Modeling Ionosphere Environments: Creating an ISS Electron Density Tool

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August 5, 2011

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Modeling Ionosphere Environments:
Creating an ISS Electron Density Tool

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The International Space Station (ISS) maintains an altitude typically between 300 km and 400 km in low Earth orbit (LEO) which itself is situated in the Earth's ionosphere. The ionosphere is a region of partially ionized gas (plasma) formed by the photoionization of neutral atoms and molecules in the upper atmosphere of Earth. It is important to understand what electron density the spacecraft is/will be operating in because the ionized gas along the ISS orbit interacts with the electrical power system resulting in charging of the vehicle. One instrument that is already operational onboard the ISS with a goal of monitoring electron density, electron temperature, and ISS floating potential is the Floating Potential Measurement Unit (FPMU). Although this tool is a valuable addition to the ISS, there are limitations concerning the data collection periods. The FPMU uses the Ku band communication frequency to transmit data from orbit. Use of this band for FPMU data runs is often terminated due to necessary observation of higher priority Extravehicular Activities (EVAs) and other operations on ISS. Thus, large gaps are present in FPMU data. The purpose of this study is to solve the issue of missing environmental data by implementing a secondary electron density data source, derived from the COSMIC satellite constellation, to create a model of ISS orbital environments. Extrapolating data specific to ISS orbital altitudes, we model the ionospheric electron density along the ISS orbit track to supply a set of data when the FPMU is unavailable. This computer model also provides an additional new source of electron density data that is used to confirm FPMU is operating correctly and supplements the original environmental data taken by FPMU.

Nomenclature

ISS	=	International Space Station
LEO	=	low Earth orbit
FPMU	=	Floating Potential Measurement Unit
EVA	=	Extra Vehicular Activity
COSMIC	=	Constellation Observing System for Meteorology Ionosphere and Climate
NOAA	=	National Oceanic and Atmospheric Association
TT&C	=	Telemetry, Tracking, and Command
NSF	=	Science Foundation
NASA	=	National Aeronautics and Space Administration
CDAAC	=	COSMIC Data Analysis and Archival Center
UCAR	=	University Center for Atmospheric Research
NGDC	=	National Geophysical Data Center

I. Introduction

Environmental modeling is an essential component to the continuing function of the International Space Station. Because the ISS is located in the ionosphere and this region's characteristic ionized gas, devices such as the FPMU provide a monitoring system for potentially hazardous conditions both to the spacecraft as well as its human inhabitants. However, the FPMU reliance upon the Ku-band communication frequency introduces time

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intervals during which the FPMU is unavailable to collect data. Another system is developed as a backup for the FPMU when EVAs and other video related monitoring and communication require the use of the Ku-band. This secondary model implements data collected from a constellation of six satellites known as COSMIC.

COSMIC provides electron density profiles over a range of altitudes which allow for observation of electron density behavior along the ISS orbit track. Electron density directly influences the amount of charge built up on areas of the ISS and must be monitored to keep track of spacecraft charging for the safety of the ISS crew as well as the electronic systems. The monitoring of charge build up on ISS is a high priority as evidenced by the FPMU being implemented onboard the ISS with the condition that it is mandatory for safe ISS operation. A secondary monitoring system independent of the FPMU constraints is desirable in conjunction with the FPMU to provide total electron density environment coverage for the ISS from both a scientific and safety standpoint.

II. Background

The Floating Potential Measurement Unit (FPMU) was designed to measure several variables pertaining to the ISS environments including ISS floating potential, plasma temperature, and plasma density. Although the primary focus of FPMU is to monitor ISS charging, electron density and electron temperature measurements are also implemented to determine the cause of ISS charging. The system itself is composed of four probes: a floating potential probe (FPP), a plasma impedance probe (PIP), a wide-sweep Langmuir probe (WLP) and a narrow-sweep Langmuir probe (NLP). For detailed descriptions of the components, see Ref. 1[1]. Fi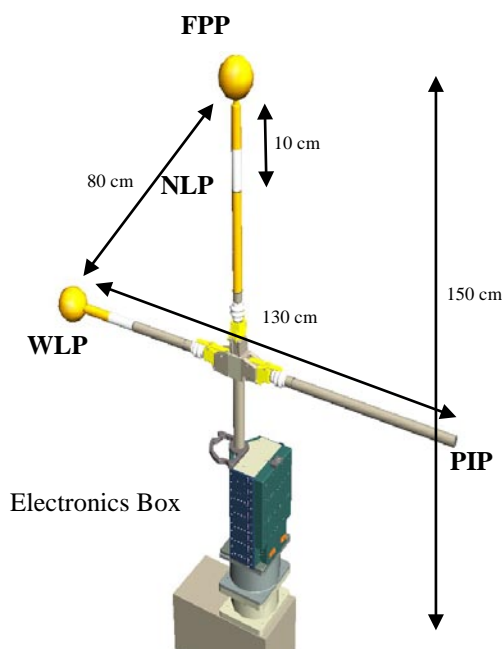gure 1 displays the FPMU component orientation. For this study, the electron density data collected from the WLP and NLP have the most precedence. Although the PIP is also able to collect electron density data, it is considered to be an experimental probe and not fully functional. Due to the system's autonomous controls with either an on or off state as well as its reliance upon the Ku-band, no single component of the system may be left operational for continuous data collection. Barjatya et al. describes FPMU as a "'snapshot' instrument for ionospheric density and temperature measurements."[2] A secondary electron density tool with full time data collection at ISS altitudes is ideal as a backup system for FPMU. COSMIC is a scientifically based mission with the desired full time functionality suited for such a tool.

FPP

10 cm

80 cm **NLP**

130 cm

150 cm

WLP

PIP

Electronics Box

Figure 1. FPMU Diagram.

