Merging Regional Climate Models and Remote Sensing Datasets to Estimate Mountain Snow Water Equivalent: Proof-of-Concept in the Tuolumne Watershed

MICHAEL T. DURAND[1,2], MELISSA L. WRZESIEN[3], JESSICA LUNDQUIST[4], LAURA HINKELMAN[5], KARL RITTGER[6], JEFF DOZIER[7], TAMLIN M. PAVELSKY[3], SARAH B. KAPNICK[8], AND KRISTEN RASMUSSEN[9]

ABSTRACT

Large-scale high-resolution estimation of snow water equivalent (SWE) in mountainous areas is challenging. Two approaches currently deployable at continental scale are SWE reconstruction and regional climate model (RCM) simulation. Here, we present a method that produces a simultaneous estimate of daily mass and energy balances at 500 m resolution, including SWE timeseries, informed by RCMs and constrained by observations in a way similar to SWE reconstruction. We formulate this as a constrained optimization problem; we seek to minimize the difference between our estimates and observed MODIS snow-covered fraction (SCF) and CERES irradiance, as well as RCM SWE from 3-km Weather Research and Forecasting (WRF) model simulations, subject to mass and energy balances constraints. This problem is readily solved using off-the shelf software. We compute Tuolumne watershed SWE (where it flows into the Hetch Hetchy reservoir: 775 km^2 or 3,612 MODIS pixels) in the Sierra Nevada, USA for water year 2009, a year with average snow accumulation. We validate against snow pillows and snow course data. We find that the SCF and irradiance observations constrain the WRF estimates significantly, with final RMSE of 66 mm and 98 mm at two snow pillows within the watershed, about 15% of peak SWE. Across the watershed, the total SWE volume estimated by our algorithm (0.34 km^3) compared well to high-resolution (90 m) SWE reconstruction (0.38 km^3), while WRF alone was too high (0.45 km^3). Our method represents a compromise, leveraging the beneficial qualities of both RCMs and reconstruction, and producing a simultaneous estimate of mass and energy fluxes and storages applicable to mountain regions.

[1] School of Earth Sciences, The Ohio State University, Columbus, OH, USA
[2] Byrd Polar and Climate Research Center, The Ohio State University, Columbus, OH, USA
[3] Department of Geological Sciences, University of North Carolina, Chapel Hill, NC, USA
[4] Department of Civil and Environmental Engineering, University of Washington, Seattle, WA, USA
[5] Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, Seattle, WA, USA
[6] Institute of Arctic and Alpine Research, University of Colorado, Boulder, CO, USA
[7] Bren School of Environmental Science and Management, University of California, Santa Barbara, CA, USA
[8] Geophysical Fluid Dynamics Laboratory, National Oceanic and Atmospheric Administration, Princeton, NJ, USA
[9] Department of Atmospheric Science, Colorado State University, Fort Collins, CO, USA