The Unique Asian Monsoon Tropopause Structure and Its Role in Large Scale Transport and Mixing

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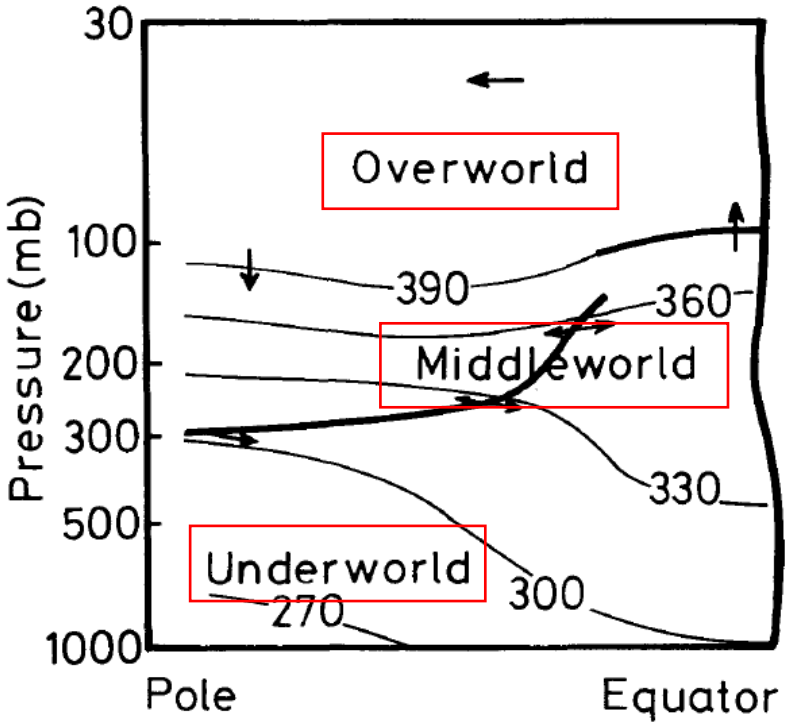
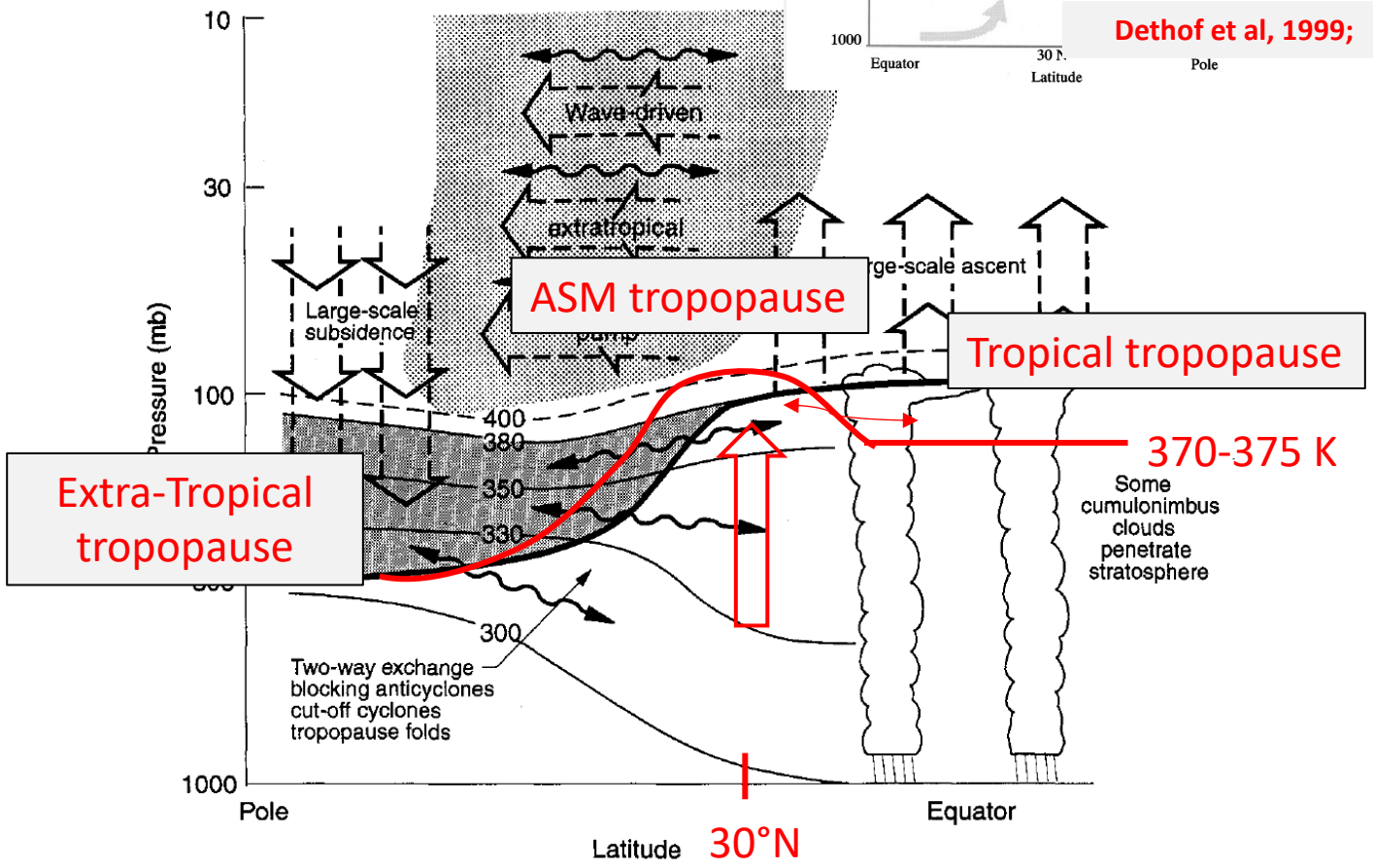
Important Dynamic Structures for STE

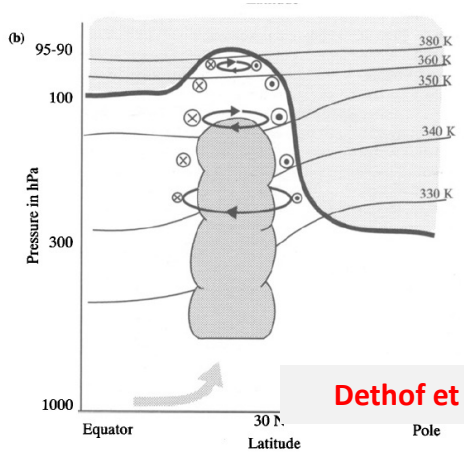
"Towards a PV-θ view of the general circulation"

Hoskins, 1991



Holton et al., 1995

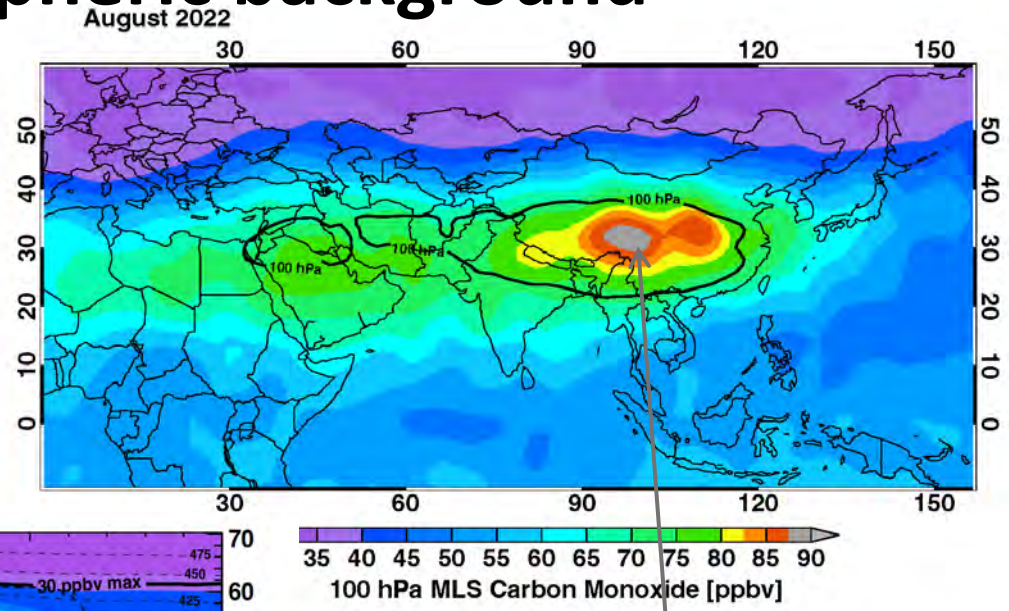




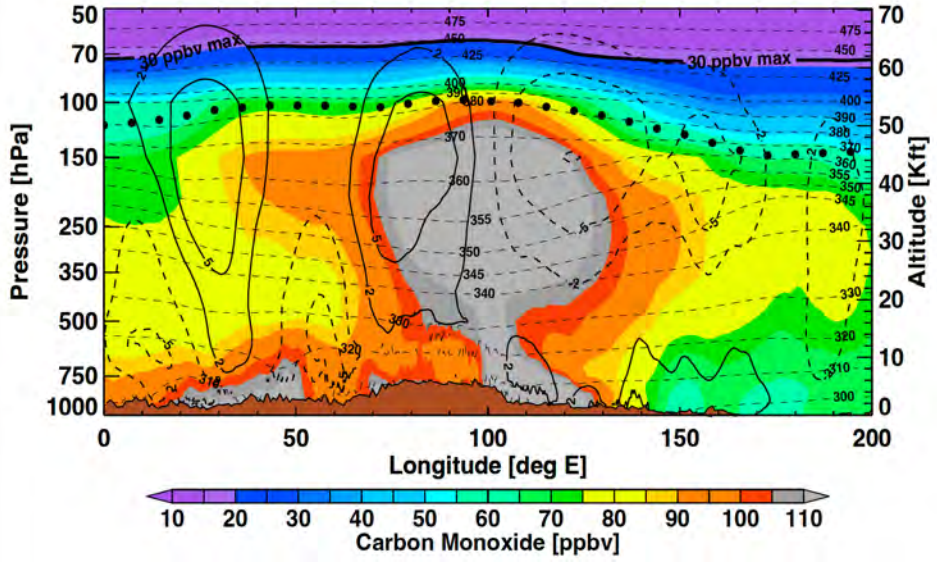
Dethof et al, 1999;

