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Inverse modelling of Carbonyl Sulfide (COS): towards nonlinear model and satellite data assimilation

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Atmospheric Carbonyl Sulfide (COS) is a useful tracer for assessing gross primary production (GPP). COS is also an important contributor to stratospheric sulfate aerosols (SSA) which cool the climate. However, the global budget of COS remains unresolved due to insufficient observations. We implemented a linear inversion framework within the TM5-4DVAR global chemistry transport model constrained by NOAA surface network to investigate the sources and sinks of COS (Ma et al., 2020). To close the gap between sources and sinks, we focused on inversions that optimize what is thought to be a "missing" source amounting to 432 GgS a^{-1}. We found that a tropical missing source was likely, which could either be an indication of an underestimated ocean source, or overestimated biosphere uptake. Additionally, we found the biosphere uptake to be underestimated at higher latitudes of the Northern Hemisphere. Inversions were validated with HIPPO aircraft data, NOAA airborne profiles and satellite data (MIPAS, TES and ACE-FTS), indicating an underestimation of COS in troposphere. We further implemented a first-order dependency of COS biosphere flux on COS mole fractions in the atmosphere boundary layer, which renders the inversions nonlinear. As expected based on the known drawdown of COS by biosphere uptake, it is found that the dependence of the biosphere flux on COS mole fractions reduced the budget gap by 137 GgS a^{-1}. We further optimized COS fluxes separately over ocean and land, accounting for the first-order dependency of biosphere uptake on COS mole fractions. These results suggest that the missing COS sources may originate from the ocean (207 GgS a^{-1}), despite recent work in which the ocean is explicitly studied suggesting otherwise. Understanding this apparent discrepancy will be an important topic to elucidate. In the future, we plan to take the advantage of available satellite data products to better constrain the COS flux budget in the tropics. COS products from the MIPAS and TES satellites are good candidates for data assimilation in the current model.