

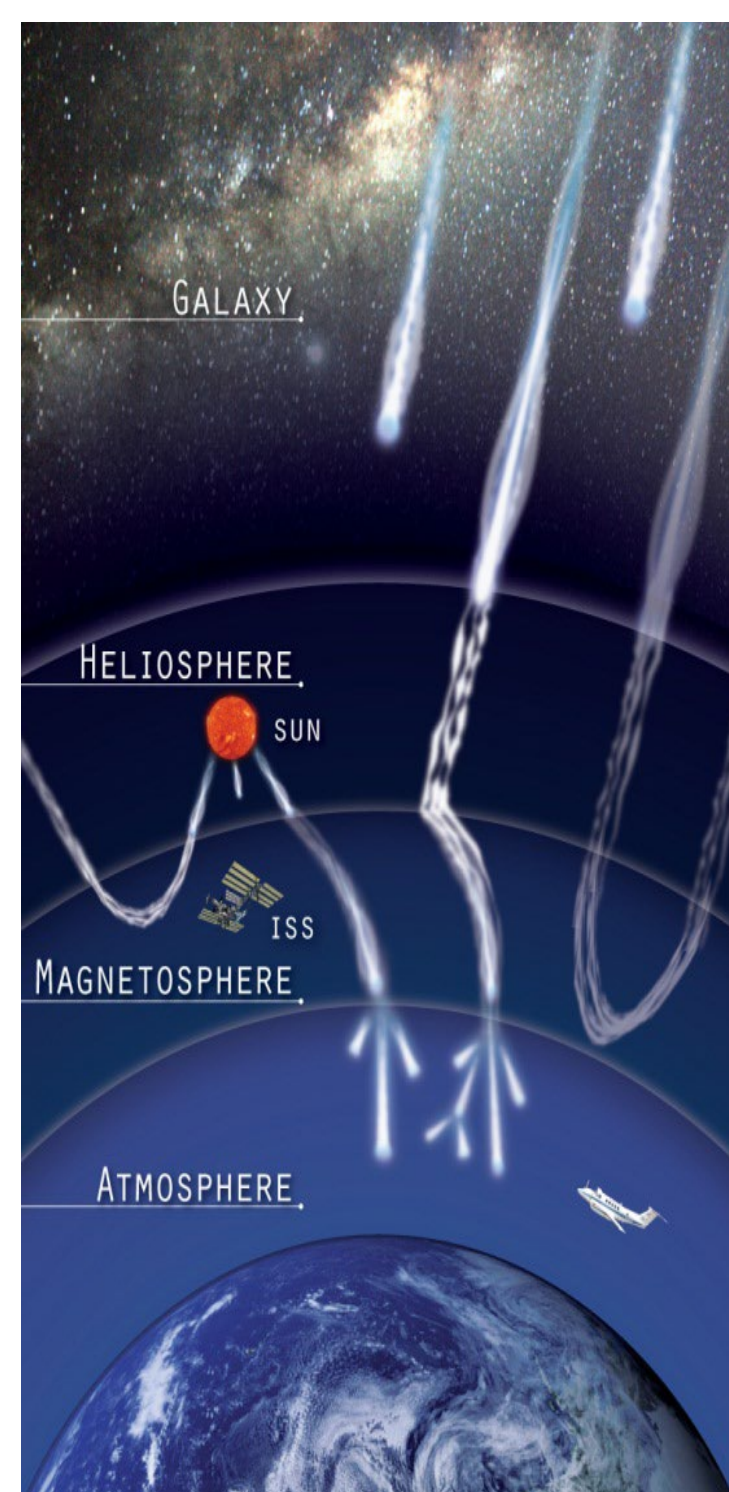
Forecasting SEP Atmospheric and Space Radiation By Coupling UMASEP and NAIRAS Models

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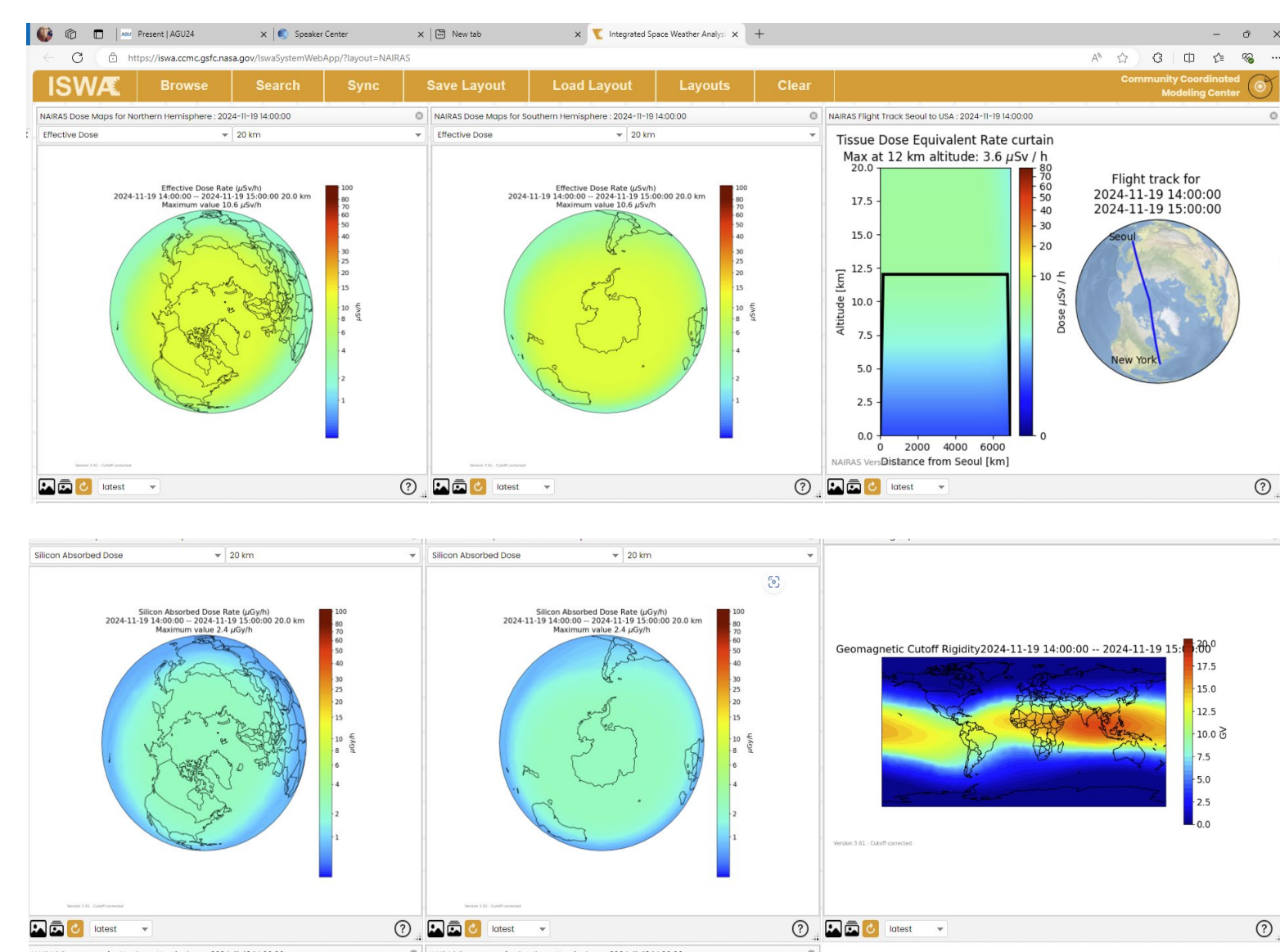
1.0 NAIRAS Model Description

