Air Force Research Laboratory

Integrity ★ Service ★ Excellence

AP9 V1.50.001 Model Validation Summary Report

28 September 2017

AE9/AP9/SPM Development Team

AFRL

AP9 V1.50.001 Validation

Satellite	Sensor	Orbit	Time Period	Energies (MeV)
POES N15	SEM2 MEPED	LEO 850 km, circular, 98.7°	Jul 1998 – Dec 2011	>16, >35, >70, >140
SAMPEX	PET	LEO ~440-~680 km*, 98.7°	1992 – 2009	20, 24, 27-37, 50, 67, 80, 85-120, 120-200, 200-300

* Altitude decreased during the mission

POES N15

POES data processing:

- POES data is processed based on response functions in POES/METOP SEM-2 OMNI Flux Algorithm Theory and Software Description, J. Machol, 27 Mar 2012 (see AE9/AP9 V1.50.001 Model Validation Full Report for details).
- Uncertainties in absolute fluxes are on the order of a factor of 2-3 for 16-70 MeV channels, based on comparisons to conversions using other reported response functions.
- The >6.9 MeV channel is not used due to significant electron contamination.
- POES results are treated as omnidirectional averages (i.e., no modeling of proton pitch angle distribution and instrument angular response).

Content:

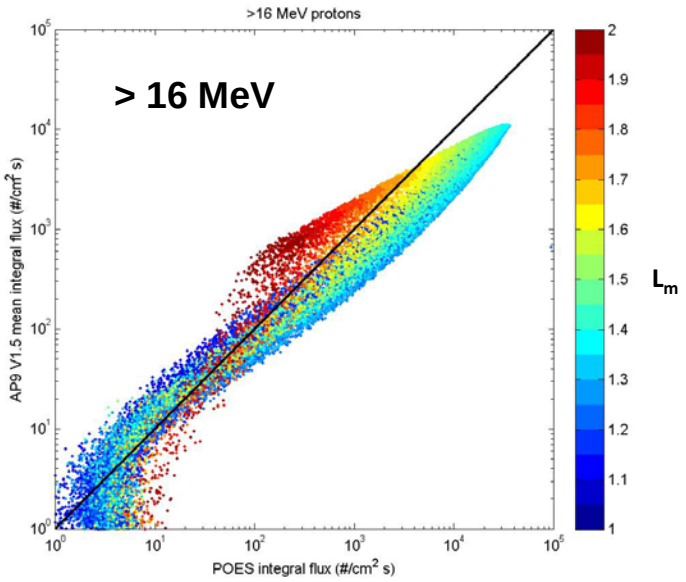
- Slides 5-10 compare AP9 V1.50 mean to POES observations from Jan 1999 (solar min) and Jan 2005 (solar max).
- Slides 11-25 compare AP9 V1.50 Monte Carlo results (40 runs) for 2005 to POES observations from Jul 1998 to Dec 2011 (full solar cycle).

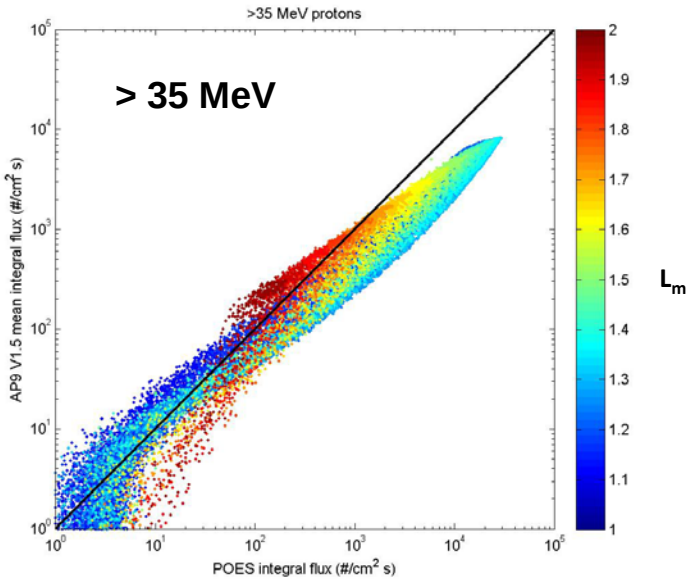
POES N15

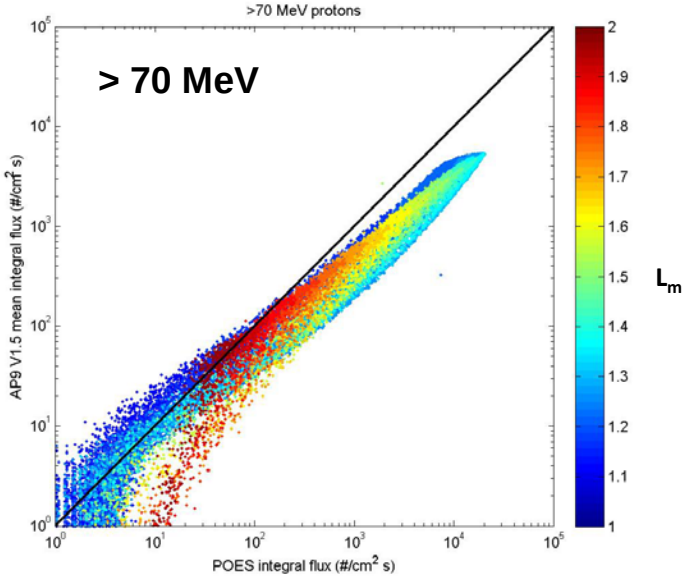
Summary:

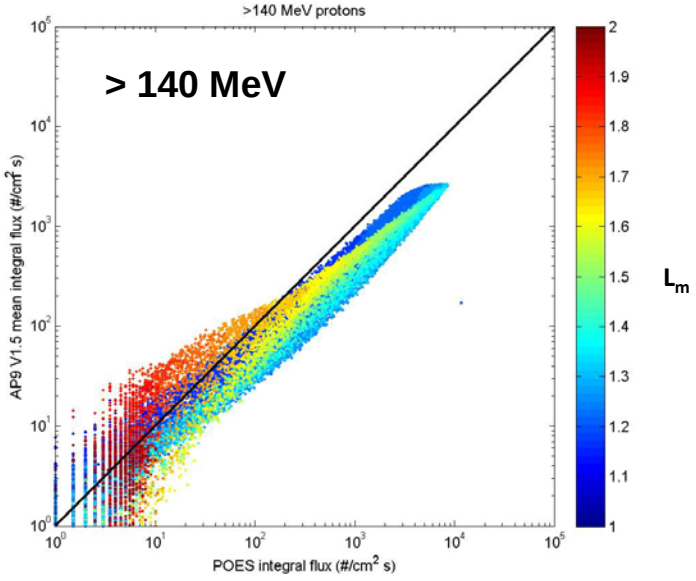
- AP9 V1.50 reproduces the geographic extent of the South Atlantic Anomaly (SAA) as observed by POES.
- AP9 V1.50 fluxes are ~3x lower than POES for SAA peak fluxes.
- At the edges of the SAA (where fluxes are diminishing), AP9 V1.50 and POES tend to have similar median profiles, although differences may reach 3-10x where fluxes have fallen to 10^{-2} – 10^{-4} of SAA peak levels.
- Range of annual fluences observed by POES fall within the ranges represented by AP9 Monte Carlo results.

POES proton data and AP9 V1.50 mean flux scatter plot, Jan 1999 (after solar min)

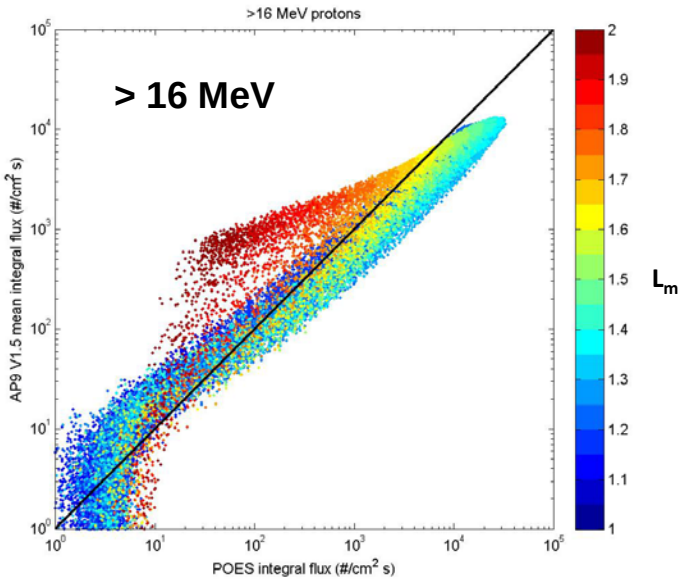


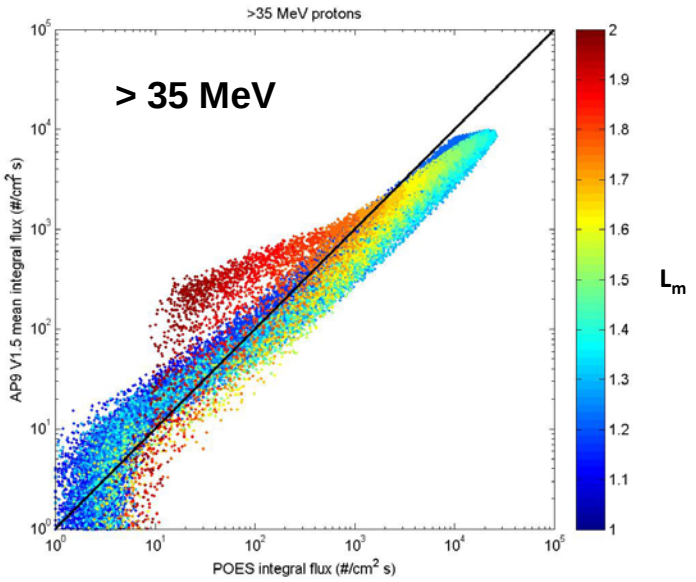


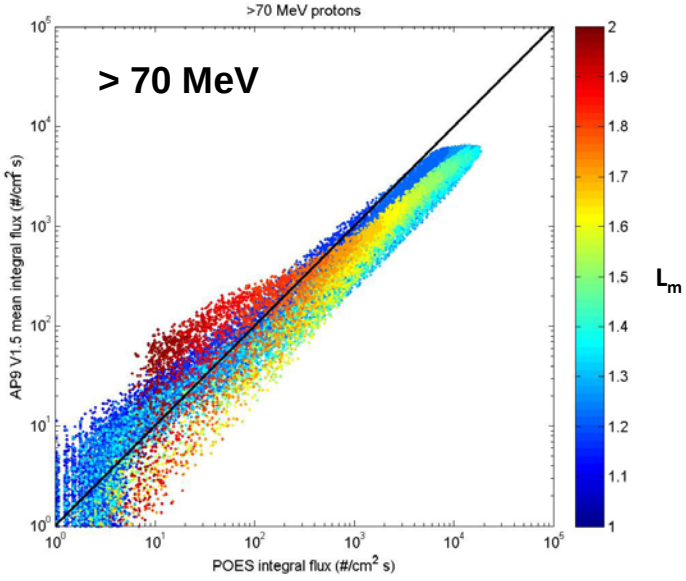


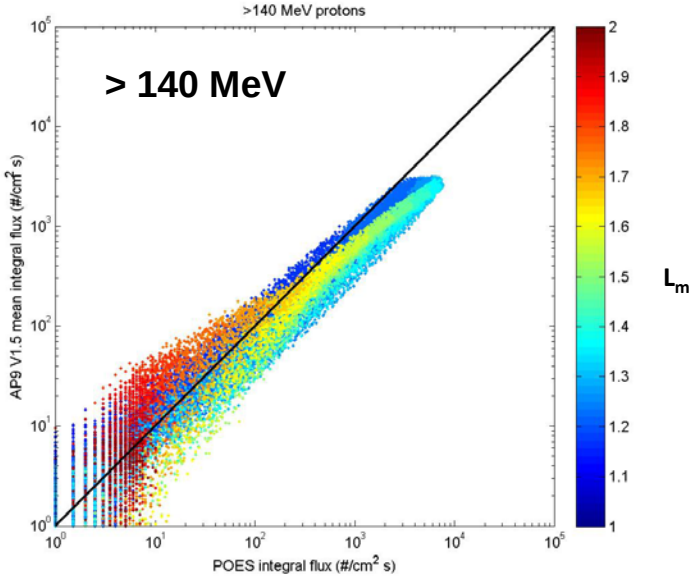


POES proton data and AP9 V1.50 mean flux scatter plot, Jan 2005 (after solar max)



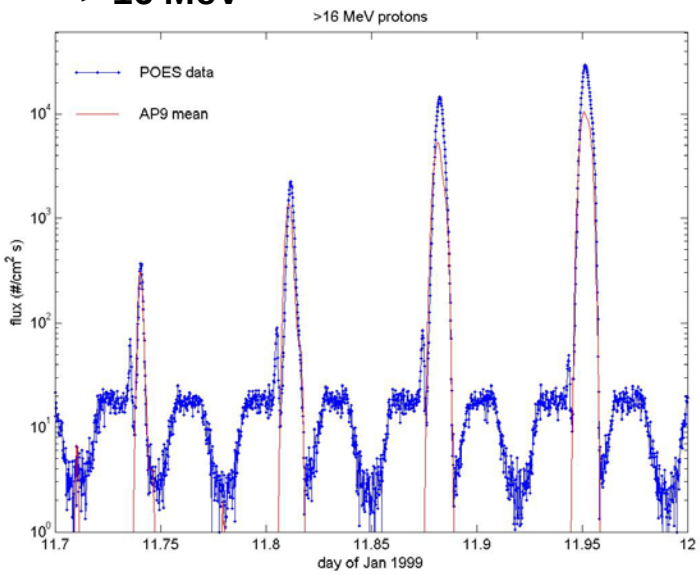




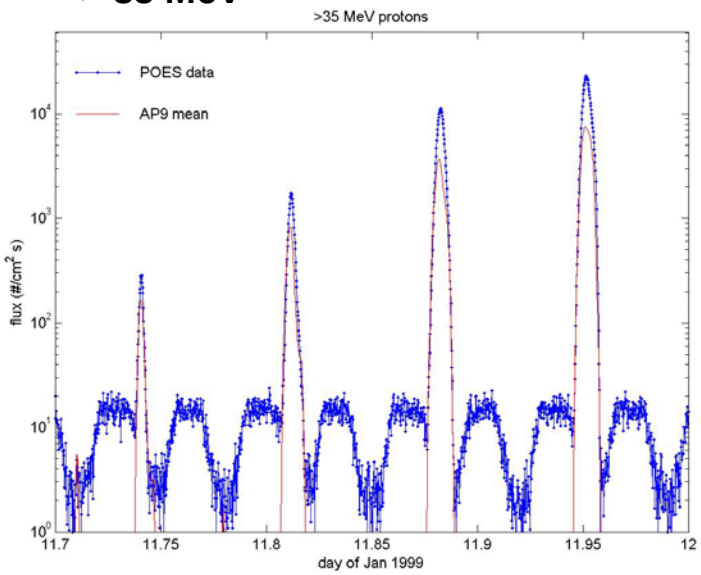


POES and AP9 V1.50 mean proton flux time series, Jan 1999 (after solar max)

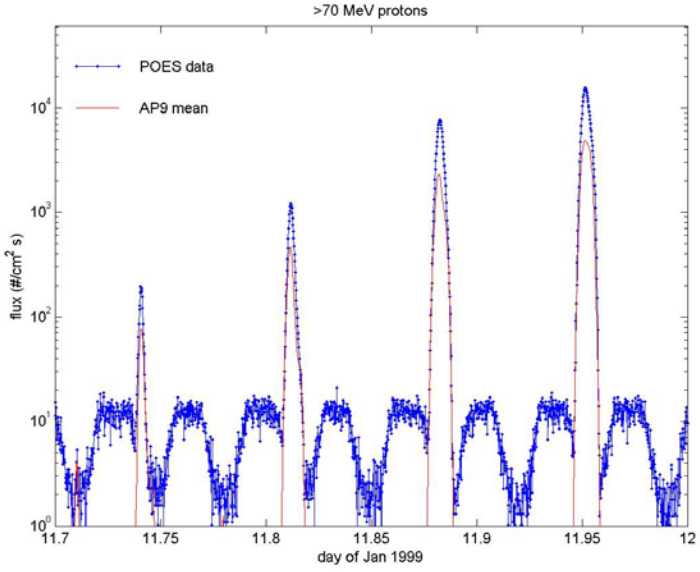
> 16 MeV



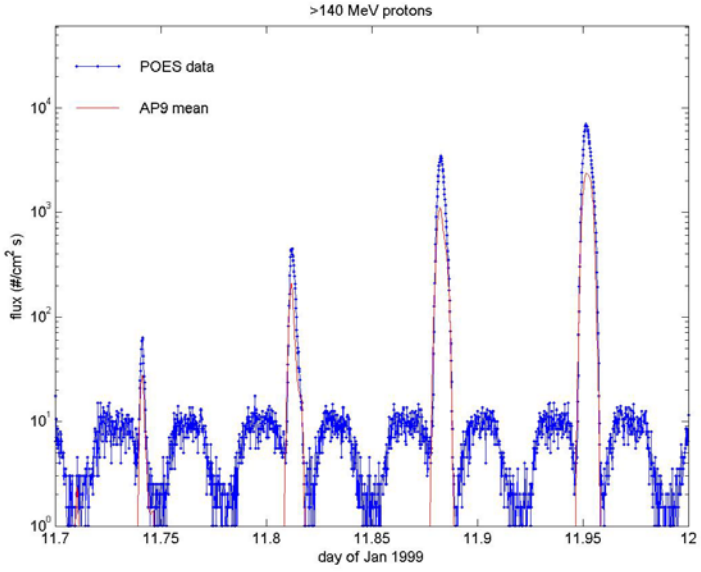
> 35 MeV



> 70 MeV

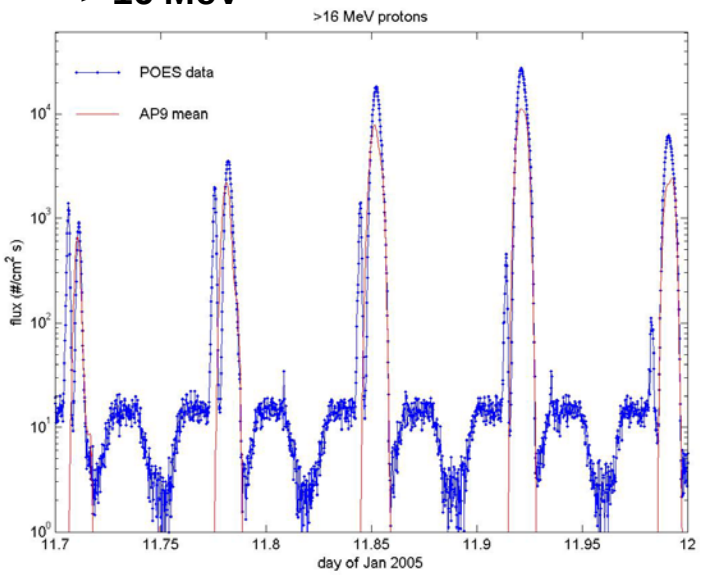


> 140 MeV

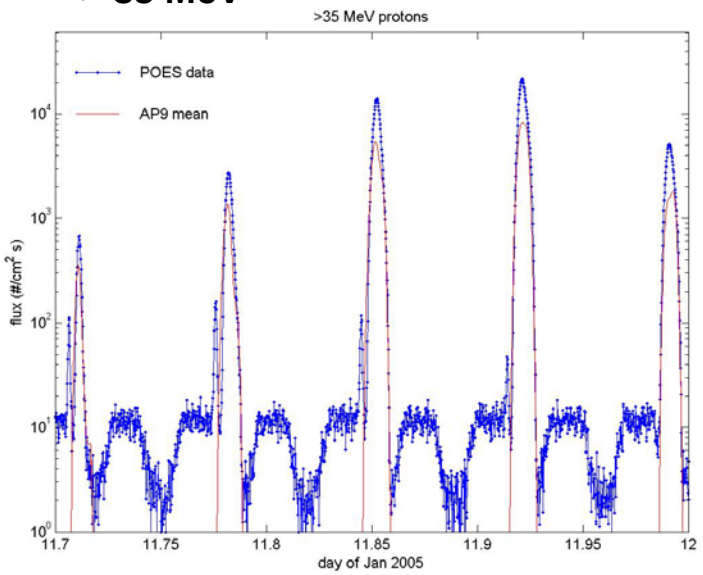


POES and AP9 V1.50 mean proton flux time series, Jan 2005 (after solar min)

