



Annual Progress Report
2005-2006 Budget Year

March 2006

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CLIMAS Annual Progress Report: 2005-2006

TASK AREA: Core Office

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I. Progress for Budget Year February 1, 2005 - January 31, 2006

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 decision-makers; (2) pages covering recent conditions, forecasts, and forecast verification – including maps, graphs, and text; and (3) an executive summary that highlights the main features of the climate of the Southwest during the past month. CLIMAS sends the SWCO to over 2000 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. We now produce the SWCO in partnership with Arizona Cooperative Extension. Together, the CLIMAS Core Office and Arizona Cooperative Extension garnered partial funding for the SWCO from Arizona's Technology and Research Initiative Fund's (TRIF) Water Sustainability Program (through a disbursement by the SAHRA NSF Science and Technology Center at the University of Arizona). During 2005-2006, we further refined the format of the SWCO. Through partnership with Arizona Cooperative Extension, we improved distribution of the SWCO to rural stakeholders in Arizona. Climate extension specialist Michael Crimmins is now the lead content editor for the Southwest Climate Outlook (SWCO). In 2005, Dr. Melanie Lenart began a series of news articles, one of the most highly praised aspects of the SWCO, focusing on the potential impacts of climate change on the Southwest. Most articles prominently feature NOAA science and research, including efforts by NOAA's Climate Prediction Center, Earth System Research Laboratory (formerly Climate Diagnostics Center), RISAs, and regional climate centers.

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 Cooperative Extension's Climate Science Applications Program

(funded, in part, by NOAA). We anticipate producing an edited compendium of Dr. Lenart's climate change articles as a resource for Southwest decision makers. We are working with colleagues from the University of Arizona's Udall Center for Public Policy, the Western Water Assessment RISA, Servicio Meteorologico Nacional (SMN – the Mexican meteorological agency), Proteccion Civil Sonora (the State of Sonora department of emergency management), the University of Sonora and others to create a U.S.-Mexico border region climate outlook (see Project E, below).

A.4. Plans for 2006-2007. The CLIMAS Core Office plans to work with Arizona Cooperative Extension to expand Cooperative Extension's nascent county-level climate information and analysis program. In December, 2005 the CLIMAS Core Office began plans for incorporating SWCO input from the New Mexico State Climate Center. New Mexico State Climate Center participation in the SWCO is contingent upon finding further funds to release time for the assistant state climatologist to participate; CLIMAS will attempt to garner additional funding for this purpose during the upcoming year. CLIMAS and Arizona Cooperative Extension will conduct a stakeholder evaluation of the SWCO during 2006-2007.

A.5. Leveraged funding. The UA-ISPE and the UA Department of Soil, Water, and Environmental Science provided funding through July 2005; the state of Arizona's Technology Research Initiative Fund's Water Sustainability Program (through a disbursement by the SAHRA NSF Science and Technology Center) will continue to provide funding through June 2007.

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 2005-2006, we held briefings in Tucson and Phoenix.

A.7. Non-CLIMAS Project Partners and Contributors. University of Arizona Cooperative Extension; NOAA-ESRL; National Weather Service Forecast Offices; Arizona State Climatologist; University of New Mexico; SAHRA; Western Regional Climate Center; NOAA Climate Prediction Center.

Project B: Drought Research and Related Activities

B.1. Description. In 2005-06, the CLIMAS Core Office continued a multi-year program of drought-related research and educational outreach that is highly integrated and coordinated with the efforts of the Arizona Governor's Drought Task Force (GDTF). CLIMAS drought research was funded, in part, by the Arizona Technology and Research Initiative Fund (TRIF). The research, coordinated with the Southwest Climate Outlook and other CLIMAS outreach activities, examined drought from a variety of physical and social science perspectives. Our drought research activities focused mainly on aspects of drought planning and monitoring.

The key topics for CLIMAS 2005-2006 drought research and outreach were as follows:

- Drought climatology and impacts research and monitoring;
- Impediments to drought planning in rural areas;
- Drought and climate education for decision-makers.

B.2. Accomplishments to date. CLIMAS continues to serve on the Arizona drought monitoring technical committee. CLIMAS program manager, Gregg Garfin, is co-chair of the monitoring technical committee (MTC), and assistant research scientist Ben Crawford is a member of the MTC. CLIMAS contributes to the monthly Arizona Drought Monitor Report, as well as to MTC decisions and revisions to drought monitoring methods and protocols. The Core Office is working closely with the NOAA-National Weather Service on development of the National Integrated Drought Information System in Arizona and New Mexico.

Core office scientists Garfin, Crawford and McCord, in conjunction with Arizona Cooperative Extension (Mike Crimmins, and Kim McReynolds), are helping the Arizona Department of Water Resources to implement county-level drought impacts monitoring. They have attended meetings to develop a pilot "Local Area Impacts Assessment Group" in southeastern Arizona's Cochise County; Garfin and McCord have given presentations at these meetings.

Each week, the core office serves as the hub for a meeting to assess Arizona drought conditions. Assistant research scientist Ben Crawford and GRA Casey Thornbrugh coordinate this activity and provide weekly reports to the U.S. Drought Monitor. Thornbrugh has also developed key contacts with Arizona's native nations and tribes, which improves drought impact reporting to the U.S. Drought Monitor. In 2005, Thornbrugh developed a pilot drought impacts database for Arizona; he reported on this work at the AMS Applied Climatology conference in 2005.

In response to stakeholder and agency partner requests, the Core Office is engaged in a variety of research projects and data provision activities. In 2005-2006, the Core Office developed text and figures for the first chapter of the nine volume Arizona Department of Water Resources' Arizona Water Atlas. The Core Office is following up on previous CLIMAS paleoclimate research by developing a climatology of Southwest precipitation trends and variability since 1000 AD. This research is being conducted in conjunction with former CLIMAS PI Malcolm Hughes. In addition, CLIMAS is serving as a consultant on a paleoclimate study that is being conducted by The Nature Conservancy. In response to stakeholder demand for information on the impacts of climate changes on drought in the last 100 years, the Core Office is conducting a study to compare the 1950s drought and the drought of the last decade. Preliminary results of the 1950s-2000s drought study were presented at the June, 2005, AMS Applied Climatology conference. The Core Office also presented a comparison of pre-historic, historic, and current drought coping strategies, entitled "Weathering the Big One: A Review of Coping with Severe Sustained Drought in the Southwest" at the 2005 New Mexico Drought Summit.

In 2006, Core Office program manager Garfin was invited to serve as an associate of the NSF Drought Impacts on Regional Ecosystems network (DIREnet – <http://www.mpcer.nau.edu/direnet/>).

In 2005-2006, the Core Office collaborated with various entities to convene drought capacity building workshops in Arizona and New Mexico. Workshops were convened in conjunction with meetings of the New Mexico Rural Water Association, Arizona Hydrological Society, and Southeast Arizona Ag Day and Trade Show. More details on these workshops can be found below in Project D and Project H.

B.3. Accomplishments anticipated by end of Budget Year. The Core Office will continue our integrated drought research, work on drought monitoring, and coordinate with ADWR on aspects of drought plan implementation. We plan to complete a draft Arizona NIDIS plan, in collaboration with the National Weather Service, Phoenix forecast office. We plan to submit climate information for several more chapters of the Arizona Water Atlas by the end of the budget year. We also plan to complete our paleoclimate research by the end of the budget year. Core Office investigator Garfin will convene drought panel discussions at the 4th NOAA Climate Prediction and Applications Science Workshop, and at the Monsoon Region Climate Applications workshop.

B.4. Plans for 2006-2007. We plan to devote considerable resources to understanding the connection between standard hydrometeorological variables and multi-sector drought impacts. We will accomplish this through refining our drought impacts database, through our drought plan implementation activities (in collaboration with Arizona Cooperative Extension), and through partnership with the National Drought Mitigation Center. The CLIMAS Core Office will continue to co-chair the Arizona MTC; we will work with MTC members to provide monthly drought status reports to the Arizona Department of Water Resources. We plan to work closely with Cooperative Extension on publishing primers and other materials for stakeholders, as well as articles for trade journals. We plan to work more closely with the New Mexico Drought Task Force on drought monitoring, drought impact reporting, and improving connections between stakeholders and state drought efforts.

B.5. Leveraged funding. The aforementioned activities are leveraged with funds obtained from an Arizona Technology and Research Initiative Fund (TRIF) disbursement through the SAHRA NSF Science and Technology Center.

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; New Mexico Drought Task Force; DIRENET; Natural Resource Conservation Districts; Arizona Water Institute; Arizona Cooperative Extension.

Project C: Fire-Climate Research and Decision Support

C.1. Description. The CLIMAS Core Office remains active in fire-climate research and outreach. During 2005-2006, the Core Office devoted significant effort to collaborating with partners at the National Interagency Coordination Center's (NICC) Predictive Services Group (PSG) and the Program for Climate, Ecosystems and Fire Applications (CEFA) at the Desert Research Institute. For the fourth consecutive year, CLIMAS, NICC-PSG, and CEFA worked closely to marshal resources, garner institutional support, and enhance our successful workshop process for the 2006 National Seasonal Assessment Workshops (NSAW). The workshops are designed to produce climate-informed regional- and national-scale seasonal fire potential outlooks for the 2006 fire seasons, for each of the NICC-NPSG Geographic Area Coordination Centers (GACCs) in the United States.

For 2006, two NSAW workshops will again be held, one for the eastern, southern, and southwestern United States, and one for the western United States and Alaska. As in 2005, CLIMAS, NICC-NPSG, and CEFA are coordinating with NOAA and USDA-Forest Service scientists to provide training on the subjects of long-term climate variability, teleconnections, monthly-seasonal climate forecasts, monsoons, and use of remotely-sensed vegetation data. Additionally, in 2006, we plan a North American Seasonal Assessment Workshop (NASAW), to be held in conjunction with the Western United States and Alaska workshop. Goals for the NASAW include improved cross-border information flow, tri-national exchanges of ideas and methodologies for predicting fire potential, development of initial protocols for a North American fire potential product (like the US Drought Monitor), and transfer of a proven RISA process to partners in Canada and Mexico.

C.2. Accomplishments to date. The 2005 NSAW: Western States & Alaska workshop was held March 28-April 1, 2005, hosted by the Western Water Assessment RISA at the NOAA Skaggs Building, in Boulder, Colorado. Some significant improvements associated with this meeting include: (1) a 1.5 day climate information and techniques training (with participation by scientists from the Western Water Assessment RISA, NOAA Earth System Research Laboratory, and Western Regional Climate Center), and (2) improved feedback from participants. The 2006 NSAW: Eastern, Southern, and Southwest Geographic Areas was held January 17-20, 2006, at the US Fish & Wildlife Service National Conservation Training Center, in Shepherdstown, West Virginia. NOAA-CPC lead forecaster, Ed O'lenic, contributed significantly to training on the components of the NOAA seasonal climate outlooks. Dan Graybeal (Northeast Regional Climate Center), David Zierden (Southeast Climate Consortium RISA), and Gregg Garfin (CLIMAS) provided training on interannual and multidecadal climate variability, and teleconnections.

In conjunction with NICC-PSG and CEFA, the CLIMAS Core Office produced proceedings, a one-page fact sheet, and an article in *Wildfire Magazine* on each of the NSAW workshops. The fact sheets allow us to rapidly turnaround the key forecast assessments and cautions, and to 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. In addition, CLIMAS program manager Gregg Garfin briefed participants in the National Predictive Services Group annual meeting about progress on the workshops, and garnered feedback on participant needs. Garfin presented a poster on the NSAW process to forest managers at the Society of American Foresters-Mexican Society of Foresters bi-annual meeting. The NSAW “success story” was featured in the 2005 *Our Changing Planet*, and in the annual report of the Office of the Federal Coordinator for Meteorology.

C.3. Accomplishments anticipated by end of Budget Year. The combined 2006 NSAW: Western States & Alaska and the NASAW are set for April 4-7, 2005 at the NOAA Earth System Research Laboratory in Boulder, Colorado. Training instructors include experts from NOAA-ESRL, National Weather Service, and the University of New Mexico. In addition to NOAA-CPC forecasts, forecasts by the NOAA-funded Experimental Climate Prediction Center (Scripps Institution of Oceanography), the NOAA-funded International Research Institute for Climate and Society, Western Water Assessment RISA, and the California Applications Program RISA will be featured. Conference proceedings will be printed by the end of May, 2006. A brief summary of the NASAW will be completed and distributed to funding agencies.

C.4. Plans for 2006-2007. We expect to devote extra effort to making the NSAW process and products more useful. First, we will work with the GACCs to identify key stakeholders to receive priority notification of NSAW predictions. We will devote significant effort to improving communication between NWS and GACC meteorologists. We will make an effort to improve NWS participation in the NSAW meetings. We will also work with NICC-PSG and CEFA to include greater involvement in NSAW planning for those RISAs that want to be involved. NICC-PSG has vague plans to include Hawaii in future workshops; involvement in NSAW by the Pacific Islands RISA might accelerate this process (if so desired by NICC-PSG). We will put further effort into the North American Seasonal Assessment Workshop process. This will probably require (1) improved engagement with Canadian and Mexican colleagues and, (2) discussions with high-level officials in Canada and Mexico in order to secure official sanction for an online North American Fire Potential forecast product. We will devote effort to transitioning the NSAWs to NICC-PSG, CEFA, and the forecast agencies by securing higher levels of commitment from the forecast agencies, working to establish better relationships between NICC-PSG and the forecast agencies, and involving officials from higher levels in the forecast agencies in the process.

C.5. Leveraged funding. The USDA-Forest Service (through NICC-NPSG), the BLM (through its Fire Aviation Division), and NOAA-CPO (through CDEP) provided additional funding for the NSAW workshops.

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-ESRL; NOAA Regional Climate Centers; Western Water Assessment; California Applications Program; Southeast Climate Consortium; Scripps

Institution of Oceanography; USDA-Forest Service Pacific Northwest Research Laboratory; New York State Forest Rangers; New Jersey Forest Service; Maine Forest Service; California Department of Forestry; Florida Division of Forestry; Michigan Department of Natural Resources; Minnesota Department of Natural Resources; U.S. Bureau of Land Management; South Dakota School of Mines and Technology; Bureau of Indian Affairs, Texas Fire Service; State of Vermont Department of Forests, Parks & Recreation; Servicio Meteorologico Nacional (SMN); Comision Nacional Forestal (CONAFOR); Instituto Nacional de Investigaciones Forestales, Agricolas y Pecuarias (INIFAP); Environment Canada; Ontario Ministry of Natural Resources; Parks Canada.

Project D: Coordination with University of Arizona Cooperative Extension

D.1. Description. University of Arizona Cooperative Extension is a key stakeholder and partner in CLIMAS vulnerability, ranching, drought, and economic decision research. 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 2005-2006, the Core Office worked closely with climate extension specialist Michael Crimmins on a variety of projects, chiefly focused on engaging stakeholders, conducting workshops, establishing Internet resources, improving drought monitoring, as well as extension and outreach.

CLIMAS program manager Gregg Garfin and Crimmins have teamed up to co-organize a series of workshops to build stakeholder capacity to use drought and climate change information in decision-making. In 2005-2006, we co-organized two workshops to assist the Arizona Department of Water Resources in efforts to implement the Arizona Drought Preparedness Plan. We conducted a half-day workshop on drought climatology and planning at the Arizona Hydrological Society annual symposium; Kathy Jacobs (at the time a cooperative extension water resources specialist; now director of the Arizona Water Institute) collaborated with us in this effort. We also conducted a half-day workshop on drought climatology and community drought monitoring opportunities at the Southeastern Ag Day and Trade Show.

Garfin and Crimmins are advising NASA Space Grant graduate fellow Shoshana Mayden on a project to build capacity within the newspaper and television media to better understand and more accurately report on climate variability and change issues. The motivation is that news media reaches far more citizens through their reporting, on a regular basis, than scientists can hope to reach through standard channels, such as peer-reviewed publications, professional meetings, and stakeholder workshops. With funding assistance from the NOAA-CPO, we will hold a small workshop on February 15, 2006. The NASA/GISS Climate Impacts Group will contribute data and analyses to the workshop. Workshop materials can be found at the following URL:
http://www.ispe.arizona.edu/events/climate_trail/.

Garfin, Crimmins, and CLIMAS acting lead-PI Andrew Comrie, are collaborating with the NOAA Climate Services Division to host the 4th NOAA Climate Prediction and Applications Science Workshop. The workshop will be held March 21-24, 2006, in Tucson, Arizona. We are planning to include some innovations in the workshop, such as moderated panel discussions on topics that include drought, water resources, and the NOAA Climate Test Bed. Andrea Ray and Bradley Udall, of the Western Water Assessment, will facilitate two of the panel discussions.

As a step in the process of transitioning the Southwest Climate Outlook to a service-oriented operational entity, climate extension specialist Michael Crimmins now acts as the lead content editor for the (SWCO). More information on the SWCO is in the description for Project A (above).

During 2005-2006, the CLIMAS Core Office worked closely with UA Cooperative Extension to develop and convene the second in a series of annual workshops to address issues of ecosystem change due to drought, and to investigate the potential impacts of climate change on Southwest landscapes. The entire Core Office staff participated in the Climate and Vegetation Change Steering Committee, as did extension specialist Crimmins and others. The workshop, held January 25-26, 2006, was held in conjunction with the annual meeting of the Society for Range Management (Arizona Section). Approximately 100 land use managers and ranchers attended the workshop. The workshop featured plenary talks by CLIMAS PI Gregg Garfin, as well as a number of experts from Arizona and New Mexico. The highlight of the workshop was a half-day exercise, co-developed by Crimmins and others, to examine the potential effects of climate variability and change on rangeland ecosystems, using a conceptual grassland state-and-transition model. Participants worked through a credible climate change scenario for the years 2000-2050, and, given variable financial resources each decade, explored potential ecosystem changes and management responses through extended small-group discussions. Core Office researcher Melanie Lenart wrote an article on the workshop (<http://cals.arizona.edu/climate/ws/srm2006/srm2006.htm>). In collaboration with Crimmins, Core Office researcher Niina Haas developed a rigorous multi-faceted assessment of changes in participant understanding of climate and attitudes toward climate and ecosystem changes, as well as an evaluation of the workshop. Haas's methods include pre-conference telephone interviews, written survey instruments, recording several of the small-group discussions, and post-conference interviews.

As mentioned in the description of Project B, the Core Office and Mike Crimmins are collaborating (in conjunction with the Arizona Department of Water Resources, and the Arizona Drought Monitoring Committee) on projects to help implement the Arizona Drought Preparedness Plan.

Crimmins and the Core Office staff are collaborating on development of a Southwest Climate Change Web Portal at the University of Arizona. This work is described in Project F, below.

As mentioned in Project B (above), the Core Office coordinates a University of Arizona consortium to report to the U.S. Drought Monitor. Crimmins is part of this group, and helps Core Office staff to facilitate exchange of drought information with county extension agents, including garnering drought impacts information from extension agents.

Core Office program manager Gregg Garfin collaborated with extension agent Chris Jones (lead coordinator of the climate-ecosystems workshops) on abstracts and poster presentations to summarize the work of the Climate and Vegetation Change Steering Committee at several conferences, including the 5th International Conference on Forest Vegetation Management.

In 2005-2006, Core Office staff served as co-authors and reviewers of Cooperative Extension Fact Sheets on climate and vegetation change. The fact sheets will be used by county extension agents to explain potential climate change impacts on Arizona forest ecosystems. Core Office program manager Garfin co-authored the climate curriculum for UA Cooperative Extension's Master Watershed Steward program (<http://ag.arizona.edu/watershedsteward/>).

D.3. Accomplishments anticipated by end of Budget Year. Core Office researcher Niina Haas will complete her assessment of the outcomes of the Climate Change and Rangelands workshop, and present her results to the Climate and Vegetation Change Steering Committee.

D.4. Plans for 2006-2007. The Core Office will continue to work with UA Cooperative Extension to garner secure funding for the Southwest Climate Outlook. We are also working with UA Cooperative Extension to generate county-level quarterly climate newsletters.

The CLIMAS Core Office will continue to work closely with the UA Cooperative Extension Climate and Vegetation Change Steering Committee to develop the 2007 workshop on Climate and Vegetation Changes in Southwest Riparian Areas; the workshop will be held in conjunction with the annual meeting of the Arizona Riparian Council.

We will continue to work closely with extension agents throughout the state, and with climate extension specialist Mike Crimmins, on refining our climate knowledge transfer activities. We are planning several capacity building workshops on drought and volunteer drought monitoring. We are also planning a second workshop for the news media, with an emphasis on reaching rural newspaper journalists.

The Core Office will work with Climate Extension specialist Crimmins to provide county-level climate information to Arizona stakeholders.

