Year 2 Progress Report: Climate Variability Team

The white paper produced in year one ("The Climate of the Southwest") has been translated into to a journal article, and sent the article out for pre-submission review by noted experts at other institutions. Together with articles derived from the other year 1 CLIMAS papers, this article will form part of a special issue of the journal *Climate Research*.

In response to stakeholder and team requests for data, a subset of climate data for the Southwest has been downloaded from NCDC. These data include (monthly station data, and period of record data for all longer-term stations. The data will be made available in graphical and digital form on the CLIMAS web site as an extension to the meta-database developed from the year 1 white paper.

In consultation with the Forecasting team, Social Science teams, and stakeholders, user-oriented informational materials on climate variability have been developed. A slide show is available through the CLIMAS web site; a Powerpoint presentation, as well as brief descriptive paragraphs are also available now for use at public meetings, as well as in focus group sessions, interviews, reports, and other venues.

Work has been initiated on downscaling and interpolation of instrumental and paleo-climate information to fine spatial scales; a scale of approximately 1 km is being targeted. Artificial neural networks are being used to perform the diagnostic and modeling phases of the research, along with NCAR/NCEP reanalysis data and local and regional station data. The general approach is to empirically model links between local surface/paleo data and atmospheric circulation.

Detailed climate variability analyses of instrumental and paleo-climate data for the Southwest have been initiated. This entailsidentifying nature and causes of interannual and decadal variation as they vary sub-regionally. In particular, in order to improve prediction capabilities, work is underway to identify important controlling processes and their complex interactions for the summer half-year (monsoon) and the winter half-year (mid-latitude systems).

A very productive start has been made with regard to investigating climate and health linkages through research on Valley Fever (coccidioidomycosis), which examines the strong but complex links between wet and dry periods, their variability, and the incidence of this disease, which is endemic to the Southwest.

Team members: Andrew Comrie, Malcolm Hughes, Tereza Cavazos, Fen Biao, Pau Sheppard, David Brown, Korine Kolivras.

Publications

Sheppard, P., Comrie, A., Packin, G., Angersbach, K., and Hughes, M., 1999: *The Climate of the Southwest*. CLIMAS White Paper.

Kolivras, K., Johnson, P., Comrie, A. and Yool, S., 1999: Environmental Variability and Coccidioidomycosis (Valley Fever). *Aerobiologia*, in review.

Presentations

The National Assessment of Climate Change, Panel Discussion, 95th Annual Meeting of the Association of American Geographers, March 23-27, 1999, Honolulu, HI.

Linking climate variability to forest fire severity in the Southwest. Presented at 95th Annual Meeting of the Association of American Geographers, March 23-27, 1999, Honolulu, HI.

Modeling Temperature at Fine Spatial Scales for Global Change Impacts. Presented at Arizona/NASA Space Grant Undergraduate Research Internship Symposium, Tempe, Arizona, April 9-10, 1999.

Predictive Spatial Modeling of Coccidioidomycosis Infection in Arizona. Presented at Annual Symposium of the Pan-American Aerobiology Association, Tucson, Arizona, May 28-June 1, 1999.

Climate Variability in the Southwest: An Integrated Assessment. Presented at the 16th Annual Pacific Climate Workshop on Climate Variability of the Eastern North Pacific and Western North America (PACLIM), Santa Catalina Island, CA, May 24-27, 1999.

Climate Variability in the Southwest: An Integrated Assessment. Presented at the American Society of Civil Engineers, 26th Annual Water Resources Planning and Management Conference, Phoenix, AZ, June 5-9, 1999.

Climate and Valley Fever (with K. Kolivras), in W. Sprigg and T. Hinkley, Southwest Regional Component of the National Climate Assessment. Presented at American Geophysical Union, Spring Meeting, June 1999.

Year 2 Progress Report: Forecast Team

Forecast Review: Review of the state of weather, climate, and hydrologic forecasting for the Southwest is complete. The effort required extensive review of archival and Web sources of information, along with extensive interaction with key forecast entities. The resulting white paper provides a comprehensive review of the state of forecasting for the region, highlights important issues, and identifies areas where further research could contribute to better forecasting through evaluation of forecasts, improvements in modeling, and improvements in forecast products and their communication. The white paper is being used as the basis for an article in Climate Research, as part of a special issue on climate variability issues in the Southwest, and for Web-pages and fact sheets targeted at the general public and specific stakeholder groups.

Recognition of the slow transition of research into operational practice in hydrologic forecasting, resulting from the forecast review, led to the organization of a special session at the Spring Meeting of the American Geophysical Union, "Towards Improved Incorporation of Hydrologic Research into Water Management Practices and Policies" (1-4 June 1999). The session consisted of presentations by 7 invited speakers on 1) the growing importance of management and policy relevance of research projects within large hydrologic research programs, 2) institutional and bureaucratic realities that affect incorporation of research products into management practices and policies, and 3) case study experiences, both rewarding and frustrating, in transferring hydrologic research and technology to resource managers and policy makers. Session attendance and discussions were excellent, resulting in a distinct shift in perspective within the NWS Office of Hydrology regarding the role of hydrologic models other than API and SAC-SMA. For the first time, NWS/OH publicly recognized the need for considering non-NWS hydrologic models and forecast techniques in generation of operational products. Significant technical and institutional barriers still exist, but this shift in perspective is a necessary first step.
Team Members: Holly Hartmann

