CALIFORNIA APPLICATIONS PROGRAM

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Demand Side Assessment

- **Who are the major stakeholders for your RISA?**

  Major stakeholders for the California Application Program (CAP) include international, federal, state, county, and local agencies that provide regulatory, public safety, and resources to the public.

  A few examples:

  - Tony Westerling and Tim Brown are working with federal fire agencies (USDA Forest Service, BLM, National Park Service as well as State and local agencies).
  - Kosta Georgakakos and group are working with Army Corps of Engineers, US Bureau of Reclamation, National Weather Service, and the State of California Department of Water Resources, to develop a better forecast system (days to months lead times) for water resources management, and in particular reservoir management, in central and northern California.
  - Kelly Redmond is working with federal and state officials on methods for drought assessment and monitoring, within the state and for dealing with waters that cross state boundaries. He is also working with the California Energy Commission and other state agencies in an effort to develop and better disseminate climate information, and to improve climate monitoring for California and the surrounding region.
  - Alexander Gershunov is working with Mexican scientists to elucidate effects of climate variability and climate change as they affect water and other resources in Mexico and the US/Mexico border region.
  - Mike Dettinger is working with a collective of state and federal team members to provide science based guidance to the CALFED Bay-Delta program, a state/federal partnership to develop and implement a long-term comprehensive program to restore ecological health and improve water management in the San Francisco Bay and upstream Sacramento/San Joaquin delta region.
  - Randy Hanson is working with a group of water purveyors in the Ventura and Monterey Bay areas and with the state (California Department of Water Resources) in the Central Valley to develop ways of providing simulations and related forecasts of conjunctive ground-water/surface-water use needed for water-resource management and guidance for water transfers, sales and purchases.
  - Dan Cayan is working closely with the California Energy Commission in conducting a physical climate science program to explore potential impacts of climate change and variability in California. He is also working with a team of university and state scientists and public health officials to understand climate linkages to encephalitis and West Nile virus and the mosquito populations that transmit these diseases.

- **What processes are used to include stakeholders in the research planning process, the research implementation process, and the research reporting process?**

  In several cases an ongoing research interaction was already present. In others, new topics were selected such as vector-born diseases transmitted by Mosquitoes such as Wes Nile Virus and Encephalitis; Kawasaki disease that may be transmitted by an unknown infectious agent, and lilacs as a nation-wide precursor to global climate change. Much of current CAP work has sprung from stakeholders expressing an interest in a climate related issue, and seeking to contact or interact with those in the climate community. Another method has been the publicizing of results (e.g., Sierra Snowpack prospects with climate change) that have led stakeholders to identify themselves

because of their intense interest in the implications. Other CAP projects have been the outgrowth of ongoing research that stakeholders are involved in to varying degrees where the stakeholder is interested in a more rigorous assessment of climate in their resource management issues.

Occasional briefings have been arranged for state agency personnel: both technical staff and mid and upper level policy makers. Also there have been a number of briefings to state legislators, through hearings, individual discussions, and at meetings or conferences, in both university and government venues.

- **How are stakeholder interactions evaluated?**

  In this particular RISA project, there has not been so much a formal evaluation of interactions, but rather, through routine conversation and other feedback, a continual process of adjustment to needs and directions, expressed by both sides of the interaction.

  One measure of stakeholder interest has been the degree of enthusiasm for engaging in mutual projects and for assisting with leveraging of additional funding, and for adoption of findings in policy and procedures. In this regard, the CAP project seems to have met with abundant success.

- **What has your RISA learned from the process of stakeholder interaction, and how have its decision processes changed as a result?**

  All of the standard issues that have arisen in other RISAs have been present in this one, including the need for sustained long-term interactions, and the necessity of maintaining close contact. Also, responsiveness and outreach are qualities highly valued by the particular constituencies that CAP has chosen to address, many in the political arena or in the public eye, and this RISA has paid a lot of attention to this.

  In California, CAP has been instrumental in raising the awareness of climate change and variability as issues of concern to the state, and can claim considerable responsibility for the high profile that climate now has in this state. These include likelihoods, magnitudes, impacts, uncertainty, and especially vulnerability. Another key factor is the credibility of the institution, a factor that is hard to overestimate, and that helps open doors and keep them open, with people who are difficult to reach. Finally a listing of links to resent newsworthy articles are also provided for stakeholders that want to keep abreast of the latest societal impacts of climate (http://meteora.ucsd.edu/cap/reading_room.html).

