NDVI time series over Europe from 40 years of AVHRR data – the TIMELINE NDVI product

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.. and Martin Bachmann, Martin Boettcher, Andreas Dietz, Mathias Hofmann, Grit Kirches, Igor Klein, Detmar Krause, Simon Plank, Thomas Popp, Philipp Reiners, Sebastian Roessler, Thomas Ruppert, Alexander Scherbachenko, Ranjitha Vignesh, Meinhard Wolfmüller, Hendrik Zwenzner and Stefan Dech

German Remote Sensing Data Center (DFD)
German Aerospace Center (DLR)

Knowledge for Tomorrow

Effects of climate change on land surface & atmosphere

- Influence of climate change on
    - Vegetation period & productivity
    - Number and frequency of wild fires
    - Start, extent and duration of snow cover
    - Land and sea surface temperature
    - Cloud coverage
    - …

- Remote sensing is a unique tool to quantify changes over long time spans

Mapping geophysical products from ~40 years of AVHRR data
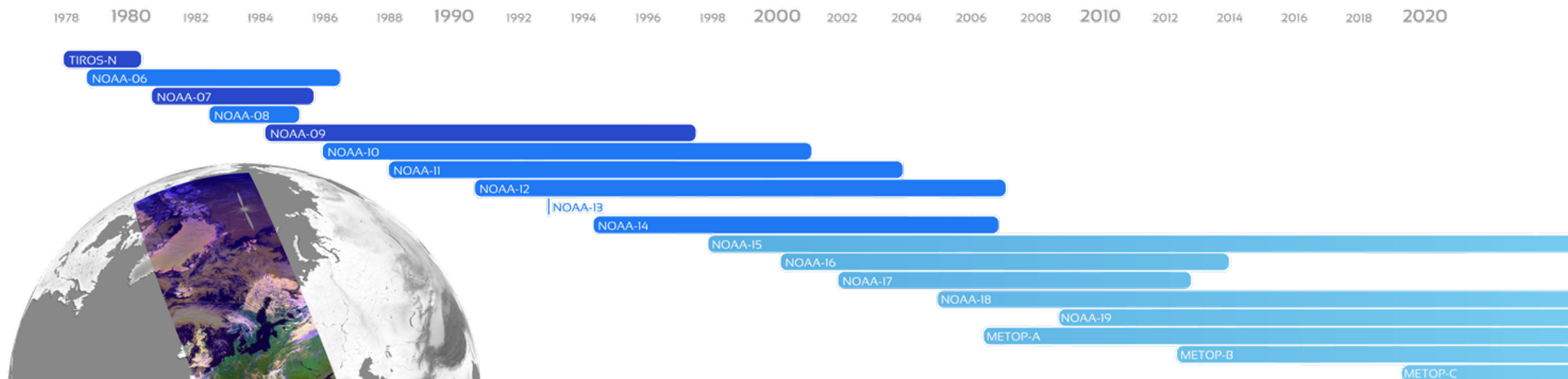

AVHRR Sensor Generations: 1 2 3

Sensors (on 13 different platforms)**:**
AVHRR-1 (4 channels), AVHRR-2 (5 channels) & AVHRR-3 (6 channels)
onboard NOAA 7 - 19 [integrated] and MetOp-A, -B, & -C [being integrated]
Resolution: 1km (LAC + HRTP data)
Coverage: Europe and North Africa

Challenges of working with AVHRR data

Spectral response curves of channel 1

- Variety of AVHRR sensors   → Normalization of sensors
- Noise & errors in data   → Sophisticated L1B processing, adjusted algorithms & accuracy measures

- Missing on-board calibration   → Recalibration of the data
- Orbit drift   → Correction of angular effects
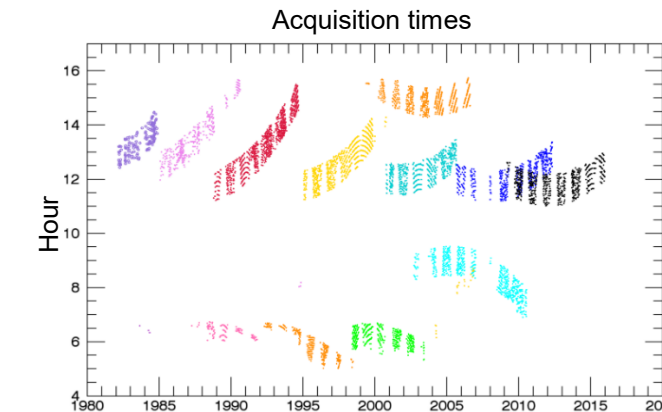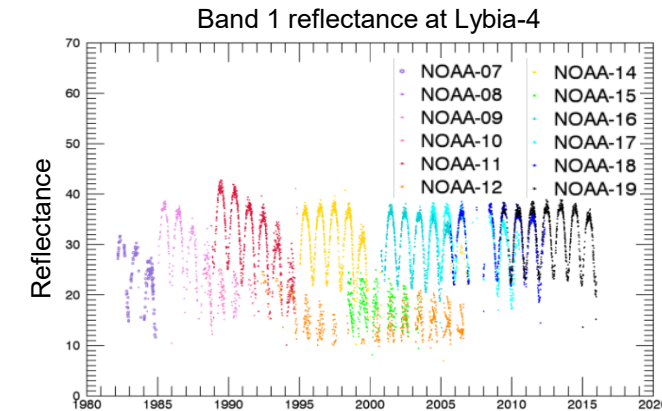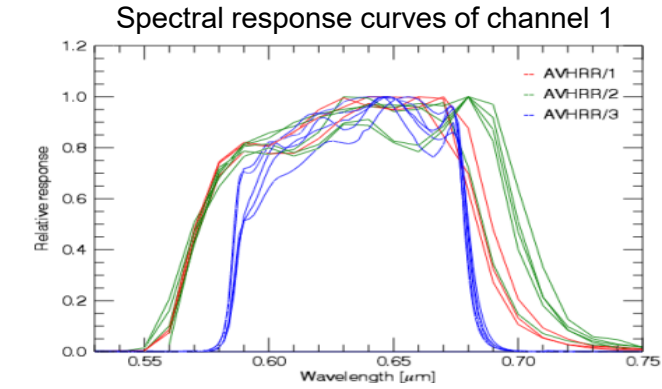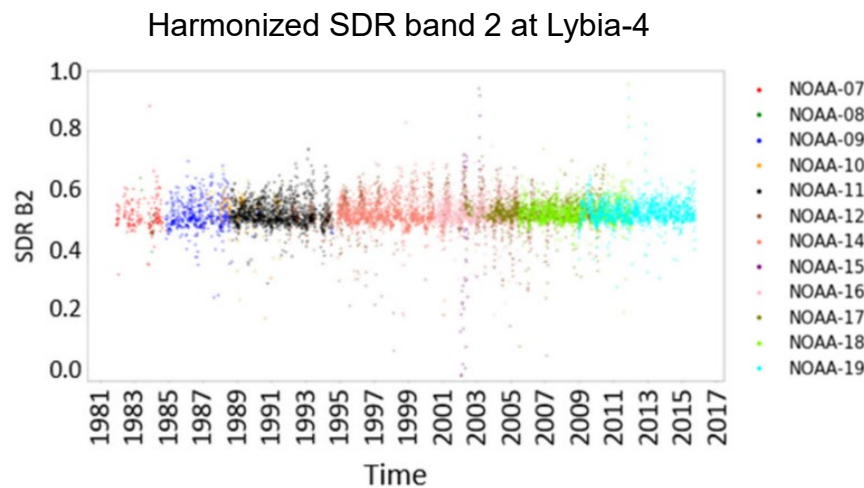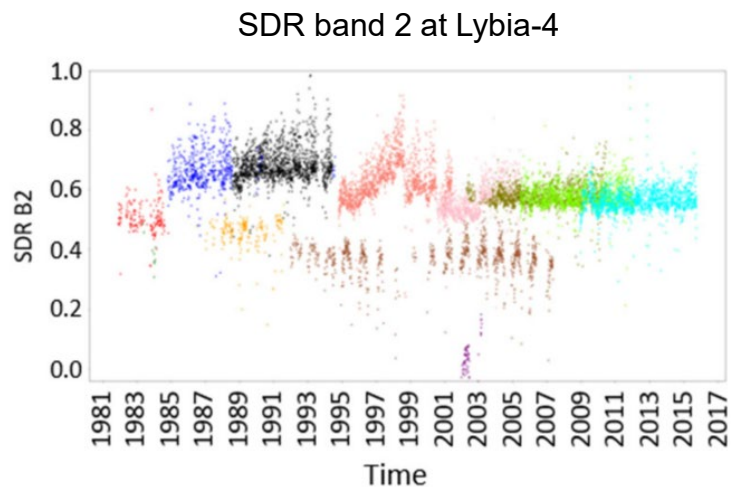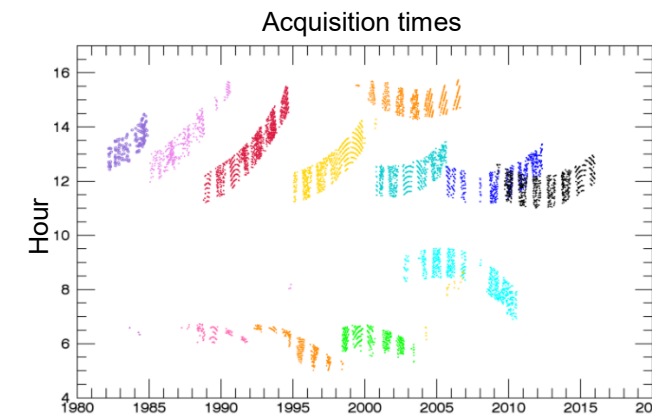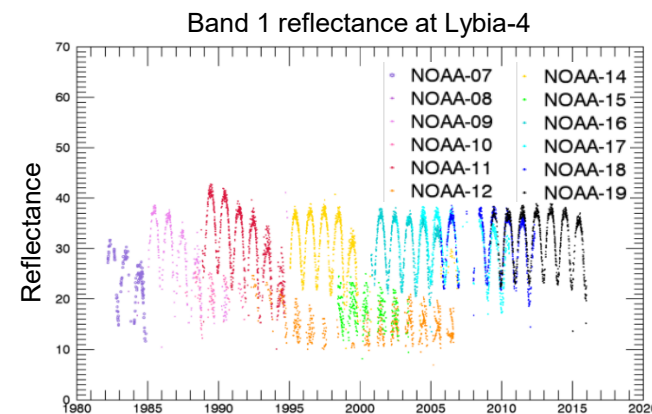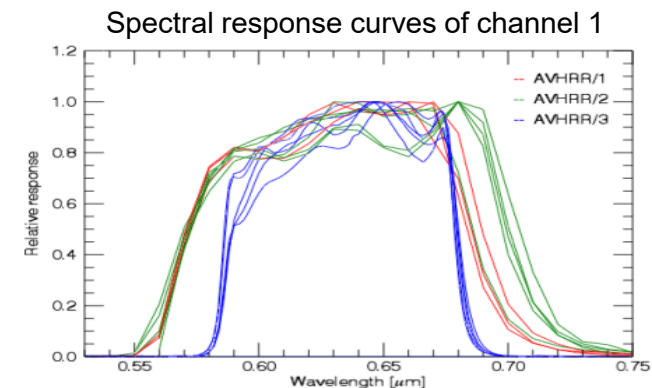- Different acquisition times   → Product-specific correction of time effects
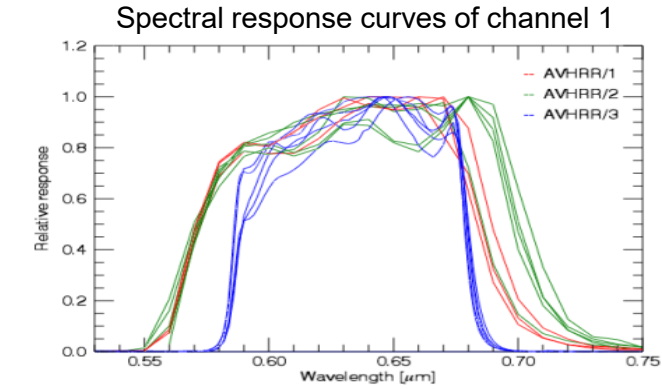
(Bachmann & Müller 2015; Dech et al. 2021)