1997-98 El Nino Forecasts: The 1997-98 El Nino provided a unique opportunity for the assessment of access, interpretation, and use of hydroclimatic information and forecasts by water management agencies in the Southwest. Toward this end, detailed case study analysis was conducted through semi-structured in-depth interviews with key personnel from 16 different agencies responsible for emergency management and water supply, with jurisdictions ranging from urban to rural and local to regional. The effort provided unique details about the impact of the 1997-98 El Nino on agency operations, which hydroclimatic forecasts were consulted, how the products were interpreted and used, and factors affecting integration of forecasts into agency operations. This work has been well received by both forecast providers and forecast users (e.g., 7 invited presentations). Efforts are underway to develop a series of journal articles directed at the climate forecasting (in the special issue of Climate Research), water management, and emergency management communities, as well as being incorporated into Web-pages and fact sheets targeted at the general public and specific stakeholder groups.
Team Members: Tom Pagano, Holly Hartmann

Forecast Evaluation: Seasonal Water Supply Outlooks: Contacts developed at the Forecast Assessment Workshop under year 1 activities led to attendance at a meeting of seasonal water supply forecast providers (e.g., CBRFC, NRCS) and major forecast users (e.g., Bureau of Reclamation, Upper Colorado River Commission). That opportunity was used to mine CBRFC archives, gathering all available historic water supply outlooks (back to the 1940s) and forecast procedure documentation. Through coordination with the NRCS, these water supply outlooks have been used to create a unique database that enables, for the first time, comprehensive forecast evaluations. This database contains monthly naturalized flows for gage locations throughout the Southwest, and operational forecasts of water supplies, including the "most probable", "reasonable maximum", and "reasonable minimum" forecasts.

Preliminary forecast quality analysis is underway for 5 locations (the Salt, Gila, Gunnison, and San Juan Rivers, and Lake Powell inflow), and within year 2 will be extended to the remaining locations. The water supply forecast evaluations are much more comprehensive than the limited evaluations of the past, considering 10 different aspects of forecast quality through a distributions-oriented analysis approach (Murphy, 1993). Among other issues, the analysis resolves questions that differ based on stakeholder perspective. For example, in an operations context, one relevant question is what confidence might a user place in a specific forecast for an extreme condition. In a planning context, the more relevant question is what confidence might a user have that a specific extreme condition will be predicted in a forecast. Evaluation of the historic outlooks is appropriate, because many water management decisions have been made using those forecasts, providing a more realistic assessment of vulnerability to climate variability and forecast uncertainty.

Evaluation of the forecasts made using the most recent set of regression equations will also be evaluated within year 2. The current suite of regression equations used to generate the water supply outlooks has been acquired from the NRCS and CBRFC. Those equations will be used in a reanalysis setting to create a sufficient sample for a distributions-oriented evaluation of current forecast methodologies. Extant evaluations consider only overall measures of bias and standard error.
Team Members: Paul Whitaker, Holly Hartmann

Forecast Evaluation: CPC Monthly and Seasonal Temperature and Precipitation Outlooks: Evaluations of the CPC monthly and seasonal climate outlooks are underway as well. While extant evaluations generally consider only overall measures of forecast quality and large regions, these evaluations are specific to small regions within the Southwest and consider multiple measures of forecast quality using a distributions-oriented approach (Murphy, 1993). Initial evaluations are being made using the CPC database of climate outlooks, tercile class limits, and observations for regions comprised of several climate divisions, from 1995-present (forecast methodologies shifted significantly in January 1995). Initial analysis shows that forecasts for the Southwest have among the highest variability in the U.S. (i.e., the forecasts are more sharp than for other regions). Comparison of forecasts made for the same season, but with diminishing lead times, enables identification of forecast inconsistency (i.e., forecast climate anomalies change in their direction).

Additional work planned under year 2 includes acquisition of CPC climate outlooks prior to 1995. While forecast techniques have changed, it is appropriate to assess the historical archive of forecasts, because many resource management decisions have been made using those forecasts, providing a more realistic assessment of vulnerability to climate variability and forecast uncertainty. Although reanalysis-type evaluations are beyond the scope of this task, evaluations will consider the objective requirement that climatologic probabilities be issued where techniques have only marginal skill.
Team members: Tom Pagano, Holly Hartmann, Constance Brown

Evaluation of Gridded Snow Estimates: Evaluation of databases of airborne and satellite snow data, issued by the NWS National Operational Hydrologic Remote Sensing Center (NOHRSC) on CD-ROM, shows that only 3 years (1996-1998) of usable data are available, although CDs have been issued for 9 years. Comparison of basin-wide snow water equivalent estimates with seasonal streamflows for watersheds in the Colorado River Basin show violation of the water balance for some watersheds. This suggests that, for those basins, hydrologic response is dominated by processes other than snowmelt (e.g., low elevation precipitation, flow diversion or regulation), complicating hydrologic modeling and the potential for improved forecasting via improved snow estimation. Other basins, however, satisfy the water balance and identify test basins for evaluating the value of gridded snow products for improved water supply forecasting.
Team Members: Fan Li

Other: In conjunction with the CLIMAS Core Office, the forecast organized a special session, "Climate Assessment Project for the Southwest", and a follow-on technical discussion/workshop, at the 26th Annual Conference of the Water Resources Planning and Management Division, American Society of Civil Engineers, Tempe, AZ, 8-12 June 1999. The workshop discussion provided new opportunities for CLIMAS interaction with communities along Arizona's Mogollon Rim concerning climate variability and water supplies. Discussion with the civil engineers in attendance also demonstrated the need for more effective communication about the implications of long-term climate variability for water supplies as indicated by proxy records (e.g., tree rings). T. Pagano and H. Hartmann served as workshop panelists.

At the request of NASA, H. Hartmann represented CLIMAS at a press conference, "The U.S. National Assessment seeks answers to the consequences of climate change across the continent," at the Spring 1999 meeting of the American Geophysical Union, Boston, MA, May 31 – June 4, 1999. CLIMAS activities and results were presented to a diverse press corps audience. Press questions focused on the potential for increased water conflicts, especially in the Southwest.