ASM appears as a “tropospheric bubble” in stratospheric background

MLS CO
August 2022
100 hPa layer



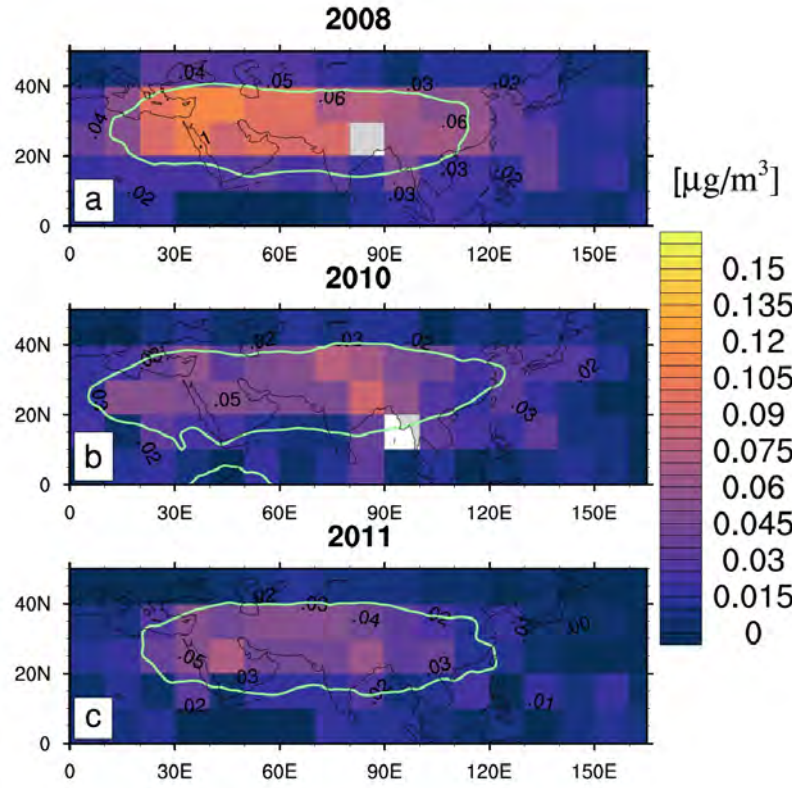
Tropospheric Air



NASA GEOS-FP model CO
August 2022
Average of 20°-40°N

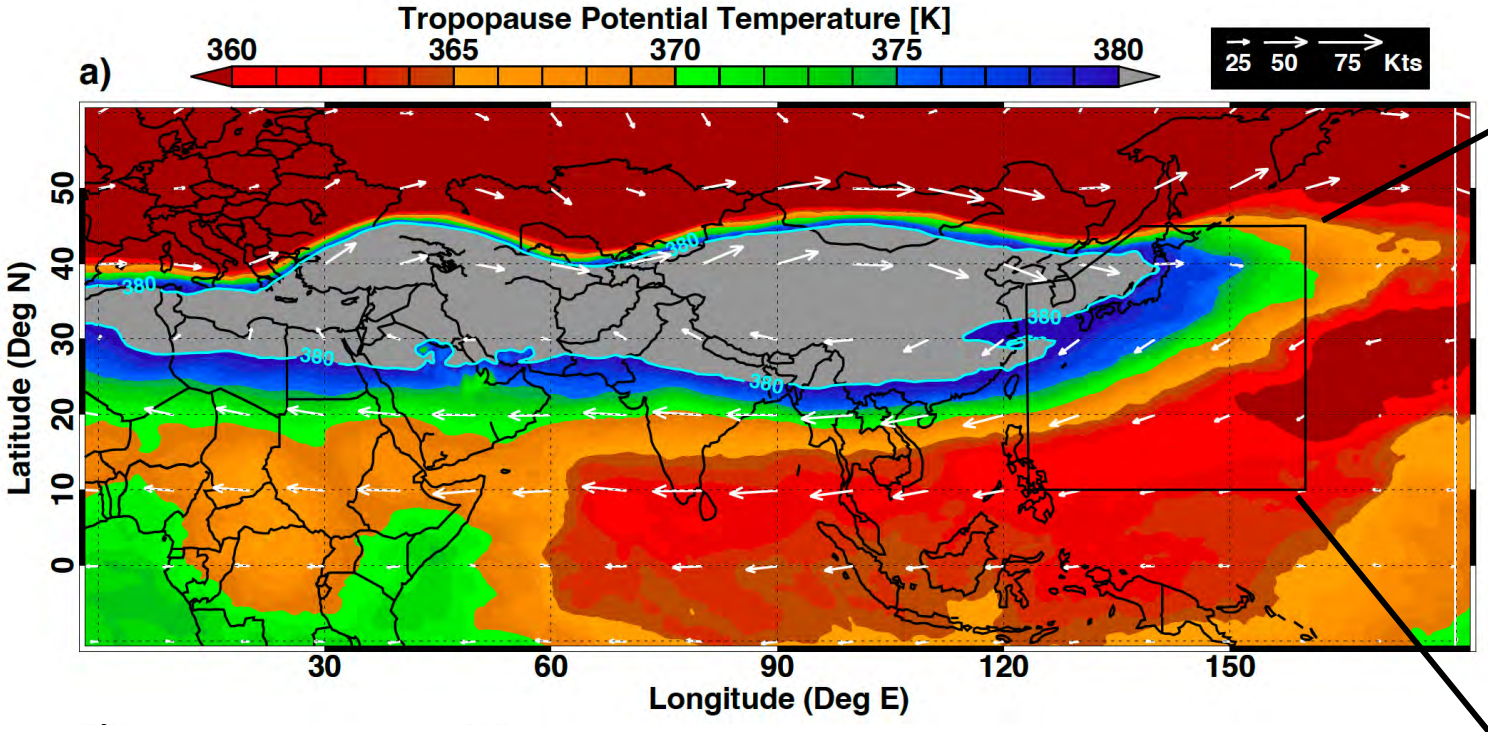
Tropopause intersection at 16 km

