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Achieving 10m regional crop CO_2 flux mapping in AGRICARBON-EO through a bayesian assimilation of Sentinel2 reflectances in SAFYE-CO2

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DYNAFOR UMR 1201 | INRA - INP TOULOUSE

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CESBIO

session A3.04 Agriculture - Methods and Algorithms, Science, Applications and Policy 24/05/2022 8h45

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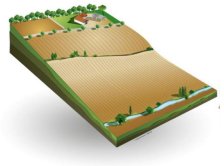
CONTEXT: CARBON FARMING and MRV

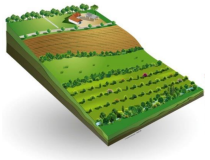
Agro-ecosystems and carbon storage:

- 4/1000 (Minasny et al. 2018, Amelung et al. 2020)
- Conservation, tillage, cover crops … => Carbon farming

National & international Initiatives:

- Label bas carbone (France)
- GREEN deal
- Voluntary carbon market





cover crops
crop rotations
agroforestry

Soil monitoring, reporting and verification framework
adapted from Smith P. et al (2020) *Global Change Biology*

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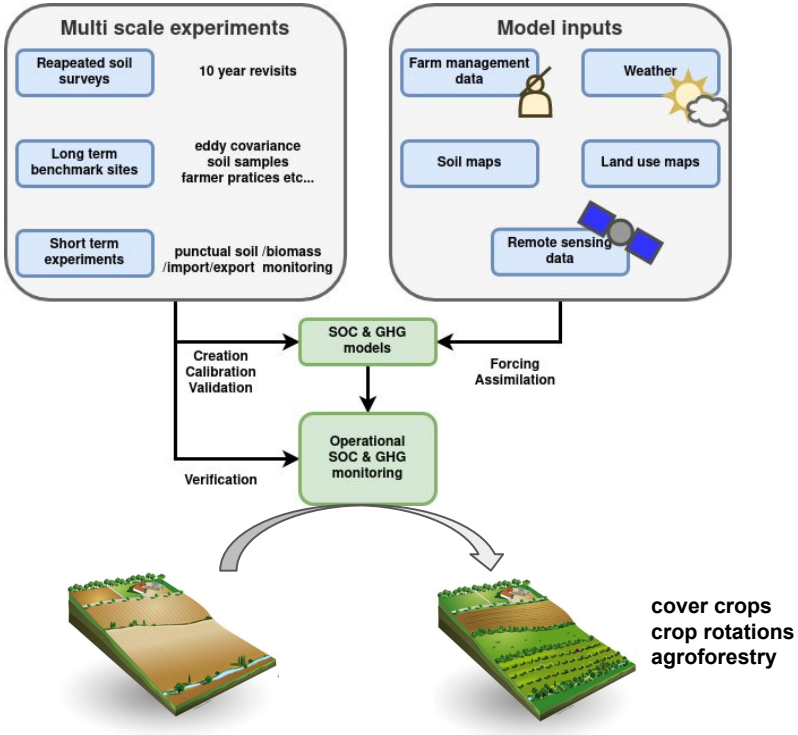
International scientific cooperation for soil carbon MRV:

- **CIRCASA**(2017-2021)
  - conceptual framework
- **ORCASA** (2022-2024)
  - methodological framework + Prototypes
- **IRC Soil Carbon** (2024-)

*For scaling, the **MRV framework** relies on **satellite products** & **models***



Soil monitoring, reporting and verification framework
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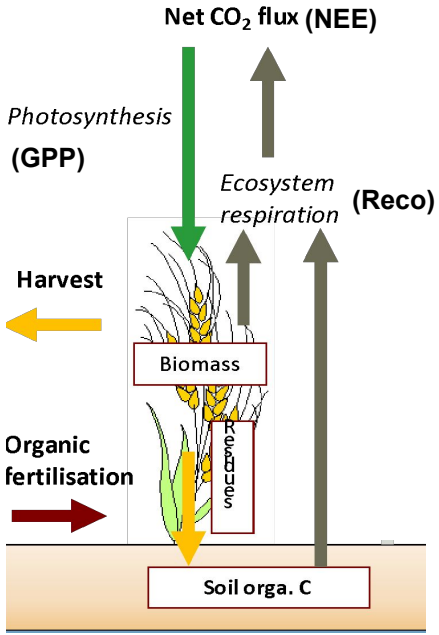
Objective: Quantify the carbon budget components

