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Methane in the climate system -- from the last glacial to the future

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Between the last glacial maximum (LGM) and preindustrial times (PI), the atmospheric concentration of CH_4, as shown by reconstructions from ice cores, roughly doubled. It then doubled again from PI to the present. Ice cores, however, cannot tell us how that development will continue in the future, and ice cores also cannot shed light on the causes of the rise in methane, as well as the rapid fluctuations during periods such as the Bolling-Allerod and Younger Dryas.

We use a methane-enabled version of MPI-ESM, the Max Planck Institute for Meteorology Earth System Model, to investigate changes in methane cycling in a transient ESM experiment from the LGM to the present, continuing onwards into the future for the next millennium. The model is driven by prescribed orbit, greenhouse gases and ice sheets, with all other changes to the climate system determined internally. Methane cycling is modelled by modules representing the atmospheric transport and sink of methane, as well as terrestrial sources and sinks from soils, termites, and fires. Thus, the full natural methane cycle – with the exception of geological and animal emissions – is represented in the model. For historical and future climate, anthropogenic emissions of methane are considered, too.

We show that the methane increase since the LGM is largely driven by source changes, with LGM emissions substantially reduced in comparison to the early Holocene and preindustrial states due to lower temperature, CO_2, and soil carbon. Depending on the future climate scenario, these dependencies then lead to further increases in CH_4, with a further doubling of atmospheric CH_4 easily possible if one of the higher radiative forcing scenarios is followed. Furthermore, the future increases in CH_4 will persist for a long time, as CH_4 only decreases when the climate system cools again.