CLIMAS 2000 Accomplishments


Our Pilot Stakeholder Survey, and subsequent survey work in the Middle San Pedro River Valley, urban water sector, and ranching sector, as well as with tribal entities, has informed the research agendas of the natural science team members. Most notable among our accomplishments in meeting stakeholders' stated needs has been the intensive work carried out on downscaling historical and paleo information to fine spatial scales, and development of evaluations of key seasonal forecasts. Work on understanding the Monsoon, likewise, is an outgrowth of needs expressed by emergency managers, ranchers, and water managers for better summer forecasts. The winter snowpack modeling effort is an outgrowth of a workshop held during the first year of the project for river forecasters whose work covers the Southwest. Working toward development of better local information and forecasting capabilities with regard to lightning, evapotranspiration, and soil moisture are additional needs identified through our stakeholder interactions.

Our climate and health initiative, focusing on the connections between climatic conditions and Valley Fever, a fungal disease endemic to parts of the Southwest, provided an opportunity to develop skill in assessing climate impacts on public health. These skills will be called upon, and expanded, as our investigations widen to include other climate-sensitive disease conditions and vectors and other geographical areas.

SSV

Air-conditioning, wells, and flood control projects have allowed the majority of residents in the Southwest to perceive themselves as largely unaffected by climate extremes. However, previous research by CLIMAS social scientists in the Middle San Pedro River Valley revealed that if you are a farmer, a rancher, or a migrant worker in southeastern Arizona, events such as droughts, high temperatures and short periods of excessive rain can wreak havoc in one's ability to make a living.

CLIMAS team members have continued to make progress towards understanding more precisely the ways in which residents of the Southwest are vulnerable to climate variability. They have expanded their vulnerability case studies to the Sulphur Springs Valley of Southeastern Arizona, a region dependent on groundwater for irrigation. Their fieldwork has included interviews with a wider range of small-scale agriculturists such as corn farmers, nut orchard growers, fruit growers, U-Pick vegetable producers and chili farmers, as well as seasonal and migrant labor. This research has revealed that there is a great deal of diversity in terms of people's concerns with climate variability. Some vegetable growers may welcome a summer drought; as one farmer said, "droughts are good because I can decide when and how much to water. This decreases the incidence of disease and the need for weeding." Several consecutive years of drought, however, can be devastating. An increase in reliance on groundwater irrigation may lead to a decline in aquifer levels and a substantial increase the costs of pumping. While for many this combination has resulted in bankruptcy and the abandonment of agriculture, for others
it has led to the development and adoption of more water efficient irrigation systems. Heavy rains at the wrong time can also be devastating, especially during the fall harvest when farmers may lose their crops and migrant laborers find themselves stranded and with no income. For orchard growers, frosts are of major concern.

Interactions with team members working in the forecast evaluation/integration, climate processes/teleconnections, and climate/hydrology dynamics modules and with key stakeholders will be essential for assuring solid knowledge of important climate, hydrology, and forecast factors pertinent to the study areas. These interactions have already been initiated.

In the process of identifying vulnerability to climate variability, we also continue to investigate stakeholder needs for specific types of climate information. Local farmers have expressed interest, and also skepticism, in the use of seasonal forecasts to assist them in agricultural decision-making.

**Community Vulnerability Assessment:**
Vulnerability mapping initiative. Emphasizing identification of differences in and access to resources, technologies, and economic opportunities, as well as on the influence of policy and institutional factors on adaptation capabilities and strategies.

In-depth community surveys, development of a socioeconomic and demographic profile using available census and other data, identification of points of climate vulnerability, and use of need for climate information.

Developed in-depth information on rural community climate vulnerabilities.

**IVc. Community Profiles**
In Year 3, assessment of vulnerability, information needs, and coping strategies will continue and expand into the more rural, agriculture-based Sulphur Springs Valley (Cochise County) where the climate vulnerability has not been buffered to any great extent. An associated draft working paper is currently being circulated among CLIMAS team members.

**Feedback to Project and Stakeholders**
- Collaborated with Urban Water study group on Benson component
- Results of surveys stressed the importance of downscaling of climate information and problems with spatial boundaries (zones) of climate forecasts for forecasting assessment group
- A draft working paper is available via the CLIMAS website.
- Highlighted areas of climate sensitivity and status of information needs in the Middle San Pedro River Valley region
- Introduced concept of buffering as a means of climate variability coping and adaptation
- Collaborating with local county Cooperative Extension Offices
Water
Institutional analysis for the urban water sector. Our preliminary investigations highlighted the importance of continuing and expanding this aspect of the project, for many of the barriers to effectively addressing vulnerability through use of climate information reside in the institutional and policy frameworks of entities operating at all scales from the local to the national and even international.

