Towards a synergistic use of Sentinels 2, 3 and 5P for SIF based estimates of Gross Primary Productivity at 1 km

Johannes Gensheimer[1], Markus Reichstein[1], Luis Guanter[2], Zayd Hamdi[1], and Gregory Duveiller[1]

[1]Max Planck Institute for Biogeochemistry, Jena, Germany; [2]Universitat Politècnica de València (UPV), Spain

25.05.2022

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living planet symposium | BONN 23–27 May 2022

TAKING THE PULSE OF OUR PLANET FROM SPACE

Within the ESA Sen4GPP project

EUMETSAT ECMWF EUSPA

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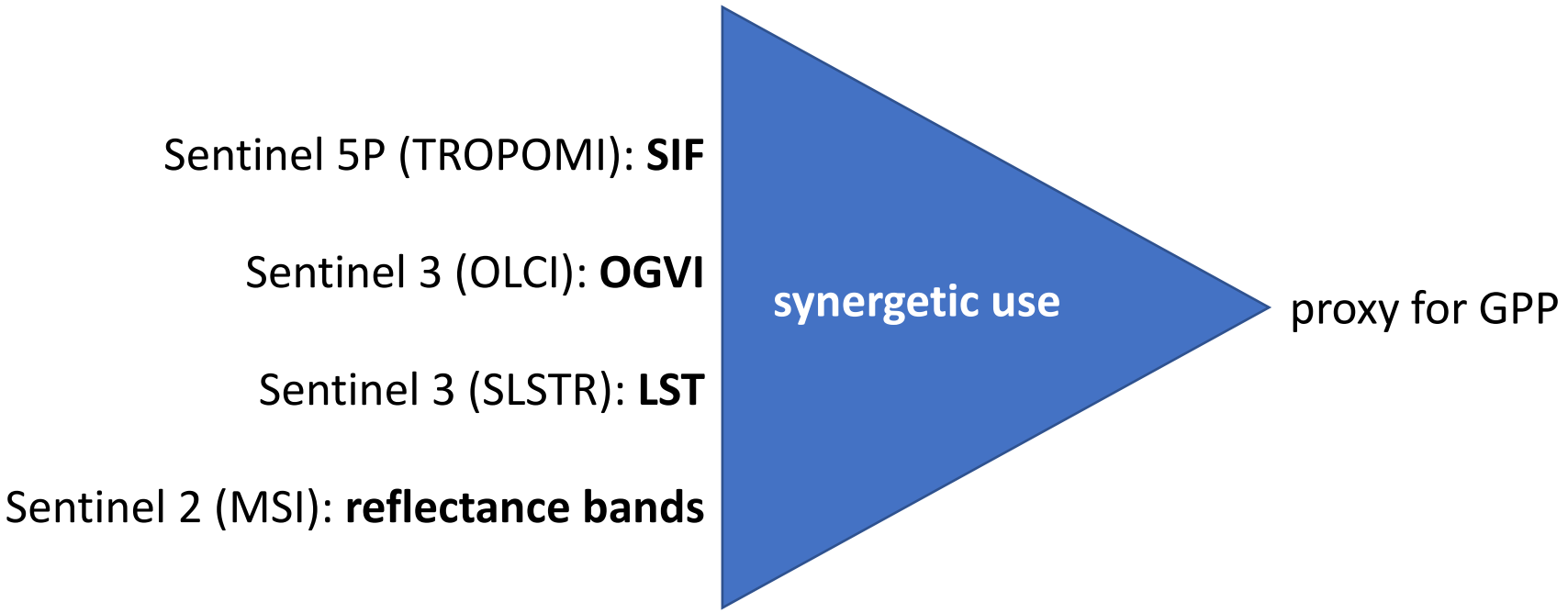
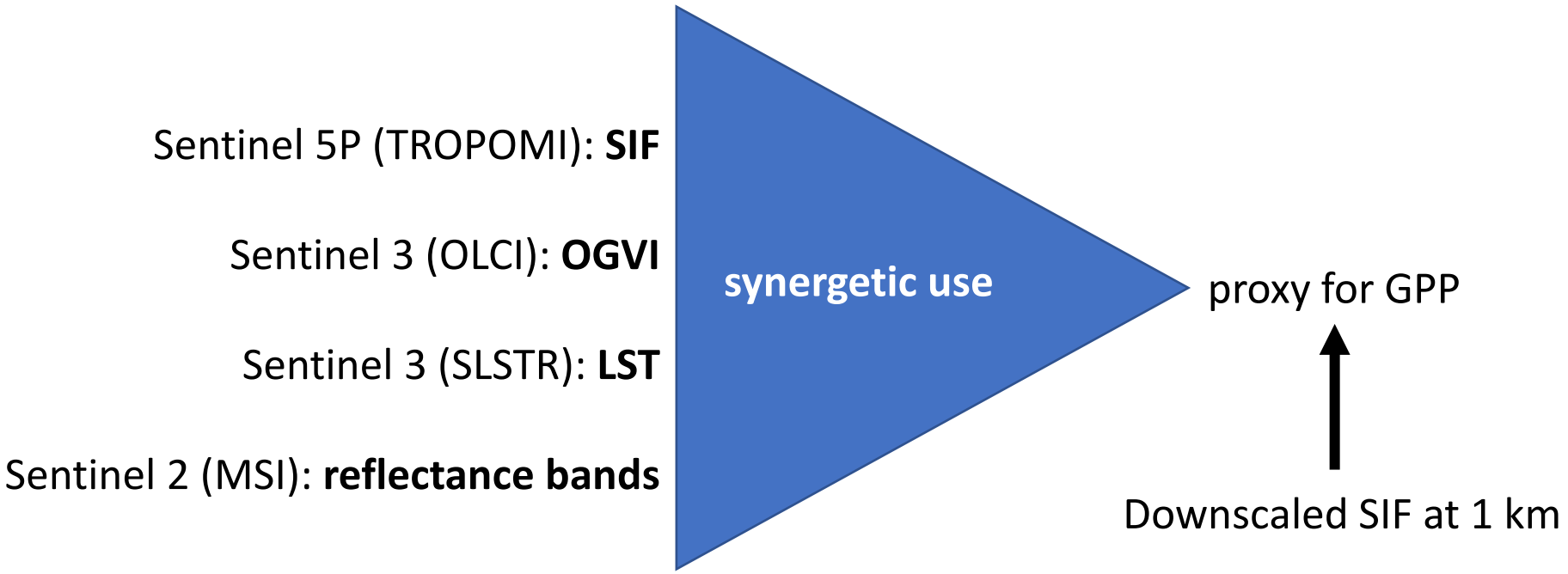
→ THE EUROPEAN SPACE AGENCY

Our Objective

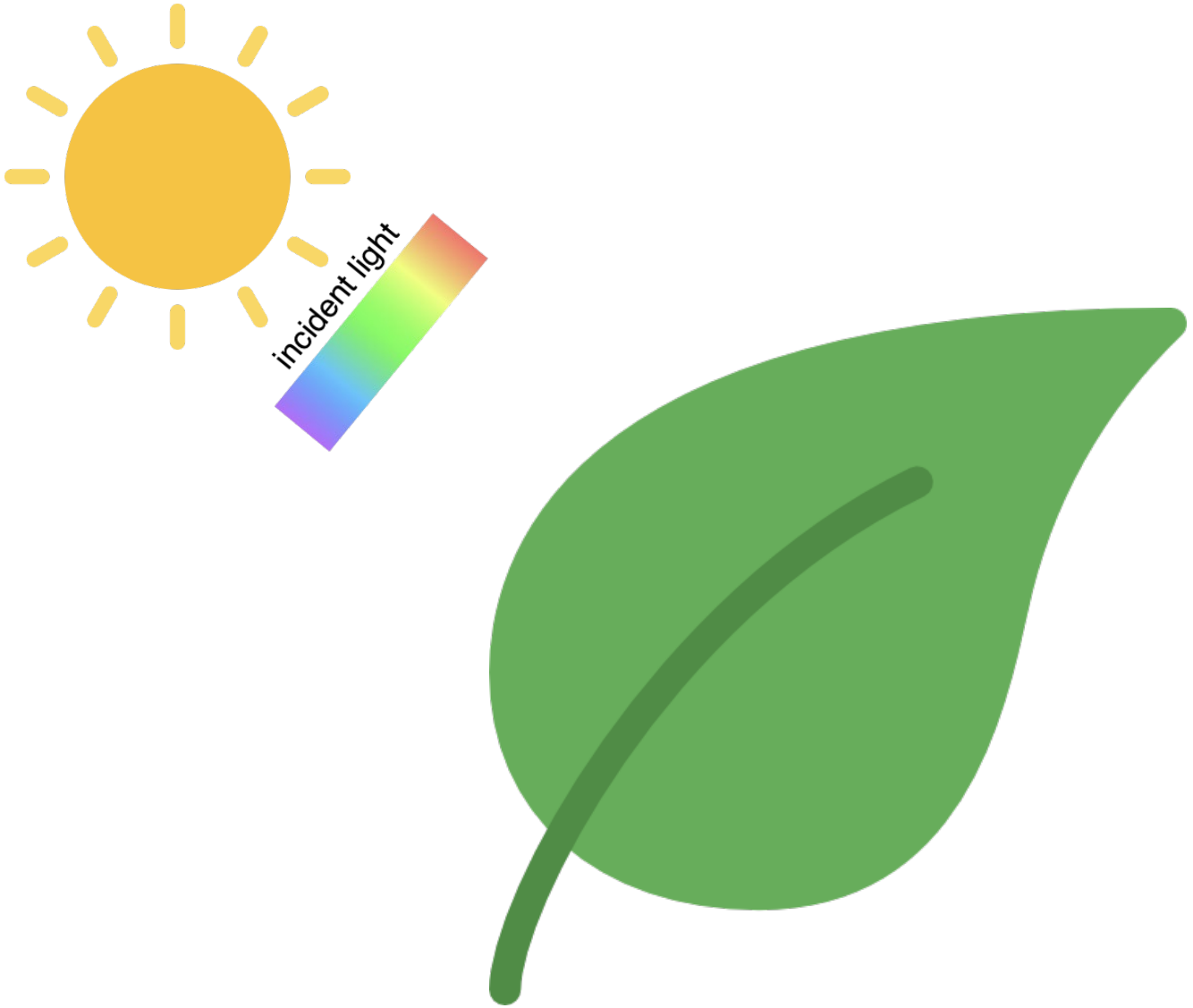


Our Objective



What is solar induced-chlorophyll fluorescence (SIF)?

Max Planck Institute
for Biogeochemistry



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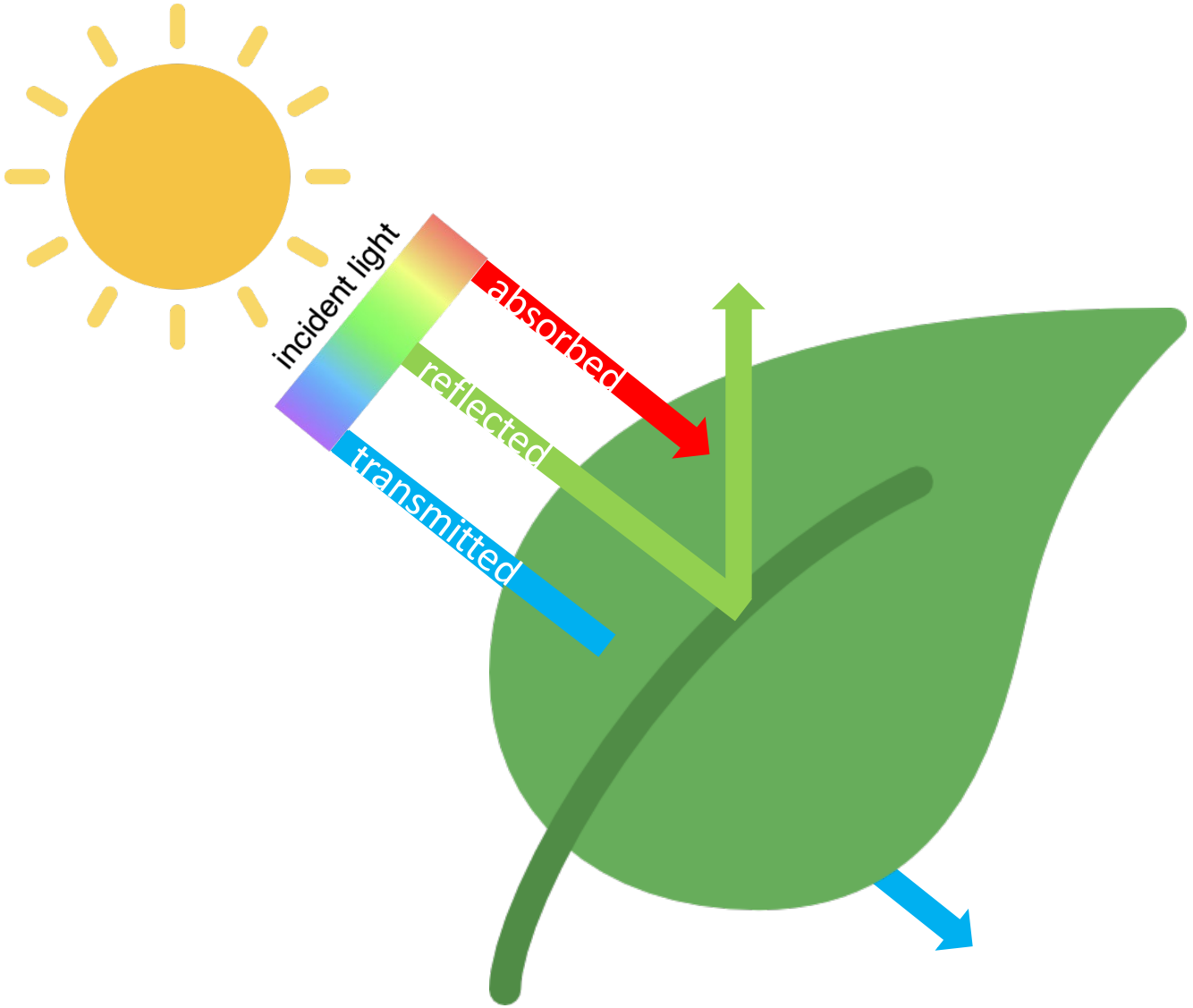

What is solar induced-chlorophyll fluorescence (SIF)?

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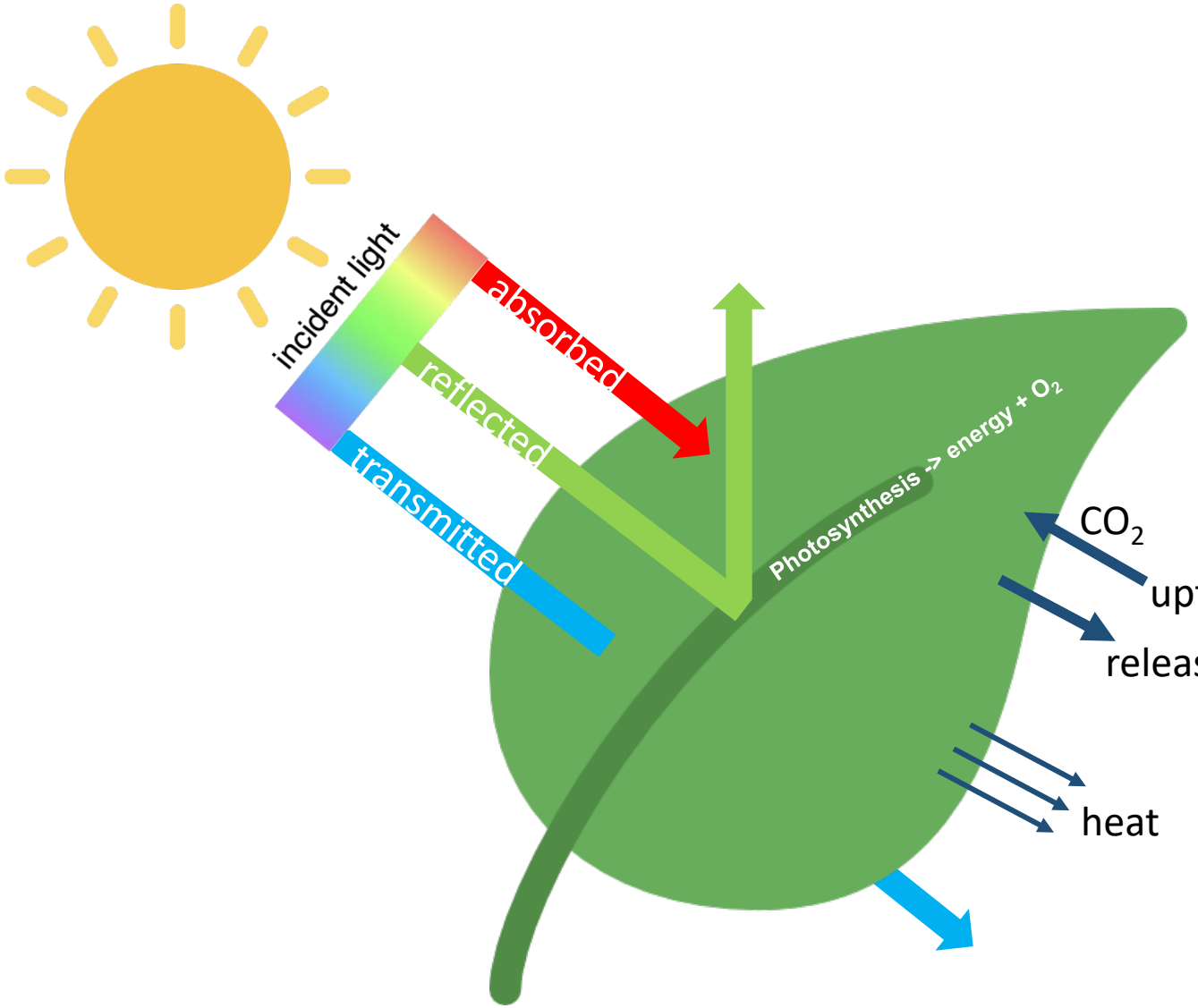

What is solar induced-chlorophyll fluorescence (SIF)?

