Magnetic Field Models for Geospace Particle Tracing

AMPS Interface Documentation

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1 Total field representation

AMPS typically represents the magnetic field as

$$\mathbf{B}(\mathbf{r}, t) = \mathbf{B}_{\text{int}}(\mathbf{r}, t) + \mathbf{B}_{\text{ext}}(\mathbf{r}, t), \tag{1}$$

where $\mathbf{B}_{\text{int}}$ is the internal (main) field and $\mathbf{B}_{\text{ext}}$ is the magnetospheric current system contribution.

2 Internal field (IGRF / dipole)

For most applications, $\mathbf{B}_{\text{int}}$ is modeled using IGRF (or a dipole approximation for sensitivity testing). The internal field provides the dominant contribution near Earth and controls low-altitude cutoffs.

3 Empirical external field models (Tsyganenko family)

Empirical models represent $\mathbf{B}_{\text{ext}}$ using parametrizations constrained by spacecraft observations. Typical inputs are solar-wind dynamic pressure, IMF B_y/B_z, Dst, and/or Kp.

T96

Tsyganenko (1996) provides a widely used external field model suitable for many cutoff studies.

TS05 / T15

Storm-time models incorporate additional drivers and are designed to capture disturbed intervals. These are often preferred for event-realistic SEP cutoff calculations.

4 MHD-driven fields (BATSRUS / GAMERA)

For highest fidelity, AMPS can ingest a 3D time-dependent magnetic field from a global MHD model. In this mode:

- The MHD solution provides $\mathbf{B}(\mathbf{r}, t)$ (and optionally $\mathbf{E}$).
- Particle tracing uses spatio-temporal interpolation on the MHD grid.
- Boundary surfaces (magnetopause, inner boundary) should be consistent with the MHD domain.

This option is computationally heavier but can reproduce event-specific structures not captured by analytic fits.

5 Notes for cutoff calculations

- Using a storm-time external model (e.g., TS05/T15) can change R_C by several GV at mid-latitudes.
- Time dependence can be critical during rapid Dst changes; ensure Δt in tracing resolves the driver cadence.
- Consistency with the electric field model matters for drift trajectories, especially in the inner magnetosphere.

6 References (selected)

- Tsyganenko, N. A. (1996). "Effects of the solar wind conditions on the global magnetosphere configuration..." *JGR*.
- Tsyganenko, N. A., & Sitnov, M. I. (2005). (TS05). *JGR*.
- Tsyganenko, N. A., & Andreeva, V. A. (2015). (T15). *JGR*.