Is There Evidence of Convectively Injected Water Vapor in the Lowermost Stratosphere Over Boulder, Colorado?

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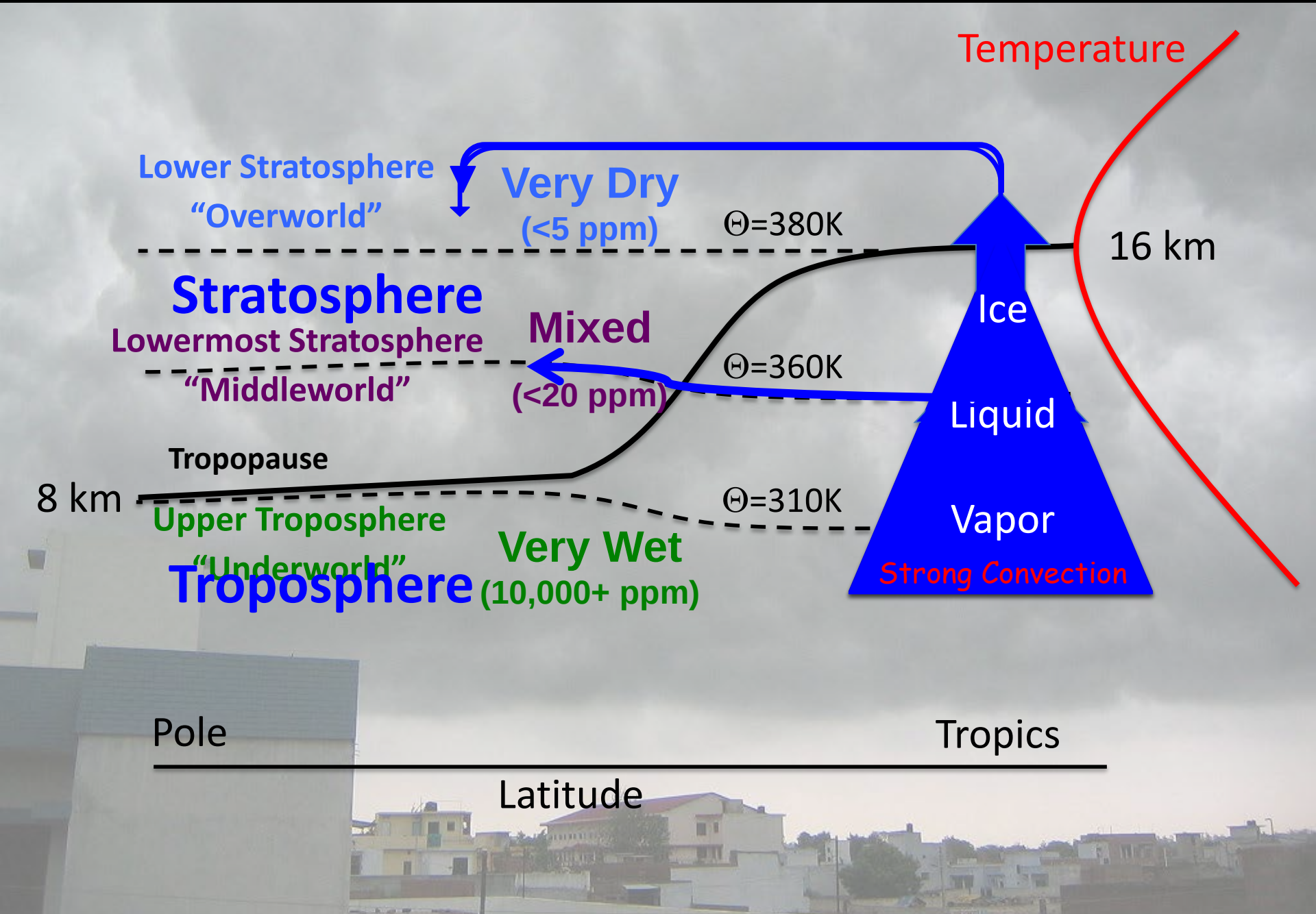
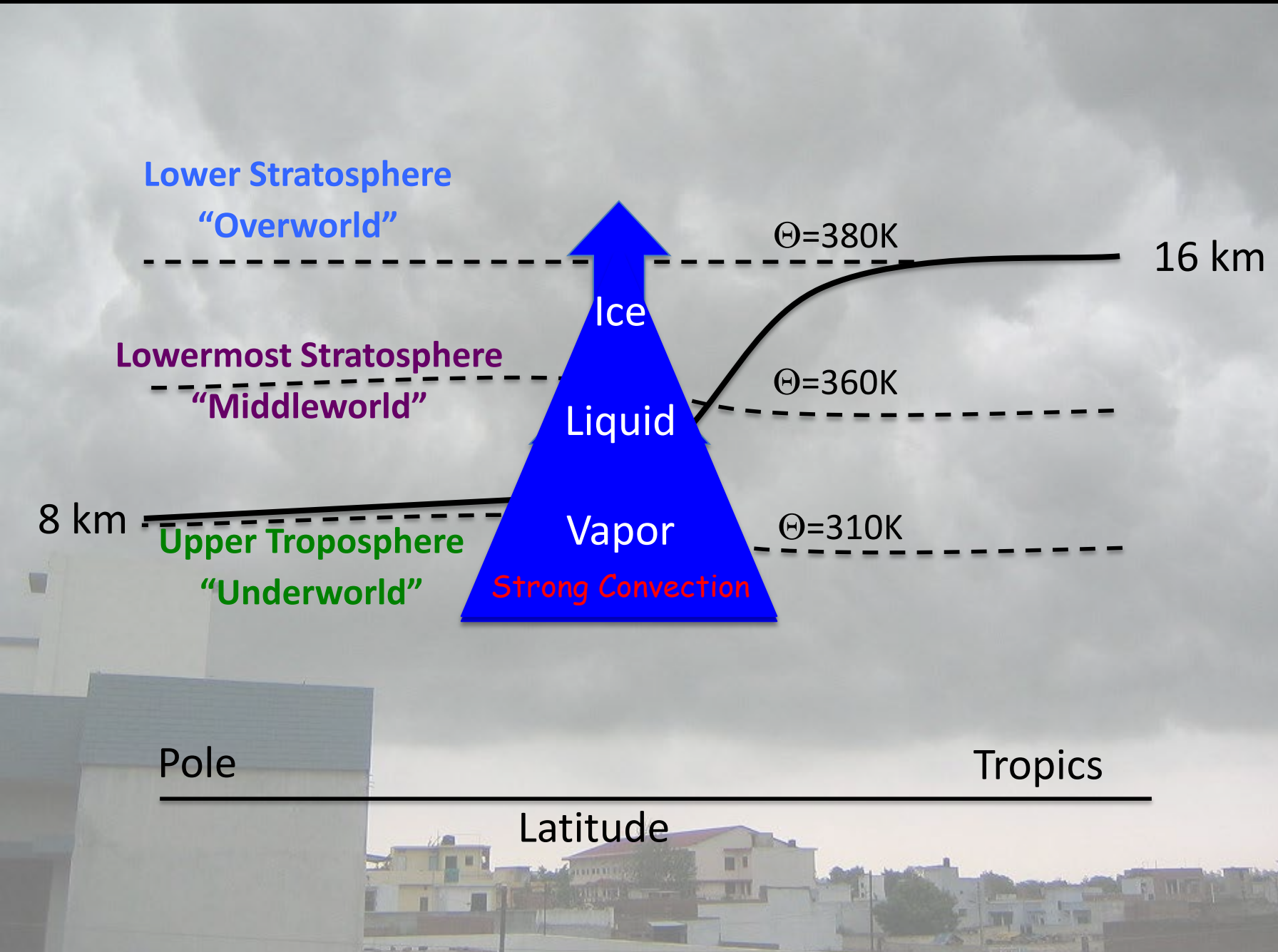
Transport of Water Vapor: Tropical Source



