

Detecting the Drought-Response Difference in Semiarid Ecosystems on the Mongolian Plateau: 10-Year Observation Using GOSAT SIF and MODIS PRI

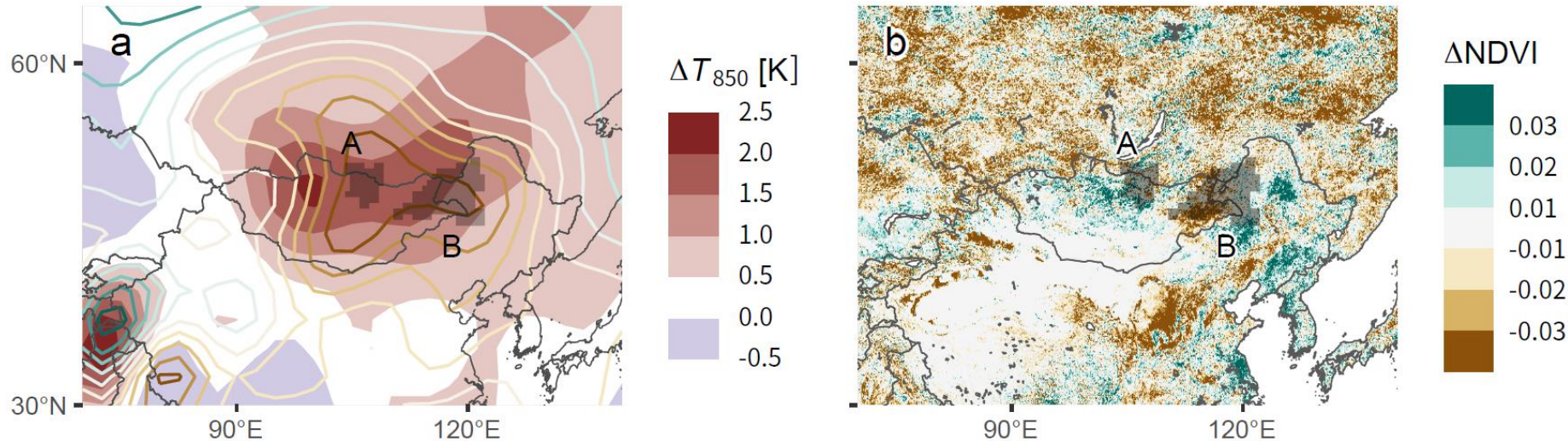
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National Institute for
Environmental
Studies

Can satellite SIF distinguish the drought-response difference between forest and grassland?



- The Mongolian plateau has experienced a severe drought since the late 1990s.
- Satellite NDVI decreased in the eastern steppe grassland (Area B), while there is no clear change in the northern taiga forest (Area A).
- GPP may decreased also in the taiga?

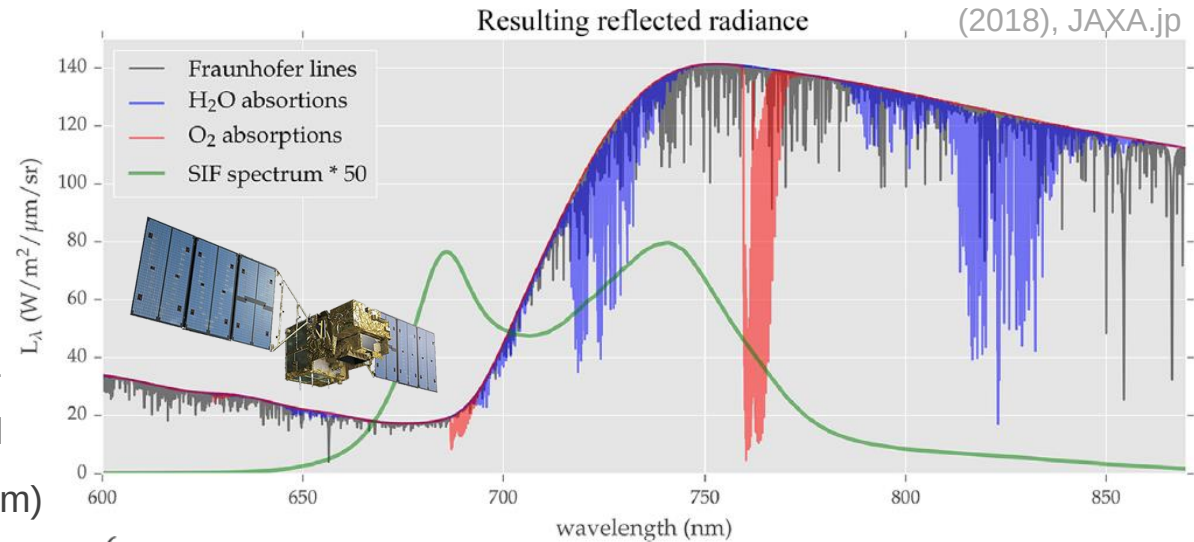
We used GOSAT satellite (launched in 2009) to evaluate the long-lasting drought impact.



Satellite data

GOSAT TANSO-FTS

- **SIF** was retrieved from Fraunhofer lines (756.0–759.1 nm) in-filling signal by spectral fitting (band 1 FWHM: 0.025 nm)
- Footprint: 10.5-km dia. circle
- Local pass time: 13:30–14:00

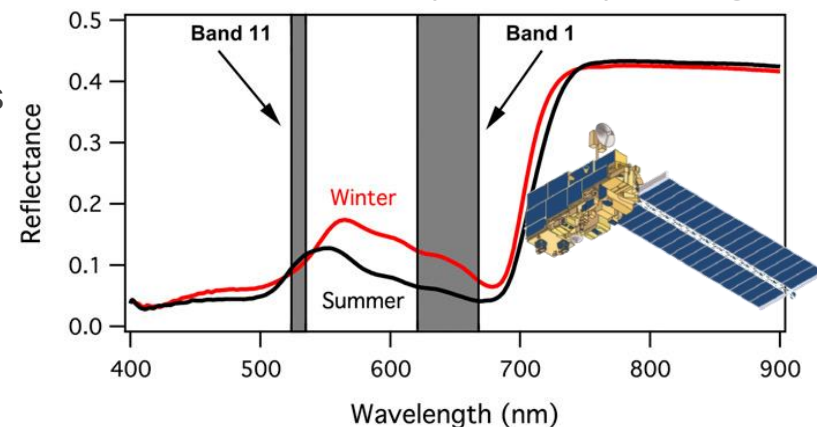


$$\begin{cases} L^\lambda(SIF^\lambda, \alpha) = SIF^\lambda + \langle I_0^\lambda \rangle \sum \alpha_i \lambda_i \\ \arg \min \left\| S_\varepsilon^{-\frac{1}{2}} \left(y^\lambda - L^\lambda(SIF^\lambda, \alpha) \right) \right\|_2 \end{cases} \quad \text{*Angle bracket denotes convolution of ILSF}$$