Challenges of working with AVHRR data

- Variety of AVHRR sensors
- Noise & errors in data

- Missing on-board calibration
- Orbit drift
- Different acquisition times

→ Normalization of sensors

→ Sophisticated L1B processing, adjusted algorithms & accuracy measures

→ Recalibration of the data

→ Correction of angular effects

→ Product-specific correction of time effects

(Bachmann & Müller 2015; Dech et al. 2021)

Spectral response curves of channel 1

Band 1 reflectance at Lybia-4

Acquisition times

Challenges of working with AVHRR data

- Variety of AVHRR sensors
- Noise & errors in data

- Missing on-board calibration
- Orbit drift
- Different acquisition times

→ Normalization of sensors
→ Sophisticated L1B processing, adjusted algorithms & accuracy measures
→ Recalibration of the data ⎤
→ Correction of angular effects ⎦ Harmonization
→ Product-specific correction of time effects

Spectral response curves of channel 1

Band 1 reflectance at Lybia-4

SDR band 2 at Lybia-4

Harmonized SDR band 2 at Lybia-4

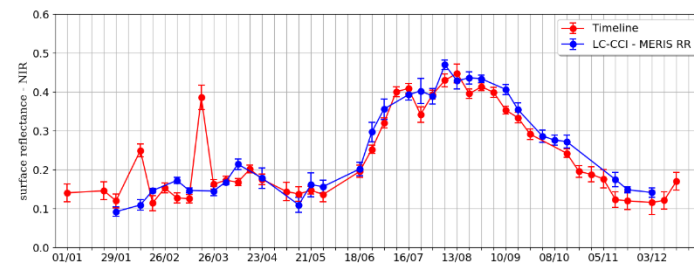Acquisition times

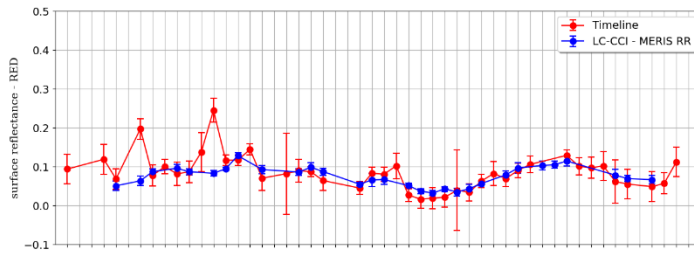(Bachmann & Müller 2015; Dech et al. 2021)

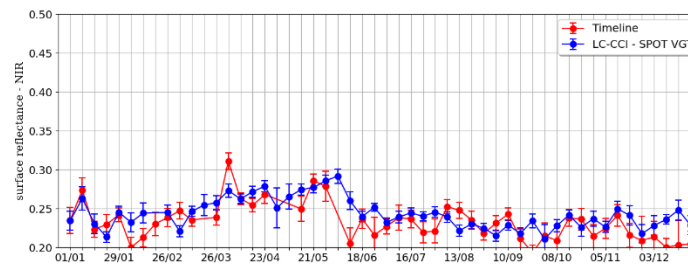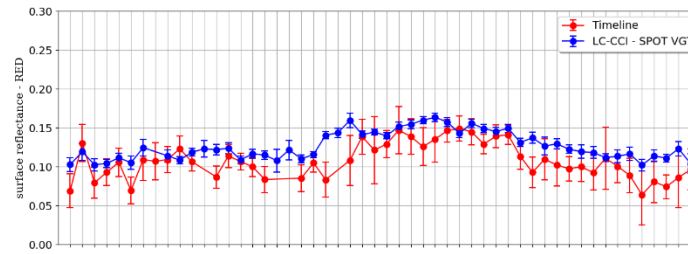# TIMELINE product validation – preliminary results

Comparison of TIMELINE AVHRR Surface Directional Reflectance (SDR) data with SDR data from other sensors
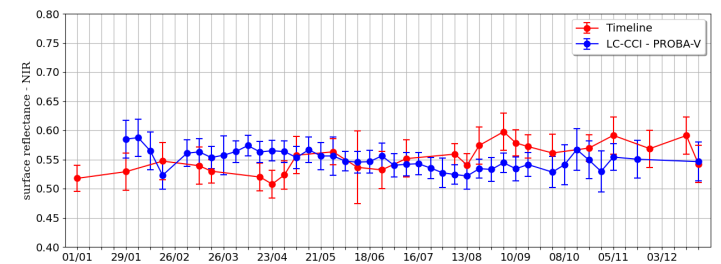

Europe_Rice_Cultivation - year 2010

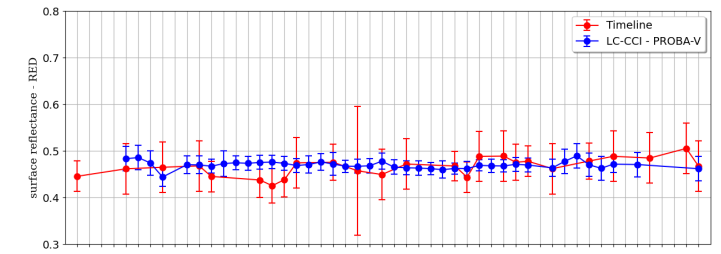CEOS_La_Crau - year 2010

CEOS_Libya4 - year 2015

AVHRR (TIMELINE)   AVHRR (TIMELINE)   AVHRR (TIMELINE)

