



02A – The Natural Space Radiation Environment Guided Activity

ENGR-E 399/599

Microelectronics Radiation Effects and Reliability



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APPLIED PHYSICS LABORATORY

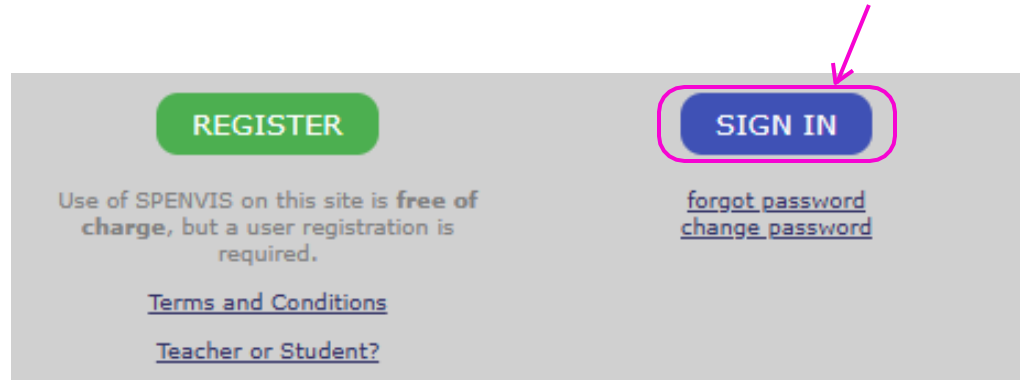


SCALE
Scalable Asymmetric Lifecycle Engagement

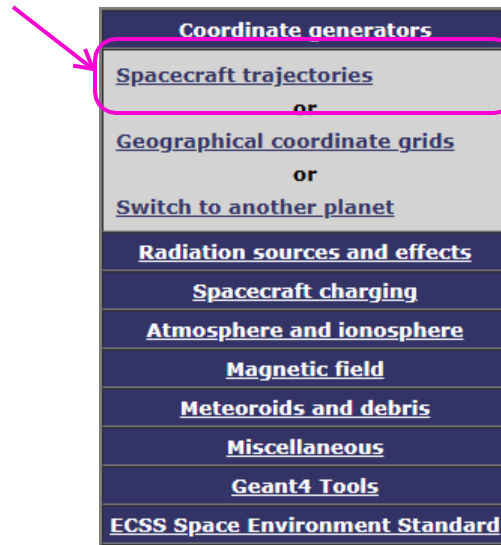
Sign in to SPENVIS




- <https://www.spenvis.oma.be/>



Use the Coordinate Generator to create a trajectory



Use the Coordinate Generator to create a trajectory



Trajectory generation: use orbit generator ▼

Number of mission segments: 1 ▼

Mission end: total mission duration ▼

Mission duration: 2 years ▼

Satellite orientation: one axis parallel to the velocity vector ▼

Account for solar radiation pressure: no ▼

Account for atmospheric drag: no ▼

Use the Coordinate Generator to create a trajectory



Segment title:
Starlink Mid Latitude

Orbit type: general

Orbit start: calendar date

01 Jan 2026 00 : 00 : 00

Representative trajectory duration [days]: 30

Altitude specification: perigee and apogee altitudes

Perigee altitude [km]: 530

Apogee altitude [km]: 530

Inclination [deg]: 53

R. asc. of asc. node [deg w.r.t. gamma50]: 0

Argument of perigee [deg]: 0

True anomaly [deg]: 0

Output resolution

1.	60.0	s below	20000.0	km
2.	240.0	s below	80000.0	km
3.	3600.0	s elsewhere		

Number of mission segments: 1


Segment 1: Starlink Mid Latitude

Orbit type: general
Orbit start: 1/1/2026 0:0:0
Trajectory duration: 30 day(s)



<< Back Run Combined Run





Explore the outputs





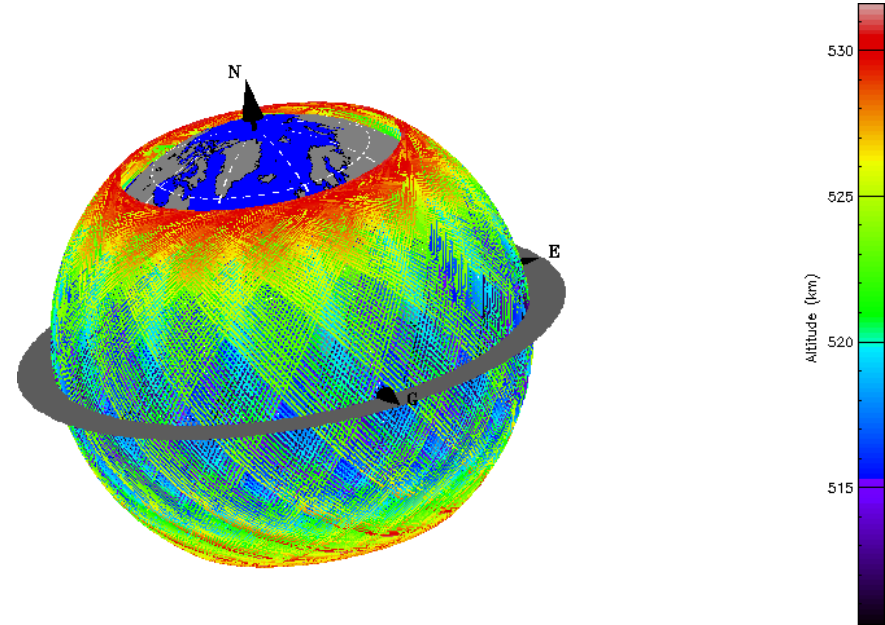
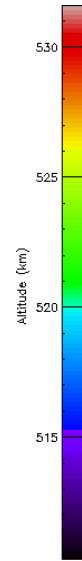
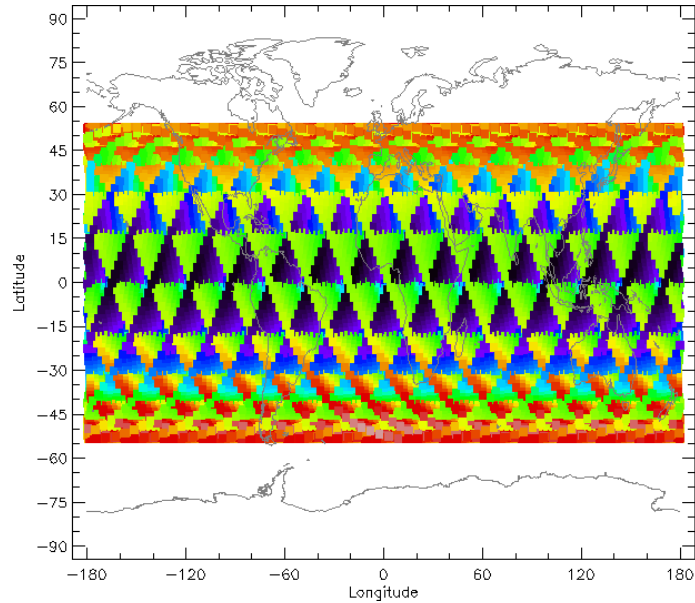
SPENVIS Project: A4RES
Orbit generator
Results

Tables	Plots
Report file Spacecraft coordinates  Attitude vectors 	
New plots	
<input type="checkbox"/> Orbit parameters as a function of time for mission segment 1 ▼	
<input checked="" type="checkbox"/> World map ▼ of the altitude ▼ for mission segment 1 ▼ with linear ▼ rainbow colour ▼ scale	
<div></div> <div> Portable Network Graphics (PNG) ▼</div>	


