

Impact of Hunga Tonga volcanic eruption on the low latitude intraseasonal oscillations



Ankita Chaurasia ^{1,2*}, Amitava Guharay¹

¹ Space and Atmospheric Sciences Division, Physical Research Laboratory, Ahmedabad, GJ, India
² Department of Physics, Indian Institute of Technology, Gandhinagar, GJ, India



*Presenting author: ankitachaurasia2211@gmail.com

ABSTRACT

The Hunga Tonga–Hunga Ha’apai (HTHH) volcano erupted on 15 January 2022 ranks among the most powerful events of recent decades, producing a wide range of atmospheric disturbances. This study explores its influence on intraseasonal oscillations (ISO) using satellite measurements and reanalysis datasets. Analysis of Outgoing Longwave Radiation (OLR), Precipitation amount (RF), and Specific Humidity (SH) indicates a marked strengthening of 20–40 day variability around the event time with an eastward-propagation. In contrast, the zonal wind (U) showed no response, indicating decoupling between convection and wind during the eruption. Examination of solar F10.7 flux around the eruption period revealed no clear contribution, supporting a volcanic rather than solar origin of the observed oscillation. A notable enhancement was also detected in the DE3 (eastward diurnal tide, wavenumber 3) amplitude in the lower stratosphere, suggesting that the eruption modified local convective activity and wave dynamics. Overall, the results highlight how a major atmospheric disturbance such as a volcanic eruption can perturb intraseasonal variability and tidal behavior, with potential consequences for energy transport and the coupling of different atmospheric layers.

OBJECTIVES

- Identification of ISO variability associated with the Hunga Tonga–Hunga Ha’apai volcanic eruption.
- Assessment of the extent of the ISO response to determine whether it was localized or regional.
- Evaluation of the eruption’s impact on atmospheric tides and wave dynamics.

BACKGROUND

- The Hunga Tonga–Hunga Ha’apai (HTHH) volcano (20.536°S, 175.382°W) is an **underwater caldera** about 70 km northwest of Nuku’alofa (Brenna et al., 2022).
- On January 15, 2022, it erupted violently, generating strong **atmospheric disturbances** (Yamazaki et al., 2022).

