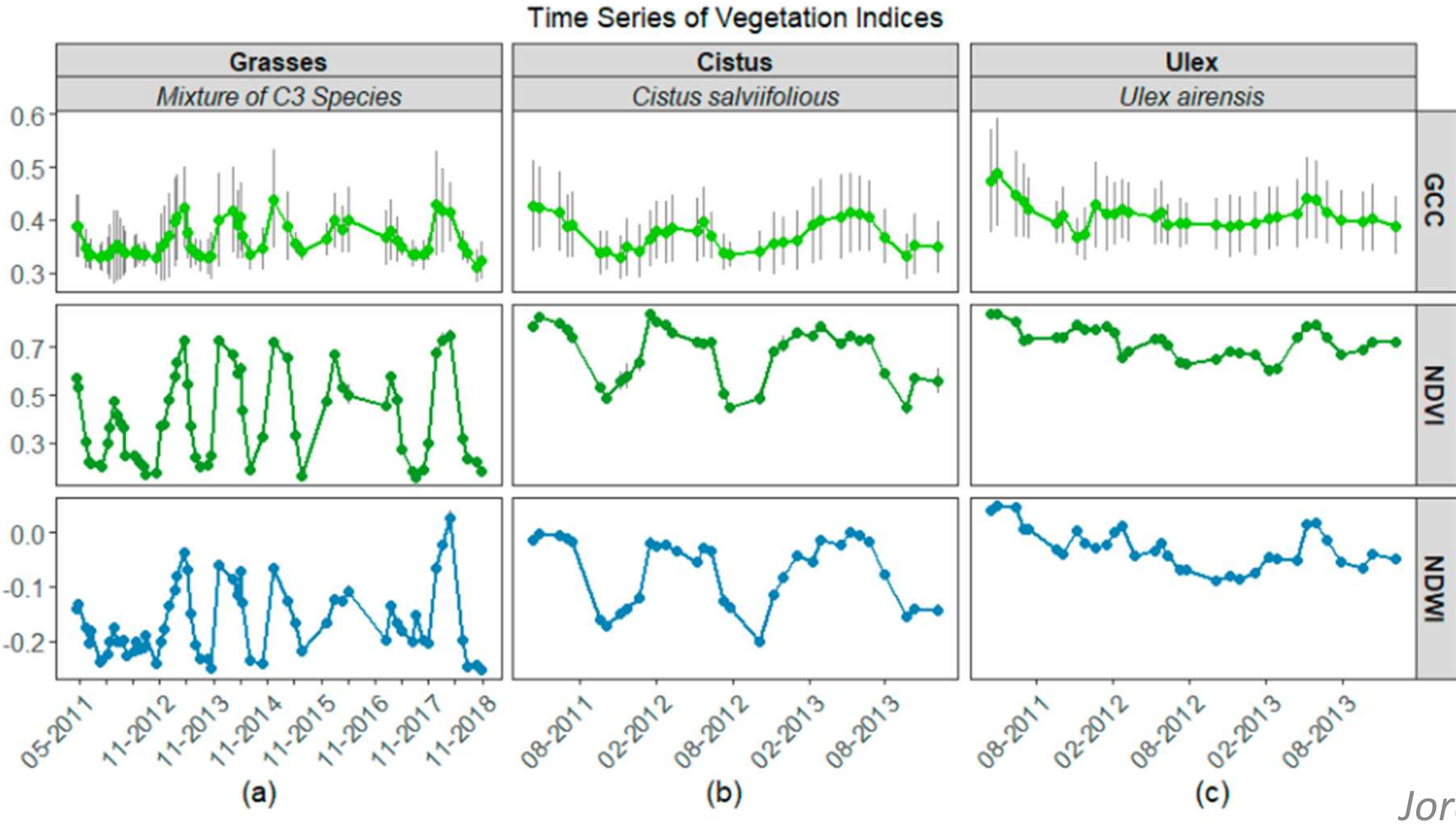
ISA

- IN-SITU COLLECTION OF VEGETATION IMAGES AND REFLECTANCE
- SET-UP FOR SENSORS DEPLOYED ON UAV PLATFORMS.
- DATA UNCERTAINTY
- MONITORING PHENOLOGY AND STRESS WITH SATELLITE OBSERVATIONS
- TEMPORAL AND SPATIAL MISMATCH BETWEEN GROUND AND SATELLITE OBSERVATIONS

LECTURE 3-27/05/2026



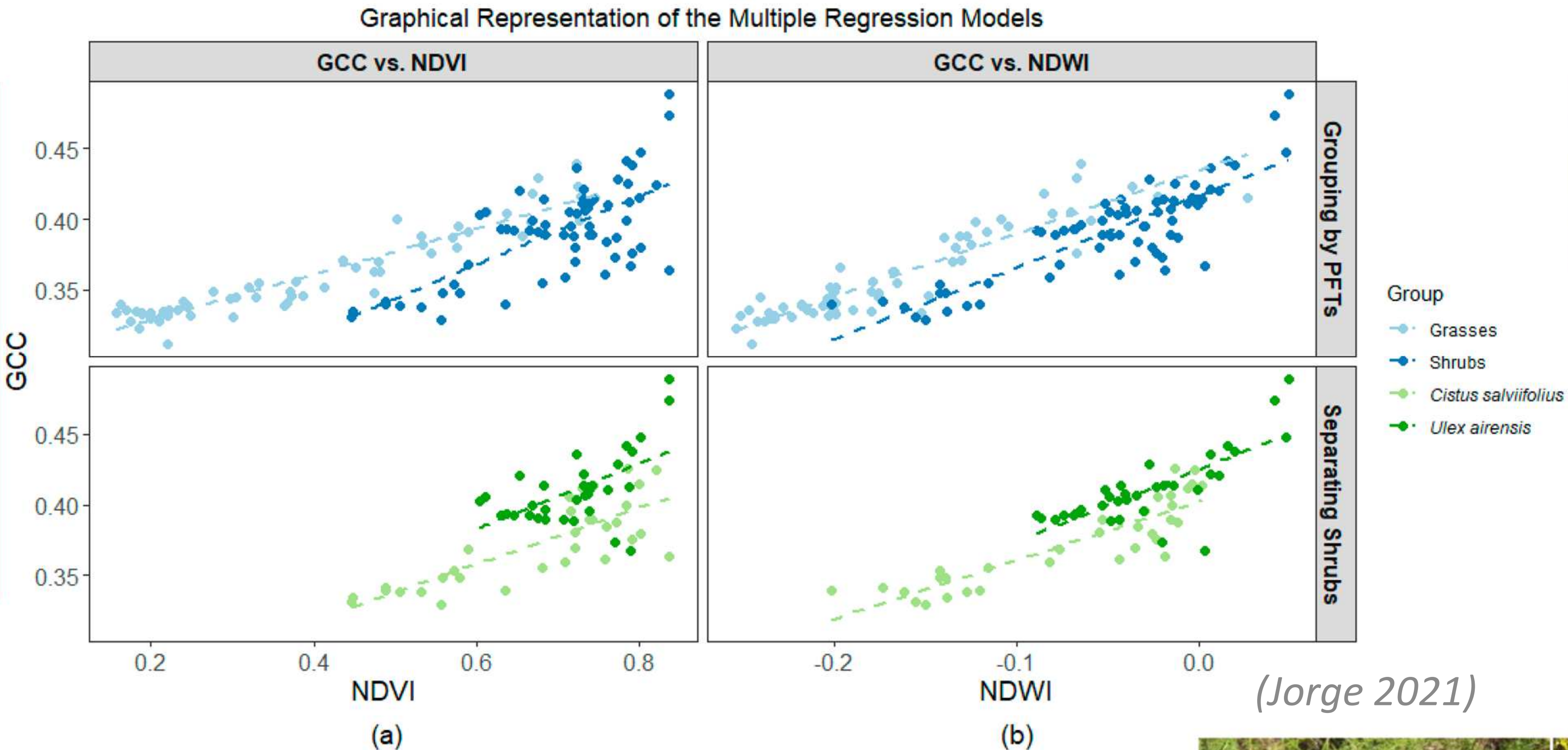
Jorge 2021

Digital photographs and vegetation reflectance collected in different vegetation types

