The Global Ionosphere Thermosphere Model and Results from the April 2002 Storm

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GITM

Newly created global ionosphere thermosphere model (GITM) to model the neutral and ion composition, temperature, and dynamics from 95-500+ km altitude.

GITM is a fully parallel code which has been run on 80 processors.
GITM Physics

GITM solves for:

- 6 Neutral Species
- 5 Ion Species
- Neutral winds
- Neutral Temperatures
- Ion and Electron Convection
- Ion and Electron Temperatures
- Solves in Altitude coordinates
A Flexible Model

One of the most important aspects of the new model is flexibility:

• Can stretch grid in latitude and altitude. Parallel decomposition in lat/lon blocks. Have run on 80 PEs.

• Can use Apex or dipole.

• Can use almost any high latitude electric potential / auroral precipitation model you want (AMIE, Weimer, Fuller-Rowell and Evans, etc).

• Can restart from previous run or start from scratch using MSIS and IRI.

• All terms are clearly defined - you can easily turn them off and on to do numerical experimentation.
Grid Variability

- Can run GITM as a 1D code for very high resolution altitude studies at a single location.
- Can run GITM as a 2D (Latitude vs Altitude or Longitude vs Altitude) code.
- Can run in a limited 3D region.
- Can run in parallel in 3D covering all longitudes and either all latitudes (messaged passing over the pole) or a limited latitude band.
- Boundary conditions play important role in 3D limited region runs.
Physics and Chemistry

- GITM uses subcycling to resolve chemistry in both the neutrals and the ions. This allows us to model non-steady-state chemistry - in fact our local chemistry time step can be reduced to 0.001 seconds.
- All advection is explicit - this means that the global time step is limited by the smallest cells and largest velocities. Typical time step in quiet time is around 1.5 seconds, while during a storm it can be reduced to 0.2 seconds.
- April 2002 storm ran in real time on 80 processors (2 degrees latitude by 5 degrees longitude resolution).
Space Weather Reanalysis

- DoD funded project to model 1 solar cycle worth of space weather.
- Based at NOAA’s National Geophysical Data Center.
- We have modeled all of 1997-2001 using both AMIE and GITM.
- Data will be available over the web soon.
- This really tests the robustness of the model!!
- We have used 140,000 CPU hours to run 1997-1998.
Cause and Effect

We used GITM to simulate the thermosphere and ionosphere during the May 1998 storm using AMIE and the Weimer [1996] electric field models. These different models produce very different Joule heating rates, which change the thermospheric temperature structure.

Weimer [1996]  
![Thermospheric temperature structure](image1.png)

AMIE  
![Thermospheric temperature structure](image2.png)
Grid for April 2002

- 2 degree Latitude
- 5 degrees Longitude
- 50 points in Altitude (95-750 km)
GITM Results

- [e-] at 500 km.
- Get clear fountain effect.
GITM Results

- Temperature at 350 km
- Joule Heating in the auroral zone observed
GITM Results

- $\log([\text{NO}])$ at 115 km altitude
- Strongly driven by aurora with small dayside component
Data Products

- Can track satellites and output at the same cadence as the satellite observations.
- With GUVI, we track 23 points along the swath, and output all altitudes for each 15 second measurement.
- So, from model results we can examine temperature profiles, [e-] and neutral densities, and winds - along GUVI swath at all altitudes.
- Use for validation or for putting TIMED measurements into a global context.
GUVI - GITM
Comparison for April 17, 2002
• Auroral structure is reproduced very well.
Limb Data

- Because we output all altitudes at each satellite location, we can reproduce limb data.
O/N2 Global Ratios

- Start at a constant pressure level and integrate up.
O/N2

• Run with no activity for 24 hours.
• Run with $B_z = -20$ nT for 12 hours.
• But - Little to no Aurora.
Summary

• GITM is a new thermosphere - ionosphere model, which solves for many major and minor ion and neutral species.
• Uses a flexible grid structure and altitude coordinates.
• Can run using AMIE or statistical models of potential and electron precipitation.
• Solves most quantities explicitly and does not assume chemical equilibrium to solve for any species.
• Small time steps - 1.5 seconds typical.
• Can fly satellites through simulation to make direct comparisons at same temporal resolution as satellite measurements.
• Can use satellite tracking capability for validation and putting measurements into the global context. This is quite important when you only have 1 local time sector.
• http://csem.engin.umich.edu/~ridley/GITM