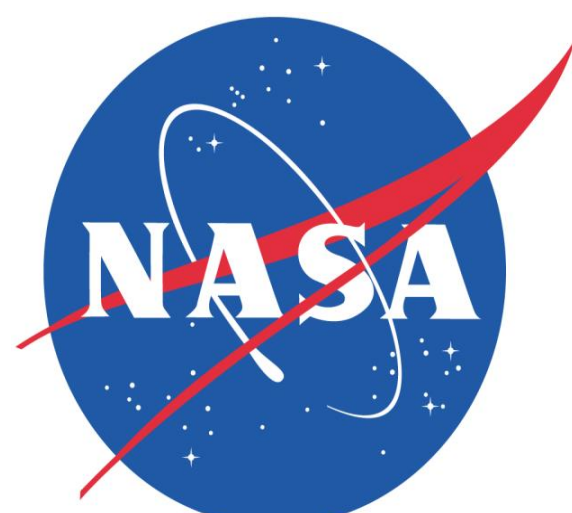
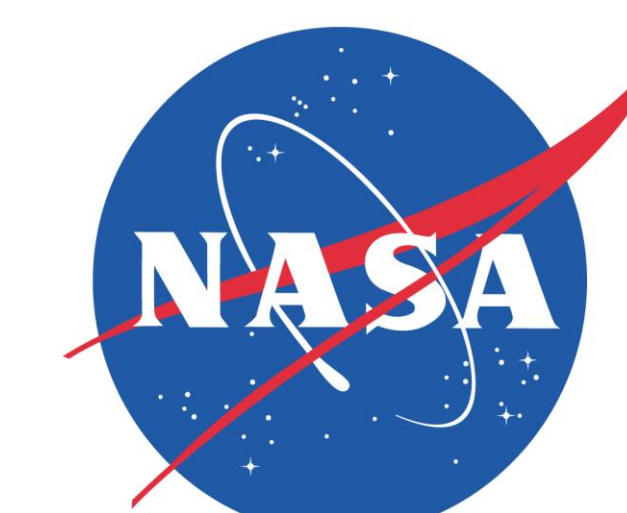




NAIRAS Model Updates and Improvements to the Prediction of the Ionizing Radiation Environment from the Earth's Surface to Geospace



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1.0 NAIRAS Model Description

• Nowcast of Aerospace Ionizing Radiation System (NAIRAS) Model

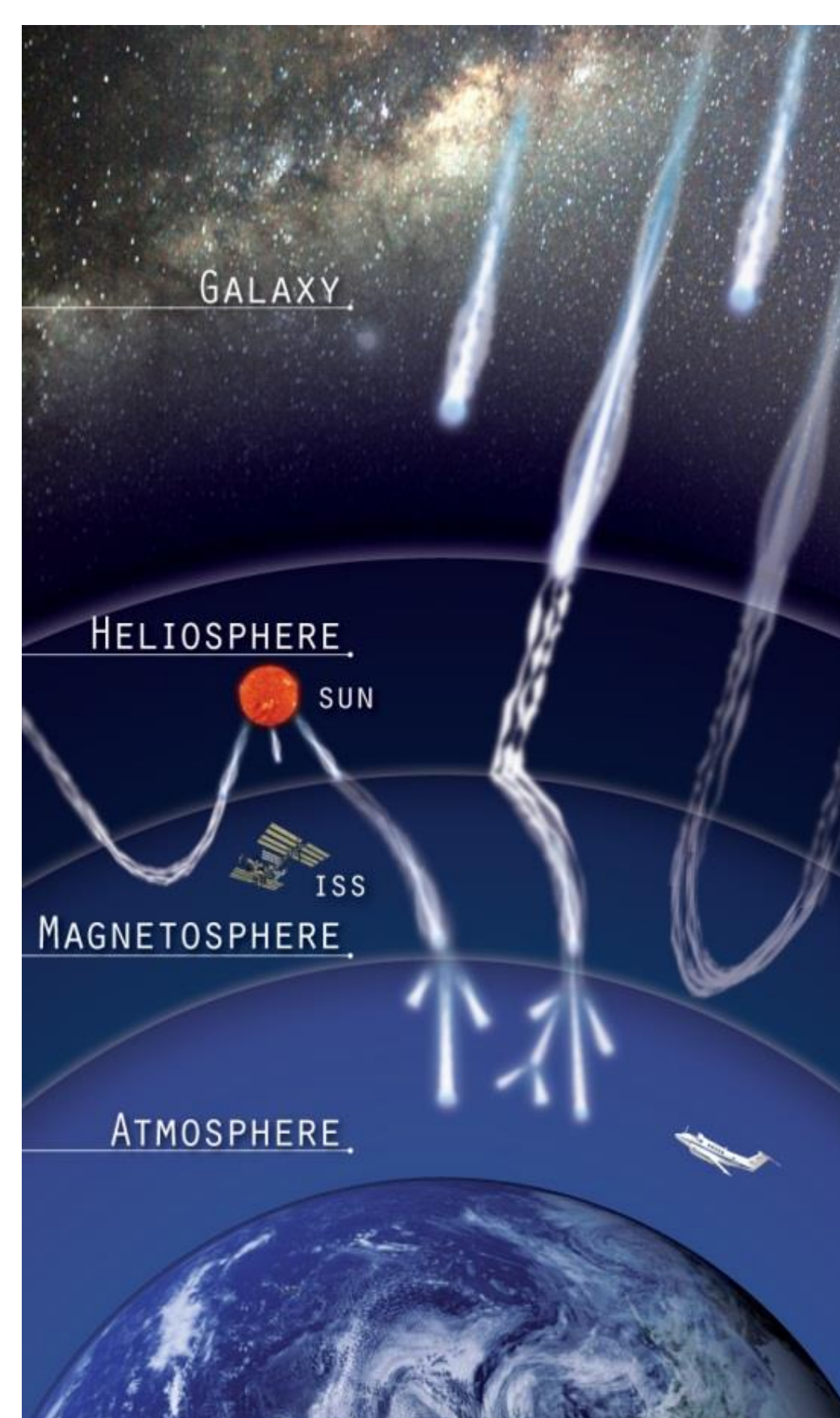
- Running in real-time on LaRC computer cluster since 2011, results hosted on Space Environment Technologies server/website
- Running in real-time at CCMC since 2020

