FLEX-Fluorescence 2026 Workshop

03 – 06 March | Bonn University, Germany

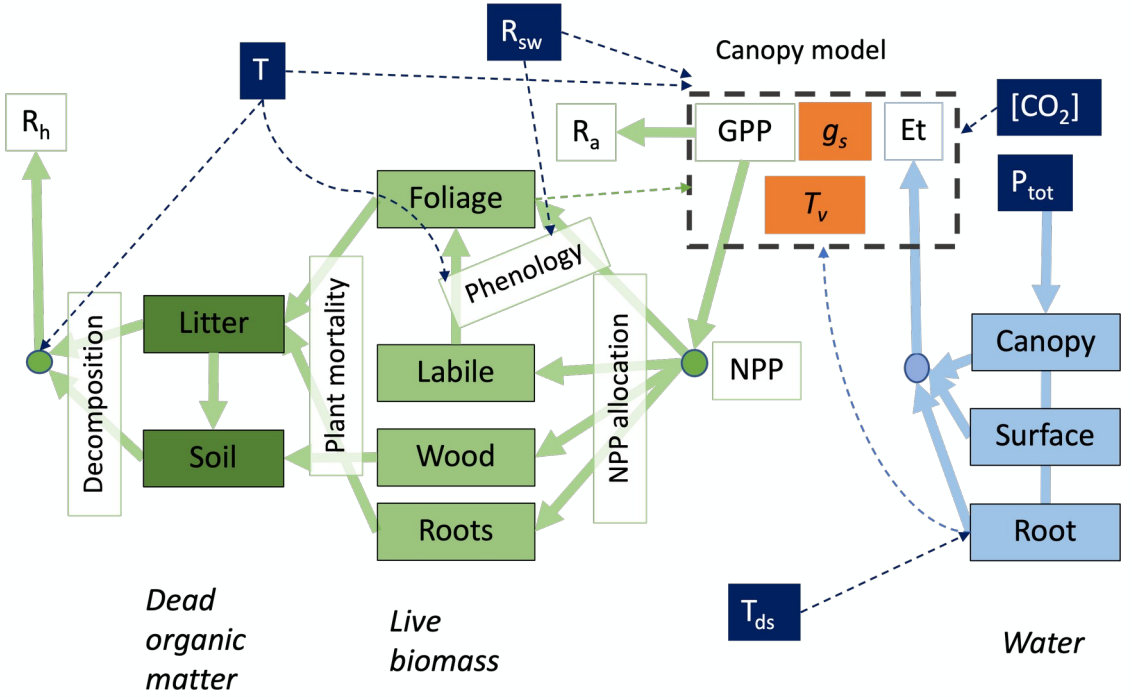
Terrestrial Carbon Community Assimilation System

Thomas Kaminski[1], Tristan Quaife[2], Tea Thum[3], Wolfgang Knorr[1], Michael Voßbeck[1], Mathew Williams[4], Luke Smallman[4], Marko Scholze[5], Sönke Zaehle[6], Peter Rayner[1], Susan Steele-Dunne[7], Mariette Vreugdenhil[8], Timothy Green[4], Mika Aurela[3], Alexandre Bouvet[9], Emanuel Bueechi[8], Wouter Dorigo[8], Tarek El-Madany[6], Marika Honkanen[3], Yann Kerr[9], Anna Kontu[3], Juha Lemmetyinen[3], Hannakaisa Lindqvist[3], Arnaud Mialon[9], Mirco Migliavacca[10], Tuuli Miinalainen[3], Amanda Ojasalo[3], Shaun Quegan[11], Pablo Reyez Muñoz[12], Nemesio Rodriguez-Fernandez[9], Mike Schwank[13], Jochem Verrelst[12], Songyan Zhu[14], Dirk Schüttemeyer[15], Matthias Drusch[15]

1: The Inversion Lab, Germany;
2: University of Reading, UK;
3: FMI, Helsinki, Finland;
4: University of Edinburgh, UK;
5: University of Lund, Sweden;
6: MPI BGC Jena, Germany;
7: TU Delft, The Netherlands;
8: TU Wien, Austria;
9: CESBIO Toulouse, France;
10: DG Joint Research Centre, European Commission, Italy;
11: University of Sheffield, UK; 12: University of Valencia, Spain;
13: University of Southampton, UK;
14: Swiss Federal Institute for Forest, Snow and Landscape Research, Switzerland;
15: ESA, ESTEC, The Netherlands

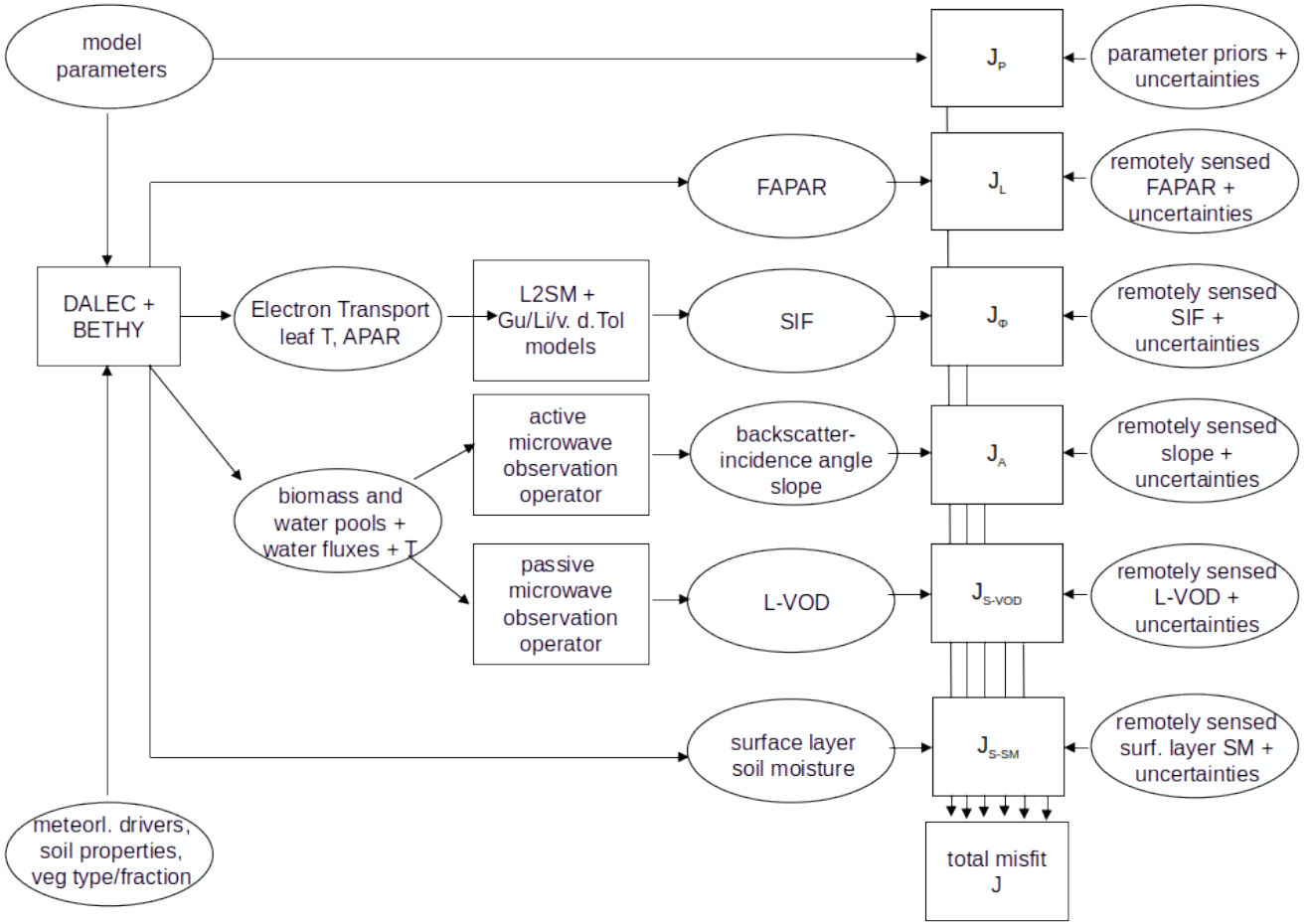
What is TCCAS?