Research on the current and potential use of climate forecasting in water management in the United States (Pagano et al. submitted, Carter 2000), especially concerning policy makers' information needs and constraints for data incorporation into resource decision making. From this effort, some common insights can be identified:

**Feedback to Project and Stakeholders**

- Developing an urban water provider database from survey results
- The sensitivity analyses working paper is available for CLIMAS and public use. The institutional analyses and vulnerability analyses working papers will be completed in early summer 2000.
- The Benson sensitivity analysis provided a sectoral link between urban water study and community case study. Developed test climate scenarios, guided by the climate variability team, hydrologists, and water managers
- Initial results have provided important insights for dissemination and formatting of climate information for stakeholders.
- Participating in the Safe-Yield task force. The task force was initiated by the Arizona Department of Water Resources to identify water management issues in the state's Active Management Areas (AMAs), with ultimate goals of improving the chances of achieving safe-yield, including possible legislative changes to the Arizona Groundwater Management Code.

Hydrology
Within the Hydrology activities in CLIMAS, in-depth, structured interviews with water managers (water supply and emergency managers) have been carried out in Arizona to assess their use of climate information and forecast products during the 1997-98 El Niño season (Pagano et al. submitted (a), Pagano et al. submitted (b)). In this process, the Hydrology team identified strengths and limitations of products, delivery processes, and institutional characteristics of water decision-making in Arizona. It also examined the role of climate vis-à-vis other factors affecting water management decision and developed connections with Arizona water management agencies. As a result, the CLIMAS Hydrology team has held a workshop directed at water managers focusing on Climate Forecasts and Water Management.

Moreover, other research initiatives have been carried out in the context of CLIMAS. Morehouse (2000) and Carter (2000) suggest that although risk and uncertainty posed by climatic stresses in Arizona may remain at manageable levels given current water management contingency plans and system redundancy, many issues remain unresolved. Among those are
equity issues relative to water supply and use, different institutional capacity to implement and enforce policy, growing levels of population and urban development, and lack of preparedness to extreme climate impacts. Regarding transboundary water management, Morehouse et al. (forthcoming) point out the potential implications of a deep, sustained drought to the already conflictous water management of the shared use of the Santa Cruz river water resources between the states of Arizona, U.S. and Sonora, Mexico. They recommend deeper cooperation among water managers and planners on both sides of the border as well as further binational analysis and concerted actions to averting/mitigating climate-related stresses in the shared water system.

Cross-Sector and Cross-Region Comparative Analysis of Policy and Decision Making—Water and Fire Management:
Comparative studies across regions and countries and policy systems (e.g. comparison between water management and fire management in collaboration with Barbara Morehouse) focusing on the commonalities and distinctiveness of each system and how it affects the use of climate forecasting information.

C.3. SECTORAL ASSESSMENTS
Research into climate impacts on individual sectors, including urban and rural water, agriculture and ranching, health, tourism and recreation. Because sectorally based research often involves the need to consider conditions in other geographical areas, taking a sectoral approach also provides an important avenue for integrating across assessments. For example, due to the very high level of interconnectedness of agricultural production with national and global markets, producers are frequently as concerned about conditions in other areas as they are about conditions in their own locality.

C.3.2 Climate and Fire Management
Climate-Fire Workshops:
Annual Fire-Climate workshop.

C.3.3. Health
Evaluate climate impacts in the health sector. We selected valley fever as a critical and understudied, climate-sensitive disease for the Southwest. We were fortunate to link up with a stakeholder group made up of environmental and health researchers and professionals. Interactions among the group have been facilitated by the University of Arizona’s Valley Fever Center for Excellence (VFCE), who strongly encouraged our work in this area. The work we carried out on valley fever connects with the winter and summer climate variability components of CLIMAS research.

Valley fever (coccidioidomycosis) is caused by inhaling the spores of a soil-dwelling fungus (Coccidioides immitis) that is endemic to the deserts of the Southwest. The life cycle of C. immitis is such that fungal growth responds to various sequences of moisture and temperature conditions, including a period of drying when the spores can become airborne. This regional disease has national importance in that 6,000 to 8,000 severe cases occur in the United States
each year; 50 to 100 of those who contract the disease die and overall treatment costs amount to some $60 million per year.

