Supporting information for

Global modelling of soil carbonyl sulfide exchanges

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Table S1. Soil textures for the USDA texture classification.

<table>
<thead>
<tr>
<th>USDA texture classes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1- Sand</td>
</tr>
<tr>
<td>2- Loamy sand</td>
</tr>
<tr>
<td>3- Sandy loam</td>
</tr>
<tr>
<td>4- Silt loam</td>
</tr>
<tr>
<td>5- Silt</td>
</tr>
<tr>
<td>6- Loam</td>
</tr>
<tr>
<td>7- Sandy clay loam</td>
</tr>
<tr>
<td>8- Silty clay loam</td>
</tr>
<tr>
<td>9- Clay loam</td>
</tr>
<tr>
<td>10- Sandy clay</td>
</tr>
<tr>
<td>11- Silty clay</td>
</tr>
<tr>
<td>12- Clay</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Initial</th>
<th>Substituted</th>
</tr>
</thead>
<tbody>
<tr>
<td>ES-LMA 3- Sandy loam</td>
<td>3- Sandy loam</td>
</tr>
<tr>
<td>DK-SOR 3- Sandy loam</td>
<td>3- Sandy loam</td>
</tr>
<tr>
<td>IT-CRO 3- Sandy loam</td>
<td>4- Silt loam</td>
</tr>
<tr>
<td>Code</td>
<td>Type</td>
</tr>
<tr>
<td>--------</td>
<td>---------------</td>
</tr>
<tr>
<td>AT-NEU</td>
<td>3 - Sandy loam</td>
</tr>
<tr>
<td>ET-JA</td>
<td>3 - Sandy loam</td>
</tr>
<tr>
<td>FI-HYY</td>
<td>2 - Loamy sand</td>
</tr>
<tr>
<td>US-HA</td>
<td>1 - Sand</td>
</tr>
</tbody>
</table>
Table S3: First-order parameters.

<table>
<thead>
<tr>
<th>Parameter name in ORCHIDEE</th>
<th>Parameter name in the model description</th>
<th>Description (unit)</th>
<th>Specificity</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Empirical model</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ksoil</td>
<td>$k_{soil}$</td>
<td>Proportionality factor for soil COS fluxes (pmol COS $\mu$mol$^{-1}$ CO$_2$)</td>
<td>(-)</td>
<td>$\pm$1.08 pmol COS $\mu$mol$^{-1}$ CO$_2$</td>
</tr>
<tr>
<td><strong>Mechanistic model</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FCA</td>
<td>$f_{CA}$</td>
<td>CA enhancement factor (unitless)</td>
<td>PFT-dependent</td>
<td>See Meredith et al., (2019) Table 1</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>$\alpha$</td>
<td>COS production parameter (unitless)</td>
<td>PFT-dependent</td>
<td>See Text S1 and Table S5</td>
</tr>
<tr>
<td>$\beta$</td>
<td>$\beta$</td>
<td>COS production parameter ($^\circ$C$^{-1}$)</td>
<td>PFT-dependent</td>
<td>See Text S1 and Table S5</td>
</tr>
</tbody>
</table>
### Table S4: Second-order parameters.

