Reducing uncertainties in land surface phenology for improved modelling of vegetation-climate dynamics

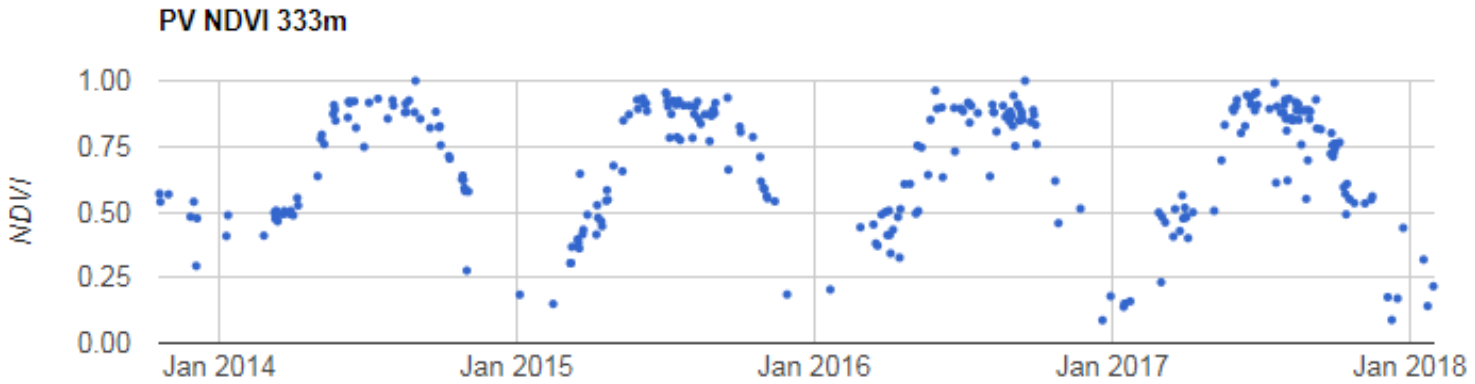
Adrià Descals, Aleixandre Verger, Gaofei Yin, Kevin Bórnez, Iolanda Filella, and Josep Peñuelas

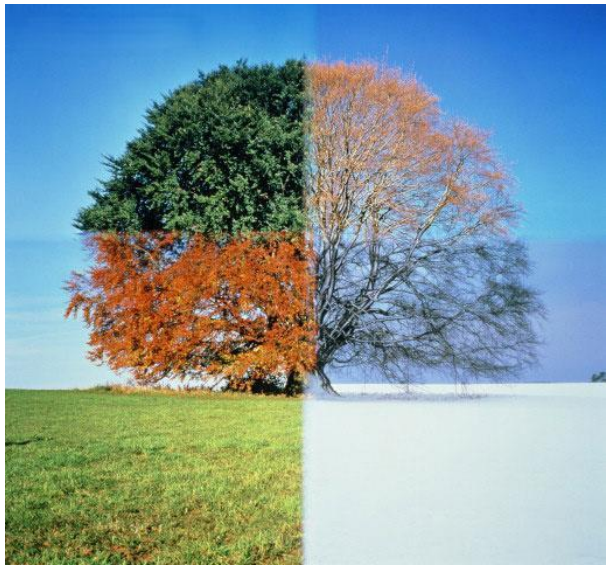
CREAF *(Centre for Research on Ecology and Forestry Applications)*

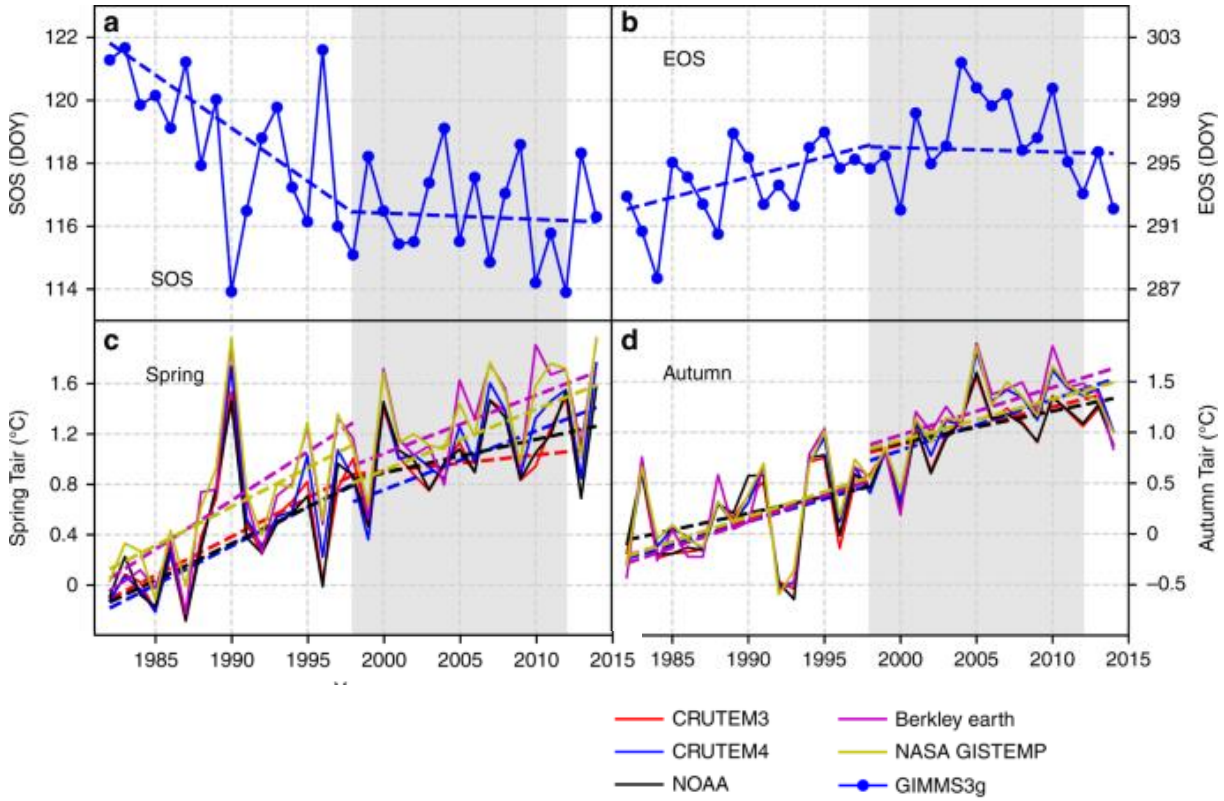
- **Phenology** : **life cycle events** influenced by seasonal and interannual **variations in climate.**

VEGETATION PHENOLOGY ← TEMPERATURE, LIGHT AVAILABILITY, WATER AVAILABILITY *(and others)*

- **Land surface phenology (LSP)** is the **seasonal pattern of variation** in vegetated land surfaces **observed from remote sensing**.







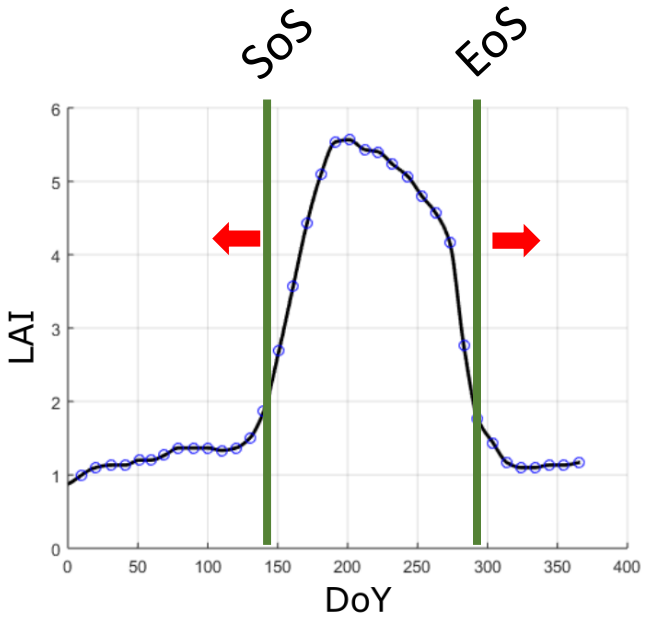
Wang et al. (2019). No trends in spring and autumn phenology during the global warming hiatus. *Nature communications*, *10*(1), 1-10.

