



Annual Progress Report
2004-2005 Budget Year

March 2005

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CLIMAS Annual Progress Report: 2004-2005

TASK AREA: Core Office

PI: Dr. Jonathan Overpeck, Institute for the Study of Planet Earth

Researchers:

Dr. Gregg Garfin (Program Manager), Dr. Melanie Lenart, Dr. David McGinnis, Dr. Jean Morrill (Research Scientists, Core Office);

Joe Abraham, Rick Brandt, Rebecca Garcia, Alexa Gilbert, Susan Simpson, Casey Thornbrugh (GRAs, Geography and Regional Development); Sean Downey (GRA, Anthropology), Srinivasa Ponnaluru (GRA, Agricultural and Resource Economics), Rahul Srivastava (GRA, Urban Planning)

I. Progress for Budget Year 2004-2005

Project A: CLIMAS Southwest Climate Outlook

A.1. Description. The Southwest Climate Outlook (SWCO), an extension of the 2002-2003 END InSight initiative, is a monthly drought and climate report for Arizona and New Mexico. Each month, the SWCO includes (1) a multi-page newsletter article, written in an easy-to-comprehend journalistic style, featuring a topic of interest to Southwest decisionmakers; (2) pages covering recent conditions, forecasts, and forecasts verification – including maps, graphs, and text; and (3) an executive summary highlighting the main features of the climate of the Southwest during the past month. CLIMAS sends the SWCO to approximately 1600 stakeholders through an e-mail listserv, with hot links to a PDF version; the information is duplicated in HTML format on the CLIMAS web site.

A.2. Accomplishments to date. During 2004-2005, we improved the format of the SWCO, and garnered favorable feedback from recipients in a summer 2004 survey. Until October, 2004, when Arizona drought planning activities were completed, the SWCO was provided to the Arizona Governor's Drought Task Force (GDTF); the GDTF served the SWCO through their web site, and in print copies at GDTF public meetings. In 2004, news articles, one of the most highly praised aspects of the SWCO, included contributions from partners, such as Arizona Cooperative Extension, and the University of Arizona Water Resources Research Center. Several articles featured NOAA science, including East Pacific hurricane forecasts, the NAME project, and a round table discussion on drought – with participants from NOAA-CDC. In addition, the NOAA Western Water Assessment RISA launched the "Intermountain West Climate Outlook," based on the SWCO, and with advice and input from CLIMAS.

The U.S. Bureau of Reclamation provided funding for the SWCO during 2004; since then, the project has been funded through a partnership between the CLIMAS Core Office, the University of Arizona Institute for the Study of Planet Earth (UA-ISPE), and the University of Arizona Department of Soil, Water, and Environmental Science. CLIMAS is in the process of transitioning this successful product to operations through Arizona Cooperative Extension (see below for details); Climate Extension Specialist,

Mike Crimmins, now co-manages the content of the SWCO with the CLIMAS Core Office.

A.3. Accomplishments anticipated by end of Budget Year. We will continue to provide monthly climate information through the CLIMAS News listserv, the CLIMAS website, and through the Arizona Climate Extension Specialist (funded, in part, by NOAA). By June 2005, we will generate a SWCO spin-off pilot project – a U.S.-Mexico border region climate outlook. The aforementioned pilot project is being conducted in conjunction with a NOAA-funded project assessing decision maker use of climate information in northern Mexico.

A.4. Plans for 2005-2006. We expect transition the SWCO to Arizona Cooperative Extension. We believe that Arizona Cooperative Extension is the best choice for handoff, as (1) they have extensive experience providing technical information to stakeholders throughout Arizona, (2) by providing information through their network of extension agents and specialists we ensure that rural stakeholders (including watershed alliances), and those without regular access to the Internet, will have access to the information, and (3) the new Climate Extension Specialist will be able to provide technical support and the type of personal guidance and interaction that is the hallmark of Cooperative Extension throughout the United States. In fact, Mike Crimmins, the Climate Extension Specialist, has already reported that cooperative extension agents in several counties are interested in distributing the SWCO more widely through their face-to-face interactions with rural stakeholders, watershed alliances, and other interested decision-makers. The CLIMAS Core Office has plans to work with Crimmins, the National Weather Service, and the State Climatologist, in order to provide county-level climate information and analysis through Cooperative Extension.

A.5. Leveraged funding. The U.S. Bureau of Reclamation provided funding during the 2004 calendar year. The UA-ISPE and the UA Department of Soil, Water, and Environmental Science will provide funding through July 2005.

A.6. Leveraged activities.

A.6.1. Greater than 50% CLIMAS funding. CLIMAS-SAHRA Press Briefings. The CLIMAS Core Office continued its series 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). During 2004-2005, we held three more briefings, focused on climate change (including a screening of *The Day After Tomorrow* for Arizona media, followed by a “reality check” with CLIMAS and SAHRA scientists), urban water, and wildfire. In August, 2004, researcher Lenart gave a presentation on stakeholder preferences for climate products at the Ecological Society of America’s annual conference.

A.7. Non-CLIMAS Project Partners and Contributors. Arizona Governor's Drought Task Force; U.S. Bureau of Reclamation; Arizona Department of Water Resources; University of Arizona Cooperative Extension; NOAA Climate Diagnostics Center; National

Weather Service Forecast Offices, Arizona State Climatologist, University of New Mexico, SAHRA.

Project B: Drought Research

B.1. 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 mainly on drought planning, and are designed to inform, augment, and complement Arizona drought planning activities conducted by the GDTF, and by the Arizona Drought Monitoring Committee (ADMC).

The key topics for CLIMAS 2004-2005 drought research are as follows:

- Drought climatology and drought monitoring;
- Theoretical framework for long-term monitoring and assessment of drought vulnerability;
- Drought mitigation and adaptation strategies;
- Drought exacerbated human-wildlife conflicts at the wildland-urban interface;
- Impediments to drought planning in rural areas;
- Drought and climate impacts on tourism and recreation.

Drought educational materials and outreach, produced in coordination with the GDTF (i.e., CLIMAS Southwest Climate Outlook – see Project A), synthesizes recent climatological conditions and forecasts and packages them in a manner that is accessible and easy for laypeople and non-experts to understand.

B.2. Accomplishments to date. In collaboration with members of Arizona's multi-agency Drought Monitoring Committee (ADMC), CLIMAS established a system for monitoring drought, reporting drought status, and triggering drought response. Part of the aforementioned was an exercise, coordinated by CLIMAS Core Office researcher Gregg Garfin, in which stakeholders evaluated ADMC hindcasted drought status. CLIMAS Core Office researcher Gregg Garfin serves as co-chair of the ADMC, and has devoted considerable effort to coordinating ADMC activities. Garfin briefed the GDTF at several public meetings (see below), and presented the state's drought monitoring and trigger system to stakeholders at 6 public meetings in rural Arizona during Fall 2004. In May, 2004, Garfin provided Arizona Governor Janet Napolitano with briefing materials on the state of the drought; Garfin briefed the Central Arizona Project Governing Board on drought and climate change, and he presented a keynote talk at a January 2005 Water Conservation Leadership Forum attended by Governor Napolitano and Senator John McCain. Garfin also led ADMC efforts to improve Arizona drought monitoring infrastructure, based on the model of the Oklahoma Mesonet. Garfin wrote a narrative and budget which are being used by the Arizona Department of Water Resources

(ADWR) as the basis of proposed legislation to improve the state's drought monitoring capabilities. Garfin is working with Sandy Whitney of ADWR on drought plan implementation projects, including: developing an Arizona drought monitoring web site, and developing drought impacts monitoring protocols. Garfin, along with CLIMAS PI Morehouse, and associate/collaborator and University of Arizona extension specialist Katharine Jacobs, are co-authors of several Arizona Drought Preparedness Plan and State Conservation Strategy chapters. Jacobs and Garfin published a peer-reviewed paper on Arizona drought planning; Jacobs, Garfin, and Morehouse have a paper on drought planning in press.

During 2004, CLIMAS drought and society researchers delivered several white papers to the GDTF. The papers were made available to the public on the Governor's Drought Task Force web site. Parts of these papers were incorporated into the content of the Arizona Drought Preparedness Plan. In addition, CLIMAS drought and society researchers are involved in a variety of research and activities that will give insight and guidance to the Arizona Department of Water Resources as that agency implements the state drought preparedness plan.

- Researcher Jenna McPhee, in conjunction with Comrie and Garfin, delivered *Drought and Climate in Arizona: Top Ten Questions & Answers*, a white paper on Arizona drought climatology, to the GDTF in March, 2004. It is available through the CLIMAS website, and was distributed in print at a number of statewide drought meetings. In Fall 2004, McPhee, Comrie and Garfin produced *Drought and Climate of the Upper Colorado River Basin Region: The FAQs*. The paper is in review; this spring it will be delivered to the Arizona Department of Water Resources, and it will be made available in print and as a PDF on the CLIMAS website.
- Researcher Simpson delivered *Impacts of Drought on Arizona's Wildlife and in Increasing Urban Human-Wildlife Conflicts: The Confounded Influence of Ecology, Animal Behavior, and Human Societal Values* to the GDTF in June, 2004. She and Garfin are revising the manuscript for publication in *Human Dimensions of Wildlife*. Simpson is continuing her research on perceptions of drought and human-wildlife interactions; the research is the basis of her M.A. research.
- In conjunction with CLIMAS PI Barbara Morehouse, Garfin and graduate students analyzed newspaper articles from 2002-2004, in order to garner lessons learned about how drought-surface water issues are portrayed in the popular press. Their study contrasted events in Arizona with those in New Mexico. They submitted a manuscript entitled "Discursive Framing of Drought" to *Global Environmental Change*.
- In conjunction with CLIMAS PI George Frisvold, researcher Ponnaluru is developing a statistical model to explain relationships between drought, tourism in national and state parks, and intervening socioeconomic factors. His research will be the basis of a Master's thesis, and will provide guidance to the National Park Service, Northern Arizona University, and the Arizona Department of Water Resources drought plan implementation effort. Ponnaluru's research is funded through the CLIMAS Core Office; Garfin is an advisor on climatology issues.

- Researcher Abraham completed a draft manuscript *Assessing Drought Impacts and Vulnerabilities for Long-Term Planning and Mitigation Programs*, that will be submitted this spring to *Natural Hazards*, pending review by his Ph.D. dissertation committee. (N.B. – the paper is the first chapter of his dissertation).
- Researcher Downey delivered *Drought Mitigation and Adaptation: Discussions with State Drought Planners* to the GDTF in July, 2004. Downey, with Abraham and Garfin are revising the manuscript for submission to a peer-reviewed journal in spring 2005.
- Researcher Gilbert conducted interviews, on impediments to drought plan implementation in rural Arizona, with key stakeholder contacts in the Little Colorado River Basin and Mogollon Rim country. Her white paper manuscript, which will provide invaluable guidance to the ADWR, will be completed by June, 2005.
- In response to an Arizona Drought Preparedness Plan recommendation for collection of drought impacts data, and in response to needs expressed by the public during GDTF Drought Plan workshops, researchers Thornbrugh and Garfin, in conjunction with ADWR and the National Drought Mitigation Center, are developing a drought impacts database and protocols for data collection and input. A preliminary version and accompanying white paper will be completed by June, 2005. One component of the drought impacts database is a drought newspaper article archive, from which researcher Rebecca Garcia is developing an Arizona Drought timeline and accompanying narrative.
- Researcher Brandt delivered a new reservoir status map to USDA-NRCS in May, 2004. CLIMAS received positive feedback on the map in a web-based survey of the product.

The CLIMAS *drought and society work group* meets biweekly to discuss progress, potential synergy in research efforts, and conceptual issues regarding drought and drought impacts. During 2004, Garfin was a member of the integrated team for the Western Governors' Association National Integrated Drought Information System (NIDIS), and contributed to the WGA's 2004 NIDIS report. In Fall 2004, Garfin, along with ADWR's Sandy Whitney, presented a seminar on drought to Project CENTRL – Cooperative Extension's rural leadership program.

B.3. Accomplishments anticipated by end of Budget Year. We will continue our integrated drought research, work on drought monitoring, coordination with ADWR on aspects of drought plan implementation. By the end of the budget year, we expect to complete several of the aforementioned studies, including the following: drought and tourism impacts, drought and human-wildlife conflicts, impediments to drought plan implementation, and creation of a preliminary drought impacts database for Arizona. Core Office researcher Jean Morrill, in collaboration with Garfin and CLIMAS PI Andrew Comrie, has initiated a project to compare the relatively cool drought of the 1950s with the relatively warm drought of recent years; the preliminary results of this project will be closely integrated with CLIMAS climate change research. The research will be presented at the AMS 15th Annual Conference on Applied Climatology in Savannah, Georgia in June 2005.

The Core Office, in collaboration with CLIMAS Team member Holly Hartmann, will present a day-long training on drought, climate variability, forecast evaluation, and drought planning at the annual meeting of the New Mexico Rural Water Association (March 21, 2005). Several of our drought and society research team members will be presenting preliminary results of their research at the 101st Annual Meeting of the Association of American Geographers (April 5-9, 2005); researcher Abraham (in collaboration with Andrea Ray of the Western Water Assessment RISA) has organized two sessions entitled "Climate-Society Interactions in North America: Applied and Interdisciplinary Research" at the aforementioned meeting. CLIMAS drought researchers will give presentations on drought climatology and drought monitoring at the American Meteorological Society 15th Conference on Applied Climatology (June 20-24, 2005).

B.4. Plans for 2005-2006. We will continue to examine drought sensitivities and vulnerabilities in Arizona, refinements in drought planning and local drought plan implementation, as well as development of drought impact monitoring methodologies. We plan to continue our work in close coordination with the ADWR. The CLIMAS Core Office will continue to co-chair the ADMC; we will work with ADMC members to provide monthly drought status reports to the Arizona Department of Water Resources. The CLIMAS Core Office, in collaboration with the Udall Center for Public Policy, has applied to the Arizona Technology Research Initiative Fund for support to study and facilitate local/regional drought plan development and implementation in the Upper Verde River Basin. We plan to work closely with Cooperative Extension on publishing primers and other materials for stakeholders, as well as articles for trade journals.

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).

B.6. Leveraged activities.

B.6.2. Intra-CLIMAS Spin-offs. CLIMAS Core Office drought research is coordinated with economics research conducted by CLIMAS PI George Frisvold. Drought research activities are also well-coordinated with other CLIMAS research and outreach activities, including the CLIMAS Southwest Climate Outlook. Several CLIMAS researchers will present a day-long training on drought and other topics to the annual meeting of the New Mexico Rural Water Association.

B.6.3. CLIMAS-related. CLIMAS drought researchers and other CLIMAS team members continue to contribute to the U.S. Drought Monitor. CLIMAS works with National Weather Service forecast offices, USGS, USDA-NRCS, Arizona Division of Emergency Management, Arizona Department of Water Resources, the Salt River Project, and the State Climatologist on state drought monitoring. At the request of CLIMAS, Climate Extension Specialist Mike Crimmins was invited to join the Arizona Drought Monitoring Committee.

B.7. Non-CLIMAS Project Partners. Arizona Governor's Drought Task Force; U.S. Bureau of Reclamation; Arizona Department of Water Resources; National Weather Service; USDA-NRCS Arizona; Arizona State Climatologist; U.S. Geological Survey, Tucson; Salt River Project; Arizona Division 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 2004-2005, the Core Office devoted significant effort to collaborating with partners at the National Interagency Coordination Center's (NICC) National Predictive Services Group (NPSG) and the Program for Climate, Ecosystems and Fire Applications (CEFA) at the Desert Research Institute. For the third consecutive year, CLIMAS, NICC-NPSG, and CEFA worked closely to marshal resources, garner institutional support, and enhance our successful workshop process for the 2005 National Seasonal Assessment Workshops (NSAW). The workshops are designed to produce climate-informed regional- and national-scale seasonal fire potential outlooks for the 2005 fire seasons, for each of the NICC-NPSG Geographic Area Coordination Centers (GACCs) in the United States.

For 2005, two NSAW workshops will again be held, one for the eastern and southern United States, and one for the western United States and Alaska. In addition, CLIMAS, NICC-NPSG, and CEFA are coordinating to provide a 1.5 day climate training, on the subjects of long-term climate variability and monthly-seasonal climate forecasts, to GACC personnel.

C.2. Accomplishments to date. The 2004 National Seasonal Assessment Workshop (NSAW): Western States & Alaska workshop was held March 30-April 2, 2004. Workshop participants moved ahead on a learning curve for incorporating climate information and forecasts into pre-season outlooks. The 2005 National Seasonal Assessment Workshop (NSAW): Eastern & Southern States meeting was held, January 19-21, 2005. The 2005 NSAW was a significant improvement over the 2004 workshop. Participants were better prepared, and two of the climatologists (Dan Graybeal of the Northeast Regional Climate Center, and David Zierden of the Southeast Climate Consortium RISA) developed forecasts and analysis products specifically for the NSAW workshop. Once again, participants worked together successfully to produce outlooks for their region, and to share assessment and forecast techniques and insights. Participants contributed important suggestions for new climate services products, as well as ways to improve dissemination of the pre-season outlooks to fire managers in their regions. Participation by NOAA-CPC forecasters, NOAA Regional Climate Centers, and RISAs contributed to the success of the workshops.

The CLIMAS Core Office produced proceedings, a one-page fact sheet, and a press release for each of the NSAW workshops. The fact sheets allow us to rapidly turnaround the key forecast assessments and cautions, and communicate these to managers in print and PDF format. The proceedings, requested by participants for their interactions with

managers, provide more substantial information, as well as a record of recommendations about the workshop process. Core Office researcher Melanie Lenart has been instrumental in improving the content and style of the aforementioned deliverables.

C.3. Accomplishments anticipated by end of Budget Year. The 2005 NSAW: Western States & Alaska workshop is set for March 28-April 1, 2005 in Boulder, Colorado. The workshop will take place at the NOAA-CIRES Climate Diagnostics Center, and will be hosted by the NOAA Western Water Assessment RISA. In response to participant requests, and in an attempt to build participant capacity to understand and use climate forecasts and long-term climate information, the 2005 NSAW: Western States & Alaska workshop will include a 1.5-day training session. Training instructors include experts from NOAA-CDC, Western Regional Climate Center, and the University of New Mexico. (N.B. – National Weather Service fire meteorologists were invited to the training).

CLIMAS Core Office researcher Gregg Garfin, in coordination with NICC-NPSG, and CEFA co-authors will submit workshop summaries to the trade journals *Wildland Firefighter* and *Wildfire*. Garfin, along with NICC and CEFA co-authors plan to submit a manuscript on the NSAW process to a peer-reviewed journal.

C.4. Plans for 2005-2006. We plan to devote effort to developing a North American Seasonal Assessment Workshop. This impetus for this initiative is three-fold: (1) to respond to a request for Canadian participation, by NSAW: Eastern & Southern participants; (2) to contribute to a NOAA-funded project to incorporate climate information into decision making in northern Mexico (see *Social Science* Task Area); and (3) to improve international collaboration in fire management by opening dialogue through a process, NSAW, with established success in the U.S. CLIMAS Core Office activities will be closely coordinated with our partners, NICC-NPSG and CEFA, as well as with NOAA-CPC, and the NOAA RISAs. As always, we strive to achieve incremental improvements in the NSAW process and products. We will devote effort to transitioning the NSAWs to NICC-NPSG, CEFA, and the forecast agencies by securing higher levels of commitment from the forecast agencies, working to establish better relationships between NICC-NPSG and the forecast agencies, and involving officials from higher levels in the forecast agencies in the process.

Goals for the 2006 NSAWs, include the following: (1) improve fuels assessment activities by increasing the involvement of eastern and southern states' land management participants; (2) improve communication between the GACCs, RISAs, and RCCs; (3) improve communication of outlook results to management; (4) identify additional training topics and opportunities. The CLIMAS Core Office expects to organize a session on "Partnership processes to improve fire management" at the American Meteorological Society Sixth Symposium on Fire and Forest Meteorology, in October 2005.

C.5. Leveraged funding. The USDA-Forest Service (through NICC-NPSG) and NOAA-OGP (through CLIMAS) provided additional funding for NSAW workshops travel.

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.7. Non-CLIMAS Project Partners and Contributors. National Interagency Coordination Center National Predictive Services Group (and their 11 Geographic Area Coordination Centers); the Program for Climate, Ecosystems and Fire Applications (CEFA/DRI); NOAA-CPC; NOAA-CDC; NOAA Regional Climate Centers; Scripps Institution of Oceanography; USDA-Forest Service Pacific Northwest Research Laboratory; NOAA RISAs; New York State Forest Rangers; New Jersey Forest Service; California Department of Forestry; Florida Division of Forestry; Minnesota Department of Natural Resources; U.S. Bureau of Land Management; South Dakota School of Mines and Technology; Bureau of Indian Affairs.

Project D: Coordination with University of Arizona Cooperative Extension

D.1. Description. Beginning in 2003, the CLIMAS Core Office put considerable effort into establishing a working relationship for research and operations activities with University of Arizona Cooperative Extension. Cooperative Extension has been a key stakeholder and partner in CLIMAS vulnerability, ranching, drought, and economic decision research. CLIMAS has determined that coordination with Cooperative Extension agents and specialists multiplies the effectiveness of CLIMAS efforts to: reach stakeholders with information; assess needs for climate research, information, and decision support; and evaluate the effectiveness of decision support products.

D.2. Accomplishments to date. During 2004-2005, with NOAA-OGP funding, CLIMAS helped place two extension specialists in Arizona. Katharine Jacobs is a climate-oriented Water Resources Extension Specialist, and Michael Crimmins is the nation's second Climate Extension Specialist. Specialist Jacobs, who has an extensive background in water resources management, has been instrumental in contributions to Arizona drought planning and CLIMAS drought research and outreach. Jacobs has already garnered funding to investigate, with CLIMAS economist Bonnie Colby, ways to improve long-term water supply management in the Colorado River Basin through the use of climate information. With merely two months on the job, Crimmins has already made connections with the Arizona Drought Monitoring Committee, National Weather Service (Phoenix), and extension agents throughout Arizona. Crimmins has joined CLIMAS Core Office researcher Garfin in co-editing the CLIMAS Southwest Climate Outlook (SWCO). Through Crimmins' nascent extension activities, he has already increased SWCO circulation by over 100 stakeholders.

During 2004-2005, the CLIMAS Core Office, CLIMAS PI Andrew Comrie, the USGS, Northern Arizona University, and University of Arizona Cooperative Extension, collaborated on a workshop address issues of abrupt vegetation change due to drought, fire, insect infestation, and to investigate the potential impacts of climate change on Southwest forests. The Core Office researchers Garfin and Lenart participated in the

steering committee, as did extension specialists Jacobs and Crimmins. The workshop, held February 7-9, 2005, succeeded in bringing together approximately 100 forest management stakeholders and scientists to examine climate variability and change and potential management needs and responses. The workshop featured plenary talks by CLIMAS PIs Jonathan Overpeck and Thomas Swetnam. The approximately 100 participants included managers of state, national and tribal forests, researchers from UA and Northern Arizona University and the U.S. Forest Service, and some graduate students. The 35 people who submitted workshop evaluation forms gave the workshop a rating of 4.6 out of 5. In addition to helping land managers understand the most up-to-date information about climate change, the workshop gave climatologists insight into what types of products and information might be useful in the future. CLIMAS also contributed a climate and drought curriculum for UA Cooperative Extension's Master Watershed Steward program.

D.3. Accomplishments anticipated by end of Budget Year. By mid-April, the *Climate and Vegetation Change Steering Committee* will finalize workshop fact sheets that: assess the state of knowledge on each topic (e.g., insect outbreaks, natural resources management, invasive species dispersal, etc.), chronicle management needs for climate research and information, provide links to information, and assess insertion points for outreach and education. These documents will be used by Cooperative Extension and CLIMAS in outreach to stakeholders. Workshop co-organizer Chris Jones and Core Office researcher Gregg Garfin will collaborate on a paper on workshop process and outcomes, to be presented by Jones at the 5th International Conference on Forest Vegetation Management, in Corvallis, Oregon, June 20-24, 2005. Climate extension specialist Crimmins and Core Office researcher Garfin plan to submit a proposal to NSF on informal climate and environmental education.

