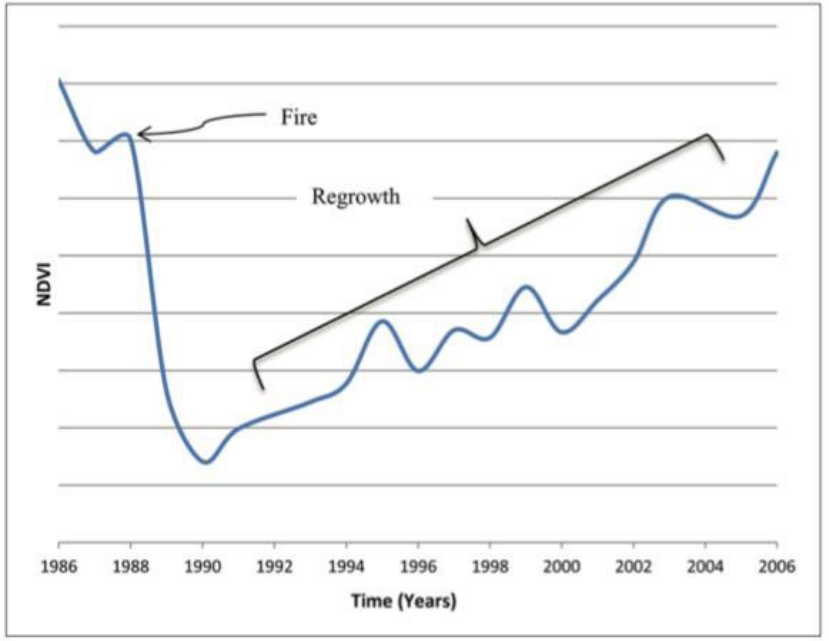
Immerzeel , W.W. et al. (2009). Large scale monitoring of snow cover and runoff simulation in Himalayan river basins using remote sensing, Remote Sensing of Environment

Satellite Time Series

Gradual vs. Abrupt Changes

- Gradual changes:
  - Insect infestation in forests
  - Land degradation
  - Forest recovery
- Abrupt changes:
  - Wildfire
  - Deforestation
  - Urban development

Example: Forest recovery after wildfire in Yellowstone National Park



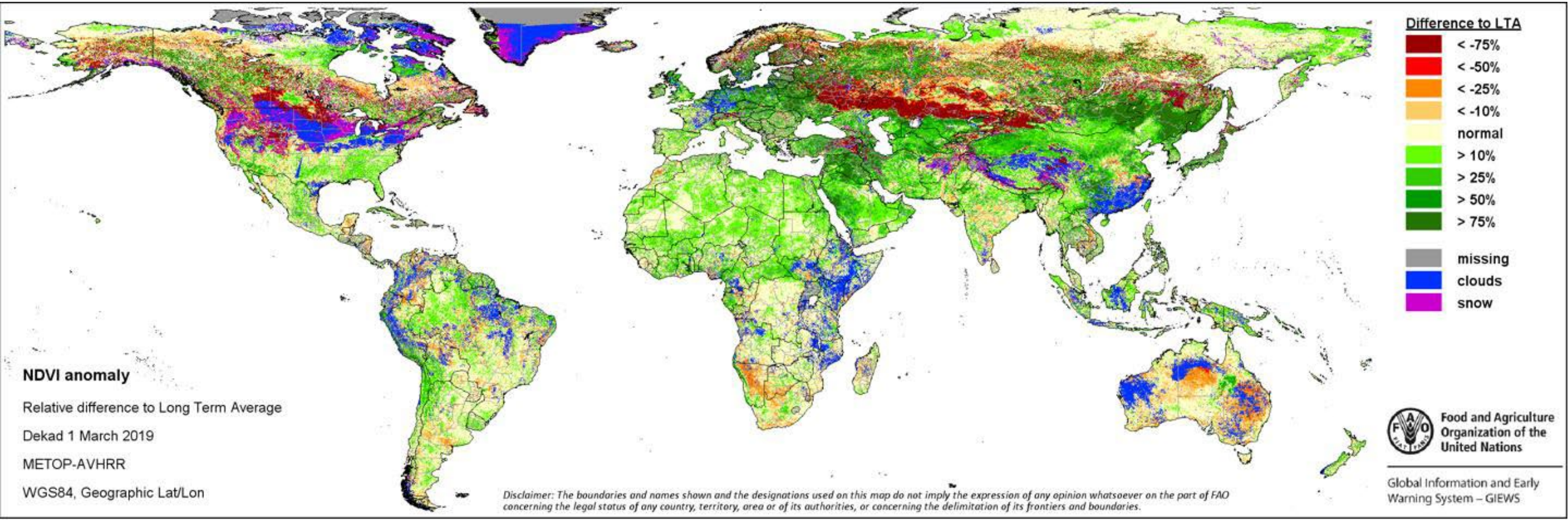
Changes in NDVI values between 1986 and 2006 for one site in Yellowstone National Park

