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Linking the uncertainty in modelling of tropical stratospheric water vapour to simulated arctic ozone losses

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Introduction

Stratospheric water vapor plays a key role in atmospheric chemistry. It e.g influences the chemical ozone loss via controlling the PSC formation in the polar stratosphere. The amount of water entering the stratosphere through the tropical tropopause differs substantially between chemistry-climate models because the present-day models have difficulties in capturing the whole complexity of processes that control the water transport across the tropopause. As a result there are large differences in the stratospheric water vapour between the models. In this study we investigate the sensitivity of simulated Arctic ozone loss to the amount of water which enters the stratosphere through the tropical tropopause.

Model and simulations

The FinROSE–ctm (Damski et al., 2007) is a global model of the stratosphere and mesosphere. The model produces the distribution of 35 species. The chemistry describes around 110 gas phase reactions and 37 photodissociation processes. The model chemistry includes heterogeneous processing and PSC sedimentation.

Here FinROSE is driven by ECMWF meteorological fields and prescribed tropospheric abundances of the chemical species. The model was run with a horizontal resolution of 3 $\times$ 6 degrees at 40 hybrid levels, from the surface up to 0.1 hPa (ca. 65 km). Several simulations of the Arctic winters between 2010 and 2015 were performed with different water vapour concentrations at the tropical tropopause. The Interim simulation corresponds to ERA-Interim, min and max values approximately correspond to those from the driest and the wettest CCMVal-2 models, 0.6 $\times$ Interim (Min) and 1.6 $\times$ Interim (Max) (Gettelman et al. 2010). Results for the Arctic winters 2010/11, 2013/14 and 2014/15 are presented here.

