GC42A-04 1115h

Cultural Eutrophication of Crawford Lake, Ontario: Effects of Disturbance Upon a Pristine and Pre-modified System

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Lake eutrophication, a condition where human activities increase nutrient input rates to aquatic ecosystems, thereby stimulating blooms of algae, is a major global water quality problem. Yet, the prehistoric dimension of eutrophication remains relatively undescribed, in part due to limitations in the temporal resolution of paleoenvironmental archives and, perhaps, equally influenced by the preconception (especially in North America) that population density and agricultural practices of native inhabitants would not be large enough to significantly impact local ecology. Here we present fossil diatom assemblages, organic and inorganic carbon accumulations, C/N ratios and calcite δ^{13}C values from a 1000-year sediment core recovered from Crawford Lake, Ontario, Canada that describe cultural disturbance and eutrophication related to Iroquoian settlement of the watershed in the 13^{th} century and to Canadian logging and agriculture in the 19^{th} century. Geochemical and biological data show increased nutrient availability and productivity associated with first evidence for human activity in the watershed at 1268 AD. Sediment accumulation rates of organic and inorganic carbon increase, and higher C/N ratios indicate export was caused by higher rates of algal productivity. A increase in calcite δ^{13}C values show a dissolved inorganic carbon (DIC) pool increasingly enriched in ^{13}C, as ^{12}C is increasingly utilized by primary producers. Diatom assemblages change from a meso-oligotrophic flora to an assemblage dominated by species indicative of nutrient-rich waters within just a few years. Following abandonment of the Crawford Lake watershed by 1486 AD geochemical proxies record a gradual decrease in productivity, related to decreased nutrient loading. Diatoms, however, remain in a meso-eutrophic assemblage. A second period of cultural disturbance, related to Canadians with plow agriculture and deforestation, begins in 1867 AD. Primary productivity is again elevated, yet the diatom assemblages do not change significantly. Carbon isotopes also show little response, potentially due to light limitation of benthic primary producers. We use multivariate statistical analysis to describe the relationship of specific diatom species to increased productivity and to highlight the differing responses in diatom assemblages between the two periods of cultural disturbance. This work emphasizes the importance of initial perturbations to pristine systems, and indicates that a deep historical perspective may be useful for lake and aquatic ecosystem managers.

GC42A-05 1130h

INTERPRETING THE HISTORY OF LAKE ANOXIA USING IRON AND SULFUR GEOCHEMISTRY

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Over the last thousand years, anthropogenic activities, such as land cultivation and atmospheric pollution, have increased the flux of growth-limiting nutrients to several North American lakes. The most common effect of this enhanced nutrient supply is a dramatic increase in the abundance of aquatic plants and algae. When these organisms die, the organic carbon in their remains falls through the water column and is oxidized by dissolved oxygen. Thus, eutrophic lakes are characterized by seasonally or permanently anoxic bottom waters because the rate of organic carbon oxidation exceeds the rate at which oxygen is replenished. The depletion of water column oxygen adversely affects lake ecosystems by decreasing water quality and by altering the community structure of fish and algae populations. In this study we examine the history of lake anoxia in two North American lakes, Half-Moon Lake in Michigan and Crawford Lake in Ontario. Sediment freeze cores and water column samples were taken from each site and both lakes contained well-preserved varved sediments. The sediments were analyzed for FeH (HCl-extractable iron), AVS (acid-volatile sulfur), CRS (chromium-reducible sulfur), d34S(CRS), CaCO3, CH2O, C/N, and d13C (CaCO3). Water samples were analyzed for pH, O2, cations, anions, and d34S(SO4). Today, Half-Moon Lake is seasonal anoxic while Crawford Lake has not overturned in the past 15 years. Geochemical and biological data indicate that both lakes have experienced cultural eutrophication events in the 1800-1900s related to European-style agricultural practices. In addition, Crawford Lake experienced an earlier eutrophication episode around 1325 A.D. related to Iroquoian settlement of the area. Each eutrophication event showed an increase in the mass accumulation rate of pyritic sulfur, suggesting that sediments were exposed to longer durations of low-O2, H2S-rich waters during periods of cultural eutrophication. The geochemical parameter DOP (degree of pyritization) is defined as pyrite Fe/(pyrite Fe + FeH) and quantifies the fraction of iron that is converted into pyrite. DOP values from Half-Moon Lake are low (0.1) prior to European settlement and increase to high values (>0.7) after European settlement. In Crawford Lake, our preliminary data indicate that the Iroquoian horizon has lower DOP values than the European horizon. This indicates that the water column was less sulfidic (more oxygen-rich) during the 1300s than in the 1800-1900s. These results show that Fe and S geochemistry can be used to document the history of lake anoxia.