- **Nowcast of Aerospace Ionizing Radiation System (NAIRAS) Model**
 - Running in real-time since 2011
 - Running in real-time at Community Coordinated Modeling Center (CCMC) since 2020
- **Key (Vintage) Model Features**
 - 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 Developments**
 - Extend from atmosphere to space environment, now including trapped protons (TRP-p) and electrons (TRP-e)
 - SEP heavy-ions (Z=2-92, A=4-238) added
 - Single-Event Effects (SEE) radiation risk assessment quantities added (differential/integral flux/fluence)
 - Real-time products at 20 km to support military high-flyers
 - Run-on-Request (RoR) @ CCMC ([search NAIRAS CCMC](#))



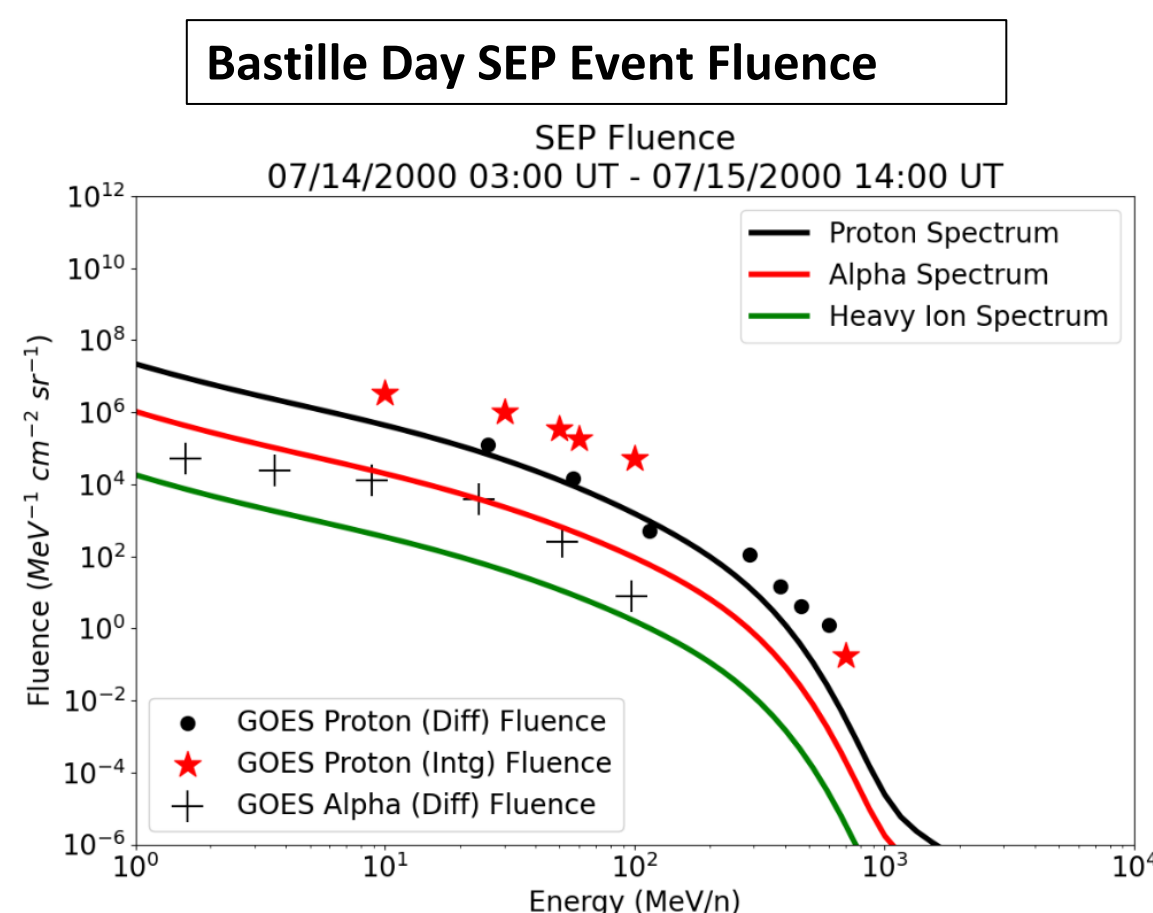
2.0 Real-Time Aviation Radiation Dose

Availability: CCMC Integrated Space Weather Analysis System (iSWA)



3.0 NAIRAS SEP Spectral Fitting

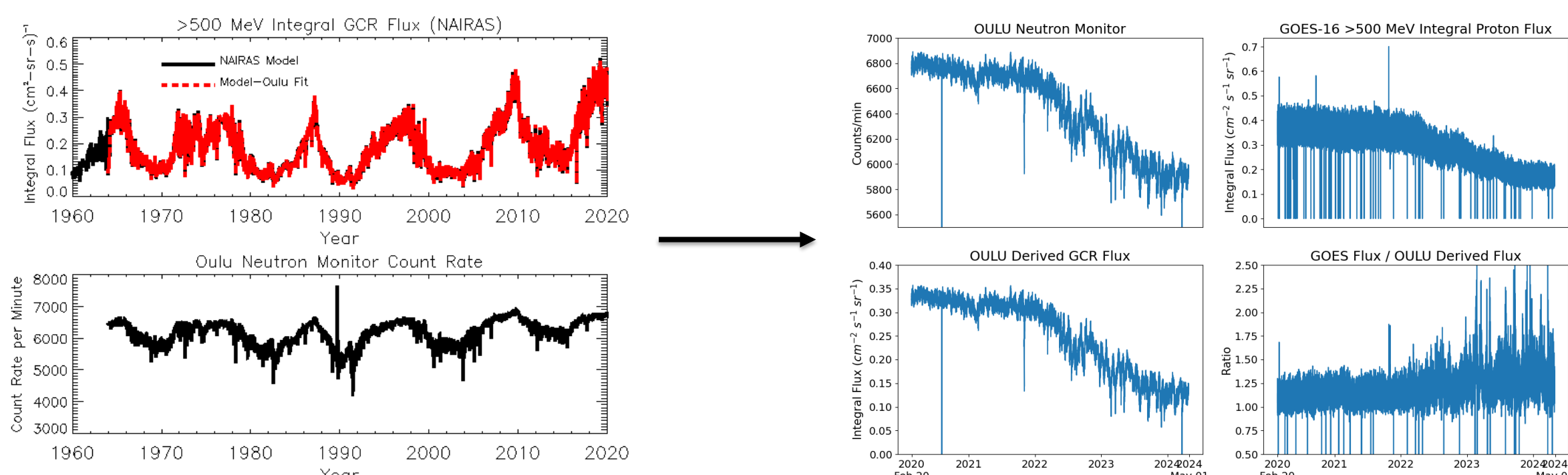
- **Protons**
 - Fit spectrum to GOES integral proton flux
 - Galactic cosmic ray (GCR) background subtraction applied to GOES-16+ (SEISS sensor system, 2020+) >500 MeV integral proton flux measurements
 - Fit four functional forms
 - Choose solution with minimum chi-square
- **Alpha**
 - Retain proton spectral shape from previous step
 - Scale proton spectrum by optimal normalization factor using GOES alpha differential flux
- **Heavy-Ion (Z > 2)**
 - Scale alpha spectrum from previous step using element/alpha abundance ratios
 - **Major heavy-ion abundance ratios:** using GOES alpha and ACE Solar Isotope Spectrometer (SIS) element flux measurements (Xapsos *et al.*, 2007)
 - **Minor heavy-ion abundance ratios:** using ACE/SIS and International Sun-Earth Explorer-3 (ISEE-3) element flux measurements (Reames, 1998)
 - **Remaining heavy-ion abundance ratios:** using photospheric emission measurements with a scale factor of 4 if the first ionizing potential is less than 10 eV (Grevesse, 2019)



