Radiation Background for Polar Orbits

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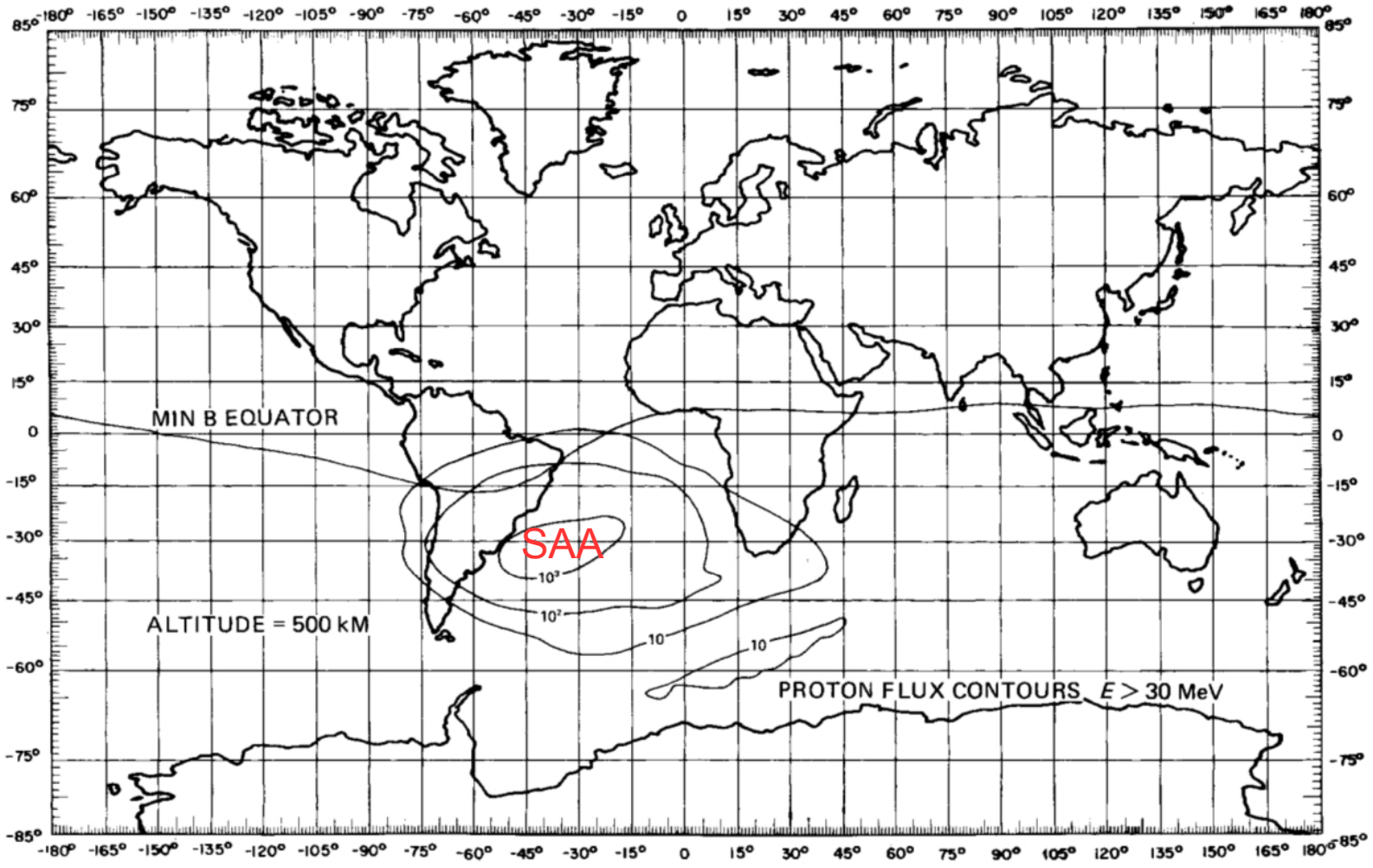
Proton Flux

Trapped radiation *(cont.)*

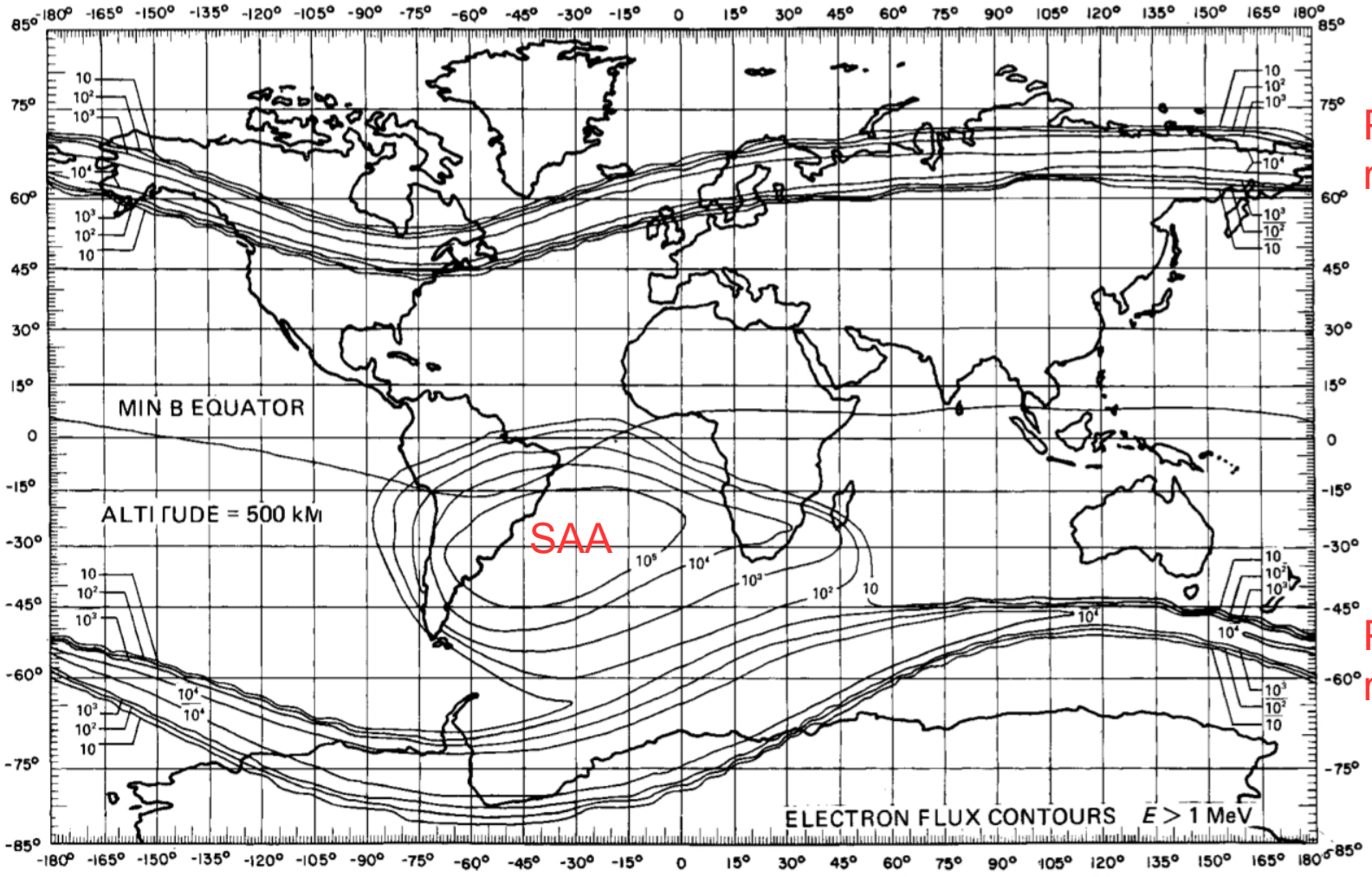
Omni-directional flux in protons $cm^{-2}\,s^{-1}$. (Adapted from Stassinopoulos, E.G., *World Maps of Constant B, L, and Flux Contours* NASA SP-3054, 1970.)



Martin V. Zombeck, Handbook of Space Astronomy and Astrophysics, Cambridge University Press, 2007

Electron Flux

Omni-directional flux in electrons $cm^{-2}\,s^{-1}$. (Adapted from Stassinopoulos, E.G., *World Maps of Constant B, L, and Flux Contours*, NASA SP-3054, 1970.)



Martin V. Zombeck, Handbook of Space Astronomy and Astrophysics, Cambridge University Press, 2007

Lomonosov Satellite

Spacecraft*Lomonosov* satellite built by VNIIEM (Russia)

Launch Vechicle & Place Sojuz 2.1a, Vostochny cosmodrome

Launch Date Apr. 2016

Orbit & Altitudesun-synchronous **polar at 480 km**

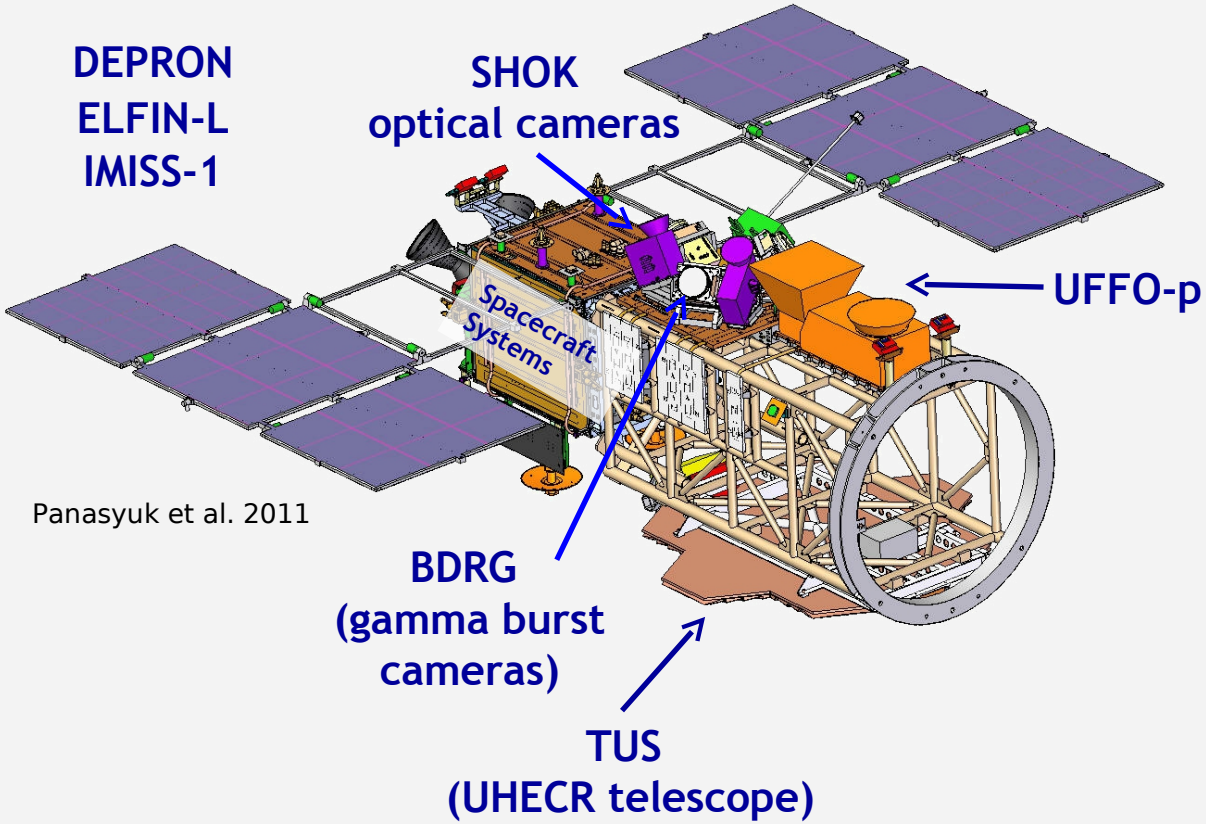
Total / Payload Mass450 kg / 150 kg

Mission Lifetime3 years

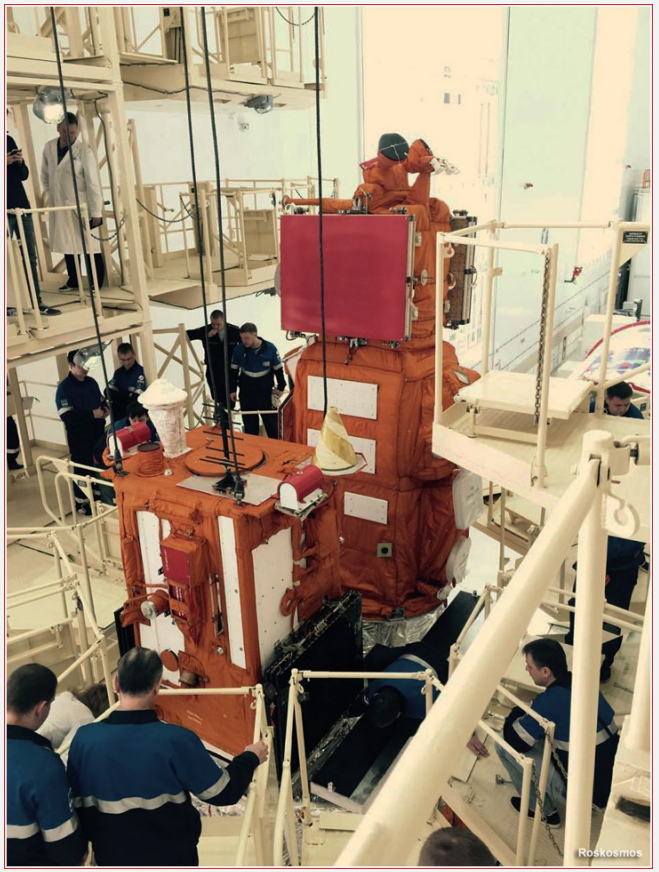
Orientation accuracy~ 5'

