
Implementation of vegetation and soil carbonyl sulfide (COS) exchanges in the Land Surface Model ORCHIDEE

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Context: COS potential as a Gross Primary Production (GPP) proxy

Objectives

Implementation of an accurate representation of ecosystem COS exchanges in the Land Surface Model ORCHIDEE

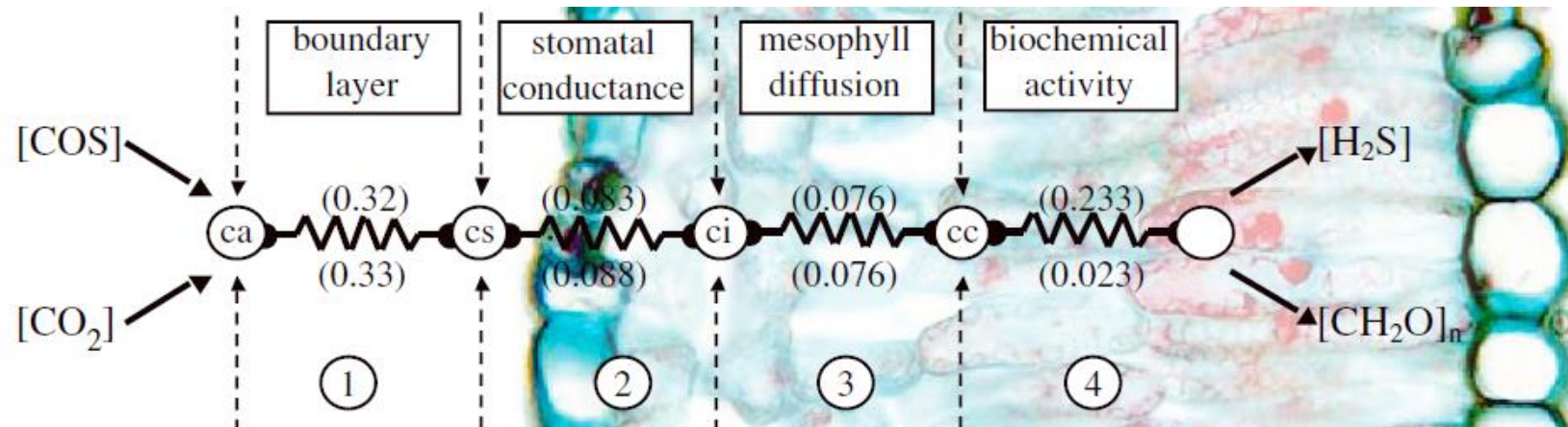


Vegetation COS flux model + Soil COS flux model

Use data assimilation techniques to constrain GPP-related parameters

Vegetation COS flux model

- Mechanistic representation of COS diffusion through the leaf



Resistance analog
model of CO₂ and COS
(Berry et al., 2013)

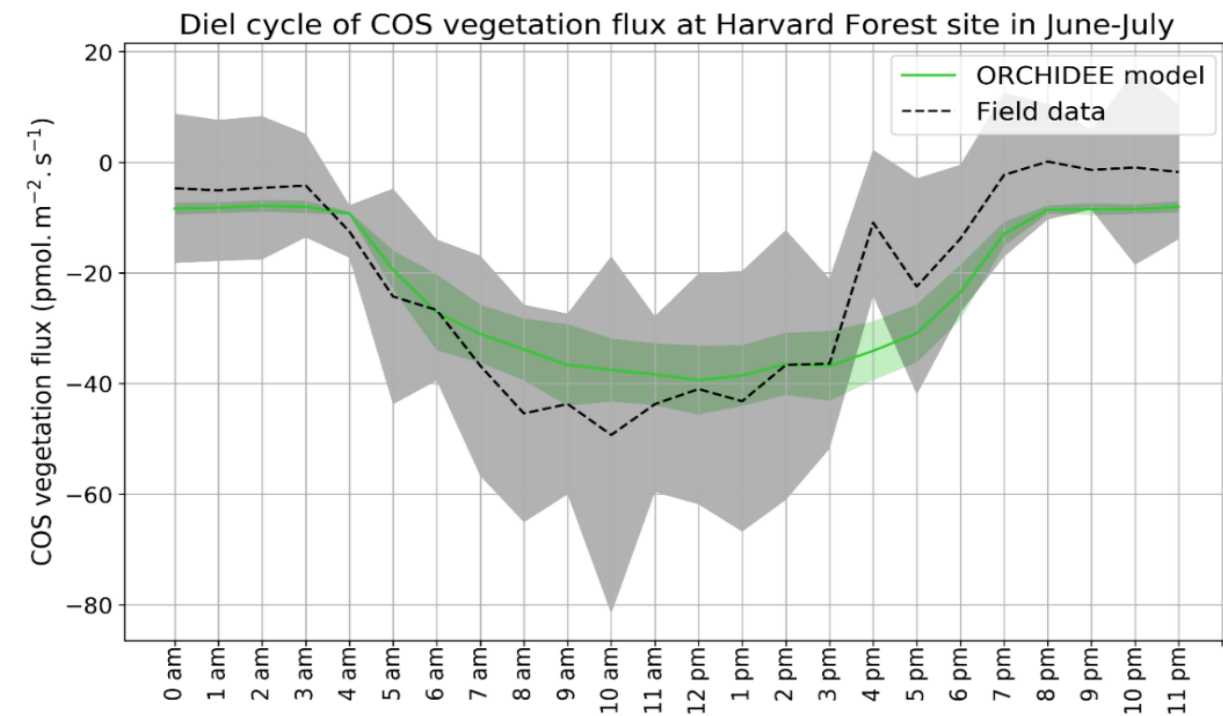
$$F_{COS} = [COS]_{atm} * \left[\frac{1.56}{g_{B_Water}} + \frac{1.94}{g_{S_Water}} + \frac{1.0}{g_{I_COS}} \right]^{-1}$$