Aqua MODIS

- **Band-1 PRI** (a.k.a CCI) was obtained from the bands 1 & 11 (620–670 & 526–536 nm) in MAIAC BRF C6
- Band 11 pixel size: 1 km
- Local pass time: 10:30–12:00 & 12:30–14:00
- **Landcover** (IGBP & MOD44B), **fPAR/LAI**, **GPP** products were used for screening & comparison

Gamon et al. (PNAS 2016), NASA.gov



Data processing (to deal with sparse observations by GOSAT)

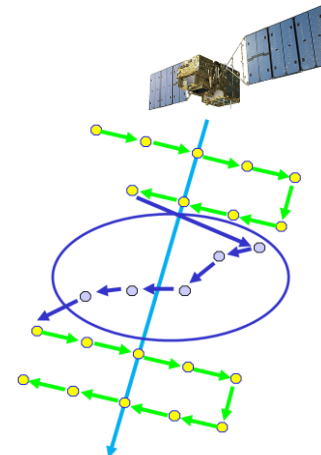
1. Climate Zoning

Determine the boundaries of taiga & steppe areas by cluster analysis using MERRA-2 reanalysis data (monthly PAR, rain, T_a , VPD) to ensure meteorological homogeneity
2. Get MODIS/MERRA-2 Data within GOSAT Footprint

Extract the MODIS pixels & MERRA-2 meshes those included within each GOSAT footprint and observed at the same day/time
3. Landcover Screening

Select GOSAT soundings that have 100% grassland & <15% woodland for steppe; and >40% woodland for taiga using MODIS IGBP landcover and MOD44B
4. Cloud Screening & Outlier Removal*

Bin the SIF data according to APAR and remove outliers based on $1.5 \times \text{IQR}$ rule
5. Areal & Monthly Averaging for SIF
6. Data cleaning for SIF yield

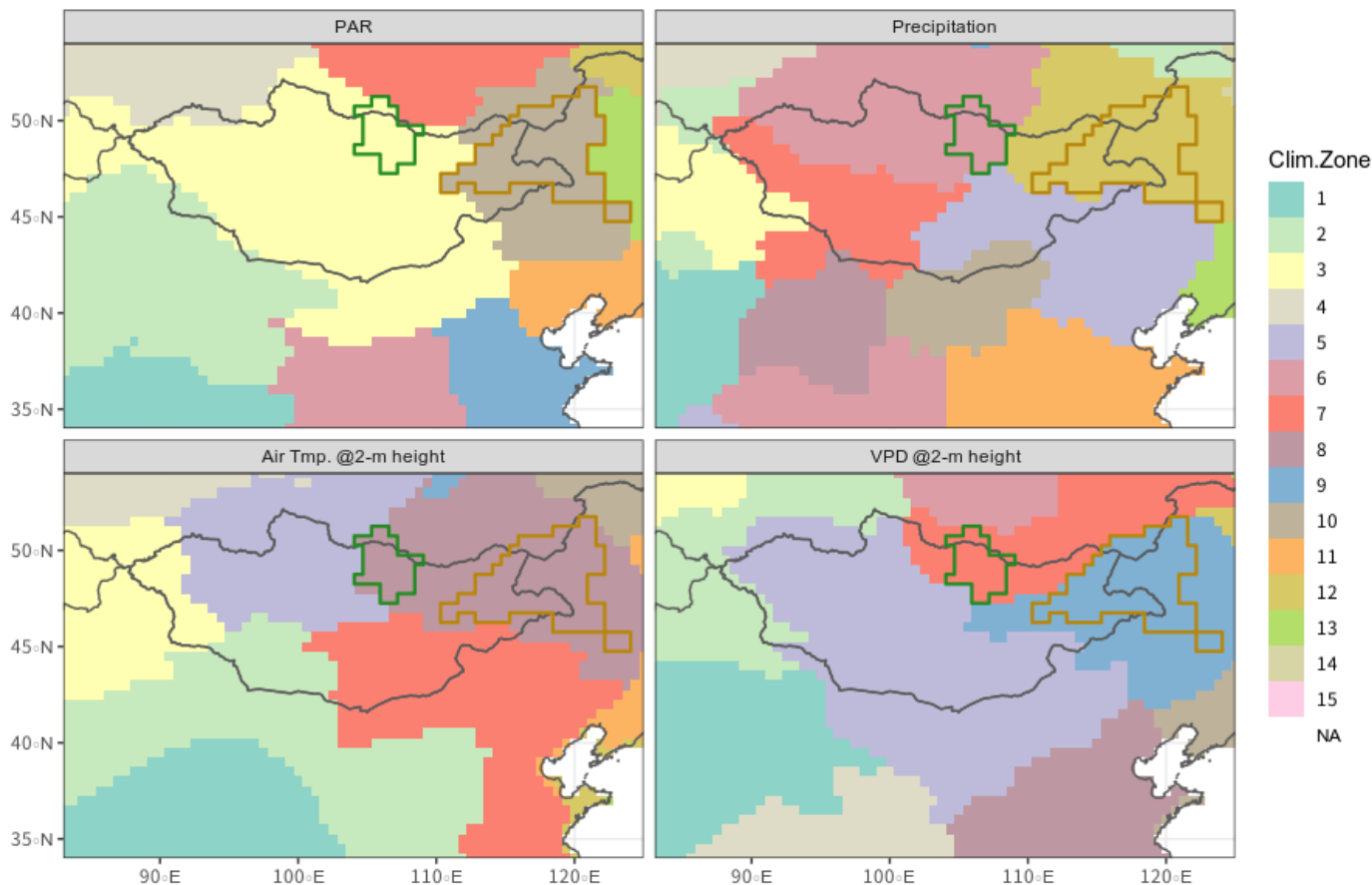


* MODIS products quality flags and GOSAT-FTS quality criteria (e.g. SNR) were checked beforehand

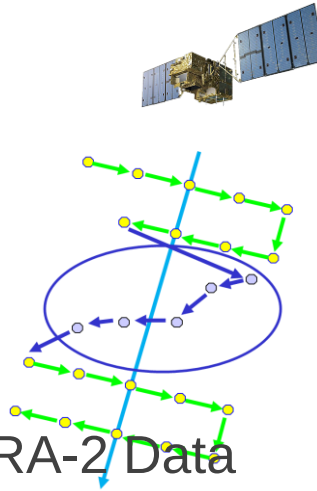
Data processing (cont.)