GC42A-06 1145h INVITED

Biogeochemical Cycling and Contamination of Mercury in Arctic Alaska: Modern and Historic Atmospheric Fluxes.

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Our research in the U.S. Arctic is focused on (a) atmospheric Hg deposition and contamination of lakes and watersheds, (b) in-lake cycling of Hg, especially methylHg, and (c) the behavior and fate of elemental Hg, whose production and mobilization via water-air exchange are quite significant. These studies are being conducted in the lacustrine and tundra wetland environs near the Arctic LTER Site at the Toolik Field Station (68°38' N, 149°38' W). Atmospheric Hg deposition over the last several centuries has been established with dated sediment archives from five carefully selected (i.e., headwater; small watershed) remote arctic lakes. Mercury budgets for the study lakes have been constructed from atmospheric, water column, watershed, and sedimentary investigations. Results indicate that (1) impact from anthropogenic Hg in the Arctic is of similar magnitude to that at temperate latitudes; (2) whole-lake Hg sedimentation determined using 55 210Pb-dated cores from the five small lakes demonstrates a 3-fold increase in atmospheric Hg deposition since the advent of the Industrial Revolution, (3) the linear correlation between Hg and 210Pb found in rainwater from other locations is observed in the Arctic, and this behavior can be used to constrain the wet atmospheric flux of Hg to lakes and watersheds, (4) volatilization accounts for about 20% of the Hg losses (evasion and sedimentation) from lakes, and (5) another source term is needed to balance the evasional and sedimentation sinks. This additional flux, though small, is comparable to direct atmospheric Hg deposition. It may be due to some combination of Springtime Hg Depletion Events and more generalized deposition of reactive gaseous Hg species in this tundra region, which is about 150 km from the Arctic Ocean.

GC43A CC: 220 C-E Thursday 1330h

Environmental Records With Anthropogenic Impacts III Posters

Presiding: **J C Varekamp,** Wesleyan University**; T C Ku,** Wesleyan University

GC43A-01 1330h POSTER

Tritium Accumulation in Salt Marsh Sediments From the Severn Estuary, UK

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Two shallow sediment cores (to 0.5 m) have been collected from salt marshes in the Severn estuary, UK, as part of a study of the impact of tritium (3H) discharges into the estuary. These discharges are atypical; they have routinely contained both tritiated water (HTO) and organically bound tritium (OBT) since 1982. Tritium present as HTO is usually assumed to be diluted and dispersed on release into the marine environment. However the organic component of this discharge has resulted in significant accumulation of 3H in the estuarine sediments (0.8 Bq/g fresh weight) and biota (24.8 Bq/g dry weight in flounder (McCubbin et al, 2001)). The tritium profiles from the dated salt marsh cores correlate with the decay-corrected organic 3H discharge record. This chronological record suggests that tritium has been retained over decadel timescales, with limited loss by organic matter degradation. This indicates that the tritiated organic molecules are refractory. The apparent persistence of 3H labelled sediments in the estuary has implications for the long-term impact on the environment of 3H discharges containing high proportions of OBT.

GC43A-02 1330h POSTER

Paleoproductivity Indicators in Long Island Sound

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Oxygen depletion in bottom waters is considered to be the most pressing environmental problem affecting Long Island Sound (LIS). Summer anoxia occurs as a result of two factors: 1) Stratification of the water column due to warming of the shallow water preventing mixing and thus homogeneous distribution of oxygen. 2) Eutrophication resulting in increased primary productivity leading to a greater oxygen demand in the bottom waters as the larger amount of organic matter decays. The goal of this project is to create a paleoproductivity record for LIS and to attempt to link recent increases in productivity with anthropogenic nutrient sources, most notably wastewater treatment plant effluent. Two cores, WLIS-75 from the western narrows and B1GGC1 from near the mouth of the Housatonic River, have been analyzed for biogenic silica (BSi), total carbon, nitrogen, and sulfur. The BSi data was obtained through analyses of timed sequential extracts from an alkaline solution that reacted with the sediment at 85 C. Sediment densities were calculated from measured core water contents and assumed dry rock densities. A preliminary age model was developed using the onset of mercury pollution (about 1820 AD) as a reference point. At around 1800, the C, N, S and BSi concentrations all start to increase. In WLIS-75, BSi was higher throughout the core compared to core B1GGC1, suggesting an overall higher rate of productivity in the western section of LIS. In both cores the mass accumulation rates of BSi, C, N, and S increased exponentially over the last 300 years. A coarse layer was deposited around 1950-1960 in core WLIS-75, and is marked by abundant coarse debris of rocks and coal fragments. This layer may represent a flood deposit or stem from local (illegal?) dumping; its presence impacts the data for the last 30-40 years of the core. A

strong correlation between total S and total C is observed, suggesting that Sulfide formation is limited by the amount of labile organic matter present. The data from the two cores show strong evidence for eutrophication over the last 200 years, with a strong increase in the N supply.

