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Supplement of

Global modelling of soil carbonyl sulfide exchanges

Camille Abadie et al.

Correspondence to: Camille Abadie (camille.abadie.research@gmail.com)

Table S1. Soil textures for the USDA texture classification.

USDA texture classes
1- Sand
2- Loamy sand
3- Sandy loam
4- Silt loam
5- Silt
6- Loam
7- Sandy clay loam
8- Silty clay loam
9- Clay loam
10- Sandy clay
11- Silty clay
12- Clay

Table S2. USDA textures initially assigned in ORCHIDEE and the substituted textures from the observations at the studied sites. Textures are in bold when the imposed texture differs from the one initially assigned in ORCHIDEE.

	Initial	Substituted
ES-LMA	3- Sandy loam	3- Sandy loam
DK-SOR	3- Sandy loam	3- Sandy loam
IT-CRO	**3- Sandy loam**	**4- Silt loam**
AT-NEU	3- Sandy loam	3- Sandy loam
ET-JA	3- Sandy loam	3- Sandy loam
FI-HYY	**2- Loamy sand**	**3- Sandy loam**
US-HA	**1- Sand**	**3- Sandy loam**

Table S3: First-order parameters.

Parameter name in ORCHIDEE	Parameter name in the model description	Description (unit)	Specificity	Range
Empirical model				
ksoil	k_{soil}	Proportionality factor for soil COS fluxes (pmol COS µmol^{-1} CO_2)	(-)	±1.08 pmol COS µmol^{-1} CO_2
Mechanistic model				
FCA	f_{CA}	CA enhancement factor (unitless)	PFT-dependent	See Meredith et al., (2019) Table 1
α	α	COS production parameter (unitless)	PFT-dependent	See Text S1 and Table S5
β	β	COS production parameter (°C^{-1})	PFT-dependent	See Text S1 and Table S5

12 **Table S4: Second-order parameters.**

Parameter name in ORCHIDEE	Description (unit)	Specificity	Range
Photosynthesis parameters			
Vcmax25	Maximum rate of Rubisco activity-limited carboxylation at 25°C (µmol m^{-2} s^{-1})	PFT-dependent	±45% (Mahmud et al., 2021)
Zroot	Root profile in empirical plant water stress function calculation (m)	PFT-dependent	See Mahmud et al. (2021)
Tmin	Minimum photosynthesis temperature (°C)	PFT-dependent	Vegetated PFTs: -9, 1 (Mahmud et al., 2021)
Tmax	Maximum photosynthesis temperature (°C)	PFT-dependent	Vegetated PFTs: 50, 60 (Mahmud et al., 2021)
Conductance parameters			
g0	Residual stomatal conductance when irradiance approaches zero (mol m^{-2} s^{-1} bar^{-1})	PFT-dependent (C_3 or C_4 plant types)	C_3 plants: 0.00565, 0.00685 C_4 plants: 0.01675, 0.02075 (Mahmud et al., 2021)
Phenology parameters			
SLA	Specific leaf area (m^2 gC^{-1})	PFT-dependent	See Mahmud et al. (2021)
Soil hydrology parameters			

n	Van Genuchten water retention curve coefficient n (unitless)	Soil texture-dependent	±40% (Dantec-Nédélec et al., 2016)
a	Van Genuchten water retention curve coefficient a (unitless)	Soil texture-dependent	±50% (Dantec-Nédélec et al., 2016)
Ks	Hydraulic conductivity at saturation	Soil texture-dependent	±40%
θWP	Volumetric water content at wilting point (%)	Soil texture-dependent	±20% (Dantec-Nédélec et al., 2016)
θFC	Volumetric water content at field capacity (%)	Soil texture-dependent	±20% (Dantec-Nédélec et al., 2016)
θR	Residual volumetric water content (m^3 m^{-3})	Soil texture-dependent	±20% (Dantec-Nédélec et al., 2016)
θSAT	Saturated volumetric water content (m^3 m^{-3})	Soil texture-dependent	±20% (Dantec-Nédélec et al., 2016)
θTransp_max	Fraction of saturated volumetric soil moisture above which transpiration is maximum (unitless)	Soil texture-dependent	±20% (Dantec-Nédélec et al., 2016)
C_dry	Dry soil heat capacity (J m^{-3} K^{-1})	Soil texture-dependent	±20% (Dantec-Nédélec et al., 2016)
Post carbon uptake and allocation parameters			
soilC	Scalar on the active soil C pool content to account for uncertainty in spinup (unitless)	(-)	0.5, 2 (Mahmud et al., 2021)

