Ionospheric Weather Monitoring by FORMOSAT-3 and ground-based GPS receivers

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Content

• The 7 January 2015 Dst= -99nT magnetic storm
• Ionospheric DA model (F3/C)
• TGIM model (F3/C + gb GPSR)
• Magnetic+ (F3/C + gb GPSR)
• Summary
The FORMOSAT-3/COSMIC program is an international collaboration between Taiwan and the United States that will use a constellation of six remote sensing microsatellites to collect atmospheric data for weather prediction and for ionosphere, climate and gravity research. Data from the satellites will be made freely available to the international scientific community in near real-time.
FORMOSAT-3/COSMIC

- FORMOSAT-3/COSMIC Constellation was launch at 01:40 UTC, April 14, 2006 (Taiwan Time: April 15 2006) at Vandenberg Air Force Base, CA. Minotaur Launch

- Maneuvered into six different orbital planes (inclination ~72°) for optimal global coverage (at ~800 km altitude).

- Five out of Six satellites are in good health and providing science data.
GPS Radio Occultation

Wavelength and amplitude of in the vertical direction

Global 3D structure
Distribution of occultation events observed by FORMOSAT-3
7 January 2015 storm

Sunspot Number (SSN)

Solar Flux (F10.7)

Planetary K Index

DST Index

nT

Date (2015/01)
Ionospheric Assimilation Model

NCAR Thermosphere Ionosphere E-GCM
FORMOSAT-3/COSMIC (Electron density profiles)
Data Assimilation Research Testbed

Lee et al. [JGR 2012, JGR 2013], Hsu et al. [JGR 2015]
NmF2 map

Along 120°E
Taiwan Global Ionosphere Map (TGIM model)

IGS GPS Receivers (total electron content; TEC)
FORMOSAT-3/COSMIC (vertical TEC)
Spherical harmonic surface functions

Sun et al. [2015]
Magnetic EOF Data Assimilation model

IGS GPS TEC
FORMOSAT-3/COSMIC (Radio Occultation TEC)
International Reference Ionosphere (IRI)
Kalman Filter with a 3-D Error Covariance
Empirical orthogonal functions (EOF)

Lin et al. [AMT 2015]
Storm signatures in TGIM and EOF DA
13:00 UTC Jan 07 2015

Jan 06 2015

EOF DA
TGIM
CODE GIM
RO Observation

Jan 07 2015

DA TEC Jan 06 2015 13:00UT
TGIM Jan 06 2015 13:00UT
CODE GIM Jan 06 2015 13:00UT
Trace Jan 06 2015 13:00UT

Jan 07 – Jan 06

DA TEC Difference 13:00UT
TGIM Difference 13:00UT
CODE GIM Difference 13:00UT
Ionospheric Data Assimilation 3-D structure
13:00 UTC Jan 07 2015

DA 13:00UTC Jan 07 2015

FORMOSAT-3 & FOMORSAT-7
Ionospheric Data Assimilation
3-D structure Difference
13:00 UTC Jan 07 2015
FORMOSAT-7/COSMIC-2

(a) Mission Orbital Planes

(b) FORMOSAT-7/COSMIC-2
- 2nd Launch inclination angle ~ 72 degrees
- 1st Launch inclination angle ~ 24 degrees
- Precise Orbit Determination Antenna
- Tri GNSS receiver
- Occultation Antenna
- Solar Panel
- Toward the Earth
- ram direction

FORMOSAT-3 & FOMORSAT-7
<table>
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<th><strong>FORMOSAT-3/COSMIC</strong></th>
<th><strong>FORMOSAT-7/COSMIC-2</strong></th>
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<tbody>
<tr>
<td><strong>Exterior Design</strong></td>
<td><img src="#" alt="FORMOSAT-3/COSMIC" /></td>
<td><img src="#" alt="FORMOSAT-7/COSMIC" /></td>
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<tr>
<td><strong>Sequence</strong></td>
<td></td>
<td>1&lt;sup&gt;st&lt;/sup&gt; Launch</td>
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<td><strong>Constellation</strong></td>
<td>6</td>
<td>6</td>
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<tr>
<td><strong>Mission Orbit Altitude</strong></td>
<td>800 km</td>
<td>520-550 km</td>
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<tr>
<td><strong>Inclination Angle</strong></td>
<td>72°</td>
<td>24-28.5°</td>
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<td><strong>Mission Payload</strong></td>
<td>GOX</td>
<td>TriG</td>
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<td><strong>RO Signals</strong></td>
<td>GPS</td>
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<td><strong>Launch Schedule</strong></td>
<td>Launched in 2006</td>
<td>2016</td>
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- Descriptions are provided by NSPO (http://www.nspono.org.tw).
- F7/C2 is illustrated by Surrey Satellite Technology LTD.
F7/C2 vs F3/C

With 6 satellites + GPS, 60 minutes
About 80-100 profiles per hour

With 12 satellites + GPS, 60 minutes
About 400 profiles per hour
Ionospheric Weather Monitoring

- Solar activity variations
- Seasonal variations
- Monthly variations
- Tidal effects
- Diurnal variations
- Semi-diurnal variations
- Disturbed period effects
- Other temporal variations
- Irregularities

Could it be advanced by F7/C2?

Latitudinal slices are at -120°, -60°, 0°, 60°, and 120° longitude with an interval of ±2.5°.

F3/C observations at 08:00 UT within 2 hours x 30 days accumulation period

Electron Density #/cm²

Latitudinal slices are at -120°, -60°, 0°, 60°, and 120° longitude with an interval of ±2.5°.

FORMOSAT-3 & FOMORSAT-7
Simulated F7/C2 observations at 08:00 UT within 1 hour x 1 day accumulation period

12 satellites, 28 GPS and 24 GLONAAA

Lee et al. [2013]
Summary

• TIEGCM DA for the first time includes the neutral atmosphere which can be used to carry out the long term ionospheric weather prediction.

• TGIM issues the global TEC map every 10 minutes currently with a 4-hour time delay.

• EOF DA provides the global 3D electron density structure.

• The three models detect the ionospheric signatures of the 7 January 2015 storm.

• TGIM+EOF DA will be the next product for the short term ionospheric weather prediction.

• FORMOSAT-7/COSMIC-2 shell open a new chapter for the ionospheric weather monitoring and Prediction.
Thank you!!