

columns were set up as anaerobic by introducing nitrogen gas, and 4 columns aerobic with oxygen gas. Seven columns contain 500 mL by volume of aquifer core and 1,500 mL native surface water, 2 columns contain native surface water to serve as controls. Two columns contain sterilized core, and 1 column contains native core with deionized water. Each column was sampled at 2, 4, 8, 12, and 16 weeks. The objectives of the experiments are to determine potential chemical reactions, to evaluate the potential for ASR injection to methylate mercury, to determine the time required for stored water to methylate mercury, and the conditions under which methylation may occur in ASR stored water.

B23B-03 1415h

Hg Deposition to Lakes in Northern New England Inferred at Multiple Scales From ²¹⁰Pb-Dated Sediment Cores

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Mercury (Hg) contamination of aquatic systems is recognized to be a problem of global consequence, and Hg bioaccumulation poses significant risks to piscivorous animals and humans who consume gamefish. In order to quantify historical and current Hg deposition to the northern New England landscape, we dated and performed Hg analyses on sediments cores from various lakes at local and regional scales. In this presentation, we contrast results of three studies: a regional assessment of Hg deposition to the VT-NH landscape (10 lakes); a localized study of deposition to the Lye Brook Wilderness of southern VT (four lakes); and the first-ever dated assessment of sediment Hg deposition history for Lake Champlain (three sites + one adjacent inland lake). At the VT-NH scale, total Hg (HgT) fluxes to sediments ranged from 5 to 17 $\mu\text{g}\cdot\text{m}^{-2}\cdot\text{yr}^{-1}$ during pre-industrial times, and from 21 to 83 $\mu\text{g}\cdot\text{m}^{-2}\cdot\text{yr}^{-1}$ presently. Present-day HgT fluxes are between 2.1 to 6.9 times greater than pre-1850 fluxes, and atmospheric Hg deposition to the VT-NH region was estimated at 21 $\mu\text{g}\cdot\text{m}^{-2}\cdot\text{yr}^{-1}$. This agrees well with measured HgT deposition, when re-avoidance of Hg is accounted for. Hg fluxes to lake sediments have declined in recent decades, owing to reductions in atmospheric Hg deposition to the lake surfaces. In the high-elevation Lye Brook Wilderness landscape, baseline, peak, and present accumulations were higher than those estimated from the VT-NH dataset, a finding that highlights the roles of elevation, watershed size, and dissolved organic carbon export in mediating Hg transport. Available data from the Lake Champlain Basin show the influence of historical and current watershed sediment delivery due to land cultivation, and more recently to land-use conversion. These studies jointly indicate that watershed export of legacy Hg continues despite declines in present-day deposition rates, contributing to the impression that Hg retention by watershed soils has declined.

B23B-04 1430h

Increases in methylmercury export from a sulfate-amended peatland: A consequence of an altered microbial consortia?

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An experiment at the Marcell Experimental Forest, Minnesota is ongoing to test the hypothesis that increased atmospheric sulfate deposition to northern peatlands is responsible for increased methylmercury

yields from these ecosystems. A peatland, divided into an upslope control portion and a downslope experimental portion, has had elevated levels of sulfate applied to the experimental portion using an extensive irrigation network for several seasons. Increases in methylmercury yield from the system were apparent early in the experimental manipulation. In 2002, peat cores were extracted from the control and experimental areas of the peatland to evaluate whether or not changes in the peat sulfur geochemistry, microbial community structure, and/or mercury methylation potential could be attributed to the sulfate additions. Mercury methylation potential was assessed using a stable isotope addition to incubated intact peat cores, which were subsequently sliced and frozen until analyses. The microbial community structure was assessed using a modified solid-phase extraction followed by phospholipid fatty acid (PLFA) analyses. Although only minor differences in sulfur geochemistry and methylation potential were detected, the treatment cores had increased abundances of Desulfovibrio-group and Desulfobacter-group biomarkers compared to the control cores, and the effect was greatest in the near surface peat. In the control cores, the abundances of sulfate-reducers in both groups increased with depth. These results suggest that increased sulfate loading may cause a shift in microbial community structure and abundance in favour of known mercury methylators.

