Trend analysis with MODIS data (in R)

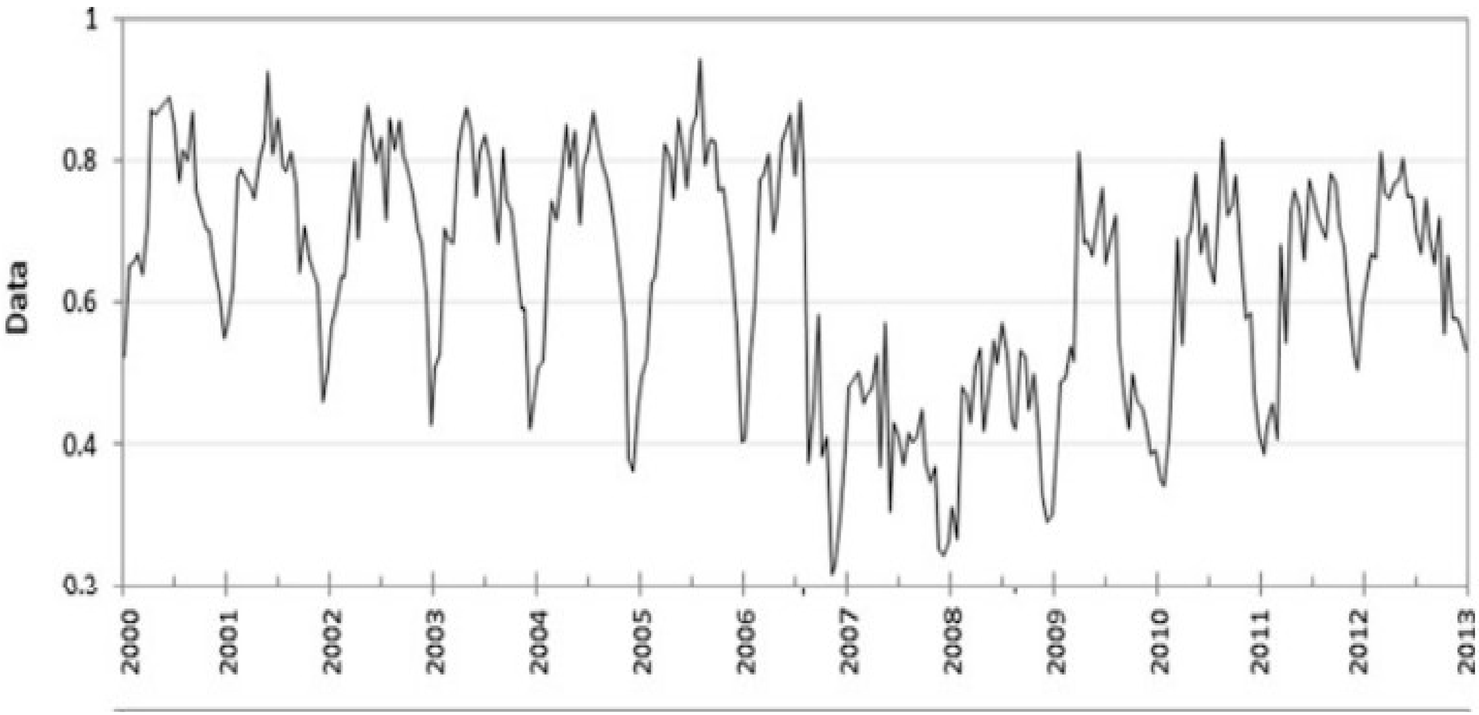
Introduction to satellite-based time series analysis to detect trends in biomass

Trend analysis with MODIS data (in R)

1) Introduction to trend analysis
2) Introduction to the MODIS data
3) Practice: Download and handling of MODIS time series
4) Practice: Analysis of MODIS time series