CLIMAS team members have accomplished a better understanding of the basic relationships between climate and valley fever and have developed a suite of monthly multivariate predictive models.

We now have a working forecast model of valley fever incidence for Pima County.

The project received local news coverage when, based in part on analysis of antecedent climate conditions, a prediction was issued for increased valley fever incidence during the late Fall of 1999.

**Feedback to Project and Stakeholders**
- Collaborating with the Climate Variability group
- Collaborating with UA valley fever center and associated research entities
- Introduced epidemiological methodology to the CLIMAS project-climate impacts on health concerns
- Showing relationships between climate and disease incidence in the Southwest
- Working towards predictive models of disease occurrence for use by health professionals

**C.4. CLIMATE, HYDROLOGIC, AND VULNERABILITY FORECAST EVALUATION AND INTEGRATION**

Our extensive interactions with water managers, wildland fire managers, ranchers, and farmers throughout the Southwest, through CLIMAS activities over the past three years, have consistently revealed that perceptions of poor or unknown forecast quality have limited use of climate forecasts in real-world applications (Pagano et al. 1999, Conley et al. 1999, Morehouse 2000). Repeatedly, users proffer that their lack of confidence in seasonal forecasts derives from their lack of any quantitative basis for judging past performance. Perhaps counterintuitively, clear and consistent communication of uncertainty can increase forecast credibility (O'Grady and Shabman 1990). Performance evaluations of climate forecasts have periodically appeared in the scientific literature (Bettge et al. 1981, Priesendorfer and Mobley 1984, Barnett and Priesendorfer 1987, O'Lenic 1990, Livezey 1990, Murphy and Huang 1991, Wilks 2000). However, results are not easily applied to specific natural resource management decisions, because they reflect concerns of climate modelers and forecasters, not decision-makers. Thorough understanding of forecast performance can enhance the potential for decision-makers to respond appropriately to both climate anomalies and forecasts of their occurrence.

While natural resource management stakeholders do share some common concerns, they are also extremely diverse. Each has a specific context within which they must evaluate the risks and rewards of incorporating new technology, including advanced climate and hydrologic forecasts, into their operations. Further, each has different capabilities to access, interpret, and understand seasonal forecasts and performance evaluations. While some stakeholders have sufficient resources to sustain internal expertise and produce their own forecasts, others must access and interpret forecasts made by others, even though they have no special training. The latter situation
presents a real challenge to forecasting agencies and “end-to-end” research programs: to provide useful forecast products that can be properly interpreted even by non-specialists.

Finally, climate forecast techniques presently evolve more rapidly than hydrologic forecast techniques or formal water management procedures (Hartmann et al. 1999). Improved climate prediction capabilities are being initially incorporated into water management decisions informally, using subjective, ad hoc procedures on the initiative of individual water managers, based in part on their confidence in the predictions (Pagano et al. 2000b). While improvised, these decisions are not insignificant. For example, the Salt River Project, among the largest water resource management agencies in the Colorado River Basin and primary supplier to the Phoenix metropolitan area, decided in August 1997 to substitute groundwater with reservoir releases, expecting increased surface runoff during a wet winter related to El Nino. With that decision, they risked losses exceeding $4 million in an attempt to realize benefits of $1 million (Pagano et al. 2000b). Overconfidence in forecasts can be even more problematic than lack of confidence, as a single incorrect forecast that provokes costly shifts in operations can devastate user confidence in subsequent forecasts (Glantz 1982). Ongoing evaluations are essential for informing water managers about the appropriate level of confidence to place in seasonal predictions.

The relatively slow pace of change in operational hydrologic forecasting derives in part from the focus of large research programs on the next generation of forecast tools rather than incremental improvements to current operational forecast methods (Hartmann et al. 1999). Additionally, there has been a notable lack of attention paid to the ongoing evaluation of present operational hydrologic forecasts, resulting in the absence of any quantitative basis for forecast credibility (Hartmann et al. 1999). Finally, lack of performance tracking precludes accurate assessments of the improvements in forecasts to be offered by advanced research programs, observation technologies, and modeling capabilities.