Franks, S et al. (2013). Monitoring forest regrowth following large scale fire using satellite data A case study of Yellowstone National Park, USA, European Journal of Remote Sensing

Satellite Time Series

Anomalies

- Relative difference from a long term average
- Example: FAO Global NDVI Anomalies



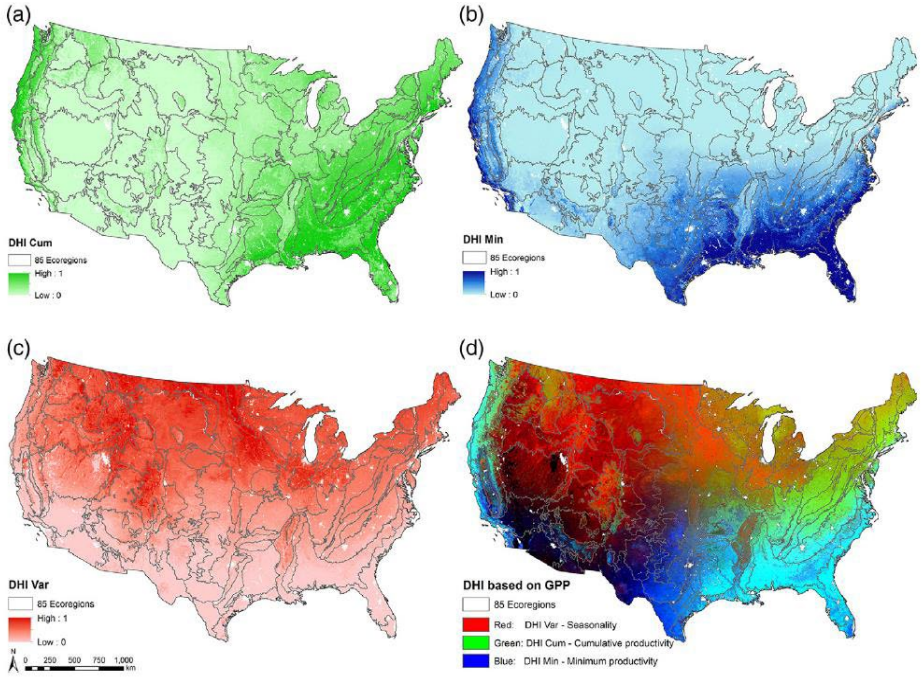
http://www.fao.org/giews/earthobservation/

Satellite Time Series

Environmental Descriptors

- Use time series of satellite observations to derive environmental descriptors
- Example: Dynamic Habitat Indices (DHIs) use time series of satellite observations of greenness to describe vegetation dynamics to understand bird species richness