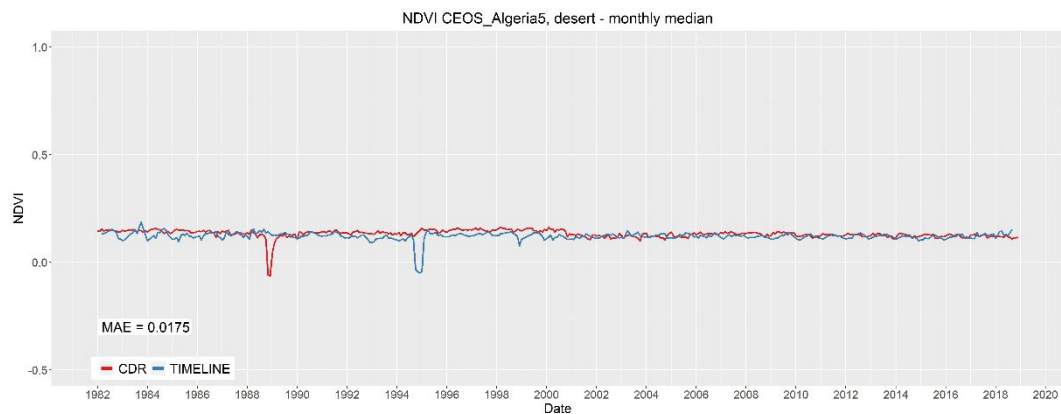MERIS (CCI)   SPOT-VGT (CCI)   PROBA-V (CCI)
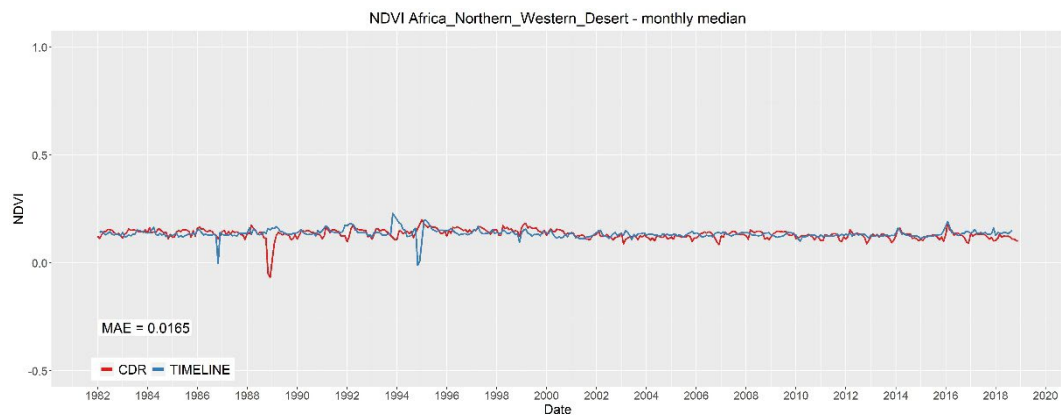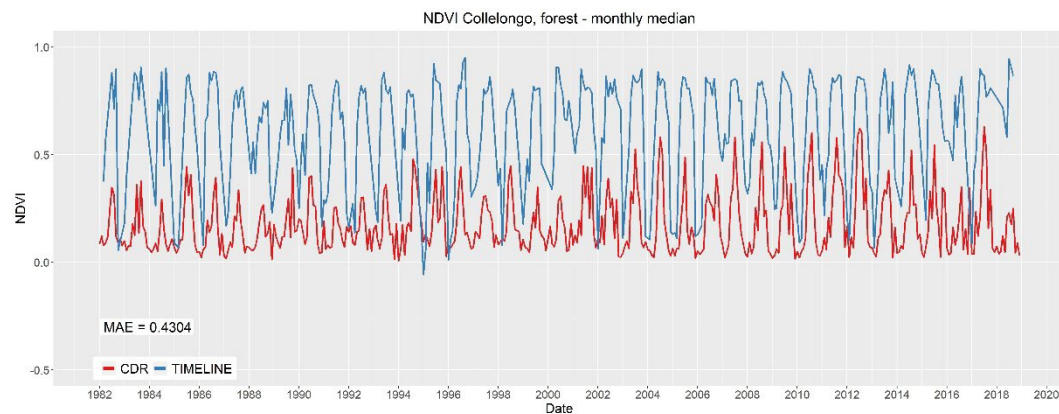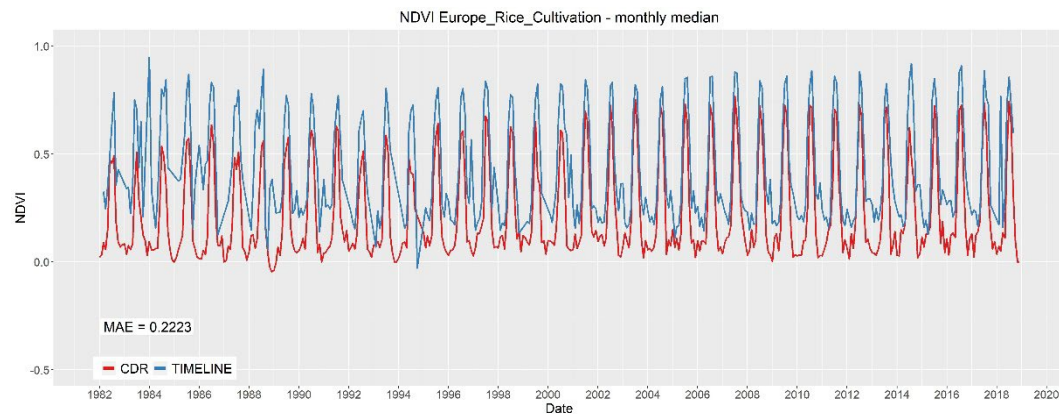
(G. Kirches / Brockmann Consult)

TIMELINE product validation – preliminary results

Comparison of TIMELINE AVHRR Surface Directional Reflectance (SDR) data with NOAA CDR AVHRR NDVI v5

Desert sites

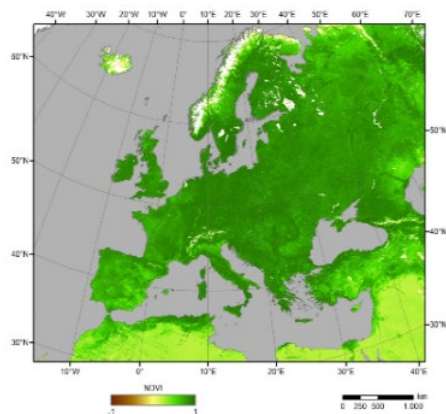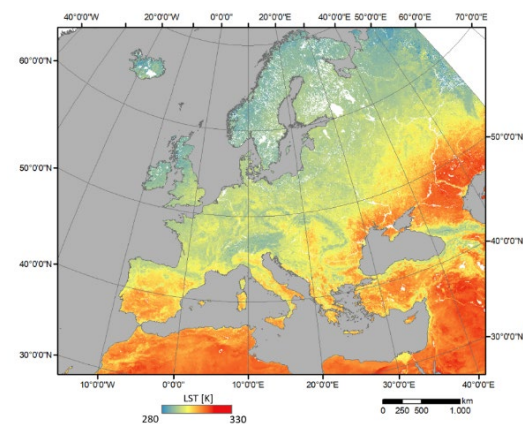Vegetated sites

(Vermote et al. 2014)
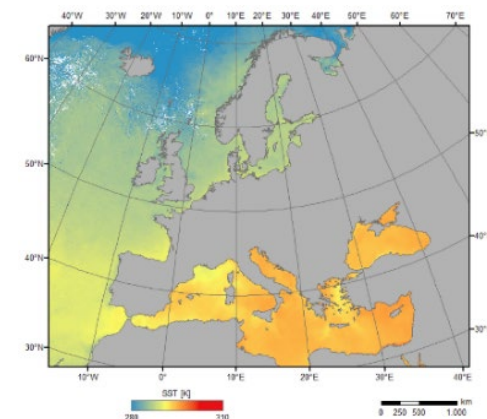
TIMELINE Product examples
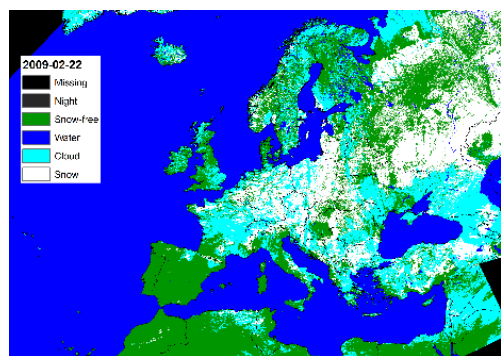
Monthly NDVI (May 2007)
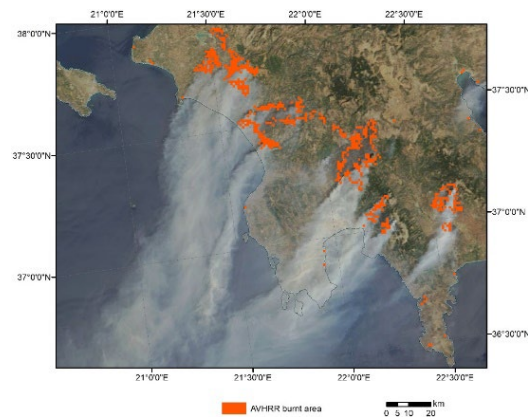
Mean LST (August 2007)

Mean SST (July 2007)

Daily SC (February 22nd 2009)

Burnt area, Greece (August 26–30, 2007)

Cloud FC (July 2001, 14:00-15:00)
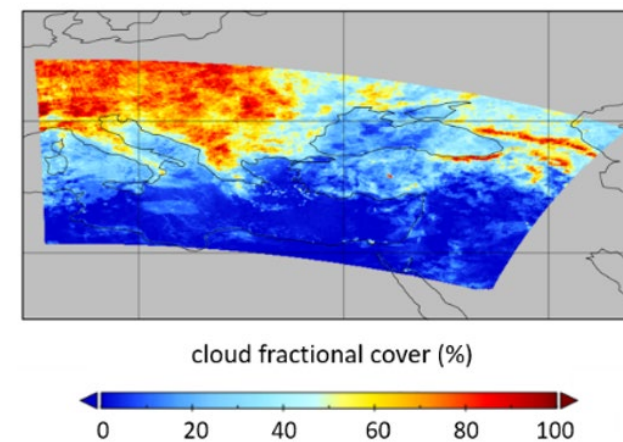
Generation of TIMELINE L3 NDVI composites

