Disturbing the Middle Atmospheric Balance: The Enduring Impact of Hunga Tonga-Hunga Ha'apai volcanic eruption

by

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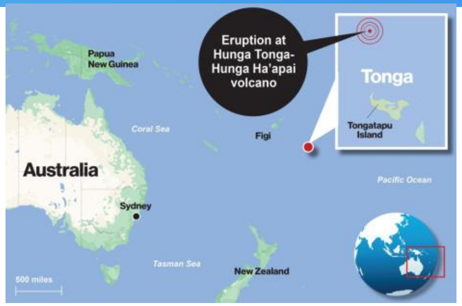
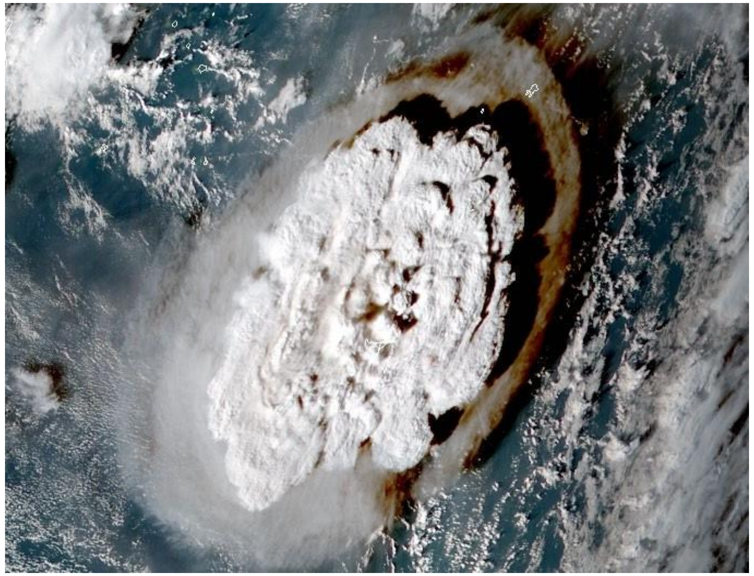
Hunga-Tonga Hunga-Ha'apai: Location, eruptive history



- Hunga Tonga–Hunga Ha‘apai is located in the South western portion of the Pacific Ocean.

- The eruption that occurred at 0400 UTC on 15th January 2022 generated a plume that reached the upper troposphere within a few hours.

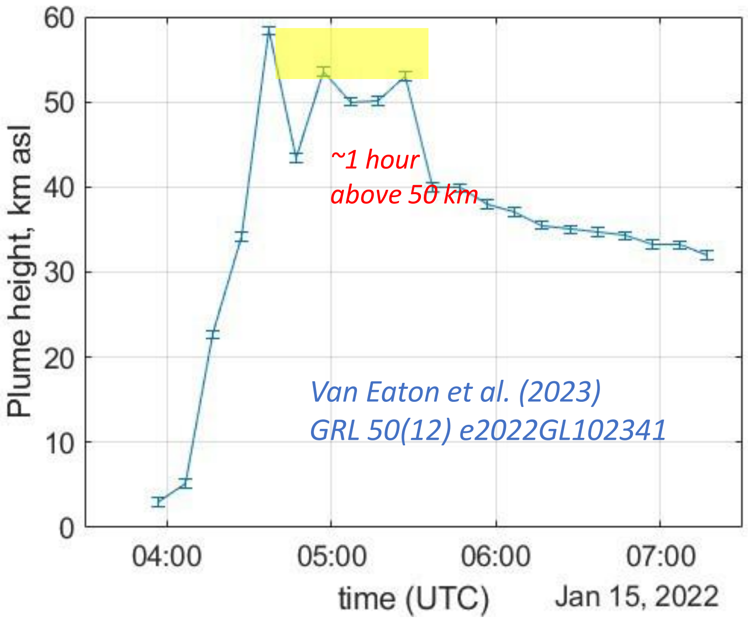


Himawari 8 images, public domain

*NASA, https://tinyurl.com/2p8m7byn

- Later evidence showed that the plume reached heights of 35-40 km with some debris reaching a maximum height of 48 km.

- The bulk of plume that lingered for days after the eruption was in stratosphere at heights of 18-30 km.