Publications

Hartmann, H.C., R. Bales, and S. Sorooshian, 1999. Weather, Climate, and Hydrologic Forecasting for the Southwest U.S., Report of the Climate Assessment Project for the Southwest, Institute for the Study of Planet Earth, University of Arizona, Tucson, AZ.

Hartmann, H.C., R. Bales, and S. Sorooshian, 1999. Weather, climate, and hydrologic forecasting for the Southwest U.S. In: Proceedings of the 26th Annual Conference of the Water Resources Planning and Management Division, American Society of Civil Engineers, New York, NY.

Hartmann, H.C., R. Bales, and S. Sorooshian, 2000. Weather, climate, and hydrologic forecasting for the Southwest U.S.: a review and assessment. Climate Research (submitted).

Pagano, T.C., 1999. The role and usability of climate forecasts for flood control and water supply agencies in Arizona: a case study of the 1997-98 El Nino. M.S. Thesis, Department of Hydrology and Water Resources, University of Arizona, Tucson, AZ.

Pagano, T.C., H.C. Hartmann, and S. Sorooshian, 1999. Seasonal forecasts and water management in Arizona: a case study of the 1997-98 El Nino event. In: Proceedings of the 26th Annual Conference of the Water Resources Planning and Management Division, American Society of Civil Engineers, New York, NY.

Pagano, T.C., H.C. Hartmann, and S. Sorooshian, 1999. The role and usability of climate forecasts for flood control and water supply agencies in Arizona: a case study of the 1997-98 El Nino. In: Preprint Volume of the 14th Conference on Hydrology, American Meteorological Society, Boston, MA, pp.277-281.

Pagano, T.C., H.C. Hartmann, and S. Sorooshian, 2000. The role and usability of climate forecasts for water management in Arizona: a case study of the 1997-98 El Nino. Climate Research (submitted).

Presentations

Hartmann, H.C., 1999. Hydrologic forecasting for the U.S. Southwest. Global Change Seminar, University of Arizona, Tucson, AZ, 16 February (invited).

Hartmann, H.C., T. C. Pagano, R. Bales, and S. Sorooshian, 1999. The state of climate and hydrologic forecasting for the U.S. Southwest: an assessment. Spring Meeting, American Geophysical Union, Boston, MA, 1-4 June. *EOS, Transactions,* American Geophysical Union, 80(17S): 22.

Hartmann, H.C., R. Bales, and S. Sorooshian, 1999. Weather, climate, and hydrologic forecasting for the Southwest U.S. 26th Annual Conference of the Water Resources Planning and Management Division, American Society of Civil Engineers, Tempe, AZ, 6-9 June (invited).

Hartmann, H.C., R. Bales, and S. Sorooshian, 1999. A guide to weather, climate, and hydrologic forecasts for the U.S. Southwest. San Pedro Conference, Department of Agriculture, Cananea, Mexico and Bisbee, AZ, 7-10 November.

Whitaker, P. H.C. Hartmann, T.C. Pagano, R. Bales, and S. Sorooshian, 1999. Seasonal forecasts for water resources in the U.S. Southwest: applications and evaluations. Climate Diaganostics and Prediction Workshop, National Weather Service, Tucson, AZ, 1-5 November.

Whitaker, P. H.C. Hartmann, T.C. Pagano, R. Bales, and S. Sorooshian, 1999. Seasonal forecasts for water resources in the U.S. Southwest: applications and evaluations. San Pedro Conference, Department of Agriculture, Cananea, Mexico and Bisbee, AZ, 7-10 November.

Pagano, T.C., H.C. Hartmann, and S. Sorooshian, 1998. Use of climate data in public policy. Monthly Meeting, Southeast Arizona Chapter of the American Meteorological Society, Tucson, AZ, 19 November (invited).

Pagano, T.C., H.C. Hartmann, and S. Sorooshian, 1999. The role and usability of climate forecasts for flood control and water supply agencies in Arizona: a case study of the 1997-98 El Niño. 14th Conference on Hydrology, American Meteorological Society Meeting Hydrology, Dallas, TX, 10 January.

Pagano, T.C., H.C. Hartmann, and S. Sorooshian, 1999. Water management and climate forecasts: a case study of the 1997-98 El Niño in Arizona. Monthly Meeting, Arizona Hydrological Society, Tucson, AZ, 9 February (invited).

Pagano, T.C., H.C. Hartmann, and S. Sorooshian, 1999. Interannual climate variability and water management in Arizona: a case study of the 1997-98 El Nino. Department of Hydrology and Water Resources Seminar Series, University of Arizona, Tucson, AZ, 24 February (invited).

Pagano, T.C., H.C. Hartmann, and S. Sorooshian, 1999. A case study of the 1997-98 El Niño in Arizona: a focus on water management. CLIMAS Seminar, Institute for the Study of Planet Earth, University of Arizona, Tucson, AZ, 1 April (invited).

Pagano, T.C., H.C. Hartmann, and S. Sorooshian, 1999. Water management and climate forecasts: a case study of the 1997-98 El Niño in Arizona. 9th Annual Hydrology Research Exposition, University of Arizona, Tucson, AZ, 7 April (invited).

Pagano, T.C., H.C. Hartmann, and S. Sorooshian, 1999. Improving hydrologic forecast products through interaction with water management agencies in Arizona. Spring Meeting, American Geophysical Union, Boston, MA, 1-4 June. *EOS, Transactions,* American Geophysical Union, 80(17S): 23.

Pagano, T.C., H.C. Hartmann, and S. Sorooshian, 1999. Seasonal forecasts and water management in Arizona: a case study of the 1997-98 El Niño. 26th Conference on Water Resources Planning and Management, American Society of Civil Engineers, Tempe, AZ, 7 June.