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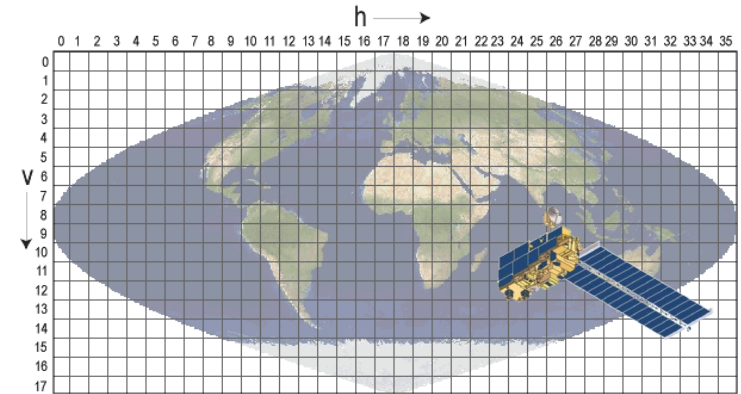
Determine the boundaries of **taiga** & **steppe** areas by cluster analysis using MERRA-2 reanalysis data (monthly PAR, rain, T_a , VPD) to ensure meteorological homogeneity



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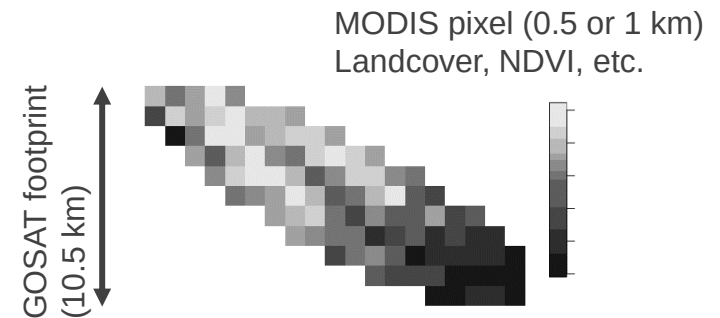
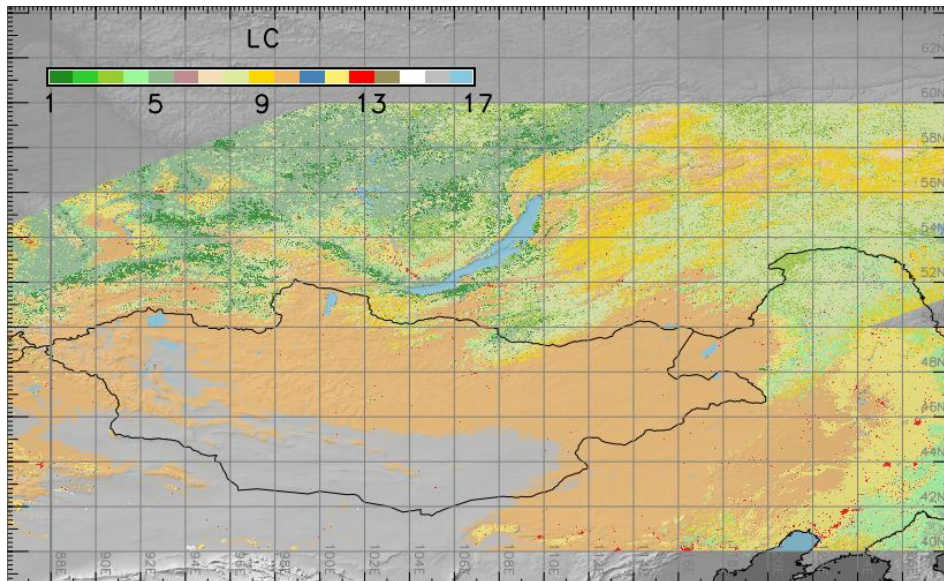
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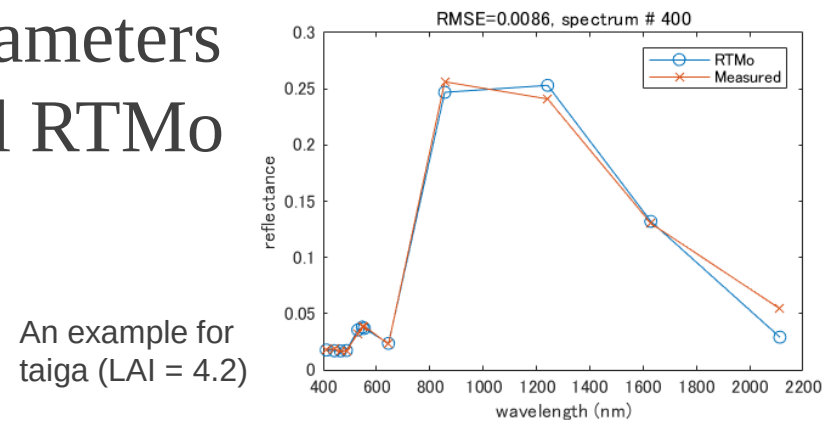
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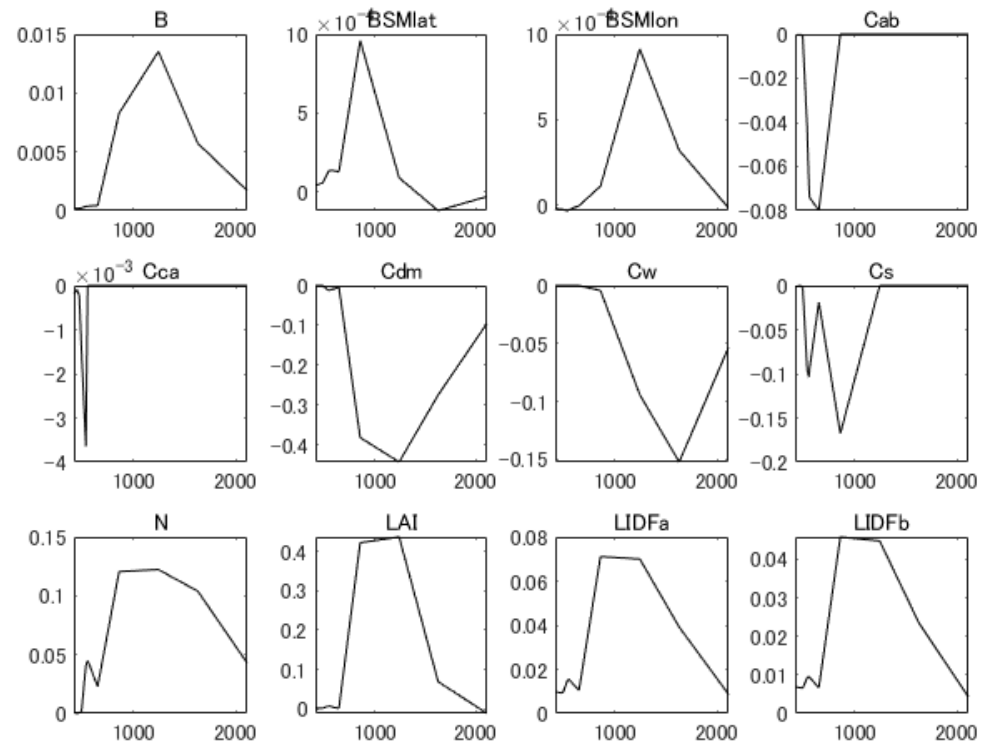