<< Back

Explore the outputs



Modeling charged particle populations

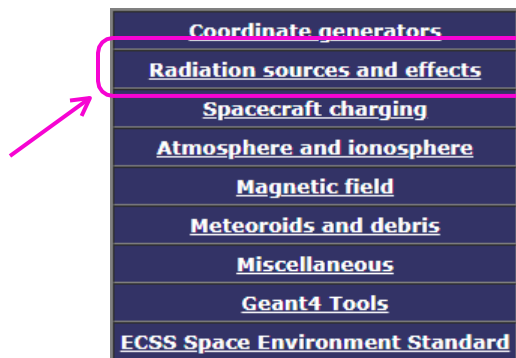


 UP

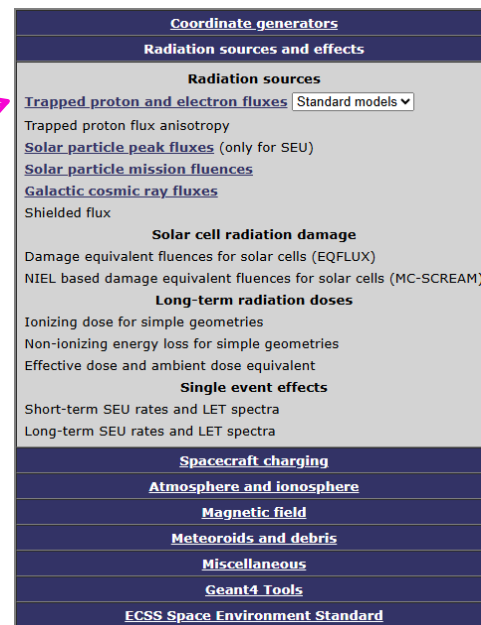
SPENVIS Project: A4RES
Orbit generator
Results

Output
Help

- Click UP and return to Main Menu
- Click RADIATION SOURCES AND EFFECTS
- Let's start with Trapped Particles



- [Coordinate generators](#)
- [Radiation sources and effects](#)**
- [Spacecraft charging](#)
- [Atmosphere and ionosphere](#)
- [Magnetic field](#)
- [Meteoroids and debris](#)
- [Miscellaneous](#)
- [Geant4 Tools](#)
- [ECSS Space Environment Standard](#)



Coordinate generators

Radiation sources and effects

Radiation sources

[Trapped proton and electron fluxes](#)

Trapped proton flux anisotropy

[Solar particle peak fluxes](#) (only for SEU)

[Solar particle mission fluxes](#)

[Galactic cosmic ray fluxes](#)

Shielded flux

Solar cell radiation damage

Damage equivalent fluences for solar cells (EQFLUX)

NIEL based damage equivalent fluences for solar cells (MC-SCREAM)

Long-term radiation doses

Ionizing dose for simple geometries

Non-ionizing energy loss for simple geometries

Effective dose and ambient dose equivalent

Single event effects

Short-term SEU rates and LET spectra

Long-term SEU rates and LET spectra

Spacecraft charging

Atmosphere and ionosphere

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Meteoroids and debris

Miscellaneous

Geant4 Tools



ECSS Space Environment Standard

Run AP8 / AE8



- **SPENVIS includes options for Trapped Particles**
 - IRENE (Ver. 1.50), SSREM, CRRESPRO, ...
 - AP8 / AE8 is fast for illustrative purposes

Trapped radiation models

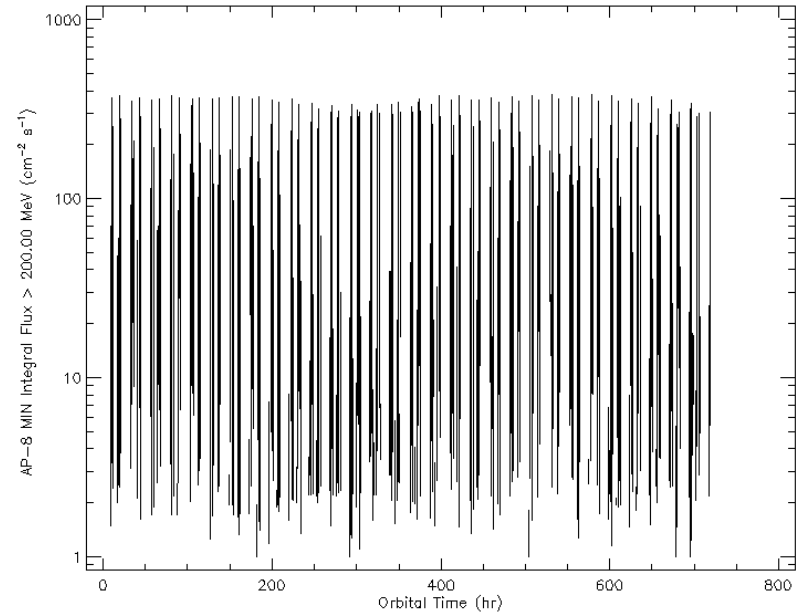
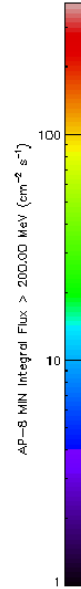
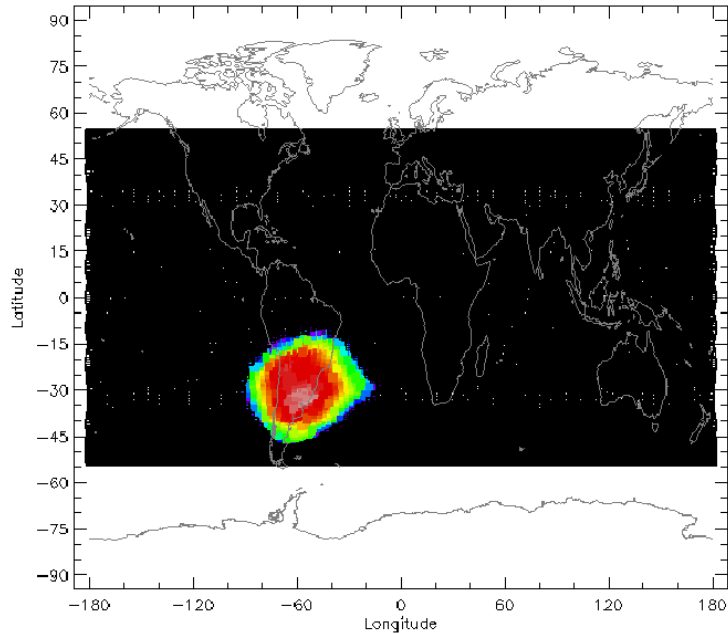
Proton model: AP-8 ▼	Electron model : AE-8 ▼
Model version: solar minimum ▼ Threshold flux for exposure(/cm2/s): 1.00	Model version: solar maximum ▼ do not include ▼ local time variation Confidence level: 50.000% ▼ Threshold flux for exposure(/cm2/s): 1.00
Model developed by: 	Model developed by: 

Explore the outputs

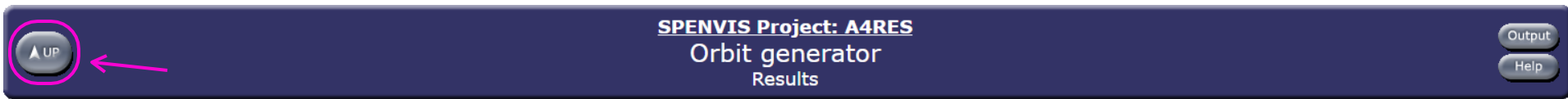


- **Generate a Proton spectrum for this mission (flux vs. energy)**
 - Review the Report file
 - [What sort of information is available here?]
- **Generate a Time plot of proton flux >200 MeV for this mission**
- **Generate a World map of proton flux >200 MeV for this mission**
 - [Why 200 MeV?]
 - [What sort of observations can you make?]

