Modeling Convection of Water Vapor into the Mid-latitude Stratosphere

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Abstract

The direct injection of water vapor into the mid-latitude from the troposphere into the stratosphere by moist convection during the North American monsoon has been observed in isotopic data by in situ aircraft measurements (Hanisco et al. 2007). Convective injection has a strong seasonality occurring during the late spring and summer months and is associated with mesoscale convective systems (MCS). The consequent elevated levels of stratospheric water vapor may lead to catalytic destruction of stratospheric ozone in the mid-latitudes thereupon resulting in increased UV exposure at the Earth's surface and increased risk to public health (Anderson et al. 2012). Climate models, however, do not directly inject water into the mid-latitude stratosphere by convection and so are not useful tools for predicting trends in mid-latitude water vapor. To address this issue, we undertook a modeling study to investigate the convective injection of water vapor from the troposphere into the stratosphere in the mid-latitudes. Models have been previously used to simulate convection from the troposphere to the stratosphere (Homeyer et al. 2014). We used the Advanced Research Weather and Research Forecasting (ARW-WRF) model at a 3-km resolution to resolve convection over the eastern United States during August of 2007. To assess the capability of ARW to simulate deep convection we plan to compare the morphology and the depth of stratospheric injection of the model output to NEXRAD data provided by Professor Ken Bowman.

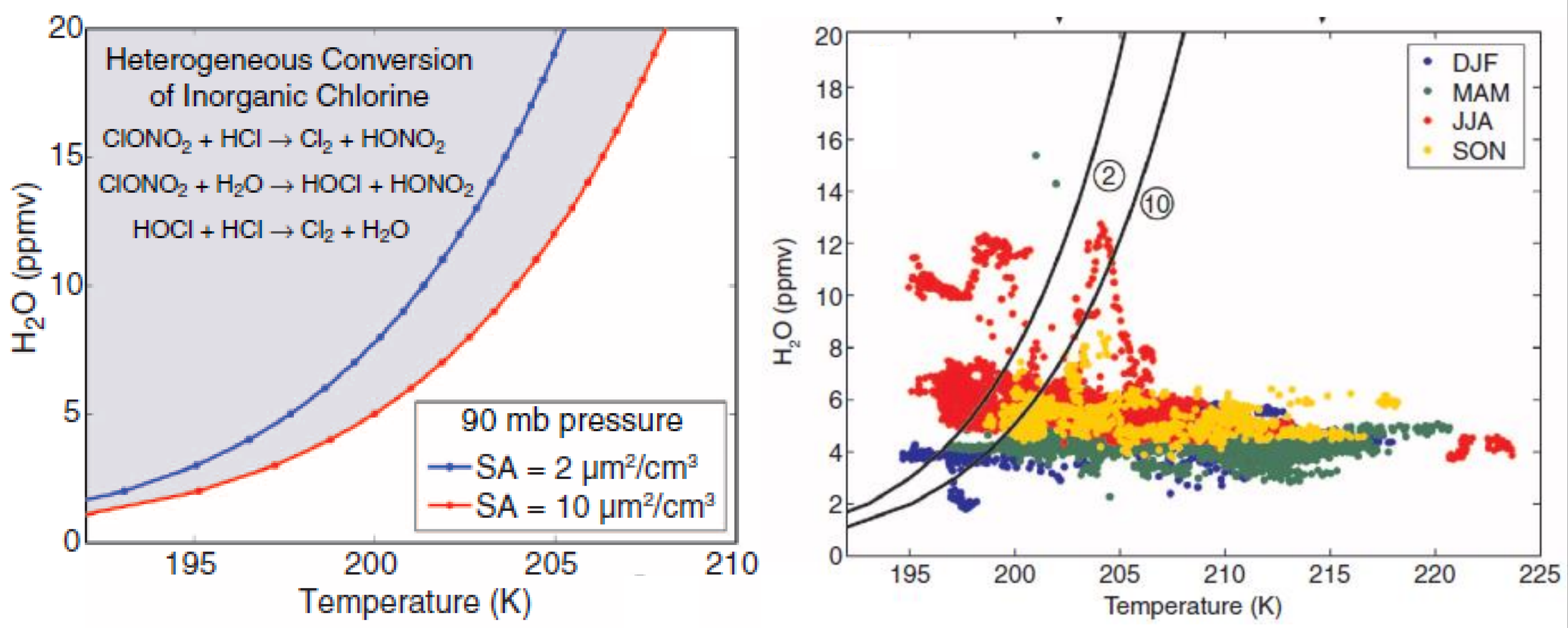


Figure 1a: Water vapor and temperature dependence of heterogeneous activation of inorganic chlorine reactions for two sulfate aerosol surface areas. Higher water vapor and lower temperatures favor the conversion of inorganic chlorine to free radical chlorine which catalytically destroys ozone.

