Year 3 Progress Report: Community Integrated Assessment Team

Middle San Pedro River Valley Assessment: A white paper on work in the Middle San Pedro River Valley region has been produced (available via the CLIMAS Web site) and translated into a journal article, which is in review. Together with articles derived from other CLIMAS papers, this article will form part of a special issue of the journal Climate Research.

Sulphur Springs Valley Assessment: Using the concept of "buffering," which we introduced during year two, as a guiding research focus, CLIMAS team members have continued to make progress towards understanding more precisely the ways in which residents of the Southwest are vulnerable to climate variability. Our work has focused on development of a socioeconomic and demographic profile using available census and other data, identification of points of climate vulnerability, and use of/need for climate information. We have collaborated with local county Cooperative Extension offices in order to the best identify both issues and informants. CLIMAS team members have continued the vulnerability mapping initiative began in years 1 and 2. Emphasis is on the following areas: identification of differences in and access to resources, technologies, and economic opportunities, as well as on the influence of policy and institutional factors on adaptation capabilities and strategies.

Vulnerability case study work has been expanded to the Sulphur Springs Valley of Southeastern Arizona, a region dependent on groundwater for irrigation. Fieldwork has included interviews with a wider range of small-scale agriculturists such as corn farmers, nut orchard growers, fruit growers, U-Pick vegetable producers and chili farmers, as well as seasonal and migrant labor. This research has revealed that there is a great deal of diversity in terms of people's concerns with and responses to climate variability. Some agriculturalists prefer drought conditions, as it gives them greater control over the quantity and timely delivery of water to their crops, whereas others have been devastated by drought. Similarly, increased reliance on groundwater irrigation may lead to declining aquifer levels and increased pumping costs; however, it also leads to the adoption of more water efficient irrigation systems.

Climate Information and Vulnerability Reduction: In the process of identifying vulnerability to climate variability, we also continue to investigate stakeholder needs for specific types of climate information. Local farmers have stressed the importance of downscaling of climate information, a point that has informed the research agenda of our climate variability team. Local farmers have also expressed interest, and also skepticism, in the use of seasonal forecasts to assist them in agricultural decision-making. Interactions with team members working in the forecast evaluation/integration, climate processes/teleconnections, and climate/hydrology dynamics modules and with key stakeholders will be essential for assuring solid knowledge of important climate, hydrology, and forecast factors pertinent to the study areas. These interactions have already been initiated.

Team Members: Tim Finan, Marcela Vasquez-Leon, Colin West

Publications

Austin, D., P. Barabe, N. Benequista, A. Fish, A. Gardner, E. Hansen, T. McGuire, S. Stewart, and P. Tschakert, 2000. *An Assessment of Climate Vulnerability in the Middle San Pedro River* (T. Finan and C. West, Eds.). CLIMAS Report Series CL3-00, Institute for the Study of Planet Earth, University of Arizona, Tucson, AZ.

Finan, T.J., D. Austin, T. McGuire, and C.T. West, 2001. Reducing Climate Vulnerability in the Southwest U.S.: A Study in Buffering. *Climate Research*, in revision.

Year 3 Progress Report: Pilot Border Study Team

Pilot border study team activities were scaled back, due to the fact that Dr. Liverman has been on sabbatical during Year 3 of CLIMAS. Border study activities during Year 3 were limited to small projects on the variability of climate in northern Mexico, and an examination of the causes and impacts of the most severe drought on record in Mexico, the extended drought of the 1950s. Much of this work has been carried out by Dr. Tereza Cavazos, a member of the CLIMAS climate variability team.

Climate and climate variability of the Conchos Basin, Chihuahua, Mexico: We selected the Conchos basin for study, as it is of great bi-national relevance. The Conchos basin provides from 75 to 80 percent of the Rio Grande mainstem flow. Droughts on the Conchos have great significance for bi-national treaties and agreements between the US and Mexico and have widespread impacts in northern Mexico. We have been working on an assessment of both the physical and human dimensions of climate in the Conchos river basin, focusing on the nature, causes and predictability of climate variations and on changing vulnerability in the basin. We have completed a paper in which special attention is given to the atmospheric and ocean forcing mechanisms associated with extreme droughts. It was found that persistent droughts are linked to decadal variations in the North Pacific suggesting some possibility for prediction. An abstract of a draft paper on this subject can be found at http://geog.arizona.edu/~cavazos/Conchos.htm

We have also completed a draft report on changes in water demand and land use in the Conchos basin. The report shows that demand is increasing rapidly and that drought impacts have been severe in the 1990s. Moreover, the failure of Mexico to meet flow obligations into the Lower Rio Grande/Bravo from the Conchos is creating tension between the two countries.

Causes and impacts of the 1950s droughts in Northern Mexico: In a related study, we have been looking at the most serious drought on record in northern Mexico, that of the 1950s, to see what insights it provides into climate impacts, vulnerabilities and needs for information in the basin. We have been looking at seasonal and interannual precipitation anomalies in Northern Mexico from the late 1940s to the early 1960s to identify the extent of the drought. We have been using the University of Delaware monthly precipitation data set, which has 0.5° resolution. Although, the data set has some biases, it gives a good idea of the spatial distribution of the anomalies. We have also been compositing atmospheric and oceanic patterns associated with wet and dry years and comparing the composites with the PDSI and precipitation anomalies.

We have begun to analyse data on how northern Mexico changed between 1945 and 1970, and whether we can detect the impact of the 50s drought in land use and population changes. It appears that the agriculture of the region changed dramatically in this period, with increases in irrigation, fluctuations in cattle herds, and out-migration from rural areas occurring as a result of interactions between climate and socioeconomic factors.

In the next step to this research, we will try to interview Mexican farmers and get information from Mexican newspapers and old Mexican agriculture magazines. This activity will give us a picture of the human dimension impact of the droughts.

Outreach: We have continued general outreach work and links on climate and society in the Border region. We have provided information to one of President Vicente Fox's transition team on climate change and variability issues, and have continued to work with the World Wildlife Fund and other non-governmental organizations to provide information on climate information in Mexico.

Team Members: Diana Liverman, Tereza Cavazos, Erika Trigoso

Publications

Liverman, D.M. and R. Merideth, 2001. Climate and Society in the Southwest: The Context for a Regional Assessment. *Climate Research*, in revision.

Liverman, D.M., B. Yarnal and B.L. Turner, 2001. The Human Dimensions of Global Environmental Change. In G. Gaile and C. Wilmott, eds., *Geography: A Millennial Assessment*, in review.

