

The Long-lived Plume of the Pacific NW PyroCb Event: Diabatic Lofting and Radiative Effects of Aerosol and Water Vapor

Pat Kablick, Mike Fromm, Gerald Nedoluha,

US Naval Research Lab - Washington, DC

Hugh Pumphrey,

University of Edinburgh, United Kingdom

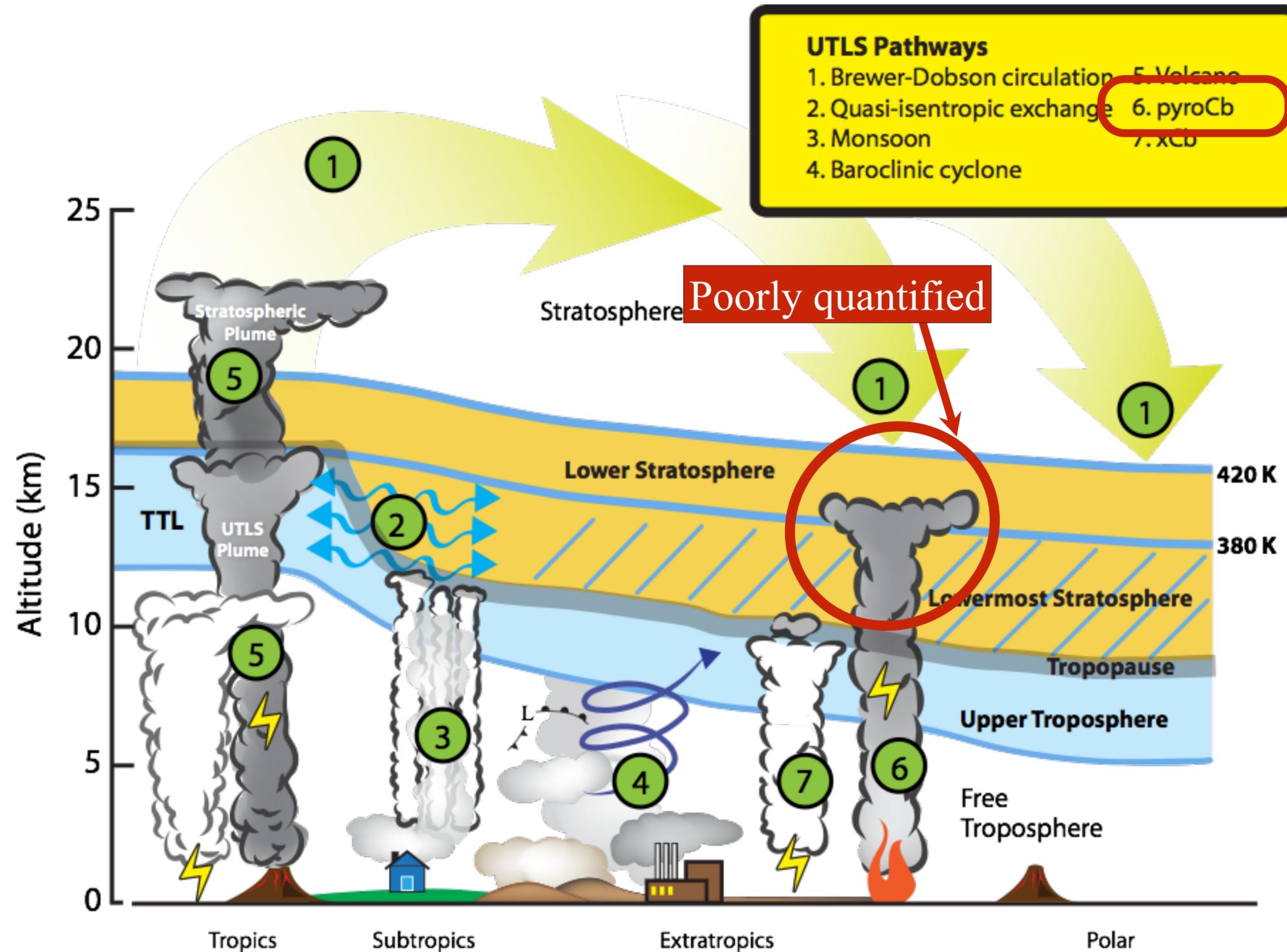
Michael J. Schwartz,

Jet Propulsion Laboratory, Cal. Tech., Pasadena, CA

Zhanqing Li

University of Maryland, College Park, MD

Brewer-Dobson circulation and UTLS

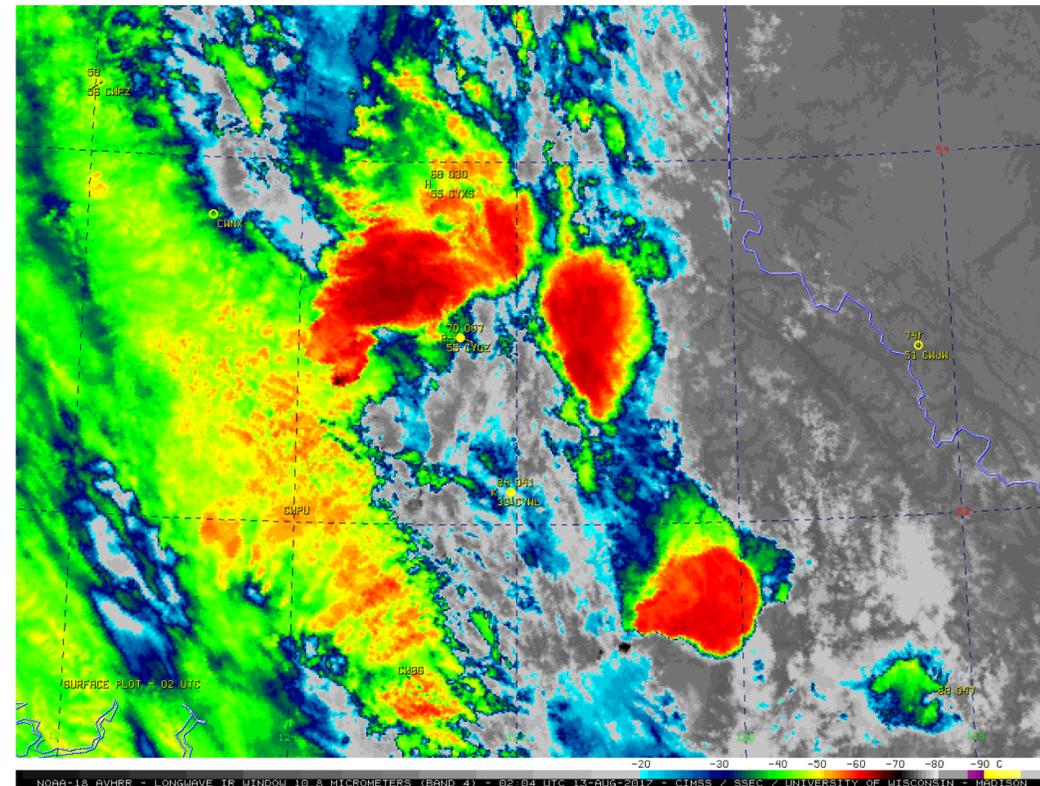


August 2017 Pacific NW PyroCb Event (PNE)

12 August 2017 PNE

- 5 pyroCb total: 4 in BC, 1 in Washington
- Convection was in advance of approaching cold front
- Long duration event.
- Extremely large amounts of smoke, gases and cloud ice were directly-injected into the UTLs, up to 13 km.