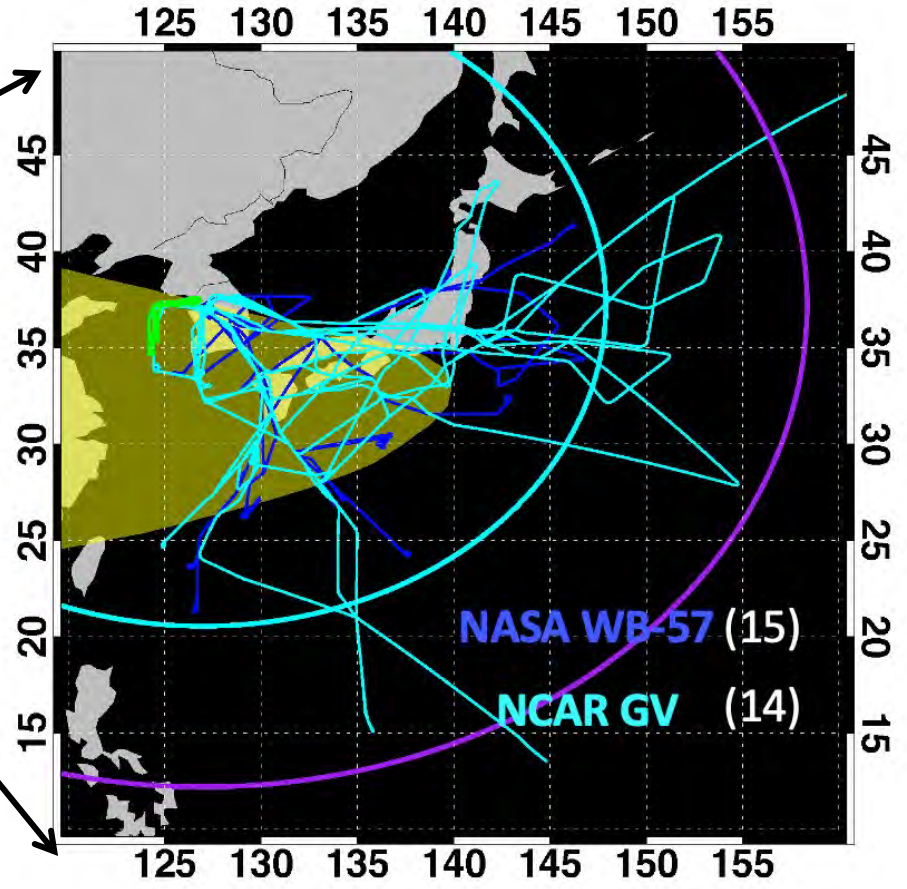
MIPAS AN aerosols at 16 km



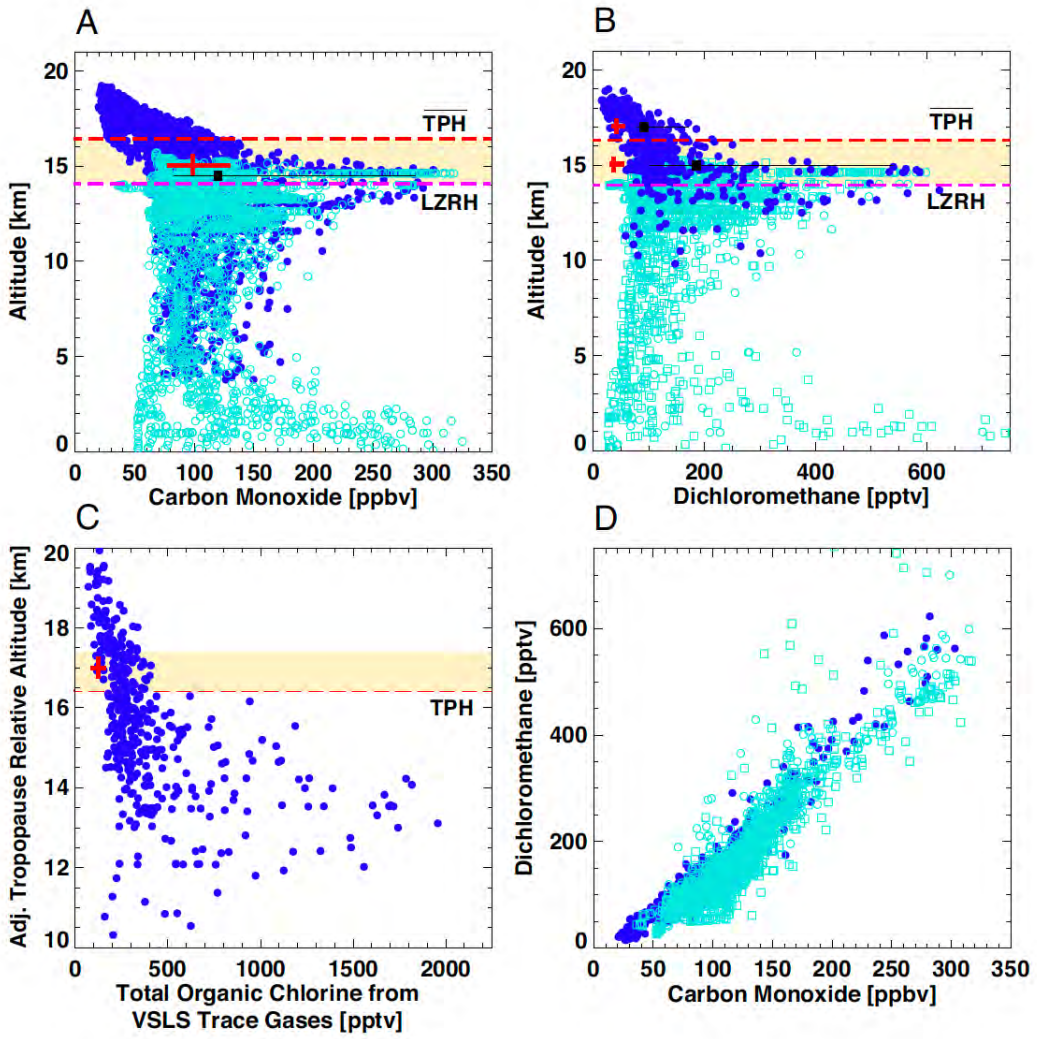
Zhu et al., Submitted

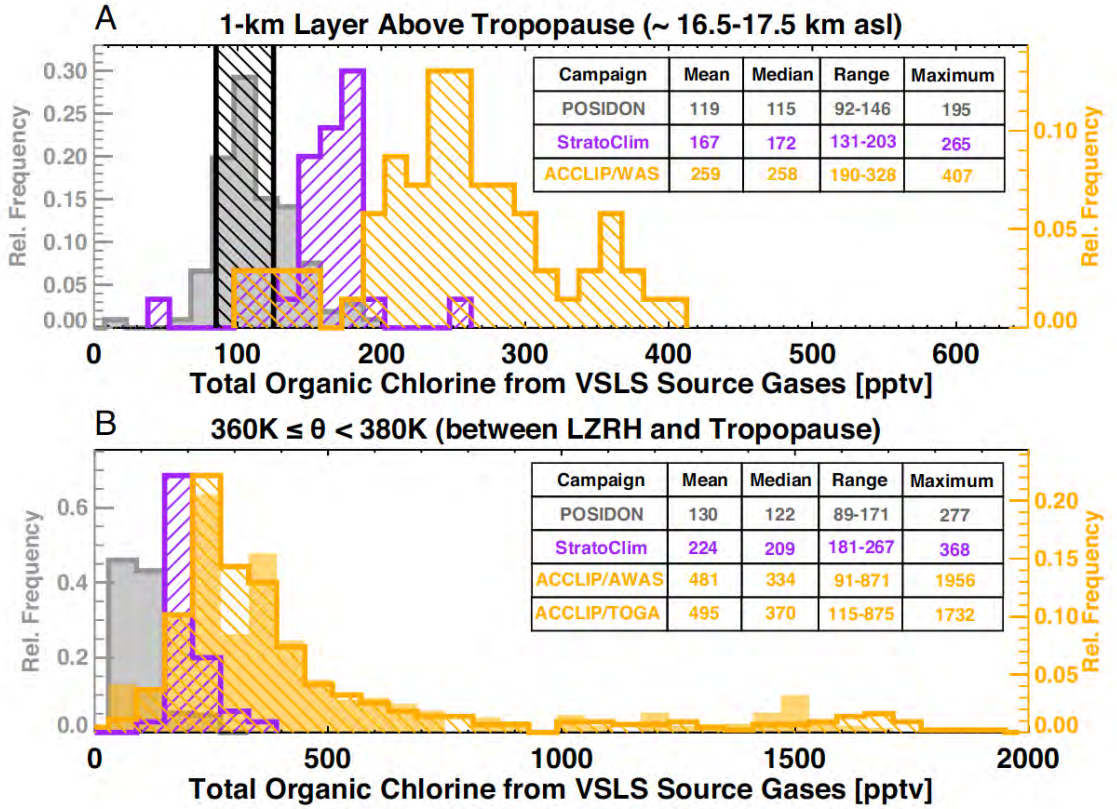
Tropopause Potential Temperature, August 2022





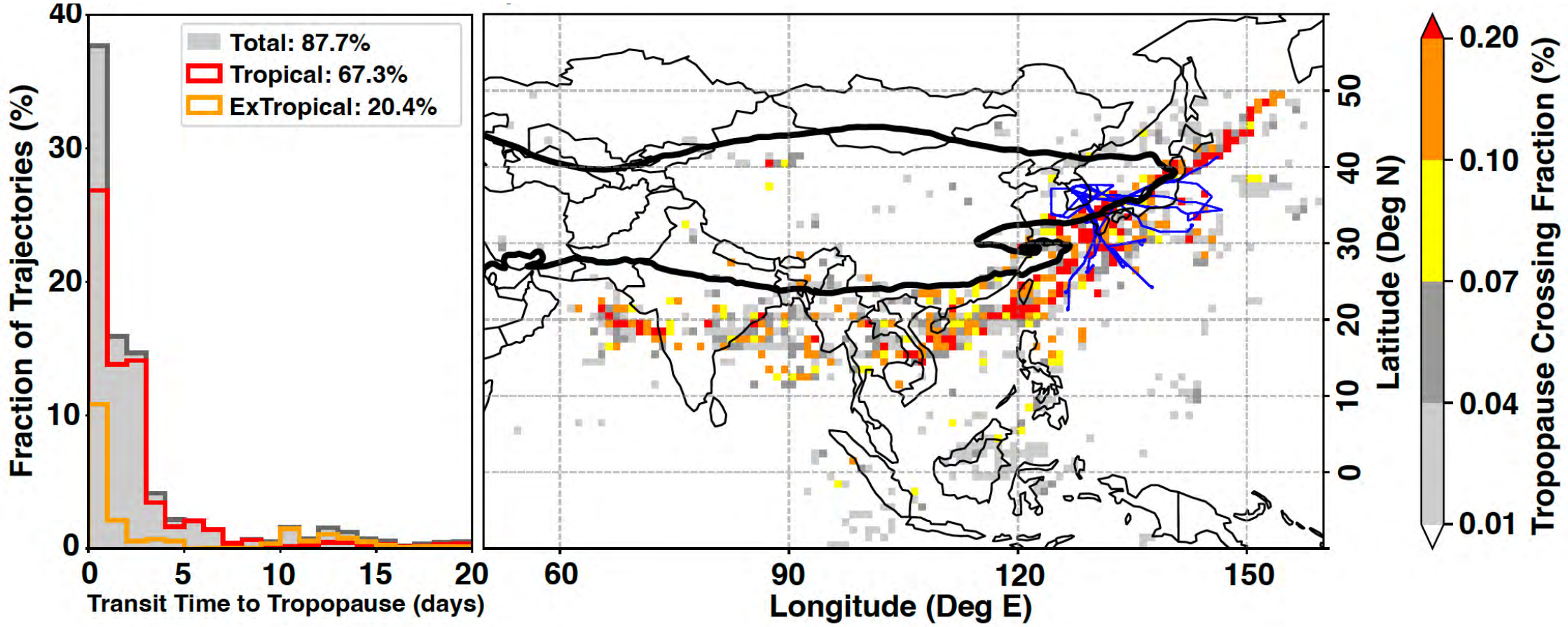
ACCLIP VSLS "LZRH" ➔ Level of clear sky zero radiative heating



