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Isolating wetland CH_4 emissions using the additional constraints of $\delta^{13}CH_4$, and C_2H_6 in a inverse modeling framework

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Wetlands are the largest single source of atmospheric methane (CH_4). However, estimates of their relative contribution to the atmospheric CH_4 budget are highly uncertain. Models of CH_4 fluxes from wetlands, which reflect our understanding of the processes driving these fluxes, disagree strongly in their estimates of the total contribution of wetlands to the CH_4 budget and in the variability of the fluxes in space and time. Atmospheric CH_4 observations can provide a top-down constraint on wetland CH_4 flux estimates. Results from atmospheric inverse modeling studies highlight the importance of tropical wetlands in driving interannual variability of atmospheric CH_4. Nevertheless, atmospheric observations in the tropics are scarce, with large areas of strong emissions not covered by the atmospheric observation network. Furthermore, the Bayesian framework, often used in atmospheric inverse modeling, preferentially projects signals onto spatiotemporal regions with large a-priori uncertainty, which is the case of tropical wetlands. Since a large lack of knowledge exists as well for other non-wetland sources of atmospheric CH_4, signals from these could be wrongly allocated to tropical wetlands. The CH_4 stable carbon isotope signal ($\delta^{13}CH_4$) and co-emitted species such as ethane (C_2H_6) can provide additional constraints which may be use to discriminate wetland from non-wetland CH_4 emissions. We describe the set-up of an inverse modeling framework based on the Jena Inversion System and the TM3 transport model that optimizes CH_4 fluxes to fit the observed atmospheric CH_4, $\delta^{13}CH_4$, and C_2H_6 signals. The fluxes are optimized with the constraint that each source process was assigned a characteristic range of $\delta^{13}CH_4$ signals and methane-to-ethane ratios (MERs). An additional characteristic of our set-up is that no seasonal or interannual variability was included in the wetland a-priori estimate to ensure that all variability is derived exclusively from observations. A-priori estimates for wetland CH_4 emissions were composed of the temporal mean per gridcell of the six global models that participated in the Wetland and Wetland CH_4 Inter-comparison of Models Project (WETCHIMP) models. The a-priori uncertainty was derived by combining the temporal variability and the variability among the models per gridcell. Interestingly enough, both $\delta^{13}CH_4$ and C_2H_6 signals drive the scaling of the fluxes in a similar direction. Nevertheless, the uncertainty in the characteristic emission ratios among the CH_4, $\delta^{13}CH_4$, and C_2H_6 tracers must be assessed carefully to avoid giving too many degrees of freedom to the inversion system and thus matching the atmospheric signals with minimal changes in the fluxes. Optimized fluxes can be used to find relationships between CH_4 emissions from wetlands and their meteorological drivers.