Carbon budget components at intra-field scale over large aeras by assimilating satellite data in the AgriCarbon-EO processing chain

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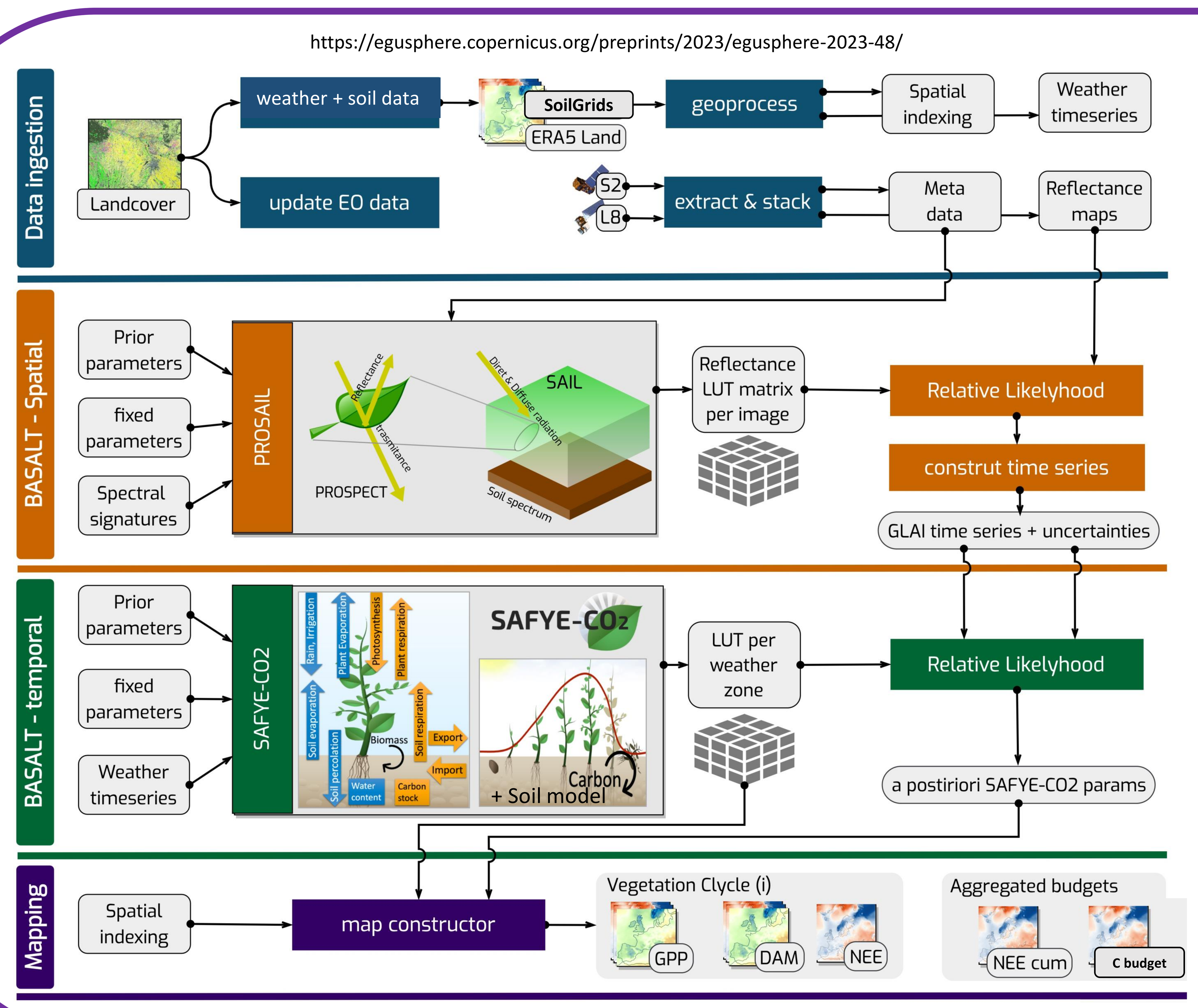
Context

