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High Water Vapor and Associated Signatures from MLS in the Monsoon Lower Stratosphere: Implications for Posited Ozone Destruction

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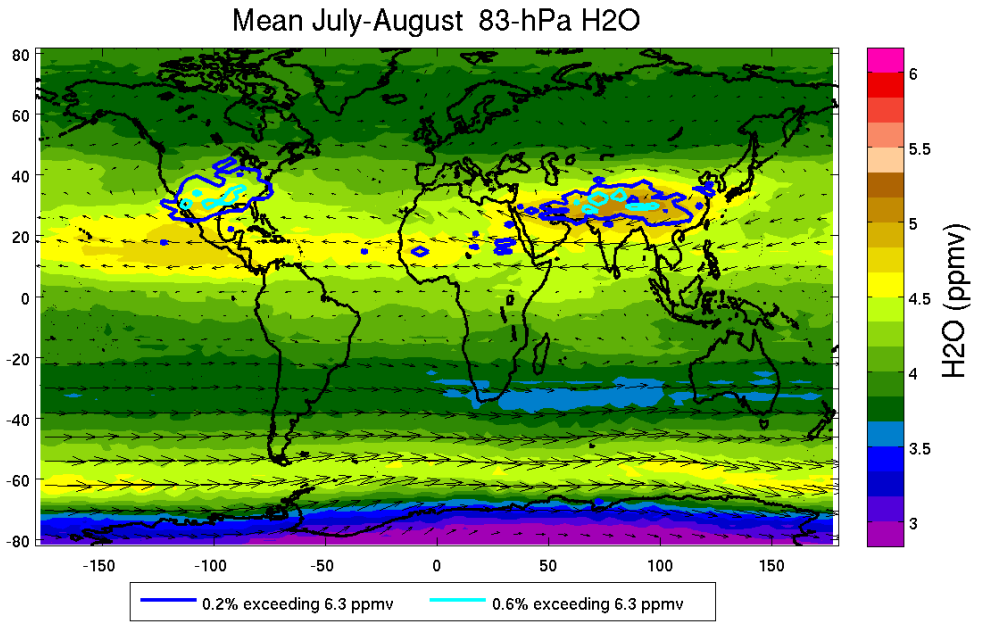
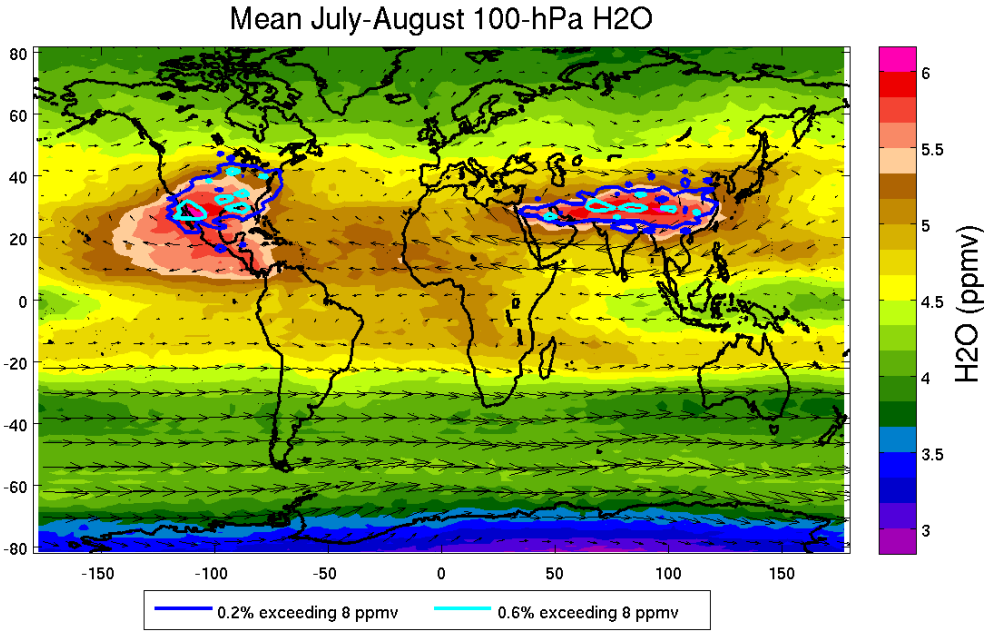
High H_20 in the 10-Year MLS Atmospheric Composition Record

