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Methane Past, Present and Future -- 250-year Methane Trend from a Fully Interactive Earth System Model Simulation

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Methane (CH_4) is the second most important anthropogenic greenhouse gas. Its Global Warming Potential over 100 years (GWP_{100}) exceeds 28 times that of CO_2. Methane surface concentrations have steadily increased since the pre-industrial due to industrialisation combined with fossil fuel use. In 1850, around the onset of heavy industrialisation in Europe and North America, the CH_4 mole fraction was approximately 700 ppbv, and since then it has increased 2.5-fold to slightly more than 1830 ppbv in 2015. Fossil fuel use, raising of livestock, and cultivation of rice are the dominant contributions to the atmospheric methane burden at present with significant emissions from natural wetlands also playing a central role.

Here we present first results from the UK Earth System Model (UKESM1.0). The default release version of UKESM1.0 has been extended to represent the methane cycle fully interactively, including dynamic wetlands with global CH_4, full stratospheric-tropospheric CH_4 chemistry, and CH_4 surface deposition. The extended configuration is capable of simulating the climate feedbacks on methane wetland emissions which are typically neglected in current Earth system models. Our simulation is driven with anthropogenic CH_4 emissions from CMIP6. We conducted fully-coupled transient simulations of the atmospheric CH_4 burden from 1850 to 2100 based on the historic and two future scenarios (SSP3-7.0 and SSP1-2.6) scenarios.

We compare the time series of global CH_4 surface concentrations between the default CH_4 concentration-driven configuration of UKESM1.0 with the fully-interactive emissions-driven configuration. Surface concentrations for the emissions-driven simulation show reasonable agreement with the concentration-driven simulation, but a low bias in the fully interactive simulation gradually emerges after about 1920 which reaches approximately -250 ppbv in the 2000s. We then present a full-cycle CH_4 budget analysis based on decadal means for every 50 years between 1850 and 2100. We demonstrate that methane burden and surface mole fractions are expected to return to their 1930s values under SSP1-2.6, albeit with the natural methane sources still heavily disturbed from their original state. We also produce a detailed analysis of the contribution of wetland CH_4 emissions for the 250 years of simulation.