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A weighting scheme to incorporate large ensembles in multi-model ensemble projections

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Multi-model ensembles can be used to estimate uncertainty in projections of regional climate, but this uncertainty often depends on the constituents of the ensemble. The dependence of uncertainty on ensemble composition is clear when single model initial condition large ensembles (SMILEs) are included within a multi-model ensemble. SMILEs introduce new information into a multi-model ensemble by representing region-scale internal variability, but also introduce redundant information, by virtue of a single model being represented by 50–100 outcomes. To preserve the contribution of internal variability and ensure redundancy does not overwhelm uncertainty estimates, a weighting approach is used to incorporate 50-members of the Community Earth System Model (CESM1.2.2), 50-members of the Canadian Earth System Model (CanESM2), and 100-members of the MPI Grand Ensemble (MPI-GE) into an 88-member Coupled Model Intercomparison Project Phase 5 (CMIP5) multi-model ensemble. The weight assigned to each multi-model ensemble member is based on the member's ability to reproduce observed climate (performance) and scaled by a measure of historical redundancy (dependence). Surface air temperature (SAT) and sea level pressure (SLP) diagnostics are used to determine the weights, and relationships between present and future diagnostic behavior are discussed. A new diagnostic, estimated forced trend, is proposed to replace a diagnostic with no clear emergent relationship, 50-year regional SAT trend.

The influence of the weighting is assessed in estimates of Northern European winter and Mediterranean summer end-of-century warming in the CMIP5 and combined SMILE-CMIP5 multi-model ensembles. The weighting is shown to recover uncertainty obscured by SMILE redundancy, notably in Mediterranean summer. For each SMILE, the independence weight of each ensemble member as a function of the number of SMILE members included in the CMIP5 ensemble is assessed. The independence weight increases linearly with added members with a slope that depends on SMILE, region, and season. Finally, it is shown that the weighting method can be used to guide SMILE member selection if a subsetted ensemble with one member per model is sought. The weight a SMILE receives within a subsetted ensemble depends on which member is used to represent it, reinforcing the advantage of weighting and incorporating all initial condition ensemble members in multi-model ensembles.