Terrestrial Carbon Community Assimilation System

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Motivation

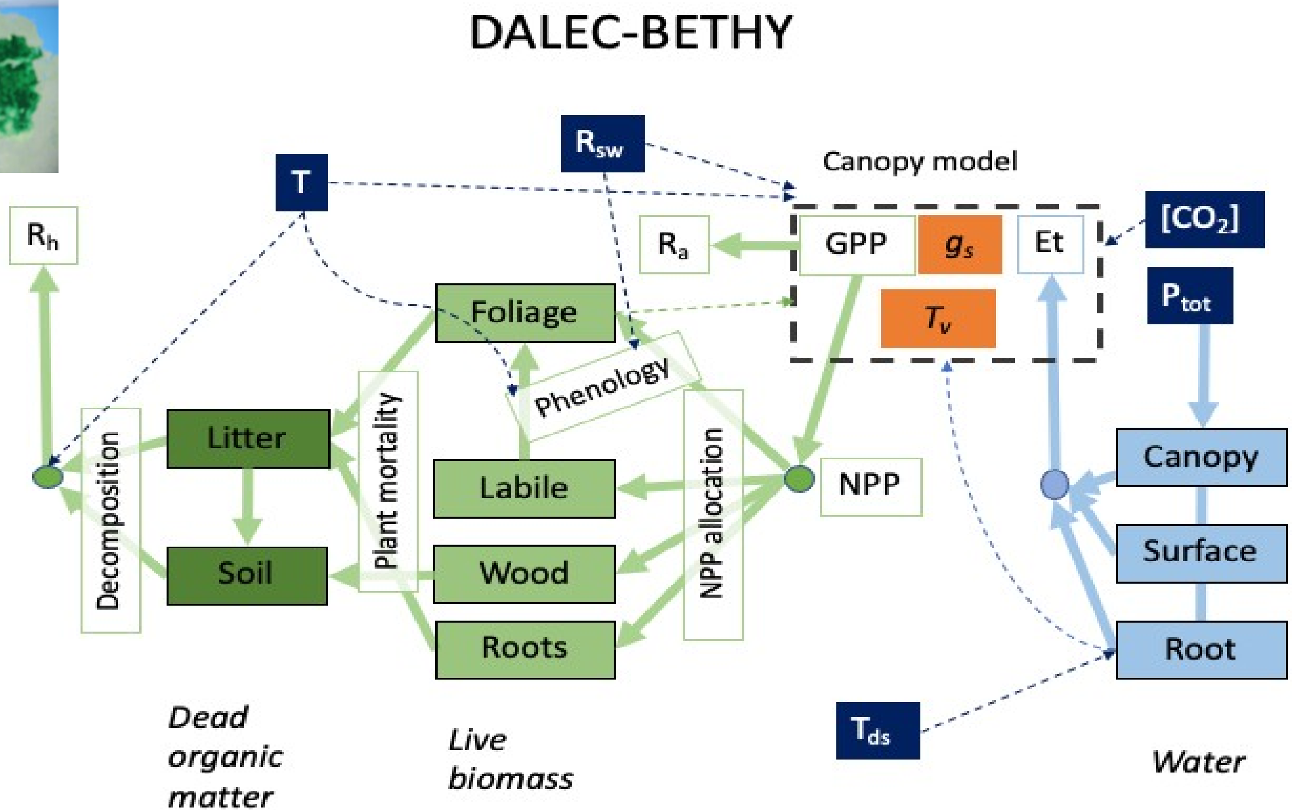
ESA Invitation to tender dated 18/02/2020:

"*At the same time, a number of* ***satellite missions from ESA and other Space Agencies are being developed***, ***each of them addressing one or more geophysical parameters related to the carbon and water cycles****. In a few years from now, the* ***FLEX and BIOMASS missions*** *will provide new data related to photosynthetic efficiency and gross primary productivity and above ground biomass, respectively. These measurements will* ***complement information*** *that is already available* ***from low frequency passive microwave measurements*** *(soil moisture, vegetation optical depth) (e.g. Mecklenburg et al. 2012, Rodriguez-Fernandesz et al. 2018), active microwave measurements (vegetation water content and roughness), and* ***optical measurements*** *yielding information on vegetation greenness and structure, e.g. phenology, chlorophyll content, and leaf area index (e.g. Maisongrande, Duchemin and Dedieu 2004). While there is an* ***obvious complementarity*** *in the different data provided by each one of such missions, so far there are no specific plans to combine the data together. This is primarily because these measurements a) exhibit different sensitivities to the various geophysical parameters, b) address geophysical parameters characterised by different spatial and temporal variabilities, and c) sample a range of spatial and temporal scales.*"

Motivation

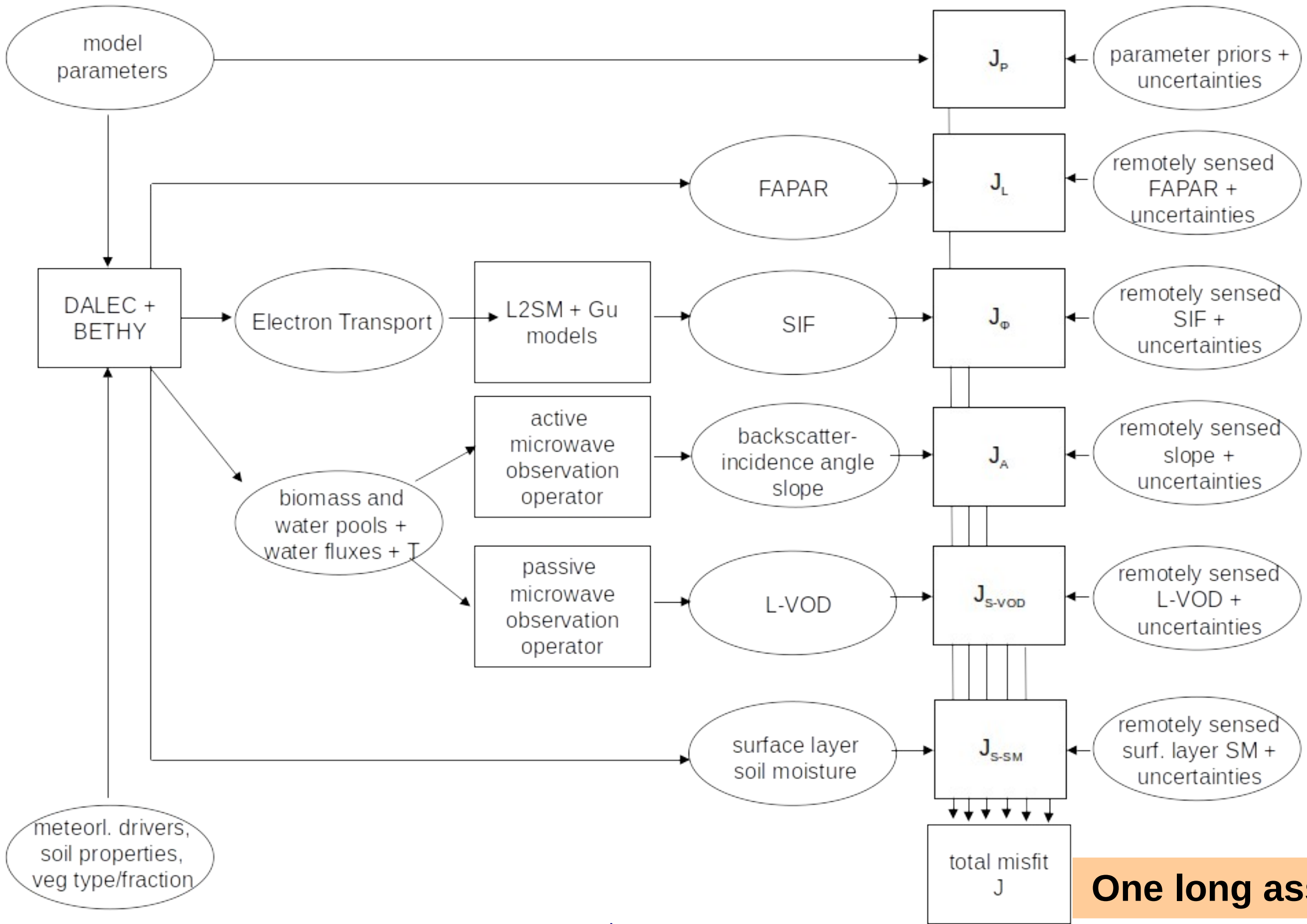
- Combined team of experts in Modelling, DA, field observations, satellite observations
- Work on regional and site scales
- Collect data base
- Select/Develop suitable model + observation operators and assimilation system
- Assimilation of optical, passive and active microwave observations on the swath
- Landsurface Carbon Constellation (LCC) Project started in October 2020
- https://lcc.inversion-lab.com/