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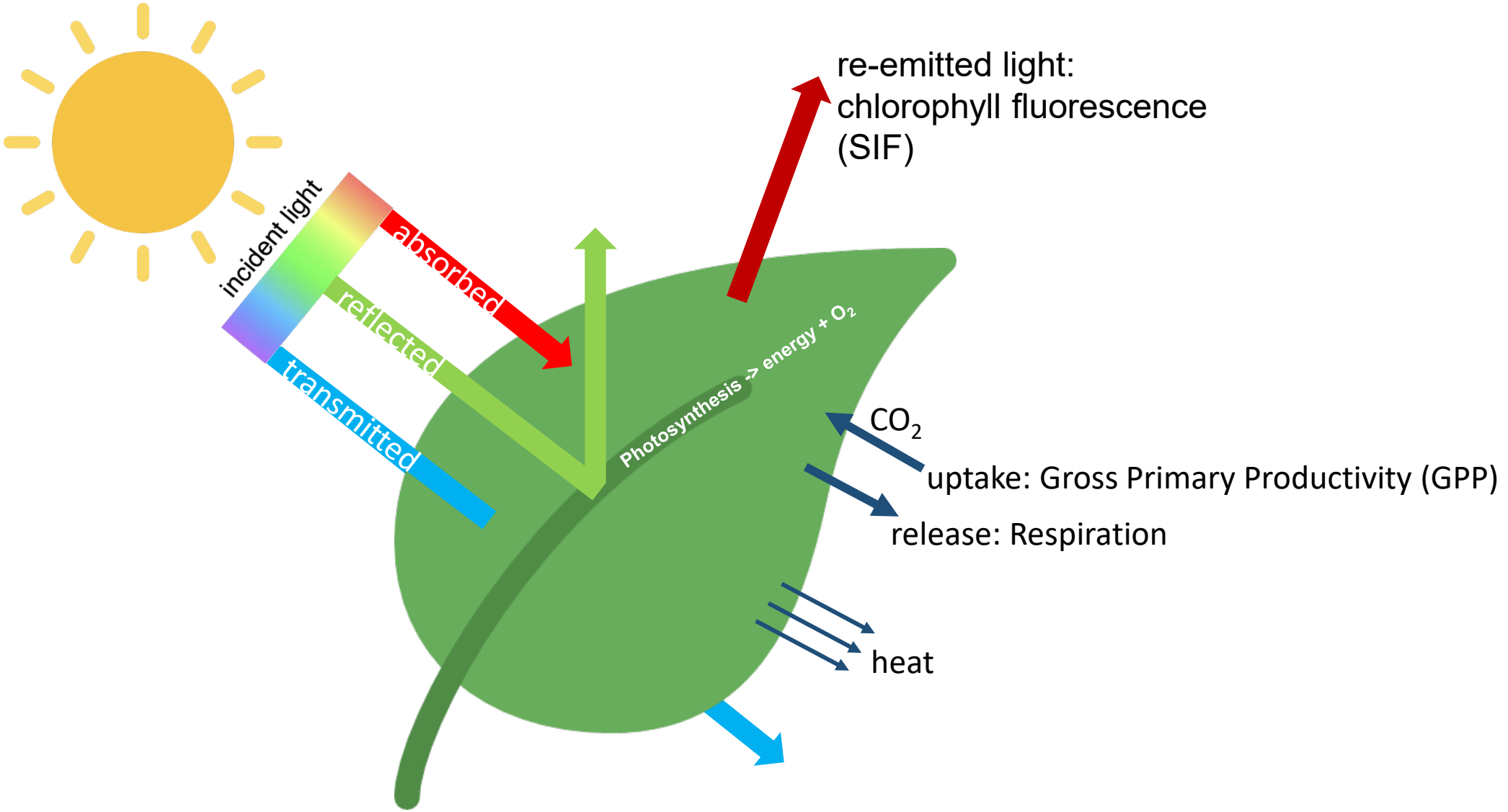

Relationship of SIF and GPP

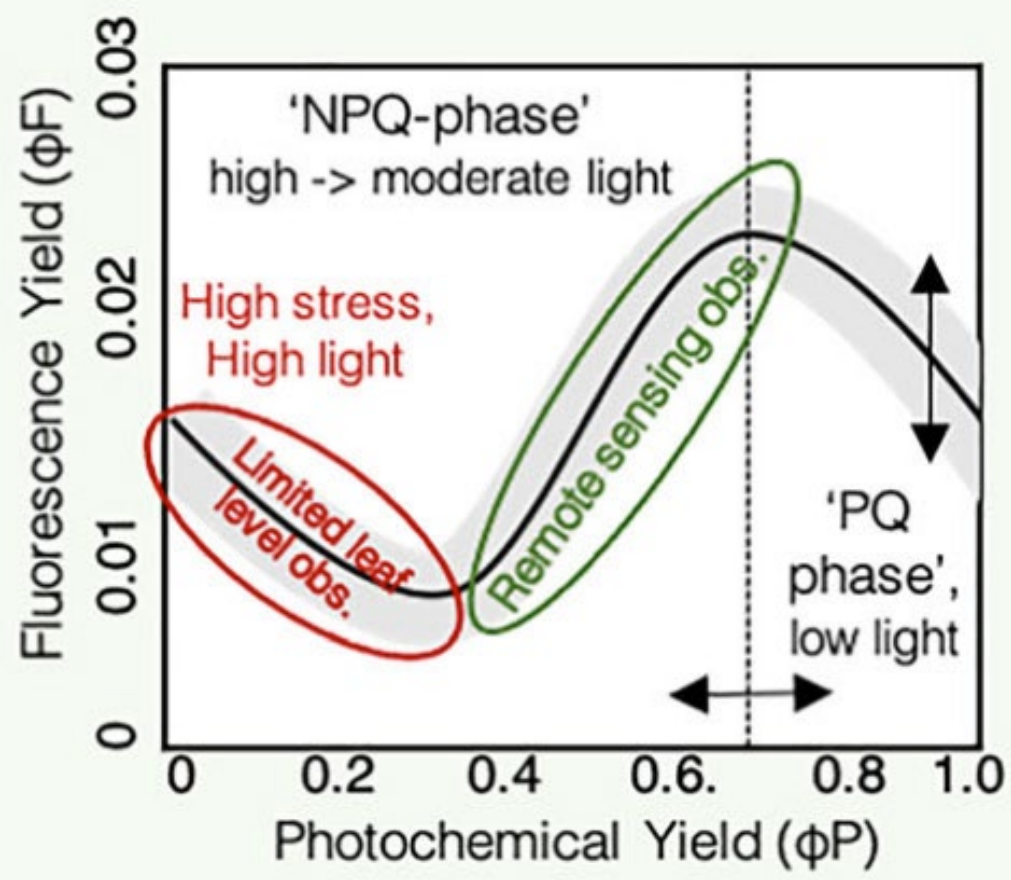

Figure from **Magney, T. S., Barnes, M. L., & Yang, X. (2020). On the covariation of chlorophyll fluorescence and photosynthesis across scales. *Geophysical Research Letters*, *47*(23), e2020GL091098.**

Ground-based GPP measurements

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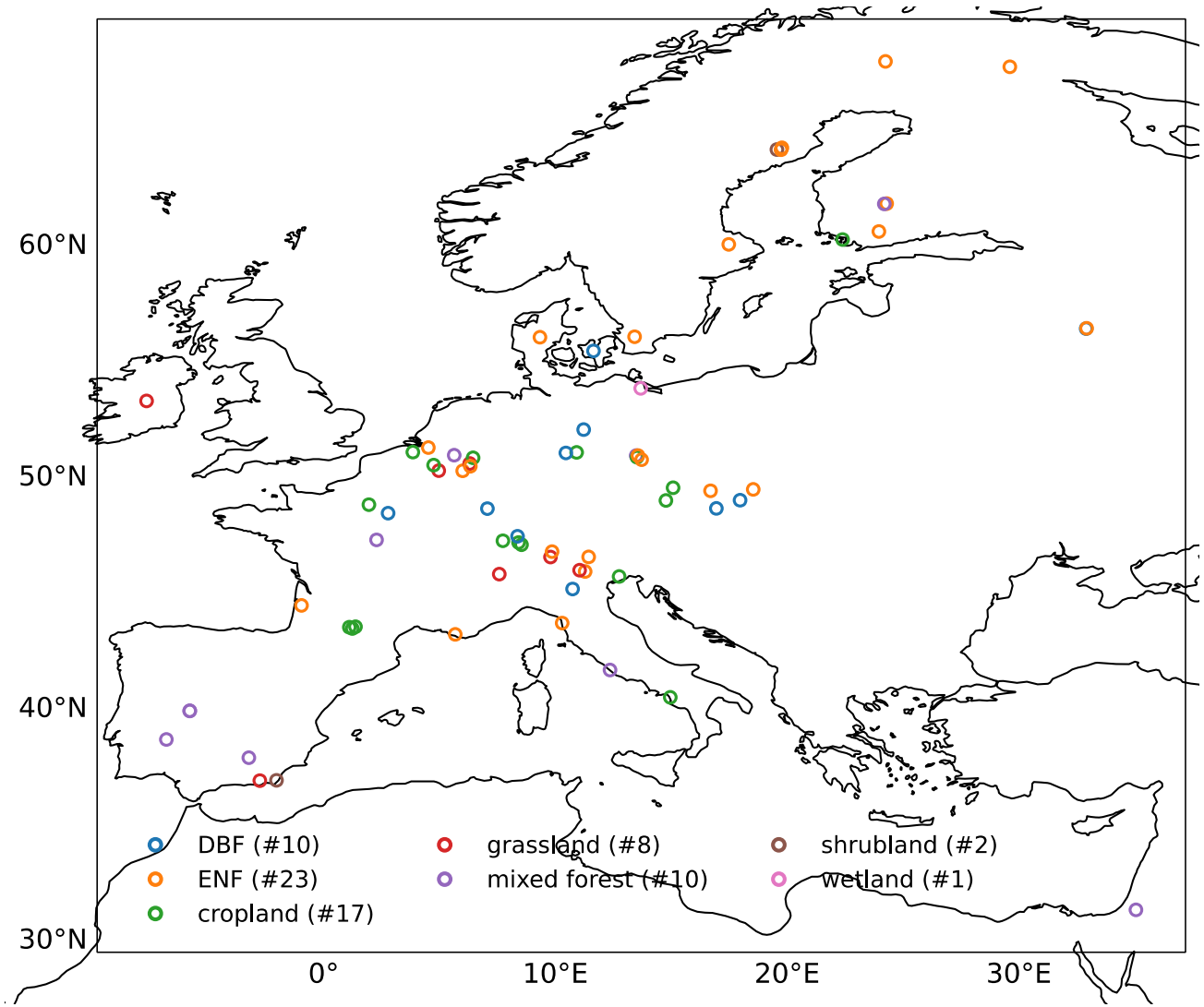

Ground-based GPP measurements: Data cleaning

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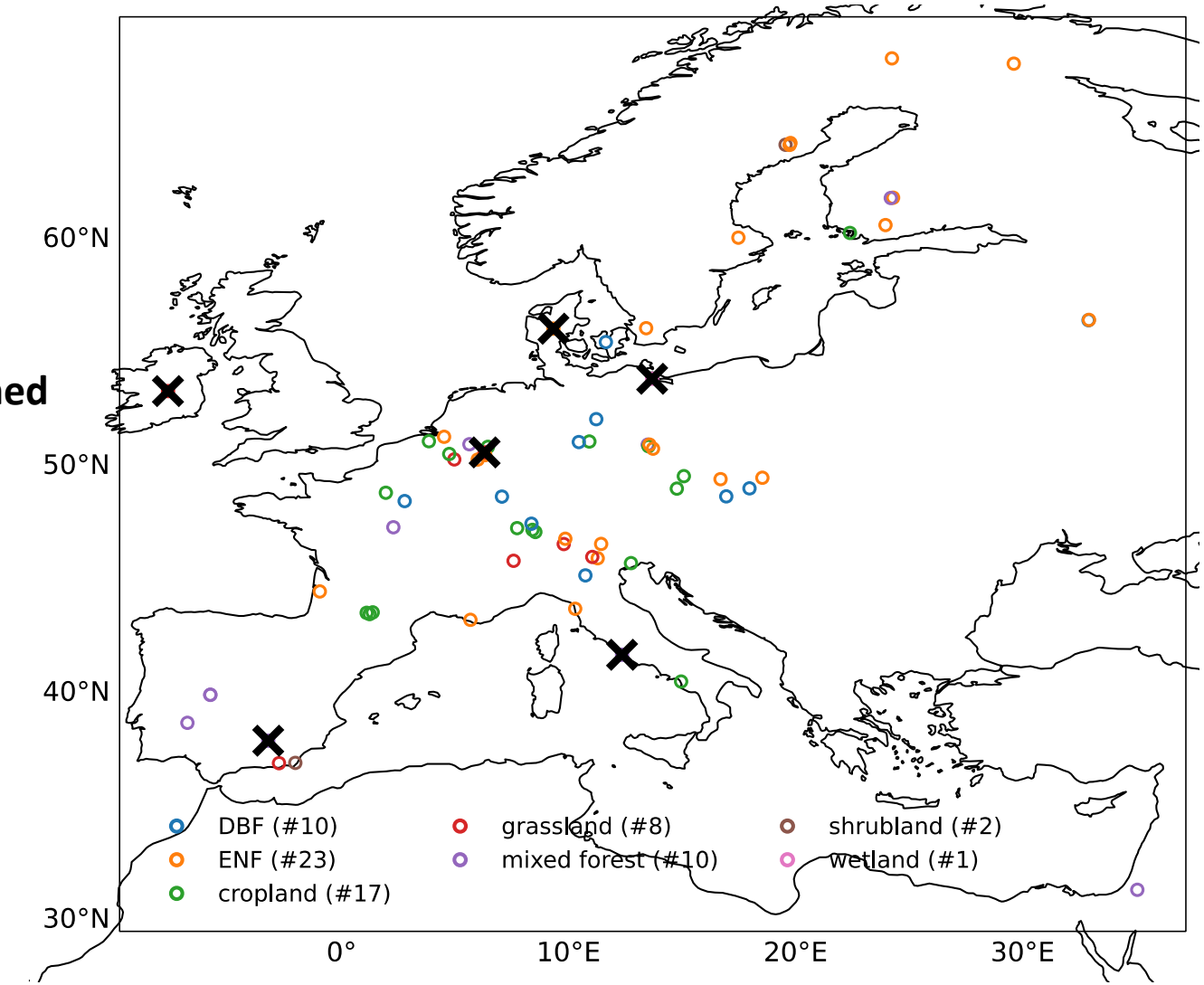
Due to artifacts in the GPP data that are not yet explained (e.g., constant GPP for one year)



Ground-based GPP measurements

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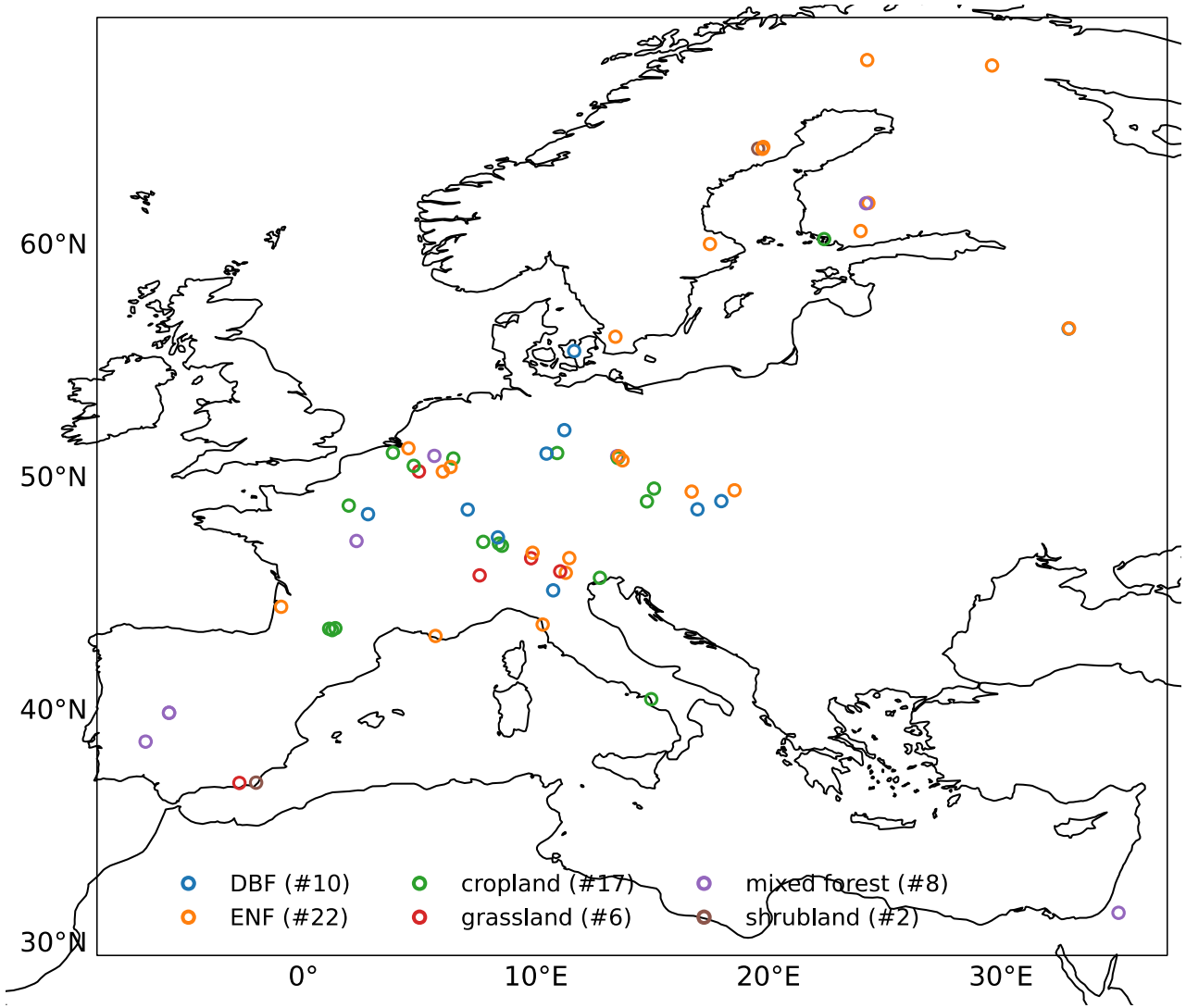

