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Irreducible uncertainty in near-term climate projections

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If the Paris agreement at the Conference of Parties 21 (COP21) is implemented very effectively, we might witness falling greenhouse-gas emissions from around year 2020 onward, perhaps according to the scenario RCP2.6. It is unclear whether such emissions reductions would lead to identifiable near-term climate responses in "iconic" quantities of wide scientific and public interest, due to the contamination of the forced climate response by internal variability. Here I provide a new perspective on the resulting irreducible uncertainty in near-term climate projections, by analysing very large (100-member) ensembles of the state-of-the-art climate model MPI-ESM-LR with the help of a formal theory of event causation that was developed in epidemiology [1] and recently introduced into climate science [2].

I concern myself with the technical question of whether decadal-timescale climate events can be attributed to the policy change implied by the changeover from scenario RCP4.5 (interpreted in the near term as a no-mitigation scenario) to scenario RCP2.6 (mitigation scenario, implementing the Paris agreement). I restrict myself to the simple event definition asking whether a linear climate trend, for example in global-mean surface temperature (GMST), over the period 2021–2035 is smaller than the linear trend over the period 2006–2020. Thus I compare the fifteen-year periods after and before the maximum in emissions. For quantities for which we expect a declining forced trend in a warming climate, I ask whether the trend over the period 2021–2035 is larger than the trend over the period 2006–2020.

Trends in GMST are larger over the period 2021–2035 than over 2006–2020 in one-third of all realisations in the mitigation scenario RCP2.6, compared to around one-half in the no-mitigation scenario RCP4.5. *More likely than not*, mitigation is neither necessary nor sufficient to achieve a GMST trend reduction in the comparison of these two periods – instead, whether a trend reduction occurs depends largely on the specific realisation of internal variability. For a trend reversal in the Atlantic Meridional Overturning Circulation over these periods, mitigation is even *very unlikely* to be either necessary or sufficient. By contrast, mitigation is *more likely than not* necessary to effect a decrease in upper-ocean heat content change. Viewed retrospectively from year 2035, a climate response to a successful Paris agreement might thus be identifiable, but only in select few quantities.

[1] Pearl, J. *Causality: models, reasoning, and inference.* (Cambridge University Press, 2000).
[2] Hannart, A., Pearl, J., Otto, F. E. L., Naveau, P. & Ghil, M. Causal counterfactual theory for the attribution of weather and climate-related events. *Bull. Amer. Meteor. Soc.* **97**, 99-110 (2016).