Community land surface model: D&B model



New implementation

Observation operators and data assimilation (on the swath)



One long assimilation window

Simulation on the footprint
PFT map provides spatial detail

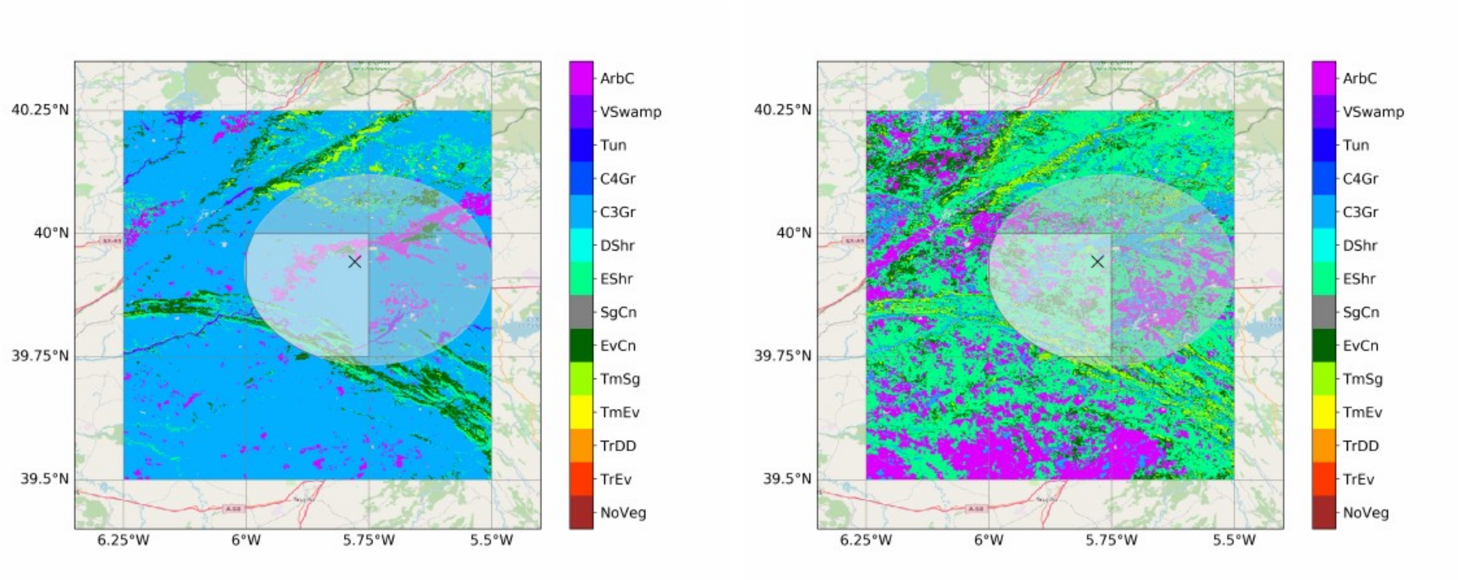
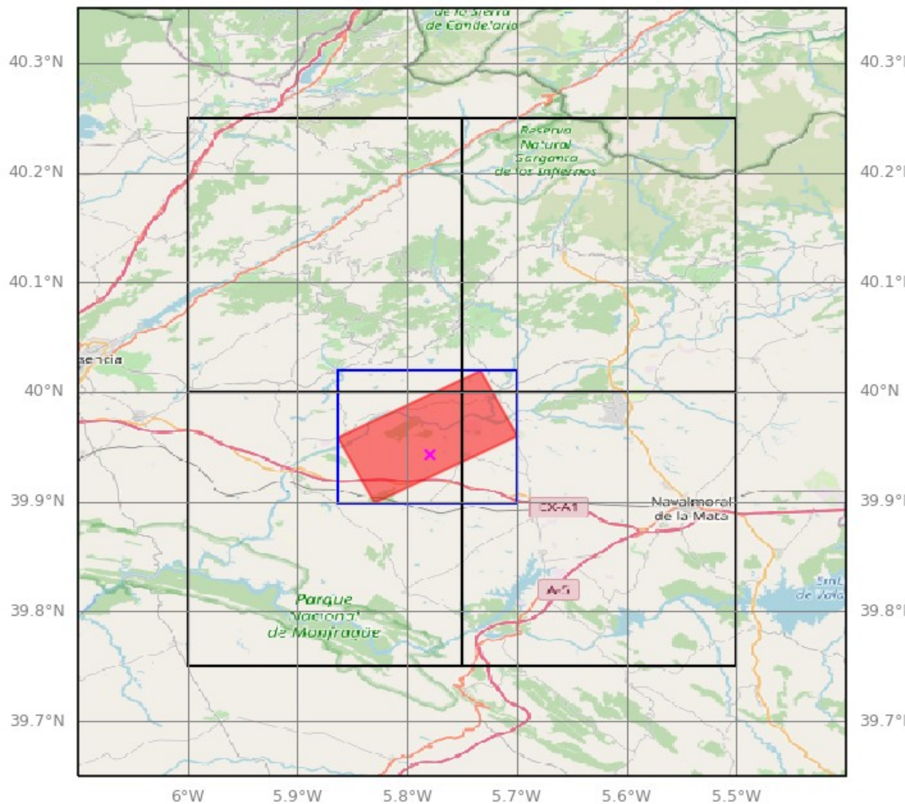