Ground-based GPP measurements

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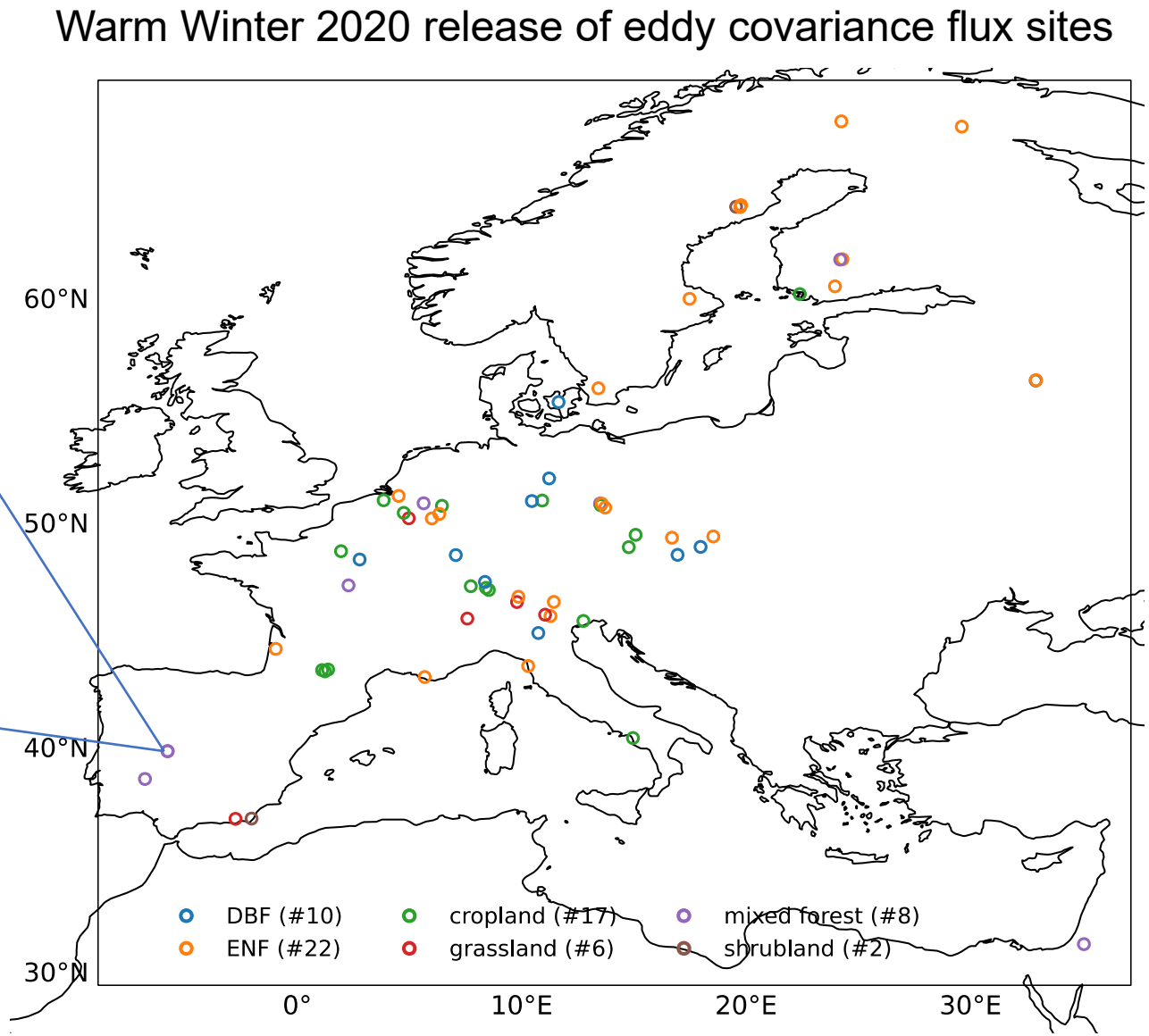
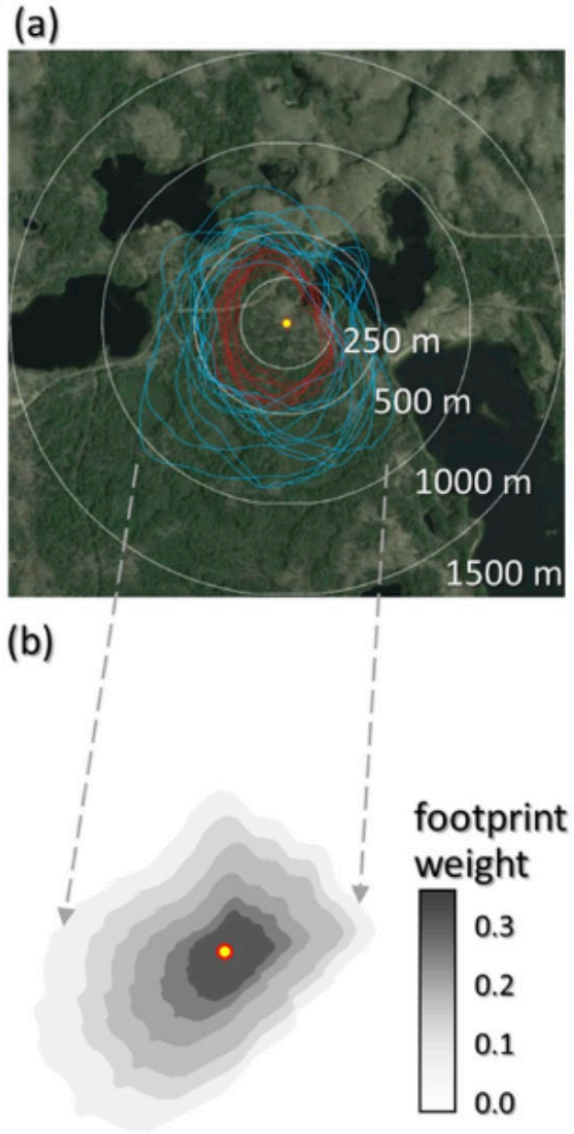
Measuring carbon fluxes at ground-based stations with eddy covariance technique



Influencing footprint of eddy covariance measurements

US-Syv



Eddy covariance footprint

- In the range of hundreds of meters (or above)
- Dependent on conditions like e.g. weather, tower height, …

Figure from **Chu et al. (2021). Representativeness of Eddy-Covariance flux footprints for areas surrounding AmeriFlux sites. Agricultural and Forest Meteorology, 301, 108350.**

Estimating GPP from SIF

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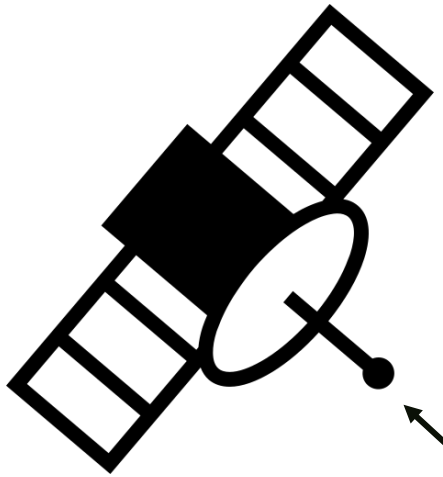
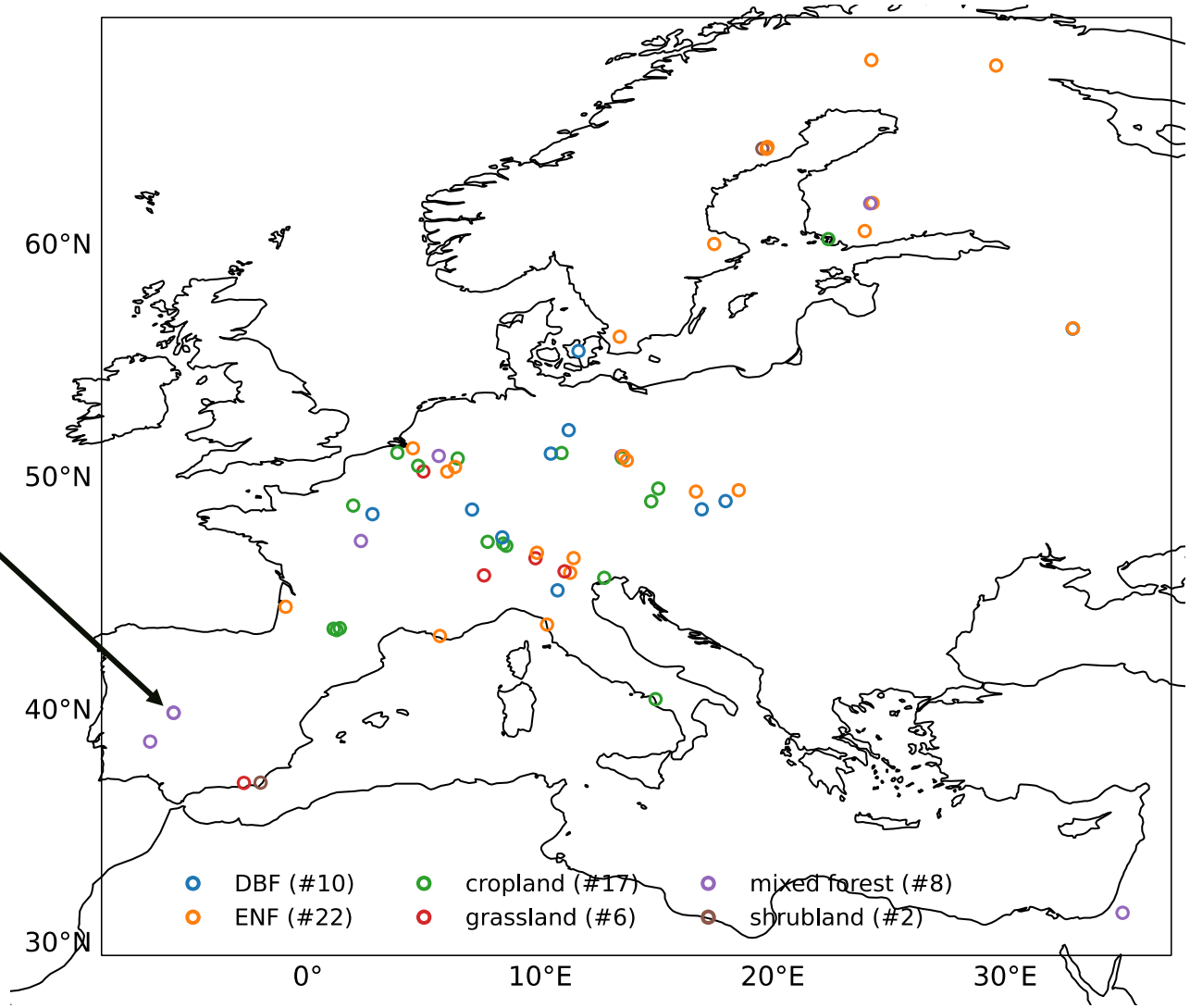


Validating/comparing satellite data against stationary data



Estimating GPP from SIF

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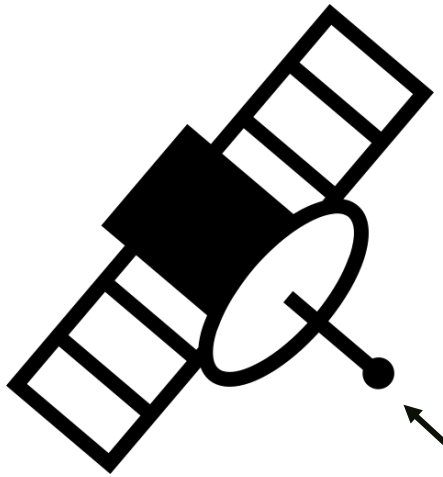
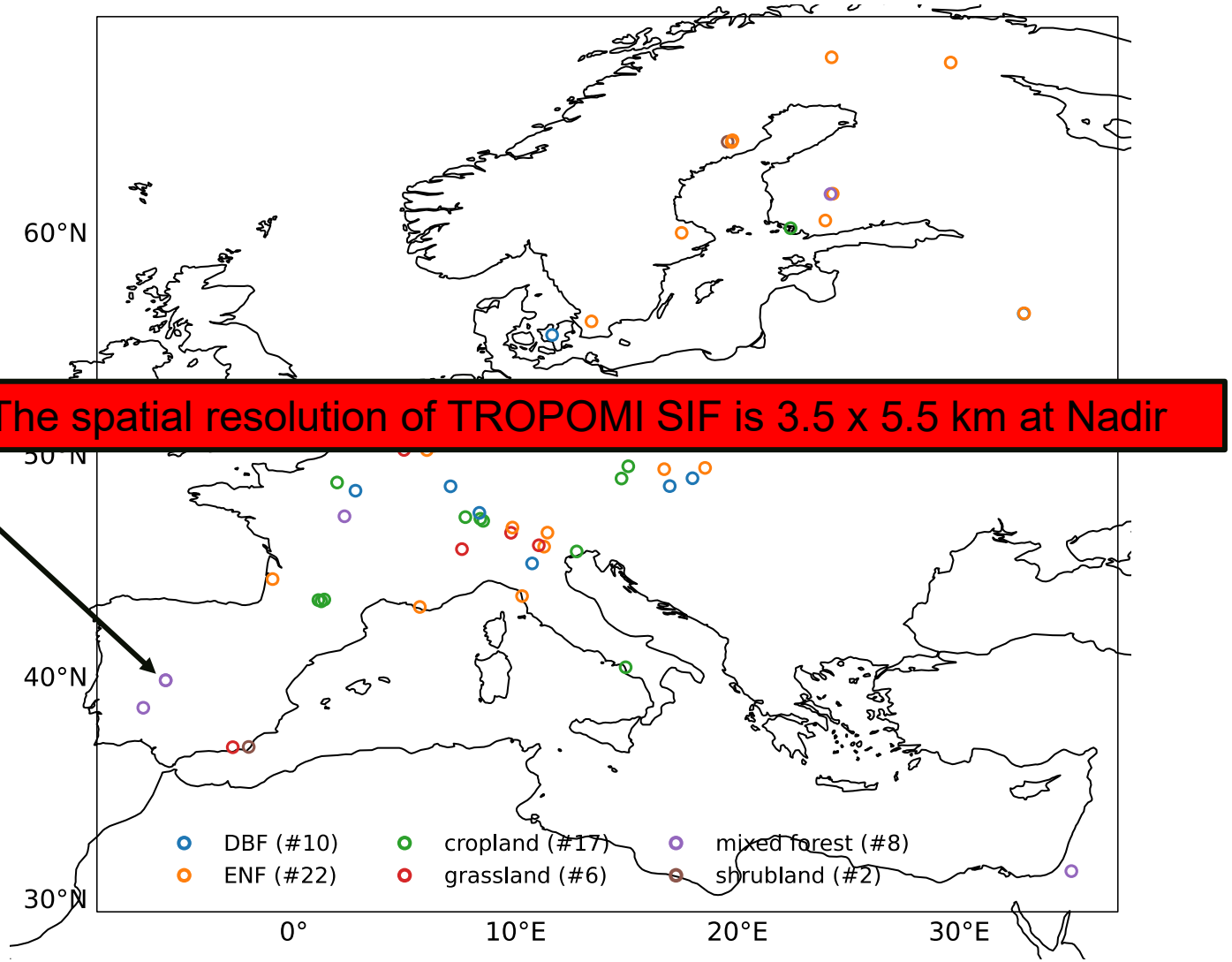


