
Project Title: Climate Assessment for the Southwest (CLIMAS) “VARIABILITY, SOCIAL VULNERABILITY AND PUBLIC POLICY IN THE SOUTHWESTERN US-Phase 2”

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Performance Period: February 2006. January 2007

-What are your current areas of focus?:

Climate Variability and Change. (a) Impact of retreating Northern Hemisphere storm track on Southwest climate (Overpeck); (b) Spatial variation of Southwest precipitation and causes of fine-scale variations (Comrie); (c) Implementing use of climate change knowledge in decisionmaking by Tucson Water (Garfin); (d) Climate Change Web Portal for the Southwest (Garfin/Crawford, Overpeck); (e) Examination of social networks for optimal climate change information dissemination and capacity building (Garfin, Morehouse); (f) Arizona Water Atlas climatology (Garfin/Crawford); (g) Climate change in the Southwest (compendium) (Garfin/Lenart).

Decision Support. (a) Implementation of Climate Information Delivery and Decision Support System (CLIDDSS) for use by multiple stakeholders (PACIS, IRI, Border Climate Summary) (Hartmann); (b) Expansion of Forecast Evaluation Tool (FET) capabilities (Hartmann); (c) Automated Hydrologic Threshold Alert System (AHTAS) (Hartmann); (d) Downscaling NOAA-CPC climate predictions to station scale (Comrie).

Drought. (a) Implementation of Arizona Local Drought Impact Groups and drought impact reporting system (Garfin); (b) Re-evaluation of Arizona drought triggers and transfer of drought trigger methodology to New Mexico (Garfin); (c) Climatology of pre-historic drought in Arizona and New Mexico (Garfin/Crawford).

Fire. (a) North American Seasonal Assessment Workshops (Garfin); (b) Development of a collaborative monthly U.S. Fire Forecast (Garfin); (c) Examination of institutional structures and use of climate information in fire management decision-making (Morehouse); (d) Examination of climate-fire relationships on multi-decade timescales over western North America (Swetnam); (e) History of stand-replacing fires using tree-ring and alluvial fan records (Swetnam).

Floods. (a) Hydroclimatic classification of Arizona flood records for integration with Arizona Flood Warning System (Hirschboeck); (b) Identifying cultural factors that affect risk perception and behavior during flashfloods (in conjunction with floodplain managers) (Hirschboeck).

Integrated Assessment. (a) Retrospective self-examination of CLIMAS project (Morehouse).

Knowledge Transfer. (a) Examination of social networks in the diffusion of water resources information on the Colorado Plateau (Garfin, Morehouse); (b) Re-evaluation of Southwest Climate Outlook (Garfin); (c) Climate forecast, outreach, professional

development videoconferences (Garfin); (d) Training NWS forecasters in probabilistic forecast evaluation and interpretation (Hartmann).

Navajo Nation. (a) Evaluation of hydrometeorology observation network (Garfin); (b) Analysis of climatology, paleoclimatology, and connections with traditional knowledge (Overpeck).

Public Health. (a) Mosquitoes, Microclimate, and The Environment (Comrie); (b) Annual regional air quality workshops (Comrie); Impact of wildland fires on urban air quality and visibility (Comrie) .

Resource Economics. (a) Climate Variability and Snow-Dependent Local Economies (Colby); (b) Demand for Climate and Weather Information for Agricultural Decision-Making (Frisvold); (c) Climate Variability, Water Transactions and Adaptation Strategies (Colby); (d) Climate, Agricultural Technology Adoption, and Water Use (Frisvold); (e) Climate, Water Availability, and Southwest Park Visitation (Frisvold).

U.S.-Mexico Border Region. (a) Monthly climate information product (Garfin); (b) Role of climate in perceptions about land and resource conservation (Wilder).

Vulnerability. (a) Climate vulnerability assessment in rural and exurban communities in Arizona and New Mexico's Colorado Plateau area (Finan).

