In-Situ F2-Region Plasma Density and Temperature Measurements from the International Space Station

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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 F2 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 in-situ measurement.

Then, we 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 located on the ISS stacker 63 days.

Figure 2: Typical ISS ground track.

Probe Description
FPP - a gold-plated sphere of radius 5.08 cm isolated from chassis ground by approximately 10−4 Ω. FPP - a short dipole antenna electrically isolated from the ISS that measures the electrical impedance at 266 steps from 100 Hz to 20 MHz. In one second and tracks the UHF resonance at 512 Hz. WLP - a gold-plated sphere of radius 5.08 cm that performs a 2.054-V voltage sweep from −20 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 - a gold-plated cylinder with radius 1.43 cm and length 5.08 cm that performs a 2-volt-point 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.

For each Langmuir probe, the voltage varies from low to high over one second and from high to low the next second with the collected current measured in two gain channels.

Sample Data

Figure 4 summarizes FPMU data for orbit day 2007062. 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). The middle panel shows the density derived from the FPP, WLP, and NLP. The bottom panel shows the electron temperature derived from the WLP and NLP (Wright et al., 2008).

Figure 5: Sample data from each of the FPMU four probes from 20070620.

Table 1: Measured parameters, units, and orders of magnitude changes for the FPMU.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Order of Magnitude Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>FPP</td>
<td>V</td>
<td>10−6 − 10−5</td>
</tr>
<tr>
<td>WLP</td>
<td>V</td>
<td>10−3 − 10−2</td>
</tr>
<tr>
<td>NLP</td>
<td>V</td>
<td>10−2 − 10−1</td>
</tr>
</tbody>
</table>

Table 2: Operation dates of FPMU instrument suite.

<table>
<thead>
<tr>
<th>Year</th>
<th>Month</th>
<th>Day</th>
<th>WLP</th>
<th>NLP</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>1</td>
<td>1</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>2007</td>
<td>2</td>
<td>1</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>2007</td>
<td>3</td>
<td>1</td>
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</tr>
<tr>
<td>2007</td>
<td>4</td>
<td>1</td>
<td>Yes</td>
<td>Yes</td>
</tr>
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</table>

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 Atmospheric Server (DIAS) digisondes, and the TIMED Global Ultraviolet Imager (GUVI). Differences between the WLP and these instruments are given below where the difference = difference/average of the two measurements. (Coffee et al., 2006).

Figure 6: Sample data from each of the FPMU four probes from 20070620.

Figure 7: Difference in temperature between WLP on Jun 1 and Jun 2007.

Figure 8: Difference in density between WLP and NLP.

Figure 9: Difference in temperature between WLP and NLP.

Figure 10: Observation of nighttime equatorial holes.

Data Verification - Densities

Table 3: Comparison of plasma density and temperatures derived from the FPMU and DIAS.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>FPMU</th>
<th>DIAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>10−9 cm−3</td>
<td>1.14</td>
<td>1.22</td>
</tr>
<tr>
<td>Temperature</td>
<td>K</td>
<td>40</td>
<td>45</td>
</tr>
</tbody>
</table>

Observations of Nighttime Equatorial Holes

Since operation started in 2006, the FPMU plasma probes, WLP, NLP, and PIP have observed several nighttime equatorial holes extending to densities below 1x10−9 cm−3. Figure 9 below shows continuous examples of deep density cavities during active geomagnetic conditions occurring on March 9, 2006. Panels in Figure 10 present the geomagnetic indices for this day.

Figure 11: Observation of nighttime equatorial holes.

Summary and Future Operations

Since August 2006, the FPMU has been operated during several data sessions and is meeting its primary requirement of providing floating potential measurements of the ISS and its secondary requirement of providing measurements of the local ionospheric plasma. It will continue to operate during intermittent data campaigns at least through 2006 and possibly through 2010. Potential science goals of interest to the I-T community that could be addressed by the FPMU include:

- Studying F density perturbations, "Motion of light ion troughs and plasmapause boundary during geomagnetic storms.
- Storm time variations of density and temperatures in equatorial anomaly regions.
- Electron temperature and density associated with sub-auroral ion drift (SAID) regions.
- Electron temperatures in stable auroral red (SAR) arcs. Collaboration studies with ground based remote sensing (ISR, ionosondos) and spaced based in-situ (CEOS, CHAMP, COSMIC, GPS) ionospheric (tomography) sensors.
- Validation of real-time ionospheric forecast models (SAIM, etc.)
- Interaction of large vehicles with ionospheric plasma.

References, Acknowledgments
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Figure 12: Observation of nighttime equatorial holes.

Figure 13: Observation of nighttime equatorial holes.

Figure 14: Observation of nighttime equatorial holes.

Figure 15: Observation of nighttime equatorial holes.