Validating/comparing satellite data against stationary data

Warm Winter 2020 release of eddy covariance flux sites



The spatial resolution of TROPOMI SIF is 3.5 x 5.5 km at Nadir

Remote Sensing SIF over tower locations

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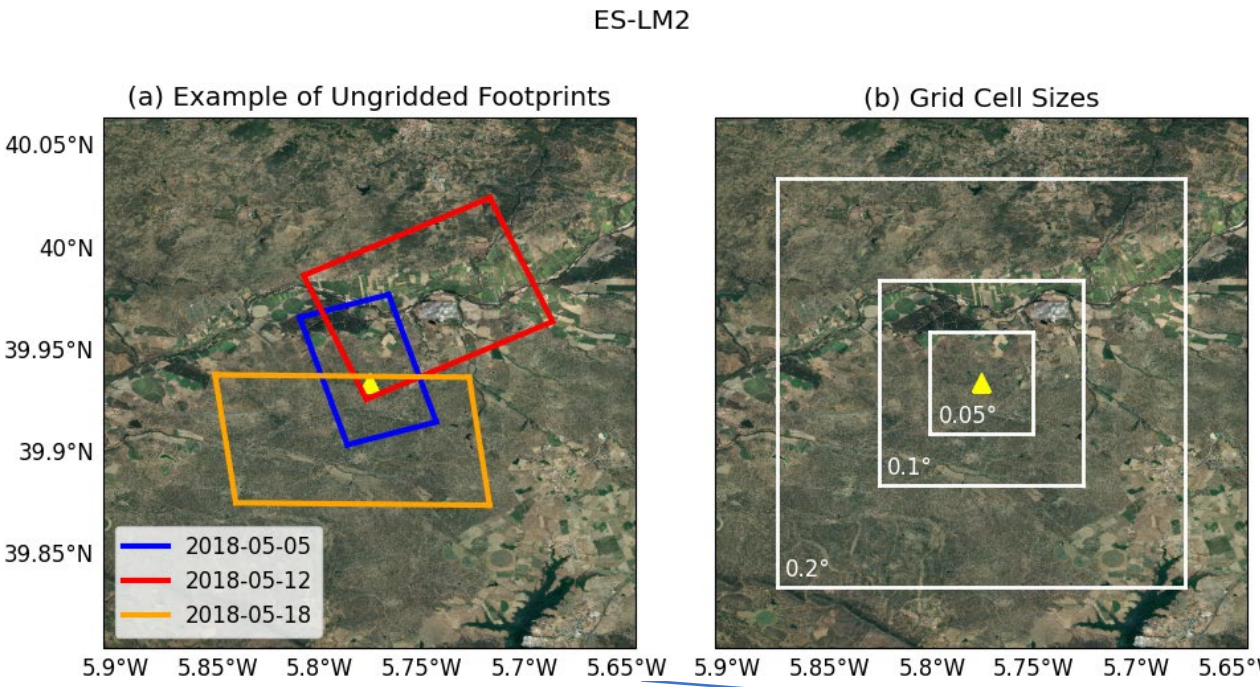
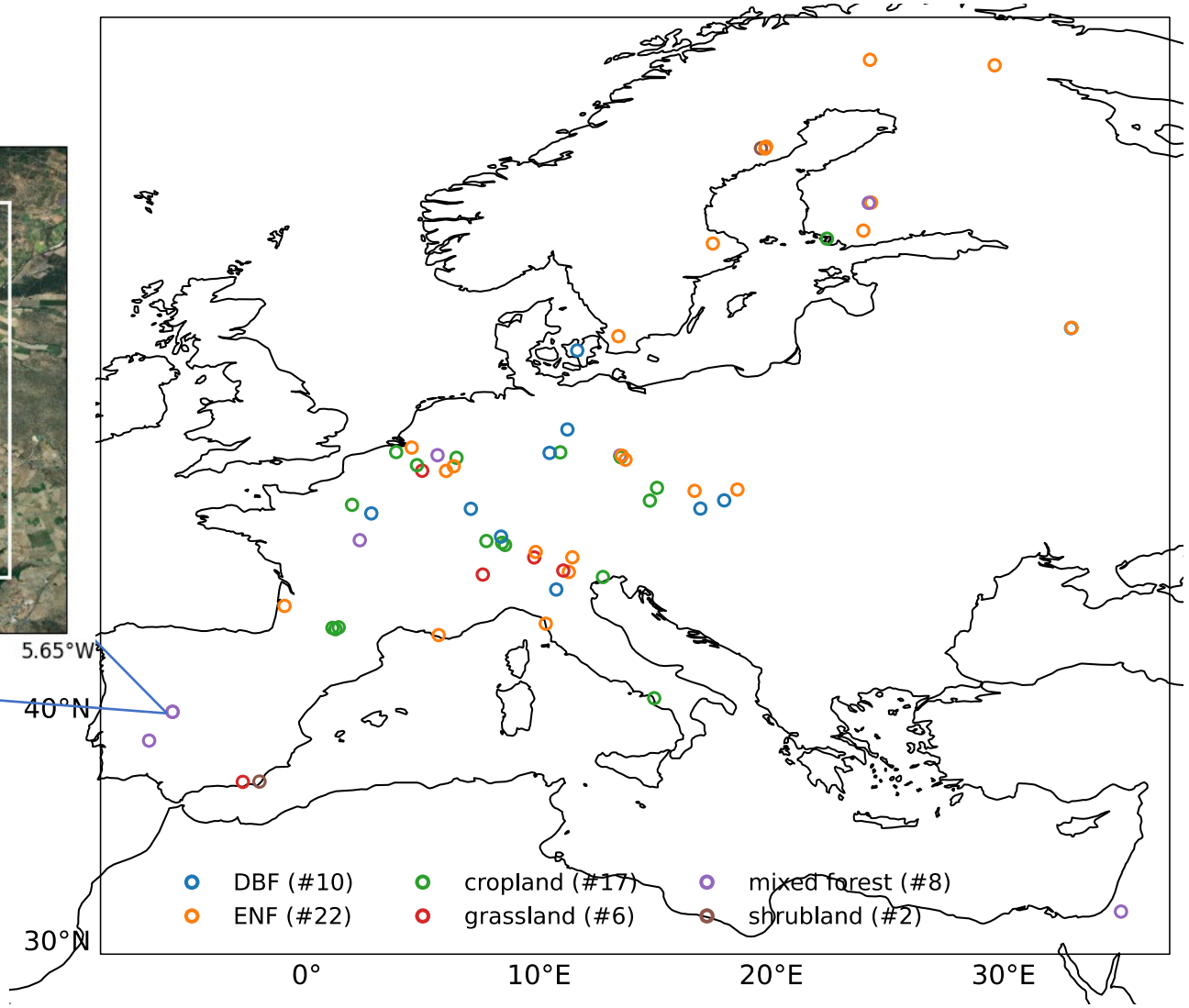


Warm Winter 2020 release of eddy covariance flux sites



Spatial heterogeneity in 0.05° pixel

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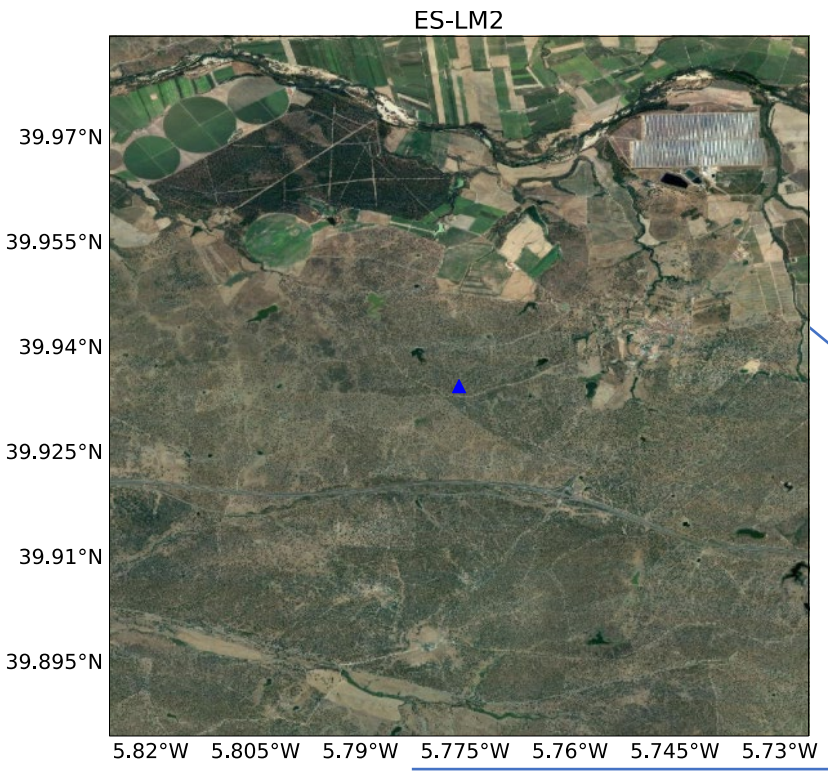
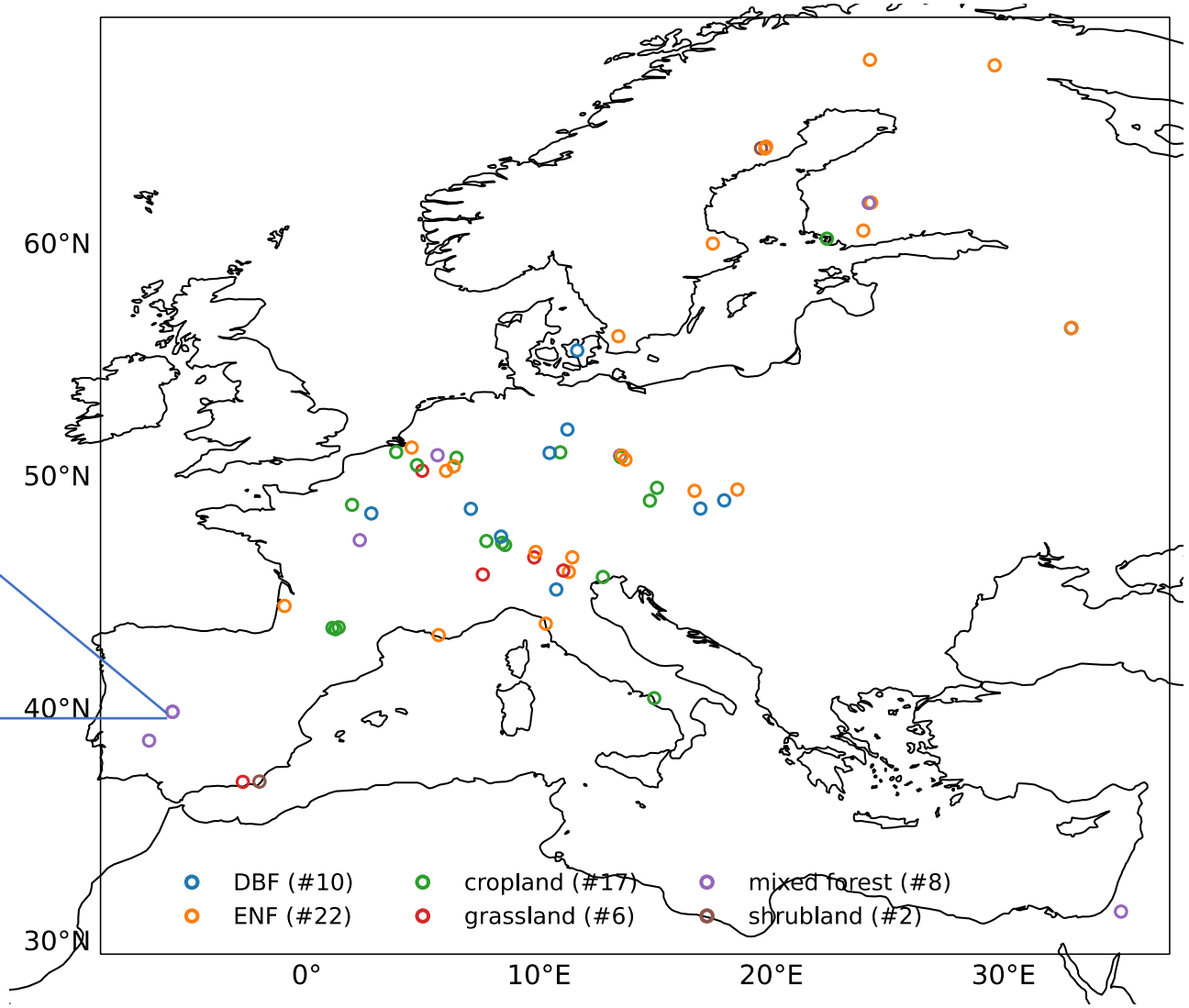


Warm Winter 2020 release of eddy covariance flux sites



Downscaling TROPOMI SIF to 1 km

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Duveiller et al. (2020)

Light use efficiency (LUE) calibration

$$SIF = f(V) \cdot f(W) \cdot f(T)$$

the function is calibrated with a moving window of low-resolution samples

Turner et al. (2020)

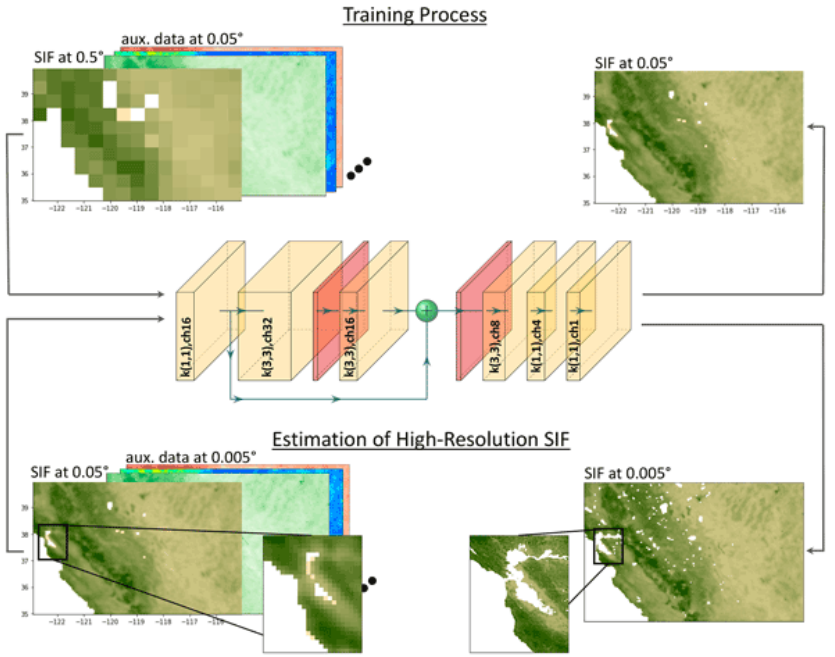
Distributing SIF photons based on greenness/vegetation index

$$SIF_{i,j} = \overline{SIF} \cdot \frac{V_{i,j}}{\overline{V}}$$

TROPOMI footprints are weighted by vegetation index and oversampled over 16 day moving window

Gensheimer et al. (2022)

Deep Learning superresolution



V: vegetation index, W: water index, T: temperature proxy

Downscaling TROPOMI SIF to 1 km

Max Planck Institute
for Biogeochemistry

Duveiller et al. (2020)

Light use efficiency (LUE) calibration

$$SIF = f(NIRv) \cdot f(NDWI) \cdot f(LST)$$

the function is calibrated with a moving window of low-resolution samples

Turner et al. (2020)

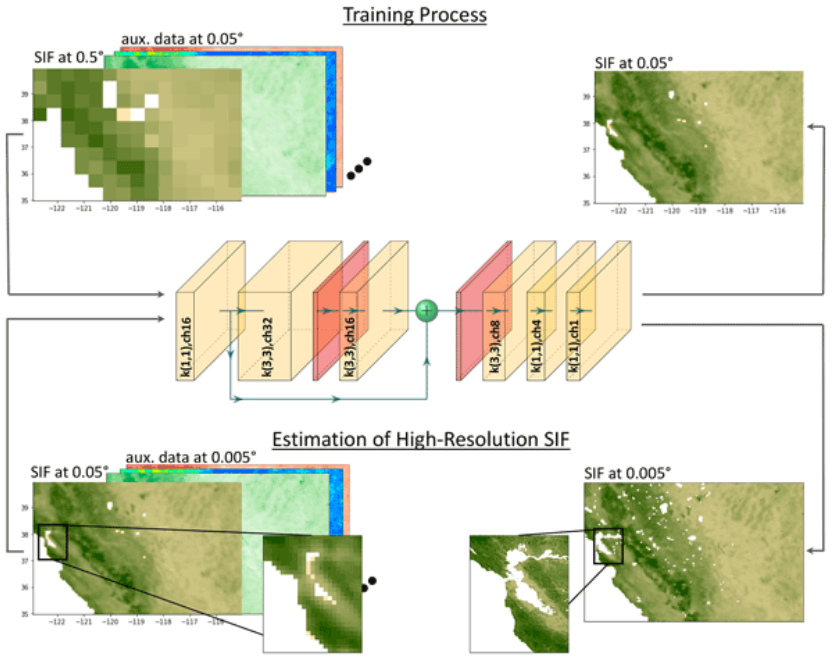
Distributing SIF photons based on greenness/vegetation index

$$SIF_{i,j} = \overline{SIF} \cdot \frac{NIRv_{i,j}}{\overline{NIRv}}$$

TROPOMI footprints are weighted by vegetation index and oversampled over 16 day moving window

Gensheimer et al. (2022)

Deep Learning superresolution



Original studies used MODIS. Turner et al. at daily resolution with 16-day moving window oversampling.

