CALFED Progress Report
California Sea Grant College Program

ConfirmationNumber: 20110506105238

ProjectYear_2A: 2nd | ProjectNo_2C: R/SF-34

Printed: 5/6/2011 11:11:45 AM | TypeQuestionnaire_2B: Final Report

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Project Information

ProjectNo_2C: R/SF-34 | StartDate_3a: 10/1/2008 | EndDate_3b: 9/30/2010
ProjectTitle_4: Investigating the Frequency and Magnitude of Floods in the Sacramento-San Joaquin Valleys under Changing Climate

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CMPositionTitle_7N: Executive Manager for Climate Change

Additional Research Mentors and Community Mentors

Additional Research Mentors_8

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Additional Community Mentors_9

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Project Objectives: Please type your responses, and answer the questions in a style appropriate for laymen.

ProjectObjectives_10

California's mountainous topography, exposure to occasional heavily moisture-laden storm systems, and varied communities and infrastructures in low lying areas make it highly vulnerable to floods. The goal of this Bay-Delta program funded CALFED postdoctoral project was to investigate how warmer temperatures and possible changes in precipitation might cause changes in the frequency of occurrence and the intensity of floods in the Sacramento-San Joaquin Valleys. Sacramento-San Joaquin Valleys are the primary watersheds in California that historically have been buffered from winter floods because precipitation usually came in the form of snow-pack instead of rainfall. In particular, water managers in the Sacramento-San Joaquin River watersheds in California have expressed great concern about such changes because this region is the hub of California's water supply and also because of the large and growing population that lives in the lowlands of these river systems.

The proposed research addressed the following research questions:

(i) To what extent do simulated flood statistics emulate historical observations?
(ii) How and why do extreme events of simulated streamflows change under current projections of future climate?
(iii) How does uncertainty in the GCM model results impact the extreme events statistics?
(iv) To what extent are projected changes in flood frequencies and magnitudes being indicated in historical observations? How large would the changes need to be recognized as such?

Summary of progress in meeting each of these goals and objectives

ProgressSummary_11

As stated in the first year progress report, the project investigation was based upon downscaled daily precipitation and temperature simulations from General Circulation Models (GCMs). The project work involved a two-fold assessment. In the first year of the project, analyses were performed using a smaller set of GCMs to determine how floods change under projected climate change. The focus was to identify the potential causes of flood increase. In this part of the project, data from three GCMs were downscaled using a statistical downscaling method Constructed Analogues (CA). The downscaled meteorologies were fed into a hydrologic model (Variable Infiltration Capacity). The hydrologic model was also driven by an observed gridded historical meteorology developed at the University of Washington. The Variable Infiltration Capacity (VIC) model output, from historical and from projected climate change runs, is used to evaluate possible changes in annual maximum 3-day flood magnitudes and frequencies of floods greater than selected historical thresholds.

There are several layers of uncertainty related to GCMs: each GCM runs with its own horizontal and vertical discretization of the atmospheric layer, different parameterization schemes, and different initial conditions. To address that, in the second year of the project, data from sixteen different GCMs from two future emission scenarios were used. All of these GCMs are referenced in the Intergovernmental Panel on Climate Change Fourth Assessment Report (IPCC AR4). The GCMs data were downscaled using a different statistical method called Bias-Correction and Spatial Disaggregation (BCSD) method. The downscaled data were made available from a concurrent project supported by California Energy Commission. Based on the methodology developed in the first year of the project, analyses were repeated using this larger set of GCMs to examine the question of whether the different flood drivers have increased or decreased in moving to the larger ensemble. Thus, in this project, uncertainties related to GCMs were investigated, to some extent, by analyzing downscaled precipitation and temperature data from different GCMs, from two future emission scenarios, covering a range of temperature and precipitation changes.

Additionally, in the second year, a set of analyses were performed to explore the sensitivity of flood statistics as simulated by VIC to prescribed uniform changes in temperature and precipitation of the past observed historical period (1915-2003).