AVHRR 10.8 μm



AVHRR 3.9 μm

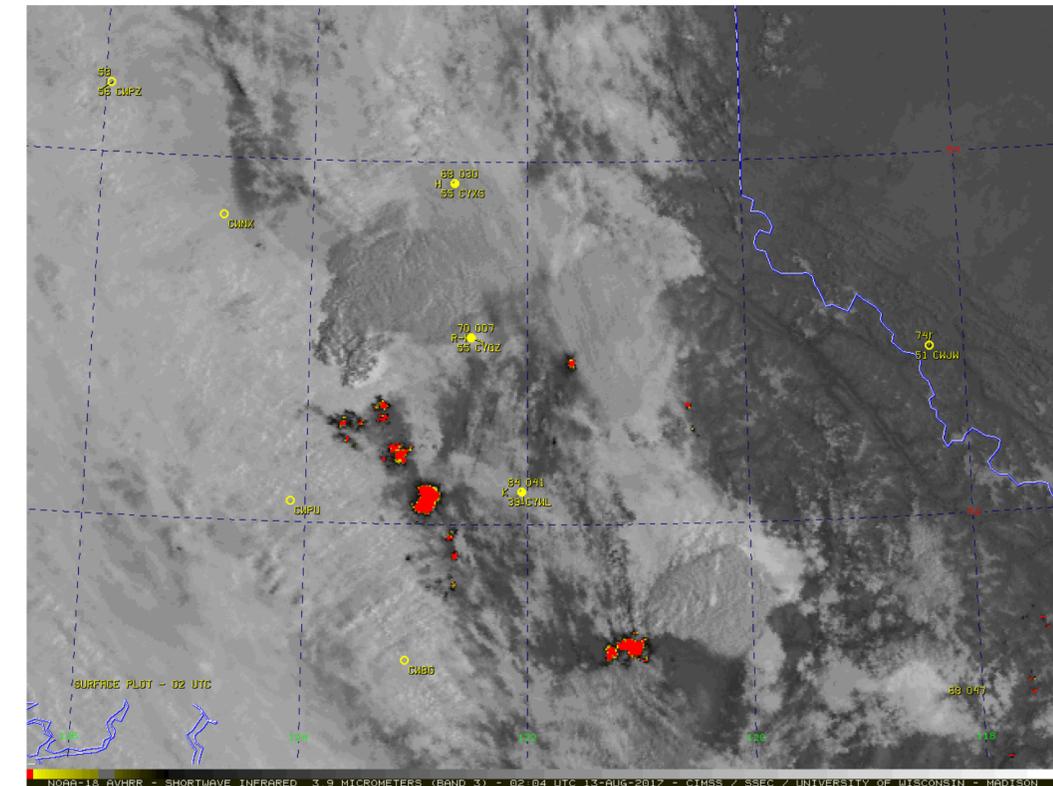
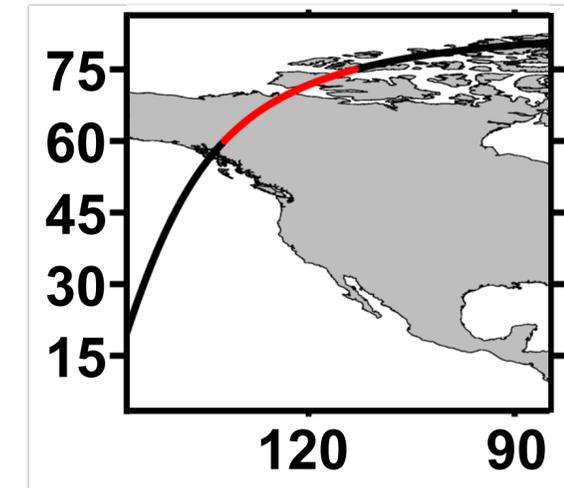


Image credit: Scott Bachmeier (CIMSS pyroCb blog)

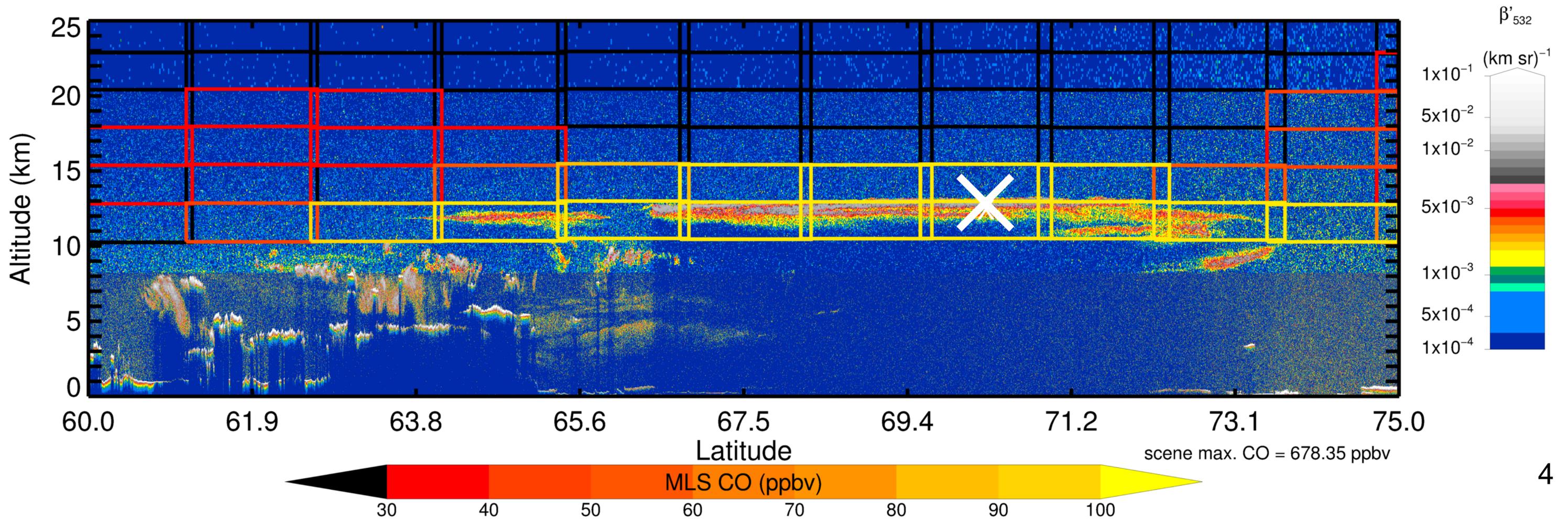
Typical signals of intense pyroCb:
cold thermal IR and warm shortwave IR

1st reliable CALIOP observation

- First unambiguous UTLS plume observation by A-Train is on 14 August.
- Fully attenuated CALIOP lidar beam with MLS CO > 670 ppbv, z ~ 13 km.



