Electric Field Models Used for Particle Tracing

AMPS Interface Documentation

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1 Decomposition

In AMPS geospace transport runs, the total electric field is represented as a superposition

$$\mathbf{E}(\mathbf{r},t) = \mathbf{E}_{\mathrm{cor}}(\mathbf{r},t) + \mathbf{E}_{\mathrm{conv}}(\mathbf{r},t) + \mathbf{E}_{\mathrm{ind}}(\mathbf{r},t), \tag{1}$$

where the terms correspond to corotation, large-scale convection, and inductive (time-varying $\mathbf{B}$) contributions. The interface allows you to enable/disable each contribution depending on the model combination you need.

2 Corotation electric field

Corotation is the electric field in the inertial frame associated with plasma corotating with Earth:

$$\mathbf{E}_{\mathrm{cor}} = -(\boldsymbol{\omega} \times \mathbf{r}) \times \mathbf{B}, \tag{2}$$

with Earth's rotation rate $\omega = 7.292\,115\,9 \times 10^{-5}\,\mathrm{rad\,s^{-1}}$. This term is most relevant in the inner magnetosphere and is frequently included when tracing particles that drift near Earth.

3 Volland–Stern convection (Kp-parameterized)

A commonly used robust model for global convection is the Volland–Stern potential. A simple form for the electric potential in the equatorial plane is

$$\Phi(r,\theta) = A\, r^{\gamma}\, \sin\theta, \tag{3}$$

where r is radial distance, θ is the azimuthal angle, γ controls shielding, and A controls intensity. The convection electric field is then

$$\mathbf{E}_{\mathrm{conv}} = -\nabla\Phi. \tag{4}$$

In the interface, A is derived from Kp using standard empirical relations; γ is user-controlled.

4 Weimer (solar-wind / IMF driven)

Weimer-type models are data-driven empirical reconstructions of the ionospheric electric potential as a function of IMF and solar-wind conditions. In practice, AMPS uses the mapped electric field/potential as a time-dependent driver for more event-realistic runs. Typical inputs include IMF B_y, B_z, solar-wind speed, and dipole tilt.

5 Inductive electric field from $d\mathbf{B}/dt$

When the magnetic field varies in time, Maxwell–Faraday requires

$$\nabla \times \mathbf{E}_{\text{ind}} = -\frac{\partial \mathbf{B}}{\partial t}. \tag{5}$$

A physically consistent minimal model (used when $\partial \mathbf{B}/\partial t$ is spatially uniform in the region of interest) is

$$\mathbf{E}_{\text{ind}}(\mathbf{r}) = -\frac{1}{2}\,\mathbf{r} \times \frac{d\mathbf{B}}{dt}. \tag{6}$$

This choice satisfies $\nabla \times \mathbf{E} = -d\mathbf{B}/dt$ and is unique up to an added gradient field (gauge).

Inputs in the interface. The UI accepts dB_x/dt, dB_y/dt, dB_z/dt in GSM with units of nT/min. Internally you should convert to T/s.

6 References (selected)

- Volland, H. (1973). "A semiempirical model of large-scale magnetospheric electric fields." *JGR*.
- Stern, D. P. (1975). "The motion of a proton in the equatorial magnetosphere." *JGR*.
- Weimer, D. R. (2005). "Improved ionospheric electrodynamic models..." *JGR*.