. Another key feature is that the evaluation efforts explicitly reflect the seasons, lead times, variables, and criteria important to decision-makers, and represent a direct response to stakeholder comments. Linkages to sectors other than water management are primarily through the evaluation of climate forecasts, including official forecasts (CPC 2000), experimental forecasts (Barnston 2000, IRI 2000), and research forecasts that may evolve within CLIMAS or elsewhere (ECPC 2000). For the water management sector, we place additional emphasis on seasonal water supply forecasts, because they play a significant role in the operational of many water management agencies, including reservoir regulation for seasonal flood control (Burke and Stevens 1984) and water allocation to users in times of shortage (Glantz 1982); their use is, in some cases, required by law.

The ongoing and proposed activities are well matched with RISA goals. The focus on current and imminent forecasts provides immediate relevance to stakeholders, while also giving us a starting point for initiating conversations about advanced technologies and products. Providing forecast evaluations helps meet expectations generated by earlier CLIMAS activities, because they are a direct response to stakeholder requests. Our research agenda was developed based on broad input across multiple sectors.

*Evaluation of seasonal climate forecasts:* Evaluation of seasonal climate outlooks has advanced to the stage that interactions with stakeholders have been initiated, with the goal of presenting
evaluation of results and obtaining feedback on the effectiveness of the analyses, criteria for evaluation, effectiveness and understandability of graphical evaluation products/explanations.

**Evaluation of experimental probabilistic water supply outlooks:** The CBRFC has, since 1994, generated experimental seasonal water supply outlooks in a probabilistic format based on an ensemble streamflow prediction (ESP) approach (Day 1985). Although these forecasts use a relatively simple dynamic rainfall-runoff model (SAC-SMA) developed in the 1970s (Burnash et al. 1973, Burnash 1995), the ESP forecasts are seen as conceptually more advanced than current operational forecasts based on regression equations. The ESP forecasts are probabilistic rather than deterministic because they use multiple historical meteorological sequences as inputs to create multiple forecasts that are arranged into a probability distribution, and the rainfall-runoff model can track moisture storage conditions within a watershed (e.g., snowpack, soil moisture). Because the experimental ESP forecast record is short and seasonal forecasts accumulate slowly, comprehensive evaluation of the improvements offered by the methodology requires a hindcast/reanalysis approach. This approach, currently being utilized by the CLIMAS team with the cooperation of the CBRFC, is producing evaluations that are in fact the first of their kind for ESP forecasts within the NWS River Forecast Centers. The comprehensive evaluation considers criteria that can accommodate probabilistic forecasts, including the Ranked Probability Score (Wilks 1995) and the diagnostic evaluation measures of Murphy and Winkler (1987, 1992). The ESP forecasts are also being compared to the historical official forecasts through transformation into a single quantity (e.g., ESP median forecast, “best” ensemble member).

**Improve Statistical Seasonal Water Supply Outlooks:** This task was rated at the highest priority in a CLIMAS workshop attended by members of the operational and research forecasting communities (CLIMAS, 1998) and has been reinforced in our ongoing interactions with stakeholders. Although many large research programs are directed at improved hydrologic modeling and forecasting, the present rate of transition into operational tools is slow (Hartmann et al. 2000); the present generation of hydrologic forecast tools is likely to be in place for years to come. However, there are significant opportunities for relatively rapid improvement of the operational seasonal water supply outlooks, based on recent improvements in the skill of climate forecasts. The statistical regression approach used to generate current NWS RFC seasonal water supply outlooks has the capacity to incorporate variables for ENSO-state and the CPC climate outlooks. Presently, only the Southern Oscillation Index (SOI) is used for some watersheds in southern Arizona (e.g., Gila River). More recently developed ENSO measures may be more appropriate, especially the Multivariate ENSO Index (Wolter and Timlin 1993). However, while using a climate index as an exotic variable in the regression equation may capture the present understanding of climatic teleconnections, the choice of indices may not be revisited for a decade or more. In contrast, the mix of tools used to produce CPC climate outlooks is constantly evolving. The techniques available for incorporation of CPC climate forecast skill are limited because there is only a short time series (1995-2000) of current-generation CPC forecasts available and CPC forecast skill is continually evolving with new understanding of the climate system. Further, the CPC forecasts are probabilistic and spatially distributed, while the water supply outlook regression equations are deterministic and use point measurements.

Several steps are required:
Assessment of the value and role of historical official water supply outlooks in water management decisions within the Colorado River Basin: Throughout the winter and spring, the National Weather Service (NWS) Colorado Basin River Forecast Center (CBRFC) and the Natural Resources Conservation Service (NRCS) jointly issue water supply outlooks covering the upcoming season of snowmelt runoff (Hartmann et al. 1999). The outlooks are used to regulate reservoir releases, interbasin water transfers, and fulfillment of water allotments. In Phase 1, we coordinated with these agencies to develop a comprehensive database of historical official forecasts and reconstructed “naturalized” flows, extending back to the 1950s for locations within the Colorado River Basin. We are nearing completion of a comprehensive evaluation of those forecasts (Whitaker et al. 2000a,b,c), which will provide a baseline for evaluating improvements in predictability through use of newer models, data, and/or forecast procedures.

