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Capturing uncertainty from internal variability in climate attribution within single realisations

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Attribution of regional climate change to anthropogenic forcing within the single realisation available from observations is an important but challenging goal for statistical methods in climate science. The correlation of regional conditions with global temperatures is a popular approach, especially in the context of attribution of impacts on downstream sectors such as health or economic outcomes. However, the influence of internal variability on this approach remains unquantified.

Here, we use large ensembles from three climate models as an idealised setting to quantify the role of internal variability for attribution of temperature and precipitation extremes. For temperature extremes, internal variability contributes uncertainties which exceed 50% of the climate change signal across at least 35, 25, and 5% of the global surface area in the MIROC6, MPI-ESM1-2-LR and CanESM5 models respectively. We demonstrate that a block-bootstrapping procedure applied to individual ensemble members can accurately capture the different levels and patterns of uncertainty observed within each large ensemble - opening the door to a robust application to the single realisation available in observations. For precipitation extremes, relative uncertainties are substantially larger - exceeding 100% of the climate change signal over 85, 70 and 50% of the global surface area. Moreover, applying block-bootstrapping to individual realisations does not accurately reproduce these uncertainties, indicating limits to this attribution approach for precipitation extremes at current levels of global warming. Spatial aggregation of precipitation extremes to scales of 5-10 degrees reduces uncertainties and improves the performance of the bootstrap, but does not do so entirely.

This work provides a basis for climate impact attribution from single climate realisations which can robustly capture the uncertainty driven by internal climate variability.