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Development of a coupled FLEXPART-TM5 CO_2 inverse modeling system

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Inverse modeling techniques are used to derive information on surface CO_2 fluxes from measurements of atmospheric CO_2 concentrations. The principle is to use an atmospheric transport model to compute the CO_2 concentrations corresponding to a prior estimate of the surface CO_2 fluxes. From the mismatches between observed and modeled concentrations, a correction of the flux estimate is computed, that represents the best statistical compromise between the prior knowledge and the new information brought in by the observations. Such "top-down" CO_2 flux estimates are useful for a number of applications, such as the verification of CO_2 emission inventories reported by countries in the framework of international greenhouse gas emission reduction treaties (Paris agreement), or for the validation and improvement of the bottom-up models used in future climate predictions.

Inverse modeling CO_2 flux estimates are limited in resolution (spatial and temporal) by the lack of observational constraints and by the very heavy computational cost of high-resolution inversions. The observational limitation is however being lifted, with the expansion of regional surface networks such as ICOS in Europe, and with the launch of new satellite instruments to measure tropospheric CO_2 concentrations. To make an efficient use of these new observations, it is necessary to step up the resolution of atmospheric inversions.

We have developed an inverse modeling system, based on a coupling between the TM5 and the FLEXPART transport models. The coupling follows the approach described in Rodenbeck et al., 2009: a first global, coarse resolution, inversion is performed using TM5-4DVAR, and is used to provide background constraints to a second, regional, fine resolution inversion, using FLEXPART as a transport model. The inversion algorithm is adapted from the 4DVAR algorithm used by TM5, but has been developed to be model-agnostic: it would be straightforward to replace TM5 and/or FLEXPART by other transport models, thus making it well suited to study transport model uncertainties. We will present preliminary European CO_2 inversions using ICOS observations, and comparisons with TM5-4DVAR and TM3-STILT inversions.

Reference:
Rödenbeck, C., Gerbig, C., Trusilova, K., & Heimann, M. (2009). A two-step scheme for high-resolution regional atmospheric trace gas inversions based on independent models. Atmospheric Chemistry and Physics Discussions, 9(1), 1727–1756. http://doi.org/10.5194/acpd-9-1727-2009