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## Joint ${\bf CO}_2$ 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.