Post-Eruption Climate Impacts:

GEO Limb Observations of PSC and Aerosol from Hunga Tonga-Hunga Ha'apai (HT-HH)

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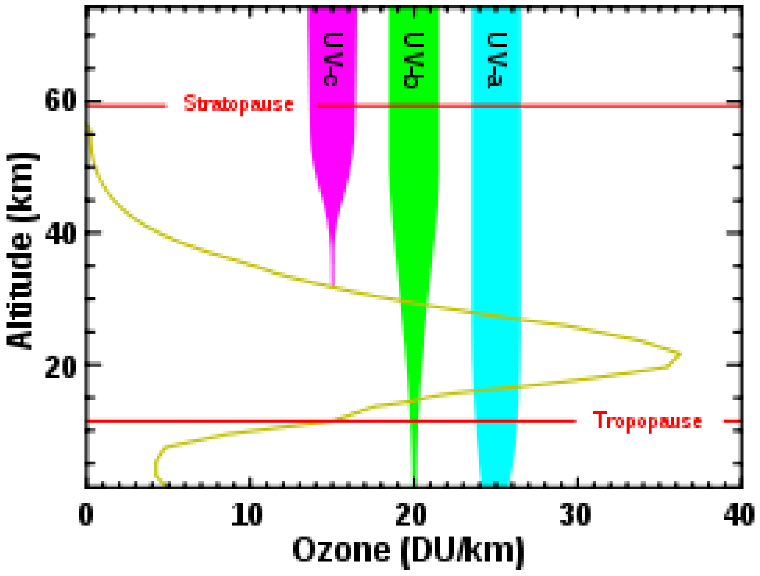
Ozone Loss and Recovery

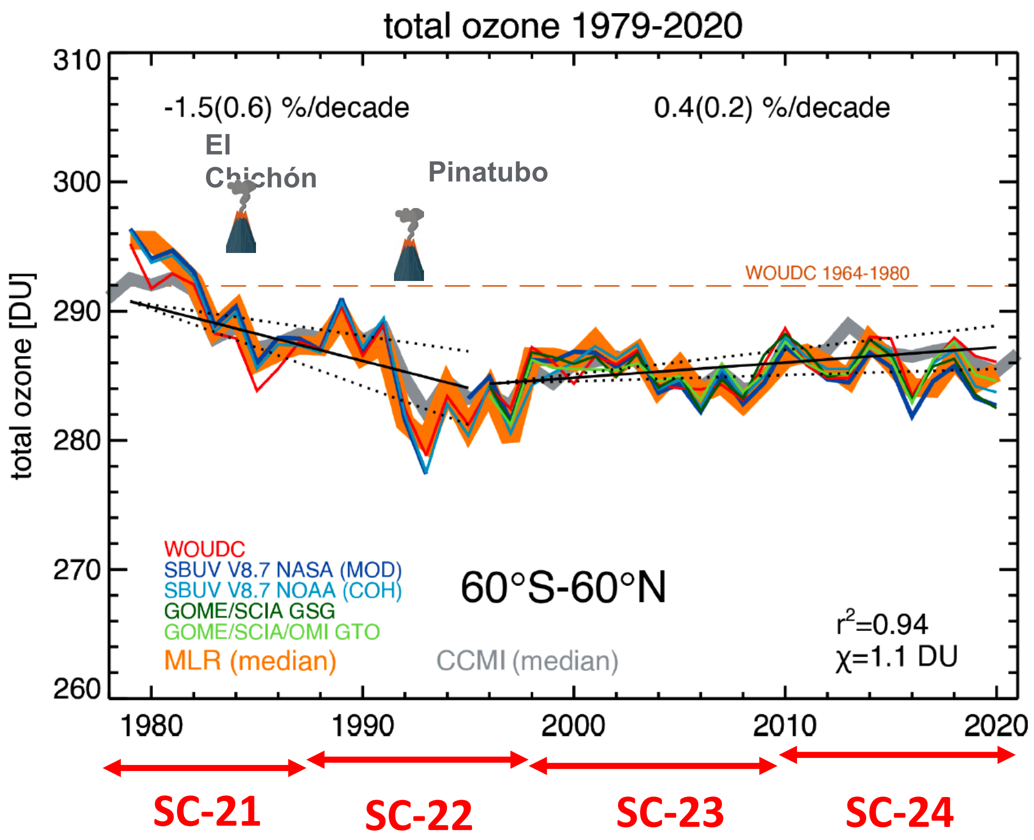
Ozone photolysis

$$O_2 \xrightarrow[\text{(radiation } \lambda < 240 \text{ nm)}]{\text{photon}} 2\,O$$

$$O + O_2 + M \longrightarrow O_3 + M$$



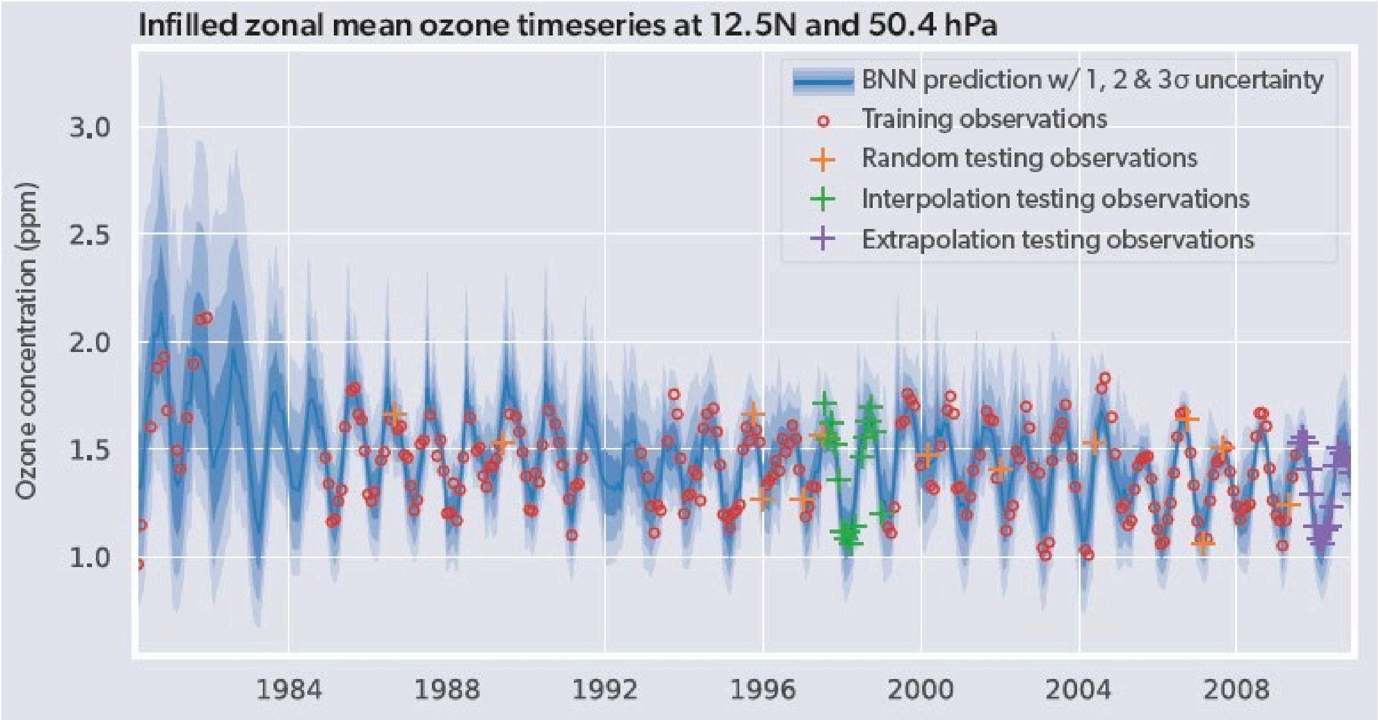
Weber et al. (ACP, 2022)



- Solar cycles are evident in ozone loss and recover periods
- Solar irradiance spectra at wavelengths < 240 nm are critical in ozone photolysis
- Factors important for ozone loss and recovery
  - ❖ anthropogenic forcings (e.g. ozone-depleting substances)
  - ❖ Natural forcings (e.g., dynamics, volcanic aerosol/h2o, solar irradiance)