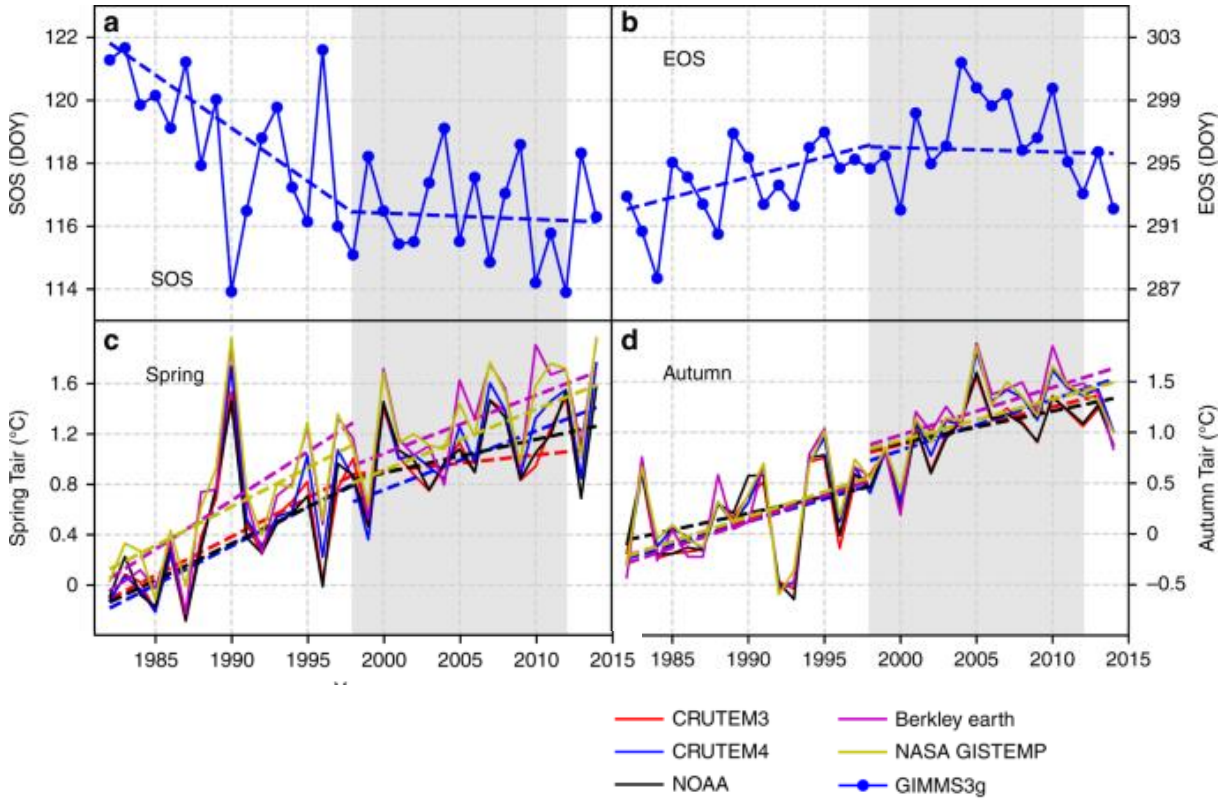
Length of growing season ↑

TEMPERATURE ↑

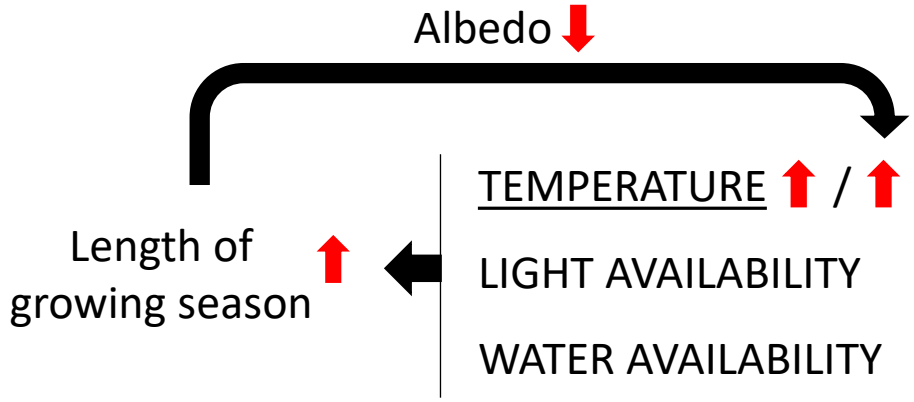
LIGHT AVAILABILITY

WATER AVAILABILITY

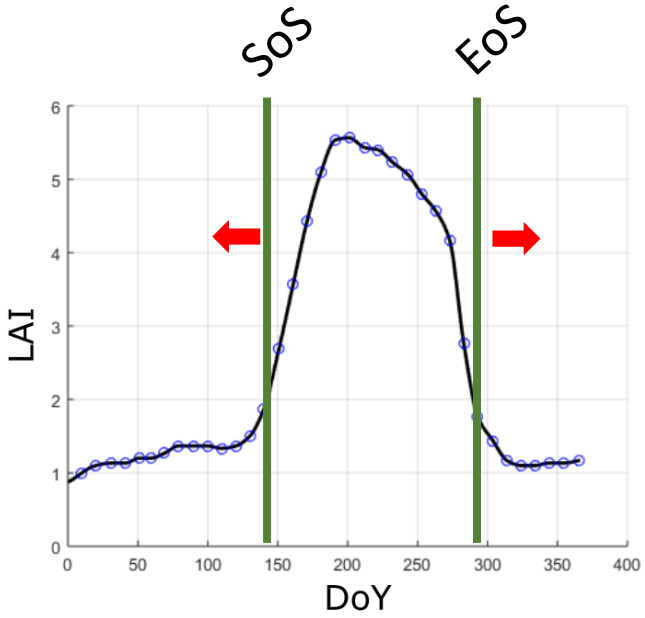


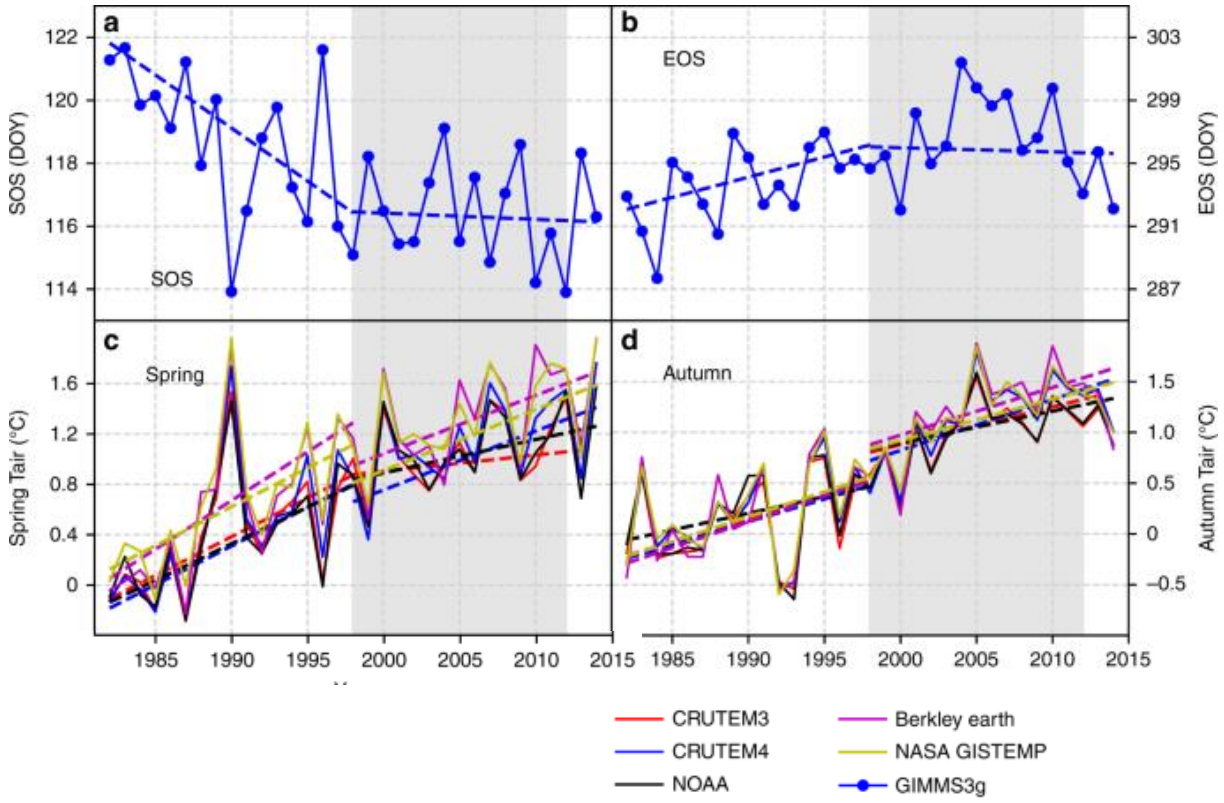


Wang et al. (2019). No trends in spring and autumn phenology during the global warming hiatus. *Nature communications*, *10*(1), 1-10.



Peñuelas et al. "Phenology feedbacks on climate change." *Science* (2009)





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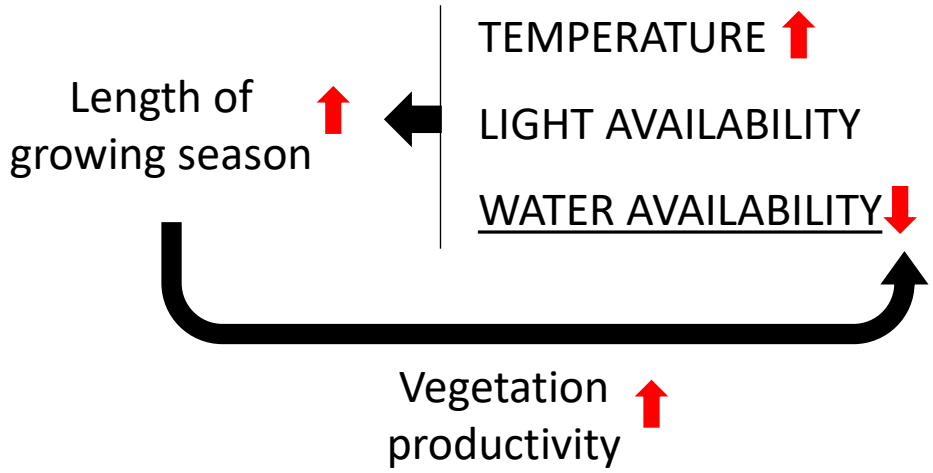
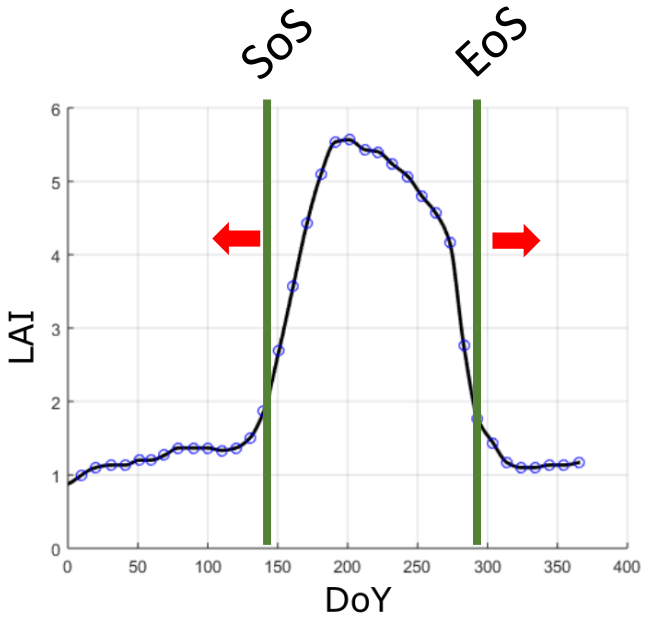
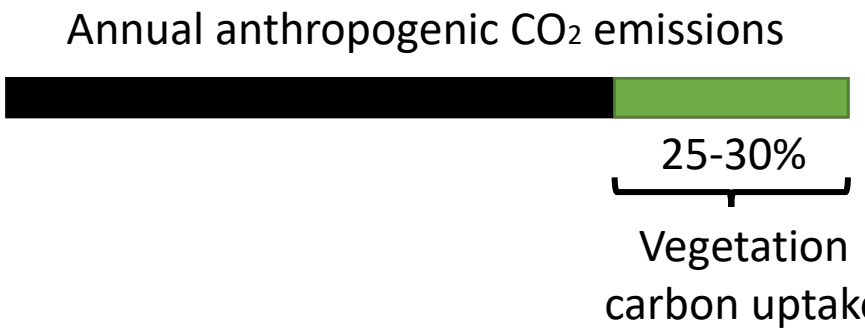
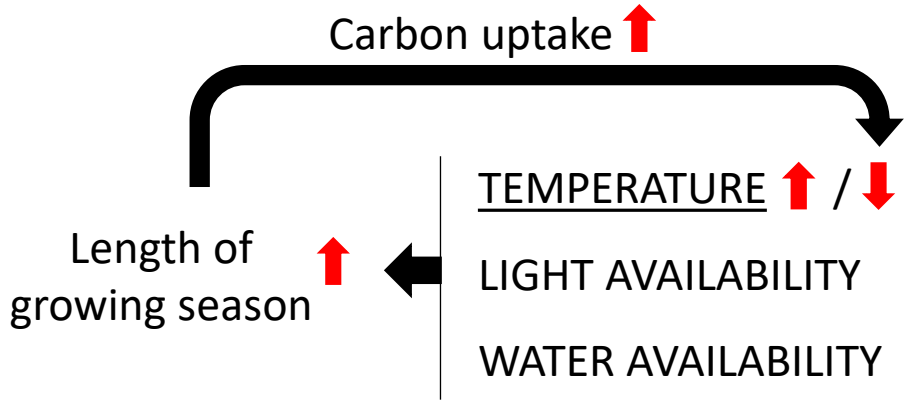




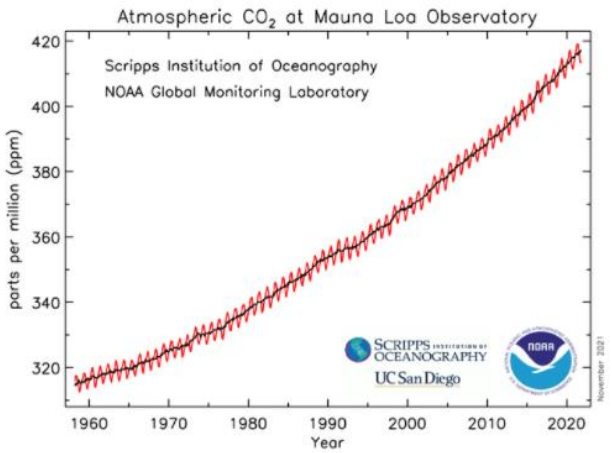


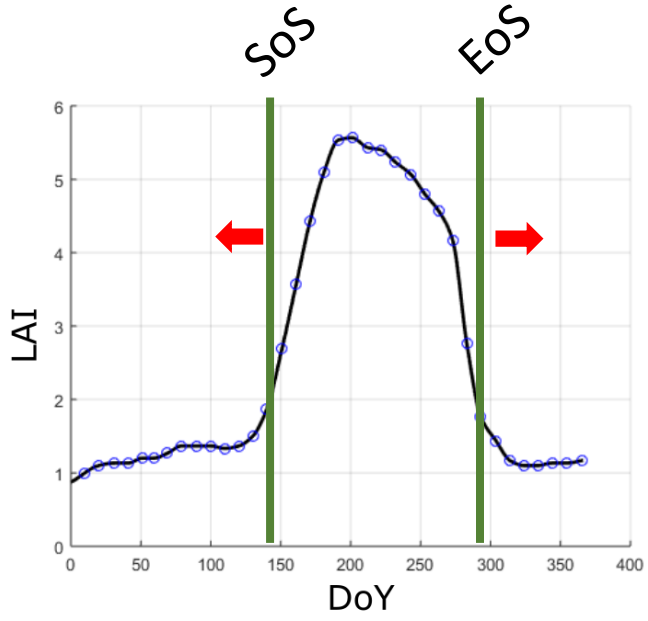


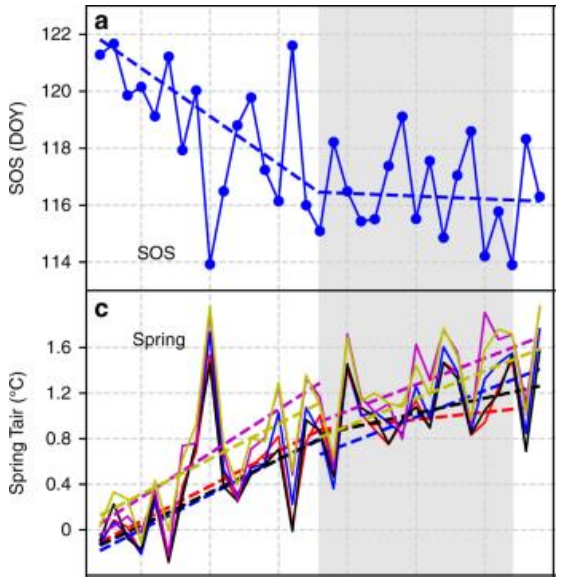
- Terrestrial ecosystems removes about a quarter of anthropogenic CO_2 emissions from the atmosphere every year.