Mean Day Power 300 W

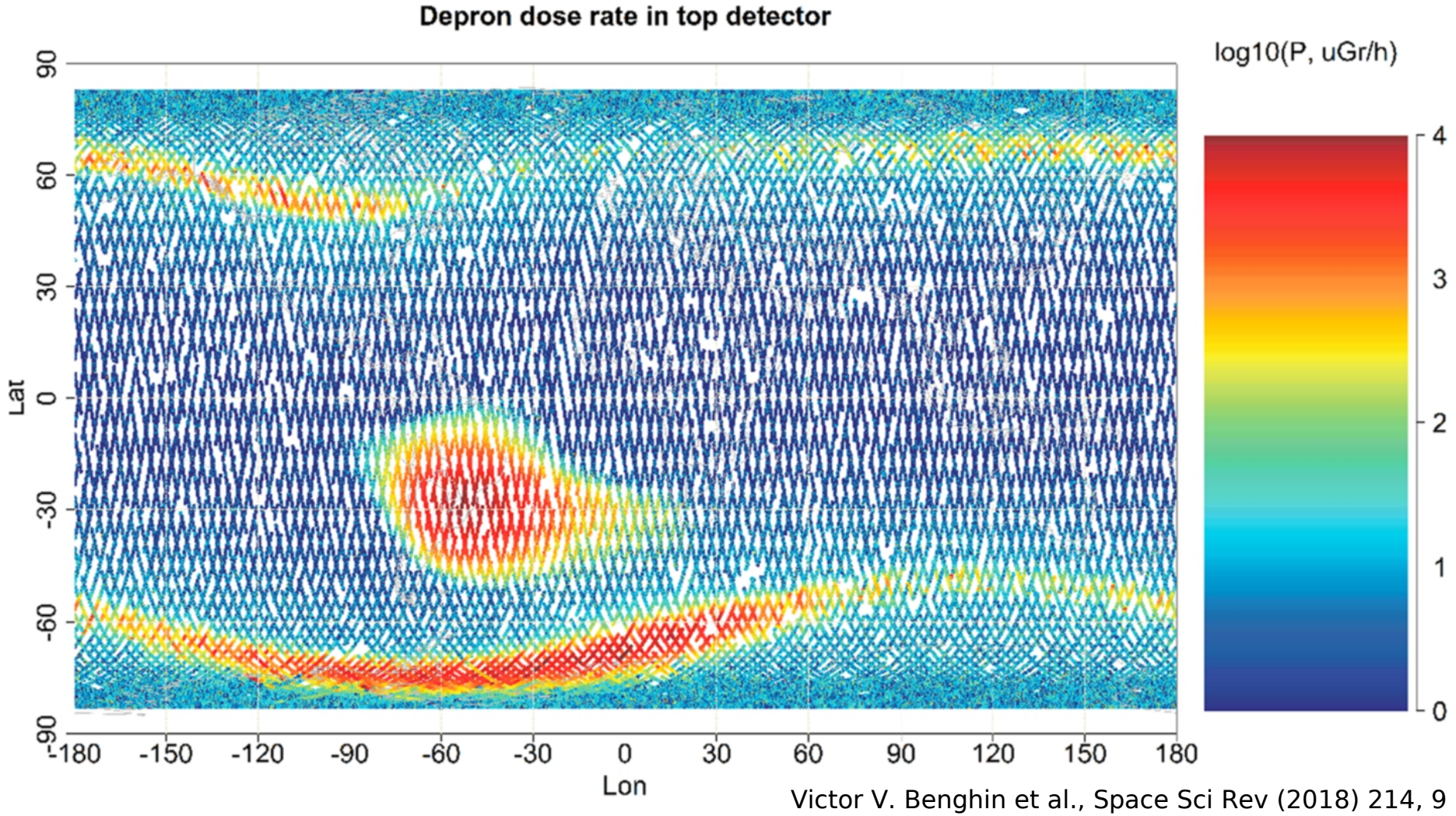
Data rate3 GBytes per day



Panasyuk et al. 2011



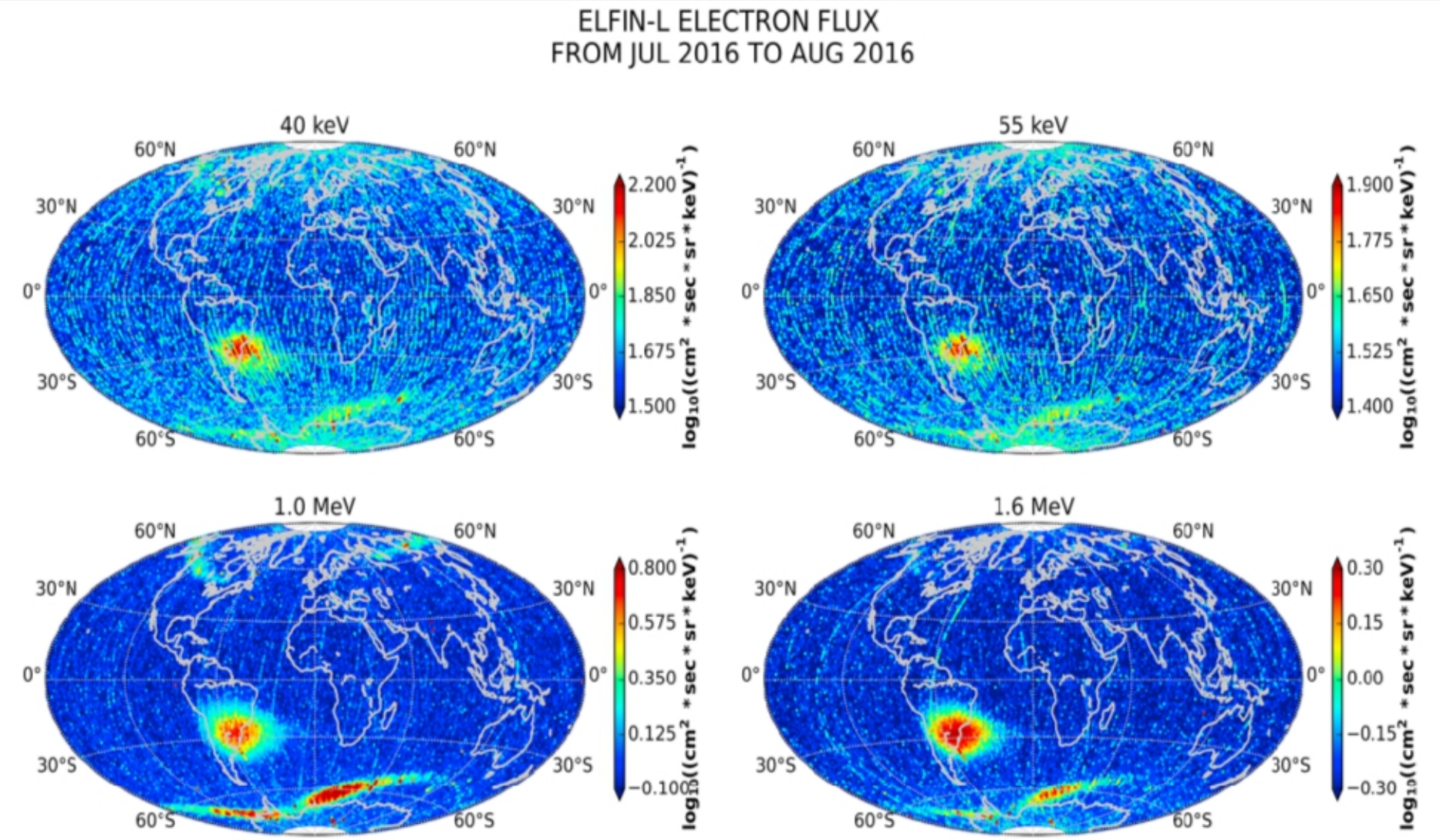
Measurement of Dose Rate from *Lomonosov*/DEPRON



Victor V. Benghin et al., Space Sci Rev (2018) 214, 9

Fig. 5 Global map of radiation conditions onboard the Lomonosov satellite obtained for one week of measurements in August 2016

Measurement of Electron Flux from *Lomonosov*/ELFIN-L



Y.Y. Shprits et al., Space Sci Rev (2018) 214, 25

Fig. 18 Measurements for 4 electron energy channels on ELFIN-L averaged over July 2016 to August 2016. Currently measurements are presented for all observed by the instrument's local pitch angles

Scintillation Detector *Lomonosov*/BDRG

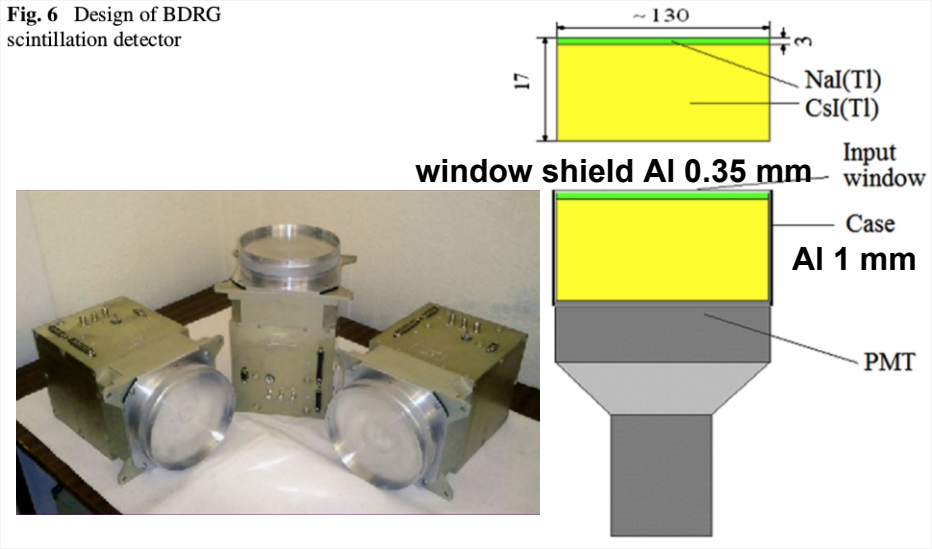


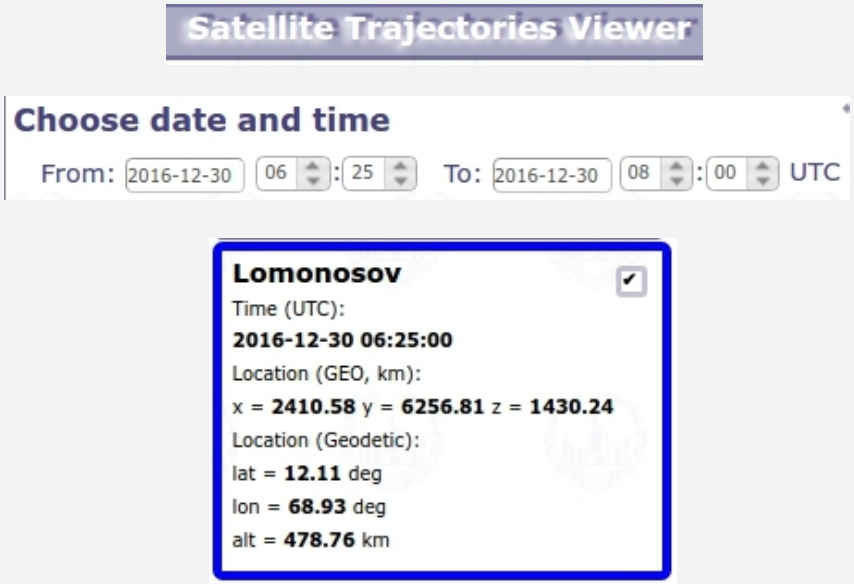
Fig. 6 Design of BDRG scintillation detector

S. I. Svertilov et al., Space Sci Rev (2018) 214, 8

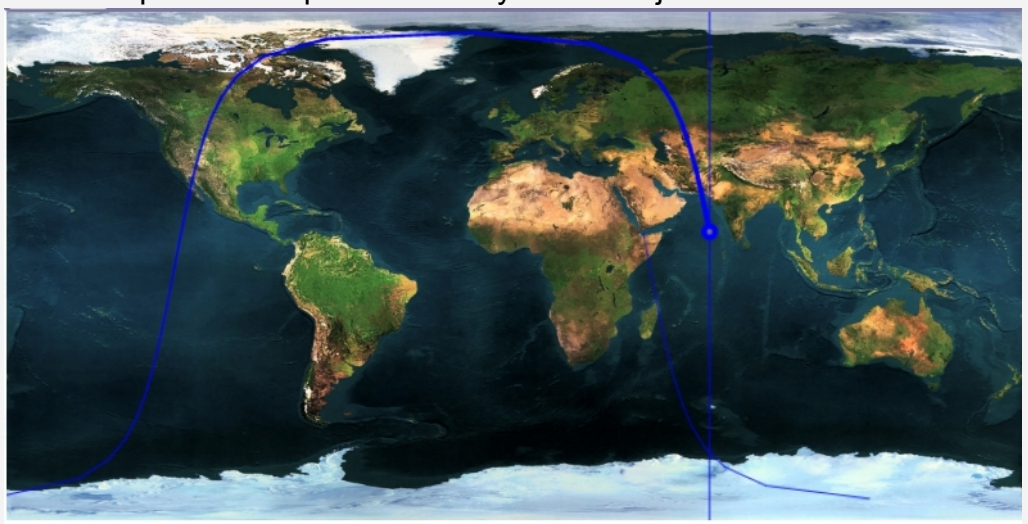
Parameter, units	Value
Energy range, MeV	0.01–3.0
Effective area (for three detectors), cm^2	~ 360
Time resolution, ms	1 (for the burst mode)
Mass (for one detector module), kg	5.5
Information capacity, MByte/day	~ 500
Field of view, sr	2
Field of effective source location, sr	2
Sensitivity to the burst detection, erg/cm^2	~ 10^{-7}
Accuracy of burst source location	~ 2–4° (for brightest events)
Expected number of detected bursts per year	~ 100
Power consumption, W	22.5

The NaI(Tl) is placed on top of the CsI(Tl) crystal and both scintillator layers are viewed simultaneously by a single Hammamatsu R877 Photomultiplier Tube (PMT). The thickness of the NaI(Tl) layer is optimized for the soft part of energy range. Working ranges are 0.01–0.5 MeV for the NaI(Tl) scintillator and 0.05–3 MeV for the CsI(Tl) unit.

