Research Opportunities: SWOP

—— Sounding Water vapor, Ozone, and Particle

during the Asian summer monsoon (2009 ~ 2016 ~ ……)

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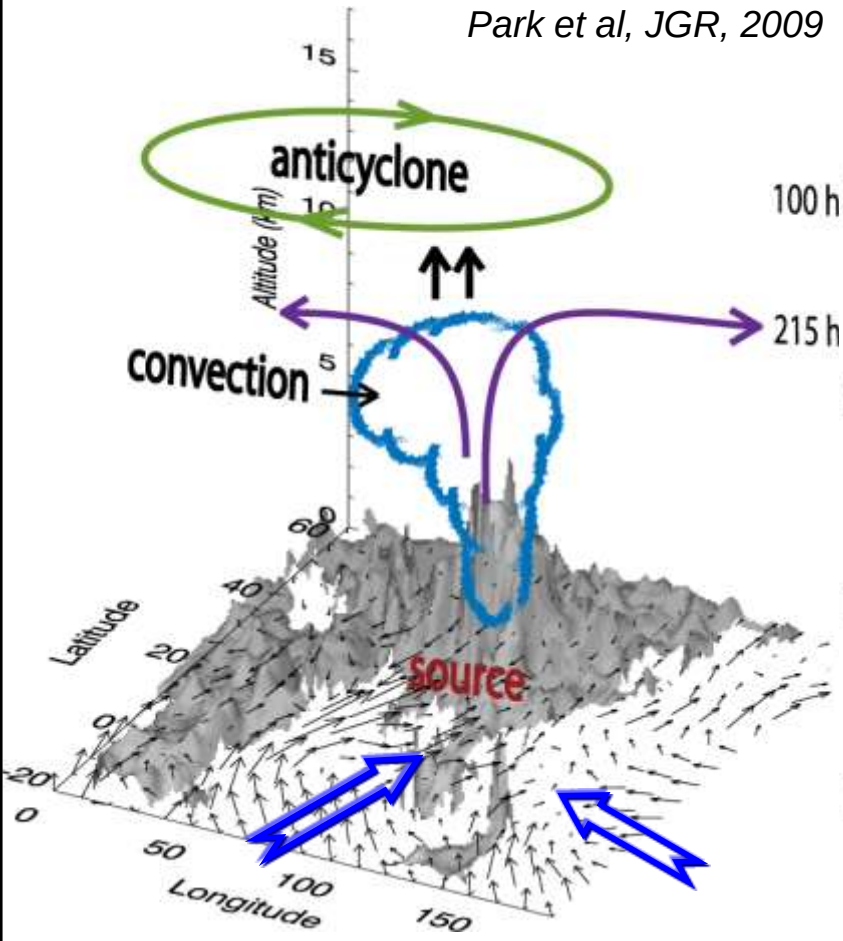
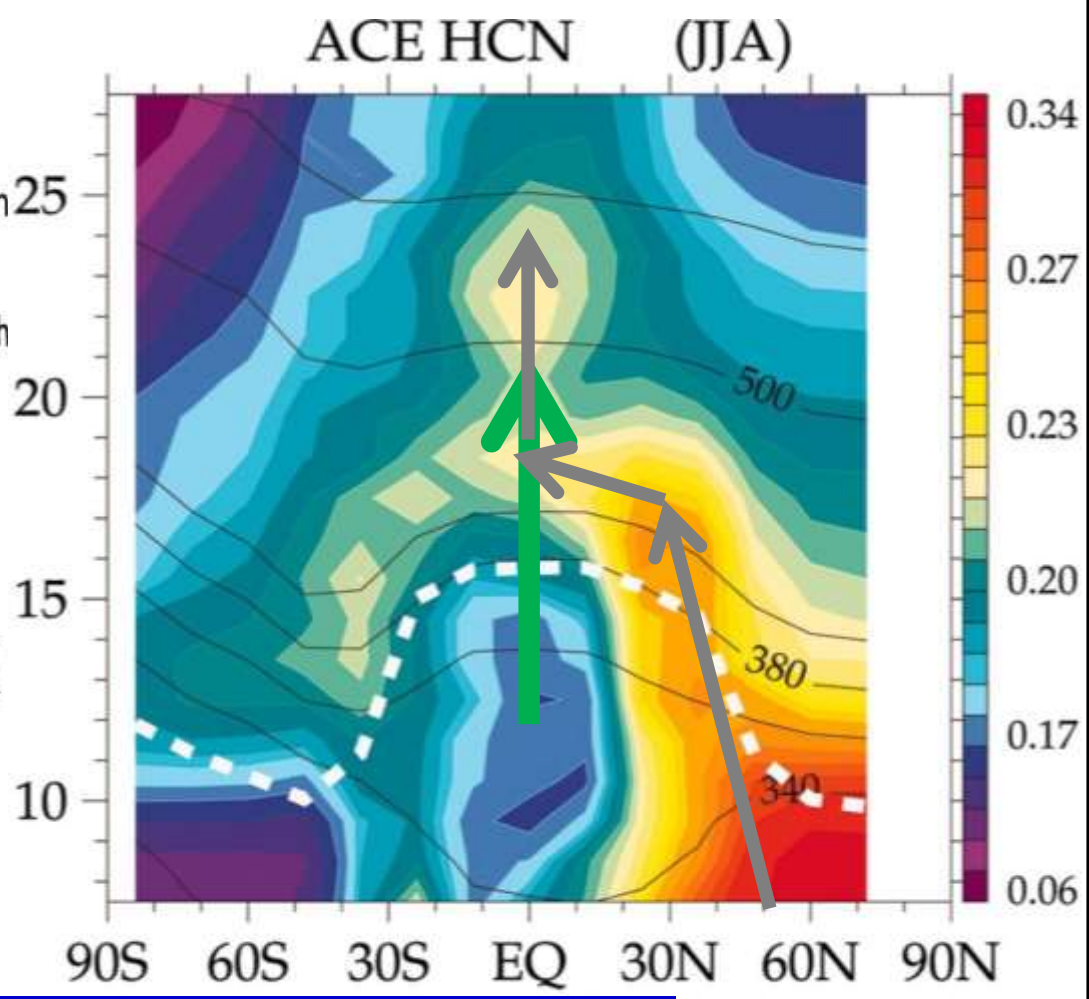
H. Vömel, L. L. Pan (NCAR); F. Weinhold (ETH);

D. Hurst, R.-S. Gao, S. Liu, E. Hall, A. Jordan, S. Oltmans (ESRL/NOAA)

ASM is a pollutant pathway to stratosphere!

Park et al, JGR, 2009





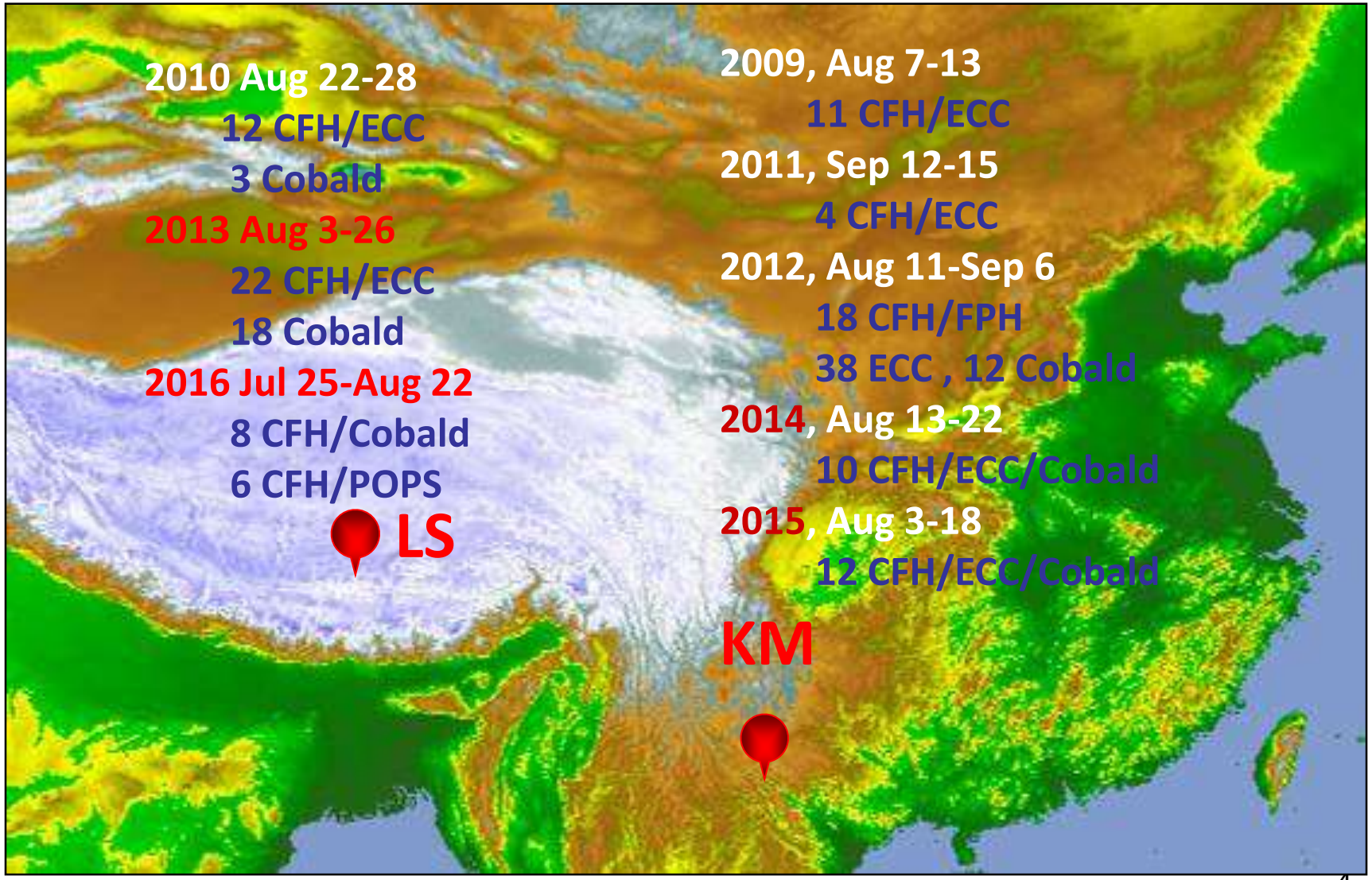
Randel et al. Science 2010

- ✓ **TTL: Gate to the stratosphere. It's clean.**
- ✓ **ASM: Another gate? But it's a gate for pollutants!**