• Key Model Features

- Global ionizing radiation environment model
- Physics-based **HZETRN** (High Charge (Z) and Energy TRAnsport) code
- Real-time inclusion of solar energetic particle (SEP) radiation
- Real-time solar-magnetospheric effects on radiation (cutoff model by Kress *et al.* [2004, 2010])

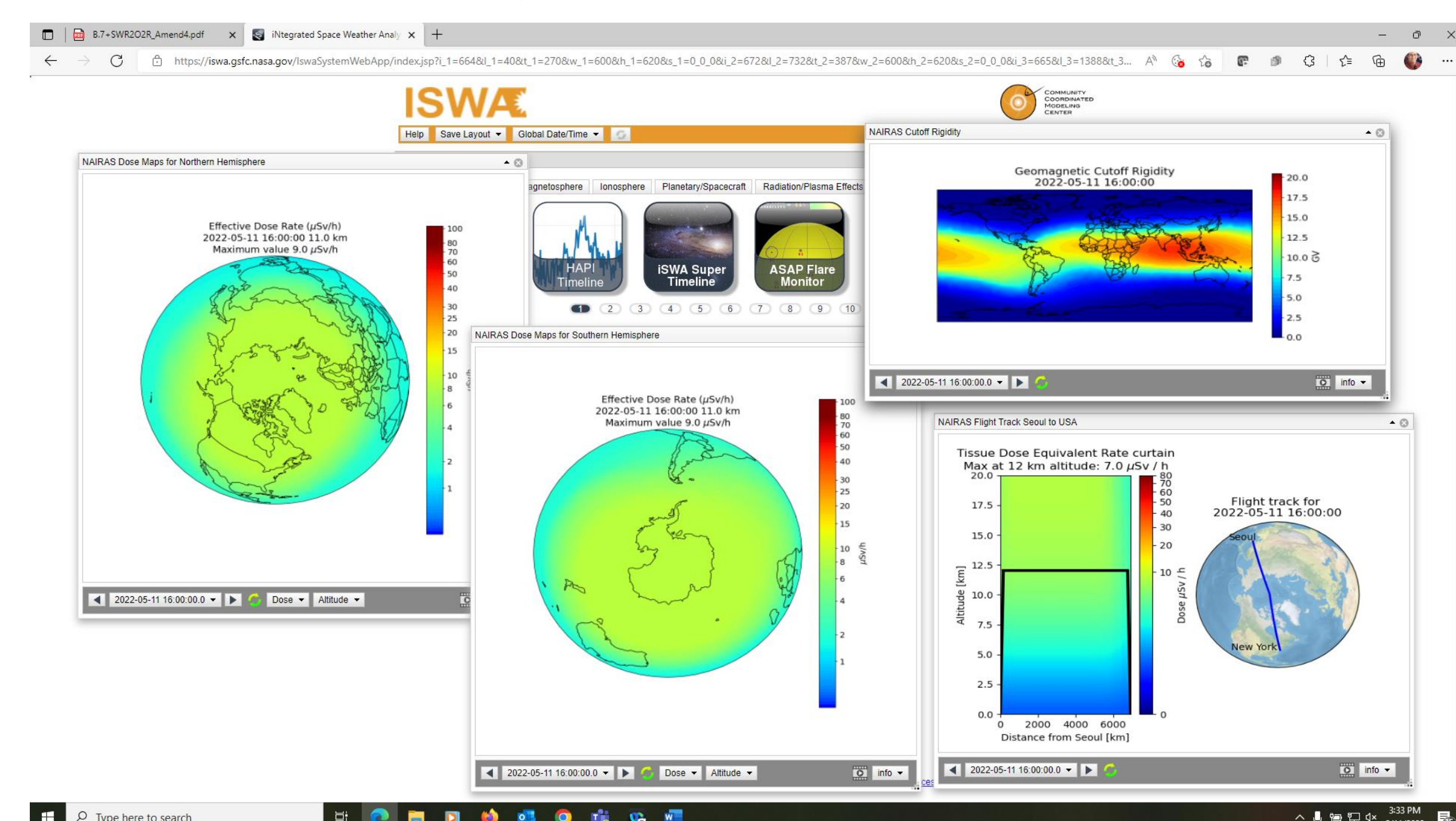
• New/Current Model Development

- Improved SEP dose nowcast and forecast
- Extend to low-Earth orbit (LEO) environment
- Single-Event Effects (SEE) radiation risk assessment quantities
- Run-on-Request (RoR) @ CCMC