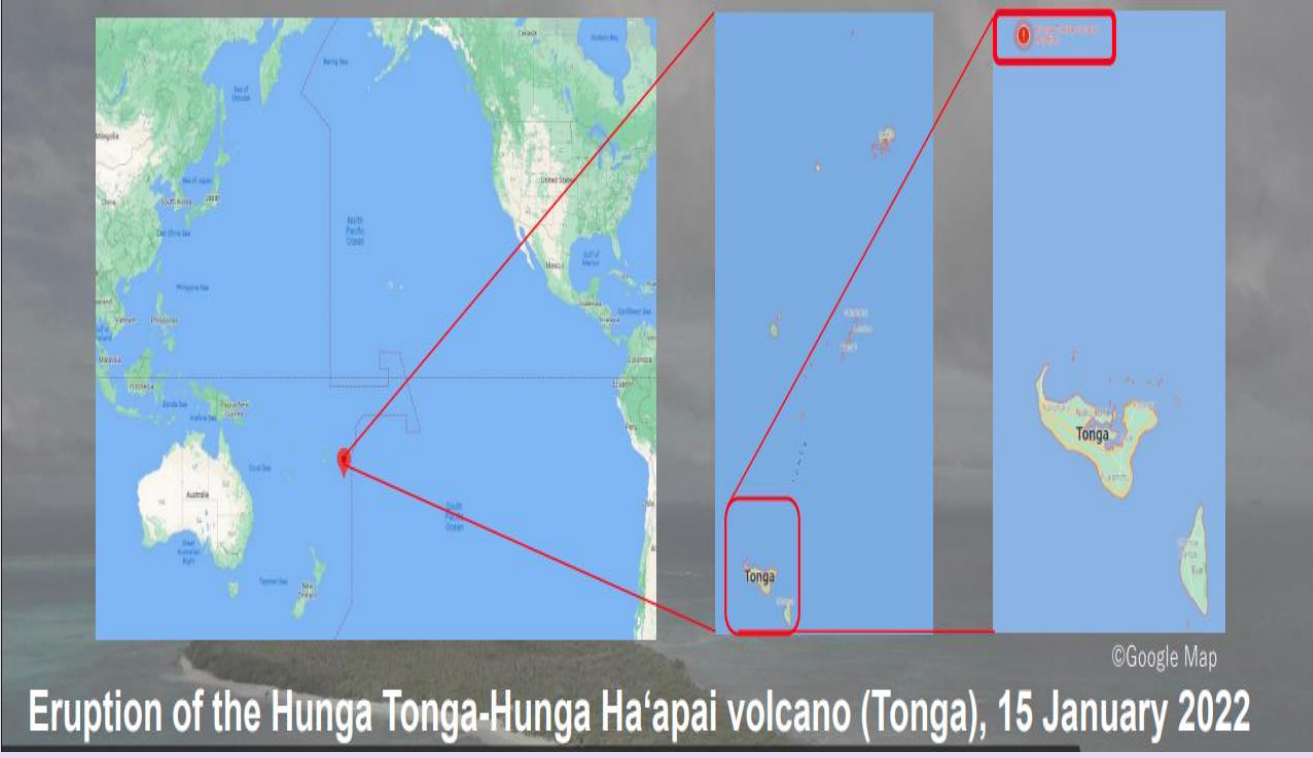


Fig. 1- Location of HTHH on map (Credit-Asian Disaster Reduction Center)

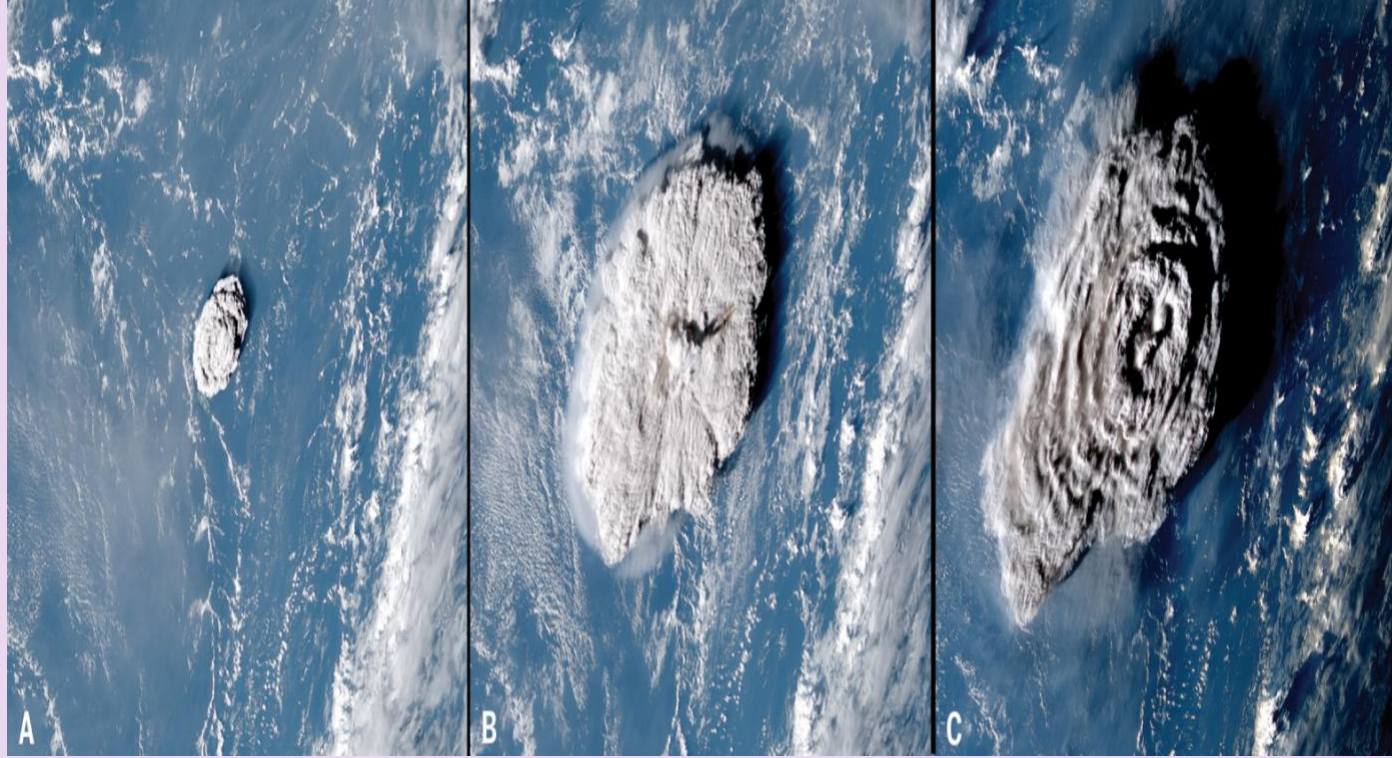


Fig. 2- The Hunga-Tonga eruption viewed from the Himawari-8 weather satellite (Proud et al., 2022).