Liverman D.M. and K. O'Brien, 2000. Southern Skies: International Environmental Policy in Mexico. In W.C. Clark, J. Jaeger, J. van Eijndhoven, and N. Dickson, eds., *Learning To Manage Global Environmental Risks: A Comparative History Of Social Responses To Climate Change, Ozone Depletion And Acid Rain*. Cambridge, Mass.: The MIT Press.

Yetman, D., D. Liverman and A. Burquez, 2001. The Drought of the 1950s in Sonora. Chapter in Betancourt, Julio, *The Drought of the 1950s in the Southwest*. Forthcoming.

Presentations

Liverman, D.M. START/CIRA Workshop on Integrated Regional Assessment. Invited paper on "Institutions for collaborative environmental research in the Americas: A case study of the Inter American Institute for Global Change (IAI)", October 2000.

Liverman, D.M. NOAA Office of Global Programs, Panel Meeting. "Regional Assessments - A view from the Southwest and the social sciences". October 2000.

Liverman, D.M. Santa Fe, RISA workshop, September 2000.

Liverman, D.M. Department of Geography, University of Georgia. "The nature, causes and consequences of environmental change in Mexico". September 2000.

Liverman, D.M. Workshop on Impacts of Climatic Variations on Water Resources: A Focus on Borders in the Americas. Invited paper on "Challenges to Collaboration Across Borders in Global Change Research-The Case of the IAI." Santa Barbara, California, July 2000.

Liverman, D.M. Department of Geography, University College London. "US-Mexico Border Environment: Global restructuring and local response". May 2000.

Liverman, D.M. Association of American Geographers, Pittsburgh, Pennsylvania. "Panel discussion on Regional Assessment". April 2000.

Liverman, D.M. University of California, San Diego. "The Hidden geographies of Mexican Land Use change". March 2000.

Liverman, D.M. Latin American Studies Association, Miami, Florida. Institutions for collaborative environmental research in the Americas: A case study of the Inter American Institute for Global Change (IAI). March 2000.

Year 3 Progress Report: Native American Studies Team

Renewable Energy and Climate: A renewable natural energy CD was completed, which include understandable explanations of four forms of energy: wind, solar, biomass, and geothermal energy and on relevant climate factors. The product was submitted to the InterTribal Council of Arizona (ITCA) at a special meeting of the organization's Air Working Group. The CD is designed to be interactive, much like a web page. It contains pictures and explanations of how to use each energy source, and a discussion of energy resources in Arizona. This CD also contains information from the tribal energy inventory, GIS data, and links for where to find more information. Because the CD was created as a partner effort between the University of Arizona and ITCA, the ITCA staff was asked to review it prior to release. That review is now underway.

Native Peoples/Native Homelands Project: We facilitated the finalization of the agreement between the University of Arizona and the University of New Mexico's (UNM) Native Peoples/Native Homelands project. The project is being run out of the Center for Applied Spatial Analysis (CASA). The project goals are as follows: to explore and evaluate venues for GIS outreach to Arizona Tribes, and to support Native American students with an interest in GIS and applications. The project partners include University of New Mexico Native Peoples/Native Homelands, University of Arizona Native American Student Affairs, University of Arizona Center for Applied Spatial Analysis, University of Arizona Bureau of Applied Research in Anthropology/Southwest Assessment Project for the Southwest, Tohono O'odham Nation, Southern Paiute Consortium, InterTribal Council of Arizona/Environmental Protection Agency. We anticipate that the project will benefit CLIMAS by establishing a GIS framework for tribes that can be used to spatially analyze climate impacts on tribal lands. In order to facilitate the goals of this project, we have held two teen-young adult GIS workshops and we have done extensive outreach in the area of fire and climate (see below). A report of the teen-young adult workshops is being prepared.

Fire and Climate in Indian Country: In response to fires in Indian Country, we have established contact with several tribes regarding the relationship between climate and fire on tribal lands. We have established *contacts* with the UNM Native Peoples/Native Homelands project, the All Indian Pueblo Council, and the Southwest Indian Polytechnic Institute in Albuquerque, NM. We have established *partnerships* with the Kaibab Band of Paiute Indians in northern Arizona and the Fort Mojave Indian Tribe in California and Arizona. As a result of these interactions, we have focused our efforts on a thorough study of institutional factors associated with managing for climate-related wildfire hazard. Case studies of recent fires are being used to gather information. We identified a Kaibab tribal member to serve as a field assistant and began interviews in November 2000. We have met with representatives of the Tribe, the Bureau of Indian Affairs, the Bureau of Land Management, the U.S. Forest Service, and several municipalities and have found significant interest in the project. We will continue fieldwork in January and February and complete this project by the end of March, 2001.

Team Members: Diane Austin, Sherri Gerlak, Barbara Wolf.

Publications

Austin, D., S. Gerlak, C. Smith, 2000. *Building Partnerships with Native Americans in Climate-Related Research and Outreach.* CLIMAS Report Series CL2-00, Institute for the Study of Planet Earth, University of Arizona, Tucson, AZ. Draft.

Presentations

Austin, D. Building Partnerships with Native Americans in Climate-Related Research and Outreach, a summary of research findings to members of the University of New Mexico Native Peoples/Native Homelands Group.

Year 3 Progress Report: Ranching Team

The ranching team is in the process of compiling a profile of ranches within each of the Natural Resource Conservation Districts (NRCDs) in southern and southwestern Arizona. The profile includes the number of ranches, types of ranching operations, and level of management. We are looking for links between ranch size, type of operation and management style, climate information needs and drought management strategies.

Over the course of Year 3, a team comprising graduate students from the hydrology/forecast team and ranching team have arranged and attended 14 meetings in NRCDs around the state. Attendance at these meetings has ranged from five to 45 NRCD members. The attendees expressed high interest in the excellent presentations and materials on climate variability and forecasting in the region, prepared by CLIMAS team members Holly Hartmann and Tom Pagano. Initially, participants were given (or mailed) questionnaires to fill out after the meetings. However, it soon became evident that ranchers preferred to provide the requested information through interviews with a team member. This led us to modify and streamline the questionnaire so that certain kinds of basic information about topics such as current use of climate forecasts could be gathered at the NRCD meetings. The questionnaire, together with the presentations, has not only facilitated collection of information from these stakeholders, but has also served to stimulate interest among the ranchers in obtaining additional climate information. Further, the process has resulted in more ranchers volunteering to participate in lengthier personal interviews.

