Longitudinal structure in electron density at mid-latitudes: upward-propagating tidal effects

Hui Wang(h.wang@whu.edu.cn)，Kedeng Zhang
Dept. of Space Physics, School of Electronic Information, Wuhan University, China

Abstract

- This work studies the upward-propagating migrating and non-migrating tidal effects from the lower atmosphere on the longitudinal variation of electron density (ΔNe) in both the E and F regions at midlatitudes during the 2002 March equinox. A total of 12 runs are conducted using the Thermosphere Ionosphere Electrodynamic General Circulation model for theoretical investigation. The ΔNe at altitudes above 200 km is affected by upward-propagating tides, with maximum values attained around 300 km. Migrating tides result in reduced longitudinal differences in the Ne over North America and in the Southern Hemisphere, while non-migrating tides induce a wave-4 pattern in both hemispheres. The non-migrating effect is weaker than the migrating effect after penetrating into the F region. The neutral composition (i.e., ratio of atom oxygen to molecular nitrogen) is dominant in regulating the ΔNe in both the migrating (accounting for approximately 64%) and non-migrating (about 60%) tidal penetration processes. The ΔNe caused by the tidal meridional wind (accounting for approximately 70%) is stronger than the tidal zonal wind (about 30%) under both the migrating and non-migrating tidal conditions, except in the Southern Hemisphere under migrating tidal input. This work contributes to our understanding of the mechanisms for the longitudinal modulation of the ΔNe at midlatitudes.

Motivation

- Whether or not the lower atmosphere is closely coupled to the mid-latitudinal ionosphere is still not well understood.
- What is the role of the lower atmosphere tides in the E and F regions?
- How do lower atmosphere tides affect the low and upper ionosphere?

Model

TIEGCM:

- Size: 2.5 º× 2.5 º
- hemispheric power=39 GW
- cross polar cap potential=60kV
- F107=200 w/m²/Hz

case:

- without tides (migrating and non-migrating)
- with migrating (non-migrating) tides
- without tides under zero neutral

CHAMP observations

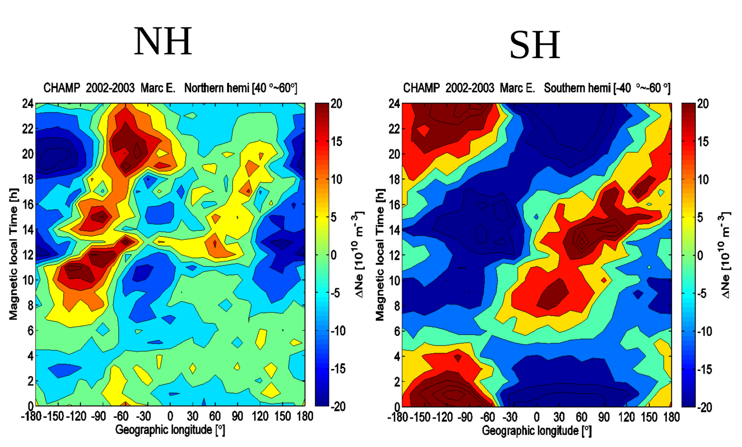

Figure 1. Longitudinal and magnetic local time variations of the residual electron density(ΔNe) observed by CHAMP

- A wave-2 structure: one peak and trough over NA (180°W−0°), another peak and trough over the Europe-Asia sector(0−180°E) in the Northern Hemisphere;
- A wave-1 structure (one peak and trough) in the Southern Hemisphere;