-Who are your main stakeholders/partners?:

Climate Variability and Change. The Nature Conservancy, New Mexico Office of the State Engineer (NM OSE), Sonoran Institute, Tucson Water, Arizona Department of Water Resources (ADWR), Natural Resource Conservation Districts, Border Legislative Conference

Decision Support. International Research Institute for Climate and Society, NOAA/NWS Climate Services Division, UCAR Cooperative Program for Operational Meteorology, Education and Training (COMET), and a wide variety of registered FET users (including public agencies, private organizations [energy and commodity firms], and individuals)

Drought. ADWR, Arizona Local Drought Impact Groups (Cochise County, Pima County, Navajo County, Santa Cruz County, Pinal County), New Mexico Drought Working Group (NMDWG), Arizona Association of Conservation Districts

Fire. National Interagency Coordination Center, USDA-Forest Service, Southwest Coordination Center (Albuquerque), Society of American Foresters

Floods. Arizona Flood Warning System

Knowledge Transfer. Arizona Cooperative Extension, Society for Range Management, Sustainable Tucson Coalition, Mountain Studies Institute, National Weather Service, Arizona journalists, Malpai Borderlands Group

Public Health. Arizona Department of Health and Human Services, Pima Association of Governments (and other regional air quality managers, including EPA, WGA), Pima Department of Environmental Quality

Resource Economics (including water). Arizona Department of Agriculture, US Bureau of Reclamation, U.S. Institute for Environmental Conflict Resolution, Arizona Field Office: Farm Foundation, ADWR

Tribal. Cocopah Tribe, Navajo Nation, San Carlos Apache Tribe

U.S.-Mexico Border. Asociacion de Usuarios Ejidatarios del Rio Hardy y Colorado (AEURHYC), CONAFOR, National Wildlife Federation, Servicio Meteorologico Nacional, SEMARNAT and INIFAP (Fire and land managers in Mexico), Sonoran Institute

Vulnerability. State, federal, and local water resources and land management stakeholders in northeastern Arizona and northwestern New Mexico

-Top 5-7 highlights of research, stakeholder collaboration, tool development during the period of performance (last year):

Climate Variability and Snow-Dependent Local Economies: Two specific case studies have been completed (Sunrise Park Ski Resort, owned by the White Mountain Apache Tribe, and Snowbowl, located on US Forest Service land near Flagstaff. Our findings confirm the central importance of snowmaking as a potential adaptation mechanism and of reliable water supplies to make snow. We find that while snow-making investments could reduce ski season uncertainty at both resorts, this also would reinforce the ski resorts' and the local winter economy's dependence on winter snow-based recreation. Using detailed background information on climate change, ski recreation and snow depth data, we developed a preliminary model of snow depth as related to recreational visits and local economic activity. In addition, we have estimated increased costs of snowmaking at higher temperatures. We briefed the press with the results of this study in spring 2006; a peer-reviewed publication is in review in the journal *Climate Research*.

Mosquitoes, Microclimate, and The Environment: Vector born diseases are reemerging as a major health threat in many areas where they were once thought to be eradicated or suppressed. Shifts in the range of these diseases and their vectors may be closely correlated with climate variability and climate change. In the southwestern United States, West Nile Virus has raised considerable concern as it has established itself among several mosquito populations and has caused illness and death in a number of residents. The Dengue Fever vector, *Aedes aegypti*, is also present in the southwest. Although no Dengue Fever cases have been reported in the United States outside of Texas, the disease is endemic in communities just over the Mexican border. The objective of this research is to better understand and possibly predict the dynamics of mosquito populations based on climate variability and change. This is being done through the creation of a dynamic mosquito population model which uses climate data for input (temperature, precipitation, daylight hours). Thus far, the majority of work has been dedicated to developing the dynamic model using Stella 9.0 software. A current model to predict *Aedes aegypti* is near completion and work has started on model development for *Cx. Quinquefasciatus*. ***These will be the first dynamic climate-mosquito simulation models that are available.*** Initial model run findings:

- Occurrences of consecutive days of precipitation may be more important than total precipitation
- In Arizona, higher elevations tend to be temperature limited while lower elevations tend to be precipitation limited
- Low winter rain events may be detrimental to population developments later in the year
- Permanent water sources may be vital to allow *aegypti* populations to survive the winter

After completion of the model with calibration for both *Aedes aegypti* and *Cx. Quinquefasciatus*, the model will be validated against mosquito count data and then refined to ensure proper quality. The model will then be run for different areas of Tucson with the appropriate land use and land type incorporated into the runs. The mosquito population output will then be incorporated into a GIS to produce a map illustrating

relative population statistics for Tucson. Lastly, the model may be run for future climate scenarios in order to predict how future climate change in the southwest could affect mosquito and disease abundance.