- Several compositing approaches tested:
  - MVC, multiple criteria compositing (stepwise constraints or weighted), MODIS back up,…

- Criteria for evaluating compositing methods:
  - Occurrence of artefacts or data gaps
  - NDVI saturation
  - Local variance of viewing geometry
  - Steadiness of time-series
  - Similarity to other products (e.g. MODIS)

→ Weighted compositing approach utilizing:
  - NDVI
  - satellite zenith
  - sun zenith
  - relative azimuth
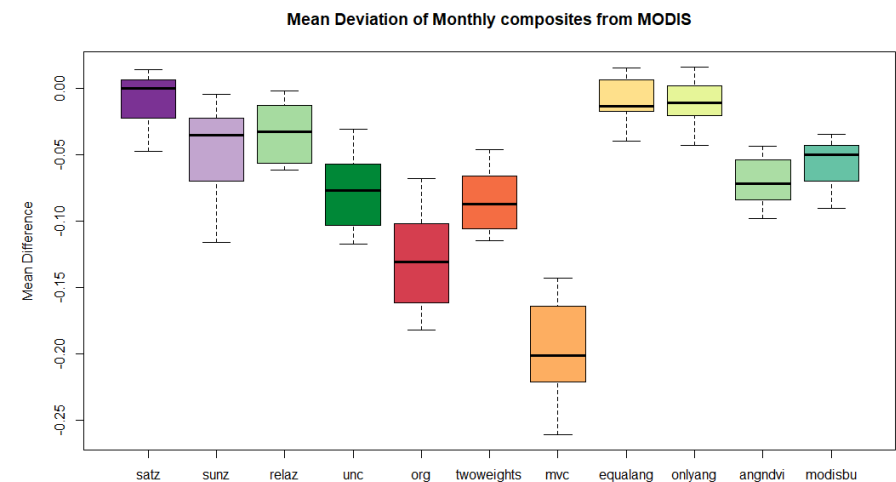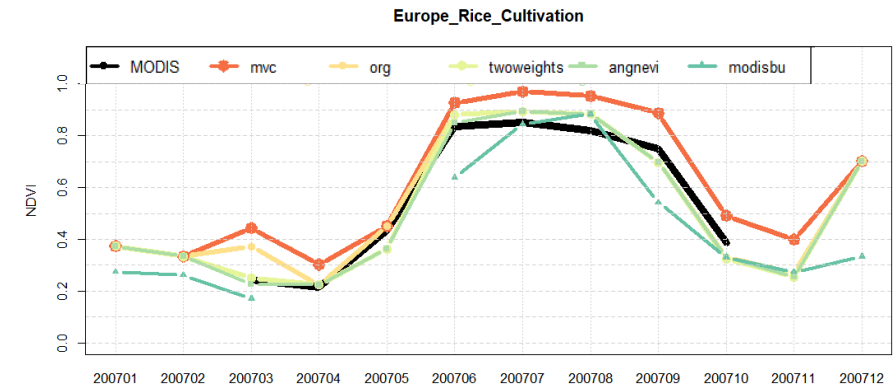
(Asam et al., in prep.)

TIMELINE L3 NDVI products

- Three TIMELINE L3 NDVI products:
  - Daily NDVI composites
  - 10-day NDVI composites
  - Monthly NDVI composites

- NetCDF file, 1km resolution (6 bands: NDVI, quality flag, DOY, time, variance, number of observations)

- Major advantages…
  - Homogeneous AVHRR time-series
  - High temporal resolution
  - Long time-series
- … allow for, e.g.
  - ➢ Trend analyses with long data baseline
  - ➢ Analyses of phenological metrics

Monthly NDVI composite for May 2012
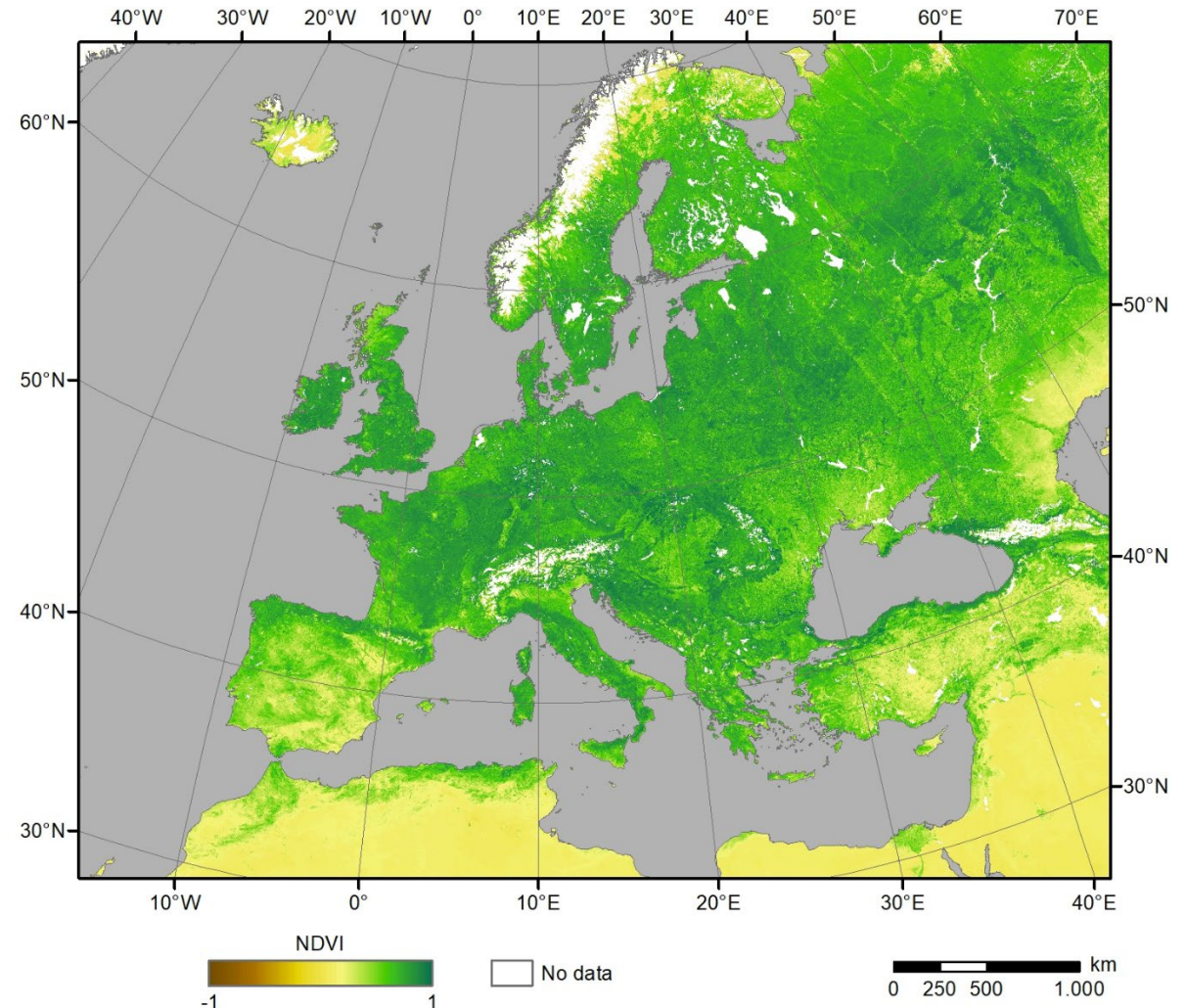
Changes in summer NDVI 1982–2018

- Monthly NDVI composites 1982–2018

- Mean seasonal NDVI (spring, summer, autumn)