with $g_{I_COS} = \alpha V_{cmax}$

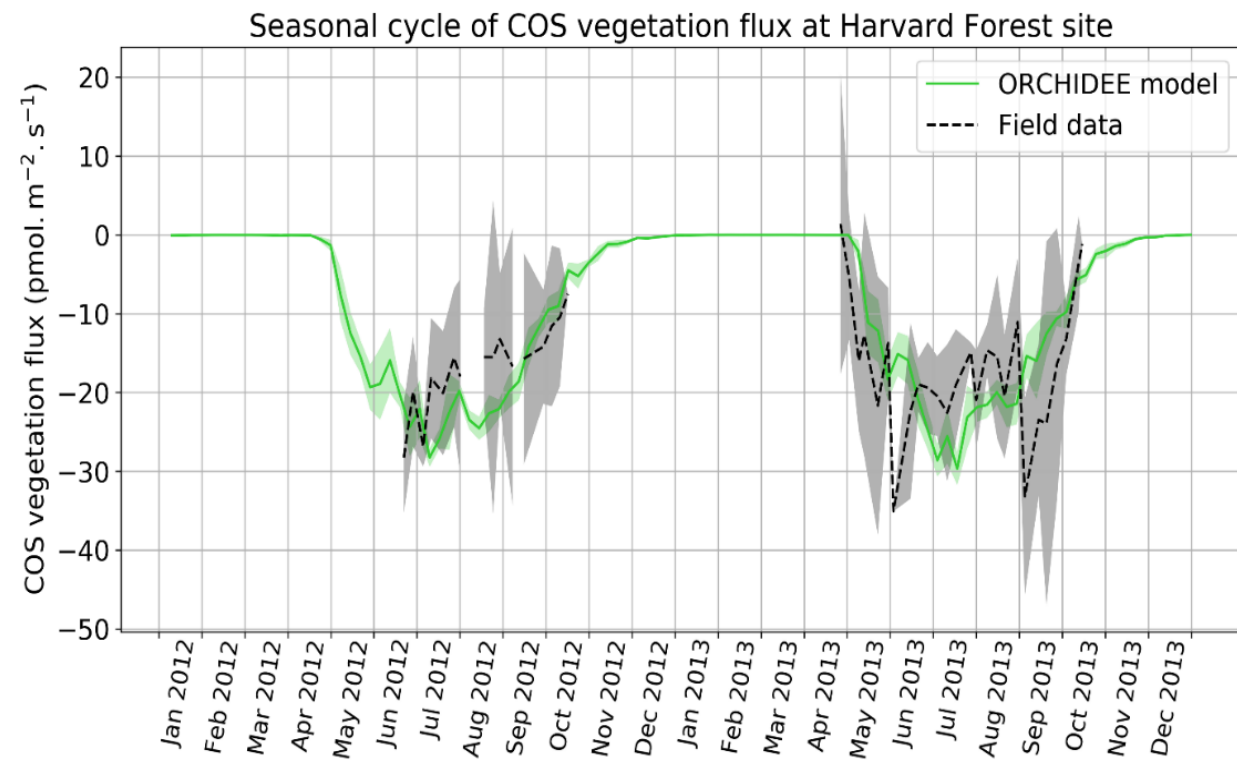
[COS]_{atm}: atmospheric COS concentration

g_{B_Water} , g_{S_Water} , g_{I_COS} : boundary layer, stomatal, intern conductance

