Potential Impacts of Climate Change and Variability for the California Region

California Regional Workshop Report

Report to:
United States Global Change Research Program
National Assessment

Sponsored by:
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California Assessment Conducted by:
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Updates, Additions, and Corrections to this Workshop Report

This report reflects the best efforts of multiple authors and note-takers to capture a wide range of information presented at the workshop. It also includes supplementary information provided by participants. Updates, additions, and corrections are welcome, as this report will be used as a working document to support the on-going California regional assessment effort.

The document is intended as reflection of information and input provided at the workshop. In many areas additional information is needed. As this information becomes available, we will seek to include it in this report. We therefore request that updates, additions, and corrections be forwarded to us. The preferred format is as a Microsoft Word or Microsoft Excel attachment or as an e-mail text message.

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Executive Summary

The California regional workshop verified that potential impacts of climate change and variability for California's economy, environment, and society are significant. The assessment of these potential impacts is a large and complicated task. As part of the United States Global Change Research Program's (USGCRP's) national assessment efforts, the California regional assessment conducted a major workshop in Santa Barbara in March, 1998. Over 150 experts and stakeholders from throughout the region and from other parts of the country spent three days in intensive sessions examining potential implications of climate change and variability for the state. The plenary presentations, topical breakout sessions, and other material generated at the workshop is summarized in this report. The White Paper drafted for the California workshop has also been updated and is included here.

The California workshop was particularly successful in exploring potential economic, environmental, and social impacts due to the strong participation of leading business and local/state government stakeholders. Building on the region's considerable scientific strengths, the business participants in particular were able to put the potential impacts in perspective. As the Chief Economist of Pacific Gas and Electric (PG&E, one of the nation's largest energy utilities) observed, for example, the social impacts of potential climate change may fall disproportionately on those at the lower end of the income scale, because their livelihoods are often closely tied to the natural environment. Other concerns expressed at the workshop relate to the region's already over-stressed water supply systems, fire danger, agricultural production, extreme weather events, and impacts of sea level rise on coastal areas.

Environmental implications of potential climate change were also of considerable concern to participants. With the nation's second-largest number of threatened and endangered species and a number of critical ecosystems experiencing serious difficulties, potential climate change impacts may be significant. From coastal fisheries to alpine ecosystems, potential climate change and variability threatens the region's unique and valuable environment.

The workshop was intended to bring together key stakeholders and knowledgeable experts in a variety of fields relating to climate change and variability to consider what potential changes might mean for the region. The quality of participants and presenters was exceptional, and the workshop provided an extremely valuable opportunity for dialogue and information exchange. This workshop report does not purport to cover every potential impact of importance, nor is it a full analysis of the impacts. A great deal of work remains to be done to better understand specific potential impacts and the relationships of those impacts to each other and to larger systems. The California workshop and this report are important steps on a path toward better understanding of potential impacts of climate change and variability for the region.

California Regional Workshop Report

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Invitation

Participants in the California Workshop and Assessment effort are invited to post papers on this web site. Please submit documents via e-mail to: **wilkinso@envst.ucsb.edu**

Workshop Overview

March 9–11, 1998
Santa Barbara, California

The California Regional Climate Change Workshop is part of a nation-wide assessment project organized by the United States Global Change Research Program. The National Center for Ecological Analysis and Synthesis at the University of California, Santa Barbara, hosted the California Regional Workshop to discuss the potential impacts of climate change and variability.

Regional scoping workshops represent the first step in conducting a regional assessment. Twenty-two workshops encompassing every state and territory in the U. S., span from May 1997 to September 1998. Each workshop is sponsored by one or more government agencies, and is carried out by coordinators from local institutions. Each workshop will be followed by additional assessment activities to pursue the questions and information needs identified by workshop participants and to further develop and engage the network of interested and active individuals in the region. Information from each regional assessment will also be integrated into a Synthesis Report.

The purpose of the workshop was to begin the process of identifying areas of concern and opportunity regarding potential climate impacts. The workshop was intended to help clarify California's primary vulnerabilities and identify prospects for effectively responding to change by implementing new technologies and business ventures, and establishing resilience of both physical and policy systems.

Some 150 people attended the three-day Santa Barbara workshop. Speakers representing academic, research, business, policy, public, and private sectors discussed California climate variability from a variety of perspectives. More than 25 breakout sessions were held during the course of the conference, allowing small groups of stakeholders to discuss specific issues relating to the potential effects of global climate change on California. The conference format also provided time for ad hoc breakout sessions, giving the opportunity for individuals with similar concerns to discuss topics not addressed in the scheduled sessions.

Participants in breakout sessions were encouraged to include discussion of the following issues as they related to the session topic:

- Identify current stresses affecting the region, its natural resources, and economic sectors. Consider the dynamics of critical systems and the key drivers affecting them. In addition to stresses, what are the important trends and changes that are taking place? Include natural, economic, social, and other factors. Where are they headed? How will they influence California?

- Consider how climate variability and climate change might either amplify or dampen these stresses, or create new ones (including possible surprises).For example, how might climate change and variability affect investment decisions, trade patterns, resource costs, land-use patterns and land values, productivity of natural and human systems? Who will be more or less vulnerable to these changes?

- Identify new information that would allow people and organizations to better understand the linkage between current stresses and climate variability and climate change. To support appropriate and cost-effective responses to changes, what information needs exist, and what research is needed to answer important questions? In some cases, information sharing may be highly beneficial. In others, new research will be needed. What specific recommendations can this group offer?

- Identify win-win coping strategies that will help address the stresses created by climate change and variability as well as non-climate stresses. How can a better understanding of the potential impacts of climate change lead to better decisions in the immediate time frame? What strategies will solve existing problems while at the same time helping to deal with climate change?

California Workshop on Climate Variability and Change

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Plenary Sessions Notes

Global Climate Change and Variability: The Science of Climate Change and the Assessment Process in the United States

Robert Corell, Director, U. S. Global Change Research Program; Assistant Director for Geosciences, National Science Foundation

The National Assessment Process is conducted by the U. S. Global Change Research Program (USGCRP). The USGCRP is a federal interagency research program established by the 1990 Global Change Research Act to combine and coordinate the research and policy development interests of several departments and agencies of the U. S. Government and Executive Offices of the President. The USGCRP is mandated by legislation with the responsibility to undertake scientific assessments of the implications of climate change for the United States. The USGCRP is organized under the auspices of the Subcommittee on Global Change Research (SGRC), which includes representatives of the following agencies:

Department of Agriculture,
Department of Commerce (National Oceanic and Atmospheric Administration and National Institute of Standards and Technology),
Department of Defense,
Department of Energy,
Department of Health and Human Services,
Department of Interior,
Department of Transportation,
Department of State,
Environmental Protection Agency,
National Aeronautics and Space Administration,
National Science Foundation,
Smithsonian Institution,
Tennessee Valley Authority,
Agency for International Development,
Office of Science and Technology Policy,
Council of Economic Advisors,
Office of Management and Budget,
and the intelligence community.

Global change encompasses the full range of natural and human-induced changes in Earth’s environment. Global change can be defined as changes in the global environment—including alterations in climate, land productivity, oceans and other water resources, atmospheric chemistry, and ecological systems—that may alter the capacity of Earth to sustain life. Issues related to global change include:

- seasonal to interannual climate variability
- long-term climate change and variability—decades to centuries
- changes in stratospheric ozone, UV radiation, and atmospheric chemistry
- changes in land cover and in terrestrial and marine ecosystems, including land use, urbanization, population trends, ecology, biodiversity, etc.

Increased scientific knowledge of global change can reduce the vulnerabilities of human and ecological systems to major environmental changes. USGCRP supports research on seasonal to interannual climate change to help expand society's capabilities to anticipate climatic events such as drought, floods, and heat waves. Better understanding of changes in temperature and precipitation patterns and their impacts on crops, forests, water resources, and human pathogens will enable society to be better prepared to cope with potentially costly future changes in climate on time scales of decades to centuries. Similar benefits will be evident with respect to enhances knowledge about the impacts of increased UV levels associated with ozone depletion, changes in biological diversity, and changes in the productivity of land and water resources.

USGCRP focuses on the scientific study of Earth systems and its components. Its research is organized around a framework of observing, documenting, understanding and predicting global change. USGCRP employs interdisciplinary approaches to analyze information, explore new technologies, and examine existing and new theories to assess the consequences of these changes and the vulnerability of human and ecological systems to their impacts. From these assessments, USGCRP will help develop the tools and capabilities to conduct integrated assessments to synthesize and communicate this body of knowledge to policy makers and stakeholders.

The U. S. National Assessment of the Potential Consequences of Climate Variability and Change, of which this conference is a part, also stemmed from the Global Change Act of 1990. The Act states that the federal interagency committee for global change research "shall prepare and submit to the President and the Congress an assessment which:

1. Integrates, evaluates, and interprets the findings of the Program and discusses the scientific uncertainties associated with such findings;

2. Analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and

3. Analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years."

The National Assessment will provide a detailed understanding of the consequences of climate change for the nation and will examine possible coping mechanisms to adapt to climate change. It will be conducted as a public-private partnership emphasizing a process driven by needs of stakeholders throughout the country who are best positioned to identify the priority information needs and the most rewarding ways of responding.

[Sources: Workshop Presentation; USGCRP Web site: www.usgcrp.gov]

Modeling Climate Change and Future Climates

Michael MacCracken, Executive Director, National Assessment Coordination Office, U. S. Global Change Research Program

General Circulation Models (GCMs) are the primary tool for understanding and predicting natural climate variations and providing reliable estimates of anthropogenic climate change. Models are not perfect, but they are improving.

GCMs mathematically simulate the interactions of the atmosphere, oceans, and land masses, which together determine Earth's climate. Confidence in GCMs stems from physical laws as well as their ability to reproduce past and current climates. Using past weather records and data from boreholes, ice core samples, tree rings, and coral reefs, scientists construct estimates of temperatures, precipitation, and to some extent atmospheric composition for the past five to six centuries.

Observational data shows that the average global temperature has increased about 1° F since the mid-19th century. The global temperature is warmer now than at any time since at least 1400, and perhaps warmer than it has been for many thousands of years. Warming is apparent in temperature records as well as in physical evidence such as retreating mountain glaciers, reduced springtime snow cover, and rising sea levels.

By comparing past climate data to GCM simulations, researchers can gauge the reliability of the models. A variety of models for the 19th and 20th centuries are being conducted. Model predictions show with increasing agreement with changes observed over the past 30 to 50 years. The closest agreement occurs when simulations that couple ocean, atmosphere, and land surface also take into account greenhouse gases and sulfate aerosol particles.

Accurately projecting GCMs into the future depends on largely future greenhouse gas emissions. Highly uncertain forecasts of global population growth, land use, energy consumption, economic stability, technological solutions, and many other variables lead to a variety of possible outcomes.

As the Intergovernmental Panel on Climate Change has stated, the balance of evidence suggests that human activities are contributing to climate change, and that there has been a discernible influence on global climate.

[Sources: Workshop Presentation; "Climate Change: The Evidence Mounts Up," M. MacCracken, in *Nature*, Vol. 376, pp. 645-646; "Is the Climate Changing? Indeed it is" M. MacCracken and T. Karl in *Bob Ryan's 1997 Almanac and Guide for the Weatherwise.*]

Climatically Sensitive California: Past, Present, and Future Climate

Norman Miller, Staff Scientist, Earth Sciences Division, Lawrence Berkeley Laboratory

INTRODUCTION:

California is sensitive to climate variability and climate change. California represents the world's seventh largest economy, with an increasing population, rapidly developing industries, and expanding societal demands. Climate variability and climate change impose stresses on California's infrastructure. The climate science community has indicated that global temperature is increasing, wet season precipitation events are becoming more extreme, and sea level is rising (Intergovernmental Panel on Climate Change [IPCC] 1995). These changes impact fresh water systems, land use, industry, natural ecosystems, and environments. The focus of this overview paper is to indicate some of these potential impacts, provide some insight into future projections of California climate, and indicate what might be done to reduce hydroclimate related risks.

Fresh water is a major driver to the success of California's prosperity. Agriculture, urban development, information technology, among others, depend on the availability of water resources. California's water comes primarily from northern California mountainous river basins with some Colorado River allocations. Late Winter, Spring, and Summer runoff from high elevation mountains provides the needed water resources during the long dry season (April to November). Decreases in this water supply may force a change in the existing demand.

California's water resources infrastructure is based on a network of reservoirs, levees, and canals. This extensive water conveyance system is not fully designed for current and future climate variations, climate change, and land use change. Reservoirs serve as water storage and flood control systems. During the wet season, reservoirs and levees provide flood protection. During this time of year, communities within floodplains are protected from heavy precipitation events and are at a reduced risk of flooding and extensive loss. Wet season dam releases frequently occur during periods when reservoirs are at very high levels. Such releases are required to provide storage capacity for additional inflow from runoff, while protecting the integrity of dam structures. These releases need to be timed to minimize any potential downstream flooding. At present, river forecasters rely on 48-hour weather forecast information to make decisions on the amount to be released and on high streamflow and runoff estimations. Wet season heavy precipitation events may stress levee systems that run the length of the central valley. For example, the Winter 1997 central valley floods were due to a warm January storm producing an unexpected large amount of runoff to an already water stressed levee system. This occurrence of flooding implies that the safety and functionality of the reservoir and levee systems in California are sensitive to wet season heavy precipitation.

Additionally, wet season storms often cause increased erosion and landsliding, especially developed regions that may lack proper drainage of runoff during extreme weather events. This has been seen throughout California during the 1998 El Niño that was particularly strong during February, where property losses approached $500 million. During wet seasons with extensive periods of heavy precipitation and saturated soils, agriculture is hampered due to crop damage and delays in planting. Storm and land use induced sediment loading to river systems may impact aquatic ecosystems. Other ecosystems, including migratory birds, may also be damaged due to loss of habitat, breeding grounds, or food supply.

Long dry periods reduce the available water resources to the state. Water reduction was common during the multi-year droughts that occurred in the 1930s, 1980s, and during other dry periods. Drought impacts are most pronounced in urban centers, natural habitats, and in agricultural productivity. During the 1980s drought, Californians experienced water rationing, the San Joaquin delta received below average fresh water, and agro-industry felt some cutbacks in their water usage. Decreased fresh water not only inconveniences our society, but significantly impacts ecosystems dependent on fresh water. The resulting increased salinity in the San Joaquin delta significantly reduced the health of fish habitats.

In general, land use change, such as deforestation and urbanization, will amplify the risk and potential loss associated with increased wet season precipitation and long drought periods in California. Coupled with temperature increases, it may harm species biodiversity. As California continues to expand, we need to plan for the future in a responsible fashion. In the next section, climate patterns, indicators, and natural variability are discussed. This is followed by a section on climate projection requirements and projected California climate. The conclusions focus on where do we go from here.

CLIMATE PATTERNS, INDICATORS, AND TRENDS

California is characterized by a Mediterranean climate with wet winters and long dry summers. Precipitation and temperature patterns during the winter and spring have been associated with large-scale patterns in the North Pacific atmospheric circulation (Cayan and Peterson, 1989; Redmond and Koch, 1991). Cool wet (warm dry) seasons have been correlated to the position of the Aleutian low pressure center. If the Aleutian low is positioned far eastward (i.e. Gulf of Alaska)), then there is an increased likelihood for

California to have a cool wet Winter and Spring. The opposite (warm dry Winter and Spring) is expected for a far westward position of the Aleutian low. Cayan et al. (1993) have indicated this pattern in their analysis of streamflow for the Smith, Consumnes, and San Joaquin River basins.

This general description is complicated by other processes, such as warm eastern equatorial Pacific sea surface temperatures. During the Fall of 1997, the eastern equatorial Pacific sea surface temperature was several degrees above normal and remained above average well into the Spring of 1998 causing a large increase in California precipitation. This warming was due to the naturally varying El Niño Southern Oscillation (ENSO). The large warm water pool provided moisture into the atmosphere which precipitated out when it reached California. The heavy precipitation during January and February of 1998 was directly related to this phenomenon. The Aleutian low pressure was in a westward position and a high pressure ridge was to south. This combination of atmospheric patterns, among other complex interacting processes, set the storm track direction during the intense January-February 1998 precipitation. ENSO has a natural cycle on the order of once every four years. A measure of the occurrence of ENSO is the Southern Oscillation Index (SOI). The Southern Oscillation Index is a measure of the pressure difference between Tahiti and Darwin, Australia. A negative value is an indication of an El Niño year, while a positive value indicates a La Niña year. There has been speculation about the effect of Green House Gases (GHGs) on the variation in the occurrence and strength of El Niños, however, at this time there is not sufficient evidence to indicate that such a link exists.

