Three-dimensional Structures of Tropical Nonmigrating Tides Resolved from COSMIC2 GNSS RO Data

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Mathematical expression of tides

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

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

- n = 1: diurnal; n = 2: semidiurnal; …
- If s = n, migrating tides; s ≠ n, non-migrating tides
- Zonal phase speed: $C_{ph} = \frac{d\lambda}{dt} = -\frac{n\Omega}{s}$
- Letter/number code identification:

  DW1: migrating diurnal tide;

  DE3: eastward propagating diurnal tide of zonal wavenumber 3;

  SW2: migrating semidiurnal tide

Dataset

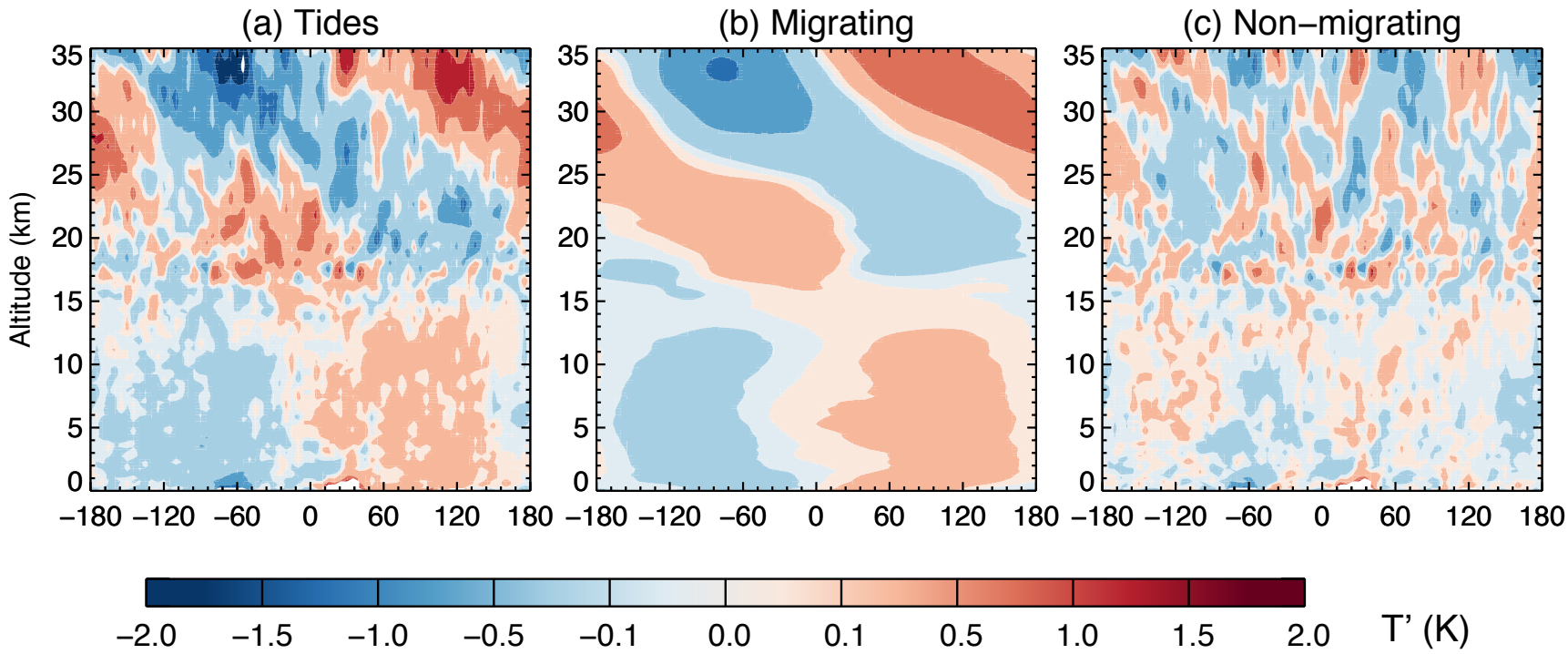
- wetPf2 data from Oct. 2019 – Sep. 2020

Data Analysis Method

1. Daily COSMIC2 RO data were firstly prepared in grid bins of 1° in longitude, 1° in latitude;
2. For each grid point, the daily mean ERA5 was subtracted from the original RO obs to obtain the residuals.
3. Multi-daily residuals were further composited together based on the months.
4. Diurnal variations (mig+nonmig) in UT for each grid (grid size could be different, 5°x1.5° herein) were extracted by applying the harmonic analysis.