TIEGCM simulations

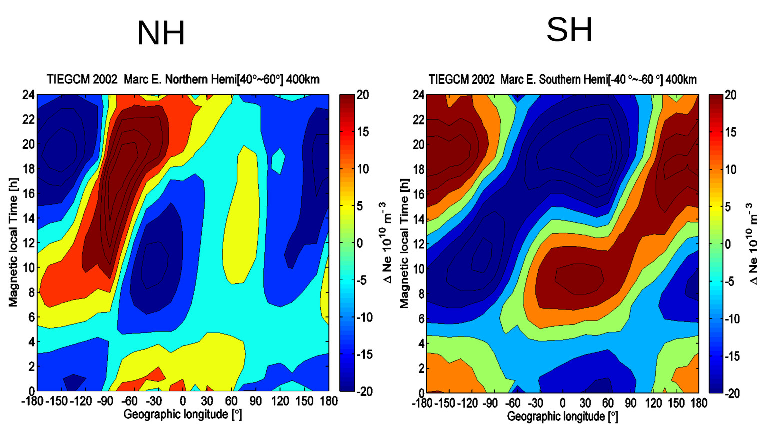

Figure 2. Longitudinal and magnetic local time variations of the residual electron density(ΔNe) simulated by TIEGCM

- The wave-2 and wave-1 longitudinal patterns in the Northern and Southern Hemispheres are well reproduced;
- The hemispheric and local time asymmetries are also well reproduced by the TIEGCM model.

Tidal effects

Migrating tidal effects

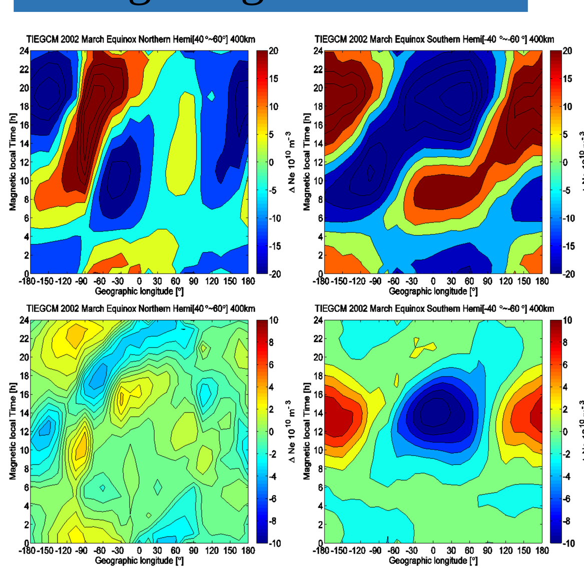

Figure 3. (Top) the longitudinal variation of electron density with migrating tides (base run). (Bottom) Residual ΔNe driven by migrating tides

- A wave-1 structure due to migrating tidal effects existed in both hemispheres.

Non-migrating tidal effects

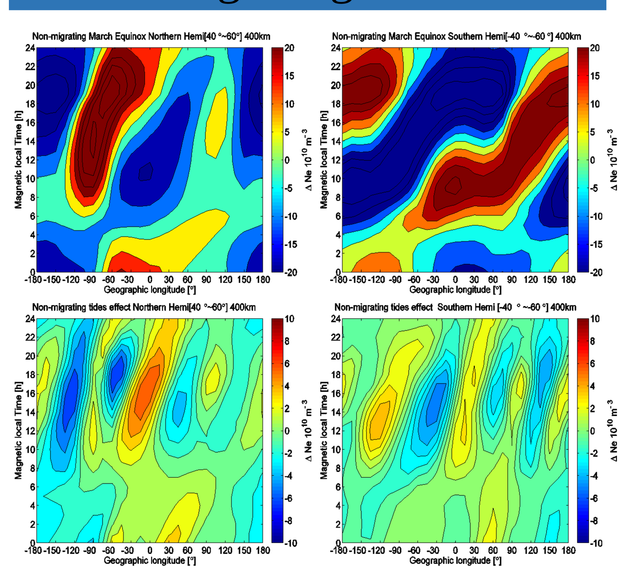

Figure 4. the same as figure 3, but for non-migrating tidal.

- A wave-4 structure due to non-migrating tidal effects exists in both hemispheres.

