Potential use of remote sensing data on canopy and soils to represent surface-atmosphere exchange of pollutants and GHG

Benjamin Loubet, Pedro Herig Coimbra, Erwan Personne, Raia Sylvia Massad, Patrick Stella, Sophie Génermont, et al.

ECOSYS, INRAE, AgroParisTech, Université Paris-Saclay

The importance of soil water content

nature communications

Article

https://doi.org/10.1038/s41467-023-41851-0

Temperature extremes of 2022 reduced carbon uptake by forests in Europe

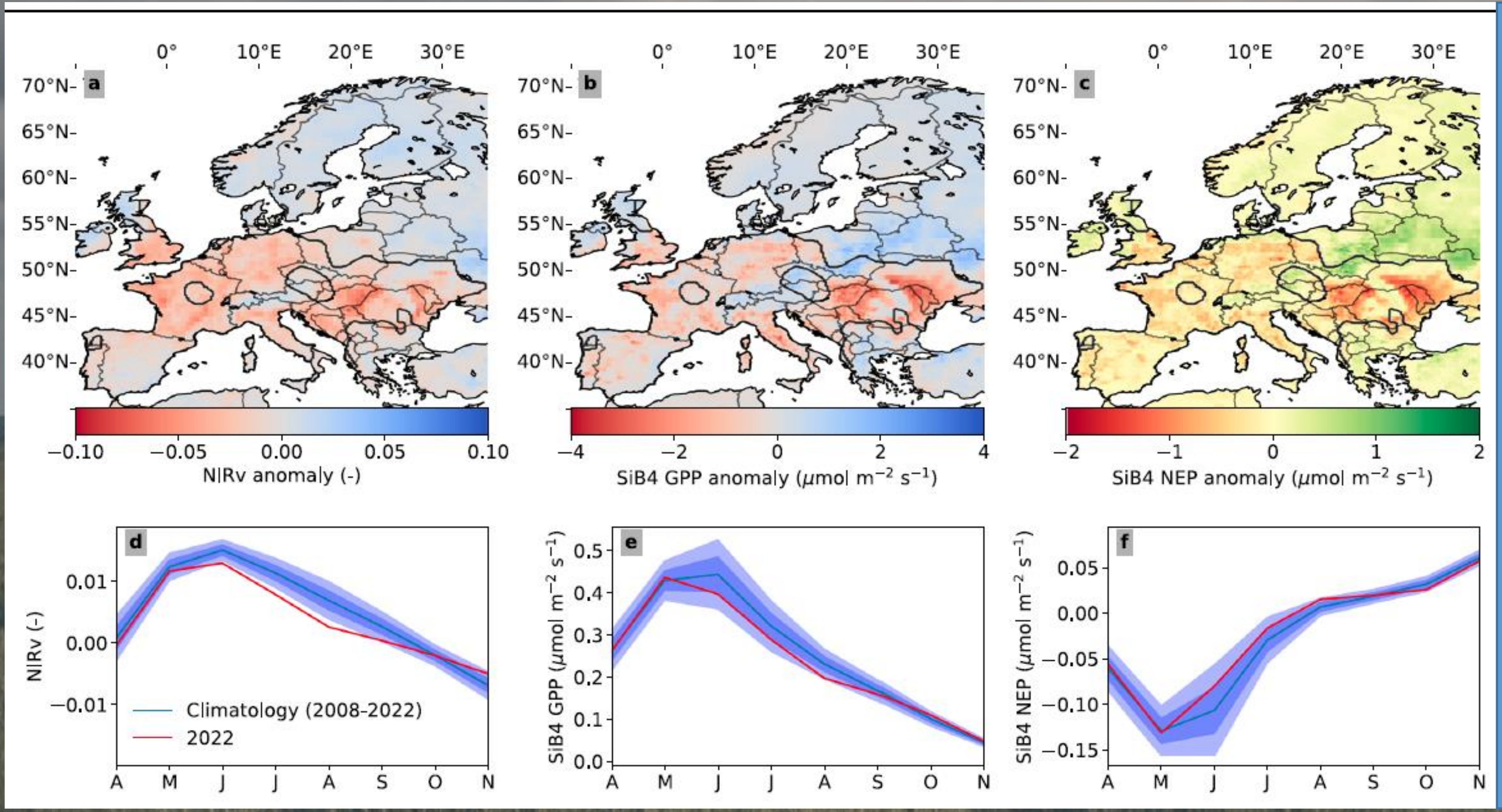
Received: 20 April 2023

Accepted: 30 August 2023

Published online: 06 October 2023

Check for updates

Auke M. van der Woude[1,2], Wouter Peters[1,2], Emilie Joetzjer[3], Sébastien Lafont[4], Gerbrand Koren[5], Philippe Ciais[6], Michel Ramonet[6], Yidi Xu[6], Ana Bastos[7], Santiago Botía[7], Stephen Sitch[8], Remco de Kok[2,9], Tobias Kneuer[10], Dagmar Kubistin[10], Adrien Jacotot[11], Benjamin Loubet[12], Pedro-Henrique Herig-Coimbra[12], Denis Loustau[13] & Ingrid T. Luijkx[2]



The European carbon sink has diminished by 60 TgC in 2O22

30% less compared to a normal « year »

NIRv: vegetation index
GPP: gross primary prod.
NEP: net ecosystem prod.
SIB4: model

ICOS Integrated Carbon Observation System

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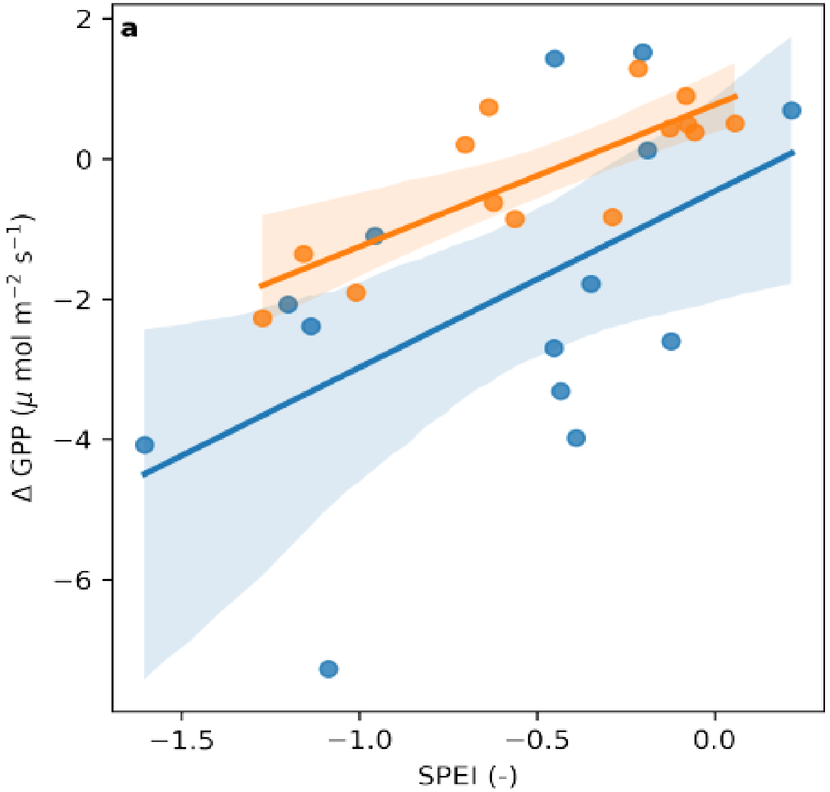
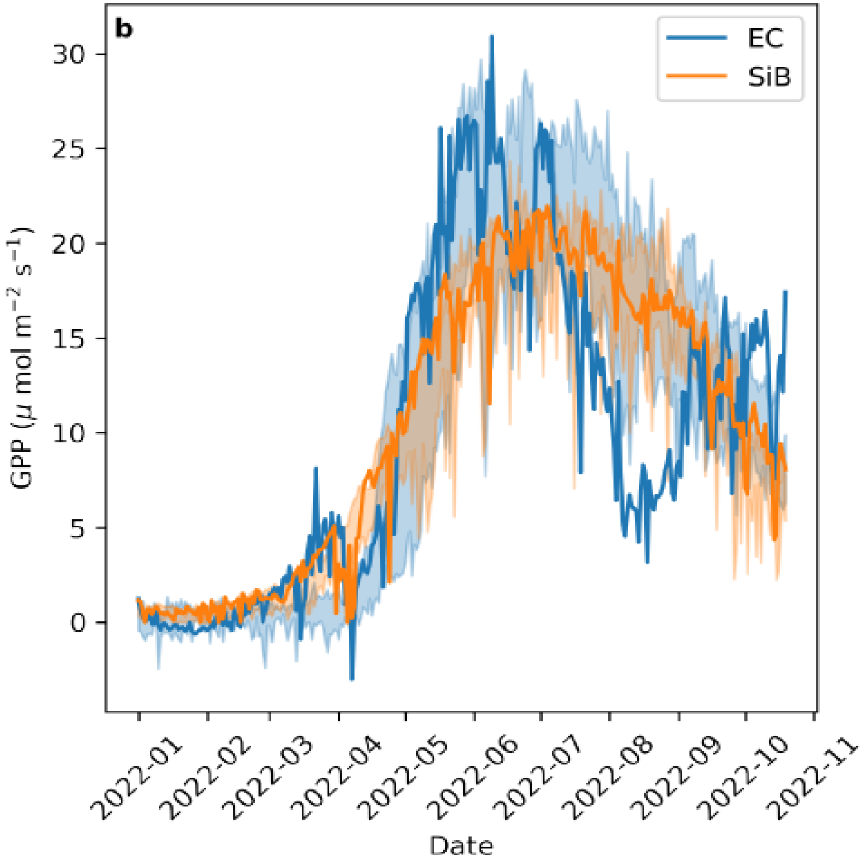
All sites



