just under 30% of aboveground biomass. This management regime is becoming increasingly common throughout the region. Prior to harvest, the stand contained about 76 Mg C $ha^{-1}$ (30 $m^2 ha^{-1}$ basal area) in above- and below-ground live biomass. Harvesting removed about 15 Mg C $ha^{-1}$ (SEM=2.1), and created about 5.3 Mg C $ha^{-1}$ (SEM=1.1) of aboveground and 5.2 Mg C $ha^{-1}$ (SEM=0.7) of root/stump detritus. Leaf-area index and litterfall declined by about 40% with harvest. Approximately half of the harvested wood was used for paper products (half-life of 3.5 years) and half for longer-lived wood products (half-life of 45 years). In a nearby, unharvested stand, eddy covariance measurements indicated that net ecosystem exchange (NEE) averages about 1.8 Mg C $ha^{-1}$ $y^{-1}$. A comparison of NEE at unharvested and harvested stands, both pre- and post-harvest, indicated that NEE declined following the harvest by about 18%, which is less than expected based on basal area and LAI changes. Both daily uptake and nocturnal respiration declined after harvest. Soil respiration declined slightly with harvest, suggesting no major soil C loss after harvest; harvesting had little effect on soil moisture and temperature. When decay of paper and wood products is included in a preliminary carbon budget, we predict that the forest will be a net C source to the atmosphere for at least 5 years, assuming pre-harvest growth rates of trees. How quickly the carbon balance becomes positive will depend largely on whether post-harvest tree growth rates increase.

### B12E-08 1525h

### Assessing Biogeochemical Cycling in Forested Ecosystems Through Integration of Remotely-Sensed Forest Structure with an Ecosystem Model

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Forested landscapes are generally composed of a heterogeneous mixture of patches that reflect the complex interaction of processes occurring at many spatial and temporal scales. Whether caused by natural disturbances, such as blow downs and fire, management practices, such as logging and agriculture, or varying climatic factors, both ecosystem structure and carbon fluxes will vary strongly as a result of differences in successional stage. Forest structural measurements, such as canopy characteristics and biomass, are key elements in furthering our understanding of the carbon budgets of forested ecosystems because they provide the observational evidence from which the impacts of various processes may be assessed. They also provide what is often the only means of determining successional status and edaphic controls, and are thus critical for both initialization and validation of carbon modeling approaches. Identifying and tracking these structural differences through space and time has been extraordinarily difficult, given the burden and limited scope of field-based methods, and the limited efficacy of most remote sensing approaches. In this paper we explore the potential for assessments of biogeochemical cycling in forests using a combined field, remote sensing and modeling approach. Our focus is on the fusion of various remote sensing data, including lidar and multispectral methods, with limited field based observations, to provide trajectories of successional status that can then be used to initialize and validate ecosystem models. We provide examples using the Ecosystem Demography (ED) model for both tropical and temperate forests. Our results in these areas show that initialization of the ED model with remotely sensed data on forest structure, in particular canopy height, allows for estimates of carbon stocks within few percent of field-based methods, greatly constrains consequent estimates of carbon flux. This approach thus provides a promising means for observing the effects of various disturbance and management regimes on forested ecosystem structure and associated carbon fluxes.

## B12F MCC: 2000 Monday 1600h

## Environmental Assessment From the Width, Anatomy, and Chemical Composition of Tree Rings II *(joint with A, H, GC)*

***Presiding:*** **T E Lewis,** U.S. Environmental Protection Agency**; T Yanosky,** U.S. Geological Survey

### B12F-01 1600h

### Tree-Ring Evidence for Volcanic Eruption Effects on Temperate and Boreal Tree Net Primary Productivity

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The 1991 Pinatubo eruption and the apparent increased terrestrial carbon uptake in 1992 and 1993 have motivated interest in understanding the impact on plant productivity of the climate and radiative change resulting from volcanic eruptions that generate large stratospheric aerosol loadings. We used tree ring width series to look for anomalously high or low tree growth following 10 large eruptions since 1500 (not including Pinatubo) that resulted in stratospheric aerosol loadings comparable to Pinatubo's. We obtained cross-dated ring width series from the International Tree Ring Data Bank, developed regional mean width indices, and used a Monte Carlo approach to test for significant departures in the indices following eruptions. Boreal zone trees (north of 50°N) showed significantly reduced widths (∼5% below average) for several years centered around years 4-6 after eruptions. Temperate zone (35°-50°N) trees in eastern North America showed significantly increased (by ∼6%) widths on years 0-2 after eruptions. Temperate zone trees in western North America showed a smaller increase, and trees in Europe showed no increase. We tentatively suggest that eruption-induced cooling causes the growth reduction in boreal trees, whereas the differing regional patterns found in temperate trees could be due to a combination of differences in eruption climate effects between regions, temperature versus moisture limited growth depending on ambient climate, and enhancement of tree light use efficiency in closed-canopy forest because of an increase in diffuse light fraction. Our findings invite additional research to clarify how regional climate and ecology modulate the effects of eruptions on tree growth and to assess the net effect of eruptions on global plant productivity. A series of annual tree carbon increment compiled from coring in plots of Harvard Forest, Massachusetts (42.5°N, 72.2°W), as well as other series for eastern North America do not show increased growth following the Pinatubo or the 1982 El Chichón eruptions. For this region, non-volcanic climate variation may be more important than any eruption effects in causing interannual variability in net primary productivity after any individual eruption.

