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

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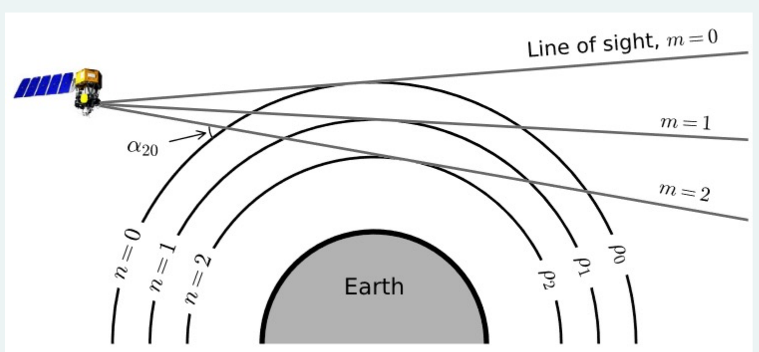
Abstracts

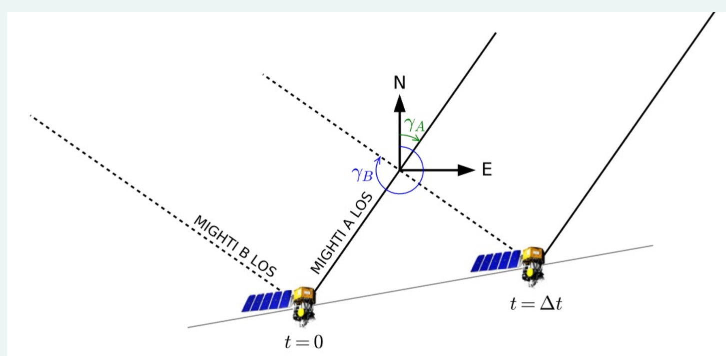
In this study, the climatology of dayside E-region neutral wind shears has been examined using two-years' data (2020-2021). Specifically, we focus on the large wind shears with a magnitude larger than 20 m/s/km. The results show that the probability of occurrence of large shears is strongly dependent on the altitude, with the vertical profile varying with shear direction, latitude, season, and local time. In general, below 110 km altitude, large negative shears of the eastward wind are most likely to happen during summer at 9-11 LT in 25°N-40°N latitudes, while large positive shears tend to occur in 10°S-10°N latitudes. The discrepancies in positive and negative large shear distributions indicate different potential global tidal influences. Large-shear occurrence probabilities above 110 km are generally small, except in latitudes above 10°N during the winter for positive shears.

Background

MIGHTI instruments



Observation geometry for a MIGHTI interferogram [Harding et al. 2017]



Observation geometry for the MIGHTI cardinal wind retrieval. [Harding et al. 2017]

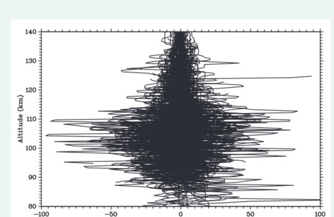
- Limb & LOS obs. of green & red line transition of oxygen. Daytime altitude profile: 90-300 km (~3 km resolution)
- MIGHTI A&B: ~90° offset meas. at same location determine zonal & meridional components. Cadence: 30-60 s

Unique, continuous daytime data for winds & shears' vertical distribution studies

Previous results

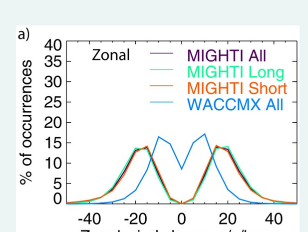
rocket & radar

- Shears frequently > 40m/s/km, large shears often near the Richardson instability threshold, vertical scale of few km or less

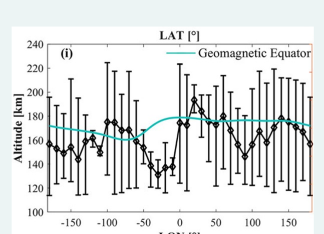

Superposition of rocket shear profiles [Larsen et al. 2002]

MIGHTI

- Small and large-scale maximum shears exhibit similar distribution patterns.
- Ion drag influences suggested by abrupt changes in sectors of mag.-geo. Equator deviation



Distribution of the max. shear magnitudes [England et al. 2022]



Mean reversal altitude of meridional wind [Huang et al. 2023]

Data & Selection of Strong Shears

- **Dataset selection (v05)**
  - 2020-2021 except for 26 Apr to 14 Aug 2021 period
  - ~91-132 km Altitudes, 0900-1600 hr LTs, 10^0S-40^0 N latitudes
  - Removal vertical profiles if error from zero-wind phase correction > 10 m/s between two adjacent altitude points . Selected data have error < ~10 m/s in winds and ~5 m/s/km in shears.

