Title: Long-term droughts in the Hudson River Valley – Developing Zn, Ti, and K in marsh sediments as proxies for drought/fire and erosion

Introduction

Droughts in the Hudson River Valley have been documented for recent centuries (Cook and Jacoby, 1977). However, millennial-scale records for the region are lacking, making it difficult to place the anthropogenic era in historical context. Longer records are crucial for estimating natural variations in climate that affect the Hudson River watershed, which provides water resources for New York City's 10 million inhabitants. In the lower Hudson Valley, Pederson et al (2005) documented the presence of abundant charcoal and changes in forest dominants during the Medieval Warming Interval (MWI) between 800 and 1350 AD. Recent discovery of the same charcoal maximum at the same time upriver is confirmation of this regional signal in the Hudson Estuary (Sritrairat et al., 2006). Regional studies along the North Atlantic seaboard support our drought/fire hypothesis of the major shifts in the Hudson Valley. To the south along the Atlantic seaboard, Brush (1986) found warmer, drier conditions with increased charcoal from A.D. 1000–1200 in cores from Chesapeake Bay. Cronin et al. (2003) used Mg/Ca based temperature reconstructions of ostracode shells to identify the first half of the Medieval Warm Interval (MWI) in their record, and Willard et al. (2003) identified drought intervals in the late Holocene. Producing long, detailed records of climate from three northeastern watersheds to compare with regional and North Atlantic records (Bond et al., 2001) will improve our understanding of the forcing for these changes along the Atlantic seaboard.

The paleodroughts of the eastern US far surpass the instrumental record droughts in intensity and duration. Understanding the spatial and temporal patterns, including the frequency and duration of past droughts in the eastern US is essential for establishing drought mechanisms. Climate modelers learn best about the hydrological sensitivity of the region through paleoarchives. This is particularly important as climate warming impacts the highly populated eastern US. Here we propose a study of the Holocene drought record in the northeastern US using geological, chemical, and biological proxies.

The primary goal of this study is to produce a record of climate variability at the decadal to centennial scale for the Hudson Valley over much of the Holocene, as the marshes we propose to study (Piermont, Iona, Constitution) date to about 6000 years BP. A major limitation to regional-scale paleoecological studies is that the methods typically employed are very time-consuming and extremely tedious, with a single record of the full suite of paleoecological indicators often taking years to produce. In order to rapidly assess the regional drought history of the northeastern US, we have embraced an emerging geochemical approach based on advances in X-Ray Fluorescence (XRF) spectroscopy to give us a quick stratigraphic record of droughts and changes in erosion which appear thus far to correlate with charcoal abundance and supply of inorganic material. Based on this rapidly acquired stratigraphic information, we can target key transitions in the elemental stratigraphy and optimize the number of samples on which to apply the full suite of paleoecological indicators in order to characterize the vegetational and climatic signals within the sediment.

Results from a previous Climate Center grant (Peteet, Kenna, and Sritrairat, 2006) include elemental analysis of the upper 2.5 meters of a core collected in the Piermont Marsh have shown: 1) Zinc concentrations closely parallel microscopic counts of charcoal, which are linked to droughts/fires, and 2) Titanium and potassium concentrations closely parallel changes in inorganic content, which is linked to changes in erosion/sediment supply to this site.

KEY QUESTION: *Can we find robust elemental signals measured further downcore in marsh sediment cores such as zinc, titanium, and potassium that can be correlated to existing drought/erosion/fire records from pollen and spores, charcoal, macrofossils, foraminifera, and organic/inorganic sedimentation?* We note that we have submitted an NSF proposal based on this topic to study three northeastern rivers in February 2008.

Research Plan

We will focus our work on sediments collected from tidal marshes, which are very efficient sediment traps for both river and upland particulate material. These depositional environments are ideal for the acquisition of continuous stratigraphic sequences, are resistant to erosion (McCaffrey and Thompson, 1980), and contain abundant plant remains for C-14 chronology. Our preliminary results indicate that the marsh cores spanning 6000 years are continuous marsh peat with loss-on-ignition (LOI) values ranging from 20-60%, and are never as low as marsh? or river channel sediment (.05 -5%).

The initial focus of our project will be in Piermont Marsh, Hudson River, where we have reconstructed long-term drought records through paleoecology (Pederson et al., 2005; Peteet et al., 2006). We first plan to continue developing geochemical proxies (Zn, Ti, and K) for these Holocene records, and then compare them to the existing paleoecological data. Next, we will explore two sites along a salinity gradient in a similar fashion for comparison

(Iona/Constitution and a site further to the north, possibly Catskill or Athens). Existing data at upstream locations indicate that drought patterns are consistent (Sritrairat et al., 2006).