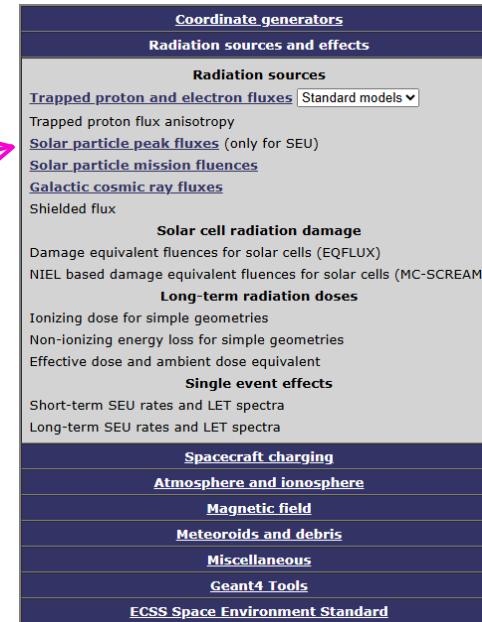
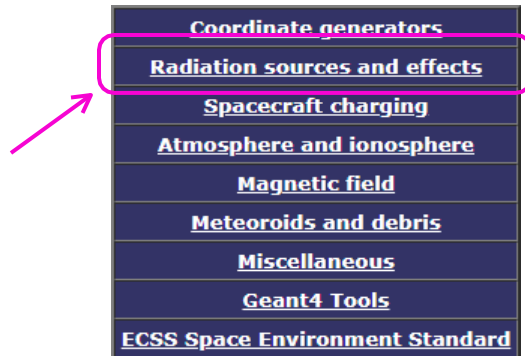
Explore the outputs



Modeling charged particle populations



- Click UP and return to Main Menu
- Click RADIATION SOURCES AND EFFECTS
- Let's add Solar particles



Run CREME-96 Worst Day (WD)



- Other options available (SAPPHIRE, CREME-86, ...)
- Why CREME-96?
 - Compatibility with SIRE-2, CREME-MC, ...
- Leave the Magnetic shielding as defaults

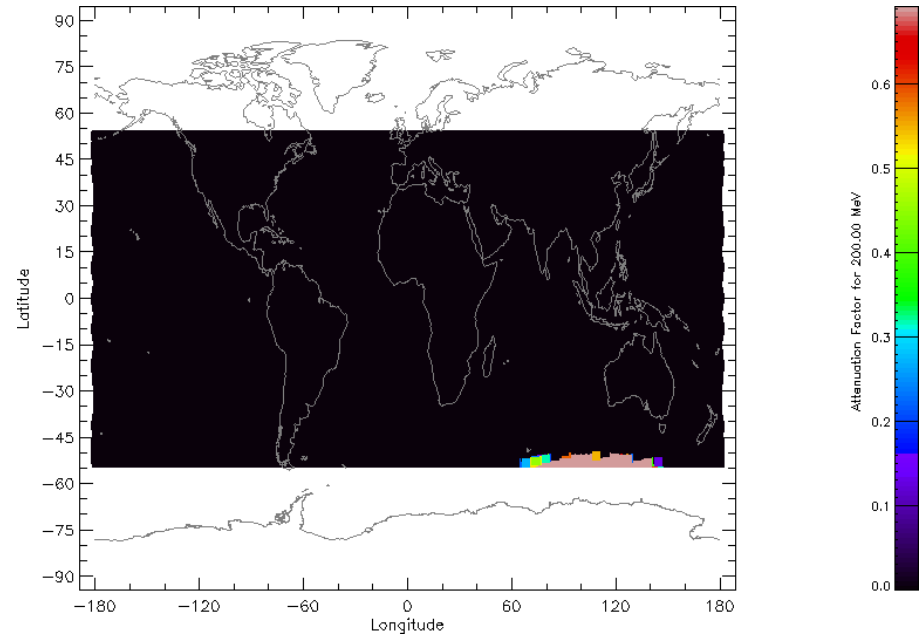
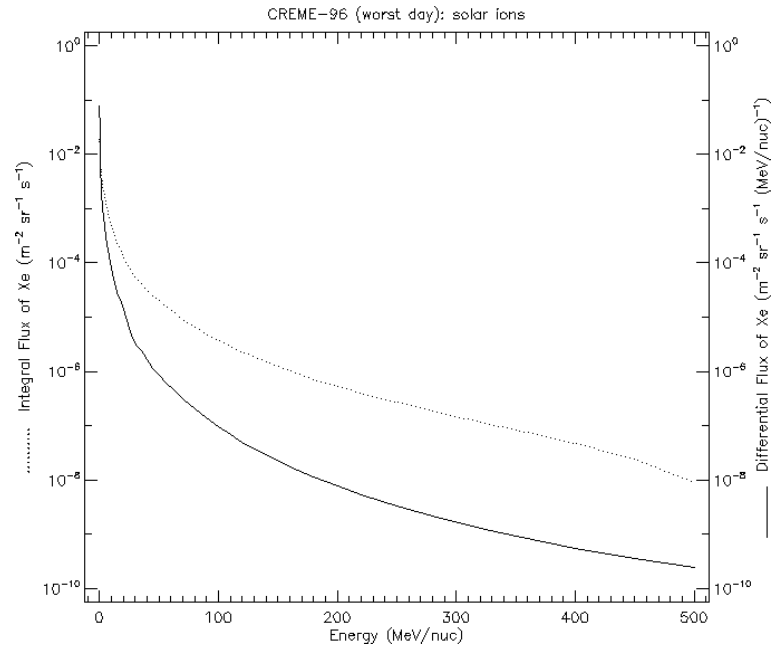
A screenshot of the CREME-96 software interface. It features a dark blue header bar with the text 'Solar particle flux model:' followed by a dropdown menu set to 'CREME-96'. Below this is another dark blue bar with 'Ion range:' followed by two dropdown menus set to 'H' and 'U'. A light gray bar contains three radio buttons: 'Worst Week' (unselected), 'Worst Day' (selected with a blue dot), and 'Peak 5-minute-averaged fluxes' (unselected). Below this is a dark blue bar with the text 'Magnetic shielding: on (quiet magnetosphere)' and an 'edit' button. At the bottom, there are three buttons: 'Reset', 'Run', and 'Combined Run'.

Explore the outputs





- **Generate a Heavy Ion spectra for Xe ($Z=54$) for this mission (flux vs. energy)**
- **Generate a World map of proton attenuation factor for >200 MeV for this mission**
 - [Why 200 MeV?]
 - [What sort of observations can you make?]

Explore the outputs





Modeling charged particle populations

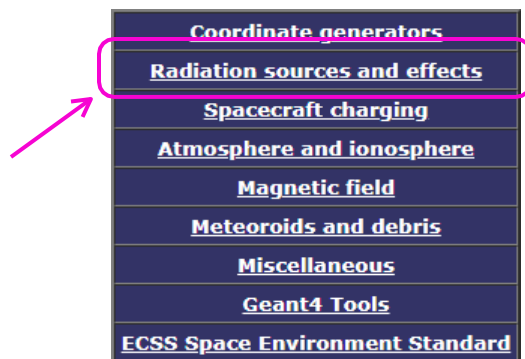


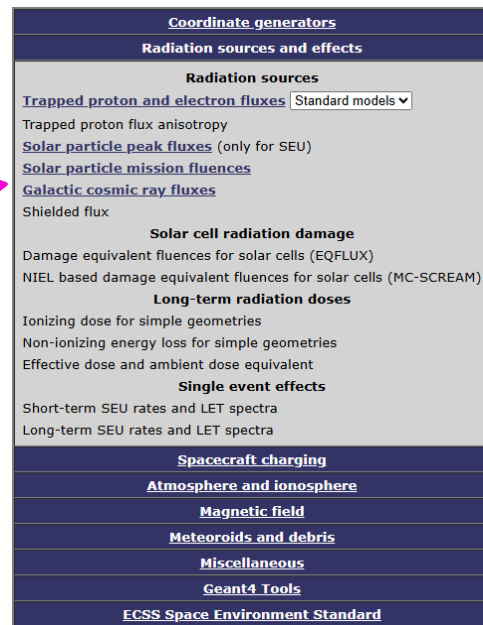
SPENVIS Project: A4RES
Orbit generator
Results

