Status of the of Trapped Model AE9/AP9/SPM (IRENE) for the ISS Environment

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WRMISS19, 9-11 September 2014, Krakow, Poland

Outline

- Why a new trapped model?
- A quick review of Budapest presentation (WRMISS18, Sep. 2013)
- Availability of AE9/AP9/SPM on SPENVIS
  I. Implementation on the current version SPENVIS-4 (IRENE)
- Missing databases in AE8/AP8 and different run modes of AE9/AP9
- AE9/AP9 spectral (energy) gridding for a GTO orbit
- AP9 ISS environment simulation (4 April 2014)
  I. Perturbation vs. Monte Carlo mode (advantages/disadvantages)
- AP9 model verification with CRRES Model (4 July 2011)
- AP9 validation using POES and TACSAT4 satellites measurements
  I. January 1999 (after cycle 22 solar minimum)
  II. January 2005 (after cycle 23 solar maximum)
  III. October 2011
- Summary and current/future works

Why a New Trapped Model

- Currently there are ~ 1100 satellites in orbit:
  I. ~ 500 in low Earth orbit (LEO)
  II. ~ 70 in medium Earth orbit (MEO), mostly US-GPS and RU-GLANOSS
  III. ~ 450 in geosynchronous/geostationary orbit (GEO)
  IV. ~ 35 in highly elliptical orbit (HEO)

- ~ 80% of global financial markets rely on US-GPS satellites atomic clocks for synchronization (cesium or rubidium)*

*US GPS clock error ~ 50 nano sec./day

*RU GLANOSS clock error: better than US-GPS ???

*EU-ESA Galileo (Munich/Fucino)

- Global space industry revenue ~ $300 billions in 2012
  I. Communication ~ $180 billions
  II. TV (transmission, etc…) ~ $90 billions
  III. Radio broadcast (XM, Sirius, etc…) ~ $5 billions
  IV. Others ~ $25 billions

Review of WRMISS18 (part I)

- AE8/AP8 are **static models** (1964/1972 maps) with following limitations
  I. Lacks **probability distribution** or **error bars** (i.e. no statistics)
  II. Lacks **sufficient spectral (energy) coverage** for plasmas and energetic electrons/protons
  III. Are only **omni-directional**
  IV. Lacks **sufficient spatial coverage** for most orbits (**MEO**, **GEO**, **GTO, HEO,** …)
  V. AE8/AP8 **under/over predict** most measurements

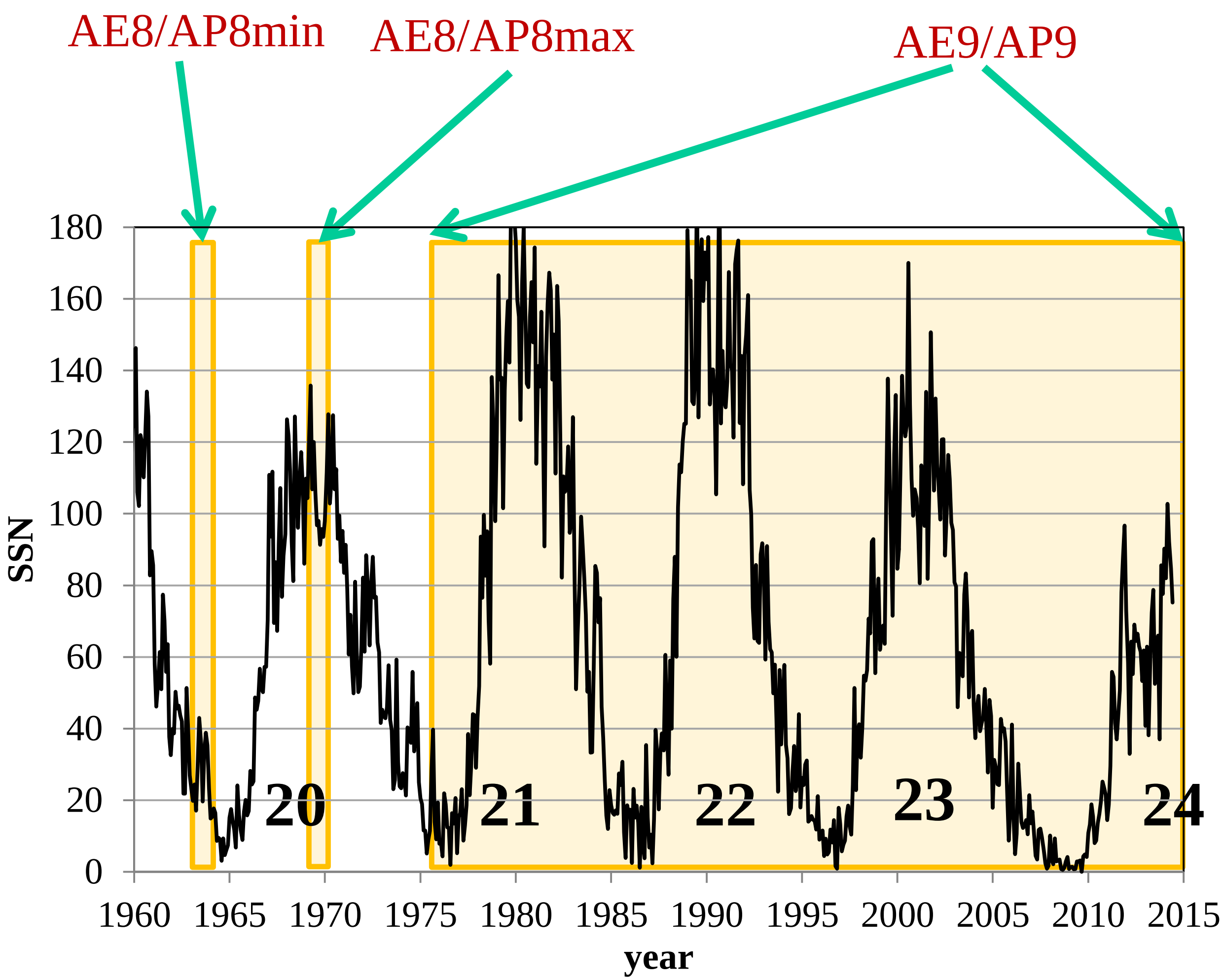
- In order to overcome the above limitations, US developed AE9/AP9/SPM
  I. **SPM** is **Space Plasma Model** with directional (anisotropy) capabilities
  II. In Budapest I mentioned that AE9/AP9 (no SPM) will be licensed to **SPENVIS**

- As of now AE9/AP9 model is not yet used for **ISS daily operations**

- No **ISS external measurements** were included in developing the AE9/AP9/SPM

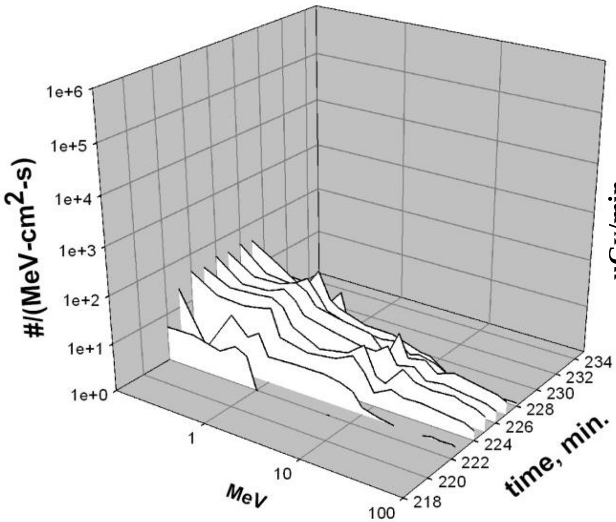
For the rest of the talk: AE8/AP8 will be called "old model"
AE9/AP9 will be called "new model"

