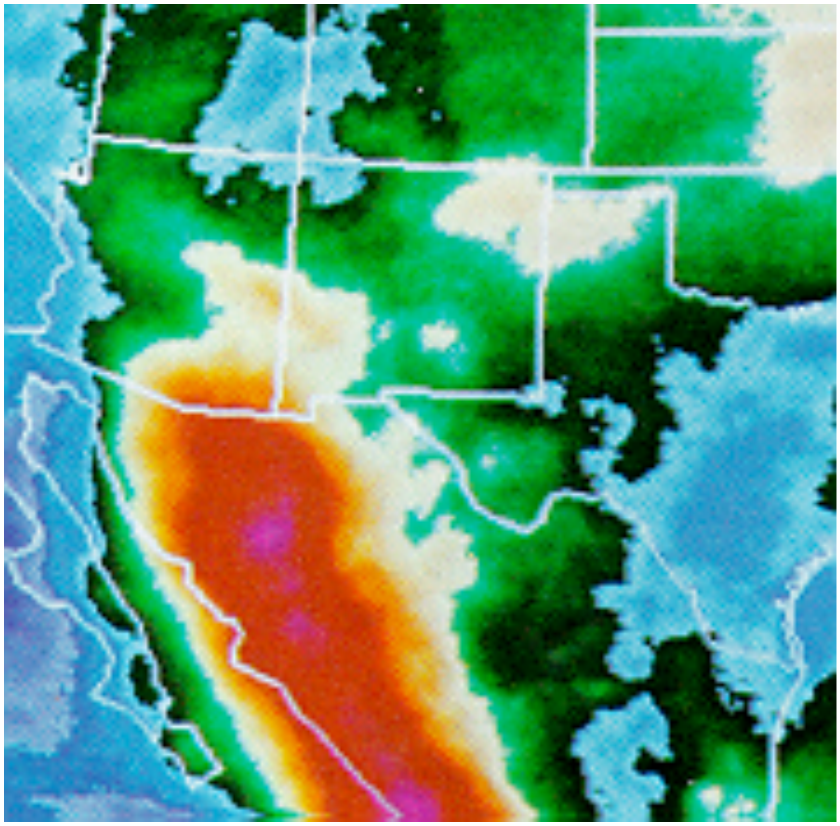

Report on

Research Opportunities for
Climate and Society Interactions in the North American Monsoon Region

February 2002*

Based on the
Workshop on Applications and Human Dimensions of Monsoon Research
18-20 June 2001
Loews Ventana Hotel
Tucson, AZ

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The Institute for the Study of Planet Earth (ISPE), University of Arizona
and
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Foreword

This report describes opportunities for integrated research in the bi-national North American Monsoon region with respect to summer precipitation. Currently, two general approaches can be seen in this region. First, there are programs based on a science view of the problem, such as the Pan American Climate Studies, and GEWEX American Prediction Program in which physical scientists have developed research plans based on their best judgment of what research will advance understanding of they physical system. On the other hand, regional integrated science and assessment projects, such as the CLIMAS program, and other human dimensions researchers are looking at how people locally and regionally understand the influence of climate on their activities.

The report is based on discussions and breakout group reports from a *Workshop on Applications and Human Dimensions of Monsoon Research*, held June 18-20, 2001 in Tucson, AZ. The goal of the workshop was to begin addressing how to integrate the climate and societal interactions research approaches, so that science plans and projects might be informed by the understanding of the vulnerabilities, concerns, and needs of those affected by monsoons, *and* at the same time, human dimensions, applications, and assessment might be informed by the state of knowledge and anticipated advances in physical science understanding.

The workshop was not intended as an “outreach” workshop, but rather one in which people were assembled people who understand and have studied potential users’ needs in this region with respect to summer precipitation. The participants have acted either as academic observers, or as managers, policymakers, and analysts, including: water resource managers, fire managers, emergency managers concerned with flood and drought forecasts and energy issues, the public health sector, and agricultural extension staff, and BLM employees who interact with ranchers and farmers. In addition, we invited physical scientists involved in monsoon region research and in the development of the NAME science plan, program managers, who are currently or might fund work in the region. Thus the workshop was designed for “inreach”, in which we hoped to provide an opportunity for interaction among representatives of key user communities, social scientists and applications experts, and North American monsoon researchers.

The goal of the workshop was to develop this interaction by linking the monsoon research community with the well-developed research community that is already working on climate and societal interactions and on monsoon-region applications of climate information. A critical step will be to articulate how integrated regional science can assess the usefulness of monsoon climate information (e.g., what are the societal issues affected by the monsoon, what sorts of information do users specifically need, when is the information needed, and at what temporal and spatial scales should the information be provided). In essence, a "roadmap" needs to be developed of how NAME scientific findings could be used in applications activities. As a result of this workshop both communities will be prepared to prospect for niches where the scientific findings of NAME might be useable.

Equally important, the workshop was designed to foster productive working relationships among relevant NOAA programs: GEWEX American Prediction Program (GAPP), the Pan American Climate Studies Program (PACS), and the Regional Integrated Science and Assessments Program (RISA).

The following report provides a summary of many of the human dimensions and climate and societal interactions in the region, and then identifies some of the issues that must be considered in undertaking stakeholder-driven, problem-oriented activities in the bi-national monsoon region. It presents several initial themes in which research could begin. It also identifies a number of activities that could promote bi-national cooperation and the use of monsoon information in the region.

This report describes:

1. Establishment of a two-way conversation between the climate-societal interactions and human dimensions research communities in the region and the monsoon research community and development of ongoing working relationships among the GAPP, PACS, and RISA programs.
2. Several themes for stakeholder-driven (i.e., problem-oriented and user- driven) science related to monsoon research, which addresses issues that are important in the region and are influenced by variability of the monsoon.
3. A plan for theme teams to develop research plans that will outline potential human dimensions, applications, and assessment efforts that may be done in tandem with NAME.
4. Actions that can be initiated soon in addition to research planning which could help integrate AAHD research with NAME and other warm season precipitation research.

Information on the workshop and on climate and society interactions research in the monsoon region is available on the conference web page, http://www.ispe.arizona.edu/events/monsoon.

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Key Issues

The key findings of the workshop identified three major areas of opportunity as well challenges facing an effort to enhance interaction among key user communities, social scientists and applications experts, and North American monsoon climate researchers. All three challenges represent critical steps within the broader effort to provide improved climate information to support more informed decision-making.

1. Development of the framework to facilitate synergist integration of physical science research and climate-society interactions research in the North American Monsoon region will be critical. Establishment of this framework is necessary to ensure that subsequent research provides insights into how climate information and products are and could be used, while simultaneously identifying applications for future research to develop experimental climate products.

2. Selection of critical natural resource or society-relevant problems that are affected by North American Monsoon climate and are place-based issues. This problem-oriented research focuses on identifying what climate information is wanted and when, and how such information relates to specific decisions within the problem solving process. In interactions with users, desired climate products are identified and the usefulness of prototype climate products is assessed. The place-based orientation ensures that the identified user needs and interests in regionally based climate information guide research to enhance understanding of climate variability in the intermountain western

3. Enhanced network of key observations and data management for improved real time monitoring and prediction of user defined climate information and products that complements the suite of key observations and data management needed to meet NAME climate dynamics and processes study research objectives. Significant overlap is anticipated between the observations and data management needed for NAME physical science research and climate-society interactions research. However, recognized differences in the formats, timing, time scales, spatial scales and presentation of data needed to meet user defined climate information and products will require climate-society interactions funding to augment existing and/or planned NAME physical science resources for observations and data management.

Transcending these three NAME areas of opportunity to enhance interaction among key user communities, social scientists and applications experts, and North American monsoon climate researchers, is the interplay of the relatively continuous physical landscape of the NAME study region (in terms of climate and biology) and the distinct political/cultural/economic/and institutional boundary separating the United States and Mexico. Superimposition of this boundary problem on to the NAME study region is recognized as an additional complication that will need to be overcome in the process of working to ensure 1) Development of the framework to facilitate synergist integration of physical science research and climate-society interactions research in the North American Monsoon region, 2) Informed selection of critical natural resource or society-relevant problems that are affected by North American Monsoon climate and are place-based issues, and 3) establishment of an enhanced network of key observations and data management for improved real time monitoring and prediction of user defined climate information and products. The critical nature of this relatively sharp contrast in political, cultural, economic, and institutional operating environments across the bi-national US/Mexico border will be a unique challenge within the USGCRP (e.g., NOAA, NASA, NSF) portfolio of climate-society interactions research and assessment activities.

Overview of the North American Monsoon

Monsoons are characterized by seasonal reversal of prevailing wind, with this seasonal wind shift often accompanied by major changes in weather, i.e., summer rains, with often abrupt onset, and winter dryness. A major monsoon occurs over Asia, and a weaker monsoon over North America. In both regions, the monsoon process is driven by: land mass is colder than the ocean in winter, but this land- sea contrast reverses in summer. Winds are forced by seasonal changes in the pressure gradient forces related to the temperature difference (his figure, cool/hot): higher sea level pressure (SLP) over land in winter forces offshore flow at the surface, but in the summer, lower SLP over land forces onshore flow at the surface.

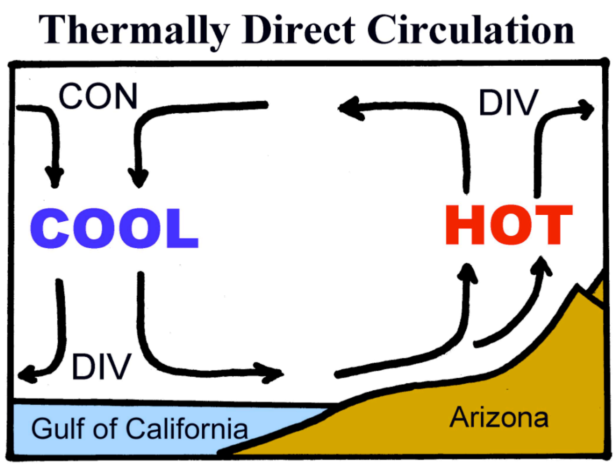

Figure 1: Thermally-driven monsoonal air circulation regime, courtesy R. Maddox, University of Arizona

Over southwestern North America there is a continental-scale monsoon-like circulation regime that is associated with the summertime precipitation climatology of the region. While some aspects of the seasonally varying climate over the southwest U.S., Mexico and Central America have been well described, others have not. Large-scale patterns of drought and streamflow anomalies have been empirically linked to potentially predictable Pacific SST anomalies on interannual to decadal time scales. Links between the summer monsoon in southwestern North America and summertime precipitation in the Great Plains of the United States may have predictive value at the seasonal time scale.

The structure of the low-level circulations that supply moisture from the tropics along the Gulf of California and from the Gulf of Mexico, the precipitation patterns and associated divergent circulations, and the moisture and energy budgets over the core North American monsoon region remain largely unvalidated and incompletely understood. Dynamical understanding of the seasonal march of rainfall and its variability over Mexico and Central America is incomplete. The meteorological observation and analysis system for this region must be improved to describe and understand relationships among low-frequency anomalies of the warm season precipitation regime and the nature and frequency of significant weather events such as hurricanes and floods.

In the North American Monsoon (NAM) region, 10-30% or more of the annual rainfall occurs in July, the month the monsoon usually begins. It is often preceded by a dry period in May and June. Weather phenomena associate with the NAM include thunderstorms and lightning, summer floods, and windstorms. In years in which the monsoon is weak, seasonal drought may occur.

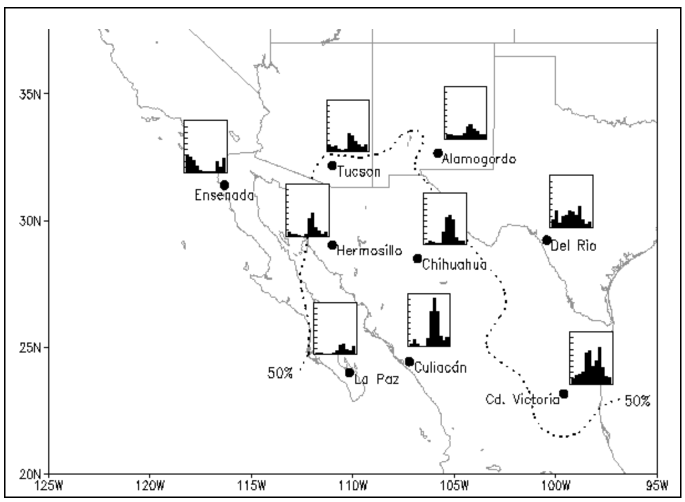

Figure 2: Seasonality of precipitation by month for the Julian calendar year. The dotted line denotes the northern limit of region in which the monsoon accounts for more than of the half the annual rain fall, courtesy R. Maddox, University of Arizona

Monsoonal precipitation is an intermittent stochastic process. Individual precipitation events occur in association with synoptic, diurnal, and mesoscale atmospheric circulation systems. The number and / or intensity of these events over a month or season can vary substantially from year to year. Part of this time-averaged variability appears to be a response to subtle variations in the distribution of tropical SSTs, but the mid-latitude response to tropical ocean anomalies is regionally and seasonally dependent.

