Statistical Study on Plasma Velocities in Bottom-side Ionosphere Over Low Latitude Hainan Station: Digisonde Measurement

Guojun Wang, Jiankui Shi, Maosheng He, Xiao Wang, Zheng Wang, Zhengwei Cheng, Sheping shang, Quanhan Li

National Space Science Center, Chinese Academy of Sciences

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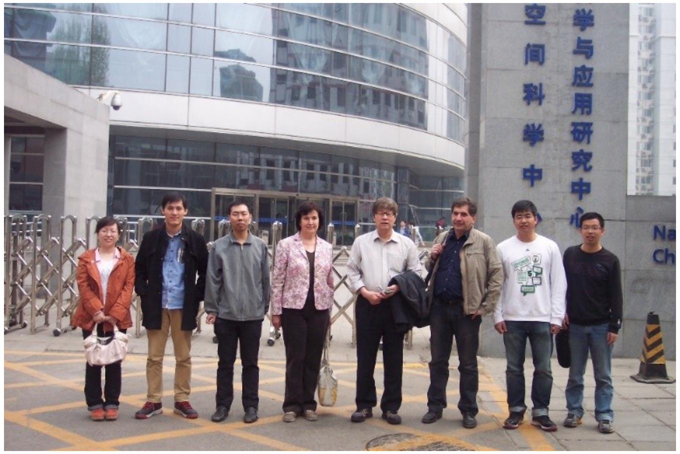
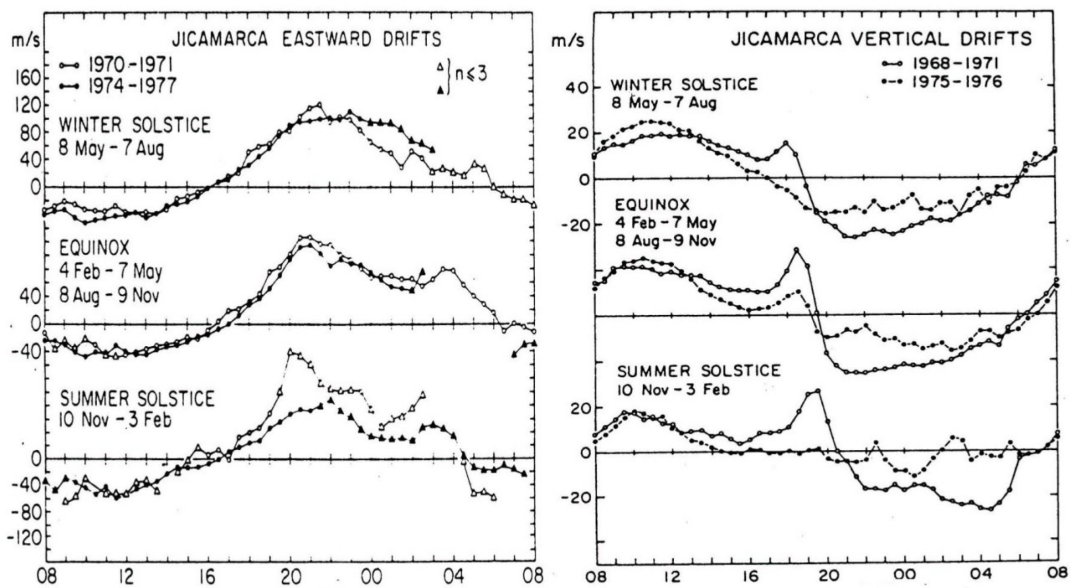
1. Introduction

Chinese-Russian Joint Research on Ionosphere

- Since 2000, NSSC and ISTP established cooperation on the Ionospheric research
- Many joint papers and a Book published
- Apply for joint project on ionospheric research from NSFC and Russian side
- Exchange Digisonde observation data
- Exchange visit scholar nearly each year
- … observation



- The ionospheric plasma drifts in F region are very important for the ionospheric dynamics.
- The drifts are usually controlled by electric field and neutral winds.
- Many studies have been done with Radar and satellite observation.
- For example, Fejer et al. (1991) showed the Jicamarca Eastward Drifts (left) and Vertical (right) Drifts derived from ISR in different seasons.

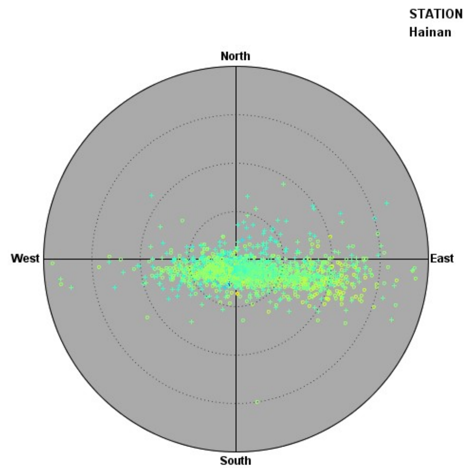


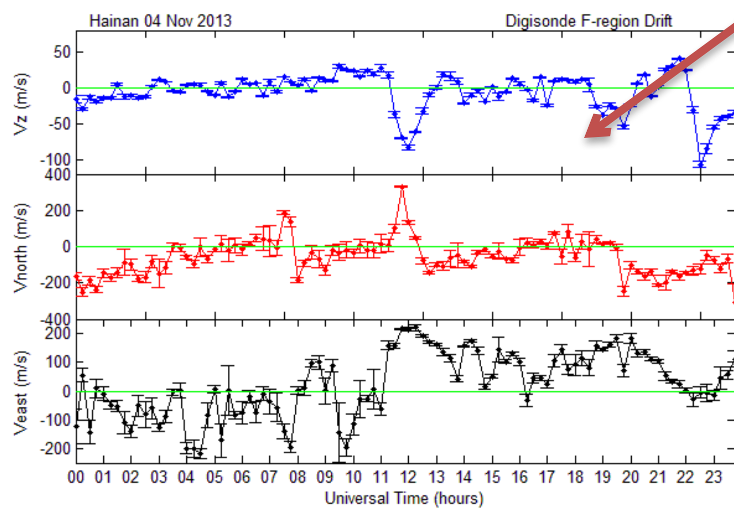
However, there is no corresponding study for east Asian sector.

