



Validation of Ionospheric Measurements from the International Space Station (ISS)

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Introduction

The International Space Station orbit provides an ideal platform for in-situ studies of space weather effects on the mid and low-latitude F-2 region ionosphere. The Floating Potential Measurement Unit (FPMU) operating on the ISS since Aug 2006, is a suite of plasma instruments: a Floating Potential Probe (FPP), a Plasma Impedance Probe (PIP), a Wide-sweep Langmuir Probe (WLP), and a Narrow-sweep Langmuir Probe (NLP). This instrument package provides a new opportunity for collaborative multi-instrument studies of the F-region ionosphere during both quiet and disturbed periods. This presentation first describes the operational parameters for each of the FPMU probes and shows examples of an intra-instrument validation. We then show comparisons with the plasma density and temperature measurements derived from the TIMED GUVI ultraviolet imager, the Millstone Hill ground based incoherent scatter radar, and DIAS digisondes. Finally we show one of several observations of night-time equatorial density holes demonstrating the capabilities of the probes for monitoring mid and low latitude plasma processes.



Figure 1. FPMU deployed on the ISS starboard S1 truss.

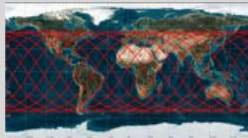


Figure 2. Typical ISS ground track.

Configuration, Measurement Parameters

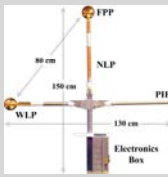


Figure 3. FPMU layout (Wright et al., 2008)

Sensor	Measured Parameter	Rate (Hz)	Effective Range
FPP	V_f	128	-180 to +180 V
WLP	N T_e V_e	1	10^{16} to $5 \cdot 10^{17} \text{ m}^{-3}$ 600 to 10,000 K -20 to 80 V
NLP	N T_e V_e	1	10^{16} to $5 \cdot 10^{17} \text{ m}^{-3}$ 600 to 10,000 K -180 to +180 V
PIP	N	1	$1 \cdot 10^{16}$ to $4 \cdot 10^{17} \text{ m}^{-3}$

Table 1. Measured parameters, rates, and effective ranges for the FPMU.

The FPMU operation is autonomous with either an on or off state. The only control is over the operation of a heater in the WLP. It is mounted to a camera port with data transmitted via the Ku-band. The camera interface allows for high bandwidth ~ 6,776 12-bit words each second.

Probe Description

FPP – Floating Potential Probe - gold-plated sphere of radius 5.08 cm isolated from chassis ground. 'Floats' at a potential within a few kTe of the plasma potential providing a reference for measuring the ISS potential.

PIP – Plasma Impedance Probe - a short dipole antenna electrically isolated from the ISS that measures the electrical impedance at 256 steps from 100 KHz to 20 MHz in one second. Electron density derived from upper hybrid frequency.

WLP – Wide Sweep Langmuir Probe – gold plated cylinder of radius 5.08 cm. Performs a 2,048-point voltage sweep from -20 V to 80 V relative to chassis ground. Two different voltage step sizes (25 mV and 250 mV) are used. An internal heater allows surface cleaning.

NLP – Narrow Sweep Langmuir Probe - a gold-plated cylinder with collector radius 1.43 cm and length 5.08 cm. Performs a voltage sweep from -4.85 V to +4.85 V about a reference potential determined by the FPP. A constant voltage step size of 12 mV is used.

Intra-Probe Data Comparison

seconds. The collected current is measured with two gains. Figures 4 summarize FPMU data for orbit day 2007/062. The top panel contains floating potential measurements from the FPP, WLP, and NLP. The ISS charges negative with respect to the plasma (graphed as a positive number here). Numbered labels for this panel are annotated on the right. The middle panel shows the density derived from the PIP, WLP, and NLP. The bottom panel shows the electron temperature derived from the WLP and NLP (expanded from Wright et al. 2008).

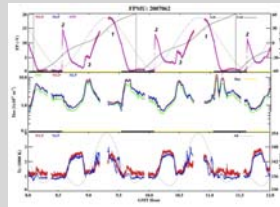


Figure 4. Sample data from each of the FPMU four probes from 2007/062.

- Call outs for top panel
1. $(V_e \times B) \cdot L$
 2. eclipse exit, solar array driven charging
 3. equatorial noon, charging also caused by biased solar arrays.

FPMU Operation Record

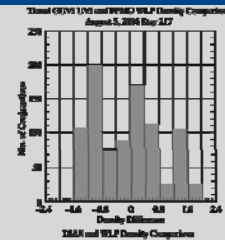
Approx. GMT Duration	Calendar Days	Approx. GMT Duration	Calendar Days
215:22.30 - 220:14.30	Aug 3 - 8, 2006	023:23.45 - 031:16.00	Jan 22 - Feb 6, 2008
022:19.15 - 031:00.00	Jan 22 - 30, 2007	067:16.57 - 074:22.28	Mar 7 - 14
060:12.00 - 063:00.00	Mar 1 - 3	086:00.00 - 088:23.57	Mar 26 - 28
083:12.00 - 084:12.00	Apr 13 - 14	099:13.30 - 101:09.32	Apr 8 - 10
123:00.23 - 124:00.00	May 3	126:23.42 - 131:01.05	May 4 - 10
165:10.23 - 169:04.00	Jun 14 - 18	141:01.06 - 153:23.52	May 20 - Jun 1
187:03.47 - 191:00.00	Jul 6 - 9	170:23.56 - 173:00.00	Jun 18 - 21
243:13.00 - 247:03.00	Sep 10 - 14	225:00.14 - 228:00.30	Aug 12 - 16
301:18.10 - 307:02.00	Oct 28 - Nov 3	233:00.26 - 236:23.54	Aug 19 - 23
312:05.52 - 312:10.33	Nov 8	238:23.45 - 243:00.01	Aug 25 - 30
324:22.35 - 327:19.05	Nov 20 - 23	246:14.06 - 250:00.02	Sep 4 - 6
354:14.56 - 355:23.53	Dec 20 - 21	253:00.03 - 255:06.44	Sep 9 - 11
		260:18.37 - 269:23.31	Sep 25
		276:23.24 - 308:17.50	Oct 2 - Nov 4

Table 2. Operation dates of FPMU instrument suite.

