N) SST, the so-called Atlantic Multidecadal Oscillation (AMO), may influence long-term summer moisture trends and modulate Pacific teleconnections over North America. To examine this linkage, we compare a new, tree-ring based proxy for the AMO (A.D. 1567-1991) with gridded reconstructions of drought (1700-1978) and hydroclimatic variability (late 1500s-Present) across North America. Our AMO reconstruction, which includes 13 tree-ring chronologies from Eastern North America, Western Europe, Scandinavia and the Middle East, captures both interannual (r = 0.78) and decadal-scale (10 yr) variability (r = 0.94) in observed SST over the North Atlantic Basin. Reconstructed AMO is significantly correlated with reconstructed drought frequency and intensity throughout North America, particularly in the central and southern Rockies and western Great Plains. This is not only true for the interval of the gridded PDSI reconstructions (1700-1978), but also for a suite of proxy records from the Western US that overlap with the complete AMO reconstruction. Specifically, the late-16th and mid-20th Century (1930s and 1950s) “megadroughts”, as well as current drought in the Western US, occurred during strong, persistent warm phases of the AMO. In addition, wet spells in the early 17th, 19th and 20th centuries correspond with cool regimes in North Atlantic SST. The coherency of drought events across major river basins and climatic regions of the Western US also increases when warm phases of the AMO coincide with cool phases of the PDO. Overall, these analyses demonstrate the potential for using Atlantic SSTs to understand drought variability throughout North America, and the need to reevaluate Pacific-North American teleconnections in light of larger-scale SST fluctuations.

GC52A-03 1415h

Melting Arctic Sea Ice Dries the American West

Jacob O Sewall[1] ((831) 459-3504; jsewall@es.ucsc.edu)

Lisa Cirbus Sloan[1] (lcsloan@es.ucsc.edu)

[1]Department of Earth Sciences University of California Santa Cruz, 1156 High Street, Santa Cruz, CA 95064

Over the last century, Arctic sea ice cover has decreased dramatically and many researchers expect that future greenhouse warming will exacerbate this trend. The prospect of a warmer Arctic with less ice raises many environmental and economic questions, one of which is: How will reduced Arctic ice cover effect extrapolar climates? Using the fully coupled NCAR CCSM we completed a multi-century simulation of global climate responses to reduced Arctic sea ice cover. While the global average climate response is muted, regional responses to the imposed forcing are significant. One of the more striking regional responses is a shift in storm tracks that drives a 50-100% increase in annual evaporation minus precipitation over the American West, a region where limited water resources are already a significant problem. This result highlights two well-known aspects of climate change: (1) relatively small global changes can be composed of significant regional changes and (2) changes in one region can have a large impact on distant locations. Both of these facts will become increasingly important as researchers and policy makers attempt to untangle the looming thicket of climate change impacts and feedbacks.

GC52A-04 1430h

A Widespread Trend Towards Earlier Streamflow Timing Across North America Over the Past 5 Decades

Iris T. Stewart[1] (istewart@meteora.ucsd.edu)

Daniel R. Cayan[1] (dcayan@ucsd.edu)

Michael D. Dettinger[1] (dettinge@merced.ucsd.edu)

[1]Scripps Institution of Oceanography, 9500 Gilman Dr., La Jolla, CA 92093, United States

This study examined the year-to-year variations in the timing of streamflow since the late 1940's for a network of gauges across North America from the United States and Canada. Within this network, a predominant fraction of streams exhibit a trend towards earlier occurrence of the major seasonal flows. Advances in seasonal flows ranged from one to four weeks earlier. This result is seen from inspection of monthly and seasonal fractional flow, the date of the center of mass for flow (CT), and for snowmelt-dominated streams, the start of snowmelt streamflow pulse. There is considerable spatial coherence of streamflow timing changes in regions including much of western North America, the Midwestern United States, and the Atlantic region. Both snowmelt and non-snowmelt dominated streams exhibited earlier streamflow timing, although non-snowmelt streams in the far western United States tended to display later timing. The earlier timing of snowmelt-derived streamflow in the western United States and western Canada was most strongly connected with warmer winter and spring temperatures. Surprisingly though, significant trends towards earlier timing of streamflow are not only observed throughout the West, but also in three eastern and southern regions of North America, where precipitation and streamflow are more evenly distributed throughout the water year. Correlations of streamflow timing with Pacific Decadal Oscillation (PDO) and the Southern Oscillation Index (SOI) indicate that a significant fraction of the variability is related to interannual and decadal climatic modes.