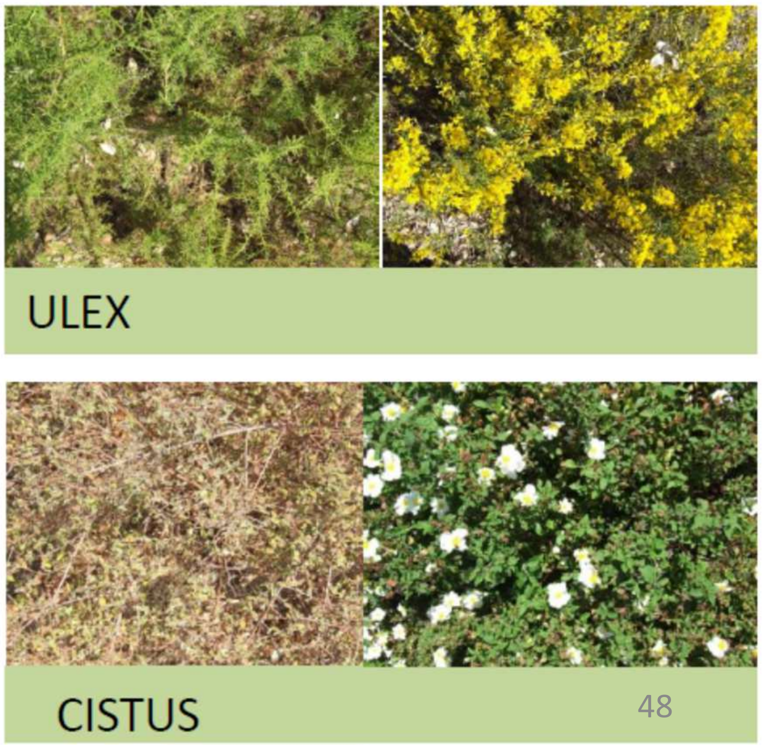
-nadir view

-clear sky

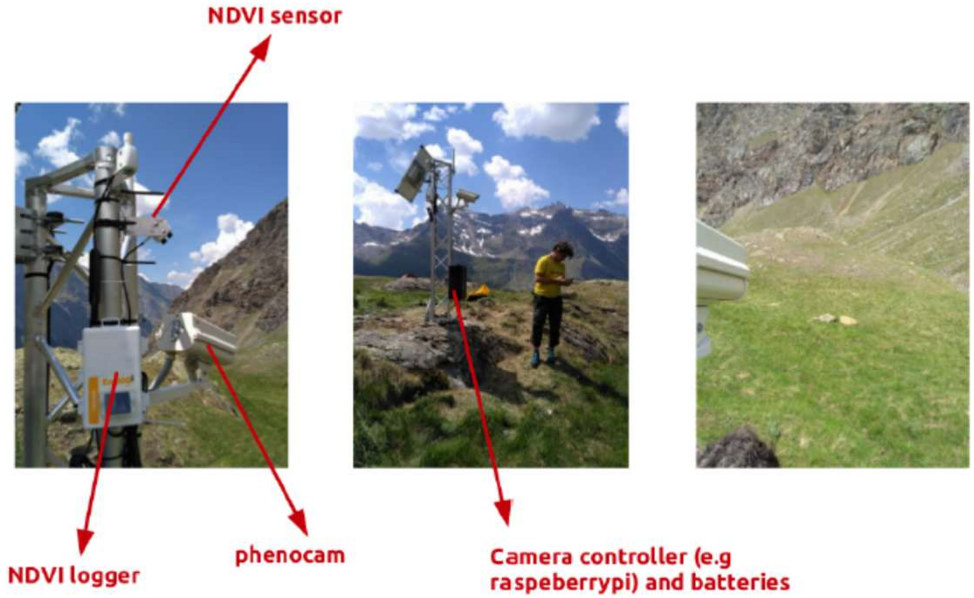
-close to midday



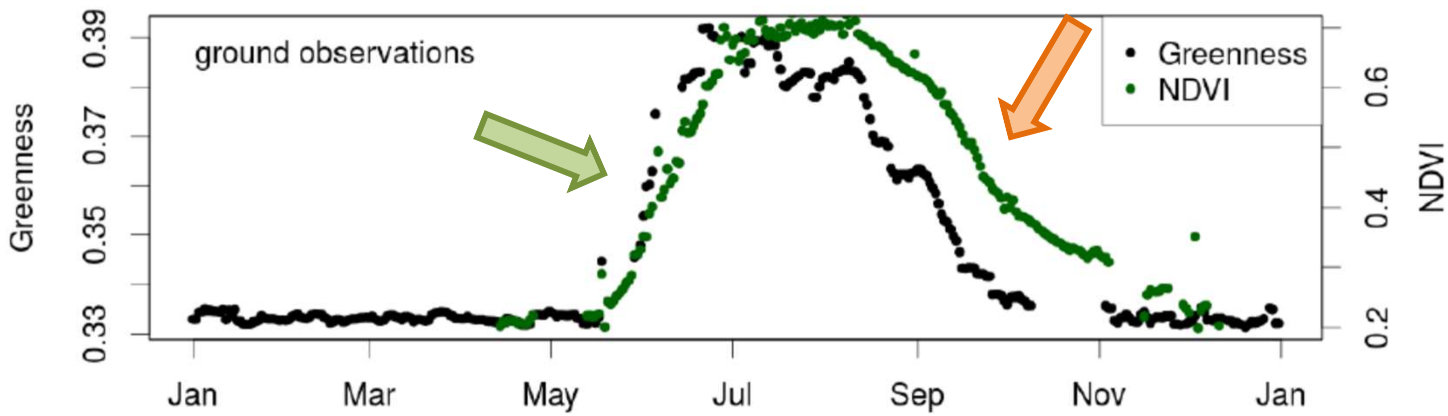
(Jorge 2021)