◆Since 2003, at Hainan station, DPS4 has measured the plasma drifts from Sky map [Scali and Reinisch, 1995].

3D plasma velocities

Sky map





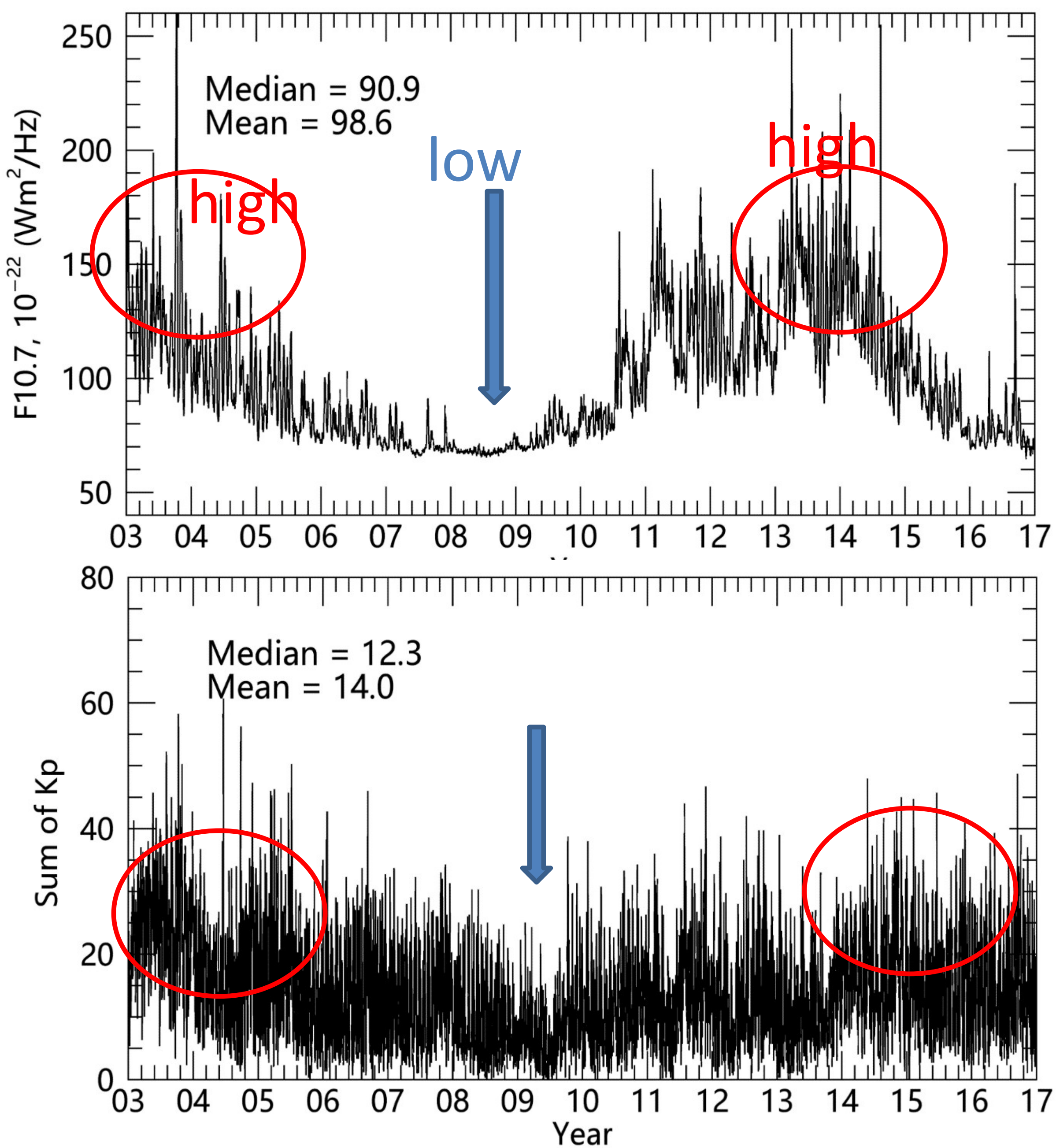
◆Here,we perform a statistical study on the bottom-side F region plasma velocities within two levels of F10.7 and two levels of Kp.

2. Observation Data

- Instrument: DPS-4
- Location : Hainan (Fuke) station (19.5°N, 109.1°E, MagL. 9.5°N), China
- Period: 2003.1 -2016.12
- Resolution: 15 min

- Data and Selection method: plasma drifts with 30% measured errors are chosen.