https://www.cesbio.cnrs.fr/agricarboneo/agricarbon-eo/

The ORCaSa project aims at preparing the emergence of an International Research Consortium (IRC) on Soil Carbon. Among its objectives is the **development of an operational processing chain allowing to monitor cropland carbon budgets and its components** (CO_2 fluxes, biomass production…) for various context of applications: voluntary C market, insetting, CAP, NDCs. The monitoring tool shall be compliant with the MRV theoretical framework described by Smith et al. (2020) and shall meet the technical specifications described by the CIRCASA consortium (https://www.circasa-project.eu/). Among other things, the tool shall include a high resolution and large scale process based modelling approach (TIER 3) relying on remote sensing data assimilation for accurate biomass estimates with a modular structure allowing uncertainty estimates and ensemble soil modeling exercises, a robust and reliable data infrastructure providing seamless access to multiple users and using FAIR principles (e.g. Copernicus) and it should offer the possibility to verify SOC stock changes and the other carbon budget components against a range of in-situ data (soil sampling in the field and at long term experimental trials, flux tower networks…). The AgriCarbon-EO processing chain that was developed to fulfill those requirements is described hereafter.

The Agricarbon –EO pre-operationnal processing chain

https://egusphere.copernicus.org/preprints/2023/egusphere-2023-48/

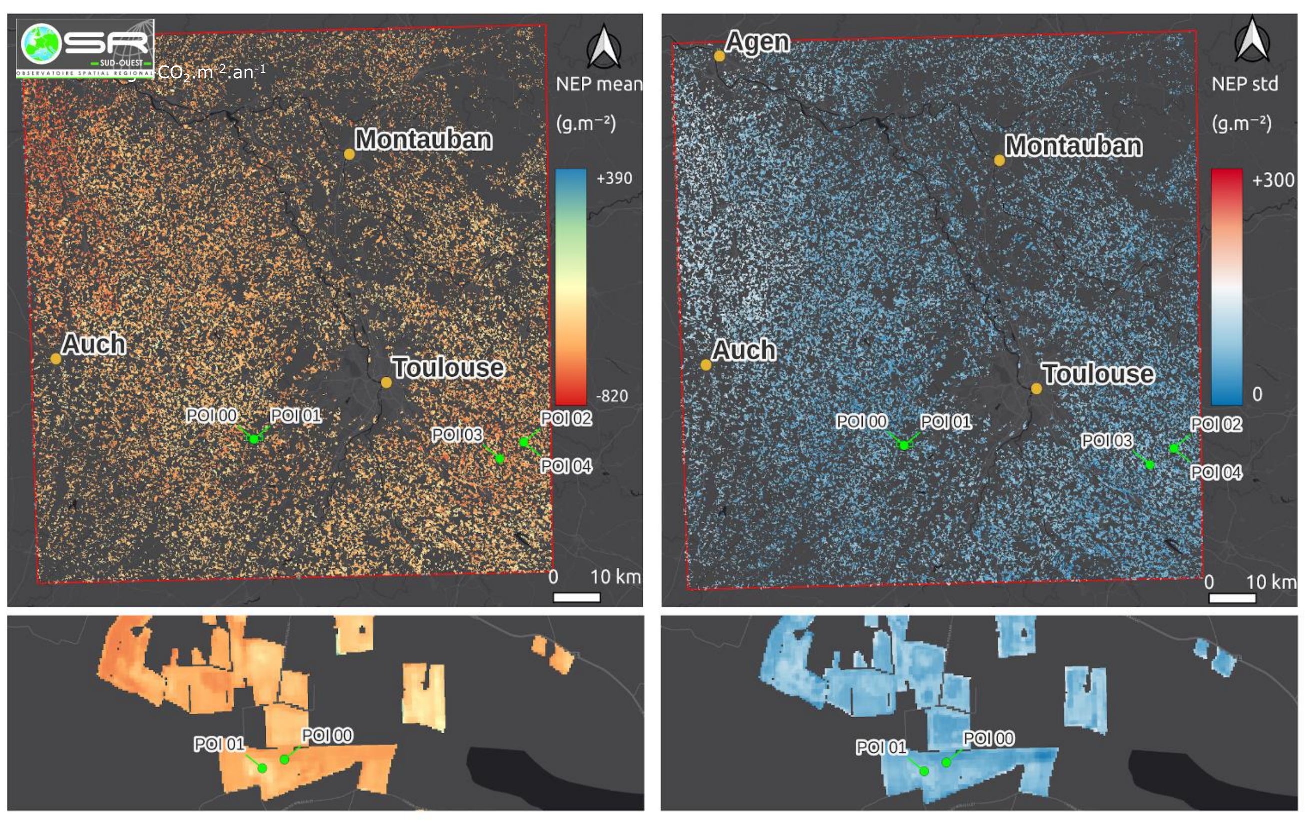


- Generation of the simulation spatio-temporal grid