- The Terrestrial Carbon Community Assimilation System (TCCAS) is built around the newly developed D&B terrestrial biosphere model.
- The focus of TCCAS is the combination of a diverse array of observational data streams with the D&B model to yield a consistent picture of the terrestrial carbon, water and energy cycles.
- The development of TCCAS was funded through the carbon cluster of the European Space Agency



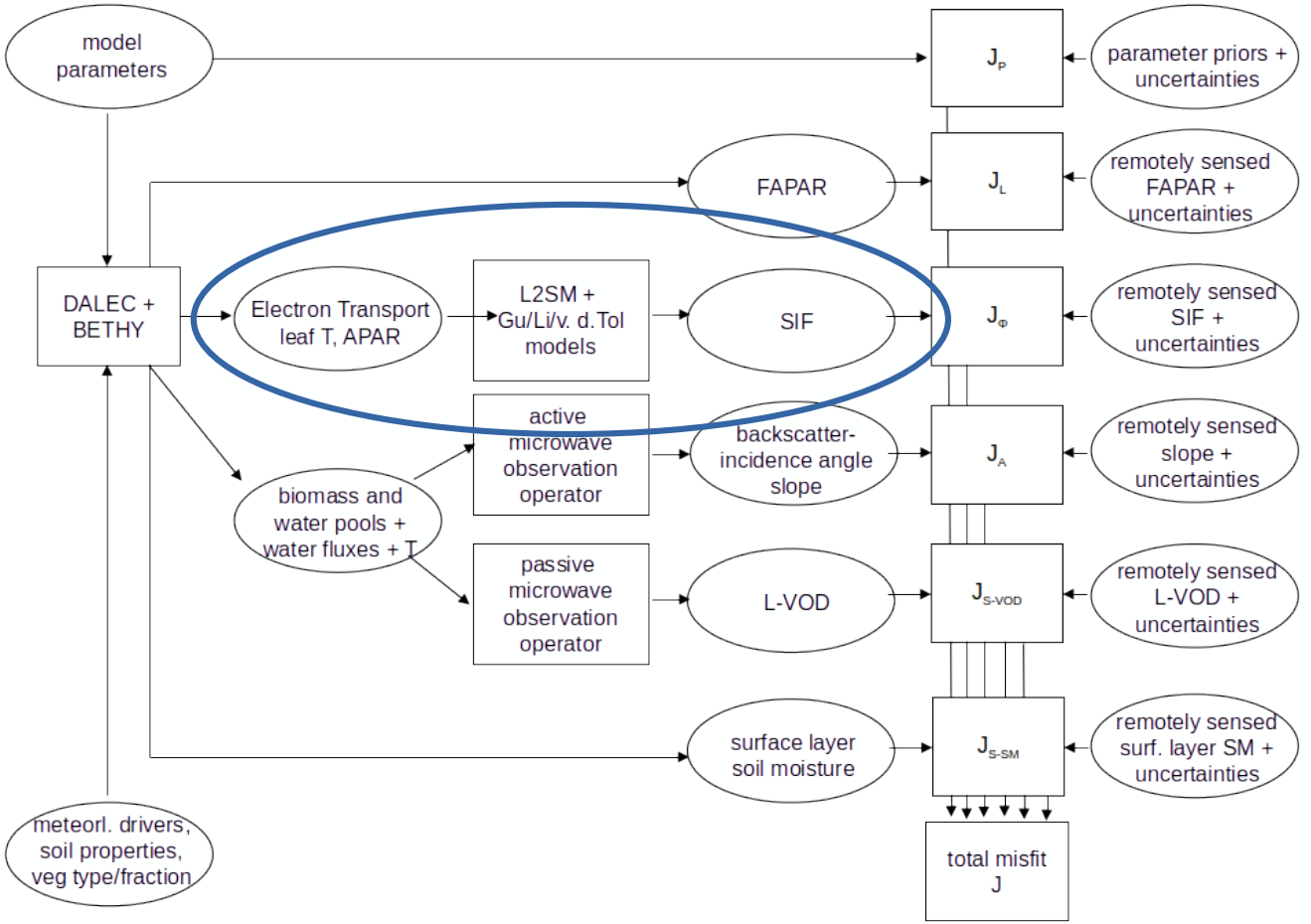
What does TCCAS offer?

- Open source community system
- Observation operators for optical as well as active and passive microwave observations
- Assimilation on the footprint
- Tangent and adjoint codes
- Modular setup
- Computational efficiency
- Tested on point to regional scales
- Can operate at high resolution
- Experienced developer team
- Documentation
- User support and training

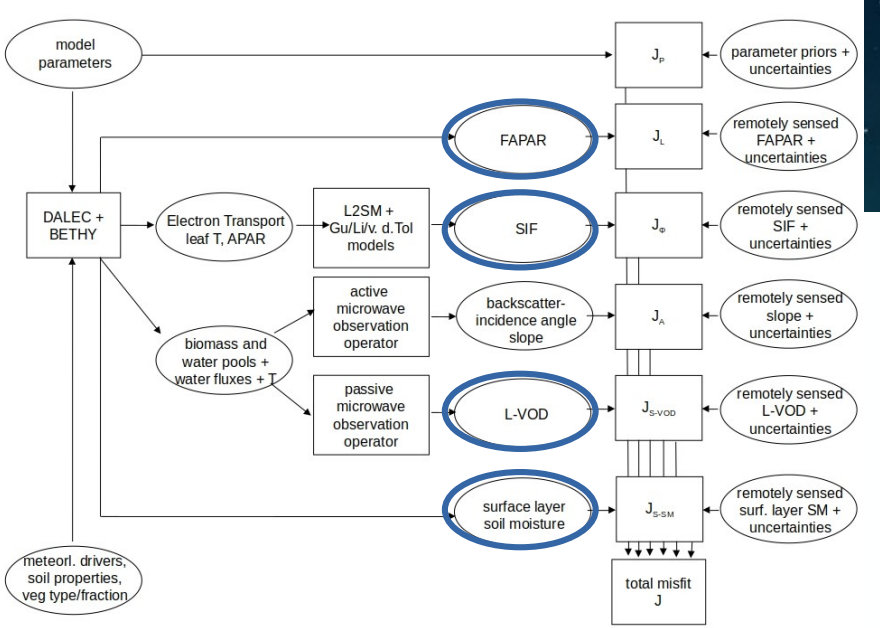


Observation Operators for SIF

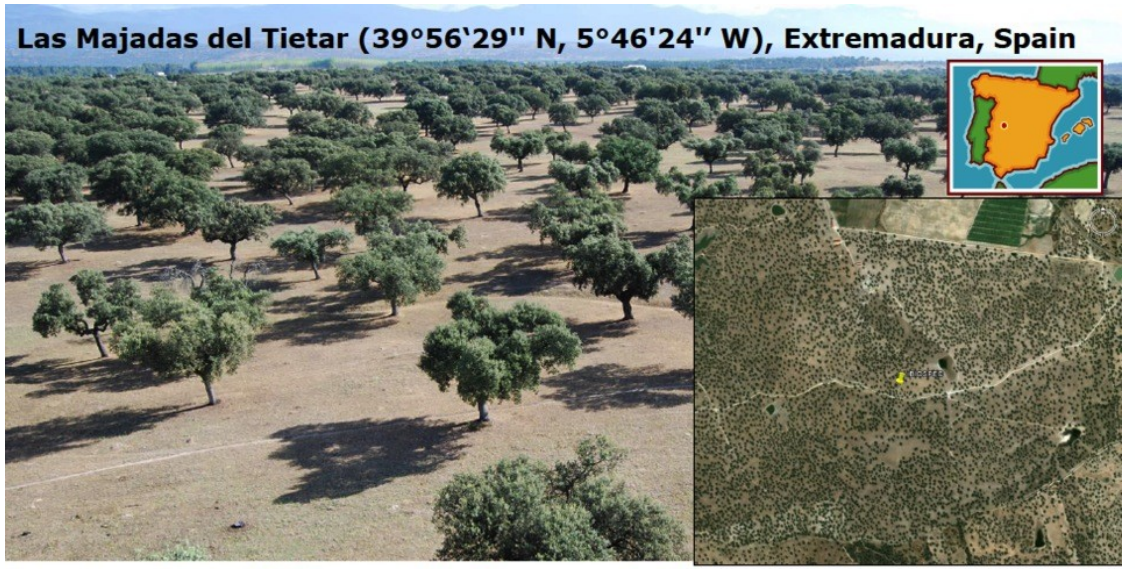
- Leaf level source:
  - Gu et al. (2019):
    Electron Transport
  - Van der Tol et al. (2014)
    Electron Transport, APAR
  - Li et al. (2019)
    Electron Transport, APAR, T_{leaf}
- RT: L2SM, Tristan Quaife (2025)
- Spectral conversion: Oak or Pine spectra observed by Magney and Frankenberg (2019)



