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Uncertainty Associated with Modeling the Global Ionosphere

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Recommended Citation
A study has been conducted of the effect that different physical assumptions have on global models of the electron density distribution. The study was conducted with the ionosphere Forecast Model (IFM) and the ionosphere Plasmasphere Model (IPM) developed by Utah State University. Both physics-based, time-dependent, global models use the same empirical models for the neutral atmosphere (MSIS) and neutral wind (Horizontal Wind Model, HWM), but the altitude range, thermal structure, number of ion species, and magnetic field source are different. The IFM covers the altitude range from 90–1400 km, calculates the densities for four ions (NO+, O+, N2+, O2+), has a simple prescription for calculating H+, and is based on a tilted dipole magnetic field. The IPM extends from 90 km to 2000 km, includes six ion species (NO+, O+, N2+, O2+, He+, H+), and is based on the International Geomagnetic Reference Field (IGRF), and allows for inter-hemisphere flow. Therefore, the comparison of these models will elucidate the quantitative effect of these differences. In addition, simulations were conducted to study the effect of uncertainties in the zonal wind, secondary electron production, O+/O collision frequency, tidal structure, and state of plasmasphere re-filling. The simulations were conducted for a wide range of solar, seasonal, and geomagnetic activity levels. Quantitative results will be given that establish the importance of the various physical processes.

**O+/O Collision Frequency Comparison**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–60°E</td>
<td>53.2%</td>
<td>53.2%</td>
<td>53.2%</td>
</tr>
<tr>
<td>60°E–120°E</td>
<td>53.2%</td>
<td>53.2%</td>
<td>53.2%</td>
</tr>
<tr>
<td>120°E–180°E</td>
<td>53.2%</td>
<td>53.2%</td>
<td>53.2%</td>
</tr>
<tr>
<td>180°E–240°E</td>
<td>53.2%</td>
<td>53.2%</td>
<td>53.2%</td>
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<tr>
<td>240°E–300°E</td>
<td>53.2%</td>
<td>53.2%</td>
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</tr>
<tr>
<td>300°E–450°E</td>
<td>53.2%</td>
<td>53.2%</td>
<td>53.2%</td>
</tr>
<tr>
<td>450°E–600°E</td>
<td>53.2%</td>
<td>53.2%</td>
<td>53.2%</td>
</tr>
</tbody>
</table>

**Zonal Wind Comparison**

- Setting the zonal winds to zero causes the enhancement over Madagascar to decrease for both solar minimum and solar medium from 80–142.
- The maximum increase in TEC occurs at 102 for both cases.
- Maximum 12 TECU decrease during solar minimum.
- Maximum 40 TECU decrease during solar medium.

**Daytime Production Comparison**

- Decreasing the daytime production multiplication factor as a linear function of F10.7 resulted in decreased TEC values for all three geophysical conditions.
- The maximum decrease in TEC occurs at 142 for all three cases.
- Greatest decrease of 50 TECU occurred during solar maximum.
- Maximum 7 TECU decrease during solar minimum conditions.
- Maximum 30 TECU decrease during solar medium conditions.

**Tidal Structure Comparison**

- Including tidal forcing causes both enhancements and depletions in TEC and 400 km Ne as a function of longitude.
- The maximum changes in TEC and 400 km Ne occur at 131.
- Changes in TEC range from ~10% to 23%.
- Changes in 400 km Ne range from 10% to 44%.
- The smallest changes occur during case 3 and the largest changes occur during case 1.

**Summary and Conclusions**

The combination of empirical model output and robust physics in a physics-based model can lead to erroneous and inconsistent features in the model output. These errors are due to the uncertainty in the model parameters and need to be corrected before the model output can be used. This study examined the effects of the uncertainty in five physical parameters in the IFM. These parameters included the O+/O collision frequency, zonal wind, secondary electron production, nighttime E x B drifts, and tidal structure. The uncertainty for each parameter was evaluated by comparing a default run of the IFM to a run with the parameter adjusted for three different sets of geophysical conditions. The comparisons showed that the effects these uncertain physical parameters are significant and can be non-linear across both space and time. It was found that doubling the O+/O collision frequency increased increased densities above the F2 peak and decreased densities below the F2 peak.

- Greatest density increase occurred just prior to max for all three cases.
- Greatest density decreased occurred near mid-latitude for all three cases.
- NeF2 at mid-latitude locations was found to increase 30–140% at night.

- Doubling the O+/O collision frequency resulted in increased densities above the F2 peak and decreased densities below the F2 peak.
- Decreasing the daytime production multiplication factor as a linear function of F10.7 resulted in increased nighttime low latitude TEC for all three geophysical cases.
- Maximum increase in TEC occurs at 002 for all three cases.
- Maximum 40 TECU decrease occurred during solar minimum.
- Maximum 7 TECU decrease during solar minimum conditions.
- Maximum 30 TECU decrease during solar medium conditions.

- Including tidal forcing causes both enhancements and depletions in TEC and 400 km Ne as a function of longitude.
- The maximum changes in TEC and 400 km Ne occur at 131.
- Changes in TEC range from ~10% to 23%.
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