SPEI: soil water index

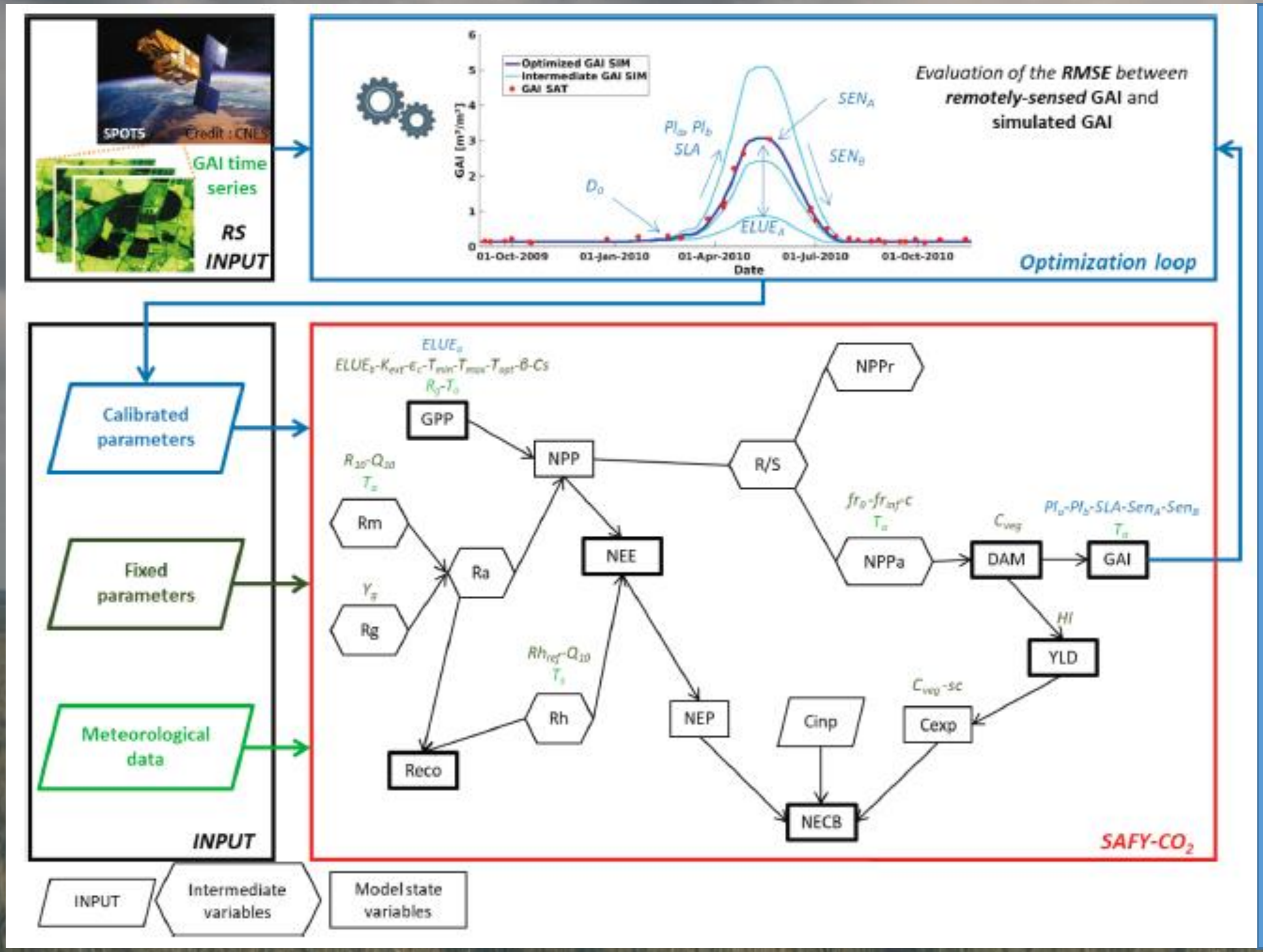
FR-Hes (French beech forest in Nancy)



The main difference between the in situ measurement (EC) and the model (SIB) is the wrong representation of soil water in the model

GPP: gross primary productivity
EC: eddy covariance measurement
SIB4: vegetation model