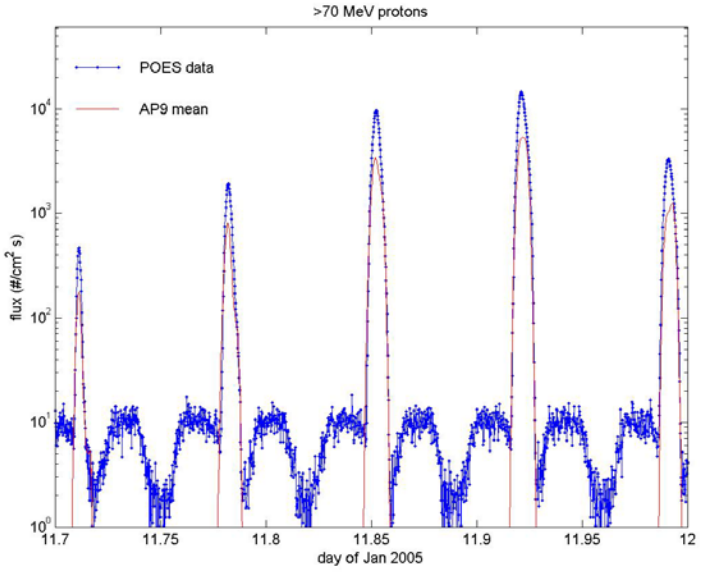
> 16 MeV



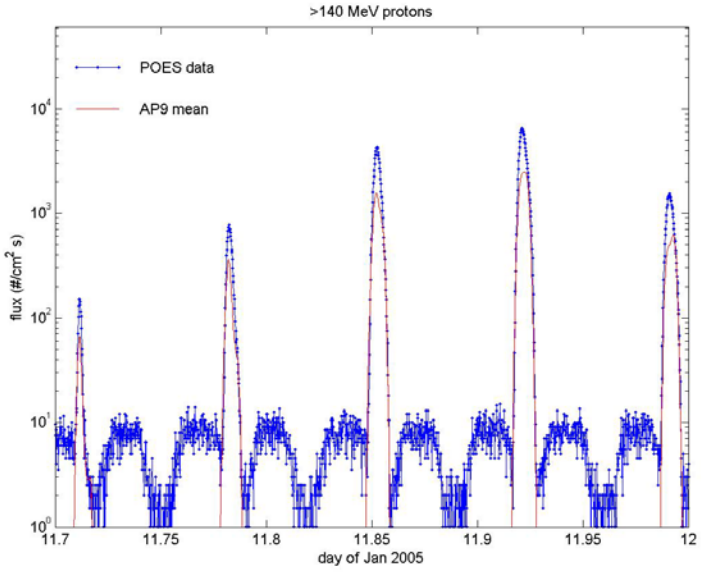
> 35 MeV



> 70 MeV

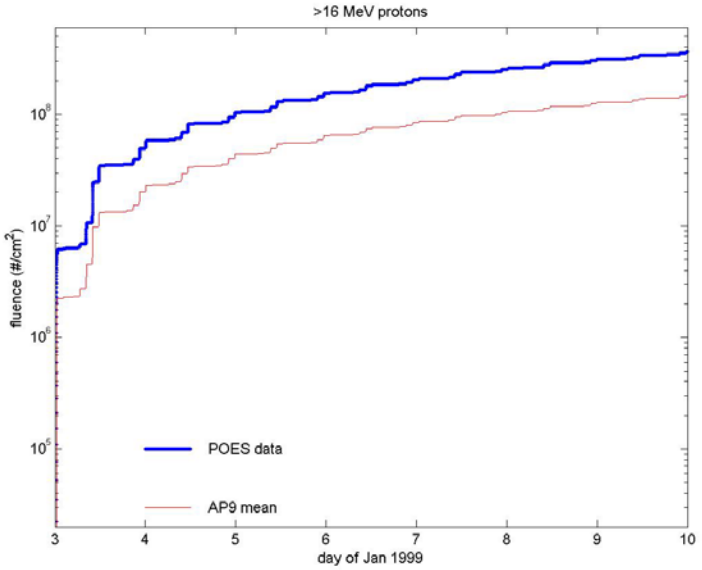


> 140 MeV

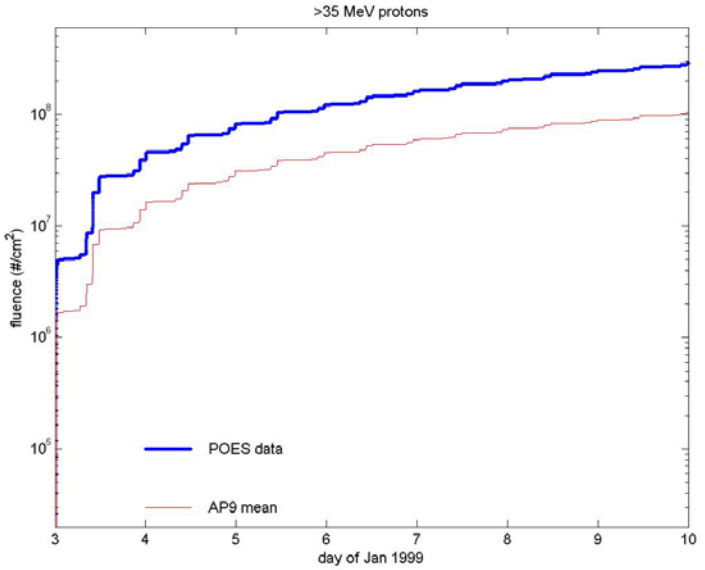


POES and AP9 V1.50 mean proton fluence time series, Jan 1999 (after solar min)

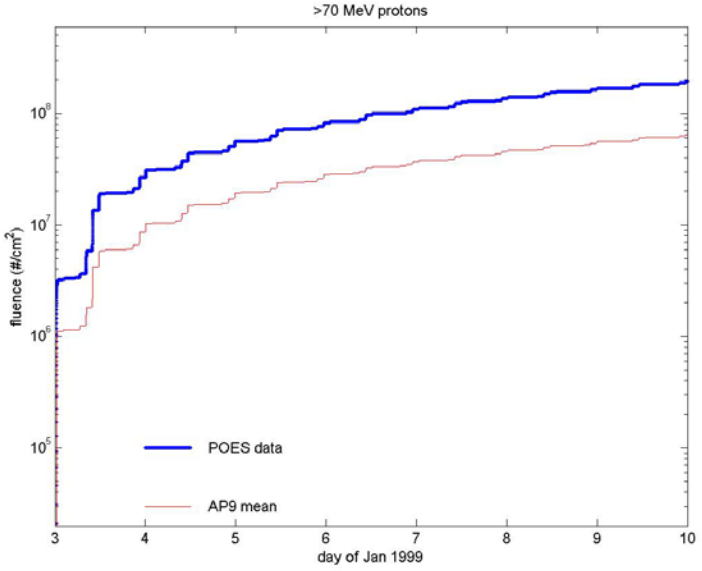
> 16 MeV



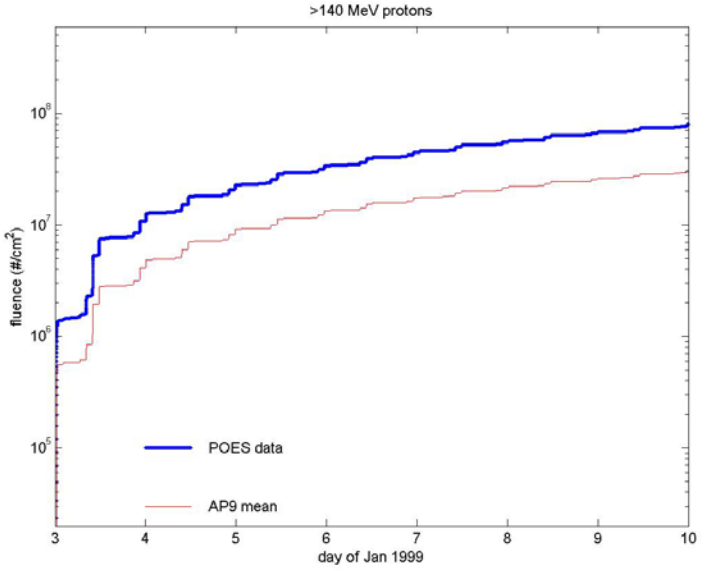
> 35 MeV



> 70 MeV

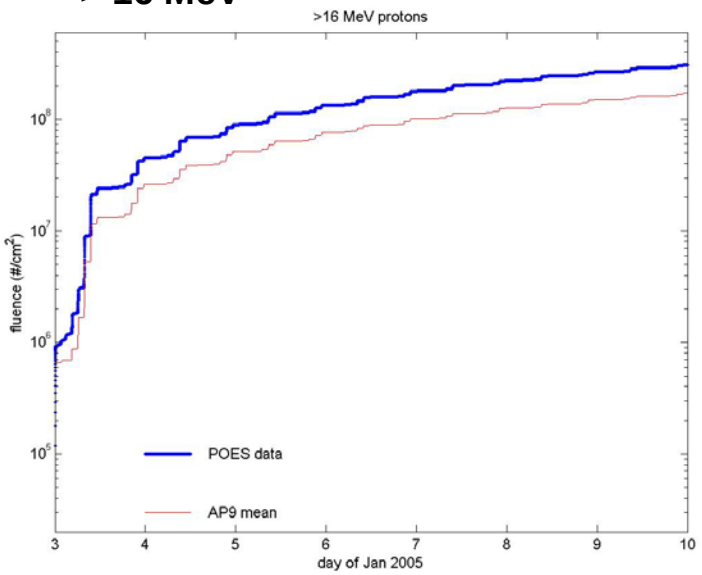


> 140 MeV

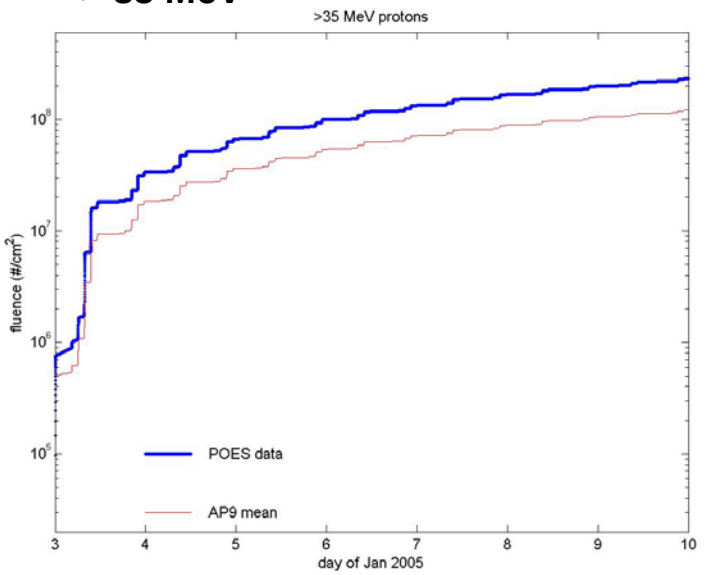


POES and AP9 V1.50 mean proton fluence time series, Jan 2005 (after solar max)

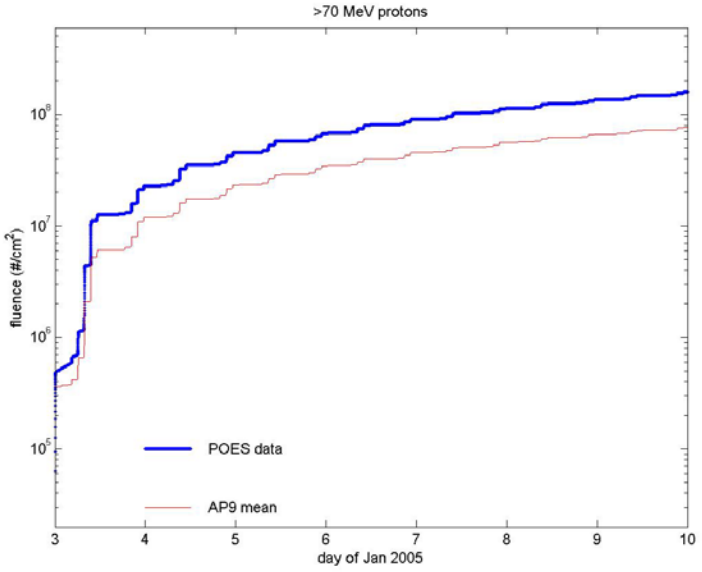
> 16 MeV



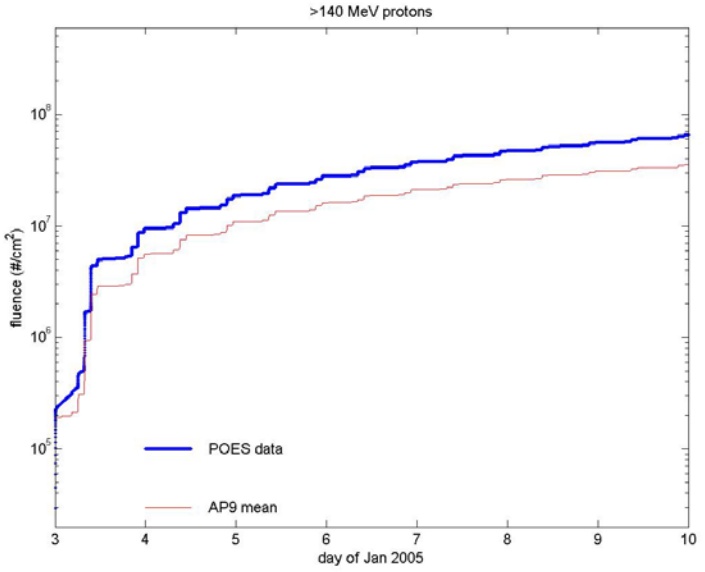
> 35 MeV



> 70 MeV

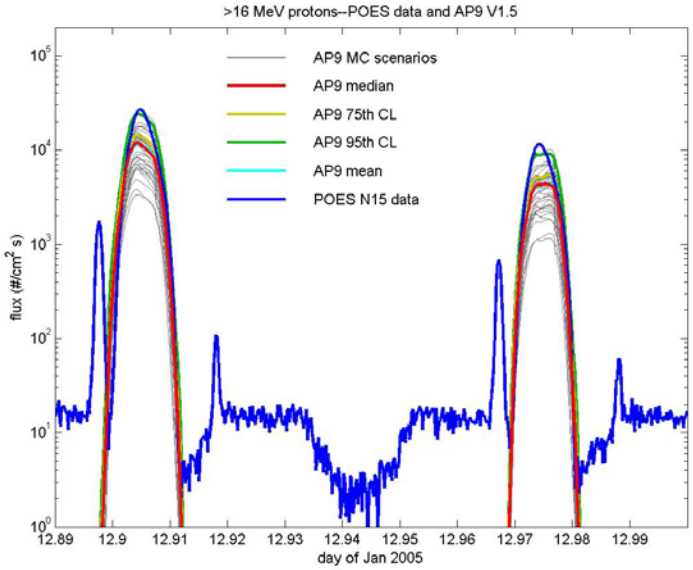


> 140 MeV

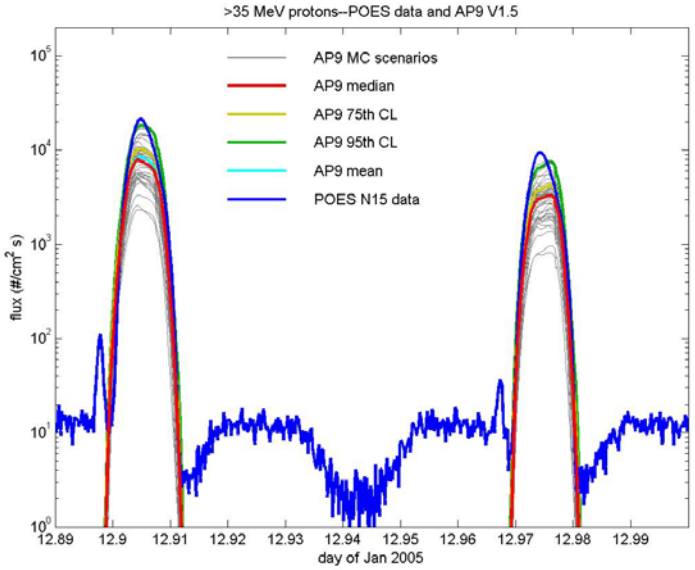


POES and AP9 V1.50 Monte Carlo proton flux time series, Jan 2005 (after solar max)