However, evidence suggests that temperature has been increasing since the industrial revolution due to increased Green House Gas (GHG) emissions into the atmosphere. There have been numerous studies (e.g. Keeling et al., 1995) that show a strong correlation between global temperature and the atmospheric concentration of carbon dioxide. Based on 287 borehole measurements, global temperature from 1500 to present have been determined (Pollack et al., 1998). The significance of this data is that global temperature has increased 0.5° C from 1500 to 1900, and 0.5° C from 1900 to present. That is, measurements indicate that during the last 100 years global temperature has increased at the same rate as the 400 years prior to 1900. The temperature oscillation shown for the period 1860 to present is based on surface measurements. There are a number of other measurements (tree ring data, core sediments, isotope analysis) that agree with this result.

These large-scale patterns and trends can be seen in California by looking at the freshwater inflow into the San Joaquin delta as an indicator of inter-annual precipitation in the Sierra. Using carbonate oxygen 18 isotopes from sediment cores, Ingram et al. (1996) were able to infer the amount of freshwater inflow for the time period 1200 to 1980. This long time series approximately indicates that there were long dry periods (1420-1460, 1500-1600, 1625-1630) as well as periods of above average precipitation and inflow (1225-1400, 1660-1720, 1800-1880). We are currently in a period of above average fresh water inflow, due to the large amount of water exported from the delta for agriculture and urban use.

IS THERE AN ENHANCED CLIMATE VARIATION IN THE HYDROLOGIC CYCLE?

Observed temperature indicators from the Second Assessment Report of the International Panel on Climate Change (IPCC, 1996) provide numerical estimates on global changes in the near surface air and near surface ocean temperatures (0.3 - 0.6° C increase), Northern Hemisphere snow cover (10% decrease), and mountain glaciers (general retreat), with high levels of measurement confidence. This information and related findings suggest that a serious effort to better understand the impacts of climate variability and change in California.

The majority of California's water supply includes eight major Northern California river basins that provide snowmelt runoff as reservoir storage and water transport to Southern California. These eight basins; the American, Feather, Merced, Sacramento, San Joaquin, Stanislaus, Tuolumne, and the Yuba. Possible climate change impacts on the timing of California runoff was first pointed out by Roos (1987). Several modeling and analysis studies followed (e.g. Gleick, 1987; Roos, 1989; Cayan and Henderson, 1989; Lettenmeir and Ghan; 1990, Redmond and Koch; 1991; Aquado et al. 1992; Cayan and Riddle, 1993; Dettinger and Cayan, 1995; Jeton et al., 1996).

Area-averaged minimum temperature measurements (1975-1995) representative of a region that includes Sacramento and Lake Tahoe adjusted to seasonal oscillations indicates an increase of 0.086° C per year, which is somewhat faster than the fitted maximum temperature increase for the same period. These increases in the last twenty years are not reflected in the long historical record, however, they tend to be in agreement with observed early season snowmelt as well as increases in GHG concentrations in the atmosphere. The significance of the minimum temperature increasing at a faster rate than the maximum temperature is a reduction in the daily temperature difference, which plays an important role in the hydrologic cycle.

Dettinger and Cayan (1995) have analyzed the above eight river basins for the percent of annual runoff that occurs as Spring (April to June) runoff during the period 1910 to 1990. An Eight-Rivers Index indicates that there is a statistically significant decrease in the percent of Spring runoff. The American River basin alone showed a 10% decrease in Spring runoff to annual runoff during the 1950 to 1990 period.

The northern coastal Russian River basin response to precipitation (1900 to 1995) is indicated by the river stage height at Guerneville. The river has exceeded flood stage (32 feet) about once every three years during the first half of this century. However, during the second half of the century, flood stage is exceeded more frequently. This suggests an increase in extreme wet season precipitation events since approximately 1950.

These observations of California's climate response require an investigation of possible future scenarios. Such "what if" studies help to shed light on the potential risks, provide planners with needed information, and in general will help to educate our society on climate variability and climate change.

CLIMATE PROJECTION REQUIREMENTS

Climate projections have two general requirements; the modeling system should be well validated and the public has sufficient confidence in these results to act on them. Individual model components (e.g. cloud physics module, snow budget module, runoff module) should be carefully studied for proper conceptual representation of their processes. Comparison to observation data, remotely-sensed, and synthesized data will indicate how well each model performs. Once this is accomplished to an acceptable level, then coupled model systems are validated. A major task is acquiring the extensive data base for these model validations and analyses.

Coupling models for understanding climate response at a range of scales is a complicated task. GHG related climate projections have been produced at the global scale for the past two IPCC Reports (1990, 1996). These scales (grids with lengths of order 100 - 500 km) are too coarse for understanding processes at the surface such as, riverflow, agriculture, and socio-economic impacts. The concept of downscaling climate information for hydrologic modeling was presented by Hoestetler (1992). One of the difficulties of downscaling global climate information (grids with length scales of order 100 - 500 km) to ecologic, hydrologic, and socio-economic fine-scales (1 - 100 m) is the lack of data within the global length scales that are needed for understanding processes that are sensitive to change at the fine scales. One approach to this downscaling problem is the use of regional climate system models. Regional climate system models use the global-scale information as input to limited area models which interactively calculate atmospheric and land surface processes with grid scales of order 10 km. The difference between the global and regional-scales is apparent. California is represented by less than ten global-scale grid points, while the regional-scale provides thousands of points of gridded climate information. This difference is important when modeling the effects of atmospheric moisture moving above mountains that global-scale models may completely miss.

To provide fine-scale climate, information area-weighted variables or probability distributions may bridge this spatial gap. There are other types of fine scale approaches that perform well for short (1-2 day) simulations, but have not yet proven useful for climate simulations. Modeling hydrology with spatial information requires either the area-weighted values or distribution values that represent the river basin being studied. As an example, the Russian River basin can be broken down into sub-basins, where each sub-basin contains many small catchments. There are still many data needs for understanding climate at fine-scale and this is an ongoing effort from various groups within the climate research community.

EXAMPLES OF CLIMATE MODEL VALIDATION

Climate model validation is best understood by comparing climate simulations to observations, model comparisons, and statistical analyses. The IPCC (1996) provides a number of global model intercomparisons, observational comparisons, and statistical analyses. For the period 1860 to 1990, the IPCC has compared observed global-scale temperature with simulated temperature with increasing GHG concentration and aerosol concentration. A large-scale model validation of ocean models is the ability to simulate the ENSO cycle. The comparisons show good agreement (0.63 correlation) between the observed and simulated western boundary sea level height changes with time.

Comparing regional scale models of precipitation in California for the 1994-1995 precipitation season with the simulated precipitation from the Regional Climate System Model (RCSM) with large-scale input provided by the National Oceanic and Atmospheric Administration validates river basin-scale hydrologic models for the period 1982-1984. The total verification (1978 to 1984) indicates an 0.84 correlation when the hydrologic model is forced by observed precipitation for streamflow. The coupled large-scale to regional-scale to basin-scale system shows good predictive capability for the period January to March 1995.

These types of model exercises indicate the level of component and coupled model validation. Based on these types of results, one can better understand how well we project future climate with current models.

PROJECTED CALIFORNIA CLIMATE VARIATION AND ITS IMPACTS

Drawing from observations and previous model studies (Lettenmeir and Ghan, Gleick) there is good confidence indicating that California will likely experience a continued trend of increasing temperature, increased extreme weather events, extended drought periods, and sea level rise. Some specific California effects are an early snowmelt, increased flooding, increased erosion and landslides, decreased water resources for extended periods, and low lying regions under water.

A regional simulation of the effects of doubled atmospheric carbon dioxide based on a large-scale model (NCAR’s CCM2) and NCAR Regional Climate model (RegClim) indicated changes in alpine regions. Winter and Spring snow depth is a function of elevation for present CO_2 and 2 x CO_2 levels. The 2 x CO_2 studies indicate that the snow level is considerably higher in elevation and that the total snowpack is substantially decreased. By estimating the corresponding runoff for this study, we can see that the Winter runoff is very high under 2 x CO_2 conditions, while the Spring and Summer runoff is quite low. A study of the American River basin with a projected 4.4° C temperature increase also shows the early runoff. These studies and the earlier work by Lettenmeir and Ghan, Gleick, and others tend to agree with the IPCC.

Roos has calculated the effect of a 30 cm sea level rise on the frequency of high stage height on the San Joaquin River near Antioch, a region with levees protecting low lying areas. What was once considered a 100-year event will quickly become a 10-year event.

These results lead us to ask questions about planning and developing within the California floodplains and other sensitive areas. The 100-year flood plain is based on a short historical record that does take into account climate change during this century. It is clear that this and related concerns need to be addressed. New developments within flood plains need to be accessed for long-term costs. The erosion at Pacifica has been known since the 1950s, yet houses have been built close to the cliffs requiring a proposed $1.5 million seawall.

WHERE DO WE GO FROM HERE

Understanding climate, advancing our monitoring systems, coordinating research, and providing well validated information that the public and policy makers can trust is an important direction that we need to focus on. Coordinated climate research, assessment, and outreach centers throughout California are an important approach toward understanding the impacts of Climate change in California. Universities, National Laboratories, and non-profit centers should work to complement each others ongoing capabilities. Legislatures will need to become educated on these issues and make well informed policy for long term solutions. The media needs to move away from sensationalism and focus more on educating society on issues that are of substance.

[Source: Workshop Presentation]

Socio-Economic Implications of Climate Change for California
Tapan Munroe, Chief Economist, Pacific Gas and Electric Company

Economically, this is the best decade we've had since the '60s, maybe better. Munroe calls this the "Nirvana Economy": modest output growth, low inflation, stable interest rates, low unemployment, steady income growth, and consumer confidence. The stock market continues to boom, inflation is in check, interest rates have remained steady, and the federal government has balanced the budget. There are no signs that the economy is slowing.

The Los Angeles basin is the largest manufacturing center in the U. S. While aerospace in southern California lost nearly 40% of its jobs (some 40,000) since the early '70s, the entertainment industry has gained more than 90,000 jobs.

But there are still problems with the economy. The economy of the '90s is one of high growth, but also high risk, unlike the high growth and high security of the 1950s.

Since 1978, the wealthiest 20% of the population saw a 30% gain in income, but the poorest 20% saw income drop 27%. Only 40% of the population had gains—60% had losses.

Wealthiest	20%	30% increase in income
	20%	5% increase in income
	20%	6% decrease in income
	20%	18% decrease in income
Poorest	20%	27% decrease in income

80% of economic growth is in small businesses, but 80% of all small businesses fail within their first 5 years. Therefore, economic prosperity could decline as many small businesses fail.

The wealth gap can only be decreased through better access [and use of] training, education, and workforce preparedness. Rural/agricultural California needs to diversify in order to decrease unemployment and increase income. Agriculture won't create more jobs or more wealth.

In natural-resource dependent industries such as Central Valley agriculture, unemployment is as high as 25%. This area is already stressed, and will be highly vulnerable to continued stresses from climate change.

New construction (measured by building permits) is not growing at the same rate as the rest of the economy: in 1994, 97,000 permits were issued; in 1996, the figure dropped to 94,000. Despite the economic recovery, in 1998, an estimated 106,000 will be issued, still far below the late 1980s rates of 250,000 to 300,000 permits issued annually.

The growing crises in the Asian economies could have serious repercussions for California industries, particularly electronics, which is closely tied to Asian production and markets.

Climate change has the potential to dramatically affect California's economy, but few businesses or government agencies take change into account when forecasting economic trends.

[Source: Workshop Presentation; Tappan Munroe, "1997 California: Continued Economic Recovery and Restructuring," PG&E, 1997]

The Art of the Long View: Creating Scenarios for Alternative California Futures

Peter Schwartz, President, Global Business Network

In 1898, looking around us, we could not possibly have predicted 1998. How can we expect to know 2098 based on what we know now? Scenarios are tools for ordering perceptions about alternative futures in which today's decisions might play out. Scenarios present alternative images instead of extrapolating current trends from the present. A scenario is not a prediction, but a systematic and imaginative exploration of what is plausible.

Creating scenarios requires planners to question their assumptions about how the world works and to seek out diverse views that challenge accepted wisdom so they can anticipate possibilities that might be missed or denied. Using scenarios is a way to rehearse the future. By recognizing the warning signs, one can avoid surprises, adapt, and act accordingly. The end result of scenario planning is not necessarily a more accurate picture of the future, but better decisions today.

Scenario planning follows systematic and recognizable phases, but also requires creative thinking. The process is highly interactive, intense, and imaginative. It begins by isolating the decision to be make, challenging perceptions, and seeking information, often from unorthodox sources. The next steps identify and analyze driving forces, predetermined elements, and critical uncertainties. These factors are then prioritized according to importance and uncertainty. The exercises culminate in three or four carefully constructed scenarios, each representing a plausible alternative future. Planners can then devise actions that make sense across all or many scenarios.

In building scenarios, it is becoming increasingly important to consider environmental forces and their implications for the future of business and society. California will have to add climate change and variability into all planning processes in order to avoid surprises. Perhaps scenarios can also help California make decisions today to create a more desirable future.

The question of sustainability is one that must be addressed in building scenarios. Since the industrial revolution, mechanized industrial production, increased natural resource use, and improvements in health care and consequent rise in population have placed numerous and growing stresses on the natural environment. As the 21st century approaches, the world is experiencing a global population that has tripled in this century, with startling consequences: steadily expanding land use; loss of biodiversity; a rate and scale of natural resource consumption that in hundreds of years has led to the depletion of stocks that took tens of thousands or even millions of years to accumulate; degradation of the quality of air, water, and land, and anthropogenic climate change.

By the early 1990s, fossil fuel combustion and deforestation were releasing roughly eight billion tons of carbon into the atmosphere every year. Such artificial emissions represent a 20% increase over natural flows. The total amount of carbon present in the atmosphere is increasing by about 4 billion tons a year. Carbon dioxide concentrations have increased from an estimated 280 parts per million in 1750, to 315 in 1958, and 357 in 1993.

Some of the elements that will need to be considered in scenario planning for California's future include the possibilities of hyper-change created by technology, population increases, natural resource depletion, and political fragmentation. Basic strategies of many businesses—and people—include primarily a "more of the same" approach. But losses force change. Scenarios are a way to anticipate the changes and adopt adaptive strategies to avoid losses.

The subject of the nation's oil use of is a prime candidate for scenario planning. Oil imports are our Achilles' heel (witness the 1970s' oil crisis). How well are we prepared to deal with a decline in supplies? If we reduce our dependency now by developing non-oil sources of energy, the U. S. can avoid possible international tensions and conflicts, while creating new industries to replace a declining one.

[Sources: Workshop Presentation; Global Business Network Web site: www.gbn.org; "Sustainability: The Source of the Crisis," Hardin Tibbs, Global Business Network, 1996.]

From Rio to Kyoto: International Policy Process
John Fialka, Wall Street Journal. Keynote Address.

Fialka reported for the Wall Street Journal on the global warming treaty negotiations which took place in Kyoto, Japan, in December 1997.

The negotiations were contentious. The U. S. delegation was not supported by the Senate, which charged that curbing energy use will knock the U. S. out of the global economy. OPEC nations are opposed to any fossil fuel restrictions. Small island nations, which stand to lose everything if sea level rises significantly, vehemently sought tighter emissions cuts. With their long history of dominance by imperialistic foreign powers, African nations resist any form of direction from developed countries, especially concerning energy use. China and India, the most populated nations on Earth, are the big coal consumers of the future. Asia, Africa, and other developing nations do not want any energy restrictions imposed on them when energy is seen as the key to national development and prosperity. The disagreements led to eight days of stalemate. Vice President Al Gore stepped up to vow flexibility on the part of the U. S., particularly regarding emissions trading.

In the end diplomats from more than 160 nations approved the treaty, which requires industrial nations to cut emissions of greenhouse gases starting in 2008. The agreement states that the European Union would reduce its emissions by 8% below 1990 levels, the U. S. by 7%, and Japan by 6%. The U. S. was unsuccessful in securing ‘meaningful’ participation in emissions cuts by developing nations, a detail that Senate leaders declared would prevent the treaty from being ratified by the U. S.

The treaty relies heavily on emissions trading, patterned after a successful U. S. model used to cut sulfur emissions. An international body called the Clean Development Fund would facilitate trading emissions credits as a commodity, allowing companies or nations that reduce their emissions beyond their quotas to sell permits to others that need them. Some economists have predicted that this would create a $120 billion-a-year market. If ratified, the treaty is expected to start a gradual economic realignment worldwide, creating winners and losers.