2017/08/14 11:20 UTC

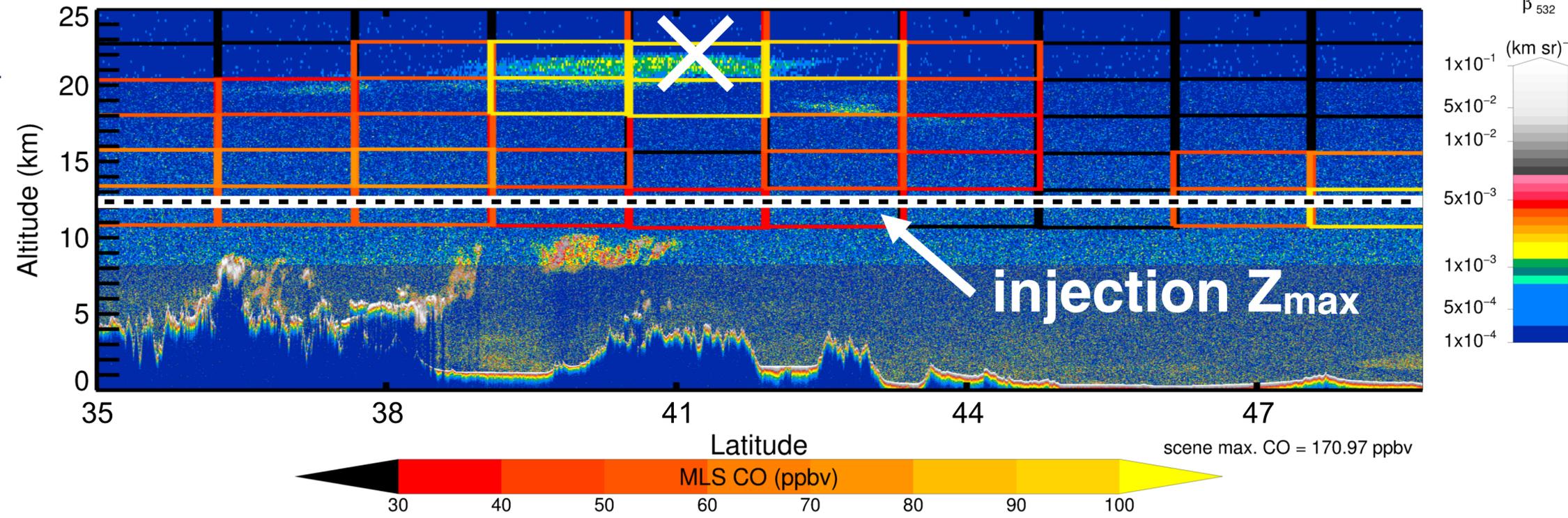


Plume evolution in LS (+1 month)

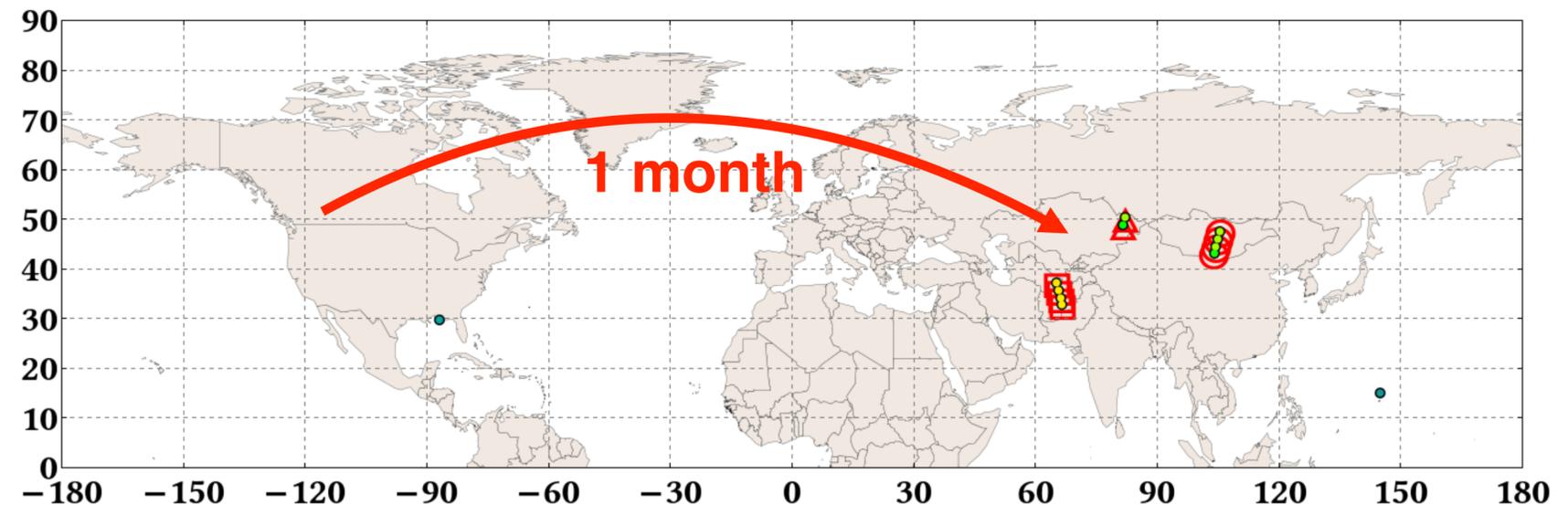
Skipping 1 month ahead

- One section of plume has undergone about 10 km of diabatic lofting!
- CALIOP experienced data outage on 12 Sept., but most recent observation (3 Sept.) in the area agrees with MLS.

2017/09/03 ~21:00 UTC



- After 1 month (12 Sept.), plume separates into 3 distinct sections.