GC52A-05 1445h

Continental Summer Dryness in the New GFDL Climate Model

Kirsten L Findell[1] (609-452-6530; klf@gfdl.noaa.gov)

Thomas L Delworth[1] (609-452-6565; td@gfdl.noaa.gov)

[1]Geophysical Fluid Dynamics Lab, Princeton University, P.O. Box 308, Princeton, NJ 08542, United States

In this work, we revisit the question of continental summer drying in a doubled-CO2 environment using the latest version of the Geophysical Fluid Dynamics Labs (GFDL) model of the atmosphere and land surface coupled to a mixed layer (slab) ocean. Two highly significant differences between this new model and earlier GFDL models are the increased resolution (2.5° longitude x 2.0° latitude and 17 vertical levels vs. 3.75° longitude x 2.25° latitude and 14 vertical levels for the previous model), and the inclusion of both a diurnal cycle and a seasonal cycle (the earlier models only had the latter). Results from these earlier models showed, among other things, an increase in wintertime rainfall over most mid-latitude continental regions when CO2 is doubled, an earlier snowmelt season and onset of springtime evaporation, and a higher ratio of evaporation to precipitation in summer. These factors led to large-scale increases in soil moisture in winter and decreases in summer in mid-latitudes in the doubled-CO2 experiment. The new model shows similar results, and the processes discussed above are important in this model as well. In addition, we find that changes in atmospheric circulation are playing an important role in regional hydrologic changes, particularly in Western Europe. Additional experiments have been run to isolate the feedback from the land surface from the role of the atmospheric changes caused by the doubling of CO2. These simulations show that the CO2 impacts alone explain the majority of the results, while the land surface feedbacks serve to strengthen the observed signals. Experiments to isolate the role of the CO2-induced changes to the sea surface temperature on the atmospheric circulation are currently underway.

GC52A-06 1500h INVITED

Columbia River Flow And Drought Since 1750

Ze‘ev Gedalof[1] (1-250-472-4733; zeev@uvtrl.geog.uvic.ca)

David L. Peterson[2]

Nathan J. Mantua[3]

[1]University of Guelph, Department of Geography, Guelph, ON N1G 2W1, Canada

[2]USDA Forest Service, Pacific Northwest Research Station 400 N 34th Street, Suite 201, Seattle, WA 98103, United States

[3]University of Washington, Climate Impacts Group Joint Institute for the Study of the Atmosphere and Oceans Box 354235, Seattle, WA 98195, United States

A network of drought sensitive tree-ring chronologies is used to reconstruct flow on the Columbia River at The Dalles, Oregon, since 1750. The reconstruction explains 30 percent of the variability in mean water-year flow, with a moderate fraction of unexplained variance caused by underestimates of the most severe low-flow events. Residual statistics from the tree-ring reconstruction, as well as an identically specified reconstruction using instrumental records, exhibit a positive trend over the twentieth century. This finding suggests that the relationship between drought and streamflow has changed, consistent with results from hydrologic models. Both the reconstructed streamflow and the models suggest that changes in land cover over the 20th century have led to increases in runoff relative to precipitation. Lowpass filtering the reconstructed flow record suggests that persistent low flows during the 1840s were probably the most severe of the past 250 years, but that flows during the 1930s were nearly as extreme. The period from 1950 to 1987 is anomalous in the context of this record for having no notable multiyear drought events. A comparison of the flow reconstruction to paleoproxy records of the Pacific Decadal Oscillation (PDO) and El Niño / Southern Oscillation (ENSO) supports a strong 20th century link between large-scale circulation and streamflow, but suggests that this link is very weak prior to 1900.