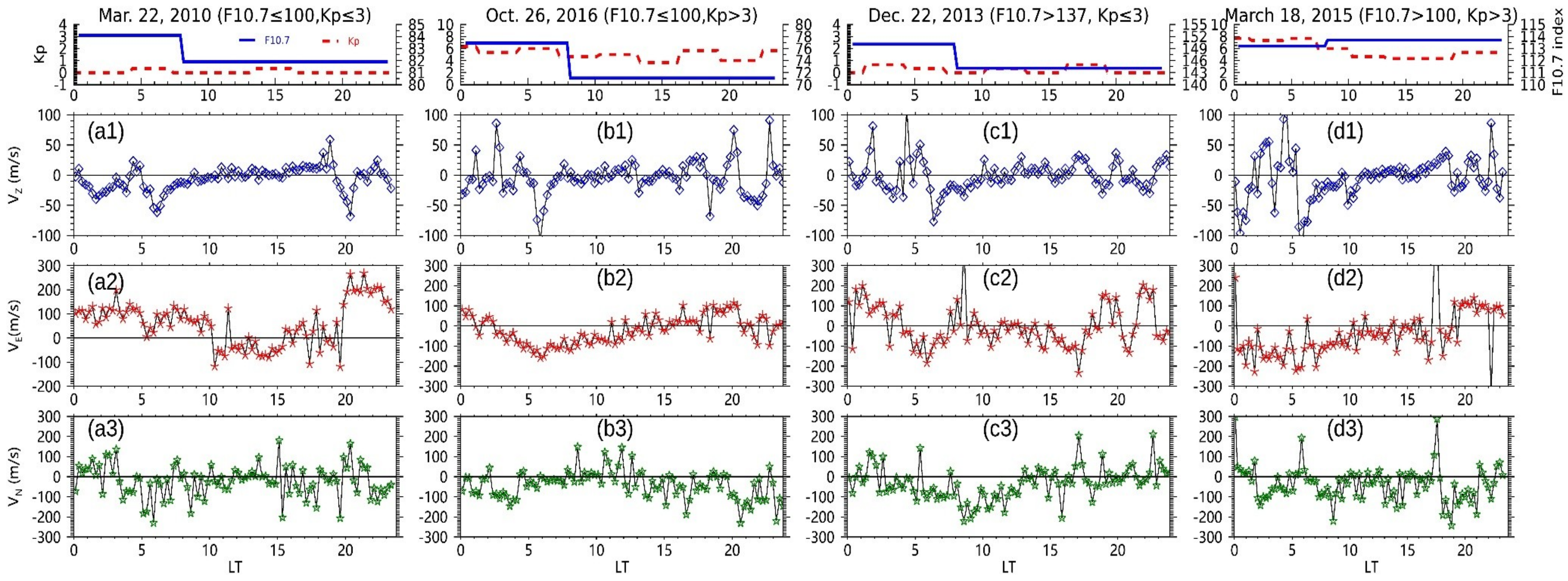
10.7 cm Solar Radio Flux and Sum of Kp during 2003 -2016



We divided our data into four divisions according to F10.7 ≤ 100 sfu, F10.7 >100 sfu, Kp ≤ 3, and Kp >3.

3. Analysis Results

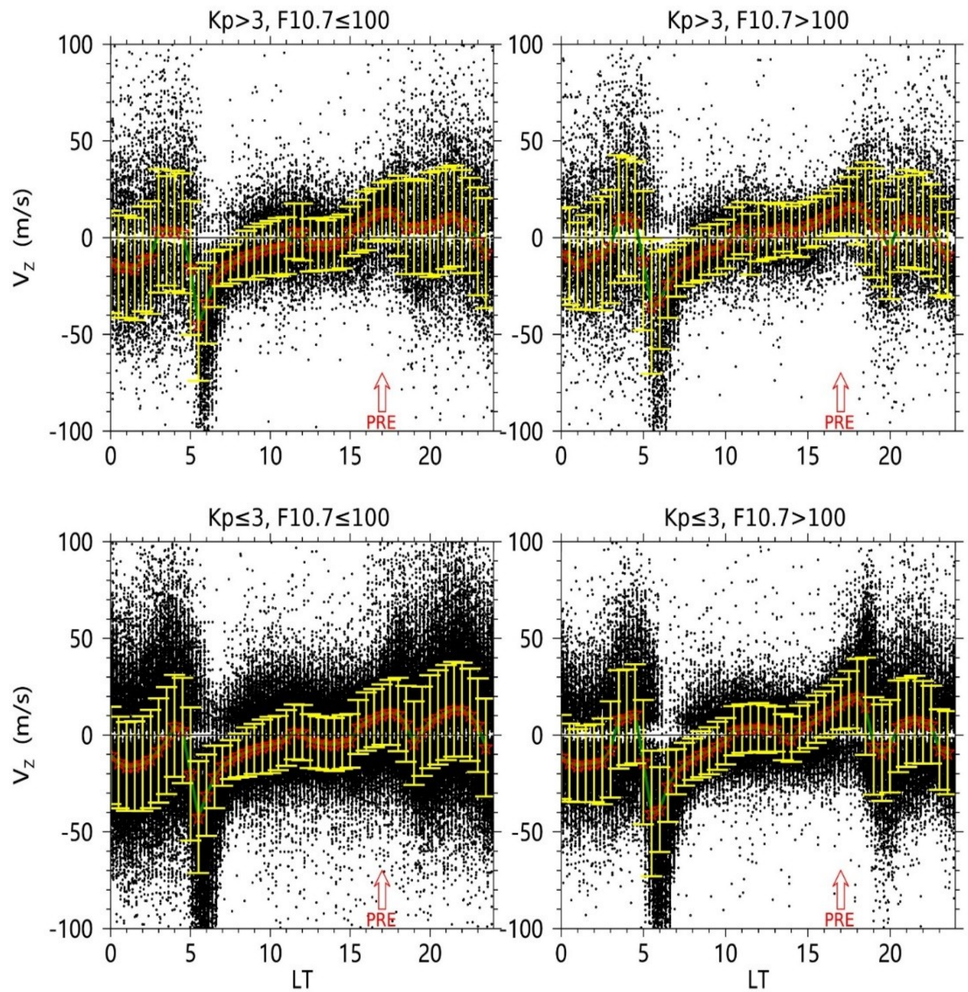
Typical diurnal variation of ionospheric drift velocities observed with Digisonde

