The imprint of stratospheric transport on column-averaged methane

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Model simulations of column-averaged methane mixing ratios (XCH_4) are extensively used for inverse estimates of methane (CH_4) emissions from atmospheric measurements. Our study shows that virtually all chemical transport models (CTM) used for this purpose are affected by stratospheric model-transport errors. We quantify the impact of such model transport errors on the simulation of stratospheric CH_4 concentrations via an a posteriori correction method. This approach compares measurements of the mean age of air with model age and expresses the difference in terms of a correction to modeled stratospheric CH_4 mixing ratios. We find age differences up to ~ 3 years yield to a bias in simulated CH_4 of up to 250 parts per billion (ppb). Comparisons between model simulations and ground-based XCH_4 observations from the Total Carbon Column Network (TCCON) reveal that stratospheric model-transport errors cause biases in XCH_4 of ~20 ppb in the midlatitudes and ~27 ppb in the arctic region. Improved overall as well as seasonal model-observation agreement in XCH_4 suggests that the proposed, age-of-air-based stratospheric correction is reasonable.

The latitudinal model bias in XCH_4 is supposed to reduce the accuracy of inverse estimates using satellite-derived XCH_4 data. Therefore, we provide an estimate of the impact of stratospheric model-transport errors in terms of CH_4 flux errors. Using a one-box approximation, we show that average model errors in stratospheric transport correspond to an overestimation of CH_4 emissions by ~40 % (~ 7 Tg yr^{-1}) for the arctic, ~ 5 % (~ 7 Tg yr^{-1}) for the northern, and ~ 60 % (~ 7 Tg yr^{-1}) for the southern hemispheric mid-latitude region. We conclude that an improved modeling of stratospheric transport is highly desirable for the joint use with atmospheric XCH_4 observations in atmospheric inversions.