Transport of Water Vapor: Mid-Latitude Source



The Big Questions

Global Perspective

Is convection an important source of stratospheric water vapor?

What is the impact of convectively-sourced WV on the radiation budget and climate?

North American Mid-Latitude Convection Studies

Anderson et al. (2012) measured 10-18 ppm WV in the LS over the south-central USA during summertime and postulated that frequent and widespread convective injection of WV into the overworld could cause significant ozone losses over populated areas.

Schwartz et al. (2013): 8 years of MLS data in the LS (100 hPa) over the North American monsoon region (July, August) showed WV >8 ppm only 2.5% of the time.

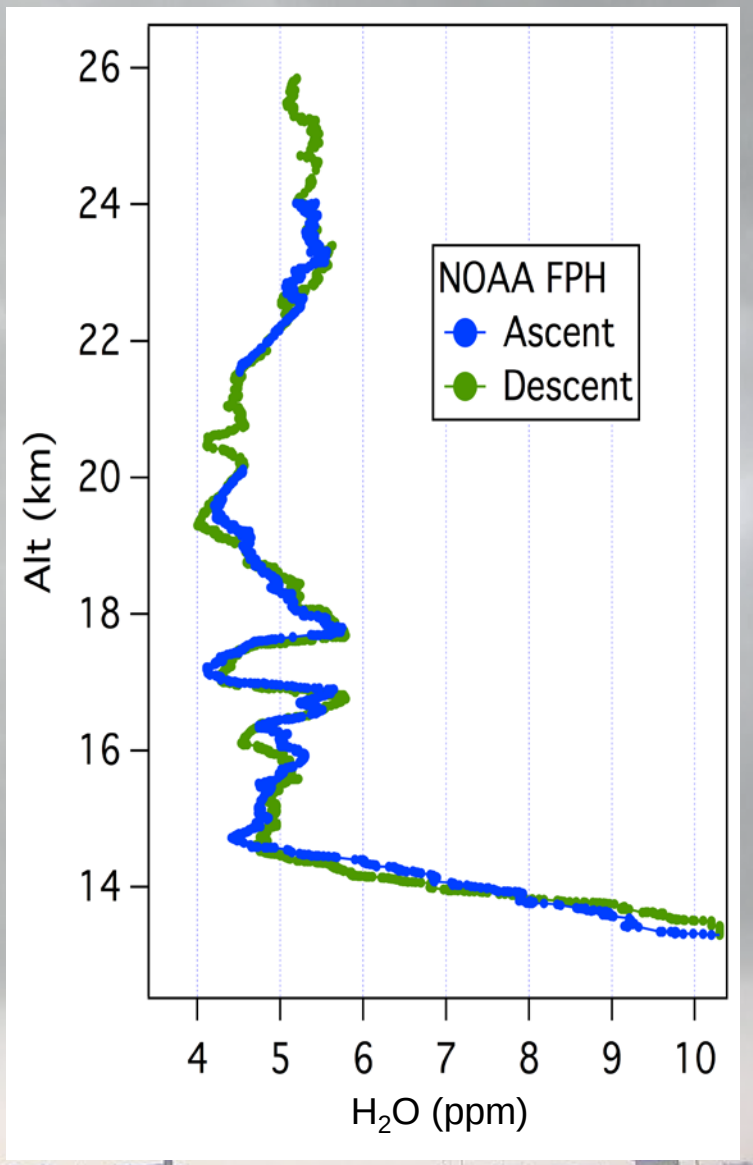
Are MLS measurements with 3-km vertical resolution able to detect potentially thin wet layers deposited in the LS by convective overshooting?

Homeyer et al. (2014) linked 60-225 ppm WV in the lowermost stratospheric middleworld over the south-central USA in May 2012 to mesoscale convective systems, with some evidence of convective injection into the overworld.

- Does convection frequently reach the lower stratospheric “overworld” with potential implications for stratospheric ozone?
- or does convection predominantly reach only the lowermost stratospheric “middleworld”?