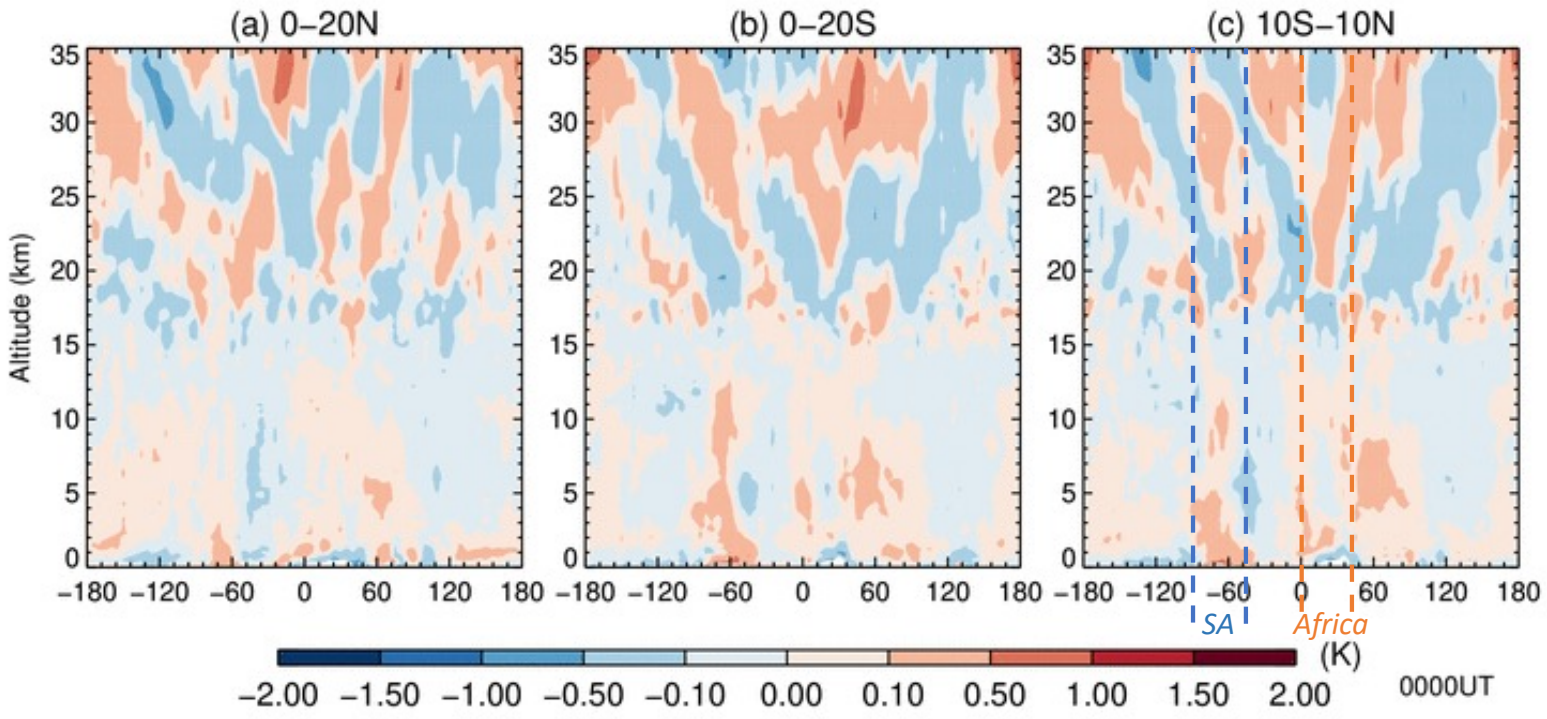
Tides = Migrating + Non-migrating

January, 1200 UTC, 10N-10S



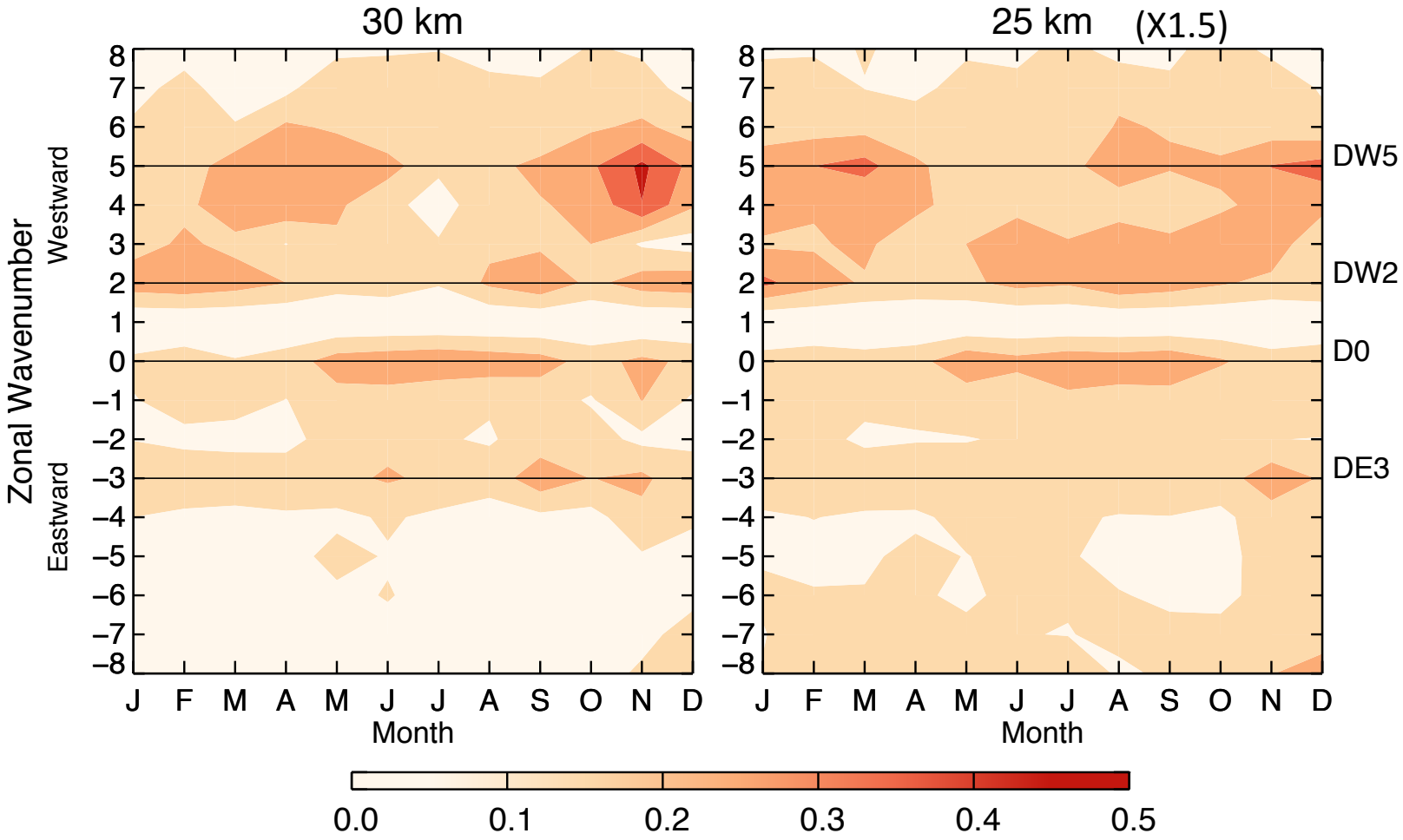
Nonmigrating tides have comparable amplitude (~1K in the stratosphere) as migrating ones, though migrating tides are essentially dominant.

Longitude vs. altitude distributions of the yearly mean nonmigrating tides averaged over (a) 0-20N, (b) 0-20S and (c)10S-10N.



- A distinctive 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.
- Vertical wavelength is ~ 20 km, zonal wavelength is ~ 8000 km

Month vs. zonal wave number distributions of the nonmigrating diurnal tides averaged over 10S-10N at heights of 30 km and 25 km.