### B12F-02 1615h INVITED

### Paleoflood records from anatomical tree-ring signatures

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Records derived from trees growing in temperate regions have provided annually resolved paleohydrological data that span the last several hundred or thousand years. Unfortunately, conventional tree-ring parameters are often insensitive to shorter-term hydrological fluctuations, such as floods, that occur too quickly to be recorded in ringwidth or isotopic series. Paleoflood reconstructions derived from tree rings have been more successful developing flood records using anatomical signatures (flood rings) caused by defoliation or inundation. Although paleoflood records developed from tree rings are much shorter than those developed from geological evidence, their brevity is offset by their exceptional utility for dating floods to a specific year. Like other flood proxies, flood-ring records can shed light on the past frequency of extreme floods, thereby providing a long-term context for contemporary observations. In some situations, flood-ring records enable one to infer the magnitude of paleofloods based on analogy with more recent floods for which stage and discharge measurements are available. The annual resolution of tree rings also allows flood-ring records to provide credible evidence for synchronized flooding in separate drainage basins, and to tightly constrain linkages between extreme floods and potential forcing mechanisms. With complementary records from tributary rivers and streams, it is possible to obtain additional details concerning the relative contributions of individual sub-basins to past extreme floods. Ultimately, extended flood records derived from tree-ring data may be used to test assumptions of stationarity in annual flood series data, and to develop more accurate estimates of the probability of extreme flooding.

### B12F-03 1630h

### Interpreting Environmental Change and Nutrient Cycling Using Major Element and Strontium Isotope Ratios in Tree Rings

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In northeastern US forest ecosystems affected by acid deposition, calcium and other base cations have been leached from the soil exchange complex thereby increasing the possibility that calcium could become a limiting nutrient and negatively affect ecosystem health. Three of the most significant contributions of calcium to the soil exchange complex are atmospheric deposition, silicate mineral weathering, and non-silicate weathering. Strontium isotope and Ca/Sr ratios can be used to identify the relative inputs from these sources and determine whether they have changed over time. Strontium isotopic compositions and Ca/Sr ratios of tree rings hold promise for interpreting and understanding changes in calcium sources and availability in forest ecosystems. However, before tree rings can be used as a reliable archive for environmental perturbations several important issues must be resolved. These include 1) the degree of differential uptake of Ca and Sr by different tree species, and 2) the degree of translocation of Ca and Sr between growth rings. A manipulation experiment at the Hubbard Brook Experimental Forest (HBEF), NH was conducted, in which wollastonite pellets were applied to an experimental watershed. The wollastonite, with Ca/Sr and 87Sr/86Sr ratios distinct from sources to the soil exchange complex, serves as an environmental tracer. By monitoring the uptake of wollastonite into foliage we demonstrate that the degree of fractionation between Ca and Sr is small and that Ca/Sr ratios provide a good monitor of Ca sources to trees. Uptake into roots of selected species suggests there is not significant physiological discrimination against strontium assimilation in favor of calcium. We also explored the degree of mobility of Ca and Sr once it is incorporated into growth increments by determining the presence of the tracer in older growth increments. We developed a multi-step chemical leaching procedure to isolate a reservoir of Ca in wood that represents Ca utilized by the tree during the time of cell wall formation. Applying these methods to tree cores of sugar maple and red spruce allows us to establish a long-term chemical record, indicating that there has been a significant change in calcium sources to northern forests over the past 80 years. In conjunction with decades of foliar, forest floor, and soil chemistry data at HBEF, and one of the longest watershed water chemistry records in the world, the dendrochemical record provides a powerful addition to our understanding of past watershed chemistry.