D.4. Plans for 2005-2006. The CLIMAS Core Office will continue to work closely with the UA Cooperative Extension *Climate and Vegetation Change Steering Committee* to develop two workshops vegetation and climate change; one will focus on grasslands, and the other on riparian areas. 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, and to facilitate implementation of the Arizona Drought Preparedness Plan in rural communities, we will coordinate with extension agents in Yavapai County on identifying stakeholder needs and community vulnerabilities. Core Office researcher Garfin plans to collaborate with Climate Extension specialist Crimmins, the Arizona State Climatologist, and the National Weather Service on providing county-level climate information to Arizona stakeholders.

D.5. Leveraged funding. The University of Arizona Department of Soil, Water and Environmental Science provides additional funding for the water resources and climate extensions specialists.

D.6. Leveraged activities.

D.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).

D.7. Non-CLIMAS Project Partners. University of Arizona Cooperative Extension.

Project E: U.S.-Mexico Border Climate and Outreach

E.1. Description. The Core Office collaborates with CLIMAS PIs Barbara Morehouse and Margaret Wilder, as well as with the Udall Center for Public Policy on assessing northern Mexico stakeholders' needs for climate information, as well as providing climate information and analyses to border-region stakeholders.

E.2. Accomplishments to date. Core Office researcher Melanie Lenart supervised research to garner information about climate products, research, and data for the area near Cananea, Mexico, as part of a bi-national effort to form an alliance in the Upper San Pedro River watershed. Lenart also worked with Henry Diaz of NOAA-CDC to arrange an April 26 -27, 2004 workshop to explore setting up a regional climate Center at the University of Sonora in Hermosillo, Mexico. The workshop was effective in setting the stage for collaboration between CLIMAS and the future regional climate center.

Core Office researcher Gregg Garfin gave presentations on drought history, drought planning, and borderlands drought impacts at meetings of the EPA's Border 2012 group, and the Good Neighbor Environmental Board (an independent panel to advise the President on border environmental issues). Contacts made at the Border 2012 meeting opened the door to conversations about collaboration on drought planning with Mexico's Comision Nacional del Agua. Garfin, CLIMAS graduate researcher Rick Brandt, and NOAA-funded CLIMAS and Udall Center for Public Policy researchers developed a prototype climate outlook product for the U.S.-Mexico border region.

E.3. Accomplishments anticipated by end of Budget Year. CLIMAS and Udall Center for Public Policy researchers will work with Mexican colleagues to develop collaboration on the border region climate outlook product. We expect to flesh out the prototype and distribute it to border-region stakeholders by June, 2005.

E.4. Plans for 2005-2006. Pending feedback from Mexican colleagues and stakeholders, we will move forward to garner resources for a full-scale version of the border-region climate outlook product. Cooperative Extension is a potential partner on this project.

E.5. Leveraged funding. Through a NOAA Human Dimensions of Global Change grant, the Udall Center for Public Policy provided partial salary funding for Melanie Lenart in 2004.

E.7. Non-CLIMAS Project Partners. Udall Center for Public Policy, Comision Nacional del Agua (CNA).

Project F: Climate Change

F.1. Description. During 2004-2005, the Core Office initiated CLIMAS research into the observed and potential effects of climate change in the Southwest. Activities include trade journal and Southwest Climate Outlook articles, public presentations, press briefings, and climatological and socio-ecological research.

F.2. Accomplishments to date. Core Office researcher Melanie Lenart was lead author, along with Gregg Garfin and Jonathan Overpeck on an article in the trade journal *sonorensis* (the journal of the Arizona-Sonora Desert Museum). (N.B. – *sonorensis* has a circulation of 40,000). The article summarized potential climate change effects in the Sonoran Desert region. A shortened version of the article ran as a Sunday feature in the *Tucson Citizen*. Climate change was the focus of a CLIMAS-Cooperative Extension workshop in February, 2005. CLIMAS PIs Jonathan Overpeck and Tom Swetnam gave keynote talks at the workshop. CLIMAS researchers Lenart and Garfin and extension specialist Jacobs gave presentations on potential climate change effects on urban water supply at a Phoenix press briefing in December, 2004.

F.3. Accomplishments anticipated by end of Budget Year. Core Office researchers Jean Morrill and Gregg Garfin, along with CLIMAS PI Andrew Comrie, will present information about the effect of observed temperature increases on drought in rural Arizona at the American Meteorological Society 15th Conference on Applied Climatology in June, 2005.

F.4. Plans for 2005-2006. CLIMAS will continue to investigate observed climate changes in the Southwest. The Core Office will continue to work with Arizona stakeholders to assess needs for climate change information and decision-support.

Project G: Team Integrated Project (TIP)

G.1. Description. In 2004-2005, building upon its previous integrated assessment activities in Arizona, the CLIMAS team began work on a Team Integrated Project in the Upper Little Colorado River Basin in northern Arizona. The basin was selected as an area with a high potential for water-related conflict by the Department of Interior Water 2025 report. In the TIP, the CLIMAS team will focus intensively on the Upper Little Colorado 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 plan to 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.

G.2. Accomplishments to date. In August 2004, Core Office and CLIMAS Vulnerability Team members scoped the region for one week, making contact with key stakeholders,

agencies, and organizations in the region. Team members interviewed key contacts. CLIMAS Team members contributed to a 92-page white paper, designed to provide CLIMAS investigators with background on the region's culture, economy, hydrology, climate, institutions, policy, and history. The Core Office and Vulnerability Team collaborated on compiling the aforementioned document and presenting salient findings to the CLIMAS PIs at a January, 2005 CLIMAS PIs mini-retreat.

In creating the foundation for the TIP, Core Office researcher Lenart gave several presentations to the Bureau of Indian Affairs and White Mountain Apache Tribal Council on drought, precipitation forecasts, ENSO, and fire. In response to tribal stakeholder requests, Lenart worked with vulnerability team researcher Jodi Perin to develop a GIS-based analysis to identify whether forest stand density has a detectable influence on tree mortality from insect outbreaks, after taking into consideration microclimate effects. In response to TIP-region stakeholder requests, Lenart developed several SWCO feature articles. Lenart also attended three community workshops in the region, including the Natural Resources Working Group (a partnership of private sector, municipal, and NGO leaders), the Four Corners Sustainable Forests Partnership, and the Apache-Sitgreaves National Forest Stewardship Project Monitoring Group. Lenart's efforts have helped build relationships between CLIMAS and the region's stakeholders. Graduate researcher Alexa Gilbert performed her research on impediments to drought plan implementation in the TIP region.

G.3. Accomplishments anticipated by end of Budget Year. Core Office and other CLIMAS team members will continue to attend regional stakeholder meetings.

G.4. Plans for 2005-2006. The CLIMAS Core Office will continue to coordinate team research activities in the TIP region. Vulnerability team members will begin research and rapid ethnographic assessment of the region's stakeholders during summer, 2005. The Core Office, in collaboration with CLIMAS PI Andrew Comrie, will investigate regional climatology and observed climate changes. Researcher Lenart will conduct a survey of stakeholder groups in the TIP region, in order to (1) assess the institutional and economic barriers to land management practices in response to climate-related forest mortality events, and (2) assess perceptions of climate change and issues of providing "carbon credits" as part of the effort to reduce risk of global warming. Stakeholder groups for Lenart's research include forest managers, forest product entrepreneurs, NGOs, wildland- and urban interface residents, and insurance and real estate agents. The Core Office plans to develop a web site devoted to TIP-region climatology and information resources.

G.7. Non-CLIMAS Project Partners. University of Arizona Cooperative Extension.

Project H: Project Management

H.1. Project description. The Core Office continues to coordinate the project and monitor the budget. We continue to hold bi-weekly team meetings and twice annual team mini-retreats. The Core Office publishes the quarterly CLIMAS Update newsletter (edited by Melanie Lenart), which is mailed to approximately 1,400 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, media contacts, and maintains the CLIMAS web site and databases. Important changes occurred in Core Office staffing during the 2004-2005 budget year. Research scientist David McGinnis was hired in March 2004, but within several months left the project for personal reasons; Jean Morrill was hired in January 2005.

H.2. Accomplishments to date. The Core Office invited stakeholders and prominent researchers to present their perspectives and concerns at team meetings. We held mini-retreats in September 2004 and January 2005. The mini-retreats 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 2004-2005 mini-retreats is that the CLIMAS team is developing a new round of peer-reviewed papers on integrated assessment methodology and stakeholder engagement. In May, 2004, CLIMAS hosted a meeting and exchange with colleagues from the NSF Human Environment Research Observatories. In September, 2004, Core Office manager Gregg Garfin and CLIMAS researcher Holly Hartmann interviewed New Mexico stakeholders, in order to scope possibilities for CLIMAS-stakeholder collaborations in that state. In November, 2004, CLIMAS hosted a meeting and exchange with colleagues from the new NSF Decision Making Under Uncertainty Center, *Decision Center for a Desert City* (Arizona State University).

H.3. Accomplishments anticipated by end of Budget Year. The Core Office, in conjunction with the four University of Arizona water centers and the Institute for the Study of Planet Earth, will continue dialogue and explore opportunities for collaboration with the NSF Decision Center for a Desert City. 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. 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.

H.4. Plans for 2005-2006. We plan to spend much effort in the following areas: (1) coordinating the TIP in the Upper Little Colorado River Basin, (2) developing further collaborative projects with Arizona Cooperative Extension, (3) continuing provision of drought and climate information to stakeholders (Southwest Climate Outlook), in partnership with Arizona Cooperative Extension, (4) continuing our drought research and outreach activities, (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 (Lenart), (7) analyzing use and usability of CLIMAS climate information products, (8) establishing relationships with

New Mexico stakeholders. 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.

The Core Office expects the following personnel changes in 2005-2006:

- Researcher Melanie Lenart will reduce her hours to 0.50 FTE and will concentrate on science writing, press releases, trade journal articles, stakeholder outreach in the TIP region, and TIP survey research;
- We will hire a Core Office social scientist to improve stakeholder engagement, enhance team coordination, and conduct research on the use and usability of CLIMAS research and products.
- Researcher Jean Morrill will be leaving the project for personal reasons. We will hire a Core Office climatologist/hydrologist.

Project I: RISA and NOAA-OGP Coordination.

I.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.

I.2. Accomplishments to date. In November, 2004, CLIMAS Program Manager Gregg Garfin presented an update of CLIMAS activities to the PNW-CIG RISA. Garfin, Philip Mote, and Lara Whitely-Binder discussed plans to convene a RISA session at the 2006 AAAS meeting. In summer, 2004, CLIMAS hosted SECC RISA program manager Keith Ingram and climate extension nationalist Clyde Fraisse. The CLIMAS Core Office coordinated with the WWA RISA to host and co-organize the 2005 NSAW: Western States & Alaska workshop and training. During 2004, the Core Office also hosted WWA researcher Andrea Ray, who gave a presentation on her work with water resources stakeholders in Colorado. The Core Office works regularly with Andrea Ray on developing applied climatology research associated with the North American Monsoon Experiment. At the invitation of RISA colleagues, Garfin presented papers on *Regional Climate Variability and Decisionmaking in the Southwest* at the 2004 AGU Fall Meeting, and *Climate Variability and U.S. Forests: Fire Potential and Forest Resources* at the 2004 Soil Science Society of America Annual Meeting.

I.3. Accomplishments anticipated by end of Budget Year. In collaboration with the Western Water Assessment RISA, the CLIMAS Core Office is coordinating a May 5, 2005 workshop on improved use of paleoclimatic data by Colorado River Basin water resources managers.

I.4. Plans for 2005-2006. The Core Office plans to develop a plan for inter-RISA coordination on a RISA session for the 2006 AAAS meeting. In addition, the Core Office

plans to develop a “climate boot camp” for National Association of Science Writers journalists, in conjunction with other RISAs.

II. Publications

In print

Garfin, G.M., T. Brown, R. Ochoa, H. Hockenberry. 2004. National Seasonal Assessment Workshop: Western States and Alaska, Phoenix, AZ, March 30-April 2, 2004. Final report. CLIMAS/ISPE, Tucson, 18 pp.

Jacobs, K., and G.Garfin. 2004. Arizona’s drought planning: focusing on adaptation. *Water Resources Impact* 6(4):14-17.

Jacobs, K. L., G. M. Garfin, and B. J. Morehouse. 2005. Climate science and drought planning. *Journal of the American Water Resources Association*. In press.

Lenart, M., G. Garfin, and J. Overpeck. 2004. The heat is on. *Sonorensis* 24(1): 20-28.

McPhee, J. C., A. C. Comrie, and G. M. Garfin., 2004. Drought and Climate in Arizona: Top Ten Questions and Answers. Final Report. March, 2004. (CLIMAS White Paper, prepared for the Governor’s Drought Task Force.) CLIMAS/ISPE, Tucson, 22 pp. (<http://www.ispe.arizona.edu/climas/learn/drought/Drought%20Q&A.pdf>).

Submitted/In Review

Sonnett, J., B. J. Morehouse, T. D. Finger, G. Garfin, and N. Rattray. Discursive framing of drought. Submitted to *Global Environmental Change* January 17, 2005.

To be submitted by June 1, 2005.

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

Downey, S., J. Abraham, G. Garfin. Drought mitigation and adaptation: conversations with state drought planners. To be submitted to *Water Resources Impact*.

Garfin, G., K. Jacobs, and H. Hartmann. Techniques for effective stakeholder engagement at meetings. To be submitted to *EOS Transactions of the American Geophysical Union*.

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

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

Simpson, S. and G. Garfin. Impacts of drought on increasing urban human-wildlife conflicts. To be submitted to *Human Dimensions of Wildlife*.

III. Presentations at Professional Meetings/Conferences

Abraham, J., and G. Garfin, 2004. Developing theory and methodologies for drought vulnerability assessments: state drought planning in Arizona. Presentation to the Association of American Geographers 100th Annual Meeting, Philadelphia, PA, March 18, 2004.

Abraham, J., 2004. Enhancing Pro-Active Drought Mitigation in Arizona. Presentation (invited) to the Arizona Water and Pollution Control Association annual meeting, Mesa, AZ, May 7, 2004.

Abraham, J., 2004. Enhancing Pro-Active Drought Mitigation in Arizona: Insights From A National Survey of State Drought Planning Impact & Vulnerability Assessments. Presentation (invited) to the Arizona Hydrological Society annual conference, Tucson, AZ, September 17, 2004.

Garfin, G., 2004. Climate Information, Stakeholder Insights, and Arizona Drought Planning. Presentation to the Association of American Geographers 100th Annual Meeting, Philadelphia, PA, March 18, 2004. Also, session organizer for two sessions entitled Drought, Water Supply, Fire: How Does Place-Based Science Serve Society?

Garfin, G., 2004. Long-term Climate Variability and Change in the Southwest: Observations and Predictions. Presentation (invited) to the Central Arizona Water Conservation District Board, Yuma, AZ, April 2, 2004.

Garfin, G., 2004. Drought Monitoring and Reporting for Arizona. Presentation (invited) to the Arizona Water and Pollution Control Association annual meeting, Mesa, AZ, May 7, 2004.

Garfin, G., 2004. Arizona Drought: Long-term Perspectives and Current Status. Presentation (invited) to the Pima Association of Governments Watershed Forum, Tucson, AZ, June 23, 2004.

Garfin, G., 2004. Arizona Drought: Present, Past & Future; Arizona Drought Monitoring. Two presentations (invited) to the EPA Border 2012 Meeting, Tohono O'odham Nation, Sells, AZ, August 27, 2004.

Garfin, G., 2004. Arizona Drought. Invited class presentation for Project CENTRL Class XVII, Seminar 8 – Natural Resources, Flagstaff, AZ, October 15, 2004.

Garfin, G., 2004. Borderlands Drought. Presentation (invited) to the Good Neighbor Environmental Board Meeting, Douglas, AZ, October 17, 2004.

Garfin, G., 2004. Climate Variability and U.S. Forests: Fire Potential and Forest Resources. Presentation (invited) to the American Society of Agronomy/Crop Science Society of America/Soil Science Society of America annual meeting, session on the Impact of Climate Variability on Agricultural and Natural Resource Management, Seattle, Washington, November 3, 2004.

Garfin, G., 2004. Regional Climate Variability and Decisionmaking in the Southwest. Presentation (invited) to the American Geophysical Union annual Fall Meeting, San Francisco, CA, December 16, 2004.

Garfin, G., 2005. The Climatic Cycles and Precipitation Forecasts for the Southwest. Presentation (invited) to the ThinkAZ/Arizona Republic Water Conservation Leadership Forum, Tempe, AZ, January 7, 2005. (Presentation available: http://www.thinkaz.org/pub_natural.html).

Posters

Garfin, G. M., and others, 2004. Contributions of regional integrated assessment to coping with vulnerability to climate in central Arizona's Mogollon Rim and White Mountains. Mountain Climate Symposium, Lake Tahoe, CA, May, 2004.

Gilbert, A., S. Simpson, S. Ponnaluru, R. Brandt and C. Thornburgh, 2005. CLIMAS Drought Research. Southeastern Arizona Ag Day and Trade Show, Willcox, AZ, February 3, 2005.

Meetings organized

Garfin, G. M., 2004. National Seasonal Assessment Workshop: Western States and Alaska, Phoenix, AZ, March 30-April 2, 2004; co-organized meeting; co-authored proceedings.

Garfin, G. M., and M. Lenart, 2005. National Seasonal Assessment Workshop: Eastern and Southern States, Shepherdstown, WV, January 19-21, 2005; co-organized meeting; co-authored proceedings (Lenart lead author).

Lenart, M., Comrie, A., Garfin, G.M., Jacobs, K., Crimmins, M., 2004-2005. Workshop on Climate Variability & Ecosystem Impacts in Southwestern Forests and Woodlands, Sedona, AZ, February 7-9, 2005. In collaboration with the University of Arizona Cooperative Extension. Co-organized meeting; developed agenda; secured participation of some of the speakers.

IV. Outreach Activities

Garfin, G.M. 2004. The Climate Assessment for the Southwest. Presentation to the Natural Resources Working Group, Pinetop, AZ, August 16, 2004.

Garfin, G. M. 2004. Arizona Drought. Invited presentation for a class on drought and natural resources at the Project CENTRL Rural Leadership Program, Class XVII, Seminar 8, October 15, 2004.

Garfin, G. M. 2004. CLIMAS: a RISA-to-RISA Update. Presentation to the Pacific Northwest Climate Impacts Group, Seattle, Washington, November 2, 2004.

Garfin, G. M., S. Simpson, C. Thornbrugh, C. West. 2005. CLIMAS Drought and Vulnerability Research. Display table at the Annual Southeastern Arizona Ag Day and Trade Show, Willcox, AZ, February 2, 2005.

Lenart, M. 2004. Presentation on climate variability and summer 2004 fire risk to Bureau of Indian Affairs, San Carlos, AZ. April 13, 2004.

Lenart, M. 2004. Presentation to Bureau of Indian Affairs at White Mountain Apache Tribal Council, Hon-dah, AZ. May 11, 2004.

Lenart, M. 2004. High School Practicum on long-term climate variability and paleoclimate data. San Carlos Apache Reservation. June 8, 2004.

Arizona Governor's Drought Task Force (GDTF) Meetings (Garfin) 2004

March 29, Monitoring Technical Committee Meeting

April 29, Monitoring Technical Committee Meeting

May 12, Public meeting, Sierra Vista, AZ; *Arizona Drought Update*

June 9, Monitoring Technical Committee Meeting

June 16, Executive Committee Meeting

June 28, Executive Committee Meeting

July 7, Monitoring Technical Committee Meeting

July, 14, Monitoring Technical Committee Meeting

July, 21, Monitoring Technical Committee Meeting

July, 26, Monitoring Technical Committee Meeting

July 28, Public meeting, Phoenix, AZ; *Monitoring Technical Committee Report*

August, 4, Monitoring Technical Committee Meeting

September 8, Public meeting, Prescott, AZ; *Arizona Drought Monitoring*

September 9, Public meeting, Pinetop, AZ; *Arizona Drought Monitoring; Arizona Drought Status Report*

September 14, Public meeting, Safford, AZ; *Arizona Drought Monitoring; Arizona Drought Status Report*

September 15, Public meeting, Tucson, AZ; *Arizona Drought Monitoring; Arizona Drought Status Report*

September 20, Drought trigger stakeholder evaluation meeting, Phoenix, AZ
September 21, Public meeting, Yuma, AZ; *Arizona Drought Monitoring; Arizona Drought Status Report*
September 22, Public meeting, Kingman, AZ; *Arizona Drought Monitoring; Arizona Drought Status Report*
October 6, Public meeting, Phoenix, AZ
November 17, Monitoring Committee Meeting

2005

January 26 Monitoring Committee Meeting

CLIMAS-SAHRA Press Briefings (Garfin, Lenart, Jacobs, Overpeck, Hartmann, Molotch)

April 2, 2004 – Phoenix, AZ

May 25, 2004 – Tucson, AZ

December 7, 2004 – Phoenix, AZ

V. Human Resource Development

Rahul Srivastava's CLIMAS-inspired M.S. thesis on the role of drought in county and municipal hazard planning was completed in summer 2004. 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: Social Science Research

PI: Dr. Barbara Morehouse, Institute for the Study of Planet Earth

Researchers: John Sonnett (GRA, Sociology); Thomas Finger (GRA, Environmental History)

I. Progress for Budget Year 2004-2005

Project A: Newspaper Analyses of Drought Discourse in Arizona

A. 1. Description. Analysis of newspaper articles about drought (B Morehouse, G Garfin, J Sonnett, T Finger).

A.2. Accomplishments to date. Submitted article to Global Environmental Change, January 2005.

A.3. Accomplishments anticipated by end of Budget Year. Receipt of reviews, revisions, accepted for publication.

A.4. Plans for 2005-2006. Project is completed.

A.5. Leveraged funding. J. Sonnett salary, beginning January 2005, is covered by supplemental funding available to B. Morehouse.

A.6. Leveraged activities.

A.6.1. Greater than 50% CLIMAS funding. Methods now being applied, under fire research funds available to B. Morehouse, to analysis of newspaper coverage of wildland fire, 2000-2004.

Project B: Environmental History of the Upper Little Colorado Watershed

B. 1. Description. Contribute environmental history information to the CLIMAS Team Integrated Project in Upper Little Colorado; produce thesis of environmental history of key Mormon settlements in this area.

B.2. Accomplishments to date. Contributions made to white paper providing background information on the area. Research is continuing.

B.3. Accomplishments anticipated by end of Budget Year. Completion of local field research for integrated assessment project and initiation of thesis draft.

B.4. Plans for 2005-2006. Finish thesis by end of summer 2005.

Project C: RISA Brochure

C. 1. Description. Production of RISA brochure (B Morehouse, S Mayden)

C.2. Progress: Brochure completed and printed.

C.3. Accomplishments anticipated by end of Budget Year.: Distribution to RISAs; completion of prototype CLIMAS brochure insert: this will be the suggested format for inserts produced by the other RISAs.

C.4. Plans for 2005-2006. Prepare CLIMAS inserts targeted to specific audiences

C.5. Leveraged funding. ISPE salary for S Mayden; supplemental funding from NOAA RISA program.

Project D: Climate Impacts & Information use in the Upper San Pedro River Basin

D. 1. Description. Assess use of climate information in the Upper San Pedro River Basin on the US/Mexico (PIs: R Varady, A Browning-Aiken, B Morehouse, M Wilder; M Lenart – CLIMAS postdoctoral researcher; GM Garfin – CLIMAS project manager). [See related project, *Core Office Task Area Project E*]. CLIMAS contribution is provision of climate information for workshops and other such activities and co-authorship of papers arising from the project.

D.2. Accomplishments to date. Climate workshop organized in Hermosillo; workshop held in Cananea, paper submitted for review to *Journal of Climate*.

D.3. Accomplishments anticipated by end of Budget Year. Workshop to be held at technological institute in Cananea on climate and its impacts. Drafts of three papers to be submitted for peer-reviewed publication.

D.4. Plans for 2005-2006. Organize additional meetings to discuss binational provision of climate information for the border area of the Upper San Pedro River. Publication of peer-reviewed papers.

D.5. Leveraged funding. Separate NOAA funding [R Varady PI] for this project.

Project E: Decision Calendars for Fire Management

E. 1. Description. Characterize decision calendars used by fire managers and identification of where/when climate information can be most productively introduced. [Inter-RISA project: A. Westerling, B. Morehouse; Graduate Research Assistant T. Corringham].

E.2. Accomplishments to date. Interviews completed; paper drafted.