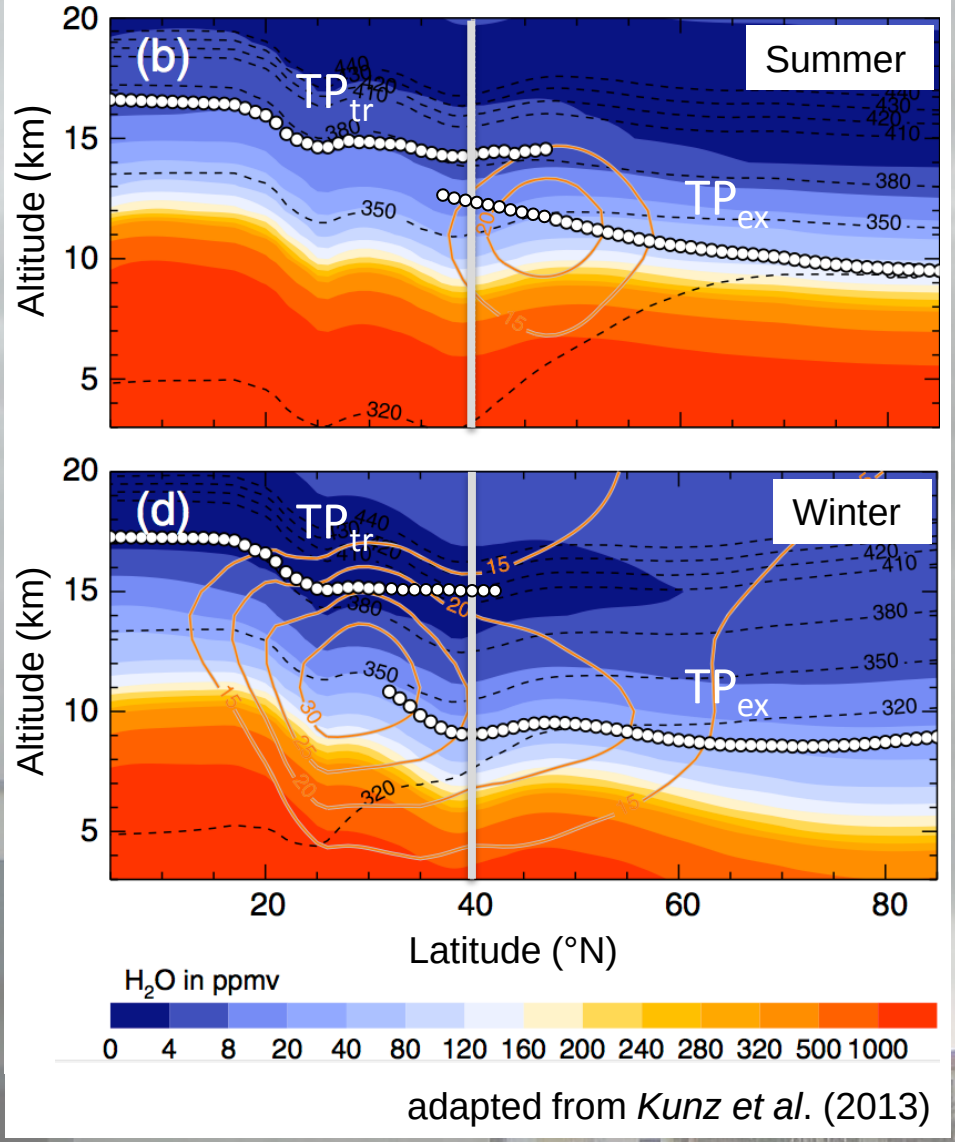
NOAA Frost Point Hygrometer (FPH)

- Monthly FPH soundings at Boulder since 1980 (N=404)
- Vertical Resolution of 5-10 m from surface to ~26 km. 250-m averages used here.
- FPH measures stratospheric WV with an accuracy of ±10% (±0.5 ppm in LS)

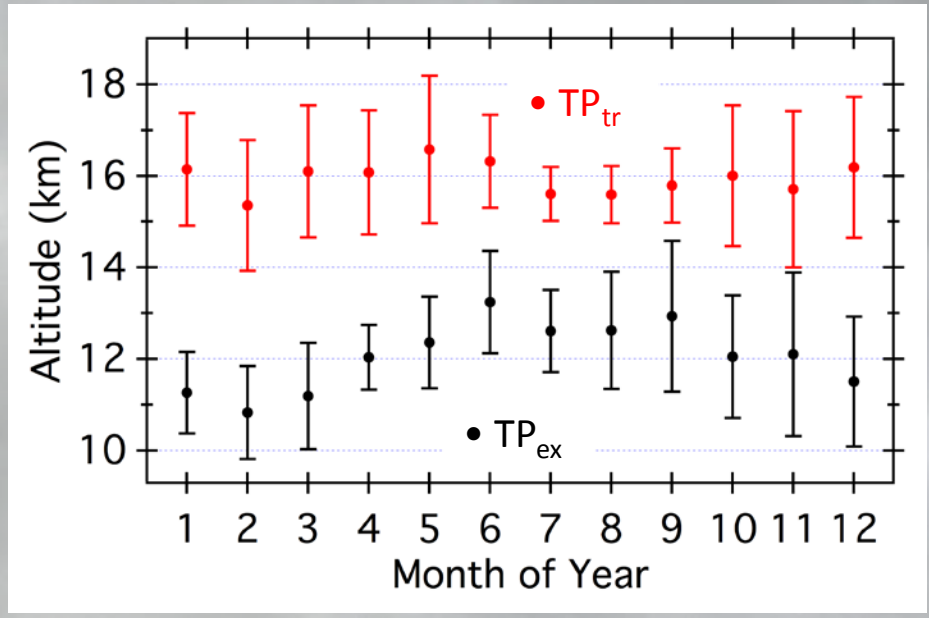


Tropopause Dynamics over Boulder (40°N, 105°W)