Assimilation Example: Majadas de Tietar



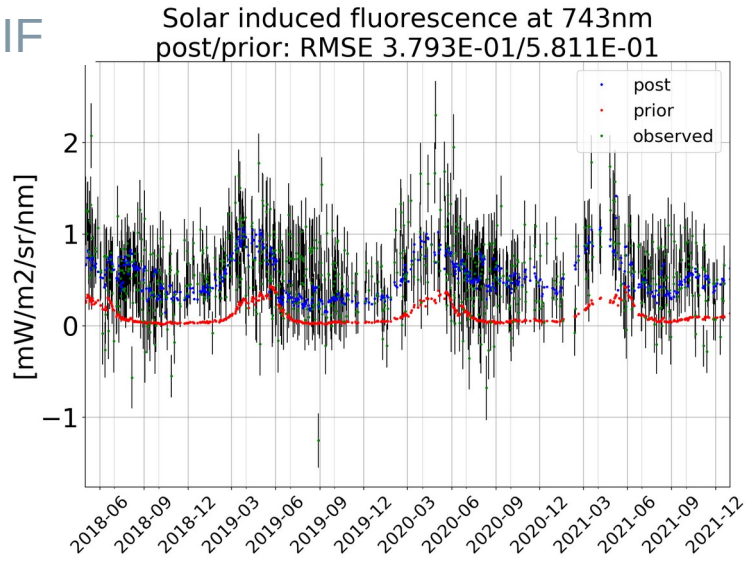
- Savannah site in Extremadura, Spain
- C3 grass and temperate evergreen trees
- Spin up 2015+2016
- Assimilation window 2017-2021
- Joint assimilation of:
  - FAPAR: JRC-TIP, twostream RT
  - SIF: TROPOSIF, Gu model
  - L-VOD: SMOS, empirical
  - surface layer soil moisture: SMOS



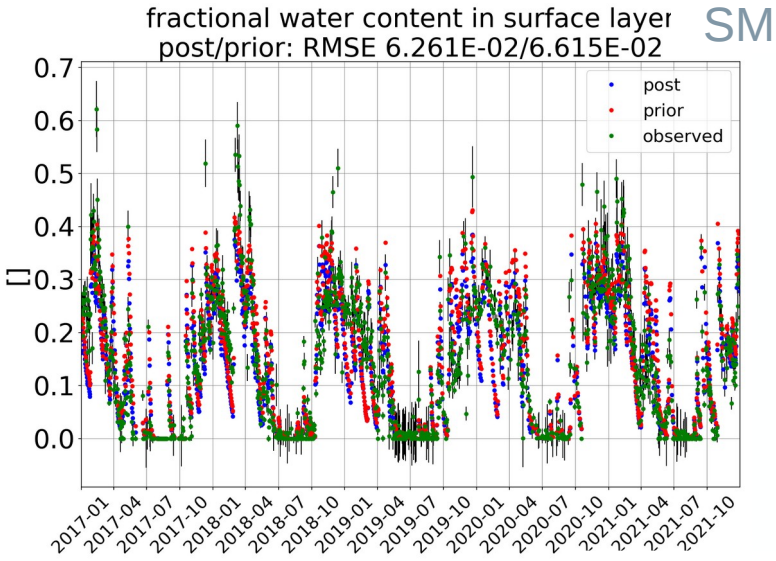
Ecosystem: ***dehesa*** Mediterranean Holm Oak open woodland (Savanna)

Example: Las Majadas de Tietar
Assimilation (left/middle) and validation (right) variables

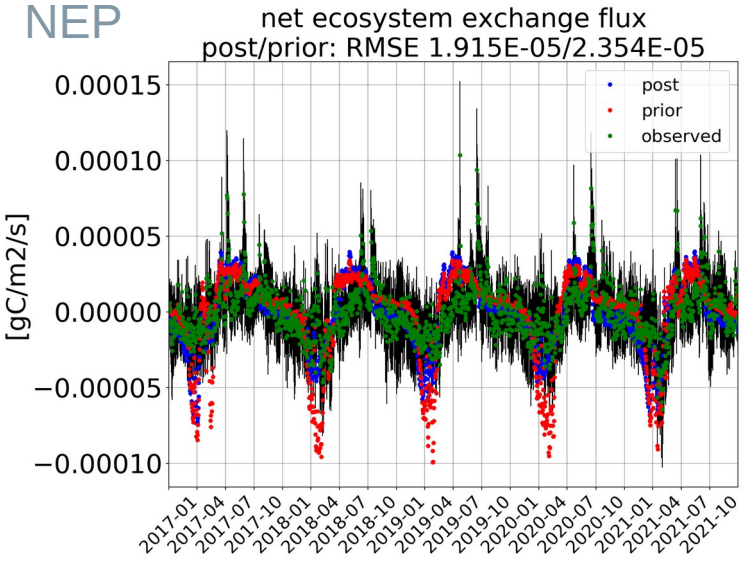
SIF



SM

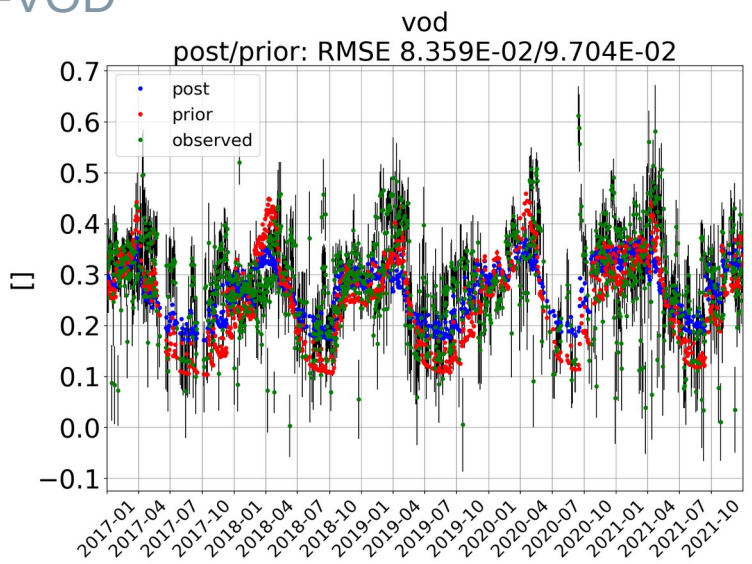


NEP

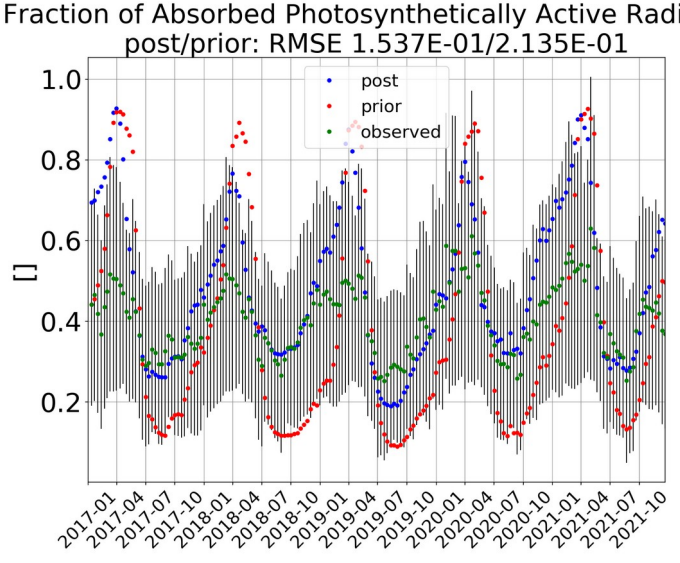


Obs (green), prior (red), posterior (blue)