Migrating tidal effects

Tidal wind effects

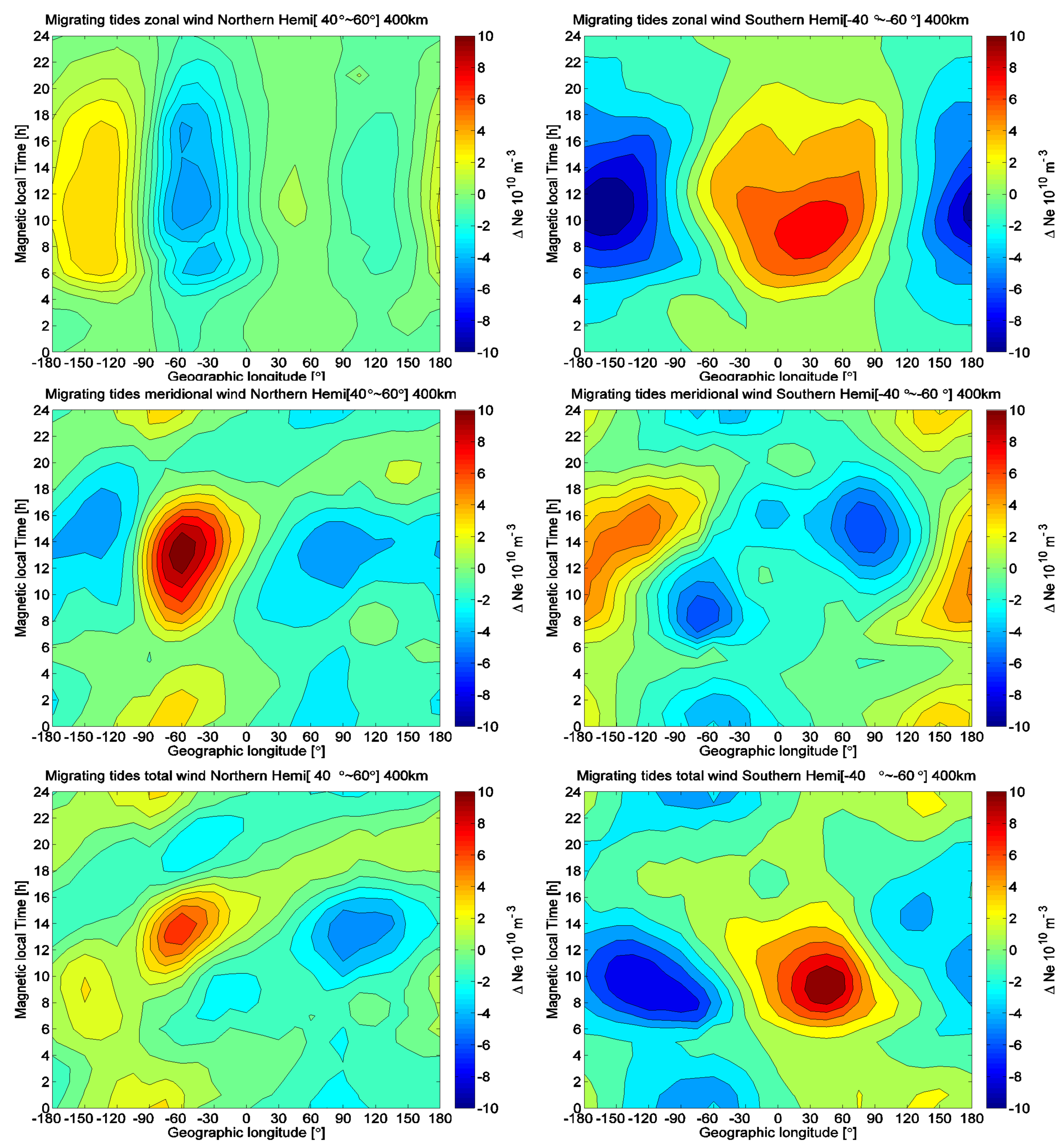

Figure 5. The tidal wind effects in ΔNe. (top: zonal wind; middle: meridional wind; bottom: total wind)

- The meridional wind played stronger roles than the zonal wind in the Northern Hemisphere, while weaker in the Southern Hemisphere.
- The total wind effects resembled more to the meridional wind in the northern hemisphere and zonal wind in southern hemisphere.