<table>
<thead>
<tr>
<th>Parameter name in ORCHIDEE</th>
<th>Description (unit)</th>
<th>Specificity</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Photosynthesis parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vcmax25</td>
<td>Maximum rate of Rubisco activity-limited carboxylation at 25°C (µmol m(^2) s(^{-1}))</td>
<td>PFT-dependent</td>
<td>±45% (Mahmud et al., 2021)</td>
</tr>
<tr>
<td>Zroot</td>
<td>Root profile in empirical plant water stress function calculation (m)</td>
<td>PFT-dependent</td>
<td>See Mahmud et al. (2021)</td>
</tr>
<tr>
<td>Tmin</td>
<td>Minimum photosynthesis temperature (°C)</td>
<td>PFT-dependent</td>
<td>Vegetated PFTs: - 9, 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(Mahmud et al., 2021)</td>
</tr>
<tr>
<td>Tmax</td>
<td>Maximum photosynthesis temperature (°C)</td>
<td>PFT-dependent</td>
<td>Vegetated PFTs: 50, 60</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(Mahmud et al., 2021)</td>
</tr>
<tr>
<td><strong>Conductance parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| 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  
<pre><code>                         |                                                                                   |                        | C\(_4\) plants: 0.01675, 0.02075     |
</code></pre>
<p>|                             |                                                                                   |                        |                              |
| <strong>Phenology parameters</strong>    |                                                                                   |                        |                              |
| SLA                         | Specific leaf area (m(^2) gC(^{-1}))                                          | PFT-dependent          | See Mahmud et al. (2021)     |
| <strong>Soil hydrology parameters</strong> |                                                                                   |                        |                              |</p>
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Unit</th>
<th>Range</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>Van Genuchten water retention curve coefficient n (unitless)</td>
<td></td>
<td>Soil texture-dependent</td>
<td>±40% (Dantec-Nédélec et al., 2016)</td>
</tr>
<tr>
<td>a</td>
<td>Van Genuchten water retention curve coefficient a (unitless)</td>
<td></td>
<td>Soil texture-dependent</td>
<td>±50% (Dantec-Nédélec et al., 2016)</td>
</tr>
<tr>
<td>Ks</td>
<td>Hydraulic conductivity at saturation</td>
<td>Soil texture-dependent</td>
<td></td>
<td>±40%</td>
</tr>
<tr>
<td>θWP</td>
<td>Volumetric water content at wilting point (%)</td>
<td>Soil texture-dependent</td>
<td></td>
<td>±20% (Dantec-Nédélec et al., 2016)</td>
</tr>
<tr>
<td>θFC</td>
<td>Volumetric water content at field capacity (%)</td>
<td>Soil texture-dependent</td>
<td></td>
<td>±20% (Dantec-Nédélec et al., 2016)</td>
</tr>
<tr>
<td>θR</td>
<td>Residual volumetric water content (m$^3$ m$^{-3}$)</td>
<td>Soil texture-dependent</td>
<td></td>
<td>±20% (Dantec-Nédélec et al., 2016)</td>
</tr>
<tr>
<td>θSAT</td>
<td>Saturated volumetric water content (m$^3$ m$^{-3}$)</td>
<td>Soil texture-dependent</td>
<td></td>
<td>±20% (Dantec-Nédélec et al., 2016)</td>
</tr>
<tr>
<td>θTransp_max</td>
<td>Fraction of saturated volumetric soil moisture above which transpiration is maximum (unitless)</td>
<td>Soil texture-dependent</td>
<td></td>
<td>±20% (Dantec-Nédélec et al., 2016)</td>
</tr>
<tr>
<td>C_dry</td>
<td>Dry soil heat capacity (J m$^{-3}$ K$^{-1}$)</td>
<td>Soil texture-dependent</td>
<td></td>
<td>±20% (Dantec-Nédélec et al., 2016)</td>
</tr>
<tr>
<td>soilC</td>
<td>Scalar on the active soil C pool content to account for uncertainty in spinup (unitless)</td>
<td>(-)</td>
<td></td>
<td>0.5, 2 (Mahmud et al., 2021)</td>
</tr>
</tbody>
</table>

Post carbon uptake and allocation parameters
| soil_Q10          | Temperature dependency factor for heterotrophic respiration (Q10=$\exp^{\text{SOIL}_Q10}$) (unitless) | (-)       | FI-HYY: 0.53, 1.36 (Barba et al., 2018)  
US-HA: 0.88, 1.37 (Giasson et al., 2013) |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Min_SWC_resp</td>
<td>Minimum soil wetness to limit the heterotrophic respiration (unitless)</td>
<td>(-)</td>
<td>0.1, 0.6 (Mahmud et al., 2021)</td>
</tr>
</tbody>
</table>
The values of the $\alpha$ and $\beta$ 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),

$$P_{\text{Meredith}} = P_{\text{ref}} \cdot Q_{10}^{\frac{(T - T_{\text{ref}})}{10}}$$  \hspace{1cm} (S1)