Measurement of Count Rate from Scintillation Detector *Lomonosov*/BDRG



http://dec1.sinp.msu.ru/~lucymu/satTraj/Lomonosov.html



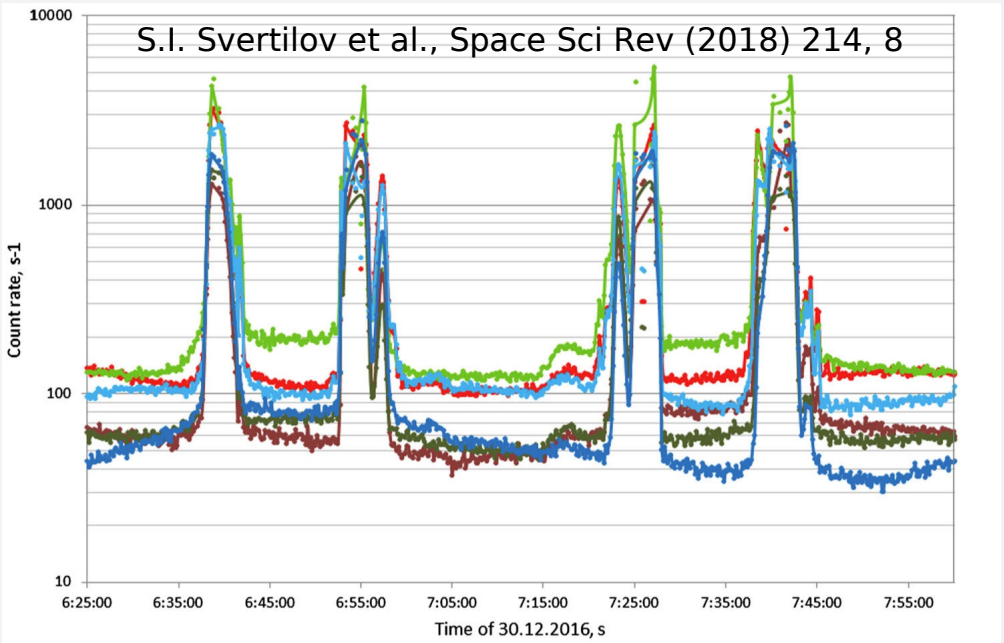
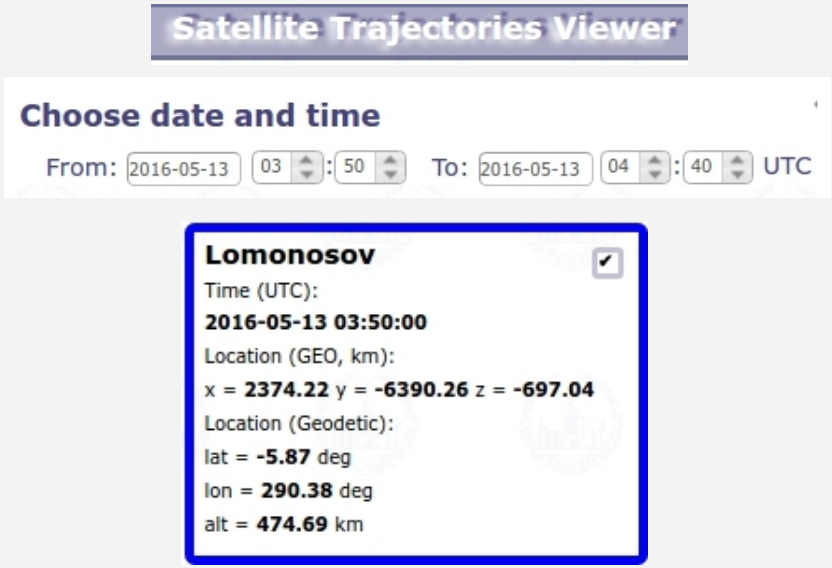


Fig. 14 *Upper panel*: Count rate variations in the BDRG NaI(Tl) monitoring channels along the orbit: BDRG-1 20–35 keV (*light red line*), 6–10 keV (*dark red line*), BDRG-2 20–35 keV (*light green line*), 6–10 keV (*dark green line*), BDRG-3 20–35 keV (*light blue line*), 6–10 keV (*dark blue line*).

Measurement of Count Rate from Scintillation Detector *Lomonosov*/BDRG



http://dec1.sinp.msu.ru/~lucymu/satTraj/Lomonosov.html

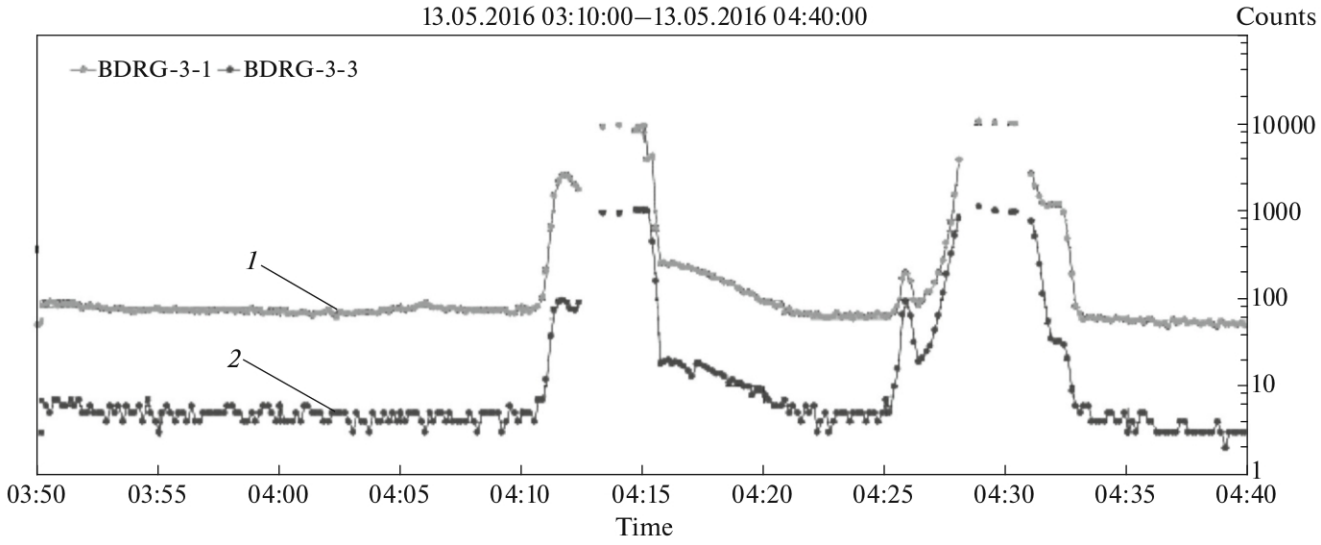


Fig. 1. Count rates of the BDRG instrument (BDRG-3 box) in channels: (*1*) NaI(Tl), energy release of 30–50 keV; (*2*) NaI(Tl), energy release of 100–200 keV.

M. I. Panasyuka et al. 2018, Physics of Particles and Nuclei, 49, 109

Radiation Belts, Electron and Proton Flux

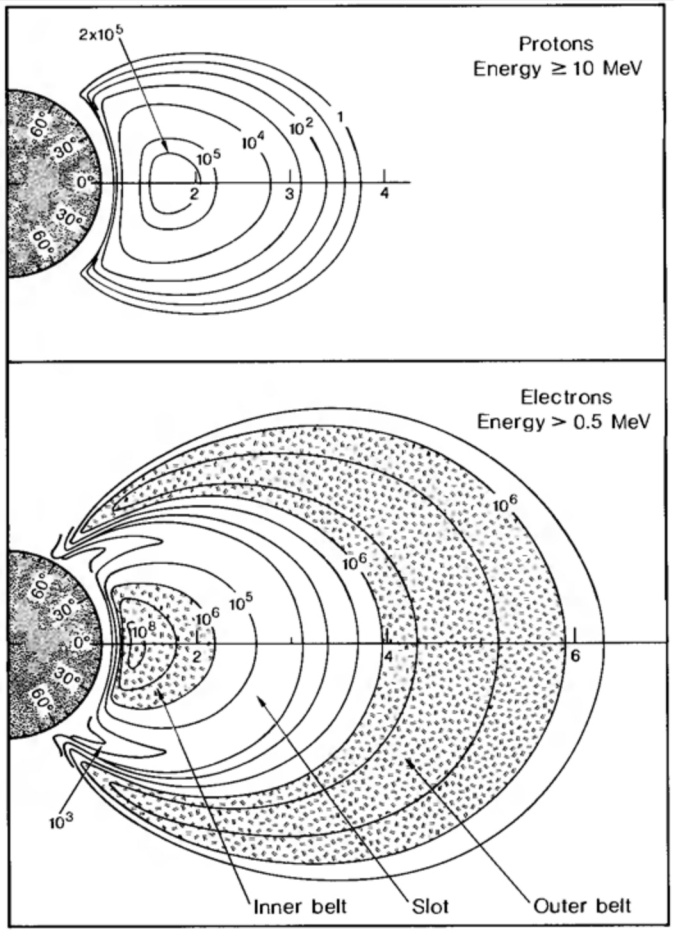


FIG. 1.20. Earth's radiation belts. The top panel shows the contours of the omnidirectional flux (particles per square centimeter per second) of protons with energies greater than 10 MeV. The bottom panel shows the contours of the omnidirectional flux of electrons with energies greater than 0.5 MeV.

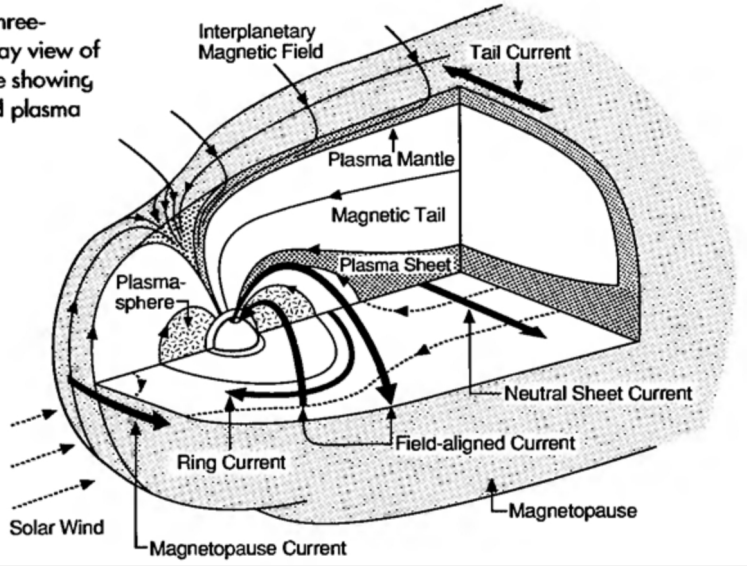


FIG. 1.18. Three-dimensional cutaway view of the magnetosphere showing currents, fields, and plasma regions.

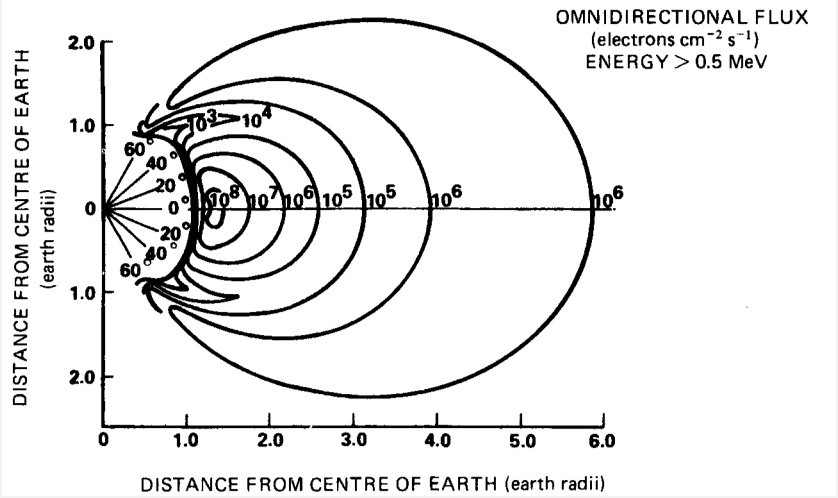
M. G. Kivelson and C. T. Russell 1995, *Introduction to Space Physics*

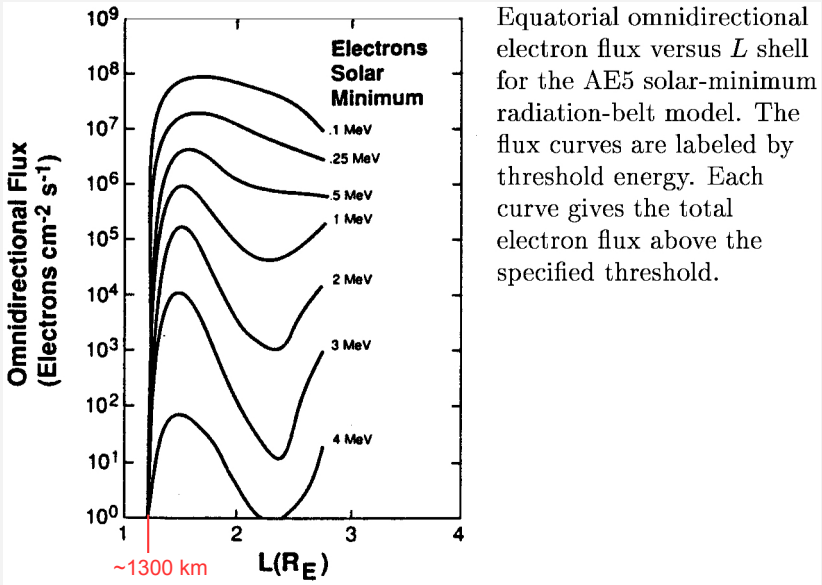
Electron Flux

• **AE-8 & AP-8 models:** NASA models of **electron (AE maps)** and **proton (AP maps)** fluxes based on measurements from more than 20 satellites from 60's and 70's. Taken as standard models, still widely used. Good sky coverage and large energy range.

- Sawyer, D. M., and J. I. Vette 1976, *AP-8 Trapped Proton Environment for Solar Maximum and Solar Minimum*, NSSDC/WDC-A-R&S 76-06
- Vette, J. I. 1991, *The AE-8 Trapped Electron Model Environment*, NSSDC/WDC-A-R&S 91-24
- Vette, J. I. 1991, *The NASA/National Space Science Data Center Trapped Radiation Environment Model Program (1964-1991)*, NSSDC/WDC-A-R&S 91-29

Electron distribution in the Earth's field. (Published by Vette in August 1964.)





Equatorial omnidirectional electron flux versus L shell for the AE5 solar-minimum radiation-belt model. The flux curves are labeled by threshold energy. Each curve gives the total electron flux above the specified threshold.

M. V. Zombeck, *Handbook of Space Astronomy and Astrophysics*

- Large gradient in electron flux at altitude about 1300 km.