Model evaluation against field measurements



RMSD = $8.0 \text{ pmol m}^{-2} \text{ s}^{-1}$

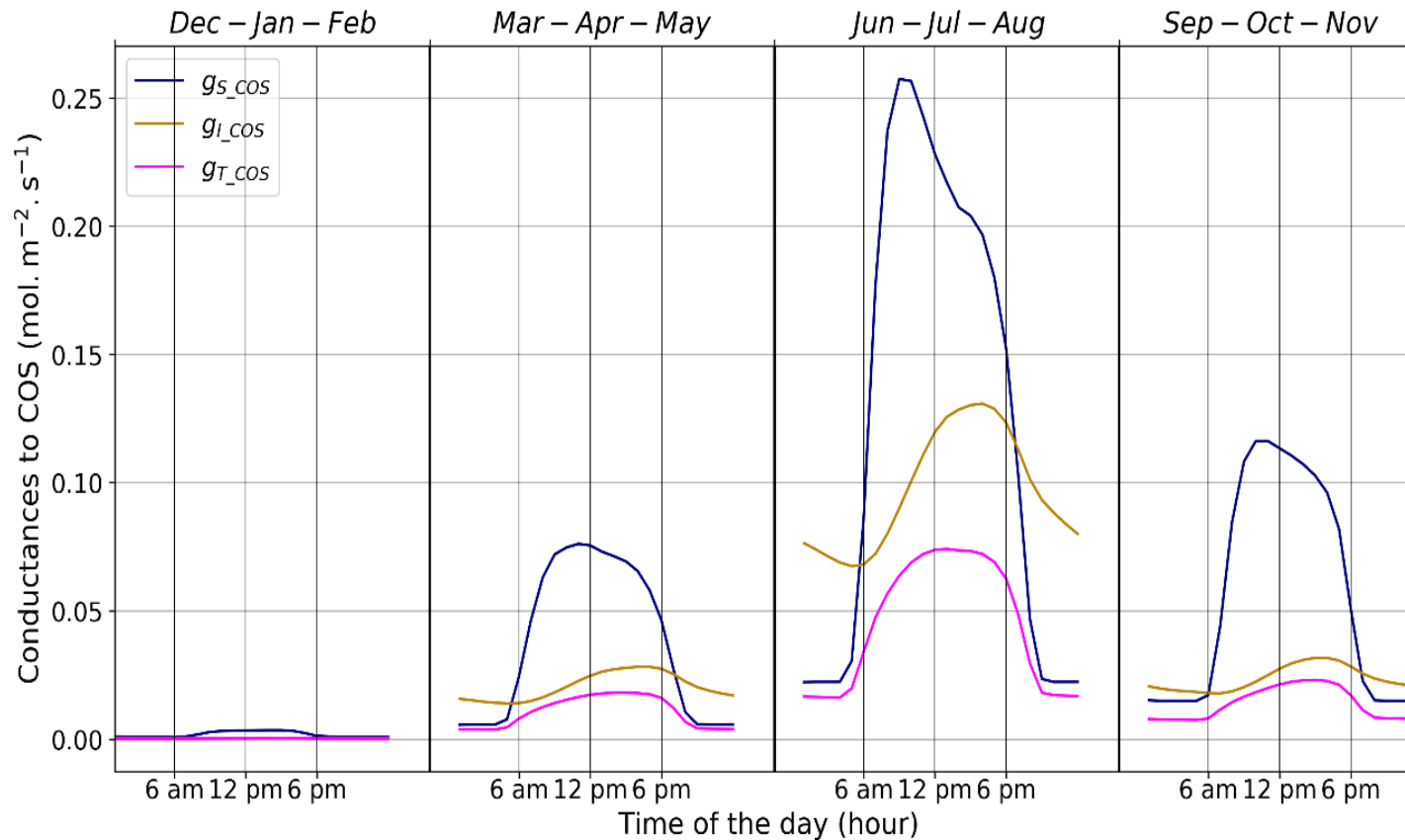


RMSD = $7.5 \text{ pmol m}^{-2} \text{ s}^{-1}$

Maignan et al. (accepted)

Information on the limiting conductance to COS diffusion

a. Diel cycles of g_{S_COS} , g_{I_COS} and g_{T_COS} for each season at the Harvard site in 2012