Initial Hudson Data and Interpretation

Figure 1 shows the results of our initial zinc measurements on sediments collected from the Piermont North core site. These are results are overlain with the charcoal data and C-14 converted chronology from the same site (Pederson et al., 2005). The Zn-charcoal comparison suggests that the downcore records of both of these parameters are very similar, though the sampling resolution of the Zn is lower than that of charcoal. The MWI as documented by C-14 from approximately 800-1350 AD in this core is associated with prolonged drought as identified by large increases in charcoal, changes in forest dominance from oak to pine and hickory, and declines in wetter species. The clear relationship between Zn and charcoal in the data holds promise for the development of a new and significantly more rapid method of identifying charcoal, and thus droughts.

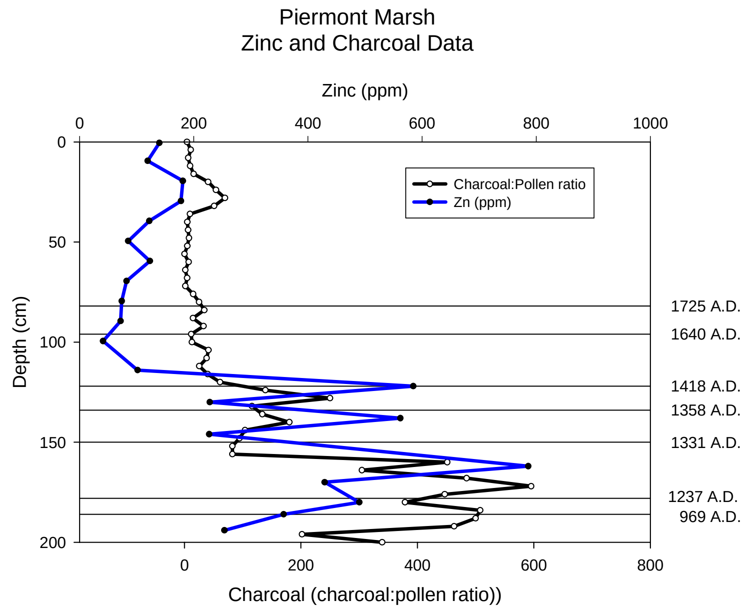

Figure 1. Results of zinc measurements made on dry homogenized sediments from Piermont marsh compared to charcoal data expressed as charcoal to pollen ratio.

Several lines of evidence indicate that elevated levels of Zn might be associated with biomass burning and charcoal, and concentrates in the residues of combustion which typically contain high levels of Zn (Llorens et al., 2001). Zn has been shown to be highly enriched in plant material compared to soils and rocks, with native species containing levels from one to three orders of magnitude greater than sandstone, shale and carbonates (5-82 ppm) (Connor and Shacklette, l975). Plants actively take up and sequester Zn, and levels of Zn are measured in hickory ash as great as 10,000 ppm and in pine ash as great as 2,100 ppm. The MWI drought as documented in the Piermont core is consistent with higher charcoal and higher concentrations of zinc during this time. An additional line of evidence for a strong Zn-drought relationship is that Cowgill (l989) found an increase in plant Zn concentrations as water availability declines. Based on these data, Zn has enormous potential as a drought indicator in marsh sediments of the Northeast. Because Zn is much easier and faster to measure than charcoal, we have the capability to dramatically increase the sampling resolution as well as the number of cores and sites to provide more detailed records over larger spatial scales.

The results of initial K and Ti on sediments collected from the Piermont North core site are shown in Figure 2. These results are overlain with the organic and inorganic content from the core and the C-14 converted chronology from the same site (Pederson et al. 2005). Throughout the record, organic content remains relatively constant while inorganic content dramatically shifts due to changes in erosion and delivery of sediment to the core site. High inorganic content between 200 and 120 cm depth was dated to the MWI (850-1350 AD) and interpreted as an erosional signal, probably from drought. The increase in inorganic content from approximately 1725 to the drop at 30 cm was interpreted as erosion to the watershed due to European settlement. When compared to the inorganic data, Ti and K both exhibit a strikingly similar downcore pattern. These elements are typically found in clay minerals kaolinite, illite, and chlorite, as well as K feldspar. The increase in the minerals at the time of more inorganic input is consistent with the interpretation of erosion in the watershed. The compelling agreement of the two data sets suggests that they are interchangeable. Similar to the approach with Zn, we should be able to obtain rapid stratigraphic records of hydrological change at our study sites.