Proton Flux

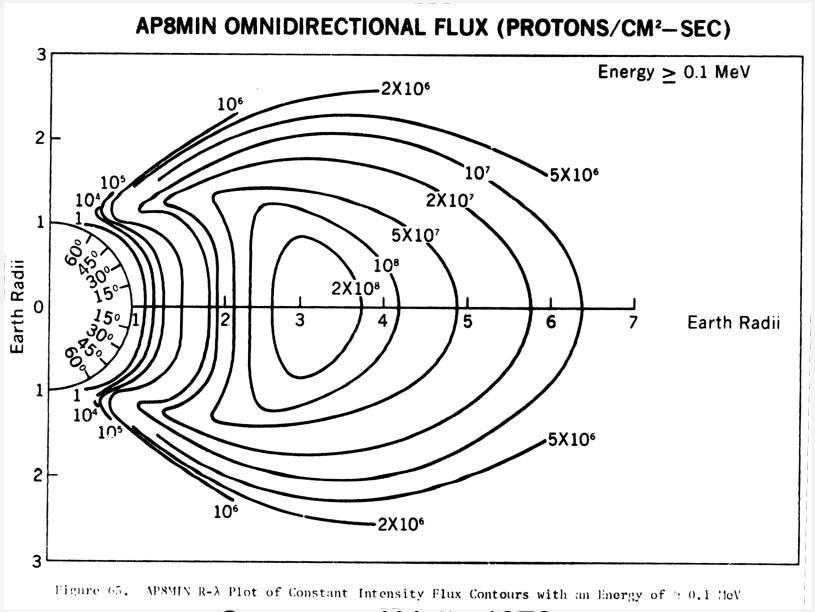


Figure 65. AP8MIN R-λ Plot of Constant Intensity Flux Contours with an Energy of ≥ 0.1 MeV

Sawyer and Vette 1976

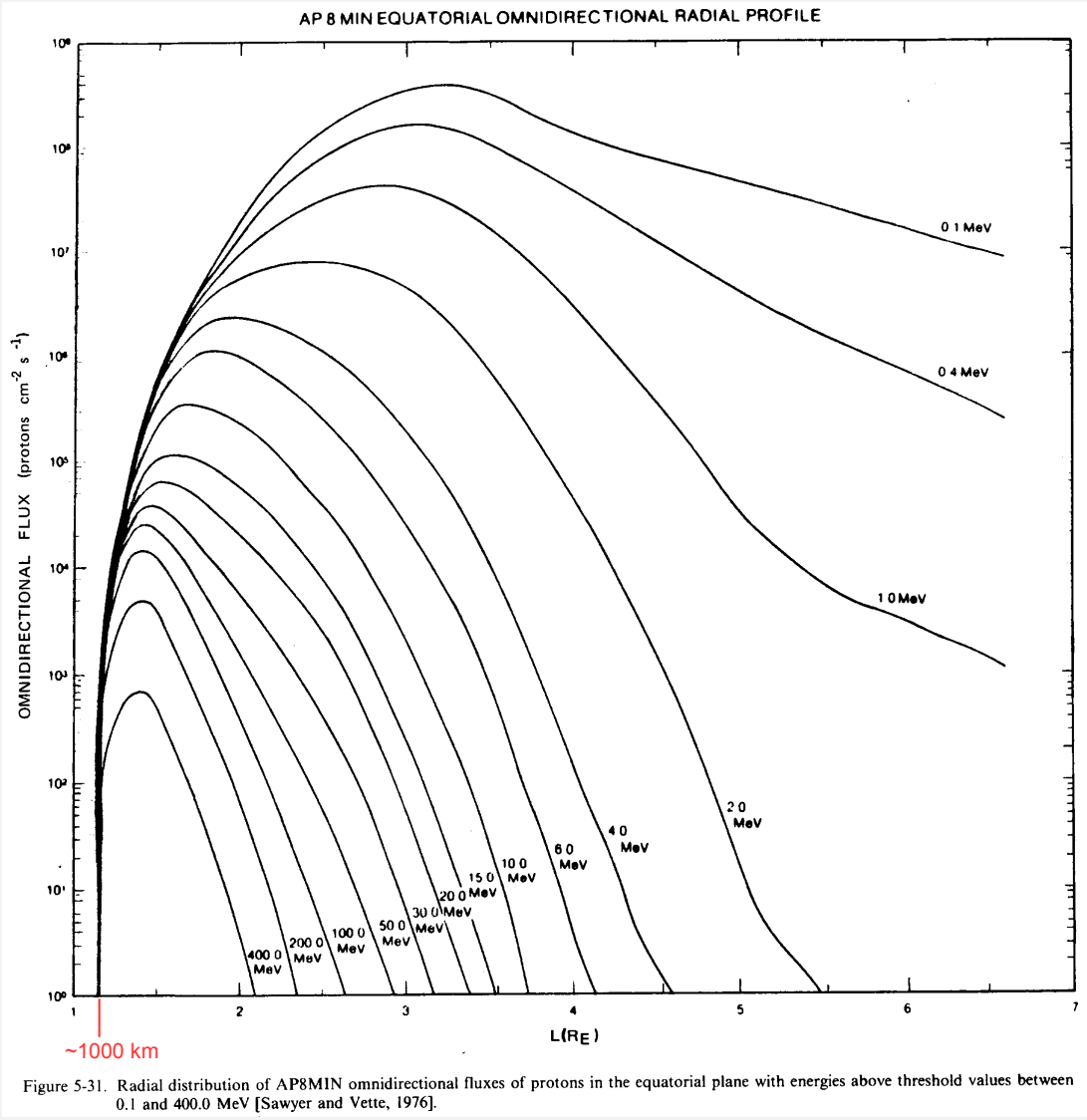


Figure 5-31. Radial distribution of AP8MIN omnidirectional fluxes of protons in the equatorial plane with energies above threshold values between 0.1 and 400.0 MeV [Sawyer and Vette, 1976].

A. S. Jursa 1985, Handbook of Geophysics and Space Environment

- Large gradient in the proton flux at altitude about 1000 km.

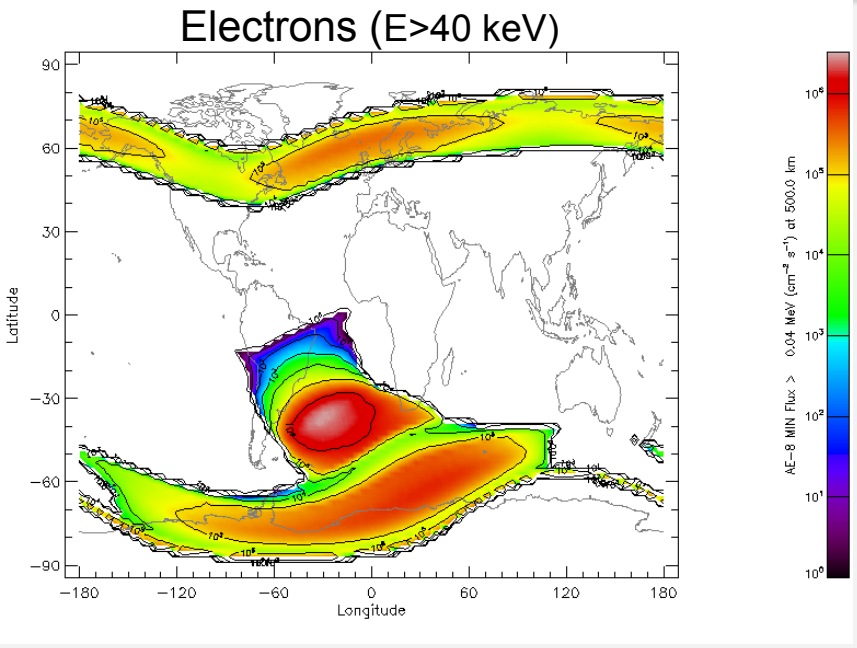
SPENVIS

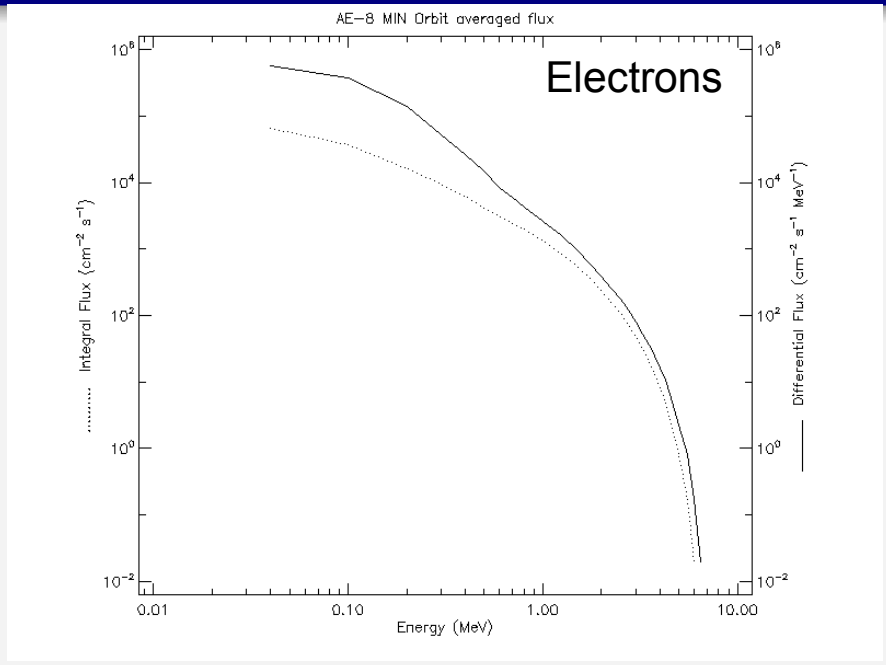
www.spenvis.oma.be

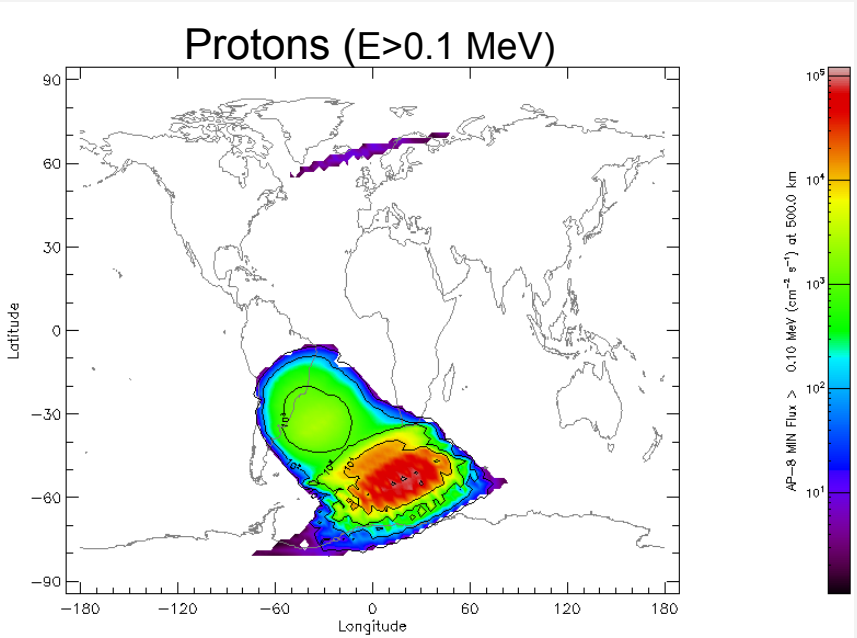
- ESA's **SP**ace **ENV**ironment **I**nformation **S**ystem, a web interface to models of the space environment and its effects. Uses AE-8 & AP-8 and other models, eg. AE-8 MIN update ESA-SEE1 and SAMPEX-PET model PSB97.

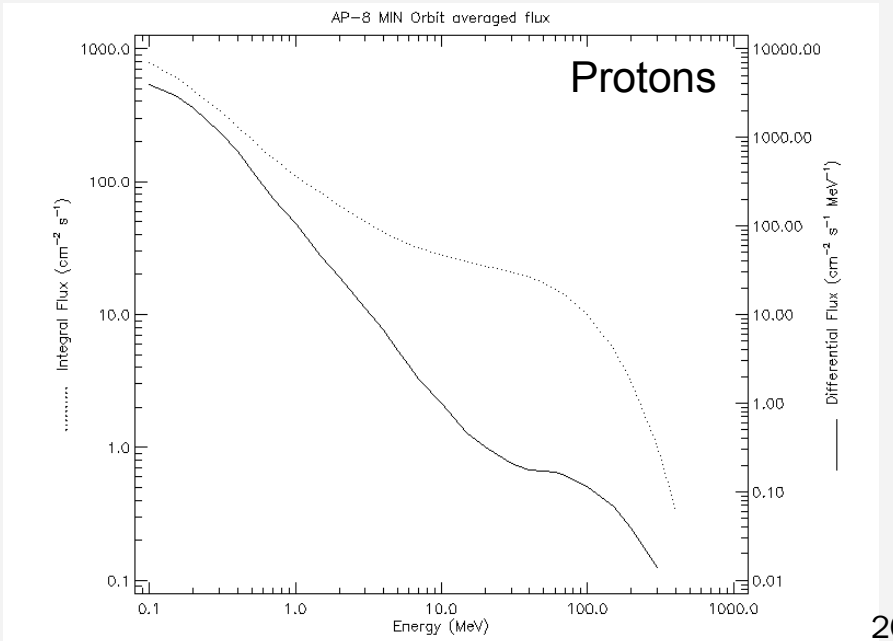
From Norbert W.: There is the **OneWeb** proposed satellite constellation of approximately 882 satellites to provide global Internet. Satellites at altitude ~1200 km with possibility to attach scientific payload. So I checked background at different altitudes with SPENVIS.