### B12F-04 1645h INVITED

### Dendrochemistry of base cations in red spruce: the fallacy of the passive recorder

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Chemical analysis of red spruce (Picea rubens Sarg.) was conducted as part of a regional investigation on

the response of forest trees and forest soils to acidic deposition. The goal of our dendrochemical research was to test the hypothesis that dendrochemistry provides a marker system for the occurrence and the timing of chemical changes in the tree rooting environment. Stringent comparisons of individual and aggregated radial trends of Ca, Mg, Mn, and K indicated that far from being a passive record of the external environment, dendrochemical patterns of these elements were based upon the factors of: 1) the active exclusion and preferential uptake and translocation of elements, 2) tree maturation from the formation of juvenile to mature wood, 3) wood maturation from sapwood to heartwood, 4) the interaction of tree wounding, infection, and tree response, and finally 5) changes in the external environment. Dendrochemical patterns need to be interpreted with consideration of these internal influences before attributing patterns to the external environment. Sample trends and qualitative models based on these factors will be presented. Preliminary analysis of Picea, Abies, Juniperus, Acer, Nothofagus, and Betula indicated that they may be even more rigorously limited in their utility as recorders of environmental factors that affect base cations.

### B12F-05 1700h INVITED

## Measuring Mercury and Other Elemental Components in Tree Rings Using Particle Induced X-Ray Emission

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There has been considerable interest in measuring heavy metal pollution, such as mercury, using tree ring analysis. Since 1970, this method has provided a historical snapshot of pollutant concentrations near hazardous waste sites. Traditional methods of analysis have long been used with heavy metal pollutants such as mercury. These methods, such as atomic fluorescence and laser ablation, are sometimes time consuming and expensive to implement. In recent years, ion beam techniques, such as Particle Induced X-Ray Emission (PIXE), has been used to measure pollutant concentrations in tree rings. PIXE is very useful in characterizing samples containing large numbers of elements. Most of the existing research in this area has been completed for low to medium atomic number pollutants, such as titanium, cobalt, nickel, and copper. Due to the reduction of sensitivity, it is often difficult or impossible to use traditional low energy (few MeV) PIXE analysis for pollutants with large atomic numbers. For example, the PIXE detection limit for mercury was recently measured to be about 1 ppm for a spiked Southern Magnolia wood sample. This presentation will compare PIXE and standard chemical concentration results for a variety of wood samples.

### B12F-06 1715h

## Applications of Tropical Isotope Dendroclimatology in Thailand

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Reconstructing the terrestrial expression of tropical climate variability over the last several centuries remains a challenge despite advances in the development of a variety of proxy records (e.g. corals, speleothems, ice cores). The use of traditional dendrochronological techniques has been hindered in the tropics because of invisible or indistinct banding in the wood. The seasonality in rainfall and relative humidity in the tropics, while not large enough to cause the creation of visibly distinct rings, may still generate seasonal signals in the oxygen and carbon isotopic composition of tree cellulose. Recent analytical advances in sample preparation, chemical extraction and continuous flow gas-source mass spectrometry have made possible the recovery of long term seasonal isotopic records in tropical trees. Previously, we have demonstrated that these techniques are capable of resolving seasonal climate signals on a variety of tropical tree species from Indonesia, including some for which no visible growth rings are present. We further explore this approach using trees from monsoonal northern Thailand in an attempt to characterize the most suitable species for this application. Analysis of $\delta^{18}O$ of cellulose from 10 trees coming from 4 different regions of northern Thailand highlights the difficulties in developing these new records as many species show very irregular seasonality. In contrast, some species show very regular and pronounced seasonality in $\delta^{18}O$. In addition, seasonal variations in $\delta^{13}C$ can assist with chronology when seasonal variability in $\delta^{18}O$ is less distinct. The coherence between oxygen isotopic records extracted from different tree species growing in the same geographical region confirms the existence of a common environmental control. Comparison with instrumental records of precipitation is complicated by a high degree of spatial variability between sparsely distributed stations. This suggests the potential for creating an alternative index of regional meteorological conditions using a network of many isotope dendrochronological records.