Non-wind tidal effects

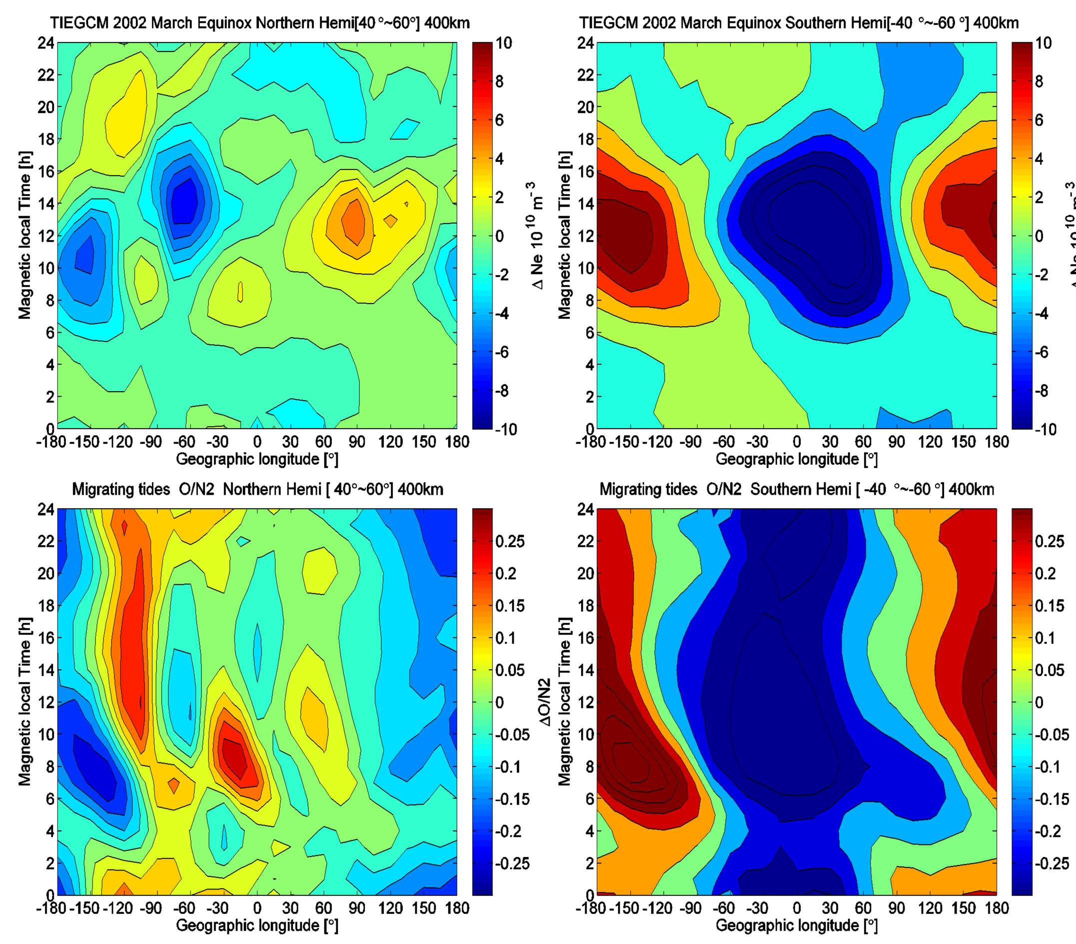

Figure 6. (top) tidal non-wind effects; (bottom) longitudinal variation of neutral composition.

- The non-neutral wind effects were nearly out of phase, as well as larger than the neutral wind effect, especially in the Southern Hemisphere.
- The neutral composition variation played important roles in ΔNe.