Using the ensemble future climate projections, the project revealed an increased flood risk in Northern and Southern Sierra under projected future climate, regardless of wetter/drier climate, due to different combinations of changing storm intensity, snowline and winter soil moisture.

The principle findings:

Continued in Additions_19

PROJECT MODIFICATIONS: Please explain any substantial modifications in research plans, including new directions pursued. Describe major problems encountered, especially problems with experimental protocols and how they were resolved. Describe any ancillary research topics developed.

Modifications_12

No major modifications were undertaken in the second year.

BENEFITS AND APPLICATIONS: Suggest the relevance of these new findings to management. Describe any accomplishment, that is significant effects your project has had on resource management or user group behavior. CALFED is looking for "management cue" (see http://science.calwater.ca.gov/pdf/soemgmtcues.pdf).

BenefitsApplic_13

Some hydrologic consequences of climate change are relatively straightforward (earlier snowmelt; more precipitation as rain). The investigations to date indicate, at the most basic level, that flood-frequency impacts of current climate change projections may not be at all straightforward. Instead, so far, results suggest that even in a single drainage, future flood frequencies are likely to be complex and interwoven responses to many aspects of the climate changes, including possible changes in the magnitudes of largest storms, frequencies and sequencing of large storms, temperatures during storms as well as between storms, and seasonality of storms, with no single climate change dominating the overall flood responses. At the basin to basin level, the complex mix of climate forcings and vulnerabilities is further complicated by the fact that responses differ considerably from basin to basin depending on the topography in the various basins. This means that projections of flood changes with climate change are very likely to be basin dependent, and are likely to require full hydrologic modeling rather than simpler rules of thumb of the sort that might work with some other hydrologic responses.

California is currently facing by many urgent issues concerning floods and will need to make decisions in the context of possible climate changes. A notable result of the project is that, almost regardless of broad changes in mean precipitation in the future-climate scenarios evaluated (whether overall dry or wet in future), the 50-year flood (2% exceedence) increased in both the Sacramento and, especially, San Joaquin watersheds. This project result calls for more detailed simulations and analyses to develop much confidence in real-world and actionable predictions about flood-regime changes. For managers, the bottom line message for managers should be that, regardless whether the future will be wetter or drier, risks from floods and therefore the need for greater

attention and amelioration of floods should be (fairly confidently) expected to increase.

PUBLICATIONS: List any publications, presentations, or posters that have resulted from this funded research. Give as many details as possible, including status of paper (e.g., in review; in press), journal name, conference location and date of presentation. Please note (as outlined in the conditions of the award) that each fellow is required to submit an abstract for an oral or poster presentation at each State of the Estuary conference and CALFED Science Conference during the duration of the fellowship.

Publications_14

Articles

Das T., Dettinger M.D., Cayan D.R. and Hidalgo H.G. Potential increase in floods in California's Sierra Nevada under future climate projections, Climatic Change. (In revision)

Das T., Cayan D.R., Maurer E., Dettinger M.D. and Pierce D.W. Probabilistic forecast of change in flood characteristics in California under future climate. (In preparation)

Abstract and presentations

Das T., Dettinger M.D., Cayan D.R. and Hidalgo H.G. 2010. Potential increase in floods in California's Sierra Nevada under future climate projections. Bay-Delta Science Conference, September 2010, Sacramento.

Das T., Dettinger M.D., Cayan D.R. and Hidalgo H.G. 2010. Potential increase in floods in California's Sierra Nevada under future climate projections. CWEMF, February 2010, Asilomar, California, 2010.

Das T., Hidalgo H.G., Dettinger M.D. and Cayan D.R. 2008. Increased flood risks in the Sacramento-San Joaquin Valleys, CA, under climate Change. VI Annual California Climate Change Conference, September 2009, Sacramento, California.

Das T., Hidalgo H.G., Dettinger M.D. and Cayan D.R. 2008. Increased flood risks in the Sacramento-San Joaquin Valleys, CA, under climate Change. EOS Transactions, American Geophysical Union. 2008 Fall Meeting, San Francisco, California.