- Derivation of seasonal NDVI trends
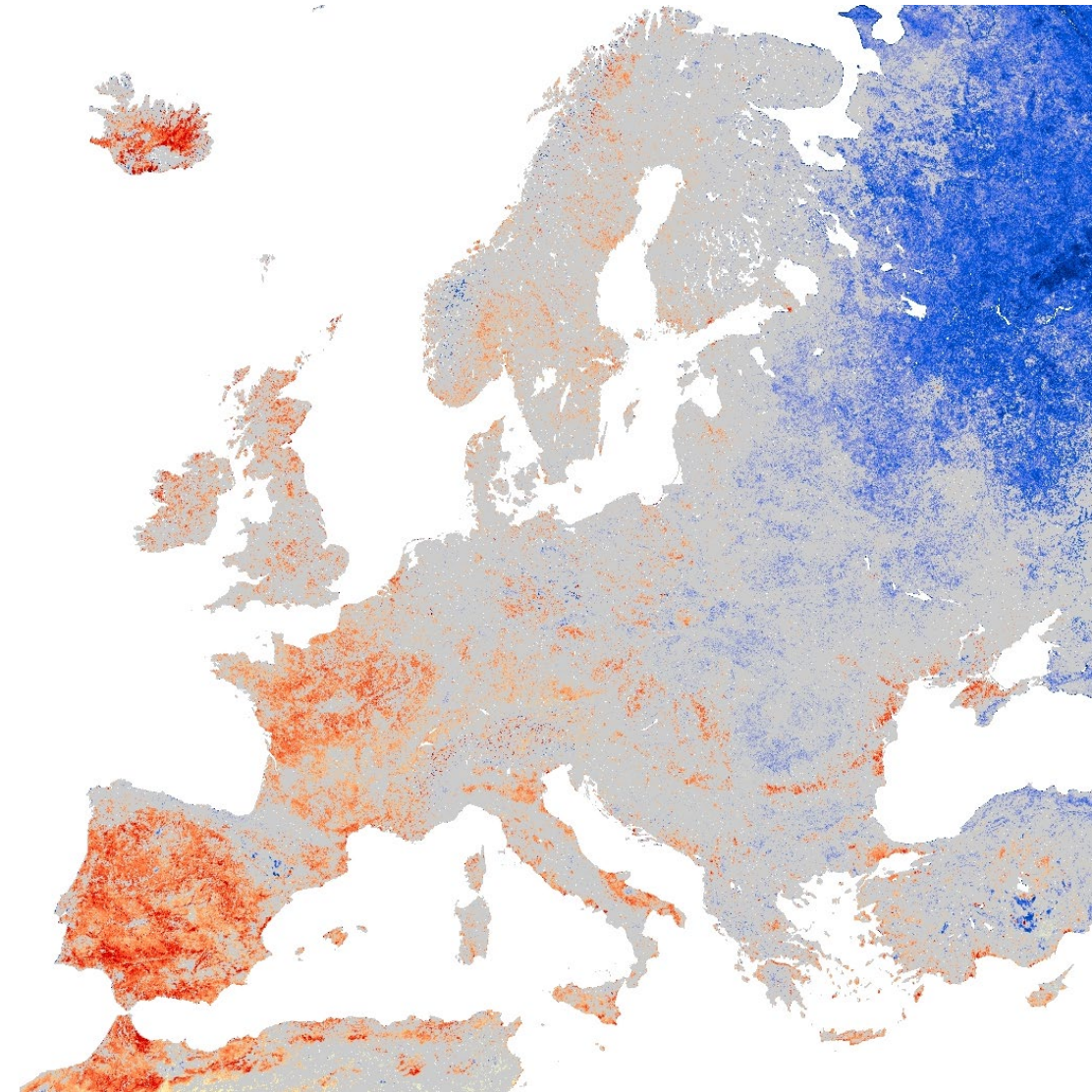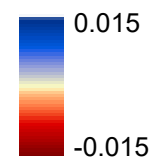 - Mann-Kendall test
  - Theil-Sen slope estimator
  - Significance level 0.05

→ Linear NDVI trend 1982-2018 for
  summer months (June, July, August)

(Eisfelder et al., in prep.)

Summer NDVI trend 1982-2018

No significant trend (p≥0.05)

NDVI trend [year^{-1}]

0.015

-0.015

Changes in summer NDVI 1982–2018

- Summer NDVI trend 1982-2018 → analyses for different land cover classes on country level
- For stable land cover pixels (based on ESA-CCI LC 1992-2018)

→ All vegetated areas: NDVI decrease in Western Europe

(Eisfelder et al., in prep.)

Vegetation (all)

Summer NDVI trend 1982-2018: mean for LC on country level

No significant trend (p≥0.05)

NDVI trend / 36 years

- 0.100
- 0.075
- 0.050
- 0.025
- 0.000
- -0.025
- -0.050
- -0.075
- -0.100
- -0.125
- -0.150
- -0.175

Changes in summer NDVI 1982–2018

- Summer NDVI trend 1982-2018 →
  analyses for different land cover classes
  on country level
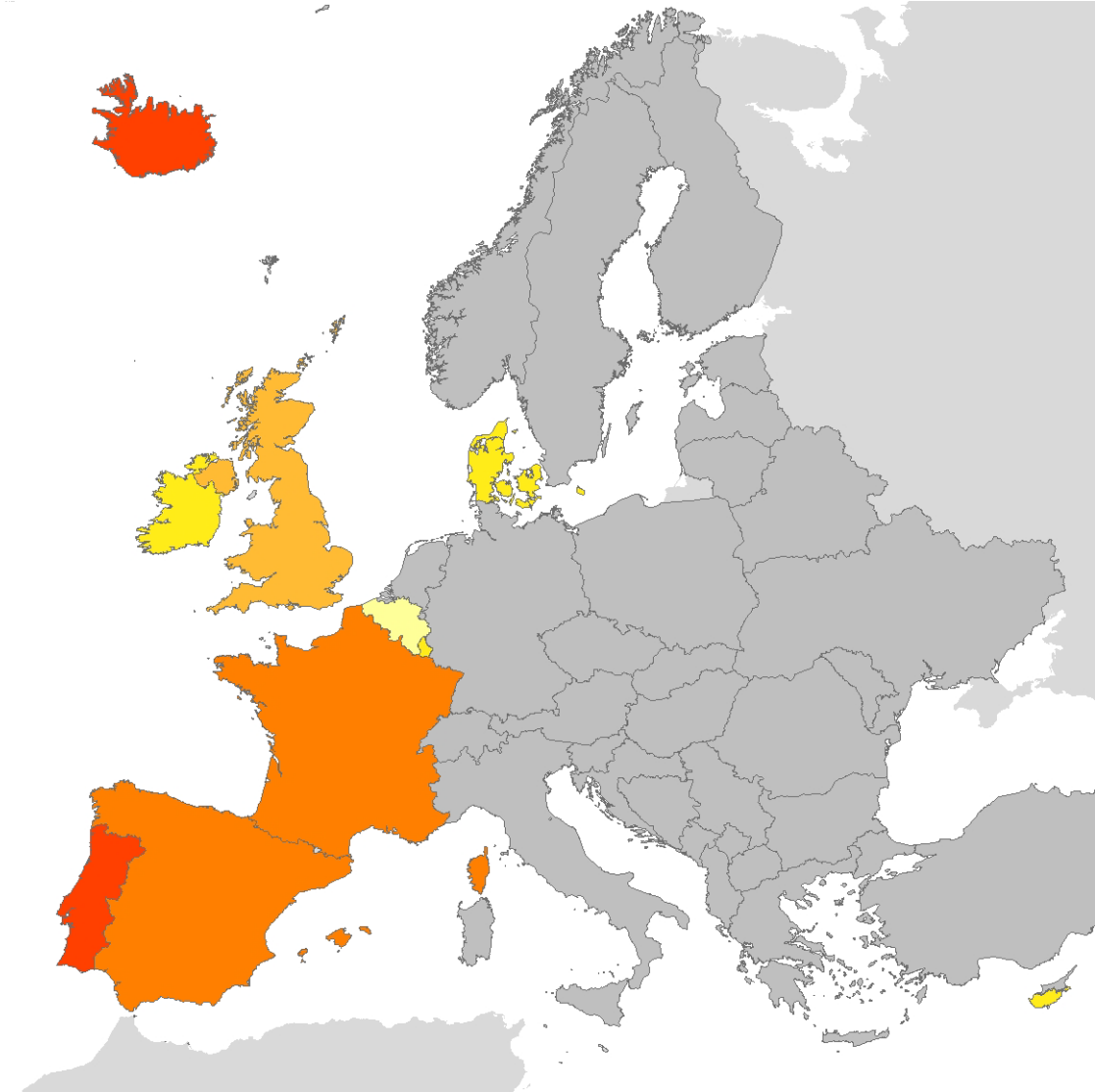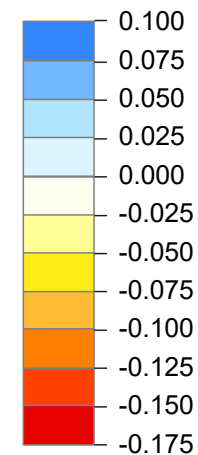- For stable land cover pixels (based on
  ESA-CCI LC 1992-2018)

→ All vegetated areas: NDVI decrease in
  Western Europe
→ Cropland: NDVI decrease in Western
  and Central Europe

(Eisfelder et al., in prep.)

Cropland

**Summer NDVI trend
1982-2018: mean for
LC on country level**

No significant
trend (p≥0.05)

NDVI trend / 36 years

- 0.100
- 0.075
- 0.050
- 0.025
- 0.000
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Changes in summer NDVI 1982–2018

- Summer NDVI trend 1982-2018 →
  analyses for different land cover classes
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- For stable land cover pixels (based on
  ESA-CCI LC 1992-2018)

