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Demystifying model uncertainty and internal variability in climate change projections over the 21st century

Martin Gomez-Garcia[1] and Alexander Pui[2]
[1]Nippon Koei R&D Center, Climate Change and Sustainable Development Team, Tsukuba, Japan (gomez-mr@n-koei.jp)
[2]University of New South Wales, Climate Change Research Center (Alexander.Pui@marsh.com)

Overall uncertainty in climate model projections is composed of scenario, model, and internal variability components. While scenario uncertainty is expressed by considering different climate scenarios, model uncertainty and internal variability components are largely ignored by climate information service providers. Instead, model projections are often expressed through the ensemble mean, which may lead to both overly optimistic assessments of risk, or on the other hand misinformed maladaptation strategies.

Here, we propose a new uncertainty quantification approach that better informs end users of climate projections, showing that the multi-model internal variability, owing to its chaotic nature, is in fact virtually irreducible, and that model uncertainty grows moderately throughout the 21st century. For three future scenarios, we quantified the global internal variability of two metrics: annual precipitation (PRCP) and boreal summer average maximum daily temperature (TXJJA), by employing a single realization of each CMIP6 climate model. Our results showed that observed internal variability of the 1981-2010 period for the TXJJA metric has a negligible variation throughout the 21st century for all three scenarios. For the PRCP metric, small changes of internal variability were detected towards the end of the 21st century in the most adverse scenario (SSP3-7.0). Importantly, we observed that characterizing uncertainty in such manner produced a nuanced, and non-misleading results compared to that of the ensemble mean approach. Furthermore, the proposed uncertainty quantification approach can be expanded to similarly evaluate the uncertainty in indices of extreme weather.