Three-dimensional Structure of Tropical Nonmigrating Tides and their Response to MJO Resolved from the Radio Occultation Data

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Abstract

By analyzing multiyear RO observations, the tropical nonmigrating tides in the free troposphere and lower stratosphere are investigated. Nonmigrating tides clearly demonstrate internal gravity wave characteristics, excited from two major continents, Africa and South America; and propagating westward and eastward from the source. Those dominant wavenumbers, such as DE3 and DW5, D0 and DW2, show clear seasonal variability and different propagating modes. Further investigation by compositing RO data based on MJO phases, indicates the MJO convection can influence the diurnal temperature amplitude modestly, constrained over the land, with nonsynchronous phases with MJOs.

Research Objectives

- Detection of three dimensional structure of nonmigrating tides from RO observations, including their latitudinal-vertical structure and seasonality.
- Investigation of the possible response of nonmigrating tides to the latent heat release associated with MJO convection.

Data

- RO temperature & refractivity data (downloaded from the CDAAC wetPrf) from different missions (listed below) during 2007-2015 are collected.

Missions	Orbit*	Inclination Angles (deg)	Orbit Altitude (km)	Data Ranges (yr.doy)
CHAMP	Polar, non-SSO*	87.2	350-450	2001.138-2008.279
C/NOFS	Low inclined, non-SSO	13	400-850	2010.060-2015.193
COSMIC	**6** Polar, non-SSO	72	~800	2006.112-
GRACE	Polar, non-SSO	89	475	2007.059-2016.091
MetOp-A	Polar, SSO	98.7	817	2007.274-2015.365
MetOp-B	Polar, SSO	98.7	817	2013.032-2015.365
SAC-C	Polar, SSO	98.2	705	2006.068-2011.215
TerraSAR-X	Polar, SSO	97.44	514	2008.041-2016.121

**SSO: Sun-Synchronous Orbit*

- ERA-Interim global reanalyses during the same period are used to calculate the daily means. In this study, ERA-Interim are presented as a gridded dataset at 1.5° spatial resolution, 6 hr temporal resolution, and 37 atmospheric levels from 1000 hPa to 1 hPa.

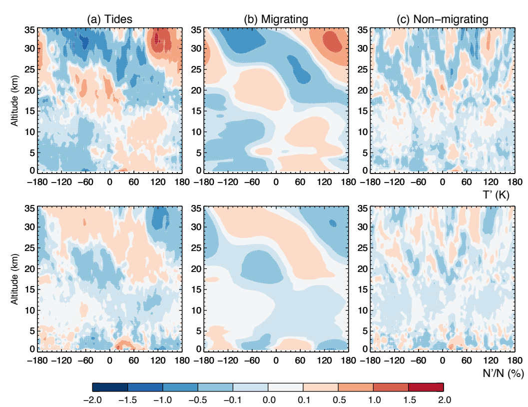

Fig. 1. Longitude-altitude distributions of (a) both migrating and nonmigrating tides, (b) migrating tides, and (c) nonmigrating tides at 1200 UTC averaged over 10°S-10°N, in DJF, derived from composite RO temperature (upper) and relative refractivity (lower) data.

Analysis Method

- Daily RO data were firstly prepared in grid bins of 1.5° in longitude, 1.5° in latitude and 0.5 km in altitude.
- For each grid point, the daily mean from ERA-Interim was subtracted from the original RO data to obtain the residuals.
- Multiyear daily residuals were further composited together based on the seasons or/and MJO phases.
- Diurnal variations (including both migrating and nonmigrating components) in UT for each grid (grid size could be different, 5°x5° herein) were extracted by applying the harmonic analysis. Results are shown in **Fig. 1a**.
- Migrating (**Fig. 1b**) and nonmigrating (**Fig. 1c**) components were further separated using *Sakazaki*'s method [2015]. Three-dimensional structures of nonmigrating tides can be demonstrated (**Fig. 2**).
- Space-time spectral analysis was also performed on the diurnal variations to decompose them into zonal wave numbers (as below) and their characteristics can be examined for each component (as shown in **Fig. 3**).

$$\sum_{n,s} A_{n,s}\cos(n\Omega t_{UT} + s\lambda - \Phi_{n,s}) = \sum_{n,s} A_{n,s}\cos(n\Omega t_{LT} + (s-n)\lambda - \Phi_{n,s}),$$

$\Omega=2\pi/24$ (h^{-1}); n=cycles/day; λ=longitude; s=zonal wave number

3D Structure of Nonmigrating Tides

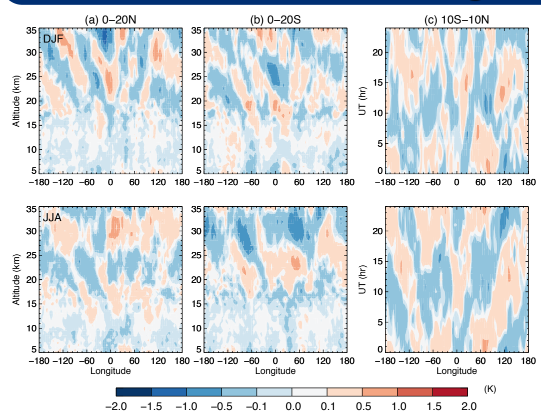

Fig. 2. Longitude-altitude distributions of nonmigrating tides averaged over (a) 0-20°N and (b) 0-20°S, at 1200 UTC for DJF (upper) and JJA (lower), along with (c) hovmöller plot averaged over 10°N-10°S at 30 km.