Pagano, T.C., 1999. Use of climate forecasts for water management in Arizona: a case study of the 1997-98 El Nino. First Inter-American Institute/University of Miami Summer Institute on Interdisciplinary Global Change Science in the Americas, Miami, FL, 11-30 July (invited).

Sorooshian, S., T.C. Pagano, and H.C. Hartmann, 1999. Climate forecast use in Southwestern US water management: lessons learned from the 1997-98 El Nino. Workshop on the Impacts of the 1997/99 ENSO, Taiwan Central Weather Bureau, Taipei, Taiwan, 6 October.

Pagano, T.C., 1999. Climate in a nutshell. Malapai Borderlands Group, Douglas, AZ, 22 May (invited).

Pagano, T.C., 1999. Climate in a nutshell. Southern Arizona Cattleman's Protective Association, Marana, AZ, 9 October (invited).

Year 2 Progress Report: Urban Water Team

The Urban Water Study is focusing on two areas during Year 2: conducting a survey of water providers, and continuing the institutional analysis begun during Year 1.

Water Provider Survey: A survey, which includes mailed and in-person components, was initiated in summer, 1999. The mailed portion of the survey is based on a mailed questionnaire used successfully by the Penn State CIRA team, with modifications to suit the Southwest context. The in-person interviews follow a semi-structured format to ensure that key information is collected as well as to allow for individual responses. In the initial phase, the written survey was mailed to all large water providers in the Phoenix, Tucson, and Santa Cruz AMAs. A total of 49 surveys were sent out, 24 of which were returned. Seventeen of those returning the mailed survey have been interviewed in person. The survey is still in progress, with completion anticipated in early December.

The mailed survey provides a profile of the provider in terms of size of operation, expansion activities, and so on, while the personal interviews focus on managers' actions, climate information needs, and related topics. The process used for the large water providers will be repeated for a carefully identified subset of the small water providers, of which there are several hundred. Results of the survey will provide important insights for future efforts to disseminate climate information and forecasts to stakeholders in this sector. A working paper summarizing the results of the survey will be available shortly after the first of the year.

Institutional Analysis: The most significant institutional factors affecting the sensitivity and/or vulnerability of urban water systems to climatic impacts have been identified, and analysis of these factors is underway. A decision was made to delay completion of the analysis in order to incorporate information arising from a series of meetings initiated in late summer 1999 by the Arizona Department of Water Resources (ADWR). These meetings, conducted under the aegis of a Safe Yield Task Force, are addressing many insitutional issues in the Tucson and Phoenix AMAs that important to include in the CLIMAS analysis. At least one member of the Urban Water team has attended all of the Tucson AMA meetings. Team members also attended two initial Phoenix meetings; however, because progress in forming active committees in that AMA has been much slower, a decision was made to rely on mailing of meeting minutes and other materials from the Phoenix group to identify issues germane to the CLIMAS effort. A preliminary working paper from this part of the project is being drafted at this time; it is anticipated that the paper will be available by the end of the year, although modifications will probably be needed if the Safe Yield Task Force process continues beyond that date.

Team Members: Barbara Morehouse, Rebecca Carter, Petra Tschakert, Diana Liverman, Roger Bales, Diane Austin

Publications

Morehouse, Barbara. Climate impacts on urban water resources in the Southwest: The importance of context. Accepted for publication in the April 2000 special issue of the *Journal of the American Water Resources Association*. The special issue features papers presented at the April 1999 Specialty Conference on Potential Consequences of Climate Variability and Change to Water Resources of the United States, held in Atlanta.

Morehouse, Barbara and Rebecca Carter. The implications of climate variability for effluent management in Ambos Nogales. Abstract accepted; article submitted for review. To be published in a special issue of *Natural Resources Journal*.

Morehouse, Barbara, Rebecca Carter, and Petra Tschakert. An analysis of the climate sensitivity of urban water systems in Phoenix, Tucson, and Sierra Vista, Arizona. *Climate Research* (submitted).

Working Paper: "Assessing the Vulnerability of the Southwest's Urban Water Sector to Climatic Variability: Preliminary Sensitivity Analysis," by Rebecca H. Carter, Petra Tschakert, and Barbara J. Morehouse.

Presentations

Tschakert, Petra and Barbara Morehouse. Sensitivity of water resources in the Upper San Pedro Basin to climatic variability. Poster presented at "Divided Waters-Common Ground," a conference on the San Pedro Basin, Cananea, Sonora, Mexico and Bisbee, Arizona, November 10-13, 1999.

Carter, Rebecca, Petra Tschakert, and Barbara Morehouse. Assessing the Vulnerability of the Southwest's Urban Water Sector to Climate Variability. Paper presented at the 26th Annual Water Resources Planning and Management Conference of the American Society of Civil Engineers (ASCE), Tempe, Arizona, June 6-9, 1999.

Morehouse, Barbara. Climate Variability and Urban Water Resources in the Southwest. Paper presented at the AWRA Specialty Conference on Potential Consequences of Climate Variability and Change to Water Resources in the United States, Atlanta, Georgia, May 10-12, 1999.

Tschakert, Petra. Vulnerability of Urban Water Supply and Demand to Climatic Variations in the Southwest. Paper presented at the Applied Anthropology Annual Meeting, Tucson, Arizona, April 22, 1999.