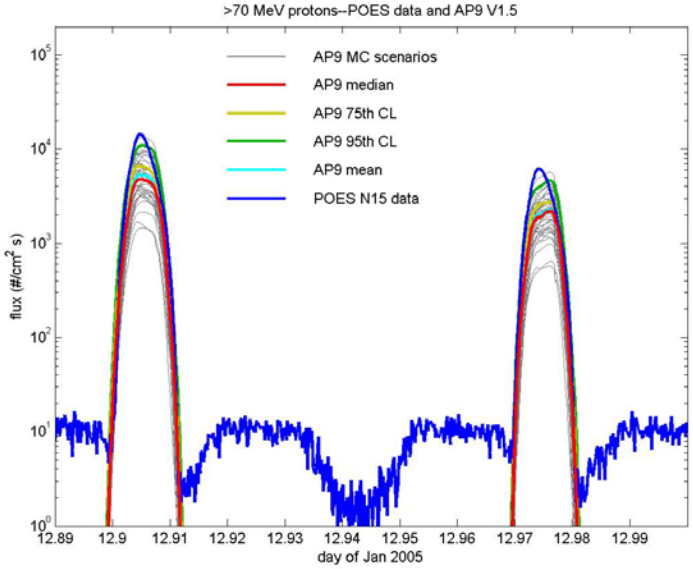
> 16 MeV



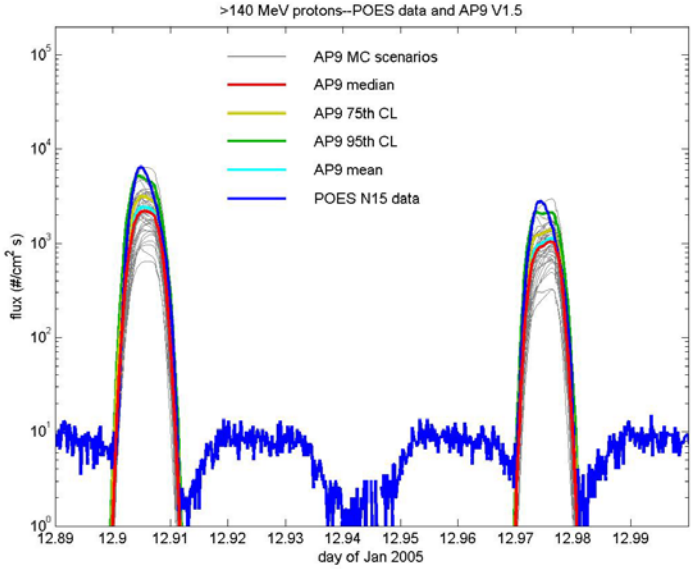
> 35 MeV



> 70 MeV

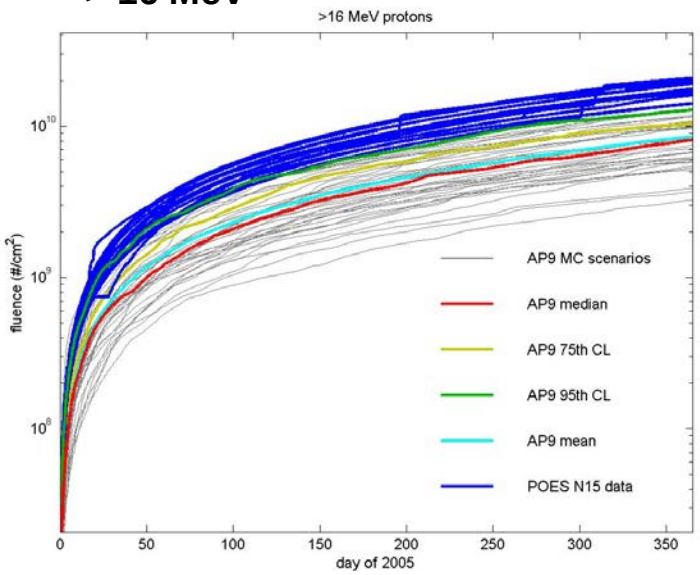


> 140 MeV

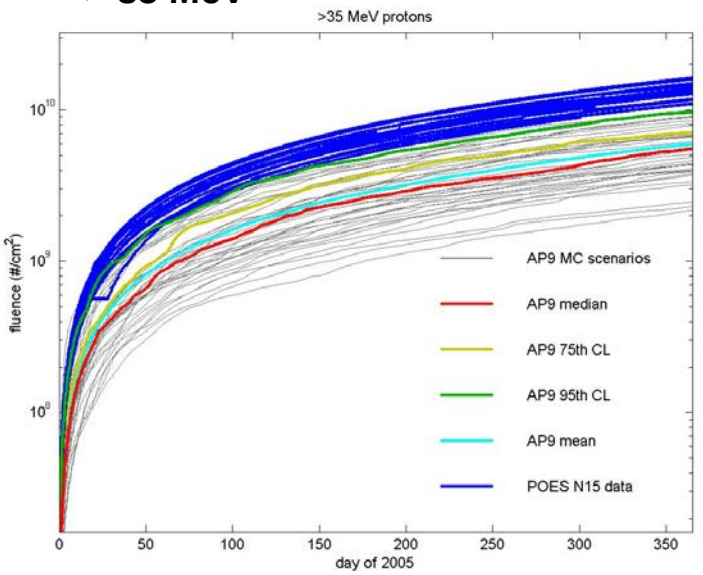


POES and AP9 V1.50 Monte Carlo proton fluence time series

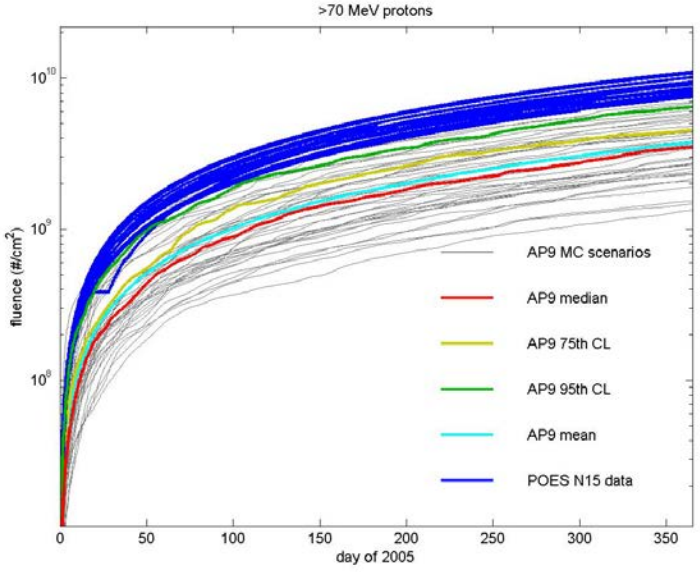
> 16 MeV



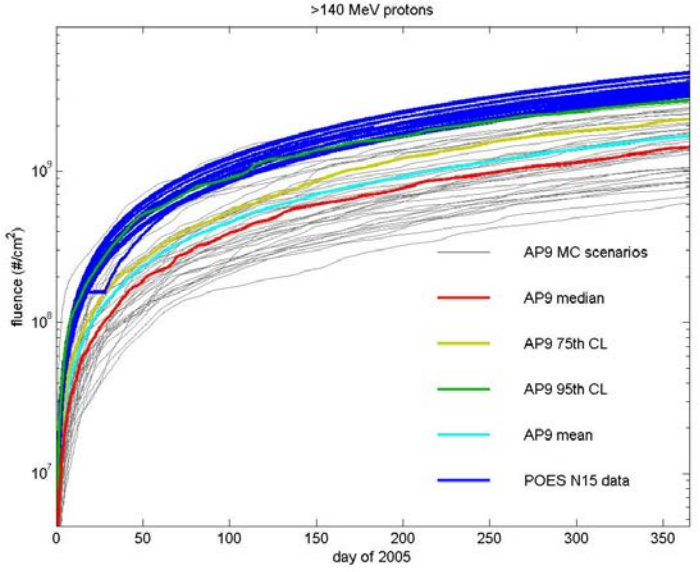
> 35 MeV



> 70 MeV

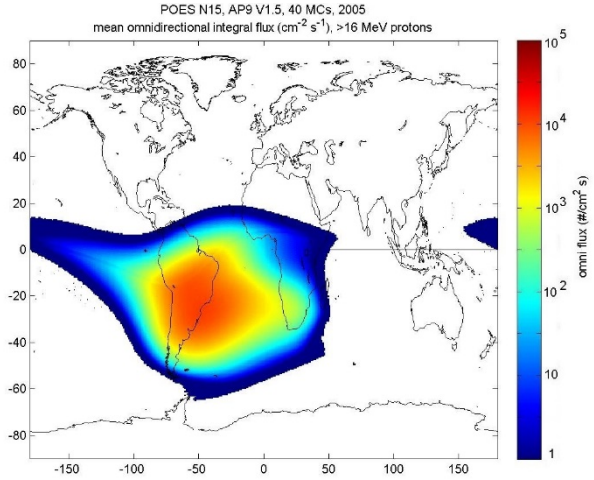


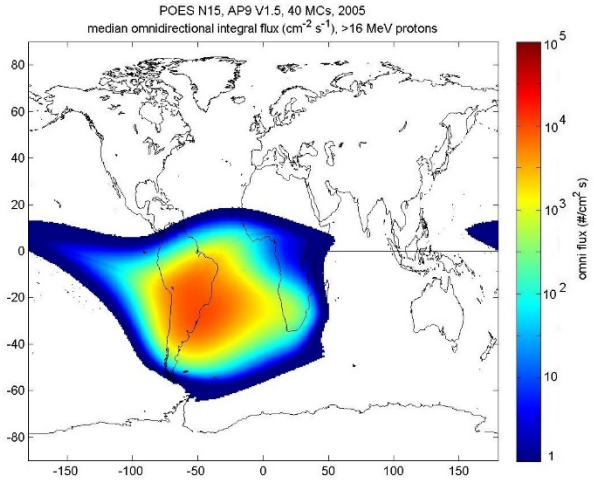
> 140 MeV

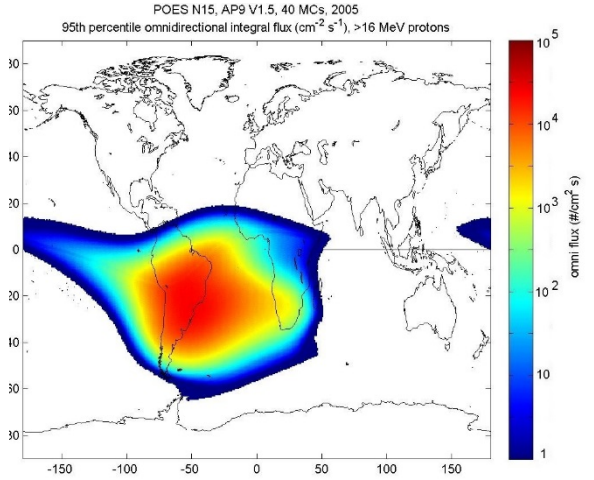


>16 MeV protons

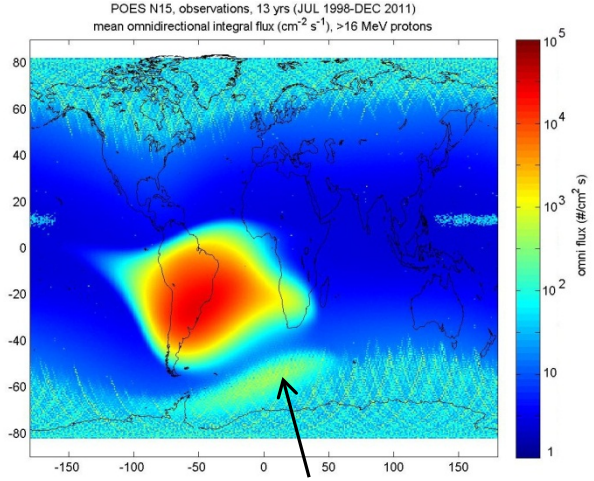
AP9 V1.50 Monte Carlo results



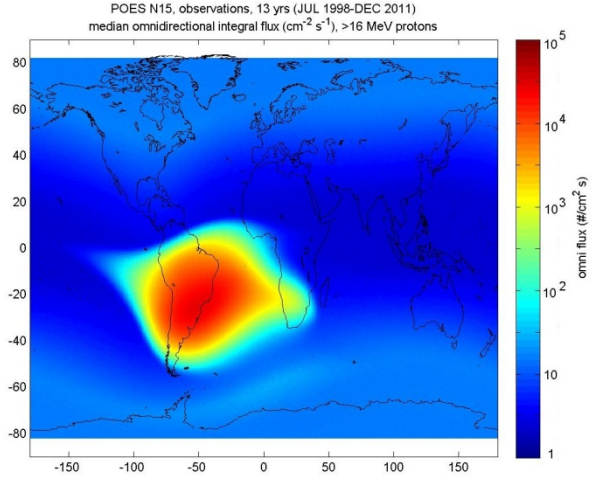


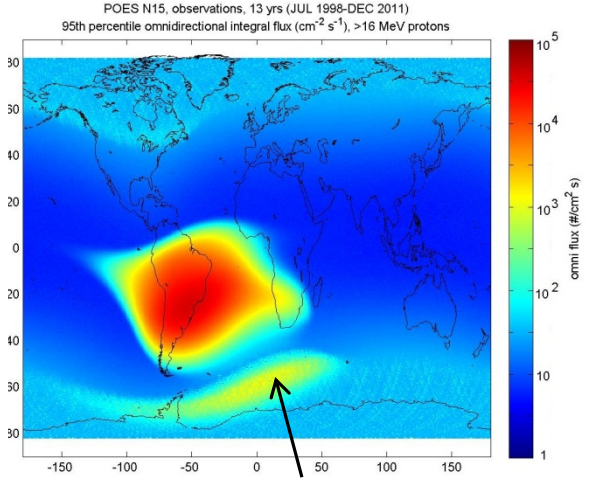


POES NOAA-15 data, 1998-2011



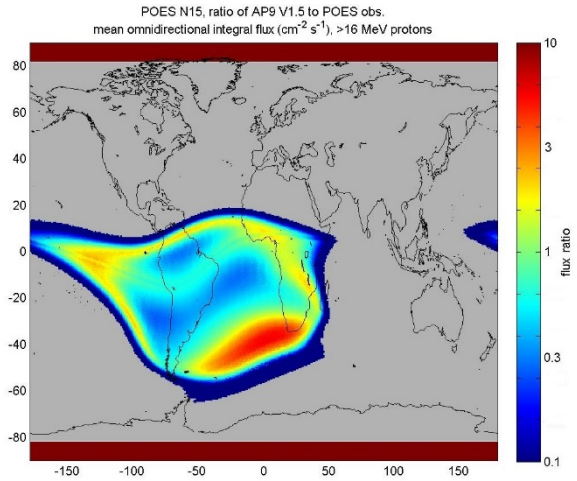
electron contamination

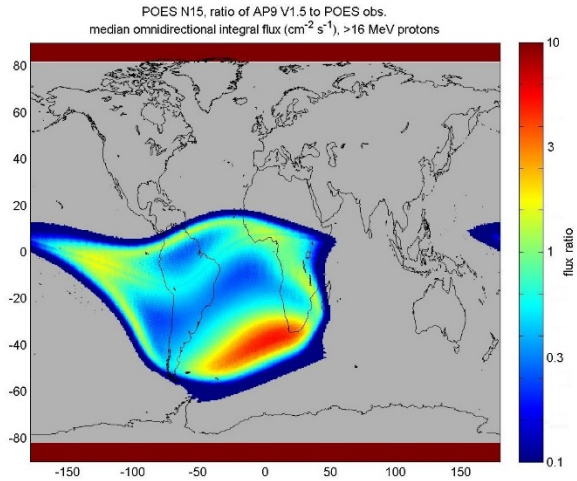


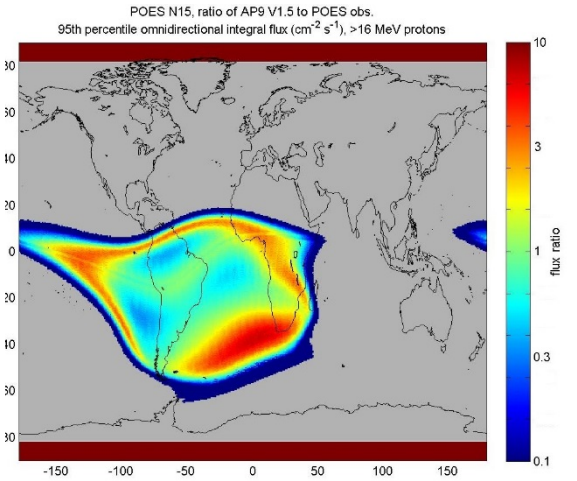


electron contamination

>16 MeV protons—ratio of AP9 V1.50 to POES data

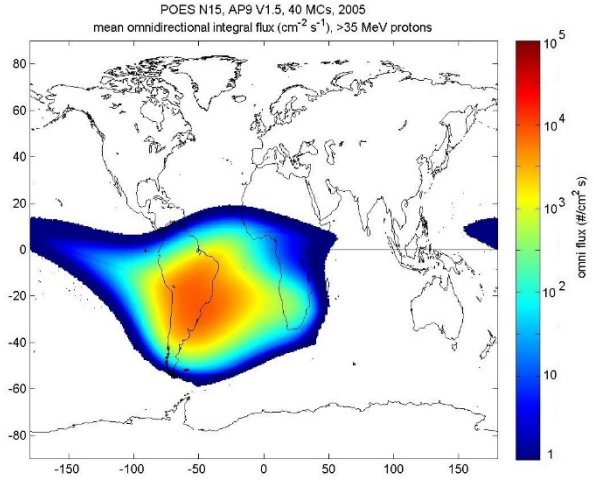


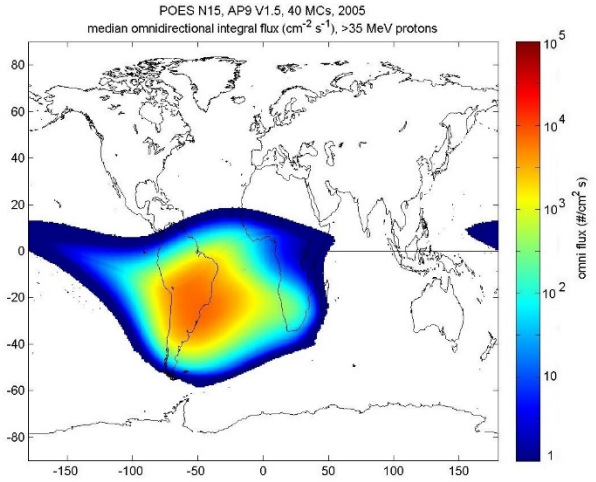


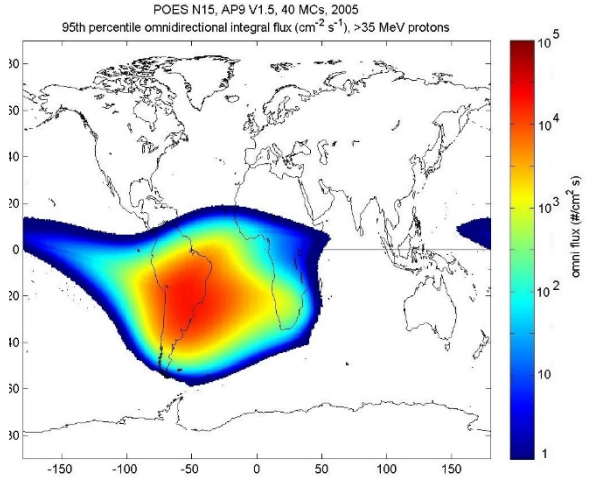


>35 MeV protons

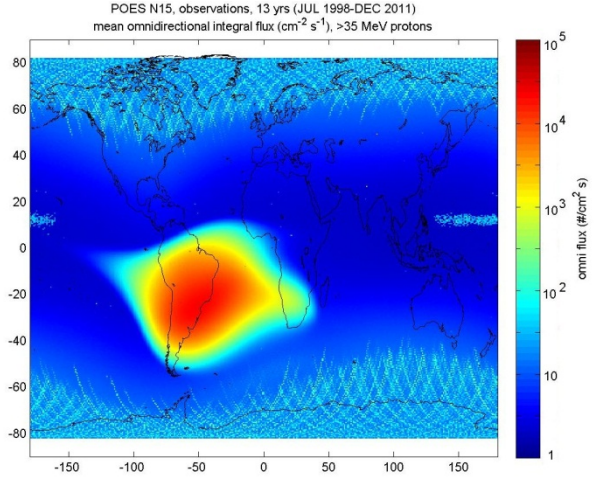
AP9 V1.50 Monte Carlo results

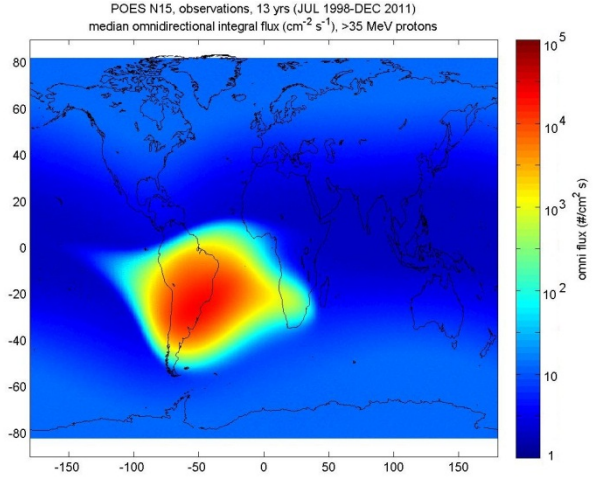


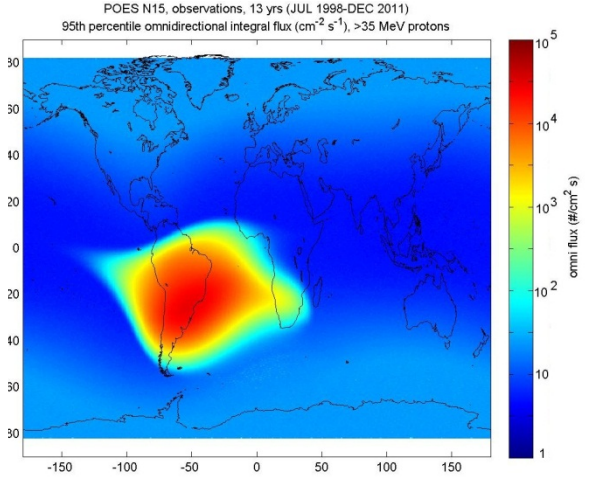




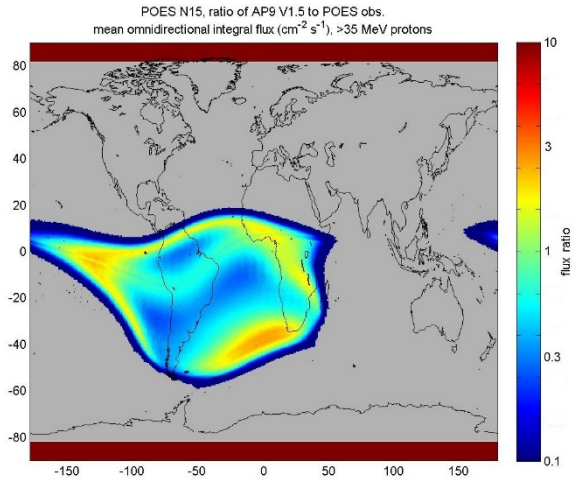
POES NOAA-15 data, 1998-2011

