SA11B-3939 Mid-latitude Ionospheric Disturbances Due to Geomagnetic Storms at ISS Altitudes

Joseph I M[...]d Emily M Willis
NASA, Mar[...]ace Flight Center
Hu[...] AL USA

Linda Neergaard Parker
Jacobs Technology, ESSSA Group
Huntsville, AL USA

Introduction

Spacecraft charging of the International Space Station (ISS) is dominated by interaction of the US high voltage solar arrays with the F2-region ionosphere plasma environment. ISS solar array charging is enhanced in a high electron density environment due to the increased thermal electron currents to the edges of the solar cells. High electron temperature environments suppress charging due to formation of barrier potentials on the charged solar cell cover glass that restrict the charging currents to the cell edge [*Mandell et al.*, 2003]. Environments responsible for strong solar array charging are therefore characterized by high electron densities and low electron temperatures.

In support of the ISS space environmental effects engineering community, we are working to understand a number of features of solar array charging and to determine how well future charging behavior can be predicted from in-situ plasma density and temperature measurements. One aspect of this work is a need to characterize the magnitude of electron density and temperature variations that occur at ISS orbital altitudes (~400 km) over time scales of days, the latitudes over which significant variations occur, and the time periods over which the disturbances persist once they start.

This presentation provides examples of mid-latitude electron density and temperature disturbances at altitudes relevant to ISS using data sets and tools developed for our ISS plasma environment study. "Mid-latitude" is defined as the extra-tropical region between ~30 degrees to ~60 degrees magnetic latitude sampled by ISS over its 51.6 degree inclination orbit. We focus on geomagnetic storm periods because storms are well known drivers for disturbances in the ionospheric plasma environment.

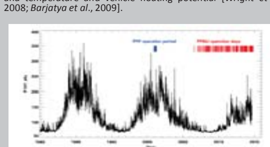
Data Sources

Ionosonde: Critical frequency f_oF2 records from ground based ionosonde sites provide electron density at the F2 peak which typically lies at or below ISS altitudes. The F2 peak is the highest electron density in the ionosphere, providing an upper bound for the Ne density that could be present at ISS altitudes. The global ionosonde network provides a good sampling of a wide range of latitudes over multiple years allowing electron density variations over extended periods of time to be easily considered.

CHAMP Digital Ion Drift Meter: In-orbit electron density and temperature data from the Digital Ion Drift Meter (DIDM) instrument on the CHAMP satellite in a ~400 km altitude near circular 97 degree inclination orbit. This instrument provides a good sampling of both electron temperature and density variations over the full range of latitudes of interest to ISS and at an altitude very near to that of ISS.

ISS Floating Potential Measurement Unit (FPMU): Electron density and temperature from the ISS Floating Potential Measurement Unit (FPMU) suite of plasma sensors provide in-situ measurements of the electron density and temperature.

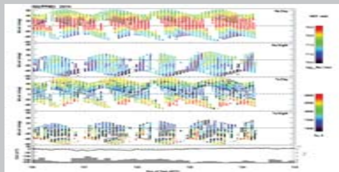
The ISS FPMU instrument suite includes two Langmuir probes, a plasma impedance probe, and a floating potential probe to provide redundant measurements of ionospheric electron density and temperature and vehicle floating potential [*Wright et al.*, 2008; *Barjatya et al.*, 2009].



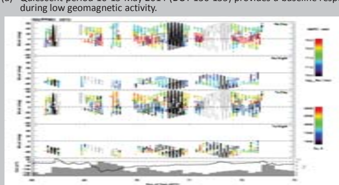
FPMU operations have sampled the end of Solar Cycle 24, the current Solar Cycle 25 solar maximum, and the minimum between the two cycles. In-situ plasma environment observations by FPMU is biased to low geomagnetic activity due to the solar minimum and relatively low solar activity conditions during the current quiet solar cycle.

ISS Floating Potential Measurement Unit

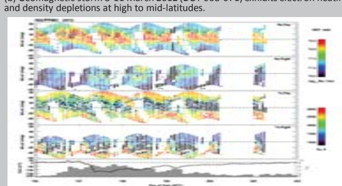
FPMU provides in-situ measurements of electron density and temperature along the ISS orbit. To date we have observed relatively small changes in density and temperature associated with geomagnetic storms in the FPMU records. All the geomagnetic storm periods shown here are GEM-CEDAR Challenge events.



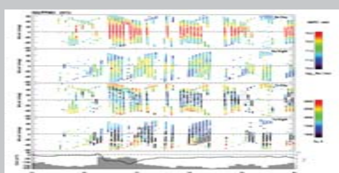
(a) Quiescent period 10-15 May 2014 (DOY 130-135) provides a baseline response during low geomagnetic activity.



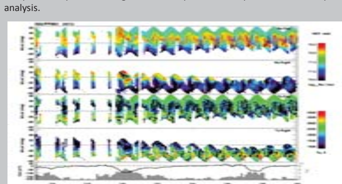
(b) Geomagnetic storm 8-11 March 2012 (DOY 068-071) exhibits electron heating and density depletions at high to mid-latitudes.



(c) Geomagnetic storm 14-17 July 2012 (DOY 196-199) exhibits some minor electron heating and plasma depletions at high latitudes.



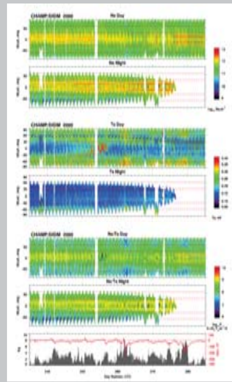
(d) Geomagnetic storm 17 March 2013 (DOY 076) exhibits minor electron heating and plasma depletions at high latitudes. Sparse records prior to storm complicate analysis.



