Verification of Terrestrial Carbon Sinks with the Terrestrial Carbon Community Assimilation System (TCCAS)

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

[1]The Inversion Lab, Hamburg, Germany, [2]University of Edinburgh, UK, [3]University of Lund, Sweden, [4]University of Reading, UK, [5]FMI, Helsinki, Finland, [6]MPI BGC Jena, Germany, [7]TU Delft, The Netherlands, [8]TU Wien, Austria
[9]CESBIO Toulouse, France, [10]University of Sheffield, UK, [11]University of Valencia, Spain, [12]Swiss Federal Institute for Forest, Snow and Landscape Research, Switzerland, [13]ESA, ESTEC, The Netherlands

1 Question

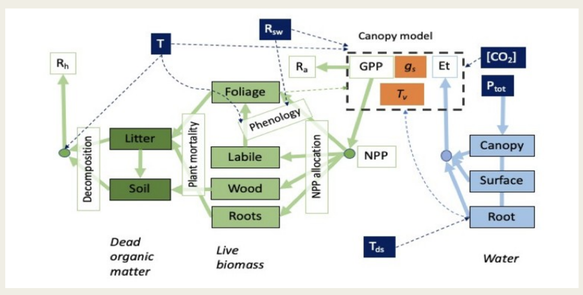
- The Paris agreement allows the use of terrestrial carbon sinks as a climate mitigation mechanism.
- Carbon Credit Schemes pay for the extra carbon uptake through an intervention in the landscape (e.g. https://cer.gov.au/schemes/australian-carbon-credit-unit-scheme)
- This requires to quantify the carbon uptake with intervention compared to a counterfactual, i.e. the carbon uptake without this intervention. Without such a calculation we cannot guarantee so-called additionality, i.e. that the extra carbon is a result of the intervention and not some other process.
- An efficient market requires these uptakes be quantified reliably and transparently.
- Ideally this quantification combines process understanding incorporated in a terrestrial biosphere model with a range of observations that constrain the model simulation.
- What role can satellite observations play in this context?

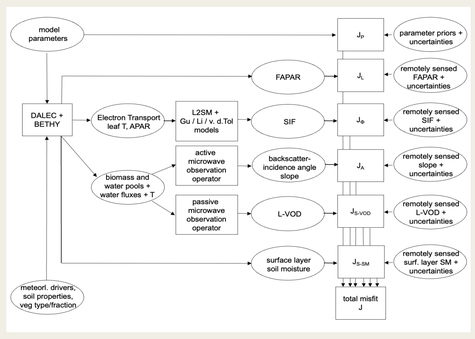
2 Approach

- We employ the Terrestrial Carbon Community Assimilation System (TCCAS) (Kaminski et al., 2025) built around the terrestrial biosphere model D&B (Knorr et al., 2025) over the Majadas de Tietar site in Spain, which is covered by grass (80%) and trees (20%).
- We demonstrate that constraining the model with satellite measurements also improves the fit to independent data i.e. produces a better model.
- We use the improved model to analyse the effect on carbon uptake of a hypothetical intervention, which consists in replacing the grass by additional trees.

3 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.
- D&B has been equipped with a set of observation operators that map the model's state variables on equivalents of observations of optical and microwave observations.
- Assimilating all data in one long assimilation window is needed to constrain slow processes

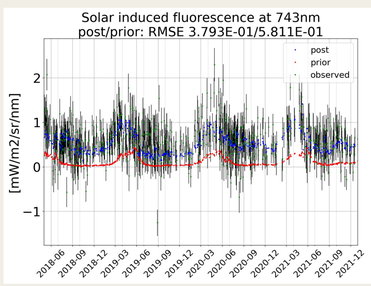


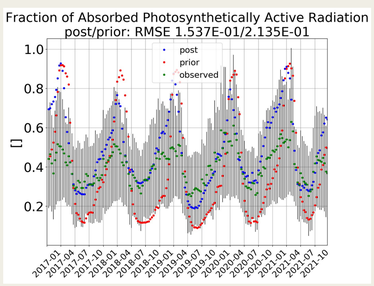


4 Simulated Carbon Uptake

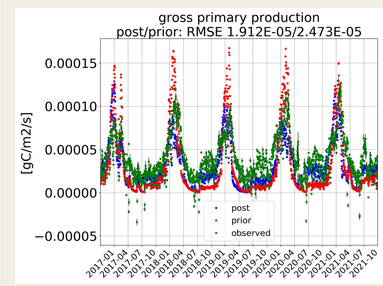
- Joint Assimilation of SIF, L-VOD, SM, FAPAR at Majadas de Tietar
- Simulation starting on Jan 1, 2015
- Assimilation of observations from Jan 1, 2017 (after spinup)
- Assimilation adjusts initial carbon pool sizes and process parameters for both grass and tree PFTs
- The data assimilation procedure improves the fit to all assimilated data streams
- The data assimilation procedure improves the fit to independent data sets provided by Eddy Covariance measurements.
- The data assimilation procedure reduces the uncertainty in simulated carbon pools, primarily for living carbon pools, because dead carbon pools do not affect the simulated equivalents of the EO data streams.