Our research results, including a profile of ranching operations and climate information needs, will be summarized in a report. A separate report will assess the impact of drought on the cattle industry in southern Arizona.

Team Members: Diana Hadley, Susan Moodie; with assistance from Holly Hartmann and Tom Pagano

Presentations

Hadley, D., S. Moodie, T.C. Pagano, H.C. Hartmann. Southwest Climate in a Nutshell. Meetings of the Arizona Natural Resource Conservation Districts and Arizona Association of Conservation Districts Summer Meeting. July-December, 2000.

Year 3 Progress Report: Urban Water Team

Water Provider Survey. During the past year, we completed a survey of 28 water providers. These providers are located in the Phoenix, Tucson, and Santa Cruz AMAs, and in the Sierra Vista subwatershed of the San Pedro River. The survey involved a written questionnaire (28 responses, for a 52% return rate), followed up by personal interviews with 22 of the respondents. A draft report has been circulated and revisions are underway. We anticipate that the final report will be published in the CLIMAS working paper series in January 2001. Results of the survey indicate that few of the providers factor climate into their management decisions currently. The pre-monsoon dry period is of concern to providers, as is the potential for flooding. Further, certain types of weather events are of significant concern, notably electrical storms, high temperatures, and high winds. Population projections and current population are the main factors determining water budgets, and the two most commonly cited responses to potential long-term decrease in water supply were drilling new wells and implementing stricter water management rules.

These findings illustrate the extent to which providers not only rely on groundwater, but (with a few notable exceptions) on groundwater that is not very sensitive to climate variability—that is, they rely on fossil groundwater. Further, the responses indicate little concern about the potential of diminishing supplies within the aquifers being pumped.

Interest in using climate information among most providers surveyed is minimal. This may be in part because none of the providers surveyed has yet had direct experience in managing water supplies under conditions of severe, persistent drought. Further, the chief stressors were identified as events (such as lightning strikes) for which climate-scale forecasts are not yet available. Yet another factor may be the lack of familiarity with climate forecasts among the providers surveyed. Finally, and no less importantly, the survey reinforced the viewpoint that maintaining an adequate revenue stream is the top priority for providers, far overshadowing willingness to think about issues such as water resource sustainability under conditions of climate variability. Yet, as population grows and competition over water increases, providers will face the challenge of managing for variability. The current high level of confidence in capacity to cope with system stresses will likely be replaced with recognition of the need for more and better information, including climate information. Through educating the next generation of water managers in climate impacts and taking advantage of opportunities to communicate climate information in relevant ways to the current managers, the stage can be set for making climate forecasts matter in this sector.

Safe-Yield Task Force Process. An important element in the institutional analysis of the urban water sector in Arizona has been participation in a task force process, initiated by the Arizona Department of Water Resources (ADWR), to assess progress toward achieving safe yield in the state's groundwater Active Management Areas (AMAs). The urban water sector team has been attending the meetings of the local Tucson Safe-Yield Task Force for more than one year, and has been successful in introducing into the state-level process an issue paper that calls for more explicit consideration of climate variability in water resource management, including formulation of laws, regulations and operational practices. Growing out of this participation, as well as other linkages the Director of ADWR invited Roger Pulwarty and Jonathan Overpeck to

give presentations on climate in the Southwest to the Governor's Commission, the state-level organization charged with recommending legislative changes based on the Safe-Yield Task Force process. A report based on insights gained from participation in the process will be published before the end of Year 3.

Team Members: Barbara Morehouse, Rebecca Carter, Roger Bales

Publications

Carter, R.H., P. Tschakert, and B.J. Morehouse, 2000. *Assessing the Sensitivity of the Southwest's Urban Water Sector to Climate Variability: Case Studies in Arizona.* CLIMAS Report Series CL1-00, Institute for the Study of Planet Earth, University of Arizona, Tucson, AZ.

Carter, R.H., 2000. *The Potential Responsiveness of Arizona Water Policies to Increased Climatic Variability.* CLIMAS Report Series CL4-00, Institute for the Study of Planet Earth, University of Arizona, Tucson, AZ. Draft.

Morehouse, B.J., 2000. Climate Impacts on Urban Water Resources in the Southwest: The Importance of Context. *Journal of the American Water Resources Association*, 36(2): 265-277.

Morehouse, B.J., R.H. Carter, and T. W. Sprouse, 2001. Assessing Transboundary Sensitivity to Drought: The Importance of Effluent in Nogales, Arizona and Nogales, Sonora. *Natural Resources Journal*, Fall 2000, forthcoming.

Morehouse, B.J., R.H. Carter, and P. Tschakert, 2001. Climate Sensitivity of Urban Water Systems in Phoenix, Tucson, and Sierra Vista, Arizona. *Climate Research*, in revision for publication.

(anonymous) 2000. Issue Climate Variability in the Context of Safe Yield. Issue paper submitted to the Governor's Water Commission; co-authored by Barbara Morehouse and Kathryn Jacobs, with input from Tucson AMA Safe Yield Task Force.

Preprints and Conference Proceedings

Morehouse, B.J., M.F. Glueck, R.C. Bales, A.C. Comrie. R.H. Carter, P.R. Sheppard, and G.M. Garfin. 2001. A vertically integrated assessment of climate impacts on water supply in Arizona. Abstract Volume 81st Annual Meeting of the American Meteorological Society, Albuquerque, NM, January, 2001.

Presentations

Morehouse, B.J., M.F. Glueck, R.C. Bales, A.C. Comrie. R.H. Carter, P.R. Sheppard, and G.M. Garfin. A vertically integrated assessment of climate impacts on water supply in Arizona. 81st Annual Meeting of the American Meteorological Society, Albuquerque, NM, January, 2001.

Morehouse, B. and H.F. Diaz. Institutional and political implications of climate impacts for water management in transboundary regions. Climatic Change: Implications for the Hydrological Cycle and for Water Management, Wengen, Switzerland, September, 2000.

Morehouse, B.J. Boundaries in Climate Science-Water Resource Discourse. Climate, Water, and Transboundary Challenges in the Americas, University of California-Santa Barbara, Santa Barbara, California, July 16-19, 2000.