Hunga-Tonga Hunga-Ha'apai: Motivation

Most of the studies focused on: Hunga impacts on

- Aerosol characterization
- Atmospheric circulation and transport
- Radiation impacts
- stratospheric mid-latitude and tropical circulation
- Chemical characteristics

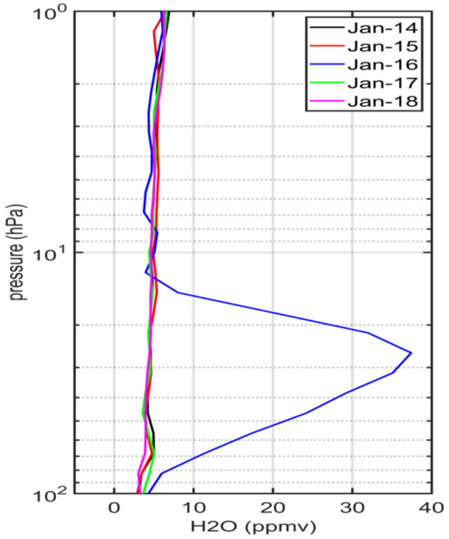
However the present focused on

To understand the changes in stratospheric water vapour and its relationship to temperature and ozone due to HT-HH eruption.

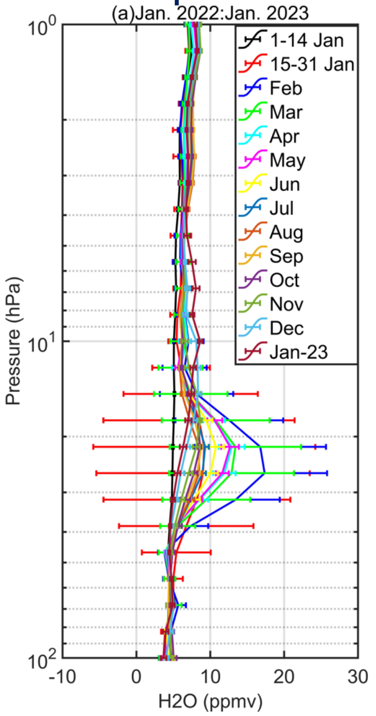
<u>Data:</u>
Microwave Limb Sounder (MLS) from January 2005-January 2024.
Merra2 wind data