Le Quéré et al., Trends in the sources and sinks of carbon dioxide. Nature geoscience, 2(12):831, 2009.

Peñuelas et al. "Phenology feedbacks on climate change." *Science* (2009)

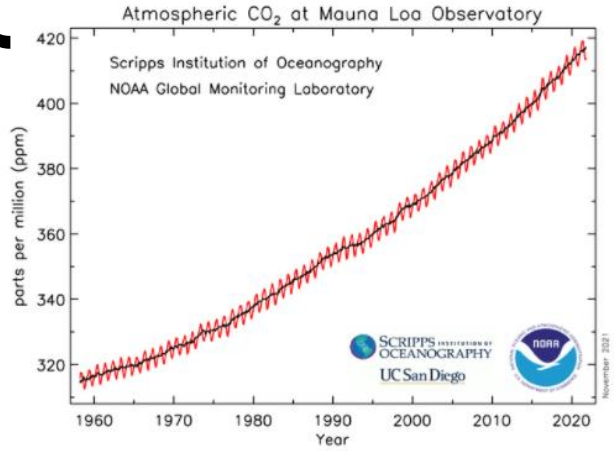






?

⬆⬆



⬆??

Carbon uptake ⬆??

Length of growing season ⬆?

TEMPERATURE ⬆⬆/⬇?

LIGHT AVAILABILITY

WATER AVAILABILITY

Science

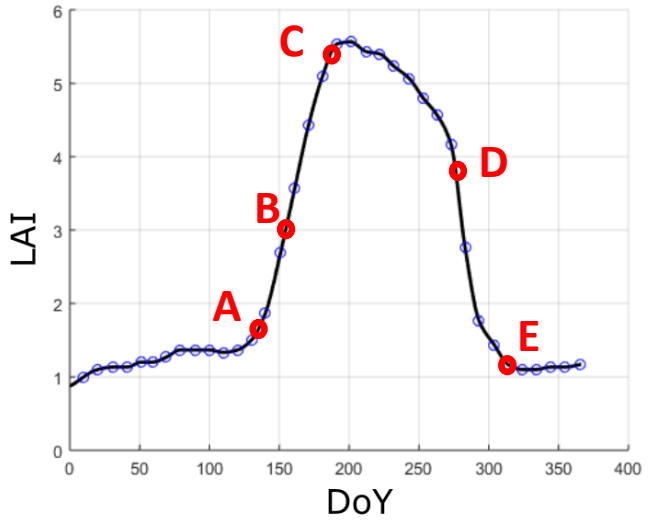
Reducing uncertainties in land surface phenology for improved modelling of vegetation-climate dynamics

- Interpretation of phenology metrics
- Phenology metric estimation
- Spatial resolution
- Variable selection

- Case study

Identification of phenophases

Phenophase: An observable stage or phase in the annual life cycle of a plant



A

B

C

D

E

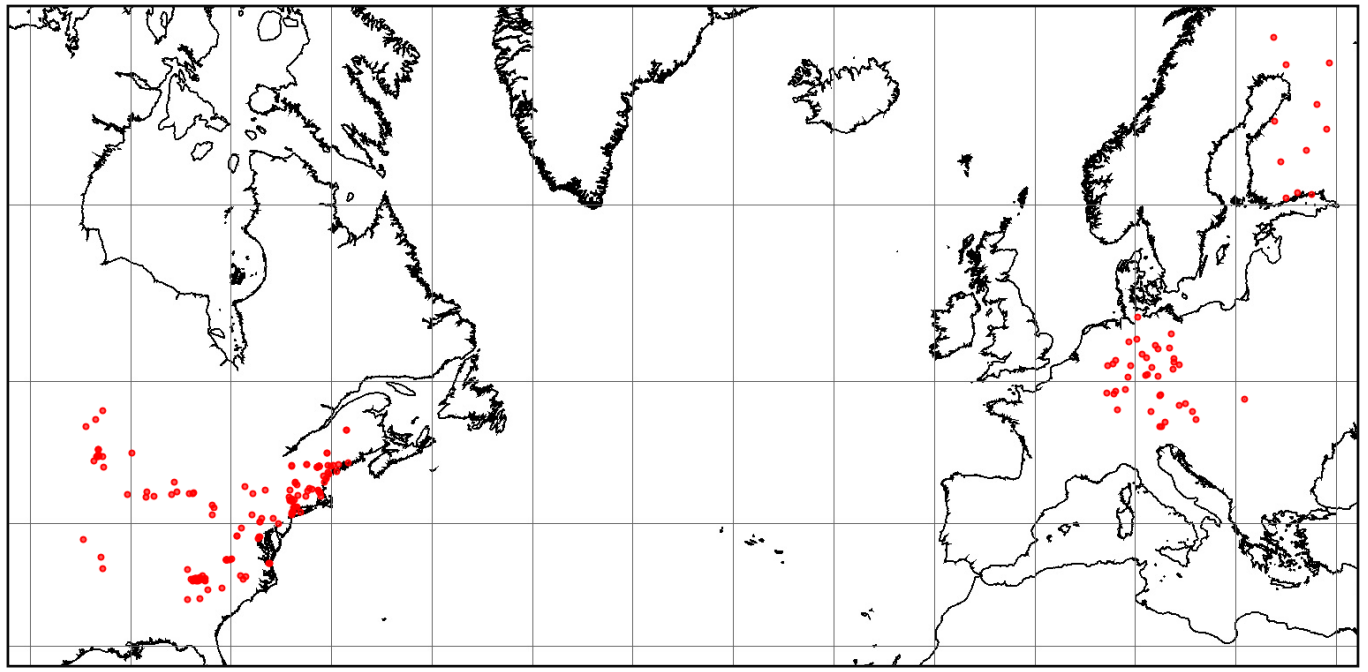
LSP ➡ Phenophase

Bornez et al., Land surface phenology from VEGETATION and PROBA-V data. Assessment over deciduous forests. *International Journal of Applied Earth Observation and Geoinformation* 84 (2020): 101974.

VALIDATION *(with in-situ measurements of pheno-phases)*

USA National Phenology Network (USA-NPN)

Pan European Phenological database (PEP725)



11,111 measurements

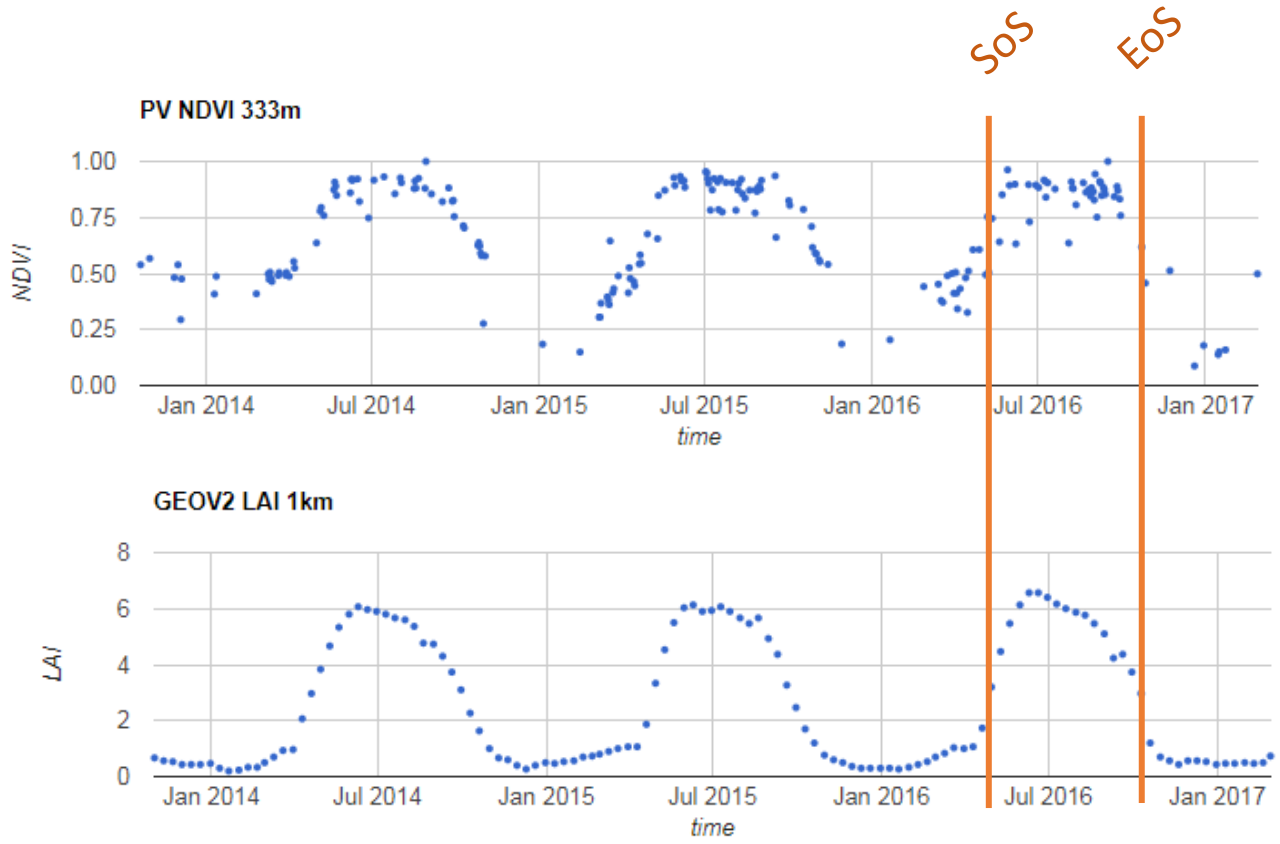
272 sites

From 2000 to 2016

Burnt Area	NDVI
Dry Matter Prod.	Soil Water Index
FAPAR	Surf. Soil Moisture
FCOVER	VCI
Leaf Area Index	VPI
Land Cover	

1. Pre-processing
(smoothing, compositing, interpolation…)

2. Estimation of phenology metrics

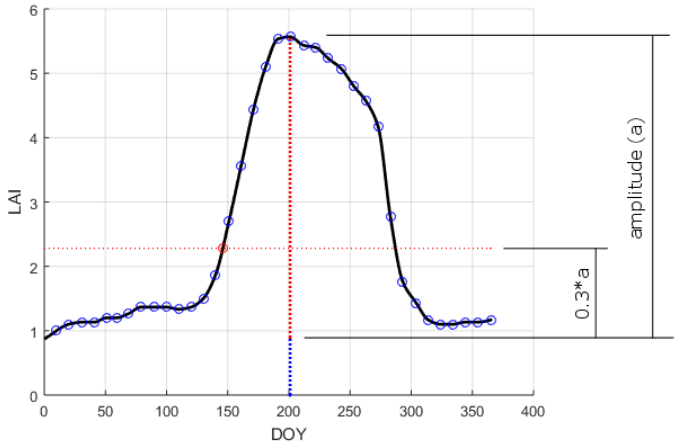


⇦ Doesn't require pre-processing!

