

# CLIMAS ANNUAL PROGRESS REPORT 2003-2004

**TASK AREA:** Core Office

**PIs:** Barbara Morehouse, Jonathan Overpeck

**Researchers:** Gregg Garfin (research scientist), Rebecca Carter, Melanie Lenart, Nan Schmidt (postdocs), Joe Abraham, Kristen Reed, Derek Eysenbach, Susan Simpson, Andrew Clark, Sean Downey, Rahul Srivastava (GRAs)

(N.b.- There have been significant changes to Core Office personnel during 2003-2004 (chronicled below). During the transition from Barbara Morehouse to Gregg Garfin as CLIMAS project manager, management and research roles were flexible; consequently, we have included Morehouse's individual research projects interchangeably with her Core Office research for 2003-2004. The CLIMAS Annual Progress Report for 2004-2005 will reflect more well-defined scope of research and duties.)

## I. Progress for Budget Year 2003-2004

### **Project A: END InSight: The CLIMAS El Niño-Drought Initiative.**

A.1. *Project description.* The END InSight initiative aimed to (a) provide information to a selected group of stakeholders regarding the interaction between the existing drought in the Southwest and the forecasted 2002-2003 El Niño, (b) determine the optimal combination(s) of climate information products for understanding unfolding conditions and making decisions, and (c) determine the usability, usefulness, and actual use of the information provided. The initiative began in summer 2002 and extended through July 2003. The capstone activity was a stakeholder/climate information producer workshop held in July 2003. The workshop successfully brought together some of the stakeholders who participated in the year-long research project and selected producers of climate-related products (including NOAA Climate Services Division). The goal was to provide feedback to the producers of climate information and to the CLIMAS research team regarding the project and its informational products, and to foster dialogue among the stakeholders themselves about how they used the information provided to address their particular climate-related issues. In addition to the monthly surveys and final workshop, regular press briefings were held, and relevant articles were collected from major newspapers in the Arizona-New Mexico study area. The news articles have been archived in a Microsoft Access database.

A.2. *Accomplishments to date.* The 2002-2003 CLIMAS annual progress report to NOAA features project accomplishments for the first eight months of the END InSight initiative. The chief accomplishments of the END InSight initiative for 2003-2004 include the following: (1) continued provision of monthly climate information to Southwest stakeholders, including a 2004 extension of the information provision aspect of the project via the Arizona Governor's Drought Task Force (GDTF) with funding leveraged through the U.S. Bureau of Reclamation (see below); (2) continuation of occasional press briefings in conjunction with SAHRA (an NSF Science & Technology Center, housed at the University of Arizona Department of Hydrology and Water Resources) – these briefings are now coordinated by postdoctoral researcher Melanie Lenart; (3) the July

2003 stakeholder/climate information provider workshop; (4) continued research on stakeholder insights for climate services; (5) outlines and draft manuscripts for two papers to be published in peer-reviewed journals (see below); (6) presentations of preliminary results from the END InSight initiative at a variety of professional meetings (see below); (7) preliminary analysis of the news article archive, including number of articles per topical category, temporal trends in the number of articles printed in each of the categories, and a website featuring major headlines; (8) information from the news article archive and climate analyses from the project were contributed to the weekly U.S. Drought Monitor and the monthly NCDC Climate Monitoring United States Drought reports.

*A.3. Accomplishments anticipated by end of Budget Year.* We will continue to provide monthly climate information through the CLIMAS website, as well as the Arizona Governor's Drought Task Force (GDTF). One paper, intended for publication in *Human Organization* is in progress, with the major remaining work involving editorial revisions of some of the text. It is anticipated that this paper will be sent to the journal for review in Spring 2004. The second paper, with considerable contributions by postdoctoral researcher Melanie Lenart and intended for the *Bulletin of the American Meteorological Society*, is still in the initial draft phase. It is anticipated that this paper will be sent to the journal for review in Summer 2004. A formal discourse analysis of the news article archive is in the research design stage; Lenart will take the lead on this activity as resources become available. It is anticipated that a paper will be submitted for publication from this collection of materials in Winter 2004-2005.

*A.4. Plans for 2004-2005.* A follow-up project is currently underway involving development and dissemination of climate information for the Arizona Governor's Drought Task Force (GDTF), which was created by executive order in March 2004 and formed in June 2004. The monthly packet of information sent out under END InSight is being and will continue to be provided in both web-based and PDF format as the CLIMAS Southwest Climate Outlook, published monthly by the CLIMAS Core Office. We will work to complete peer-reviewed and trade journal papers about the project. A formal presentation on aspects of the project related to land and wildlife management stakeholders will be presented to the Ecological Society of America in August 2004. We envision beginning a spinoff project focused on stakeholder information needs and downscaled climate information products at the watershed scale. In conjunction with the University of Arizona Udall Center for Studies in Public Policy, we have applied for state monies, through the Arizona Technology and Research Initiative Fund (TRIF), to fund a pilot project in central Arizona's Verde River watershed.

*A.5. Leveraged funding.* The University of Arizona Institute for the Study of Planet Earth and the U.S. Bureau of Reclamation have provided funding for the continuation of the END InSight initiative, renamed The CLIMAS Southwest Climate Outlook, through December 2004. The latter source of funding is largely due to the efforts of Katharine Jacobs.

*A.6. Leveraged activities:*

A.6.1. Greater than 50% CLIMAS funding. CLIMAS has expanded upon its climate information provision and knowledge transfer initiative (formerly END InSight) by leveraging with a new CLIMAS drought research and outreach initiative. The drought research and outreach activities (described below) are funded, in part, through a successful application for TRIF funding from the University of Arizona for the period June 2003-May 2005 (if second year renewal application is successful).

A.6.2. Intra-CLIMAS Spin-offs. With PI collaborator Andrew Comrie, the CLIMAS Core Office has produced and will continue to produce original drought analyses for Arizona, in conjunction with the GDTF. An initial product from our collaboration is a CLIMAS white paper, *Drought and Climate in Arizona: Top Ten Questions and Answers*, produced for the GDTF and delivered in February 2004. With PI collaborator Dan Osgood, the CLIMAS Core Office has produced drought and climate information and a PowerPoint primer on large-scale climate patterns influencing Arizona precipitation for use in Osgood's presentations to Arizona ranching conservation groups. With PI collaborator Malcolm Hughes, the CLIMAS Core Office produced Arizona Drought Fact Sheets (hardcopy and HTML versions), which provide information on the instrumental and paleoclimate droughts of record for each of the Arizona climate divisions. This information has been widely distributed through the GDTF and at CLIMAS stakeholder meetings. Along with CLIMAS research specialist Holly Hartmann, the Core Office plans to develop a prototype for future climate information provision in conjunction with Hartmann's CLIDIS web information tool.

A.6.3. CLIMAS-related. CLIMAS program manager Gregg Garfin was appointed co-chair of the GDTF Monitoring Technical Committee (see below). Garfin's appointment is directly attributable to recognition of the success of the END InSight initiative. Garfin also serves on the GDTF Executive Committee. With NOAA funding passed through CLIMAS, the Western Regional Climate Center (WRCC) is developing climate analysis web tools for Southwest stakeholders. The CLIMAS Core Office will have significant input into the features incorporated into the WRCC web tools.

*A.7. Non-CLIMAS Project Partners.* Arizona Governor's Drought Task Force; SAHRA (NSF-STC); U.S. Bureau of Reclamation; Arizona Department of Water Resources; University of Arizona Cooperative Extension; NOAA Climate Services Division; National Drought Mitigation Center; USDA-NRCS National Water and Climate Center; Western Regional Climate Center; Arizona State Climatologist.

## **Project B: Drought Research.**

*B.1. Project description.* In summer 2003, with leveraged funding from the Arizona Technology and Research Initiative Fund (TRIF), the CLIMAS Core Office embarked upon a program of drought-related research and educational outreach highly integrated and coordinated with the efforts of the Arizona Governor's Drought Task Force (GDTF). The research, also coordinated with the CLIMAS Southwest Climate Outlook (formerly END InSight; see above) and other CLIMAS outreach activities, examines drought from a variety of physical and social science perspectives. Our drought research activities focus on drought planning, and are designed to inform, augment, and complement Arizona drought planning activities conducted by the GDTF.

The key topics for CLIMAS drought research are as follows: Arizona drought climatology; theoretical framework for and decision-support tool to assist in the long-term monitoring and assessment of drought vulnerability; a comprehensive review of drought mitigation and adaptation strategies, and recommendations of strategies appropriate for Arizona; quantification of the relationship between commonly used drought indices and observed drought impacts (n.b. – oddly enough, this is unexplored territory for drought researchers); examination of the role of drought in human-wildlife conflicts at the wildland-urban interface. The research seeks to identify types and geographical areas of significant drought vulnerability in Arizona, and to examine the potential and strategies for mitigation and adaptations to long-term drought. The research specifies information needed to monitor and assess drought, delineate specific drought-condition indicators to be monitored, and detail the kinds of scientific and forecasting information to be used in drought monitoring and assessment. The research also delineates the hydrometeorological conditions associated with drought impacts across various biophysical and socioeconomic sectors (e.g., agriculture, wildlife, water resources, etc.).

Drought educational materials and outreach, produced in coordination with the GDTF (i.e., CLIMAS Southwest Climate Outlook), synthesizes recent climatological conditions and forecasts and packages them in a manner that is accessible and easy for laypeople and non-experts to understand. An additional aspect of our research focuses on a case study of drought vulnerability assessment at the sub-region or community level. Stakeholders in this research include the GDTF, Arizona Game & Fish Department, Arizona Department of Commerce, Arizona Department of Water Resources, University of Arizona Cooperative Extension, and the residents of cities and towns in north-central and southeastern Arizona, including the San Carlos Apache Tribe.

*B.2. Accomplishments to date.* In collaboration with members of Arizona's multi-agency drought Monitoring Technical Committee (MTC), we have begun analysis of key hydroclimatological variables for monitoring drought and triggering drought response. CLIMAS Core Office researcher Gregg Garfin has devoted considerable effort to coordinating GDTF MTC activities, addressing stakeholders throughout the state, and coordinating the efforts of the MTC and the GDTF Executive Committee to produce drought response triggers. Garfin and CLIMAS PIs Andrew Comrie and Jonathan Overpeck have given presentations (see below) to the GDTF at public and Executive

Committee meetings. CLIMAS Core Office researchers Garfin and Morehouse, along with CLIMAS associate/collaborator and University of Arizona extension specialist Katharine Jacobs, are authors on Arizona Drought Plan chapters (n.b. -- the Arizona Drought Plan is due to be completed by September, 2004).

CLIMAS researchers Joe Abraham and Sean Downey (TRIF leveraged funding) have prepared literature reviews on the subjects of drought vulnerability, mitigation and adaptation; they have also initiated telephone interviews with state drought planners and other decision-makers to assess the "state-of-the-art" of drought vulnerability assessments as part of drought planning, and to determine the success and effectiveness of drought mitigation and adaptation plans as implemented by other states. Researchers Abraham and Downey, along with CLIMAS Core Office researcher Derek Eysenbach, delivered a report entitled "State Drought Plan Summary: A Review of Colorado, Georgia, New Mexico and Montana Drought Plans," to the GDTF in October, 2003. Downey delivered a report entitled "Potential Drought Impacts for Arizona" to the GDTF in January, 2004. Core Office researcher Eysenbach has begun analysis of National and State Park visitation data, as well as hotel-visitation data, to assess impacts of drought in the recreation and tourism sector and establish diagnostic and prognostic links with drought index data. Core Office researcher Susan Simpson has completed a literature review summarizing the state of knowledge about wildlife physiology during drought, and the possible factors that lead to encounters between wildlife in humans in developing areas. Simpson and Eysenbach have collected wildlife population and other ecological data for pending drought impact analyses.

CLIMAS drought researchers have established a project model for conducting research, and meet biweekly to discuss progress, coordination with the GDTF, potential synergy in research efforts, and conceptual issues regarding drought and drought impacts, in conjunction with CLIMAS associate/collaborator Katharine Jacobs. Jacobs, Morehouse, Garfin are co-authoring a paper for *Water Resources Impact*, entitled "Climate Science and Drought Planning: The Arizona Experience," which will be submitted March 1, 2004. Garfin is a member of the integrated team for the Western Governors' Association National Integrated Drought Information System (NIDIS), and has participated in NIDIS meetings and teleconferences, as well as writing text for the NIDIS report, during 2003-2004.

*B.3. Accomplishments anticipated by end of Budget Year.* We will continue our integrated drought research and work on short-term white paper deliverables to the GDTF in close coordination with the GDTF calendar for developing a State Drought plan for Arizona. By the end of the budget year on June 1, we expect to deliver the following white papers: "A Primer on Conducting Vulnerability Assessments for State Drought Planning," "Effective Mitigation and Adaptation Strategies for Arizona," and "A User-friendly Guide to Accessing and Using Drought Information and Forecasts." Several of our drought research team members will be presenting preliminary results of their research at the 100th Annual Meeting of the Association of American Geographers (March 14-19); researcher Garfin has organized two sessions entitled "Drought, Water Supply, Fire: How Does Place-Based Science Serve Society?" at the aforementioned

meeting. (N.b. -- session participants include members of the Western Water Assessment RISA, the Carolinas RISA, as well as CLIMAS file research collaborator Tim Brown [CEFA, Desert Research Institute]). CLIMAS drought researchers have been invited to give presentations on drought climatology, vulnerability, and drought monitoring at the annual meeting of the Arizona Water and Pollution Control Association (May 5-7). The CLIMAS Core Office will continue to co-chair the GDTF MTC, and will address various stakeholders throughout the state on issues of drought climatology, climate forecasting, and drought-society impacts, including an invitation to brief the Governing Board of the Central Arizona Project (April 2, 2004) on long-term climate variability, the state of climate forecasting, and potential impacts of climate change on Arizona and the Colorado River Basin. By May, we expect to complete a new Southwest reservoir level, SWSI, and streamflow forecast web product, produced in collaboration with USDA-NRCS.

*B.4. Plans for 2004-2005.* We will continue our hydroclimatological analyses, provision of drought information for Arizona stakeholders, examinations of drought sensitivities and vulnerabilities to drought in Arizona, research into refinements in drought planning and implementation, as well as development of drought monitoring methodologies. We plan to continue our work in close coordination with the GDTF. The CLIMAS Core Office will continue to co-chair the GDTF MTC and work with MTC members to do the following: create and maintain a monthly Drought Monitor and drought decision-support tools for Arizona; create a system of drought mitigation and response triggers (deliverable September 2004); develop methodology to incorporate sporadic and/or qualitative data into state drought monitoring; author a peer-reviewed paper on the Arizona Drought Monitor and drought triggers. The aforementioned activities will be well integrated with the Western Governors' Association plans for a National Integrated Drought Information System.

As part of this project, we will investigate several examples of drought impacts, one from each of the GDTF subcommittee areas -- Commerce, Recreation and Tourism; Irrigated Agriculture; Municipal and Industrial Water Supply; Wildlife, Watersheds, Ranching. In each, we will focus on the combinations of social, political, economic and geographic, factors for which a lack of precipitation will exacerbate the situation sufficiently to generate adverse impacts for society. In doing so, we will focus on specific regions and communities. Particular impacts will suggest which regions of the state on which to focus. We plan to work closely with research collaborator Sharon Megdal (University of Arizona Water Resources Research Center) regarding the selection of particular communities to study. We expect to hold at least one workshop in a focus community in order to conduct interviews with stakeholders and garner first-hand information on the specifics of multidimensional drought vulnerabilities. The aforementioned activity will be coordinated with plans for a CLIMAS team-wide integrated research activity (see below).

We plan to synthesize our combined findings through white papers and in conjunction with an edited volume on the subject of drought (in conjunction with CLIMAS PI Andrew Comrie). We will also focus on refining analyses performed during Year 1, placing a strong emphasis on the generation of primers for the GDTF, peer-reviewed and trade journal publications; we will focus much of this effort on detailing key findings

regarding vulnerabilities to drought, and providing recommendations on mitigation of and adaptation to drought. We will perform the aforementioned activities in close coordination with the GDTF, personnel of the National Drought Mitigation Center, and members of the Western Governors' Association National Integrated Drought Information System integrated team.

B.5. *Leveraged funding.* The aforementioned activities are highly leveraged with funds obtained from an Arizona Technology and Research Initiative Fund (TRIF) Grant for 2003-2005 (\$99,080 total). Funding from the U.S. Bureau of Reclamation is being used to develop the Arizona water supply interactive web tool, in conjunction with USDA-NRCS.

B.6. *Leveraged activities:*

B.6.2. Intra-CLIMAS Spin-offs. CLIMAS drought research is coordinated with research on natural hazards planning and mitigation efforts in regional planning conducted by CLIMAS PI Barbara Morehouse and a graduate researcher. Drought research activities are well-coordinated with other CLIMAS research and outreach activities, including the CLIMAS Southwest Climate Outlook.

B.6.3. CLIMAS-related. CLIMAS drought researchers and other CLIMAS team members continue to contribute to the weekly U.S. Drought Monitor. The development of closer ties with Arizona and New Mexico National Weather Service forecast offices has led to the development of a CLIMAS-NWS monthly climate/drought briefing (see below), initiated by CLIMAS graduate researchers David Brown and Mike Crimmins, in coordination with the Core Office.

B.7. *Non-CLIMAS Project Partners.* Arizona Governor's Drought Task Force; U.S. Bureau of Reclamation; Arizona Department of Water Resources; Cochise County Cooperative Extension; Gila County Cooperative Extension; Yavapai County Cooperative Extension; National Drought Mitigation Center; National Weather Service Phoenix forecast office; USDA-NRCS Arizona; Arizona State Climatologist; U.S. Geological Survey, Tucson; Salt River Project; Arizona Department of Emergency Management; University of Arizona Water Resources Research Center.

## **Project C: Fire-Climate Research and Decision Support.**

*C.1. Project description.* The CLIMAS Core Office remains active in fire-climate research and outreach. During the past year, the Core Office devoted significant effort to collaborating with partners at the National Interagency Coordination Center (NICC) Predictive Services unit and the Program for Climate, Ecosystems and Fire Applications (CEFA) at the Desert Research Institute. For the second year in a row, CLIMAS, NICC, and CEFA worked closely during the Fall of 2003 and winter of 2004 to marshal resources, garner institutional support, lobby potential participants, and design a fluid and productive workshop process for the 2004 National Seasonal Assessment Workshops (NSAW). The workshops are designed to produce climate-informed regional- and national-scale seasonal fire potential outlooks for the 2004 fire seasons, for each of the Geographic Area Coordination Centers (GACCs) in the United States.

For 2004, two NSAW workshops will be held, one for the eastern and southern United States, and one for the western United States and Alaska. The Eastern & Southern states workshop was developed in response to stakeholder needs to address differences in the seasonality of fire in the eastern half of the country, and to address differences in the composition of land ownership and fire management in the eastern half of the country. In addition CLIMAS, NICC, and CEFA are coordinating to provide education (in the form of workshops) and outreach to GACC personnel on the subjects of long-term climate variability and monthly-seasonal climate forecasts. CLIMAS has taken a lead role in garnering participation from NOAA's Climate Services Division, NOAA-CPC, and IRI in a planned Fall 2004 monthly-seasonal climate forecast workshop for the GACCs. CLIMAS research specialist Holly Hartmann will also participate in the forecast workshop activity.

*C.2. Accomplishments to date.* The 2004 National Seasonal Assessment Workshop (NSAW): Eastern & Southern States meeting was held, January 27-29, 2004. The process was a significant success: participants from each of the two GACCs worked together successfully to produce outlooks for their region, had opportunities to reconcile boundary discrepancies between regions, and to share assessment and forecast techniques and insights. Another key success from the Eastern & Southern States meeting was the participation of state fuels and fire management officials, participation by representatives of the NOAA Regional Climate Centers (RCCs), participation by the Southeast Consortium RISA, a significant investment of time by NOAA-CPC climate forecaster Russell Martin for face-to-face interaction with the GACCs (in response to requests from GACC stakeholders from a 2003 NSAW workshop), and the identification of new research needs particular to fire-climate characteristics in the eastern region. NICC Predictive Services developed a preliminary national fire season outlook map from the eastern and southern Geographic Area assessments.

The CLIMAS Core Office produced proceedings and a one-page fact sheet from the 2004 NSAW: Eastern & Southern States meeting within one week of the meeting. The aforementioned was especially important in order to inform state fire management officials about the outlooks, so they could synchronize their knowledge with media requests stemming from a NICC press briefing one week after the meeting. The 2004

NSAW: Western States & Alaska meeting is set for March 30-April 2, 2004 in Phoenix, Arizona. CLIMAS Core Office researcher Gregg Garfin, in coordination with NICC, CEFA, and CLIMAS co-authors presented a paper on NSAW innovations at the AMS Forests and Fire Meteorology Symposium in November 2003; CLIMAS collaborator Tim Brown (CEFA) and co-author Garfin presented NSAW material at the 84th Annual Meeting of the American Meteorological Society in January 2004.

*C.3. Accomplishments anticipated by end of Budget Year.* We will hold the 2004 NSAW: Western States & Alaska meeting at the end of March 2004. We plan to produce a one-page fact sheet and proceedings from that meeting within one week of the meeting. By the end of the budget year, Core Office researcher Garfin and CLIMAS research specialist Hartmann plan to submit a paper on CLIMAS fire-climate workshop climate forecast evaluation tool enhancements to *Fire Management Today*, a trade journal for fire managers. Garfin, along with NICC and CEFA co-authors plan to submit a manuscript on the NSAW experience to the *Journal of Wildland Fire*.

*C.4. Plans for 2004-2005.* We plan to put considerable effort into securing additional funding for and participation in the Fall 2004 GACC Monthly-Seasonal Climate Forecast Training Workshop. CLIMAS Core Office activities will be closely coordinated with our partners, NICC and CEFA, as well as with the NOAA Climate Services Division, NOAA-CPC, and the International Research Institute for Climate Prediction. We plan to continue our involvement in planning and conducting the pre-season National Seasonal Assessment Workshops, in conjunction with NICC Predictive Services and CEFA. We plan to work toward (1) achieving incremental improvements in the NSAW process and products, and (2) transitioning this activity to NICC, CEFA, and the forecast agencies by securing higher levels of commitment from the forecast agencies, working to establish better relationships between NICC and the forecast agencies, and involving officials from higher levels in the forecast agencies in the process.