Year 2 Progress Report: Ranching Team

During the first period of Year II of the CLIMAS Ranching Project, the focus has remained on the portion of southern Arizona, specifically Pima, Cochise, and Santa Cruz counties. A similar study for Yavapai County has been initiated in order to compare and contrast vulnerability to climatic variability in the transition zone and the Colorado Plateau with the Sonoran Desert and grasslands of southeastern Arizona. This project has three major research goals. The first is to compile substantial, specific information on the number, land tenure, and economics of cattle ranches in selected portions of Arizona at the present time. The second is to determine the ways in which climate variability has affected the economy, viability, and natural resource base of the ranching industry in the past, particularly during the drought of the 1990s. The third is to determine the type of climate information that would best serve the ranching industry, along with the most efficient system by which climate information can be delivered to meet the needs of ranchers. Specific activities conducted during the past six months include the following:

Ranch Inventory: Compilation data about the number, size, and land tenure of ranches in southeastern Arizona continues. Information has been gathered from agency archives, including those of the Bureau of Land Management, the U. S. Forest Service, and the Arizona State Land Department. Information on land tenure contained in these records is being collated with information about livestock operations (number and type of cattle) obtained from records of the Agricultural Extension Service, the USDA Agricultural Census, and the Arizona Agricultural Statistical Reporting Service. The process of compiling and collating the information, which is reported in different forms by the different agencies involved is complicated and time consuming.

Climate: Climate data have been compiled for the specific areas in the portions of Arizona that currently under study. Maps comparing the biogeographical and climate regimes for the specific counties under study are being prepared, and work is underway to assemble information on some of the major ranch boundaries, so that maps of ranch boundaries can be overlaid on the biogeographical and climate maps.

Newspaper Search: The newspaper search in the Arizona Daily Star, the Nogales Oasis, the Douglas Daily Dispatch, and the Willcox Arizona Range News is nearing completion. The research has focused on periods of known drought.

Ranch Sale Data: Information on ranch sales is being compiled by several methods. For example, newspaper reports of ranch sales are noted or copied. Further, long-term ranch realtors have been identified in the three counties currently under study; interviews with these individuals will facilitate gathering information about turnover in ranch properties. Ranch sales discussed in oral history interviews are being compiled, allowing for comparison of information on climate stress with the timing of ranch sales.

Agency Information: The team developed a questionnaire for and conducted interviews with agency personnel concerning the impact of different types of ranch management,

particularly during periods of drought, on the forage and water resources of the land for which their agency is responsible. The questionnaire also investigates agency personnel opinions concerning proper management, the impacts of climate variability on natural resources, and the restrictions and limitations imposed by agency structure and organization. Over 20 interviews with agency personnel have been completed.

Individual Ranch Information and Interview Process: A detailed questionnaire has been developed and mailed to ranch owners in Cochise County. The questionnaire, for which a 40 percent response rate was achieved, is designed to gather information on variation in management practices and adjustment to climate variability (i.e., adjustment of management during "normal," wet, or drought years). The questionnaire also investigates perceptions of climate variability, specific impacts from drought, micro-climates on specific ranches, and the economics of ranching during climatic stress. In conjunction with the questionnaire, respondents are provided with a county level map on which to locate their ranch property. In addition to the questionnaire, individual interviews are being conducted. More than 10 interviews have been conducted with ranchers, with questions aimed at identifying respondents' responses to climate variability.

Stakeholder Presentations: The CLIMAS Ranching Project research team has prepared a presentation on climate variability and Southwestern climate history to be given in conjunction with submission of the questionnaire. This presentation was given in May in Douglas, AZ at the general meeting of the Malpai Borderland Group and in October in Marana, AZ at the quarterly meeting of the Southern Arizona Cattlemen's Protective Association. The Ranching and Climate Variability presentation was also given at the Yavapai Cattlegrowers Association meeting in Skull Valley on November 20. In this case, a drought remediation question-and-answer session was conducted with a small group of interested ranchers.

Team members: Thomas Sheridan and Diana Hadley, Jennifer Merrill, Mark Kaib, Hallie Eakin, Julie Conley

Presentations

Pagano, Thomas. 1999. Climate variability and its impact on Arizona's cattle industry, Malpai Borderlands Group annual general meeting, Douglas, Arizona, May, 1999.

Pagano, Thomas. 1999. Climate variability and its impact on Arizona's cattle industry, Southern Arizona Cattle Protective Association meeting, Marana, Arizona, October 1999.

Pagano, Thomas. 1999. Climate variability and its impact on Arizona's cattle industry, Yavapai Cattle Growers Association meeting, Skull Valley, Arizona, November 1999.

Hadley, Diana. 1999. Land use and climate variability in the Upper San Pedro Watershed. Divided Waters-Common Ground, San Pedro River Basin conference, Cananea, Sonora and Bisbee, Arizona, November 8-10, 1999.

Year 2 Progress Report: Integrated Case Studies Team

The Benson integrated case study demonstrated that climate variability in the Middle San Pedro River Valley, once a factor in the success of local livelihoods, has been buffered by a process of technology adoption and social organization. As such, climate vulnerability is felt mostly by the ranching sector and somewhat so by the farming sector. The rest of the population has been able to adapt to climate vulnerability in a way that minimizes its impact on the everyday affairs of life. It is possible, the growth in the valley may reach a point that climate vulnerability re-appears in the form of dwindling water supplies or quality of life issues, but that potential is not perceived by the majority of valley inhabitants at this time.

The extension of this work into its second year has followed two lines of inquiry. The first is to document this process of "buffering" as we have called it. In this regard, we have used the instrumental precipitation record to create a time line of anomalous climate events in the valley and have compared them to points of transition in the social history of the region. Armed with this background, we have identified six candidates for oral history compilation. These key informants are people who for the most part witnessed the major changes in the valley over the last half century and who will help recreate how climate vulnerability diminished through time. We will begin interviewing on October 29 and report on this in December.

The second component of this year's work is to assess a neighboring region where climate vulnerability has not been completely buffered—the Sulphur Spring Valley in Cochise County. The region of farmers and ranchers is in crisis, and their livelihoods are highly vulnerable to extreme climate variations. Here the process of buffering is as yet incomplete, and we wish to use Cochise County to identify the coping strategies of those population with great vulnerability. We have completed a literature review of the region and will begin a rapid assessment activity in Wilcox during the first week of November. We have already contact the Cooperative Extension office and solicited their assistance in identify both issues and key informants.