Process based approach => SAFYE-CO2 (Pique et al. 2020 A&B)



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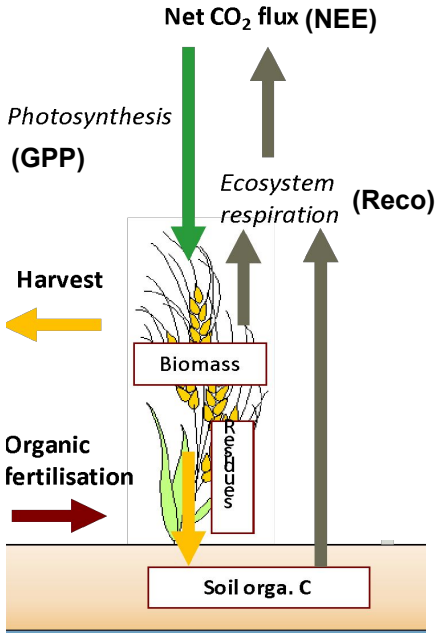


At large scale & intra field resolution:

- Regional/National Coverage
- Coherent with biophysical processes & management

Taking in account local growth variability

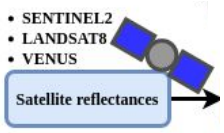
- Crop rotations ,cover crops, regrowths …
- Remote sensing data assimilation

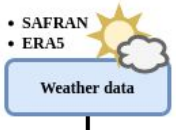
Quality assessments for each component

- Extensive validation using field measurements
- Uncertainty estimations

Argicarbon-EO =SAFYE-CO2+ bayesian assimilation

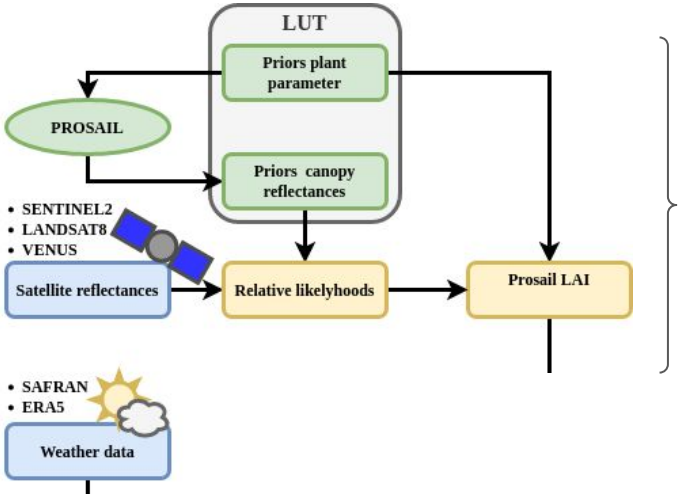
Overview of the Agricarbon-EO processing chain





Downloads, colocates and regrids data: plot contours, weather data (ERA5LAND/SAFRAN) from optical remote sensing data.

Overview of the Agricarbon-EO processing chain



Downloads, **colocates and regrids data** from optical satellites (Theia*), weather reanalysis ERA5LAND (ECMWF**)/SAFRAN & validation data

Bayesian LUT based Inversion of **Prosail** for each image to obtain **LAI +uncertainties**

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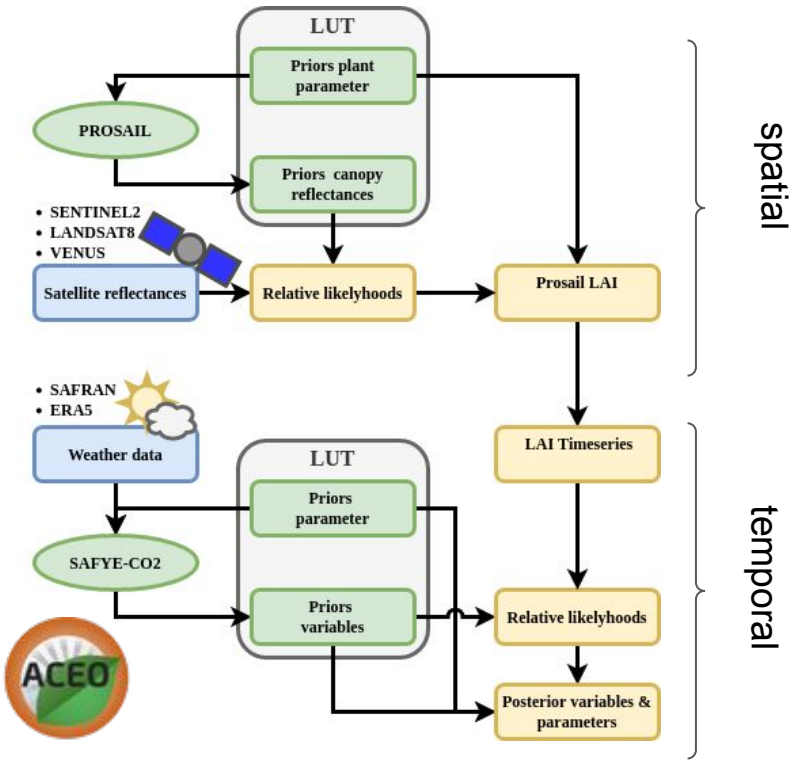

