Strong persistent cooling of the stratosphere after the Hunga eruption

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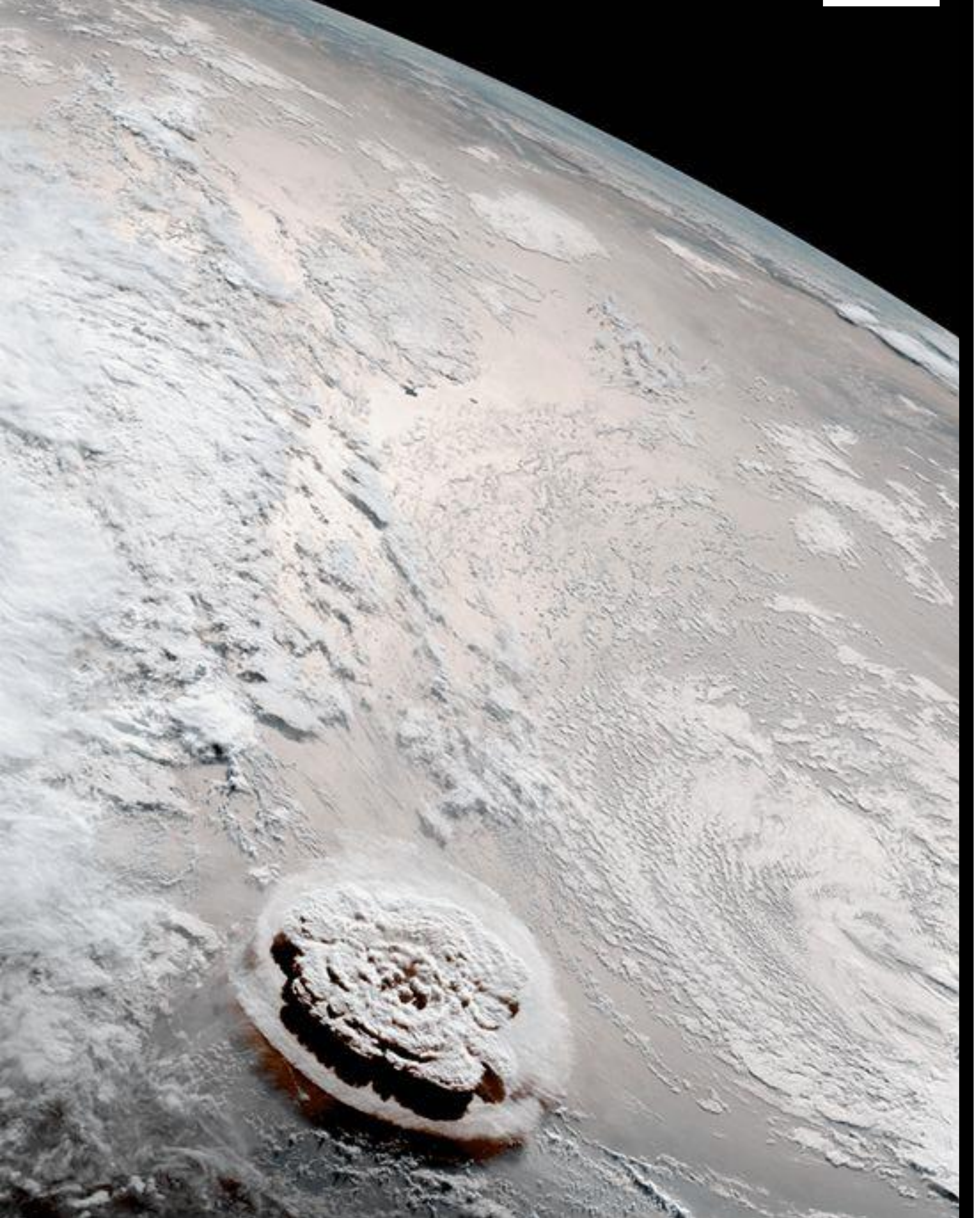

1 Introduction

In 2022, the **Hunga Tonga-Hunga Ha'apai** volcano experienced a record-breaking eruption, with a **plume reaching altitudes of 53 to 57 km**. While the aerosol injection was relatively small compared to other large volcanic events, the eruption released an extraordinary amount of water vapor - exceeding 50 megatons - into the stratosphere. This **unprecedented stratospheric hydration** represents a **unique phenomenon** in the satellite era, **influencing important climate variables** such as ozone or **stratospheric temperature.**