- Click UP and return to Main Menu
- Click RADIATION SOURCES AND EFFECTS
- Let's add GCRs



Coordinate generators
Radiation sources and effects
Spacecraft charging
Atmosphere and ionosphere
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Coordinate generators
Radiation sources and effects

Radiation sources

[Trapped proton and electron fluxes](#)

Trapped proton flux anisotropy
[Solar particle peak fluxes](#) (only for SEU)
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Long-term SEU rates and LET spectra

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Run CREME-96



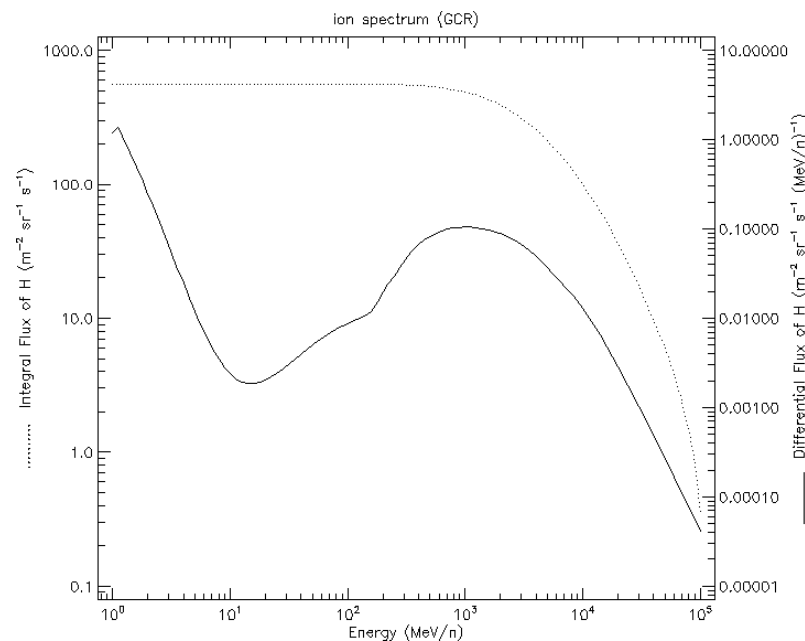
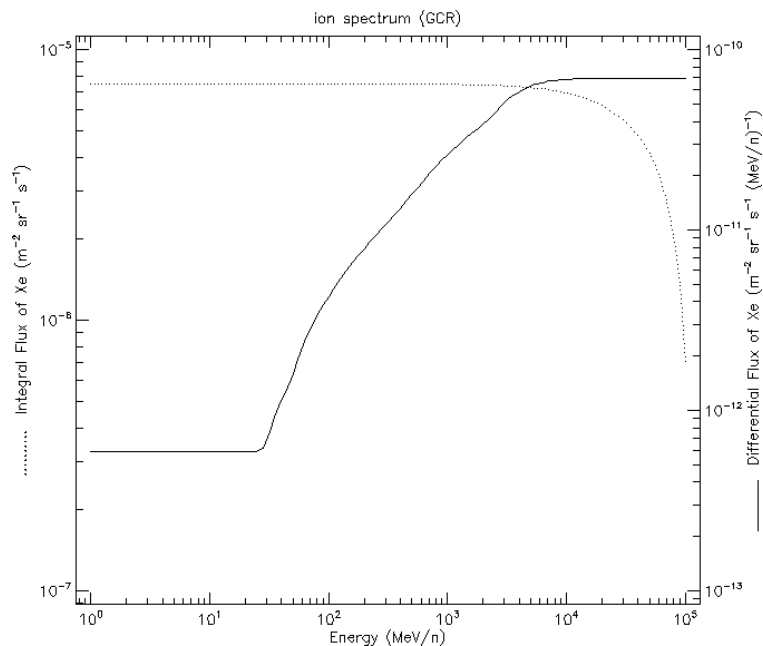
- **Other options available (ISO 15390, CREME-86, Nymmik, ...)**
- **Why CREME-96?**
 - Compatibility with SIRE-2, CREME-MC, ...
- **Leave the Magnetic shielding as defaults**

Ion range:	H	▼	to	U	▼
GCR model at 1 AU:	CREME96 ▼				
CREME-96 Sol. Min (1977)					
Magnetic shielding: on (quiet magn.)					edit

Explore the outputs



- **Generate a Heavy Ion spectra for Xe (Z=54) for this mission (flux vs. energy)**
- **Generate a Heavy Ion spectra for protons (Z=1) for this mission (flux vs. energy)**



Next steps ... on your own



- **As of now we've generated charged particle environments for a notional mid latitude Starlink-like mission**
 - Trapped protons
 - SEP protons and ions
 - GCR protons and ions
- **Repeat this process for a notional high latitude Starlink-like mission (see right)**
- **Generate the same outputs and save so we can compare**

Segment title: Starlink High Latitude

Orbit type: general

Orbit start: calendar date

01 Jan 2026 00:00:00

Representative trajectory duration [days]: 30

Altitude specification: perigee and apogee altitudes

Perigee altitude [km]: 530

Apogee altitude [km]: 530

Inclination [deg]: 97.6

R. asc. of asc. node [deg w.r.t. gamma50]: 0

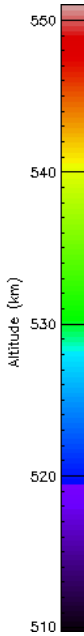
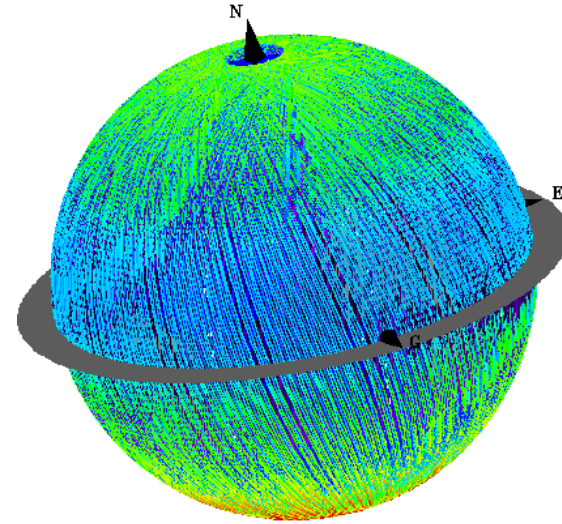
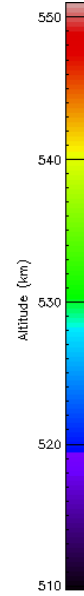
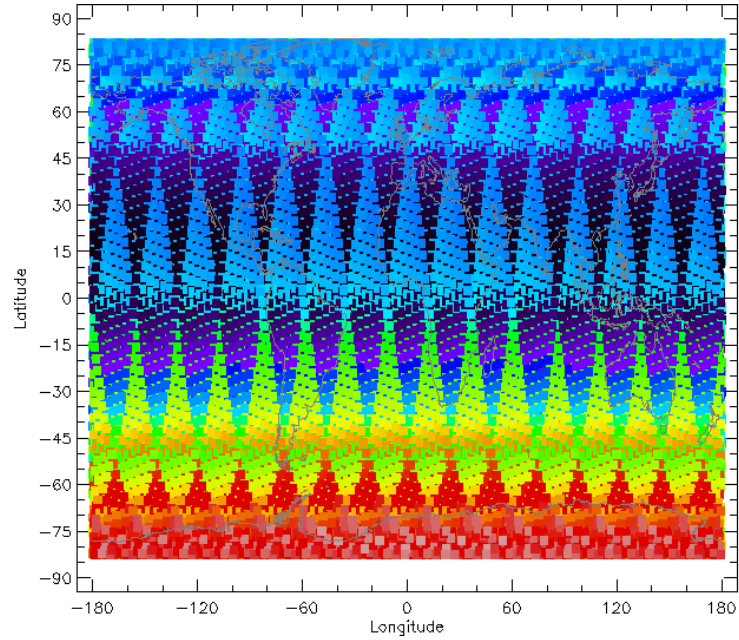
Argument of perigee [deg]: 0