GC52A-07 1520h INVITED

Quantifying Hydrologic Drought in the Sierra Nevada With Tree Rings: A Frequency-dependent Approach

David M. Meko (520-621-3457; dmeko@LTRR.arizona.edu)

University of Arizona, Laboratory of Tree-Ring Research West Stadium University of Arizona, Tucson, AZ 85721, United States

Tree-ring reconstructions for the Sierra Nevada suggest that extended droughts uncharacteristic of the instrumental period occurred more than 500 years ago. Were comparable droughts to occur today, they would likely stress water supplies in even those large basins where reservoir storage serves as a buffer against climate fluctuations. The reconstructed severity and duration of such droughts depends critically on the low-frequency runoff signal in tree rings. Yet in the Sierra Nevada, the low-frequency component of tree growth is sometimes disparate in different species, and even in different chronologies of the same species. Moreover, a sharp increase in tree-ring index over the last 100 years is present in many chronologies yet absent from the observed streamflow records. To address these discrepancies, a frequency-dependent approach to reconstruction is proposed. The main difference from the conventional reconstruction approach is filtering to separate the high-frequency and low-frequency components prior to reconstruction. Different subsets of chronologies may be selected as predictors for the two components, depending on their correlation with streamflow at the high and low frequencies. PCA is incorporated to condense the frequency-dependent variance common to multiple chronologies. The method is illustrated in a reconstruction of annual flow of the San Joaquin River, California, and results are compared with those of a more conventional reconstruction. Ranking of tree-ring chronologies by relative strength of runoff signal was found to differ markedly in the high and low frequencies. Reconstructions by the two methods are similar for the 20th century calibration period, but differ greatly at times in the distant past. For example, the frequency-dependent approach accentuates the severity of a drought in the early 1300s and the magnitude of a shift from dry to wet conditions near A.D. 1600. The method may be useful in posing alternative scenarios of severe sustained drought consistent with variations in tree growth.

GC52B MCC: 3010 Friday 1600h

Reconstructing Hydroclimatic Variability in North America: Progress, Methods, and Uncertainties II *(joint with H, PP)*

Presiding: **C Woodhouse,** NOAA Paleoclimatology Branch**; R Webb,** NOAA/OAR Climate Diagnostics Center

GC52B-01 1600h

Colorado Streamflow Reconstruction Network: A Basis for New Dendrohydrologic Techniques, Analyses, and Applications

Jeff J. Lukas[1] (303-735-8101; lukas@colorado.edu)

Connie A. Woodhouse[2] (303-497-6297; connie.woodhouse@noaa.gov)

Robert S. Webb[3] (robert.s.webb@noaa.gov)

[1]Institute of Arctic and Alpine Research, University of Colorado, 450 UCB, Boulder, CO 80309, United States

[2]NOAA Paleoclimatology Branch, NCDC, 325 Broadway, Boulder, CO 80305, United States

[3]NOAA/OAR Climate Diagnostics Center, 325 Broadway, Boulder, CO 80305, United States

We have developed a dense network across Colorado of 60 moisture-sensitive tree-ring chronologies, 300-800 years long, creating a unique resource for hydroclimatic reconstructions. This network is the basis for collaborative work with major Colorado water providers to develop high-quality streamflow reconstructions for gages critical to water management in the Upper Colorado, Gunnison, and South Platte River basins. The