Downscaling TROPOMI SIF to 1 km

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Duveiller et al. (2020)

Light use efficiency (LUE) calibration

$$SIF = f(OGVI) \cdot f(LST)$$

the function is calibrated with a moving window of low-resolution samples

Turner et al. (2020)

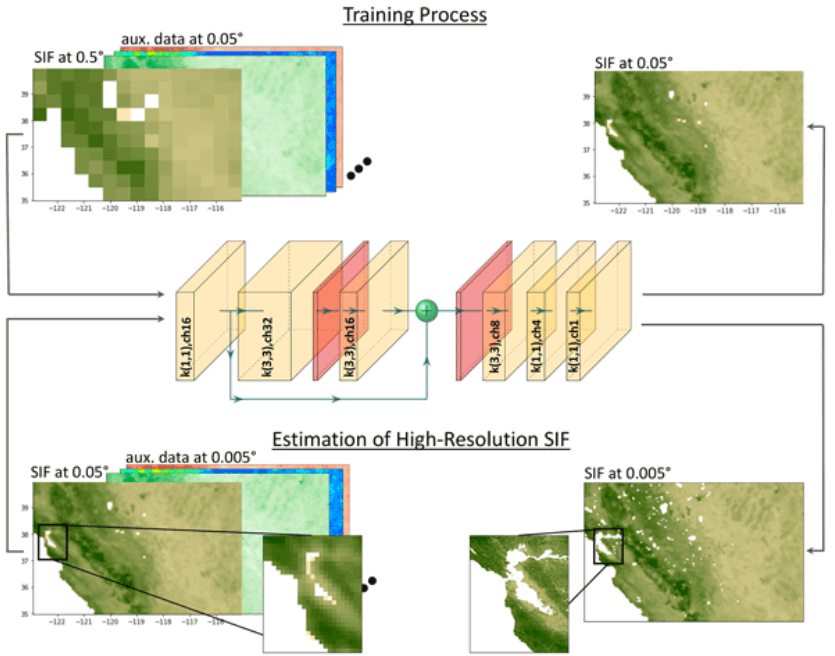
Distributing SIF photons based on greenness/vegetation index

$$SIF_{i,j} = \overline{SIF} \cdot \frac{OGVI_{i,j}}{\overline{OGVI}}$$

TROPOMI footprints are weighted by vegetation index and oversampled over 16 day moving window

Gensheimer et al. (2022)

Deep Learning superresolution



Data used

Sentinel 5P: SIF
Sentinel 3: OGVI, LST day

Sentinel 5P: SIF
Sentinel 3: OGVI

→ Now at 8-day resolution – influences oversampling

Sentinel 5P: SIF
Sentinel 3: OGVI, OTCI, LST day, SZA

Visual example of the effect of downscaling: ES-LM2

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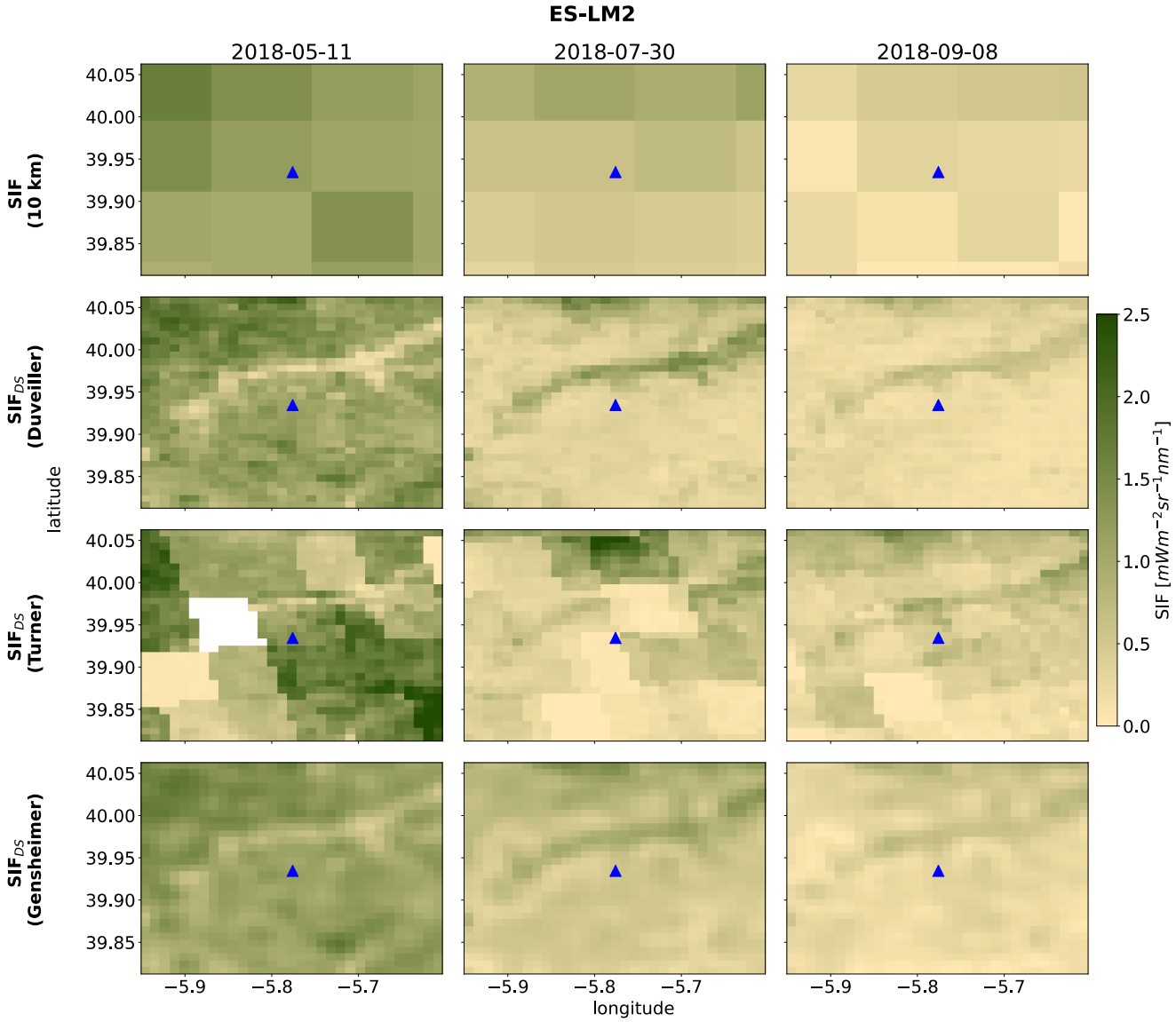

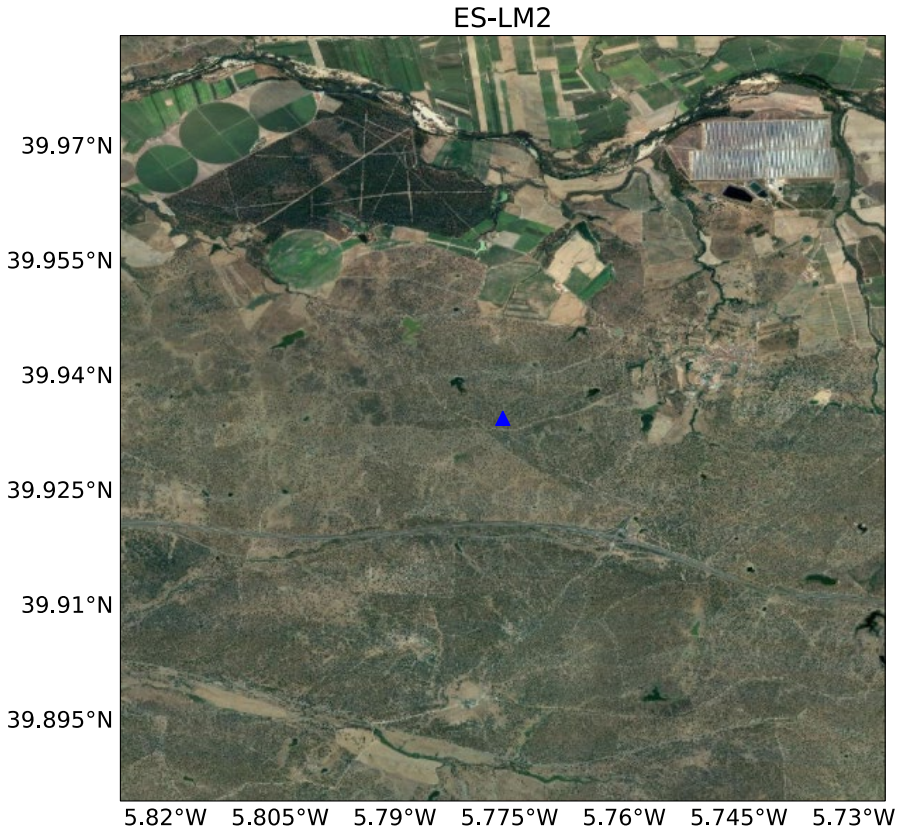

Visual example of the effect of downscaling: FR-Gri

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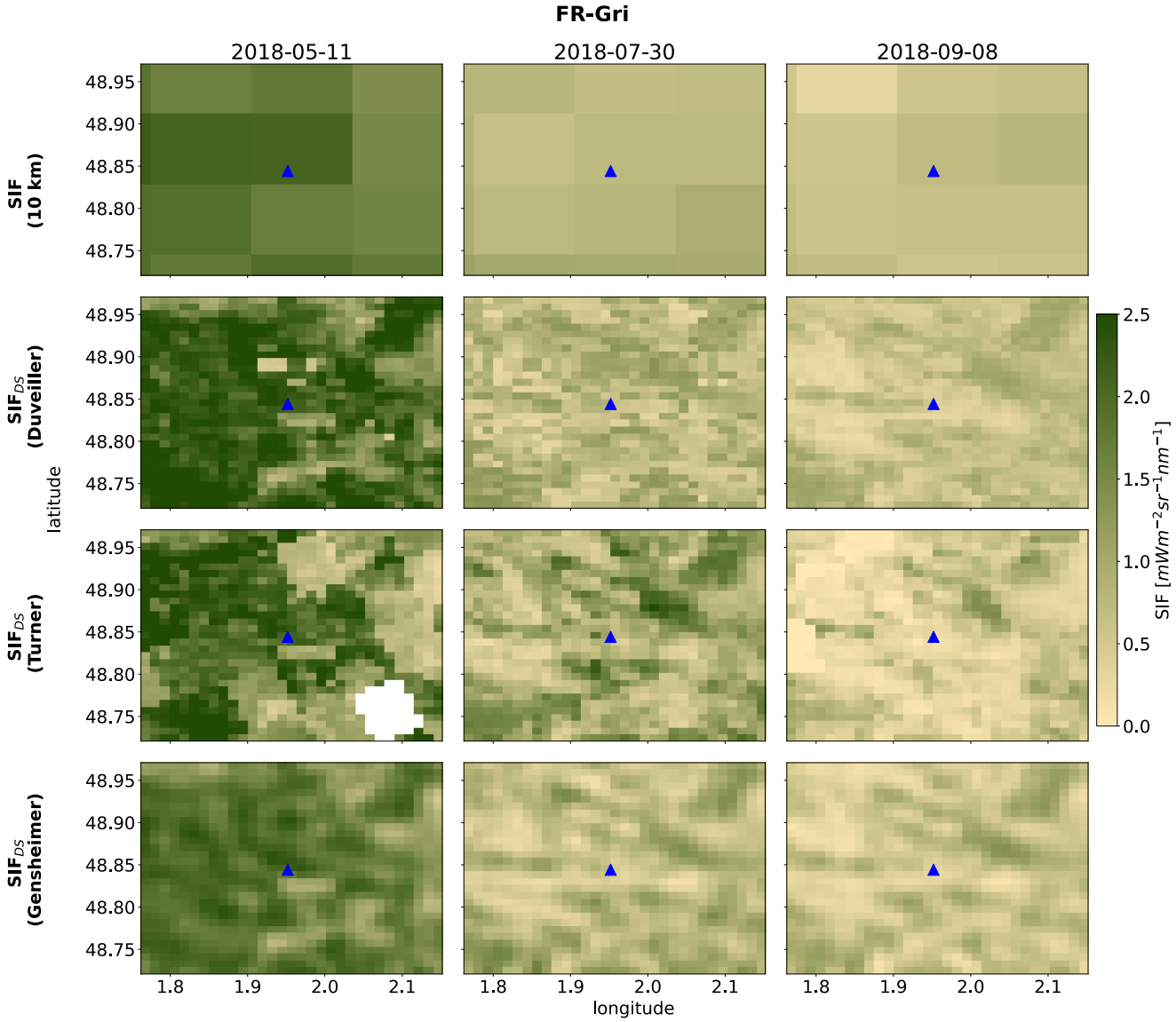
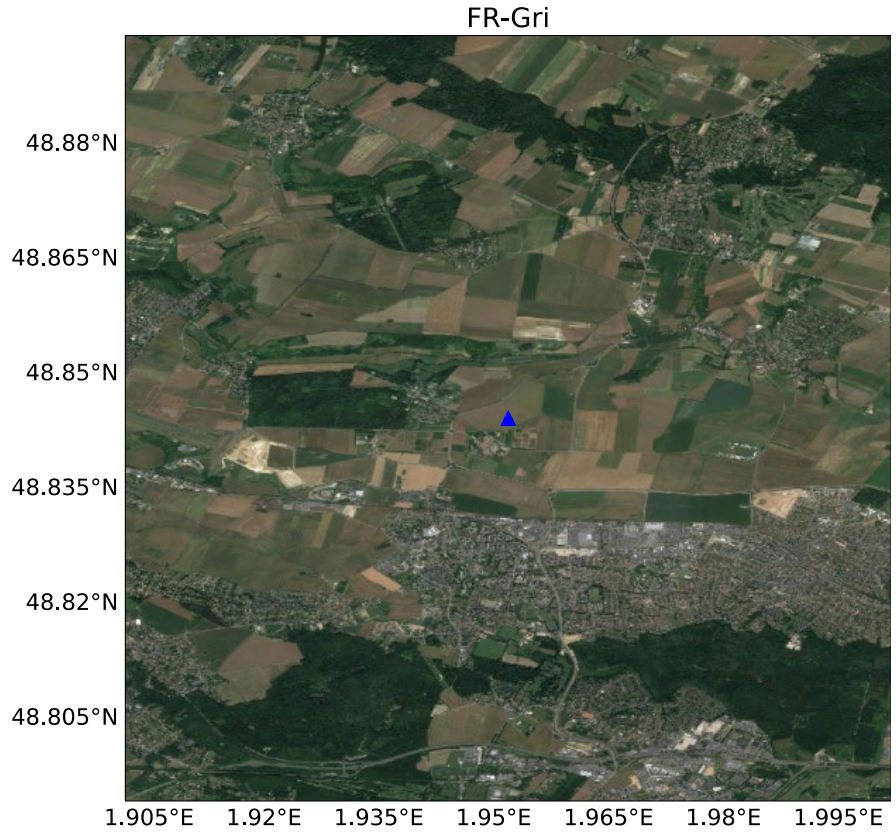
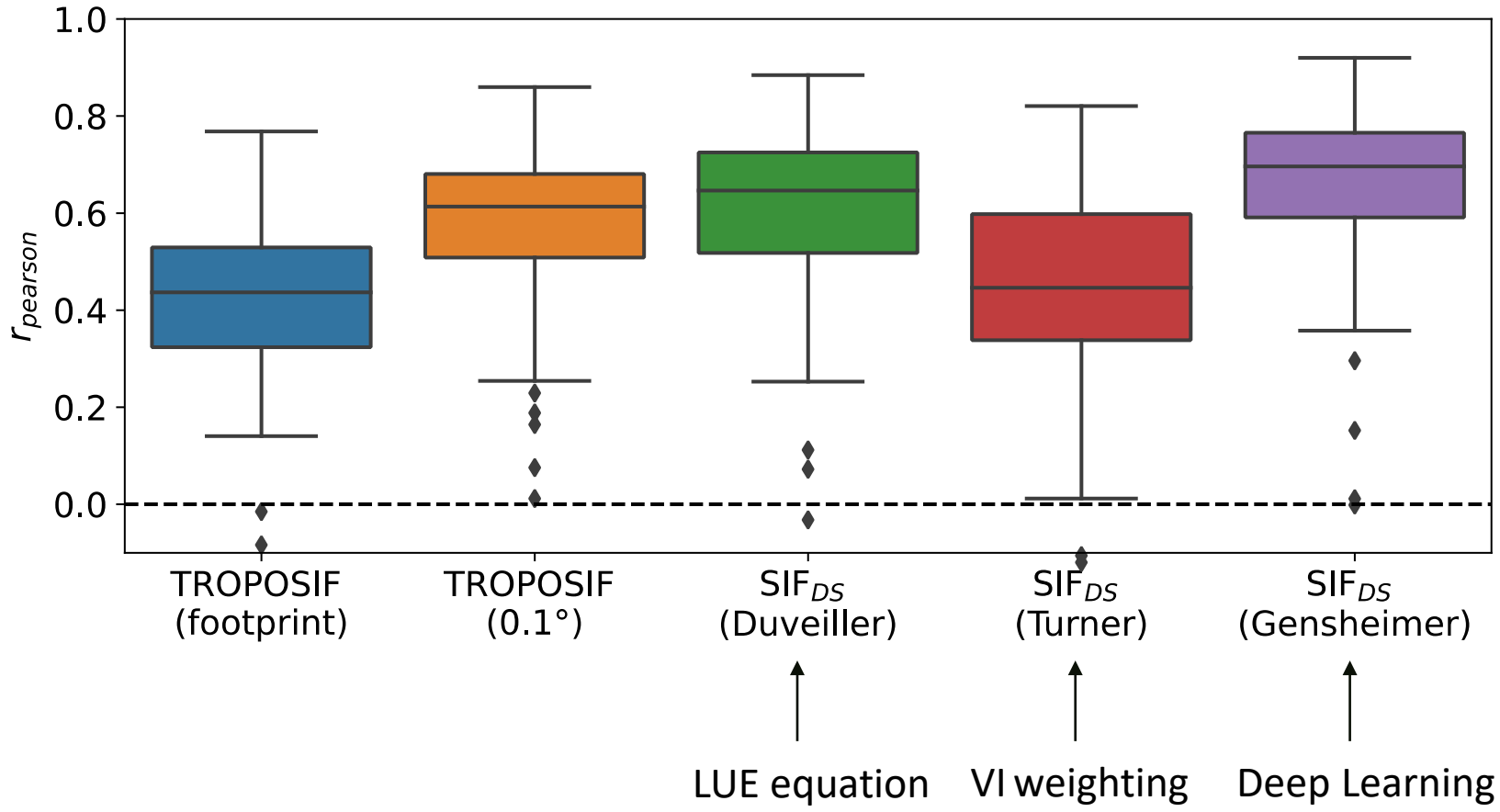




SIF vs. EC GPP



65 sites from Warm Winter 2020 dataset release over Europe.