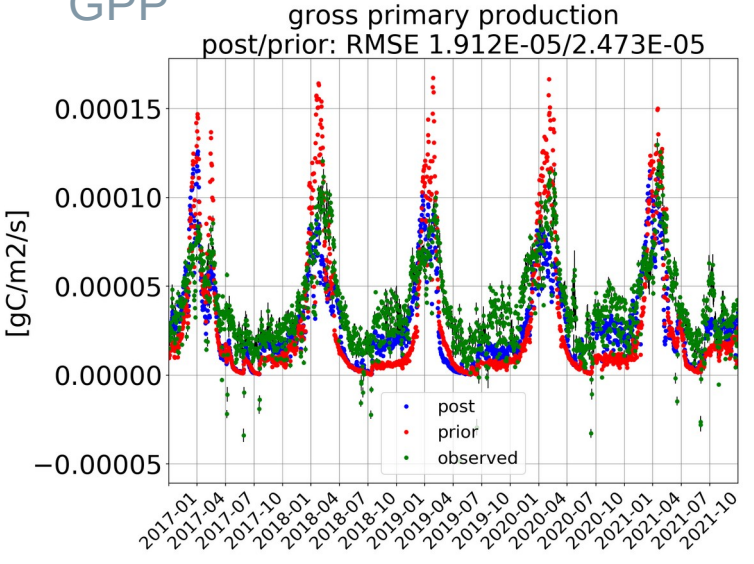
L-VOD



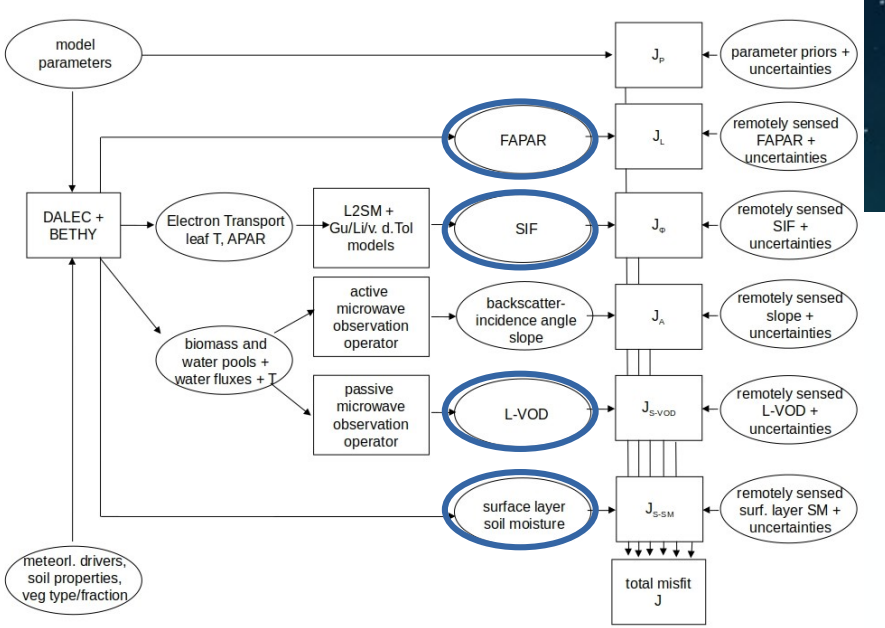
FAPAR



GPP

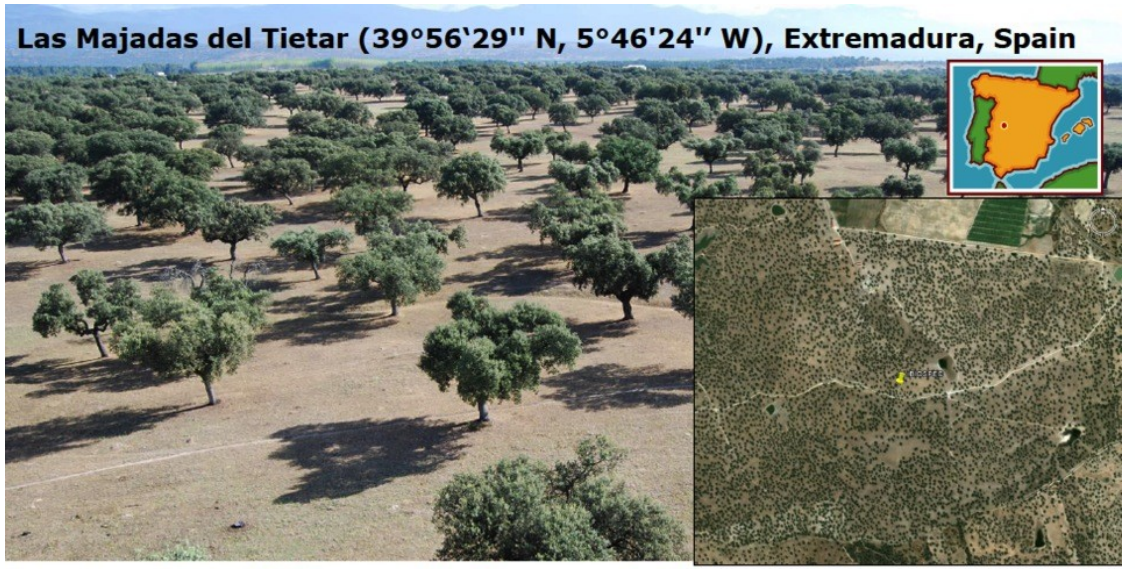


Example: Majadas de Tietar Hypothetical Intervention



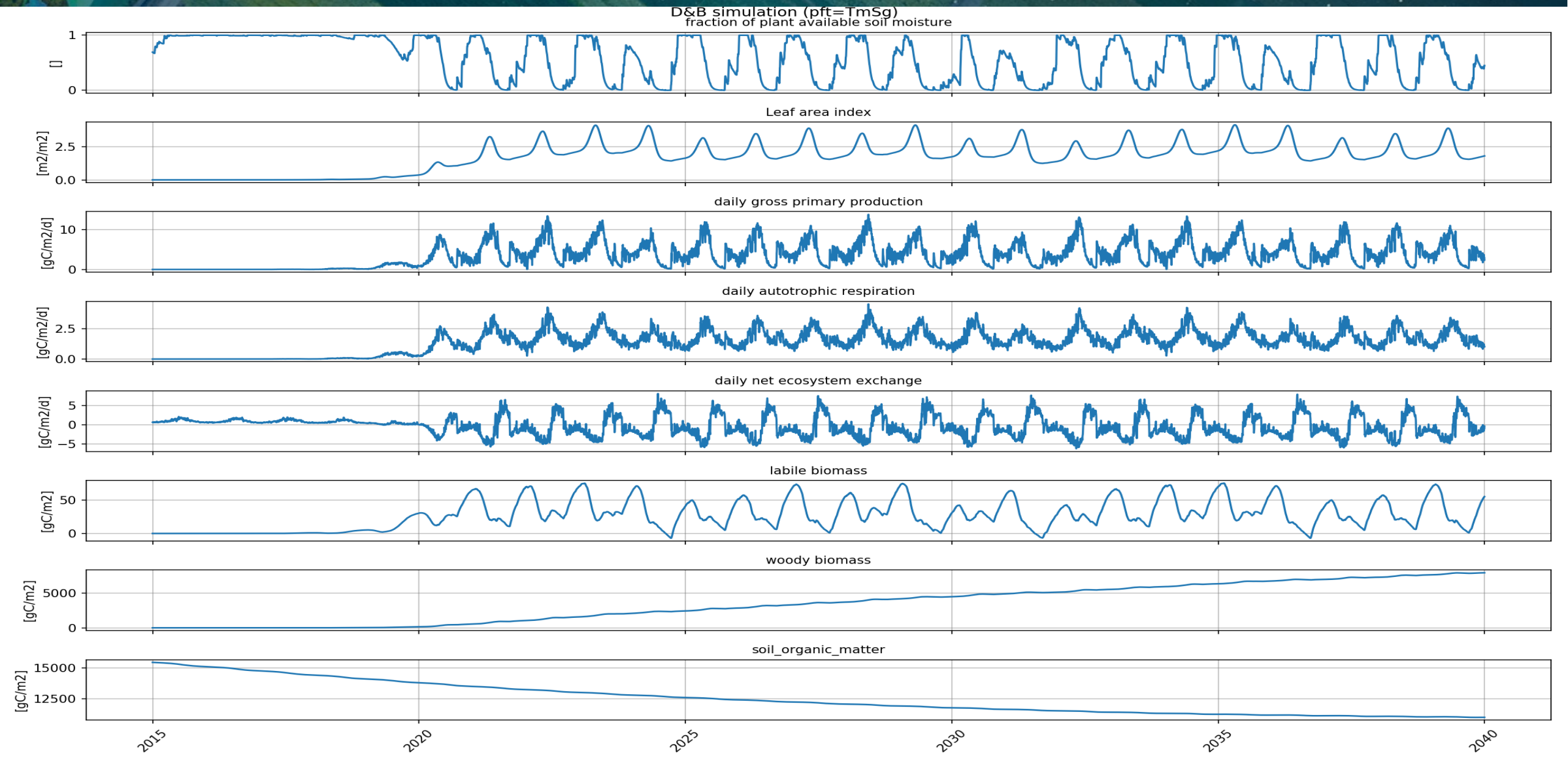
How much **extra carbon** can be **stored** through a (hypothetical) **intervention**?

- We **convert** a fraction of the area **from grass to trees** by replacing the grass with small trees.
