Extreme Events in the 14 year MLS Lower Stratospheric Water Vapor Record

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The Water Vapor Record from MLS on Aura

- The 14+ year Water Vapor (H2O) record from Aura MLS is a valuable and widely-used resource.
- There is no similar instrument in the works as a follow-on, but this instrument is generally functioning well and the spacecraft has plenty of fuel, particularly if it leaves the A-Train.

- The MLS water vapor product derives from measurements of the 183 GHz H_2O line
- In the lower stratosphere, individual profiles are measured with ~5% precision, ~3 km vertical resolution and ~10% estimated accuracy
- Comparisons with other sensors are consistent with these estimated uncertainties
- There is, however, evidence for a positive drift in MLS H_2O starting around 2010
  - Comparisons with frost point sondes indicate as much as a ~1% / year increase.
  - However, comparisons with ACE FTS imply a smaller (0.5% / year) drift.
  - We have identified changes (correctable in future data releases) in the MLS instrument behavior can account for ~0.2% / year of this drift. The remainder is unexplained as yet.

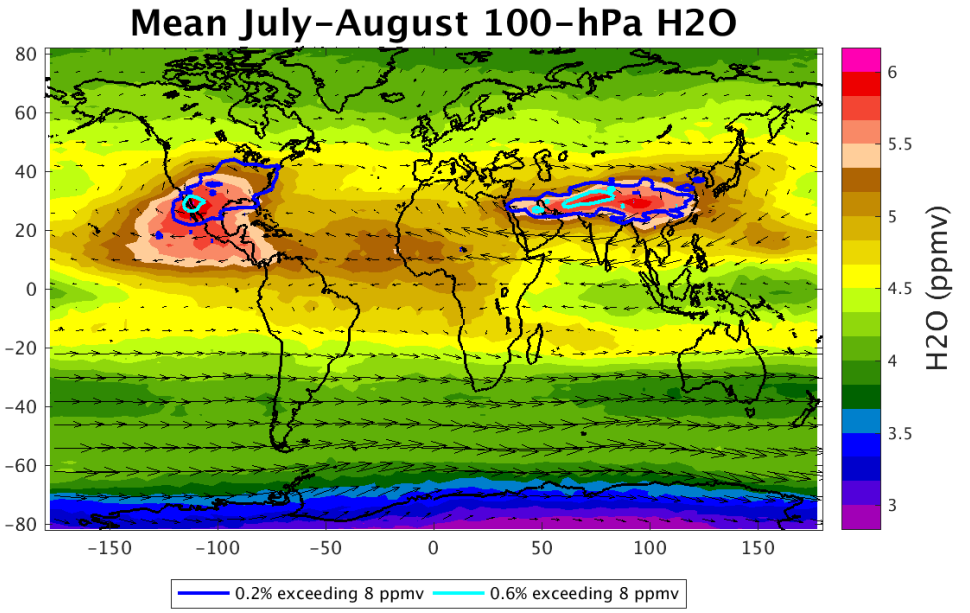
- Note: MLS still has an active science team that is happy to consult/ collaborate/ share insights.

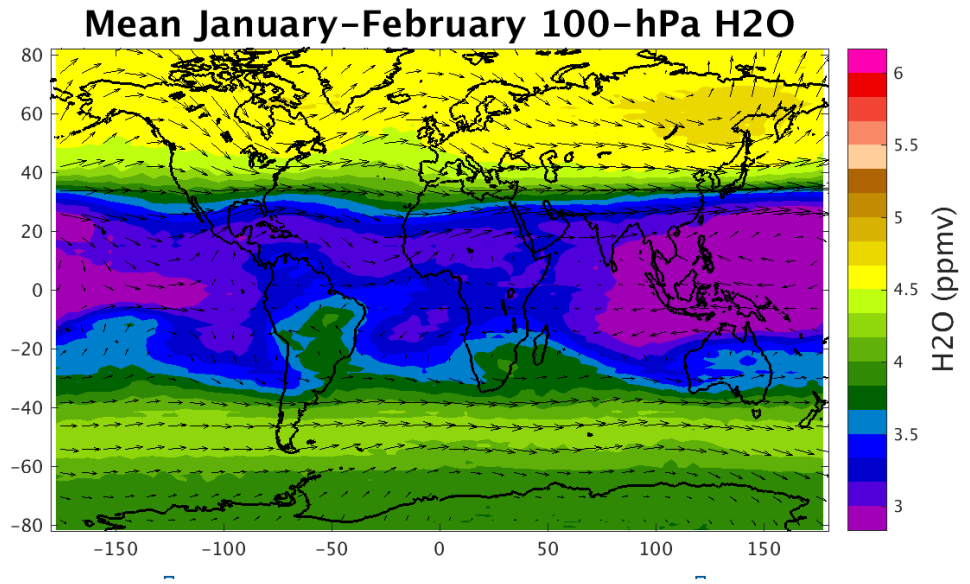
High H_2O Outliers in the Lower Stratosphere

- The work described here focuses on high-outliers in the MLS H_2O lower stratospheric record:
  - Occasional "crazy high" mixing ratios among the more than 17.7 M profiles are almost all systematic and meaningful.
  - Version 4 does have some glitches associated with satellite/instrument operations that I have removed, in addition to screening as described in the MLS data quality document.
  - High outliers can help in identification of alternate paths into the stratosphere beyond that of the BDC's general ascent through the cold tropical tropopause. While these events are rare, they may play outsized roles in lower stratospheric chemistry.
- The Summer Monsoons:
  - The Asian Monsoon Anticyclone (AMA), the North American Monsoon Anticyclone (NAMA) in northern summer and, to a lesser extent, the south Atlantic coast of South America (SA) in southern summer contain the largest climatological clusters of high H_2O at 100 hPa and 83 hPa. Highest outliers are often directly associated with overshooting convection.
- Volcanos
  - In the 14-year record, ~30 volcanic eruptions have been detected in MLS SO_2. Of these, Calbuco (April-May, 2015) , Kasatochi (August 2008) have readily detectable H2O plumes.
- Pyroconvection
  - The plume injected into the stratosphere by a PyroCb event in British Columbia (August 13, 2017) is far and away the largest injection of H2O into the LS in the MLS record.

Summer Monsoons

- The upper panel shows the climatological, July-August mean 100-hPa H2O, with contours showing where high outliers are most common.
- The NH summer monsoons are clearly the most significant global features.
- The lower panel is the same kind of plot for January-February. The TTL is extremely dry (cold), giving rise to the dry phase of the ”tape recorder” of ascending tropical stratospheric air.
- The South American monsoon has a much weaker wet signature than those of the NH monsoons.



