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Impact of recent developments in atmospheric transport modelling on the simulation of CO_2 retrievals at the global scale

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The interpretation of remote sensing measurements of CO_2 dry air mole fractions heavily relies on Atmospheric Transport Models (ATMs), through direct comparisons with forward simulations and possibly inverse modelling. However, the uncertainty of ATMs is usually hard to characterize while, when considering the differences between retrievals and simulations, ATM errors, errors in observations and errors in ATM surface boundary conditions (CO_2 sources and sinks) are deeply entangled: this situation leaves much ambiguity and subjectivity in the interpretation. Further exploration of current atmospheric modelling capabilities is therefore heavily needed.

In this study, we take the example of the global atmospheric transport model of the Laboratoire de Météorologie Dynamique (LMDz) guided by winds analyzed by numerical weather prediction centres. LMDz is part of the Earth system model of IPSL and is also used in the Copernicus Atmosphere Monitoring Service for operational CO_2 atmospheric inversions. We consider the two reference versions of LMDz that participated to Climate Model Intercomparison Project (CMIP) versions (past) 4 and (ongoing) 6. The latter one benefits from many improvements compared to the former in terms of subgrid processes (convection, boundary layer mixing), radiation processes and vertical resolution in addition to other developments and tuning. We have run these two versions forced by optimized CO_2 surface fluxes and at several horizontal resolutions for nearly two decades (1998-2014). We have compared the resulting ensemble of simulations with a large dataset of independent (unassimilated) CO_2 observations including satellite, TCCON and COCOON retrievals and aircraft profiles. We show that the differences between the simulations of the CO_2 column usually do not exceed 1 ppm. They affect the latitudinal gradient of the simulated column in a seasonal way that should impact the geographical distribution of the surface fluxes estimated by atmospheric inversions. We also show limited impact of higher vertical resolution compared to changes in physical paramaterizations. Last, we show that the years of development of LMDz by a large team between CMIP4 and CMIP6 have brought relatively small improvements to known transport issues at the hourly scale or around the Inter-tropical convergence zone, which shows the importance of continued modelling effort by the scientific community for the exploitation of CO_2 retrievals over the globe.