Figure 1b: Water vapor and temperature dependence of heterogeneous activation of inorganic chlorine reactions shown with in situ flight observations of elevated water vapor in the mid-latitude lower stratosphere. Many observations of elevated water vapor fall within the temperature regime necessary to activate the inorganic chlorine.

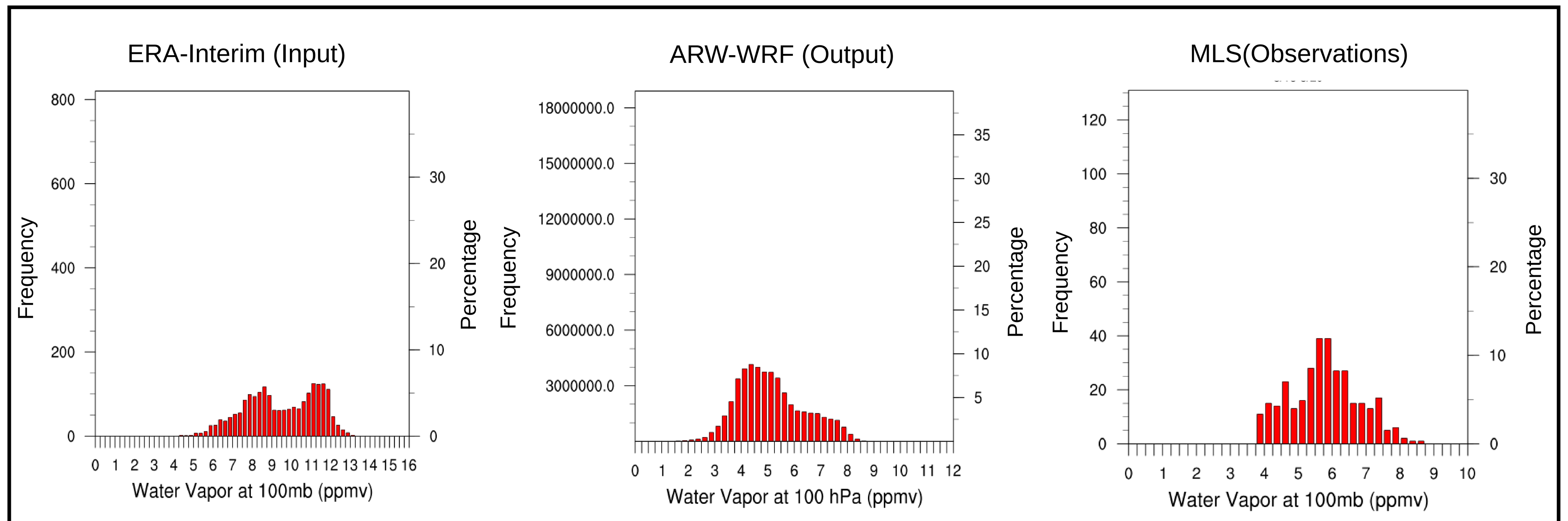
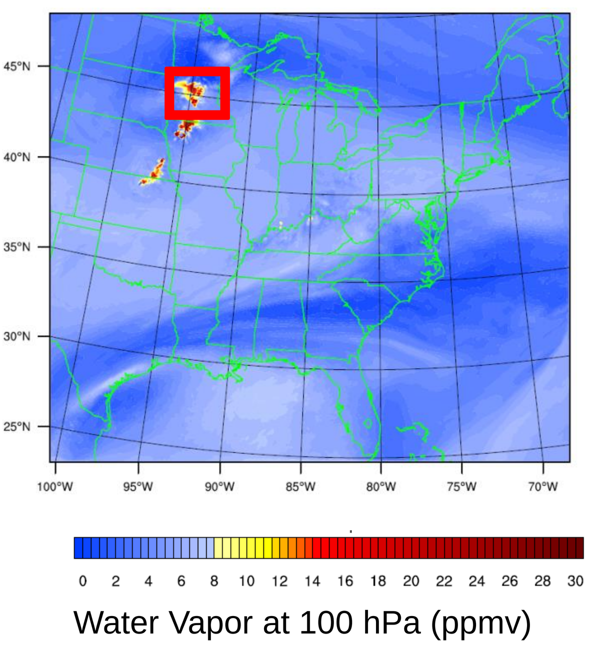


Figure 2: Histograms of water vapor concentrations (ppmv) of a) ERA-Interim reanalysis, b) WRF output, and c) MLS retrievals. ERA-interim was used for the boundary conditions for WRF, and shows higher water vapor concentrations than the MLS observations. WRF more closely matches the MLS water vapor profile.