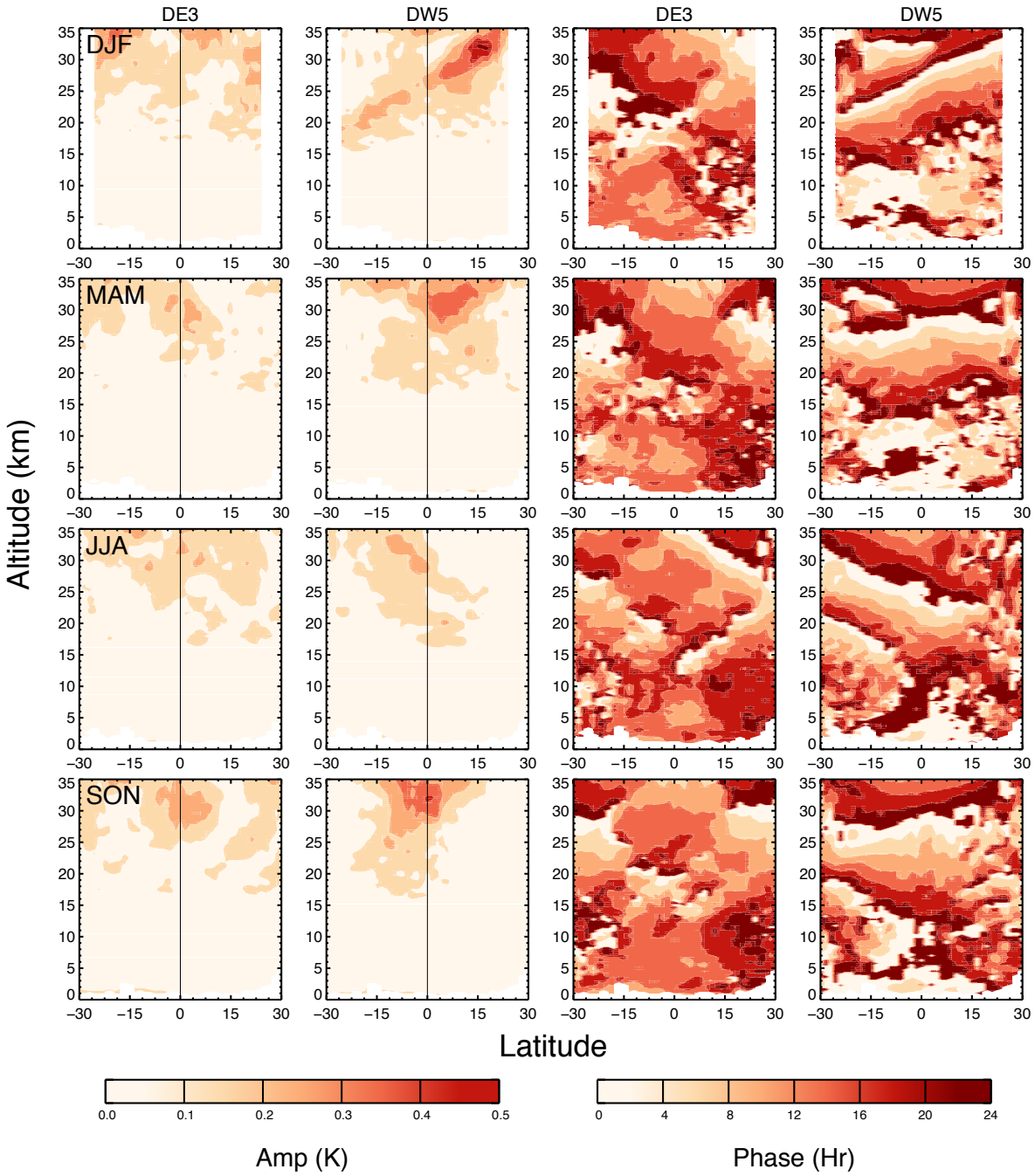


The dominant nonmigrating diurnal waves in the stratosphere are DE3, DW5, D0, and DW2.

n = 1
|s-n| = 4

=> s = -3 (DE3) / s = 5 (DW5)