E.3. Accomplishments anticipated by end of Budget Year. Submittal of paper to peer-reviewed journal.

E.4. Plans for 2005-2006. Publication of peer-reviewed paper.

E.5. Leveraged funding. CLIMAS funding to B. Morehouse for time spent contributing to the research activities.

Project F: Partnerships and Fire-Climate Decision Support

F. 1. Description. Characterize concepts of “partnerships” in collaborative development and use of climate information, using CANSAC as a case study. [Spinoff project: T. Brown, B. J. Morehouse].

F.2. Accomplishments to date. Survey protocol developed and approved. Survey is underway.

F.3. Accomplishments anticipated by end of Budget Year. Completion of survey.

F.4. Plans for 2005-2006. Analysis of survey and publication of peer-reviewed paper.

F.5. Leveraged funding. This project has separate funding [T. Brown, PI].

Project G: Wildfire Alternatives (WALTER)

G. 1. Description. Develop integrated fire-climate-society GIS model for strategic planning for wildland fire [EPA funded spinoff from CLIMAS; PIs: B. Morehouse, G. Christopherson, B. Orr, J. Overpeck, T. Swetnam].

G.2. Accomplishments to date. Completed.

G.3. Accomplishments anticipated by end of Budget Year. Book chapter in press.

G.4. Plans for 2005-2006. Publication of peer-reviewed papers.

G.5. Leveraged funding. All funding provided by EPA.

G.6. Leveraged activities. Participation of CLIMAS team in alpha-phase testing of model and use of electronic polling devices used to run Analytic Hierarchy Process.

II. Publications

In print/In press

Bales, R., D. Liverman, and B. J. Morehouse. 2004. Integrated assessment as a step toward reducing climate vulnerability in the southwestern United States. *Bulletin of the American Meteorological Association* 85(11):1727-1734.

Jacobs, K. L., and B. J. Morehouse. 2005. Why sustainability isn't a four-letter word? *Southwest Hydrology* 4(1): 14-15.

Jacobs, K. L., G. M. Garfin, and B. J. Morehouse. 2005. Climate science and drought planning. *Journal of the American Water Resources Association*. In press.

Lemos, M. C., and B. J. Morehouse. 2005. The co-production of science and policy in integrated climate assessments. *Global Environmental Change*. In press.

Varady, R., and B. J. Morehouse. 2004. ¿Cuanto cuesta? Development and water in Ambos Nogales and the Upper San Pedro Basin. In K. Kopinak (ed.), *The Social Costs of Industrial Growth in Northern Mexico*, pp. 205-248. San Diego, Center for U.S.-Mexican Studies.

Submitted/In review

Sonnett, J., B. J. Morehouse, T. D. Finger, G. Garfin, and N. Rattray. Discursive framing of drought. Submitted to *Global Environmental Change* January 17, 2005.

To be submitted by June 1, 2005

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

Corringham, T., A. Westerling, and B. J. Morehouse. Exploring use of climate information in wildland fire management: a decision calendar study. Journal tbd.

Morehouse, B. J., and M. C. Carmen. A critical look at boundary organizations as knowledge brokers. Journal tbd.

III. Presentations at Professional Meetings/Conferences

Morehouse, B. 2004. Tailored drought research and educational outreach for Arizona: Year 1 progress. Presentation to the Arizonal Hydrological Society Conference, September 17, 2004, Tucson, Arizona.

Morehouse, B., G. Garfin, T. Brown and T. W. Swetnam. 2004. Integrating fire, climate and societal factors into decision support for strategic planning in wildland fire

mangement. Paper presented at the Monitoring Science and Technology Conference, Denver, Colorado, September 22-24, 2004.

V. Human Resource Development

John Sonnet is working on his Ph.D. dissertation. Thomas Finger is working on his Master's thesis.

TASK AREA: Economics Working Group: Economic Strategies to Address Climate-related Water Supply Variability and Agricultural Concerns

PIs: Dr. Bonnie Colby and Dr. George Frisvold, Agricultural and Resource Economics

Researchers: Rosalind Bark (GRA, Hydrology and Water Resources); Jennifer Pullen, Shailaja Deva , Srinivasa Ponnaluru (GRAs, Agricultural and Resource Economics)

I. Progress for Budget Year 2004-2005

Project A: Climate Variability and Snow-Dependent Local Economies

A. 1. Description. Climate change models predict declining snow pack and shorter snow seasons, particularly at low elevation and low latitudes. Previous research has focused on low elevation ski resorts in Europe and Canada, this research adds to our knowledge by investigating the likely impact of climate change on low latitude ski resorts in the southwest USA. Our case study of Sunrise Park Ski Resort in the White Mountains, Arizona highlights interesting aspects of climate change in the southwest, specifically, the availability of water supplies to make manmade snow to adapt to reduced snowfall conditions and the importance of tribal management. The White Mountain Apache Tribe's Sunrise Park Resort is located at latitude 34° at relatively high elevation, ranging from 2,862 m to 3,385 m. Sunrise currently has snowmaking capabilities for just 10% of skiable terrain. To put this in context, climate change vulnerable low elevation, high latitude, ski resorts in central Ontario, Canada have snowmaking capabilities for 100% of skiable terrain (Scott, McBoyle, and Mills, 2003). Although, new snowmaking investments could reduce ski season uncertainty at Sunrise such investments also conversely would make the tribe more economically dependent on winter recreation. Before investing further in snowmaking a full assessment of the probable impacts of climate change, the associated increased costs of snowmaking at higher temperatures, the relative competitive position of Sunrise, and the alternative uses of such capital and water, needs to be undertaken. In addition the environmental impacts of expanded snowmaking need to be considered; namely water supply issues and the impact of water withdrawals on winter fish habitat.

A.2. Accomplishments to date. In addition to collecting detailed background information on climate change and ski recreation, snow depth data has been collected and extrapolated using SNOTEL and snow course data for the White Mountains region. Data on manmade snowmaking technical and water requirements and costs has also been collected. Previous research on the local economic dependency of the region has been revived and data sources to update this work and adapt it to the Southwest have been identified.

A.3. Accomplishments anticipated by end of Budget Year. We expect to develop a preliminary model of snow depth as related to recreational visits and local economic activity.

A.4. Plans for 2005-2006. Outreach with stakeholders in study area who are concerned about local economic dependence on winter snowpack.

A.5. *Leveraged funding.* Enhancing Supply Reliability Through Improved Predictive Capacity And Response. Principal Investigators: Bonnie Colby, Kathy Jacobs, David Meko, Bart Nijssen; approx \$320,000 awarded from US Bureau of Reclamation and TRIF funding.

Project B: Climate Variables and Water Market Prices

B.1. *Description.* The combination of persistent drought in the western United States and an over-allocated water supply has created significant resource management and policy issues. Using econometric analysis we investigate how drought influences the market price of water. Water markets have slowly evolved as the perception and distribution of water rights and usage patterns change. This research uses a rich set of water transaction data from 1987 to 2004.

B.2. *Accomplishments to date.* We have empirically modeled water markets in several western states, specifically, Arizona, New Mexico, Colorado, Nevada, and Utah.

B.4. *Plans for 2005-2006.* We plan to complete the modeling work and do stake holder outreach on the implications of drought and climate variability for regional water costs and water management.

B.6. *Leveraged activities.*

B.6.3 *CLIMAS-related.* Evaluating the Economic and Environmental Effects of Alternative Dispute Resolution, grant from Hewlett Foundation (through GHK international), \$95,000, 2003-2004.

Agricultural Water Management for Economic Viability and Environmental Quality, U.S. Dept. of Agriculture Western Regional Project W-190, approx. \$20,000 per year, 2005.

Project C: Economic Values of Riparian Corridors

C.1. *Description.* Using remote sensing vegetation indices we investigate the effect of riparian corridor and parcel greenness on house prices in Tucson, Arizona. The results of the hedonic property price analysis show that vegetation vigor and percent ground cover (two characteristics measured by vegetation indices) are significant factors in explaining house price variation in Tucson.

C.2. *Accomplishments to date.* For a ten percent increase in greenness at the parcel and nearest riparian corridor homebuyers are willing to pay 5.3 percent and 5 percent more for an equivalent home, respectively.

The research was refined further using riparian vegetation survey data in the same field area. The results of this phase of the research show that homebuyers have distinct preferences between riparian species; valuing hydro and mesoriparian species most highly. Homebuyers are also willing to pay more for a home that is located near a

riparian corridor with greater vegetation volume and species richness. The results of these investigations show that the riparian corridor adds considerable value to private property values in Tucson, Arizona, specifically those sections of the corridor that support abundant native tree species.

C.3. Accomplishments anticipated by end of the Budget Year. We will engage in stakeholder outreach to discuss study results and implications for resource management.

C.4. Plans for 2005-2006

This project is concluding within the next few months. Four journal articles have been drafted, with two submitted.

Project D: Climate, Water Availability, and Southwest Park Visitation

D.1. Description. This project addresses two related research questions. First, how does climate variability and water availability affect recreational visits to national and state parks in the Southwest? Second, what are the economic impacts of weather and environment-induced changes in visitation? Parks in the study area receive over 35 million visits annually and visitors spend over \$1.3 billion per year. This annual spending generates over 35,000 jobs. Although a small part of the overall Southwest economy, this employment and spending is quite important to local, rural economies. Accurate forecasts of visits to parks, and tourist sites in general, are of great value to the tourism industry. Tourist services are highly “perishable” goods. A vacant hotel room unused one night cannot be “stored” and used again.

Although national and state park planning documents acknowledge the importance of climate on park visitation patterns, statistical analyses of park visitation have not included climate, water availability or other environmental variables in their estimation. The project will use multivariate regression analysis to examine the contribution of climate and other environmental changes on park visitation, controlling for other factors (such as spatial patterns of economic and population growth). The second phase of research will use an input-output model to examine how climate and environmental change affect spending, income and employment in areas around parks.

D.2. Accomplishments to date. We have collected annual cross-section, time series data of park visits to Arizona state parks, New Mexico state parks, and southwestern national parks. For national parks, we have also collected monthly visit data. We have also obtained data on national park visit forecasts made by the National Park Service Public Use Statistics Office. The Public Use Statistics Office have also provided us with the data and programs of the forecasting models the Park Service uses to make their forecasts of annual visitation to each national park. Economic and geographical data has also been collected and used to develop indexes of market potential of each park and of spatial competition between parks. Other control variables include fuel prices and exchange rates.

D.3. Accomplishments anticipated by end of Budget Year. This spring, we will present preliminary findings of regression results at the invitation of the Arizona Hospitality Research & Resource Center of Northern Arizona University. The presentation will serve as a springboard for a meeting to gain stakeholder input and plan collaborations to estimate the impacts of climate induced visitation change on local economies in Northern Arizona. Srinivasa Ponnaluru will defend his Masters thesis that is based on the regression model of park visitation

D.4. Plans for 2005-2006. Two initial journal submissions are planned from our initial regression analysis. The first will focus on the relative contribution of climate and other variables to changes in different southwestern national parks over time (1979-2003). A second study will compare the results of our model with the forecasting model currently used by the National Park Service (NPS). The NPS employs time series model that forecast future park visits based solely on information about past visits. The second publication will ask the question, can park visitation forecasts be improved by including climate variables? If so, how much do they improve forecasts? The NPS Public Statistics Office has expressed great interest in our study and we also plan to share, present, and discuss our results with them.

Both the NPS and faculty at Northern Arizona University have developed (separate) input–output modeling methods to estimate economic impacts of a given level of change in park visitation. Another plan for 2005 is to bring different analysts and stakeholders together to examine the full linkage from climate/environmental change to visitation change to economic impacts. These impacts will be of interest to tourism and hospitality based industries in Northern Arizona and to city and county planning agencies. Frisvold will organize scholarly exchange, discussion and vetting of economic impact assessments at meetings of professional agricultural economic and economic organizations. Frisvold will collaborate with faculty at Northern Arizona University and other interested participating institutions to develop briefings and briefing materials for local stakeholder groups.

Econometric methods developed to estimate climate and environmental impacts on visitation will be extended to analysis of state park visitation in Arizona and New Mexico.

D.5. Leveraged funding. Frisvold has a Cooperative Extension appointment, which will allow for additional salary support for beyond CLIMAS-supported time to outreach activities related to this project.

D.6. Leveraged activities. Frisvold has a Cooperative Extension appointment, which will allow him to devote additional time beyond CLIMAS-supported time to outreach activities related to this project.

D.7. Non-CLIMAS Project Partners. Non-CLIMAS project partners include: National Parks Service (Public Use Statistics Office), Arizona State Parks, New Mexico State

Parks, Arizona Hospitality Research & Resource Center (Northern Arizona University), Arizona Office of Tourism.

Project E: Agricultural Technology Adoption and Water Use

E.1. Description. Agriculture accounts for roughly 80 percent of water consumption in Arizona and an even higher percentage in New Mexico. This means that small changes in irrigation water use has large implications for water available for other uses (domestic, commercial, industrial, and environmental). State and local planning to adjust to climate change and drought requires information on factors that affect agricultural water use.

E.2. Accomplishments to date. Deva and Frisvold have conducted preliminary statistical analysis of the 1998 and 2003 Farm and Ranch Irrigation Surveys (FRIS) of the USDA Census of Agriculture. The FRIS reports cross-tabulated data on water use, production decisions, and irrigation practice and technology choice for over 8,500 farms and ranches in Arizona and New Mexico. Using categorical data analysis techniques, Deva and Frisvold have examined how use of publicly and privately supplied information for water management, barriers to adopting more efficient irrigation practices, and participation in government water conservation programs varies by farm size and by state.

Smaller operators were more likely to rely on irrigation district staff or neighboring farmers for water management information, while large operators were more likely to rely on government agency staff and private consultants. While larger operators were more likely to rely on university / extension staff in Arizona, larger operators were less likely to do so in New Mexico.

Economic constraints were cited as the main barriers to adopting more efficient irrigation practices and technologies among operators who had investigated improvements. In Arizona, 59 percent of small operators, however, reported that they had not investigated methods to improve irrigation efficiency or conserve water. In New Mexico, this figure was 23 percent. In both states, however, the largest 20 percent of operators account for over 75 percent of water use.

USDA's EQIP program provides federal cost sharing for growers to adopt more efficient irrigation practices. States have certain latitude in administration of program funding. In New Mexico, 74 percent of EQIP contracts are with smaller farms that account for 26 percent of total state irrigation water applied. In Arizona, 65 percent of contracts are with larger farms that account for 77 percent of the water applied.

Growth accounting analysis shows that from 1998-2003, irrigation water applications fell 9 percent in Arizona. Half of this drop is attributable to reductions in planted acreage, while the other half occurred because growers applied less water per acre. In New Mexico, water applications rose 5 percent. Even though acre-feet of water applied per acre fell 2 percent, total irrigated acreage increased 7 percent.

E.3. Accomplishments anticipated by end of Budget Year. Selected results from project will be published in Spring issue of the *Arizona Review*, the University of Arizona College of Agricultural and Life Sciences primary economic outreach publication. The *Arizona Review's* circulation includes all county extension staff, staff of city and county governments, state and federal resource management agencies, agricultural groups, conservation groups, and private citizens.

E.4. Plans for 2005-2006. Frisvold and Deva will develop working papers for submission to peer-reviewed journals in the latter half of 2005. Deva will complete M.S. thesis on irrigation water use and technology choice. Research findings will be summarized and reported in Cooperative Extension publications and presentations.

E.5. Leveraged funding. An additional \$5,000 has been obtained from Cotton Incorporated to examine factors affecting conservation tillage practices in agriculture. Conservation tillage reduces wind and water erosion of the soil. Previous research has found that climate variables are important explanatory factors affecting tillage decisions.

E.6. Leveraged activities. Frisvold has begun work with Dr. Kazim Konyar in the Department of Economics, California State University – San Bernardino to develop a multi-commodity, multi-region economic model of U.S. agricultural production and input use. The model can be used to conduct simulations to estimate (a) commodity- and region-specific economic impacts of drought and (b) impacts of changes in U.S. farm programs on western water use.

E.6.2. Intra-CLIMAS Spin-offs. Frisvold will edit the Spring issue of the *Arizona Review* that will focus on climate and water-related research of Frisvold, Colby, their graduate students, and other related research by faculty of the Department of Agricultural and Resource Economics Department.

E.7. Non-CLIMAS Project Partners. Arizona Department of Water Resources, U.S. Geological Survey, National Agricultural Statistics Office, California State University – San Bernardino, Cotton Incorporated.

II. Publications

In print

Brookshire, D., B. Colby, M. Ewers, and P. Ganderton. 2004. Water Markets in the Southwest. *Southwest Hydrology* 3(2), 14-15.

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

Brookshire, D., Colby B.G., M. Ewers, and P. Ganderton. 2004. Market Prices for Water in the Semi-Arid West of the United States. *Water Resources Research* 40, W09S04, doi:10.1029/2003WR002846.

Frisvold, G. 2004. How federal farm programs affect water use, auality, and allocation among sectors. *Water Resources Research* 40, W12S05, doi:10.1029/2003WR02753.

Frisvold, G. 2004. Investing in border water quality,” *Arizona Review*. Spring. pp. 8-12, 19.

Accepted

Colby, B.G., J. Thorson and S. Britton. 2005. *Negotiations Over Tribal Water Rights*. University of Arizona Press, in press.

Orr, P., and B. G. Colby. 2005. Institutions and Incentives to Protect Water-Dependent Amenities. *Water Resources Research*, in press.

Orr, P. and Colby, B.G. 2005. Valuing Riparian Amenities. *Natural Resources Journal*, in press.

Leveraged peer-reviewed publications

Colby B. G. 2004. Tribal Water Issues: Implications for Arizona. *Arizona Town Hall Report*.

Colby, B. G. 2004. Estimating the Value of Water in a Alternative Uses. In K.W. Easter and M. Renwick (eds.), *Economics of Water Resources*. Ashgate Publishing.

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

McCann, L. and B. G. Colby. 2005. Transaction Cost Measurement Related to Environmental and Natural Resource Policies. *Ecological Economics*, in press.

III. Presentations at Professional Meetings/Conferences

Bark, R. 2004. Poster Presentation. Institute for the Study of Planet Earth Annual Fest, Tucson, AZ, October, 2004. Award: first prize (\$300), Social Science division.

Bark, R. 2004. Poster Presentation. Graduate & Professional Student Council, Student Showcase, University of Arizona, Tucson, AZ, October 2004. Award: first prize (\$250), Business Administration, Law, Economics and Public policy graduate division.

Bark, R. 2004. “Private property values and riparian corridors in Tucson, Arizona,” Rosalind H. Bark-Hodgins, Daniel E. Osgood, Bonnie G. Colby, Gabrielle Katz, and Julie Stromberg. SAHRA (Sustainability of Semi-Arid Hydrology and Riparian Areas, an NSF, Science and Technology Center) Fourth Annual Meeting: Focus on New Mexico, Albuquerque, NM, October 2004.

Bark, R. 2004. "The Value of Riparian Corridors in Desert Cities," Rosalind H. Bark, Daniel E. Osgood, Bonnie G. Colby, Gabrielle Katz, and Julie Stromberg. Arizona Hydrological Society Symposium: The Value of Water, Tucson, AZ. September 2004.

Bark, R. 2004. SAHRA (Sustainability of Semi-Arid Hydrology and Riparian Areas, an NSF, Science and Technology Center) 2nd International Symposium on Transboundary Waters Management, Tucson, AZ. November 2004.

Bark, R. 2005. "A Hedonic Valuation of Riparian Corridors in Semi-Arid Regions Using Remote Sensing Vegetation Indices", R. H. Bark-Hodgins, D. E. Osgood, and B. G. Colby. Western Regional Sciences Association, 44th Annual Meeting, San Diego, CA February 2005.

Colby, B. G. 2004. "Water as Sacred, Water as Commodity". Voices of the Southwest: The Culture of Water, a public lecture series, Albuquerque New Mexico, December 2004.

Colby, B. G. 2004. "Securing Reliable Dry Year Supplies" Utton Law School Conference, University of New Mexico, May, 2004

Colby, B. G. 2004. "Water Sales and Leases in Arizona: Price Trends, Values and Innovative Transactions" Arizona Hydrological Society Symposium: The Value of Water, Tucson, AZ. September 2004.

Frisvold, G. 2004. "Multilateral Aid and Transboundary Water Management Agreements: Lessons from Bargaining Theory," In Proceedings of the 2nd International Symposium on Transboundary Waters Management, Tucson, Arizona, Nov. 16 – 19, 2004 (CD-ROM). Sustainability of Semi-Arid Hydrology and Riparian Areas (SAHRA), University of Arizona, Tucson, Arizona.

Pullen, J. 2004. "Impact of Drought on Water Prices in the Southwestern United States" Jennifer L. Pullen and Bonnie G. Colby, Graduate & Professional Student Council, Student Showcase, University of Arizona, Tucson, AZ, October 2004. **Award:** second prize (\$125), Business Administration, Law, Economics and Public policy graduate division.

Pullen, J. 2004. Institute for the Study of Planet Earth Annual Fest, Tucson, AZ, October 2004. **Award:** third prize (\$100), Social Science division.

Pullen, J. 2004. "The Impact of Drought on Water Prices in the Southwestern United States" Jennifer L. Pullen and Bonnie G. Colby, Arizona Hydrological Society Symposium: The Value of Water, Tucson, AZ. September 2004.

IV. Outreach Activities

Colby, Advisory Committee, Utton Transboundary Resources Center, University of Colby, New Mexico School of Law.

Colby, Arizona Town Hall on Water Management, Faculty Advisory Group.

Colby, Board of Directors, Western Resource Advocates.

Colby, Nature Conservancy, Western Regional Office, Boulder, Colorado, advisor on water resource economics, water pricing and water transactions.

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

Frisvold organized working group meetings with the Arizona Department of Water Resources, U.S. Geological Survey, and National Agricultural Statistics Office to (a) determine how different agencies measured agricultural water withdrawals, consumption and irrigated acreage. Each agency relies on different definitions and estimation procedures. The goal of the meetings was to improve inter-agency understanding of these differences for more accurate and consistent reporting of ranges of water use estimates.

V. Human Resource Development

Srinivasa Ponnaluru will complete his M.S. thesis on climate, water availability and Southwest Park Visitation in the Department of Agricultural and Resource Economics in 2005. Shailaja Deva will complete her M.S. thesis on irrigation water use and technology adoption in the Southwest in 2005.

TASK AREA: Assessment and Monitoring of Vulnerability and Adjustment

PI: Dr. Tim Finan, Bureau of Applied Research in Anthropology

Researchers: Dr. Marcela Vásquez-León (Research Specialist, Bureau of Applied Research in Anthropology); Colin West, Andrea Sturtzen, Eric Pavri, Jodi Perrin, Nick Rattray, Sean Downey (GRAs, Bureau of Applied Research in Anthropology).

I. Progress for Budget Year 2004-2005

Project A: Vulnerability Research Case Studies

A.1. Description. The Climate Vulnerability Team seeks to understand the ways in which communities of the Southwest, comprising different hydrological regimes and livelihood systems, are vulnerable and adapt to climate variability. It also seeks to identify climate information needs of people whose livelihoods depend on climate. During year 2004 we completed our third vulnerability assessment case study in the Upper Gila River Valley (UGRV) and are now finishing the write-up of the final report to be presented to the San Carlos Apache Tribe, to farmers and cooperative extension agents in the UGRV, and to disseminate among other interested stakeholders.

We also began our fourth vulnerability assessment case study in the White Mountains as part of the CLIMAS Team Integrated Project (discussed below). This study area has characteristics that make it interesting from the point of view of conducting a vulnerability assessment. It also complements the team's previous study regions. The area is ethnically diverse, has livelihoods that are highly sensitive to climate variability and change, including recreational tourism, forest resources, farming, and ranching. The region also presents features of rural/urban interface where a variety of transitional livelihoods emerge and it has a variety of ecosystem types such as desert, forest, and riparian areas.

A.2. Accomplishments to date. For the UGRV case study, we are finalizing the report. We have invited the participation of Victoria Wesley from SCAT, she is completing a chapter on the relationship between drought, bark beetle and forest management in the reservation.

