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Understanding atmospheric methane variability between 2000 and 2008 using inverse modelling and a global Lagrangian transport model

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Methane (CH_4) is the second most important well-mixed greenhouse gas in terms of radiative forcing after carbon dioxide. To improve our understanding of recent CH_4 growth rate variability, focusing particularly on the latest increase since 2007 after a period of stagnation, we performed a global model simulation in combination with an emission inversion. This allowed us to quantify the temporal evolution of different methane sources during this period. In contrast to previous studies relying on Eulerian models, our simulations were performed with an enhanced version of the Lagrangian Particle Dispersion Model FLEXPART in a global domain filling mode and extended with a simple CH_4 chemistry. 3 mio particles (air parcels) were permanently transported in the model over the years 2000-2008 each carrying a set of 44 tracers representing 11 different CH_4 sources in 4 emission age classes each. A priori CH_4 emissions were taken from state-of-the-art inventories and a wetland emission model. In FLEXPART, these are picked up by the particles residing in the atmospheric boundary layer. CH_4 is subsequently lost by reactions with prescribed fields of OH and stratospheric Cl and $O(^1D)$ and deposition at the surface. Simulated concentrations are mostly in very good agreement with continuous in situ measurements and flask samples of the networks of NOAA, GAW and AGAGE. Finally, a posteriori emissions were inversely estimated using a fixed-lag Kalman smoother by analyzing modeled CH_4 concentrations against the in-situ measurements. Our results indicate that the renewed growth of CH_4 in 2007 and 2008 was mainly attributable to positive anomalies in CH_4 emissions from tropical biomass burning in 2006/2007, a positive anomaly in wet mineral soil and large rice agriculture emissions in 2007/08. Additionally, non-negligible contributions also arose from Siberian peatland emissions in these last two years of the simulation.