HT-HH volcanic eruption immediate impact on water vapor, temperature

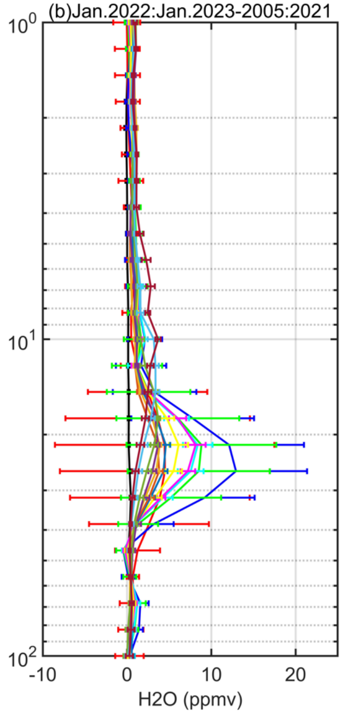
WV Profiles



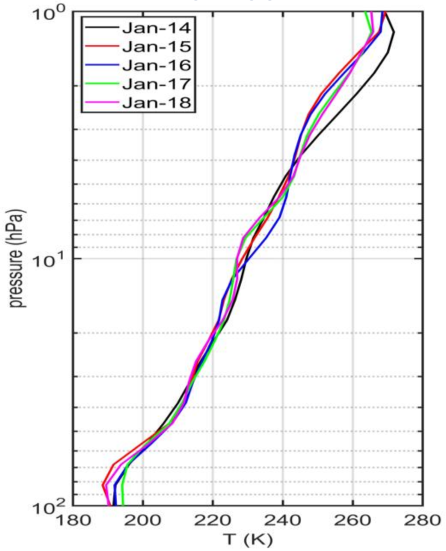
Monthly mean WV profiles



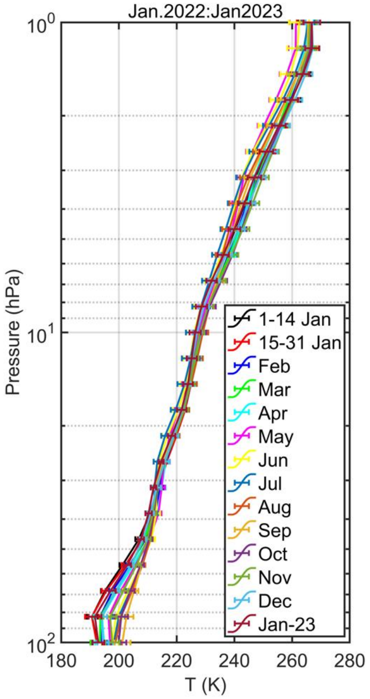
Difference



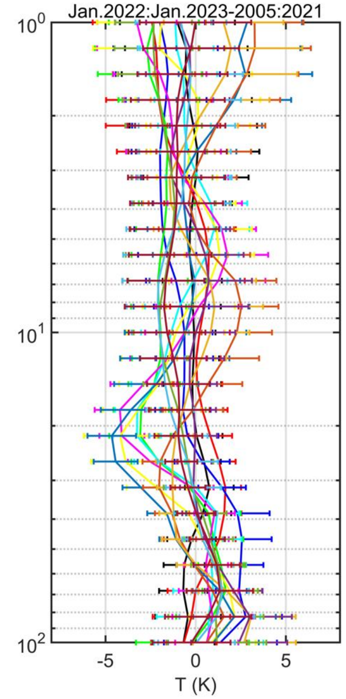
Temperature Profiles



Monthly mean T profiles



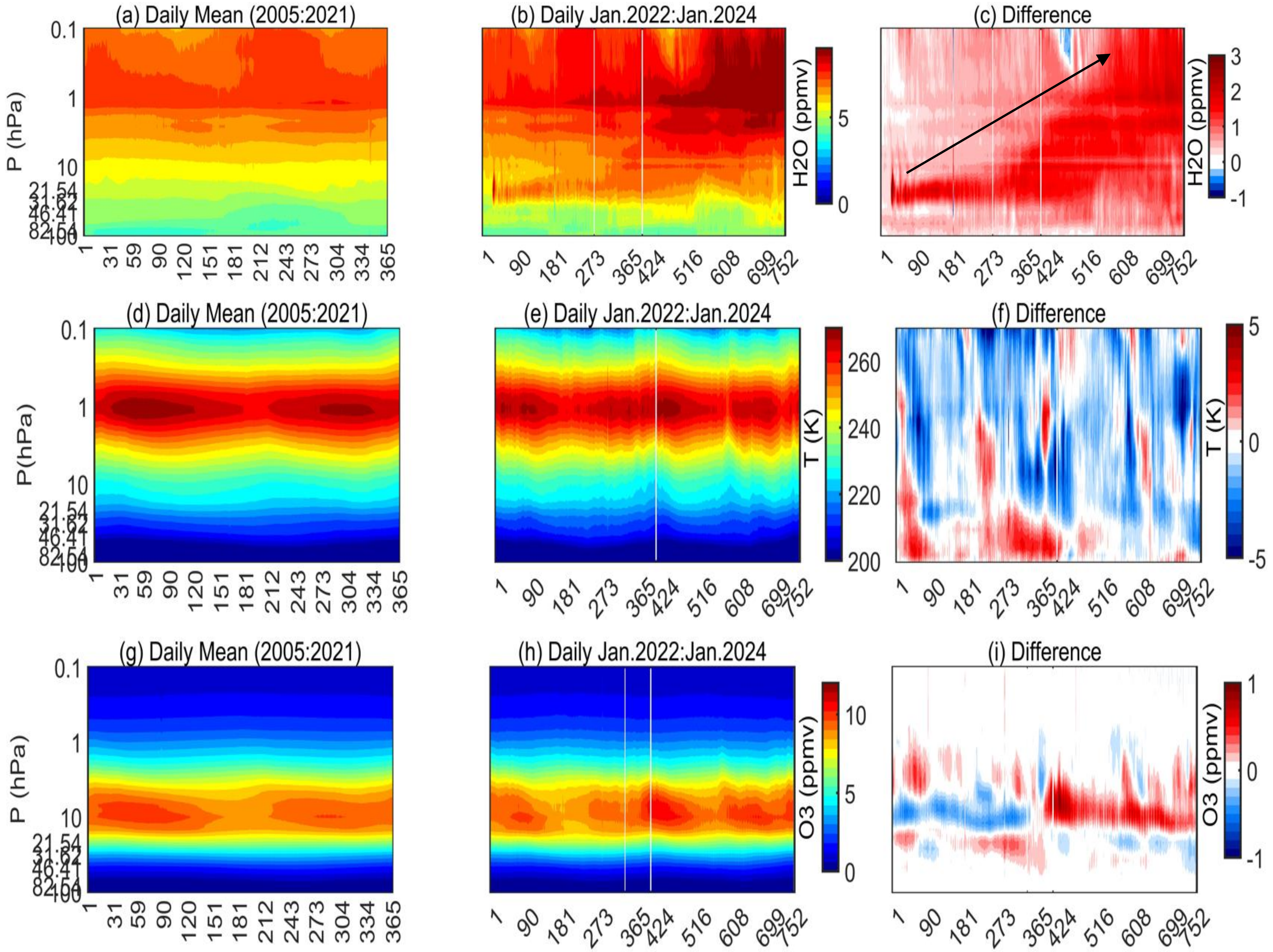
Difference



- All these profiles are averaged throughout the longitudes, and 30°S-5°N latitude band.
- Water vapor profiles shows clear increase exactly after the eruption.
- The increase in stratospheric water vapor is much larger and occurs at much warmer temperatures.