Results

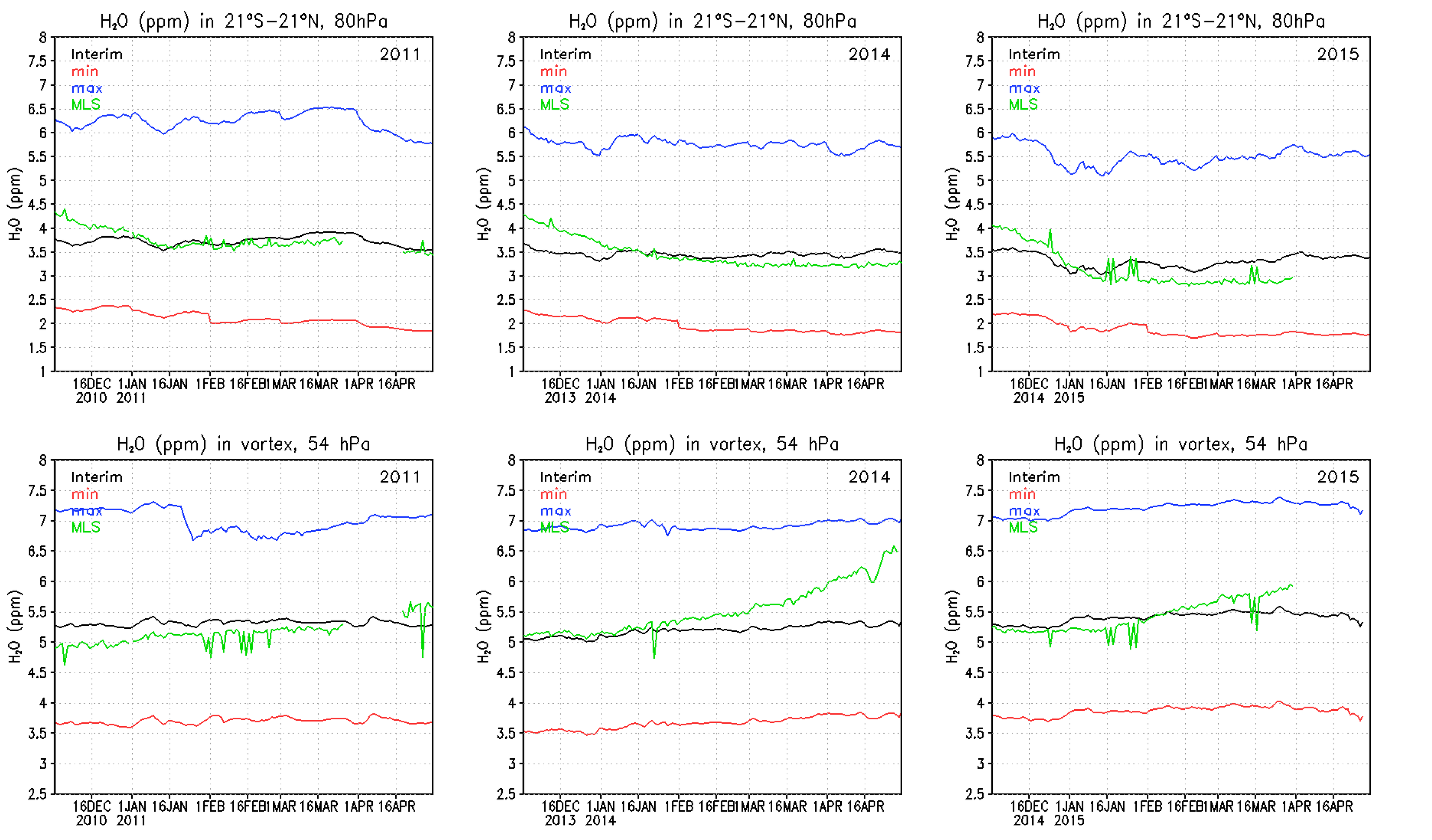

Figure 1. Upper panels: Water vapour near the tropical tropopause. Lower panels: Water vapour at 54 hPa within the Arctic polar vortex. The vortex is defined as an area where mPV > 36 PVU. The drops in the wet simulation (blue line) correspond to the formation of ICE PSCs.

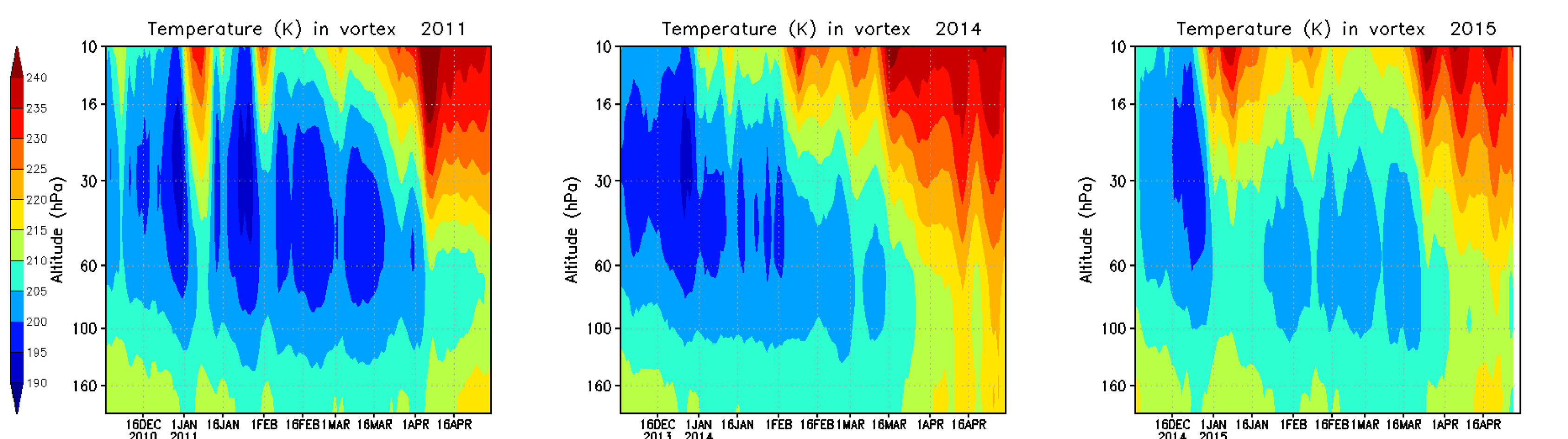

Figure 2. Average temperature in the vortex. The 2010/11 winter 2011 was included as an example of a cold vortex, and 2014/15 as a relatively warm vortex.