Year 3 Progress Report: Climate and Health Team

We selected valley fever as a critical and understudied, climate-sensitive disease for the Southwest. We have collaborated with a stakeholder group made up of environmental and health researchers and professionals. Interactions among the group have been facilitated by the University of Arizona's Valley Fever Center for Excellence (VFCE), who strongly encouraged our work in this area. The work on valley fever has been carried out in consultation with the CLIMAS climate variability research team.

Valley fever (*coccidioidomycosis*) is caused by inhaling the spores of a soil-dwelling fungus (*Coccidioides immitis*) that is endemic to the deserts of the Southwest. The life cycle of *C. immitis* is such that fungal growth responds to various sequences of soil moisture and temperature conditions, including a period of drying when the spores can become airborne. This regional disease has national importance in that 6,000 to 8,000 severe cases occur in the United States each year; 50 to 100 of those who contract the disease die and overall treatment costs amount to some $60 million per year.

CLIMAS team members have accomplished a better understanding of the basic relationships between climate and valley fever and have developed a suite of monthly multivariate predictive models. The project received local news coverage when, based in part on analysis of antecedent climate conditions, a successful prediction was issued for increased valley fever incidence during the late Fall of 1999. We now have a working forecast model of valley fever incidence for Pima County. We will use the forecast model to pilot information, in close cooperation with the VFCE and state health officials, with regard to appropriate format, style, frequency, and supporting information. The next step in the valley fever research is to work with stakeholders to identify how best to design and disseminate that information.

Team Members: Andrew Comrie, Korine Kolivras.

Publications

Kolivras, K., P. Johnson, A. Comrie, and S. Yool, 2001. Environmental Variability and Coccidioidomycosis (Valley Fever). *Aerobiologia* 17(1) in press (March, 2001).

Presentations

Kolivras, K.N. and A.C. Comrie. Climate Variability and Valley Fever. Presented at the 2nd Southwest Weather Symposium, September 21-22, 2000, Tucson, AZ.

Kolivras, K.N. and A.C. Comrie. Climate and Health: The Relationship between Valley Fever Incidence and Climatic Conditions. Presented at the 96th Annual Meeting of the Association of American Geographers, April 4-8, 2000, Pittsburgh, PA.

Kolivras, K.N. and A.C. Comrie. Exploring Climate Varibility and Valley Fever. Presented at the 4th Western Geography Student Conference, February 4-6, 2000, Boulder, CO.

Year 3 Progress Report: Hydrologic Variability, Climate Forecast Assessment and Evaluation Team

Research Status Report on Hydrologic Variability in the Southwest: Review of the hydrologic variability in the Southwest, as exemplified by Arizona, is nearly complete. The task represents a parallel effort to the CLIMAS review of natural climate variability in the Southwest (CLIMAS Report Series CL1-99). It summarizes the state of knowledge of hydrologic conditions and processes, including multiple elements of the hydrologic cycle (especially precipitation, snow, streamflow) and extreme events (flood and drought). It also addresses the role of climate drivers and variability in affecting hydrologic variability, including the implications of climatic non-stationarity and insights from paleoclimate and paleohydrology studies. Finally, it provides data sources and identifies gaps in available information, especially concerning evaporation, evapotranspiration, groundwater, and human influences.

Forecast Evaluation: Seasonal Water Supply Outlooks, Regression Forecasts: Throughout the winter and spring, the National Weather Service (NWS) Colorado Basin River Forecast Center (CBRFC) and the Natural Resources Conservation Service (NRCS) jointly issue water supply outlooks covering the upcoming season of snowmelt runoff. The outlooks are used to regulate reservoir releases, interbasin water transfers, and fulfillment of water allotments. We have been using the comprehensive database of historical official forecasts and reconstructed "naturalized" flows (developed in Year 2) to evaluate these forecasts from multiple perspectives (qualitative, graphical, and quantitative). We are nearing completion of the evaluations, which will provide a baseline for evaluating improvements in predictability through use of newer models, data, and/or forecast procedures.

Our evaluations have focused not only on performance statistics, but on issues related to interpretation and use as well. Even though the two agencies put great effort into coordinating their forecast values, users still face confusion because those forecasts can be communicated in different ways. For example, the forecasts are communicated as deterministic categorical forecasts and as probabilistic forecasts of a continuous variable, even though they are actually deterministic forecasts of continuous variables. Both forecasts also presume the user knows the long-term median flow value, which is provided only in a third type of forecast format. Also, all forecasts represent "naturalized" flows that have had some (but not all) diversions and reservoir regulation effects removed. However, these only use average effects, not actual values. This means that users cannot easily compare observed flows to the forecast flows, and the adjustments are likely to be most incorrect at precisely the times when they need to be the most accurate – during periods of drought. Our graphical comparison of the historical forecasts and observations clearly illustrates the multi-dimensional nature of evolving seasonal forecasts. While the forecast agencies do provide an annual end-of-season graphical comparison of forecasts and observations, the CLIMAS evaluations provide the first historical graphical comparisons.

Our quantitative forecast evaluations have used a diagnostic approach that is more customarily applied to weather and climate forecasts. This allows us to focus on specific conditions that are important to stakeholders. In January, forecasts overwhelmingly favor "normal" conditions; forecasts of extreme conditions are rarely made (never for the Verde River, AZ). For some rivers, including the Verde, forecast performance actually gets worse from March to April. It's

understandable that very high flows may not be forecast, due to a single late storm bringing heavy snowfall. Significantly, forecasts of extremely low flows (e.g., on the Verde) are missed even in April. This occurs even though forecasts should be best in April for Arizona rivers, because April-June has almost no precipitation and April-June flows are almost entirely dependent on the snowpack. Good forecasts of extremely low flows are important to a number of stakeholders, including junior water rights holders and riparian ecosystems managers. Research is needed to determine whether this forecast problem is due to poor quality snowpack estimates or not incorporating skillful climate outlooks, or some combination of the aforementioned. Our evaluations also look at other distributional behavior, including the probability of observations conditioned on the forecasts, which allows us to examine the willingness of forecasters to deviate from strictly climatological forecasting.