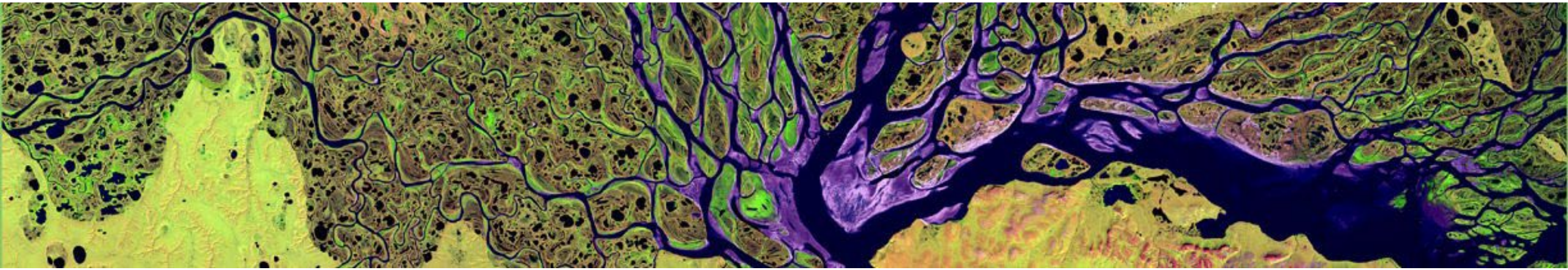
  - DHIs capture seasonal variations in energy that species can utilize in the form of food
  - Vegetation dynamics include: productivity, minimum level of perennial cover, degree of vegetation seasonality



Dynamic Habitat Indices derived from MODIS GPP 2003-2014 data (a)cumulative DHI; (b) minimum DHI; (c) variation DHI; (d) combined DHI

Hobi, ML et al. (2017). A comparison of Dynamic Habitat Indices derived from different MODIS products as predictors of avian species richness, Remote Sensing of Environment