Non-migrating tidal effects

Tidal wind effects

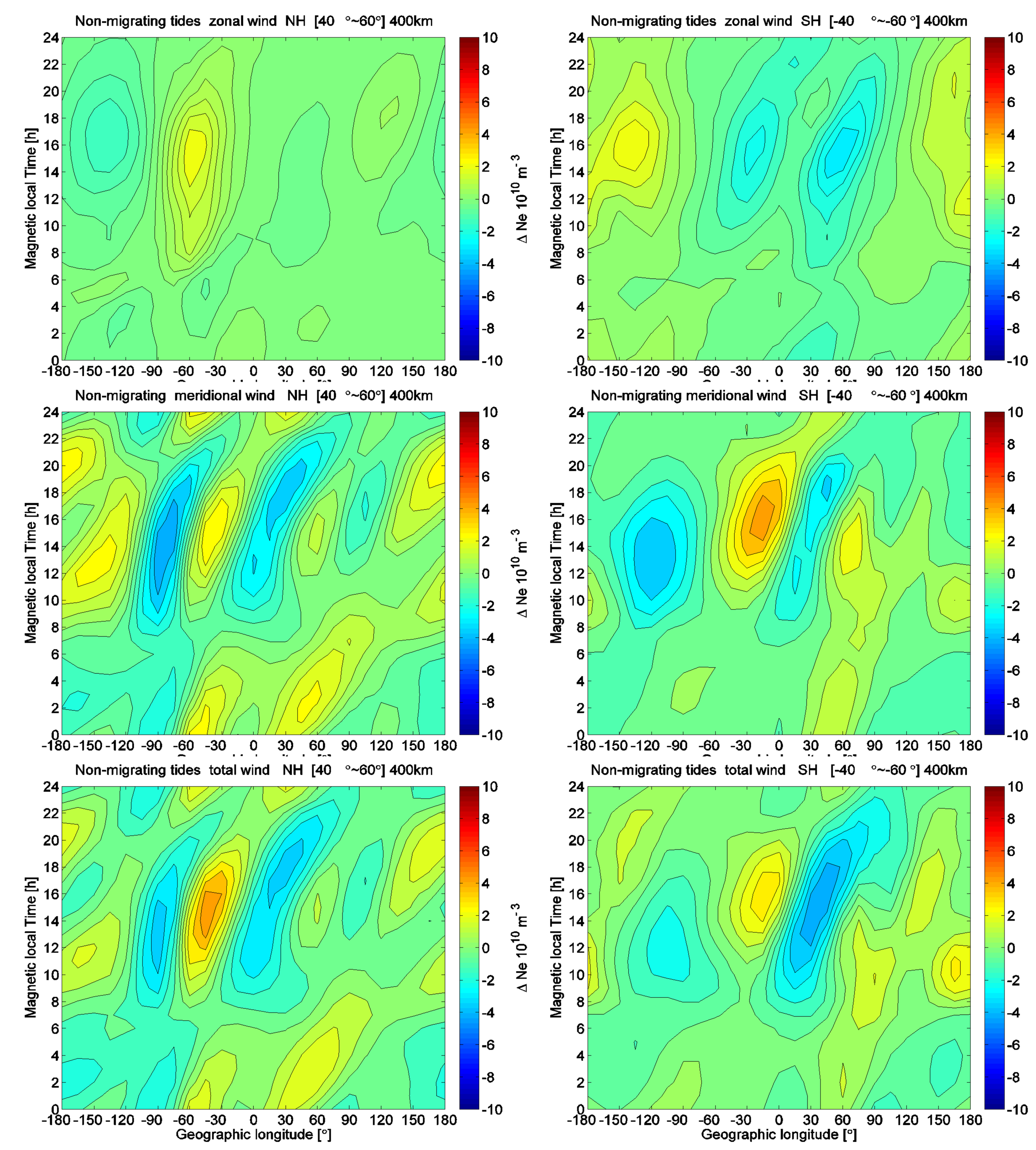

Figure 7. the same as figure 5, but for non-migrating tidal.

- There existed a wave-1 structure of ΔNe induced by the zonal wind with phase reversed in the Northern and Southern Hemispheres, and a wave-4 and wave-2 structure of ΔNe due to meridional wind which was quite similar to the total wind effects.