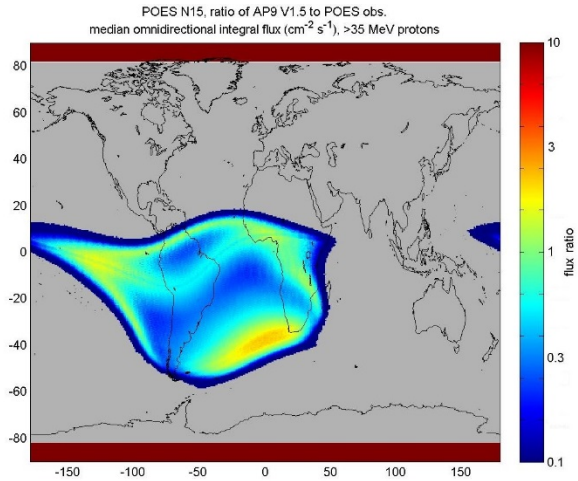


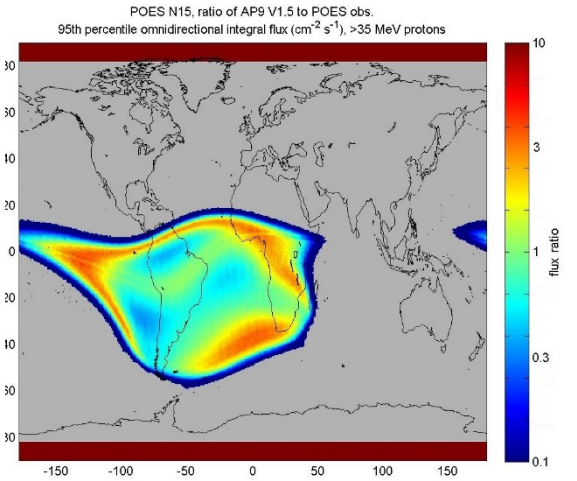




>35 MeV protons—ratio of AP9 V1.50 to POES data

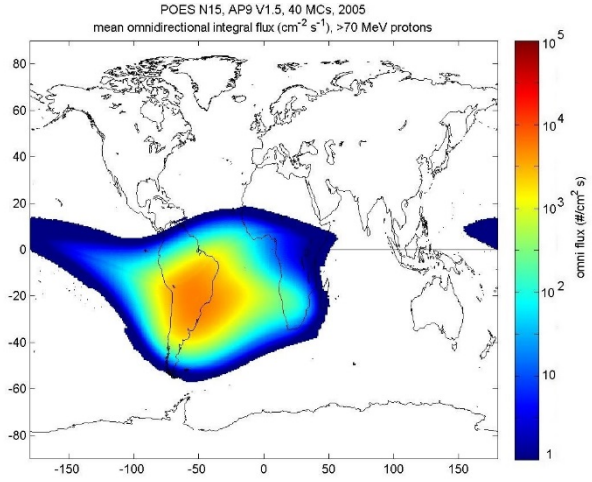


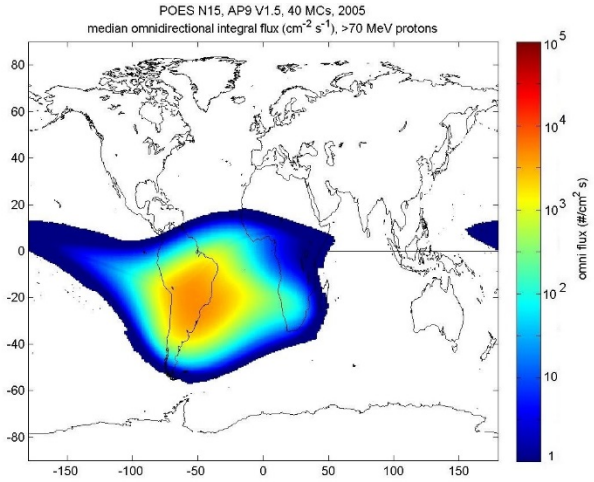


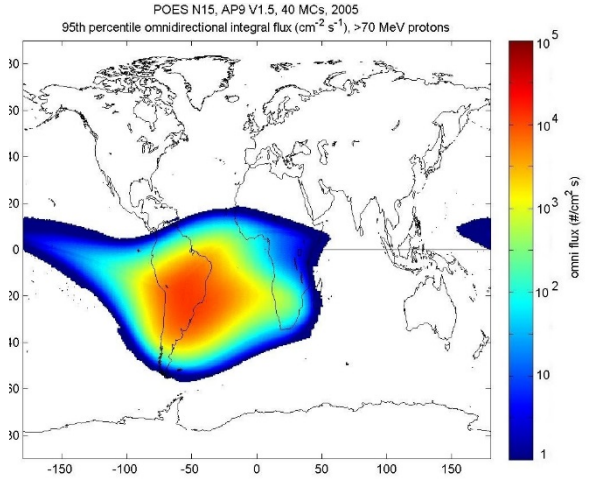


>70 MeV protons

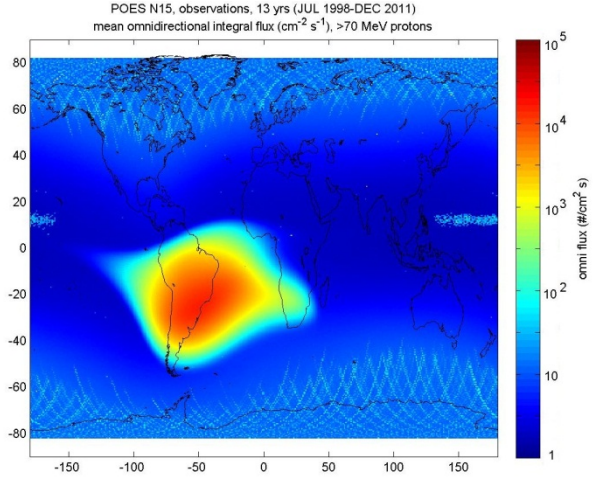
AP9 V1.50 Monte Carlo results

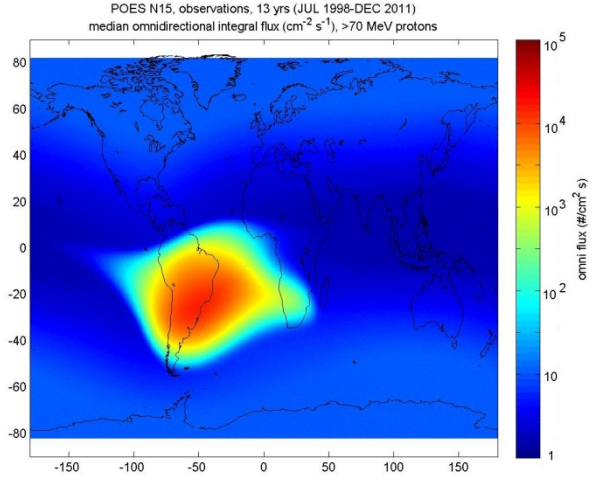


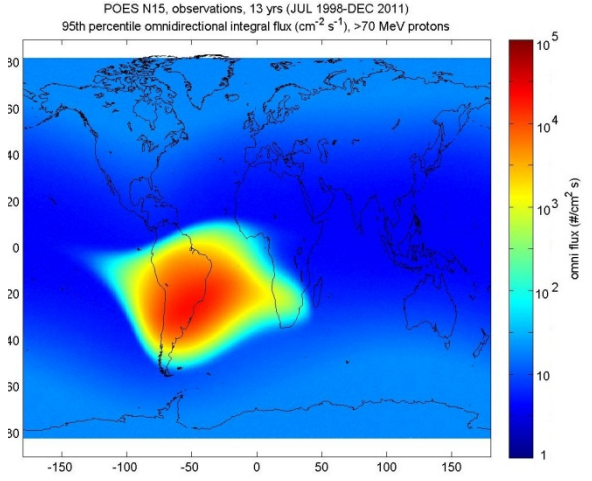




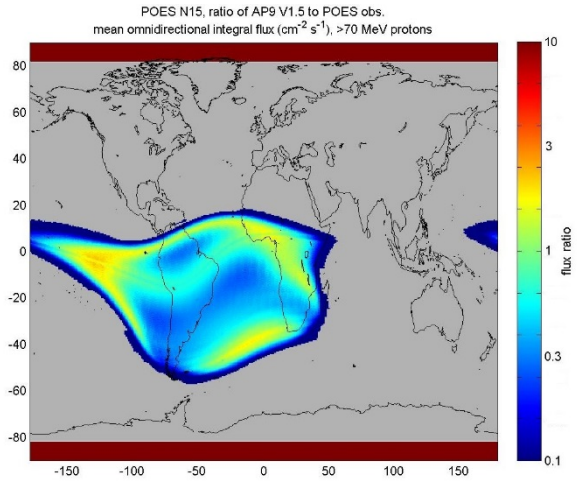
POES NOAA-15 data, 1998-2011

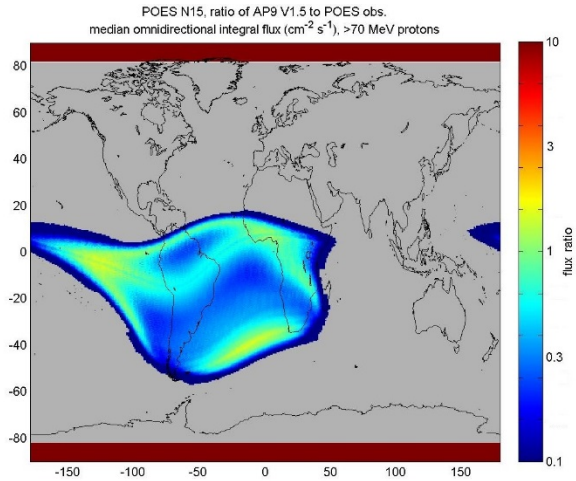


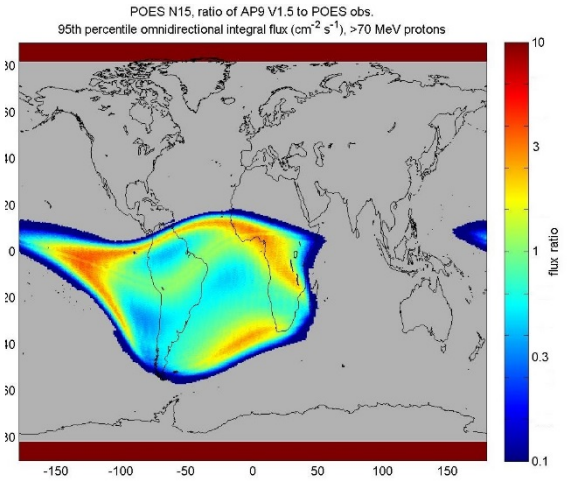




>70 MeV protons—ratio of AP9 V1.50 to POES data

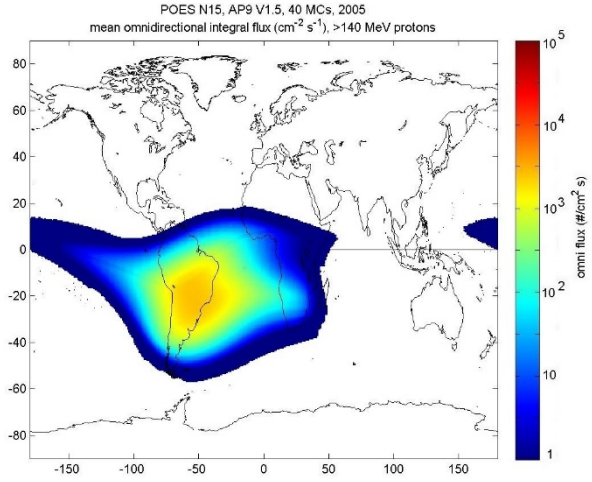


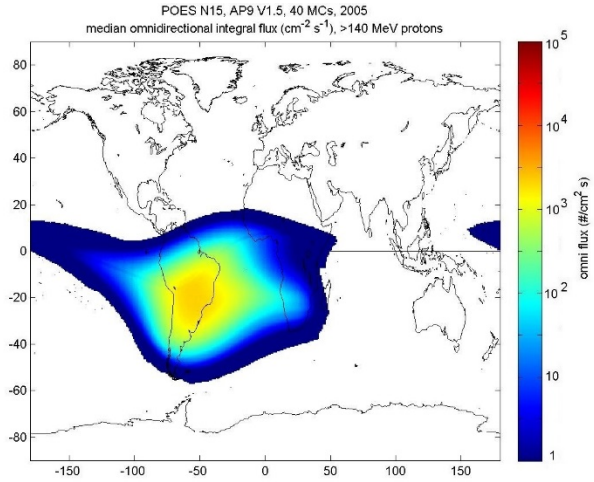


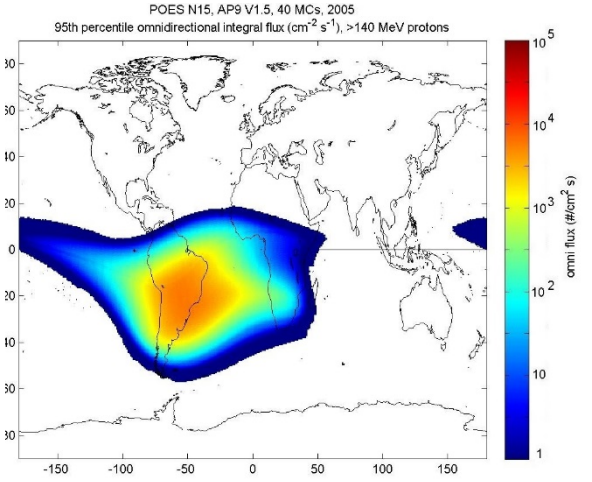


>140 MeV protons

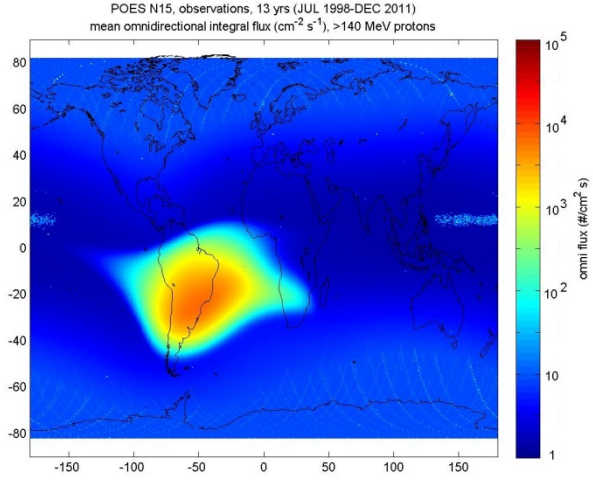
AP9 V1.50 Monte Carlo results

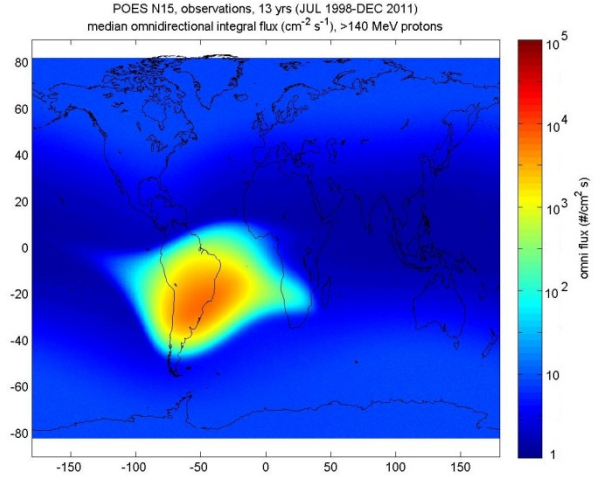


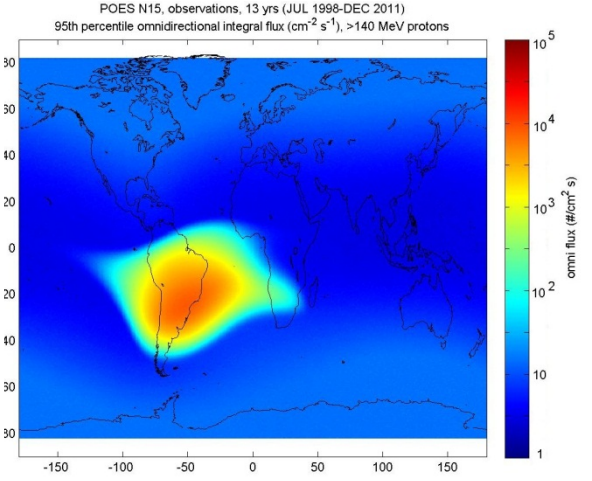




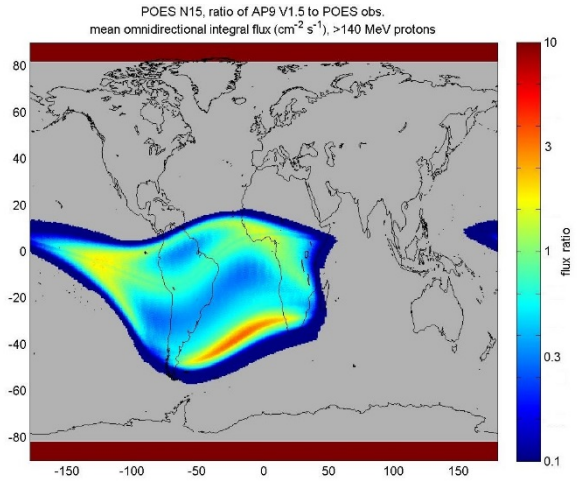
POES NOAA-15 data, 1998-2011

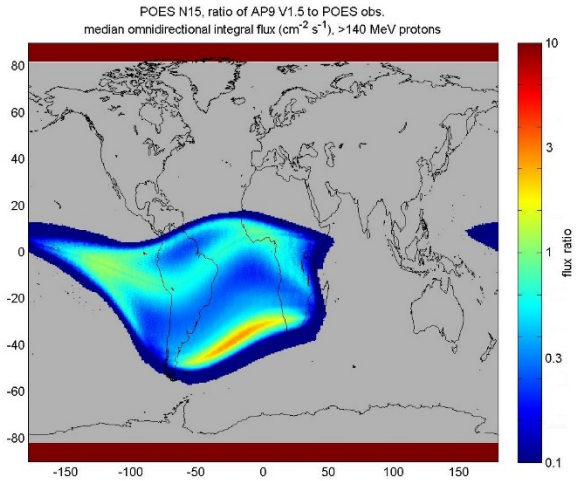


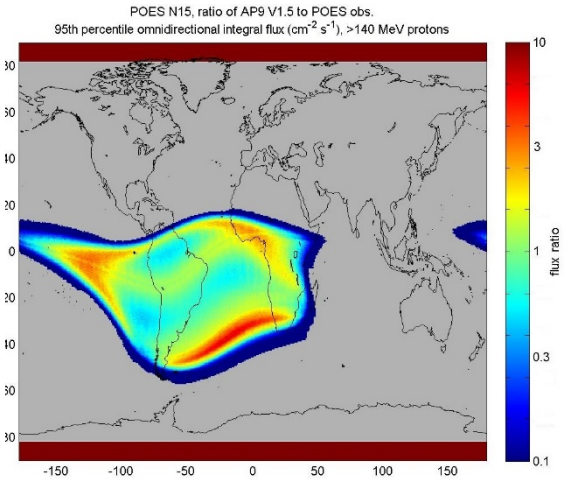




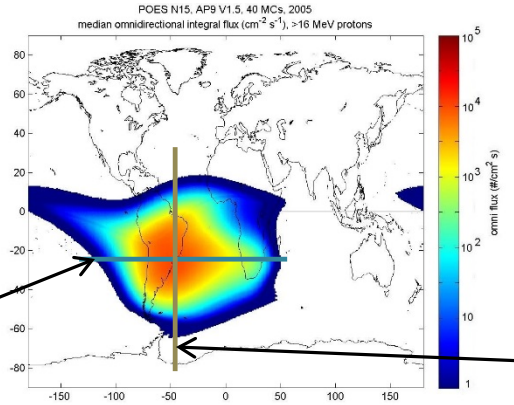
>140 MeV—ratio of AP9 V1.50 to POES data





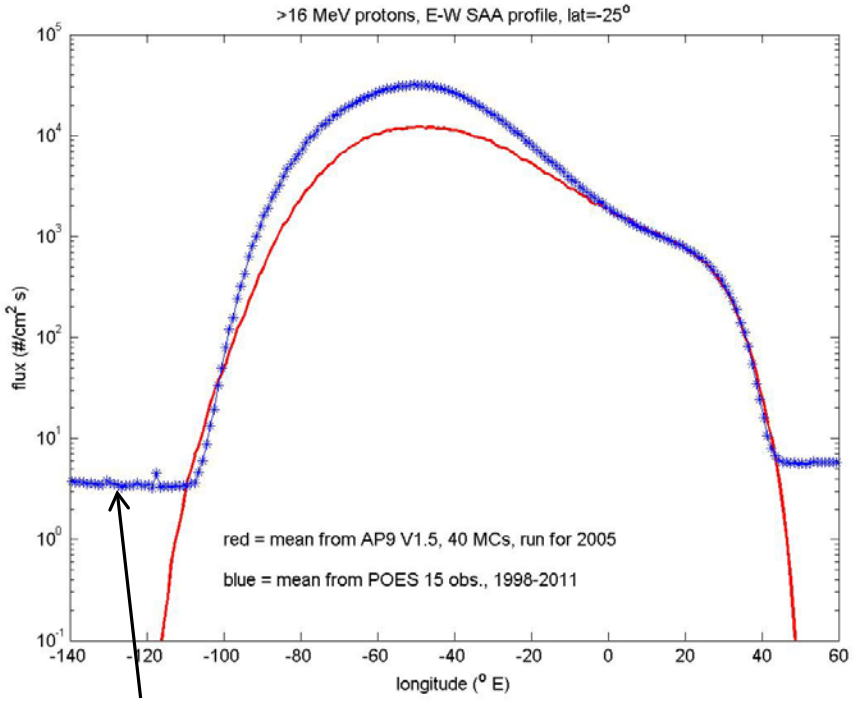


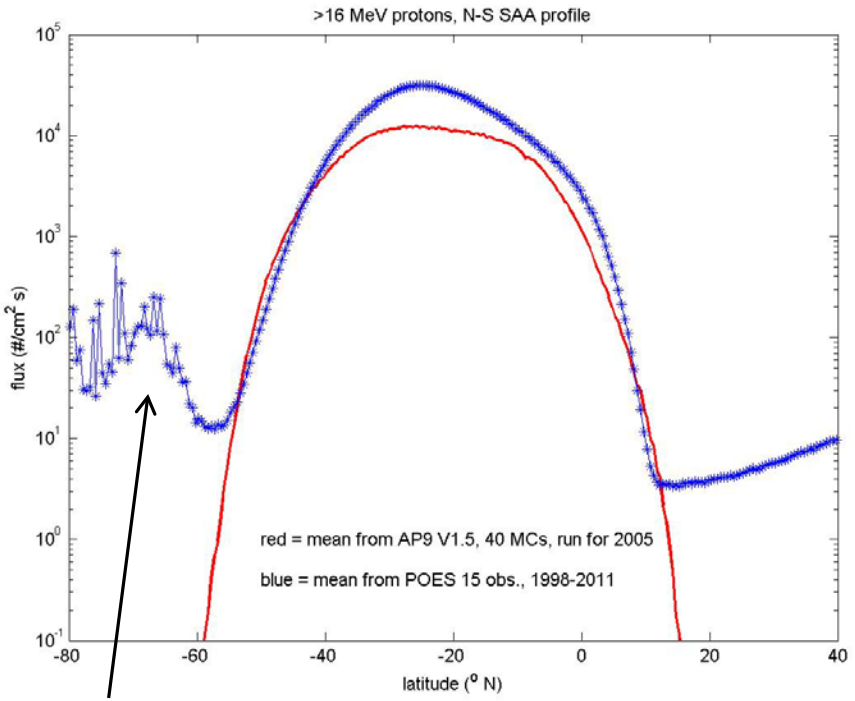
Profiles across SAA at POES orbit, >16 MeV protons