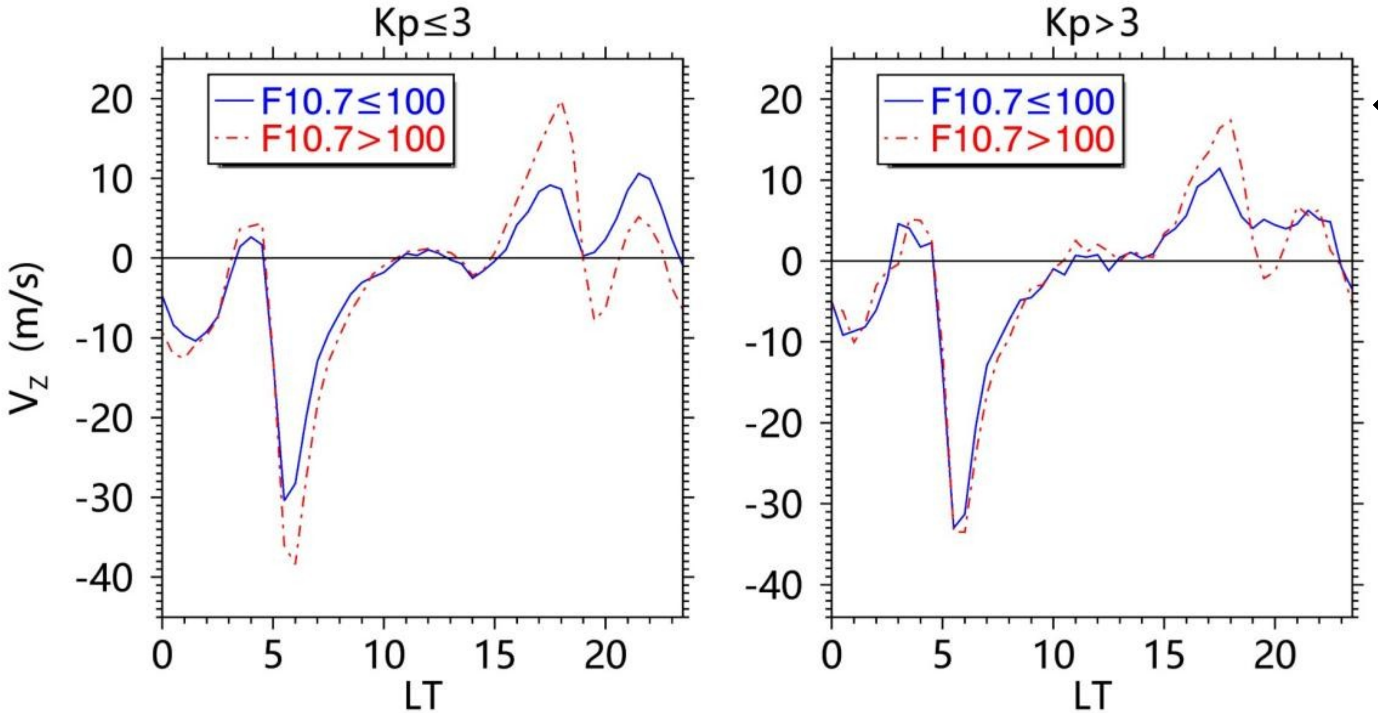


The diurnal variation of plasma drift in four conditions: (1) F107≤100 and Kp≤3, (2) F107≤100 and Kp>3, (3) F107>100 and Kp≤3, (4) F107>100 and Kp>3.

Vertical velocity (Vz)