19 streamflow reconstructions developed thus far account for 63-76% of the variance in the gaged records, and replicate drought events particularly well. The reconstructions indicate that the streamflow variability seen in the gaged record is not representative of the prior two to five centuries, and that the extreme single-year (e.g. 2002) and multiyear (e.g. 1930s) drought events in the gaged record have been exceeded in severity in the past. These reconstructions are currently being used to test water supply system resilience to a broader range of drought events than provided by the gage record. The network of tree-ring data provides the opportunity to explore new management applications of streamflow reconstructions, including techniques to investigate the uncertainty in the gage data and tree-ring models, and the fidelity with which trees represent extreme drought years, such as 2002. The network has also been used to reconstruct other hydroclimatic metrics of interest to resource managers, including April 1 snow water equivalent (SWE) and standardized precipitation index (SPI). For future work we will expand the scope of the reconstructions into other Colorado river basins, and in doing so facilitate spatial analyses of drought variability across Colorado.

GC52B-02 1615h

Does the 2002 Tree Ring Reflect Low Flow Values in the Upper Colorado River Basin?

Connie A Woodhouse[1] (connie.woodhouse@noaa.gov)

Jeffrey J Lukas[2] (lukas@colorado.edu)

[1]NOAA/NCDC Paleoclimatology Branch, 325 Broadway, Boulder, CO 80305, United States

[2]INSTAAR, University of Colorado, 450 UCB, Boulder, CO 80309, United States

Streamflow in water year 2002 was the lowest on record at many gages in Colorado. This unprecedented' event motivated water managers to consider using tree-ring-based reconstructions of streamflow to place the 2002 event into a longer context than that afforded by the gaged record. In assessing 2002 flow values relative to tree-ring reconstructed streamflow, water managers were particularly interested in how well the 2002 tree ring captured the extreme low flow values in the upper Colorado River basin. To address this, 12 previously sampled tree-ring sites in western Colorado were recollected in June 2003, and the 2002 ring was analyzed with respect to instrumental records for the 20th century. Analyses suggest that the 2002 tree ring, although consistently narrow, and completely missing in a number of samples, did not fully reflect the extreme low streamflows of 2002 since several other annual rings, in particular 1977, were generally narrower. The discrepancy between the tree rings and streamflow in 2002 was explored by examining seasonal snowpack. Snowpack measurements in the Upper Colorado River basin show April 1 snow water equivalent (SWE) values to be low in 2002, but lowest in 1977 (from 1942-2002), corresponding to the results from the 2002 tree-ring analysis. This result coincides with water managers' assessment of the spring runoff, which was much lower than expected given the April 1 snowpack in the upper Colorado River basin. During a very warm and dry April, much of the snowpack was apparently either absorbed by soils desiccated by two years of drought or sublimated into the atmosphere. While that portion of the snowpack which replenished soil moisture did not reach the stream channels, it may have benefitted tree-growth in 2002, contributing to a less extreme value for the 2002 ring width. We examine the snowpack and gage records for similar occurrences in previous years to determine how rare an event this was, evaluate the corresponding tree-growth response in these years, and discuss the implications for tree-ring reconstructions of drought.

GC52B-03 1630h INVITED

A Hierarchical Bayesian Model for Reconstructing Multiple Streamflows and Climate Indices from Tree-ring or other paleo data

Upmanu Lall[1] (212 854 8905; ula2@columbia.edu)

Manuel Ruiz Zamora[2] (m100874@hotmail.com)

Edward Cook[2] (8453658618; drdendro@ldeo.columbia.edu)

Andrew Gelman[3] (212 854 4883; gelman@neyman.stat.columbia.edu)

Edward Sperry[1] (eesrps@yahoo.com)

[1]Columbia University, Dept of Earth & Env Eng, 918 Mudd, 500 W 120th St, New York, NY 10027, United States