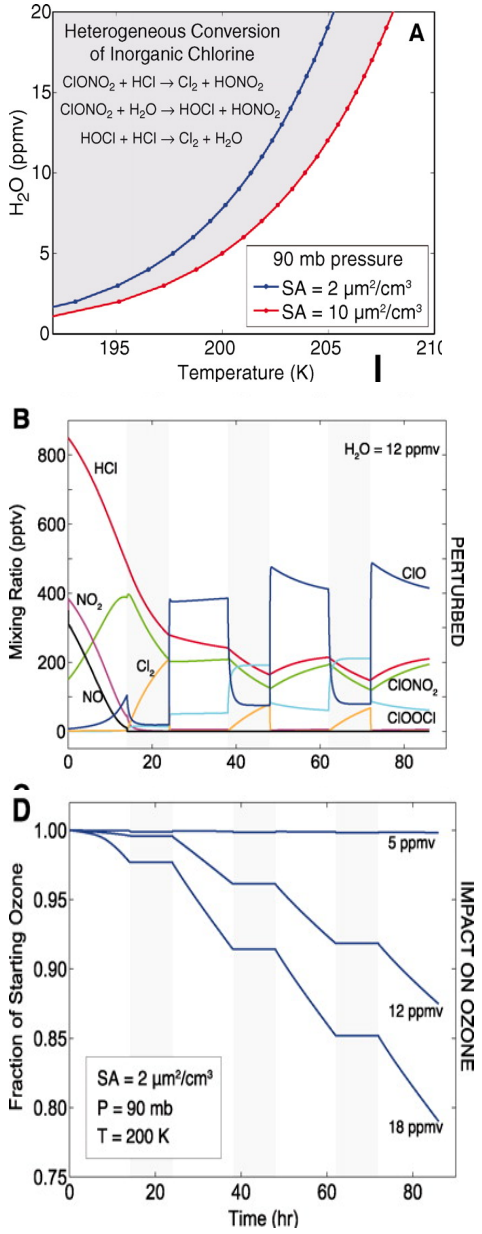
- July–August mean (2004–2014) H_2O; contours enclose regions with the greatest prevalence of high values.
- The wettest points in 10 years of MLS H_2O data, both in mean and in extreme values, are associated with the summer monsoons.
- The North American Monsoon Anticyclone (NAMA) highest extreme values are northeast of the center of the monsoon circulation and the maximum mean values.
- The Asian Monsoon Anticyclone (AMA) maximum mean and extreme values are collocated within the anticyclone.
- Anderson et al. [Science 2012] warn that high H_2O at the low temperatures of the NAMA could lead to aerosol growth, chlorine activation, and ozone destruction.
- Schwartz et al. [GRL 2013] looked for indications of such conditions and chemistry in the MLS record.