TROPOMI SIF vs. EC GPP (PFT dependent)

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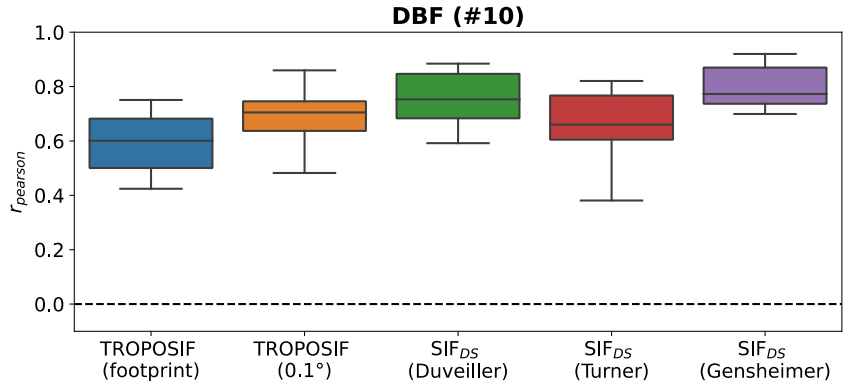

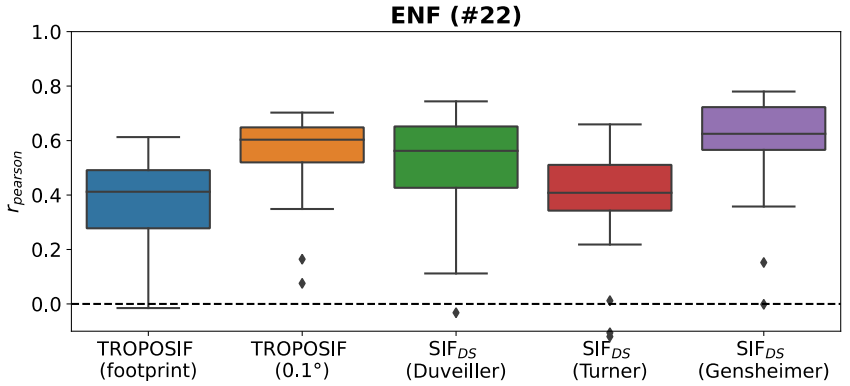

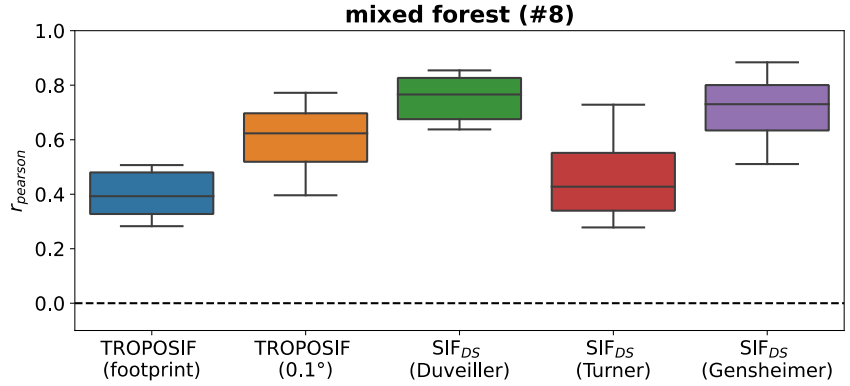

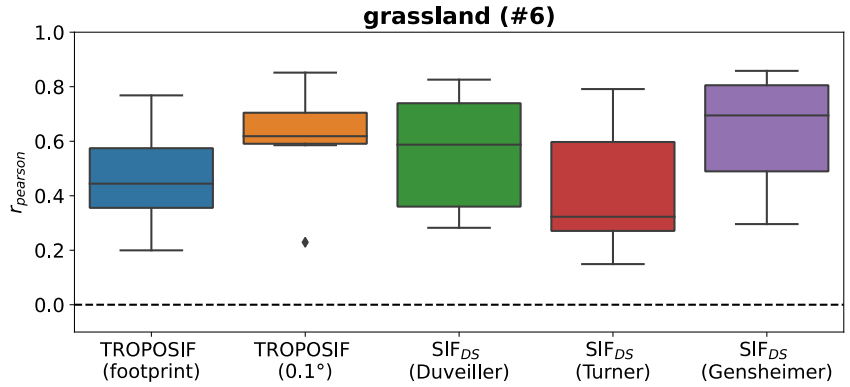

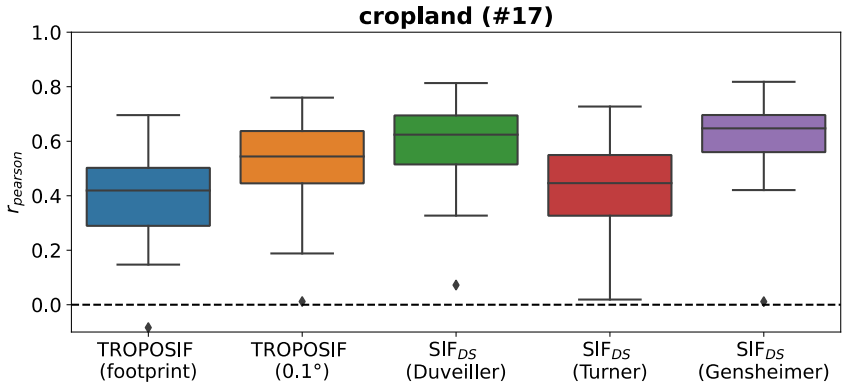

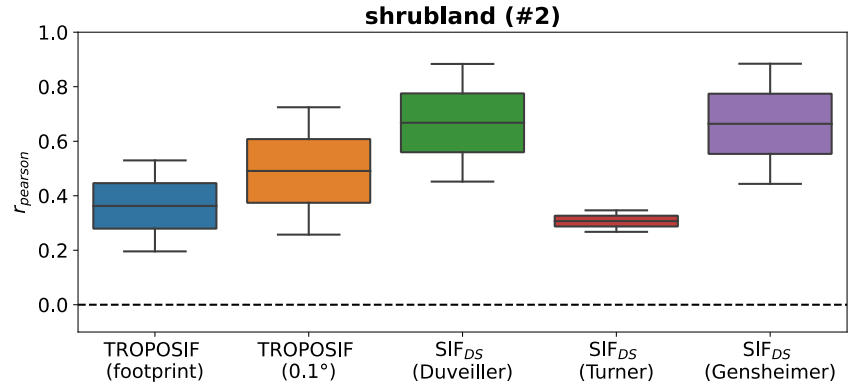

Differences between methods

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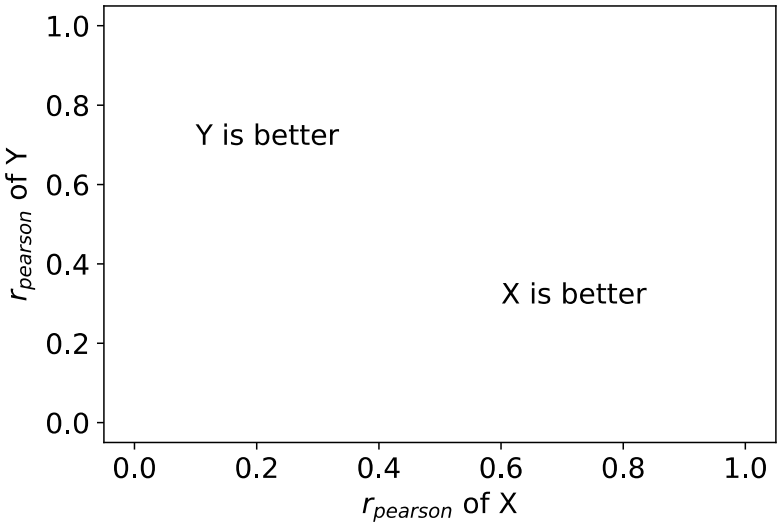

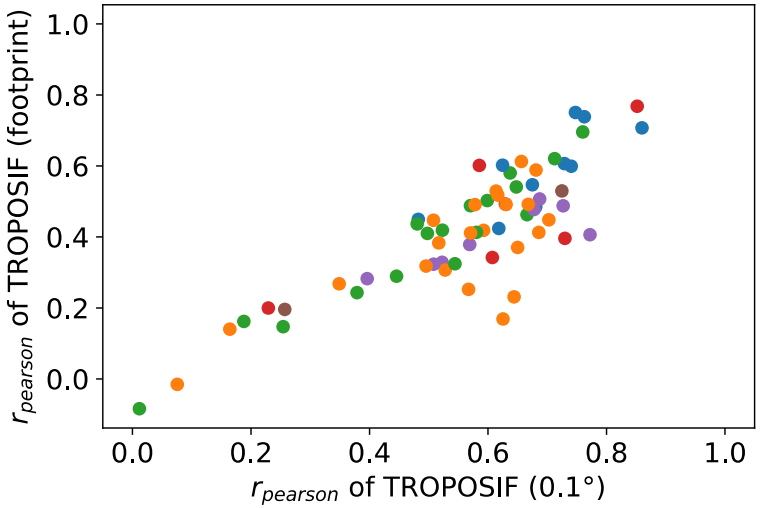

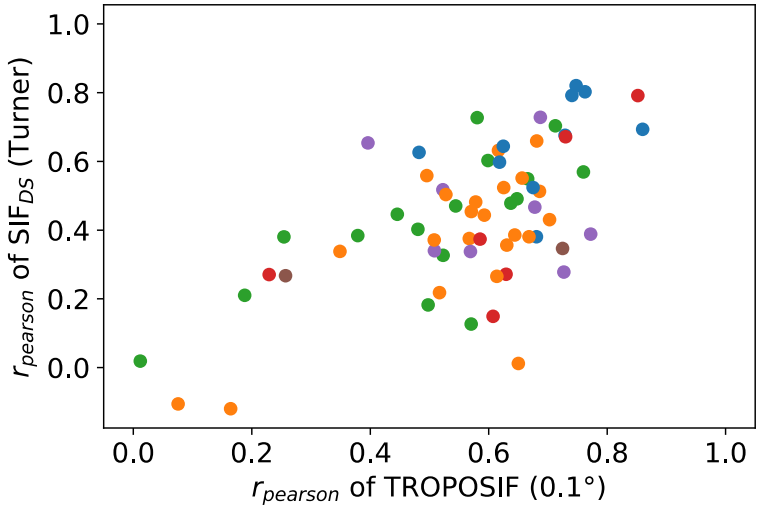

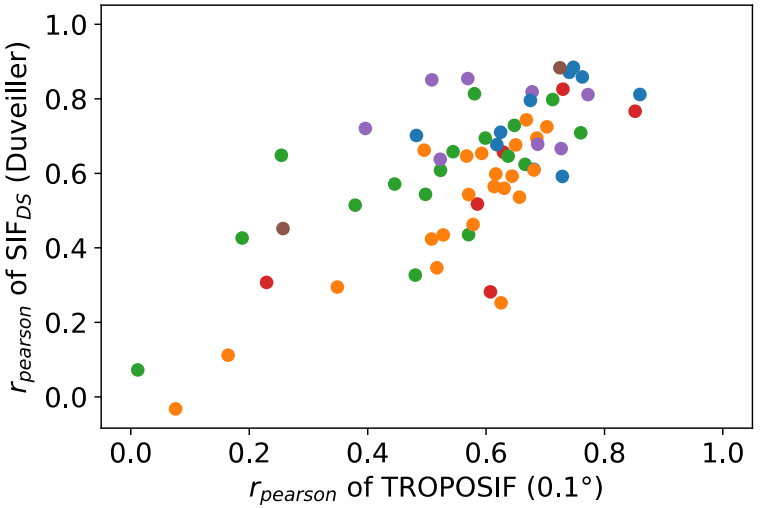

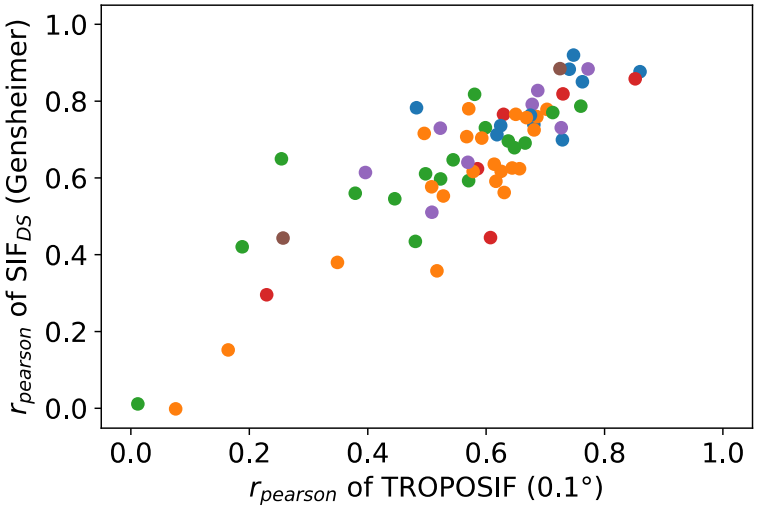

DBF (#10) · ENF (#22) · cropland (#17) · grassland (#6) · mixed forest (#8) · shrubland (#2)

Examplary sites: ES-LM2

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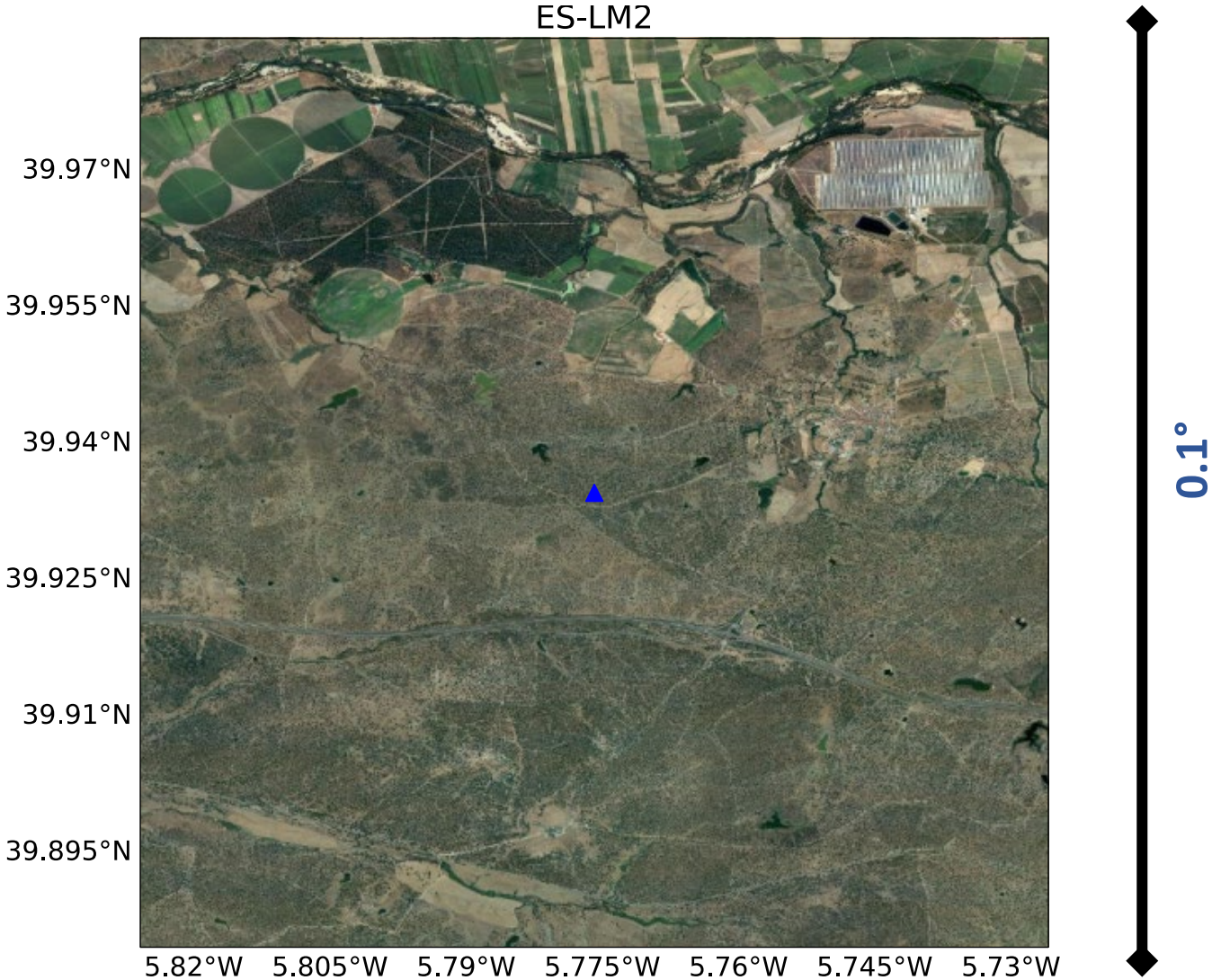