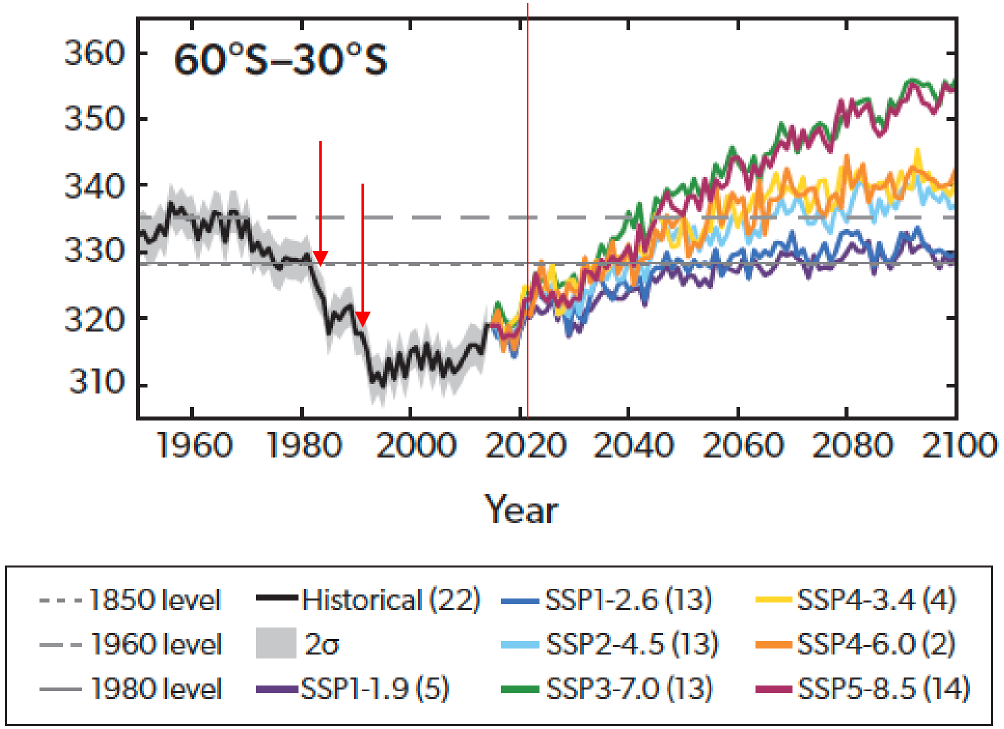
Scientific Assessment of Ozone Depletion (2022)

(WMO GAW Report #278)



SC-21 **SC-22** **SC-23** **SC-24**

without HT-HH



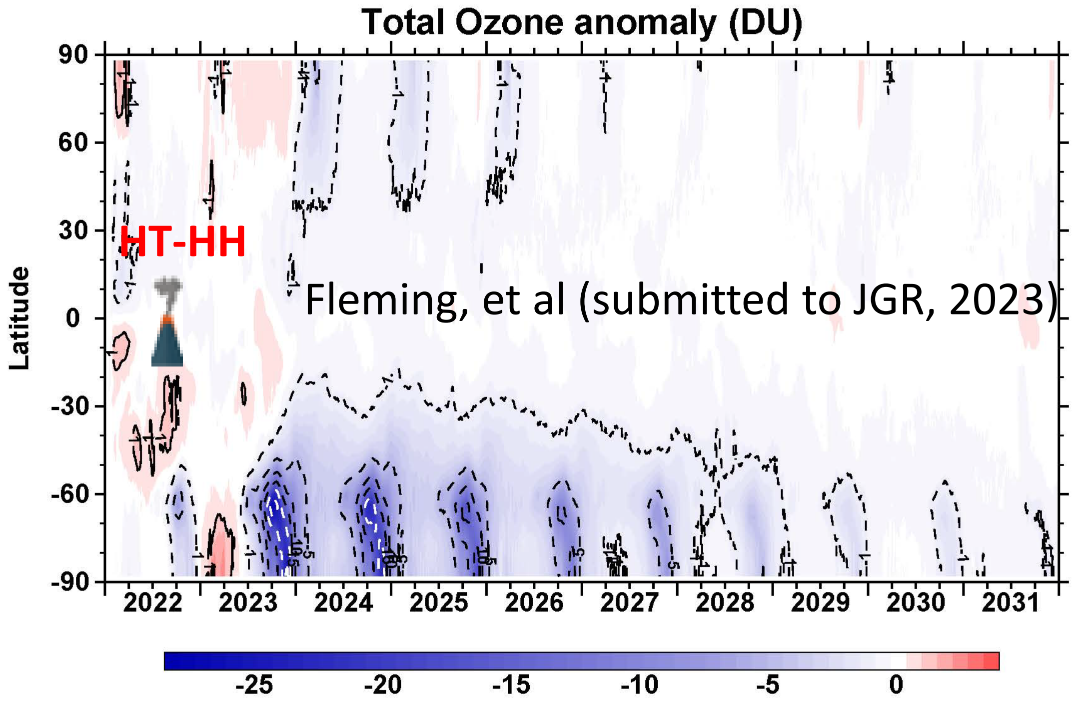
What will be climatic impacts from HT-HH?

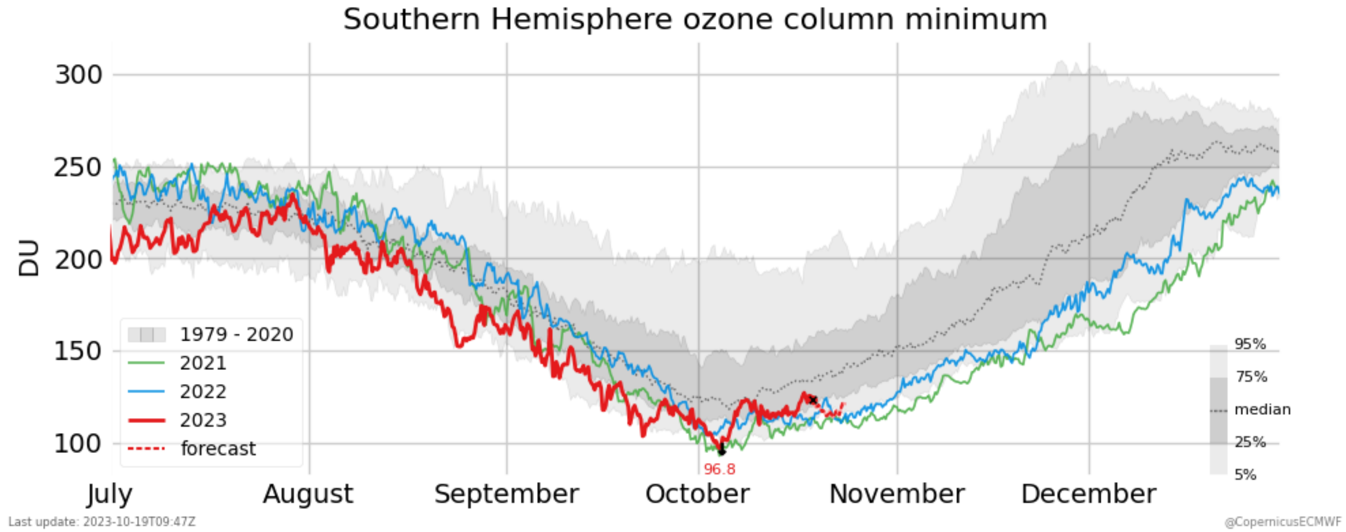
Challenges

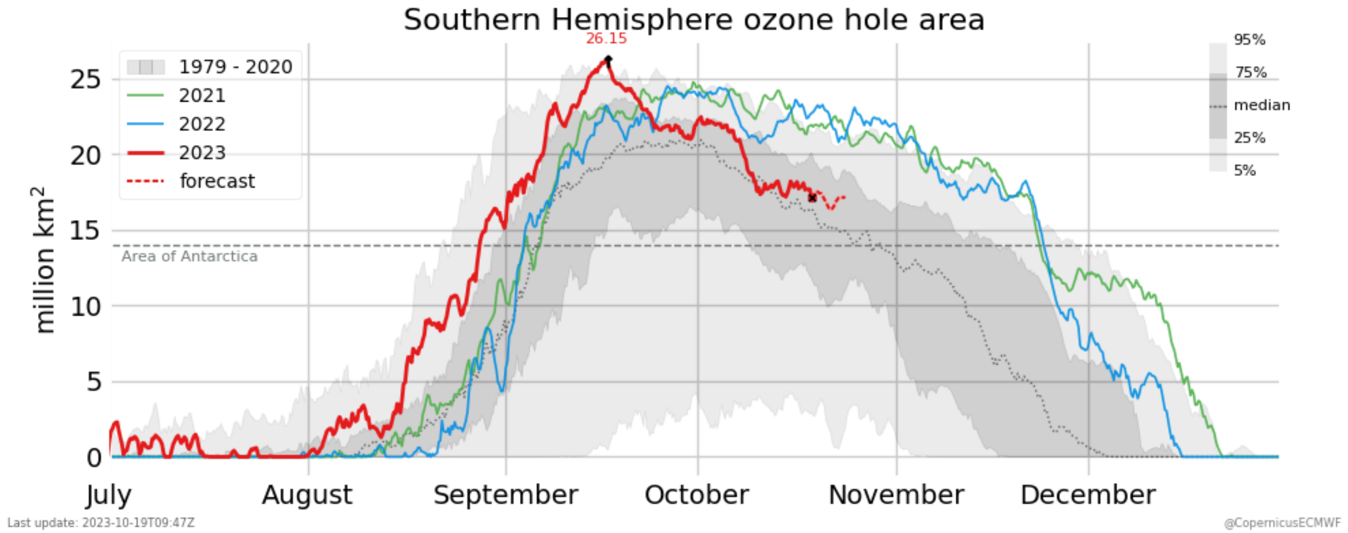
(O3 Assessment 2022)