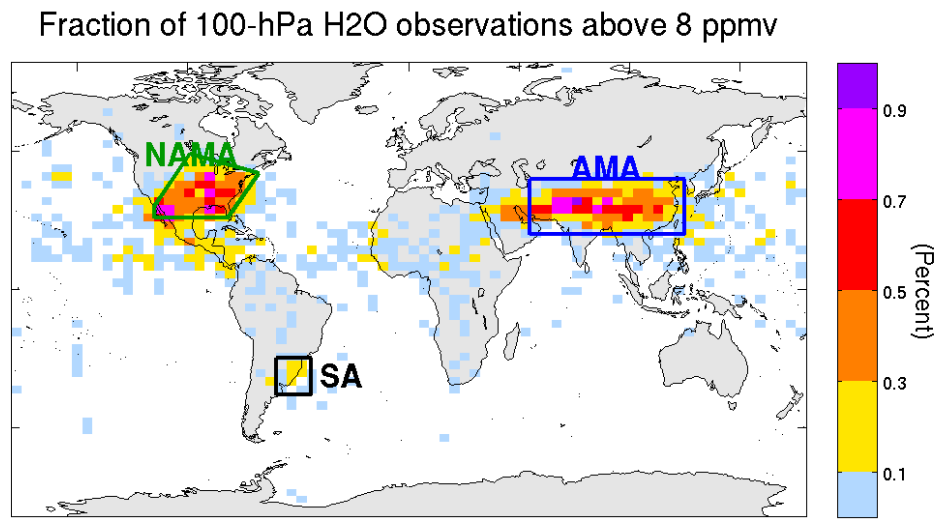
Anderson et al. [2012] Chemistry

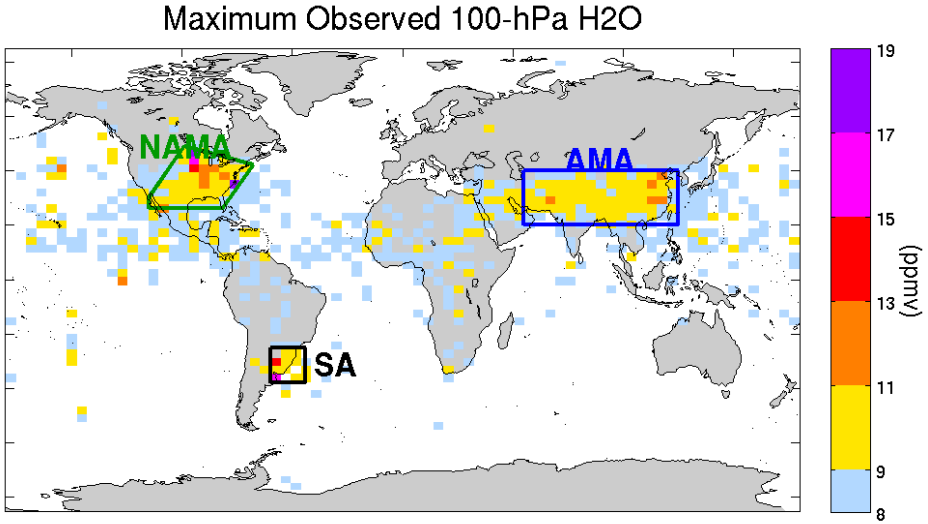
- Anderson et al. [2012] posit that the conditions for chemistry similar to that of the polar winter ozone holes occur in layers of enhanced water vapor in the North American summer lowermost stratosphere *in the current climate.*
- Growth of binary water/sulfate aerosol, activation of chlorine, and destruction of ozone are modeled.
- Rapid aerosol growth occurs beyond a cold-wet threshold.
- The top panel shows the H_2O - Temperature threshold for 10% chlorine activation in first day/night cycle. The blue curve is for nominal aerosol levels; red is for enhanced (e.g., volcanic plume) aerosol.
- The middle panel shows 3½ days of model run at 12 ppmv H2O and 200K. HCl drops from 850 to 200 pptv within two days. Daytime ClO increases from 0 to 450 pptv by the third day. Layer O_3 drops by 13% in 3.5 days.
- The bottom panel illustrates this threshold behavior. At 200 K, there is negligible O_3 loss in 3.5 days at 5 ppmv H_2O, but 15% O_3 loss at 12 ppmv H_2O.



Figures from Anderson, et al., 2012

MLS 100-hPa H_2O wet extremes (all seasons)

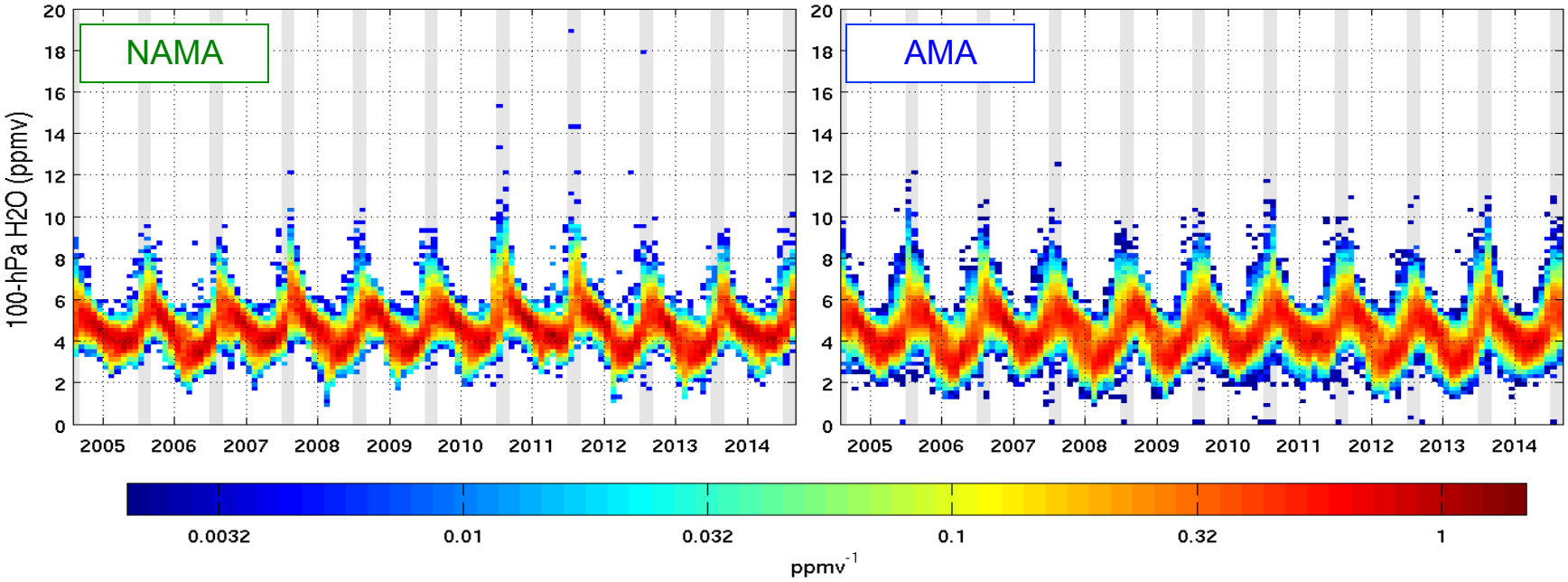




- Study boxes chosen to enclose regions of extreme values, both in terms of occurrence frequencies and maximum values in the record.
- The systematic clustering of outliers in these study boxes confirms the high quality of the MLS record.
- The wettest 100-hPa points in the record are in the northeast of NAMA.
- The AMA has a larger fraction of global 100-hPa H_2O measurements between 8 and 10 ppmv, but fewer extreme outliers above 11 ppmv.
- The SA box (in Jan–Feb) contains some of the highest extreme H_2O values in the record, although SA 100-hPa mean values are <4 ppmv.
- Many of the highest outliers outside of the study box regions can be associated with volcanic plumes.
- Statistics shown throughout this talk are based on these study boxes.