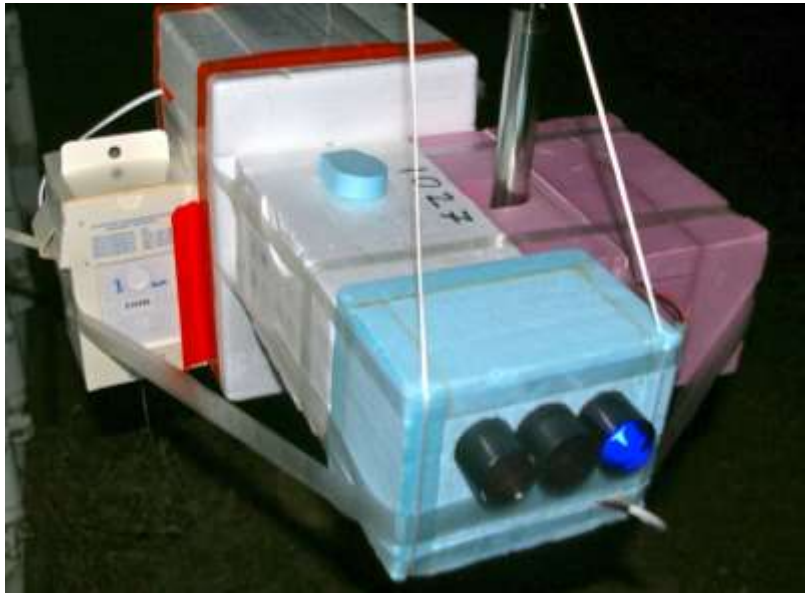
Scientific Motivation

- ✓ Satellite data and models often do not provide sufficiently resolved details for describing the transport process.
- ✓ Satellite product lacks of validation over the ASM region. In situ measurements inside the anticyclone are scarce.
- ✓ We are planning to conduct coincident in situ measurements of water vapor, ozone and particle (cirrus and aerosol) in the UTLS within the ASM anticyclone.
- ✓ These observations will be significant for quantifying the moisture and pollutant transport associated with the ASM, for identifying the transport pathway, and for understanding microphysical and chemical process in the UTLS. —— Scientific goals

Sounding Locations

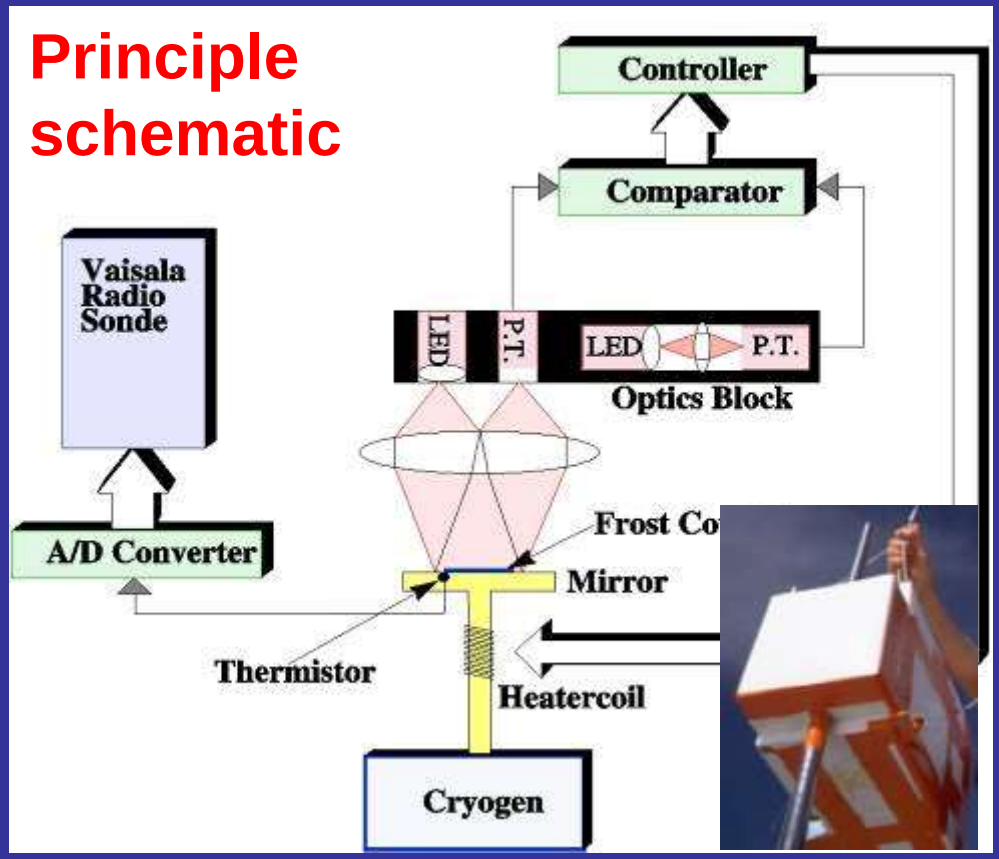


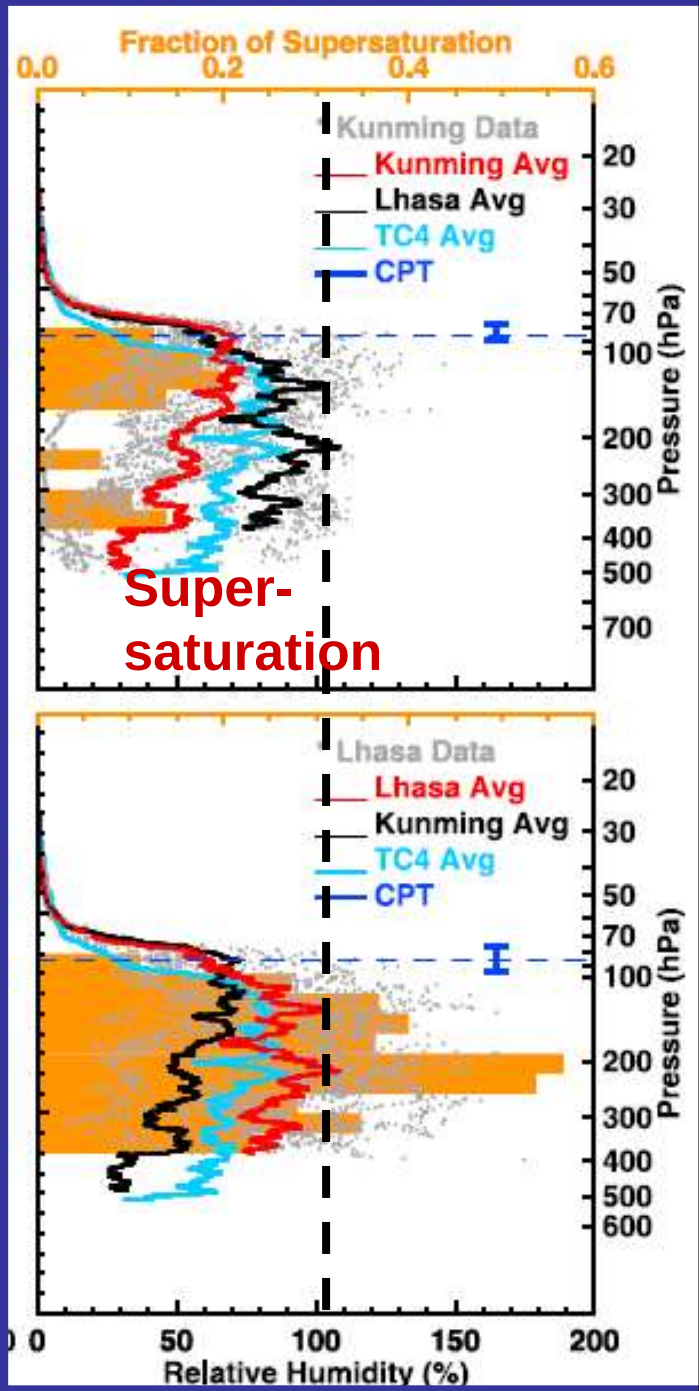
Balloon-borne sondes



- Compact Optical Backscatter Aerosol Detector (ETH) - particle
- NOAA Frost Point Hygrometer (NOAA GMD) – H_2O
- Cryogenic Frost Point Hygrometer (Vömel-DMT) – H_2O
- Electrochemical Concentration Cell ozonesonde (DMT) – O_3
- Radiosonde: P, T, U, winds (u,v) (InterMet)

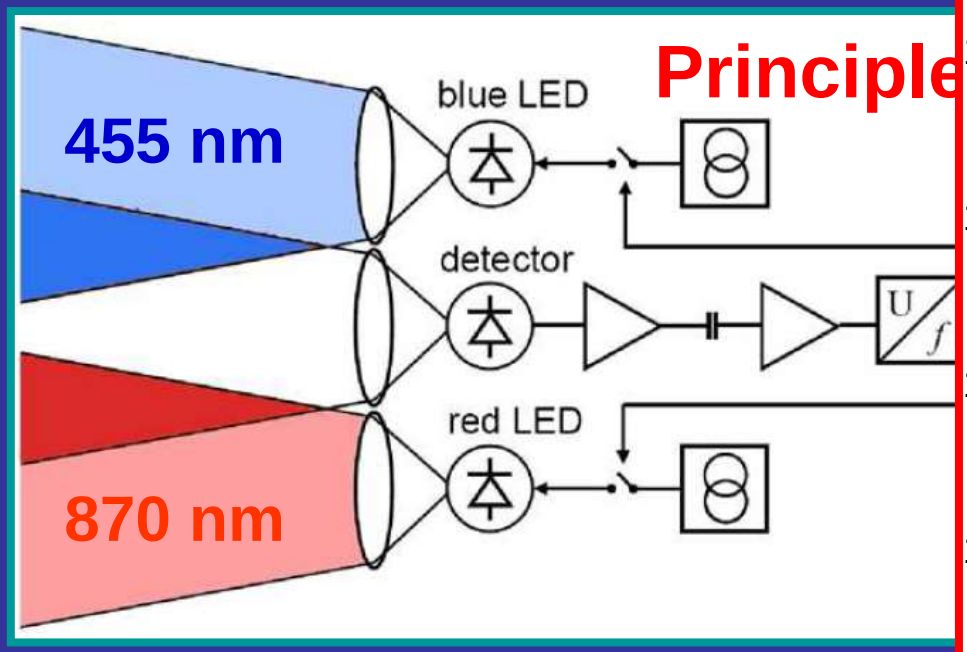
Cryogenic Frostpoint Hygrometer (CFH)