Core Office researcher Niina Haas will work with Climate Extension specialist Crimmins to develop new metrics for evaluating extension effectiveness. Haas will conduct a

review of assessment literature, including diffusion of innovation and other knowledge transfer techniques. Haas will “shadow” Crimmins, and will use a multi-method assessment approach, including ethnographic interview techniques, to evaluate knowledge transfer effectiveness. This pilot project will serve three purposes: (1) to give Haas greater exposure to rural stakeholders, (2) to introduce Cooperative Extension to new techniques for program evaluation, and (3) to evaluate techniques for assessing the value of scientist-stakeholder interactions in cases where these interactions do not lead to a clear outcome (e.g., a clear outcome is: scientist provides forecast → stakeholder uses forecast → stakeholder reaps benefit; an unclear outcome is scientist provides forecast → stakeholder consults forecast, and the information informs stakeholder thinking, but does not necessarily result in action).

D.5. Leveraged funding. Arizona’s Technology and Research Initiative Fund’s (TRIF) Water Sustainability Program (through a disbursement by the SAHRA NSF Science and Technology Center at the University of Arizona) provides partial funding for the Southwest Climate Outlook and drought capacity building workshops.

D.7. Non-CLIMAS Project Partners. University of Arizona Cooperative Extension, Society for Range Management, Arizona Riparian Council.

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

E.1. Description. In 2005-2006, the Core Office greatly expanded its role in U.S.-Mexico Border Climate and Outreach. The Core Office collaborates with CLIMAS PIs Barbara Morehouse and Margaret Wilder, as well as with the University of Arizona's Udall Center for Public Policy on assessing northern Mexico stakeholders’ needs for climate information. The Core Office is working with Mexican colleagues to improve climate-fire science interactions and fire potential prediction for North America. Moreover, the CLIMAS Core Office is part of a loose affiliation of United States and Mexican scientists, including the Western Water Assessment's Andrea Ray, endeavoring to improve monsoon region scientist-stakeholder interactions and climate applications research.

E.2. Accomplishments to date. In 2005-2006, the Core Office led a multi-institutional bi-national effort to develop a prototype climate outlook product for the U.S.-Mexico border region. With NOAA funding, 11 scientists and stakeholders met in Hermosillo, Sonora, Mexico, (January 10-11, 2006) to discuss the climate outlook; the small group developed a memorandum of understanding to work together on the climate outlook, a website, and a list of action items. The group will meet with a larger body of scientists in Guaymas, Sonora, Mexico in May, 2006, as part of a bi-national climate applications research workshop that the Core Office co-organized with NOAA-ESRL’s Andrea Ray and others. The Core Office also garnered Mexican participation in the 2006 North American Seasonal Assessment Workshop. Core Office scientists Garfin and Lenart contributed to a review article (submitted to a special issue of the Journal of Climate) on the prospects for NAME applied climate projects in the U.S.-Mexico border region.

E.3. Accomplishments anticipated by end of Budget Year. The Core Office will participate in the Monsoon Region Climate Applications workshop in May, 2006 (60-70 participants expected). We expect to develop an expanded group of partners for the climate outlook product. The Core Office will also work with U.S. and Mexican colleagues to garner funding for the outlook. We will co-produce a brief report on outcomes from the Monsoon Region Climate Applications workshop.

E.4. Plans for 2006-2007. We will work with Mexican colleagues to develop a pilot US-Mexico border climate outlook for distribution to stakeholders. We expect to receive a small amount of funding from Servicio Meteorologico Nacional, in order to get this project off the ground. We will work with our Mexican colleagues in order to garner further funding, and feedback on the pilot climate outlook. We expect to work with Mexican and Canadian colleagues to convene a second North American Seasonal Assessment Workshop. Following a model developed by the CIRMOUNT/MtnClim consortium, the organizers of the Monsoon Region Climate Applications Workshop, including the Core Office, plan to devote significant effort to building a monsoon region climate applications community. We plan to garner funding for another workshop (to be held in the 18-24 months); we will institute a moderated listserv; will expand the US-Mexico border climate outlook web site (University of Sonora) to serve as a focal point; and we will write publications on monsoon region climate applications. With regard to the latter, the Core Office plans to collaborate with the Udall Center for Public Policy and Andrea Ray to put together an edited book or white paper. In collaboration with Henry Diaz of NOAA-ESRL, we will submit a proposal to the SARP initiative in summer 2006.

E.5. Leveraged funding. NOAA's SARP program funded the January 2006 workshop in Hermosillo, Mexico. North American fire workshop funding is provided by NOAA's Climate Program Office, as well as the USDA-Forest Service, and the BLM International Program for Fire and Aviation.

E.7. Non-CLIMAS Project Partners. Udall Center for Public Policy, Western Water Assessment, NOAA-ESRL, Servicio Meteorologico Nacional, University of Sonora, Comision Nacional de Forestal, Proteccion Civil Sonora, Instituto Tecnologico de Sonora, Comision Nacional del Agua, NCAR, Centro de Investigaciones Biológicas del Noroeste, INIFAP.

Project F: Climate Change

F.1. Description. During 2005-2006, the Core Office continued research and outreach activities associated with observed and potential effects of climate change in the Southwest. Activities include trade journal and Southwest Climate Outlook articles, public presentations, press briefings, climate research, and serving as consultants to climate change advisory committees in Arizona and New Mexico.

F.2. Accomplishments to date. Core Office researcher Melanie Lenart began a series of articles, written in layperson-friendly language, focusing on the potential impacts of climate change on the Southwest. Most articles prominently feature NOAA science and research, including efforts by NOAA 's Climate Prediction Center, Earth System Research Laboratory, RISAs, and regional climate centers.

Core Office scientists are prominently represented on initiatives by the governors of Arizona and New Mexico to examine the implications of potential climate changes on the state's ecosystems and water supplies. Program Manager Garfin serves on the New Mexico Climate Change and Water Resources committee, and has been instrumental in providing data and analyses to the committee. Garfin and Core Office scientist Ben Crawford will write a section of the final New Mexico report, based on analyses done by Crawford and data provided by NOAA-ESRL. The Core Office is contributing instrumental and GCM climate analyses to the Arizona governor's Forest Health Advisory Committee climate change subcommittee report. These analyses are based on work by the Core Office and data provided by NOAA-ESRL. Core Office researcher Melanie Lenart is a lead author and co-editor of the Forest Health Advisory Committee climate change subcommittee report. Lenart's key contribution is a detailed analysis of carbon sequestration in Arizona forests.

Core Office researchers Jean Morrill and Gregg Garfin, along with CLIMAS PI Andrew Comrie, presented 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. Garfin presented information about climate change in the Southwest at the August, 2005 Arizona Water Summit, and organized a session on climate change and observed/potential Southwest ecosystem responses. Garfin presented information on climate change in the Southwest at the November, 2005, USGS Biennial Conference of Research on the Colorado Plateau. Garfin also participated in and gave a presentation at the United States Climate Change Science Program workshop, in November 2005. Garfin presented on climate change in the Southwest at the Climate and Rangelands Workshop (see Project D for details).

Garfin and Lenart gave presentations on climate change to Unitarian Universalist Church congregations in southern Arizona. CLIMAS lead investigator Jonathan Overpeck has given climate change presentations to faith-based coalitions in New Mexico.

The Core Office is serving as a consultant on a Nature Conservancy project to evaluate climate changes for USDA-Forest Service Region 3 (Southwest) ecosystems. Program

Manager Garfin is advising TNC researcher Heather Schussman on using tree-ring reconstructions to determine past rangeland ecosystem changes.

Program Manager Garfin wrote a chapter on climate change in *Climate Change in the Colorado River Basin*, a publication sponsored by the California Department of Water Resources for use at the annual meetings of the Colorado River Water Users Association, in the Association of California Water Agencies.

F.3. Accomplishments anticipated by end of Budget Year. Gregg Garfin and Mike Crimmins are advising NASA Space Grant graduate fellow Shoshana Mayden on a February, 2006 workshop to build capacity within the newspaper and television media to better understand and more accurately report on climate change issues (see Project D for details). The NASA/GISS Climate Impacts Group contributed data and analyses to the workshop. Workshop materials can be found at the following URL:
http://www.ispe.arizona.edu/events/climate_trail/.

Core Office contributions to the Arizona and New Mexico governors' climate change committees should be completed by the end of the budget year.

F.4. Plans for 2006-2007. The CLIMAS Core Office is taking the lead on a tri-university Climate Change and Drought Workshop at the Arizona Hydrological Society Symposium (September 13, 2006). The target audience for the workshop is county and municipal managers and water providers. Core Office program manager Gregg Garfin and CLIMAS lead-PI Jonathan Overpeck have been invited to speak on Southwest climate change at the 2006 New Mexico Drought Summit.

We plan to garner funding for publishing a compendium of Lenart's series of climate change articles. Lenart's articles have been cited by news media, and used as bulletins by extension and other organizations.

In collaboration with colleagues from Northern Arizona University and the USGS, we have submitted a climate change research proposal to the National Institute for Climatic Change Research (NICCR). If funded, we will initiate research, with colleagues at Northern Arizona University and the NOAA-ESRL, on potential climate change impacts on vegetation in the Great Basin desert of northern Arizona, southern Utah, and western New Mexico.

The Core Office, in collaboration with UA Cooperative Extension and the NASA Space Grant program, is planning a second climate change workshop for the news media, with an emphasis on reaching rural newspaper journalists.

The Core Office and CLIMAS lead investigator Jonathan Overpeck will continue to work with faith-based groups in Arizona and New Mexico on climate change issues.

The CLIMAS Core Office, the UA Institute for the Study of Planet Earth, and UA Cooperative Extension, will implement, expand, and improve the Climate Change Web Portal. 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.

F.5. Leveraged funding. Lenart's work on the Arizona Forest Health Advisory Community climate change report is leveraged with funds from Northern Arizona University. Climate Change Web Portal work is leveraged with funds from the University of Arizona Institute for the Study of Planet Earth.

F.7. Non-CLIMAS Project Partners. University of Arizona Cooperative Extension, Institute for the Study of Planet Earth, NASA/GISS Climate Impacts Group, The Nature Conservancy.

Project G: Team Integrated Project (TIP)

G.1. Description. The CLIMAS team has been working on a Team Integrated Project (TIP) 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. The TIP is examining the Upper Little Colorado region's climate-related challenges from many disciplinary angles. 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 members of the CLIMAS team.

G.2. Accomplishments to date. In 2005-2006, Core Office social scientist Niina Haas worked with CLIMAS Vulnerability Team members to conduct focus groups on TIP area community perceptions regarding drought.

Core Office researcher Lenart attended Natural Resources Working Group (a partnership of private sector, municipal, and NGO leaders) community workshops in the region. Lenart is working on an article about the Natural Resources Working Group, for the journal *Environment*. The article will focus on the Natural Resources Working Group as a model for successful multi-stakeholder collaborative environmental planning and community economic development; Lenart's 2004-2005 surveys of attitudes about forest resources and climate variability and change will be featured. Lenart also contributed as an invited expert participant in the White Mountains Landscape Assessment workshop, hosted by Northern Arizona University.

Core Office researcher Garfin presented results of a 2004-2005 study on impediments to Arizona drought plan implementation in the TIP area at the 2005 Arizona Hydrological Society symposium.

G.3. Accomplishments anticipated by end of Budget Year. Core Office and other CLIMAS team members will continue to attend regional stakeholder meetings. Lenart is expected to submit her article to *Environment* by the end of the budget year.

G.4. Plans for 2006-2007. The CLIMAS Core Office will coordinate team research activities in the TIP region. The Core Office plans to develop a web site devoted to TIP-region climatology and information resources. The Core Office plans to hold several capacity-building workshops on drought and climate change in the TIP region in summer and fall 2006.

G.7. Non-CLIMAS Project Partners. University of Arizona Cooperative Extension, White Mountains Natural Resources Working Group.

Project H: Coordination with NSF Centers and the Arizona Water Institute

H.1. Project description. CLIMAS is considered a peer with NSF and other multi-institution efforts to connect scientists with decision-makers. CLIMAS coordinates and initiates activities with the SAHRA (Sustainability of semi-Arid Hydrology and Riparian Areas) NSF Science and Technology Center at the University of Arizona, the DCDC (Decision Center for a Desert City) NSF Decision-making Under Uncertainty Center at Arizona State University, and the tri-university Arizona Water Institute.

H.2. Accomplishments to date. In March, 2005, the Core Office, in collaboration with SAHRA Deputy Director Kathy Jacobs and CLIMAS PI Holly Hartmann, conducted a workshop on Drought Management: Understanding and Coping with Climate Variability and Uncertainty. The workshop was held in conjunction with the annual meeting of the New Mexico Rural Water Association (<http://www.ispe.arizona.edu/climas/conferences/nmrwa2005/index.html>).

In 2005-2006, Program Manager Garfin worked with lead project leaders from DCDC to convene two workshops to bring together CLIMAS and DCDC investigators for knowledge exchange and discussions about future collaboration. Garfin has been working with DCDC investigator Andrew Ellis on a project to improve drought monitoring in Arizona. Garfin is a member of DCDC's core group for climatology.

The Core Office also contributed an initial project for the tri-university Arizona Water Institute (AWI). The AWI was created by Arizona's governor to make the most of Arizona's extensive expertise in water-related science, by stimulating collaboration between Arizona's three state universities and water-related stakeholders in Arizona. AWI consults with and collaborates with CLIMAS and NOAA-National Weather Service on NIDIS-related matters.

H.3. Accomplishments anticipated by end of Budget Year. The Core Office and SAHRA will co-convene a press briefing, in Tucson, on drought. The Core Office will join AWI director Kathy Jacobs in coordinated presentations, on drought science and planning efforts, to the Navajo Nation Environmental Protection Agency.

H.4. Plans for 2006-2007. CLIMAS will convene and host another meeting with the DCDC PIs. CLIMAS and SAHRA have plans for a July 2006 drought press briefing in Albuquerque. CLIMAS and SAHRA are also joining forces on improving drought information flow through Arizona's NIDIS program.

Project I: Outreach to and Coordination with Partners in New Mexico

I.1. Project description. CLIMAS has a mandate to work in New Mexico and Arizona, as well as the U.S.-Mexico border region. In order to improve CLIMAS visibility in New Mexico, and to enhance CLIMAS' New Mexico efforts, the Core Office has been working with various New Mexico-based agencies and institutions.

I.2. Accomplishments to date. In March, 2005, the Core Office co-organized a workshop for New Mexico rural water providers, in collaboration with SAHRA, and in conjunction with the New Mexico Rural Water Association. The workshop focused on small water providers (fewer than 1000 hook-ups), and covered topics ranging from the historic climate record, to use of interactive integrated models for exploring water supply issues, to advice on developing community drought plans.

Following the June 2005 AMS Applied Climatology conference, the Core Office initiated improved communication with the New Mexico State Climate Office, and met with New Mexico's assistant state climatologist in September, 2005. In October 2005, at the New Mexico Drought Summit, Core Office researchers Garfin and Haas gave a presentation on past, present, and future climates and the ability of New Mexico to respond to climate challenges. A result of interactions at the Drought Summit, Core Office researchers developed key contacts with New Mexico Cooperative Extension.

The Core Office was invited to contribute to the New Mexico Climate Change and water resources report to Governor Bill Richardson; the Core Office took a major role in GCM data procurement, and in analysis of GCM and instrumental data for that report.

The Core Office maintains regular communication with New Mexico's Drought Task Force and participates in task force monitoring committee meetings via telephone. The Core Office also maintains regular communication with the NOAA-National Weather Service office in Albuquerque, exchanging information on drought monitoring and drought conditions. The Core Office facilitated exchange between the drought monitoring committees in New Mexico and Arizona. The Core Office also maintains regular communication with the Southwest Coordination Center in Albuquerque.

In December 2005, Gregg Garfin traveled to New Mexico State University (NMSU), in order to develop relationships with key New Mexico investigators and potential cooperative extension partners. Garfin met with over a dozen researchers, extension personnel, state climate office personnel, and communication experts. Garfin was invited by NMSU extension to give a presentation in their water resources lecture series.

The Core Office invited University of New Mexico climatologist David Gutzler to brief GACC meteorologists on the North American Monsoon (see Project C, above).

I.3. Accomplishments anticipated by end of Budget Year. The Core Office plans to submit an article on drought in New Mexico to New Mexico Magazine. The Core Office will invite New Mexico investigators to partake in the CLIMAS renewal proposal.

I.4. Plans for 2006-2007. As a result of Garfin's December, 2005 visit to NMSU, CLIMAS and New Mexico Cooperative Extension agreed to convene a fire-climate workshop in New Mexico before the end of 2006. Part of Garfin's efforts will be to facilitate improved interactions between Arizona and New Mexico Cooperative Extension. The Core Office also plans to engage the New Mexico Nature Conservancy's Fire Learning Network in the workshop. (The latter builds on work initiated by former Core Office director Barbara Morehouse).

Core Office researcher Haas will work to develop relationships with New Mexico county and municipal managers, as part of CLIMAS plans to improve outreach to this sector. Garfin has been invited to speak at the 2006 New Mexico Drought Summit. The Core Office plans to attend, in person, New Mexico Drought Task Force meetings in 2006-2007. The Core Office also plans to garner New Mexico input to the Southwest Climate Outlook.

The Core Office and partners in the SAHRA NSF Science and Technology Center will convene a press briefing in Albuquerque, in July 2006.

I.7. Non-CLIMAS Project Partners. New Mexico State University Cooperative Extension, New Mexico Office of the State Engineer, New Mexico Drought Test Force, NOAA-National Weather Service Albuquerque Forecast Office, University of New Mexico, New Mexico Rural Water Association, Southwest Coordination Center, The Nature Conservancy (New Mexico).

Project J: Project Management

J.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 biannual CLIMAS Update newsletter (edited by Niina Haas), which is served as a PDF to approximately 2,000 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. Niina Haas has collaborated with CLIMAS PI Holly Hartmann to develop surveys that evaluate the effectiveness of the formats of various seasonal temperature and precipitation forecasts. Important changes occurred in Core Office staffing during the 2005-2006 budget year. Research scientist Jean Morrill left the project for law school. Melanie Lenart decreased her activity to half time. Social scientist Niina Haas (July 2005) and physical scientist Ben Crawford (September 2005) were hired.

J.2. Accomplishments to date. The Core Office held CLIMAS mini-retreats in October 2005 and February 2006. The mini-retreats orient new team members to the project, and facilitate and enhance team-wide dialogue on team integration and integrated assessment methodology. The Core Office has convened monthly PI meetings regarding the CLIMAS renewal proposal. Niina Haas, in collaboration with Holly Hartmann, created seasonal forecast evaluation surveys that were distributed at two conferences and began data analysis on the surveys from the first conference.

Core Office researcher Haas created a trade and professional journal database available to all CLIMAS team members in order to facilitate the transfer of research to relevant stakeholders.

J.3. Accomplishments anticipated by end of Budget Year. The Core Office will complete work on several new research and product web pages for the CLIMAS web site. 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. Niina Haas will co-author a presentation on the seasonal forecast evaluation with Holly Hartmann for the Climate Prediction and Application Sciences Workshop, held in March 2006.

J.4. Plans for 2006-2007. 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, CEFA, and the RISA network, (6) analyzing use and usability of CLIMAS climate information products, (7) strengthening relationships with New Mexico stakeholders, (8) initiating a major outreach effort to city, municipal, and county managers in Arizona and New Mexico, (9) garnering resources and strengthening relationships with colleagues in Mexico, (10) improving relationships with Arizona and New Mexico NOAA National Weather Service offices and with the NOAA National Weather Service Western Region Office.

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.

Niina Haas will continue collaborating with Holly Hartmann on the analysis of the data from the seasonal forecast evaluations, and will begin developing an article for submission to *Human Organization* or *Practicing Anthropology*.

Project K: RISA and NOAA-CPO Coordination.

K.1. Project description. The Core Office remains the focal point for sustaining interactions with other RISAs and with CPO 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-CPO and the RISA program office for information and materials.

K.2. Accomplishments to date. The CLIMAS Core Office coordinated RISA input to a white paper on RISA lessons for the NOAA drought program. Garfin presented RISA drought lessons at the November 2005 U.S. Climate Change Science Program workshop. The CLIMAS Core Office coordinated with the WWA RISA and the CAP RISA to host and co-organize the 2006 NSAW: Western States & Alaska workshop and training, and with SECC RISA scientists to develop training materials for the 2006 NSAW: Eastern, Southern, and Southwest Geographic Areas workshop. The Core Office works regularly with WWA RISA's Andrea Ray on developing applied climatology research associated with the North American Monsoon Experiment, and other U.S.-Mexico initiatives. The Core Office worked with WWA RISA scientists to host a 2005 workshop on paleohydrology. Organizers and stakeholders considered the workshop a great success; a spin-off from the workshop was a cross-RISA volume on *Colorado River Basin Climate: Paleo, Present, Future*, funded by the California Department of Water Resources.

K.4. Plans for 2006-2007. In collaboration with the Western Water Assessment RISA, the CLIMAS Core Office is coordinating a fall 2006 technical workshop on the use of paleoclimatic data in Southwest water resources management. Garfin has been invited to participate in the 2006 NOAA drought retreat. The Core Office plans to develop a plan for inter-RISA coordination on a RISA session for the 2007 AAAS meeting.