Lapse Rate Tropopauses (WMO definitions) determined from Radiosonde Temperature Profiles



adapted from *Kunz et al*. (2013)



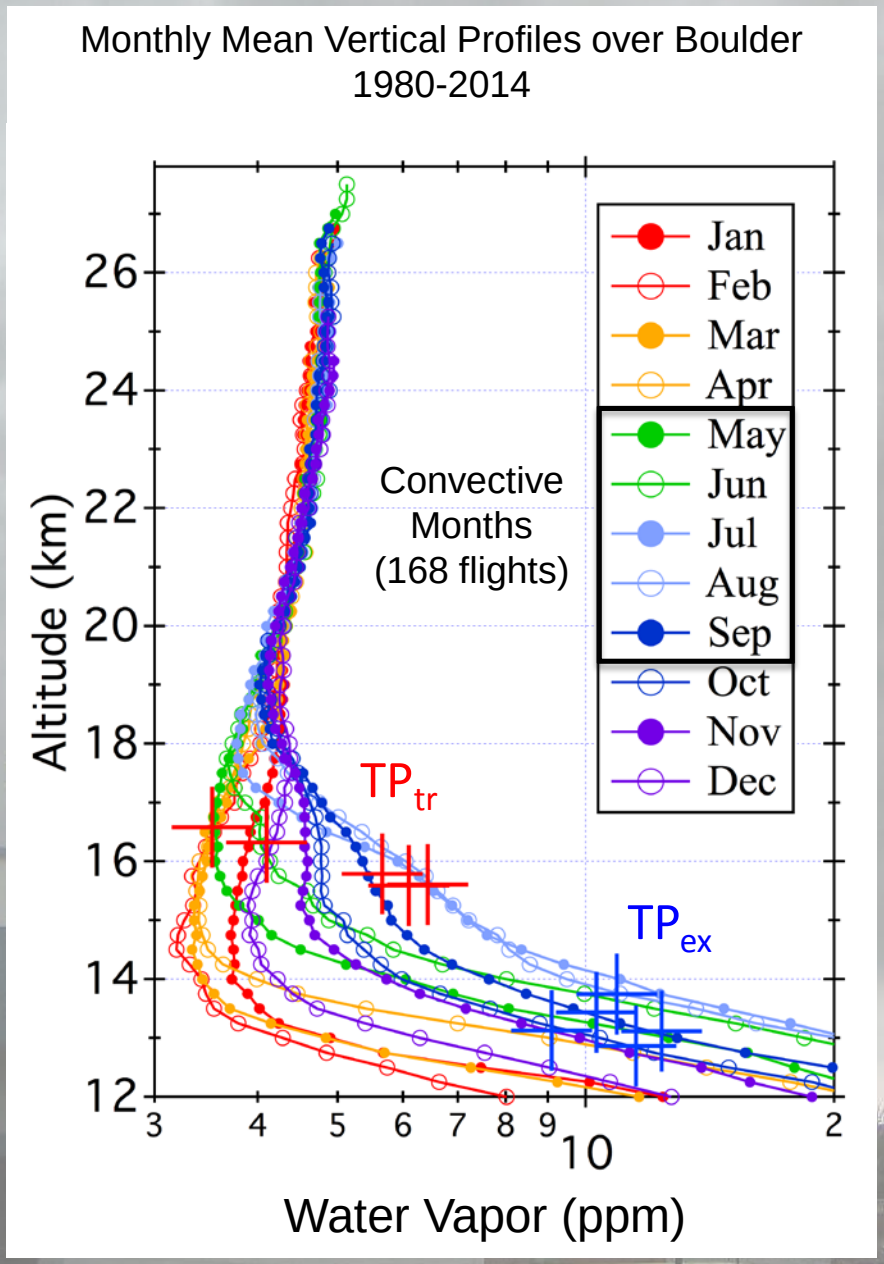
Convective Months (MJJAS) N=168

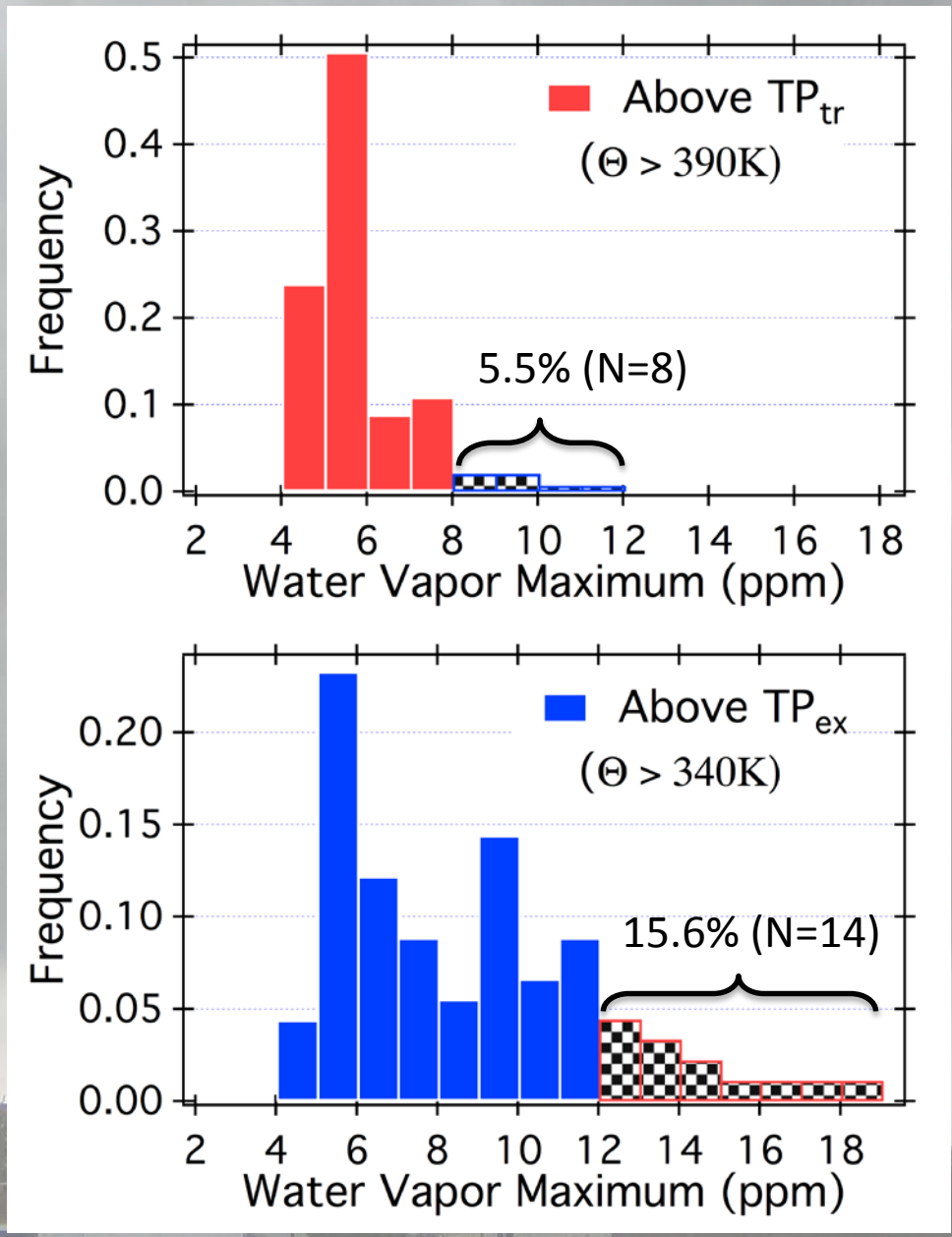
- TP_{tr} present for 88% of flights
- Double TP: 41%