- Nonmigrating tides have similar amplitude (~2K in the stratosphere) as migrating one, though migrating tides are essentially dominant.
- Tidal structures of RO T' and N'/N are well negative correlated, except for the lower troposphere.
- A distinct feature of nonmigrating tides is the westward and eastward tilted phase along the western and eastern sides of two major continents, Africa and South America, respectively, with increasing altitude.
- Spectral analysis shows the dominant wave components in the stratosphere are DE3, DW5, D0, and DW2, with clearly seasonal and latitudinal variation, and different propagating patterns.
- The pair of DE3 and DW5 is due to the heating mainly from two major continents; the pair of D0 and DW2 is likely excited by the radiative heating from the Indian Ocean to the western Pacific (60°E-210°E).

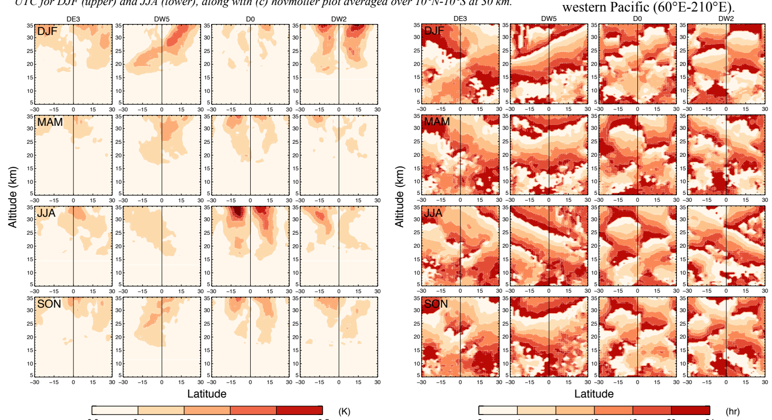

Fig. 3. Latitude-altitude distributions of DE3, DW5, D0, DW2 temperature amplitude (left) and phase (right) for DJF, MAM, JJA, SON (from top to bottom).

Impact of MJO on Tides

The influence of MJO convection on tropical thermodynamic field has been clearly demonstrated using RO data [Zeng et al., 2012]. We are questioning herein: besides the mean field, whether the MJO can modulate its diurnal cycle. In order to investigate the possible impact of MJO on tides from RO data, we composited the daily residuals based on the MJO phases defined by *Wheeler and Hendon* [2004], and then performed similar analysis to resolve the tidal signal at each grid point. The results indicate:

- Nonmigrating tides exhibits clear local maxima of the amplitude over the two major continents and the Maritime Continent (MC).
- There is certain dependence of the tidal amplitude over the MC on the MJO phase, different in summer and winter.
- No clear correlations of the tidal amplitude and location of its maximum over the MC with the strength and location of the MJO-induced convection.

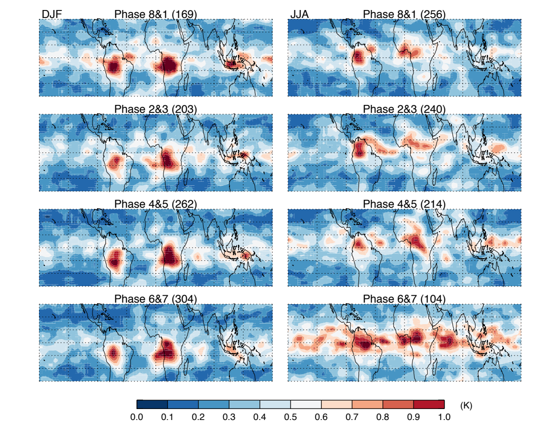

***Fig 4**. Horizontal distributions of diurnal temperature amplitude for different MJO phases (8&1, 2&3, 4&5, and 6&7) near tropopause (17 km) in DJF (left) and JJA (right). The number aside the MJO phases in each panel title gives the total number of calendar days.*

Conclusions

- The 3-dimensional structure of tropical nonmigrating tides in the stratosphere were resolved from RO observations. These nonmigrating tides excited by the longitudinal variation of tidal heating, which is mainly enhanced over two major continents. They propagate both westward and eastward, away from the sources. Seasonal variation of nonmigrating tides are also investigated. Significant D0 signals are seen during JJA, with opposite phases with respect to the equator; while the DW5 and DE2 components stand out in DJF.
- MJO tends to modify the diurnal temperature amplitude over the MC region near the tropopause, but with minor influence and shifted phases. Some uncertainty might come from temporally and spatially sparse observations and coarse spatial resolution.

References

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