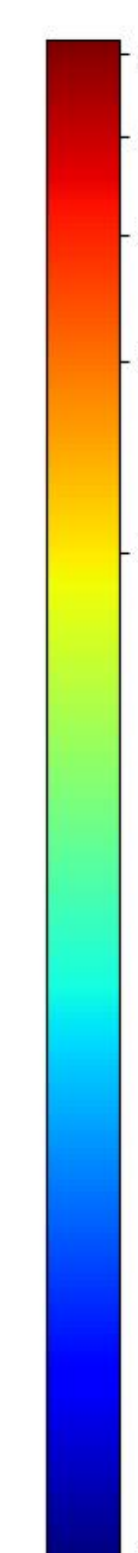
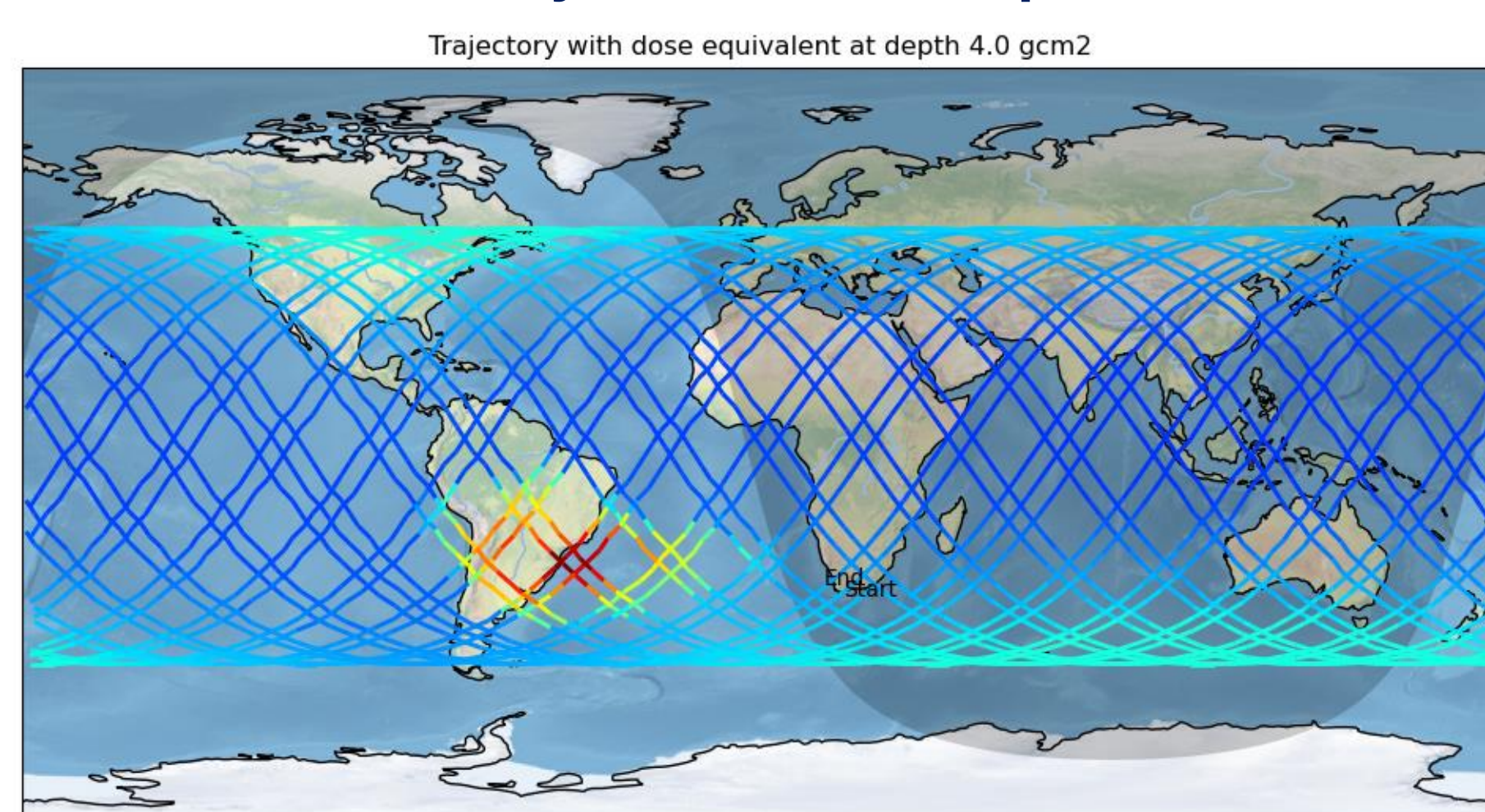
2.1 Real-Time Aviation Radiation Dose

Availability: CCMC Integrated Space Weather Analysis System (ISWA)

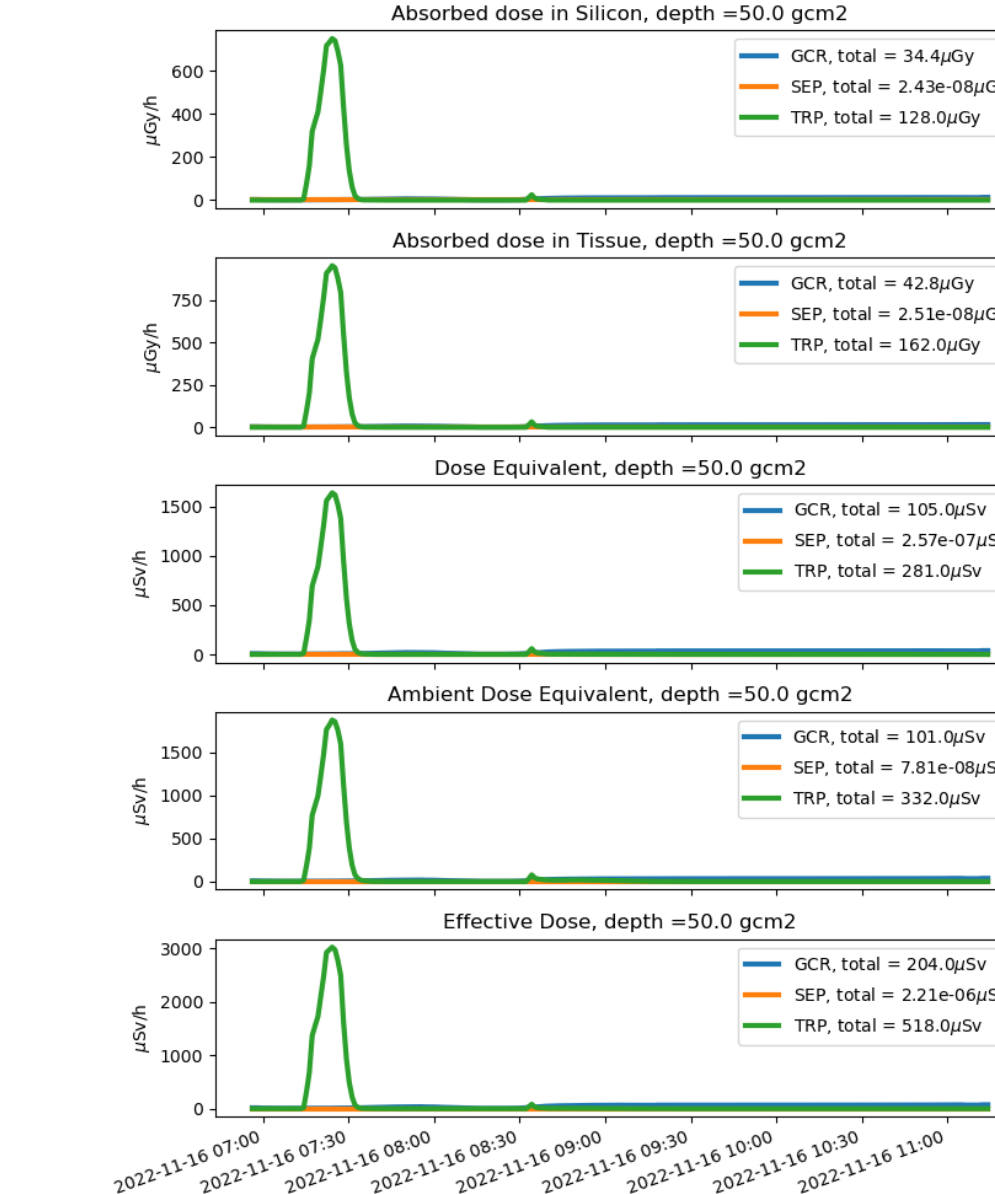
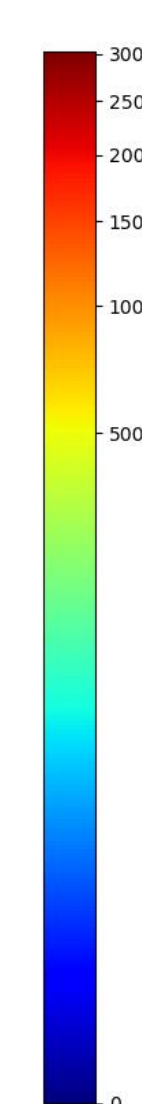


