Climatology of Dayside E-region Neutral Wind Shears from ICON MIGHTI Observations

Minjing LI[1], Yue Deng[1], Brian Harding[2], Scott England[3],
University or Texas at Arlington[1], Virginia Tech, United States[2],
University of California, Berkeley, United States[3]

Abstracts

With the neutral wind data from Ionospheric Connection Explorer (ICON) Michelson Interferometer for Global High-resolution Thermospheric Imaging (MIGHTI), we give a climatological and morphological study of large wind shears. It shows that the latitudinal, longitudinal and local time dependence is highly dependent on season as well as altitudes and hints global tidal effects. In general, strongest negative shears mostly happen at ~107 km and 113 km while positive shears at ~110 km. In summer, obvious meridional dependence shows below 107 km. Strongest shears rarely happen above 120 km. The longitudinal dependence shows wave-like structures at all altitudes but is stronger in 15°S to 15°N latitude range.

Motivation & Introduction

Large wind shears effects

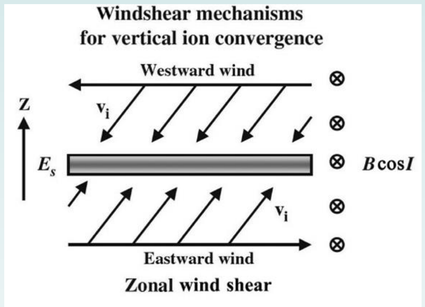


Fig.1 Zonal Wind Shear Mechanisms for vertical ion convergences [Jiuhou Lei 2021]

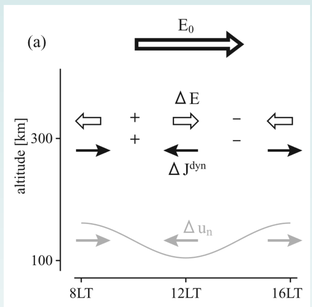
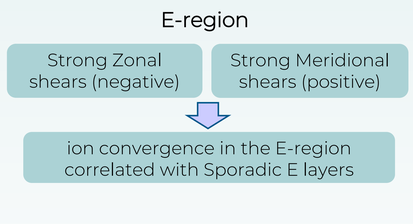
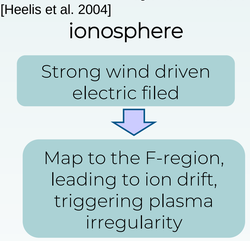


Fig.2 DE3 zonal wind in the E-region result in 4-longitudinal structure of F-region zonal electric field [Heelis et al. 2004]





The focus of this study is to give the climatology of E-region neutral wind shears, which are specifically about Local Times, latitudinal, longitudinal as well as seasonal dependences of large wind shears.

Methods

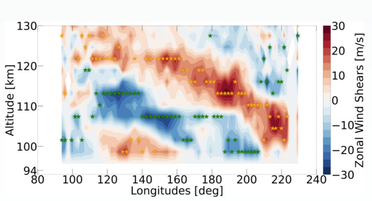


Fig.3 Zonal wind shears in the first orbit on 03-20/2020, calculated from MIGHTI Winds (L2 version4) products, methods adopted from Fig. 2 in [England et al. 2022]

— Vertical wind gradients (shears)

- green emission (557.7 nm)
- [98, 130] km Altitudes
- [0700, 1700] hr LTs
- [15⁰S, 42⁰ N] latitudes
- maximum amplitudes of altitudes labeled (Fig. 3)

— main tidal effects

- ICON_L4-1_HME_v01
- Tidal structures obtained from ICON-MIGHTI observations are fitted to Hough Mode Extension (HME).

Result 1: Altitudinal dependences

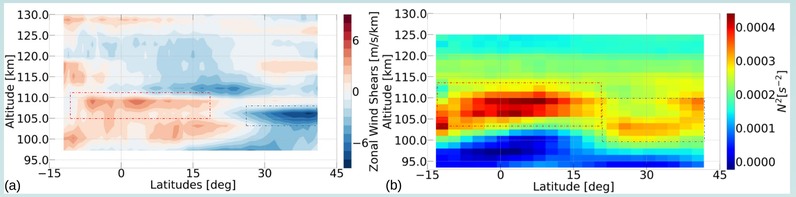


Fig.4 Mean Zonal Wind Shears (left panel a) and Brunt-Vaisala frequency (right panel b) in Summer

— Below 113 km

- positive shears dominate at 15S to 15N latitudes
- negative shears dominate at 15N to 40N latitudes
- maximum magnitude altitudes and latitudes (dashed red/blue box in Fig.4a) correspond well with maximum N^2 (Fig.4b).
- [Based on the linear theory, larger vertical shears can stay long in the region of large N^2 without breaking.]

Maximum altitudes at midlatitudes in winter is near the 113 km (not shown here), which is higher than Maximum altitudes at midlatitudes in Summer, a little above the altitude of mesopause in winter. As mentioned in [Yue 2010 et al.], N^2 reaches maximum right above the mesopause, and the mesopause at mid-latitudes is higher in winter than that in Summer, which is consistent with this result.