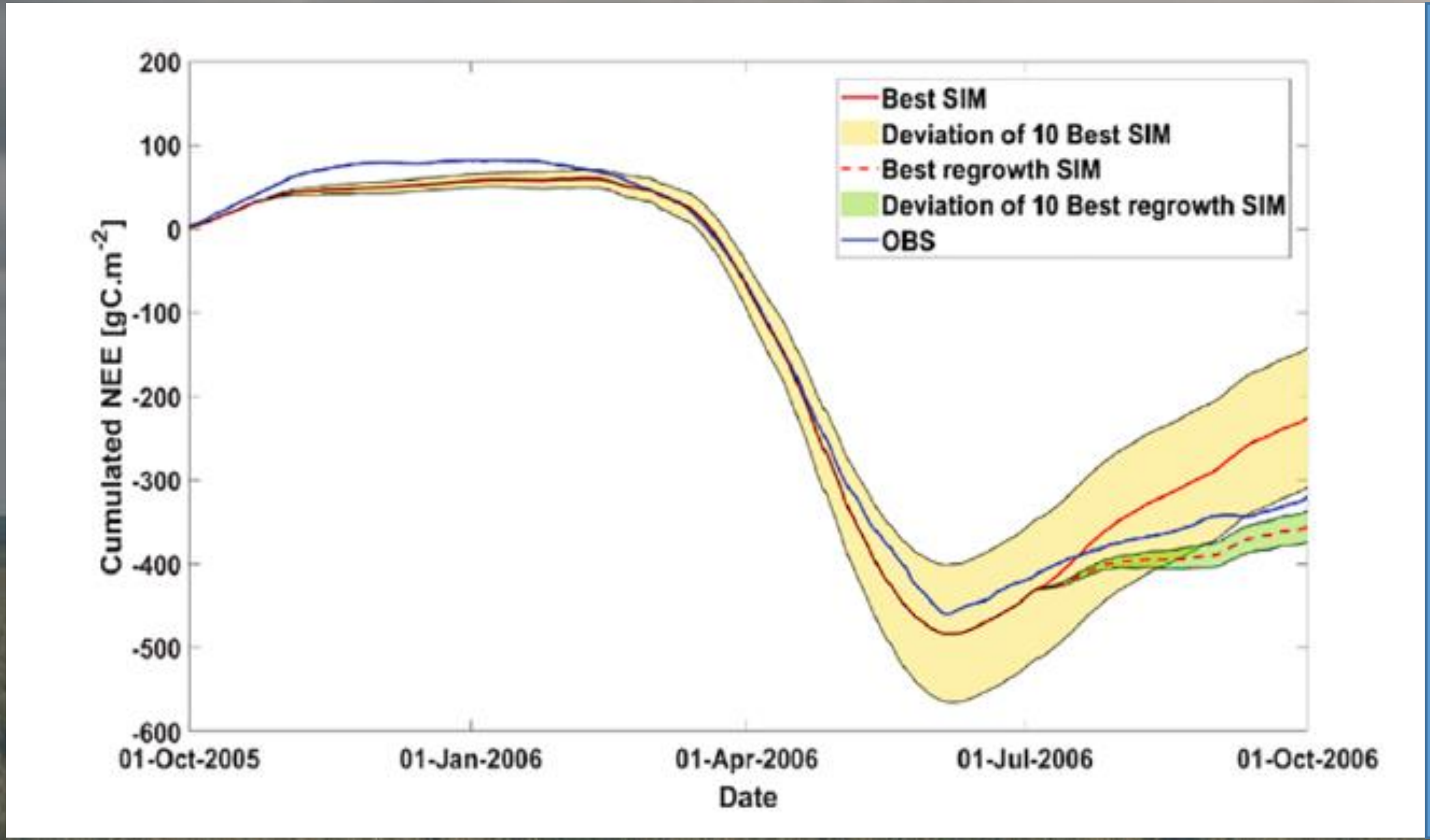
Crop carbon balance using remote sensing (SAFYE-CO_2)



- Crop model based on remotely sense green area index (GAI)
- Parameterised crop phenology is optimised to fit observed GAI
- GPP and Reco are modelled
- Reco is less constrain than GPP
- Validation against ICOS sites show discrepancies

https://doi.org/10.3390/rs12182967
https://doi.org/10.1016/j.geoderma.2020.114428

Crop carbon balance using remote sensing (SAFYE-CO_2)



Validation against ICOS sites show discrepancies during

- winter (respiration is not well modelled)
- End of summer (regrowth)

https://doi.org/10.3390/rs12182967
https://doi.org/10.1016/j.geoderma.2020.114428

Flux de CO2 annuels de grandes cultures

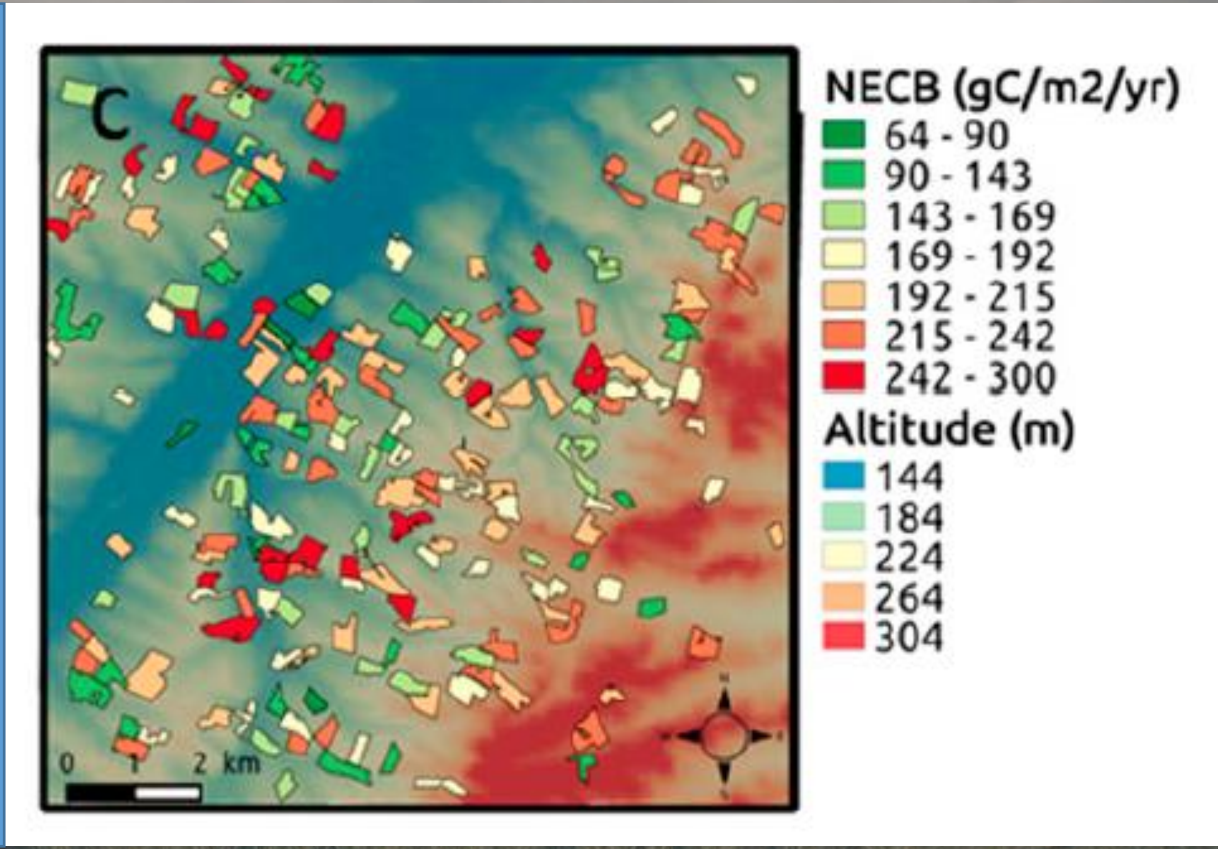
Most sites are carbon sources

RMSE of the order of 1 g C m^{-2} $jour^{-1}$ if in-situ soil information

RMSE much higher when using Global Soil Map and Soil Grid

High demand for these appraoches for « carbon farming » control

Map of net ecosystem carbon balance in close region near Toulouse



https://doi.org/10.3390/rs12182967
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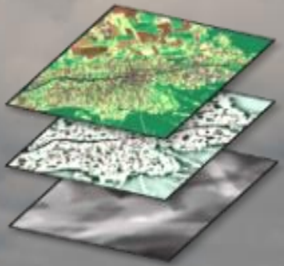
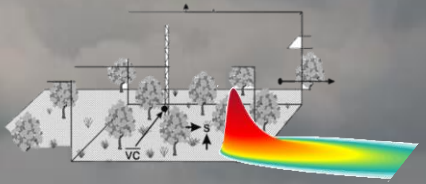
CO_2 flux quantification at high resolution