For the White Mountains case study we conducted our first intensive ethnographic research trip. We conducted over twenty-five interviews with people involved in wildfire risk mitigation, farmers and ranchers, USFS, BLM, NRCO and cooperative extension staff, local governments, and forestry and recreational personnel. Interview documents were set up for textual analysis software. We learned that there is a sizeable community of environmentally ill people residing in one of the communities. This population presents a vulnerability to climate change (heightened fire risk during drought) not previously encountered in our other case studies. We also initiated contact with the White Mountain Apache Tribe and are in the process of negotiating a Memorandum of Understanding between the Tribe and the University of Arizona.

A.3. Accomplishments anticipated by end of Budget Year. For the UGRV study we will incorporate stakeholder comments into the final report and begin to submit papers for

publication. For the White Mountains case study, we will conduct a second field trip to continue the process of intensive data collection.

A.4. Plans for 2005-2006. Complete the White Mountains case study.

A.6. Leveraged activities.

A.6.2. Intra-CLIMAS Spin-offs. The White Mountains Vulnerability Assessment Case Study is one component of the CLIMAS Team Integrated Project.

A.7. Non-CLIMAS Project Partners.

University of Arizona Cooperative Extension

San Carlos Apache Tribe.

Project B: Vulnerability Mapping of the Southwest

B.1. Description. Work on the GIS-based vulnerability mapping continued through 2004 (see CLIMAS Annual Progress Report 2002-2003 and CLIMAS Annual Progress Report 2003-2004). Building on the prototype static vulnerability maps, the Team has decided to move further and develop an on-line decision-support tool for decision makers in the Southwest. Earlier outreach with stakeholders from the Department of Economic Security, Arizona Department of Water Resources, and Arizona Cattle Grower's Association indicated that the information needs of these and other groups varied widely. Thus, this on-line decision-support tool is designed to complement the static GIS-based vulnerability map and to address the possible diversity in interests found among stakeholders. A new graduate student in anthropology, Nick Rattray, was hired for this project. He has brought extensive on-line interactive GIS mapping skills.

B.2. Accomplishments to date. Appropriate data sets were updated, added, revised and processed. A preliminary version of the online mapping tool – dubbed the “Climate Vulnerability Interactive Mapping Tool” (CVIMT) was created with a user-friendly interface. This prototype uses screen-shots and a java-based script to permit users to view maps, zoom in and out, select from a variety of themes, and access tabular data. This version was tested with a wide range of stakeholder groups at the annual Willcox Ag-Day, Feb. 2, 2005. The two students working on the CVIMT, Colin West and Nick Rattray, also have produced a design document that details the data requirements, user scenarios, and other factors so that all aspects of the tool's design and implementation will be carefully documented. Collaboration with the Upper San Pedro River Partnership – a consortium of 21 organizations in the San Pedro River Valley— has been initiated. They will be one of the pilot stakeholder groups around whose needs the CVIMT will be initially designed and they will be one of the groups that will test the tool.

A web and literature survey of other interactive mapping tools was performed to ensure that CLIMAS is not duplicating the efforts of other institutions or agencies. Moreover, state entities such as the ADWR, USGS, Tucson AMA, SAHRA, Arizona Department of Environmental Quality (ADEQ) and the UofA's Office of Arid Lands Studies (OALS) were contacted by phone to discuss their current initiatives, potential for collaboration, and risk of redundancy. All of these organizations expressed interest and support. They

also agreed to share publicly available data. Staff at these offices assured us that the CVIMT would not duplicate current efforts and actually complement them nicely due to the online and interactive components.

B.3. Accomplishment anticipated by end of Budget Year. The team will have an online version of the CVIMT available through the Center for Applied Spatial Analysis (CASA) web-site and server. It will have spatial and socioeconomic data available for display at the scale of the State of Arizona, county, zip-code, census tract, watershed, and town levels. Users will have an array of spatial tools available such as the ability to scale up or down, add or remove layers, and manipulate color ramps to show areas of high and low contrast. The tool will be presented and demonstrated in May to the entire CLIMAS Team to solicit feedback.

B.4. Plans for 2005-2006. The vulnerability mapping team will continue developing the online tool by adding data, improving the interface based on stakeholder feedback, demonstrating the tool to other user groups such as the Governor's Drought Task Force, and interacting with the Upper San Pedro Partnership. We plan to produce an online user's guide and tutorial as well. A manuscript for publication to the peer-reviewed journal *Disasters* is underway.

B.5. Leveraged funding. Jodi Perin was awarded a NASA Space Grant Fellowship to teach GIS skills to adult education classes in South Tucson. Skills, techniques, and applications she teaches are based on CLIMAS vulnerability mapping work.

CASA received funding to hire a laboratory assistant who specializes in interactive GIS. This person has been hired and the CVIMT will be one of their designated projects.

Eric Pavri was awarded a National Science Foundation Graduate Research Fellowship. A component of his research will utilize GIS, vulnerability assessment and stakeholder interaction skills he acquired as an GRA in CLIMAS.

Vasquez-Leon, M. "Environmental Indicators for Sustainable Agriculture: A Northwestern Sonora Study. In collaboration with the Colegio de Sonora." Grant from CONAHEC. 2004.

Vasquez-Leon, M. "Development of a Climate Vulnerability Index as a Knowledge-Generated Tool: Pioneering Interactive Stakeholder-Driven Research in Water Management" Proposal submitted to NSF in collaboration with the Udall center at the University of Arizona, and the University of Michigan. 2005.

B.6. Leveraged Activities.

B.6.1. More than 50% CLIMAS. The CVIMT will be a component within the larger proposed Virtual University of water information resources.

B.6.2. Intra-CLIMAS Spinoffs. Within CLIMAS, spatial data already acquired by students working on the vulnerability mapping tool was used by graduate students

working on the Arizona Drought Impacts Report (to be submitted to the Governor's Drought Task Force) to design a map of drought impacts in Arizona.

B.6.3. CLIMAS-related. Colin West returned from Burkina Faso where he was conducting dissertation research on the vulnerability of smallholder farmers to climate variability. His field methods utilized Global Positioning System (GPS) and GIS skills along with methodological training he acquired as a GRA on CLIMAS.

B.7. Non-CLIMAS Project Partners. The Center for Applied Spatial Analysis (CASA) provided laboratory facilities and expertise. The Tucson office of the USGS, ADWR, ADEQ, the Upper San Pedro Partnership, Water Resources Research Center, Office of Arid Lands Studies, and SAHRA agreed to collaborate and/or share data.

Project C: Mapping community perceptions of climate vulnerability.

C.1. Description. This project was completed this fiscal year (see CLIMAS Annual Progress Report 2003-2004). The project was designed to test some of the preliminary results of the larger climate vulnerability mapping project and focused on smaller-scale areas such as counties and watersheds. Fieldwork for the mapping project was successfully completed, data processed, and results communicated back to participants. A team of Bureau of Applied Research in Anthropology (BARA) students and graduate student research assistants from Geography and Regional Development met with individual stakeholders (i.e. ranchers, farmers, and residents) of the Sulphur Springs Valley where previous fieldwork had been done. Participants filled out a survey and then delineated areas of Cochise County that they perceive as being severely impacted by drought. They accomplished this by drawing on large paper maps of the county.

C.2. Accomplishments to date. These maps were then digitized and incorporated into a GIS. Individual perceptions of areas impacted became layers within the GIS and the researchers overlaid these layers to create a composite map of vulnerable areas within Cochise County. This composite map was presented at the Willcox AgDay in 2005. Participants appreciated the fact that their work made its way back to the community. The findings are still being analyzed and it appears that stakeholder perceptions of vulnerable areas actually mesh well with the larger vulnerability map. The Bowie sub-watershed to the east of the Sulphur Springs Valley was identified as one of the areas most impacted by drought in both the perception maps and the watershed GIS vulnerability maps.

Former CLIMAS GRA Jodi Perin and Nick Rattray have prepared a draft white paper describing the methods and theories of participatory GIS and its use for vulnerability mapping that will be featured in the CLIMAS Update Newsletter. This is to further communicate findings from the project to the larger public and the possibilities of doing participatory GIS.

C.3. Accomplishments anticipated by end of Budget Year. This component of the vulnerability mapping is completed. The white paper prepared by students will be refined

and submitted for publication in *Practicing Anthropology*, a journal for applied anthropologists and their emerging work.

C.4. Plans for 2005. The same methodology will be used to make a perception map of the CLIMAS Team Integrated Project Assessment Region in the White Mountains.

C.7. Non-CLIMAS Project Partners. The Center for Applied Spatial Analysis (CASA)

Project D: CLIMAS Team Integrated Assessment Project

D.1. Description. This project was spearheaded by the CLIMAS vulnerability team in coordination with the CLIMAS Core Office. It includes researchers from the other CLIMAS components. As stated above, the region chosen for the Integrated Assessment was the White Mountains of Arizona and a region encompassing Luna and Reserve, New Mexico.

D2. Accomplishments to date. The project has been formally presented to stakeholders in the region through project presentations delivered by members of the Vulnerability Team and the Core Office. The initial scoping on the region has been undertaken and a variety of agencies, stakeholders, and issues have been identified for further research. Team members conducted over twenty-five exploratory interviews in the White Mountains of Arizona and in the Luna and Reserve region of New Mexico. The goal of these interviews was to identify important climate impacts and vulnerabilities, important social groups, and key contacts. Sean Downey, a GRA from the anthropology department, has been hired to coordinate, in collaboration with the Core Office, activities in the Integrated Region between the Vulnerability Team and the other participating components from the larger CLIMAS group. A white paper has been produced, which summarizes existing secondary data on the region as a preliminary description of the region from social, economic, ecological, hydroclimatological, and policy perspectives. The vulnerability team contributed a chapter on livelihood systems, including a description of demographics and ethnic composition, historical development, land use patterns, and educational and healthcare resources. Nick Rattray created a GIS map of the team integrated project boundaries for the white paper. Sean Downey (Vulnerability Team), Melanie Lenart, and Jean Morrill (Core Office) planned, compiled, organized, and edited the contributions of the larger CLIMAS group to the white paper. Sean Downey also created a web-based group collaboration tool dedicated to the Integrated Project in order to facilitate communication among CLIMAS researchers located in different offices on the University campus, and affiliated researchers in other states.

D.3. Accomplishments anticipated by end of Budget Year. A second fieldtrip will be undertaken for intensive data collection by representatives of the different CLIMAS disciplinary groups.

D.4. Plans for 2005-2006. Establish partnerships with the White Mountain Apaches and other stakeholders, complete data collection phase, and begin the data analysis phase.

D.6. Leveraged activities.

D.6.2. Intra-CLIMAS spin-offs. We will work closely together with other components of the CLIMAS group in order to learn more about the process of integration and produce outputs that are highly relevant to stakeholders requiring a multiplicity of information.

II. Publications

In Print

Vásquez-León, M., and A Bracamonte. 2004. Indicadores ambientales para la agricultura sustentable: un Estudio del Noreste de Sonora. El Colegio de Sonora, Sonora, Mexico.

Submitted/In Review

West, C.T. Misreading the Arizona landscape: Challenging received wisdom on ecological destruction in southeastern Arizona. Manuscript submitted to *Human Ecology*.

To be submitted by June 1, 2004

Rattray, N., J. L. Perin, and E. Pavri. Methodology for Community-based mapping of perceptions to climate vulnerability. *Practicing Anthropology*.

Vásquez-León, M., C. T. West, and T. J. Finan. Agricultural diversification and its role in adaptation to climate variability. *Mitigation and Adaptation Strategies for Global Change*.

West, C. T., N. Rattray, and J. L. Perin. Livelihood vulnerability mapping: the case of drought and flooding in Arizona. *Disasters*.

Wolf, B., and M. Vásquez-León. Water is life: climate vulnerability in the Upper Gila River Valley (UGRV) of Southeastern Arizona.

III. Presentations at Professional Meetings/Conferences

Perin, J., and E. Pavri. 2004. GIS and qualitative research: Mapping perceptions of vulnerability to climate events in the U.S. Southwest. Presentation at CLIMAS Team meeting.

Perin, J., and E. Pavri. 2005. GIS and qualitative research: Mapping perceptions of vulnerability to climate events in the U.S. Southwest. Presentation at Society for Applied Anthropology Annual Conference, Santa Fe, New Mexico.

West, C. T., and N. Rattray. 2005. The Climate Vulnerability Interactive Mapping Tool (CVIMT). Presentation at the CLIMAS team meeting.

IV. Outreach Activities

Vásquez-León, M. 2004. Presentation of CLIMAS proposed work in the Integrated Region at the Forest Health Working Group meeting at Pinetop-Lakeside.

Vásquez-León, M. 2004. Contribution to the section on vulnerability to drought prepared by the Governor's Drought task force.

West, C. 2005. Exhibitor at the Southeastern Arizona Ag-Day and Trade Show 2005. Presented results from research done in the community and provided information on climate forecasting and research.

West, C. and N. Rattray. 2005. Presentation on the Climate Vulnerability Interactive Mapping Tool to the Upper San Pedro Partnership Technical Committee.

V. Human Resource Development

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

There has been continued training in stakeholder interaction skills along with interactive GIS skills.

Colin West applied ethnographic, GIS, and vulnerability analysis skills to his dissertation research in Bam Province, Burkina Faso through a Social Science Dissertation Research Fellowship sponsored by the Population Council.

TASK AREA: CLIMAS Border Projects

PI: Dr. Margaret Wilder, Latin American Studies/Geography

Researchers: Gigi Owen (GRA, Latin American Studies), Katherine Meehan (GRA, Geography and Regional Development)

Note: This Task Area Progress Report is incomplete as of March 1, 2005, due to unforeseeable health concerns of the P.I. Updates to Section I and the completion of Sections II-V of this task area will be submitted at a later date.

I. Progress for Budget Year 2004-2005

Project A: Decentralization of Urban Water Management in Sonora, Mexico—2003-2005

A. 1. Description. The objective is to examine whether decentralization of urban water management in Mexico has a) opened new windows for the use of climate information to achieve more sustainable long-term planning; and b) resulted in more participatory, stakeholder-based decision-making processes. Eight major Sonoran cities located throughout the state are included in the study: Nogales, Cananea, Naco, Hermosillo, Empalme/Guaymas, Obregon, Navojoa, and Alamo

A.2. Accomplishments to date. Semi-structured, open-ended interviews have been conducted with approximately 50 stakeholders in the Sonoran study sites. To complete missing data, follow-up interviews have been conducted with some respondents.

Stakeholders included in the study:

- 1) Water managers at the federal (C.N.A.), state (COAPAES and CEA), and municipal levels
- 2) NGOs (in particular, la Red Fronteriza Ecologica (the Border Environment Network)
- 3) Citizens involved in environmental education for water conservation
- 4) Academic water researchers

A.3. Accomplishments anticipated by the end of Budget Year.

A.4 Plans for 2005-2006/

A.5. Leverage funding.

In a related study focused on the Upper San Pedro transboundary region, funded by a NOAA project based at the Udall Center, I am examining the emerging river basin management organizations, the watershed councils (*consejos de cuenca*) in Sonora. There are three principal watershed councils in Sonora: the Upper Northwest (including the San Pedro River); the Rio Yaqui/Matape; and the Rio Mayo. The objectives of the watershed council study are a) to examine whether the participatory watershed councils create opportunities for more effective use of climate information and climate science for more sustainable long-term planning; and 2) to examine the process and central areas of focus of the watershed councils to analyze whether participatory decision-making process

leads to more sustainable planning for water resource use. The NOAA Udall Center project also provides significant interview and survey data for the Naco/Cananea portion of the urban water management study. In addition to interviewing stakeholders, we have also observed watershed council meetings and interviewed individual sectoral representatives (e.g., representing the sectors of urban/industrial/agriculture/ranching). Interviews and participant observation for this study continue.

Preliminary finding for this project include:

Climate Products used by Water Managers include basic products such as:

- Reservoir levels
- Meteorological data (provided by the C.N.A.'s National Meteorological System, S.N.M.)
- General hydrological data, precip and temperatures
- Formerly used a system called ERIC (Rapid Climate Information Extractor) from CLICOM dataset; several respondents told us this was outdated back in 1989; others said that an updated version is now available.
- Information from the Weather Channel
- GOES satellite and spot imaging (for disaster planning)

Climate information is tightly-held and controlled by the C.N.A. Requests for use of climate information have to be made in writing, and may not be acted upon. While water managers in the C.N.A. and in the municipal water management for Hermosillo generally seemed to have access to climate products, those in the smaller cities generally did not have this access.

Climate products identified by water managers as needed, include:

- Climate models with forecasting ability
- More extensive climate metering network
- Historical climate information would be of interest (such as tree ring data)
- More geophysical studies to assess groundwater aquifer capacities and levels
- Credible and timely forecasts (within 6 months)

Constraints to using climate science/information identified by water managers include:

- Control and flow of information is constrained (by C.N.A.)
- Financial resources to pay for drought planning and mitigation strategies
- Price of water is under-valued
- Cultural constraints: people in desert environments essentially live with drought and aridity and we know how to adapt; "drought not considered an emergency. An emergency is moving people away from their houses."

Institutional Issues identified:

Challenges

- Short-term (3 year) appointments for government officials and water managers make it difficult to engage in long-term planning and may cause risk-averse behavior
- Differential levels of access to climate information (and ability to use it effectively)
- Lack of scientific information regarding groundwater aquifer levels and environmental impacts of new proposed projects (such as piping water into Alamos from Los Muertos)
- Lack of interagency communication and cooperation (e.g., the Comision Estatal de Agua, CEA, has not formal water management role; it is advisory only; C.N.A. has jurisdiction)
- Preoccupation with day-to-day management and coping with overdrafted aquifers and record-low reservoirs leads to more of a crisis management strategy rather than a focus on long-term, sustainability issues

Opportunities

- Emerging watershed councils may open windows for use of climate science toward more sustainable planning (however, the preliminary evidence would indicate that this is NOT happening at the moment)
- Higher-level technical training of management staff
- Information-sharing potential via the Internet
- University/community interactions and collaborations, including binational—e.g., meeting held last year at UniSon to discuss community water quality testing program; meeting held last year at UniSon to discuss establishing a climate center

Social Issues

Challenges

- Resistance to residential metering in some areas (e.g. Alamos)
- Lack of culture of paying full price of water
- Uneven economic landscape and ability to pay
- Water service is intermittent; frequently not available 24 hours/day

Opportunities

- Growth of some environmental education in schools
- “New culture” of water evidenced by growing consciousness of water scarcity

The principal “success story” of this project, apart from all we are learning, is the building of closer ties with stakeholders in Sonora and developing a “climate” of trust with the water managers, particularly in the C.N.A. This, however, is a work in progress, and given that water managers frequently move around or move on with new political administrations, this is a difficult task. If we were able to help them with technology innovations that they could and would actually use, this would be a real avenue for partnership. Through ongoing conversations with between Gregg Garfin (CLIMAS Core Office) and Lucas Oros (CNA), we have learned that drought monitoring and planning is an area of common concern. We believe that this will be a fruitful area for collaboration in 2005-2006.

Project B: Conserving the Limitrophe Wetlands of the Lower Colorado River: The Colorado River International Conservation Area (CRICA)—2004-ongoing

B.1 Description. Working with a binational steering committee, we are conducting research to examine how local communities in the binational area use and value the Limitrophe wetlands, and what is the role of climate and drought in determining community perceptions of the wetlands. The Limitrophe is a 23-mile stretch of the Lower Colorado that forms the boundary between the U.S. and Mexico. The wetlands is an area of high biodiversity value and an important stopover for migrating birds on the Pacific Flyway. The wetlands is a significant part of the economy for local communities on both sides of the border; for example, it is a major attraction for the annual Yuma Birding Festival, which brings thousands to the region every year. It is also an area under environmental pressure due to the strains on the Colorado River itself; the drought; proposals for lining the All-American Canal, and increasingly, some evidence of narco-trafficking and immigrant traffic. The three principal communities involved are: the Cocopah Tribe, Yuma, Arizona, and San Luis Rio Colorado.

For the past two years, a binational steering committee of federal water and land managers, NGOs, international commissions (IBWC/CILA), and academic researchers has been meeting to develop a plan to establish the Colorado River International Conservation Area (CRICA) in the Limitrophe region. If successful, this will be the first-ever international conservation area on the U.S.-Mexico border. To date, planning for the CRICA has focused on the legal instruments that can be used by both governments (MX, US) to establish the conservation area (it is likely that each nation will establish the conservation area, and they will be contiguous rather than one overarching conservation area straddling two countries). To date, the communities and public have not participated much in these discussions, although the Cocopah Tribe is responsible for initiating the planning process. The steering committee believes it is important to understand how the local communities use and value the wetlands, to gauge public response to the proposed conservation area.

The three communities of Yuma, Arizona, the Cocopah Tribe (in Yuma/Somerton area), and San Luis Rio Colorado will be the principal study sites.

Stakeholders in the project include

- Water and Land Managers including:
International Boundary Waters Commission/Comision Internacional de Aguas y Limites (IBWC/CILA): *international*
Bureau of Reclamation; Bureau of Land Management; U.S. Fish and Wildlife;
National Water Commission (MX): *federal*
Arizona Game and Fish: *state*
- Tribal Leaders/Land and Water Managers
Cocopah Tribal leaders; relevant staff; committees
- Non-Governmental Organizations
National Wildlife Federation; Environmental Defense; Sonoran Institute; Pronatura

- Local Organizations
Boy and Girl Scouts; Yuma Chamber of Commerce; Yuma Birding Festival;
Asociacion de Usuarios Ejidatarios del Rio Hardy y Colorado (AEURHYC)

B.2. Progress to date. We have constructed a baseline social and economic database and are beginning stakeholder interviews this month. We regularly participate in steering committee meetings. This research project is in its incipient stages. At this point, the primary success has been participation by the UA CLIMAS RISA in a high-profile, high-visibility project demonstrating the promise of close transboundary cooperation on targeted projects, even facing difficult political constraints. By virtue of our participation, CLIMAS is taking a leadership role in a very significant project that highlights the critical relationship among climate knowledge and perceptions, endangered ecosystems, and social communities.

B.3. Progress expected by the end of Budget Year. Semi-structured, open-ended interviews are currently being conducted with the stakeholders and decision makers on the binational steering committee. These represent the major governmental bodies with jurisdiction over the wetlands, and NGOs active in the region. These interviews focus on three areas: a) how climate factors impact the wetlands area and what kinds of climate information might be useful to water/land managers and NGOs; b) why the agencies/NGOs consider preservation of the Limitrophe wetlands to be critical; and c) obstacles, challenges and conflicts that have arisen or can be anticipated.

B.4. Plans for 2005-2006. Surveys to be completed at community meetings to be held in the three areas in Fall 2005, using Sharpe Interactive Decision Technology (on loan from UA Dept of Geography). These allow us to survey up to 60 people at a time with instant feedback and statistics that feed into a database for future use. Survey focus will be on: a) how people currently use the wetlands area or would use it in the future (e.g., birding, hiking, fishing, camping); b) how people value the wetlands area; c) perceptions of climate and drought related to wetlands preservation (e.g., does a perception that climate is changing make them more willing to ensure wetlands preservation?).

If funding permits (TRIF grant applied for; decision due 4/05), study will be expanded to include randomized community surveys, more focus groups, and a game theoretic modeling of conflicts over resources (PI. G. Frisvold).

B.5. Leveraged funding. Wilder has applied for TRIF/WEDSP funding at the University of Arizona to expand the research capacity of this project (request: \$78,000, 7/2005-6/2006). This additional funding would allow us to do a large, randomized sampling of individuals in the 3 communities, and one of my co-PIs (G. Frisvold) would conduct a game theoretic model based on interview and context data. Decision anticipated: 4/2005

Project C: Climate and Drought K-12 Curriculum for Arizona/Sonora Classrooms

C.1 Description. We are developing a pilot curriculum aimed at 4th through 6th grades based on climate and drought. This will supplement a water education curriculum already developed and in use by Project WET at the UA. The Center for Latin American Studies is a Title VI-funded National Resource Center, one of whose principal objectives is to stimulate knowledge about Latin America within the K-12 curriculum. Thus, CLAS has an existing workshop series with teachers who receive professional development credit for participating, and receive curriculum materials.

C.2. Accomplishments to date. Assessment of Existing Resources and Needs: We have met with approximately K-12 education and environmental education experts across Tucson and the UA community; we have established email contact with interested teachers in Tucson Unified School District; we have done classroom observations; we have attended a curriculum workshop; we have gathered information from existing curriculum resources, both in print and internet-based; we have met with teachers from Magdalena, Sonora to assess their curriculum needs vis a vis this project.

