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Three-dimensional concentration fields of methane simulated with a Lagrangian model nudged with observation data

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A Lagrangian particle dispersion model (FLEXPART CTM) is used to simulate global three-dimensional concentration fields of trace gases. These fields are constrained with surface observation data through nudging, a simple data assimilation method. Such fields are of interest to a variety of applications, such as inverse modelling and satellite retrievals of greenhouse gases. Here, we apply this method to methane using 6 million model particles filling the global model domain. For each particle methane mass tendencies due to emissions based on several inventories, OH, Cl, O(^{1}D) degradation, as well as observation data nudging were calculated. Model particles were transported by mean, turbulent and convective transport driven by 1°x1° ERA Interim meteorology. Simulations need less than three days on a single CPU for a simulated time of one year. Nudging is applied at about 80 surface stations, which are mostly included in the WDCGG database or JR-STATION network in Siberia. For simulations of one year (2013), we perform a sensitivity analysis to show how nudging settings affect modelled concentration fields. These are evaluated with a set of independent surface observations and for vertical profiles in North America (NOAA/ESRL) and Siberia (YAK-AEROSIB and NIES). FLEXPART CTM model results are also compared to simulations with the global Eulerian model, TM5, based on optimized fluxes. Results show that nudging strongly improves modelled concentrations near the surface, not only at the nudging locations, but also at independent stations. Mean bias at all surface locations could be reduced from over 20 ppb to less than 5 ppb through nudging. Near the surface, FLEXPART CTM, including nudging, appears better able to capture methane concentrations than TM5, based on a larger bias of over 13 ppb in TM5 simulations. The vertical profiles indicate that nudging affects model concentrations at high altitudes, yet hardly leads to an improvement in the model results there. Averaged from 19 profile locations in North America and Siberia, root-mean square error (RMSE) changes only from 16.3 to 15.7 ppb through nudging, while the mean absolute bias increases from 5.3 to 8.2 ppb. The performance for vertical profiles is thereby similar to TM5 simulations based on optimized fluxes where we found a bias of 5 ppb and RMSE of 15.9 ppb. With this rather simple model setup, we thus provide three-dimensional concentration fields suitable for inverse modelling and satellite retrievals of methane. The method should also be applicable to other long-lived trace gases.