Tidal non-wind effects

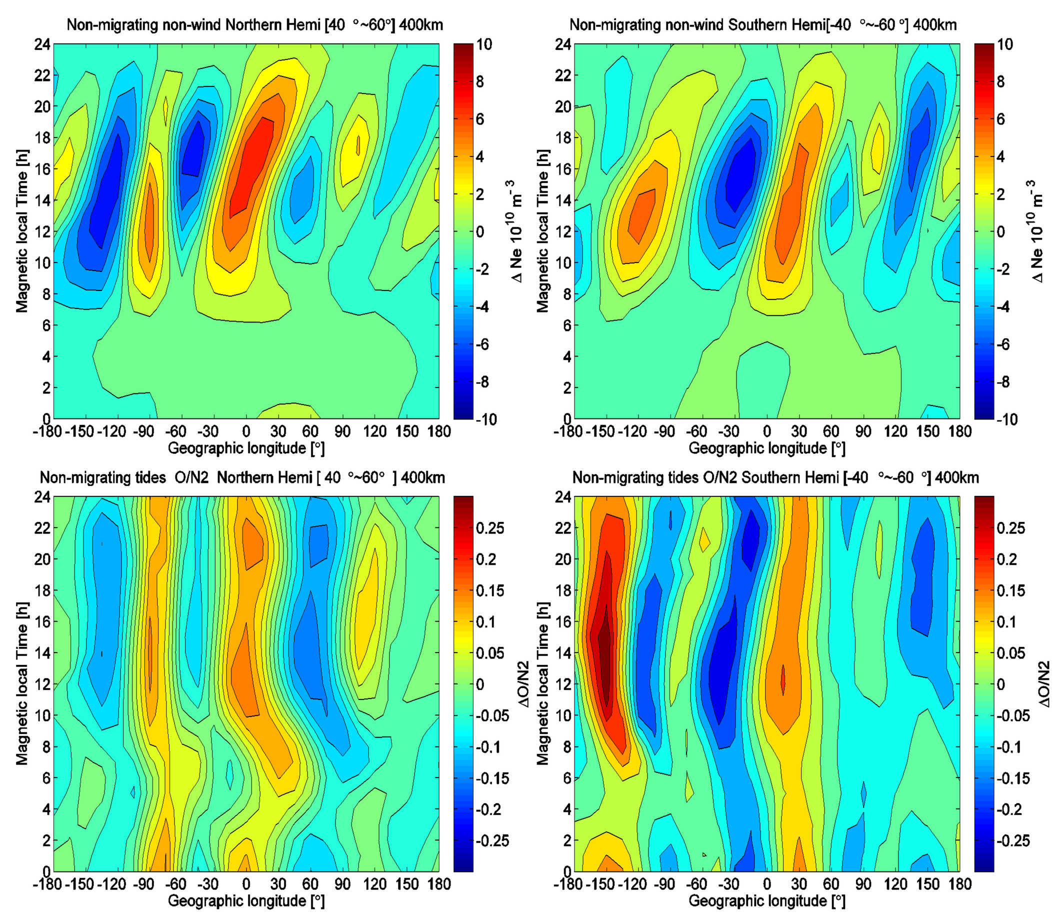

Figure 8. the same as figure 7, but for non-migrating tidal.

- Non-wind effects are nearly 180° out of phase with those of neutral winds
- The wave-4 structure of ΔNe was mainly driven by the non-neutral wind processes, with the non-wind processes being ratio between O and N2.

Summary

- The ΔNe at altitudes above 200 km are affected by upward-propagating tides.
- Migrating tides result in reduced longitudinal differences in the ΔNe over North America and in the Southern Hemisphere. Non-migrating tides result in a wave-4 structure of the ΔNe in both hemispheres, but with weaker amplitudes as compared to migrating tides.
- The neutral composition changes play dominant roles in regulating the ΔNe under both migrating and non-migrating tidal conditions.
- The ΔNe driven by tidal meridional wind is stronger than tidal zonal wind, except for the southern hemisphere under migrating tidal input.

Reference: Wang H, Zhang K. Longitudinal structure in electron density at mid-latitudes: upward-propagating tidal effects[J]. Earth, Planets and Space, 2017, 69(1): 11.