C.3. Accomplishments anticipated by end of Budget Year. A teacher workshop for local Tucson teachers is planned for Saturday, April 16. The two-hour workshop will consist of a first hour with two presentations by UA faculty, one focusing on the physical science of climate and drought; the second on the social science of climate and drought. The second hour of the workshop we will present a proposed curriculum (2-day teaching units) and ask the participating teachers to critique them and discuss them with us. Based on feedback and critique from the workshop, we will revise the curriculum materials and make them available to all workshop participants, as well as on the Climas, Udall Center and Latin American Studies websites. We will arrange with participating teachers to participate/observe in their classrooms when the materials are used.

C.4 Plans for 2005-2006. We will work over the summer to develop these materials, adapted for Sonoran needs, if necessary, for use in Sonoran schools. They will be available in Spanish, and posted on the Climas, Udall Center, and Latin American Studies websites in Spanish. We will make them available to teachers in our Magdalena exchange group and in the Nogales, Sonora school district for pilot use in their classrooms, and if funding is available, send a team member to participate/observe when in use. Future plans: The Udall Center and Climas (Anne Browning/Gregg Garfin) are seeking funds to expand the scope and impact of this environmental education project. If funding is available in the future, the K-12 curriculum project on climate and drought could be greatly expanded to include more grade levels, more interactive and web-based activities, and to ensure greater use in actual classroom settings.

C.5 Leveraged funding. This project is primarily leveraged by the NOAA Udall Center grant

C.7. Non-CLIMAS project partners. Udall Center for Public Policy.

Project D: CLIMAS Website Translation

D.1 Description. To translate the CLIMAS website into Spanish to make it accessible both to Spanish-speaking Arizonans and Mexicans in the border region of Sonora.

D.2. Accomplishments to date. We held an initial meeting with the website manager and CLIMAS Director, and have translated the first 7 pages or so of the website.

D.3. Accomplishments anticipated by end of Budget Year. These are currently undergoing additional review for technical terminology, and then will be given to the website manager for uploading onto the site in late spring or early summer 2005.

D.4 Plans for 2005-2006. This project will be continuing.

The following sections will be completed and submitted to NOAA as a later data

II. Publications

III. Presentations at Professional Meetings/Conferences

IV. Outreach Activities

V. Human Resource Development

TASK AREA: Climate, Ecology and Fire Research

PIs: Dr. Jonathan Overpeck, Institute for the Study of Planet Earth; Dr. Thomas Swetnam, Laboratory of Tree-ring Research

Researchers: Jeremy Weiss (Research Scientist, Geosciences), Allison Drake, Erica Bigio (GRAs, Geosciences)

I. Progress for Budget Year 2004-2005

Project A: Climate and Vegetation Change in Southwest North America

A.1. Description. Freezing temperatures strongly influence vegetation in the hottest desert of North America, in part determining both its overall boundary and distributions of plant species within. To evaluate recent variability of freezing temperatures in this context, minimum temperature data from weather stations in the Sonoran Desert are examined in conjunction with distributions of freeze-intolerant plant species. Analyses in this study show widespread warming of minimum temperatures during winter and spring, decreases in the number of days with freezing temperatures, and lengthening of the freeze-free season in the Sonoran Desert during the 20th century that correspond more to anthropogenic global warming than other influences such as land use and lower-frequency climate modes. Warming likely will continue at faster rates, particularly during winter, in response to increasing anthropogenic emissions of greenhouse gases. Unless these increases are significantly slowed or stopped, a future Sonoran Desert distinctly different from today possibly will result, with much greater presence of freeze-intolerant plant species typical to southern Sonoran Desert, thornscrub, and lowland forests in Sonora and Sinaloa, Mexico, areas characterized by denser and more continuous vegetation composed largely of drought-deciduous, thorny, microphyllous shrubs and trees of greater stature, and by inconspicuousness of cacti such as the iconic *Carnegiea gigantea* (saguaro). Interaction between continued warming and landscape structure, seed dispersal vectors, increased soil nitrogen, disturbances such as drought, and favorable warm season precipitation may enhance these physiognomic changes.

Warming minimum temperatures and fewer freeze events in the Sonoran Desert offer researchers opportunities to examine ecosystem response to regional disturbance. One of these opportunities is to integrate climatological and ecological observations and reconstruction techniques to determine how current freezing temperature variability and distributions of freeze-intolerant plant species in the Sonoran Desert compare to those before time periods used in this study. Fusing such techniques with ones used in this study across Sonoran Desert climate and vegetation gradients may help identify potential variables with which to monitor effects of anthropogenic global warming in the Sonoran Desert. Continued warming in the Sonoran Desert also offers researchers opportunities in regards to ecosystem response and regional disturbance that could be starting points for anticipating and mitigating effects of anthropogenic global warming in the Sonoran Desert region which includes ecosystems and endangered species of the biodiverse sky island region in southeast Arizona and northwest Mexico that borders the Sonoran Desert at higher elevations, and planning conservation, use, and management of our international lands accordingly.

A.2. Accomplishments to date.

In 2005, Weiss and Overpeck submitted a paper to *Global Change Biology*.

In February, 2004, Overpeck testified in support of Arizona State Senate Bill 1227 (State Climate Change Study Committee); Senate Natural Resources and Transportation Committee.

In February, 2004, Overpeck was a Panel Member, Plenary Session on “Managing Fish and Wildlife in the face of Climatic Variability,” 37th Annual Joint meeting of the Arizona and New Mexico Chapters of The Wildlife Society and the Arizona/New Mexico Chapters of the American Fisheries Society, Safford AZ.

A.3. Accomplishments anticipated by end of Budget Year. Continuation of the work.

A.4. Plans for 2005-2006. We plan to continue our work both on the Sonoran Desert biome, as well as more broadly on other Southwest biomes.

A.5. Leveraged funding. J. Weiss is covered by non-CLIMAS funding, and thus represents substantial leverage on Overpeck’s CLIMAS funding.

Project B: The Impacts of Climate Change and Wildfire on Sonoran Desert Grasslands

B.1. Description. The interactions of climate variability, fire, and land use will play a significant and complicated role on future vegetation change in the southwest. For her Master’s thesis research, Allison Drake has investigated the impacts of climate variability, wildfire regimes, and human activities on the vegetation dynamics at the grassland-shrubland transition zone in southeastern Arizona. Allison implemented a dynamic vegetation model to evaluate the response of vegetation to proposed changes in climate change, climate variability, and extreme drought. Working in the context of a large interdisciplinary research team, she has assessed the potential impacts of climate variability and climate change on fire dynamics, ecosystem structure and composition, biodiversity, and by extension, rangeland management, urbanization, road construction, water supply, and human health.

B.2. Accomplishments to date. Allison Drake parameterized and validated the plant-soil ecosystem model CENTURY for dominant soil types and plant functional groups along an elevation gradient in southeastern Arizona using observational measurements of above-ground plant biomass and satellite imagery. Climate change simulations included isolated effects of increased temperature, the combined effects of increased temperature with altered seasonal precipitation (Southwest Regional Assessment Group 2000), extreme drought conditions, and the impacts of fire and grazing management regimes.

Within the current range of variability, several wet years can provide enough fine fuels to carry a fire; however, CENTURY simulation results indicate that under these high production conditions, average fuel loads will be equivalent (or exceed) current high fuel conditions. Fuel loads of this magnitude are capable of sustaining fire within Sonoran

desert grasslands and shrublands, and carrying the fire toward vulnerable areas (e.g. building structures, livestock ranches, forests, and Saguaro cactus populations). Alternatively, long-term drought scenarios lead to extremely low vegetation cover which may increase erosion and intensify the degradation of grasslands and shrublands and decrease herbaceous production to levels detrimental to rangelands and agricultural fields in southeastern Arizona. Management scenarios have been evaluated for potential growth of herbaceous cover (forage and/or fuel), shrub encroachment, grazing regimes, and the frequency and intensity of fire.

The idea for this project was built upon the foundation of an EPA-sponsored Wildfire Alternatives (WALTER) project at the University of Arizona, and fills a key gap in this project (PIs: B. Morehouse, G. Christopherson, B. Orr, J. Overpeck, T. Swetnam). This interdisciplinary project seeks to improve ecosystem health and sustainability in the southwest United States through developing a better understanding of the interactions among climate, human activities, and wildfire. The GIS-based model/decision-support tool is accessible to educators, stakeholders, and decision-makers through an innovative map server on a University of Arizona Web site (<http://walter.arizona.edu>). Many associated projects are involved in the effort including, but not limited to, the NOAA-funded Climate Assessment of the Southwest (CLIMAS) program, the UA Laboratory for Tree Ring Research, the UA Center for Arid Lands Studies, and the U.S. Agricultural Research Service (ARS) all in Tucson.

Drake was awarded 2nd Prize in the 2005 Institute for the Study of Planet Earth Graduate Student Poster Competition for her poster, *Modeling the response of vegetation to potential climate changes on southwestern grasslands*.

B.3. Progress anticipated by the end of Budget Year. Allison Drake will work on her thesis and towards publication.

B.4. Plans for 2005-2006. Complete study. Allison Drake will defend her Master's degree and submit work for peer-reviewed publication.

B.5. Leveraged finding. This research was supported by the Department of Energy Global Change Education Program and the NOAA Climate Assessment for the Southwest program at the Institute for the Study of Planet Earth, University of Arizona. Satellite imagery data were provided by the Arizona Remote Sensing Center, Office of Arid Lands Studies, University of Arizona.

Drake received her 2nd year of funding from the Department of Energy Global Change Education Program Graduate Fellowship.

B.6. Leveraged activities.

Outreach Activity: Educational museum exhibit on wildfire in the Southwest

Wildfire is becoming a pressing issue in the southwest. Several large fires in the Tucson area (Bullock fire, 2003; Aspen fire, 2004) have sparked interest, questions, and concerns from the Tucson community about wildfire in the southwest. Several departments and

programs at the University of Arizona and local agencies in Tucson have expressed an interest in an educational museum exhibit that would address the issue of wildfires in the southwest. In the fall of 2003, Allison Drake proposed to design an educational museum exhibit for the University of Arizona's Flandrau Science Center as an outreach project for an honorary NASA Space Grant Fellowship. The exhibit was completed in the Spring of 2003, and is will be displayed in the Flandrau Science Center in the Spring of 2004. The display focuses on the interaction of fire, climate and society in the southwest, specifically on current fires, the fire history of the southwest, methods used to determine fire histories, and ongoing research projects related to fire at the University. At the Flandrau Science Center, the exhibit will provide an interactive digital presentation on wildfire in the southwest for all public audiences, including thousands of annually visiting students and teachers.

Grant worked with Debbie Colodner (an education and exhibit coordinator at the UA Flandrau Museum), Julia Cole (UA professor of Geosciences), and Merridith Larabee (an undergraduate with a NASA Space Grant Scholarship) to put together a museum exhibit on Wildfire and El Nino/La Nina climate patterns on the southwest. The exhibit includes two digital presentations (PowerPoint format) that will be projected onto a big screen in the main exhibit hall in the museum. One presentation is focused on wildfires in the southwest (my work), and one on El Nino/La Nina climate patterns on Tucson and the southwest (Julia Cole). An 'internet kiosk' will allow visitors of all ages to explore web pages related to the exhibit. The exhibit will include a hands-on display of corals and tree-rings, which are discussed in the digital presentations. The display will include a physical bulletin board that would contain news articles and maps about the current and year-to-date fire activity and climate patterns. A transportable version of this initial fire exhibit could also be made for educational activities in various classrooms, public workshops, the forest and park services, cooperative extension, and other non-academic groups to help educate the community on the interaction of wildfire and society in the southwest. Debra Colodner, the education director at the Flandrau Science Center, has expressed an interest in developing a large, comprehensive exhibit on wildfire in the southwest for the new Tucson Science Center (to be built in downtown Tucson as part of the Rio Nuevo Project).

Support for this exhibit came from the University of Arizona's Flandrau Science Center, the NASA Space Grant program, Arizona FIREWISE, the University of Arizona Laboratory for Tree Ring Research, and the Arizona Daily Star.

Project C: Fire Research

C.1. Description. This project aims to integrate tree-ring and alluvial fan records of fire history in a recently burned watershed in southwestern Colorado. Tree-ring methods provide annual records of the frequency, severity and extensiveness of past fires up to about 300 years at this site. The detailed tree-ring information may be correlated with patterns of inter-annual climatic variability over the same time period. Alluvial fans record the geomorphic response to past fires, and may be used to interpret the past fire frequency and relative severity over longer time scales. In this study area, up to 3,000 years of fire-related sedimentation events will be calibrated with the tree-ring record of

fire history in the same drainage. The benefits of such research include the ability to analyze fire and climate relationships – especially extreme climate, fire, and geomorphic events -- over longer time scales than attainable through modern observations or tree-ring methods alone. These insights are needed by forest and watershed managers to better anticipate and plan for future ecosystem and hydrological responses to climate variability and change.

C.2. Accomplishments to date. Field work was completed during the summer and fall of 2004. The data collection included three alluvial fan sections, each containing several fire-related sediment layers. Three plots of tree demography and several fire-scarred cross sections were also collected from throughout the basin. The frequency of fire-related sedimentation events is being documented with radiocarbon dating of charcoal pieces at the Accelerator Mass Spectrometry Laboratory of the University of Arizona. Results are expected later in the spring and summer of 2005. Tree-ring analysis of past fire behavior has begun at the Laboratory of Tree-Ring Research, and will continue through the spring and summer of 2005.

C.3. Accomplishments anticipated by end of Budget Year. A general estimate of the past fire frequency and severity based on interpretation of sediment properties and preliminary radiocarbon dating results. Tree-ring analysis will identify widespread fire years, and allow for further fire and climate analysis during the next budget year.

Bigio will present research design and preliminary results at the University of Arizona Geosciences Geodaze conference in early April, 2005, and give an additional presentation at a fire history and climate workshop in early May, 2005.

C.4. Plans for 2005-2006. Bigio will begin preparation of draft manuscripts that will form the basis of her MS Thesis in Geosciences, with an anticipated completion by December 2005.

Project D: White Mountains Team Integrated Project (TIP) Area White Paper

D.1. Description. Jeremy Weiss summarized elevation, phytogeography, riparian areas and wetlands, and temporal vegetation variability, as well as brought attention to climate and vegetation change at local and regional ecotones in the White Mountains area. He also created maps for elevation and vegetation, and figures of average seasonal and interannual vegetation variability based on remote sensing data.

Allison Drake contributed a section on the current state of rangeland ecosystems in the White Mountains. This section highlighted issues of land use (primarily fire suppression, grazing management, and the introduction of nonnative species) on Plains and Great Basin Grassland, Great Basin Desertscrub, and Alpine grasslands. She also contributed a section on the paleovegetation of the southwest.

Erica Bigio contributed sections on woodland and conifer forest, the fire history of the region, erosion hazards, and fire/climate relationships.

D.2. Accomplishments to date. Contributed several sections to the white paper: “CLIMAS Team Integrated Project: An Integrated Assessment in the White Mountains”.

II. Publications

In press

Swetnam, T. W., C. H. Baisan, and H. D. Grissinho-Mayer. In press. Tree-Ring Perspectives on Fire Regimes and Forest Dynamics in Mixed-Conifer and Spruce-Fir Forests on Mount Graham. In Proceedings of the Mounta Graham Red Squirrel Conference. To be published by UA Press.

Hessburg, P. F., E. E. Kuhlman, and T. W. Swetnam. In press. Examining the recent climate through the lens of ecology: inferences from temporal pattern analysis. *Ecological Applications*.

Submitted / In Review

Weiss, J. L., and J. T. Overpeck. 2005. Is the Sonoran Desert losing its cool? *Global Change Biology*, (submitted).

III. Presentations at Professional Meetings / Conferences

Drake, A. and J.T. Overpeck, 2005. Modeling the response of vegetation to potential climate changes on a semi-arid rangeland in southeastern Arizona. Society for Rangeland Management, February 5-11. Fort Worth, Texas.

Drake, A. and J.T. Overpeck, 2005. Will wildfire change the Sonoran Desert? 33rd Annual Geosciences Graduate Student Symposium. April 7-9. Tucson, Arizona

Swetnam, T. 2004. Presentation by Swetnam and Tree Rings and Climate Workshop, University of Arizona, April 6, 2004. Fire climatology advances in knowledge and applications supported in part by CLIMAS were highlighted.

Swetnam, T. 2004. Presentation by Swetnam at Southwest Forest Restoration Workshop, Silver City, NM, April 20, 2004. Fire climatology advances in knowledge and applications supported in part by CLIMAS were highlighted.

Swetnam, T. 2004. Presentation by Swetnam at Madrean Archipelago Ecosystems Workshop, Tucson AZ. May 12, 2004. Fire climatology advances in knowledge and applications supported in part by CLIMAS were highlighted. Proceedings paper in press.

Swetnam, T. 2004. Presentation by Swetnam at MTNCLIM Workshop, Lake Tahoe, NV. Sponsored by USFS, USGS, NSF., and others, May 26, 2004. Fire climatology advances in knowledge and applications supported in part by CLIMAS were highlighted.

Swetnam, T. 2004. Presentation by Swetnam at Global Wildfire History and Climate workshop, Fast Track Initiative of International Geosphere Biosphere Program (and Swetnam helped organize the meeting), Boulder, CO. November 8-9, 2004. Fire climatology advances in knowledge and applications supported in part by CLIMAS were highlighted.

IV. Outreach Activities

See Section B.6 for outreach work done by Drake.

Swetnam is a member of Arizona Governor Janet Napolitano's Forest Health Advisory Council (FHAC), which meets monthly. During the past year Swetnam has advised the Council on several matters pertaining to climate variability, drawing upon CLIMAS research and outreach, as information input to the Council's deliberations and recommendations to the Governor. A proposal to FHAC (by Swetnam) is being considered to develop a white paper on potential current and future climate variability and change impacts on Arizona's forests. If this proceeds, it is likely that CLIMAS could play an important advisory and input role in 2005 for this effort.

Swetnam served as panelist on a review of the 2003 Aspen Fire (Santa Catalina Mountains, Tucson), held by a USFS National fire review team. January 12, 2004. This include some review of the climate factors involved in this fire.

Swetnam met with Chester Joy and Suan Iott, General Accounting Office, on a review of national fire management policies for the Congress. Climate variation and change was a subject of discussion. January 21, 2004.

Swetnam served as chair of a review panel of NOAA's Paleoclimatology program in Boulder, CO, and developed a report to NOAA (Dave Easterling) recommending changes and support to the program. January 27-28, 2004.

Swetnam presented lecture to Continuing Education in Ecosystem management course at Northern Arizona University, Flagstaff (about 30 fire managers from throughout the US). The lecture included presentation on climate and fire interactions, drawing upon CLIMAS workshops and applications in predictive services. February 9, 2004.

Swetnam gave a lecture at UA's College of Science and College of Social & Behavioral Science Distinguished Lecturer Series, Arizona Inn, Tucson. This lecture drew upon fire-climate research and applications supported by CLIMAS. February 11, 2004.

Swetnam helped organize and participated in Fire hazard Mapping and Assessment Workshop, sponsored by the Governor's Forest Health Advisory Council, Phoenix, AZ. CLIMAS work in the area of fire climatology was discussed. February 13, 2004

Swetnam gave a lecture to National Advanced Training Center course (about 100 fire managers from throughout the nation) on Wildland Fire management S-580. This lecture highlighted new understanding of fire climatology and relevance to wildland fire management planning, CLIMAS supported workshops on these topics.

Swetnam presented a talk at Western Forest Leadership Council Meeting, Phoenix Arizona, May 4, 2004. The meeting was attended by national leadership of major land management agencies (USFS, BLM, NPS, USFWS). Arizona Governor Napolitano was present. The talk highlighted new understanding of fire climatology supported in part by CLIMAS.

V. Human Resource Development

Allison Drake is working on her thesis and will be giving two talks at local symposiums and team meetings on her research. Erica Bigio is working on her thesis and will be giving future presentations.

TASK AREA: Climate Variability - Recent

PI: Dr. Andrew Comrie, Geography and Regional Development

Researchers: Erika Wise, Jenna McPhee, Chris Uejio (GRAs, Geography & Regional Development)

WestMap Update

We are happy to report that a direct CLIMAS spinoff, known as WestMap, has recently been awarded funding via the NOAA NCTP program. WestMap is a multi-RISA, multi-stakeholder initiative to provide online fine-scale gridded climate data and analysis tools. The information to be provided by WestMap has been explicitly called-for by stakeholders and researchers in CLIMAS and other RISAs. A WestMap consortium was assembled with CLIMAS support in 2003. Several presentations of the WestMap concept have been made since then, and an additional meeting was co-funded by the Arizona Remote Sensing Center. The recently funded project is a collaboration between the UA (A. Comrie PI, M. Glueck postdoc), the Western Regional Climate Center (K. Redmond) and Oregon State University (C. Daly).

Project A: Climate & Air Quality (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 project has investigated tropospheric ozone (ozone) and particulate matter (PM) in Tucson, Arizona; Albuquerque, New Mexico; El Paso, Texas; Phoenix, Arizona; and Las Vegas, Nevada.

Data:

- Daily maximum 8-hour average ozone concentrations and 24-hr average PM₁₀ concentrations 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 PM
- 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) (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 PM 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
 - Ozone in the Southwest is most strongly correlated with mixing height, temperature, and solar radiation
 - 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
 - Ozone appears to be strongly influenced by both meteorological conditions and local emissions sources
 - Long-term ozone trends are highly variable and not particularly well-correlated across the region
 - In general, there are indications that concentrations may have decreased in recent years after several years of increases in the 1990s (Figure 1)
- PM model is more complicated, but moisture is the most important control, with wind speed and mixing height acting as secondary influences
 - PM has a strong regional correlation
 - High PM years occurred in 1995 and 1999 in the Southwest
 - Generally flat PM concentration trends were detected in the Southwest over the study period (Figure 2)
- KZ filter appears to be an appropriate method for both ozone and PM trend separation
 - Ozone adjusted trends show very large meteorological influences (Figure 3a)
 - PM not as weather-dependant (Figure 3b)

A.3. Accomplishments anticipated by end of Budget Year.

Complete publication process for the two journal papers.

Continue work examining the urban air quality impacts of fires on the urban/wildland interface.

Begin project that builds on previous air quality work to estimate exceedances that would have occurred with meteorological influences removed and uses climate-air quality relationships to build predictive models.

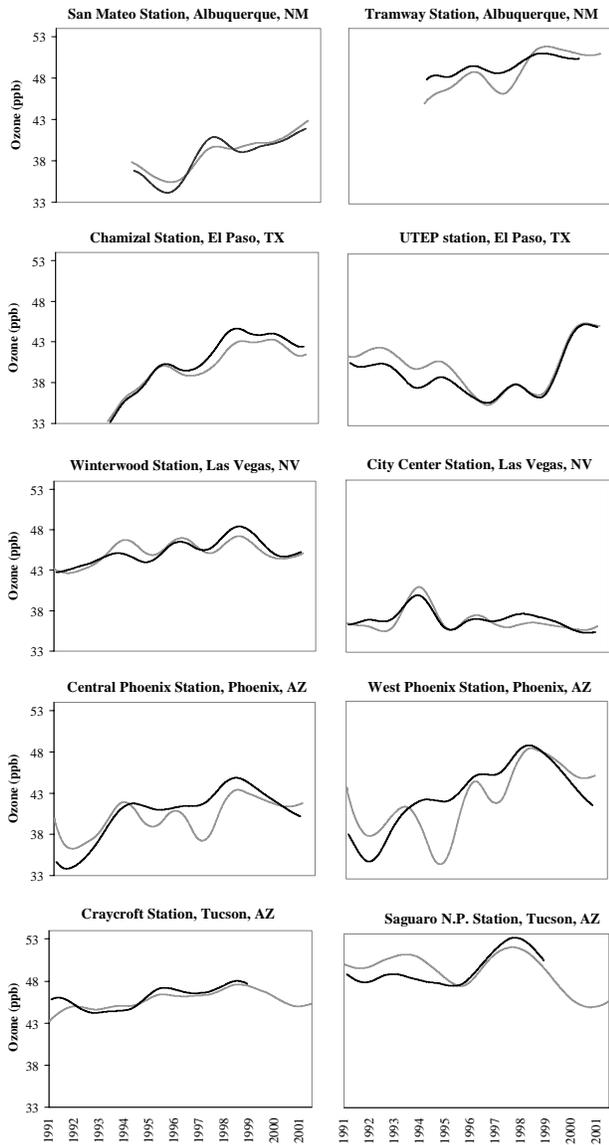


Figure 1: Models of meteorologically adjusted long-term ozone trends at each of the ten stations. Gray lines represent the unadjusted data that have been smoothed to show the long-term trend through the study period. Black lines show estimated ozone values with the influence of meteorology removed. The model of best fit was used in each case. Time is on the x-axis, and ozone (ppb) is on the y-axis.