From this preliminary data it is clear that the marsh records past abrupt and major changes in the hydrological cycle throughout the core. The high sedimentation rates in the core provide for detailed analysis to document environmental change at the decadal scale. Using geochemical and paleoecological approaches throughout the cores we will document high-resolution hydrological change.

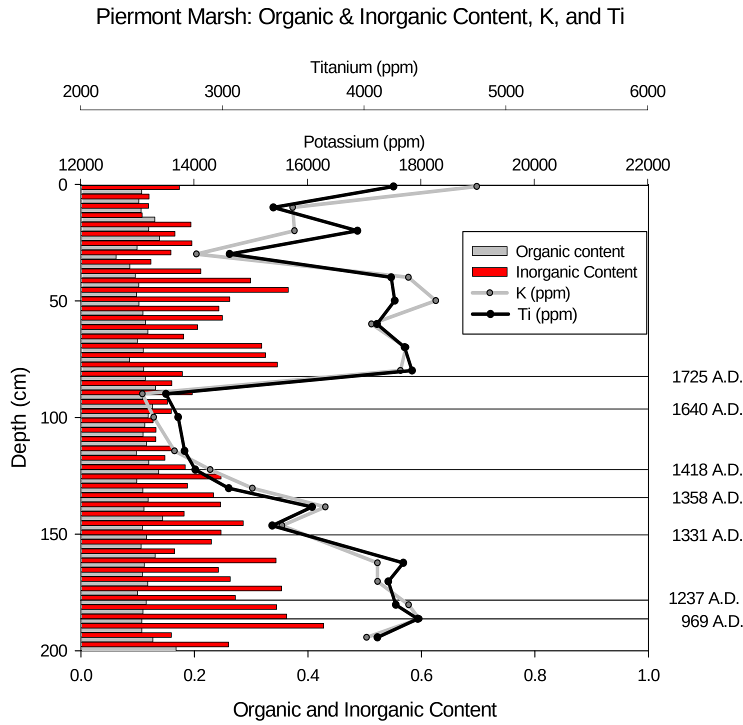

Figure 2. Results of titanium and potassium measurements made on dry homogenized sediments from Piermont marsh compared to organic and inorganic content.

Long-term Piermont Droughts– Preliminary Results

Sampling of the Piermont core at the meter-resolution downcore, we demonstrate a wide suite of marsh macrofossils which record variations in salinity (fresh-water aquatics such as *Chara* and *Nitella* vs. halophytes such as *Salicornia* in the *Chenopodiaceae*). Large changes in charcoal abundance are present, as well as variations in high marsh foraminifera such as *Trochammina macrescens* and higher salinity low marsh *Elphidium*. Preliminary pollen analysis, also at the 1-meter resolution, showed major shifts in pollen percentages downcore, with intriguing extremely high *Tsuga* pollen percentages near the base of the core. Subsequent higher resolution study (ll.2-9 m depth, 4200-3400 yrs BP) indicates rapid environmental changes. One example of a major environmental change appears at about 940 cm depth where LOI drops dramatically from 80% to 10%, foraminifera and charcoal particles disappear, and freshwater algae fossils dominate. We interpret this change as indicative of increased river flow and higher precipitation alternating with intervals of low river flow (more foraminifera, more tidal inundation, higher charcoal, and drought). We have also identified *Salicornia* and charred *Scirpus* seeds in these drought intervals, and Salicornia is especially important because it does not grow in Piermont Marsh today, presumably because the site is too fresh.

Budget

Travel	$1000
Sample grinder	$1300
Muffle furnace	$2500
Confirmatory Analyses	$2200
General Materials and Supplies	$1000
Total	$8000

Budget Justification

Travel – core collection – gas, 2 overnight stays, meals.
Sample grinder – current unit no longer functions and is needed for homogenizing dry marsh sediment for XRF measurements.
Muffle furnace – Peteet's very ancient furnace was a reject from Dave Walker's lab, has been mended many times, is probably dangerous, and utilized by many different groups (other sed. Lab members, Black Rock Forest, summer interns, etc.).
Confirmatory Analyses – Needed for XRF measurement techniques, as marsh sediments are a relatively new research initiative.
General material and supplies – core barrels, core ends, photography, disposables, etc.