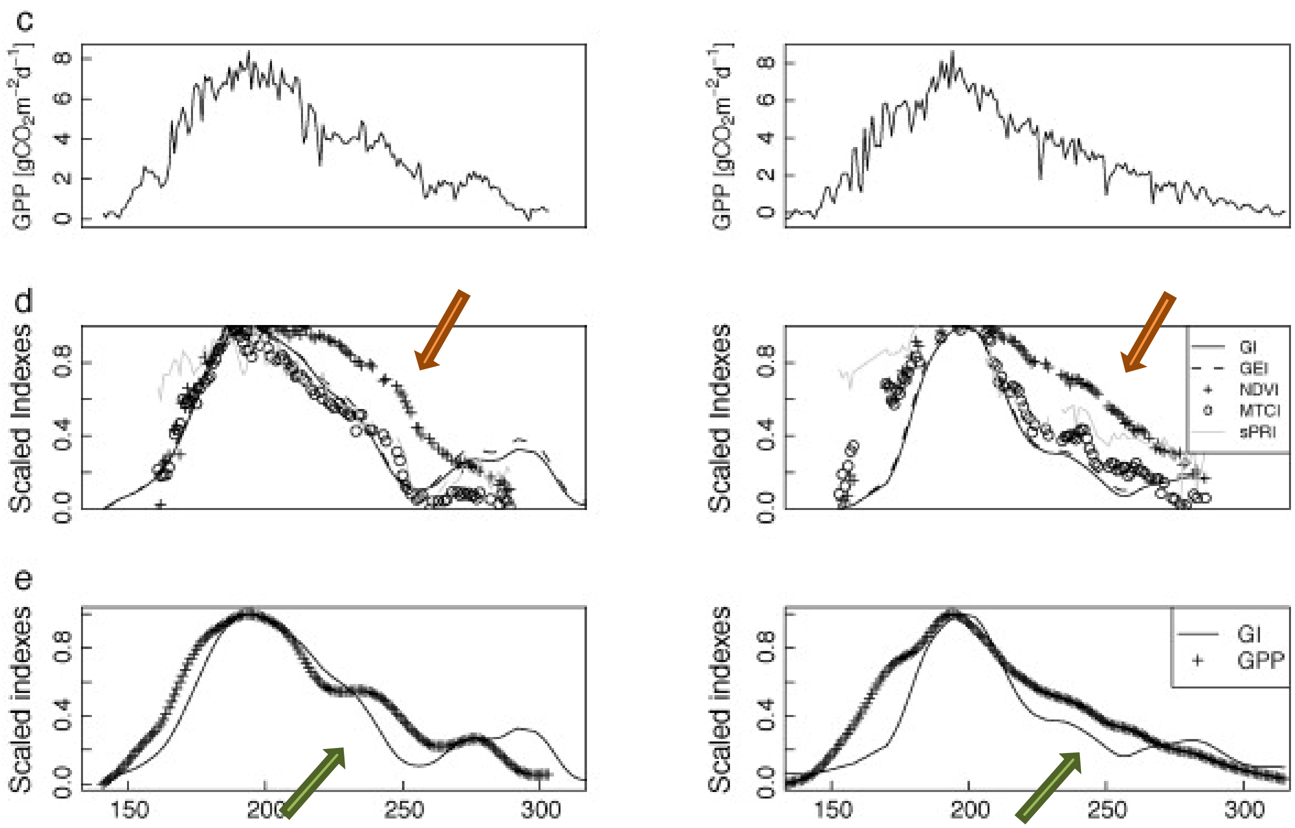
The regression between GCC and spectral NDVI (or NDWI) is specific for each plant functional type and shrub species



Sub-alpine grassland



Discrepancies were observed between GCC and NDVI trend during the senescence phase



$$NDVI = \frac{\rho 800 - \rho 600}{\rho 800 + \rho 680}$$

$$MTCI = \frac{\rho 753.75 - \rho 708.75}{\rho 708.75 - \rho 681.25}$$ chlorophyll

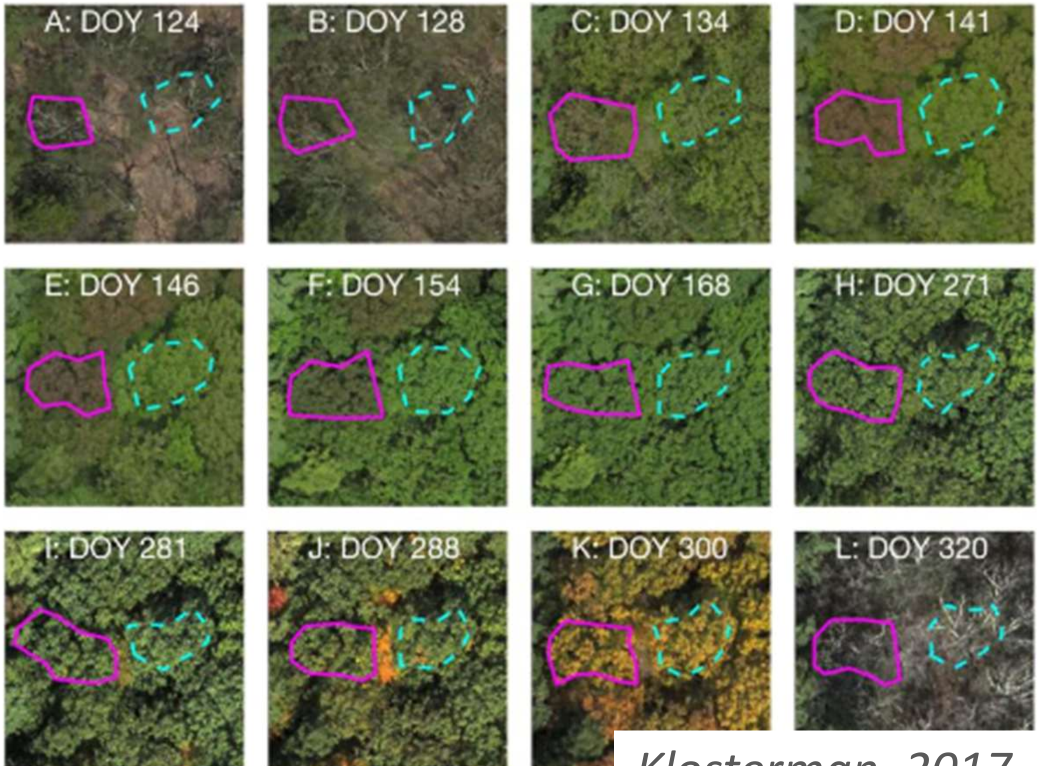
$$sPRI = \frac{((\rho_{531} - \rho_{570})/(\rho_{531} + \rho_{570}) + 1)}{2}$$

Carotenoids/chl.

GI (=GCC) , MTCI and sPRI are more sensitive to changes in pigments composition than structure (NDVI)