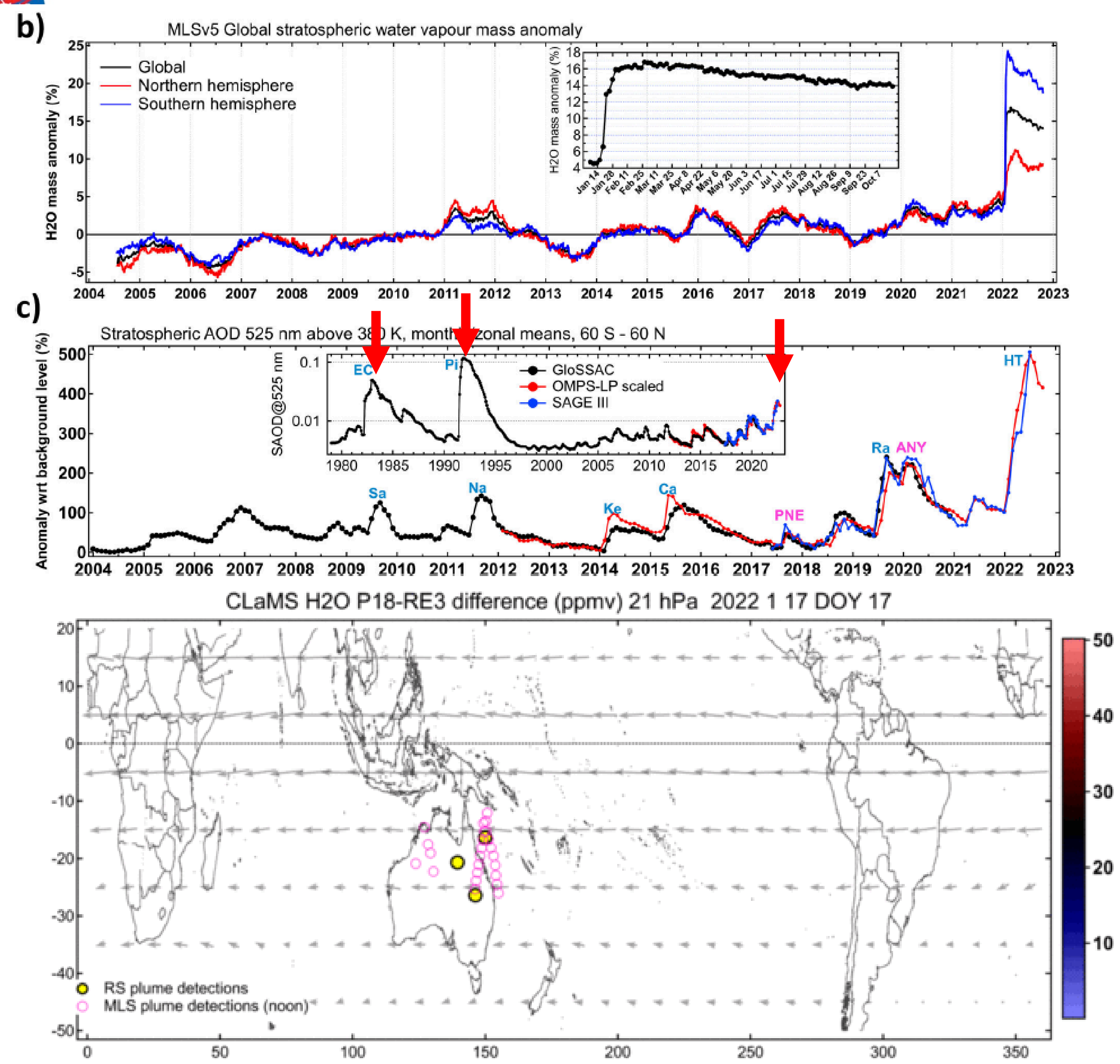
- Uncertainties in CFC emissions;
- Modeled recovery in mid-latitude lower-stratospheric ozone;
- Stratospheric aerosol injection (SAI) role;
- Influences from H2O, CH4 and CO2 increases, climate changes, wildfires and volcanic eruptions, etc

https://atmosphere.copernicus.eu/monitoring-ozone-layer









Mt Pinatubo vs HT-HH Eruptions

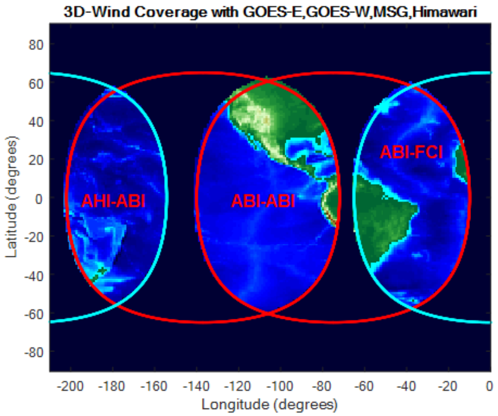
	Pinatubo	HT-HH
VEI	6	5.7
SO2	5-10 Tg	0.6 Tg
H2O	~37 Tg	~146 Tg

VEI= Volcanic Explosivity Index

Sergey Khaykin et al. (2022)

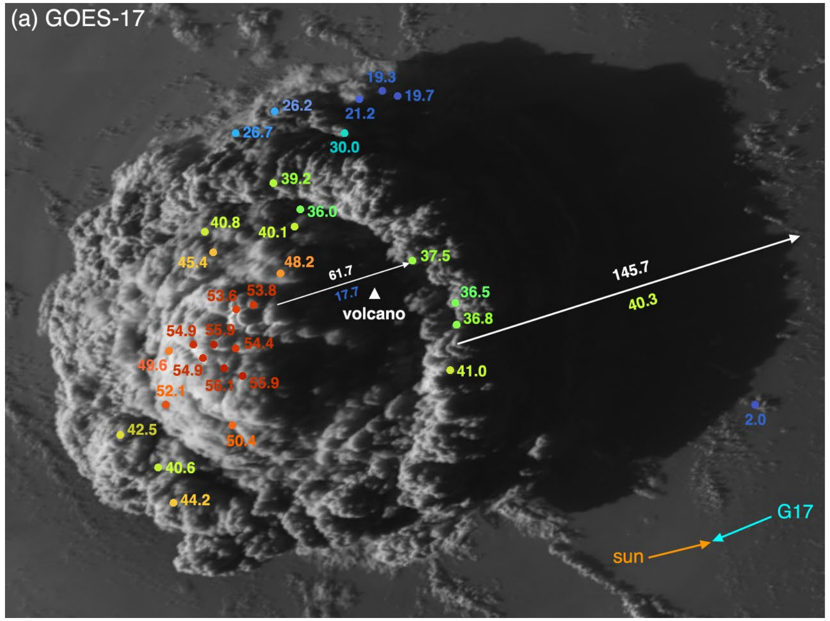
Observations of HT-HH Eruption with New Generation of Geostationary (GEO) Sensors

- Stereo winds and plume height (Carr et al., 2022; Proud et al, 2022)
- Ash plume and ice clouds (Legras et al., 2022; Sellitto et al., 2022)
- Lamb waves (Otsuka, 2022)
- Gravity waves (Wright et al., 2022)
- Brightness temperature (Gupta et al., 2022)