e^-, p^+ Fluxes and Spectra at 500 km, AE-8 & AP-8 Models, Solar MINIMUM

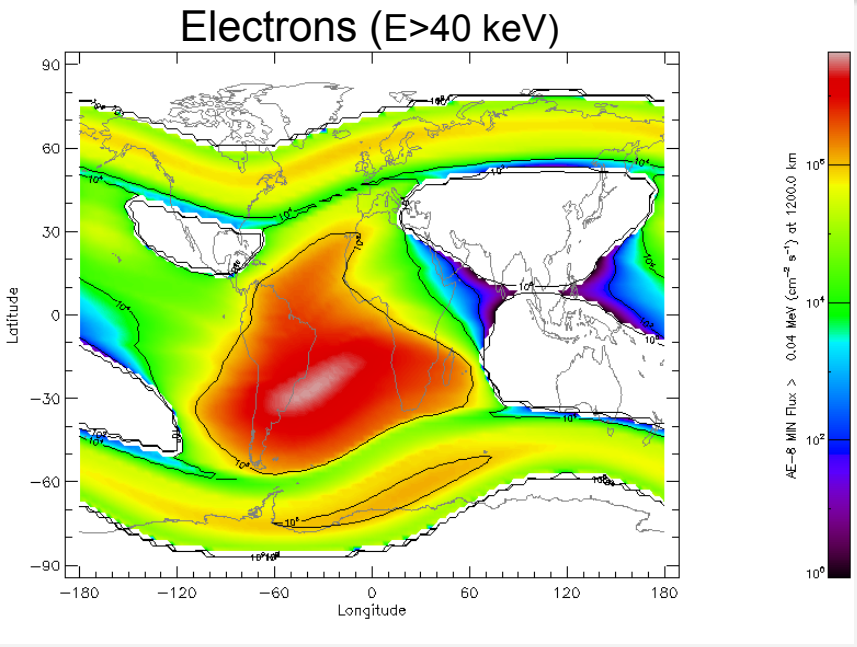


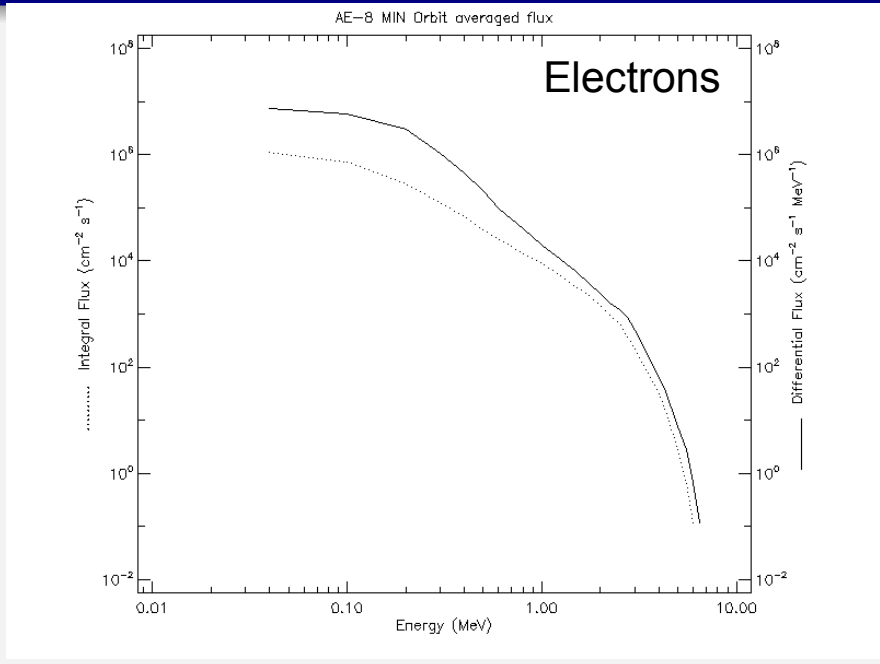


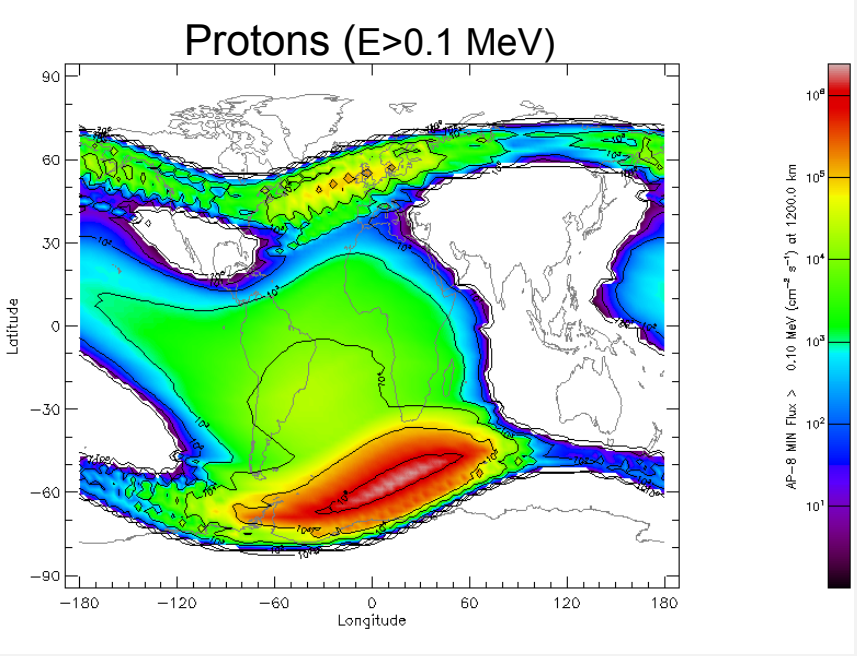


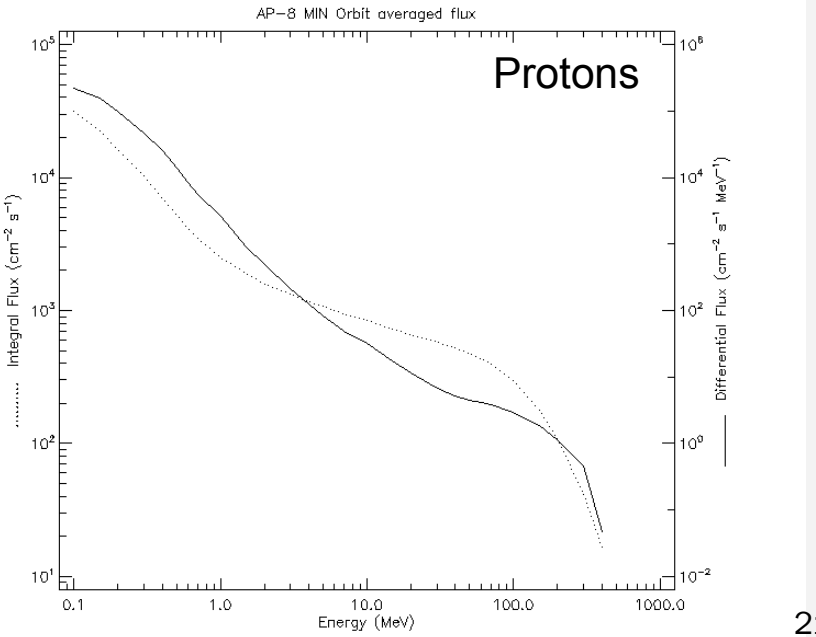


e^-, p^+ Fluxes and Spectra at 1200 km, AE-8 & AP-8 Models, Solar MINIMUM

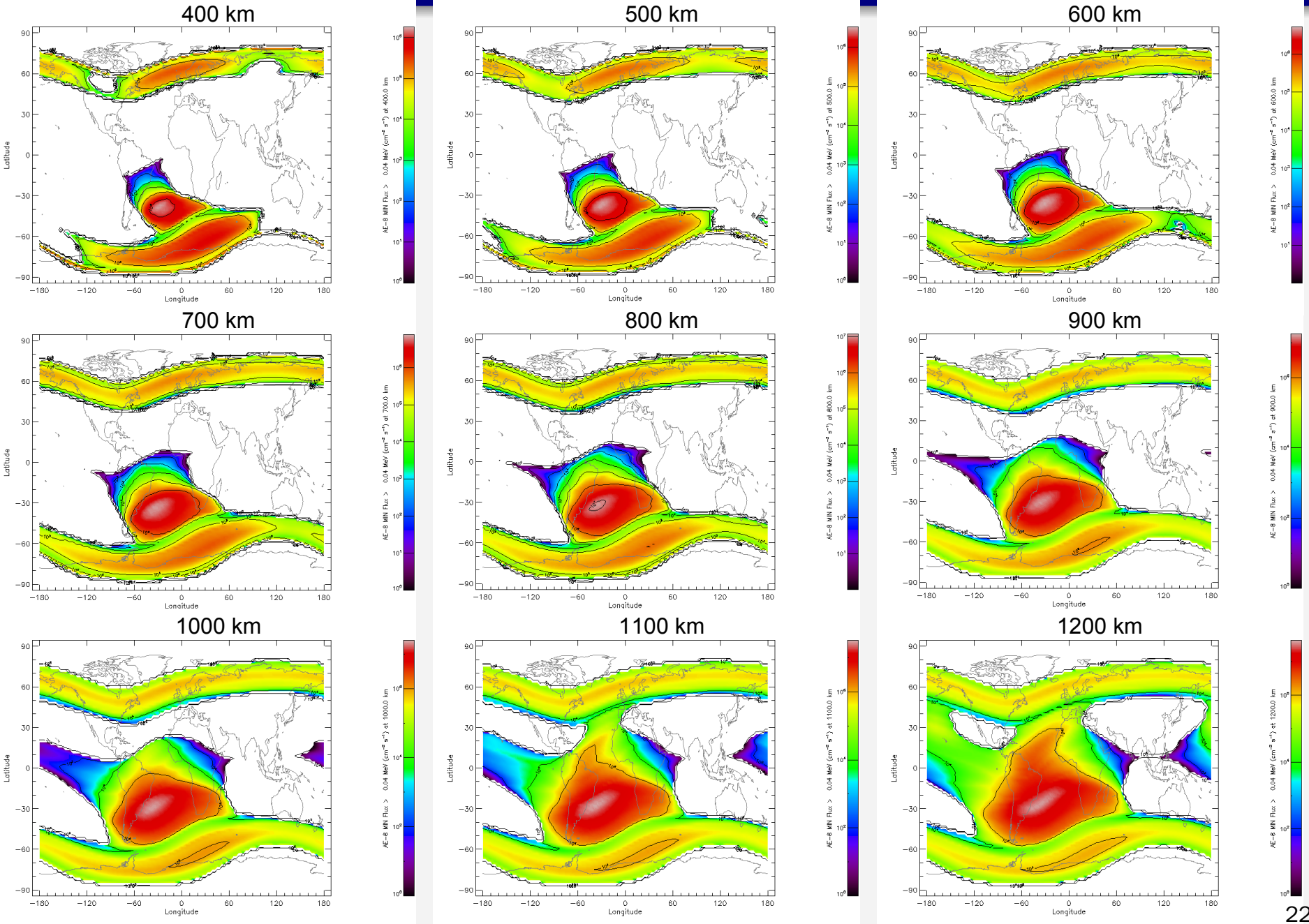




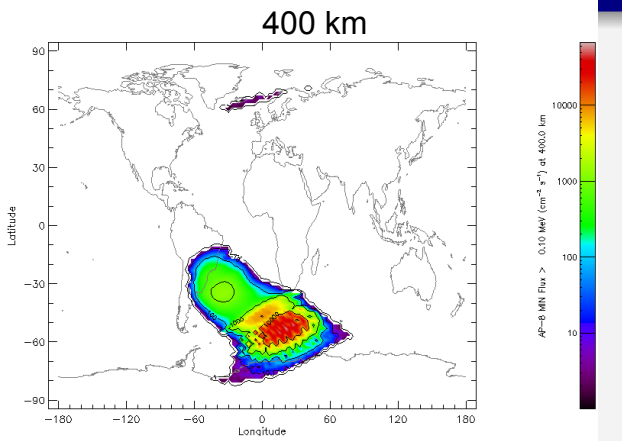


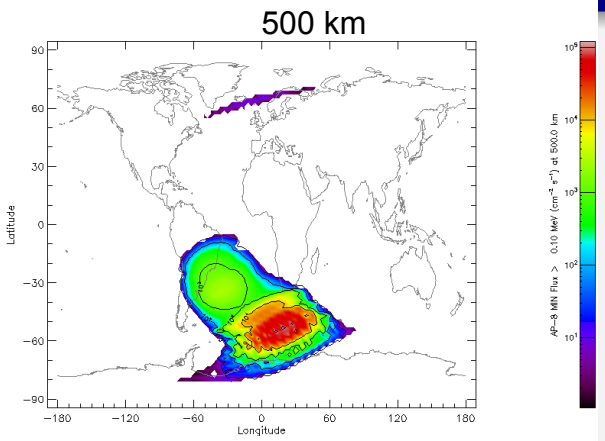


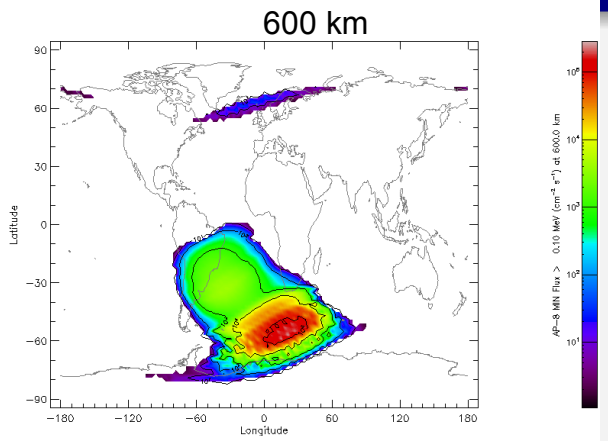
e^- (E>40keV) Fluxes for Different Altitude, AE-8 Model, Solar MINIMUM

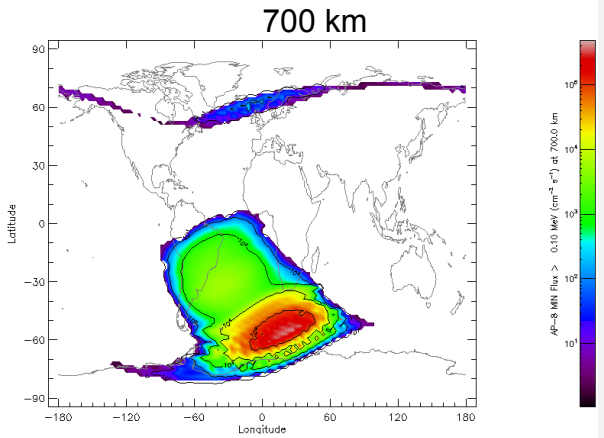


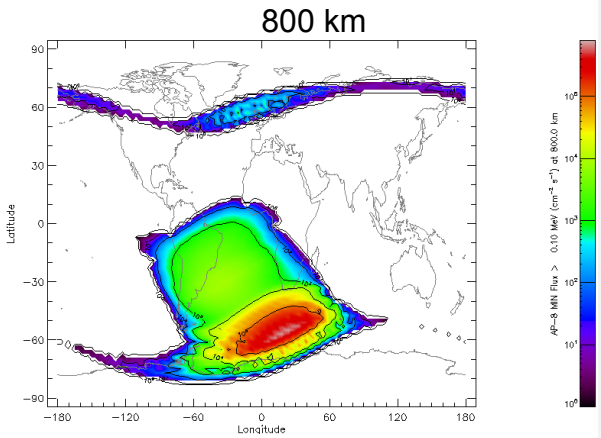
p^+ (E>0.1MeV) Fluxes for Different Altitude, AP-8 Model, Solar MINIMUM