True anomaly [deg]: 0

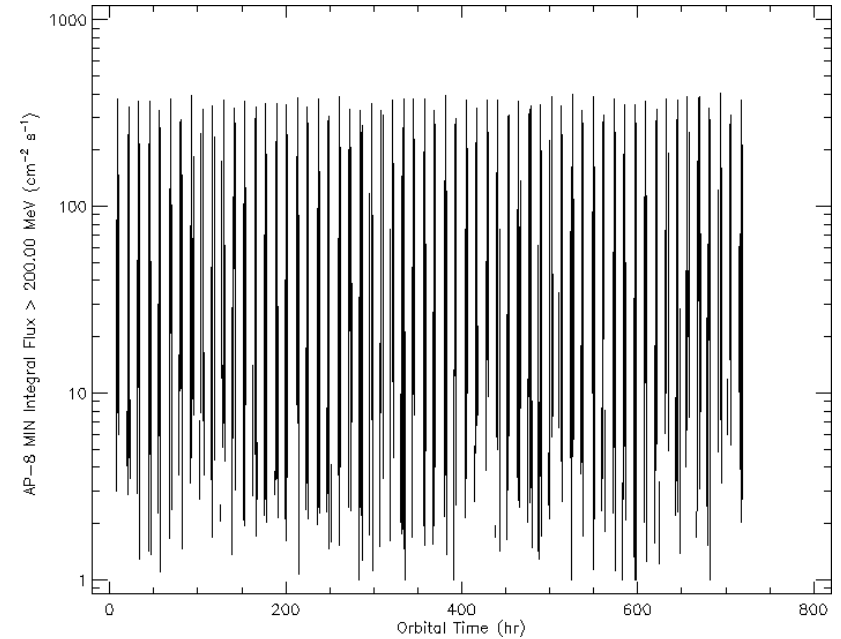
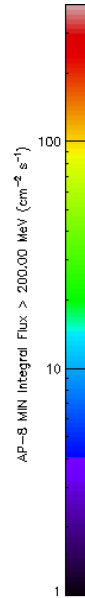
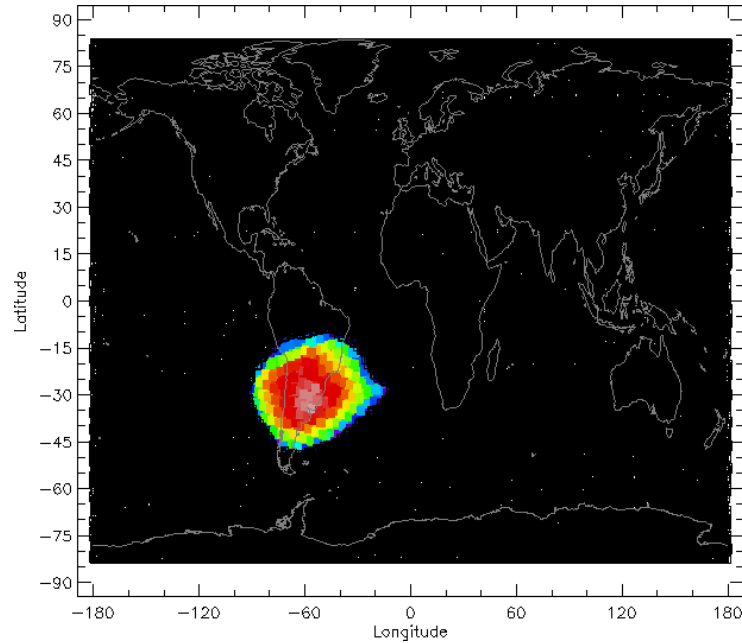
Output resolution

1.	60.0	s below	20000.0	km
2.	240.0	s below	80000.0	km
3.	3600.0	s elsewhere		

SOLUTION Trajectory



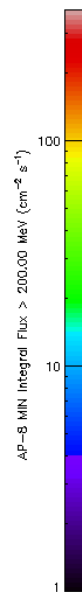
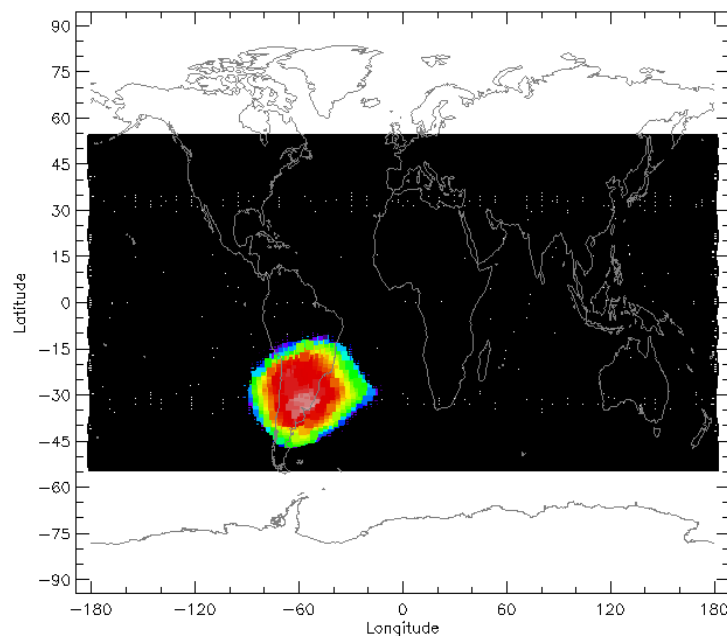
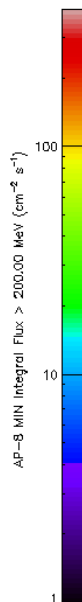
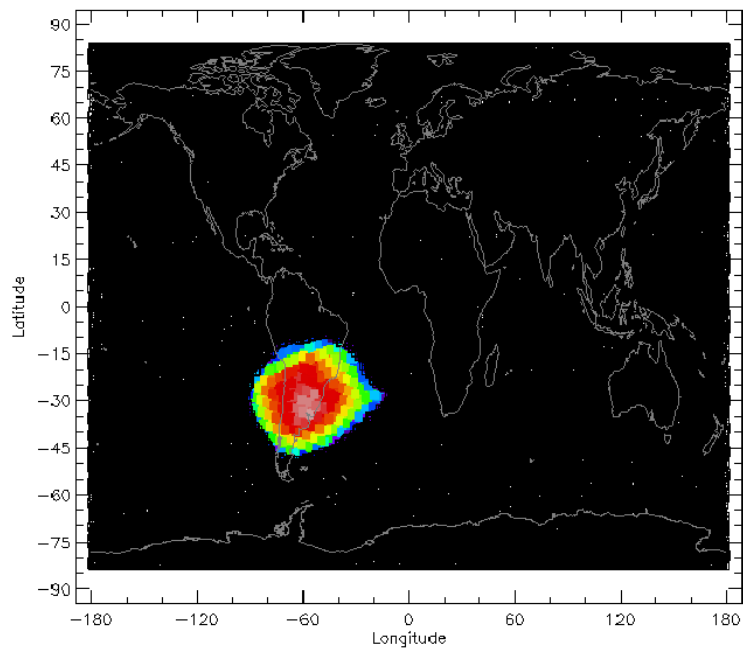
Trapped protons



