Water vapor retrievals: new applications and implications for cal/val

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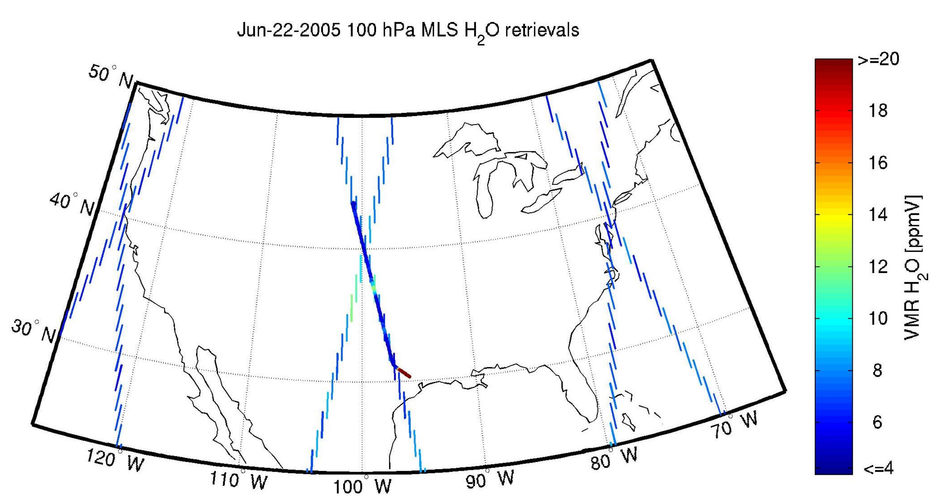
Abstract

Recent examination of observations of water vapor and halogen-containing chemical compounds in the lower stratosphere has suggested an interaction between continental convection during summer and ozone chemistry capable of substantial depletion of column ozone amounts. Understanding this interaction, its interannual variability, and possible trends in the coming decades requires robust climatologies of water vapor. The transient nature of stratospheric water vapor enhancements associated with convective events defines the spatial (both horizontal and vertical) and temporal sampling required to derive robust climatologies from different types of observing systems, including satellites. Moreover, climatological water vapor mixing ratios in the stratospheric regions of interest are very low, creating a demanding situation for validation of retrieval products. This paper will examine the relevant aspects of sampling issues and measurement uncertainty issues relevant to cal/val as defined by this new stratospheric science application.

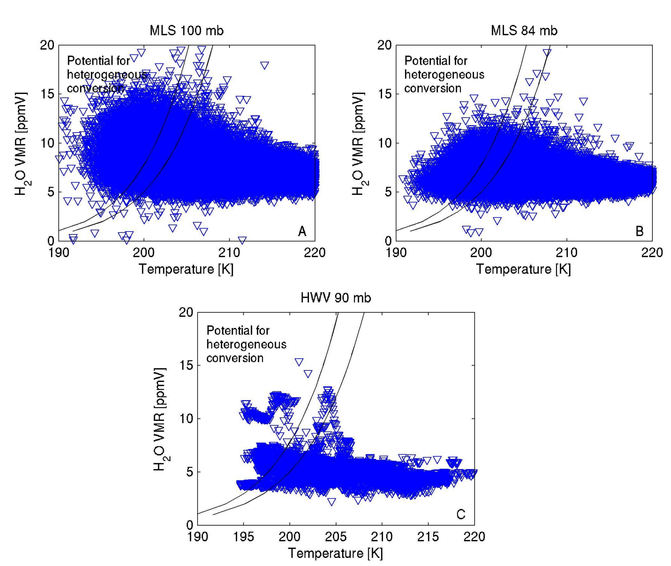
Spatial Characteristics of Enhanced Water