Goals for the 2005 NSAWs, include the following: (1) obtain increased commitment by forecast agencies and NOAA Climate Services; (2) improve fuels assessment activities by increasing the involvement of state land management participants, especially in the eastern and southern states; (3) improve communication between the GACCs, RISAs, and RCCs. In addition, we expect to work with NICC Predictive Services and CEFA on introducing post-season assessment and previous year's outlook verification activities to the workshops. Finally, pending a 2005 Joint Fire Sciences Program RFP, the CLIMAS Core Office plans to collaborate with CEFA on a proposal for an experimental RISA-like integrated assessment demonstration project for the fire research and operations community – which sorely lacks integration in their research and assessment activities.

*C.5. Leveraged funding.* NICC and NOAA-OGP have provided additional funding for the NSAW workshops.

*C.6. Leveraged activities:*

C.6.2. Intra-CLIMAS Spin-offs. The CLIMAS Core Office plans to coordinate with CLIMAS PI Thomas Swetnam on future fire-climate workshop and research activities.

C.6.3. CLIMAS-related.

C.6.3.a. WALTER/FCS-1 GIS Model. PI: Barbara Morehouse; co-investigators Jonathan Overpeck, Barron Orr, Gary Christopherson, Thomas Swetnam and Stephen Yool. Also participating, through the climate contributions of graduate student Michael Crimmins, is Andrew Comrie. The EPA STAR-funded Fire-Climate-Society GIS model, being built under the auspices of the University of Arizona's Wildfire Alternatives (WALTER) initiative has proceeded to the user-evaluation phase. Four evaluation meetings were held, one in each of the study sites (Catalina-Rincones, Huachucas, Chiricahuas, and Jemez Mountains). Results of these meetings are providing insights into how the model can be refined before formal release on the web. This project is a spinoff of the CLIMAS fire-climate meetings. A presentation of the model was made for the CLIMAS team in January 2003. The project received a six-month no-cost extension, until July 31, 2004. At that time, the model will be available to the public on the WALTER web site (<http://walter.arizona.edu>).

C.6.3.b. Decision Calendar for Fire Management. PIs: Anthony Westerling, Barbara Morehouse. This project represents an effort to work on inter-RISA research activities. Westerling and Morehouse have interviewed staff at the National Interagency Fire Center and, with graduate student Tom Corringham, have administered a survey on climate information use and decision calendar timing to selected individuals involved in fire management in the Southwest and California. A literature review has been conducted; it is anticipated that the results of the research will be sent out for review in a peer-reviewed publication in summer 2004.

C.6.3.c. Partnerships in Fire-Climate Information Development. PIs: Timothy Brown, Barbara Morehouse. Brown and Morehouse are currently working on a research project to evaluate the extent to which CANSAC, an initiative that Brown is heading up in collaboration with partners in California, qualifies as a partnership. We consider this project to be important because, although the term "partnership" is commonly used in RISA discourse, the implications of the term tend not to be deeply examined. A literature review of the papers on partnerships is completed, and a brief survey is being designed for administration to the collaborating members of CANSAC. The intent is to evaluate the extent to which the members of CANSAC believe they currently have a true partnership, and to identify what the most desirable future design of the collaboration might be, whether a partnership or something less formal. It is anticipated that the survey will be administered in spring 2004, and the results will be written up for peer-reviewed publication in summer 2004.

## **Project D: Water Resources Research**

*D.1 Project description.* “Assessment of Climate Vulnerability of Water Resources in Flagstaff, Arizona” is another installment in the ongoing CLIMAS work on climate and water resource management in the Southwest. The research was the master’s thesis project of CLIMAS graduate research assistant Kristen Reed; Morehouse was Reed’s primary advisor and Diana Liverman served on her committee. The project investigated the nature and extent of climate impacts on water supplies in Flagstaff over the past several decades, and the nature and extent of impacts of the current drought on the city’s water resource management efforts.

The Upper San Pedro River Transboundary Climate Impacts Research project is a collaboration between Core Office PI Barbara Morehouse, CLIMAS PI Margaret Wilder, Core Office postdoctoral researcher Melanie Lenart, UA Udall Center researchers Robert Varady and Anne Browning, and U.S. Department of Agriculture hydrologist David Goodrich. This project seeks to assist residents of the Upper San Pedro River Basin, particularly those in Mexico, in understanding the links between climate and water resources in the basin and in accessing and using climate information. The project, which is an outgrowth of work initiated under funding from the Dialogue on Water and Climate (DWC – a Netherlands initiative) is now operating under funding from NOAA. A survey conducted under DWC auspices provides basic information about residents’ use of climate information, water utilization patterns, and concern regarding water resource issues. Workshops were held to provide basic climate and hydrologic information.

*D.2. Accomplishments to date.* The Flagstaff research and Kristen Reed’s M.S. thesis is complete. Under the NOAA funding, the Upper San Pedro River Transboundary Climate Impacts Research work is continuing with regard to education about – and dissemination of – specifically transboundary climate information and forecasts. The CLIMAS researchers designated above are participating in compilation of a database of socioeconomic factors and research is being conducted on the implications of an institutional shift in Mexico toward governance at the watershed level. Understanding this new trend is essential to understanding where and how climate information might best be introduced into decision making processes. Other participation in the effort includes working with Mexican counterparts to identify the climate products that can best be assembled into a format useful to basin residents, and assisting with the educational process of teaching people how to properly interpret and use the information provided.

*D.3. Accomplishments anticipated by end of Budget Year.* It is anticipated that a CLIMAS white paper report (currently undergoing graphic design and reformatting) and possibly a peer-reviewed publication will be published from the Flagstaff research. The San Pedro socioeconomic factors database project, and a Sonoran Desert region climate information collection effort are expected to be completed by the end of the budget year.

*D.5. Leveraged funding.* The DWG research is a highly leveraged activity. DWG funding (~\$400,000) fuels the main thrusts of the project, including partial salary for Morehouse and Lenart.

D.6. *Leveraged activities.* (see the Upper San Pedro River Transboundary Climate Impacts Research project above).

D.7. *Non-CLIMAS Project Partners.*

University of Arizona's Udall Center for Public Policy Studies; Upper San Pedro Partnership; Departamento de Investigaciones Cientificas y Tecnologicas de la Universidad de Sonora (University of Sonora Department of Scientific Research and Technology); and Instituto de Medio Ambiente y Desarrollo Sostenible del Estado de Sonora (the Institute of Environment and Sustainable Development of Sonora).

## **Project E: Coordination with University of Arizona Cooperative Extension**

*E.1. Project description.* During 2003-2004, the CLIMAS Core Office put considerable effort into establishing a working relationship for research and operations activities with University of Arizona Cooperative Extension, as well as New Mexico State Cooperative Extension. Both of these agencies were participants in the END InSight initiative. Cooperative Extension has been a key stakeholder and partner in CLIMAS' vulnerability, ranching, and economic decision research. As the ongoing drought (1996-present) has progressed, Arizona and New Mexico's rural communities have been most severely impacted. As a result, cooperative extension agents and extension specialists, as well as rural stakeholders, have requested more information on long-term climate processes, how they affect Arizona, and the reliability of climate and drought forecasts. Moreover, extension stakeholders increasingly require decision-support information at finer spatial scales, and analyses that quantify economic ramifications of climate variability on rural communities.

*E.2. Accomplishments to date.* In May 2003, CLIMAS and University of Arizona Cooperative Extension co-organized a highly successful workshop to assess cooperative extension agents' and specialists' needs for climate information and products. The CLIMAS Core Office and CLIMAS PI Dan Osgood were involved at all stages of planning. The workshop brought together extension personnel with CLIMAS investigators and partner organizations, including U.S. Geological Survey, the Natural Resources Conservation Service, the Arizona State Climatologist, and the National Weather Service.

The workshop raised CLIMAS visibility within the cooperative extension organization, with several positive outcomes, as follows: (1) CLIMAS PIs and UA Cooperative Extension have held a series of meetings to develop a cooperative research proposal to initiate a county-level pilot project to disseminate climate information through newsletters and workshops in rural communities and to develop better decision support tools for ranching stakeholders; (2) UA Cooperative Extension agent Chris Jones (Gila County) secured funding to hold a year-long series of meetings, called the "Climate and Vegetation Change Think Tank," to address issues of abrupt vegetation change due to drought, fire, and insect infestation – the CLIMAS Core Office, along with CLIMAS PI Andrew Comrie, have been instrumental in securing the participation of key climate and ecological experts to produce a white paper on evidence for the role of long-term climate variability and change in recent vegetation changes in the Southwest, and, along with UA Cooperative Extension agents, to identify changes in management practices necessary to address landscape-scale change in the Southwest; (3) requests for CLIMAS attendance and participation at UA Cooperative Extension workshops have increased; (4) CLIMAS was invited to participate in the creation of a climate and drought curriculum for UA Cooperative Extension's Master Watershed Steward program. We also plan to formalize UA Cooperative Extension participation in CLIMAS Core Office weekly contributions to the U.S. Drought Monitor.

*E.3. Accomplishments anticipated by end of Budget Year.* We plan to continue our work with the "Climate and Vegetation Change Think Tank," and on a collaborative proposal

with UA Cooperative Extension to produce innovative research and outreach to rural communities (n.b. – the latter activity will resume with the participation of a new PI in the CLIMAS Economic Decision project [beginning spring 2004], the participation of research specialist Dave McGinnis [beginning March, 2004], and the new UA Climate Extension Specialist [beginning summer 2004]). CLIMAS PIs Bonnie Colby and Andrew Comrie have been integral participants in this process.

E.4. *Plans for 2004-2005.* The CLIMAS Core Office plans to work closely with UA Cooperative Extension on a collaborative research and outreach proposal; further, we plan to coordinate with NM Cooperative Extension on a similar partnership activity. We expect to submit a proposal to the U.S. Department of Agriculture Risk Management Agency's next RFP. We will continue to work closely with extension agents throughout the state on refining our climate knowledge transfer activities. Pending acceptance of a grant proposal to provide watershed-scale climate information to Verde River Valley stakeholders, we will coordinate with extension agents in Yavapai and Gila Counties on identifying stakeholder needs and analyzing knowledge transfer preferences through a study of the use and usability of information that we propose to provide. The aforementioned activities will be coordinated with ongoing research by the CLIMAS Vulnerability team, and with our plans for a team-wide integrated assessment of communities in the Upper Little Colorado River Basin.

E.5. *Leveraged funding.* CLIMAS Core Office participation in the Climate and Vegetation Change Think Tank is leveraged off of UA Cooperative Extension funds.

E.6. *Leveraged activities:*

E.6.2. Intra-CLIMAS Spin-offs. Future work with UA Cooperative Extension will be coordinated with plans for a team-wide integrated assessment of communities in the Upper Little Colorado River Basin (see below). Climate information provision through UA Cooperative Extension will be done in conjunction with CLIMAS research specialist Holly Hartmann's CLIDIS web information tool.

E.7. *Non-CLIMAS Project Partners.* University of Arizona Cooperative Extension; New Mexico State Cooperative Extension.

## **Project F: Project Management.**

*F.1. Project description.* The Core Office continues to coordinate the project. We continue to hold bi-weekly team meetings and to publish the quarterly CLIMAS Update newsletter (now edited by Melanie Lenart), which is mailed to approximately 1,200 stakeholders in the U.S. and Mexico, including state and federal legislators in Arizona and New Mexico. The Core Office coordinates much of the stakeholder outreach and education activities, and maintains the CLIMAS web site and databases. Important changes occurred in Core Office staffing during the 2003-2004 budget year. Barbara Morehouse assumed the position of Deputy Director of ISPE, and shifted to having responsibility only for a small CLIMAS-funded project that ties in with the Core Office's drought research. Gregg Garfin assumed responsibilities of project manager. Postdoctoral researcher Rebecca Carter resigned to pursue a job opportunity with the Sonoran Institute, a non-governmental environmental organization. She was replaced by Melanie Lenart. A second research scientist, David McGinnis, has been hired and is scheduled to begin working for CLIMAS in March 2004. McGinnis fills the spot left open by Gregg Garfin's promotion.

*F.2. Accomplishments to date.* The CLIMAS Core Office instituted a highly successful new project management tool, a once-per-semester half-day team-wide mini-retreat. The Core Office held mini-retreats in November 2003 and February 2004. The mini-retreats serve to orient new team members to the project, update team members on progress in the various team research various, and, perhaps most importantly, facilitate and enhance team-wide dialogue on team integration and cutting-edge integrated assessment methodology.

An important outcome of the mini-retreats is the development of a team-wide integrated assessment of water-related physical and social science issues in the Upper Little Colorado River Basin in central Arizona and western New Mexico. The region is characterized by rapid population growth, dependence on traditional rain-fed livelihoods, such as ranching, increasing dependence on climate-sensitive tourism and recreation livelihoods, and conflict over water and resources. In recent years, rural and tribal communities in the mountainous rim country of central and eastern Arizona have been buffeted by drought, fire, and widespread drought-driven forest dieback; moreover, urban expansion and extensive second-home development have taxed water supplies and threatened traditional ranching and forest products extraction livelihoods.

Building upon its previous integrated assessment activities in Arizona, the entire CLIMAS team will focus intensively on this specific region, viewing its climate-related challenges from many disciplinary angles in order to demonstrate a new model of integrated research and climate services that meet the needs of decisionmakers. CLIMAS team members will examine hydroclimatology, ecological and environmental change, and societal vulnerability to hydroclimatic variability and long-term climate changes. CLIMAS vulnerability assessment and economic decision project members have taken the lead on this research project, in conjunction with all aspects of the project and (literally) all members of the CLIMAS team; the Core Office will coordinate team members on project logistics, integration, and in the process of co-authoring leveraged

grant proposals. Preliminary contact with stakeholders in the region is scheduled to begin summer 2004.

Work on the CLIMAS web site continues, and substantial new content was added to the site. Among the additions were pages on our Urban Water, Snow Cover Mapping, and Paleoclimate Reconstruction projects. The Core Office, in coordination with CLIMAS graduate researchers David Brown and Mike Crimmins (who have developed close ties with the NOAA Climate Services Division), is spearheading an effort to create a CLIMAS-NWS monthly climate/drought briefing. The briefings are intended to (1) provide region-specific value-added information to supplement official NOAA-CPC climate outlooks, (2) foster better communication and coordination between CLIMAS, NWS, UA, and USGS scientists, (3) provide coordination on press briefings. CLIMAS has made initial contact with the NWS Tucson forecast office.

*F.3. Accomplishments anticipated by end of Budget Year.* We plan to complete work on several new research and product web pages, in addition to developing a new set of pages that serve as a primer on Southwest climate. Core Office postdoctoral researcher Melanie Lenart will complete work on a trade-journal article on CLIMAS ranching research results, and on an accompanying research web page. We plan to hold the first of our CLIMAS-NWS monthly climate briefings in April, 2004. The Core Office will also continue to collaborate with other team members on research and outreach activities, to organize team meetings and other meetings and workshops as needed, and to monitor the project budget.

*F.4. Plans for 2004-2005.* We plan to spend much effort in the following areas: (1) coordinating the team-wide project in the Upper Little Colorado River Basin, (2) developing a collaborative research proposal with Arizona Cooperative Extension, (3) continuing provision of drought and climate information to stakeholders (Southwest Climate Outlook), in partnership with NWS and other agencies, (4) continuing our drought research activities, including our work with the GDTF MTC, (5) developing new fire-climate research and outreach activities with partners from NICC and CEFA, (6) . examining societal aspects of impacts of the massive forest dieback in the Upper Little Colorado River Basin, as part of the team-wide project (Lenart), (7) analyzing use and usability of CLIMAS climate information products (including CLIDIS, and tools developed by the WRCC) in anticipation of establishing procedures for the NIDIS. If our CLIMAS-NWS Tucson climate briefings are successful, then we will work with NWS Phoenix and NWS Flagstaff to expand our activities. The Core Office will also continue to collaborate with other team members on research and outreach activities, to organize team meetings and other meetings and workshops as needed, and to monitor the project budget.

**Project G: RISA and NOAA-OGP Coordination.**

G.1. *Project description.* The Core Office remains the focal point for sustaining interactions with other RISAs and with OGP and the RISA program. The Core Office participates regularly in RISA conference calls and meetings, and assures that CLIMAS is represented in important RISA-related conferences and symposia. The Core Office also responds regularly to requests by NOAA-OGP and the RISA program office for information and materials.

G.2. *Accomplishments to date.* The Core Office coordinated CLIMAS representation at the CPAS workshop, as well as the Texas and the Alaska RISA scoping meetings. Barbara Morehouse joined the advisory committee of the Human Dimensions of Arctic Change (HARC) project, at the invitation of the leaders of the project. In meetings held in Arlington, Virginia in spring 2003 and in Seattle, Washington in fall 2003, as well as in several conference calls, Morehouse shared insights and experiences from CLIMAS and provided guidance on how HARC might achieve greater integration across disciplines and with stakeholders. In addition, Morehouse participated on the program review panel for the Center for Environmental and Fire Applications (CEFA) at the Desert Research Institute in Reno, Nevada. The review occurred May 7-8, 2003.

G.4. *Plans for 2004-2005.* The CLIMAS Core Office plans to develop proposals for inter-RISA research. Promising projects include (1) working with the WWA on downscaled climate forecast products for the Southwest, including improvements to their seasonal Southwest forecast, (2) working with the WWA on integrated assessment research in the Upper Rio Grande valley, (3) working, in conjunction with CEFA, on a CEFA-CLIMAS-CAP integrated assessment of post-fire management processes and climate information needs. The Core Office also plans to develop ties between CLIMAS Native American research and outreach activities and ongoing plans for NOAA-OGP to develop an Alaska RISA.

## **Project H: Natural Hazards Planning (Drought Task Force-Related)**

H.1. *Description.* As part of CLIMAS' involvement in the Arizona Drought Task Force activities, Rahul Srivastava, a graduate student in the UA Planning Department is being funded to examine county planning documents to determine (a) the extent to which they address risk from natural hazards (b) the extent to which they explicitly address drought risk, and (c) what recommendations might be made for revisions to the plans to assure that climatic risks are properly addressed. The student will be producing a master's thesis from this research, which will in turn provide the foundation for reporting, via CLIMAS, to the Governor's Drought Task Force.

H.2. *Accomplishments to date.* With PI Barbara Morehouse's guidance, Srivastava has collected: basic socioeconomic information for each county to provide contextual background; background literature, compiled into a review, on planning at the county level and on drought planning relevant to county-level planning; a preliminary list of individuals to interview regarding planning activities and documents for their county. Using these, he has prepared a draft thesis proposal.

H.3. *Accomplishments anticipated by the end of the Budget Year.* By June 1, we anticipate having completed the interviews with county officials and a draft of the master's thesis will be well underway. We also anticipate having preliminary recommendations for incorporating climate – particularly drought – into county planning documents.

H.4. *Plans for 2004.* We anticipate that this project will be completed by summer 2004.

H.5. *Leveraged funding.* This research is part of the broader leveraged project to assist Arizona in developing a cutting-edge drought planning process.

H.7. *Non-CLIMAS Project Partners.* There are no non-CLIMAS partners on this project, but the primary outside person in this endeavor is the head of the student's master's thesis committee in the Planning Department, Lucie Laurien.

## II. Publications

### In print

Carter, R.H., Morehouse, B.J., 2003. Climate and urban water providers in Arizona: an analysis of vulnerability perceptions and climate information use. CLIMAS Report Series No. CL1-03. Institute for the Study of Planet Earth, University of Arizona, Tucson, Arizona, 42 pp.

Diaz, H.F., Morehouse, B.J., (Eds.), 2003. Climate and Water: Transboundary Challenges in the Americas. Kluwer Academic Publishers, Dordrecht, 402 pp.

Diaz, H.F., Morehouse, B.J., (Eds.), 2003. Climate and water in transboundary contexts: an introduction. In H.F. Diaz and B.J. Morehouse (Eds.), Climate and Water: Transboundary Challenges in the Americas. Kluwer Academic Publishers, Dordrecht, pp. 3-24.

Gamble, J.L., Furlow, J., Snover, A.K., Hamlet, A.F., Morehouse, B.J., Hartmann, H., Pagano, T., 2003. Assessing the impact of climate variability and change on regional water resources: the implications for stakeholders. In R. Lawford et al. (Eds.), Water, Science, Policy, and Management. Water Resources Monograph 16. American Geophysical Union, Washington, D.C., pp. 341-368.

Garfin, G.M., Wordell, T., Brown, T., Ochoa, R., Morehouse, B., 2003. National Seasonal Assessment Workshop, February 25-28, 2003, Mesa, Arizona. Final report. CLIMAS/ISPE, Tucson, 24 pp.

Garfin, G.M., Brown, T., Ochoa, R., Hockenberry, H., 2004. National Seasonal Assessment Workshop: Eastern and Southern States Meeting, Shepherdstown, WV, January 27-29, 2004. Final report. CLIMAS/ISPE, Tucson, 18 pp.

Jacobs, K., and R. Pulwarty, 2003. Water Resource Management: Science, Planning and Decision-Making. In Science and Water Resource Issues: Challenges and Opportunities, American Geophysical Union Monograph.

Jacobs, K., 2003. Planning Climate and Global Change Research: A Review of the Draft U.S. Climate Change Science Program Strategic Plan. Committee report, National Research Council, National Academy Press.

Jacobs, K., and S. Luoma and K. Taylor, 2003. CALFED: An experiment in Science and Decision-making. Environment 45: 30-41.

Morehouse, B.J. 2003. Boundaries in climate-water discourse. In H.F. Diaz and B.J. Morehouse (Eds.), Climate and Water: Transboundary Challenges in the Americas. Kluwer Academic Publishers, Dordrecht, pp. 25-40.

Varady, R.G., Morehouse, B.J., 2003. Moving borders from the periphery to the center: river basins, political boundaries, and water management policy. In R. Lawford et al. (Eds.), *Water, Science, Policy, and Management*. Water Resources Monograph 16. American Geophysical Union, Washington, D.C., pp. 143-159.

#### Submitted/In Review

Bales, R.C., Liverman, D.M., Morehouse, B.J. (Accepted; in revision). Reducing climate vulnerability through integrated assessment in the southwestern United States. *Bulletin of the American Meteorological Association*.