Landsat 8, from Google Earth

Examplary sites: ES-LM2

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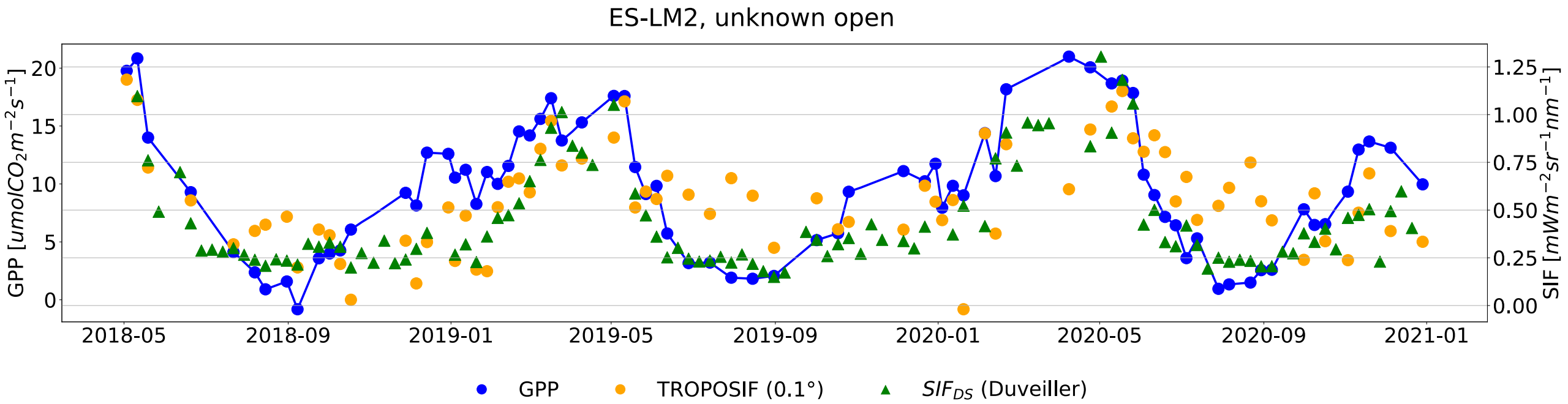
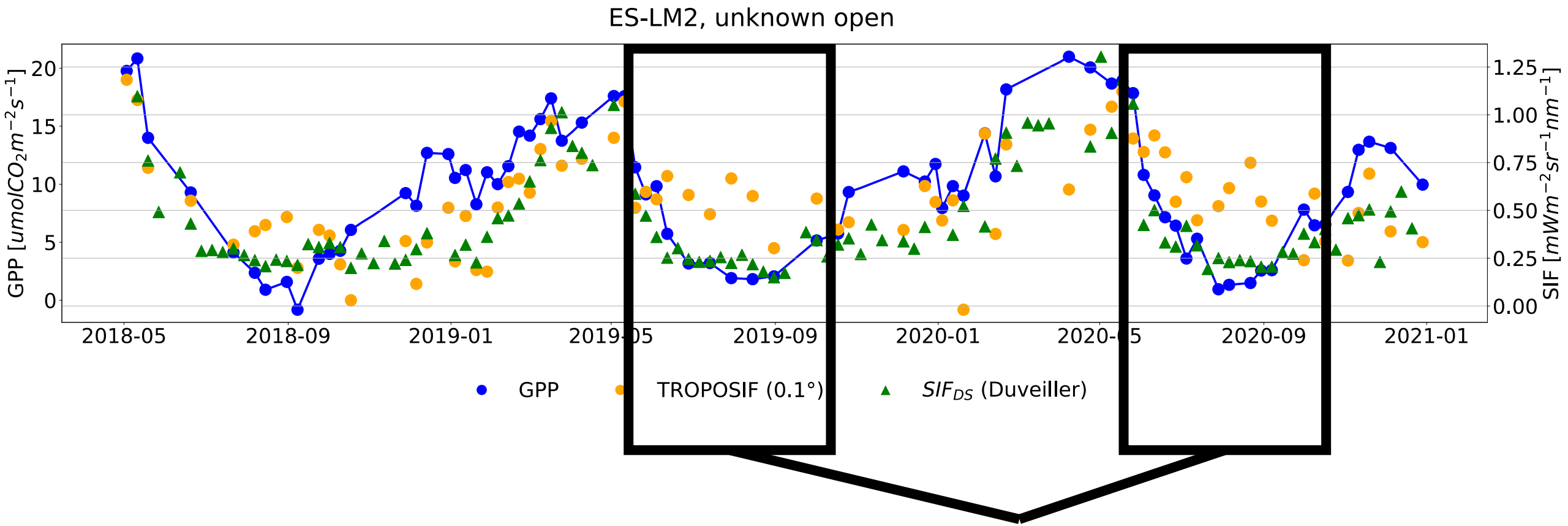


Examplary sites: ES-LM2



Downscaled SIF follows better the pattern of GPP than SIF at 0.1°

Examplary sites: FR-Gri

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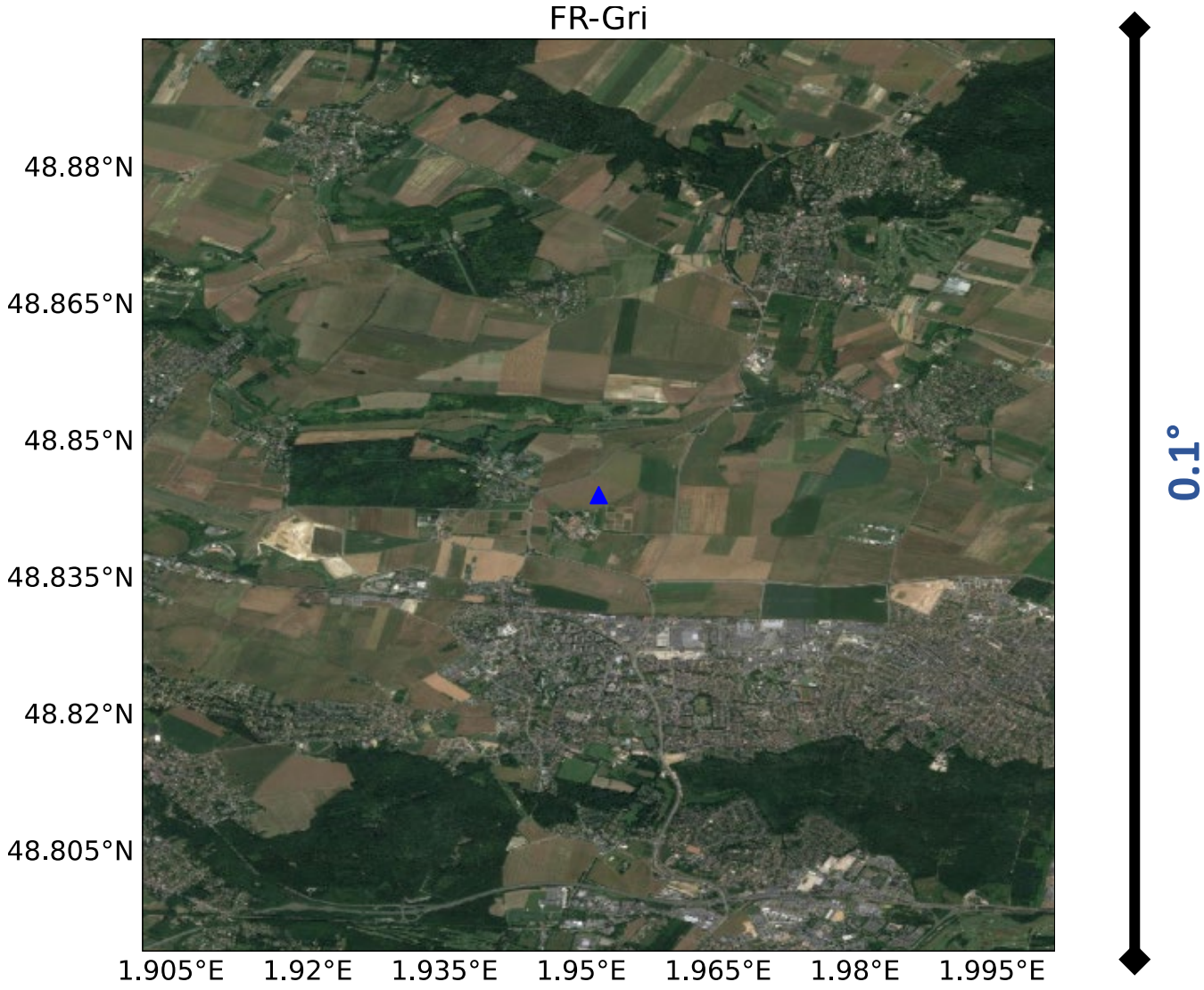

Landsat 8, from Google Earth

Examplary sites: FR-Gri

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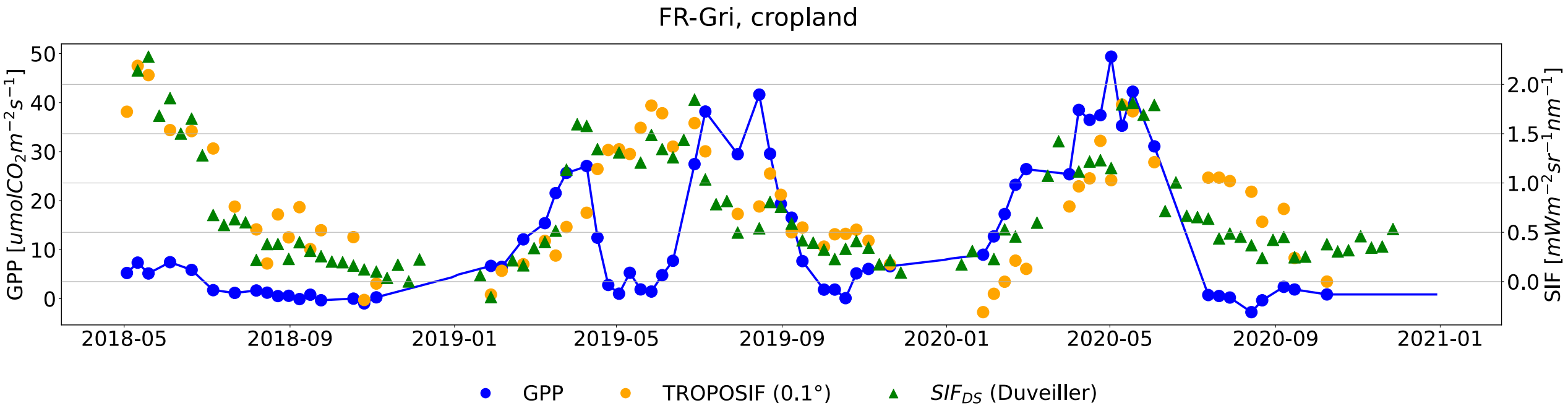

Examplary sites: FR-Gri

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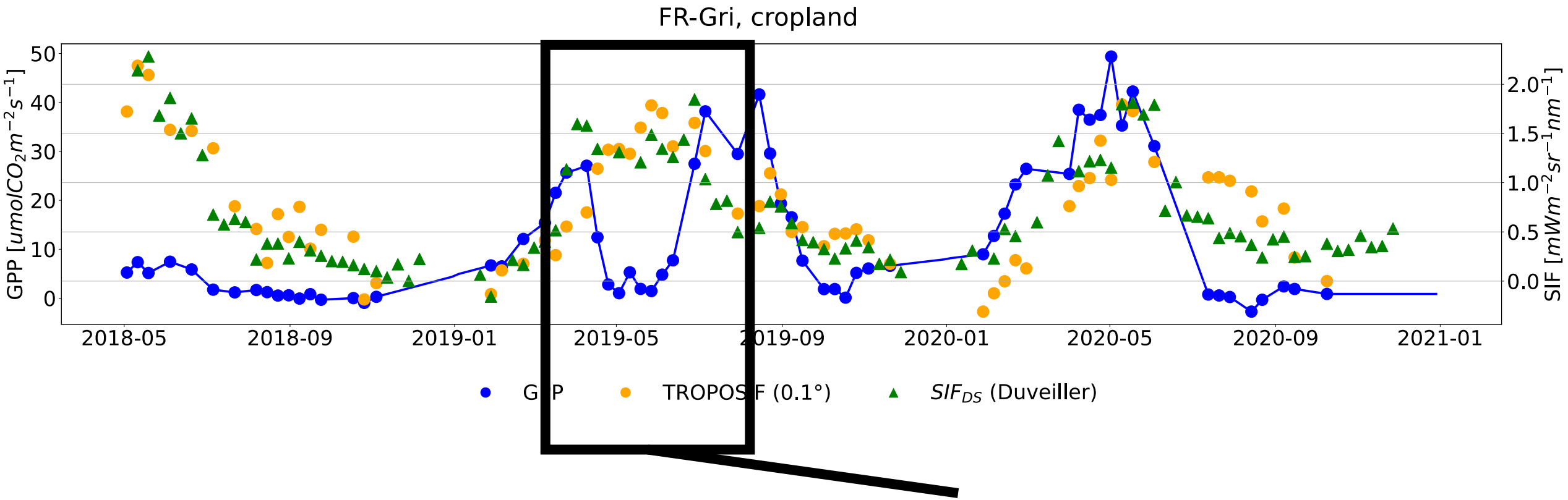

Flux tower is measuring something that is at higher resolution than gridded and downscaled SIF

Examplary sites: FR-Gri

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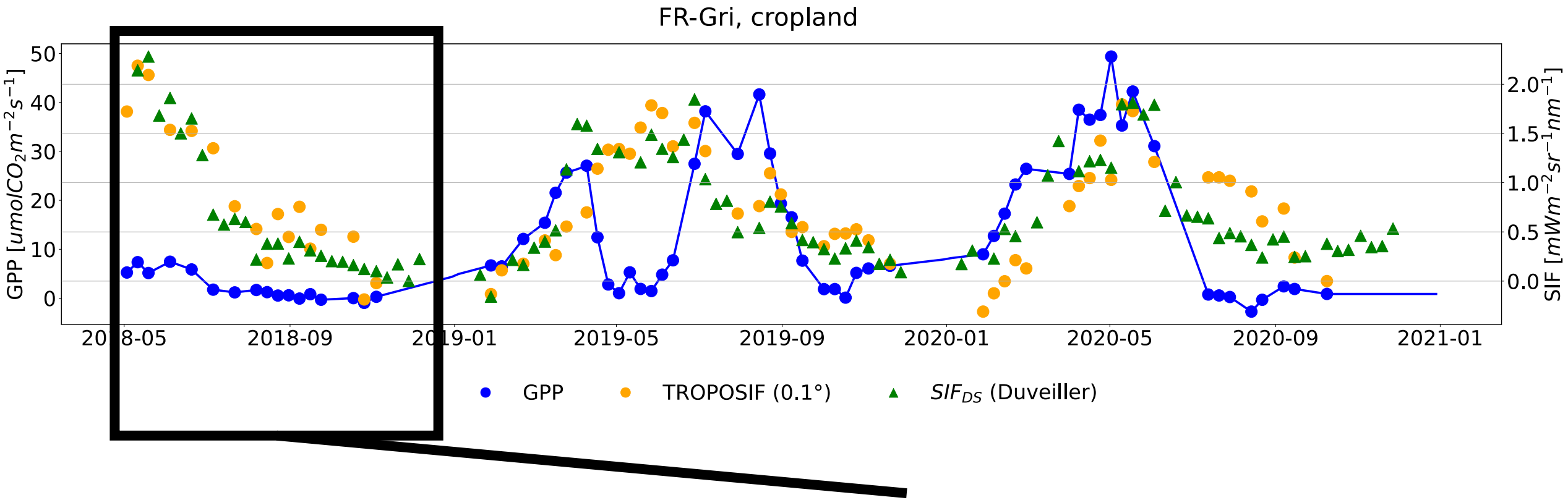

- Peak of GPP in 2018 notably lower than in 2019 and 2020
- Not visible in SIF products