The COSMIC satellites are located at an altitude of 800 km with an inclination of 72 degrees. Relative to the location of FPMU on ISS, these satellites are in a much higher orbit as well as at a higher inclination (ISS has an inclination of about 52 degrees). See Fig. 2. Launched in 2006, each satellite has a payload consisting of a GPS Radio Occultation Receiver, a Tiny Ionospheric Photometer (TIP), and a Tri-Band Beacon transmitter (TBB).[3] The GPS Radio Occultation Receiver measures ionospheric electron density profiles from orbit altitude and downward as one of its main functions and consequently is the instrument through which the data is gathered for this study. The data is downloaded every orbit by NOAA TT&C stations in Alaska and Norway as well as the NSF/NASA station in Antarctica. The data is then transferred to the CDAAC at UCAR in Colorado. The electron density data files and all other data are located and accessed in an on-line database provided by UCAR.[4] Each file represents one day and includes approximately 1,000 electron density profiles with relevant parameters such as maximum electron density, altitude of electron density measurements, and local times of maximum electron density occurrence.
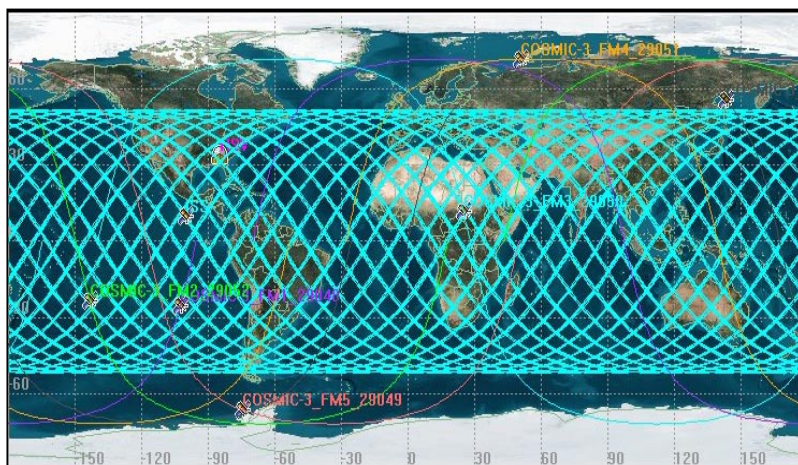
Figure 2. Orbit track of the six COSMIC satellites and the ISS. The *ISS orbit was traced over approximately a six day interval starting April 1, 2010 through 21 hr 20 min 00 sec April 5, 2010. Figure production: Satellite Tool Kit*

III.   Methodology

Knowledge of electron density variance as a function of time of day and geomagnetic conditions is essential in understanding the correlation between the secondary COSMIC data source and FPMU data. Small studies consisting of plotting electron densities throughout several time periods and at various altitudes are first conducted to become familiar with the COSMIC data. This process is also important in determining if the data is fundamentally sound by searching for particular patterns that are expected with differing times of day and contrasting geomagnetic conditions. Upon determining the data is valid and electron density behavior is understood, ISS ephemeris data files in conjunction with COSMIC data are then used to determine ionospheric conditions associated with the ISS orbit track.

A. Time Intervals: High Geomagnetic Activity v. Quiescent Geomagnetic Conditions

To become familiar with and test the validity of the COSMIC electron density data, two time intervals with differing geomagnetic conditions are chosen for comparison. These time intervals are also used for the final comparison of COSMIC and FPMU data. The first time interval is April 1-10, 2010. During the middle of this period, around April 5-6, large geomagnetic indices were detected indicating that this time period is characteristic of high geomagnetic activity. The second time interval chosen is January 21-30, 2011. This period presented minimal geomagnetic activity and is considered a good candidate for comparison with the more active April 2010 period.

Preliminary time interval selection was conducted using the Space Physics Interactive Data Resource (SPIDR)[5] database and searching for two time periods with unusually high and low Kp indices respectively. The Kp index is a geomagnetic index derived from the K index. The K index is a parameter that is derived from the maximum fluctuations of horizontal components of the Earth's magnetic field observed on a ground based magnetometer relative to a calm day during three hour intervals. Thus, the planetary Kp index is derived by calculating a weighted average of K indices from a collection of geomagnetic observatories.[6] It is designed to provide a proxy measurement summarizing geomagnetic activity generated by solar wind interactions with the Earth's magnetic field. Fig. 3 displays the Kp index plots for the April 2010 time period as well as the January 2011 time period.

The importance in choosing these differing time periods is their role in verifying the accuracy of the COSMIC data by highlighting the variations in the electron density profiles and plots caused by geomagnetic storms (April 1-10, 2010) or lack thereof (January 21-30, 2011). These variations are visually displayed in plots in the next sub section.
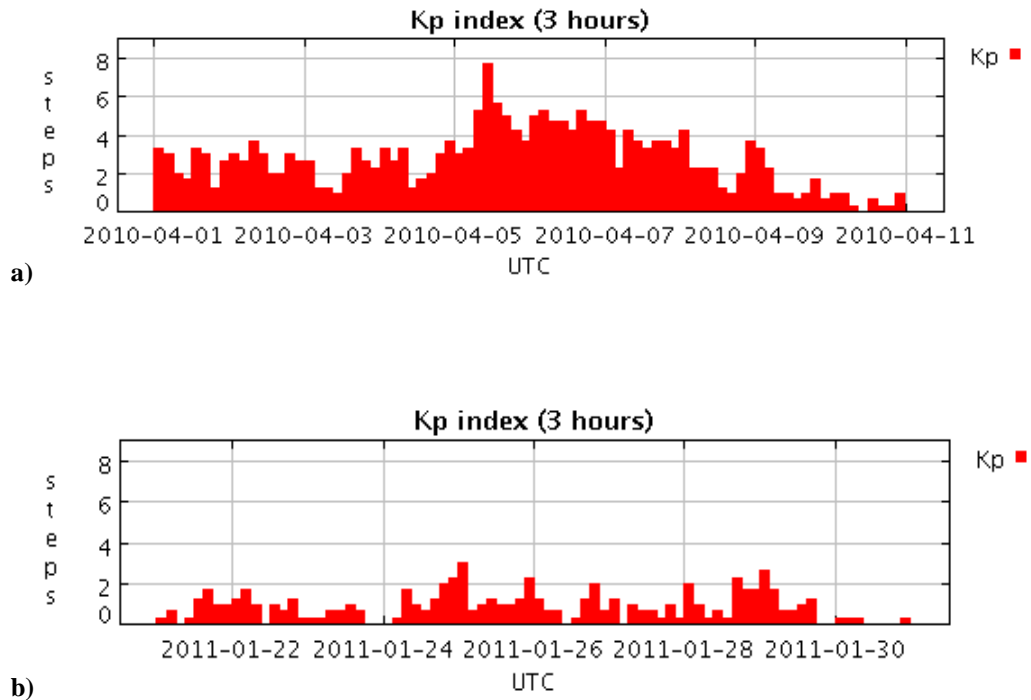
a)

b)

Figure 3. Kp indices for a) April 1-10, 2010 and b) January 21-30, 2011. *On April 5, 2010, the Kp index nearly reached 8. On average, any Kp index exceeding 6 is considered high and indicates high geomagnetic activity. [Source: NOAA/NGDC/SPIDR]*