2.2 Near Real-Time International Space Station (ISS) Effective Dose

Availability: Under Development



2.3 Near Real-Time NASA Artemis 1 Dose



3.0 Run-on-Request (RoR) @ CCMC

Availability: Spring 2023

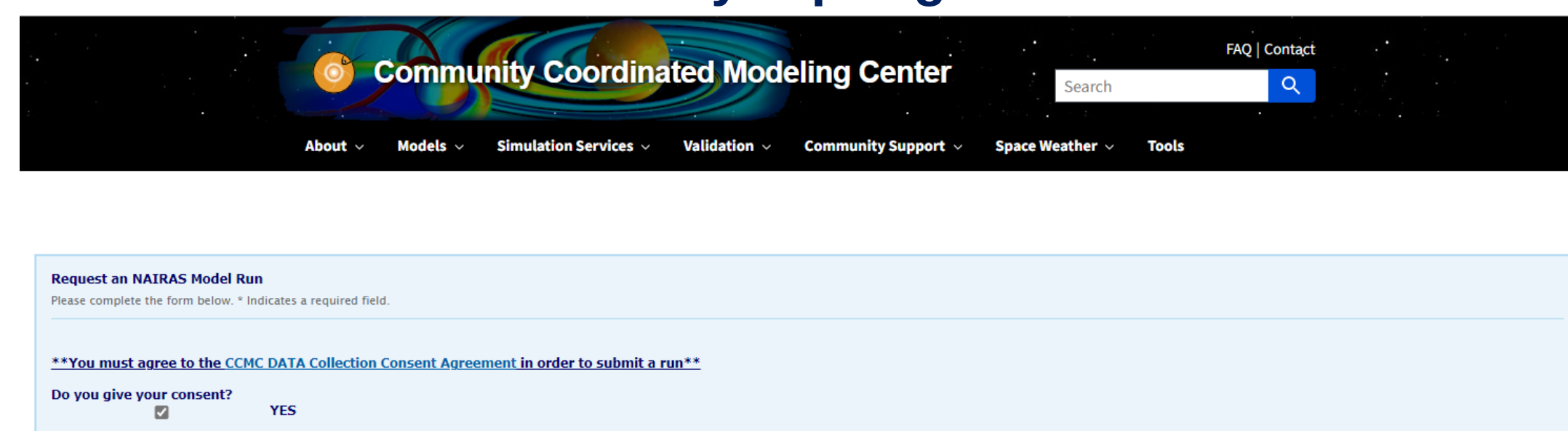


Table: RoR Capability Summary and Description

Run Option	Output Quantities	User Input
Global Dosimetric	Absorbed dose in silicon, absorbed dose in tissue, dose equivalent, ambient dose equivalent, effective dose	Start/End Date-Time
Flight Trajectory	Dosimetric & Flux/Fluence	Trajectory file (date/time/lat/lon/alt)
	Dosimetric	Shielding depths for dosimetric calculations
	Flux/Fluence	Shielding depths for flux/fluence calculations
	Integral	Lower LET/Energy bounds of integral quantity
	Differential	N/A (full model differential spectra written to output)