Large seasonal-to-interannual variations in the advective moisture supply from the oceans to the North American continent help to govern the warm season precipitation regime. There is also persuasive evidence that potentially predictable anomalies of soil moisture, snow cover and vegetation may play an important role in the seasonal variability of North American warm season precipitation patterns. Because these land surface anomalies are themselves largely determined by fluctuations of precipitation, it has been suggested that there are important feedbacks between the atmosphere and land surface that can be either positive (in which case climate anomalies are self-sustaining) or negative (self-suppressing). Diagnosis of these feedback pathways will require significant advances in the quality of observations and modeling of the NAMS domain.

The human-environment context of the monsoon region

The bi-national border region

The North American Monsoon region encompasses a bi-national region, with a number of common environmental issues along the U.S.-Mexico border. Because of this border, there are cultural dimensions and complexities brought into these environmental issues that would not be present if there were no trans-national border. If is important to recognize how the implications of the border interact with the environmental issues.

The environmental issues pose challenges for bi-national environmental management and the institutions on the border, including the role and effectiveness of environmental social movements and bi-national institutions; the political ecology of economic globalization, such as the different institutional structures on either side; the impacts of decentralization and democratization on environmental practices of local governments. Policy issues include: how to design effective institutions, mechanisms for resolving conflicts, and understanding public responses to free trade.

The international political boundary also bisects the physical geography of rivers, ecosystems, and aquifers. This geography leads to competition over transboundary and international rivers, and shared groundwater resources. Border rivers and aquifers are facing shortages due to increased usage by agricultural expansion, urbanization, and groundwater mining. At the same time, new concerns are rising such as Native American water rights and in stream flows for ecosystems and endangered species. Pollution also crosses the border affecting water quality and air quality.

Drought and climate change are two of the current environmental issues facing the region. Droughts are part of the history of the region, influencing the development of institutions and laws. Conflicts arise between the U.S. and Mexico in low water years, but the region has not experienced a recent drought approaching those seen in the paleoclimatic record. The San Pedro border watershed is an example of monsoon affects on the region: water availability on both sides of the border is influences for riparian areas, and also for town water supplies, mining, and ranching. The July-August-September has the highest variability of any season in the year, and precipitation can vary by as much as the annual average. Climate variability, including drought and river fluctuations, poses problems for water use agreements and the institutional arrangements managing them.

There are several human impacts on the transboundary system. Air pollution comes from automobiles and industry. Toxic and hazardous wastes, including heavy metals and pesticides, have impacts on health and live expectancy, and there is illegal disposal, and transfrontier shipment of waste. Urban water issues include water shortages and pollution in cities and colonias. In twin border cities such as Ambos Nogales, water and air pollution easily cross the border, creating attention for solutions on both sides. Diversion of water for human use, pollution, and land use change, poses threats to natural ecosystems, diverse flora and fauna of the region through habitat alternation. Two contemporary driving forces are the growth in maquiladoras, which predates the North American Free Trade Agreement (NAFTA), and a parallel population migration to the border region. Several bi-national agreements and institutions relate to the border and its environment:

International Boundary Commission (1889)
La Paz Agreement (1983)
Integrated Border Environmental Plan (1991)
Border XXI Program (1997)
NAFTA (1993): Border Environment Cooperation Commission, North American Development Bank, Commission for Environmental Cooperation

Two other institutional changes include the Mexican Land Reform of 1992, and the emergence of non-governmental organizations in the region, particularly Mexican NGOs such as Pronatura, Grupo de Cien, Movimiento Ecológico Mexicano. Several U.S. NGOs with interests in Mexico and the border region are: National Wildlife Federation, Audubon Society, and The Nature Conservancy. Several bi-national NGOs include: the Arizona Border Ecology Project, California Environmental Health Coalition, and the New Mexico Interhemispheric Resource Center.

Several collective responses are emerging to these bi-national environmental issues, and are not necessarily government driven projects, but driven by NGOs. Urban water issues, especially in poor communities, are being addressed by the Water Works Program (New Mexico, Texas) and Acuaférico (Ambos Nogales). A consortium funded by the Ford Foundation, the Paseo del Norte Air Quality Task Force, is working on a bi-national air quality accord. The issue of toxics and hazardous wastes has been taken up by the Border Ecology Project, Arizona Toxics, and La Red Fronteriza de Salud y Ambiente. Several institutions and public interest organizations have mounted coordinated campaigns to force creation of solutions and design of programs for the conservation of ecosystems.

The border region is thus one of bi-national cultural and economic integration, but where there are disparate economic and political institutions B and both are far from their national capitals. The national governments have established environmental management institutions and bi-national diplomacy. Economic transformation includes migration of many to the border for work in the maquiladoras; this trend is related to NAFTA and a larger globalization process. Political transformation is occurring in Mexico, with decentralization and democratization affecting the environmental practices of governments at local and state scales. Although the border is a small part of the Mexican environment, the emergence of NGOs in Mexico is raising the issue in Mexican government and politics. Finally, climate variability and climate change have implications for the current environmental issues and the institutions seeking to address them.

The ecological "non-border"

From an ecological standpoint, the border bisects a coherent ecological setting in which biophysical elements or soils, vegetation, climate, fauna, and flora are more or less constant.

Several transnational protected areas exist:

Organ Pipe Cactus National Monument (Arizona)
Cabeza Prieta National Wildlife Refuge (Arizona)
Reserva de la Biósfera el Pinacate y Gran Desierto de Altar (Sonora)
Area de Proteccion de Flora y Fauna Cañon Santa Elena (Chihuahua)
Big Bend National Park (Texas)
Area de Proteccion de Flora y Fauna Maderas del Carmen (Coahuila)
Imperial NWR (California)
Reserva de la Biósfera Alto Golfo de California y Delta Río Colorado (Baja California/Sonora)

There are also several shared aquifers: Hueco Bolson, 3000 square miles around Juarez-El Paso; the Mesilla Bolson, 7500 sq. miles around Chihuahua-New Mexico, and Mesa de San Luis, 3000 sq miles around Baja California, Sonora, California and Arizona. Two concerns with regard to these aquifers are that there are not clear rules for the governance of these resources, and the uncertainty of the impacts of climate variability and climate change for these resources.

The function of the borderland ecosystems is fundamental to support biological activity and sustainable economic development of the region. Sustaining the function of these ecosystems requires a new approach to cooperation among institutions in the region. Some possibilities are:

- Promote efforts to develop integrated strategies leading to more effective environmental governance
- Help promote transboundary regional cooperation through project to develop and apply scientific knowledge and tools
- Promote sustainable development
- Enhance efforts to more effectively manage transboundary water resources in a context of environmental, political, and economic change
- Build and enhance institutional arrangements for transboundary policy-making
- Develop climate applications: natural phenomena, anthropogenic effects
- Environmental diplomacy: through information exchange and decision making processes regarding the shared borderlands.

The Southwestern U.S.

The southwestern US also has a high population growth rate, increasing urbanization, a shift from an economy based on agriculture to a service economy; and competing claims to resources, including water, open space, and wildlands. Eighty percent of the population is urban, and 80% of the land is federally owned in AZ. Climate variability is embedded in culture, as shown by festivals around the start of the monsoon rains in Native American cultures such as the Tohono O'Odham tribe, and saints day festivals of Hispanic communities.

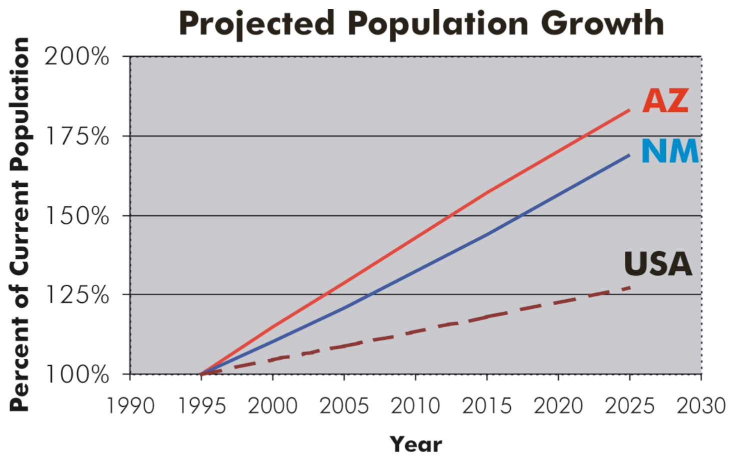

Figure 3: Projected population growth in Arizona, New Mexico, and the US as a whole, courtesy B. Morehouse, University of Arizona.

The Climate Assessment of the Southwest (CLIMAS) has studied questions such as: Who is affected by climate variability? When and where? And how? These studies have helped identify needs for climate information and forecasts, barriers to use, and opportunities for use of climate information as well as partners for more detailed studies. Five of the groups that CLIMAS has identified as affected by climate variability, and thus present opportunities for integrated study are water resource managers, fire managers, emergency managers, ranchers and farmers, and the public health sector:

- Water resource managers are interested in water supply forecasts, and thus in forecasts of the timing of monsoon onset and its duration, rainfall patterns and volumes, and lightning forecasts. Fire managers are also interested in lightning forecasts, as fires are often started by lightning. Monsoon onset and duration, seasonal to monthly forecasts of precipitation and temperature anomalies are all information that water managers say they could use. On longer time scales, they are interested in the history of fire and climate interactions, and projections of climate anomalies up to 100 years in the future.
- Emergency managers are concerned with flood forecasts and drought assessments, and energy issues. The social effects of drought, potential for mitigation to be put into place.

- Ranchers and farmers have many of the same interests: monsoon onset and duration, summer temperatures and precipitation, and winter precipitation
- The public health sector is interested in climate and weather patterns which lead disease outbreaks, including winter and summer precipitation patterns and timing. Valley fever, for example, often follows several months after a wet period. Air quality is also a public health issue related to climate.

From the perspective of CLIMAS researchers, a partnership between NAME and assessment, applications, and human dimensions programs in the region can reinforce integration of the physical science research with societal needs in the region, including the potential to be interactive, participatory, and responsive to these needs. The science program can also be an opportunity to promote regionally-focused climate services.

Water resources in northwest Mexico

Water resources management and administration in Mexico are functions of the Comisión Nacional del Agua (CNA). There are thirty-seven administrative regions.

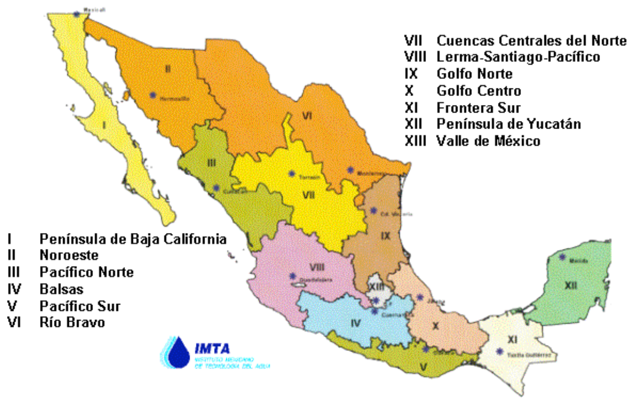

Figure 4: Administrative regions for water management in Mexico, courtesy J. Aparicio, IMTA.

In Mexico, much of the population, irrigated area, and the internal gross production are in the north, northwest, and central regions, but this area accounts for only 28% of the runoff, which is concentrated in the south.