SEP proton spectrum fit to GOES integral proton flux. GOES differential proton flux shown for comparison.

SEP spectra fit to GOES 5-min data. Fluence is 5-min fitted-spectra summed over event.

GOES-16 >500 MeV GCR Background Subtraction Approach



4.0 UMASEP-NAIRAS SEP Dose Forecast

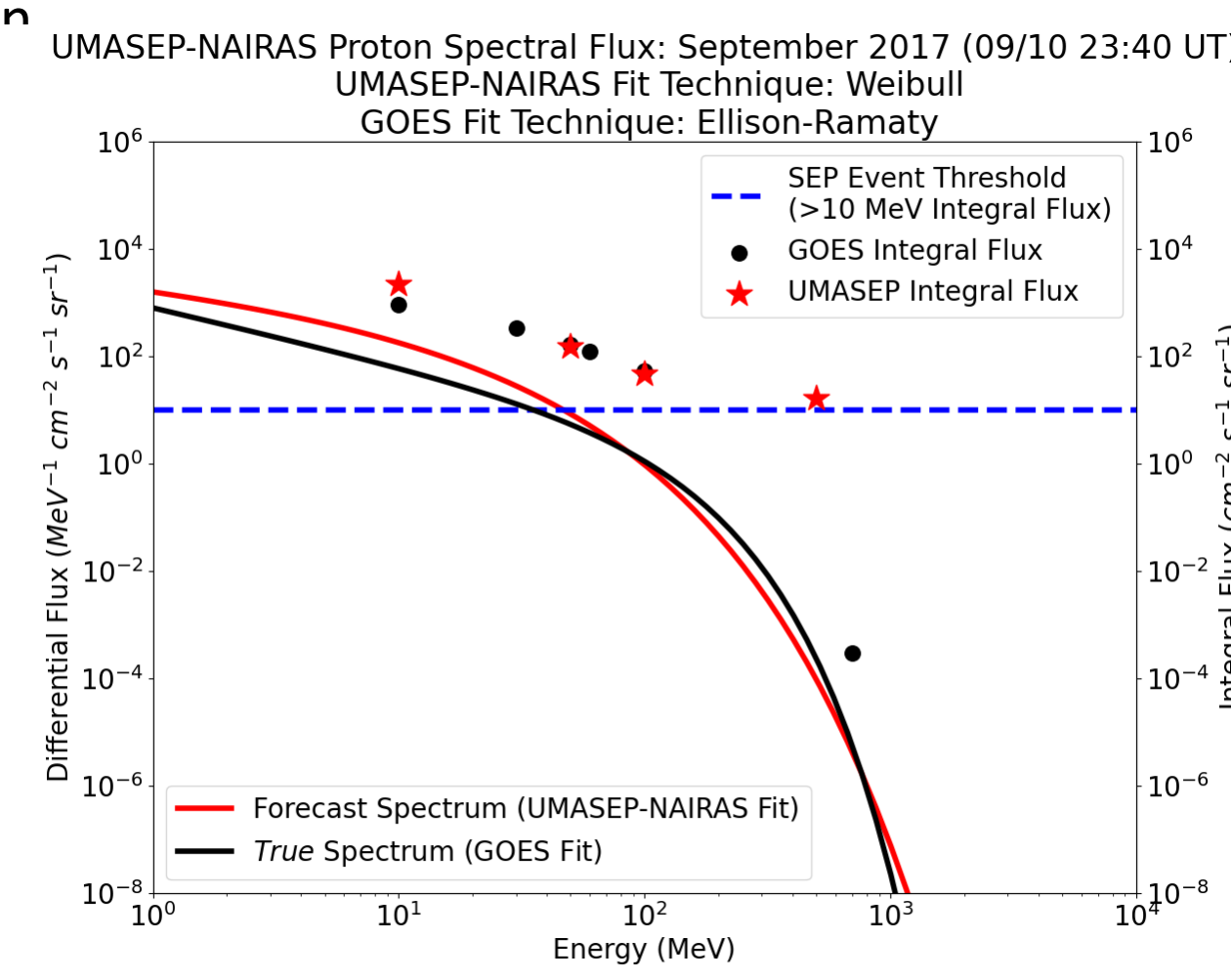
- **University of Malaga Solar particle Event Predictor (UMASEP) Model**

- **Forecast products:** free-space SEP integral proton peak flux at >10 MeV, >30 MeV, >50 MeV, >100 MeV, and >500 MeV (not used in UMASEP-NAIRAS interface)
- **Forecast windows:** 7-hours for >10 MeV, 5-hour for >50 MeV, and 3-hours for >100 MeV