### B12F-07 1730h

## Dendrochemistry of Urban Trees in an Environmental Exposure Analysis of Childhood Leukemia Cluster Areas

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Currently in the US, there are at least two ongoing clusters of childhood leukemia, where the incidence rate over the last several years has far and away exceeded the national norm. In Fallon, Nevada, a town of 10,000 people, 16 children have been diagnosed with leukemia since 1995, three of whom have died. In Sierra Vista, Arizona, a town of 38,000 people, 11 children have been diagnosed since 1998, one of whom has died. A possible third cluster of childhood leukemia and other cancers is being monitored in Elk Grove, California, a suburb of Sacramento. For the purpose of providing a suite of many elements from which to search for temporal changes in environmental chemical availability that might have possibly contributed to these clusters, increment-core samples were collected from trees within these three communities and measured for elemental concentrations using inductively coupled plasma mass spectroscopy. Two time periods of rings were analyzed, one representing the cluster period (1997 to present) and one representing some period in the past, usually dating into the early 1980s. Among many elements that were measured, only tungsten showed a reasonably consistent change through time across the several trees that were sampled initially. In many cases, tungsten increased in the rings by as much as a doubling from past to present. The obvious dendrochemistry question applies: Does this increase in tungsten through time in tree rings represent a true increase in environmental exposure to tungsten, or is it merely an internal physiological phenomenon? To date, other trees sampled away from the cluster areas have shown variable changes in their tungsten concentrations, with some increasing and others decreasing through time. A CDC study of human tissue samples from Fallon showed high tungsten levels in people of Fallon, and a USGS study of drinking water in Fallon also showed high tungsten there. Filtered samples of inhalable air in Sierra Vista have more tungsten than other nearby areas of southern Arizona. Some medical research work has shown at least a possible connection between tungsten and leukemia or cancer generally.

### B12F-08 1745h

## Wetland ecosystem hydroperiods: long-term variability reconstruction using isotopic signatures from tree rings

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In order to restore altered wetlands to their natural state and/or water levels an independent measure of past water depths will be necessary where no historical documents/data exist. Presently the United States Geological Survey (USGS), SFWMD, and the National Parks Service (NPS) maintain an extensive network of gauge stations through out South Florida, but locally, theses stations typically have data only going back for the last 20 to 30 years (and more typically only 10 years). We propose to investigate the stable isotopic signatures within ring forming tree species in several wetland settings in South Florida including Everglades National Park (ENP) and within Big Cypress National Preserve, in order to reconstruct past changes in water levels/precipitation. Our preliminary work has demonstrated that the $\delta^{13}C$ values from the annual rings of Pond Cypress (*Taxodium ascendens*) trees in the C-111 basin (Tayler Slough, south-east Everglades) has a positive correlation with rain fall amount (Fig. 2). Therefore as the amount of precipitation increases, accompanied by a relative increase in water level adjacent and around the plant, a physical drought may occur, causing a change in stomatal conductance, resulting in an increase in intercelluar $^{13}C/^{12}C$ ratios. As water levels increase the plant experiences a stress which affects the $\delta^{13}C$ values of its fixed sugars, and this signal is in turn transferred to the trunk/annual rings. Note, this relationship is the opposite of terrestrial trees, where decreases in relative precipitation are normally correlated with increasing $\delta^{13}C$ of plant material, water-stress or -limitation.

B

# B12G MCC: 3014 Monday 1600h

## Disturbance, Climate, and Management Impacts on Carbon Budgets of Forested Ecosystems III

*(joint with A, GC)*

***Presiding:*** **K A Hibbard,** Oregon State University**; M Apps,** Canadian Forest Service**; D J Barrett,** CSIRO Plant Industry

### B12G-01 1600h

## Looking at Boreal Ecosystem Dynamics With a Disturbance Perspective

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Disturbances such as fire, insect outbreaks and storm damage play pivotal roles in dynamics of terrestrial ecosystems, especially in the boreal zone. Not only do such disturbances facilitate the adaptation of these biomes to the changing environmental conditions associated with global change pressures (Overpeck et al 1990), they can also trigger changes at the landscape scale that can result in ecosystems switching from sources to sinks of atmospheric CO2 (Kurz and Apps 1999) or from sinks to sources (Kurz et al 1998). The intrinsic connection of the influence of age-class structures on ecosystem productivity and carbon cycle processes, and the focus this brings to the importance of understanding and documenting past disturbance regimes has clear implications for mitigation issues, influenced by both natural and human-induced processes. Gaining improved data for, and predictive understanding of the role of disturbances in the state and dynamics of terrestrial ecosystems, especially in the boreal zone where very large carbon stocks are affected, is clearly an important goal for terrestrial ecosystem research. Equilibrium and steady-state approaches are inadequate: disturbances are intrinsically non-linear processes associated with complex systems whose subsystem parts are driven away from equilibrium by changes within these subsystems and the interactions between them. This gives rise to a rich pattern of variation and change over both time and over space in which the complex web of interacting subsystems and non-linearities forces us to adopt new systems approaches. Emergent properties and new system states are characteristic features of such approaches. As pointed out by Per Bak (1996), self-organized criticality is the new way of viewing nature - perpetually out-of-balance, but organized in a poised state. In this