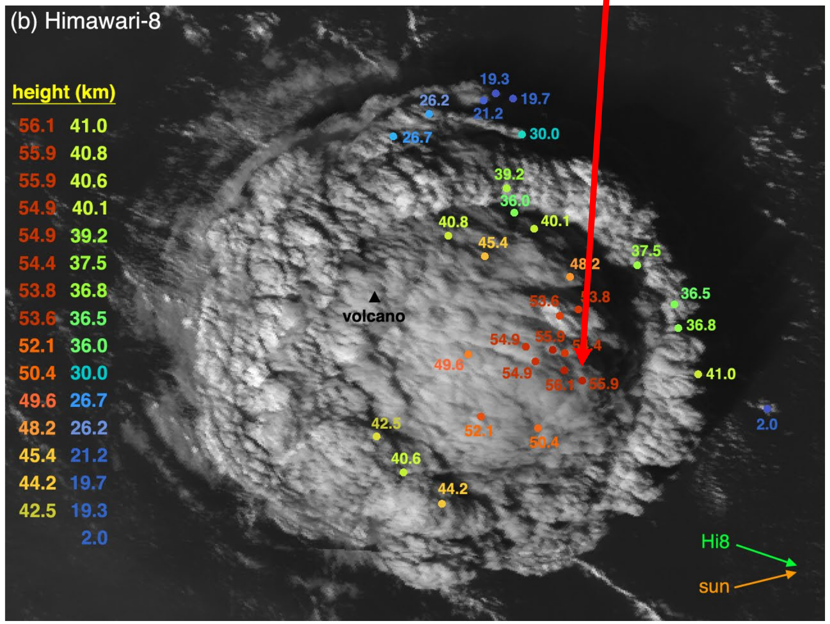


GEO-GEO
Stereo height methods
(Carr et al., 2020)

56 km



G17



H8

Method#2: Automated Stereo-Winds Method from MESO Observations (1-min)

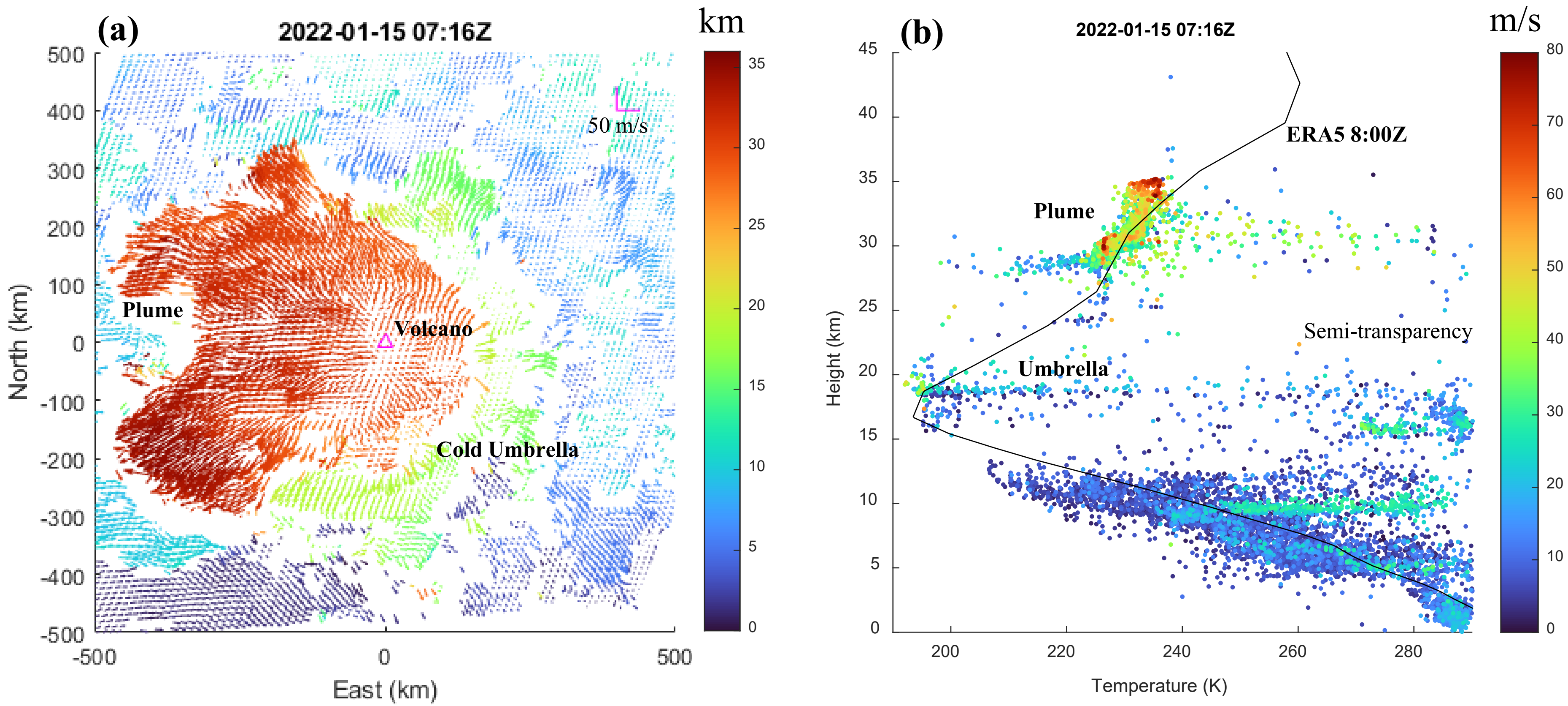


Figure 2. Panel (a) shows the jointly retrieved heights and horizontal advection vectors at their parallax corrected locations centered on the volcano (20.536° S, 175.382 ° W). The vector scale at the upper right indicate a 50 m/s wind in each direction. Panel (b) shows the assigned temperatures for each retrieval and the associated advection speed. The ERA5 temperature profile at 8:00Z has been added.

Carr et al., (2022)

Limb Observations with GEO Sensors

Himawari-8 (H8)