GPP: Gross Primary Productivity is the amount of CO_2 fixed by photosynthesis

CHALLENGES IN USING UAV IMAGES

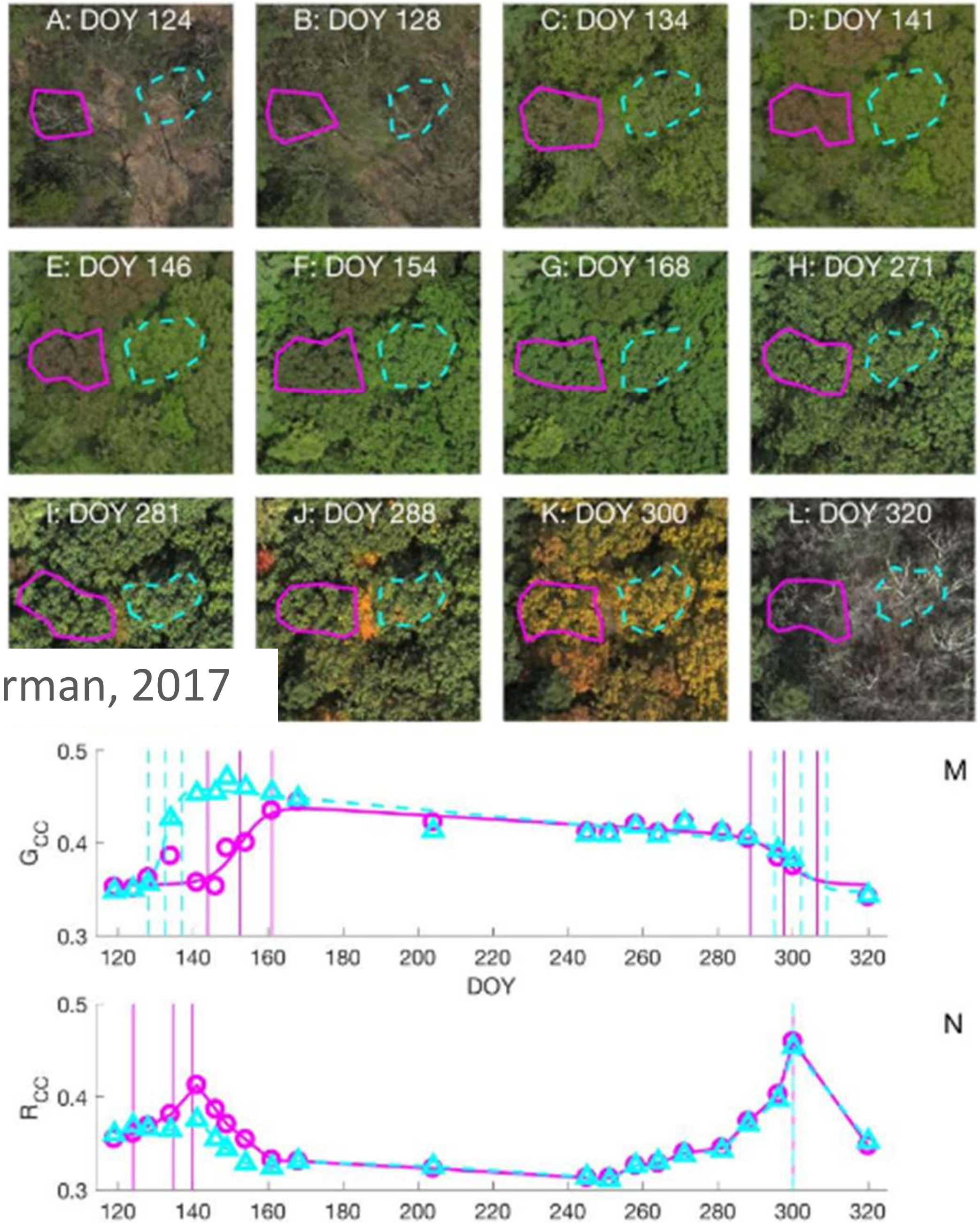


Klosterman, 2017

UAV images of trees canopies were used to asses phenology in a mixed forest.

What should we consider in the setup of the experiment to obtain good phenological observations data from UAV imagery?

Viewing angle
Temporal resolution
Flight stability: same flight path and camera angles
Accurate geolocation
Light changes



Klosterman, 2017

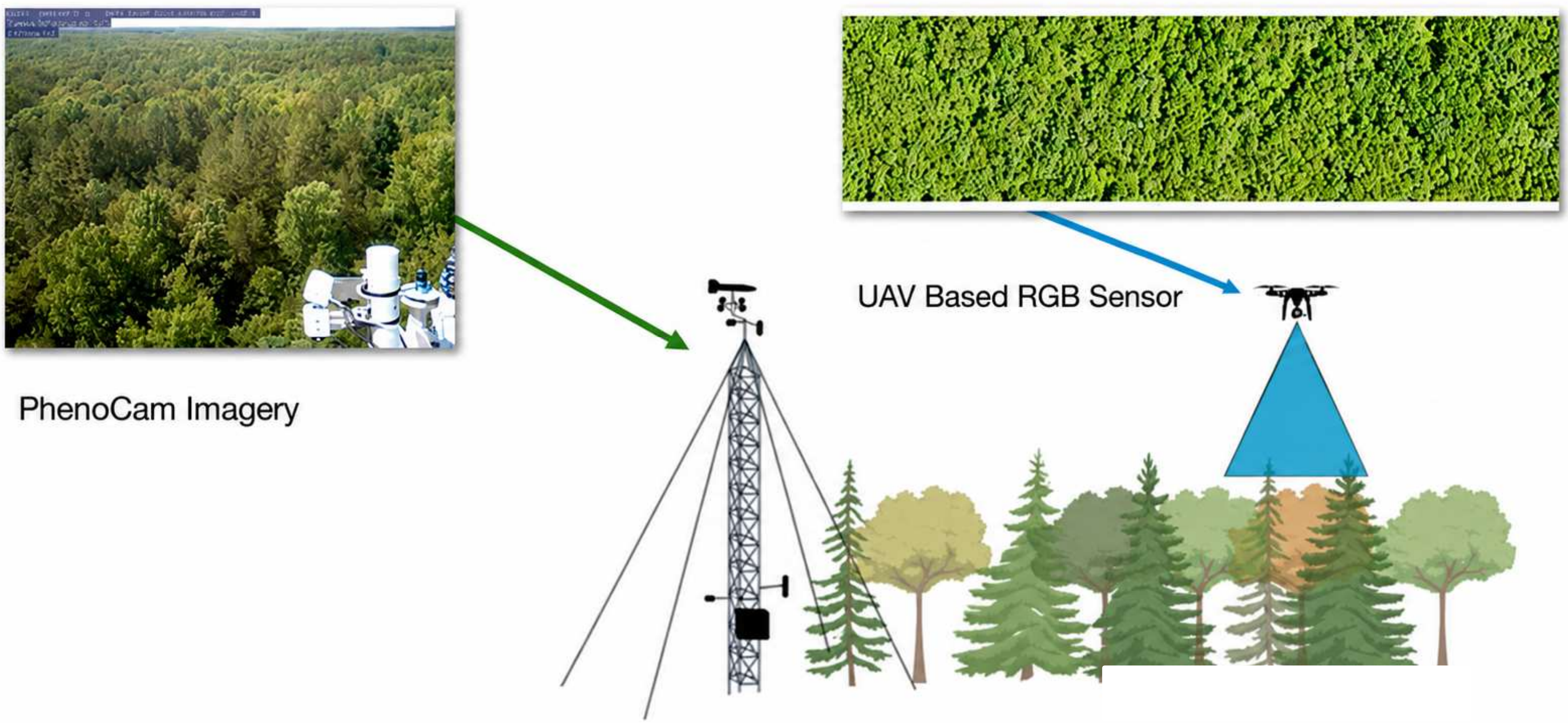
Repeated overpass over the same region.
Red oak (*Quercus rubra*) deciduous forest

Both GCC and Rcc were used to identify PTDs

GCC trend determined a later SOS in Spring in the tree with more red leaves.

