Methane Emissions from Northern High-Latitude Wetlands

Robert Harriss, Karen Bartlett, Steve Frolking, and Patrick Crill

Institute for the Study of Earth, Oceans, and Space, University of New Hampshire, Durham, New Hampshire 03824

ABSTRACT

Methane emissions from northern high-latitude wetlands are an important consideration for understanding past, present, and future atmospheric concentrations of this important greenhouse gas. In this chapter we review progress on measuring methane emissions from northern wetlands and, through a model, estimate emission variability in relation to one component of climate variability. Our conclusions are as follows: (1) Methane emissions from northern wetlands are dependent on both soil moisture and temperature. The relative influence of these soil climate parameters is quite variable from one region to another, as is the magnitude of the net emission rate to the atmosphere. Some important wetland regions have not been surveyed for methane emissions (e.g., the Siberian Lowlands); further progress on defining global emissions from northern wetlands awaits field data from these areas. (2) Our preliminary modeling of the sensitivity of methane flux from northern wetlands to variability in temperature indicates that feedbacks from this source are unlikely to significantly influence rates of climate change during the initial stages of a global warming.

Introduction

In this chapter, we review progress on estimating and understanding both the magnitude of, and controls on, emissions of methane from northern high-latitude wetlands to the atmosphere. During the past decade, the number of studies of methane emission from northern wetland environments has increased substantially, especially in North America. We use our synthesized dataset on methane emission rates and associated environmental variables to address two questions related to possible effects of global climate change:

1. How are methane emissions from northern high-latitude wetlands influenced by climate variability?
2. If a long-term global warming occurs, will methane emissions from northern

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wetlands be a significant feedback factor influencing future rates of climate change?

A Review of Data on Methane Emissions from Northern Wetlands

A summary of reported flux measurements from northern wetlands, covering a latitudinal range of 45° to 70°N is given in Table 1. These measurements span a range of over three orders of magnitude, from less than 1 to roughly 1940 $mgCH_4\ m^{-2}\ d^{-1}$ and include a wide variety of vegetation, moisture, and soil types. A single flux of 12,068 $mgCH_4\ m^{-2}\ d^{-1}$, roughly an order of magnitude greater than all others at this site, is reported from an Alberta, Canada beaver pond.[44] Since the degree of soil wetness strongly influences anoxia, a necessary condition for methanogenesis, soil moisture is a major factor controlling methane release in many sites studied to date (e.g., Refs. 29, 39, 42; Table 2). Wet soils, however, clearly vary greatly in emissions (Table 1). Moist-to-dry wetland soils (i.e., no standing water at the surface) can be both small sources or sinks to the atmosphere. In the Arctic, moist soils most frequently appear to be small sources, on the order of 0.6–11 $mgCH_4\ m^{-2}\ d^{-1}$, with dry soils frequently exhibiting negative fluxes (consumption of atmospheric methane) generally between −0.5 and −3 $mgCH_4\ m^{-2}\ d^{-1}$.[1,2,9,18,46,47]

To investigate how the climate regime may influence methane emissions from northern wetlands, it is useful to consider the major ecoclimatic zones separately. In the following sections, we first consider emissions from arctic and subarctic regions, then from boreal wetlands.

Arctic/Subarctic Methane Emissions

Measurements in subarctic and arctic tundra (> 60°N) are overwhelmingly from sites in Alaska—from Fairbanks in the interior where annual and multiyear measurements have been made,[32,48] from the coastal plain on the North Slope where a series of investigators have made measurements encompassing both large and small spatial scales,[18,29,39,46] and from coastal tundra on the delta of the Yukon and Kuskokwim Rivers where investigators have made measurements at a variety of scales using an array of measurement techniques during the NASA Arctic Boundary Layer Expedition (ABLE 3A).[1,9,33]

Time-series measurements from Fairbanks, from the same plots, demonstrate significant differences from year to year, at least in part controlled by temperature and moisture variations.[45,48] As shown in Table 1, annual emissions from some sites varied by nearly an order of magnitude and year-to-year changes were not consistent between sites. Differences between subsites within a habitat in any one year, presumably due primarily to spatial variability, were also considerable