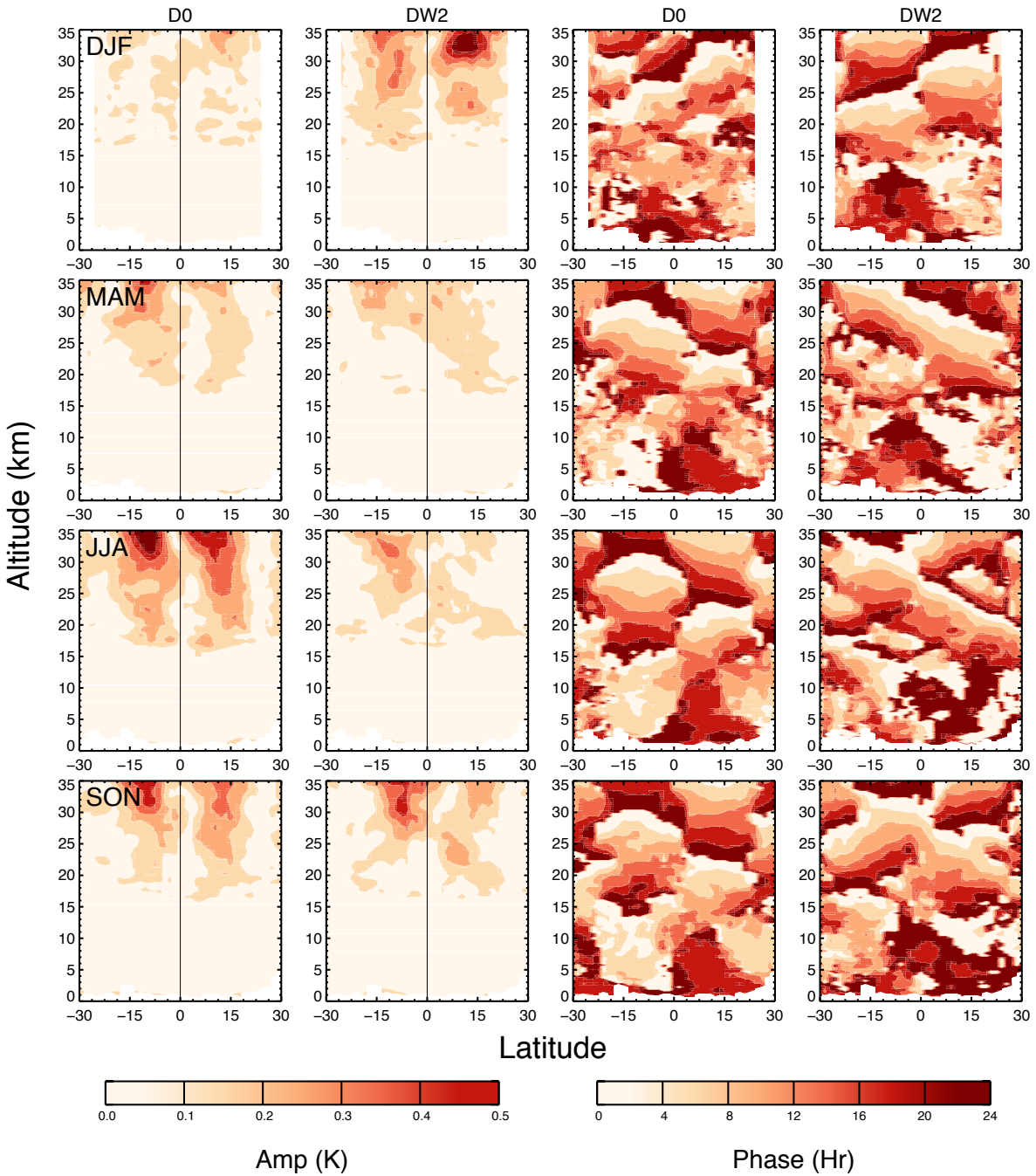
- DE3 and DW5 is due to the heating mainly from two major continents, Africa and South America.
- Latitude structure evolves with altitude.
- Tidal amplitudes show strong seasonal variations and become asymmetric along the equator.



n = 1
|s-n| = 1

=> s = 0 (D0) / s = 2 (DW2)

- D0 and DW2 is likely excited by the radiative heating from the Indian Ocean to the western Pacific (60°E-210°E).
- Hemispheric asymmetry
- Seasonal dependence
- No clear cross-hemisphere propagation



Summary

- Coherent nonmigrating tidal waves can be extracted from one-year C2RO data.
- Tropical nonmigrating tides excited by diabatic heating over two major continents, Africa and South America.
- Primary nonmigrating tides in the stratosphere are DE3, DW5, D0 and DW2, which show different seasonal variations and latitudinal evolution.