Rcc partially failed in Spring detection but identified well the peak of the senescence period for both trees

PTD ESTIMATES USING UAV IMAGES



(Atkins, 2020)

-**Phenocams** provide continuous data but have an oblique (inclined) viewing angle and limited field of view
-**UAVs** cover large areas with good spatial resolution but offers low temporal resolution

UAV-PHENOCAM COMPARISON

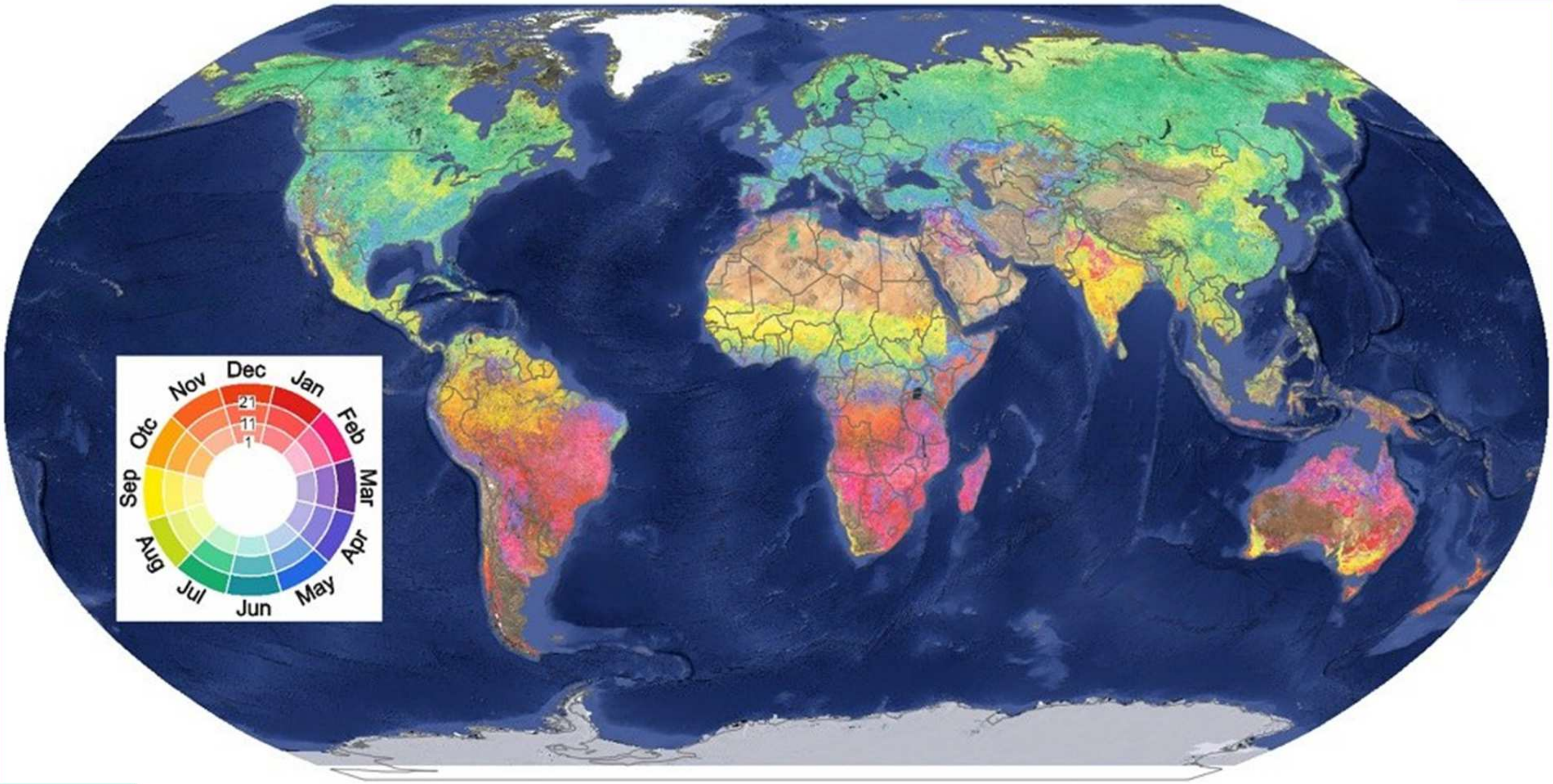
Land Surface Phenology (LSP) is the study of plant phenology at a regional to global scale as assessed from data acquired by space-borne optical sensors.

Key advantages:

- Repeated, consistent observations (e.g., every 5–16 days)
- Multi-decadal archives (e.g., MODIS since 2000, Landsat since the 1980s)
- Monitoring across scales — from plots to continents

- **Index-based** (e.g., NDVI, EVI, PRI, SIF)
- **Derived products** (e.g., LAI, FAPAR, GPP estimates)

LAND SURFACE PHENOLOGY



Global map of the date of the peak of growing season (season maximum date)
https://land.copernicus.eu/en/news/global-land-surface-phenology-2023-available

Seasonal patterns in vegetation growth and senescence can be retrieved from time series of satellite retrieved spectral vegetation indices

Time series are filtered, smoothed and phenological metrics (e.g., start of season, peak greenness) extracted