surface flux

Remote data surface model



footprint model



Bayesian inversion

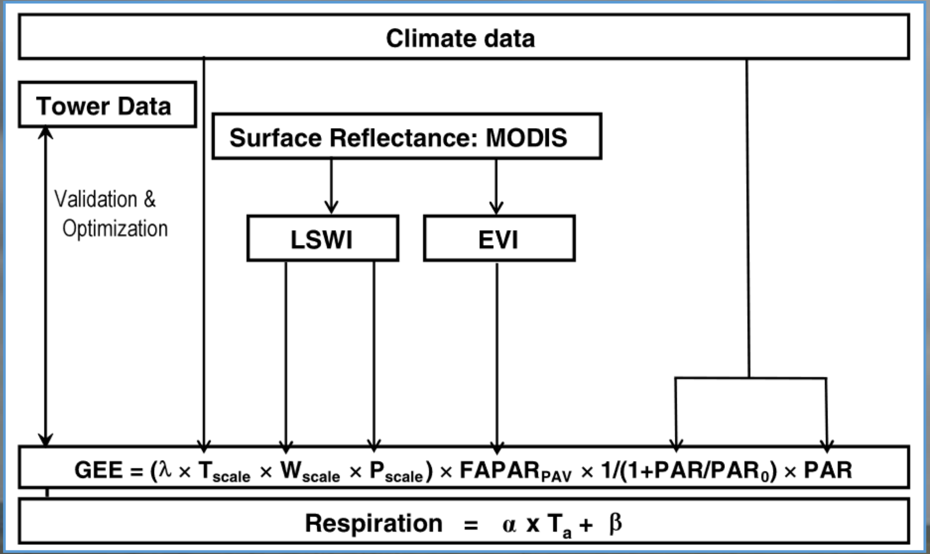
$$x^a = x^b + \underbrace{BH^T(HBH^T + R)^{-1}}_{relaxation}\underbrace{(y - Hx^b)}_{innovation}$$

y = CO2 flux
H = surface and footprint models
B and R Bayesian inversion matrixes

PhD Pedro Herig Coimbra, INRAE-LSCE, 2021-2024

CO_2 flux quantification at high resolution

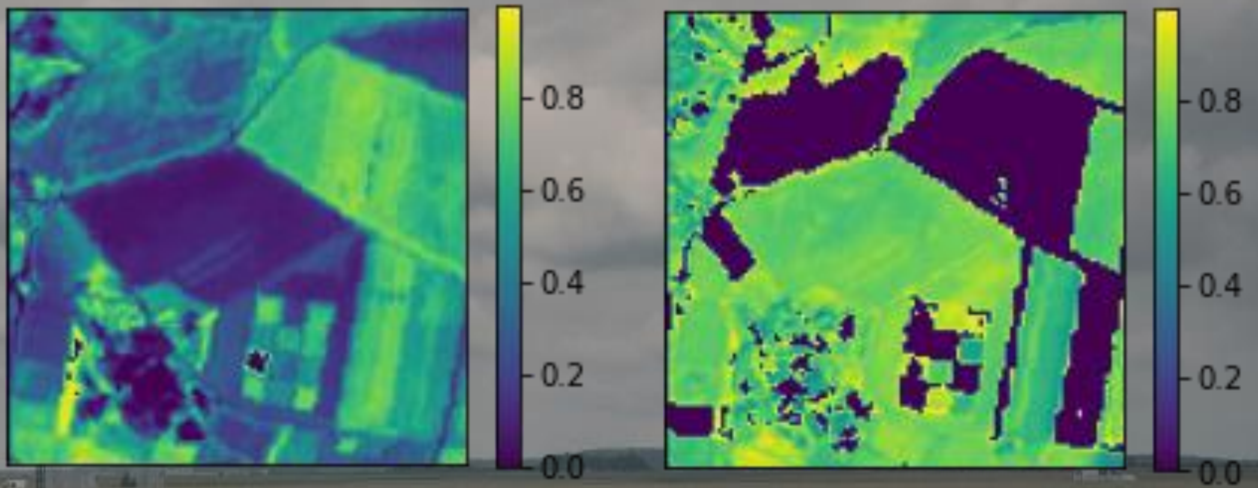
The VPRM light-efficiency model



Mahadevan (2008)

EVI (vegetation index)

18/06/2019 23/07/2019



The modified VPRM model

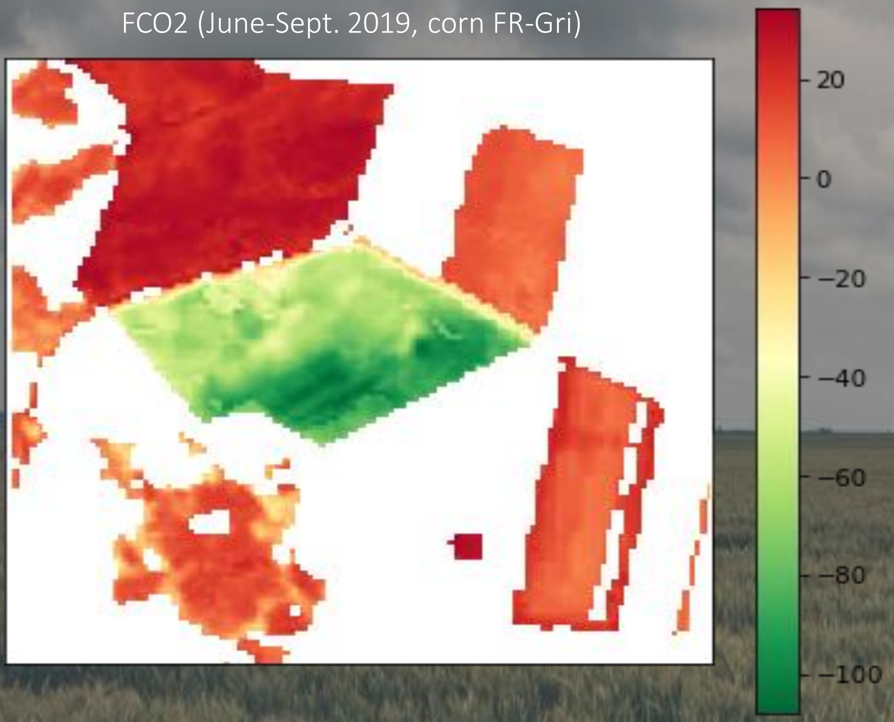
$$GPP = f(\theta) \times \lambda \times T_{scale} \times P_{scale} \times W_{scale} \times EVI \times \left(\frac{1}{1+\frac{SWRad}{SWRad_0}}\right) \times PAR$$

$$R_{eco} = f(T) \times g(\theta) \times f(GEE)$$

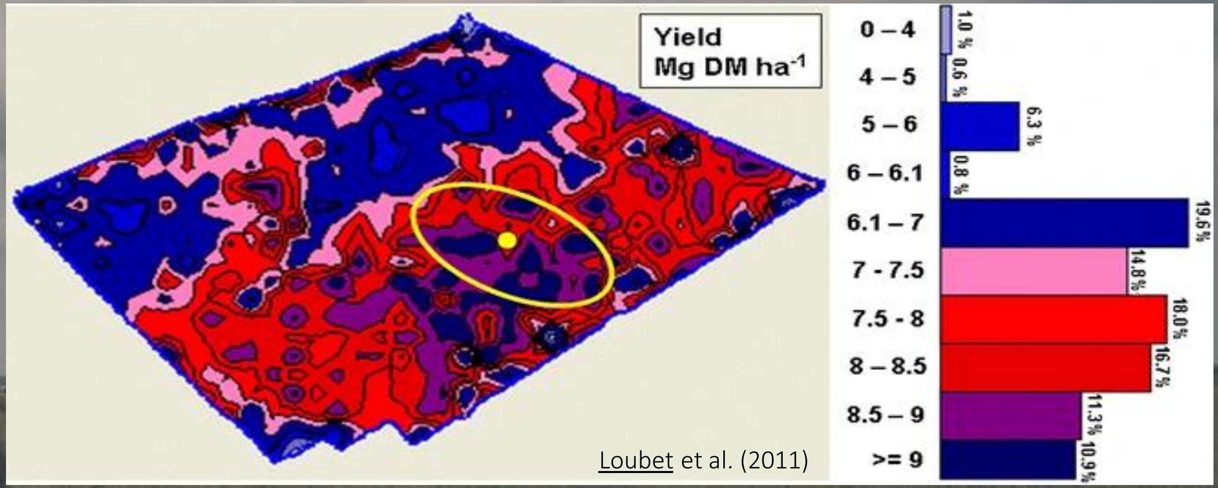
Example of CO_2 flux at the FR-GRI ICOS site