1) Introduction to Trend analysis

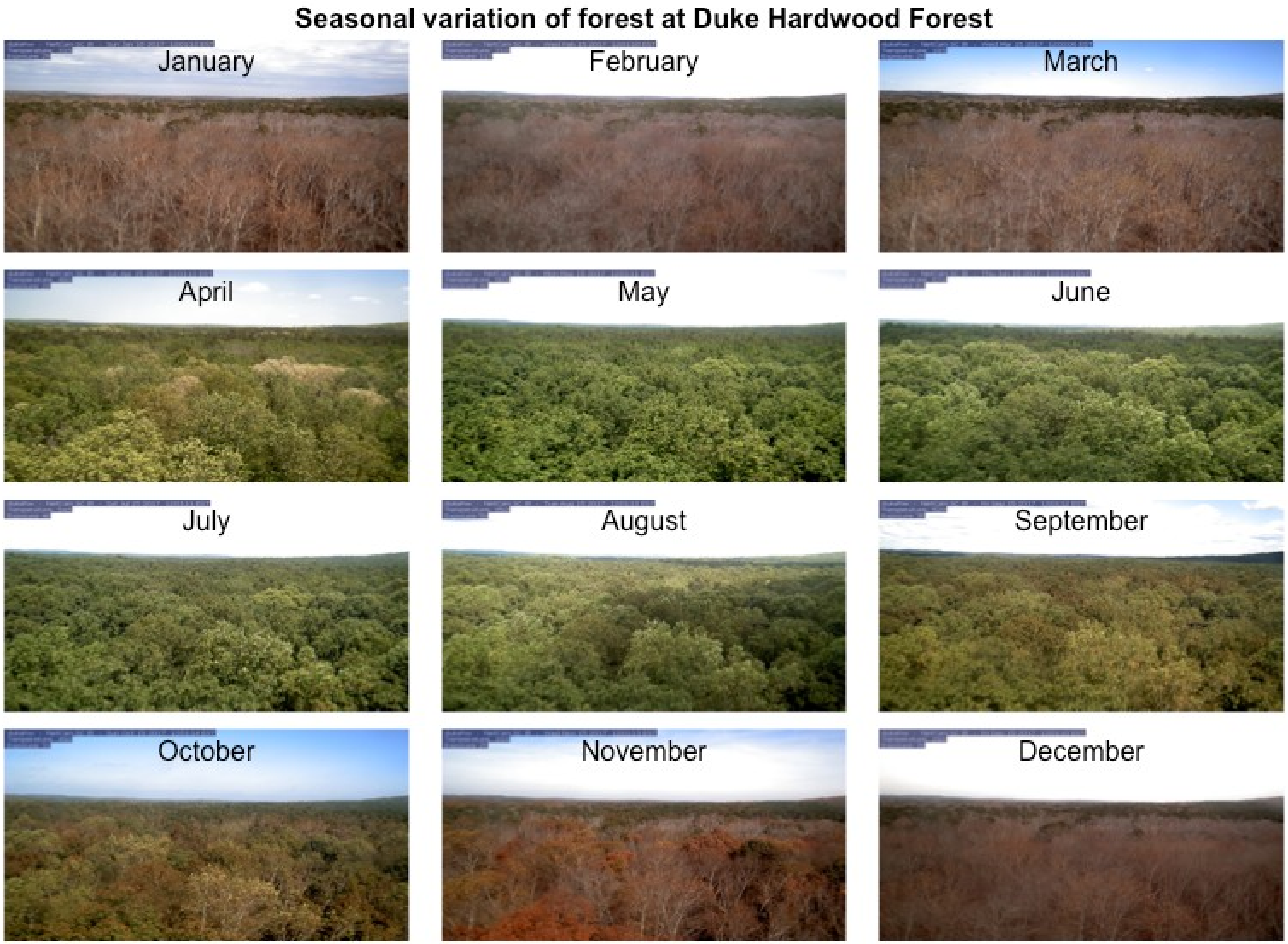
Example time series of NDVI



Fensholt et al., 2015

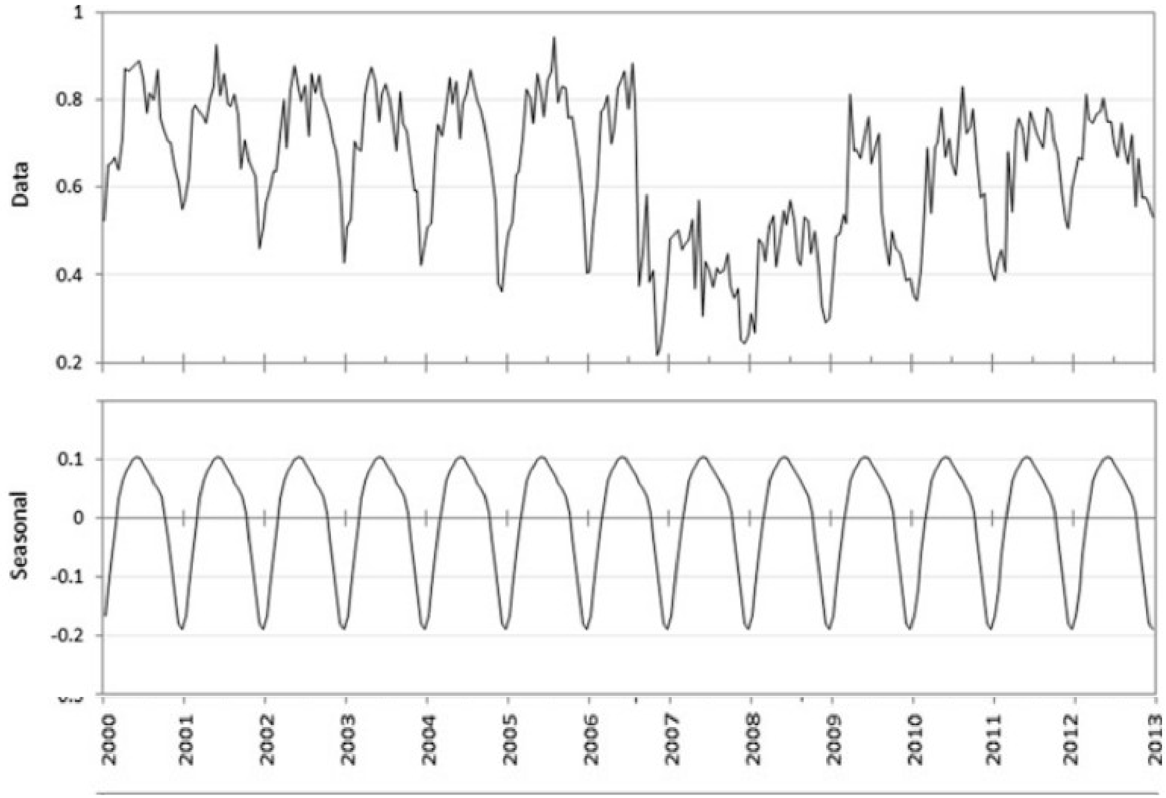
Aim: Decomposition of time series into trend, season, and remainder components
e.g. using the BFAST algorithm: https://bfast.r-forge.r-project.org/

Seasonal changes



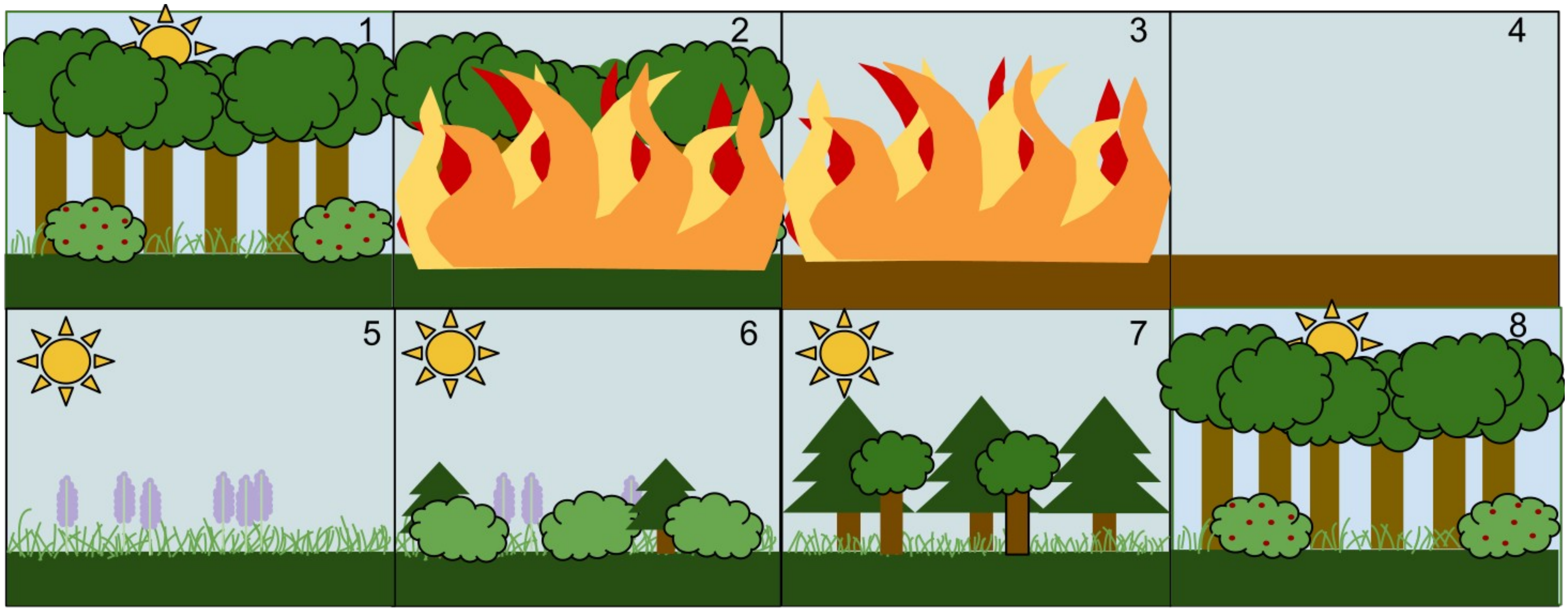
https://cran.r-project.org/web/packages/phenocamapi/vignettes/getting_started_phenocam_api.html