B23B-05 1445h

Are uplands the key to understanding possible lag times for ecosystem recovery to reduced mercury loading? Results from the first two years of mercury stable isotope additions to the uplands of the METAALICUS project

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The Mercury Experiment to Assess Atmospheric Loadings in Canada and the US (METAALICUS) is a whole-watershed Hg loading experiment being conducted at the Experimental Lakes Area in northwest Ontario. Many of the response metrics that attract attention to this project are focused on methylmercury (MeHg) formation and bioaccumulation. However, some of the most difficult questions to answer at the study site, and watersheds elsewhere, relate to responses in the uplands and wetlands, and connections to down-gradient aquatic ecosystems. Mercury studies in upland areas are in part motivated by the observation that the vast majority of past emissions now resides in soils and sediments across the globe, yet we know relatively little about the stability of this large Hg reservoir. For this aspect of METAALICUS, we applied a traceable stable isotope (²⁰⁰Hg) to the upland areas of the watershed at about 4 to 5 times the ambient rate in an attempt to answer these difficult questions. Results from the first two years of applications to the uplands and monitoring have showed several interesting, and somewhat unexpected results. The estimated annual total Hg flux (about 98% inorganic Hg) from upland runoff to the study lake (about 1500 mg) exceeds the rate of direct atmospheric Hg deposition flux by a factor of about three to four, illustrating the importance of including upland studies for aquatic ecosystems. This upland mercury flux is the dominant ambient inorganic Hg source for the study lake. In contrast, very little of this flux was MeHg.

B24A CC: 524 A Tuesday 1530h

Mercury Biogeochemistry at the Terrestrial-Aquatic Interface III

Presiding: B A Branfireun, University of Toronto at Mississauga; M Marvin-DiPasquale, U.S. Geological Survey

B24A-01 1530h INVITED

Methylmercury Formation in Marine and Freshwater Systems: Sediment Characteristics, Microbial Activity and SRB Phylogeny Control Formation Rates and Food-Chain Exposure

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Mercury research in freshwater and marine systems suggests that sediment characteristics such as organic substrate, mercury speciation, and sulfate/sulfide concentrations influence availability of inorganic mercury for methylation. Similarly, sediment characteristics also influence sulfate-reducing bacterial (SRB) respiration as well as the presence/distribution of phylogenetic groups responsible for mercury methylation. Our work illustrates that the process of methylmercury formation in freshwater and marine systems are not dissimilar. Rather, the same geochemical parameters and SRB phylogenetic groups determine the propensity for methylmercury formation and are applicable in both fresh- and marine-water systems. The presentation will include our integration of sediment geochemical and microbial parameters affecting mercury methylation in specific freshwater and marine systems. Constructed wetlands planted with *Schoenoplectus californicus* and amended with gypsum (CaSO_4) have demonstrated a capacity to remove inorganic mercury from industrial outfalls. However, bioaccumulation studies of periphyton, eastern mosquitofish (*Gambusia holbrooki*) and lake chubsucker (*Erimyzon succetta*) were conducted in order to ascertain the availability of wetland-generated methylmercury to biota. Total mercury concentrations in mosquitofish from non-sulfate treated controls and the reference location were significantly lower than those from the low and high sulfate treatments while mean total mercury concentrations in lake chubsuckers were also significantly elevated in the high sulfate treatment compared to the low sulfate, control and reference populations. Methylmercury concentrations in periphyton also corresponded with mercury levels found in the tissue of the lake chubsuckers, and these findings fit well given the trophic levels identified for both species of fish. Overall, data from this study suggest that the initial use of gypsum to accelerate the maturity of a constructed wetland may not prove beneficial with respect to the ultimate objective of mercury sequestration. Current regulations place strict requirements on dredge material placed in confined disposal facilities (CDF) as well as associated effluent waters. Although regulatory guidelines typically address total mercury concentrations, historical data specific to bioaccumulation of mercury suggest that methylmercury concentrations found in sediments and water require attention. Resource agencies are now interested in knowing the likelihood of methylmercury formation in dredge spoil since birds and fish are frequently found feeding in CDFs and the associated mixing zones. Mechanisms that influence methylmercury formation in sediments dictate that dredging of mercury-containing sediments will result in an increased availability of inorganic mercury for methylation. Prior to dredging, the undisturbed sediment contains inorganic mercury complexed to sulfide in an insoluble, unavailable form. However, hydraulic or clamshell dredging can result in an oxidation of sediments and remobilization of mercury-sulfide species thus increasing its availability for methylation. Once sediments are disposed in a CDF, sulfate-reducing bacteria profiles are re-established vertically in dredge spoil and methylmercury synthesis can readily occur.