Retrieval of leaf biochemical parameters using the radiative transfer model RTMo (SCOPE)

- According to the methods of van der Tol et al. (RSE 2016) and Verhoef et al. (RSE 2018)
- Bands 1—12 in MODIS MAIAC BRF were used to retrieval inputs
- TOC spectral irradiance (400—2400 nm) was calculated using the atmospheric radiative transfer code 6SV ver 1.1 with atmospheric data from MODIS & MERRA-2 products (AOT_{550} , column water vapor, etc)
- A priori information for LAI (MODIS), soil water content (MERRA-2)

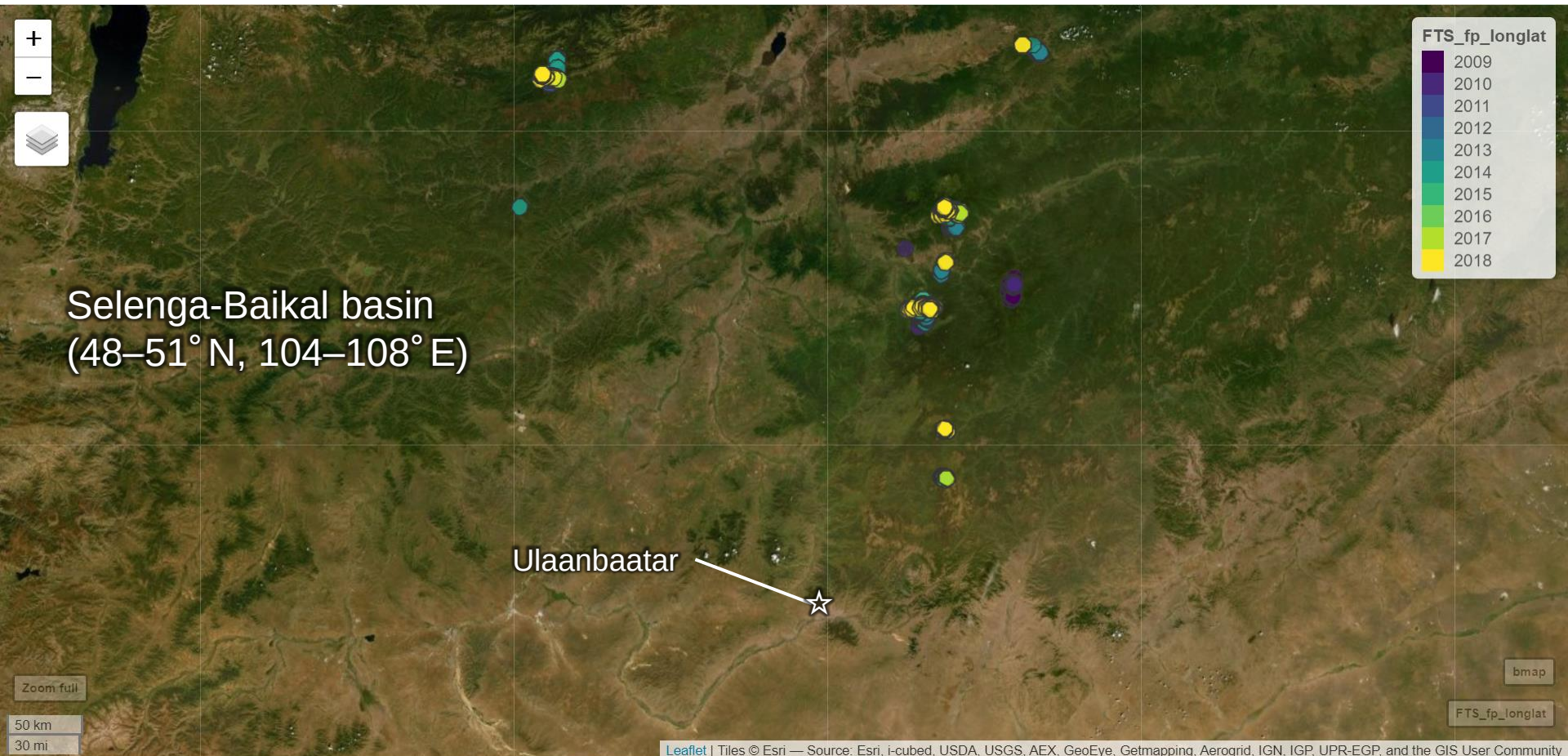
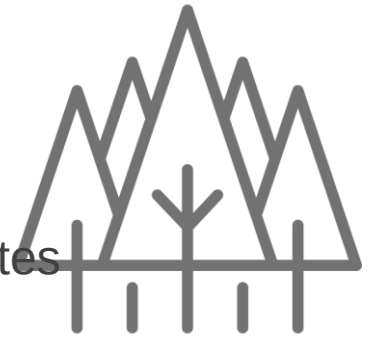