- Download (API) and formatting of input data:
  - Satellite images (Sentinel 2, Landsat 8),
  - Weather (e.g. ERA5) and soil properties data (e.g. SoilGrids or in-situ data),
  - Soon management data from FMIS (Farm Management Information Systems),
- Calculation of Green Leaf Area Index (GLAI) with the Prosail radiative transfer model + uncertainties:
  - Generation of Prosail look up tables per image,
  - Calculation of the relative likelihood of the LUT inputs knowing satellite observations,
  - Gaussian approximation of the a posteriori distribution,
- Inversion of the SAFYE-CO2 model + uncertainties:
  - Generation of SAFYE-CO2 tables by weather zone
  - Calculation of the relative likelihood of the LUT inputs knowing the inverted GLAI,
  - Estimates of biomass components, yield, CO_2 fluxes (photosynthesis, plant respiration)
  - Use of root and ABG biomass outputs from SAFYE-CO2 minus yield as biomass inputs for the soil models (AMG, COP…soon RothC) ➔ calculation of the soil organic C stock changes
- Postprocessing :
  - Construction of parameter or variable maps at daily time step or integrated over the cropping year (e.g. yield, C budget)
  - Calculation of precision statistics

Results and performances analysis

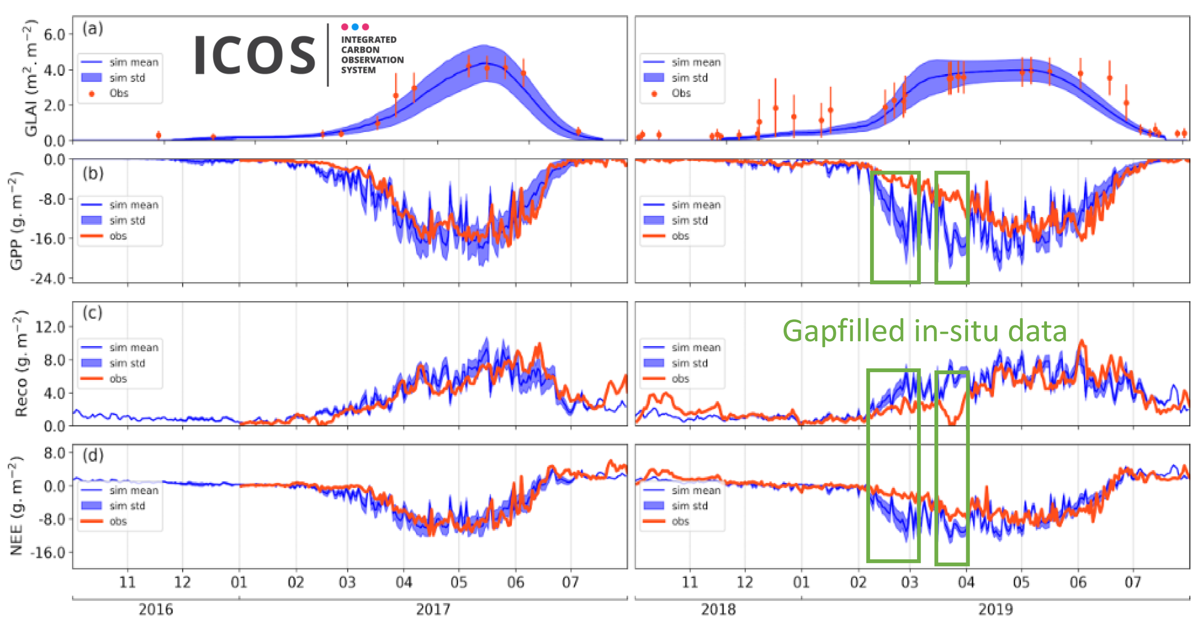
The outputs of the ACEO processing chain were evaluated against a range of in-situ data : spatialised biomass and yield data collected at the OSR near Toulouse, a range of ICOS sites covering a large range of pedoclimatic conditions and management regimes (from Southern France to Finland).