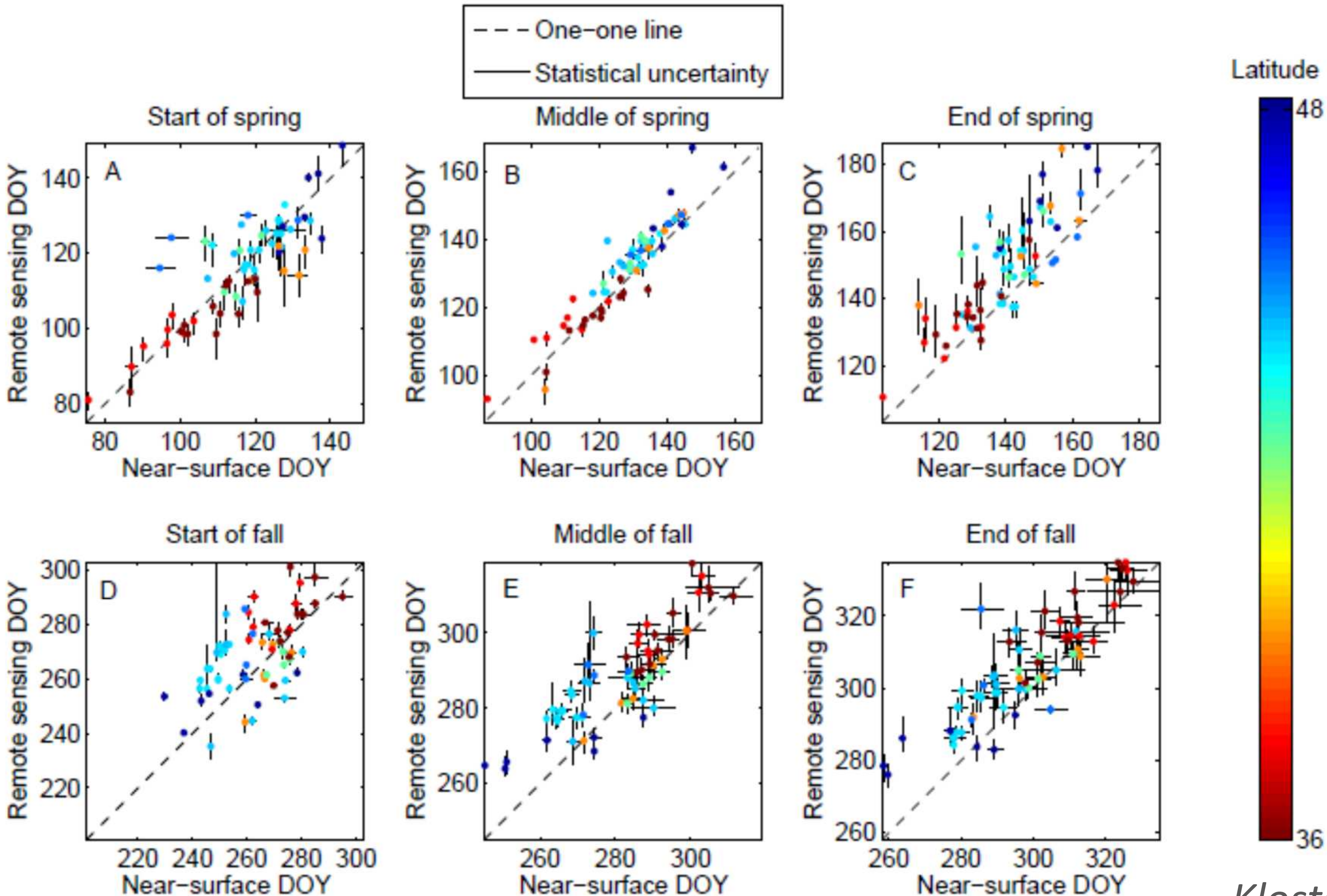
ISA

- Need for preprocessing: atmospheric correction, cloud and shadow masking
- Outlier detection and filtering
- Temporal gap filling and smoothing required due to missing data
- Limited ability to directly interpret biological processes (spectral observations can be misunderstood without direct observations)
- Trade-off between temporal frequency and spatial resolution

Common EO data sources:

LANDSAT (L8-OLI): 30m, 16 days
MODIS (MCD43A4): 500m, 8 -16 days composite
Sentinel-2 : 10-20m, 5 days

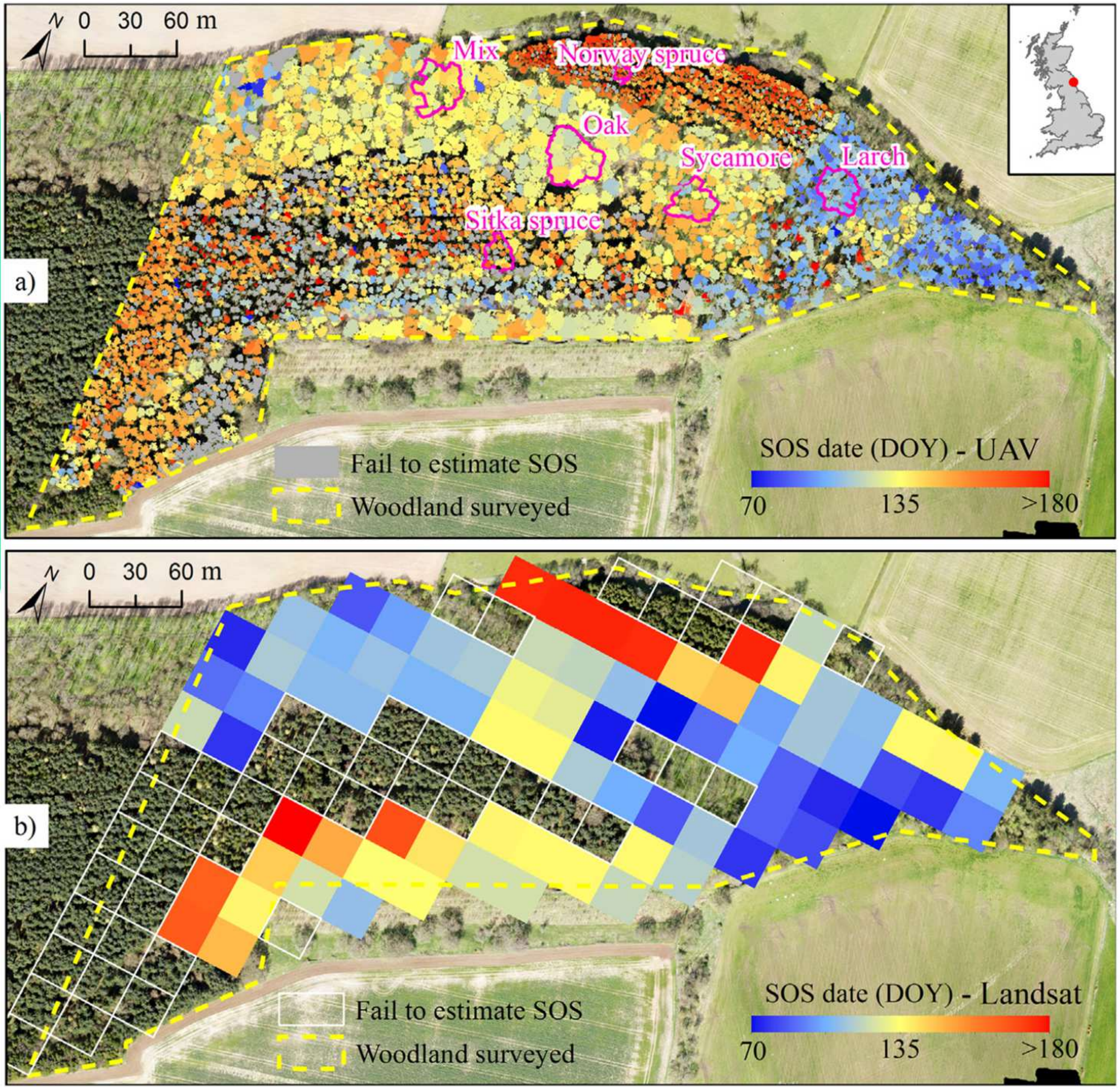
LIMITS AND TRADE-OFFS IN THE USE OF EO DATA



Klosterman, 2014

PhenoCam imagery showed smaller uncertainty than remote sensing metrics of phenology and in some cases an advance in phenological events

COMPARISON OF PHENOCAM AND MODIS



Landsat data (b) showed a lower ability to estimate phenological metrics than UAV (a) because of the low temporal resolution

The comparison is useful for validating satellite data and understanding scaling effects