Daily mean and mean difference in water vapor, temperature and ozone

Climatology daily mean 2005:2021 | **Daily mean Jan.2022-Jan.2024** | **Difference**



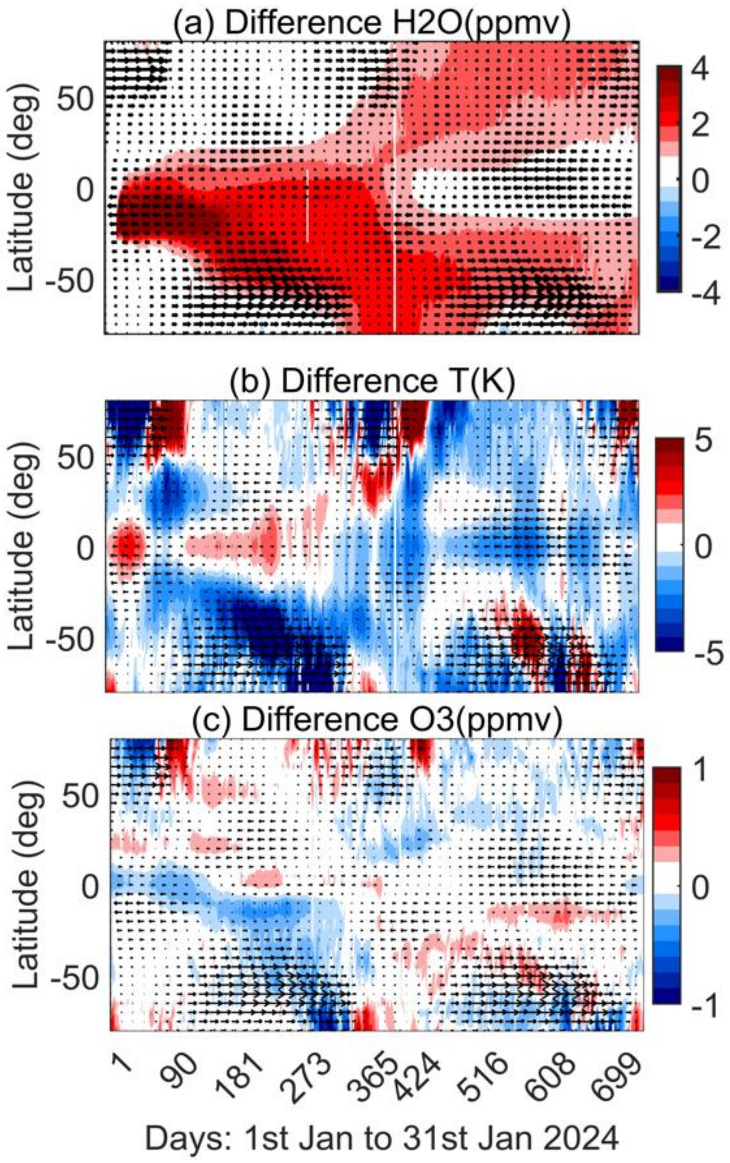
All these profiles are averaged throughout the longitudes, and 30°S-5°N latitude band.

- The WV was injected over a wide vertical range by the HT eruption, encompassing the majority of the stratosphere and its transport to higher altitudes.
- Significant increase in T (around 80 hPa) between 15 and 31 January 2022 after that it decreases
- The difference shows a moderate increase in O_3 at 23 hPa and a decrease at 10 hPa.