Feedback to Project and Stakeholders

Year 3 plans include continuation of these studies as well as the addition of a review of the state of knowledge of hydrologic variability in the Southwest.

• Organized climate and hydrologic forecast assessment workshop that led to formal quality analysis of water supply outlooks. This research is directed toward identifying forecast skill levels in varying stakeholder utilization contexts and providing the tools needed to achieve more realistic assessments of vulnerability. Information/contacts gained highlighted three areas of future research and outreach: evaluations of forecasts, model improvements, and improving forecast product communication.

• Collaborated with CLIMAS core office to organize a special paper and focus group session on SW climate assessment at the 26th Annual Conference of Water Resources Planning and Management Division of ASCE. Many attendees were practicing engineers-potential uses of the information being developed through CLIMAS.

• The working paper provides an important reference resource for other CLIMAS team members

• Prepared an ENSO/Forecasting case study report

• Participated in the Pilot Stakeholder survey

• Participated in the Spring Fire Workshop

  • Participated in Divided Waters, Common Grounds (San Pedro River cross-boundary conference)

Evaluation of distributed snow estimates and forecasts:

With the cooperation of the NWS National Operational Hydrologic Remote Sensing Center (NOHRSC) and the University of Arizona RESAC project, efforts under Phase 1 have produced a 10-year (1990-1999) database of high-resolution (1 km²) gridded snow conditions (coverage and water equivalent). Combining point, line, and areal measurements from precipitation and SNOTEL gages, NRCS snow courses, and satellite measurements, this database is the first of its kind over such an extended period. It allows, for the first time, comprehensive evaluation of the role of snow conditions in hydrologic variability and predictability.
Evaluation of climate and hydrologic forecasts during climate events: Our experience in tracking use of hydroclimatic information and forecasts during the 1997-98 El Nino event produced insights that have been critical to the success of Phase 1 efforts.

C.5. CLIMATE AND HYDROLOGIC PROCESSES AND TELECONNECTIONS
As established during Phase 1, research on climate and hydrologic processes and teleconnections is essential to addressing stakeholders' climate information needs. As discussed in Sheppard et al. 2000), the Southwest remains significantly understudied in terms of climate and related hydrologic processes.

C.5.1. Fine-Scale Gridded Climate Data (Downscaling)
Using a Digital Elevation Model (DEM) and the cooperative climate station network for Arizona, New Mexico and surrounding areas, we have developed an initial set of multivariate regression models of winter temperature and precipitation. The winter season was selected as the initial temporal study period because of the crucial role precipitation plays in the recharge of dams, aquifers, and reservoirs, and for overlap with the paleoclimate project that deals with winter moisture. Topography is the major source of spatial variability in climate data at these spatial scales, and therefore the models were based on terrain variables such as elevation, slope, aspect, latitude, and longitude. We carried out a comparative analysis of multiple spatial resolutions ranging from 1-9 km² to determine the most appropriate “fine” scale at which to model the climate variables. Our analyses showed that a single regression model was sufficient for creating gridded temperature datasets at 1 km² resolution. For precipitation, a series of sub-regional models was used rather than a domain-wide model. This technique represented a statistical improvement over the domain-wide precipitation regression model, demonstrated the changing influence of terrain predictor variables over space, and allowed for the production of 1 km² datasets analogous to those for temperature. During the remainder of year 3 we intend to finalize model development and complete production of the gridded datasets for the historical record, as far back as station densities will reasonably allow, probably circa 1950. We will also perform diagnostic studies of sub-regional climate variability identified in our data. For example, we wish to better understand the different sub-regional climate responses to ENSO and other variability indices.