Seasonal changes



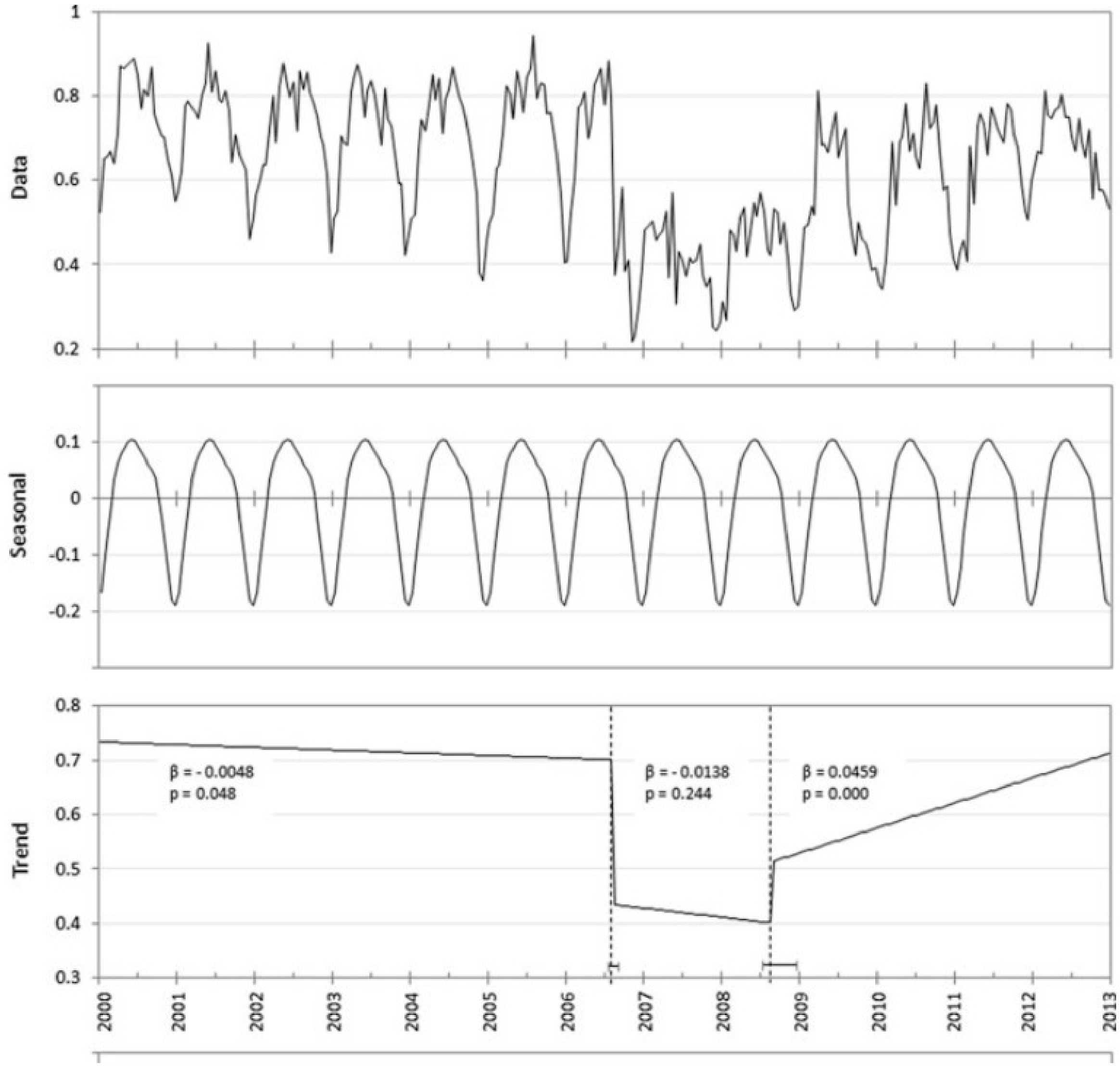
Fensholt et al., 2015

Trend (and breakpoints)



Katelyn Murphy (https://commons.wikimedia.org/w/index.php?curid=19646187)

Trend (and breakpoints)

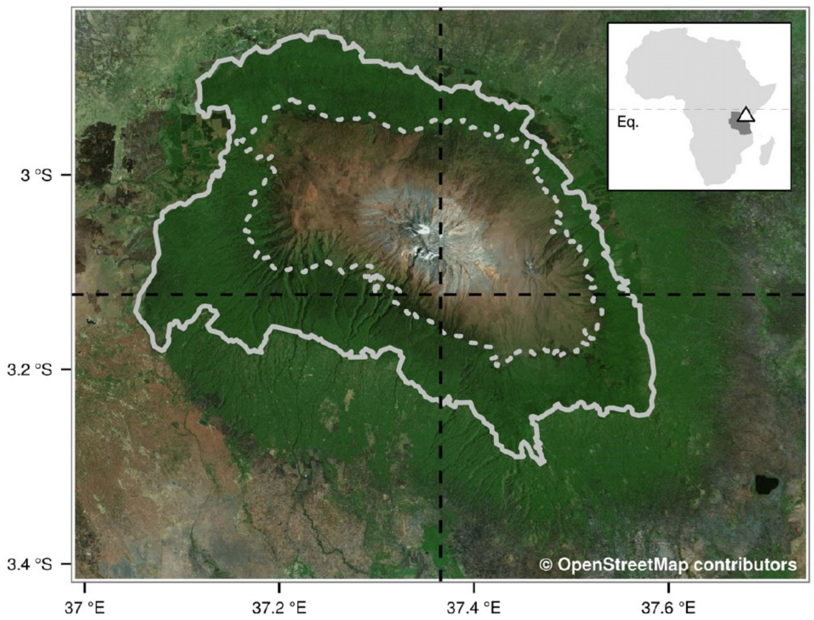


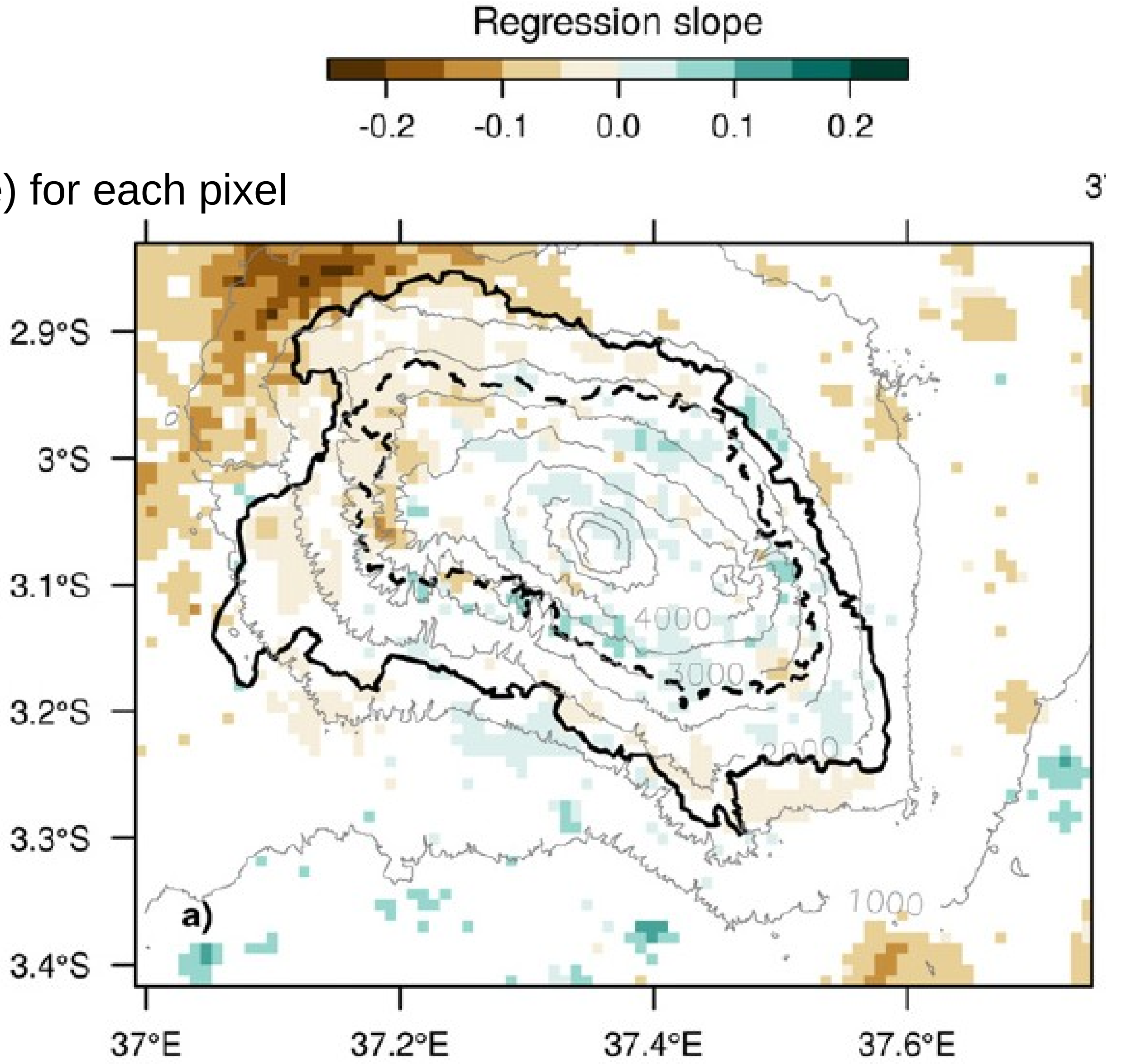
Fensholt et al., 2015

Trend (spatial)

Change of the NDVI
at the Kilimandscharo

Each satellite pixel has a time series
...So we can calculate the trend (slope) for each pixel