Comparisons (Trapped Protons)

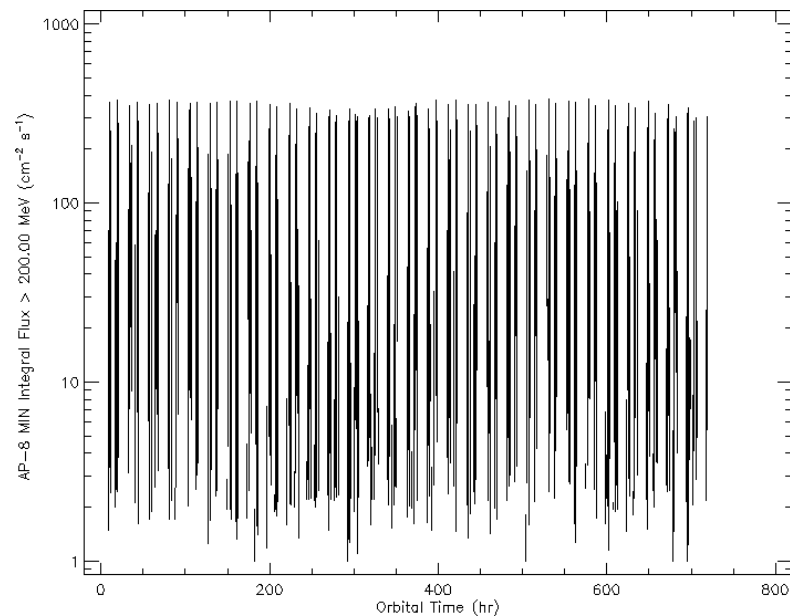
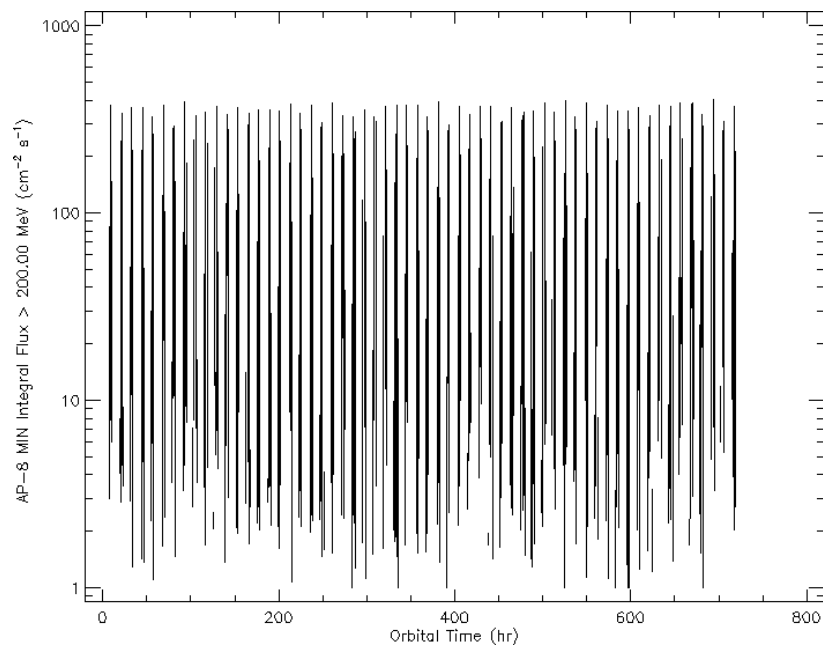


- **Make some observations about**
 - Mission / orbit average >200 MeV protons
 - Peak >200 MeV protons

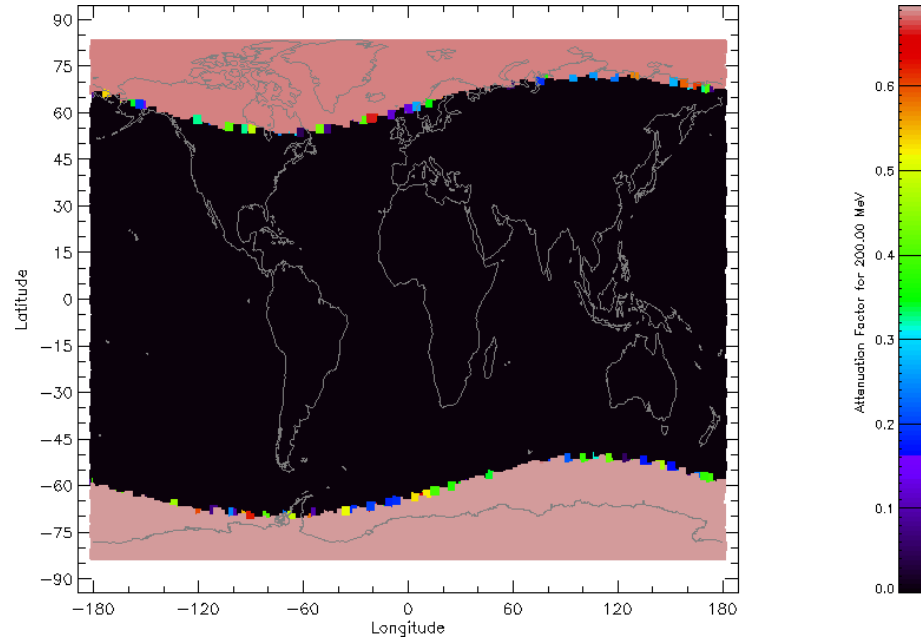
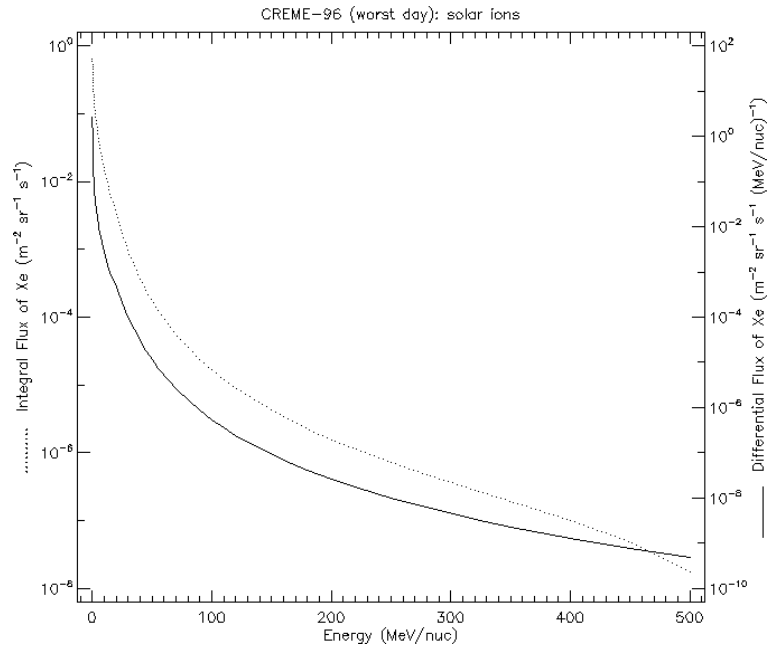


Comparisons (Trapped Protons)

- **Make some observations about**
 - Mission / orbit average >200 MeV protons
 - Peak >200 MeV protons