The Core Office also plans to improve RISA contributions to planning the 2007 NSAWs, by inviting WWA and CAP participation in workshop organization.

II. Publications

In print

Brown, T., G. Garfin, M. Lenart, and H. Hockenberry, 2005: Significant Fire Potential Outlook 2005. Proceedings EastFIRE Conference, George Mason University, Fairfax, VA, 11-13 May 2005, 4 pp.

Garfin, G. 2005. Climate change in the Colorado River Basin. In *Colorado River Basin Climate: Paleo, Present, Future*, pp. 36-44.
http://wwa.colorado.edu/resources/colorado_river/Colorado_River_Basin_Climate.pdf

Garfin, G., M. Lenart, T. Brown, R. Ochoa, H. Hockenberry. 2005. Fire Season Could Mean Double Trouble for West. *Wildfire*, May 1, 2005..

Jacobs, K., G. Garfin, and M. Lenart. 2005. More Than Just Talk: Connecting Science and Decisionmaking. *Environment* 47(9): 6-21.

Sonnett, J., B. J. Morehouse, T. D. Finger, G. Garfin, and N. Rattray. 2005. Drought and declining reservoirs: Comparing media discourse in Arizona and New Mexico, 2002–2004. *Global Environmental Change* 16:95-113.

Jacobs, K. L., G. M. Garfin, and B. J. Morehouse. 2005. Climate science and drought planning: the Arizona Experience. *Journal of the American Water Resources Association* 41: 437-445.

Lenart, M., T. Brown, R. Ochoa, H. Hockenberry, G. Garfin. 2005. National Seasonal Assessment Workshop: Western States and Alaska, Boulder, CO, March 28–April 1, 2005. Final report. CLIMAS/ISPE, Tucson, 29 pp.

Submitted/In Review

Ellis, A.W., G. Garfin, R.C. Balling, Jr., Christopher J. Graham. A Hydroclimatic Indexing Concept for Monitoring Drought Derived from the Climate of the Southwestern United States. Submitted to *Annals of the Association of American Geographers*.

Ray, A.J., G.M. Garfin, M. Wilder, M. Vásquez-León, M. Lenart, and A.C. Comrie. Applications of monsoon research: Opportunities to inform decisionmaking and reduce regional vulnerability. Submitted to *Journal of Climate*.

Arizona Cooperative Extension Fact Sheets (in peer review).

From the Workshop on Climate Variability & Ecosystem Impacts in Southwestern Forests and Woodlands held in Sedona, Arizona, February, 2005.

DeGomez, T., and M. Lenart. Natural resource management: Managing forests for climate change.

DeGomez, T., and G. Garfin. Climate Change and Ecosystem Impacts in Southwest Forests and Woodlands: Insects, Diseases, and Abiotic Disorders.

Lenart, M. and C. Jones. Carbon dioxide fertilization: Potential effects on southwestern ecosystems.

Rogstad, A., M. Crimmins, and G. Garfin. Climate Change and Wildfire Impacts in Southwest Forests and Woodlands.

III. Presentations at Professional Meetings/Conferences

Brown, T., G. Garfin, M. Lenart, and H. Hockenberry, 2005: Significant Fire Potential Outlook 2005. EastFIRE Conference, George Mason University, Fairfax, VA, 11-13 May 2005.

Crimmins, M. and G. Garfin, 2005. Communicating Climate Information to Arizona. CALS Day, session on Innovative Connections II – Research to Community. University of Arizona College of Agriculture and Life Sciences, August 23, 2005.

Crimmins, M., and G. Garfin, 2005. CLIMAS Update. U.S. Drought Monitor Forum, Washington, D.C., October 20-21, 2005.

Garfin, G. and A. Gilbert, 2005. Implementing the Arizona Drought Preparedness Plan: A Case Study of Potential Impediments. Arizona Hydrological Society's 18th Annual Symposium: "Conservation & Innovation in Water Management," Flagstaff, Arizona, September 23, 2005.

Garfin, G., 2005. Contributions of Regional Integrated Assessment to Coping with Vulnerability to Climate in Central Arizona. Presentation to the Association of American Geographers 101st Annual Meeting, Boulder, CO, April 5, 2005.

Garfin, G., 2005. Is The Drought Over? & CLIMAS' Greatest Hits! University of Arizona Water Resources Research Center Lecture Series, April 21, 2005, Tucson, Arizona.

Garfin, G., 2005. The CLIMAS Perspective on Climate Services. American Meteorological Society 15th Conference on Applied Climatology, Savannah, GA, June 22, 2005.

Garfin, G., 2005. Climate, Drought and Water Management. Arizona Water Summit, Northern Arizona University, Flagstaff, Arizona, August 3-5, 2005. (invited)

Garfin, G., 2005. Climate, Drought & Water Management. Arizona Planning Association annual meeting. Prescott, Arizona, September 29, 2005. (invited)

Garfin, G., and N. Haas, 2005. Weathering the "Big One" -- A Review of Coping with Severe Sustained Drought in the Southwest. New Mexico Drought Summit, Albuquerque, NM, October 6, 2005. (invited)

Garfin, G., 2005. The National Seasonal Assessment Workshops: Dialogue on Improvements. NIFC Predictive Services Meeting, November 1, 2005, Tucson, Arizona. (invited)

Garfin, G. M., M.A. Crimmins, and J.L. Weiss, 2005. A Brief History of Southwest Climate Changes and a Glimpse at the Future. The 8th Biennial Conference of Research on the Colorado Plateau. Northern Arizona University, Flagstaff, Arizona, November 9, 2005. (invited)

Garfin, G., G. Carbone, D. Cayan, K. Ingram, P. Mote, E. Shea, B. Udall. Walking the Talk: RISA Drought Insights for CCSP. U.S. Climate Change Science Program

workshop, Climate Science in Support of Decision Making, Arlington, VA, November 14-16, 2005. (invited)

Garfin, G., 2005. Improving the Use of Climate Information Through Outreach and Engagement with Decision-makers in the Southwestern United States. IX Foro de Predicción Climática en la República Mexicana, Guanajuato, Mexico, December 1, 2005. (invited)

Garfin, G., 2005. Drought and Climate Change in Arizona: Implications for Seed Growers. Oregon Seed Growers League 2005 Meeting, Portland, Oregon, December 5, 2005. (invited)

Garfin, G., 2006. Climate Change and Southwest Rangelands: Past, Present, Future. Society for Range Management (Arizona Section) annual meeting, San Carlos, AZ, January 25-26, 2006. (invited)

Lenart, M., G. Garfin, B. Morehouse, M. Vasquez-Leon and A. Comrie, 2005. Climate Research and Products Relevant to Mountainous Regions: Input from Stakeholders. MTNCLIM 2005: A Science Conference on Mountain Climates & Effects on Ecosystems. March 3, 2005, Pray, Montana.
http://www.fs.fed.us/psw/cirmount/meetings/mtnclim/2005/pdf/MTNCLIM_Program_final5.pdf.

Posters

Ellis, A., G. Garfin, R. Balling, Jr., and C. Graham, 2006. A Hydroclimatic Indexing Concept for Monitoring Drought Derived from the Climate of the Southwestern United States. Central Arizona – Phoenix Long-Term Ecological Research (CAP LTER) Eighth Annual Poster Symposium, January 19, 2006, Arizona State University, Tempe, Arizona.
<http://dcdc.asu.edu/research/DroughtMonitoring.pdf>

Garfin, G. M., and others, 2005. The Southwest Climate Outlook: Operational Perspectives on Communicating Climate Information to Stakeholders. American Meteorological Society 15th Conference on Applied Climatology, Savannah, GA, June 22, 2005.

Garfin, G., J. Morrill, A. Comrie, J. McPhee, S. Ponnaluru, 2005. A tale of two droughts: the effects of temperature on recent southwestern droughts. American Meteorological Society 15th Conference on Applied Climatology, Savannah, GA, June 22, 2005.

Garfin, G., B. Morehouse, T. Swetnam, M. Lenart, E. Bigio, B. Crawford, 2005. Climate and Fire Science in the Service of Society. Forest Health in the Sky Islands, bi-annual meeting of the Southwest Section of the Society of American Foresters (SAF) and the Chihuahua Section of the Mexican Association of Professional Foresters (Asociacion de Mexicana de Profesionales Forestales – AMPF), Tucson, AZ, November 10, 2005.

Jones, C., G. Garfin, 2005. Climate Change, Ecosystem Impacts, Forest Management and Extension Education. 5th International Conference on Forest Vegetation Management, in Corvallis, Oregon, June 20-24, 2005.

Thornbrugh, C.C., G. Garfin, and A.C. Comrie, 2005. Development of the Arizona Drought Impacts Database. American Meteorological Society 15th Conference on Applied Climatology, Savannah, GA, June 22, 2005.

Webb, R.S., C. Woodhouse, G. Garfin, 2005. Developing Hydroclimatic Reconstructions for Decision Support in the Colorado River Basin. Presented at Observational and Modeling Requirements for Predicting Drought on Seasonal to Decadal Time Scales, Adelphi, Maryland, May 17-19, 2005.

Woodhouse, C., R. S. Webb, G. Garfin, B. Udall, 2005. Hydroclimatic Reconstructions for Decision Support in the Colorado River Basin. U.S. Climate Change Science Program workshop, Climate Science in Support of Decision Making, Arlington, VA, November 14-16, 2005.

Meetings, Panel Sessions, Stakeholder Workshops

Garfin, G., K. Jacobs, H. Hartmann, J. Morrill, 2005. Workshop on Drought Management: Understanding and Coping With Climate Variability and Uncertainty. New Mexico Rural Water Association (NMRWA) Conference, Albuquerque, NM, March 21, 2005. Co-organizers and presenters. 40 attendees.

Garfin, G. M., M. Lenart, 2005. National Seasonal Assessment Workshop: Western States and Alaska, Boulder, CO, March 28-April 1, 2005; co-organized meeting; co-authored proceedings. 70 attendees.

Garfin, G., C. Woodhouse, R. Webb, K. Jacobs, D. Meko, 2005. Planning Workshop to Develop Hydroclimatic Reconstructions for Decision Support in the Colorado River Basin. Tucson, Arizona, May 5, 2005. Co-organizer, host organization, and presenter. 60 attendees.

Garfin, G., 2005. Panel session on Climate Services: Research, Outreach, and Stakeholder Engagement. American Meteorological Society 15th Conference on Applied Climatology, Savannah, GA, June 22, 2005. Organizer and moderator. 300 attendees.

Garfin, G., 2005. Arizona Water Summit, Northern Arizona University, Flagstaff, Arizona, August 3-5, 2005. Co-organized meeting; developed agenda; secured participation of some of the speakers. Organized session on Ecological Implications of Climate Variability and Change and moderated stakeholder panel discussion. 200 attendees.

Garfin, G. M., K. Jacobs, M. Crimmins, 2005. Drought Planning for Small Water Providers and Communities. Arizona Hydrological Society's 18th Annual Symposium:

“Conservation & Innovation in Water Management,” Flagstaff, Arizona, September 21, 2005. Co-organizer and presenter. 50 attendees.

Garfin, G., 2005. Session on Climate Variability & Water Supply. Arizona Planning Association annual meeting. Prescott, Arizona, September 29, 2005. Organized and moderated session. 500 attendees.

Garfin, G. M., 2006. National Seasonal Assessment Workshop: Eastern, Southern, Southwest Geographic Areas, Shepherdstown, WV, January 17-20, 2006; co-organized meeting; presented info on multi-decadal climate variations; co-authored proceedings. 15 attendees.

Garfin, G., M. Lenart, N. Haas, C. Jones, M. Crimmins, others, 2006. Climate and Rangelands Workshop: Beyond Boxes and Arrows, Assessing Climate Change/Variability and Ecosystem Impacts in Southwestern Rangelands. Held in conjunction with the Society for Range Management (Arizona Section) annual meeting, January 25-26, 2006. Co-organizer, sponsor, and presenter. 100 attendees.

Lenart, M., Comrie, A., Garfin, G.M., Jacobs, K., Crimmins, M., 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. 100 attendees.

IV. Outreach Activities

Garfin, G. 2005. Global Climate Change: Bringing the Message Home. Unitarian Universalist Congregation of Northwest Tucson, Arizona, June 5, 2005. 75 attendees

Garfin, G., 2005. Impacts of Global Climate on Southwest River Systems. University of Arizona Arid Lands Studies 645, September 16, 2005. Guest Lecture. 15 attendees

Garfin, G. 2005. Drought: Lessons from the Future. La Posada Forum, Green Valley, Arizona, October 28, 2005. 50 attendees.

Lenart, M. 2005. Global Warming: Science, Impacts and Policy. Unitarian Universalist Congregation of Green Valley, Arizona, June 12, 2005. 50 attendees.

Lenart, M. 2005. Student practicum for prospective natural resource students (including interactive Climate Exercise Using Examples from the Southwest, [assistance from GRA Rick Brandt]). San Carlos Apache Reservation, July 13, 2005. 20 attendees.

Lenart, M. 2005. The Latest Science on Global Warming. Grand Canyon Trust Workshop, October 8, 2005. 50 attendees.

Arizona Governor's Drought Task Force (GDTF)-Related Meetings (Garfin, Crawford) 2005

March, 2005 – Monitoring Technical Committee meeting

April, 2005 – Monitoring Technical Committee meeting

May, 2005 – Monitoring Technical Committee meeting

June, 2005 – Monitoring Technical Committee meeting; emergency drought status decision

July, 2005 – Monitoring Technical Committee meeting

September, 2005 – Monitoring Technical Committee meeting

October, 2005 – Monitoring Technical Committee meeting

October 27, 2005: *Arizona Drought Monitoring* – Cochise County Local Area Impact Assessment Group, Bisbee, Arizona

November, 2005 – Monitoring Technical Committee meeting

2006

January, 2006 Monitoring Committee Meeting

January 31, 2006: *Local Area Impact Assessment Groups and Arizona Drought Monitoring* – Cochise County Local Area Impact Assessment Group, Bisbee, Arizona

V. Human Resource Development

Susan Simpson's CLIMAS-inspired M.S. thesis defended in May 2005.

Srinivasa Ponnaluru's CLIMAS-inspired M.S. thesis defended in June 2005.

VI. Interviews and News Articles

G. Garfin, 2005. "Signs say drought easing for now." *Arizona Daily Star*, March 1, 2005.

G. Garfin, 2005. "Arizona drought 'taking a nap' expert says." *Tucson Citizen*, story by Brad Poole, April 22, 2005.

G. Garfin, 2005. "Global warming to cut water supply?" *Tucson Citizen*, story by Brad Poole, April 22, 2005.

G. Garfin, 2005. KFYI-FM, Phoenix, Arizona, June 14, 2005.

G. Garfin, 2005. *Green Tuesdays*. 92.9 KWMT-FM, Tucson, Arizona, August 11, 2005.

G. Garfin, 2005. "Warning issued on weather anomalies." *Arizona Republic*, August 28, 2005.

G. Garfin, 2005. "Clouded effort." *Arizona Republic*, August 28, 2005.

G. Garfin, 2005. "Thinning snowpack may hurt West's water supply" *Arizona Daily Star*, September 29, 2005.

G. Garfin, 2006. KOLD-TV, Tucson, Arizona. January 12, 2006.

M. Lenart, 2005. *Weather Talk*. February 26, 2005. AM 1330 KJLL, Tucson, Arizona.

M. Lenart, 2005. "Drought further jeopardizing endangered and threatened wildlife." Associated Press, story by Ananda Shorey, May 25, 2005.

M. Lenart, 2005. "Area's drought is over – barely." *Arizona Daily Star*, story by Patty Machelor, June 2, 2005.

TASK AREA: Social Science Research

PI: Dr. Barbara Morehouse

Researchers: John Sonnett, Graduate Research Assistant - now PhD (Sociology); Thomas Finger, Graduate Research Assistant (Environmental History); Sara Jensen, staff researcher

I. Progress for Budget Year 2005-2006

Project A: Discourse analysis of newspaper coverage: drought and fire

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

A.2. Progress. Paper on drought published in *Global Environmental Change*, February 2006. Paper on newspaper coverage of wildland fire: analysis and draft of paper underway

A.3. Accomplishments anticipated by end of Budget Year (June 1, 2006). Fire paper submitted for peer review and publication.

A.4. Plans for 2006-07. None - project will be completed.

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

A.6. Leveraged activities. None

A.7. Non-CLIMAS Project Partners. None

Project B: Environmental history of Upper Little Colorado area, northern Arizona

B.1. Description. Contribute environmental history information to integrated project in Upper Little Colorado (with Tom Finger)

B.2. Progress. Research and analysis completed; journal article and white paper in progress

B.3. Accomplishments anticipated by end of Budget Year (June 1, 2006). Paper submitted to journal for review/publication; white paper completed. (Note: Tom has decided to focus his thesis more directly on the Mormon aspects of his research; it is unclear at this time whether the thesis will be relevant to CLIMAS.)

B.4. Plans for 2006-07. Complete publications.

B.5. Leveraged funding. None

B.6. Leveraged activities. None

B.7. Non-CLIMAS Project Partners. None

B.8. Leveraged funding. Separate NOAA funding [R Varady PI] for this project.

B.9. Leveraged activities. None

B.10. Non-CLIMAS Project Partners. R Varady, A Browning-Aiken

Project C: Examination of RISA science-society structures and processes from science studies perspective

C.1. Description. Application of science studies concepts to evaluating CLIMAS activities

C.2. Progress. Coproduction of science and policy paper (MC Lemos and BJ Morehouse) published in *Global Environmental Change*, 2005. Paper critiquing boundary organization concept for RISAs (BJ Morehouse and MC Lemos) has been submitted for peer review to *Science, Technology and Human Values*.

C.3. Accomplishments anticipated by end of Budget Year (June 1, 2006). Publication of boundary organization paper.

C.4. Plans for 2006-07. RISA-oriented analysis based on concepts of co-production of science& policy and science citizenship; publication of peer-reviewed paper

C.5. Leveraged funding. None

C.6. Leveraged activities. None

C.7. Non-CLIMAS Project Partners. MC Lemos (left CLIMAS when moved to U Mich)

Project D: Decision calendars, climate information and wildland fire management

D.1. Description. Characterize decision calendars used by fire managers and identification of where/when climate information can be most productively introduced. [Inter-RISA project (with A. Westerling, T. Corringham-RA)]

D.2. Progress. Interviews completed; final draft underway.

D.3. Accomplishments anticipated by end of Budget Year (June 1, 2006). Draft submitted for peer review and publication.

D.4. Plans for 2006-07. Publication of peer-reviewed paper.

D.5. Leveraged funding. None

D.6. Leveraged activities. None

D.7. Non-CLIMAS Project Partners. A. Westerling

Project E: Evaluation of partnership concept in collaborative climate research/outreach

E.1. Description. Characterize concepts of “partnerships” in collaborative development and use of climate information, using CANSAC as a case study (with T Brown)

E.2. Progress. Survey completed; analysis completed; draft of paper for peer-reviewed publication underway.

E.3. Accomplishments anticipated by end of Budget Year (June 1, 2006). Draft submitted for peer review and publication.

E.4. Plans for 2006-07. None - project completed

E.5. Leveraged funding. None

E.6. Leveraged activities. None

E.7. Non-CLIMAS Project Partners. T. Brown

Project F: Inter-RISA collaboration

F.1. Description. Work with other RISAs on papers, projects, etc. For example, assisting PIs in their efforts to establish Alaska RISA

F.2. Progress. Tentative plans for trip to Fairbanks

F.3. Accomplishments anticipated by end of Budget Year (June 1, 2006). Meeting with PIs in Alaska

F.4. Plans for 2006-07. TBD based on meeting with PIs

F.5. Leveraged funding. None

F.6. Leveraged activities. None

F.7. Non-CLIMAS Project Partners. Alaska RISA PIs

Project G: EPA-funded GIS fire-climate-society decision support tool.

G.1. Description. Publication of papers from fire-climate research and model development

G.2. Progress. Analysis and writing underway (with S Jensen)

G.3. Accomplishments anticipated by end of Budget Year (June 1, 2006). One paper in penultimate draft form

G.4. Plans for 2006-07. Completion and publication of at least two papers in peer-reviewed journals

G.5. Leveraged funding. Funding from EPA-STAR program (2001-2004) to build Fire-Climate-Society GIS model

G.6. Leveraged activities. None

G.7. Non-CLIMAS Project Partners. B Orr, S Yool, G Christopherson

Project H: NSF-funded workshops on sustainability in US-Mexico borderlands

H.1. Description. Binational planning workshops to assess potential to establish binational center with offices at UA and CIAD (Hermosillo, Sonora, MX) to conduct research on sustainability in the US-Mexico borderlands, with an emphasis on the Greater Sonoran Ecoregion (with D Ferguson)

H.2. Progress. Two workshops held; proceedings drafted.

H.3. Accomplishments anticipated by end of Budget Year (June 1, 2006). Publication of proceedings

H.4. Plans for 2006-07. Pursue opportunities to initiate the centers.