- **Focus on shears > 20 m/s/km**
  - shears >20m/s/km, ~5% of total (shear calc.: at midpoint altitude, $\frac{U_{i+1}-U_i}{H_{i+1}-H_i}$)

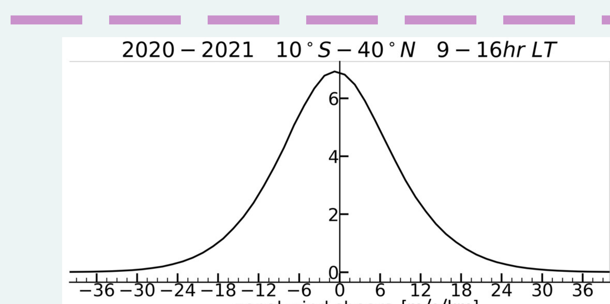


Fig 1. The probability distribution of zonal wind shears during 2020-2021

  - 20 m/s/km, much lower than critical values by Ri = 0.25
  - Underestimation from vertical res. ~ 3km and horizontal & vertical averaging in limb obs.

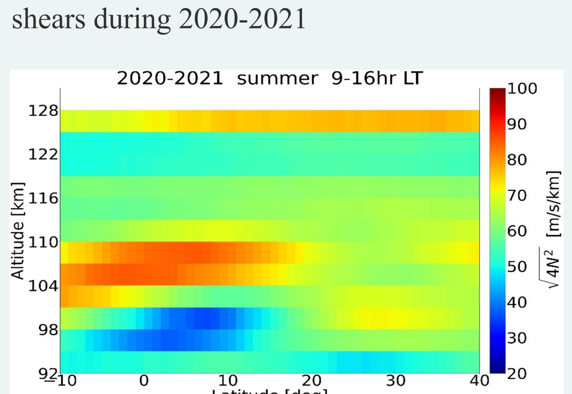