- **UMASEP-NAIRAS SEP Peak Dose Forecast: Two Different Approaches (Models)**

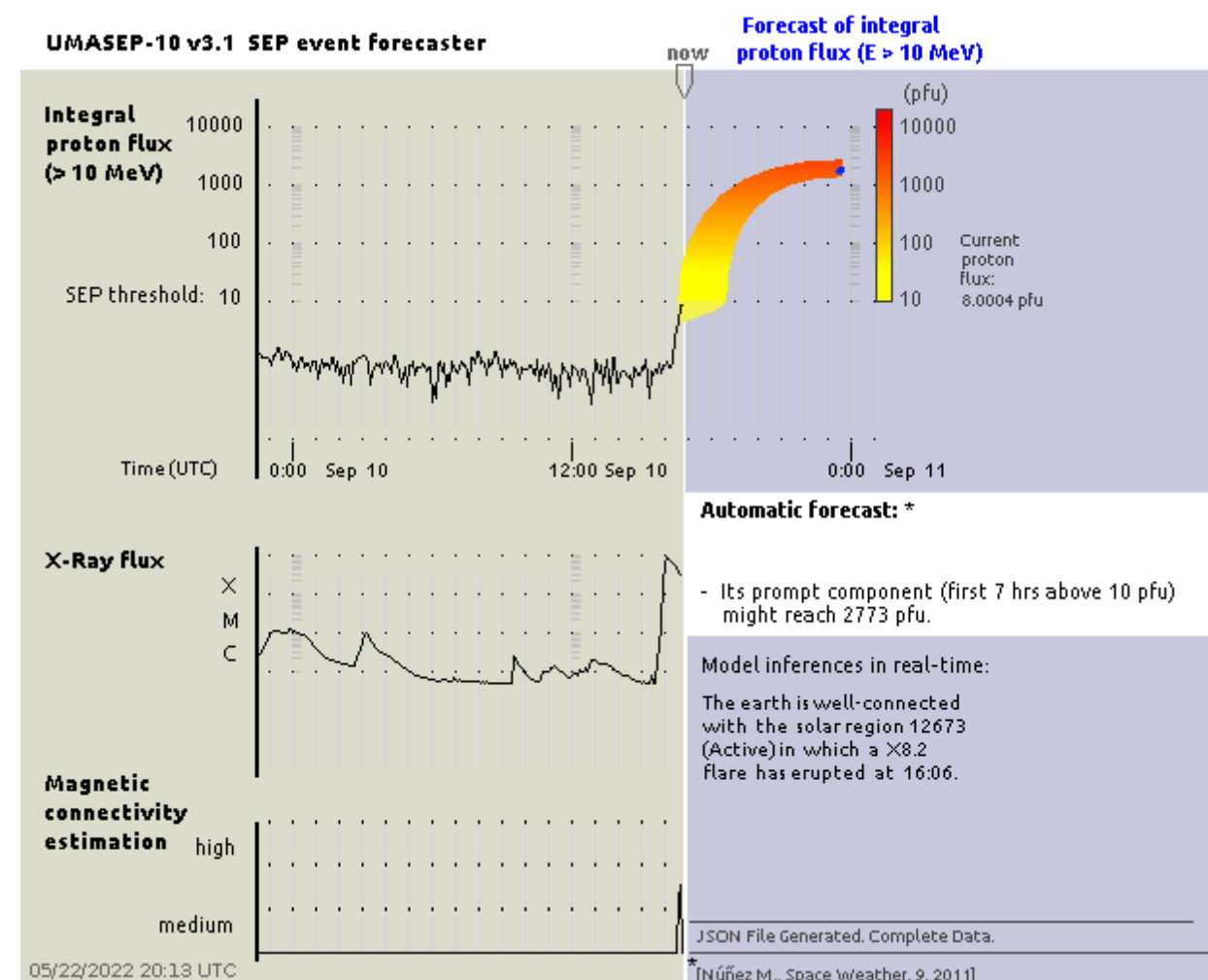
- **Physics-Based:** Replace GOES integral proton flux channels with UMASEP integral proton flux forecast products in SEP spectral fitting and subsequent transport and response function calculations
- **Empirical Model:** Based on NAIRAS calculations for historical SEP events with fit to free-space SEP integral proton flux

September 2017 SEP Event: 7 Hours After UMASEP >10 MeV Integral Proton Flux Forecast Issue Time