H.5. Leveraged funding. Funding from NSF (2004-2005)

H.6. Leveraged activities. None

H.7. Non-CLIMAS Project Partners. S Cornell, K Flessa, T Huxman

Project I: Climate impacts and use of climate information in the Upper San Pedro

I.1. Description. Assess use of climate information in the Upper San Pedro River Basin (with R Varady, A Browning-Aiken, M Wilder, GM Garfin). CLIMAS contribution is provision of climate information for workshops and other such activities and co-authorship of papers arising from the project.

I.2. Progress. Prototype climate outlook package based on design of Southwest Climate Outlook completed and successfully presented to Mexican counterparts. Workshops held to educate constituents on climate and its impacts.

I.3. Accomplishments anticipated by end of Budget Year (June 1, 2006). Paper on producing science information in transboundary context submitted for peer-review and publication.

I.4. Plans for 2006-07. Wrap up project, finish publications.

II. Publications

In Print

Ferguson, D and BJ Morehouse. 2006. *Proceedings, Workshops on Sustainability Under Uncertainty of Arid and Semiarid Ecosystems*. Institute for the Study of Planet Earth, University of Arizona, Tucson, Arizona.

Jacobs, K, GM Garfin, and BJ Morehouse. 2005. Climate science and drought planning: The Arizona experience. *Journal of the American Water Resources Association* 41(2): 437-445.

Lemos, MC and BJ Morehouse. 2005. The co-production of science and policy in integrated climate assessments. *Global Environmental Change* 15: 57-68.

Morehouse, BJ, HJ Cortner, and JG Taylor. 2005. *Proceedings, Tucson III Fire Social Science Workshop*, ISPE, University of Arizona, Tucson, AZ.

Sonnett, J, BJ Morehouse, TD Finger, GM Garfin, and N Rattray. (2006). Discursive framing of drought. *Global Environmental Change* 16: 95-113.

Submitted/Accepted

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

Carter, RH, BJ Morehouse, GM Garfin, N Schmidt, J Abraham, K Zimmerman, and S Mayden. (In Review). Making climate information matter in the US Southwest. *Human Organization*.

Morehouse, BJ and B Orr. (In Press). Walking the talk: Integrating science and community into decision support for wildland fire management. In (eds.) C. Raish and B. Kent, *Wildfire and Fuels Management: Risk and Human Reaction*.

Morehouse, BJ, G Christopherson, M Crimmins, B Orr, JT Overpeck, T Swetnam, and S Yool. Publication (In Press). Modeling interactions among wildland fire, climate, and society in the context of climatic variability and change in the U.S. Southwest. In (eds.) M. Ruth, K. Donaghy, and PH Kirshen, *Regional Climate Change and Variability: Impacts and Responses*. New Horizons in Regional Science series, Cheltenham, England: Edward Elgar Publishing.

To be Submitted by June 1, 2006

Corringham, TW, AL Westerling, and BJ Morehouse. (In Progress). Exploring use of climate information in wildland fire management: a decision calendar study.

Morehouse, BJ and MC Lemos. (In Review). An alternative to boundary organizations for characterizing iterative coproduction of science and policy. *Science, Policy and Human Values*.

III. Presentations

None

IV. Outreach

None

V. Human Resource Development

None

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, Kyle Emerick, Srinivasa Ponnaluru (GRAs, Agricultural and Resource Economics)

I. Progress for Budget Year 2005-2006

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.

A.2. Accomplishments to date. Our case studies of Sunrise Park Ski Resort in the White Mountains, Arizona and Snowbowl near Flagstaff highlight 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. Although, new snowmaking investments could reduce ski season uncertainty at both resorts such investments also conversely would make the area more economically dependent on winter recreation. 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. We have developed a preliminary model of snow depth as related to recreational visits and local economic activity. We have provided 4 conference presentations on this research and several journal articles in the final stages of preparation.

A.3. Accomplishments anticipated by end of Budget Year (June 1, 2006). We currently are examining the probable impacts of climate change, the associated increased costs of snowmaking at higher temperatures and the relative competitive position of these resorts in the Southwest skiing market. In addition, the environmental impacts of expanded snowmaking need consideration; namely water supply issues and the impact of water withdrawals on winter fish habitat.

A.4. Plans for 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 2005.

B.2. Accomplishments to date. We have empirically modeled water markets in several western states, specifically, Arizona, New Mexico, Colorado, Nevada, and Utah; as well as created a model for all the southwestern states together. We have provided 4-5 conference presentations on this work and several publications.

B.3. Accomplishments anticipated by end of Budget Year (June 1, 2006).

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

B.5. Leveraged funding. “Water Management Innovations: 25 Years of Tribal Water Settlements”, NSF Science and Technology Center, Semi-Arid Regions, 2005-06, supports one GRA.

B.6. Leveraged activities.

B.6.1 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. The research has been refined 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 budget year. We will engage in stakeholder outreach to discuss study results and implications for resource management. Four journal articles have been drafted, with two submitted.

C.4. Plans for 2006-7. Finish publication and outreach activities.

C.5. Leveraged funding. “The Value of Binational Effluent and Sustainable Watershed Management in the Upper Santa Cruz Basin.” George Frisvold and Terry Sprouse, University of Arizona Water Resources Research Center. \$62,879 from the Technology and Research Initiative Fund (TRIF) of the Water Sustainability Program (WSP) at the University of Arizona. Supports one GRA in Agricultural and Resource Economics and one in Office of Arid Lands Studies.

C.6. Leveraged activities. The TRIF-supported project estimates the impact on property values of the riparian corridor along the Upper Santa Cruz Basin in Santa Cruz County, Arizona. The main source of instream flow is effluent from the Nogales International Wastewater Treatment Plant that serves both Nogales, Arizona and Nogales, Sonora. Prolonged drought could induce a reallocation of effluent to other uses affect the extent and type of vegetation in the area. The effects of possible reallocation of effluent on vegetation and property values will be assessed.

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

D.2. Accomplishments to date. Srinivasa Ponnaluru finished his M.S. degree requirements in the Department of Agricultural and Resource Economics, writing the

thesis “Visitation to the National Parks of the Southwest: The Influence of Economic and Climate Variables.” Some major findings were:

- For every 1% drop in reservoir levels visits to Lake Mead and Glen Canyon National Recreation Areas drop 5%. Since reaching peak levels in 1983, reservoir levels in Lake Mead have fallen 5.8% and Lake Powell 2.1%, suggesting substantial drops in tourism associated with falling lake levels.
- For every 10% increase in the price of gasoline, visits to parks decline about 2%.
- Controlling for other factors, the Cerro Grande fire, accounted for a drop of over 66,000 visits to Bandelier National Monument.
- Visits were positively associated with relative humidity. This finding may result from the fact that the study was confined to the Southwest with very low humidity. Extremely low humidity is associated with desert as opposed to forest or grassland environments.

Because water-based recreation appears to be the most sensitive to climate variability we have collected data on Arizona and New Mexico state parks. Many of these state parks have lakes providing water-based recreation. We hypothesize that these parks will be sensitive to changes in water levels.

D.3. Accomplishments anticipated by end of budget year. The national parks study is based on time series-cross section (TSCS) data from 1980-2003. Many climate and environmental variables either do not change over the study period or change very slowly. We are currently re-estimating the model using new, state-of-the-art statistical techniques to address static or slowly-changing variables in TSCS estimation. Visitation data is now available for 2004, so we will test the out-of-sample forecasting ability of the model.

D.4. Plans for 2006-7. Present findings of revised national parks analysis at professional meetings. Submit study for publication in peer-reviewed economics journal. Present vetted results to stakeholders primarily in the Plateau – an area particularly dependent on water-based park visitation. Impacts of climate variability on park visitation will be of particular interest to the tourism and hospitality industries of Northern Arizona and to city and county planning agencies.

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

D.6. Leverage activities. Frisvold’s Cooperative Extension appointment allows him to devote additional time beyond CLIMAS-supported time for outreach activities related to this project. Time series-cross section data for analysis of Arizona and New Mexico state park visits will be made available to graduate students taking Agricultural and Resource Economics 549 – Applied Econometrics. Students must conduct applied statistical analysis as part of a course project. Analysis as part of course project requirements would also further CLIMAS research.

D.7. Non-CLIMAS Project Partners. These include the National Park Service, Public Use Statistics Office, Arizona State Parks, New Mexico State Parks, Arizona Hospitality Research and Resource Center (Northern Arizona University), and the Arizona Office of Tourism.

Project E: Climate, Agricultural Technology Adoption, and Water Use

E.1. Description. Agriculture accounts for 80% of water withdrawals in Arizona and 88% of withdrawals in New Mexico. Small changes in irrigation water use translate into large proportional changes in 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 affecting agricultural water use. The project also examines how changes in climate, agricultural technology choice, and agricultural technology policy affect irrigation water use and the scope for rural-urban water transfers.

E.2. Accomplishments to date. We have collected water use, cropping pattern, price and weather data to estimate econometric models of irrigation water demand throughout Arizona. One study will focus on irrigation districts along the main stem of the Colorado River, while a second will focus on major irrigation districts in the Phoenix, Tucson, and Pinal Active Management Areas (AMAs). Colorado main stem data is available on a monthly basis, while AMA data is available on an annual basis. The districts covered account for about 75 percent of irrigation water withdrawals and about 60 percent of total water withdrawals in Arizona. Some preliminary results from the AMAs suggest that a 10% decrease in precipitation would increase water use 1.3%, while a 4% increase in temperature would increase water use 1%.

We have also developed a game-theoretic model of negotiations over large-scale rural-urban water transfers. Patterned after the transfer agreement between the Imperial Irrigation District and the Metropolitan Water District (San Diego) the model explicitly accounts for strategic behavior of actors. We will use the model to examine how drought conditions, market forces, and federal commodity programs affect the terms and conditions of water transfers and the bargaining power of irrigation districts versus municipal water providers.

E.3. Accomplishments anticipated by the end of budget year. We expect to have completed data collection and made significant progress toward estimating econometric models of irrigation water demand. The effect of climate variables such as temperature and precipitation on irrigation demand will be estimated at district levels, then aggregated to larger regional levels. Results from both study areas will be used to simulate how changes in climate variables through, for example, prolonged drought might affect irrigation water use. These preliminary results will be prepared for presentation at professional meetings by summer 2006.

E.4. Plans for 2006-7. Prepare papers from the two econometric models and the game-theoretic model for submission to peer-reviewed journals. Present findings to the

Arizona Department of Water Resources and the Bureau of Reclamation. Develop outreach publications to distribute to extension clientele state-wide.

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

E.6. Leverage activities. Frisvold's Cooperative Extension appointment allows him to devote additional beyond CLIMAS-supported time for outreach activities related to this project.

D.7. Non-CLIMAS Project Partners. Arizona Department of Water Resources.

II. Publications

In print

Colby, B.G., John Thorson and Sarah Britton. 2005. *Negotiations Over Tribal Water Rights*. University of Arizona Press.

Colby, B. and J. Pullen. "Voluntary Water Transactions: What Factors Affect Price?" *Arizona Review* 3, 9.

Colby, B.G. and E. Smith-Incer, "Visitors Values of Local Economic Impacts of Riparian Habitat Preservation", *Journal of the American Water Resources Association* 41, 709-717, 2005.

Deva, S. and G. Frisvold. "Some Highlights from the 2003 Farm and Ranch Irrigation Survey," *Arizona Review* 3, 16-19.

Frisvold, G. Agriculture, Federal Farm Programs and Water Use in the Western United States. 2005. In B.G. Colby, J. E. Thorson, and S. Britton (eds.) *Negotiating Tribal Water Rights: Fulfilling Promises in the Arid West*. Tucson: University of Arizona Press.

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

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

Submitted / Accepted

Bark-Hodgins, R. and Bonnie Colby, "An Economic Assessment of the Sonoran Desert Conservation Plan", *Natural Resources Journal*, forthcoming 2006.

R. Bark-Hodgins, D. Osgood and B. Colby, "Remotely Sensed Proxies For Environmental Amenities In Hedonic Analysis: What Does Green Mean?" in

Environmental Valuation: Intraregional And Interregional Perspectives, Edited J. I. Carruthers and B. Mundy. Ashgate, forthcoming 2006.

To be submitted by June 1, 2006

Bark-Hodgins, R., D.E. Osgood, B.G. Colby and G. Katz and J. Stromberg. "Do Homebuyers Care If Their Environments Are Natural?" *The Journal of Real Estate Finance and Economics*, revise and resubmit 2006.

Deva, S. and G. Frisvold. "Farm Size, Information Use, and Water Management Decisions among Southwest Irrigators." To be submitted to *Irrigation and Drainage*.

Ponnaluru, S. and G. Frisvold. "Visitation to National Parks in the Southwest: Economics and Climate," to be submitted to *Land Economics*.

Leveraged peer-reviewed publications

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

Thorson, J., S. Britton and B. Colby, *Tribal Water Conflicts: Essays in Law, Economics and Policy*, University of Arizona Press, Forthcoming, 2006.

Colby, B.G. and Kathy Jacobs, *Water Policy for Urbanizing Arid Regions*, Resources for the Future Press, forthcoming, 2006.

III. Presentations at Professional Meetings/Conferences

Bark-Hodgins, R. and Bonnie G. Colby. An Economic Argument for Renewable Water Instream Flows. Arizona Hydrological Society, Annual Meeting, Flagstaff, AZ. September 2005.

Bark-Hodgins, R. D. E. Osgood, B. G. Colby. Hedonic Valuation of Urban Riparian Amenities Using Remote Sensing Data. American Agricultural Economics Association, Annual Meeting, Providence, RI. July 2005.

Bark-Hodgins, R., D. E. Osgood, B. G. Colby, G. Katz, J. Stromberg. Do Homebuyers Care about the 'Quality' of Natural Habitats? American Meteorological Society, 15th Conference on Applied Climatology, Savannah, GA, June 2005.

Bark-Hodgins, R. and B.G. Colby. Outstanding Student Oral Presentation award, \$150 for Climate variability and change: the economic vulnerability of the skiing industry and surrounding communities in Arizona, USA.

Deva, S. Information, Decision Making, and Water Management among Southwest Irrigators. Poster presented at 2005 Institute for the Study of Planet Earth ISPE-Fest. Tucson, AZ, October 2005. *Award:* poster first prize (\$300), Social Science division.

Frisvold, G. Climate Change: Economic Implications for the Southwest. Presented at Agriculture and Climate Change: Threats and Opportunities, a briefing for U.S. Senate Staff organized by The Environmental and Energy Study Institute and Global Legislators Organization for a Balanced Environment USA. Russell Senate Office Building, Washington DC, May 2005.

Frisvold, G. Arizona Agricultural Land and Water Use: 1945-2005. Arizona Water Summit, organized by Northern Arizona University, The University of Arizona, Arizona State University, The Indigenous Environmental Network, and Black Mesa Trust, Flagstaff, AZ, August 3-5, 2005.

Frisvold, G. Range and Livestock Economics. Climate and Rangelands Workshop: *Beyond Boxes and Arrows* – Assessing Climate Change/Variability and Ecosystem Impacts/Responses in Southwestern Rangelands, San Carlos, AZ, Jan., 2006

Pullen, J. Comparative Analysis of Drought Implications in the Colorado Big Thompson and Arizona Water Markets. Poster presented at 2005 Institute for the Study of Planet Earth ISPE-Fest. Tucson, AZ, October 2005. *Award:* poster second prize (\$200), Social Science division.

IV. Outreach Activities

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

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.

Colby and Bark, assist Pima County in riparian area and flood plain management considerations.

Colby, Assist U.S. Bureau of Reclamation staff in evaluating economics of salinity damages in southwestern U.S.

Colby, Assist U.S. Bureau of Reclamation staff in evaluating economics of irrigation forbearance agreements with farmers, as a regional drought adaptation strategy.

Colby, Assist multiple NGOs in evaluating economics of drought responses to enhance stream flows for fish and wildlife habitat in Colorado River Basin.

Frisvold, Briefed U.S. Senate staff on economic impacts of climate change on the Southwest.

Frisvold, Organized and moderated session on agriculture and water at the Arizona Water Summit, August 2005. The Water Summit attracted educators, tribal members, commercial interests, and policy makers, including the governor of Arizona.

Frisvold, Assist U.S. Geological Survey staff in evaluating impacts of federal farm programs on water use and response to drought

Frisvold, Assist Trout Unlimited staff in evaluation and design of USDA cost-share programs to protect instream flow in response to drought.

Frisvold, Assist Sonoran Institute staff in identifying USDA conservation programs to and funding sources to develop projects to protect instream flows.

Frisvold, Provided background information on agriculture for the *Draft Arizona Greenhouse Gas Inventory and Reference Case Projections 1990-2020* report to the Arizona Climate Change Advisory Group (CCAG). The CCAG is charged with developing an inventory and forecast of greenhouse gas emissions in Arizona and presenting to the Governor an action plan with recommendations to reduce the state's greenhouse gas emissions.

Frisvold, Co-edits the *Arizona Review*, the University of Arizona, College of Agriculture and Life Sciences main economics outreach publication. The Spring 2005 special issue on water resources featured publications from CLIMAS and related leveraged research projects. The *Review* is available on line and has about 650 hard-copy subscribers. Most of these are agricultural producers and producer organizations. Subscribers also include all the state cooperative extension directors, staff at state, federal, and tribal resource management agencies, and staff of both houses of the Arizona State Legislature.

V. Human Resource Development

Srinivasa Ponnaluru, completed M.S. thesis on climate, water availability, and Southwest park visitation

Rosalind Bark, PhD dissertation underway

Jennifer Pullen, M.S. thesis near completion

Shailaja Deva, M.S. thesis near completion

Kyle Emerick, M.S, thesis underway. CLIMAS-related research papers will be used to fulfill requirements for graduate courses in applied econometrics and in natural resource economics.

TASK AREA: Assessment and Monitoring of Vulnerability and Adjustment

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

Researchers: Dr. Marcela Vasquez-Leon (Assistant Professor, Bureau of Applied Research in Anthropology); Colin West, Sean Downey, Donald Anderson, Andy Sturzen (GRAs, Bureau of Applied Research in Anthropology).

I. Progress for Budget Year 2005-2006

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 2005 we completed most of the fieldwork for our fourth vulnerability assessment case study in the White Mountains as part of the CLIMAS Team Integrated Project (discussed below). This study area complements the team's previous study regions. It 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 and transitional livelihoods that are becoming increasingly common in the Southwest. For this particular case study we have built a focus on a cross-border comparison of vulnerability by including six communities from the Arizona side of the region and four from the New Mexico side. We have also paid particular attention to the ecological and historical dimensions of social vulnerability.

A.2. Accomplishments to date. We have completed the final report for our third vulnerability assessment case study in the Upper Gila River Valley (UGRV) conducted in 2004.

We are in the process of completing fieldwork for the White Mountains case study. As explained in more detail below (Project C), we have conducted 50 in-depth interviews with a wide variety of stakeholders, contacted 20 agencies, conducted 6 focus groups, and attended 3 public meetings.

A.3. Accomplishments anticipated by end of Budget Year. We will complete fieldwork for the White Mountains case study and begin data analysis. The UGRV report will be disseminated among interested stakeholders, including the San Carlos Apache Tribe, farmers and cooperative extension agents in the UGRV, institutional stakeholders. We will also submit a paper for publication on the relationships between ethnicity and climate vulnerability.

A.4. Plans for 2006-2007. We will complete our vulnerability analysis in the Southwest and segue into the decision tool (interactive vulnerability mapping, see below). To complete the activity, it will be necessary to compare other watersheds and regions of the Southwest with those studied intensely, then to attribute vulnerability values to the entire

state, including parts of New Mexico. We will also provide a synthesis methodology for how to do vulnerability analysis.

A better understanding of drought and the range of adaptive options possible will likely drive climate services over the coming generations. To contribute to the understanding of drought we plan to focus on an examination of drought history within a vulnerability/adaptation framework. This will provide a more comprehensive perspective on drought from both a natural and a social systems perspective. We will continue to focus on the Team Integrated Project region, looking at Arizona and New Mexico and we will expand our research across the US-Mexico border.

An NSF proposal entitled “Development of a Climate Vulnerability Index as a Knowledge-Generated Tool: Pioneering Interactive Stakeholder-Driven Research in Water Management” has been developed in collaboration with the Udall center at the University of Arizona and the University of Michigan. Vasquez-Leon is senior personnel in the project. If funded, it will greatly contribute and complement the historical vulnerability research on drought.

We also plan to develop a collaborative agenda with the Vulnerability Team at the Decision Center for a Desert City project at Arizona State University. Our research is highly complementary, since their focus is on urban Arizona, primarily Phoenix.

A6. Leveraged activities.

A6.2. Intra-CLIMAS Spin-offs. The White Mountains Vulnerability Assessment Case Study is one component of the CLIMAS Team Integrated Project.

Along these same lines, the PI, Finan, and former CLIMAS GRA, Don Nelson, have been using vulnerability mapping techniques in Northeast Brazil, with funding from NOAA. This mapping has been inspired by methodological advances made through the CLIMAS project.