3.1 RoR LEO (ISS-like) Dose

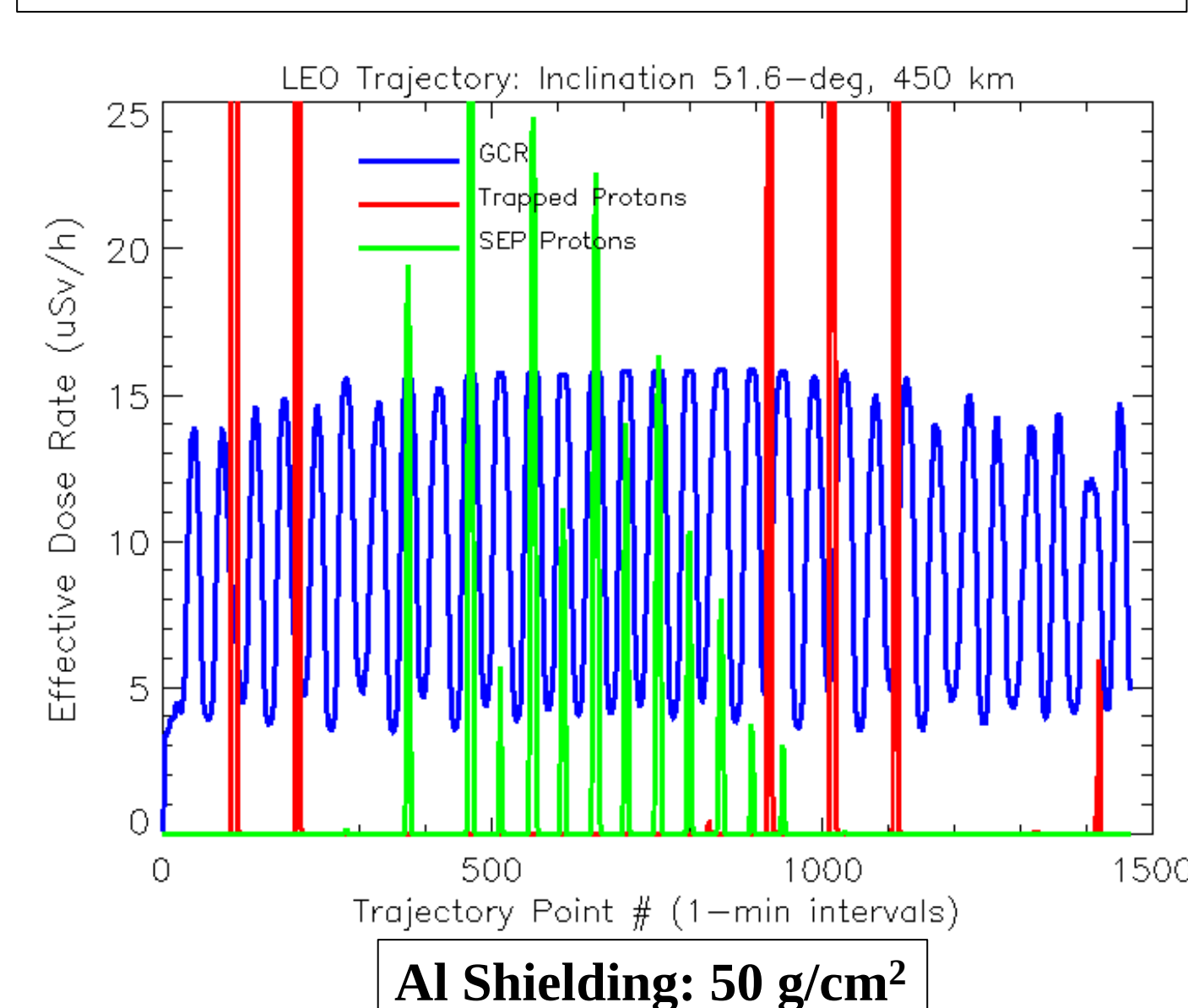
• NAIRAS Total Trajectory Effective Dose (per day)

- GCR: 215 uSv
- Trapped proton (TRP): 163 uSv
- Total: 378 uSv

• International Space Station (ISS) Total Effective Dose (per day)

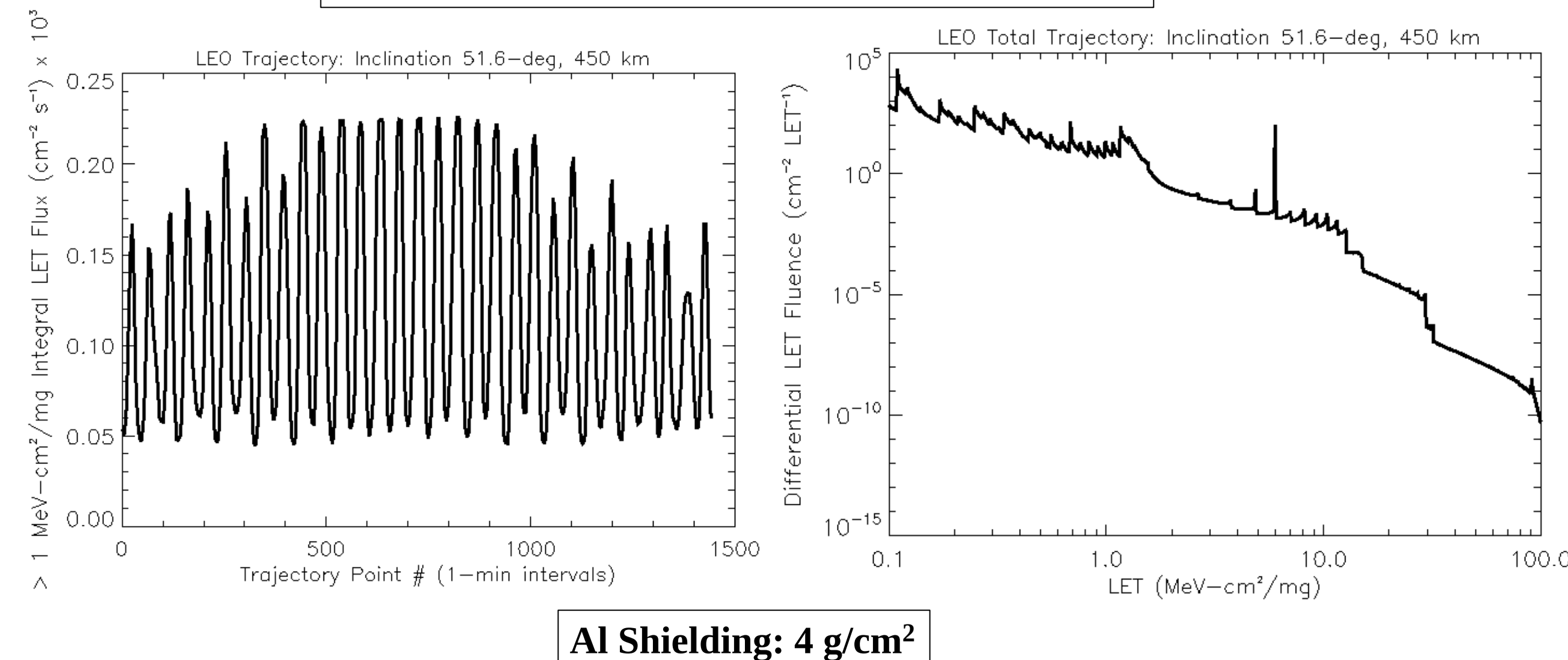
- GCR: 233 uSv (Wu *et al.*, 1996)
- TRP: 166 uSv (Wu *et al.*, 1996)
- Total: 438 uSv (Cucinotta, 2008)

