Reconstructing Proton Differential Spectra from GOES-18/19 for AMPS Boundary Conditions

AMPS Interface Documentation

February 21, 2026

1 Goal and context

The AMPS geospace transport workflow often needs an upstream (magnetopause) proton spectrum $J(E,t)$. GOES satellites provide operational particle products (integral and/or differential channels) that can be inverted into a smooth differential spectrum. This document outlines a practical reconstruction approach suitable for automated pipelines.

2 Data sources

- GOES-R series (GOES-16/17/18/19) carries SEISS particle sensors.
- For solar proton events, relevant products typically include integral flux thresholds and/or binned proton channels.

In practice, choose a cadence (e.g., 1-min, 5-min) and a time interval.

3 Forward model: from spectrum to channel measurements

Assume a parametric spectral form $J(E;\boldsymbol{\theta})$ (selected in the interface):

- Power law: $J = J_0(E/E_0)^{-\gamma}$
- Power law with exponential cutoff: $J = J_0(E/E_0)^{-\gamma}\exp(-E/E_c)$
- Band function (smooth broken power law)
- Table (piecewise log-log interpolation)

For an *integral* channel reporting $F_i(> E_i)$, the model prediction is:

$$\widehat{F}_i(\boldsymbol{\theta}) = \int_{E_i}^{\infty} J(E;\boldsymbol{\theta})\, dE. \tag{1}$$

For a *finite energy bin* $[E_{i,\min}, E_{i,\max}]$ (differential channel), the model prediction is:

$$\widehat{C}_i(\boldsymbol{\theta}) = \frac{1}{\Delta E_i}\int_{E_{i,\min}}^{E_{i,\max}} J(E;\boldsymbol{\theta})\, dE, \tag{2}$$

with $\Delta E_i = E_{i,\max} - E_{i,\min}$.

Response functions (recommended when available). If detector response matrices $R_i(E)$ are available, use

$$\widehat{C}_i(\boldsymbol{\theta}) = \int R_i(E)\, J(E;\boldsymbol{\theta})\, dE, \tag{3}$$

which reduces bias from finite energy resolution and out-of-acceptance contamination.

4 Parameter estimation

At each time t (or over a window), solve a constrained nonlinear least squares problem:

$$\boldsymbol{\theta}^*(t) = \arg\min_{\boldsymbol{\theta}} \sum_i w_i \left(C_i(t) - \widehat{C}_i(\boldsymbol{\theta})\right)^2, \tag{4}$$

where $C_i(t)$ are measured channel values and w_i are weights (often $1/\sigma_i^2$).

Regularization in time. For stable real-time products, add a smoothness penalty:

$$\lambda \left\|\boldsymbol{\theta}(t) - \boldsymbol{\theta}(t - \Delta t)\right\|^2. \tag{5}$$

5 Practical considerations

- **Anisotropy:** GOES views a specific look direction; early SEP onsets can be strongly anisotropic. Decide whether to treat GOES as a proxy for an isotropic upstream boundary or to incorporate pitch-angle information.
- **Background subtraction:** subtract pre-event background or include a background term in $J(E)$.
- **Saturation / contamination:** high-energy channels can be contaminated by penetrating particles; quality flags matter.
- **Units:** keep consistent with AMPS input (typically $\mathrm{p\,cm^{-2}\,s^{-1}\,sr^{-1}\,(MeV/n)^{-1}}$).

6 Suggested references

- Kress, B. T., et al. (2021). "Observations From NOAA's Newest Solar Proton Sensor." *Space Weather.*
- Hu, S., et al. (2022). "Calibration of the GOES high-energy proton detectors" (SWSC).
- NOAA/NCEI: GOES-R SEISS product and documentation pages.