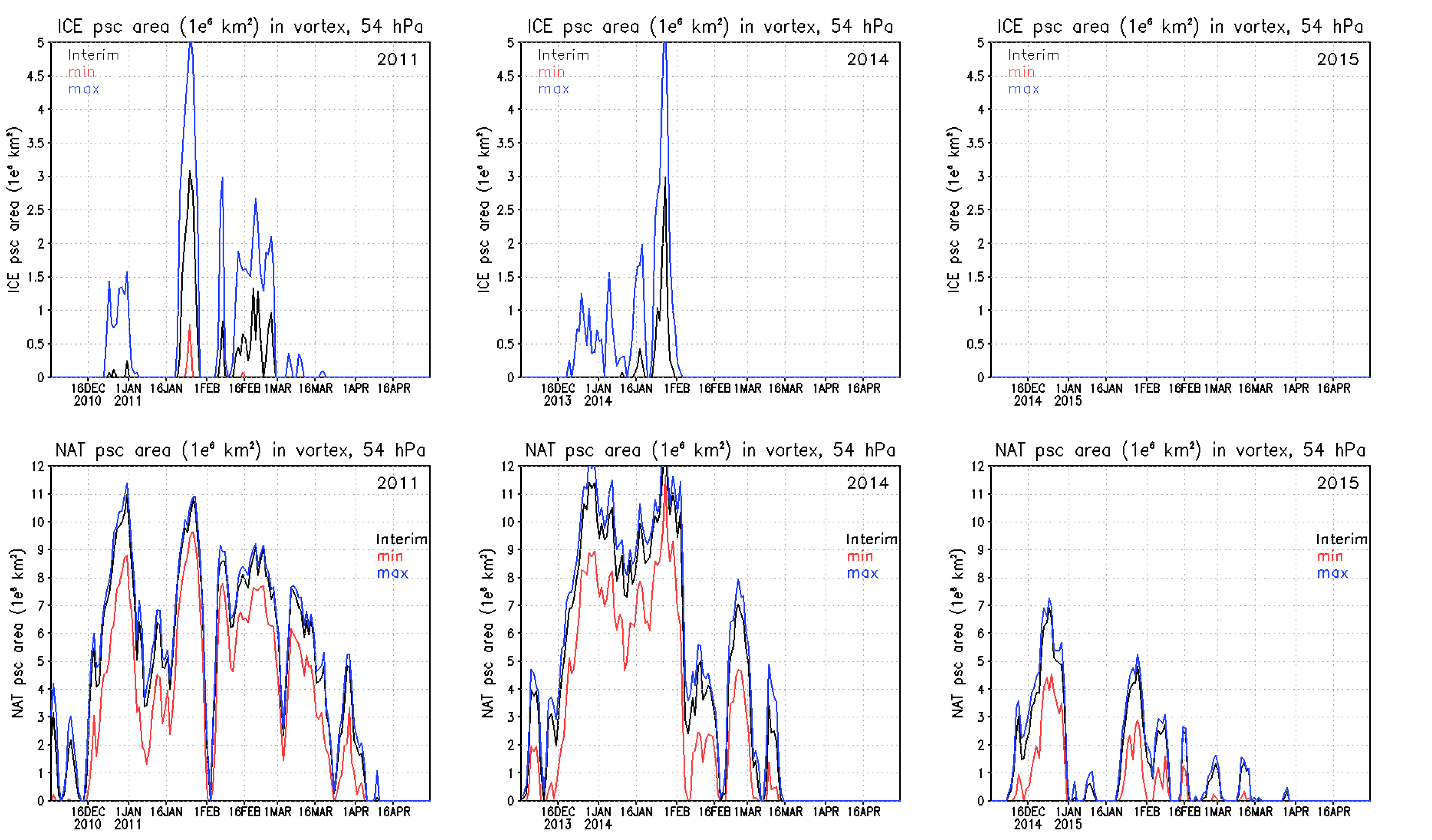

Figure 3. The area of ICE and NAT PSCs within the Arctic vortex at 54 hPa in the simulations. Upper panels: ICE PSC area. Lower panels: NAT PSC area. In 2011 only very small ICE PSC area is seen in the dry simulation despite the cold temperatures. In 2015, a relatively warm year, both NAT and ICE areas are small in all simulations.

