WEIMER ELECTRIC POTENTIAL, CURRENT, AND JOULE HEATING MODELS

1. Model content

The Weimer ionosphere model is a combination of two models, one for high-latitude electric potentials, and the other representing field-aligned currents (FAC). Combined together, the models also provide the Poynting flux into the ionosphere, which is dissipated in the ionosphere as Joule heating. The models require solar wind and interplanetary magnetic field (IMF) values for input, and output the potential in kilo-volts (kV), current in micro-Amperes per square meter, and energy flux in milli-Watts per square meter. The current and energy flux/heating are mapped to an altitude of 110 km. Input locations are specified as latitude and magnetic local time (MLT) in "modified apex coordinates," similar to "altitude-adjected corrected geomagnetic coordinates."

2. Model uncertainties and limitations

Comparing the most recent (2005) model predictions of electric potential with the DE-2 measurements of electric potential, the following results were obtained: Taking the average of the difference between the potentials at all points along the track, the median error is 6.0 kV, and in 90% of the passes the error were less than 12.3 kV. Taking the differences between the polar cap potential drop (maximum potential minus minimum potential), the median error is 8.7 kV, and 90% of the passes were within 26.6 kV. The passes where the errors are the largest use IMF measurements from the ISEE-3 spacecraft rather than IMP-8. As ISEE-3 was often located over 100 R_E away from the Earth-Sun line, the IMF measured there is sometimes not the same as what impacts the magnetopause.

The model is limited by insufficient measurements with the DE-2 satellite during times having IMF magnitudes over 15 nT. The 2005 version has a saturation curve that seems to produce reasonable values at higher IMF magnitudes, where accuracy is uncertain.

The model does not mimic the ionosphere's tendency to change faster on the dayside than on the nightside when there is an IMF transition. Also, in sudden solar wind pressure pulses, it is known that the polar cap potentials increases momentarily then decays; the model does not have that feature. The model does not have the ability to predict substorm variations, nor small, km-scale fluctuations. The electric potentials and currents in the model are always zero at the lower-latitude boundary. This model does not include the "subauroral polariza-tion streams" (SAPS/SAID), strong, subauroral ion flow following geomagnetic storms and substorms.

Currently in progress is a project to compare the integrated Poynting energy flux with changes in total thermospheric energy, as derived from density measurements with the GRACE and CHAMP satellites. Preliminary results indicate that the model can very accurately predict changes in the "global nighttime minimum exospheric temperature." At heating levels over 500 GW a reduction in the model output is required to match the measurements, indicating that the model results are too high in saturation.

3. Basis of Model

The models are based on measurements from the Dynamics Explorer-2 satellite, which orbited at altitudes of 300 to 1000 km from August 1981 to March 1983. The electric potential model is derived from measurements from the "Vector Electric Field Instrument" (VEFI), using the "double floating probe" technique. Electric potentials were obtained by integrating the electric field in the direction of motion along orbit track. The field-aligned current model is based on measurements from a triaxial fluxgate magnetometer on DE-2. An integral of the vector component perpendicular to the orbit plane was used to obtain a scalar, magnetic Euler potential along orbit paths. Simultaneous IMF measurements are from the IMP-8 and ISEE-3 satellites. IMP-8 measurements could be used only while spacecraft was on sunward side of magnetosphere and bow shock. Total number of passes available was limited by instrument duty cycles, as well as availability of IMF measurements. The processed database contains 2608 polar cap passes with electric potential, and 2403 passes with magnetic potential.

The most recent, 2005 version of the model is based on spherical cap harmonic analysis (SCHA) functions to order 2 and degree of 12. Each coefficient in the harmonic expansion varies according to the IMF and tilt angle. Potentials are zero at the lower-latitude boundary, the spherical cap half-angle. The size of this cap expands and contracts according to the IMF. Field-aligned currents are derived from the magnetic potential by two-dimensional Laplacian on the spherical surface. Poynting fluxes are derived from cross product of electric field and magnetic field perturbation. Electric field is from gradient of the electric potential function, and magnetic perturbation is from gradient of the magnetic potential function, rotated by $90°$.

4. Model input parameters

The model requires specification of location as geomagnetic latitude (degrees) and MLT (hours). IMF is specified in GSM coordinates as magnitude in Y-Z plane in nT, and "clock angle" in degrees (clock angle is zero in GSM +Z direction, $90°$ in GSM +Y direction). Solar wind velocity are in km/sec, and proton number density is in number per cubic centimeter. Optional AL index input is in units of nT. The IMF parameters should be averages over prior 15 to 20 minutes, following propagation to location of Earth if measured at L1 orbit. The dipole tilt angle in degrees is required, which controls the seasonal variation. The dipole tilt is the angle of rotation that converts between GSM and SM coordinates (positive when the Northern magnetic pole is tilted towards the Sun).

5. Publication references

Weimer, D. (1995), Models of high-latitude electric potentials derived with a least error fit of spherical harmonic coefficients, *J. Geophys. Res.*, *100*, 19,595.

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Weimer, D. R. (2005a), Improved ionospheric electrodynamic models and application to calculating Joule heating rates, *J. Geophys. Res.*, *110*, A05306, doi: 10.1029/2004JA010884.

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6. Dates of development, authors, and sponsors

Dates

1995: First publication of ionospheric potential patterns, using least-square fitting with spherical harmonics.

1996: First version of electric potential model, for arbitrary IMF inputs. Low-latitude boundary fixed at $45°$ magnetic latitude.

2000: Description of method for mapping field-aligned currents from magnetometer measurements.

2001: Revised electric potential model, and new field-aligned current model. Latitude of low-latitude boundary varies as function of IMF.

2005: Revised both models, now combined together in same program, including calculation of Poynting fluxJoule heating. Most recent revision followed in same year, using SCHA functions, with description of method for calculating geomagnetic perturbations on the ground. Polar cap half-angle varies as function of IMF.

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7. Model codes and sources

The models are all written in IDL. The latest version is distributed as pre-compiled IDL modules, which can run on various platforms using the "IDL Virtual Machine" (available at www.ittvis.com). This distribution package includes versions for interactive graphics display, as well as batch-style, gridded output to text files. Output to geographic coordinates is an option. A FORTRAN version of only the electric potential model is also available. Requests should be sent to D. Weimer (e-mail: dweimer@vt.edu). Real-time maps and updates will be posted at http://mist.nianet.org/weimer.