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Bayesian LUT based Inversion of **Prosail** for each image to obtain **LAI +uncertainties**

Bayesian LUT based assimilation of LAI time series into **SAFYE-CO2** to obtain **parameters and variables**

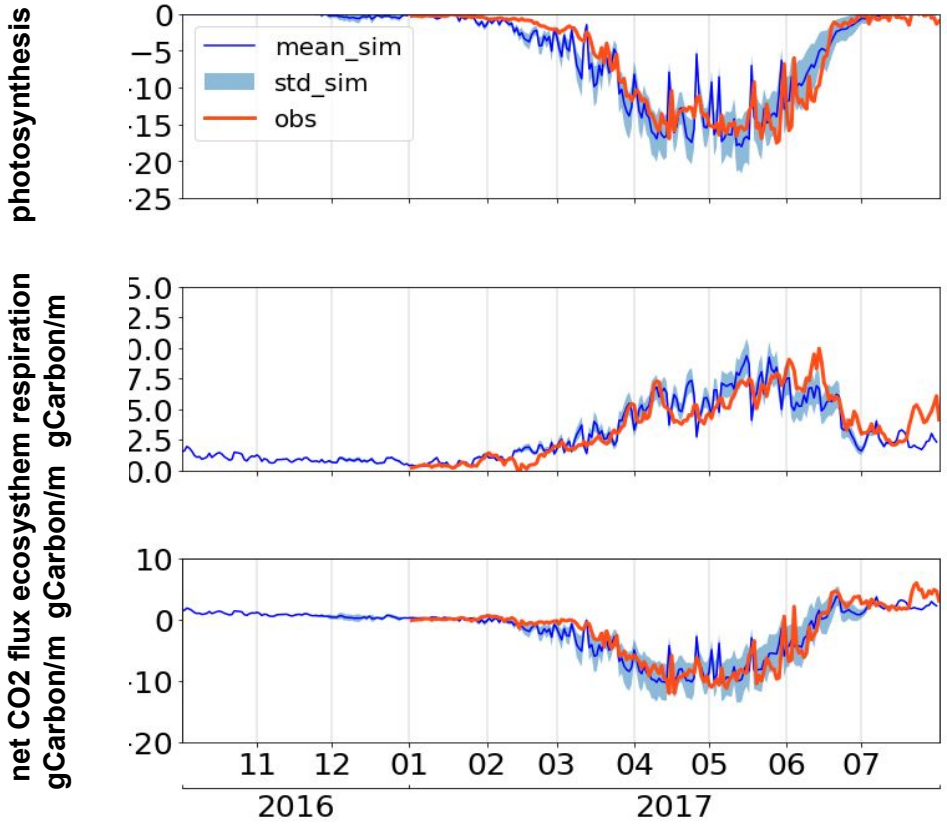
Produces

- Quality indicators & uncertainties
- Maps of variable & parameter as well as their distributions.