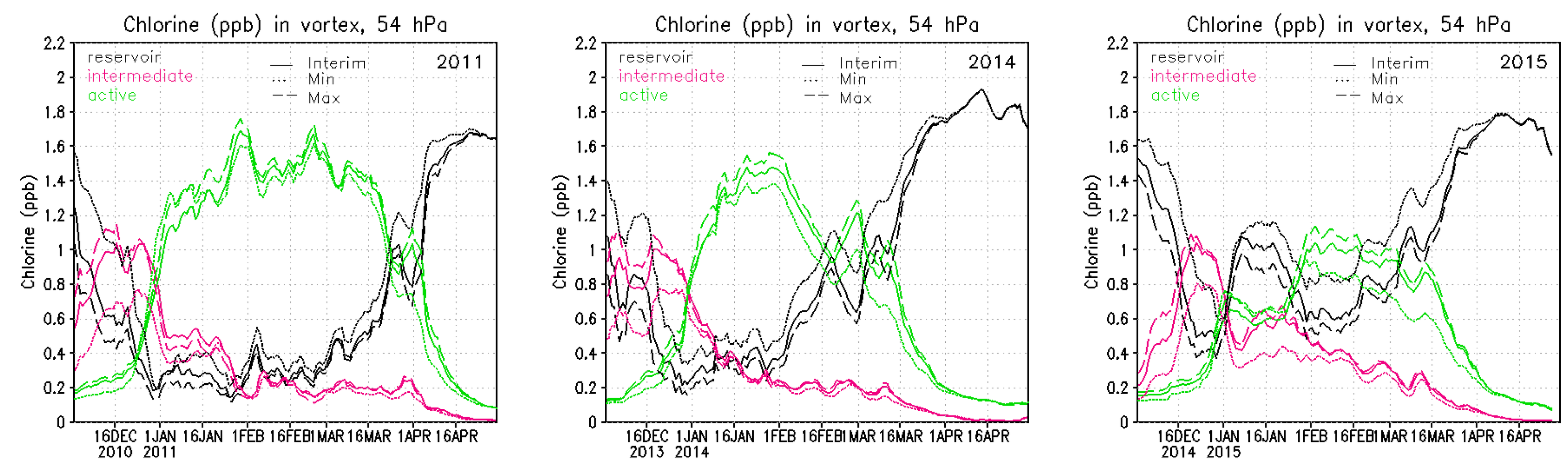

Figure 4. Chlorine species in the vortex at 54 hPa. The conversion of reservoir species and formation of ClOx correspond to the occurrence of PSCs.