Time Series Tools



Time Series Tools

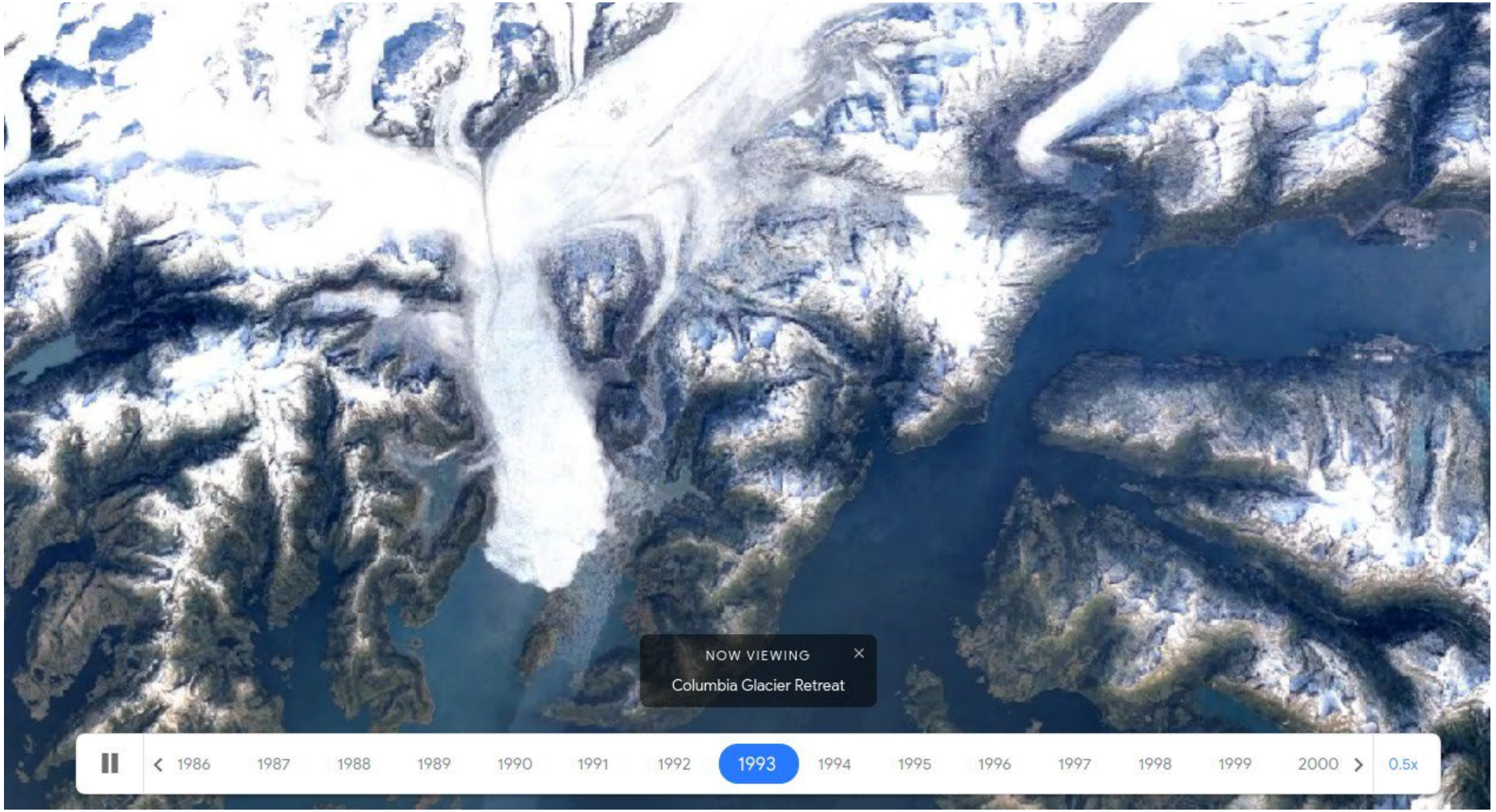
Time Series Tools

- Visualizing time series
  - Google Earth Engine Time Lapse
  - Global Forest Watch
  - NASA Earth Observatory