Berra, 2019

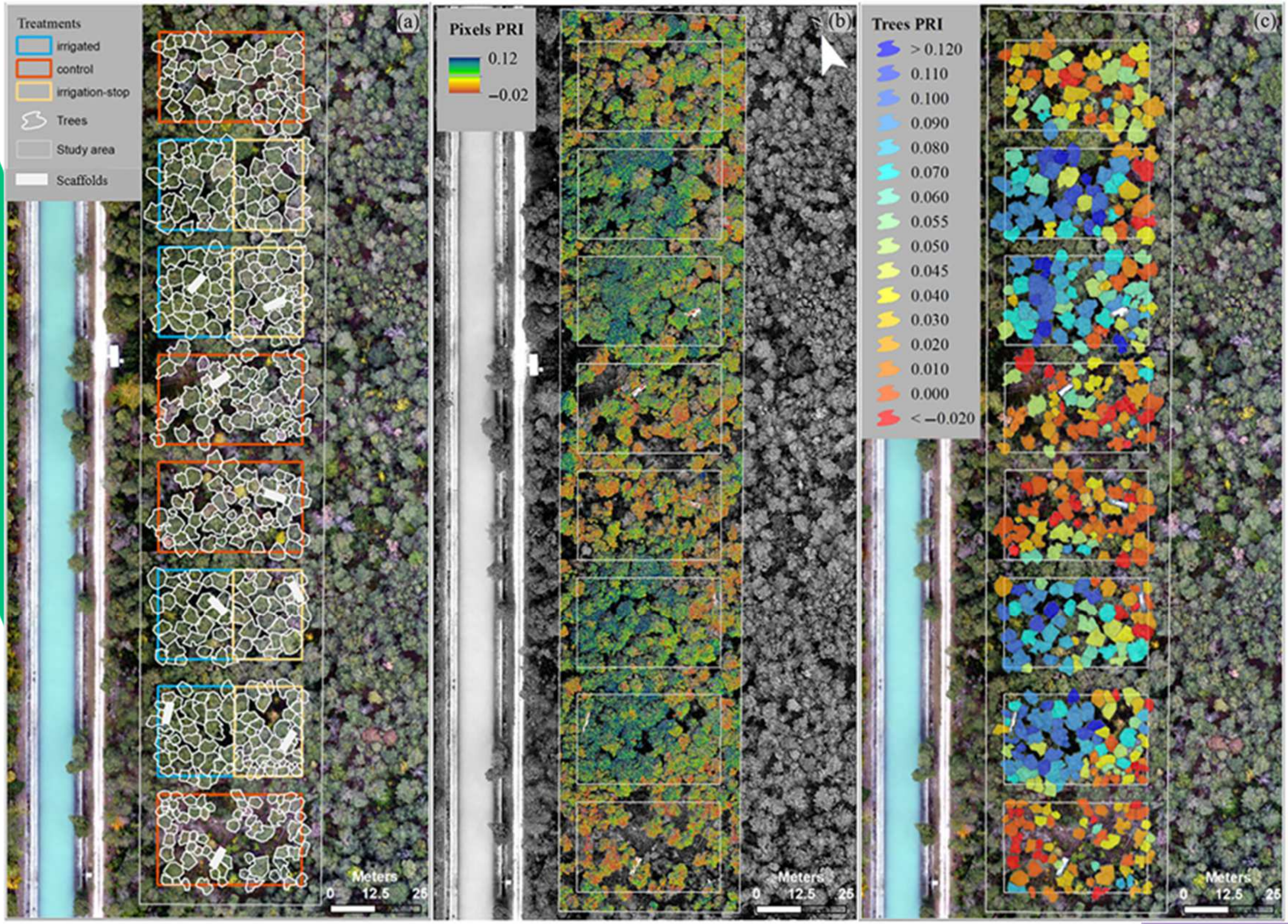
COMPARISON OF UAV AND LANDSAT

In-situ measurements are necessary for validating Remote sensing time series to ensure:

- **Accuracy**: Confirming that remote sensing indices or model outputs reflect real vegetation conditions
- **Interpretability**: Helping translate spectral signals (e.g., NDVI, SIF) into ecophysiological or agronomic metrics

Challenges in the comparison of ground vs satellite observations:

- **Spatial mismatch**: Homogeneous field plots are often small when compared to satellite pixels.
- **Temporal mismatch**: Timing of field measurements must align with satellite overpasses

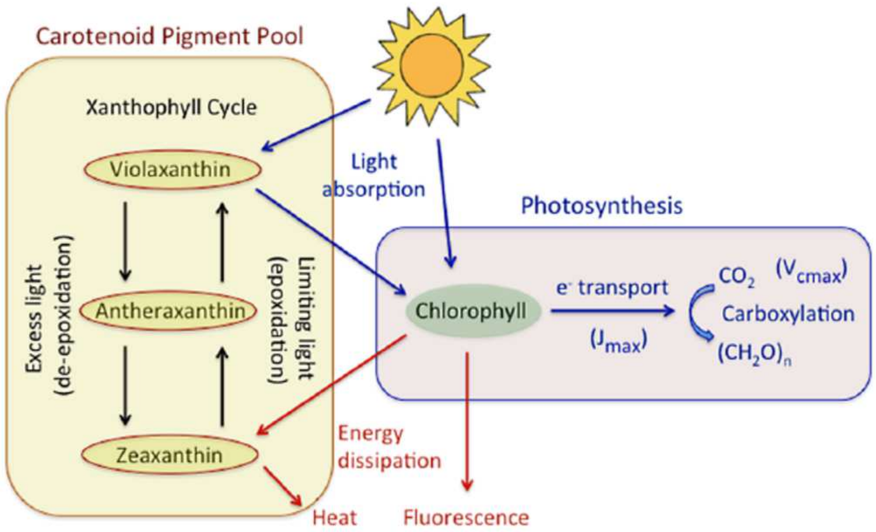


D'Odorico, 2021

100-y-old *Pinus sylvestris* forest subject to precipitation manipulation

PRI of never-irrigated trees (control) was up to 10 times lower (higher stress) than PRI of irrigated trees

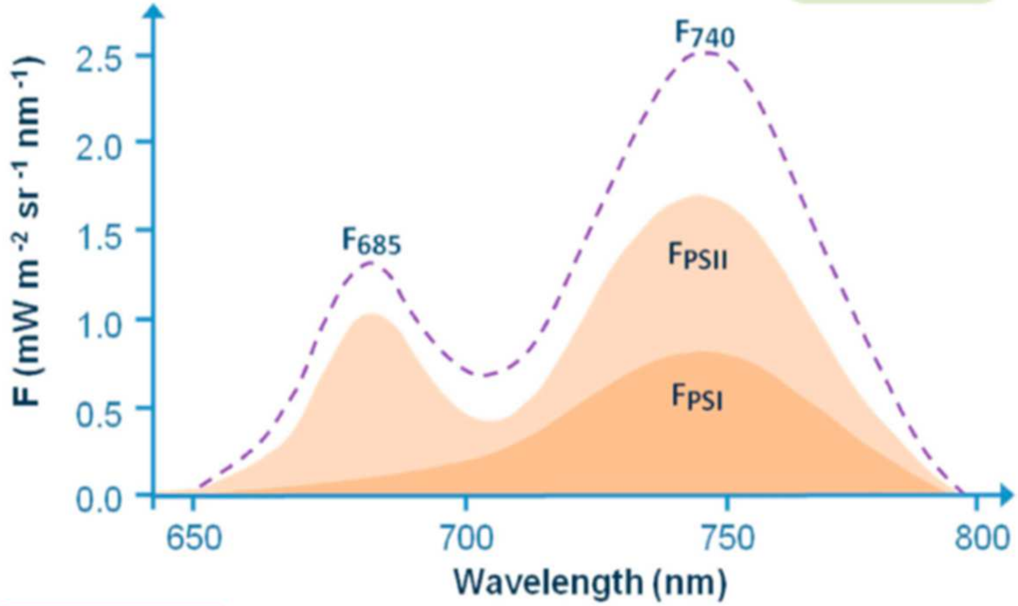
VIs sensitive to changes in photosynthetic pigments can represent physiological constraints to GPP (e.g.: PRI)