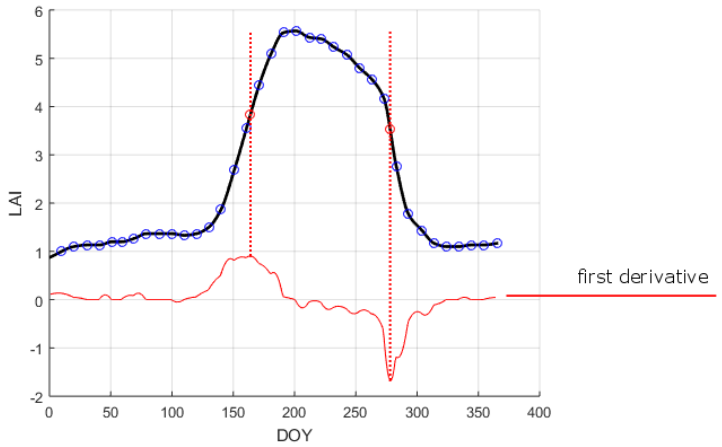
PEP725 Site ID: 6934
lat: 20.85 lon: 48.85

Phenology metric estimation

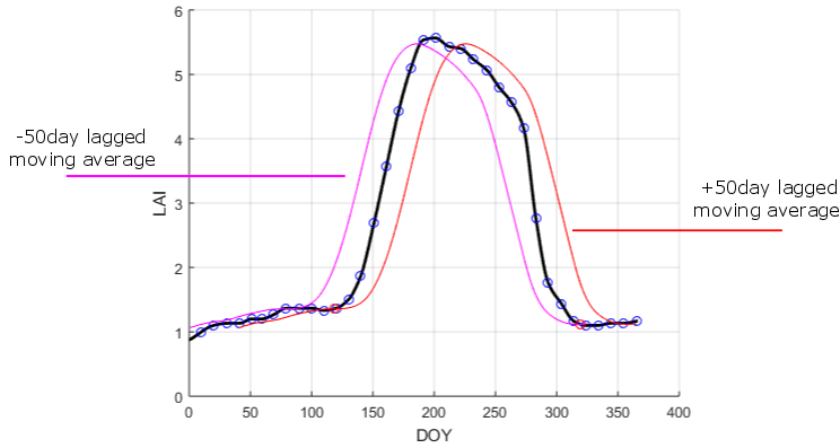
Threshold method



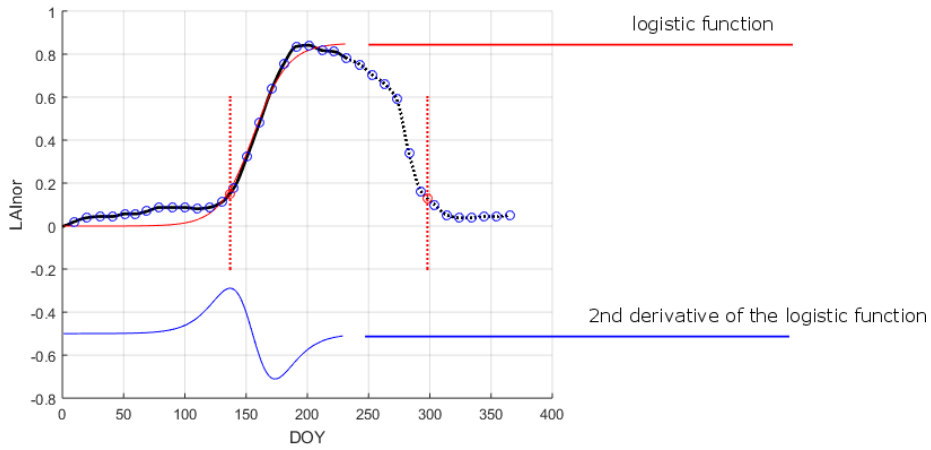
Derivatives

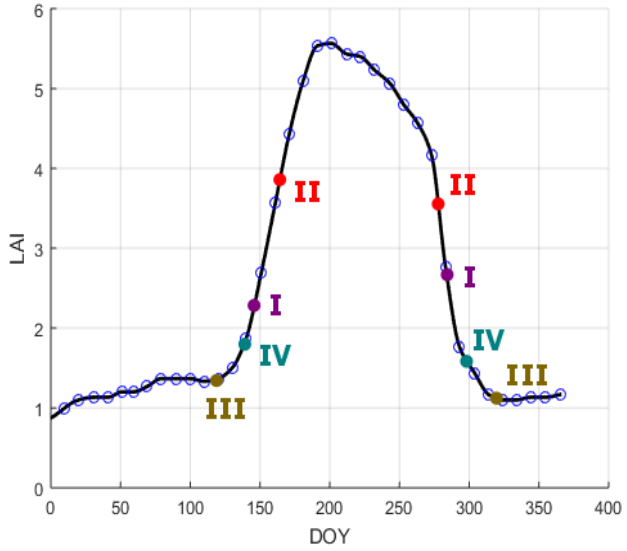


Moving average

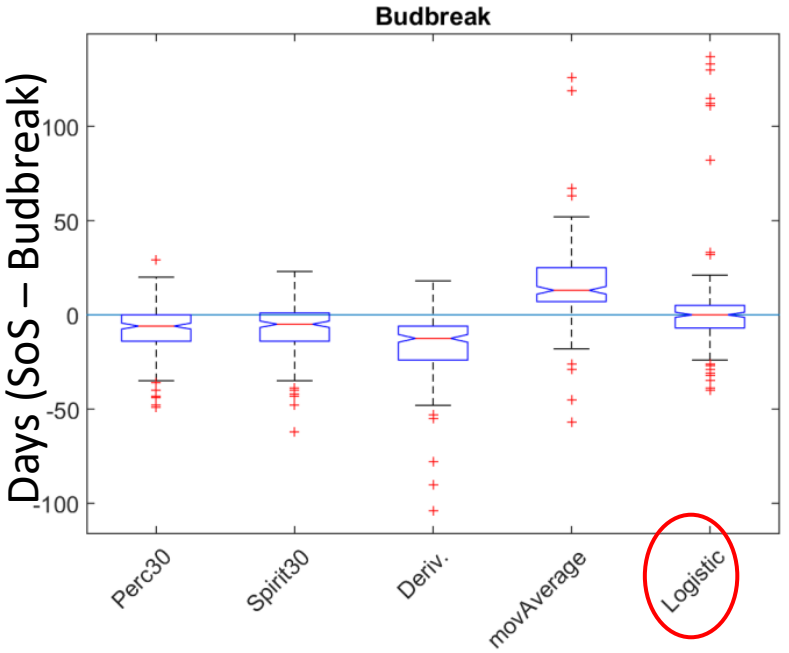


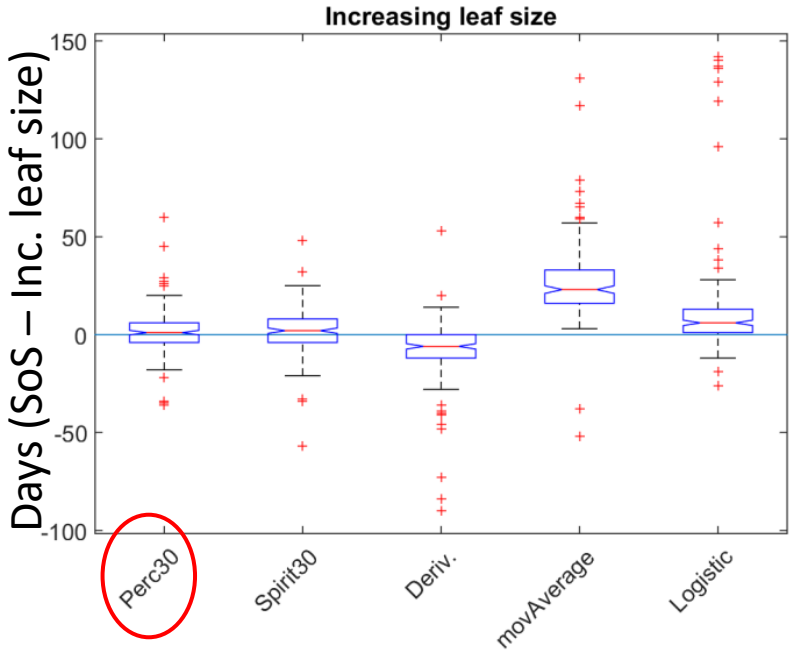
Curve fitting (logistic)