  Wild Fires -- Wildfire suppression and management are expensive; over $1,000,000,000 is spent every year on suppression. Often influenced by local to regional climate, wildfire forecasts are plausible and of great economic benefit. Forecasts for 2004 were provided along with analysis of the relations between climate and wild fires throughout the Western United States.

  Reservoir Operations -- demonstrating the utility of modern hydrologic forecasting and water resources management concepts and ideas are combined with climate information for the improved management of the Folsom Lake waters. The demonstration of the feasibility and utility of climate-hydrology forecasting and water resources management is accomplished by inter comparing retrospective studies results for current historical practices, as well as with operations adjusted with historical hydrology and hindcasts with GCMs.

  Water Resources Management -- The potential impacts of Global warming on California's water resources were addressed through the simulation of changes in snow pack. Under warmed conditions these simulations depict a severe loss of snow as indicated by changes in the snow water equivalent (SWE). By 2030, under the "business-as-usual" scenario, temperature is projected to rise about 0.6 degree Celsius, resulting in a minor decrease in April snow pack at lower elevations. However, by 2060 a temperature rise of 1.6 degree Celsius results in a loss of one-third of the total snow pack. This loss is focused in mid to lower elevations since the snow pack there is more sensitive to temperature changes than at higher, colder elevations. Regionally, this means that the northern Sierra and Cascades experience the greatest loss. These results indicate that potential global warming may result in a profound impact on a operation of reservoir systems in the Central Valley that were constructed to capture and distribute snow-melt runoff and less capable of managing additional non-snowmelt runoff.

Groundwater -- For example, for the ground-water analysis of future water availability in the Mojave River Basin was determined on the basis of climate variability cycles as opposed to indiscriminant use of historical hydrology. Similarly, the future water availability and potential effects of seawater intrusion and subsidence have been assessed for the Ventura area that incorporates climate variability.

Public Health -- In collaboration with several groups of outstanding doctors and scientists, CAP/CCCC are exploring how variations in our medium-range weather patterns to long-range climate patterns may play a role in the onset, frequency and longevity of human health problems. Vector borne diseases and Kawasaki Disease are two areas CAP/CCCC are currently researching. However, despite the existence of a state-wide surveillance system and the combined control efforts of 52 agencies with a combined budget of >$60,000,000, the activity of mosquito-borne encephalitis viruses has increased in California during the past decade. The incorporation of more recent climate models and climate data will enhance the surveillance system and related use of resources.

Different facets of the CAP project have had different reactions from stakeholders and some influence on stakeholder decision making. For example in Fire Prediction both short-term and interannual assessments are needed to help prepare for the redistribution of fire-protection resources. Similarly for Reservoir Operations the use of climate assessment by stakeholders can take on a wide spectrum of reaction that include considerations of power generation, flood control, and the sale of state and federal water For stakeholders involved with ground-water/surface-water resources, the managers are more prone to including climate data as part of their analysis of short-term decisions and are trying to align their longer-term decisions with recognized climate cycles such as ENSO and PDO. Overall, the interest in climate change (detectability, magnitude, impacts, etc) and it's relation to climate variability has become much more acute in California by State as well as by sectored interest groups. Therefore, having a sustained interest and presence in regional climate matters is critical to develop meaningful connections with stakeholders. Practitioners or specialists in other disciplines respect science partners who are respected by other scientists; this is an especially important characteristic for them to evaluate experts who are in field outside of their own.

Interest level of public and private sectors varies; RISA investigators must be ready to strike when iron is hot

The interest level of state officials in California in topics relating to climate change has increased markedly over the last year, and this RISA has positioned itself very well to respond.

On seasonal/interannual scales, stakeholders "care" about forecasts quite intensely in some years when it is perceived that climate anomalies would produce a large effect (e.g., after two years of drought). However, in other years when conditions are thought to be more "normal", there is not as much interest. Given developments in the California energy sector over the past two years, temperature is always of interest. But, not a lot can be said, typically, except for the effects of trend forcing temperatures more toward the positive than the negative anomalies.

