Equatorial-PRIMO

(Problems Related to Ionospheric Models and Observations)

• Non-coupled models (GIP, SAMI2, PBMOD, LLIONS, IFM, IPM)
  – March equinox, $F_{10.7}=120$, geomagnetic quiet condition
  – Ne, Te, and Ti are shown in longitude 120°E (to avoid differences in magnetic coordinates)
• No $E \times B$ drift, no neutral wind (Production & Loss)
• With $E \times B$ drift, no neutral wind (P&L, drift, diffusion)
• With $E \times B$ drift and neutral wind (P&L, wind, drift, diffusion)

Continuity Equation

$$\frac{\partial N}{\partial t} = q - \beta(N) - \text{div}(NV_{||})$$

- Production
- Loss
- Transport

- Perpendicular transport ($V_{\perp}$)
  - $E \times B$ drift
- Parallel transport ($V_{||}$)
  - Neutral wind effect
  - Plasma diffusion
  - Thermo expansion/contraction
- Zonal transport (neglect here)
<table>
<thead>
<tr>
<th>Model</th>
<th>Output</th>
<th>Ionosphere Coverage (km)</th>
<th>Thermosphere Coverage (km)</th>
<th>Ionosphere Resolution</th>
<th>Magnetic Coordinate</th>
<th>Photoionization</th>
</tr>
</thead>
<tbody>
<tr>
<td>IFM</td>
<td>Ni (O⁺, H⁺, NO⁺, O₂⁺), Ne, Ti, Te</td>
<td>90-1600</td>
<td>MSIS86 HWM93</td>
<td>Various</td>
<td>Best-fit IGRF dipole for each longitude</td>
<td>EUVAC</td>
</tr>
<tr>
<td>IPM</td>
<td>Ni (O⁺, H⁺, NO⁺, O₂⁺, He⁺, N₂⁺, N⁺), Ne, Ti, Te</td>
<td>90 - 20,000</td>
<td>NRLMSIS00 HWM93</td>
<td>Lon: 3.75° Lat: 1.0° at mid-lat ; &lt; 1° at low-lat</td>
<td>IGRF</td>
<td>EUVAC</td>
</tr>
<tr>
<td>LLIONS</td>
<td>Ni (O⁺, H⁺, NO⁺, O₂⁺), Ne, Ti, Te</td>
<td>90-10,000</td>
<td>NRLMSIS00 HWM93</td>
<td>Single longitude Lat: 2°</td>
<td>Best-fit IGRF dipole for longitude</td>
<td>EUVAC</td>
</tr>
<tr>
<td>PBMOD</td>
<td>Ni (O⁺, H⁺, Mol⁺), Ne</td>
<td>90 – 4000 (upper end is user selectable)</td>
<td>NRLMSIS00 HWM93</td>
<td>User Selectable (typically Long: 7.5, Lat: 1)</td>
<td>IGRF Apex</td>
<td>Hinteregger Fluxes, Jasperse CSD (1977)</td>
</tr>
<tr>
<td>GIP</td>
<td>Ni (O⁺, H⁺, NO⁺, O₂⁺, N₂⁺, N⁺), Ti, Ne, Te</td>
<td>90 - 20,000</td>
<td>NRLMSIS00 HWM93</td>
<td>Long: 4° Lat: 1°</td>
<td>IGRF Apex</td>
<td>Fluxes (Tobiska model) Cross sec. (Torr and Torr, 1982)</td>
</tr>
<tr>
<td>SAM12</td>
<td>Ni(H⁺,O⁺,He⁺,N⁺, NO⁺,N₂⁺,O₂⁺), Ti(H⁺,O⁺,He⁺),Te</td>
<td>90 – 20,000</td>
<td>NRLMSIS00 HWM93</td>
<td>Lat: 1 deg</td>
<td>IGRF-like</td>
<td>EUVAC</td>
</tr>
</tbody>
</table>
Case 1: No ExB drift, no neutral wind ($N_{\text{max}}$) $\Rightarrow$ Production and Loss

Any nighttime production? Differences in early morning and nighttime
Differences between IFM and IPM?
Case 1: No ExB drift, no neutral wind ($N_{\text{max}}$) $\Rightarrow$ Production and Loss

Te in GIP has been changed which significantly reduced the nighttime density.
Case 1: No ExB drift, no neutral wind ($H_{\text{max}}$) \(\Rightarrow\) Production and Loss

SAMI2 shows the lowest $H_{\text{max}}$ in the daytime; IPM shows the highest in the nighttime.
Offset of SAMI2 in latitude?
Case 2: With ExB drift, no neutral wind ($N_{\text{max}}$) $\Rightarrow$ P&L, drift, diffusion
Case 2: With ExB drift, no neutral wind ($N_{\text{max}} \Rightarrow P&L$), drift, diffusion

March Equinox (2LT)

March Equinox (10LT)

March Equinox (14LT)

March Equinox (20LT)
Case 2: With ExB drift, no neutral wind ($H_{\text{max}}$) $\Rightarrow$ P&L, drift, diffusion
Case 2: With ExB drift, no neutral wind ($H_{\text{max}}$) $\Rightarrow$ P&L, drift, diffusion
Case 3: With ExB drift and neutral wind ($N_{\text{max}}$) $\Rightarrow$ P&L, wind, drift, diffusion

Wind has decrease daytime density and enhance nighttime density
Case 3: With ExB drift and neutral wind ($N_{\text{max}}$) $\Rightarrow$ P&L, wind, drift, diffusion.