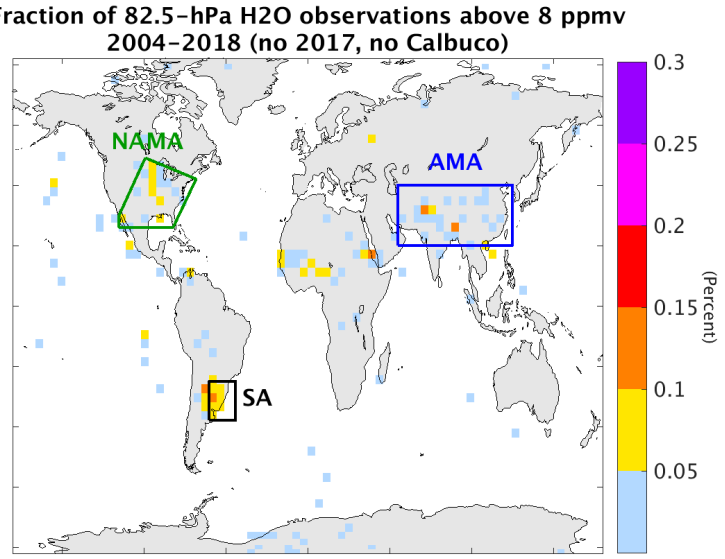


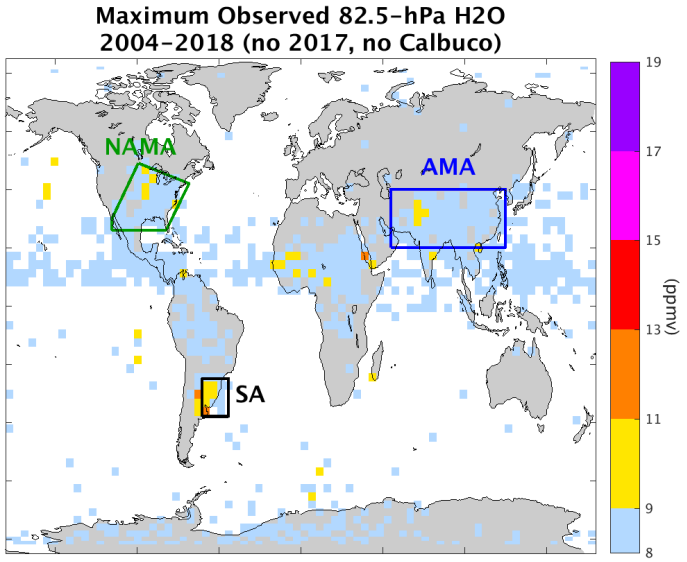
All Seasons

Fraction of Observations above 8 ppmv

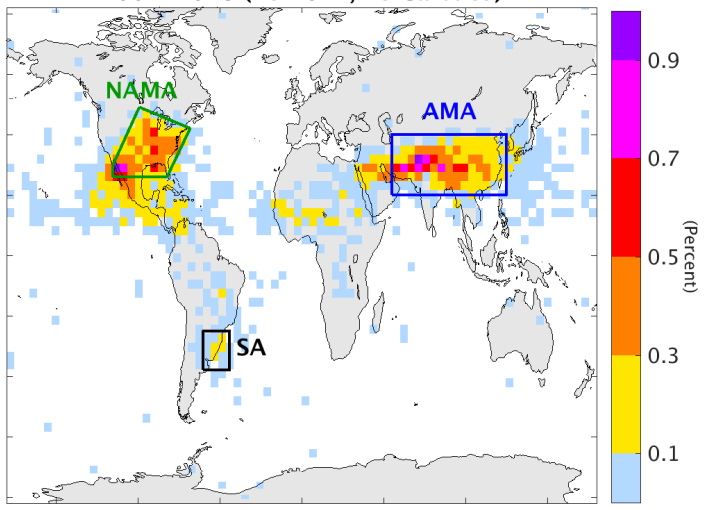
Maximum observed H2O vmr

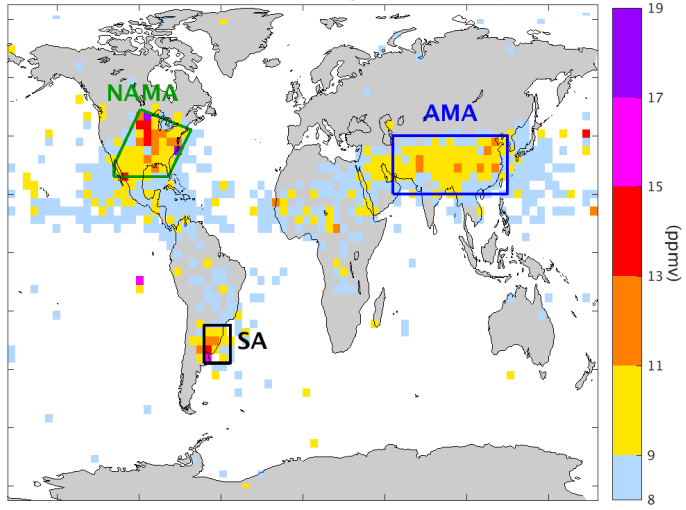
82.5 hPa



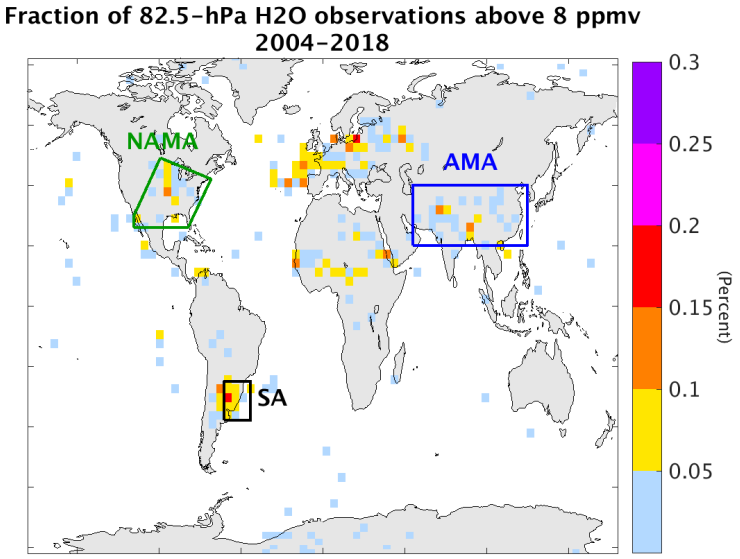


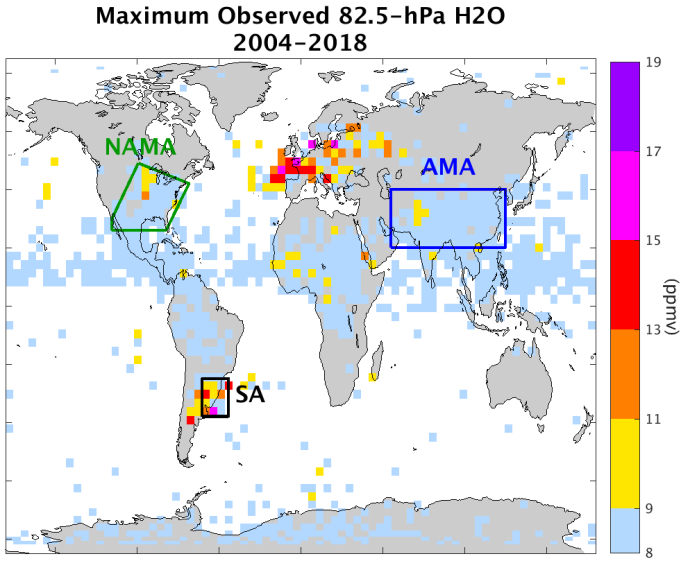
100 hPa



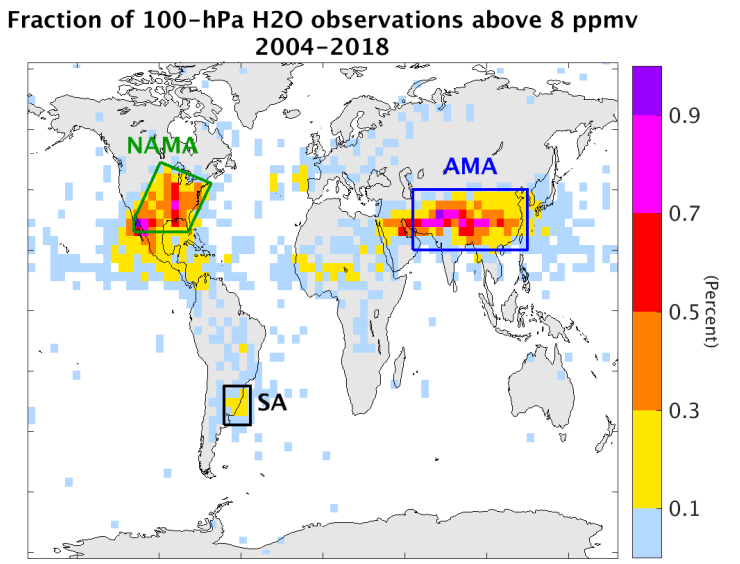


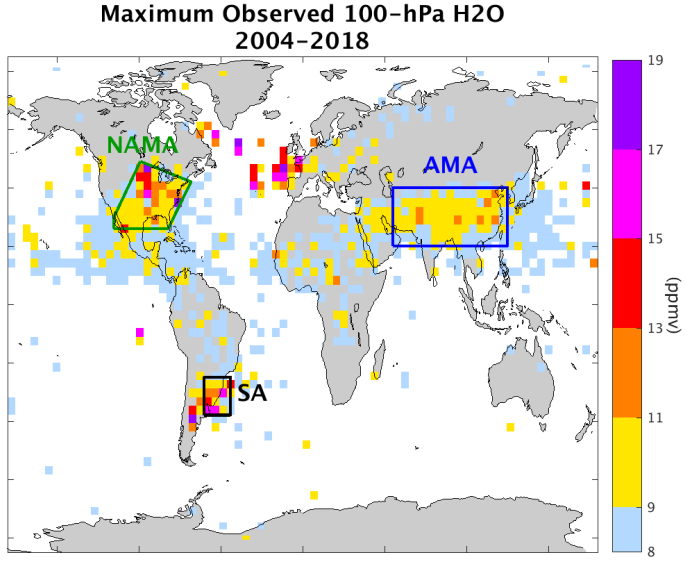
82.5 hPa



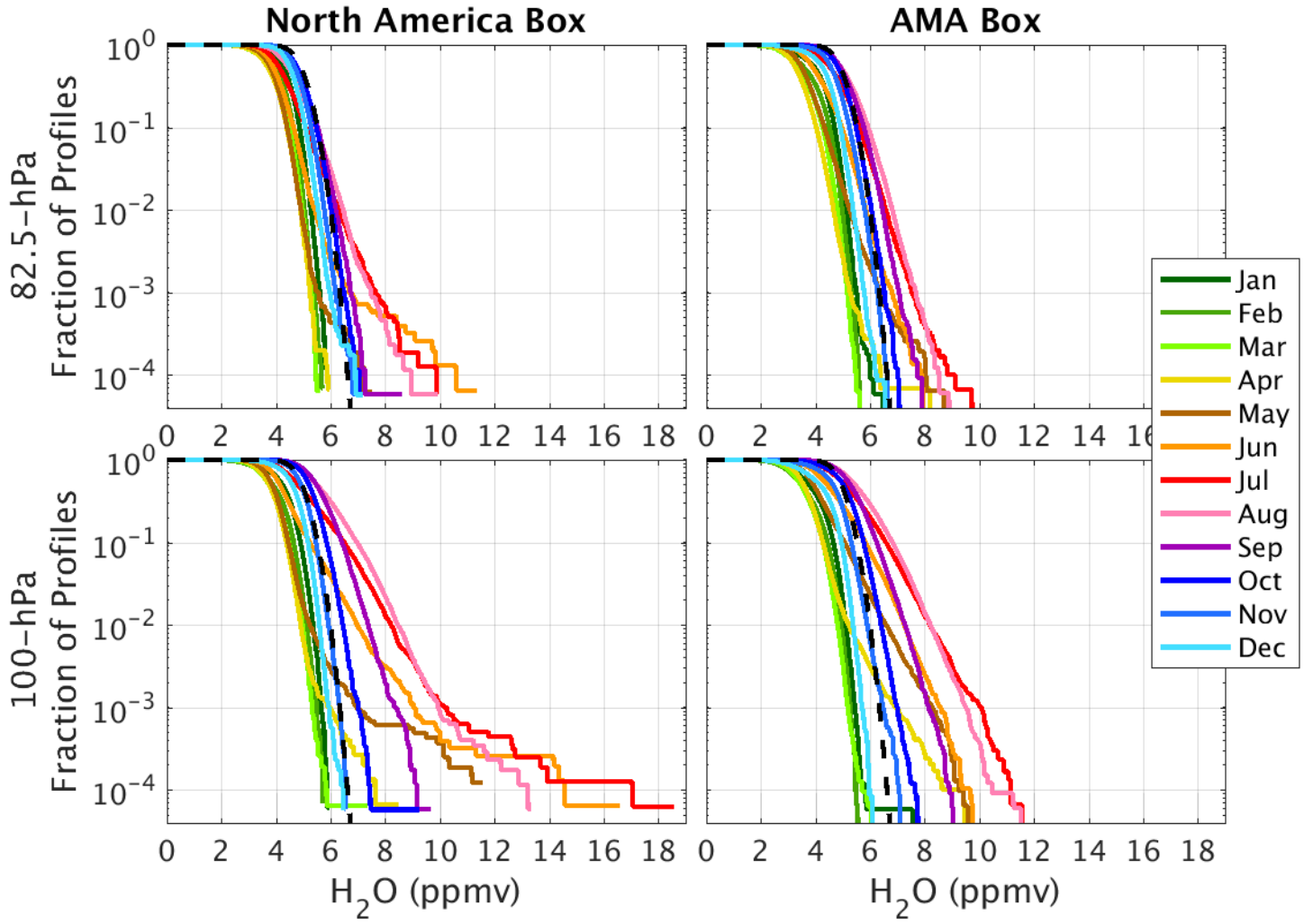


100 hPa

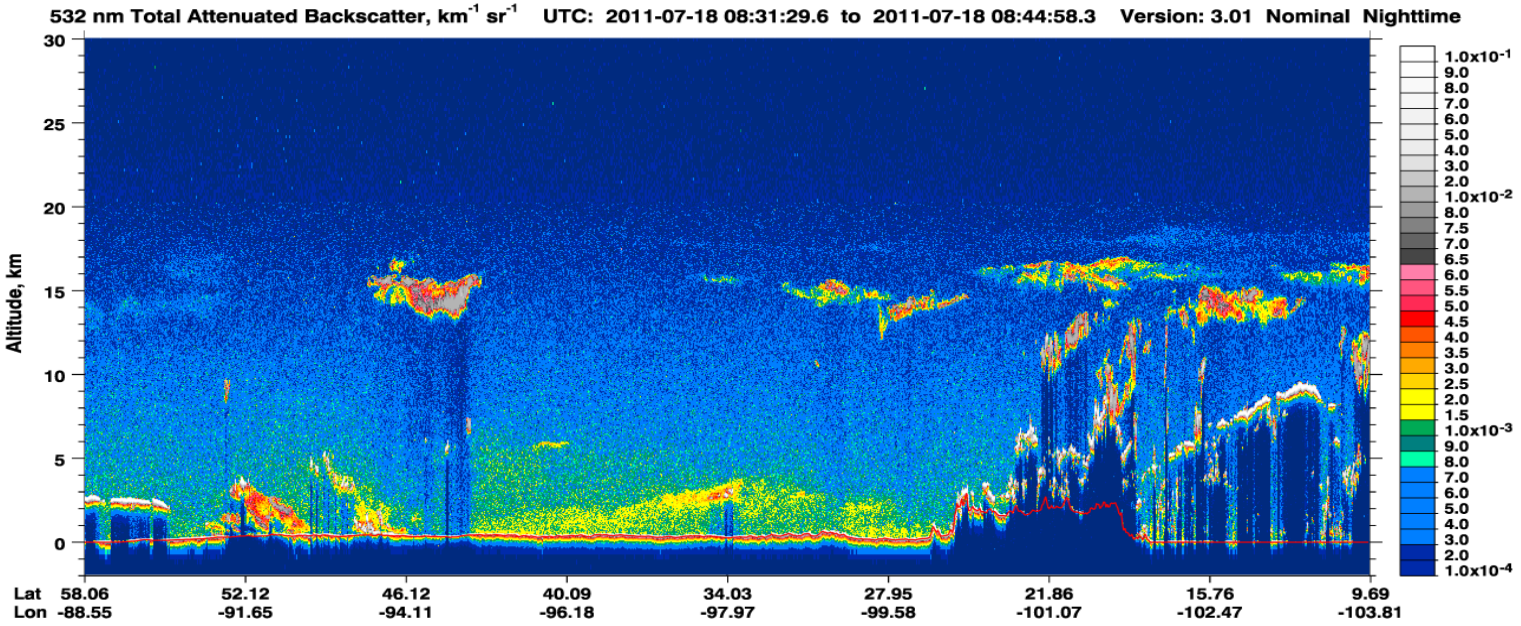


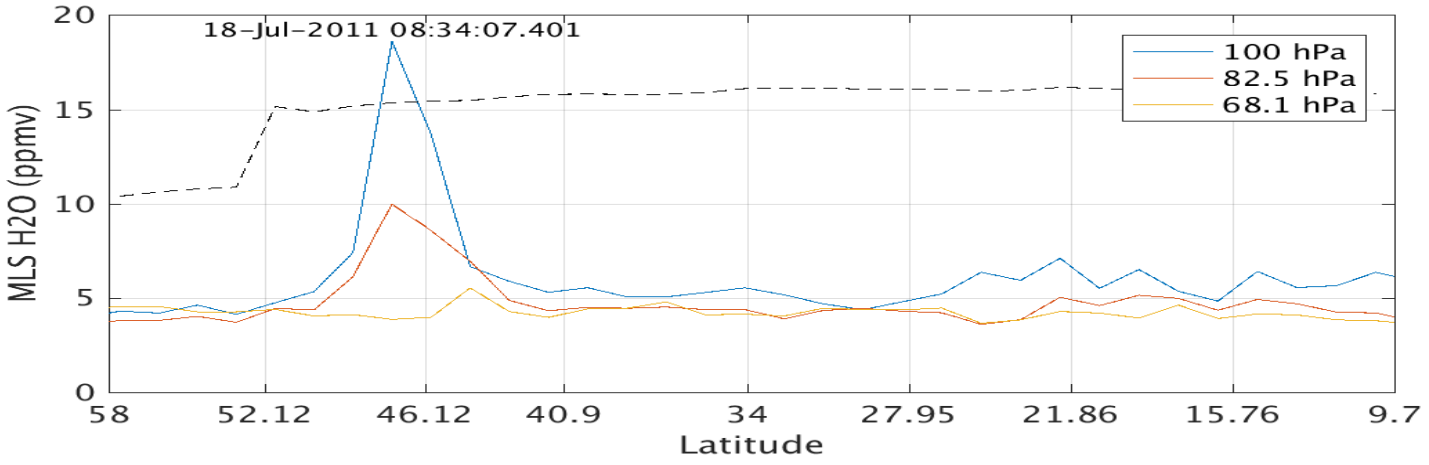


Cumulative Histograms by Month

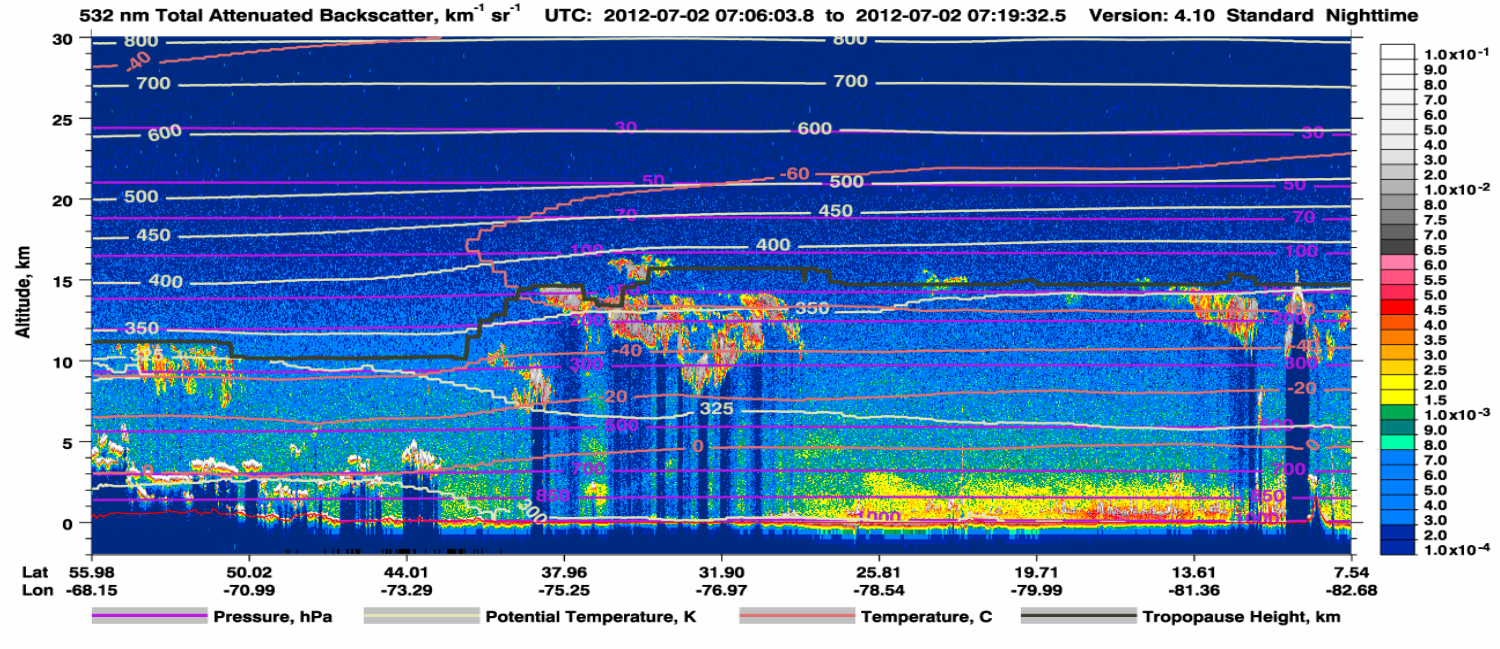


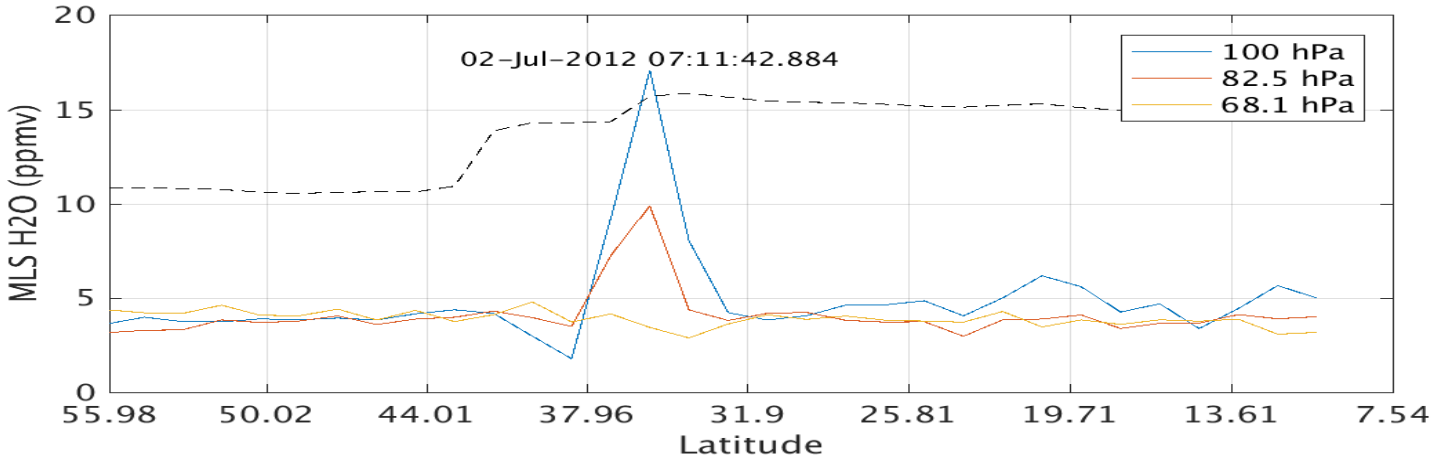
Outlier in Calipso (July 18, 2011 Minnesota)





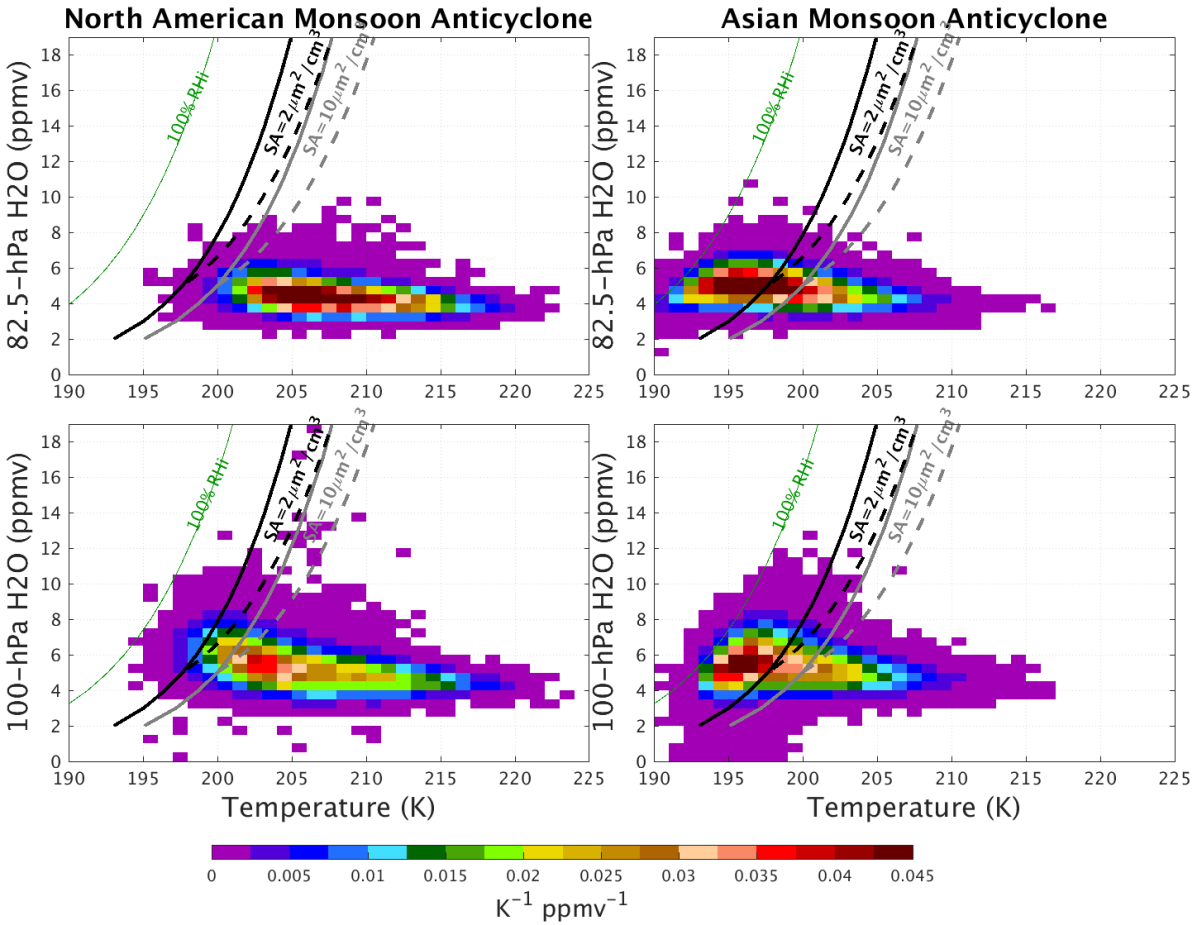
Outlier in Calipso (July 2, 2012 North Carolina)