B. Evaluate COSMIC Electron Density Data

Analysis software is developed in the MATLAB programming language to download the COSMIC electron density data and subsequently plot specific variables pertaining to the electron density profiles. This provides insight into electron density behavior in the ionosphere. The first round of plotting requires simply extracting the electron density profiles. These plots clearly show the altitude of maximum electron density as well as the magnitude of the
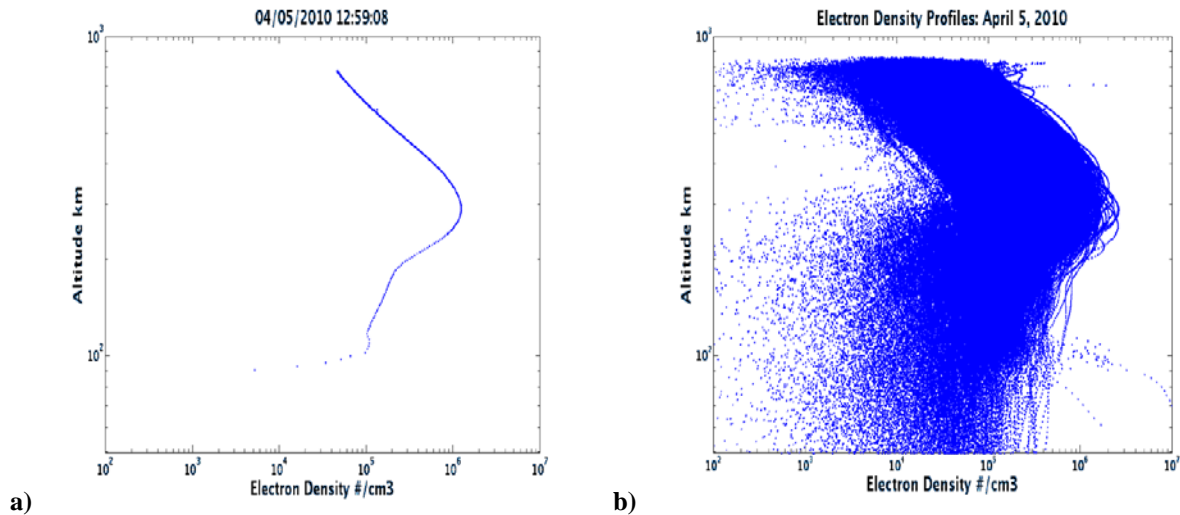

a)

b)

Figure 4. Single electron density profile from a) April 5, 2010 and all electron density profiles from b) April 5, 2010. *The bowed shape of the profiles clearly exposes the magnitude of the maximum electron density and the corresponding altitude. Figure production: MATLAB*

electron density. See Fig. 4. For each profile, data is collected between a minimum and maximum altitude. It takes anywhere between 10 minutes to less than one minute to sample the electron densities between these altitudes. Typically, the ISS altitude range occurs slightly above the electron density maximum.

a)

b)

Figure 5. The maximum electron density altitude over two ten day periods: a) April 1-10, 2010 and b) January 21-30, 2011. *Recall that during the middle of the April 2010 period there was an increase in geomagnetic activity. This is reflected in the larger distribution of altitudes seen in Fig. 5a. Figure production: MATLAB*

A second relation between the altitudes at which the electron density maximum occurs and local time is plotted for both time intervals: April 2010 and January 2011. See Fig. 5. It is seen that at midnight local time that the maximum electron densities retreat to higher altitudes, whereas during the middle of the day at noon local time, the maximum electron densities are found at lower altitudes. This is expected behavior for electron densities thus confirming the validity of the COSMIC data in this respect. Upon further inspection, influence from the high geomagnetic activity during the middle of the April period is seen in the behavior of the maximum electron density measurements. Fig. 5a displays more erratic behavior of the maximum electron densities during the geomagnetic storm with the values retreating to higher-than-normal altitudes during the night and pushing to lower-than-normal altitudes during the day when compared with the much calmer January 2011 period (Fig. 5b).

Because Fig. 5 clearly displays the maximum electron densities becoming less precise during a geomagnetic storm period as compared with the relatively regular maximum electron densities during the quiescent period, the validity of the COSMIC data is more solidified and a general understanding of how electron density behaves as a function of altitude, time, and geomagnetic conditions is achieved. This process develops an important foundation for the implementation of a secondary FPMU data source.

C. Interpolation Program

Simply downloading the COSMIC data for all altitudes is not particularly relevant to the ISS. For the purpose of obtaining electron density data along the ISS orbit track, particular altitudes of the ISS during the two time intervals are needed. This data is available in the ISS ephemeris files which contain pertinent data such as ISS latitude, longitude, and altitude for any particular time. A program in the Interactive Data Language (IDL) is developed to download the ISS ephemeris files as well as the COSMIC files and runs an original code to interpolate COSMIC data along the ISS orbit track. Electron density from the COSMIC profiles are first extracted from a range of altitudes +/- 10 km about the mean ISS altitude to obtain a set of measured COSMIC densities distributed over a variety of latitudes and longitudes. These density values are then gridded onto a Cartesian grid in local time and
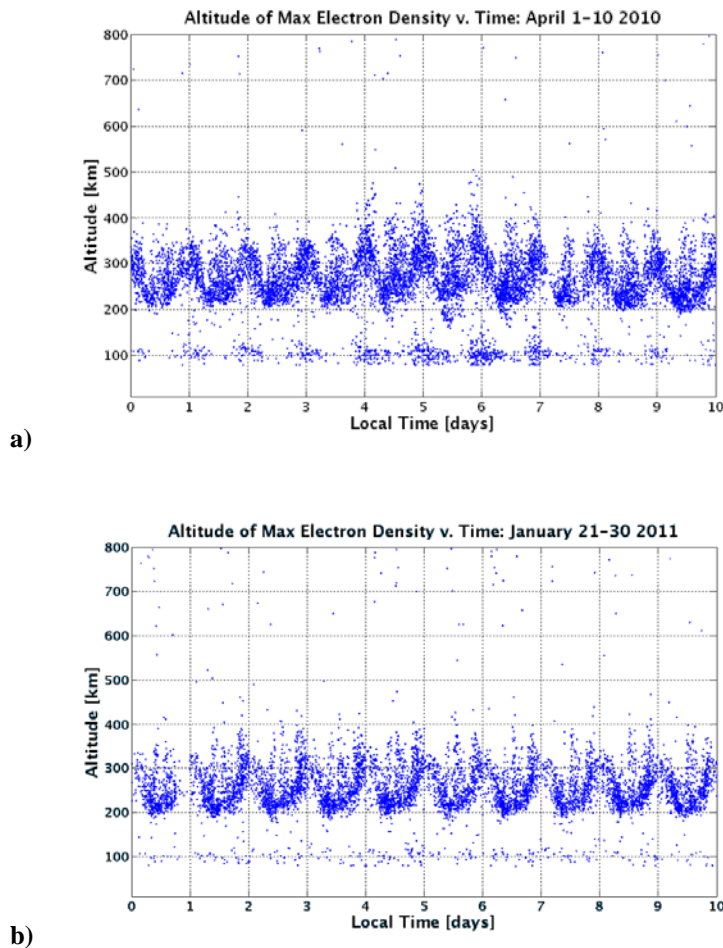
geographic latitude using the IDL TRI_SURF.PRO subroutine. Finally, electron density along the ISS orbit track is extracted from the gridded data to generate the COSMIC estimate of the electron density along the ISS orbit. Because COSMIC data is not necessarily located exactly on the ISS orbit track, the interpolation process produces an estimate for electron density measurements of ISS at a particular point in space and time.

