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New understanding achieved from 2 years of Chinese ionospheric investigations

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Abstract In the mainland of China, the number of ionospheric research groups is more than 10. Around 110 articles related to ionospheric physics have been published during 2014–2015. In this annual national report of the Committee on Space Research (COSPAR), we will outline some recent progresses in ionospheric studies conducted by the Chinese mainland scientists in the past 2 years. These investigations cover (1) the ionosphere responses to geomagnetic activities; (2) ionospheric climatology and structures; (3) couplings between the ionosphere, plasmasphere and lower atmosphere, and possible seismic signatures in the ionosphere; (4) ionospheric irregularities and scintillation; (5) ionospheric models, data assimilation and simulations; (6) ionospheric dynamics and electrodynamics; (7) progresses in the observation methodology and technique; and (8) planetary ionospheres. Such investigations will strengthen our ability to monitor the ionosphere, provide a better understanding of the ionospheric states and the underlying fundamental processes, and improve the ionospheric modeling, forecasting, and related applications.

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1 Ionosphere responses to geomagnetic activities

The most fascinating issue encountered in ionospheric studies is the ionosphere's response to geomagnetic activities; especially what drives the ionosphere away from its normal states and how to more precisely forecast such changes in the ionosphere.

A poorly understood question is the long-duration positive storms (LPSs) in the equatorial ionosphere. Here, the LPSs are identified as the relative deviation of the F2 layer peak density (NmF2) exceeds 25 % for more than 6 h. Kuai et al. [1] conducted a statistical analysis of the equatorial ionospheric LPS effects that occurred in 1998–2010. During the decade, 250 geomagnetic storms (minimum Dst < -50 nT) occurred, and only 204 storms were available for ionosonde observations at Jicamarca (12.0°S, 283.2°E), Peru. The occurrence of the 46 identified LPSs tends to decay approximately exponentially on the days after the main phase of geomagnetic storms. The disturbed electric fields are found to be essential in forming the equatorial LPSs. During the daytime LPSs, the disturbed zonal electric fields are mostly westward; for the nighttime LPSs, the significant uplifting of the F2 layer is mostly caused by an eastward electric field.

There are a few reports on the occurrences of a tongue of ionization (TOI) in the ionosphere under weak to moderately disturbed geomagnetic conditions. Utilizing the Global Positioning System (GPS) total electron content (TEC), the Defense Meteorological Satellite Program

(DMSP) measured the in situ total ion concentration and ion drift velocity, the Super Dual Auroral Radar Network (SuperDARN) measured the polar ion convection patterns, and the electron density profiles were obtained from the Poker Flat Incoherent Scatter Radar (PFISR). Liu et al. [2] investigated the source and development of TOI during a moderate geomagnetic storm on October 14, 2012, as shown in Fig. 1. Their results demonstrated that the TEC enhancements mainly came from the topside ionosphere, obvious changes are absent in the bottomside ionosphere and vertical plasma drifts. Additionally, there were no signatures of penetration of electric fields in the equatorial electrojet data and upward ion drifts at high latitudes.

The ionospheric responses to the geomagnetic activities driven by the co-rotating interaction region (CIR) events have become a hot topic in recent ionospheric studies. Chen et al. [3] analyzed the effect of the weaker geomagnetic activities on the ionospheric variability during the 2007–2009 deep solar minimum. The effect of weaker geomagnetic activities on the global electron content (GEC) shorter-term variation was significant during 2007–2009, when it was under relatively quiet geomagnetic activity. The values of GEC were positively correlated with Ap. In contrast, the GEC variation was poorly correlated with Ap at shorter-term scales during 2003–2005, except under strong geomagnetic disturbance. Statistically, the contributions to the GEC shorter-term variations were comparable with the solar irradiance, geomagnetic activity, and meteorological sources during 2007–2009.