Independent Data Verification

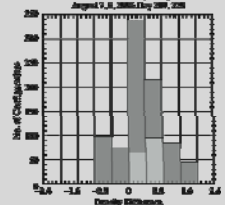
The density and temperatures derived from the WLP and NLP Langmuir probes were compared to measurements from the incoherent scatter radar (ISR) at Millstone Hill, the European Digital Upper Atmosphere Server (DIAS) digisondes, and the TIMED Global Ultraviolet Imager (GUVI). Histograms of the differences between the WLP and the instrument measurements are shown. Difference = subtraction/mean of the two measurements to provide an even weighting (Coffey et al. 2008).

Data Verification - Densities



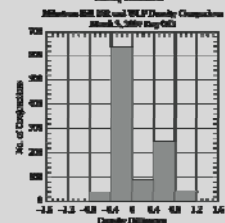
TIMED GUVI Ultraviolet Imager

Figure 5. Histogram of difference in densities between TIMED GUVI and WLP on 2006/217. Conjunction area ± 15 min, $\pm 12^\circ$ lat, $\pm 24^\circ$ lon and ± 50 km. Future conjunction areas will be smaller.



DIAS Digisondes

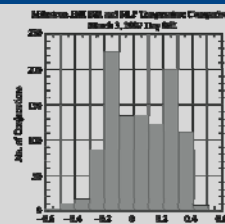
Figure 6. Histogram of difference in densities between DIAS digisondes and WLP on several days in 2006. Conjunction area ± 30 min, $\pm 1^\circ$ lat, $\pm 1^\circ$ lon and ± 25 km.



Millstone Hill Incoherent Scatter Radar

Figure 7. Histogram of difference in densities between Millstone Hill ISR and WLP on 2007/062. Conjunction area ± 15 min, $\pm 12^\circ$ lat, $\pm 24^\circ$ lon and ± 75 km.

Data Verification - Temperatures



Millstone Hill Incoherent Scatter Radar

Figure 8. Histogram of difference in temperatures between Millstone Hill ISR and NLP on 2007/062. Conjunction area ± 15 min, $\pm 12^\circ$ lat, $\pm 24^\circ$ lon and ± 75 km.

Observations of Nighttime Equatorial Holes

Since operation, the FPMU three plasma probes have observed several nighttime equatorial holes extending to densities below $1 \times 10^{16} \text{ m}^{-3}$. Figure 9 shows examples of deep density depletions during active geomagnetic conditions occurring on March 9, 2008. This data is consistent with Martinis et al. (2005) which suggests a linkage between equatorial spread F onset and the behavior of IMF B_z and IEF E_{SW} : equatorial ionospheric irregularities appear after large and consistent southward excursions in the IMF B_z (enhanced E_{SW}).

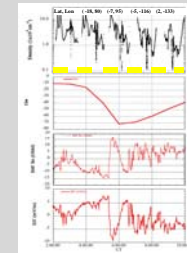


Figure 9. Several equatorial density holes observed sequentially by the WLP on March 9, 2008, day 069 during active geomagnetic conditions.

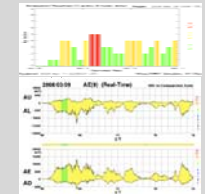


Figure 10. Kp, and auroral electrojet activity indices for March 9, 2008, Day 069.

Summary and Future Operations

Since August 2006, the FPMU has been operated during several data campaigns and is providing measurements of the local ionospheric plasma and floating potential of the ISS. Potential science goals of interest to the I-T community that could be addressed by the FPMU include:

- Spread-F density perturbations - Motion of light ion troughs and plasmopause boundary during geomagnetic storms.
- Storm time variations of density and temperatures in equatorial anomaly regions.
- Low and mid-latitude collaborative studies with ground based remote sensing (ISR, ionosonde) and space based in-situ (C/NOFS, CHAMP, COSMIC, GPS ionospheric tomography) sensors.
- Validation of real-time ionospheric forecast models (GAIM, etc.)
- Interaction of large vehicles with ionospheric plasma.

References, Acknowledgements

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Wright K. H., Jr., C.M. Swenson, D. Thompson, A. Barjatya, S.L. Koontz, T. Schneider, J. Vaughn, J. L. Minow, P. Craven, V. Coffey, L. N. Parker, and T. Bul. Charging of the International Space Station as Observed by the Floating Potential Measurement Unit: Initial Results, IEEE-Transactions on Plasma Science, 2008.

Coffey V. N., J. L. Minow, T. Schneider, J. Vaughn, P. Craven, K. Wright, Jr., L. N. Parker, T. Bul, and S. L. Koontz. Validation of the Plasma Densities and Temperatures from the ISS Floating Potential Measurement Unit, IEEE-Transactions on Plasma Science, 2008.

Martinis C. R., M. J. Mendillo, and J. Aarons. Toward a synthesis of Equatorial Spread F Onset and suppression during geomagnetic storms. J. Geophys. Res., 110, A07036, doi: 10.1029/2003JA010362, 2008.