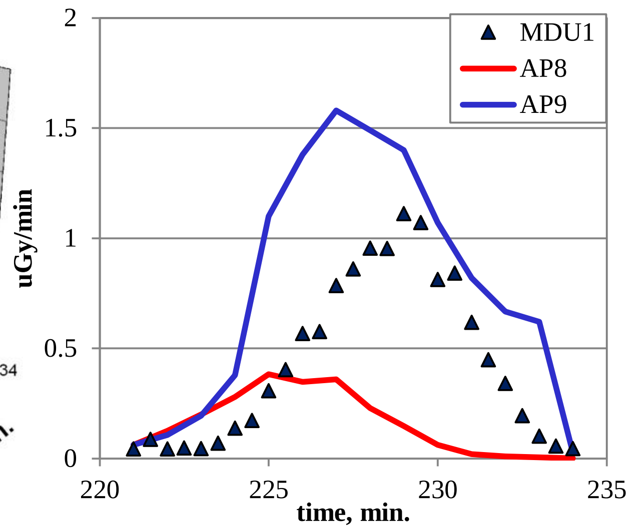
Review of WRMISS18 (part II)

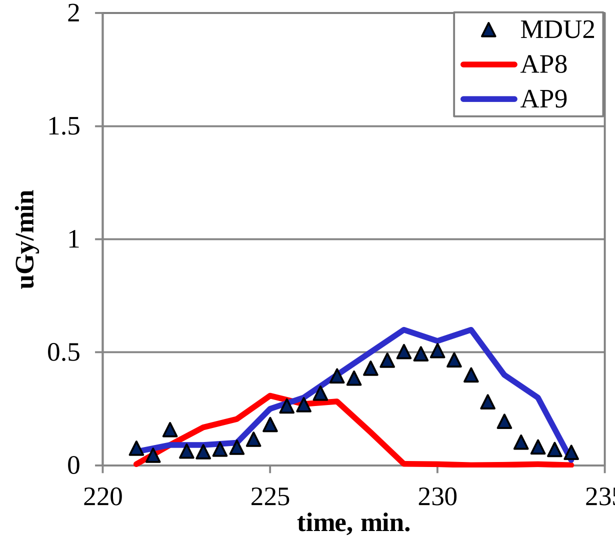


Review of WRMISS18 (part III)

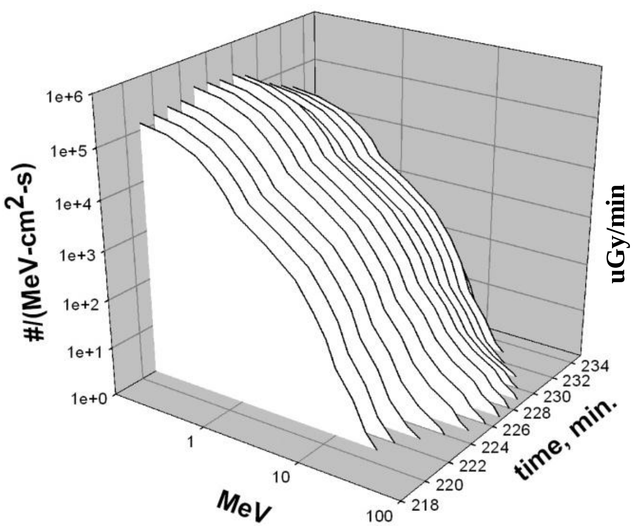
AP8max

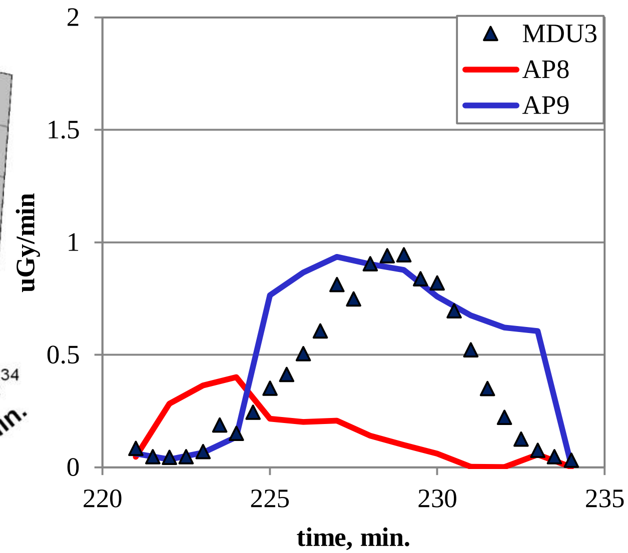


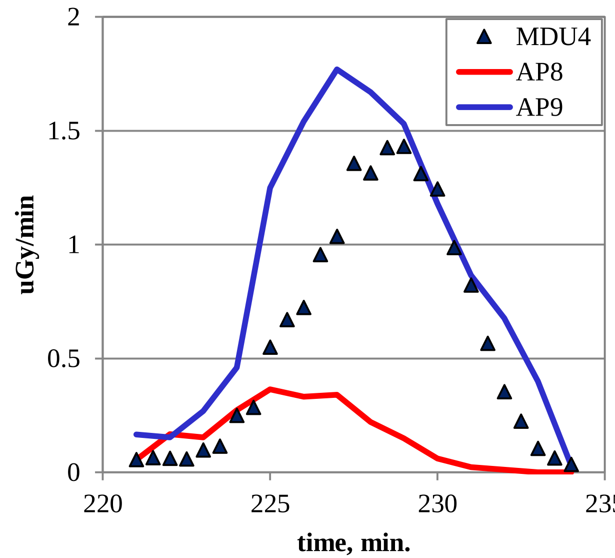




AP9







Availability of AE9/AP9 on ESA's SPENVIS-4

SPENVIS Project: TEST-FFB

Radiation sources and effects

Trapped radiation: IRENE AE9/AP9 parameters

The current version of the AP9/AE9 model is provided for evaluation purpose by its development team

AE9/AP9 model input	
Model run mode:	mean
Energies:	IS energies

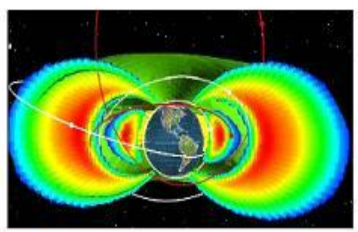
mean
percentile
perturbed
montecarlo

???

Warning: due to the size of the trajectory (4142 points) the execution time could exceed your allowed quota.

Reset | Run | << Back

Tool developed by



Missing Databases in AE8/AP8 Model

- AE8/AP8 has no database to provide information on the uncertainty in the mean flux maps due to **measurement/gap-filling** errors

- AE8/AP8 has no database to provide information on the uncertainty in the mean flux maps due to **dynamic variations** of **space weather processes**

- AE9/AP9 provides databases for both **measurement/gap-filling** errors and **dynamic variations** of **space weather processes** errors

- These databases allow **extraction of statistical information** from AE9/AP9

AE9/AP9 Runs Modes

- The AE9/AP9 model offer 4 **run modes** corresponding to various types of flux data
  - **Mean**: mean behavior of the model with no uncertainty added
  - **Percentile**: statistical behavior of the model with no uncertainty added. Uncertainty allows dynamic estimation of design margin (e.g. 99% CL) which allows study of surface or internal charging, SEU and evaluation of satellite lifetime
  - **Perturbed Mean (PM)**: adds the uncertainty in the mean flux maps due to **measurement/**and **gap-filling** errors
  - **Monte Carlo (MC)**: contains all of the **PM** uncertainty plus an estimate of the **dynamic variations** due to **space weather processes**