Forecast Evaluation: Seasonal Water Supply Outlooks, Probabilistic Forecasts: The CBRFC has, since 1994, generated experimental seasonal water supply outlooks in a probabilistic format based on an ensemble streamflow prediction (ESP) approach. Although these forecasts use a relatively simple dynamic rainfall-runoff model, the ESP forecasts are seen as conceptually more advanced than current operational forecasts based on regression equations. The ESP forecasts are probabilistic rather than deterministic because they use multiple historical meteorological sequences as inputs to create multiple forecasts that are arranged into a probability distribution, and the rainfall-runoff model can track moisture storage conditions within a watershed (e.g., snowpack, soil moisture). Because the experimental ESP forecast record is short and seasonal forecasts accumulate slowly, comprehensive evaluation of the improvements offered by the methodology requires a hindcast/reanalysis approach. We began working in this area in Year 3. We have acquired and tested all requisite model program code from the NWS Office of Hydrology, and have selected the watersheds we plan to study. We are producing evaluations that are the first of their kind for ESP forecasts within the NWS River Forecast Centers. The comprehensive evaluation considers criteria that can accommodate probabilistic forecasts, including the Ranked Probability Score. The ESP forecasts are also being compared to the historical official forecasts through transformation into a single quantity (e.g., ESP median forecast, "best" ensemble member).

Forecast Evaluation: CPC Seasonal Temperature and Precipitation Outlooks: While evaluations begun in Year 2 were focused on water management needs, in Year 3 our efforts were expanded to consider the wildland fire management and ranching sectors. Working with the CLIMAS Core Office and social science team, we participated in interviews and extended discussions with these new stakeholders, through the CLIMAS wildland fire management workshop and 13 meetings of ranching groups. As a direct result of those interactions, in Year 3 we developed an evaluation approach that recognizes the varied needs of decision makers, even within a sector (e.g., different decision calendars, relevant variables, regions, criteria), and enables incremental education of decision makers. Users consistently state that the lack of any quantitative basis for establishing forecast credibility limits their use of seasonal climate outlooks. Our interactions have made clear that conflicts in forecast communication and interpretation, such as the "climatology" designation used in cases where the CPC does not make a forecast, reduce forecast credibility as well. Thus, we have examined aspects of current forecast formats that affect the ease, accuracy, and reliability of their interpretation, and suggest that the "climatology" designation be modified to better communicate complete forecast uncertainty.

While forecast performance can be quantified in myriad ways, the criteria used in this task were selected to allow users to start with simplistic approaches and progressively shift to more complex analyses that more accurately reflect forecast performance. Instead of the system used by most agencies, where values of different criteria have varying interpretations (e.g., 1 is best, -1 worst; or 0 is best and worst is unlimited), our evaluations were given as skill scores relative to forecasts that can be made in the absence of CPC outlooks (i.e., chance or climatological probabilities).

The evaluations demonstrated how analyses targeted at specific user situations can produce different assessments of forecast performance. Results showed that climate forecast skill exists for situations important to water managers in the Lower Colorado River Basin that also use seasonal water supply outlooks produced by the NWS and Natural Resources Conservation Service (NRCS), and to Southwestern cattle ranchers using rangelands that are most productive in the winter. Climate forecast skill was lacking, however, for other situations relevant to water managers, ranchers, and wildland fire managers. In particular, water managers in the Upper and Lower Colorado River Basin face different realities concerning climate forecast skill that have important implications for their reliance on advanced seasonal forecasting technologies.

Our evaluations of seasonal climate outlooks have advanced to the stage that we have initiated interactions with stakeholders, with the goal of presenting evaluation of results and obtaining feedback on the effectiveness of our analyses, criteria for evaluation, and the effectiveness and understandability of our graphical evaluation products/explanations. In conjunction with the CLIMAS Core Office, we organized a one-day workshop, in a first-ever attempt to garner detailed insights about technical issues related to probabilistic forecasts, climate forecasts, and forecast evaluation, from the perspective of water management professionals. The workshop included representatives from local and regional water providers, emergency management agencies, the National Weather Service (NWS) local weather forecast office and NWS Colorado Basin River Forecast Center. Our discussions provided good feedback on format and content of various climate forecasts and an assessment of our evaluation tools. In addition, the discussions helped identify decision-makers' thresholds for forecast "quality" (i.e., specifically what standards forecasts must meet to be used in decision making).

Evaluation of Gridded Snow Estimates: Quality forecasts of areal snow coverage and snowpack water storage are critical to improving both regression-based and ESP water supply outlooks, as well as third-generation hydrologic models (i.e., highly distributed dynamical land surface-atmosphere models). Currently there are no official snow forecasts, except for certain conditions such as storm warnings. With the cooperation of the NWS National Operational Hydrologic Remote Sensing Center (NOHRSC) and the University of Arizona RESAC project, efforts during Year 3 have produced a 10-year (1990-1999) database of high-resolution (1 km^2) gridded snow conditions (coverage and water equivalent). Combining point, line, and areal measurements from precipitation and SNOTEL gauges, NRCS snow courses, and satellite measurements, this database is the first of its kind for such an extended period. It allows, for the first time, comprehensive evaluation of the role of snow conditions in hydrologic variability and predictability.

Also during Year 3, efforts have begun to develop a framework and evaluation of snow simulations for the western United States, produced by the Berkeley Regional Climate Simulation Model (RCSM, Kim and Miller 2000). The RCSM was selected for this initial effort because it was readily available, covers the region, and is being piloted by the NWS California-Nevada RFC for experimental forecasts. The evaluation framework is applicable to other snow forecasts as well (e.g., from the University of Colorado, Scripps). It considers watershed mass balance, spatial patterns, and linkages to large-scale atmospheric circulation patterns.

Team Members: Holly Hartmann, Tom Pagano, Fan Li, Paul Whitaker, Mary Glueck, Kristie Franz

Publications

H.C. Hartmann, R. Bales, and S. Sorooshian, 2000. A survey of weather, climate, and hydrologic forecasting for the Southwest U.S. *Climate Research* (in review).

H.C. Hartmann, T. C. Pagano, R. Bales, and S. Sorooshian, 2000. Evaluating seasonal climate forecasts from user perspectives. *Bulletin of the American Meteorological Society* (submitted).

Pagano, T.C., H.C. Hartmann, and S. Sorooshian, 2000. Climate forecasts: a new tool for hazard management in the Southwestern U.S. *Natural Hazards Observer* 24(6):7-8.

Pagano, T.C., H.C. Hartmann, and S. Sorooshian, 2000. Factors affecting seasonal forecast use in Arizona water management: a case study of the 1997-98 El Niño. *Climate Research* (accepted for publication).

Pagano, T.C., H.C. Hartmann, and S. Sorooshian, 2000. Using climate forecasts for water management: Arizona and the 1997-98 El Niño. *Journal of the American Water Resources Association* (in review).