November 02 16:00 UT – November 03 16:00 UT



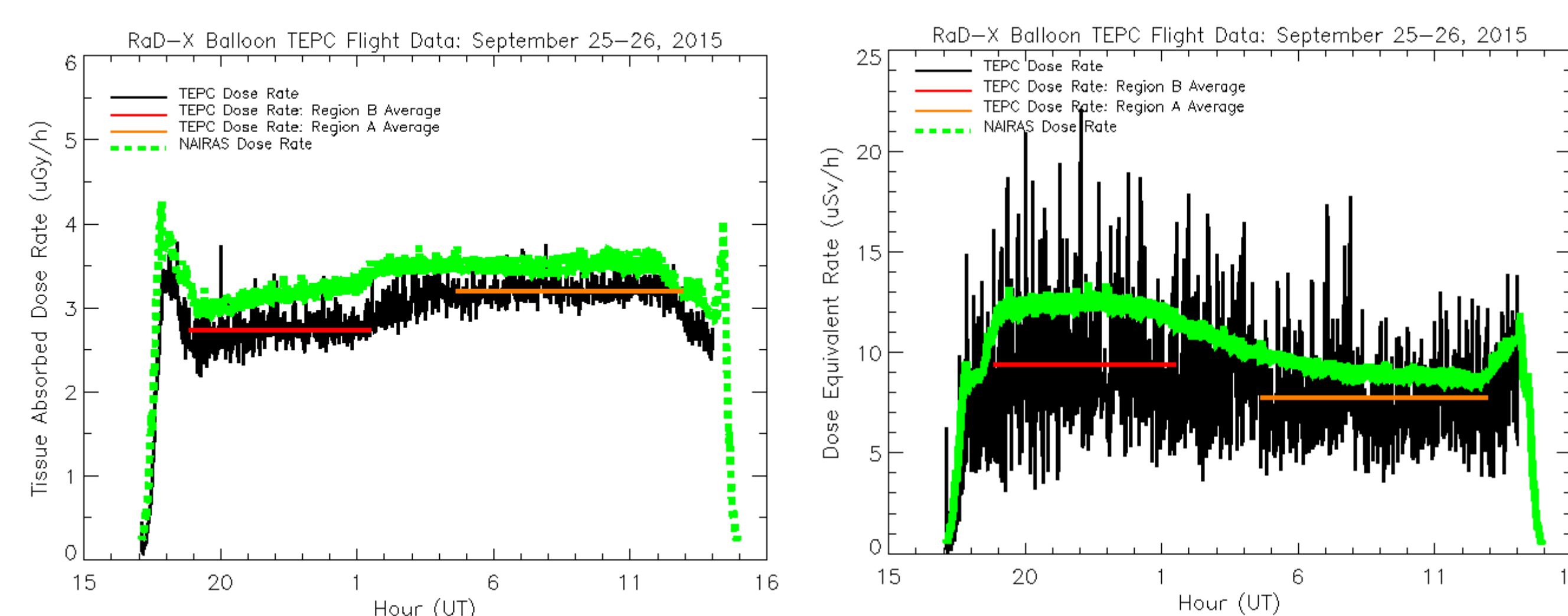
3.2 RoR LEO (ISS-like) LET Flux/Fluence

November 02 16:00 UT – November 03 16:00 UT



3.3 RoR High-Altitude Balloon Dose

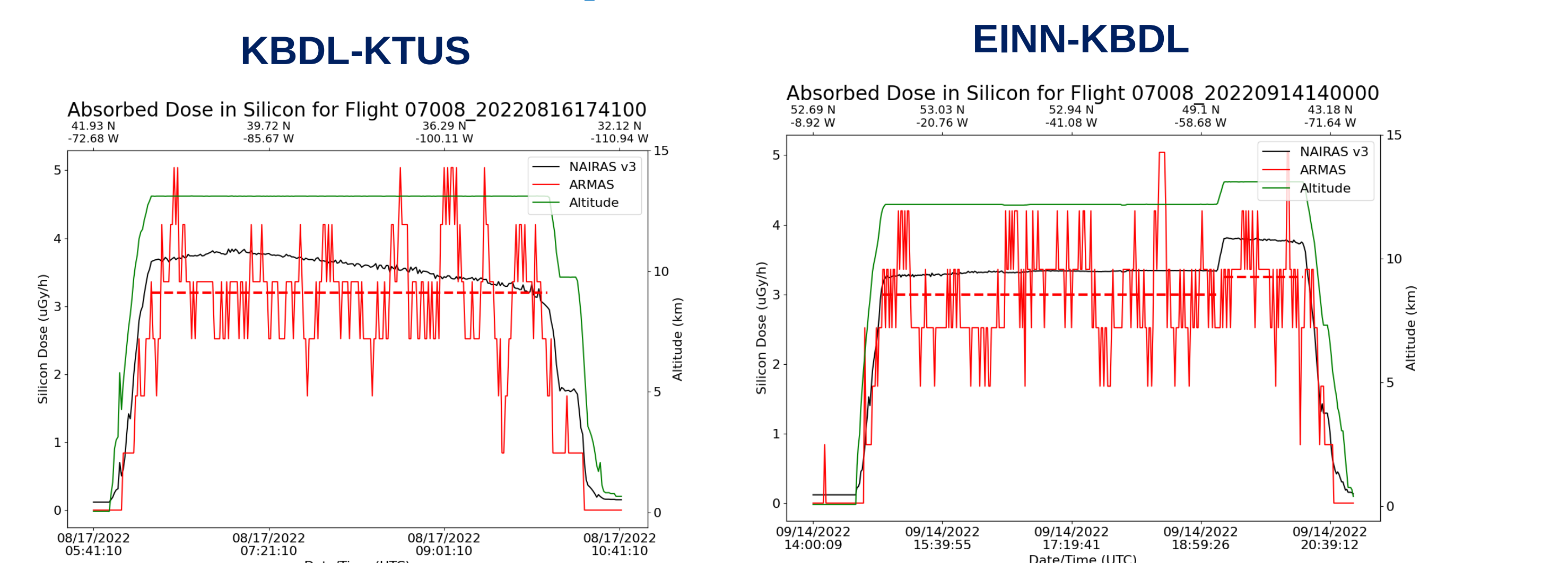
NASA Radiation Dosimetry Experiment (RaD-X) Balloon Flight