The process of assessing and integrating climate services and forecasts into local resource management procedures and agencies requires much luck and patience. Agencies, especially local agencies, are buffeted by many stresses each year and often place climate issues low among their priorities. When climate rises towards the top of their priorities, however they are eager for help, advice, and hard facts; during these intervals, much progress can be made in establishing connections and in developing long-term users of climate services. The timetable for such advances, however, is most often set by the user, and not the purveyor, of climate services.

Simple, clear illustrations are needed

Simple, clear illustrations of model results that translate atmospheric changes into regional hydrologic changes have been important "props" that have been key elements in conveying to state agencies and the public some likely impacts of climate change in the region. The estimated loss of spring snow pack has been singularly important in this regard. Also, the observed trend over recent decades toward earlier Sierra runoff and the diminishing

percentage in late spring, whether caused by global human activity or not, have at the very least given to water managers a tangible face to what is often considered a hypothetical possibility. Several sectors have expressed interest: the State Resources Agency (which encompasses water, forests, wildlife), the California Environmental Protection Agency (water and air quality), and the California Energy Commission have been quite prominent, as well as legislators who are interested in impacts in their own districts. Since we are a coastal state, the potential for accelerated sea level rise and the potential for accelerated seawater intrusion are important issues. Having a credible climate simulation model(s) at our disposal 1) to make such estimates and, perhaps as important, 2) present the results using formats and techniques more readily understood by practitioners, has been invaluable in supplying information. For example, coupling GCMs with coastal ground-water/surface-water flow models provides a mechanism to assess the impact of these changes.

We found that temperature indicators other than thermometer readings are quite effective in translating the meaning of climate change to the public or to decision makers. Phenological stages (e.g., first bloom of lilacs) and spring snowmelt runoff timing have furnished important, entirely independent and mutually corroborative evidence that spring has been arriving earlier across the West for the past three decades.

Relationships with end-users need to be cultivated

In some sectors like water resource management, in order to convince operational institutions that there is value to be gained from only modestly skillful climate forecasts, it is crucial to work closely with agencies over an extended period. It may be necessary to run their operational models side-by-side with alternative new models to demonstrate utility. It is not enough to simply provide forecasts of precipitation or streamflow; the user needs to be involved and engaged interactively throughout the various steps from climate model output to his particular application/decision.

Communication enhances credibility

ENSO has become accepted as a major driver of western weather and climate patterns. However, the "flavors" of different ENSO events and the uncertainty associated with ENSO forecasts is still not well understood and needs to be clarified. We have spent (and will continue to spend) considerable time in explaining this to media, the general public and agencies.

The memorable winter precipitation season of 2004-05 is a case in point. The extraordinary amounts of precipitation, the extended duration from early fall into late spring, the cool and extended spring, and the warm conditions in coastal waters, were not forecast, and from a physical standpoint do not seem to have much to do with ENSO, although there are a few intriguing connections.

We have a much improved understanding of wildland fire management decision-making and a much improved understanding of wildland fire mangement information needs. Climate information, though used in some strategic planning, is still not fully utilized in wildland fire management practices; especially at time scales of decades and longer. When climate forecasts are utililzed in some management applications, however, forecast skill causes many managers to be skeptical of prediction usefulness. We are convinced, though, that there are a range of forecast products beyond the short range time scales that can be of benefit to fire management. For example, statistical seasonal fire forecasts can be made with modest skill using prior years' moisture indices. The fire community has been somewhat skeptical of the value of this tool but is beginning to pay more attention. The Climate-Fire Workshops held by Climas (usually jointly with CAP fire-climate specialists) have been instrumental in promoting dialogue with the fire community. Allied with this issue, it is clear that a better organized central fire data facility would be invaluable to understand and predict climate links to anomalous fire activity across the West. The Climate, Ecosystems and Fire Applications (CEFA) group headed by Tim Brown at DRI has very much adopted a RISA-like approach, and this has been a key factor in its success.

More focus is needed on non-winter seasons and broader regions

Much of our seasonal forecast attention has been placed on winter season issues (precipitation, temperature), and we have often confined our attention to regions the scale of large watersheds (Sacramento/San Joaquin). But,

climate anomalies are not confined to one season, and the footprint of climate anomalies is often super-regional in scale. For example, California draws water and power from the Colorado River system as well as from Northern California watersheds. Also, summer climate anomalies impact summer electrical air conditioning demand, and their cross-regional interconnections have not received much attention. CAP, UW, and NOAA CDC have begun to discuss this issue and how this should be dealt with in a whole-West perspective.