- Analyzing time series
  - Open Data Cube
  - BFAST
  - QGIS
  - RStudio

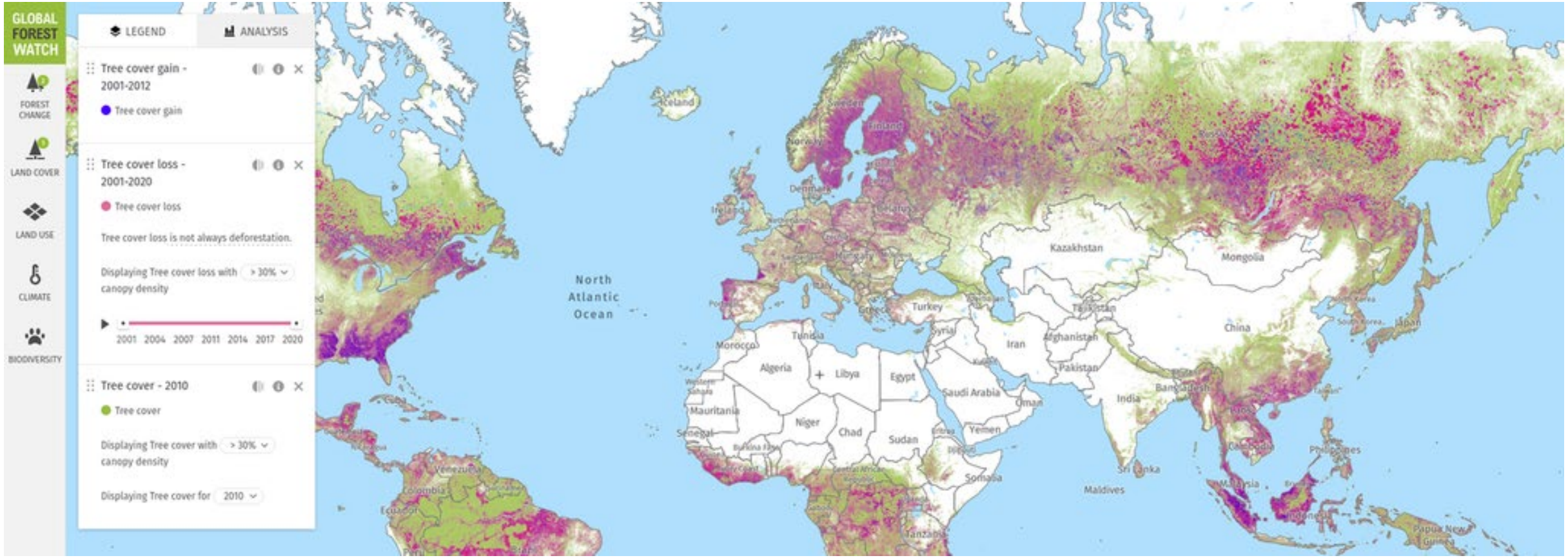
Time Series Tools

Google Earth Engine Time Lapse https://earthengine.google.com/timelapse/



Time Series Tools

Global Forest Watch



http://www.globalforestwatch.org

Time Series Tools

NASA Earth Observatory

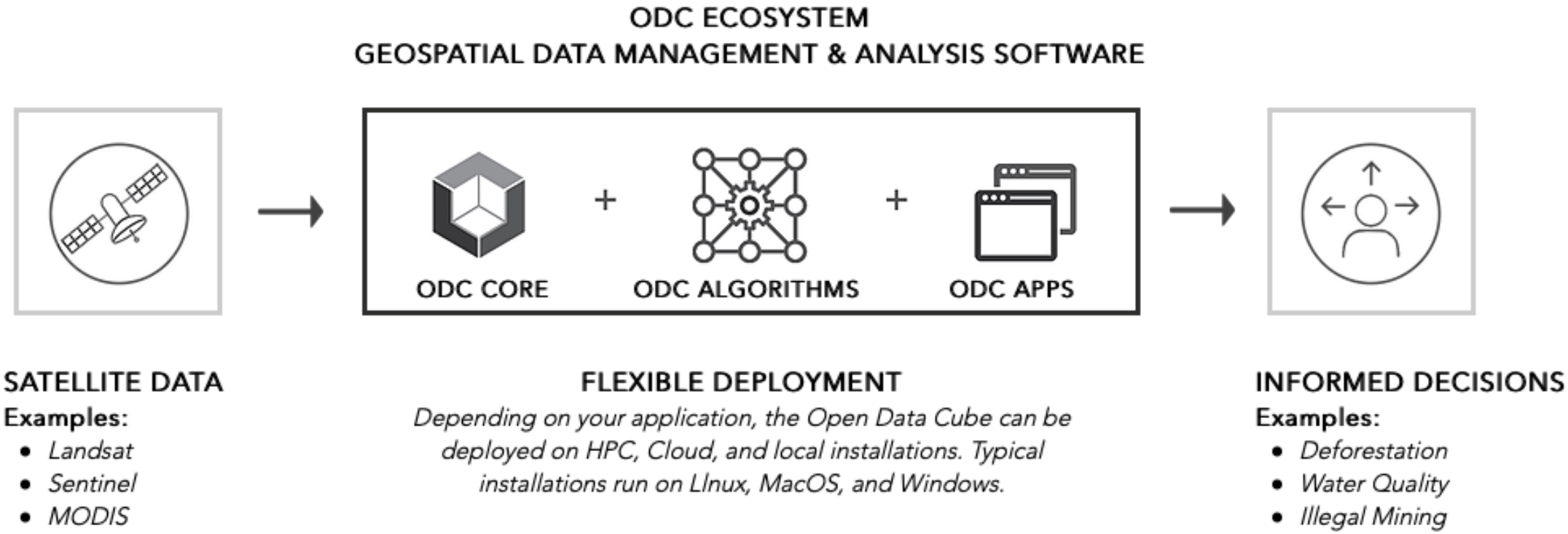
MODIS