ISO SIGNATURE

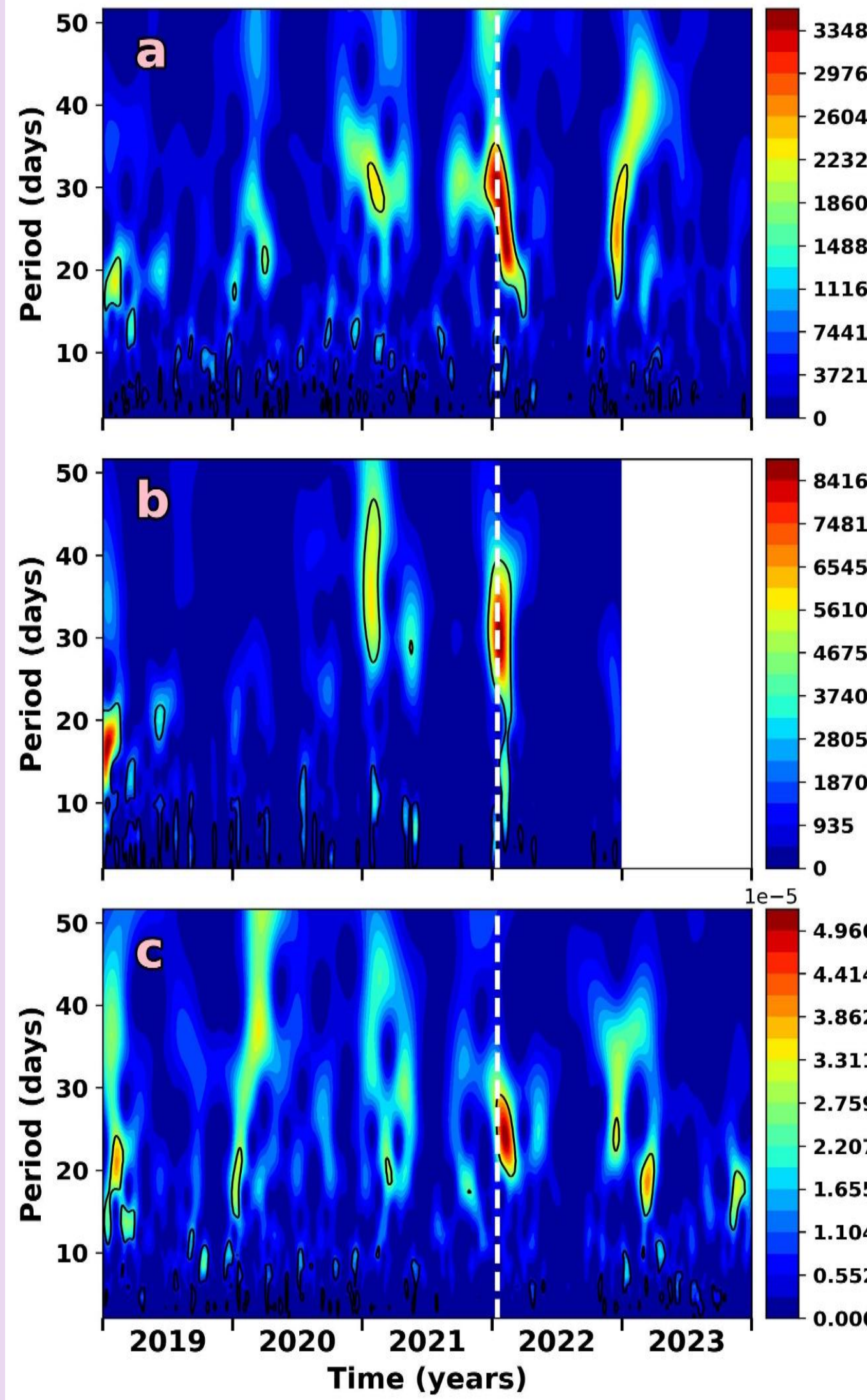


Fig. 3- Wavelet power spectra of (a) OLR, (b) RF, and (c) SH (at ~ 6 km). The time series spans from 1919 to 2023, with periods ranging from 2 to 50 days. Black curves in each plot represent 95% confidence level. Dashed white line marks the event day (15-January, 2022).