SAFYE-CO2 simulation over one Sentinel2 tile 4h

Validations of Agricarbon-EO Wheat: CO_2 fluxes

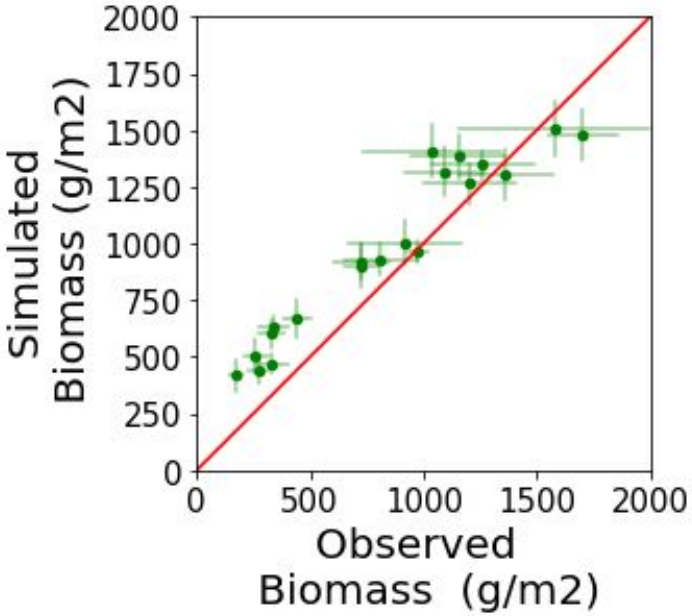
ICOS FR-Aur in 2017



- Slight overestimation of GPP at the beginning of the cycle
- Reco is less accurate
- Overall good performance

	RMSE	MAE	bias	R2
GPP	1.97	1.44	-0.41	0.90
Reco	1.12	0.87	0.08	0.75
NEE	1.55	1.18	-0.33	0.85

Validations of Agricarbon-EO Wheat: Biomass

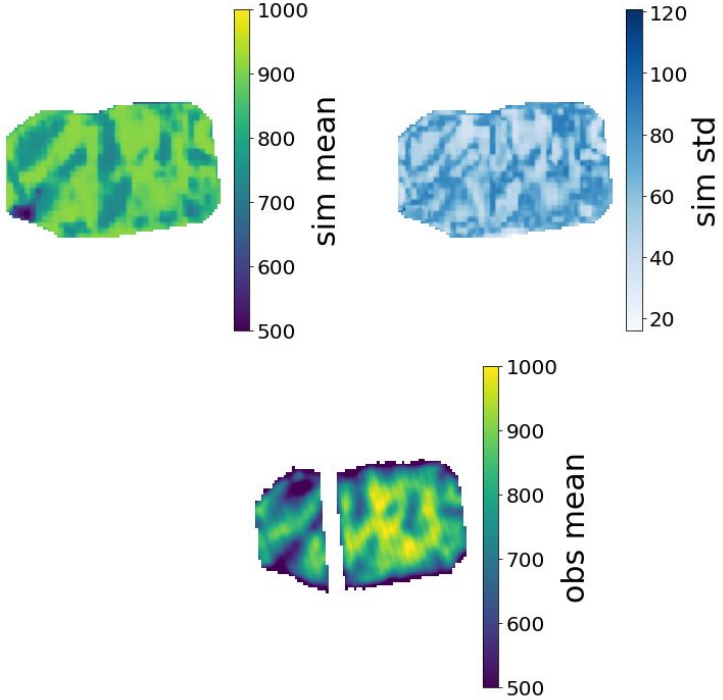


- Slight overestimation of biomass in the beginig of the growth
- High correlation and low errors given the measurement and model uncertainties