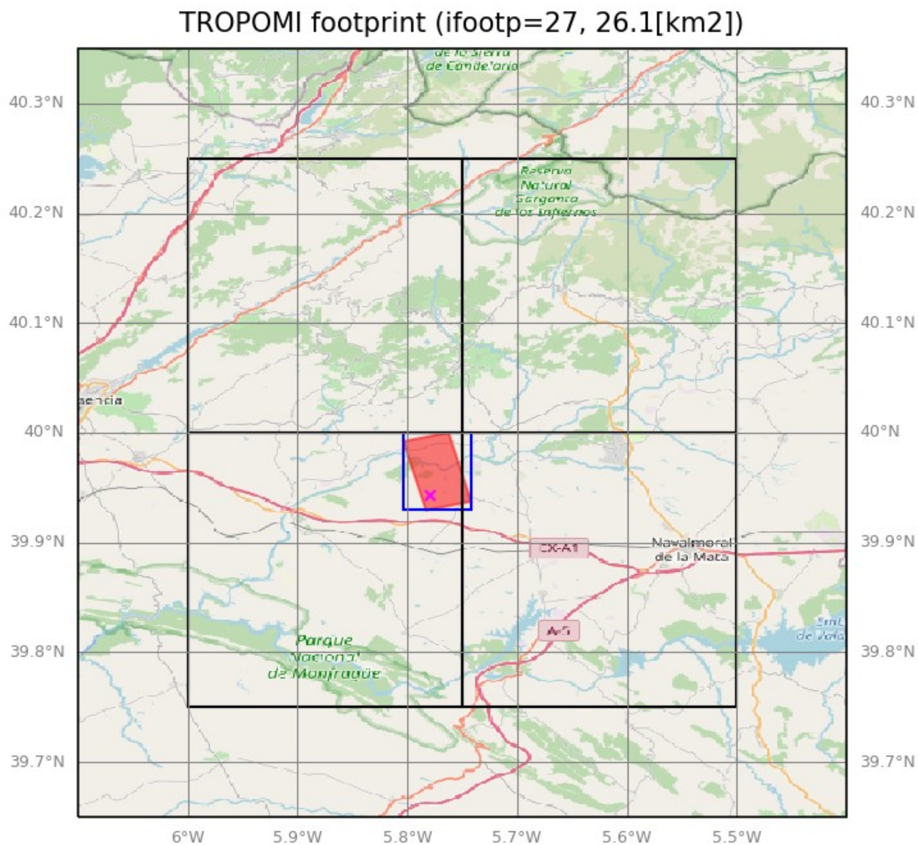
Figure 3: SMOS footprint (ellipse) along with the primary (left) and secondary (right) PFT over the grid defined by the meteorological driving data, with the location of the LM1 site indicated by a cross.

Simulation on the footprint
PFT map provides spatial detail

TROPOMI footprint (ifootp=233, 92.7[km2])



Simulation on the footprint
PFT map provides spatial detail



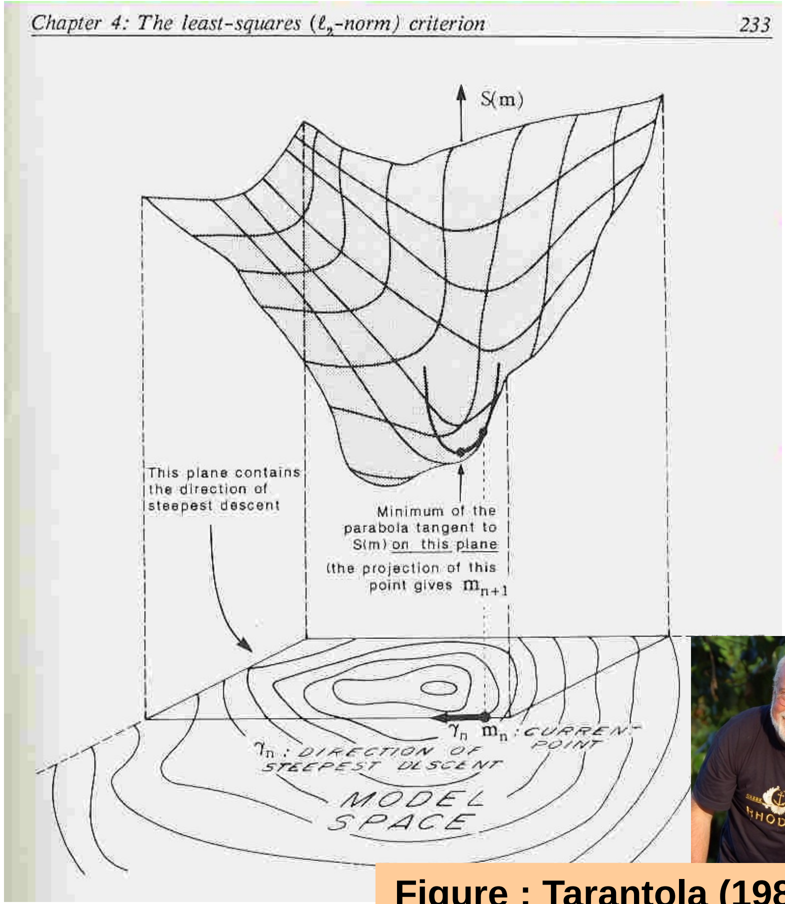
Control Space (Unknowns): Parameters + Initial Conditions