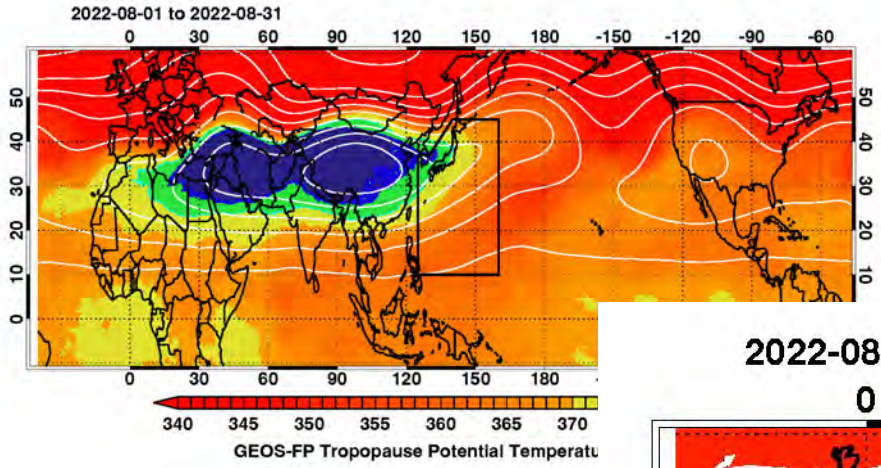


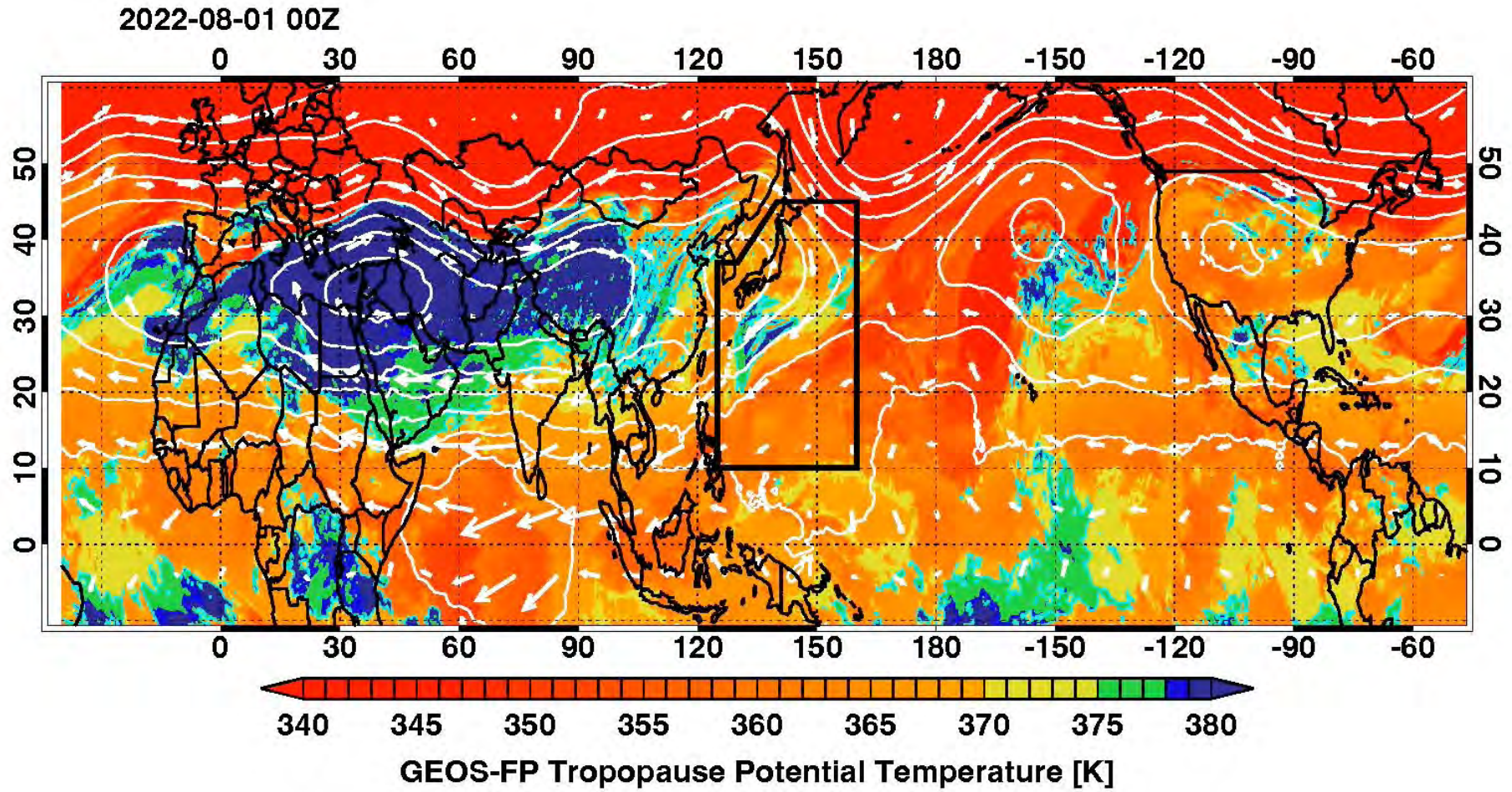
Pan, Atlas, et al., 2024 PNAS

Forward trajectory calculation of all WAS sample between 360 K and the tropopause



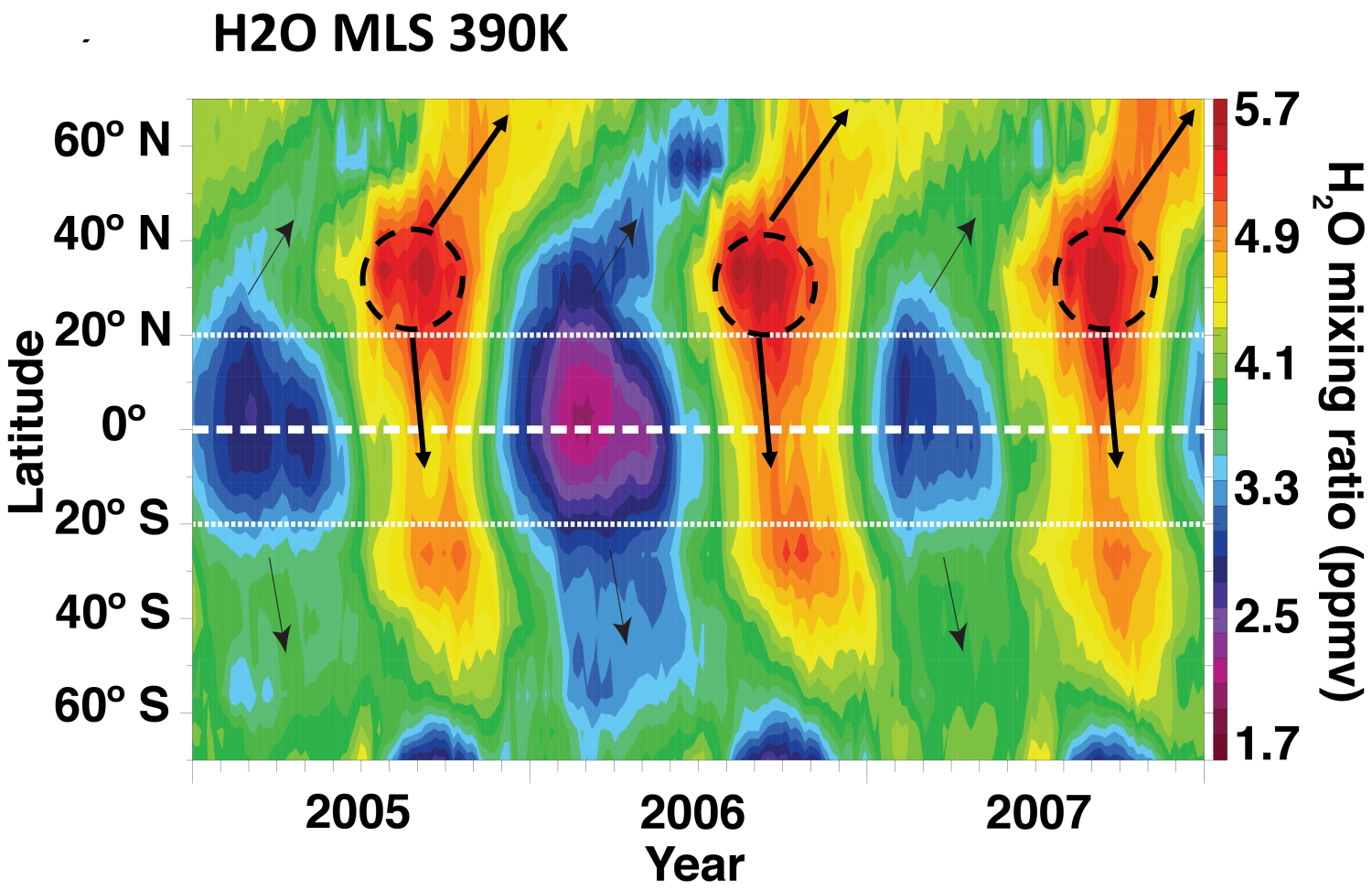
Pan, Atlas, et al., 2024 PNAS


2022-08-01 to 2022-08-31
0 30 60 90 120 150 180 -150 -120 -90 -60
50 40 30 20 10 0
340 345 350 355 360 365 370
GEOS-FP Tropopause Potential Temperatu


2022-08-01 00Z
0 30 60 90 120 150 180 -150 -120 -90 -60
50 40 30 20 10 0
340 345 350 355 360 365 370 375 380
GEOS-FP Tropopause Potential Temperature [K]