FCO2 (June-Sept. 2019, corn FR-Gri)

FCO_2



Spatial yield measured over wheat

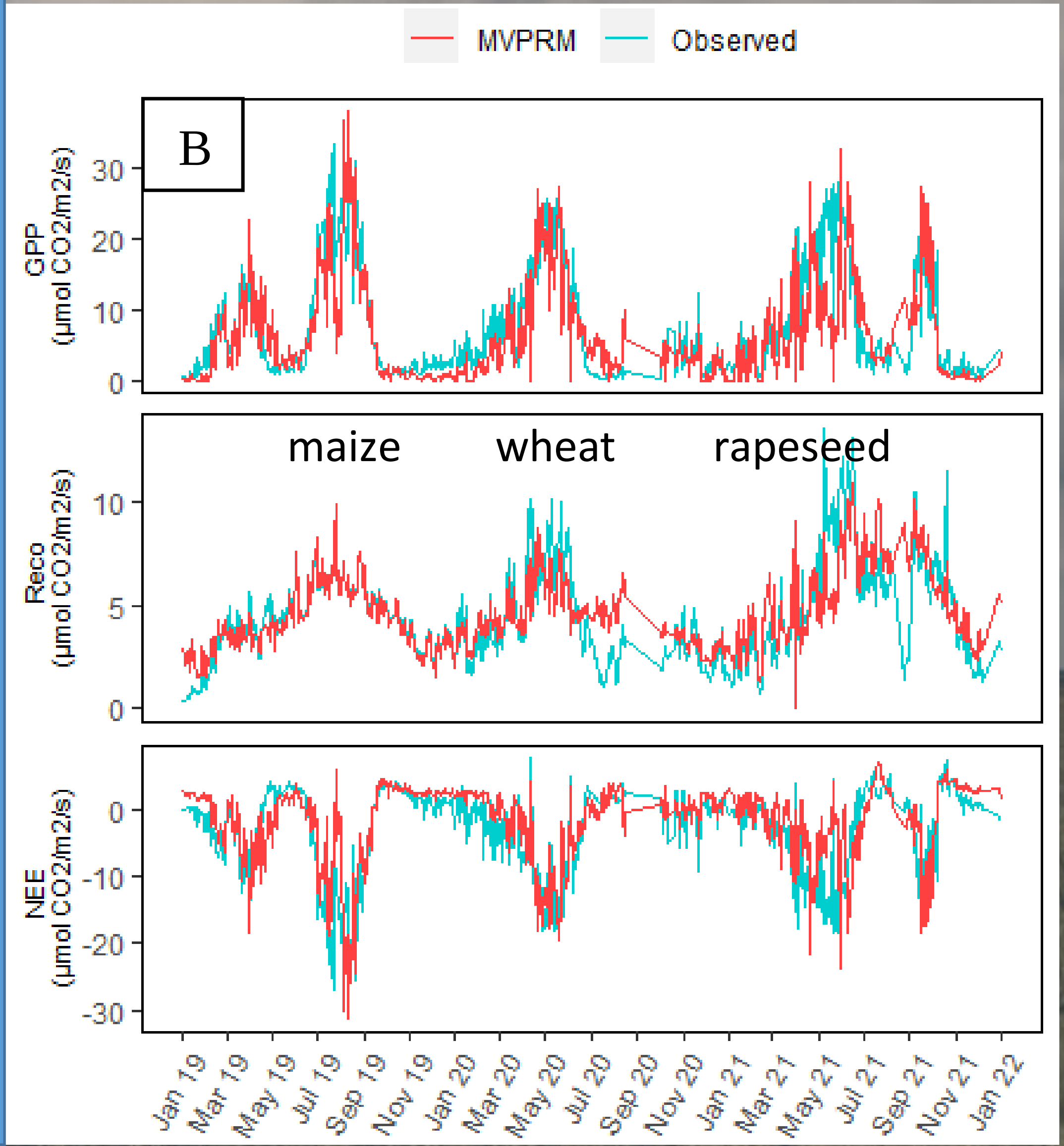


CO_2 flux quantification at high resolution

Comparison with ICOS observation is relatively good

GPP underestimated during some periods

No constraint on the overall year but use of daily values



Manuela Njiki, Master 2 report, 2023

Importance of coupling pollutant exchange with T_s e_s, T_{soil} and e_{soil}

Biogeosciences, 6, 1371–1388, 2009
www.biogeosciences.net/6/1371/2009/

Biogeosciences

SURFATM-NH3: a model combining the surface energy balance and bi-directional exchanges of ammonia applied at the field scale

E. Personne[1], B. Loubet[1], B. Herrmann[2], M. Mattsson[3], J. K. Schjoerring[3], E. Nemitz[4], M. A. Sutton[4], and P. Cellier[1]

