1. Title & Executive Summary


Executive Summary: The coupling of human and natural systems are coupled poses at least three major types of climate-related risks to human populations and economic activity in Western North America: 1) exposure of human communities to weather extremes—from cyclones to drought, 2) dependence of growing populations on limited water supplies in this arid region, and 3) climate and water-related agricultural production risk. Interactions between these urban and rural stresses, in turn, are likely to generate additional stresses. We propose to build on the work done in CRN II Project # 2048 on tropical cyclones by improving understanding of the combined impacts of East Pacific cyclones and the North American Monsoon on human systems, and by mobilizing this knowledge to improve and disseminate a specific climate diagnostic product. The ultimate goal of this activity is to introduce climate information to users in northwestern Mexico and the southwestern United States in a manner that improves policymakers’ capacity to draw connections among rapidly shifting weather conditions, long-term climatic variations, and continuously changing societal conditions in a manner that improves critical water-management decisions. Two important and potentially predictable aspects of variability in the region are tropical cyclones (Raga 2005) and the North American Monsoon. Precipitation from both phenomena can be a significant part of annual precipitation, and thus is significant for water supply and drought conditions. Both phenomena can cause flooding that emergency managers must respond to. The products of the proposed research will include a profile of fundamental risks faced in the urban and rural areas of the region, policy recommendations, and an easily accessible, periodically updated, bilingual climate-diagnostic product for the study area. By addressing the impacts of climate variability on both urban and rural areas, the project will potentially contribute to decreasing the rural (agricultural)-urban conflicts over water. Linking assessment of risks with introduction of a tailored decision tool will advance scientific understanding of how best to integrate climate science with decision making in the binational North American Monsoon Region.

The proposed research, which seeks to interlink science and societal needs, will:

- Use climate diagnostic information to identify and assess societal vulnerabilities posed by cyclonic and monsoon processes including drought in both urban and rural contexts.
- Assess the institutional and policy implications of these vulnerabilities.
- Work with stakeholders to bring the study findings to bear on assessing the salience, relevance, and credibility of the science, as well as the formulation of scientific research questions.
- Initiate knowledge transfer to relevant decisionmakers.

These objectives will be accomplished via a four-part research plan comprising the following sets of tasks: A) improve the flow of climate diagnostics for policy adoption, B) assess urban vulnerability, C) evaluate rural vulnerability, and D) conduct outreach and dissemination to managers. Significant work related to task A resulting in a prototype climate outlook product has already been accomplished. Tasks B and C form the core of new, innovative research proposed here. Task D will receive more emphasis later in the work plan period, after the recently-funded CRN II-2048 has generated results. This task is critical for the overall project, and will be linked to task A of this proposal. The proposed project duration is September 1, 2007 – August 31, 2009.

PI: Robert G. Varady, Udall Ctr. for Stud. in Public Policy, Univ. of Arizona, 803 E. 1st St., Tucson AZ 85719, USA, rvarady@email.arizona.edu; Ph: +1 (520) 626-4393; Fax: +1 (520) 626-3664.

Collaborating CRN II Project # 2048: Tropical cyclones: current characteristics and potential changes under a warmer climate. (G. B. de Raga, P.I.; Universidad Nacional Autónoma de México)
2. Introduction & Objectives
Translating climatic variability to societal risk is based on understanding and assessing vulnerability (Ray, et al. 2007a; Ray, et al. 2007b; Lemos and Morehouse 2005). This proposed project has as its central goal: To promote the exchange of climate information between scientists and policymakers in northwestern Mexico and the southwestern United States in a manner that improves critical water-management decisions and their impacts on societal risk.

The CRN II-2048 proposal states, “A better understanding of the factors involved in cyclone development under current conditions and under a warmer climate scenario will contribute to the understanding of the regional and temporal climate variability in the tropical regions of the Americas” (Raga 2005). Our proposed project, under the Small Grant Program for the Human Dimensions (SGP-HD), is focused on exchanging information on climate variability leading to improved water-resources decisionmaking in northwestern Mexico and the southwestern United States (Figure 1). Furthermore, Raga (2005) states “an increase in the number of more intense hurricanes under a warmer climate could imply an increase in the probability of landfall in the regions of study, and policy makers planning for the next few decades should be aware of such possibility.”