The results of CLIMAS stakeholder surveys indicated a large unmet need for historical climate data at a fine spatial scale (~1 km). Many aspects of the CLIMAS project, including both social science and natural science components, will profit from such a data set, as will a very broad range of climatological research and climate impact studies in the region. This spatial scale is considerably finer than the scale of the observing network, and there are many non-trivial issues involved in creating the desired data. Yet, the complex terrain and spatially variable climate of the Southwest make it a useful testbed to develop spatial models for this task. Our goal was to develop a methodology that could ultimately be used to produce several gridded datasets for the region, and which was sufficiently flexible that we could apply it to various timescales in the instrumental record as well as to paleoclimatic timescales. While this work has similarities to other approaches (e.g., PRISM), the particularly fine scale and the needed flexibility led us to develop our own tailored scheme. Ultimately, in addition to a robust methodology, we envisage a suite of gridded data available via a graphical web interface,
whereby users could specify particular pixels or area and view animated maps or download data for temperature, precipitation and other variables.

C.5.2. Climate Variability
Our CLIMAS white paper on the climate of the Southwest (Sheppard et al., in review) highlighted the importance of improving the state of knowledge regarding the North American monsoon system and its role in summer climate variability over our region. Therefore we initiated an ongoing set of diagnostic analyses into the nature and causes of monsoon-related variability for the American Southwest. Our initial foci were on intraseasonal variability of daily monsoon precipitation, and the development of experimental seasonal forecast information. In addition, the neural network techniques from this project have been integrated with the paleoclimate work to create a 1000-year reconstruction of winter precipitation in the Southwest United States.

For the diagnostic studies, we used a nonlinear classification technique to investigate the evolution of the monsoon in southeast Arizona during the 1980-1993 period. The technique successfully captures the evolution of the monsoon, the mature phase of which we found to be strongly linked to an intraseasonal mid-tropospheric wave-like anomalous height pattern over the Pacific-North American sector. This intraseasonal pattern is characterized by the largest amounts of mid-tropospheric moisture over the southwest; it is also the most common mode during the mature phase and the second wettest. In contrast, the wettest monsoon mode shows weak mid-tropospheric height anomalies over North America, but also the largest amounts of mid-tropospheric specific humidity over Arizona and New Mexico at daily time scales that may be linked to tropical forcing.

For the development of experimental forecasts, we used several winter and spring sea surface temperature (SST) indices from the Pacific and Atlantic Basins and winter and spring precipitation as predictors of all-Arizona July-August-September precipitation. We used linear regression and artificial neural networks to test their predictive skills. A P-mode principal components analysis was applied to all 11 predictors of monsoon precipitation to determine the best set of predictors. We found 3 major predictor variables: winter or spring SST indices from the North Pacific/Baja California and North Atlantic Ocean, and winter precipitation. The neural networks produced better results. Our results indicate that antecedent winter and spring conditions in the surrounding oceans, and land-surface conditions seem to modulate monsoon precipitation. In the past, the majority of the seasonal forecasts have given too much weight to tropical SSTs associated with ENSO conditions as compared to SSTs in the Atlantic basin. Our results indicate that both the North Atlantic and the North Pacific SST conditions need to be considered to achieve improved seasonal forecast of monsoon precipitation over Arizona.

C.5.3. Paleo Climate work
- The first two years of Phase 1 were devoted to the development of the CLIMAS Working Paper on the climate of the Southwest.

Our work, using paleoclimatic indicators, has contributed to progress on all three of these questions. The production of a set of high spatial resolution cool season precipitation reconstructions back to AD 1000 was chosen as an interim objective relevant to all three research questions. It would provide a locally-relevant baseline of information on interannual to century
scale variability. This is especially apposite, given the finding in the White Paper (Sheppard et al., op.cit.) of a pattern of century-scale variability in the region. We have focused on a premium set of moisture sensitive tree-ring data back to AD 1000 for the greater Southwest. This was developed with NOAA support of the project “Late Holocene climate variability from long tree-ring chronologies”, under which a set of spatial reconstructions for the region comprising California, Nevada and the Four Corners States was developed. The effective spatial resolution of these reconstructions is fairly crude, perhaps greater than 150 km. During year 3 we have experimented with alternative strategies for developing finer resolution cool season precipitation for each climate division in Arizona and New Mexico. In particular, 19 tree-ring chronologies from across the greater Southwest were used in a comparison of multiple linear regression and neural network techniques for developing transfer functions to convert tree-ring data to records of precipitation. The transfer functions were calibrated or trained on the period 1931-1988, and checked against independent data from 1896–1930. Then the transfer functions were used to reconstruct cool season precipitation back to AD 1000. Both techniques show similar skills and errors, but the neural networks tend to predict extreme events better than multiple linear regressions, whereas the latter better capture changes in the mean. This comparison of techniques was conducted by Fenbiao Ni and Tereza Cavazos (postdocs) working with Malcolm Hughes and Andrew Comrie respectively.