ZONAL PROPAGATION

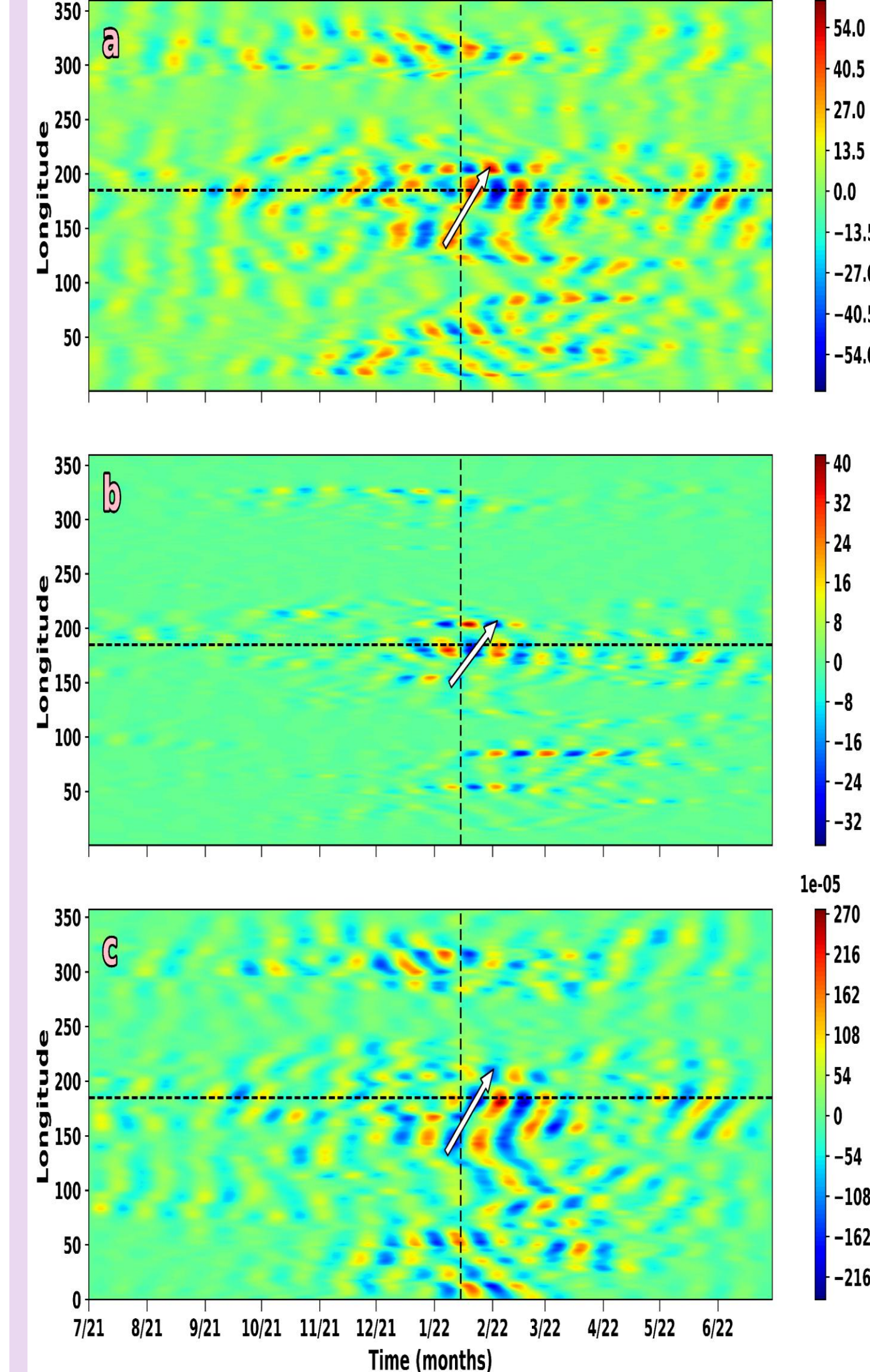


Fig. 4- Filtered (a) OLR, (b) RF, and (c) SH (at ~ 6 km), using a 20–40 day band-pass. Time series (X-axis) spans from 01-July, 2021 to 30-June, 2022, and Y-axis represents longitudes from 0° to 360°. Dashed black vertical line marks the event day (15-January, 2022) and horizontal line the event longitude (185°).