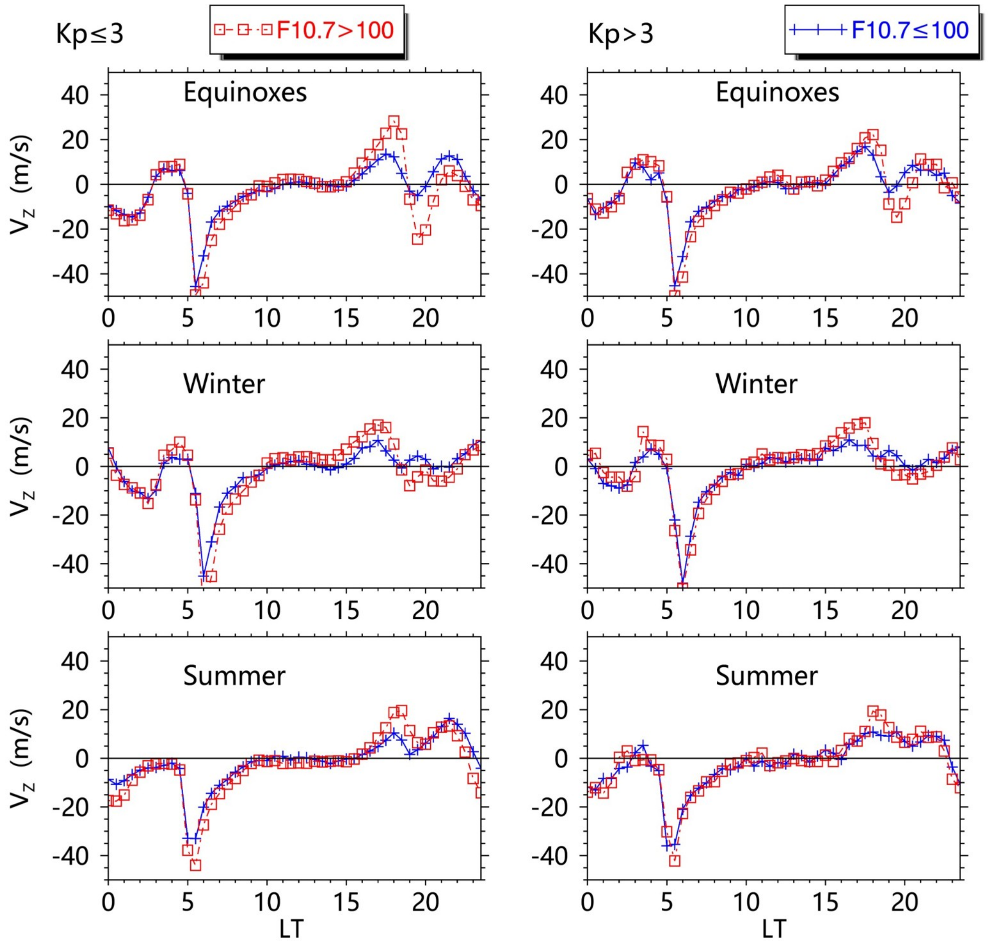
- Diurnal average Vz upward before 04:00 LT, then downward around dawn, and then recovered quickly to zero at 10:00 LT.
- Before dusk the PRE appeared with upward Vz, and after dusk the nighttime Vz downward, then raised up and turned down around midnight.
- The trend of average Vz at Hainan was similar to those observed with Digisonde at Ramey (Scali et al., 1997).





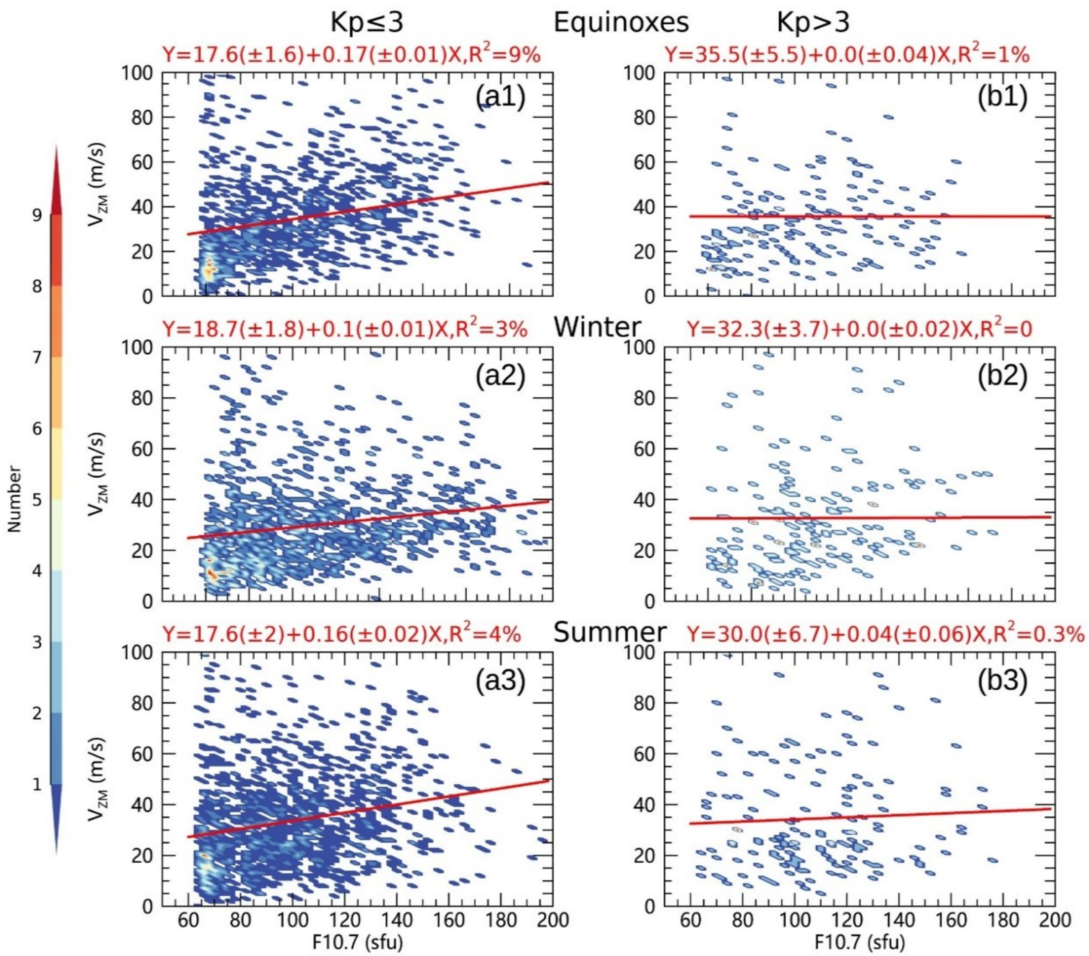
Figures depicts the response of the diurnal average vertical plasma velocities for two levels of solar flux and two levels of geomagnetic activities.

- ◆ The average diurnal Vz for two levels of solar flux for both geomagnetic activity levels, but in the PRE period they were higher during high solar flux.



The diurnal average V_Z variations at Hainan during equinox (March-April, September-October), winter (November-February), and summer (May-August) for two levels of solar flux and two levels of geomagnetic activity.