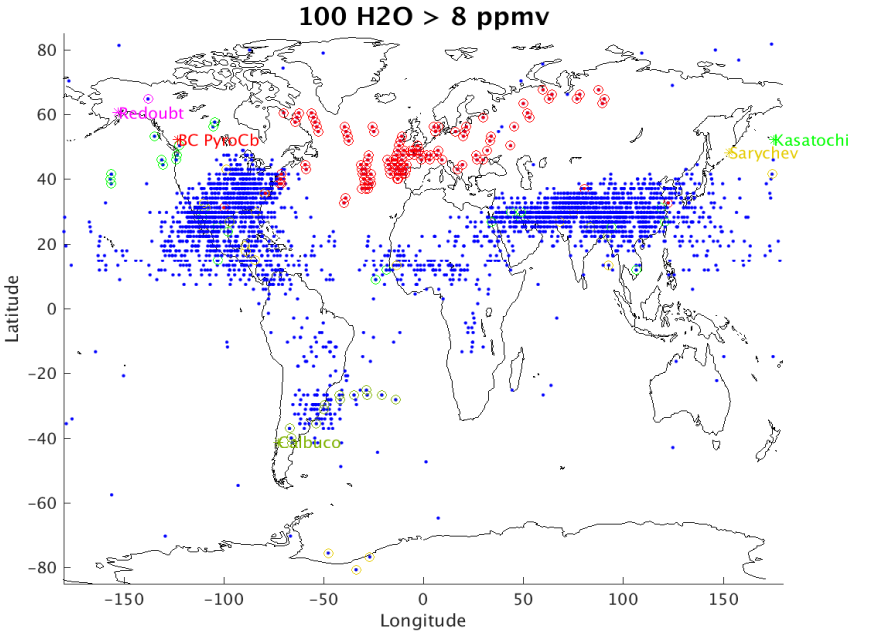


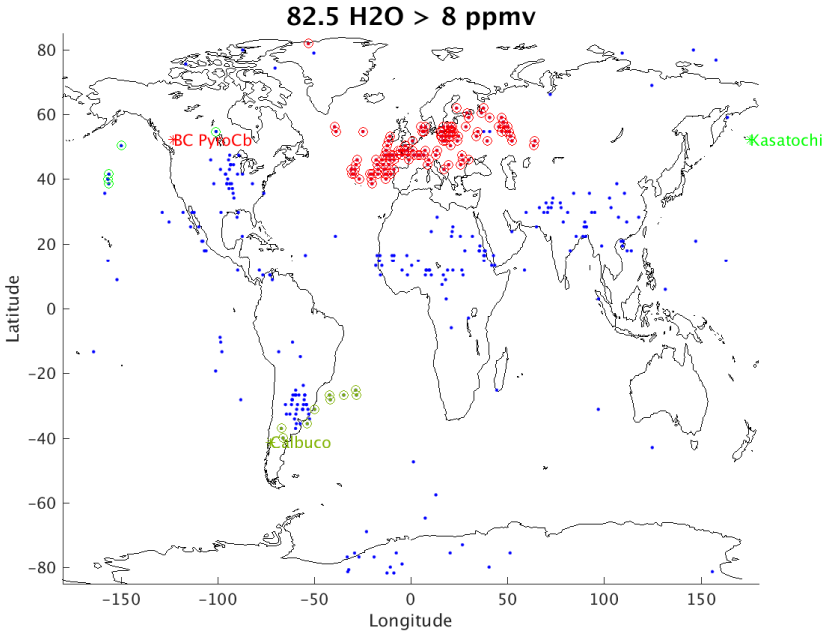
Modeled Activation of Chlorine

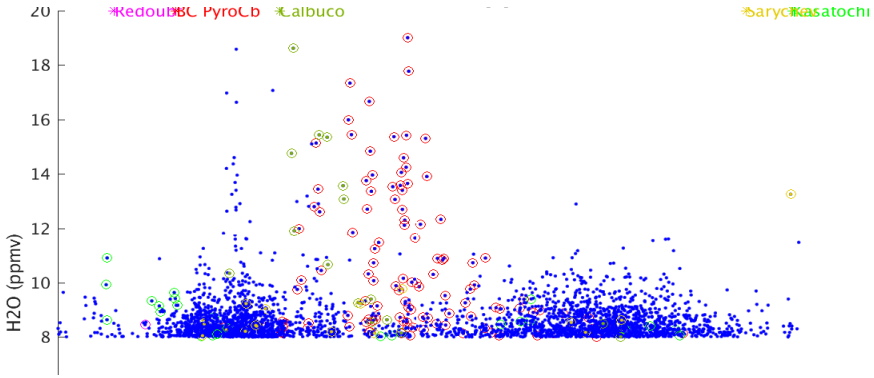
- Anderson, et al. 2012 posit that convectively-injected H2O will lead to ozone destruction over the U.S.A.
- Their model requires cold wet conditions for the growth of particles on which heterogeneous chemistry can occur.
- Joint histograms of MLS H2O and collocated reanalysis temperature are shown, with black and gray curves indicating thresholds for rapid activation.
- It is rare in the NAMA (at the resolution of MLS) for conditions to be cold/wet enough to meet Anderson et al.'s activation threshold, but common in the AMA.

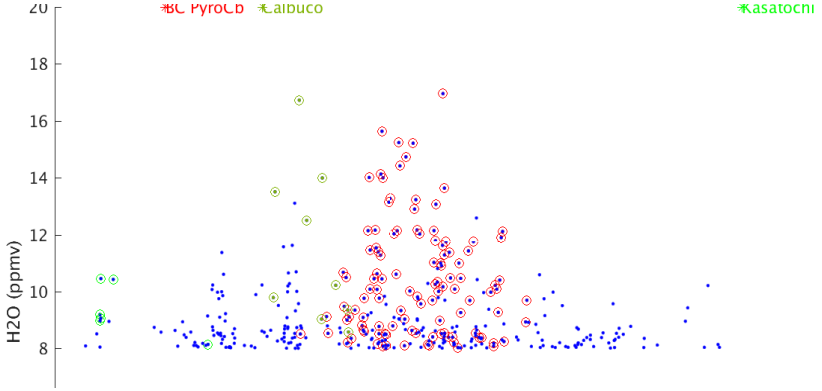


Volcanos and the BC PyroCb



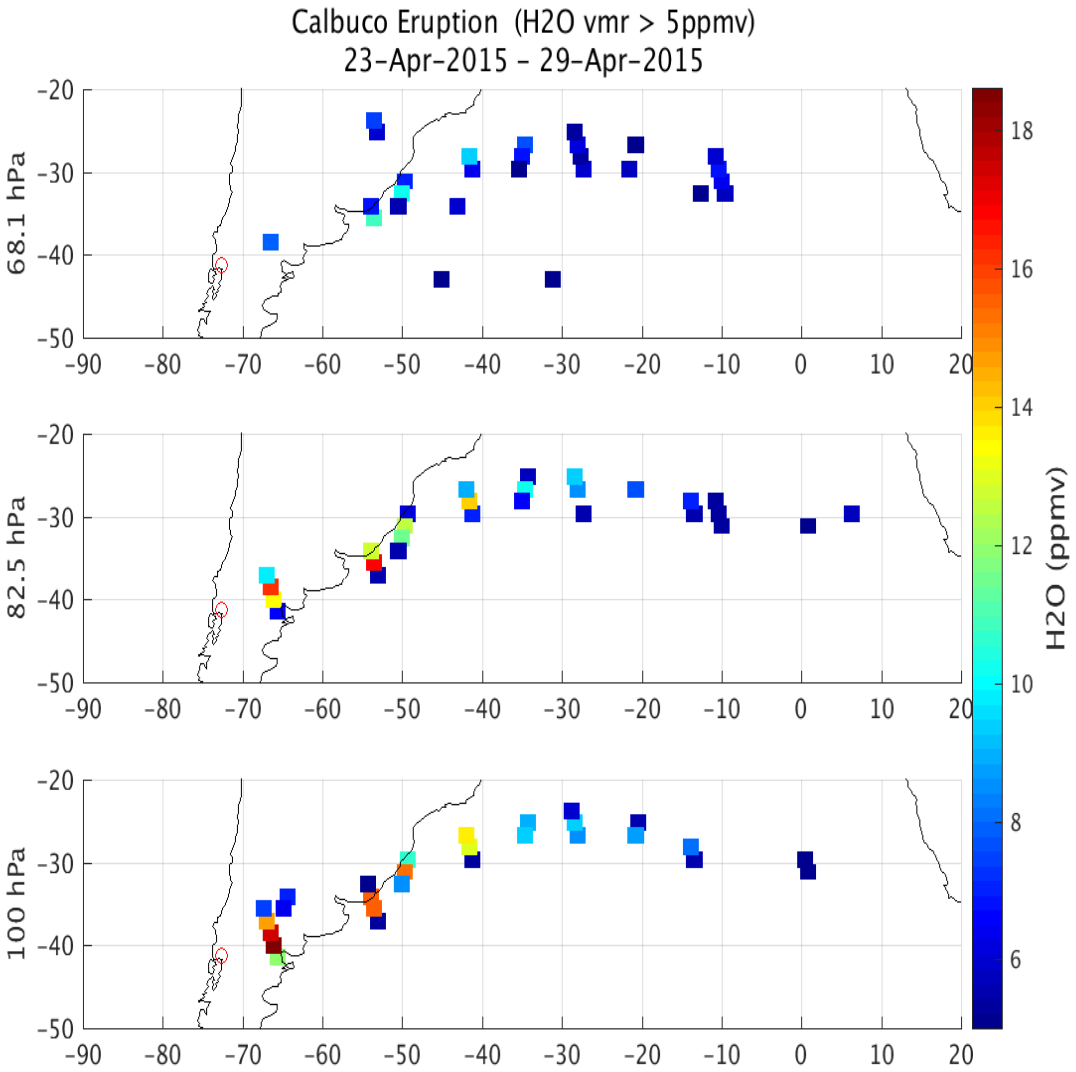




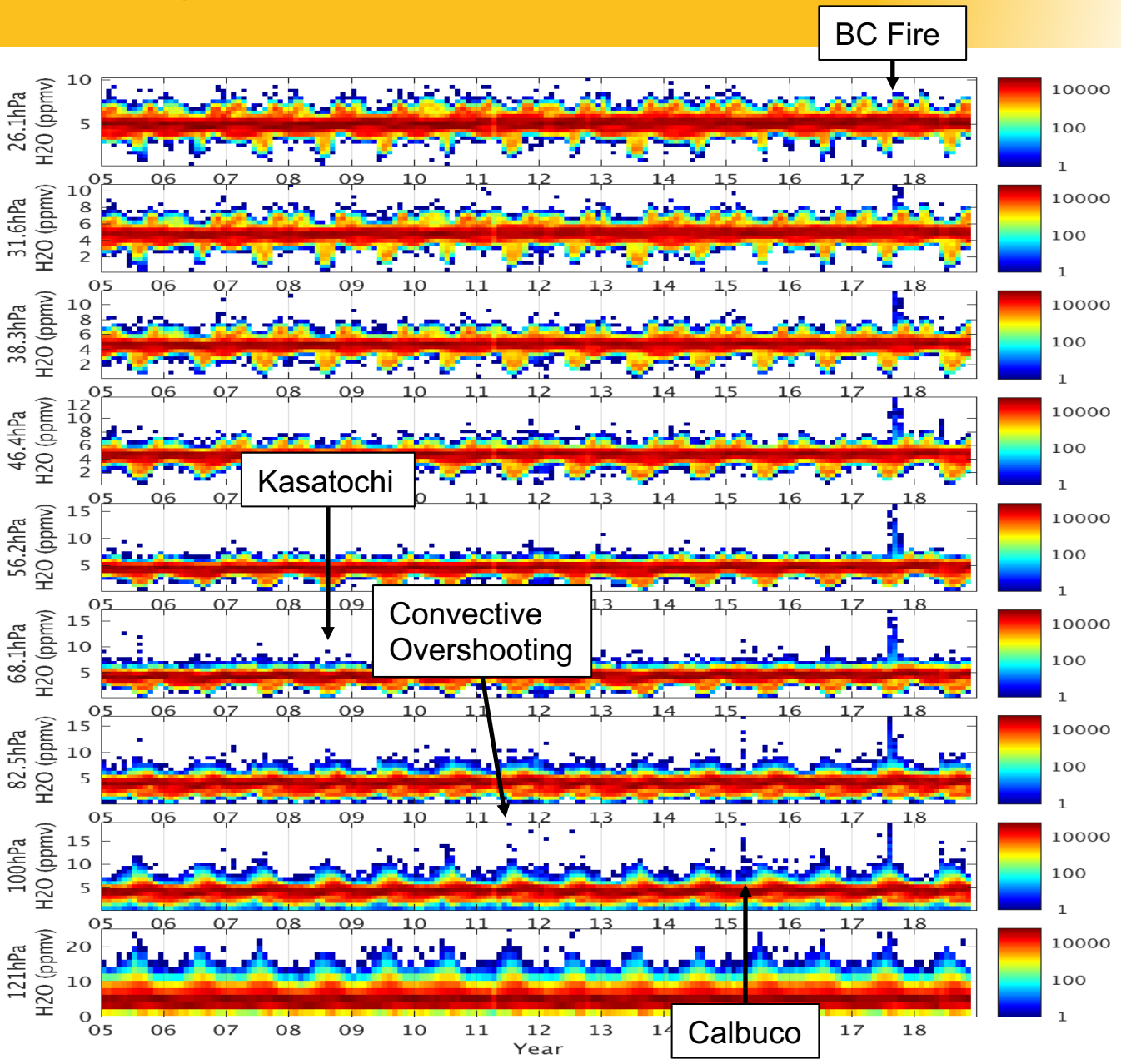


Calbuco April 2015

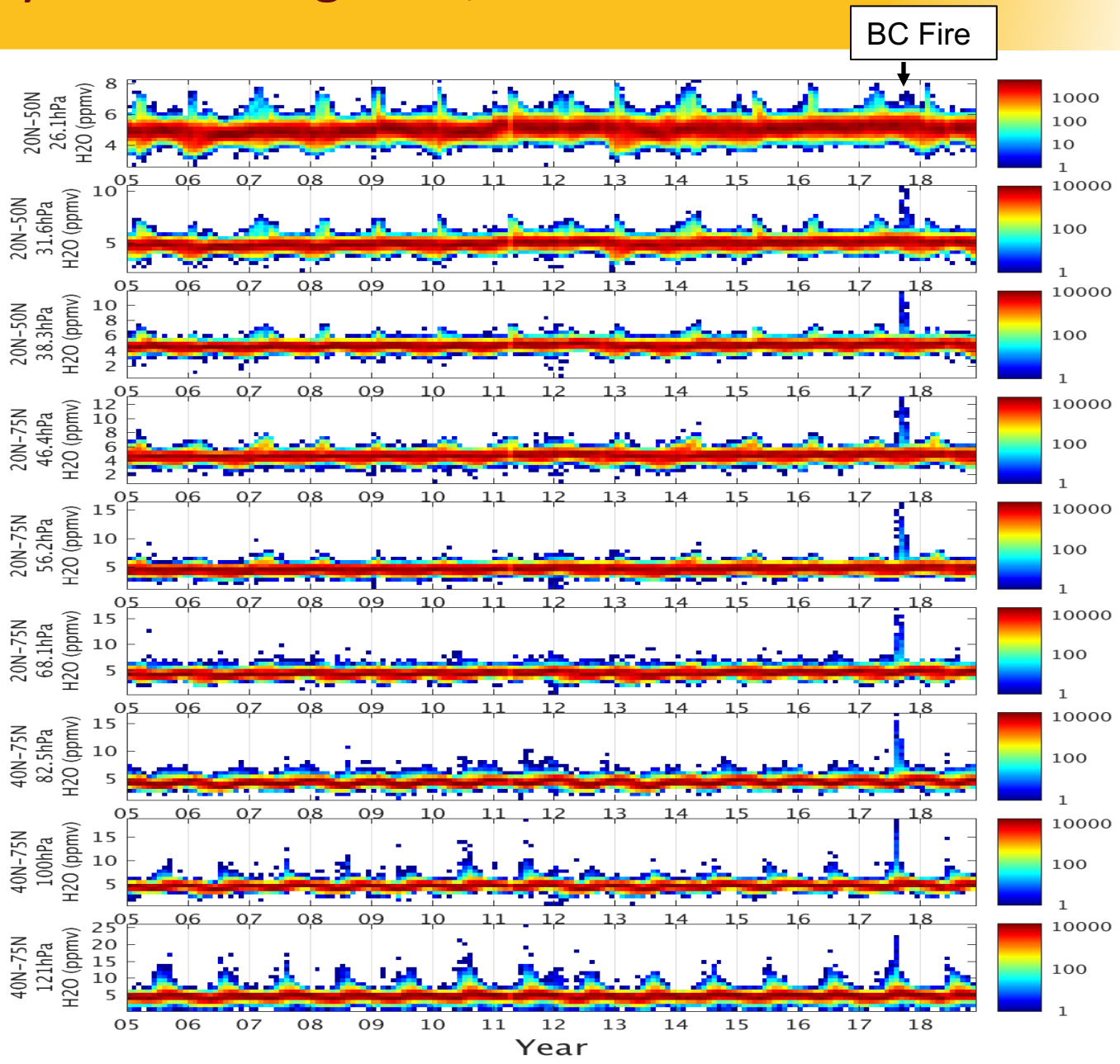
- The eruption of Calbuco in southern Chile in April, 2015 produced some of the highest 100 hPa, 82.5chPa and 68 hPa water vapor observations in the MLS record.
- Aerosol from this plume was tracked for an extended period of time and has been reported to have eventually found its way into the lower part of the southern winter polar vortex.
- However, the clear signature in MLS H2O outliers only lasts 7 days.