DATABASES

- This study uses atmospheric specific humidity and zonal wind from the Modern-Era Retrospective Analysis for Research and Applications version 2 (MERRA-2) reanalysis.
- Convective activity is represented using daily mean Outgoing Longwave Radiation (OLR) data from National Centers for Environmental Prediction (NCEP).
- Precipitation data are taken from the Global Interpolated RAINFall Estimate (GIRAFE) dataset.
- Solar activity is characterized using daily adjusted solar F10.7 flux data obtained from OMNIWeb.

EXTENT OF ISO

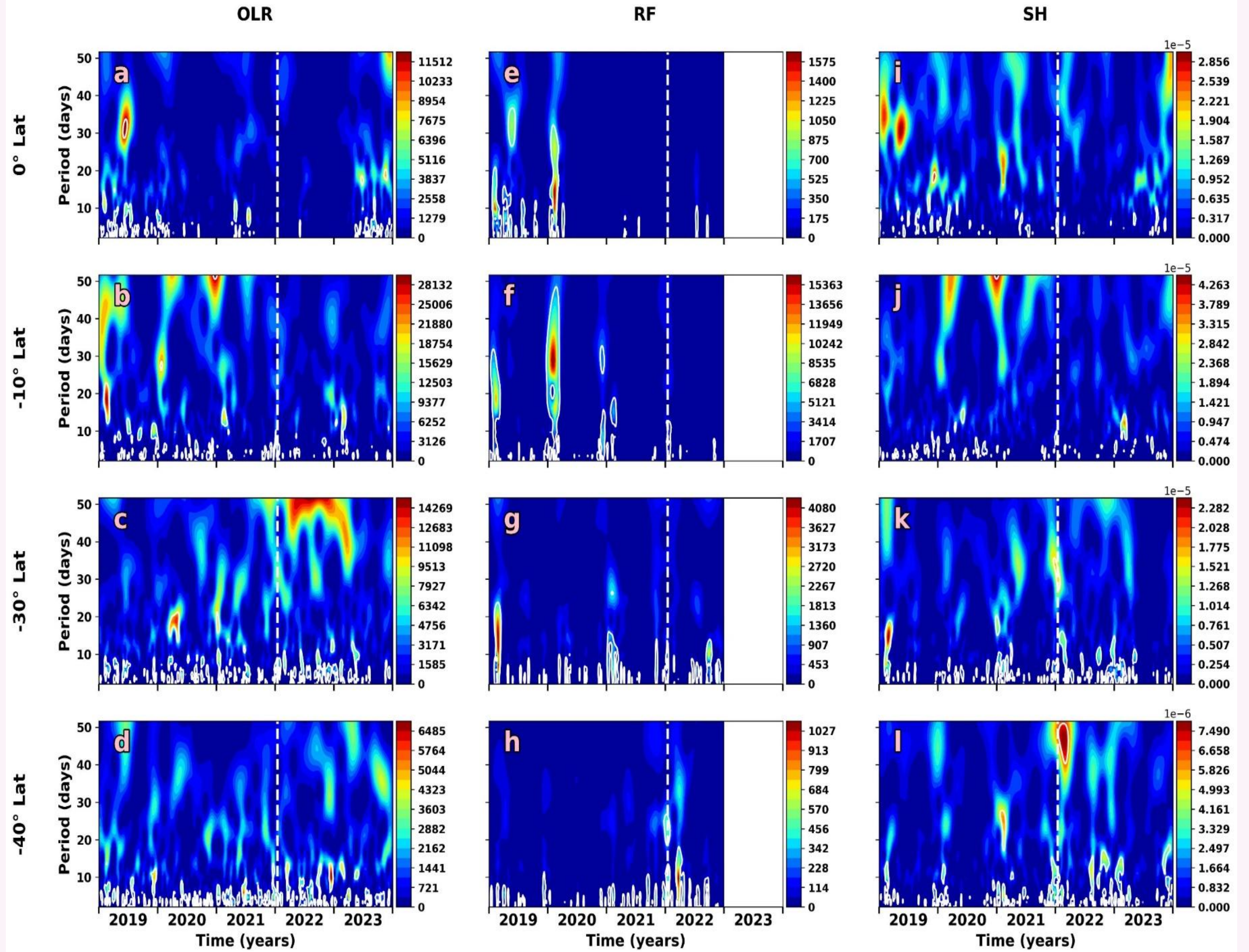


Fig. 6-Latitudinal variation of ISO analyzed using wavelet power spectra of OLR (a-d), RF (e-h), and SH (i-l) at 0°, 10°, 30°, and 40°N (from left to right).