Cyclones are one aspect of the information dissemination and assessment of vulnerability in all four task areas of this proposal, but task D specifically promotes exchange of climatic, water, and social vulnerability information with this critical CRN II-2048 goal.

We will take advantage of a range of knowledge that is becoming available from research, including that on Pacific cyclones. Cyclones are significant in this region because they may cause flooding on shorter time scales, and may provide significant amounts of the annual rainfall in any given year and are thus a factor in regional water supply and drought. We will also expand the growing body of work on understanding vulnerability of rural and urban systems in the region.

Task A. Improve the flow of climate diagnostics for policy adoption. In the drought-, flood-, and fire-prone monsoon-affected area straddling the U.S.-Mexico border, there is great need for regularized data and information exchange regarding climate knowledge, in order to improve the policy relevance and usefulness of this knowledge for decisionmakers (Ray, et al. 2007a).

Providing accurate and timely information on regional climate to water decisionmakers requires designing products that fit within their information needs and time available. One of the alternatives is to combine salient information a concise, periodically updatable, and readily understood product. This product should assemble into one place, depict, and analyze significant data and short-term trends on rainfall, temperatures, reservoir water levels, and other information needed to make scientifically valid, rational, and cost-effective decisions that respond to social, political, and financial conditions. The prototype for such a product has been developed by researchers at the University of Arizona, in cooperation with scientists at Mexico’s Servicio Meteorológico Nacional (SMN). Such a tool will contribute to building capacity for the use of climate information in the region, by helping managers and policymakers to make the key connections between four dynamic forces that are often treated as if independent: rapidly shifting weather conditions, long-term climatic variations, continuously changing societal conditions, and critical water-management decisions.
**Task B. Assess urban vulnerability.** With processed, up-to-date diagnostics on regional weather and climate, researchers can begin to examine how variability—especially pronounced in the arid-to-semiarid border region—affects already-strained and chronically scarce water supplies. In particular, the border states of Arizona (Colby and Jacobs 2006) and Sonora (Pineda 2006) have experienced rapid demographic, industrial (mostly maquiladora-related), and economic growth. This dynamic drives urban municipal and industrial water demand, while existing water resources are already either fully allocated, or over-allocated as in the case of groundwater. The focus on urban growth responds to the IAI SGP-HD strategic priority on urbanization processes, as well as to the region’s economic growth, which is largely occurring in cities and towns. The proposed comparative assessment will involve a vulnerability analysis of the interactions among climate – water – urban supply and a related institutional analysis of the implications of these vulnerabilities for existing policies and practices. Past work has demonstrated the importance of considering climate variability in water resource management, particularly in the arid and semi-arid environments of the study area (Morehouse, et al. 2002, 2000; Morehouse 2000). Water—via the domestic and binational institutions that manage its use—forms a critical link in climate-human system coupling (Browning-Aiken, et al., in review; Carter and Morehouse 2003; Carter, et al. 2000; Finan and West, eds. 2000; Liverman, et al. 1999).

**Task C. Evaluate rural vulnerability.** Climatic variability related to onset, duration, and reliability of the North American monsoon is critical for agricultural production in the region, both rainfed cropping—where this is practiced in southern, upland Sonora primarily for subsistence—and using surface (canal) irrigation throughout the region. At the same time, NAFTA policies have changed agricultural trade and farming practices, increasing production risk for farmers and ranchers in the border region. Eakin (2006) describes rural livelihoods in Mexico as “doubly exposed” to climate/water and economic risks. Farmers have adapted by increasing reliance on groundwater and therefore demand for electrical energy (Scott 2007; Scott, et al. 2004). As in B, vulnerability and institutional analyses will be employed to link risks with climate and with use of climate information. This objective responds to the strategic priority on “rural transformation, sustainability, changes in food and energy production patterns” of the IAI SGP-HD call.