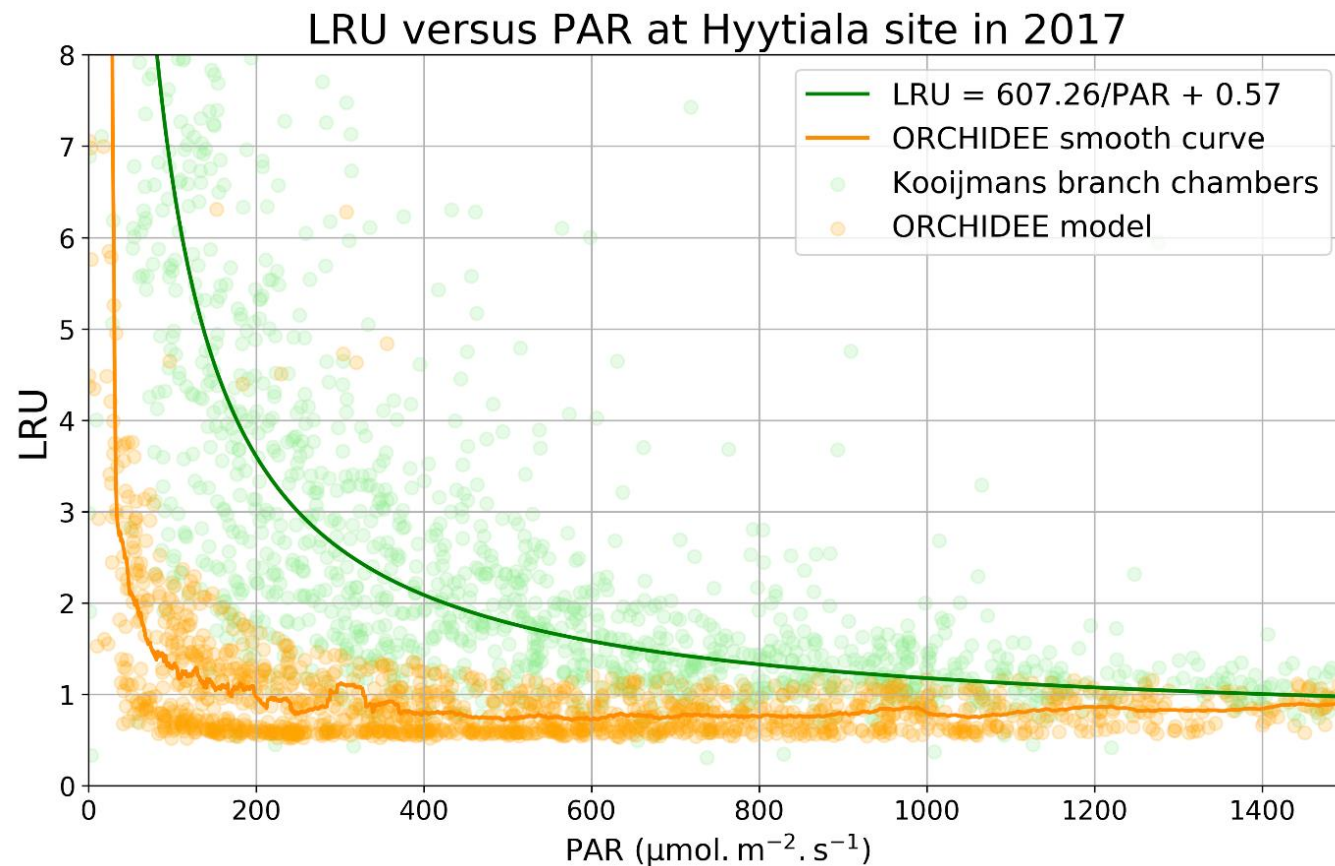


→ COS diffusion mainly limited by the stomatal conductance during nighttime

→ COS diffusion mainly limited by the intern conductance during daytime

Comparison between the vegetation model and the LRU approach

The Leaf Relative Uptake approach (LRU): $LRU_{biome} = \frac{F_{COS} [CO_2]_{atm}}{GPP [COS]_{atm}}$



→ LRU varies with light

→ The mechanistic vegetation COS model enables to account for the influence of light variations in COS diffusion