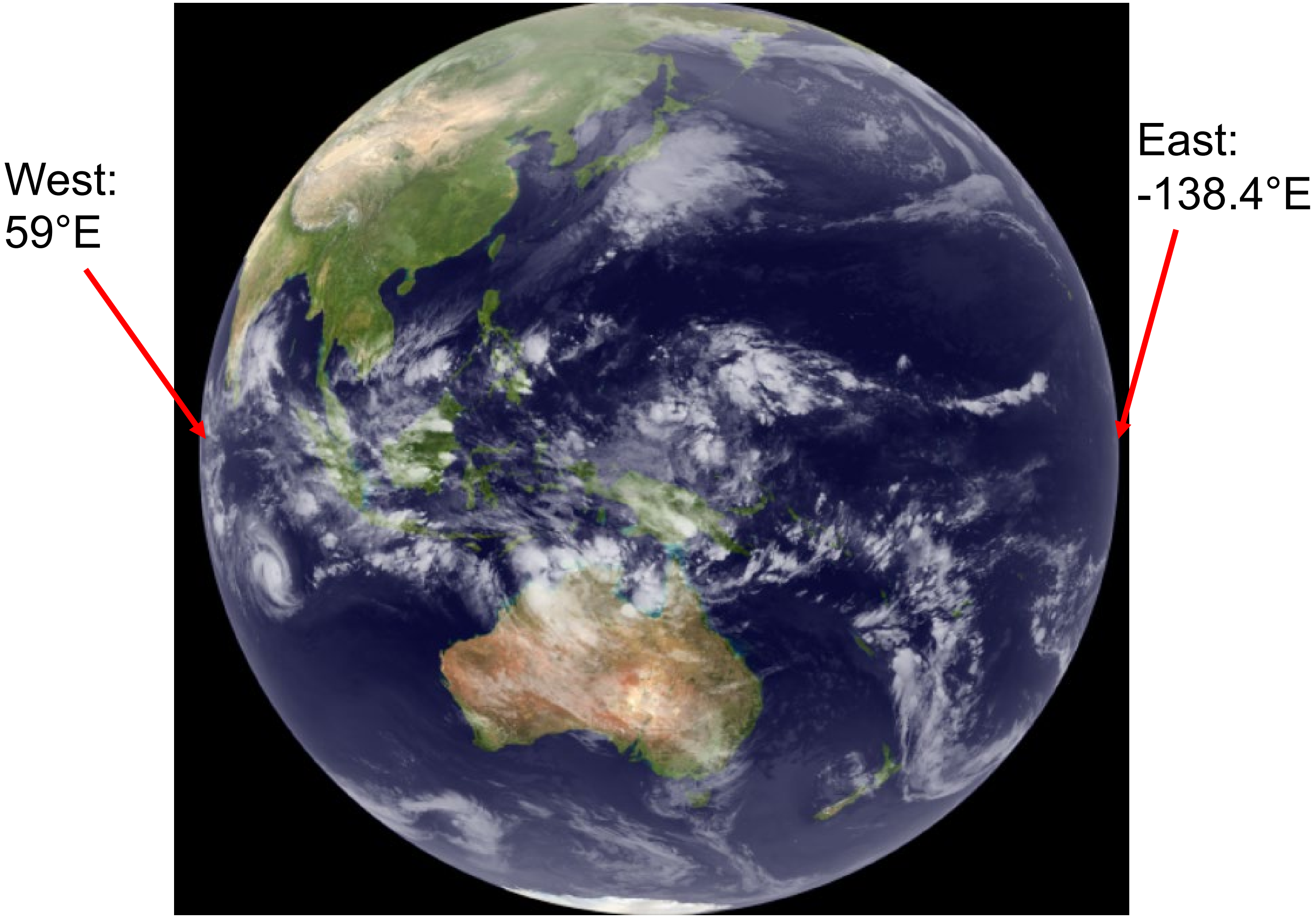
SSP: 140.7°E

Near equator/surface:
West: 59°E; East: -138.4°E

Resolution: B03 (0.64 μm) 0.5 km

Refresh rate: 10 minutes

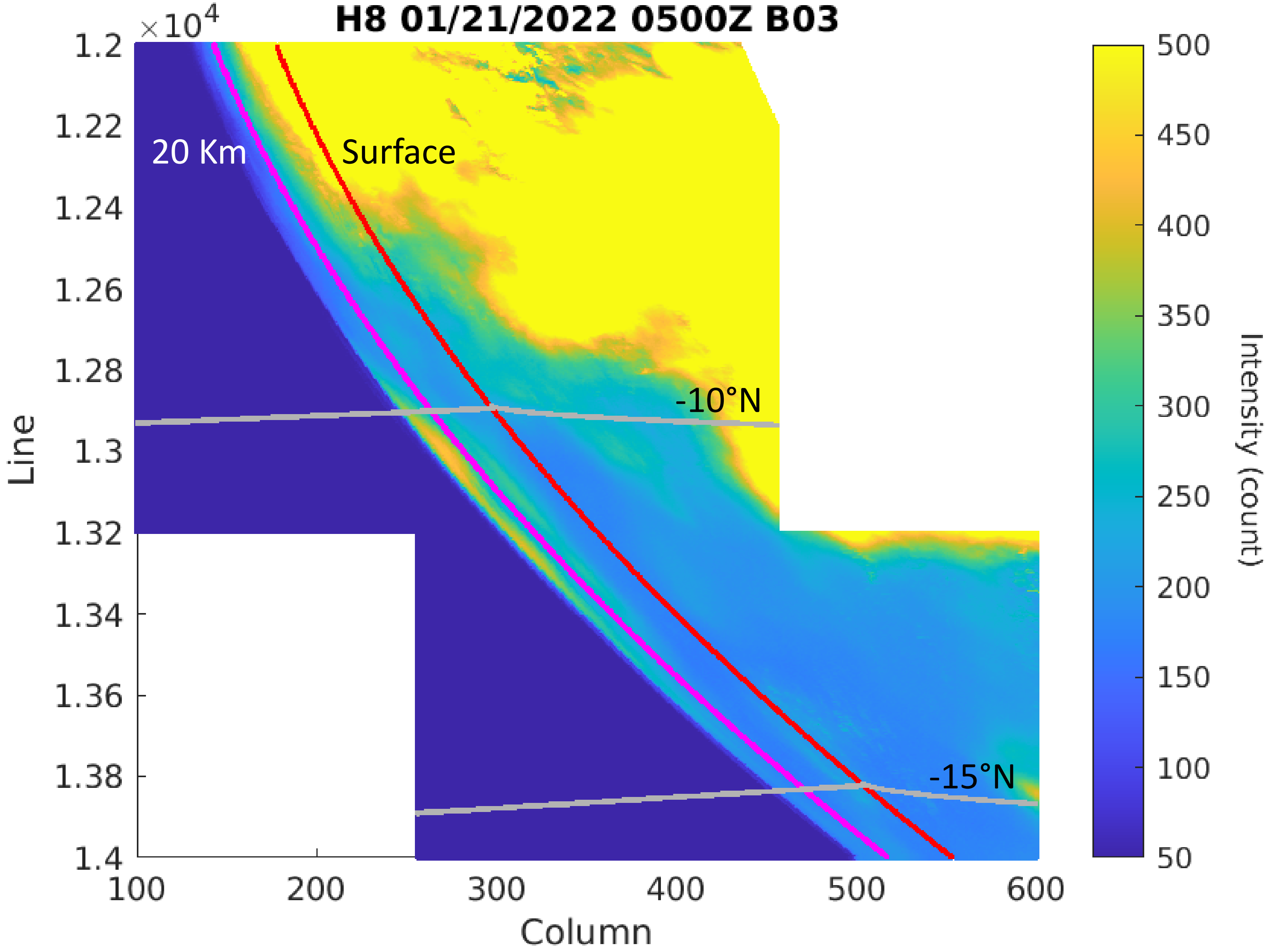
Data availability
July 7, 2015 - present



Full Disk (FLDK) Imagery

Limb Sounding Algorithm for Himawari-8 Imagery

- Image Coordinates
- LOS Vector
- Find Intersection of LOS Vector and an Earth-like Ellipsoid
- Find Geodetic Coordinates on Earth-like Ellipsoid
- Convert to Cartesian Coordinates
- Iterate to find Geodetic Sub-tangent Point



Plume Vertical Profile Comparison

Rayleigh Background

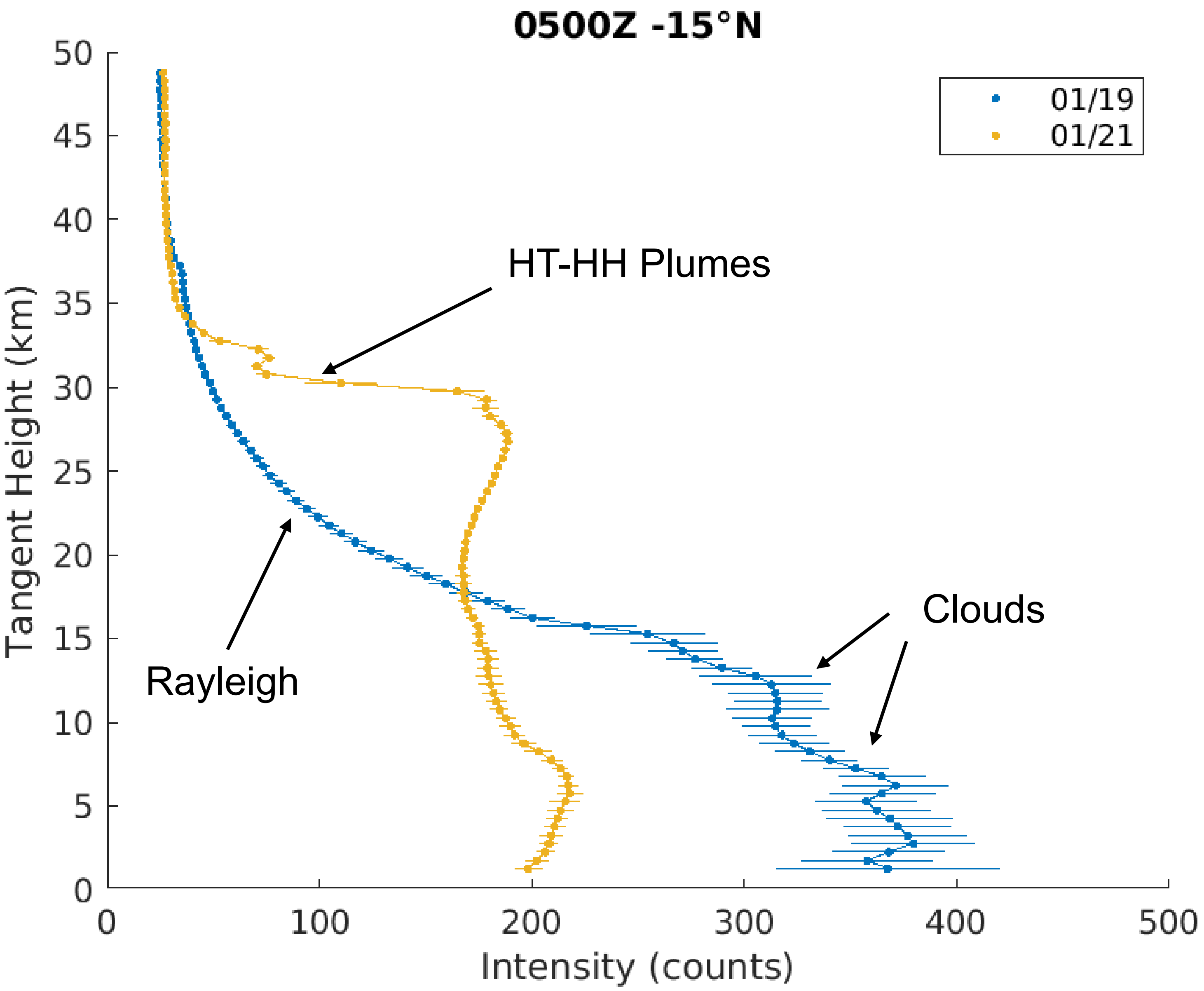
- Decreasing exponentially
- Noise count: ~20