Winter Months (DJF) N=92

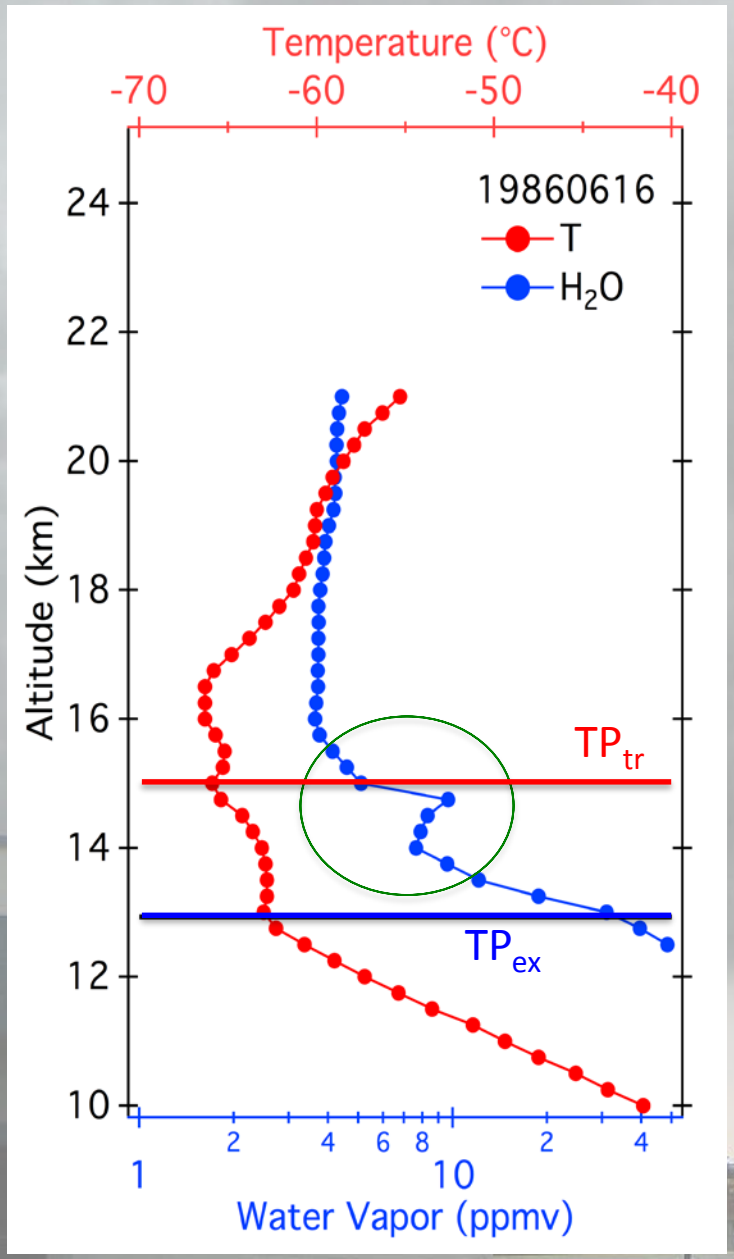
- TP_{ex} present for 100% of flights
- Double TP: 84%