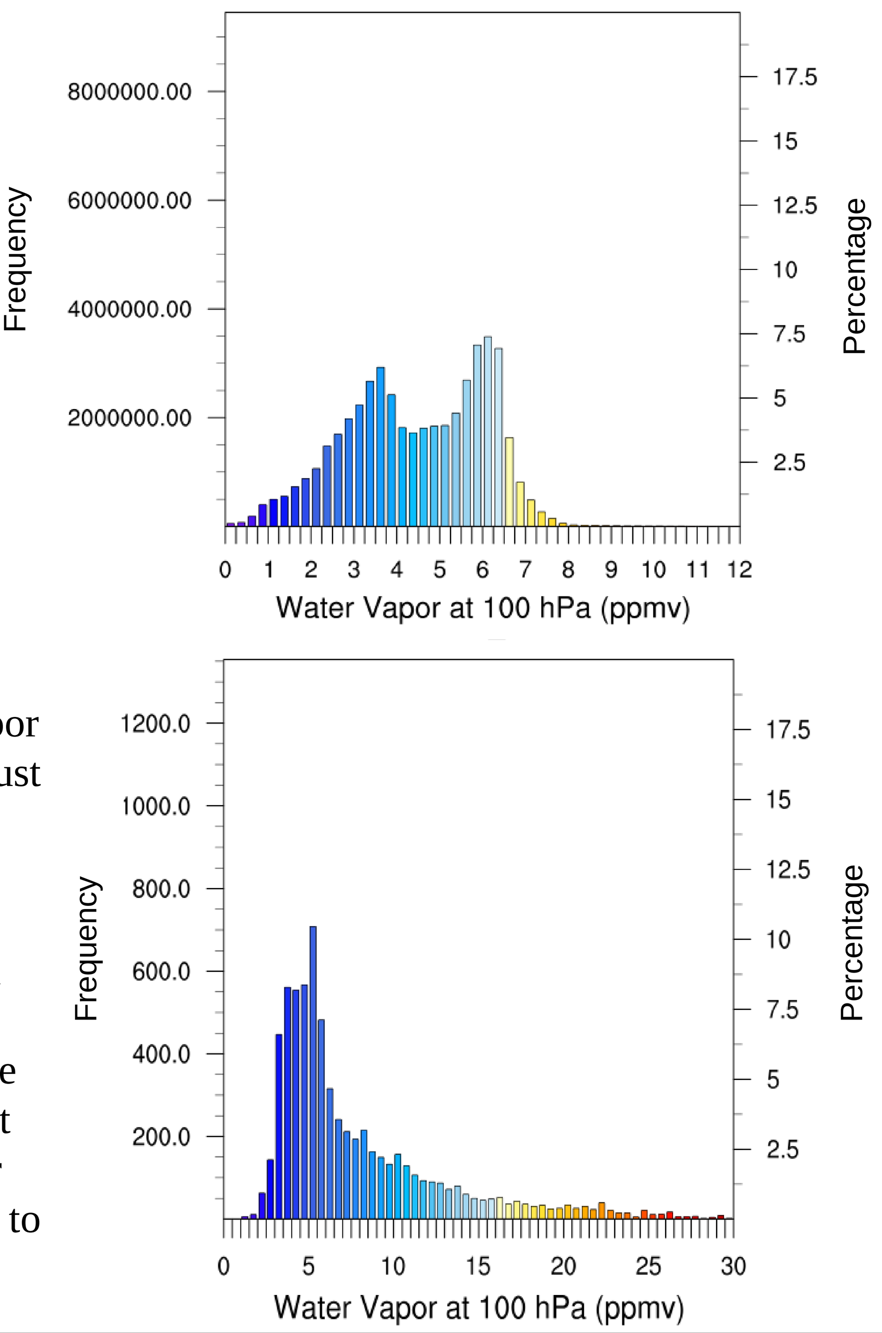


Figure 3: a) ARW-WRF water vapor concentrations at 100 hPa on August 21, 2007. b) ARW-WRF water vapor histogram for the entire shown area. c) ARW-WRF water vapor histogram for the illustrated subsection (red box). The 3 km horizontal resolution allows for the resolution of local convection that would otherwise not be visible for instance in MLS observations due to footprint averaging.