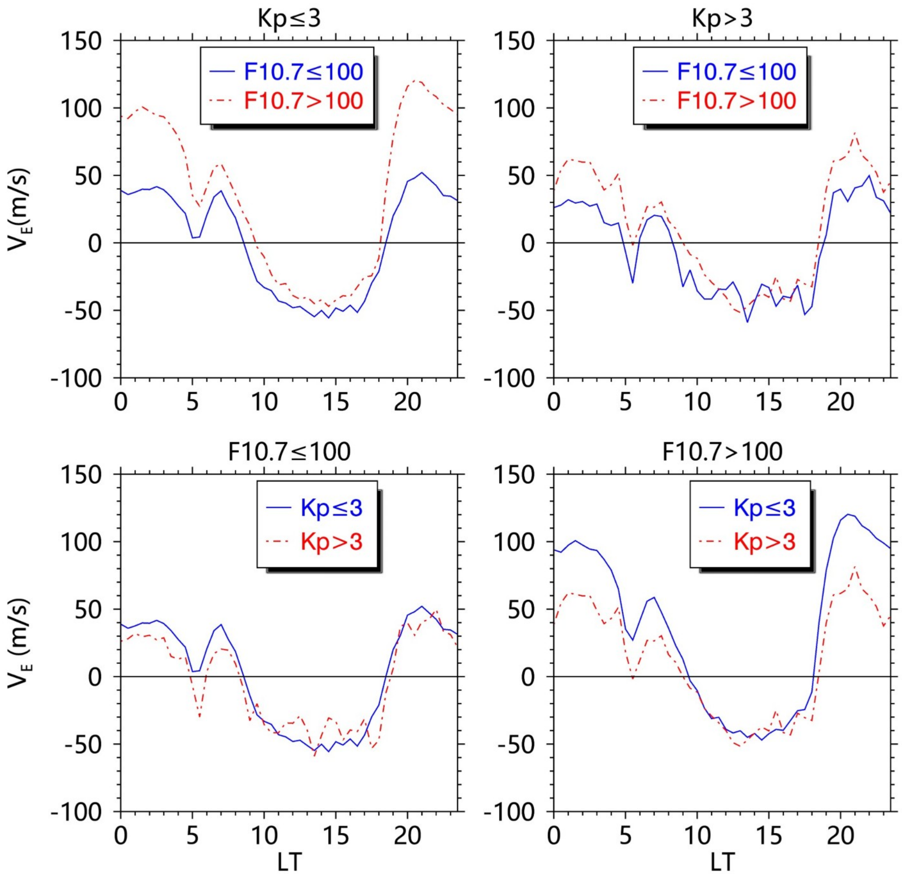
- When Kp ≤3 (the left column), the intensity of the PRE in each season with F10.7 >100 was larger than that with F10.7 ≤100.
- The intensity of the PRE was higher in equinoxes and summer than that in winter.
- The peak time of the PRE was earlier in winter and equinoxes than that in summer.
- The intensity of the peak (around 22:00LT) in equinoxes and summer when Kp >3 is less than that when Kp ≤3



Scatterplots of the maximum vertical plasma velocities (V_{ZM}) in the PRE period versus solar flux for equinox, winter, and summer.

- When Kp ≤ 3, the PRE velocities obviously increasing with F10.7 flux in all seasons. Whereas, when Kp >3, the PRE velocities had almost no variation with F10.7 flux.
- The equinox and summer results for Kp≤ 3 were consistent with the ISR observation at the Jicamarca station (Fejer et al, 1991).
- This can be explained that the disturbance dynamo E-field, usually driven by wind during high Kp, is westward in the evening hours and results in a decrease of the PRE.

Zonal drifts

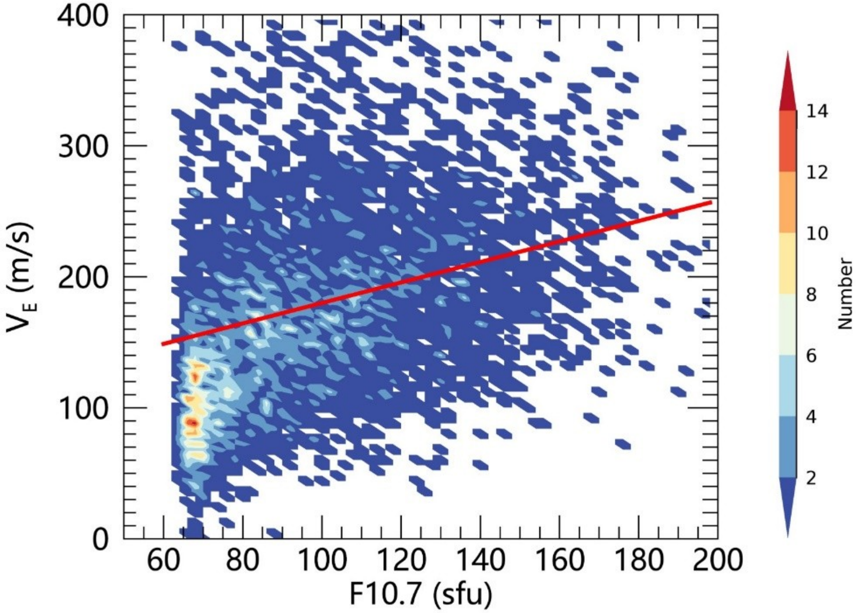


Diurnal variation of the average zonal plasma velocity V_E (eastward positive) for 2003-2016 at Hainan for two levels of solar flux and two levels of Kp.