- We perform simulations for the intervention case based on the **posterior parameter set and initial pools** sizes. For the converted fraction, the initial size of dead pools is taken from the grass and for the living pools have 1% of the sizes of the adult trees.
- We compute the **effect of intervention on carbon uptake** for **25 year time horizon** by subtracting the counterfactual case from the intervention case.

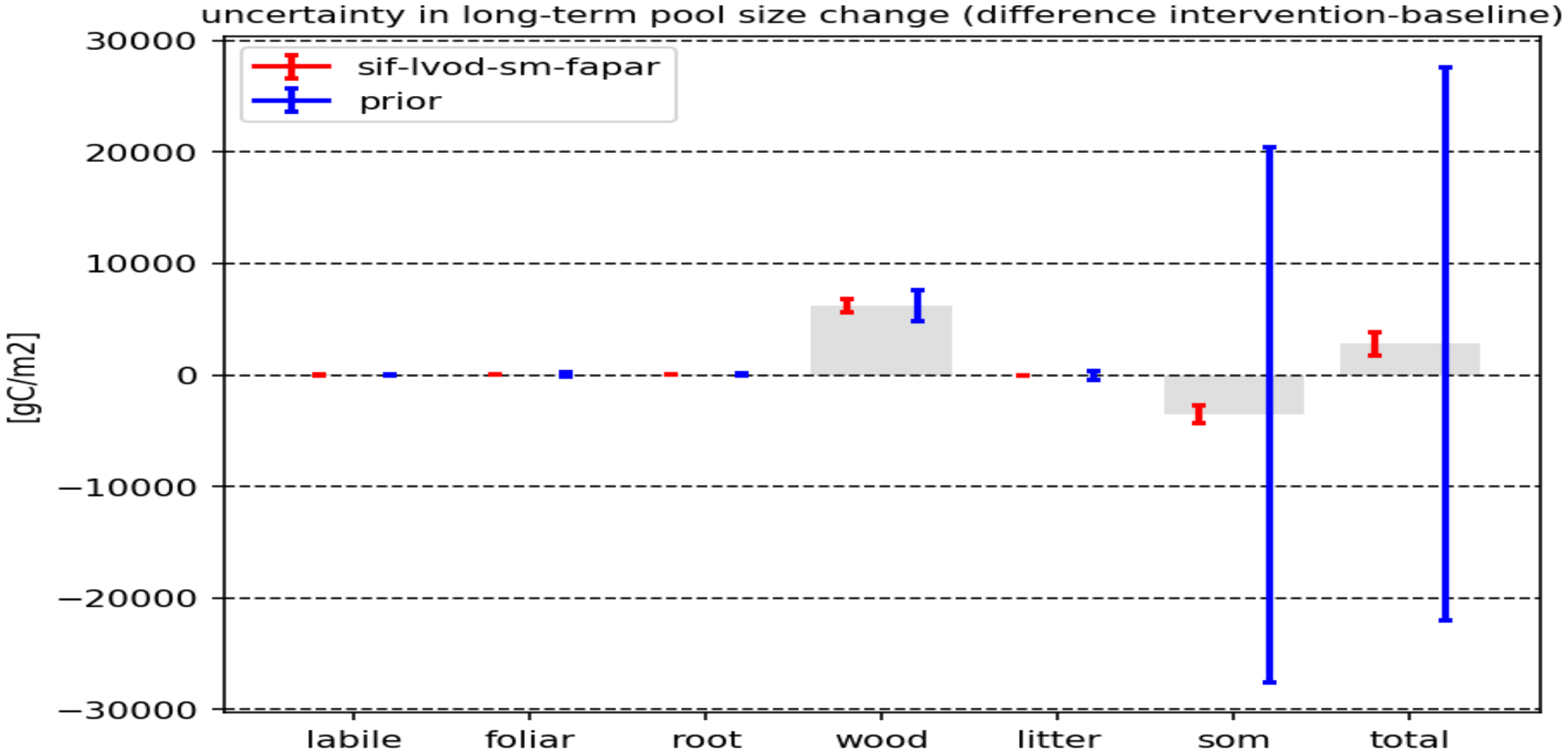


Ecosystem: ***dehesa*** Mediterranean Holm Oak open woodland (Savanna)