Browning-Aiken, A., Morehouse, B., Davis, A., Wilder, M., Varady, R., Merideth, R., Goodrich, D., Carter, R., Moreno, D., Dellinger, E., Delgado, F., Rodriguez, A., Villasenor, F., Cons, M. (Submitted). Climate, water management, and policy in the San Pedro Basin: Results of a survey of Mexican stakeholders near the US-Mexico border. Submitted to *Climatic Change*.

Jacobs, K., and J. Holway (in press). Managing for Sustainability in an Arid Climate: Lessons Learned From 20 Years of Groundwater Management in Arizona, USA. *Hydrogeology Journal*.

Lemos, M.C. and B.J. Morehouse. (Submitted; revisions requested; revisions in progress). The co-production of science and policy in integrated climate assessments. Submitted to *Global Environmental Change*.

#### To be submitted by June 1, 2004.

Carter, R., Morehouse, B., Garfin, G., Schmidt, N., Abraham, J., Reed, K. Transmitting complex scientific information to stakeholders: END InSight. To be submitted to *Human Organization*.

Lenart, M., Garfin, G., Schmidt, N., Abraham, J., Carter, R., Morehouse, B., Reed, K. Making Climate Products Matter: the CLIMAS El Nino-Drought Initiative. To be submitted to *Bulletin of the American Meteorological Society*.

Garfin, G., Wordell, T., Brown, T., Ochoa, R., Morehouse, B. The National Seasonal Assessment Workshops, an innovative approach to climate knowledge transfer for improved fire management. To be submitted to *Journal of Wildland Fire*.

Garfin, G., Hartmann, H. Partnerships in fire management knowledge transfer. *Fire Management Today*.

### **III. Presentations at Professional Meetings/Conferences**

Abraham, J., Garfin, G., 2003. U.S. Drought Monitor Comments from Southwest Stakeholders. Presentation to the US Drought Monitor Workshop, Cedar City, UT, October 1-3, 2003.

Garfin, G.M., 2003. Arizona Drought: Past, Present, Future. Presentation (invited) to USDA Water Conservation Lab (USDA-WCL), Phoenix, AZ, June 9, 2003.

Garfin, G.M., 2003. Climate Variations in the Southwest. Presentation (invited) to the USGS/U.S. Fish & Wildlife Lower Colorado River Basin Science Workshop, Parker, AZ, June 16-18, 2003.

Garfin, G.M., 2003. Feedback on Drought Monitor Products from Southwest Stakeholders. Presentation to the North American Drought Monitor Workshop, Asheville, NC, June 24-27, 2003.

Garfin, G.M., 2003. View Through A Wide Angle Lens: CLIMAS And Climate Information For Hydrological Decision Making. Presentation (invited) to the Arizona Hydrological Society 16<sup>th</sup> Annual Symposium, Mesa, Arizona, September 18-19, 2003.

Garfin, G.M., Carter, R., 2003. END InSight: Expanding the Use and Usability of Climate Information. Presentation to the Arizona Association for Environmental Education (AAEE) Conference 2003: Senders: Environmental Education in a Multicultural Society, Tucson, AZ, September 20, 2003.

Garfin, G.M., 2003. Arizona Highlands Climate & Vegetation Change and You. Presentation (invited) to the Arizona Highlands Garden Conference (Gila County Cooperative Extension), Payson, AZ, September 29-30, 2003.

Garfin, G.M., 2003. Development of a State Drought Monitor for Arizona. Presentation to the US Drought Monitor Workshop, Cedar City, UT, October 1-3, 2003.

Garfin, G.M., 2003. Arizona Drought: Real Climate, Real People, Real Challenges. Presentation (invited) to the University of Arizona Department of Geography and Regional Development Colloquium, Tucson, AZ, October 24, 2003.

Garfin, G.M., 2003. Arizona Drought Challenges. Presentation (invited) to the Interim National Drought Council Meeting, Albuquerque, NM, October 30-31, 2003.

Garfin, G.M., Wordell, T., Brown, T., Ochoa, R., Morehouse, B., 2003. The 2003 National Seasonal Assessment Workshop: A Proactive Approach to Preseason Fire Danger Assessment. Paper presented to the American Meteorological Society 5th Symposium on Fire and Forest Meteorology, Orlando, FL, November 16-20, 2003.

Garfin, G.M., 2004. Putting Recent U.S. And Southwest Drought Impacts In Perspective. Presentation (invited) to the American Meteorological Society 84<sup>th</sup> Annual Meeting, Seattle, WA, January 11-15, 2004.

Garfin, G.M., 2004. Southwest Climate Variability: Data, Information, and Knowledge for Management During Drought. Presentation (invited) to the 37<sup>th</sup> Joint Annual Meeting

of the Arizona and New Mexico Chapters of The Wildlife Society and Arizona/New Mexico Chapters of the American Fisheries Society. February 6, 2004.

Jacobs, K., Morehouse, B., 2003. Improved drought planning for Arizona. Paper presented at the Water, Climate, and Uncertainty: Implications for Western Water Law, Policy, and Management, Natural Resources Law Center, University of Colorado, Boulder, Colorado, June 11-13, 2003.

Morehouse, B.J. 2003. Water resource management and climate variability: possibilities for transboundary knowledge transfer on the US-Mexico border. Paper presented at the Human Dimensions of Climate Change meeting, Montreal, Canada,

Morehouse, B.J. 2003. Climate variability, vulnerability and adaptation in the US Southwest: Climate Assessment for the Southwest (CLIMAS). Presentation to Human Dimensions of Arctic Change (HARC) advisory group, Arlington, Virginia, May 1-2, 2003.

Morehouse, B.J. 2003. Analyzing climate impacts: Experiences from CLIMAS. Presentation to Human Dimensions of Arctic Change workshop, Seattle, Washington, October 25-26, 2003.

Morehouse, B.J. 2003. HARC Insights on Adaptation. Presentation at Insights and Tools for Adaptation: Learning from Climate Variability, Washington, DC, November 18-20, 2003.

#### Posters

Garfin, G.M. and others, 2003. CLIMAS Drought Research. Southwest Drought Summit, Northern Arizona University, Flagstaff, AZ, May 11-13, 2003.

Lemos, M.C., Morehouse, B.J., 2003. The co-production of science and policy in integrated assessments. Annual Meeting of the American Geophysical Union, San Francisco, California, December 2003.

#### Meetings organized

Garfin, G.M., 2003. Southwest Drought Summit, Northern Arizona University, Flagstaff, AZ, May 11-13, 2003. Chaired Climate Working Group; co-authored 2003 Southwest Drought Summit Summary Report; served on meeting organization steering committee.

Garfin, G.M., 2003. The University of Arizona Cooperative Extension and CLIMAS, Climate and Extension Meeting, Tucson, AZ, May 29, 2003. Co-organized meeting. Secured participation of the following partners in the meeting: USGS, Arizona State Climatologist, USDA-NRCS National Water and Climate Center, National Weather Service Tucson Forecast Office.

Garfin, G.M., 2004. National Seasonal Assessment Workshop: Eastern and Southern States, Shepherdstown, WV, January 26-29, 2004; co-organized meeting; co-authored proceedings.

#### **IV. Outreach Activities.**

Garfin, G.M., 2003. Understanding Southwest Drought. Four classes (invited) taught on June 3-5, 2003 to the Arizona Game & Fish Department Annual Department School, Flagstaff, AZ.

Perin, J., Abraham, J., Sturzen, A., 2003. CLIMAS Climate and Vulnerability Research. Booth at the Annual Southeastern Arizona Ag Day and Trade Show, Willcox, AZ, February 4, 2004.

#### ***Arizona's Governor's Drought Task Force (GDTF) Meetings (Garfin)***

##### **2003**

May 8 GDTF Public Meeting (presentation on END InSight; plus Drought and Climate Change presentation by Overpeck)

July 10 GDTF Public Meeting (Drought Update presentation)

July 16 GDTF Monitoring Committee

September 22 GDTF Monitoring Committee

September 24 GDTF Executive Committee

October 9 GDTF Monitoring Committee

October 21 GDTF Municipal & Industrial Water Committee

November 6 GDTF Monitoring and Executive Committees; organized meeting; coordinated with visitors Hayes and Svoboda from NDMC and Steinemann from Georgia Technical University; gave presentation on Arizona Drought Monitoring Challenges.

November 10 GDTF Public Meeting (presentation on GDTF MTC progress)

December 16 GDTF Monitoring Committees

February 20 GDTF Monitoring and Executive Committees

##### **2004**

January 9 GDTF Monitoring and Executive Committee

#### ***University of Arizona Cooperative Extension Climate and Vegetation Change Think Tank (Garfin)***

##### **2003**

August 20

October 17

December 15

#### ***CLIMAS-SAHRA Press Briefings (Garfin, Lenart, Jacobs, Morehouse, Hartmann)***

November 12, 2003 Tucson, AZ. Presentations included:

Garfin – The 2003 Monsoon and Tropical Storm Season: Did it Help the Drought?

Hartmann – Current El Niño, Climate, and Palmer Drought Severity Index Forecasts

Jacobs – Development of the Arizona Drought Plan

This press briefing resulted in coverage by three television stations, three newspapers and the Associated Press, and one radio interview.

## **V. Human Resource Development**

Kristen Reed's CLIMAS-inspired M.S. thesis has been completed. Joe Abraham's Ph.D. dissertation research on drought vulnerability (partially funded by CLIMAS) is in progress. Susan Simpson's CLIMAS-inspired M.S. thesis is in progress.

**TASK AREA:** Forecast Evaluation

**PI:** Holly Hartmann, Ellen Lay (professional software developer), David Lamb (professional web designer)

## **I. Progress for Budget Year 2003-2004**

### **Project A. Forecast evaluation tool (FET)**

A.1. *Description.* The FET is a software engineered web application designed to make various types of up-to-date forecast information and interactive analysis tools readily available to the user community over an extended period of time. The interactive forecast evaluation and interpretation tool became available for testing by beta-testers in March 2003. By September, it was considered stable and fully functional for widespread use. Currently, the product can perform real-time computations and produce user-determined graphics regarding the reliability of precipitation and temperature forecasts in all 102 *seasonal* climate forecast divisions of the United States.

Developing the product for widespread use required thoughtful planning because of the many challenges software developers must overcome. Software must be extendable, i.e., efficiently modified to increase its storage or functional capacity. It must be easy to maintain, i.e., easily modified to correct faults, improve performance or other attributes, and adapt to a changed environment. Software must be portable, i.e., easily transferred from one hardware or software environment to another. Software must be reliable, so that software tools and components can be used in more than one computing program or software system. This is important to us because we want to be able to use the software tools, originally developed to analyze Climate Prediction Center (CPC) forecasts, to analyze other types of forecasts as well. We want to re-use as much feature functionality as possible. Finally, software must be scalable, i.e., easily modified to provide efficient access to and fast computations even when many users connect simultaneously.

Because we are building FET on a variety of reputable, industry standard software tools, the maintenance effort primarily is the responsibility of the tool vendors; tool vendors fix their own bugs. Also, by choosing open source tools that are entirely Java-based or have been available for many platforms for many years, the application is easily portable to other platforms. Efforts undertaken in isolating all machine-dependent resources in property files, implementing self-updating code, documenting code, and developing data-update tools all help make the web application easier to maintain by other professionals with an information technology background.

A.2. *Accomplishments to date.* A series of steps are involved in maintaining the FET site, both to update the site with the more recent data as it becomes available and to keep the site running. To keep data current on site, the monthly and seasonal climate forecasts are downloaded from the CPC website every month, then carefully shrunk to two specific sizes and moved to a specific location in our image database. The web application code automatically displays the most recent forecasts we have processed in our image database. CPC data files are downloaded each month and then run through the suite of update tools that convert the data into a performance-optimized format that the web application can use. Data downloaded for 102 mega-climate divisions include: seasonal

recent observations of temperature and precipitation; monthly recent observations of temperature and precipitation; and forecast probability data of temperature and precipitation.

To keep the site running, we periodically upgrade to the latest version of the tools needed to run the site. This requires testing our site with the latest tool version, and troubleshooting if necessary. Using older versions of software tools makes the web application more dependent on a specific system set-up or architecture, and thus less transferable to other systems. Also, tool vendors sometimes refuse to support older versions of software. We annually upgrade to the latest version of Java Runtime Environment (JRE), Apache Tomcat, and Apache WebServer. Although we use free open-source tools when they are reputable, we also use commercial tools that require annual purchases of new product upgrades and license and support agreement renewals. In addition, we must test a variety of browsers running on different operating systems in order to be able to troubleshoot problems in the application code, some of which are identified by users. Constant user feedback on the site provides the corrective mechanism in the negative feedback loop of iterative software development.

*A.3. Accomplishments anticipated by end of Budget Year.* One of the new features under development is the ability to layer maps transparently on top of each other, a feature used to create the U.S. Drought Monitor. Among other uses, this will allow a user to see a CPC climate forecast optionally overlaid with two other U.S. maps: the 102 mega-climate divisions, and the state boundaries. Using the state boundaries as a guide, users can then click on their regions of interest and see the corresponding pie chart representing the seasonal forecast probabilities for that particular climate division. ESRI's Map Objects for Java commercial software package supports such a transparent layering feature as well as the addition of GIS functionality into Java applets and beans. However, it requires all maps to be layered to be in shapefile format. Shapefile format is presently the industry standard format for GIS files, so it is the file format supported by all GIS data manipulation tools.

At present, the CPC climate forecasts are images produced using the General Meteorology Package (GEMPAK), developed by the National Center for Environmental Prediction. As it is nearly impossible to accurately align image files with maps stored in GIS format, we developed a process by which data in raw GRID format could be converted to shapefile format using ESRI's ArcInfo version 8.2. Once the CPC technicians were able to successfully reproduce this process, they agreed to send us the temperature and precipitation seasonal suite of forecasts issued in November 2003 in shapefile format for a pilot test of our layering functionality. We expect delivery of these shapefile formatted forecasts any day now. If our layering feature works well, we will request that the CPC staff convert all past issued seasonal and monthly temperature and precipitation forecasts to shapefile format so that we can offer the forecast overlaid with the state boundary and 102 mega-climate division maps for every forecast on our site. In working with them, we have reached an agreement that the format conversion should be handled by them because they create the forecasts. They know how much error is

acceptable as part of the conversion process, so they can refine the contouring algorithms and parameters to produce accurate forecasts in shapefile format.

A.4. *Plans for 2004.* There are four new features currently under development:

1. A Java-based Geographic Information System (GIS) layering Application Programming Interface (API) using ESRI's Map Objects for Java software API, used to transparently overlay the CPC forecasts with both the map of the 102 mega-climate divisions and U.S. boundaries. Because this layering API is Java-based, it can be used with all of our Java-based applets and interactive charts and graphs. This layering API can also be used to optionally display maps of watershed basins, stream and river maps, county boundaries, and other types of maps on top of water supply forecasts. Overlaid maps can be hidden or shown interactively by the user.
2. Dynamic Report Generation, to be available in October 2004. This extendable abstract feature will allow the easy creation of new report elements based on pre-existing report elements and facilitate application to many different types of data. This feature will allow users to create and save in their project folders any number of custom created reports. Users can add forecasts, score maps, or other select information that they generate during their visits to the FET website. Such added information will be accompanied by written text (or disclaimer) accurately explaining the information that cannot be modified or removed. Different types of report elements can be assembled in real time to create a report, including different types of page templates, copy rights, logos, descriptive text, legends, headers, and form elements.
3. Persistent user profile. A user's profile represents a collection of user-specific settings and past work which persists across site visits. When users return to the site, their selected settings and previous work is preserved in the same state as it was when they previously logged out. The types of information that can be saved in a user's profile include: most recently chosen form element settings (e.g., checkbox, text field); user preferences (e.g., font size); all created bookmarks, which are named collections of one or more form element settings; reports created by the user; and user-created project folders containing named projects which are a collection of bookmarks and reports.
4. User session-tracking statistics. In addition to saving user-specific settings and past work, the database also stores the frequency, times and dates that users visit a particular page, the frequency and type of error codes associated with each page, and what actions the users were taking on the page at the time the error occurred. Over an arbitrary time span, database queries can be done to determine which pages are visited most frequently and during which times of the year by specific user communities. Because tracked user sessions are related to user profiles through a specific user, it is possible to numerically compile statistics that indicate which information is most useful to a particular user community. For example, a query result could indicate groundwater resource managers in the Southwest are

interested in precipitation forecasts for November-March issued 2-5 months in advance. Knowing which information and features users find most useful on the site will help prioritize the order in which features and site enhancements will be completed, as well as helps us focus our resources and efforts on how the site should be expanded in the future and which user communities to talk to about future developments they'd like to see on the site.

A.5. *Leveraged funding.* The Institute for the Study of Planet Earth has provided one year worth of funding for employment of Ellen Lay.

“Evaluation of Seasonal Hydroclimatic Forecasts from Water Management Perspectives,” GEWEX Americas Prediction Project (GAPP) GC01-168, NOAA/OAR Office of Global Programs.

NASA and Raytheon Synergy Program

NASA-University of Arizona HyDIS Project

“Building Knowledge Tools for the Use of Advanced Hydroclimatic Monitoring and Prediction in Latin America,” National Science Foundation Women’s International Science Collaboration Program, international travel grant.

A.6. *Leveraged activities.*

A.6.3. CLIMAS-related. Holly Hartmann will be traveling to Argentina this reporting year to work with colleagues at the University of Buenos Aires and others in Argentina on the use of Internet technology to deliver advanced hydroclimatic information and forecasts for the La Plata River Basin.

A.7. *Non-CLIMAS Project Partners*

National Weather Service (NWS) Climate Prediction Center; NWS Climate, Water, and Weather Services

## **Project B. Evaluate hydrologic forecasts.**

B.1 *Description.* This task area includes all activities related to evaluating hydrologic forecasts (e.g., historical seasonal water supply outlooks) and expanding the forecast evaluation webtool to include hydrologic forecasts.

B.2. *Accomplishments to date.* We assembled and updated a data set containing seasonal water supply outlook forecasts for the Colorado River Basin (136 sites on 84 water bodies) and reconstructed flow data (what the observed flow most likely would have been in the absence of diversions). We used many different methods to compare the forecast streamflows with reconstructed “observed” flows. Our analyses use traditional deterministic statistics (root mean square error, bias, correlation coefficient, etc.), categorical tests (probability of detections, false alarm rate), probabilistic measures (Brier score, ranked probability score), distribution-oriented evaluations (discrimination, reliability, sharpness), and other measures (linear error in probability space). Our

evaluation of historical water supply outlooks was extended from the 13 sites completed last year to all 136 forecast locations, and to include all selected statistics.

Work on incorporating seasonal hydrologic forecasts into our forecast evaluation webtool was slowed by the shift in focus to user project management, report generation, and user tracking. This shift occurred in part due to stakeholder input (prioritizing the information management aspects of the webtool) and in part by working in close cooperation with the National Weather Service Office of Hydrological Development (OHD) and their contract programmers (Riverside Technology, Inc.). Activities included evaluation of the draft design of the "Verification of probabilistic forecasts" application being created by RTI for the NWS, which ultimately will provide components of the computational engine for our forecast evaluation webtool related to hydrologic forecasts.

*B.3. Accomplishments anticipated by end of Budget Year.* We expect finalization and submission of manuscript on historical water supply outlook evaluations. We expect to have some seasonal water supply outlook capabilities implemented by June 1, such as a tutorial on creation and interpretation of seasonal water supply outlooks.

*B.4. Plans for 2004.* We plan to continue extension of the forecast evaluation webtool to allow assessment of hydrologic forecasts, to reach the same level of implementation that currently exists for the seasonal climate outlooks.

*B.5. Leveraged funding.* Evaluation of Seasonal Hydroclimatic Forecasts from Water Management Perspectives, GEWEX Americas Prediction Project (GAPP) GC01-168, NOAA/OAR Office of Global Programs

*B.7. Non-CLIMAS Project Partners*  
NWS OHD, Colorado Basin River Forecast Center.

### **Project C. Working with stakeholders regarding seasonal hydroclimate forecasts.**

*C.1 Description.* This task includes opportunistic interaction with stakeholders to get feedback on the impacts of our research products, and stakeholder concerns about hydroclimatic issues that can influence priorities of future activities. This task also includes developing concepts, based on our prior CLIMAS experience, about the metrics for measuring the success of stakeholder-driven research (e.g., investment return, regulatory impact, equity).

*C.2. Accomplishments to date.* We have been invited to participate in several stakeholder interaction events. For example, we worked with the NWS Climate, Water, and Weather Services Division to organize and conduct a special session on NWS seasonal climate outlooks for a national meeting of broadcast meteorologists. The meeting included discussion with the broadcasters about the difficulties in communicating probabilistic forecasts to the general public via various media venues. At the request of CLIMAS researchers involved in the END Insight Initiative, we also continued to participate in press briefings, including the preparation of materials to provide briefing participants.

We have been invited to participate in several events aimed at informing agency policy makers and research program managers about our experiences with stakeholder-driven research and interaction, webtool development, and gauging project success. For example, Holly Hartmann attended the NOAA Intra-seasonal to Interannual Prediction Program Workshop in Silver Spring, Maryland, August 12-13. The workshop aimed to further dialogue among NOAA agency personnel and hydroclimate researchers about NOAA planning, programming, and budgeting related to research on hydroclimatic variability and forecasting, including the transition of research to applications and the evaluation of research success. Hartmann also participated in a NOAA meeting on Insights and Tools for Adaptation: Learning from Climate Variability, Washington, DC, 18-20 November. The meeting aimed to synthesize key adaptation lessons learned from NOAA-supported research and applications on interannual timescales and to explore the practical implications of these insights for climate change adaptation research, decision making, and development planning in the United States.

At the invitation of the joint NASA/Raytheon Synergy Program, Hartmann (with Dr. Bisher Imam) was asked to meet with and advise the six-institution Pacific Northwest Regional Collaboratory, as that group begins a Synergy project to enhance the delivery of NASA and other earth science applications tools and data to resource managers across the region.

*C.3. Accomplishments anticipated by end of Budget Year* At the request of the American Meteorological Society's Executive Committee and Council, Hartmann (with Dr. Soroosh Sorooshian) are participating in a Mid-Term Review of the AMS Ten-Year Vision Study. This effort aims to review AMS' progress in implementing its 10-year development plan and suggest actions AMS should take to better enable the society to achieve its long-term development goals.

