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Developing multi-tracer approaches to constrain the parameterisation of leaf and soil CO_2 and H_2O exchange in land surface models

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The net flux of carbon dioxide between the land surface and the atmosphere is dominated by photosynthesis and soil respiration, two of the largest gross CO_2 fluxes in the carbon cycle. More robust estimates of these gross fluxes could be obtained from the atmospheric budgets of other valuable tracers, such as carbonyl sulfide (COS) or the carbon and oxygen isotope compositions (δ^{13}C and δ^{18}O) of atmospheric CO_2. Over the past decades, the global atmospheric flask network has measured the inter-annual and intra-annual variations in the concentrations of these tracers. However, knowledge gaps and a lack of high-resolution multi-tracer ecosystem-scale measurements have hindered the development of process-based models that can simulate the behaviour of each tracer in response to environmental drivers. We present novel datasets of net ecosystem COS, $^{13}CO_2$ and $CO^{18}O$ exchange and vertical profile data collected over 3 consecutive growing seasons (2011-2013) at the Harvard forest flux site. We then used the process-based model MuSICA (multi-layer Simulator of the Interactions between vegetation Canopy and the Atmosphere) to include the transport, reaction, diffusion and production of each tracer within the forest and exchanged with the atmosphere. Model simulations over the three years captured well the impact of diurnally and seasonally varying environmental conditions on the net ecosystem exchange of each tracer. The model also captured well the dynamic vertical features of tracer behaviour within the canopy. This unique dataset and model sensitivity analysis highlights the benefit in the collection of multi-tracer high-resolution field datasets and the developement of multi-tracer land surface models to provide valuable constraints on photosynthesis and respiration across scales in the near future.