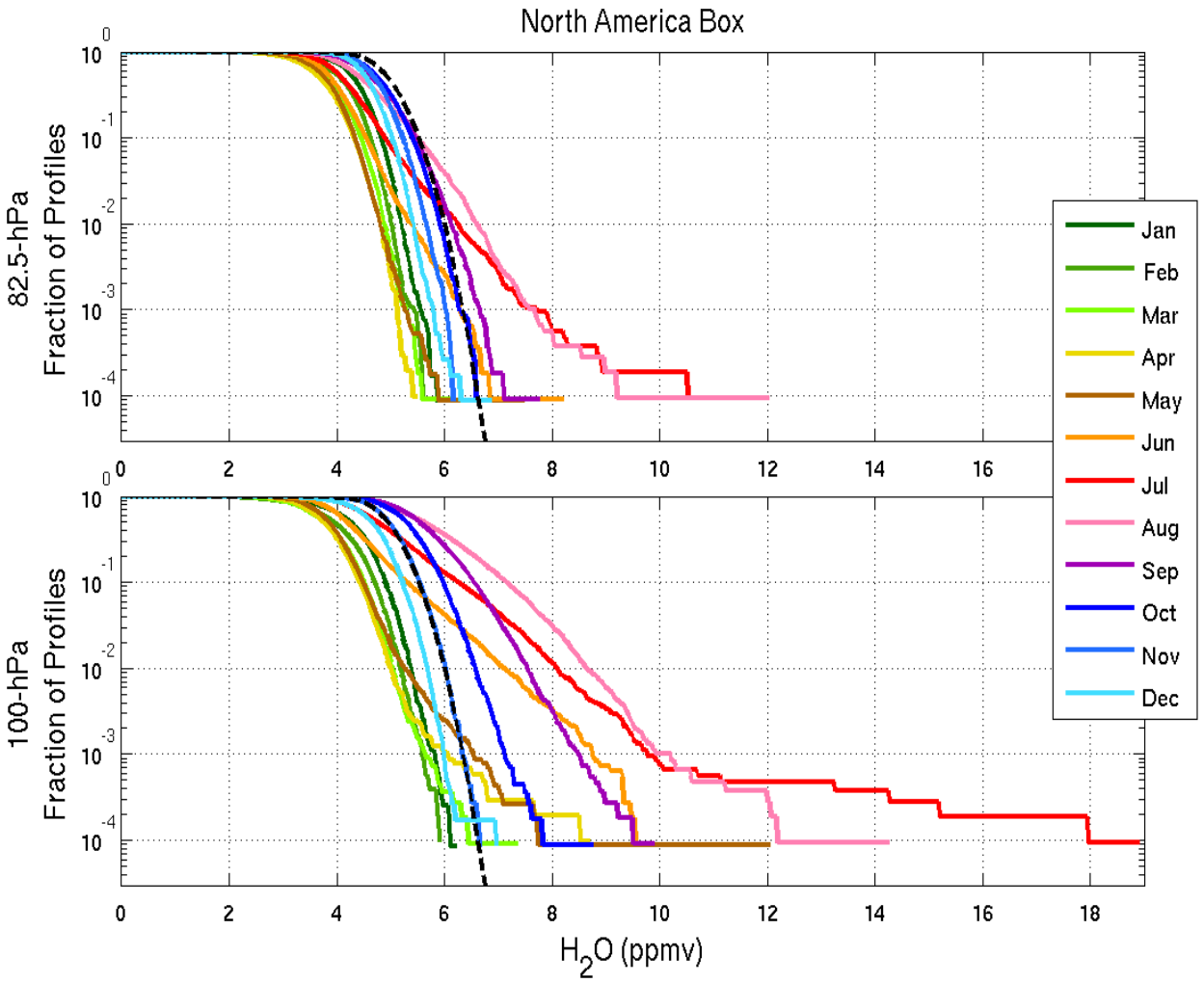
MLS H_2O Monthly Histogram Time Series

- Monthly histograms represent every profile in the two study boxes from 9/2004–9/2014. Colors are logarithmic PDFs that integrate over mixing ratio to unity for each month.
- The seasonal cycle in mean values has slightly larger amplitude in AMA than in NAMA.
- Dark blue outliers are individual MLS profiles indicative of convective injection of H_2O; they occur preferentially in July–August (shaded background), as well as May–June in AMA.
- The highest observed values occur in NAMA.
- Interannual variability can be seen both in the means and in the extreme values.
- 2010–2012 had the highest outlier values in NAMA in the 7+ years shown in the GRL paper, but 2013–2014 did not continue that "trend".