https://earthobservatory.nasa.gov/images

Time Series Tools

Open Data Cube

- Open source geospatial data management and analysis software project

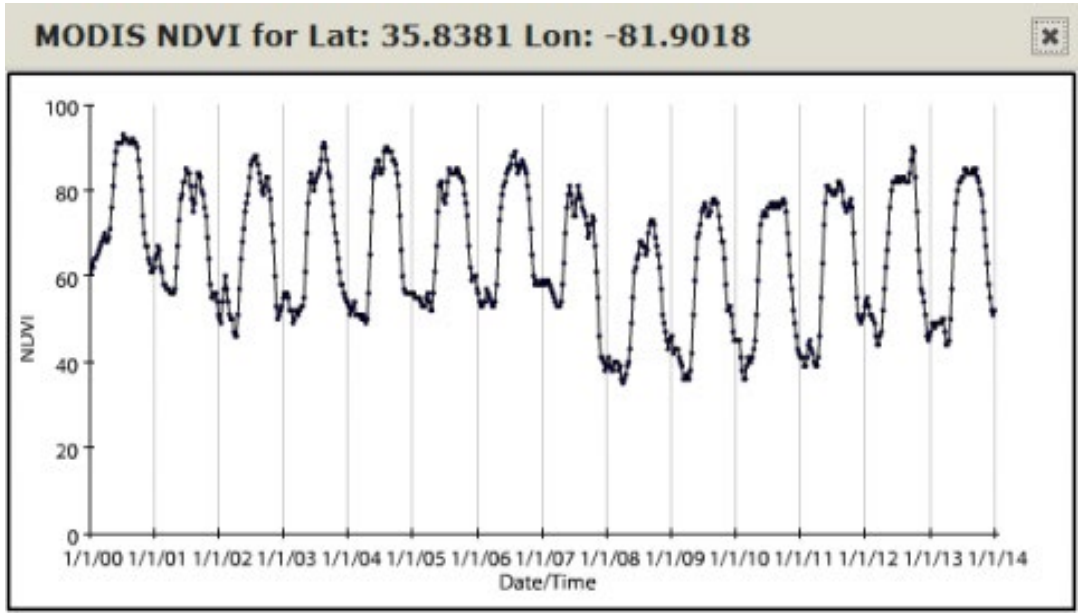


https://www.opendatacube.org | https://datacube.remote-sensing.org

Time Series Tools

Time Series Graphing

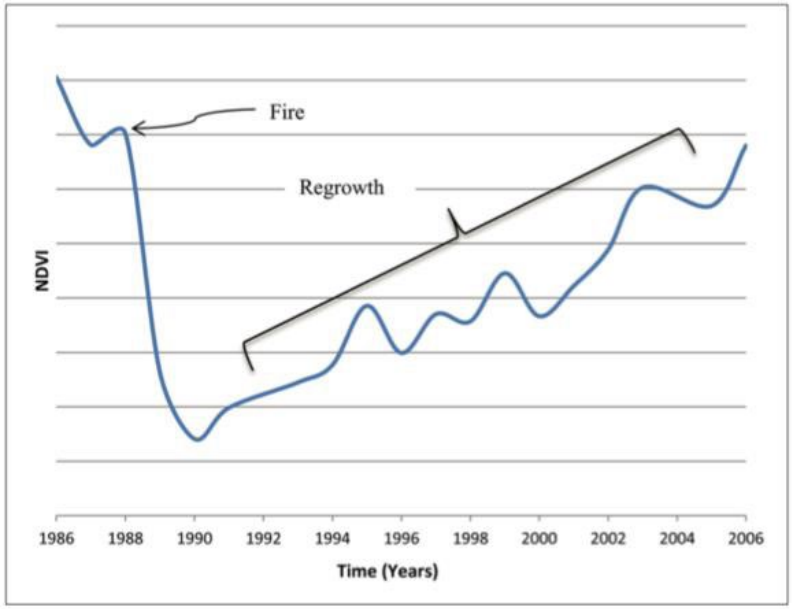
Phenology: Monthly NDVI



What are the trends?