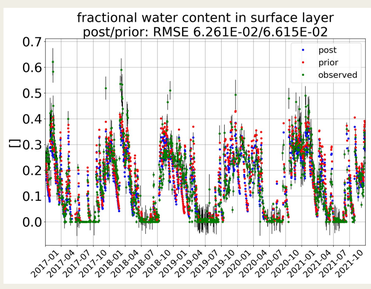
Assimilation Data

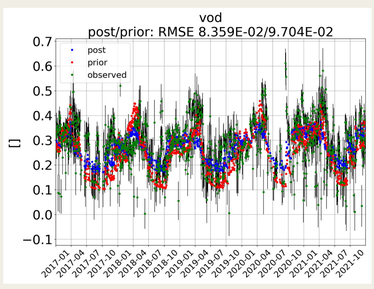


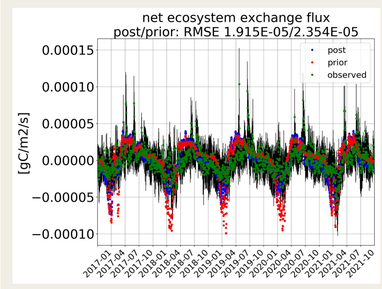


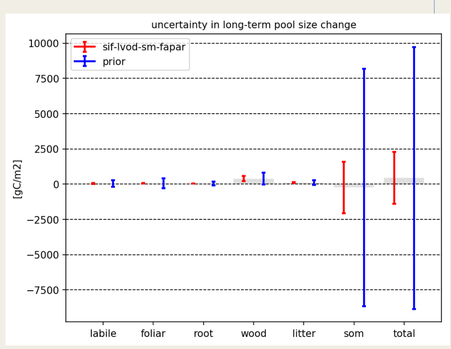
Validation Data











5 Extra Carbon Uptake Through Intervention

- 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 by subtracting the counterfactual case from the intervention case.
- We repeat the above computation under the assumption that there is no model error.

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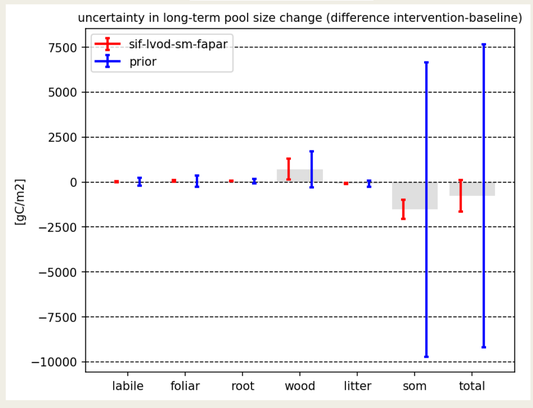
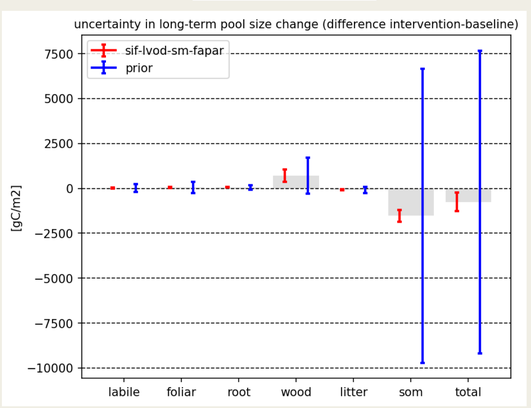
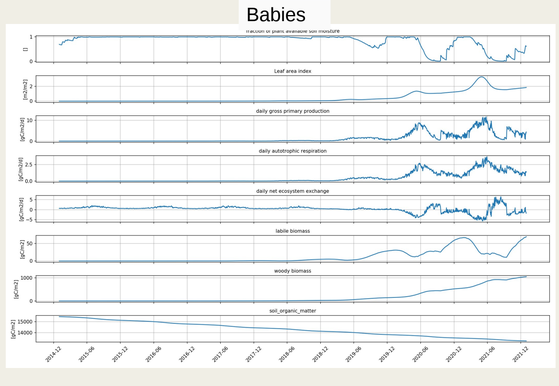


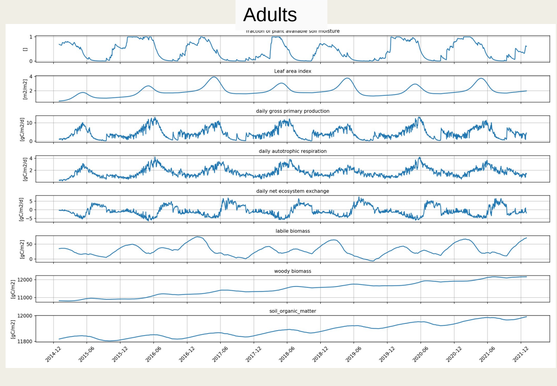
no model error



Babies



Adults



6 Conclusions and Outlook

- The combination of satellite observation and data assimilation schemes provides a powerful
instrument for assessment of carbon credits.
- The quality of the model matters, improvement of the model results in better constraint of carbon update through observations.
- The hypothetical intervention is used for demonstration, the setup can be adapted to further types of intervention and land cover.
- TCCAS can also be applied to assess the effect of planned observational data streams, e.g.
from new space missions, on the accuracy of simulated carbon uptake.

Code and Data Availability

Code, data and training material (and events) are made available through an ESA funded follow-up project on TCCAS as a community tool: https://tccas.inversion-lab.com/

Acknowledgement

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