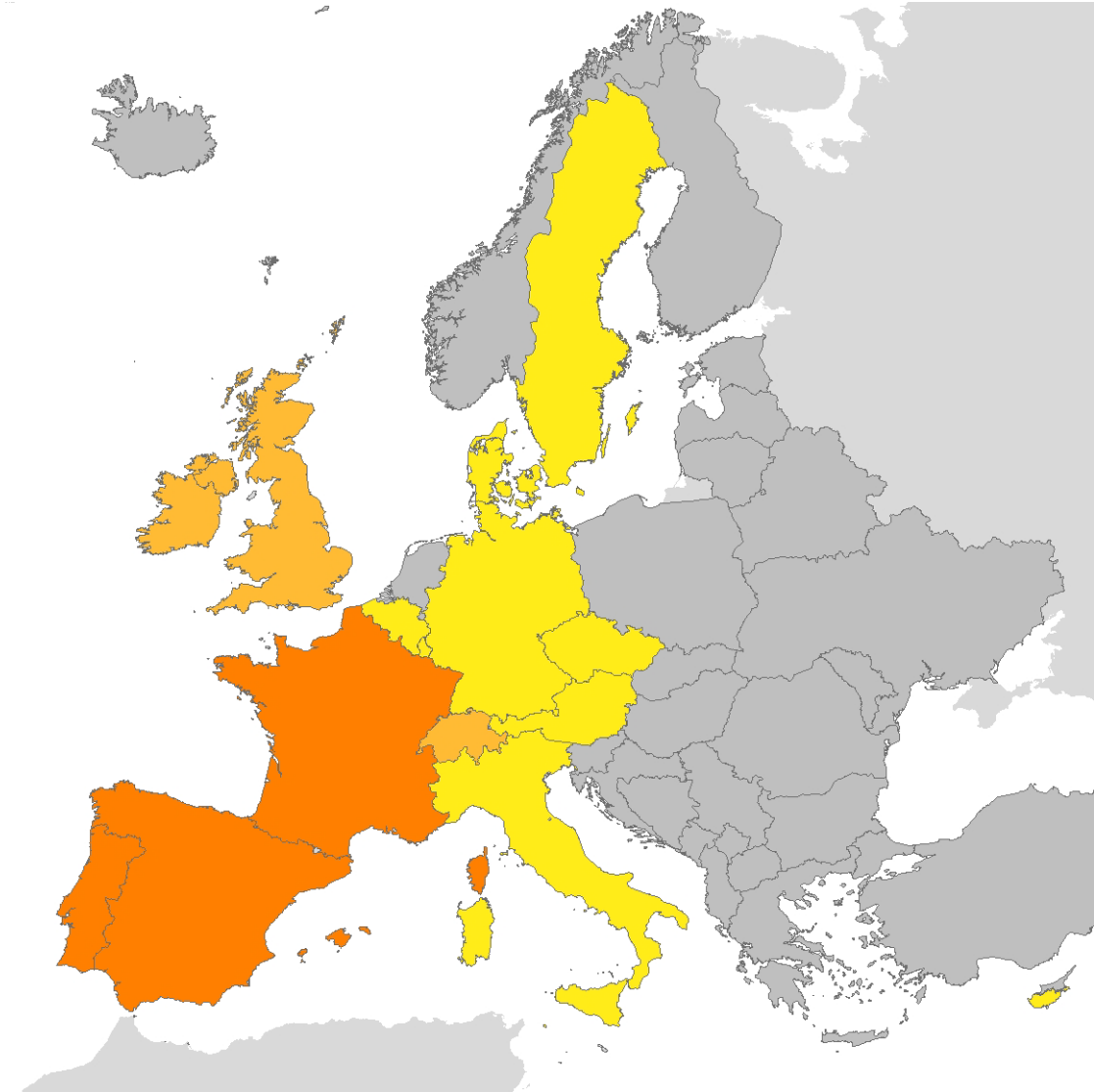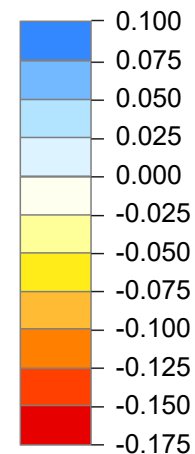→ All vegetated areas: NDVI decrease in
  Western Europe

→ Cropland: NDVI decrease in Western
  and Central Europe

→ Deciduous forest: NDVI increase in
  Eastern Europe, decrease in Western
  Europe

(Eisfelder et al., in prep.)

Deciduous forest

**Summer NDVI trend
1982-2018: mean for
LC on country level**

No significant
trend (p≥0.05)

NDVI trend / 36 years

- 0.100
- 0.075
- 0.050
- 0.025
- 0.000
- -0.025
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- -0.075
- -0.100
- -0.125
- -0.150
- -0.175
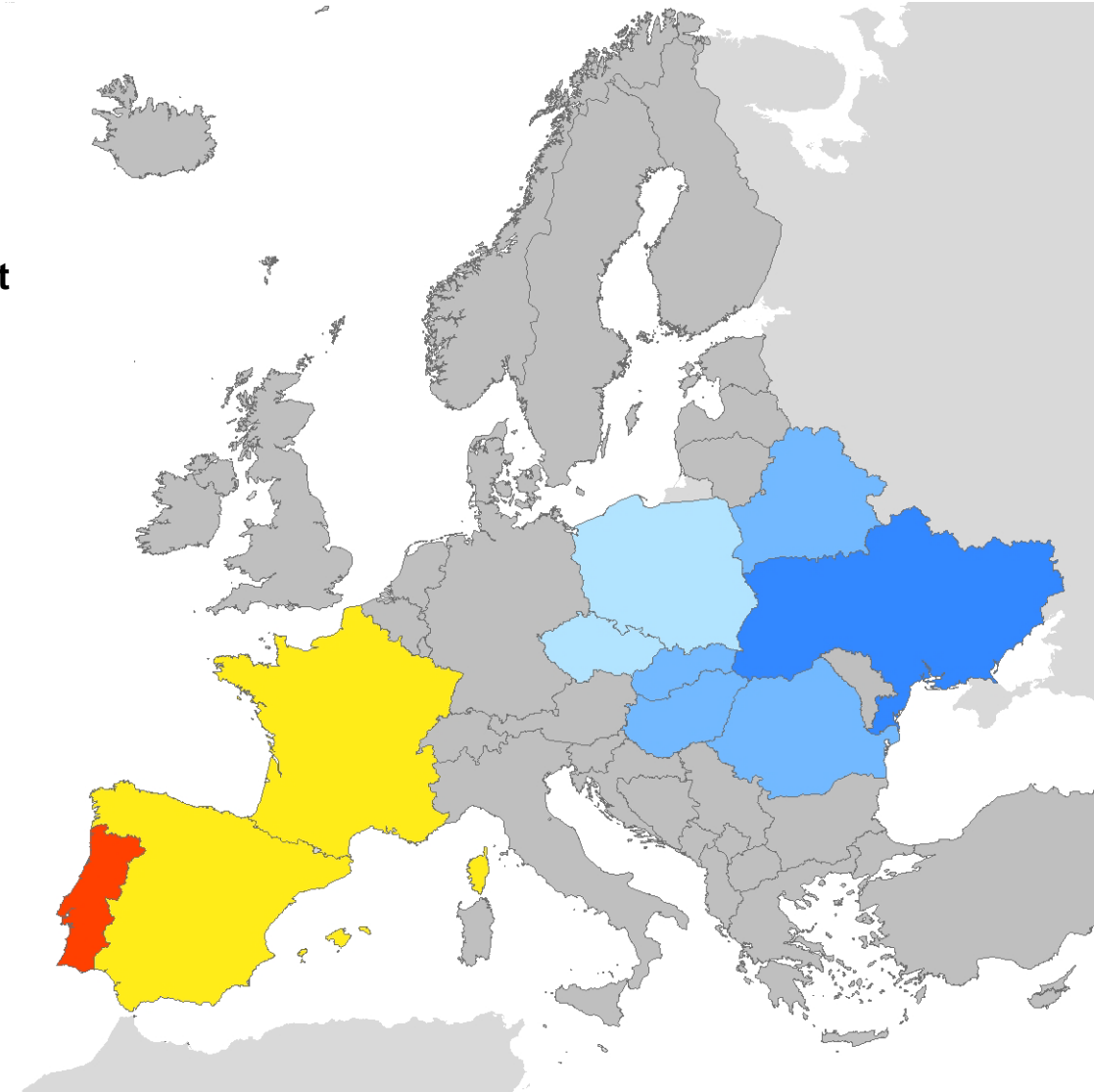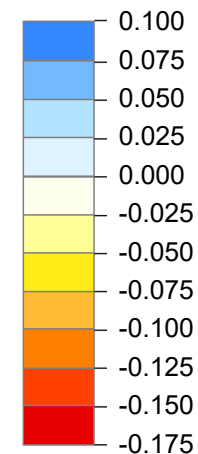
Shifts in phenology (Start Of Season - SOS) in Germany

– Years 1982 – 2018

– 10-day NDVI composite

– NDVI filtering & smoothing

– Local thresholds for SOS extraction

→ **Earlier Start Of Season in Germany**

• Grassland: Ø 7.6 days/decade

Pixelwise SOS trends for grassland

SOS sig. trend 1982 – 2018 [days/decade]

Grassland

20 days later

20 days earlier

Grassland

Regional mean: SOS trends for grassland

SOS trend [days/decade]

(Asam et al., in prep.)