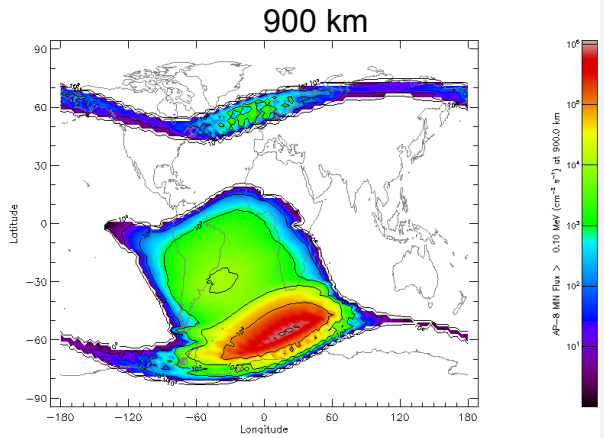


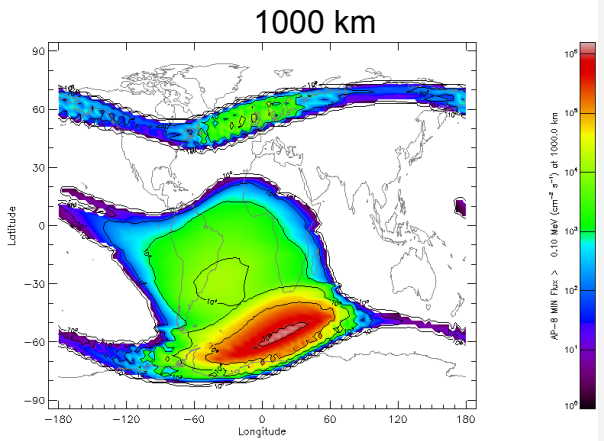


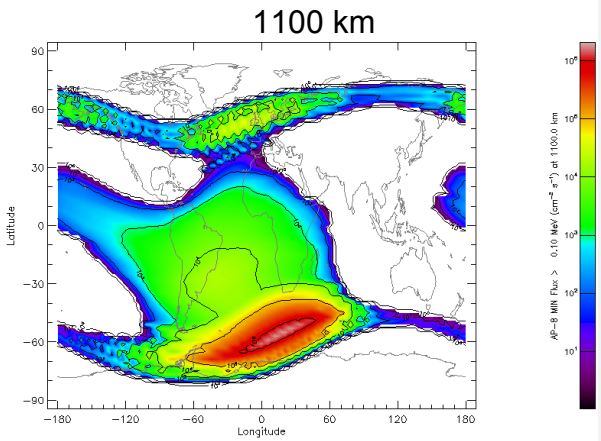


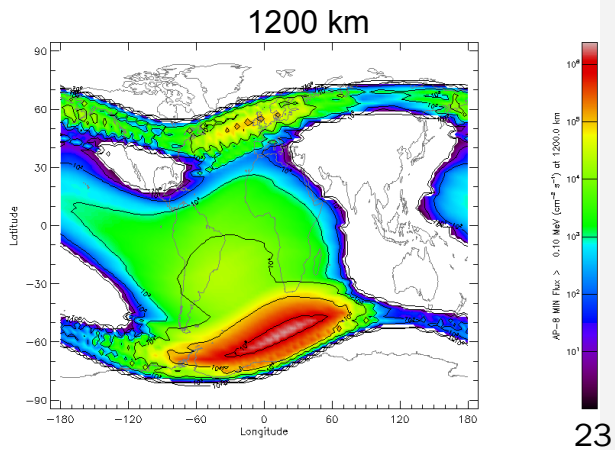




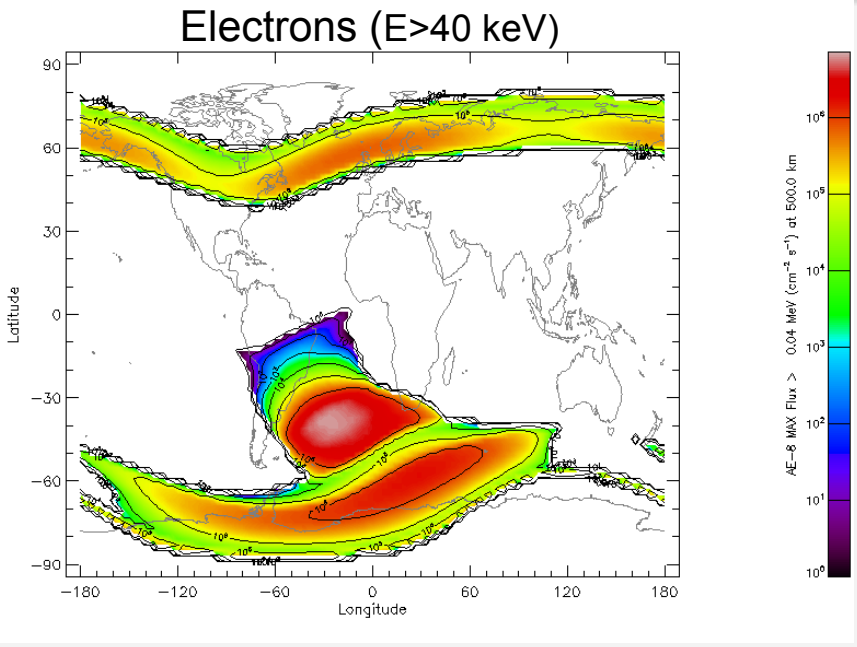


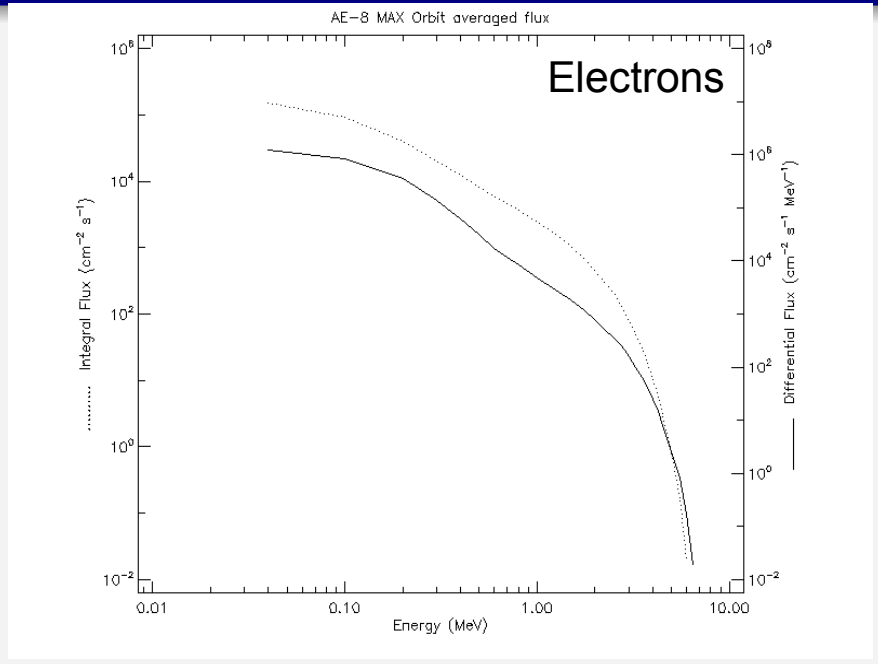


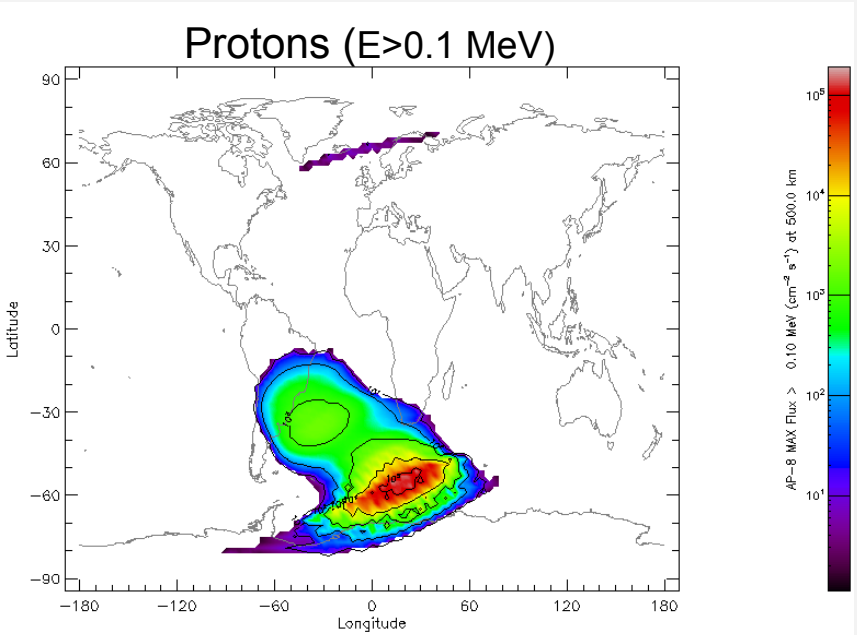


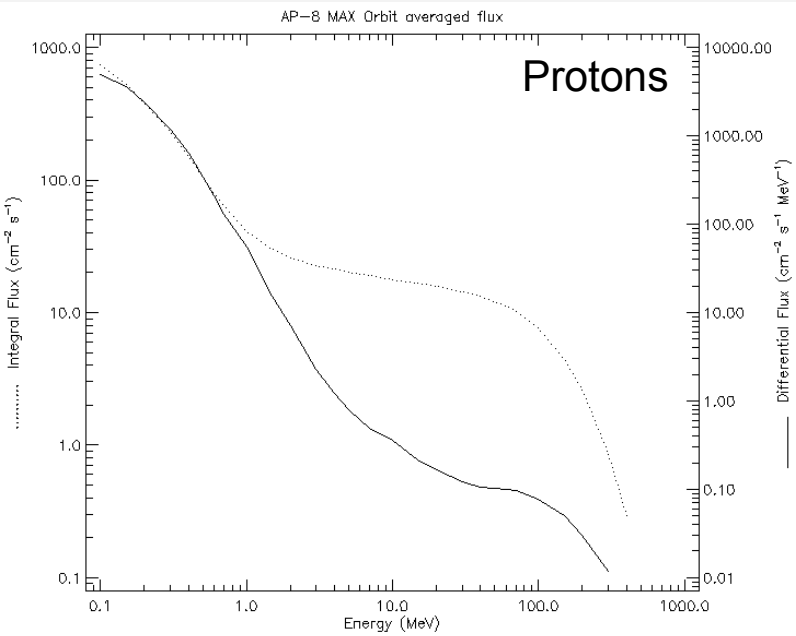


e^-, p^+ Fluxes and Spectra at 500 km, AE-8 & AP-8 Models, Solar MAXIMUM

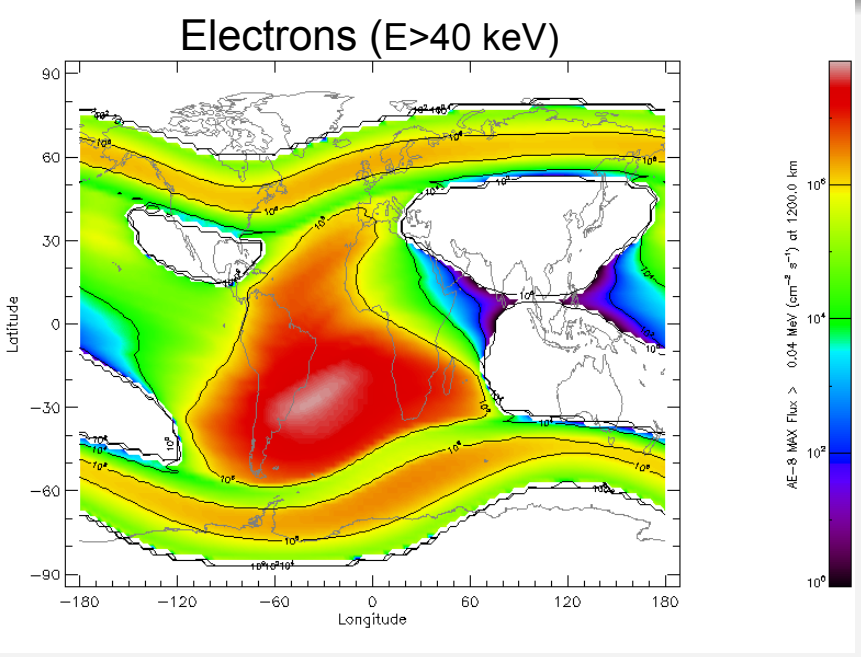


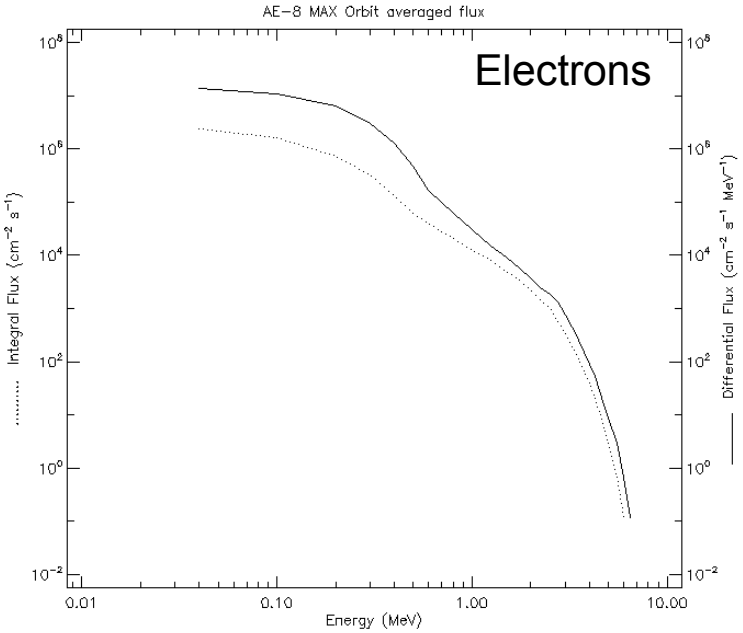


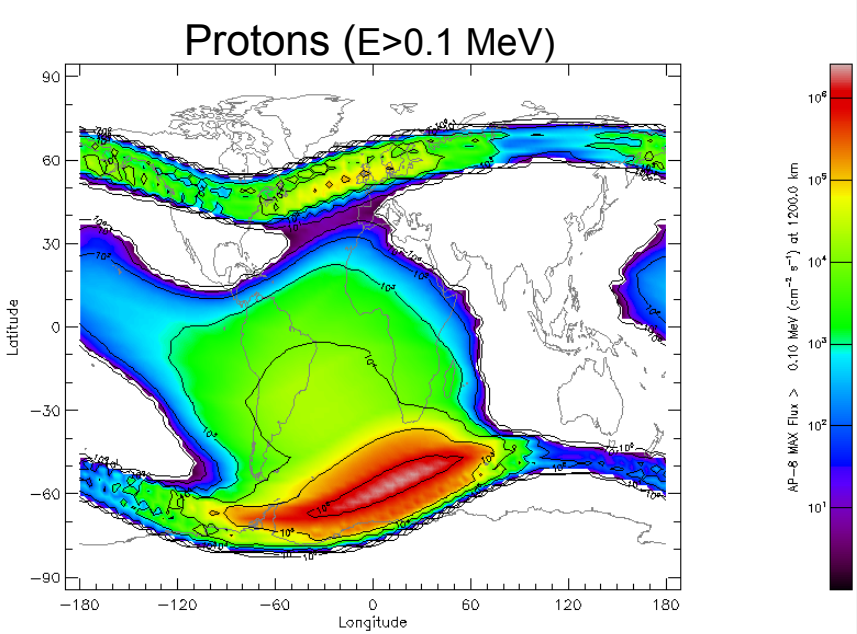


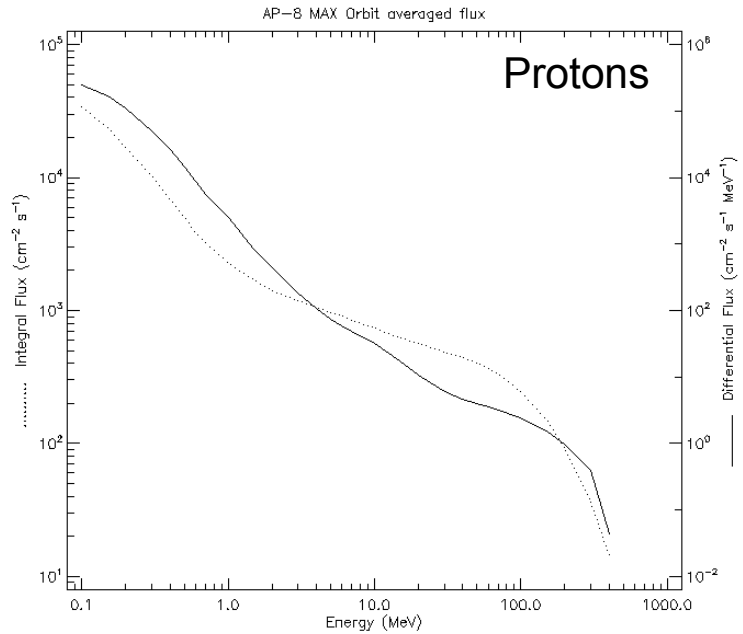


e^-, p^+ Fluxes and Spectra at 1200 km, AE-8 & AP-8 Models, Solar MAXIMUM

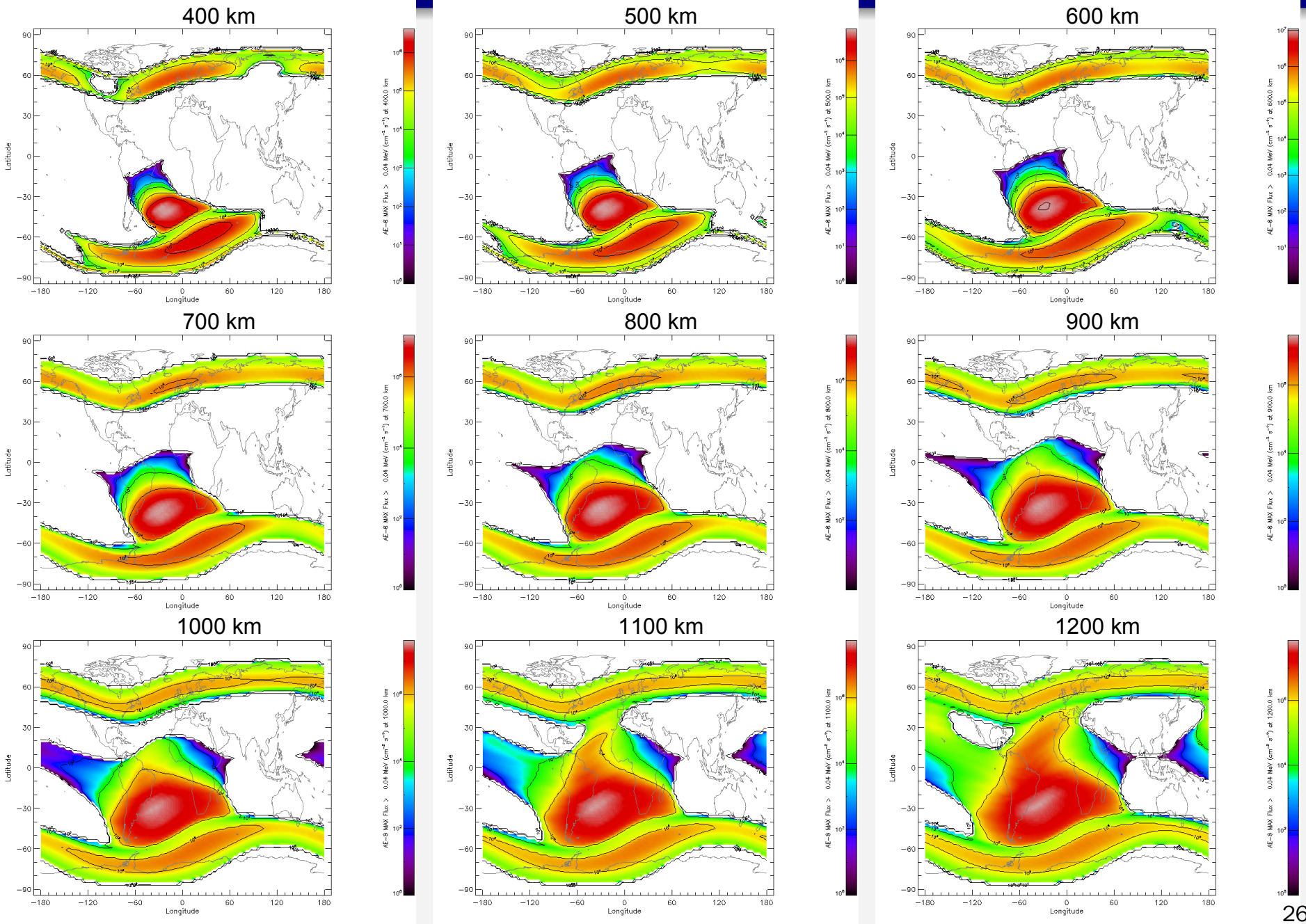




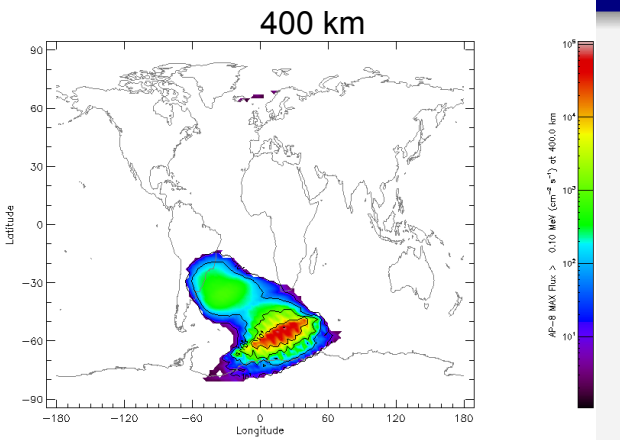


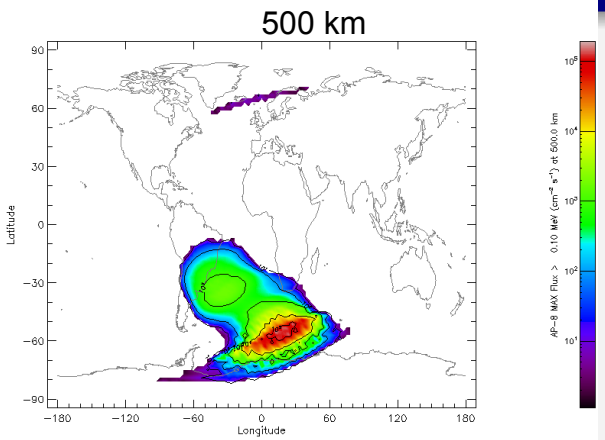