Because COSMIC samples over a large range of altitudes, the electron density data can be used to model environments for other satellites in addition to ISS. The IDL program developed for this study is general and versatile enough for the use of other spacecraft environments in varying orbits. The only variables that are specific to the spacecraft are the ephemeris files and plot labels.

IV. Results and Analysis

The interpolated COSMIC electron density values for the ISS are the foundation for development of the secondary FPMU data source. The electron densities are compiled and plotted using the original IDL program introduced in the Interpolation Program sub section. Comparisons between COSMIC and FPMU electron density data produce results that spur an investigation of FPMU electron density data. The FPMU electron density data is found to be less exact than the corresponding ion density measurements.

A. Electron Density Comparison

To visualize the interpolated electron density data, preliminary plots of an electron density contour surface at ISS altitudes are produced. The ISS orbit track is mapped on top of this surface. See Fig. 6.

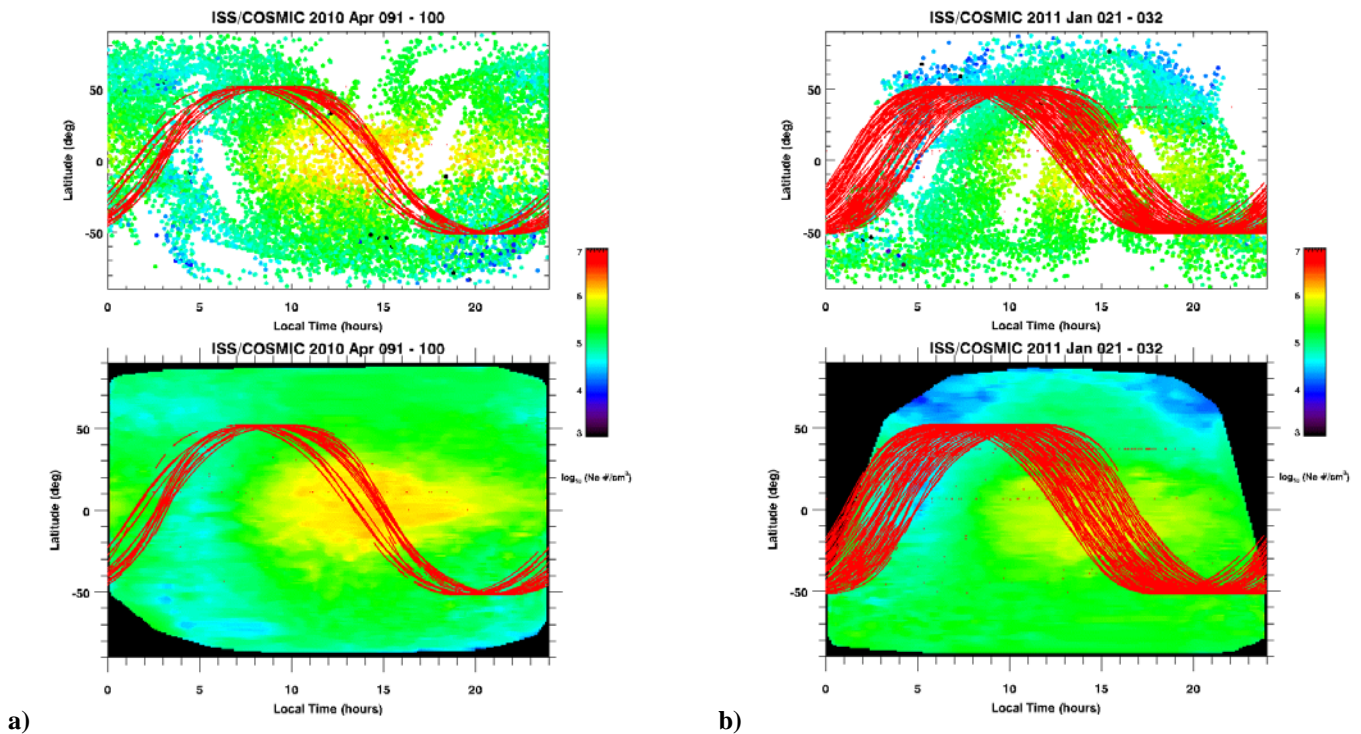a)   b)

Figure 6. Electron density data over all Earth latitudes as data points (top) and as a smoothed surface (bottom): a) April 1-10, 2010, b) January 21-30, 2011. *The ISS orbit track is overlaid in red. In the January 2011 plots, holes of very low electron densities in high northern latitudes are evident. This is an effect caused by the time of year. In January, the northern polar region is in darkness throughout the day thus causing electron density depletions in the ionosphere. Latitudes near the equator harbor higher electron density measurements around noon local time as a result of direct sunlight exposure. Figure production: IDL*

Gaps in the orbit tracks in Fig. 6a and 6b (top image) are the result of unavailable ground communication in a particular area while gaps in the electron density measurements are due to the restricted coverage area of the COSMIC constellation. The areas of missing data affect the ability to provide COSMIC data along the ISS orbit

with varying degrees depending on the exact location of ISS relative to the areas of poor COSMIC data coverage. If the ISS orbit is directly in the path of the data holes, COSMIC data will not be able to add to the FPMU measurements. However, FPMU can be used to fill in some of these data gaps thus returning the favor by supplementing COSMIC data. These results continue to improve the COSMIC data validity by providing visible evidence of the polar electron density depletions due to the season as well as high noon-time equatorial electron density magnitudes. These effects are already known and understood, thus adding credence to the COSMIC data's capabilities in space environmental modeling

