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Thermospheric Targets

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Recent decades have seen great progress in computer modeling of the global thermosphere-ionosphere system. The models are derived by solving simultaneously the conservation equations of mass, momentum, and energy that govern the concentrations, velocities, and temperatures of the ions, electrons, and neutral gases. Typically they cover heights from 80–100 to 500–700 kilometers, with resolutions of 100–1000 kilometers horizontally, 10 kilometers vertically, and tens of minutes in time; they do not deal with small-scale structure such as plasma instabilities. Some models extend down into the mesosphere (30–80 kilometers) or up to the protonosphere, the region where the dominant constituents are thermal protons and electrons. The input parameters include photochemical and transport rate coefficients and the fluxes of solar ionizing radiation and energetic particles, and the models can be run for general levels of solar and geomagnetic activity or for specific dates. Calibrated with real data, the models mimic well the behavior of the real thermosphere and ionosphere and have contributed much to understanding, besides helping the practical task of 'near-real-time modeling,' which is important for communications. They differ from purely descriptive 'empirical' models, which merely seek to describe the upper atmosphere and ionosphere, not to explain it.

Ionospheric modeling has a history dating back to the simple theory of solar-controlled layers governed by ion production and recombination [*Chapman*, 1931], which fits well the ionospheric *E* layer around 100 kilometers and the F_1 layer (around 200 kilometers), but not the denser and more complicated F_2 layer (250–400 kilometers). In later decades, ever increasing computing power made possible the two-dimensional models of the 1960s [e.g., *Kohl and King*, 1967] and today's three-dimensional models, such as the Thermosphere-Ionosphere General Circulation Model (TIEGCM) [*Roble*, 1996], the Coupled Thermosphere-Ionosphere-Protonosphere (CTIP) model [*Fuller-Rowell et al.*, 1996], and their variants and derivatives.

The two- and three-dimensional models helped to explain many ionospheric phenomena, such as the occurrence in place and time of the seasonal (summer/winter) and semiannual variations of F_2 layer electron density and the behavior of the equatorial F_2 layer, all controlled largely by the global thermospheric circulation [see, e.g., *Rishbeth*, 1998]. What more should models seek to do? Here are seven 'targets'—features of the thermosphere and ionosphere—that models still need to get right:

1. Semiannual variation of thermospheric temperature, with maxima in April and October, and the associated semiannual variation of F_2 layer height.
2. Annual or north-south asymmetry of global F_2 layer electron density, which is over 20% greater at December solstice than June solstice, the difference being 3 times the direct effect of varying Sun-Earth distance.
3. Nighttime survival of the *F* layer, especially in winter. Is the layer kept going by downward flow from the protonosphere, by ultraviolet or X-radiation from the night sky, low-energy particle precipitation, or something else?
4. Day-to-day ionospheric variability, especially of the F_2 layer, some of which can be attributed to solar and geomagnetic variations. What causes the rest?
5. Ionospheric storms. What controls how individual storms develop in universal time and local time?
6. Apparent preferences for particular timescales (e.g., 40 minutes and 26 hours), sometimes perceived in ionospheric phenomena. Are they real? If so, what is the physics?
7. Ionospheric 'memory.' The ionosphere's response to geomagnetic disturbance sometimes seems to be 'preconditioned' by previous levels of solar or geomagnetic activity. If so, what is the physics?

I apologize if any of these targets already have adequate explanations that I have missed.

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References

Chapman, S. (1931), The absorption and dissociative or ionizing effect of monochromatic radiation in an atmosphere on a rotating Earth, *Proc. Phys. Soc. London, 43*, 26–45.

Fuller-Rowell, T. J., D. Rees, D., S. Quegan, R. J. Moffett, M. V. Codrescu, and G. H. Millward (1996), A coupled thermosphere-ionosphere model (CTIM), in *STEP Handbook of Ionospheric Models*, edited by R. W. Schunk, pp. 217–238, Utah State Univ., Logan.

Kohl, H., and J. W. King (1967), Atmospheric winds between 100 and 700 km and their effects on the ionosphere, *J. Atmos. Terr. Phys., 29*, 1045–1062.

Rishbeth, H. (1998), How the thermospheric circulation affects the ionospheric F2-layer, *J. Atmos. Sol. Terr. Phys., 60*, 1385–1402.

Roble, R. G. (1996), The NCAR Thermosphere-Ionosphere-Mesosphere-Electrodynamics General Circulation Model (TIME-GCM), in *STEP Handbook on Ionospheric Models*, edited by R. W. Schunk, pp. 281–288, Utah State Univ., Logan.

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