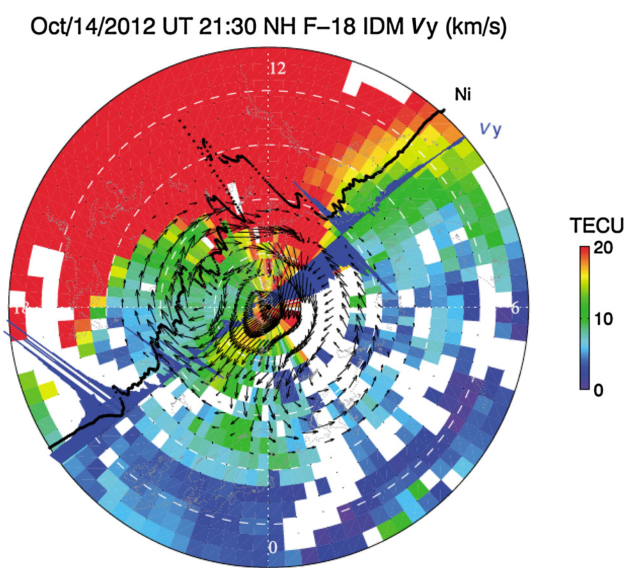

Fig. 1 Polar view of absolute TEC, cross-track velocity (*V*y, blue line), and total plasma density (Ni, dark dotted line) in the magnetic latitude (40°–90°) and the magnetic local time coordinate. The *y*-axes for *V*y and Ni are perpendicular to the orbit. The plasma convection pattern observed by SuperDARN is also superimposed. The DMSP progressed from the nighttime sector to the morning sector. After Liu et al. [2]

Chen et al. [4] conducted an epoch analysis of global ionospheric responses to the recurrent geomagnetic activities. They analyzed 79 CIR events from 2004 to 2009. At high and middle latitudes, the TEC showed significant positive responses on the first day of the epoch. At all latitudes, most of the positive TEC effects always occurred 2–6 h after the CIR started at the local daytime and 10–18 h later at local nighttime. Case studies indicate that the positive response had a strong dependence on the southward component of the interplanetary magnetic field (IMF Bz) and solar wind speed. Negative responses following at the high latitudes of the American continent were related to the storm-time thermospheric composition (O/N_2) changes. During the recovery phase, the TEC positive disturbance at low latitudes sometimes could last 2–4 days, whereas at the middle to high latitudes the disturbance lasted only for 1 day in most cases. Moreover, the ionospheric response in North America was stronger than in Europe and Asia.

Liu et al. [5] used the three-year observations of the Fabry–Perot interferometers (FPI) at Xinglong (40.2°N, 117.4°E) and Millstone Hill (42.6°N, 71.5°W) to study the planetary wave-type oscillations (PWTOs) in thermospheric winds at a height of 250 km. The oscillations with periods of 4–19 days exhibit annual and semiannual variations. As an extension, Liu et al. [6] included the 11-year (1989–1995 and 2010–2013) FPI data to investigate the 6–30 days oscillations of the thermospheric winds. There are prominent quasi-27-day oscillations in the zonal winds, highly correlated to the same periodic oscillations in Kp and SW during the solar maximum. The high correlation of the PWTOs to the solar wind speed and Kp indicates that the oscillations in the thermospheric neutral winds may possibly be influenced by the CIRs, the related high-speed solar wind, and the recurrent geomagnetic activity.

Liu et al. [7] used observations by multiple instruments including GPS TEC, the critical frequency of F2-layer (foF2) and peak height (hmF2) from ionosondes, vertical ion drift measurements from C/NOFS, and far ultraviolet airglow measured by the Thermosphere–Ionosphere–Mesosphere Energetics and Dynamics (TIMED)/Global Ultraviolet Imager (GUVI) to investigate the profound negative ionospheric disturbances at the middle and low latitudes during the July 14–17, 2012, geomagnetic storm. They ascribed a strong inhibition of the equatorial ionization anomaly (EIA) over East Asia in the recovery phase on July 16 to the combined effects of the intrusion of neutral composition disturbance zone and the long-lasting daytime westward disturbance dynamo electric field (DDEF). The daytime periodical intrusion of the negative phases