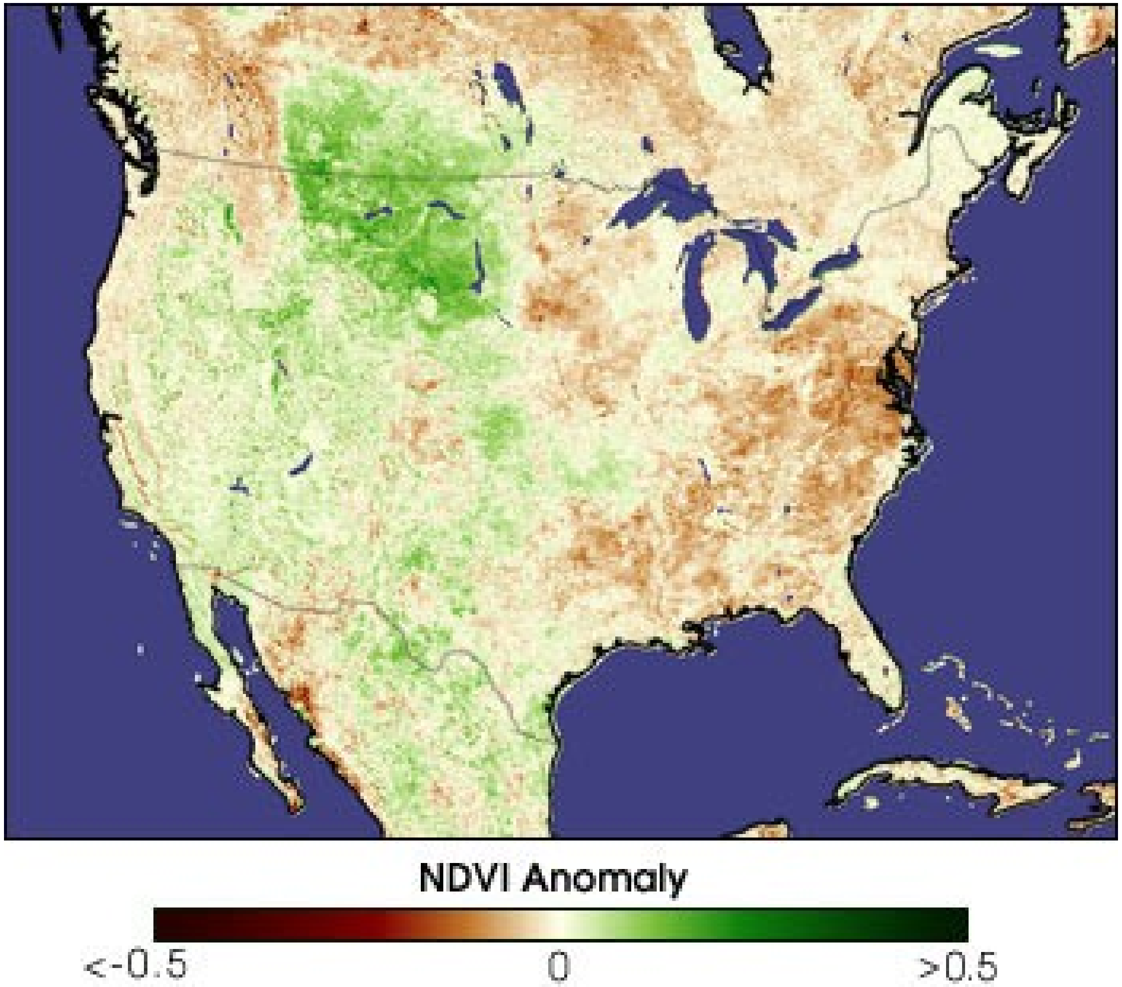




Detsch et al., 2016

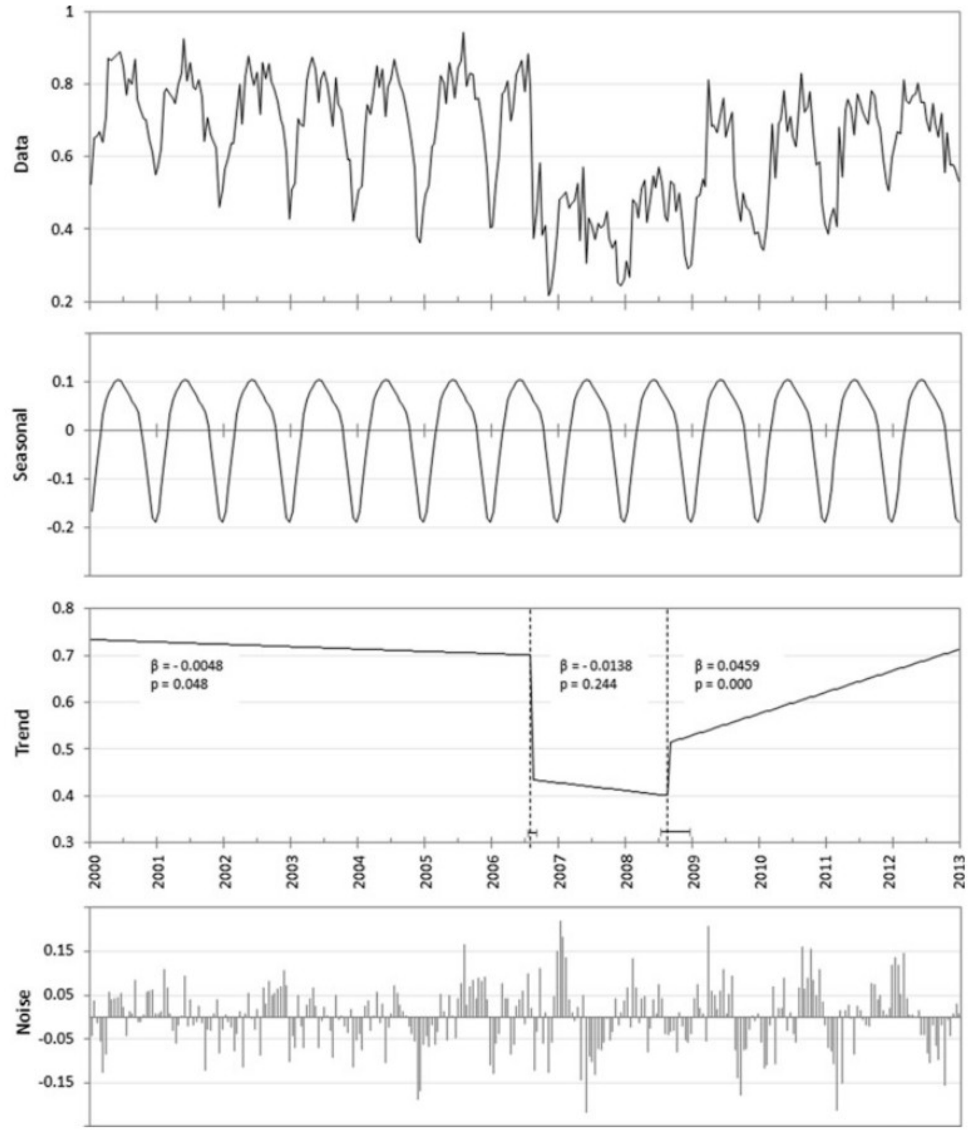
Anomalies

- e.g. extreme events
- But also noise in the data



https://earthobservatory.nasa.gov

Anomalies



Fensholt et al., 2015

2) Introduction to MODIS data

MODIS

- Moderate Resolution Imaging Spectroradiometer (MODIS)
- onboard 2 NASA Satellites: Terra&Aqua
- Since 1999
- 36 spectral channels (VIS-TIR)
- 2x per day (4 in total)
- 250m-1km spatial resolution

MODIS Produkts

- https://modis.gsfc.nasa.gov/data/dataprod/
- Vegetation indices, fire frequency, Land surface temperature, land cover, etc
- Often provided as daily, 16-days, yearly composites

MODIS NDVI

- Available as 16-Day product
- Global, 250m
- Product-ID: MOD13Q1 (Terra) and/or MYD13Q1 (Aqua)

Data Availability

- LP DAAC: Land Processes Distributed Active Archive Center
- The Level-1 and Atmosphere Archive & Distribution System (LAADS) Distributed Active Archive Center (DAAC)

3) Download and handling of MODIS data

Data Download in R via the MODIS package

- https://cran.r-project.org/web/packages/MODIS/index.html
- MODIS package for Acquisition and Processing of MODIS Products

Getting started:

```
library(MODIS)

#EarthdataLogin() # urs.earthdata.nasa.gov download MODIS data from LP DAAC

lap = "/home/hanna/Documents/Data/MODIS/"
MODISoptions(lap, outDirPath = file.path(lap, "PROCESSED")
             , MODISserverOrder = c("LPDAAC", "LAADS"), quiet = TRUE)
```