***PM** and **MC** selections require ‘number of scenarios (runs)‘. I will show results for 10 scenarios later

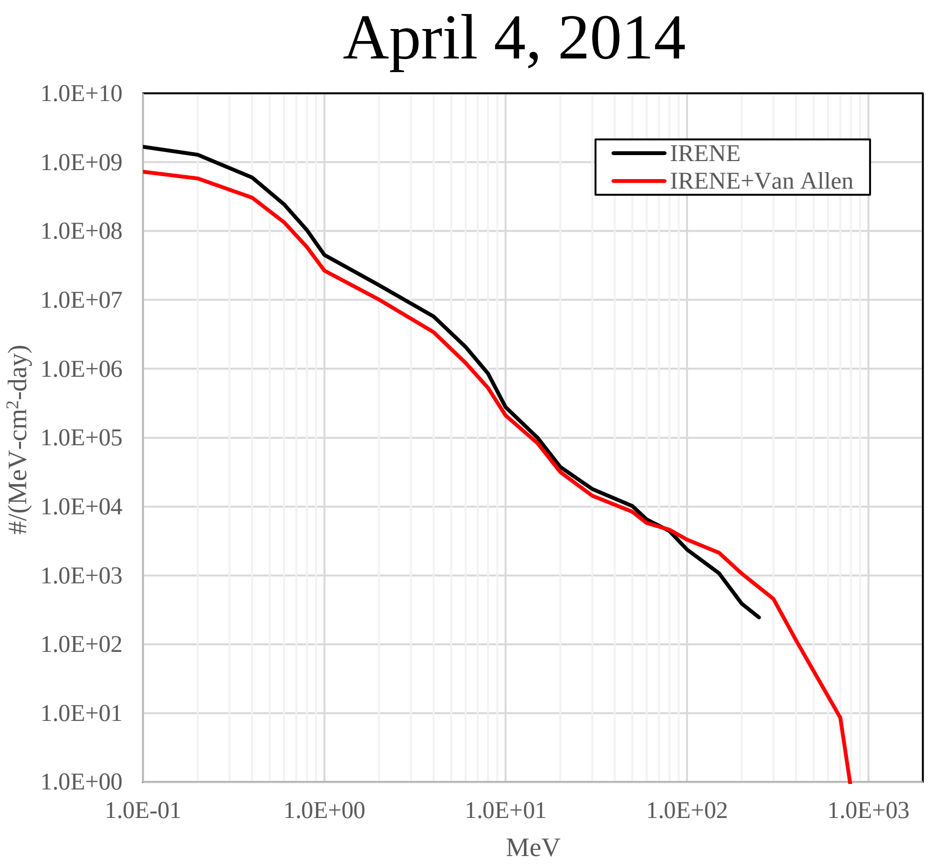
Energy Bins Differences (part I)

Default IRENE grid

Proton Energies (MeV)	0.1, 0.2, 0.4, 0.6, 0.8, 1, 2, 4, 6, 8, 10, 15, 20, 30, 50, 60, 80, 100, 150, 200, 250
Electron Energies (MeV)	0.04, 0.07, 0.1, 0.25, 0.5, 0.75, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8

Latest version (1.2) Proton Energies (MeV)	0.1, 0.2, 0.4, 0.6, 0.8, 1, 2, 4, 6, 8, 10, 15, 20, 30, 50, 60, 80, 100, 150, 200, 300, 400, 700, 1200, 2000

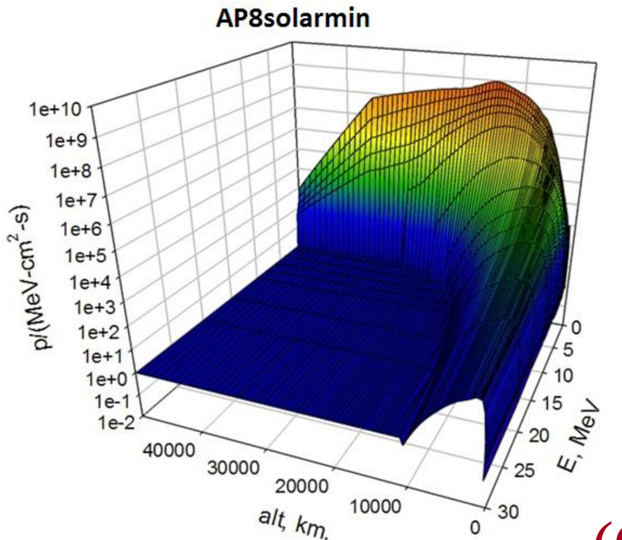
Energy Bins Differences (part II)

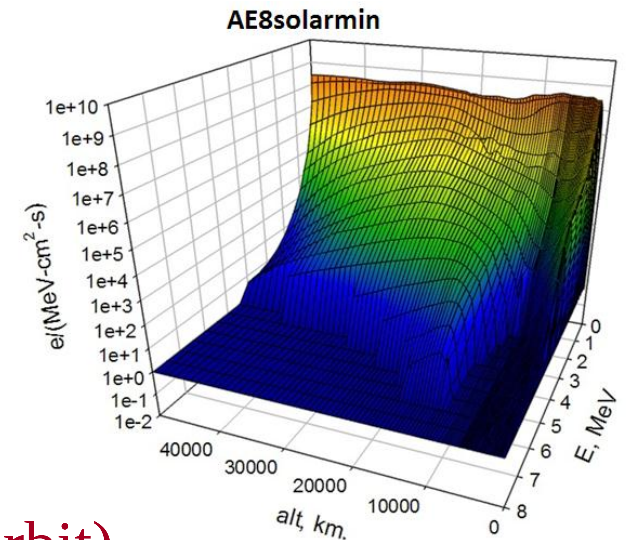


Aluminum 1016 g/cm^2

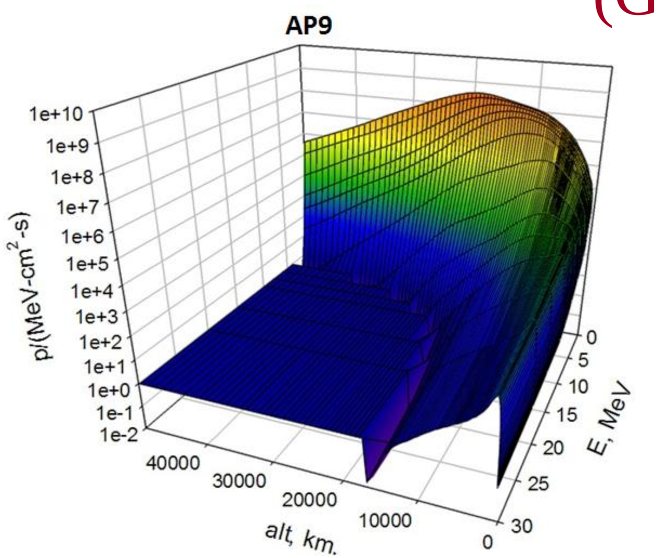
Water 805.4 g/cm^2

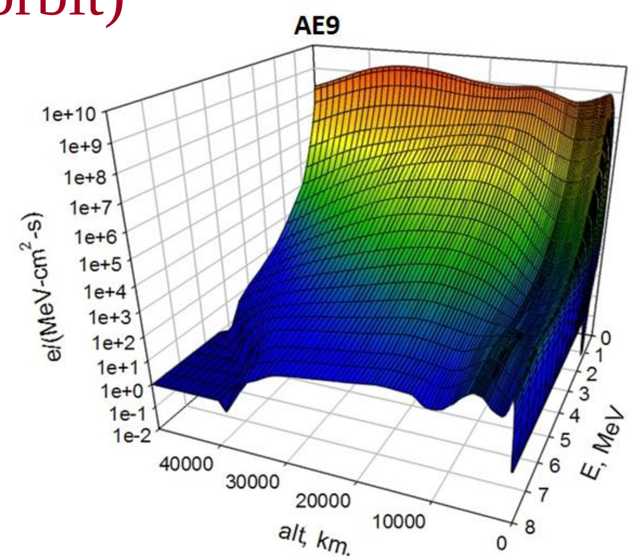
Energy Bins Differences (part II)