Project B: Vulnerability Mapping of the Southwest

B.1. Description. Work on the GIS-based vulnerability mapping continued through 2005 (see CLIMAS Annual Progress Report 2003-2004 and CLIMAS Annual Progress Report 2004-2005). A major achievement was the debut of the Climate Vulnerability Interactive Mapping Tool (<http://rasas.geoserve.arizona.edu/ims/vmap/site/index.htm>). This online decision-support tool incorporates GIS layers into an interactive web-based mapping program. The CVIMT permits users to zoom in and out, add and subtract layers, and view tabular data. Although still in the alpha-stage of development, interactions with stakeholder organizations indicate that it fills a need for easily accessible spatial data.

B.2. Accomplishments to date. Datasets used in previous static GIS-based vulnerability maps were updated. Metadata and sources for each of these layers were put into a Microsoft Access database. Possible sources for similar data for New Mexico were also entered into the Access database. The CVIMT prototype was presented to CLIMAS and received welcome comments and critiques on May 15, 2005. The design document that

details the purpose, goals, and requirements for the CVIMT has been updated and placed online within the CVIMT web-page. Feedback on the CVIMT was also solicited from the Upper San Pedro River Partnership, ADWR, USGS, and the Arizona Department of Economic Security. Feedback was overwhelmingly positive.

Graduate student Colin West presented a poster of the alpha-version of the CVIMT at the NCAR *GIS in Weather, Climate, and Impacts Workshop 2005* that took place in Boulder, CO in July, 2005. Discussions with other workshop participants revealed that the CVIMT is an innovative tool that could easily take advantage of other GIS products produced by NCAR and the National Drought Mitigation Center.

CLIMAS and BARA also hosted Dr. Kema Ranatunga from the Australian Bureau of Rural Sciences (BRS). Dr. Ranatunga visited CLIMAS and BARA for two weeks to learn about our climate vulnerability mapping. The BRS is initiating its own GIS-based climate vulnerability mapping of the country and Dr. Ranatunga is charged with leading this effort.

B.3. Accomplishments anticipated by end of Budget Year. The team will have a publication ready for submission to the peer-reviewed journal *Disasters*. Also, the CVIMT will be integrated with the CLIMAS Forecast Evaluation Tool in such a way that facilitates digital capture of maps for importing into documents using SOAP calls.

B.4. Plans for 2006-2007. A post-doctoral researcher and graduate student will be hired to continue progress on the CVIMT. Their effort will be concentrated on extending coverage to New Mexico and performing user-testing with the USPP and other stakeholder organizations. This testing is necessary to ensure that the CVIMT is usable by decision makers and caters to their needs and technological abilities. As per requests by the CLIMAS team, the livelihood vulnerability maps will also be incorporated into the CVIMT.

B.5. Leveraged funding. Web-programming and scripting for the CVIMT was completed by Doug Meredith, the online database specialist employed by CASA. Doug's time was supported through his salary by CASA.

Colin West received funding from the Arizona State Museum Raymond Thompson Endowment to purchase an ArcGIS site-license, which enables him to demonstrate the project on a laptop to stakeholder groups.

The ADWR, USFS, USGS, and Drought Mitigation Center donated spatial datasets to the project.

Colin West received a Graduate Student Travel Grant from NCAR to attend the NCAR *GIS in Weather, Climate, and Impacts Workshop 2005* that took place in Boulder, CO in July, 2005.

B.6 Leveraged Activities

B.6.2 Intra-CLIMAS Spinoffs. Within CLIMAS, spatial data already acquired by students working on the vulnerability mapping was shared with other CLIMAS graduate students such as Rosalind Bark for her work on agriculture in the TIP.

B.6.3. CLIMAS-related. Colin West is completing his dissertation on livelihood adaptations to climate variability in Burkina Faso using GIS skills he acquired as a GRA in CLIMAS.

B.7. Non-CLIMAS Partners. The Center for Applied Spatial Analysis (CASA) provided computer facilities and expertise. The Tucson office of the USGS, ADWR, ADEQ, the Upper San Pedro Partnership, Water Resources Research Center, the Office of Arid Lands Studies, SAHRA, Arizona Department of Economic Security, the Tucson office of The Nature Conservancy, the Bureau of Land Management, and the Coronado National Forest shared spatial data and/or expertise.

Project C: CLIMAS Team Integrated Assessment Project

C.1. Description. As part of the CLIMAS Team Integrated Project in the White Mountains of Arizona, and Western New Mexico, BARA initiated a project to investigate the role played by institutional arrangements in buffering individuals and households from climate variability. We define “institutions” broadly to encompass both formal institutional structures (such as local, county, State, and Federal governments) and other less structured forms of organization (such as the Mormon church, watershed groups, and irrigation districts or acequias). A key part of this project is a cross-border comparison of the role and utility of these institutions.

The methodological approach taken in this project is to conduct a series of interviews and focus groups in communities in Eastern Arizona and Western New Mexico. When appropriate, team members have also attended community meetings. Individuals who have conducted fieldwork for this project include Sean Downey, Colin West, Niina Haas, and Don Anderson.

C2. Accomplishments to date. A series of interviews and focus groups have been conducted. Colin West conducted preliminary interviews in June, July and August of 2005. Part of this fieldwork was dedicated to arranging focus groups and identifying participants and sponsors. Colin spoke with and/or interviewed representatives from the Natural Resources Conservation Service, Apache Natural Resources Conservation District, USFS Apache-Sitgreaves National Forest, Nutrioso Creek Watershed Partnership, Coalition of Arizona/New Mexico Counties, Lyman Lake State Park, Upper Little Colorado River Watershed Partnership, and other individual ranchers and farmers. Colin West and Niina Haas ran an agency staff focus group in Springerville in September, 2005 with representatives from the Apache-Sitgreaves National Forest, USDA Farm Service Agency, Arizona Department of Environmental Quality, Arizona State Land Department, and Arizona Game and Fish. This was the first time that such an inter-agency focus group had taken place to discuss the current drought and participants appreciated the opportunity to learn from one another.

Sean Downey spoke with and/or interviews representatives from the Springerville Chamber of Commerce, St. John's Chamber of Commerce, Natural Resources Conservation Service (AZ and NM), Apache Natural Resources Conservation District, USFS Apache-Sitgreaves National Forest, USFS Gila National Forest, Eagar Water Department, Springerville Water Department, Tucson Electric Power's Springerville Generating Plant, Salt River Project's St. John's Generating Plant, Alpine Water Department, Luna Irrigation Company (*Acequia*), and the Luna Stake of the Mormon Church. He also conducted interviews with residents from Springerville, Eagar, St. Johns, Concho, Luna, Glenwood, Alpine, and Reserve. Sean Downey and Niina Haas ran a focus group in August 2005 that included representatives from Eagar Water Department, Springerville Water Department, Alpine Water Department, United States Forest Service, and Arizona State Land Department.

Colin West and Sean Downey presented preliminary results from the interviews and focus groups in the TIP to a CLIMAS Team meeting in October, 2005. The goal of this presentation was to inform other teams of progress and also to discuss opportunities for intra-CLIMAS collaboration.

C.3. Accomplishments Anticipated by end of Budget Year. We expect to continue fieldwork and data collection through the end of the budget year. A report will also be prepared to describe the institutional component of the TIP

C.4. Plans for 2006-2007. By the end of Summer 2006, we hope to conclude fieldwork and data collection and be engaged in data analysis, and manuscript preparation. We will prepare a manuscript for submission to the peer-reviewed journal *Human Organization*.

The IA activity currently lacks the integrative component and any predictive ability. With primary data collection complete, in the fall 2006 we plan to actively engage other CLIMAS research teams on interdisciplinary, collaborative analysis that will benefit from a multi-disciplinary approach. We will focus on integrating data sets into some form of model (perhaps agent-based) that can eventually be tested in regions where climate-related policy is a public priority. Ideally, such a model would assess the impacts of climate change on a given region and predict the constraints/opportunities for adaptation to, for example, more frequent drought.

C.6. CLIMAS related activities. There is an opportunity to involve the environmental historians and the climatologists in creating a socio-ecological model highlighting how the Mormon Church provided critical buffering resources to its members during several periods of drought, and other forms of climate variability over the past 100 years.

Another opportunity for collaboration would be with the economists, where it might provide fruitful to use quantitative economic data to examine AZ/NM differences in several economics indicators, including park visitation, general tourism, and lumber sales.

A third idea we are considering is to extend BARA's work with the GIS Vulnerability mapping to into Catron county, NM and to include layers that represent the institutional spheres we are identifying in our fieldwork, and which can be included as factors affecting climate vulnerability.

II. Publications

In Print

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

Submitted

Ray, Andrea J., G. Garfin, M. Wilder, M. Vásquez-León, M. Lenart, and A. Comrie. Applications of Monsoon Research and Forecasts: A review and synthesis. *Journal of Climate*.

To be submitted by June 1, 2006

Vasquez-Leon, M. and C. West. 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*.

West, C. T. and M. Vásquez-León. Misreading the Arizona landscape: challenging received wisdom on ecological destruction in southeastern Arizona. *Human Organization*.

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

III. Presentations at Professional Meetings/Conferences

West, C. T. Climate Vulnerability Interactive Mapping. 2005. Poster presented at the NCAR GIS in Weather, Climate, and Impacts Workshop, Boulder, CO.

West, C. T. 2005. Preliminary Results of the Vulnerability Team Assessment in the TIP and Opportunities for Collaboration. Presentation at CLIMAS Team meeting.

Rattray, N. 2006. Climate Vulnerability Mapping in the Southwest United States. 2006. Presentation proposed for the Society for Applied Anthropology Annual Conference, Vancouver, BC.

IV. Outreach Activities

West, C. T. and N. Haas. 2005. Drought Focus Group – Agency Staff. Focus group with land management agency staff in Springerville, Arizona.

Dowey, S., N. Haas, and C. T. West. 2005. Drought Focus Group – Water Providers. Focus group with area water providers in Springerville, Arizona.

Downey, S. and D. Anderson. 2005. Drought Focus Group – Small Businesses and Tourism. Focus group with small business owners and individuals involved with tourism from Springerville, Eagar, and other areas around Springerville, Arizona.

Vasquez-Leon, M. participated in a meeting with the Decision Center for a Desert City at Arizona State University, Tempe.

TASK AREA: U.S.-Mexico Border: Climate, Water Management and Social Stakeholders

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

Researchers: Gigi Owen, GRA

I. Progress for Budget Year 2005-2006

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

A.1 Description. Working with a bi-national steering committee, we are conducting research to examine how local communities in the bi-national 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 are an area of high biodiversity value and an important stopover for migrating birds on the Pacific Flyway. The wetlands are 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 bi-national 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 the 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)

A.2. Progress to date. We have constructed a baseline social and economic database and have conducted semi-structured, in-depth interviews with about 40 stakeholder representatives from both U.S. and Mexico. We regularly participate in steering committee meetings and we are participating in the NSF Colorado Delta Researchers coordination activities. 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.

A.3. Progress expected by the end of Budget Year 2006. “Decisionmaker” interviews currently being conducted with the stakeholders and decision makers on the binational steering committee will be completed. These represent the major governmental bodies with jurisdiction over the riparian area 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.

A.4. Plans for 2006-2007. We will coordinate community stakeholder research in the Limitrophe region with the National Wildlife Foundation, beginning with a researchers’ meeting tentatively planned in Tucson for April 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 University of Arizona Department 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 4/2006), the study will be expanded to include randomized community surveys and more focus groups.

A.5. Leveraged funding. Wilder has applied for TRIF/WEDSP funding at the University of Arizona (UA) to expand the research capacity of this project (request: \$58,000, 7/2005-6/2006). Project consultant Dr. Randy Gimblett, professor of Agricultural

Economics, has extensive expertise in surveying communities about their use of natural and recreation areas. This additional funding would allow us to do a large, randomized survey sampling of individuals in the 3 communities. Decision anticipated: 4/2006.

**Project B: “Climate Change Beyond Borders” and “Drought Beyond Borders”:
Climate and Drought K-12 Lesson Plans for Arizona/Sonora Classrooms**

B.1 Description. We are developing a pilot set of lesson plans aimed at 4th through 6th grades based on understanding physical and social factors associated with regional climate change and drought in Arizona and Sonora. This will supplement a water education curriculum already developed and in use by Project WET at the UA. The Center for Latin American Studies (CLAS) 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.

B.2. Accomplishments to date. The climate change and drought lesson plans have been completed and are currently being made available on CD-ROM to interested individuals, teachers and groups. The lesson plans have undergone extensive expert review from scientists and teachers, and have revised based on input we received. We have met with approximately 25 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; and we have met with teachers from Magdalena, Sonora to assess their curriculum needs vis-a-vis this project.

B.3. Accomplishments anticipated by end of Budget Year. In company with collaborators at the Udall Center for Public Policy, we plan to hold a meeting to release the lesson plans, make CD-ROM versions available in Spanish and English, and encourage professionals to begin using the materials in the classroom. In March 2006, the Center for Latin American Studies will distribute CD-ROM versions to Sonoran teachers during planned school visits there. In addition, within two months (by April 2006) we plan to make the lesson plans available via three websites, including CLIMAS, Udall Center, and Center for Latin American Studies.

B.4 Plans for 2005-2006. The lesson plans will be available in Spanish, and posted on the CLIMAS, Udall Center, and Latin American Studies websites in Spanish and English. 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: By the end of April 2006, Wilder will complete the initial phase of the lesson plans and anticipates no further immediate involvement in expanding the lesson plans. However, the Udall Center is 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.

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

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

Project C: CLIMAS Website Translation

C.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.

C.2. Accomplishments to date. The majority of the CLIMAS website has been successfully translated into Spanish. However, as new material is added to the site, we will continue efforts to translate the principle components of the site.

C.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.

C.4 Plans for 2006-2007. This project will be continuing.

II. Publications

In print/In press

Wilder, M. and P.R. Lankau, 2007: Paradoxes of decentralization: neoliberal reforms and water institutions in Mexico. *World Development*. In press.

Wilder, M. and S. Whiteford, 2005: Flowing uphill toward money: groundwater management and ejidal producers in Mexico's free trade environment. *Changing Structure of Mexico: Political, Social, and Economic Prospects*, Laura Randall, ed. New York: M.E. Sharpe. In press.

Wilder, M., 2005. Water, power, and social transformation: neoliberal reforms in Mexico. *VertigO: La revue électronique en sciences de l'environnement* 6(2).

Submitted/In review

Ray, A., G.M. Garfin, M. Wilder, M. Lenart, and A. Comrie. Applications of monsoon research: opportunities to inform decisionmaking and reduce regional vulnerability. Submitted to *Journal of Climate Research* December 2005.

To be submitted by June 1, 2006

Varady, R., M.C. Lemos, and M. Wilder. Understanding stakeholder processes in the Colorado River Delta Region: policy networks, conservation, and institutional change. To be submitted to *Water Resources Journal*.

III. Presentations at Professional Meetings/Conferences

Wilder, M. 2006. Water and the State: Transforming the Governance Paradigm in Mexico. Latin American Studies Association meeting, San Juan Puerto Rico, March 17, 2006.

Wilder, M. 2005. Water and Local Communities: Emerging Management Perspectives in Mexico and Honduras. Conference of Latin Americanist Geographers (CLAG), 2005 Annual Meeting, Morelia, Michoacan, Mexico, October 27, 2005.

Wilder, M. 2005. Water, Governance and the State: Narratives and Denouements of Decentralization in Mexico. Association of American Geographers annual meeting, Denver, Colorado, April 9, 2005.

Wilder, M. 2005. Binational Communities and Cooperation: Assessing Public Values Toward the Lower Colorado River and Delta. International Transboundary Waters Conference, Tucson, Arizona, November 17, 2005.

IV. Outreach Activities

“Climate Change Beyond Borders” and “Drought Beyond Borders”: Climate and Drought K-12 Lesson Plans for Arizona/Sonora Classrooms (see Project B above)

Member, NSF Sustainability Under Uncertainty Workshops, Tucson, Arizona, January and May 2005

V. Human Resource Development

Four thesis committees (2 chaired, 2 member) on Climas-relevant topics.

TASK AREA: Climate, Ecology, and Fire Research

PIs: Dr. Thomas Swetnam, Laboratory of Tree-Ring Research (Note: PI Jonathan Overpeck was on sabbatical leave in 2005-2006).

Researchers: Erica Bigio (GRA)

I. Progress for Budget Year 2005-2006

Project A: Fire Climatology in the Western US

A.1. Description. I collaborated with Thomas Kitzberger (University Comahue, Bariloche Argentina), Thomas Veblen (University of Colorado), Peter Brown (Colorado State University), and Emily Heyerdahl (US Forest Service, Fire Lab, Missoula MT) on compiling a western US fire scar chronology network and assessing broad-scale patterns of fire-climate relations. This resulted in a spatial-temporal analysis of 241 fire scar chronologies extending over the past 5 centuries.

I also am in collaboration with Anthony Westerling, Dan Cayan, Hugo Hidalgo and Mike Dettinger (California Applications Program, RISA) on modern fire climatology investigations in the western US.

A.2. Progress. We (Kitzberger, Veblen, Brown, Heyerdahl, and Swetnam) analyzed relations between regional and sub-regional patterns of fire, Palmer Drought Severity Index, El Nino-Southern Oscillation Indices, Pacific Decadal Oscillation, and Atlantic Multi-Decadal Oscillation. We found that since AD 1550, drought and forest fires co-varied across western North America, but in a manner contingent on the states of ocean-atmosphere processes. Certain phases of ENSO and the PDO are associated with fire occurrence that is synchronous within regions, and sometimes asynchronous among them. In contrast, fires are synchronous (i.e. positively correlated annually) across the West during warm phases of the Atlantic Multidecadal Oscillation (AMO). The current state of the AMO suggests that we can expect an increase in widespread fires across the western US in coming decades.

We (Westerling, Cayan, Hidalgo, Dettinger, Swetnam) have analyzed the past 30 years of large fire occurrence records from Forest Service documentary sources for the western US, in association with temperature, precipitation, streamflow, snowpack, and drought indices. We find strong trends of increasing fire occurrence in recent decades, and moderate to strong correlations with almost all of these climate variables. We also find that the length of the "fire season" has increases, and more large fires occur during years with earlier spring onset than during years with later spring onset.

A.3. Accomplishments anticipated by end of Budget Year (June 1, 2006). We have a manuscript that is currently in review on the paleofire research (Kitzberger et al), and hopefully it will be in press by June 2006.

We are currently working on a manuscript on the modern fire climatology research (Westerling et al.) and I expect it will be submitted by June 2006.

A.4. Plans for 2006-07. I am reducing my direct role in CLIMAS through the remainder of the current grant, and my colleague from the Tree-Ring Lab, Dr. Katie Hirschboeck will be increasing her involvement. Her research involves paleoclimate reconstructions of river flows and floods, including research on the Colorado and Salt Rivers in Arizona.

A.5. Leveraged funding. The collaborators on the above listed projects are all funded by various other sources, including the CAP RISA.

A.6. Leveraged activities. None.

A.7. Non-CLIMAS Project Partners. Thomas Kitzberger (University Comahue, Bariloche Argentina), Thomas Veblen (University of Colorado), Peter Brown (Colorado State University), and Emily Heyerdahl (US Forest Service, Fire Lab, Missoula MT), Anthony Westerling, Dan Cayan, Hugo Hidalgo and Mike Dettinger (California Applications Program RISA)

Project B: The integration of tree-ring and alluvial fan records of fire history at the Missionary Ridge Fire, Durango, Colorado.

B.1. Description: The goal of this research project is to combine two methods of fire history at the same study sites. There are multiple methods of studying fire history, which allow scientists to assess fire and climate relationships over a range of time scales. Tree-ring methods provide a record of the timing, severity and relative extensiveness of past fires, yet these records are limited in length. While these records have annual precision, they usually cover the period from 1600 – present. Evidence from alluvial fan deposits can provide millennial length records of fire history, which may be correlated with records of climate variability.

The study focuses on a 1 km² watershed, which was severely burned by the recent Missionary Ridge Fire of June 2002, near Durango, Colorado. Debris flow and flood activity following the fire incised alluvial deposits throughout the burned area. In the study watershed, post-fire debris flow activity exposed a record of late Holocene alluvial deposition in the walls of the incised channel. The sediment deposits have abundant charcoal, indicating a fire-related process of mobilization and deposition. This site has provided the ideal opportunity to combine tree-ring and alluvial fan records of fire history at the same study site. The tree-ring record will help interpret the fire regime associated with the young sediment deposits. In turn, the sediment record will extend the record of fire history for the watershed.

B.2. Progress: The field work, lab work and analysis was completed for the project. This included sampling a plot of trees for age structure analysis, and reviewing radiocarbon dates of the sediment samples in the field. Analysis included interpreting fire severity information from the tree-ring data, as well as evaluating the timing of sediment deposits from radiocarbon dating methods. The results are being reviewed and

written up right now.

B.3. Accomplishments anticipated by end of Budget Year (June 1, 2006). The project will be completed by the end of the Budget Year including a preliminary draft of a manuscript, soon to be submitted for publication.