B24A-02 1600h

Microbial Mercury Cycling in San Francisco Bay Sediments: From Regions to the Rhizosphere

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The San Francisco Bay (SFB) estuary is hydrodynamically diverse ecosystem with extensive mercury contamination associated with historic gold and mercury mining wastes, and in a region with an unprecedented number of wetland restoration projects planned or ongoing. Wetlands are known to be active areas for the microbial transformation of Hg(II) to methylmercury (MeHg), which bioaccumulates in the food web. A better understanding of this microbial process, in these restored wetlands and other sub-habitats, is critical if Hg contamination is to be successfully managed in this system. An examination of MeHg production and degradation in sediments has been conducted at multiple spatial scales throughout the SFB estuary and its tributaries over the past four years. At the regional scale, we will present data from the brackish Bay, the delta, and rivers and reservoirs in tributary watersheds. Within the freshwater delta and river regions, a new project is focusing on emergent marsh, non-vegetated open water, and submerged-macrophyte zones. At the smallest scale, we consider microbial Hg cycling in the root zone (rhizosphere) of dominant wetland plants and propose a conceptual model of the key biogeochemical reactions that may make this transitional zone one of the most important with respect to Hg(II)-methylation.

B24A-03 1615h

Methylation and Release of Mercury From the Solid Phase. What Comes First?

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It is a well-known fact that methylation leads to a dramatic increase in the bioavailability of mercury (Hg). All recent observations support the notion that Hg methylation is almost exclusively an anaerobic process. According to the reigning paradigm, methylation of Hg takes place in the cytoplasm of anaerobic bacteria, notably sulfate-reducing bacteria. It is believed that certain forms of inorganic divalent Hg (Hg(II)), can readily diffuse across the cell membrane. In addition, a recent study suggested that active uptake may occur when Hg is bound to low weight organic molecules. In the cytoplasm, cobalamin-dependent biochemical pathways, designed to methylate substrates other than Hg(II), are held responsible for the methylation of Hg(II). However, recent results from studies in a Swedish wetland (within the project "Svartsjöprojektet", aiming at understanding Hg dynamics in a Hg-polluted river-lake system) have led us to question whether Hg methylation does occur exclusively within cells. A provocative interpretation of our results is that methylation preceded the release of Hg from the solid phase, e.g. that Hg(II) sorbed to solid surfaces was methylated and subsequently released as methyl Hg to the sulfidic water. I will discuss this possibility in light of existing evidence that Hg methylation is an intra cellular process.

B24A-04 1645h

Mercury methylation in forested uplands; how important is it?

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Episodic fluxes of mercury during high flows at the headwater catchment at the Sleepers River Research Watershed in Vermont indicate that uplands are an important source of total mercury (Hg) to known downstream methylation sites (i.e. large wetlands). Methylmercury (MeHg) behavior in streamwater, soil water, and sediment porewater coupled with high potential methylation rates suggests that forested uplands may be significant source areas for MeHg as well. In a July 2003 incubation, potential Hg methylation rates exceeded potential demethylation rates by factors of 1.6 each in shallow (0-4 cm) swamp and riparian soils and by 19.6 in anoxic stream sediments. The stream sediment had the greatest methylation rate of 7.5 ng/g of wet sediment / day. However, MeHg concentrations in filtered (0.4 um) porewater at these sites ranged only from 0.07 to 0.37 ng/L, similar to the range at low-lying wetland sites elsewhere in Vermont (0.06 to 0.56 ng/L). In Sleepers River headwaters as well as larger Vermont rivers, most of the MeHg export occurs during snowmelt and summer / fall storms, with nearly all of the MeHg occurring in the particulate phase. Stream total Hg and MeHg concentrations were consistently correlated, suggesting a common source, probably soil organic matter. The methylation efficiency (ratio MeHg / total Hg) was near 2% in the Sleepers River headwaters, similar to that in Vermont rivers draining large wetland systems, indicating that the methylation process originates in the headwaters.

B24A-05 1700h

Hg Concentrations in Epiphytic Lichens Trace Atmospheric Deposition

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Mercury is emitted to the atmosphere by anthropogenic and natural sources, the dominant form being the gaseous elemental Hg⁰. The residence time in the atmosphere is relatively large, and may reach several months. The rate at which mercury is removed from the atmosphere might be highly variable and depends on environmental conditions. Some authors suggested that the presence of agents such as ozone, OH, NO₃ and chlorine species may oxidise Hg⁰ leading to an important reduction of its residence time and a significant increase of atmospheric deposition. This study aims to characterise the Hg concentration in lichen samples in order to document the variability of atmospheric fall-out. Lichens are of particular interest because their epiphytic character makes them totally dependant of atmospheric nutrients, so that their chemical composition reflects that of atmospheric matter. Lichens hanging on tree branches were sampled in various location of the boreal forest of northern Quebec. The Hg concentrations measured in lichens vary from 2 to 0.2 ppm and decrease systematically from the coast of Hudson Bay towards inland at the scale of hundreds of km. Hg content is highly correlated with halogen elements in lichens. The best correlation is found between mercury and iodine. This suggests that the presence of halogen species are effective for oxidising elemental gaseous Hg in the atmosphere, leading to an increase of total Hg fall out by a factor of 10 in coastal environments relative to continental environments.