Monthly Histograms of MLS LS H2O (2005-2018)

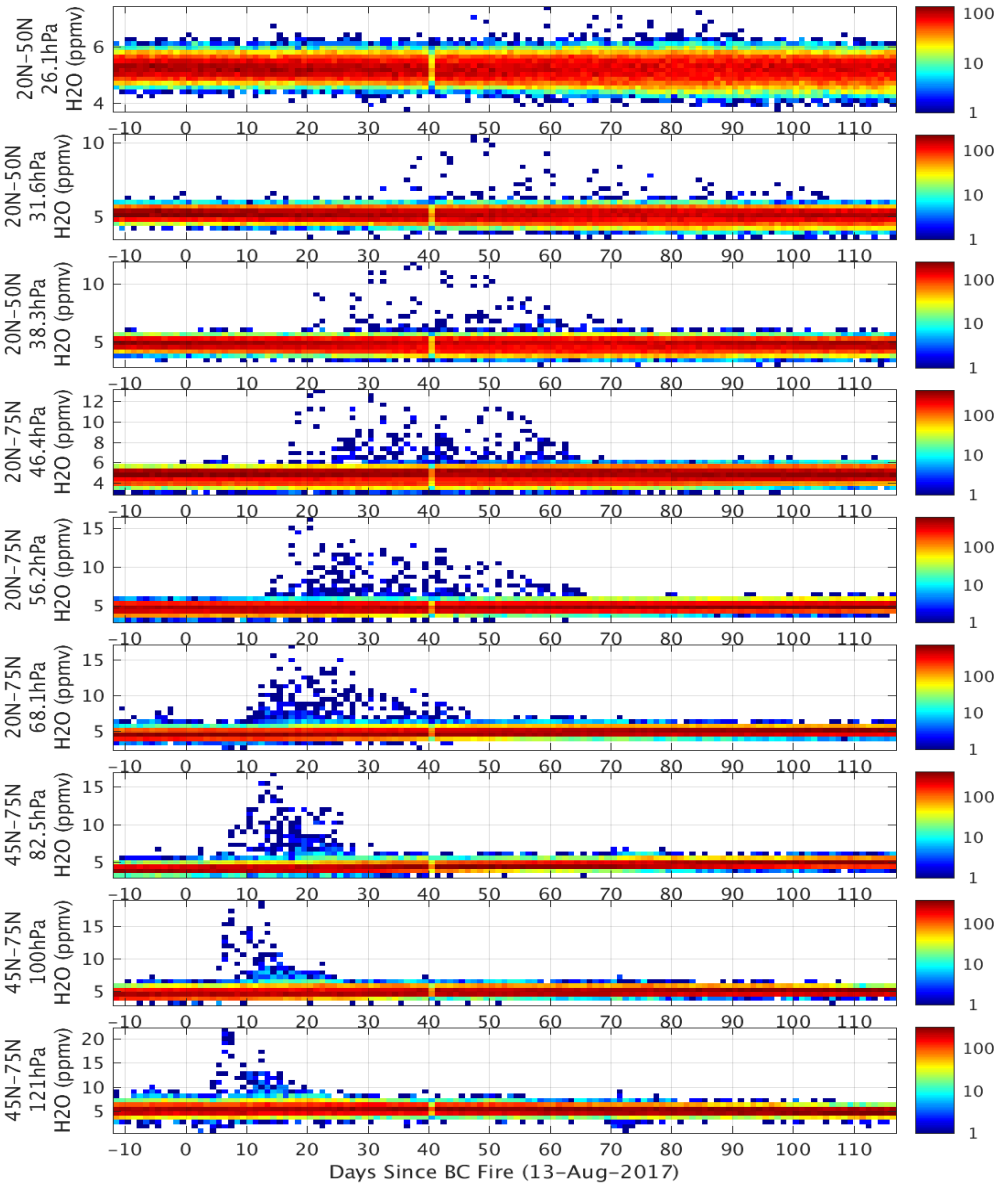


Monthly H2O Histograms, Northern mid-Latitudes

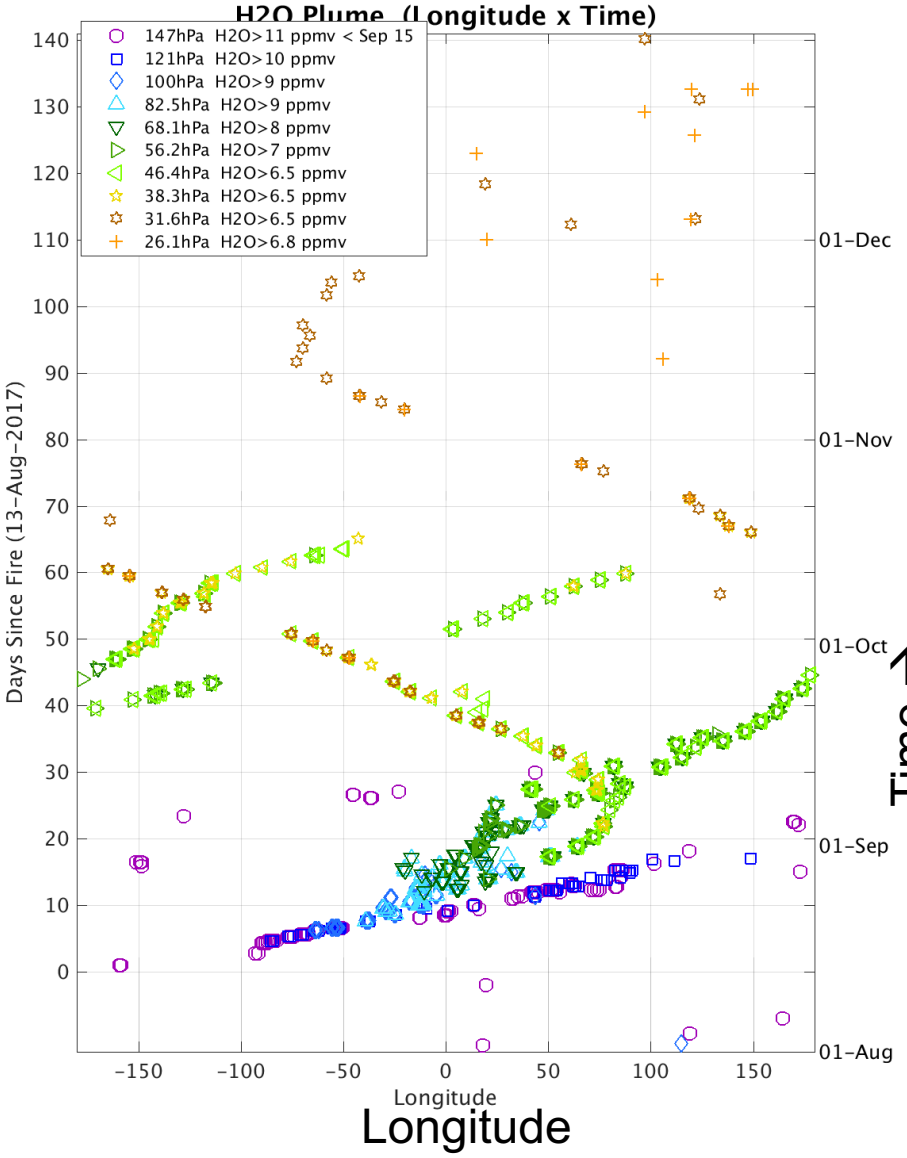


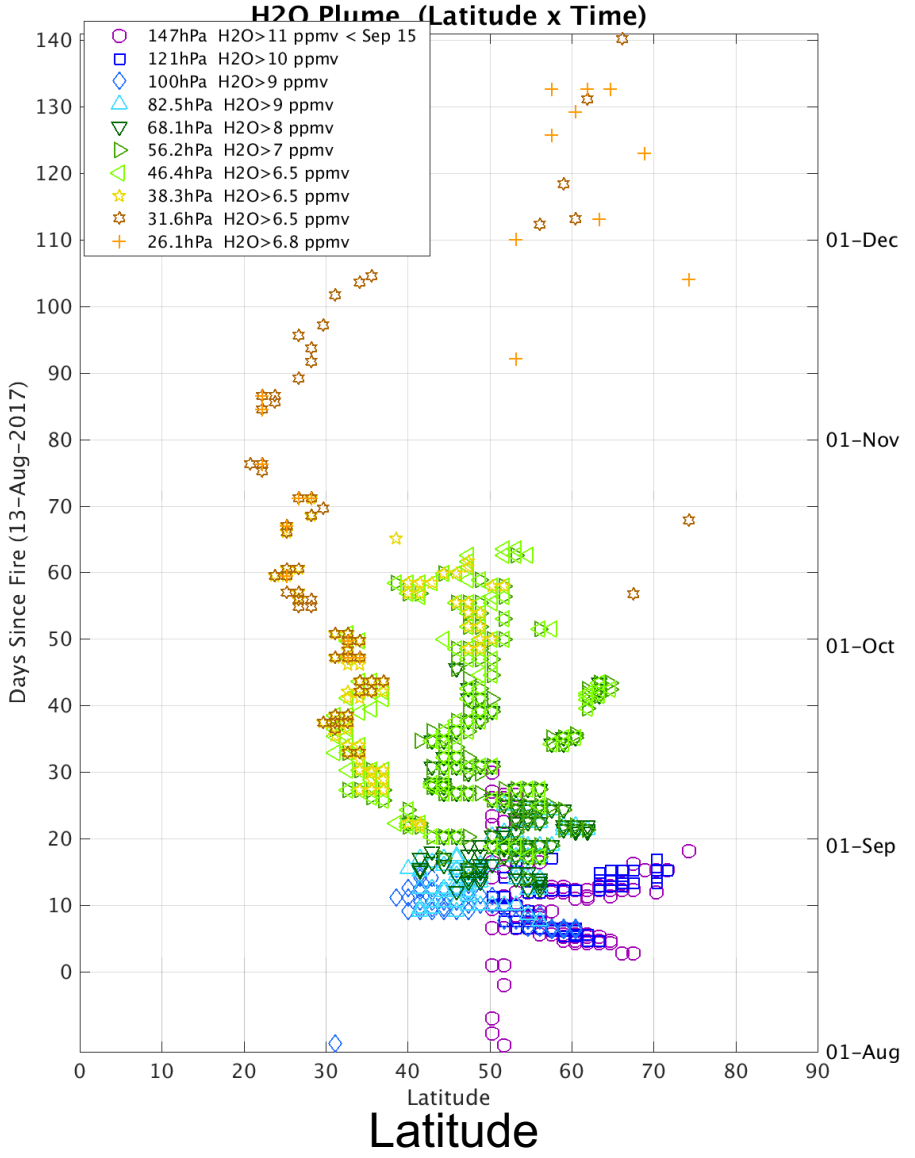
Daily histograms of LS H2O after the BC PyroCb

- This plume produced the highest H2O mixing ratios in the MLS record throughout the lower stratosphere.
- Clear signatures can be seen for over 100 days.
- Latitudes were restricted at the highest levels to avoid any possible inclusion of descending ~7ppmv mesospheric water vapor (from oxidation of methane.)

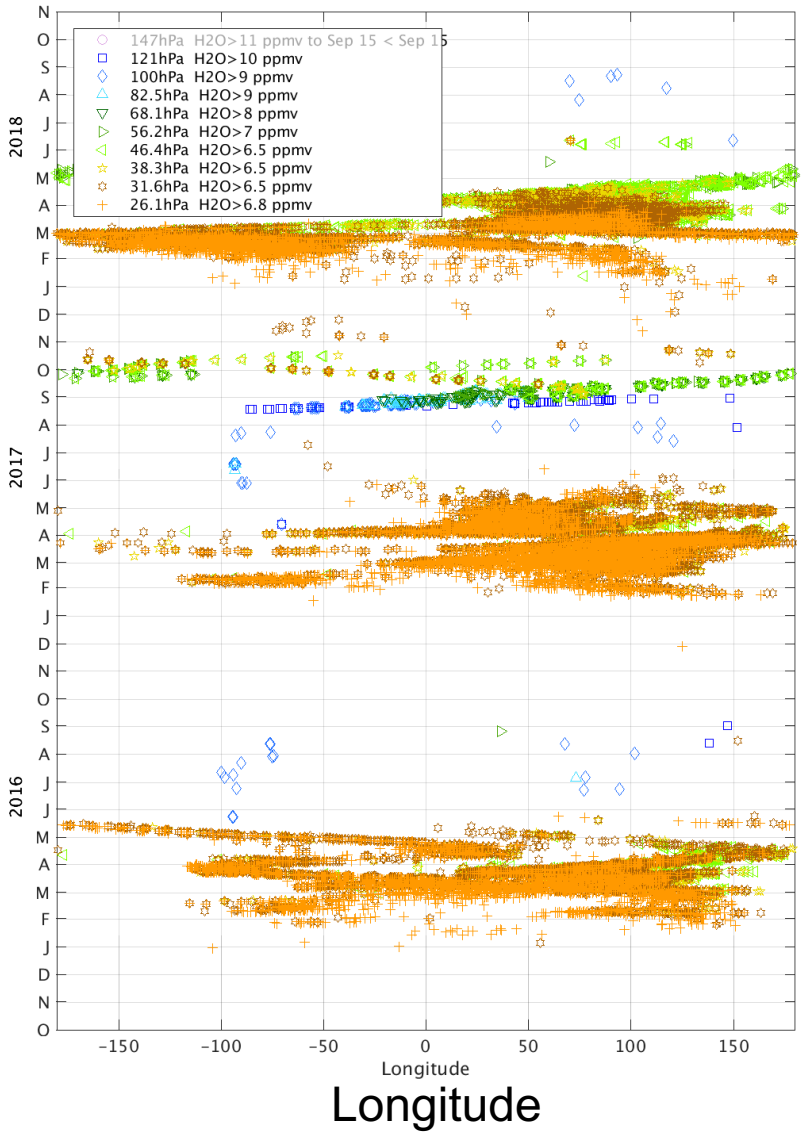


H2O Plume (Time vs Longitude and Time vs Latitude)