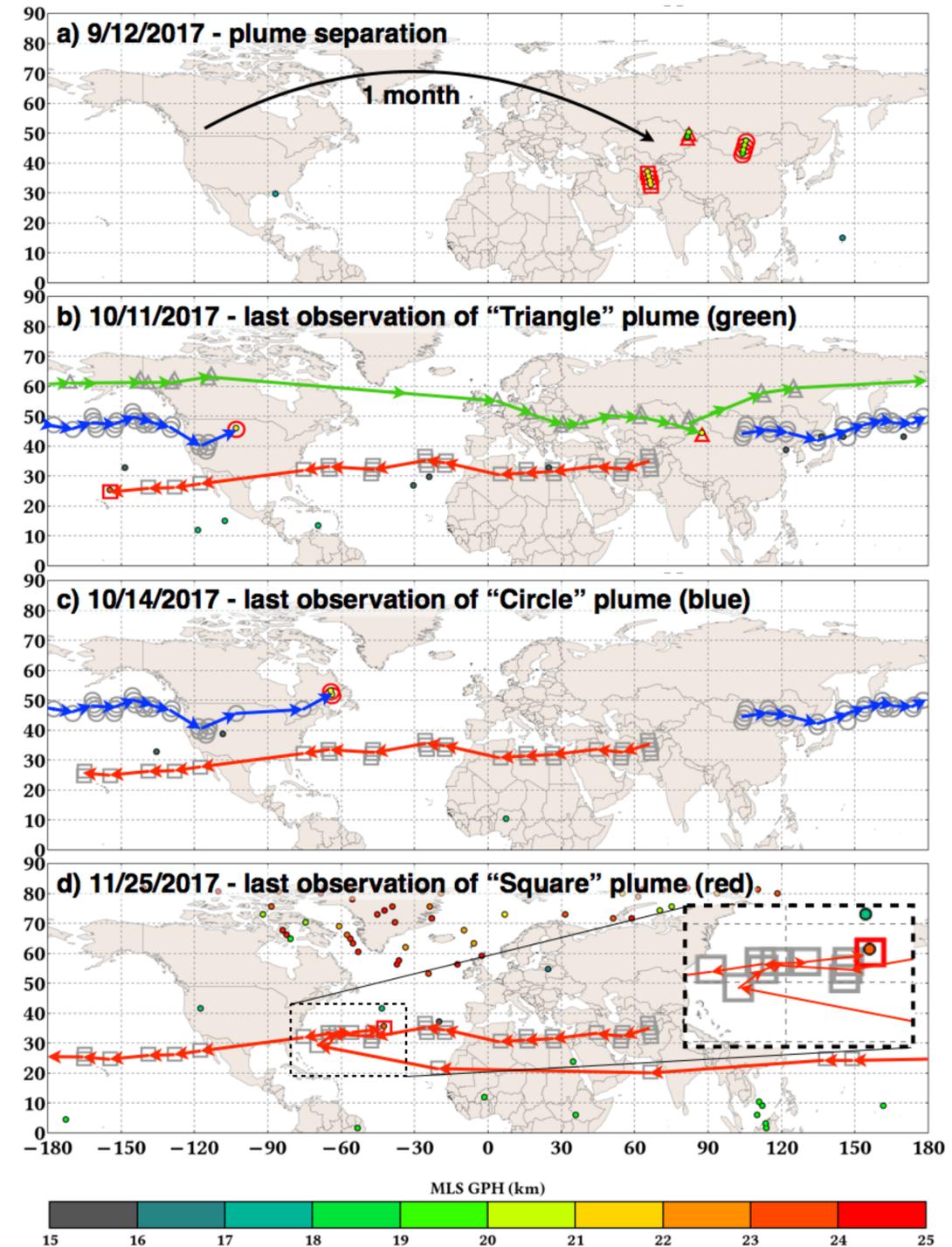


Plume evolution in LS (3 months)

Tracking plume sections: confirmation with MLS

Plume section of interest (red-line) is observable for >3 months and completely circumnavigates the globe on a westward trajectory, after moving eastward from North America.

Kablick et al. (in prep.) *Mon. Wea. Rev.*

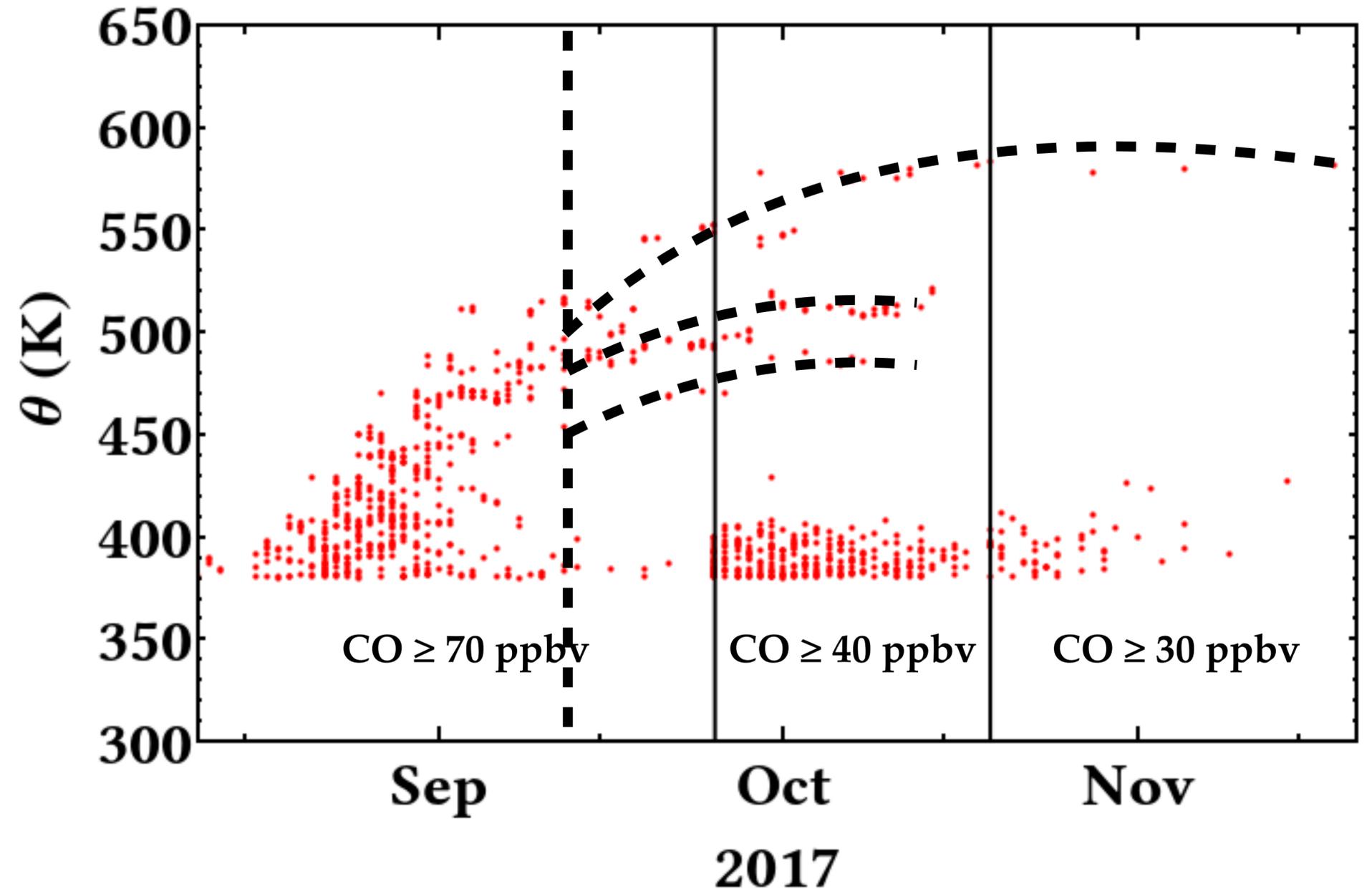


PNE plume evolution in UTLs

Thresholding with MLS H₂O

- Large enhancements in MLS CO and H₂O are co-located.
- CALIOP suffered data gap in mid-September, but MLS was able to pick up the slack using gas retrievals.
- Diabatic plume rise is apparent.