**Task D. Conduct outreach and dissemination to managers.** While flood disaster response is in the hands of local and regional civil defense authorities, planning and water management operations (of reservoirs) for the particular area of study are vested in the Comisión Nacional del Agua (CONAGUA), Gerencia Regional Noroeste (GRNO) in Hermosillo. Improved information on Pacific cyclone activity (particularly “presence, track and intensity” as proposed in CRN II-2048) will support regional decisionmaking. At the same time, river basin councils that incorporate a broad range of stakeholders are being established as part of trends towards decentralized water management in Mexico, although there has progress in this regard has been slow in the GRNO area. However, water resource allocation including major reservoir operations remains under central CONAGUA control. The proposed set of activities will examine and assess the degree to which flood and water shortage forecasting and reservoir operations related to cyclone and drought contingency planning are included in decentralized water management planning and operations, and will promote exchange of information as a means to support the decentralization process in decisionmaking. This objective addresses the strategic priority on “institutional responses to GEC related uncertainties and environmental decision-making” of the IAI SGP-HD call, and contributes to the IAI mission to promote policy relevance and usefulness of IAI-supported science for decisionmakers.

3. **Methodology**

The methodology proposed for the tasks described above is as follows:

**Task A.** Based on NOAA and SMN climate forecasts and CRN II-2048 data, the team will develop a climate-diagnostic product for the study area, as recommended in a recent workshop on
applications of climate information in the region (Ray, et al. 2007b). A prototype “Resumen del Clima de la Frontera” (RCF) produced by the NOAA-supported Southwest Climate Assessment Program (CLIMAS) program, (http://www.ispe.arizona.edu/climas/forecasts/borderoutlook_prototype.pdf), is already available; however, further research and development as well as information exchange with regional managers will be required to better address water-resources variability associated with climate extremes, both flood and drought. The RCF prototype is modeled on the highly successful Southwest Climate Outlook produced by CLIMAS (Jacobs, et al. 2005; Garfin and Morehouse 2003), which each month summarizes climatic information for the Arizona-New Mexico region of the southwestern United States (http://www.ispe.arizona.edu/climas/forecasts/swoutlook.html). The RCF currently uses probabilistic seasonal forecasts from the IAI multi-model outlook, as well as analogue-statistical forecasts from SMN (2nd edition of RCF); U.S. and Mexican climatologists add region-specific value with text interpretations of the forecasts and other products. We will improve the RCF with the addition of medium-range (8-14 day) forecasts generated by the NOAA Earth Systems Research Lab (Hammill, et al. 2006). Gridded climate data, MM5 models output, and IPCC 4AR scenario analysis generated by CRN II-2048 will be linked with the improved RCF through feature articles that introduce RCF users to issues related to East Pacific and Caribbean tropical cyclones, forecast challenges, forecasts (NOAA National Hurricane Center East Pacific forecasts; http://www.nhc.noaa.gov/), and impacts research. Similar feature articles are one of the most highly praised features of U.S. climate summary products produced by CLIMAS and the NOAA-CIRES Western Water Assessment (Carter, et al. In revision). We will enlist technicians and students in the CRN II-2048 network and summer school to draft articles for the RCF; with help from CLIMAS staff, the translational science effort led by Garfin and Ray will generate material for non-technical audiences.

**Task B.** We propose to conduct comparative assessment of water supply vulnerability and institutional lack-of-fit in coupled large city-small town pairs (“combines”): Tucson, Arizona, with Hermosillo, Sonora (each approximately one million inhabitants), and Sierra Vista, Arizona with Cananea, Sonora (each approximately 50,000 inhabitants). The rationale for scaled combines is institutional and physical; compliance with assured water supply rules in Arizona’s urban-centered Active Management Areas is mirrored—although somewhat opaquely—by water growth planning for large urban centers in Mexico. Both Tucson and Hermosillo have sought to offset water supply-demand gaps and variability (principally related to the North American monsoon and East Pacific cyclones studied by CRN II-2048) through inter-basin water transfers. The growth of towns, while smaller in scale, is more erratic from the perspective of institutions (planning and investment) and access to water supply (groundwater, small surface sources). In this context, the expansion of towns also involves water tradeoffs with non-municipal water sources, e.g., in Sierra Vista, Arizona. In contrast, a large mining operation in Cananea, Sonora, is the greatest water user and for that reason it keeps its own weather (precipitation and temp) records. The comparative approach will identify to what extent information on cyclones and the North American Monsoon is incorporated in decisionmaking on water supply, conservation programs, identifying and negotiating alternative water sources, and any growth limits (planned or actual) in the combines studied.

