NRL SAMI2/3 IONOSPHERE MODEL AT CCMC

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Welcome to the SAMI2 Open Source Project

The purpose of this site is to freely distribute the NRL low- to mid-latitude ionosphere code SAMI2 (Sami2 is Another Model of the Ionosphere). It is hoped that the code will be used for research and education, and that the code can be improved through community feedback. The code was originally developed by Drs. J.D. Huba and G. Joyce. Recently, Dr. M. Swisdak has made a number of improvements and corrections.

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1/07: Release of sami2-0.98
This release improves the SAMI2 model and corrects several problems in sami2-0.97. The changes are described in the file README-0.98
Magnetic field: IGRF-like
Interhemispheric
Nonorthogonal, nonuniform fixed grid
Seven (7) ion species (all ions are equal): $\text{H}^+$, $\text{He}^+$, $\text{N}^+$, $\text{O}^+$, $\text{N}_2^+$, $\text{NO}^+$, and $\text{O}_2^+$
  - Solve continuity and momentum for all 7 species
  - Solve temperature for $\text{H}^+$, $\text{He}^+$, $\text{O}^+$, and $\text{e}^-$
Plasma motion
  - $\textbf{E} \times \textbf{B}$ drift perpendicular to $\textbf{B}$
  - Ion inertia included parallel to $\textbf{B}$
Neutral species: NRLMSISE00 and HWM93
Chemistry: 21 reactions + recombination
Photoionization: Daytime (EUVAC) and nighttime
**Ion Continuity**

\[
\frac{\partial n_i}{\partial t} + \nabla \cdot (n_i \mathbf{V}_i) = P_i - L_in_i
\]

**Ion Velocity**

\[
\frac{\partial \mathbf{V}_i}{\partial t} + \mathbf{V}_i \cdot \nabla \mathbf{V}_i = -\frac{1}{\rho_i} \nabla P_i + \frac{e}{m_i} \mathbf{E} + \frac{e}{m_ic} \mathbf{V}_i \times \mathbf{B} + \mathbf{g} + \nu_{in} (\mathbf{V}_i - \mathbf{V}_n) - \sum_j \nu_{ij} (\mathbf{V}_i - \mathbf{V}_j)
\]

**Ion Temperature**

\[
\frac{\partial T_i}{\partial t} + \mathbf{V}_i \cdot \nabla T_i + \frac{2}{3} T_i \nabla \cdot \mathbf{V}_i + \frac{2}{3} \frac{1}{n_i k} \nabla \cdot \mathbf{Q}_i = Q_{in} + Q_{ij} + Q_{ie}
\]
**Electron Momentum**

\[ 0 = -\frac{1}{n_em_e} b_s \frac{\partial P_e}{\partial s} - \frac{e}{m_e} E_s \]

**Electron Temperature**

\[ \frac{\partial T_e}{\partial t} - \frac{2}{3} \frac{1}{n_e k} b_s^2 \frac{\partial}{\partial s} \kappa_e \frac{\partial T_e}{\partial s} = Q_{en} + Q_{ei} + Q_{phe} \]
MAGNETIC FIELD

Modeling the earth’s ionosphere

- Low- to mid-latitude: closed field lines
- Appropriate field: IGRF
- Modeled as IGRF-like: a dipole field is fit to the IGRF for the longitude of the simulation (vary offset and tilt)
- Important assumption: field lines are equipotentials
EMPIRICAL MODELS

Inputs

- **NRLMSISE-00** (Picone et al)
  - Neutral composition H, He, O, N, N\(_2\), O\(_2\)
  - Neutral temperature \(T_n\)
- **HWM** (Hedin)
  - Neutral wind \(V_n\) (meridional/zonal)
- **Electric field** (Fejer/Scherliess)
  - \(E \times B\) drift \(V_E\) (vertical at magnetic equator)
NONORTHOGONAL EULERIAN GRID

Present grid: ‘1 zone’
CCMC OUTPUTS

- 2D color contour plot
- 1D line plot (altitude/latitude)
Example: ion dynamics as a function of time
Global low- to mid-latitude ionosphere model
IGRF-like magnetic field
Zonal drifts
Parallelized with MPI:
   Requires Beowulf cluster
Nominal longitudinal resolution:
   $2^\circ - 4^\circ$
Outputs: TEC, $nmf2$, $hmf2$
Example: global/temporal change in TEC
$Q_{phe}$ based on simple model developed by Bailey (e.g., SUPIM)

SAMI2 had an adjustable parameter ‘cqe’ that affects $Q_{phe}$

Other comparisons to data suggest another parameter be included, e.g., $\alpha Q_{phe}$

Major upgrade by Varney
- physics based photoelectron physics model
- computationally expensive
IMPROVE SAMI2 $T_e$ MODEL

Photoelectron heating term had to be modified: $\alpha = 0.2$

**Jicamarca data**

**SAMI2**
global SAMI3 (±89° magnetic latitude)
electrostatic potential
  • self-consistent low-latitude dynamo potential
    HWM07 to provide neutral wind
  • high-latitude potential: Weimer

ETA: late spring/early summer