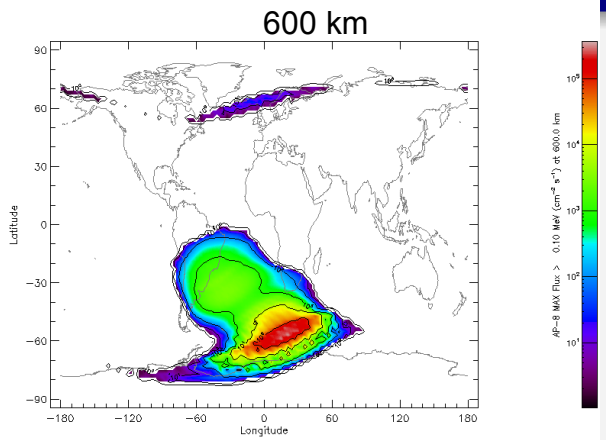
e^- (E>40keV) Fluxes for Different Altitude, AE-8 Model, Solar MAXIMUM

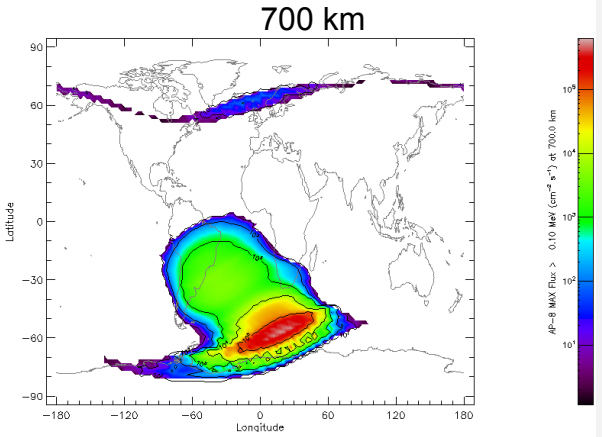


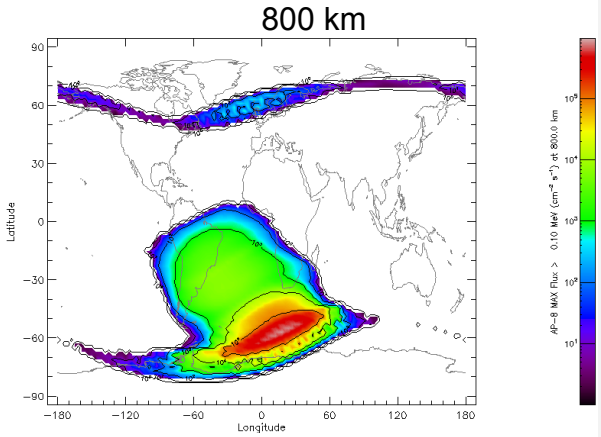
p^+ (E>0.1MeV) Fluxes for Different Altitude, AP-8 Model, Solar MAXIMUM

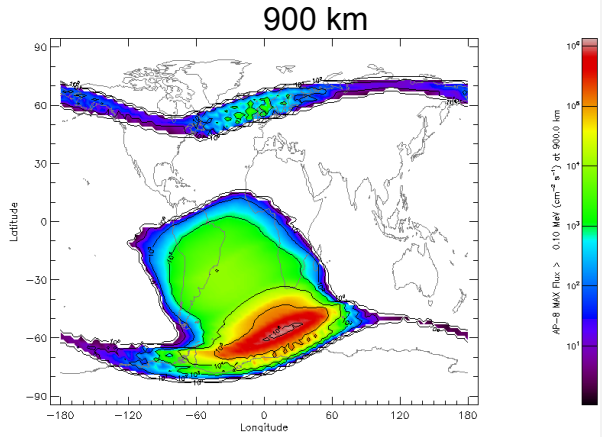


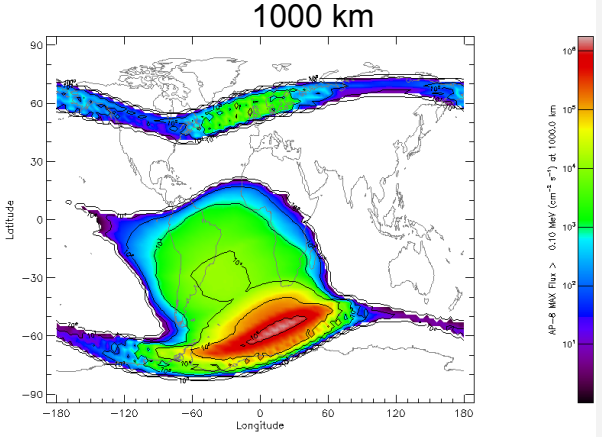


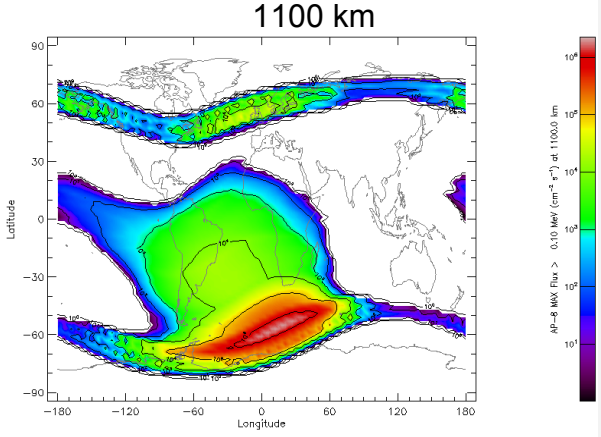


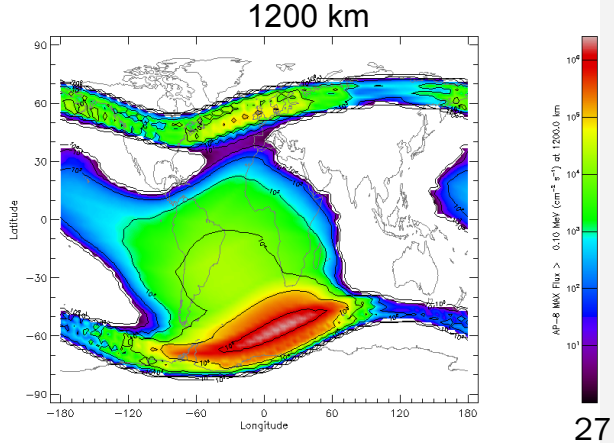












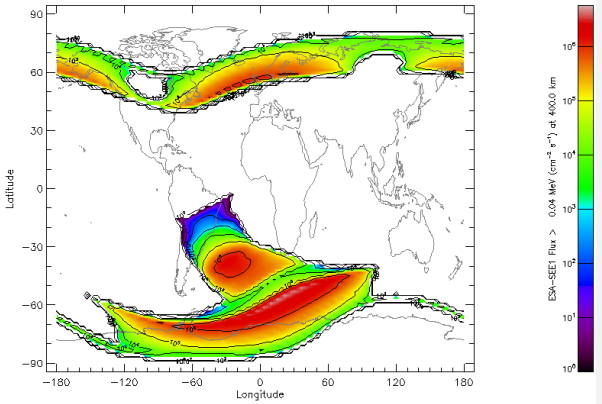
Other Models Available in SPENVIS

- **AE-8 update, ESA-SEE1, model:**
  CRRES/MEA satellite data (0.1 - 1.7 MeV) from 1990-1991 were used to update AE-8 MIN model. Vampola, A. L. 1996, *Outer Zone Energetic Electron Environment Update*, Final Report of ESA/ESTEC Contract No.