East-west profile

North-south profile



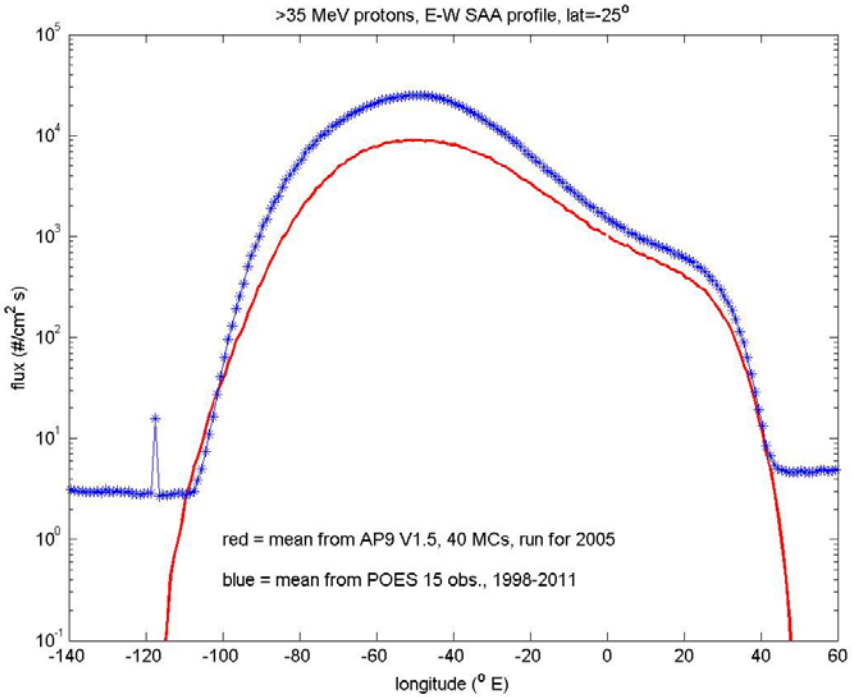


POES MEPED background

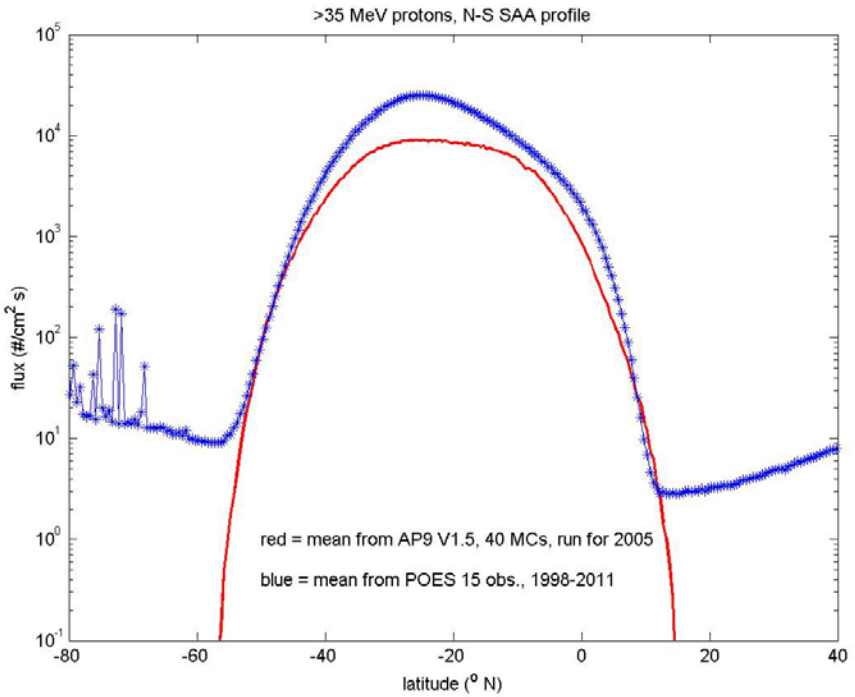
electron contamination

Profiles across SAA at POES orbit, >35 MeV protons

East-west profile

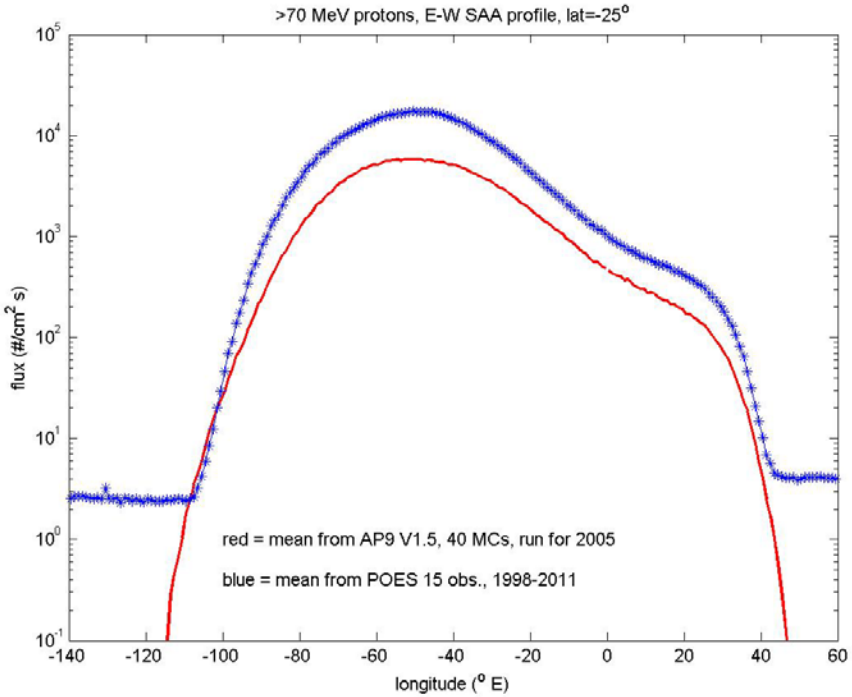


North-south profile

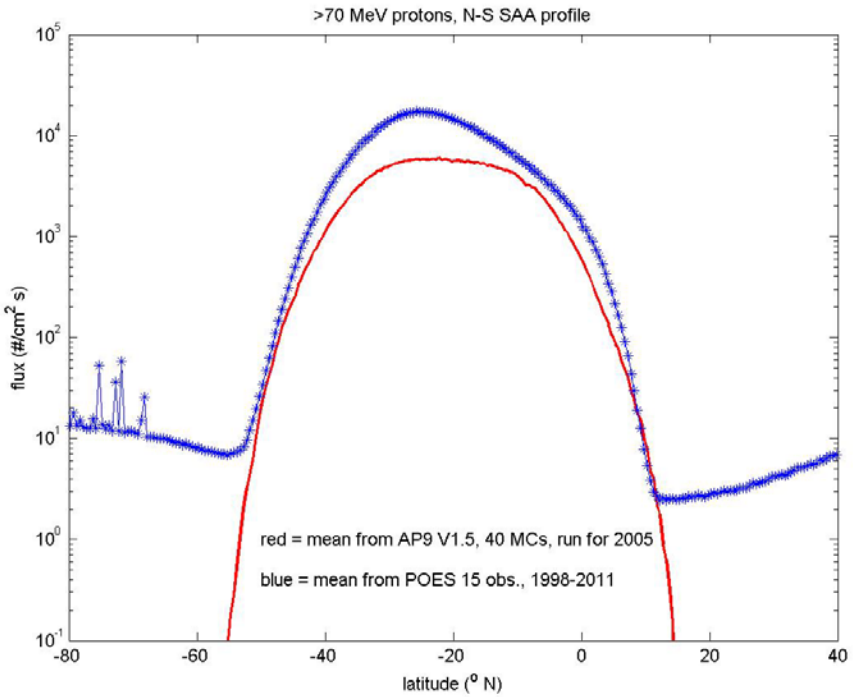


Profiles across SAA at POES orbit, >70 MeV protons

East-west profile

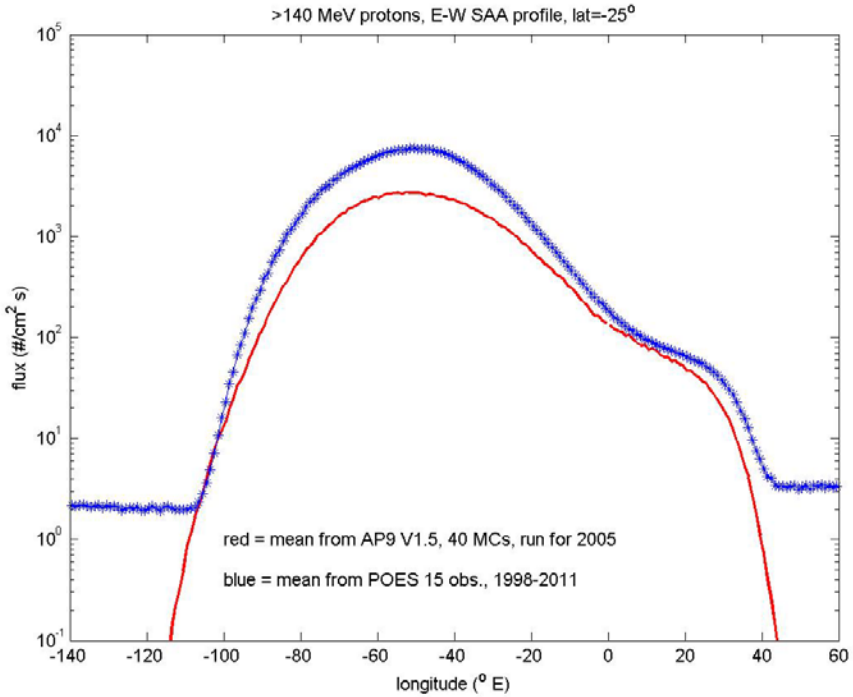


North-south profile

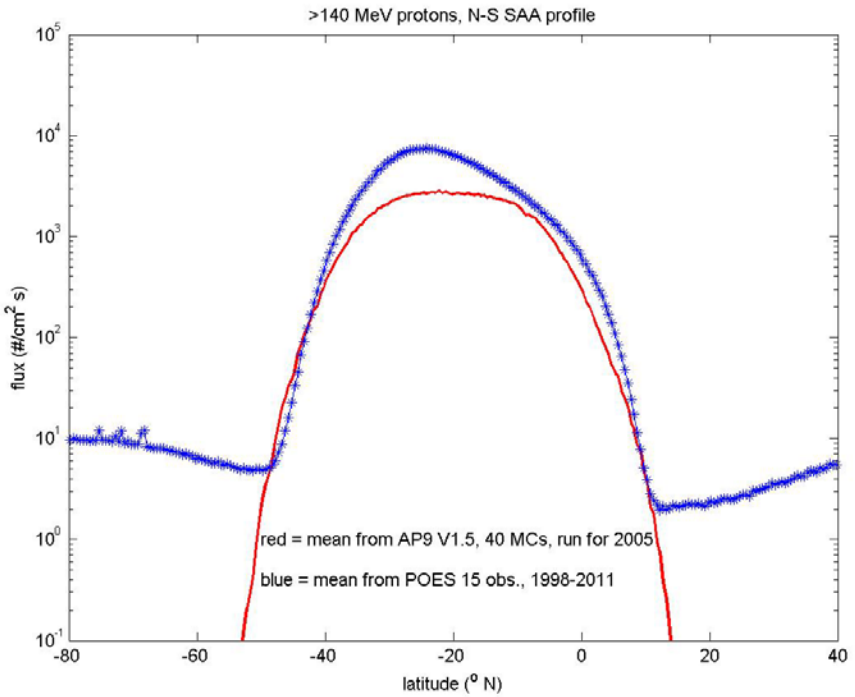


Profiles across SAA at POES orbit, >140 MeV protons

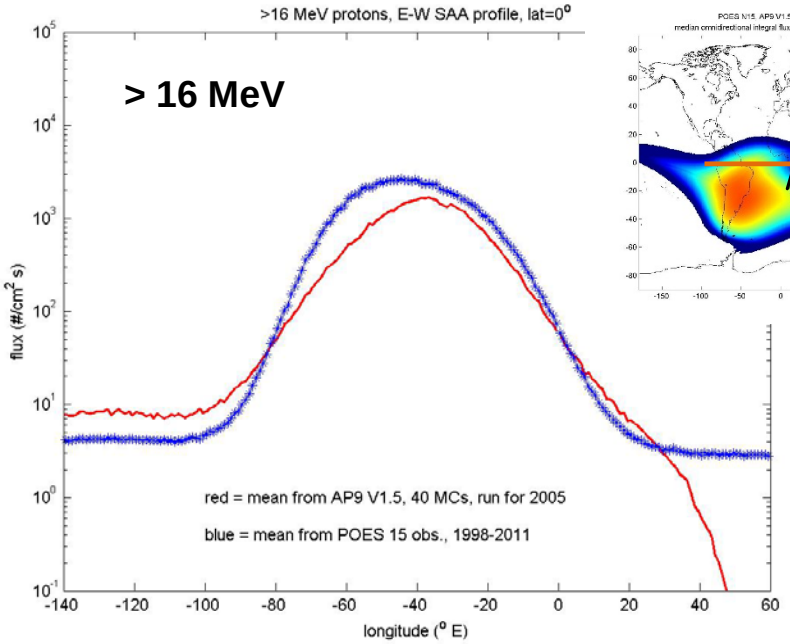
East-west profile

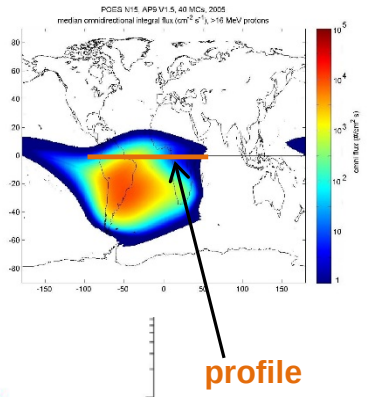


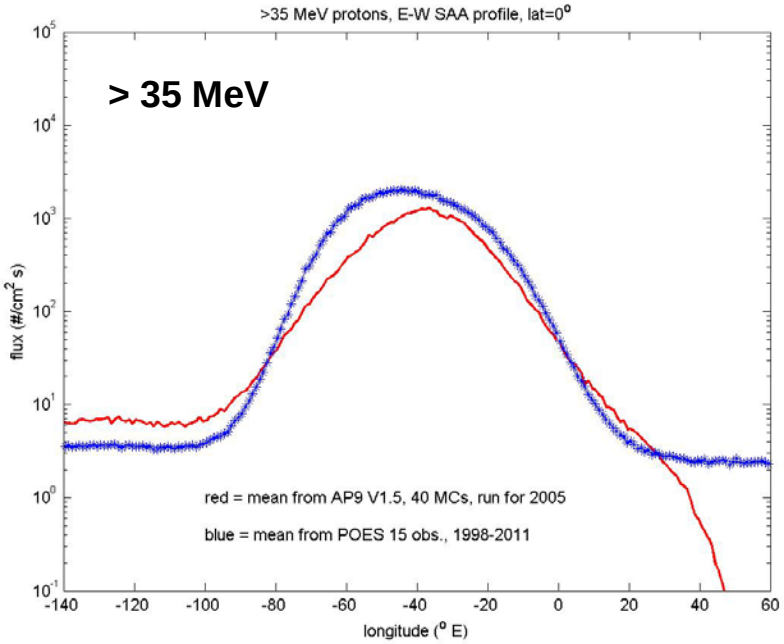
North-south profile

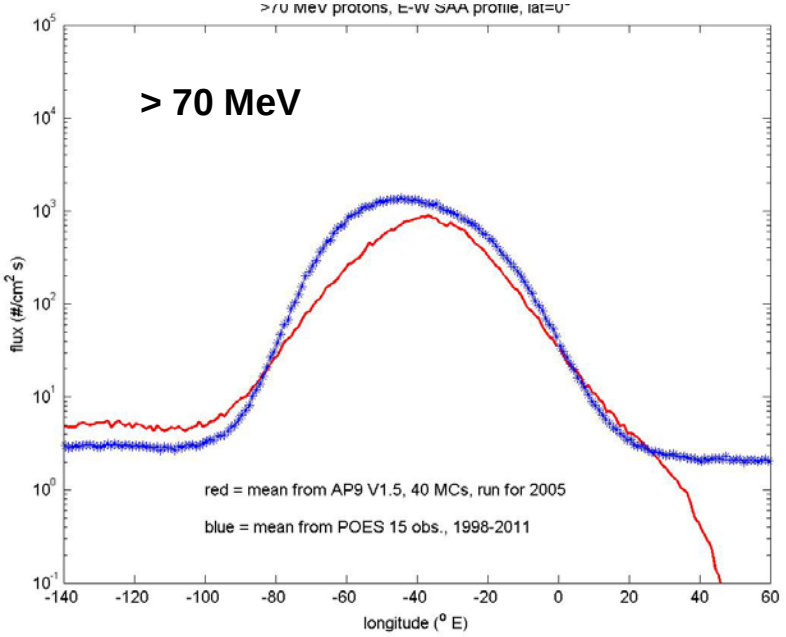


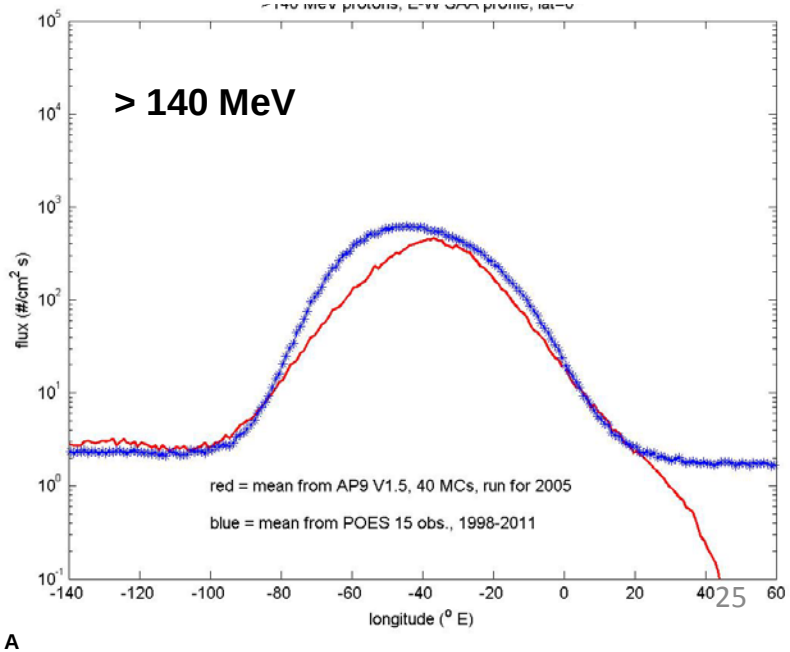
Profile across north edge of SAA at POES orbit: East-west profile at equator











SAMPEX

SAMPEX data processing:

- PET unidirectional fluxes are from the SAMPEX data center website [http://www.srl.caltech.edu/sampex/DataCenter/].
- PET data used is limited to locations in the SAA and to samples with pitch angles of 90°± 5° in the instrument boresight; the PET field-of-view is 16° half angle.
- AP9 omnidirectional fluxes are divided by 4 to estimate directional flux in PET FOV, with this ratio derived from AP9 mean runs comparing directional fluxes in the PET FOV to omnidirectional fluxes.
- PET data are binned in 40 km altitude bins spanning the 420-700 km altitude range sampled by SAMPEX during this time period; SAMPEX altitude declined during the mission, so time sampling of a given altitude range may be limited.

Content:

- Slides 28-42 compare AP9 V1.50 Monte Carlo results to SAMPEX observations from 1992-2009, sorted by altitude, sampling the SAA region.

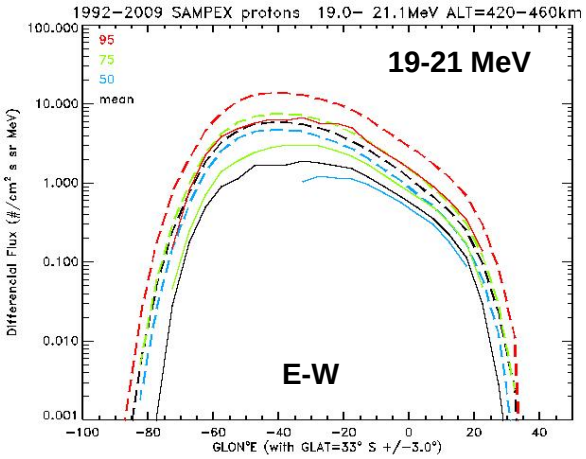
SAMPEX

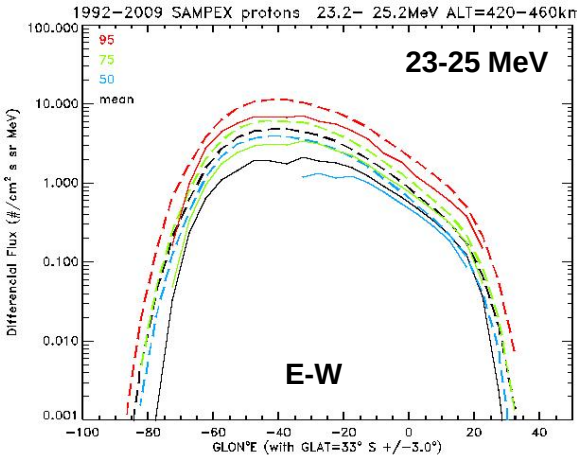
Summary:

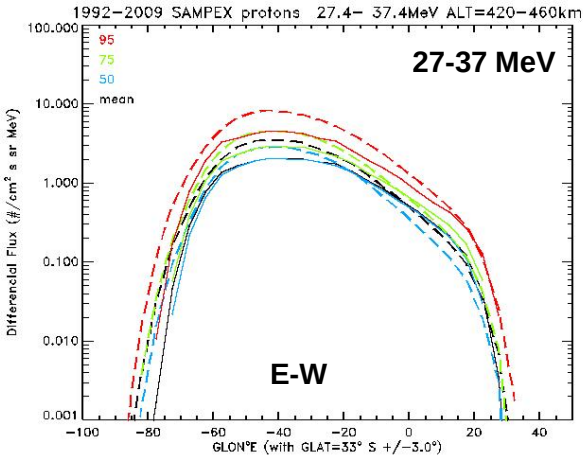
- AP9 V1.50 fluxes are typically 2-3 times higher than SAMPEX fluxes for energies of 19 – 37 MeV and typically 2-5 times lower than SAMPEX for energies of 85 – 300 MeV, while agreement at intermediate energies is better at some altitude ranges.
- AP9 V1.50 and SAMPEX flux profiles across the SAA are generally similar, although some comparisons are compromised by limited SAMPEX data coverage at some geographic locations.
- The range between mean and 95th confidence levels in AP9 V1.50 is generally similar to or less than the range observed in SAMPEX data.