soil_Q10	Temperature dependency factor for heterotrophic respiration ($Q10=exp^{SOIL\_Q10}$) (unitless)	(-)	FI-HYY: 0.53, 1.36 (Barba et al., 2018) US-HA: 0.88, 1.37 (Giasson et al., 2013)
Min_SWC_resp	Minimum soil wetness to limit the heterotrophic respiration (unitless)	(-)	0.1, 0.6 (Mahmud et al., 2021)

Text S1: Determination of the variation range for α and β parameters.

The values of the α and β parameters are found in Whelan et al. (2016), but no range of variation is given. A similar expression of the production term is defined in Meredith et al. (2018),

$$P_{Meredith} = P_{ref} * Q_{10}^{\frac{(T - T_{ref})}{10}} \quad \text{(S1)}$$

with P_{ref} (mol m^{-3} s^{-1}) the COS flux at T_{ref} (°C).

Using the correspondence between the production term describe in Whelan et al. (2016) and Meredith et al. (2018),

$$e^{\alpha + \beta * T} = P_{ref} * Q_{10}^{\frac{(T - T_{ref})}{10}} \quad \text{(S2)}$$

$$\alpha = \log\left(P_{ref} * Q_{10}^{-\frac{T_{ref}}{10}}\right) \quad \text{(S3)}$$

$$\beta = \frac{1}{10}\, log\,(Q_{10}) \quad \text{(S4)}$$

Using the identity $\log(a * b^x) = \log(a) + x * \log(b)$ and taking the derivatives, we obtain the following error propagation:

$$\Delta\alpha = \frac{\Delta P_{ref}}{P_{ref}} + \frac{\Delta Q_{10}}{Q_{10}} \quad \text{(S5)}$$

$$\Delta\beta = \frac{1}{10} * \frac{\Delta Q_{10}}{Q_{10}} \quad \text{(S6)}$$

Meredith et al. (2018) indicate a ±1 uncertainty on Q_{10} and a 50% uncertainty on P_{ref}.

$$\Delta\alpha = \frac{0.5 * P_{ref}}{P_{ref}} + \frac{1}{e^{10*\beta}} \quad \text{(S7)}$$

$$\Delta\beta = \frac{1}{10} * \frac{1}{e^{10*\beta}} \quad \text{(S8)}$$

Table S5: Ranges of variation for α and β parameters.

PFT	$\Delta\alpha$	$\Delta\beta$
1 - Bare soil	NA	NA
2 - Tropical broad-leaved evergreen	1.41	0.0364
3 - Tropical broad-leaved raingreen	1.41	0.0364
4 - Temperate needleleaf evergreen	1.26	0.0304
5 - Temperate broad-leaved evergreen	1.26	0.0304
6 - Temperate broad-leaved summergreen	1.26	0.0304
7 - Boreal needleleaf evergreen	1.26	0.0304
8 - Boreal broad-leaved summergreen	1.26	0.0304
9 - Boreal needleleaf summergreen	1.26	0.0304
10 - C_3 grass	1.35	0.0340
11 - C_4 grass	1.35	0.0340
12 - C_3 agriculture	1.46	0.0383
13 - C_4 agriculture	1.46	0.0383
14 - Tropical C_3 grass	1.35	0.0340
15 - Boreal C_3 grass	1.35	0.0340