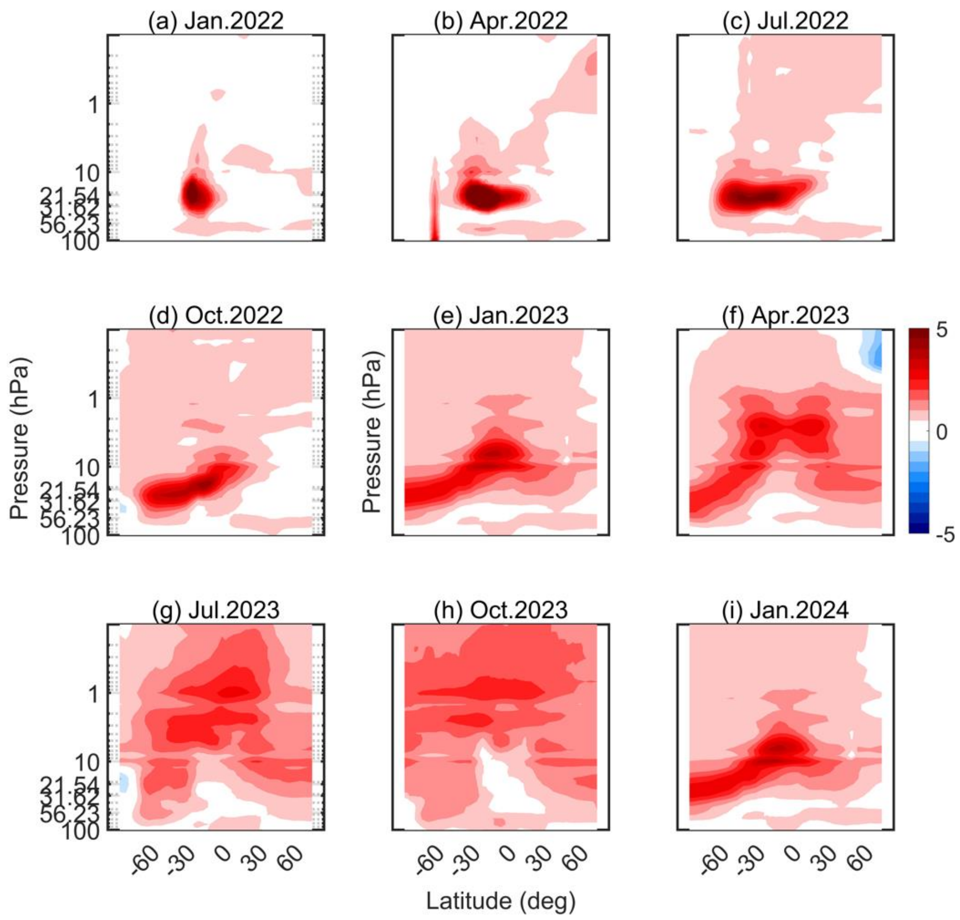
Basha et al., 2023

Meridional variation of water vapor, Temperature and ozone

Day wise anomaly with respect to latitude
(averaged throughout the longitudes and 38-10 hPa vertically)