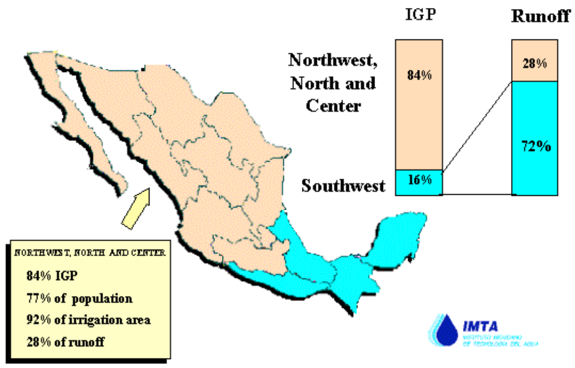

Figure 5: Water and gross domestic product (IGP) for regions of Mexico, courtesy J. Aparicio, IMTA

The Northwest Mexico is extremely arid and the precipitation in this region is primarily in the summer. As in the southwestern U.S., the population in Mexico is growing, and is increasingly urbanized. One example is the management of water in the Pacifico Norte administrative region (III). Within the northwest region there is more water in the south, but better land for agriculture in the north; more rain falls in the mountains east of the coast. Several dams in the mountains collect water, which is then used in irrigation of more than two million acres of land. This system is known as SHINO, the integrated hydrologic northwest system.

The Instituto Mexicano Tecnología del Agua (IMTA) is studying the relationship between ENSO, crop productivity and water availability. At both the core monsoon and the regional scales, the warm season precipitation has a strategic importance to Mexico. Therefore, seasonal climate forecasts in the region would have considerable social and economic impact. But forecasts of the large-scale seasonal impacts of ENSO are not provided in a temporal or spatial scale to be useful for hydraulic infrastructure planning. A major effort is needed to build forecasting capabilities for region-specific systems such as the monsoon.

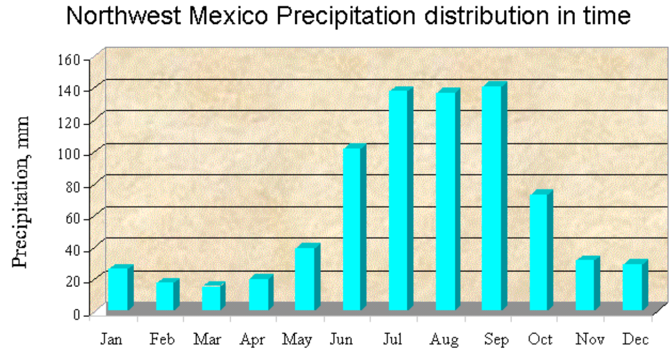

Figure 6: Annual recipitation distribution in Northwest Mexico, courtesy J. Aparicio, IMTA.

The Rio Grande/Río Bravo

A second river basin shared between the U.S. and Mexico is the Rio Grande/Río Bravo. In contrast with the border-crossing Colorado River, the Rio Grande/Río Bravo defines the border for many miles, and there are two dams on the border: La Amistad and Falcón. A treaty between the US and Mexico is based on flows from both sides of the border: the countries share equally the flows from the main Rio Grande/Río Bravo. The flows from the Mexican Río Conchos, Río Salado, and other tributaries are split 2/3 to Mexico and 1/3 to the U.S. over a 5-year period. When the active capacity of the US portion of the La Amistad and Falcón reservoirs is filled with water that is the property of the US, the 5 year cycle is considered ended and a new five year cycle begins.

The five-year cycle is intended to adjust for the variability in the basin. Droughts in the Mexican part of the basin in the last several years have prevented Mexico from meeting its share for more than 5 years. This part of the basin is influenced by ENSO. Compared to climatological means, summers and winters of El Niño tend to be wet, and La Niña is associated with average conditions. The middle and lower Rio Grande are influenced by the monsoon precipitation and variability. Unlike the snowmelt-dominated runoff of the upper part of the basin, summer precipitation represents a large portion of inflows. The relationship rivers, dams, and major diversions in the basin are shown in the following figure.

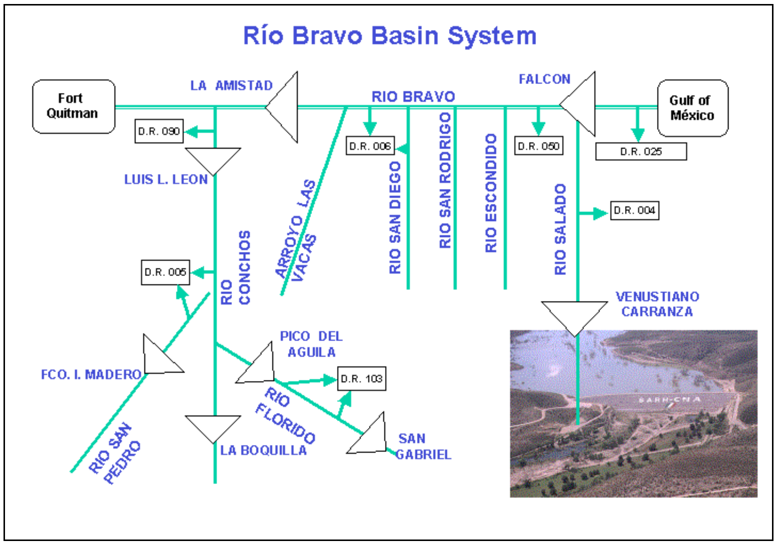

Figure 7: Rio Bravo Basin system, courtesy J. Aparicio, IMTA

Within the US, there interstate compacts for both the Rio Grande and Pecos rivers. The compact between New Mexico and Texas does not allow a debit, or under delivery of water in a water year. After two dry years, New Mexico may under deliver this fall, and thus be required to make up the amount in the spring. In the Rio Grande Compact between NM and Texas, NM has almost always carried a debit, but accrued a credit during some wet years in the 1990s.

In addition to interstate compacts, there are two major issues on the Rio Grande: first, the water rights on the Middle Rio Grande have not been adjudicated, but is thought to be over-allocated. There is a contentious process ongoing to adjudicate the river. The adjudication issue has become important as more water is being used in the Middle Rio Grande Valley for many purposes, and because there is less surplus upstream. Several demands for water have more political and judicial or legal clout than previously. These include environmental uses of water to protect ecosystems and endangered species, but also cultural uses by the acequias and pueblos in the region. The second major issue is implementation of recovery program for the silvery minnow, an endangered fish in the Middle Rio Grande. The minnow has been negatively affected by low water in the river, which is sometimes essentially dry during the irrigation season. Under the Endangered Species Act, the USBR may be forced to release water for the fish.

In response to these issues, the USBR is becoming more of a natural resource management agency, not just managing water. They are seeking ways to maximize the use of Aevery drop@ of water, through detailed planning. Currently, detailed planning occurs on short-term and daily operations time scales, but planning on medium and longer time scales is more limited. In order to plan more carefully, the USBR would like to improve its water supply and demand forecasting.

Water supply is affected by climate variability: in the headwaters, snowpack supplies most of the runoff for reservoirs such as Heron in the Upper Rio Grand; but in the middle and lower Rio Grande, summer precipitation, including monsoon variability, can have a significant contribution to reservoirs. In the Pecos River basin, monsoon moisture controls both supply and demand. The USBR currently uses Natural Resource Conservation Service and National Weather Service runoff forecasts. These are incorporated into the Upper Rio Grand Water Operations Model (URGWOM). The model uses spring runoff forecasts (monthly from March through July) from the Natural Resource Conservation Service and NOAA West Gulf River Forecast Center to produce calendar year daily forecasts for the sites marked with a yellow sun in the figure below.

Figure 8. Schematic of URGWOM forecasting model above Elephant Butte Reservoir, courtesy S. Boelman, USBR. URGWOM forecast model produces calendar-year daily forecasts for the sites marked with a yellow stars, based on spring runoff forecasts.

Demand forecasts are important in order to plan carefully to meet these demands in operations. On longer time scales, they are concerned with demand from future growth and growing municipal and industrial uses. On shorter time scales, they use daily temperature and wind speed to estimate evapotranspiration (ET) as part of demand forecasting. Winds are a major factor because wind increases evapotranspiration dramatically. A USBR "ET Toolkit" is used (www.usbr.gov/rmsg/nexrad). ET is higher in the lower reservoirs (Elephant Butte). They also estimate river "losses" to groundwater, which are proportionately higher during low flow conditions.

There is potential for climate and weather forecasts to improve water demand and supply forecasts. Weather forecasts can be useful for forecasting ET, which is a predictor of irrigation demands. Irrigation demands as well as natural ET is important for managing specific reaches of rivers. For example, they are trying to make operational plans 5-6 days out for the Tiffany reach of the Pecos; ET can alter the anticipated amount of water in the river significantly. Wind speed is particularly important. With regard to seasonal forecasts, in these basins in which summer precipitation is an important part of annual inflows to reservoirs, a seasonal forecast of the monsoon could be important both in forecasting supply and demand.

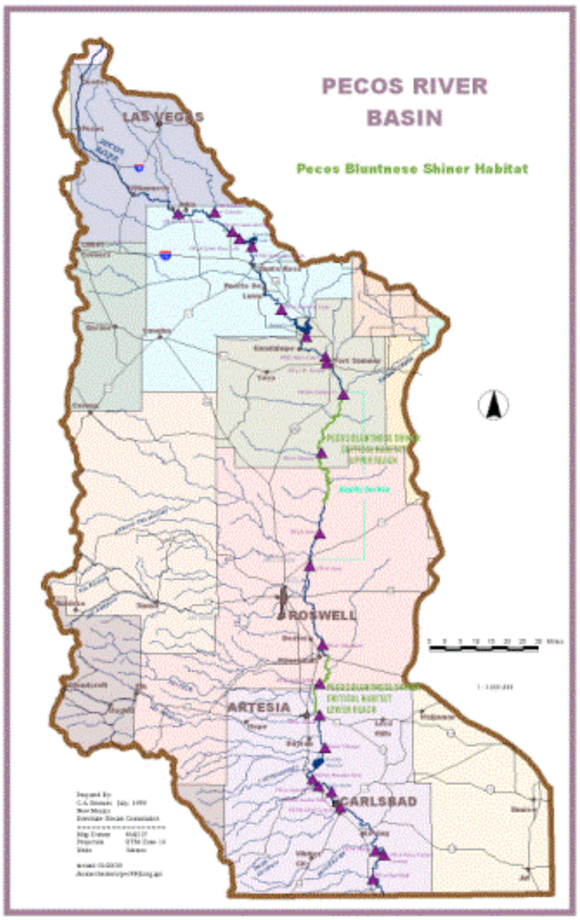

Figure 9: Pecos River Basin, a tributary of the Rio Grande, courtesy S. Boelman, USBR.

Integrated Research

Three talks on examples of integrated research programs were presented at the workshop, as experiences to draw from. These examples related to fire and climate, climate and health, and weather and emergency management.

The North American "Firesoon"

The Climate, Ecosystem, and Fire Applications (CEFA) program at the University of Nevada Desert Research Institute was established and is maintained under a 5-year Assistance Agreement with the Bureau of Land Management (BLM) National Office of Fire and Aviation to:

- Perform studies and applied research to improve the understanding of relationships between climate, fire and natural resources
- Serve as a liaison between the user and the research community by providing product training, assisting in technology transfer and eliciting user feedback
- Produce and provide climate and weather information directly for fire and ecosystem decision-making and planning
- Improve operational fire weather forecasting using new knowledge of climate and meteorology
- Develop and maintain a data warehouse for fire, ecosystem and related climate information
- Develop a human dimensions component

CEFA partners include the Bureau of Land Management, the U.S. Forest Service, the California Department of Forestry and Fire Protection, the National Park Service, the California Interagency Fire and Forecast Warning Units, the Scripps Institution of Oceanography California Applications Program (CAP) and Experimental Climate Prediction Center (EPCP), the National Fire Intelligence Coordination Center, the International Research Institute (IRI), and the Western Regional Climate Center (WRCC).

The monsoon interacts with fire risk and fire management in a number of ways. The fire season in the Southwest is typically May through early July, with monsoon onset determining the when fire managers might potentially to release firefighters and associated resources from the southwest to fight fires in other regions. With the onset of the monsoon, fire risk drops dramatically in the southwest, but increases in Nevada, northern Utah, and southern Idaho due to increased dry thunderstorms in that area. Prescribed burns are fires set to burn off areas to avoid potentially larger fires in the future: the Cerro Grande fire in the Los Alamos area started as such a prescribed burn. Prescribed fires typically begin post-monsoon, when the risk of larger fires decreases. However, there is an increasing desire among fire managers to perform spring and summer burns. Precipitation is the *least important variable* in the view of fire managers engaged in fire-risk management. The most important include relative humidity, and dry versus wet thunderstorms, because of the potential for high lightning from dry storms to start fires.