*C.4. Plans for 2004.* Plans are to continue stakeholder and agency interaction activities, where opportunities exist. We plan publications on metrics for measuring success of stakeholder-driven research.

*C.7. Non-CLIMAS Project Partners*

NWS Office of Climate, Water, and Weather Services; American Meteorological Society

## **II. Publications**

### In Print

Franz, K.J., Hartmann, H.C., Sorooshian, S., and R. Bales, 2003. Verification of National Weather Service ensemble streamflow predictions for water supply forecasting in the Colorado River Basin. *Journal of Hydrometeorology*, 4, 5-1118.

Lawford, R., Fort, D., Hartmann, H., Eden, S., 2003. Water: Science, Policy, and Management. *Water Resources Monograph*, 16. American Geophysical Union, Washington, 415 pp.

Hartmann, H.C., Bradley, A., Hamlet, A., 2003. Advanced hydrologic predictions for improving water management. In: Lawford, R. Fort, D., Hartmann, H., Eden, S. (Eds.), Water: Science, Policy, and Management. Water Resources Monograph, 16. American Geophysical Union, Washington, pp.285-307.

Gamble, J.L., Furlow, J., Snover, A.K., Hamlet, A.F., Morehouse, B.J., Hartmann, H., Pagano, T., 2003. Assessing the impact of climate variability and change on regional water resources: the implications for stakeholders. . In: Lawford, R. Fort, D., Hartmann, H., Eden, S. (Eds.), Water: Science, Policy, and Management. Water Resources Monograph, 16. American Geophysical Union, Washington, pp.341-368.

*To be submitted by June 1, 2004*

Hartmann, H.C., Garfin, G.M., Morehouse, B., Bales, R., Vásquez-León, M., Pagano, T.C., Eakin, H., Sorooshian, S., 2004. Forecast assessment: a key element in stakeholder-driven integrated climate assessments. Global Environmental Change.

Garfin, G.M. Hartmann, H.C., 2004. Climate forecasts for fire management: insights from the CLIMAS Fire-Climate workshops. Fire Management Today.

Morrill, J.C., Hartmann, H.C., Bales, R., 2004. Evaluation of historical water supply outlook forecasts in the Colorado River Basin. Journal of the American Water Resources Association.

Hartmann, H.C., 2004. Seasonal climate forecasts. The Encyclopedia of World Climates, Kluwer Publishers.

Hartmann, H.C., 2004. Use of climate information in water resources management. Encyclopedia of Hydrological Sciences, John Wiley and Sons.

### **III. Presentations at Professional Meetings/Conferences**

Hartmann, H.C., Sorooshian, S., 2004. Helping resource managers understand hydroclimatic variability and forecasts: a case study of stakeholder-driven research. 7th Biennial Conference on Integrating Science and Management on the Colorado Plateau, Northern Arizona University, Flagstaff, AZ, 3-6 November.

Hartmann, H.C., Pagano, T. Lay, E., Imam, B., Sorooshian, S., 2003. A customizable online forecast assessment tool to support improved resource management decisions. 7th Biennial Conference on Integrating Science and Management on the Colorado Plateau, Northern Arizona University, Flagstaff, AZ, 3-6 November.

Hartmann, H.C., 2003 (invited). Communication, dissemination, and evaluation: learning from climate variability research. Insights and Tools for Adaptation: Learning from Climate Variability, NOAA/OAR Office of Global Programs, Washington, DC, 18-20 November. (synthesize key adaptation lessons learned from NOAA-supported research and applications on interannual timescales and to explore the practical implications of

these insights for climate change adaptation research, decision making, and development planning in the U.S.)

Hartmann, H.C., Imam, B., Lay, E., Lamb, D., Sorooshian, S., 2003. Customized on-line climate forecast evaluations: a tool for improving natural resources management under climate uncertainty. Water, Climate and Uncertainty: Implications for Western Water Law, Policy, and Management, Natural Resources Law Center, University of Colorado School of Law, Boulder, CO, 11-13 June.

Hartmann, H.C., 2003. Helping broadcast meteorologists understand and communicate probabilistic forecasts. 32nd Conference on Broadcast Meteorology, American Meteorological Society, Seattle, WA, 10-11 August.

Hartmann, H.C., Imam, B., Lay, E., Lamb, D., Sorooshian, S., 2004. Helping resource managers apply seasonal predictions: considerations of equity in providing knowledge development and decision support tools. 84th Annual Meeting of the American Meteorological Society, Seattle, WA, 11-15 January.

Hartmann, H.C., Imam, B., Lay, E., Lamb, D., Sorooshian, S., 2003. Helping water managers use advanced hydroclimatic science and predictions through Internet-based forecast assessment. GEWEX Americans Prediction Project Annual Meeting, NOAA Office of Global Programs, Seattle, WA, 21-24 July.

#### **IV. Outreach Activities**

Hartmann, H.C., 2003. Climate forecasts and forecast uncertainty. CLIMAS and Extension Meeting, University of Arizona, Tucson, AZ, 29 May.

Hartmann, H.C., 2003. Current El Niño, climate, and Palmer Drought Severity Index forecasts, and how to interpret them. CLIMAS-SAHRA and Partners END Initiative Press Meeting, Tucson, AZ, November.

Website address for access to the Forecast Evaluation Tool:

<http://hydis4.hwr.arizona.edu/ForecastEvaluationTool/index.html>

**TASK AREA:** Climate variability/Paleoclimatology

**PI:** Malcolm K. Hughes

**Researchers:** Kurt F. Kipfmüller (postdoc), Fenbiao Ni (postdoc)

## **I. Progress for Budget Year 2003-2004:**

### **Project A. Online 1000-year Climate Reconstructions**

A.1. *Description.* Paleoclimate information is rapidly becoming an important part of water resources planning and risk management activities. Tree rings provide a useful tool to help extend climate records further back in time than is contained within the instrumental record. Tree rings act as a *proxy*, providing information on pre-historic climate variability before weather stations were in service. Statistical models can be developed to relate tree growth to climate during periods when instrumental records are available. These relationships are then applied to periods prior to the instrumental record to reconstruct past precipitation back a thousand years.

In an effort to make paleoclimate information accessible to stakeholders in the Southwest, we have developed an on-line dataset comprised of reconstructions of cool-season precipitation (November-March) for state climate divisions in Arizona and New Mexico. Information available for each state climate division includes a summary of the long-term and instrumental climate data with respect to periods of below- and above-normal rainfall over varying periods of time. The relative magnitude of the recent Southwest drought is highlighted with respect to the paleoclimate record to provide a context of recent and past drought periods. Further, the quality of the reconstruction for each climate division is provided as additional information concerning the accuracy of the reconstructions.

A.2. *Accomplishments to date.* All reconstructions and webpage design are complete and accessible on-line. Summary data has also been completed. The results are posted in a user-friendly format for access by stakeholders at the following CLIMAS web address: <http://www.ispe.arizona.edu/climas/research/paleoclimate/product.html>. In coordination with the CLIMAS Core Office, a series of Drought Fact Sheets were produced, based on the aforementioned research.

A.3. *Accomplishments anticipated by end of Budget Year.* The paleoclimate portion of CLIMAS is complete and no further work is anticipated.

## **II. Publications**

### *Leveraged peer-reviewed publications.*

Hughes, M.K. and G. Funkhouser. 2003. Frequency-dependent climate signal in upper and lower forest border trees in the mountains of the Great Basin. *Climatic Change* 59, 233-244

## **III. Presentations at Professional Meetings/Conferences**

Hughes, M.K., D. Meko, 2003 (invited). The record of natural climate variability over the

Central Valley watershed.CALFED conference Sacramento, CA, Jan 14-16 2003

Hughes, M.K., G.Funkhouser, M.Salzer and F. Ni, 2003 (invited). Changing climate response of high-elevation tree rings in semi-arid mountains – implications for paleoclimate reconstruction. Joint Assembly European Geophysical Society/American Geophysical Union, Nice, France, April 6-11, 2003.

Hughes, M.K., N. Graham, D.Meko, F. Ni, and G. Funkhouser, 2003 (invited) SW United States Drought: A Tree-Ring Perspective, PAGES/CLIVAR International Workshop on Drought, Tucson, AZ, November 18-21, 2003.

#### **IV. Outreach Activities**

Hughes, M.K., 2003. KUAT interview regarding drought in the Southwest was televised on Arizona Illustrated program in July 2003.

**TASK AREA:** The Assessment and Monitoring of Vulnerability and Adjustment

**PI:** Tim Finan

**Researchers:** Marcela Vásquez-León (Postdoc), Barbara Wolf (GRA), Colin West (GRA), Eric Pavri (GRA), Andrea Sturzen (GRA), Jodi Perin (GRA)

## **I. Progress for Budget Year 2003-2004**

### **Project A: Vulnerability Research in the Upper Gila River Valley**

*A.1. Description.* The Climate Vulnerability Team seeks to understand the ways in which southwestern communities with different hydrological regimes and livelihood systems are vulnerable to and adapt to climate variability. It also seeks to identify climate information needs of people whose livelihoods depend on climate. During 2003, we completed our third vulnerability assessment case study in the Upper Gila River Valley (UGRV). This study area was chosen for the presence of surface water (the Gila River), as a follow up to the team's previous study of groundwater-dependent agriculture in the Sulphur Springs Valley. The area was also chosen because of institutional complexity in dealing with water distribution – jurisdiction over the river is divided between Federal, State, and Tribal governments. The region has diverse stakeholders. The presence of the San Carlos Apache Tribe, a highly vulnerable ethnic group, allows comparison with Anglo stakeholders in the region. We also were able to examine a variety of rural livelihoods such as those dependent on cotton farming, ranching, timber production, mining, hunting, gathering, and recreation.

Conflict in the region has been exacerbated in the presence of long-term drought. The Gila River's flow is dependent primarily on snowmelt in the Gila Mountains of New Mexico and along the Mogollon Rim. In addition to this variable climatic factor, farmers' access to the river's water is strictly regulated by the federal Gila River Water Right Decree of 1935. Additionally, UGRV farmers' right to pump groundwater is being challenged by the San Carlos Apache Tribe, Gila River Indian Community, and other parties, in a lawsuit that claims the groundwater pumped is subsurface flow of the Gila River to which the tribes have prior water rights. Thus a variety of livelihoods in the UGRV are affected not only by variable precipitation, but by a complex legal and political climate as well.

*A.2. Accomplishments to date.* We conducted more than 70 interviews with Anglo and Native American farmers and ranchers, basket-makers and specialists in medicinal plants at the San Carlos reservation, the Bureau of Land Management, the Natural Resource Conservation Service and cooperative extension staff, tribal and local governments and irrigation district officials, forestry and recreational personnel. Interview documents were set up for text analysis software. A substantial portion of a final report has been written, including chapters on historical adaptations, water law, history and status of the water conflict in Upper and Middle Gila River Valley as it relates to long term drought.

*A.3. Accomplishments anticipated by end of Budget Year (June 1, 2004).* The report will be finished and reviewed by stakeholders.

A.4. *Plans for 2004.* In 2004, we plan to move to our fourth case study. This will be in the Little Colorado River (Showlow and Payson in AZ, and Luna, NM). This region was chosen by the CLIMAS team for a team-wide integrated watershed project (see below).

A.7. *Non-CLIMAS Project Partners.* University of Arizona Cooperative Extension, and the San Carlos Apache Tribe. A member of the San Carlos Apache Tribe has been invited to write one chapter for the report on the relationship between drought, bark beetle and forest management in the reservation.

**Project B: Vulnerability mapping based on Geographic Information Systems (GIS)**

B.1. *Description.* Work on the GIS-based vulnerability map was undertaken through 2003 (see CLIMAS Annual Progress Report 2002-2003). The focus was on developing a prototype drought vulnerability map for the Southwest. Based on the data survey, as well as on key informant interviews and the ethnographic data collected over the past three years, several key variables were identified and mapped as significant indicators of vulnerability to drought.

B.2. *Accomplishments to date.* Main activities included data surveying, agriculture and census data collection, including information on agricultural employment (from the U.S. Census Bureau), location and numbers of migrant workers (from the Arizona Department of Economic Security), and information on water providers across the state of Arizona (from the Arizona Department of Water Resources), compilation and coding for spatial attribution. This was accomplished through online searches and personal interviews with field contacts, as well as through contact with persons and institutions at the University of Arizona, including the Agricultural Economics department, the Arizona Water Resources Research Center, the School of Renewable Natural Resources, and individuals at the state Health and Human Services.

B.3. *Accomplishments anticipated by end of Budget Year.* The team will continue to work on deriving the core variables from collected data and developing the data at appropriate scales for the different users envisioned.

B.4. *Plans for 2004.* We plan to continue to expand the vulnerability map data collection activity. We will digitize and organize all collected interview data so that they can be displayed, along with other layers of geographic information, on an interactive digital map.

B.7. *Non-CLIMAS Project Partners.* A NOAA-funded project in northeastern Brazil that addresses issues in drought mitigation planning using climate forecasts as a trigger for interventions was used as a model to develop some of the methodological approaches that are being applied to the CLIMAS Vulnerability map. The Center for Applied Spatial Analysis (CASA) provided laboratory facilities and expertise that have contributed to the mapping project.

### **Project C: Mapping community perceptions of climate vulnerability.**

*C.1. Description.* This project grew out of an ongoing attempt to produce a GIS-based vulnerability map for the state of Arizona. This work focuses on smaller-scale areas than the vulnerability map project (e.g. counties, water management areas), and attempts to integrate detailed ethnographic analysis with GIS spatial representation. The Bureau of Applied Research in Anthropology (BARA) climate vulnerability team is developing and field-testing a methodology through which we can contribute the unique research approach of the social sciences to others in the CLIMAS project, by using the GIS-based map as an integrating tool to which all members of the CLIMAS project can contribute. The work is conducted in areas where the vulnerability team has previously produced detailed ethnographic reports. Fieldwork consists of administering a survey to stakeholders such as farmers, ranchers, foresters, and extension agents whose livelihood is potentially impacted by climate events such as drought. By drawing on maps provided to them by the research team, stakeholders identify areas where climate events affect the region in which they live, distinguishing between physical occurrence and the socioeconomic impact of climate events. The research team also records stakeholders' explanations for their choices. The research team digitizes the maps produced by stakeholders, uses GIS software to combine the spatial data and to identify areas where stakeholders' perceptions of vulnerability to climate events are most strongly concentrated, and accounts for stakeholders' comments in the stages of analysis and reporting of results.

*C.2. Accomplishments to date.* This project began in January 2004 and is in its initial stages. The research team has created a survey instrument and maps, pilot-tested the survey methodology at an agricultural fair in the pilot study area of Arizona's Sulphur Springs Valley, revised the survey instrument, and has begun to digitize and spatially analyze the data collected.

*C.3. Accomplishments anticipated by end of Budget Year.* By June 1, fieldwork for the pilot study in the Sulphur Springs Valley and the Upper Gila River will be completed, data will be digitized and analyzed, and GIS overlays for various climate events will have been created. The research team will also produce a preliminary written report and prepared a methodology paper for publication and a PowerPoint presentation for professional meetings.

*C.4. Plans for 2004.* This pilot study will inform the effort to develop a CLIMAS Team Integrated Watershed Level Assessment (see D below). We will contribute to the integrated portion of the CLIMAS project through creating maps and participating in interviews that focus on mapping local experts' perceptions of vulnerability to climatic events. We will also capture and analyze some of this interview data so that it can be displayed in a GIS format. This data will be compatible both with GIS data that has already been collected, and any future GIS data collected by CLIMAS team members.

#### *C.6. Leveraged activities.*

C.6.2. Intra-CLIMAS Spin-offs. We have begun creating a base map of the area for the CLIMAS Team Integrated Watershed Level Assessment (see D below).

C.6.3. CLIMAS-related. This work draws on the experience of the WALTER Project (Barbara Morehouse, PI), using map-based interviews to map stakeholder perceptions.

C.7. *Non-CLIMAS Project Partners.* The University of Arizona Center for Applied Spatial Analysis (CASA) provided laboratory facilities and expertise that have contributed to the mapping project.

### **Project D. CLIMAS Team Integrated Watershed Level Assessment**

D.1. *Description.* An Integrated Watershed Level Assessment will be undertaken by the CLIMAS team, including researchers from each different aspect of the project. The team-wide integrated assessment is being spearheaded by the CLIMAS Vulnerability team, in coordination with the CLIMAS Core Office, and the CLIMAS Team. The watershed chosen is the Upper Little Colorado River Basin (ULCRB), which includes Payson and Show Low, AZ, and Luna, NM. The area features ethnic diversity, a rural urban interface, a variety of ecosystem types (desert, forest, and riparian areas), and livelihoods that are highly sensitive to climate variability and change (recreational tourism, forest resources, ranching and farming).

D.2. *Accomplishments to date.* After considering several possible watersheds to conduct an integrated assessment, the entire CLIMAS team agreed on the Upper Little Colorado River Basin study region. The CLIMAS Vulnerability team has begun the creation of a base map of the socioeconomic and physical features of this area.

D.3. *Accomplishments anticipated by end of Budget Year.* By June 1, we will have a map of the area and will make initial contacts with stakeholders. We will begin the process of drafting of a Memorandum of Understanding (MOU) with the White Mountain Apache Tribe.

D.4. *Plans for 2004.* We will initiate intensive ethnographic data collecting, as part of a larger effort to collect data on the ULCRB that are relevant to the different disciplines within CLIMAS. A series of visits to the study site will be carried out by the CLIMAS Vulnerability team and representatives of the other CLIMAS disciplinary work groups.

D.6. *Leveraged activities.*

D.6.2. *Intra-CLIMAS Spin-offs.* This case study includes the study region where the CLIMAS team will work closely together in order to learn more about the process of integration and produce outputs that are highly relevant to stakeholders requiring a multiplicity of information. This process was initiated in cooperation with CLIMAS PI Bonnie Colby (Economic Decision Analysis).

## **II. Publications**

### In print.

Finan, T. J., West, C. T., Austin, D., McGuire, T. 2003, Processes of Adaptation to Climate Variability: a Case Study from the U.S. Southwest. *Climate Research*

21(3): 299-310.

Vásquez-León, M., Liverman, D. 2004. The Political Ecology of Land-Use Change: The Case of Affluent Ranchers and Destitute Farmers in the Mexican Municipio of Alamos. *Human Organization*.63 (1), 21- 33.

Vásquez-León, M., West, C.T., Finan, T.J. 2003, A Comparative Assessment of Climate Vulnerability: Agriculture and Ranching on Both Sides of the USMexico Border. *Global Environmental Change*. Vol. 13 (3), 159-173.

West, C.T., Vásquez-León, M. 2003, Testing Farmers' Perceptions of Climate Variability: a case study from the Sulphur Springs Valley, Arizona. In: Orlove, B. and Strauss, S. (Eds.) *Weather, Climate, Culture: Building Anthropological Bridges from Past to Future*, Berg Publishing: New York.

West, C.T. 2003, Misreading the Arizona Landscape: Questioning the Received Wisdom on Ecological Destruction in Southeastern Arizona. *The Kiva*.

Submitted/In Review.

Vásquez-León, M., Moody, J. Hispanic Farmers and Agricultural Migrant Workers: Social Networks and Adaptation to Climate Variability in Southeastern Arizona. *Human Ecology*.

To be submitted by June 1, 2004.

Perin, J., Pavri, E. Methodology for Community-based mapping of perceptions to climate vulnerability.

Vásquez-León, M., Wolf, B., West, C.T., Pavri, E., Sturzen, A., Wesley, V. Finan, T. Water is Life: Climate Vulnerability in the Upper Gila River Valley (UGRV) of Southeastern Arizona. CLIMAS Report. Institute for the Study of Planet Earth. University of Arizona, Tucson, Az.

Vásquez-León, M., West, C.T., Finan, T.J. Agricultural Diversification and Climate Forecasting Information Needs. *Ambio or Climatic Change*.

West, C.T., Garfin, G., and Pagano, T. Farmers' Perceptions of Rainfall Variability: Validation with Meteorological Data and Links to ENSO and PDO. *Climatic Change*.

Wolf, B., Vásquez-León, M., Osgood, D. The Role of Crop Insurance and Government Assistance in Mitigating the Impacts of Climate Variability: a case study of agriculture in the US Southwest. *Likely Journal: Global Environmental Change/Bulletin of the American Meteorological Society*.

### **III. Presentations at Professional Meetings/Conferences**

Perin, J., Pavri, E. 2004. Methodology for community-based mapping of climate vulnerability perceptions. Society for Applied Anthropology Annual Meeting, Dallas, Texas.

Vásquez-León, M., Wolf, B. 2004. The Role of Climate information in Water Conflict: the case of the Upper Gila River, Arizona. Paper presented at the Climate Prediction Applications Science Workshop. Research and Applications on Use and Impacts Tallahassee, Florida, March 9-11

Vásquez-León, M., Wolf, B. 2003, Social Vulnerability and Climate Risk in the Southwest: Ranching, Farming, Forestry, and Recreation. San Carlos Apache Tribe, San Carlos Indian Reservation, Arizona.

Vásquez-León, M. 2003, The Human Dimensions of Biodiversity Conservation and Sustainable Resource Use: The Role of Climate Forecasting in Marine Fisheries Management. Paper presented at the Open Meeting of the Human Dimensions of Global Environmental Change Research. Montreal, Canada.

Vásquez-León, M., 2003, Social Vulnerability and Climate Risk in the Southwest: Ranching, Farming, Forestry, and Recreation. San Carlos Apache Tribe, San Carlos Indian Reservation, Arizona.

West, C. T., Pavri, E. 2003, Mapping Social Vulnerability to Climate Variability: The Case of Arizona. Poster presented at the ISPE-Fest.

West, C., Nelson, D., Jahred, M. 2003, Vulnerability mapping, presentation at CLIMAS Team meeting.

Wolf, B. 2003, The role of climate in water conflict in the Upper Gila River Valley (UGRV). Poster presented at the ISPE Fest Student Competition.

Wolf, B. 2004, How communal does communal management have to be? Presentation on panel "Research Among Native North Americans: Ethics, Law and Relations, Part II" Society for Applied Anthropology Annual Meeting, Dallas, Texas.