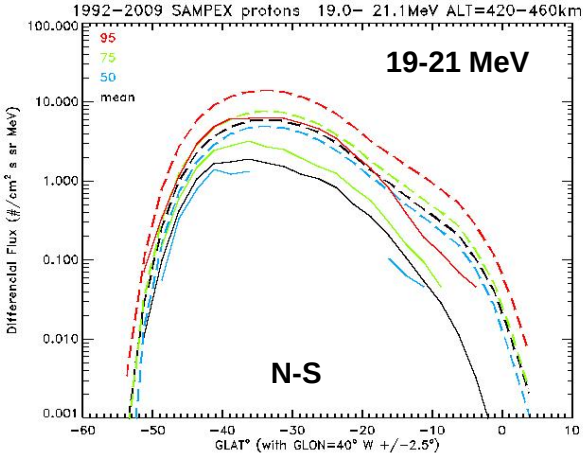
SAA profiles, ~440 km, 19-37 MeV

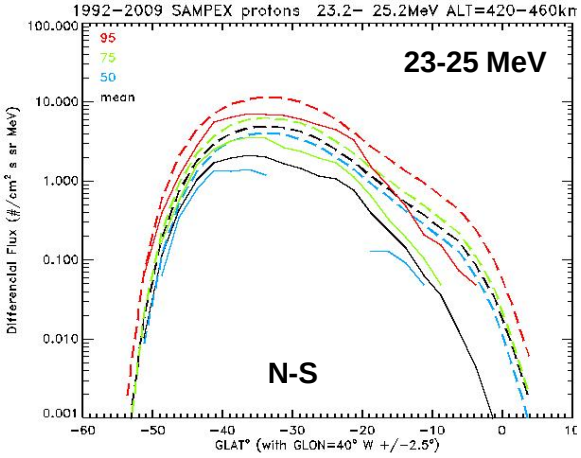
solid lines—SAMPEX data
dashed lines—AP9 V1.5

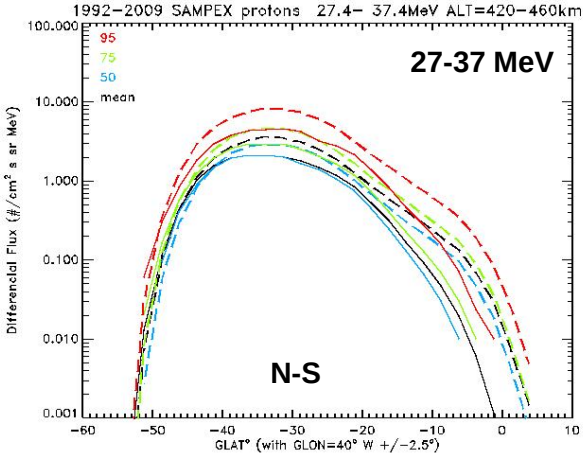






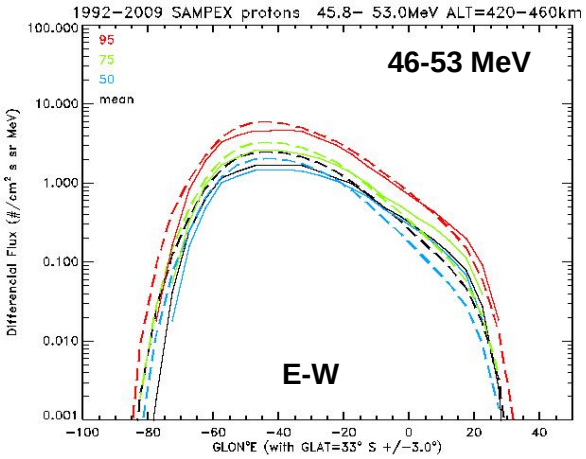


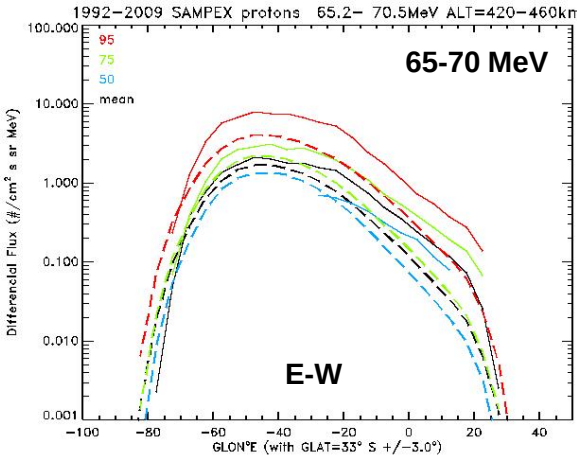


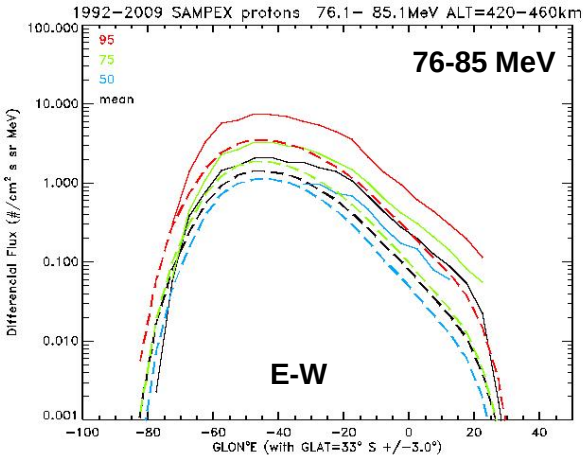


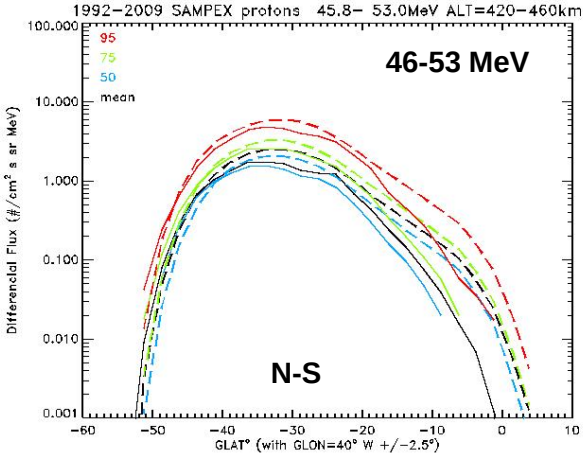
SAA profiles, ~440 km, 46-85 MeV

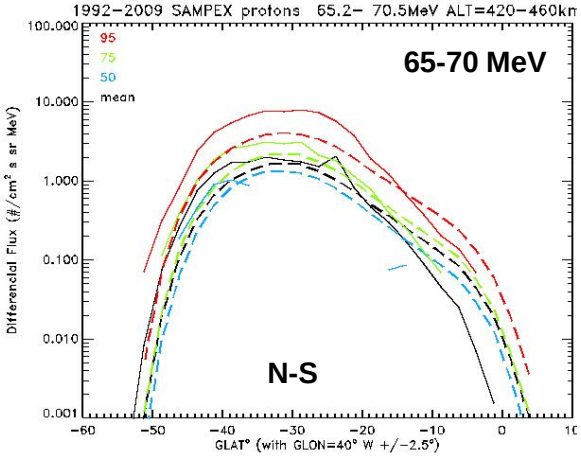
solid lines—SAMPEX data
dashed lines—AP9 V1.5

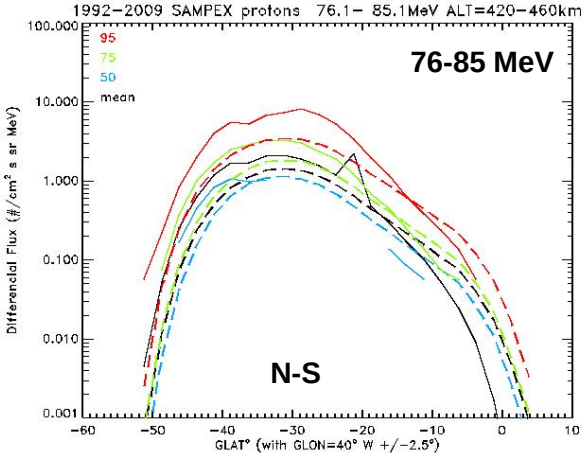






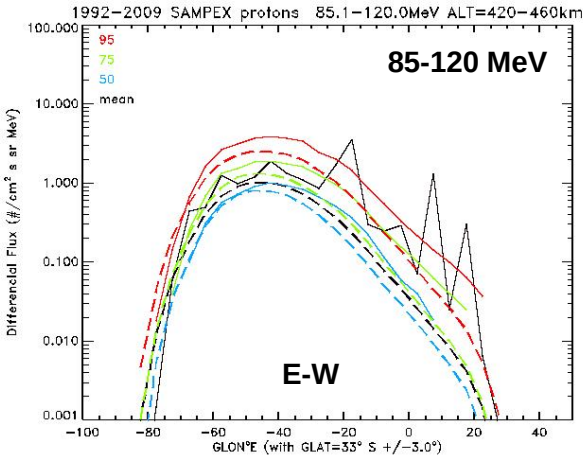


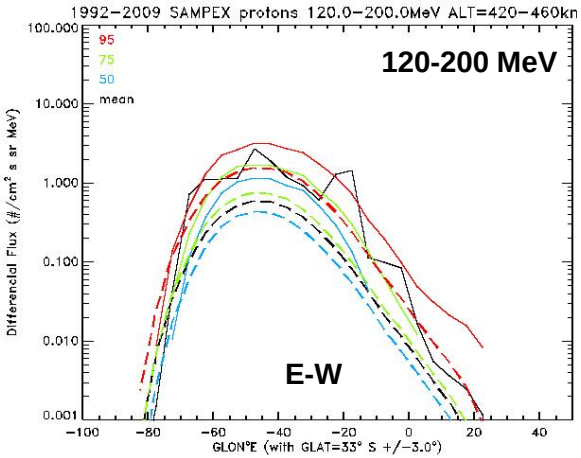


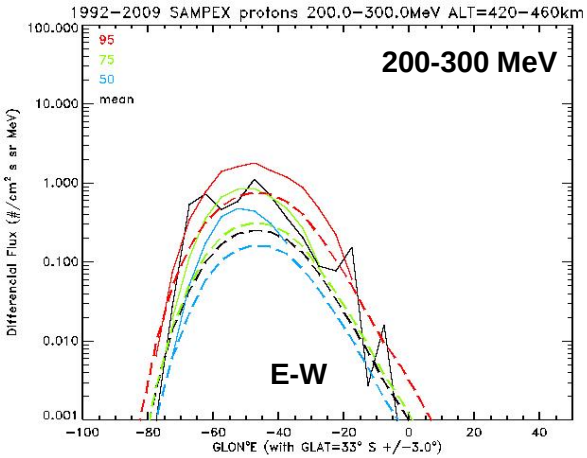


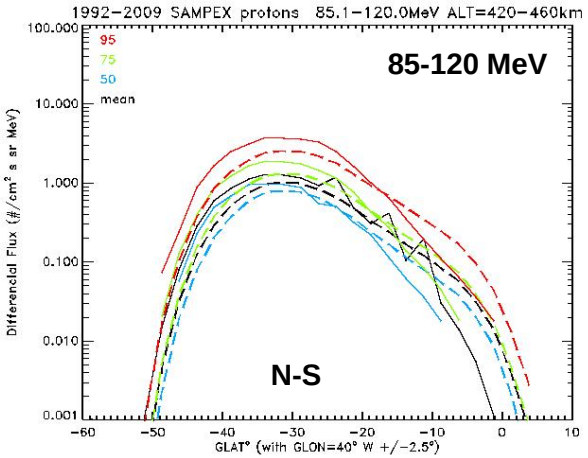
SAA profiles, ~440 km, 85-300 MeV

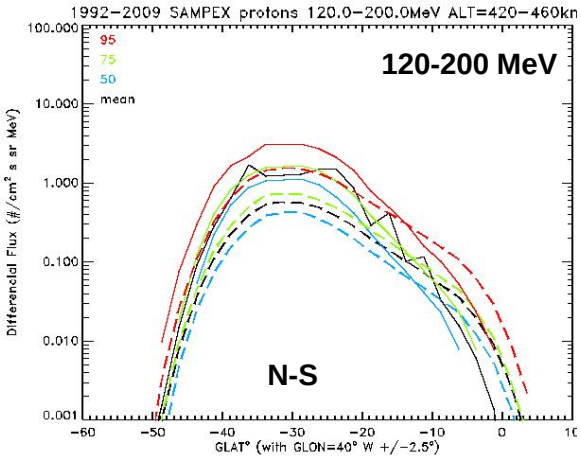
solid lines—SAMPEX data
dashed lines—AP9 V1.5

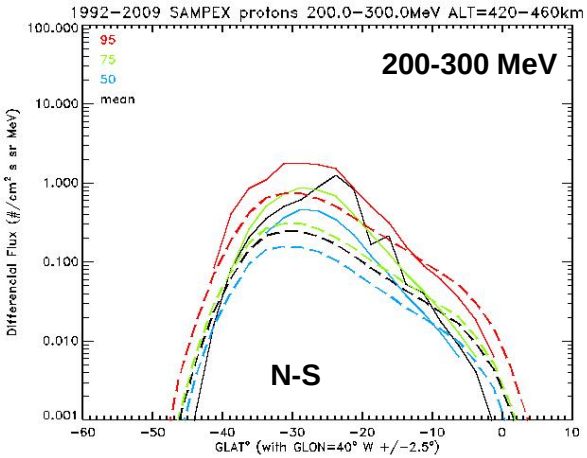






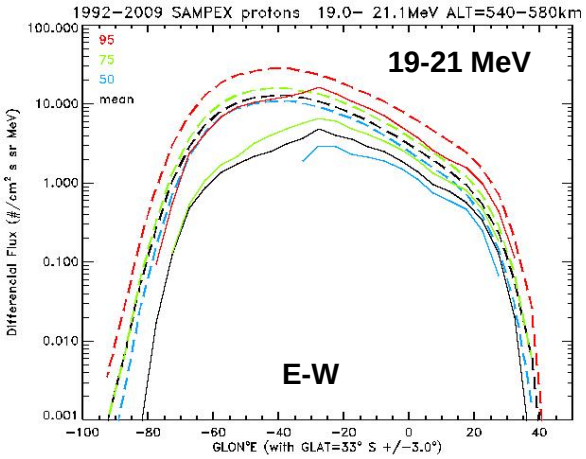


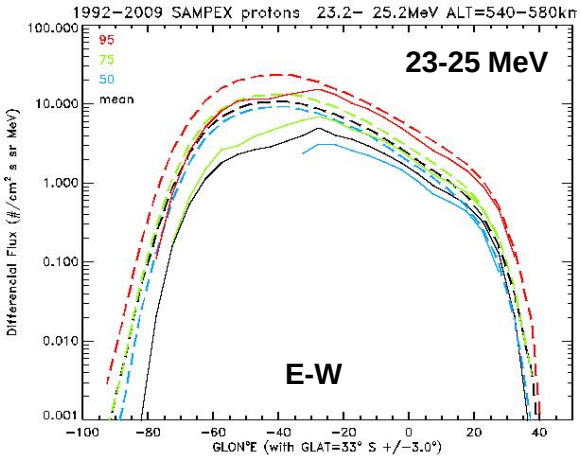


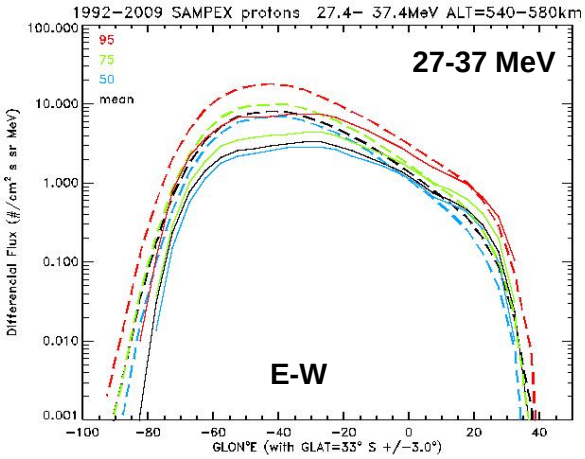


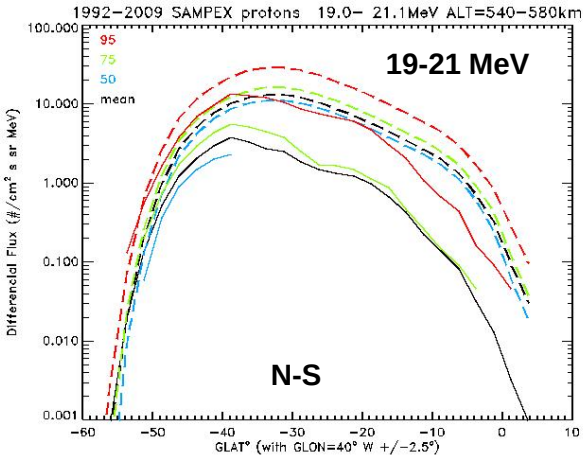
SAA profiles, ~560 km, 19-37 MeV

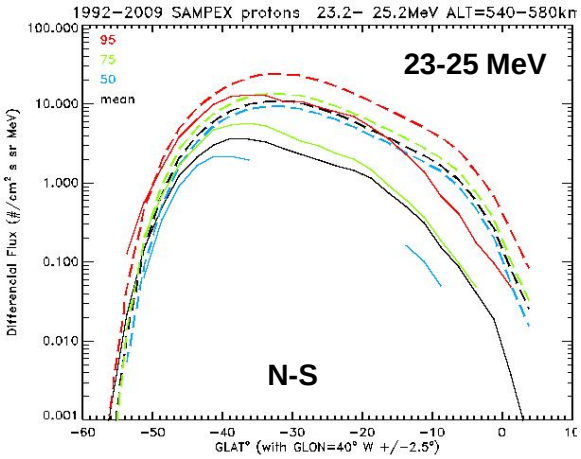
solid lines—SAMPEX data
dashed lines—AP9 V1.5

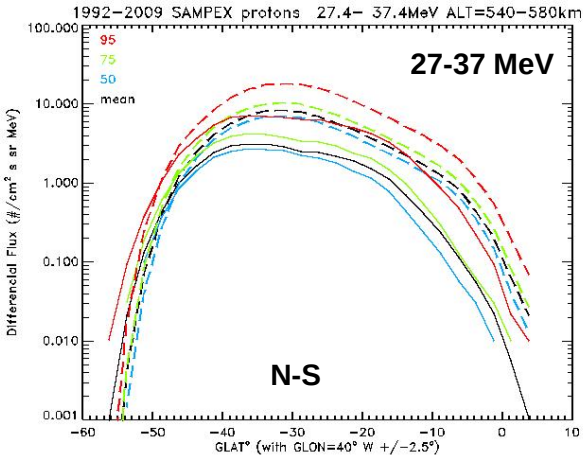






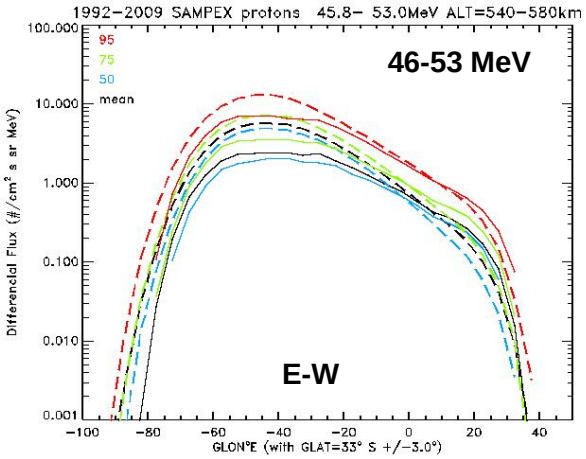


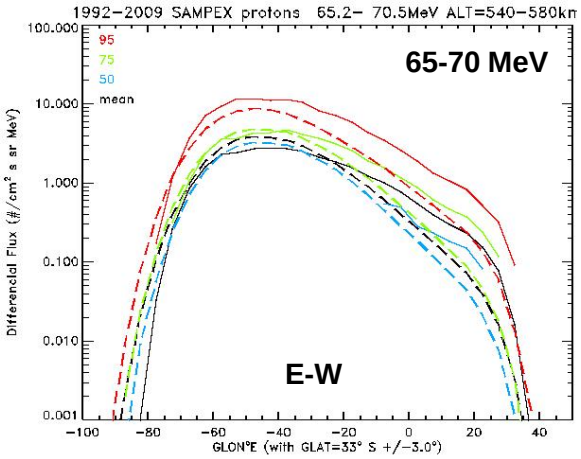


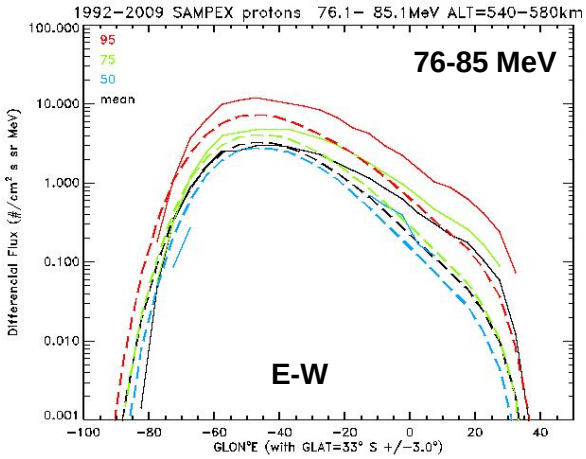


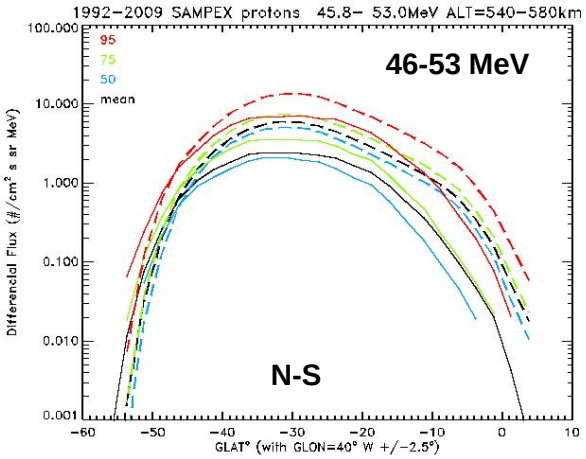
SAA profiles, ~560 km, 46-85 MeV

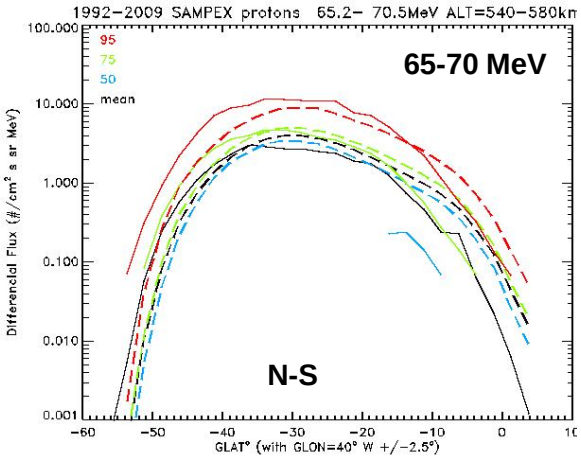
solid lines—SAMPEX data
dashed lines—AP9 V1.5