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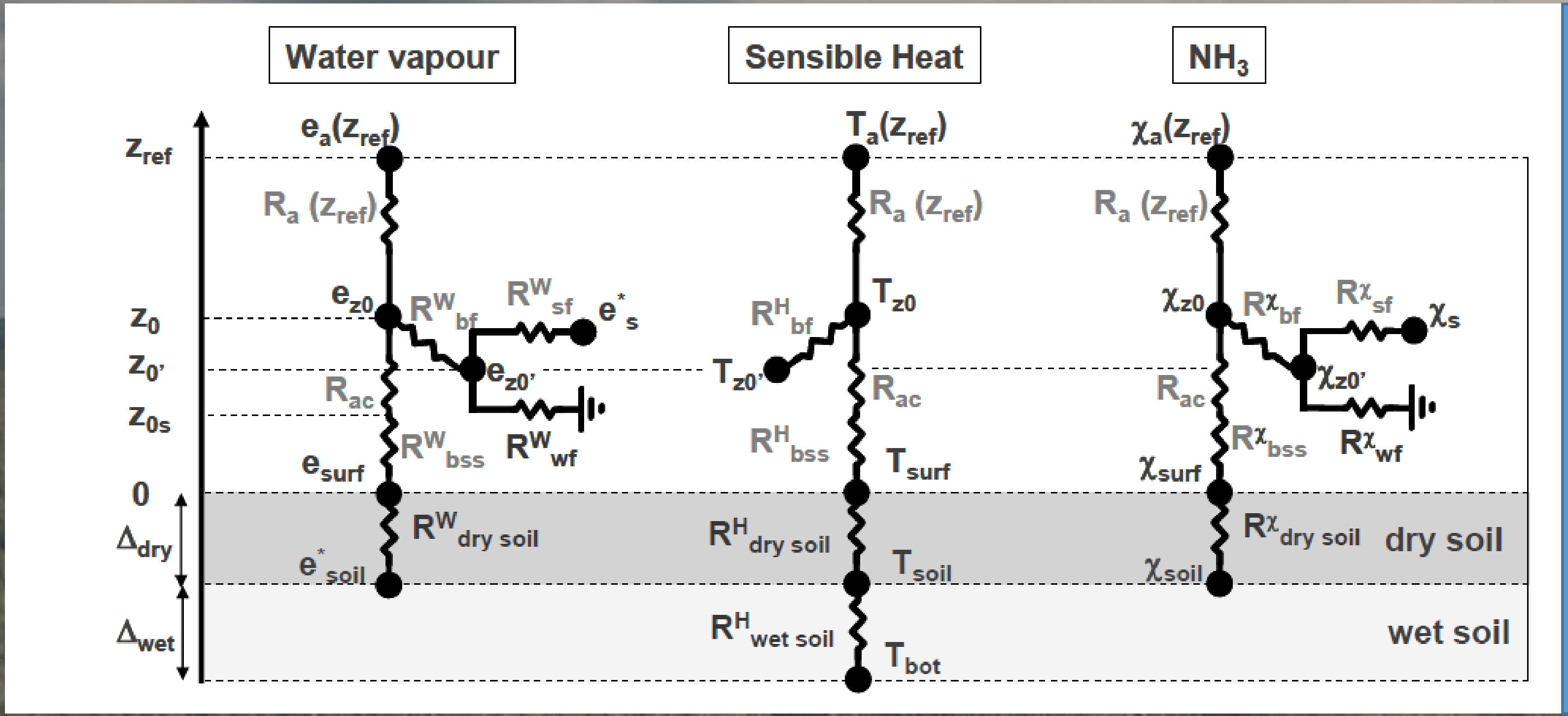
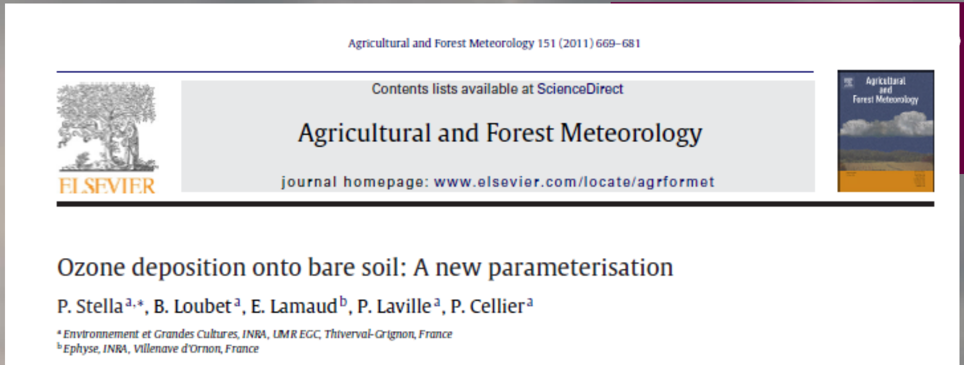
[2]Agroscope Reckenholz-Tänikon Research Station ART, Reckenholzstrasse 191, 8046 Zürich, Switzerland
[3]Plant and Soil Science Laboratory, University of Copenhagen, Faculty of Life Sciences, Thorvaldsensvej 40, 1871 Frederiksberg C, Copenhagen, Denmark
[4]Centre for Ecology and Hydrology, Edinburgh Research Station, Bush Estate, Penicuik, Midlothian, EH26 0QB, UK



Ammonia, ozone, NOx, and N2O fluxes are highly dependent on surface temperature and humidity

Models combines heat and pollutants exchanges

Ozone fluxes


Agricultural and Forest Meteorology 151 (2011) 669–681

Contents lists available at ScienceDirect

Agricultural and Forest Meteorology

journal homepage: www.elsevier.com/locate/agrformet

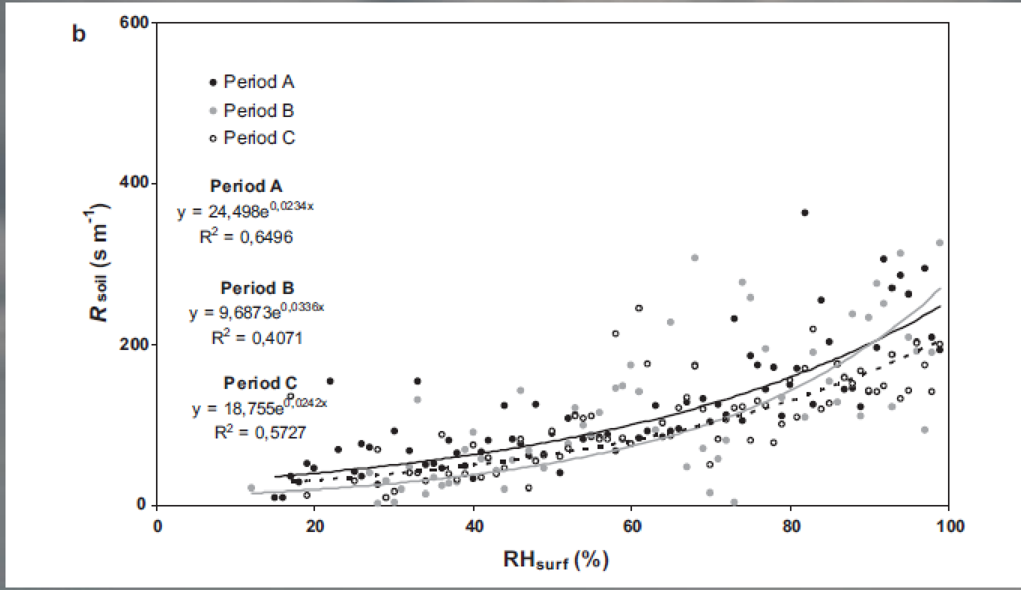
ELSEVIER

Ozone deposition onto bare soil: A new parameterisation

P. Stella[a,*], B. Loubet[a], E. Lamaud[b], P. Laville[a], P. Cellier[a]

[a] Environnement et Grandes Cultures, INRA, UMR EGC, Thiverval-Grignon, France

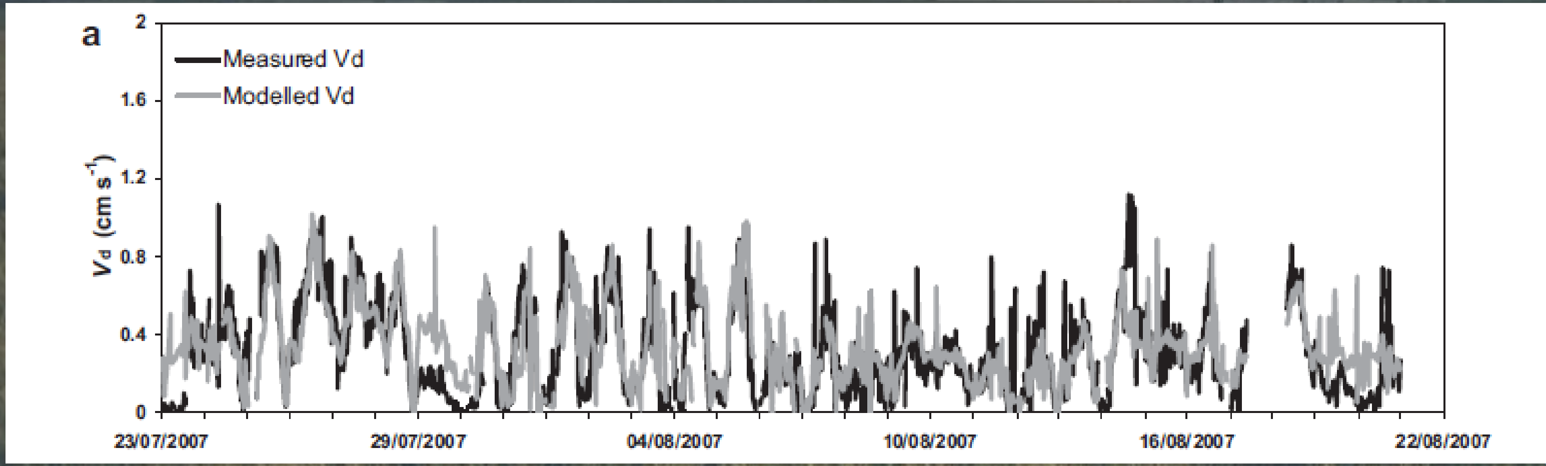
[b] Ephyse, INRA, Villenave d'Ornon, France