[2]Columbia University, LDEO, 64 Rte 9W, Palisades, NY 10964, United States

[3]Columbia University, Deprtment of Statistics,, New York, NY 10027

Reconstruction of annual or seasonal streamflow at multiple locations or of multiple climatic indices (e.g., PDSI at many locations, or ENSO, PDO, NAO) is sometimes of interest using an array of common paleo predictors. The predictands may be correlated with each other, and the form of each regression between predictand and predictors may also be very similar. Principal or Canonical Component Methods have been used to address this regression problem, after transformation of the data sets to be approximately Normally distributed. An alternative to such methods is presented here. A hierarchical model considers that the regression coefficients are random variables, and seeks to make inferences about the parameters (e.g., they may be Normally distributed, with a certain vector of means and a covariance matrix) of a model that describes the distribution of these variables. Further, the parameters of such a model may in turn be considered to be random variables and one can seek a model that describes them, leading to a multilevel modeling approach. Generally, a diffuse prior distribution is assumed for the parameters at the end of the hierarchy, and a Markov Chain Monte Carlo approach is used to learn or estimate the parameters of the distribution at each level of the hierarchy. Here, we use such an approach in a Generalized Linear Modeling framework - the distribution of the predictand is directly considered to correspond to a parametric family, instead of using transformations to Normality, and a set of basis functions (not necessarily linear) is used to relate the predictors to the predictands. An uncertainty distribution of parameters and hence of estimates is derived automatically as part of the model learning process. We present examples of the applications of these methods and contrast the results with those obtained using PCA/CCA.

GC52B-04 1650h

Tree-Ring derived Ensemble Streamflow Reconstructions for the Gunnison River Basin

Robert S Webb[1] (303 497 6967; Robert.S.Webb@noaa.gov)

Connie A Woodhouse[2] (303 479 6297; Connie.Woodhouse@noaa.gov)

[1]NOAA-CIRES Climate Diagnostics Center, 325 Broadway, Boulder, CO 80305, United States

[2]Paleoclimatology Program NOAA/NESDIS/NCDC, 325 Broadway, Boulder, CO 80305, United States

Multicentury tree-ring records of hydroclimatic variability are now being considered in assessments of the regional risk of multiyear droughts and the expected occurrence interval of extreme drought. Critical questions being raised when tree-ring reconstructions are considered in the decision process focus on describing and quantifying uncertainty in the annual stream flow reconstructions. Potential sources of uncertainty in the reconstructions are: 1) measurement errors in both the instrumental data and the tree-ring data, and 2) model calibration errors due to the less than perfect relationship between tree-ring data and hydroclimatic variables. As an alternative to standard reconstruction approaches using a single "best" tree-ring calibration model, we use a suite of regression models to reconstruct each of five streamflow records in the Gunnison River Basin for the past 600 years. Our ensemble tree-ring reconstruction approach draws on the ensemble methodology used in operational weather and climate forecasting prediction. Application of an ensemble of regression models in tree-ring reconstructions of past hydroclimatic variability allows for a more realistic representation of uncertainty in the development and application of regression model relationships between tree-ring indices and hydroclimatic variability. The ensemble approach allows for the possibility that a suite of models based on a variety of calibration and independent verification periods can provide a more accurate representation of the past. While most individual regression model ensemble members explain less of the variance than the full period calibration model, the regression model ensemble mean provides a more robust reconstruction that includes an estimate of the uncertainty. A comparison of the recurrence interval of historically low flows in the Gunnison Basin estimated using our ensemble tree-ring reconstructions and using standard tree-ring reconstructions is used to illustrate the impact of including uncertainty in analyses.

GC52B-05 1705h

Long-Term Variability in River Flow and Associated Lake Levels in the Canadian Prairie Provinces: Applied Dendrohydrology

Glen M MacDonald[1] (310-825-1071; macdonal@geog.ucla.edu)

David M Meko[2] (520-621-3457; dmeko@ltrr.arizona.edu)

Roslyn A Case[3] (310-392-6462; rcase@mclam.com)

[1]Department of Geography UCLA, 405 Hilgard Ave, Los Angeles, CA 90095, United States

[2]Laboratory of Tree-Ring Research, The University of Arizona, Building 58T, Main Office Room 105 West Stadium, Tucson, AZ 85721, United States