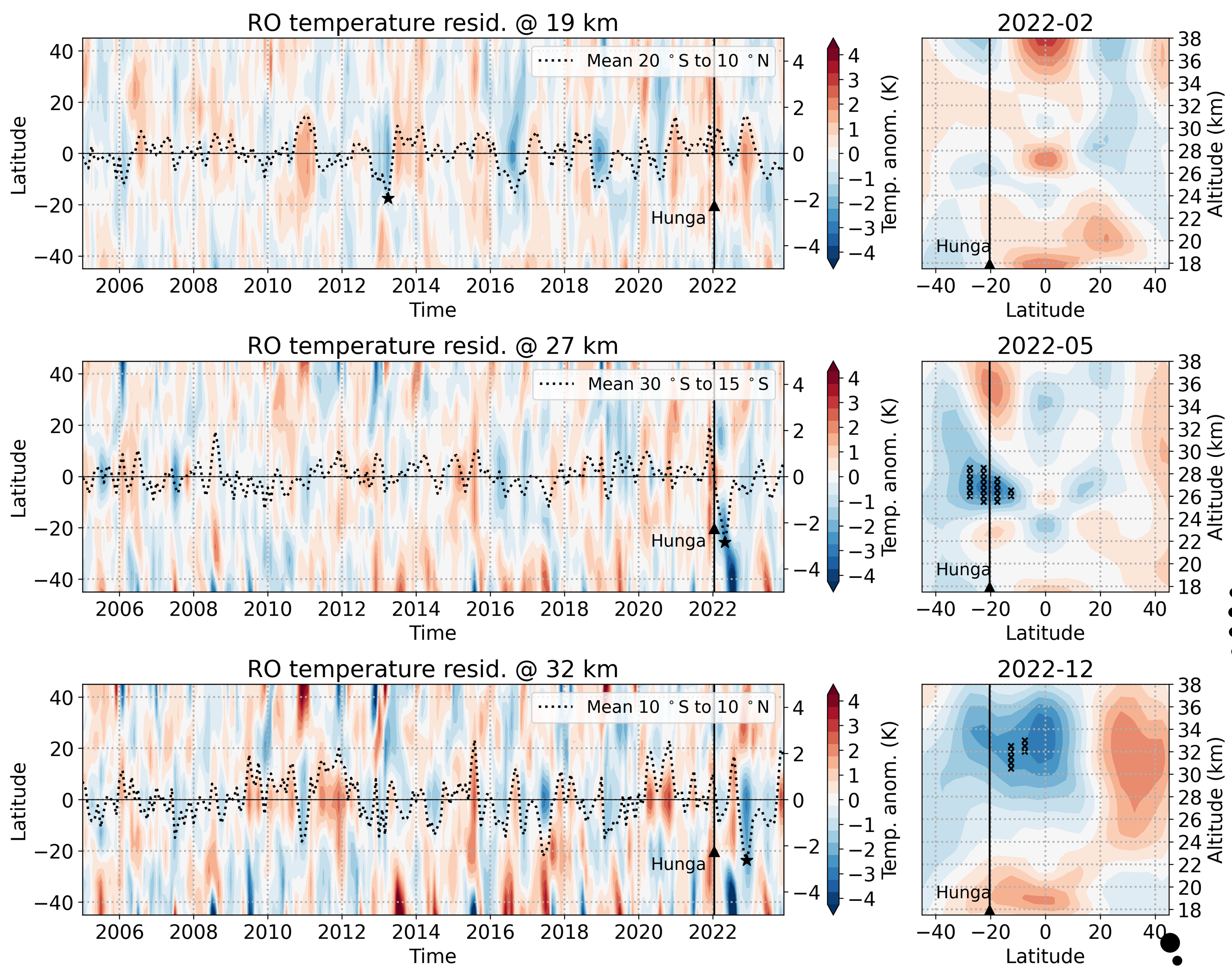

Fig. 2: Monthly mean temperature anomalies after subtracting QBO, ENSO and variability connected to the high latitudes. The dashed lines indicate the average anomalies across specific latitude regions, while markers in the right panels highlight anomalies that deviate by more than three standard deviations. Star symbols indicate the strongest anomalies in the time series.