Jacobian values for spectra # 400



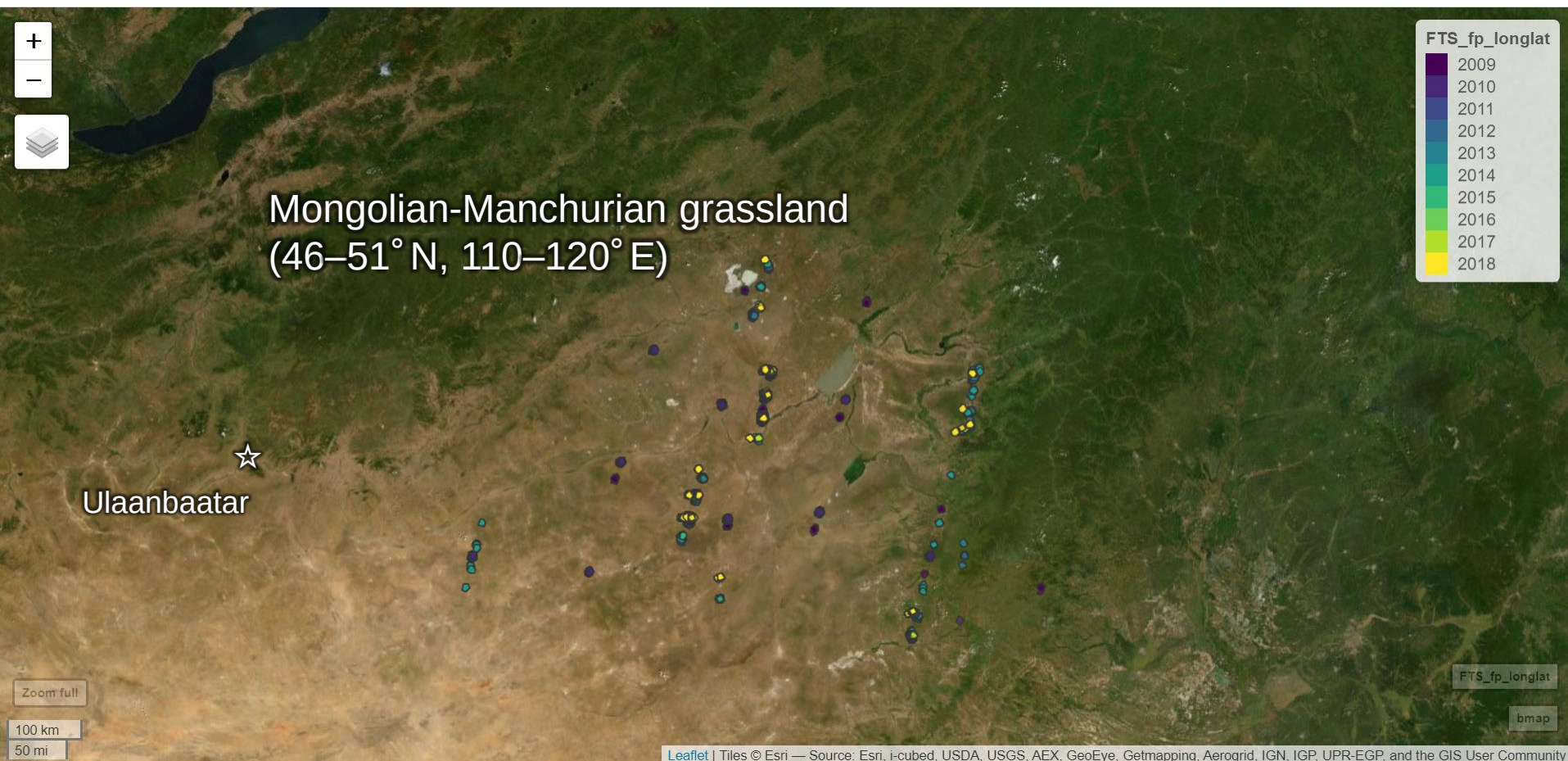
Taiga (Area A)

- Ann. precipitation < 350 mm, T_a ranges -35 — 35°C
- Forests are distributed on mountains. Siberian larch dominates this area (with some birch and evergreen needleleaf trees)



Steppe (Area B)

- Ann. precipitation < 350 mm, T_a ranges -35 — 35°C
- Perennial C3 grassland
(*Stipa krylovii*, *Leymus chinensis*, etc. according to Li et al. 2007)

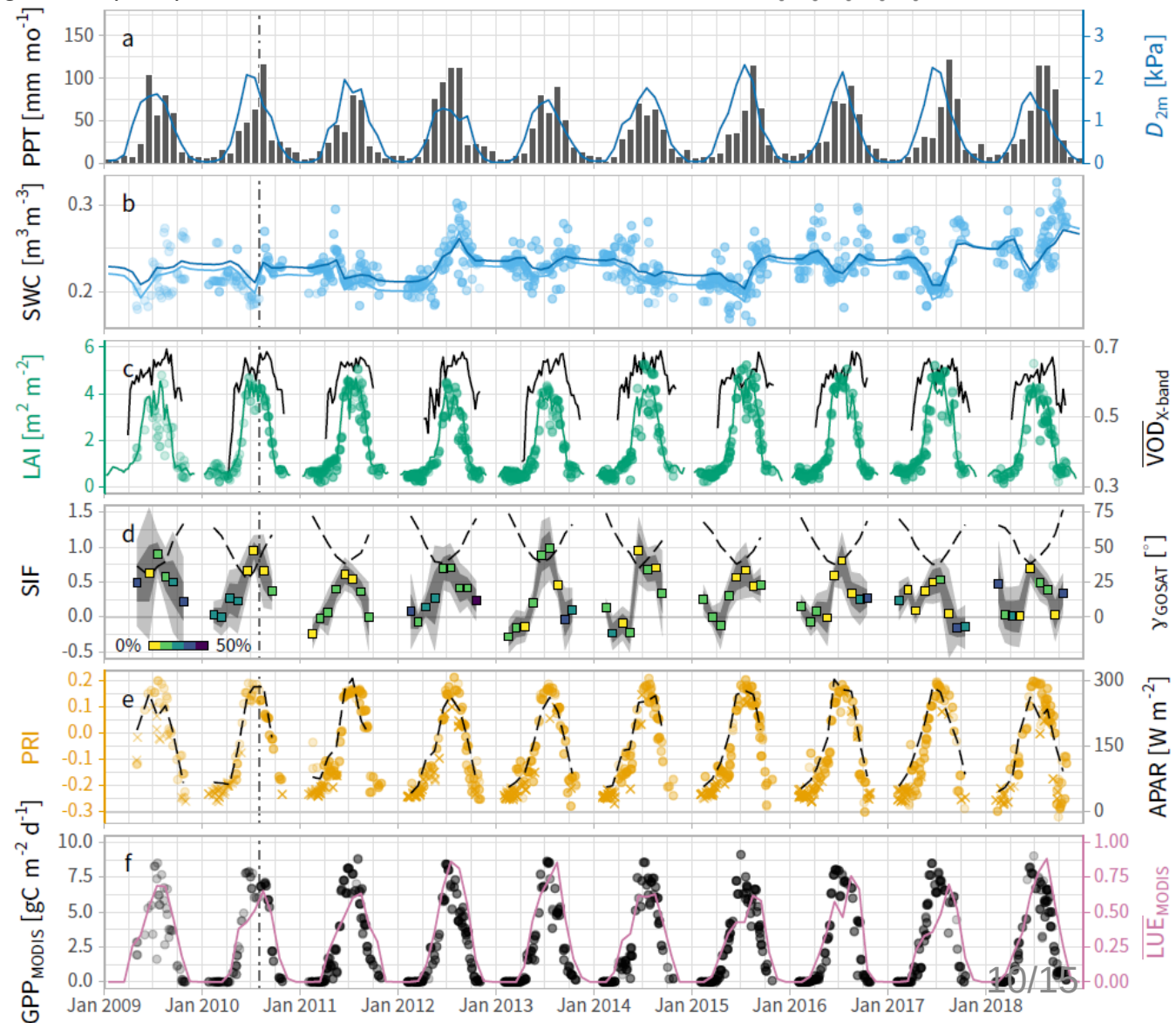


Result: 10-year changes in Taiga

Each circle corresponds to each GOSAT footprint; Continuous lines indicate areal means.
The unit of SIF is $[\text{mW m}^{-2} \text{ nm}^{-1} \text{ sr}^{-1}]$, colors show the cloud cover fraction.
VOD was obtained from Moesinger et al. (2020).