The Clinton administration says that the treaty will force the U. S. to use energy more efficiently and businesses will develop new energy-saving technologies without curbing economic growth. Environmental groups argue that the treaty will spur reliance on alternative fuel, helping those industries grow. The treaty also includes mechanisms that will promote protection of tropical rain forests which serve as carbon dioxide sinks.

There are many opponents to the treaty, however. Some have vowed that "business, labor, and agriculture will campaign hard and will defeat it." Critics claim that the costs of bringing down carbon dioxide emissions would double the price of crude oil, natural gas, and coal, and the effects would be felt throughout the economy. If the industrial nations are forced to bear the brunt of emissions cuts, large industries with high energy costs will be compelled to move their operations to developing nations that are not being required to cut emissions, resulting in tremendous U. S. job losses.

Some economists figure that rising energy costs could result in a $2,000 a year increase for every household in the nation, likening it to a tax increase no politician would condone. Others believe that figure is far too high, and that if policies are implemented carefully, households, industry, and the economy will have time to adapt.

Given the resistance expected from industry, the treaty is not likely to be ratified anytime soon. Energy industry lobbies, especially coal, claim that an increased global carbon dioxide level will be good for crops, but the treaty will only make energy more expensive and farmers will be forced out of business. Labor is opposed to the treaty, arguing that by forcing the U. S. to make disproportionate cuts, they will lose their jobs to workers in nations not subject to such stringent restrictions.

Underlying much of the opposition in this country is a lack of scientific comprehension that would enable people to understand the problems and the risks of climate change, and how they contribute to them, and how they can minimize them.

Climate change is a grassroots problem, but the people who understand the problem and its potential consequences—primarily scientists, academics, and science journalists—haven't done a good job of educating the public and politicians.

European nations seem much more willing to face the issues of climate change and search for solutions. The U. S., however, does not seem to understand the risks. America tops the world in emissions production, but we are likely to be surpassed by China as its per capita energy use climbs. The U. S. must regain its sense of global stewardship and take the lead in addressing climate change.

People believe that problems on the scale of climate change will be solved by others—scientists, industry, other nations. But everyone contributes to climate change, and if everyone chooses to leave the solutions to others, the problems will never be resolved. We need to tackle the situation with better education and grassroots activism. The gaps in understanding need to be filled by those who know before any progress can be made. Businesses, communities, labor, religion, and other groups must be brought in to join the scientists and environmentalists. By developing a sense of interdependence and trust, these groups can work together to create solutions that will address all their concerns.

[Sources: Workshop Presentation; Wall Street Journal articles by Fialka, December 10, 11, 12, 1997]

Climate Impacts on the Ecosystem Services Underpinning California's Economy and Quality of Life

Walter Oechel, Director, Global Change Research Group; San Diego State University

Camille Parmesan, Research Scientist, National Center for Ecological Analysis and Synthesis, UCSB

Peter Gleick, Director, Pacific Institute for Studies in Development, Environment, and Security

Oechel led the presentation with some observations of current climate trends as well as hypotheses about future change and impacts.

In the future, if atmospheric carbon dioxide continues to increase, temperate regions are likely to experience greater changes than tropic or boreal regions. However, northern regions are not warming uniformly. Since 1960, Alaska has warmed at a much more rapid pace, averaging 1.25° C per decade. More recently, southern Greenland has been getting colder, a possible precursor to the failure of the North Atlantic cycling which has brought warmer waters north and resulting in a relatively warm Europe.

For vegetation, there will be mixed results. As carbon dioxide increases in the atmosphere, photosynthesis increases, generating more plant matter. This also increases the amount of fuel available to burn, heightening fire hazards in many regions. Water efficiency also increases as CO_2 rises, but at the same time, the leaf area increases, allowing for more evapotranspiration, resulting in no net change in water use. Extinction rates will also probably increase as climate changes. Plants cannot migrate quickly enough to keep up with the rate climate change we are experiencing and predicting, and endangered species plans thus far are not accounting for rapid change.

Resource impacts are a function of population multiplied by resource use per person. When one factor increases, resource impacts increase. Developing nations are eager to improve their standard of living, which usually means greater consumption of resources. This will result in continuing growth of emissions—and accelerating climate change—unless consumption of fossil fuels and deforestation are curtailed.

Parmesan has been studying species shifts worldwide as indicators of climate change. Consistent with predictions of climate change, populations of some butterflies are observed to be dying out in their southern ranges and extending their northern limits. In the western U. S., a 0.7° C rise in average temperatures has resulted in a 105 km northward shift in the range of one butterfly species. Similar shifts have been observed in Europe.

In the 1930s and ‘40s, warming was observed mostly in daytime temperatures. The current warming trend is evident mostly nighttime temperatures.

Prehistoric episodes of climate warming were much slower than today’s rapid rate of change. In the past, species could adapt and evolve as the climate slowly changed. Today, animals cannot adapt quickly enough, and in a human-dominated landscape, species can’t easily migrate through human densities. With species less mobile than butterflies, rapid climate change will not allow animals to shift, and extinction rates may accelerate.

While increased photosynthesis resulting in more plant matter is another impact of increased carbon in the atmosphere, a side effect of this is that the carbon-nitrogen ratio is plants is disturbed, and the food quality of crops in reduced.

Gleick specializes in California water issues, and made these observations:

In general, climate change will bring about a more vigorous hydrologic cycle because higher temperatures result in greater evaporation. Global averages, however, aren’t really relevant regionally, and there will be a great deal of variation at the local level. In California, additional rainfall won’t be evenly distributed. In the north, already a relatively wet region, more precipitation will fall, while the dry south will probably get drier. A warmer climate will result in more precipitation falling as rain rather than snow at high elevations, reducing the snowpack. This in turn will cause greater runoff in spring—increasing the danger of flooding—but less in summer—by as much as 50%. These changes will affect natural ecosystems, farming, recreation, and hydroelectricity generation, and drastically alter water management practices in California. The Colorado River supplies a significant amount of water to southern California. If a change in precipitation patterns decreases the river’s flow by 10%, reservoir storage will decrease by as much as 30%, causing a 30% decrease in hydroelectricity generation and an increase in salinity which would violate standards. Such decreases in hydroelectricity generation will also result in more fossil fuel burning to produce electricity, leading to higher CO_2 emissions.

The more we learn about the possible impacts, the more intelligent decisions we can make to adapt to or mitigate the impacts. The costs of planning ahead will always be less than the costs of reacting to emergencies.

[Source: Workshop Presentation]

Cutting-Edge Research on Impacts of Global Change in the Western U. S.

Ruth Reck, National Director, National Institute for Global Environmental Change; UC Davis

Tom Suchanek, Western Regional Director, National Institute for Global Environmental Change; UC Davis

Over the last 43 years, an 80% decline in offshore zooplankton has been documented—and is coincident with a 1.5° C temperature increase.

Greenland ice cores document climate going back 60,000 years, and reveal climate flickering—rapid swinging from cold to warm climates in a matter of decades. Does this indicate that our current rapid warming trend isn't unnatural?

Current research to help answer this question includes investigations of CO_2 fluctuations, and comparing old growth forests with clearcut and second growth forests. The Hadley climate model developed last year coupled atmospheric and oceanic circulation patterns to more accurately depict climate change, and may improve long-term climate predictions.

A California Climate Initiative: Exploring Stakeholder Collaboratives for a Sustainable Future

Jeff Dozier, Dean, Donald Bren School of Environmental Science and Management, UCSB
Jim McWilliams, Professor, Institute of Geophysics and Planetary Physics, UCLA
Linda _________, Bechtel Group
Michael Moore, Commissioner, California Energy Commission

The issue of climate change is largely not understood by the public, and it is incumbent on academia to communicate the state of knowledge to laypeople. Public opinion is part of the decision-making process, and atmospheric scientists must participate in shaping public opinion. Recycling was largely a grass-roots idea that was spread by informed, concerned individuals to municipalities and businesses, resulting in widespread public support. Understanding of climate change issues can also become widespread if scientists communicate with the public.

Environmental information must also be translated by scientists and academics for lawmakers, economists, and corporations so that public policy will be formulated by informed decision-makers. At the same time, scientists must continue to refine the state of knowledge.

Better measurements, models, and monitoring are needed to comprehensively analyze climate changes over the next 20 years. The immediate goal is to provide an assessment of the range of uncertainty and the likelihood of various changes, as well as to improve the ability to detect early clues which will help narrow the range of possibility. Developing climate scenarios can help influence decision-makers and thus influence the future. The state of knowledge is growing such that we may be able to choose the future we want.

Funding for these activities is of course critical to the process. Universities, governments, industry, and businesses are all needed to contribute to the effort. The immediate obstacle is convincing these entities that a better environment is a valuable asset worthy of significant investment. The challenge is to create an awareness that non-market goods are as beneficial in the long term to profitability as conventional products.

Most governments, businesses, and individuals are focused on relatively short-term planning, and the long-term effects of current trends are difficult to address. Day-to-day needs and crises take precedence over the intangible possibilities of long-term change. Other long-term issues that are often not addressed include sustainable economic growth, environmental protection, and equity. The public must grapple with the notion that the problems of today may have been preventable if they were addressed earlier, and project that notion to future problems.

The response to global change will largely be a technological one. Research into physical science and economic impacts is needed to develop technology to reduce GHG emissions, as well as to improve response to change. The shifts in business practices, industrial processes, governmental controls, and personal behavior will take time to become mainstream. Federal subsidies, tax breaks, and other incentives are needed to encourage industry to make such shifts. Industry is often reluctant to make changes because of the need for large capital investments as well as a perception of high risk. “Incubator funding” by government is needed to stimulate industry.

Breakout Sessions

A comment on the following section:

The breakout session notes are presented here in the workshop report as they were submitted. All of the note-takers were volunteering their time, and most of the notes were submitted at the workshop in hand-written form. It is possible that in the process of typing the notes for this report we have inadvertently altered or misinterpreted the handwritten content. We are also lacking information on who to credit for taking notes in a number of sessions. For those who were involved in the workshop, please help us supplement and/or correct the information as necessary and provide names for the note-takers. Additional information is welcome. We would also be grateful for any additional notes which have escaped our round-up efforts.

Each breakout group was asked to address the following questions:

Questions to be Addressed in Breakout Sessions

Breakout discussion leaders and participants should feel free to take the conversation in directions which are interesting and useful to participants. Please do not feel constrained by the questions below to the exclusion of points of specific interest to the group.

It would be helpful for the larger objectives of the workshop and the national assessment process if you would include discussion of the following issues:

1. Identify current stresses affecting the region, its natural resources and economic sectors.

Consider the dynamics of critical systems and the key drivers affecting them. In addition to stresses, what are the important trends and changes that are taking place? Include natural, economic, social and other factors? Where are they headed? How will they influence California's future?

2. Consider how climate variability and climate change might either amplify or dampen these stresses, or create new ones (including possible surprises).

For example, how might climate change and variability affect investment decisions, trade patterns, resource costs, land-use patters and land values, productivity of natural and human systems? Who will be more or less vulnerable to these changes?

3. Identify new information that would allow people and organizations to better understand the linkage between current stresses and climate variability and climate change.

To support appropriate and cost-effective responses to changes, what information needs exist, and what research is needed to answer important questions? In some cases, information sharing may be highly beneficial. In others, new research will be needed. What specific recommendations can this group offer?

4. Identify win-win coping strategies that will help address the stresses created by climate variability and climate change as well as by non-climate stresses.

How can a better understanding of the potential impacts of climate change lead to better decisions in the immediate time frame? What strategies will solve existing problems while at the same time helping to deal with climate change?

NOTE: The White Paper was developed to create a basis for discussion. You may wish to refer to it for basic information on different sectors and issues. If there are corrections or additions to it, please help us identify them through this workshop process.

Breakout Sessions Notes

Breakout Session A2
ENERGY SYSTEMS

Co-Chairs: Claude Poncelet, Pacific Gas & Electric;
Jan Sharpless, California Energy Commission

Notes by: Ken Wilcox, California Energy Commission

Stresses to the energy system—framing some of the concepts from a state energy policy perspective:

- Interconnections among sectors, both supply and demand
- Policy concerns are driven by economic impacts; strive for economic efficiency
- Quality of life issues. Air quality has driven transportation and some other energy issues
- Fuel diversity as a means to deal with stresses

Future drivers of energy system:

- Air quality
- Toxicity issues, e.g.; diesel, MTBE
- Fuel cells—how soon, what types?
- Adoption of reformulated gasoline and diesel by other states; use of oxygenates
- Electricity restructuring--effects are uncertain

Will restructuring have effects that will counteract our policy actions? Example: falling electricity prices may increase demand, thus leading to increased emissions.

Will electricity poles and wires be obsolete in 15 years? A variety of opinions on this, but a sense that this is a good example of scenario thinking.

Transmission and distribution (both wires and pipelines) are extremely vulnerable to climate change. $1 billion in damage to PG&E system this year from El Niño. This could add impetus to distributed generation—PVs, fuel cells in residences, micro-turbines (the latter two initially fueled by natural gas). Venture capitalists are now investing in fuel cells in a big way. Distributed generation raises air quality concerns, however.

Licensing large power plants in a competitive atmosphere could be difficult. Hard to get air quality offsets—will interbasin trading be allowed? This is another factor pushing toward smaller, modular systems.

Unregulated energy marketers may determine which way electricity generation evolves. Efficiency is a part of the package of services that they sell. Unclear how much attention they will pay to the residential market. (Currently, not much.)

Policy makers looking for a way to affect the direction of the electricity system should look for areas where regulatory and market forces coincide. These are the leverage points.

The U. S. has very cheap energy, which causes problems. Should we support carbon taxes? A consensus that it would be political suicide, so won't happen.

One rejoinder from the participants: Energy prices aren't a major factor in the growing sectors of the economy, e.g. high-tech, entertainment. These people are more interested in reliability than energy costs.

Partnership for a New Generation of Vehicles is pushing efficiency (mpg) in ways that could compromise public health and air quality (diesel hybrids).

Possible effects on energy system from climate change:

- Will it give a boost to nuclear energy?
- What will it do to hydroelectricity in California?
- Would climate change affect wind power potential?
- Will it exacerbate urban heat island effects?
- Coastal power plants are vulnerable.
- CO_2 reduction credits could boost landfill gas capture and combustion. (Some Canadian firms are already doing this to gain credits, even though credit system not yet adopted.)
- Investment ratings of utilities could change—e.g., downgraded for utilities heavily dependent on coal. Insurance industry and banks could further add to the financial pressure on companies to avoid climate-damaging actions.

Varying opinions on whether businesses react to long-term risks.

How should we make our energy system more resilient?

The impediment to action: developing politically acceptable options. This implies a big role for public education re: climate change.

Dealing with public perceptions is difficult, due to short attention spans. How do you get their attention? Answer: proceed on several fronts—cost-effective efficiency equals saving money; air quality benefits; assuring continued reliability of the system; improving the quality of their lives. That is, make the message address the larger social fabric, not just energy.

(The $23 billion saved due to California efficiency standards from their inception through 1995 breaks down as follows: $10.4 billion for appliance standards and $3.7 billion and $8.9 billion for nonresidential and residential building standards, respectively.)

Breakout Session A3
COASTAL LAND USE

Co-Chairs: Jo Bodovitz, The California Trust;
Madeline Glickfield, CGS Research Institute

Notes by: John Wise, US EPA

The term "coastal land use" should be considered broadly to include not only the terrestrial coastal zone, but also, offshore islands, upland watersheds, littoral zones, marine ecosystems, and established marine refuges.

New institutions are not needed. Indeed, the Coastal Commission and local governments are the appropriate bodies for planning and decision-making.

We considered impacts/stresses from global climate changes in two contexts:

- built environment
- natural environment

For impacts to the natural environments (e.g.: water temperature warming and species changes, flooding and freshwater impacts, wetland inundation, beach bluff erosion) we would strive to enable nature to take its course, with natural adaptation, new equilibrium conditions, etc. being re-established over time. We should intensively study and research such ecological phenomena; and strive to avoid interfering with such processes (such as premature harvesting of emerging fishery stocks).

For impacts to the built environment (houses, roads, ports, airports, delta levees) we should establish strategies priorities such as:
a) Defend with engineered fortifications assets of high strategies value such as airports, ports, delta levees (for water supply security).
b) Relocate (or engineer alternative solutions) vital assets to higher ground.
c) For less strategies aspects of the built environment (housing on coastal bluffs), simply retreat and let nature take its course.