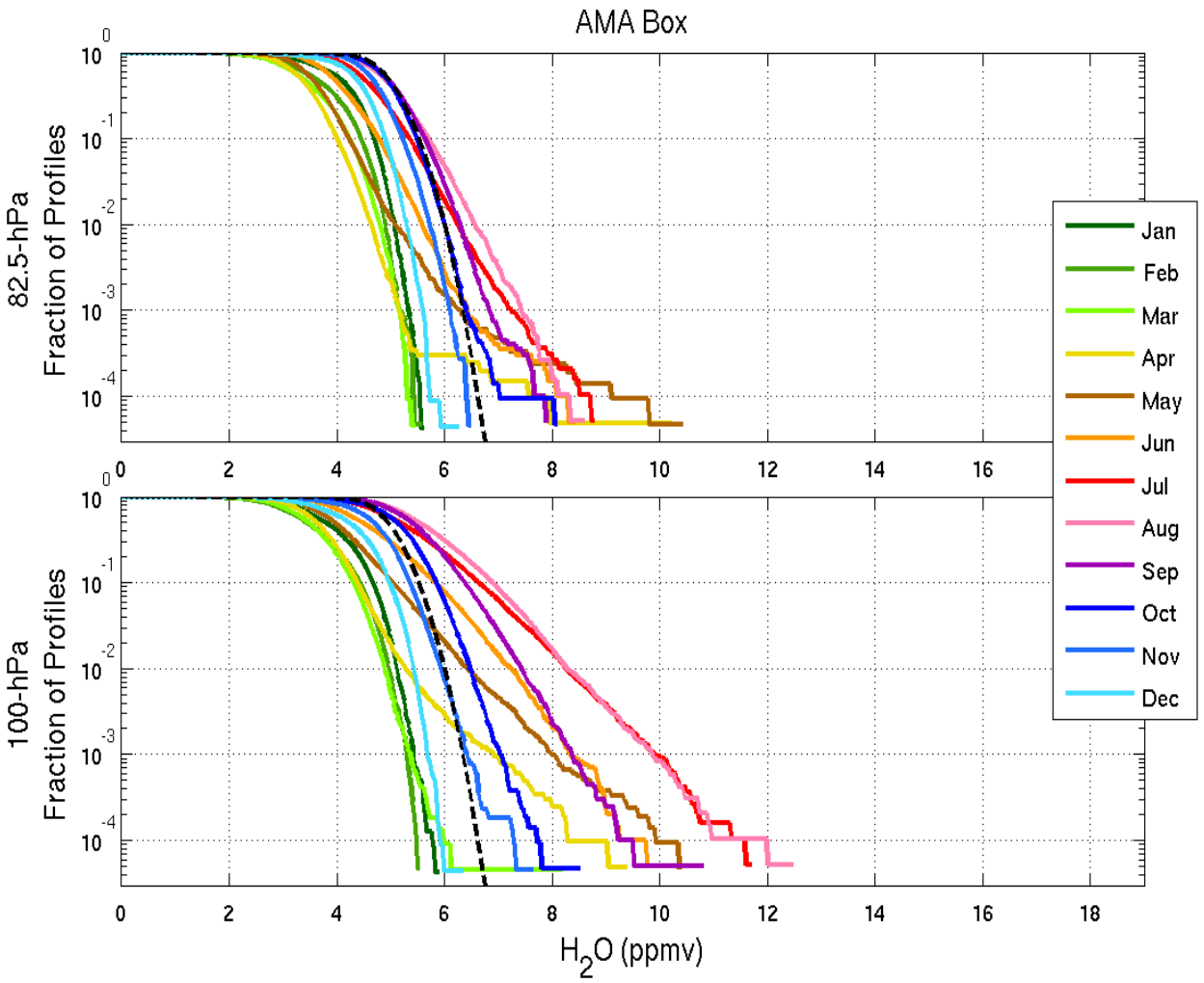
Cumulative H_2O Histograms (North American Monsoon Study Box)

- Curves are the fraction of profiles in the box whose H_2O mixing ratios exceed a given value in a given month.
- Note the logarithmic y-axis scale; the “floor” is due to one point of ~10,000 in NAMA in a given month, and “steps” are additional points.
- Dashed lines (identical on all plots) are a reference Gaussian.
- Summer non-Gaussian tails are high outliers from the core distribution due to convective injections.