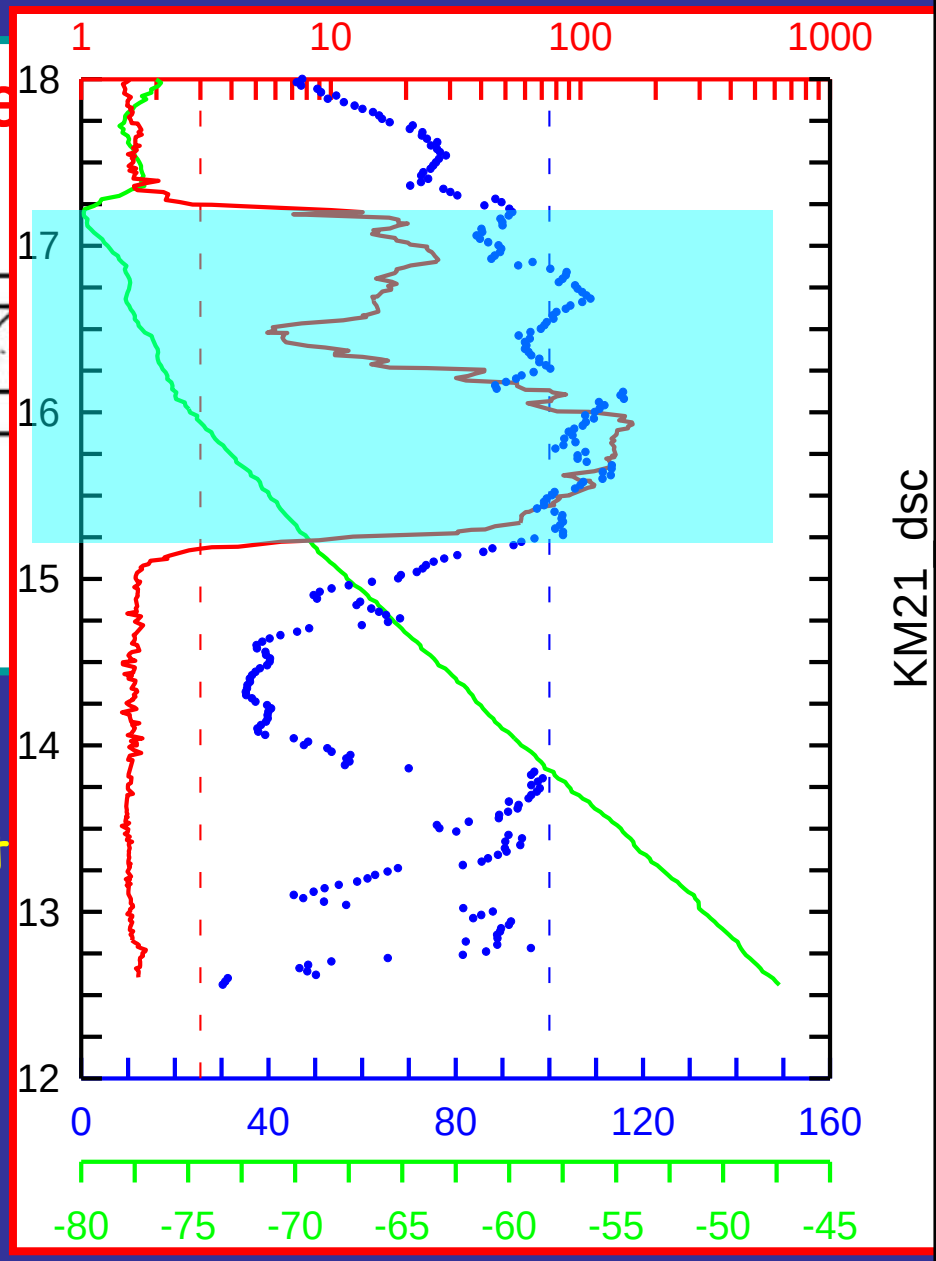


- ✓ CFH measures H_2O with high accuracy., which is used to understand the microphysics combined with COBALD measurements.

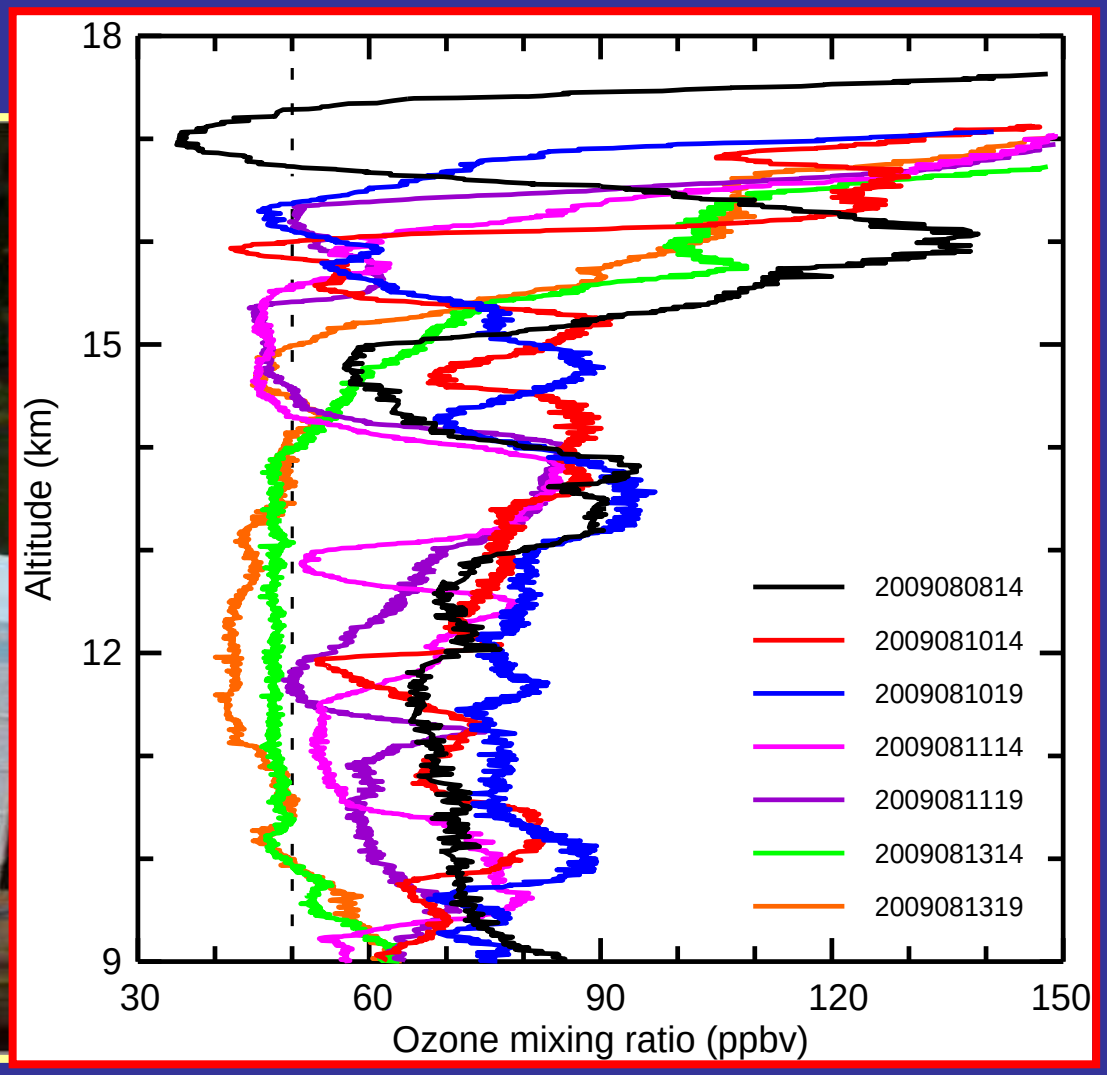
COBALD



- COBALD detects cloud and aerosol particles by emitting light at two wavelengths (455nm, 870/940nm), and receiving the back-scattered signal.



ECC Ozonesonde



✓ Deep convection signals can be found in ozone profiles.

POPS – a newcomer in 2015 & 2016

- ✓ Printed Optical Particle Spectrometer (POPS): a lightweight, low-cost detector -- Ru-shan Gao (NOAA)
- ✓ Measure profiles of aerosol size spectrum

Sounding information

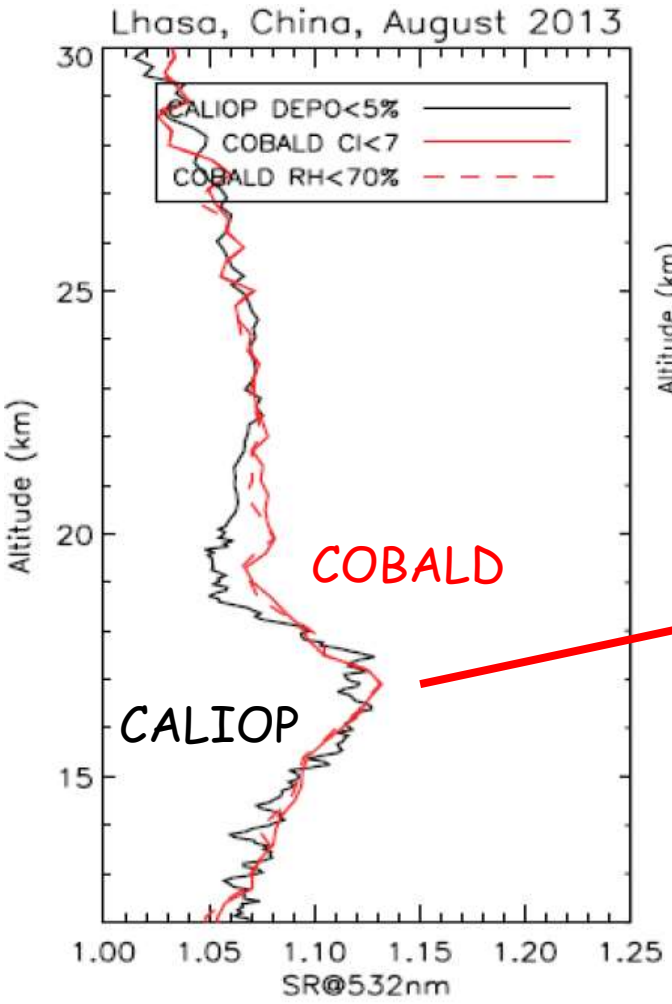
Period: 2009-2016 (11+12+4+38+22+10+12+14 = 123)