[3]McDaniel Lambert Inc, 1608 Pacific Ave., Venice, CA 90291, United States

Understanding natural variability in river flow and lake levels is a major concern in water policy formulation and the development of resource management strategies in the prairie provinces of Canada. Two particularly high profile concerns are: 1. The natural variability in flow of the Saskatchewan River system, and 2. The natural variability in flooding of the Peace-Athabasca Delta system. The Saskatchewan basin recently experienced a severe multi-year drought between 2000 and 2003 that saw annual river flows decrease by 25 percent from their 20th century averages and precipitated sharp exchanges between the provinces regarding water rights. The Peace Athabasca-Delta is one of the largest freshwater delta systems in the world and of international importance under the Ramsar Convention. Pronounced dry periods over the past 30 years have led to debates and concerns regarding the natural variability of the delta hydrologic regime and the detection and management of the impact of W.A.C. Bennett Dam which was built on the Peace River in the 1960's. Instrumental records of river flow, floods and lake levels in western Canada extend back only about 100 years, are discontinuous, and insufficient for assessment of long-term variability for planning purposes. Tree-ring records from the southern and central portions of Alberta and Saskatchewan provide reconstructions of river flow in the Saskatchewan River system that extend back from 300 to 1100 years. The records indicate that 20th century mean flows were 6.5 to 8.6 percent higher than long-term means. Multi-annual to multi-decadal periods of low flow, without analogues in the last 100 years, occurred during the mid 1800's and early 1700's. The period of 900 to 1300 was typified by consistently low flows including multi-decadal periods in which flows did not reach long-term or 20th century mean values. The policy difficulties experienced during the most recent drought suggest an inability of present water management strategies to cope with the potentially more severe and prolonged droughts that are a natural part of the system. A reconstruction based on tree-ring chronologies from throughout western Canada indicates that the Athabasca River experienced flows that were 32 percent below the long-term mean during an extended period of low flow in the mid 1800's. This dry period corresponds with the episode of low flow evident in the adjacent Saskatchewan River system. In contrast, a similar reconstruction for the more northerly Peace River does not exhibit any evidence of prolonged or severe low flows during the mid 19th century. An episode of low flow on the Athabasca and Peace rivers, and portions of the Saskatchewan system, during the late 1880's and early 1890's corresponds to a prolonged period of low water levels on Lake Athabasca that appears longer in duration and similar in magnitude to the epiode of initial low lake levels and delta drying that was experienced following completion of Bennett Dam.

GC

GC52B-06 1720h

Hydroclimatic Variability in the Northern Interior of North America

Dave J. Sauchyn[1] (306-337-2299; sauchyn@uregina.ca)

Antoine L. Beriault[1] (306-337-2294; sauchyn@uregina.ca)

Jennifer N. Stroich[1] (306-337-2298; stroichj@uregina.ca)

Ge Yu[1] (306-337-2293; uyuge200@uregina.ca)

[1]Prairie Adaptation Research Collaborative, University of Regina 150 - 10 Research Drive, Regina, SK S4S 7J7, Canada

The least annual precipitation in the western interior of North America occurs in the northern Great Plains. A subhumid climate extends to high-latitudes in the rainshadow of the western cordillera. We have established a network of 42 moisture-sensitive tree-ring chronologies extending from the plains of Montana, Alberta and Saskatchewan to the boreal shield of the Northwest Territories (NWT). A network of this geographic extent enables the analysis of annual to decadal hydroclimatic variability at a range of spatial scales. The hydroclimatic signal is relatively coherent along a north-south gradient; paleo drought is evident at relatively high latitudes in the western NWT. There is less consistency from west to east. The variability over time is marked at many sites by a mid-19 century shift from the dominance of decadal variance (sustained wet and dry conditions) to more interannual variance that characterized the 20th century and thus the instrumental hydroclimatic record. Because stream flow integrates precipitation of over months and watersheds, it is generally more highly correlated with residual tree-ring width than precipitation data. Residual tree-ring width accounts for 30-60% of the variance in