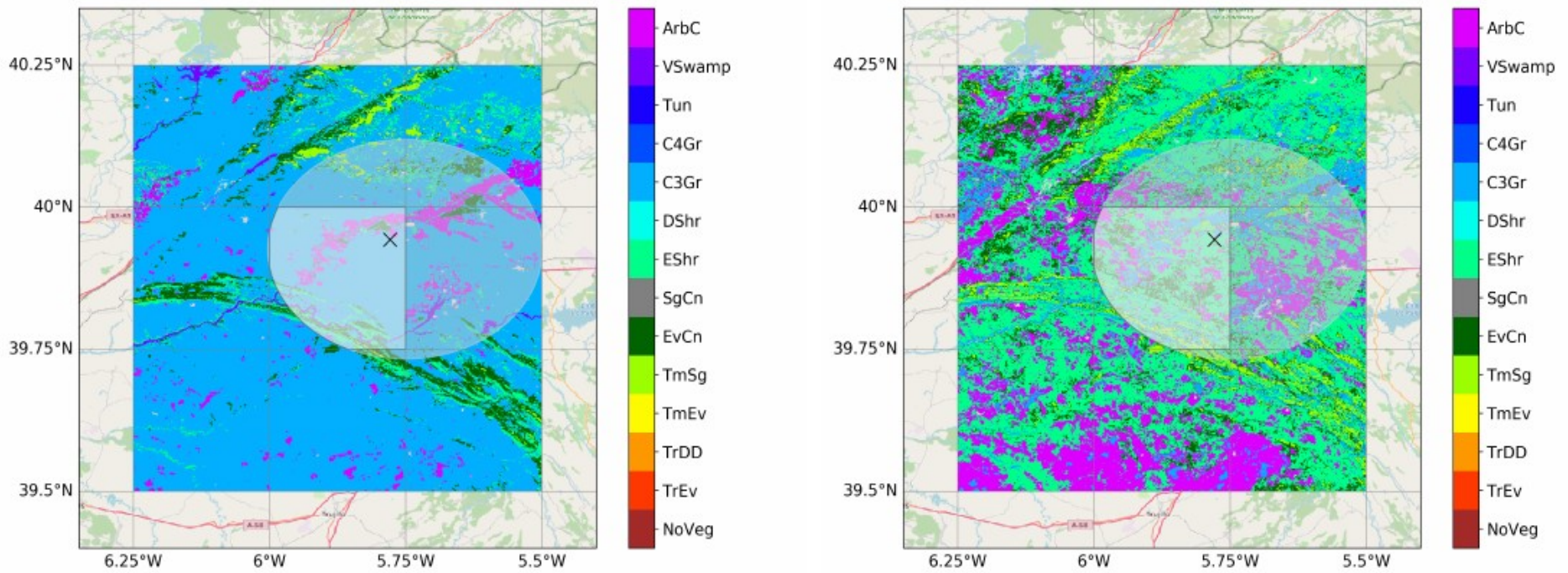
Baby trees


D&B simulation (pft=TmSg)
fraction of plant available soil moisture
[]
1
0
Leaf area index
[m2/m2]
2.5
0.0
daily gross primary production
[gC/m2/d]
10
0
daily autotrophic respiration
[gC/m2/d]
2.5
0.0
daily net ecosystem exchange
[gC/m2/d]
5
0
−5
labile biomass
[gC/m2]
50
0
woody biomass
[gC/m2]
5000
0
soil_organic_matter
[gC/m2]
15000
12500
2015
2020
2025
2030
2035
2040

Difference in pool size changes over 25 years (intervention-baseline)



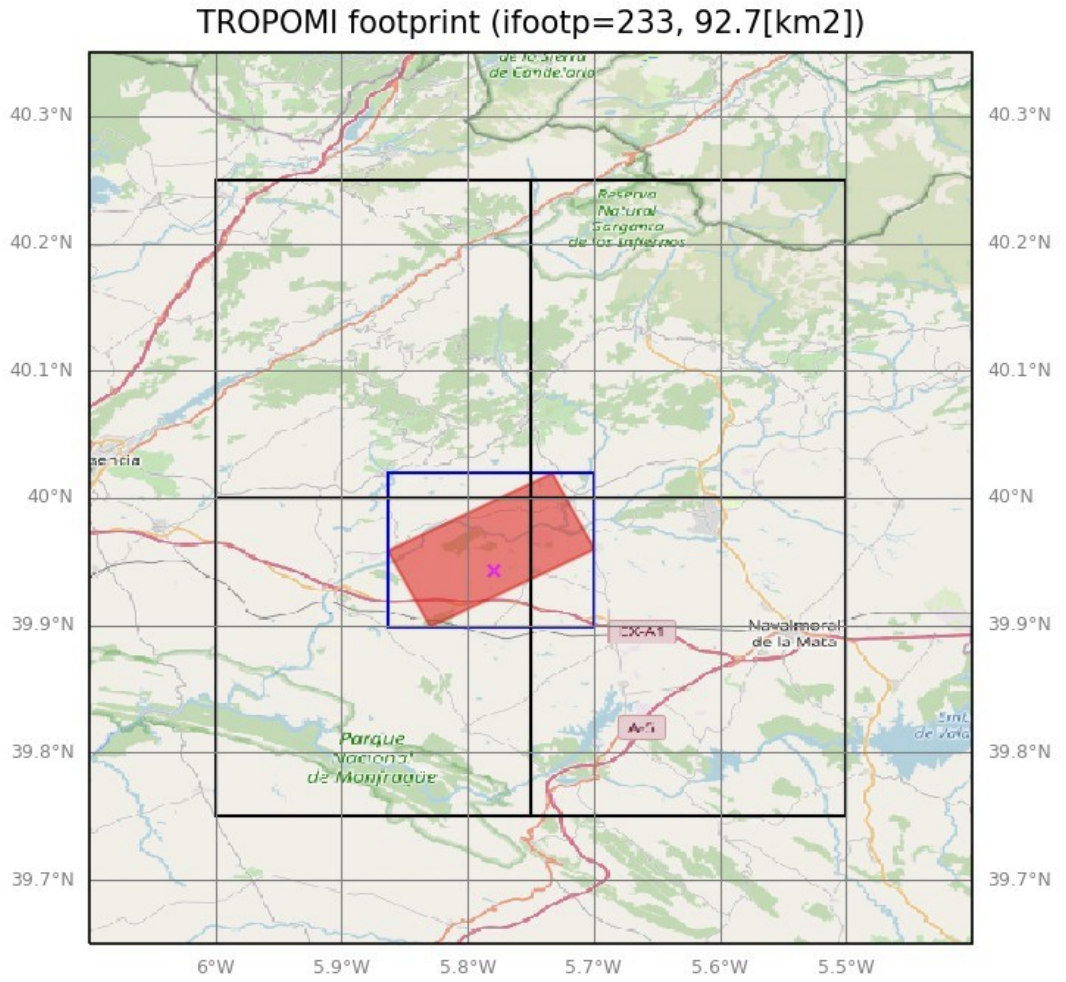
Simulation on the footprint/target area
Example: SMOS

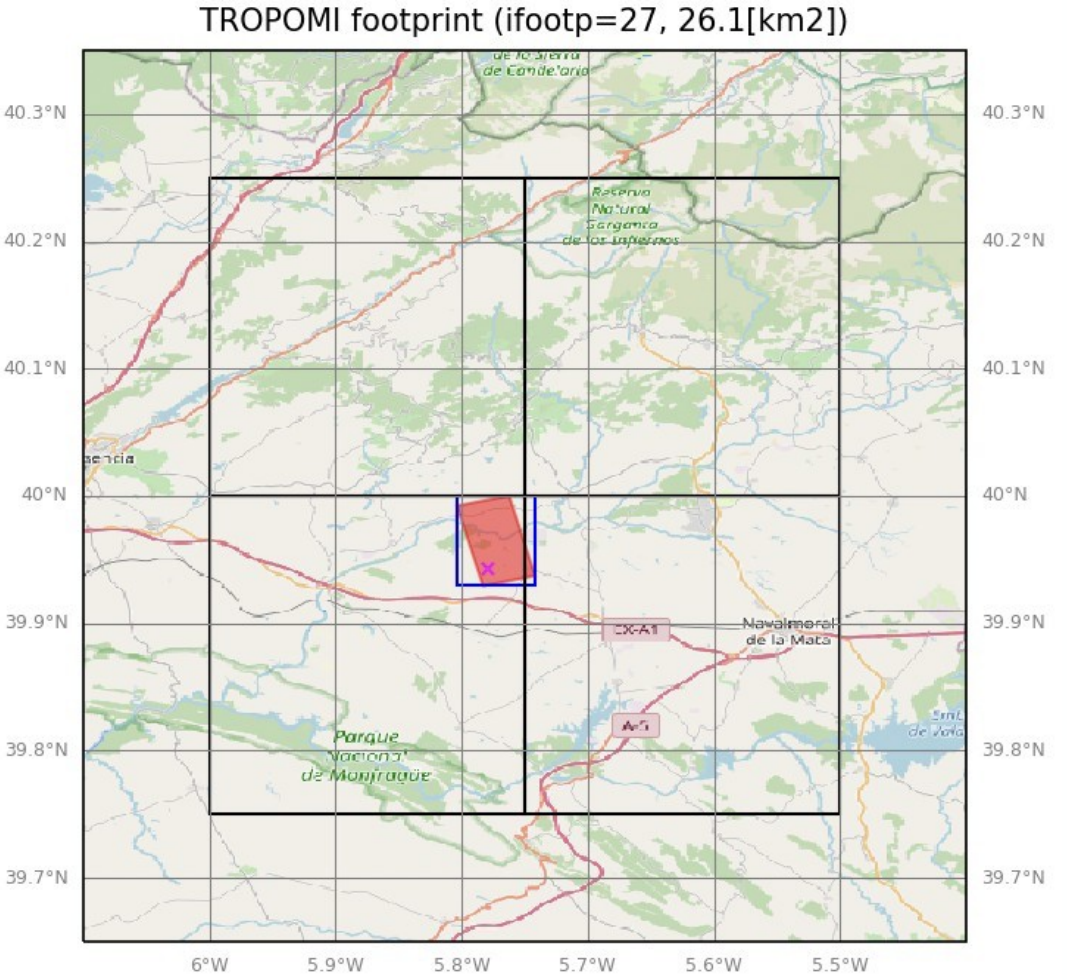


100m Landcover: Copernicus Land, Buchhorn et al. (2019)