Example of net annual CO_2 fluxes at 10m resolution for straw cereals in 2017 (left average and right uncertainty) in South West France



Downloading data takes about 1 day but the run itself takes about 4h

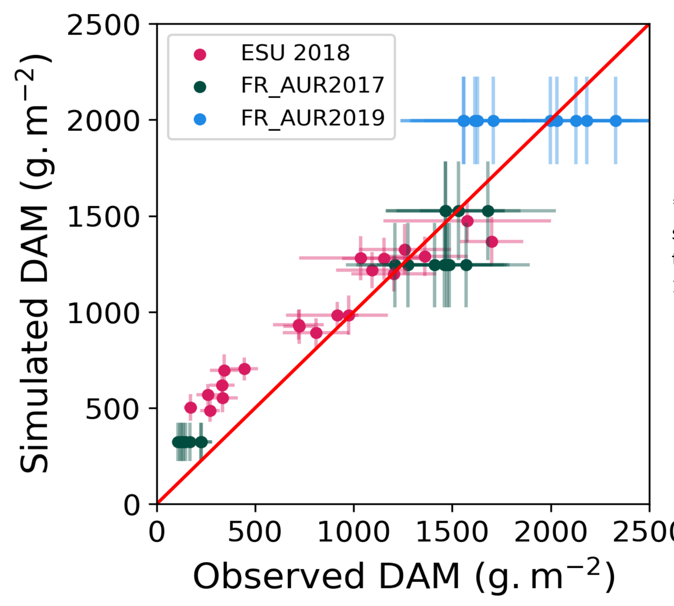
GLAI & CO_2 fluxes at Auradé (FR_Aur) site in 2017 & 2019 for winter wheat



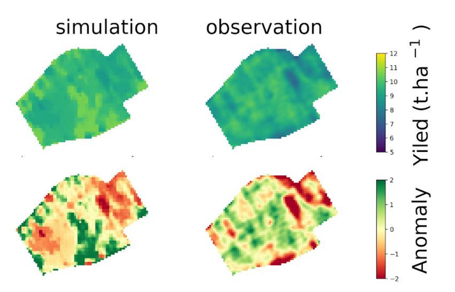
Year:	stats	2017	2019
GLAI	Bias (m2.m-2)	0.26	0.35
	R2	0.93	0.88
	RMSE (g.m-2)	0.48	0.64
GPP	Bias (g.m-2)	0.36	1.23
	R2	0.91	0.76
	RMSE (g.m-2)	1.91	3.43
Reco	Bias (g.m-2)	0.03	-0.33
	R2	0.62	0.60
	RMSE (g.m-2)	1.91	1.59
NEE	Bias (g.m-2)	0.38	0.89
	R2	0.88	0.88
	RMSE (g.m-2)	1.69	2.40

