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Modelling wetland methane emissions in response to idealised Dansgaard-Oeschger events

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Ice-core records from Greenland indicate that the climate of the last glacial (and most probably previous glacial periods) was extremely unstable, with evidence for a series of rapid (decadal time-scale) jumps in surface temperature of the order of 10°C, known as Dansgaard-Oeschger (D-O) events. The records of atmospheric methane concentrations derived from both Greenland and Antarctic ice-core data also show a number of abrupt rises which parallel many D-O events recorded in Greenland, with an amplitude of up to half the glacial-interglacial atmospheric concentration difference. These methane jumps imply that the affects of D-O events are not confined to Greenland or the North Atlantic, but could have had an influence on regions of natural methane production, such as wetlands. However, there is no generally accepted physical mechanism which explains these transitions, although a rapid acceleration of the meridional overturning circulation and associated heat transport to the Northern Hemisphere is generally favoured. Uncertainty, therefore remains surrounding the underlying causes of D-O warmings and the associated changes in vegetation that would be required to plausibly explain methane concentration observations.

Here we present the first results from a bottom up modelling approach to D-O events in which models of the coupled climate system, global vegetation and global wetlands are used together in an attempt to quantitatively assess the mechanism outlined above. We have produced a suite of coupled global climate model simulations of idealised Dansgaard-Oeschger events using the coupled general circulation model FAMOUS, a fast version of HadCM3. Each model run uses a last glacial maximum state background state with 21k orbital parameters, trace gas concentrations and ICE-5G 21k ice sheet distribution. A transient freshwater forcing is used to perturb the modelled meridional overturning circulation in order to replicate a generic D-O event. The resulting climate states are then used to drive the Sheffield Dynamic Vegetation Model, output from which is used to run the Cao et al (1996) wetland and methane emissions model.

The results show a consistent, strong reduction in wetland methane emissions in response to Heinrich type events, with a more muted, but still significant, emissions increase during the D-O warming phase. The magnitude is roughly a third of the glacial to interglacial difference as simulated with FAMOUS. The source of the increased emissions is almost exclusively the Northern hemisphere extra-tropics, in agreement with previous studies. The model setup is also used to assess the influence of the background climatic state, and to a limited extent, that of (climate) model parametric uncertainty.