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15. SUBJECT TERMS

a number of new characteristics of equatorial plasma horizontal drift
strong evidence that penetration electric field associated with southward IMF during the main phase of magnetic storms increases the generations equatorial plasma bubbles in the evening sector.

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FINAL TASK REPORT – FA9550-09-1-0321

Research Title: **Investigations of penetration electric fields and low-latitude ionospheric disturbances during intense geomagnetic storms**

Principal Investigator: Dr. Sunanda Basu/Dr. Chao-song Huang

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Research Objectives: This project is to investigate how the solar wind/interplanetary magnetic field (IMF) controls the equatorial ionospheric dynamics during intense geomagnetic storms.

Summary of Progress:

We have found that the zonal electric field in the dusk equatorial ionosphere correlates well with the variations of the interplanetary electric field dawn-dusk component (IEF Ey) for up to 21 hours during intense magnetic storms. The eastward penetration electric field can continuously exist for 8 hours during steady southward interplanetary magnetic field (IMF). The vertical component of the ionospheric electric field is ~5% of the IEF Ey, and the zonal electric field is ~10% of the IEF Ey. The IMF has important effects on the plasma horizontal drift. The ion horizontal drift enhancement is westward during southward IMF and eastward during northward IMF. We have also found that the longitudinal and seasonal variations of the plasma density and drift velocity in the evening equatorial ionosphere show complex characteristics. The longitudinal structure of the ion density and velocity show a wave-4 pattern during the equinox months, a wave-3 pattern in northern summer, and a wave-2 pattern in northern winter. The longitudinal structure becomes significantly different from the wave-4 pattern in the longitude regions with large magnetic declination. Our study reveals a number of new characteristics of the equatorial plasma horizontal drift in the east-west direction.

An important issue in low-latitude ionospheric space weather is how magnetic storms affect the generation of equatorial plasma bubbles. We have studied the measurements of the ion density and velocity in the evening equatorial ionosphere by the Defense Meteorological Satellite Program (DMSP) satellites during 22 intense magnetic storms. The DMSP measurements show that deep ion density depletions (plasma bubbles) are generated after the interplanetary magnetic field (IMF) turns southward. The time delay between the IMF southward turning and the first DMSP detection of plasma depletions decreases with the minimum value of the IMF *Bz* , the maximum value of the interplanetary electric field (IEF) *Ey* , and the magnitude of the Dst index. The results of this study provide strong evidence that penetration electric field associated with southward IMF during the main phase of magnetic storms increases the generation of equatorial plasma bubbles in the evening sector.

An unexpected feature revealed by the measurements of the C/NOFS satellite is the presence of broad plasma depletions (thousands of kilometers in longitude) near dawn during deep solar minimum. We found the plasma bubbles observed in the midnight–dawn sector originate in the evening sector. The continuous growth of the plasma bubbles in the evening sector and the slow decay after midnight determines that most plasma bubbles become fully developed and are easily detected after midnight. The plasma flow inside the plasma bubbles is strongly upward throughout the entire nighttime. We have proposed a new causal mechanism for the generation of wide plasma bubbles and broad depletions. A series of plasma bubbles is generated through the Rayleigh-Taylor instability process over a large longitudinal range. These plasma bubbles grow and merge to form a wide bubble, and multiple wide bubbles can further merge to form broad plasma depletions. An important property of the mechanism is that the broad plasma depletions result from merging of multiple plasma bubbles. We have also reported the new observations of zonal drift of plasma bubbles and proposed a mechanism that determines the difference between the bubble zonal drift and ambient plasma drift

Publications:

1). Huang, C.-S., F. Rich, O. de La Beaujardiere, and R. A. Heelis, "Longitudinal and seasonal variations of the equatorial ionospheric ion density and eastward drift velocity in the dusk sector," J. Geophys. Res., 115, A02305, doi:10.1029/2009JA014503, 2010.

2). Huang, C.-S., F. J. Rich, and W. J. Burke, "Stormtime electric fields in the equatorial ionosphere observed near the dusk meridian," J. Geophys. Res., 115, doi:10.1029/2009JA015150, in press, 2010.

3). Sahai, Y., F. Becker-Guedes, P. R. Fagundes, A. J. de Abreu, R. de Jesus, V. G. Pillat, J. R. Abalde, C. R. Martinis, C. Brunini, M. Gende, C. S. Huang, X. Pi, W. L. C. Lima, J. A. Bittencourt, and Y. Otsuka, "Observations of the F-region ionospheric irregularities in the South American sector during the October 2003 "Halloween Storms", Ann. Geophys., 27, 4463–4477, 2009.

4). Huang, C.-S., O. de La Beaujardiere, P. A. Roddy, D. E. Hunton, R. F. Pfaff, C. E. Valladares, and J. O. Ballenthin (2011), Evolution of equatorial ionospheric plasma bubbles and formation of broad plasma depletions measured by the C/NOFS satellite during deep solar minimum, J. Geophys. Res., 116, A03309, doi:10.1029/2010JA015982.

5). Huang, C.-S., O. de La Beaujardiere, R. F. Pfaff, J. M. Retterer, P. A. Roddy, D. E. Hunton, Y.-J. Su, S.-Y. Su, and F. J. Rich (2010), The zonal drift of plasma particles inside equatorial plasma bubbles and its relation to the zonal drift of the bubble structure, J. Geophys. Res., 115, A07316, doi:10.1029/2010JA015324.

6). Huang, C.-S., F. J. Rich, and W. J. Burke (2010), Stormtime electric fields in the equatorial ionosphere observed near the dusk meridian, J. Geophys. Res., 115, A08313, doi:10.1029/2009JA015150.

7). Huang, C.-S., (2011), Occurrence of equatorial plasma bubbles during intense magnetic storms, Int. J. Geophys., doi:10.1155/2011/401858

8) Huang, C, -S., (2012), Statistical analysis of dayside equatorial ionospheric electric fields and electrojet currents produced by magnetospheric substorms during sawtooth events, *J. Geophys. Res.,* 117, A02316, doi:10.1029/2001JA017398.