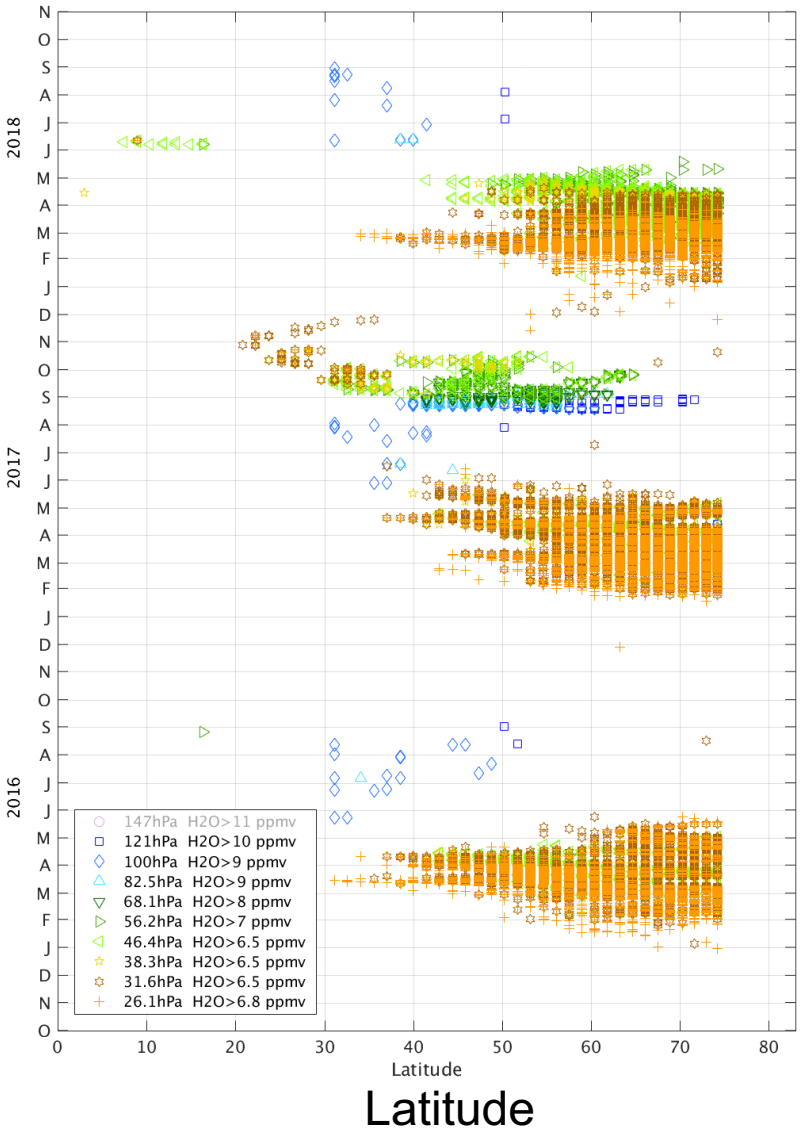




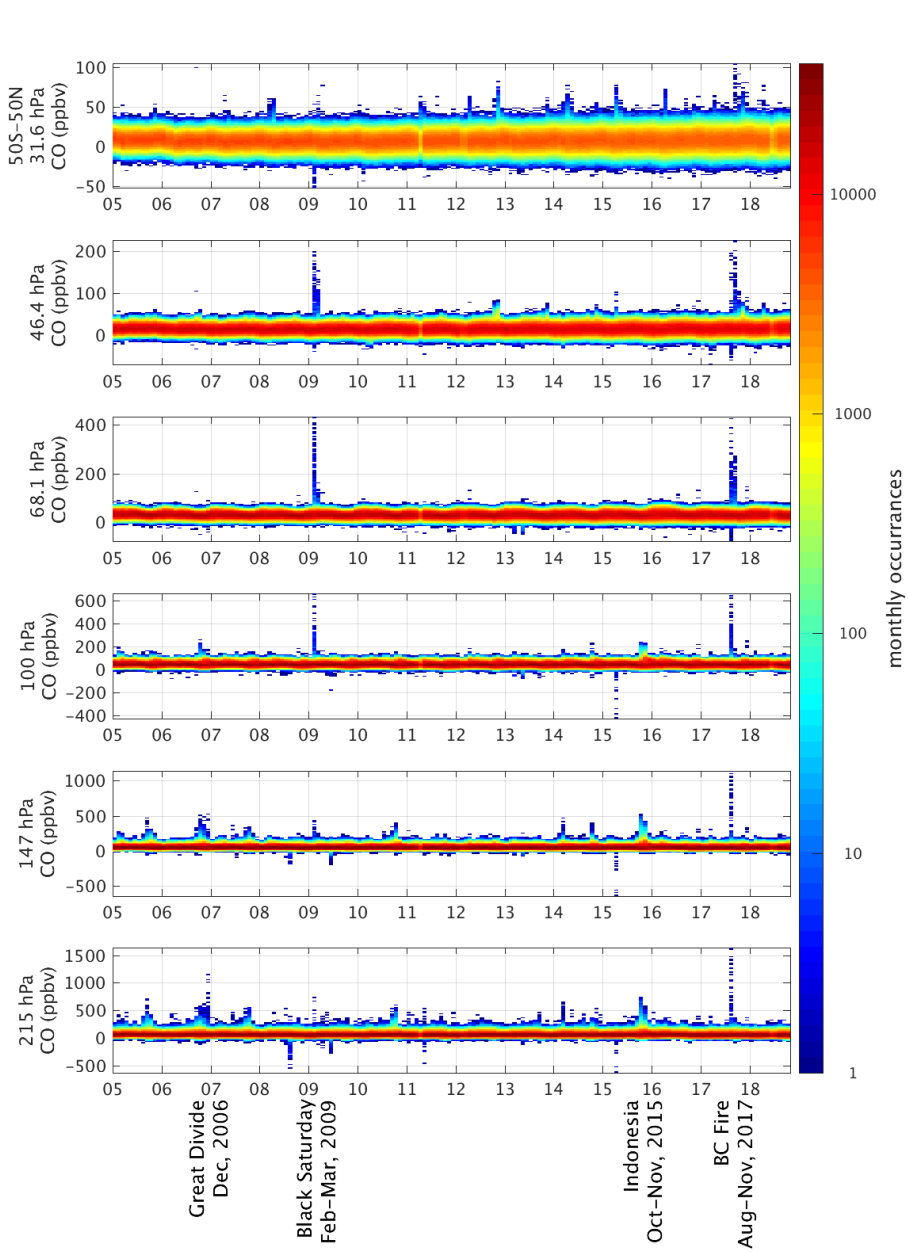
H2O Plume (Longitude Time) and (Latitude Time)

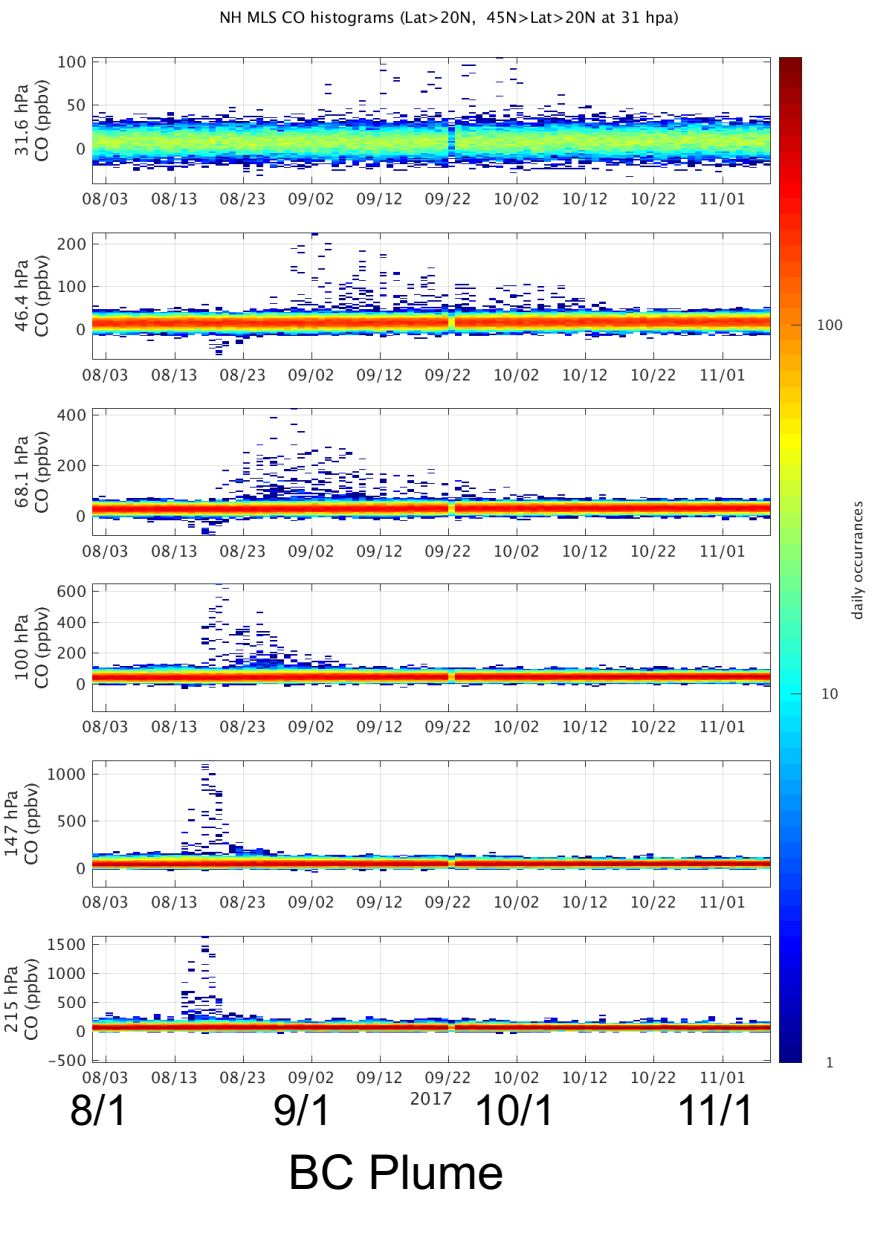


Time (3 years) →

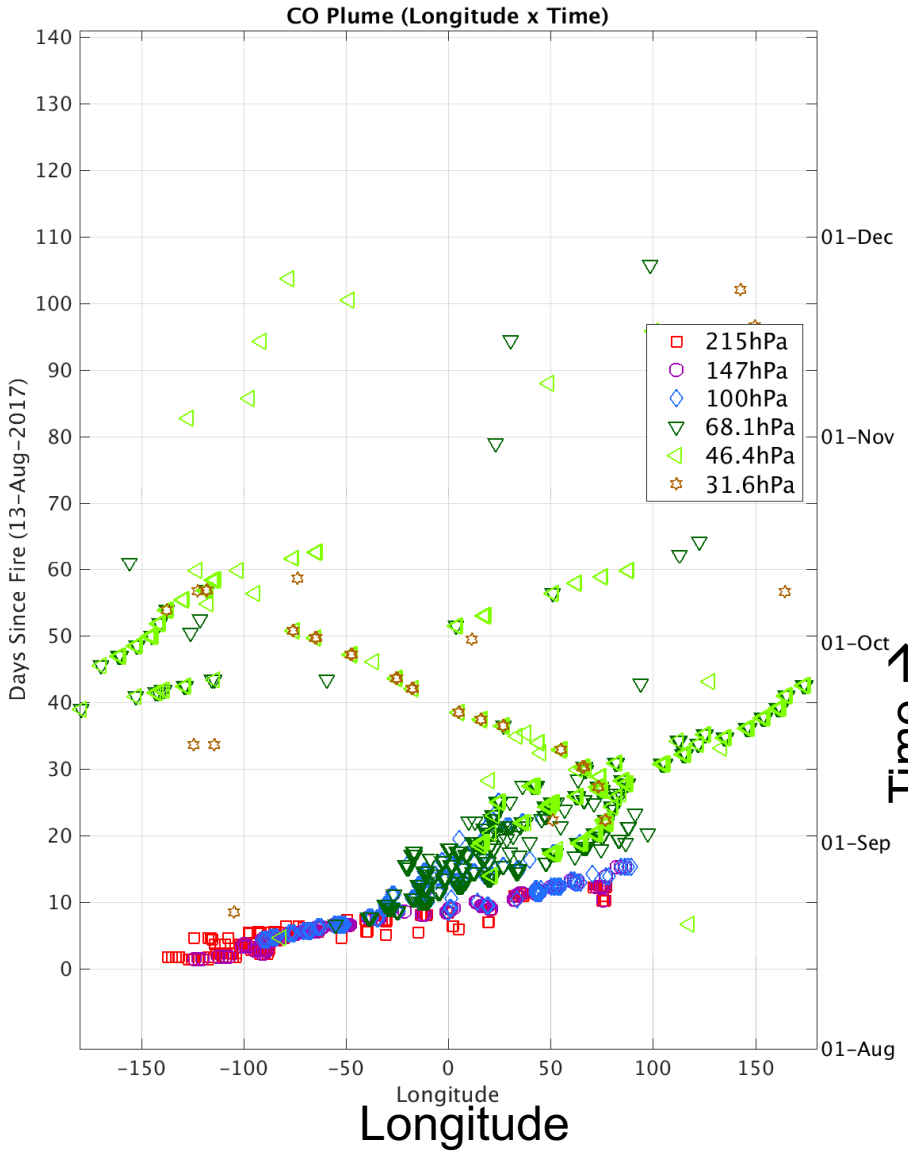


CO Timeseries 215 hPa—31 hPa

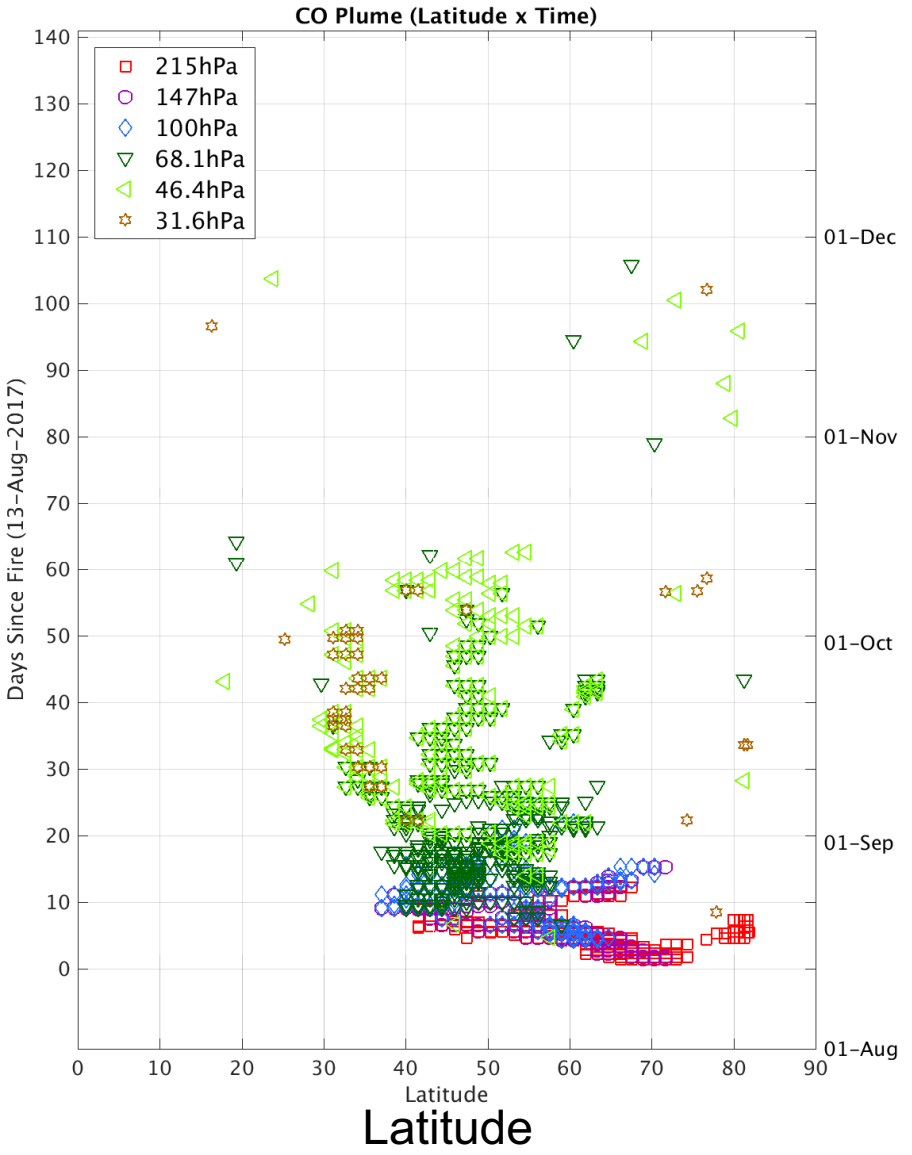




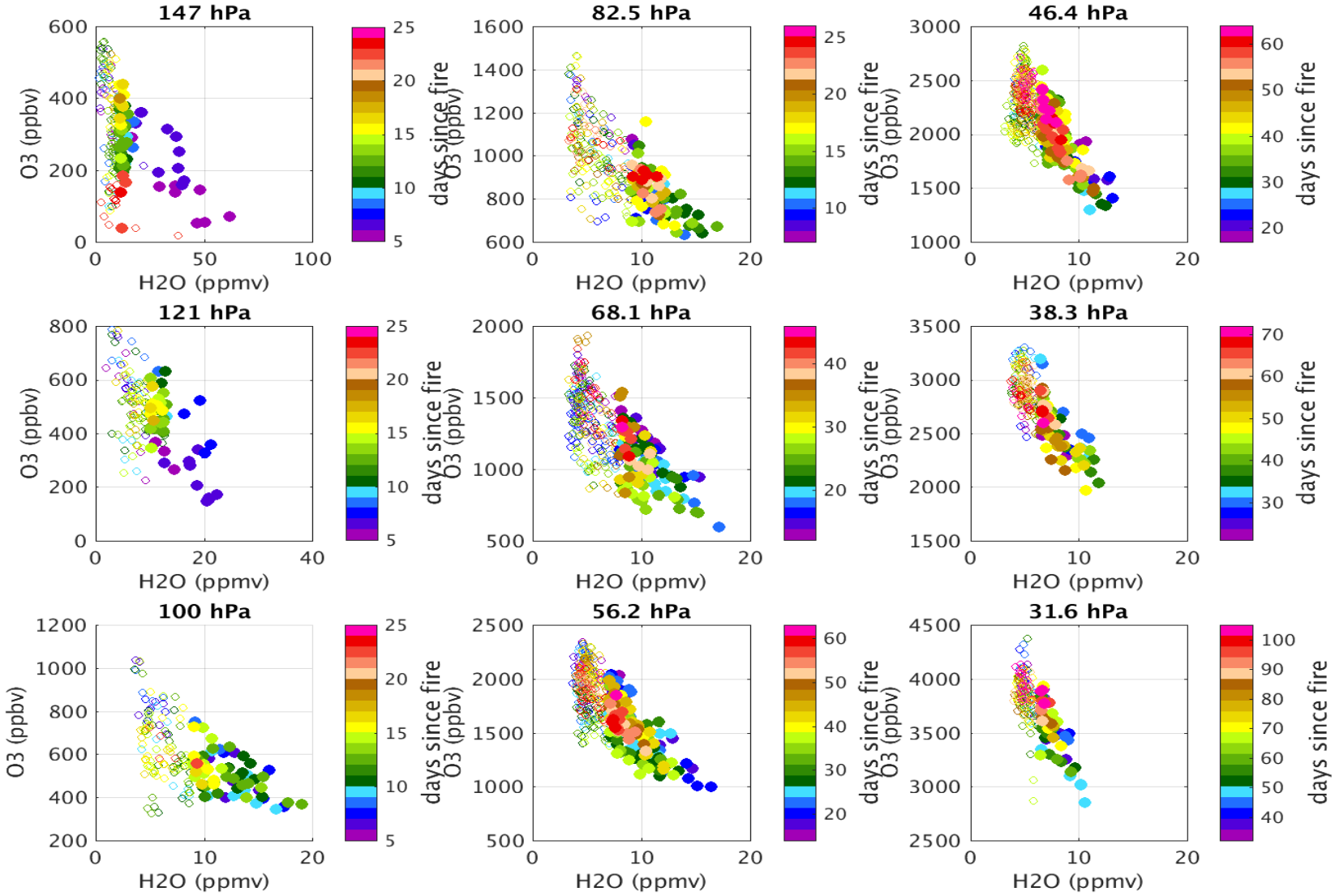
BC CO Plume



Time →



Ozone vs H2O in the BC PyroCb Plume



Conclusions

- Overshooting convection in the Monsoons is the most common source of high outliers at 100 hPa and 83 hPa in the northern summer. The significance of this source of elevated H2O for LS chemistry (particularly ozone destruction) is a matter of current study in the community.
- There have been no large (e.g. Pinotubo-scale) volcanic eruptions in the Aura MLS time period, but H2O plumes from several volcanos have been observed. Mixing ratios in the Calbuco plume up to 68 hPa are as high or higher than any associated with the summer monsoons, but are events of significant volcanic elevation of H2O are rare and short lived in the record.
- The plume from the B.C. PyroCb of 2017 is, by far, the largest and longest-lived injection of H2O into the stratosphere observed by MLS. It is much wetter than the plume of the Australian Black Saturday PyroCb, which had a similar signature in carbon monoxide.
- If fire complexes like that which gave rise to the B.C. PyroCb become more common in a changing climate, such plumes could have an increasingly significant impacts on the chemistry of the stratosphere.