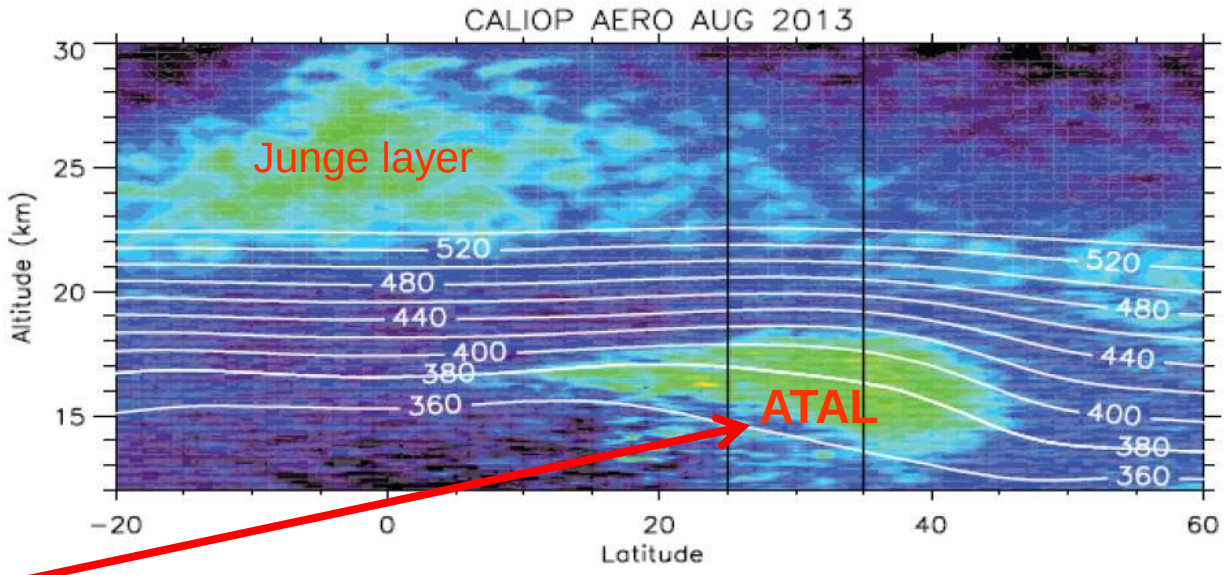
Totally, we have

- **ozone**: ECC (123)
- **water vapor**: CFH/FPH (103)
- **cloud and aerosol**: COBALD (63)
- **aerosol size distribution**: POPS (9)

Obs. highlights – ATAL issues

1. COBALD data confirms the ATAL finding from CALIOP

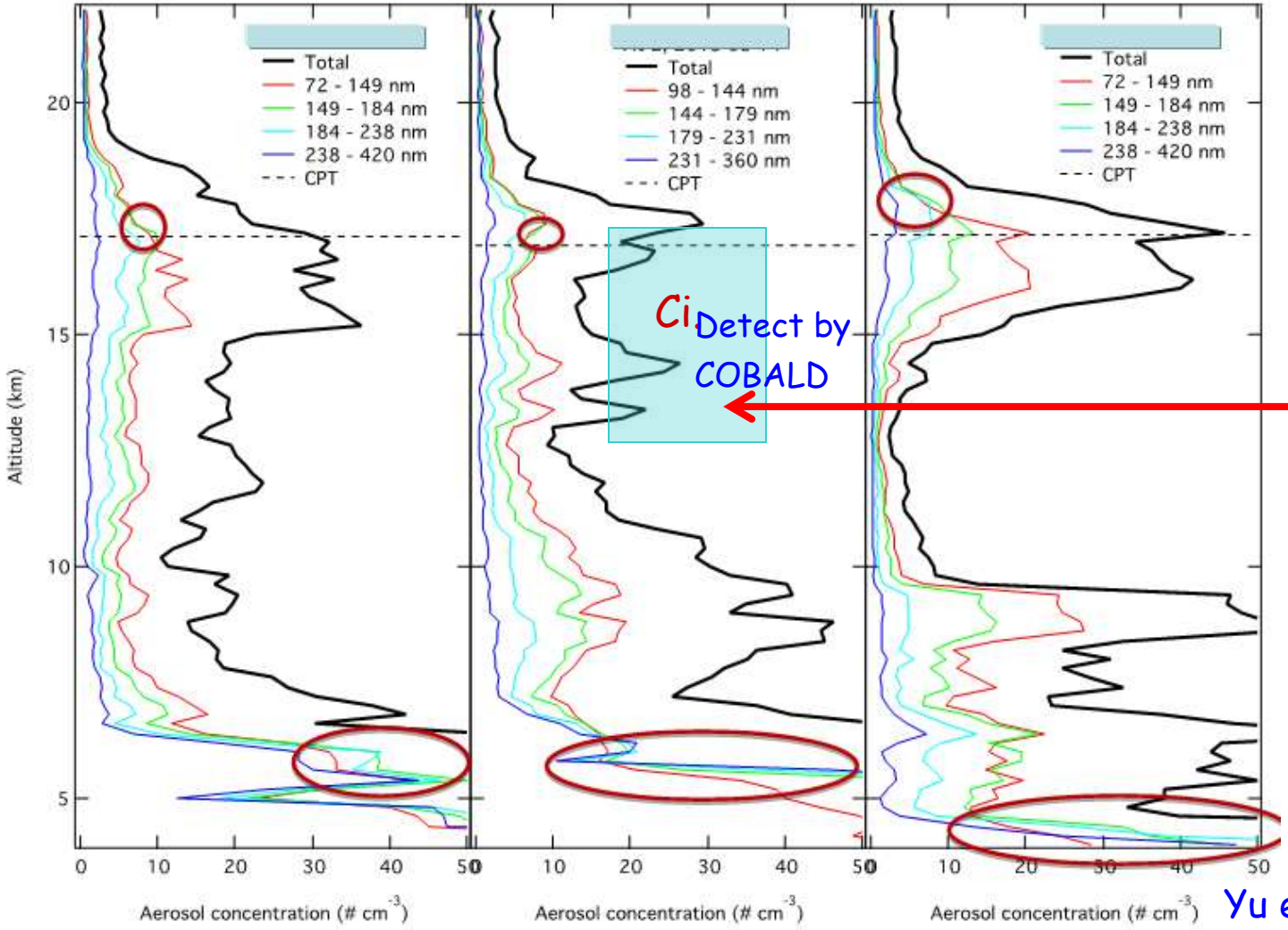




Vernier et al. JGR 2015

Obs. highlights – ATAL issues

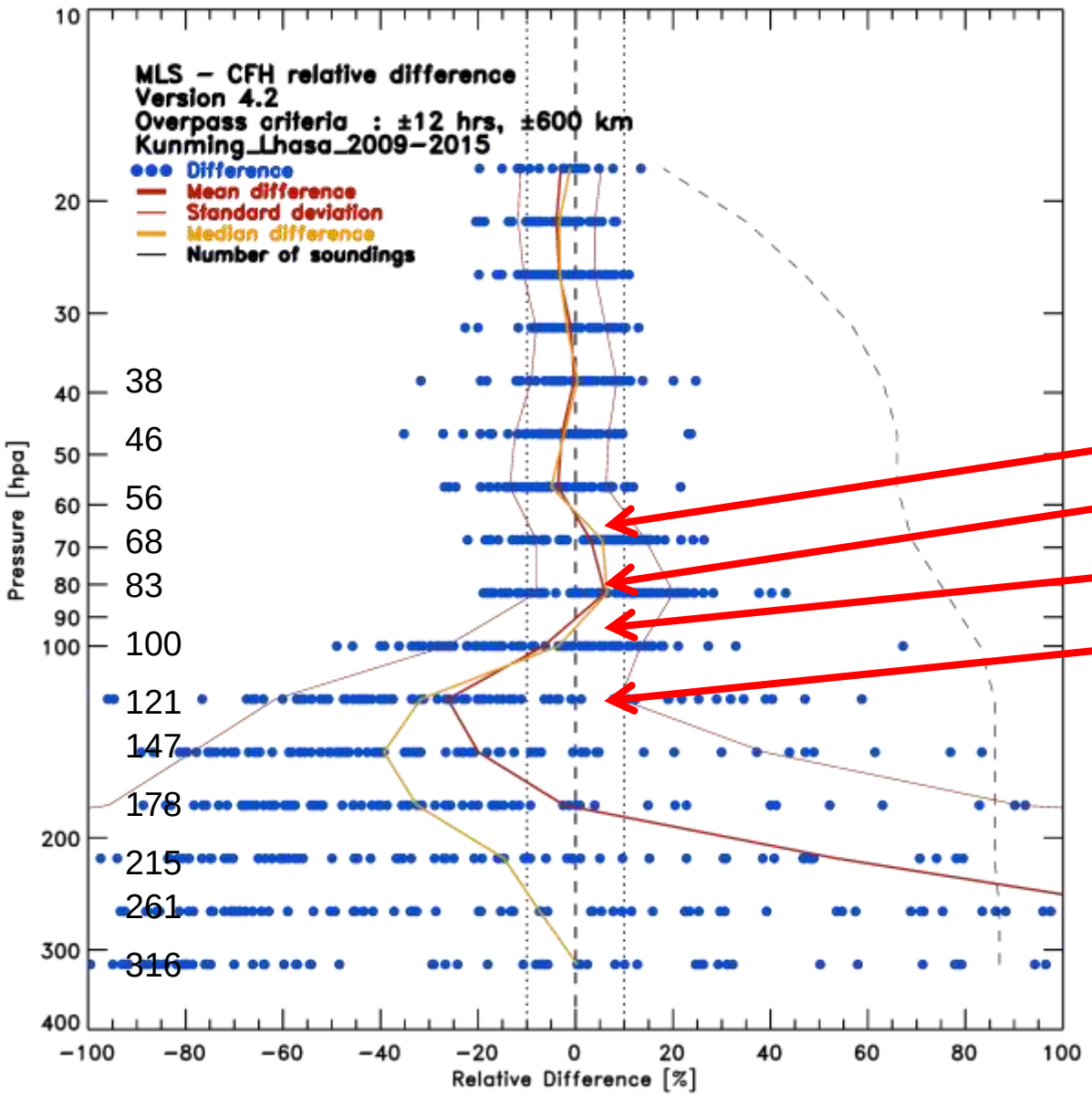
2. POPSs see size distribution profile in the ATAL



1. Enhance 14-19km
2. Extend 2km above CPT
3. Interstitial aerosol

Yu et al. PNAS Accepted
Ru-Shan Gao, talk

Obs. highlights – MLS Validation



H_2O rel. diff.
(MLS – CFH)