Region A: 21 km < Z < 27 km; Region B: Z > 32.5 km

POC: Christopher.J.Mertens@nasa.gov

3.4 RoR US Corporate Aircraft



4.1 SEP Events: Improved Modeling

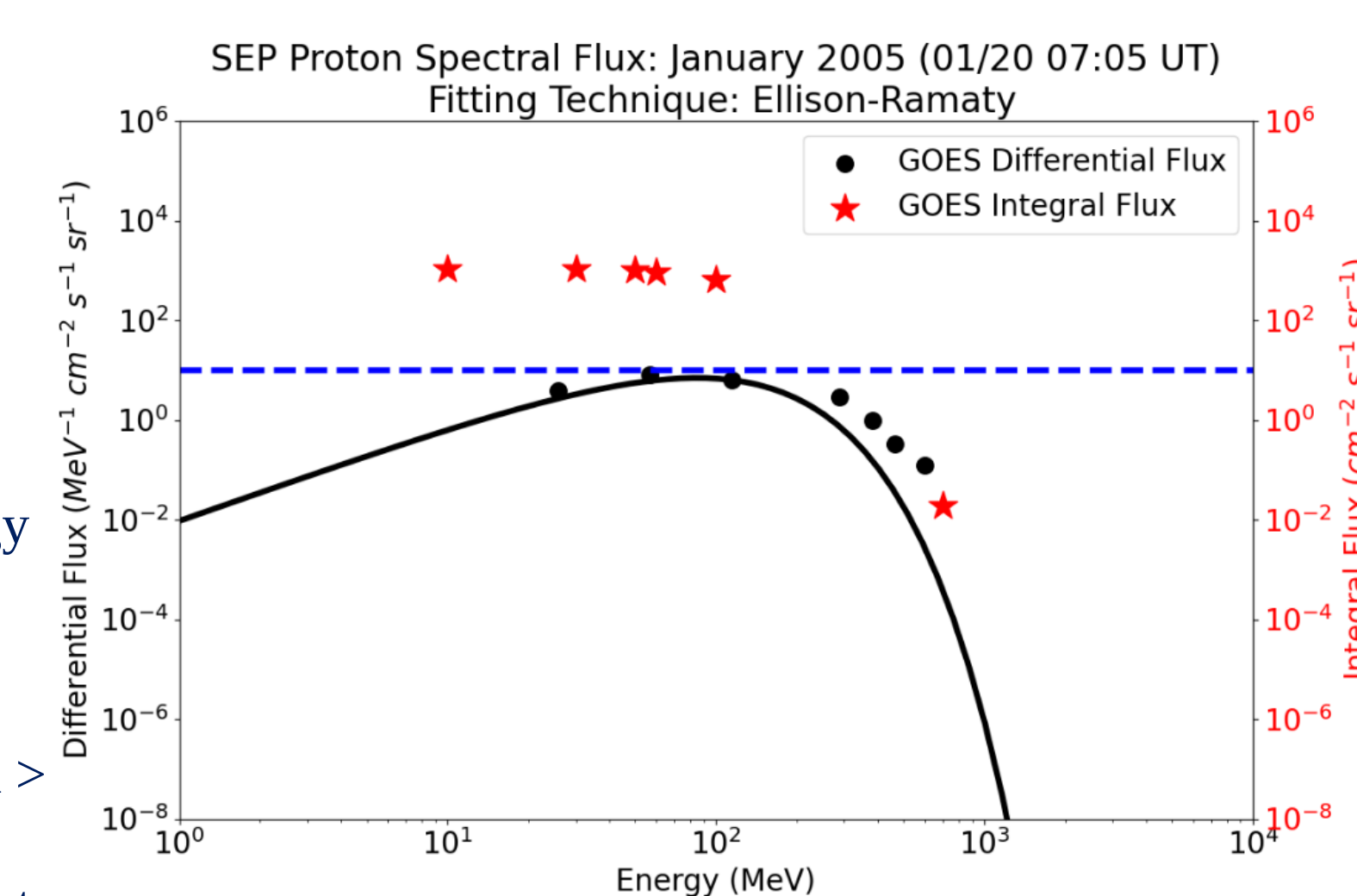
• New Approach

- Fit spectrum to GOES integral proton flux rather than differential flux measurements

• Benefits

- Improved robustness
 - Difficulty fitting GOES differential channels at event onset and for weak-to-moderate events
 - Extrapolation beyond highest differential energy channel (~500 MeV) requires introducing arbitrary and subjective criteria
 - 50% or more of SEP effective dose at large material depths (aviation altitudes) comes from > 500 MeV protons
- Preliminary simulations using neutron monitor data suggest fitting to GOES integral proton flux may better represent the relativistic protons during GLEs