Data Download in R via the MODIS package

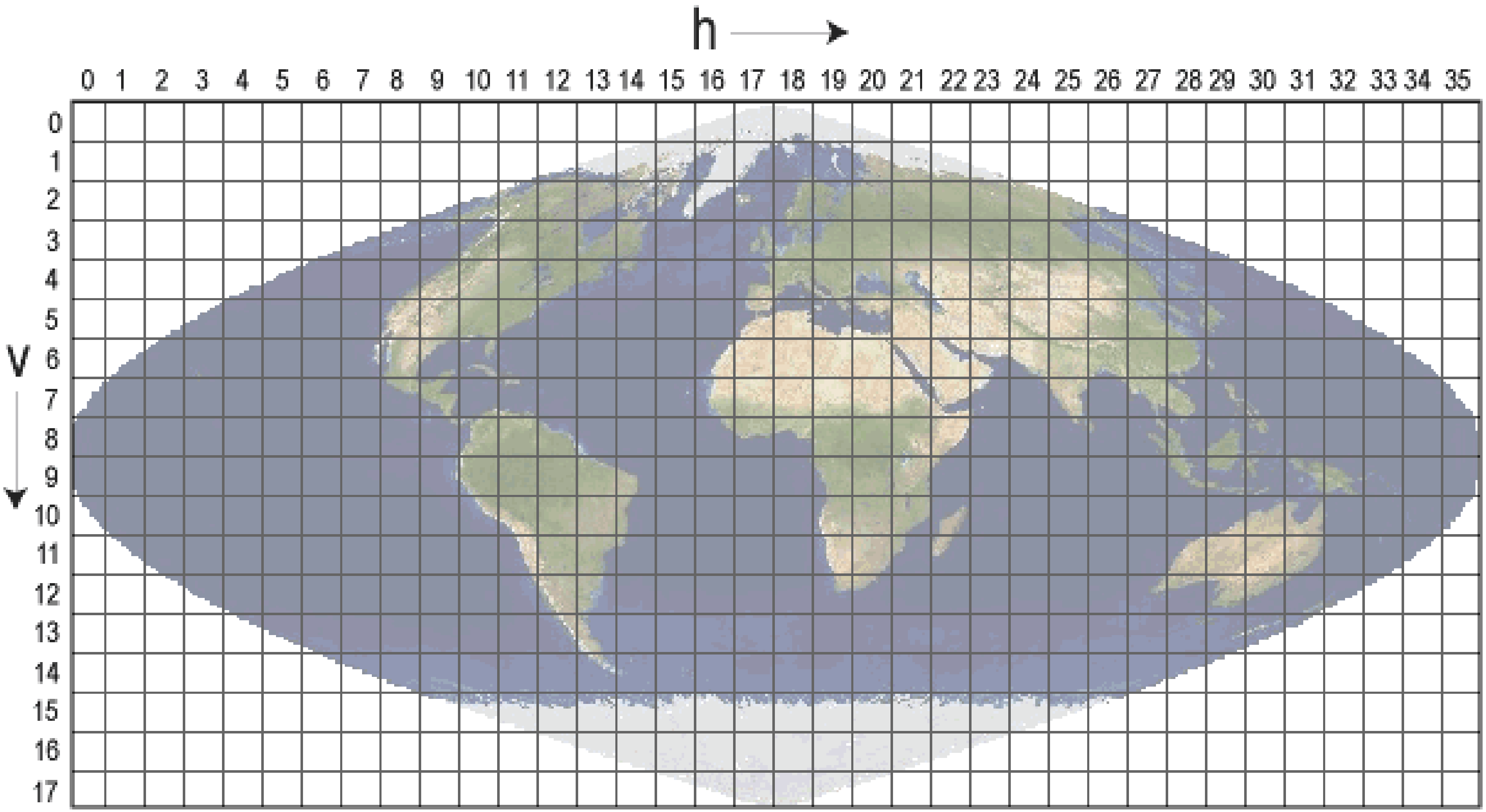
Download data:

Product. Look up at https://modis.gsfc.nasa.gov/data/dataprod/

```
### download data
getHdf("MOD13Q1",begin = "2002.01.01", end = "2020.01.01",
          tileH = 18, tileV = 3)
```

MODIS tile. See next slide

Data Download in R via the MODIS package



https://modis-land.gsfc.nasa.gov/MODLAND_grid.html

Process data

- Extract only relevant bands
- Projection
- ...

Specify job so that only data that are not yet processed are processed

```
### process data (extract NDVI only)
runGdal(job="NDVI_Germany","MOD13Q1",begin = "2002.01.01", end = "2020.01.01",
        tileH = 18, tileV = 3
        , SDSstring = "100000000000")
```

Only NDVI band. See e.g. layers in https://lpdaac.usgs.gov/products/mod13q1v006/ See next slide