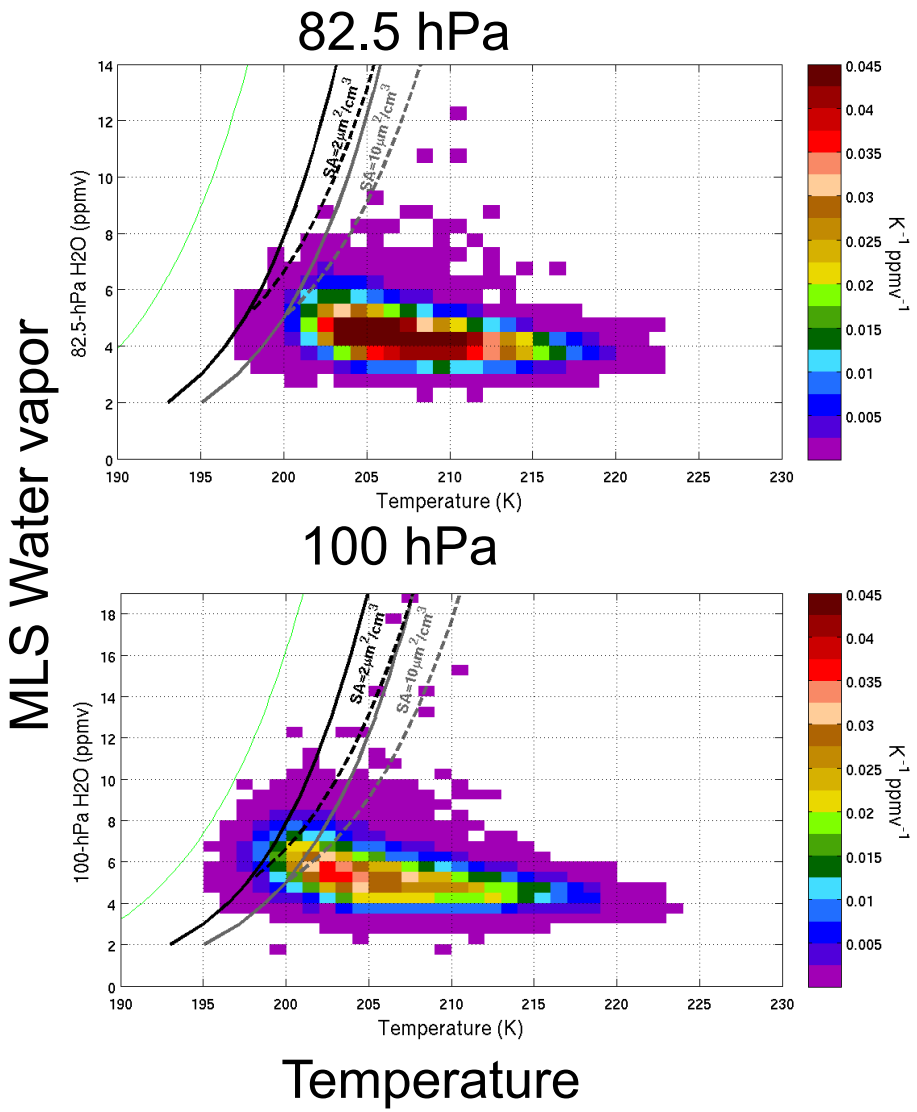
Cumulative H2O Histograms (Asian Monsoon Anticyclone)

- AMA has a larger fraction of 100 hPa values >8 ppmv than NAMA in July (red curve), but a smaller fraction in August (pink curve).
- AMA high outliers are evident beginning in April (yellow curve), much earlier than in NAMA.
- The highest July-August (red and pink curves) extremes are lower in AMA than those in NAMA.



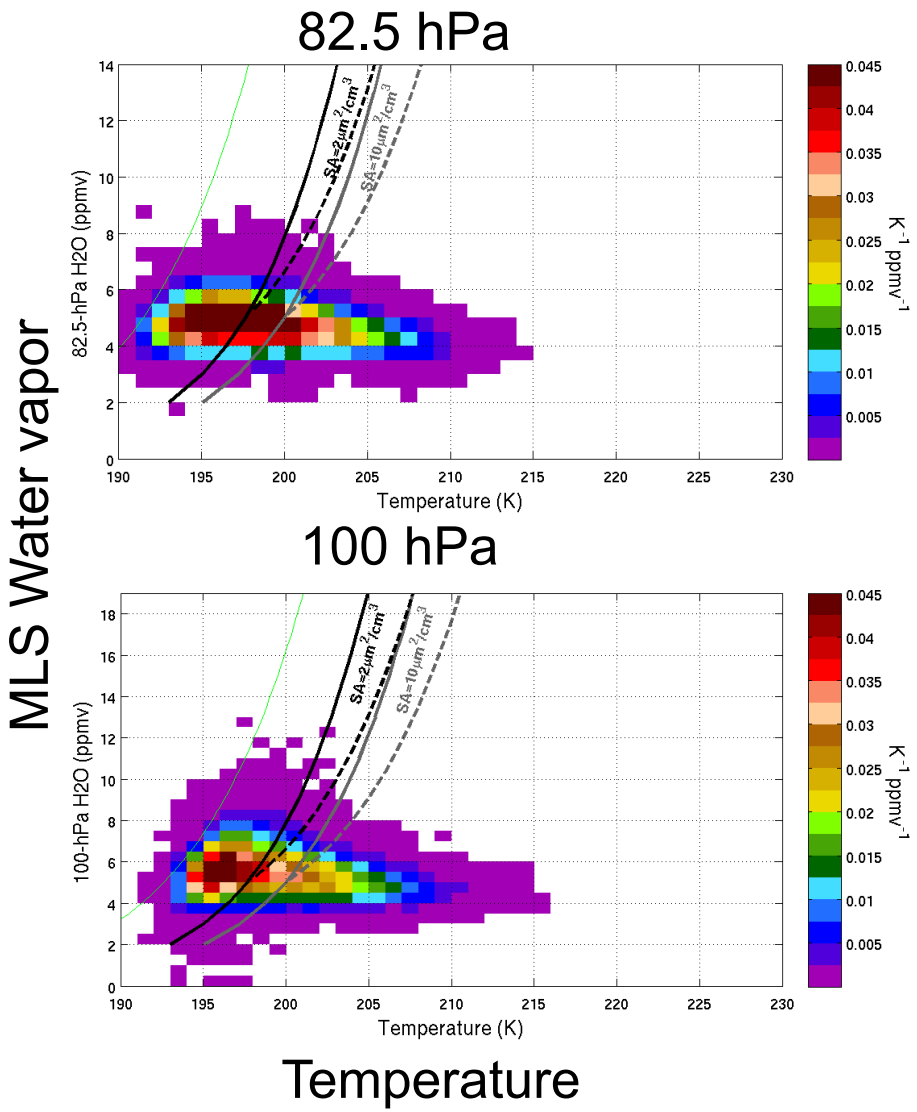
North American July-August Joint H_2O-Temperature PDFs