- ✓ Consistent SIF data with relatively small noise was obtained since 2011.
- ✓ LAI & PRI show little interannual variation, while SIF changed significantly.

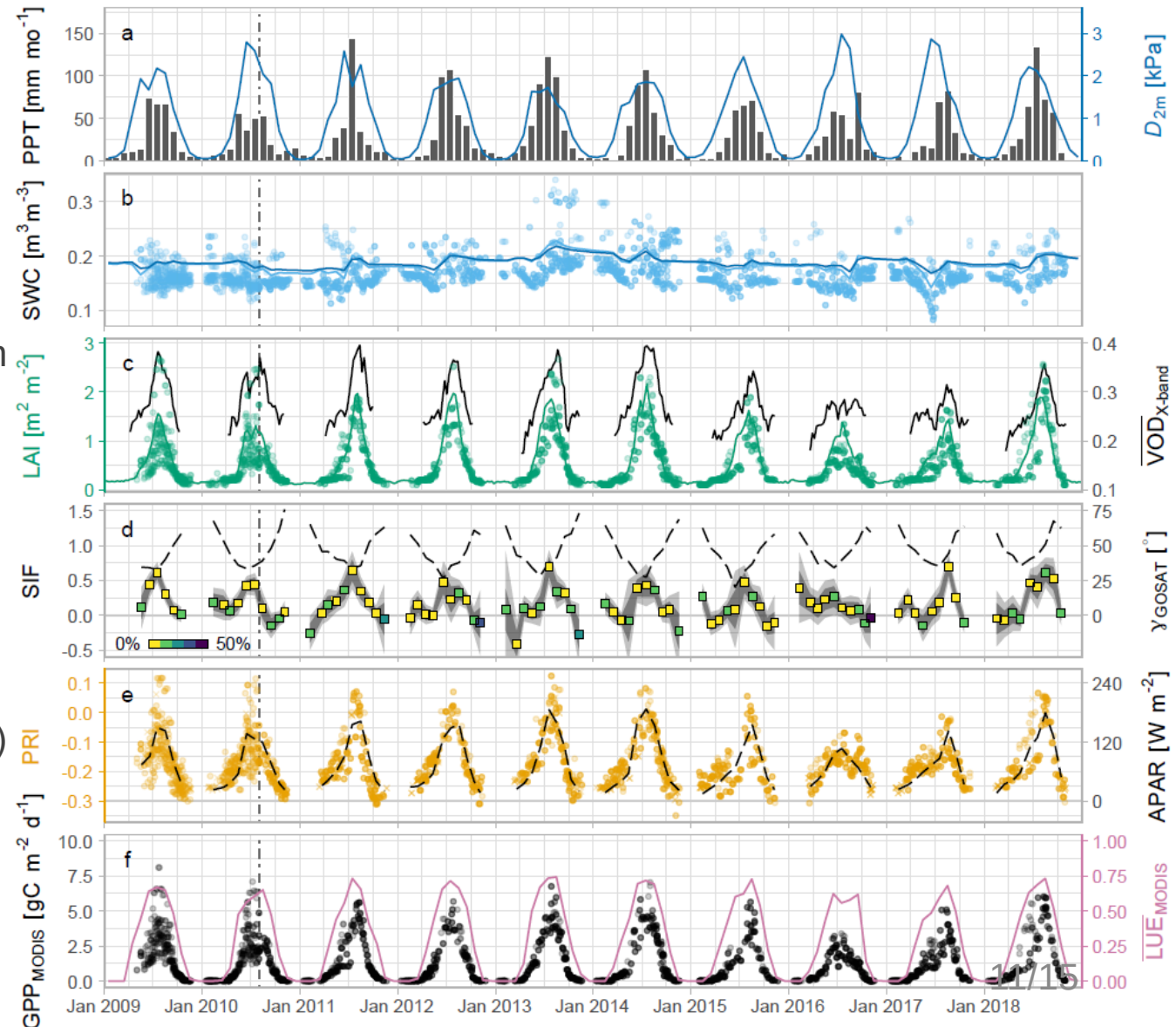


Result: 10-year changes in Steppe

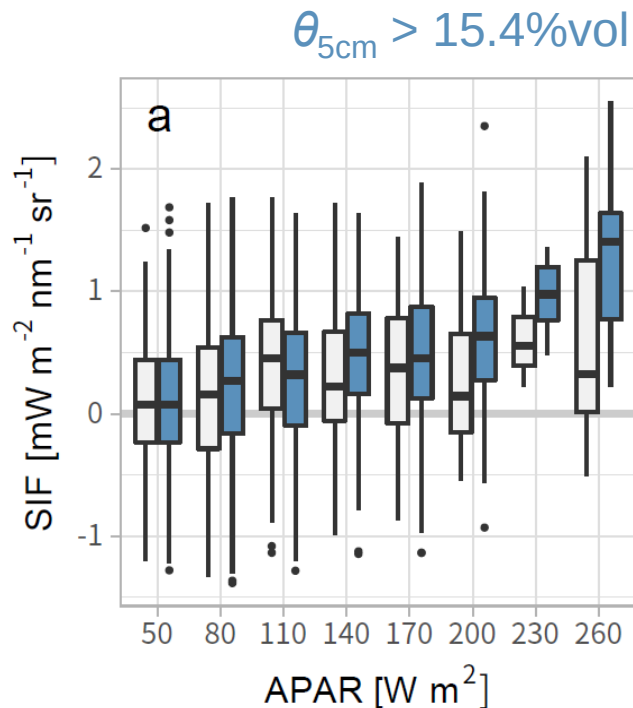
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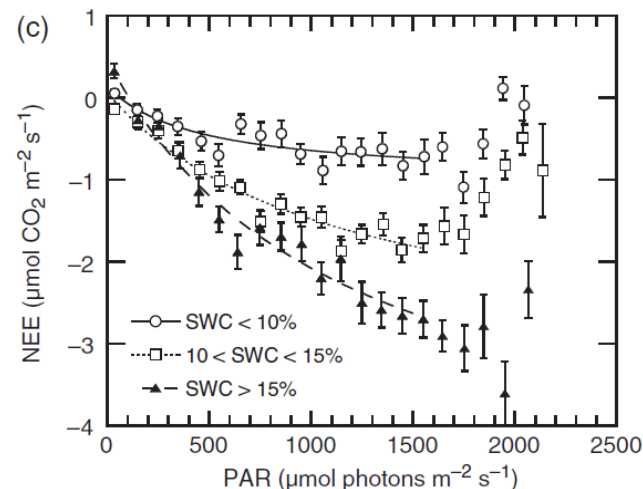
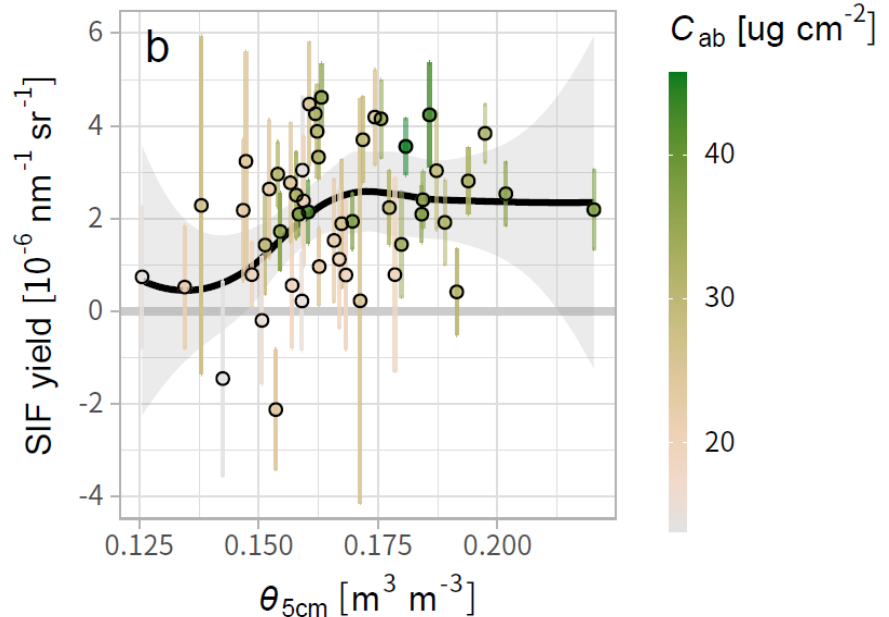