CONVECTION-WIND RELATIONSHIP

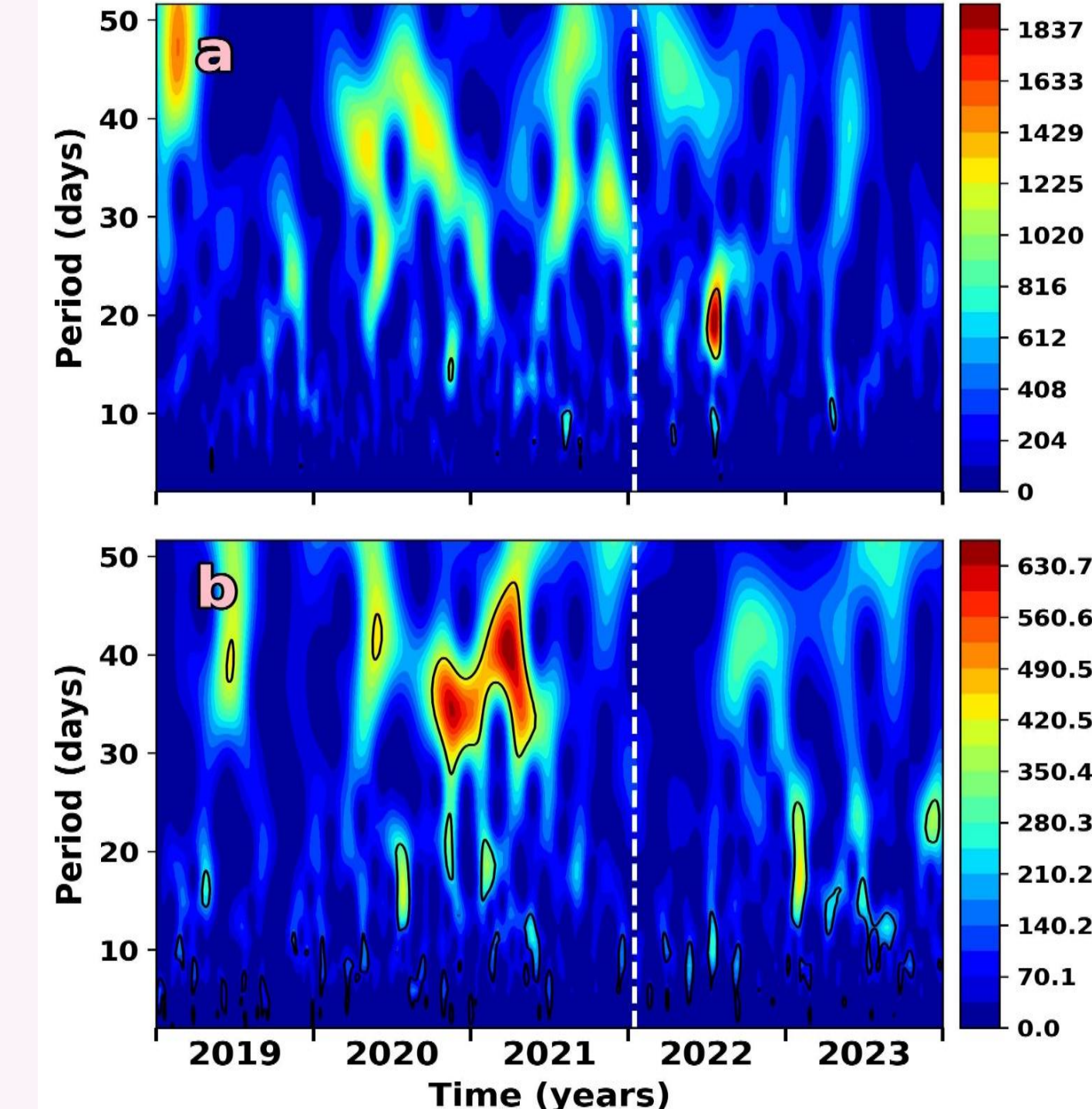


Fig. 7- Wavelet power spectra of Zonal wind at (a) 250 mb (10 km), (b) 850 mb (1.5 km).