Fig 2. Calculated shear magnitudes from R_i = 0.25

Results

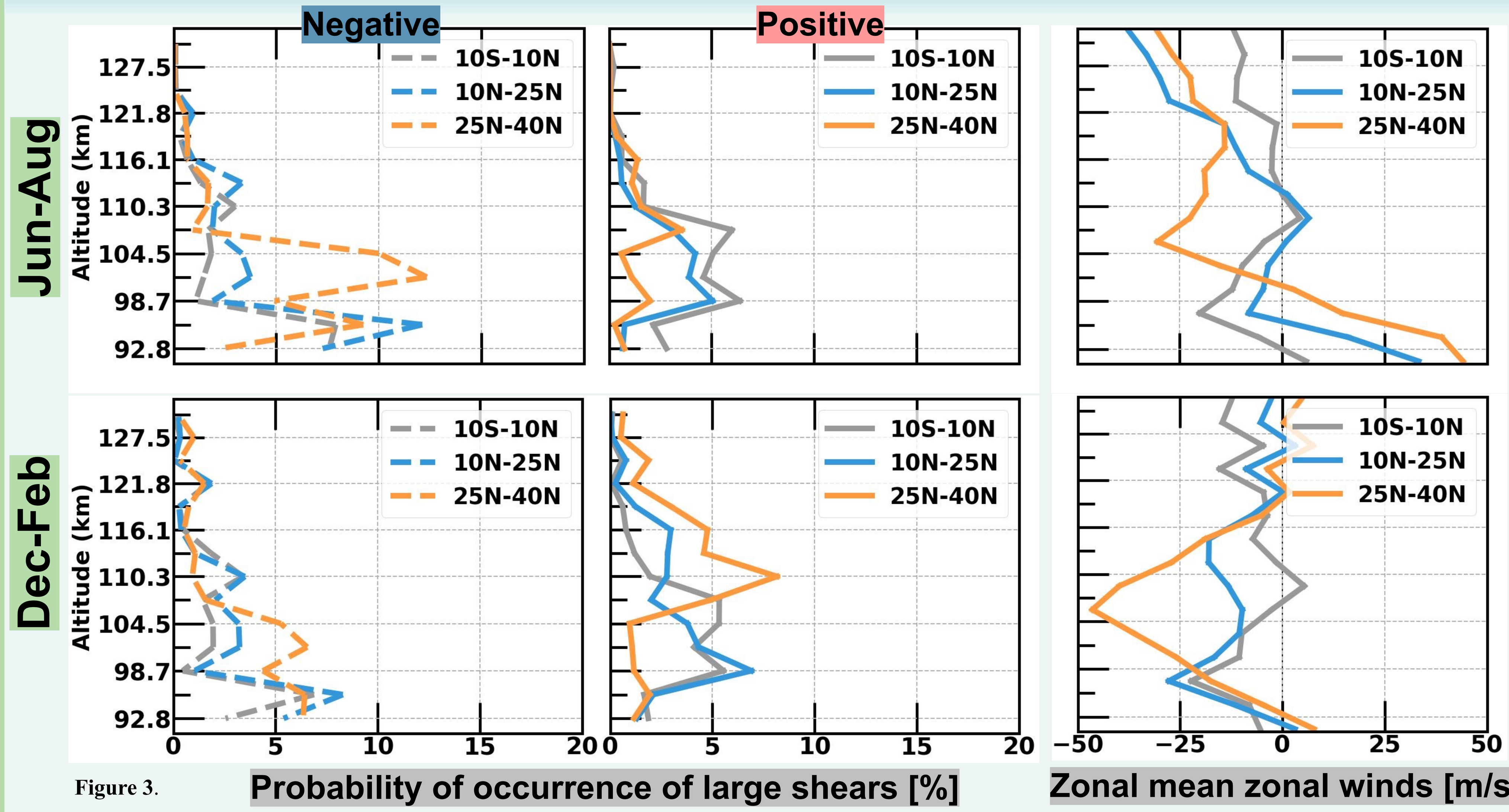
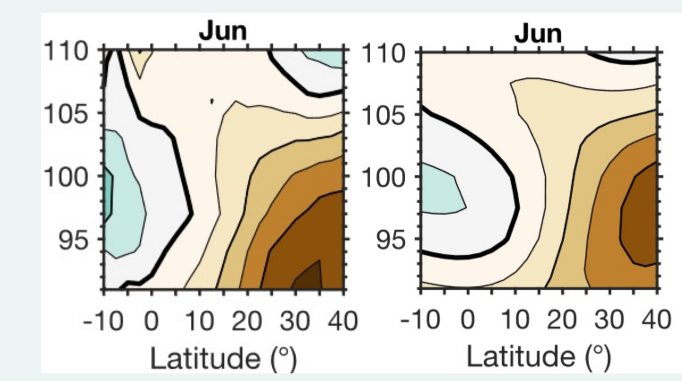


Figure 3.

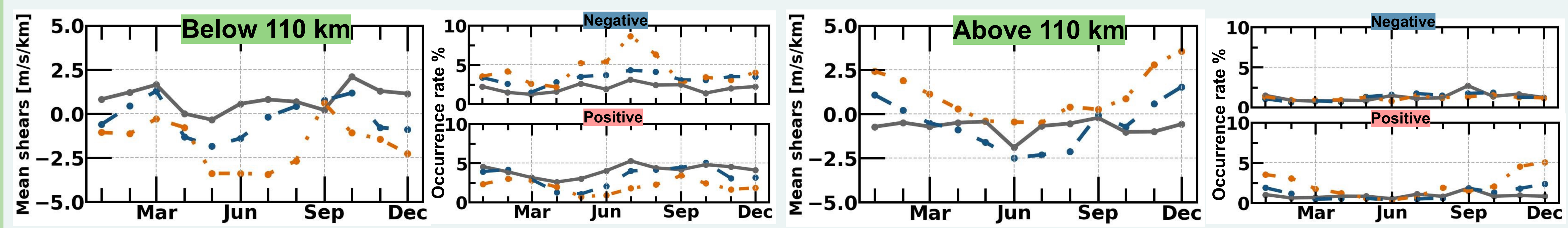
➢ Altitudinal dependences

- Associated with altitudinal wind variations.
  - $25^0N - 40^0N$: trend switch from westward to eastward at 106 km, within 91-120 km altitudes.
  - $10^0S - 10^0N$: westward to eastward at ~97 km, within 91-109 km.
- The vertical trend consistent across seasons, speed varies.