	RMSE	MAE	bias	R2
DAM	197.20	174.81	-138.75	0.92

Validation over punctual biomass field measurements in 2018

Validations of Agricarbon-EO Wheat: Yield

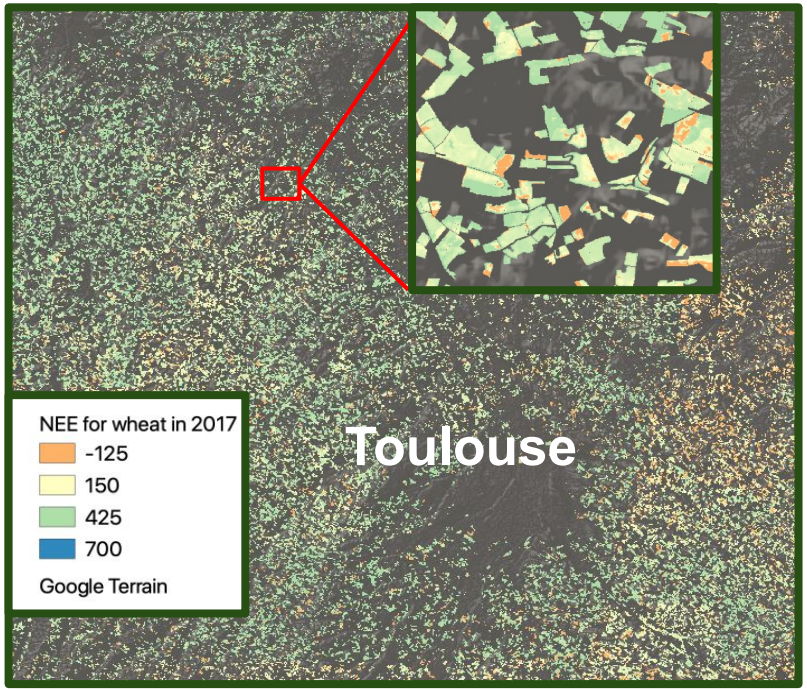


Validation using harvest maps in 2017

- Representation of spatial variability
- lack of amplitude in the simulations.
- more expertise on harvest maps needed

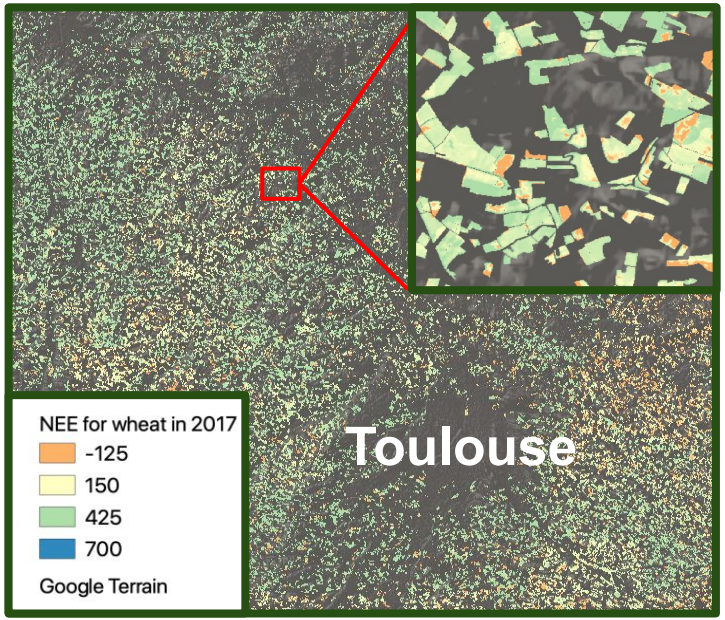
Application: carbon budgets over a sentinel2 tile

10m resolution map of straw cereal Net annual CO2 fluxes:
T31TCJ Sentinel2 tile (110 x 110 km)

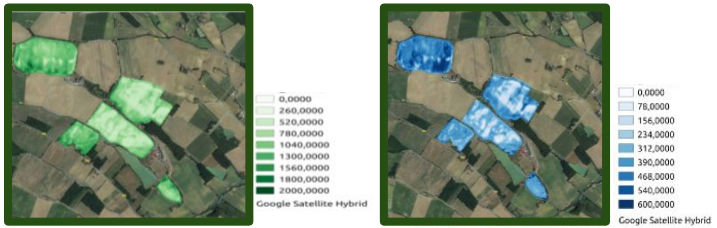


Application: carbon budgets over a sentinel2 tile

Large scale 10m resolution map over the T31TCJ Sentinel2 tile (110 x 110 km)



Net annual CO2 flux (gC-CO2/m2/yr)