SOLAR INFLUENCE

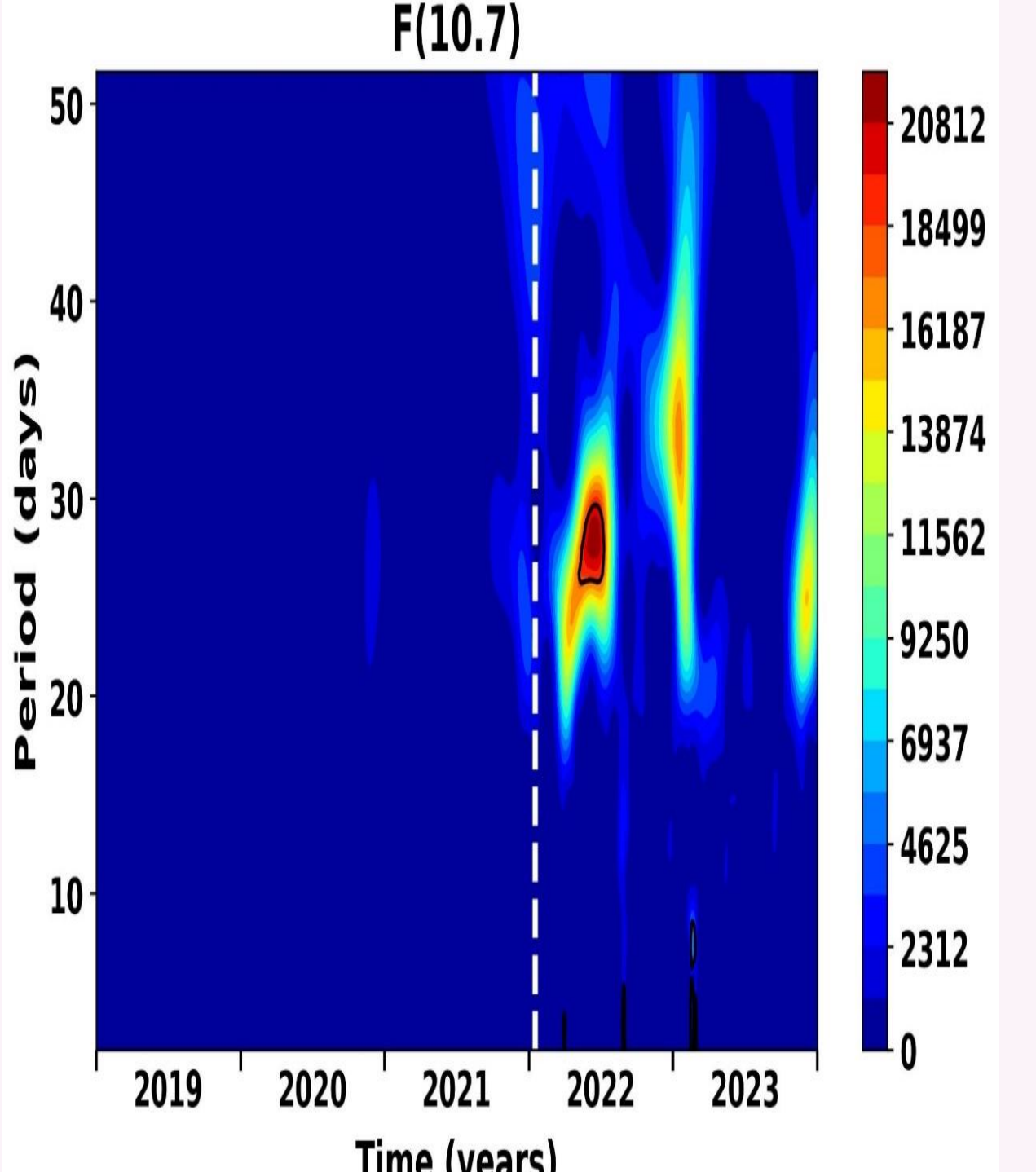


Fig. 8- Wavelet power spectrum of Solar F10.7 flux.