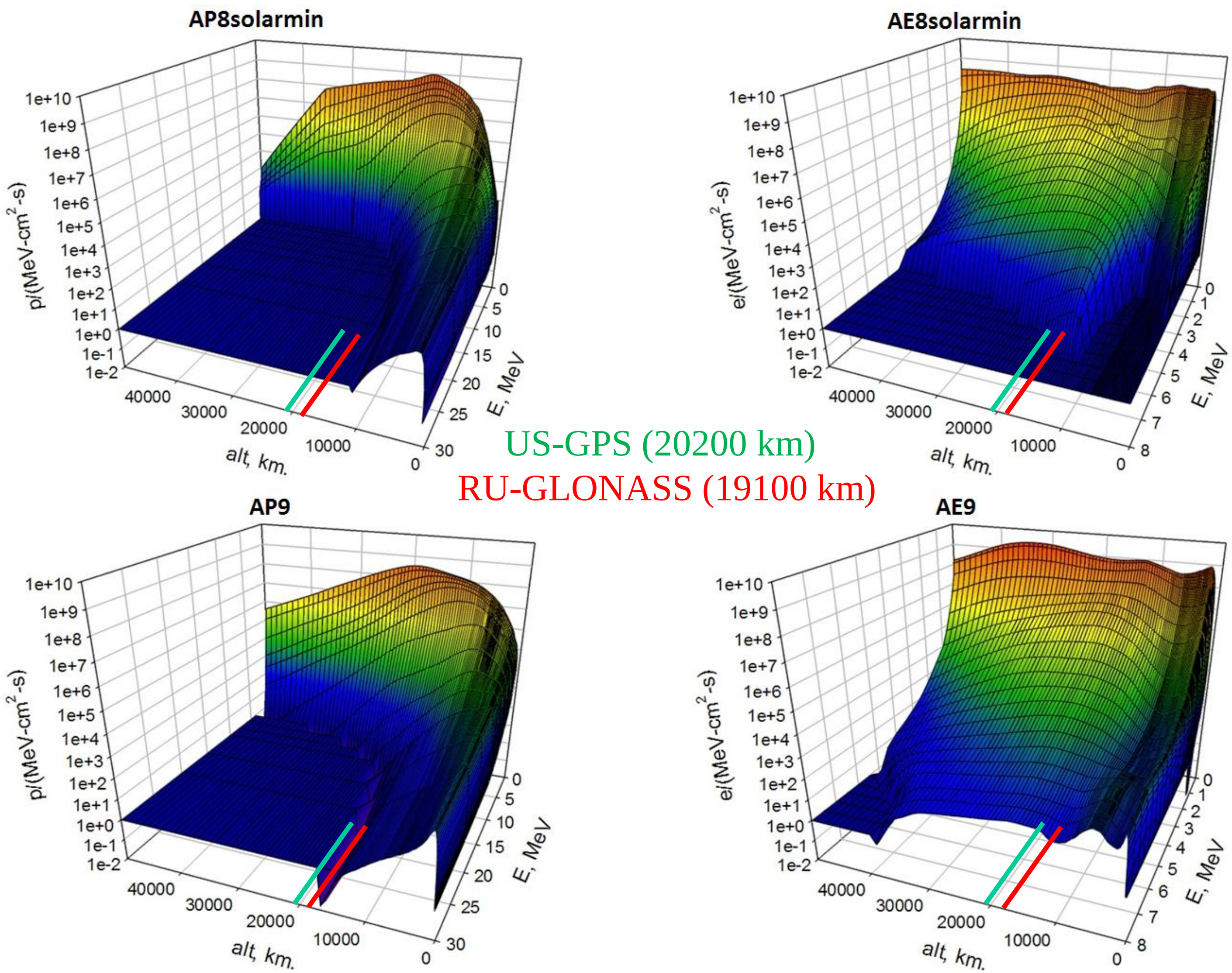


(GTO orbit)

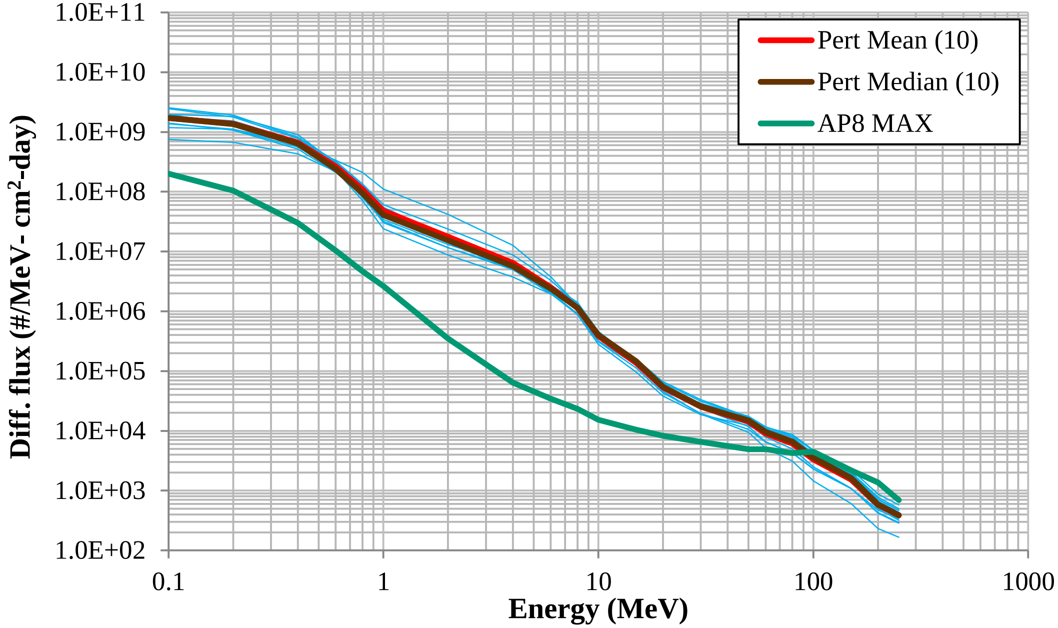


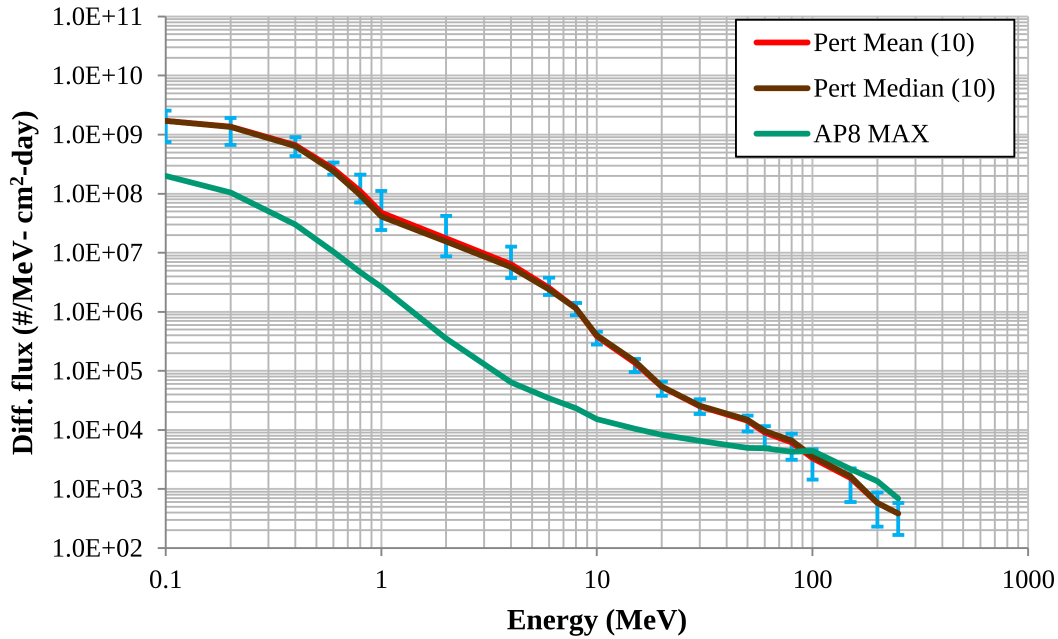


Energy Bins Differences (part III)