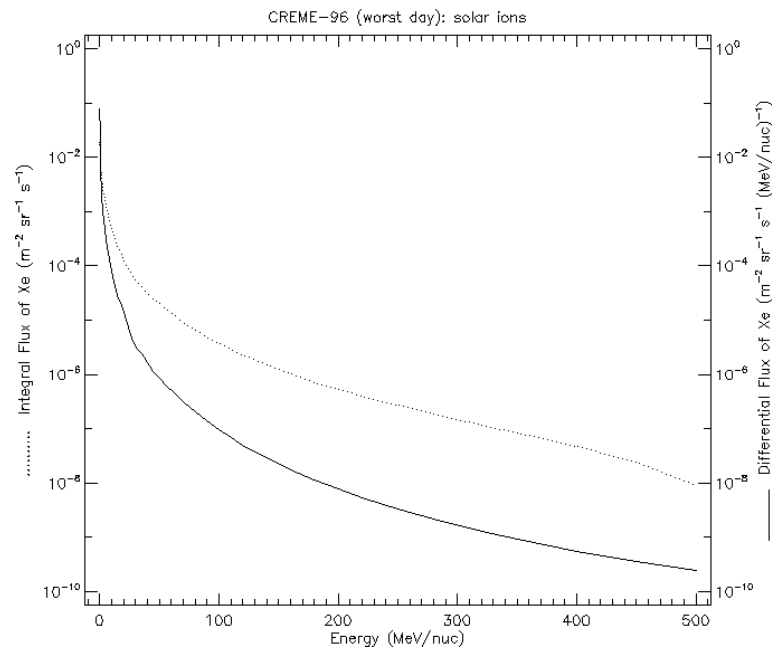
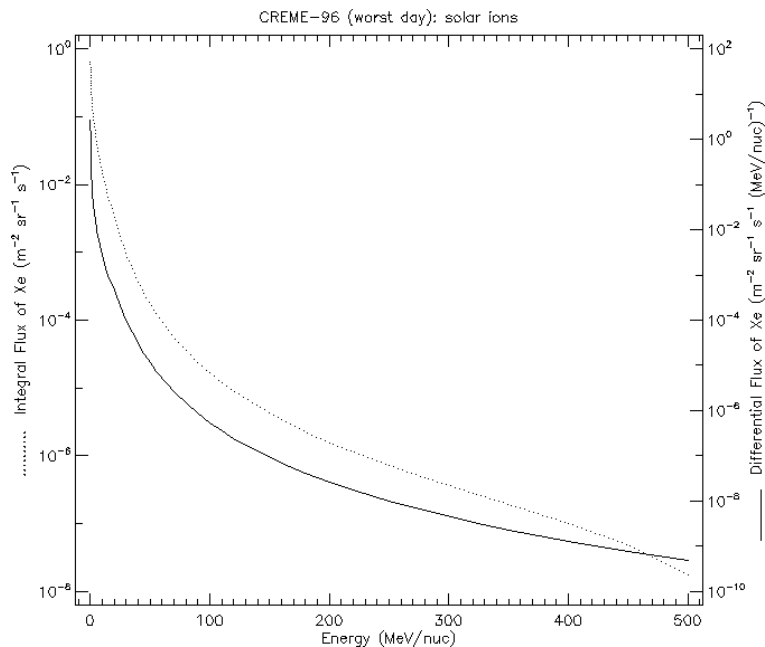
Worst Day



Comparisons (Worst Day)



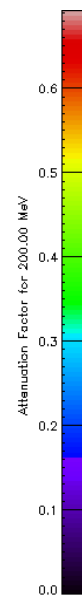
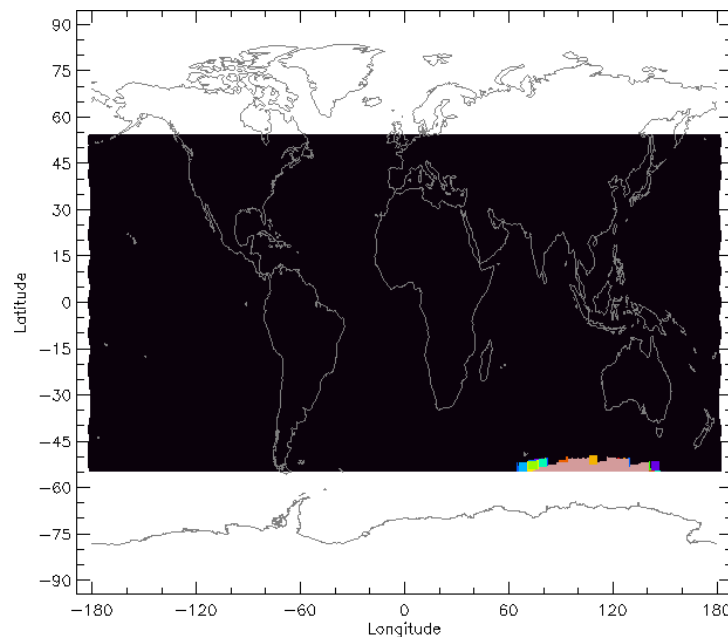
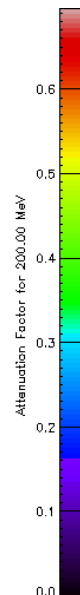
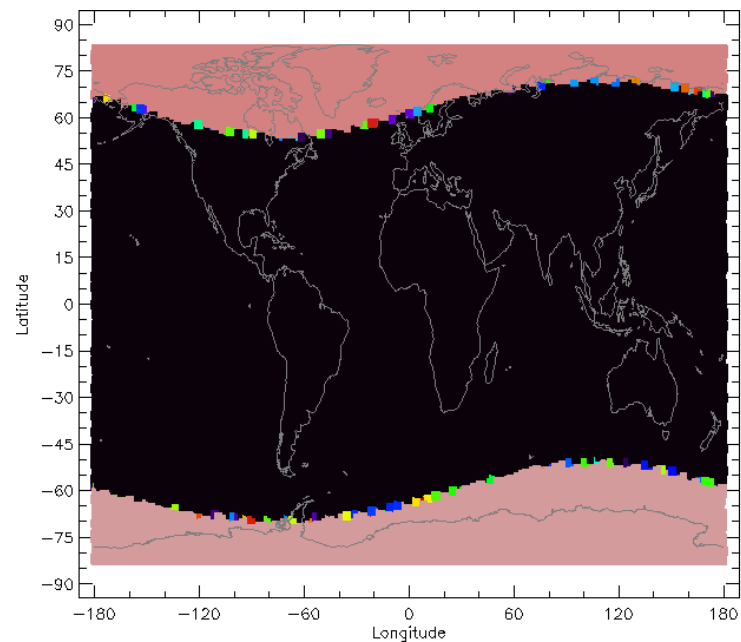
- **Make some observations about**
 - Fluxes and energies of Xe ions



Comparisons (Worst Day)