Wolf, B., Vásquez-Leon, M., West, C.T., Pavri, E., Sturzen, A. 2003, Water is Life: Climate Vulnerability in the Upper Gila River Valley. Presentation at BARA Colloquium series.

Wolf, B., Vásquez-Leon, M., West, C.T., Pavri, E., Sturzen, A. 2003, Climate Vulnerability in the Upper Gila River Valley (UGRV). Presentation at the CLIMAS team meeting

#### **IV. Outreach Activities**

Perin, J., Sturzen, A., Abraham, J. 2004 Exhibitors at Southeastern Arizona Ag-Day and Trade Show 2004. Presented results from research done in the community and provided information on climate forecasting and research.

Wesley, Victoria 2004, The Effects of Drought on Our Tribal Forest. San Carlos Tribal Forest Resource Program. Stakeholder and member of the San Carlos Apache Tribe, invited talk at the Feb. 19 CLIMAS Team meeting.

Wolf, B. 2003, Contributed a short piece on tribes and fire to the CLIMAS website.

Wolf, B. 2004, Contributed an article to the CLIMAS Update Newsletter on drought and water litigation.

Wolf, B. 2003, Presented poster and preliminary results to the San Carlos Apache Tribe.

#### **V. Human Resource Development**

Students are being trained in field research and ethnographic data analysis. There has also been substantial training on the use of GIS and mapping.

The climate vulnerability mapping project in conjunction with the Integrated Watershed Level Assessment will form the basis of Jodi Perin's Ph.D. research.

CLIMAS alumnus, Colin West (M.A.), is applying methods developed by the CLIMAS vulnerability assessment team to his Ph.D. research in West Africa.

**TASK AREA:** U.S.-Mexico Border Research

**PI:** Margaret Wilder, Assistant Professor, Latin American Studies

**Researchers:** Katharine Meehan (GRA)

### **Progress for Budget Year 2003-2004**

#### **Project A. Decentralization and Water Institutions in Sonora**

A.1. *Description.* Wilder joined the CLIMAS team in August 2003 to lead efforts in the area of U.S.-Mexico Border Research, with assistance from Meehan. We are working on a study, "Decentralization and Water Institutions in Sonora," focusing on the new water management arrangements in Mexico that resulted from national water reforms instituted in 1992 and after. This study focuses on questions of institutional capacity in these water management structures, with particular reference to the utilization and application of climate and environmental science data in institutional planning, and the participation of water users and stakeholder groups in decision-making processes. Study sites in Mexico will include the urban areas of: Cananea, Naco, Nogales (all in transboundary watersheds), Hermosillo, and one city in southern Sonora yet to be determined, as well as irrigation districts including the Rio Yaqui and Altar-Pitiquito-Caborca. The work in Cananea/Naco in the Upper San Pedro Basin was begun under the auspices of a NOAA project funded in the UA's Udall Center for Public Policy Studies.

A.2. *Accomplishments to Date.* To date we have: 1) Begun compiling a database of socioeconomic characteristics of the Mexican municipalities (and, where relevant, their transboundary sister cities in the United States.); and 2) Initiated fieldwork in Naco, Cananea, Nogales and Hermosillo.

A.3. *Accomplishments anticipated by end of Budget Year.* By the end of this budget year, we will have 1) Completed the database of socioeconomic characteristics for Mexican municipalities included in the study area; 2) Completed fieldwork; and 3) Begun writing an article on our water institutions research to be submitted for publication in a refereed academic journal by September 1, 2004.

A.4. *Plans for 2004.* In 2004, we plan to expand this work on institutional capacity of decentralized water institutions with a Mexican colleague (Dr. Patricia Romero Lankao of the National Autonomous University-Xochimilco) and seek leveraged funding sources to expand the study into other dynamic regions of Mexico. We plan to begin a new project in the Lower Colorado River and Delta transboundary region in partnership with the Sonoran Institute and a working group of environmental NGOS and the Cocapah Tribe. This project will assess community valuation of the riparian resources in the Colorado River and Delta regions in a binational context.

A.6. *Leveraged activities.*

A.6.2. *Intra-CLIMAS Spinoffs.* With PI Collaborator Andrew Comrie, and his HERO project team, including Dr. Cynthia Sorrensen, we are working on a joint publication regarding environment and globalization using the Nogales

transborder communities (Nogales, Arizona and Nogales, Sonora, Mexico). We anticipate submitting this article for publication in Fall 2004.

A.6.3. CLIMAS-Related. The current study of decentralization of water institutions in Sonora is leveraged by funding from the Udall Center's NOAA-funded project in the Upper San Pedro watershed. In that related project, we are looking specifically at three newly-forming river basin councils in Sonora, including the Upper Northwest (*Alto Noroeste*) which includes the Upper San Pedro watershed and extends west to the Altar-Pitiquito-Caborca area; as well as separate river basin councils in the Rio Yaqui and the Rio Mayo. We are assessing whether river basin councils engaged in watershed-level planning with all water-user sectors create opportunities for effective stakeholder utilization of climate and environmental science and planning toward environmental sustainability.

## **II. Publications**

### *In-print*

Wilder, M., 2000. Border Farmers, Water Contamination, and the NAAEC Environmental Side Accord to NAFTA," *Natural Resources Journal*, Fall, 873-894.

Wilder, M., 2000. The 'New Culture' of Water and the Communal Farmers of the Yaqui Valley, Sonora, *Estudios Sociales* 10, 19: 63-97. Published in Spanish. (Journal is refereed, and is officially recognized on Mexico's list of refereed academic journals.)

### *Submitted/In Review.*

Wilder, M., Romero-Lankao, P., forthcoming. Paradoxes of Decentralization: Water Reform and Social Implications in Mexico. Submitted 2/27/2004 to World Development. Browning-Aiken, A., Wilder, M., Carter, R. Disjuncture Between Policies and Practices in the Mexican Water Sector: Case Studies from Sonora, Mexico. Submitted for consideration in international conference proceedings and publication (June 2003).

## **III. Presentations at Professional Meetings/Conferences**

Wilder, M., 2003. Neoliberal Water Reforms and Small-Scale Producers in Northern Mexico: Challenges and Opportunities. International Human Dimensions of Global Climate Change Open Meeting, October 18, 2003, Montreal.

Wilder, M., 2003. Transforming Water and Agriculture: Mexican Restructuring and Impacts on Small Farmers. Association of American Geographers annual meeting, New Orleans, March 23, 2003.

Wilder, M., 2004. Transformation of the Mexican Water Sector: Decentralization and Evolving. Latin Americanist Geographers (CLAG), 2004 Annual Meeting, May 19-21, 2004, Antigua, Guatemala.

#### **IV. Outreach Activities**

Sonoran Ecoregion Human Dimensions Task Force, 2003 (Sonoran Institute)  
UA Task Force on Universidad de Sonora's Nogales Campus Planning (Pres. Likins)  
Gannett Pacific Group Border Collaborative Editors and Reporters, Tucson AZ, January 8, 2004.

Smith Scholars Presentation, K-12 Teachers Professional Development, May 2003

#### **V. Human Resource Development**

In the last year, Margaret Wilder has chaired seven master's of arts committees for students in Latin or Geography, and has served on an additional four committees.

**TASK AREA:** Economic Strategies to Address Climate-related Water Supply Variability, Economics Working Group

**PIs:** Bonnie Colby and Daniel Osgood

**Researchers:** Rosalind Bark (GRA, partially CLIMAS funded), Jennifer Kanipe (GRA), Ryan Sohm (GRA)

## **I. Progress for Budget Year 2003-2004**

### **Project A: Economic Values, Decisions, and Risk Management**

*A.1. Description.* The Economic Values, Decisions, and Risk Management component of CLIMAS is new to the CLIMAS project, having started one-and-a-half years ago. We briefly report on our four ongoing focus areas: 1) climate vulnerability and risk management strategies for the ranching sector; 2) economic values generated by riparian habitat; 3) effect of climate variability on water supply costs; and 4) developing a menu of practical water management strategies to improve dry-year water supply reliability. The common themes we explore among each of the economics focus areas are tradeoffs among competing resource uses and values, decisions in the face of uncertainty, and designing public policies and incentives to encourage optimal management of limited resources.

Our work provides an economic framework to understand how climate variability information can influence ranching decisions such as stocking and culling rates. We have developed a ranch model that incorporates economic theory and climate variability information in rangeland management decisions. Precipitation is crucial to successful ranching in the arid Southwest. Ranchers, cattle, and precipitation are modeled as interactive resources which jointly determine the aggregated size of the herd given varying climate conditions such as those that may occur in El Niño and La Niña years. This project also investigates ranch financial viability and how different types of climate information can best be used by ranchers.

Urban residents may seem to be more buffered than rural ranchers from the effects of climate variability on precipitation and water supplies. Nevertheless, there are important economic linkages between climate and economic values for urban residents. We measure the economic value of water-dependent riparian resources in Tucson using the hedonic valuation method. This method statistically links property values to a set of attributes that influence property values, such as number of bathrooms, living area, school district and distance to an amenity. By controlling for other factors that impact house values, the method identifies homebuyers' valuation of environmental amenities. This technique allows economists to place a monetary value on riparian habitat. Such habitat is highly vulnerable to climate-related water supply vulnerability, as it is typically "last in line" for the water supplies necessary to maintain riparian vegetation.

*A.2. Accomplishments to date.* We are applying the ranch decision model to a specific ranching community, the San Carlos Apache Reservation. Cattle grazing on the reservation depend upon forage as their primary source of sustenance. We have collected data on cattle characteristics for a Registered Hereford Herd owned and maintained by

the San Carlos Apache Tribe. We also use data from the 1000-year tree-ring reconstructions of cool season precipitation for Arizona Climate Division No. 4, developed earlier this year with CLIMAS support (See Climate Variability/Paleoclimatology task area). And we are using El Niño/Southern Oscillation (ENSO) data for Arizona precipitation in our model. These sources provide the ranching model with the range of climate conditions that we consider for rangeland and herd management. Preliminary results suggest that an improvement in the ability to predict seasonal ENSO state would lead ranchers to make more confident stocking decisions in response to droughts than wet years. Forecasts may decrease ranch vulnerability and reduce environmental pressure on rangelands.

As part of this project, we have provided a series of climate risk management extension education classes to private and Native American livestock managers using a mobile computer laboratory. We presented and discussed paleoclimate data and ENSO and Pacific Decadal Oscillation (PDO) processes, along with regional climate outlooks. Ranchers worked through a Planning for Profitability exercise, which explores how climate affects management decisions such as restocking, culling, supplemental feed purchase, along with the financial viability of their ranch. Ranchers also played the RightRisk educational ranch risk management computer game. Typical decisions include the timing and sale of cattle and advance purchase of supplemental feed. The game includes several sources of uncertainty, ranging from prices to climate variability. Profits are calculated and ranchers compared their initial profits with the outcomes of others. These workshops provided ranchers with climate risk information as well as the tools and intuition to apply the information and to relate it to their existing knowledge base. These sessions have been well received. In a follow up evaluation, 86% of respondents reported that the sessions had changed the way that they made ranch management decisions.

Regarding valuation of riparian habitat, our preliminary research indicates that there is a 6% premium for the value of single-family residences located within a tenth of a mile of large riparian corridors. We are now in the midst of statistically analyzing not only how proximity to a riparian zone impacts house prices, but also whether prices are statistically linked to the biological value of the riparian habitat. Fieldwork completed in our study area in the late spring and early summer of 2003 included sites that have higher quality hydriparian habitat and those with no habitat, i.e. a fully concrete-treated wash. The statistical relationship between riparian habitat quality and economic values will be immensely useful for understanding how climate variability affects this sector, and for considering policy issues such as limits on groundwater pumping near riparian areas and habitat conservation policies.

In addition to quantifying the link between habitat and economic values, we are examining whether reliable riparian habitat quality indicators can be derived from remote-sensing data, specifically the Normalized Difference Vegetation Index (NDVI) and the Soil-Adjusted Vegetation Index (SAVI). If these remote-sensing indices are appropriate proxies for vegetation density or species richness, then future studies on climate variability, riparian habitat and economic values will require less labor-intensive fieldwork.

We are researching user-friendly strategies for managing water supplies in the face of increased climate variability, focusing particularly on effective drought responses. These strategies are drawn from world-wide experience with river basin management in arid regions. This “menu” will include a background on each strategy, its strengths, weaknesses and suitability for various circumstances, where it has been used and with what effect, legal and social issues, and third party concerns and impacts. It is intended for use by municipal, state, tribal, federal and irrigation district water managers to mitigate the costs and conflicts associated with water supply variability. An early version of this menu has had preliminary “ground-truthing” in meetings with stakeholders and with federal water managers in New Mexico and in Colorado. We also are compiling an extensive data base on water prices and transactions in the western United States over a 15-year period. We are beginning to analyze the effect of water supply variability on water prices.

*A.3. Accomplishments anticipated by end of Budget Year.* Graduate research assistant Ryan Sohm is expected to finish his work applying the ranch decision model to the San Carlos Apache Reservation ranching community in mid-2004.

*A.4. Plans for 2004.* Work with the agricultural sector will be directed toward three groups, provided we have adequate funding. First, we will complete the ranch operations modeling and continuing development of outreach tools for ranchers, including internet tools used to help make management decisions given climate variability. The second “agricultural” group is ranchette owners who operate their small ranches for recreation/lifestyle values and who now constitute a major land use in the rural West. Ranchette analysis is ongoing and will enable quantification of the value of climate forecasts to this increasingly important sector. The third agricultural sector we propose to focus upon is irrigated agriculture, the largest consumptive water user in the entire CLIMAS study area. Understanding this sector is essential to understanding and optimizing regional responses to climate-related water supply variability. Not only is this sector itself affected in complex ways as water supply variability changes, it also has a cascading effect on all other sectors. This is due to the fact that adaptation strategies by municipal, recreational and environmental water users (such as endangered fish recovery programs) typically rely on being able to use water customarily used in irrigated agriculture. The economic, social and legal ramifications of this are explored under the focus described below.

We currently are analyzing the effects of climate variability and climate information on constituencies that rely on healthy riparian habitat for a mix of services including recreation, wildlife habitat, flood control, water filtration and open space. Such constituencies include property owners, regional residents, water utilities and public agencies responsible for water supply, water quality and flood control. We are collecting new data on riparian habitat characteristics that will enable us to more precisely identify the components of riparian ecosystems that provide various types of economic benefits and their susceptibility to climate variability. These data will be analyzed and publications and outreach activities initiated in fall, 2004.

We are researching user-friendly strategies for managing water supplies in the face of increased climate variability, focusing particularly on effective drought responses. Budget permitting, a web-based or publication-based outreach effort on our findings will begin in fall, 2004. We are compiling an extensive data base on water prices and transactions in the western United States over a 15-year period, and are beginning to analyze the effect of water supply variability on water prices. This analysis should be completed, with results available for publication and outreach activities in mid-2005, budget permitting.

#### *A.5. Leveraged funding.*

“New Approaches to Resolving Tribal Water Conflicts,” grant from SAHRA, NSF Science and Technology Center, Semi-Arid Regions, \$22,000, one research assistant, 2002-04.

“Agricultural Water Management for Economic Viability and Environmental Quality,” U.S. Dept. of Agriculture Western Regional Project W-190, approx. \$20,000 per year, 1999-2004.

“Measuring the Economic Value of Desert Riparian Habitat,” grant from SAHRA, NSF Science and Technology Center, Semi-Arid Regions, \$26,000, one research assistant, 2003.

Evaluating the Economic and Environmental Effects of Alternative Dispute Resolution, grant from Hewlett Foundation (through GHK international), \$95,000, 2003-2004.

*A.6. Leveraged activities.* We received funding for “Risk Management Training for Western Livestock Producers – Year II” (USDA Western Center for Risk Management) to continue outreach to ranchers on climate-related risk management. With the Hewlett Foundation funding mentioned above, we are evaluating different strategies used to address environmental disputes in the western U.S., many of which are linked to climate variability. We are documenting and assessing progress on negotiated water settlements and analyzing water management practices on Native American reservations, with leveraged funding from SAHRA.

## **II. Publications**

### In print

Colby, B. G, 2004. The Role of Markets in Reallocating Irrigation Water, chapter in Encyclopedia of Water Science, New York: Marcel Dekker.

Colby, B.G., 2003. Economic Characteristics of Successful Environmental Dispute Resolution Outcomes, chapter 15 in Evaluating Environmental and Public Policy Dispute Resolution Programs and Policies, R. O'Leary and L. Bingham, editors, Resources for the Future Press, p 301-325.

Colby, B.G., 2003. Economics of Urban Water Demand and Supply, chapter in Managing Urban Water Demand, N. Buras, editor, Kluwer Academic Publishers.

Colby, B., S. Wishart, 2003. Riparian Areas Generate Premium for landowners, Arizona Review, Spring, p. 12-13.

Orr, P., Colby, B.G., 2004. Institutions and Incentives to Protect Water-Dependent Amenities, Water Resources Research, forthcoming.

Sengupta, S., Osgood, D., 2003. The Value of Remoteness: A Hedonic Estimation of Ranchette Prices. Sanchita Sengupta and Daniel Osgood. Ecological Economics, Vol 44 91-103

Tronstad, R., Osgood, D., Teegerstrom, T., 2004. The Role of Electronic Technologies for Reaching Underserved Audiences. Russell Tronstad, Daniel Osgood, and Trent Teegerstrom. American Journal of Agricultural Economics Proceedings. In Press.

Submitted/In Review:

Brookshire, D., Colby, B., Ewers, M., Ganderton, P. in press, 2004. Water Markets in the Southwest, Southwest Hydrology.

McCann, L., Colby, B.G. Transaction Cost Measurement Related to Environmental and Natural Resource Policies (under review).

Osgood, D. Regulation of Information Intensive Production: Agricultural Drainage and Government Weather Information. American Journal of Agricultural Economics. (will revise and resubmit)

Moreno, G., Osgood, D., Sunding, D., Zilberman, D. Investment Incentives and the Reliability of Property Rights: Evidence from Water Use in the American West. Journal of Agricultural and Resource Economics (submitted)

Leveraged peer-reviewed publications

Colby, B. G., in press 2004. Estimating the Value of Water in a Alternative Uses, chapter in Economics of Water Resources, K.W. Easter and M. Renwick, eds, Ashgate Publishing, forthcoming.

Colby, B.G., Thorson, J., 2004. Smoke on the Water: One Hundred Years of Litigation and Negotiations Over Tribal Water Rights, University of Arizona Press, forthcoming.

Colby, B.G., Crandall, K., Bush, D., 2004. Water Right Transactions: Market Values and Price Dispersion, chapter in Economics of Water Resources, K.W. Easter and M. Renwick, eds, Ashgate Publishing, forthcoming.

Colby, B. G., d'Estrée, T.P., 2004. *Braving the Currents: Resolving Conflicts Over the Water of The American West*, Kluwer Academic Publishers, 207 pages, forthcoming.

### **III. Presentations at Professional Meetings/Conferences.**

Colby, B. 2003. Innovative Responses to Water Supply Variability. Aspen Global Climate Change Institute in Aspen, Colorado in June, 2003. The attendees at the three-day workshop included federal water managers from around the western U.S., environmental NGOs, and scientists from government agencies and from universities.

Colby, B. 2004. Enhancing Water Supply Reliability for Water Providers, National Center for Atmospheric Research in Boulder, Colorado, March 2004.

Colby, 2003 (invited). Water Transfers: Agricultural to Non-agricultural Uses, Arizona Agribusiness Forum, 2003.

Colby, 2003 (keynote presenter). Markets to Achieve Flexibility in Water Use. U.S. Institute for Conflict Resolution, 2003.

Colby, B., 2003. Innovative Responses to Water Supply Variability Risks, Seminar, Department of Hydrology and Water Resources, 2003.

Colby, B., 2003 (invited keynote speaker). Water Supply Reliability in the Context of Climate Change. University of Colorado Natural Resources Law Center Conference, Boulder, 2003.

Osgood, D., 2004. The Role of Electronic Technologies for Reaching Underserved Audiences. Allied Social Science Association Meetings, 2004. San Diego, California

Osgood, D, 2003. Potential for climate education and forecasts in extension programs. Western Extension Meetings. Daniel Osgood. 2003. Las Vegas, NV

Osgood, D., 2003. Research Validation and Verification, panel member. Regional Integrated Sciences and Assessments National Program Meeting, NOAA Office of Global Programs. 2003. Carefree, Arizona.

Osgood, D., 2003. Land markets and the destruction of environmental amenities on the urban fringe. AERE session of the American Agricultural Economics Association Meetings, 2003. Montreal, Canada.

Osgood, D., 2003. The Value of Remoteness: A Hedonic Estimation of Ranchette Prices. WCC55 Rangelands Symposium, 2003. Reno, Nevada.

Osgood, D., 2003. Uncertain ET and the Tragedy of the Commons: Information-based management tools in irrigated agriculture. University of Arizona Department of Hydrology Seminar, 2003. Tucson Arizona.

#### Meetings organized

PI Bonnie Colby organized and moderated a session entitled “Strategies to Induce Provision of Environmental Benefits by Agricultural Interests” at the Western Economic Association International Meetings in Denver in 2003. The session focused on assessing the strengths and weaknesses of voluntary programs to facilitate environmental restoration, given climate-related water supply variability’ with an emphasis on acquiring water for environmental purposes in the western United States.

Colby will co-chair a conference on New Mexico Water Supply Vulnerability and Planning to be held in Albuquerque in May, 2004.

#### **IV. Outreach Activities**

Bonnie Colby and Rosalind Bark have been conferring with Pima County resource managers, at their invitation, to help design effective strategies for the county to acquire and restore ecologically valuable riparian habitat.

Colby has been working with conservation groups active Colorado, New Mexico and Arizona to identify practical and cost-effective measures to maintain riparian habitat in the face of variability in surface water flows, with such variability expected to increase with climate variability. The upper Rio Grande, San Pedro and Upper Colorado Rivers were the focus of meetings Colby attended in 2003-04.

Colby participated in an invitation-only workshop sponsored by the Hewlett Foundation on Assessing Environmental Outcomes of Community-Based Collaboratives in 2003. Attendees included representatives of foundations, environmental NGOS and community-based collaboratives, along with researchers and conflict resolution practitioners. The group focused on how to assess the results of collaborative problem-solving efforts intended to address conflicts over scarce resources, many of which are exacerbated by climate variability.