seasonal and annual precipitation and streamflow. The unexplained variance reflects the tendency for tree-ring widths to underestimate unusually wet conditions, because soil properties and tree physiology limit the response of tree growth to precipitation. Our interest, however, is primarily in dry conditions and low flows. Tree-rings are a particularly good proxy of the timing and duration of drought. This research addresses concerns about the socio-economic and environmental impacts of drought in this region and about water supply forecasting based on relatively short instrumental records. From tree rings, we are able to extend hydrometric records beyond the several decades of instrumental data, although the short length of gauge records presents a challenge for calibrating and validating the tree-ring based reconstructions. The application of our proxy hydroclimate records to drought and water supply planning requires that the data be delivered and used in the context of risk assessment. Therefore, we have taken a Monte Carlo approach to expressing uncertainty in the tree ring reconstruction and to estimating probability of drought, annual and seasonal precipitation and streamflow below specific thresholds.

GC52B-07 1735h

The History of Fire on the Northern Plains, USA, and its Response to Holocene Drought-Cycles

Kendrick Brown[1] (kendrik@duke.edu)

Jim Clark[1] (jimclark@duke.edu)

Eric Grimm[2] (grimm@museum.state.il.us)

Joe Donovan[3] (donovan@geo.wvu.edu)

Pietra Mueller[2] (mueller@museum.state.il.us)

[1] Duke University, Department of Biology Box 90338, Durham, NC 27708, United States

[2] Illinois State Museum, Research and Collections Center 1011 East Ash Street, Springfield, IL 62703, United States

[3] West Virginia University, Department of Geology and Geography 425 White Hall P.O. Box 6300, Morgantown, WV 26506, United States

Extensive drought has periodically gripped large regions of the United States in the past. The “Dust Bowl” of the 1930’s in the central plains is perhaps one of the most vivid examples of prolonged drought, climatic extremes, dust storms, crop failure and general human hardship. The impact of future drought conditions potentiated by greenhouse gas emissions may indeed exceed the devastation wrought during historical droughts and thus mandates examination of past drought variability. Two long cores from Kettle Lake (North Dakota) and Brush Lake (Montana) were collected to study past drought variability in the northern plains. An age-depth model was developed for the cores by fitting a locally weighted loess curve to AMS radiocarbon dates obtained from the cores. The cores were continuously sub-sampled at high resolution (1 cm) for pollen, charcoal, and sediment mineralogy. Pollen was extracted using standard techniques and charcoal was sieved from the sediment at 180 um resolution and its area determined through optical microscopy. Mineralogy was determined using x-ray diffraction. The data reveal that the mid-Holocene was exceptionally warm and dry and that several fire regimes existed throughout the Holocene. In general more fire characterized the early- and late-Holocene with less fire during the mid-Holocene. Spectral analysis of the multi-proxies reveals that 100- to 130-year drought cycles persisted during the early-Holocene in the northern plains. Drought cycles are also observed during the late-Holocene interval. The dry phases of the cycles are characterized by a decline in grasses and fire and an increase in forb vegetation and erosion. The forb response during the mid-Holocene is one of fluctuating Ambrosia pollen whereas Artemisia pollen cycles in the late-Holocene. This change in pollen response may reflect a change in the seasonality of drought from winter to summer over that time. Fires are more common during the wet phases of the drought cycles because more moist conditions permit grassland expansion, resulting in greater fuel continuity.

Reference Style for Abstracts

When referencing a meeting abstract, please use the following format, which indicates that this abstract volume is a supplement to the regular *Eos* issue. This format meets all AGU requirements for a complete reference.

Pfister, R. G., and M. S. Nestler, Sharing community data, services and tools using the EOS clearinghouse (ECHO), *Eos Trans. AGU, 84*(46), Fall Meet. Suppl., Abstract U41B-0006, 2003.