B.4. Plans for 2006-07. Project will be completed.

B.5. Leveraged funding. Leveraged funding includes two summer research grants. The Mountain Studies Institute awarded a mini-grant of \$300 for field work. The Colorado Scientific Society awarded a \$500 grant for field work.

B.6. Leveraged activities. All radiocarbon dating was conducted at the NSF Accelerator Mass Spectrometer Facility at the University of Arizona. I worked as an intern to process all the radiocarbon dates for this project at no cost to the CLIMAS project.

B.7. Non-CLIMAS Project Partners.

II. Publications

Hessburg, P. F., E. E. Kuhlman, and T. W. Swetnam. 2005. Examining the recent climate through the lens of ecology: Inferences from temporal pattern analysis. *Ecological Applications* 15(2):440-457.

Swetnam, T. W. 2005. Fire histories from pine-dominant forests in the Madrean Archipelago. Pages 35-43, In: *Connecting mountain islands and desert seas: biodiversity and management of the Madrean Archipelago II*. Gottfried, Gerald J.; Gebow, Brooke S.; Eskew, Lane G.; and Edminster, Carleton B., compilers. 2004 May 11-15; Tucson, AZ. Proceedings RMRS-P-36. Fort Collins, CO: U.S. http://www.fs.fed.us/rm/pubs/rmrs_p036/rmrs_p036_035_043.pdf

III. Presentations at Professional Meetings/Conferences

Swetnam, T. 2005. Living with Fire in the Southwest – long-term perspectives and collaborative prospects. Invited talk at Fire & Society workshop, sponsored by Institute for the Study of Planet Earth (?), Tucson, AZ, January 11 (approximately 20 persons present, fire researchers mainly)

Swetnam, T. 2005. Climate-induced ecological disturbances in the Western U.S. Invited plenary talk at Climate Variability & Impacts Workshop, Sedona, AZ, sponsored by UA, US Forest Service, and others, January 7-9 (approximately 100 persons present, researchers, managers, stakeholders)

Swetnam, T. 2005. Presentation at symposium on Dendrochronology at the American Association for the Advancement of Science, Southwestern and Rocky Mountain Division 80th Annual Meeting, Tucson, AZ, April 13-16 (I also organized this symposium, which featured several speakers from LTRR). Abstract prepared and included in program.

Swetnam, T. 2005. Invited departmental seminar, University of Minnesota, Geography, April 15

Swetnam, T. 2005. Talk at Fire History & Climate Synthesis Workshop, Flagstaff, AZ May 2-6. Approximately 40 attendees. I was a primary organizer of this meeting (with Scott Anderson, NAU) See abstracts at <http://www4.nau.edu/firehistory/>

Swetnam, T. 2005. Post-fire conversion of forest to non-forest: Do we need a new theory? Annual Ecological Society of America meeting, Montreal, Canada, August 8-12 (approximately 100 persons present, mainly scientists and students)

Swetnam, T. 2005. Using fire and climate history for assessing current and future fire hazards. Attended Climate Change Science Program Workshop, and presented a poster (on WALTER fire project) Arlington, VA, November 14-15

Swetnam, T. 2005. Fire Climatology: using knowledge of climate variability and change in assessing fire risk. Invited plenary talk on fire climatology to USGS Fire Science Symposium, December 5-9, Tucson, AZ.

Bigio, E. 2005. The integration of tree-ring and alluvial fan records of fire history at the Missionary Ridge Fire, Durango, CO. University of Arizona, Geosciences department annual student research symposium (Geodaze).

Bigio, E., T. Swetnam, C.H. Baisan, and J. Frechette 2005. The integration of tree-ring and alluvial fan records of fire history at the Missionary Ridge Fire, Durango, CO., Fire History and Climate Synthesis in Western North America, Flagstaff, AZ.

Bigio, E., T. Swetnam, C.H. Baisan, and J. Frechette 2005. The integration of tree-ring and alluvial fan records of fire history at the Missionary Ridge Fire, Durango, CO. Geological Society of America Meeting, Salt Lake City, UT; Special session: Geologic Applications of Tree-Ring Studies.

Bigio, E., T. Swetnam, C.H. Baisan, and J. Frechette 2005. The integration of tree-ring and alluvial fan records of fire history at the Missionary Ridge Fire, Durango, CO. Laboratory of Tree-Ring Research weekly seminar series.

Bigio, E., T. Swetnam, C.H. Baisan, and J. Frechette 2005. The integration of tree-ring and alluvial fan records of fire history at the Missionary Ridge Fire, Durango, CO. Talk presented at CLIMAS weekly team meeting.

IV. Outreach Activities

Tom Swetnam:

2003-present Member of Coordinating Group of Consortium for Integrated Climate Research in Western Mountains (CIRMOUNT), organizing of MTNCLIM Workshops, 2003, 2004, 2005. (This is a cross-RISA endeavor, involving representation RISA from Washington, Colorado and California groups especially)

2004-present Chair, Ad Hoc, External Science Advisory Group for NOAA Paleoclimatology Program, Boulder, Co. (Conducted program review, January 27-28, 2005)

2005-present Appointment by Arizona Governor Janet Napolitano to Climate Change Advisory Group, a board tasked to advise the Governor on potential policy and executive initiatives to reduce greenhouse gas emission from the state of Arizona

Traveled with “Desert Speaks” KUAT film crew to California and New Mexico, and filmed at tree-ring sites and interviewed on topics of droughts and forest fires. Two, week-long excursions, June 20-24, and September 5-9

Participated in video interview with Korean documentary film maker, in Tree-Ring Lab, on tree rings and climate change, July 2

Lecture to Continuing Education in Ecosystem Management course at Northern Arizona University, School of Forestry. (3 hours of lecture each year, to approximately 50 fire and forest managers), first week of February

Invited lecture on fire and climate history in Traditions 104 course “Sonora” for John Messina, Southwest Studies Center, University of Arizona. 3rd week in February

Lecture to “Advanced Fire Use” S-580 training course, National Advanced Fire Resource Institute, Tucson, AZ, approximately 100 high-level fire managers, Forest Supervisors, Park Superintendents, etc. 1 hour lecture, usually 3rd week of March

TASK AREA: Climate Variability

PI: Andrew C. Comrie

Researchers: A. Erika Wise (GRA), B. Jenna McPhee (\$0 – NOAA-NWS-WRH), C. Chris Uejio (GRA), and D. James Tamerius (GRA)

WestMap Update

A direct CLIMAS spinoff, known as WestMap, was awarded funding via the NOAA NCTP program in 2005. 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. The 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). We expect beta products and stakeholder testing to begin during calendar 2006.

I. Progress for Budget Year 2005-2006.

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 first phase of the project examined 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. In the second phase, wildfire impacts on particulate matter concentrations are being examined. In the third phase, prediction of air pollutant extremes and air quality under climate change scenarios will be studied.

A.2. Accomplishments to date.

Phase 1: The project 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
 - PM not as weather-dependant

Phase 2: Phase 2 aims to improve understanding of the extent to which wildland fires affect particulate matter (PM) and visibility (and by extension, human health and haze) in urban areas. Fire-PM, PM-visibility, and PM-climate-fire relationships are being examined.

Data:

- Fire
 - Wildfires: 1990-1999
 - 2002 and 2003 Bullock and Aspen Fires
- PM
 - PM10: 24hr averages 1990-2004; PM10 and PM2.5: hourly 1999-2004
 - Meteorological
 - Daily 1990-2004; hourly 2002-2004
 - Visibility
 - Hourly nephelometer 2000-2004
 - All data limited to the May-June-July fire season

Methods:

- GIS buffer used to restrict 1990-1999 fires to those that burned >250 acres within 45km radius of Tucson
- PCA, clustering, and compositing used to examine each day over the 1990-1999 time period and each hour during the case study fires
- Overall fire history statistically examined in conjunction with 24hr PM10 and meteorological data
- Detailed analyses of the Bullock (2002) and Aspen (2003) fires incorporated 1hr PM10, PM2.5, meteorology, and visibility data

Results:

- Outcome of PCA/clustering displays progression of synoptic conditions coinciding with the MJJ fire season (Figure 3)
- Highest (top 5%) of PM days were typically associated with dry/hot or dry/windy conditions (Figure 4)
- No significant effects of wildfire were detected in Tucson PM concentrations
- Examining short-term (hourly) data revealed:
 - Spikes in PM concentrations
 - Better correlation with wind direction
 - Fire effects on visibility
- Visibility and PM data correspond well with a few noteworthy exceptions
- High 24-hr PM correlated with dry conditions; 1-hr PM with humid
- Tucson's relatively low PM during the case study fires may have resulted from a wind direction-wind speed relationships
- When examined over time scales of days to years, fires burning near Tucson's urban-wildland interface do not significantly affect PM air quality in the metropolitan area
- On shorter (hourly) time scales, spikes of high PM are apparent and are likely influenced by wind speed and direction

Future work:

- Addition of July 2005 Florida Fire
- Comparison to ADEQ smoke model and dispersion model estimates

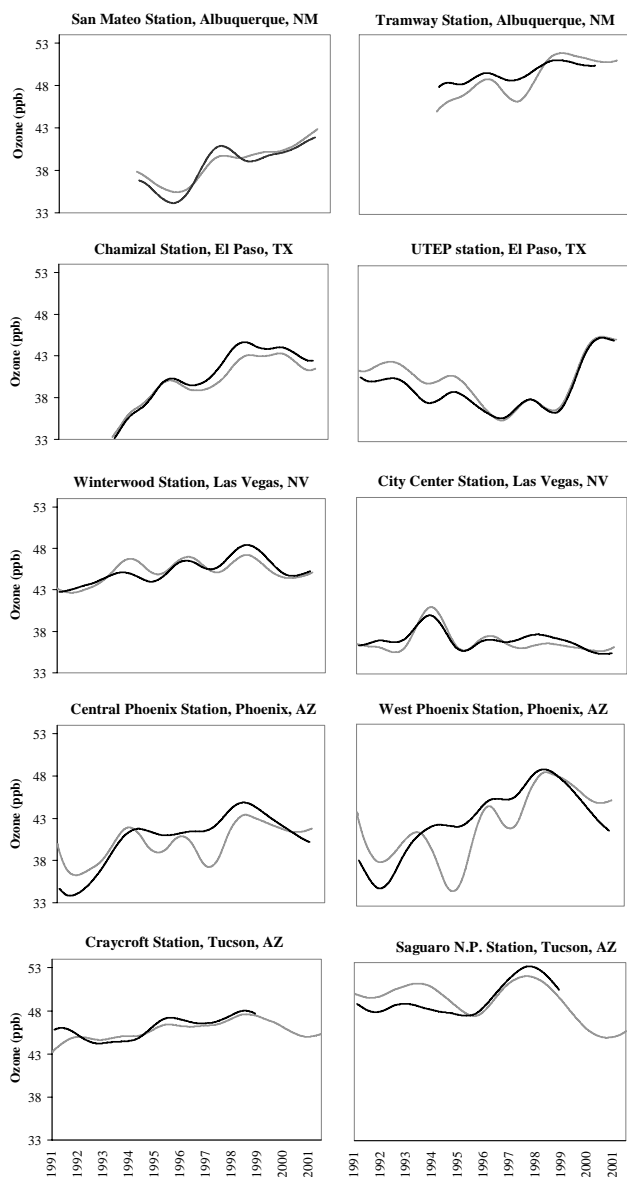


Figure 1: Models of meteorologically adjusted long-term ozone trends at each of the ten stations. Gray lines represent the unadjusted data that have been smoothed to show the long-term trend through the study period. Black lines show estimated ozone values with the influence of meteorology removed. The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

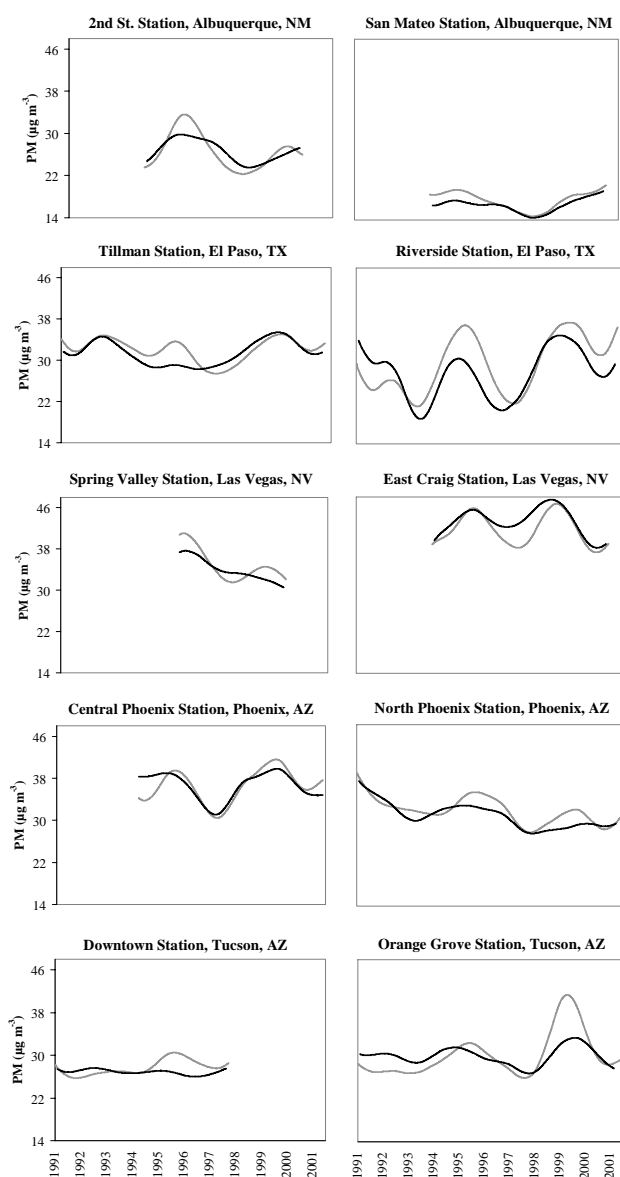


Figure 2: Models of meteorologically adjusted long-term PM trends at each of the ten stations. Gray lines represent the unadjusted data that have been smoothed to show the long-term trend through the study period. Black lines show estimated PM values with the influence of meteorology removed. The model 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.

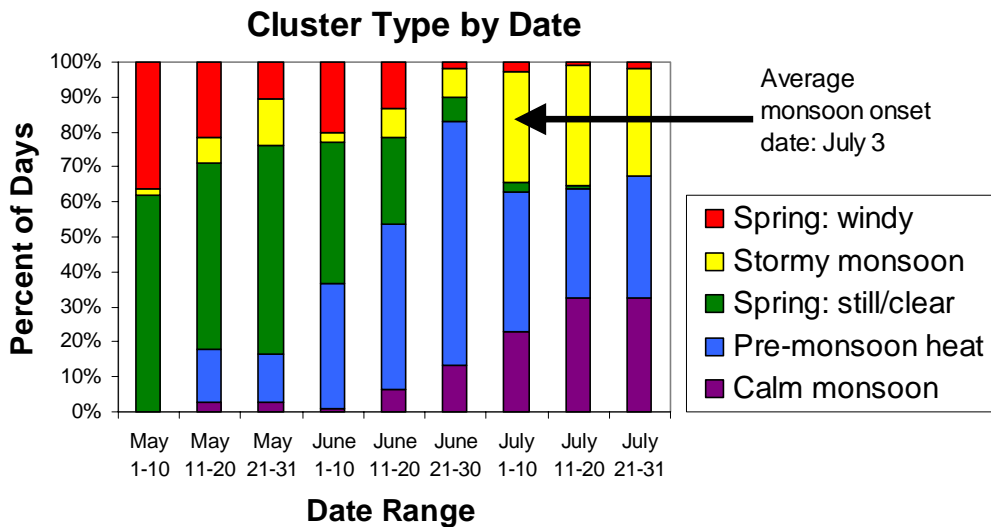


Figure 3: Climate cluster type by date over the MJJ fire season. Abrupt shift in cluster types follow the average monsoon onset date.

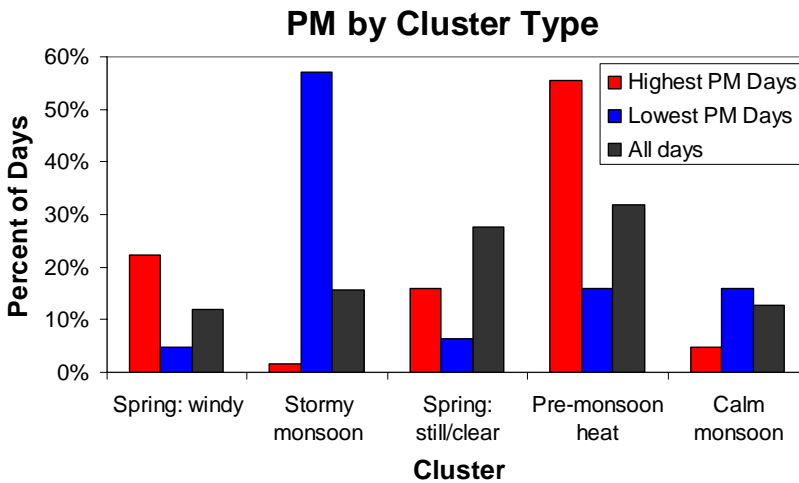


Figure 4: Highest and lowest PM values by climate type over the MJJ fire season. Highest (top 5%) of PM days were typically associated with dry/hot or dry/windy conditions

A.3. Accomplishments anticipated by end of Budget Year (June 1, 2006).

- Submit fire-PM study for journal publication
- Progress on 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

A.4. Plans for 2006-2007.

- Complete predictive model study listed in A3 above.
- Project change for Erika Wise (within Comrie PI tasks): Begin investigation to study hydroclimatic variability in the West at different scales, including watershed-scale streamflow and climate reconstruction and process-based upscaling linking West-wide circulation patterns to local hydrologic responses. Available paleoclimate data suggest that there have been more severe and widespread droughts in the pre-instrumental period than what has been experienced in the past century, and projections from global circulation models indicate that mid-latitude continental interiors will experience increased summer dryness and probability of drought under global warming scenarios. Previous studies have found that there has already been a shift in the timing of snowmelt in the study area, with potentially detrimental effects on Western rivers. This study aims to have implications for water availability and climate change impacts. Better water planning will be aided by this research on the physical processes that impact two particular water basins, as well as the processes that control the flux between basins – a vital component of mitigating drought and flood impacts. The climatically-sensitive region examined in this study should provide insight into hydroclimatic relationships that are linked to climate change-related processes and help place recent changes in the context of natural climatic variability.

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, in late 2004. The exact support amount was not provided (but on the order of several thousand dollars). PAG recently funded the third workshop of this kind in January 2006 (again, exact amount not known, but several thousand dollars).

A.6. Leveraged activities.

At the January 2006 Southwest air quality forum we presented updates of our work to air quality stakeholders and decision-makers from across the Southwest. We continued developing our relationships with regional stakeholders.

A.6.1. Greater than 50% CLIMAS

CLIMAS funded the research work, Pima Association of Governments funded the workshops.

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
U.S. Forest Service

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

B.1. Description. The overall objective of this project is to evaluate and extend 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. 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 (where CLIMAS alumna Jenna McPhee is now employed by WRH to complete the precipitation downscaling study for NWS).

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. 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 and 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. Preliminary precipitation results are in progress; we expect final results by December 2006.

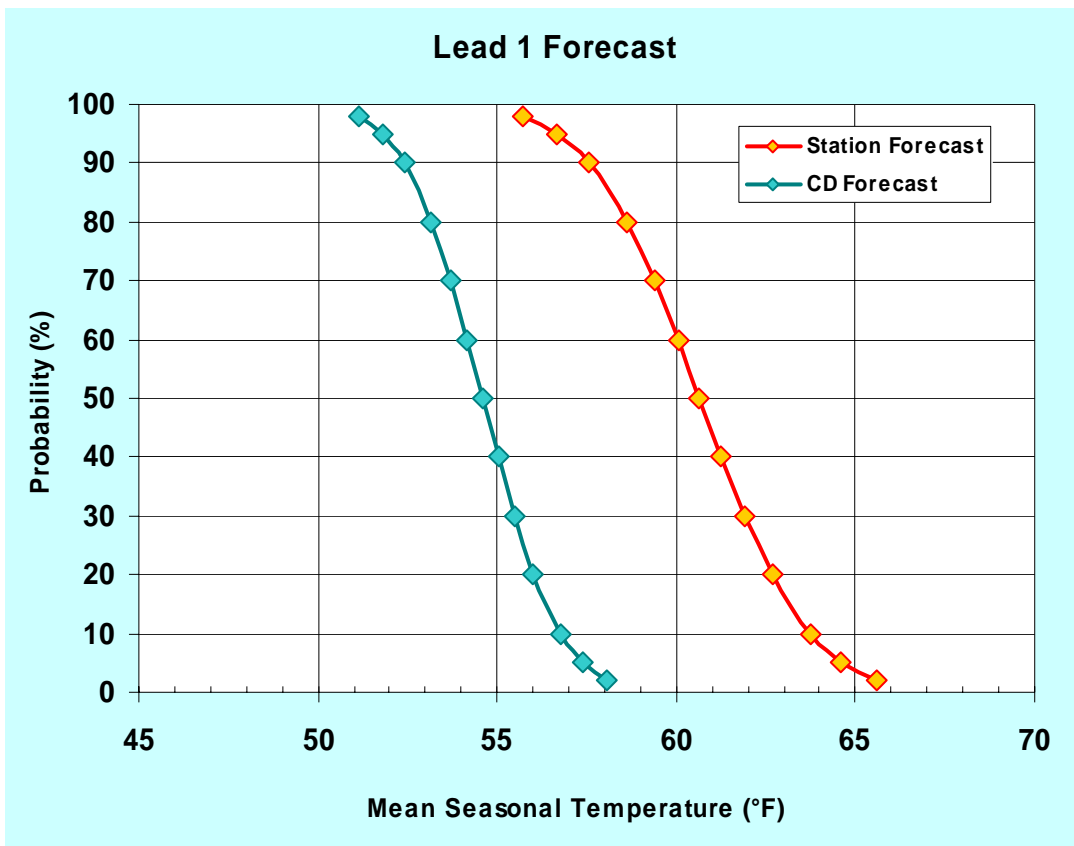


Figure 4: Downscaled POE forecast for Tucson for the January 2005 Lead One Outlook, which corresponds to February-March-April Season. The blue-green curve represents the original CPC forecast for the SE Arizona mega-climate Division and orange curve depicts the downscaled forecast for Tucson.