<5% above 68mb

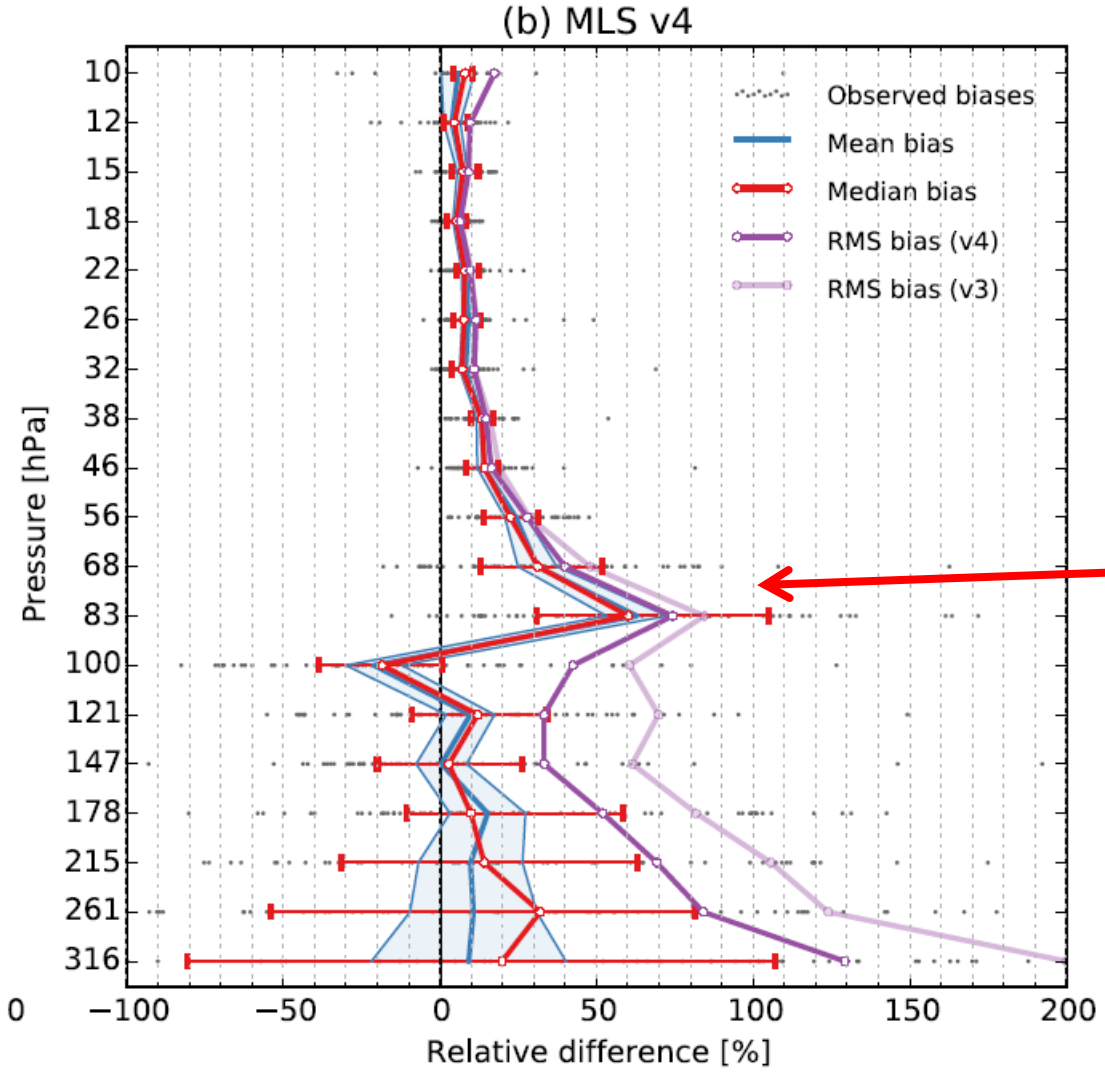
+7% @83mb

–7% @100mb

larger bias & dev.

Similar plot Can be found in
Yan et al. AMTD, 2016

Obs. highlights – MLS Validation



O_3 rel. diff.
(MLS – ECC)

bias abrupt jump

Yan et al. AMTD, 2016

RESULTS -- Statistics

1. TTL boundaries:

bottom

top

KM

H: 17.30±0.43

T: 193.7±1.7

Θ: 384.2 ±8.4

LH

H: 17.54±0.53 +0.24km

T: 195.2 ±1.7 +1.5K

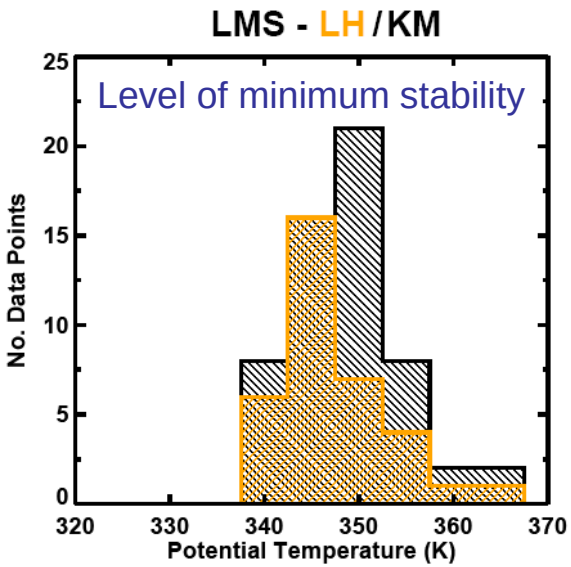
Θ: 390.4 ±10.3 + 6K

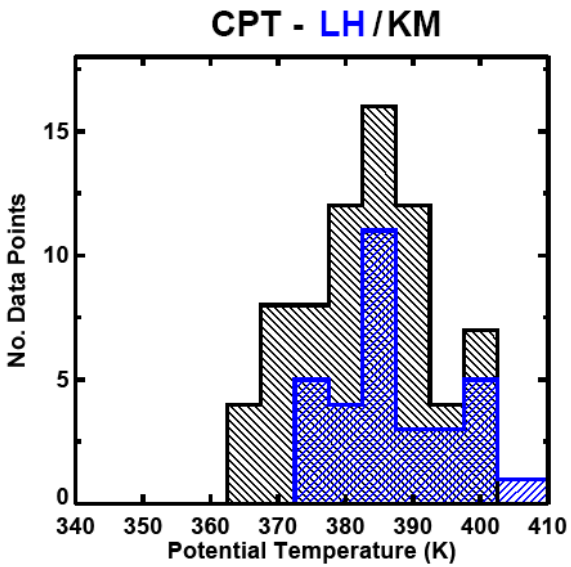
TC[4]

