Climatology and Characteristics of F Region Ionospheric Plasma Irregularities Observed by COSMIC Radio Occultation Receivers

Chris Watson¹, N. Pedatella²

¹COSMIC Program Office, University Corporation for Atmospheric Research, Boulder, CO, USA.
²High Altitude Observatory, National Center for Atmospheric Research, Boulder, CO, USA.
Irregularities in COSMIC RO TEC

- 1 Hz podTec files – Total Electron Content (TEC)

- Detrending the TEC reveals “medium scale” (~2-50 km) irregularities

- In general, perturbations in 1 Hz TEC are due to larger scale irregularities than those that directly cause scintillation of the GPS signal
Outline

• Analysis of 1 Hz COSMIC podTEC data for irregularity detection

• Development of irregularity database

• Climatology of irregularities
  • Solar terminator
  • Nighttime equatorial and mid-latitude regions
  • High Latitudes
Data and Method of Analysis

Quiet TEC:

Disturbed TEC:
Data and Method of Analysis

For each “TEC Structure” larger than 0.1 TECU in amplitude, we collect:

<table>
<thead>
<tr>
<th>Characteristics (units)</th>
<th>External Parameters</th>
<th>Tangent Point Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Amplitude (TECU)</td>
<td>• IMF Bx/By/Bz</td>
<td>• AACGM MLT/Lat</td>
</tr>
<tr>
<td>• Scale Size (km)</td>
<td>• SW Dynamic Pressure</td>
<td>• Geomagnetic MLT/Lat</td>
</tr>
<tr>
<td>• Vertical Gradient (TECU/km)</td>
<td>• M-I Coupling Rate</td>
<td>• Geographic Long/Lat/LT</td>
</tr>
<tr>
<td>• ROTI (TECU/km)</td>
<td>• Ap Index</td>
<td></td>
</tr>
<tr>
<td>• S4 index (Max, 9sec Average)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Ray path orientation (relative to geomagnetic field)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

• 4 years (2007-2008, 2012-2013) of data processed so far
Global - Summary of irregularity observations

![Graph showing irregularities observed per month from 2007-2008 and 2012-2013.]

- **a) Irregularities observed per month**
- **b) 1 Hz RO TEC observations per month**
- **c) Irregularities observed per 1 Hz TEC measurement**

![Graph showing daily F10.7 Solar Flux from 2007 to 2013.]

Daily F10.7 Solar Flux

- **Graph showing data from:**
  - 01/01/2007
  - 01/01/2009
  - 01/01/2011
  - 01/01/2013
Occurrence rate of Irregularities – Lower F region (120-250 km)
Examples of irregularities near solar terminator
Irregularity Occurrence Near Solar Terminator

**Dawn**

**May-July, 2012**

**Aug-Oct 2012 - Dawn Terminator Occurrence (120-250 km)**

**Dusk**

**May-July, 2012**

**Aug-Oct 2012 - Dusk Terminator Occurrence (120-250 km)**
Dusk Terminator Characteristics (Fall 2012)
Examples of nighttime equatorial irregularities (Kp < 2)
Occurrence of Nighttime Equatorial (-10 – 10 MLAT) Irregularities
Occurrence of Nighttime Equatorial (-10° to 10° MLAT) Irregularities

Equatorial Latitude (-10° to 10° MLAT) occurrence of F region irregularities

Winter (North) 07/08  Spring (North) 07/08  Summer (North) 07/08  Fall (North) 07/08

% Occurrence of Spread-F at Baguio, Philippines (5 deg MLAT) Ionosonde [Glover, 1960]

% OCCURRENCE OF SPREAD-F

1953-55  1956-58

0 10 20 30 40

LOCAL TIME

18 20 22 0 2 4 6 8

MLT (hours)

Altitude (km)

120 160 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 540 560 580 600

MLT (hours)

Winter (North) 12/13  Spring (North) 12/13  Summer (North) 12/13  Fall (North) 12/13

0
Characteristics of Nighttime Equatorial (-10 – 10 MLAT) Irregularities

Irregularity Amplitude

Equatorial (-10° to 10° MLat) Amplitude of F region irregularities

Irregularity Scale Size

Equatorial (-10° to 10° MLat) Scale Size of F region irregularities
Examples of nighttime mid-latitude irregularities (Kp < 2)
Occurrence of Nighttime Mid-Latitude (30 – 60 MLAT) Irregularities
High Altitude (400-700 km) Occurrence Rate

May-July

November - January
High Altitude (400-700 km) Amplitude

May - July

November - January
Occurrence Rate – AP Index

AP < 9

AP > 12

620-720 km

520-620 km

420-520 km

320-420 km

220-320 km

120-220 km
Summary and Ongoing Work

• COSMIC 1 Hz RO TEC provides global climatological picture of medium scale (~2-50 km) F region irregularities, as well as characteristics of irregularities in particular local time and latitude regions.

• Plan to analyze entire COSMIC dataset, as well as data from other RO missions (e.g. CHAMP)

• Long term plan involves development of a climatological data product available to the scientific community.

• Ongoing work involves characteristics of irregularities during sudden stratospheric warming, geomagnetic storms, magnetospheric substorms.

• RO provides good vertical resolution, but poor horizontal resolution. Technique for quantifying uncertainties in climatological maps due to assumption of irregularity localization at tangent point.
Acknowledgements

Research funding is from the National Science Foundation (NSF) and National Aeronautics and Space Administration (NASA), via the University Corporation for Atmospheric Research (UCAR). Solar wind data was obtained from the OMNI database on CDAWeb (http://cdaweb.gsfc.nasa.gov/). Geomagnetic indices are from the National Geophysical Data Center (NGDC) of the National Oceanic and Atmospheric Administration (NOAA).