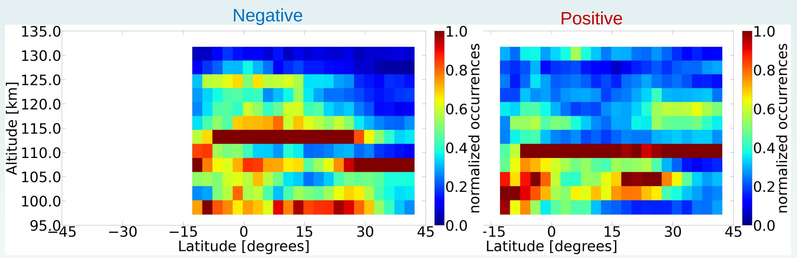


Fig.5 Normalized altitudinal occurrences in each latitude bin for maximum negative shears (left panel) and positive shears (right panel) in Summer

- Strongest negative shears mostly happen at ~107 km from 25N to 40N latitudes and 113 km from 10S to 20N latitudes.
- Strongest positive shears mostly happen at ~110 km from -15S to 40N latitudes.

Compare Fig.4 and Fig.5, we can see in some latitudinal region such as from 20N to 40N at 110 km do have largest occurrence rate, but don't have large enough magnitudes and potentially be averaged out by the opposite sign of shears thus not obvious in Fig.4a which represents average magnitudes.

Result 2: Longitudinal and Local time dependences

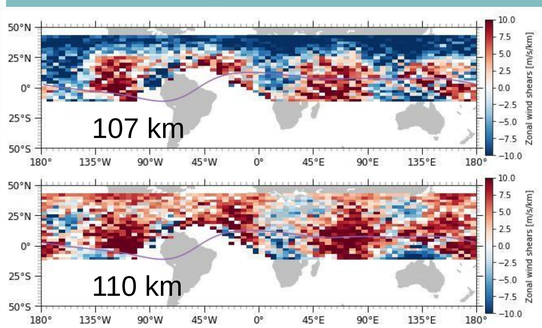


Fig.6 Latitude vs. Longitude dependence of mean zonal wind shears in Summer

- At ~107 km, Negative shears dominate over ~25N to 40N latitudes. Strong positive shears dominate over ~10S to 20N latitudes with strong longitudinal structures. (similar for altitudes below 107 km)
- Positive and negative shears are dominated at 110 and 113 km respectively with weak meridional dependences
- Above 120 km, shear magnitudes are weak as well meridional dependences.

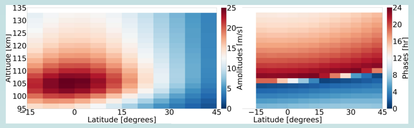


Fig.7 HME DE3 components
Amplitudes (left panel), Phases (right panel)

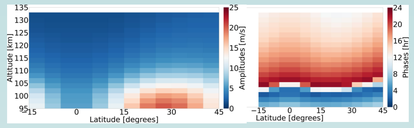


Fig.8 HME DW1 components.

Fig.7 and Fig.8 shows the two of three largest HME extensions in summer. From Fig. 7, DE3 has large amplitudes at altitudes ~100-113km and have large vertical wave numbers from 106 to 112 km, which probably contribute to obvious wave structure of shears from 15S to 15N latitudes, and this structure can go up to the highest altitudes in the study domain (as DE3 can transport vertically up to F-region).
Fig. 8 shows DW1 have large amplitudes from 15N to 40N latitudes and large vertical wavenumbers 105 to 109km. This potentially contributes to large negative shear at and below 107 km from 25N to 40N latitudes.

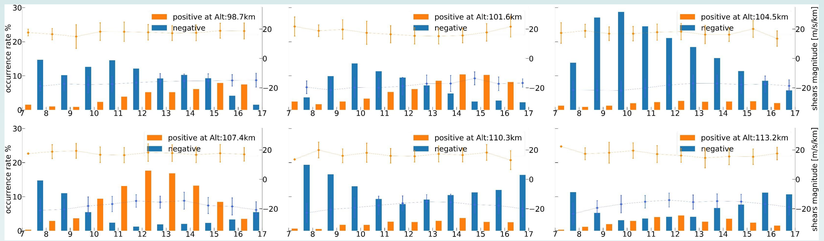


Fig.8 Maximum occurrence rates **in summer** vary with LTs (x-axis) and altitudes (labeling in each panel) from 20N to 40N llatitudes. Blue and orange bars represent negative and positive shears respectively. Scattered dots denote mean shear magnitudes.

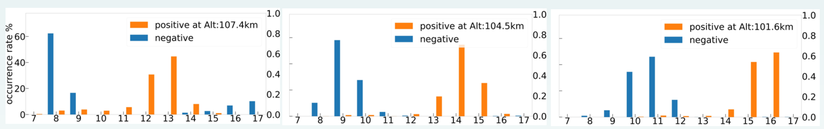


Fig.9 Same as Fig.8 but for SW2 components

Local time dependences are strongly dependent on altitudes as well as season (summer situation shown in Figure.8). Occurrences become minor above 115 km, which implies LT dependence is closely related with upward transporting waves with relatively small vertical wavelength. At ~101, 105 and 107 km altitudes, the LTs dependence of strong shears are similar to that of SW2 (see Fig.8 and Fig.9), but at other altitudes it's more like a superposition of global tides as well as in-situ wave effects.

Conclusions

- Large zone wind vertical shears show a strong altitudinal dependence. Largest negative shears happen mostly at ~107 km and ~113 km altitudes, while positive happen at ~110 km.
- Strong meridional dependence happens below 107 km, with strong longitudinal wave structure mainly over 10S to 20N latitudes. Strong positive and negative shears dominate respectively at 110 and 113 km. Above 107 km, the meridional dependence becomes weak, while wave-like zonal structures can be seen at all altitudes (~ 98 - 130 km).
- The LT dependence of strong shears strongly depends on altitudes as well as season.