#	varname	PFT	active	prior	sigma	min	max	nbound	process	description (don't use commas!)
1	vmax	3	1	0.000041	0.0000082	0.00001	0.00008	2	photosynthesis	maximum carboxylation rate at ref. Temperature [mol(CO2) / m^2 s]
2	vmax	9	1	0.000042	0.0000084	0.00001	0.00008	2	photosynthesis	maximum carboxylation rate at ref. Temperature [mol(CO2) / m^2 s]
3	root_depth_scale	-1	1	1.	0.2	0.	5.	1	soilwater	"root_depth_scale"
4	soil_theta_scale	-1	1	1.	0.2	0.	5.	1	soilwater	"soil_theta_scale"
5	DALEC P1	3	1	0.0003038811	0.00006077622	0.00001	0.01	2	cbalance+pheno	fractional turnover rate of litter to soil organic matter at 0oC
6	DALEC P2	3	1	0.4016085	0.0803217	0.2	0.8	2	cbalance+pheno	fraction of gross primary productivity allocated to autotrophic respiration
7	DALEC P3	3	1	0.04980515	0.00996103	0.01	0.5	2	cbalance+pheno	fraction of gpp-ra allocated to leaves
8	DALEC P4	3	1	0.3553572	0.07107144	0.1	0.8	2	cbalance+pheno	fraction of gpp-ra-alloc_fol-alloc_lab allocated to fine roots
9	DALEC P5	3	1	1.104317	0.2208634	1.001	8	2	cbalance+pheno	maximum leaf lifespan
10	DALEC P6	3	1	0.00006646695	0.00001329339	0.000009	0.001	2	cbalance+pheno	fractional daily turnover of the wood pool
11	DALEC P7	3	1	0.005876034	0.0011752068	0.001368925	0.02	2	cbalance+pheno	fractional daily turnover of the fine root pool
12	DALEC P8	3	1	0.006875432	0.0013750864	0.0001141	0.02	2	cbalance+pheno	fractional daily turnover of the litter pool to heterotrophic respiration
13	DALEC P9	3	1	0.00002478762	0.000004957524	1.37E-06	9.13E-05	2	cbalance+pheno	fractional daily turnover of the soil organic matter pool to heterotrophic respiration
14	DALEC P10	3	1	0.05102073	0.010204146	0.019	0.08	2	cbalance+pheno	coefficient for exponential temperature sensitivity for litter decomposition and litter and som turnover to heterotrophic respiration
15	DALEC P11	3	1	22.29913	4.459826	1.64	42	2	cbalance+pheno	Canopy photosynthetic efficiency parameter
16	DALEC P12	3	1	74.3057	14.86114	10	350	2	cbalance+pheno	Day of year for maximum labile turnover to foliage (i.e. bud burst)
17	DALEC P13	3	1	0.2200071	0.04400142	0.01	0.5	2	cbalance+pheno	fraction of gpp-ra-alloc_fol allocated to labile pool (which supports seasonal leaf growth)
18	DALEC P14	3	1	74.18161	14.836322	10	100	2	cbalance+pheno	Number of days over which labile turnover to leaves occurs
19	DALEC P15	3	1	157.3799	31.47598	10	350	2	cbalance+pheno	Day of year for maximum leaf turnover to litter (i.e. leaf senesence)
20	DALEC P16	3	1	54.62658	10.925316	20	150	2	cbalance+pheno	Number of days over which leaf turnover to litter occurs
21	DALEC P17	3	1	67.66937	13.533874	20	180	2	cbalance+pheno	Leaf carbon per unit leaf area
22	DALEC P1	9	1	0.002584829	0.0005169658	0.00001	0.01	2	cbalance+pheno	fractional turnover rate of litter to soil organic matter at 0oC
23	DALEC P2	9	1	0.5392843	0.10785686	0.2	0.8	2	cbalance+pheno	fraction of gross primary productivity allocated to autotrophic respiration
43	DALEC IC P22	3	1	12.89959	2.579918	1	2000	2	cbalance+pheno	Initial size of the litter pool (NOTE: this is for foliage and fine root only)
44	DALEC IC P23	3	1	11818.84	2363.768	200	250000	2	cbalance+pheno	Initial size of the soil organic matter pool (NOTE: this is the soil plus wood litter)
45	DALEC IC P18	9	1	60.98822	12.197644	1	2000	2	cbalance+pheno	Initial size of the labile pool
46	DALEC IC P19	9	1	24.8358	4.96716	1	2000	2	cbalance+pheno	Initial size of the foliage pool
47	DALEC IC P20	9	1	10.63674	2.127348	1	2000	2	cbalance+pheno	Initial size of the fine root pool
48	DALEC IC P21	9	1	89.56923	17.913846	1	30000	2	cbalance+pheno	Initial size of the wood pool
49	DALEC IC P22	9	1	16.35128	3.270256	1	2000	2	cbalance+pheno	Initial size of the litter pool (NOTE: this is for foliage and fine root only)
50	DALEC IC P23	9	1	15469.69	3093.938	200	250000	2	cbalance+pheno	Initial size of the soil organic matter pool (NOTE: this is the soil plus wood litter)

Example for site in Spain

Variational data assimilation

- Uses gradient of cost function in iterative seach of the control space
- Gradient information efficiently provided by so-called adjoint code of J(x)



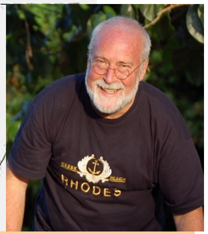
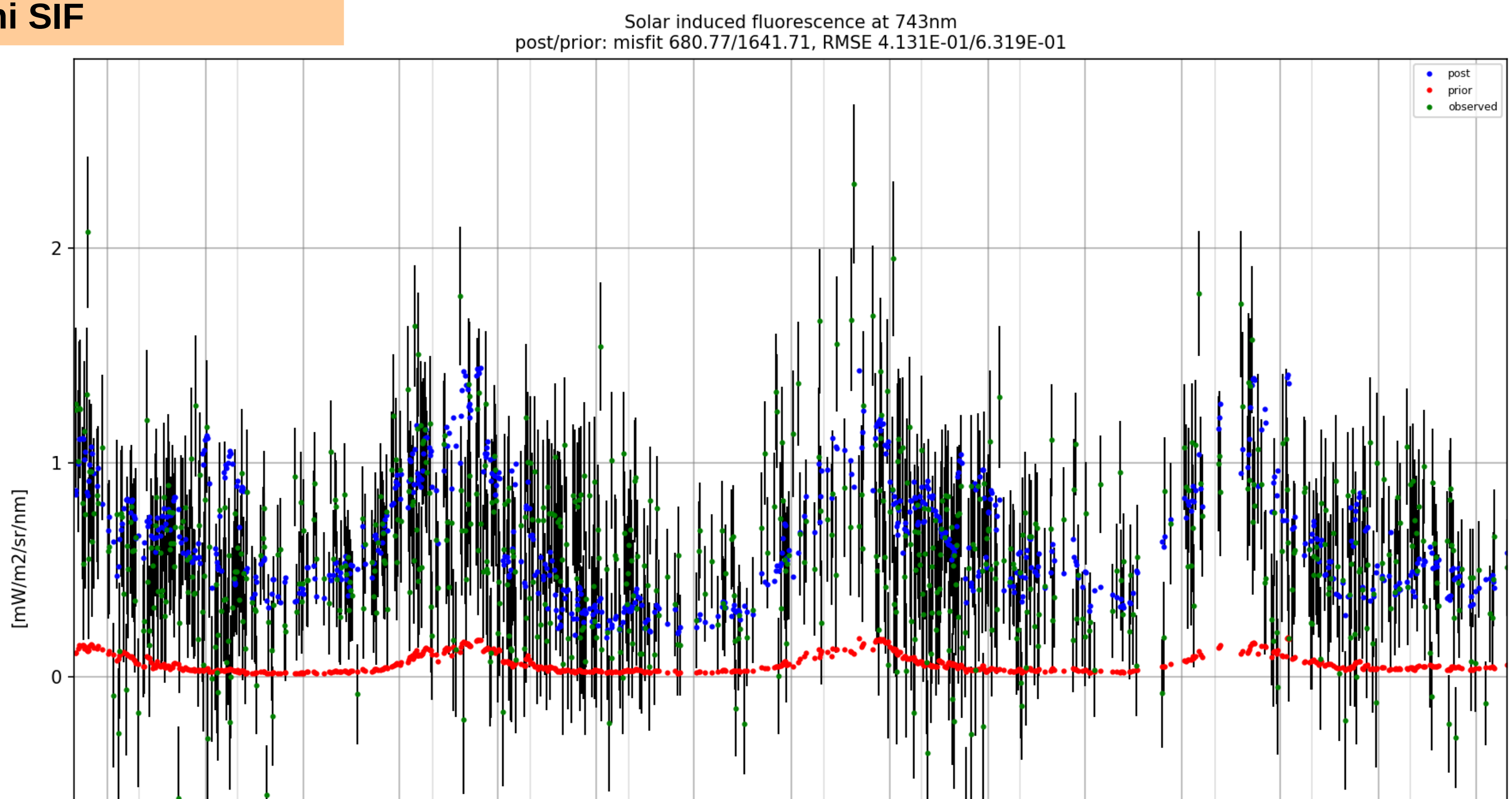
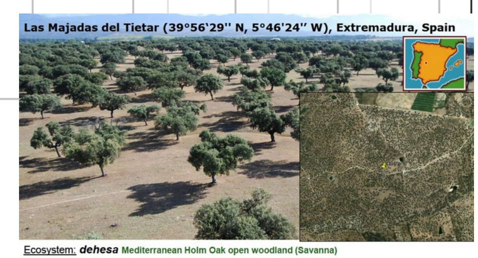


