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Climate Change and California Water Resources: A Survey and Summary of the Literature

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Pacific Institute for Studies in Development, Environment, and Security

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Another product of this effort is a new, searchable, electronic bibliography of the water and climate literature. Over 3,000 citations are available to be searched by title, author, keyword, region, and more, at http://www.pacinst.org/resources.

The Public Interest Energy Research Program (PIER) of the California Energy Commission is an integrated, multidisciplinary effort to explore the potential implications of climate change for California's economy, ecosystems, and health. Designed to complement national and international studies, the project will provide California-specific but preliminary information on climate change impacts. Many efforts are already underway, and the section Research Needs describes future priorities. For example, PIER is funding a climate change research program of core research activities at UC Berkeley and UC San Diego (Scripps). Scripps is developing a comprehensive meteorological and hydrological database for the state representing historical conditions for the last 100 years. The database will be very useful for regional model inter-comparison work and the study of climatic trends. Scripps is also testing a dynamic regional climate model (Regional Spectral Model) simulating climatic conditions in California for the last 50 years a high-resolution model and they are testing new statistical downscaling techniques with the goal of capturing extreme events. Finally, they are installing meteorological and hydrological sensors in key areas/transects in California to track a changing climate and provide a richer database for future regional model enhancements and evaluations.

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agencies and including the participation of a wide range of stakeholders could be a valuable tool for policymakers and planners, and we urge such an assessment to be undertaken in the near future.

2. Climate Change and Impacts on California Water Resources

Overview of Modeling

Projecting regional impacts of climatic change and variability relies first on General Circulation Models (GCMs), which develop large-scale scenarios of changing climate parameters, usually comparing scenarios with different concentrations of greenhouse gases in the atmosphere. This information is typically at too coarse a scale to make accurate regional assessments. As a result, more effort has recently been put into reducing the scale and increase the resolution of climate models through various techniques such as downscaling or integrating regional models into the global models. The resulting finer-scale output can then be analyzed for given watersheds, ideally with the incorporation of other hydrologic parameters such as local evaporation, transpiration, soil conditions, topography, snowpack, and groundwater.

Models are typically calibrated by comparing model runs over historical periods with observed climate conditions. It should be emphasized that these model results are not intended as specific predictions, but rather are scenarios based on the potential climatic variability and change driven by both natural variability and human-induced changes. Nonetheless, they are useful for assessing potential possible future conditions.

Temperature

Modeling results from GCMs are consistent in predicting increases in temperatures globally with increasing concentrations of atmospheric greenhouse gases resulting from human activity. Higher temperatures are of particular interest and concern for California water systems because of their effect on Sierra snowpack accumulation and snowmelt and other hydrologic variables, addressed below. Recent work by Snyder et al (2002) has produced the finest-scale temperature and precipitation estimates to date. Resulting temperature increases for a scenario of doubled CO_2 concentration are 1.4-3.8 degrees C throughout the region (Figure 1). This is consistent with the global increases predicted by the Intergovernmental Panel on Climate Change (2001). Sample temperature results from two different GCMs are also presented below in Figures 2a,c. In a regional model of the Western United States, Kim et al (2002) project a climate warming of around 3 to 4 degrees C. Of note in both studies is the projection of uneven distribution of temperature increases. For example, regional climate models show the warming effects are greatest in the Sierra Nevada Mountains, with implications for snowpack and snowmelt (Kim et al. 2002, Snyder et al. 2002). Similar results have been noted in Barnett et al. (2003).

Precipitation

In general, while modeling of projected temperature changes is broadly consistent across most modeling efforts, there are disagreements about precipitation estimates. Considerable uncertainties about precise impacts of climate change on California hydrology and water resources will remain until we have more precise and consistent information about how precipitation patterns, timing, and intensity will change. Some recent regional modeling efforts conducted for the western United States indicate that overall precipitation will increase (Giorgi et al. 1994, Kim et al. 2002, Snyder et al. 2002), but considerable uncertainty remains due to differences among larger-scale GCMs (Figure 1 and 2). Where precipitation is projected to increase, the increases are centered in Northern California (Kim et al. 2002, Snyder et al. 2002, Figure 1) and in winter months. More general large-scale precipitation results from two different GCMs are also presented below in Figures 2b,d. Further work is in progress to extend and