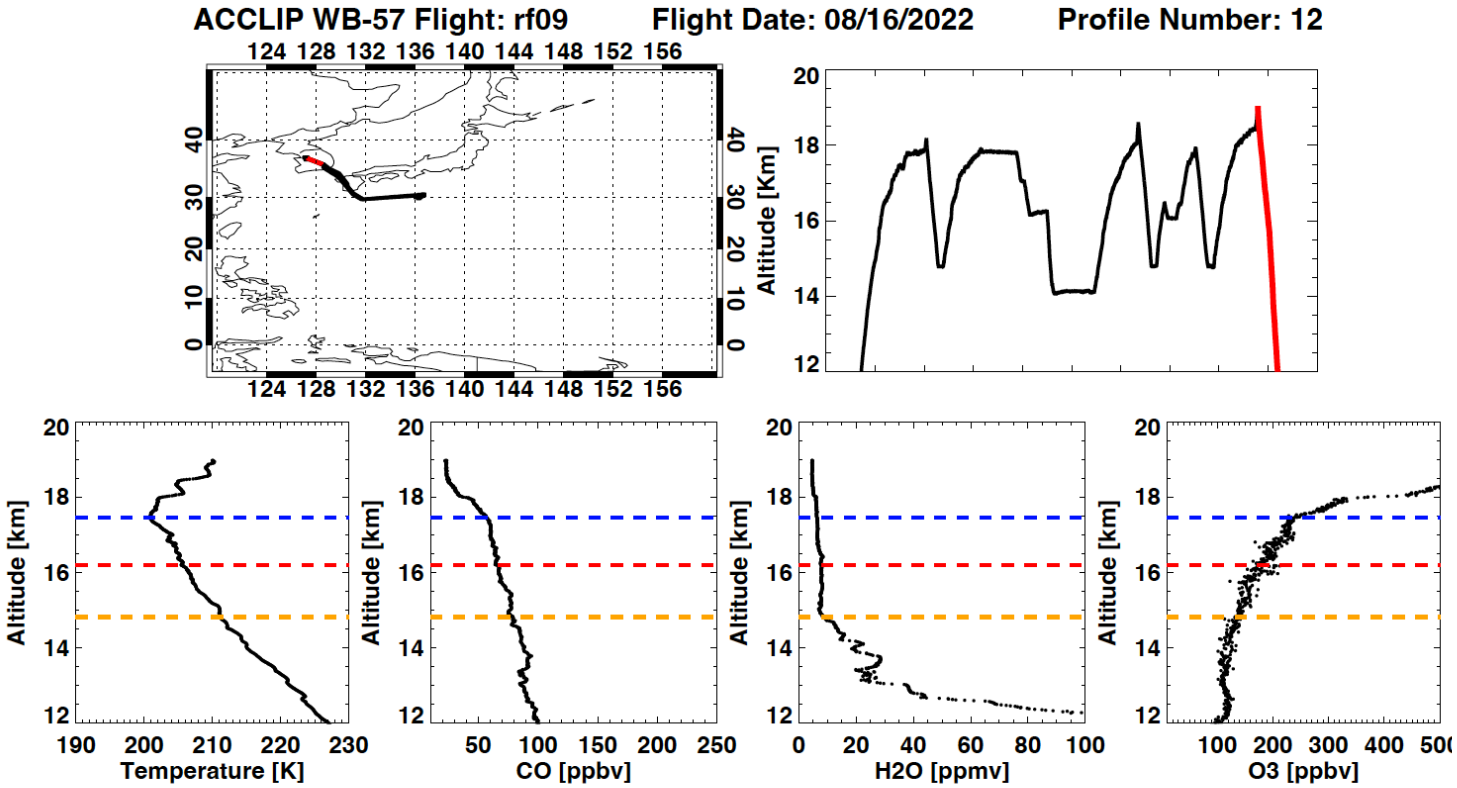
Asian Summer Monsoon – a fountain flooding the stratosphere?

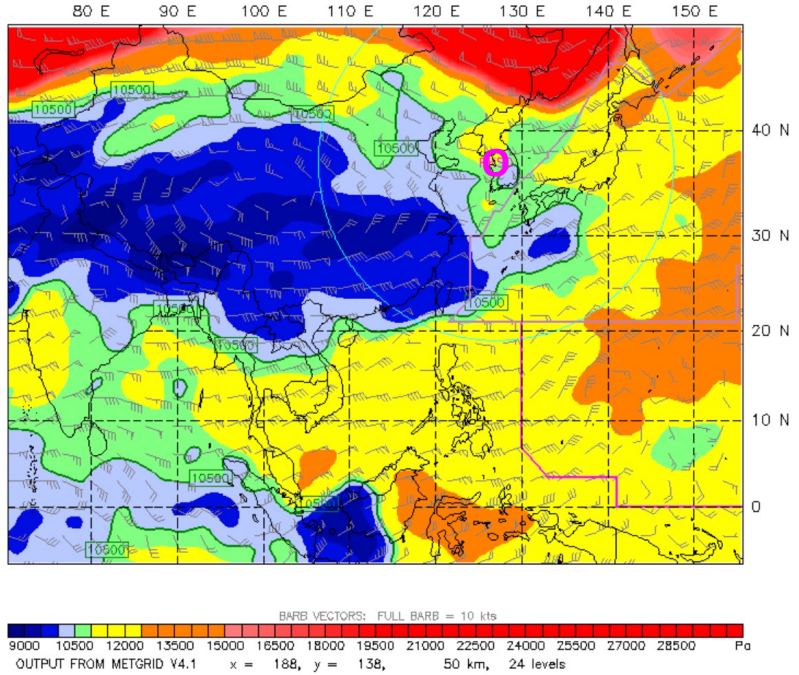
transport to stratosphere via monsoon



Randel and Jensen 2013

Tropopause Determination using WB-57 in situ T profiles



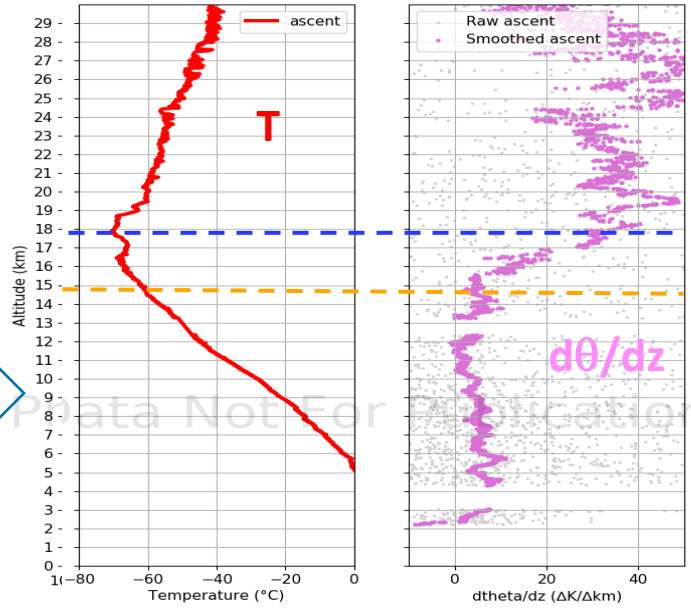


Cold Point

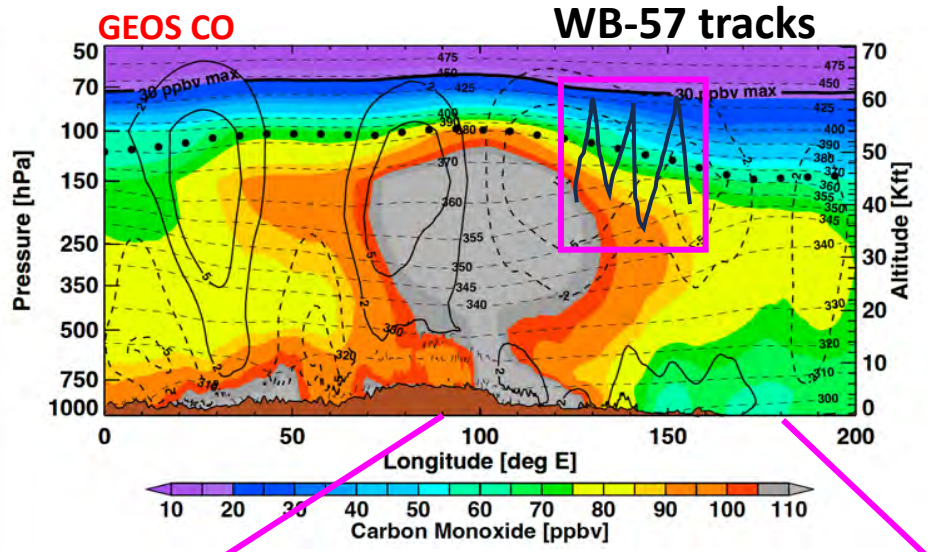
Lapse Rate Tropopause (WMO modified)