Backup Slides:

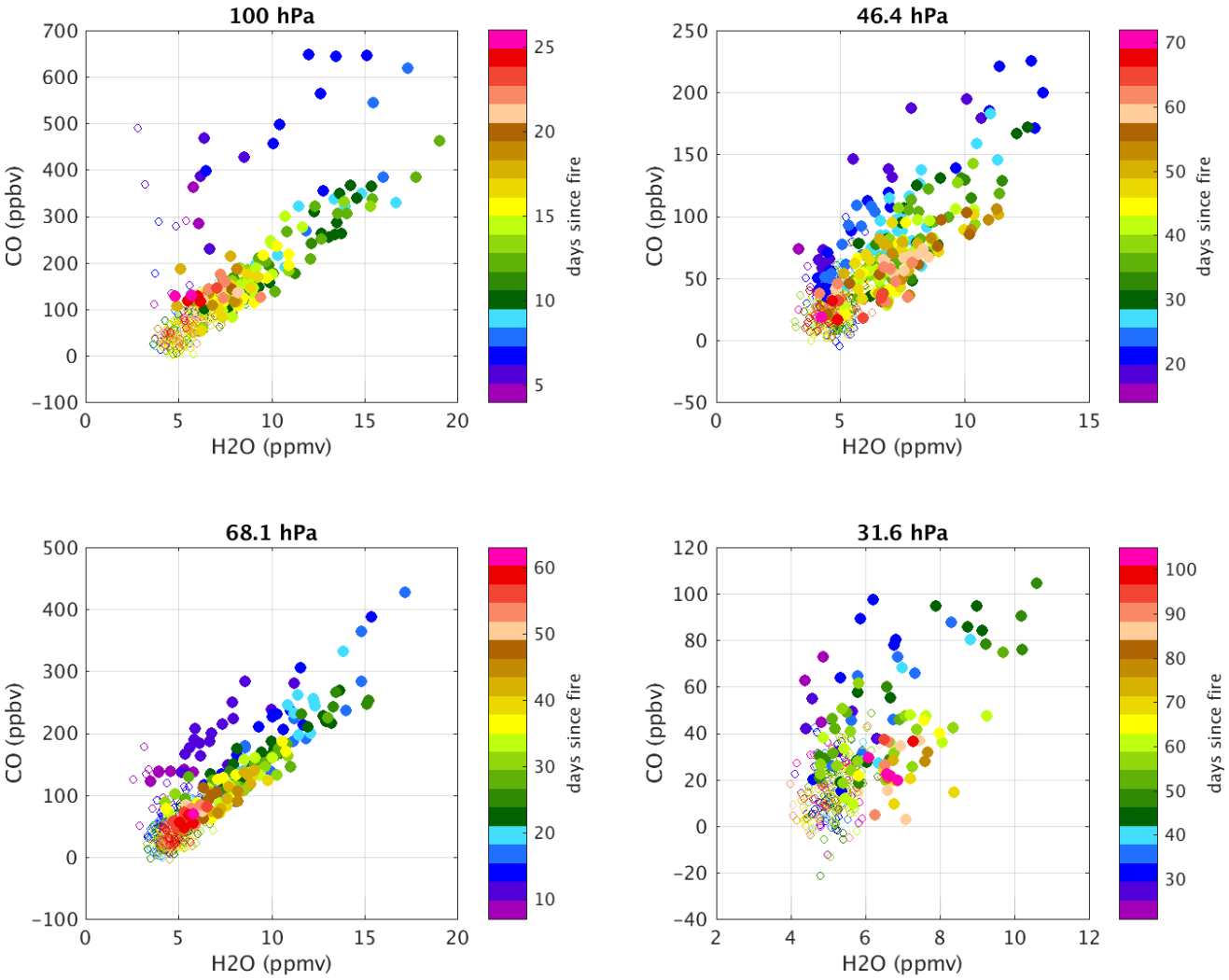
Constituent Correlations in the BC Fire Plume

Lower-Strat MLS Products for PyroCb Plume Studies

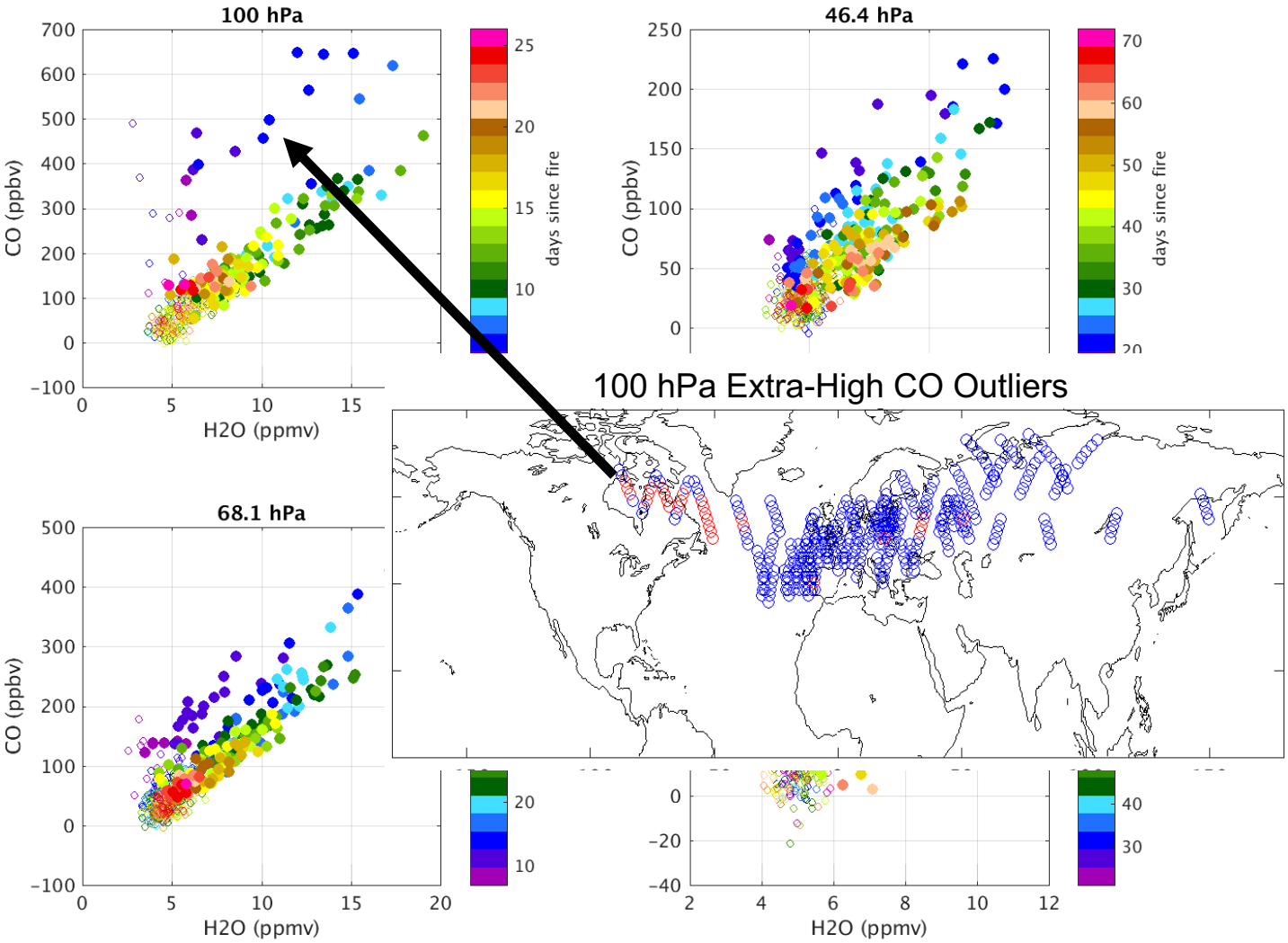
DOWNLOAD AND READ THE DATA QUALITY DOCUMENT
Contact the science team if you have questions

	LS VAvk FWHM	LS HAvk FWHM	Useful Vertical range	Precision	Estimated Accuracy	Retrieval resolution
CO	5 km	425 km	215-0.0046 hPa	9—14 ppbv	~50%	6/decade
H2O	3.1 km	190 km	316—0.002 hPa	5—10%	4—9%	12/decade
O3	2.5 km	350 km	261—0.02 hPa	60 ppbv + 3%	100 ppbv + 7%	12/decade
HNO3	4 km	400 km	215—1 hPa	0.6 ppbv	1—1.5 ppbv	6/decade
CH3CN	5.5 km	500 km	147—1 hpa	50 pptv	100%	6/decade
CH3Cl	5.5 km	450 km	147—4.6 hPa	100 pptv	30--50%	6/decade
CH3OH	5 km	350 km	Contact MLS	1 ppbv	100 %	6/decade
HCl	3 km	300 km	147—0.32 hPa	0.2ppbv, 50%	0.2 ppbv, 25%	6/decade
HCN	10 km	300 km	21—0.1 hPa (HCP)	50%	poor*	6/decade
ClO	3 km	~400 km	147—1 hPa	0.1 ppbv	0.2 ppbv*	6/decade
T	3.7 km	165 km	261—0..001 hPa	0.6 K	1—2 K	12/decade

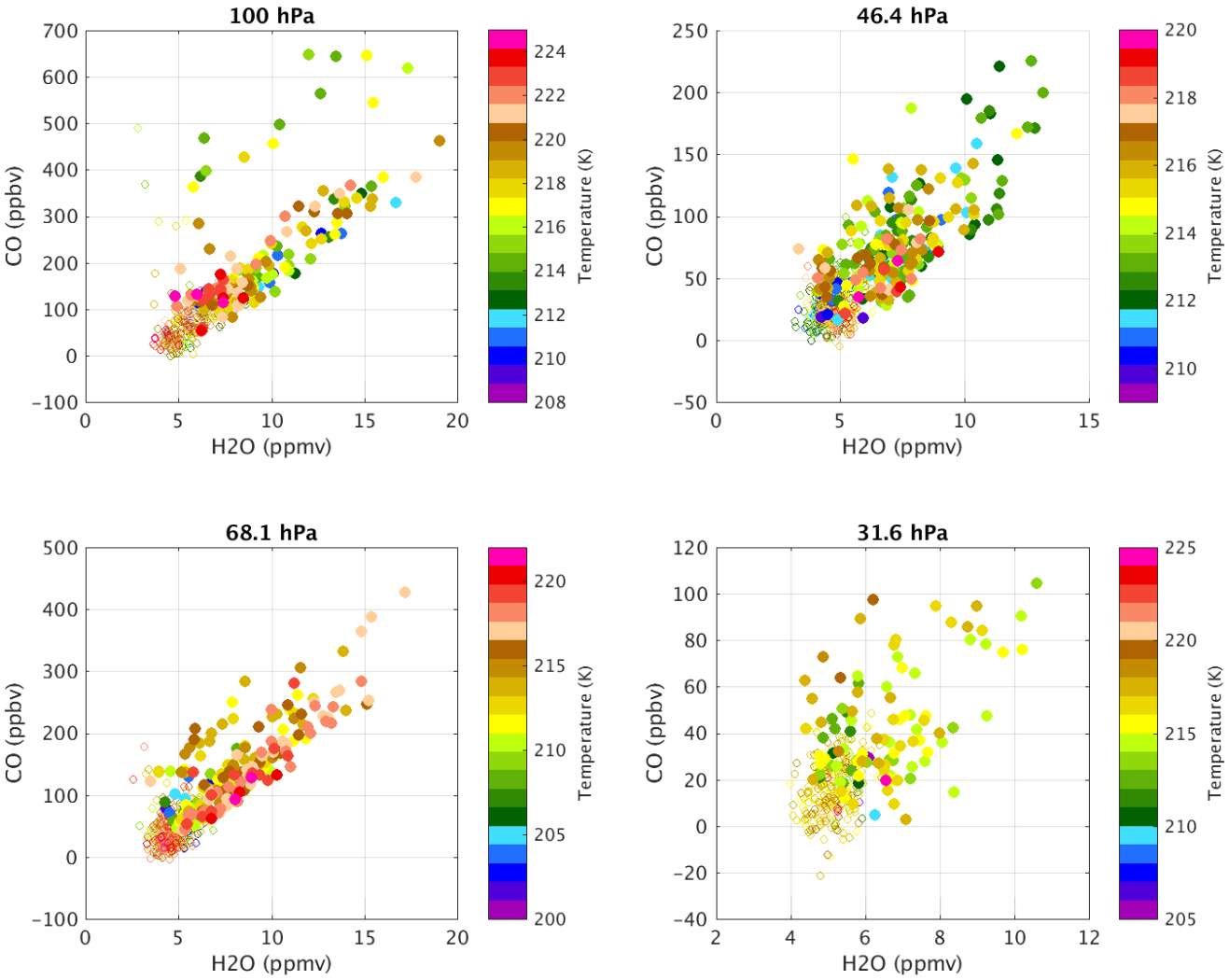
CO vs H2O Correlation (colored by time since fire)



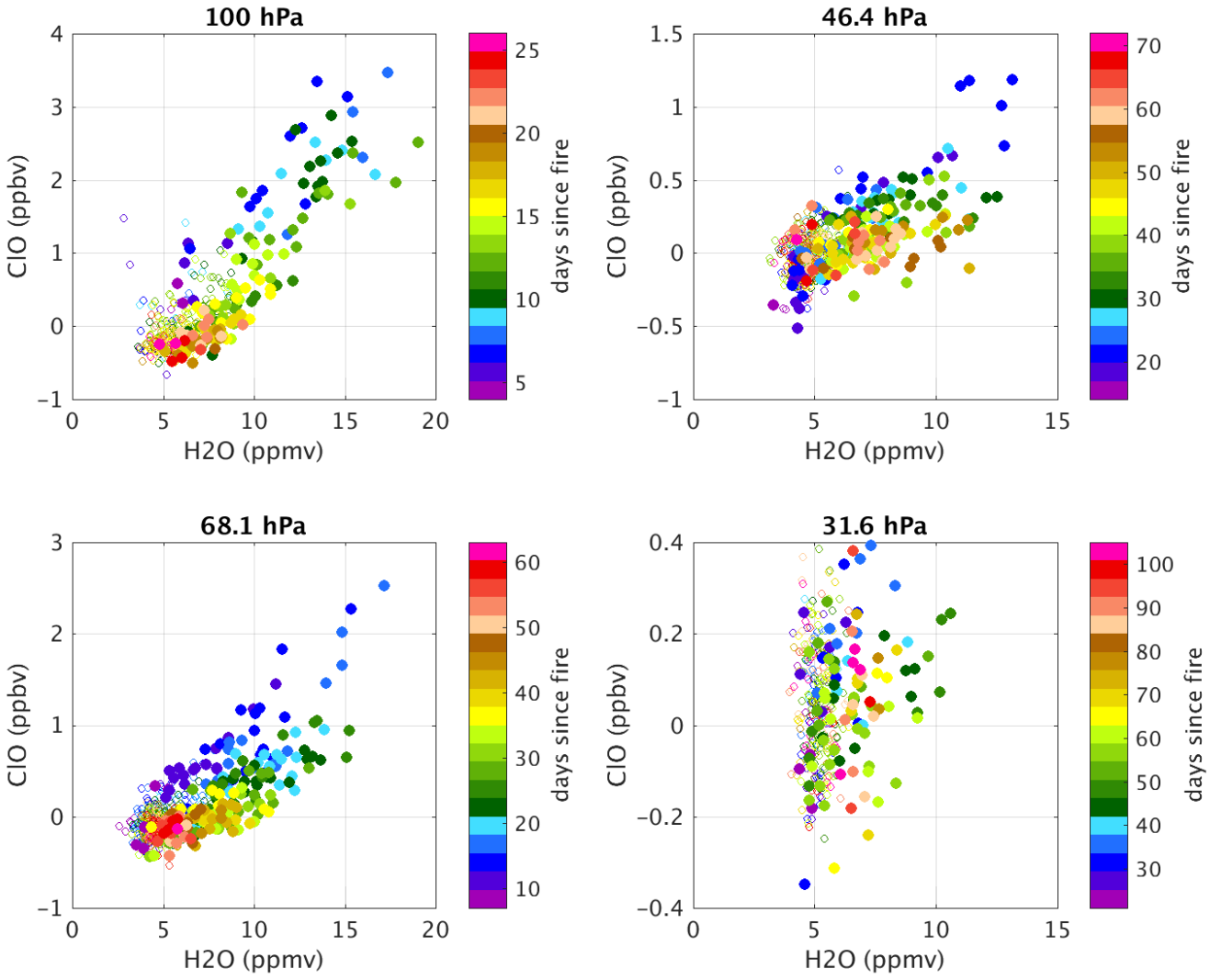
CO vs H2O Correlation (colored by time since fire)