Statistics on the CO_2 fluxes include gapfilled periods

Validation against ESU* measurements at regional scale for winter wheat



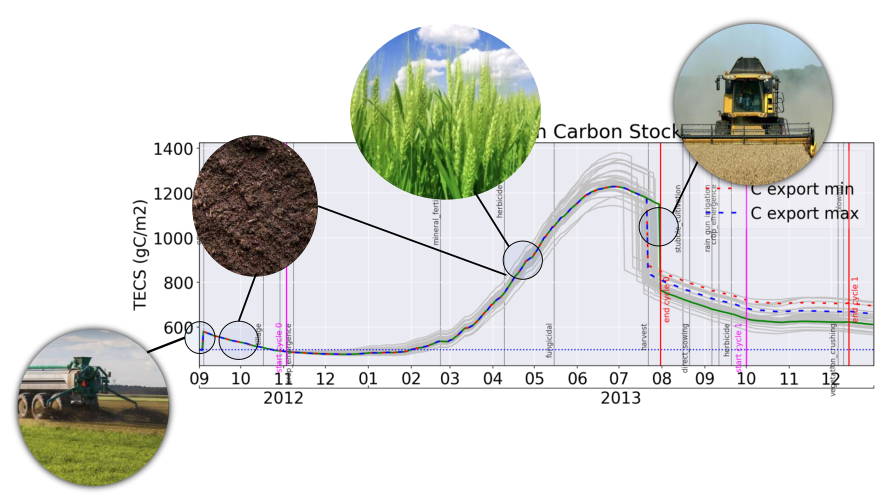
*ESU measurements = five biomass samples over 2m² each collected in the center and at the 4 angles of a 10 x 10 m geolocalised square



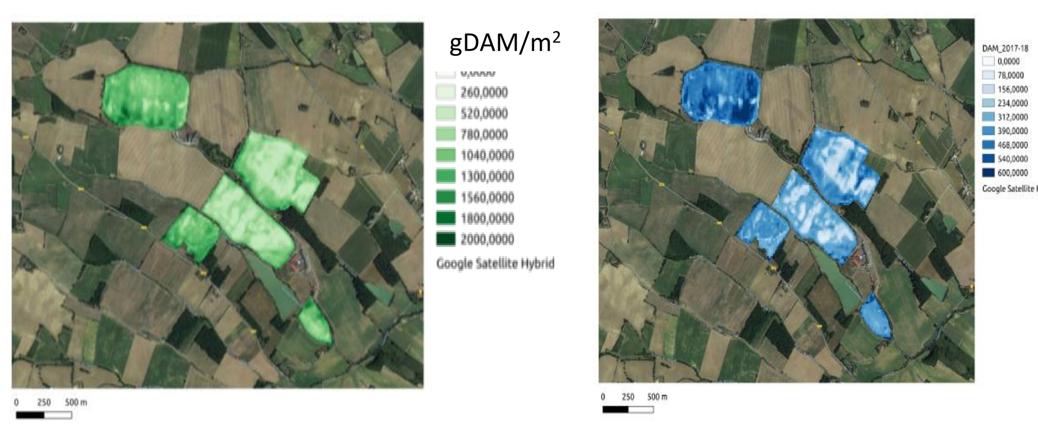
Comparing yield estimates against combined harvester

A dynamic spatialised vision of the cropland C stocks

Temporal evolution of the Total Ecosystem Carbon Stock at 10 m resolution



Map of cover crop biomass at 10 m resolution (left) and associated uncertainty (right) at the Villeneuve farm (Bézéril, France)



C budget map at 10m resolution in 2019, for a crop rotation wheat/cover crop/corn at the Villeneuve farm (Bézéril, France) ➔ coupling AMG and SAFYE-CO2 in ACEO

10m resolution maps make it possible to define an optimal soil sampling plan (high precision/low cost) for :
1) validation at pixel scale ➔ next step
2) representative delta SOC stocks at plot/farm level

Conclusions & perspectives

- Diagnostic approach only but some scenarii can be tested (e.g. straw export or not),
- High automatisation process, large scale, high resolution, components validation + uncertainty analysis at low cost of implementation and compliant with CIRCASA’s requirements,
- Limited to a few crop species ➔ progressive integration of new crops (OSR, ICOS & JECAM networks) + partnerships (private & academic),
- The use of optical satellite data can be limiting in areas concerned with long cloudy conditions ➔ assimilation of radar satellite data (SAR) to overcome this issue,
- Progressive coupling of new soil models (➔ ensemble approach): coupling with soil models became relevant as in-situ soil data are increasingly available (e.g. C market),
- Main limitation for a systematic large scale application is access to farmer’s data.