Preprints and Conference Proceedings

H.C. Hartmann, T. C. Pagano, R. Bales, and S. Sorooshian, 2000. Evaluating seasonal climate forecasts from the perspective of users in the U.S. Southwest. Proceedings, 2nd Southwest Weather Symposium, Tucson, AZ.

Presentations

Hartmann, H.C., T.C. Pagano, R. Bales, and S. Sorooshian. Evaluating seasonal climate forecasts from user perspectives. Presented at the 2nd Southwest Weather Symposium, September 21-22, 2000, Tucson, AZ.

Hartmann, H.C., T.C. Pagano, C. Brown, R. Bales, and S. Sorooshian. Seasonal climate forecasts for water management: applications and evaluations. Spring Meeting, American Geophysical Union, Boston, MA, 31 May – 3 June, 2000.

Hartmann, H.C., T.C. Pagano, C. Brown, R. Bales, and S. Sorooshian. Evaluation of official seasonal climate forecasts for water resources applications in the U.S. Southwest. 10th Annual Hydrology Research Exposition, University of Arizona, Tucson, AZ, 5 April, 2000 ***(received HWR Award of Excellence).***

Li, F., R.C. Bales, H.C. Hartmann, Z.-L. Yang, J. Kim, N Miller and S. Sorooshian. Evaluating Seasonal Snow Simulations from a Mesoscale Atmospheric Simulation Model in the Western U.S. with High-Elevation Data Sets. 81st Annual Meeting of the American Meteorological Society, Albuquerque, NM, January, 2001.

Pagano, T.C., H.C. Hartmann. Southwest Climate in a Nutshell. Presented at meetings of the Arizona Natural Resource Conservation Districts and Arizona Association of Conservation Districts Summer Meeting. July-December, 2000.

Pagano, T.C. How good are climate forecasts? Evaluations from a user's perspective. Graduate and Professional Student Council Student Showcase, University of Arizona, Tucson, AZ, 10-11 November ***(received 2nd Place Award in Agriculture and Environmental Sciences)***.

Welles, E., H.C. Hartmann, H. Gupta, and S. Sorooshian. What is a good probability forecast? Presented at the 2nd Southwest Weather Symposium, September 21-22, 2000, Tucson, AZ.

Whitaker, P., H.C. Hartmann, R. Bales, and S. Sorooshian. Seasonal water supply forecast performance: issues and evaluations. Presented at the 2nd Southwest Weather Symposium, September 21-22, 2000, Tucson, AZ.

Whitaker, P., H.C. Hartmann, R. Bales, and S. Sorooshian. Seasonal water supply forecast performance: issues and evaluations. Spring Meeting, American Geophysical Union, Boston, MA, 31 May – 3 June, 2000.

Whitaker, P., H.C. Hartmann, R. Bales, and S. Sorooshian. Evaluation of seasonal hydrologic forecasts in the Colorado River Basin. 10th Annual Hydrology Research Exposition, University of Arizona, Tucson, AZ, 5 April, 2000.

Year 3 Progress Report: Climate Variability Team

Downscaling Southwest Climate Data: In response to stakeholder and team requests for data, we have successfully developed models for downscaling winter climate data for the Southwest to 1 km^2 resolution. Our goal was to develop a methodology that could ultimately be used to produce several gridded datasets for the region, and which was sufficiently flexible that we could apply it to various timescales in the instrumental record as well as to paleoclimatic timescales. We developed multivariate regression models of winter temperature and precipitation using a Digital Elevation Model (DEM) and NOAA/NWS cooperative climate station network for Arizona, New Mexico and surrounding areas. The winter season was selected as the initial temporal study period, because of the crucial role precipitation plays in the recharge of dams, aquifers, and reservoirs, and for overlap with the paleoclimate project that deals with winter moisture. Topography is the major source of spatial variability in climate data at these spatial scales, and therefore the models were based on terrain variables such as elevation, slope, aspect, latitude, and longitude. Our analyses showed that a single regression model was sufficient for creating gridded temperature datasets at 1 km^2 resolution. For precipitation, a series of sub-regional models was used rather than a domain-wide model.

Monsoon Variability and Prediction: We initiated an ongoing set of diagnostic analyses into the nature and causes of monsoon-related variability for the American Southwest and we developed an experimental seasonal forecast model. We found that a nonlinear classification technique successfully captures the evolution of the monsoon, the mature phase of which we found to be strongly linked to an intraseasonal mid-tropospheric wave-like anomalous height pattern over the Pacific-North American sector. This intraseasonal pattern is characterized by the largest amounts of mid-tropospheric moisture over the southwest; it is also the most common mode during the mature phase and the second wettest. In contrast, the wettest monsoon mode shows weak mid-tropospheric height anomalies over North America, but also the largest amounts of mid-tropospheric specific humidity over Arizona and New Mexico at daily time scales that may be linked to tropical forcing. We determined that neural networks produced better experimental forecasts than linear regression techniques. Our results indicate that antecedent winter and spring conditions in the surrounding oceans, and land-surface conditions seem to modulate monsoon precipitation. In the past, the majority of the seasonal forecasts have given too much weight to tropical SSTs associated with ENSO conditions as compared to SSTs in the Atlantic basin. Our results indicate that both the North Atlantic and the North Pacific SST conditions need to be considered to achieve improved seasonal forecast of monsoon precipitation over Arizona.

Paleoclimatic Reconstruction (Precipitation): Our paleoclimate research team has produced a set of high spatial resolution cool season precipitation reconstructions back to AD 1000, in order to provide a locally-relevant baseline of information on interannual to century scale variability. The effective spatial resolution of these reconstructions is fairly crude, approximately 150 km. Thus, during Year 3 we have experimented with alternative strategies for developing finer resolution cool season precipitation for each climate division in Arizona and New Mexico. In particular, 19 tree-ring chronologies from across the greater Southwest were used in a comparison of multiple linear regression and neural network techniques for developing transfer functions to convert tree-ring data to records of precipitation; the transfer functions were used to reconstruct cool season

precipitation back to AD 1000. Both techniques show similar skills and errors, but the neural networks tend to predict extreme events better than multiple linear regressions, whereas the latter better capture changes in the mean.