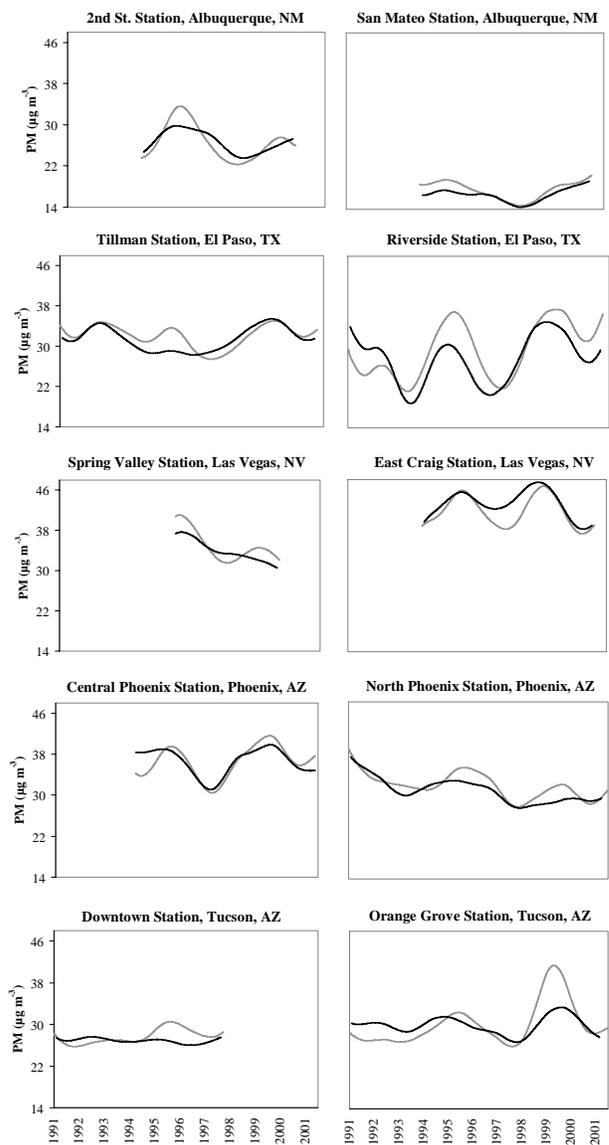


Figure 2: Models of meteorologically adjusted long-term PM trends at each of the ten stations. Gray lines represent the unadjusted data that have been smoothed to show the long-term trend through the study period. Black lines show estimated PM values with the influence of meteorology removed. The model of best fit was used in each case. Time is on the x-axis, and PM ($\mu\text{g m}^{-3}$) is on the y-axis.

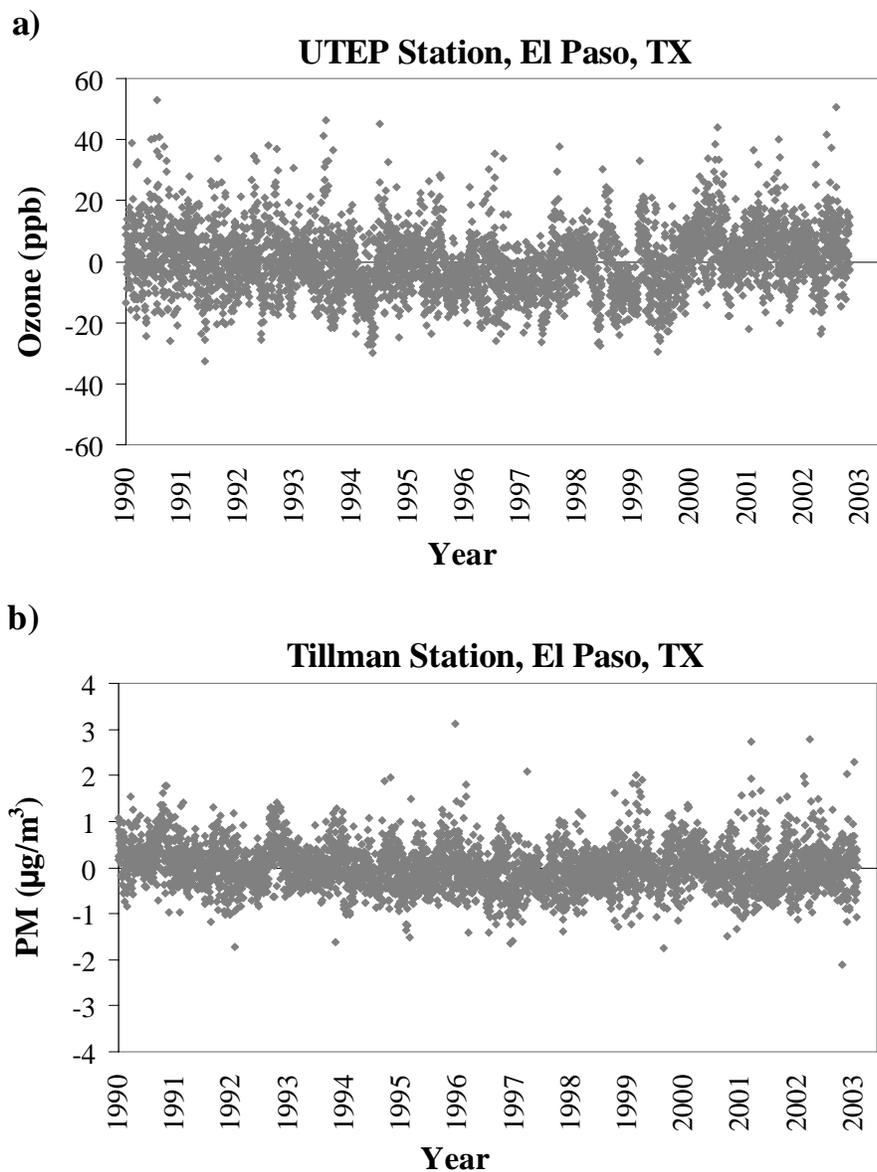


Figure 3. Example of differences between daily values of adjusted and unadjusted ozone (a) and PM (b) in El Paso, TX. These graphs suggest how daily ozone and PM values would have differed if weather conditions had been uniform over the time period. The range of values in these examples are typical of the results seen in each of the cities, and indicate the relative large effects of meteorological adjustment for ozone as compared to PM.

A.4. Plans for 2005-2006.

Complete projects listed in A.3 above

Investigate specific health and disease-related concerns related to climate change and variability that will be appropriate for further research/

A.5. Leveraged funding.

Pima Association of Governments funded the second Southwest-wide stakeholder workshop of air quality managers from city, regional and state agencies covering Las Vegas, Phoenix, Tucson, Albuquerque and El Paso. The exact support amount was not provided (but on the order of several thousand dollars).

A.6. Leveraged activities.

A.6.1. Greater than 50% CLIMAS. The second workshop was a day-long meeting in December 2004 that included presentations and discussions from the participants, reviewing ongoing work and highlighting climate-related issues. We continued developing our relationships with the regional stakeholders, presenting study results and discussing implications and future enhancements. CLIMAS funded the research work, PAG funded the workshop.

A.7. Non-CLIMAS Project Partners.

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

Desert Research Institute

Arizona Department of Transportation

Institute for Tribal Environmental Professionals

Matrix CGI Consulting

Clark County Department of Air Quality and Environmental Management

Pinal County Air Quality Department

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

B.1. Description.

Task 1: Drought in the Southwest Study

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.

Project Wrap-up: Coordinated work with TRIF, Governor's Drought Task Force, and CLIMAS Core Office/ISPE to produce a white paper for task force and others to use. The paper is in Top 10 FAQ style and was published by CLIMAS/ISPE in March 2004. It includes an 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. We conducted the same type of study for the entire Colorado River Basin area to complement the Arizona work. This was compiled into another comprehensive report and is currently undergoing final revision. We also completed a similar historical drought analysis for New Mexico to round-out our coverage of drought history for the Southwest.

Task 2: Integrated Assessment (IA) Project

The CLIMAS team integrated assessment project examines all relevant societal and environmental aspects of climate impact assessment in the White Mountains region of Arizona and New Mexico. Each P.I. team within CLIMAS is contributing to the overall study. The initial product is a comprehensive internal white paper that provides a range of background information on the region, including climate variability and history, economics, hydrology, ecology, agriculture, livelihoods, and policy.

Our contribution (McPhee, Uejio, Wise et al.) to the white paper was to characterize the climate history and the nature and causes of spatio-temporal climate variability in the IA region. We obtained and summarized observational climate data from all stations in the IA region, following data quality and continuity tests, as well as tree-ring data for the area. Products included an instrumental and paleoclimate database, summary graphics, and the relevant text for the white paper.

Task 3: Downscaling climate predictions for local applications

The overall objective of this project is to evaluate a particular downscaling method being utilized by the National Weather Service (NWS) in order to make large-scale probabilistic climate forecasts, such as those disseminated by the Climate Prediction Center, more applicable and effective at the local level. In this evaluation, we will also investigate the scale relationships linking the NOAA established mega-climate divisions to local-scale data. The primary purpose of this diagnostic evaluation is to help determine the relative confidence or skill of the forecasts (and essentially the downscaled forecasts) for particular forecast periods. The research on downscaling climate outlooks is a direct outcome from an initial partnership developed between our Applied Climate for Environment and Society (ACES) lab group as part of CLIMAS, and the National Weather Service Weather Forecast Office (NWS-WFO) in Tucson. The partnership has

since grown to include the NOAA Climate Services Division and the NWS Western Region Headquarters.

Initial tasks: Conducted a comprehensive literature review and gathered information on the downscaling methodologies that could be utilized to downscale probabilistic climate forecasts. Developed research plan for the downscaling work.

Current tasks: Utilize the NWS/CSD methodology for climate forecast downscaling and test it over different areas of interest in the Western United States. Conduct a study of the scale-relationships linking the mega-climate divisions and their respective stations to determine how regional and local climates differ.

Future tasks: In concert with CSD/WRH partners we intend to provide not only the Tucson NWS-WFO but all WFOs and a wide range of stakeholders with locally-downscaled climate forecast information. These forecasts translate probabilistic regional-scale climate forecasts down to the station level, including local temperature or precipitation data in real units, making the forecasts more useful for many stakeholders. We will produce a peer-reviewed publication once this work is completed.

B.2. Accomplishments to date.

Drought History and Top 10 FAQs.

The comprehensive report on drought in Arizona was published by CLIMAS in March. (Please see the “Drought and Climate in Arizona: Top Ten Questions and Answers” pdf document for full graphics and results.)

Additionally, we completed a similar historical drought analysis for the Upper Colorado River Basin and compiled it into a report for CLIMAS in July.

Similar analyses were completed for New Mexico.

Data:

- 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).

Methods:

- 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 the UCRB’s climate variability and extremes over various spatial and temporal scales.

Results:

- Major droughts of the entire Basin area as evident in the instrumental record (Late 1890s – early 1900s, Early 1930s, 1950s, Mid 1970s, Late 1990s to present)
- Due to its location, the UCRB region experienced the major droughts occurring in both the SW and the Great Plains during the last century.
- Figure 1 shows the number of UCRB climate divisions falling below 75% of average annual water year precipitation.
- The Upper Colorado River Basin region has a relatively weaker ENSO signal as compared to the Lower Basin, due to the fact that it is fairly centered between the two strong correlated poles: the SW and the NW.
- Different parts of the Upper Basin experience different ENSO signals and the progression of signal change from the South to the North is evident. The northern portions act more like the Northwest in connection with ENSO phases and the southern divisions act more like the Southwest. (see Figure 2)

The analyses were compiled in a comprehensive report titled “Drought and Climate of the Upper Colorado River Basin: The FAQs”.

- 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 UCRB drought including history, long term averages, seasonality, interannual and long-term spatial and temporal variability, extremes, and climatic forcing.

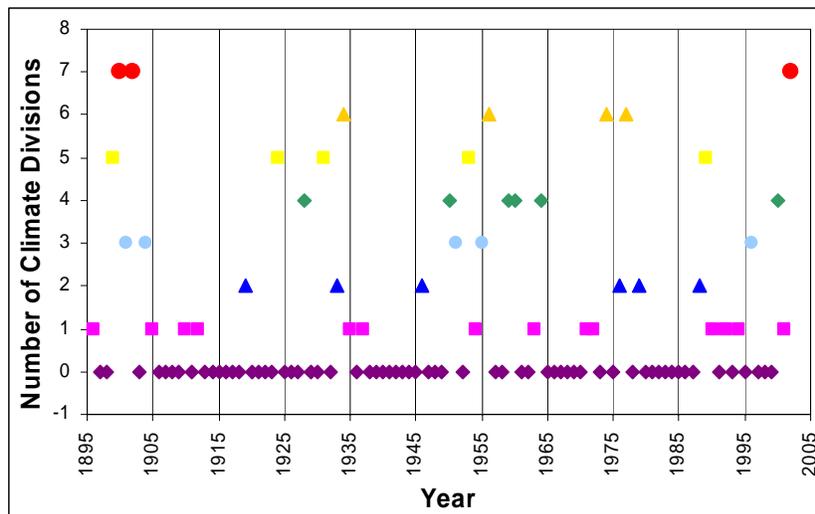


Figure 1: Number of Upper Colorado River Basin climate divisions that received less than 75% average water year precipitation. The three red circles at top indicate the years when 7 of the 8 climate divisions were simultaneously unusually dry (1900, 1902, & 2002).

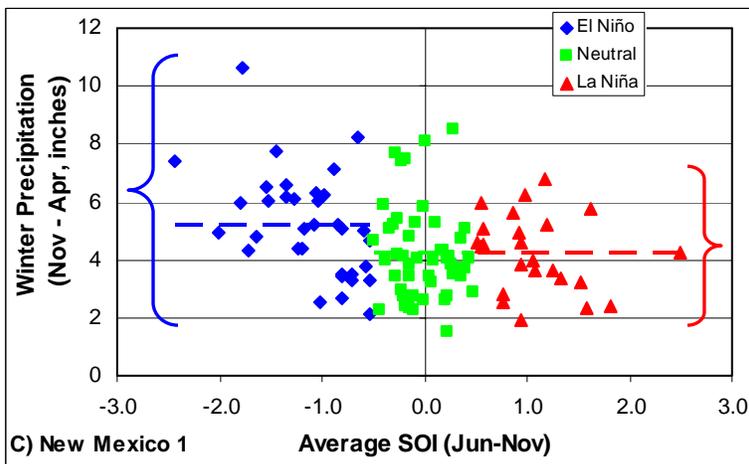
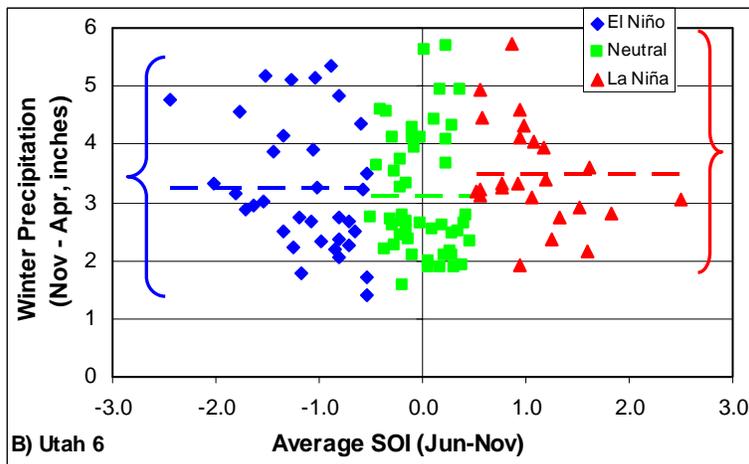
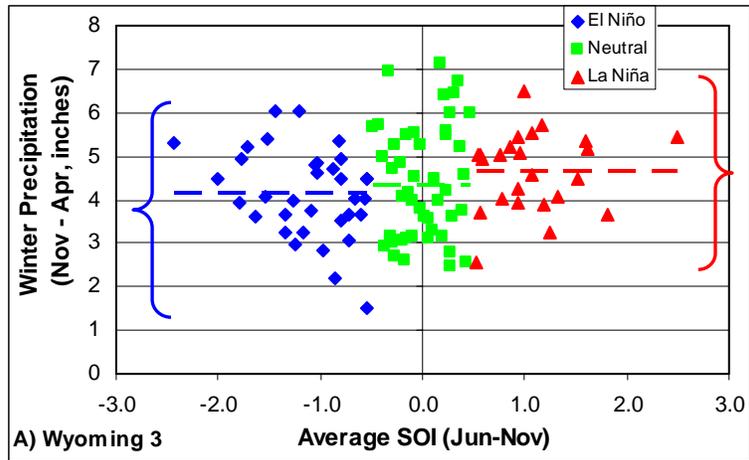


Figure 2: Southern-Oscillation Index (SOI; 1896-2001) as a function of winter precipitation (inches) for Wyoming CD 3 (A), Utah CD 6 (B) and New Mexico CD 1 (C). Brackets illustrate the range of El Niño and La Niña winter precipitation totals.

Figure 16c. Ratio of wet to dry El Niño events.

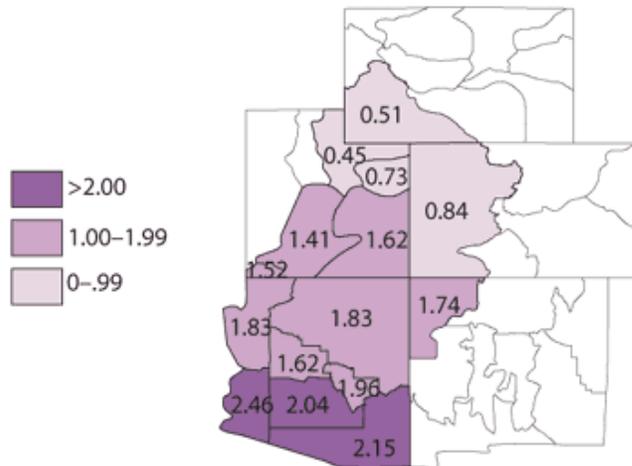


Figure 3: Three figures from the SW Climate Outlook detailing ENSO effects on the Colorado River Basin.

TIP Integrated Assessment Area – Climate History

Performed a historical climate analysis for the Team Integrated Project (TIP) White Paper Data & Methods:

- Collected and formatted monthly average maximum/minimum temperature and monthly total precipitation data from 18 different NWS COOP stations across the IA region of interest from the Western Region Climate Center, stations were chosen based on length and quality of record.
- Total precipitation split into water years and seasons (winter: Nov-Apr and summer: Jul-Aug)
- Utilized Ropelewski and Jones (1987) SOI averaged over the months of June-November in order to determine link between ENSO and winter precipitation in the IA region.
- Simple statistical analyses helped produce descriptive graphics for the purpose of outlining the underlining “story” of the climate of the TIP region

Results:

- See examples from the White Paper.

Downscaling Climate Forecasts for Local Applications

Background:

- After gathering information and completing a literature review and research proposal we determined that we would utilize the NWS regression-based method to downscale the Climate Prediction Center (CPC) probabilistic forecasts (Probability of Exceedence Outlooks), which are produced for the mega-climate divisions, in order to make them more useful and effective at the local level (station).

Data & Methods:

- Mega-division monthly mean temperature and monthly total precipitation from 1971-2000 to develop regression equations for all (12) 3-month seasons.

- Probability of Exceedence (POE) Forecasts from the CPC, produced and disseminated on a monthly basis for 13 lead times: each 3-month season out to a year
- Tested the method for downscaling temperature at Tucson International Airport.

Results:

- Downscaled forecasts show the relative difference in climate between the station and mega-division (Figure 4). Tucson is warmer than its mega-division by about 8 degrees Fahrenheit on average.

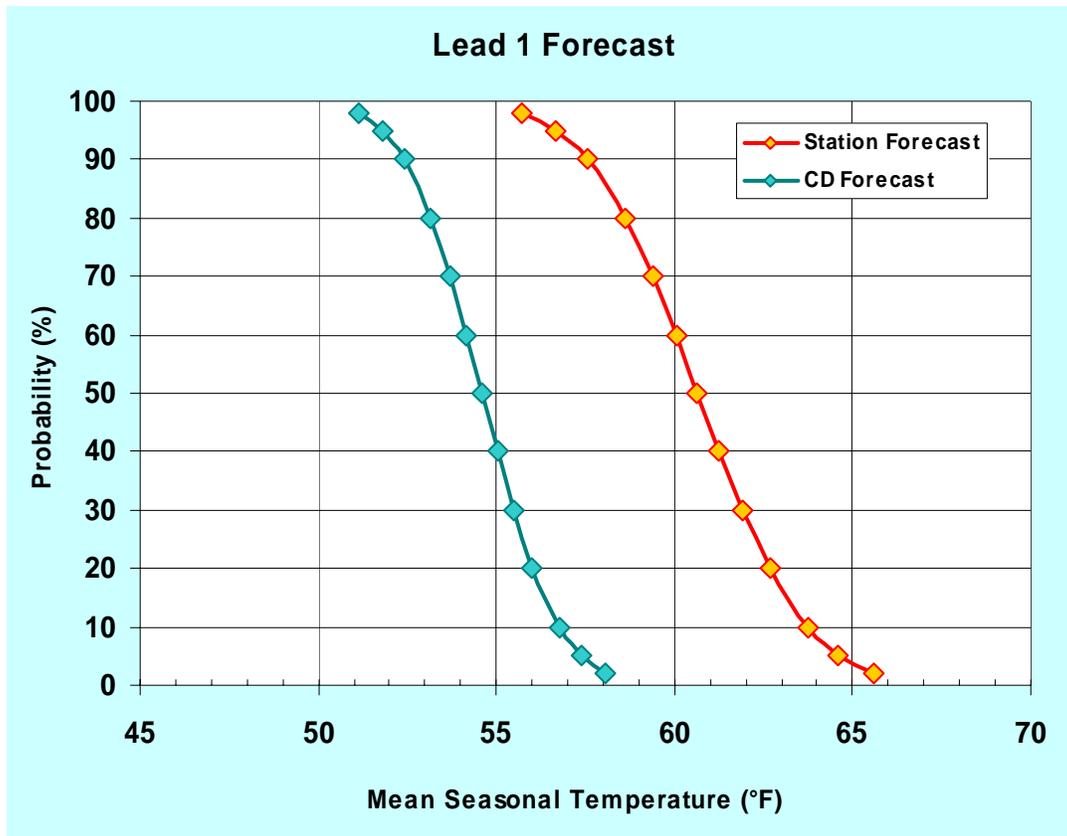


Figure 4: Downscaled POE forecast for Tucson for the January 2005 Lead One Outlook, which corresponds to February-March-April Season. The blue-green curve represents the original CPC forecast for the SE Arizona mega-climate Division and orange curve depicts the downscaled forecast for Tucson.

B.3. Accomplishments anticipated by end of Budget Year.

The final revisions are currently underway for the Top Ten FAQ paper for the UCRB. Complete climate forecast downscaling and climate division to station scale-relationship assessment. Temperature is complete; precipitation is in progress, likely completed by summer/fall 2005 in partnership with NOAA NWS-WRH and NOAA CSD.

Present the “downscaling climate predictions for local applications” at two upcoming conferences:

- Climate Predictions Applications Science Workshop, March 15-17th, Palisades, New York
- 101st Annual Meeting of the Association of American Geographers, April 5-8th, Denver, Colorado

Write peer-reviewed paper that synthesizes findings of the research.

Evaluate possibilities for dissemination in late 2005. For example, possibly organize and hold a workshop for the NWS-WFO Tucson and other CLIMAS stakeholders on the method and products, as well as obtain feedback on product format, style, etc.

Work with G Garfin and J. Morrill (CLIMAS Core Office) on a comparison of recent droughts in the TIP area; work will be presented at the 15th Conference on Applied Climatology in Savannah, Georgia, in June 2005.