Order of SDS

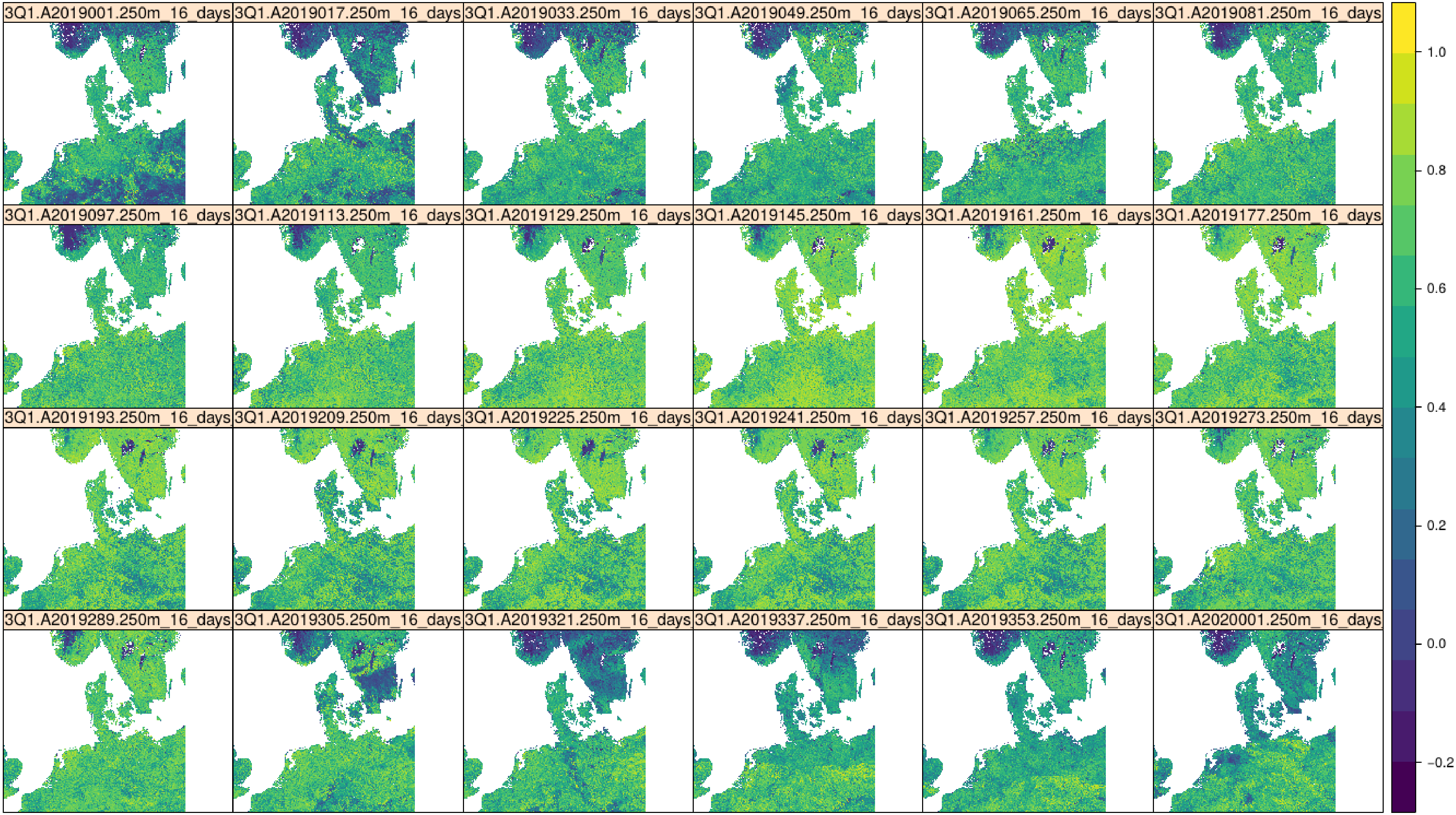
Layers

SDS Name	Description	Units	Data Type	Fill Value	No Data Value	Valid Range	Scale Factor
250m 16 days NDVI	16 day NDVI	NDVI	16-bit signed integer	-3000	N/A	-2000 to 10000	0.0001
250m 16 days EVI	16 day EVI	EVI	16-bit signed integer	-3000	N/A	-2000 to 10000	0.0001
250m 16 days VI Quality	VI quality indicators	Bit Field	16-bit unsigned integer	65535	N/A	0 to 65534	N/A
250m 16 days red reflectance	Surface Reflectance Band 1	N/A	16-bit signed integer	-1000	N/A	0 to 10000	0.0001
250m 16 days NIR reflectance	Surface Reflectance Band 2	N/A	16-bit signed integer	-1000	N/A	0 to 10000	0.0001
250m 16 days blue reflectance	Surface Reflectance Band 3	N/A	16-bit signed integer	-1000	N/A	0 to 10000	0.0001
250m 16 days MIR reflectance	Surface Reflectance Band 7	N/A	16-bit signed integer	-1000	N/A	0 to 10000	0.0001
250m 16 days view zenith angle	View zenith angle of VI Pixel	Degree	16-bit signed integer	-10000	N/A	0 to 18000	0.01
250m 16 days sun zenith angle	Sun zenith angle of VI pixel	Degree	16-bit signed integer	-10000	N/A	0 to 18000	0.01
250m 16 days relative azimuth angle	Relative azimuth angle of VI pixel	Degree	16-bit signed integer	-4000	N/A	-18000 to 18000	0.01
250m 16 days composite day of the year	Day of year VI pixel	Julian day	16-bit signed integer	-1	N/A	1 to 366	N/A
250m 16 days pixel reliability	Quality reliability of VI pixel	Rank	8-bit signed integer	-1	N/A	0 to 3	N/A

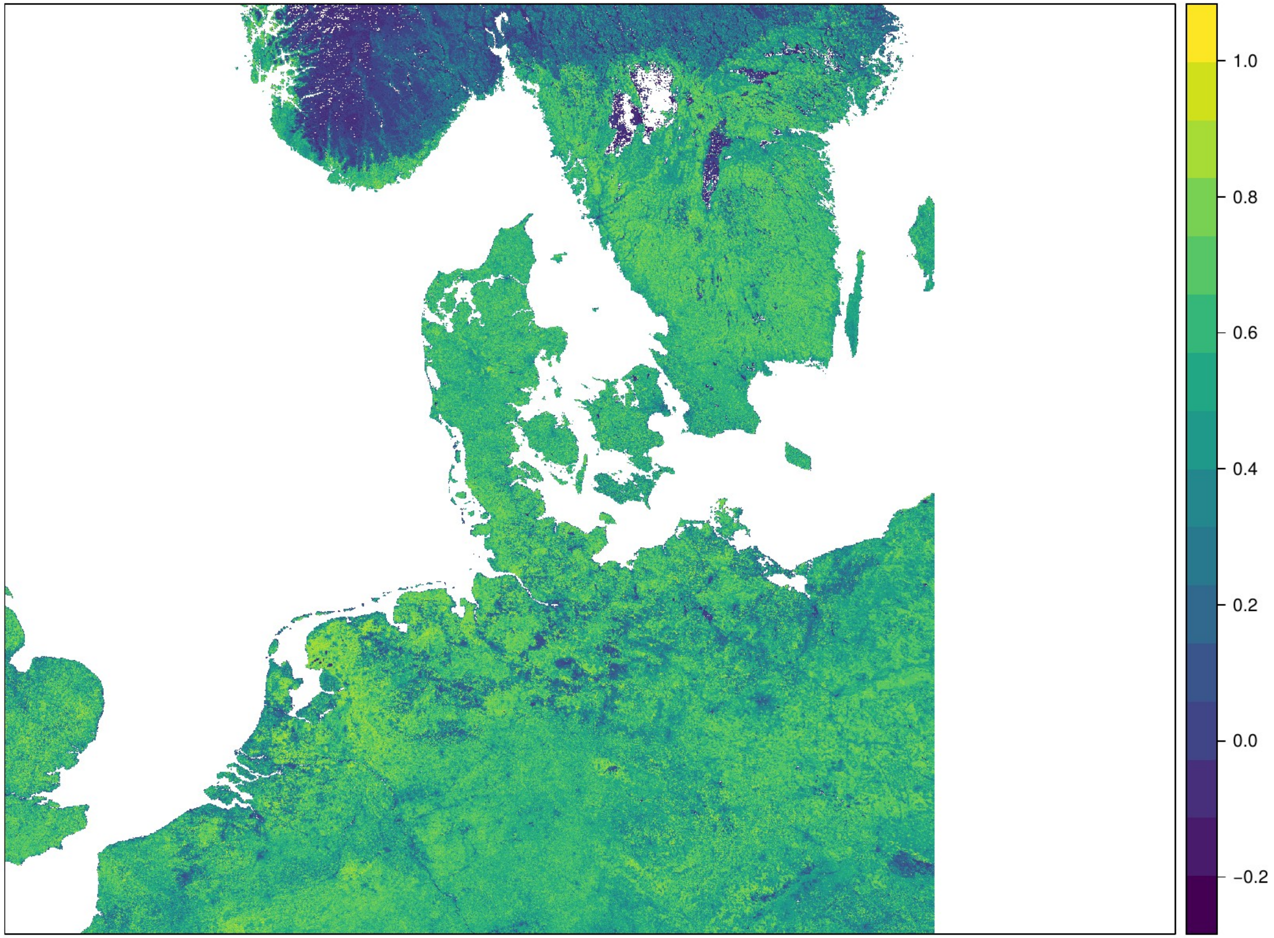
Load and visualize the data

```
library(raster)
library(viridis)
# Path to the Processed MODIS data:
setwd("/home/hanna/Documents/Data/MODIS/PROCESSED/NDVI_Germany/")

# Load all MODIS data:
dat <- stack(list.files())

# Visualize a single MODIS scene (note: unit is NDVI*0.0001):
spplot(dat[[1]]* 0.0001,col.regions=viridis(100))
```