For new development of any kind, authorize the Coastal Commission (or local government) to consider "risk-of-harm" from impacts of global climate change. After due consideration of risk-of-harm, developments may be approved only with:
a) No assured warranty of safety of loss
b) Private insurance to underwrite the risk
c) Self-insurance to bear any costs or losses

Full disclosure of potential risk (i.e.: coastal erosion, beach houses, earthquake, slope stability, fire danger, flooding, etc.) should be used to inform the due diligence process. After disclosure, the risk/liability shift from the public sector to the private sector. Thereafter, any development in the coastal area would be tempered by incorporation of risk and cost calculus.

Breakout Session A4

COMMUNITY IMPACTS AND INITIATIVES

Co-Chairs: Andy Lipkis, TreePeople ;
Catherine McKalip, President's Council on Sustainable Development

Notes by: Catherine McKalip

Introductions and organization descriptions of attendees began the session. Andy talked about what TreePeople is and does—it is a citizen-based forestry organization that emphasizes environmental justice through simultaneous community development and empowerment. Jobs are created, resources are conserved and money is saved by increasing green space in LA to capture water (e.g.: rainfall) and keep it in the local ecosystem rather than lose it to runoff, where it generally becomes polluted and results in further ecosystem damage and a need to import water.

Catherine commented that this project seems a perfect example of sustainable development in that it is a multi-faceted approach, simultaneously solving several areas of concern: water availability and quality, county money, jobs, education, community building, keeping money in the local area, less waste, and approaching the problem with the intention of solving the root issue, rather than taking a "band-aid approach", while creating other benefits.

Catherine then described a Community Forum that the PCSD held in conjunction with its recent meeting in Atlanta, GA. In cooperation with several Atlanta community organizations, the PCSD convened a Community Forum on Quality of Life and Climate Change which was intended to relate climate change to the things that the people of Atlanta already cared about and draw some connections between the issues, in other words, to make climate change real to the community. Over 200 participants heard several presentations on climate change (science, impacts, technology and economics) and then divided into four groups to look at quality of life issues within these areas: work / economy, home / family, outdoors / recreation, learning / information. Each group was asked to:

1) identify issues of concern
2) identify any relationships of those issues to climate change
3) invent solutions that would solve their quality of life concerns and climate change at the same time

Interestingly, many concerns were the same amongst the four groups, and participants found after some reflection that many of their concerns did relate to climate change, some directly and some indirectly, some causally and some would be adversely affected by climate change impacts.

The valuable lesson for the PCSD after convening this forum was that it is helpful to ask first what people care about, and then draw the linkages to climate change. A discussion along these lines ensued—that many issues of concern to many different groups do indeed relate to climate change, though it may not be obvious on the surface. An interesting example given was engaging the Jewish interests in the Middle East as increased energy efficiency and local renewable energy resources decreases reliance on Arab oil imports and thus increases energy security and energy independence.

Education was often mentioned as a key driver for people to become interested and willing to act. Green marketing and information provided will help people who want to do the right thing and need to be shown how or what to do. Trees for Travel, a program which has shown that one tree planted offsets the carbon emissions from 4.000 miles of airplane travel, is used as a marketing tool by several eco-tourism and other tour operators.

Discussion then centered around a need for economic and other information that makes the case for shifting resources. We need to see where we are wasting resources and re-think our approach to a variety of problems so that resources are conserved and used wisely. Indicators need to be developed at the community level and used in decision-making. Communities need to identify their strengths and how to preserve them as well as problems they face and how to identify progress (indicators or milestones).

Stresses that California will face in the next decades:

• non white majority in the next decade—political, economic and social ramifications, increased economic stratification
• water issues and increase in demand by a variety of sectors
• education challenges: lack of environmental literacy, inability for people to see connections between various environmental issues and other concerns, and schools are a primary means of disseminating information as children take home to families.
• ISTEA reauthorization / transportation issues generally
• electricity deregulation—urban growth boundaries vs. Density issues

All of these relate to climate change in some way—either through ability to understand and talk about it, through causing increased emissions, through climate change exacerbating these concerns. . . . in a myriad of ways.

Blair Henry from the Northwest Council on Climate Change, (a grass-roots group formed in an ad-hoc manner following the Regional Climate Workshop there) reported that they are looking at increasing public support and awareness past the "70% mark" as something that politicians then cannot ignore. It is imperative that people begin to understand how climate change will impact every sector of the community either through the impacts of climate or mitigation efforts.

To make an honest effort to avoid "dangerous human interference with the climate", we will need to go far beyond Kyoto. Thus everyone must realize this and begin to make changes. This implies rather dramatic changes from the way we do things today. For example, oil is a $1 trillion per year industry—that's $2 billion per day in revenue! Meanwhile one of the chief sources of oil in the US, Alaska, is experiencing climate changes above what is predicted for 100 years in the future!

How will we reconcile the economic, social and environmental effects of switching fuels? What sectors/ activities will still use fossil fuels, and which need to change to other energy sources? How do we make the necessary changes happen in a realistic and fair manner?

Breakout Session A5
PUBLIC EDUCATION AND INFORMATION

Co-Chairs: Kelly Sims, Ozone Action;
Wilson Orr, Sustainability and Global Change Program,
Prescott College

Notes by: Kelly Sims and Wil Orr

RECOMMENDATIONS

1. The flow of scientific information to the public should be institutionalized and sustained, just as the public has committed long term funding to climate science research. Reciprocity between the taxpayer and the climate science community is essential to:

- Provide the public with a return on its tax dollar investment.
- Maintain public support for continuing climate science research.

2. The information flow should be formalized as a Local Climate Information and Response Program (LCIRP) to:

- Package simply, visually, and forcefully the climate science
- End the public doubt and confusion on global warming
- Portray dynamically and factually the range of local impact scenarios
- Present community and individual response options which empower the public with "things they can do" to reduce personal and local contributions to CO_2 emissions.
- Document success stories from other response strategies implemented around the country; "give folks a way out. . ."
- Build a sustained and two-way dialog between the public and the science communities.
- Clarify for individuals, where ever they plug into a community's fabric that climate change is happening "on their watch." Their contributions to climate change are personal; their efforts to reduce their impact footprints can make a difference. In fact, the only thing that will make a difference is personal action motivated by a renewed sense of personal and community stewardship.
- Build a media/outreach plan into each grant. These program elements should meet some performance for interaction beyond the normal university/college boundaries to involve those doing the science with those paying for it.
- Capitalize on the "here, now, credible" experience of prediction and public awareness demonstrated for the current El Niño. Integrate the lessons learned of coastal and island communities in dealing with climate change and variability.

3. A strong LCIRP element should be a proactive engagement with professional organizations from every sector of our socio-economic domain. These include churches, engineering, women's professional, environmental, planning, and a wide range of other organization types. A broad involvement of the constituency, leadership, and credibility of these organizations should be cultivated.

4. The potential costs of not responding proactively to climate change vis-à-vis the costs of a default standby response mode need to be quantified, publicized, and debated. They will differ for nearly every community; getting this discussed locally is a proven way of involving people as it involves their money.

5. LCIRP activities should commence immediately, building on the momentum of the Regional Workshop Program. There is value in the communication inertia and local awareness produced by this activity. A parallel research agenda should be initiated to:

- Identify methodologies by which the mega-issues of our time can be communicated to ordinary people in meaningful ways which initiate informed mitigation measures.

- Identify optimum processes and suitable communication technologies to accomplish LCIRP.

- Determine an appropriate mix of methodologies, processes, and technologies for a range of community types by region, economic base, ethnic and cultural mix, and local values/traditions. These are only a few of the factors which must be respected in bringing credible, outside, and complex information to new places.

COMMENTS

1. It's difficult to envision sustained taxpayer support for what many ordinary people envision as an elite scientific research program which is totally bureaucratized, feeds at the taxpayer's trough, and produces only disputable and irrelevant science.

2. There is a declining level of practical environmental awareness and sense of personal stewardship in many urban areas.

3. Communication. the feedback of concise and compelling information, to taxpayers is a basic obligation of the federal agencies. To not do this breaks trust with the public's right to a reasonable return on their tax investments.

4. We are in different stages of debate regarding climate change. While the economic debate in much of Washington has replaced haggling over the science the majority of the country still don't perceive the science as clear, compelling, or finalized.

5. Communication of an extremely complex issue to local areas already dealing with their own problem agenda is challenging. Perhaps that is why we do it so poorly.

Breakout Session A6
PUBLIC PERCEPTIONS OF CLIMATE ISSUES

Co-chairs: Richard Berk, Professor of Sociology and Statistics, UCLA
Bud Laurent, Supervisor, San Luis Obispo County

Notes by: Teresa Rounds

What is public opinion?
"People form opinions based on advertising."
"Public opinion is that which congressmen base their votes on."
"Public opinion is based on inadequate information leading to incomplete understanding."
"Most people actually get their opinions from talk shows, op-ed, etc."
"The public's rules are different than scientist's rules" for determining the validity of the projections of consequences of climate change.
"[Natural resource management agencies] have failed to get their message across, and therefore public opinions about resource issues are not informed."

Statements such as these began the discussion about public perceptions of climate change. However, not all shared the pessimism: "Public opinion is a framework for dialog."

Public opinion about climate change must be gauged. The extreme opinions get the most attention, but the range of opinions is as important.

There were differing opinions in the room, perhaps reflecting differing opinions in the general public. Most agreed that climate change is well under way due to human influences, and that the variability and ultimate changes will create extreme disruption to human activities as well as global biodiversity. Others, however, believe that the level of uncertainty about the inevitability of climate change is actually rising.

"If the evidence is there, industry is willing to act," said an industry spokesman, but industry is not convinced. Scientists in the room believe the evidence is compelling; industry does not. Industry, say the scientists, is reluctant to change, and therefore argue that since scientific certainty isn't 95%, there is no reason to act. However, there is rarely 95% certainty about anything, and there <u>is</u> reason to act.

The discussion returned to public opinion. What is public perception about climate change? It appears that there is widespread awareness or the problem. People—that is to say people who are not well-informed on the subject—can characterize climate change as rises in temperatures, sea level, and precipitation, but there is little understanding of how those changes could affect their lives. People tend to think that only a change of 10° to 15° would cause noticeable change, and don't realize that a 2° increase would be significant. For example, people don't know that there is only a 4° C difference in global average temperatures between now and the last ice age.

Scientists, in other words, aren't doing their jobs of informing the public about the science behind the issue to climate change, or about the ways change could affect people's lives directly. People don't want to give up what is familiar because of a future possibility, nor do they want to believe that their actions today will negatively affect the future.

Public education about climate change is critical, but there are inherent problems in communicating bad news. An important way to help people understand the potential consequences of climate change is to craft scenarios that will make climate change hypotheses realistic and relevant. A significant shift in behavior is often instigated only in response to crisis, or to hope. If experts can send their messages about the causes, consequences, and potential risks associated with climate change, perhaps hope will prevail, and crisis averted.

Many participants agreed that, unfortunately, the costs of any problem and the value of its solutions must be established before people can grasp its impacts. Climate change must be put in dollar terms so that people can compare the pros and cons of altering our lifestyles today.

Several approaches to public education on climate change were suggested. Primary was the need for scientists to communicate their findings. Science news writers and reporters were recommended as primary targets, and they need to be educated as well in order to accurately convey the information accurately.

Another crucial audience to reach is children. The mechanisms of climate systems, human influences on climate, and the consequences of change must be incorporated into the curricula so that future decision-makers are aware of the importance of climate on their lives. The value of such awareness will be that the next generations will be able to prepare for and adapt to change, or to avert it entirely.

Participants:
Ralph Kahn, JPL
Ed Frazier, TRW
Jerry Rogers, General Motors

Louis Pitelka, University of Maryland
Philip Mote, University of Washington
Frank Quinn, Great Lakes Environmental Research Lab
Peter Kuch, EPA
Barbara Morehouse, University of Arizona
Mike MacCracken, USGCRP
Kelly Redmond, Desert Research Institute
Maureen Kennedy, Redefining Progress
Tom Burns, Chevron
John Foster, EPA
Fred Wagner, Utah State University
Camille Parmesan, NCEAS

Breakout Session A7
IMPACTS AND OPTIONS FOR WATER SYSTEMS

Co-chairs: Susan Munves, Conservation Coordinator, Environmental Programs; Maurice Roos, Chief Hydrologist, California Department of Water Resources

Notes by: Maurice Roos

Water supply systems in California are already stressed in dry years with lack of sufficient supply for all uses. In a sense, climate change just adds an additional increment to water resource problems and perhaps a little more urgency in finding solutions. Urban growth and water demand are expected to increase further with increases in environmental requirements as well.

Some of the primary impacts of global warming on water systems are:

1. A change in runoff patterns with less snow and snowmelt and more winter runoff. This effect will vary in time and place; generally the effect will be stringer in the lower elevations of the northern Sierras and less in the higher elevations of the southern Sierras. The net result will be some loss in natural regulation of the snow peak (winter water is usually lost to reservoir flood control releases and not storable) which can only be offset by replacement reservoir storage or reduced demands.

2. It is possible that more floods and larger floods will occur--due to a greater fraction of winter precipitation running directly off and potentially greater intensity of flood producing storms in a warmer atmosphere. Possible solutions to handle this would be increased downstream channel flood capacity to permit greater use of water storage for water supply. Floodplain use changes to permit more land to be inundated is also an option.

3. Sea level rise, partially as it may affect the Sacramento San Joaquin Delta. Many islands are below sea levees protected precariously by weak level on poor peat foundations. It is not known if they can be built to withstand a 0.5 meter rises economically; if levees fail, fresh water transfer for export would be affected. Salinity intrusion from the ocean would be a little worse because of higher seal level and because the spring amounts of uncontrolled snowmelt runoff would be less. As far as we could tell, CalFed is not considering sea level rise (or global climate change) in their delta alternatives. It would seem that the isolated facility (peripheral canal would be a more attractive option if climate change is considered.

4. Possibly more variation with more extreme floods and droughts. Not too much faith should be placed in currently computed magnitude and frequency of floods and droughts.

5. Warmer water temperatures could be a problem for salmonid populations, since these fish near the southern end of their range now in California and show signs of stress in the warmer years. The problem is inadequate dissolved oxygen; other water quality parameters. such as pH, are not altered to the point of having an effect.

6. Sea level rise could also affect sewage facilities (which are often built near sea level) and from drainage works in coastal and bay cities. Maybe more waste water can be reclaimed and recycled as a partial alternative to building sea walls for these existing installations.

7. Ground water recharge maybe be lessened by higher evaporative demands during the winter wet season or shorter periods of excess runoff for spreading (artificial recharge) as a result of a shifting runoff patterns. Additional reservoir evaporation may slightly affect some surface reservoir supplies.

8. Demand for water is often regarded as fixed; there may be ways to reduce urban and agriculture water demand economically. Maybe we should look at changing crops or dry year fallowing. Recognize that extensive fallowing has an impact on local rural economies.

9. It was observed that water agencies often have to seize opportunities as the come to make their systems more robust; they can’t always wait for the ‘optimum’ time.

Breakout Session B2
MARINE FISHERIES AND ECOSYSTEMS

Co-Chairs: Craig Fusaro, Director, Joint Oil/Fisheries Liaison Office;
George Boehlert, Director, Pacific Fisheries Environmental Laboratory,
National Marine Fisheries Service

Notes by: George Boehlert

Introductory Comments: Approximately 10 to 12 participants engaged in a lively discussion of the issues. This was the sole breakout session specific to the marine environment and consequently the topical area was quite broad; interests of the participants likewise varied. This is a timely subject, since the United Nations Environmental Program designated 1998 the Year of the Ocean, and in June, an "Ocean Summit" will be held in Monterey, CA including leading ocean scientists, and, perhaps, the President and Vice-president. A viewgraph was shown reminding attendees of the four questions asked of the breakouts (stresses, climate change amplification/dampening, new information, win-win strategies).

In *Nature's Services* (1997. G. Daily, ed.), Peterson and Lubchenko review five marine ecosystem services, exclusive of marine fisheries, including:

1. global materials cycling
2. transformation, detoxification, and sequestration of pollutants and societal wastes
3. support of coastal ocean-based recreation, tourism and retirement industries
4. coastal land development and valuation
5. provision of cultural and future scientific values

A specific ecosystem benefit is the moderation of coastal community average temperatures.

Marine fisheries provide a number of services:

1. a source of healthy, high-quality protein for direct consumption
2. employment and multiplier effects from commercial fishing activities
3. recreational (sport-) fishing, estimated at over $5 billion in direct and indirect contributions to the California economy
4. recent forest studies suggest that salmonids contribute significant nitrogen and phosphorus to forest ecosystems as their carcasses decay instream or are carried into the forest by various birds and mammals.
5. support for seabird and marine mammal populations, generating another multi-million dollar "watching" industry.