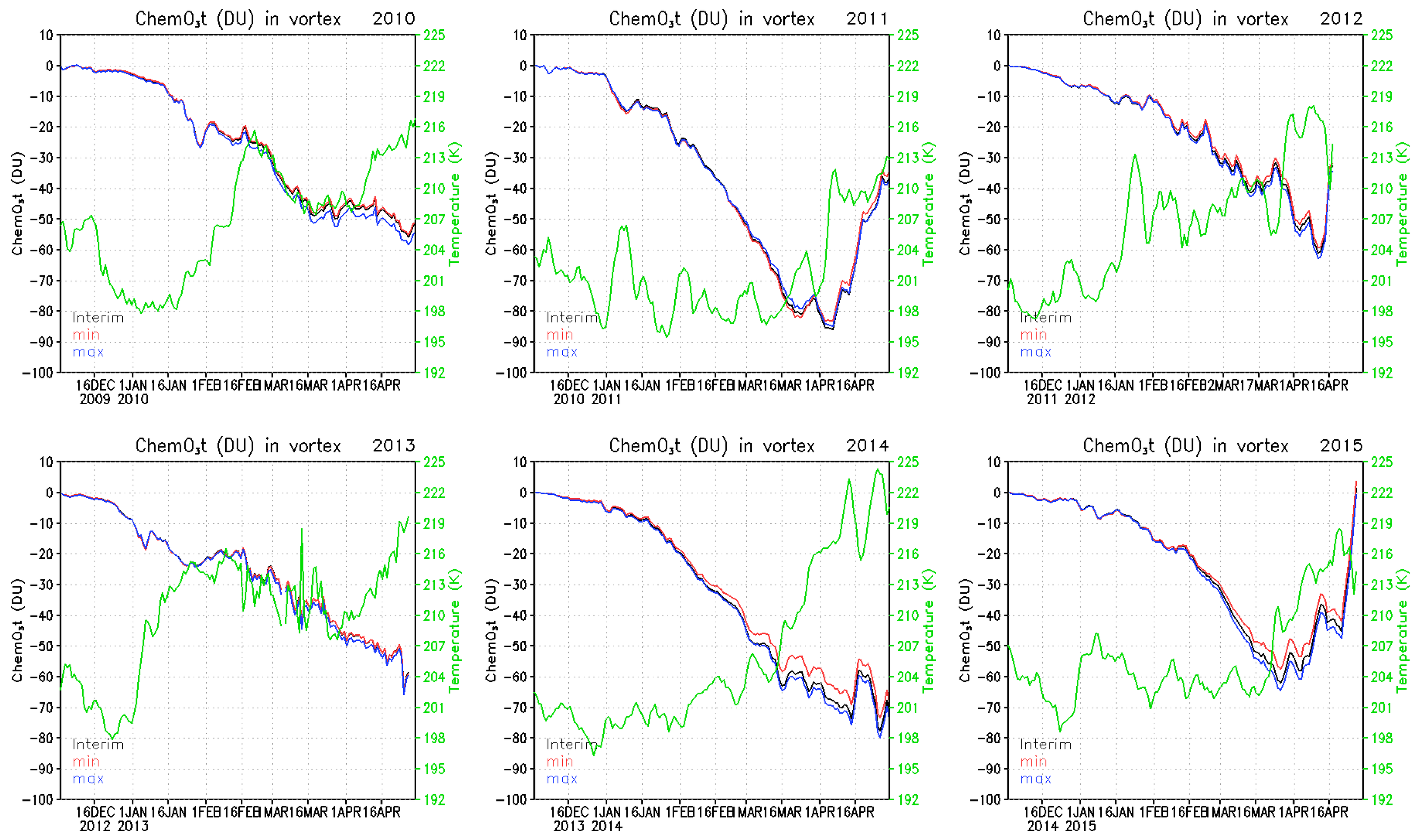

Figure 5. Chemical ozone loss (black, blue and red) and temperature (green) within the Arctic polar vortex between 2010 and 2015. The chemical ozone loss is deeper in the cold years.

