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A next-generation tool for bias-correcting RCM inputs to enhance regional climate projections

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Abstract: Accurate regional climate projections require realistic large-scale boundary conditions from Global Climate Models (GCMs). However, GCMs often exhibit systematic biases that propagate into Regional Climate Models (RCMs), degrading the skill of downscaled simulations. While post-processing bias correction is commonly applied to RCM outputs, this can compromise dynamical consistency and limit the physical realism of projections. Pre-downscaling bias correction—applied directly to RCM inputs—offers a physically coherent alternative, improving RCM performance while preserving internal dynamics.

We present Sub-Daily Multivariate Bias Correction version 2 **(**SDMBCv2), an open-source Python package designed for sub-daily, multivariate bias correction of full atmospheric fields and sea surface temperature for both historical and future simulations. Building on the original SDMBC framework, SDMBCv2 introduces a Python-based workflow with high-performance computing support via Dask, flexible horizontal/vertical interpolation, compatibility with diverse GCM formats, and integration of multiple bias correction approaches across temporal scales (sub-daily to seasonal). The system corrects mean, standard deviation, lag-1 autocorrelation, and lag-0 cross-correlation, using a nested, quantile-mapping approach to preserve inter-variable dependencies while improving temporal persistence.

We evaluated SDMBCv2 using ACCESS-ESM1.5 as the driving GCM and ERA5 as the reference. Performance was assessed for wind speed, air temperature, specific humidity, and SST using mean absolute error (MAE), bias, and Kolmogorov–Smirnov (K–S) tests. Across calibration and validation periods, SDMBCv2 consistently reduced mean biases, improved variability representation, and corrected persistence and inter-variable coupling. The results demonstrate that SDMBCv2 not only improves univariate statistics but also restores multivariate physical relationships critical for realistic climate simulations. This capability is particularly relevant for reproducing extreme events, compound hazards, and diurnal cycles in RCMs.

By addressing a key gap in the dynamical downscaling chain—biases in RCM inputs—SDMBCv2 supports more credible regional climate projections for impact assessments, infrastructure planning, and climate adaptation strategies.

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