Kaufman and Dayton, in another chapter of *Nature's Services*, note that "The sea provides three kinds of goods."

1. bulk raw materials that have low unit value, such as seaweed and cluepid fishes
2. high-value species like shellfish and top carnivores (billfish, tuna, sharks)
3. materials and live organisms with very high nonfood value, taken in small quantities

Because of time constraints, not all topics were addressed. Marine fisheries dominated the discussion. We place the discussion summary in the context of the four questions asked of the breakout sessions below. Items with asterisks under the first key question were added to this document by the co-chairs because of their importance.

Discussion Summary: It was pointed out in the session that environmental changes in the ocean are already upon us. Retrospective analysis of decadal-scale changes in the North Pacific are a current area of active research, and some evidence exists for increasing incidence of El Niño events over the last decade. Biological changes are evident, such as dramatically reduced zooplankton biomass and seabird populations in waters off the Southern California Bight and distributional changes in many fish populations. Research on the biological phenomena associated with these changes can be beneficially applied as proxies of anticipated changes that may occur under conditions of climate change. That major changes is already here was pointed out by current paleogeological research at UCSB. Oxygen isotope analysis of the past 100 years from cores shows that the conditions of warming, and likely increasing mixed layer depth, have occurred since 1916 and accelerated since 1960. A further assessment of the past 11,000 years suggests that conditions since 1960 are unprecedented. The data imply that there has been a significant relaxation of the California Current and a likely strengthening of the countercurrent, leading to lower nutrient levels and lower biological productivity in the region. These plus other results suggests that the California marine region is highly sensitive to climate change, making it an optimal location for research on climate change impacts on marine systems.

1. Current stresses affecting the region, its natural resources, and economic sectors.

Overfishing; Many stocks of marine fishes off California are overfished or impacted in other ways, such as reductions or impacts to essential habitat. Overfishing has affected the natural state of these populations and can be observed not only in changes in standing stocks but also in truncated age distributions, reduced genetic diversity, and altered predator-prey relationships. Time series of biological information, such as fisheries catch data, are relatively short (typically 30 years or less in duration) and thus our ability to assess the baseline, or natural condition, is limited. This leads to "creeping baseline syndrome", wherein science's view of the natural, or desirable system differs from that free from human impacts. With declining fish stocks, pressure will increase for coastal fish farming ventures, resulting in a new set of stresses, including waste production and coastal space requirements.

Excess harvesting capacity: California's fishing fleets have the ability to harvest more fish than the system can sustain. This represents an ecological problem in that it exacerbates overfishing, and also an economic problem associated with displacements as fish stocks decline. Fishing fleets are highly mobile and are typically able to move from one resource to another; thus the fishing industry is often able to stay ahead of management, creating new problems. A specific problem discussed was the live fish fishery off California, which is poorly managed and is taking far more fish than can be sustained, including fish smaller than the age at first reproduction. In a general sense, fisheries management is conducted on a single species basis and is not able to respond as rapidly as is needed to changing biological and economic conditions.

Ocean as a repository: California's coastal ocean is used as a repository for a variety of wastes, including thermal (from power plants), excess salts from desalination plants, and treated sewage. Nutrient loading, runoff from rains and sewage treatment plants cause changes in the coastal ocean that have been implicated in toxic algal blooms.

Carbon emissions from maritime industry: Many vessels in the maritime industry are outmoded and have unregulated diesel engines, resulting in greater carbon emissions than are required for the level of power generated.

Coastal development impacting estuarine/marsh areas: Coastal development has drastically impacted wetlands and salt marshes in California as well as estuaries farther north. This has far-reaching effects on biological populations as well as the interface between freshwater and marine ecosystems.

Changed freshwater inflow to the coastal ocean: Increasing human population leads to increasing water use. The patterns of natural freshwater flow to the coastal ocean is generally reduced, both in total amount and in the seasonal pattern of release. The effects of reduced freshwater flow on the coastal ocean are largely unknown.

Protected species issues: Marine mammals and other protected species such as sea otters in the coastal ocean have captured the interest of the public. While some populations remain at low levels, others have expanded rapidly, leading to conflicts over space and resource use.

Pollution and oil spills: Non-point source pollution from urban and agricultural runoff may interact with other stresses to magnify changes possible due to regional climate change or increased variability. Offshore point sources such as oil and gas platforms may add to this burden due to the at-sea discharge of drilling muds, cuttings, and/or produced waters in federal leases.

2. How climate variability/change might amplify or dampen stresses or create surprises.

Fisheries are subject to environmental variability in several ways, and extant fisheries management regimes are not particularly skilled at taking environmental variability into account. Biological effects can be dramatic. Fish distributions can change. As shown during El Niño events, northward extensions of pelagic populations occur rapidly and may result in positive stimulus to some fisheries, such as those for tuna or billfishes. Others, such as squid fisheries, may suffer because of lack of availability of the resource to the gear types used. Demersal resources, such as benthic rockfish or most invertebrates (e.g., abalone) respond more slowly to thermal changes, often by a gradual northward extension of the range (if appropriate habitat exists) and a loss of the southern parts of the population. Effects may not be seen for long periods, as much as decades in the case of long-lived fishes which may not even mature or enter the fishery until over age 10. If the total system productivity continues to decline as noted above, higher trophic levels will decline apace. A potential problem here is that with warming and a deepening thermocline, it is possible that upwelling may continue or even increase but will be biologically ineffective because it will no longer bring nutrient-rich water to the surface.

Overfished populations are particularly vulnerable to environmental change and may be at greater risk. As an example, higher storm frequency or longer intervals of elevated thermal conditions may result in poor reproduction for periods sufficiently long to endanger the continued existence of the stock or species. A good example is provided by salmon, where a continued run of consecutive extreme years could cause a local population to go extinct. Overfished populations, which often have truncated age distributions and reduced genetic diversity, may be less able to respond to environmental changes. Economic aspects of fisheries may also be impacted. It is uncertain that the influx of southern species could replace reduced production of traditional coastal fisheries, despite mobility of the fleets. Additionally, mobile fleets from other impacted areas could exert additional local fishing pressure.

Extreme weather events and rising sea level could also have major effects on coastal development with impacts to infrastructure having severe ecological effects. Failure of sewage treatment plants could lead to increased sewage spills. Increased rainfall could cause major sediment influx to the coastal ocean. Coastal development has reduced the scope for wetland, salt marsh, or estuarine expansion with rising sea level, resulting in major impacts to nursery habitat for many biological resources.

3. New information to allow people and organizations to better understand the linkage between stresses and climate variability/change.

Change is occurring in the ocean environment off California. The recent publicity about El Niño over the last year has increased public awareness of the role that the ocean-atmosphere system plays in our daily lives. It also serves as an important entree into further educating the public on the kinds of dramatic changes that may occur in the face of more extended climate change. It was noted that El Niño-induced changes in marine resources and fisheries impacts should be summarized and used to further inform the public.

Strategies are being developed for coping with possible changes in terms of mitigation programs. One was described which has addressed fuel-efficiency in California fishing vessels, managed through the California Energy Commission and assisted through the Sea Grant/Cooperative Extension/Marine Advisory program, providing low-interest loans for increasing the fuel-efficiency of fishing vessels and gear (new fuel efficient diesels, better gear or operating practices). Another program was described which re-powered fishing vessels with more fuel-efficient (and less pollutant-emitting) marine diesel engines as air-quality offsets for offshore oil industry development, either through oil company programs or the local Air Pollution Control District.

4. Win-win coping strategies that will help address the stresses.

Develop resource management systems able to respond to change: Overfishing and excess harvesting capacity of fishing fleets must be dealt with by resource management agencies. It is critical that management develop approaches that can respond rapidly and maintain harvesting capacity consistent with available resources. Management paradigms that lead to sustainable fisheries in the face of environmental uncertainty are needed; the need exists to move from single species management to multi-species or ecosystem management. Adaptive management is one approach, in which management actions are treated as experiments. A new paradigm developing for resource management is the use of harvest refugia, or "no-take zones". This approach addresses many of these problems by protecting some portion of the resource from exploitation. It may be particularly appropriate near the northern end of the range for species that may be expanding in that direction under increasing ocean temperatures.

Socioeconomic effects: In achieving a new balance in harvesting ocean resources, thought should be given to developing new management strategies in conjunction with fishers themselves. It may also be useful to phase new strategies into play in an adaptive way which minimizes socioeconomic disruptions to coastal communities in which commercial and recreational fishing play a significant role, while maximizing our opportunities to achieve true sustainability in the face of regional climate variability and change.

Improve monitoring in the marine environment: Inadequate monitoring of the marine environment leads to an inability to assess the nature and magnitude of environmental change. Improved characterization of physical and biological conditions is required to conduct the research required for a response to changing environmental conditions.

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Participants:
Arve Sjovold, Santa Barbara Environmental Coalition
Chris Tooker, California Energy Commission
Dave Siegel, UCSB, Bren School of Env. Sci. & Mgmt
Ed Cassano, NOAA/Channel Isl. Nat. Mar. Sanctuary Manager
Mark Eckenrode, Minerals Management Service
Peter Frumhoff, Union of Concerned Scientists
David Lund, NOAA-OGP
Vijaya Jammalamadaka, Santa Barbara County APCD
Jim Kinnett, UCSB Geology Department and Marine Sci. Inst.
Lee Moldaver, Santa Barbara Environmental Coalition
Gil Garcia, Santa Barbara City Council

Breakout Session B6

THE DYNAMICS OF WATER SYSTEMS AND THE POTENTIAL IMPACTS OF CLIMATE CHANGE

Co-chairs: Peter Gleick, Director, Pacific Institute;
John Melack, Professor, Biology and Environmental Science and Management, UCSB

Notes by: ___________

Environmental water use is often in direct conflict with human use.

Conflicts between water needs—people, plants, flood control, recreation, wildlife, agriculture, etc.—are pervasive.

The Dept. of Water Resources feels that the prospect of climate change in the future is irrelevant in the face of the day-to-day immediate concerns of managing water in California. The question of “Is this problem real?” has changed to “So what?” The case hasn’t been made, and they don’t have time to deal with what seems to be a remote possibility.

Climate change is only part of the overarching issue of sustainability. How should we do things so that we can keep doing them?

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Attendees:
Chris Bernabo, Science & Policy Associates
Frank Quinn, Great Lakes Environmental Research Lab
Larry Gage, Department of Water Resources
Dan Tunnicliff, Orange County Sanitation
Ed Frazier, TRW
Jananne Sharpless, California Energy Commission
Jeff Sandberg, U. S. Bureau of Reclamation
Matt Peterson, Global Green USA
Mike MacCracken, USGCRP
Todd Hinckley, USGS
Wil Orr, Sustainability & Global Change Program
Wendy Reid, Sacramento Municipal Utility District

Breakout Session B7

AGRO-ECOSYSTEMS AND THE IMPACTS OF CLIMATE CHANGE

Chair: Don Ermin, Director, Centers for Water and Wildlands Resources

Notes by: ____________

Agricultural Climate Change Research Agenda

1. How will the change of intra-annual distribution of precipitation alter the availability of water to agriculture?

2. How will sequences of weather change affect plant yield and health?

3. How will climate change and variability affect pest and disease problems?

4. How will California agriculture adapt, structurally, to increased weather variability?

5. Institutional obstacles to adaptation to climate change in agriculture (water laws, endangered species, etc.)

6. Impact of energy regulation on performance and productivity.

7. Impact of climate change on competitiveness of California agriculture.

Breakout Session B8

DESERT ECOSYSTEMS: CLIMATE CHANGE IMPLICATIONS FOR BOUNDARY SHIFTS AND SPECIES DISTRIBUTION AND COMPOSITION

Co-chairs: Kelly Redmond, Regional Climatologist/Deputy Director, Western Regional Climate Center;
Fred Wagner, Director, Desert Ecology Center, Utah State University

Notes by: Kelly Redmond

I gave a short intro presentation to get the ball rolling. During that, some offhand comments about the current status of the national surface observing systems (generally staying the same or declining in usefulness) led us off on a tangent, the discussion got diverted in that direction. (This "tangent" is very important and extremely relevant to climate change, but served as something of a hiccup, given the short time available, on the way to discuss California desert issues).

By "California Deserts" we were emphasizing the region that gets roughly five inches or less of precipitation, but this area is affected by climate conditions in nearby wetter areas, because those areas are sources of recharge.

The climate there is marginal already. Plants and animals are under a constant state of stress from the austere and demanding climate. Many places are near the limit for all life. Seemingly small changes may move living circumstances from difficult to impossible.

The California portion of the southwest desert receives a greater fraction of its annual precipitation in winter (half or more) than does most of the rest of the desert further east in Arizona and southern Nevada. It thus makes a difference whether precipitation changes (were they to occur) happen in the winter or in the summer. The effects of winter increases (for example) would not necessarily balance the effects of equal summer decreases, because of the different overhead structure (that is, the efficiency of precipitation in translating to biological or hydrological results is temperature dependent, and in general winter precipitation is hydrologically much more efficient than summer precipitation) [thus, the overhead involved in translating precipitation into runoff, for example].

The climate of deserts is highly variable in time, especially when expressed in relative terms. The drier the climate, the more this is correct. We looked at the past 102 years of July-June 12-month precipitation for the Southeast Desert Basins Climate Division. The coefficient of variation (mean divided by standard deviation) is 0.38. For winter (Oct.-Mar.), the corresponding c.v. is 0.46, and for the summer half year (Apr.-Sept.) is 0.56.

Although there is strong interannual variation, there is also considerable variability in decadal means, with 10-year running averages having taken observed excursions of 20-25 percent above or below the long term mean during this same 102 years.

We also pointed out the influence that El Niño plays in the desert. In the winter months it leads to more days with rain, and to more rain per rainy day. La Niña brings the opposite. El Niño and La Niña play a considerable role in explaining the year-to-year variations in climate, to which most certainly all natural biological systems in the region have adapted over the ages, and also probably a role in the decade-to-decade variations.

Because of their low precipitation, small absolute shifts are large percentage shifts. A shift of an inch could be 30-50 percent of the annual total, and would also mean a change of several days with precipitation, either way.

In general, the drier the climate, the greater the contribution to the annual total that comes from the one or two biggest events during the year. For example, at a moderately dry place (Reno, annual 7.5") the wettest day (out of the 51 annually with measurable precipitation) brings 13 percent of the annual precipitation, on average. At a drier place (Las Vegas, 4.1", 27 days of rain), the wettest day brings 19 percent. At Death Valley (2.3", 17 days), the wettest day brings 25 percent, and at Brawley (3.0", 16 days of rain), the wettest day brings 33 percent.

It should be emphasized that, although water is rare in the deserts, it is the principal agent of change. These are strongly intermittent systems, hydrologically, where nothing much happens for long intervals, and then, wham!, a lot changes in a hurry, perhaps mostly because of a few days, or even hours, each decade or two. Erosive forces become very large for a short amount of time, and then sink back into oblivion. Individual climate events leave their stamp on desert ecosystems for a long time.

The extreme variability makes it that more difficult to detect long-term change. There also appear to be regimes of behavior, lasting a few decades, that must be factored in when making a determination that something has changed. Single events can influence time series analysis quite strongly. With the very noisy time series, we would like to aggregate (multi-station) records to track climate, but this needs to be done consistently over time, and that subject could afford to be revisited (nationally).

A very large stress on this region is the huge and burgeoning population centers nearby, on all sides (South Coast, Las Vegas, Lower Colorado, Arizona cities, etc.). Cities are further encroaching on fragile desert environments, recreational access is greatly increased, and these areas tend to be treated as something of a playground.

Although they have other effects too, these population centers use a lot of water. Palm Springs was reported to have about 90 golf courses, in a very arid climate. There is an explosion of development in general, and much of this development is affluent, and thus brings higher resource demands per capita. The affluent portion probably does not "connect" as well to the desert, feeling that they can buy their way out of any inconvenience associated with the severe climate.

Another important point is that we need to much better understand the 20th century climate in a longer context, of at least several hundred years. As it turns out, because of their lack of moisture, evidence of past climates is preserved much longer and in more intact form in deserts than in other climates. Much of our most valuable paleo evidence is from the arid Southwest. Much of this evidence is also more or less in "plain sight", or is found in the bottom lands (the playas, for example), which are most subject to disturbance from the rapidly encroaching population. Thus, important evidence is "at risk" from human disturbance. Possibly, we should be thinking of mechanisms to forestall potential losses, akin to the archeological requirements to survey for irreplaceable cultural artifacts or evidence before large permanent land surface alterations such as developments can proceed. Maybe this idea should be broadened to include past climatic evidence vulnerable to permanent loss.

We do not have high quality and also readily accessible (these are not the same!) information on time trends in important measures of the status of physical, biological and cultural systems. It seem exceedingly difficult to obtain credible information for these regions.

It was also pointed out that basic understanding of deserts, and especially of their differences (in function, structure, needs, susceptibility to disruption and disturbance) from the rest of the state, probably lags behind the understanding of other regions in California.

It appears that some portion of requisite knowledge about these systems, and about what is taking place within them, does exist, but is not readily accessible to a larger audience, who do not know where to go for information. This issue arose in every breakout session and in the main sessions.

Not just for deserts, but for all systems, I would make the general point that we may be able to predict climatic consequences, if steady progress continues, at the regional scale within the next five to 10 years. This pertains to the drivers of climate change. But, the response depends on the interaction between the climatic forcing (which will still have uncertainty, especially at regional scales) and a host of extraordinarily complicated biological and cultural systems, for which there is little hope of ever modeling predictive outcomes with the requisite detail and believability. There isn't enough input information, we can't afford to acquire all that is needed, and the background state cannot be held constant. The presence of chaotic and highly non-linear behavior in this response leads me to believe that it is quite likely that we will never be able to make predictions about human and biological responses—that are credible to enough people—before the answer is made apparent simply through the passage of time itself. That is, our predictive capability may barely keep up with events, or may even fall behind. From studies of complex systems, there is serious reason to believe that detailed impact predictions are not even a theoretically attainable, let alone a practical goal. To a certain extent, we will have to just watch.

This being the case (but even if it weren't) this means that we have to make sure that we have long term monitoring in place for the physical, biological and cultural processes that are felt will be most strongly impacted. This in turn means that a long-term commitment to monitoring is absolutely essential, for climate, for biology, for hydrology, and for other related systems. Furthermore, in terms of the real world of public support, one does not have to subscribe to the urgency of the underlying causative problem to accept the notion that more and better monitoring is a good thing to do, no matter what.

Along these lines, it is thus vital that we keep our long-term monitoring systems intact and healthy. They are constantly threatened with termination and reduction in number and/or quality. This is particularly true for the purely climatic information, but also for biological and hydrological data gathered at university field stations in the region.

These latter comments on monitoring apply to all systems, not just deserts.

Since there was and will always be a desire for more background information about our present climate, it might be helpful to say some things about where such information can be found. I would offer, in this direction, the very considerable amount of climate information that can be found at our web site, http://www.wrcc.dri.edu, which has many of the items that people were asking about, in terms of simple factual background. We are averaging about 25,000 hits a day on this, as there is a very big demand for the information.

Breakout Session C3

CALIFORNIA PILOT PROJECT ON THE USE OF CLIMATE FORECAST INFORMATION (NOAA)

Co-chairs: Ants Leetmaa, Director, Climate Prediction Center, NOAA;
Claudia Nierenberg, Economist, Office of Global Programs, NOAA

Notes by: ______________

Key points:

Need to identify data sources; that is, we need to know what's out there and where to get it.

Need to package information in useful and understandable forms and provide it at the right times (this will be different for different users). This will require continuing dialogue between providers and users—including feedback on the forecast products and how they are being used and identification of information needs. This information must be timely and updateable–a continuum of information from climate outlooks to real-time data.

Need to recognize the value of a proactive approach, rather than reacting to crises.

Need to share new forms of collaboration and information.

Need to develop credibility/trust in longer-range forecasts; this will be a slow process of education.

There is a need for interpretation of forecasts to work with users to learn what forms of forecast information are understandable and usable.

Forecasters must recognize the need to work with forecast users to learn what forms of forecast information are understandable and usable.

Examples of forecast use:

Orange County Sanitation didn't know where to look at El Niño data when preparation and planning for the storms began (or should have begun). Needed to:

- work with cities to reduce inflow
- begin a public awareness campaign
- develop a high flow emergency response plan

Three-to-five day forecasts were not far out enough, so when they learned about weekly threats assessment (in December 1997), they began to use it.

They were becoming aware of what is available through dialogue. now that we know the information is there we will continue to use it (can use forecasts as much as a year in advance and weekly threat assessments). Three-to-five day forecasts and real-time data will be altered as time goes on.

William Mumbleau, information and technology services for Los Angeles County Metropolitan Transportation Authority, went into ‘high activation mode’ last year [as El Niño warnings were being publicized], although management was saying ‘wait till raindrops hit’. He saw the value of proactive vs. reactive (crisis driven) response. For example, he anticipated increase in maintenance costs for buses due to flooding damage to bus batteries.

He started by trying to find out where data is

Information must be timely and updateable, it must be integrated. How the data is packaged is very important. Information must be shared and disseminated to users as well as to the scientific community (to do impact assessments).

Department of Water Resources’ use of short-range forecasts (five-to-ten days) depends on the staff meteorologist

This year, for example, use of CDC long-range forecast:

• river runoff projections at start of year looking at/for periods of exceedance

• regular updates are important

• longer-term forecasts must demonstrate their credibility

Need information on the probability distributions (especially on the dry side which is where farmers and operators must hedge their bets).

This year’s precipitation patterns in the Sierra seems to be similar to 1982-83; patterns not at all like 1996-97 when the rainfall was mostly coastal. Snowdepth also seems to look like 1982-83.

Breakout Session C4
CLIMATE MODELING AND CALIFORNIA

Co-chairs: Mike MacCracken, Executive Director, National Assessment, USGCRP;
Norman Miller, Staff Scientist, Earth Sciences Division, LBL

Notes by: Teresa Rounds

How to establish credibility of models?

Nearly infinite variables affect climate modeling:
atmospheric chemistry (CO_2, ozone, other gases, particulates, etc.)
clouds
dynamics
land surface
terrestrial ecosystems
human activities
solar radiation
volcanism
oceans currents, chemistry
marine ecosystems
ice
biosphere

Clouds are difficult to represent accurately and thoroughly in models.

“Heat islands” of large cities, criticized by skeptics as skewing the global warming trends, are averaged out and are not significant. Surface temperatures are determined by averaging minimum and maximum temperatures.

1943 was an anomalously warm year, largely because of the way temperatures were taken at sea—near the wheelhouse without lights because of threats of ships being detected. In non-war years, temperatures are taken away from direct heat-reflectors such as the wheelhouse.

Sea ice is a significant influence on ocean currents, and changes in the amounts of sea ice could radically alter ocean circulation. Large influxes of freshwater from rivers (heavier storms), melting glaciers, etc., could change sea chemistry and also alter ocean circulation.

Models often actually underestimate the sensitivity of the climate.

The Max Planck Institute models of paleoclimate indicates that the past 10,000 years have seen a relatively stable climate, but that could change.

El Niño-Southern Oscillation condition is only one kind of variability—there are also Pacific Decadal Oscillations and North Atlantic Oscillations, for example; and we don't fully understand their origins or cycles.

Detection of change—IPCC has gathered this evidence of change:
Rising temperatures.
Rising sea level.
Diminishing glaciers.
Diminishing polar sea ice.
Increased ground temperatures.
Increased evaporation-precipitation cycles.
Stratosphere is cooling while troposphere is warming.
The rate of warming is greater in higher latitudes, which indicates change rather than fluctuation.
Southern hemisphere is warming.
Northern hemisphere warming is stalling due to increased aerosols, (from pollution, volcanoes, etc.)

The uncertainty of climate change lie not in whether it is happening, but rather whether it is a natural variability we are seeing or it is human-induced.

Like the difference between a civil trial and a criminal trial—do we convict with the preponderance of evidence, or acquit because there is a shadow of a doubt?

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Attendees:
Barbara Freese, Michigan Attorney General's Office
Ken Wilcox, California Energy Commission
Jim Young, Southern California Edison
John Melack, UCSB
Ed Frazier, TRW
Ralph Kahn, JPL
Frank Davis, NCEAS

Breakout Sessions D5 and D7

COSTS AND BENEFITS OF CLIMATE CHANGE IMPACTS IN CALIFORNIA; BENEFITS OF ADAPTATION AND MITIGATION

Co-chairs: Elieen Shea, Center for the Application of Research on the Environment;
Charles Kolstad, Professor of Economics and Environmental Science and Management, UCSB

Notes by: __________

Climate change is not perceived as a problem because the public doesn't have a clear understanding of the consequences on individuals, businesses, and communities.

We should pursue both additional research and a program of translation/communication (to raise awareness and encourage integration of climate change into decision making).

Current approach of quantifying costs to a sector associated with temperature change and/or sea level rise doesn't cut it. Among other things, we need improved understanding of:

- the timing and pace of anticipated changes (e.g.: accounting for abrupt versus slow change and/or models which account for the transition to a new state)
- the geographic differences in the nature of impacts—even within a state
- impacts of changes in variability versus changes in the end state
- second- or third-order impacts and the consequences of response options (e.g.: if drought conditions produce a decision to leave land fallow there will be consequences for local work forces and services to communities.
- effective adaptation/mitigation must be iterative with continuous information on current state of the physical system and the results and consequences of the decisions already taken
- the distributional nature of consequences—geographically and socially (there will be winners and losers)

It is likely that businesses and communities will adapt but they will need much improved information and a better understanding to do so effectively.

Constructing scenarios of change to use in addressing consequences would be valuable but recommend much more detailed looks at individual sectors and communities which incorporate some of the missing into noted above.

There may be some value in using natural variability analogs (e.g.: quantifying impacts of this year's El Niño and exploring what might happen if those conditions were to change—that is, become more persistent or more frequent).

Don't forget to look at potential adaptation / mitigation opportunities not just direct impacts and costs (e.g.: changing crops to take advantage of a new CO2 and / or temperature regime).

Comments:

How costs / benefits are estimated:

1. start with a model of anticipated physical changes
2. detail consequences for the ecosystem or sector of interest
3. quantify costs / benefits
4. provide estimates of uncertainty

To date, quantification of costs has been embarrassingly simple, usually temperature increase or sea level rise; not dynamic but equilibrium end state.

How can we do something for California specifically? There are two possibilities:

1. An accounting approach:

Construct scenarios, to get at geographic consequences:

- precipitation changes
- temperature changes / seasonal

Then run through sectors looking at how they might adapt or mitigate

-or-

2. How an individual sector responds to changes:

Take a specific sector and look along the standard GDP / Temperature curve.

Difficulties associated at either (or both) the production end of final demand end, and there are ecosystem effects which are difficult to quantify.

What about incorporating third party effects (e.g.: issues associated with an agricultural response to drought being to lay fallow which cause multiple (second and third order) effects on other sectors?

This has not been looked at in the past—we tend to address crop yields or land values of local economies.

We can address this by looking at analogous climate regimes but that does not address the transition period.

What about talking to water managers, farmers, etc?

A warmer world is just going to compound existing water demands. If you limit access for farmers fields and lay fallow, workers will be put out of work.

Current approaches do not account for variability or secondary costs associated with mitigation.

Some discussion of the variability of some response options (such as fallowing):

What about the possibility of serious consideration of conservation and / or efficiency?

What about reclaiming sewage outfall? This has been discussed, using Santa Barbara's example of using this water for irrigation (an example of using tertiary treated water).

Scenario: What would happen to central valley with a 20% decrease in water availability?

There would probably be no impact in Sacramento Valley (because they have older water rights); other users would be affected.

This illustrates a problem with current approaches; infrastructure and agriculture will respond and must account for the results of those responses.

Is the problem that input-output models aren't up to the task of integrating the response to new situations and / or integrating the response of other sectors?

Any exploration of building in a new market signals for water which might modify behavior (i.e. a price increase when shortages are being experiences)? (In Tucson they tried this but it resulted in a total change in city council).

There are official estimate of water themes throughout the year.

What about water futures on the commodities market (to spread the risk?)

Some switching to different crops is going on now but tends to be toward perennials which limit flexibility.

Kolstad:

What about coastal communities' vulnerability to losses due to climate change (change in sea level and change in variability).

- This kind of adaptation has a cost (adaptation measures will address this, like the Dutch have done).
- The Great Lakes example raises the question of who is going to pay those costs

(flood insurance as a handout; similar experience in California with fire insurance—these kings of subsidies make the potential costs worse). This raises the issue of looking at strategies to improve / increase resilience (e.g.: don't re-build on cliffs).

- What about the economic costs associated with decreased tourism due to coastal erosions? This raises distributional issues, for example, some parts of California might benefit while others lose. Again, this is a question of who pays.

How to get the domino effect of second and third level impacts:

- We need to do this kind of quantification.
- One option is to look at scenarios that use natural variability analogs.

The issue of public perception:

- There is a real public perception problem of looking at changes in the climate because no one understands it (e.g.: this year's ENSO event).
- Public perception problem boils down to simple information that convinces an individual.

A big problem: short term memories of natural disasters is three years:

- The translation of consequences is really important, beyond a simple temperature change (i.e.: we don't trace simple effects back to real consequences to real people). This becomes a research question and a communication question.

We need to recognize that the impacts are very regional, and that the timing and pace of the change is very important (i.e.: we are not thinking about abrupt changes or the transition to a new state).

We should not forget to look at potential opportunities (e.g.: changing crops to take advantage of new conditions, especially CO_2 enrichment.

"Ad hoc" Breakout Session

BRINGING THE MESSAGE HOME: PROMPTING LOCAL ACTION

Co-chairs: Judy Corbett, Executive Director, Local Government Coalition;
Bud Laurent, San Luis Obispo County Supervisor

Notes by: Bud Laurent

A. To increase local receptivity of the messages from the scientific community on the subject of climate change / global warming, it is necessary to do the following:

1. Increase understanding by:

   a. finding champions of the message who are trusted by the public to help translate science into public opinion;

   b. refining the scope of the problem into messages that resonate in the public ear

   c. focus on who we are as humans, and what motivates us in positive ways.

2. Focus education efforts on the following (in addition to the general public):

   a. scientists, to better understand local needs;

   b. local elected representatives

   c. non-profit and non-governmental organizations

   d. youth

   e. teachers

3. Devise local actions (both immediate and long-term) which will lead to:

   a. changing individual and community behavior contributing to global warming

   b. altering the built environment to minimize loss of investment (and re-investment) due to weather impacts (e.g.; blufftop and hillside construction, floodplain development, general grading policies, etc.)

B. Challenges to accomplishing "A" above:

1. Bridging the gaps between federal, state and local governments;

2. Accurately identifying the fears and hopes which motivate people;

3. Identifying and reaching some of the larger players in the dialogue:

   The larger utilities
   Voters
   Insurance companies
   FEMA

C. Points to emphasize to improve understanding in both the public and private sectors which will lead to changing fundamental policies:

1. Insurance companies should be interested in both profits and accountability (their and their customers: premium rates should account for local or regional hazards, and not be nationalized;

2. FEMA subsidies should be based on sustainable results, not simply replacing structures in harm's way (accountability with taxpayers' money);

3. There is a linkage between renewable energy sources and climate change, and consumers in a deregulated energy market have power through their choices;

4. Government programs need to be consistent, coherent, and understandable, and improved communication between agencies at all levels is fundamental to this;

5. There is a need to better appreciate possible unintended consequences of public policies (such as coastal protection policies forcing growth into other inappropriate areas).

D. Samples of target actions:

1. Identifying critical constituencies and participants in local actions;

2. Identifying local concerns and developing resonating messages;

3. Identifying regional issues to create a sense of common purpose across a broader spectrum;

4. Develop incentives for behavioral change
   a. local: GIS-based modeling (e.g.; "Smart Places")
   Permits streamlined for sustainable projects
   Improved Title 24 enforcement
   b. State: Renewable energy research and development tax credits
   Photovoltaic buy-back policies
   c. Fed: Tax credits for renewable energy research and development;

5. Develop analyses of the full costs of economic and land use policies and strategies toward developing life cycle costing on which to base local decision-making;

6. Legislation establishing goals and timetables for CO_2 emission reductions (á la AB 939 which established goals and timetables for solid waste reduction for local jurisdictions);

7. Establish individual and community incentives for behavioral and structural changes:

   a. Civic involvement encouraged through marketing;
   b. Regional incentives through recognition and reward;
   c. Local incentives to:
      1. Go beyond compliance by giving good projects higher priorities
      2. Honor quality over expedience
      3. Exercise greater local control and accountability over energy choices;

8. Disseminate information from federal and state sources on sustainability ("Clean Cities," "Rebuilding America," "Industries of the Future," etc.);

9. Reform and stabilize local government's revenue sources to end fiscalization of land use—type decisions which promote sprawl and wasteful energy use;

10. Create forums to present reasons and opportunities for

regional cooperation and provide funds for these sorts of regional efforts;

11. Increase consumer understanding of energy imbedded in building materials and material recyclability;

12. Mimic Austin, Texas, "Green Building" program;

13. Develop mortgages which give credit for energy efficiencies and location (in-fill, rather than sprawl), working with banking industry to resolve constraints which presently hinder development of sustainable lending policies.