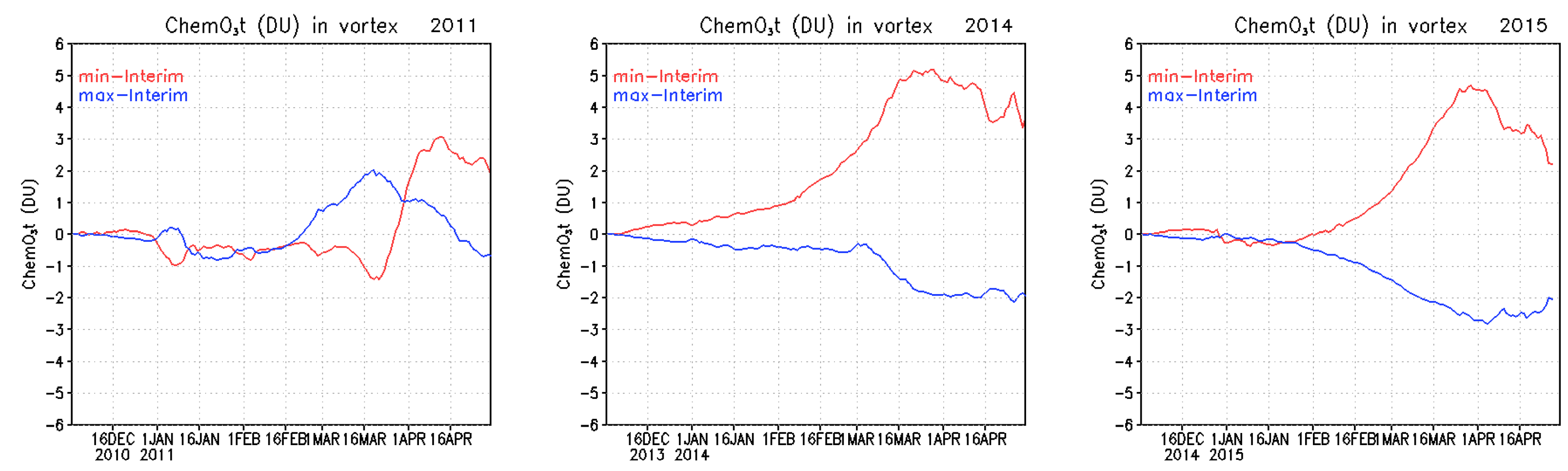

Figure 6. Difference in chemical ozone loss in the vortex due to changes in water vapor concentration. In the winter 2010/11 the differences are smaller than in other years. The amount of water vapour has a larger effect on ozone in warm years than in cold years.

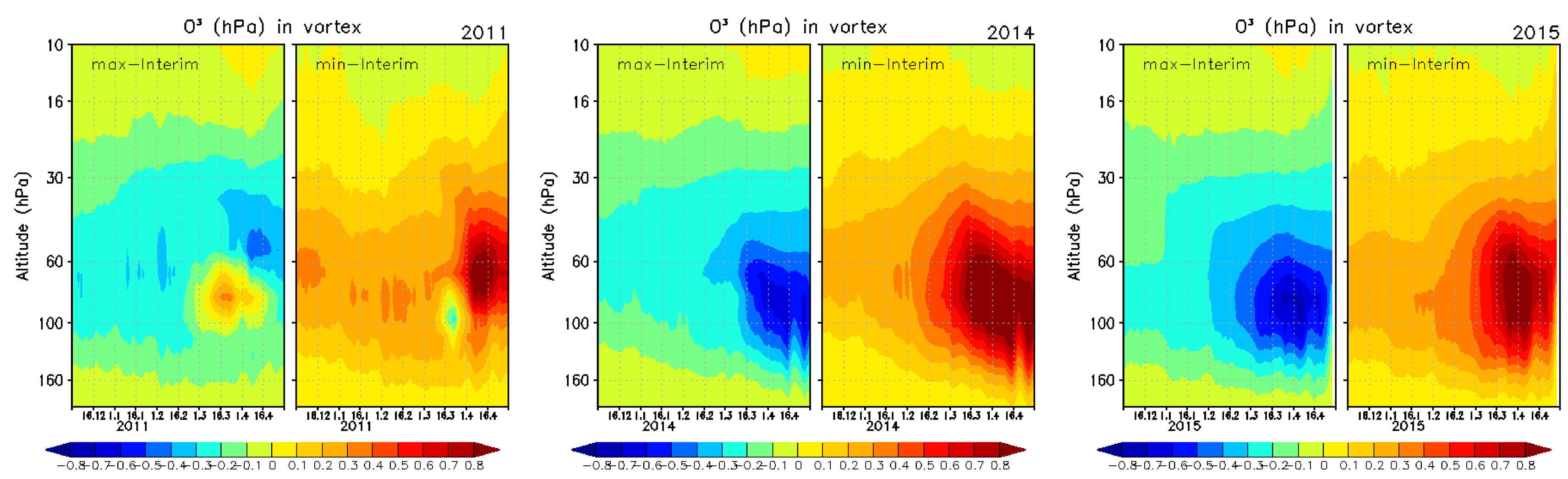

Figure 7. Ozone partial pressure difference in the vortex. The effect of the water vapour concentration is more pronounced in warm years than in cold years.

Key findings

- The simulations show differences in Arctic water vapour, PSC areas and chlorine activation, and the results indicate a sensitivity of Arctic ozone loss to tropical water vapour.
- The temperature defines the ozone loss, but during warmer years a change in water vapour concentration has a larger effect.
- Model differences in tropical water vapour may lead to differences in simulated Arctic ozone loss; too dry models would underestimate Arctic ozone loss.

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References

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Gettelman, A., et al., 2010: Multimodel assessment of the upper troposphere and lower stratosphere: Tropics and global trends, J. Geophys. Res., **115**, D00M08, doi:10.1029/2009JD013638.

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