N.H. Potential temperature of MLS H₂O ≥ 7 ppmv

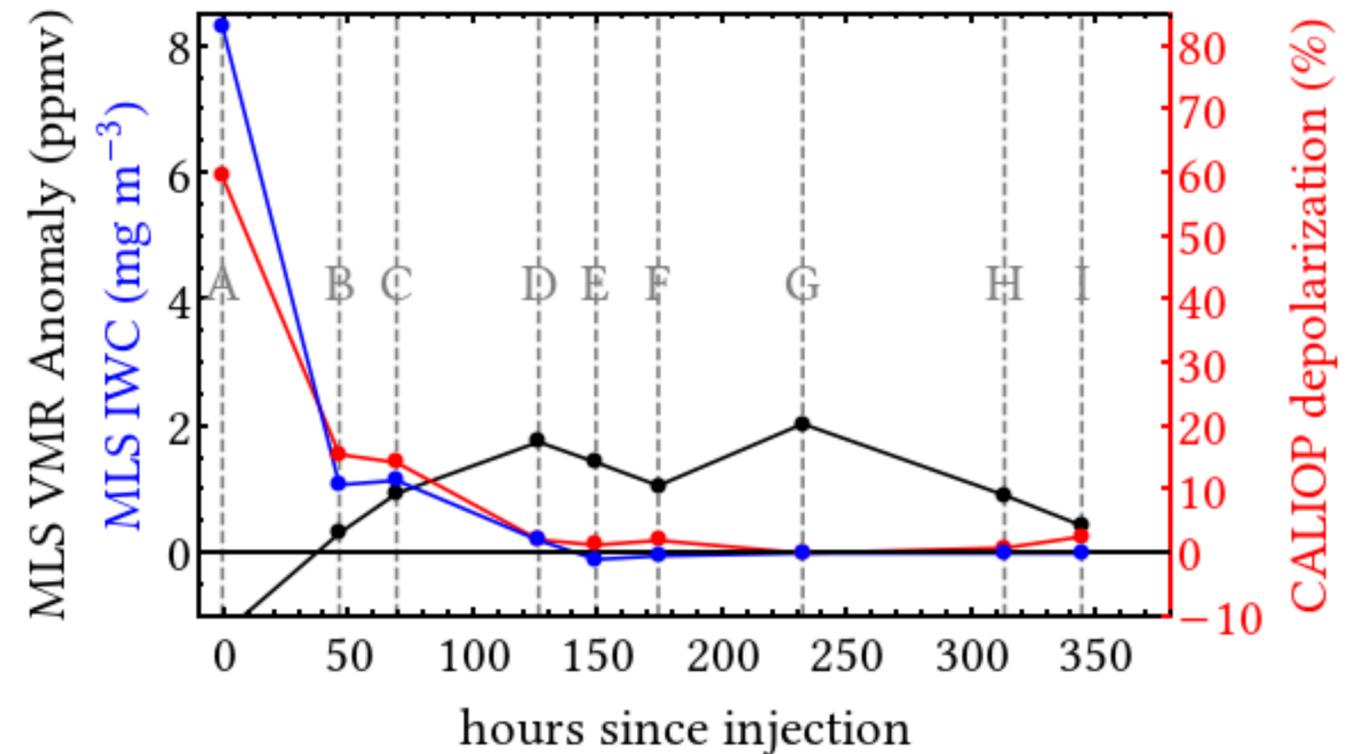
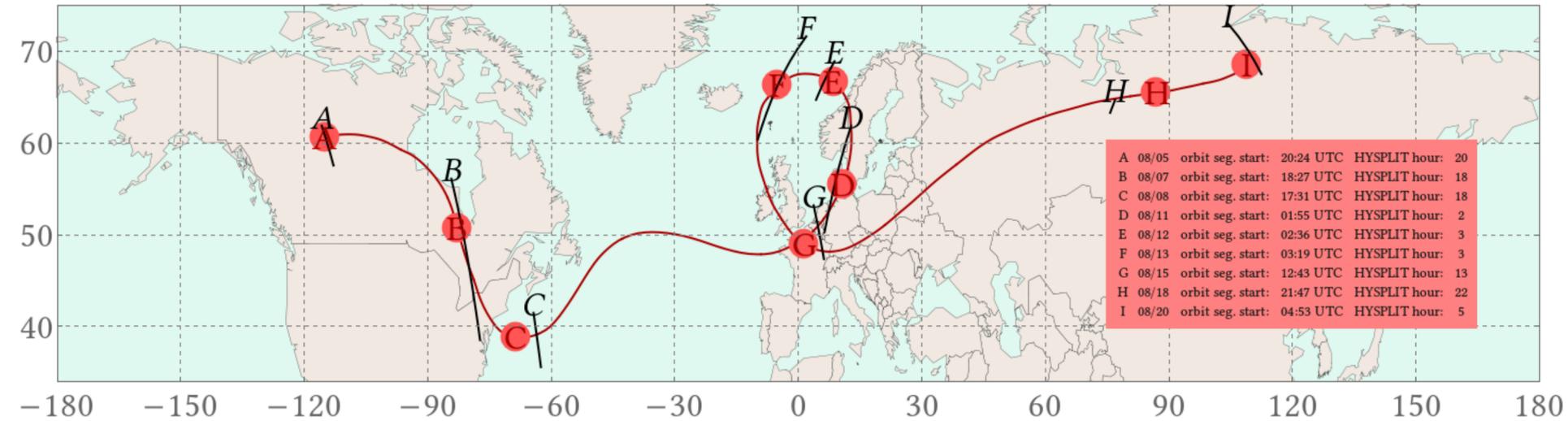


How do pyroCb impact UTLS water?

Recently published case study: Great Slave Lake, August 2014

- Besides direct-injection of H₂O, ice microphysics may play a role: inefficient removal of small ice particles leads to long-lived cirrus, and sublimation of ice down-stream.
- CALIOP and MLS are well-suited to the task of tracking these plumes.