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

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

$$e^{\alpha + \beta T} = P_{\text{ref}} \cdot Q_{10}^{\frac{(T - T_{\text{ref}})}{10}}$$  \hspace{1cm} (S2)

$$\alpha = \log \left( P_{\text{ref}} \cdot Q_{10}^{\frac{T_{\text{ref}}}{10}} \right)$$  \hspace{1cm} (S3)

$$\beta = \frac{1}{10} \log \left( Q_{10} \right)$$  \hspace{1cm} (S4)

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

$$\Delta \alpha = \frac{\Delta P_{\text{ref}}}{P_{\text{ref}}} + \frac{\Delta Q_{10}}{Q_{10}}$$  \hspace{1cm} (S5)

$$\Delta \beta = \frac{1}{10} \cdot \frac{\Delta Q_{10}}{Q_{10}}$$  \hspace{1cm} (S6)

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

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

$$\Delta \beta = \frac{1}{10} \cdot \frac{1}{e^{10\beta}}$$  \hspace{1cm} (S8)
Table S5: Ranges of variation for $\alpha$ and $\beta$ parameters.

<table>
<thead>
<tr>
<th>PFT</th>
<th>$\Delta \alpha$</th>
<th>$\Delta \beta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Bare soil</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>2 - Tropical broad-leaved evergreen</td>
<td>1.41</td>
<td>0.0364</td>
</tr>
<tr>
<td>3 - Tropical broad-leaved raingreen</td>
<td>1.41</td>
<td>0.0364</td>
</tr>
<tr>
<td>4 - Temperate needleleaf evergreen</td>
<td>1.26</td>
<td>0.0304</td>
</tr>
<tr>
<td>5 - Temperate broad-leaved evergreen</td>
<td>1.26</td>
<td>0.0304</td>
</tr>
<tr>
<td>6 - Temperate broad-leaved summergreen</td>
<td>1.26</td>
<td>0.0304</td>
</tr>
<tr>
<td>7 - Temperate needleleaf evergreen</td>
<td>1.26</td>
<td>0.0304</td>
</tr>
<tr>
<td>8 - Boreal broad-leaved summergreen</td>
<td>1.26</td>
<td>0.0304</td>
</tr>
<tr>
<td>9 - Boreal needleleaf summergreen</td>
<td>1.26</td>
<td>0.0304</td>
</tr>
<tr>
<td>10 - C$_3$ grass</td>
<td>1.35</td>
<td>0.0340</td>
</tr>
<tr>
<td>11 - C$_4$ grass</td>
<td>1.35</td>
<td>0.0340</td>
</tr>
<tr>
<td>12 - C$_3$ agriculture</td>
<td>1.46</td>
<td>0.0383</td>
</tr>
<tr>
<td>13 - C$_4$ agriculture</td>
<td>1.46</td>
<td>0.0383</td>
</tr>
<tr>
<td>14 - Tropical C$_3$ grass</td>
<td>1.35</td>
<td>0.0340</td>
</tr>
<tr>
<td>15 - Boreal C$_3$ grass</td>
<td>1.35</td>
<td>0.0340</td>
</tr>
</tbody>
</table>
Figure S1: Mean seasonal cycle of monthly atmospheric COS concentrations over 2010-2019.

Figure S2: Mean spatial distribution of atmospheric COS concentrations over 2010-2019.
Figure S3: Spatial distribution of dominant plant functional types (PFTs) in ORCHIDEE over 2010-2019. The map resolution is 0.5° x 0.5°.