Implication of Climate Variability on Arctic Peatland Carbon Fluxes in Eastern Hudson Bay Lowlands, Manitoba, Canada

Anna Hall, Anna Westervelt, Cameron Adams, and Phil Camill
Bowdoin College Department of Earth and Oceanographic Science

Introduction

The Arctic peatland carbon pool represents one of the largest carbon sinks on Earth and is estimated to store 1,700 billion tonnes of carbon, more than 60% of the total atmospheric carbon pool (Shieh et al., 2011). As these ecosystems are subjected to a warmer climate, increased fire severity (magnitude and/or frequency) and heightened microbial respiration (due in part to melting permafrost) have the potential to return much of this stored carbon to the atmosphere, resulting in a positive feedback effect on climate warming. It is important, therefore, to better understand how warmer climates affect the balance between carbon sequestration and release in these peatland ecosystems.

Ultimately, warming climate is expected to increase peat decomposition and fire frequency, which can be exacerbated by climate-driven plant succession (Camill et al., 2009). These factors lead to increased carbon release to the atmosphere. However, warming climate also initially boosts primary production, leading to increased carbon sequestration (Yu et al., 2009). Determining whether the ecosystem will act as a net carbon sink or source depends on the relative magnitudes and timing of these factors.

Here we aim to learn more about this carbon pool by observing the response of overall Arctic peatland carbon accumulation rates to past climate trends. We compare carbon accumulation during known warm intervals, such as the Holocene Thermal Maximum (HTM: ~6500-3500 BP) and Medieval Warm Period (MWP: 1200-600 BP), and cool intervals, such as the Little Ice Age (LIA: ~600-200 BP) (Camill et al., 2012). The beginning of the HTM in the Hudson Bay Lowlands was a period of strong seasonality, meaning the area was subjected to longer, more extreme winters and summers. Understanding the peatland response to periods of past warming, such as the HTM, is of particular importance given the predictions for current climate warming. By analyzing these natural variations in climatic conditions and their effect(s) on the peatland ecosystems, we hope to answer the following questions for our study region:

1) How has carbon accumulation varied across the warming and cooling trends of the mid-late Holocene?
2) What (if any) is the relationship between fire severity and carbon accumulation?
3) Are fire severity and microbial respiration more or less influential than gross primary production in controlling carbon accumulation rates during warm periods?

Study Region

We analyzed data from 25 peat cores which were collected in 2008-09 in the forest-tundra of northern Manitoba, Canada. We collected additional peat cores in the summer of 2012 at 36 sites near the Hudson Bay Lowlands of Churchill, Manitoba, Canada. The 2012 cores are not included in the data presented here.

Methods

Twenty-five peat cores were collected and analyzed for N, C, and bulk density to determine mass carbon and nitrogen. C-14 dates and an age-depth model were used with carbon mass to calculate carbon accumulation rates for each depth interval. Areal charcoal concentration was calculated using macroscopic charcoal analysis to be used as a proxy for fire severity (magnitude and frequency).

Results

Figure 2. On a large time scale, carbon accumulation and areal charcoal concentration appear to have a negative relationship. These data suggest that either:
1. An increase in fire severity due to climatic influences leads directly to a decrease in carbon accumulation rates by releasing stored peatland carbon to the atmosphere, or
2. There exists a third variable responsible for periods of both low peak productivity/high fire severity and high peak productivity/lows fire severity. This variable could be related to varied temperature and water dynamics associated with changing climate.

Figure 3. (a) On a 200-year time scale there is little apparent relationship between individual charcoal and carbon accumulation peaks and troughs. (b) On a 100-year time scale, charcoal peaks and carbon accumulation rates are not correlated. These data suggest that there is not an immediate casual relationship between fire and carbon accumulation but rather climatic influences drive both the fire severity and NPP independently and inversely. Fire severity varies with climate changes on a 100-year time scale, increasing during the MWP and decreasing with the onset of the LIA to the present. (c) There is no significant change in carbon accumulation rates with increasing fire severity.

Summary

Carbon sequestration and release in Arctic peatlands of the Hudson Bay Lowlands of Manitoba, Canada are mediated by multiple interrelated climatic factors including temperature, hydrology, plant succession, and fire severity. During warm periods of the mid to late Holocene, carbon accumulation rates in this region were found to increase while during cooler periods these rates were lower. Although carbon accumulation and fire severity seem to be inversely correlated, fires do not appear to directly influence rates of carbon accumulation. Low past consumption by fires or external inputs of charcoal (originating from nearby fires or deposited from burning aboveground plant material) could explain this deviation from the expected negative relationship.

If future warming patterns reflect past observed climatic trends, then Arctic peatlands in this region can be expected to increase carbon storage and act as a stronger sink of atmospheric carbon.

References


Press releases:

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