Load and visualize the data

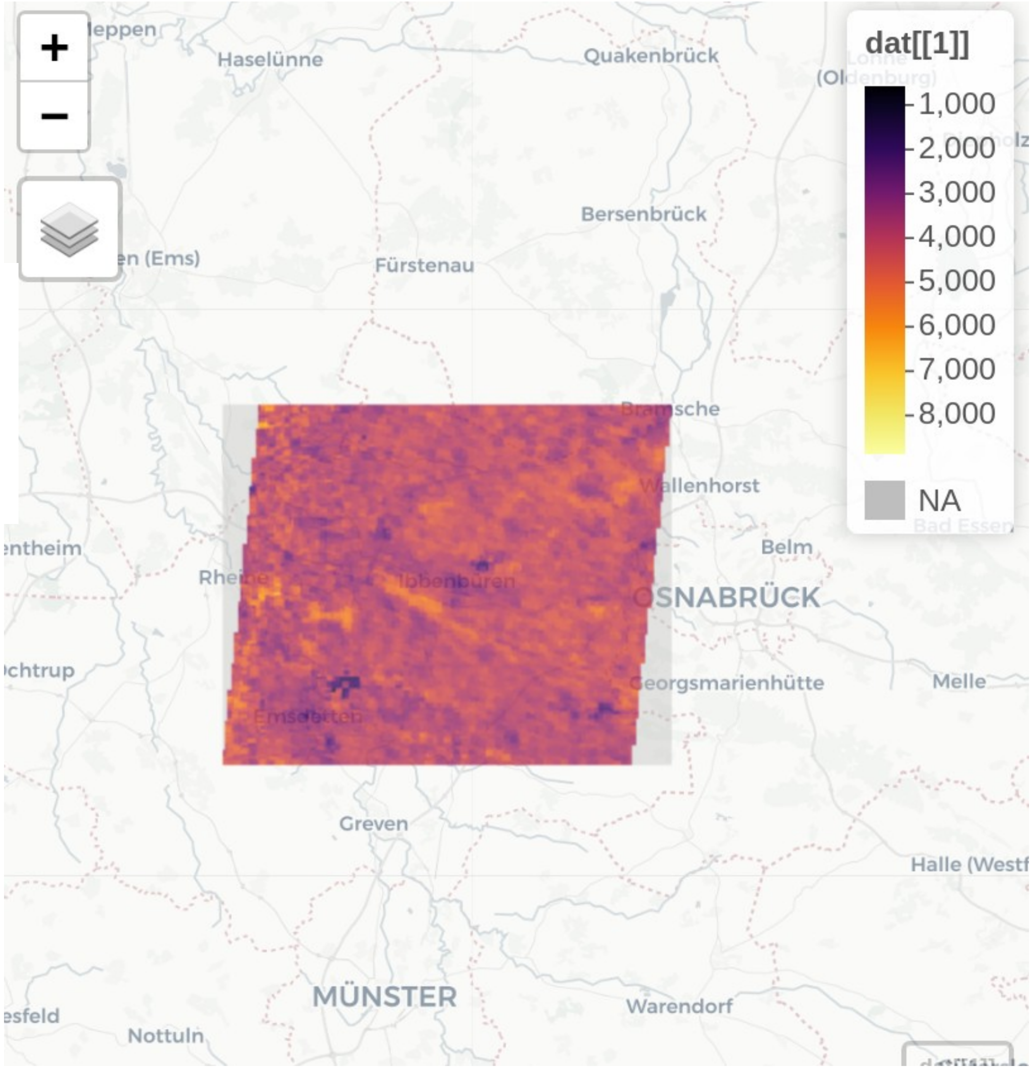


Load and visualize the data



Crop data to area of interest

```
# crop to area of interest:
dat <- crop(dat,c(506632.5, 541380.9,
                  5797432, 5827779))
mapview(dat[[1]])
```



4) Time series analysis with MODIS data

Spatial time series analysis

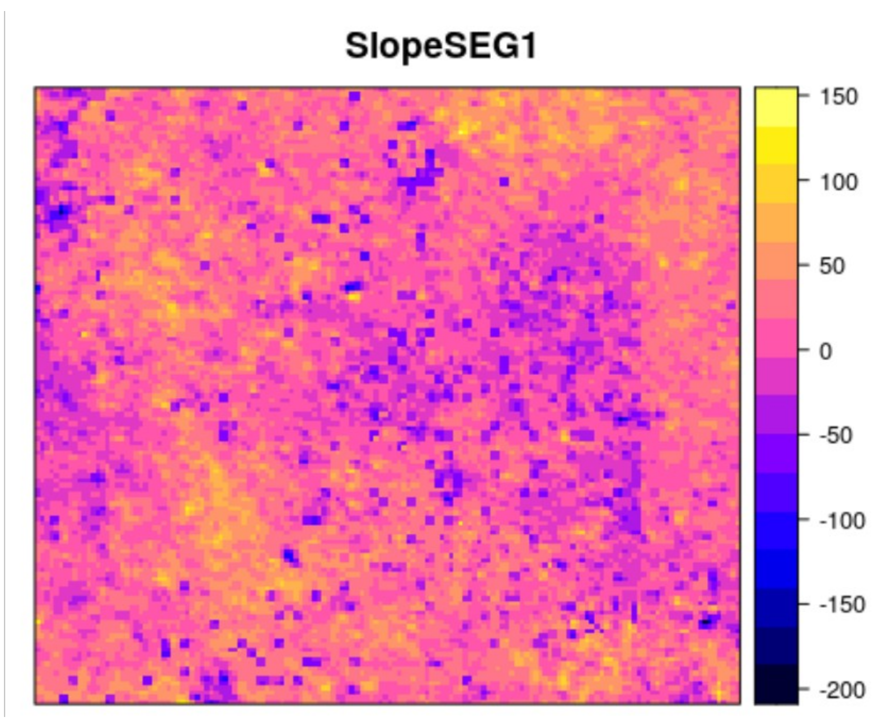
- Time series decomposition for each MODIS pixel
- R packages: “**greenbrown**” (https://greenbrown.r-forge.r-project.org/) or bfastSpatial (http://www.loicdutrieux.net/bfastSpatial/)

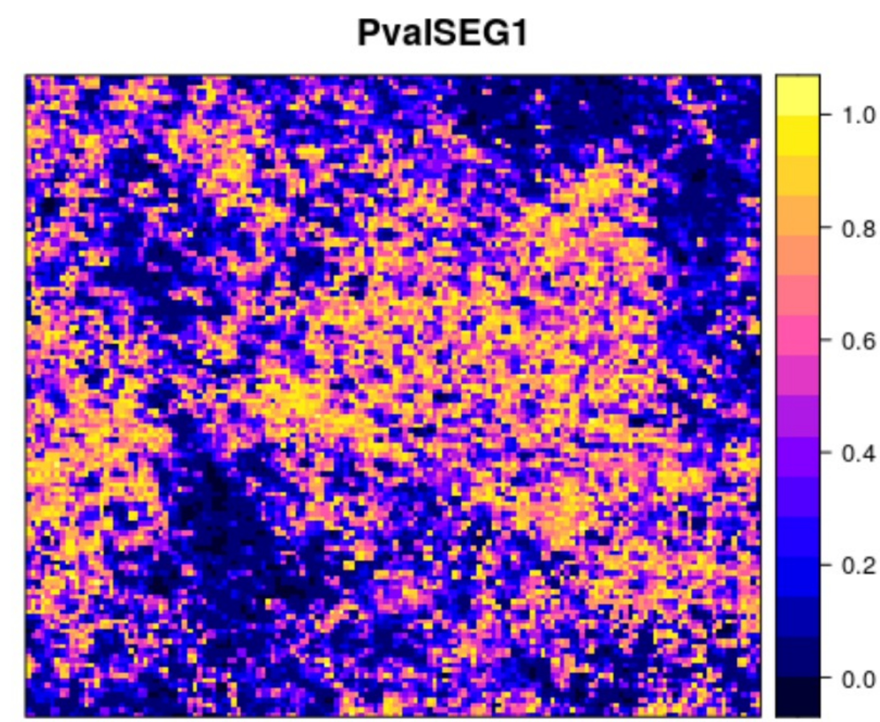
Calculate trend

```r
library(greenbrown)

trend <- TrendRaster(dat, start = c(2002, 1),
                     freq = 23, method="AAT")
plot(trend)
```

Beginning of time series

Number of layers from the same year

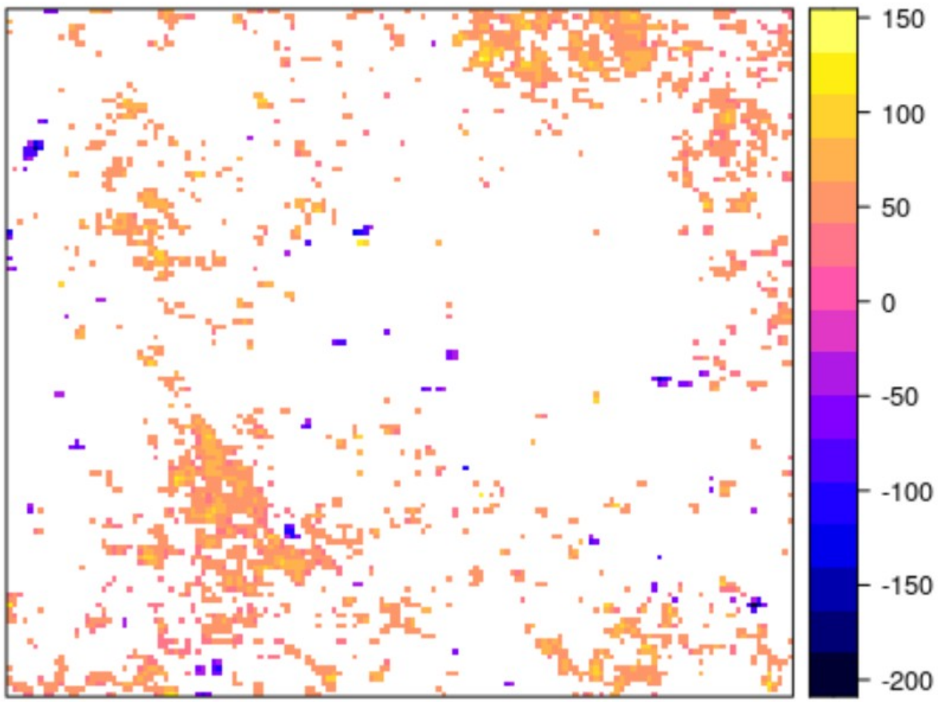




Slope only for significant trends

Focus only on areas where the trend is significant

```
mask <- trend$SlopeSEG1
mask[trend$PvalSEG1>0.05] <- NA
masked_trend <- mask(trend$SlopeSEG1,mask)
```



