Data Adoption Justification Memo (for California's Fifth Climate Change Assessment): Dynamically Downscaled Datasets

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Methods and Prior Relevant Work

Projections from 9 Global Climate Models (GCMs) were transformed to high-resolution via a process called dynamical downscaling (DD), which calculates the high-resolution weather and climate based on the physics of the atmosphere and the original GCM data. This process was developed in the late 1980s but requires enormous computational power. That is why, until now, DD has not been used in California Climate Change Assessments. Computational limitations still prevent the DD team from applying the method to dozens more GCMs. Specifically, we embedded a Regional Climate Model (RCM), called the Weather Research and Forecasting (WRF) model (Skamarock et al. 2019), within GCMs across the California region to focus its computer power in a way that allowed for high-resolution topography (3-km grid length, and 40 vertical levels), coastlines, and small-scale features in the overlying weather and climate to be resolved. GCMs were dynamically downscaled to 45 km, then to 9 km, and then 3km (Figs 1,2), so each of the models that have a 3-km domain also has a 45-km and 9-km domain. All downscaled simulations use the third Shared Socioeconomic Pathway (SSP3), covering the 1980-2100 time period.

The 9 DD simulations were broken into two groups; an initial 4 simulations, and a second set of 4 simulations. The development of the 4 non-bias corrected GCM simulations (the "original" simulations) is documented in the Memo on the Development and Availability of Dynamically Downscaled Projections Using WRF, (Rahimi-Esfarjani, 2022b) and an evaluation of their performance is provided in the Memo on the Evaluation of Downscaled GCM Using WRF (Rahimi-Esfarjani, 2022a). For the second set of 4 simulations, we removed climatological biases in GCMs before DD, a process referred to as *a priori* bias correction (BC; see Pierce, et al, 2023 on bias correction and its use in EPC-20-006) and added variables such a hub-height winds to support energy sector planning. One model, EC-Earth3-Veg, was part of the original set of simulations and served as a test case for the new set of models by running a second simulation with a priori BC, however, it was before adding the additional variables. Thus 5 of the DD simulations have *a priori* BC applied, but only 4 have both *a priori* BC applied and results with new additional variables. A memorandum on the 5 bias corrected downscaled GCM simulations (the second set) is currently being developed. We also downscaled a reanalysis (ERA5) from 1980-2020 to evaluate the biases in our DD methodology for both sets of downscaled GCMs and, for the original set of simulations, the downscaled ERA5 experiment contains outputs from 1950-2021. All dynamically downscaled datasets are in an open data bucket on Amazon S3.

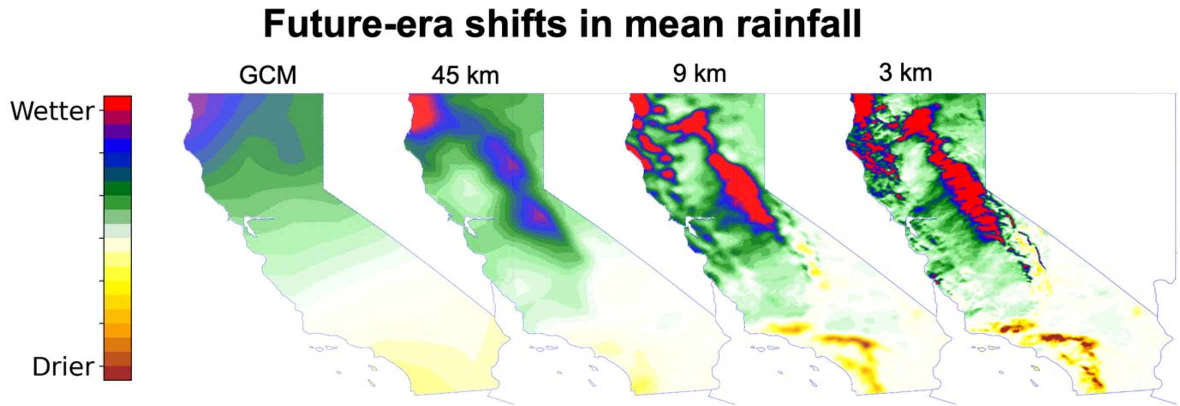

Figure 1. Differences in the climate change signal of annual precipitation across the different product grids, beginning on the left with the GCM and ending on the right with the 3-km California grid simulation.

QA/QC & Uncertainty

Krantz et al. (2021) assessed the skill of GCMs in simulating regional weather and climate phenomena and created a ranked list. Only a selection of the GCMs saved the necessary data for DD. Using this list and eliminating the GCMs that did not save the necessary data, the DD team downscaled the remaining best performing GCMs. Despite this check for GCM quality, as well as extensive testing to identify the best RCM configuration to use, unrealistically large biases in dynamically downscaled precipitation, temperature, and snow were found for our 4 GCM simulations that were not bias corrected prior to DD; these biases were not found in the downscaled ERA5 simulation. We repeated one experiment (EC-Earth3-Veg) with a BC of the mean GCM fields performed before downscaling. This simulation exhibited much smaller biases akin to those in the downscaled ERA5 simulation and mostly within the range of observational uncertainty. We also took steps to improve the realism of sea-surface temperatures in the Gulf of California, which are not resolved in GCMs.

In response to demand for new downscaled simulations containing hub-height winds and variables of relevance for photovoltaic (PV) power generation, we dynamically downscaled 4 additional GCMs. Given recent advances in our understanding of the effects of BC in DD (Rahimi et al., 2024; Risser et al., 2024), we decided to implement BC in these new experiments (memo in preparation). As with the prior EC-Earth3-Veg experiment, the downscaled solutions for these experiments' historical-era climates were substantially more realistic compared to the original four experiments.

Guidance or Caveats on Best Practices for Use of Data Products

For each downscaled simulation, we provide the full 6-hourly RCM datastream and hourly datastream for select variables. Further, we postprocessed a daily datastream for 42 land and atmospheric variables; these variables are either daily means, minima, or maxima. All data is described here. Only the newest-four simulations with BC contain the wind- and PV-relevant variables in their hourly datastreams. Given the large dynamically downscaled precipitation, snow, and temperature biases in the original four GCMs (without BC), these data may be less suitable for impacts studies compared to the simulations performed with *a priori* BC. Based on this we recommend only using the *a priori* bias corrected DD models unless implications of biases have been carefully considered and factored into analyses and results.

Additionally, the hourly datastreams were tailored to provide the requisite data to drive land-surface and hydrology models, perform demand forecasting, and ascertain flash flooding risk. The daily postprocessed datastream, however, is tailored to be lightweight and enable community usability.

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