Computation of an optimized LRU per biome

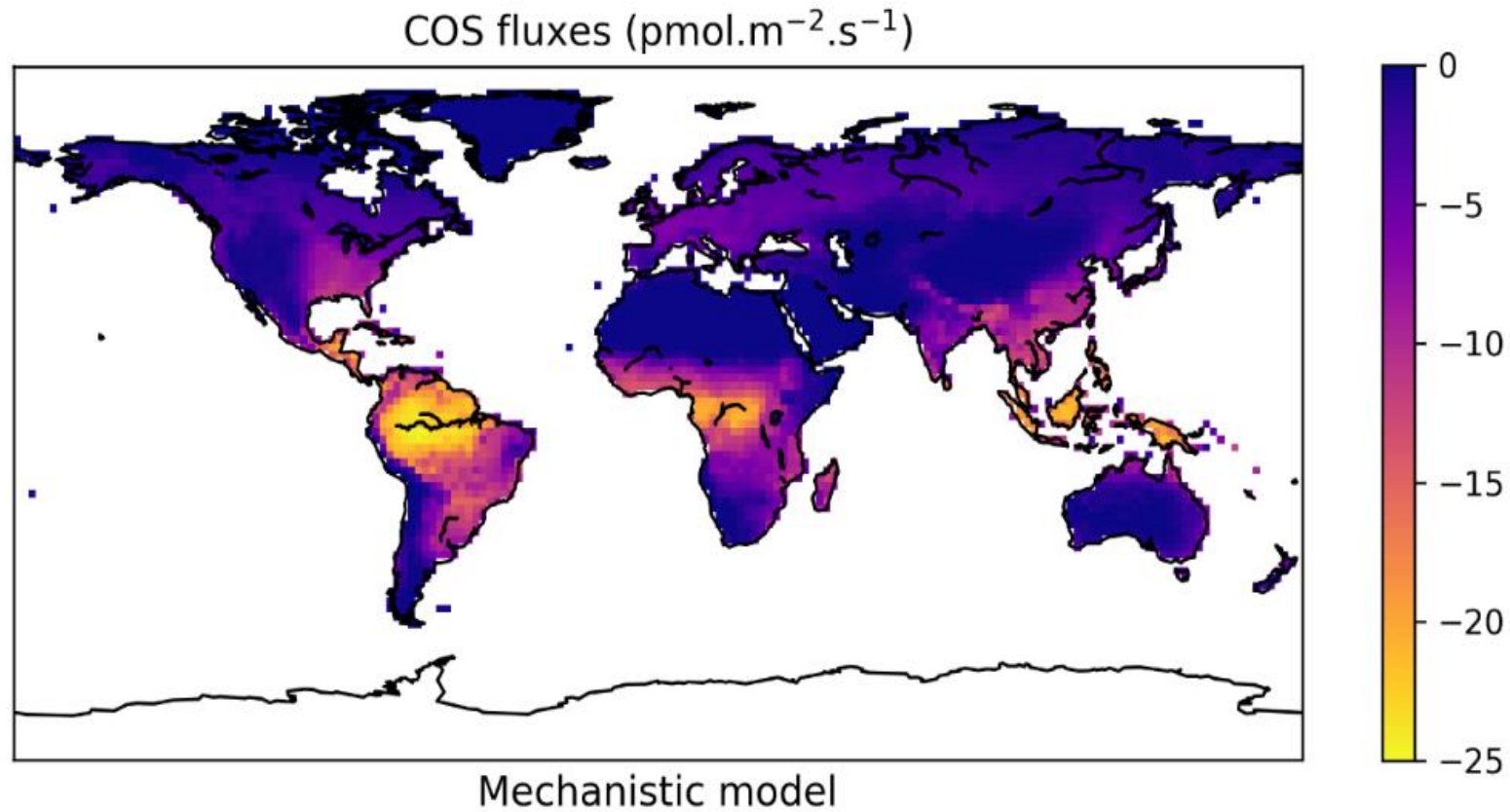
- Computed using a monthly climatology of modelled GPP and COS fluxes

$$LRU_{Opt_{biome}} = \frac{\sum_{n=1}^N F_{COS}^{Mod}(n) GPP^{Mod}(n) \frac{[COS(n)]_{atm}}{[CO_2(n)]_{atm}}}{\sum_{n=1}^N \left(F_{COS}^{Mod}(n) \right)^2}$$

n: number of grid cell-month simulated fluxes where the biome is present in the monthly climatology