B24A-06 1715h

Mercury in the Environment, Global Climate Change and Ozone Depletion Chemistry: Recent Evidence for Multiple Linkages

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This synthesis paper provides a discussion of recent scientific evidence documenting multiple linkages between atmospheric mercury cycling, global climate change factors (GCC) and ozone depletion chemistry. Previously researchers have hypothesized that GCC could enhance the mobilization and bioaccumulation of mercury in ways that could increase the risk of human exposure. Recent scientific research focused upon mercury emissions and mercury cycling in the environment has yielded an improved understanding of biogeochemical processes. These studies provide insights from both field and laboratory measurements and from all of the environmental compartments involved in mercury cycling. Taken together, the results of these scientific studies document multiple relationships between mercury cycling, GCC factors and ozone depletion chemistry. These complex relationships promote the cycling

of mercury in the environment, i.e., increasing the mobilization and bioavailability of mercury in the environment. First, recent findings demonstrate that the rate of oxidation of elemental mercury to reactive gaseous mercury increases with increased solar radiation, in turn elevating the level of mercury released from soils, substrate and polar snow pack. The increased rate of the oxidation of elemental mercury is documented to be contemporaneous with tropospheric ozone depletion events in polar studies. Second, an increase in the release of mercury from substrate occurs with increased temperature as demonstrated during forest fires and in mercuriferous geology. Third, mercury bioaccumulation in fish has been closely linked to the production of dissolved organic carbon, with an increase in bioaccumulation levels possible with increased water temperature. As a result, this paper suggests a new term, the "Muir Effect" for describing multiple linkages that occur in complex environmental cycles. The Muir Effect is named after well-known American naturalist, John Muir.

B31A CC: 220 C-E Wednesday 0830h

Multitemporal Remote Sensing of Vegetation II Posters

Presiding: C Song, University of North Carolina at Chapel Hill; W B Cohen, USDA Forest Service

B31A-01 0830h POSTER

Monitoring Forest Succession Using Multitemporal Landsat Images: Factors of Uncertainties

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This study evaluates uncertainty factors in using multitemporal Landsat images for subtle change detection, including atmosphere, topography, phenology, sun and view angles. The study is based on monitoring forest succession with a set of multiple Landsat TM/ETM+ images spanning 15 years over the H. J. Andrews Experimental Forest in the Western Cascades of Oregon. The algorithms for removing atmospheric effects from remotely sensed images evaluated include a new version of dark object subtraction (DOS3) method, the dense dark vegetation (DDV) method, the path radiance (PARA) approach, and the 6S radiative transfer codes. We found that the DOS3 approach under-corrects the image, and the recently developed DDV and PARA approaches can produce surface reflectance values closely matching those produced by 6S using in situ measurements of atmospheric aerosol optical depth. Atmospheric effects reduce NDVI and Greenness, and increase Brightness and Wetness. Topography modifies Brightness and Greenness, but has minimal effects on NDVI and Wetness, and it interacts with sun angle. Forest stands at late successional stages are more sensitive to topography than younger stands. Though the study areas are covered predominantly by evergreen needle leaf forests, phenological effect is significant. Sun angle effects are confounded with phenology, and reflectance values for stands at different successional stages are related to sun angles nonlinearly. Though Landsat has a small field of view angle, the view angle effects from overlapping Landsat scenes for a mountainous forested landscape may not be ignored when monitoring forest succession with multitemporal images.

B31A-02 0830h POSTER

Trace metal content and micromorphology as proxies for bleaching in the modern coral *Porites divaricata*

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Morphology and trace metal content of scleractinian corals have previously been used as proxies for past environmental conditions, but no proxy for the health of ancient corals currently exists. Skeletal material associated with bleached and non-bleached tissue from recent *Porites divaricata* was analyzed with SEM and ICP-AES. Differences in both morphology and trace metal content were found in samples associated with bleached and non-bleached tissue. SEM analysis showed skeletal corallites associated with unbleached tissue have well-defined septal denticles. Skeletal corallites associated