ASPEN-TIMEGCM

Thermospheric General Circulation Models (TGCMs) have been developed by the National Center for Atmospheric Research (NCAR) since the early ‘80s to study the global temperature, circulation, and chemical structure of the thermosphere and its response to solar and auroral activity. The latest 3-D coupled thermosphere-ionosphere-mesosphere-electrodynamics general circulation model (TIMEGCM) predicts winds, temperatures, major and minor composition, electron densities and self-consistent electrodynamic quantities globally from 30 km to about 600 km altitude (Roble and Ridley, 1994). The standard NCAR model uses a fixed geographic grid with a 5° x 5° horizontal resolution, and a vertical resolution of a half neutral scale height. (Recent versions of the TIMEGCM can also be run with a 2.5° horizontal resolution and a quarter scale height vertical resolution). The model time-step is typically 2-3 minutes, but rapid changes and storms usually require less than 1 minute time-steps to maintain model stability.

The codes were initially developed for a CRAY Supercomputer environment. Recently, the TIMEGCM code was ported to a distributed parallel computing environment, and is called the Advanced Space Environment (ASPEN)-TIMEGCM. The new code runs on Beowulf clusters, or on individual high-end PCs. The ASPEN code has been thoroughly tested and validated to ensure it produces the same results as the NCAR codes, given the same inputs, to within numerical accuracy of the personal computers. The standard model runs about four times faster than real-time on a single high-end PC in a Linux environment, and a 24 hour simulation requires about 6 hours of CPU time. Efficient speed-up can be achieved with 3 or 4 PCs in parallel.

An important part of the TIMEGCM success has resulted from its detailed input specification. The inputs required by the model include the solar flux at 57 key wavelengths, parameterized by the $F_{10.7}$ flux. Typically the $F_{10.7}$ flux is available once per day, so short-term variability such as flare effects are not captured with any fidelity. However, day-to-day variability and longer-term effects like the 27 day solar rotation effect, and 11 year solar cycle are well reproduced.

The TIME-GCM inputs include high latitude particle precipitation and electric fields. Roble and Ridley (1987) developed an analytical formulation of the auroral oval, and introduced the use of the Heelis convection model (Heelis et al, 1982). The Heelis model provided an analytical formulation for the shape of the potential pattern, including distortions from the effect of the IMF B_Y component. The magnitude of the potential had to be specified, and was usually estimated from an empirical relationship with the Kp or Hemispheric Power (Hp) index. Other global models have used (and still use) Heppner-Maynard potential patterns (Heppner and Maynard, 1987). The use of indices such as Kp and Hp to drive first principles models limits the cadence and fidelity of the high-latitude input drivers to the models, with a consequent loss of fidelity in the model predictions. Realizing these limitations, Crowley et al (1989) were the first to use assimilated electric fields and auroral precipitation specified by the AMIE technique to drive a global thermosphere-ionosphere model. By using the AMIE fields, they were able to obtain better agreement between the observed and modeled atmospheric responses. In fact, these new simulations were so accurate that they led to the discovery of an important structure in the high latitude neutral density and composition (Crowley et al., 1996). The TIMEGCM can be driven by AMIE, but for the current paper, the Heelis model was driven by cross-cap potential derived from the Weimer empirical model, and ACE solar wind data were used to drive the Weimer model.

The Roble and Ridley (1987) formulation of the auroral oval and associated particle precipitation requires some way of driving the auroral radius, particle flux, and mean energy as a function of magnetic local time and latitude. Usually the driver was the cross-cap potential, which was unknown, and had to be derived from an empirical relation with an index such as Kp or hemispheric power (Hp). For the present paper, we derived the hemispheric power from NOAA and DMSP satellite measurements and used it to specify the particle properties.

In general, the tides are specified from a tidal climatology at the lower boundary and propagate up through the model domain, although they can be tuned for specific dates if sufficient tidal data are available.