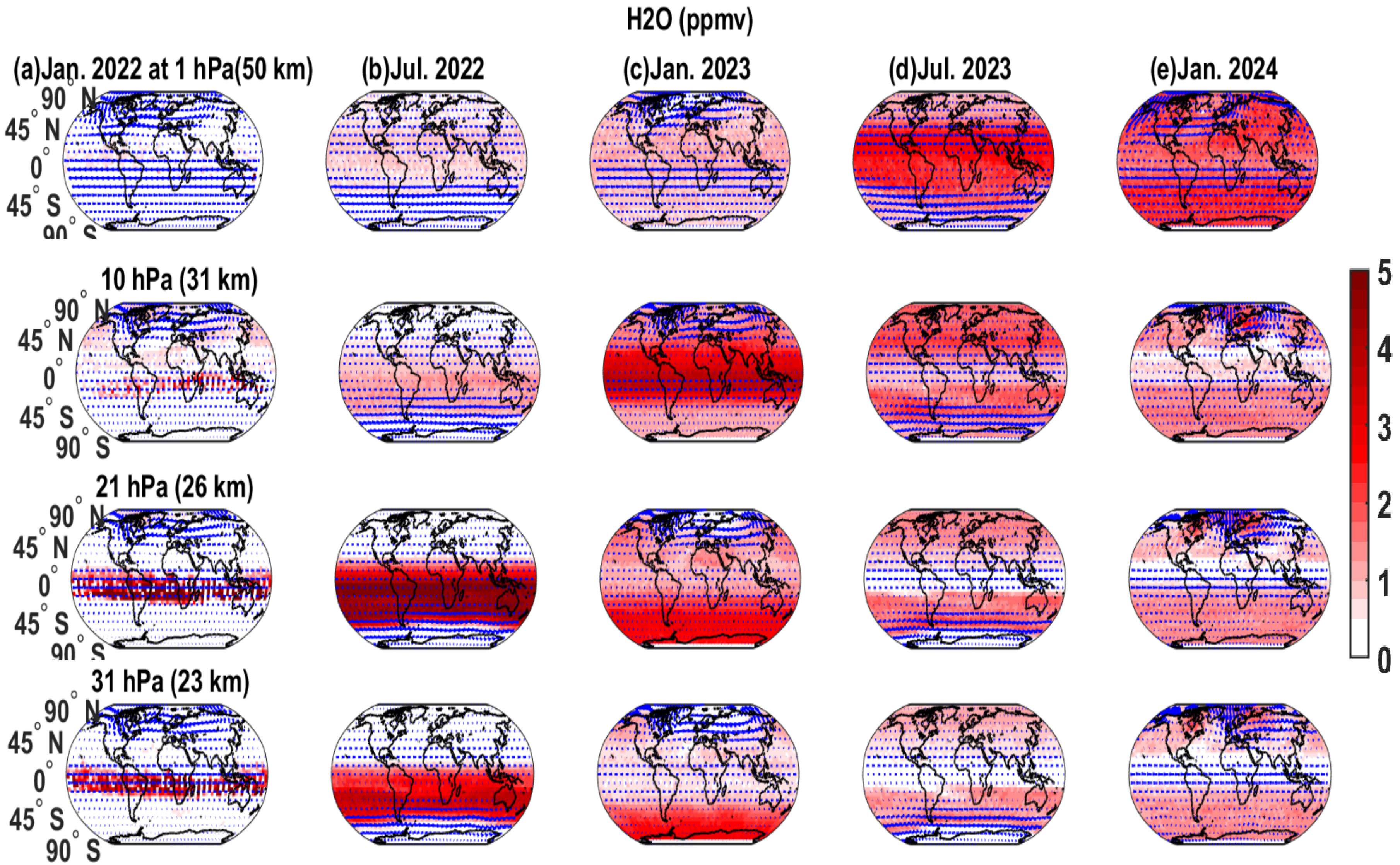


Meridional variation of monthly mean water vapor mixing ratio anomaly



- WV begins to descend towards the SH polar latitudes and reaches poles from November onwards whereas in NH, the WV reaches towards midlatitudes from December onwards.
- Decrease in T and O3 is clearly observed where enhancement in the region where water vapor increases.
- In terms of meridional variation, the transport of water vapor vertical from 68 hPa to 1 hPa is depicted is clearly depicted.

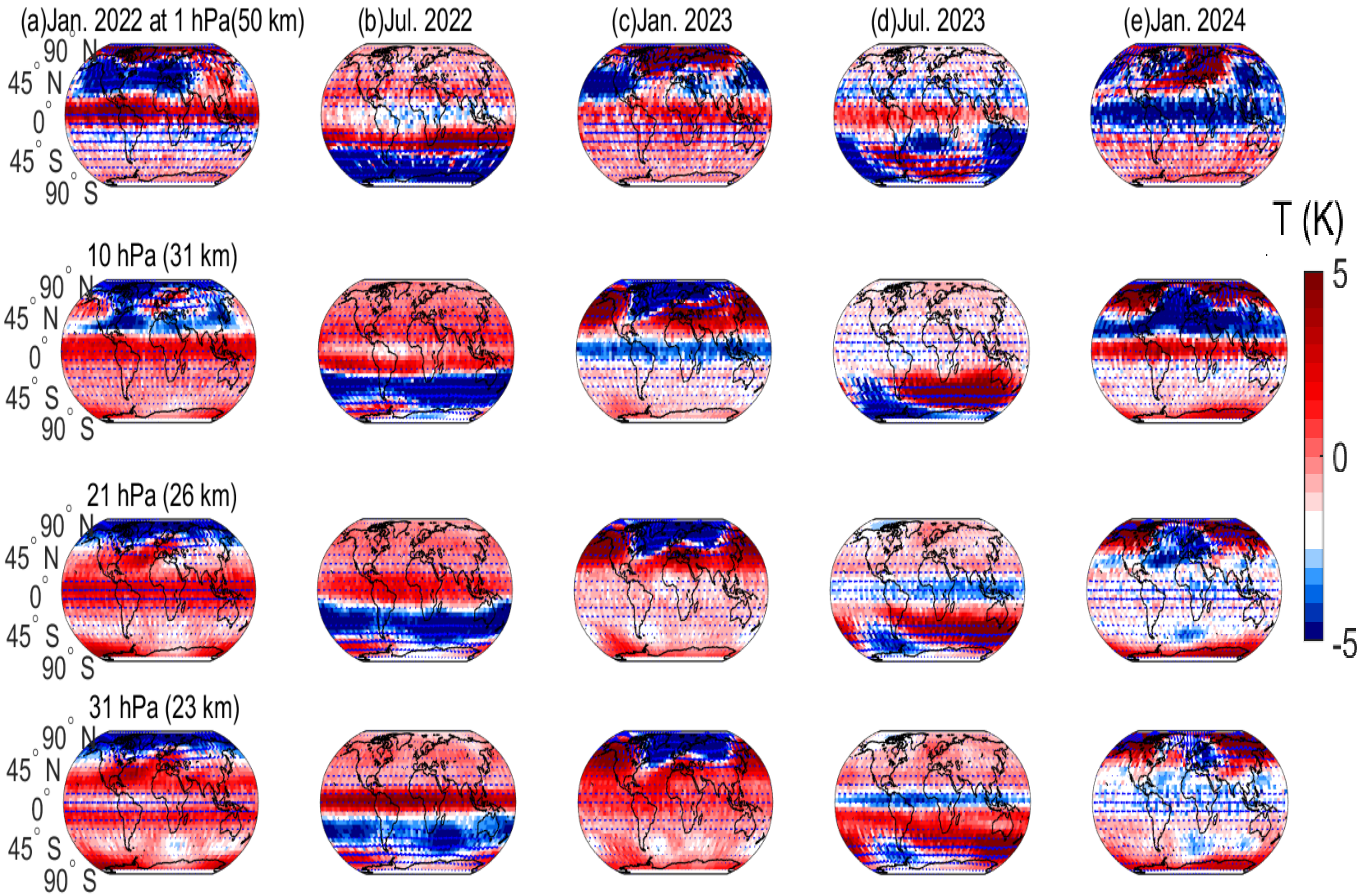
Spatial mean difference in water vapor mixing ratio



- ➢ The WV ejected by the eruption dispersion through the SH in July at 31 and 21 hPa. From Jan. 2023 onwards the water vapor transport to higher altitdes.

