THE INTERPLAY BETWEEN SOURCES OF METHANE AND BIOGENIC VOCS IN GLACIAL-INTERGLACIAL FLUCTUATIONS IN ATMOSPHERIC GREENHOUSE GAS CONCENTRATIONS AND THE GLOBAL CARBON CYCLE

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ABSTRACT

Recent analyses of ice core methane concentrations have suggested that methane emissions from wetlands were the primary driver for prehistoric changes in atmospheric methane. However, these data conflict as to the location of wetlands, magnitude of emissions, and the environmental controls on methane oxidation. The flux of other reactive trace gases to the atmosphere also controls apparent atmospheric methane concentrations because these compounds compete for the hydroxyl radical (OH), which is the primary atmospheric sink for methane. In a series of coupled biosphere-atmosphere chemistry-climate modelling experiments, we simulate the methane and biogenic volatile organic compound emissions from the terrestrial biosphere from the Last Glacial Maximum (LGM) to present. Using an atmospheric chemistry-climate model, we simulate the atmospheric concentrations of methane, the hydroxyl radical, and numerous other reactive trace gas species. Over the past 21,000 years methane emissions from wetlands increased slightly to the end of the Pleistocene, but then decreased again, reaching levels at the preindustrial Holocene that were similar to the LGM. Global wetland area decreased by 14% from LGM to preindustrial. However, emissions of biogenic volatile organic compounds (BVOCs) nearly doubled over the same period of time. Atmospheric OH burdens and methane concentrations were affected by this major change in BVOC emissions, with methane lifetimes increasing by more than two years from LGM to present. This would represent a change in methane concentration of ca. 350 ppb. Thus, glacial-interglacial changes in atmospheric methane concentrations would have been modulated by BVOC emissions. In addition, the increase in atmospheric methane concentrations since the mid-Holocene are captured in our results without invoking the hypothesized major increase in anthropogenic emissions over this period. The sustained increase in total BVOC emissions since the LGM would have had a measurable impact on the global carbon cycle as a whole. While the interplay between BVOC and wetland methane emissions since the LGM cannot explain the entire record of ice core methane concentrations, consideration of BVOC source dynamics is central to understanding ice core methane and CO_2.

INTRODUCTION

Mechanisms to explain millennial-scale variability in atmospheric methane (CH_4) concentrations are poorly understood. Recent analyses of ice core CH_4 concentrations, interhemispheric gradients, and carbon isotope composition ($\delta^{13}C$-CH_4) have suggested that changes in CH_4 emissions from wetlands drove prehistoric changes in ice-core CH_4 [*Chappellaz, et al.*, 1997; *Chappellaz, et al.*, 1993; *Crutzen and Bruhl*, 1993; *Martinerie, et al.*, 1995]. The theory has been that a glacial world, with its relatively cold oceans, would have been drier than the present, and wetland area, and hence CH_4 emissions, would be suppressed. The reduction in the area of boreal wetlands and lower CO_2 concentrations, leading to depressed vegetation productivity, could have had a generally negative effect on net CH_4 emissions. However, results of recent modelling work using global biochemical process models, indicated that glacial-interglacial changes in wetland area and methane emissions may have been smaller than earlier supposed, and not large enough to effect the observed changes in atmospheric CH_4 concentrations [*Kaplan*, 2002; *Valdes, et al.*, 2005].

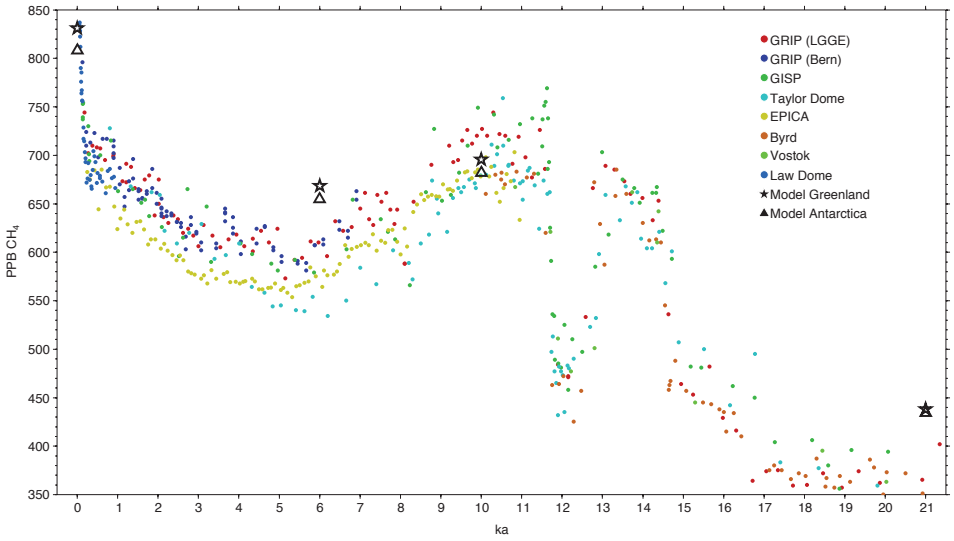

Figure 1. Atmospheric CH_4 concentrations measured in Greenland and Antarctic ice cores and simulated by BIOME4-TG/ LMDz-INCA.

METHODS

The method used in this study incorporates a stepwise, offline coupling of several models. A global climate model (UM-GCM) was used to simulate paleoclimate at 1 ka intervals from the LGM to the present. This GCM output was used by a global vegetation model (BIOME-TG) to calculate vegetation distribution (biomes), wetland area, CH_4 emissions from wetlands, and BVOC emissions from the terrestrial vegetation. The surface flux fields of CH_4 and BVOC from BIOME4-TG were used as forcings for an atmospheric chemistry-climate model (LMDz-INCA). Using this combination of models, we are able to make a complete 3D synthesis of the global methane cycle, and simulate OH burden, CH_4 lifetime, and atmospheric CH_4 concentrations, which may be directly compared to ice-core measured CH_4.

RESULTS AND CONCLUSION

Sensitivity studies conducted with the coupled BIOME4-TG/LMDz-INCA biogeochemistry-climate modelling system indicate that the increase in atmospheric CH_4 concentrations since the LGM was at least partially driven by the increase in BVOC emissions from the terrestrial vegetation (Fig. 1). Our sensitivity studies imply that the observed increase in methane concentrations can be understood in terms of a reduced sink rather than an increased source. Whereas wetland CH_4 emissions remained relatively constant during the deglaciation period and the Holocene until the preindustrial epoch (maximum variation of less than 20%), BVOC emissions from the terrestrial vegetation almost doubled. The near doubling of BVOC surface fluxes occurred due to changes in the composition of plant ecosystems at tropical latitudes, an expansion of the vegetation to higher latitudes, and the growth of the boreal forest after the melting of the Pleistocene ice sheets.

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