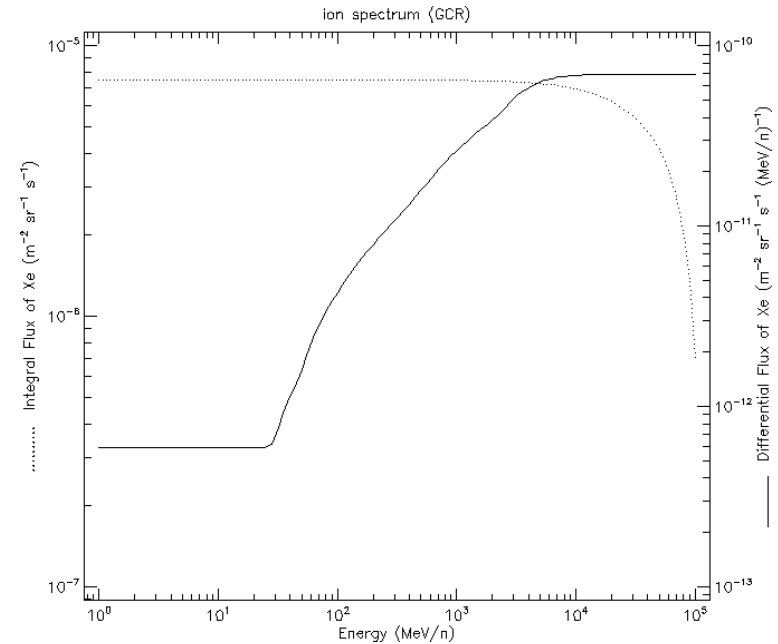
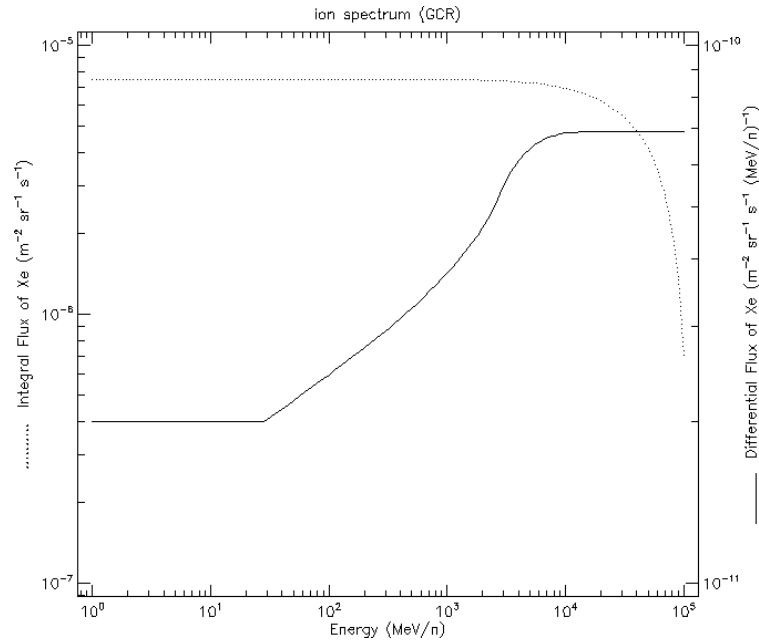
- **Make some observations about**
 - Access of >200 MeV protons
 - Is the mission susceptible in a WD environment?



Comparisons (GCRs)



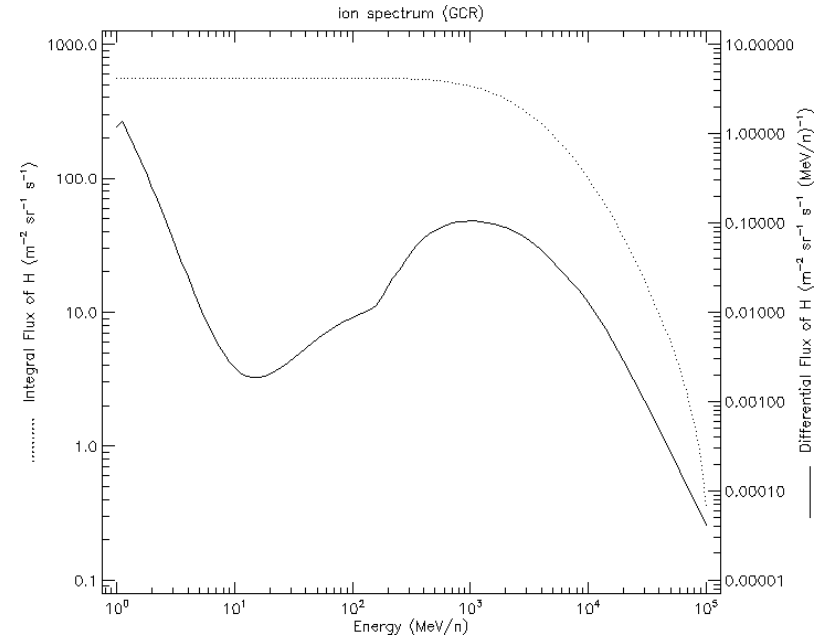
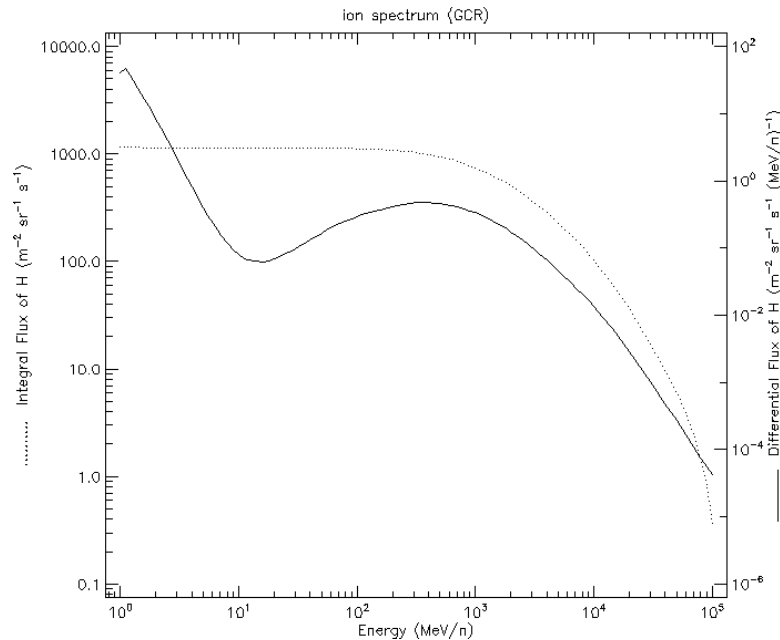
- **Make some observations about**
 - Fluxes and energies of Xe ions



Comparisons (GCRs)



- **Make some observations about**
 - Fluxes and energies of Xe ions



Homework 2



1. Using SPENVIS, model the following two orbits

- Assume a mission start date of Jan 1, 2026
- Use the following models:
 - Trapped Protons and Electrons: Standard AE-8 (solar max., 50% confidence level), AP-8 (solar min.)
 - CRÉME-96 solar particle model (Worst Day)
 - ESP-PHYCHIC solar particle model for total fluence (95% confidence level)
 - CRÉME-96 galactic cosmic ray model (solar min.)

Polar LEO (POES, IRIDIUM)

Mission Duration	7 years
Apogee	825 km
Perigee	825 km
Inclination	98.8 deg
RAAN ¹	0 deg
Argument of Perigee	0 deg
True Anomaly	0 deg

HEO (Van Allen Probes, MMS)

Mission Duration	2 years
Apogee	70000 km
Perigee	2500 km
Inclination	28 deg
RAAN	0 deg
Argument of Perigee	0 deg
True Anomaly	0 deg

¹Right Ascension of the Ascending Node

Homework 2



2. Provide the following charts for each mission:

- Trapped proton spectra
- World maps of the trapped proton flux (for >10 MeV and >200 MeV)
- Solar proton ($Z=1$) and heavy ion flux spectra for He ($Z=2$) and Fe ($Z=26$)
- World maps of the 200 MeV solar proton attenuation factor
- Mission average solar proton ($Z=1$) and heavy ion fluence spectra for He ($Z=2$) and Fe ($Z=26$) **from solar particle mission fluences*
- GCR spectra of protons ($Z=1$), He ($Z=2$), and Fe ($Z=26$)

Homework 2



- 3. Name three differences in each of these orbits, as compared to the in-class example of a notional Starlink LEO orbit**
- 4. What is the integral flux of trapped protons of energy 1 MeV or greater? What about for 200 MeV or greater?**
- 5. For the life of each of these missions, how does the total fluence of solar protons of 200 MeV or greater to compare to the Starlink LEO mission? Provide the expected ratio (fluence of desired mission)/fluence of Starlink LEO.**
- 6. Which mission sees the highest flux of GCR of $Z=2$ and higher? How about $Z=26$ and higher? Why?**