B.4. Plans for 2005-2006. Finish downscaling project and write peer-reviewed paper on results.

B.6. Leveraged activities.

B.6.1. Greater than 50% CLIMAS. Emerging potential for collaboration and staff funding from NOAA NWS-WRH in 2005-06.

B.6.3. CLIMAS-related. TRIF funding for Arizona drought research and outreach (Garfin P.I.).

B.7. Non-CLIMAS Project Partners.

National Weather Service Tucson WFO
NOAA Western Region Headquarters
NOAA Climate Services Division

Project C: West Nile Virus and Climate (Comrie & Uejio)

C.1. Description. This research project examines the macro- and microclimatic relationships between West Nile Virus (WNV), mosquito vectors of the disease, avian hosts, and humans in the Southwest. Utilizing unique datasets from Tucson and other semi-arid areas of the world, the arid region-specific nature of WNV transmission and epidemic generation are being investigated. Stakeholders include county and state health departments and university researchers. We hope to elucidate climate controls on WNV in the Southwest and work towards development of a appropriate model of climate-vector-host relationships for the region.

C.2. Accomplishments to date.

Crafted an initial literature review of historical and contemporary WNV epidemics domestically and globally, and strategies for modeling mosquito-borne diseases.

Investigated the quality, length, and availability of local sources of Southwestern mosquito and avian data.

Gathered preliminary input on research areas of interest from Pima County Health Officials, Arizona Department of Health Services Vector Borne and Zoonotic Disease Section, and University of Arizona Entomologists and Epidemiologists.

Because no relationship between WNV transmission and climatic variables has been quantified in the literature, the first stage of the research was to determine if spatial and temporal patterns of WNV epidemics exist. A retrospective study of the spatial and temporal patterns of precipitation, temperature, and minimum temperature surrounding multiple WNV epidemics in South Africa was conducted. Certain regions of South Africa are climatically similar to sections of the Southwestern US and important South African climate signatures may be applicable to the Southwestern US.

Data:

- Monthly temperature, minimum temperature, and precipitation data was examined from July 1930 to June 1989 for 19 stations from the NCDC's Global Historical Climatology Network version 2 and 2 Beta. This dataset encapsulated all of the noted WNV epidemics

Methods:

- Calculation of monthly temperature, minimum temperature, and precipitation anomalies from monthly climatologies of these variables.
- Compositing of the climatic variables surrounding the years of WNV epidemics.
- Creation of interannual and seasonal precipitation timeseries to examine temporal patterns of climatic variables preceding epidemic years.
- Correlation maps examine the spatial cohesiveness of interannual and seasonal precipitation anomalies throughout the region.

Results:

- Compositing of precipitation anomalies in WNV epidemic years yields a pattern of wetter than normal early summer conditions followed by drier than normal late summer conditions.
- This summer precipitation cycle may amplify the length or magnitude of WNV epidemics
- WNV epidemics occur when interannual summer precipitation transitions from multi-year periods of drought to wetter than normal summer precipitation.
- Canonical El Nino years appear to be related to drier than normal summer precipitation preceding WNV epidemics while some La Nina years appear to be related to wetter than normal summer precipitation that may induce WNV epidemics.
- Anomalously high surface air temperature may also induce WNV epidemics.

Epidemic/zootic Years PPT Anomaly Sensitivity Testing for N=3 and N=4

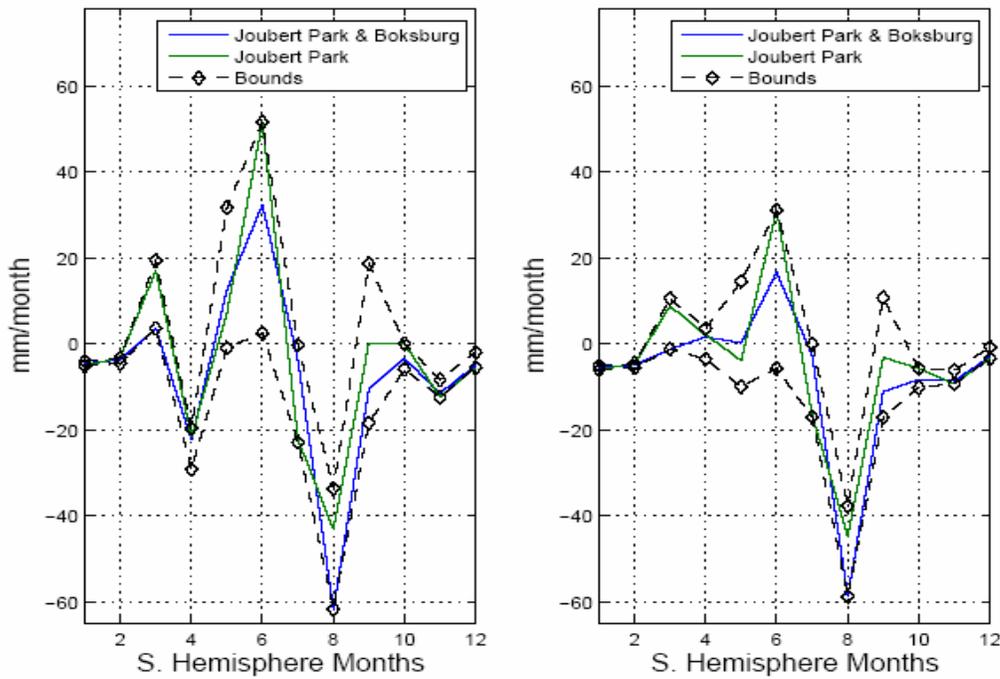


Figure 1. Compositing of anomalous monthly precipitation from monthly climatologies during the 3 WNV/SIN epidemic and 4 epizootic years. Sensitivity analysis was conducted to test spatial variability of summer precipitation anomalies in WNV/SIN epidemic years. Drier than normal late summer precipitation follow wetter than normal early summer precipitation.

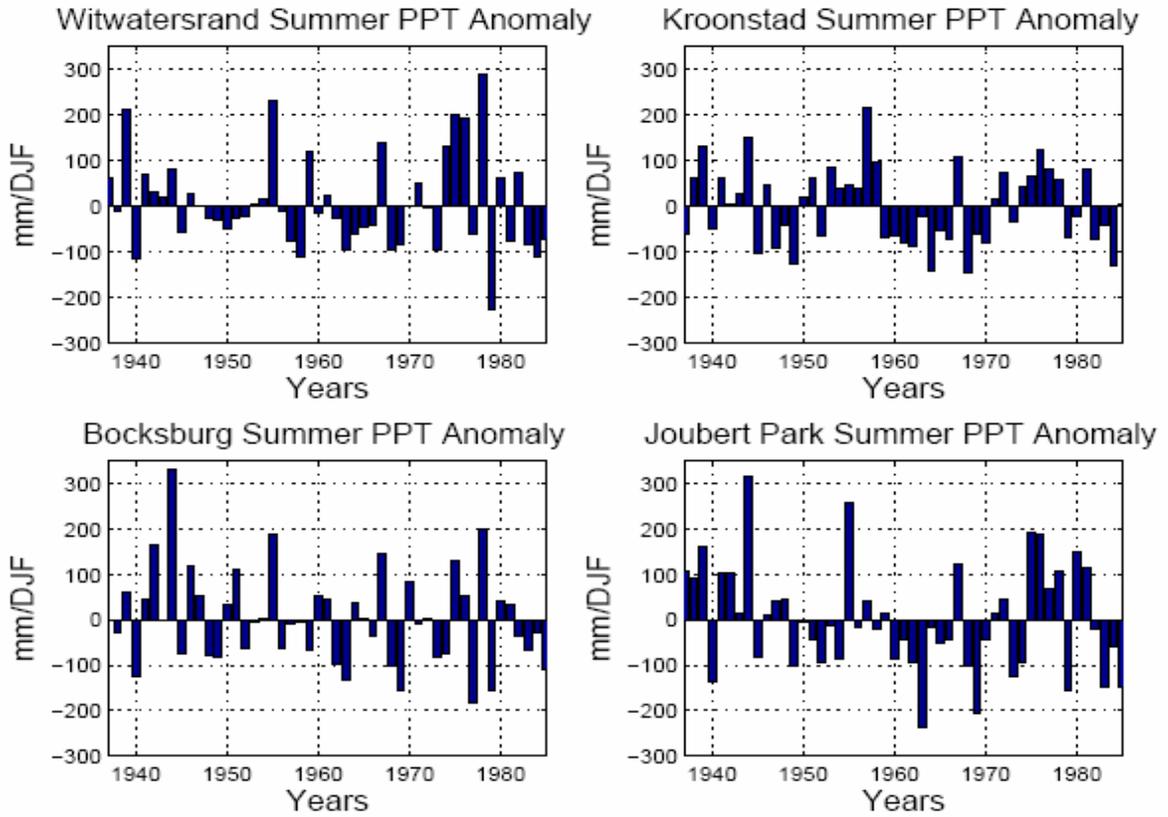


Figure 2. Southern hemisphere summer precipitation anomalies from summer precipitation climatology from June 1930-July 1989. Interannual variability of summer precipitation anomalies exhibits generally cohesive fluctuations of anomalously dry and wet years.

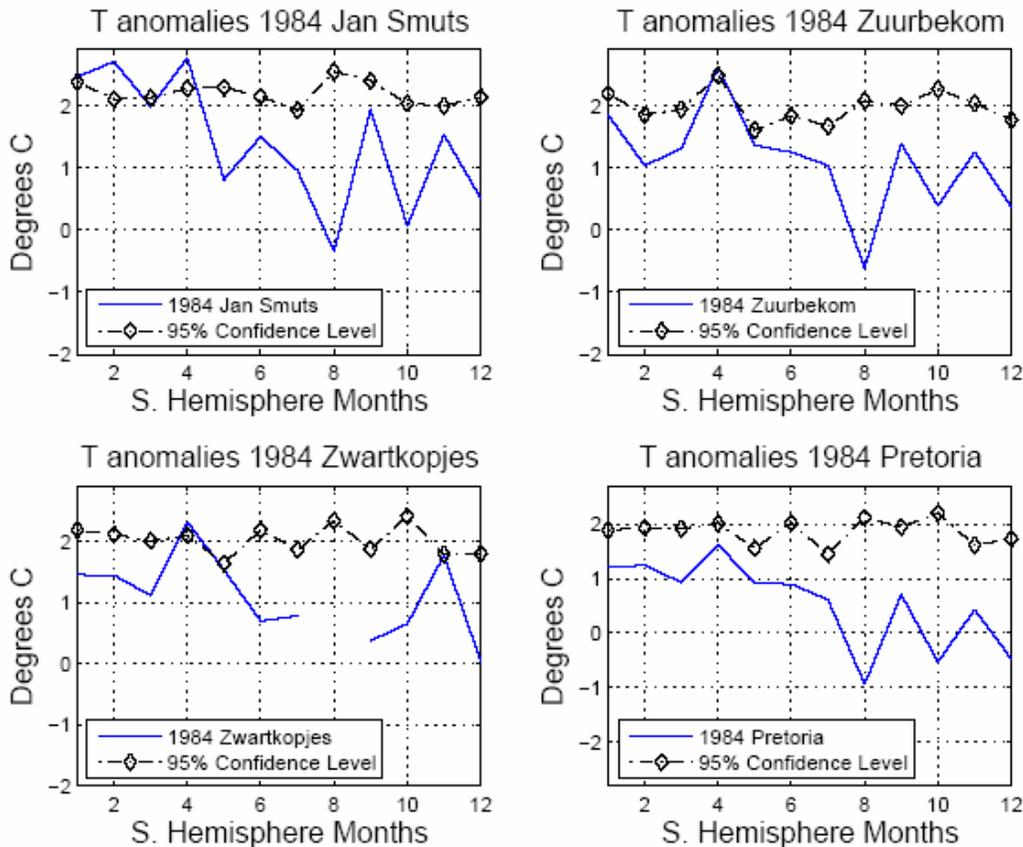


Figure 3. Average surface air temperature anomalies at different South African locations during the WNV/SIN epidemic/epizootic of 1984. Anomalously high temperatures may have exacerbated or helped to induce an epidemic/epizootic.

For the second phase of the project, the complex relationships between WNV vectors, hosts, and humans will be analyzed for the Southwestern US. Based on stakeholder input, an appropriate model reflecting current scientific knowledge about WNV relationships will be developed and validated for the Southwestern US.

C.3. Accomplishments anticipated by end of Budget Year

Commence development on an empirical statistical, parameterized, or numerical model of disease vectors, hosts, habitats, and microclimatic relationships surrounding WNV transmission.

Collect data for model development and validation.

Complete final draft and submit a paper on the South African retrospective study for publication.

Formally establish and develop a group of stakeholders to provide further input into the project.

C.4. Plans for 2005-06

The second phase of the project as outlined in subsection C.2. will be the primary focus in 2005-06. In conjunction with this focus, possible leveraged funding activities surrounding Dengue Fever, Valley Fever, West Nile Virus, and mosquitoes will be

pursued. University of Arizona entomologists and epidemiologists have expressed their desire to learn more about the macro and micro-climatic relationships between mosquitoes and disease transmission. Dr. Paul Robbins, who recently joined the department of Geography, is also investigating multidisciplinary leveraged funding opportunities on mosquito-borne disease.

C.5. Leveraged funding. None at this time, but several possibilities pending.

C.6. Leveraged activities.

C.6.3. CLIMAS-related. Dr. Korine Kolivras, who was previously funded by this CLIMAS has finished her work on Dengue Fever in Hawaii and taken the position of Assistant Professor at Virginia Tech. Korine applied a mixed-methods approach to investigate Dengue Fever. She analyzed climatic patterns of variability, geospatial associations between the vector, host, and humans, and qualitative methods to learn more about the local residents.

C.7. Non-CLIMAS Project Partners.

Arizona Department of Health and Human Services

II. Publications

In print.

Brown, D. B. and A. C. Comrie. 2004. A winter precipitation 'dipole' in the Western United States associated with multidecadal ENSO variability. *Geophysical Research Letters* 31, doi:10.1029/2003GL018726.

Kolivras, K. N. and A. C. Comrie. 2003. Modeling valley fever incidence based on climate conditions in Pima County, Arizona. *International Journal of Biometeorology* 47:87-101.

Kolivras, K. N. and A. C. Comrie. 2004. Climate and infectious disease in the southwestern United States. *Progress in Physical Geography*. 28(3):387-398.

McPhee, J. C., A. C. Comrie, and G. M. Garfin., 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.

Wise, E. K., and A. C. Comrie. 2005. Meteorologically-adjusted urban air quality trends in the southwestern United States. *Atmospheric Environment*, in press.

Wise, E. K., and A. C. Comrie. 2005. Extending the KZ filter: Application to ozone, particulate matter, and meteorological trends. *Journal of the Air and Waste Management Association*, in press.

Wise, E. K. and A. C. Comrie. 2004. Assessing Meteorological Controls on Ozone Trends in the Southwestern United States. In Zerefos, C.S. (ed), *Proceedings of the XX Quadrennial Ozone Symposium*. University of Athens, Athens, Greece.

Submitted/In Review

Comrie, A.C. 2005. Climate factors influencing coccidioidomycosis seasonality and outbreaks. *Environmental Health Perspectives*, in review.

To be submitted by June 1, 2005

McPhee, J. C. 2005. Downscaling Climate Predictions for Local Applications. Master's Thesis.

Uejio, C.K., and A. C. Comrie. 2005. A retrospective study of the climatological conditions surrounding West Nile Virus epidemics in South Africa. In preparation for *Emerging Infectious Diseases* or *Environmental Health Perspectives*.

Wise, E. K. and A. C. Comrie. 2005. Air quality associated with Tucson-area wildfires. *Int. J. Wildland Fire* (or an air quality journal).

Leveraged peer-reviewed publications

Abraham, J.S. and 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* 54:914–925.

Komatsu, K., V. Vaz, C. McRill, T. Colman, A. Comrie, K. Sigel, T. Clark, M. Phelan, R. Hajjeh, and B. Park. 2003. Increase in coccidioidomycosis – Arizona, 1998-2001. *Morbidity and Mortality Weekly Report* 52:109-112.

Park, B. J., K. Sigel, V. Vaz, K. Komatsu, C. McRill, M. Phelan, T. Colman, A. C. Comrie, D. W. Warnock, J. N. Galgiani, and R. A. Hajjeh. 2005. An epidemic of coccidioidomycosis in Arizona associated with climate changes, 1998-2001. *Journal of Infectious Diseases*, in press.

III. Presentations at Professional Meetings/Conferences

McPhee, J.C., and A. C. Comrie. 2005. Downscaling Climate Predictions for Local Applications. Climate Prediction Applications Science Workshop, Palisades, New York, March 2005.

McPhee, J.C., and A. C. Comrie. 2005. Downscaling Climate Predictions for Local Applications. Annual Meeting of the Associations for American Geographers, Denver, CO, April 2005.

Uejio, C.K. and A.C. Comrie. 2005. *Exploring Relationships Between Climate and West Nile Virus*. To be presented at the 101st Annual Meeting of the Association of American Geographers, April 5th-9th, 2005, Denver, CO.

Wise, E.K., and A. C. Comrie. 2004. Assessing Meteorological Controls on Tropospheric Ozone Trends in the Southwestern United States. Presented at the 20th Quadrennial Ozone Symposium, 1-8 June 2004, Kos, Greece. (Poster)

Wise, E.K. 2004. Assessing Meteorological Controls on Air Quality Trends in the Southwestern United States. Presented at the 100th Annual Meeting of the Association of American Geographers, 14-19 March 2004, Philadelphia, PA. (Paper)

Wise, E.K., and A. C. Comrie. 2004. Air Quality and Climate Variability in the Southwestern United States. Presented at the Air Quality in the Southwest Forum, 7 December 2004, Tucson, AZ. (Paper)

IV. Outreach Activities

Project A

- First Pima County stakeholder meeting - 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
- First Southwest regional stakeholder meeting - August 2003
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
- Second Southwest regional stakeholder meeting - December 2004
 - Represented organizations:
 - Arizona Department of Environmental Quality
 - Arizona Department of Transportation
 - Institute for Tribal Environmental Professionals
 - Pima County Department of Environmental Quality
 - Pima Association of Governments
 - U.S. Environmental Protection Agency
 - University of Arizona
 - Arizona State University
 - Matrix CGI Consulting
 - Western Governor's Association
 - Maricopa County Environmental Services
 - National Park Service
 - Clark County Department of Air Quality and Environmental Management
 - Pinal County Air Quality Department

Project B

Continuing partnerships with the National Weather Service Weather Forecast Office (NWS-WFO) in Tucson, NWS-WRH and NOAA CSD. We plan to host a future workshop on the downscaling method that will promote potential local climate products for the NWS-WFO and other CLIMAS affiliated stakeholders in the region.

Also, various presentations of the Top Ten Drought material were made to stakeholder groups in Arizona and New Mexico. (Comrie).

Project C

Weekly informal West Nile Virus meetings with Pima County Health Officials, University of Arizona Entomologists, and other interested individuals.

V. Human Resource Development

Erika Wise (GRA) had completed her completed her Master's thesis and published two journal papers. In addition, she attended Climate and Health Summer Institute, 21-28 July 2004, National Center for Atmospheric Research, Boulder, CO.

Jenna McPhee (GRA) is using the work in Project B as the basis of her Master's work, and the research will become her thesis in mid-late 2005

Christopher Uejio (GRA) is basing his Master's thesis work on the Project C research. The thesis will be completed in 2006 and will likely result in two journal papers.

TASK AREA: Hydrology: Forecast Evaluation

PI: Dr. Soroosh Sorooshian (University of California, Irvine)

Researchers: Dr. Holly Hartmann (Research Scientist, Hydrology and Water Resources)

I. Progress for Budget Year 2004-2005

Project A: Knowledge Development and Decision Support Tools - Forecast Evaluation Tool (FET) and Climate Data and Information System (CliDIS)

A.1. Description

Forecast Evaluation Tool: The online Forecast Evaluation Tool (FET) is an Internet website that any decision maker can use to assess the seasonal temperature and precipitation outlooks issued by the NWS CPC, for any part of the continental United States. Users can test their forecast interpretation skills, efficiently monitor the time evolution of the climate forecasts and subsequent observations, and place the forecasts in the context of recent and historical observations. They can also evaluate how well the seasonal climate outlooks have matched the subsequent actual climate conditions for the regions, lead times, seasons, and performance criteria relevant to their specific decision making situations. Based on feedback from interested decision makers, we are expanding the Internet webtools to include seasonal water supply outlooks issued by the NWS and USDA Natural Resources Conservation Service and features that allow efficient management of hydroclimate information from a variety of sources.

CliDIS: The Climate Data and Information System (CliDIS) is a software-engineered interactive web application that approaches information delivery and decision support from a knowledge development paradigm. It reflects that decisions are made through the integration of knowledge and wisdom, with the latter more complex, diverse, and changeable than can be practically programmed in computerized tools. Thus, knowledge development is the most appropriate place for *systemically* providing improved forecast and information products for supporting the broadest range of decisions in an *equitable* manner (i.e., accommodating different levels of technical capabilities). CliDIS incorporates climate forecast and information products using a forecast assessment framework that provides consistency in assessing different forecast products, in ways that allow individuals to use results at the level they are capable of understanding, while offering opportunity for shifting to more sophisticated criteria. The forecast assessment framework that includes: 1) tutorials, 2) allowing users to explore the time-evolution of forecasts and observations, 3) user-customized assessments of forecast skill, and 4) placing predictions in the context of historical and recent observations. Because the plethora of climate information from multiple sources impedes routine use of available products, CliDIS is also designed to include information management tools, whereby individuals can: 1) use project folders to store selected products for multiple applications and efficient access over repeated site visits, and 2) generate PDF reports that ensure inclusion of ancillary information combined with the ability to add customized interpretive comments (e.g., for delivery of information by intermediaries such as extension agents or state climatologists). Dynamic report generation also enables more equitable access to digitized products, through intermediaries using traditional hardcopy but in a structured form. CliDIS also tracks webtool usage to provide ongoing feedback

to operational agencies, science managers, and researchers about which products are preferred by various types of users and applications. CliDIS was designed explicitly for transfer to operations and to be scalable to serve intense usage (hundreds of users at one time).

A.2. Accomplishments to date

The FET has operated *without failure* over the past year, through continued software maintenance for upgrades in underlying tools (e.g., Apache TomCat server software) and code optimization. The FET now has over 100 registered users (i.e., that are not also project developers), including users at universities, private companies, many units of NOAA and the National Weather Service (NWS), international groups, and state resource management agencies, among others.

Over this past year, we have been involved in a significant re-design of FET. The design changes were made by web designer, David Lamb, based largely on comments from on-going users, prior user interactions, and input from CLIMAS web design and usability team. The re-design includes re-design of the entry page (which includes registration and Sun JAVA instructions), main page, access to forecast archive, historical context (former 'Past as Prologue' track), and forecast performance evaluation. The re-design included implementation of re-usable GUI widgets for selecting forecast seasons, forecast issue dates, and flexible list of selection of historical years, among others. Several of the widgets have been reused in multiple locations within the FET webtool.

This year has seen significant testing and demonstration of the extendibility of the underlying FET code. Ellen Lay, system programmer, added multiple additional features to the FET code, e.g., the dynamic selection of historical years for analog selection, and use of non-tercile probability distribution categories (for streamflow observations). The extensions also included enabling all user choices to be output to objects that can be saved in user profiles (for use system customization and CliDIS information management components). This means that the FET now remembers past user selections as long as the session is active; ultimately this information will be stored in the CliDIS system data base.

It should be noted that the quick response in extending FET capabilities, to enable flexible selecting of historical years for forecast performance evaluation were key to the FET being selected to be an integral component of training for all Climate Focal Points (forecasters with climate forecast responsibilities) at all local NWS Weather Forecast Offices (WFOs) over the next several years. All NWS WFOs will use the FET in their assessment of the NWS CPC seasonal climate forecasts, prior to WFO generation of local climate outlook products.

We hired a JAVA programmer for the summer, Quan Fu Fan, using fund from the GEWEX project, to begin extending the FET to historical streamflow observations. Those extensions included being able to select individual forecast stations, display of monthly (rather than seasonal) data, use of quintile probability distribution divisions, flexible handling of variable periods of record for observation and forecast availability.