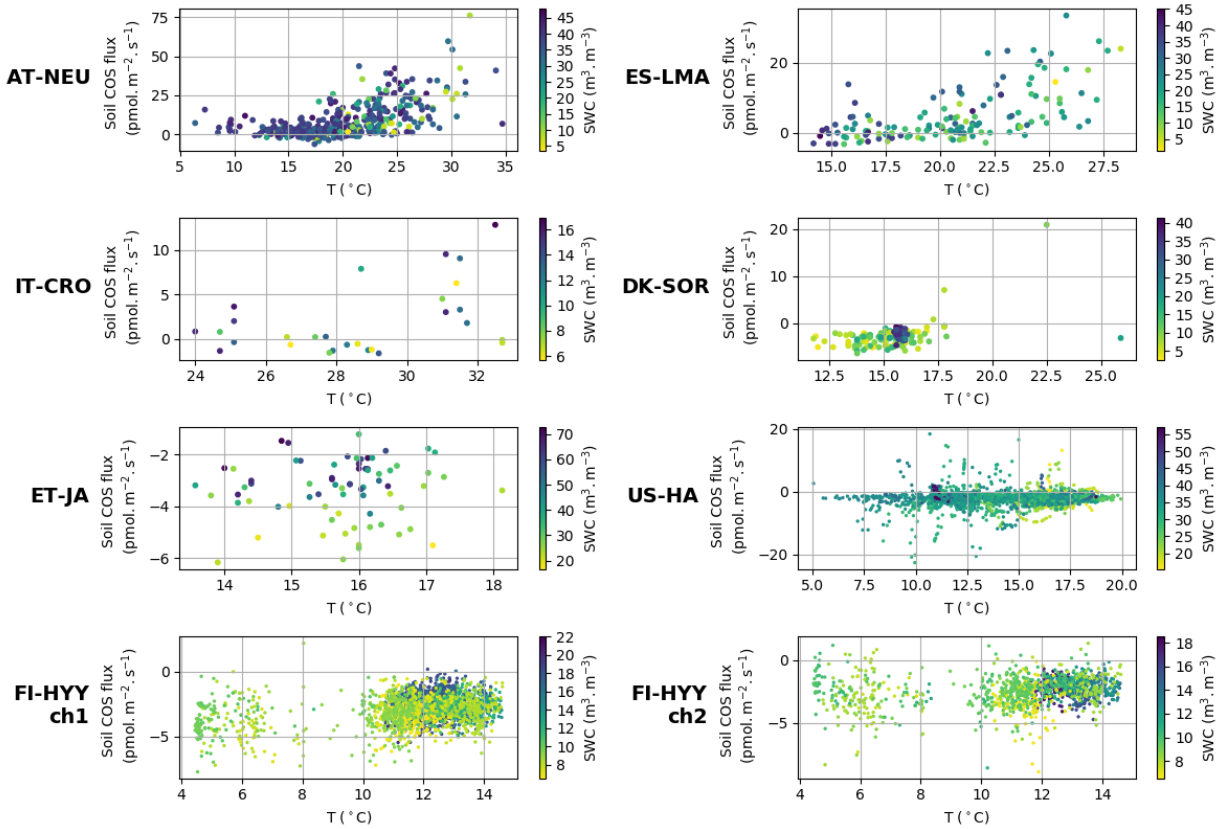

Figure S1: Observed net soil COS flux (pmol m^2 s^{-1}) versus soil temperature (°C) and soil water content (SWC) ($m^3.m^{-3}$) at AT-NEU, ES-LMA, IT-CRO, DK-SOR, ET-JA, US-HA and FI-HYY.

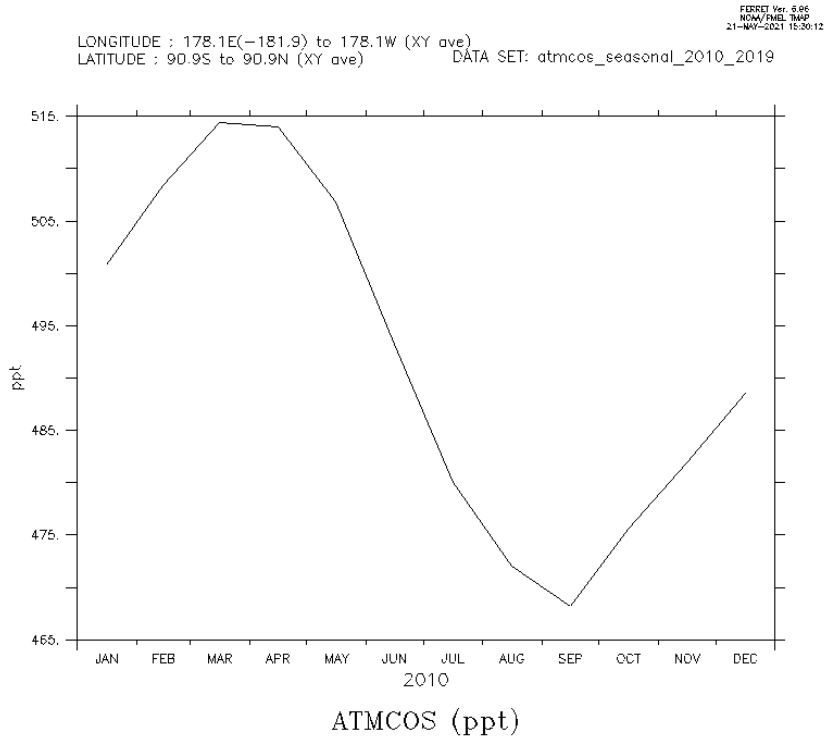

Figure S2: Mean seasonal cycle of monthly atmospheric COS concentrations over 2010-2019.