CEFA makes a number of monthly and seasonal forecasts available to users, evaluates these forecasts, and is developing value-added monthly and seasonal climate forecasts for wildfire planning. Examples include: experimental mixing height product based on the output of the NCEP Eta model; incorporating vegetation characteristics into climate model forecasts; California hourly fire danger; determining what relationships are between the southwest monsoon, and wildfire, prescribed burns and fire use, and development of lighting climatology information for the entire west. Relative humidity anomalies are important to this user group, and CEFA makes a humidity anomaly product available on several time scales (monthly, below).

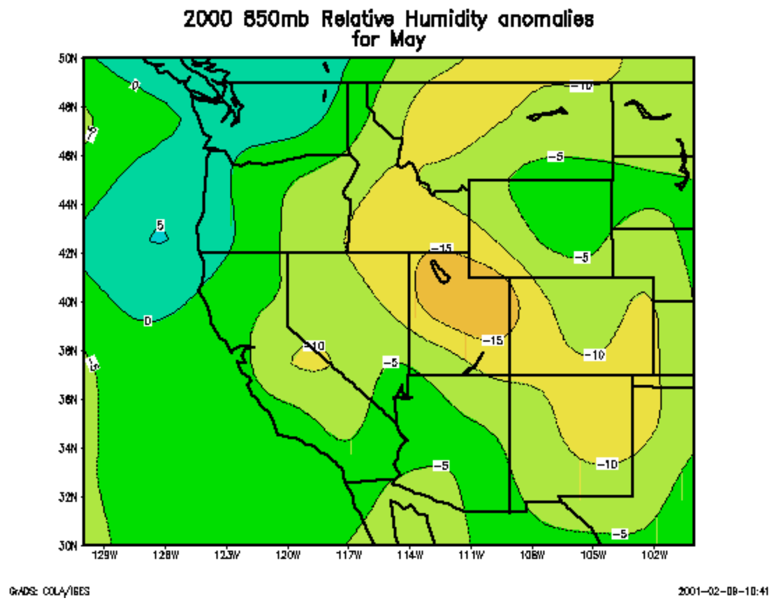

Figure 10: Relative humidity anomalies near the surface (850mb), an example of a product from CEFA, courtesy T. Brown, Desert Research Institute.

Typically, there is a rapid ending of the Southwest large fire season, usually the first week of July, with the beginning of the monsoon. This also marks the beginning of the period when fire can be utilized for prescribed burns in this are. At this point there is also an *increased* risk of dry thunderstorms across Nevada, northern Utah, and Southern Idaho. Some findings from CEFA=s interactions with state fire management officers, coordinators, and fuel specialists are:

- The monsoon affects wildfire and prescribed fire/fire use activity in a critical way
- Managers indirectly use historical monsoon climate information. Fuels specialists say they do not use it
- Monsoon forecast information is used to plan for when the fire season will end.
- Improvements they would like to see are more accurate 6-10 day and monthly forecasts
- Monsoon information that is desired but currently not have available includes information on characterization of the monsoon and quantification of variables
- This information could change fire management decision-making or planning by

improving decision-making on resource availability and allowing for more seasonal fire use planning and execution

- These CEFA partners think that the economic impact of monsoon information could be $10=s to $100=s K to > $1M in a big year.

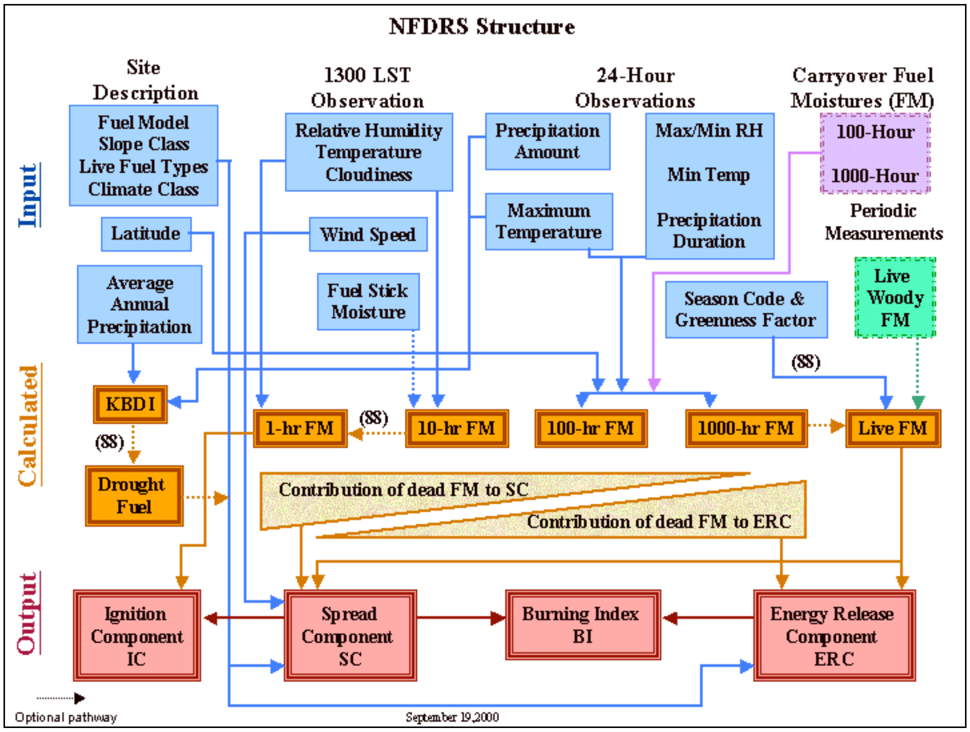

Figure 11: The NFDRS analysis system shows some of the information that goes into indices of fire risk, and into fire managers decision making and planning. The NFDRS uses inputs including weather conditions a and forecasts to generate indices such as 1000-hour fuel moisture, potential for spreading, energy release, and burning index. Courtesy T. Brown, Desert Research Institute.

One way CEFA communicates with their partners is via a web page. The climate and weather information they make available and more information on CEFA, is available at www.dri.edu/Programs/CEFA

Climate and Valley Fever

Valley fever is a respiratory disease resulting from the inhalation of airborne spores from the soil dwelling fungus, *C. immitis*. Although the majority of those infected are asymptomatic (60%), a small number experience potentially fatal conditions as a result of infection. Valley fever is endemic to the southwestern US and Mexico (map below), and as well as parts of Central and South America. In the USA there are 6,000 to 8,000 severe cases resulting in 50-100 deaths with the costs of treatment are estimated at $60 million/year. Infection may occur when spores of a soil-dwelling fungus, *C. immitus*, become airborne and are inhaled. The fungus responds to changes in climate conditions: the fungus is most often found in soil following a rainy period, but a subsequent dry period is required for spores to become airborne.

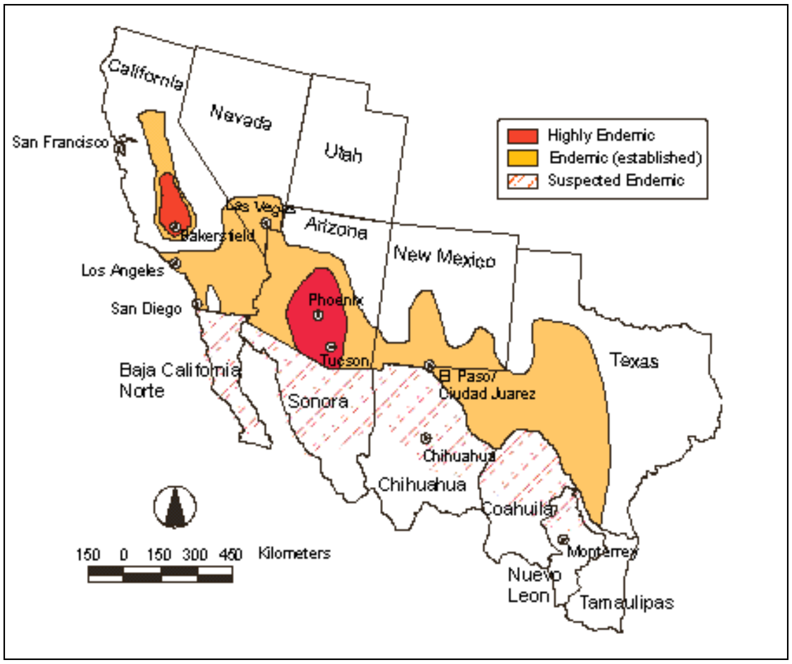

Figure 12: Endemic areas for Valley Fever, courtesy A. Comrie, University of Arizona.

The aims of this research are to:

- understand the relationship between climate variability and valley fever incidence, to develop a multivariate predictive model, in tandem with climate forecasts
- coordinate the research with interdisciplinary UA group (plant pathology, epidemiology, VFCE, USGS)
- Involve stakeholders so that the results can be useful to state health officers and health care providers
- Work with public health officials to make recommendations to highly susceptible people based on climate conditions
- Develop the capability to make forecasts of valley fever incidence 3-9 months in advance, in real-time and with climate forecasts

A number of climate variables were found to have a significant relationship with incidence of Valley Fever. Most of the critical climate variables that can be used to predict the incidence of Valley Fever lead the onset by one year or longer prior providing a potentially important predictive tool for public health management. The climate and valley fever project has developed a better understanding of a complex relationship between climate and incidence of valley fever. Predictive models have been developed, and these experimental tools will be shared with a larger valley fever research group, including public health officials. The next steps in this research will include creating an improved valley fever endemicity map based on understanding of climate relationships, and considering the interaction of climate variability and climate change on the extent of the endemic area. Future research will explore similar climate-disease relationships for dengue fever and encephalitis.

The CALJET/PACJET experience: bridging research and operations

The Pacific Land-falling Jets Experiment (PACJET) and California Land-falling Jets Experiment (CALJET) address short-term winter weather prediction along the U.S. West Coast, emphasizing precipitation forecasting. The experiments were designed to bring researchers and forecasters together to test how new data could help better predict flood-producing storms. PACJET's first field phase was conducted in January-February 2001; CALJET was performed during the 1997-98 EL Nino. Both CALJET and PACJET examine the difficult process of weather forecasting on the West Coast, including: a) the relationship between El Nino and coastal storms, b) the value of new observations to the forecast process, c) how weather forecasts affect key sectors of California's economy, and d) how affected groups interpret and use weather information.

The CALJET experiment provided forecasters with data to increase forecast lead times during a very rainy season. For example, on February 3, 1998, meteorologists at the National Weather Service's Monterey Forecast Office issued a flash flood warning for the Pescadero Creek region on the California coast six hours in advance of the actual event. Data provided by scientists flying CALJET aircraft missions hundreds of miles off the coast made it possible to issue this forecast with much greater lead time than the National Weather Service's 2005 goal of 60 minutes.

Extra time in response to a flood emergency can be significant. For example, in the case of reservoirs, decisions by managers are critically dependent on the quality and lead time of precipitation forecasts. With several hours lead-time on both the beginning and end of heavy precipitation, it is possible to make adjustments to reservoir levels that carefully avert flooding and/or dam failure. Further, these adjustments can be made without compromising previous decisions regarding water supply, a particularly scarce resource in the west.

Because of the value of additional lead-time, the California Department of Water Resources, the Governor's Office of Emergency Services (OES) and the San Mateo County Sheriff's Division of Emergency Response all used information from the CALJET field experiment during 1998. The intense media response to the El Nino event, in addition to the improved forecasts, led the State of California OES to request a four-week extension of CALJET. This favorable response from the state and local emergency and water management communities was a catalyst in planning for a strong user component in PACJET. Extensive outreach and briefing activities have been conducted in response to CALJET and in planning for PACJET, with the goal of linking research to operational forecasting needs and forecast users.

To prepare for PACJET, the U.S. Army Corps of Engineers, the California Governor's Office of Emergency Services Coastal Region, San Mateo County, the California Nevada River Forecast Center, the Navy, the Pacific Coast Federation of Fisherman's Associations, National Weather Service forecasters, and private meteorological services provided input on the development of potential forecast products. In addition, two workshops focusing on all aspects of the weather research-to-operations process were held. One product for end users that emerged from the September 1999 workshop is a schematic designed to give users accurate descriptions of critical characteristics of storms offshore, outside the range of coastal observing systems, and often with their full characteristics not observed by satellite. The importance of particular storm characteristics for forecasters and forecast users helped PACJET scientists select which information should be included in the schematic. Of particular significance are the characteristics of the low-level jet. From these discussions, PACJET scientists also learned of the importance of the melting level, which is the altitude above which precipitation is in the form of snow. The melting level is important because of its impact on transportation and determining what fraction of mountainous watersheds would accumulate snow rather than produce runoff. Because no normal data sources offshore can observe the melting level, it is a key variable that PACJET seeks to measure.