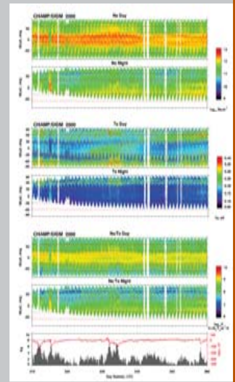
(e) Geomagnetic storm periods 26-30 June 2013 (DOY 177-181) and 5-9 July 2013 (DOY 186-190) exhibit electron heating at mid-latitudes. The June storm event exhibits a positive electron density storm response, one of the few in our data set.

[...]CHAMP Digital Ion Drift Meter

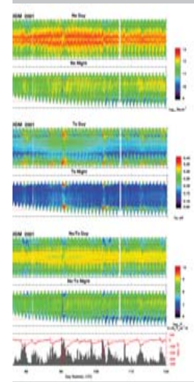
CHAMP DIDM records provide a convenient method for evaluating latitude distributions of electron density a[...] disturbances. Possible ISS solar array charging environments are indicated by the Ne/Te ratio proxy, enhancements in the ratio suggest a charging threat. For the geomagnetic storm events shown here the proxy typically indicates no change or a reduction in the charging th[...]



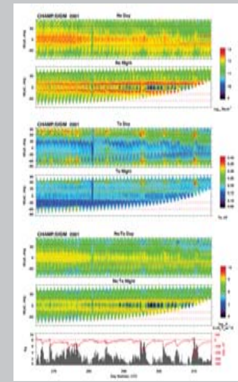
(a) 22 August – 11 October 2000



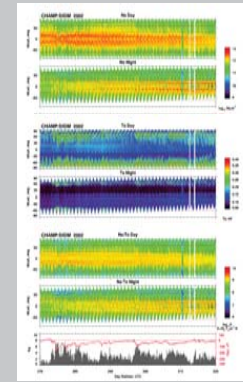
(b) 5 November – 25 December 2000



[...]arch – 30 April 2001



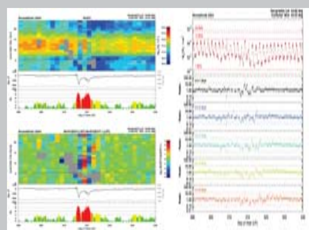
(d) 22 September – 11 November 2001



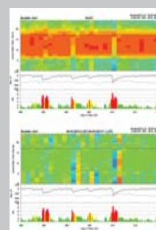
(e) 27 September – 16 November 2002

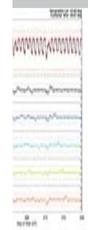
Ionosonde – Individual Storms

Ionosonde records provide a convenient method for characterizing storm time variations in F2 region plasma density. Records are [...]ctron density as a function of local solar time and day of year and then the arrays shifted by one day to evaluate the change in density over a 24 hour period. In addition, the measurements are shifted by N = 1, 2, ..., 5 days to look for changes in electron density over periods of a few days.

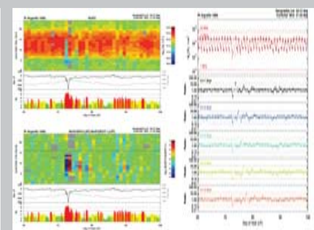


(a) Isolated storm period at 44.6° magnetic latitude, electron density disturbance persists for ~4 days.

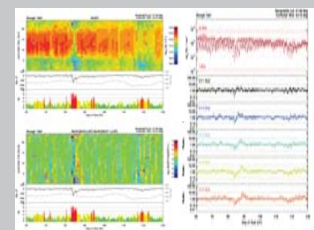




(b) Multiple storms at 48.6° ma[...]lectron density disturbance ~1 days for[...]



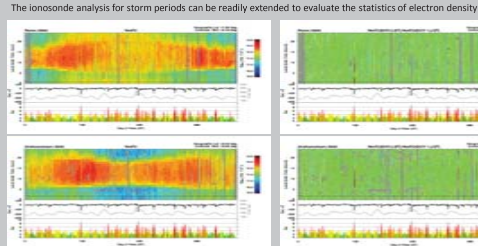
(c) Multiple storms at 41.2° magnetic latitude, electron density disturbances persist for multiple days.

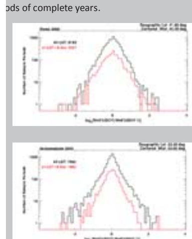


(d) Multiple storms at 54.1° magnetic latitude.

Ionosonde – Extended Period Studies

The ionosonde analysis for storm periods can be readily extended to evaluate the statistics of electron density [...]ods of complete years.





Summary

Ionosphere records evaluated to date of relevance to ISS show relatively small variations of importance to ISS charging. We continue to look for additional storm (and other) events that might provide evidence for stronger charging environments with enhanced electron density and suppressed electron temperature conditions over time scales of days or less. We encourage input from the science community regarding specific events that may help us identify additional charging environments.

Acknowledgements

CHAMP DIDM data was provided by Dr. David Cooke, Air Force Research Laboratory. Ionosonde parameters from the global network of ionosonde stations are distributed by NOAA's National Geophysical Data Center (through the SPIDR interface). Financial support for MSFC personnel and FPMU operations is provided by the ISS Program through ITA MSE-04.

References

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Wright, Jr., K.H., C.M. Swenson, D.C. Thompson, A. Barjatya, S.L. Koontz, T.A. Schneider, J.A. Vaughn, J.I. Minow, P.D. Craven, V.N. Coffey, L.N. Parker, and T. Bui, Charging of the International Space Station as observed by the Floating Potential Measurement Unit: Initial results, *IEEE-Trans. Plasma Sci.*, 36, 2280, 2008.