When the COSMIC electron densities are presented in a scatter plot over local time, it is found to track well with the original FPMU data from each time period. The peak in the electron density magnitude can be seen around noon local time for both sets of data which corresponds well with electron density behavior discussed in the Methodology section. See Fig. 7.
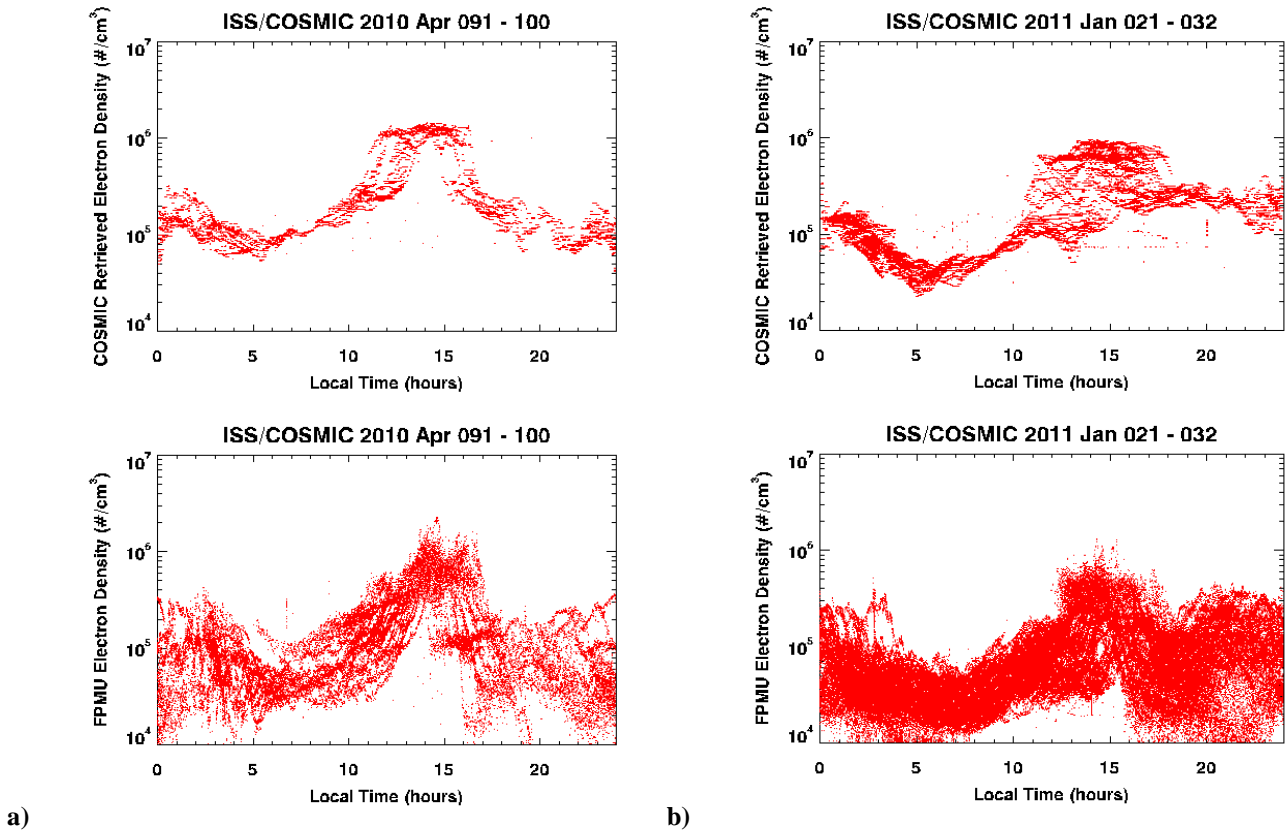

a)   b)

Figure 7. COSMIC electron density data (top) compared with FPMU electron density data (bottom): a) April 1-10, 2010, b) January 21-30, 2011. *The COSMIC electron density data corresponds well with the original FPMU electron density data which verifies COSMIC's worth as a secondary electron density source for ISS. Figure production: IDL*
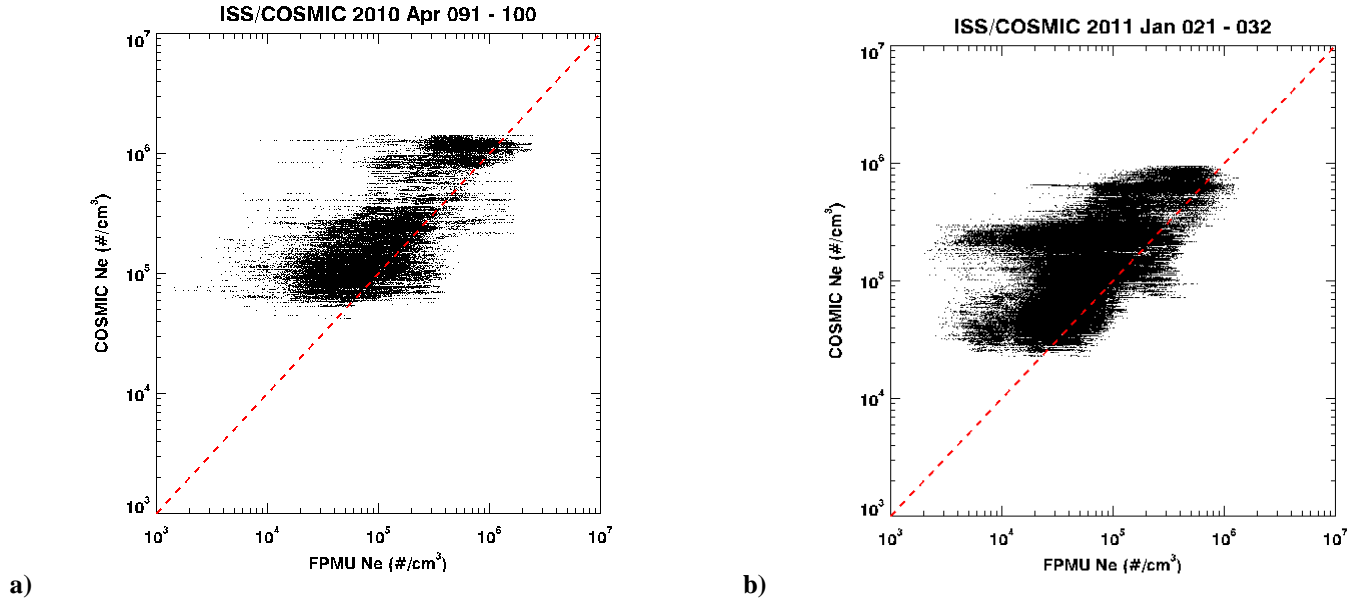
Figure 8. 1:1 Correlations Plots: COSMIC v. FPMU. *Figure production: IDL*