Cloud variability

- < 18 km

HT-HH Plumes

- > 30 km

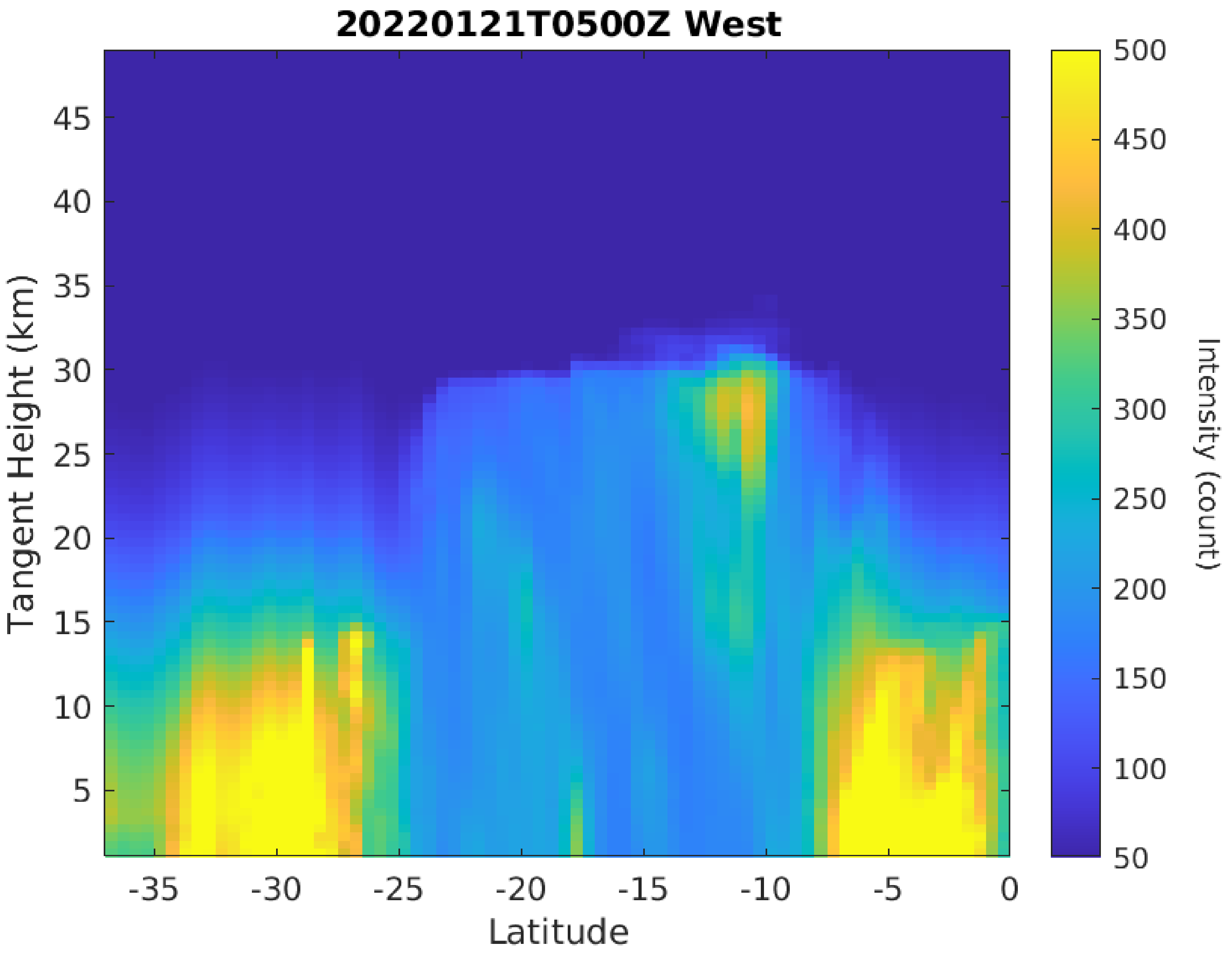


Latitude Distribution of Plume Top

Cloud variability
- < 15 km

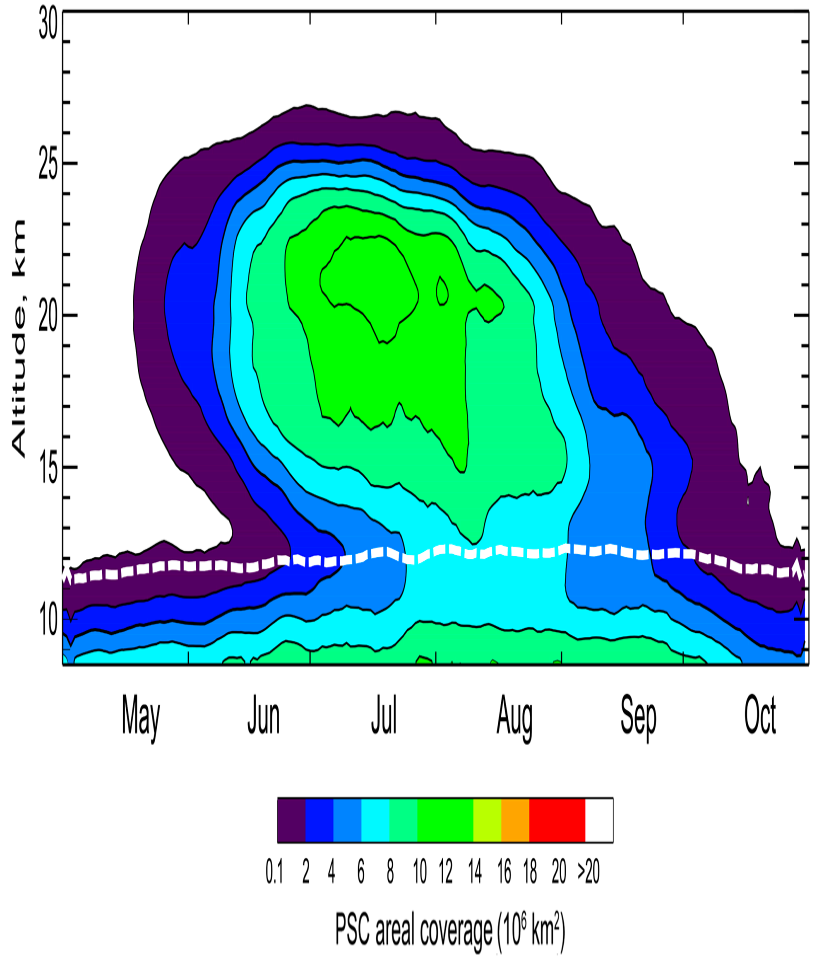
Plume top slope
- 29 km at -24°N to
- 33 km at -9°N