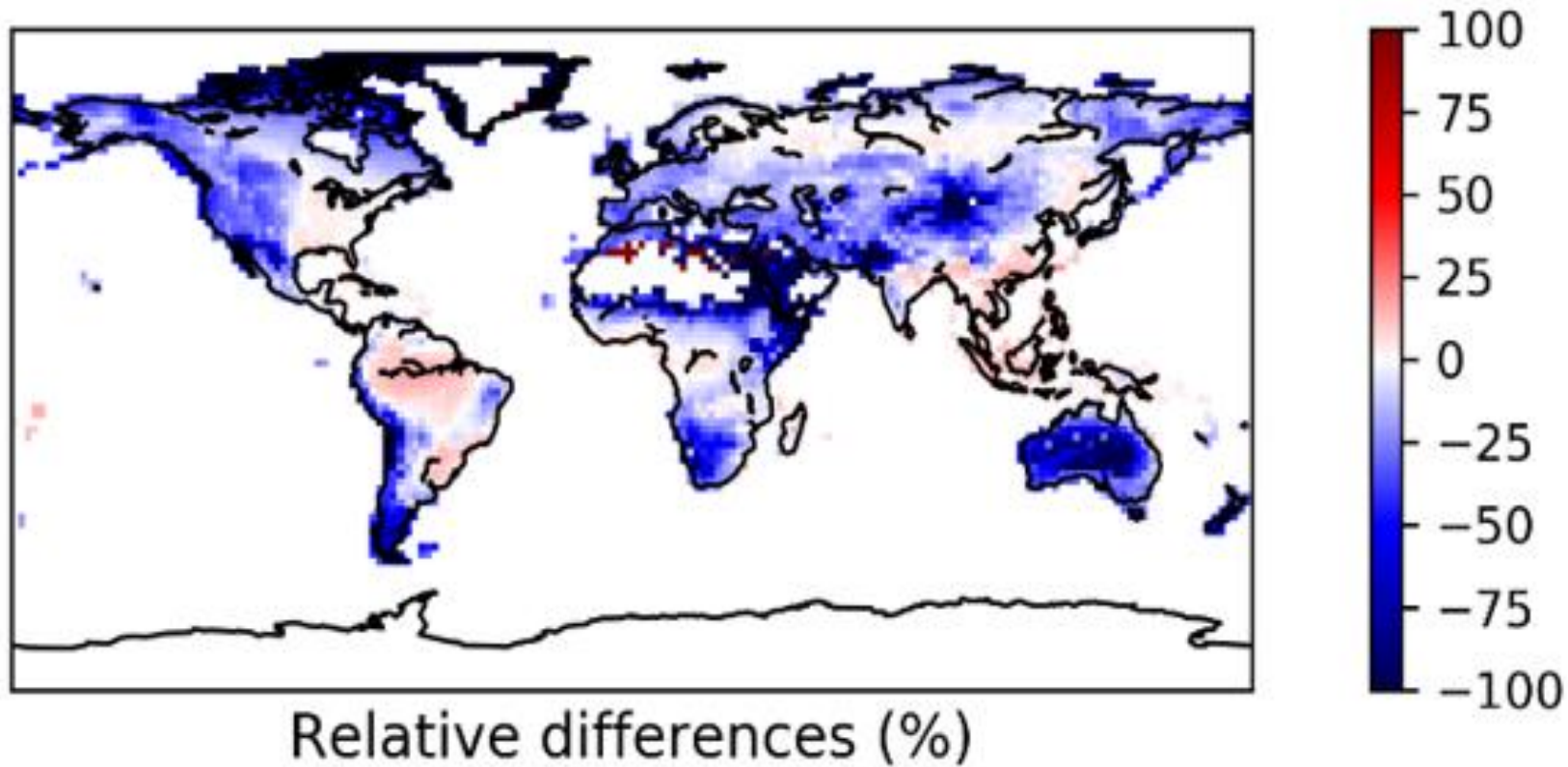
From site-scale fluxes to global-scale fluxes

