Evaluation of the Newly Coupled WRF3-CLM3.5 with CCSM3 Forcing

Yan Bao¹, Zachary M. Subin¹, Jiming Jin², Norman L. Miller¹

¹University of California, Berkeley, CA, 94720-4740 USA
²Utah State University, Logan, UTAH, 84322-5210 USA

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For a number of years we have been advancing regional climate and land surface-land use change modeling to account for a number of processes, including plant functional types, nutrient cycling, groundwater interactions, lateral subsurface transport, and advanced snow accretion/depletion processes (e.g. Jin and Miller 2005; Jin et al. 2007; Kueppers et al. 2008). Here we have coupled and tested version 3 of the Weather Research and Forecasting (WRFV3) with version 3.5 of the Community Land Model (CLM3.5), and our coupled code, WRF3-CLM3.5, is forced with input provided by Community Climate System Model version 3 (hereafter WRF3-CLM3.5/CCSM3). This newly coupled code is one of the three regional climate models (RCMs) that are part of the California 2010 Assessment Report. At present, we are completing a series of integrations for 1985-1995 and for projected 21st century time-slice scenarios at 30-km resolution for the western U.S. and nested 10-km resolution for CA (Fig. 1). This recent effort required new WRF Preprocessing System (WPS) code development and improvements to the CLM3.5 data structures in order to properly link CCSM3 with WRF3-CLM3.5.

This work follows on the RCM enhancement and baseline intercomaprisom project, where each model was forced by reanalysis and evaluated against observations and to each other (Miller et al. 2009). Results indicated that the WRF-CLM3 code performed well. In the present study with WRF3-CLM3.5, our simulations provide quantification of the propagation of large-scale model biases, resulting an amplification of moisture and temperature overestimates. This is as much and in some cases more of a limiting factor in regional climate simulation than the regional models. To quantify the impact of CCSM3, we have calculated and compared the temperature, precipitation, and moisture flux on WRF3-CLM3.5, and have evaluated moisture flux along the 30km eastern nudge boundary.

A multi-year set of WRF3-CLM3.5/CCSM3 model simulations, evaluations, and initial results for the historical period are presented. Model results are compared to the Parameter-elevation Regressions on Independent Slopes Model (PRISM) and the North American Regional Reanalysis (NARR). The resulting land surface climate
output from WRF3-CLM3.5/CCSM3 is a focus of the results discussed here.

WRF3-CLM3.5/CCSM3 reproduces the spatial distribution of precipitation reasonably well for most of the A and B domains. However, it is seen that large-scale biases generated within CCSM3 propagate through the downscaled system, resulting in an overestimate of seasonal (November to March) rainfall in parts of northern CA and to some extent an underestimate along the southern coastal regions (Fig. 2). In general, WRF3-CLM3.5/CCSM3 produces a relatively significant warm bias in 5-year mean daily maximum and minimum near-surface air temperature. Figure 3 shows the daily maximum air temperature (minimum near-surface air temperature not shown here). A warm bias in the eastern Pacific sea surface temperature (SST) fields within CCSM3 explains part of this bias. It is also seen that WRF3-CLM3.5/CCSM3 results in an underestimate of snow equivalent water, which is likely due to the feedback of warm surface temperature.

To quantify these findings further, we have created three CCSM3 sub-regions that are within the western domain of the 30-km nudging area and compared the area average 700 hPa and 850 hPa moisture flux (Uq) advected into domain A. Figure 4 shows Uq timeseries for each CCSM3 sub-region and the WRF3-CLM3.5 overlap.

The boxed regions in the time series in Fig. 4a indicate that the Uq values are overpredicted within CCSM3 by 12 to 86 percent, and result in a similar overprediction within WRF3-CLM3.5 by 12 to 88 percent in different levels and regions.

As we complete the full set of dynamically downscaled climate projections for CA the moisture flux and SST biases will be incorporated into our final analysis. The three RCM simulations will in turn become the ensemble that is used for a number of impacts studies on CA sectors.

Figure 1. Model domains used in this study. A. Western United States and Eastern Pacific Oceans, 30km resolution; B. California, Nevada, Eastern Pacific Ocean, 10km resolution.
Figure 2 Cumulative November-March rainfall, climatological mean for PRISM (left top), WRF3-CLM3.5 (right top), NARR (left bottom), and the difference between WRF3-CLM3.5 and PRISM (right bottom) (units: mm).
Figure 3 Climatological seasonal mean of daily maximum 2m air surface temperature during December –February, and difference with PRISM (Unit: K), as in Fig. 2.
Figure 4 Moisture flux propagating in different regions. (a) Different research regions. D1: 40°-50°N, 120°-140°W; D2: 30°-40°N, 120°-140°W; D3: 20°-30°N, 120°-140°W; D4: 32.5°-42.5°N, 112.5°-120°W, the color map is terrain height of domain D01 and d02 is the id in mother domain and nesting domain (b) Moisture flux in D1, D2, D3, here output of WRF3-CLM3.5 with 30 km resolution are used (Unit: g.Kg^{-1}.m.s^{-1}) (c) Moisture flux in D4 domain, here output of WRF3-CLM3.5 with 10 km resolution are used (Unit: g.Kg^{-1}.m.s^{-1}).

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References:


