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Comparing atmospheric transport models for future regional inversions over Europe – Part~1: mapping the atmospheric CO_2 signals

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Abstract. The CO_2 source and sink distribution across Europe can be estimated in principle through inverse methods by combining CO_2 observations and atmospheric transport models. Uncertainties of such estimates are mainly due to insufficient spatiotemporal coverage of CO_2 observations and biases of the models. In order to assess the biases related to the use of different models the CO_2 concentration field over Europe has been simulated with five different Eulerian atmospheric transport models as part of the EU-funded AEROCARB project, which has the main goal to estimate the carbon balance of Europe. In contrast to previous comparisons, here both global coarse-resolution and regional higher-resolution models are included. Continuous CO_2 observations from continental, coastal and mountain sites as well as flasks sampled on aircrafts are used to evaluate the models' ability to capture the spatiotemporal variability and distribution of lower troposphere CO_2 across Europe. >sup>14CO_2 is used in addition to evaluate separately fossil fuel signal predictions. The simulated concentrations show a large range of variation, with up to ~10 ppm higher surface concentrations over Western and Central Europe in the regional models with highest (mesoscale) spatial resolution.

The simulation – data comparison reveals that generally high-resolution models are more successful than coarse models in capturing the amplitude and phasing of the observed short-term variability. At high-altitude stations the magnitude of the differences between observations and models and in between models is less pronounced, but the timing of the diurnal cycle is not well captured by the models.

The data comparisons show also that the timing of the observed variability on hourly to daily time scales at low-altitude stations is generally well captured by all models. However, the amplitude of the variability tends to be underestimated. While daytime values are quite well predicted, nighttime values are generally underpredicted. This is a reflection of the different mixing regimes during day and night combined with different vertical resolution between models. In line with this finding, the agreement among models is increased when sampling in the afternoon hours only and when sampling the mixed portion of the PBL, which amounts to sampling at a few hundred meters above ground. The main recommendations resulting from the study for constraining land carbon sources and sinks using high-resolution concentration data and state-of-the art transport models through inverse methods are given in the following: 1) Low altitude stations are presently preferable in inverse studies. If high altitude stations are used then the model level that represents the specific sites should be applied, 2) at low altitude sites only the afternoon values of concentrations can be represented sufficiently well by current models and therefore afternoon values are more appropriate for constraining large-scale sources and sinks in combination with transport models, 3) even when using only afternoon values it is clear that data sampled several hundred meters above ground can be represented substantially more robustly in models than surface station records, which emphasize the use of tower data in inverse studies and finally 4) traditional large scale transport models seem not sufficient to resolve fine-scale features associated with fossil fuel emissions, as well as larger-scale features like the concentration distribution above the south-western Europe. It is therefore recommended to use higher resolution models for interpretation of continental data in future studies.

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