Collaborations with large institutional programs are key

California has begun the largest restoration program in the world, CALFED. This $30 billion 30-year effort is an attempt to involve a broad range of stakeholders in a comprehensive plan to restore the Sacramento / San Joaquin delta and San Francisco Bay and improve water quality and ecosystem function. Climatic processes are the most important external driver of these hydrologic systems, and climatic variability can be expected to cause myriad consequences. CAP has been quite influential in raising the climate connection to a significant level of visibility within the CALFED program. We have used a unique biological indicators of winter precipitation, blue oaks, to discover that wet and dry episodes of 6 to 8-year and approximately 15-year duration are a significant feature in the Central Valley climate of the past 400 years. These heretofore largely unrecognized shorter periods are familiar to those who have recently lived through the late 1980s/ early 1990s drought, and the subsequent very wet six years of the mid 1990s. CAP and collaborators have been commissioned by CALFED to summarize the role of climate variability and change in CALFED issues and to propose areas that need dealing with by CALFED science activities. We have also provided input to the current update of the California Water Plan to guide and coordinate beneficial use of California's water resources. Gaining the notice and trust of key individuals has enormous importance in our ability to inject scientific information into institutional decision making processes.

Climate data needs to be updated and maintained

Climate data archives are struggling to keep up with volumes of data that are collected by an assortment of observational networks. There is a new generation of remote sensing and numerical model data that needs to be properly archived and made accessible. In addition there is a need for integration of data bases and a continual need to disseminate, utilizing technological advances as well as other methods.

Better monitoring is critical to present and future needs

On the other hand, crucial parts of the western climate (broadly interpreted from atmosphere, ocean, hydrology and ecology) are very poorly monitored. For example, we know that spring snowmelt runoff is occurring earlier in recent decades but don't have the fundamental information to elucidate how this is occurring in mountain snow zones. Often there is little support for these measuring and monitoring activities even though these are resources that are critical for making decisions of ours and of future generations. During a series of visits to the major California agencies affected by climate, it became clear that the state, with the 7th largest economy in the world, has poor access to its own climatic history, and in particular to carefully de-biased diagnostic measures of recent climatic trends in temperature and precipitation, and how these vary on a seasonal basis and geographic basis within this extremely diverse state. We have taken preliminary first steps to develop a suite of such indicators in a new effort coordinated by the California Environmental Protection Agency. Also, together with Henry Diaz (CDC and Western Water Assessment RISA Program in Boulder) and others, we have crafted a plan to organize a high elevation monitoring and research across the West (acronym “CIRMOUNT”) and have arranged for the inaugural meeting of key investigators and agency officials this fall. In California, we have also used seed funds from CAP to build up a high elevation climate monitoring network for the Sierra Nevada, along its 400 mile length, and several cross-range transects at different latitudes. Such information is crucial to the state for present and future decision making.

Global and regional models are crucial tools

Global model runs for both long (seasonal-decadal) and short (1-4 week) forecasts are needed to investigate predictability and process-related questions relating to climate impacts. CAP is working with J. Whittaker at CDC to run and assemble a historical medium range forecast dataset and has achieved approximately 10 years of 10+

member ensemble forecasts for 1-15d time leads, but this requires a lot of computer resources, considerable data management and progress is incremental.

Regional numerical models are still in a state of development, but are beginning to provide information at the regional and local scales. More work is needed to produce simulations and interpolations at the local and regional scale fidelity necessary for managers and policy makers.

Modelers are increasingly moving to smaller scales. As an exercise in applied climatology, there is a strong need to develop gridded versions of observed data sets that are both accurate and that are suitable for comparing retrospective model results with reality.

Crossing disciplines between climate science and human dimensions requires meaningful collaborations

One of our greatest challenges is to forge links between climate science and social science, policy and health science communities. Human health data is available for analysis related to climate effects, but in many cases is short duration, parochial, embargoed because of confidentiality issues, and difficult to acquire. It is almost essential to work with experts in the medical or epidemiological area to provide meaningful advice and collaboration in this area.