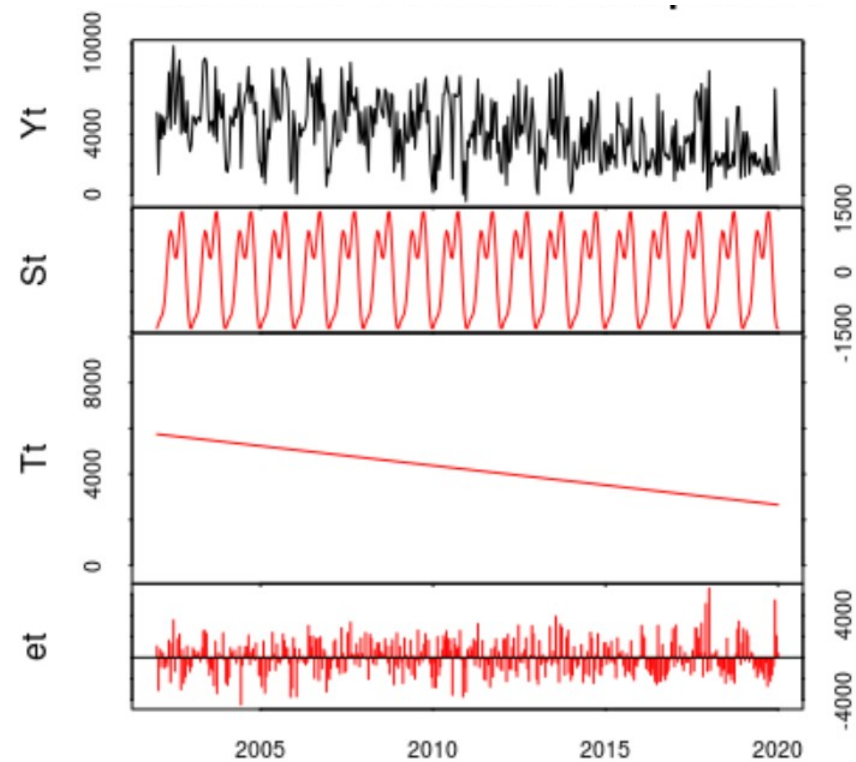
Further processing and visualization

- e.g. crop to area of interest with raster::crop
- Write to file with raster::writeRaster
- Nice visualization e.g. with the tmap package
- Interactive visualization with mapview
- … helpful resource: https://geocompr.github.io/

Time series analysis for single pixels

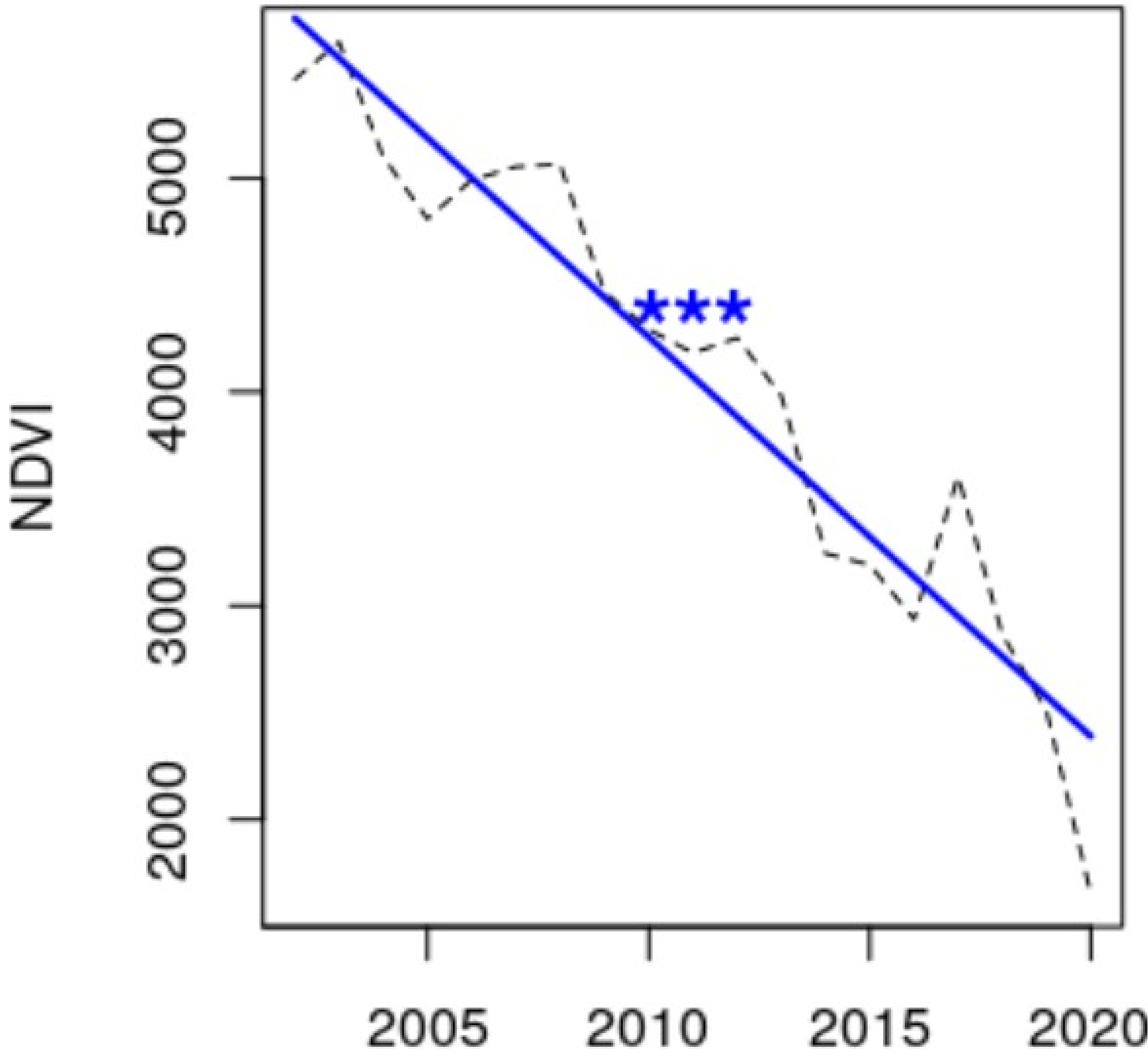
```
##########################################################
#Inspect single pixel location
##########################################################
mostnegchange <- dat[which(values(masked_trend)==min(values(masked_trend),na.rm=T))]
datats <- ts(as.vector(mostnegchange),frequency=23,start=c(2002,1))
ts_bf <- bfast(datats,season="harmonic",max.iter = 1)
plot(ts_bf)
```

e.g. use the pixel with the strongest negative trend



Time series analysis for single pixels

```
#or use the greenbrown package:
ts_gb <- Trend(datats)
plot(ts_gb)
```



Suggestions

- Spatial Trend allows for an area-wide estimation of trends but interpretation is hard
- Trend analysis for a single pixel gives much more insights but limited to that one pixel
- Suggestion: Instead of single pixels you could look at the average time series for an entire homogeneous area (e.g. one pasture)