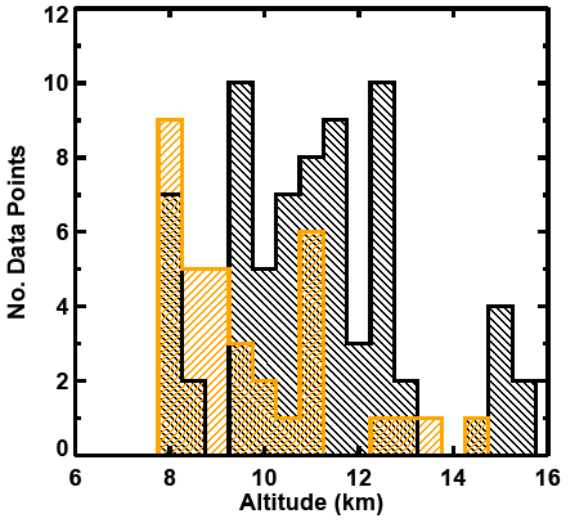
H: 16.6 ± 0.7 km

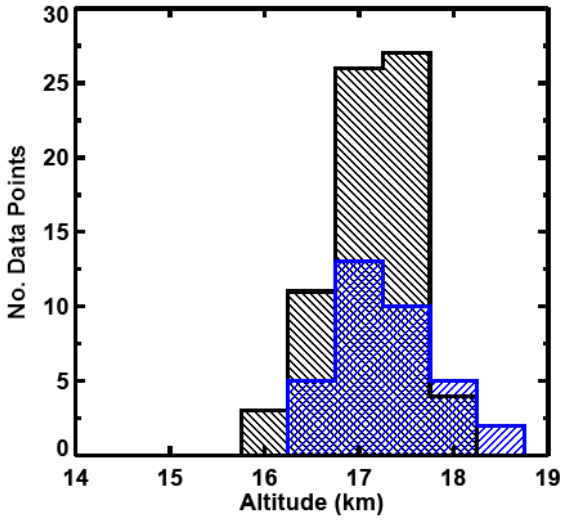
Θ: 375.1 ±13 K

Pan et al. JGR, 2014







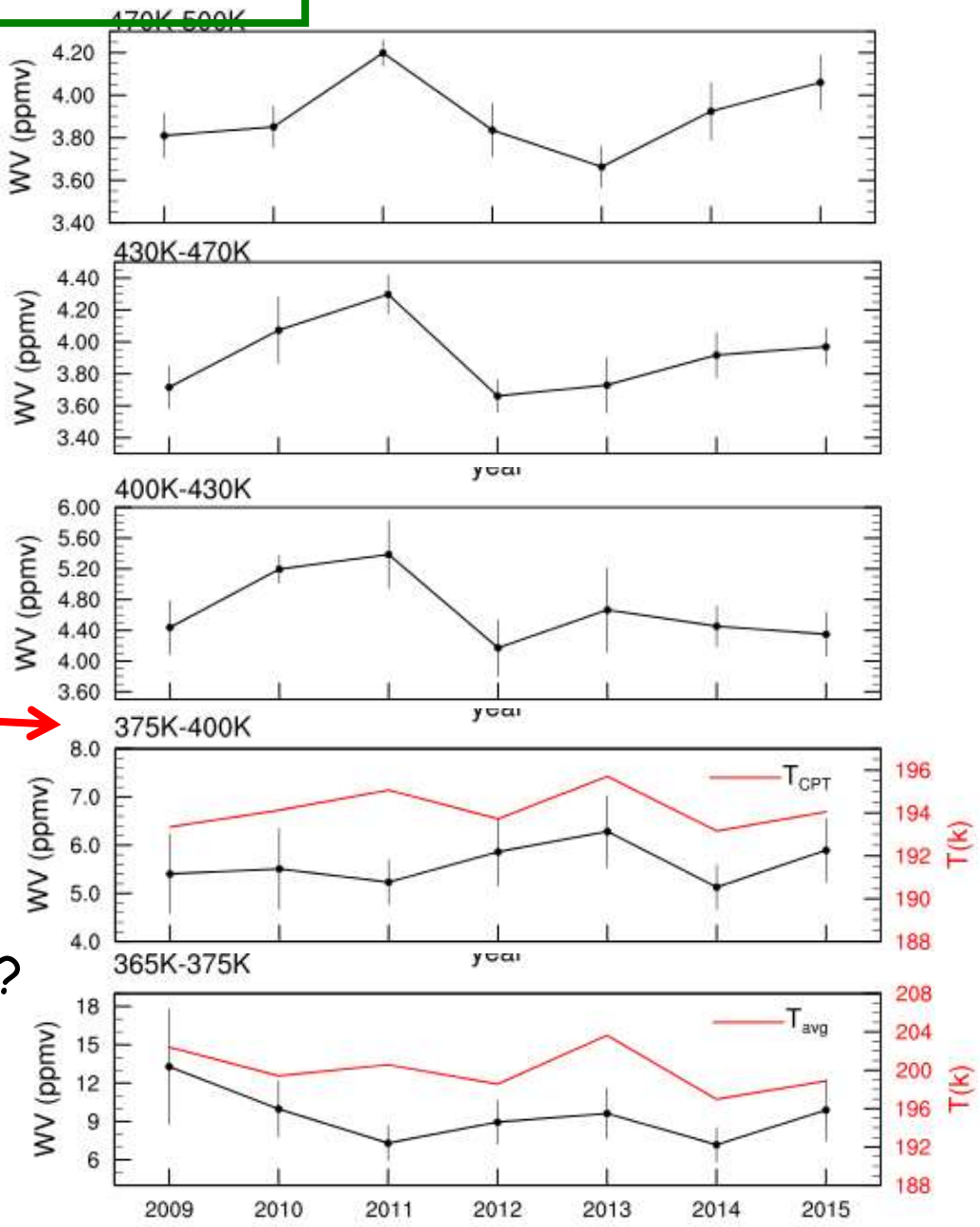


RESULTS -- Statistics

2. Interannual variation of H_2O in the UTLS

Decoupled with lower levels

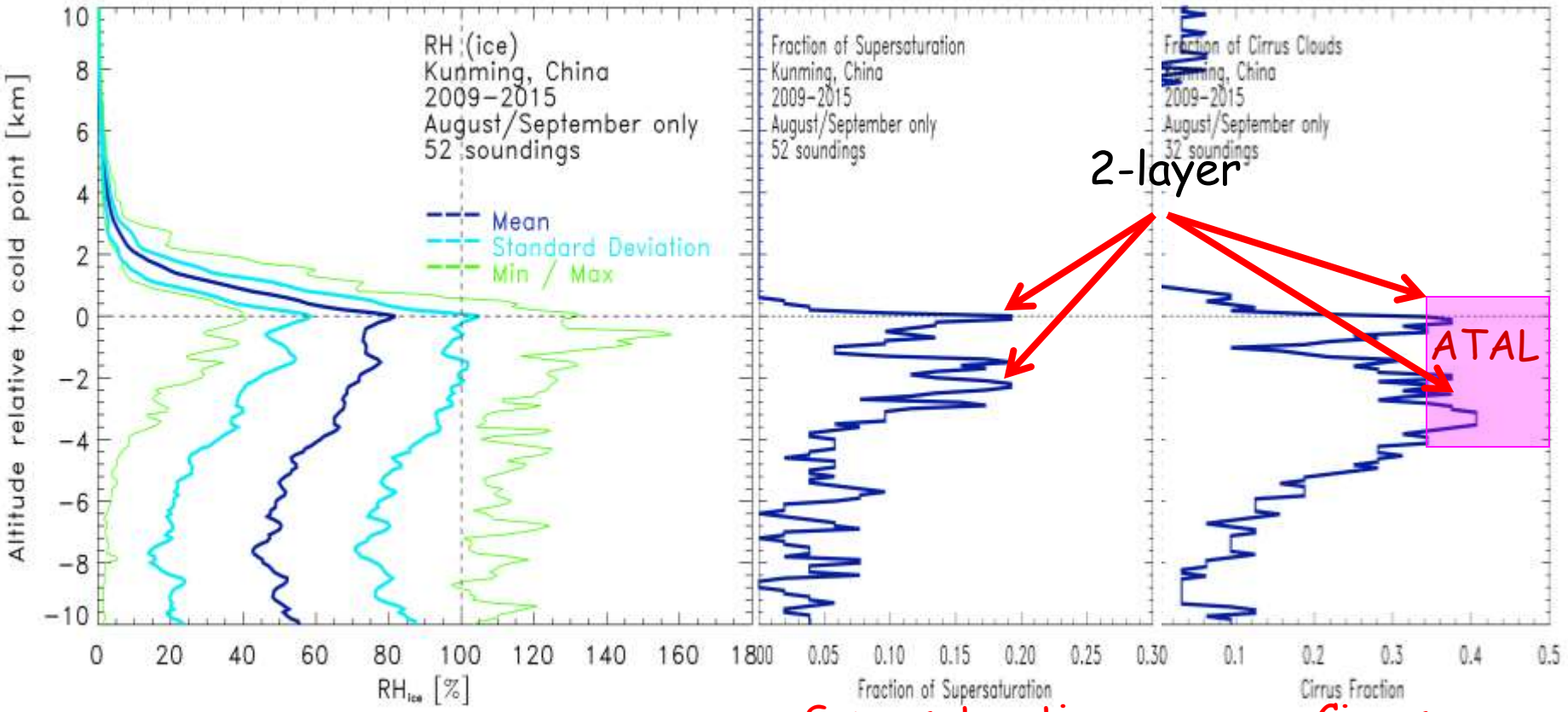
Interannual variation tuned by T?