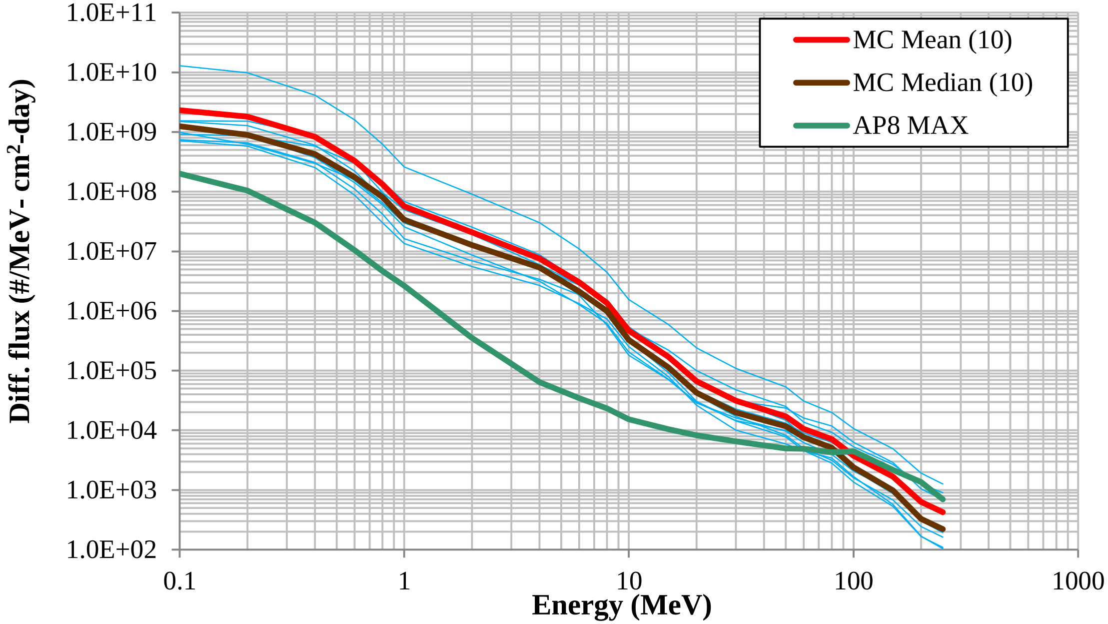


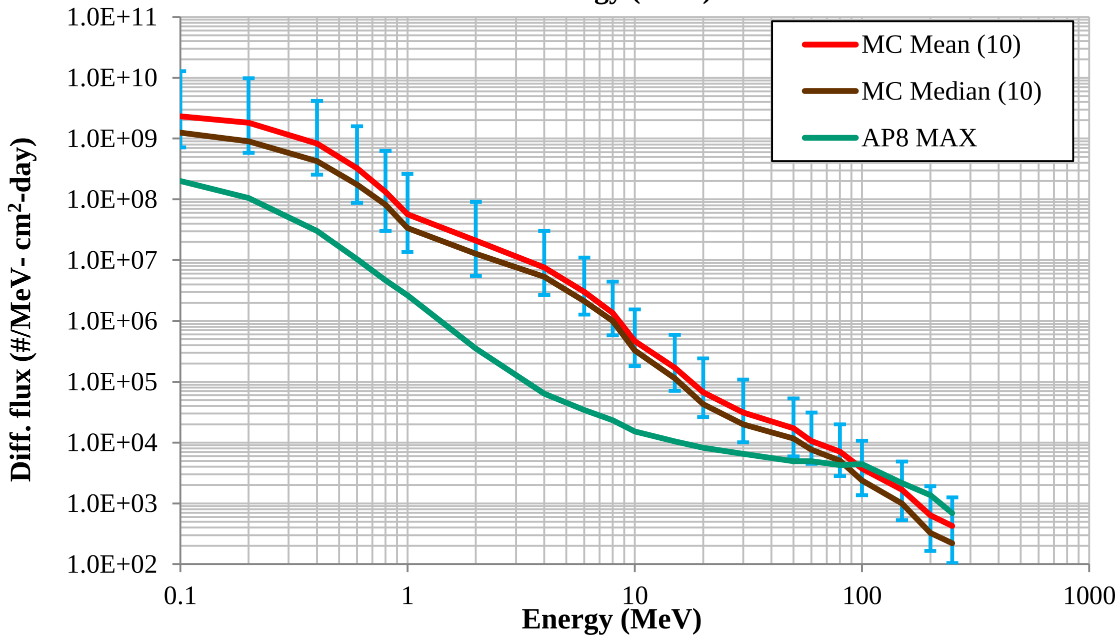
PM Mode (10) AP9 ISS Spectra (4 April 2014)



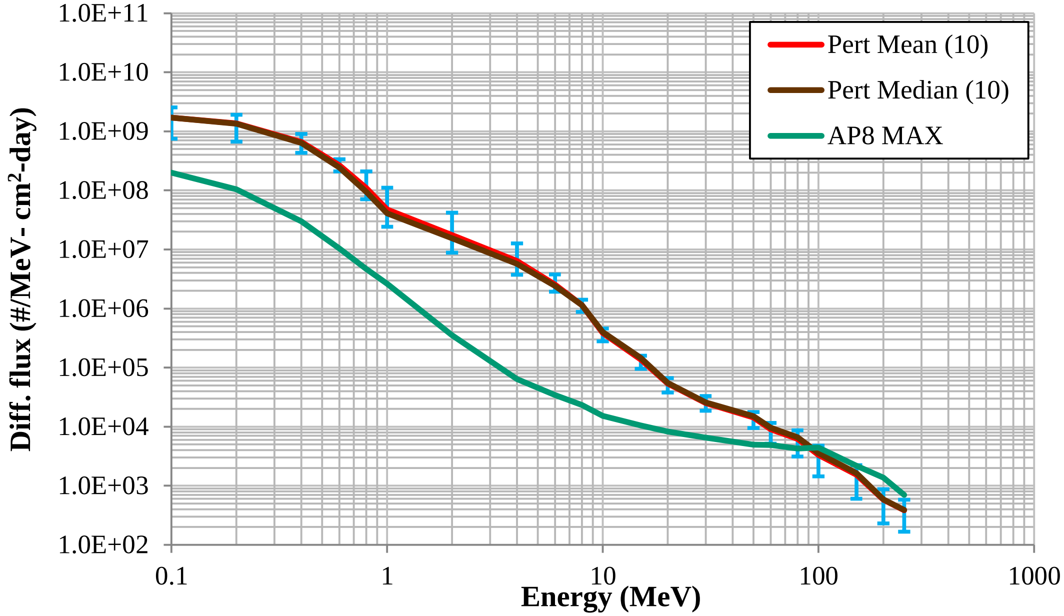


MC Mode (10) AP9 ISS Spectra (4 April 2014)

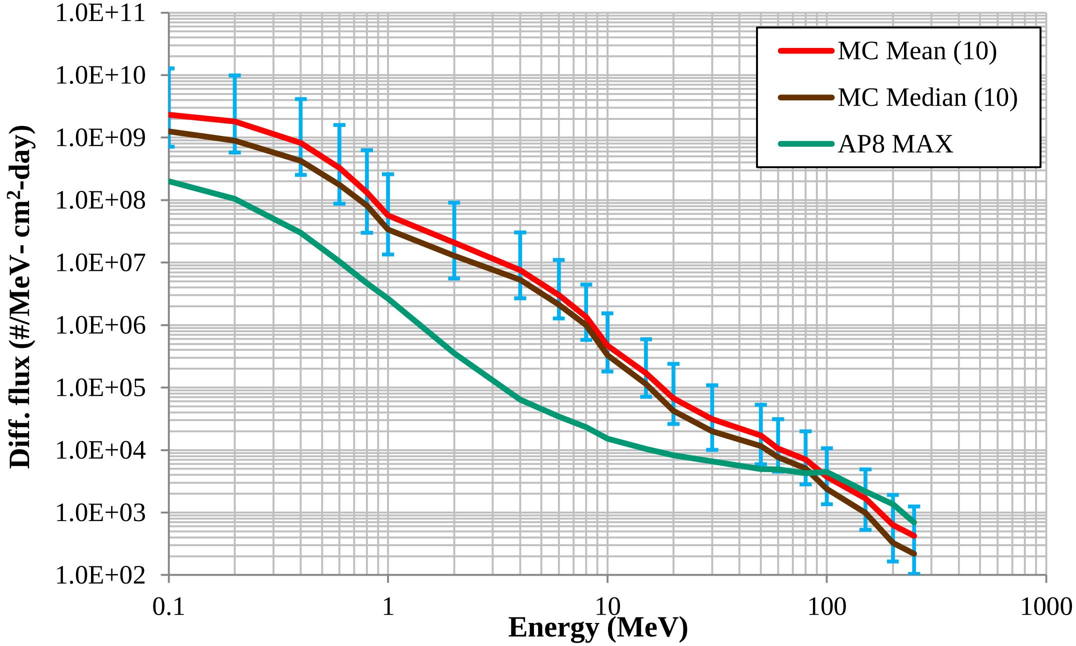




ISS, PM/MC Modes Comparison (4 April 2014)



