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Assessing Precipitation, Snowpack and Runoff over Colorado's Headwater Bas using a High Resolution Coupled Atmosphere-Hydrology Model

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The headwaters region of Colorado that includes, among others, the Colorado, Platte, Rio Grande and Arkansas Rivers, is one of the key source regions for water in the Southwest as ~85% of the streamflow for the Colorado River comes from snowmelt in this region. This region also is a particularly difficult area for global climate models to properly handle, with inconsistent snowpack trends in this region from different models despite consistent predictions of temperature increases in this region from all climate models from both the 3rd and 4th IPCC reports (2001, 2007). A recent analysis of the 2007 IPCC 4th Assessment global models by Hoerling and Eischeid (2006,Southwest Hydrology) indicates that the combination of increased temperature and weak to no trends in snowfall will produce unprecedented drought conditions over the next 50 years in the Southwest due to a strong increase in evapotranspiration associated with the increased temperature.
While the above predictions based on global models indicate dire consequences for the Southwest, it should also be noted that the AR4 indicates that global models typically perform poorly in mountainous regions due to the poor depiction of terrain as well as significant uncertainty in detailed hydrometeorological processes (i.e. cloud/precipitation microphysics, embedded convection and cloud-scale circulations, snowpack and snow ablation, and runoff generation in complex terrain) that currently limit model simulation skill. Colorado's headwaters region is dominated by high altitude snow melt, so climate assessments in this region using global models are particularly uncertain. However, simple increases in model resolution without clearer understanding and representation of hydroclimatic processes controlling water resources will not be sufficient for improving model performance. It is therefore critical to examine climate impacts in this region using detailed coupled atmosphere-hydrology models in order to more realistically simulate precipitation, sublimation, and runoff processes, as well as their impact on managed water systems.

This paper will present preliminary results of a series of a high-resolution atmosphere model simulations using the Weather Research and Forecast (WRF) model coupled to a physically-based distributed hydrologic model. The 'end-to-end' modeling system will be evaluated using historical observations as well as ongoing field data collection efforts. Model sensitivity tests under current climate conditions will be presented as a prelude to research aimed at defining the impact of future climate conditions on Rocky Mountain snowfall processes. A second emphasis of this research is placed on proper simulation of snowmelt and runoff. The land modeling component of these high-resolution WRF simulations includes a modeling scheme that explicitly simulates the horizontal redistribution of surface runoff and shallow groundwater across sloping terrain, channel and reservoir routing processes and the impact of incoming shortwave insolation and terrain shading on sloping surfaces. Preliminary results from cool and melt season snowpack and snow ablation periods will be presented.