Horizontal smearing
- -25°N to -8°N

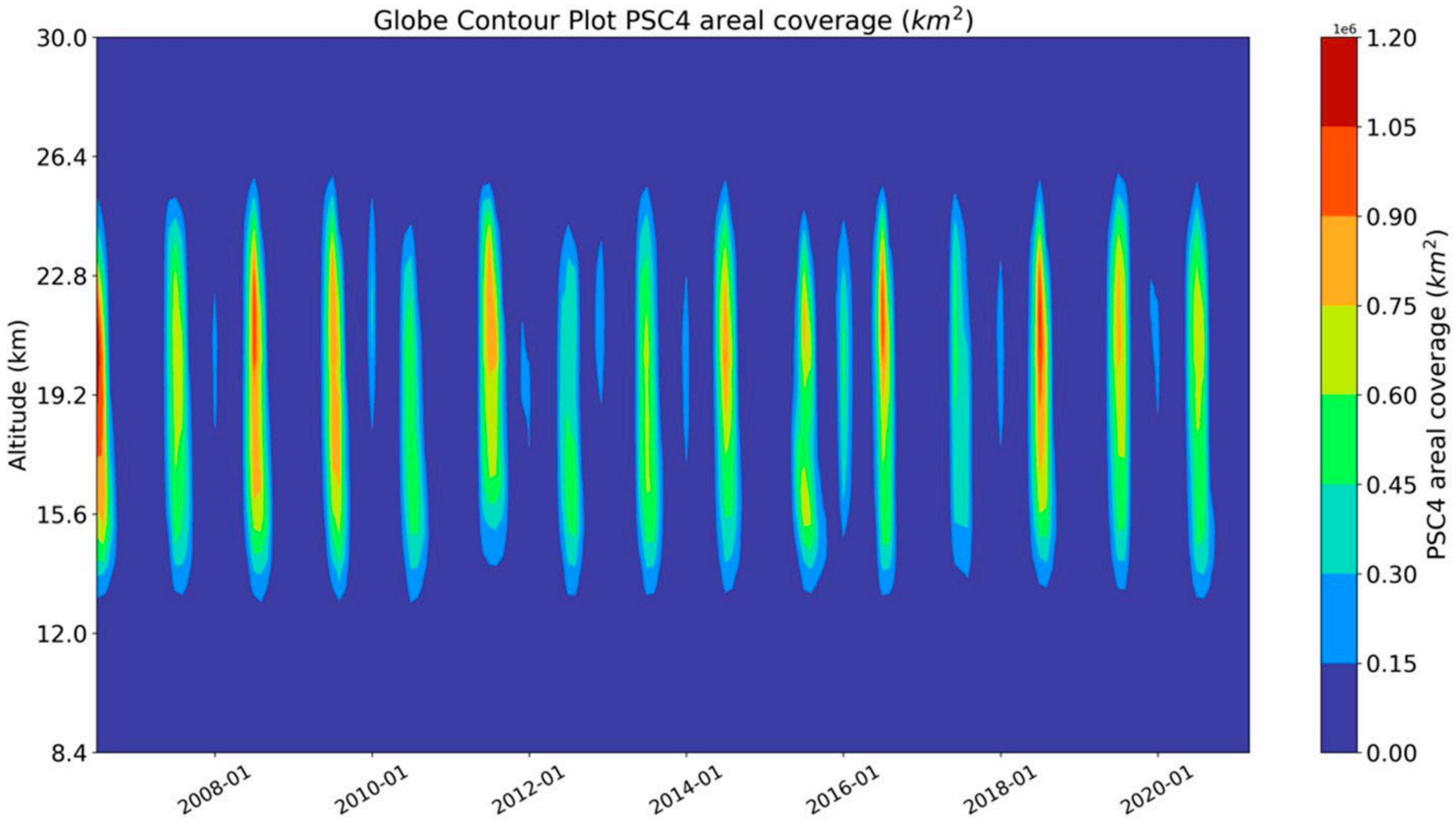


Polar Stratospheric Clouds (PSCs) from CALIPSO Lidar (2006-2023)

Pitts et al. (2018)