Zonal mean zonal winds in June using MIGHTI (left) and HWM14 model (right) in 91- 110 altitudes [Yamazaki et al. 2023]

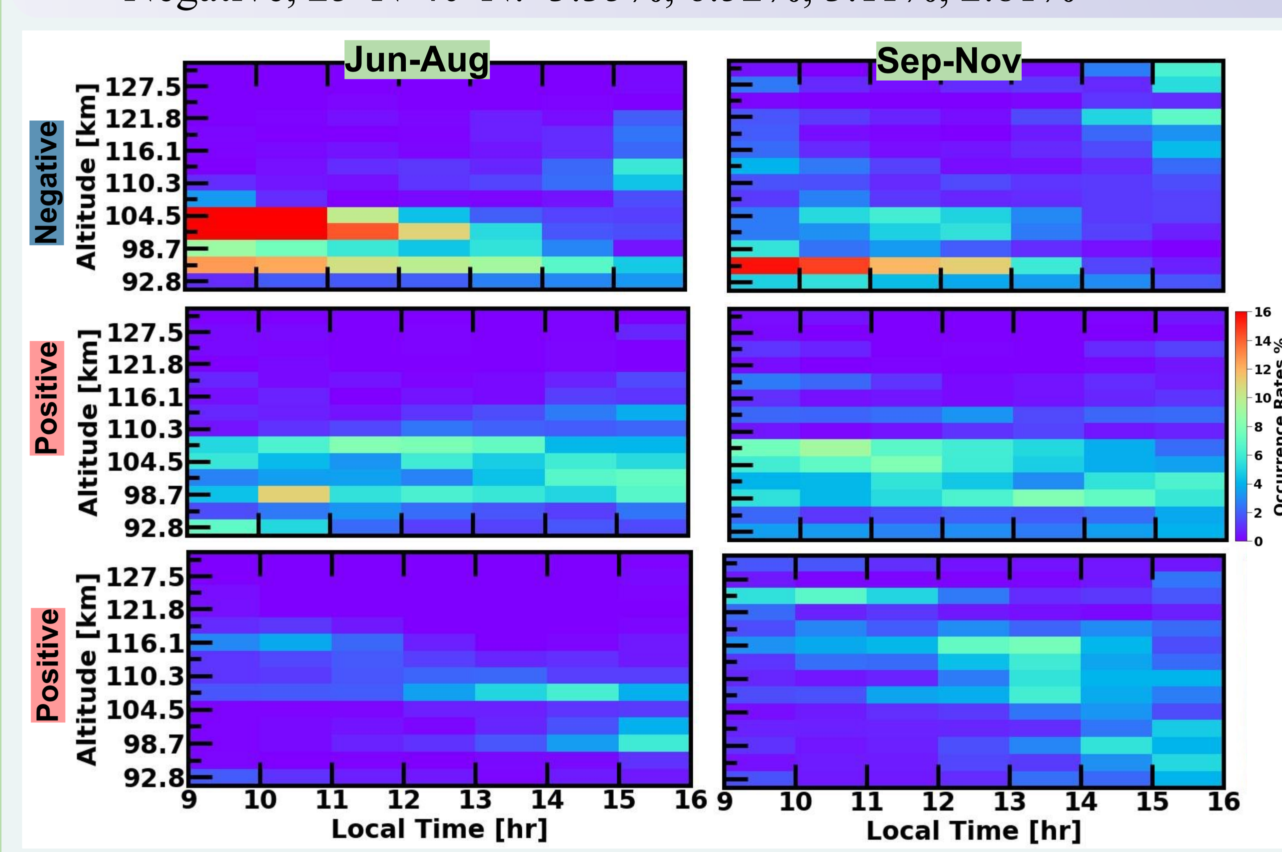
- westward jest near the equator & eastward jet in the mid-latitude possibly associated with wave dissipation.