B. Ion Density Comparison

The correlation comparison between COSMIC and FPMU data results in a less than satisfactory correlation. See Fig. 8. For both time periods, COSMIC electron densities do not correlate with FPMU electron densities. This indicates that there are possible inconsistencies in one or both of the data sets. It is recommended that the FPMU team inspect the FPMU electron density data. Preliminary investigations have yielded possible inconsistencies in FPMU electron density measurements when compared with the FPMU ion density measurements. Because neutral plasma is characteristic of the ionosphere and consequently of the ISS space environment, it can be assumed that there are equal numbers of electrons as ions. Therefore, it is expected that FPMU ion densities compared with COSMIC electron densities would yield the same results as when comparing the FPMU electron densities with COSMIC electron densities. However, when the ion density parameters are added to the IDL program and checked for consistency in correlation plots, the results clearly show that the COSMIC electron density measurements correlate much better with FPMU ion density measurements than FPMU electron densities. See Fig. 9 for correlation plots from January 21-30, 2011.
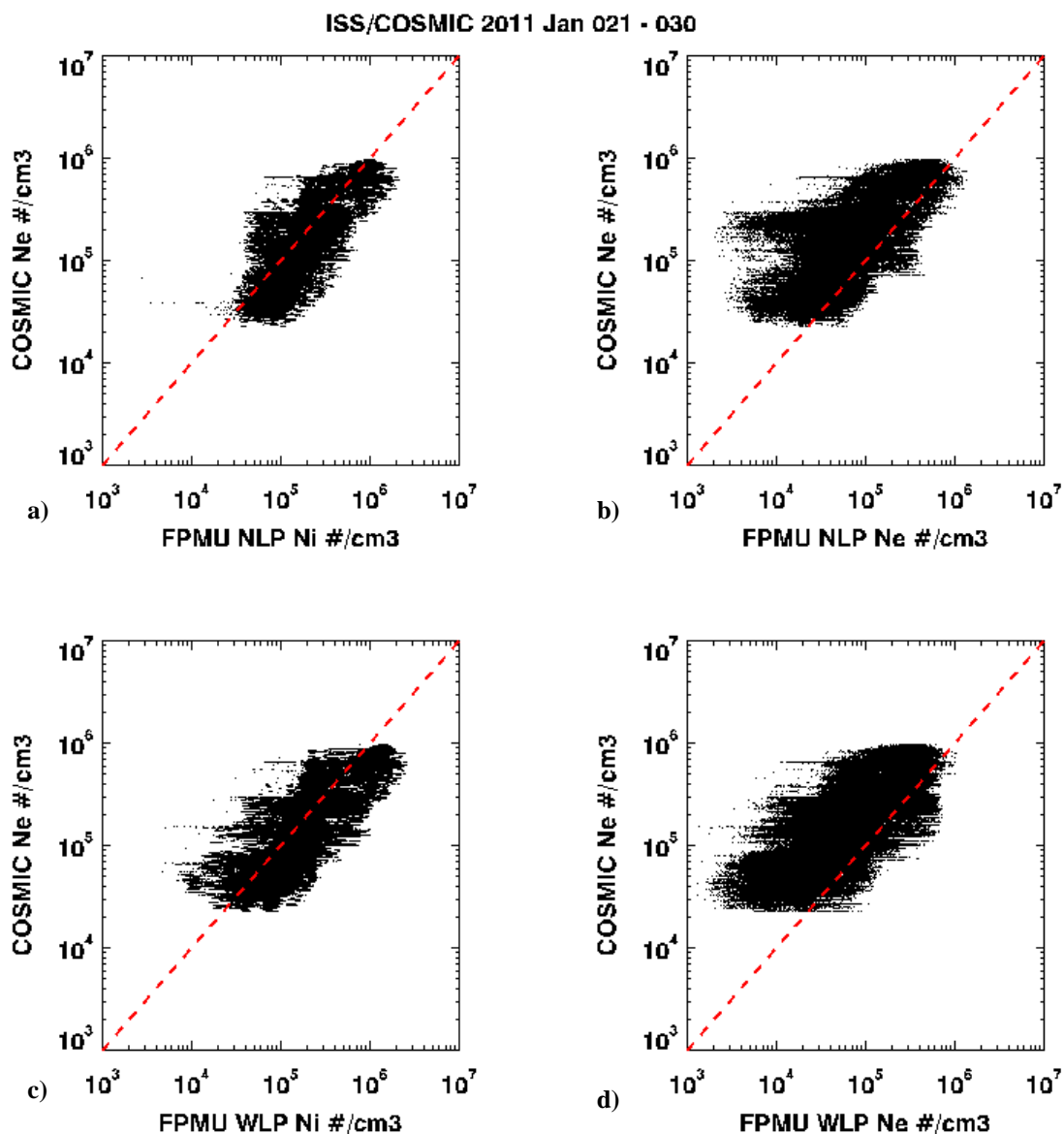
Figure 9. Correlations Plots: January 21-30, 2011. *Fig. 9b and Fig. 9d are the original comparisons between FPMU and COSMIC electron densities except b) used data from FPMU NLP and d) uses data from FPMU WLP. Fig. 9a and Fig. 9c are the comparisons between FPMU ion densities and COSMIC electron densities with a) using data from NLP and c) using data from WLP. Figure production: IDL*

Upon further inspection of Fig. 9, it is noted that the best correlation is represented in Fig. 9c which compares FPMU WLP ion densities with COSMIC electron densities. Although the comparison of FPMU NLP ion densities with COSMIC electron densities (Fig. 9c) yields a relatively good comparison, it is not as precise as Fig. 9a. As a secondary result, the WLP probe on FPMU produces the best samples for this study. It is recommended that the electron density data from FPMU is analyzed for potential contamination. While the discrepancies are being dealt with, the best comparison for the secondary ISS electron density tool (COSMIC data) is FPMU WLP ion density measurements.