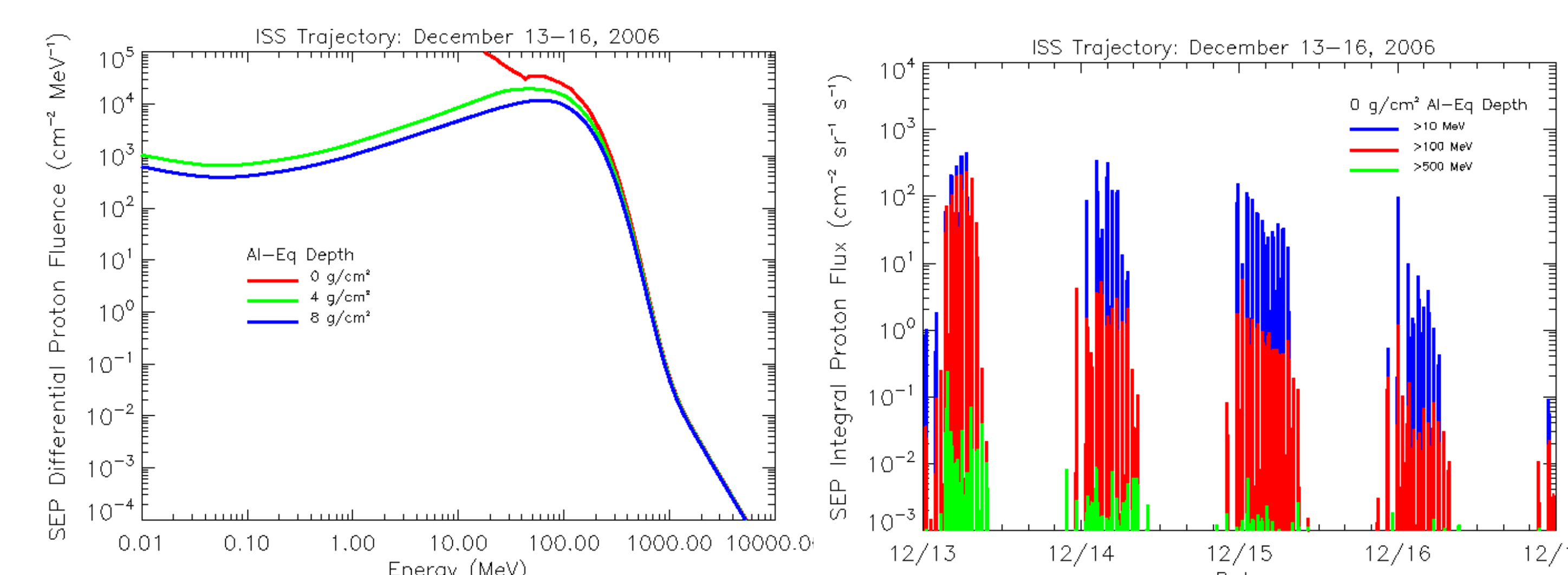
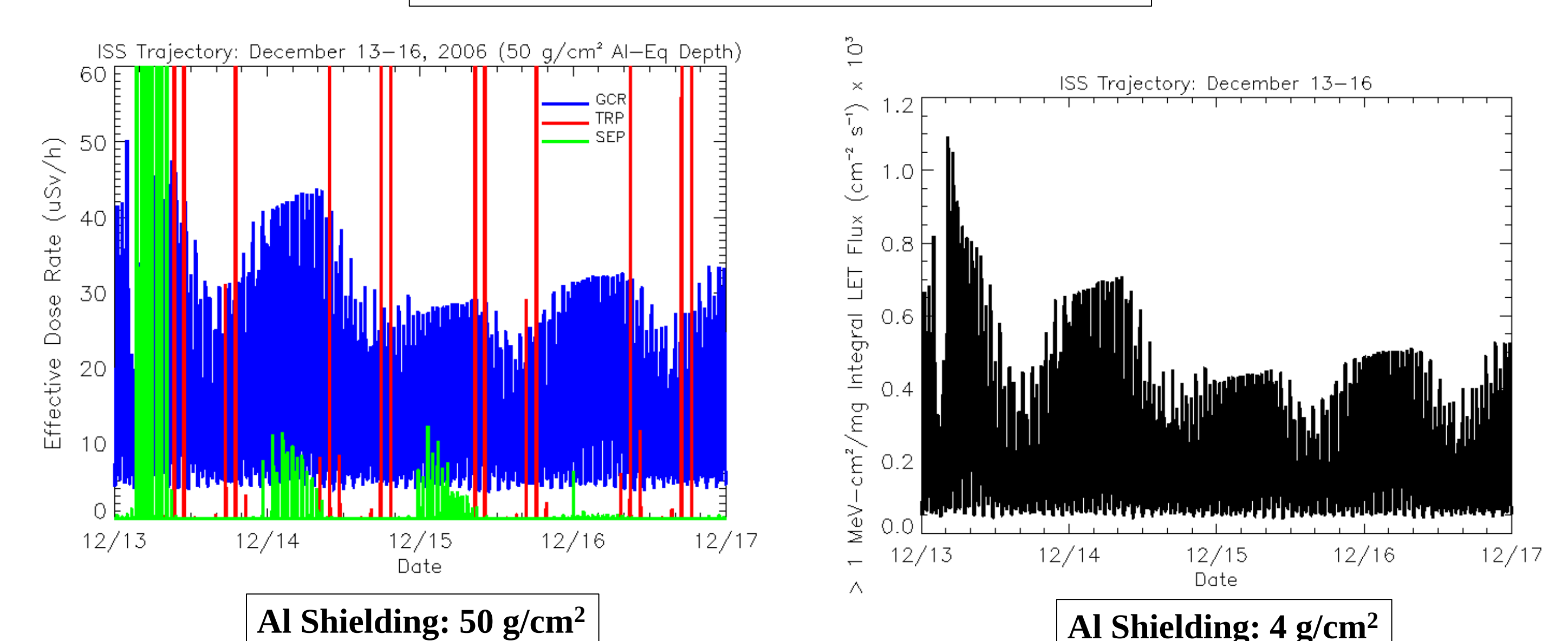
- New integral flux fitting approach provides a SEP proton spectrum forecast (See AMS 2023 Talk!)



SEP proton spectrum (black line) fit to GOES integral flux and comparison to GOES differential proton flux. Horizontal blue line indicates NOAA/SWPC SEP event threshold for >10 MeV proton flux.

4.2 SEP Events: ISS Radiation

December 13 00:00 UT – December 17 00:00 UT



5.0 Summary

• Major NAIRAS Code Deliverables to CCMC

- NAIRAS Real-Time Global Dosimetric Quantities (**Publicly Available Now**)
- NAIRAS RoR Capability (**Publicly Accessible in Spring 2023**)
- NAIRAS Improved SEP Proton Spectral Fitting Algorithm (**Operational in early 2023**)

• Significant Improvements and Extensions to NAIRAS Model

- NAIRAS predictions now include both dosimetric quantities to assess human radiation exposure and differential/flux quantities to assess SEEs in avionic system

- NAIRAS dose comparisons to measurement data: < 30% for all dosimetric quantities at altitudes from 0-40 km (RaD-X data and ARMAS aircraft data)

- SEP Dose Forecast Development: see AMS 2023 talk!