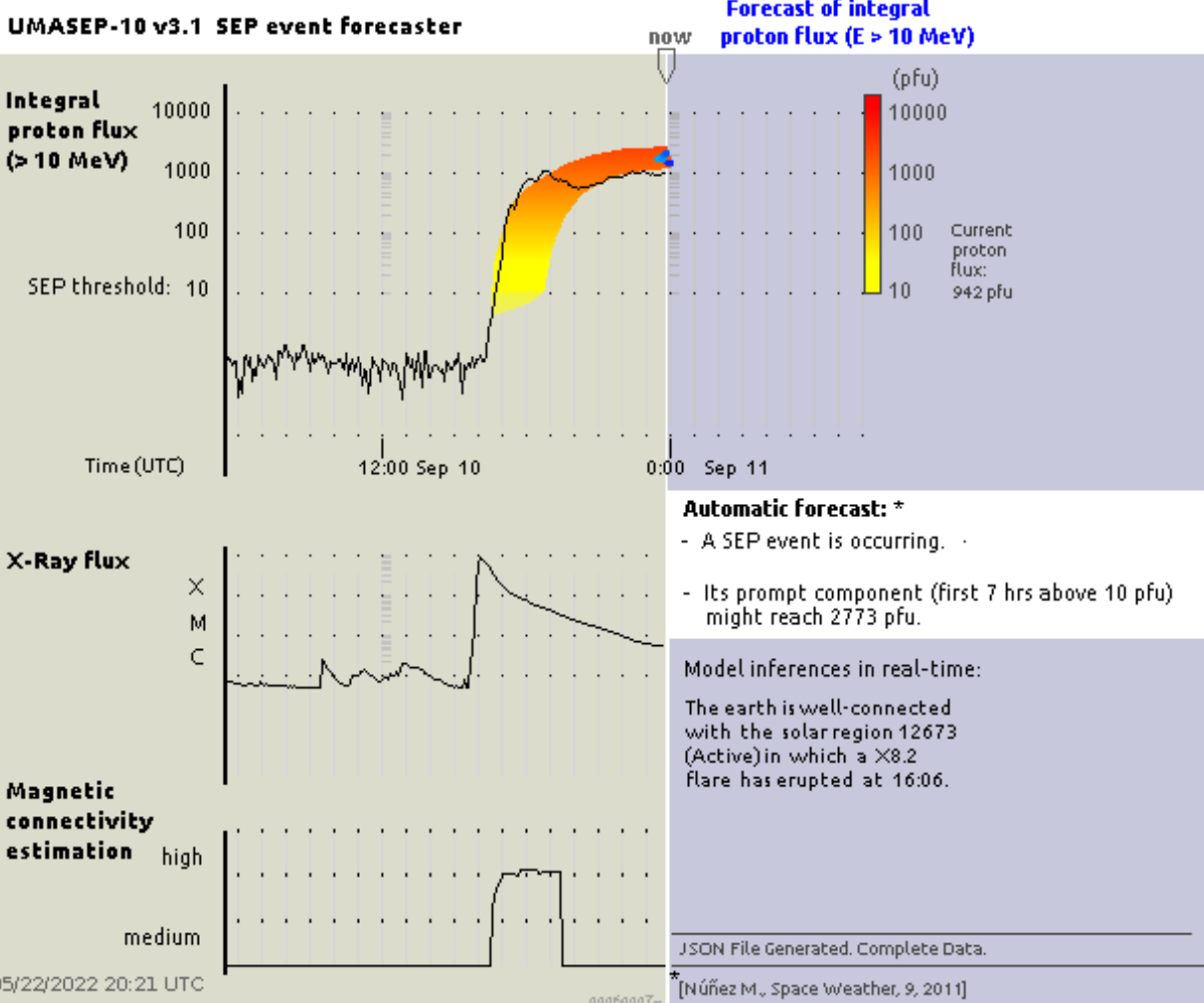


Example Below: >10 MeV Peak Integral Proton Flux

Forecast Issue Time 09/10/2017 16:40 UT



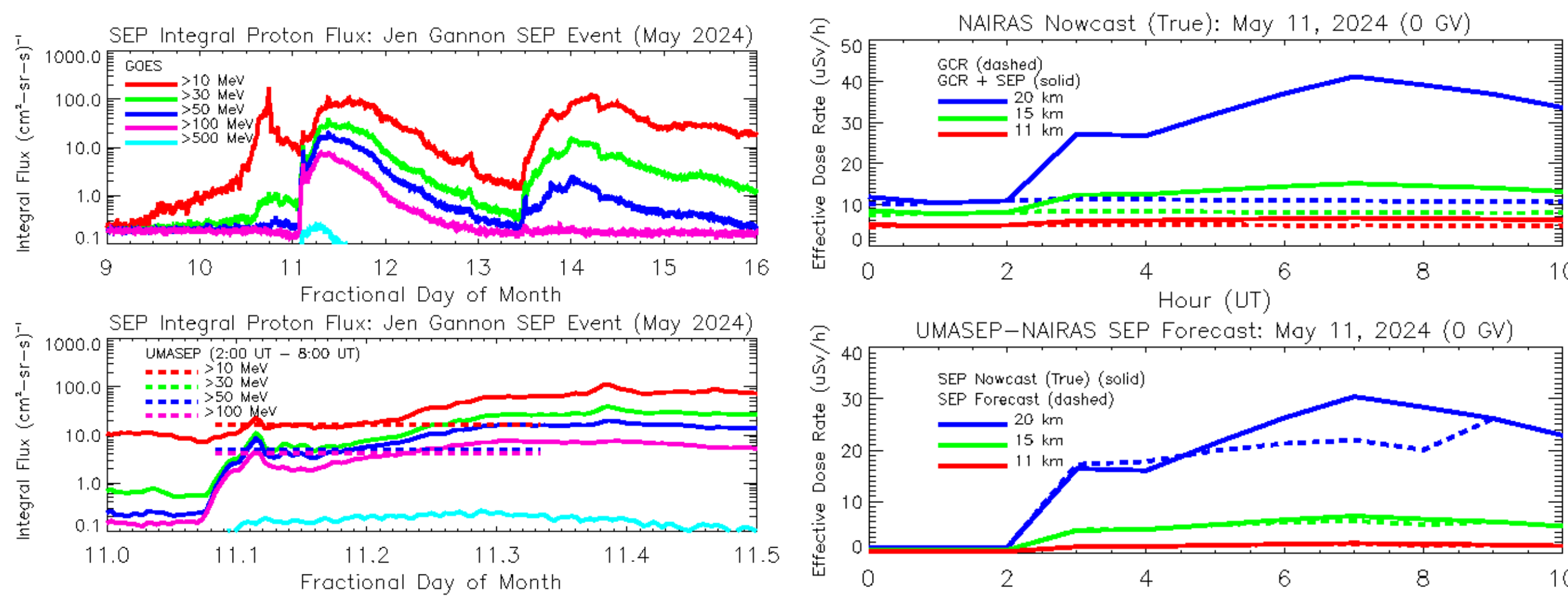
Forecast Window: Issue Time + 7 hours



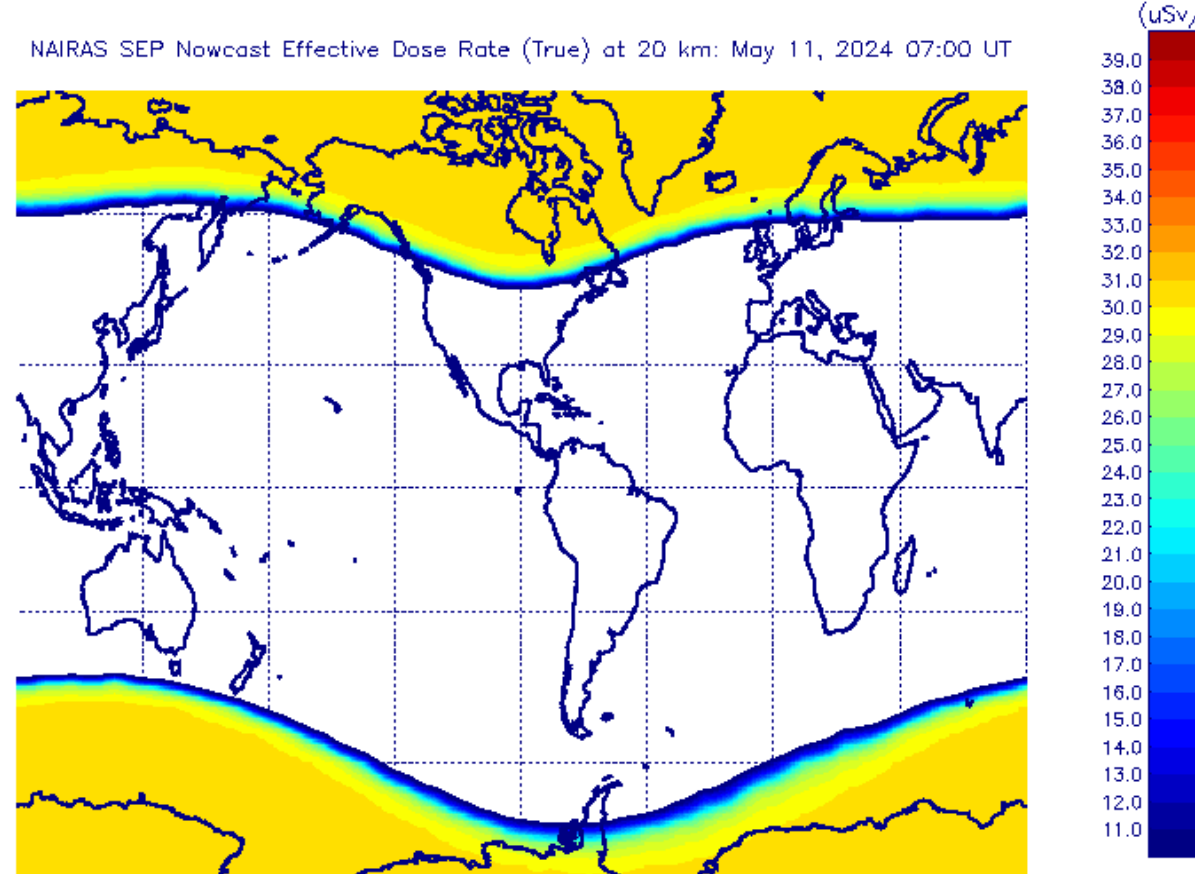
Other UMASEP Peak Integral Proton Flux Forecast Products: >30 MeV, >50 MeV, >100 MeV, >500 MeV