- ➢ Most previous volcanoes were limited to 46 hPa, whereas the HT volcano reached ~1 hPa.

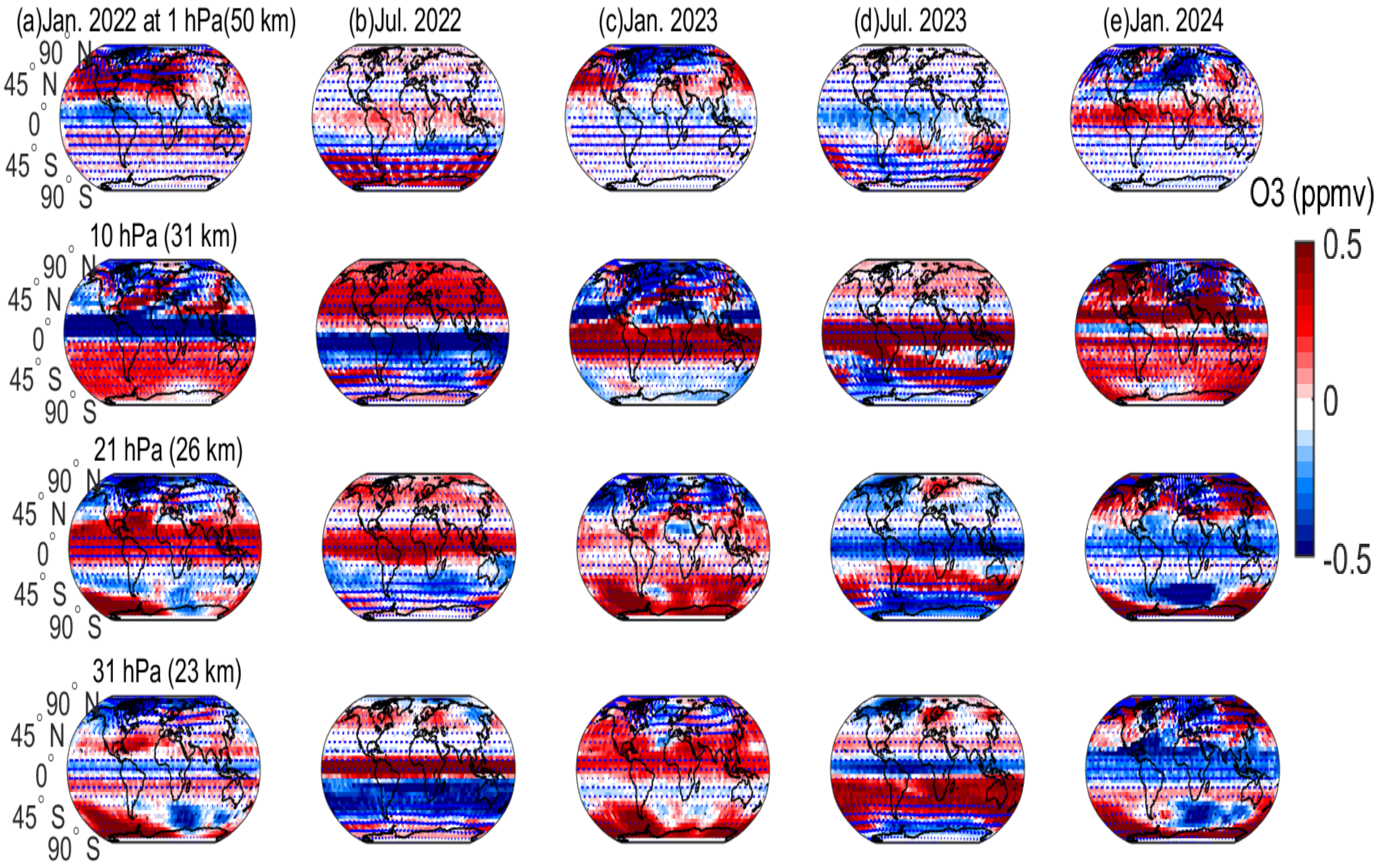
Spatial mean difference in temperature



- Increase in temperature immediately following the volcanic eruption.
- Temperature decreases drastically ~5 K in SH in July 2023. The decrease is clearly observed in the region where WV increases.
- The decrease in temperature (cooling) is observed in SH due to IR radiative cooling via water vapor.
- The Hunga eruption caused a **hydration of the stratosphere** resulting in an intense and **long-lived stratospheric cooling**.
- **The cooling** show close **agreement with** the temporal evolution of the **water vapor plume**.

