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A mechanistic description of the global COS cycle consistent with atmospheric measurements and its potential to evaluate gross primary production of vegetation models

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Accurate estimates of the gross carbon fluxes – photosynthesis and respiration – are essential to predict the ecosystem carbon fluxes and stocks and their evolution in a changing climate. The gross primary productivity (GPP) in the current dynamic global vegetation models (DGVMs), however, shows large differences in terms of mean values, phase and amplitude. As large scale measurements of the GPP are not possible, their estimates are usually based on indirect tracers.

Carbonyl sulfide (COS) has been proposed as a tracer of GPP since COS and CO₂ are dominantly taken up by plants via the same enzyme during photosynthesis. Thus leaf uptakes of COS and CO₂ are often found to be proportional, with a coefficient of proportionality (LRU) that is species-dependant according to laboratory measurements. However contrarily to CO₂, atmospheric records of COS over the last decades show a strong seasonal cycle but with no significant trend, which implies roughly equilibrated sources and sinks of COS at the global scale.

Most recent estimates of COS uptake by plants using this LRU concept led to larger sinks over land than initially estimated. In order to maintain a closed atmospheric budget, a compensatory COS source had to be found, with the ocean being suggested as the most likely candidate. In this work, we propose a new mechanistically-based parameterization of the major sources and sinks of COS, allowing to close the global atmospheric budget.

For the ocean, we used the ocean general circulation and biogeochemistry model NEMO-PISCES to assess the marine source of COS. Using the simulated organic compounds at the surface, we derived a direct source of COS through the COS photo-production as well as an indirect source through the emissions of sulfur compounds (DMS). The resulting simulated global fluxes correspond to a net source of COS of around 800 GgS yr⁻¹, spatially and temporally consistent with the suggested missing source.

For the land, we considered most anoxic soils to be net sources of COS and oxic soils to be COS sinks. We then assumed that the COS uptake by oxic soils was either proportional to tabulated H₂ deposition velocities or derived from a mechanistically-based reaction-diffusion model. Both estimates lead to an equilibrated global COS budget.

In this presentation, we will first describe the spatial and temporal variations of these new surface fluxes, highlighting the main characteristics and uncertainties. These monthly fluxes can be further transported with global transport models to simulate the temporal variations of the atmospheric COS concentrations at surface stations and compare to the observations. We will illustrate the potential of COS to identify GPP biases at continental scale in terms of seasonal phase and amplitude.

Keywords: carbonyl sulfide, COS, carbone cycle, photosynthesis, DMS