- **How did you develop your process for eliciting stakeholder needs/wants?**

  This has evolved somewhat through time. Initially, most research topics stemmed from ongoing interactions between the research community and local stakeholders. We also tried to concentrate on topics of wide interest. Not too many of these efforts have "run their course" and most of them are expected to remain as significant issues for the foreseeable future. With resource limitations we have been careful to select new topics and areas on a case by case basis.

Supply Side Assessment

- **Briefly describe the research agenda for your RISA.**

  Four primary thrusts:

  Providing improved forecasts and other climate information for 1) water resources, 2) wildfire and 3) human health concerns and to 4) develop an improved climate data and monitoring capacity for the California region. Problems addressed involve synoptic to climate change time scales. Collaboration with key stakeholders who represent interest of broader stakeholder groups and have needed expertise in "foreign" disciplines is a key aspect of our strategy. These thrusts are collectively building a capability to apply quantified climate services such as precipitation, temperature, wind, and humidity to reservoir operation, snow pack evaluation, fire prediction, vector-disease assessment, air quality assessment, and ground-water/surface-water flow simulations.

- **How does your RISA set its own research priorities?**

  Stakeholder interest, "tractability" of problems and issues, and the likely quality of science are key criteria. As a team largely of university or federal/nonprofit scientists who are evaluated by our published, creative output, so quality of science problems is a necessary component of our work, even if it is very applied. Also, CAP has a modest budget so is only able to sustain a relatively small core team. Thus we must exercise restraint in taking on problems and have been selective in focusing on problems that are suited to some core disciplinary strengths.

- **How has this agenda evolved over the duration of the RISA? What new projects have been started that were not anticipated at the beginning of the RISA? What projects have been terminated, and why?**

  Our initial intuition of three key study areas (water, fire, health) has proved to be on target in terms of stakeholder

interest and has provided fertile and societally useful problems. The feedback we receive from stakeholders backs this up. As CAP has matured, through interactions w a variety of stakeholders we have recognized the gap between a) the need for high resolution and high quality climate information and b) our community's ability to deliver it, so we have added an emphasis on climate observation and climate data, which transcends locales and sectors.

- **In your RISA, what is the balance between research on new subjects, and assessment/compilation of existing knowledge? How is this balance determined?**

  In California, interest in potential climate change impacts turns out to be very strong and appears to be growing. Consequently, some work that initially was more focused on seasonal-interannual variability has shifted focus toward climate change time scales. We have shifted attention in climate-health from Kawasaki's disease to a new effort involving air quality; however, our longstanding work with a group studying vector borne disease remains. Ground water efforts are now migrating regionally, from coastal California aquifers in the south-central portion of the state to the central valley.

- **Please describe the specific ways that knowledge is disseminated from your RISA. How would you assess the relative importance of various dissemination mechanisms, such as peer-reviewed publications, other types of publications, web-based presentations, public fora, etc.?**

  This has been in the form of peer-reviewed publications, presentations at conferences, workshops, and meetings with stakeholders and related citizen groups, along with numerous responses to news organizations. There has also been interaction with influential NGOs. As a leveraged outgrowth of CAP there has been a concerted attempt to reach the public directly with such efforts as the California Climate Data Archive and a monthly newsletter for the state, with articles and data (www.calclim.dri.edu). Many of these efforts are interlinked with national and regional synthesis activities, in part through presence on high level advisory committees and in program management activities are also quite important. A few examples: Dettinger is on Calfed Water Science Committee; .Redmond is on National Academy teams, Cayan is on California Climate Change committee for California Energy Commission and directs the physical science component of the state-supported California Climate Change Center. We maintain a CAP web site http://meteora.ucsd.edu/cap/.

Reconciliation/Managing Ecology of Supply and Demand

- **In what ways have considerations of supply for research shaped the evolution of your research agenda?**

  Because we have chosen topics that are related to ongoing applied research we have developed a list that is related to topics recognized by CAP members as areas where climate services could make a difference. We feel it would be counterproductive to select topics where there was little chance of offering anything very new, even if there were a demand for such information. We do not want to get stretched too thin, so we have restricted the primary thrusts to 3-4 main topics.