$$V_d(z) = \frac{1}{R_a(z) + R_{b\,O_3} + R_{soil}}$$

$$R_a(z) = \frac{u(z)}{u_*^2} - \frac{\Psi_H(z/L) - \Psi_M(z/L)}{k u_*}$$

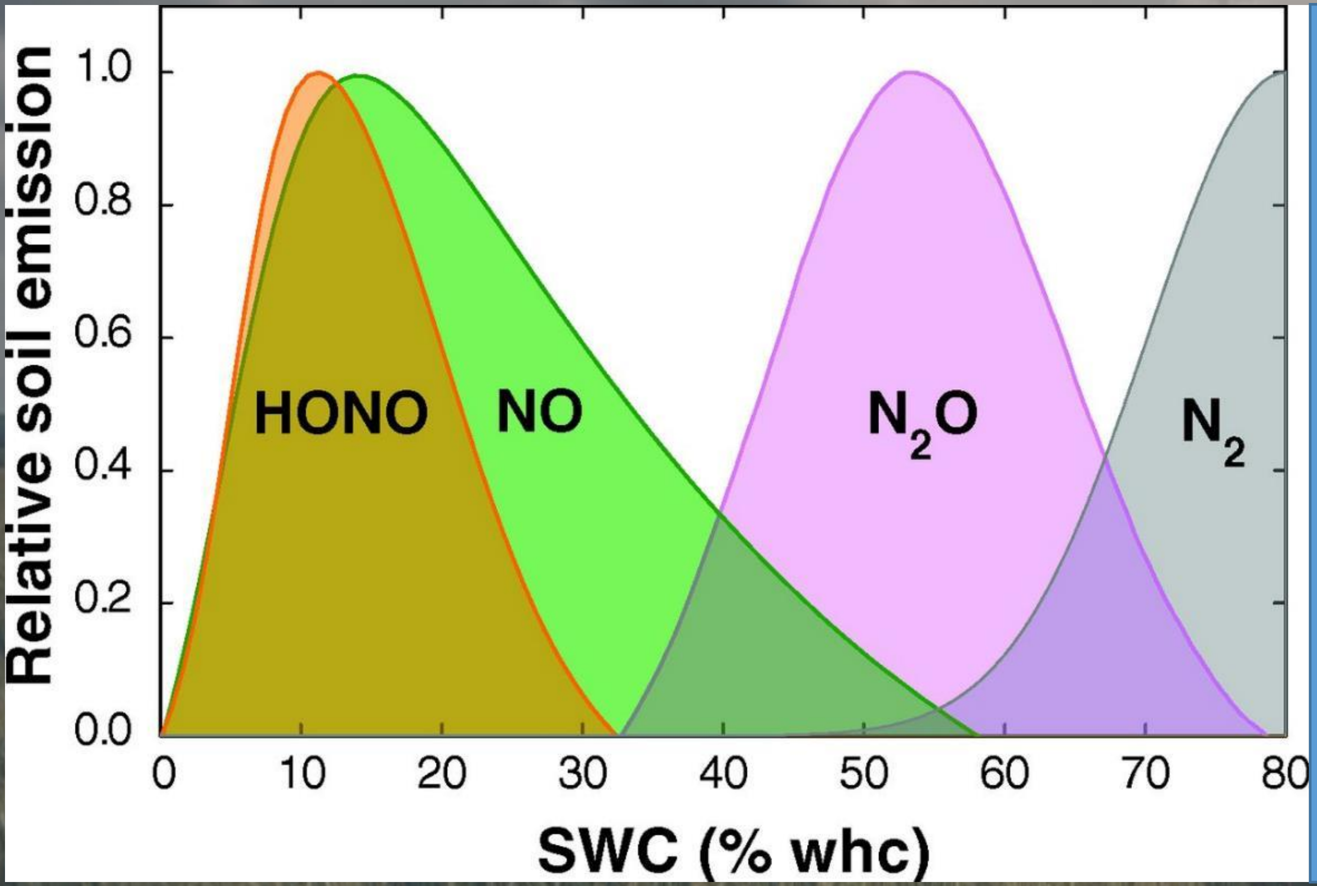
$$R_b = (B_{St} u_*)^{-1}$$



Soil resistance for ozone better represented by surface relative humidity than air relative humidity

HONO Emissions from Soil Bacteria as a Major Source of Atmospheric Reactive Nitrogen

R. Oswald,[1,2]*† T. Behrendt,[1,3]† M. Ermel,[1,2]† D. Wu,[1,4] H. Su,[5] Y. Cheng,[5] C. Breuninger,[1] A. Moravek,[1,6] E. Mougin,[7] C. Delon,[8] B. Loubet,[9] A. Pommerening-Röser,[10] M. Sörgel,[1] U. Pöschl,[5] T. Hoffmann,[2] M.O. Andreae,[1] F.X. Meixner,[1] I. Trebs[1]*



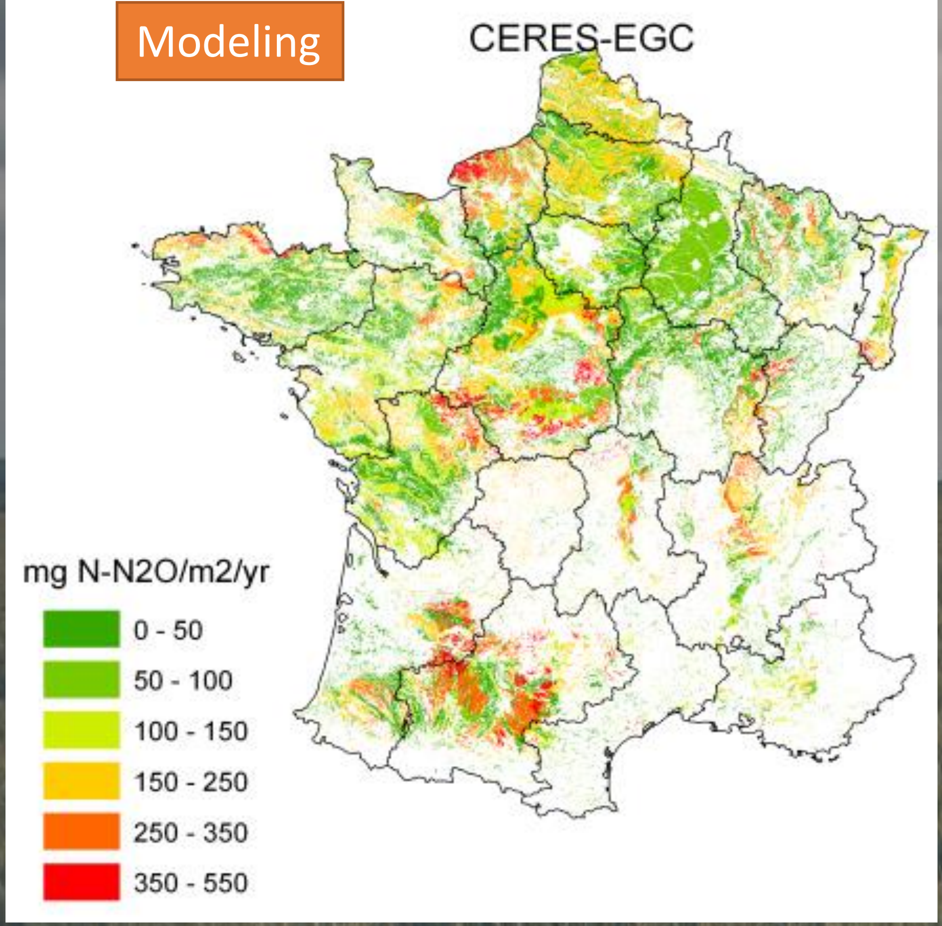
Soil water content is key for N species emissions partitioning