- Solid curves show chlorine activation thresholds from Anderson et al. [2012]: Black = nominal sulfate aerosol; Gray = enhanced (volcanic) aerosol conditions.
- Dashed curves apply within an unresolved 1-km enhanced H_2O layer embedded in a 5-ppmv background.
- Most of the highest July–August NAMA H_2O values occur at temperatures too high for activation in the current climate.



Asian Monsoon July-August Joint H_2O-Temperature PDFs

- Solid curves show chlorine activation thresholds from Anderson et al. [2012]: Black = nominal sulfate aerosol; Gray = enhanced (volcanic) aerosol conditions.
- Dashed curves apply within an unresolved 1-km enhanced H_2O layer embedded in a 5-ppmv background.
- The July–August AMA is, on average, slightly wetter but significantly (~5 K) colder than the July–August NAMA.
- The peak in the July–August AMA H_2O PDF is within Anderson et al.'s activation regime for binary sulfate aerosol growth in the current climate.

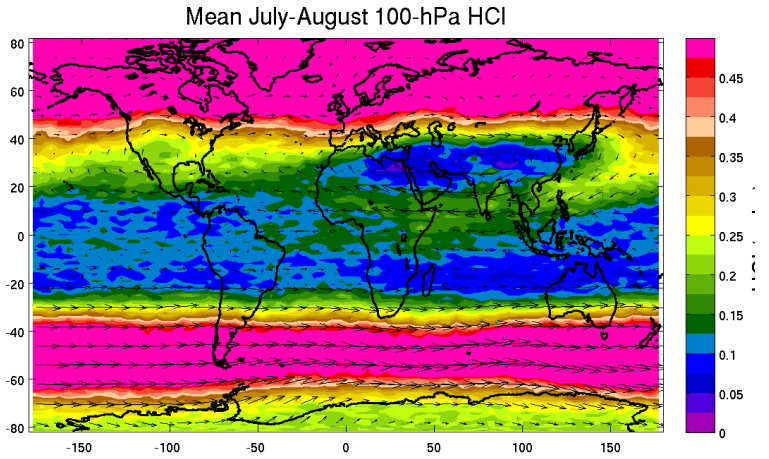


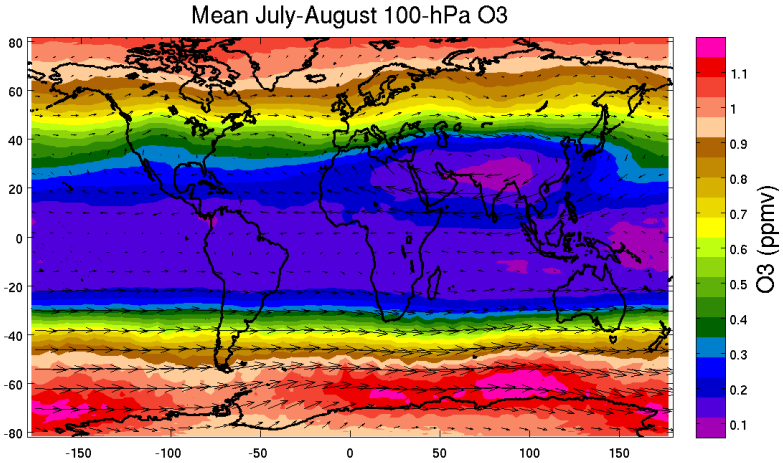
HCl and O_3 Signatures in the July-August NAMA

- Anderson modeled 85% reduction in HCl within two days of convective injection, and 13% reduction of O_3 within four days.
- We compare HCl and O_3 in cold wet parcels with those in equally cold but drier parcels.
- MLS observes ~3% lower HCl and O_3 at 100 hPa, ~6% lower HCl and O_3 at 83 hPa within the activation regime than in drier parcels at the same temperature. (HCl at 83 hPa is interpolated from 68 hPa and 100 hPa observations.)
- At least some portion of these reductions is expected from dilution of lowermost stratospheric abundances by the convectively injected tropospheric air that supplied the high H_2O.
- Schwartz et al. [2013] concluded that signatures of alarming O_3 loss are not observed in the July–August NAMA in the current climate.
- However, as Anderson et al. notes, a colder wetter lowermost stratosphere may result from climate change, worsening ozone loss.