- **What tensions have arisen between stakeholder needs, demands, and expectations, and the scientific capabilities and priorities of the RISA? How have those tensions been addressed or resolved?**

  We seem to have been lucky or prescient in this regard. We do not seem to have been exposed to strong tensions between unrealistic expectations and what can be delivered. Also we have tried to proactively defuse such expectations if they seemed too wildly optimistic.

  We have, however, dropped further investigations in the Ventura area for now because local water purveyors have control issues over the analysis and distribution of information that may affect their ability to buy and sell water as well as intermittent litigation that preclude the pursuit of additional research in a more open or public arena.

- **How does your RISA evaluate the appropriateness of stakeholder needs (e.g., from the standpoint of public/private sector roles and responsibilities)?**

  There are regional differences in how the public conducts its business. In many ways the success that CAP has enjoyed is because this is California, and the state has a different mode of operation, and philosophical background, than do other areas. There is greater predilection for state agencies to cooperate, and there has traditionally been a high degree of openness and transparency in state government, and more particularly, at the mid-levels of government institutions. Also, there has been a strong technical component to many state activities. Finally, just for shear scale, even the smallest of these groups are working with sizeable resources. It is telling that the state expenditures just for mosquitoes is about $100 million a year. There is a widespread sense that government and public agencies, and the state educational system, have a strong role to play in addressing common problems, and CAP directly taps into that.

- **How are stakeholders identified? Which stakeholder groups are most important in influencing your RISA research agenda? Why? Which stakeholder groups are least important? Why?**

  In the arid West, and in California as well, water is pretty much king (though there are many princes). So anything that relates to water commands immediate attention. We could not afford to not address this issue. Also (on clear days) much of the state can look up and see that white mass of snow draping the mountains to the east. With all its connections, though, there are ample opportunities to link to related problems. State and other public agencies have certainly been the most influential stakeholders, because they have huge issues to wrestle with, and because the CAP participants have a solid reputation in these areas, and the host institution is well regarded throughout the state.

- **How does your RISA evaluate its research planning process?**

  We have not developed a formal process in the manner that some other RISAs have. There are many opportunities for discussion through the course of a year among subsets of investigators, and we usually try to meet as a larger group in association with some other meeting, or assemble at Scripps. A smaller circle of co-investigators notes areas that do not seem to be as productive. This group in turn leaves most of the final decisions regarding directions and funding in the hands of the PI. Disruptions, uncertainties, and extended delays in the annual funding cycle have made systematic approaches much more difficult in the last year or two.

- **What lessons in the process of the reconciliation of supply of and demand for science are relevant to the broader implementation of the CCSP?**

  Many new forms of analysis are not readily accepted by some sectors that have a long tradition of using historical climatology as the basis for forecasting or planning, such as ground-water/surface-water purveyors. Melding results from these traditional forms of analysis with those from the more recent approaches, centered around physically based modeling, is a considerable challenge.

  The biggest challenge remains finding a match between that which we do know or which we can know, and what others want to know. The biggest need in keeping this tension as low as it can be is for constant communication between the two sides of the ledger. Each side must understand the operating environment of the other side, the imperatives at work, the constraints faced, the audiences they must react to, the cultural landscape, the huge role of non-climatic issues, the ways in which information is processed, the uncontrollable forces that are at work, the role of groupthink, attitudes about knowledge and knowing, and most especially how decisions get made and how judgments are formed afterward about the correctness of those decisions.

  A very large lesson for the demand side seems to be that one cannot expect instant answers, Answers will likely not be definite but probabilistic, and that patience is needed to develop these approaches, educate the stakeholders on their usefulness and perhaps how to apply them and demonstrate the marginal benefits of these probabilistic estimates. The discovery process can only be forced so much. The equivalent large lesson from the supply side is that users must be engaged early on and taken seriously, and that this takes significant time and energy and resources, and a willingness to think in more than engineering terms.

For this interplay to be productive, there must be a greater and improved societal understanding of how science and the discovery process works, what science is and what it is not. The biggest misconception in this regard is that science is about certainty, whereas in truth doubt plays the central role, and our goal is to reduce the attendant uncertainty wherever we can, acknowledge that this cannot be reduced to zero, and yet strongly reiterate that knowledge that is uncertain is not useless.