- Annual max., min., or mean

Disturbances: Annual trends



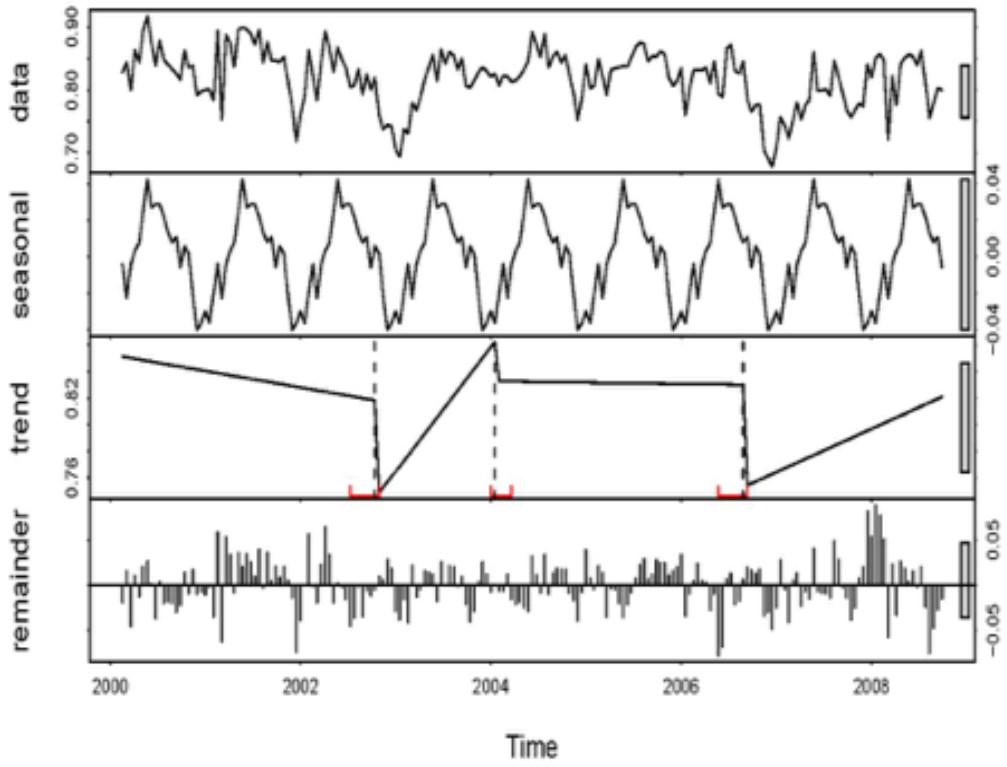
Changes in NDVI values between 1986 and 2006 for one site in Yellowstone National Park

Time Series Tools

BFAST: Breaks for additive Seasonal and Trend Methods

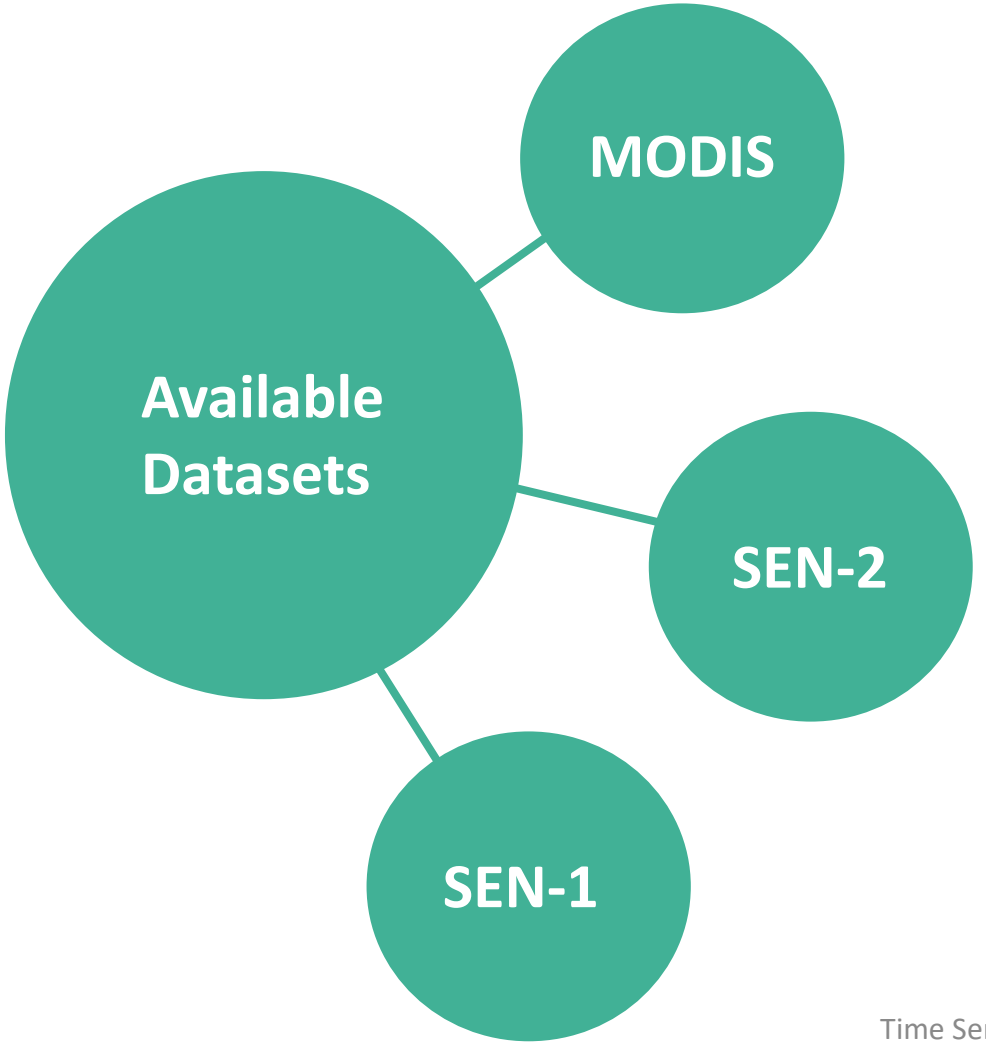
- Decomposes time series satellite data into trend, seasonal and remainder components
- Allows you to pinpoint the location and timing of changes
- Available as an R package: http://bfast.r forge.r project.org