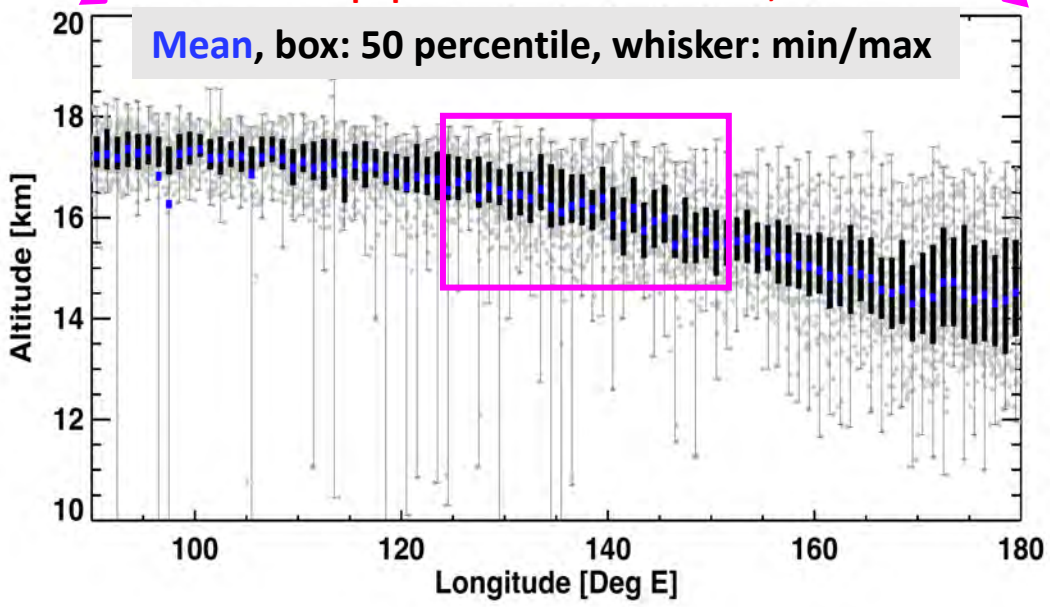
WMO modified 2

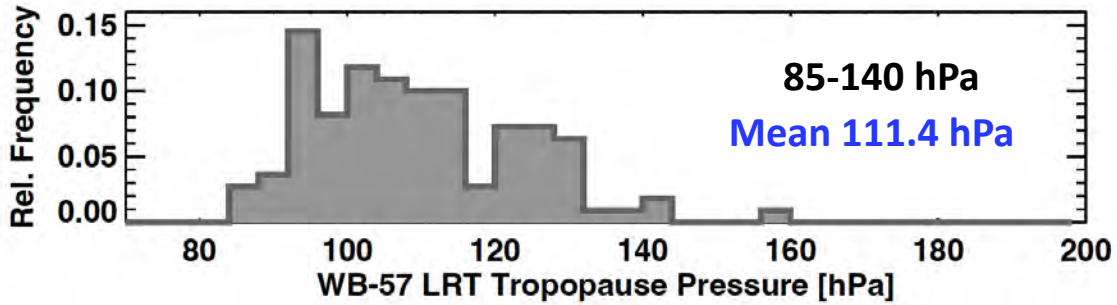
Osan Sounding

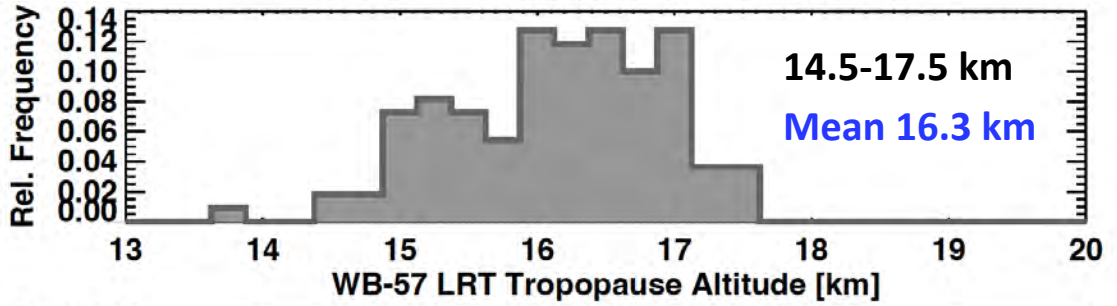


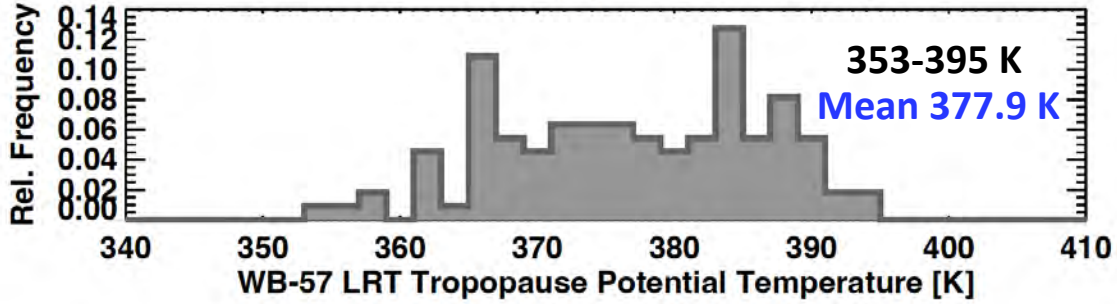
Distributions of Tropopauses Determined using WB-57 MMS T Profile







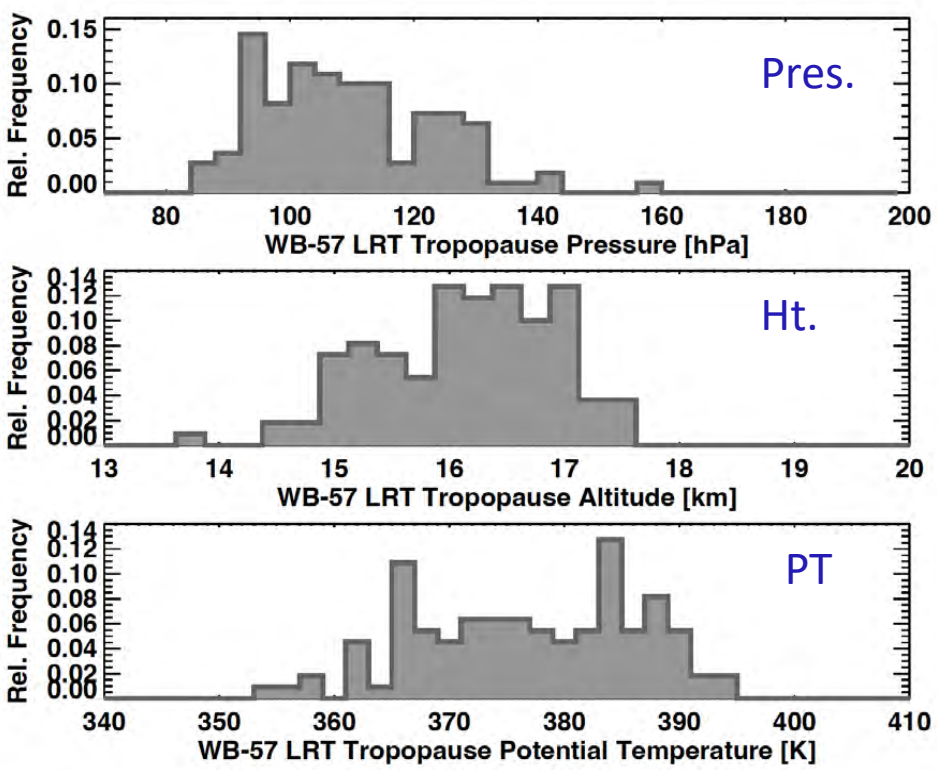


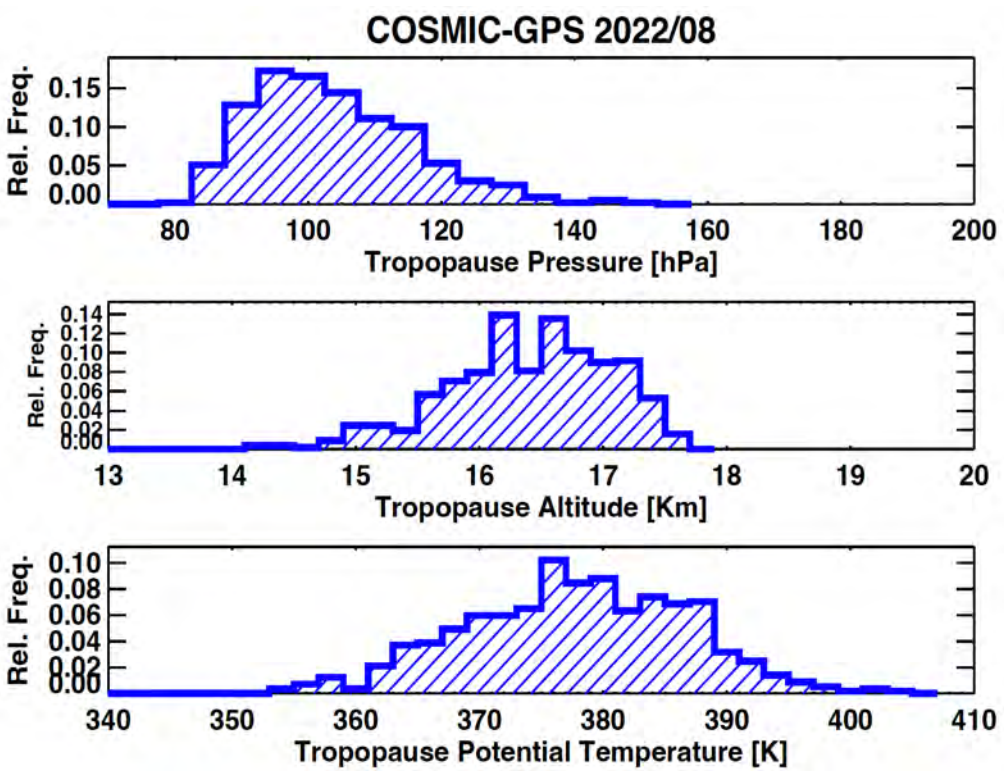


Total of 110 profiles

WB-57 in situ tropopause: a large vertical spread

Comparison between the WB-57 & COSMIC shows that the in situ trop. statistics is representative of the region





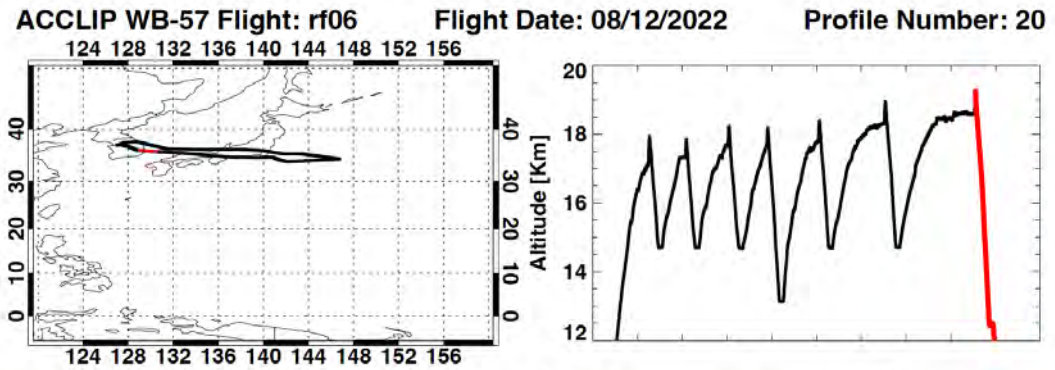
Total of 110 profiles

Lat: 25°-37.5° N, longitude: 125° -140 E

Similar results for GFS and ERA5

Unique ASM tropopause behaviors and the existence of a “Mixing Zone”