- ✓ Large Interannual variations in PPT & LAI; strong correlation ($r = 0.9$) was found.
- ✓ SIF changed with LAI (& APAR) in general, but anomalous reductions occur sometimes (e.g. July—August in 2016)



Steppe's SIF changes nonlinearly with surface soil water content ($\theta_{5\text{cm}}$)

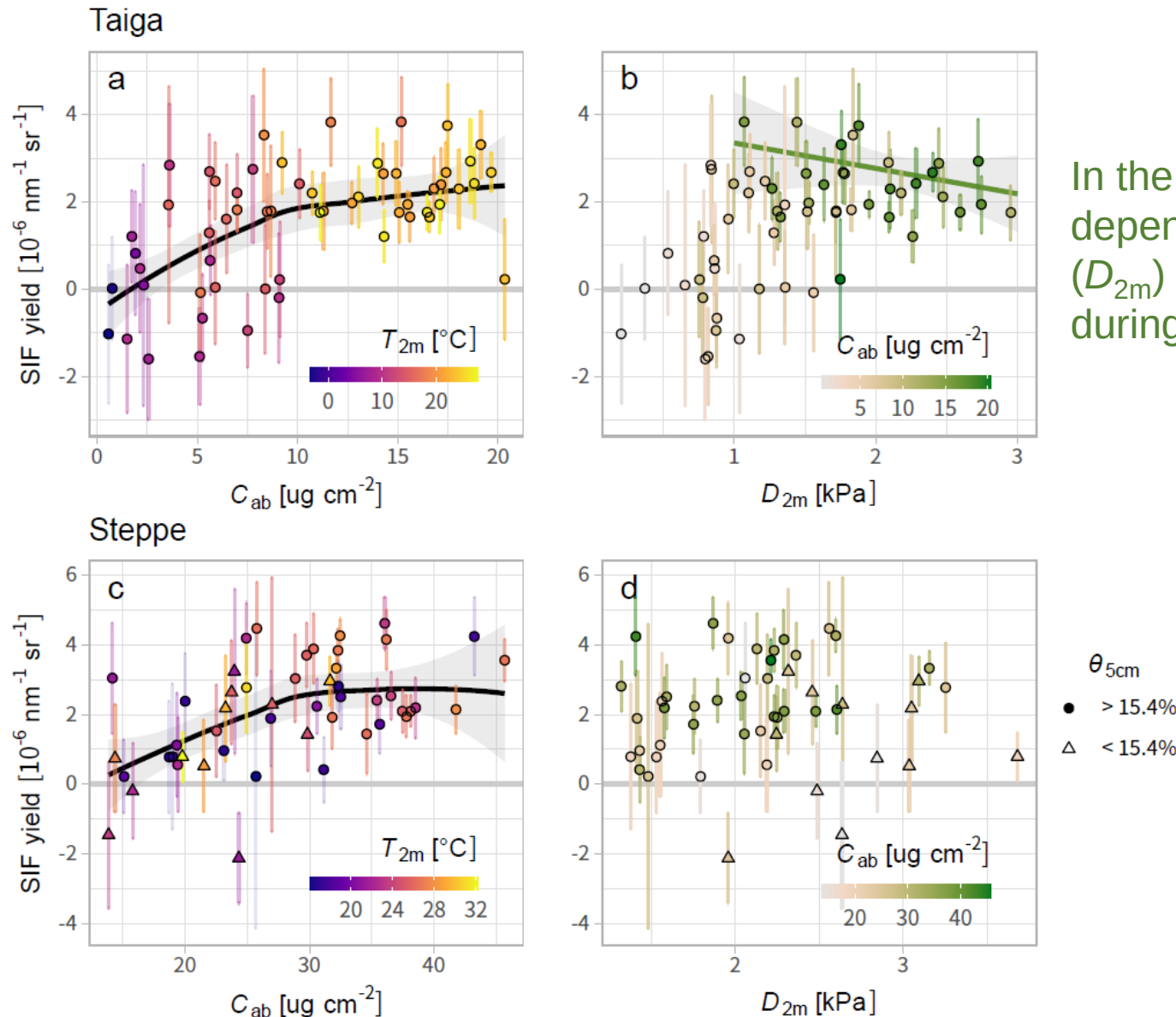


- ✓ The apparent value of wilting point SWC (= 15.4%) agree well with eddy-covariance results in the study area (Li et al. *GCB* 2007)



