Modeling modern methane emissions from wetlands 1980-present

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Methane is one of the important greenhouse gases and plays an important role in atmospheric chemistry. Its contribution to the current greenhouse effect is about 22%. Since the beginning of the industrialization the atmospheric methane concentration has increased by a factor of 2.5. This increase continues until present, however, since the early 1990s the growth rate has decreased. Superimposed on this trend is considerable interannual variation. Currently natural wetlands are the largest methane source, however, current estimates of the wetland source strength are still uncertain, ranging from about 145 Tg yr^{-1} [*Houweling et al*., 1999, and references therein] to 230 Tg yr^{-1} [*Hein et al*., 1997]. In addition, they are believed to contribute considerably to interannual variations and particular anomalies. Wetland emissions depend highly on the climate, i.e., on soil temperature and water table. In this study, the history of global wetland emissions from 1980-present has been simulated using a process-based methane-hydrology model that derives methane emissions from natural wetlands as a function of soil temperature, water table, and Net Primary Productivity. ECMWF and NCEP re-analyses were used as model forcing.

Until recently, development of global process models to derive methane emissions from wetlands was hindered due to limited (quantitative) process knowledge and sparse field data for model testing. The global process-based, climate-sensitive methane-hydrology model used in this study has two components. The methane model [*Walter et al*., 1996; *Walter and Heimann*, 2000] simulates the process of methane production, methane oxidation and transport within a 1-dimensional soil column (Figure 1). It has been tested at 6 different test sites in North America (e.g. Figure 2), Europe and Central America. The hydrologic model derives the variation of the water table in wetlands using a simple water balance equation for a 'bucket' modified for wetland conditions. Sub-grid scale variations in the water table due to microtopography (hummock/hollow) are not yet considered [*Walter et al*., submitted].

The methane-hydrology model was applied to the period from 1982-1993 using ECMWF reanalyses as model forcing. We calculated total annual methane emissions from wetlands to be 260 Tg yr^{-1} which is at the high end of current estimates (Figure 3). Annual methane fluxes are lower in higher latitudes because of the shorter productive period, and HNH emissions constitute about 25% of the total wetland emissions. On a global and annual basis only 60% of the produced methane is emitted, the rest is re-oxidized in soil. A comparison between the meridional pattern of calculated annual methane emissions with a result from an inverse modeling study shows good agreement.

Simulated methane emissions show a pronounced seasonal cycle and strong interannual variations (Figure 4). In higher latitudes the seasonal cycle of methane emissions is controlled by the seasonal cycle of temperature; in lower latitudes the seasonal cycle of methane emissions is controlled by the seasonal cycle of the water table. Simulated methane emission anomalies were compared to observed growth rate anomalies from the NOAA/CMDL network. Our results suggest that in the HNH growth rate anomalies can, to a large extent, be explained by wetland emission anomalies; in the tropics, however, simulated methane emission anomalies do not compare well with observed growth rate anomalies suggesting that contributions from other sources, such as biomass burning and/or the sink are more important than in the HNH. In the HNH variations in temperature and water table affect variations in methane emissions in equal parts; globally the influence of temperature variations is slightly stronger (60%). Our results suggest that reduced methane emissions from HNH wetlands caused by coinciding negative temperature and water table anomalies, strongly contributed to the observed negative growth rate anomaly in 1992.

Sensitivity tests of the global methane-hydrology model revealed that uniform temperature changes of °C result in changes in methane emissions of about % independent of the latitude and environmental conditions. Uniform changes in precipitation by % alter simulated methane emissions by about %. These results indicate how large changes in methane emissions from wetlands can be under possible changed climatic conditions in the future.

The global methane-hydrology model has been simplified into a multi-linear regression model deriving methane emission anomalies from temperature and precipitation anomalies. Results of the simplified model compare well with the results of the more complex methane-hydrology model. The regression model has been applied to the period 1980-present using NCEP reanalyses as climate forcing. The results show that methane emission anomalies strongly contributed to both the large negative growth rate anomaly in 1992 (see above) and the large positive growth rate anomaly in 1998. In 1999 both the atmospheric methane growth rate and wetland emission anomalies decrease again.

Several limitations in the methane-hydrology model have been identified which are omission of 1. sub-grid scale variations in peat chemistry, 2. sub-grid scale variations in the water table due to microtopography, and 3. temporal variations in the wetland area; further limitations are 4. limited test data (tropical wetlands, data representative of larger areas and covering longer periods), 5. limited process knowledge (e.g. plant-mediated transport), and 6. limitations in the global input data (precipitation; vegetation). Reduction of these limitations requires further modeling efforts (1, 2, 3, 6), more test data (4), improved process knowledge (1, 5) and better input data (1, 2, 3, 6).

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