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Assessment of climate change over Singapore based on a multi-site multivariate downscaling approach

Xin Li and Vladan Babovic
National University of Singapore, Singapore (xinli@u.nus.edu)

Climate scenarios for multiple climate variables at multiple locations are often desired to investigate the distributed impact of climate change. One of the challenges that remain in climate downscaling community is to realistically preserve the inter-site, inter-variable dependencies as well as the temporal structure of the observed climate field in the downscaled climate simulations and projections. To tackle this problem, this study proposes an integrated multi-site multivariate downscaling framework—combining quantile mapping (QM), stochastic weather generator (WG) and Empirical Copula (EC) approaches—to downscale global climate model outputs from monthly, grid-scale to daily, station-specific scale. In this integrated scheme, the QM method is used to spatially downscale the monthly large-scale climate model outputs; then the WG approach is used to temporally downscale the monthly data to daily data by perturbing the WG parameters according to the predicted changes from large-scale climate models; at last, the observed inter-site, inter-variable dependencies as well as the temporal structure are restored based on the EC approach. The proposed methodology is used to downscale monthly precipitation, maximum and minimum temperature from nine general circulation models (GCMs) under two Representative Concentration Pathways (RCPs) 4.5 and 8.5 scenarios to daily series at four weather stations in Singapore for the future periods of 2021-2050 and 2071-2100. The climate change impact over the Singapore region is assessed by comparing the climatology of the three meteorological variables in the future periods to that of the baseline period (1985-2014). As expected, the observed inter-site, inter-variable dependencies as well as the temporal structure are successfully reconstructed using the proposed approach. Based on the downscaling results, mean annual precipitation, maximum and minimum temperatures are projected to change by -20.0-24.6%, 0.5-6.1 °C, and 0.3-5.7 °C, respectively, across the GCMs, RCPs, and stations in the future periods. Seasonal total precipitation during the northeast monsoon (November till February) and southwest monsoon (June till September) seasons is projected to change by -32.3-43.2% and -29.7-47.4%, respectively. These findings could help to develop adaption strategies for Singapore in the context of climate change.