Participants:
Judy Corbett
Gil Garcia
Madelyn Glickfield,
Sandra Henderson
Bud Laurent, Matt Peterson
Wendy Reid
Paul Rosenstein
Candace Skarlatos

California Regional Assessment
The Next Steps

The University of California, Santa Barbara (UCSB) will continue the California Regional Assessment work through the National Center for Geographic Information and Analysis (NCGIA) as part of the National Assessment being conducted by the US Global Change Research Program (USGCRP) and the White House Office of Science and Technology (OSTP). Stakeholders and scientists from a wide range of perspectives have been included in the California climate change impacts assessment process though the first phase of work, which involved a major workshop held on March 9-11, 1998 and related meetings and research activities. The regional effort was designed to create an ongoing process of assessment and collaboration on the assessment of the potential impacts of climate variability and change.

Objectives

The workshop and related activities created a process through which scientists and stakeholders addressed the following questions as posed by the USGCRP and the OSTP:

1) identify key environmental stresses of importance to the California region,
2) identify and assess the impact of increased climate variability and climate change as they might interact with these stresses,
3) determine information needs to better understand and cope with these changes, and
4) identify coping mechanisms which might minimize stresses and address climate change issues.

The Phase II work will address on-going regional and national assessment activities to build on the highly successful first phase. Specific tasks and priorities are outlined below.

Coordinating Organization in California

National Center for Geographic Information and Analysis (NCGIA), University of California, Santa Barbara

Assessment Coordinator:
Robert Wilkinson
Lecturer, Environmental Studies Program

wilkinso@envst.ucsb.edu
phone: (805) 569-2590
fax: (805) 569-2718

Advisory and Steering Support

The Phase I activities, including the California Regional Workshop, were advised and supported by both Steering and Advisory Committees. The Chair of the Steering Committee, Jeff Dozier, Dean of the Bren School of Environmental Science and Management at UCSB, (earth systems scientist) has agreed to continue in this important leadership role. The committees will be reconstituted with additional members for the next phase.

Project Description

The following is an overview of the next steps for the California Climate Assessment.

Phase II: California Regional Assessment of Potential Impacts of Climate Change and Variability

OSTP and USGCRP have developed a multi-year assessment process including regional workshops (20 throughout the US) and follow-on assessment activities in each region. NSF is the sponsoring agency for the California region. One key product of the regional assessment process is ultimately a summary document on potential impacts to the region (building on the white paper, the synthesis from the regional meetings, and follow-on research and stakeholder activities in each region). The results of the California Regional Workshop and Phase I activities (including the white paper, workshop meeting, and stakeholder meetings leading up to the workshop) were positive. This proposal requests fund for the next phase of work, which will identify the top issues for focused research activities.

To determine appropriate efforts for the region, Steering and Advisory Committee members have been consulted regarding useful next steps for California. As with the preparations for the workshop, the various interests and concerns of the research community and the stakeholders, including leading state and federal agencies, academic participants, business leaders, local government players, and other interested parties, are being taken into consideration.

Two Major Components of the Impacts Assessment Work Will be Examined

There are two major tasks for future climate impacts assessment work in the California region:

1) The first task is to follow up on critical sectoral components of the regional assessment as identified at the regional workshop. This will involve convening smaller meetings of stakeholders and experts on issues that require further analysis.

2) The second task is to work with scientists who are currently conducting research on key elements of the climate impacts issue (e.g. integrating the modeling of climate, water, fire, land-use, etc. and ecosystems and economic/social systems research) to coordinate their efforts and focus the outputs on assessments of potential climate impacts. The work involves coordination and support of interested parties who are working on climate change elements. The workshop has produced an impressive initial set of players who are interested in moving forward soon.

In the interest of setting initial priorities and providing a basis for immediate action, four specific elements of each of these two components are identified below:

Part 1: Sectoral Meetings

At least four "sectoral" areas merit particular consideration and focused follow-on work for the California region. They are:

1. coastal impacts (including natural systems and infrastructure and built aspects)
2. water (including supply, drought/flooding, and quality concerns)
3. agriculture (looking at both natural systems and market impacts)
4. urban centers (including that larger human infrastructure and support systems)

It is anticipated that the project will host, or preferably co-host, meetings on each of these topics to fill in key areas of the California regional assessment. Some of these efforts may be undertaken in conjunction with the respective sectoral assessment efforts, such as water and coastal impacts. (While we have a fair idea of the impacts involved in each sector, we did not have sufficient time at the workshop to reach the level of detailed discussion that is needed.) There are undoubtedly other important sectors which will require follow-on work. Further research activities will be planned to accommodate additional sectoral topics which emerge from our work.

Part 2: Research Priorities

In addition to rounding out the information and involvement of important sectors in the region, several research topics have been identified which should be addressed. Again, there are undoubtedly other areas which merit attention and which may emerge as we move forward. The four priority research "thrusts" identified are:

1. integrated regional impacts modeling project
2. ecological systems impacts assessment
3. communities and infrastructure impacts assessment
4. business and economic impacts

Each research thrust should involve a team of researchers and stakeholders from universities, labs, state and federal agencies, the private sector, and NGOs. These teams will build on the successful regional workshop process and add appropriate players as needed. Future assessment work should involve both direct support for certain research efforts and cooperation with research that is already funded but not coordinated. There is already significant funding in place for a number of research projects which could be highly leveraged (e.g. the modeling work with LBL, Scripps, state agencies, etc.).

1. ***integrated regional modeling project***

   This project would involve coordination of currently-funded work (e.g., at Lawrence Berkeley Lab on climate change at the regional scale, Scripps Institute work funded through NOAA, state resources agencies on issues such as water planning and fire-fighting, and NGOs such as the Pacific Institute, and others). The objective is both coordination of research efforts across critical sectoral areas of interest and sharing of existing information between research projects.

2. ***ecological systems impacts assessment***

   Climate-induced changes in ecological systems may involve profound impacts to both natural and managed systems. Ecosystem impacts and links to existing management challenges, from fire-fighting to agriculture to watershed management, is potentially considerable. State and local agencies will be key stakeholders to involve in this effort.

3. ***communities and infrastructure impacts assessment***

   The national assessment effort has determined that urban centers and the general area of communities and infrastructure should be handled at the regional assessment level (vs. developing a specific sectoral assessment process). This places a specific and important task before the regional assessment efforts to adequately address those concerns. The California region has significant urban/community/infrastructure issues linked to water supply, transportation and communications, fire, sea-level rise, health, and other concerns. System resilience and the capacity to adapt to and mitigate change is a critically important issue for the region.

Fortunately, we succeeded in bringing together leading players in this area including local government associations, (e.g. Local Government Commission) elected officials and planners at the local level, state and federal agencies concerned with these issues (e.g. CalTrans, Department of Water Resources, Bureau of Reclamation), and professional associations such as the American Planning Association (APA) and the American Institute of Architects (AIA). We need to pull this considerable talent together to assess California region-specific concerns. I suspect this process will in turn yield additional research questions to address.

4. business and economic impacts

Impacts of climate change and variability on California's trillion dollar economy are at once complex and critically important to business and the economy. One of the major accomplishments of the California regional workshop and the numerous pre-meetings held in preparation for it was the high quality and diversity of business participation. In follow-up discussions with business participants I have received extremely positive feedback and a strong interest in continuing the assessment. I would like to move quickly to maintain a valuable and significant level of interest and commitment.

California Regional Assessment Workshop Program

MONDAY, March 9

8:00 am - 9:00 am Registration and Continental Breakfast

9:00 am - 10:45 am **Santa Ynez** Plenary Session

Welcome to the California Regional Workshop on Climate Change and Variability

Jim Reichman, Director, National Center for Ecological Analysis and Synthesis
University of California, Santa Barbara
Jeff Dozier, Dean, Donald Bren School of Environmental Science and Management
University of California, Santa Barbara, and Chair, Steering Committee for the California Workshop

The California Climate Assessment: Goals and Process for the Workshop

Robert Wilkinson, Coordinator, California Workshop on Climate Change
Lecturer, Environmental Studies Program, University of California, Santa Barbara

Global Climate Change and Variability: The Science of Climate Change and the Assessment Process in the United States

Robert Corell, Director, US Global Change Research Program, and Assistant Director for Geosciences, National Science Foundation

Modeling Climate Change and Future Climates

Mike MacCracken, Executive Director, National Assessment Coordination Office
US Global Change Research Program

Climatically Sensitive California: Past, Present, and Future Climate

Norman Miller, Staff Scientist, Earth Sciences Division, Lawrence Berkeley Laboratory

Visualizing Climate Change Impacts at the Local Level: A California Case Study

Wil Orr and Hoyt Johnson
Sustainability and Global Change Program, Prescott College
Ashton Shortridge, Researcher

National Center for Geographic Information Analysis, University of California, Santa Barbara

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10:45 am-11:00 am Break

11:00 am -12:00 noon **Santa Ynez** Plenary Session

Socio-Economic Implications of Climate Change for California
Tapan Munroe, Chief Economist, Pacific Gas and Electric Company

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12:00 noon - 1:30 pm Lunch **San Rafael**

The Art of the Long View: Creating Scenarios for Alternative California Futures
Peter Schwartz, President, Global Business Network

1:30 pm - 2:30 pm Open Discussion Time

2:30 pm-5:30 pm Breakout Sessions
Breakout Discussions on Potential Climate Impacts to Human Systems

San Miguel W

1. **Urban Centers and Suburban Sprawl: Growth, and the Impacts of Climate Change**
   Nancy Skinner, Director, International Council for Local Environmental Initiatives
   Paul Wack, Lecturer, Environmental Studies Program, UCSB
   Judy Corbett, Executive Director, Local Government Commission

San Miguel E

2. **Energy Systems**
   Claude Poncelet, Pacific Gas & Electric
   Jan Sharpless, Commissioner, California Energy Commission

Santa Rosa W

3. **Coastal Land Use**
   Jo Bodovitz, The California Trust
   Madelyn Glickfeld, Senior Research Fellow, Claremont Graduate School Research Institute

Santa Rosa E

4. **Community Impacts and Initiatives**
   Andy Lipkis, President, TreePeople
   Catherine McKalip, President's Council on Sustainable Development

Santa Cruz W

5. **Public Education and Information**
   Kelly Sims, Science Policy Director, Ozone Action
   Wilson Orr, Director, Sustainability and Global Change Program, Prescott College

Santa Cruz E

6. **Public Perception of Climate Issues**
   Richard Berk, Professor of Sociology and Statistics, UCLA
   Bud Laurant, Supervisor, San Luis Obispo County

Anacapa W

7. **Impacts and Options for Water Systems**
   Susan Munves, Conservation Coordinator, Environmental Programs
   Maurice Roos, Chief Hydrologist, Department of Water Resources

Anacapa E

8. **Transportation Systems: Mobility and the Climate Issue**
   Thomas Crumm, Manager Envisioning & Alternative Futures Development, General Motors
   Al Sweedler, Professor of Physics, San Diego State University

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6:00 pm - 7:30 pm Reception **Lobby**

7:30 pm Dinner **San Rafael**

From Rio to Kyoto: International Policy Process

John Fialka, *Wall Street Journal*

<u>TUESDAY, March 10</u>

9:00 am- 10:30 am **Santa Ynez** Plenary Session

Climate Impacts on the Ecosystem Services
Underpinning California's Economy and Quality of Life

Walter C. Oechel, Director, Global Change Research Group and San Diego State University
Camille Parmesan, Research Scientist, National Center for Ecological Analysis and Synthesis, UCSB
Peter H. Gleick, Director, Pacific Institute for Studies in Development, Environment, and Security

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10:30 am - 11:00 am Break

11:00 am-12:30 pm Breakout Sessions
Breakout Sessions on Key Ecosystem Sectors

San Miguel W

1. **<u>New Ecosystem Distributions and Ecotones: Planning for Ecosystems, Habitat, and Preserves for 2050 and beyond</u>**
   Hal Mooney, Professor, Biological Sciences, Stanford University
   Rachael Craig, Kent State University
   Camille Parmesan, NCEAS

San Miguel E

2. **<u>Marine Fisheries and Ecosystems: Coastal Marine Services, Nursery Functions, Pelagic and Blue Water Fisheries, and Effects of Water Temperature Changes and Changes in Upwelling</u>**
   Craig Fusaro, Director, Joint Oil/Fisheries Liaison Office
   George Boehlert, National Marine Fisheries Service

Santa Rosa W

3. **<u>Managing Rangeland, Chaparral, and Oak Woodland Ecosystems for Water Yield, Fire, Grazing, and Habitat</u>**
   Frank Davis, Deputy Director, National Center foe Ecological Analysis and Synthesis

Santa Rosa E

4. **Habitat Conservation Plans (HCP), Natural Communities Conservation Plans (NCCP), and Multiple Species Conservation Plans (MSCP) and Biodiversity in the Context of Climate Change**
   Jim Young, Southern California Edison
   Walter Oechel, Director, Global Change Research Group and San Diego State University

Santa Cruz W

5. **Forestry, Forest Impacts, and Climate Change**
   William Stewart, Director, California Department of Forestry and Fire Protection
   Tom Suchanek, Director, Western Regional Director of NIGEC, at UC Davis

Santa Cruz E

6. **The Dynamics of Water Systems, Inland Water Ecosystems, and Potential Impacts of Climate Change**
   Peter Gleick, Director, Pacific Institute
   John Melack, Professor, Biology and Environmental Science and Management, UCSB

Anacapa W

7. **Agro-Ecosystems and the Impacts of Climate Change**
   Don Ermin, Director, Centers for Water and Wildlands Resources

Anacapa E

8. **Desert Ecosystems: Climate Change Implications for Boundary Shifts and Species Distribution and Composition**
   Kelley Redmond, Desert Research Institute
   Fred Wagner, Director, Ecology Center, Utah State University

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12:30 pm - 1:30 pm Lunch **San Rafael**

Special Presentation on the National Institute for Global Environmental Change (NIGEC): Cutting-Edge Research on Impacts of Global Change in the Western U.S.

Ruth Reck, National Director, NIGEC, at UC Davis
Tom Suchanek: Western Regional Director of NIGEC, at UC Davis

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1:30 pm - 2:30 pm Open Discussion Time

2:30 pm - 4:30 pm Breakouts Sessions

Breakout Discussions on Topics of Special Interest and Self-Organized Meetings

(Time is available here for meetings which participants wish to organize themselves to address topics of specific interest.)