**Task C.** We propose to characterize the combined climatic and economic forcing of the agricultural groundwater-energy nexus through an examination of trends in monsoon onset, total rainfall, and intra-seasonal rainfall deficits (defined in agricultural terms) correlated to groundwater pumping as derived from data on energy consumption, aggregate crop production, and traded virtual water (the water embedded or required to produce agricultural commodities, e.g., groundwater-irrigated vegetables). Important macro-level policy questions to be addressed in this component stem from the hypothesis that the same climatic uncertainty that drives agricultural groundwater demand influences hydroelectric generation by Sierra Madre Occidental reservoirs in Chihuahua, Sonora (the two northern Mexican states with the highest agricultural groundwater demand), and Nayarit. Shifting power generation to thermal sources would in turn increase
greenhouse gas emissions and exacerbate climate feedbacks. Cyclone-induced inflows are hypothesized to “reset” or substantially mitigate drought conditions in the study area reservoirs; however, groundwater has significantly longer lag times (both physically for recharge to occur, and institutionally for pumps once installed and operational to be retired or for groundwater to be re-allocated to non-agricultural uses).

**Task D.** Water management in Mexico is undergoing a process of decentralization, stemming from the 1992 Ley de Aguas Nacionales and its 2004 revisions, with increasing authority vested in regional CONAGUA and SMN offices. The Gerencia Regional Noroeste (GRNO) in Hermosillo, Sonora forecasts floods with technical support from the NOAA National Weather Service. Improved understanding of potential flood impacts resulting from cyclones and North American Monsoon activity will be communicated to forecasters and to disaster contingency planners. The information needs of decisionmakers will be elicited through at least two interactive workshops, one held in Hermosillo and the second in Mexico City, thereby strengthening two-way information flows (scientists to decisionmakers and the reverse). An assessment of current policy on climatic data and contingency planning (for cyclones and drought) will be synthesized through observation of this communication and from indepth interactions with decisionmakers.

### 4. Networking & Interdisciplinary Collaboration

This project is conceived of as a three-pillared collaboration: natural science – social science – decisionmaking, with the crucial human dimensions translational science undertaken by policy analysts with background and experience in all three pillars. As demonstrated, “translation” occurs in both directions, i.e., for the case of CRN II-2048, information flows to social scientists and decision-makers as well as the reverse—priorities and knowledge needs of decision-makers and societal stakeholders conveyed to climate modelers.

Furthermore, significant advancement in understanding the structure, evolution and variability of the North American Monsoon has occurred over the past several years as a result of the internationally-coordinated North American Monsoon Experiment (NAME) research program (Higgins and Gochis 2007; Gochis, et al. 2006; Higgins, et al. 2006). Because of this progress, there now exists an ideal opportunity to transfer improved understanding and prediction methodologies for seasonal precipitation and streamflow to regional stakeholders and decisionmakers, thereby reducing regional vulnerability related to weather and water-resources variability (Ray, et al. 2007a).

The workshops and summer school to be conducted as part of CRN II-2048 offer an excellent forum to orient natural scientists on human dimensions by building human impacts assessments into that project. Furthermore, the Instituto Mexicano de Tecnología del Agua (IMTA) is a collaborator on both CRN II-2048 and our proposed project.

The roles of the co-PIs (with task responsibilities identified by A-D) are as follows:

- **Robert G. Varady (University of Arizona, Udall Center for Studies in Public Policy; public policy)** – Overall team leader. In addition, he will assess the policy implications of human dimensions of climatic and water-resources uncertainty (contributing to A), as well as addressing information flows and institutional decisionmaking (contributing to D).
- **Christopher A. Scott (University of Arizona, Udall Center for Studies in Public Policy and Dept. of Geography; geography and hydrology)** – Deputy team leader. In addition, will lead C focusing on risk and exposure in agriculture, groundwater and energy dependence, and implications of climatic and water variability on rural producers.
- **Anne Browning-Aiken (University of Arizona, Udall Center for Studies in Public Policy and Sustainability of Semi-arid Hydrology and Riparian Areas – SAHRA; anthropology)** – Will contribute to urban and rural adaptation to climatic and water-resources uncertainty (B and C).
• Gregg Garfin (University of Arizona, Institute for the Study of Planet Earth; geosciences) – Will lead A. Preparation and dissemination of the Climate Outlook product and exchange of information between CRN II-2048 and regional climate diagnostics.
• David Gochis (National Center for Atmospheric Research; hydrology) – Primary point of contact for North American Monsoon Experiment Scientific Working Group, working on monsoon-cyclone linkages as input to the Climate Outlook (contributing to A and D).
• Martín Montero (Instituto Mexicano de Tecnología del Agua; atmospheric sciences) – Will lead D with responsibility for translational science and exchange of information with regional water managers and planners (contributing to A).
• Barbara Morehouse (Univ. of Arizona, Inst. for the Study of Planet Earth; geography) – Institutional aspects of climate risk and collaborative production of science and policy (A, B, D).
• Nicolás Pineda (El Colegio de Sonora; public policy) – Will lead B devoted to climate and water variability implications for expanding urban populations.
• Andrea Ray (National Oceanic and Atmospheric Administration; geography) – Linkages with ongoing regional science and human dimensions programs at NOAA, particularly geared toward the U.S.-Mexico binational context (contributing to A).