Colby taught a Continuing Education Series Course, Environmental Economics for Public Land Managers, at the Bureau of Land Management National Training Center, Phoenix. 1 day of lecture, 37 students, federal agency staff from western states, 2003.

Colby attended meetings in her role on the Board of Directors, Western Resource Advocates, 2003-04.

Colby attended meetings of The Nature Conservancy, Western Regional Office, Boulder, Colorado, as adviser on water resource economics, water pricing and water transactions, and riparian area management, 2003-04.

Colby, advisor to U.S. Institute for Environmental Conflict Resolution’s research program on measuring costs of conflict and resolution.

Colby served as proposal reviewer for NOAA Competitive Research Grants Program.

Osgood, D. 2003. Climate and Ranching. Drought Recovery Workshop March, 2003, Camp Verde, Arizona.

Osgood, D., 2003. Ranching with Drought: How to handle risk in the livestock industry. Kingman Arizona April 2003, Supai (Havasupi Reservation) Arizona May 2003, Tuba City (Navajo/Hopi Reservation) Arizona May 2003, Fredonia Arizona Presented by Russell Tronstad and Trent Teegerstrom June 2003, Payson Arizona Presented by Russell Tronstad at the Southwest Indian Agricultural Association Conference, January 2003, Laughlin, Nevada.

Osgood, D., 2003. Integrating Climate Education into the RightRisk Program. Western Livestock Research and Extension Coalition, May 2003, Denver Colorado.

Osgood, D., 2003. The University of Arizona Cooperative Extension and CLIMAS. Climate and Extension Meeting, Planning Committee Member, Session Moderator. University of Arizona. May 2003, Tucson, Arizona.

Osgood, D., 2003. Cooperation in AG Decisions. Arizona 4-H Teen Congress. July 2003, Tucson, Arizona.

Sohm, R., D. Osgood and B. Colby. Climate Variability and Rangeland Management. Poster presentation, ISPE-Fest. November 2003 Tucson, Arizona.

#### **IV. Human Resource Development**

Ryan Sohm is expected to finish his master's thesis on Climate Variability and Rangeland Management in May 2004.

#### **Awards**

Bark, R. G. Katz, J. Stromberg, D. Osgood, and B. Colby. New Approaches to Assessing and Valuing Riparian Resources in Arid Regions. Poster. 3rd Annual SAHRA meetings. October 2003. Tucson Arizona. Award for outstanding poster presentation.

Bark, R. 2003. Graduate & Professional Student Council, Student Showcase, University of Arizona, Tucson, Arizona. First prize, Business Administration, Law, Economics and Public policy graduate division. November 2003.

**TASK AREA:** Climate Variability / Recent climatology

**PI:** Andrew C. Comrie

**Researchers:** Erika Wise (GRA), Jenna McPhee (GRA), Rick Brandt (GRA)

**Brief WestMap Update:**

The WestMap initiative was put into place with 2003-2003 CLIMAS funds, but WestMap activities continue through to the present. The WestMap consortium of several western RISAs, and a number of agencies/offices is an effort to coordinate science and funding in order to produce historical time-series of fine-scale gridded climate data across the West and the entire country, to be available online along with error and uncertainty estimates and a graphical analysis interface. Several presentations at professional meetings were made (Comrie), and additional WestMap meetings were organized among the group as well as with new partners, in particular the Arizona Remote Sensing Center (Stuart Marsh, Barron Orr, et al.) who provided leveraged travel support for C. Daly (OSU – PRISM). ARSC is interested in developing the web interface for gridded climate data along with development of geospatial tools for remotely sensed data. We continue to pursue appropriate funding for this fundamental data set and associated tools.

**Project A: Air Quality/Health and Climate (Comrie & Wise)**

A.1. *Description.* The purpose of the task is to work with stakeholders to provide an improved understanding of how climate variability influences air quality in the Southwest, and to better assess the probability of climate variability threatening air quality across the region. The project examines ozone and particulate matter across a range of cities in the Southwest in order to determine how climate variability influences air quality trends in the region.

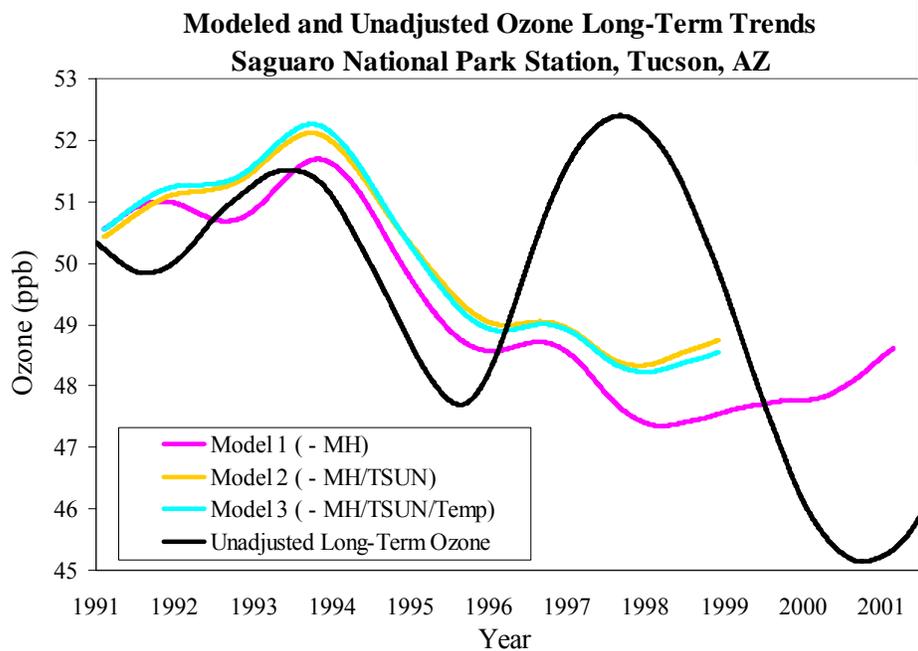
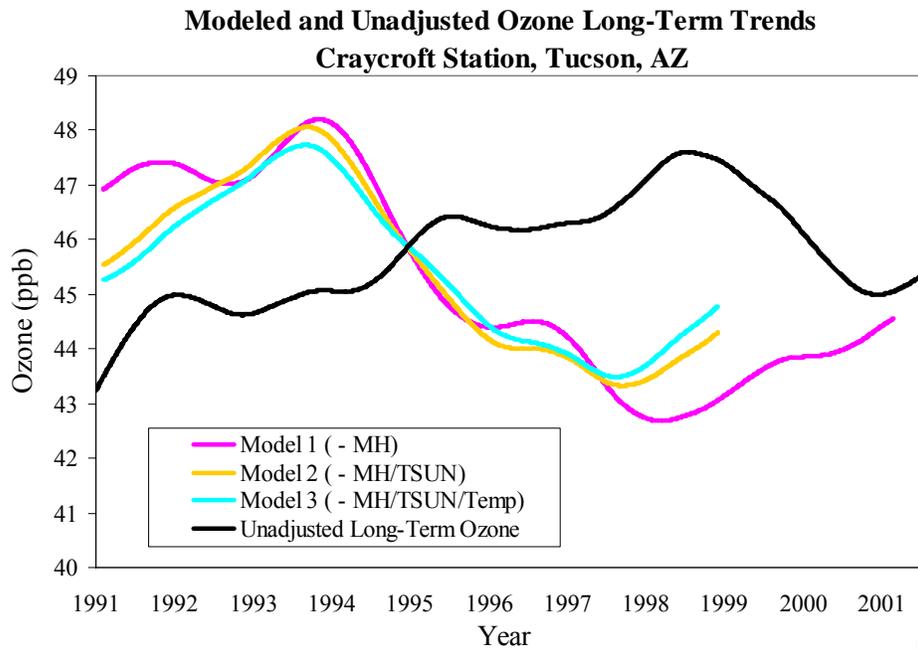
A.2. *Accomplishments to date.* The first phase of the project investigated tropospheric ozone (ozone) and particulate matter (PM) in Tucson, Arizona.

- Data:
  - Daily maximum 8-hour average ozone concentrations and 24-hr average concentrations of Particulate Matter smaller than 10 microns (PM<sub>10</sub>) were analyzed for the time period 1990 to 2003, along with daily values of maximum surface temperature, solar radiation, precipitation, dew point temperature, average wind speed, relative humidity, and mixing height.
- Methods
  - Stepwise regression was used to evaluate the relationship between pollutants and meteorological variables, producing a set of recommended models for ozone and particulate matter.
  - KZ filter method was used to separate each variable into its temporal components
  - Individual meteorological variables and sets of variables suggested by the models were regressed on the ozone and PM components
  - KZ(365,3) (i.e, of 365 day length with three iterations) filter was applied to the sum of the residuals from the components of the adjusted air quality time series, producing long-term, meteorologically adjusted ozone and particulate matter trends.
- Results

- The trends (Figures 1 and 2) represent changes in pollutant concentrations attributable to sources other than the removed meteorological variables, such as emissions or policy changes
- Preferred ozone model removes mixing height and solar radiation
- PM model is more complicated, but the combination of relative humidity and mixing height explains most of the variation
- Unlike other parts of the country, where temperature tends to control ozone, mixing height (stability) seems to be the strongest meteorological influence on ozone in Tucson
- KZ filter appears to be an appropriate method for both ozone and PM trend separation
- Adjusted trends show small, but potentially significant, meteorological influences (Figures 2 and 3)
- Associations between meteorological variables and ozone and PM concentrations used to determine the historical number of “critical” ozone and PM days (Figure 5)

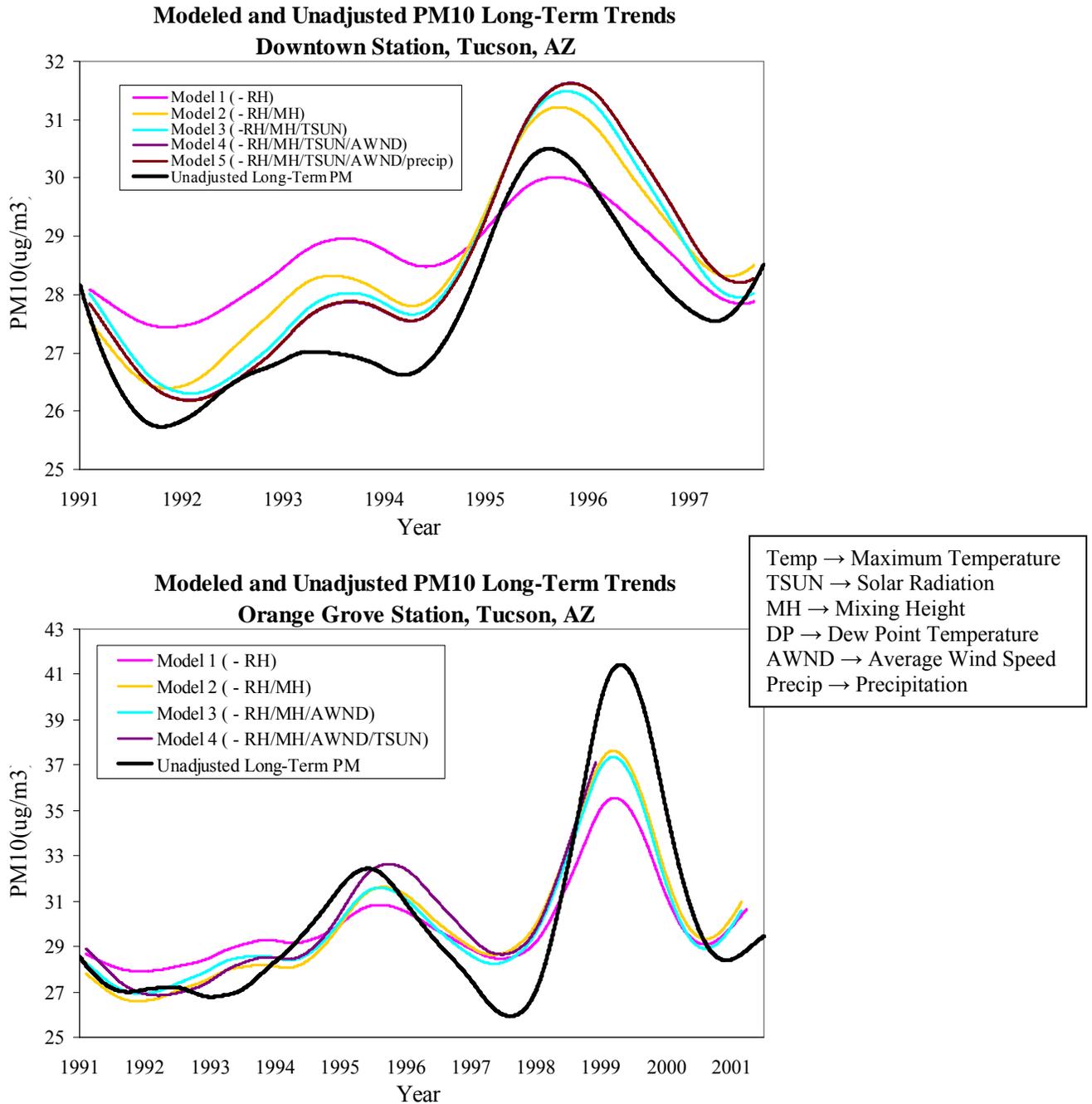
The second phase of the project is still in progress: ozone and PM data are being analyzed for Albuquerque, New Mexico; El Paso, Texas; Phoenix, Arizona; and Las Vegas, Nevada

- Preliminary results:
  - Ozone: mixing height appears to be the biggest influence in Las Vegas, whereas temperature and solar radiation are bigger in Phoenix, Albuquerque, and El Paso
  - PM: relative humidity, mixing height, and wind speed seem to be strongest predictors in all cities

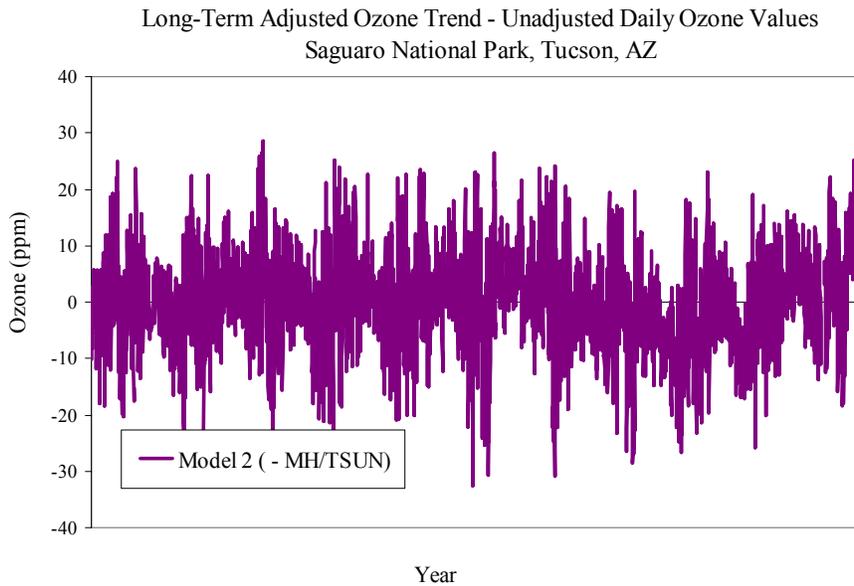
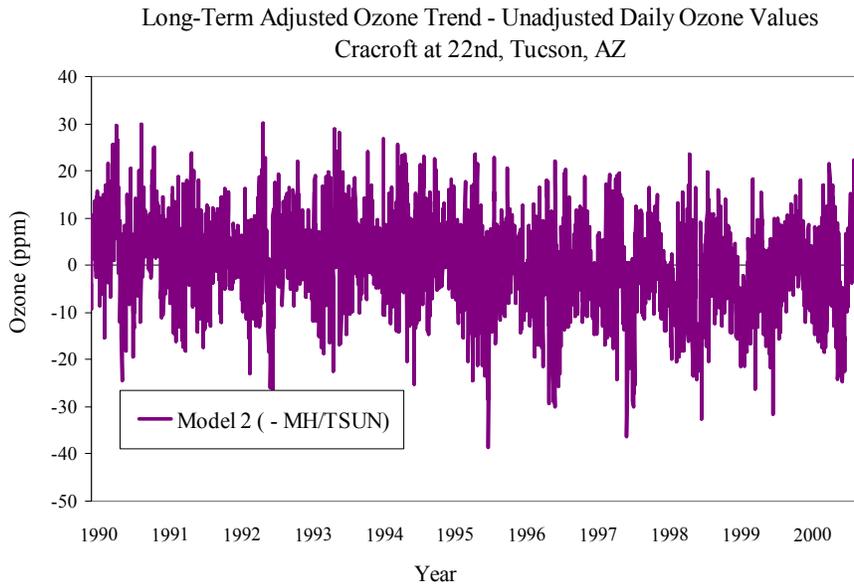


Temp → Maximum Temperature  
 TSUN → Solar Radiation  
 MH → Mixing Height  
 DP → Dew Point Temperature  
 AWND → Average Wind Speed  
 Precip → Precipitation

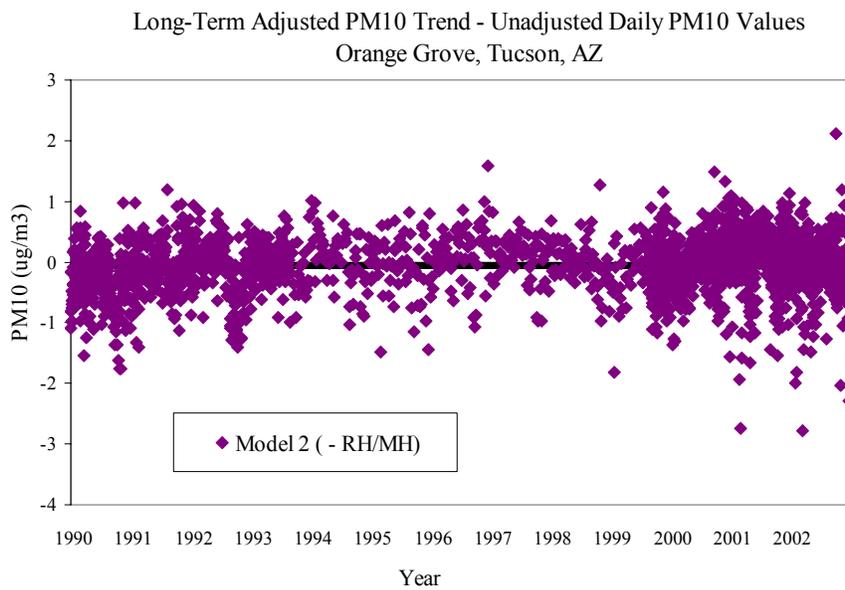
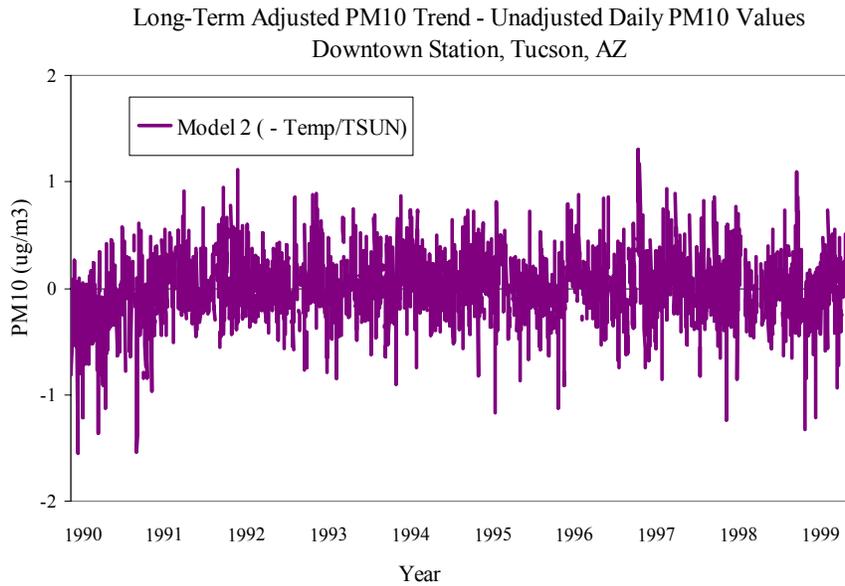
**Figure A1:** Models of meteorologically adjusted long-term Craycroft ozone (above, top) and Saguaro National Park ozone (above, bottom) trends, along with the long-term unadjusted trends. The black line is simply the raw data that has been smoothed to show the long-term trend through time. Each colored line shows estimated ozone values with the influence of one or more meteorological variables (listed after the model number) removed.