In addition to the workshops, PACJET planning included a series of user group meetings to:

- reach more groups that would benefit from PACJET data and information,
- tap into the needs of individual groups and encourage more dialogue on how those needs might be met through PACJET, and
- develop better methods for transferring weather information to users.

Examples of positive outcomes from these meetings include:

- The meetings held with emergency managers in both California and Washington introduced the program to a wider audience of potential users and identified geographical regions that could benefit from the experiment. Consequently, the program is poised for a dramatic increase in the number of counties utilizing PACJET weather products.
- A PACJET briefing at the Army Corps of Engineers District offices in San Francisco, it was recommended that a PACJET working group of individuals and agencies that manage federal and state reservoirs should be formed in the near future. Better quantitative precipitation and melting level forecasts would impact decisions these managers must make regarding adjustment to reservoirs.
- A broadcast meteorologist from Sacramento now participates in planning sessions for PACJET, after she heard a CALJET briefing at the California Weather Symposium in 1999. Her station is planning to beta-test a new format for wind profiler data, including monitoring of the melting level for transportation applications.

Outreach efforts have been built into CALJET and PACJET from their inception. They address a key challenge in meteorological research: exploring the relevancy of promising new research to the real world that decision-makers operate within. Most important, however, is the emphasis on creating a continuous feedback loop whereby new ideas from research can be combined with the real-world needs of forecasters and forecast users to help identify new directions for both research and applications.

Existing climate-related activities in the region

Studies of climate and society interactions in the monsoon can build on a number of ongoing efforts in the basin. The North American Monsoon Experiment (NAME) is one, and is described first below; several other efforts are described as well. There are many federal and state agencies operating in the region, but these are not described here.

The North American Monsoon Experiment (NAME)

NAME is an internationally coordinated, joint CLIVAR – GEWEX process study aimed at determining the sources and limits of predictability of warm season precipitation over North America. The NAME science plan, is available on their web page: www.cpc.ncep.noaa.gov/products/precip/monsoon/NAME.html . NAME is managed by a Science Working Group that is approved by CLIVAR (U.S. and International) in consultation with U.S. GEWEX. The scientific basis of NAME is that state-of-the-art climate models do not accurately represent the spatial / temporal variability of warm season precipitation. A fundamental first step towards improving prediction is the clear documentation of the major elements of the warm season precipitation regime and their variability within the context of the evolving Ocean-Air-Land annual cycle. A number of studies over the past decade have revealed the major elements of a North American warm season Monsoon System (NAMS). The NAMS provides a useful framework for describing and diagnosing warm season climate controls and the nature and causes of year-to-year variability. The NAMS provides a physical basis for determining the degree of predictability of warm season precipitation over the region.

The NAME objectives are to promote a better understanding and more realistic simulation of:

- The evolution of the monsoon and its variability.
- The response of the warm season circulation and precipitation patterns to slowly varying boundary conditions (e.g. SST, soil moisture).
- The diurnal heating cycle and its relationship to the seasonally varying mean climate.
- Intraseasonal variability of the monsoon.

These objectives will be addressed by a symbiotic mix of diagnostic, modeling and prediction studies together with enhanced observations. NAME studies will constitute a multi-scale approach in both space and time; this approach will include focused activities in the core monsoon region (Tier I), on the regional-scale (Tier II) and on the continental-scale (Tier III). Each Tier has a specific research focus aimed at improving warm season precipitation prediction, and activities related to each tier will proceed concurrently. The tiers are shown on the map below.

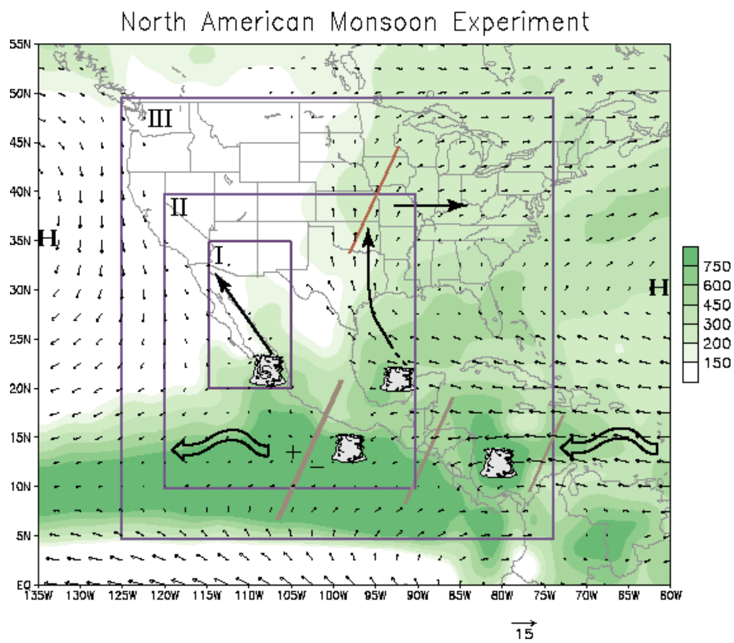

Figure 13: Schematic illustrating the multi-tiered approach of NAME. The schematic also shows mean (July-September 1979-1995) 925-hPa vector wind and merged satellite estimates and raingauge observations of precipitation (shading) in millimeters. Circulation data are taken from the NCEP/ NCAR Reanalysis archive, figure courtesy W. Higgins, NCEP.

Implementation of NAME will include Empirical and modeling studies that carry forward the US CLIVAR/GEWEX Warm Season Precipitation Initiative (2000 onward), and initiate new elements. Field activities are planned in the core monsoon region during the summers of 2003-2004, including build-up, field, analysis and modeling phases (2001-2008). An Intensive Observing Period (IOP) will operate for a period of 4 summer months (JJAS) during 2003 and 2004 to coincide with the peak monsoon season and maximum diurnal variability. Other activities include:

- Compile and analyze real time / historical data (e.g. hourly / daily rainfall data) from Mexico.
- Plan and establish observing networks (raingauge, wind profiler, radar, radiosonde, pilot balloon, Ron Brown). Rainguage stations are shown below; approximately 60 new event logging gauges in SW-NE transects, will sample gradients in rainfall from the Gulf of California to the Sierra Madre Occidental.
- Conduct a NAME Model Intercomparison Project (NAMIP).
- Coordinate with other CLIVAR/GEWEX field programs and with the operational centers.

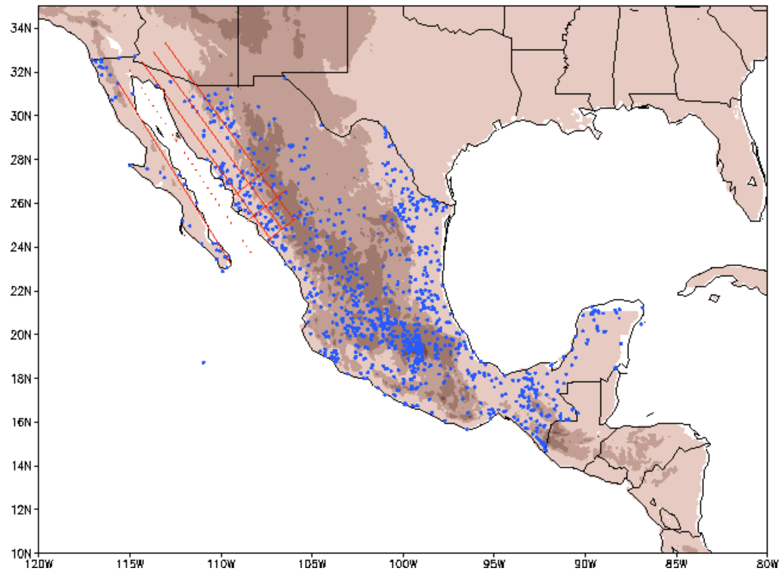

Figure 14: Rainguages which will be used for NAME, figure courtesy W. Higgins, NCEP.

Anticipated benefits of NAME include:

1. Improved simulations of warm season precipitation over and near tropical and subtropical land areas in regional and global coupled models.
2. Advancements in the development of the real-time climate observing system.
3. The production of consistent data sets over North America.
4. Joint international experience in the development and exploitation of in situ and satellite data products.
5. Improved short-term climate prediction.

Regional Climate Modeling System for Central America

A regional modeling system is being developed at the Center for Geophysical Research (CIGEFI) at the University of Costa Rica in collaboration with scientists from the Universidad Nacional Autónoma de México (UNAM). This system should significantly improve the prediction skill of the regional climate system, of the regional scientific infrastructure, and it will provide a unique opportunity to enhance regional collaboration among National Weather and Hydrological Services and other regional institutions. Regional forecasts could be used as an additional tool to produce user information for planning of activities and for the amelioration of socio-economic impacts of regional climate systems. The regional modeling system has spatial resolution similar to MM5, higher than General Circulation Models, and is driven by time dependent boundary conditions provided by models such as the CCM3 and ECHAM2.

The Regional Water Resources Committee of the Central American Isthmus (Comite Regional de Recursos Hidraulicos; CRRH) serves as the regional manager for this project. The CRRH is guided by a Board of Directors, composed of the Chairmen of the National Committees of

Meteorology, Hydrology and Water Resources of the governments of Guatemala, Belize, El Salvador, Honduras, Nicaragua, Costa Rica and Panama. A strong working relationship exists between NOAA/OGP, the Universidad de Costa Rica, and the Universidad Nacional Autónoma de México, and the project will benefit producers and users of climate-related information in Mesoamerica. Atmospheric scientists working along with regional based institutions and national meteorological services from Central America have shown great interest in developing capabilities in their own research laboratories for performing numerical model simulations and forecasts of regional climate. The project is supported by NOAA/OGP Climate and Societal Interactions Program.

Semi-Arid Land-Surface-Atmosphere Program (SALSA)

SALSA is a multi-agency, multi-national research effort that seeks to evaluate the consequences of natural and human-induced environmental change in semi-arid regions. The ultimate goal of SALSA is to advance scientific understanding of the semi-arid portion of the hydrosphere-biosphere interface in order to provide reliable information for environmental decision-making. It is funded by NASA and USDA. The initial location for focused SALSA research is the Upper San Pedro River Basin. (www.tucson.ars.ag.gov/salsa/)

Climate Assessment for the Southwest (CLIMAS)

CLIMAS is a NOAA-funded Regional Integrated Science and Assessment Program, which are studying the climate and society interactions of the Southwestern U.S., with a particular focus on the Lower Colorado and border regions. CLIMAS areas of study have included Water management, ranching and farming, sensitivity of the Southwest's urban water sector to climate variability, and building partnerships with Native Americans in climate-related research and outreach. CLIMAS sponsors an annual Fire and Climate Workshop. (www.ispe.arizona.edu/climas)

Sustaining semi-arid hydrology and riparian areas (SAHRA)

SAHRA is an NSF-funded Science and Technology Center at the University of Arizona Department of Hydrology and Water Resources. SAHRA has partners in SAHRA's mission is to promote sustainable management of water resources in semi-arid regions, through stakeholder-driven interdisciplinary research, aggressive public outreach and strong education initiatives, leading to rapid dissemination and application of cutting-edge scientific knowledge. SAHRA integrates stakeholder-driven research, education and knowledge transfer efforts that span the physical and behavioral sciences so as to produce information, analysis, curricula, expertise, and ultimately information that can increase hydrologic literacy and positively impact water policy and water resources management. (stc420r1.hwr.arizona.edu/about/index.html)

Inter-American Institute for Global Change Research (IAI)

The IAI (ww2.iai.int) was established in 1992 by a formal agreement among more than 17 countries in the Americas, as a result of an idea formally proposed by President George Bush at the 1990 White House Conference on Science and Economics Research Related to Global Change. It is dedicated to the advancement of societally-relevant global change research in the region and has a focused program in the area of seasonal to interannual climate variability and research applications. The Brazilian Instituto Nacional de Pesquisas Espacias (INPE) currently hosts the IAI Directorate, which serves a leadership and coordination function for IAI research activities. Understanding global scale climate and environmental phenomena depends upon collaboration among various players, including states. The IAI was conceived as a mechanism to facilitate this collaboration and to provide scientific information to support decision-making. (ww2.iai.int)

IAI is a significant instrument to enhance capacity building and to promote collaborative research on global environmental change in the Americas. Jointly funded research and training played an important role in the El Niño event of 1997-98, providing much of the regional scientific underpinnings for discussions with stakeholders regarding the nature of El Niño, and the potential utilization of climate information in preparedness efforts. The IAI served as a framework for the dissemination of climate forecasts and information during the event. NOAA and IAI joined with other regional and international partners to co-sponsor a series of Climate Outlook Forums (see below), Applications Workshops and Conferences throughout the region, with several activities in Mexico and Central America. The IAI funds several Collaborative Research Networks in the region. One of these is "Climate Variability and its Impacts in the Mexican, Central American and Caribbean Regions, " the main objective of this three year project is to improve our understanding of the elements that control regional climate variability in Mexico, Central America and Caribbean, in order to provide more accurate and adequate climate predictions to fulfill some of the needs of particular socioeconomic sectors. Changes in water availability in the Mexico, Central America and Caribbean region on intraseasonal time scales are of major concern because of their impacts on agriculture, hydropower generation and the environment

In February 2001 IAI sponsored a regional training course, "Curso Regional sobre Producción y Usos Practicos de Pronósticos - Preparandonos para la Variabilidad Climática y los Eventos Meteorológicos Extremos en Mesoamérica", in San José, Costa Rica.

