Study of the Accuracy and Spatial-Temporal Resolution of Ionospheric Data Assimilation due to Ingestion of RO Observations from Satellite Constellations

Dr. G. S. Bust; Dr. L. Dyrud, Dr. J. Fentzke, Dr. D. Smith
JHUAPL
Dr. S. Datta-Barua
IIT
Objectives

To study the effect of adding satellite data sources – particularly RO occultations upon ionospheric data assimilation accuracy
To understand the effects and limitations of IDA4D and EMPIRE and how they can be improved
To provide a long term sand-box by which we can access the improvements of IDA4D and EMPIRE with new data / methods
Ionospheric Simulations

TIEGCM
October 25, 2011 Storm
5x5 Degrees resolution
Geophysical indices from JHUAPL TIMED Web site
GSWM for lower boundary conditions
Time steps 150 seconds
Outputs saved every 15 minutes

IRI + Structure
Start with any smooth background. IRI in this case
Add an arbitrary number of structures represented by Gaussian depletions / enhancements
Structures are allowed to drift, grow and decay
Each depletion/enhancement is characterized by
Percent variation in density

Starting central latitude, longitude, altitude

Scale lengths in latitude, longitude altitude – all different

3D drift velocity

If there is growth / decay of the structure, the starting time for growth, the growth rate, the ending time for decay and decay rate
## 5 Gaussian Structures for this Study

<table>
<thead>
<tr>
<th>Variables</th>
<th>GD 1</th>
<th>GD 2</th>
<th>GD 3</th>
<th>GD 4</th>
<th>GD 5</th>
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</thead>
<tbody>
<tr>
<td>Lat0 (deg)</td>
<td>45 degrees</td>
<td>35</td>
<td>15</td>
<td>25</td>
<td>-35</td>
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<tr>
<td>Lon0 (deg)</td>
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<td>290</td>
<td>90</td>
<td>180</td>
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<td>Alt0 (km)</td>
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<td>250</td>
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<td>Sig_lat (deg)</td>
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<td>2</td>
<td>15</td>
<td>5</td>
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<td>Sig_lon (deg)</td>
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<tr>
<td>Sig_alt (km)</td>
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<td>250</td>
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<tr>
<td>Vlat (m/s)</td>
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<tr>
<td>Vlon (m/s)</td>
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<td>500</td>
<td>0</td>
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<tr>
<td>Valt (m/s)</td>
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<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Start Time</td>
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<td>14.5 UT</td>
<td>14.75</td>
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<tr>
<td>End Time</td>
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<td>N/A</td>
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<td>N/A</td>
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<td>Gth Rate (1/s)</td>
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<td>Dec Rate (1/s)</td>
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<td>.002</td>
<td>0.0</td>
<td>0.0</td>
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</table>
Data Simulations

GPS
~600 ground stations were selected such that none were closer than ~ 1 degree to each other
For Oct 24-25 2011, the actual GPS geometry and visible satellites were used
Then the data was simulated from the simulated ionosphere
No errors added, but IDA4D adds representation errors regardless

Occultations
Actual IRIDIUM orbits for an entire day were used for all 66 satellites
GPS ephemeris for the GPS satellites
Simulate actual occultation geometry and TEC
IDA4D was run with IRI as a background
Completely separate for TGCM comparisons
Smooth background for GD structure
2 hours with 5 minute temporal updates

EMPIRE was run on the IDA4D outputs for TGCM
No production and loss, which is an issue
No real quality control – hot off the presses a day or so ago by Seebany Datta-Barua
So, lots of checking left to do
Gauss Depletion/Enhancement Plots: Truth, GD1 and 2
Slice at 270 Longitude @ 15 UT
TGCM EMPIRE: Horizontal Drifts. GPS Only

TGCM: 5 degrees = 100 m/s
TGCM EMPIRE: Horizontal Drifts. 24 Occs

TGCM: 5 degrees = 100 m/s
Vertical Ion Drifts: Florida Region

TGM Vertical Ion Velocity

GPS Only

Estimated vertical drift [m/s] near FL at (37° mag N, -12° mag E)

Altitude [km]

14.2 14.4 14.6 14.8 15 15.2 15.4

UT hour

14.0 14.5 15.0 15.5 16.0

TIME UT

Estimated vertical drift [m/s] near FL at (37° mag N, -12° mag E)

Altitude [km]

14.2 14.4 14.6 14.8 15 15.2 15.4

UT hour

14.0 14.5 15.0 15.5 16.0

TIME UT

5 Occs
Make a permanent test bed
   Add additional simulations both First principles and empirically added structures

Add additional data sources – topside TEC and in-situ density

Also add wind and ion drift “data”

Study effects of data on IDA and EMPIRE
   Particularly add Kalman filter to EMPIRE

   Set up baseline metrics and quantify performance in terms of version of algorithm, number and types of data

Study improvements in accuracy spatial-temporal resolution as function of new data sources