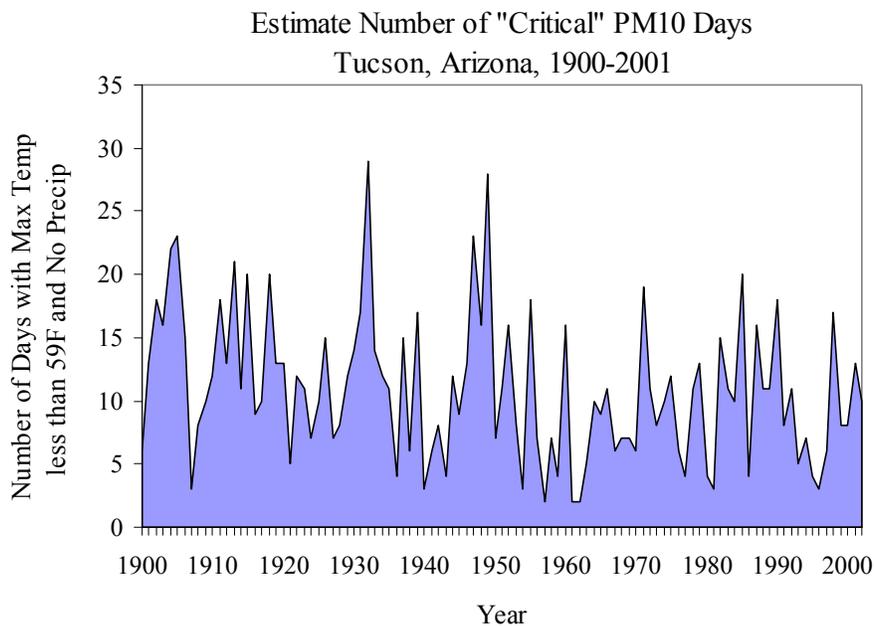
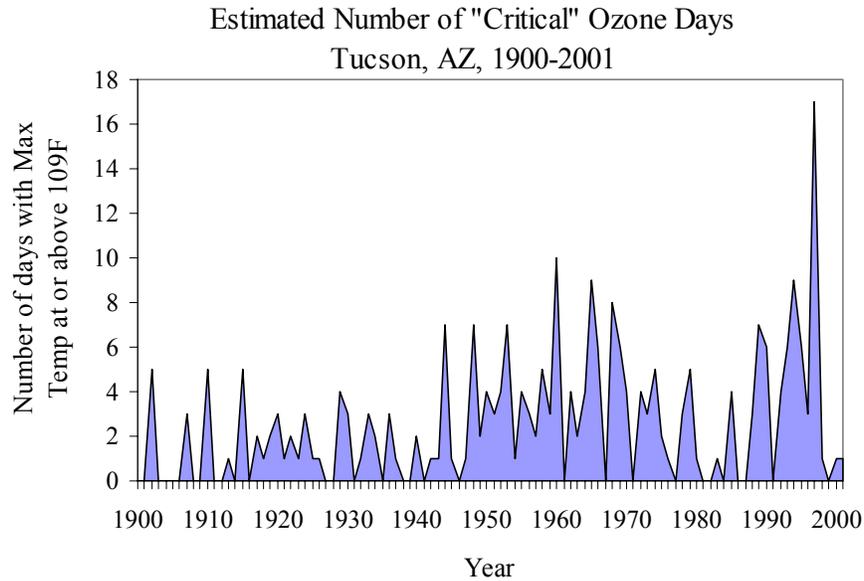
**Figure A2:** Models of meteorologically adjusted long-term Downtown PM (above, top) and Orange Grove PM (above, bottom) trends, along with the long-term unadjusted trends. The black line is simply the raw data that has been smoothed to show the long-term trend through time. Each colored line shows estimated PM values with the influence of one or more meteorological variables (listed after the model number) removed.



**Figure A3:** Differences between daily values of adjusted and unadjusted Cracroft ozone (above, top) and Saguaro National Park ozone (above, bottom) trends. These graphs suggest how different daily ozone values would have been if weather conditions had been “normal” over the time period.



**Figure A4:** Differences between daily values of adjusted and unadjusted Downtown PM (above, top) and Orange Grove PM (above, bottom) trends. These graphs suggest how different daily PM values would have been if weather conditions had been “normal” over the time period.



**Figure A5:** Estimated historical number of “critical” ozone (above, top) and PM (above, bottom) days. The calculated associations between meteorological variables and ozone and PM concentrations over the last 10 years were applied to the historical record and used to estimate historical ozone and PM values. The threshold meteorological conditions associated with “bad” ozone and PM days in Tucson over the last 10 years were matched against the historical record and used to estimate historical high ozone and PM values.

*A.3. Accomplishments anticipated by end of Budget Year (June 1, 2004).*

- Repeat analyses described above in El Paso, Texas; Phoenix, Arizona; Las Vegas, Nevada; and Albuquerque, New Mexico
- Hold another Southwest regional stakeholder meeting to present findings
- Submit two papers for publication

*A.4. Plans for 2004.*

This specific project will be ending in Summer 2004. However, the overall Air Quality/Health and Climate initiative that it currently represents will continue. Plans for 2004-2005 include a return to more specific health and disease-related concerns. In particular, there are good opportunities to leverage CLIMAS funding with other studies in the region on dengue and mosquitoes. There are ongoing dengue studies (NOAA, NSF) in Arizona and Sonora involving the P.I. (Comrie) that include mosquito surveillance and examination of climate controls that could benefit from the CLIMAS stakeholder approach. Public health (and entomology) stakeholders are interested in the role of climate variability as it influences disease outbreaks and the expansion of endemic areas. Given the overlap of the mosquito vector for other emerging infectious diseases, we will also evaluate the potential to include West Nile Virus in our study.

*A.5. Leveraged funding.*

Pima Association of Governments funded a Southwest-wide stakeholder workshop of air quality managers from city, regional and state agencies covering Las Vegas, Phoenix, Tucson, Albuquerque and El Paso. The support was on the order of \$10,000, and was organized by the Udall Center at the UA.

*A.6. Leveraged activities.*

***A.6.1. Greater than 50% CLIMAS***

The workshop was a day-long meeting in April 2003 that included presentations and discussions from the participants, reviewing ongoing work and highlighting climate-related issues. We established important relationships with the regional stakeholders, which enabled us to obtain the necessary data and elucidate the relevant local issues for our study. CLIMAS funded the research work, PAG funded the workshop.

***A.6.3. CLIMAS-related***

Korine Kolivras, previously funded under this element of CLIMAS for the valley fever study, is conducting research on the climate, environmental and social dimensions of the recent dengue outbreak in Hawaii. Expected: three publications.

*A.7. Non-CLIMAS Project Partners.*

Arizona Department of Environmental Quality  
Arizona State University  
Clark County Department of Air Quality  
Desert Research Institute  
Maricopa Association of Governments  
Maricopa County Environmental Services  
National Park Service

Pima Association of Governments  
Pima County Department of Environmental Quality  
Pinal County Air Quality Control District  
U.S. Environmental Protection Agency  
Western Governor's Association

## **Project B: Climate Variability – Drought (Comrie & McPhee)**

### *B.1. Description.*

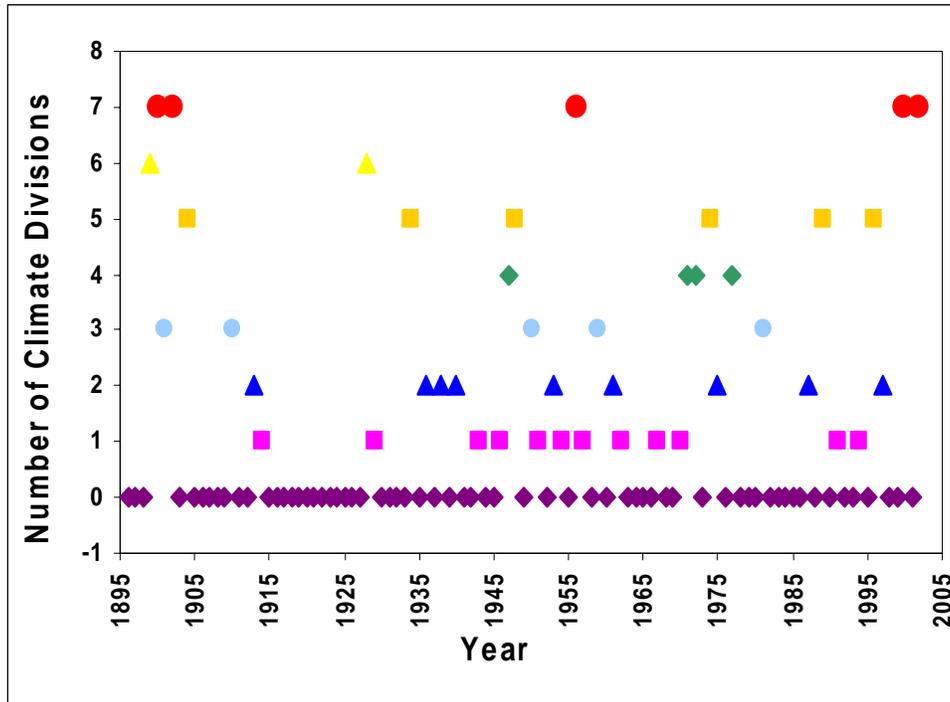
The overall objective of this project is to achieve a comprehensive understanding of the nature and causes of drought in the Southwest, with emphasis on the instrumental period spanning the last century.

- Initial task: co-ordinated work with TRIF, Governor's Drought Task Force, and CLIMAS/ISPE to produce a white paper for task force and others to use. The paper is in Top 10 FAQ style. It included a historical analysis of drought in Arizona: using instrumental data, to "synthesize existing scientific knowledge about past, present, and potential future drought within the state of Arizona in a manner that is intelligible and useful for drought monitoring and assessment."
- Current task: Conduct the same type of study for the Colorado River Basin area to complement the Arizona work.
- Future tasks: Development of atmospheric process-oriented research on the causes of and variability on drought, spatially and temporally, across the Southwest. This potentially includes examinations of finer-spatial scales (PRISM data), the role of elevation, predictability, and the intersection of drought and global change.

### *B.2. Accomplishments to date.*

- During the past semester we completed a historical analysis on drought in Arizona for the period 1895-2002. Simple statistical analyses were performed on data gathered from several different sources to create an overview of drought conditions over the past century in Arizona.
  - Precipitation-related data was analyzed for each of the seven NOAA climate divisions for Arizona covering the period of 1895-2002.
    - Monthly precipitation and the Palmer Drought Severity Index (PDSI) from the National Climatic Data Center (NCDC).
      - The monthly precipitation data was broken down into water years (Oct-Sept) and the seasons of winter (Nov-Apr) and summer (Jul-Sept).
      - These separations allowed for practical interpretations of the data, making them useful for stakeholders and the public.
    - Standardized Precipitation Index (SPI) computed using software from the National Drought Mitigation Center (NDMC).
    - Southern Oscillation Index (SOI) was obtained for the period of 1895-2001 from the Climate Diagnostics Center (CDC).
- Simple statistical analyses were performed on the data including the annual and long-term mean, standard deviation, and coefficient of variation.

- In addition, we plotted time series, sorted the data and calculated precipitation percentages for each climate division, which revealed Arizona’s climate variability and extremes over various spatial and temporal scales.
- Results highlight three major statewide drought periods: the early 1900s, the 1950s and 1998-present. Drought affecting only parts of the state occurs more frequently, and spatial variability of drought highlights large physiographic differences within the state.



**Figure B1:** The number of climate divisions that received less than 75% average water year precipitation. The five years when all climate divisions were very dry simultaneously: 1900, 1902, 1956, 2000, 2002.

NOTE: The “Drought and Climate in Arizona: Top Ten Questions and Answers” document (CLIMAS web site) contains full graphics.

- The analyses were compiled in a comprehensive report titled “Drought and Climate in Arizona: Top Ten Questions and Answers”.
  - The information presented offers support for the Arizona Governors Drought Task Force (GDTF) activities, which include determining triggers for drought mitigation and response actions, based on observed hydroclimatic and other information.
  - The Q&A format allowed for complete and straightforward explanations to educate non-specialists, including stakeholders, decision-makers and the lay public.

- The questions and answers cover the major climate-related aspects of Arizona drought including history, long term averages, seasonality, interannual and long-term spatial and temporal variability, extremes, and climatic forcing.

*B.3. Accomplishments anticipated by end of Budget Year (June 1, 2004).*

- The final revisions are currently underway for the Top Ten Q & A paper and we expect the final product to be delivered to the GDTF in the upcoming weeks of February.
- An appendix for the Top Ten paper will be provided in the next month to serve as supplemental material for all seven climate divisions
- Over the next month we will be performing the same drought history study on parts of the Colorado River Basin (CRB) in the same manner as Arizona.
  - The CRB is very important to Arizona's water supply and must be considered for a comprehensive analysis on drought for the GDTF.
  - The report on the CRB is scheduled for completion by March of 2004 and will serve as an attachment or supplement to the Top Ten Q & A paper.
- We are beginning to develop (as part of Jenna McPhee's Master's thesis research) research on a finer-spatial scale analysis of drought over the Arizona region to look closer at the nature and causes of drought from an atmospheric point of view.
  - Possible research topics include analyzing 4km gridded precipitation data over the area to better define regions that behave similarly in terms of drought (rather than climate divisions), studying differences in elevation of drought (climate variability) or linking drought behavior to climatic phenomena such as El Nino-Southern Oscillation or the Pacific Decadal Oscillation. See also the broader objectives above.

*B.4. Plans for 2004-2005.*

As outlined above, we will be developing drought research as an outgrowth of stakeholder interactions. This includes work on the climatic causes of drought and its variability, spatially and temporally, across the Southwest at horizontal and vertical scales that are as yet unexamined.

*B.5. Leveraged funding.*

Parallel funding from Arizona Prop. 301 (TRIF) for complementary drought work.

*B.6. Leveraged activities.*

A range of coordinated drought outreach and research headed by Gregg Garfin of the CLIMAS Core Office.

*B.6.2. Intra-CLIMAS Spin-offs*

See B.6. above.

*B.6.3. CLIMAS-related*

University of Arizona TRIF drought planning research (Garfin P.I.).

*B.7. Non-CLIMAS Project Partners.*

Arizona Governor's Drought Task Force.

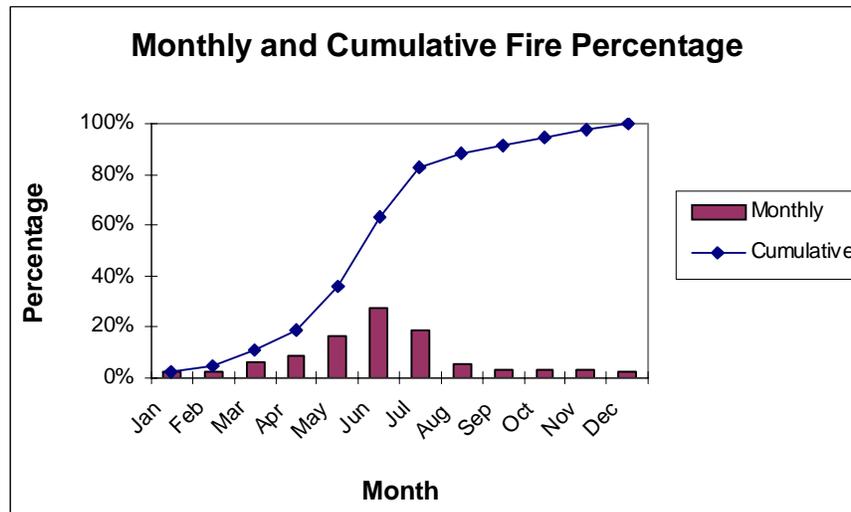
## Project C: North American Monsoon Variability (Comrie & Brandt)

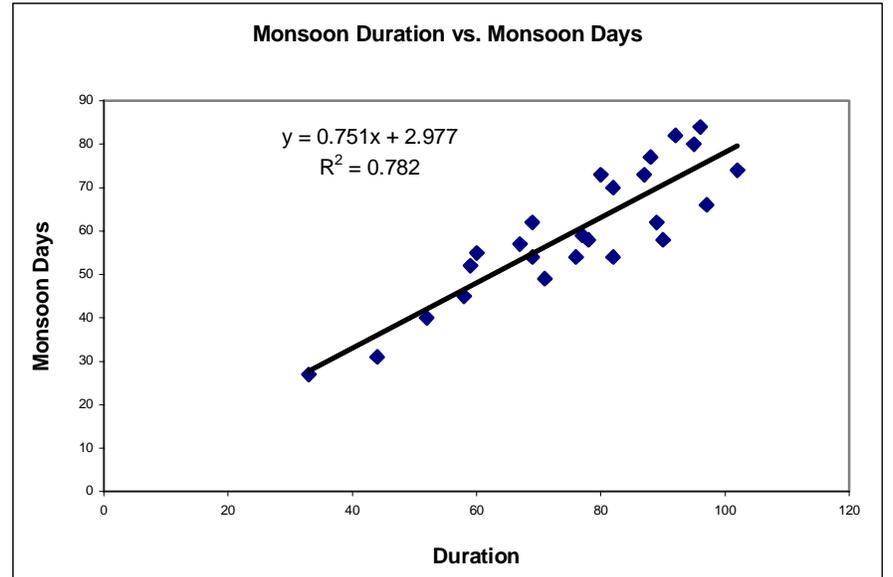
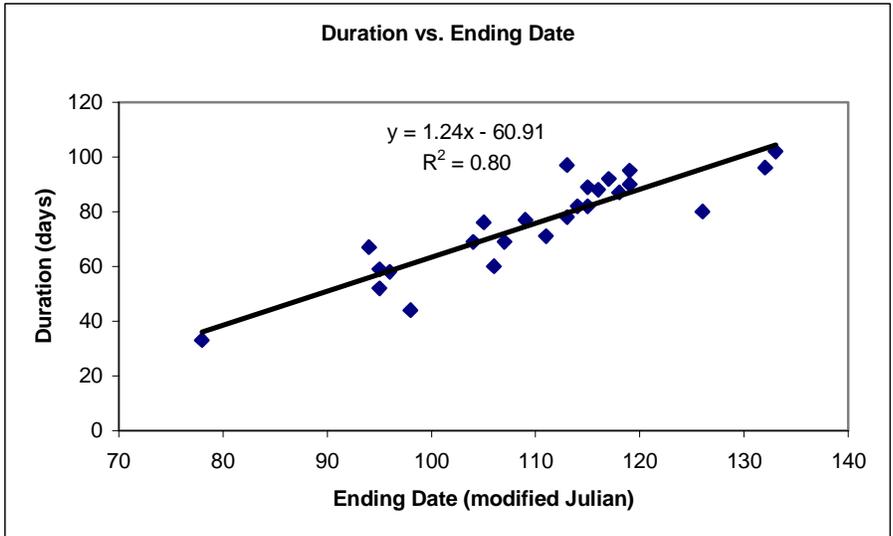
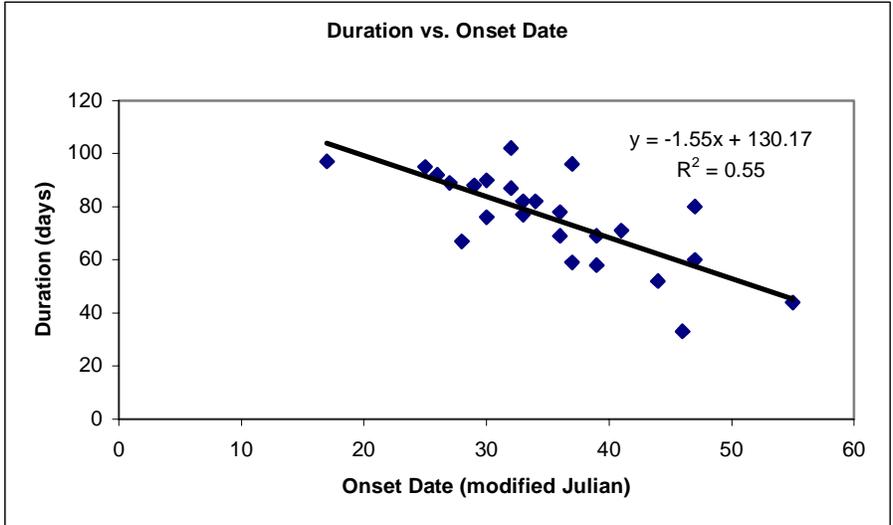
### C.1. Description.

This project picks up on CLIMAS monsoon work carried out by Tereza Cavazos a few years ago. That project focused on predictors of seasonal and intra-seasonal monsoon behavior. The current project investigates the intraseasonal and interannual variability of the North American Monsoon System (NAMS) in the southwestern United States. The first portion of the study focuses on the statistical relationships and variability between the wildfire season and the NAMS in southeastern Arizona from 1977-2001. Part two looks at the variability of monsoon bursts and breaks (i.e., moisture advection during the monsoon) and their possible relationship to fire activity in the region. The final section will concentrate on the spatial and temporal differences in precipitation during the monsoon in Arizona and western New Mexico.

### C.2. Accomplishments to date.

- Performed initial literature reviews for each section with continued updates.
- Refined definition of criteria for monsoon onset and ending across the region.
- Developed database of monsoon onset and ending (and burst/break) dates.
- Analyzed individual characteristics of fire patterns and of monsoon onset and ending dates in SE Arizona from 1977-2001
- The figures below show summary statistics for Tucson, representing southern Arizona. Note that the core fire season peaks in June and then ends abruptly during July, and it is therefore strongly influenced by the monsoon. Interestingly, and perhaps counter to conventional wisdom, the duration of the monsoon is more strongly dictated by the ending date than by the onset date. As expected, longer monsoons contain more days meeting monsoon (“burst”) criteria.





C.3. *Accomplishments anticipated by end of Budget Year (June 1, 2004).*

- Complete the first portion of the study and improve understanding of the relationships between wildfire and NAMS; present findings at Association of American Geographers meeting in mid-March; poster session at PACLIM meeting at end of March
- Perform initial analyses to investigate the climatology of monsoon bursts and breaks and associated fire activity

C.4. *Plans for 2004.*

- Complete part two of the study by mid-fall semester (bursts, breaks, and wildfire)
- Obtain pertinent data and perform analyses to add to understanding of spatio-temporal variability of monsoon precipitation; have at least half of last section completed by end of December

C.5. *Leveraged funding.*

NASA Space Grant graduate fellowship funding for Mike Crimmins.  
WALTER (EPA Star Grant; B. Morehouse, PI) and related stakeholder workshop activities.

C.6. *Leveraged activities.*

C.6.3. CLIMAS-related (e.g., WALTER)

WALTER; Coordination with Mike Crimmins' NASA Space Grant outreach work

C.7. *Non-CLIMAS Project Partners.*

NASA Space Grant  
Southwest Fire Managers (broadly)

## **II. Publications.**

### In print.

Kolivras, K.N. and Comrie, A.C., 2004. Climate and infectious disease in the southwestern United States. *Progress in Physical Geography*, in press.

McPhee, J.C., Comrie, A.C., Garfin, G.M., 2004. Drought and Climate in Arizona: Top Ten Questions and Answers. CLIMAS White Paper, prepared for the Governor's Drought Task Force. Available from ISPE/CLIMAS.

### *Recently appeared in print from previous CLIMAS support:*

Brown, D.P., Comrie, A.C. 2002. Spatial modeling of winter temperature and precipitation in Arizona and New Mexico, U.S.A. *Climate Research* 22, 115-128.

Brown, D.P., Comrie, A.C., 2002. Sub-regional seasonal precipitation linkages to SOI and PDO in the Southwest United States. *Atmospheric Science Letters* 3, 94-102.