Further discussions with the FPMU team (K. Wright, personal communication, 2011) provided an explanation for these observations. The densities derived from the ion saturation region of the WLP I-V curve are the best measurements due to the "tricky" nature of deriving densities from the electron saturation region of the curve. He suggested calibrating the Ne values to the Ni values and only utilizing the space potential points to derive densities when the ion saturation current is very low. This could eliminate the problem of faulty electron density values. The problem with the Ne values is that they are dependent on the voltage dependent current collection area of the Langmuir probes which is not adequately treated by the current analysis routines used by the FPMU team. Since the ionosphere is quasi-neutral, measurement of the plasma density from the ion saturation region of the WLP instrument provides the best measurement of the plasma density (and therefore electron density) from the FPMU instrument, consistent with the findings in this work.

V. Conclusions

The COSMIC data has proven to be a satisfactory candidate for a secondary ISS electron density tool. Preliminary plots comparing COSMIC electron densities with FPMU electron densities displayed similar results while understanding that FPMU electron density measurements may be skewed. The discovery that FPMU ion density measurements rather than FPMU electron density measurements are more suited to comparison with COSMIC data is a secondary result of this study but no less important. COSMIC data has uncovered several discrepancies with the data produced by primary electron density detector, FPMU, onboard the ISS. With this new information uncovered, the FPMU team can now reassess FPMU's functionality and prevent any further distribution of inaccurate data. Environmental modeling for spacecraft, especially for a spacecraft that is a base for human activity, is paramount for successful operation.

Perhaps the major strength of the COSMIC data is that it is an incredibly versatile source that can be applied to many other orbits and missions. Although there are other instruments independent of the COSMIC constellation in place to measure electron density and other space environment parameters, large databases such as the one COSMIC offers allows for a more comprehensive understanding of LEO environments and also can act as a calibration tool for other devices as was the case with FPMU.

Acknowledgements

References

[1]Wright, K. H., Swenson, C. M., Thompson, D. C., Barjatya, Aroh, Koontz, S. L., Schneider, T.A, Vaughn, J. A., Minow, J. I., Craven, P.D., Coffey, V. N., Parker, L. N., and Bui, T. H., "Charging of the International Space Station as Observed by the Floating Potential Measurement Unit: Initial Results," *IEE Transactions on Plasma Science*, Vol. 36, No. 5, 2008, pp. 2280-2293.

[2]Barjatya, A., Swenson, C. M., Thompson, D. C., and Wright, Jr., K. H., "Invited Article: Data analysis of the Floating Potential Measurement Unit aboard the International Space Station," *Review of Scientific Instruments*, 80, 041301, 2009.

[3]Fong, C., Yen, N. L., Chu, C., Yang, S., Shiau, W., Huang, C., Chi, S., Chen, S., Liou, Y., and Kuo, Y, "FORMOSSAT-3/COSMIC Spacecraft Constellation System, Mission Results, and Prospect for Follow-On Mission," *Terr. Atmos. Ocean. Sci.,* Vol. 20, No. 1, 2009, pp. 1-19.

[4]"CDAAC Data Access," *Constellation Observing System for Meteorology Ionosphere and Climate* [online database], URL: http://www.cosmic.ucar.edu/ [cited 27 July 2011].

[5]*Space Physics Interactive Data Resource* [online database], URL: http://spidr.ngdc.noaa.gov/spidr/ [cited 27 July 2011]
[6]*NOAA/Space Weather Prediction Center*, URL: http://www.swpc.noaa.gov/info/Kindex.html [cited 27 July 2011]

MODELING IONOSPHERE ENVIRONMENTS
Creating an ISS Electron Density Tool

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Mentor: Dr. Joseph Minow EV44, Natural Environments Branch

ABSTRACT

The International Space Station (ISS) maintains an altitude typically between 300 km and 400 km in low Earth orbit (LEO) which itself is situated in the Earth's ionosphere. The ionosphere is a region of partially ionized gas (plasma) formed by the photoionization of neutral atoms and molecules in the upper atmosphere of Earth. It is important to understand what electron density the spacecraft is/will be operating in because the ionized gas along the ISS orbit interacts with the electrical power system resulting in charging of the vehicle. One instrument that is already operational onboard the ISS with a goal of monitoring electron density, electron temperature, and ISS floating potential is the Floating Potential Measurement Unit (FPMU). Although this tool is a valuable addition to the ISS, there are limitations concerning the data collection periods. The FPMU uses the Ku band communication frequency to transmit data from orbit. Use of this band for FPMU data runs is often terminated due to necessary observation of Extravehicular Activities (EVAs) and other operations on ISS. Thus, large gaps are present in FPMU data. The purpose of this study is to solve the issue of missing environmental data by implementing a secondary electron density data source, derived from the COSMIC satellite constellation, to create a model of ISS orbital environments. Extrapolating data specific to ISS orbital altitudes, we model the ionospheric electron density along the ISS orbit track to supply a set of data when the FPMU is unavailable. This computer model also provides an additional new source of electron density data that is used to confirm FPMU is operating correctly and supplements the original environmental data taken by FPMU.

BACKGROUND

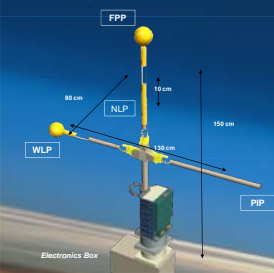### I. Floating Potential Measurement Unit (FPMU)

Figure 1 (above): Drawing of FPMU showing the four probes and electronics box which is bolted onto ISS.

Purpose
• Provide data to validate ISS Plasma Interaction Model (PIM)
• Characterize charging effects on ISS
• Support EVA plasma hazard reduction projects

Operational Elements
• FPP: Floating Potential Probe
• WLP: Wide-sweep Langmuir Probe
• NLP: Narrow-sweep Langmuir Probe
• PIP: Plasma Impedance Probe

Limitations
• No data collection during EVAs and other operational activities

Significance to Study
• Primary source of in situ environmental characteristics measurements
• Not 100% operational
• Need a backup source that measures same variables as FPMU

II. Constellation Observing System for Meteorology Ionosphere and Climate (COSMIC) *study data source

Purpose
• Mission focuses on terrestrial weather and climate, space weather, and geodetic research
• Joint effort between United States and Taiwan
• Data obtained from satellites is downloaded every orbit by NOAA TT&C stations
• Use electron density profiles and related data for model