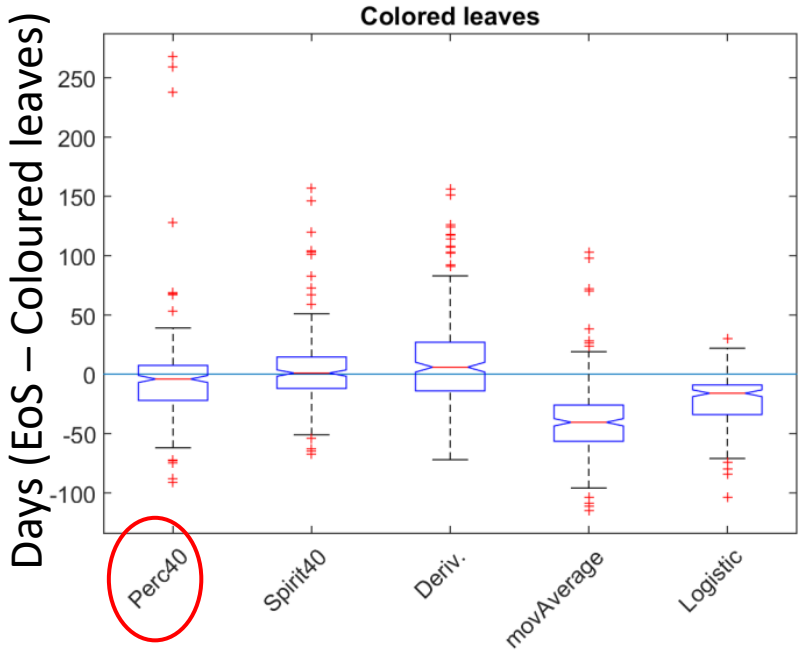


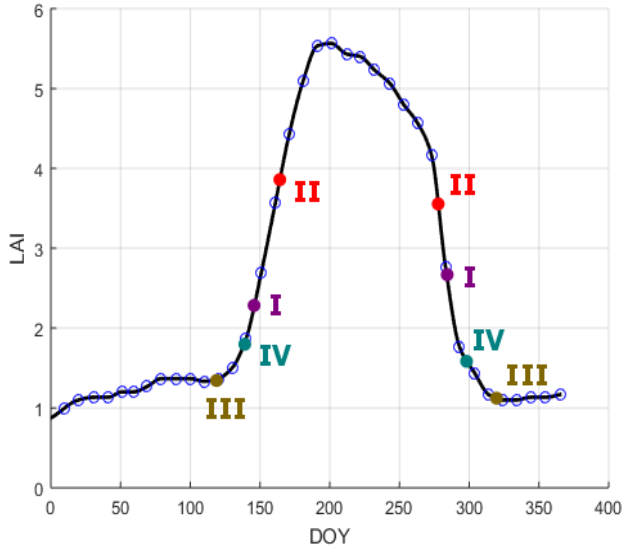


I Threshold (30, 40)
II Derivatives
III Moving Average
IV Logistic function









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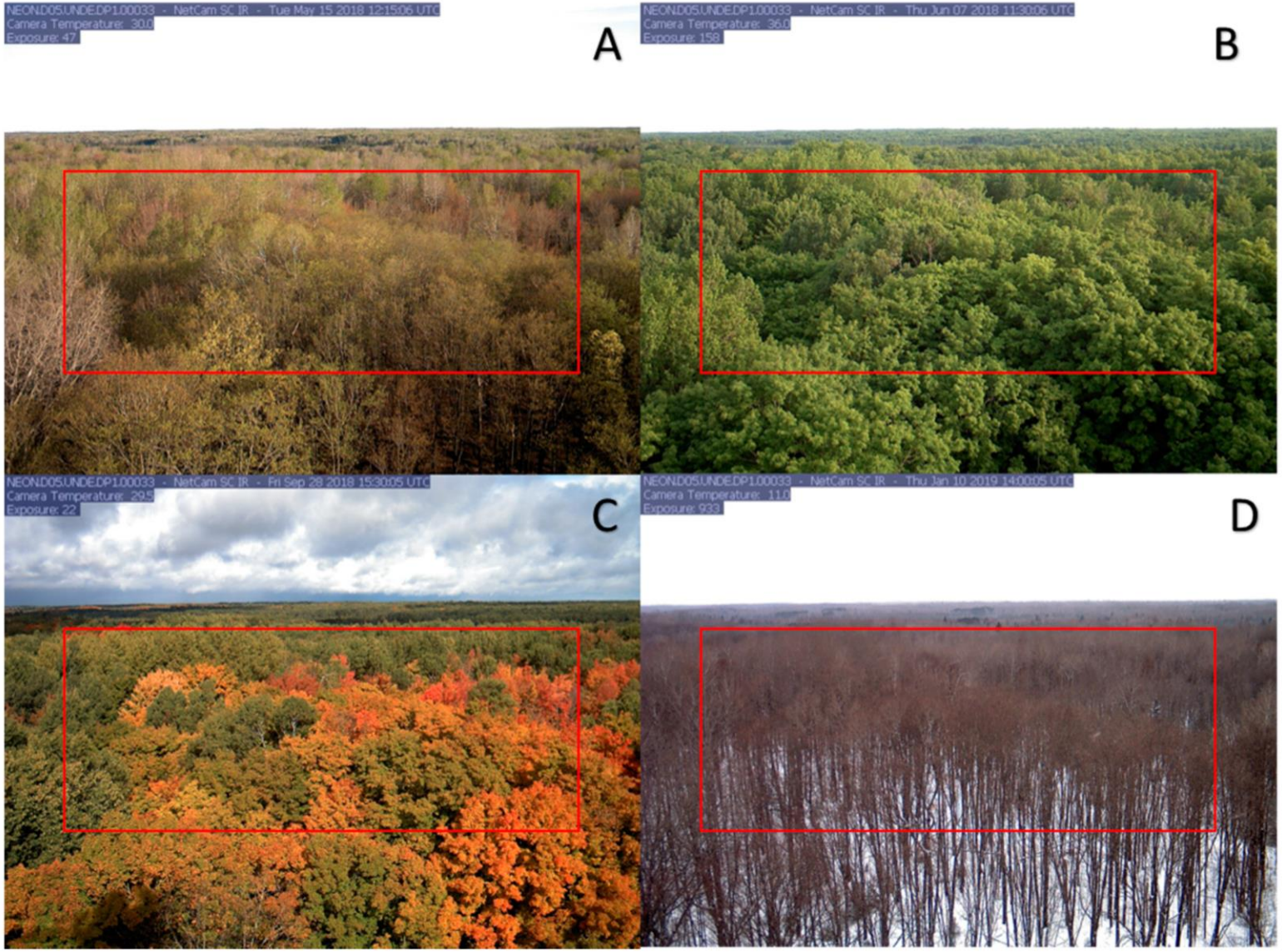
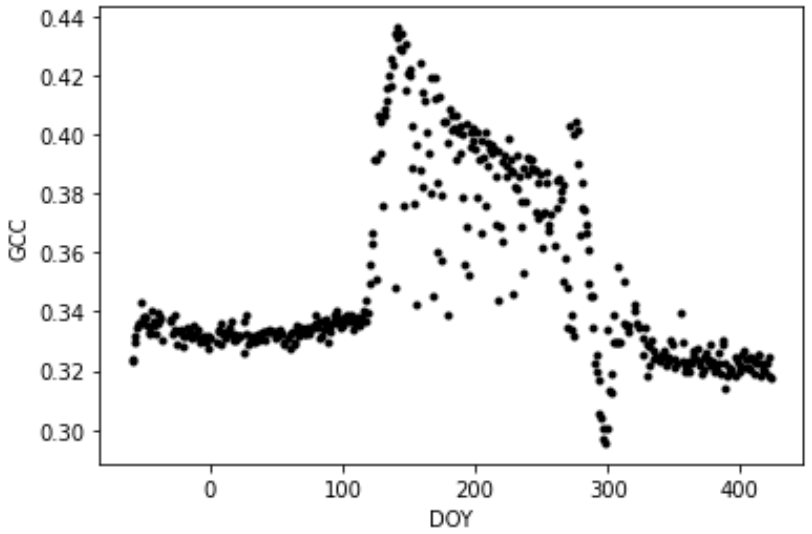
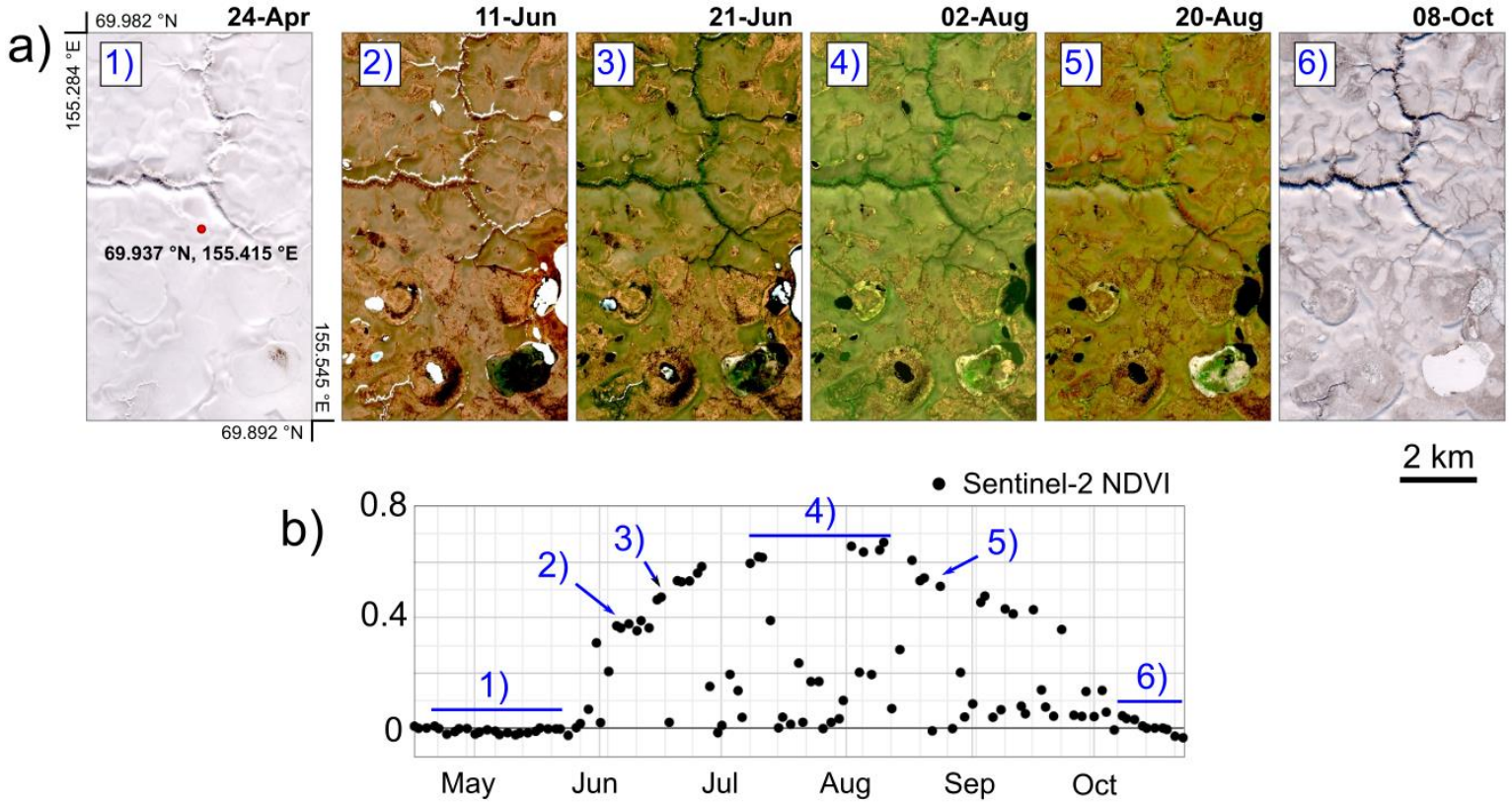


© www.neonscience.org

PhenoCam site Acadia



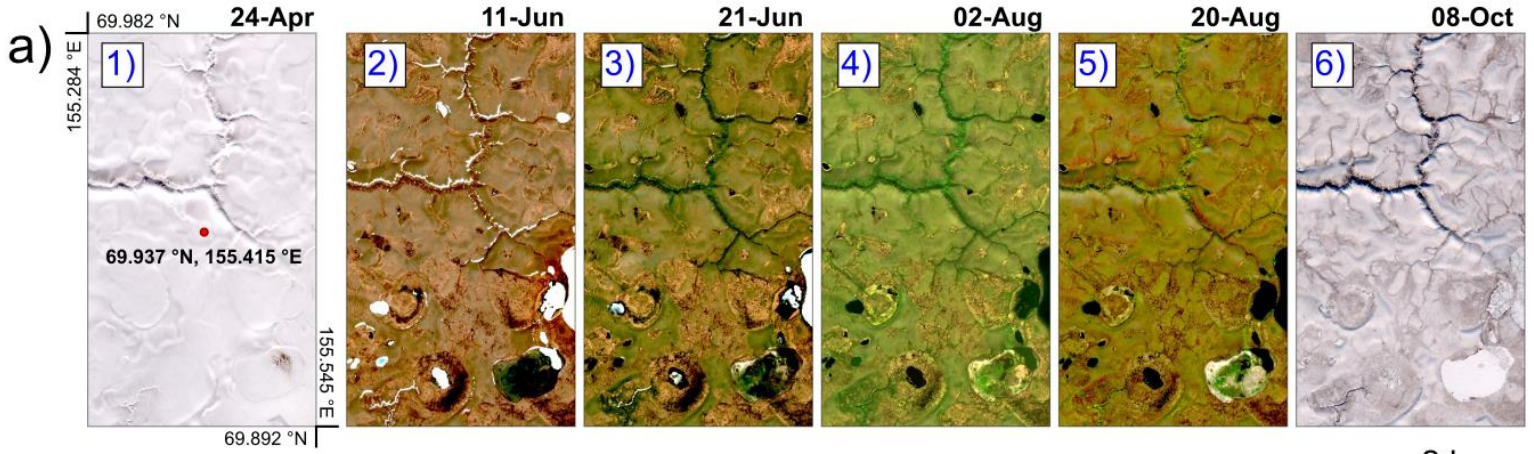
Bórnez et al. "Evaluation of VEGETATION and PROBA-V phenology using phenocam and eddy covariance data." *Remote Sensing* 12.18 (2020): 3077.

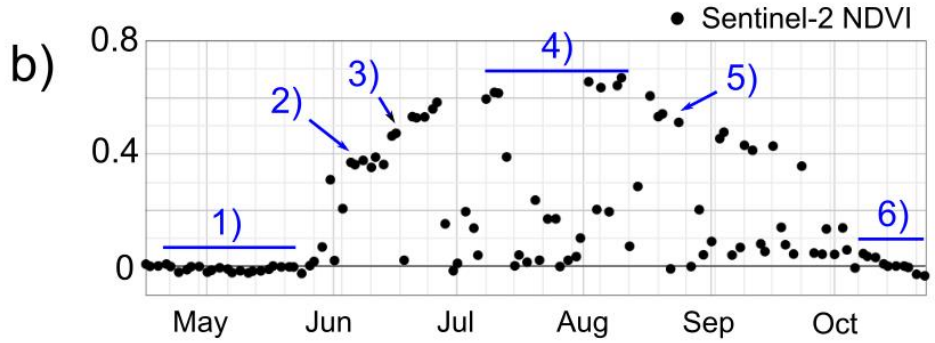


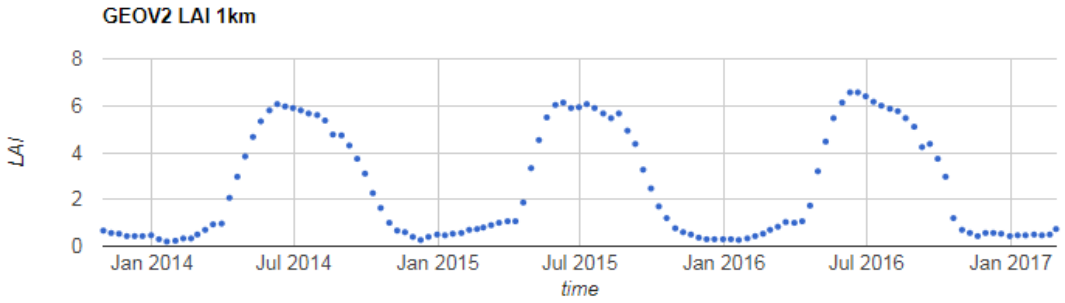
Descals, et al. “Improved estimates of arctic land surface phenology using Sentinel-2 time series.” *Remote Sensing* 12.22 (2020): 3738.