UNESCO/HELP

Hydrology for the Environment, Life and Policy (HELP) is a United Nations Environment, Scientific, and Cultural Organization (UNESCO) program with the goal to deliver social economic and environmental benefit to stakeholders though sustainable and appropriate use of water by directing hydrological science towards improved integrated catchment management. HELP seeks to break a "paradigm lock" in which process hydrology is separated from water managers and other stakeholders. Thus, water related observations will be collected in large catchments, but not just physical measurements: sociological, economic and legal data will be collected as well. This framework is intended to allow water law and policy experts, water resources managers, and water scientists to work together on water-related problems. The involvement of stakeholders is intended to produce results that are directly beneficial to society's needs. One of the catchments that HELP has designated to work in is the San Pedro basin, which drains north from Sonora into southeastern Arizona. (www.nwl.ac.uk/in/help)

Climate and weather related institutions in the region

Studies of climate and society interactions in the monsoon draw information from a number of climate and weather related institutions in the region. A subset of these climate and weather related institutions and information brokers are described below; however, there are many additional federal and state agencies operating in the region.

Comisión Nacional del Agua

In Mexico, water management and development and weather prediction are housed in the same agency, the Comisión Nacional del Agua, or CNA, with headquarters in Mexico City. There are 37 hydrological regions in Mexico, with 13 administrative regions for water management. These regions are defined by basins and cross political boundaries of states in Mexico, and there is an office in each region. (www.CNA.gob.mx). Two major divisions are the Servico Meteorológico Nacional (SMN), the Mexican weather service (smn.cna.gob.mx). and Instituto Mexicano Tecnología del Agua (IMTA), the Mexican water resources technology agency. The IMTA hydrometeorology group is responsible for development and transfer of technology, as well as scientific research in issues related to hydrometeorological phenomena. It creates and implements studies, methods, databases and objective tools for the analysis and prediction of weather and climate (galileo.imta.mx/mm5.index.html)

Western Regional Climate Center and other climate and weather information brokers

The WRCC is one of six regional centers funded by NOAA to provide access to data and products of regional interest. Products are continuously evolving based on what is learned from requests for information. The WRCC Internet site has been expanded to provide western state maps showing the most recent hourly wind direction, speeds, and gusts; dew point and temperature fields; and barometric pressures. This information is used by forecasters and others to determine the development of weather systems. Detailed climate summaries for more than 1,800 locations throughout the West are also provided. Information is on a broad range of climate variables --from daily temperature and precipitation to heating degree days--can easily be obtained. (www.wrcc.dri.edu)

Other climate and weather information brokers in the western U.S. include:

- The National Weather Service Weather Forecast Office in Tucson, which produces a convective storm outlook: www.wrh.noaa.gov/tucson/
- The Colorado Basin River Forecast Center (www.cbrfc.noaa.gov) and West Gulf River Forecast Center for the Rio Grande (http://www.srh.noaa.gov/wgrfc/)
- Arizona State Climatologist (geography.asu.edu/azclimate), and New Mexico State Climatologist
- National Resource Conservation Service

Experimental Climate Prediction Center

The Scripps ECPC (ecpc.ucsd.edu) is one of the NOAA Applied Research Centers engaged in experimental climate prediction. EPCP southwest products are on the web at: ecpc.ucsd.edu/projects/uastc/. ECPC is attempting to develop an integrated global to regional climate prediction capability by:

- Identifying coupled modes of interannual variability
- Persistent surface anomalies in the ocean and land have a strong influence upon atmospheric features that would otherwise be unpredictable beyond a few weeks.
- Developing models capable of predicting these modes
- Experimental state of the art dynamical and statistical models are being acquired from national centers (e.g. NCEP) as well as being developed within the ECPC.
- Evaluating the predictive capability of these models
- Experimental predictions are made routinely to evaluate how well these models can predict at various time scales ranging from days to years.
- Transferring methodologies to NCEP, IRI, and Regional Application Centers.
- ECPC has transferred parts of its prediction methodology to a number of regional application centers. We also work with NCEP and IRI, as well as the regional application centers, to further develop and apply various experimental prediction techniques.

The California Applications Project:

The California Applications Program (CAP; meteora.ucsd.edu/cap/) aims to develop improved forecasts for interested users in California and the surrounding region. By working directly with users, the program will be able to evaluate forecasts from the user perspective to improve their usefulness and to develop new forecast application strategies. Their objectives are to: 1) evaluate weather and climate forecasts for California , 2) improve local models and forecasts of water resources and fire risks , 3) tailor and disseminate forecasts to local users. Their approaches are:

- Downscale climate forecasts and simulations from global to regional to local scales
- Provide a variety of forecasts in real time
- Determine forecast reliability using historical hindcasts
- Work directly with users to develop useful forecast applications

Regional Climate Outlook Fora

The NOAA/OGP Climate and Societal Interactions program has organized a series of regional climate outlook for a in Caribbean countries, and countries of Central and South America. These for a are aimed at creating consensus seasonal precipitation forecasts and better understanding user needs for climate information. Fora are intended to bridge gaps in information and technical capability; facilitate research cooperation and data exchange within and between regions, and improve coordination within the climate forecasting community. Meetings included both forecast users and producers, with the goal of maximizing forecast utility within the limits of predictive capabilities. This effort is organized by with funded from USAID Office of Foreign Disaster Assistance (OFDA) and NOAA-OGP, with cooperation from the WMO, IAI, IRI, and others. In 1998, there was a Climate Outlook Forum for the Mesoamericas, May 18-19, 1998, Panama City, Panama. An assessment of the Climate Outlook Fora is available at: www.ogp.noaa.gov/mpe/csi/pdf/PretoriaSumRpt2.pdf.

The NOAA Climate Diagnostics Center:

Climate Diagnostics Center (CDC) works to advance understanding and predictions of weather and climate variations on time scales ranging from a week to centuries. To achieve its mission, CDC develops and applies a wide range of research methods, particularly emphasizing state-of-the-art diagnostic techniques, to elucidate fundamental processes governing climate phenomena such as droughts, floods, and the El Niño-Southern Oscillation, and to identify the causes of longer-term (decadal to centennial) climate variations. CDC also performs extensive intercomparisons of observational and climate model data, an activity vital to improving current research and prediction models. In addition to its basic climate research, CDC provides an extensive range of experimental climate services. A common objective of within these experimental climate services is to address NOAA's goal of improving mechanisms for dissemination of climate and weather products by providing:

- Enhanced weather and climate monitoring products.
- Experimental climate forecasts.
- WWW based value-added access, analysis, and visualization tools for climate data.

Recommended Themes and pilot activities

Workshop participants articulated four key areas for stakeholder-driven, problem oriented research and applications. Key themes are

1. Fire and Climate: an area in which there can be progress quickly,
2. Ecosystem Management: an area in which a number of programs and NGOs are working, but there is a potential to address the interaction of climate variability with ecosystems,
3. Integrated Water management, including water and health
4. Rainfed systems: there are important rainfed systems, both natural ecosystems and dryland farming and ranching on both sides of the border.

In addition, six activities were identified that should be initiated in the near term, which will cross-cut the themes above, as well as stand on their own. The workshop participants recommended that teams be identified to develop implementation plans for each of these activities.

1. Research, applications and assessment activities around the four themes. Teams should develop interdisciplinary, problem-oriented, and place-based plans and lead implementation in these initial themes: Fire and climate, ecosystem management, dryland/rainfed systems, and integrated water management.
    a. Plans should include a summary of ongoing activities (research, applications, assessment) and identify potential funding sources
    b. Teams should entrain others who were not at the workshop but who are key to studies and activities
    c. Teams should liaison with NAME science planning
2. Monsoon regional observations and data systems. The workshop participants recommended building on the NAME observations to develop a mesonet for the bi-national monsoon region. The plan for this development should be interdisciplinary, stakeholder- *and* science-guided. This activity should build on efforts begun in 1993 as part of the EMVER experiment. This activity should:
    a. Include real time access to monitoring and research observations, provide coordinated data management and access, NAME-collected data, but other relevant information

3. Promote development of regional climate services, including a functional regional forecast center in northwest Mexico, and one for the Southwestern U.S. This activity should take advantage of existing institutions and develop new ones as appropriate. In NW Mexico, it should build on efforts begun during and after the 1993 EMVER experiment.

Several teams will also address cross-cutting issues that need special attention. Teams will work on making these things happen across other themes and activities:

4. Building lasting partnerships

5. International/bi-national issues, including links to CLIVAR/VAMOS, HELP, IRI, and others
6. Outreach and awareness. This component will take shape as the other specific themes develop, i.e., as there are products and information to reach out with.

Implementation issues

Building lasting partnerships and trust

- Interdisciplinary
- stakeholder-based
- interactive
- designed to improve understanding and perceptions
- reduce conflicts in resource management

Stakeholder Guided Science

- process studies
- modeling
- prediction
- break barriers on spatial and temporal scales, variables, disciplinary, seasonality
- need to plan programs with both user priorities and scientific feasibility in mind

Stakeholder Guided Observations and Data Systems

- satellite as well as *in situ*
- long-term observations versus field campaign
- real time access versus long-term archive
- legacy issues, what observations to leave behind when this project is done?
- prioritize both by user priorities and scientific program needs

Findings of the discussion sessions of the workshop

1. NAME is not stakeholder driven, but will provide a foundation for integrated climate and society studies. There is a need to break traditional scale, variable, disciplinary, and paradigm "locks".

2. To meet the North American monsoon climate and societal interactions research goals will require the addition of stakeholder-guided observations and data systems, not just science guided. More variables should be considered for observation and analysis, variables more relevant to users' need.

3. Tackle the hard issues as well as the easy, and those that are primarily cross-disciplinary.

4. Get users ready to use information via outreach and working with them, as in SALSA and PACJET. The bonus will be regional and place-based support for the NAME research program.

5. Credibility of forecasts issue – a better understanding is needed of the affect and use of a low probability forecast. How much certainty is needed? It likely differs among variables. For example, confidence in the onset may be more important to some users than a lower confidence seasonal precipitation prediction.

6. Partnerships are a *process* not just a workshop or implementation of a worldwide web server. They require personal relationships and institutional relationships as well. Adopt the CLIMAS perspective of stakeholders as any person, group or institution that could contribute to or benefit from the success of NAME and Monsoon CSI, or that has the capacity to use climate information. Potential stakeholders include: water resource managers, fire managers, emergency managers concerned with flood and drought forecasts and energy issues, the public health sector, and agricultural extension land management officials who interact with ranchers and farmers.

7. There is support for both assessment and applications activities in Mexico, associated with seasonal- and intra-seasonal climate variability. Mexican participants noted support, and both Mexican and US investigators are interested in participating in assessment activities that do not stop at the US border. In particular, interest was expressed in a RISA-like assessment for the border regions.

8. Several specific aspects of interannual and seasonal variability were noted as of interest to various user groups, although often for different reasons and different potential purposes:
    a) temporal variability within and between monsoons
    b) spatial variability
    c) onset and canicula
    d) peripheral areas of the monsoon also important

9. Data management is needed which addresses the bi-national nature of the monsoon and societal interactions with it. Too many maps and datasets stop at the border.

Additional comments from workshop participants can be found in Appendix 3, an integrated summary of discussion group findings.