In parallel with this collaborative work with Drs. Cavazos and Comrie, Drs. Hughes and Ni have developed histories (reconstructions) of two features of large-scale circulation (ENSO and PDO) back to AD 1000 through their influence on tree growth in the west. The Pacific Decadal Oscillation (PDO) is described by Mantua et al. (1997) as a “robust, recurring pattern of ocean-atmosphere climate variability centered over the mid-latitude North Pacific basin.” As index, they use the leading eigenvectors of North Pacific sea surface temperatures. Gershunov and Barnet (1998) show that the predictability of the regional effects of El Niño-Southern Oscillation (ENSO) is linked to the phase of the PDO. Reversals of PDO are known from around 1940 and 1976, and one may be under way at the time of writing, leading to decreased predictability of the effects of ENSO in our region. Thus, there is considerable practical value to CLIMAS stakeholders in knowing if these PDO reversals are part of a pattern. It turns out that the trees are able to capture the main features of PDO change (Figure 1), and provide a record 989 years long, which has a clear and strong oscillation of 73 years period (Figure 2). A similarly informative reconstruction of ENSO has been produced, and the relationship between the two is currently under investigation. Following presentation of these last results at the Santa Fe RISA PIs meeting Dr. Hughes has initiated, with Dr. Miles of University of Washington and Dr. Cayan of Scripps, a small workshop with the aim of developing a more robust reconstruction of the PDO and its regional teleconnections for the whole of the West, from the Gulf of Alaska to Baja California.

II. NATURAL CLIMATE VARIABILITY IN THE SOUTHWEST

A review of the status of knowledge about climate and climate processes in the Southwest region was identified as a key priority for the integrated research effort, both by CLIMAS team members and by stakeholders. This review provides a common foundation regarding the current status of knowledge about climate in the region, and provides a context for subsequent CLIMAS research. Both instrumental and paleo archives have since been incorporated into a formal working paper, The Climate of the Southwest, CL1-99, publicly available through the CLIMAS website or by contacting the CLIMAS core office. Another main emphasis of this task group, and a major Year 3 focus, is downscaling and
interpolation of instrumental and paleo data to a target scale of 1km through neural network modeling, reanalyses of NCAR/NCEP reanalysis data, and local/regional station data. This will provide information concerning the nature and causes of interannual and decadal variation on the subregional level. It will also contribute to improved prediction and better understanding of controlling processes and interactions for the summer (monsoon) and winter seasons (mid-latitude systems). Year 3 efforts will comprise a continuation and expansion work begun in previous years. In collaboration with the Border Studies task group, Year 3 work will also include an investigation of cross-border climate processes, specifically the summer monsoon, and the 1950's drought in northern Mexico.

Feedback to Project and Stakeholders

- The working paper helped identify the kinds of research priorities needed for CLIMAS to improve understanding of the climate dynamics in the Southwest and ultimately benefit stakeholders. It is used as a primary resource by CLIMAS team members.
- Downscaling project resulted in part from the outcome of the Pilot Stakeholder survey (e.g., Ranching sector emphasized a great need for information on smaller scales)
- Participated in the ASCE meeting formal focus group discussion concerning the use of paleoclimate data
- Participated in the Climate and Hydrologic Forecast workshop: skill, communication and interpretation of forecasts
- Worked with forecasting, social science, and stakeholder groups to develop user-oriented materials (slide show, presentations, descriptive materials) on climate variability
- Working closely with Border Studies team to investigate cross-boundary climate processes, vulnerability, and impacts on local scales.

C.7. OUTREACH/CORE OFFICE

Since inception of the project, the Core Office has played a pivotal role in coordinating research activities, fostering team interactions and integration, and building ongoing links with stakeholders. We distribute an informative newsletter, which has evolved over time in response to stakeholder feedback, and we maintain and regularly update an official CLIMAS website. Whether it is holding workshops, responding to media requests, representing the project at meetings and conferences, or contributing time and effort to the CLIMAS teams to achieve specific research goals, the Core Office has continued to provide much of the “glue” that holds the project together, and to sustain the project’s identity in the public and research arenas.

integrate the natural and social science components of CLIMAS in the analysis, interpretation, and communication of climate and hydrologic information to regional stakeholders. Key task areas have included building and maintaining the CLIMAS website, stakeholder outreach activities, project coordination, and network building. In addition, the core office participates in a wide variety of conferences and meetings to represent CLIMAS activities.

