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Uncertainties in atmospheric tracer modeling: is there hope for quantification of regional scale Greenhouse gas exchange fluxes through inversions?

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Information on Greenhouse gas exchange between surface and atmosphere on regional scales is contained in atmospheric concentration data, and the scientific community is hoping to retrieve part of this information from observational networks with increased density such as the tall tower networks in Europe and the US. Requirement to access this flux information is a modeling system that combines process modelling (e.g. biosphere, fossil fuel emissions) with atmospheric transport modelling. Inverse analysis then principally allows constraining the state of the system, i.e. one can learn about the processes that control trace gas fluxes. However, such modeling systems are associated with uncertainties that have to be quantified in order to retrieve quantitative information. In addition to the uncertainty in the measurement itself and the a priori uncertainty (incompleteness of prior knowledge), a number of model uncertainties need to be considered: aggregation error (uncertainty due to spatial and temporal resolution of the model), flux model representation error (due to processes not represented in the flux model), advection error (due to uncertainty in the winds in assimilated meteorological data), vertical redistribution error (due to uncertainty in convective fluxes and in the mixed layer height). The uncertainty in boundary layer vertical mixing depth is probably the largest of these, since it directly affects every simulated mixing ratio in the boundary layer. Particularly for determining fluxes of CO2 from observed mixing ratios this is an issue, since changes in mixed layer height covary with biospheric CO2 fluxes on various timescales (the so called rectifier effect). Understanding these uncertainties is therefore prerequisite for utilizing the information contained in the measurements of atmospheric mixing ratios. Especially quantification of uncertainty covariances in space and time, i.e. the off-diagonal elements of the covariance matrix,

are important, since they control the information content. These uncertainties can be derived by propagating the uncertainty, starting from the error in the process (e.g. the uncertainties in winds) to the mixing ratio error. In case of the advection error, this has been done with the STILT (Stochastic Time Inverted Lagrangian Transport) model. for advection. In this paper we discuss the application of error propagation in case of the error in vertical mixing. Uncertainties in modeled mixed layer heights, including spatial and temporal error covariances, are obtained from comparisons to mixed layer heights derived from high resolution radio soundings. The estimated uncertainties are compared to the other sources of error (prior, advection error, aggregation error) and to the observed variability for CO2.