Paleoclimatic Reconstruction (Circulation Indices): In parallel with this collaborative work between CLIMAS paleoclimate and modern climate variability team members, we have developed reconstructions of two features of large-scale circulation, El Niño-Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO), back to AD 1000. The PDO is described as a robust, recurring pattern of ocean-atmosphere climate variability centered over the mid-latitude North Pacific basin. As it is possible that a reversal of the PDO may be under way at the time of writing, leading to decreased predictability of the effects of ENSO in our region, there is considerable practical value to CLIMAS stakeholders in knowing if these PDO reversals are part of a pattern. We have determined that the PDO has a clear and strong oscillation of 73 years period. A similarly informative reconstruction of ENSO has been produced, and the relationship between the two is currently under investigation. Following presentation of these last results at the Santa Fe RISA PIs meeting, we, with the cooperation of the Pacific Northwest and California Applications Project RISAs, have initiated a small workshop with the aim of developing a more robust reconstruction of the PDO and its regional teleconnections for the whole of the West, from the Gulf of Alaska to Baja California.

Climate of the US-Mexico Border: In collaboration with the CLIMAS Pilot Border Study Team, we have investigated cross-border climate processes, specifically the summer monsoon, and the 1950's drought in northern Mexico. The results of this work are the topic of a paper in progress.

During the remainder of Year 3 we intend to finalize model development and complete production of the gridded datasets for the historical record, as far back as station densities will reasonably allow, probably circa 1950. We will also perform diagnostic studies of sub-regional climate variability identified in our data. For example, we wish to better understand the different sub-regional climate responses to ENSO and other variability indices. We intend to produce a suite of gridded data available via a graphical web interface, whereby users could specify particular pixels or area and view animated maps or download data for temperature, precipitation and other variables.

Team Members: Andrew Comrie, Malcolm Hughes, Tereza Cavazos, Fenbiao Ni, David Brown

Preprints and Conference Proceedings

Brown, D.P. and A.C. Comrie, 2000. Spatial modeling and scale analysis of winter climate variability in Arizona and New Mexico. Proceedings, 2nd Southwest Weather Symposium, Tucson, AZ.

Cavazos, T., F. Ni, M. Hughes, A. C. Comrie, and G. Funkhouser, 2000. Using regression and neural networks to reconstruct circulation indices and precipitation in the Southwest. Abstract Volume 81st Annual Meeting of the American Meteorological Society, Albuquerque, NM, January, 2001.

Presentations

Brown, D.P. and A.C. Comrie. Spatial modeling and scale analysis of winter climate variability in Arizona and New Mexico. Presented at the 2nd Southwest Weather Symposium, September 21-22, 2000, Tucson, AZ.

Brown, D.P. and A.C. Comrie. Winter climate variability in Arizona and New Mexcio. Presented at the American Water Resources Association 2000 Annual Spring Specialty Conference, May 1-3, 2000, Anchorage, AK.

Brown, D.P. and A.C. Comrie. Spatial modeling of winter climate variability in Arizona and New Mexico. Presented at the 96th Annual Meeting of the Association of American Geographers, April 4-8, 2000, Pittsburgh, PA.

Cavazos, T. Applications of regional climate downscaling to climate variability and climate change studies. Scripps Institution of Oceanography, May 2000.

Cavazos, T. Applications of regional climate sownscaling to climate variability. Spring Colloquium of the Department of Geography and Regional Development, University of Arizona, April 2000.

Cavazos, T. Using artificial neural networks in climate variability studies. Department of Geography Colloquium, Arizona State University, March 2000.

Cavazos, T., A. C. Comrie, and A. Gershunov. Seasonal forecast of monsoon precipitation in Arizona using linear and nonlinear techniques. Second Southwest Weather Symposium, Tucson, AZ, Sep 21-22,2000.

Cavazos, T., F. Ni, M. Hughes, A. C. Comrie, and G. Funkhouser, 2000. Using regression and neural networks to reconstruct circulation indices and precipitation in the Southwest. 81st Annual Meeting of the American Meteorological Society, Albuquerque, NM, January, 2001.

Hughes, M.K, Funkhouser, G. and F. Ni. Decade to century scale variability in soil moisture in the southwestern United States. International Conference on Dendrochronology for the Third Millennium in Mendoza, Argentina, April 2000

Ni, F. Analysis and reconstruction of the relationship between a circulation anomaly feature and tree rings: linear and nonlinear approaches. April 2000, Laboratory of Tree-Ring Research, The University of Arizona.

Ni, F. Reconstructing an upper air anomaly feature over the Pacific Northwest using tree rings: fuzzy logic and regression approaches. March 2000, Department of Atmospheric Sciences, The University of Arizona.

Year 3 Progress Report: Core Office

The Core Office has been concentrating on the following key task areas under the Year 3 budget: the CLIMAS web site, stakeholder outreach, Fire and Climate meeting coordination and organization, RISA coordination, network building, and project coordination. The Core Office has also continued its participation in conferences and meetings and is engaged in a variety of other activities. Progress in each of these areas is summarized below.

Web Site: The CLIMAS web site has been completely redesigned and reorganized. The web site now features PDF versions of all CLIMAS reports and CLIMAS Update newsletters, as well as PowerPoint educational slide shows of climate-related topics of interest to stakeholders. Slide show topics include The Climate of the Southwest, Colorado River Basin Water Issues, Southwest Climate in a Nutshell: A Tool for Ranchers, Forecasting in the Southwest: An Introduction, and Water Resources in the San Pedro River Basin. Efforts are underway to construct Web pages devoted to our upcoming Fire and Climate workshop, as well as educational materials and Web links related to our new Fire and Climate initiative. Since mid-summer we have been able to update our specially tailored Southwest climate outlook every two months. Materials regarding CLIMAS sponsored or co-sponsored conferences may also now be found on our web site.

Stakeholder Outreach: Together with team members Holly Hartmann and Thomas Pagano, the CLIMAS Core Office sponsored a stakeholder workshop on November 16, 2000 to discuss issues regarding climate forecasting and water management. The workshop included selected representatives from local and regional water providers, emergency management agencies, the National Weather Service (NWS) Tucson weather forecast office and NWS Colorado Basin River Forecast Center (Salt Lake City). It was a first-ever attempt to garner detailed insights about technical issues related to probabilistic forecasts, climate forecasts, and forecast evaluation, from the perspective of water management professionals. Participants identified key elements of forecast products that will improve the ease, accuracy and reliability of interpretation by water managers and others. The second area of focus was a review of several tools for evaluating how good the forecasts have been for the Southwest over the past five years. The Core Office continues to publish a quarterly newsletter, which, with the help of our publication- and Web-designer, has been redesigned to have a more pleasing and professional look. The Core Office, with the assistance of the Udall Center, continues to maintain a relevant stakeholder address database and mailing list for publications and announcements.