Average **Standard deviation**

Cover crop biomass estimations

Application: carbon budgets over a sentinel2 tile

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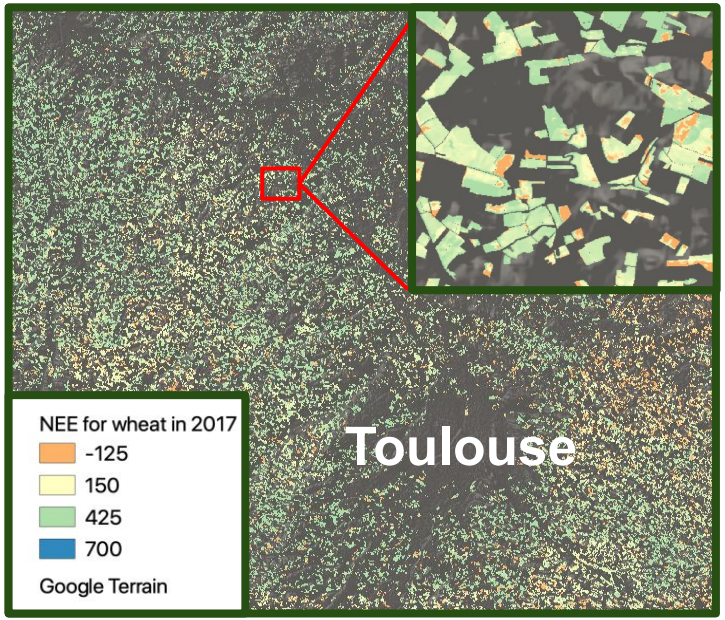
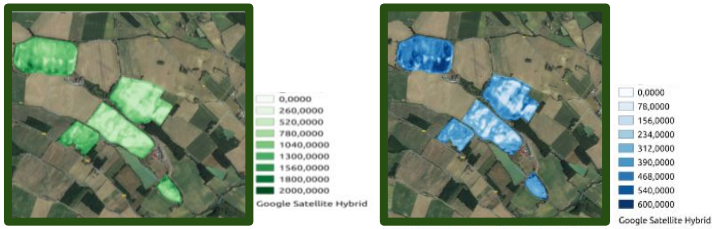


Net annual CO2 flux (gC-CO2/m2/yr)

+

Farmer data
(C imports/exports)

+



Average **Standard deviation**

Cover crop biomass estimations

=

High resolution carbon budgets map.

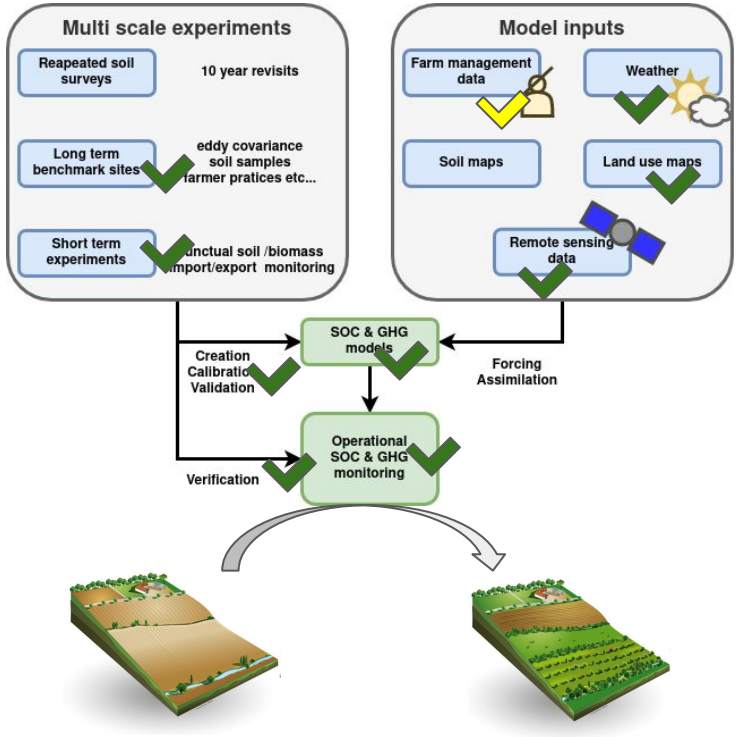
Conclusions:

Agricarbon EO:

- ➢ Monitor Carbon budget components
- ➢ Large scale & intra field resolution
- ➢ Local growth variability
- ➢ Quality assessments