As anticipated, the product of this year's activity will be a white paper on the dynamics of buffering, comparing the MSPRV and Sulphur Springs Valley cases.

Team members: Tim Finan, Colin West

Year 2 Progress Report: Native American Component

The Year Two Activities in the Native American component of CLIMAS fall into two areas: (1) building collaborative partnerships in Arizona and New Mexico; and (2) providing information to the InterTribal Council of Arizona's project to assess the feasibility of renewable energy sources and associated technologies on tribal lands. Activities in the first area have been very successful, with working relationships with both the NASA-funded Southwest Native Peoples/Native Homelands project funded through the University of New Mexico's Earth Data Analysis Center and the InterTribal Council of Arizona. The team has participated in three meetings since June, developed two research proposals, and received a $20,000 subcontract from UNM to expand the Native Peoples/Native Homelands project into Arizona. University of Arizona faculty have made two trips to New Mexico, and the research team members from New Mexico have met once in Tucson. A quarterly meeting in Phoenix is planned for January 5.

Work is just beginning in the second area, with participation in a meeting of the environmental managers for all the Arizona tribes facilitated by the InterTribal Council of Arizona environmental program staff and assisting with design of a questionnaire for the Arizona tribes. Resources from both NOAA and NASA will be used to complete the climate and socioeconomic aspects of the energy and technology assessment, according to the schedule provided in Table 1. The GIS database being prepared at the Center for Applied Spatial Analysis will be used to compile and analyze the relevant data.

Team members: Diane Austin, Caroline Smith

Outline of University of Arizona Tasks to Support ITCA Renewable Energy Assessment

Task	Due to ITCA
Task 1. Help develop a questionnaire to be sent to tribes by the end of September.	September 28
Task 2. Gather information about renewable energy sources and alternative technologies, including the requirements for using these sources and technologies.	December 15
Task 3. Gather information about the potential for tribal use of the energy sources and technologies, including climate (e.g., days of solar radiation, wind patterns) and perceived need. Create a Geographic Information Systems (GIS) database to analyze the information.	December 15
Task 4. Prepare a presentation of the information for the Arizona tribal environmental managers.	February 1

Year 3 Progress Report: US-Mexico Border Pilot Study 1999

Climate issues and impacts in the Southwest US cannot be easily isolated from those in northern Mexico. During the startup phase of CLIMAS it became evident that neither the physical or human components of the project could be undertaken and fully understood without some consideration of conditions along the border and in northern Mexico. For example, the importance of the North American monsoon and the occasional hurricane, with source regions in or across Mexico, requires our climate analysts to seek Mexican climate data and other information on circulation and surface conditions in northern Mexico.

In the realm of impacts and vulnerability, the ranching study showed that the economic context for ranching is quite sensitive to conditions in Mexico, with drought in northern Mexico sending thousands of cattle at low prices into the highly interconnected livestock markets, and with a routine and long established practice of sending cattle to the US for final fattening and sales of alfalfa and other feed from the US to Mexico. The hydrological and water studies highlight the importance of rivers and aquifers that span the US-Mexico border, ranging from the Colorado and Rio Grande to the San Pedro and Santa Cruz rivers in Southern Arizona. The climate sensitivity and future water demands of cities such as Nogales, Arizona or river basins such as the San Pedro is closely tied to developments in Nogales, Sonora and the Mexican portion of the San Pedro, including the large mining community of Cananea, Sonora. Intense drought in northern Mexico in this decade has also been linked to increased flows of undocumented migrants from Mexico to the US, to disease outbreaks in Mexican border communities, and to degradation and fire damage in regionally significant ecosystems.

It is also clear that some of our stakeholders are managing resources in a transboundary context. For example, there are water managers at Federal (International Boundary Water Commission), State (Arizona Department of Water Resources) and local (Nogales City manager) levels who need information on climate and its impacts in adjacent areas of Mexico. Land resources managers in the San Pedro are very interested in conditions in the Mexican portion of the shared river basin, and other groups, such as ranchers and health managers, have also expressed interest in Mexican conditions. There are a large number of binational environmental organizations and environmental groups that are interested in the ways climate may affect ecosystems that span the border.

In 1999, we began a small initiative within CLIMAS to examine climate vulnerabilities, impacts and potential stakeholder needs in the US-Mexico border region. The initiative built on some previous work by Diana Liverman and colleagues on climate impacts in Mexico and on climate and a 1998 report that she drafted for the North American Commission on Environmental Cooperation (CEC) on climate change and transboundary water resources. The objective of the pilot phase was to bring together information on climate variability and climate impacts along the border, identify research gaps and to begin some discussions with stakeholders. The work was conducted by Diana Liverman with assistance from one graduate assistant in Fall 1999.

Team members: Diana Liverman, Tereza Cavazos, Lydia Breunig

Activities:

1. Review of what is known about climate variability in northern Mexico - collection of published articles and data, especially those published in Spanish and less accessible. Ongoing, now with the help of CLIMAS postodoctoral researcher Tereza Cavazos, an expert in the climate of northern Mexico.

2. Compilation of information on the impacts of climate variability in northern Mexico that so far includes more than 200 news articles, and some time series of crop yields and reservoir levels.

3. Discussions with stakeholders through the mechanism of presentations at workshops and conferences discussing climate and environmental issues on the border and publicizing the CLIMAS project.

4. Writing several overview articles and other publications related to the human dimensions of environmental changes and climate variability in the U.S.-Mexico border region.