RISA Network Coordination: On November 29-30, 2000, the CLIMAS Core Office sponsored a day of meetings and interviews with California Applications Project members Dan Cayan and Mike Dettinger. The meeting allowed the two RISAs to apprise each other of research activities and to discuss key areas for coordinated research opportunities.

The Core Office coordinated CLIMAS participation in the Santa Fe RISA meeting, and assisted with development of a one-page summary of project activities as well as a five-page summary of the funded RISAs and their contributions to society.

Fire and Climate Meeting Coordination and Organization: The CLIMAS Core Office has spent considerable effort coordinating with the Program for Climate, Ecosystem, and Fire Applications (CEFA) at the Western Regional Climate Center, the Institute for the Study of the Planet Earth, and the Laboratory of Tree-Ring Research in order to organize (1) a second annual meeting on the topic of fire and climate and (2) a one-day workshop for Arizona and New Mexico fire managers on the same topic. The meeting, scheduled for February 2001, will expand on our timely, highly relevant and well received February 2000 workshop, "The Implications of La Niña and El Niño for Fire Management."
We have targeted important regional and national-level participants for the scheduled February 2001 meeting. The meeting will place a greater emphasis on identifying and implementing stakeholder needs, as well as creating connections between the fire management and climate research communities in order to foster dialogue, examine institutional structure and policy, and create research opportunities for a variety of timely and relevant topics associated with the interaction between climate, fire, ecology and society. The one-day workshop will allow regional fire, land-use and emergency managers, national and regional climatologists and regional meteorologists to convene for dialogue on stakeholder needs and stakeholder education regarding the use of climate forecasts and evaluation of the latest climate forecasts. In addition, we have produced a proceedings volume from our first annual Fire-Climate workshop. The proceedings are available in PDF format on our web site.

Based on information gleaned from these workshops, we will be targeting fire managers for a pilot suite of products that will be produced by the integrated CLIMAS team. Work currently underway at the California Applications Project RISA is anticipated to provide valuable input to the CLIMAS climate-fire initiative as well. Discussions between CLIMAS team members, have indicated that future CLIMAS fire-climate research will be well integrated between the natural science and social science components of our research teams.

Project Coordination: The Core Office spent a considerable amount of time coordinating team efforts for our September RISA review meeting in Santa Fe. The Core Office continues to maintain two listservs (one for the larger interested community and one for CLIMAS team members). The Core Office also continues to hold bi-weekly team meetings, monthly Postdoc meetings and PI meetings. The Core Office continues working to ensure that CLIMAS team members participating relevant meetings, conferences, and other such events, and that team members maintain open communications with each other hand with the Core Office. The Core Office also continues to ensure that working papers are completed, subjected to internal review, and transferred to our web site in a timely fashion.

Network Building: The Core Office has been working with Andrea Ray and Robin Webb at CDC to assure that social science is recognized in the new North American Monsoon Experiment (NAME) initiative. An outgrowth of interactions with CDC is agreement that CLIMAS would hold a NAME workshop at ISPE in Spring 2001.

The Core Office funded a visit by Dr. David Gutzler of the University of New Mexico, to give a talk to CLIMAS team members about his climate research in the Southwest. This visit was intended as a prelude and network-building strategy preparatory to including Dr. Gutzler in

Phase 2 of the project with regard to his monsoon research. Our proposal for Years 4-6 includes funding for Dr. Gutzler in Year 6.

Barbara Morehouse participated in a meeting of the Three States and Tribes assessment, funded by Caitlin Simpson under the Human Dimensions of Global Change Program. The meeting provided an opportunity to discuss links between the two projects, particularly with regard to work going on with water managers and Pueblos in New Mexico and with the Zuni and Navajo Nations.

Native American Outreach: Barbara Morehouse gave climate assessment talks to two groups of Native American high school students. The first talk "Why is it important to know about past and future climate?" was presented at the First Annual Native American Teen Environmental/GIS Workshop, The University of Arizona, Tucson, Arizona, August 5, 2000. The second talk, "Our Climate: Past, Present and Future" was given in a more informal setting to Kaibab Paiute teens and their chaperones at the offices of the Bureau of Applied Research in Anthropology, August 22, 2000. A summary of climate information sources useful to the Kaibab Paiute Tribe, complete with active web links, was provided to the Tribe at their request in late November 2000.

Team Members: Barbara Morehouse, Gregg Garfin

Publications

CLIMAS Update Newsletter (quarterly)

CLIMAS Web Site

Regularly updated climate forecast commentary and hot links

Preprints and Conference Proceedings

R. C. Bales and B.J. Morehouse, 2001. The Climate Assessment Project for the Southwest: An Integrated Approach. Abstract Volume 81st Annual Meeting of the American Meteorological Society, Albuquerque, NM, January, 2001.

Morehouse, B.J., 2000. The value of understanding natural climate variability and its impacts as a bridge to thinking about climate change. Extended Abstract for the proceedings volume of the International Conference on Climate Change Communication, June 22-24, 2000.

Presentations

R. C. Bales and B.J. Morehouse. The Climate Assessment Project for the Southwest: An Integrated Approach. Annual Meeting of the American Meteorological Society, Albuquerque, NM, January, 2001.

Morehouse, B.J. The value of understanding natural climate variability and its impacts as a bridge to thinking about climate change. International Conference on Climate Change Communication, June 22-24, 2000.

Morehouse, B.J. Invited paper on "Paleo information and drought assessment in the Southwest." 16th Biennial Meeting of the American Quaternary Association, Fayetteville, Arkansas, May 22-24, 2000.

Other

Morehouse, B.J. Co-organized, with H. Diaz of CDC, symposium on Climate, Water, and Transboundary Challenges in the Americas, University of California-Santa Barbara, Santa Barbara, California, July 16-19, 2000.

Morehouse, B.J. Co-organized, with A. Comrie, illustrated paper session on climate variability, "Making Climate Research Relevant," 96th Annual Meeting of the Association of American Geographers, Pittsburgh, PA, April 4-8, 2000.

Morehouse, B.J. and A. Comrie. Co-organized, with Andrew Comrie, roundtable discussion on "Geography as an Integrative Discipline" with focus on integrated assessments, 96th Annual Meeting of the Association of American Geographers, Pittsburgh, PA, April 4-8, 2000.