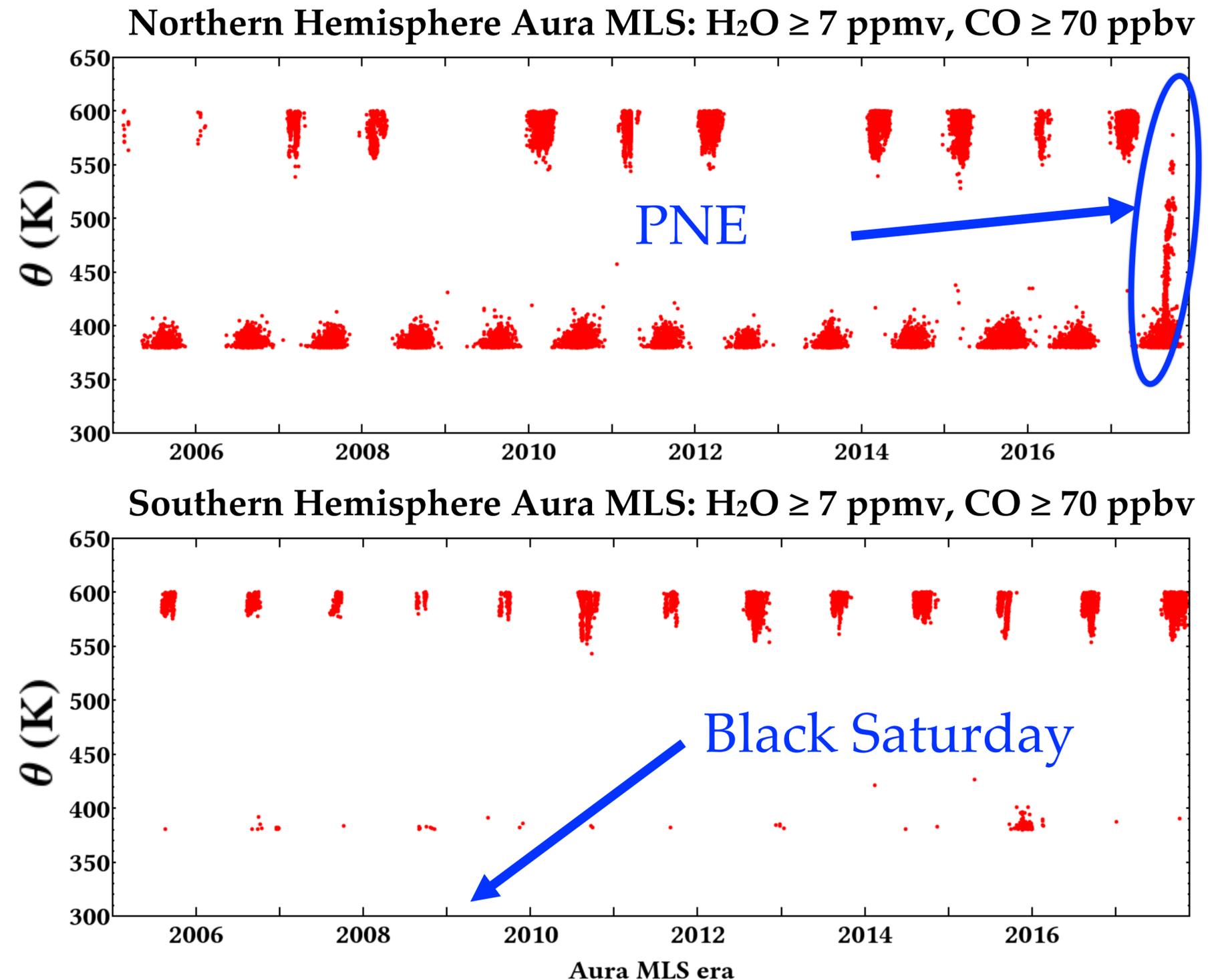
Kablick et al. (2018) *J. Geophys. Res.*



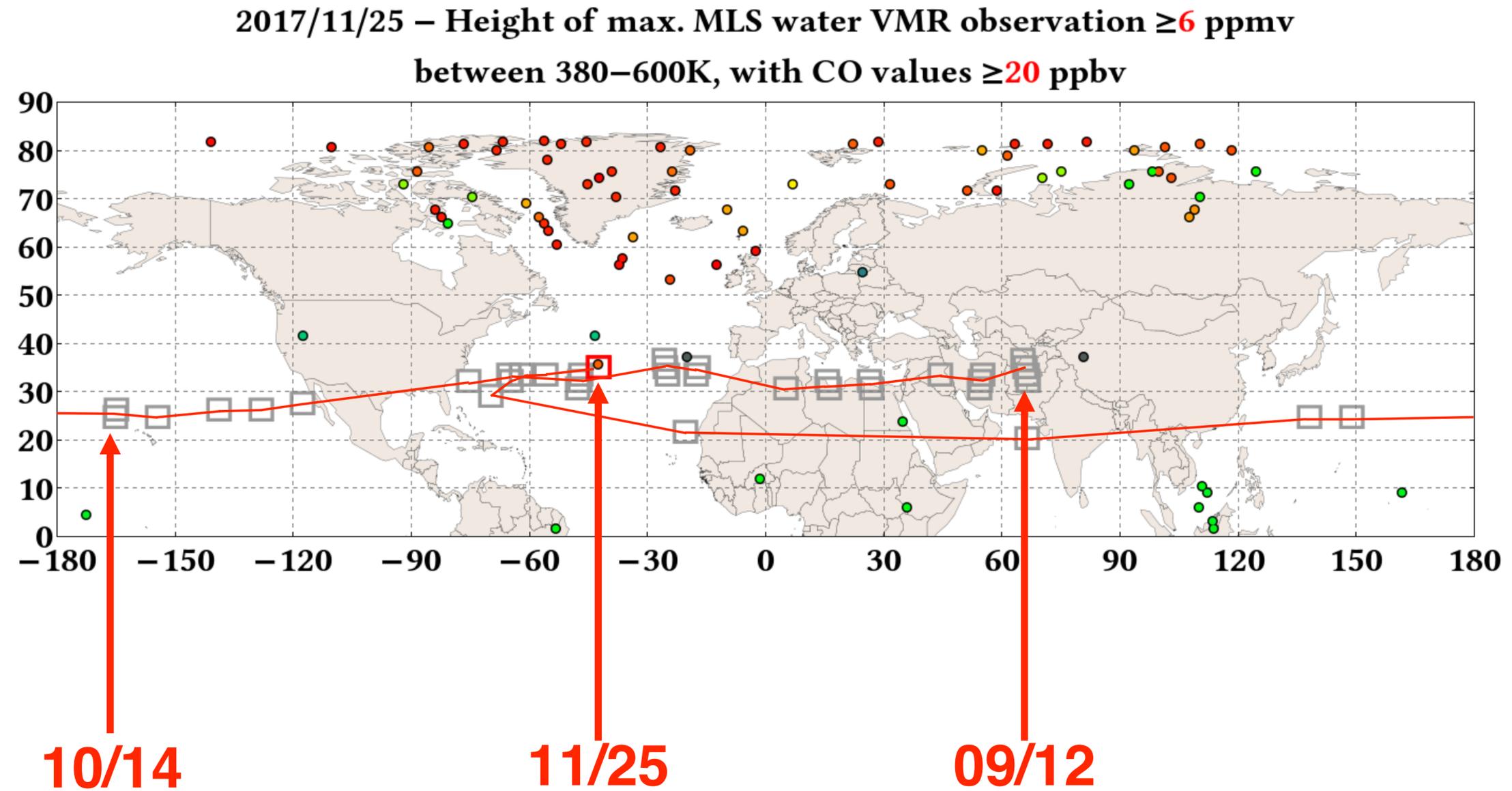
Entire Aura MLS H₂O record

- The 2017 PNE is unprecedented in the current observation era in terms of observed water vapor impact.
- Annual signals from Polar Vortex and Asian Monsoon are only other signals using this threshold.
- Similar statistics for S.H. show no events at this magnitude.