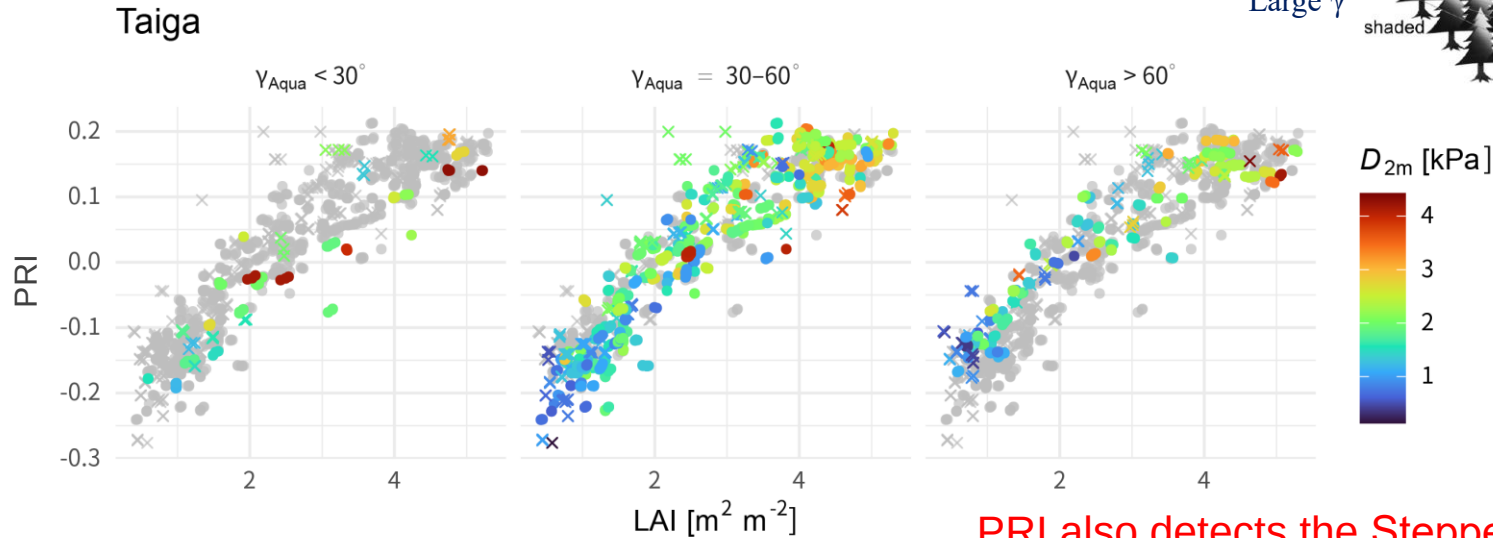
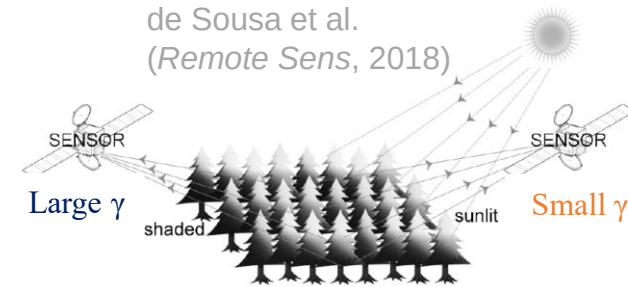
(Li et al. *GCB* 2007)

SIF yield (calculated from MODIS fPAR & MERRA-2) correlates with air temperature (T_{2m}) and retrieved chlorophyll content (C_{ab})

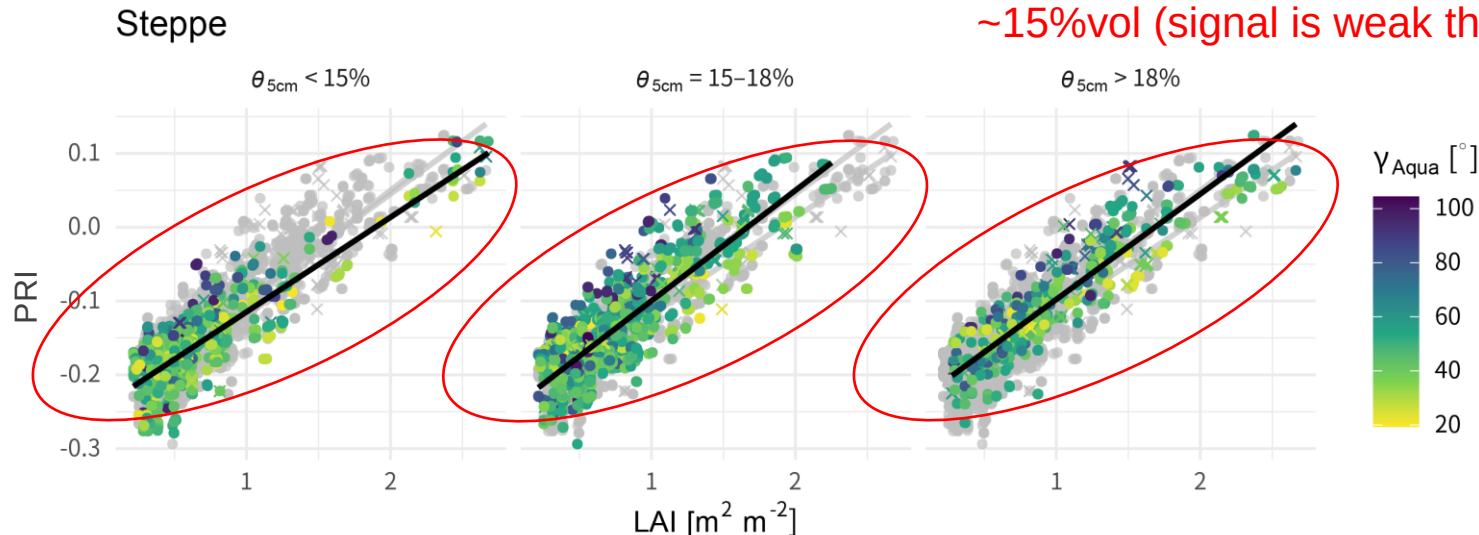


In the taiga, weak dependence on VPD (D_{2m}) was found during summer.

PRI strongly correlates with LAI, but also with satellite phase angle (γ_{Aqua})



PRI also detects the Steppe's wilting point
~15%vol (signal is weak though)



Coming soon...

We will evaluate the drought impact on GPP using the process-based model SCOPE

Rodgers et al. (*New Phytol*, 2017)