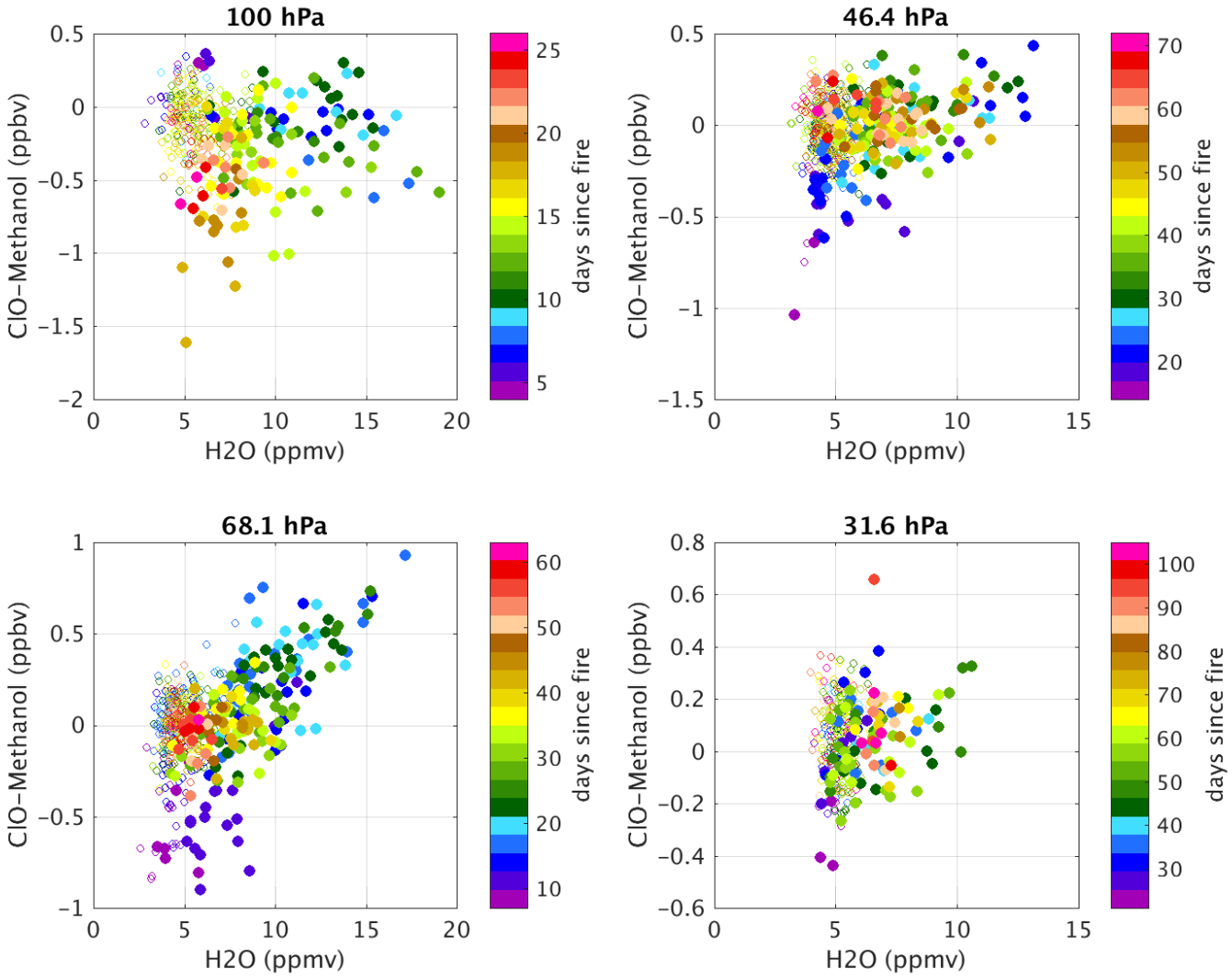
CO vs H2O Correlation (colored by Temperature)



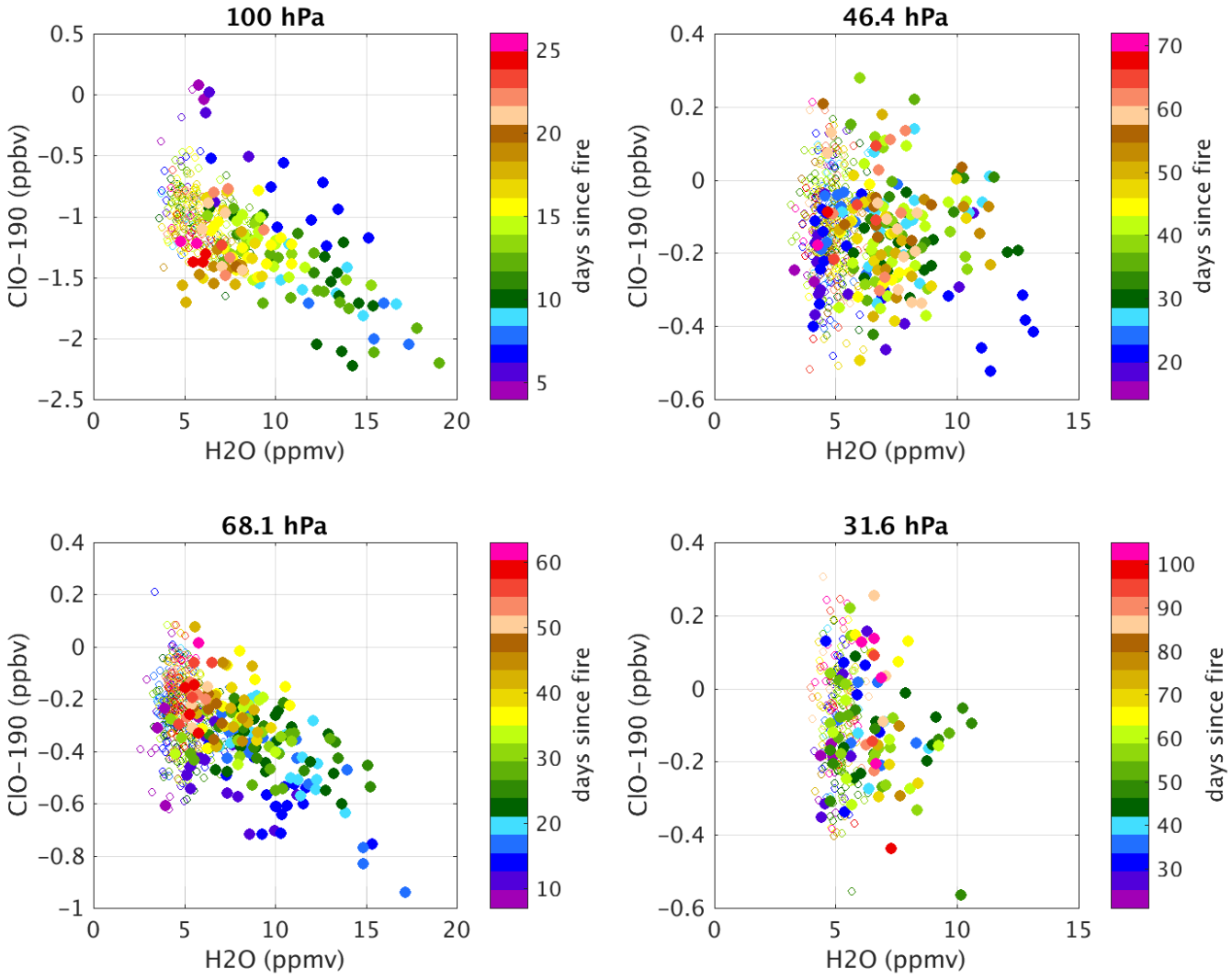
Plume ClO vs H2O (640-GHz, CH3OH Interference)



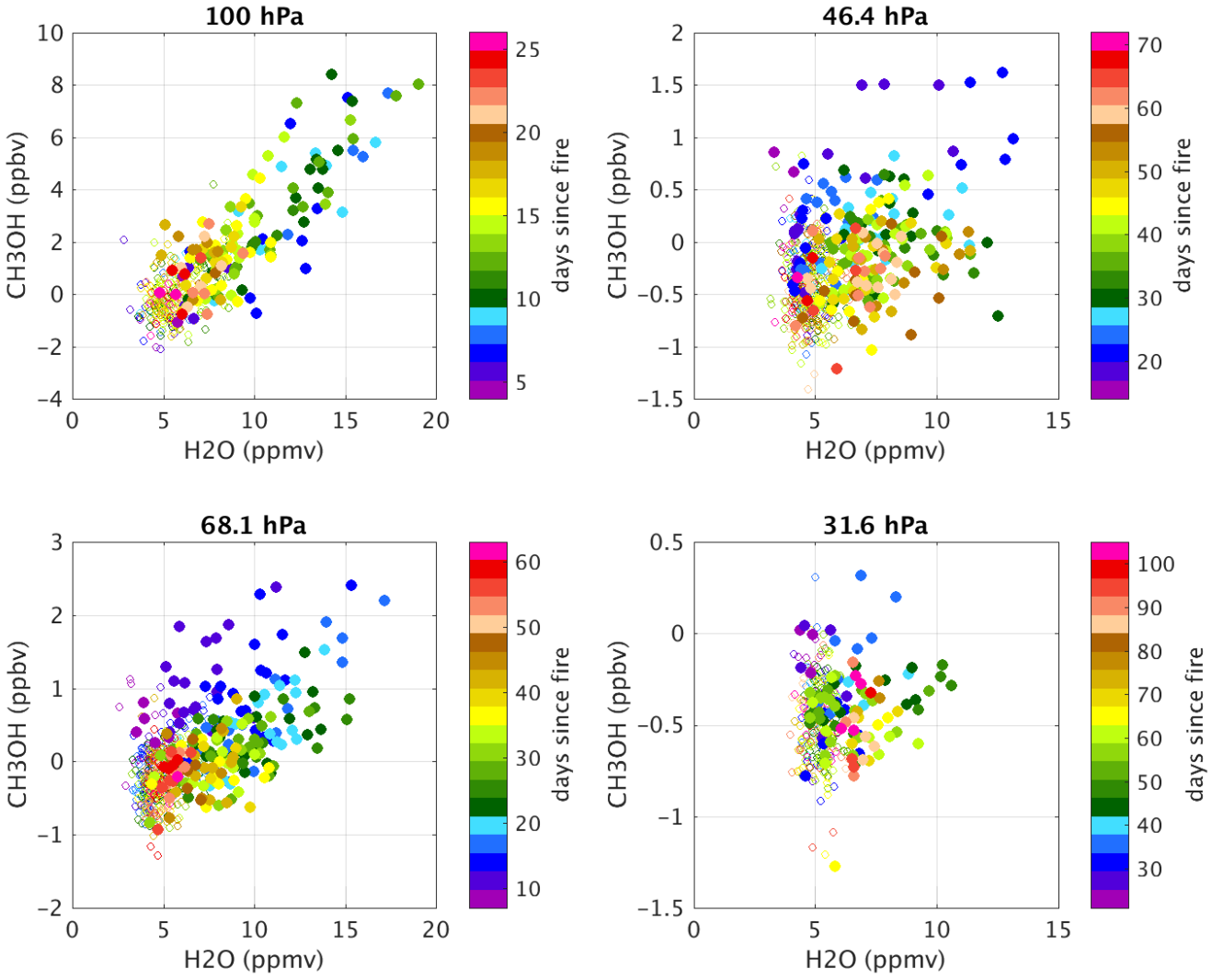
ClO-Methanol vs H2O (640-GHz, retrieve CH3OH)



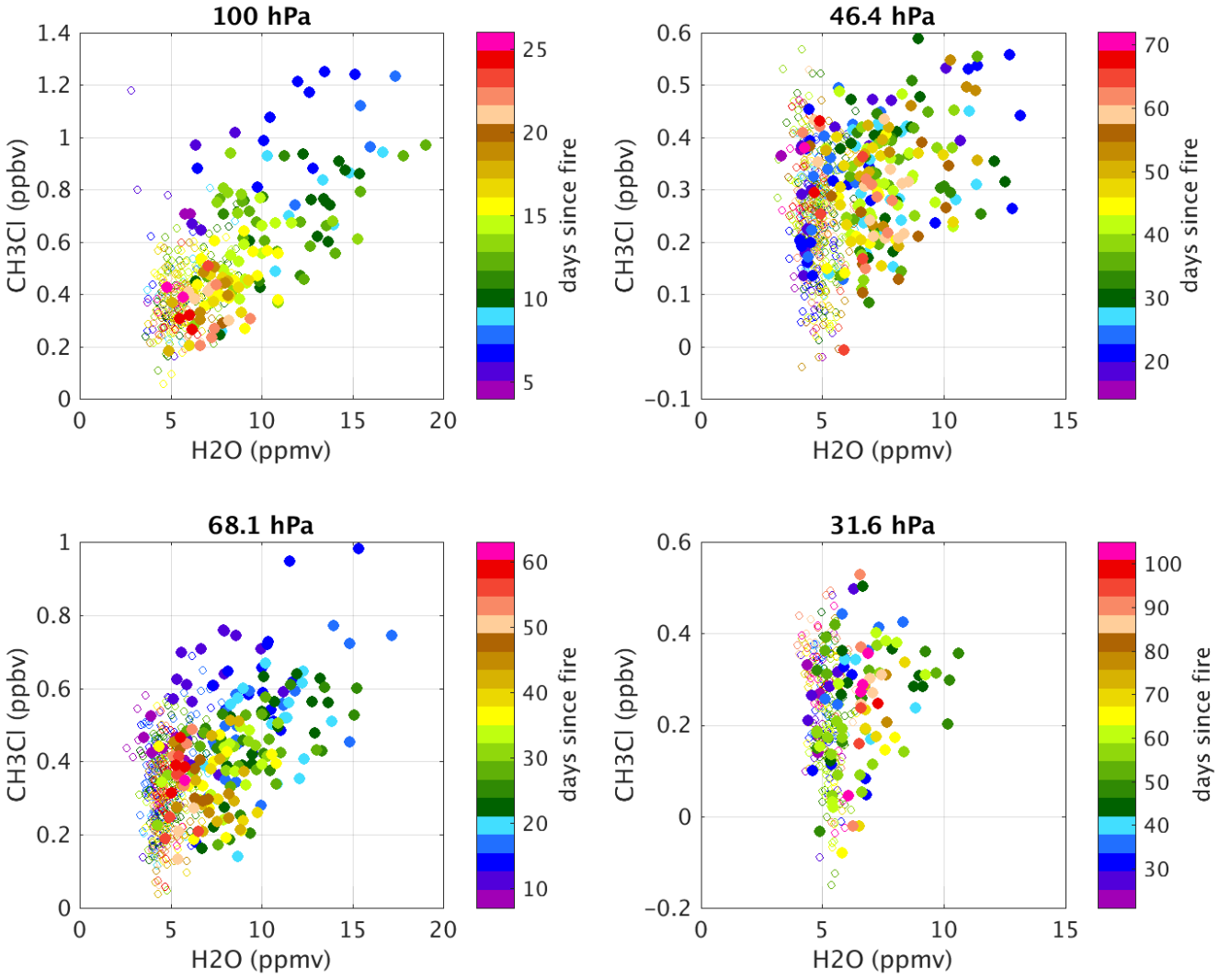
ClO-190 vs H2O (190-GHz, should show same correlation)