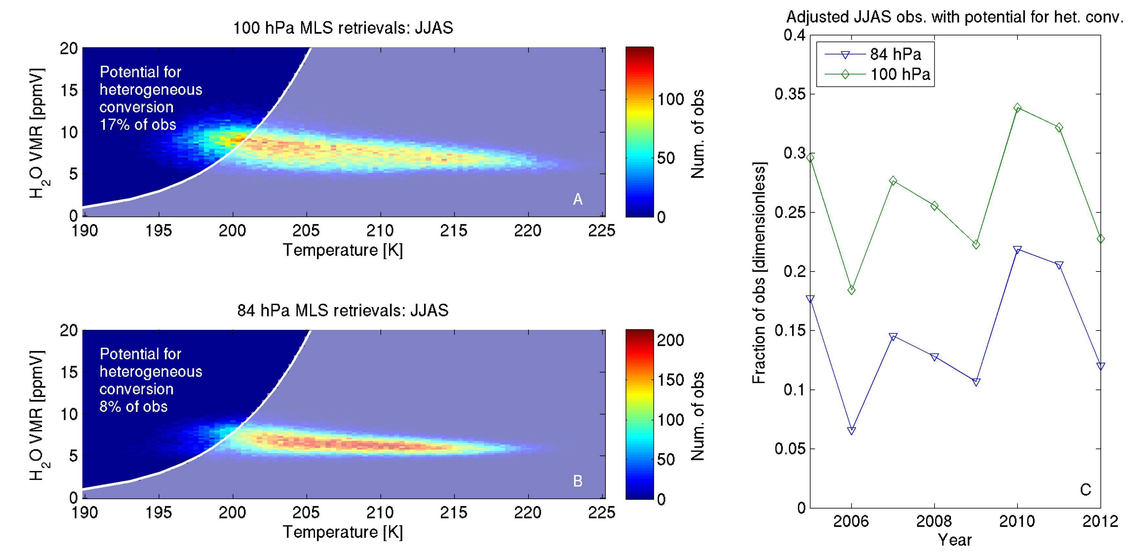
Coincident measurements by in situ aircraft measurements (Harvard Water Vapor Ly-α hygrometer) and NASA Microwave Limb Sounder (MLS) on EOS-AURA) display relevant spatial scales for observed lower stratospheric water vapor enhancements compared to satellite spatial weighting kernel (shown to scale by rectangular bars). The area of increased water, relevant for chemical processes, may underfill satellite footprint, leading to under-representation of water vapor mixing ratio.

A Climatology of Lower Statospheric Water Vapor

A scatter plot of all MLS water vapor retrievals for June-July-August for 2005-2012, inclusive, over the continental United States sector, at the 84 hPa and 100 hPa level (panels A and B), plotted against the temperature retrieved by MLS. Similar data for the Harvard Water Vapor in situ measurements show reinforce the detection of water vapor-temperature values with the potential for heterogeneous activation of inorganic chlorine into free radical form.

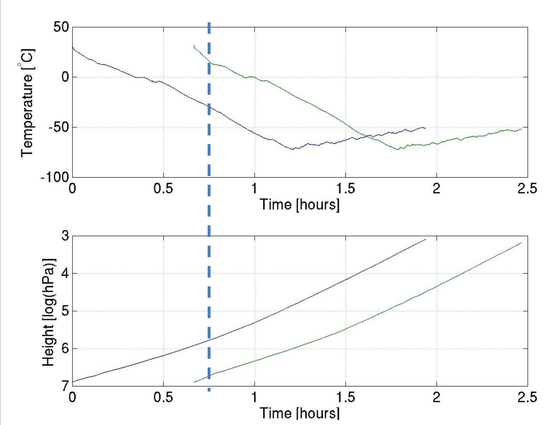


Statistical Analysis

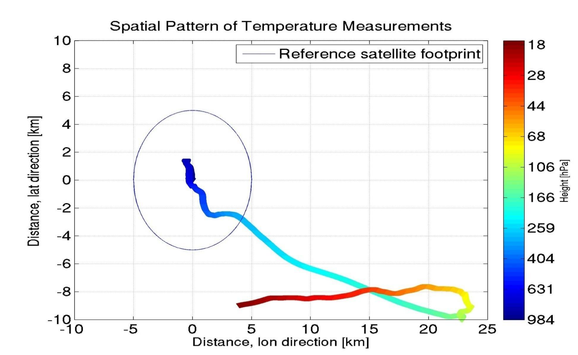


Observational evidence for elevated water vapor at low temperature from Microwave Limb Sounder (MLS) retrievals. Two-dimensional histograms of the number of observations for bins of temperature and water vapor are shown for June-July-August-September for 2005-2012, inclusive, for 100 mb (panel A) and 84 mb (panel B). The white curve shows a representative threshold for initiation of heterogeneous chlorine chemistry for 2 mm^2 cm^{-3} aerosol surface area density (Anderson et al. 2012). The fraction of observations found in the areas to the left of the white curves are calculated for 2005-2012 inclusive (panels A and B) and for each year (panel C).

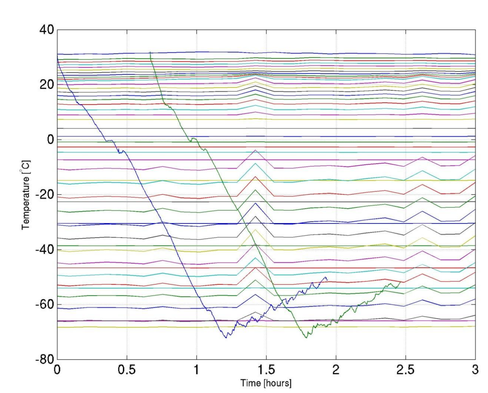
Implications for Calibration/Validation



Radiosonde ascent rates mean that sonde measurements occur over a period of hours, compared to seconds or less for satellite measurements.