- Below 110 km (Prob. in Mar-May, Jun-Aug, Sep-Oct, Dec-Feb): Positive, 10°S-10°N : 2.9%, 4.64%, 4.51%, 2.64%, Negative, 25°N-40°N: 3.35%, 6.52%, 3.11%, 2.81%
- Above 110 km
  Prob. mostly < 1%, barring in 25°N-40°N for positive shears during fall & winter (2.79% & 2.45%).

➢ Seasonal dependences

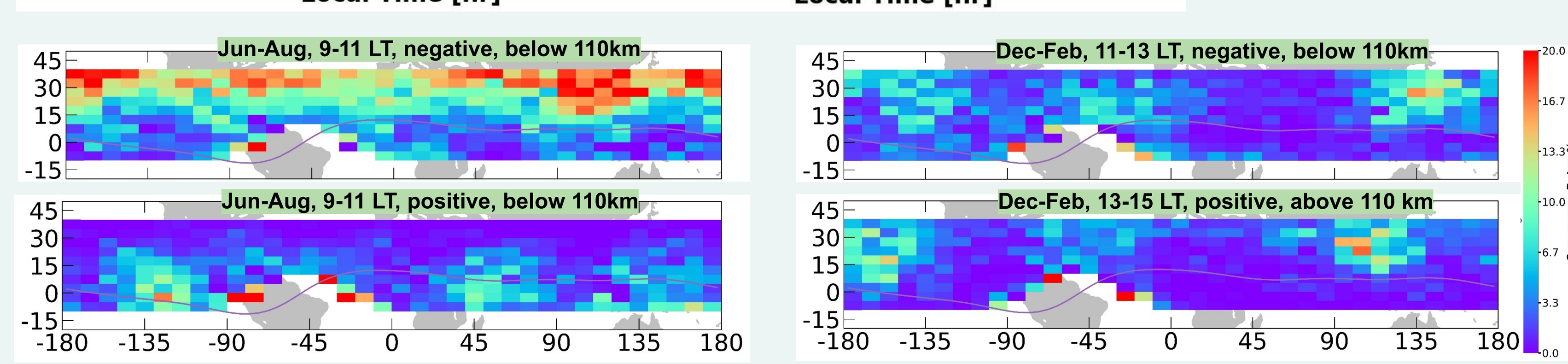
Below 110 km:
negative: 25°-40° Lat. (stronger in the summer Hemi.);
positive: 10°S-10°;
opposite above 110 km.



➢ Local-time dependences

- **Negative,** 25^0N- 40^0N, below 110 km: Prob. in summer account for 15.2%, 7.8%, and 3.9% of total data in 9-11, 11-13, and 13-15 LT ranges, respectively
- **Positive,** 10^0S- 10^0N, below 110 km: Prob. in summer comprise 5%, 4.9%, 4.5%
- **Positive,** 25^0N- 40^0N, downward phase progression rates, approx. between 1.5 km/hr(DW1) and 3.6 km/hr (SW2)

Latitude have larger influence on the LT-altitude distribution pattern than seasons; Large negative shears show stronger LT dependence than positive ones.



➢ Latitude-longitude dependences

- 9-11 LT
  Negative: summer above 20°N, higher at 90°E-130°E & 150°E-140°W; mirrors 105&108 km alt. pattern.
  Positive: longitudinal structure (WN3/4) below 15°N; 105&108 km pattern; eastward inclination at 108 km with Lon./LT. slightly > 3.75°/hour of DE3
- 11-13 LT & 13-15 LT in winter, pattern at higher altitudes tends to follow that at lower altitudes in opposite direction, suggesting an association with wave phenomena

Conclusions

- ❑ Large shears are most likely to occur below 110 km.
  - negative: summer, 25°N-40°N latitudes, 9-11 LT
  - positive: summer & fall, 10°S-15°N latitudes, consistent longitudinal structures across 9-11 LT
- ❑ Shear occurrences drop significantly above 110 km, except for enhancements in 25°N-40°N during fall and winter for positive shears
- ❑ Large shear behaviors are possibly associated with global tides