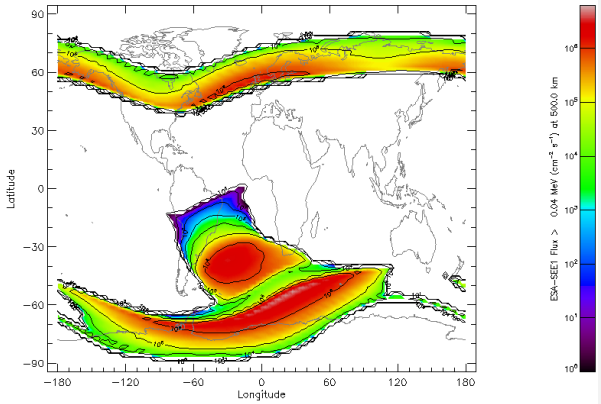
- **SAMPEX/PET PSB97 model:**
  Low altitude (< about 600 km) trapped proton model for solar minimum conditions (1994-1995), based on measurements made by the Proton/Electron Telescope (PET) onboard the SAMPEX satellite. Energy range 18.5 - 500 MeV.
  Heynderickx, D., M. Kruglanski, V. Pierrard, J., et al. 1999, *A Low Altitude Trapped Proton Model for Solar Minimum Conditions Based on SAMPEX/PET Data*, IEEE Trans. Nucl. Sci., 46, 1475

e^- (E>40keV) Fluxes for Different Altitude, AE-8 Update ESA-SEE1 Model, Solar MINIMUM

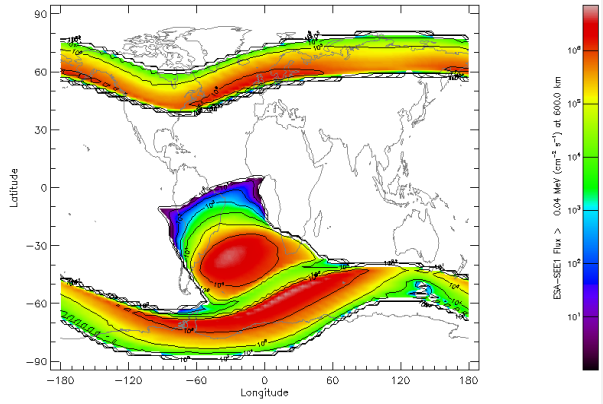
400 km



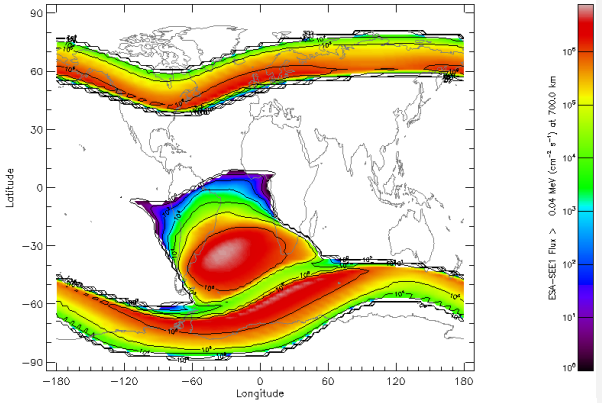
500 km



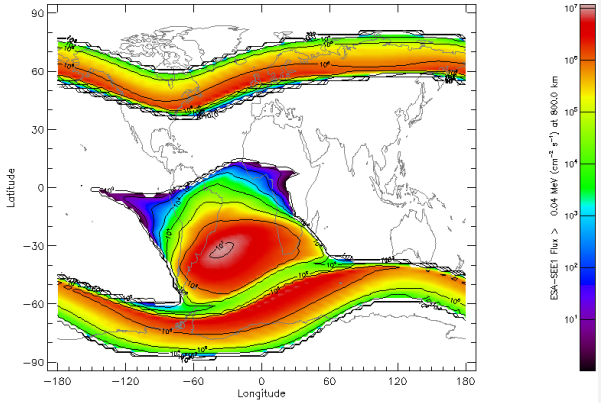
600 km



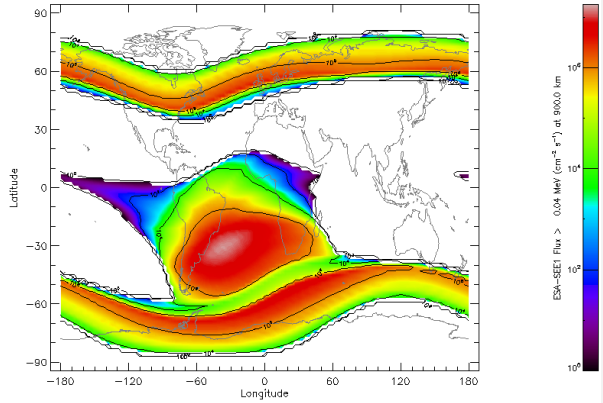
700 km



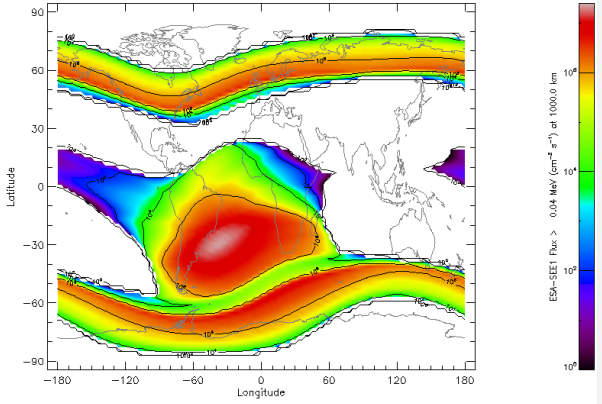
800 km



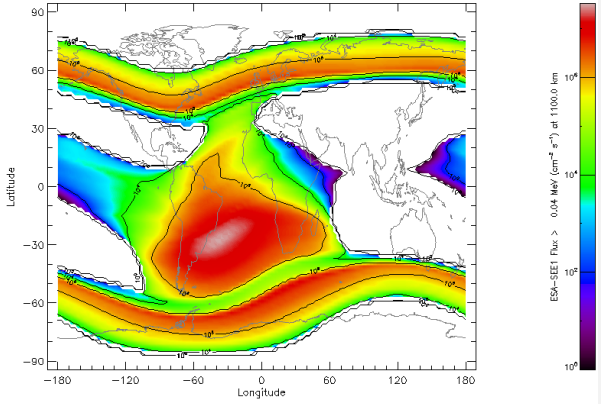
900 km



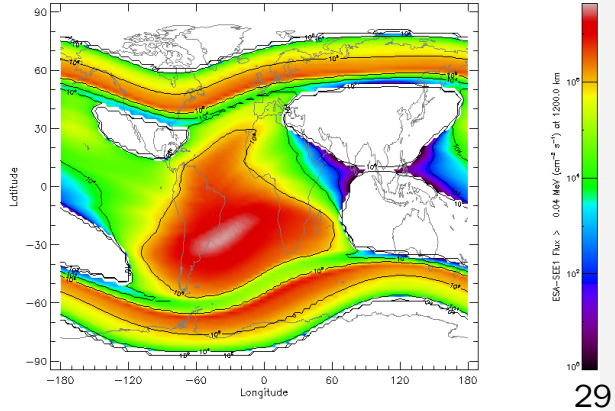
1000 km



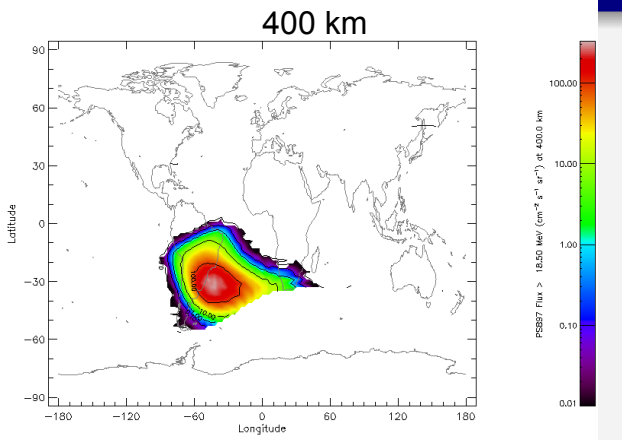
1100 km

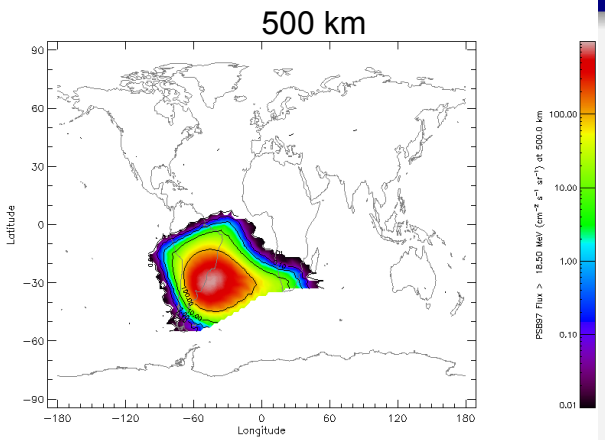


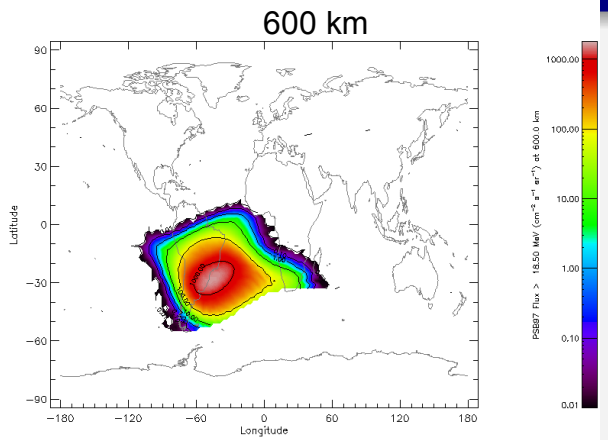
1200 km

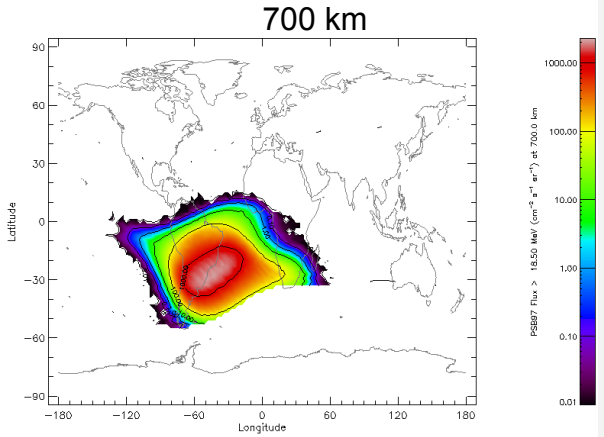


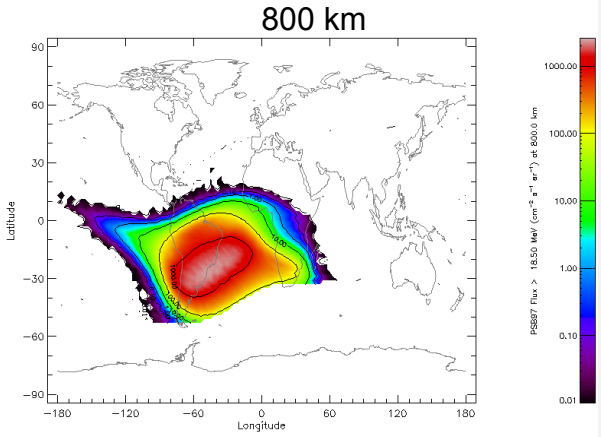
p^+ (E>18.5 MeV) Fluxes for Different Altitude, SAMPEX/PET PSB97 Model, Solar MINIMUM

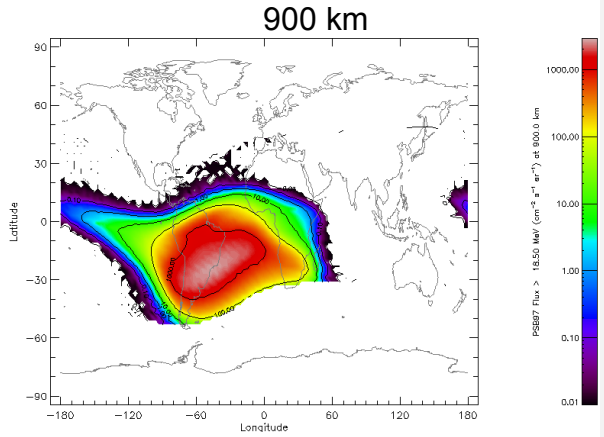


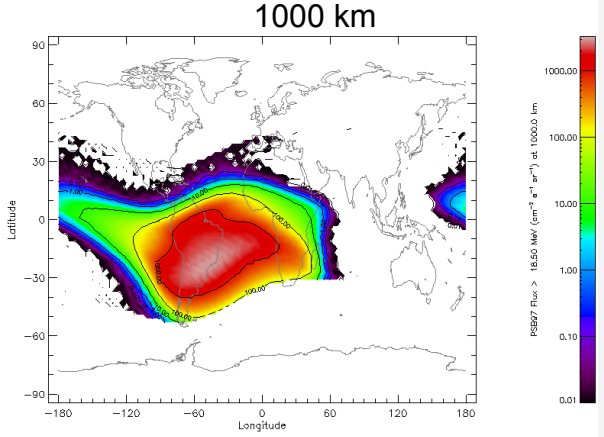


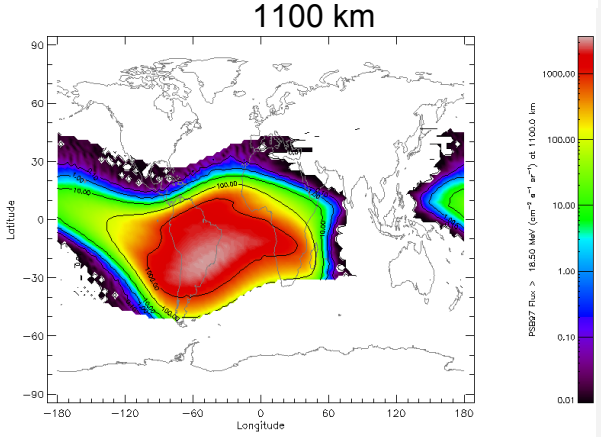


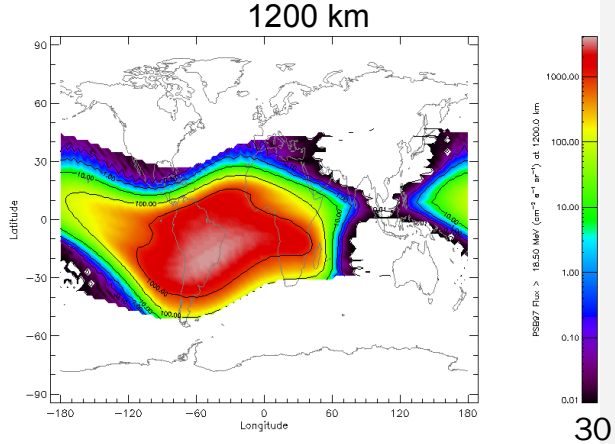












Summary

- At altitude 1200 km the background electron and proton flux is much larger than at 500 km.

- Orbits with altitude < ~800 km and inclination < ~40° provides relatively good background conditions.