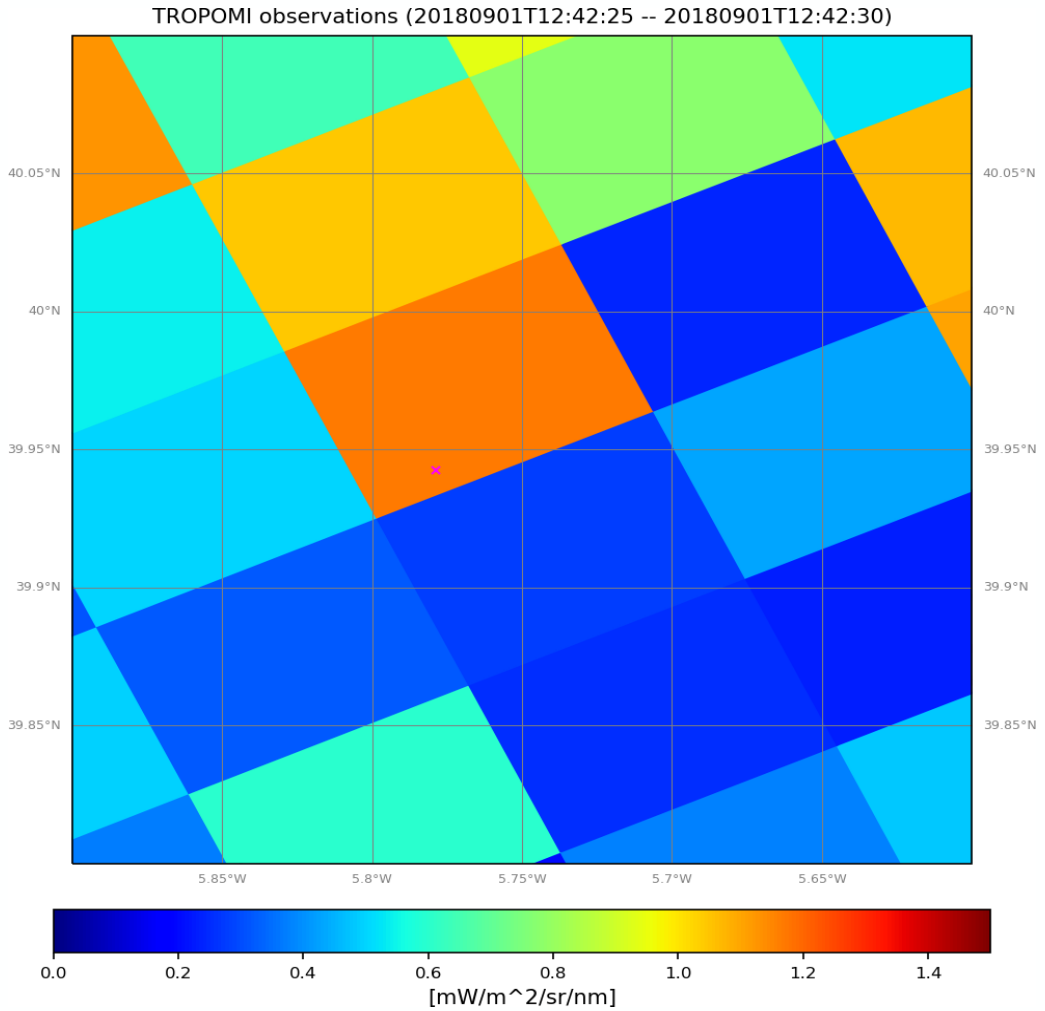
Figure 3: SMOS footprint (ellipse) along with the primary (left) and secondary (right) PFT over the grid defined by the meteorological driving data, with the location of the LM1 site indicated by a cross.

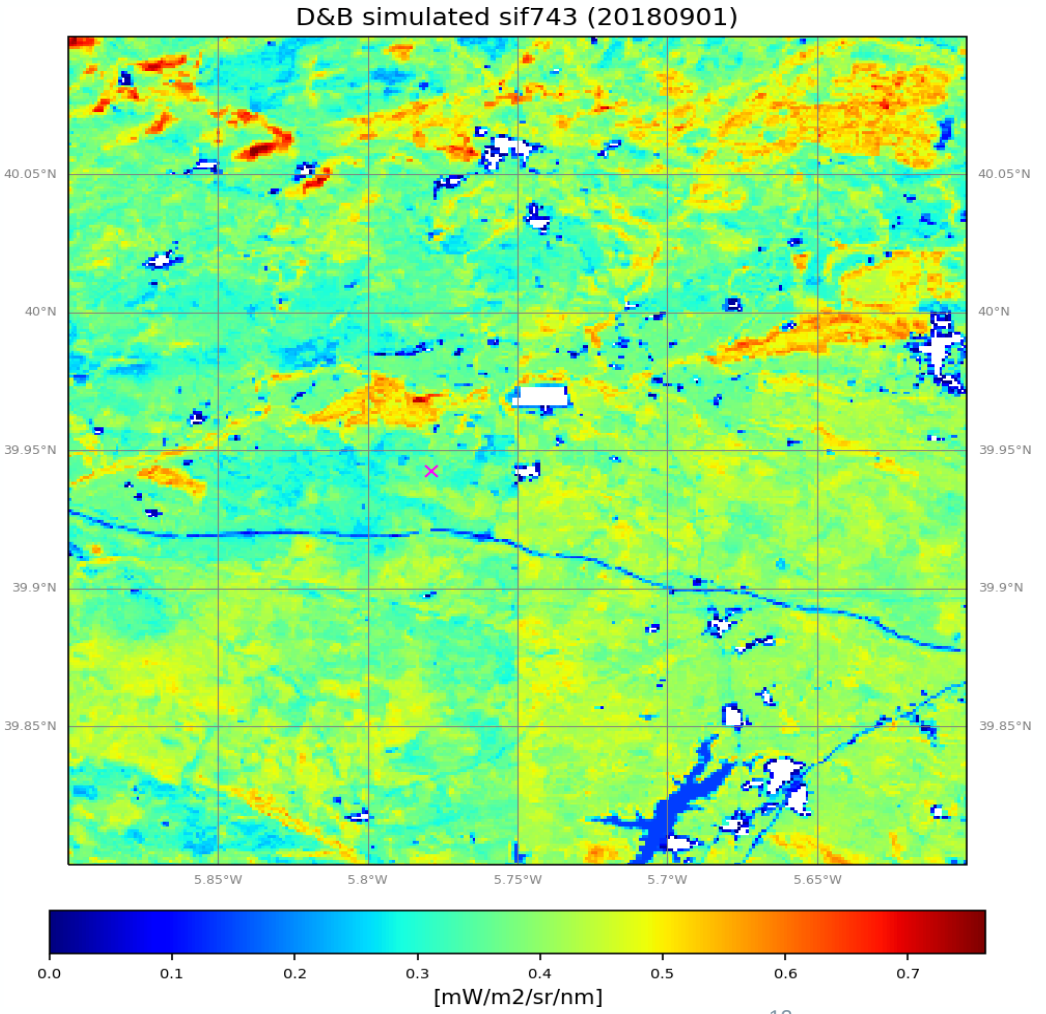
Simulation on the footprint/target area
Example: TROPOMI