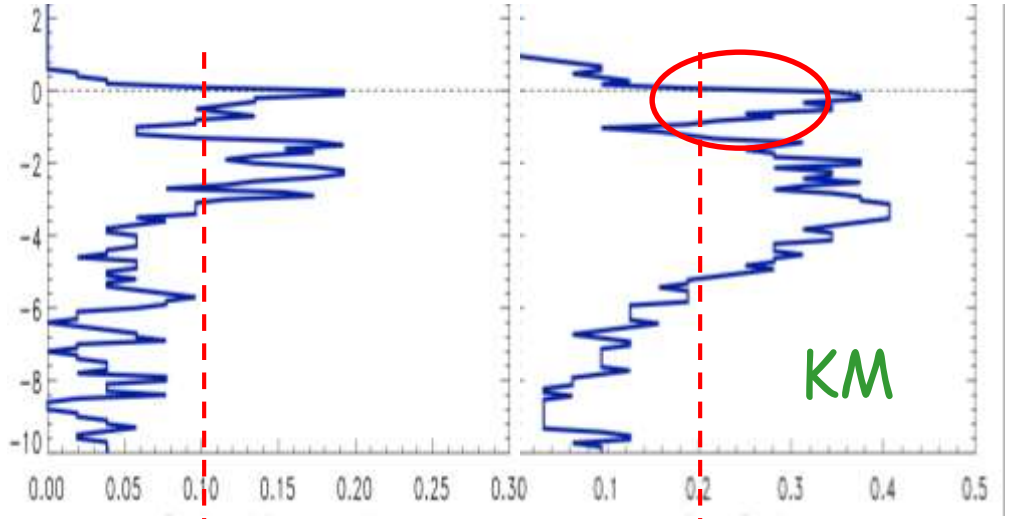
RESULTS -- Statistics

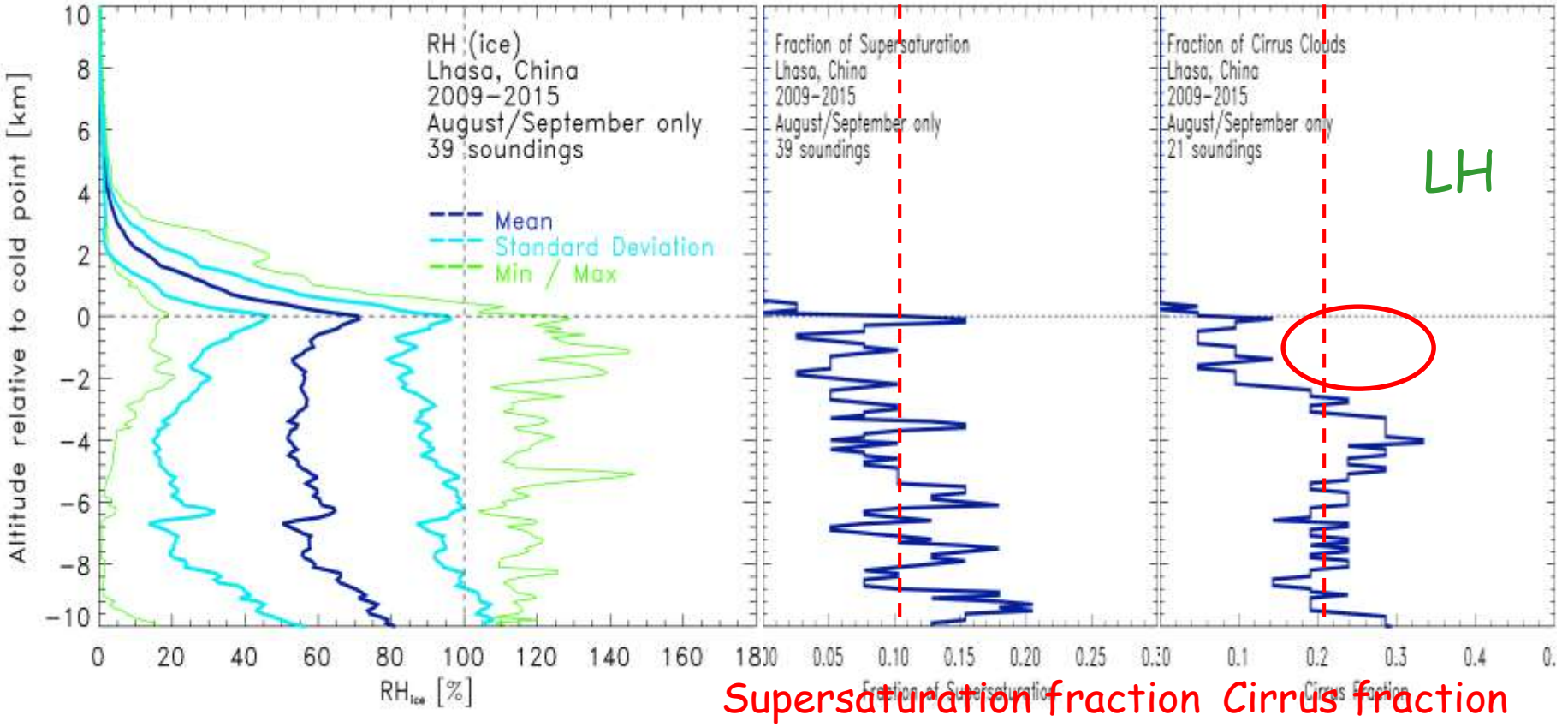
3. RHi, super-saturation, cirrus

KM



For Lhasa

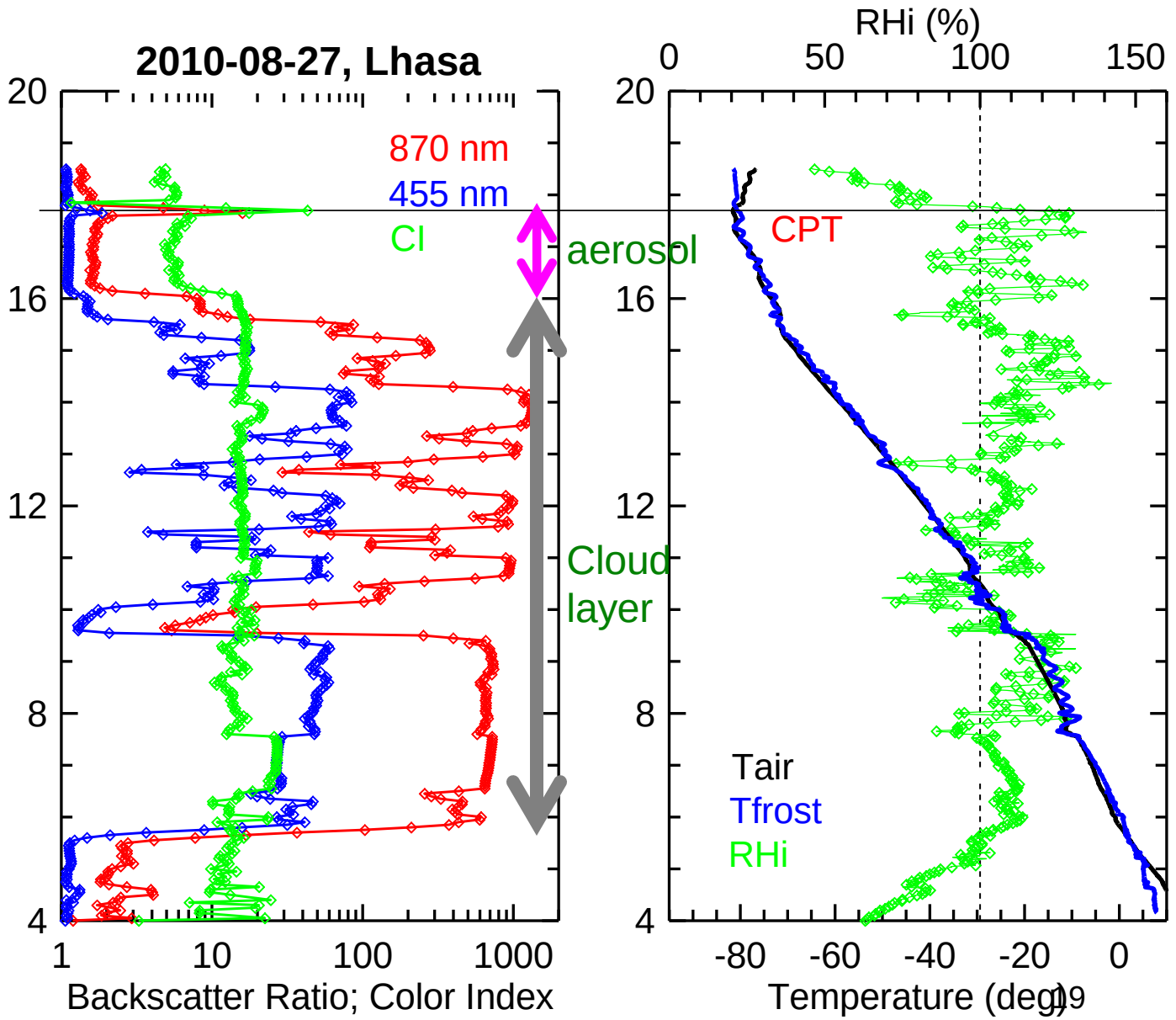

KM


RH (ice)
Lhasa, China
2009–2015
August/September only
39 soundings
Mean
Standard Deviation
Min / Max
Altitude relative to cold point [km]
RH$_{ice}$ [%]
Fraction of Supersaturation
Lhasa, China
2009–2015
August/September only
39 soundings
Fraction of Cirrus Clouds
Lhasa, China
2009–2015
August/September only
21 soundings
LH
Supersaturation fraction
Cirrus fraction

Some cases

Case 1:

A deep layer of supersaturated air & cloud – thickness 10km

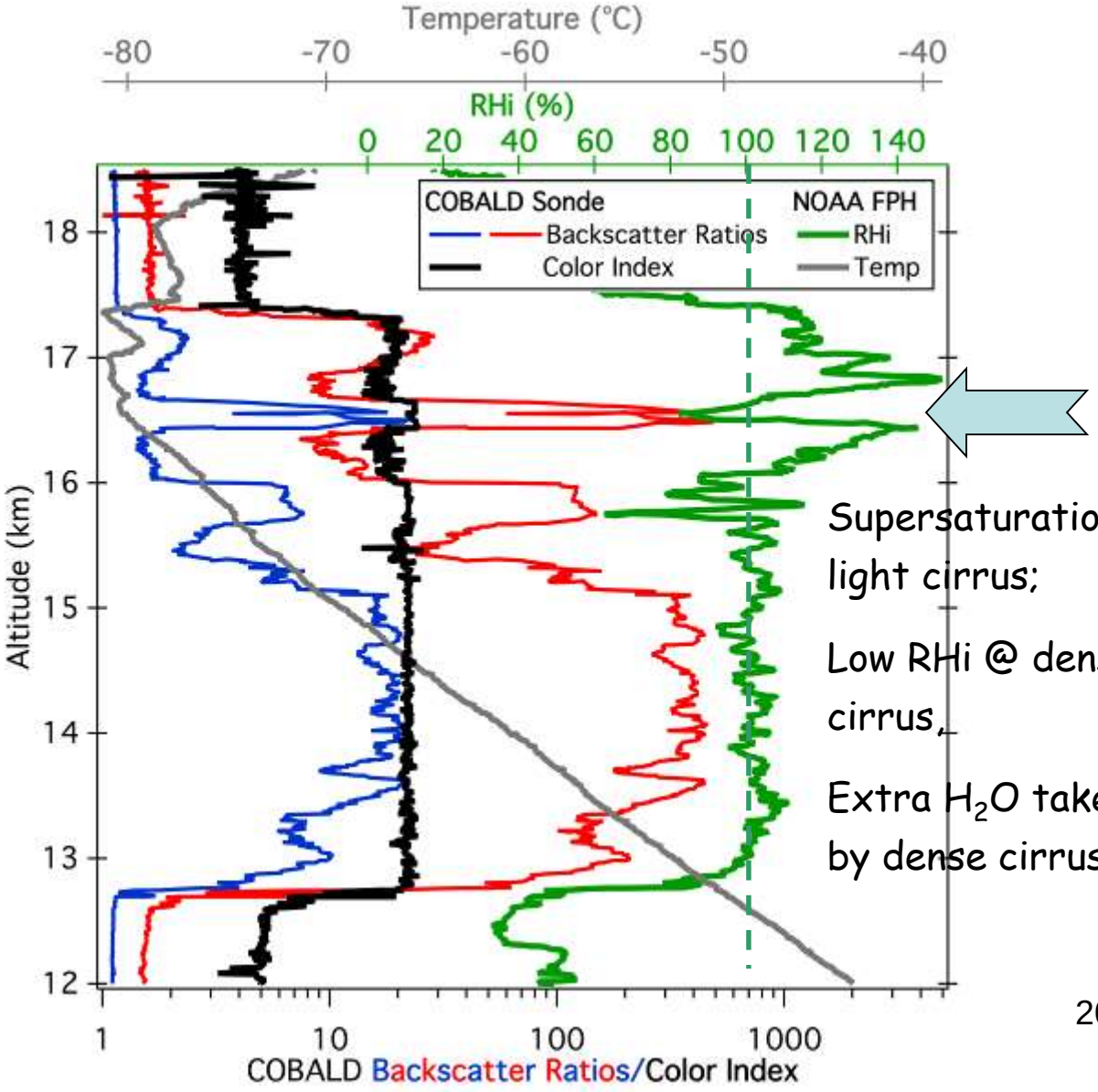


Some cases

Kunming, 20 Aug'12

Case 2:

Anti-correlation between cirrus layer and supersaturation



Supersaturation @ light cirrus;