- The diurnal variations of VE similar for all four conditions.
- In daytime, the zonal velocities were westward and did not vary much with solar and geomagnetic activity.
- At nighttime, VE was larger at high levels of solar flux, especially for magnetically quiet conditions.
- For low F10.7 the nighttime velocity was not dependent on Kp; however for high F10.7, VE was significantly larger during magnetically quiet compared to the smaller values during the disturbed.
- This implies that the nighttime eastward velocity was obviously suppressed by geomagnetic activity

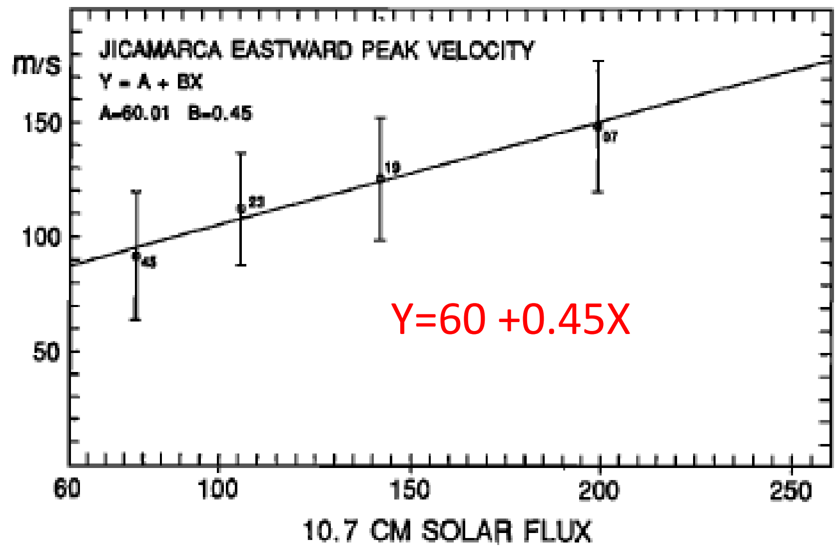
Comparison between Jicamarca and Hainan

Hainan $Y=101.7(\pm3.6)+0.78(\pm0.03)X$, $R^2=11\%$



Scatterplot of the maximum of the daily nighttime eastward velocity versus solar flux.

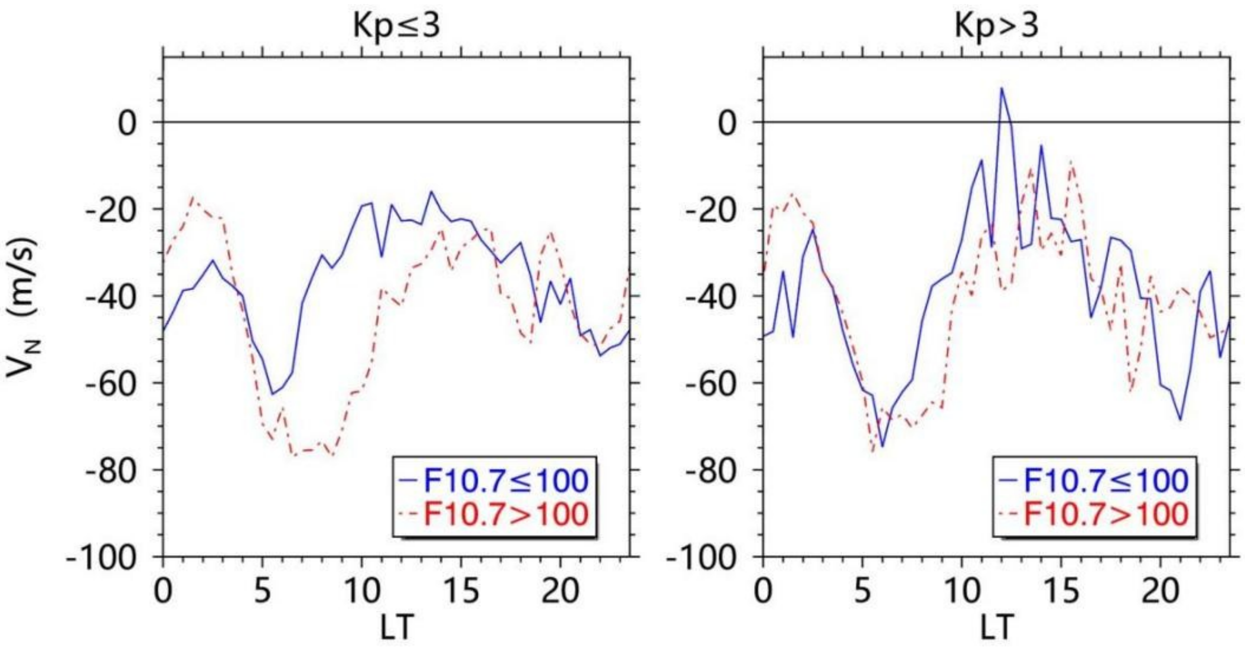
Jicamarca



The result from from ISR measurements at Jicamarca (Fejer et al., 1991)

The maximum velocity increased with solar flux. The slope of the fitted line is 0.85 which is larger than the corresponding value of 0.45 derived from ISR measurements at Jicamarca (Fejer et al., 1991).

Meridional drifts



Diurnal variation of the average meridional plasma velocity V_N (northward positive)

- The direction of V_N was southward at all times, irrespective of solar flux and geomagnetic activity.
- At daytime, the southward velocity disturbances were stronger for high Kp level.
- The maximum of southward plasma velocities occurred in the morning.