Detecting Anomalously High WV Above Boulder

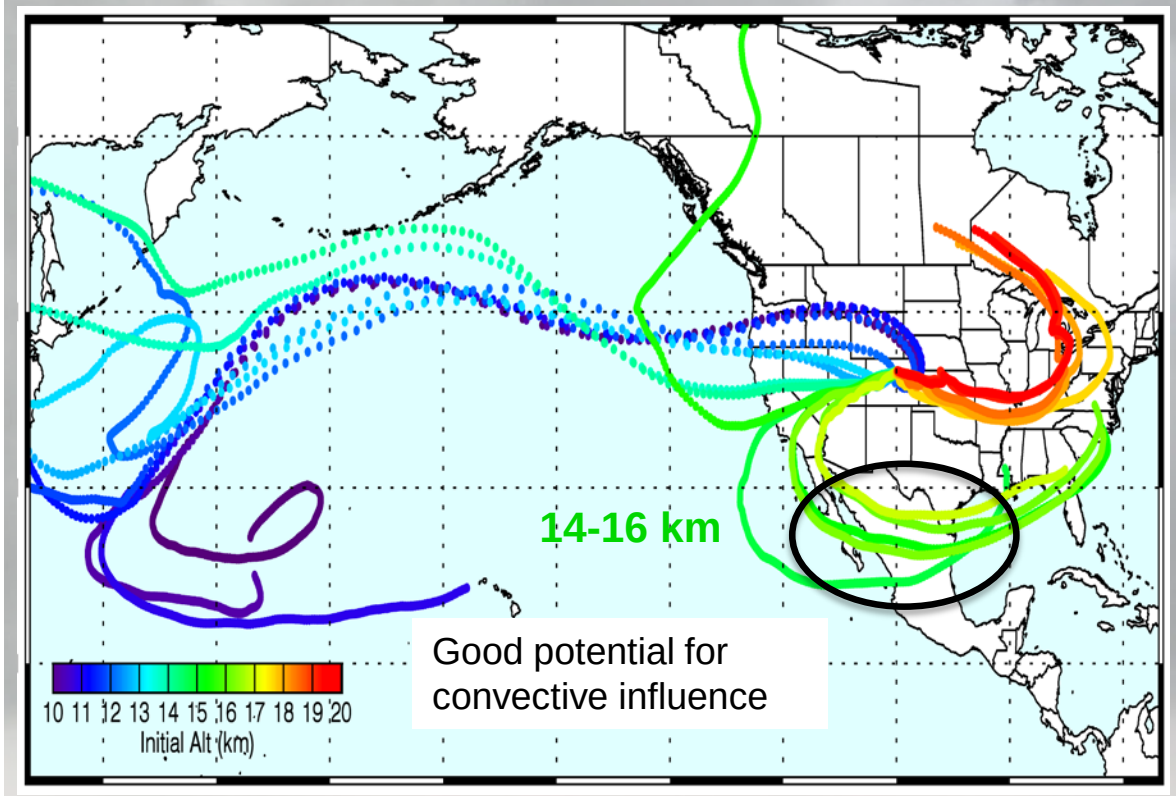




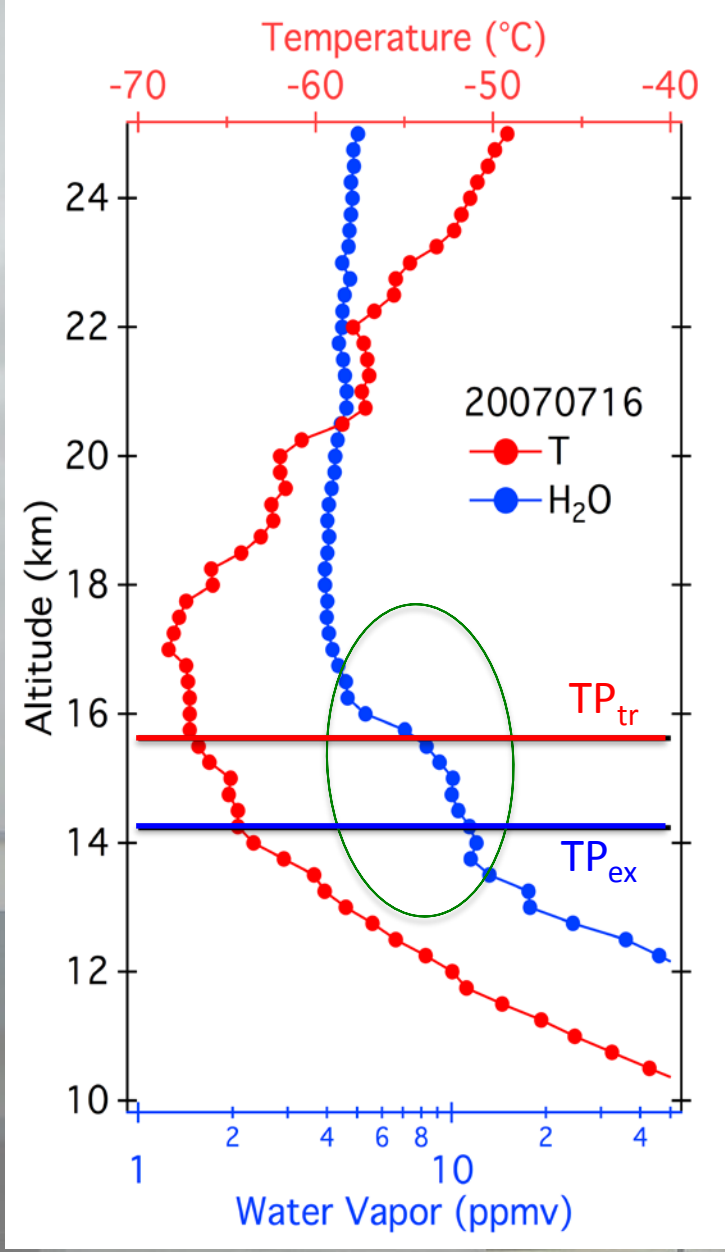
Convective Influence above TP_{ex}?