Radiosondes drift with ambient winds so that measurements are distributed in space beyond the confines of a typical sounder footprint.

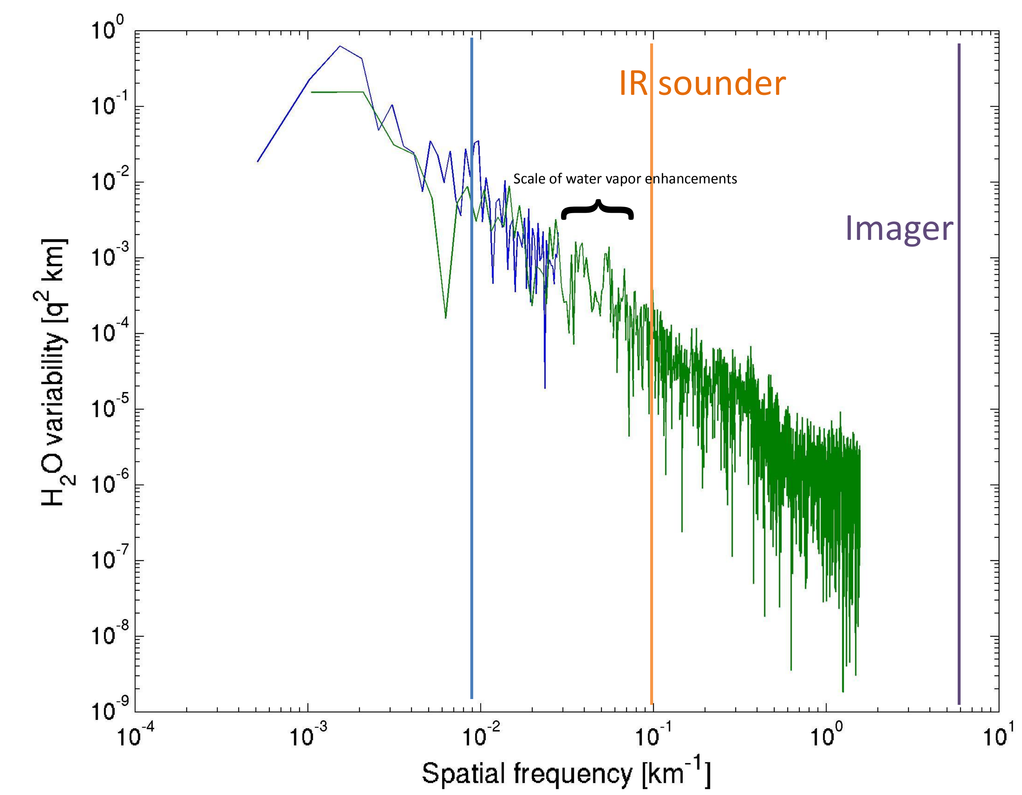


The frequent vertical profiles obtained by a ground-based, uplooking infrared sounder provide atmospheric measurements capable of adding additional spatial information to match profiling characteristics of satellite instruments.

Calibration/validation campaigns may utilize radiosondes together with ancillary measurements (Tobin et al. *JGR* 2006) such as ground-based infrared sounders, multi-channel microwave radiometers, or LIDARs to compensate for the mismatch in space and time, and the mismatch in spatial and temporal resolution, between different measurement systems.

Spatial Scales and Measurement Types

Water vapor enhancements associated with convective injection and transport have horizontal spatial scales that fall between the distances associated with the along-track resolution of a limb sounder and the nadir footprint of an infrared sounder. The challenge in identifying these transient events is that they occur in the lower stratosphere, where temperature gradients are small, introducing a sensitivity problem relative to higher water levels below the tropopause.



The spatial power spectrum of water vapor in the lower stratosphere taken from measurements (Harvard Water Vapor, June 22, 2005) and reanalysis (from NASA's Modern Era Reanalysis, MERRA) illustrate the variability at various spatial scales. These different spatial scales are associated with different atmospheric processes, and represent different measurement challenges for different scientific objectives.

Summary

- Both in situ aircraft measurements and satellite measurements reveal significant enhancements of water vapor at low temperatures in the lower stratosphere
- These temperature and humidity conditions have the potential to activate the heterogeneous conversion of inactive chlorine to free radical form
- Developing a reliable climatology of these events requires frequent measurements with good spatial coverage and spatial resolution of tens of kilometers
- No current satellite system provides all the desired sampling characteristics for this problem
- Calibration/validation techniques that leverage state-of-the-art multi-sensor methods could help ensure maximum value for these critical water vapor measurements