4. Some Discussions

(1) on Vertical Drift (Vz)

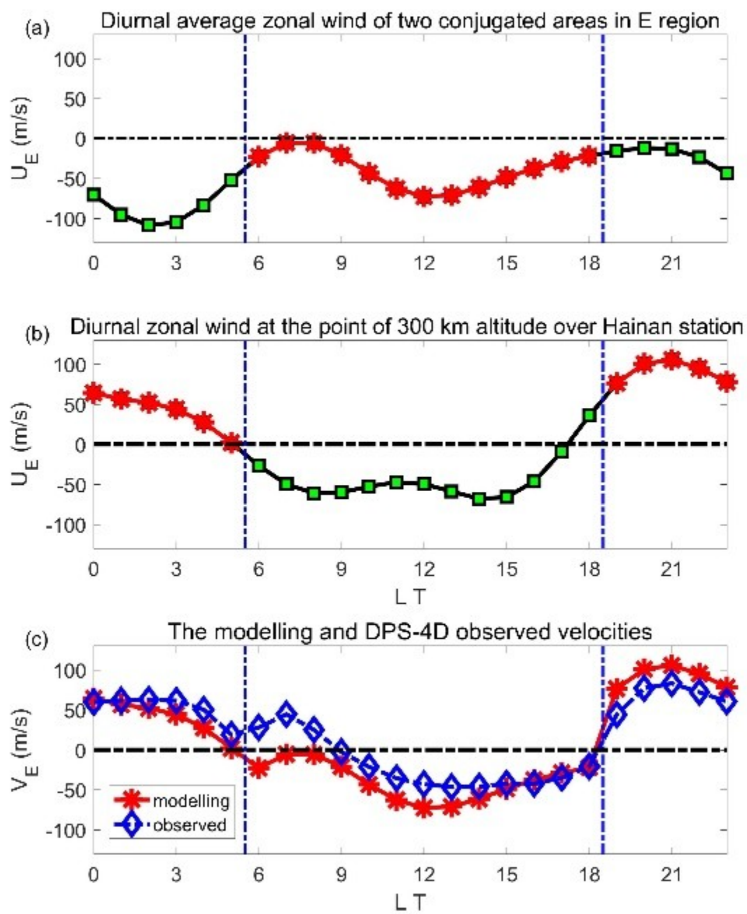
- Digisonde in Drift mode measures ionospheric velocities below F2 peak (hmF2). The measured plasma velocities should be the sum of the velocities due to **E**×**B** drift, gradient drift, gravity drift, curve drift, dragging (by wind), and others. At low latitude the **E**×**B** drift should be the main contributor to the measured plasma velocities. Sometimes, the wind also is important to the plasma drift.

- There are three major differences between Hainan (HN) and Jicamarca (JI) stations:

  - ✓ (1) In morning Vz quickly turned downward over HN, but it upward over JI;
  - ✓ (2) It is near zero on 10:00-16:00 LT over HN whereas it stayed upward over JI;
  - ✓ (3) In the pre-midnight period, Vz had a positive peak over HN, whereas it almost kept downward over JI.

- These differences may be due to the different location, detected height, and instruments.

on Zonal drift



(a) The diurnal E-region average zonal wind (from the model HWM14) of two conjugated areas at the geomagnetic field line at 300 km altitude over the Hainan station (green for the nighttime, and red for the daytime),

(b) the diurnal F-region zonal wind at 300 km altitude over the Hainan station calculated by HWM14 (red for the nighttime and green for the daytime), and

(c) the diurnal zonal plasma velocities (red stars) from HWM14 and the diurnal zonal velocities (blue diamonds) observed in the F-region over the Hainan station.

- That the variation of the model velocity is well consistent with the observation support the view that in the F region the nighttime zonal plasma velocity was controlled by the nighttime zonal wind, and the daytime zonal plasma velocity could be caused by the zonal neutral winds at the two conjugated areas in the E region (Rishbeth, 1971; Woodman, 1972).

Summary

The drift data obtained by DPS4 at low latitude Hainan station from 2003 to 2016 have been analyzed for their local time and seasonal variations with two levels of solar and magnetic activities.

I. The magnitude of diurnal variation of vertical drift (especially PRE during Equinoxes) increases with solar activity, but they are little affected by geomagnetic activity.

II. The eastward drifts mainly occur during nighttime, and they increase significantly with solar flux but decrease with magnetic activity. Whereas, the westward drifts appear during daytime, and they do not change greatly with solar and magnetic activities.

III. Meridional drifts almost are southward direction and do not change significantly with solar and magnetic activities.

IV. **E×B** drift should be the main contributor to the measured vertical velocities. the wind is important to the zonal plasma drift.

Digisonde in China

The 10 digiondes have been established in Chinese Meridian Project Phase II, where, Our Institute NSSC have 5 digisondes at Jiashi, Kuerle, Naqu, Yuzhong, and Binchuan. And the information stations are listed as following:

English station's names	Longitude	Latitude
Pujiang	103.62E	30.31N
Guilin	110.35E	25.35N
Boluo	114.49E	23.5N
Weihai	121.8E	37.18N
Jiashi	76.78E	39.5N
Kuerle	86.26E	41.55N
Naqu	92.41E	31.68N
Yuzhong	104.14E	35.95N
Binchuan	100.6E	25.58N
Changcheng	-58.96E	-62.22N

Since September 2023, these instruments run about one year and obtain more than 280 Gb data including the five type data (.RSF, .SAO, .PNG, .DFT and .VEL).

Both Sides (our team and ISTP team) will continue to do joint research on the ionosphere.

谢谢！　！

Спасибо! !