B.3. Accomplishments anticipated by end of Budget Year (June 1, 2006).

- Complete climate forecast downscaling and climate division to station scale-relationship assessment. Temperature is complete; precipitation is in progress, likely completed by end 2006 in partnership with NOAA NWS-WRH and NOAA CSD.
- Write peer-reviewed paper that synthesizes findings of the research.

- Dissemination in concert with NWS-WRH in late 2006/early 2007. 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.

B.4. Plans for 2006-2007.

- Finish downscaling project and write peer-reviewed paper on results.

B.5. Leveraged funding.

Jenna McPhee is no longer funded directly by CLIMAS. Following collaboration with NWS-WRH she was hired to the Salt Lake City WRH office to work on this project along with NOAA CSD, among other duties. Dollar value equivalent to 1.0 FTE NOAA employee.

B.6. Leveraged activities.

Completion of seasonal forecast downscaling by Jenna McPhee at NWS-WRH.

B.6.1. Greater than 50% CLIMAS.

100% NOAA NWS-WRH funding from mid-2005 to present.

B.7. Non-CLIMAS Project Partners.

National Weather Service Tucson WFO

NOAA Western Region Headquarters

NOAA Climate Services Division

Project C: Mosquitoes, Microclimate, and the Environment (Comrie & Uejio)

C.1. Description

Task 1: Ecological Niche Modeling of West Nile Virus vector mosquito habitat

West Nile Virus (WNV) surveillance data has broad spatial coverage, limited temporal coverage and is spatially biased to known foci of mosquito activity. Furthermore, the spatial extents of mosquitoes that transmit WNV (*Cx. tarsalis* and *Cx. quinquefasciatus*) are not well documented in Arizona. We explore how a spatial model, the Genetic Algorithm for Rule-set Production (GARP) provides insight into the climatic and environmental characteristics of the habitats of mosquitoes that transmit WNV.

GARP is a data adaptive and machine driven algorithm that combines ecological niche theory and empirical field work to inductively define a theoretical area where a species can sustain a population. Coverages of climatic averages and extremes, environmental variables, and measures of human alterations to the environment which approximate or correspond to a mosquito's life cycle are input into the model. For a peri-domestic species like *Aedes aegypti*, this niche may be characterized by temperatures above freezing, monthly rainfall greater than 100mm, vegetated (green) areas, and residential areas. Different spatial patterns of seasonal and annual climatic variables and biosocial variables form the best predictive models for each species. We explore novel methods of spatially analyzing an ecological niche to further understand WNV transmission at different spatial and temporal extents. This research project is one of the primary components of Chris Uejio's Master's thesis.

Task 2: Summation of Southwestern Climate during the years West Nile Virus has been transmitted in Arizona

To encourage the utilization of climatic information by Arizona Department of Public Health (AZDHS) stakeholders, we provided a summary of weather and climate during the 2002-2004 WNV transmission seasons (May-October) and preceding winter. We highlighted cities and counties in the state that had abnormal climate conditions and found a qualitative correspondence with increased WNV transmission and above average rainfall. We also provided NOAA CPC mid-term climate forecasts of temperature and rainfall for the upcoming 2005 WNV transmission season to the stakeholders.

Previously, AZDHS decision makers were unaware of climate forecasts and the CLIMAS Southwest Climate Outlook analysis of climate anomalies across the state. Through additional dialogue, we were able to clarify climate misconceptions. For example, decision makers had assumed that the entire region experienced above average winter rainfall during the 2004 ENSO event. In reality, the southeastern and northeastern portions of Arizona received below average winter season rainfall. As the WNV transmission season progressed, we would inform public health decision makers of any changes to the original long lead forecasts. Every two months, we contact AZDHS decision makers to discuss current climate variability, answer additional questions, and receive input on the West Nile Virus mosquito habitat model (Task 1).

Task 3: The Re-invasion of *Aedes aegypti* into southern Arizona/northern Mexico.

During the past year, this project has elucidated the fundamental relationships between biophysical and biosocial landscape features and *Ae. aegypti* mosquito habitat in the Southwest. In tropical locations, *Ae. aegypti* is the primary vector of Dengue viruses and Yellow Fever. For the set of Dengue viruses alone, it is estimated that tens of millions of people are annually infected and there are hundreds of thousands of cases of severe Dengue Hemorrhagic Fever. Within the past decade, *Ae. aegypti* has re-merged in Southern Arizona and it continues to spread across southwestern and central Arizona. This study quantifies the relative importance of micro-climatic, local vegetation, irrigation, running water, and air conditioning in two border cities and Tucson, Arizona over three years.

Our contribution entailed processing, quality control, and interpolation of hourly climate data for 68 stations at the three locations from 2002-2004. Next, we conducted multivariate logistic regression analysis and longitudinal statistical analysis (Generalized Estimating Equation) and interpreted the results. A manuscript summarizing the results and implications of this study is currently in preparation for submission to the *American Journal of Tropical Medicine and Hygiene*.

C.2. Accomplishments to date

Task 1: Ecological Niche Modeling of West Nile Virus vector mosquito habitat

By synthesizing mosquito physiological principles with ecological niche theory, time-specific mosquito habitat patterns can be modeled at different resolutions. Ecological niche modeling empirically derives habitat relationships and minimizes the effect of spatial biases or unequal sampling strategies in the surveillance data.

Data:

- Monthly surveillance data of *Culex tarsalis* and *Culex quinquefasciatus* presence across Arizona from May-October from the Arizona Department of Health Services.
- The proposed biophysical variables either have direct or indirect influences on the mosquito or are inherently related to a component of its lifecycle (Table 1).

Table 1. Environmental and socio-economic variables used to predict potential mosquito habitat at the state resolution (1km)

Class of Variable	Variable	Data Source	Reference
Climate	temperature, rainfall	PRISM	ocs.orst.edu/prism/
Water Bodies	Distance to lakes and/or major streams,	Arizona Electronic Atlas	atlas.library.arizona.edu
Soils	Percent sand, silt, clay 1m soil, depth to bedrock	CONUS	soilinfo.psu.edu/index
Vegetation	Greenness	NDVI -AVHRR	rangeview.arizona.edu
Digital Elevation Model	elevation, slope, aspect	GTOPO30	edc.usgs.gov/products/elevation/gtopo30/gtopo30.html
Tendency to pool water	Compound Topographical Index	HYDRO1k	edc.usgs.gov/products/elevation/gtopo30/hydro/index.html
Land Usage	Land Cover Classes	North America Land Cover Data Base v.2	Edcsns17.cr.usgs.gov/glcc/na_int.html

Methods:

- Spatial modeling is conducted with a desktop version of the Genetic Algorithm for Rule Set Production (www.lifemapper.org/desktopgarp/). GARP is a data adaptive, non-parametric, artificial intelligence program. Instead of forcing a single method to describe disparate mosquito habitats, GARP differentially applies four statistical routines to optimize the model fit of the dataset (logistic regression, range rules, bioclimatic envelopes, and atomic rules).
- Jackknifing generates a parsimonious and generalizable model and determines the relative importance of human alterations to the landscape and biophysical variables (Tbl. 1).
- A rule set describing mosquito presence is iteratively developed by a process of data sampling, rule selection, evaluation of the goodness of fit, preservation or rejection of a rule and additional rule generation until there is minimal improvement in predictive accuracy.
 - Half of the 45-60 unique monthly mosquito presence records are utilized in model development and the remaining points are reserved for internal validation.
 - A fitness function “naturally selects” the best conditional rules that minimize the grid cells predicted absent by the model that actually hosts mosquitoes in the validation dataset (omission) and preserves them. The remaining rules are stochastically perturbed by an algorithm that mimics the process of genetic recombination.
 - The final rule set is developed and grid cells of mosquito occurrence are projected across the spatial domain to visualize the time-specific ecological niche.

Results:

- Physical properties such as the percent of sand and silt in the 1st m of the soil profile and the depth to bedrock are important variables to define the fundamental niche of both *Culex* species
- Maximum, minimum, and average climatic variables at different seasonal intervals or averaged over an entire year have differential influences on *Culex tarsalis* and *quinquefasciatus* fundamental niches
 - *Culex tarsalis* preferentially breeds in perennially wet environments such as irrigated fields, wetlands, and lakes and this may be reflected by the inclusion of annual instead of summer season rainfall in the model.
 - *Culex tarsalis* appears to be sensitive to maximum temperature while maximum temperatures are not detrimental or conducive to *Culex quinquefasciatus*.
 - *Culex quinquefasciatus* exhibits a bimodal population cycle that is influenced by both late winter/spring and summer rainfall. The summer population peak is more pronounced and this may be reflected by the inclusion of the average summer rainfall coverage over winter or annual rainfall.
- The predicted fundamental niche of *Culex tarsalis* is a viable representation of the maximum spatial extent of the mosquito. There is a clear effect of slope and both frontal and monsoonal rainfall on the spatial heterogeneity of viable mosquito habitat. The *Culex quinquefasciatus* fundamental niche is too conservative.

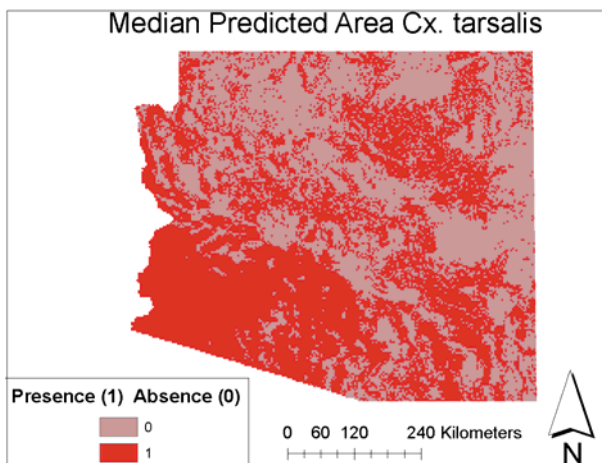


Fig. 1 Median predicted area of *Cx. tarsalis* following the best subsets model selection procedures. The influence of slope and annual average rainfall is apparent in the areas of predicted presence.

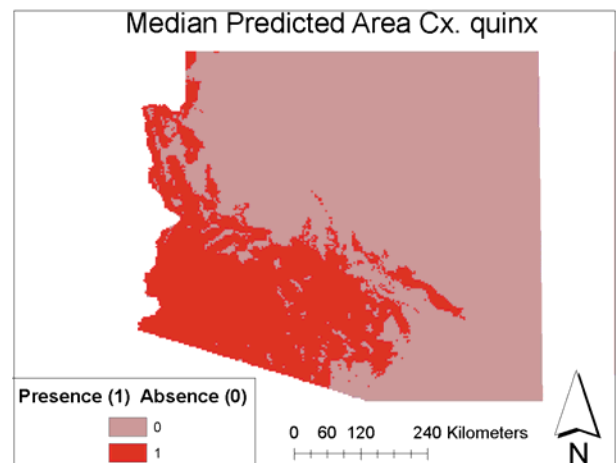


Fig. 2 Median predicted area of *Cx. quinquefasciatus* following the best subsets model selection procedures. This fundamental niche appears to lead to mosquito under prediction in the southeastern and northwestern portion of the domain

Task 2: See previous section

Task 3: The Re-invasion of *Aedes aegypti* (henceforth *Ae. aegypti*) into southern Arizona/northern Mexico.

Data:

- Three years of *Ae. aegypti* presence or absence collected at 68 sites in Tucson, Arizona, Nogales, Arizona, and Nogales, Mexico during the months of July, August, and September.
- Unique dataset of hourly micro-climatic variables and housing characteristics (Tbl. 2).

Table 2. Biophysical and biosocial independent variables that may be conducive to *Ae. aegypti* in three cities between Nogales, MX and Tucson, AZ.

Variable	Character
Location	Nogales, MX, Nogales, AZ, and Tucson & Tubac
Year	2002, 2003, 2004
Vegetation Area	3 Ordinal Classes
Max, Min, Avg Temperature	Continuous
Saturation Vapor Deficit	Continuous
Relative Humidity	Continuous
Running water	Presence/absence
Swamp Coolers	Presence/absence
Irrigation	Presence/absence

Methods:

- Two multivariate logistic regression models determine the relative importance of the independent variables (Tbl. 2) to mosquito presence in the week before mosquito collection and the four days of mosquito collection. Unique regression models are generated for the months of July, August, and September from 2002-2004 which result in 18 logistic regression models.
- In addition to individually analyzing presence/absence in each month of each year, a Generalized Estimating Equation (GEE) longitudinally analyzes presence/absence for each month across all three years. A GEE is a covariance pattern model that directly models the correlation of repeated measures on each site
 - The GEE uses a logit link function to assess binomial outcome of presence/absence.
 - To determine the optimal repeated measures correlation structure, the quasi-likelihood values are compared.
 - A backward stepwise variable selection procedure generate the final model.

Results:

Table 3. Odds Ratios, standard errors, p-values, and confidence intervals of Generalized Estimating equation for each month over three years. Red variables are statistically significant at the $p < .05$ level.

July	Odds Ratio	Std. Err	z	P> z 	[95%	CI]
Vegetation Class 2	1.16	0.54	0.32	0.746	0.47	2.89
Vegetation Class 3	6.81	3.77	3.47	0.001	2.30	20.16
Maximum Temperature	0.92	0.04	-2.02	0.043	0.85	1.00
August	Odds Ratio	Std. Err	z	P> z 	[95%	CI]
2003	0.65	0.31	-0.92	0.36	0.26	1.63
2004	0.30	0.17	-2.15	0.032	0.10	0.90
Vegetation Class 2	2.03	1.01	1.43	0.153	0.77	5.38
Vegetation Class 3	7.45	4.55	3.29	0.001	2.25	24.67
Saturation Vapor Deficit	4.50	2.61	2.59	0.01	1.44	14.05
Nogales, Arizona	0.46	0.26	-1.39	0.164	0.15	1.37
Tucson & Tubac	0.15	0.10	-2.8	0.005	0.04	0.57
September	Odds Ratio	Std. Err	z	P> z 	[95%	CI]
2003	0.42	0.21	-1.77	0.076	0.16	1.10
2004	0.34	0.14	-2.64	0.008	0.16	0.76
Vegetation Class 2	3.21	1.73	2.17	0.03	1.12	9.24
Vegetation Class 3	2.62	1.47	1.71	0.087	0.87	7.87
Relative Humidity	1.09	0.04	2.55	0.011	1.02	1.16
Nogales, Arizona	0.21	0.12	-2.75	0.006	0.07	0.64
Tucson & Tubac	0.16	0.09	-3.31	0.001	0.06	0.48

- Pre, during, and post monsoon, vegetation is strongly conducive to *Ae. aegypti* presence.
- In a subtropical location, micro-climatic variables influence *Ae. aegypti* presence/absence in a manner that is consistent with mosquito physiology.
 - Before the onset of the monsoon, increased maximum temperatures are detrimental to *Ae. aegypti* presence.
 - Controlling for vegetation, during the monsoon relatively warmer and drier and warmer locations are favorable for *Ae. aegypti*.
 - After the end of the monsoon, greater relative humidity is conducive to *Ae. aegypti* presence.
- Although not directly captured by variables in the regression model, differences in human ecology between the three study sites exert an important control on *Ae. aegypti* presence/absence.

C.3. Accomplishments anticipated by end of Budget Year

- Refine and improve the skill of the predictive West Nile Virus vector mosquito habitat models for Arizona.
- Develop time-specific mosquito habitat models and examine the correspondence of the models with the spatio-temporal dynamics of West Nile Virus transmission. Time-specific ecological niches are generated by incorporating more dynamic lagged vegetation and climatic variables into the fundamental niche model.

- Submit “The Re-invasion of *Aedes aegypti* (henceforth *Ae. aegypti*) into southern Arizona/northern Mexico” (Task 3) paper.
- Formally present the predictive mosquito habitat models to Arizona Department of Health stakeholders.

C.4. Plans for 2006-07.

We will continue to actively pursue leveraged funding and collaborative research relating to Dengue Fever, Valley Fever, West Nile Virus, and mosquitoes. Our work on West Nile Virus in South Africa implies that the western United States may be susceptible to West Nile Virus epidemics. By examining the climatic signature of genetically related viruses (St. Louis Encephalitis) that are transmitted by the same mosquito species as West Nile Virus, we can verify the strength of a climate and epidemic relationship. We are also working on a pilot project examining heatwave mortality, societal vulnerability, and resilience in Phoenix, Arizona.

C.5. Leveraged funding

A Valley Fever (Coccidioidomycosis) Public Health Decision Support System Based on Climate and Environmental Changes. U.S. Environmental Protection Agency (with S. Yool), 2006-2007.

Converging NASA Mission Measurements and Products with the Rapid Syndrome Validation Project (RSVP) Decision Support System to Validate and Benchmark Public Health Medical Alerts and Early Warning Forecasts. National Aeronautics and Space Administration (with UNM & UA Co-P.I.s), 2004-2008.

We have applied for two years of support from the National Science Foundation, Geography and Regional Science Program, with P. Robbins J.P. Jones and E. Willott. Title: Geographies of Insects and Institutions: Mosquito Governance in the US Southwest. This project will combine an institutional ethnography of local, state, and federal institutions charged with managing the mosquito with our portion, modeling mosquito distributions at different spatial extents.

C.6. Leveraged activities

N/A.

C.7. Non-CLIMAS Project Partners.

Arizona Department of Health and Human Services

Project D: Climate Variability – Winter Precipitation Anomalies (Comrie & Tamerius)

D.1. Description. The principal objective of this task is to increase the understanding of finer scale climate variability in the US Southwest by focusing on the spatial and temporal distribution of precipitation anomalies. We use PRISM 4km gridded precipitation data and statistical techniques to identify spatial relationships between regions and precipitation anomalies. Furthermore, we are preparing to use the newly available North American Regional Reanalysis dataset to establish correlations between the precipitation anomaly patterns and various climate variables. Establishing relationships may lead to better climate forecasting for the Southwest US.

D.2. Accomplishments to date. December 2005 white paper “Spatial Inhomogeneities of Winter Precipitation Anomalies in the Southwestern United States”

Data:

- Monthly PRISM 4km gridded precipitation datasets for the defined winter months (December – March) from 1979 – 2003.
- Anomaly data were created from the PRISM data for each individual winter season and month for the US Southwest.
- Average monthly 500mb geopotential heights from North American Regional Reanalysis (NARR), which is a product of the National Centers for Environmental Prediction (NCEP).
- The NARR data was analyzed using the Grid Analysis and Display System (GrADS)

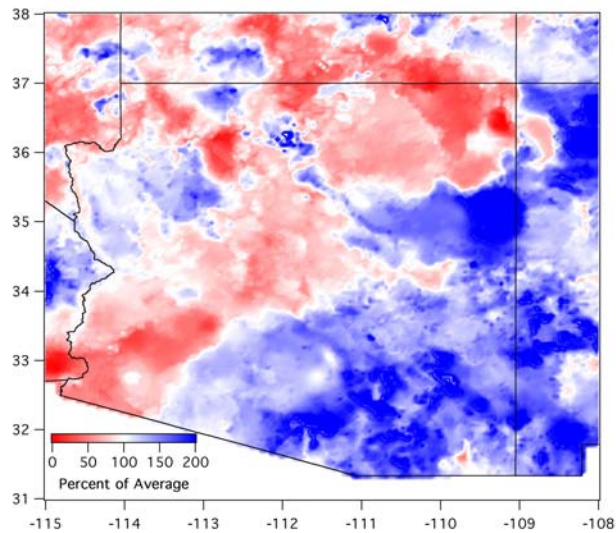
Methods:

- Exploratory qualitative analysis was performed on the spatial distribution of winter precipitation anomalies of the Southwest US.
- The corresponding seasonal and monthly North American 500mb geopotential heights were examined.
- Precipitation and geopotential data at monthly and seasonal scales were examined to determine broad relationships that exist between the distribution of precipitation and the location and strength of troughs.