FR-Gri – Sentinel 2 NDVI

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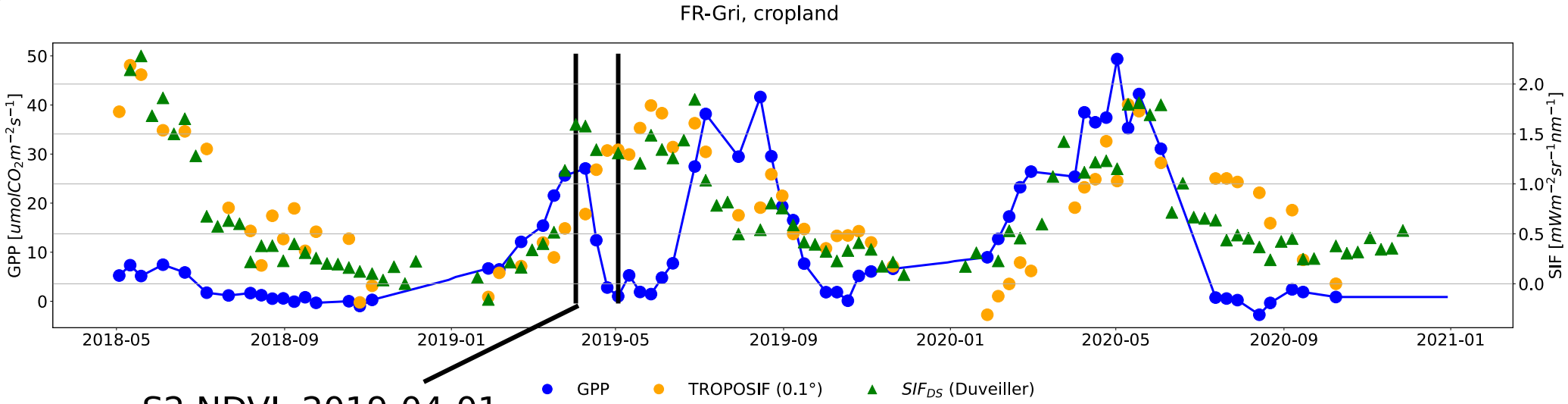

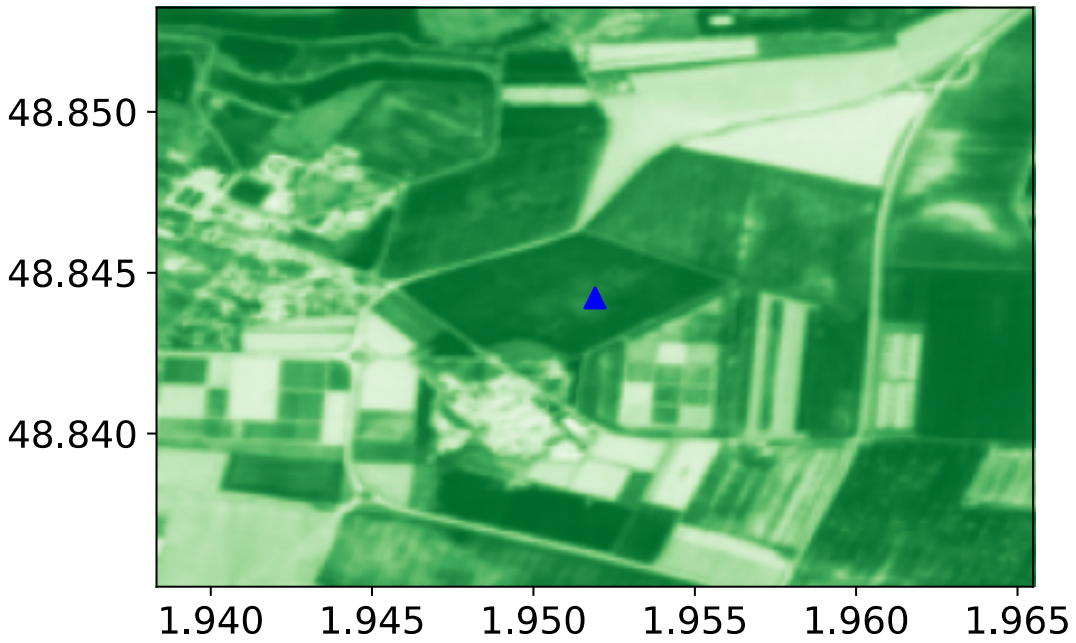

FR-Gri – Sentinel 2 NDVI

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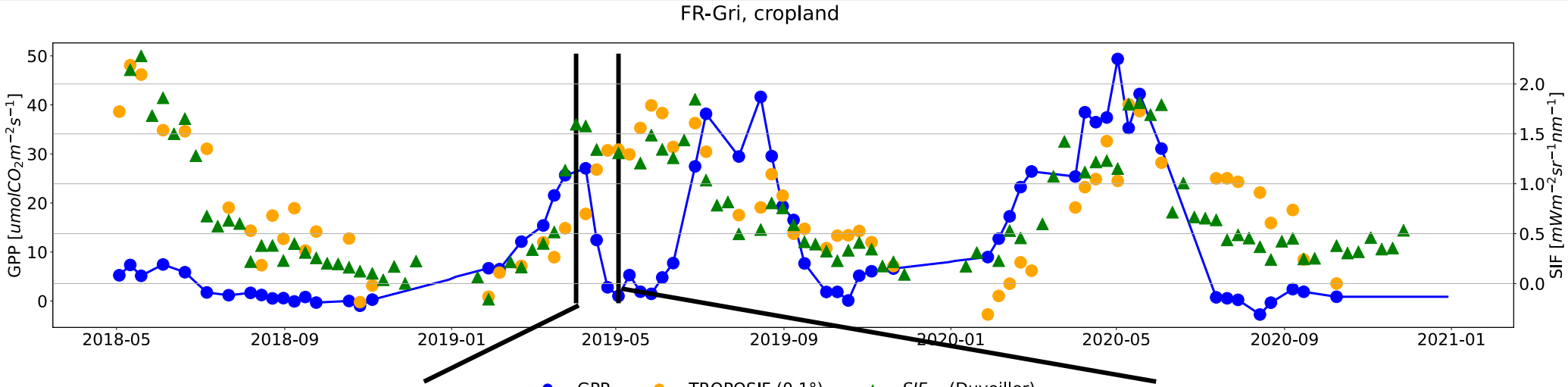
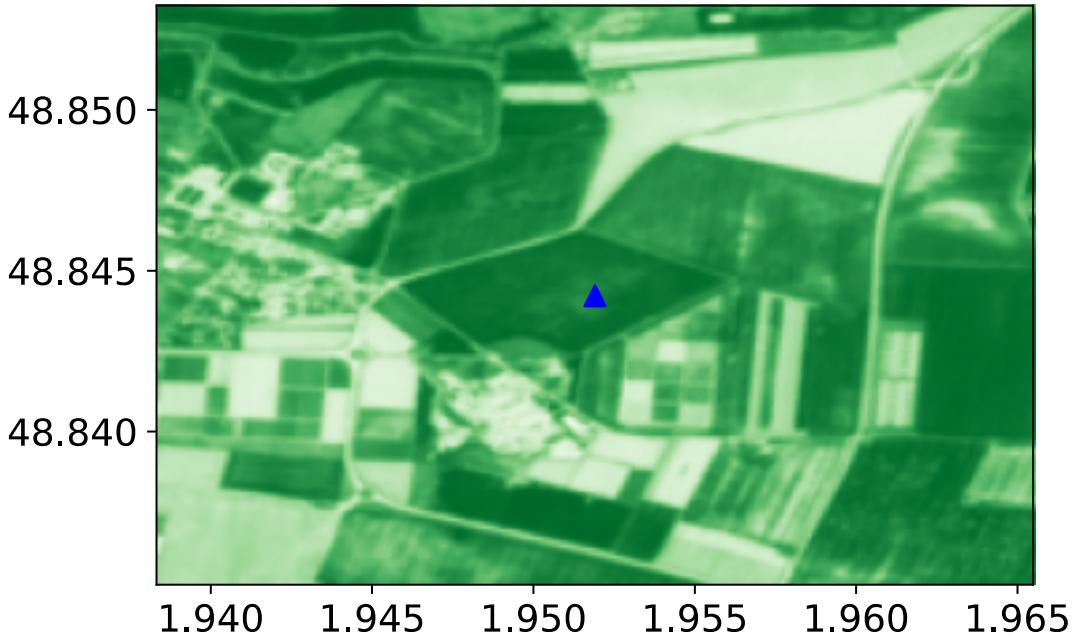


S2 NDVI, 2019-04-01



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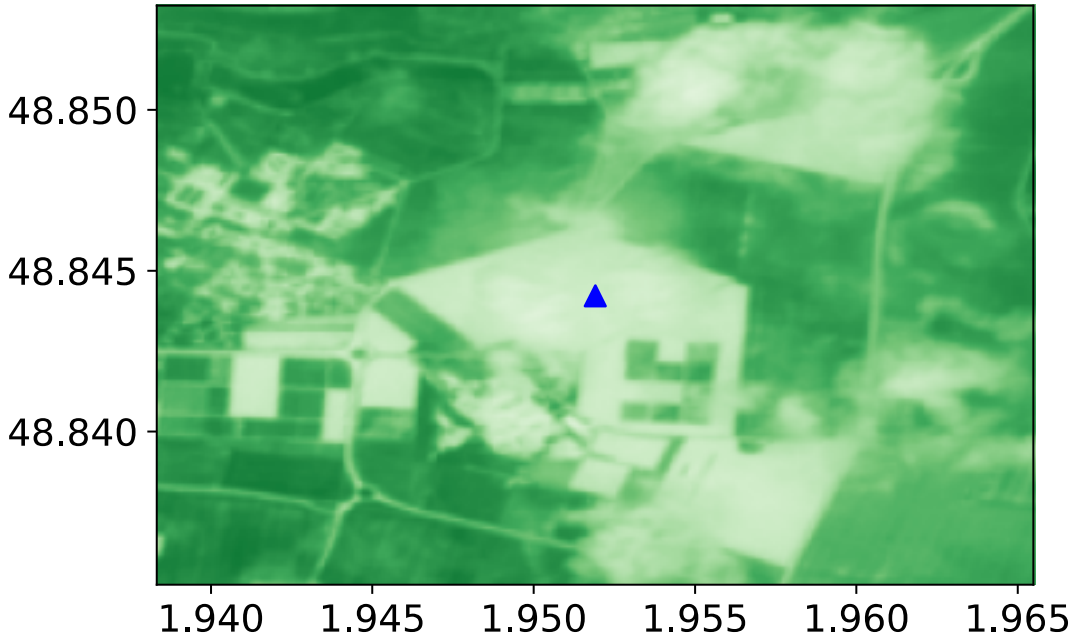

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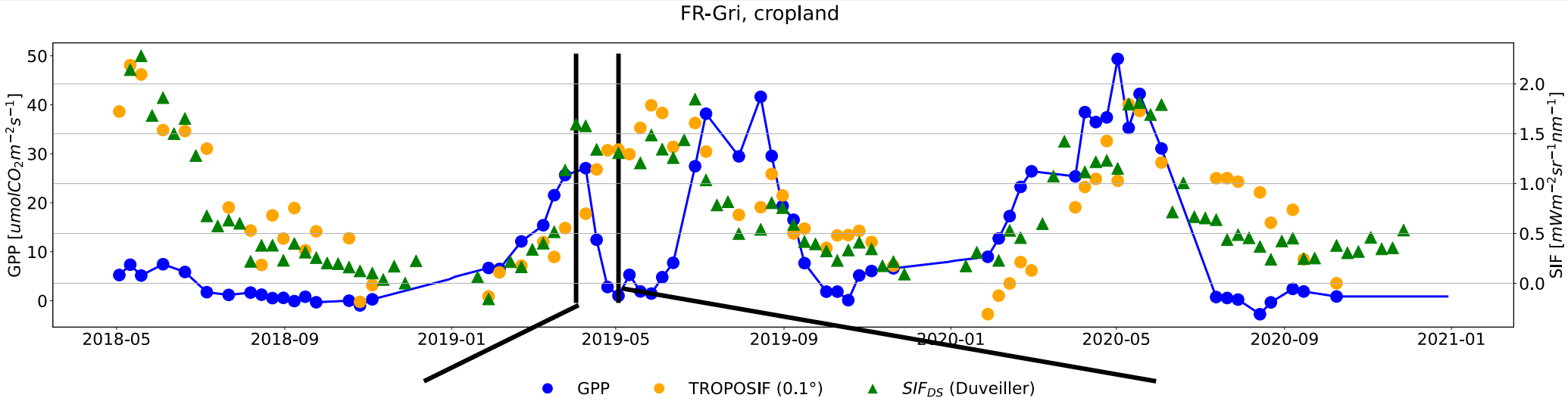

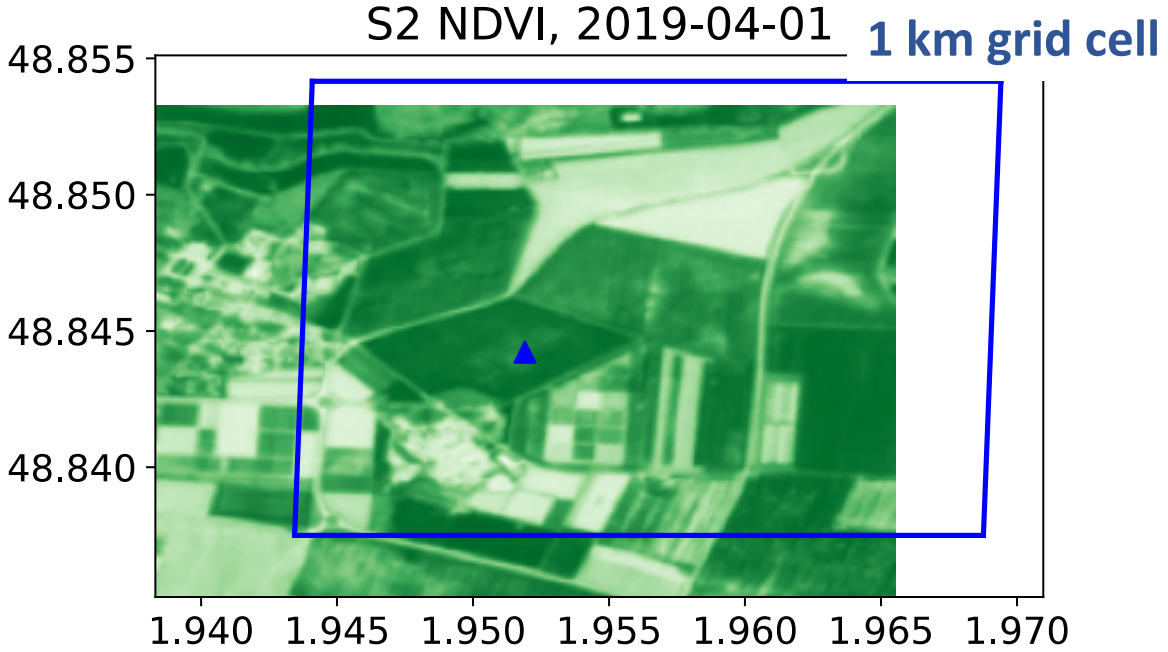

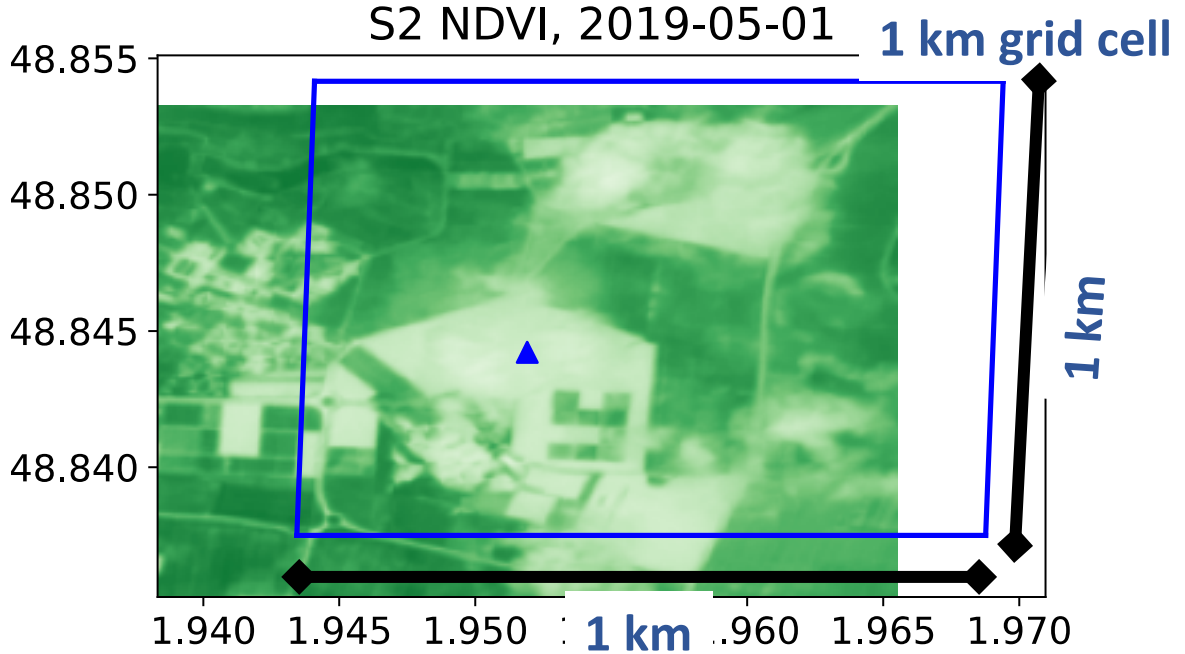

Conclusion

General Results

- Applying weighted gridding increases the correlation of SIF from TROPOMI to GPP.
- Downscaling methods are benchmarked – they further improve the correlation to GPP.
- Huge spread in the correlation of SIF to GPP between tower sites.

Perspectives

- We need to understand the variability in correlation between sites.
  - Account for heterogeneity with Sentinel 2?
- Extrapolate the knowledge we get from towers to the area of Europe.

Downscaling Methods

Duveiller et al., 2020

Turner et al., 2020

Gensheimer et al., 2022