5.0 SEP Dose Forecast: May 10-12, 2024

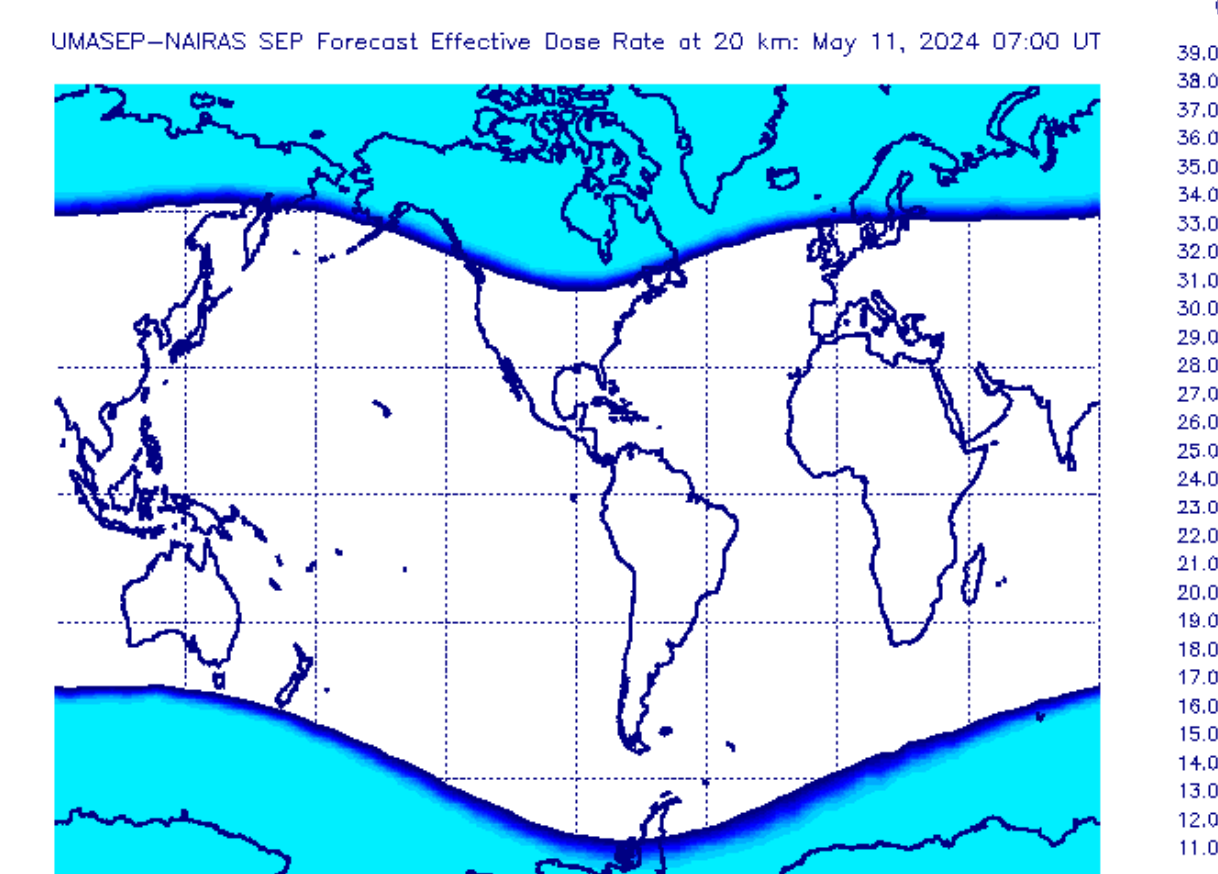
5.1 Atmosphere



"True"