PM mode (10)



MC mode (10)

AP9 Model Verification with Other Models (part I)

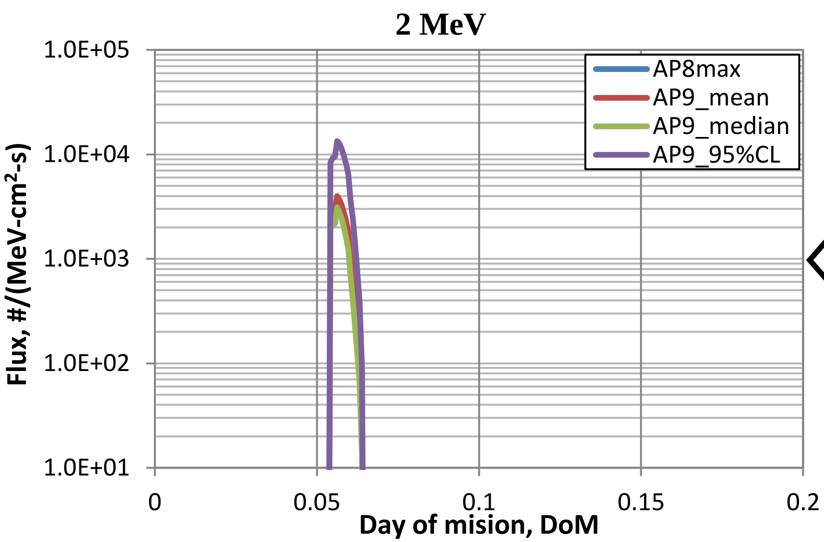
Satellite/Sensor	Orbit	Energy range
Protons		(MeV)
CRRES/PROTEL	50 km×33000 km,18°	2.0 - 80

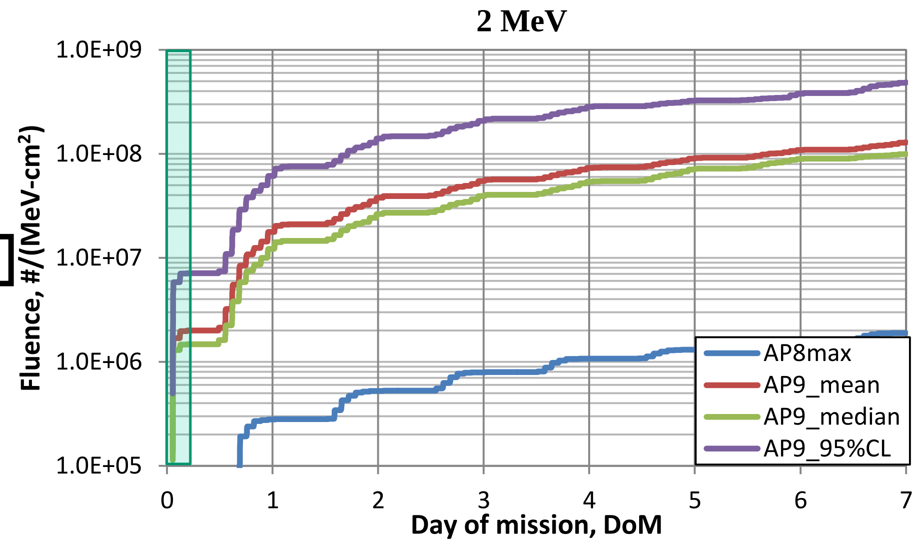
All **AP9** scenarios ran for **1 week** mission time
All **AP9** scenarios used **10 Monte Carlo** runs
For **AP9** only aggregated mean, median and 95%CL values are included
For **AP8** only **mean** values are available

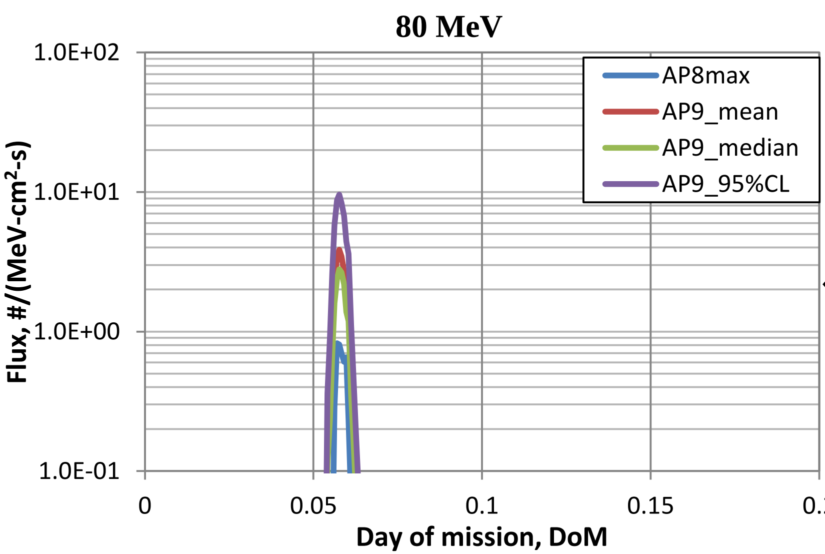
CRRES: Combined **R**adiation and **R**elease **E**xperiment **S**atellites

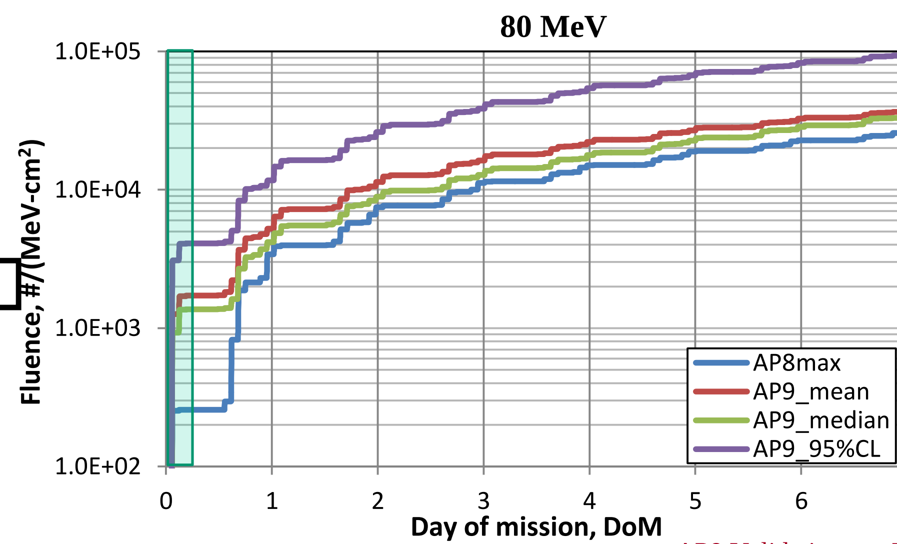
AP9 Model Verification with Other Models (part II)

AP8/AP9/CRRESPRO differential flux/fluence comparisons
LEO-ISS, 400 km X 51.6 deg., circular, epoch 04-Jul-2011