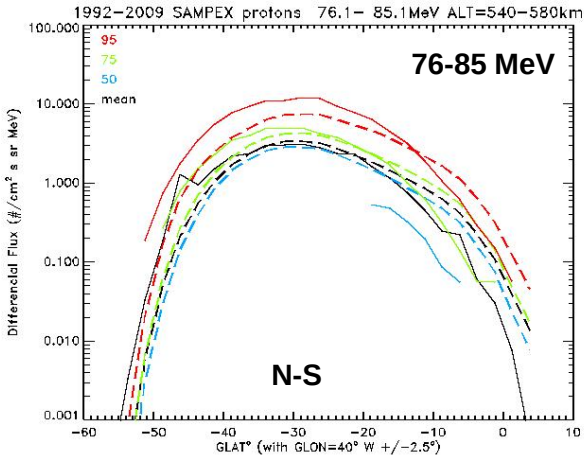






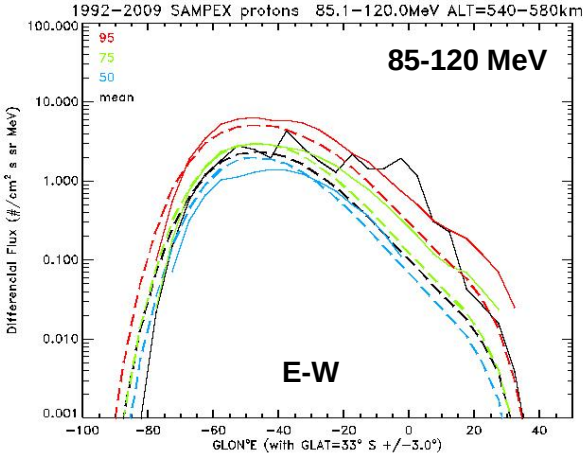


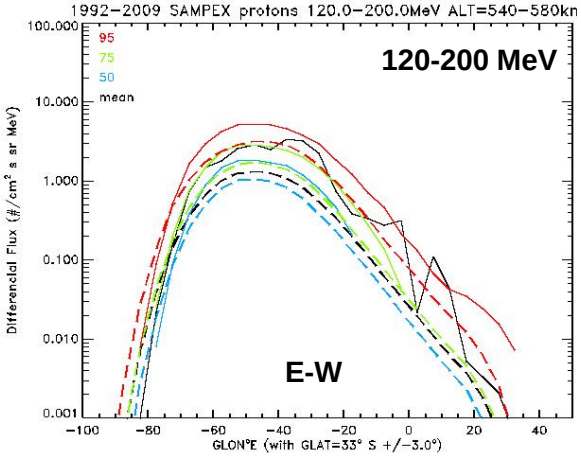


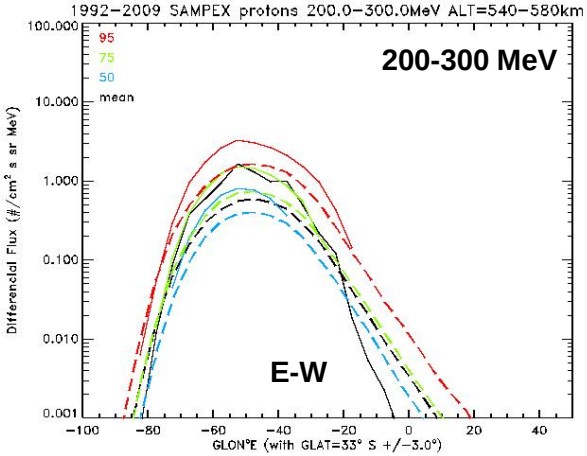


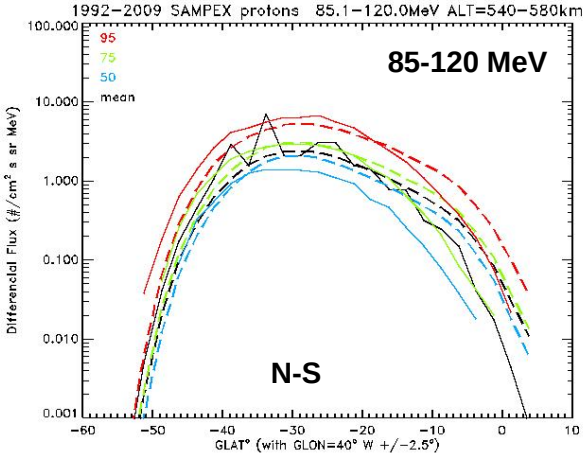
SAA profiles, ~560 km, 85-300 MeV

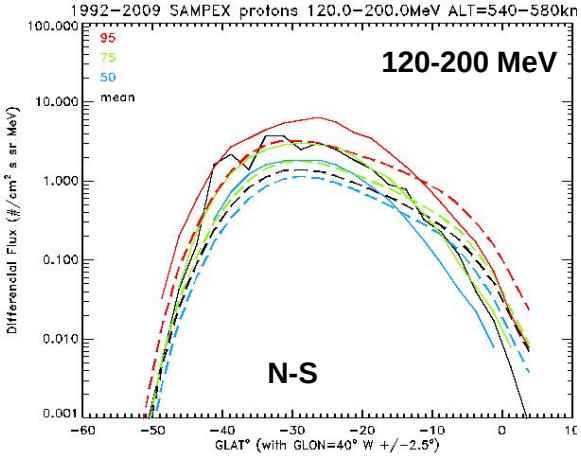
solid lines—SAMPEX data
dashed lines—AP9 V1.5

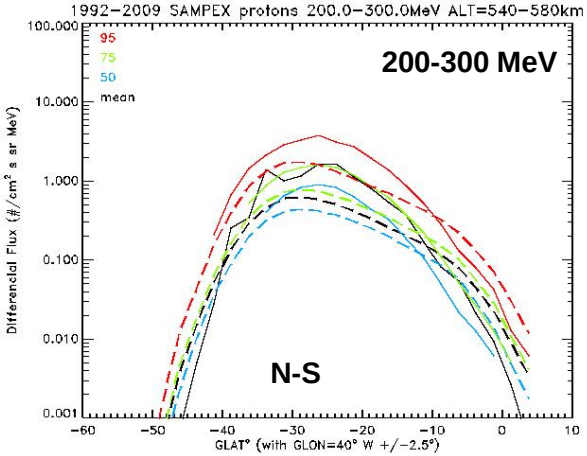






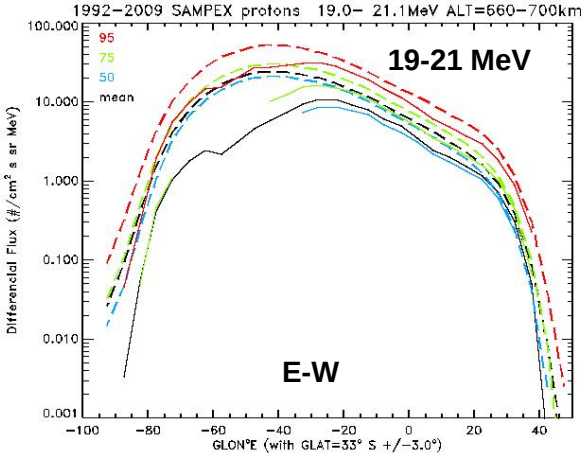


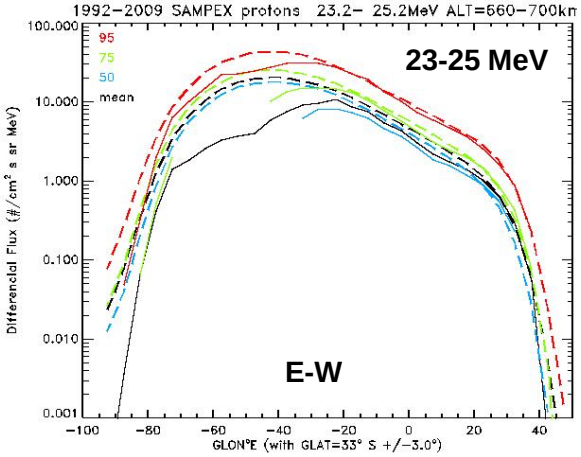


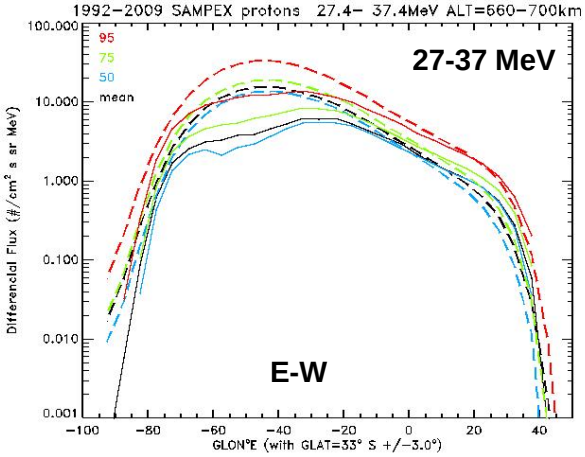


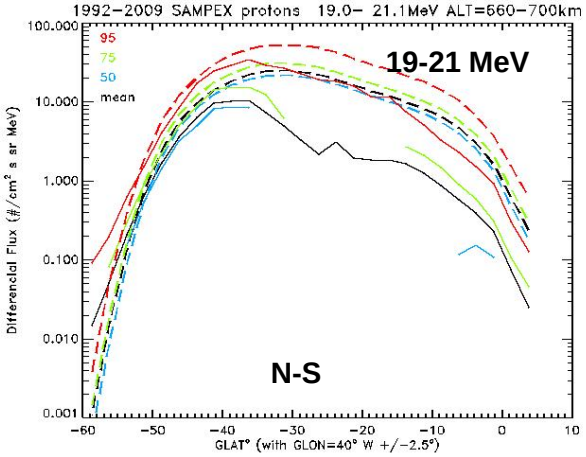
SAA profiles, ~680 km, 19-37 MeV

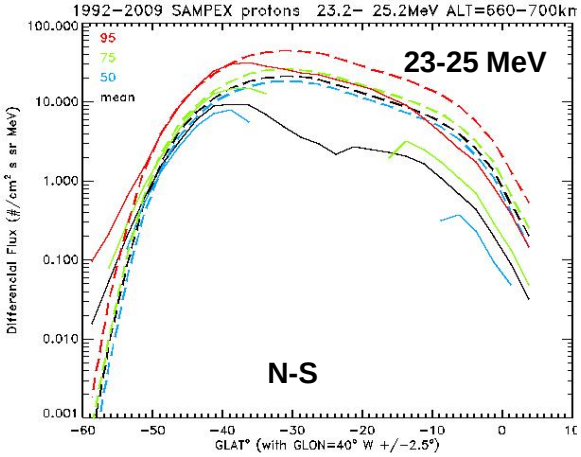
solid lines—SAMPEX data
dashed lines—AP9 V1.5

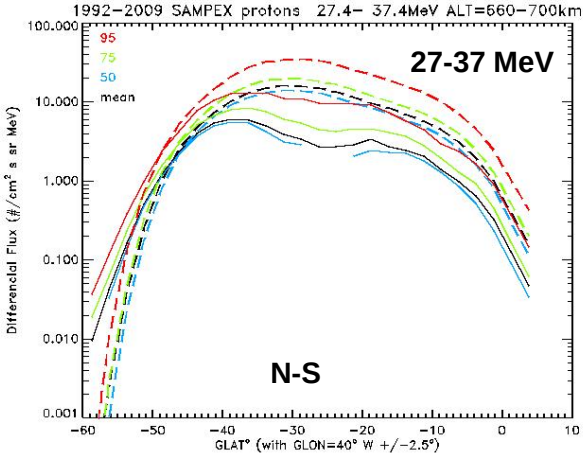






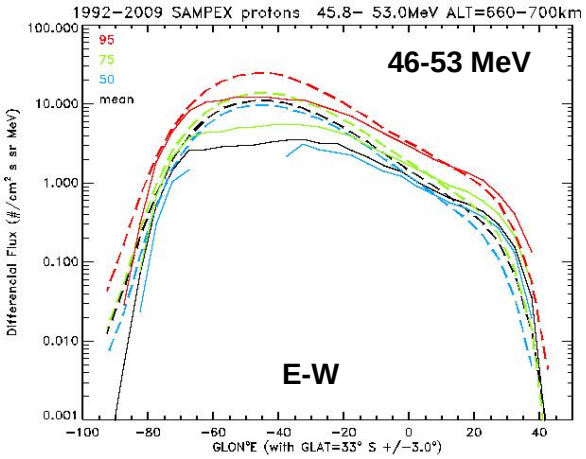


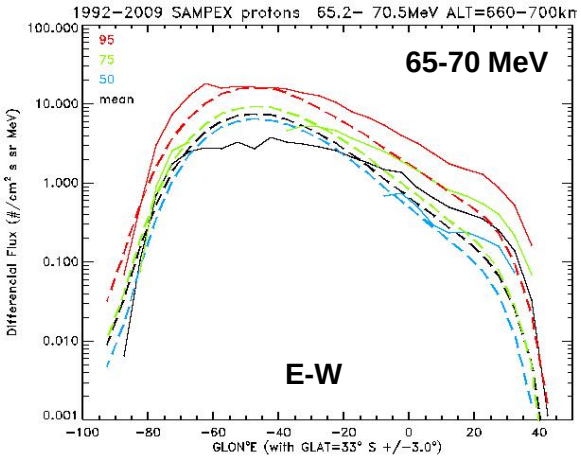


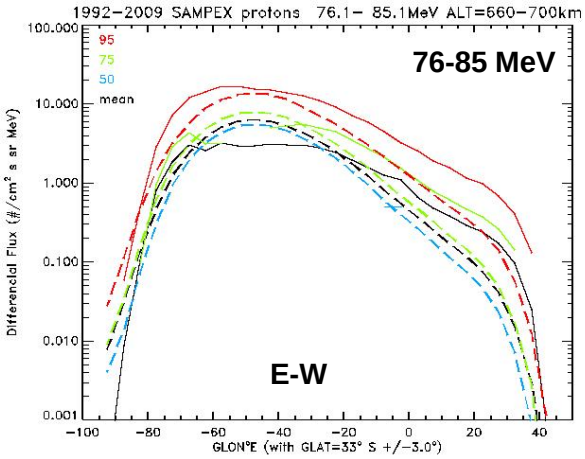


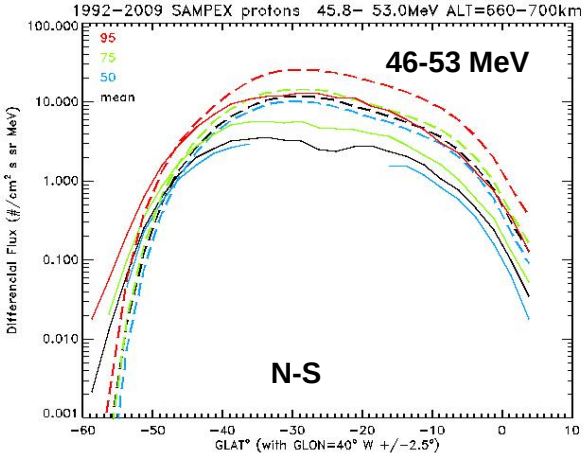
SAA profiles, ~680 km, 46-85 MeV

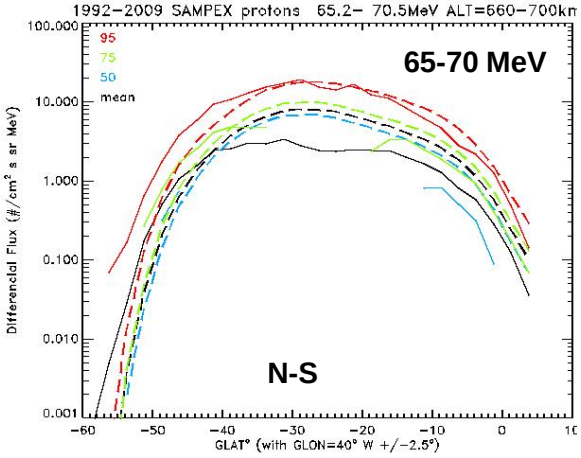
solid lines—SAMPEX data
dashed lines—AP9 V1.5

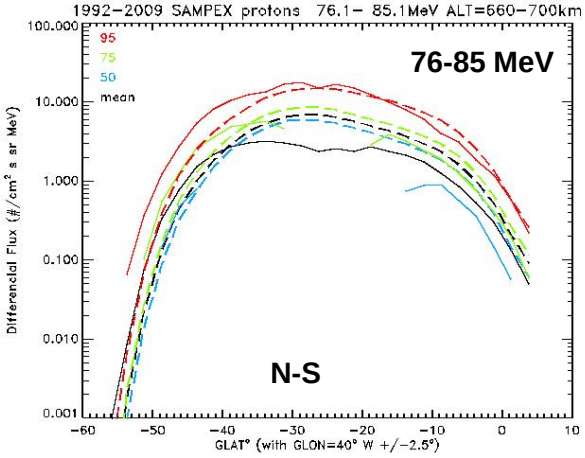






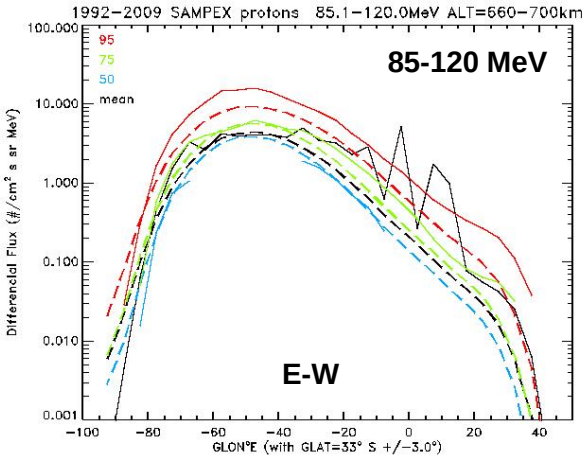


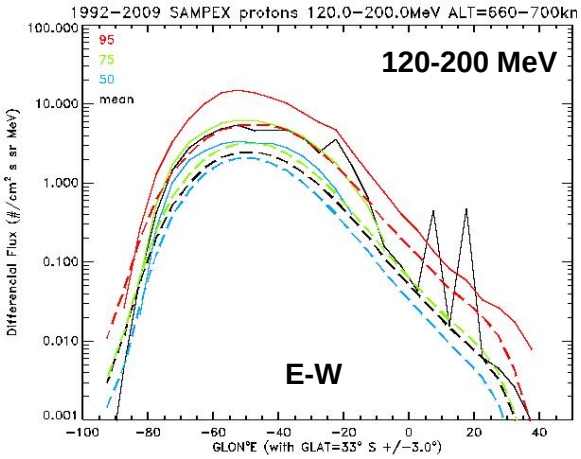


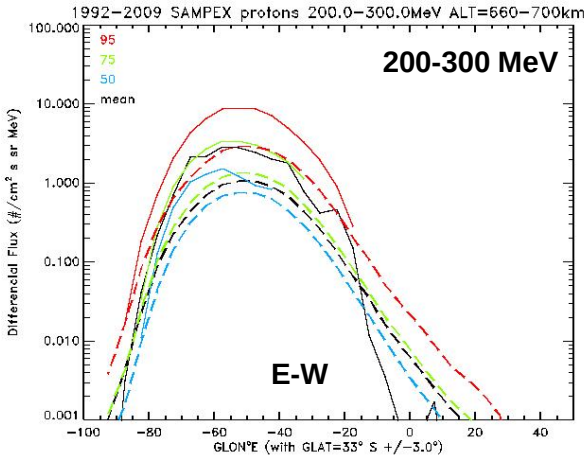


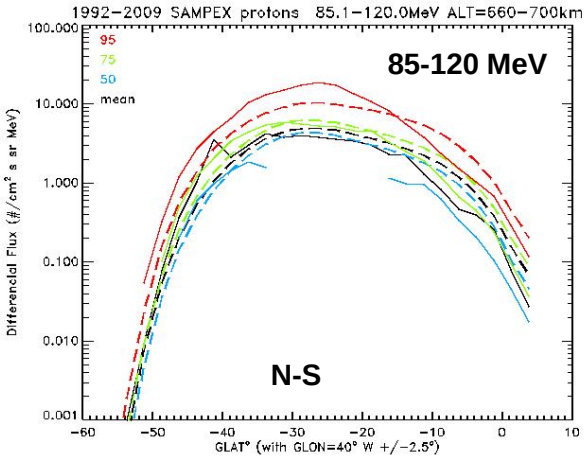
SAA profiles, ~680 km, 85-300 MeV

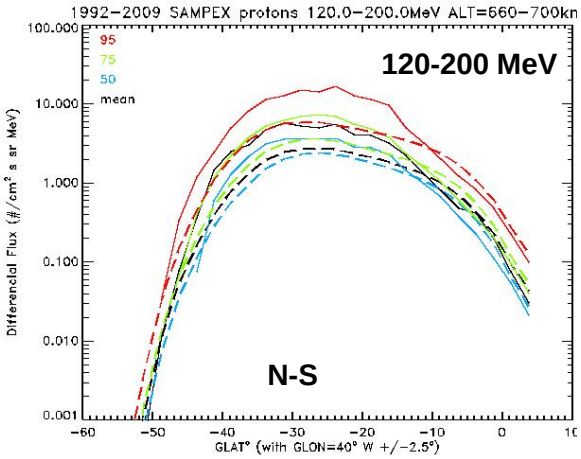
solid lines—SAMPEX data
dashed lines—AP9 V1.5