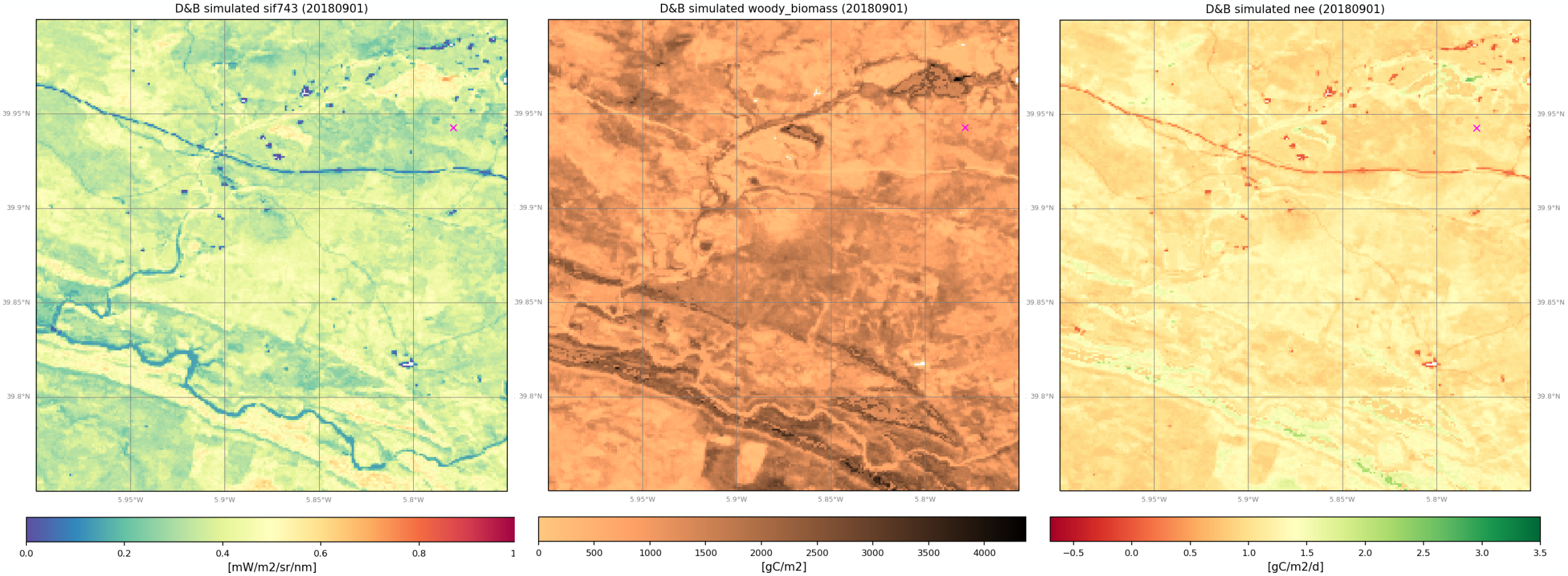


Spatial Detail
Examples: TROPOMI (left) and simulated (right) SIF





Posterior simulation over a region in Spain at 100 m resolution
SIF (left), Woody biomass (middle), NEE (right)



Documentation

esa

tccas.inversion-lab.com/documentation.html

New Chrome available

Terrestrial Carbon Community Assimilation System

Documentation and Training

Documentation of D&B and TCCAS is provided in the following forms:

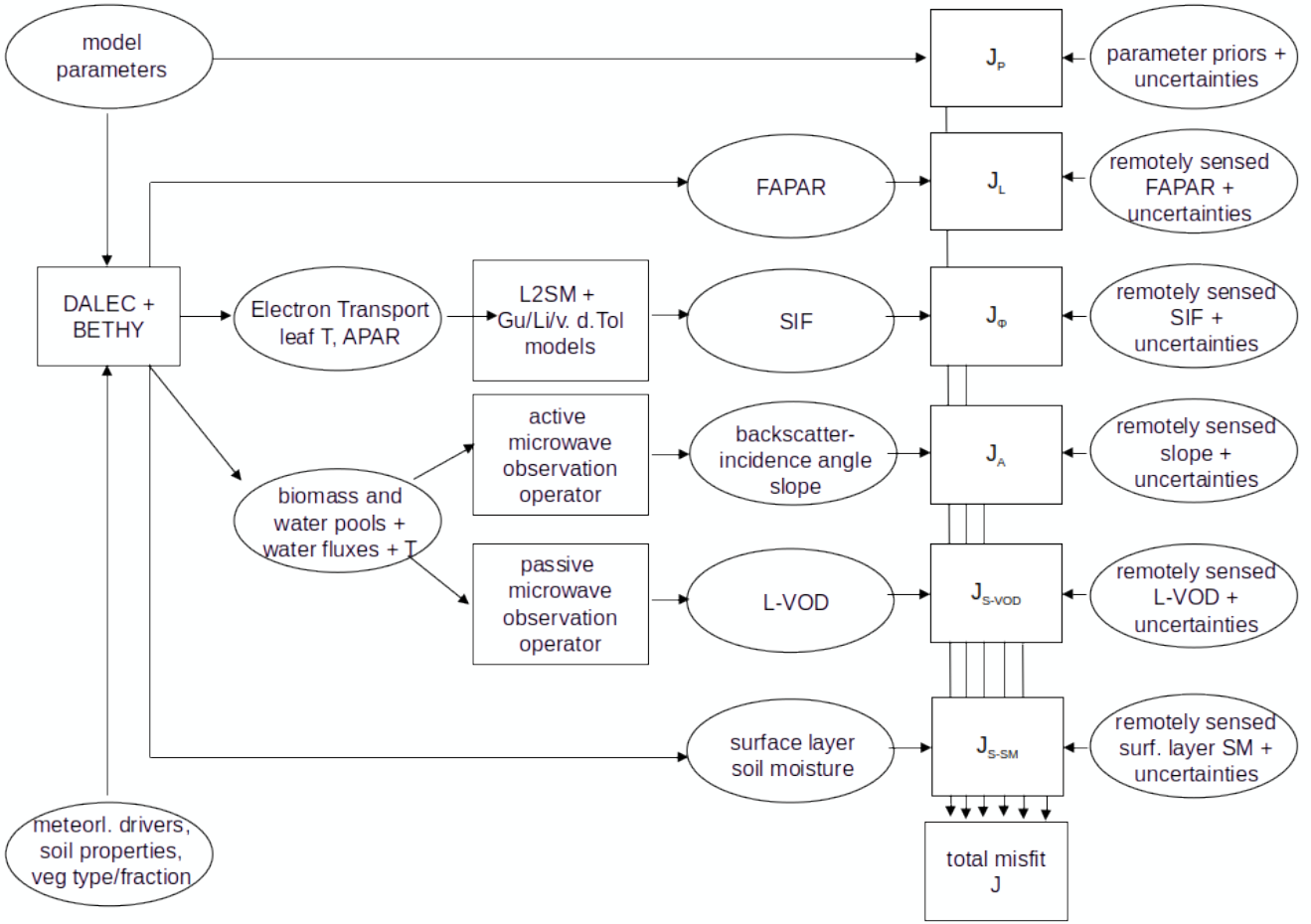
- User Manual with Examples
- FAQs
- Licence
- Publications

Upcoming TCCAS training events:

User Training

Training/Teaching events:

- Edinburgh, May 2024
- On line, June 2024
- ESRIN, October 2024
- Bonn: Seminar, Winter 2024/2025
- Living Planet Symposion, June 2025
- Nanjing, August 2025
- Hamburg, September 2025



Summary and further information

Summary

- TCCAS provides an integrated perspective on carbon, water and energy cycles
- Combines information from multiple missions (synergy) with D&B process understanding
- Can monitor relevant variables – including gross and net carbon fluxes - in space and time
- Tested with TROPOMI in preparation for FLEX
- Documented and Open Source

Further information

- https://tccas.inversion-lab.com
- TCCAS@Inversion-Lab.com
- Thomas.Kaminski@Inversion-Lab.com