Determining Stratospheric Water Vapour Variability in Global Climate Models

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Water vapour is a key greenhouse gas and its concentrations entering the stratosphere are strongly influenced by cold temperatures at the tropical tropopause where dehydration is strongest. While the drivers of the annual cycle in tropical stratospheric water vapour are fairly well understood, the processes that determine variations on interannual and longer timescales are subjects of ongoing investigation. The extensive variety of model climatologies and predictions for the tropical tropopause implies large uncertainty, which hinders confidence in trends of stratopsheric water vapour. Additionally, many models do not exhibit variability of comparable strength to observations since the 1990s.

Variability of lower stratospheric air parcels is naturally associated with their Lagrangian history. Therefore, we use offline kinematic trajectory calculations to analyse the Lagrangian Dry Point characteristics of air parcels entering the stratosphere in a non-hydrostatic global climate model. Trajectories are calculated from 3-D winds and temperature provided at 6-hour intervals from HadGEM3-UKCA for multi-year integrations under 2000 and 2100 conditions.

First we compare annual cycle properties of Lagrangian Dry Point events against reanalysis. Extending findings from reanalysis data, variations in the sampled temperature field on timescales of less than one month have a significant effect on dehydration. We also show that by instead sampling a temperature field of a different time period, responses of stratospheric water vapour can be attributed to changes in transport or temperature field.

We then show that while water vapour concentrations predicted by the trajectory calculations for the 2000 and 2100 integrations are smaller than the model's Eulerian field, interannual variations correlate better than simpler temperature-based proxies, suggesting that the important contributions to interannual variability are captured by the trajectory calculation. While the differences between the 2000 and 2100 calculations are relatively small, we find no evidence that the large-scale processes represented by the trajectory calculation cannot account for the corresponding stratospheric water vapour trend.

We extend the above investigations to integrations with a wider range of climate forcing scenarios and quantify the roles of different model processes (convection, ice lofting, sublimation, etc.) in setting the water vapour concentrations entering the stratosphere. Results from this work will be reported in the presentation.

These findings are useful when considering the model representation of processes contributing to their reported water vapour trends.

Key words: water vapour; stratosphere; climate model; variability; transport