July-August HCl and O_3 in the Asian Monsoon Anticyclone July-August

- Because of its lower temperatures, the AMA has far more profiles in Anderson et al.'s activation regime than does the NAMA.
- HCl and O_3 are both lower at the same pressure levels in the AMA than in the NAMA at least in part because the July–August AMA has a higher tropopause than the July–August NAMA, with typical AMA tropopause pressures below 100 hPa.
- The low HCl and O_3 of AMA (compared to their zonal mean values) are largely explained by dynamics, with monsoon parcels influenced by ascending tropospheric air, but a role for the chemical mechanisms of Anderson et al. [2012] is not ruled out by our preliminary analyses.



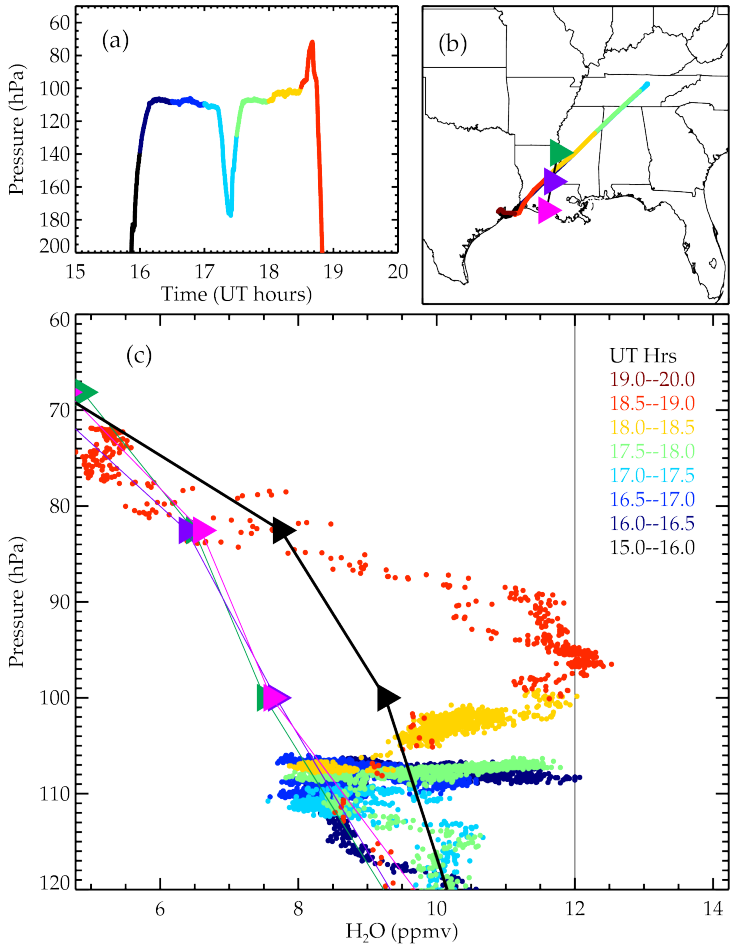


Summary

- MLS has made more than 20,000 July–August profiles of the North American Monsoon and more than 40,000 July–August profiles of the geographically more extensive Asian monsoon, providing an excellent statistical view of these features.
- MLS shows the North American and Asian Monsoon Anticyclone lowermost stratosphere to be unusually wet in summer, both in mean values and in extreme values.
- The Anderson et al. [2012] model's initial 850 pptv of HCl is much higher than we typically see at the lowest July–August NAMA temperatures.
- There is no indication of alarming mid-latitude summer ozone loss due to the Anderson et al. [2012] mechanism in the current climate of North America.
- The Asian Summer Monsoon is colder than the NAMA, and the Anderson et al. mechanisms are not ruled out as contributors to observed low O_3 and HCl levels.
- StratoClim could provide a tremendous amount of insight.

HWV in situ H2O case study August 13, 2007

- Anderson, et al. observed a ~1-km thick, 12-ppmv H2O layer extending over more than 100 km.
- The Harvard in situ water vapor instrument (HWV) measured high H2O intrusions on half of North American summer flights targeting convective outflow.
- Back trajectories to convection suggest enhancements persist at these levels for several days..
- Black triangles are the convolution of the HWV profile with MLS ~3-km averaging kernels. Colored triangles are closest MLS profiles ~13 hours later.
- "Pretty good" collocation was not enough for MLS to see this event.



Adapted from Figure 1 from Anderson 2012