IMPACT OF ISO ON TIDES

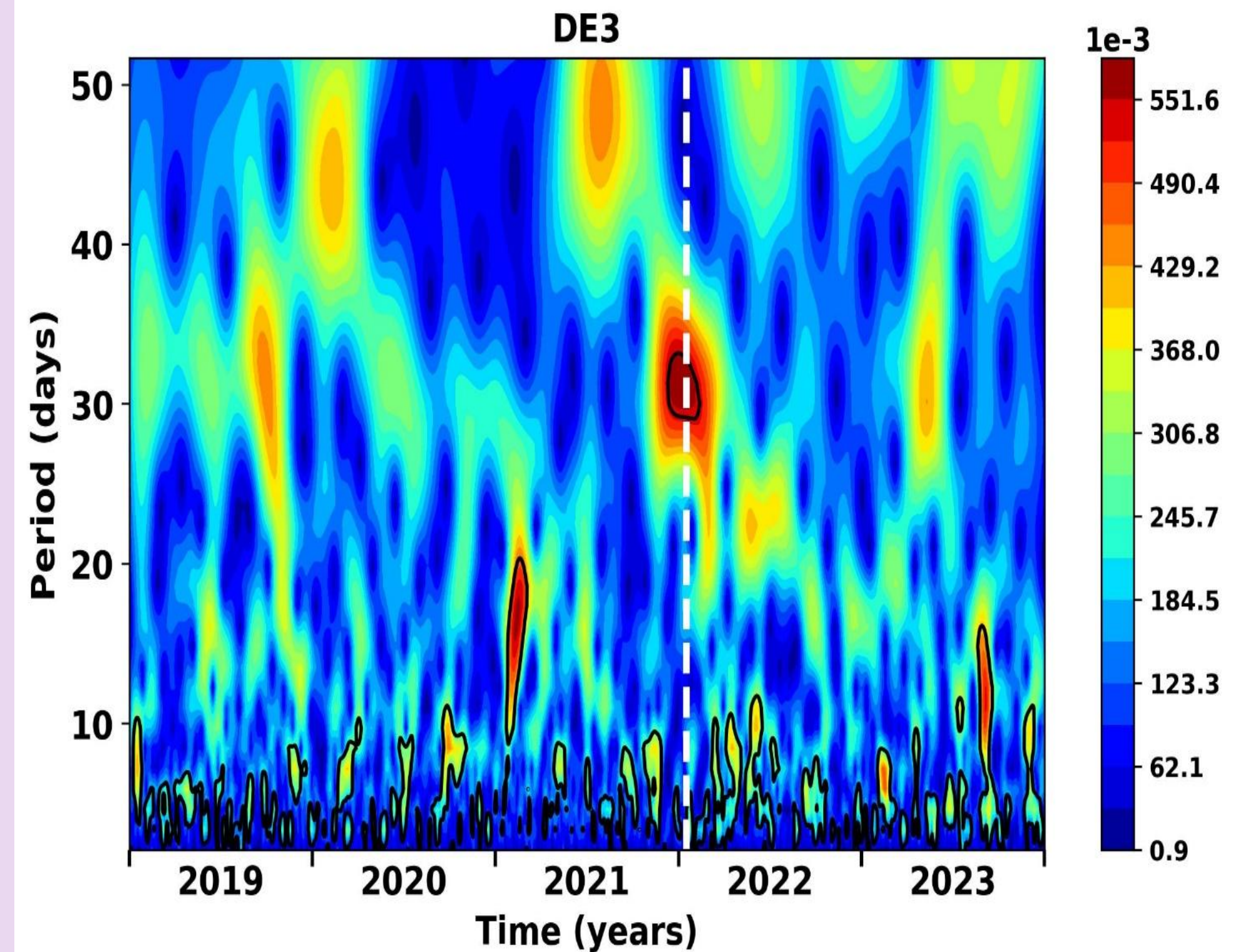


Fig. 5- Wavelet spectrum of DE3 (Diurnal eastward-propagating tide with zonal wavenumber 3) amplitudes at 20 km, showing a clear enhancement during the event period. the color bar indicates amplitude (m/s) in this case.

CONCLUSIONS

- A pronounced intraseasonal variability (ISO) signature was observed in OLR, RF, and SH following the HTHH volcanic eruption on 15 January 2022, with spectral power concentrated in the 20–40 day band.
- The ISO activity was found to be localized near the HTHH volcano, with no consistent feature at other latitudes.
- Solar variability had an insignificant influence on the observed ISO feature.
- Band-pass filtered results showed eastward phase propagation near the volcano
- Among the atmospheric tides, DE3 exhibited a discernible response within the ISO period band, indicating modulation of local convective activity and associated wave dynamics.
- The observed ISO signature suggests that the powerful HTHH eruption played an important role in driving the localized intraseasonal activity.
- The results provide new insight into the interaction between volcanic forcing, convection, atmospheric waves, and tidal variability.
- Overall, the study demonstrates localized ISO variability and associated tidal modulation following the HTHH eruption, contributing to the understanding of atmospheric responses to extreme geophysical forcing.

ACKNOWLEDGMENT

The present work is supported by the Department of Space (Government of India). Please find detailed discussions and references here.