Figure : Tarantola (1987)

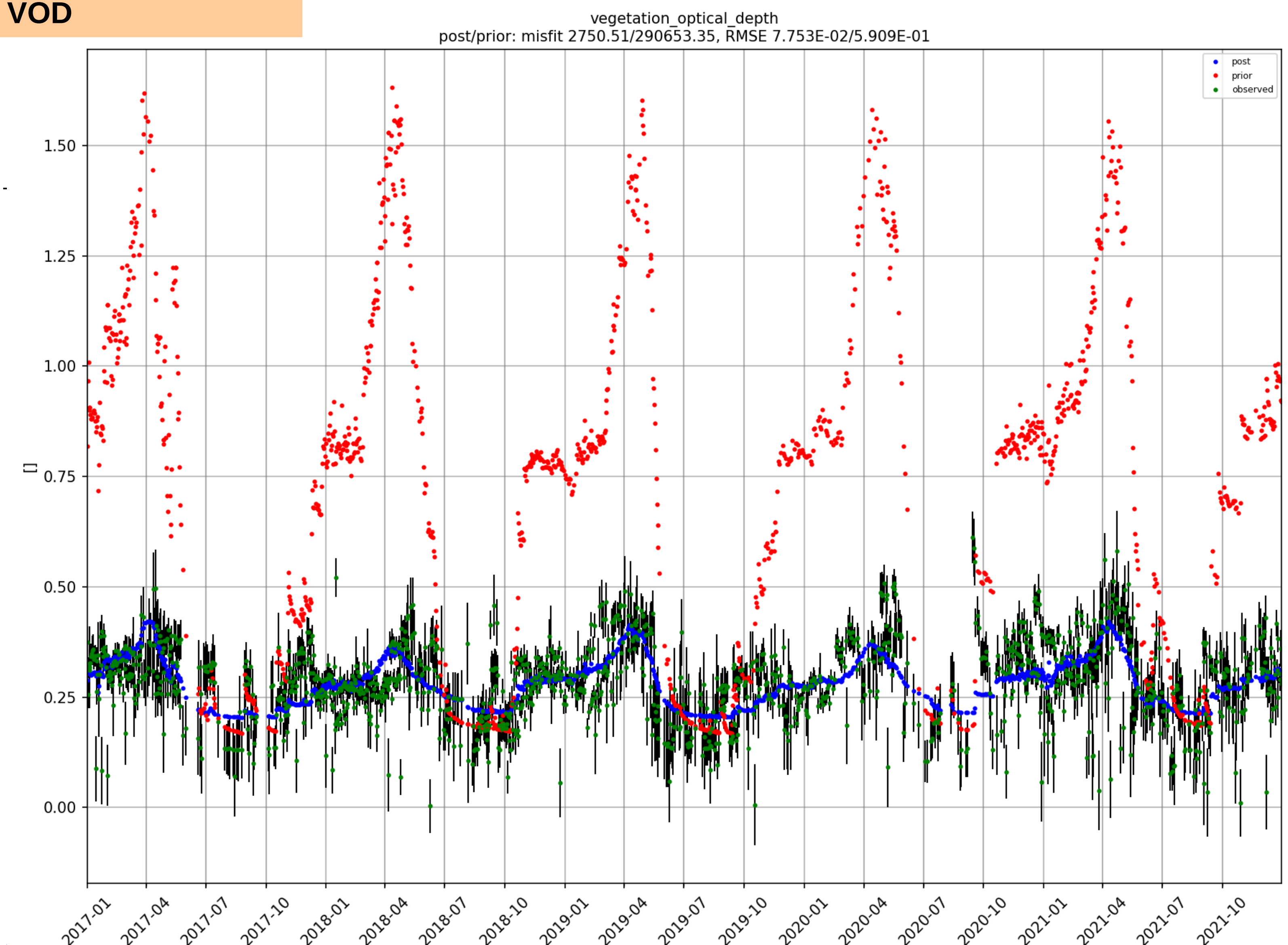
Tropomi SIF





Site-scale assimilation at Majadas de Tietar, Extremadura, Spain :
Simulation : 2015 - 2021
Assimilation window : 2017-2021
Data Streams : SIF, LVOD, surface layer SM