NDVI time series of a pine plantation

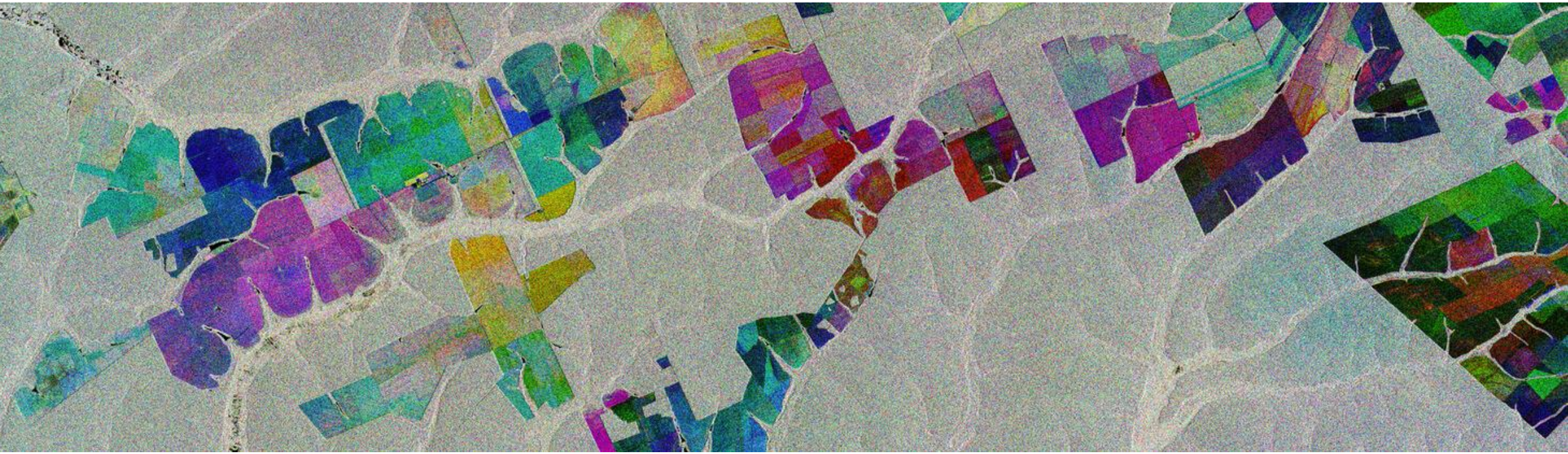


Verbesselt , J. et al. (2010). Detecting trend and seasonal changes in satellite image time series. Remote Sensing of Environment 114 (1): 106-115

Time Series Datasets



- **MODIS** (2004 – present):
  NDVI, 16-days, 250 m
- **Sentinel-2** (2021 - 2022):
  monthly mean,
  all available bands, 10 m
- **Sentinel-1** (2021 + 2022):
  2021: VV, VH backscatter,
  12-days, 20 m



Thank you very much for your attention!
Questions?