San Miguel W

1. **California Greenhouse Gas Emissions Inventory**
   Guido Franco, California Energy Commission

San Miguel E

2. **Regional Ecosystem Impact Studies: Union of Concerned Scientists and the Ecological Society of America**
   Peter Frumhoff, Union of Concerned Scientists

Santa Rosa W

3. **California Pilot Project on the Use of Climate Forecast Information (NOAA)**
   Ants Leetmaa, Director, Climate Prediction Center, NOAA
   Claudia Nierenberg, International Economist, Office of Global Programs, NOAA

Santa Rosa E

4. **Climate Modeling and California: Discussion of the Science**
   Norman Miller, Staff Scientist, Earth Sciences Division, LBL
   Mike MacCracken, Executive Director, National Assessment Coordination Office, US Global Change Research Program

Santa Cruz W

5. **(To Be Determined by Participants)**

Santa Cruz E

6. **(To Be Determined by Participants)**

Anacapa W

7. **(To Be Determined by Participants)**

Anacapa E

8. **(To Be Determined by Participants)**

4:30 pm-6:00 pm **Santa Ynez** Plenary Session

Reports from Discussion Groups

6:00 pm - 7:30 pm Reception **Lobby**

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WEDNESDAY, March 11

9:00 am - 10:30 am **Santa Ynez** Plenary Session

A California Climate Initiative:
Exploring Stakeholder Collaboratives for a Sustainable Future

Jeff Dozier, Dean, Donald Bren School of Environmental Science and Management, UCSB
Jim McWilliams, Professor, Institute of Geophysics and Planetary Physics, UCLA
Larry Papay, Senior Vice President, Bechtel Group
Michael Moore, Commissioner, California Energy Commission

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10:30 am - 11:00 am Break

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11:00 am-12:30 pm
Breakouts Discussions Exploring Opportunities for Collaboration and Research Priorities Following the Morning Presentations

San Miguel W

1. **Exploring a Program for 2020 Foresight: Building an Alliance**
   Jim McWilliams, Professor, Institute of Geophysics and Planetary Physics, UCLA
   John Wise, Environmental Protection Agency, Region IX

San Miguel E

2. **Redefining Progress: New Technologies and Approaches to Deal With Climate Change**
   Jim Dehlsen, Enron Renewable Energy Corporation
   Maureen Kennedy, Director, Redefining Progress

Santa Rosa W

3. **Creating a California Collaborative to Address Climate Change Issues**
   Jeff Dozier, Dean, Donald Bren School of Environmental Science and Management
   Michael Moore, Commissioner, California Energy Commission

Santa Rosa E

4. **Community-Based Collaboratives to Address Climate Change**

Kelley Sims, Science Policy Director, Ozone Action
Blair Henry, Chair, Northwest Council on Climate Change

Santa Cruz W

5. **Developing Strategies to Quantify Potential Costs and Benefits of Climate Change Impacts in California**
   Charles Kolstad, Professor of Economics and Environmental Science and Management, UCSB

Santa Cruz E

6. **Private Sector/Research Institute Collaboratives on Climate**
   Larry Papay, Senior Vice President, Bechtel Group
   Jim Cole, California Institute for Energy Efficiency

Anacapa W

7. **Multiple Benefits of Climate Change Adaptation and Mitigation Strategies**
   Eileen Shea, Center for the Application of Research on the Environment, Institute of Global Environment and Society

Anacapa E

8. **International Dimensions of Climate Change Impacts in California**
   Chris Bernabo, President, Science and Policy Associates
   Claude Poncelet, Pacific Gas & Electric

12:30 pm - 1:30 pm Lunch **San Rafael**

1:30 pm-3:30 pm **Santa Ynez** Plenary Session

Summary of the Top Issues for California and Plans for Follow-On Activities

Jeff Dozier, Dean, Donald Bren School of Environmental Science and Management, University of California, Santa Barbara, and Chair, Steering Committee for the California Workshop
Robert Wilkinson, Coordinator, California Workshop on Climate Change

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3:45 pm - ***Closing Comments***

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CLIMATICALLY SENSITIVE CALIFORNIA:
HYDROCLIMATE SENSITIVITY AND RESPONSE IN CALIFORNIA

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INTRODUCTION:

California is sensitive to climate variability and climate change. California represents the world's seventh largest economy, with an increasing population, rapidly developing industries, and expanding societal demands. Climate variability and climate change impose stresses on California's infrastructure. The climate science community has indicated that global temperature is increasing, wet season precipitation events are becoming more extreme, and sea level is rising (Intergovernmental Panel on Climate Change [IPCC] 1995). These changes impact fresh water systems, land use, industry, natural ecosystems, and environments. The focus of this overview paper is to indicate some of these potential impacts, provide some insight into future projections of California climate, and indicate what might be done to reduce hydroclimate related risks.

Fresh water is a major driver to the success of California's prosperity. Agriculture, urban development, information technology, among others, depend on the availability of water resources. California's water comes primarily from northern California mountainous river basins with some Colorado River allocations. Late Winter, Spring, and Summer runoff from high elevation mountains provides the needed water resources during the long dry season (April to November). Decreases in this water supply may force a change in the existing demand.

California's water resources infrastructure is based on a network of reservoirs, levees, and canals. This extensive water conveyance system is not fully designed for current and future climate variations, climate change, and land use change. Reservoirs serve as water storage and flood control systems. During the wet season, reservoirs and levees provide flood protection. During this time of year, communities within floodplains are protected from heavy precipitation events and are at a reduced risk of flooding and extensive loss. Wet season dam releases frequently occur during periods when reservoirs are at very high levels. Such releases are required to provide storage capacity for additional inflow from runoff, while protecting the integrity of dam structures. These releases need to be timed to minimize any potential downstream flooding. At present, river forecasters rely on 48-hour weather forecast information to make decisions on the amount to be released and on high streamflow and runoff estimations. Wet season heavy precipitation events may stress levee systems that run the length of the central valley. For example, the Winter 1997 central valley floods were due to a warm January storm producing an unexpected large amount of runoff to an already water stressed levee system. This occurrence of flooding implies that the safety and functionality of the reservoir and levee systems in California are sensitive to wet season heavy precipitation.

Additionally, wet season storms often cause increased erosion and landsliding, especially developed regions that may lack proper drainage of runoff during extreme weather events. This has been seen throughout California during the 1998 El Niño that was particularly strong during February, where property losses approached $500 million. During wet seasons with extensive periods of heavy precipitation and saturated soils, agriculture is hampered due to crop damage and delays in planting. Storm and land use induced sediment loading to river systems may impact aquatic ecosystems. Other ecosystems, including migratory birds, may also be damaged due to loss of habitat, breeding grounds, or food supply.

Long dry periods reduce the available water resources to the state. Water reduction was common during the multi-year droughts that occurred in the 1930s, 1980s, and during other dry periods. Drought impacts are most pronounced in urban centers, natural habitats, and in agricultural productivity. During the 1980s drought, Californians experienced water rationing, the San Joaquin delta received below average fresh water, and agro-industry felt some cutbacks in their water usage. Decreased fresh water not only inconveniences our society, but significantly impacts ecosystems dependent on fresh water. The resulting increased salinity in the San Joaquin delta significantly reduced the health of fish habitats.

In general, land use change, such as deforestation and urbanization, will amplify the risk and potential loss associated with increased wet season precipitation and long drought periods in California. Coupled with temperature increases, it may harm species biodiversity. As California continues to expand, we need to plan for the future in a responsible fashion. In the next section, climate patterns, indicators, and natural variability are discussed. This is followed by a section on climate projection requirements and projected California climate. The conclusions focus on where do we go from here.

CLIMATE PATTERNS, INDICATORS, AND TRENDS

California is characterized by a Mediterranean climate with wet winters and long dry summers. Precipitation and temperature patterns during the winter and spring have been associated with large-scale patterns in the North Pacific atmospheric circulation (Cayan and Peterson, 1989; Redmond and Koch, 1991). Cool wet (warm dry) seasons have been correlated to the position of the Aleutian low pressure center. If the Aleutian low is positioned far eastward (i.e. Gulf of Alaska)), then there is an increased likelihood for California to have a cool wet Winter and Spring. The opposite (warm dry Winter and Spring) is expected for a far westward position of the Aleutian low. Cayan et al. (1993) have indicated this pattern in their analysis of streamflow for the Smith, Consumnes, and San Joaquin River basins.

This general description is complicated by other processes, such as warm eastern equatorial Pacific sea surface temperatures. During the Fall of 1997, the eastern equatorial Pacific sea surface temperature was several degrees above normal and remained above average well into the Spring of 1998 causing a large increase in California precipitation. This warming was due to the naturally varying El Niño Southern Oscillation (ENSO). The large warm water pool provided moisture into the atmosphere which precipitated out when it reached California. The heavy precipitation during January and February of 1998 was directly related to this phenomenon. The Aleutian low pressure was in a westward position and a high pressure ridge was to south. This combination of atmospheric patterns, among other complex interacting processes, set the storm track direction during the intense January-February 1998 precipitation. ENSO has a natural cycle on the order of once every four years. A measure of the occurrence of ENSO is the Southern Oscillation Index (SOI). The Southern Oscillation Index is a measure of the pressure difference between Tahiti and Darwin, Australia. A negative value is an indication of an El Niño year, while a positive value indicates a La Niña year. There has been speculation about the effect of Green House Gases (GHGs) on the variation in the occurrence and strength of El Niños, however, at this time there is not sufficient evidence to indicate that such a link exists.

However, evidence suggests that temperature has been increasing since the industrial revolution due to increased Green House Gas (GHG) emissions into the atmosphere. There have been numerous studies (e.g. Keeling et al., 1995) that show a strong correlation between global temperature and the atmospheric concentration of carbon dioxide. Based on 287 borehole measurements, global temperature from 1500 to present have been determined (Pollack et al., 1998). The significance of this data is that global temperature has increased 0.5° C from 1500 to 1900, and 0.5° C from 1900 to present. That is, measurements indicate that during the last 100 years global temperature has increased at the same rate as the 400 years prior to 1900. The temperature oscillation shown for the period 1860 to present is based on surface measurements. There are a number of other measurements (tree ring data, core sediments, isotope analysis) that agree with this result.

These large-scale patterns and trends can be seen in California by looking at the freshwater inflow into the San Joaquin delta as an indicator of inter-annual precipitation in the Sierra. Using carbonate oxygen 18 isotopes from sediment cores, Ingram et al. (1996) were able to infer the amount of freshwater inflow for the time period 1200 to 1980. This long time series approximately indicates that there were long dry periods (1420-1460, 1500-1600, 1625-1630) as well as periods of above average precipitation and inflow (1225-1400, 1660-1720, 1800-1880). We are currently in a period of above average fresh water inflow, due to the large amount of water exported from the delta for agriculture and urban use.

IS THERE AN ENHANCED CLIMATE VARIATION IN THE HYDROLOGIC CYCLE?

Observed temperature indicators from the Second Assessment Report of the International Panel on Climate Change (IPCC, 1996) provide numerical estimates on global changes in the near surface air and near surface ocean temperatures (0.3 - 0.6° C increase), Northern Hemisphere snow cover (10% decrease), and mountain glaciers (general retreat), with high levels of measurement confidence. This information and related findings suggest that a serious effort to better understand the impacts of climate variability and change in California.

The majority of California’s water supply includes eight major Northern California river basins that provide snowmelt runoff as reservoir storage and water transport to Southern California. These eight basins; the American, Feather, Merced, Sacramento, San Joaquin, Stanislaus, Tuolumne, and the Yuba. Possible climate change impacts on the timing of California runoff was first pointed out by Roos (1987). Several modeling and analysis studies followed (e.g. Gleick, 1987; Roos, 1989; Cayan and Henderson, 1989; Lettenmeir and Ghan; 1990, Redmond and Koch; 1991; Aquado et al. 1992; Cayan and Riddle, 1993; Dettinger and Cayan, 1995; Jeton et al., 1996).

Area-averaged minimum temperature measurements (1975-1995) representative of a region that includes Sacramento and Lake Tahoe adjusted to seasonal oscillations indicates an increase of 0.086° C per year, which is somewhat faster than the fitted maximum temperature increase for the same period. These increases in the last twenty years are not reflected in the long historical record, however, they tend to be in agreement with observed early season snowmelt as well as increases in GHG concentrations in the atmosphere. The significance of the minimum temperature increasing at a faster rate than the maximum temperature is a reduction in the daily temperature difference, which plays an important role in the hydrologic cycle.

Dettinger and Cayan (1995) have analyzed the above eight river basins for the percent of annual runoff that occurs as Spring (April to June) runoff during the period 1910 to 1990. An Eight-Rivers Index indicates that there is a statistically significant decrease in the percent of Spring runoff. The American River basin alone showed a 10% decrease in Spring runoff to annual runoff during the 1950 to 1990 period.

The northern coastal Russian River basin response to precipitation (1900 to 1995) is indicated by the river stage height at Guerneville. The river has exceeded flood stage (32 feet) about once every three years during the first half of this century. However, during the second half of the century, flood stage is exceeded more frequently. This suggests an increase in extreme wet season precipitation events since approximately 1950.

These observations of California's climate response require an investigation of possible future scenarios. Such "what if" studies help to shed light on the potential risks, provide planners with needed information, and in general will help to educate our society on climate variability and climate change.

CLIMATE PROJECTION REQUIREMENTS

Climate projections have two general requirements; the modeling system should be well validated and the public has sufficient confidence in these results to act on them. Individual model components (e.g. cloud physics module, snow budget module, runoff module) should be carefully studied for proper conceptual representation of their processes. Comparison to observation data, remotely-sensed, and synthesized data will indicate how well each model performs. Once this is accomplished to an acceptable level, then coupled model systems are validated. A major task is acquiring the extensive data base for these model validations and analyses.

Coupling models for understanding climate response at a range of scales is a complicated task. GHG related climate projections have been produced at the global scale for the past two IPCC Reports (1990, 1996). These scales (grids with lengths of order 100 - 500 km) are too coarse for understanding processes at the surface such as, riverflow, agriculture, and socio-economic impacts. The concept of downscaling climate information for hydrologic modeling was presented by Hoestetler (1992). One of the difficulties of downscaling global climate information (grids with length scales of order 100 - 500 km) to ecologic, hydrologic, and socio-economic fine-scales (1 - 100 m) is the lack of data within the global length scales that are needed for understanding processes that are sensitive to change at the fine scales. One approach to this downscaling problem is the use of regional climate system models. Regional climate system models use the global-scale information as input to limited area models which interactively calculate atmospheric and land surface processes with grid scales of order 10 km. The difference between the global and regional-scales is apparent. California is represented by less than ten global-scale grid points, while the regional-scale provides thousands of points of gridded climate information. This difference is important when modeling the effects of atmospheric moisture moving above mountains that global-scale models may completely miss.

To provide fine-scale climate, information area-weighted variables or probability distributions may bridge this spatial gap. There are other types of fine scale approaches that perform well for short (1-2 day) simulations, but have not yet proven useful for climate simulations. Modeling hydrology with spatial information requires either the area-weighted values or distribution values that represent the river basin being studied. As an example, the

Russian River basin can be broken down into sub-basins, where each sub-basin contains many small catchments. There are still many data needs for understanding climate at fine-scale and this is an ongoing effort from various groups within the climate research community.

EXAMPLES OF CLIMATE MODEL VALIDATION

Climate model validation is best understood by comparing climate simulations to observations, model comparisons, and statistical analyses. The IPCC (1996) provides a number of global model intercomparisons, observational comparisons, and statistical analyses. For the period 1860 to 1990, the IPCC has compared observed global-scale temperature with simulated temperature with increasing GHG concentration and aerosol concentration. A large-scale model validation of ocean models is the ability to simulate the ENSO cycle. The comparisons show good agreement (0.63 correlation) between the observed and simulated western boundary sea level height changes with time.

Comparing regional scale models of precipitation in California for the 1994-1995 precipitation season with the simulated precipitation from the Regional Climate System Model (RCSM) with large-scale input provided by the National Oceanic and Atmospheric Administration validates river basin-scale hydrologic models for the period 1982-1984. The total verification (1978 to 1984) indicates an 0.84 correlation when the hydrologic model is forced by observed precipitation for streamflow. The coupled large-scale to regional-scale to basin-scale system shows good predictive capability for the period January to March 1995.

These types of model exercises indicate the level of component and coupled model validation. Based on these types of results, one can better understand how well we project future climate with current models.

PROJECTED CALIFORNIA CLIMATE VARIATION AND ITS IMPACTS

Drawing from observations and previous model studies (Lettenmeir and Ghan, Gleick) there is good confidence indicating that California will likely experience a continued trend of increasing temperature, increased extreme weather events, extended drought periods, and sea level rise. Some specific California effects are an early snowmelt, increased flooding, increased erosion and landslides, decreased water resources for extended periods, and low lying regions under water.

A regional simulation of the effects of doubled atmospheric carbon dioxide based on a large-scale model (NCAR's CCM2) and NCAR Regional Climate model (RegClim) indicated changes in alpine regions. Winter and Spring snow depth is a function of elevation for present CO_2 and 2 x CO_2 levels. The 2 x CO_2 studies indicate that the snow level is considerably higher in elevation and that the total snowpack is substantially decreased. By estimating the corresponding runoff for this study, we can see that the Winter runoff is very high under 2 x CO_2 conditions, while the Spring and Summer runoff is quite low. A study of the American River basin with a projected 4.4°

C temperature increase also shows the early runoff. These studies and the earlier work by Lettenmeir and Ghan, Gleick, and others tend to agree with the IPCC.

Roos has calculated the effect of a 30 cm sea level rise on the frequency of high stage height on the San Joaquin River near Antioch, a region with levees protecting low lying areas. What was once considered a 100-year event will quickly become a 10-year event.

These results lead us to ask questions about planning and developing within the California floodplains and other sensitive areas. The 100-year flood plain is based on a short historical record that does take into account climate change during this century. It is clear that this and related concerns need to be addressed. New developments within flood plains need to be accessed for long-term costs. The erosion at Pacifica has been known since the 1950s, yet houses have been built close to the cliffs requiring a proposed $1.5 million seawall.

WHERE DO WE GO FROM HERE

Understanding climate, advancing our monitoring systems, coordinating research, and providing well validated information that the public and policy makers can trust is an important direction that we need to focus on. Coordinated climate research, assessment, and outreach centers throughout California are an important approach toward understanding the impacts of Climate change in California. Universities, National Laboratories, and non-profit centers should work to complement each others ongoing capabilities. Legislatures will need to become educated on these issues and make well informed policy for long term solutions. The media needs to move away from sensationalism and focus more on educating society on issues that are of substance.