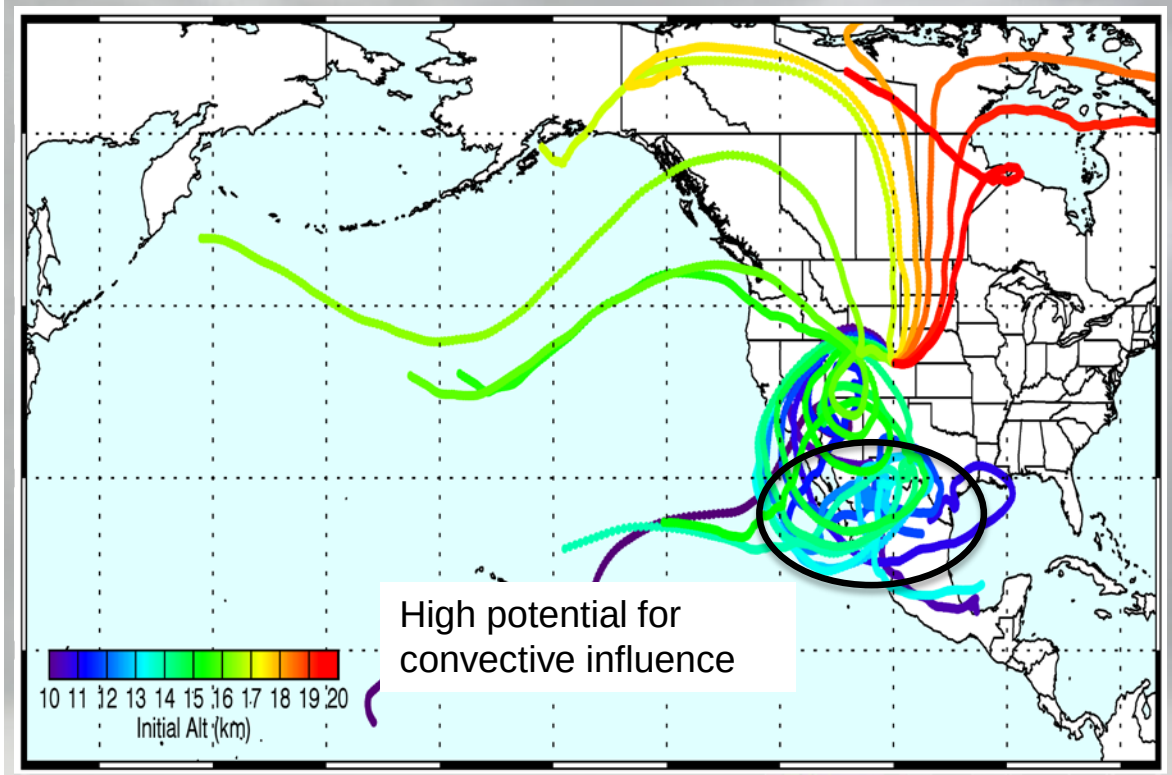
10-day back trajectories: 1 hr steps, 100 m resolution



Convective Influence above TP_{ex} and TP_{tr}?



10-day back trajectories: 1 hr steps, 100 m resolution



Findings from Boulder FPH Profiles (May-Sep)

- WV > 12 ppm above TP_{ex} for 14 FPH flights (~15% of flights with TP_{ex})
- WV > 8 ppm above TP_{tr} for 8 FPH flights (~5% of flights with TP_{tr})
- 10-day back trajectories indicate possible convective influence for 5 of 21 flights with anomalously high WV in the stratosphere

<u>This analysis suggests (for Boulder)</u>

- Some evidence of convective influence in the “middleworld”, but high WV is mostly due to northward flow of tropical air through TP break
- Infrequent evidence of convective influence in the “overworld”

<u>Caveats</u>

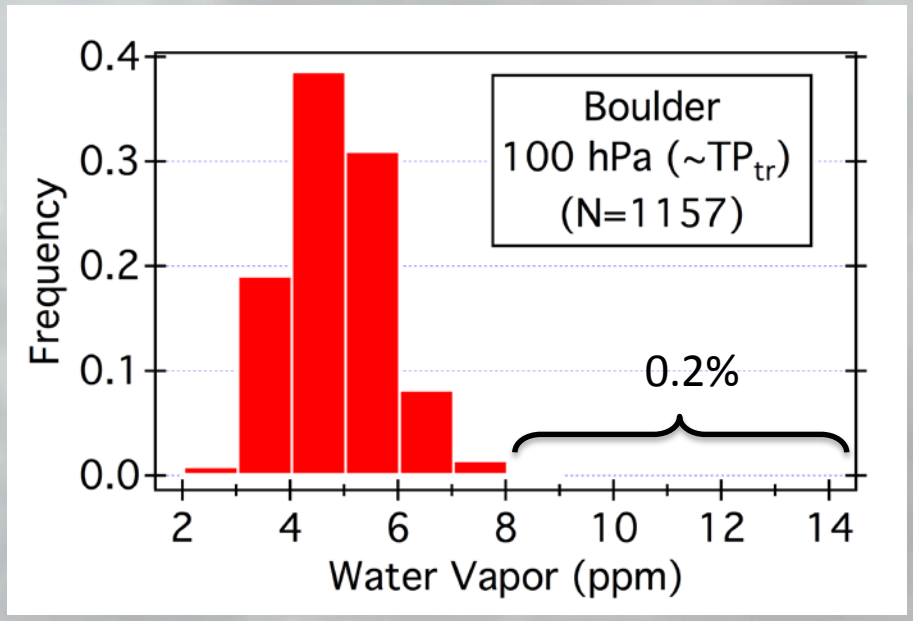
1. Boulder too close to Rockies to sample mesoscale convective systems
2. 10:00 FPH launches at Boulder do not target local convection
3. No IWC measurements but RHi << 100% when WV is anomalously high

