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Quantifying the effect of model development in climate predictions

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Climate data from the Coupled Model Intercomparison Project (CMIP) is widely used in various scientific studies. CMIP has evolved through several phases (CMIP5 being the latest), both in order to better serve the data users and to remain representative of the state of scientific understanding being embedded to existing global climate models. Improving the scientific process understanding in these climate models has, however, ambiguous effects to the projections of future climate change. Are the improved climate model projections always superior compared to the older ones?

We analyze temperature, precipitation and mean sea level pressure from those idealized climate simulations where global CO_2 concentration is increased 1 % annually, from 13 climate models that have each participated to CMIP2, CMIP3 and CMIP5. Using this multi-ensemble sample with identical climate forcing in all of the simulations, we are able to quantify the effect which model development has to the climate model projections in a multi-model framework.

We apply analysis of variance (ANOVA) method to our data and divide the total uncertainty in future climate predictions into three components of: characteristic model-specific differences, systematic part of climate model development shared by all models in the ensemble and unsystematic part of it. The unsystematic model development component is the largest over most of the world, while the systematic part is the smallest. This indicates that (i) the selection of the version of a particular model has a larger impact on climate projections than the choice of the basic model, while (ii) the systematic changes from one model generation to another have the smallest impact. The latter indicates that deterministic multi-model-mean estimates have improved very little due to model development. Only regionally, near the sea ice borderline for temperature and additionally over the mid-latitudes for mean sea level pressure, the part of model development shared by all of the models is significantly larger that would had been achieved using random data. Model-specific differences are the most important uncertainty source over several land regions for temperature, while these regions are located over sea for mean sea level pressure. For precipitation, each of the patterns is very noisy and any obvious improvement in climate model projections is hard to assess.

Multi-model-mean estimates of future climate change have little room for improvement, as the effects of model development on climate projections are mostly unsystematic. Process-based assessment of the disagreement between different climate models could have more potential in improving temperature predictions as compared to individual development of each climate model. We argue that most of the practically achievable information on large-scale climate change is already available. However, on a smaller scale potential for improvement can be larger.