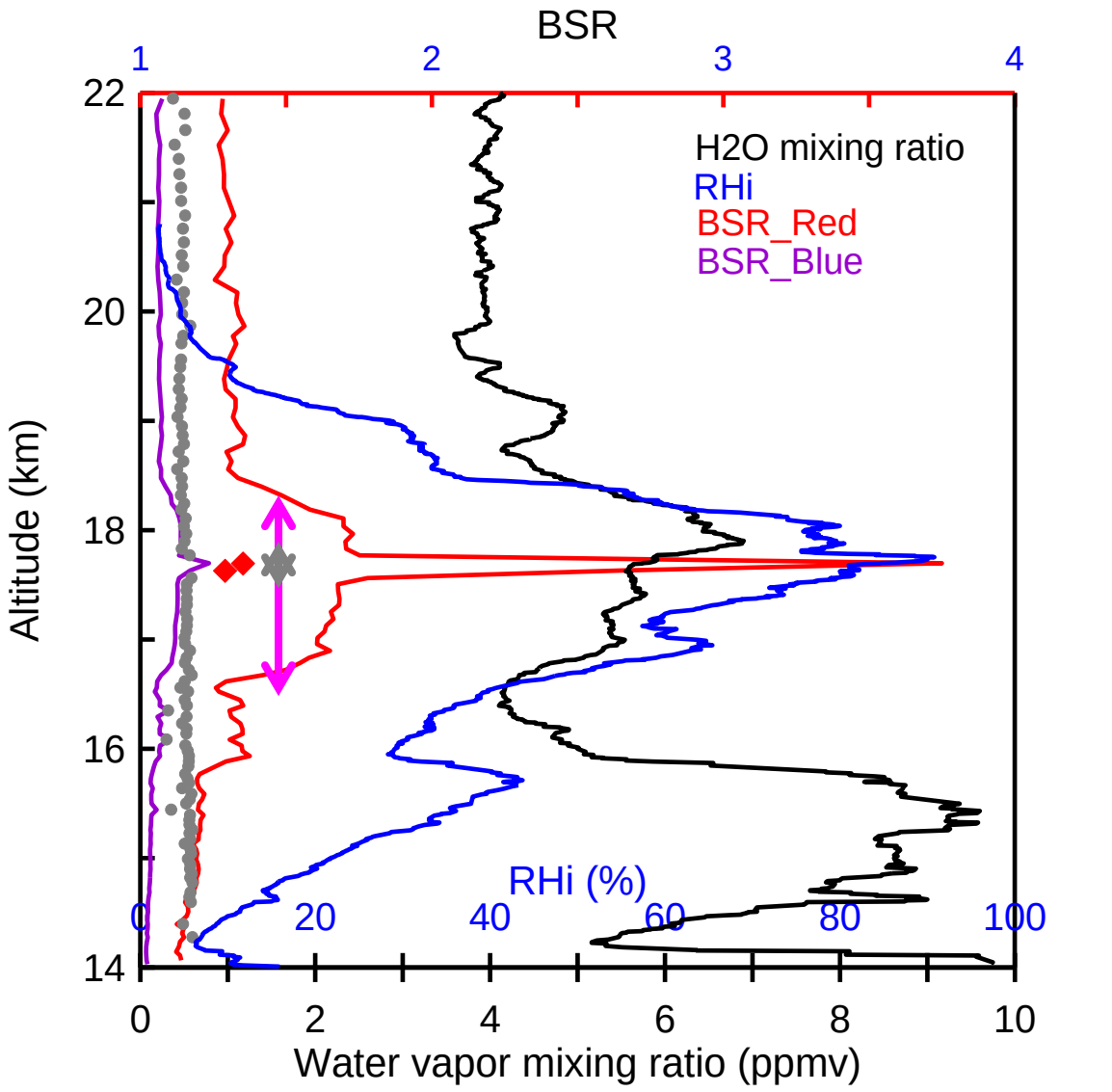
Low RHi @ dense cirrus,

Extra H_2O taken by dense cirrus.

Some cases

Case 3:

Aerosol-cirrus oupling:
Hygroscopic swollen, or evaporation?

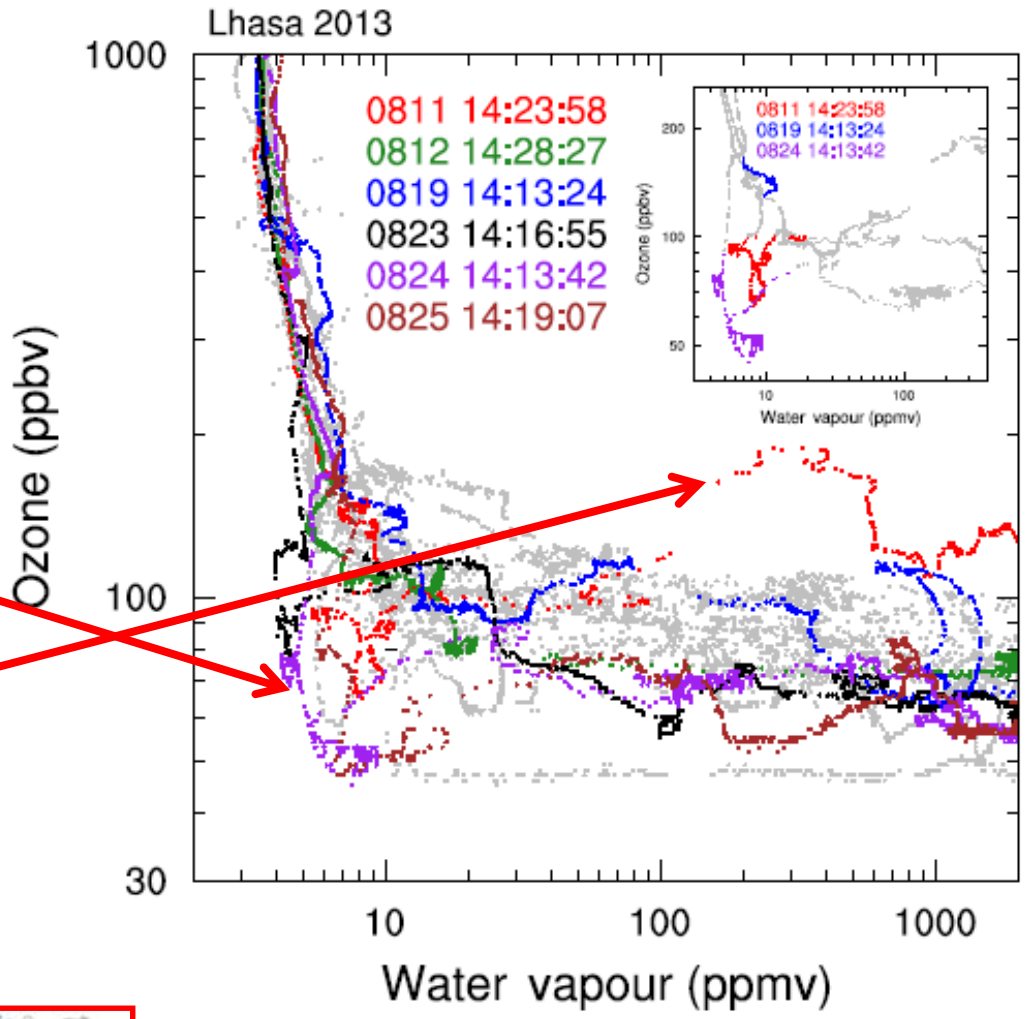


21

Some cases

Case 4:

- Typhoon transport
- Stratospheric intrusion



Atmos. Chem. Phys., 17, 4657–4672, 2017
www.atmos-chem-phys.net/17/4657/2017/
doi:10.5194/acp-17-4657-2017

Atmospheric Chemistry and Physics
EGU

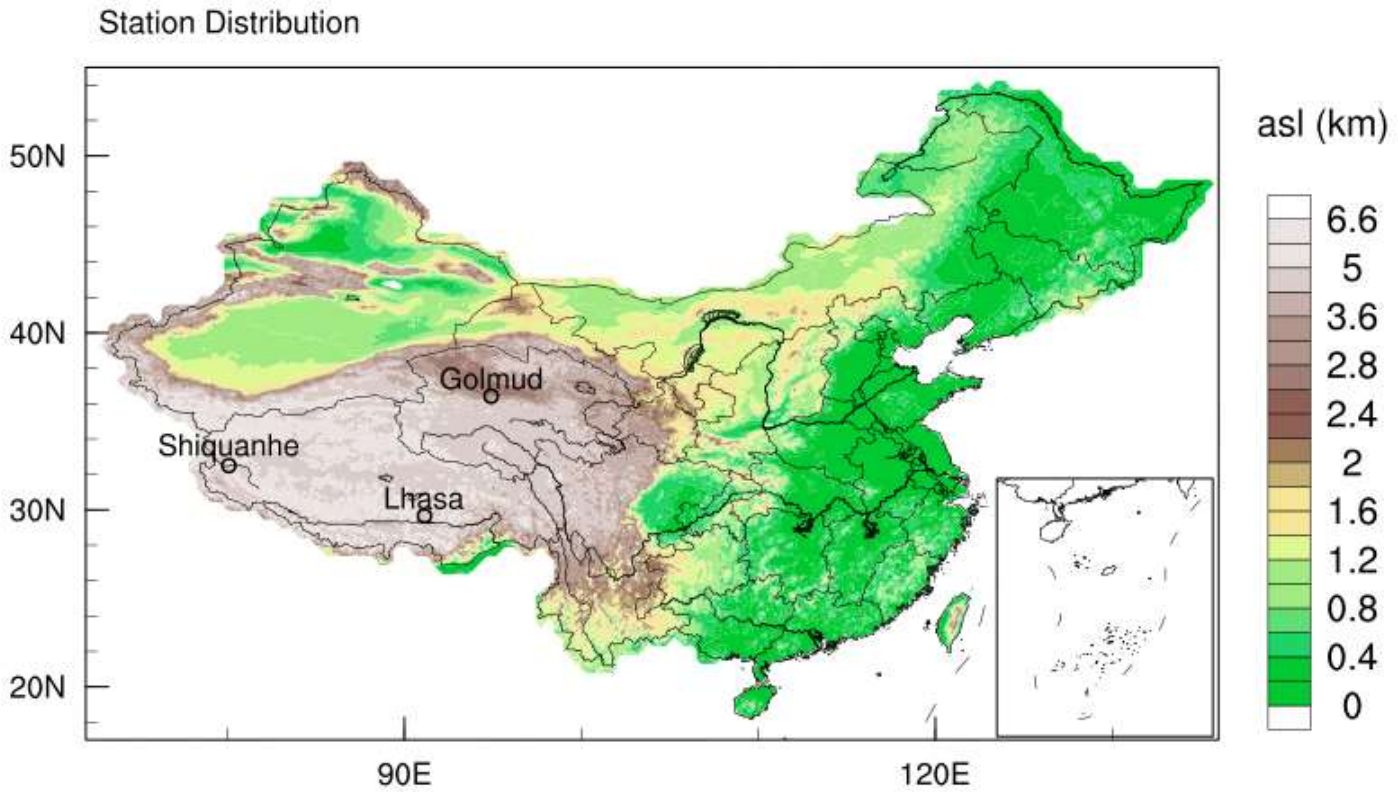
Impact of typhoons on the composition of the upper troposphere within the Asian summer monsoon anticyclone: the SWOP campaign in Lhasa 2013

Dan Li[1,2], Bärbel Vogel[2], Jianchun Bian[1,3], Rolf Müller[2], Laura L. Pan[4], Gebhard Günther[2], Zhixuan Bai[1,3], Qian Li[1], Jinqiang Zhang[1], Qiujun Fan[1,3], and Holger Vömel[5]

O_3 correlations for balloon profiles measured over
ust 2013 (grey colour). The profiles measured on 11–
re impacted by tropical storm Jebi and measurements
25 August were impacted by typhoon Utor or Trami.
hree profiles influenced by tropical cyclones are high-
lighted (inset).

International collaboration:

Match sounding in 2016 summer



Balloon measurements 2016 from China

Balloon measurement 2016 every other day from Lhasa, Shiquanhe, Golmud

Lhasa (29.66° N, 91.14° E, 3650 m): ECC (O3) / CFH (H2O) / COBALD (Aerosol)

Shiquanhe (32.5° N, 80.08° E, 4279 m): ECC (O3) / CFH (H2O) / COBALD (Aerosol)

Golmud (36.42° N, 94.9° E, 2809 m): ECC (O3)

Summary

1. SWOP data: ATAL, satellite validation, TTL structure, supersaturation-cirrus, cirrus-aerosol coupling, dynamical transport, …; Trend and case study
2. SWOP collaboration: match sounding campaign (StratoClim): balloon-borne sensors (COBALD, POPS, …)

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Thanks for your attention!