GC43A-03 1330h POSTER

Development of Micropaleontological and Geochemical Indicators of Eutrophication in the St. Lawrence Estuary

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Recent measurements show that an estimated 1300 km2 of the bottom of the St. Lawrence Estuary is now bathed by hypoxic waters (i.e., waters containing less than 62.5 μM or 2 mg/l of dissolved oxygen). Eutrophication is one of the possible causes of hypoxia. An increased flux of nutrients from the watershed would lead to an increase surface productivity and organic carbon flux to the bottom waters. The microbially-mediated remineralization of this organic carbon will result in the progressive depletion of dissolved oxygen in the bottom waters. We have analysed sediment cores collected in the lower St. Lawrence Estuary in order to investigate temporal changes in productivity since the pre-colonial period and to identify evidence of eutrophication. The chronology of the cores is based on 210Pb measurements. The upper part of the box cores (upper 20 cm) is characterized by a very high sedimentation rate of 0.74 cm/yr. In the lower part of the core, sedimentation rates decreased to 0.28 cm/yr. Organic carbon content and its Δ13C signature were used to reconstruct the fluxes, provenance and nature of the organic matter. The concentration and assemblages of dinoflagellates cysts served to estimate the variation in planktonic productivity whereas the abundance of benthic foraminifera and their organic linings were used to estimate variations in benthic production. The data clearly show an increase in the Δ13C of preserved organic matter since the 70's, which we interpret as a shift toward enhanced contribution from a marine source of organic carbon. This shift corresponds to a significant increase in dinocyst concentration, possibly reflecting an increase in primary production of the surface waters. Moreover, there is an increase in the concentration of organic linings of benthic foraminifera suggesting a concomitant increase of benthic production.

GC43A-04 1330h POSTER

Radiocarbon Studies of Long Island Sound Sediments

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We analyzed organic material and carbonate shells from core samples in Long Island Sound (LIS) for d13C and radiocarbon to investigate changes in reservoir ages due to anthropogenic changes in the carbon cycle. In addition, we dated shells from several LIS cores to establish chronologies for the development of the Sound from the marine incursion to modern day sedimentation. Reservoir ages in estuaries vary spatially and temporally due to the added old dissolved carbon from freshwater as well as changes in marine and freshwater fluxes and mixing processes. Sources of reservoir changes can be traced with the combined use of d13C and 14C in shells. This study used the time-dependent marine reservoir curve (Stuiver and Brazunias, 1993) to calculate local LIS reservoirs. Reservoir ages in Long Island Sound seem to increase steadily from 1000 AD to 1500 AD at a rate of .2 reservoir years/14C years (dR decreases from -137 to -353 14C years). Reservoirs after 1750 AD range from -464 to 185 14C years, showing no spatial or temporal trends. The d13C of carbonates also vary more during this time period. The input of dissolved terrestrial old carbon' via rivers was probably higher during the Medieval Warm Period. After colonization, increased anthropogenic carbon input from sewage and watershed export as well as oxidation of the enhanced primary productivity contributed both young and older carbon to the Sound causing extremely variable and localized reservoirs. Our 14C measurements on marine mollusks from before 8000 BP show a steady sedimentation rate of 1.6 mm/year in Eastern LIS. These dates suggest that the marine incursion occurred at about 11,000 BP. Our 14C measurements on terrestrial organic debris from the LIS cores show significantly older dates than those from carbonates in the same samples, suggesting that most terrestrial particulate organic matter is several 1000 years old before it enters the Sound. For the early history, the organic carbon was possibly first stored in glacial lake deposits before it was transported to LIS. If so, the chronology of the marine incursion into LIS, which is largely based on radiocarbon dates of organic matter, may have to be revised.

