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An observational constraint on the uncertainty in stratospheric water vapour projections

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Future increases in stratospheric water vapour (SWV) risk amplifying climate change and slowing down the recovery of the ozone layer. However, state-of-the-art climate models strongly disagree on the magnitude of these increases under global warming[1,2]. Uncertainty primarily arises from the challenges inherent in modelling the many complex processes leading to dehydration of air during its tropical ascent into the stratosphere[3]. Here we derive an observational constraint on this longstanding uncertainty factor in Earth's climate change response. Following a statistical learning approach[4,5], we infer historical co-variations between the UTLS temperature structure and tropical lower SWV concentrations. For climate models, we demonstrate that these historically constrained relationships are also highly predictive of the SWV response under strong 4xCO_2 forcing. By extension, we obtain an observationally constrained range for concentration changes per degree of global warming of 0.31±0.39 ppmv K^{-1} (90% confidence interval). Our constraint represents a 50% decrease in the 95th percentile of the climate model uncertainty distribution, which has major implications for surface warming, ozone recovery, and the tropospheric circulation response under climate change.

Across 61 climate models from the 5th and 6th phases of the Coupled Model Intercomparison Project (CMIP), we therefore find that a large fraction of future model projections is inconsistent with observational evidence. In particular, frequently projected strong increases (>1 ppmv K^{-1}) are highly unlikely. We further demonstrate that our constraint on tropical lower SWV can be translated into also reduced uncertainty in the radiative SWV feedback (by 0.05 W m^{-2} K^{-1}). This uncertainty reduction is comparable in size to the overall feedback responses in biogenic volatile

organic compounds (BVOCs) or ozone[6], and is thus of great relevance for policymakers.

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