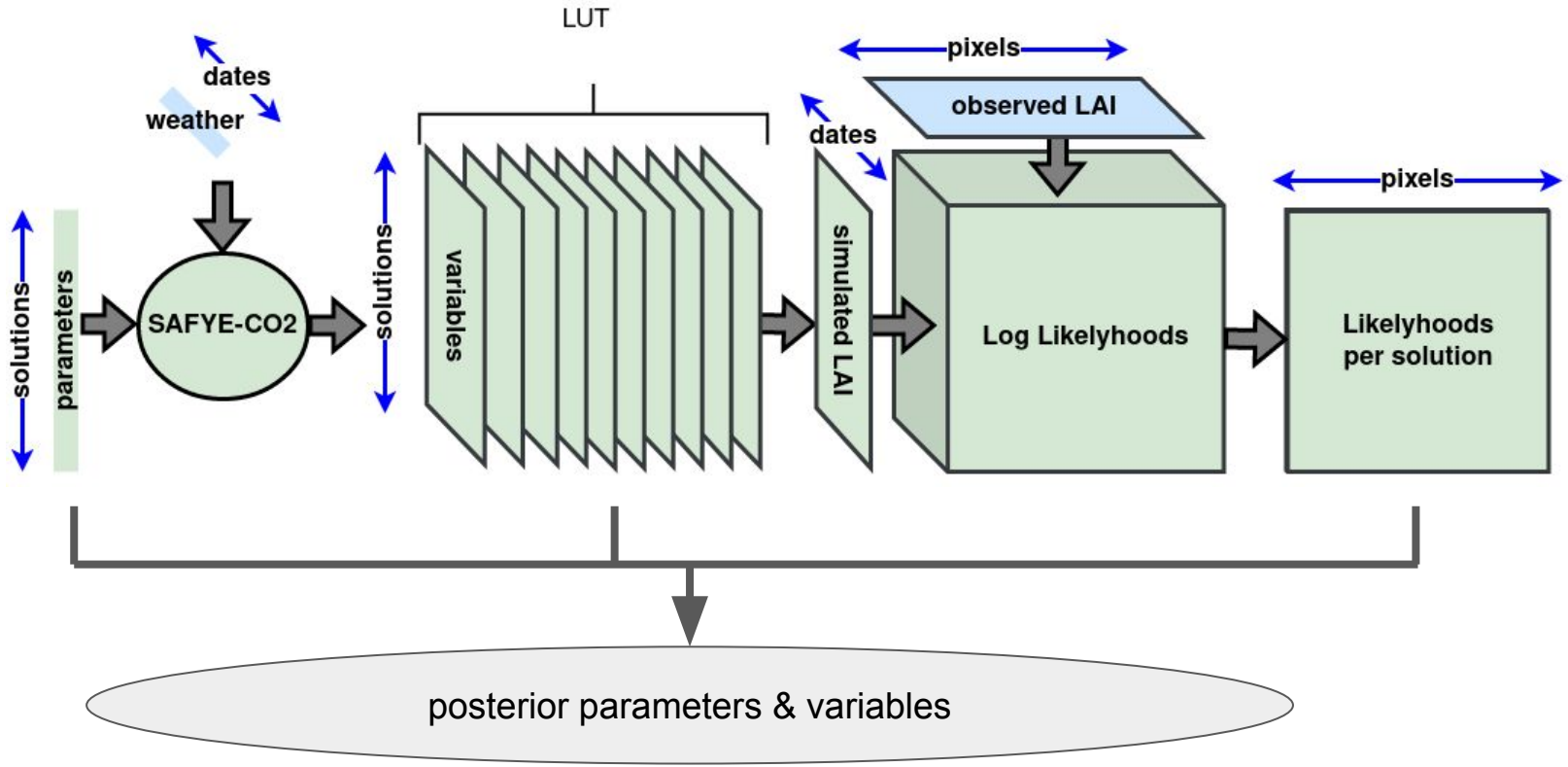
MRV compatible demonstrator

- ➢ Streamline the access to farmer data
- ➢ Introduce SOC model
- ➢ Assimilate other remote sensing products.



Soil monitoring, reporting and verification framework
adapted from Smith P. et al (2020) *Global Change Biology*

