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Water vapour changes due to greenhouse gases and aerosols: A PDRMIP multi-model study

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Water vapour is a key component in the hydrological cycle, and understanding how the hydrological cycle responds to natural and anthropogenic drivers is a burning research topic. While global mean precipitation increases by 1-3%/K in a warming climate, atmospheric water vapour increases by 6-7%/K according to the Clausius-Clapeyron relation. Tropospheric water vapour is also an important feedback mechanism to increased surface temperature and thus important to understand.

This study investigates the sensitivity of water vapour and its lifetime to various drivers, namely CO_2, CH4, solar radiation, black carbon and sulphate. Results from 10 different PDRMIP (Precipitation Driver and Response Model Intercomparison Project) models have been analysed and separated into contributions occuring on fast and slow time scales. Results from CMIP5 models have been used to analyse historical and future changes in the water vapour lifetime.

Preliminary results show that the feedback (slow) response of atmospheric water vapour to changes in near-surface temperature tend to agree across the different drivers and is fairly close to the Clausius-Clapeyron relation. However, the total response vary considerably between drivers with BC showing the strongest increase in water vapour column with global mean surface temperature change (9.7%/K) and sulphate showing the weakest increase (6.4%/K). These differences can be explained by rapid adjustments (fast response), e.g., with black carbon initiating a strong heating of the atmosphere.

The water vapour lifetime is expected to increase from 8.2 days (present-day) to 9.9 days towards the end of the century (assuming RCP8.5), based on CMIP5 models, due to water vapour increasing more than precipitation in a warming climate. The water vapour lifetime sensitivity in CMIP5 models is lower for future (0.47 days/K) than historical (0.55 days/K). PDRMIP results show a strong water vapour lifetime sensitivity for BC (1.1 days/K) and indicate that a stronger impact of black carbon in the historical than the future could explain the higher water vapour lifetime sensitivity in the CMIP5 models. PDRMIP model results explain the historical change in water vapour lifetime from CMIP5 results relatively well.