Operational Elements
• Constellation of 6 satellites
• Orbital altitude of 800 km
• Orbital inclination of ± 80° latitude
• GPS radio occultation receiver
• Tiny Ionospheric Photometer (TIP)
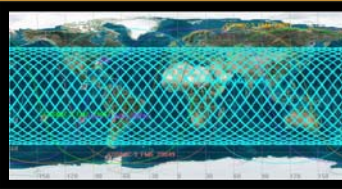• Tri Band Beacon (TBB)

Figure 2: Orbital pathways of all six COSMIC satellites as well as the ISS. ISS orbit was traced over approximately a six day interval starting April 1, 2010 and going through 21 hr 20 min 00 sec April 5, 2010. Figure production: Satellite Tool Kit

OBJECTIVES

I. Design a secondary ionosphere environment model independent of Ku band frequency and able to fill in missing data from FPMU

Secondary Objectives
• Confirm FPMU is operating correctly
• Supplements original FPMU data

Materials
• COSMIC electron density profiles
• ISS ephemeris data
• Programming software (MATLAB, IDL)
• Satellite Tool Kit
• FPMU data for comparison

METHODS

I. Time Intervals : High Geomagnetic Activity v. Calm Geomagnetic Conditions

April 1-10, 2010 (days 091-100)
• Above average geomagnetic activity
• Large geomagnetic storm: April 5
• Small amount of FPMU data available

January 21-30, 2011 (days 021-030)
• Calm geomagnetic period
• Suited for comparison with more active period
• Good FPMU data coverage

Significance of Contrasting Time Intervals

• Verify that COSMIC data is sound by showing variations in electron density profiles and plots due to geomagnetic storms or lack thereof

• Provides interesting insight into how electron density is affected by geomagnetic storm periods

II. MATLAB: COSMIC Data Download

• Used to become familiar with electron density variation in the ionosphere
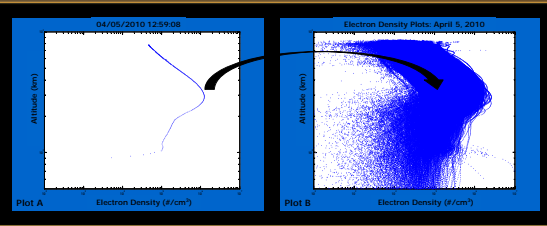

Figure 3 (above): Plot A displays a single electron density profile derived from the COSMIC electron density data taken on April 5, 2010 at 12 hr 59 min 08 sec. The bowed shape of the curve clearly exposes the magnitude of the maximum electron density and the corresponding altitude.
Plot B displays all electron density profiles for an entire day thus giving an idea of electron density fluctuations throughout a 24 hour period.
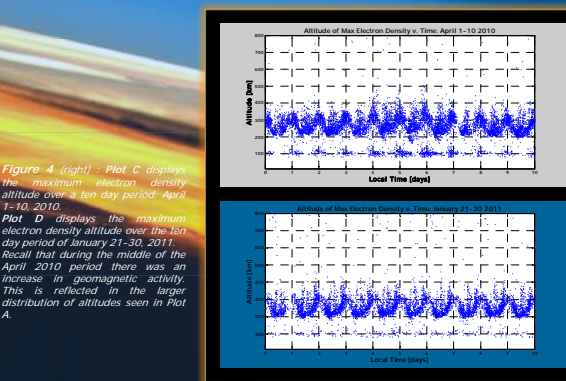

Figure 4 (right) : Plot C displays the maximum electron density altitude over a ten day period: April 1-10, 2010.
Plot D displays the maximum electron density altitude over the ten day period of January 21-30, 2011. Recall that during the middle of the April 2010 period there was an increase in geomagnetic activity. This is reflected in the larger distribution of altitudes seen in Plot A.

III. IDL: Interpolation Program

• Download COSMIC data and ISS ephemeris files

• Run program that interpolates COSMIC data along ISS orbits to produce FPMU-like electron density v. local time plots

• Primary tool to reach objective

Figure 5: Orbital path of ISS around Earth and location of ISS on April 5, 2010 at 20 hr 00 min 00 sec. Extrapolation of COSMIC data along this orbit requires using electron density measurements taken near ISS orbit to predict electron densities directly along the orbital path. Figure Production: AGI Viewer 9

RESULTS

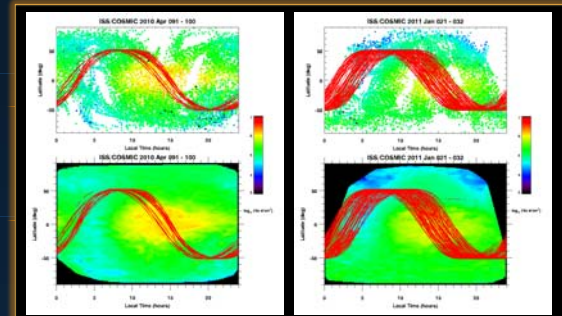### I. ISS Orbit with Electron Density Contour Surface

Figure 6 (above): Plot E displays electron density data points with varying degrees of magnitude across all Earth latitudes with the ISS orbital path during the period of April 1-10, 2010 overlaid. Plot F displays the electron density data as a smooth surface with the ISS orbit overlaid once again.
Plot G correlates with Plot E and Plot H correlates with Plot F except the target period for G and H is January 21-30, 2011.

II. Electron Density Values v. Local Time: FPMU/COSMIC Comparison

CONCLUSIONS
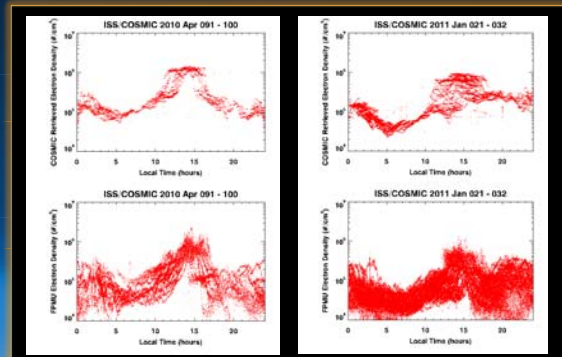
Summary
• COSMIC electron density data generally consistent with FPMU (see Figure 7)
• Secondary ISS Electron Density Tool successfully developed
• General code can be used to model any satellite environment in Earth orbit

Continuing Work
• Figure 8 shows there are slight discrepancies between COSMIC and FPMU electron densities
• If ion densities are tested, find that these discrepancies are no longer present
• FPMU could potentially have corrupt data--recommended FPMU team look into this further

Figure 8: Comparison of COSMIC electron density data (Ne) with FPMU electron density data . The data is not centered on the 1:1 dashed line indicating inconsistencies in one or both data sources.

REFERENCES