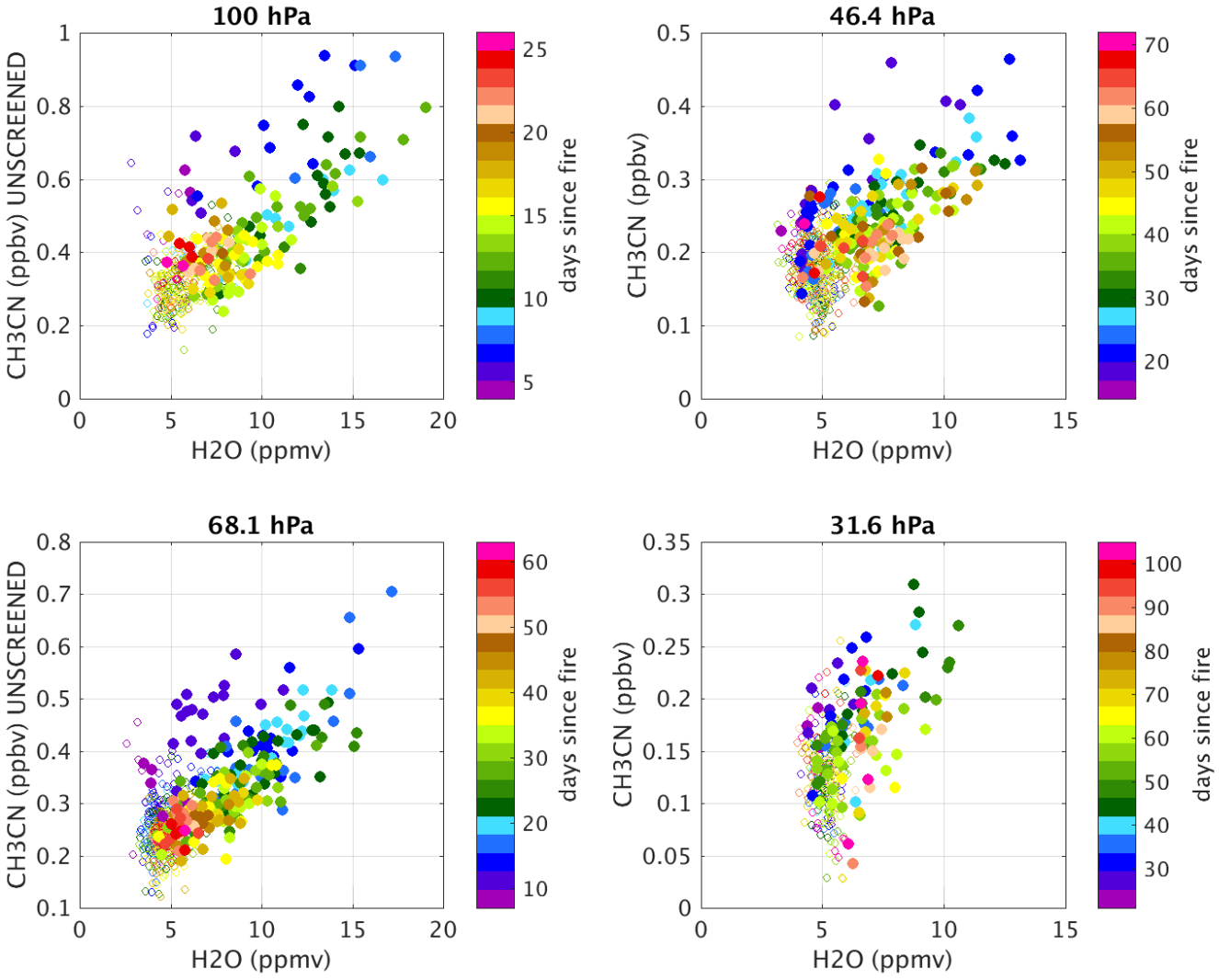
CH3OH vs H2O


100 hPa
CH3OH (ppbv)
H2O (ppmv)
days since fire
46.4 hPa
CH3OH (ppbv)
H2O (ppmv)
days since fire
68.1 hPa
CH3OH (ppbv)
H2O (ppmv)
days since fire
31.6 hPa
CH3OH (ppbv)
H2O (ppmv)
days since fire

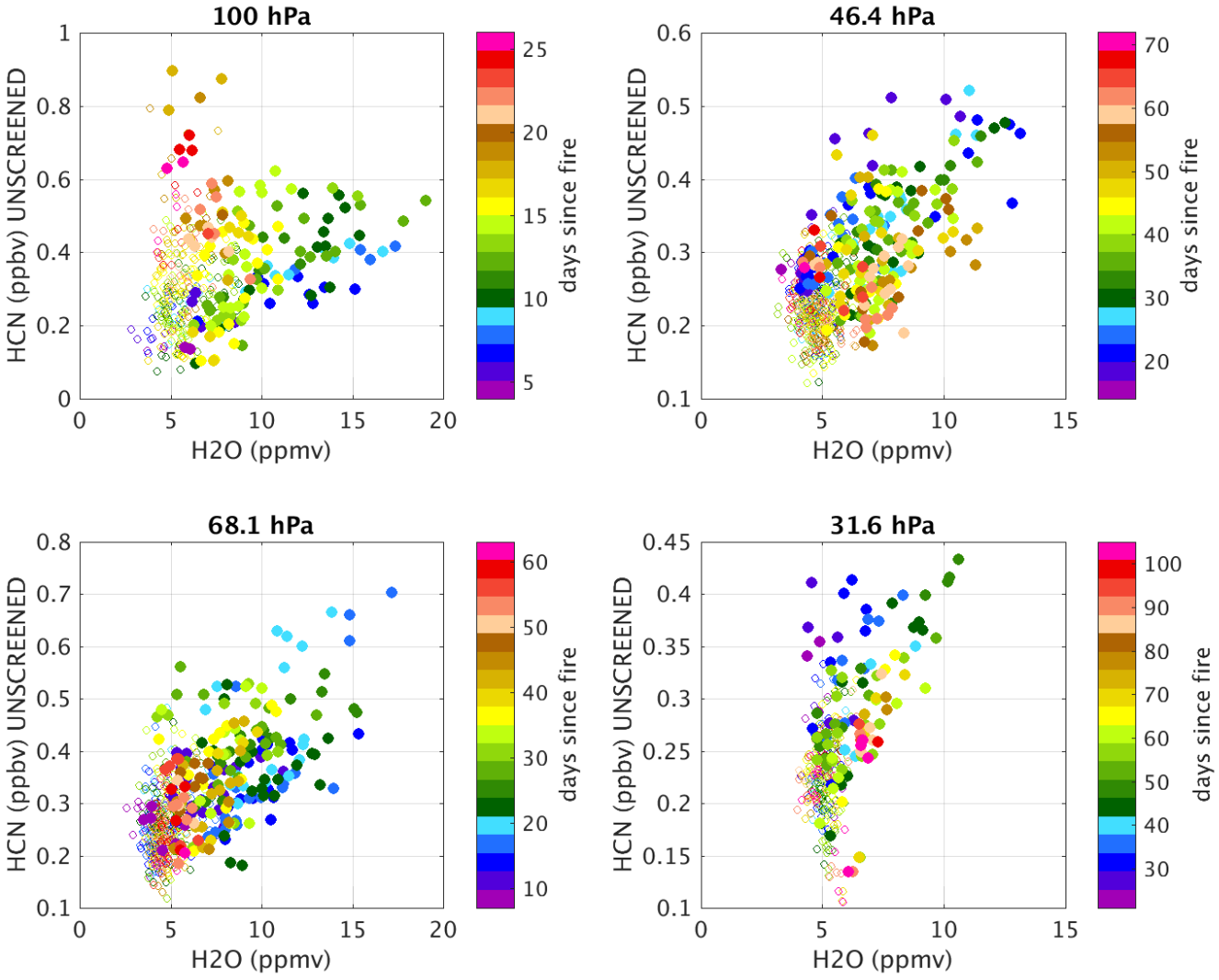
CH3Cl vs H2O


100 hPa
CH3Cl (ppbv)
H2O (ppmv)
days since fire
46.4 hPa
CH3Cl (ppbv)
H2O (ppmv)
days since fire
68.1 hPa
CH3Cl (ppbv)
H2O (ppmv)
days since fire
31.6 hPa
CH3Cl (ppbv)
H2O (ppmv)
days since fire

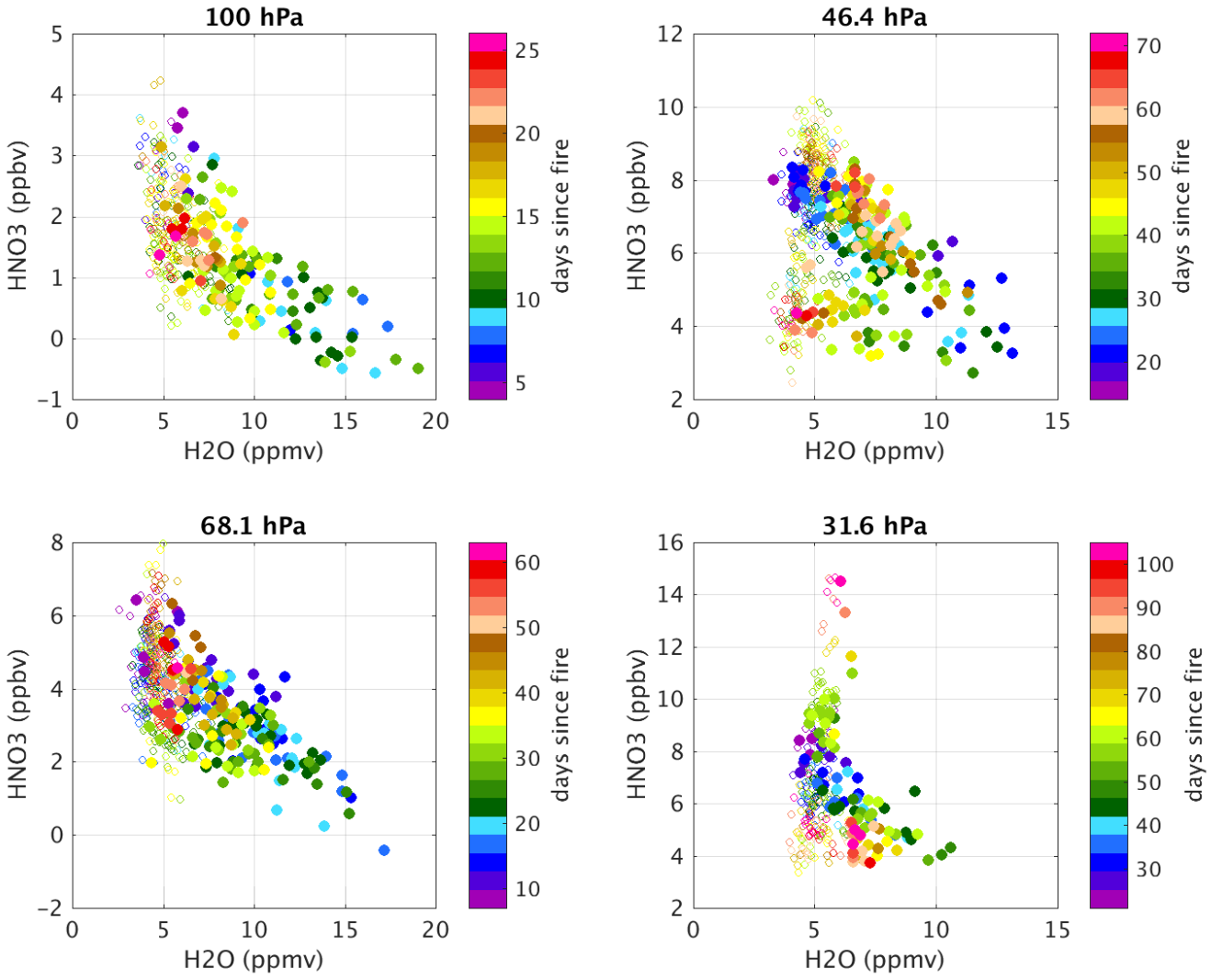
CH3CN vs H2O


100 hPa
CH3CN (ppbv) UNSCREENED
H2O (ppmv)
days since fire
46.4 hPa
CH3CN (ppbv)
H2O (ppmv)
days since fire
68.1 hPa
CH3CN (ppbv) UNSCREENED
H2O (ppmv)
days since fire
31.6 hPa
CH3CN (ppbv)
H2O (ppmv)
days since fire

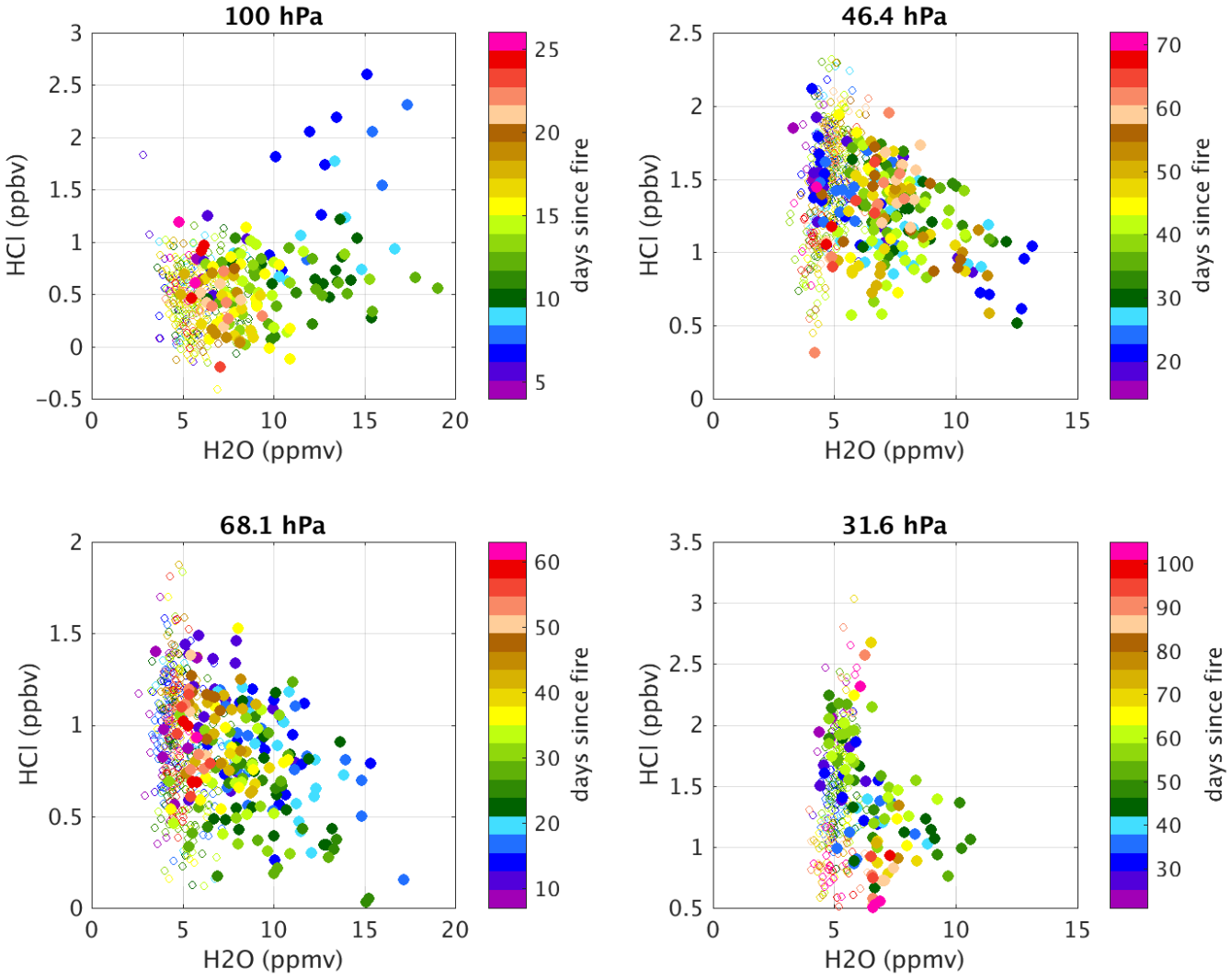
HCN vs H2O


100 hPa
HCN (ppbv) UNSCREENED
H2O (ppmv)
days since fire
46.4 hPa
HCN (ppbv) UNSCREENED
H2O (ppmv)
days since fire
68.1 hPa
HCN (ppbv) UNSCREENED
H2O (ppmv)
days since fire
31.6 hPa
HCN (ppbv) UNSCREENED
H2O (ppmv)
days since fire

HNO3 vs H2O


100 hPa
HNO3 (ppbv)
H2O (ppmv)
days since fire
46.4 hPa
HNO3 (ppbv)
H2O (ppmv)
days since fire
68.1 hPa
HNO3 (ppbv)
H2O (ppmv)
days since fire
31.6 hPa
HNO3 (ppbv)
H2O (ppmv)
days since fire

HCl vs H2O


100 hPa
HCl (ppbv)
H2O (ppmv)
days since fire
46.4 hPa
HCl (ppbv)
H2O (ppmv)
days since fire
68.1 hPa
HCl (ppbv)
H2O (ppmv)
days since fire
31.6 hPa
HCl (ppbv)
H2O (ppmv)
days since fire

Conclusions

- MLS clearly provides a rich data set for investigation of the composition of the 2017 BC PyroCb plume.
- There is way too much to cover in a 15 minute talk.
- There are more talks coming that will look at MLS data.
- Generally, combustion products are enhanced and stratospheric sources are reduced in the plume.
- I look forward to hearing what the modelers have to say.