Kablick et al. (in prep.) *J. Climate*

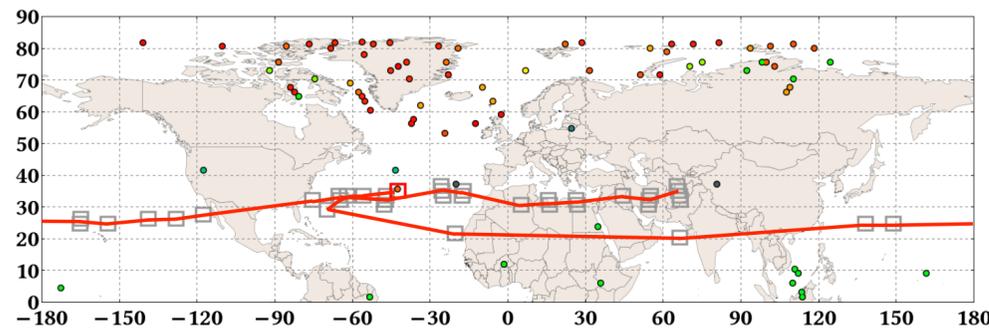


Plume evolution in LS (3 months)

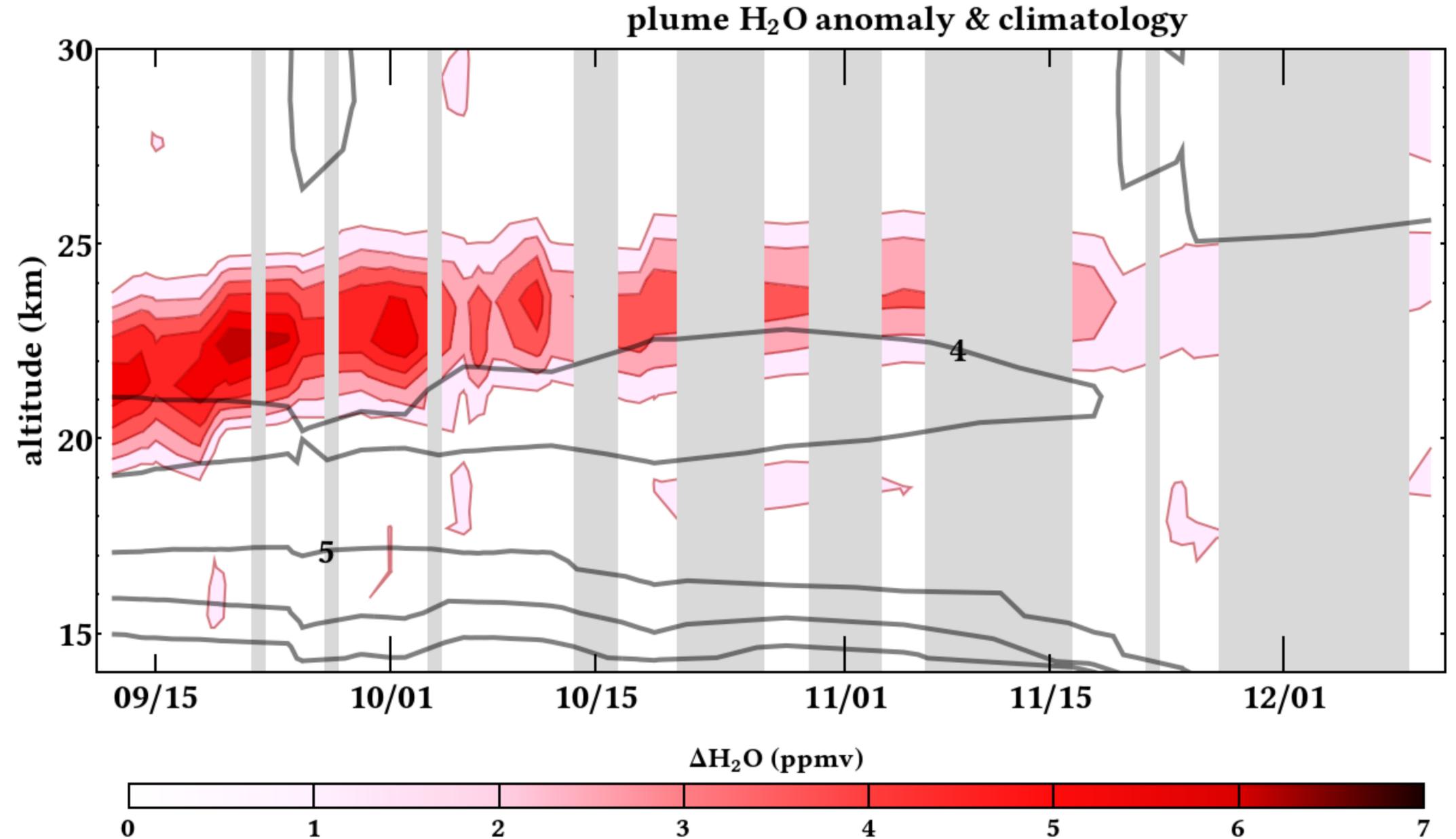


PNE water vapor anomalies

MLS observations of main plume >2 months after September 12th separation



- Water vapor anomalies as large as 7 ppmv >1 month after pyroCb.
- Diabatic rise continues for the remainder of the observable life.

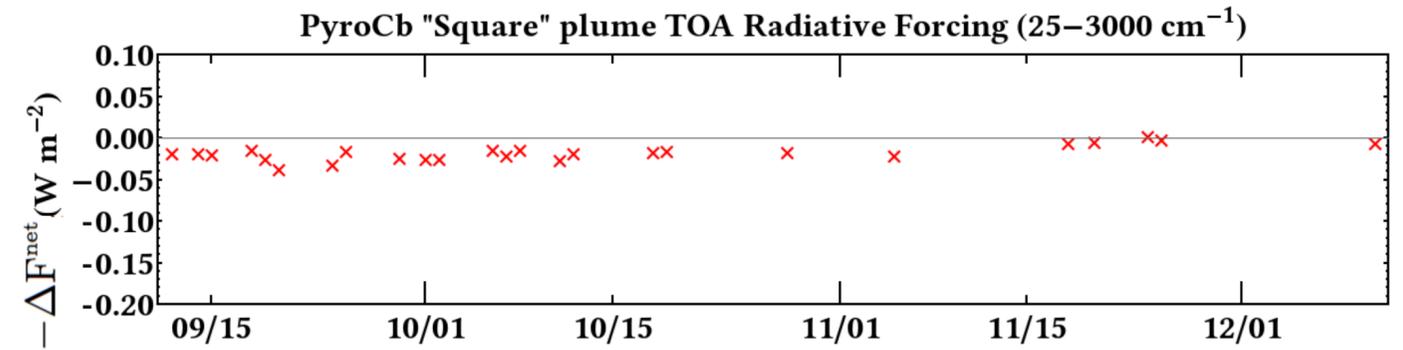


H₂O radiative forcing (LBL longwave)