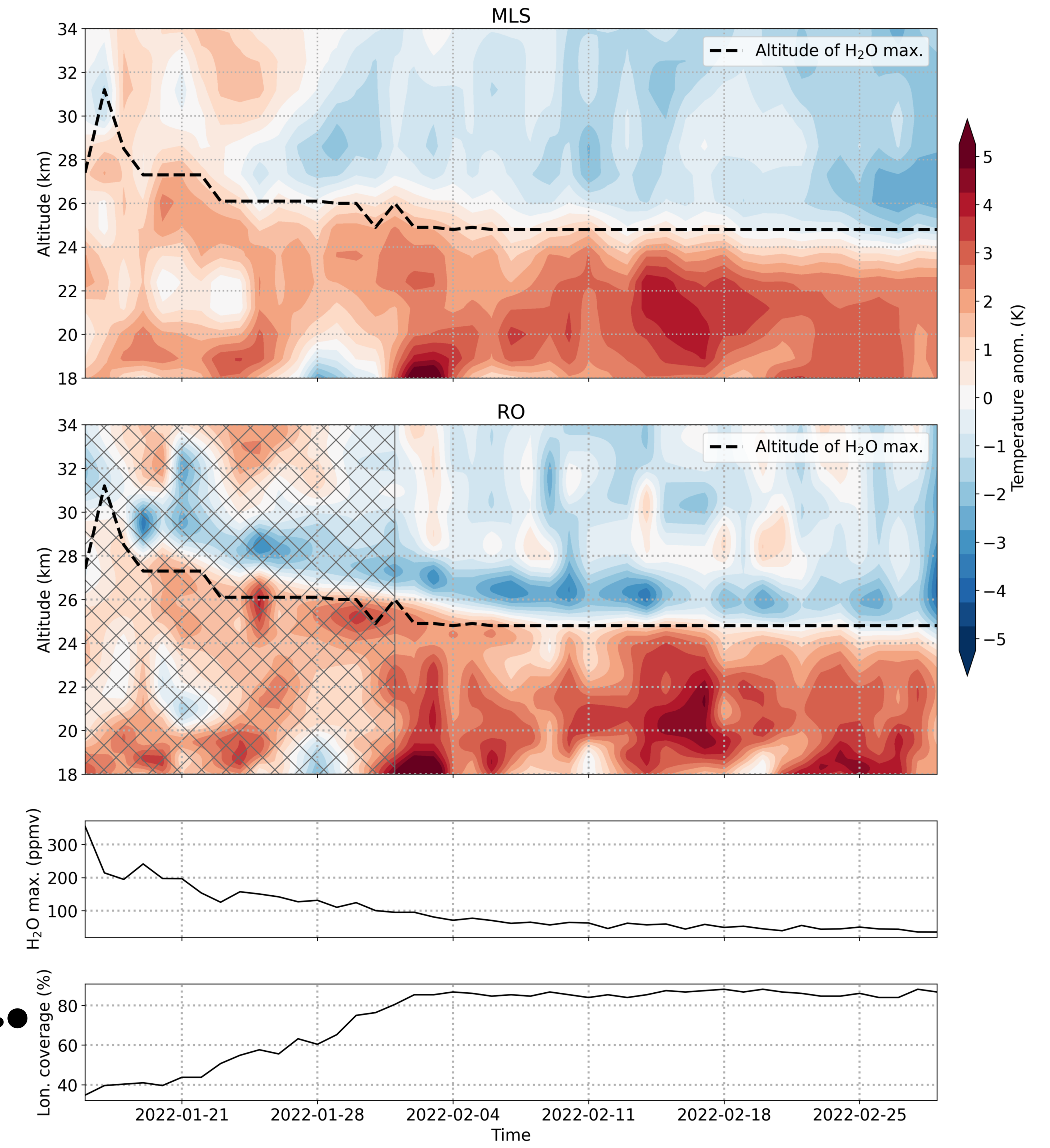

Fig. 1: Temperature anomalies from MLS and RO measurements within the core region of the early water vapor plume.

2 Results

Shortly after the eruption a **temperature dipole structure**, **following the altitudinal evolution** of the water vapor plume is visible in the temperature anomalies from **MLS and radio occultation (RO) measurements co-located with the plume**. A strong cooling above the altitude of the water vapor maximum and a warming below is observable (radiative cooling vs. GHG effect).
As the **plume spreads**, exceptionally **strong negative temperature anomalies** occur over the **whole latitude bands**. When natural variability is accounted for, these anomalies are the **strongest** in the entire time series **from 2005 to 2023**.