Drought and Climate Change Outreach and Stakeholder Engagement: CLIMAS investigators, staff, and graduate students engaged with numerous stakeholders through workshops, presentations, sustained engagements and partnerships. Three key highlights include: (a) partnering with the Arizona Statewide Drought Program (ADWR) to implement Local Drought Impact Groups in 5 counties, co-authoring an annual report to Arizona Governor Napolitano (including resource requests for monitoring and public outreach programs) and briefing the Governor's Drought Interagency Coordinating Group on policy decisions, such as the re-declaration of USDA Drought Emergency status for 14 Arizona counties; (b) co-authoring a Climate Change Impacts on New Mexico Water Resources report, and briefing the New Mexico Legislature on this issue in August 2006; (c) conducting three workshops on drought and climate change for [i] rural communities, [ii] water and municipal managers, and [iii] news journalists.

U.S.-Mexico Border Research and Outreach: CLIMAS researchers made significant strides in studies on U.S.-Mexico resource management, and developed partnerships with Mexican scientists and agency personnel to produce climate and fire products for the border region. Work by Margaret Wilder established the effect of policy reforms in Mexico on water management, opportunities to introduce climate information into management decisions, and factors affecting bi-national collaboration on Colorado River water and riparian land management. Wilder is a member of the Colorado River International Conservation Area Steering Committee, and she has made tremendous progress in evaluating how perceptions of climate influences stakeholder decisions on riparian restoration of the Lower Colorado River (including over 600 surveys). In other efforts, the CLIMAS Core Office (in collaboration with the UA Udall Center and the Western Water Assessment) conducted two workshops on monsoon-region climate applications and coordinated a core group devoted to the development of a bi-national climate newsletter for border-region stakeholders. A prototype newsletter (Border Climate Summary/Resumen del Clima de la Frontera [http://www.ispe.arizona.edu/climas/forecasts/borderoutlook_prototype.pdf]), was unveiled at the 2006 North American Drought Monitor Meeting and a second edition was developed in early 2007, in collaboration with the Servicio Meteorologico Nacional. The Core Office also developed connections with key Mexican climate and fire scientists in conjunction through co-organizing the 1st North American Seasonal Assessment Workshop. The Workshop produced a unified Canada-U.S.-Mexico fire potential outlook; however, we do not anticipate securing governmental approval of an official tri-national product until 2008.

Navajo Nation Traditional and Modern Climate Information Pathways:

The goal of this research is to investigate past (instrumental and paleoclimatic) climate change in the region of the Navajo Nation, as well as climate perceptions of selected Navajo stakeholders (i.e., farmers and livestock owners). The focus is on interannual-to-

decadal-scale climate variability, as well as climate change. Accomplishments over the last year include:

- Completed gathering climate data (paleoclimate, observational) on the central Navajo Nation of the Southern Colorado Plateau.
- The Navajo Nation Chapters of Lukachukai, Tsaile/Wheatfields, and Crystal all passed resolutions supporting research of the investigator, on climate change and variability in the Chuska Mountains. The resolutions were necessary since a significant portion of the research deals with human subjects (Navajo Nation IRB, Navajo Nation Historic Preservation Office, and the University of Arizona Institutional Review Board). The appropriate permits and exemptions were received from all review boards and offices.
- Completed 20 interviews with farmers and/or livestock owners in the vicinity of the Chuska Mountains. The interviews were composed of semi-structured and open-ended interviews.
- Led a weeklong outreach program with Monument Valley High School students (Navajo Nation). The program was formatted to encourage student interest and inquiry into climate-landscape processes and socio-cultural implications through a culturally enriching and appropriate framework and place-based examples. The students designed a class poster based on their experiences throughout the week.

Understanding the Role of the Northern Annular Mode in Southwest Climate: The goal of this research is to investigate the role of the Northern Annual Mode in modulating wintertime climate of the Southwest – in particular, Southwest precipitation. The focus is on interannual to decadal-scale climate variability, as well as climate change. As noted below, stakeholders have demonstrated significant interest in the watershed dynamics and ecosystem services aspects of the project. The IPCC WG1 Fourth Assessment has made this work a top priority. Results indicate the Southwest will continue to dry out into the future. Accomplishments over the last year include:

- Demonstrated the existence of a relationship between the Northern Annular Mode (NAM) and early spring (February – April) temperature and precipitation in the Southwest, with impacts on vegetation in the late spring and early summer (March – May). Positive phases of the annular mode are associated with warmer and drier springs, and with reduced NDVI (a satellite-based measure of vegetation) in the early summer.
- Developed a proposal to validate and use a hydrologic and dynamic vegetation model to describe likely changes to selected watersheds in the Southwest under projected climate change. The joint hydrologic and dynamic vegetation model, LM3v, is appropriate for use on watersheds at 10km-scale in the Southwest; it was designed to integrate well with use NOAA's GFDL CM2 and CM2.1 general circulation models.
- Evaluated interest and needs of various stakeholders, with particular emphasis on types of information, spatial and temporal scale, as well as useful projection lengths. The following organizations are interested in the results of this project and use of the output: New Mexico chapter of The Nature Conservancy (ecosystem services), University of Arizona Cooperative Extension (watershed dynamics and ecosystem services), and Salt River Project Water Resource

Operations (watershed dynamics). There are excellent prospects for collaborating with TNC to incorporate output from this project into their climate impacts model.

Knowledge Development and Decision Support Tools - Forecast Evaluation Tool (FET), Climate Information Delivery and Decision Support System (CLIDDSS): The online Forecast Evaluation Tool (FET) is an Internet website that any decision maker can use to assess the seasonal temperature and precipitation outlooks issued by the NWS CPC. The Climate Information Delivery and Decision Support System (CLIDDSS) is a software-engineered interactive web application that 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). Highlights of 2006-07 progress include:

- A third year of FET operation without failure, through continued software maintenance for upgrades in underlying tools and code optimization.
- In collaboration with the NWS Climate Services Division, we continued to expand support for evaluating the 3-month local temperature outlooks, by adding more stations, helping to troubleshoot their data management, and advising on product design issues.
- The number of registered users continues to grow in number and diversity, with registrants representing all sectors: universities, private companies, many units of NOAA and the National Weather Service (NWS), international groups, regional/state/local resource management agencies, and individual decisionmakers (including large agribusiness, financial institutions, energy corporations, and risk management companies).
- Using Google search terms for “climate forecast evaluation,” the FET ranks the highest, with instructions for using the FET ranking second.
- In 2006-07, the FET was used in professional development courses in Oregon, Colorado, and Missouri. Notably, through our collaboration with the NWS Climate Services Division, the FET continues to be an integral part of the official training for every designated ‘climate focal point’ within every local NWS Weather Forecast Office (WFO). In 2006, each of the 122 WFOs, plus several NWS River Forecast Centers, had at least one person trained in FET use.
- CLIDDSS was successfully used to generate the second issue of the US-Mexico Border Climate Summary, demonstrating functionality and progress in implementation in an operational setting. Final development awaits feedback from potential users.
- Newly added CLIDDSS capabilities include increased flexibility for external product providers, greater user control of page layouts, and the ability of users to add their own customized products and pages without requiring external availability. *The latter extension addresses the need for private sector users to isolate proprietary information, enabling CLIDDSS to be a tool for facilitating, rather than competing with, private sector applications.*

-List of tools/models/methods, etc...:

Web-based Tools:

- Forecast Evaluation Tool (FET)
- The Climate Information Delivery and Decision Support System (CLIDDSS)
- Automated Hydrologic Threshold Alert System (AHTAS)
- Valley Fever Prediction Tool

Models, Methods:

- Dynamic hydrologic and vegetation model LM3v (Climate research)
- USDA Farm and Ranch Irrigation Surveys (FRIS); USDA Agricultural, Food, and Public Policy Preference Survey (Use of climate information in agriculture)
- Social Network Analysis (information flow and penetration into stakeholder “markets”)
- Game theory analysis of irrigation and water transfer decision-making
- Statistical downscaling of NOAA-NWS-CPC climate outlooks
- Genetic Algorithm for Rule-set Production (GARP) (climate-disease modeling)
- Stella-GIS mosquito habitat and population prediction model
- Hedonic modeling (water transfer pricing and drought)
- Synoptic hydroclimatology (climate-flood relationships)

-List of stakeholder workshops/media briefings/newsletters/listserves,etc...:

Stakeholder Meetings				
Date	Who	Role	Meeting	Where
February 1, 2006	Garfin	Co-organizer	Southwest Climate and Hydrology Workshop at the Annual Southeastern Arizona Ag Day and Trade Show.	Willcox, AZ
February 15, 2006	Garfin	Advisor	On the Trail of Climate Change: a NASA Space Grant Workshop	Tucson, AZ
April 4-7, 2006	Garfin	Co-organizer	NSAW Western States and Alaska 2006	Boulder, CO
April 4-7, 2006	Garfin	Co-organizer	North American Seasonal Assessment Workshop 2006	Boulder, CO
April 10, 2006	Hartmann	Co-organizer	The use of climate information in water resources management/water resource planning in a changing climate.	Corvallis, OR
June 13-15, 2006	Hartmann	Session leader	Understanding CPC Seasonal Outlooks; Understanding the Quality of CPC Products. Operational Climate Services Residential Training Courses, National Weather Service	Kansas City, MO
June 27, 2006	Hartmann	Co-organizer	Hydrologic Forecast Verification. Advanced Hydrologic Training, NWS Cooperative Program for Operational Meteorology, Education, and Training (COMET) Program	Boulder, CO
September 13, 2006	Garfin	Co-organizer	Arizona Hydrological Society Drought and Climate Change Workshop	Glendale, AZ
October, 2006	Overpeck	Co-organizer	Climate Variability & Change in the San Juan Mountains: A Scientist-Stakeholder Dialogue	Durango, CO
December 1, 2006	Garfin	Organizer	Tucson Water climate change briefing	Tucson, AZ
December 13, 2006	Garfin	Co-organizer	VIDEO BRIEFING:Climate, Drought, ENSO	Arizona
January 24-26, 2007	Garfin	Co-organizer	2007 NSAW:Eastern, Southern, and Southwestern States	Shepherdstown, WV
Media Briefings				

February 10, 2006	Garfin	Co-organizer	MEDIA BRIEFING: Upper Colorado River Basin Current Conditions, Snowpacks and La Nina	Tucson, AZ
December 12, 2006	Garfin	Co-organizer	MEDIA BRIEFING: El Nino, Drought, AWI, AHIS, RAINLOG, SRP	Phoenix, AZ
Professional Meetings				
February 10, 2006	Garfin	Co-organizer	DCDC (NSF center)-CLIMAS meeting	Phoenix, AZ
March 21–24, 2006	Garfin	Co-organizer	Fourth NOAA Climate Prediction Applications Science Workshop (CPASW)	Tucson, AZ
March 22, 2006	Garfin	Organizer/Moderator	NOAA-CPASW Drought panel session	Tucson, AZ
May 8-11, 2006	Garfin	Co-organizer	Monsoon Region Climate Applications: a binational workshop	Guaymas, Sonora, Mexico
May 8-11, 2006	Garfin	Organizer/Moderator	MRCA drought and natural hazards panel session	Guaymas, Sonora, Mexico
July, 2006	Overpeck	Organizing committee member	Retreat of the NOAA Climate Working Group focused on improving NOAA's ability to provide the nation with drought information	Santa Fe, NM

-List of links with other NOAA programs (eg. NWS, NCEP, Labs, CDEP ARCs, RCCs, etc...):

- NWS Climate Services Division
- NWS Phoenix, Tucson, Albuquerque, Flagstaff Weather Forecast Offices
 - And... WFOs nation-wide
- NWS Colorado Basin River Forecast Center
 - And... RFCs nationwide
- NWS Western Region Headquarters
- NWS Central Region Headquarters
- NOAA Climate Working Group
- Western Regional Climate Center
- Northeast Regional Climate Center
- Southern Regional Climate Center
- NOAA-ESRL
- Scripps Experimental Climate Prediction Center
- NOAA-GFDL
- NOAA-IRI
- NOAA-NWS Climate Test Bed
- NWS Office of Hydrologic Development
- NOAA Climate Prediction Center

-List of current cross-RISA activities:

- Monsoon Region Climate Applications (WWA)
- National/North American Seasonal Assessment Workshops (CAP, WWA, SECC, ACCAP)
- Paleohydrology Workshops (WWA)
- Implementing AgClimate in New Mexico (initial dialogues) (SECC)
- Implementing Dynamic Drought Index Tool in Arizona (working with Arizona Statewide Drought Program) (CISA)
- Proposals for funding for incorporation of historical streamflow forecasts and observations within FET (CIG)
- FET Professional Development Course in Oregon (CIG)
- Water - East and West. Oil, Water, and Oregon Symposium (CIG)
- Proposal: Paleohydrologic Data and Knowledge for Decision Support in the Colorado River and Adjoining Basins (WWA)
- Customized Information Management Tools for PRIDE Products and Applications (Pacific RISA)