This provided the demonstration of distributed webtool code development, including having multiple developers working on the 'build system'; the software development team implemented a recursive build system, whereby each developer builds their own code independently, and then incorporates the complete product after full testing, with capabilities for recovery in the event of unanticipated difficulties.

This year also saw continued advances in the preliminary development of CliDIS. Webpages for information management (e.g., management of user profile preferences, project folders, and PDF-generated reports) have been designed. Templates have been designed for all FET-related pages. All underlying software tools have been evaluated, selected, and integrated into the 'build system', which, when invoked links tools with appropriate system management parameter files, class libraries, etc. The 'persistence layer' that manages interactions between GUIs and the system database has been developed to work for some situations; there are still problems associated with storing applet parameter objects, but that is expected to be resolved over the coming months. The MapObjects tool has been updated and the overlay worked into the interface design; however, map projection issues remain to be resolved as well. In conjunction with this effort (which will allow overlay of multiple maps, e.g., the US Drought Monitor), the CPC has implemented our code to produce their seasonal climate outlooks maps as 'shapefiles' and has delivered suitable files to us for 2003; they will convert other maps over the coming months as well.

This past year, we put considerable effort into securing additional funding for continued development of the forecast evaluation tool. We responded to three calls for proposals:

1. NOAA Climate Transition Program (NCTP): Transition to Operations of an Advanced Interactive Internet-based Climate Information Delivery and Decision Support System Total Cost: \$335,731 for 3 years
2. NOAA Climate Dynamics and Experimental Prediction (CDEP) Program: Facilitating Systemic Advancement in the Delivery of Hydroclimatic Forecast Products: Linking ARC Research and Decisionmakers Using the Forecast Assessment System Total Cost: \$600,039 for 3 years
3. NOAA Human Dimensions of Global Change Research (HDGCR) Program: Forecasts that Communicate: Assessment, Development, and Delivery of Probabilistic Forecasts that Foster Easy, Accurate, and Reliable Interpretation Total Cost: \$149,923 for 18 months

It appears that we will receive full funding for the HDGCR proposal, although we have not yet received official paperwork.

We also submitted a proposal upon request, to the NOAA NWS Climate, Water, and Weather Services Division (CWWSD): Technology Transfer of an Internet-based Interactive Climate Forecast Evaluation Tool Total Amount, Total Cost: \$39,984 for 4 months. This project was originally conceived as a simple software transfer to a CWWSD server. However, based on our subsequent discussions, the CWWSD now has a greater appreciation of institutional limitations to user-customized internet applications handled by federal agencies, as well as the variety of policy decisions CWWSD must make before

actual transfer of code occurs. Our involvement is helping CWWSD consider their long-term vision for efficiently providing climate information to many users.

As part of the effort to ensure sustainability of FET/CliDIS development, we have worked with other RISAs to explore opportunities for collaboration. Based on discussions with the Southeast Climate Consortium in March 2004, Keith Ingram and Clyde Fraisse visited our group to learn from our software development projects. We discussed design and implementation processes, including distributed development, platform and database independence, and problem reporting, among other issues.

A.3. Accomplishments anticipated by end of Budget Year.

Finalization of FET re-design.

- implementation of revised 'bubble plot' design
- update of forecast tutorial

Initial activities for ultimate transfer of FET to NWS CWWSD.

- provide input to CWWSD regarding policy decisions about software transfer preferences
- develop text for Section 508 compliance (Americans with Disabilities Act requirements for electronic information access)

Preliminary extension of FET that will facilitate use of FET by all NWS local Weather Forecast Offices (WFO) in their new responsibilities to deliver local seasonal climate outlook products and constituent services.

- include climate forecast station data
- add additional verification measures (continuous RPSS, Heidke skill score)

Leverage NOAA HDGCR and NWS CWWSD funding to hire an advanced JAVA programmer, Damien Hammond, who was instrumental in early prototype development of the FET. Mr. Hammond has the experience to efficiently implement some of the more difficult aspects of CliDIS. The FET and CliDIS are evolving to be simply too large for a single programmer to effectively manage and continue to develop along multiple fronts.

A.4. Plans for 2005-2006.

Obtain increased commitment by NOAA, NWS CPC, and NWS CWWSD for sustained maintenance, development, and extension of the FET.

Complete initial implementation of CliDIS, including user profiles, project folders, and report generation capabilities. Also includes incorporation of additional climate products, e.g., the CPC Drought Monitor, as identified by the CLIMAS Core Office.

Complete incorporation of historical streamflow forecasts and observations within FET for stations used in our hydrologic forecast evaluation research. This includes obtaining recent observations from the NWS Colorado Basin River Forecast Center.

A.5. Leveraged funding.

The Institute for the Study of Planet Earth provided one year of funding for Ellen Lay, the FET JAVA programmer.

NOAA NWS Climate, Water, and Weather Services Division: Technology Transfer of an Internet-based Interactive Climate Forecast Evaluation Tool Total Amount, Total Cost: \$39,984 for 4 months (PI: H. Hartmann). Note: This funding was originally intended for transfer of the Forecast Evaluation Tool software to NWS CWWSO servers. However, the NWS CWWSO has become highly interested in our professional development, forecast communication, and product formatting capabilities, and so the project will focus more on those activities over the next year.

NOAA GEWEX Americas Prediction Project (GAPP): Evaluation of seasonal hydroclimatic forecasts from water management perspectives, GC01-168, NOAA/OAR Office of Global Programs (this project ended 30 September 2004).

A.7. Non-CLIMAS Project Partners.

NWS Climate, Water, and Weather Services Division (CWWSO)

NWS Climate Prediction Center (CPC)

Project B: Hydrologic Forecast Evaluation

B.1. Description. This task area includes all activities related to evaluating hydrologic forecasts (e.g., historical seasonal water supply outlooks).

B.2. Accomplishments to date. H. Hartmann has continued to work with partners at the NWS Office of Hydrologic Development (OHD), in conjunction with B. Imam and K. Franz at the University of California-Irvine. These efforts primarily are focused on developing approaches for operational verification of hydrologic forecasts, including both short-term deterministic forecasts and seasonal probabilistic forecasts. Accomplishments include development of a proposal with UC-Irvine, upon request by the NWS OHD. The purpose of this project is to develop methods of validating short-term ensemble stage and flow forecasts that can be used for run-time quality control during the operational forecast process. As such, verification methods must be: (1) practical to implement in the operational forecast environment, where product issuance schedules are fast-paced, and (2) based on commonly available data at throughout the national system. Activities have included initial conferencing and meeting with NWS River Forecast Center personnel.

We also submitted a proposal upon request, to the NOAA NWS Office of Hydrologic Development: Real-time Verification and Quality Control of Probabilistic Forecasts, Total cost: \$80,000, for 9 months (contract submitted through the University of California-Irvine, with H. Hartmann serving as independent subcontractor).

Jean Morrill (working with PI Roger Bales) has nearly completed her historical Colorado Basin forecast evaluation report. With her return to CLIMAS, that report and associated journal articles should be completed in early in the next budget year.

B.3. Accomplishments anticipated by end of Budget Year.)

Complete journal articles on evaluation of historical water supply outlooks for the Colorado River Basin (H. Hartmann with J. Morrill & R. Bales).

Both UC-Irvine and H. Hartmann receive installation of NWS River Forecast System, and complete training on running the system, by Riverside Technology, Inc.

B.4. Plans for 2005-2006. Complete all reports and journal articles.

Continue to build relationships with partners at UC-Irvine and NWS Office of Hydrology.

Develop partnerships with NRCS NWCC and CIG-U Washington, to lead to ongoing evaluation of their hydrologic forecasts.

B.5. Leveraged funding.

NOAA NWS Office of Hydrologic Development: Real-time Verification and Quality Control of Probabilistic Forecasts, Total cost: \$80,000, for 9 months (contract submitted through the University of California-Irvine, with H. Hartmann serving as independent subcontractor for \$9600)

B.6. Leveraged activities.

B.6.3. CLIMAS-related. Real-Time Verification and Quality Control of Probabilistic Forecasts: H. Hartmann serves as an outside contractor with UC-Irvine. Funds come through Riverside Technology, Inc., originating from NWS Office of Hydrology.

B.7. Non-CLIMAS Project Partners.

University of California-Irvine Center for Hydrometeorology and Remote Sensing
NWS Office of Hydrologic Development

Project C: Integration of Stakeholders in Hydrologic Research and Outreach

C.1. Description. This project encompasses activities designed to engage stakeholders about hydroclimatology issues and/or results and products derived from our other projects (Knowledge Development and Decision Support Tools and Hydrologic Forecast Evaluation). The goal is to identify research issues that can make systemic impact on NOAA climate services, through transferability across multiple sectors and regions, and through scalability to a large number of users – while also serving the unique needs of the specific decision makers with whom we develop or maintain on-going relationships. The objective of activities under this project is to advance the dialogue between stakeholders and our research team (and CLIMAS), both in terms of how decision makers can use the results and tools related to CLIMAS research, and in terms of decision maker needs for diverse types of hydroclimatic research, information, products, and tools.

C.2. Accomplishments to date. H. Hartmann contributed to the development of the CLIMAS Team Integrated Project in the White Mountains/Mogollon Rim region of Arizona and New Mexico, through project conceptualization, field work and white paper development.

CLIMAS has forged deeper ongoing relationships with the SAHRA NSF-STC, through H. Hartmann's appointment as SAHRA staff. A significant joint CLIMAS-SAHRA activity is the development and conduct of a day-long training session, "Drought Management: Understanding and Coping with Climate Variability and Uncertainty" for the New Mexico Rural Water Association. This event provides an opportunity for CLIMAS to extend meaningful stakeholder relationships into New Mexico with an important water resources management group (water providers serving communities less than 50,000 in population), through interactive workshop sessions on climate variability, paleoclimatology and climate change, climate forecasts, and drought management plans; sessions on integrated modeling and innovative water transfers are being led by SAHRA researchers.

H. Hartmann worked with a variety of water resources management agencies and organizations in Argentina for several weeks, including local community politicians, university researchers, and federal water management and flood alert agencies. The objective was to review the potential for joint collaboration on the use of Internet technology to deliver advanced hydroclimatic information and forecasts for the La Plata River Basin, particularly the potential to build on CLIMAS knowledge development and decision support tools. This work directly resulted in the later visit of Daniel Vila, an operational forecaster from the Hydrologic Alert System for the La Plata Basin, National Water Institute of Argentina, to the University of California-Irvine, with the purpose of exploring opportunities for applying satellite-based precipitation estimates for improved flood forecasts for the La Plata River Basin.

At the request of the American Meteorological Society Executive Committee and Council, H. Hartmann participated in the Mid-term Review of the AMS Ten-Year Vision Study. This effort aimed 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. The Mid-term Review was accepted by the Executive Committee and Council and the annual AMS meeting, January 2005.

H. Hartmann was appointed to the Advisory Committee for the National Environmental Education and Training Foundation and American Meteorological Society Watershed Curriculum Project. This involves periodic review of the professional development materials being created for use in training broadcast and other media meteorologists about watershed response to climate variability, natural change, and human impacts.

C.3. Accomplishments anticipated by end of Budget Year.

In conjunction with SAHRA researchers, CLIMAS will be conducting a significant professional development training event - Drought Management: Understanding and Coping with Climate Variability and Uncertainty, New Mexico Rural Water Association

Annual Training Conference, Albuquerque, New Mexico, 21 March 2005. This day-long workshop includes sessions, led by CLIMAS researchers, on climate variability (J. Morrill), paleoclimatology and climate change (G. Garfin), climate forecasts (H. Hartmann), and drought management planning (K. Jabobs). The workshop is designed to be highly interactive and provide feedback to CLIMAS researchers about this sector's needs and interests in hydroclimatic research, information, products, and tools. This event may serve as a springboard for developing a standardized interactive training event for the water provider sector in Arizona, the Southwest, and the West.

H. Hartmann will be conducting two sessions, one on seasonal climate outlooks and another on the Forecast Evaluation Tool, as part of a training event for all local NWS Weather Forecast Office Climate Focal Point forecasts in the NWS Western Region. These sessions are a precursor to ongoing nation-wide training events that will be held throughout the U.S. over the next several years, involving all local NWS WFOs.

C.4. Plans for 2005-2006.

Continue to work on the CLIMAS Integrated Team Project. The role of the hydrology team is to participate in stakeholder engagement activities as requested by the social science team, and to determine a hydrologic research agenda based on assessments of stakeholder needs and interests.

Refine professional development training materials and course designs related to hydroclimatic forecasts, based on NMRWA and NWS CWWSO and WRH training experiences. This includes work with CWWSO to determine effective formats (and to avoid non-effective formats) for proposed new NWS climate forecast products. This work is leveraged through funding by NWS CWWSO, which is expected to grow over the coming several years.

Demonstrate implications of improper communication of total uncertainty in seasonal climate outlooks from risk-based and economic decision making framework (with Bonnie Colby). This work derives from the continued misunderstanding, especially on the part of the climatological research and operations communities, about the difference between statements that seasonal climate forecasts show 'equal chances' or 'unknown chances' of the tercile categories occurring during the forecast period. This work will result in a journal article for the Bulletin of the American Meteorological Society.

Continue to develop collaborative projects with external groups, including water resources management organizations and researchers in Argentina, and other RISA groups, among others, as opportunities develop. The objective of such projects will be to (1) provide feedback to CLIMAS concerning decision makers needs for hydroclimatic research, information, products, and tools, and (2) continued development, with an emphasis on long-term sustainability and transfer to operations, of CLIMAS knowledge development and decision support tools.

Continue support of the Advisory Committee for the National Environmental Education and Training Foundation and American Meteorological Society Watershed Curriculum Project.

C.5. Leveraged funding.

NOAA NWS Climate, Water, and Weather Services Division: Technology Transfer of an Internet-based Interactive Climate Forecast Evaluation Tool Total Amount, Total Cost: \$39,984 for 4 months (PI: H. Hartmann). Note: This funding was originally intended for transfer of the Forecast Evaluation Tool software to NWS CWWSO servers. However, the NWS CWWSO has become highly interested in our professional development, forecast communication, and product formatting capabilities, and so the project will focus more on those activities over the next year.

American Academy for the Advancement of Science (AAAS)/National Science Foundation (NSF) Women's International Science Collaboration (WISC) program: Building Knowledge Tools for the Use of Advanced Hydroclimatic Monitoring and Prediction in Latin America, Total Amount: \$3970 for 3 weeks travel to Argentina (PI: H. Hartmann).

C.6. Leveraged activities.

C.6.1. Greater than 50% CLIMAS. Professional development and product development activities for the NWS CWWSO. Their funding pays for travel, but not personnel costs.

C.6.2. Intra-CLIMAS Spin-offs. Work with B. Colby on risk-management implications of improper communication of total uncertainty of seasonal climate outlooks.

C.7. Non-CLIMAS Project Partners.

SAHRA NSF-STC

American Meteorological Society/National Environmental Education and Training Foundation

NWS CWWSO, Western Region Headquarters, WFOs

II. Publications

In print/In press

Hartmann, H.C. 2005. Use of climate information in water resources management. In Anderson, M.G. (ed.), *Encyclopedia of Hydrological Sciences*. John Wiley and Sons Ltd., West Essex, UK (in press).

Submitted / In review

Hartmann, H.C., G.M. Garfin, B. J. Morehouse, M. Vásquez-León, S. Sorooshian, and R. C. Bales. 2005. Forecast assessment: a key element in stakeholder-driven integrated climate assessments. *Global Environmental Change* (in review).

To be submitted by June 1, 2005

Franz, K., H. C. Hartmann, E. Welles, and S. Sorooshian. The challenge of identifying and implementing an operational verification process for probabilistic hydrologic forecasts. *Journal of Hydrometeorology*.

Garfin, G., K. Jacobs, and H. Hartmann. Techniques for effective stakeholder engagement at meetings. *EOS Transactions of the American Geophysical Union*.
Welles, E., H. C. Hartmann, and S. Sorooshian. Standardized evaluation procedures for single-valued river stage forecasts. *Journal of Hydrometeorology*.

Hartmann, H.C., B. Imam, B., and S. Sorooshian. A user-centric decision support system for seasonal forecasts. *Bulletin of the American Meteorological Society*.

Hartmann, H. C., J. C. Morrill, and R. C. Bales. Performance of seasonal water supply outlooks in the Colorado River Basin. *Journal of the American Water Resources Association*.

Morrill, J. C., H. C. Hartmann, and R. C. Bales. Evaluation of seasonal streamflow outlook forecasts for the Colorado River Basin. *Journal of Hydrometeorology*.

Websites

University of Arizona. 2004. Forecast Evaluation Tool. <http://hydis6.hwr.arizona.edu/ForecastEvaluationTool/> (Last accessed February 26, 2005).

III. Presentations at Professional Meetings/Conferences

Hartmann, H.C., 2004. A tool for improving natural resource management under climate uncertainty: customized forecast evaluations using the Internet. 29th Annual Climate Diagnostics and Prediction Workshop, Madison, Wisconsin, 18-22 October.

Hartmann, H.C., B. Imam, E. Lay, D. Lamb, and S. Sorooshian, 2004. A tool for improving natural resource management under climate uncertainty: customized forecast evaluations using the Internet. Climate Prediction Workshop at the 29th Annual Meeting of the American Association of State Climatologists, Ithaca, New York, 10-13 August. Invited presentation.

IV. Outreach Activities

Hartmann, H.C. 2004. Helping decision makers understand hydroclimatic variability and forecasts: a case study of integrated research and products. Secretariat of Water Resources, Buenos Aires, Argentina, 8 July 2004. Invited presentation.

Hartmann, H.C. 2004. Helping decision makers understand hydroclimatic variability and forecasts: a case study of integrated research and products. University of Santa Fe, Santa Fe, Entre Rios, Argentina, 12 July 2004. Invited presentation.

CLIMAS Integrated Project Scoping trip, communities on the Mogollon Rim, Arizona and New Mexico, 18-20 August 2004 (H. Hartmann). Included interviews with a variety of stakeholders in communities on the Mogollon Rim, Arizona and New Mexico.

Hartmann, H.C. 2004. Creating climate products and tools which are accessible and useful for NWS customers and decision makers. NWS Southern Region Headquarters Climate Steering Committee, Silver Spring, Maryland, 14-16 September. Invited interactive workshop.

2004 New Mexico Drought Summit, Albuquerque, New Mexico, 27-28 September 2004 (H. Hartmann). Included attendance at the summit and follow-up interviews with selected summit participants. Led directly to development of training workshop at the New Mexico Rural Water Association Annual Training Conference (described below).

Colorado River Basin Water Year 2005 Outlook Briefing, Salt Lake City, Utah, 9 November 2004 (H. Hartmann). Led to writing of article for EOS on techniques for effective stakeholder engagement at meetings, with G. Garfin and K. Jacobs (in progress, submission expected by 1 June 2005).

Meeting with staff of NWS Western Region Headquarters and NWS Climate, Water, and Weather Services Division, Salt Lake City, Utah, 19 November 2004 (H. Hartmann). Meeting addressed potential inclusion of Forecast Evaluation Tool (FET) in the development of NWS professional training materials and workshops. Led directly to inclusion of FET in NWS professional training materials and courses planned over the next three years. Invited meeting.

Hartmann, H.C., 2004. Helping decision makers understand hydroclimatic variability and forecasts: a case study of integrated research and products. SAHRA NSF-STC Meeting, Tucson, Arizona, 23 November 2004. Invited presentation.

Hartmann, H.C., 2005. Creating climate products and tools which are accessible and useful for NWS customers and decision makers. NWS Western Region Headquarters Climate Steering Committee, Tucson, Arizona, 17 February. Invited interactive workshop.

Meeting with M. Temofeyeva of the NWS Climate, Water, and Weather Services Division, University of Arizona, Tucson, AZ, 18 February 2005 (H. Hartmann). Meeting addressed formats of NWS climate products under development, to facilitate effective communication and reliable interpretation. Invited meeting.

Hartmann, H.C., 2005. Forecast assessment: tactics, techniques, and tools. Climate Impacts Group Seminar Series, JISAO-University of Washington, Seattle, Washington, 8 February 2005. Invited presentation. Also met with CIG researchers to explore potential collaborative projects.

TASK AREA: Hydrology: Snowpack and Water Supply Outlooks

PI: Dr. Roger Bales (University of California, Merced)

Researchers: Kevin Dressler and Noah Molotch (GRAs, Hydrology and Water Resources), Noah Molotch (GRA), Dr. Jean Morrill (Research Scientist, CLIMAS core office)

Progress for Budget Year 2004-2005

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

A.1 Description. Measurement accuracy and forecast are important when considering the role of hydroclimatic variability and uncertainty in water resources and other resource management decisions. The processes controlling the hydrologic cycle in mountainous regions are highly variable in time and space, requiring remote sensing to observe regionall-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 hydrologic processes requires dynamic simulations tailored to the scale of the application.

Two separate tasks were undertaken to achieve these goals. The first involved evaluation of historical water supply outlooks. Stakeholders also need to better understand the uncertainties associated with snowpack and snowmelt runoff forecasts. The second task, involved 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 hydrologic processes at different scales, and hence improve water supply outlooks, we have undertaken investigations in water supply outlooks. A paper describing the results of our analysis of the historical official water supply forecasts is in progress and will be submitted this year. Jean Morrill (currently Core Office) and Holly Hartmann (see Task Area: Forecast Evaluation, PI S. Sorooshian) are working on this project.

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 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 data.

We are assimilating spatial snowcover products into the PRMS hydrologic model, using basins in the upper Rio Grande and Upper Salt River as test basins. 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 preparation, for submittal this spring when K. Dressler defends his dissertation. This spring we will begin using MODIS data.

We have used stakeholder interaction to determine the utility of snow product improvement in enhancing stakeholder decision-making. We will use the 2005 Western Snow Conference as a forum to continue researcher-stakeholder dialog.

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. Dressler is expected to complete his doctoral dissertation. We also expect to submit the forecast assessment paper.

A.4. Plans for 2005. We plan to continue 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. This effort will be primarily supported by NASA funds, pending availability of additional NOAA-OGP funds.

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 is 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/In press

Bales, R., D. Liverman, and B. J. Morehouse. 2004. Integrated assessment as a step toward reducing climate vulnerability in the southwestern United States. *Bulletin of the American Meteorological Association* 85(11):1727-1734.

Molotch, N.P., R. C. Bales, M. T. Colee, and J. 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*.

To be submitted by June 1, 2005

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

Dressler, K., G. Leavesley, R. Bales, S. Fassnacht, Streamflow estimation from hydrologic model assimilation of remotely sensed snow information in snowmelt dominated basins.

Molotch, N., Bales, R. C. Assessing snow telemetry (SNOTEL) station representativeness using field-based methods, remotely sensed data, and statistical models.

Morrill, J., R. C. Bales, and H. C. Hartmann. Evaluation of seasonal streamflow outlook forecasts for the Colorado River Basin.

III. Presentations at Professional Meetings/Conferences

Bales, R., J. Dozier, N. Molotch, T. Painter, R. Rice, Mountain hydrology of the semi-arid Western U.S.: Research needs, opportunities and challenges, *Eos Trans. AGU*, 85, Fall Meet. Suppl., Abstract U51A-04, 2004.

Dressler, K. A, G. Leavesley, R. Bales, S. Fassnacht, Streamflow estimation from hydrologic model assimilation of remotely sensed snow information in snowmelt dominated basins, *Eos Trans. AGU*, 85, Fall Meet. Suppl., Abstract C31A-0288, 2004.

Molotch, N. P., R.C. Bales. Evaluation of the representativeness of automated snow water equivalent sensors in the Rio Grande headwaters using intensive field observations, remotely sensed snow cover data, and distributed snowmelt models, *Eos Trans. AGU*, 85, Fall Meet. Suppl., Abstract U53A-0701, 2004.

IV. Outreach Activities

In fall 2004 and again in spring 2005 R. Bales met with stakeholders at the California Department of Water Resources to plan future use of remote sensing snow products.

A forum on remote sensing snow products is planned for the spring 2005 Western Snow Conference.

N. Molotch participated in a drought press conference.

V. Human Resource Development

Noah Molotch completed his dissertation. *Estimating the spatial distribution of snow water equivalent and snowmelt in mountainous watersheds of semi-arid regions.*

Department of Hydrology and Water Resources, University of Arizona, Tucson, AZ, 2003 210 p.

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