Summary and Conclusions

The workshop identified three major areas of opportunity as well challenges facing an effort to enhance interaction among key user communities, social scientists and applications experts, and North American monsoon climate researchers. All three challenges represent critical steps within the broader effort to provide improved climate information to support more informed decision-making.

1. Development of the framework to facilitate synergistic integration of physical science research and climate-society interactions research in the North American Monsoon region is critical. Establishment of this framework is necessary to ensure that subsequent research provides insights into how climate information and products are and could be used, while simultaneously identifying applications for future research to develop experimental climate products.

2. Selection of critical natural resource or society-relevant problems that are affected by North American Monsoon climate and are place-based issues. This problem-oriented research focuses on identifying what climate information is wanted and when, and how such information relates to specific decisions within the problem solving process. In interactions with users, desired climate products are identified and the usefulness of prototype climate products is assessed. The place-based orientation ensures that the identified user needs and interests in regionally based climate information guide research to enhance understanding of climate variability in the intermountain west. The workshop participants identified four initial themes for problem-oriented and place-based research:

   i. Fire and climate
   ii. Ecosystem management
   iii. Integrated water management
   iv. Dryland/rainfed systems

3. An enhanced network of key observations and data management is needed to provide real time monitoring and prediction of user defined climate information and products. These user-driven products would complements the suite of key observations and data management needed to meet NAME climate dynamics and processes study research objectives. There are differences in the formats, timing, time scales, spatial scales and presentation of data needed to meet user defined climate information and products will require climate-society interactions To meet this need, funding will be required to augment existing and/or planned NAME physical science resources for observations

and data management.

Transcending these three NAME areas is the reality that the relatively continuous physical landscape of the NAME study region is bisected by the boundary separating the United States and Mexico. Superimposition of this boundary problem on to the NAME study region is recognized as an additional complication that will need to be overcome in the process of working to ensure 1) Development of the framework to facilitate integration of physical science research and climate-society interactions research in the North American Monsoon region, 2) Informed selection of critical natural resource or society-relevant problems that are affected by North American Monsoon climate and are place-based issues, and 3) establishment of an enhanced network of key observations and data management for improved real time monitoring and prediction of user defined climate information and products. The critical nature of this relatively sharp contrast in political, cultural, economic, and institutional operating environments across the bi-national US/Mexico border will be a unique challenge within the USGCRP (e.g., NOAA, NASA, NSF) portfolio of climate-society interactions research and assessment activities.

Appendices

A1. Participants list
A2. Agenda
A3. Integrated Summary of Discussion Group findings
A4 List of Posters
A5. Invitation Letter

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A2. Agenda

Note: presentations available on www.ispe.arizona.edu/events/

Workshop on Applications and Human Dimensions of Monsoon Research
18-20 June 2001
Loew's Ventana Hotel
Tucson, AZ

Monday evening session, 18 June:

Opening reception and talks, 6 -9pm

Overview of the North American Monsoon: Bob Maddox (University of Arizona)

The North American "Firesoon" in the West: Postmortem on the 2000 season and outlook for the 2001 season, and a discussion of integrated research on climate and fire: Tim Brown (Desert Research Institute, Reno, NV)

Tuesday a.m. 19 June

8:30 Purpose of this workshop: charge to participants, and short summary of monsoon related research programs (Jonathan Overpeck, Univ of Arizona/ISPE, and Andrea Ray, NOAA/Climate Diagnostics Center)

Short self-introductions of all workshop participants

9:00 Staking a claim in NAME, "Summer"-izing Climate Science in the North American Monsoon Region" (Barbara Morehouse, Institute for the Study of Planet Earth, University of Arizona)
9:30 Environmental Issues along the U.S.-Mexico Border: Drivers of Change and responses of Citizens and Institutions (BobVarady, Udall Center for Public Policy, University of Arizona)
10:00 Water Resources Issues in Mexico (Javier Aparicio, Instituto Mexicano de Tecnología del Agua)
10:30 Rio Grande Water issues (Shawn Boelman, USBR)
11:00 Break
11:15 Border Oasis: Ecosystems of the monsoon region (Ruben Lara, Pronatura Peninsula De Baja California)
11:45 Summary of key issues and general discussion session. A "discussant" will summarize the key issues submitted by the speakers before the meeting and any that came up during the morning, and lead the discussion.

Lunch at the hotel, 12:15-1:15

Tuesday afternoon

Examples of Integrated Research (in addition to fire-climate research talk Monday night)

1:15 Climate and health: valley fever project (Andrew Comrie, University of Arizona)

1:35 CALJET: lessons from a pilot applications project (Marty Ralph, NOAA/Environmental Technology Lab)

2:00 Discussion groups a brainstorming session on opportunities for integrated research and opportunities for interactions.

5:00 End discussions

6:00 Poster session and cash bar (any participant may bring a poster)

7:00 Workshop Group Dinner at the hotel

Wed a.m. 20 June

Begin in plenary

8:30 Short talks on programs in the region, max 10 min/speaker:
Monsoon research (GAPP, PACS, NAME),
UNESCO/HELP (Varady), SAHRA (Sorooshian),
Mexican projects/agencies
Overview of the RISA program: Implementing interdisciplinary programs (Roger Pulwarty, NOAA Office of Global Programs)
Others as appropriate

9:30 Brainstorming groups reports, 15 min each + general discussion and charge for next discussion groups

10:30 Break

10:45 Discussion groups to discuss issues for a roadmap for integrated research, issues for stakeholder-driven physical science research, potential applications activities, links to operational agencies, potential HD research, joint projects associated with GAPP/PACS/NAME observations and predictions

12:30-1:30 Lunch at the hotel

Wednesday afternoon

1:30: Discussion group reports and general discussion, including how to provide to NOAA recommendations on integrated science for the region

Wrap up by 4pm

A3. Integrated Summary of Discussion Group findings

Knowledge Gaps: Physical Science

Atmospheric and ocean linkages:

- Regional mid-monsoon drought and SSTs, diurnal cycle of convection, AZ/NM monsoon disconnect, Gulf surge, Caribbean low level jet, warm pool, Hadley circulation (sub-kilometer, sub-regional, cross-regional, macro scales all are important)

Land-atmosphere linkages:

- Climate affected by land use change (urbanization, irrigation), regional hydrology

Climate impacts:

- Climate affects fire, water, crops, range production, energy production, ecosystem dynamics & biodiversity (species migration, invasive exotics, ‘pests’, disease), aquifer recharge, vegetation (nitrogen fixation via lightning)
- Is survivability of Sonoran pronghorn fawns related to monsoon onset?
- How is lengthening growing season affecting natural vegetation, species migration?
- Precipitation and temperature should not be the only end points (forecasts)
- Problem of defining the onset/end of the monsoon (e.g. address inconsistency between PHX and TUS NWS offices to get a regional consistency)

Observation and data management systems:

- Should include critical variables, ‘difficult’ variables (soil moisture, humidity)
- Network density, integration (water vapor/isotopes/GPS), standardization
- Data management plan should address:
    a. Communication and exchange of data sets needs to deal with international institutional issues: precipitation data set exchange might serve as an example for information exchange.
    b. Inventory of current “products” -- these might be useful now but not widely distributed.

Field Programs

- What more can we learn from the field components: Is the data we already have good enough? Can we identify observations that we need routinely? The priority for some cooperative agencies is data exchange (to get RAOBs in Mexico, may have to hook onto someone locally with a vested interest).
- Explore idea of complimentary observations with both EOP and later activities (e.g. border pollution measurement during monsoon field work).
- Plan to assess the enhanced observing period (EOP) – involve the users to see how the improvements helped their activities.
- Draw lessons from the CALJET/PACJET experience: e.g. work with some specific partners to use the research observations during the period they are available, to determine how this additional information can improve a product or decision they make.

PACJET worked with emergency managers to use the data to improve flood alerts.

Monsoon history:
- Proxy measures (ethnographic, paleoclimatic)
- Description at decadal to centennial scales

Metrics:
- For assessing improvements in models & predictions
- Involve the users to see how the improved observations in the enhanced observing period (EOP) helped with their activities
- Need an educational component with forecasts -stakeholder satisfaction and surveying them for a response
- Detecting change under 'noisy' conditions

Knowledge Gaps: Human Dimensions

Over arching issues:
- How do we successfully entrain human dimensions into a science research program?
- As with the 3-tiered spatial aspect of the NAME plan (Gutzler), it is necessary to link the physical research to the human dimension on various spatial and social scales (across political borders; areas adjacent to the core monsoon region)
- Aim research at the users' sensibilities and vulnerabilities to monsoon variation (e.g. things of high priority to the stakeholder)
- Identification of stakeholders can be an exhausting task – a long list could be made, including anyone who has a use for enhanced monsoon information. May be helpful to organize the list based upon the product desired or used. Diagnostic research helps to identify stakeholders and their relationship to the monsoon (e.g., wildfire hazard, public health threats, soil erosion, electricity demand)
- What aspects will be unique to monsoon CSI that are not addressed by OGP efforts, including: Human Dimension Program, Regional Impact Assessment projects, GAPP issues related to water resources?
- To what degree should user concerns drive NAME research *as well as* being science-driven? NAME Science Plan can be a catalyst to engage users; Synergistic effects (e.g., CALJET)
- Scientists can be flexible. They need to know what is most relevant.
- Integrated modeling approach may be useful to deal with human dimensions issues: could include analyses of direct relevance to decision making (e.g., fire potential)
- Need for comparative studies – between products, between communities, US/Mexico, within each

Identifying stakeholders, understanding user needs:
- A problem of perspectives: Users ask for what they think science can provide. Scientists provide products that they think users can use.
- Poll potential stakeholders to determine what type of forecast and temporal scale is

important to them

- There are regional variations in user needs but there are also common needs: move beyond cross-border differences to understand common needs
- Can we identify specific groups of users, what their decisions are, and how they go about making them?
- Different groups north & south
- General definitions (e.g., monsoon onset) may not be relevant to all users
- How are products utilized by different groups? What level of confidence do they have going into this? (Does a farmer use a surge forecast in the same manner as a rancher?)
- Hold multiple Monsoon CSI workshops with types of decision makers affected by the monsoon. Target specific user communities that might benefit from NAME science research. Let users describe activities -> identify decisions -> information needs, and Identify variables, time scales, and lead times that might focus NAME research.
- Need ways of organizing how we think about stakeholders, several ways, not mutually exclusive:
  a. organize based upon their temporal requirements: real time observation (enhanced network, tools) versus forecasts of varying temporal scales (accuracy)
  b. identify potential stakeholders based upon current scientific research strengths (i.e. begin with those with an interest in short-term forecasting and work temporally outward from there)
  c. identify stakeholders based upon their desired temporal scale
  d. identify stakeholders for which the scientific feasibility of meeting their priorities is high (the high priority-high feasibility corner of the Overpeck box)

<u>Vulnerability studies</u>:

- Ultimate goal is to increase the user's resiliency and adaptability to the monsoon, but to do this, need to understand vulnerability, resiliency, adaptability
- Both climate linkages, non-climate linkages exist
- Trends in vulnerabilities: the region in is flux; pressures on users may increase vulnerabilities
- Need a forward looking approach in NAME to foresee future urgent needs
- Drought-related vulnerabilities: migration, community 'health'/development, repercussions
- Relative role of summer and winter conditions
- Demands on resources (water, energy)
- Social drivers (increasing population, urbanization, other stresses)
- Equity (environmental control, adaptive strategies, access)
- Vulnerability (natural resource sectors, transboundary)
- Relative importance of adaptability vs. predictability

<u>Institutional studies</u>:

- Management of common property resources
- Interactions in core monsoon region
- Capacities (ecosystem management organization for core monsoon region, overcoming

political constraints)
- National security: relation to socio-environmental stresses (water wars), leadership in response and adaptation

Decision making:
- Over arching question is: How do we make our work relevant to decision-making?
- need to understand how decisions are influenced by current level of understanding & products (warnings: timing, interpretation),
- Research on use of uncertain information: How is low-skill information used in decision making? This is an important problem in climate forecasting; we are not going to do much better in the near future.
- Identify decision loci amenable to using new information

Requirements for science to be useful:
- Access, variables, involvement in measurement process, effective dissemination methods
- There is a match between the information that users may desire and what climate forecasts can actually provide.

Metrics:
- How to value 'user needs'?
- Value of info at varying spatial & temporal scales
- There is a mismatch between the information that users may desire and what climate forecasts can actually provide.
- Asses utility and value of science in decision making (economics and other ways of valuing)

What's Needed to Make the Science Useful?

