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On the potential of GHG emissions estimation by multi-species inverse modeling

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Reducing anthropogenic emissions of greenhouse gases is one of the most important elements in mitigating climate change. However, as emission reporting is often incomplete or incorrect, there is a need to independently monitor the emissions. Despite this, in the case of CO_2 one typically assumes that emissions from fossil fuel burning are well known, and only natural fluxes are constrained by atmospheric measurements via inverse modelling. On the other hand, species such as CO_2, CH4, and CO often have common emission patterns, and thus share part of the uncertainties, both related to the prior knowledge of emissions, and to model-data mismatch error.
We implemented the Lagrangian transport model STILT driven by ECMWF analysis and short-term forecast meteorological fields together with emission sector and fuel-type specific emissions of CO_2, CH4 and CO from EDGARv4.3 at a spatial resolution of 0.1 x 0.1 deg., providing an atmospheric fingerprint of anthropogenic emissions for multiple trace gases. We combine the regional STILT simulations with lateral boundary conditions for CO_2 and CO from MACC forecasts and CH4 from TM3 simulations.
Here we apply this framework to airborne in-situ measurements made in the context of IAGOS (In-service Aircraft for a Global Observing System) and in the context of a HALO mission conducted for testing the active remote sensing system CHARM-F during April/May 2015 over central Europe. Simulated tracer distributions are compared to observed profiles of CO_2, CH4, and CO, and the potential for a multi-species inversion using synergies between different tracers is assessed with respect to the uncertainty reduction in retrieved emission fluxes. Implications for inversions solving for anthropogenic emissions using atmospheric observations from ICOS (Integrated Carbon Observing System) are discussed.