- Cavazos, T., Comrie, A.C., Liverman, D.M., 2002. Intraseasonal wave anomalies associated with wet monsoons in Southeast Arizona. *Journal of Climate* 15, 2477-2490.
- Kolivras, K.N., Johnson, P., Comrie, A.C., Yool, S.R. 2001. Environmental variability and coccidioidomycosis (Valley Fever). *Aerobiologia* 17, 31-42.
- Komatsu, K., Vaz, V., McRill, C., Colman, T., Comrie, A., Sigel, K., Clark, T., Phelan, M., Hajjeh, R., Park, B., 2003. Increase in coccidioidomycosis – Arizona, 1998-2001. *Morbidity and Mortality Weekly Report* 52, 109-112.
- Kolivras, K.N., Comrie, A.C., 2003. Modeling valley fever incidence based on climate conditions in Pima County, Arizona. *International Journal of Biometeorology* 47, 87-101.
- Ni, F., Cavazos, T., Hughes, M.K., Comrie, A.C., Funkhouser, G., 2002. Cool season precipitation in the Southwestern United States since AD 1000: Comparison of linear and nonlinear techniques for reconstruction. *International Journal of Climatology* 22, 1645-1662.

Submitted/In Review.

- Brown D.P., Comrie A.C., 2004. A winter precipitation “dipole” in the Western United States associated with multidecadal ENSO variability. *Geophysical Research Letters*. in review.

To be submitted by June 1, 2004.

- Brandt, R.R., Comrie, A.C., Yool, S.R., 2004. Analysis of the impact of the North American Monsoon System on wildfire occurrence in southeastern Arizona. To be submitted to *International Journal of Wildland Fire*, *Journal of Climate*, *International Journal of Climatology*, or similar.
- Wise, E.K., Comrie, A.C., 2004. Determining meteorological controls on tropospheric ozone and particulate matter air quality in Tucson, Arizona. In preparation for *Atmospheric Environment* or *Journal of the Air and Waste Management Association*.
- Wise, E.K., Comrie, A.C., 2004. Assessing climate-related air quality trends in the Southwestern United States. In preparation for *Atmospheric Environment* or *Journal of the Air and Waste Management Association*.

Leveraged peer-reviewed publications.

- Abraham, J.S., Comrie, A.C., 2004: Real-time ozone mapping using a regression-interpolation hybrid approach, applied to Tucson, Arizona. *Journal of the Air and Waste Management Association*, in press.
- Diem J.E., Brown D.P., 2003.. Anthropogenic impacts on summer precipitation in Central Arizona, USA. *Professional Geographer* 55, 343-355.

Wright, E., Long, A., Comrie, A.C., Leavitt, S., Cavazos, T., Eastoe, C., 2001. North American monsoonal moisture sources revealed using temperature, precipitation, and precipitation stable isotope timeseries. *Geophysical Research Letters* 28, 787-790.

### **III. Presentations at Professional Meetings/Conferences.**

- McPhee, J.C., Comrie, A.C., Garfin, G.M. (2004) "A Climatology of Drought for Arizona: An Example of Stakeholder Outreach". Poster Presentation, Annual Meeting of the American Meteorological Society, Seattle, WA, January 2004
- McPhee, J.C., Comrie, A.C., Garfin, G.M. (2004) "A Climatology of Drought for Arizona: An Example of Stakeholder Outreach". Poster Presentation, Annual Meeting of the Association of American Geographers, Philadelphia, PA March 2004
- McPhee, J.C., Comrie, A.C., Garfin, G.M. (2004) "A Climatology of Drought for Arizona: An Example of Stakeholder Outreach". Poster Presentation, 21st Annual Pacific Climate Workshop on Climate Variability of the Eastern North Pacific and Western North America, Monterey, CA March 2004.
- Wise, E.K. 2003. Meteorologically-Adjusted Air Quality Trends in Tucson, Arizona. Presented at the 66th Annual Meeting of the Association of Pacific Coast Geographers, September 17-20, 2003, Portland, OR.
- Wise, E.K., A.C. Comrie. *Assessing Meteorological Controls on Air Quality Trends in the Southwestern United States*. To be presented at the 100<sup>th</sup> Annual Meeting of the Association of American Geographers, March 14-19, 2004, Philadelphia, PA.

### **IV. Outreach Activities.**

- First Pima County stakeholder meeting held in December 2002  
Represented organizations:
  - Arizona Department of Environmental Quality
  - Pima County Department of Environmental Quality
  - Pima Association of Governments
  - U.S. Environmental Protection Agency
  - University of Arizona
- Second Pima County stakeholder meeting April 2003  
Represented organizations:
  - Pima County Department of Environmental Quality
  - Pima Association of Governments
  - University of Arizona
- Second Southwest regional stakeholder meeting (August 2004 tentative)  
Represented organizations:
  - Arizona Department of Environmental Quality
  - Pima County Department of Environmental Quality
  - Pima Association of Governments
  - U.S. Environmental Protection Agency
  - University of Arizona
  - Western Governor's Association
  - Maricopa Association of Governments
  - Maricopa County Environmental Services

- National Park Service
- Arizona State University
- Clark County Department of Air Quality
- Desert Research Institute
- Pinal County Air Quality Control District
- Presentation of the Top Ten Drought material to the Governor's Drought Task Force (Comrie).

#### **V. Human Resource Development (e.g., theses, training)**

Erika Wise (GRA): master's thesis, two journal papers, multivariate statistics training, time-series analysis training, is now applying for Ph.D. programs in the climate and health field (incl. UA).

Korine Kolivras (GRA for earlier valley fever study): subsequently completing Ph.D. dissertation on dengue in Hawaii, recently hired as an Assistant Professor at Virginia Tech based in part on her work for CLIMAS. She will be continuing her career as a climate & health researcher.

Climate Variability-Recent, Project B forms the basis of Jenna McPhee's Master's work, and the process research will become her thesis in 2004-2005.

Climate Variability-Recent, Project C is the focus of Rick Brandt's Ph.D. dissertation work. Rick recently passed his comprehensive examinations and he is developing the monsoon-fire question in several dimensions, as outlined earlier in this section. He is likely to have a large part of the work completed over summer 2004, possibly continuing through December 2004 depending on findings and on the subsequent breadth and depth of necessary climatological work.

**TASK AREA:** Snowpack and water supply outlooks

**PI:** Roger Bales

**Researchers:** Kevin Dressler, Noah Molotch (GRAs)

### **Progress for Budget Year 2003-2004**

#### **Project A. Assess utility of seasonal water supply outlooks and regional hydroclimatic patterns, with particular emphasis on snowpack.**

*A.1 Description* Forecast evaluation results were to springboard exploration of the role of hydroclimatic variability and uncertainty in water resources and other resource management decisions. Particular emphasis was placed on remote-sensing snow products developed under NASA-RESAC (Regional Earth Science Application Center) and both experimental and operational products developed by NWS-NOHRSC (National Operational Hydrologic Remote Sensing Center), as a means to evaluate and improve outlook skill. As a first priority for decision-making, water resource managers want to know how much snow is in the mountains and how rapidly it is being depleted.

Two separate tasks were undertaken to achieve these goals. The first involved spatial evaluation of water supply outlooks, gridded (experimental) outlooks and snow products (time series of Snow-Covered Area and Snow Water Equivalent). In addition, stakeholders need to better understand the uncertainties associated with snowpack and snowmelt runoff forecasts. This leads to the second task, which is exploring with the stakeholders how improvements in the snow products enhance stakeholder decision-making. The processes controlling the hydrologic cycle in mountainous regions are highly variable in time and space, requiring remote sensing to observe regional and global-scale processes and intensive field observations to observe hillslope-scale phenomena. Currently, our understanding of the processes occurring at these two scale extremes is largely disconnected, inhibiting the transferability of studies at the different scales and limiting the accuracy of water supply forecasts. Further, the spatial and temporal non-linearity of surface hydrological processes requires dynamic simulations tailored to the scale of the application. Thus, our efforts have been aimed at merging ground-based and remotely sensed observations within hydrologic models. A third task, which links the first two tasks with other CLIMAS investigations, involves writing papers and giving talks that give a synthesis of CLIMAS results and knowledge.

*A.2 Accomplishments to date.* In an effort to transfer the understanding of hydrological processes at different scales, and hence improve water supply outlooks, we have undertaken investigations in water supply outlooks, in gridded (experimental) snowmelt outlooks incorporating remote sensing data, and in snow pattern assessment from estimates of snow-covered area and snow water equivalent. Analyses and figures regarding NWS-NOAA water supply outlooks were completed in fall 2003. A paper by Franz et al. submitted in 2003 was published, while a paper based on the analysis should be ready to submit by June 1. A paper describing the results of our analysis of the historical official water supply forecasts is in progress.

Water supply outlooks rely heavily on point ground-based observations of snow water equivalent made at snow courses and snow telemetry (SNOTEL) stations. Increasing demand (i.e. by stakeholders such as in the Salt River Project) for spatially distributed estimates of SWE has fueled our interest in using statistical models to spatially distribute point SWE observations. Uncertainty in the output of these statistical models is enhanced by error in physiographic independent variables. We evaluated this uncertainty by comparing the results of snow distribution models using a variety of input digital elevation models. Snow distribution models are extremely sensitive to the digital elevation models used to derive independent variables and to the selection of variables (paper in press). In an effort to improve forecasts, remotely sensed snow surface albedo data were incorporated into a spatially distributed snowmelt model. Model accuracy increased substantially with the inclusion of these new data. A paper about the gridded (experimental) snowmelt outlooks incorporating remote sensing data is in press.

Snow products at resolutions coarser than about 1 km<sup>2</sup> fail to capture the variability in terrain that controls snowcover in mountains, especially considering that during much of the year snow primarily occurs in high-elevation areas that are a few km to tens of km wide. The RESAC remotely sensed AVHRR fractional snow-covered area (SCA) product was compared with the NOHRSC binary product to characterize the resolution issue. This fractional product gives significantly different snow coverage than do binary products, resulting in 20-50% differences in basin-wide snow water equivalent (SWE) estimates. Areas with persistent snowcover are relatively reproducible from year to year, and correspond to higher elevations. However, the annual maximum snow extent, or area with any snowcover during the year, exhibited significant interannual variability, and was not well-correlated with maximum SWE. While the current SCA and combined SCA-SWE product are a clear step toward improved spatial snow estimates, there are several areas for possible future improvement, including: i) using vegetation information to improve snow mapping in forested areas; ii) developing more-representative ground-based measurements; and iii) using data with more spectral properties, such as MODIS, to improve separating snow from other landcover. A manuscript is in progress for submission to Water Resources Research.

We have used stakeholder interaction to determine the utility of snow product improvement in enhancing stakeholder decision-making. Our collaboration with U.S. Geological Survey researchers has transferred our improved snowmelt and snow distribution algorithms closer to the sort of operational snowmelt runoff models used by the Bureau of Reclamation. During the next reporting period we plan to realize the utility of these improved algorithms for stakeholder decision-making. A synthesis paper on CLIMAS results and knowledge, submitted in 2003, has been accepted by the Bulletin of the American Meteorological Society, pending minor revisions.

*A.3. Accomplishments anticipated by end of Budget Year.* We anticipate the development of the first experimental forecasts (proof of concept) using gridded snow data, for upper Rio Grande and Salt River headwaters. We also plan to complete a manuscript on analysis of snow persistence patterns using gridded data. Noah Molotch is expected to complete his doctoral work on snow telemetry.

*A.4. Plans for 2004.* We plan to devote considerable effort toward working with water resource stakeholders and researchers not only in the CLIMAS region but across the West to facilitate and assess the use of snow products to enhance stakeholder decision-making. As part of this effort we will continue collaborating with researchers responsible for developing the operational snowmelt models used by stakeholders (e.g. USGS, NOAA operational forecasting centers). By interacting with these groups we hope to identify the critical needs for experimental forecasts and provide snowpack information and improved snowmelt algorithms to satisfy needs. Our knowledge and use of standard snowpack products (e.g. from NOAA-NWS) and involvement with the development of custom products (e.g. NASA-REASoN) will facilitate the proposed improvement to stakeholder decision support.

We aim to initiate/continue a number of experimental uses for improved snow information through partnerships with the applications community and other researchers (e.g. fire risk management, flood hazard evaluation, and agricultural vulnerability to climate stresses). Our annual one-day workshop, planned for fall 2004, will engage stakeholders in discussions covering issues such as data quality, user interfaces, value-added products, successful application, problems encountered, and future user needs. Through the workshop and our complimentary efforts described above we hope to demonstrate the need for a NOAA and/or private sector system to serve custom snow information to stakeholders on demand. As a demonstration exercise in support of stakeholder interaction, we plan to improve the ability of water-supply forecasts and decision-support tools (e.g. NWS forecasting tools) to make use of standard and custom snow products. Increasing the complexity of operational algorithms will enable the incorporation of the best-suited snow information. On-going leveraged research (e.g. SAHRA) will develop these value-added algorithms and will provide the basis for assessing the ability of the algorithms to improve model performance.

A major source of uncertainty in snowmelt runoff modeling, and hence water supply forecasts, is our ability (or inability) to understand the distribution of hydrometeorological variables. Our research will use micrometeorological observations to estimate uncertainty in spatially distributed estimates of hydrometeorological variables. The spatial data will be used to force energy balance snowmelt models of varying degrees of complexity at high resolution (i.e., 0.5 to 1 km<sup>2</sup>). This spatial modeling and complex representation of the energy balance will facilitate the assimilation of multiple snow products (i.e., spatial SCA from remote sensing, spatial SWE from SCA blended w/ remote sensing, and ground measurements) into the modeling procedure.

*A.5. Leveraged funding*  
NASA REASoN grant

*A.6. Leveraged activities*

Our NASA-REASoN project is a collaborative effort with the University of California-Santa Barbara (UCSB). The main focus of the UCSB efforts will be to develop and produce on-demand remote sensing snow products, primarily from MODIS and LANDSAT (and possibly AVHRR). This award compliments the CLIMAS scope of

work in that its aim is to connect snow remote-sensing products developed and distributed under this REASoN project with applications in snowmelt runoff modeling. We will work closely with both the research and applications community to incorporate information derived from these snow products into experimental modeling systems.

## **II. Publications**

### In print

Franz, K.J., Hartmann, H.C., Sorooshian, S., Bales, R.C., 2003. Verification of National Weather Service ensemble streamflow predictions for water supply forecasting in the Colorado River basin, *Journal of Hydrometeorology*, 4(6): 1105-1118.

### In press

Molotch, N.P., Bales, R.C., Colee, M.T., Dozier, J., in press. Estimating the spatial distribution of snow water equivalent in an alpine basin using binary regression tree models: the impact of digital elevation data and independent variable selection, *Hydrological Processes*.

### Submitted/In review

Bales, R.C., Liverman, D.M., Morehouse, B.J., accepted pending revisions. Reducing climate vulnerability through integrated assessment in the southwestern United States, *Bulletin of the American Meteorological Society*.

### To be submitted by June 1, 2004

Bales, R. C., Dressler, K.A., Imam, B., Lampkin, D., Fassnacht, S.R., in preparation. Fractional snow cover in the Colorado River and Rio Grande basins, 1995-2002.

Molotch, N.P., Bales, R.C., in preparation. Assessing Snow Telemetry (SNOTEL) station representativeness in the Rio Grande headwaters using field-based methods and statistical models. *Water Resources Research*.

### Leveraged peer-reviewed publications

Molotch, N.P., Painter, T.H., Bales, R.C., Dozier, J., 2004. Incorporating remotely sensed snow albedo into spatially distributed snowmelt modeling, *Geophysical Research Letters*, VOL. 31, L03501, doi:10.1029/2003GL019063.

Molotch, N.P., Fassnacht, S.R., Bales, R.C., and Helfrich, S.R., 2004. Estimating the distribution of snow water equivalent and snow extent beneath cloud-cover in the Salt-Verde River basin, Arizona, in press, *Hydrological Processes*, VOL. 18, doi: 10.1002/hyp.1408.

## **III. Presentations at Professional Meetings/Conferences**

Bales, R., Satellite snowcover perspective on the drought: Colorado and Rio Grande basins. Proceedings of the 71<sup>st</sup> Western Snow Conference, 21-24 April 2003, Scottsdale, Arizona.

Bales, R., Brice, R., Imam, B., Lampkin, D., 2003. Seasonal and interannual variability in Colorado River and Rio Grande snowcover patterns: 1995-2002. *Eos . Trans. American Geophysical Union*, 84(46), Fall Meeting Supplemental Abstract C41B-0969, 8-12 December 2003, San Francisco, California.

Dressler, K.A., Fassnacht, S. R., Bales, R.C., 2003. Snow covered area and vegetation data considerations in modeling snowmelt streamflow for two southwestern US headwater basins. IUGG General Assembly, 30 June – 11 July, Sapporo, Japan.

Molotch, N.P., Painter, T.H., Bales, R.C., Dozier, J., 2003. Optimization of binary regression tree models for estimating the spatial distribution of snow water equivalent in an alpine basin, Proceedings of the 71<sup>st</sup> Western Snow Conference, 21-24 April 2003, Scottsdale, Arizona, USA (Best Paper Award).

Bales, R. C., 2003. Fractional snow cover in the Colorado River and Rio Grande basins, 1995-2002, paper presented at 12<sup>th</sup> Paclim meeting, Integrated Climate Research in Mountain Regions, 6-9 April 2003, Pacific Grove, CA.

#### **IV. Outreach Activities.**

Bales participated in Merced River Stakeholders (Upper and Lower) meetings (October 2003-February 2004) to develop hydrology information dialogue with the Central Valley and Sierra foothills communities.

At the SAHRA annual meeting in October 2003, we discussed the operational implications of our on-going research in the Rio Grande headwaters with Rolf Schmidt-Petersen of the New Mexico Interstate Stream Commission. We also delivered our value-added snowmelt algorithms to George Leavesley of the U.S. Geological Survey to be developed into a module for the Modular Modeling System (MMS) and integrated into the Bureau of Reclamation's operations.

Bales attended March 2003 and follow-up meetings with resource managers in Sequoia-Kings Canyon and Yosemite National Parks and Sierra National forest.

Bales spoke at February 2004 meeting with Panoche water district in San Joaquin Valley about long-term climate and hydrology research agenda for the valley.

February 2004 talk at San Joaquin Parkway trust in Fresno, a group representing many decision-makers in the middle San Joaquin basin.

#### **V. Human Resource Development**

Noah Molotch is expected to complete his doctoral work in May 2004.

Kevin Dressler is expected to complete his doctoral work in late 2004.

**TASK AREA:** Fire Research  
**PI:** Thomas W. Swetnam  
**Researchers:** Erica Bigio (GRA)

## **I. Progress for Budget Year 2003-2004**

### **Project A: History of Southwest Crown Fires and Geomorphic Response.**

A.1. *Description.* This project began in January 2004, although formal interactions with CLIMAS were established during 2003-2004 bi-weekly team meetings and mini-retreats. Funding for this work has commenced with support for a Geosciences graduate research assistant, Erica Bigio, during the spring semester 2004. The project focuses on persistent long-term climate processes affecting the Southwest, such as drought, and the role of major droughts in creating conditions conducive to high-intensity crown fires. Crown fire history is a topic of interest to fire management stakeholders, especially due to their role in leading to post-fire flooding and debris flows.

A.2. *Accomplishments to date.* Work has just begun on a developing a research plan for Bigio's master's thesis research.

A.3. *Accomplishments anticipated by end of Budget Year (June 1, 2004).* We expect to complete a study plan for Bigio's thesis research, which will focus on long-term climate and fire relationships in the Southwest, specifically the role of major droughts and high-intensity crown fires in leading to flooding and debris flows. We expect to have collected preliminary tree-ring samples from at least one study site.

A.4. *Plans for 2004.* We plan to firm up research plans, identify study sites, and begin collecting samples and data.

A.5. *Leveraged funding.* Bigio was recruited to come to the UA in fall 2003, and the Laboratory of Tree-Ring Research supported her during fall 2003 through a teaching assistantship.

A.6. *Leveraged activities.*

A.6.3. CLIMAS-related. CLIMAS PI Swetnam continues collaborations with co-PIs on the WALTER (EPA Star Grant; B. Morehouse, PI) project.

## **II. Publications**

### Submitted/In Review.

Hessburg, P.F., Kuhlman, E. E., Swetnam, T.W. Interdecadal drought and wetness patterns in the Northwest United States, 1675-2000. In review, *Ecological Applications*.

### Leveraged peer-reviewed publications.

T. T. Veblen, Baker, W., Montenegro, G., Swetnam T.W., (Eds.), 2003. *Fire and Climatic Change in Temperate Ecosystems of the Western Americas*. *Ecological Studies* Vol. 160. Springer, New York, 444 pp.

Swetnam, T. W., Baisan, C.H., 2003. Tree-ring reconstructions of fire and climate history in the Sierra Nevada and Southwestern United States. In: T. T. Veblen, W. Baker, G. Montenegro, and T. W. Swetnam, (Eds.), Fire and Climatic Change in Temperate Ecosystems of the Western Americas. Ecological Studies Vol. 160. Springer, New York, pp. 158-195.

Milne, B.T., Moore, D. I., Betancourt, J. L., Parks, J. A., Swetnam, T.W., Parmenter, R.R., Pockman, W.T., 2003. Multidecadal drought cycles in south-central New Mexico: Patterns and consequences. In D. Greenland, D. G. Goodin, and R. C. Smith (Eds.), Climate Variability and Ecosystem Response at Long Term Ecological Research (LTER) Sites. Oxford University Press, New York, pp. 286-307.

Westerling, A. L., Swetnam, T. W., 2003. Interannual to decadal drought and wildfire in the Western US. EOS, Transactions of the American Geophysical Union, 84(49):545-560.

### **III. Presentations at Professional Meetings/Conferences.**

Swetnam, T., 2003. Fire and Climate in SE Arizona and the Southwest. Mount Graham Red Squirrel Symposium, Safford, AZ. May 21, 2003.

Swetnam, T., 2003. Fire, Climate and People. Arizona Geological Society meeting, Tucson, AZ Jun 3, 2003.

### **IV. Outreach Activities.**

CLIMAS PI Tom Swetnam currently serves on the Arizona Governor's Forest Health Advisory Council. The council's function is to provide scientifically-based advice and recommendations to the governor on matters relating to forest fires, forest health, forest restoration issues in the state of Arizona (see <http://www.governor.state.az.us/FHC/>).

### **V. Human Resource Development**

Bigio's master's thesis research.