Flight Track

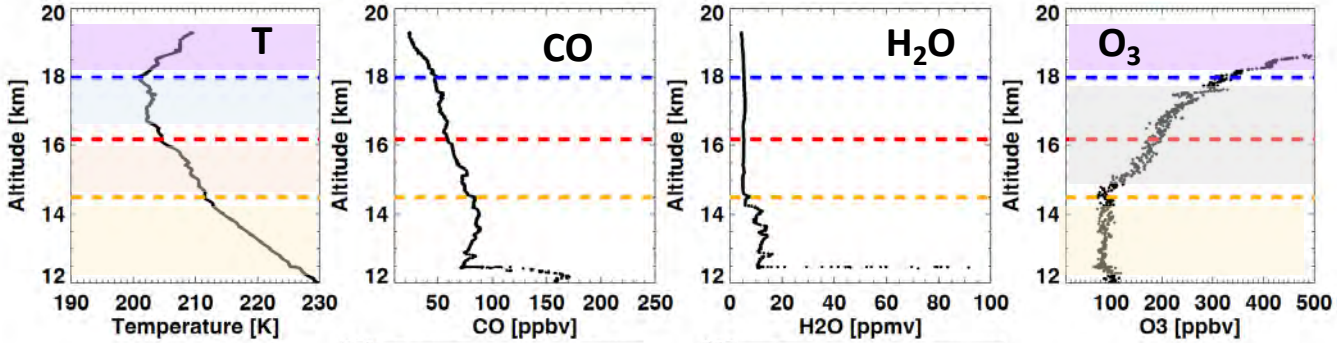


Profiles

Cold Point

“WMO Trop.”

modified Trop.



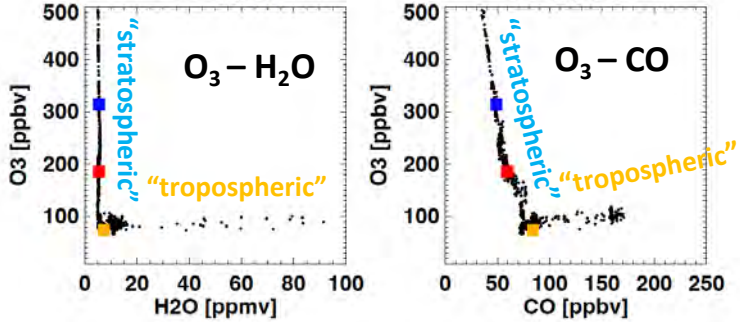
“the over-world”

“transition-mixing zone”

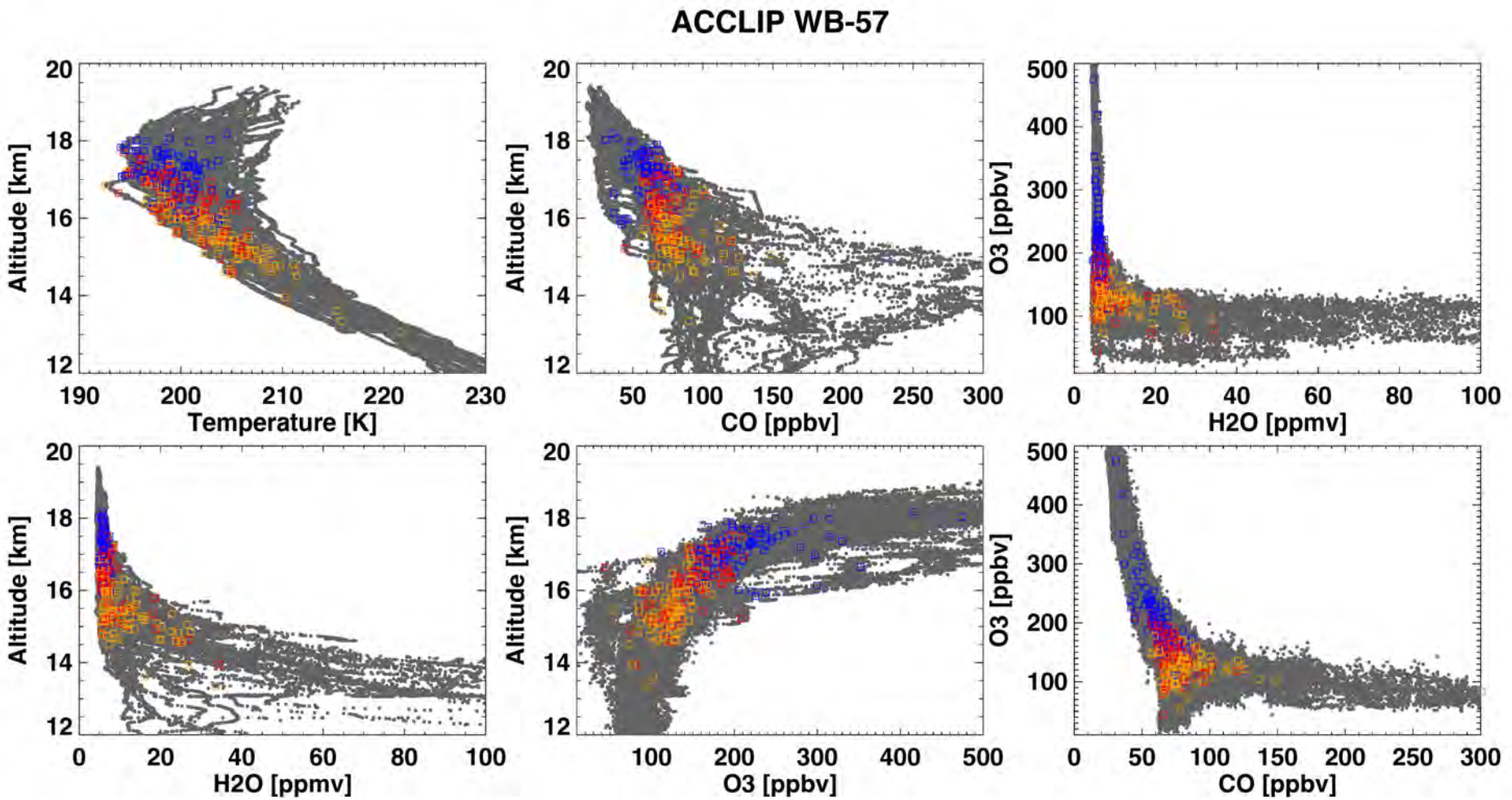
“tropospheric”

paralleled to “the lowermost-stratosphere”