Feedback to Project and Stakeholders

- Publication of the CLIMAS Update newsletter
- Holds regular CLIMAS team meetings
Develops and maintains the CLIMAS web site
Taught UA graduate-level semester workshop on interdisciplinary, integrated research
Writes press releases and articles
Holds Stakeholder Advisory Committee meetings
Undertakes surveys of stakeholders: in-person (Pilot Stakeholder Assessment), web (Convective Outlook w/ National Weather Service), etc.
Participating in the national Southwest Regional Assessment meetings, report writing and review
Participating in the Safe-Yield Task Force sponsored by Arizona Department of Water Resources
Arranges for CLIMAS team members to attend CLIMAS related conferences and workshops
Serves as direct point of contact for team members and stakeholders
Manages overall CLIMAS project and project budget

IVb. Ranching Community.

A working paper, CLIMAS Ranching Case Study: Year 1, CL3-99, is available via the CLIMAS website or directly from the Core Office. Year 3 work plans include extending the project into additional contrasting regions, Coconino, Yavapai, and possibly, Pinal counties.

Feedback to Project and Stakeholders

- Developed a presentation on climate variability and SW climate history in collaboration with the Forecasting task group. The presentation was given by members of the Forecasting team at meetings of the Malpai Borderland Group, Southern Arizona Cattlemen’s Protective Association, and the Yavapai Cattlegrowers Association when the ranching questionnaires were distributed. The presentation currently resides on the CLIMAS web site for ready access by stakeholders and other CLIMAS team members.
- Extensively uses of climate variability and forecasting working paper as background material when meeting with stakeholders
- Research has involved archival research and interactions with many agencies including: BLM, USFS, Arizona State Lands Department, Agriculture Extension, USDA Agricultural Census, Arizona Agricultural Statistical Reporting Service.
- Actively participated in the Pilot Stakeholder survey

V. TRIBAL STUDIES

This team’s initial objectives were to establish a collaborative partnership in Arizona (InterTribal Council of Arizona (ITCA)) and New Mexico (All Pueblo Council) between CLIMAS and the Native American tribes. Out of these interactions, a project was identified to provide information to the ITCA to facilitate an assessment of the feasibility of using renewable energy sources and associated technology on Indian lands. Assessments of climate and socio-economic aspects of energy and technology have led to a development of a climate information CD (which includes information on wind, temperature, sunny days, etc.) in coordination with the UA Center for Applied Spatial Analysis. The CD is under going tribal review and is intended to be used by individual tribes in their own regions of Arizona. Work in Year 3 will include the continuation of program development as additional tribes and organizations become aware of the opportunities offered through the project and help guide the direction of the research program. For example, the Southern Piute Consortium has requested assistance with an
examination of traditional responses to drought and use of mitigation strategies in the Four Corners area. With assistance of Consortium director, researchers will incorporate tribes from southern Utah, southern Colorado, northwestern New Mexico, and northern Arizona to gather the information.

**Feedback to Project and Stakeholders**

- Continuing interaction with key tribal groups (InterTribal Council of Arizona and All Pueblo Council, NM) to identify specific projects where CLIMAS and tribes could collaborate on analysis of climate impacts. Answers to the research question will provide the foundation for identifying specific projects in collaboration with interested tribes.
- Developed a working paper (currently under tribal review) describing “how to work with tribes” as well as Native American-US Government Indian Policy history, to address the need for such knowledge among CLIMAS team members.
- Climate CD has the potential to be adapted to other contexts in the SW
- Participating in the National Assessment program

**VI. BORDER REGION**

Year 3 efforts will build on the results of earlier work on past climate and hydrological variability in the Southwest and border region to identify periods of severe drought in the instrumental and proxy records. It will also build on the assessments of climate forecasts in the Southwest to identify the types of forecasts issued for northern Mexico and the extent of their use (in collaboration with researchers at UNAM and IMADES in Mexico and colleagues at Scripps). In addition, the team intends to better integrate stakeholders from the border region and northern Mexico into CLIMAS activities.

**Feedback to Project and Stakeholders**

- Participated in the Divided Waters, Common Grounds (San Pedro River) Conference. Conference discussions included issues of management of the San Pedro River in a binational context. The conference clearly showed the need for consideration of the vulnerability and variability on the Mexican side of the border.
- Completed multiple reviews, and publications on climate impacts in the border region, which helped identify several high priority research questions that might be addressed in CLIMAS and related projects.