SMOS VOD



vegetation_optical_depth
post/prior: misfit 2750.51/290653.35, RMSE 7.753E-02/5.909E-01
post
prior
observed
[]
1.50
1.25
1.00
0.75
0.50
0.25
0.00
2017-01
2017-04
2017-07
2017-10
2018-01
2018-04
2018-07
2018-10
2019-01
2019-04
2019-07
2019-10
2020-01
2020-04
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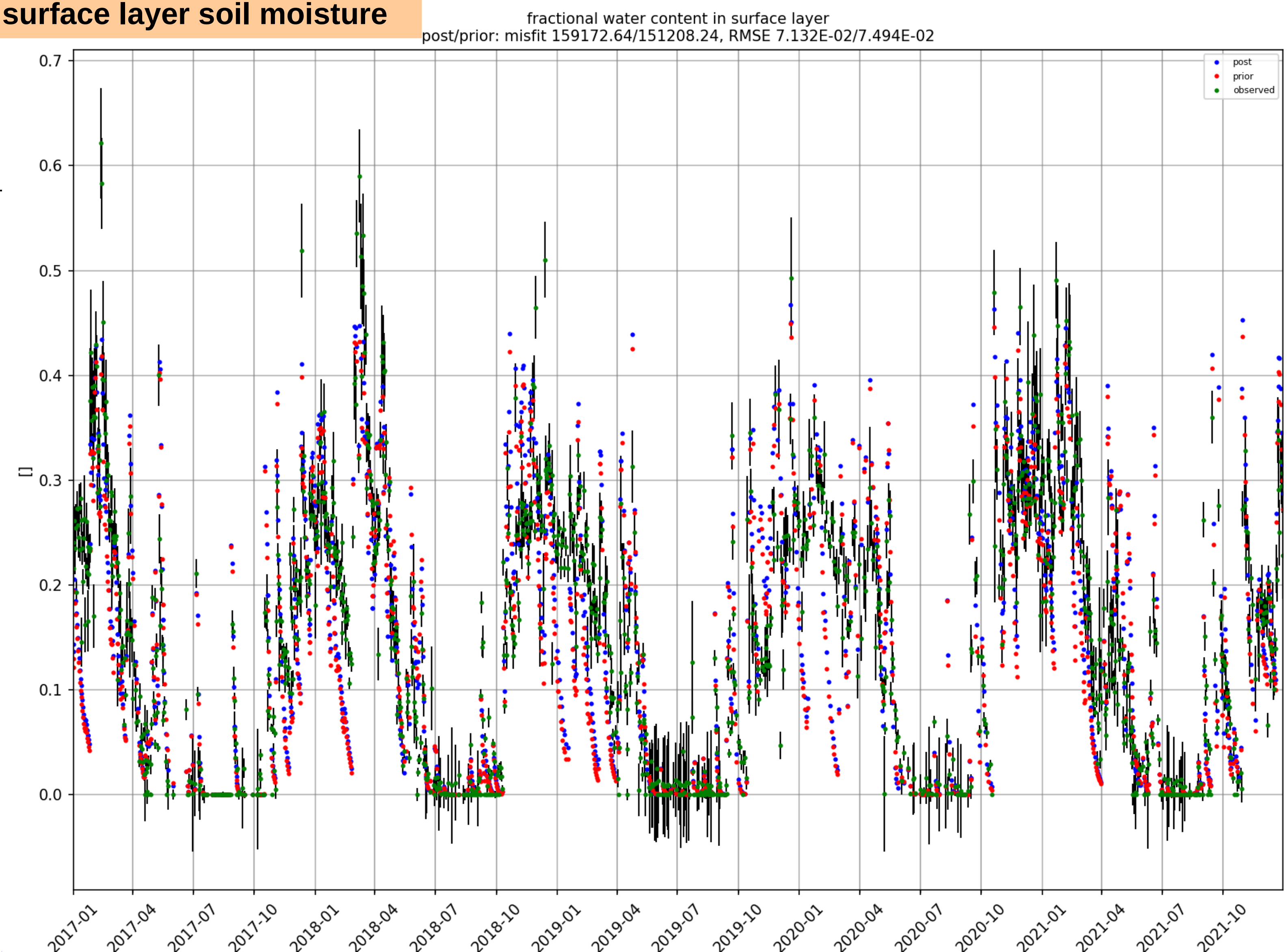
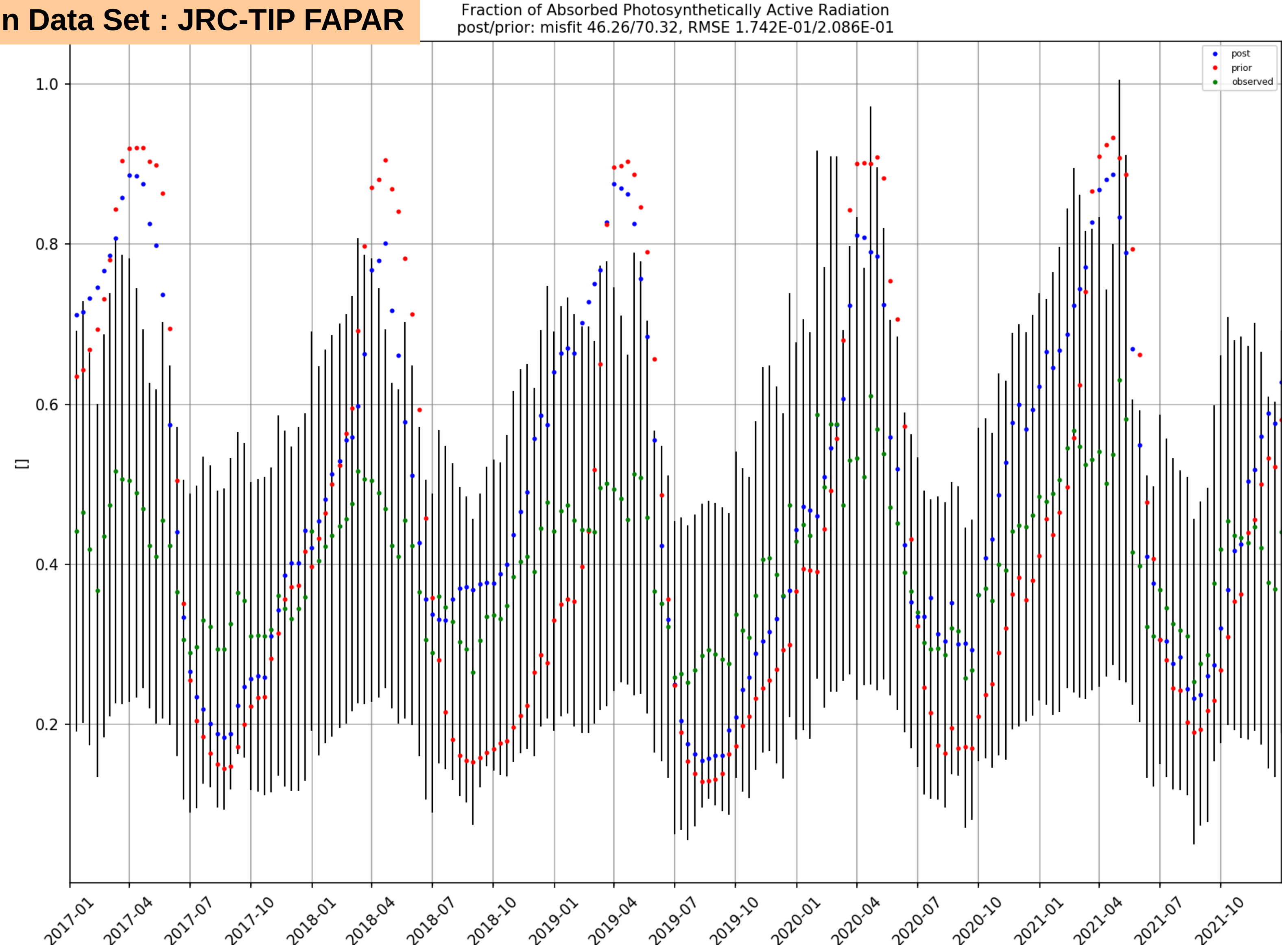
2020-10
2021-01
2021-04
2021-07
2021-10