“in tropical, arid, and semi-arid ecosystems […] NBAR-EVI2 time series do not closely resemble logistic growth patterns”

Gray et al., "User guide to collection 6 MODIS land cover dynamics (mcd12q2) product." *NASA EOSDIS Land Processes DAAC* (2019).



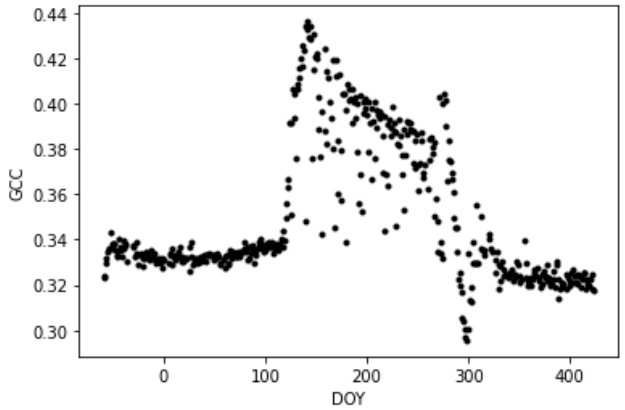




⇦

Doesn't require pre-processing!

Phenocam site Acadia



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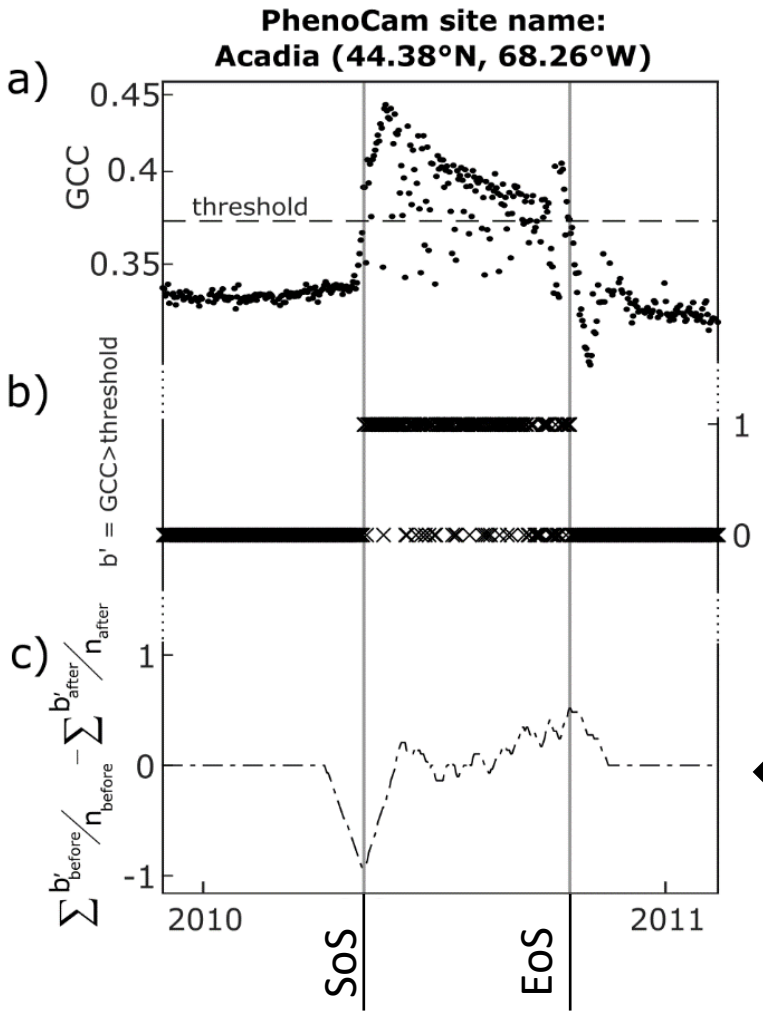


Raw time series

Binary time series

Difference in ratio before – after threshold

Advantages:

- Threshold-based method
- No need for time series pre-processing
- Does not distort time series
- Fast computing times
- Implementation in cloud-based platforms

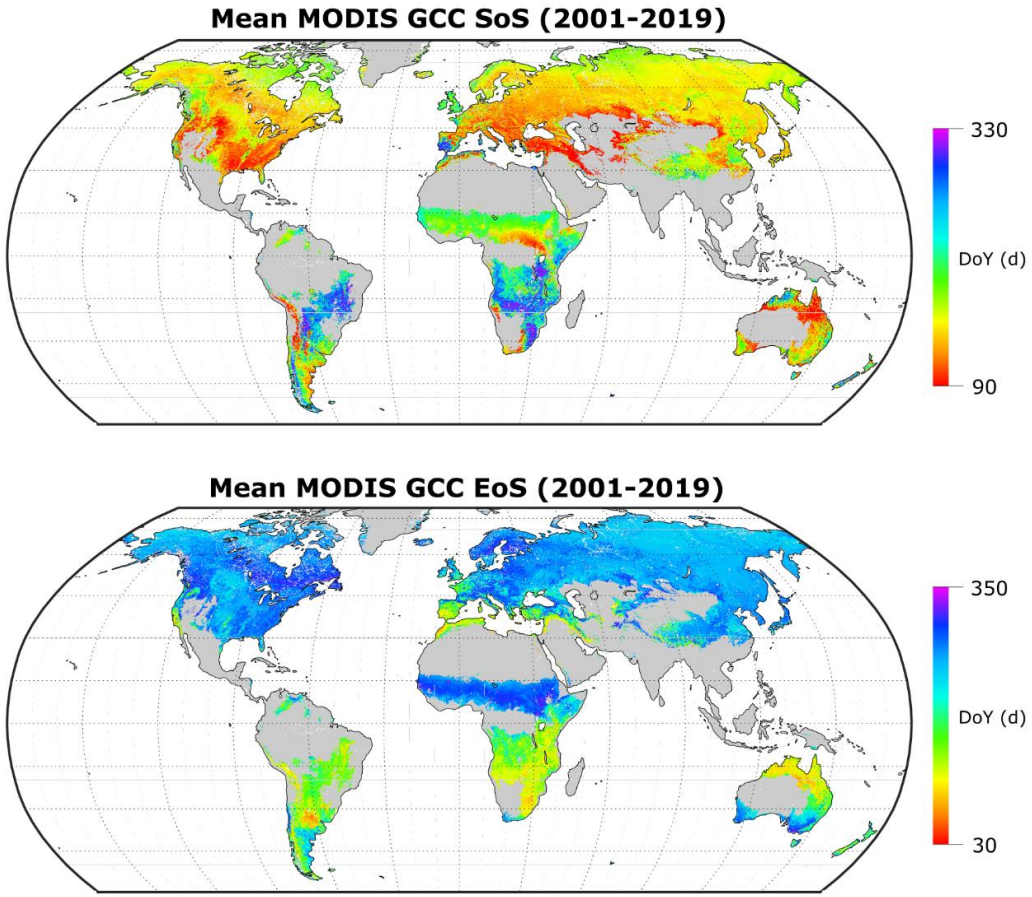
Google Earth Engine

Descals et al. "A threshold method for robust and fast estimation of land-surface phenology using google earth engine." *IEEE JSTARS*14 (2020)

Python and Earth Engine code:
https://github.com/adriadescals

GitHub

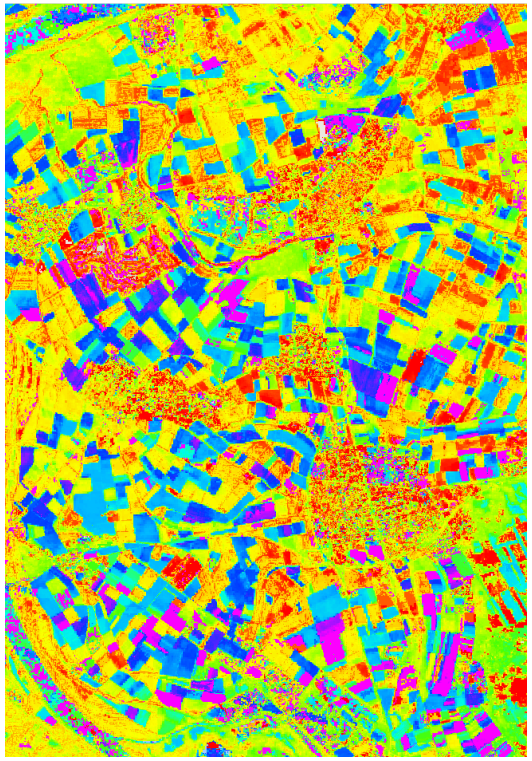
Global and high-resolution land-surface phenology



Worms (Germany)

1km

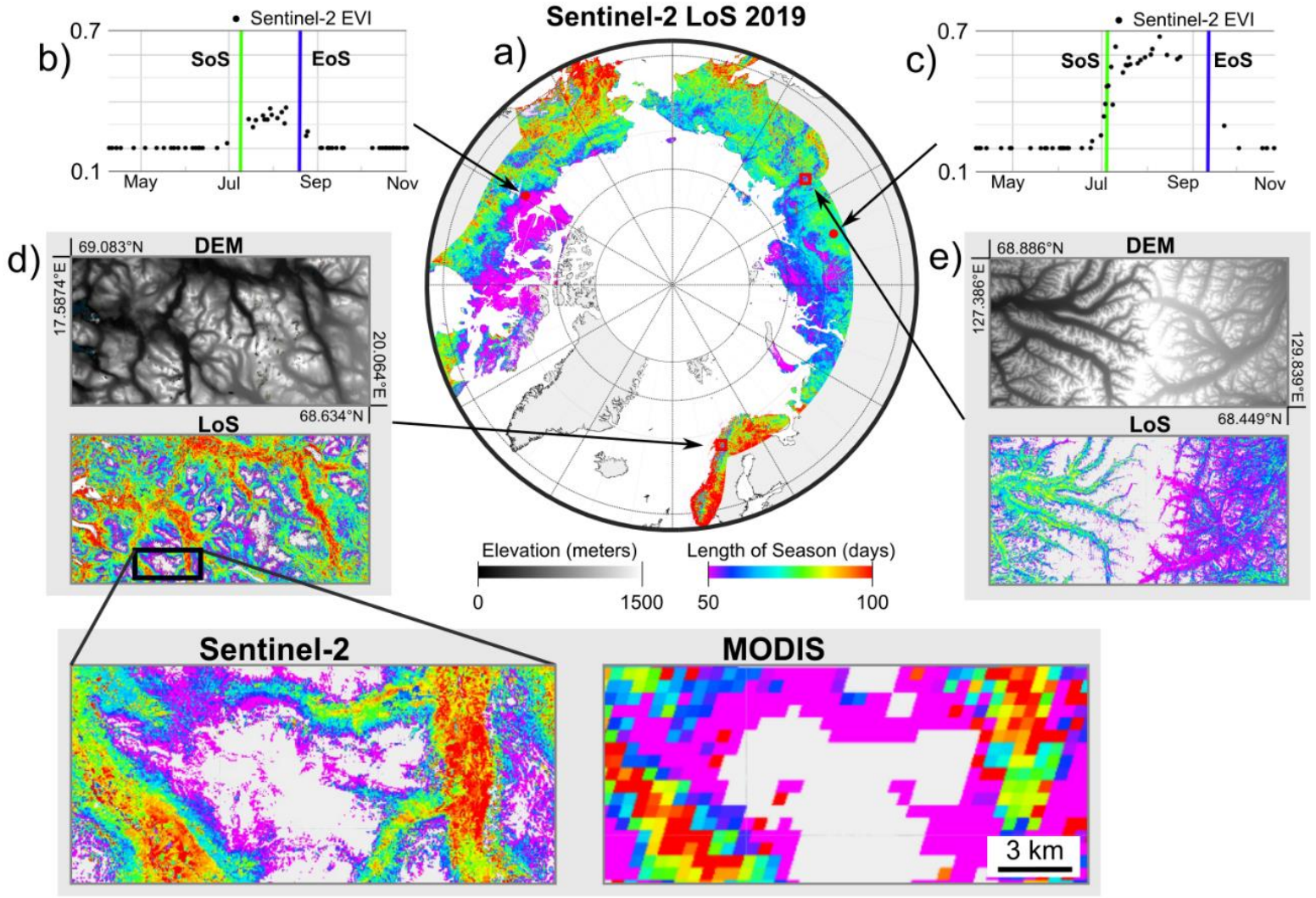
SoS 2017 Sentinel-2 (10m)