Assimilation & bayesian Inversion



Models: PROSAIL & SAFYE-CO2

Prosail

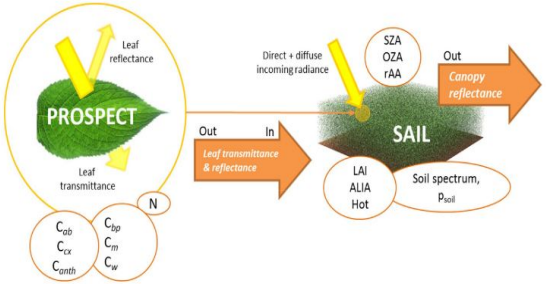
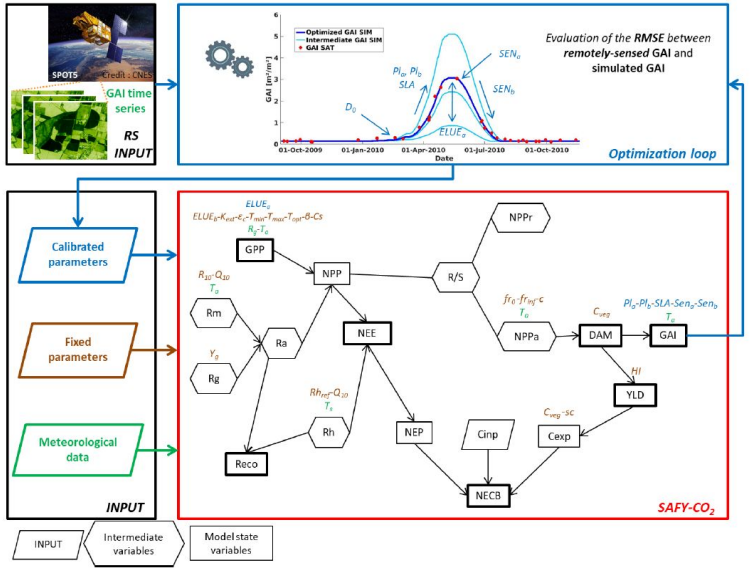


Figure 1. Calculation of canopy reflectance using the coupled PROSPECT + SAIL models. Variable symbols are explained in Table 1 and in the text.

Katja Berger et al. (2018)

1D radiative transfer model
Widely used in the community

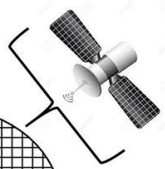


Simple agronomic model

7) Spatial soil re-sampling survey grid (M/V)

- Same sites – resampled each decade
- Used for ground-truthing SOC change
- Used for ground-truthing activity data

t 0 year
t+10 years
t+20 years, etc.



6) Remote sensing (M/R/V)

- Verify activity data
- Inputs to run models
- Soils and vegetation

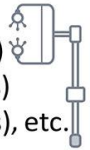
5) Activity data (M/R)

- Management data
- Field / farm level
- Self-reporting

2) Shorter-term experiments (M)

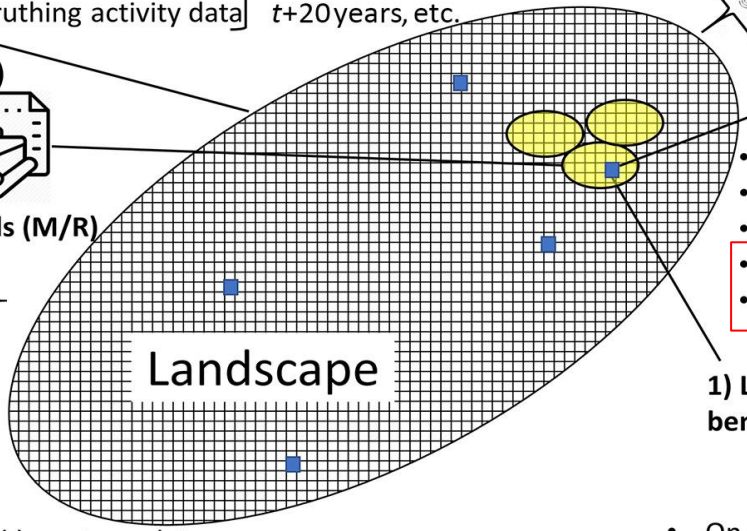
- At long-term sites
- Measure fluxes
- Investigate processes
- Develop novel tools
- Calibrate models

t 0 (days)
t+*x* (days)
t+*y* (days), etc.



4) Spatial data to drive models (M/R)

- Climate
- Soils
- Land cover, etc.



3) SOC / GHG models (M/R)

- Developed using short- and long-term data
- Calibrated using short- and long-term data
- Evaluated against long-term data
- Applied to derive tier 2 EF
- Applied using spatial data as tier 3 methodology
- Verified using survey data and remote sensing

SOC change over time

1) Long-term experiments at benchmark sites (M)

- On different land uses
- Different treatments
- Long term SOC measurement (decades) or chronosequence

t 0 year
t+10 years
t+20 years, etc.

Key: ■ = long-term experiment ● = farm

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