Coordinated Space-Based Observations of Equatorial Plasma Bubbles Using TIMED/GUVI and DMSP

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GUVI/SSUSI Disk Imaging

Limb Scan

Cross-track scan perpendicular to orbit

74°/98° Inclination
GUVI/SSUSI Disk Imaging

Equatorial arcs

Equatorial Plasma Bubbles (EPB)

Limb Scan

GUVI 1356 Å

Cross-track scan perpendicular to orbit

74°/98° Inclination

Disk Scan

Equatorial arcs
Goal: Recover Altitude Information from LEO Disk Images

- Algorithm for tomographically reconstructing multi-dimensional ionospheric electron density profiles from GUVI (or SSUSI) disk observations
- Statistical inversion of discrete forward model of UV brightness from ionospheric electron density

Tasks for the CEDAR Postdoc Award

<table>
<thead>
<tr>
<th>Year</th>
<th>Task</th>
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</thead>
<tbody>
<tr>
<td>Jan-June 2007</td>
<td>Automated Bubble Detection Algorithm</td>
</tr>
<tr>
<td></td>
<td>Midlatitude hmF2/NmF2 Retrievals</td>
</tr>
<tr>
<td>July-Dec. 2007</td>
<td>GUVI EPB Climatology</td>
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<tr>
<td></td>
<td>SSUSI F16/F17 EPB Imaging</td>
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<tr>
<td>2008</td>
<td>SSUSI/GUVI Coordinated Observations</td>
</tr>
<tr>
<td></td>
<td>EPB Prediction/Growth Studies</td>
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</table>
Tomographic Reconstruction of $n_e$

- 3-D section of ionosphere along orbit path
- Assume invariance along field lines for that segment
- Distinct overlapping scans with respect to altitude vs. longitude profile allow for tomography

$$I_{1356} \sim \int n_e^2$$
EPB Observations at Conjugate Locations

- Compares with GUVI summary image
- Location and width of bubble
- Structure consistent along field lines
Bubble Structures Seen by GUVI

- Multiple bubble structures, 40 km longitudinal resolution
- Bifurcated structure seen with secondary instability
Cornell Narrow Field Imager Comparison

• Comparison with 7774 Å ground-based imager
• Reconstructed image shows excellent agreement with the CNFI image
• Westward tilt, overall shape, and bubble width all agree

Reconstructed image for 2002 day 265

Hawaii imager data for 2002 day 265

Courtesy of M. Kelley (Cornell) & J. Makela (UIUC)
Automated EIA and EPB Detection

- SVD analysis identifies EIA peaks and separates bubbles from background
- Inversions run at North and South EIA peaks

[from Henderson 2006]
Implications for EPB Science

- Observations of separation, symmetry, and density of EIA peaks
- Long-term observations contribute to plasma bubble climatology
- Characterization of bubble structures

### Atlantic Longitudes

<table>
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<tr>
<th></th>
<th>Summer</th>
<th>Equinox</th>
<th>Winter</th>
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<tbody>
<tr>
<td>Total Instances</td>
<td>47</td>
<td>90</td>
<td>68</td>
</tr>
<tr>
<td># of Bubbles</td>
<td>5</td>
<td>48</td>
<td>42</td>
</tr>
<tr>
<td># of Nonbubbles</td>
<td>42</td>
<td>42</td>
<td>26</td>
</tr>
<tr>
<td>% Occurrence</td>
<td>10.64%</td>
<td>53.33%</td>
<td>61.76%</td>
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### Indian Longitudes

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<tbody>
<tr>
<td>Total Instances</td>
<td>47</td>
<td>90</td>
<td>68</td>
</tr>
<tr>
<td># of Bubbles</td>
<td>6</td>
<td>44</td>
<td>28</td>
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<tr>
<td># of Nonbubbles</td>
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<td>40</td>
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<tr>
<td>% Occurrence</td>
<td>12.77%</td>
<td>48.89%</td>
<td>41.18%</td>
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### Pacific Longitudes

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<tbody>
<tr>
<td>Total Instances</td>
<td>47</td>
<td>90</td>
<td>68</td>
</tr>
<tr>
<td># of Bubbles</td>
<td>10</td>
<td>60</td>
<td>28</td>
</tr>
<tr>
<td># of Nonbubbles</td>
<td>37</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>% Occurrence</td>
<td>21.28%</td>
<td>66.67%</td>
<td>41.18%</td>
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Characterization of EPB

- No tilt: bubble recently formed
Characterization of EPB

- $n_m F_2 = 1.4 \times 10^6 \text{ cm}^{-3}$, $h_m F_2 = 380 \text{ km}$
Characterization of EPB

\[ \frac{\partial n}{\partial h} \approx 10^4 \text{ cm}^{-3}/\text{km for bottomside} \]
What’s Next?

• Long-term database of EPB reconstructions
• Climatological studies of EPB occurrence (extension to 2005-2007)
• Quantitative characterization of bubble structure
• Validation of hmF2, NmF2 with models (GAIM, IRI, etc.) and data
• Application of inversion technique to SSUSI data
• GUVI and SSUSI coordinated observations of EPBs
• More coordinated observations with ground-based instruments (radars, imagers, ionosondes)