Das T., Hidalgo H.G., Dettinger M.D. and Cayan D.R. 2008. Increased flood risks in the Sacramento-San Joaquin Valleys, CA, under climate Change. 2008 CALFED Science Conference, October, 2008. Sacramento, California.

The fellow was participated in the following projects during the fellowship period, which were not supported by CALFED Bay-Delta Postdoctoral fund.

Cayan D.R., Das T., Pierce D.W., Barnett T.P., Tyree M. and Gershunov A. 2010. Future dryness in the southwest US and the hydrology of the early 21st century drought, Proceedings of the National Academy of Sciences, 107(50), 21271-21276, doi: 10.1073/pnas.0912391107.

Maurer E.P., Hidalgo H.G., Das T., Dettinger M.D., and Cayan D.R. 2010. The utility of daily large-scale climate data in the assessment of climate change impacts on daily streamflow in California, Hydrology and Earth System Sciences, 14, 1125-1138, doi:10.5194/hess-14-1125-2010.

Dettinger M.D., Ralph F.M., Hughes M., Das T., Neiman P., Cox D., Estes G., Reynolds D., Hartman R., Cayan D., and Jones L. Design and quantification of an extreme winter storm scenario for emergency preparedness and planning exercises in California, Natural Hazards. (In review)

Westerling A.L., Bryant B.P., Preisler H.K., Holmes T.P., Hidalgo H.G., Das T. and Shrestha S.R. Climate Change and Growth Scenarios for California Wildfire, Climatic Change. (In revision)

COOPERATING ORGANIZATIONS: List those agencies and/or persons who provided financial, technical or other assistance to your project since inception. Describe the nature of their collaboration.

CoopOrganiz_15

Scripps Institution of Oceanography and U.S. Geological Survey:
Dr. Daniel R. Cayan, Scripps Institution of Oceanography and U.S. Geological Survey.
Dr. Michael D. Dettinger, U.S. Geological Survey and Scripps Institution of Oceanography.

Dr. Cayan and Dr. Dettinger participated in the project as research mentors.

California Department of Water Resources:
Dr. Michael Anderson, California Department of Water Resources
Dr. John Andrew, California Department of Water Resources

Dr. Anderson and Dr. Andrew supported in the project as community mentors.

AWARDS: List any special awards or honors that you, or mentor or members of the research team, have received during the duration of this project.

Awards_16

None in the second year

KEYWORDS: List keywords that will be useful in indexing your project.

Keywords_17

Flood frequency analysis, climate change, general circulation models, California

PATENTS: List any patents associated with your project.

Patents_18

None

Additions: Additional information can be added here. Please begin the text with the number of the question you are adding to.

Additions_19

ProgressSummary11:

- The ensemble climate model projections used in this project suggest wetter average conditions for Northern Sierra and drier conditions for Southern Sierra by end of the 21st century.
- There is a general tendency toward increases in the magnitudes of 3-day flood events.
- By the end of the 21st century, all climate model projections yield larger floods for both the moderate elevation Northern Sierra Nevada watershed and for the high elevation Southern Sierra Nevada, regardless of change in mean precipitation.
- The ensemble climate model projections show fewer snowy days under future climate, as compared to historical period in Sierra Nevada.
- Increase in simulated 50 years flood (2% exceedence) discharge become statistically larger (at 95% confidence level) than that can be expected due to natural variability, by as early as 2035. The natural variability is simulated using a long (750 years) global climate model control simulation.

Two manuscripts describing the results are being prepared. One manuscript describing the first year of the project is in revision in Climatic Change. The second manuscript describing the second year project work on probabilistic forecast of change in flood characteristics in California under future climate is in preparation.

Cooperating_Organizations_15

Santa Clara University:

Professor Edwin Maurer provided downscaled climate model data used in the second year of the project dealing with probabilistic forecast of change in flood characteristics in California under projected climate change.

California Energy Commission:

California Energy Commission supported to develop some of the downscaled climate data used in the project.