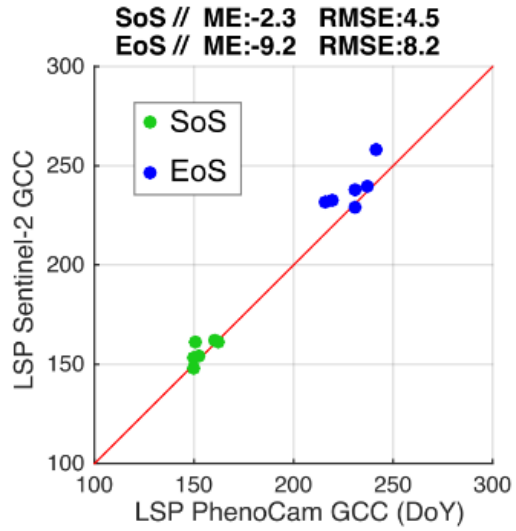


SoS

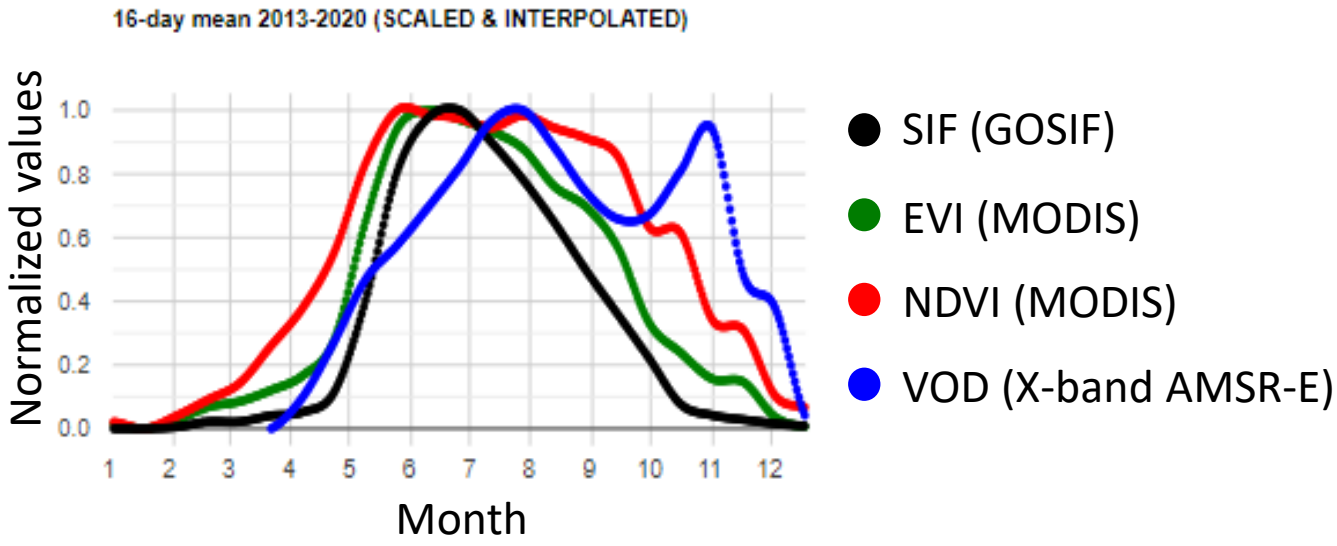
30 75 180

10-m resolution land-surface phenology

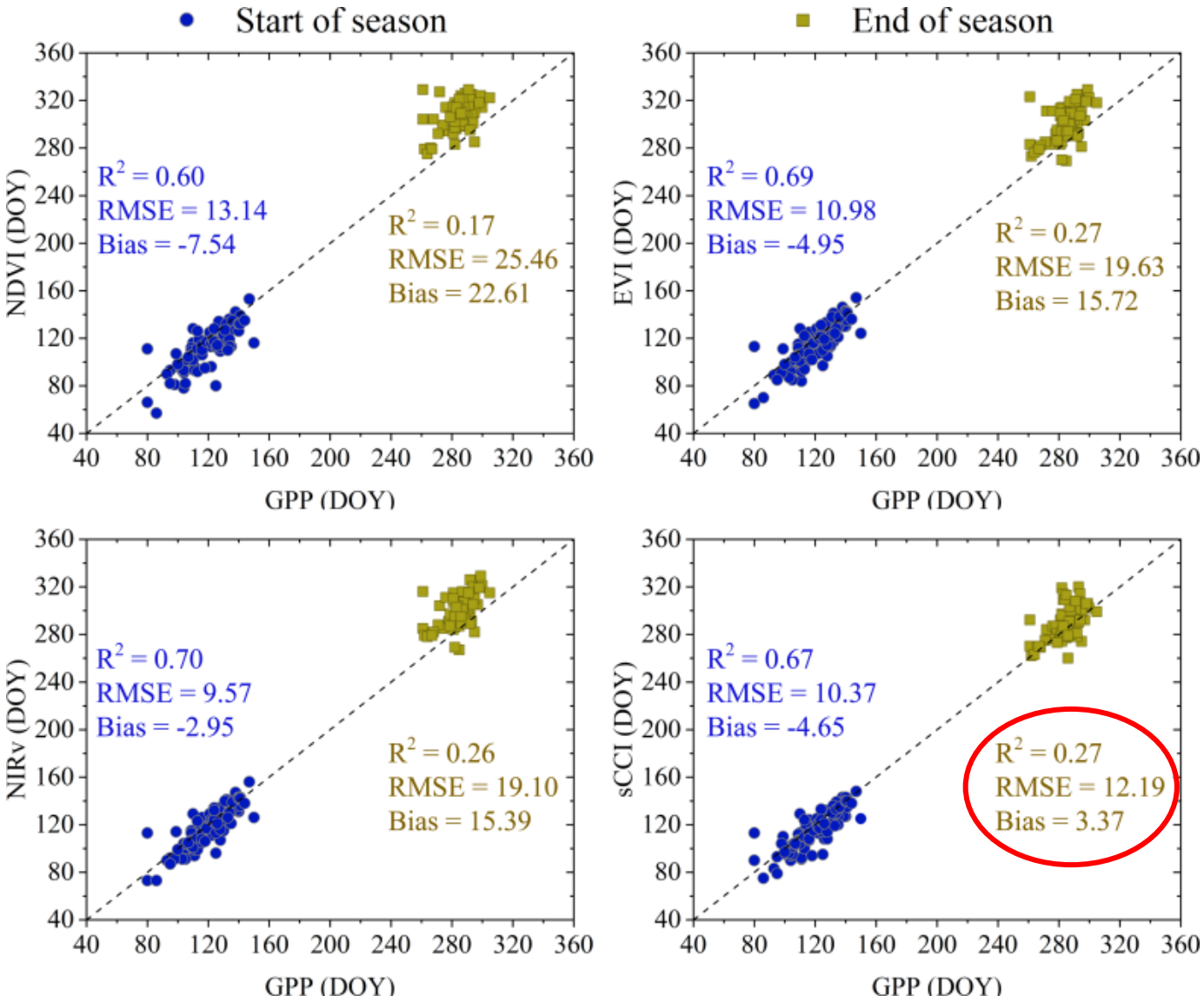




Descals, et al. “Improved estimates of arctic land surface phenology using Sentinel-2 time series.” *Remote Sensing* 12.22 (2020): 3738.



- Structural indices (NDVI - Leaf area index)
- Physiological indices (chlorophyll/carotenoid index (CCI) – Gross Primary Production)



- Chlorophyll/carotenoid index (CCI) best suited for tracking GPP phenology

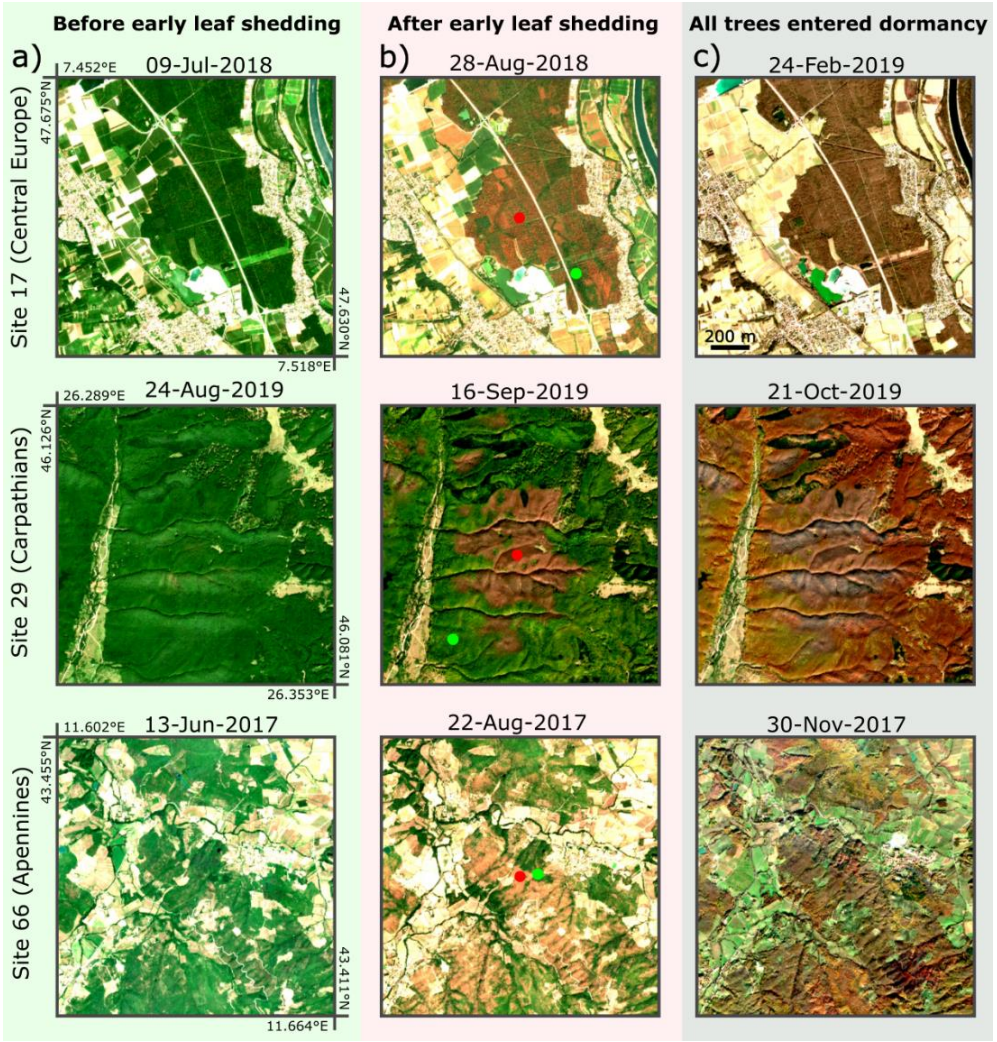
Yin et al. "Divergent estimates of forest photosynthetic phenology using structural and physiological vegetation indices." *Geophysical Research Letters* 47.18 (2020)