GC43A-05 1330h POSTER

Benthic Foraminifera in the Changing Ecosystem of Long Island Sound

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Long Island Sound (LIS) is an estuary in a heavily urbanized region; Long Island lies to its South, New York City (NYC) to its West and Connecticut to its North. The Connecticut River contributes >70% of the fresh water influx. LIS has a narrow opening to the West (into East River), but exchange with the ocean occurs dominantly at its eastern end, resulting in an east-west gradient in salinity. An east-west gradient is also present in indicators of anthropogenic contamination in the surface sediments (e.g., trace metals) because western LIS is close to the major source of anthropogenic input (NYC). In addition, bottom currents focus fine-grained, contaminant-loaded sediments there. Since the early 1970's western LIS and parts of central LIS have suffered summer hypoxia, probably as a result of increased algal growth caused by anthropogenic nitrogen input. Benthic foraminifera are eukaryote heterotrophic organisms with a calcareous or agglutinated test. We investigated changes in their populations over time in about 2m-long gravity cores in westernmost (WLIS75GGC1; 73^o 40'W, 40^o 52'N, 19m waterdepth) and coastal central LIS (B1GGC1; 73^o 4'W, 41^o 10'N, 8m water depth), to document environmental changes over the last millennium, including the time of European settlement and the industrial revolution and population increase. An age model was derived from metal pollution records and ^{14}C dating. Before European settlement, the low-diversity benthic faunas in core B1GGC1, at a depth within the zone of light penetration, were dominated by *Elphidium excavatum*, a species feeding on living diatoms. In western LIS (below the zone of light penetration) this species was less abundant and *Elphidium incertum* and *Buccella frigida* were common. In both cores, the absolute abundance of benthic foraminifera and the relative abundance of *Elphidium excavatum* increased in the early 1800's, coinciding with a time of rapid increase in human population around LIS and slightly before an increase in trace metal concentration. The ecological changes may have been caused by increased productivity of diatoms resulting from beginning anthropogenic eutrophication. From the middle 1960's on, absolute foraminiferal abundance decreased and *Ammonia beccarii*, formerly absent or rare, became common to dominant in WLIS75GGC1; in B1GGC1 a similar but less severe change started in the 1970's. The increase in relative abundance of *A. beccarii* could have been caused by hypoxia (possibly in conjunction with rising bottom water temperatures), but both *Ammonia* and *Elphidium* species survive hypoxia in the laboratory. We suggest that high N/Si resulting from strong eutrophication might favor primary producers other than diatoms (e.g., dinoflagellates, cyanobacteria), making *E. excavatum* less competitive. The LIS coastal ecosystem thus changed significantly with the enhanced nutrient input associated with human population growth in the middle 1800's, and again with more severe eutrophication over the last few decades.

URL: http://ethomas.web.wesleyan.edu/lisweb

GC43B CC: 524 C Thursday 1330h

Continental Energy Balance, Land-Surface Processes, and Surface Temperature II

Presiding: **R N Harris,** University of Utah**; H Beltrami,** St. Francis Xavier University

GC43B-01 1330h

Solar Radiation and Climate Change in the Great Plains

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The global average air surface temperature has increased about 0.6°C over the 20th century (Houghton et al. 2001). This warming has resulted in a 10% decrease in the extent of snow cover observed from satellite, and about two weeks reduction in the annual duration of lake and river ice cover in the mid- and high latitudes of the Northern Hemisphere from ground-based observations (Houghton et al. 2001). In the Great Plains, we found ground-surface warming increases systematically with latitude from 0.4°C per century at 41.1°N to 2.0°C per century at 49.4°N (Gosnold et al. 1997). This project expands our study to investigate coherence between ground-surface temperatures, solar radiation, and all other relevant meteorological data. We have collected more than 20 years of surface meteorological data, such as soil temperatures, surface air temperatures (SAT), precipitation, and downward solar radiation, from the High Plains Regional Climate Center (HPRCC) in Lincoln, Nebraska since 1981. The daily mean values of meteorological data within the states of Kansas, Nebraska, South Dakota, and North Dakota have been binned and averaged to 0.5-degree latitude intervals to study temporal and latitudinal variations of soil temperatures, SAT, and solar radiation as well as their coherences. This area covers the latitudes of 37°N to 49°N, and the longitudes of 95°W to 104°W. Through this study, we are attempting to answer the following questions: (1) How does this warming trend relate to solar radiation? (2) How does this warming trend relate to the satellite-measured 10% decrease in the extent of snow cover since late 1960's and the ground-based observed 2-week reduction in the annual duration of lake and river ice over the Great Plains? (3) What is the coherence between the SAT and soil temperature during the study period? (4) What are the causes of this observed warming trend?

GC43B-02 1345h INVITED

Landcover change and Climate

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Recent modeling studies have shown that human changes in landcover can affect surface climate on both regional and global scales. Changes in landcover are relayed to the atmosphere as changes in moisture and energy balances and through perturbations to biogeochemical cycles. We will present examples of these effects on a variety of time and spatial scales. Landcover change in the tropics is also associated with simulated changes in large scale circulations such as the Hadley and Walker cells, and monsoon circulations resulting in climatic effects that are non-localized and global in extent. Recently observEd changes in natural circulation regimes such as the NAO/AO and ENSO are responsible for a large portion of the observed global surface warming in recent decades. Because landcover changes appear to affect these circulations, it is possible that the effect of landcover changes may explain some part of the discrepancy between climate change simulations and observations.