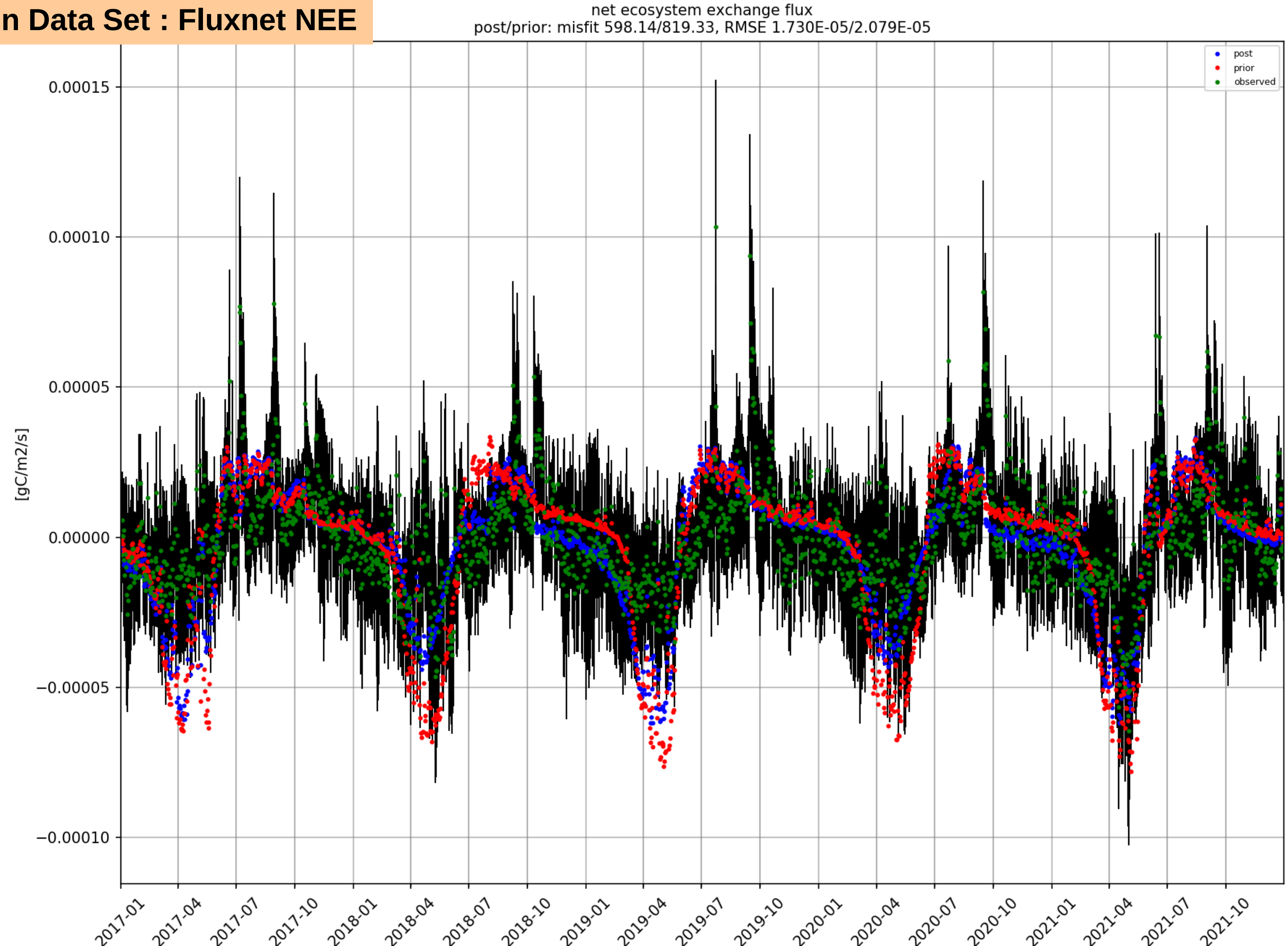
SMOS surface layer soil moisture



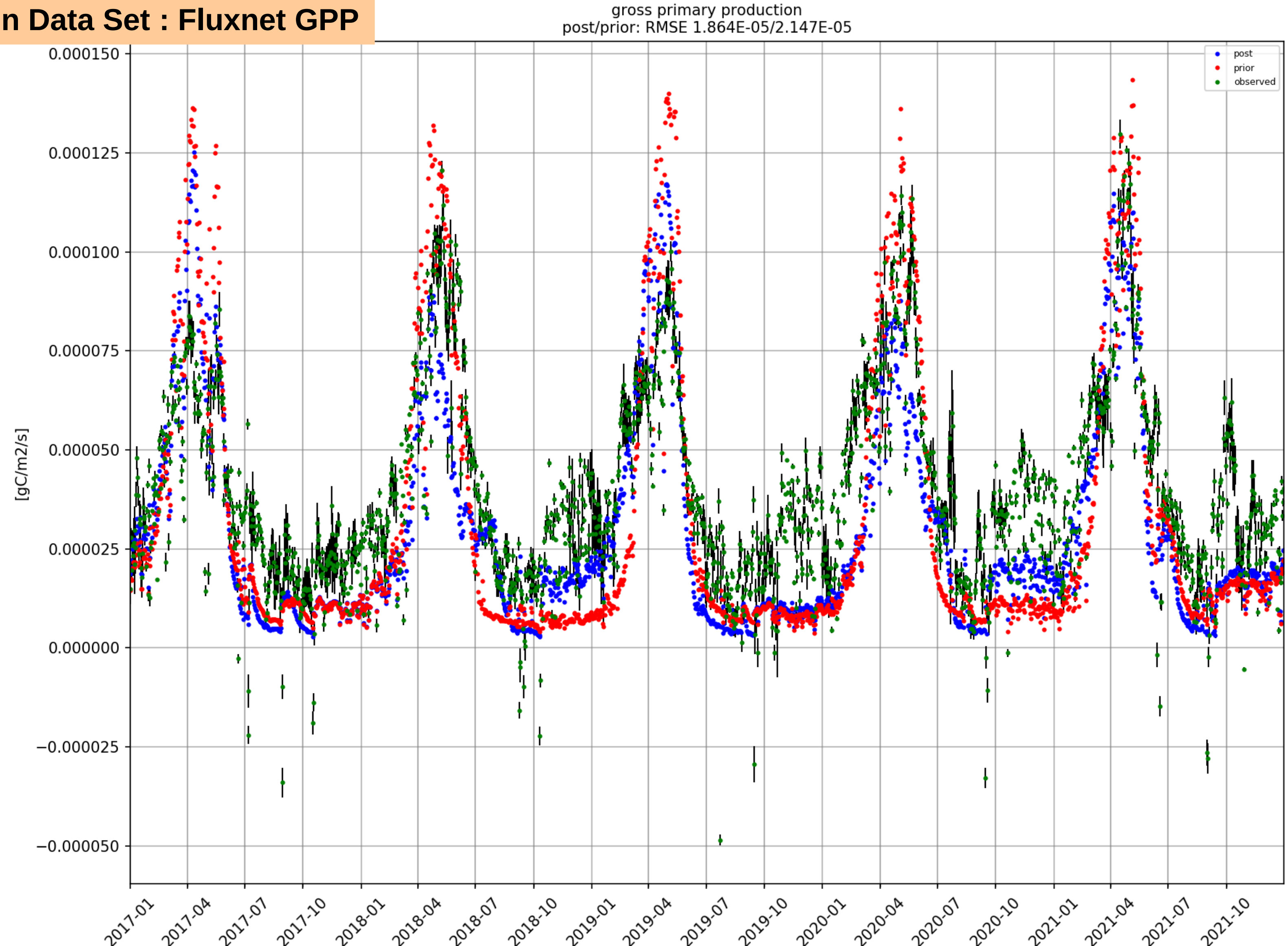
Valiation Data Set : JRC-TIP FAPAR



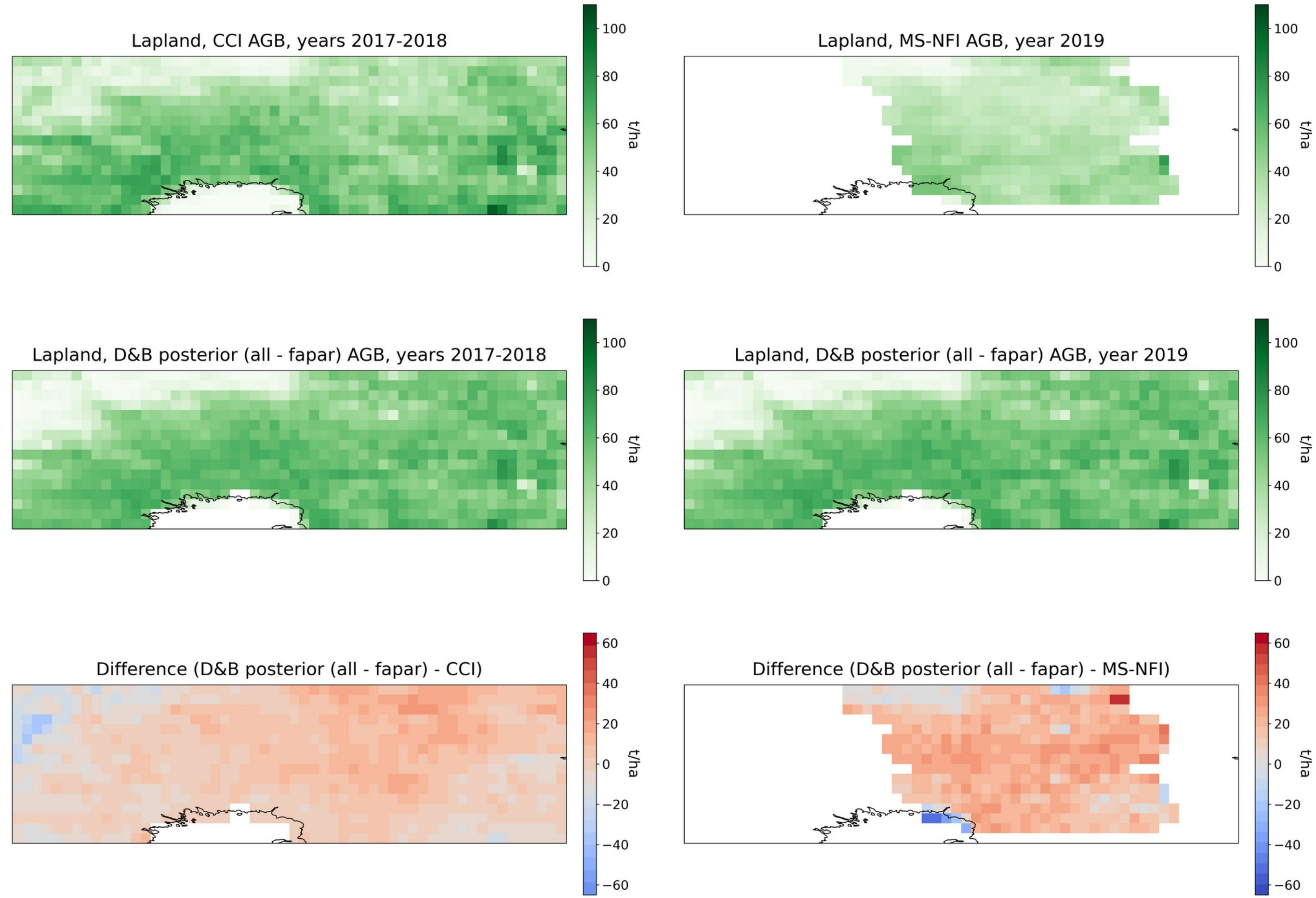
Valiation Data Set : Fluxnet NEE



Valiation Data Set : Fluxnet GPP



Example of posterior validation
2 AGB products over Lapland



Regional-scale assimilation
Simulation : 2015 - 2021
Assim. window : 2017-2021
Data Streams :
SIF
LVOD
surface layer SM

Take home

DALEC & BETHY model (D&B) +

Terrestrial Carbon Community Assimilation System (TCCAS):

- developed **for simulation and assimilation of EO and field data**
- to **provide an integrated perspective on terrestrial carbon and water cycles**
- flexible implementation of observation operators, to allow assimilation “on the swath”
- field data essential for model development and validation
- includes tangent and adjoint codes for efficient data assimilation (system needs to be applicable at high spatial resolution)
- **to be released to public domain as community tool** for use by larger group beyond the LCC team
- **ESA funded followup project to promote TCCAS as community tool:** https://tccas.inversion-lab.com/
- Work with experts on field and satellite observations, if you can! It is challenging but much more fun than working isolated within the respective communities