Simulating and Understanding Variability in Runoff from the Sierra Nevada

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This study aims to understand the origins of recent and future changes in snowpack and runoff in the Sierra Nevada using both observational and modeling techniques. Together, observations and models indicate the snowpack will likely undergo dramatic changes in the coming decades; moreover that those changes are already detectable and well underway.

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To study the snowpack from an observational perspective, we examined snow station observations and surface temperature data. First-of-the-month snow water equivalent measurements were combined from two data sets to provide sufficient data for statistical analysis of snowpack evolution during the snow season from 1930 to 2007. The monthly data is used to calculate peak snow mass timing to assess variability in timing and magnitude of snow accumulation and melt from February 1st to May 1st. Since 1930, there has been a trend towards earlier snow mass peak timing by 0.4 days per decade. Since 1948, regional March temperatures have also increased at a rate of 0.4ºC per decade. Statistical analysis shows that the trend in snow mass peak timing can be explained by its sensitivity to local March temperatures. The snow mass peak timing is shown to shift earlier in the season by 1.3 days per 1ºC increase in March temperatures. Given scenarios of warming in California, we can expect to see acceleration in this trend; this will reduce the warm season storage capacity of the California snowpack.

This observational study paints a picture of a rapidly changing snowpack already responding to global climate change. These results are consistent with the modeling component of our study. To model the changing snowpack, we carried out a climate simulation with a 36-km regional atmospheric model covering all of California. In this simulation, the model is forced at its lateral boundaries with output from a global model simulating future climate change. This allows us to examine the effect of increasing greenhouse gases on the Sierra snowpack. By the mid-21st century, we project significant decreases in snow water equivalent averaged over the wet season in the Sierra Nevada. The projected snow decrease is especially large in the lower-elevation northern Sierras. Here it is about 30-40% in fall and almost 60-80% in winter. The decrease in snow is due to a significant decrease in snowfall and is likely augmented by increased likelihood of melting due to warming. Though the likelihood of snow melting is greater in the warmer climate, reducing snowpack, the amount of snowmelt itself decreases throughout the cold season in response to the reduced snowfall. Again, the largest reduction occurs in the northern Sierra Nevada where the snowmelt decreases by 38% and 54% for fall and winter, respectively.

We are also actively working to improve simulations of hydrologic processes in regional climate models. We have undertaken a 12 km resolution simulation of the current climate of entire state of California, with higher resolution nests of up to 4km in the hydrologically-critical region of the Sierras. We found that increasing model resolution significantly improves the realism of the precipitation and snowpack distributions in the Sierras. However, through comparison with streamflow observations in undisturbed watershed in the High Sierras, we also determined that the model melts water too early in the spring season. The reason for this has been traced to a bias in the model's handling of the amount of sunshine reflected by snow-covered surfaces. We are working to correct this bias, and anticipate producing a much more realistic simulation of the current and future behavior of the Sierra snowpack. The improved model and the accompanying observational snow data sets we've developed will be invaluable resources for prediction and understanding of water resources in California.

Publications

Kapnick S, Hall A (2009) Observed climate-snowpack relationships in California and their implications for the future. Accepted to Journal of Climate.

Kapnick S, Hall A (2009) Observed Changes in the Sierra Nevada Snowpack: Potential Causes and Concerns. Submitted for publication in the 2009 Climate Action Team Report to the Governor and Legislature.

Kim, J, Fovell, R, Hall, A, Kapnick, S, Li, Q, Liou, K N, McWilliams, J, Qu, X, Xue, Y, Chao, Y, Eldering, A, Friedl, R, Waliser, D (2009) A Projection of the Cold Season Hydroclimate in California in Mid-Twenty-First Century Under the SRES-A1B Emission Scenario. Submitted for publication in the 2009 Climate Action Team Report to the Governor and Legislature.

Professional Presentations

Waliser, Duane, Hughes, Mimi, and Kapnick, Sarah, Anthropogenic Climate Changes in California: Hydroclimate, Snowpack, and Santa Ana Winds, California Climate Change Conference, Sacramento, CA, September 2008.

Kapnick, Sarah, Observed Climate-Snowpack Relationships in California and Their Implications for the Future (poster), Sacramento, CA, September 2008.

Collaborative Efforts

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