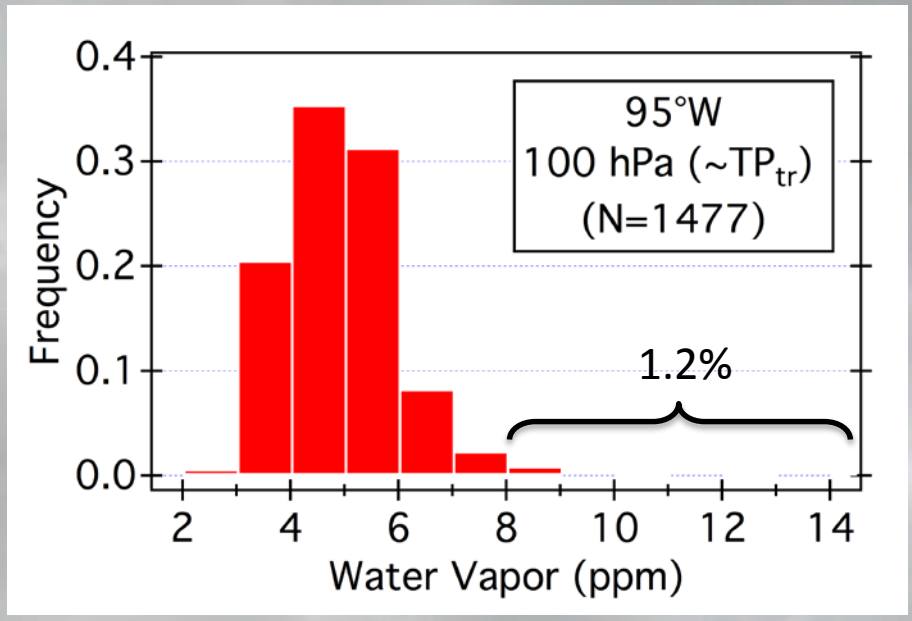
<u>Suggested Improvement</u>

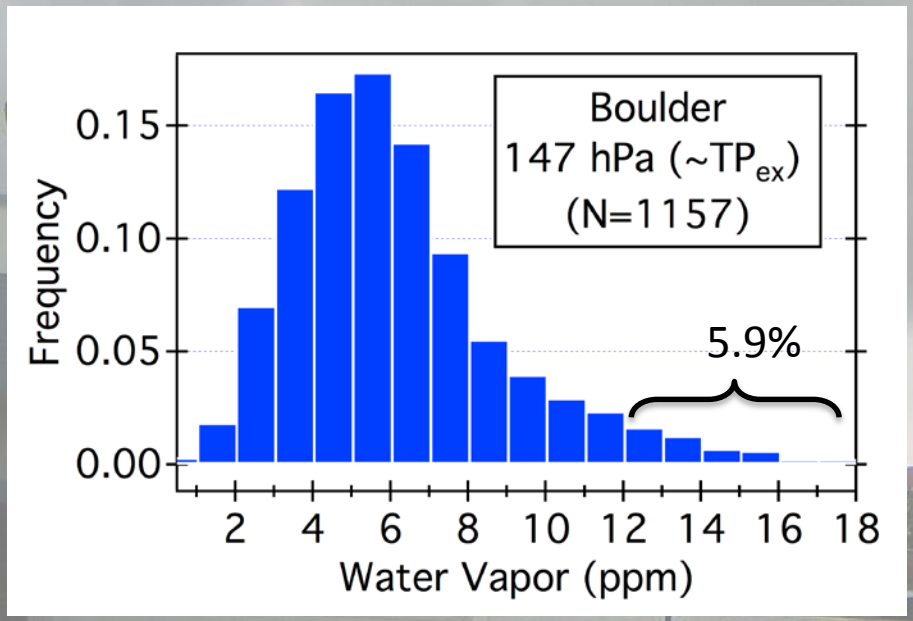
1. Move Boulder to the east or the Rocky Mountains to the west

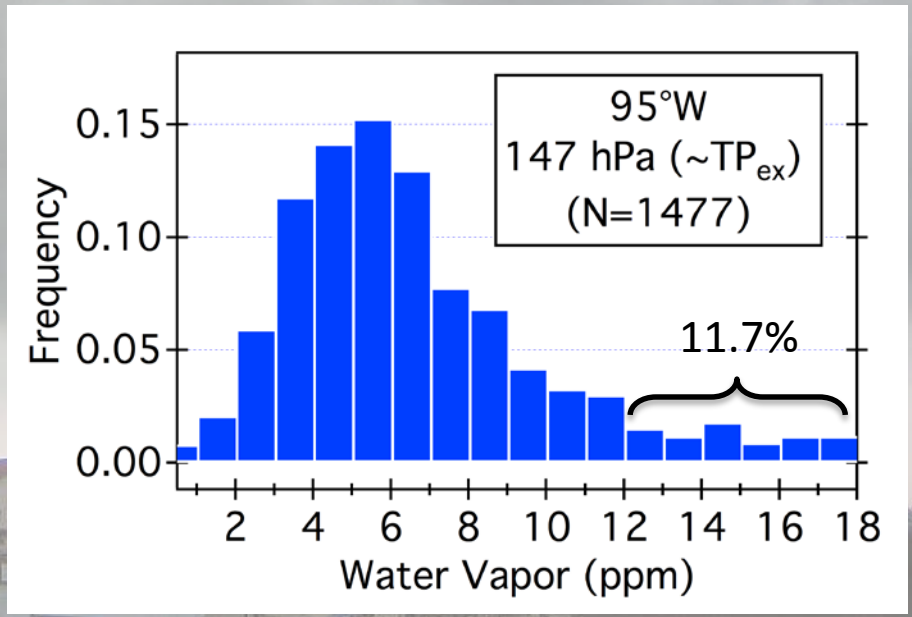
MLS WV at Boulder (40°N, 105°W) and (40°N, 95°W)

MLS retrievals for May-September: ±2° latitude, ±2° longitude









Summary and Conclusions

Observations of High WV during May-Sep (2004-2014)

Instrument	Site	Above	Freq	Above	Freq
FPH	Boulder	TP_{ex}	15.6%	TP_{tr}	5.5%
MLS	Boulder	147 hPa	5.9%	100 hPa	0.2%
MLS	40°N, 95°W	147 hPa	11.7%	100 hPa	1.2%

- Over these two locations, anomalously high WV is observed much more frequently in the middleworld than in the overworld.
- Convective influences are observed < 6% of the time in the overworld above Boulder and 10° east of Boulder.
- Only 25% of the high WV observations over Boulder are linked (by back trajectories) to the N. American monsoon region.
- The stratospheric layers of high WV over Boulder may be too thin to be detected as anomalously “wet” by MLS retrievals with 3 km vertical resolution.