Results:

- Preliminary examination suggests that there may be broad climatic variables that influence the sub-regional distribution of winter precipitation in the US Southwest.
- There is enough evidence to warrant further investigation on the relationships between positions and strengths of troughs over the US Southwest and Eastern Pacific and spatial distributions of precipitation anomaly patterns.

Figure 1. An example of precipitation anomalies created with PRISM data. The figure demonstrates that during February of 1986 portions of the Southwest received over 200% of average rainfall while other portions received less than 25%. Climate variables that are associated with these patterns are being investigated in this project.



D.3. Accomplishments anticipated by end of Budget Year (June 1, 2006).

- Use statistical techniques to examine relationships between spatial distributions of precipitation anomalies in sub-regions of US Southwest.
- Use statistical techniques to explore correlations between various climate variables and spatial distributions of precipitation anomalies.
- Develop stakeholder interactions that can help to provide specific questions and feedback for subsequent research.
- Present preliminary results at AAG Annual Meeting March 8, 2006.
- Poster presentation at NOAA Climate Prediction Applications Science Workshop, March 21-24, 2006.

D.4. Plans for 2006-2007.

- We will continue to examine correlations between various climate variables and spatial distribution of precipitation anomalies. Depending on results of future research, we may broaden the study region encompassed, establish influence of ENSO , and prepare a paper to submit for publication.

D.5. Leveraged funding.

N/A

D.6. Leveraged activities.

N/A

D.7. Non-CLIMAS Project Partners.

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

II. Publications

In print

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

Comrie, A.C., 2005: Climate factors influencing coccidioidomycosis seasonality and outbreaks. *Environmental Health Perspectives* 113, 688-692.

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.

Park, B.J., Sigel, K., Vaz, V., Komatsu, K., McRill, C., Phelan, M., Colman, T., Comrie, A.C., Warnock, D.W., Galgiani, J.N. and Hajjeh, R.A., 2005: An epidemic of coccidioidomycosis in Arizona associated with climate changes, 1998-2001. *Journal of Infectious Diseases* 191, 1981-1987.

Wise, E.K. 2005. Air Quality Effects from Southeast Arizona Wildfires. *Bulletin of the American Meteorological Society* 86 (12): 1719-1721.

Wise, E.K. 2005. Urban Air Quality Impacts of Wildfires in the U.S. Southwest. *Pacifica* Fall 2005: 1, 5-6.

Wise, E. K., and A. C. Comrie. 2005. Meteorologically-adjusted urban air quality trends in the southwestern United States. *Atmospheric Environment* 39, 2969-2980.

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* 55, 1208-1216.

Submitted/In Review

None

To be submitted by June 1, 2006

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

Uejio, C. K. Climatic, Environmental, and Geographic Analysis of *Culex* spp. in relation to West Nile Virus. Master's Thesis.

Uejio, C.K. Mosquito. In the Encyclopedia of Environment and Society, Paul Robbins (ed.), Sage Publications. To be submitted (March 2006).

Uejio, C.K., and A. C. Comrie. 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. Impact of Wildfires on Southeastern Arizona Particulate Matter Air Quality. To be submitted to *International Journal of Wildland Fire*.

Leveraged peer-reviewed publications

Hayden, Mary H., Kathleen Walker, Frank Ramberg, Chris Uejio, Rafael Moreno, Linda O. Mearns, and Craig R. Janes (2006). The Re-invasion of *Aedes aegypti* along the US/Mexico Border. To be submitted to *The American Society of Tropical Medicine and Hygiene*.

III. Presentations at Professional Meetings/Conferences.

Hayden, M.H. and Uejio, C.K. (2006) The Re-invasion of *Aedes aegypti* in southern Arizona/northern Mexico. American Meteorological Society Annual Meeting, Atlanta, GA, January 29-February 2.

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

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

Tamerius, J.D. and Comrie, A.C. (2006) Spatial Inhomogeneities of Winter Precipitation Anomalies in the Southwestern United States. Association of American Geographers, Chicago, IL, to be presented March 7-11, 2006.

Tamerius, J.D. and Comrie, A.C. (2006) Spatial Inhomogeneities of Winter Precipitation Anomalies in the Southwestern United States (poster). Climate Prediction Applications Science Workshop, Tucson, AZ, to be presented March 21-24, 2006.

Uejio, C.K. and Comrie, A.C. (2006) Fundamental Niche of West Nile Virus Vector Mosquitoes at Telescoping Extents. Association of American Geographers, Chicago, IL, to be presented March 7-11.

Uejio, C.K. and Comrie, A.C. (2005) Climatic Influences on West Nile Virus Epidemics in South Africa: A Retrospective Study (Poster). American Society of Tropical Medicine and Hygiene, Washington, DC, December 11-15.

Uejio, C.K. and Comrie, A.C. (2005) Fundamental Niche of West Nile Vector Mosquitoes at Telescoping Scales. Association of Pacific Coast Geographers, Phoenix, AZ, October 19-22.

Uejio, C.K. and Comrie, A.C. (2005) Ecological Niche Theory Applied to West Nile Virus (Poster). 2nd NCAR GIS Initiative Workshop: GIS in Weather, Climate and Impacts, Boulder, CO, July 6-8

Wise, E.K. 2006. Impacts of Wildfires on Pima County Particulate Matter. Presented at the Air Quality Trends in the Southwest Forum, Tucson, AZ, January 9, 2006.

Wise, E.K. 2005. Urban Air Quality Impacts of Wildfires in the U.S. Southwest. Presented at the 68th Annual Meeting of the Association of Pacific Coast Geographers, Phoenix, AZ, October 19-22, 2005.

Wise, E.K. 2005. Air Quality Impacts of Wildfires in Southeastern Arizona. Presented at the American Meteorological Society's 15th Conference on Applied Climatology, Savannah, GA, June 20-24, 2005.

Wise, E.K. and A. C. Comrie. 2005. Impact of Wildfires on Urban Particulate Matter Concentrations in Tucson, Arizona. Presented at the 101st Annual Meeting of the Association of American Geographers, Denver, CO, April 5-9, 2005.

IV. Outreach Activities.

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

Third Southwest regional stakeholder meeting – January 2006

Represented organizations:

- Arizona Department of Environmental Quality
- Desert Research Institute
- Pima County Department of Environmental Quality
- Pima Association of Governments
- U.S. Environmental Protection Agency
- University of Arizona
- Arizona State University
- Western Governor's Association
- Maricopa County Air Quality Department
- Maricopa Association of Governments
- Clark County Department of Air Quality and Environmental Management
- Pinal County Air Quality Department

Continuing partnerships with the National Weather Service Weather Forecast Office (NWS-WFO) in Tucson, NWS-WRH and NOAA CSD.

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 completed master's thesis and began her Ph.D. work. She has published four articles based off of CLIMAS research and has attended conferences for professionalization and training.

CLIMAS work forms the basis of Jenna McPhee's master's research, which will become her thesis in mid-late 2006.

Christopher Uejio (GRA) is basing his master's thesis work on this research. The thesis will be completed in 2006 and will likely result in two or more journal papers.

James Tamerius is using his research from this project for his Master's thesis, which is scheduled to be completed in 2007.

TASK AREA: Hydrology: Forecast Evaluation

PI: Dr. Holly C. Hartmann, Department of Hydrology and Water Resources

Researchers: Ellen Lay, Damian Hammond (software programmers)

I. Progress for Budget Year 2005-2006

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

A.1. Description

Forecast Evaluation Tool: The online Forecast Evaluation Tool (FET) is an Internet website that decision makers 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.

CLIDDSS: The Climate Information Delivery and Decision Support System (CLIDDSS) is a software-engineered interactive web application that approaches information delivery and decision support from a paradigm of *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). Because the plethora of climate information from multiple sources impedes routine use of available products, CLIDDSS consists of information management tools that allow individuals to: 1) use project folders to store selected products for multiple applications and efficient access over repeated site visits, 2) share their product suites with identified groups for discussion and consensus interpretation, and 3) 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. CLIDDSS 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. CLIDDSS 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. For a second year, the FET has operated *without failure*, through continued software maintenance for upgrades in underlying tools (e.g., Apache TomCat server software) and code optimization. We have implemented almost the entire

webtool re-design that was developed last year. Based on continued feedback from users, we have designed and implemented additional significant changes as well, including more user-friendly GUI widgets (e.g., a more efficient way to select multiple forecasts for evaluation). This year continued to see demonstration of the extendibility of the underlying FET code. At the request of the Climate Services Division, Office of Weather, Water, and Climate Services, we added the ability to evaluate forecasts for Alaska and downscaled outlooks issued for individual stations.

The number of registered users has grown by nearly 50% over the past year, with over 150 registrants representing all sectors: universities, private companies, many units of NOAA and the National Weather Service (NWS), international groups, and regional/state/local resource management agencies. The FET has been featured in outreach efforts by CLIMAS (e.g., “Forecast Evaluation Tool How-To” by Melanie Lenart, Southwest Climate Outlook, November 2005). The FET has also been used in a number of professional development courses over the past year (see list in Outreach section). Notably, through our collaboration with the NWS Climate Services Division, FET is now part of the official training program for designated ‘climate focal points’ within the local NWS Weather Forecast Offices (WFOs). A representative from each WFO, and others (e.g., from NWS River Forecast Centers) participates in 2 classes that feature the FET, including a computer laboratory. A large number of new FET users come from within NOAA, including the NWS, WFOs, and RFCs. The increasing perceived and actual utility of the FET is reflected in its growing use by others, outside CLIMAS, to evaluate forecast skill and communicate that to their stakeholders. Additionally, we are being asked by others (e.g., the University of New Hampshire, the Natural Resources Conservation Service [NRCS]) to collaborate on proposals for using the FET with stakeholders in their regions and extending the webtool’s functionality to include new types of forecasts.

A major accomplishment this year is the successful prototype implementation of CLIDDSS, with a demonstration of the basic underlying functionality contained in the system design (e.g., management of user profile preferences, project folders, and PDF-generated reports). We continue to expand the prototype user interface and product linkages. Several groups (e.g., National Climatic Data Center, Western Water Assessment, East-West Center, International Research Institute for Climate Prediction) have expressed strong interest in collaborating to include their products, or products desired by their stakeholders, in CLIDDSS.

In recognition of our equitable and user-centric approach to developing hydroclimatic webtools, we were asked by stakeholders in the Pacific Northwest to participate in development of a new tool, an Automated Hydrologic Threshold Alert System (AHTAS), for real-time monitoring and notification of streamflow events related to hydropower production, and web-based documentation of event causes and consequences. This tool builds on the underlying foundation of CLIDDSS for the documentation components. It has proved highly useful and has already been extended to unforeseen applications (monitoring lake restoration activities).

We continued to put considerable effort into securing additional funding for sustained development of the FET and CLIDDSS. We responded to two 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: \$434,659 for 3 years
2. Pacific Region Integrated Data Enterprise (PRIDE): Customized Information Management Tools for PRIDE Products and Applications, Total Cost: \$94,670 for 1 year

We also were asked to collaborate with others in their proposals.

3. Sector Applications Research Program (SARP): Improving Stakeholder Adoption of Forecasts of Climate Variability and Strategic Environmental Trends: Northeastern U.S. Case Studies, Total Cost: \$434,659 for 3 years
4. Sector Applications Research Program (SARP): Drought Planning and Conservation: Training Modules for Multiple Applications in the Water Sector, \$204,881 for 3 years
5. The University of New Hampshire Earth System Observatory: Assessing Coastal Ecosystem Impacts through a White Water-to-Blue Water Continuum
6. Western Caucus Pooled Fund: The North Umpqua Foundation, North Umpqua Hydrologic Threshold Alert System, Total Cost: \$13,667 for 1 year

A.3. Accomplishments anticipated by end of Budget Year

Finalization of FET re-design, including implementation of revised ‘bubble plot’ design.

Advance of the FET from ‘beta version’ to ‘full release’.

Prototype demonstration of linking CLIDDSS with external climate information products and applications (with the International Research Institute for Climate and Society [IRI]).

A.4. Plans for 2006.

Extensive outreach to increase awareness of the FET, including stakeholders, decision makers, information intermediaries, and the research community.

Obtain increased commitment by NOAA, NWS CPC, and NWS CSD for sustained maintenance, development, and extension of the FET. Anticipated efforts include extension of FET to include additional forecast evaluation metrics, extend the non-evaluation webtools (e.g., historical analogs) to Alaska and station locations, and further develop intuitive graphical user interface components.

Develop proposals for funding for incorporation of historical streamflow forecasts and observations within FET for stations used in our hydrologic forecast evaluation research. Collaborative partners will include the NRCS National Water and Climate Center (NWCC), the NWS River Forecast Centers (RFCs), and the RISA at the University of Washington.

Complete initial implementation of CLIDDSS, 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.

Develop collaborations with organizations to link their products and applications with CLIDDSS.

Continue to develop equitable and user-centric software tools for decision makers. This includes further development of AHTAS, and exploring the possibility of others (e.g., user-customized tools for developing personal drought indices with monitoring and alert capabilities, based on the work of Gregg Garfin and the Arizona state climatologist).

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 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.

NOAA NWS Climate, Water, and Weather Services, Climate Services Division: Technology Transfer of an Internet-based Interactive Climate Forecast Evaluation Tool Total Amount, Total Cost: \$39,984 over the past 12 months.

A.6. Leveraged Activities

The extension of the FET to include Alaska and downscales forecasts, and our professional development activities have been leveraged through contracts with the NWS Climate Services Division.

Development of the Automated Hydrologic Threshold Alert System (AHTAS). This is likely to expand into a significant tool for information monitoring and event management, with broad application.

A.7. Non-CLIMAS Project Partners

NWS Office of Climate, Water, and Weather Services, Climate Services Division (CSD)
NWS Climate Prediction Center (CPC), North Umpqua Foundation

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. With the return of Jean Morrill during the summer, her report on historical Colorado Basin forecast evaluation and associated journal articles progressed to near completion.

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. In that effort, we have learned the operation of the NWS River Forecast System (NWSRFS), and have had extensive discussions with operational forecasters at several River Forecast Centers about their approach to forecasting and verification.

By invitation, Hartmann participated in the workshop, “Hydrology Research into Operations” held by the NWS Office of Hydrologic Development (OHD) and River Forecast Centers (RFCs). We have been encouraged to work with western RFCs and others (e.g., NRCS) to extend our FET to include their hydrologic forecasts (including shorter-term forecasts), and additional evaluation criteria, among other features.

B.3. Accomplishments anticipated by end of Budget Year 2006. Submit journal article on evaluation of historical water supply outlooks for the Colorado River Basin

Complete project with OHD and UC-I on hydrologic verification systems.

B.4. Plans for 2006. Continue to build relationships with partners at UC-Irvine and NWS Office of Hydrology, NWS OHD and RFCs, NRCS NWCC, and CIG-University of Washington

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. CLIMAS has forged deeper ongoing relationships with the SAHRA NSF-STC, through H. Hartmann’s appointment as SAHRA staff concerned with program-wide stakeholder engagement activities. A significant joint CLIMAS-SAHRA activity was 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. The SAHRA Annual Meeting was also changed to include significant stakeholder participation. Collaboration with Niina Haas has resulted in evaluations of seasonal climate forecasts through the use of surveys and key informant interviews, both administered at professional meetings.

C.3. Accomplishments anticipated by end of Budget Year 2006. Through SAHRA, Hartmann will be involved in an Integrated Modeling Workshop in late March. That workshop will feature a day of researcher-stakeholder engagement focused on defining, constructing, analyzing, and assessing scenarios in support of water resources management.

C.4. Plans for 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 CWSD and WRH training experiences.

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.

C.5. Leveraged funding. 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.

The NSF Science and Technology Center (STC) for the Sustainability of Semi-Arid Hydrology and Riparian Areas (SAHRA): 1/3 FTE for Hartmann.

C.6. Leveraged activities

C.6.1. Greater than 50% CLIMAS

Professional development and product development activities for the NWS CSD. Their funding pays for travel, but not personnel costs.

C.7. Non-CLIMAS Project Partners

SAHRA NSF-STC

NWS CSD, Western Region Headquarters, WFOs

II. Publications

To be submitted by June 1, 2006

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

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

Morrill, J., Hartmann, H.C., and R. Bales. An assessment of water supply outlook forecasts in the Colorado River Basin. *Journal of Hydrometeorology*.

Websites

University of Arizona. 2006. Forecast Evaluation Tool. <http://fet.hwr.arizona.edu/ForecastEvaluationTool/> (Last accessed February 26, 2006).

III. Presentations at Professional Meetings/Conferences

Hartmann, H.C., 2005. User-centric evaluation of NWS seasonal climate outlooks. Climate Prediction Applications Science Workshop, Palisades, New York, 15-17 March.

Hartmann, H.C., 2005. Linking water management and hydroclimatic research advances: tactics, techniques, and tools. 5th International Scientific Conference on the Global Energy and Water Cycle, Costa Mesa, CA, 20-24 June 2005.

Hartmann, H.C. and R.L. Hartmann, 2005. An automated hydrologic threshold alert system for the Umpqua River Basin, OR. Annual Conference, American Water Resources Association, Seattle, WA, 7-10 November.

Hartmann, H.C., 2005. Effecting Systemic Change in Climate Information Delivery and Decision Support. Workshop on Climate Science in Support of Decision Making, U.S. Climate Change Science Program, Arlington, VA, 14-16 November 2005.

Hartmann, H.C., 2006. Academic interactions with the public and private sectors: opportunities and challenges. Symposium on the Public/Private Sector Partnership, 85th Annual Meeting of the American Meteorological Society, Atlanta, GA, 31 January. Invited presentation.

Hartmann, H.C., 2006. The use of climate information in water resources management. Symposium on Climate Variability and Change, 85th Annual Meeting of the American Meteorological Society, Atlanta, GA, 29 January - 2 February. Invited presentation.

IV. Outreach Activities

Hartmann, H.C., 2005. Helping decision makers understand hydroclimatic variability and forecasts: considerations in providing knowledge development and decision support tools. National Water and Climate Center, Natural Resources Conservation Service, Portland, OR, 17 June. Invited presentation.

Hartmann, H.C., 2005. Helping decision makers understand climate variability and forecasts: considerations in providing knowledge development and decision support tools. Seminar Series, International Research Institute for Climate Prediction, Palisades, NY, 15 September. Invited presentation.

Hartmann, participated in roundtable discussion on forecasts for climate and streamflow, 18 November. Discussion transcript was featured in Southwest Climate Outlook, December 2005.

Hartmann, Watershed Science Advisory Committee, Watershed Curriculum Project, American Meteorological Society and the National Environmental Education and Training Foundation

Hartmann, H.C., 2005. Hydrology Research into Operations Workshop, National Weather Service Office of Hydrologic Development and River Forecast Centers, Park City, UT, 3-7 October. Invited panelist.

Hartmann, H.C., 2005/6. Understanding CPC Seasonal Outlooks; Understanding the Quality of CPC Products. Operational Climate Services Residential Training Courses, National Weather Service, Kansas City, MO, 30 August - 1 September, 20-22 September, 1-3 November 2005, 10-12 January. Professional development training course taught.

Hartmann, H.C., 2005. Understanding CPC Seasonal Outlooks; Understanding the Quality of CPC Products. Alaska Region Climate Service Science Workshop, National Weather Service, Anchorage, AK, 7-10 June. Professional development training course taught.

Hartmann, H.C., 2005. Understanding CPC Seasonal Outlooks. Alaska Region Climate Service Media Workshop, National Weather Service, Anchorage, AK, 8 June. Professional development training course taught.

Hartmann, H.C., 2005. Understanding CPC Seasonal Outlooks; Understanding the Quality of CPC Products. Western Region Climate Workshop, National Weather Service, Kansas City, MO, 24-26 May. Professional development training course taught.

Hartmann, H.C., 2005. Climate Forecasts and Forecast Uncertainty. Component of Training Course "Drought Management: Understanding and Coping with Climate Variability and Uncertainty", New Mexico Rural Water Association, 27TH Annual

Technical Conference, Albuquerque, NM, 21 March. Professional development course taught.

Hartmann was co-organizer of one-day course, Drought Management: Understanding and Coping with Climate Variability and Uncertainty, New Mexico Rural Water Association, 27TH Annual Technical Conference, Albuquerque, NM, 21-24 March 2005. Professional development course consisting of six classes, with three taught by CLIMAS researchers and three coordinated with the Center for Sustainability of Semi-arid Hydrology and Riparian Areas (SAHRA) The success of this class led to New Mexico State University conducting a similar course, on their own, this year.

V. Human Resource Development

Hartmann received training on operating the National Weather Service River Forecast System (NWSRFS) from Riverside Technologies, Inc. (RTi), 4-8 April, Irvine, CA.