- Spatial distribution of vegetation COS fluxes



Spatial discrepancy introduced with the LRU approach

- Differences between mechanistic and LRU-based fluxes

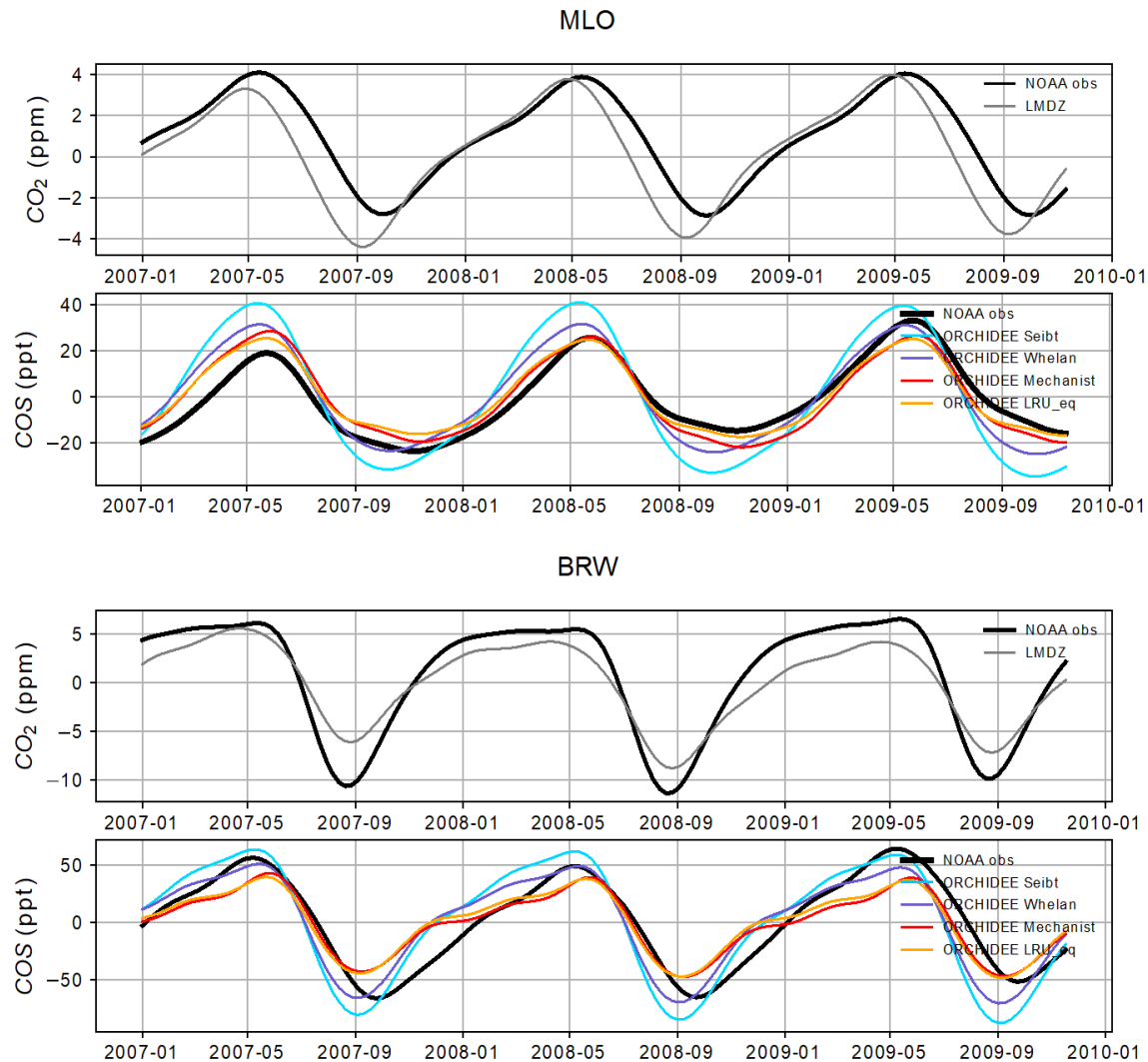


Vegetation contribution to COS global budget

	Kettle et al. (2002)	Montzka et al. (2007)	Suntharalingam et al. (2008)	Berry et al. (2013)	Launois et al. (2015b)			This study
					ORC.	LPJ	CLM4	
Period study	circa 1990-2000	2000-2005	2001-2005	2002-2005	2006-2009			2000-2009
Uptake by plants	-238 (± 30)	-730 to -1500	-490 (-460 to -530)	-738	-1335	-1069	-930	-756

Transport of COS fluxes with LMDz

- Evaluation of COS concentrations against NOAA measurements (Mauna Loa and Barrow stations)



ORCHIDEE Seibt: transport using LRU values from Seibt et al. (2010)