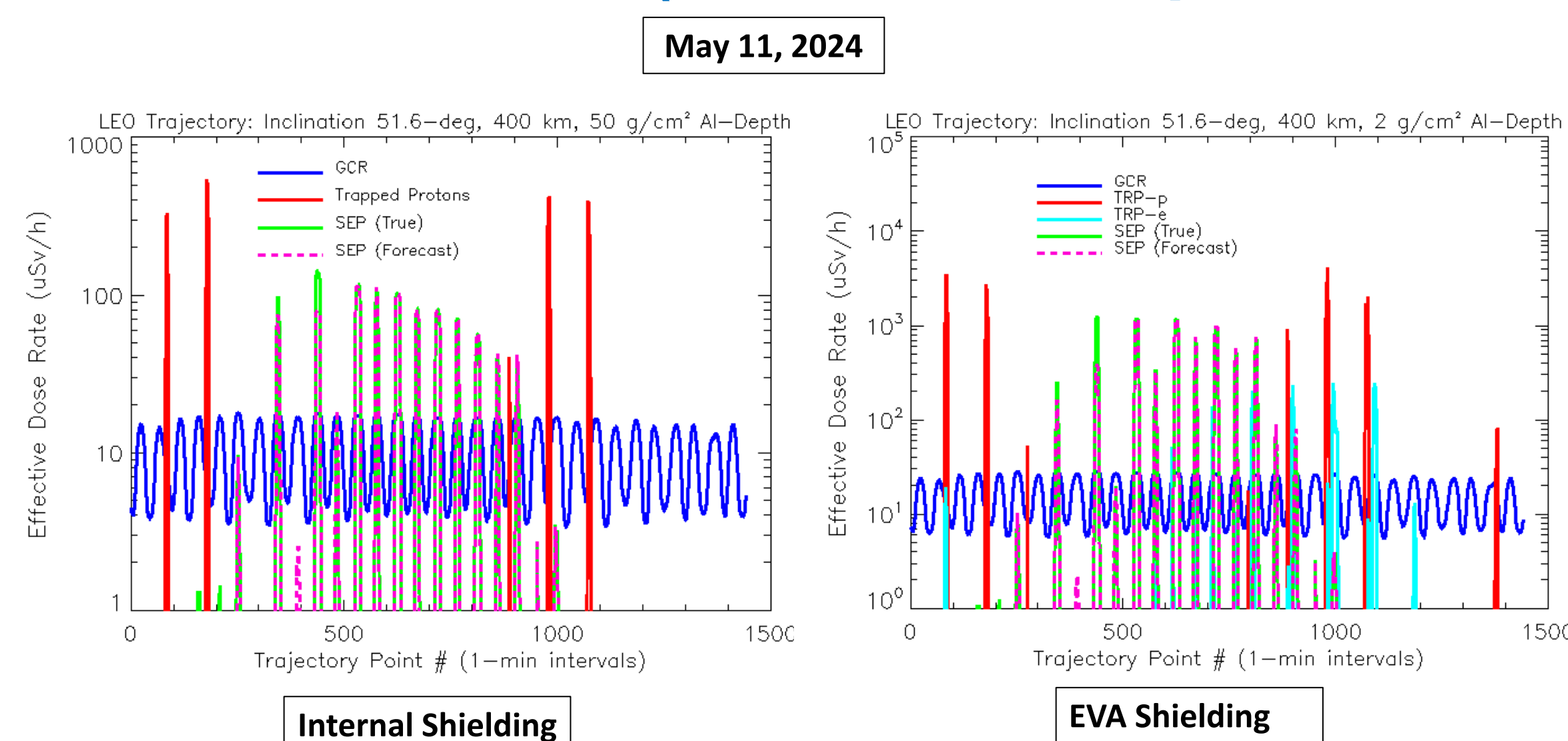


Forecast



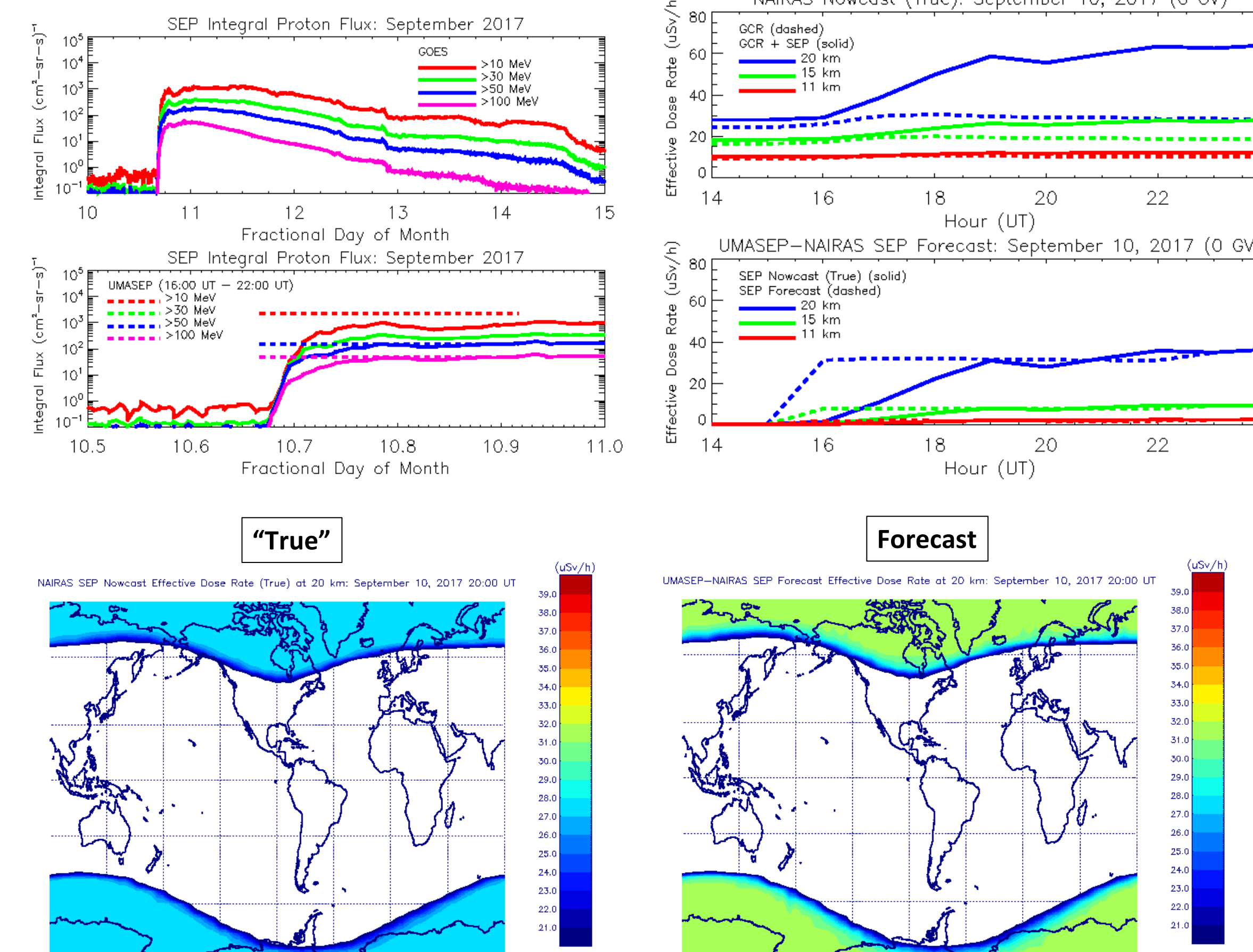
POC: Christopher.J.Mertens@nasa.gov

5.2 Low-Earth Orbit (International Space Station)

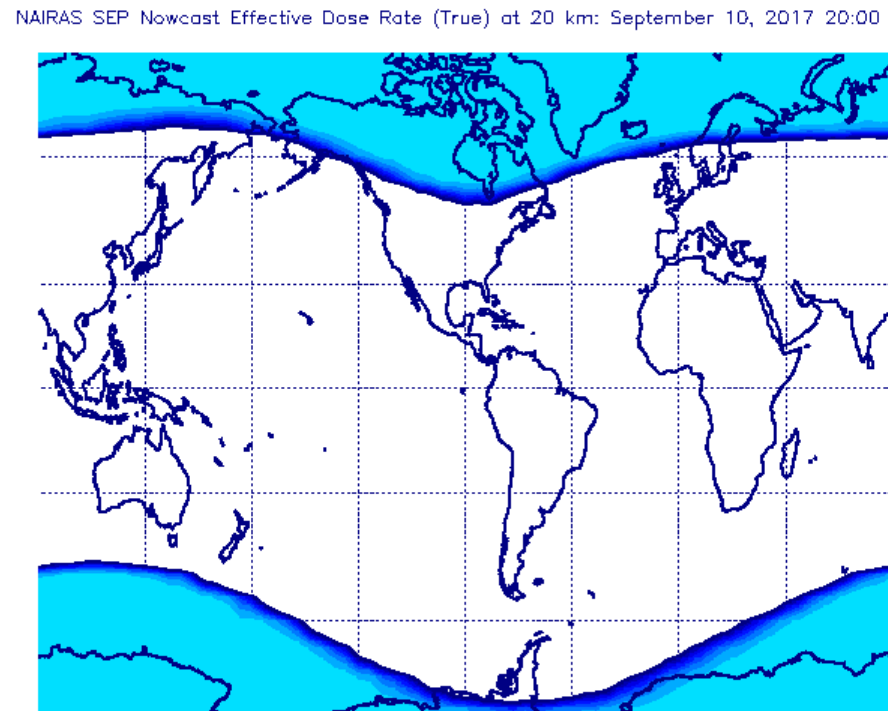


6.0 SEP Dose Forecast: September 2017

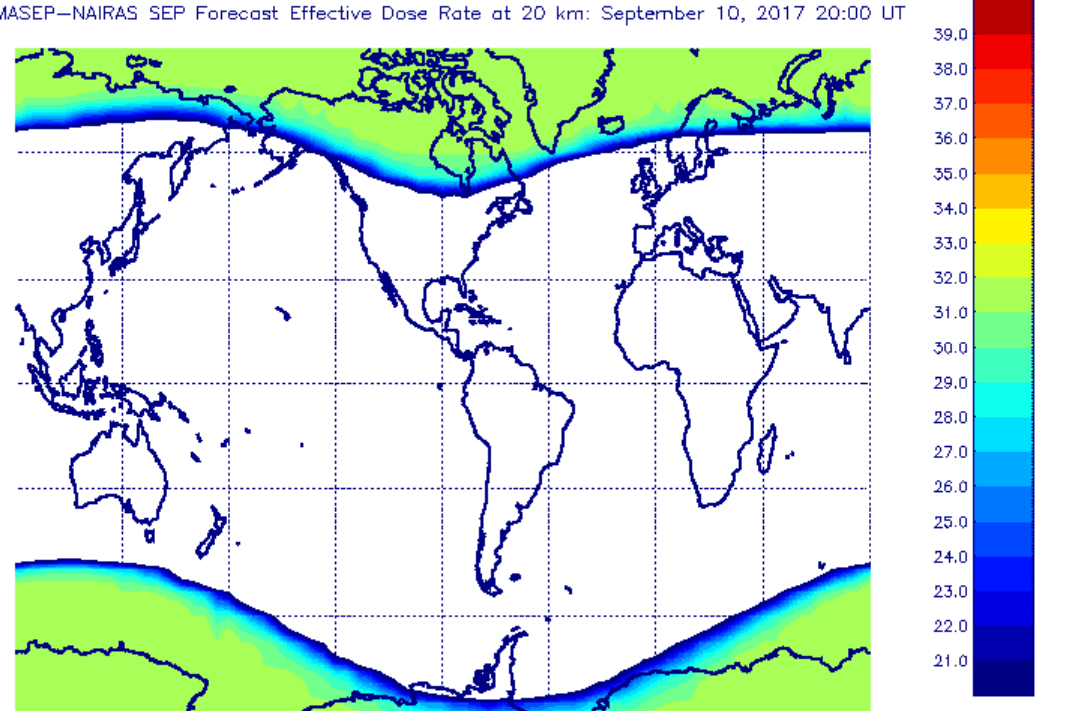
6.1 Atmosphere



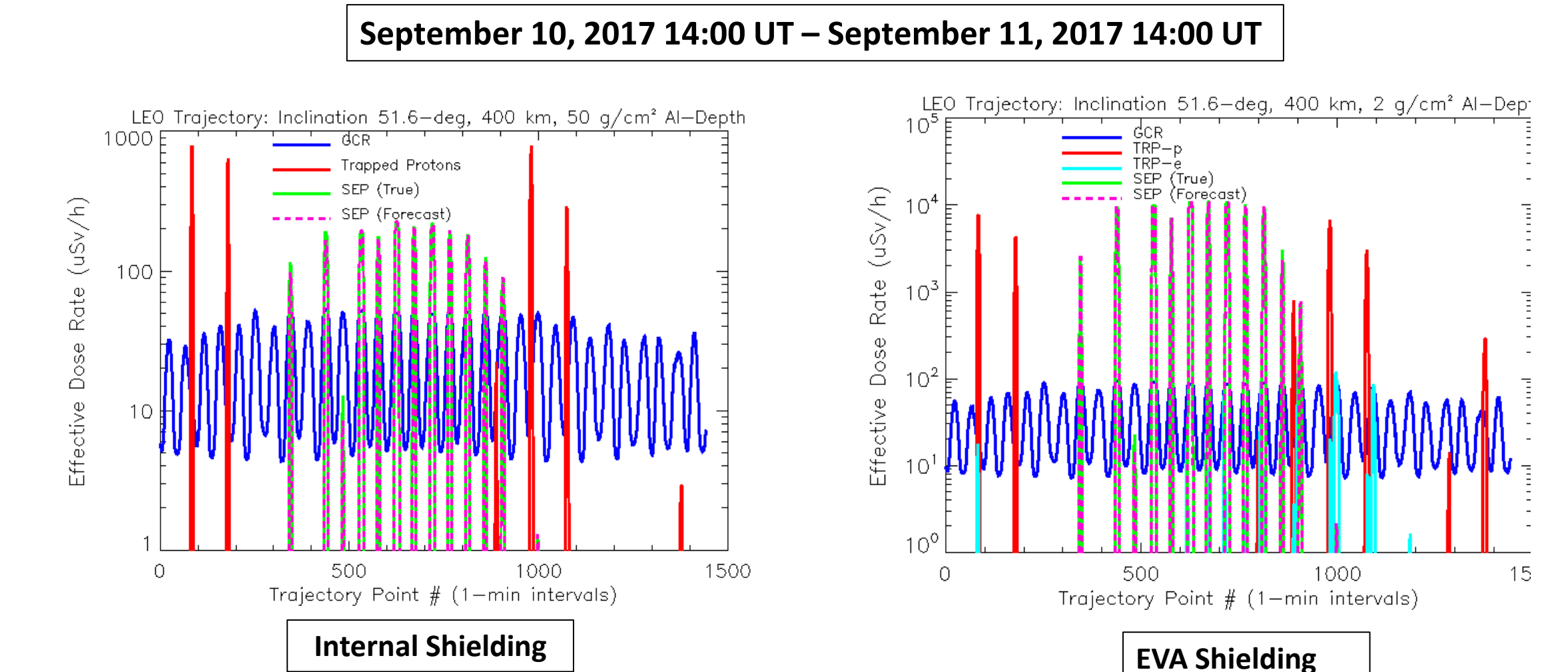
"True"



Forecast



6.2 Low-Earth Orbit (International Space Station)



7.0 Summary

- **UMASEP-NAIRAS SEP Dose Forecast Approach Promising**
 - Capability to forecast SEP dose quantities from Earth's surface to space
- **May 2024 SEP Event**
 - SEP/GCR enhancement at commercial aviation altitudes insignificant
 - SEP/GCR enhancement at 20 km (military high-flyers) is factor 3
 - Maximum forecast bias error of peak dose at 20 km -30%
 - SEP/GCR enhancement at International Space Station (ISS) is factor 10 (internal) and 100 (EVA)
 - Maximum forecast bias of day-total peak ISS/internal dose is -7% and ISS/EVA dose is -12%
- **September 2017 SEP Event**
 - SEP/GCR enhancement at commercial aviation altitudes insignificant
 - SEP/GCR enhancement at 20 km (military high-flyers) is 30%
 - Maximum forecast bias error of peak dose at 20 km +/- 13%
 - SEP/GCR enhancement at ISS/internal is factor 10 and ISS/EVA is factor 100
 - Maximum forecast bias of day-total peak ISS/internal dose is -3% and ISS/EVA dose is -1%
- **UMASEP-NAIRAS Aviation Radiation Forecast Operational at CCMC in 2025**