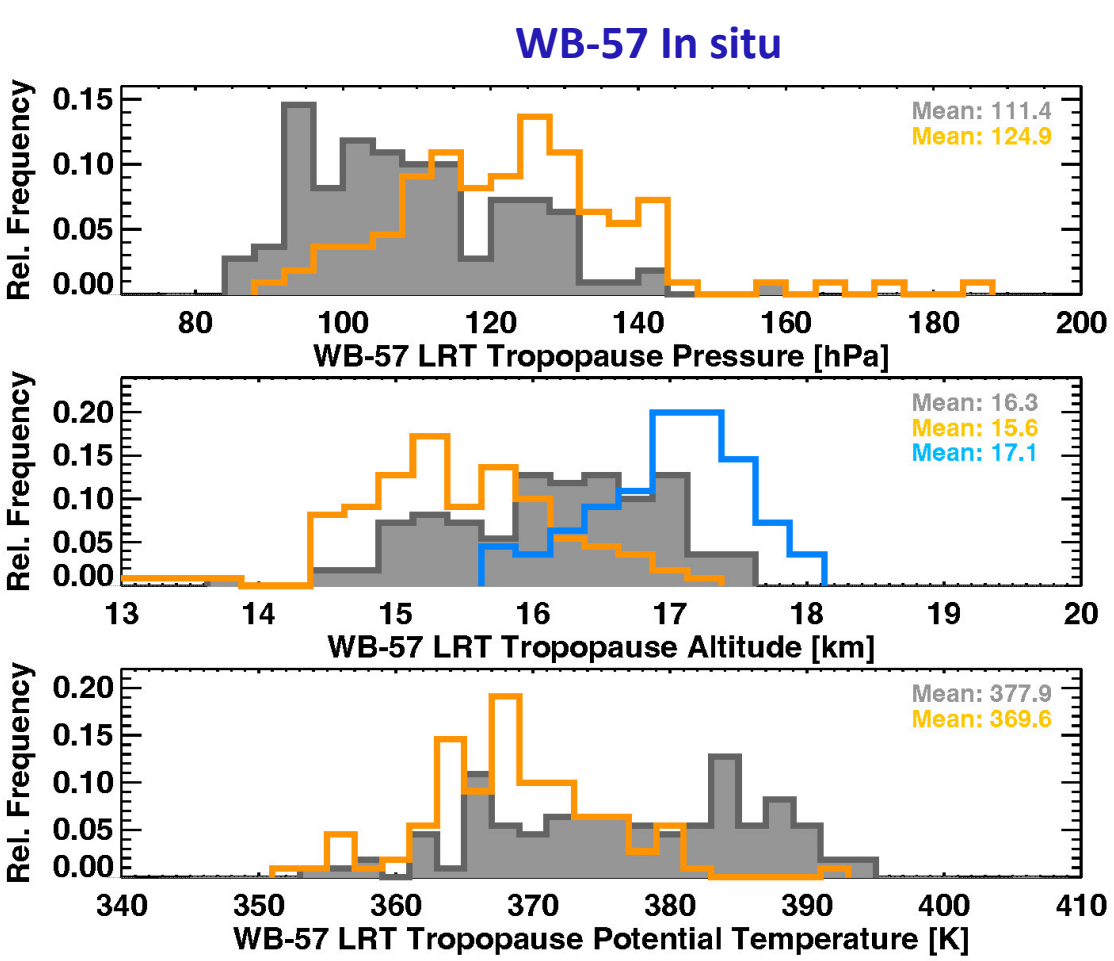
Tracer-Tracer Space

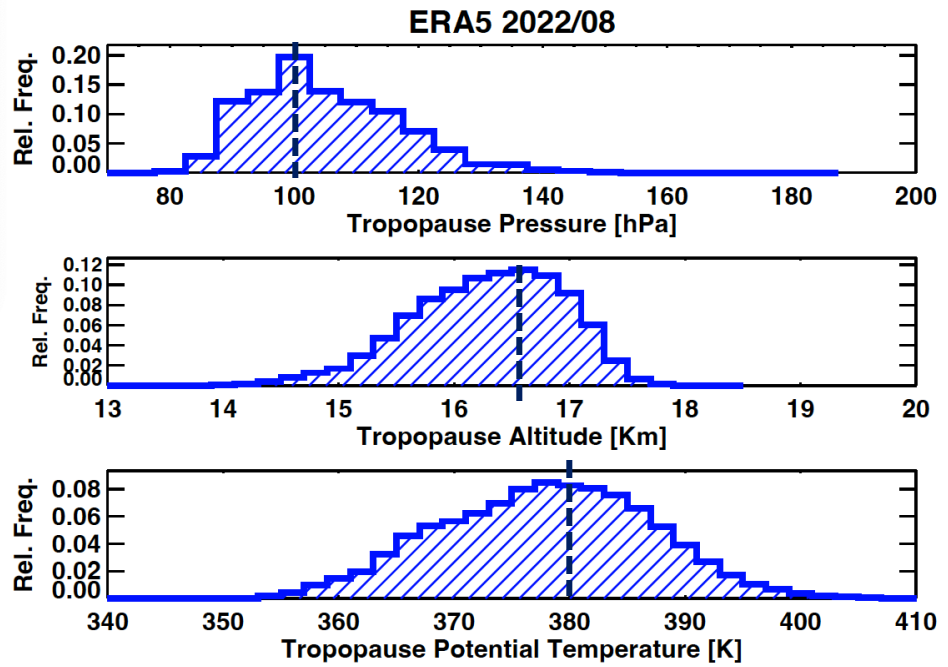


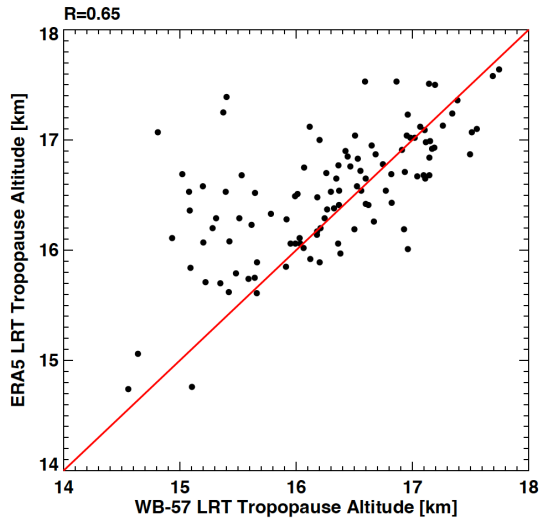
Three candidates in altitude and tracer space



How well the in situ and ERA5 tropopause product agree?

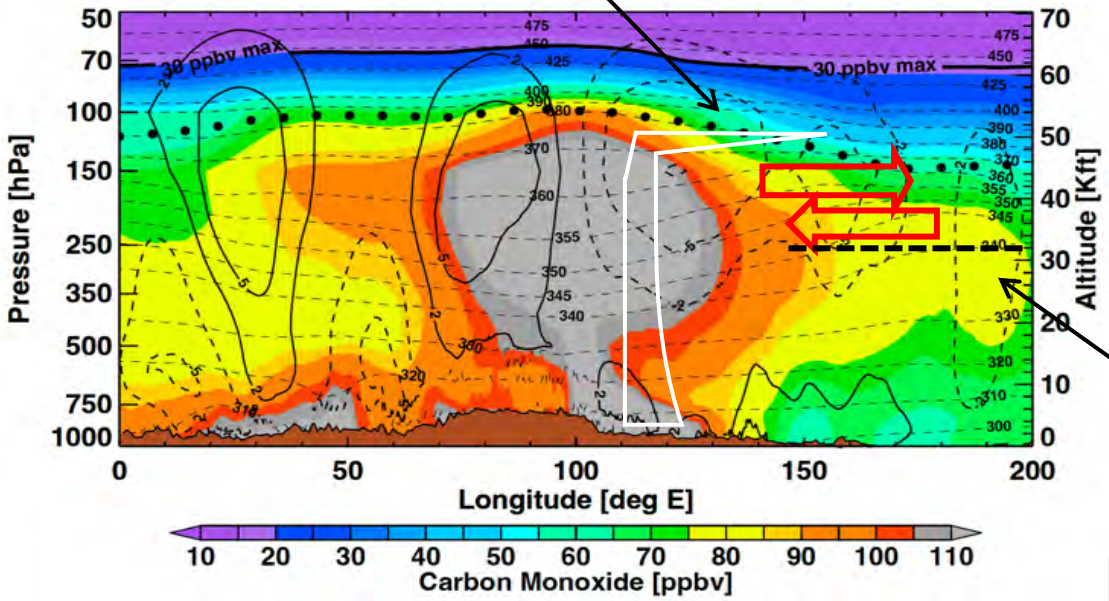


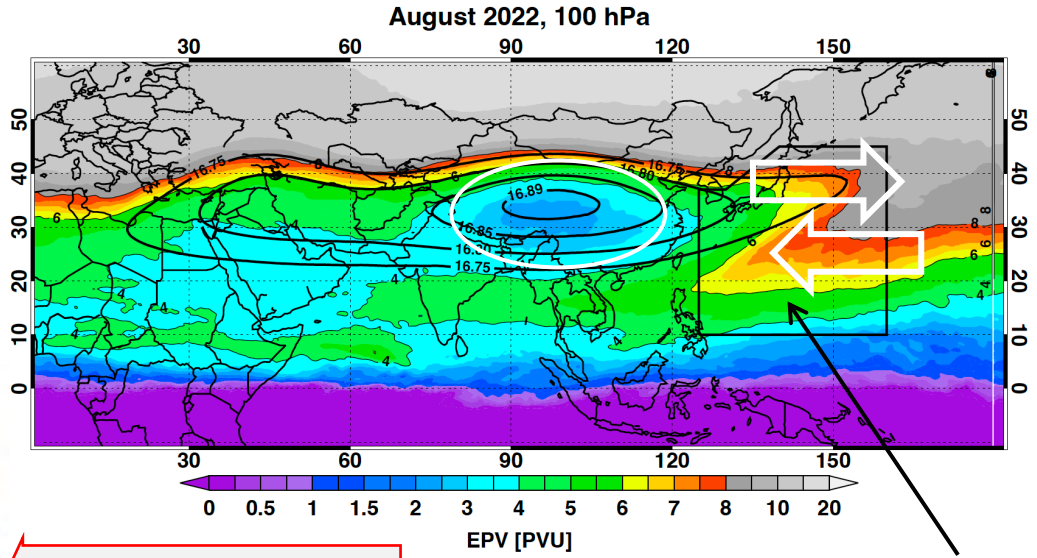




August 2022 Mean EPV at 100 hPa

High tropopause from eastward horizontal flow anticyclone





Mixing zone

Extra-tropical tropopause outside the anticyclone

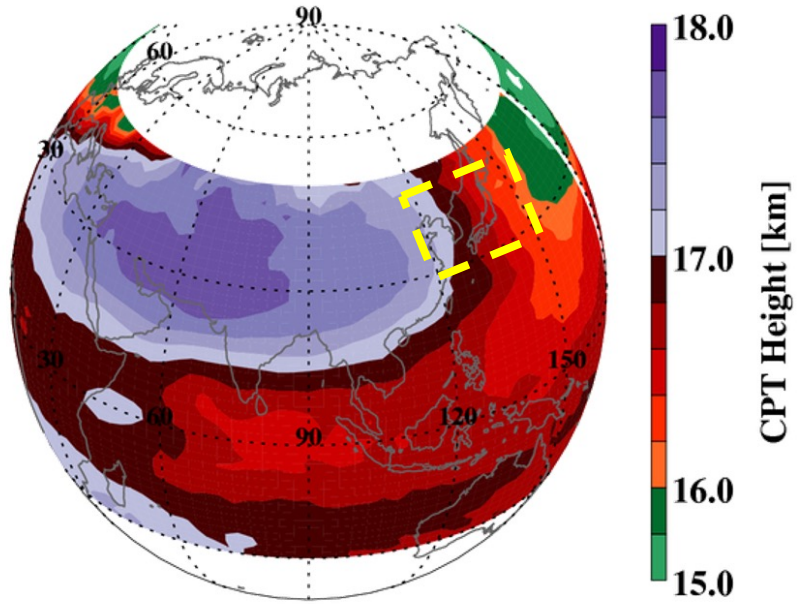
"Z-shaped" average PV structure indicates the region of persistent anticyclonic mixing between the stratospheric (H. Lat.) and tropospheric ""low lat.) air

Key Points:

The Asian summer monsoon (ASM) tropopause is a different type of tropopause: i.e.,

"Tropical Tropopause", "Extra-tropical tropopause" and "ASM tropopause"

- ASM: higher than the tropical tropopause – a large-scale "**overshooting tropospheric bubble**"
- The ACCLIP flight domain was at the eastern edge of the bubble, a region dominated by **horizontal flow & "quasi-isentropic mixing**"
- The region outside the anticyclone has a **double tropopause structure**, the eastward shedding and the equatorward anticyclonic mixing create a mixing zone



Cold Point Tropopause (JJA)
COSMIC GPS

Munchak and Pan 2014