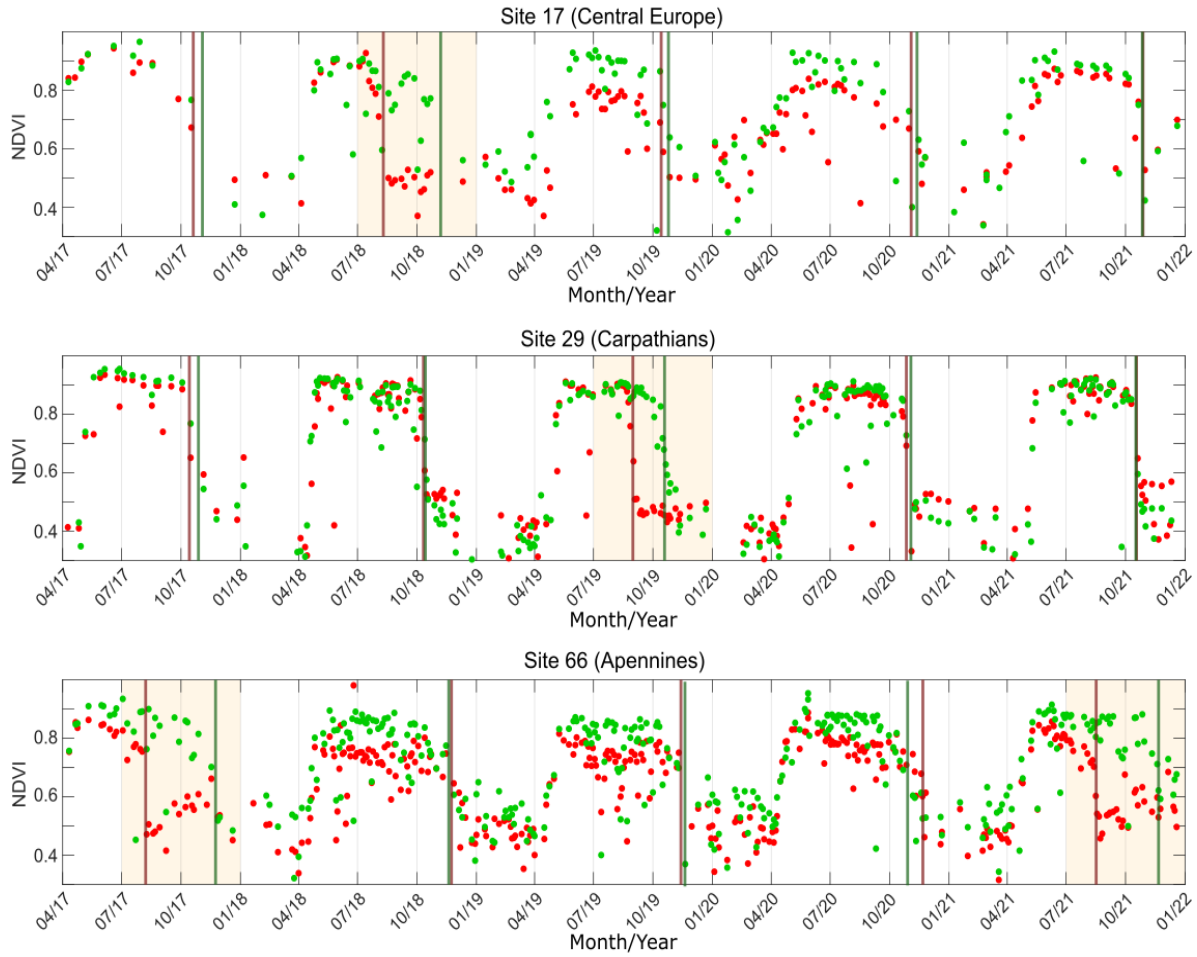
Reducing uncertainties in land surface phenology for improved modelling of vegetation-climate dynamics

- Interpretation of phenology metrics
- Phenology metric estimation
- Spatial resolution
- Variable selection

- Case study

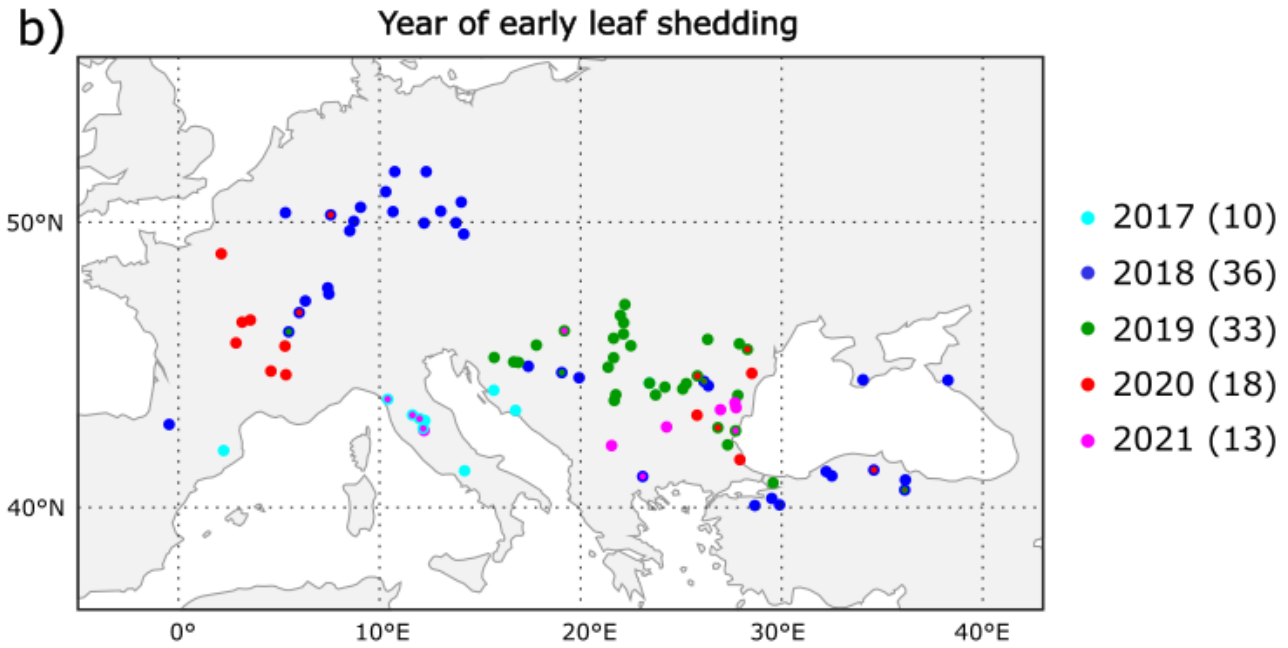
Early leaf shedding in deciduous forests



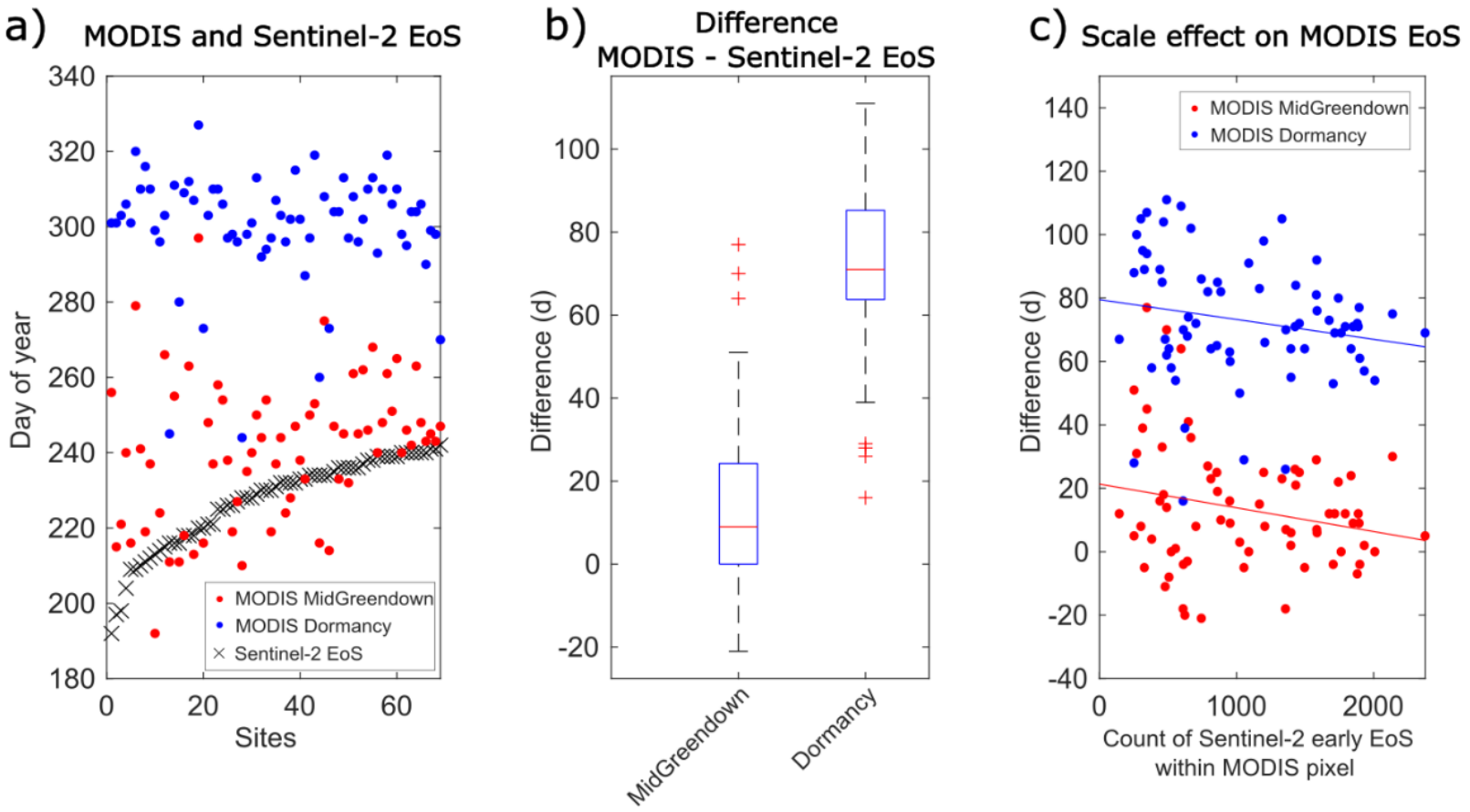


- Early leaf wilting in Centre Europe

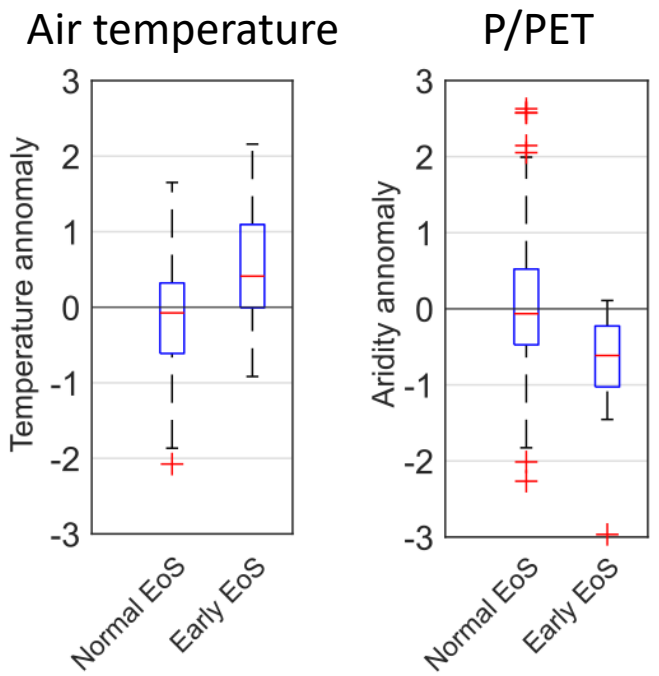
Brun et al. "Large-scale early-wilting response of Central European forests to the 2018 extreme drought." *Global change biology* (2020)



- We show widespread early leaf shedding every year in the Sentinel-2 time series (2017-2021)



- MODIS Land cover dynamics overestimates the EoS in early leaf shedding sites



Early leaf shedding is related to anomalously high temperatures and aridity conditions

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- Phenophase: leaf shedding
- Spatial resolution: 10 meters
- Time series: NDVI (leaf biomass)
- LSP method: Threshold method (10%)