Publications

Yetman, D., Liverman, D. and Burquez, A. The drought of the 1950s in Sonora. Chapter in Betancourt, J. The Drought of the 1950s in the Southwest. Forthcoming. (Examines the impacts of the most severe drought in the instrumental record on agriculture and population in Sonora)

Liverman, D.M., R. Varady, O. Chávez, and R. Sánchez, 1999. Environmental issues along the U.S.-Mexico border – drivers of changes and the response of citizens and institutions. Annual Review of Energy and Environment.. Forthcoming. (Overview of major issues and general environmental stakeholders on the US-Mexico border including a brief discussion of climate issues).

Liverman D.M. 1999. Vulnerability and Adaptation to Drought in Mexico. Natural Resources Journal 39(1):99-115. (Article on drought in Mexico that uses the 1990s drought in northern Mexico as a case study).

Liverman D.M. and L. Breunig. 1999. Land use change and climate change in the greater Chihuahuan Desert Ecoregion. Report for the World Wildlife Fund. (This report commissioned by WWF examines environmental change in the Chihuahuan desert and includes a discussion of climate variability and impacts).

Liverman, D.M. and Kourous, G. 1999. Climate Change and the Borderlands. Borderlines 56 7(5) May 1999. (This article, written for a widely distributed monthly newsletter for the US-Mexico border region provides an overview of climate issues, a list of resources - including the CLIMAS core office - and generated several inquiries from stakeholders).

Diana Liverman also co-authored two National Research Council reports in 1999 that set out broad research agendas relevant to CLIMAS:

Liverman, D.M. et al. 1999. Human Dimensions of Global Environmental Change: Research Pathways for the Next Decade. Committee on the Human Dimensions of Global Change and Committee on Global Change Research, National Research Council, National Academy Press, Washington DC. 100 pp.

Stern, P.C., Easterling W.E. et al. 1999. Making Climate Forecasts Matter. Panel on the Human Dimensions of Seasonal-to-Interannual Climate Variability; Committee on the Human Dimensions of Global Change, National Research Council. 192 pp.

Presentations

Second Annual Conference on the US-Mexico Border Environment (Tijuana, April 1999)

IAI Summer Institute on Climate Variability and Human Society (Miami, July 1999)

Universidad Autonoma de Ciudad Juarez, Conference on Climate Change (Ciudad Juarez, September 1999)

Universidad de Sonora, Roundtable discussion on collaborative research (Hermosillo, October 1999)

Chihuahuan Desert Research Symposium (Alpine, Texas, October 1999)

San Pedro-Cananea conference (Cananea, November 1999)

Year 2 Progress Report: Core Office

The Core Office has been concentrating on four key task areas under the Year 2 budget: the CLIMAS web site, stakeholder outreach, project coordination, and network building. The Core Office also continued its participation in conferences and meetings, and engaged in a variety of other activities. Progress in each of these areas is summarized below.

Web Site: A second 0.50 FTE research assistant was added to the Core Office when Kurt Angersbach transferred from the Climate Variability team to the Core Office during the first week of August. Addition of this new staff member has allowed the Core Office to devote more attention to reorganizing the CLIMAS web site and adding more content. The web site now features regionally pertinent climate commentary, as well as links to key operational, experimental, and research forecasts. A PowerPoint presentation of the climate working paper is available on the CLIMAS site, as is the paper itself. Work is currently underway to add the forecast working paper, together with a PowerPoint summary. The working papers for the urban water, Middle San Pedro, and ranching studies will be on the web by early 2000.

Stakeholder Outreach: The on-line survey for the NWS-Tucson Office Convective Outlook web site was reactivated, and analysis of the results is underway. An updated report based on the survey will be available on the CLIMAS web site soon. March and June issues of the *CLIMAS Update* newsletter were mailed to more than 600 people, and were posted on the CLIMAS web site. A combined Fall-Winter issue will be published before the end of 1999.

The CLIMAS core office sponsored a stakeholder workshop on November 22, 1999 to discuss the Winter 1999-2000 forecast, revisit the climate events of the past year in comparison to the forecasts, and discuss climate impacts and information needs with participants. Kelly Redmond was the guest speaker; also giving presentations were Paul Sheppard of the Tree Ring Lab, and Andy Bryant of the NWS Tucson Office.

Together with team member Holly Hartmann, and as part of the ASCE 26th Annual Water Resources Planning and Management Conference (Tempe, Arizona, June 6-9, 1999) the Core Office arranged for a session on CLIMAS research activities, followed by a special focus group to discuss participants' understanding and actual/potential use of three information products: the CPC seasonal climate outlook, a water supply outlook, and a paleo/historical reconstruction of past climate trends. This meeting provided useful information and contacts with individuals in the water resource management and engineering community.

As noted in the Urban Water Study progress report, the Core Office has been active on the Safe-Yield Task Force being sponsored by the Arizona Department of Water Resources. Participation has been very useful for networking with water providers in the area, and most especially in identifying current issues and concerns in which climate is a factor. Such interactions will facilitate anticipated Core Office outreach efforts aimed at disseminating climate information and forecasts to water resource managers and decision makers.

To maintain linkages forged a year ago, Barbara Morehouse continues to serve as a board member for the Arizona Environmental Industry Cluster organization; she assisted in organizing and conducting its September 1999 meeting, which was devoted to water issues in Tucson. Individuals representing the major water utility, a large mine, and the university were guest speakers.

The Core Office held Stakeholder Advisory Committee meetings on January 15 and September 24 to update committee members on research activities, and to encourage input as to what sorts of research/outreach activities they recommend.

Project Coordination: The Core Office spent a considerable amount of time and effort to ensure that the Year 1 working papers were completed, copied, and distributed to all PIs, team members, stakeholder advisory committee members, and others in an efficient and timely manner. An executive summary of the working papers was written by the Program Manager. 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 with guest speakers and/or special themes, to hold PI meetings on a monthly basis. The Core Office continues working to ensure that CLIMAS team members participate in relevant meetings, conferences, and other such events, and that team members maintain open communications with each other and with the Core Office.