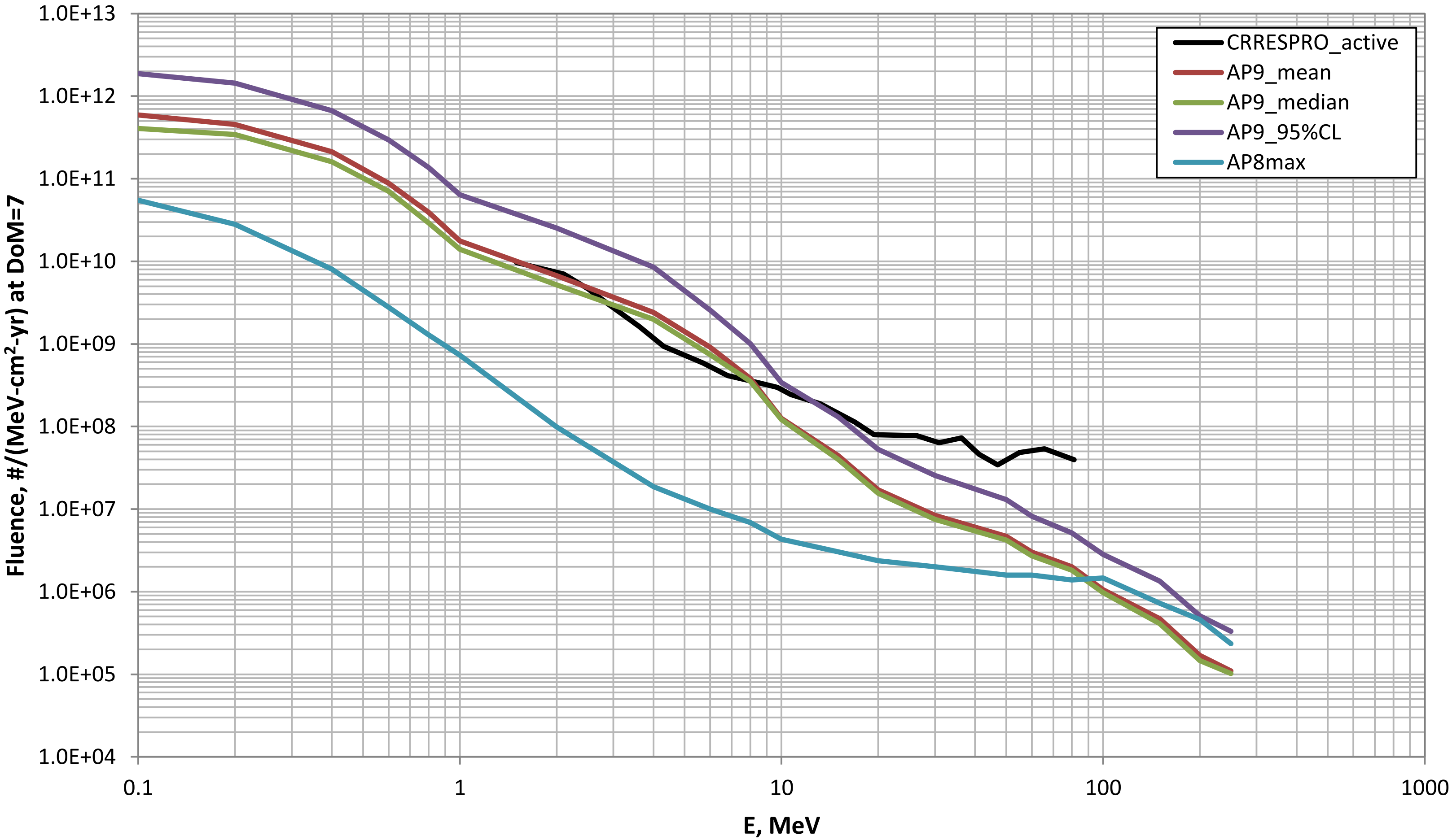






AP9 Model Verification with Other Models (part III)

AP8/AP9/CRRESPRO differential fluence comparison
LEO-ISS, 400 km X 51.6 deg., circular, epoch 04-Jul-2011



AP9 Model Validation Matrix (part I)

AP9 Validation

Satellite	Sensor	Orbit	Time Period	Energies (MeV)
POES	SEM2 MEPED	LEO 850 km, circular, 98.7°	Jul 1998 – Dec 2011	>~~16~~, >36, >70, >140
TACSAT4	CEASE	MEO 735 km x 12024 km, 63.5°	Oct 2011 Dec 2012	>~~16~~, >~~29~~, >~~39~~, >44, >72

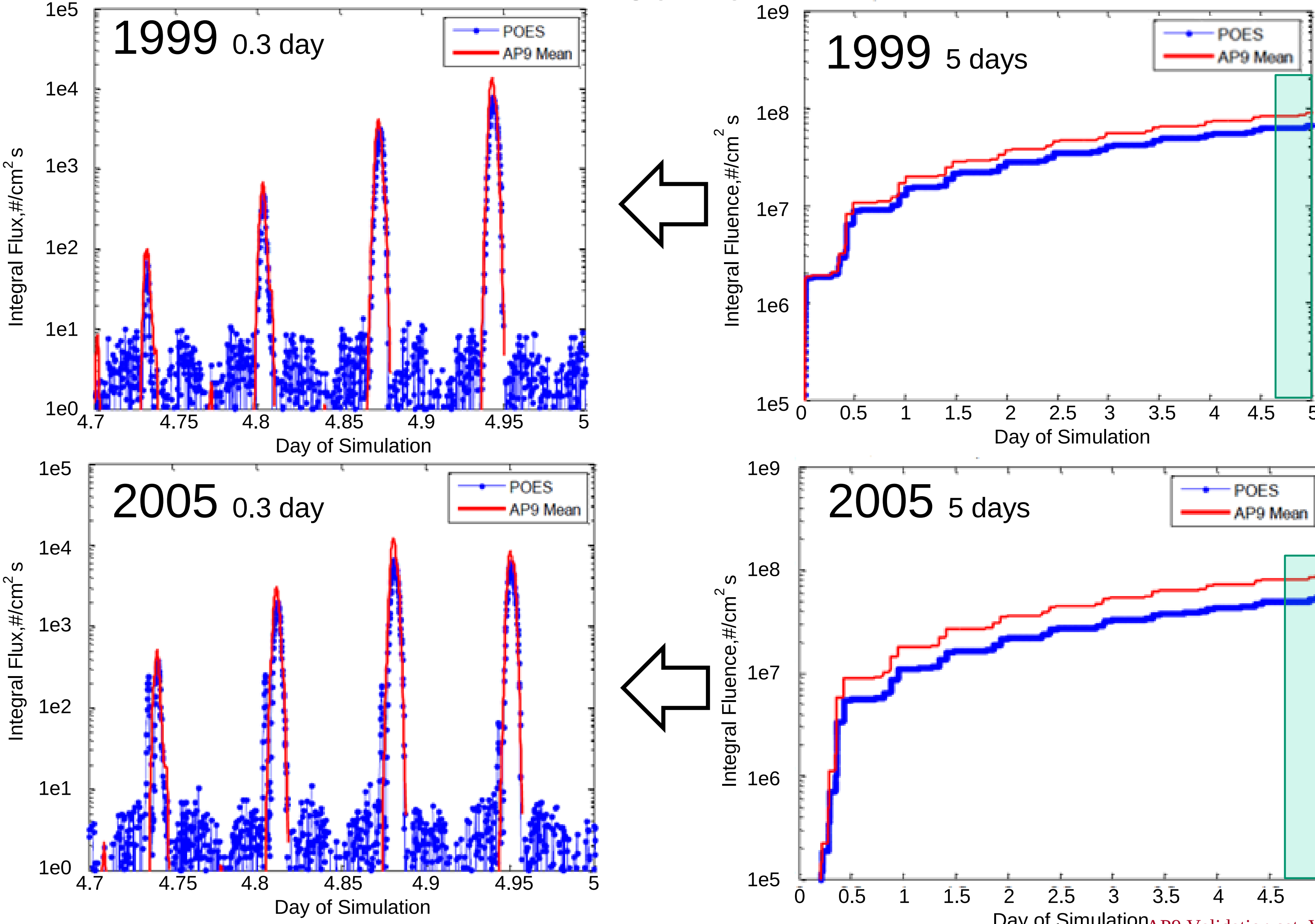
POES Validation epochs:
Jan. 1999 (after cycle 22 solarmin)
Jan. 2005 (after cycle 23 solarmax)