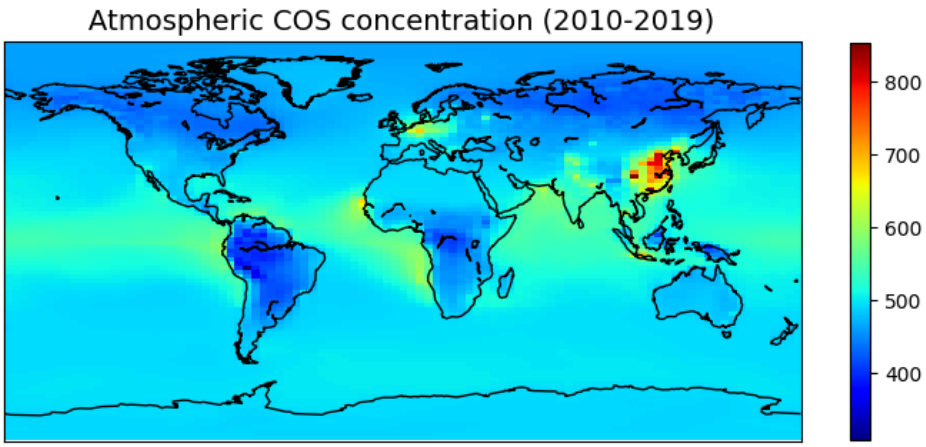

Figure S3: Mean spatial distribution of atmospheric COS concentrations over 2010-2019.

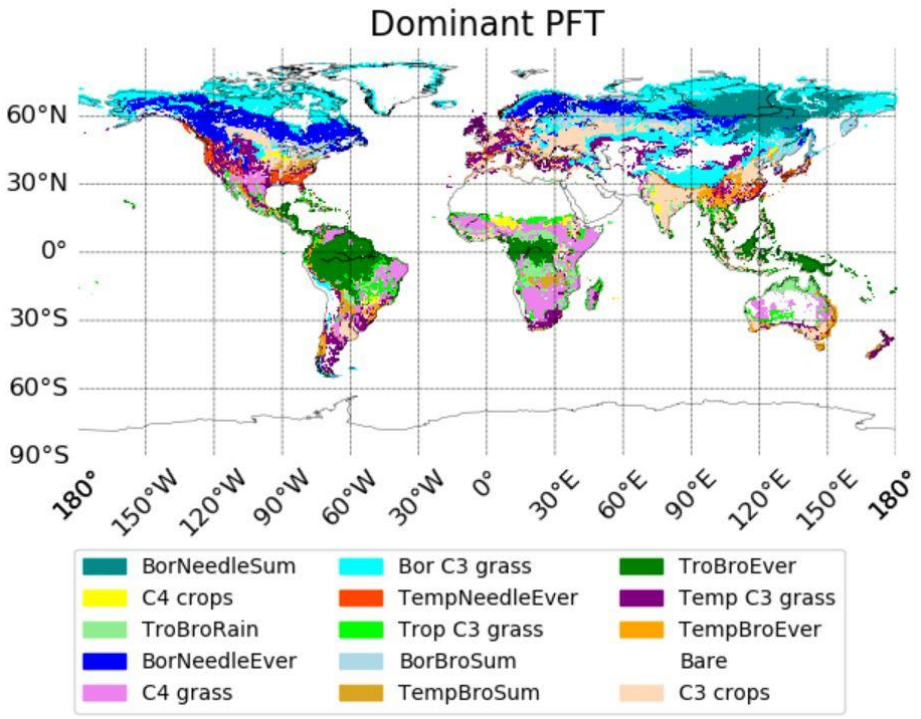

Figure S4: Spatial distribution of dominant plant functional types (PFTs) in ORCHIDEE over 2010-2019. The map resolution is 0.5°x0.5°.