Shifts in phenology (Start Of Season - SOS) in Germany

− Years 1982 – 2018
− 10-day NDVI composite
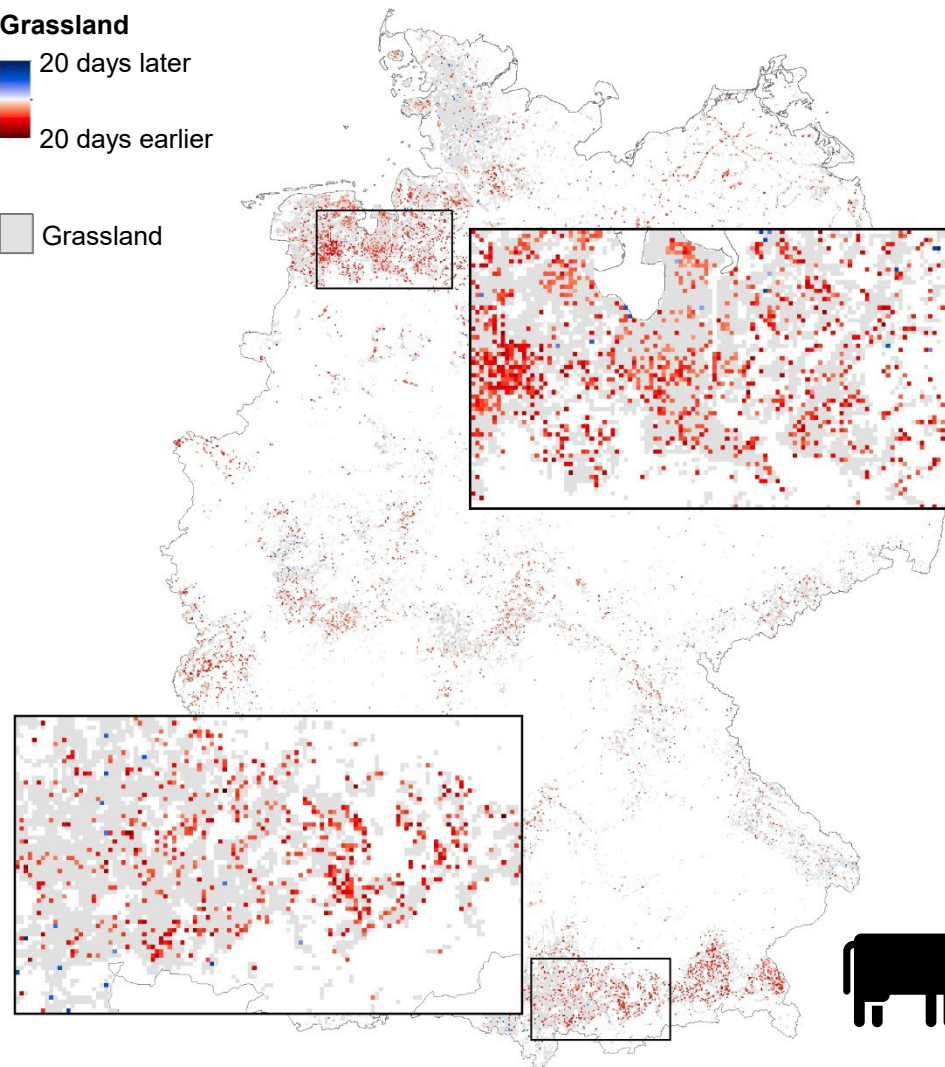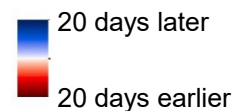− NDVI filtering & smoothing
− Local thresholds for SOS
  extraction

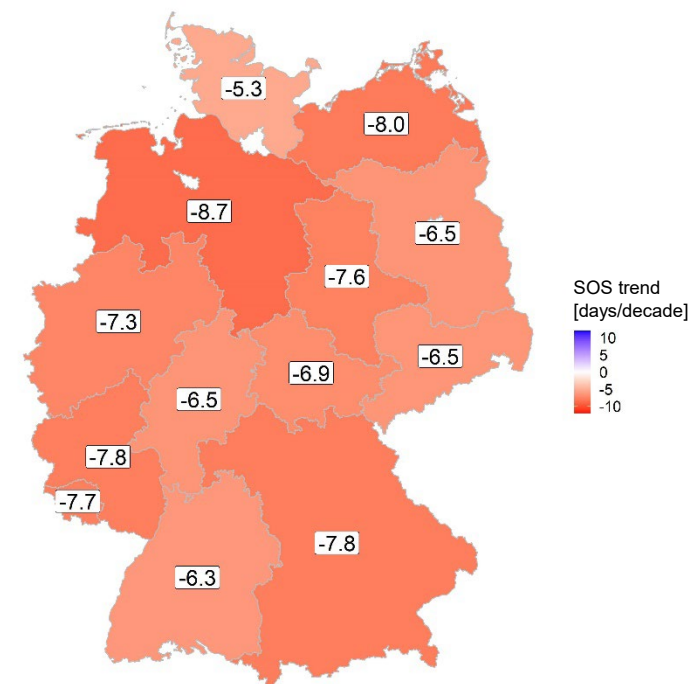→ **Earlier Start Of Season in Germany**
• Grassland: Ø 7.6 days/decade
• Cropland: Ø 7.8 days/decade

Pixelwise SOS trends for cropland

SOS sig. trend 1982 – 2018 [days/decade]
Cropland
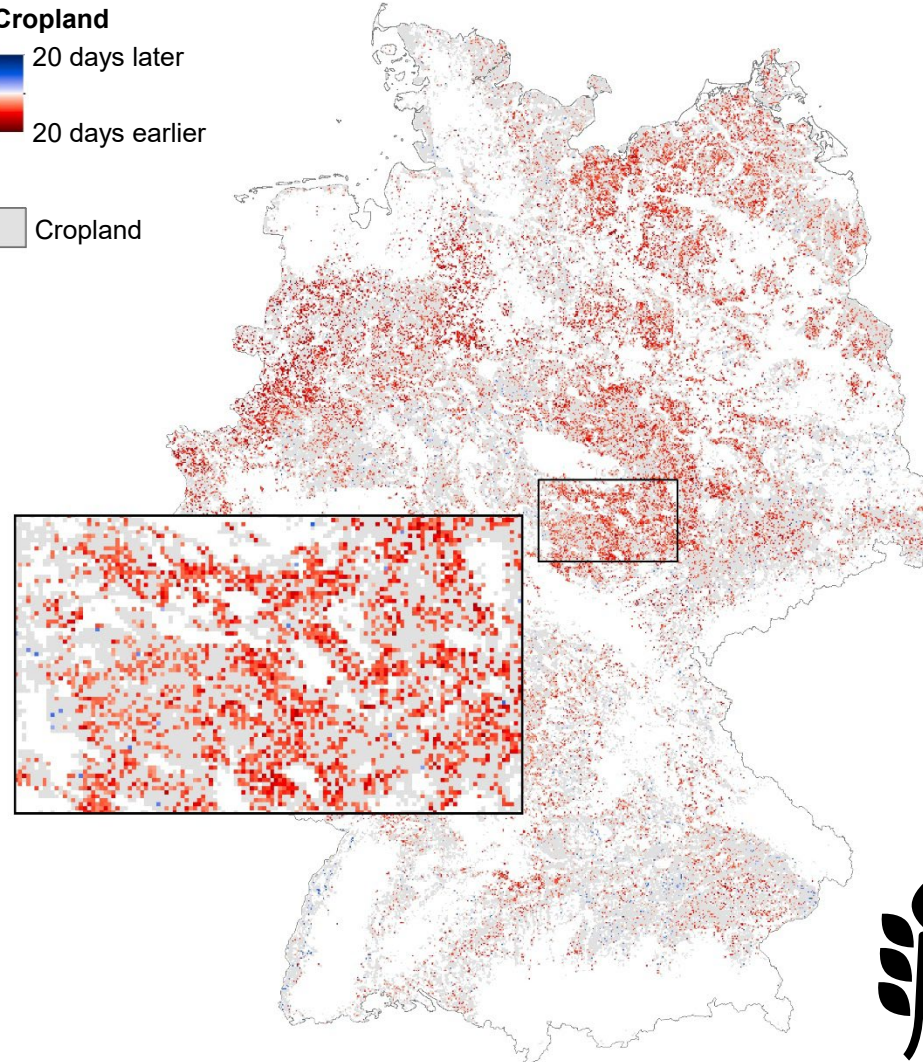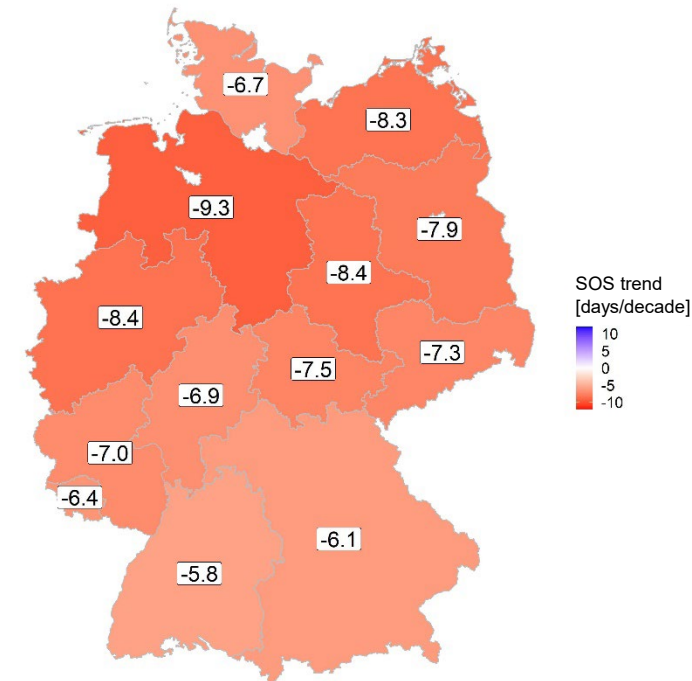20 days later

20 days earlier

Cropland

Regional mean: SOS trends for cropland

SOS trend
[days/decade]

10
5
0
-5
-10

(Asam et al., in prep.)