Network Building: Through presentations at conferences and meetings, as well as through other formal and informal interactions, the Core Office has been highly successful in building links to individuals in the public, academic and private sectors. Considerable interest has been expressed in the results of research into stakeholders' use of and need for climate information, as well as in the findings emerging from the various research projects currently underway. The Core Office will continue to take advantage of opportunities to build upon existing links and to establish additional connections with entities for exchanging information, experiences, and ideas. Such connections are crucial for leveraging existing resources, and for ensuring that CLIMAS remains embedded in the local and regional contexts, and linked to related activities going on elsewhere.

Barbara Morehouse served on the organizing committee for a conference, Divided Waters, Common Ground, held in Cananea, Sonora and Bisbee, Arizona in November 1999. The conference was initiated by the USDA Agricultural Research Service in Tucson, and was organized by entities associated with the SALSA program. The aim was to bring decision makers and community members together with scientists working in the upper San Pedro River basin in order to disseminate research findings, identify ways to transmit knowledge to local decision makers, and ascertain local information/research needs. Five posters were presented by CLIMAS team members, and a formal presentation on the CLIMAS was given. CLIMAS participants took part in the discussions and breakout sessions. This conference provided an excellent opportunity to begin identifying climate impacts and climate information needs in the transboundary context of the San Pedro watershed, and for establishing recognition of CLIMAS among participants and community members.

The Core Office has been working with Henry Diaz, CDC, on holding a proposed conference next July on "The Impacts of Climatic Variations on Water Resources: A

Focus on Border Regions." The Core Office has also been interacting with Kelly Redmond regarding a proposed stakeholder pilot project whereby a selected group of stakeholders would be regularly provided with climate forecast information for the coming year. This project would be similar to the one conducted with a group of California stakeholders by Claudia Nierenberg and Katie Mastrianni on the recent El Niño winter.

Together with the Udall Center and other campus entities, CLIMAS co-sponsored a visit on October 21-22, by noted scholar David Eaton of the University of Texas-Austin. Barbara Morehouse represented the Core Office at a Border Drought Workshop organized by the US Bureau of Reclamation and held in El Paso, Texas October 11-13, 1999, and at a November 15,1999 meeting organized by the U.S. Departments of Treasury and State on border economic development.

Barbara Morehouse gave a presentation on CLIMAS and participated in a Southwestern climate/stakeholder workshop organized by Kelly Redmond, Andrea Ray, and Dave Gutzler of UNM that was held in Albuquerque on October 15. In August 1999 (Phoenix) and September 1999 (Tucson), she participated in scoping meetings aimed at developing relationships with Native American tribes in the region.

The Core Office gave presentations on CLIMAS at the Climate Diagnostics Workshop, held in Tucson November 1-5, 1999, and at the "Divided Waters-Common Ground" conference on the San Pedro Basin, held in Cananea, Mexico and Bisbee, Arizona November 8-10, 1999. CLIMAS presentations were also given by the Core Office at the PacClim meeting, May 24-27, 1999, and at other meetings, as noted below.

Other Activities:
Gave a presentation on CLIMAS to the InterAmerican Institute, Tucson, Arizona, November 19, 1999.

Hosted Ed Miles, including meeting with CLIMAS team members, February 22, 1999.

Hosted Greg Knight and Marietta Staneva from Penn State, including holding special CLIMAS team meeting, January 29, 1999.

Co-taught (with Stuart Marsh, UA Arid Lands Studies) graduate workshop (GC597) on how to conduct interdisciplinary, integrated research on climate variability and its impacts, January –May, 1999. The final product was a web site featuring an examination of water and climate in the Tucson basin.

Team members: Barbara Morehouse, Petra Tschakert, Kurt Angersbach

Publications
CLIMAS Update Newsletter (quarterly)

First-Year Research Results for the Forecast, Climate, Ranching, Urban Water, and Community Studies (drafts), June 24, 1999.

CLIMAS web site

Presentations

Morehouse, Barbara. Climate Assessment for the Southwest. Presentation at the conference, Divided Waters-Common Grounds, Cananea, Mexico and Bisbee, Arizona, November 8-10, 1999.

Morehouse, Barbara. It's not always sun and gains—Assessing the impacts of climate variability in the Southwest. Paper presented at the Climate Diagnostics Workshop, Tucson, November 1-5, 1999.

Morehouse, Barbara, Roger Bales, and Diana Liverman. Climate Assessment Project for the Southwest. Paper presented at the 26th Annual Water Resources Planning and Management Conference Tempe, Arizona, June 6-9, 1999.

Morehouse, Barbara. Researching climate variability and its impacts in the Southwest. Poster (presented by Holly Hartmann), American Geophysical Union Annual Meeting, Boston, June 1-4, 1999.

Morehouse, Barbara. Climate assessment in the Southwest: The centrality of stakeholders. Paper presented at the Sixteenth Annual PACLIM Workshop, Wrigley Institute for Environmental Studies, Two Harbors, Santa Catalina Island, California, May 24-17, 1999.

Morehouse, Barbara. Panel participant, The National Assessment of Climate Change II: the Assessments. Association of American Geographers Annual Meeting, Honolulu, Hawaii, March 23-27, 1999.

Morehouse, Barbara. Co-organizer (with Andrew Comrie) and chair, illustrated paper session, The National Assessment of Climate Change III: The View from Two Regions. Association of American Geographers Annual Meeting, Honolulu, Hawaii, March 23-27, 1999.

Morehouse, Barbara. Exploring Integrated Climate Assessment in the Southwest. Presentation to Western Water Assessment group, University of Colorado-Boulder, March 5, 1999; also met with members of team writing NOAA climate impacts assessment proposal, March 4, 1999.