3 Discussion

The **temperature anomalies** after the Hunga eruption show a **clear correspondence with** the **water vapor distribution**. In the months following the eruption, pronounced negative temperature anomalies occur in the SH subtropics, closely following the water vapor plume. As the water vapor is transported upwards in the tropics, unusually **strong negative temperature anomalies** occurred in the **tropical mid-stratosphere** (> 30 km) **until mid 2023**.
While dynamical cooling due to the Hunga-driven strengthening of the SH polar vortex (SH winter 2022, Fig. 2 bottom) plays a role at high SH latitudes (Wang et al., 2023), **radiative cooling by water vapor is the main cause of the anomalies in the subtropics and tropics.**

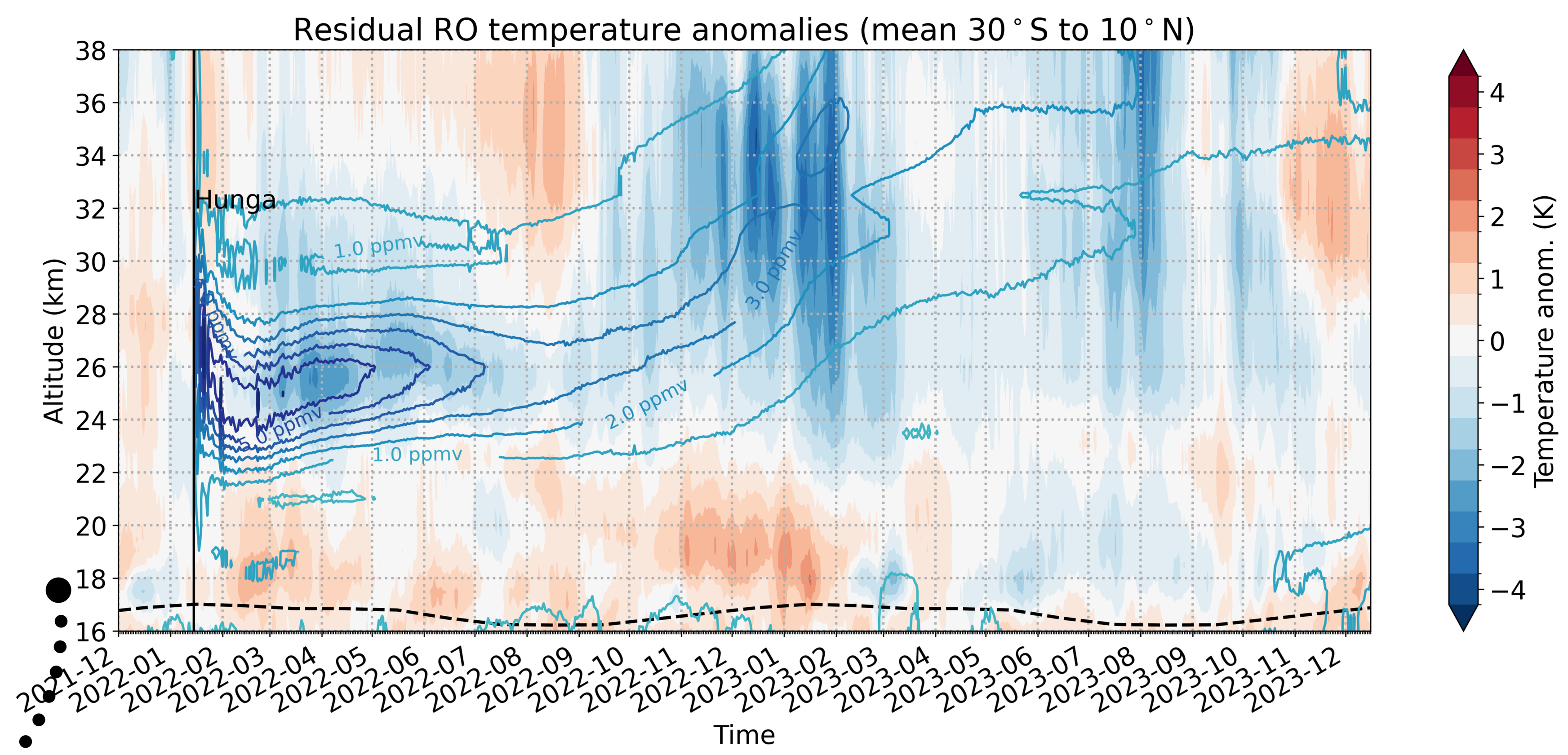

Fig. 3: Zonal mean RO temperature anomalies after excluding natural variability modes. Contour lines represent the MLS water vapor mixing ratio (ppmv).