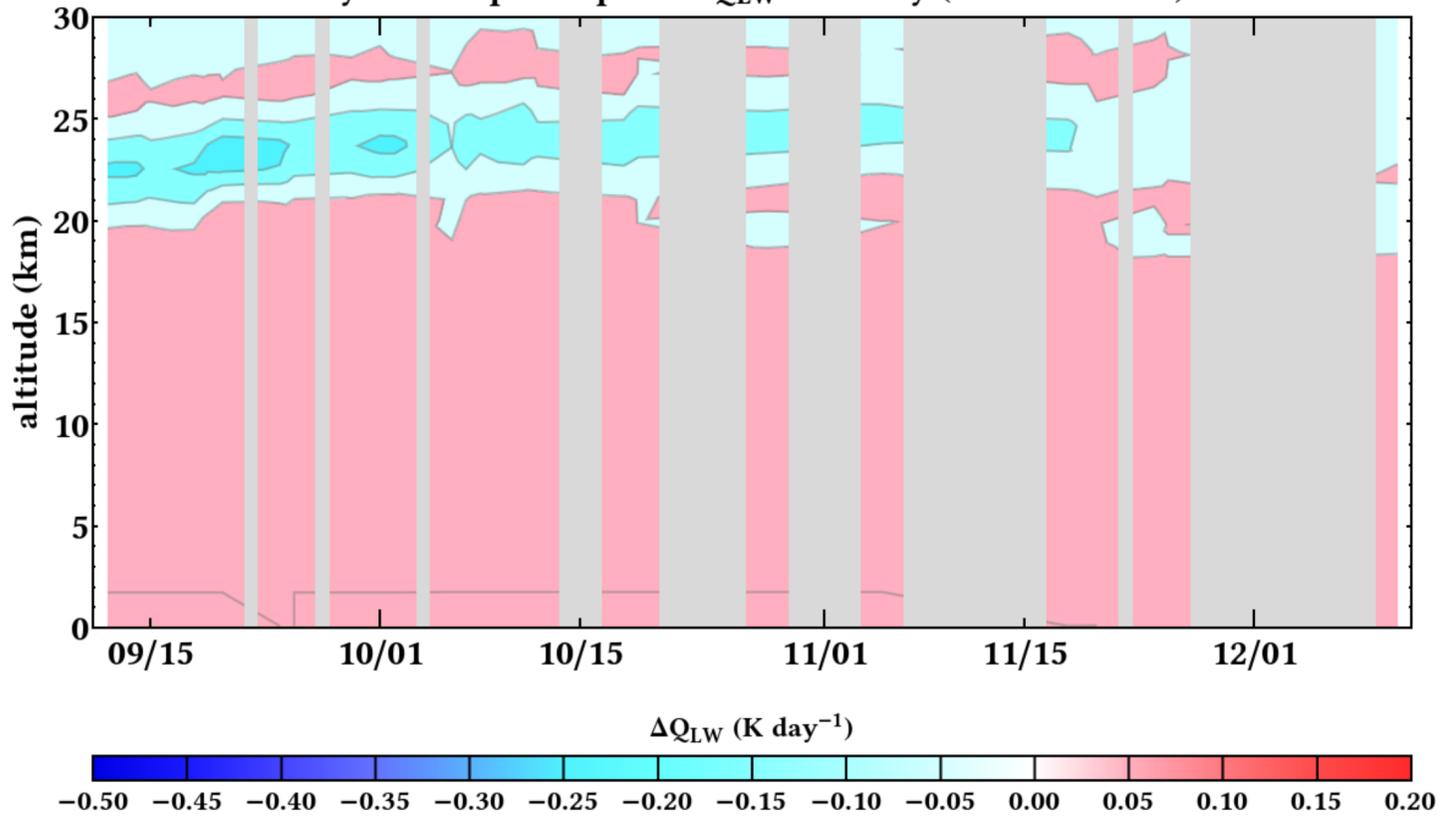
$$\Delta F^{\text{net}} = (F^{\uparrow} - F^{\downarrow})_{\text{anomaly}} - (F^{\uparrow} - F^{\downarrow})_{\text{control}}$$

$$RF = -\Delta F^{\text{net}}$$

RF < 0



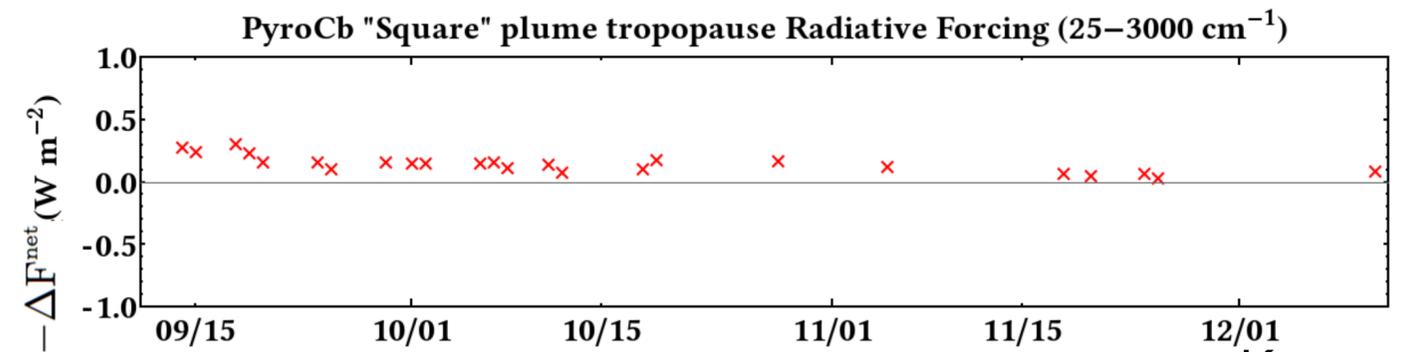
PyroCb "Square" plume Q_{LW} anomaly (25–3000 cm⁻¹)



ΔQ < 0 within plume
and > 0 at tropopause



RF > 0



Conclusions and future work

- **PNE is unprecedented** in several ways:
 1. Volcano-like large aerosol loading: early CALIOP **AOD > 10**
 2. Extreme diabatic rise from aerosol heating: CALIOP/MLS estimates **$\Delta\theta > 225$ K** and **$\Delta z > 10$ km**
 3. Large local LS H₂O enhancements: MLS observes **values as great as 12 ppmv** ($\Delta q > 7$ ppmv)
- **H₂O anomalies perturb local stratospheric heating rates** by **-0.5 K day⁻¹** within the plume with **negligible surface forcing**.
- More information and cases are needed, and would help to assess overall LS impact.