5. Policy/Societal Relevance
Climate-related variability in water resources is the principal challenge in the northeastern Mexico and southwestern United States region, which is prone to extreme droughts and floods. While this project proposes to examine human vulnerability to cyclone and flood events, three of the tasks address the multiple dimensions of climate-water-society linkages. Cyclones and robust monsoons carry direct impact risks for vulnerable populations. At the same time, the water replenishment value of these events is fundamental to changing societal dynamics and economic activity, including rapidly expanding urban centers in the region as well as a dynamic agriculture sector. The research team is particularly interested in reconciling these seemingly contradictory phenomena by means of a process that places great importance on improved access to reliable information and science. Resulting improvements in communication between scientists, water managers, and decisionmakers are the key to better policymaking in both countries.

6. Summary Statement
Following from the SGP-HD objectives, this project is conceived to directly address human dimensions of climate and water-resources uncertainty through assessment of urban and rural vulnerabilities to climate extremes (cyclones and drought), policy and institutional analysis of societal susceptibility to climatic impacts, identification of the information flows required for adaptive water-resources management to account for uncertainty, and the initial exchange of knowledge with decisionmakers aimed at mitigating the vulnerabilities identified. To summarize, task A will yield coupled cyclone prediction (from our partner CRN II-2048) with a climate outlook product that is currently under development. Tasks B and C will produce assessments of urban and rural vulnerabilities to climate extremes that will support, through workshops, a process of adaptive management and decisionmaking aimed at mitigating societal risks. Finally, task D will encourage scientists (those in this proposed project and in CRN II-2048) to exchange knowledge needs with regional water managers, primarily in northwestern Mexico.

In the course of accomplishing the project’s objectives, the research team will produce a host of tangible and presumably useful outputs: a periodically-produced and issued climate diagnostic product for the monsoon region; a workshop joining scientists, stakeholders, managers, and decisionmakers; a number of peer-reviewed scientific (including social-scientific) publications and conference presentations; and various article and publications for the non-scientific public. The overarching result, we hope, will be improved impact of climate science on decisionmaking and policy, and a subsequent round of scientific research formulation that is more closely in tune with societal needs.
Appendices

7. Plan and Timetable

Timeline of Activities and Associated Expenditures

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8. References


9. Potential Reviewers

M Pilar Cornejo R. de Grunauer
(Oceanography)
Research Scientist
FIMCM-ESPOL
Campus Gustavo Galindo V
PO Box 09-01-5863
Guayaquil, Ecuador
Phone: +593-4-2269468
pcornejo@espol.edu.ec

Maria-Carmen Lemos
(Public policy/environmental policy)
Associate Professor
School of Natural Resources and Environment
University of Michigan
2006 Dana Building
440 Church St.
Ann Arbor, MI 48109-1041, USA
Phone: +1 (734) 764 9315
lemos@umich.edu

Victor Magaña Rueda
(Atmospheric sciences)
Professor
Centro de Ciencias de la Atmósfera
Ciudad Universitaria
Mexico City, Coyoacan 04510 MEXICO
victormr@servidor.unam.mx

Roberto Sánchez Rodríguez
(Planning/environmental policy)
Professor and Director
UC MEXUS
3324 Olmsted Hall
University of California—Riverside
Riverside, CA 92521-0147, USA
Phone: +1 (951) 827-3519
roberto.sanchez-rodriguez@ucr.edu