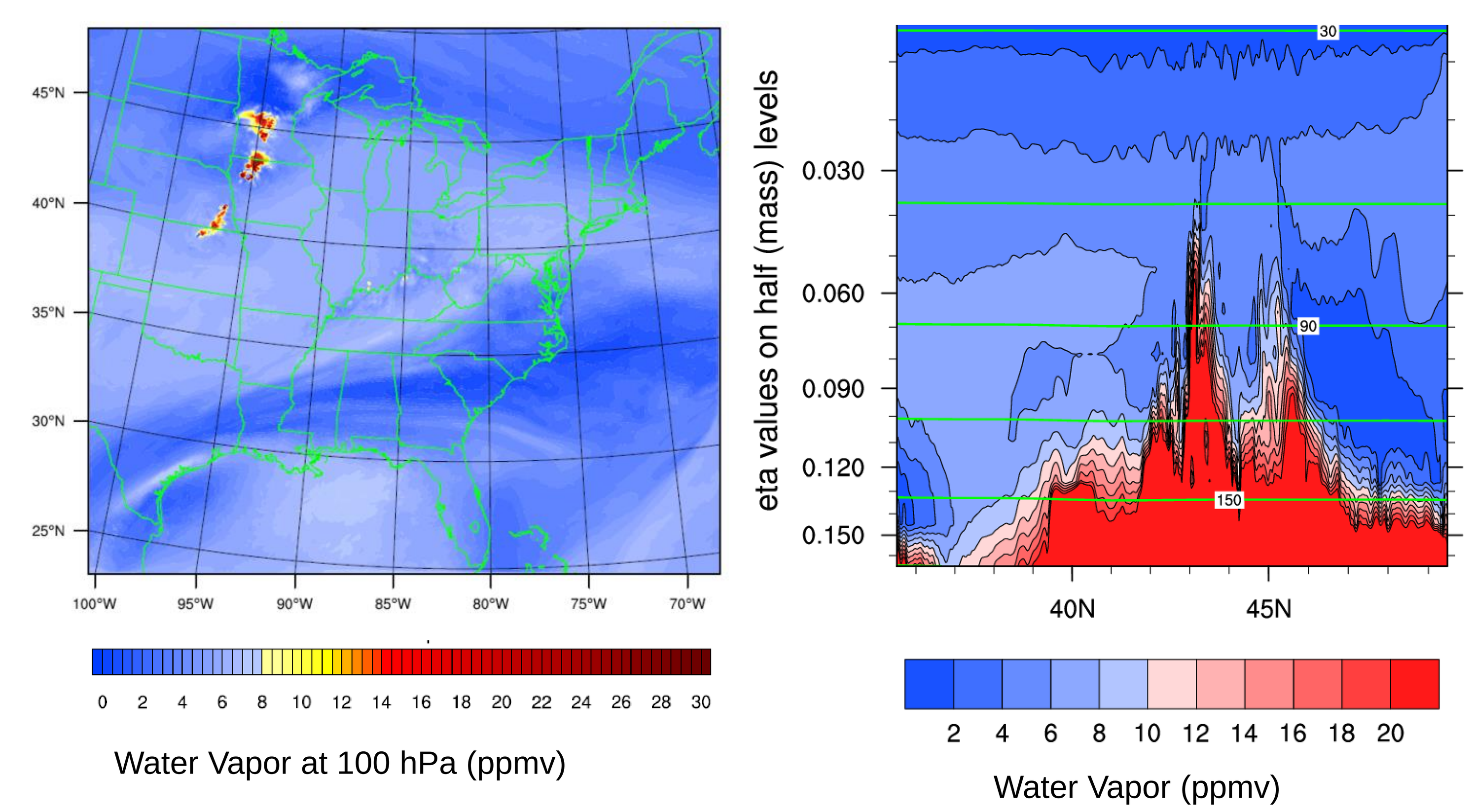


Figure 4: a) ARW-WRF water vapor concentrations at 100 hPa on August 21, 2007. b) ARW-WRF Vertical cross section along 95 W with pressure in hPa in green contours. The convective penetration seen at the 100 hPa pressure level is visible at two points.

Conclusions

Utilizing Advanced Research Weather and Research Forecasting (ARW-WRF) at high horizontal resolution allowed us to resolve local convection during the summer months over the mid-latitudes United States. In the model we saw several instances of convective injection and elevated water vapor concentrations up to 70 hPa. The high temporal and spatial resolution of ARW-WRF allowed us to visualize these events that MLS observations would miss due to averaging of the satellite's footstep. Next we will investigate the ability of ARW to simulate deep convection by comparing the morphology and the depth of stratospheric injection of the model output to NEXRAD data provided by Professor Ken Bowman.