March Equinox (2LT)

March Equinox (10LT)

March Equinox (14LT)

March Equinox (20LT)
Jicamarca Longitude (Previous results)

March Equinox (2LT)

March Equinox (10LT)

March Equinox (14LT)

March Equinox (20LT)
Case 3: With ExB drift and neutral wind ($H_{\text{max}}$) ➔ P&L, wind, drift, diffusion
Case 3: With ExB drift and neutral wind ($H_{\text{max}}$) $\Rightarrow$ P&L, wind, drift, diffusion
<table>
<thead>
<tr>
<th>Model</th>
<th>Temp Calculation</th>
<th>Height gradient of ExB drift</th>
</tr>
</thead>
<tbody>
<tr>
<td>IFM</td>
<td>Titheridge model for Ti and Te</td>
<td>Different between 2000 and 3000 km Apex altitude.</td>
</tr>
<tr>
<td>IPM</td>
<td>Titheridge model for Ti and Te</td>
<td>Drift tappers of between 1000 and 1500 km apex altitude.</td>
</tr>
<tr>
<td>LLIONS</td>
<td>Titheridge model for Ti and Te with Te=Ti=Tn at ~110km</td>
<td>No gradient</td>
</tr>
<tr>
<td>PBMOD</td>
<td>Titheridge model for Ti and Te</td>
<td></td>
</tr>
<tr>
<td>GIP</td>
<td>Titheridge model for Te Energy Equ for Ti</td>
<td>0 at 100km 300-1000km F&amp;S &gt;2000km Richmond electric field model between 1000 to 2000km linear interpolation is applied</td>
</tr>
<tr>
<td>SAMI2</td>
<td>Ion Temp Equ. Electron Temp Equ.</td>
<td>E x B velocity ramps down to 0 below 150 km with 10 km decay above 150 km F&amp;S with no altitude dependence.</td>
</tr>
</tbody>
</table>
GIP and IPM test runs for height dependent drift input

**ExB, no wind**

**No gradient 1000-2000km**

**No gradient 100-300km**

GIP and IPM test runs for height dependent drift input
Temperature: No ExB drift, no neutral wind

Solid line: Ti (O+)
Dashed line: TE
Temperature: With ExB drift, no neutral wind

Solid line: Ti (O+)
Dashed line: TE
Temperature: With ExB drift and neutral wind

Solid line: Ti (O+)

Dashed line: TE
Equation for Ion Neutral Collision Frequency (O-O+)

**SAMi2** uses Baily and Balan [1996] in cgs,

\[ \nu_{in} = 4.45 \times 10^{-11} n(O) T^{1/2} (1.04 - 0.067 \log_{10} T)^2 \]

**IFM, IPM, LLIONS, and PBMOD** use Schunk and Nagy [1980] in cgs,

\[ \nu_{in} = 3.67 \times 10^{-11} n(O) T^{1/2} (1 - 0.064 \log_{10} T)^2 \]

**GIP** uses Raitt et al. [1975] in MKS,

\[ \nu_{in} = 3.42 \times 10^{-17} n(O) T^{1/2} (1.04 - 0.067 \log_{10} T)^2 \]

\[ T = (T_i + T_n)/2 \]
Electron Temperature at Magnetic Equator

<table>
<thead>
<tr>
<th>LT</th>
<th>IRI</th>
<th>LLIONS</th>
<th>IFM</th>
<th>IPM</th>
<th>SAMI2</th>
<th>GIP</th>
<th>PBMOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>956.4</td>
<td>884.9</td>
<td>Same as LLIONS</td>
<td>889.9</td>
<td>832</td>
<td>1295</td>
<td>946.21</td>
</tr>
<tr>
<td>10</td>
<td>1326.1</td>
<td>1293.6</td>
<td></td>
<td>1297.7</td>
<td>948</td>
<td>2466</td>
<td>1264.77</td>
</tr>
<tr>
<td>14</td>
<td>1273.9</td>
<td>1288.3</td>
<td></td>
<td>1286</td>
<td>1053</td>
<td>2761</td>
<td>1262.29</td>
</tr>
<tr>
<td>20</td>
<td>1085.6</td>
<td>1216.8</td>
<td></td>
<td>1255</td>
<td>929</td>
<td>1484</td>
<td>1264.68</td>
</tr>
</tbody>
</table>