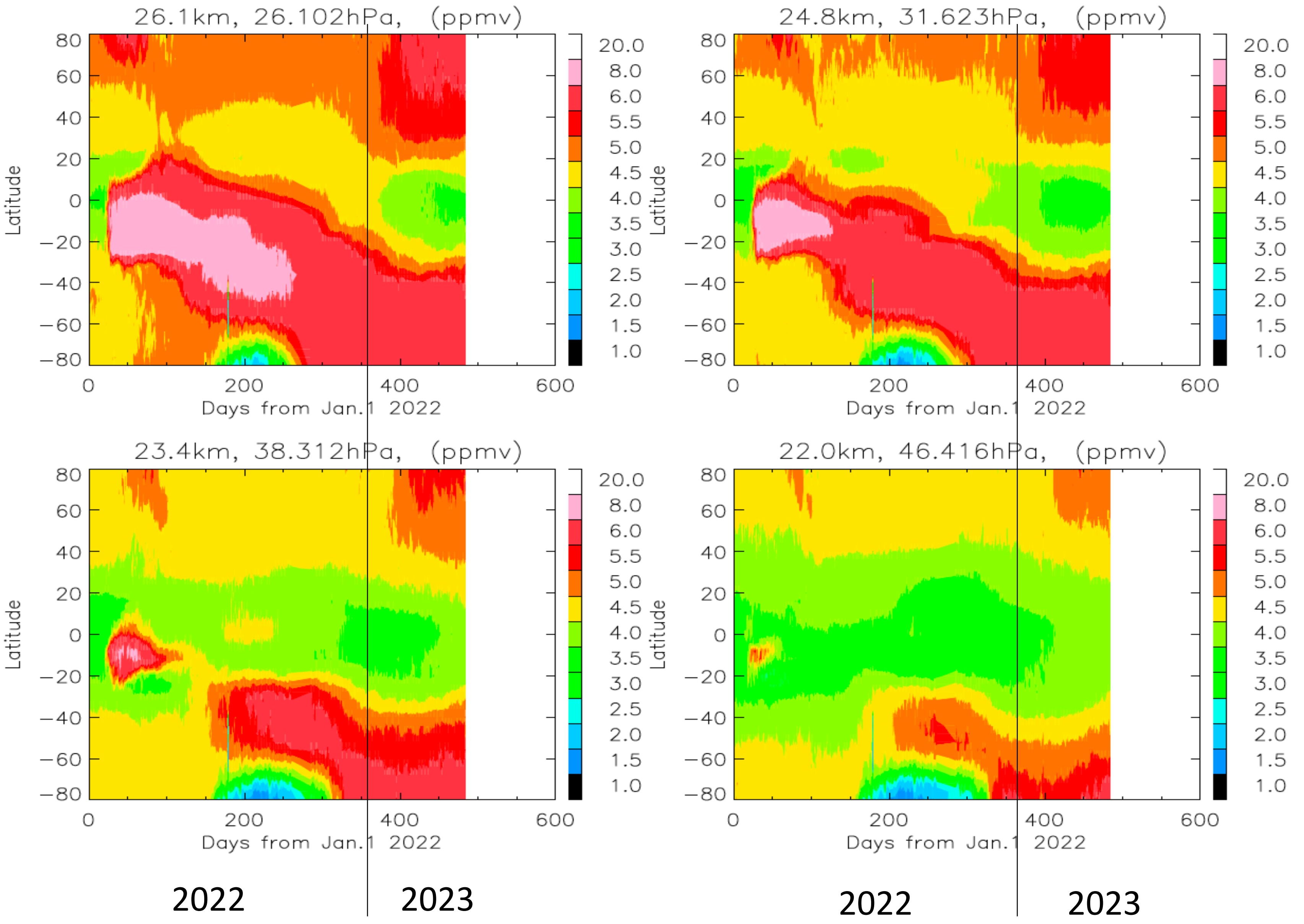


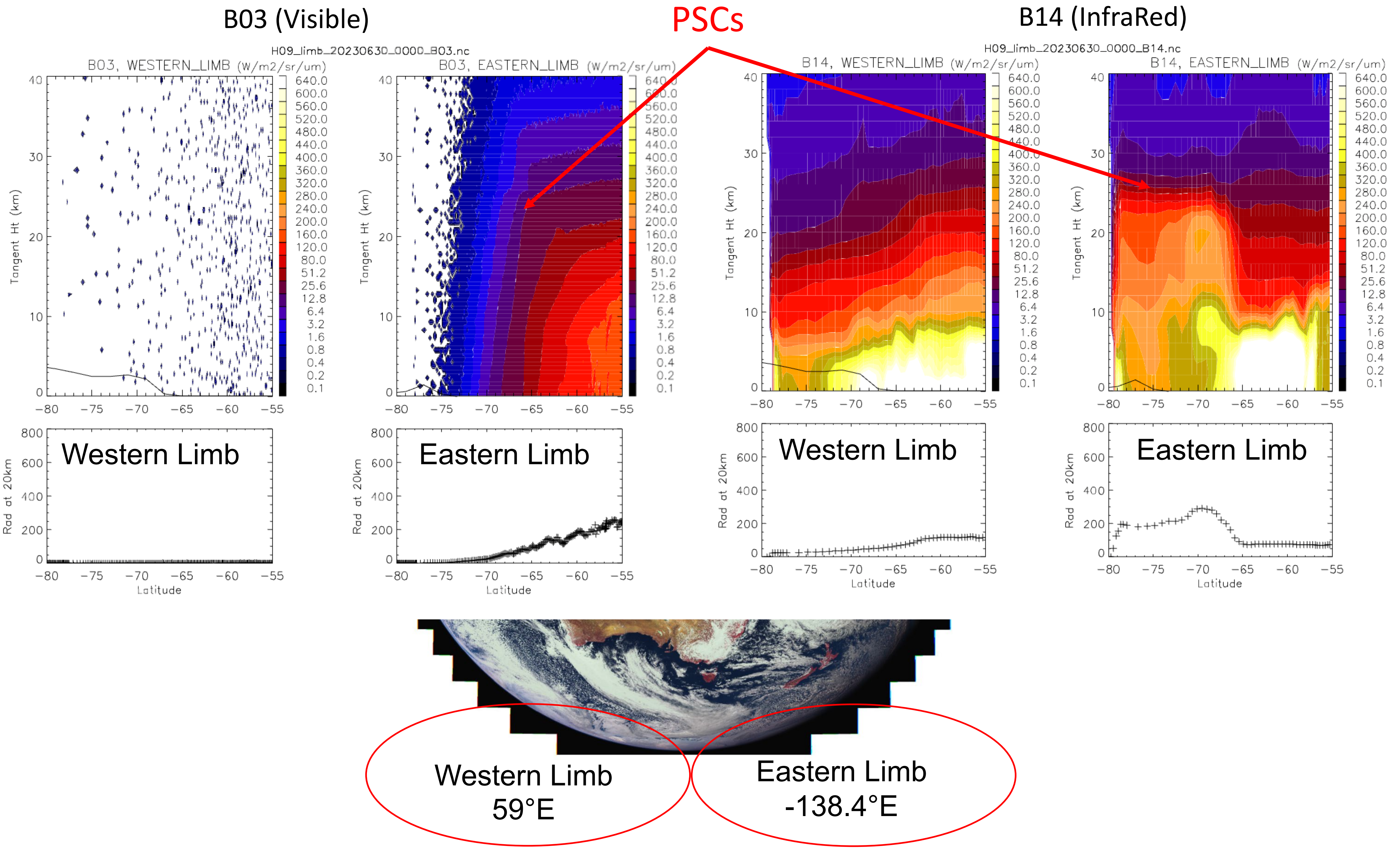
Koutsougiannis et al. (2023)



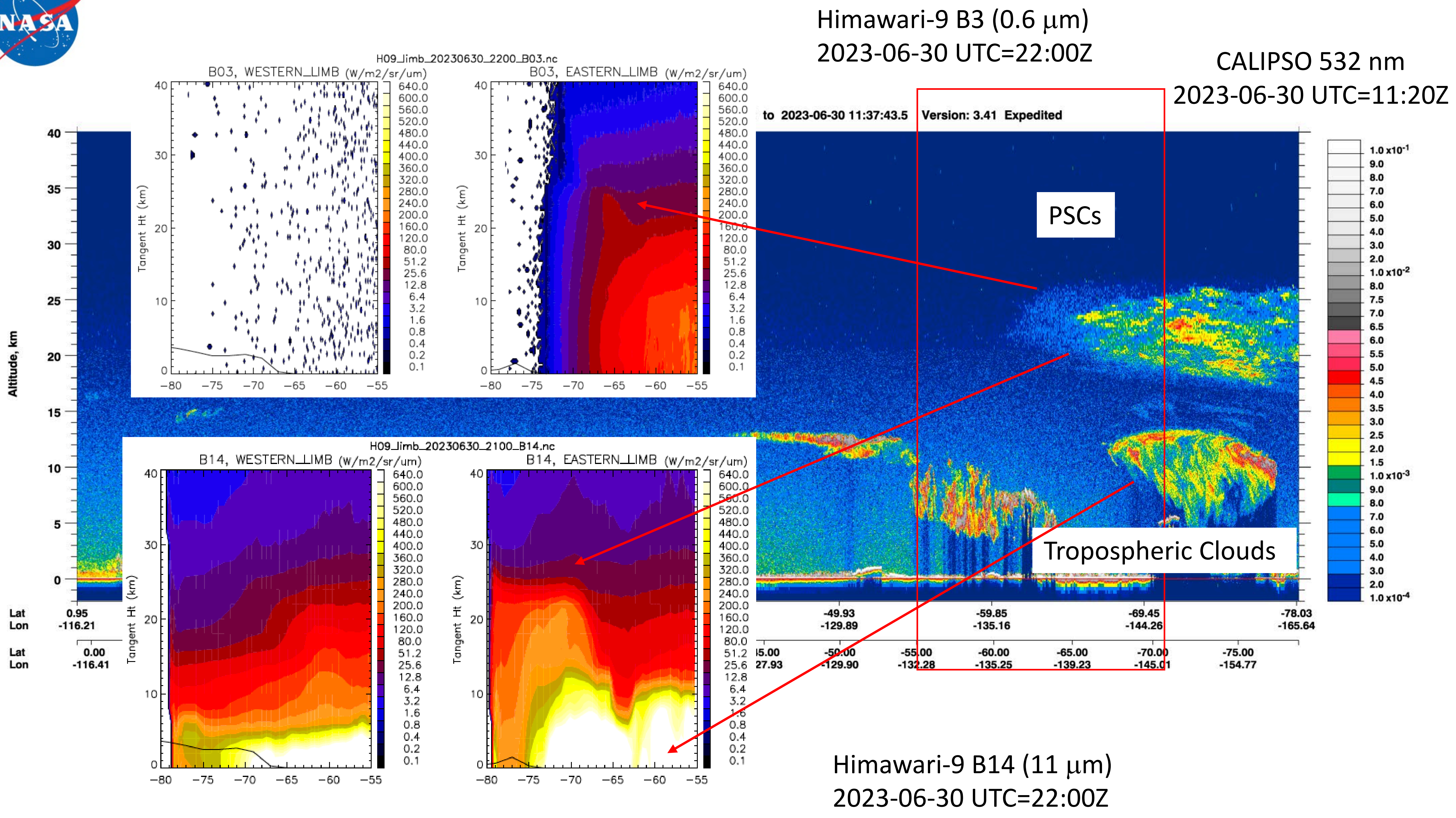
Stratospheric H_2O from HT-HH and Implication for PSCs

- There is 20-30% more H_2O in SH lower stratosphere in 2023
- More polar stratospheric clouds (PSCs) are likely tc form, if the 2023 polar temperature is similar to 2022
- More PSCs in 2023 woulc lead to more O_3 loss in the SH





B03 (Visible)
PSCs
B14 (InfraRed)
H09_limb_20230630_0000_B03.nc
B03, WESTERN_LIMB (W/m2/sr/um)
B03, EASTERN_LIMB (W/m2/sr/um)
H09_limb_20230630_0000_B14.nc
B14, WESTERN_LIMB (W/m2/sr/um)
B14, EASTERN_LIMB (W/m2/sr/um)
Tangent Ht (km)
Rad at 20km
Latitude
Western Limb
Eastern Limb
Western Limb
Eastern Limb
Western Limb
59°E
Eastern Limb
-138.4°E


Himawari-9 B3 (0.6 µm)
2023-06-30 UTC=22:00Z
CALIPSO 532 nm
2023-06-30 UTC=11:20Z
H09_limb_20230630_2200_B03.nc
B03, WESTERN_LIMB (W/m2/sr/um)
B03, EASTERN_LIMB (W/m2/sr/um)
Tangent Ht (km)
to 2023-06-30 11:37:43.5 Version: 3.41 Expedited
PSCs
Altitude, km
H09_limb_20230630_2100_B14.nc
B14, WESTERN_LIMB (W/m2/sr/um)
B14, EASTERN_LIMB (W/m2/sr/um)
Tropospheric Clouds
Lat
Lon
Himawari-9 B14 (11 µm)
2023-06-30 UTC=22:00Z

Summary

- HTHH is very different from previous eruptions (El Chichón, Pinatubo) in amount of stratospheric H2O injection: a good test/challenge to climate models (e.g., removal processes, PSCs)
- Climatic impacts of post-HTHH eruption remain to be seen in the coming years
- A novel GEO limb developed for stratospheric aerosol and PSC sounding, to continue monitoring PSC variations after CALIPSO
- Future work
  - PSC detection algorithm with H8 IR bands
  - Recommendation: Unmask GOES-16,17,18 limb data

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