Oswald et al. Science 2013

Regional variations in N_2O fluxes in France

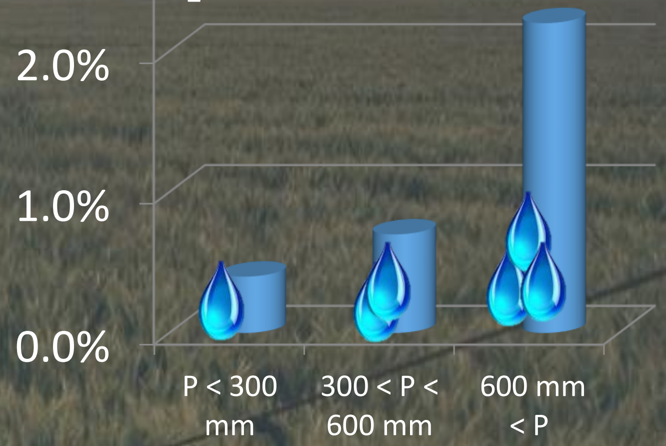
Crops emissions

Modeling



Emissions are higher
- In N fertilisation area
- In well watered soils

N_2O emission factor

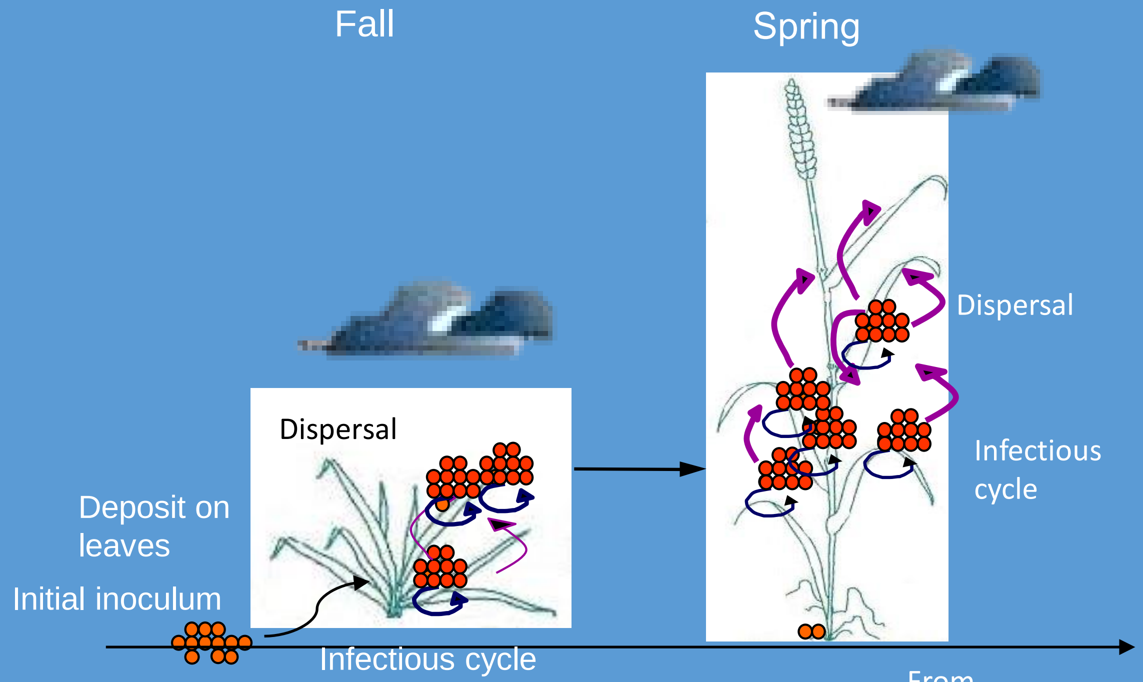


Fungal diseases

Septoria and brown rust on wheat

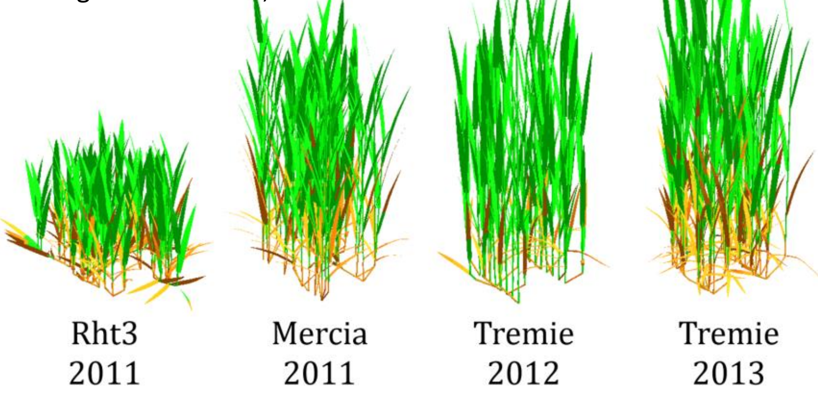
Spores grow in wet conditions

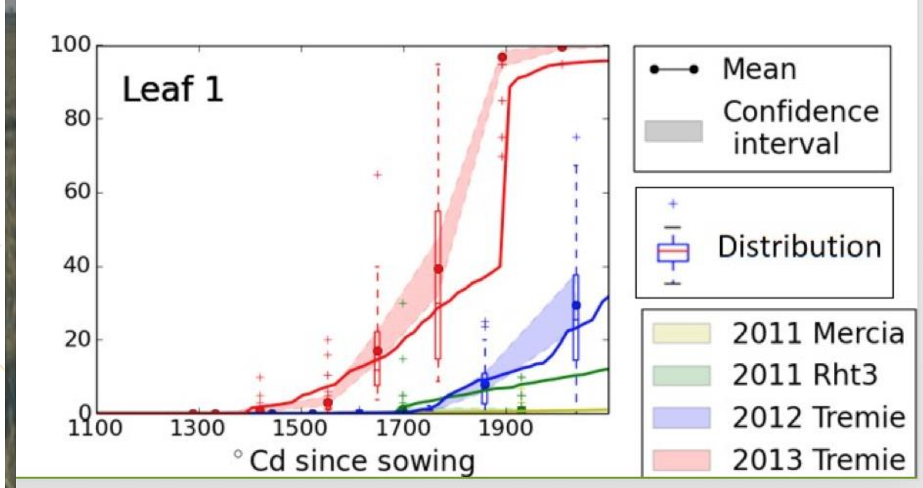
Dispersal by rain and wind



From
Robert *et al.* (2008)

Robert et al. 2007, 2018,
Garin 2012,
Précigout et al. 2018, 2020





Example of disease growth on several wheat varieties

Conclusions

- To improve model and operational tools for surface fluxes of pollutants and greenhouse gases:
- A need for
  - high resolution leaf area and biomass
  - High resolution soil water content
  - Leaf and soil temperatures
  - Soil texture
- More links between satelite data providers and modelers
- Calibration sites are key for these developments