Basha et al., 2023

Spatial mean difference in ozone mixing ratio



- Large decrease in O_3 is noticed at 31.60 in SH.
- At 10 hPa, increase in O_3 is observed in SH during January to April and the decreases in later months.
- Significant decrease is observed during the months of July and October at 31.61 hPa when compared to other pressure levels.

Basha et al., 2023

Summary and conclusions

- The very intense and unusual HTHH eruption generated an stratospheric plume with a huge amount of water vapor injected that remained well above normal 2 years after the eruption.

- One of the most notable characteristics of this HT explosion is the highest altitude (to stratospheric altitudes (1 hPa, or 47.6 km)) of ejection of water vapour which was not seen in previous eruptions.

- Spatial variation of water vapour shows the transport from lower to higher altitude with respect to time (Jan.2022 to Jan 2024). During January 2024, the stratospheric WV reaches the mesospheric altitudes from stratospheric levels.

- Our findings show an increase in temperature immediately following the volcanic eruption. Later, a significant decrease in temperature (cooling) is observed as a result of IR radiative cooling via water vapour.

- Increased water vapour results in cooling throughout the stratosphere, with the greatest values in the polar lower stratosphere. The temperature decreases by a maximum of ~5 K from May to November, with strong dispersion towards SH polar latitudes due to the strong eastward wind.

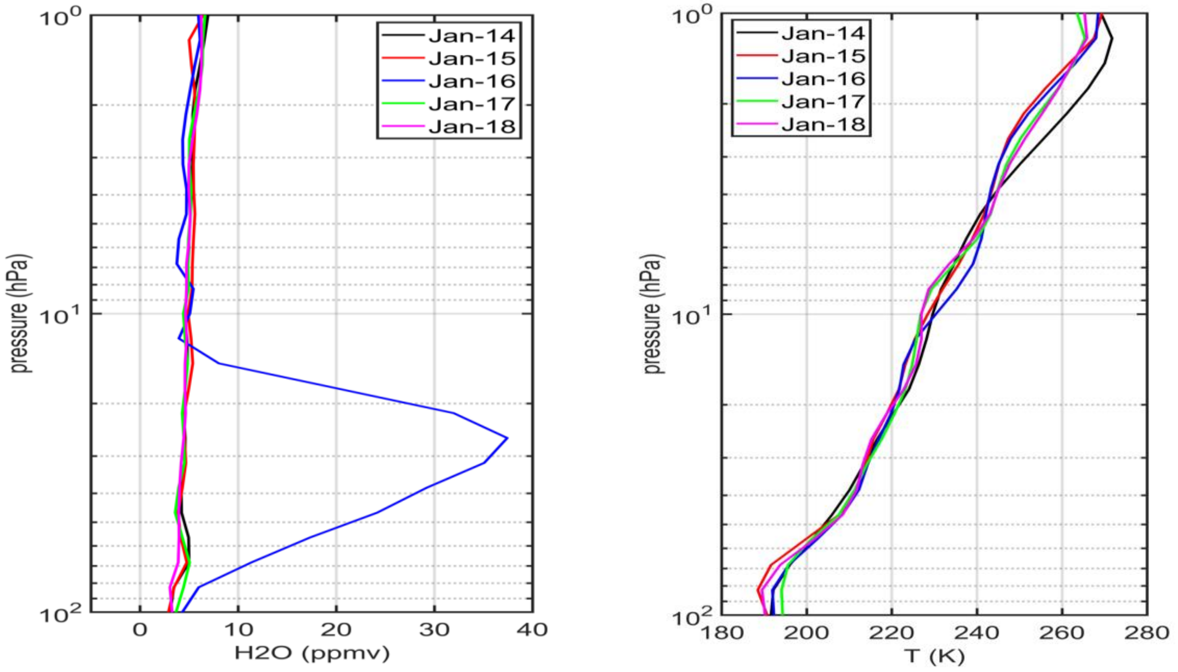
- A decrease in the ozone is observed due to an increase in water vapour at stratospheric altitudes.

- Even after 2-year of completion of eruption, the WV, T and O3 didn’t reach to their background values.

- The HTHH eruption provides a natural testbed to show how increased water vapor in the stratosphere can impact throughout the middle atmosphere.

Thank you

Extra slide



- A decrease in the ozone is observed due to an increase in water vapour at stratospheric altitudes. Because of increased water vapour in the stratosphere, OH concentrations rise, slightly increasing O_3 production via the CH_4 oxidation cycle but worsening O_3 depletion via the HOx cycle, resulting in a net decrease in O_3.

Daily variation of water vapor mixing ratio and temperature from 14th-18th January 2022 averaged throughout the longitudes, and 30°S-5°N latitude band.