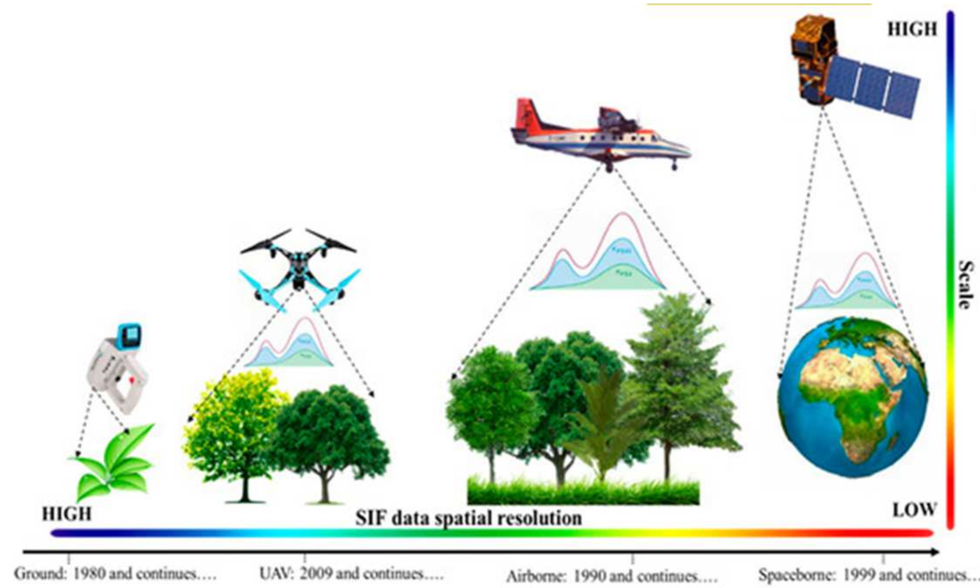


$$\text{PRI} = \frac{\rho 531 - \rho 570}{\rho 531 + \rho 570}$$

When leaves experience stress conditions they dissipate heat by triggering the xanthophyll cycle. This molecular change in photosynthetic pigments modifies the reflectance at 531nm

PHOTOCHEMICAL REFLECTANCE INDEX - PRI

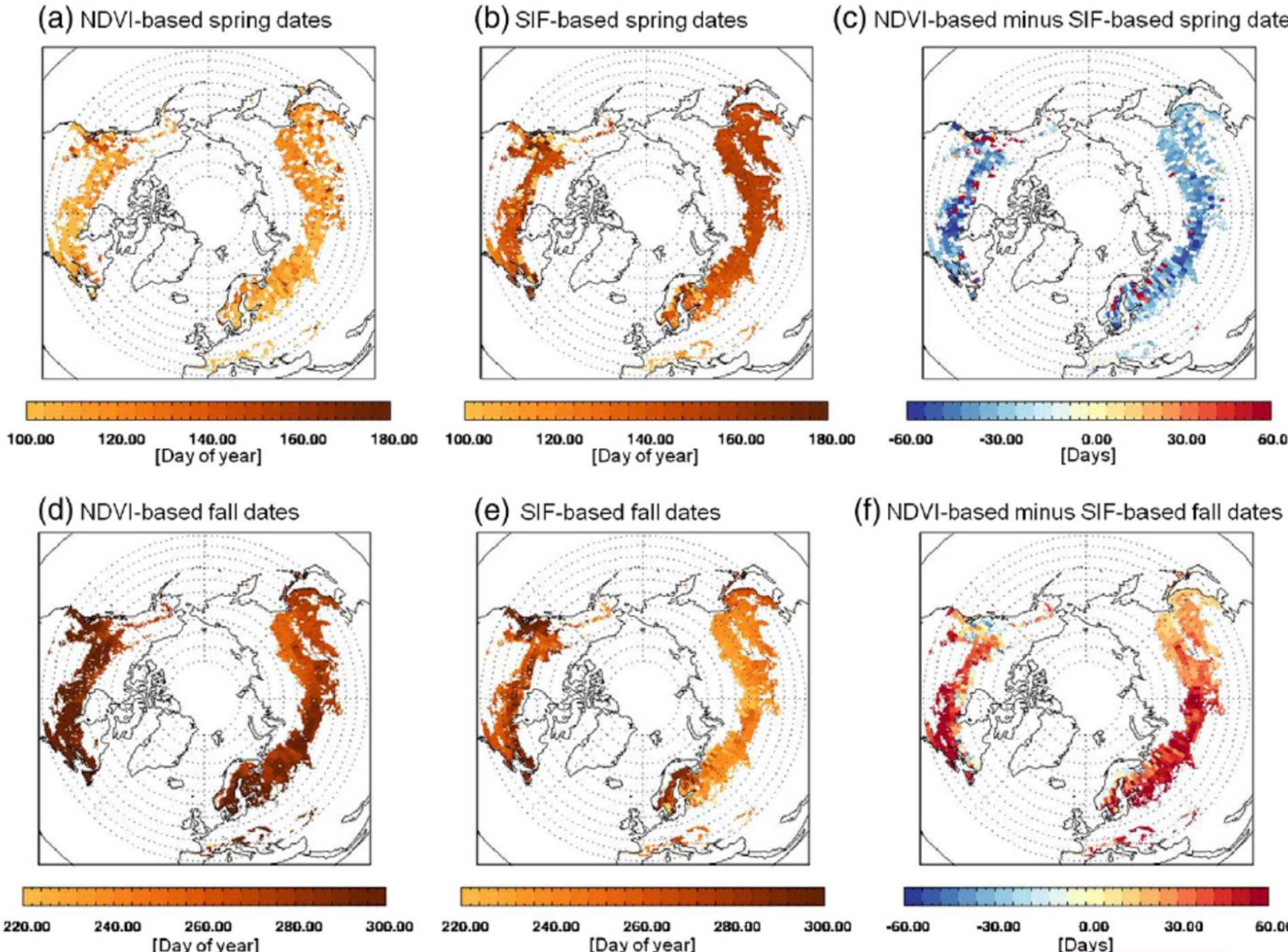




SIF (Solar Induced Fluorescence) can be considered a real-time indicator of photosynthetic activity.

- SIF limitations:

SIF signal is weak and requires high spectral resolution (<1nm) and signal-to-noise ratio.
It is affected by canopy structure and plant functional type
The interpretation of results can be complex since it depends on species, structure, and physiology



SIF -> changes in photosynthesis

NDVI-> changes in canopy structure

(Jeong, 2017)

NDVI rises approximately two weeks earlier in the spring and remains high for about five weeks longer in the fall compared to SIF

- COMPARE DIFFERENT PTD METHODS FOR THE EXTRACTION OF PHENOLOGY PARAMETERS IN PHENOPIX.
- COMPLETE YOUR WORK

LECTURE 3 – PRACTICE – 27/05/2026

Use the greenProcess function to obtain PTDs and plot.

Based on the results of the greenExplore function apply one or more fitting methods:

-Available options: **spline**, **beck**, **elmore**, **klosterman**, **gu**.

-Available options: **trs**, **derivatives**, **klosterman**, **gu**

You can calculate uncertainty (uncert= TRUE) (be aware the bootstrap can slow your computer)

-FINAL FITTING AND THRESHOLDS

Describe the target selected

Add meteorological information at your analysis

Don’t forget the instructions for work presentation

COMPLETE THE ASSIGNMENT