Observation systems:
- Assess relative to user needs *as well as* science/research program needs
- Information must be:
  a. timely: real-time, monitoring/status reports
  b. accurate: including uncertainties
  c. accessible: real-time access, web-based, 1-stop shopping
  d. relevant variables: temperature, precipitation, humidity, cloudiness, soil moisture, air quality, model runs, metrics of model and prediction performance
  e. correct scales: high resolution (hours, days, sub-kilometer)
- It will be important to involve regional institutions in the field programs, such as those in Sonora, Sinaloa and Baja California. Many activities, such as deploying and maintaining a dense rainguage network can be done effectively with local personel.

Get stakeholders involved in ground floor
- Involve them so they have sense of ownership or investment

- Find out what various groups of stakeholders want in terms of observations and monitoring (see notes above on how to organize stakeholders) – is it observations (better data), better understanding of the processes (monsoon-process relationships), or forecasts?

Integrative Issues

Partnerships:

- Be hyper-cooperative, increase institutional involvement (federal to local, academic community, multi-national), include smaller agencies (NWS WFOs)
- Participate in external efforts (AZ Flood Warning System: inter- vs. intra-net issues)
- Increase visibility: provide materials for their newsletters, go to their workshops, send faxes or email updates. Web pages are great, but people have to come to them, we need to *go to them.*
- It is also important to conduct meetings in Hermosillo or further south in the Mexican monsoon region, to explain the NAME objectives and seek interest from the civil and industrial sector in Mexico. These meetings will have to be in Spanish, as many will not speak English.
- Need to communicate with partners in "ordinary times" as well as in unusual times when there is an ENSO anomalies or strong/weak monsoons; this will help build trust and also is an opportunity for two-way learning
- Look for opportunities to develop cross-border partnerships.
- Develop partner-based observation systems (involve NGOs & stakeholders in measurement process)
- Build partnerships by working to understand perspectives and experiences of potential users, and translate these into science issues.
- Hold a Monsoon CSI workshops with decision makers affected by the monsoon, perhaps several workshops targeted to specific user communities that might benefit from NAME science research. Let users describe activities -> identify decisions -> information needs, and identify variables, time scales, and lead times that might focus NAME research.
- Conduct Monsoon CSI meetings south of the border – US investigators need to venture south of the border
- Consider starting a RISA-like activity for northwest Mexico, centered at a university there, such as CISESE or IMADES

Science/public interactions:

- Basis for disconnect between science and users (perceptions of science or products, independence of decisions from science information), effective public education, mechanisms for sustainable integrative stakeholder-driven research
- Need to understand perspectives and experiences of potential users, and translate these into science issues. Good communication skills are key.

Border issues:

- Monsoon-related forecasts could potentially be used on both sides of the border. Can this

information be produced in a way that won't enhance conflicts, but rather, be effective in conflict resolution?
- There are social science issues associated with cross-border decisions. Do we know how to address these concerns?

NAME institutional capacity:
- Climate "crises", such as ENSO anomalies or strong/weak monsoons as opportunities and focusing events for prototyping and developing interactions; but need to maintain communication in "normal" years as well
- Transition of research into operational activities (information requests),
- Need mechanisms for sustained interaction & communication (common language) across research communities and with stakeholders,
- Develop metrics for assessing NAME Program and project effectiveness
- Where are there opportunities for an end-to-end prediction system?

Sustainability of NAME research:
- Build political support for NAME research (communication with politicians)
- Post fieldwork infrastructure: after the end of field activities, how much user interest will there be? have to keep human integration sustained after the field work to keep user interest up; then, interest naturally rebounds down the road as skill (e.g. forecast) increases (good intentions of this project must be maintained beyond the field work)

Building a legacy

- NAME legacy should include spinoff products, new practices, partnerships
- Creation of the framework needed for the continual synergistic integration of physical science research and climate-society interactions research in the North American Monsoon
- An enhanced network of key observations and data management is needed to provide real time monitoring and prediction of user defined climate information and products.
- Promote in transboundary regional cooperation and sustainable development through the application of scientific knowledge and tools.
- Enhance efforts to more effectively manage transboundary water resources in a context of environmental, political and economic change
- Set a long-term goal that NAME and associated CSI work can stimulate, such as a functional regional forecast center in NW Mexico. Such a center should get support from a blend of government agencies, industries, and universities in the region. This center could oversee NAME related observing and monitoring systems after the main field phase of NAME.
- Contribute to the infrastructure, understanding of users needs, and cultivation of users that is needed to develop climate applications and climate services.

A4. Posters Presented

Event-based Study of Interannual Variations in Summertime Precipitation Over the Southwestern United States - Bruce Anderson

CCM3 simulations of the monsoon - Raymond W. Arritt

The North American Monsoon's Effect on Land Surface Predictability - Kristi Arsenault

Verification of Ensemble Streamflow Predictions - Allan Bradley

Climate, Ecosystem, and Fire Applications (CEFA) - Tim Brown

Using Regression and Neural Networks to Reconstruct Cool-Season Precipitation in the Southwestern USA - Tereza Cavazos, Fenbiao Ni, Malcolm K. Hughes, Gary Funkhouser, and Andrew Comrie

CLIMAS: Climate and Fire Management Studies - Gregg M. Garfin, Barbara J. Morehouse, Thomas W. Swetnam

The Sensitivity of North American Monsoon Convection to Parameterization in a Regional Climate Model - David Gochis

What is a good probability forecast? - Holly Hartmann

AWARDS System and ET Toolbox - Curtis Hartzell

Climate Variability and Valley Fever - Korine Kolivras and Andrew Comrie

GEWEX American Prediction Program - Rick Lawford

Climate Assessment for the US-Mexico Border and Northern Mexico - Diana Liverman, Tereza Cavazos, Maria Carmen Lemos, Erika Trigoso, and Melissa Hart

User Studies in the Interior West: Analysis of Current Uses of Climate Information and User Needs for Water Management - Andrea Ray and Robin Webb

Low Temperature and other Climatic Trends at Organ Pipe Cactus National Monument - Peter Rowlands

The North American Monsoon Experiment (NAME) Science Plan - Jae Schemm and Wayne Higgins

Climate Change in Southeastern Arizona? Farmers' Perceptions and Meteorological Data - Colin West, Marcela Vásquez León, and Olivia Armenta

Exploratory Long-Range Hydrologic Forecasting for Columbia River Basin - Andrew Wood

A5. Workshop Invitation

Dear Colleague:

We are organizing a workshop to assess the potential applications and uses for climate research in the North American Monsoon region. As you are probably aware, there has been an effort to develop a research program titled "The North American Monsoon Experiment." NAME is a proposed internationally coordinated, joint CLIVAR-GEWEX process study aimed at determining the sources and limits of predictability of warm season precipitation over North America, with emphasis on time scales ranging from seasonal-to-interannual. In addition to scientific objectives, the NAME science and implementation plan states that its researchers should interact with applications, assessment, and human dimensions (AAHD) researchers on the potential use of NAME science by end users (http://www.cpc.ncep.noaa.gov/products/precip/monsoon/NAME.html). The goal of our workshop will be to develop this interaction by linking the monsoon research community with the well-developed research community that is already working on climate and society interactions and on monsoon-region applications of climate information. A critical step will be to articulate how integrated regional science can assess the usefulness of monsoon climate information (e.g., what are the societal issues affected by the monsoon, what sorts of information do users specifically need, when is the information needed, and at what temporal and spatial scales should the information be provided). In essence, a "roadmap" needs to be developed of how NAME scientific findings could be used in applications activities.

Because of your research expertise and interests, you have been identified as an important participant in our efforts to articulate the links and begin developing the applications based on the existing and proposed monsoon research. The workshop will provide an opportunity for interaction among representatives of key user communities, social scientists and applications experts, and North American monsoon researchers. Equally important, it will foster productive working relationships among relevant NOAA programs GEWEX American Prediction Program (GAPP), the Pan American Climate Studies Program (PACS), and the Regional Integrated Science and Assessments Program (RISA).

The workshop will be held June 18-20, 2001, at the Loew's Ventana Canyon Resort in the Catalina Mountains near Tucson, AZ. The workshop, which is being sponsored by the NOAA Office of Global Programs, will be hosted by the Institute for the Study of Planet Earth, University of Arizona. The workshop will begin Monday evening with a Mini- Symposium on Monsoon Research, followed by two days of focussed presentations and brainstorming sessions (through late afternoon Wednesday).

The workshop is being held sufficiently in advance of the deadline for proposals written to GAPP and PACS, so that proposals may benefit from the exchange of information and ideas at this workshop. In turn, greater familiarity with monsoon research plans, will enable AAHD researchers to submit proposals complementing monsoon science activities to appropriate funding sources. As a result of this workshop both communities will be prepared to prospect for niches where the scientific findings of NAME might be useable. Expected results from this workshop include:

1) Establishment of a two-way conversation between the AAHD community in the region and the monsoon research community and development of ongoing working relationships among the GAPP, PACS, and RISA programs.
2) Articulation of issues for stakeholder-driven (i.e., problem-oriented and user-driven) science related to monsoon research.
3) Integration of AAHD research with NAME and other warm season precipitation research.
4) An integrated science plan to be provided to the NOAA Office of Global Programs for use in their science planning that will outline potential human dimensions, applications, and assessment efforts that may be done in tandem with NAME, including efforts related to the enhanced observation period.

Please respond to this invitation to Andrea Ray, 303-497-6434, or andrea.ray@noaa.gov. We have a limited amount of travel funds to support invited participants, so please indicate whether you need travel support or whether you can fund your own travel. Information on workshop logistics and travel information will be sent separately at a later date, and will also be available on the conference web page, http://www.ispe.arizona.edu/events/monsoon.

Best regards,

Jonathan Overpeck	Andrea J. Ray
Institute for the Study of Planet Earth	NOAA Climate Diagnostics Center
University of Arizona, Tucson, AZ	Boulder, CO

Co-organizers

A6. Acronyms

AAHD	Applications, Assessments and Human Dimensions programs
BLM	Bureau of Land Management
CDC	NOAA Climate Diagnostics Center
CALJET	California Land-falling Jets Experiment
CAP	Scripps Institution of Oceanography California Applications Program
CBRFC	Colorado Basin River Forecast Center
CDEP	NOAA Climate Dynamics and Experimental Prediction Program
CEFA	Climate, Ecosystem, and Fire Applications
CICESE	Centro de Investigaciones y de Estudios Superiores de Ensenada
CIGEFI	Center for Geophysical Research at the University of Costa Rica
CLIMAS	Climate Assessment of the Southwest, University of Arizona
CLIVAR	International Climate Variability program
CONACYT	Consejo Nacional de Ciencia y Tecnología
CRRH	Comite Regional de Recursos Hidraulicos
CSI	NOAA/OGP Climate and Societal Interactions Program.
EPCP	Experimental Climate Prediction Center
HD	NOAA Human Dimensions of Global Change Program
GAPP	GEWEX American Prediction Program
GEWEX	Global Energy and Water Cycle Experiment
IMADES	Instituto del Medio Ambiente y el Desarollo Sustenable
IMTA	Instituto Mexicano Tecnología del Agua
IOP	NAME Intensive Observing Period
IRI	International Research Institute for Climate Prediction
ISPE	Institute for the Study of Planet Earth, University of Arizona
LAC	NOAA Latin American and Caribbean Applications Program
NAFTA	North American Free Trade Agreement (1993)
NAM	North American Monsoon region
NAME	North American Monsoon Experiment
NAMIP	NAME Model Intercomparison Project
NASA	U.S. National Aeronautics and Space Administration
NCEP	National Centers for Environmental Prediction
NFDRS	National Fire Danger Rating System
NGOs	Non-governmental organizations
NOAA	U.S. National Oceanic and Atmospheric Administration
NSF	U.S. National Science Foundation
OGP	NOAA Office of Global Programs
PACS	NOAA Pan American Climate Studies Program
PACJET	Pacific Land-falling Jets Experiment
RISA	Regional Integrated Science and Assessments Program
SAHRA	Sustaining semi-arid hydrology and riparian areas, University of Arizona
SALSA	Semi-Arid Land-Surface-Atmosphere Program
SHINO	Integrated hydraulic system of northwest Mexico
SLP	Sea level pressure

UNAM	Universidad Nacional Autónoma de México
URGWOM	Upper Rio Grand Water Operations Model
USGCRP	U.S. Global Change Research Program
USBS	U.S. Geological Survey
WGRFC	West Gulf River Forecast Center
WRCC	Western Regional Climate Center