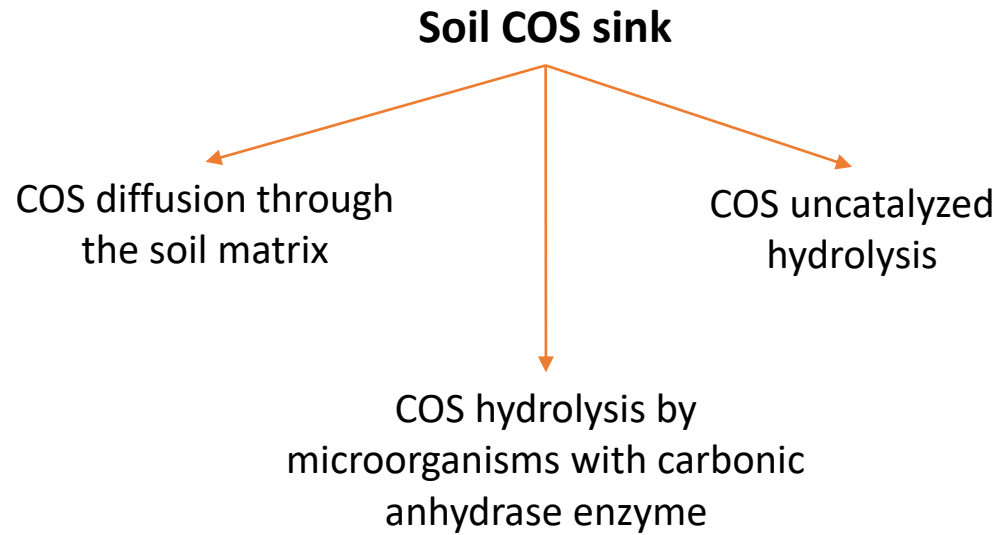
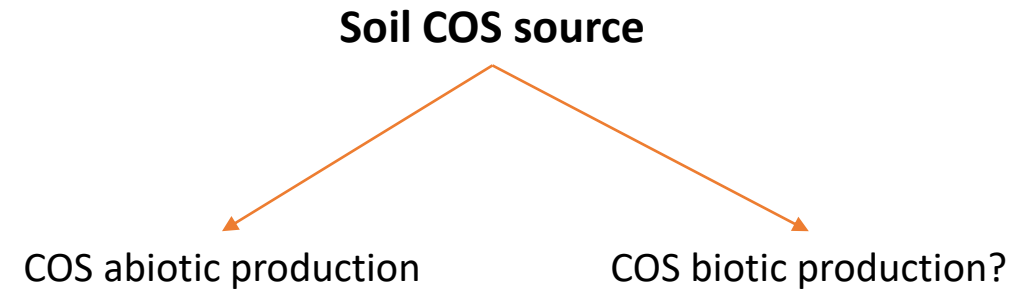
ORCHIDEE Whelan: transport using LRU values from Whelan et al. (2018)

→ The mechanistic vegetation COS model without any calibration performs similarly to the LRU approach

Next steps for vegetation COS flux model

- Consider variable atmospheric COS concentrations in the diffusion model instead of a constant average of 500 ppt
- Use available field measurements to optimize the model parameters:
 α in g_{I_COS}
- Data assimilation to better constrain GPP-related parameters

Soil COS exchanges



→ Soils contribute to ecosystem COS exchanges

→ Soil contribution to COS global budget

Context: Soil COS exchanges need to be accounted for in ecosystem COS exchanges and differentiated from vegetation COS fluxes

Implement soil COS exchanges in the Land Surface Model ORCHIDEE



ORCHIDEE
LAND SURFACE MODEL

Compare an empirical and a mechanistic representation

Objectives

- Evaluate soil COS flux models against field measurements
- Compare the use of 2 soil classifications: Zobler versus USDA
- Quantify the impact of considering a constant versus a variable atmospheric COS concentration
- Represent soil COS flux spatial distribution
- Evaluation the soil contribution to COS global budget
- Transport soil COS fluxes with the LMDz transport model

- **Empirical model**

Soil COS uptake proportional to total soil respiration R :

$$F_{soil,empirical} = -k_{soil} * R$$

Adapted from Berry et al. (2013)

$k_{soil} = 1.2 \text{ mol COS/mol CO}_2 \rightarrow$ constant to converts CO_2 production from respiration to a COS uptake (Yi et al., 2007).

No representation of soil COS production.

- **Mechanistic model**

Soil COS flux based on the mass balance equation:

$$\frac{\partial \varepsilon_{tot} C}{\partial t} = -\frac{\partial F_{diff}}{\partial z} + P - U$$

Ogée et al. (2016)

- F_{diff} : COS diffusion through the soil matrix
- P : COS abiotic production
- U : COS uptake by soil microorganism hydrolysis and uncatalyzed hydrolysis

Soil COS production function of soil temperature:

$$P = e^{\alpha + \beta * T}$$

Whelan et al. (2016)

Available field measurement sites of soil CO₂ fluxes