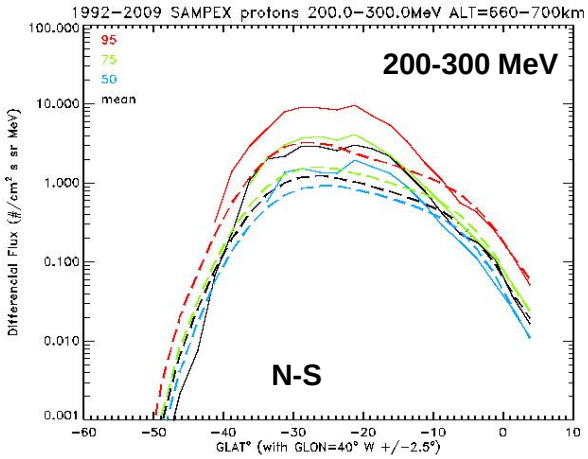








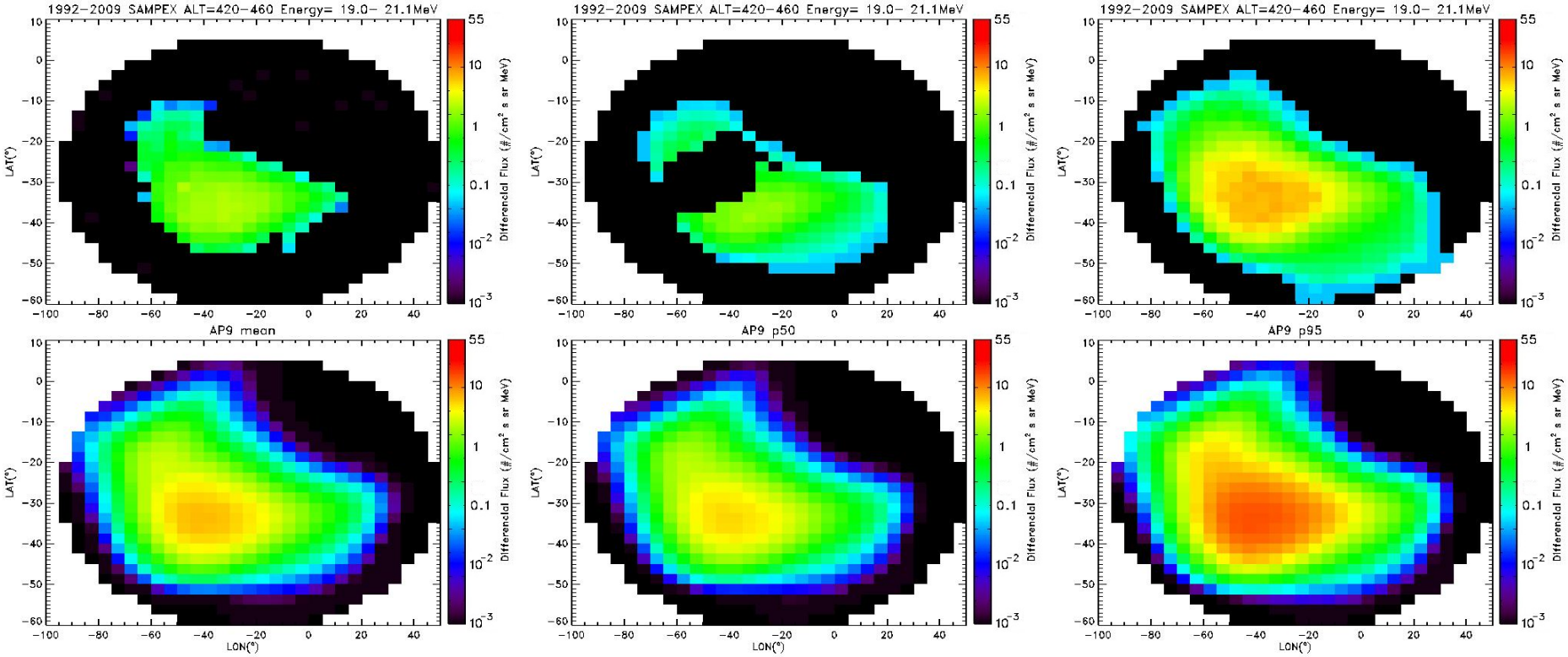




SAA fluxes, ~440 km, 19-21 MeV

Top: SAMPEX data

mean **50% CL** **95% CL**

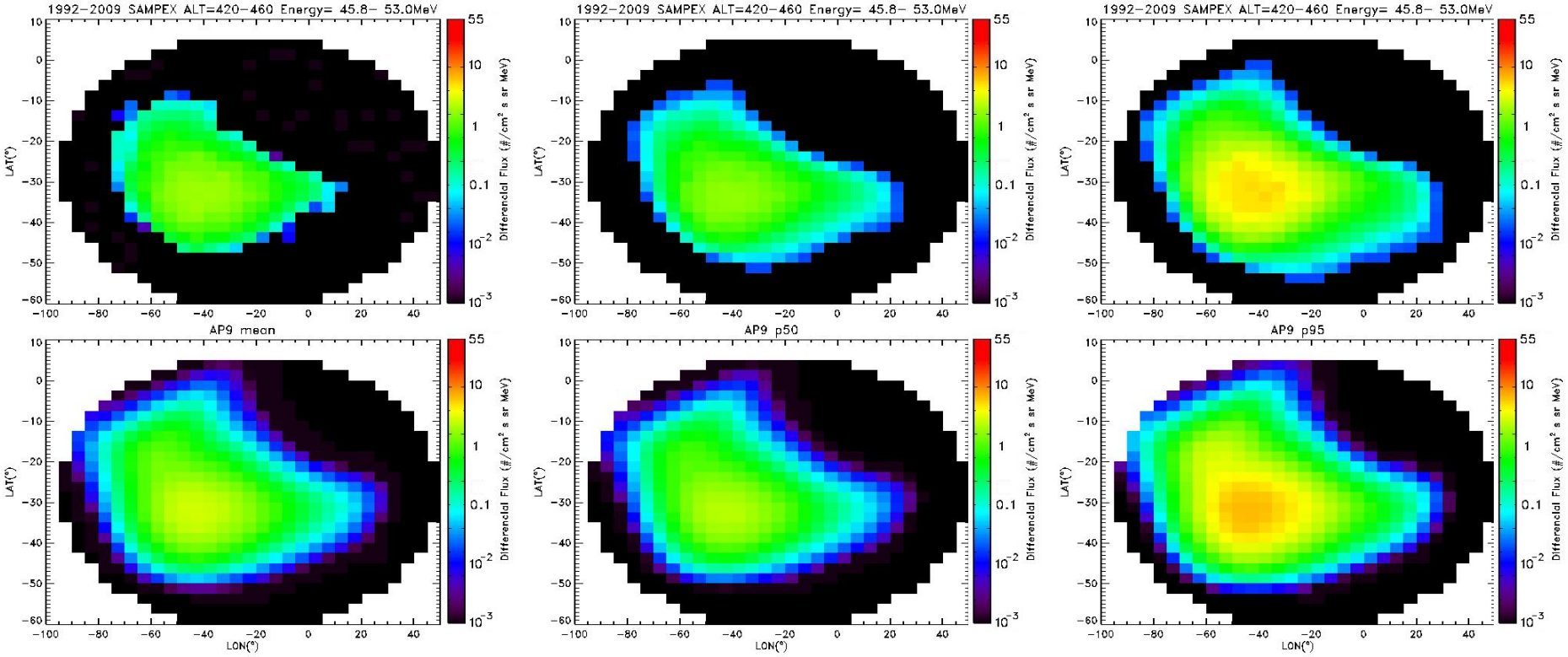


Bottom: AP9

SAA fluxes, ~440 km, 46-53 MeV

Top: SAMPEX data

mean **50% CL** **95% CL**

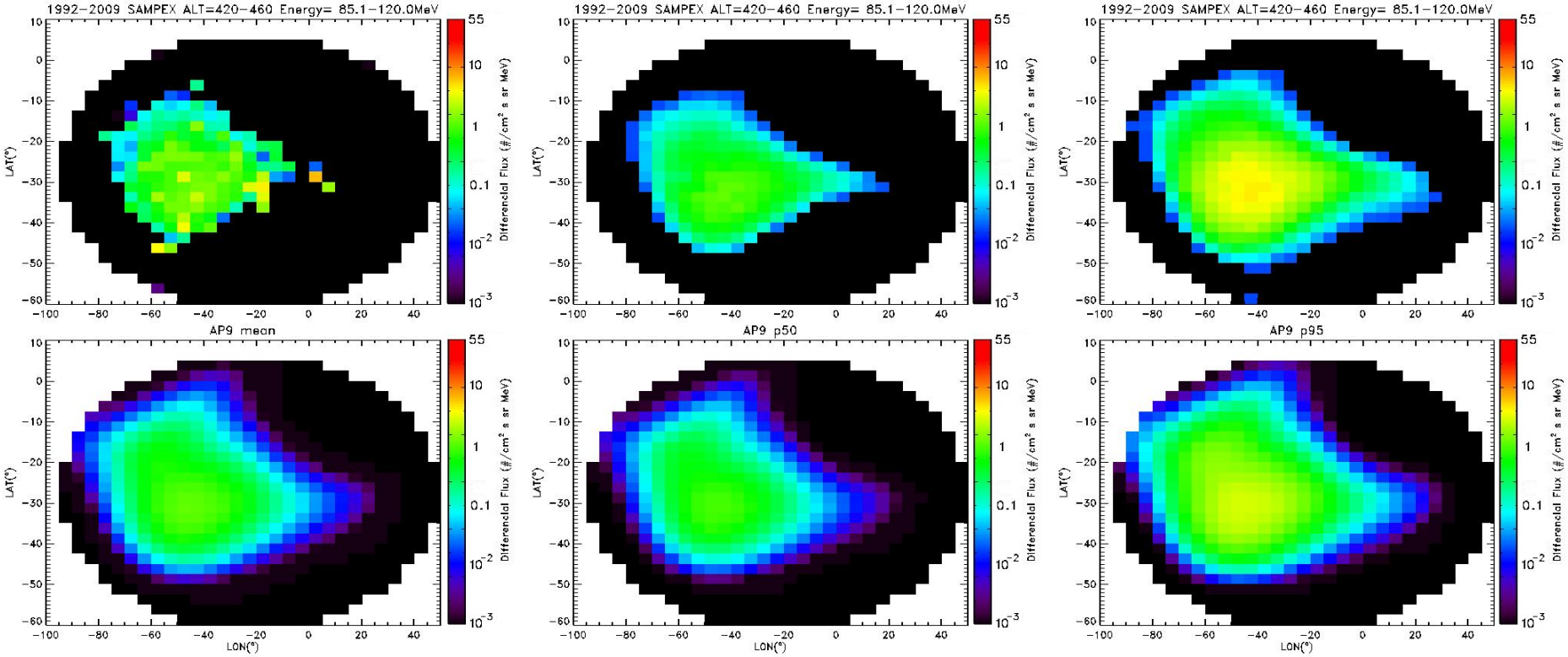


Bottom: AP9

SAA fluxes, ~440 km, 85-120 MeV

Top: SAMPEX data

mean **50% CL** **95% CL**

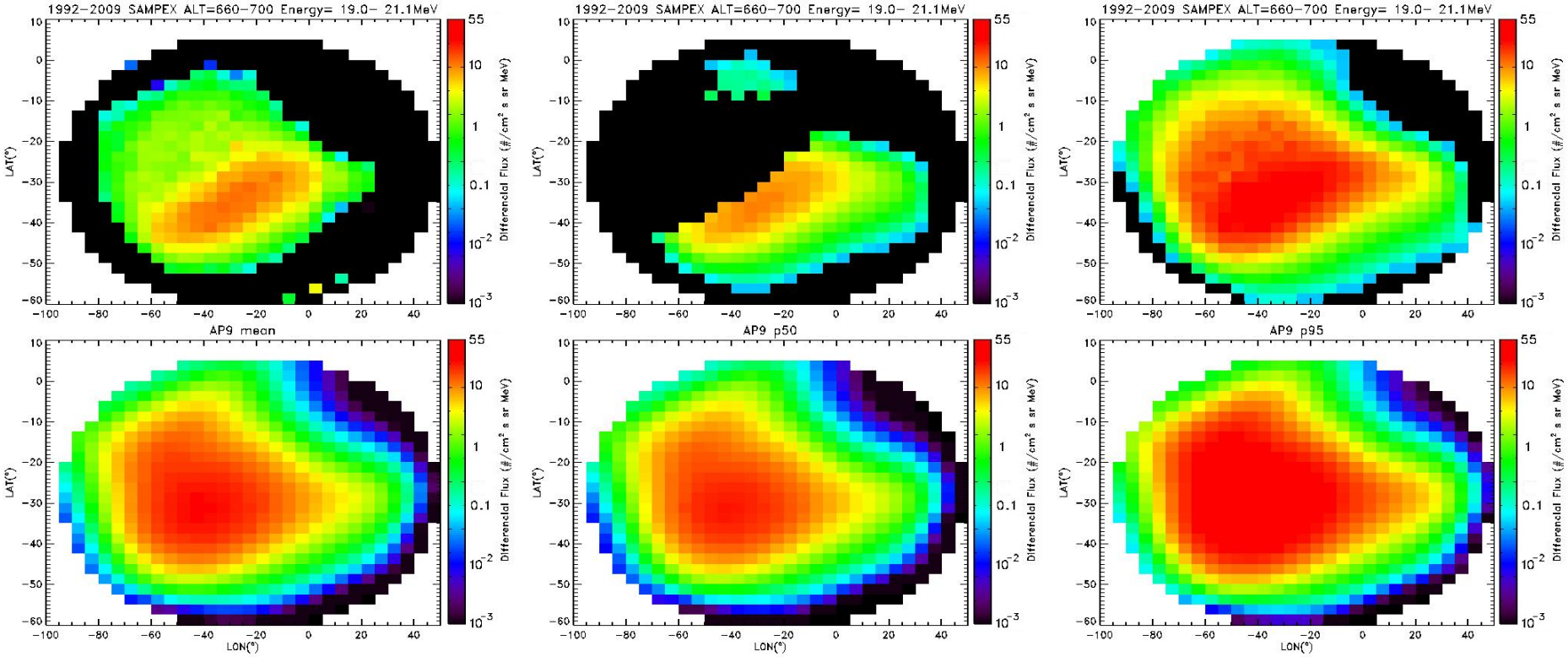


Bottom: AP9

SAA fluxes, ~680 km, 19-21 MeV

Top: SAMPEX data

mean **50% CL** **95% CL**

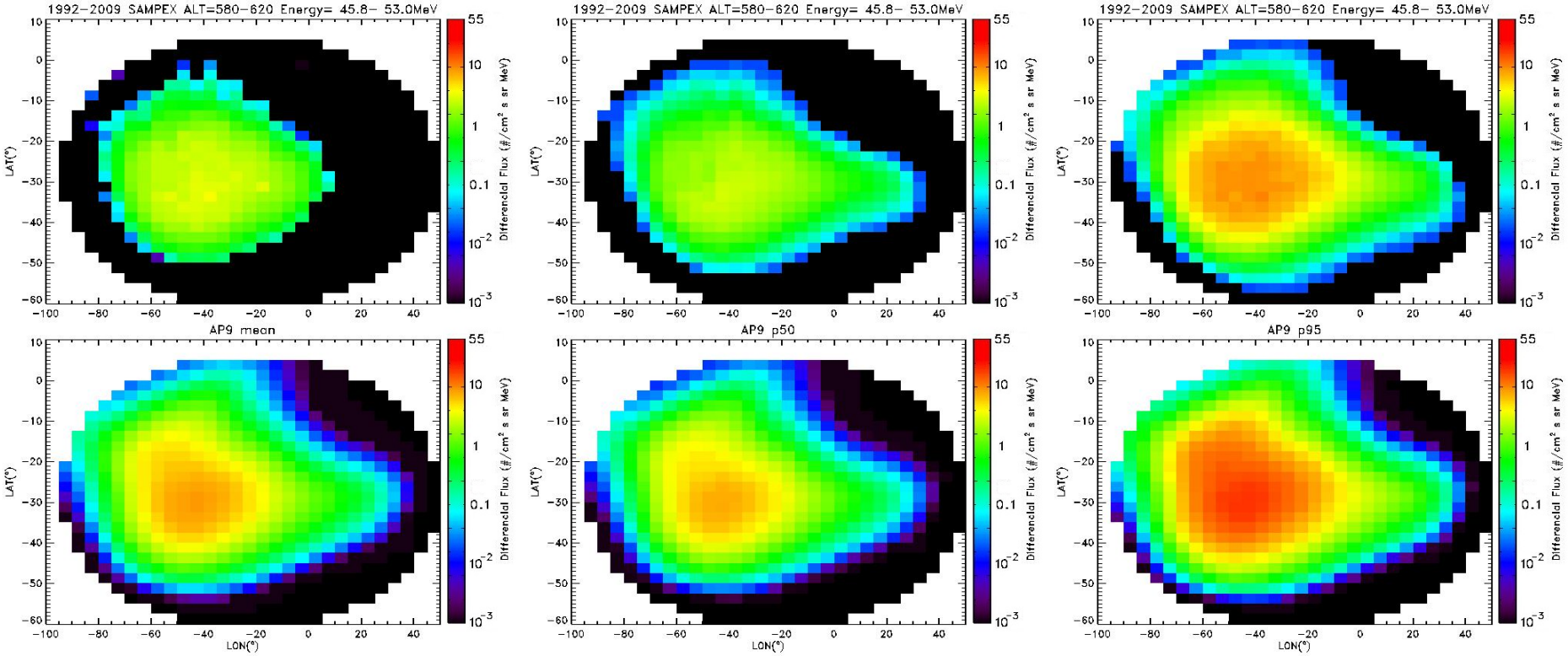


Bottom: AP9

SAA fluxes, ~600 km, 46-53 MeV

Top: SAMPEX data

mean **50% CL** **95% CL**

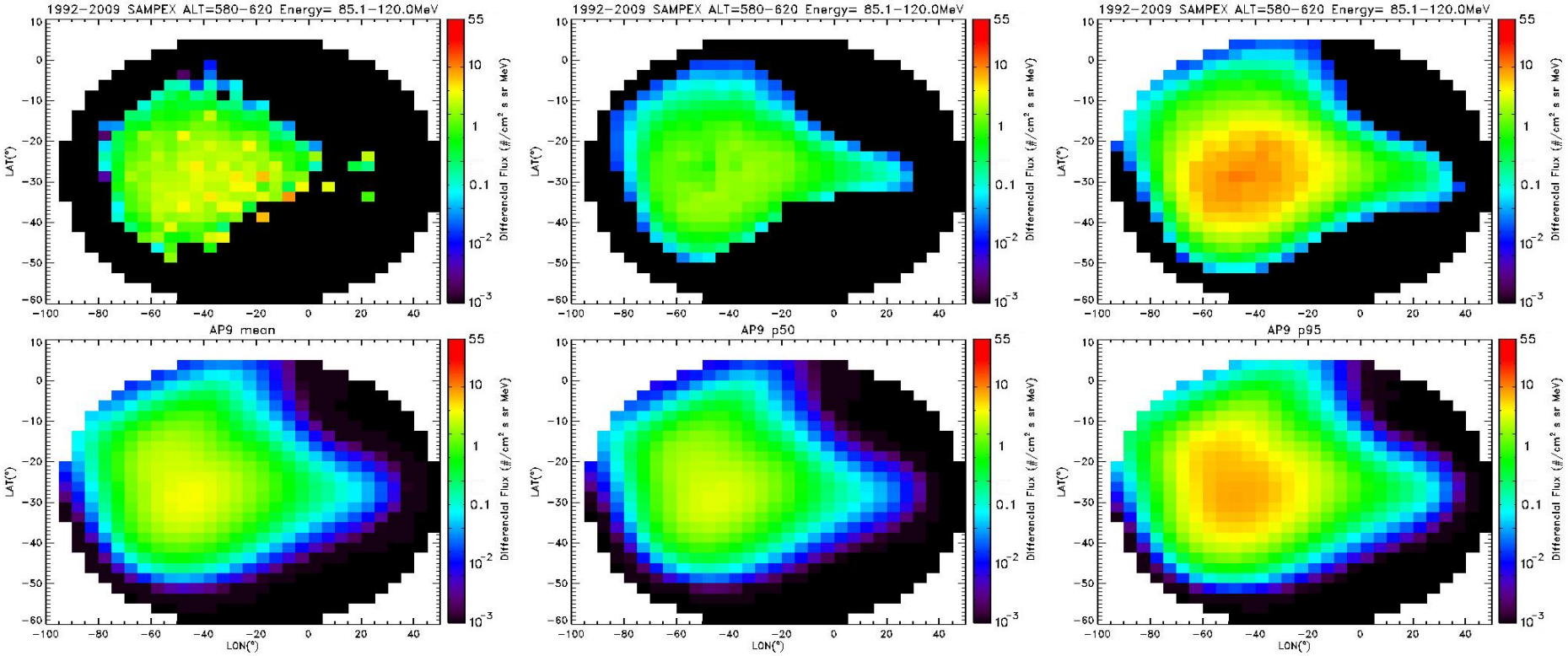


Bottom: AP9

SAA fluxes, ~600 km, 85-120 MeV

Top: SAMPEX data

mean **50% CL** **95% CL**

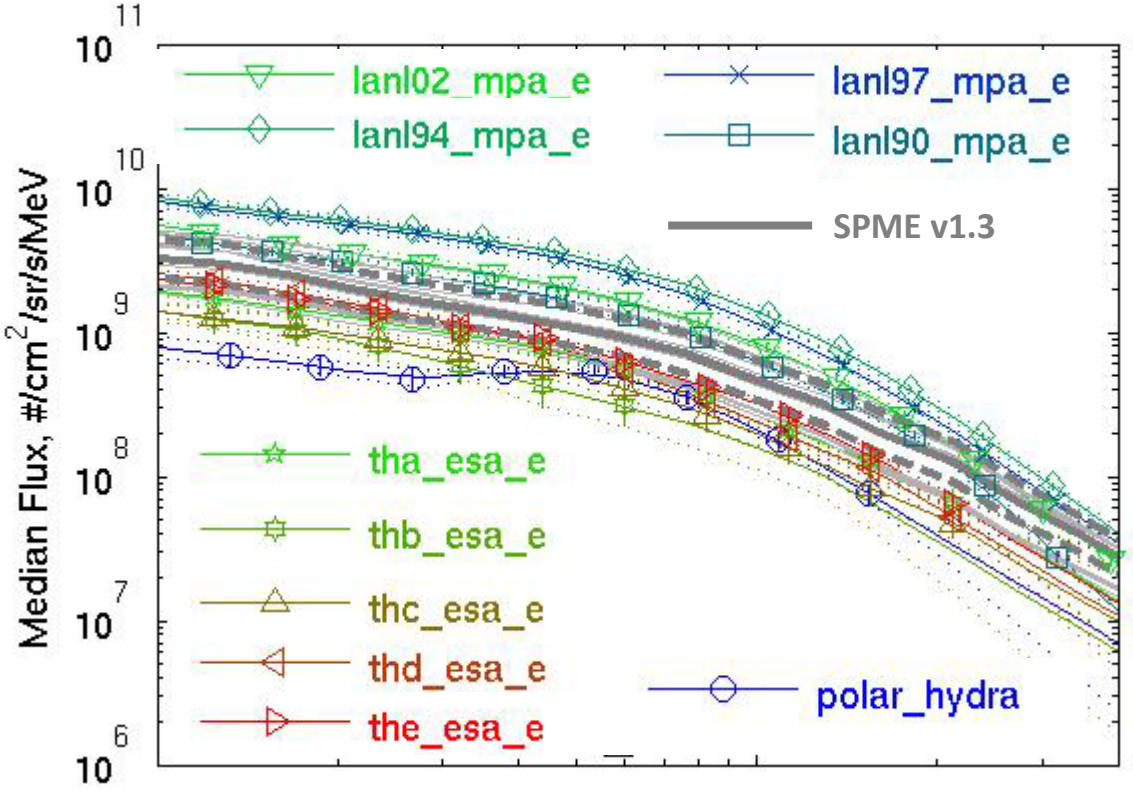


Bottom: AP9

Comments on Model/Data Comparisons

Model Error Bars versus Data Sets

Median and 1-s for each data set and the model



Electron Plasma Model (SPME), v1.3
L_m=7, a=35 (i2=4, i3=11, ired=88, ifull=94)

- The data sets spread over about a factor of 10.
- The model error is about a factor of 3.
- The model error is *small* because there are many data sets.
- If the model error covered the spread of the data *it would never shrink no matter how many data sets we added.*
- The model error bars are designed so that a model update with a new data set will still fall within the error bars of the prior model release.

We do not expect any individual data set to fall within the model error bars.