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Joint CO_2 state and flux estimation with the 4D-Var system EURAD-IM

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Atmospheric CO_2 inversion studies seek to improve CO_2 surface-atmosphere fluxes with the usage of adjoint transport models and CO_2 concentration measurements. Terrestrial CO_2 fluxes –anthropogenic emissions, photosynthesis, and respiration– bear large spatial and temporal variability and are highly uncertain. Additionally to the high uncertainty of the three CO_2 fluxes itself, regional inversion studies suffer from uncertainty of the boundary layer height and atmospheric transport especially during night, leading to uncertainty of atmospheric CO_2 mixing ratios during sunrise. This study assesses the potential of the 4-dimensional variational (4D-Var) method to estimate CO_2 fluxes and atmospheric CO_2 concentrations jointly at each grid cell on a regional scale. Identical twin experiments are executed with the nested EURopean Air pollution Dispersion-Inverse Model (EURAD-IM) with 5 km resolution in Central Europe with synthetic half hourly measurements from eleven concentration towers. The assimilation window is chosen to start from sunrise for 12 hours. We find that joint estimation of CO_2 fluxes and initial states requires a more careful balance of the background error covariance matrices but enables a more detailed analysis of atmospheric CO_2 and the surface-atmosphere fluxes.