Shifts in phenology (Start Of Season - SOS) in Germany

- Years 1982 – 2018
- 10-day NDVI composite
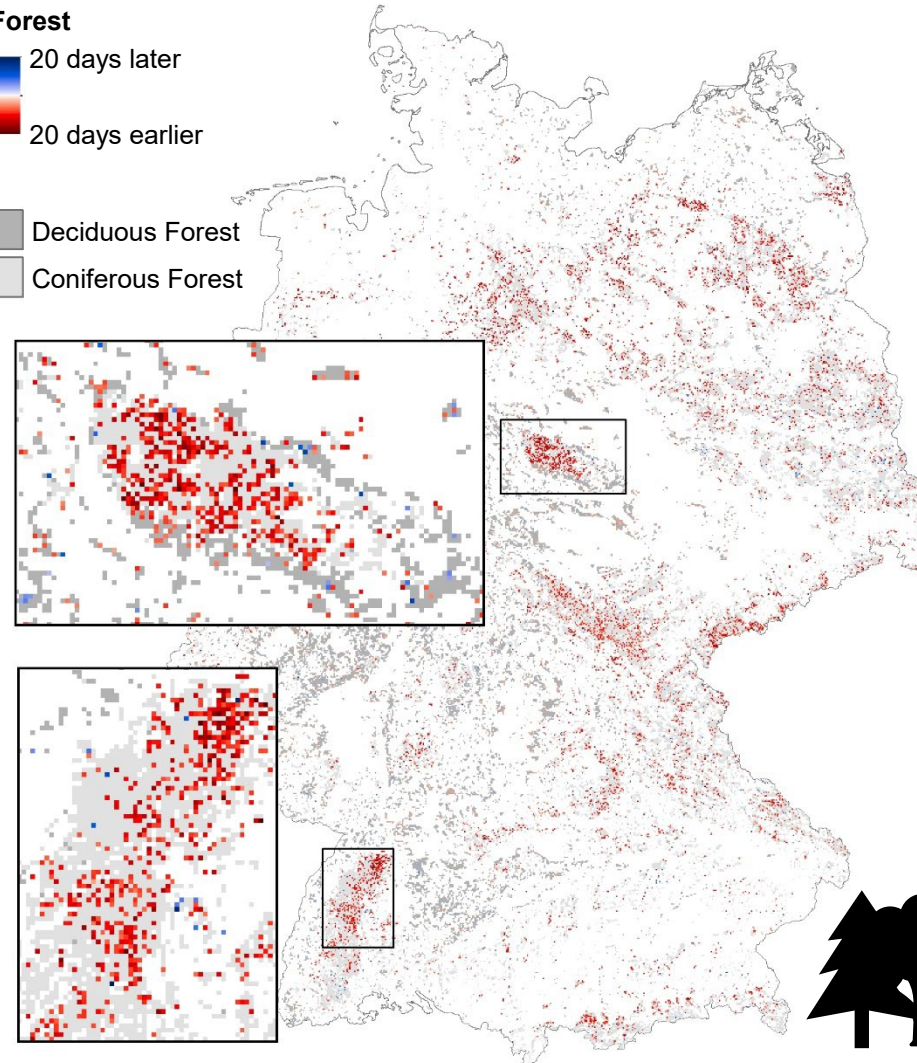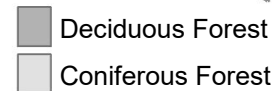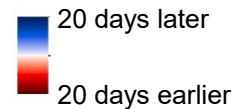- NDVI filtering & smoothing
- Local thresholds for SOS extraction

→ **Earlier Start Of Season in Germany**
- Grassland: Ø 7.6 days/decade
- Cropland: Ø 7.8 days/decade
- Forest: Ø 8.6 days/decade

Pixelwise SOS trends for forest

SOS sig. trend 1982 – 2018 [days/decade]

Forest
20 days later

20 days earlier

Deciduous Forest
Coniferous Forest

Regional mean: SOS trends for forest


(Asam et al., in prep.)
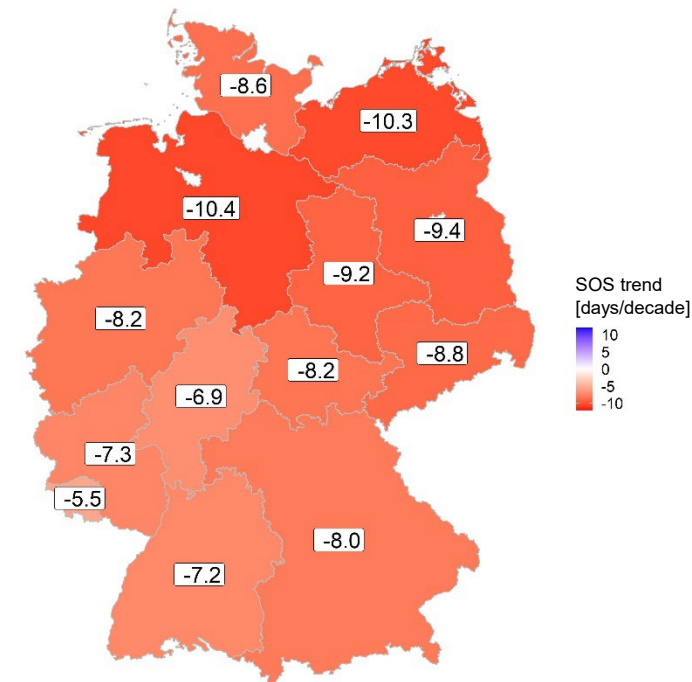
Summary & Outlook

TIMELINE project
- Use of ~40 years of AVHRR data
- Europe-wide products with 1 km resolution
- Land, sea and atmosphere products
- Free and open dissemination intended

- TIMELINE level 3 NDVI product suite
  - Daily, 10-day, monthly composites
  - Publication on compositing algorithm in preparation
  - Product validation ongoing
  - Further analyses planned (e.g. NDVI and LST, NDVI phenology and snow cover, …)
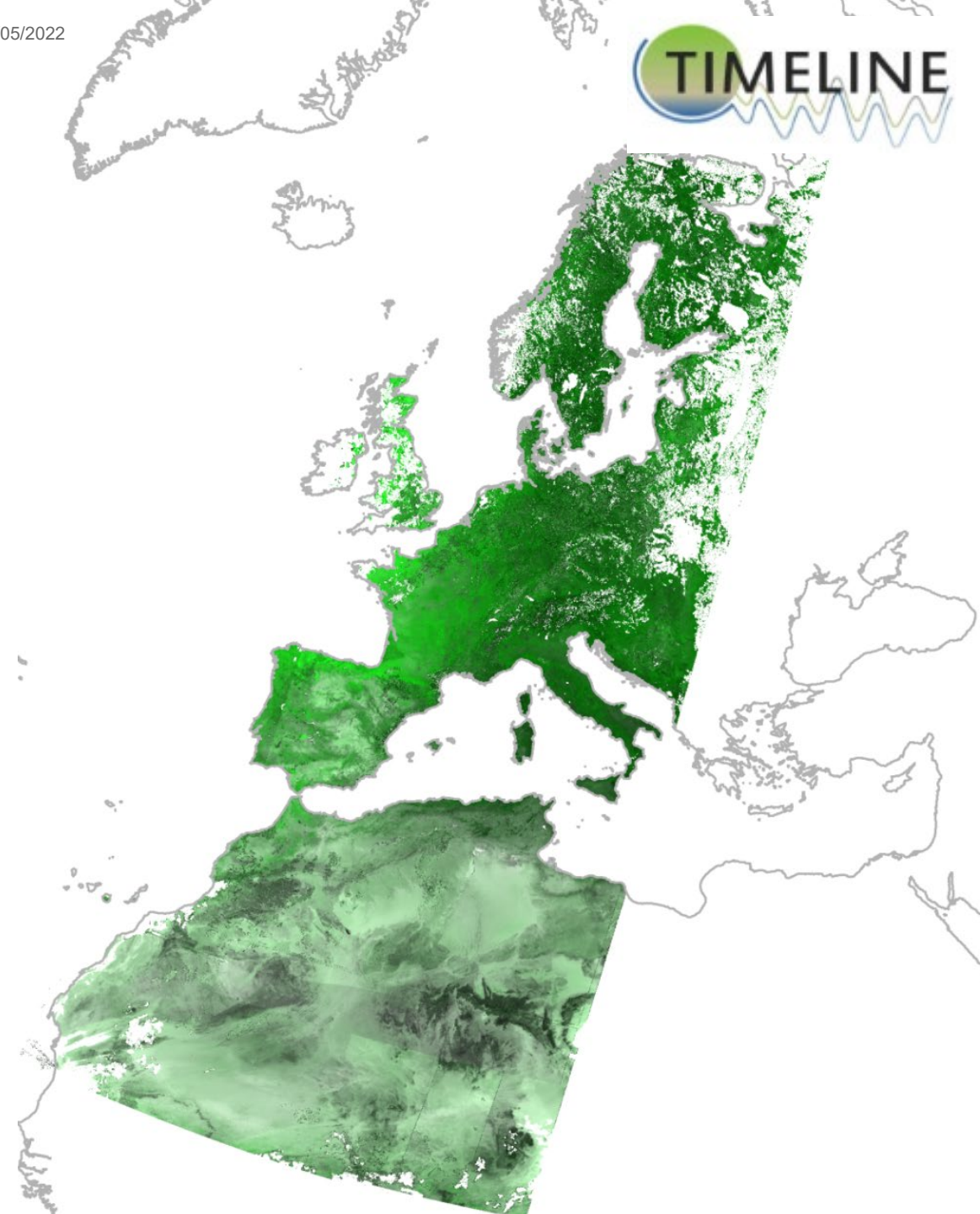
Further information

→ www.timeline.dlr.de

@ ESA LPS22

see today

Session B4.01:
Long-term dynamics of Land
Surface Temperature over Europe
and North Africa (Poster Board 31)

Session B4.02.1:
Snow Cover in Europe derived
from historical AVHRR Data – a
TIMELINE thematic processor