TACSAT4 Validation epoch:
Oct. 2011

: Excluded due to electron contamination

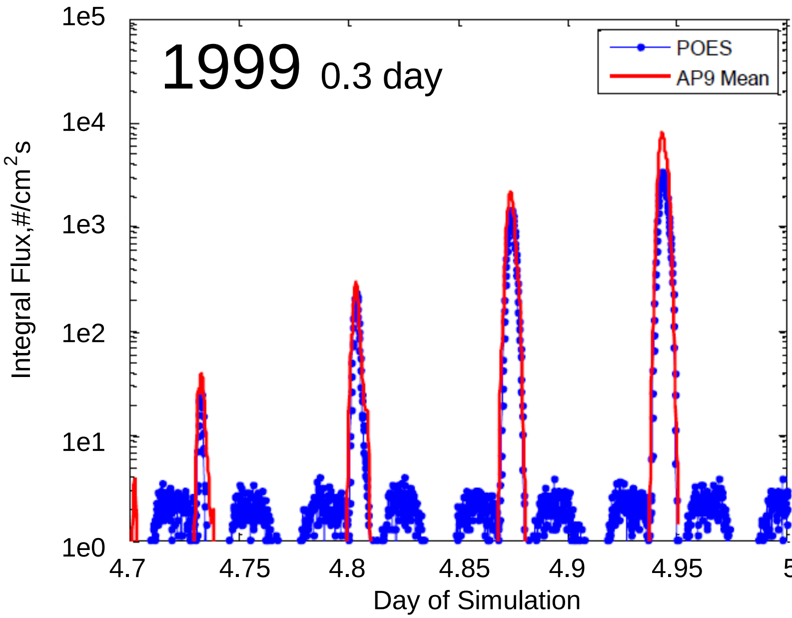
January 1999/2005 AP9 Validation, POES (part II)

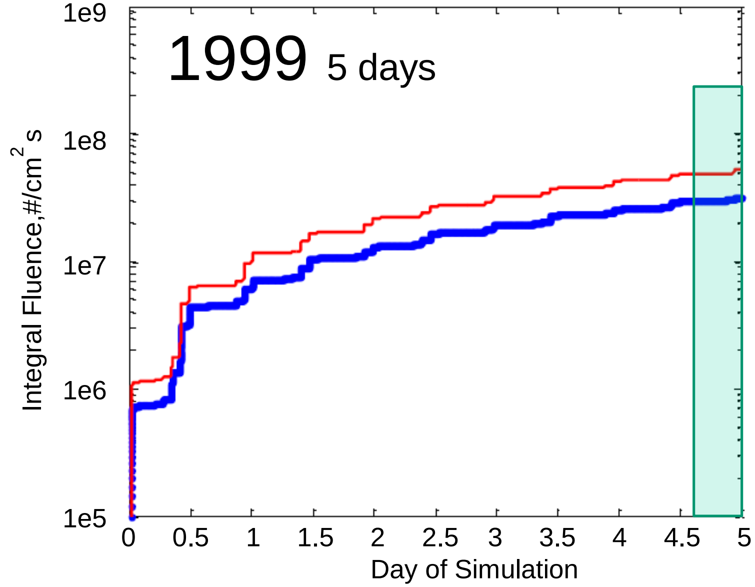
> 36 MeV

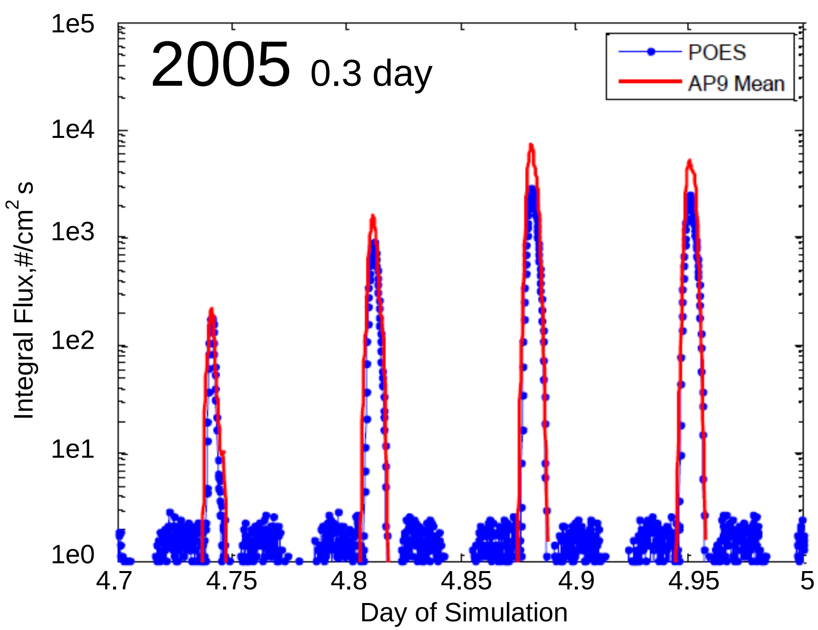


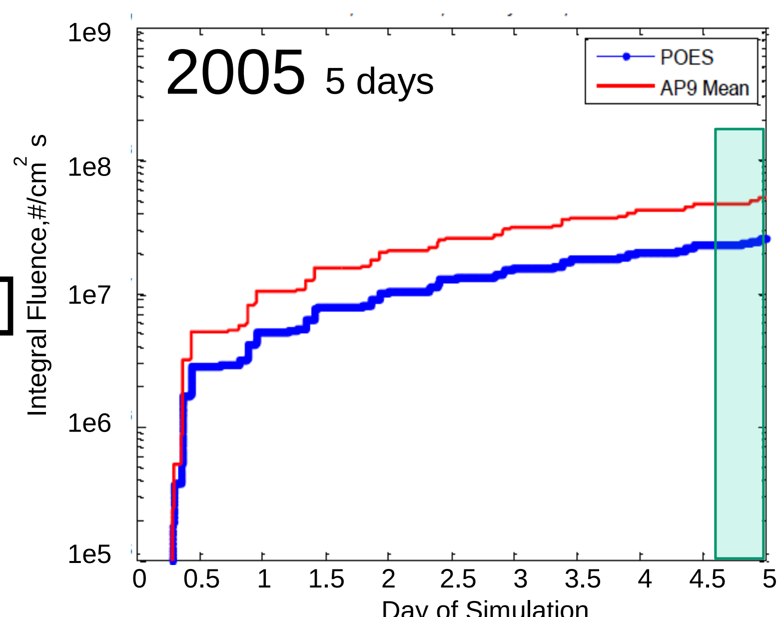
January 1999/2005 AP9 Validation, POES (part III)

> 70 MeV



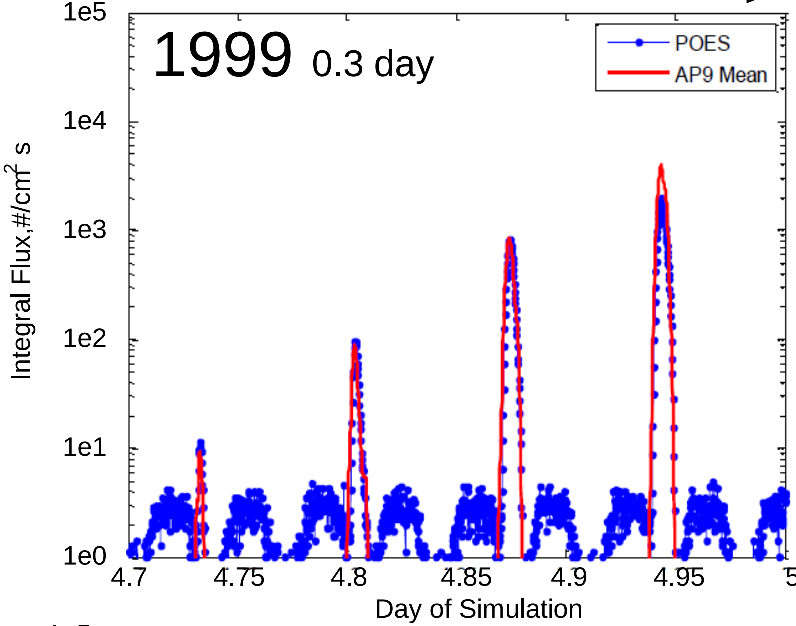


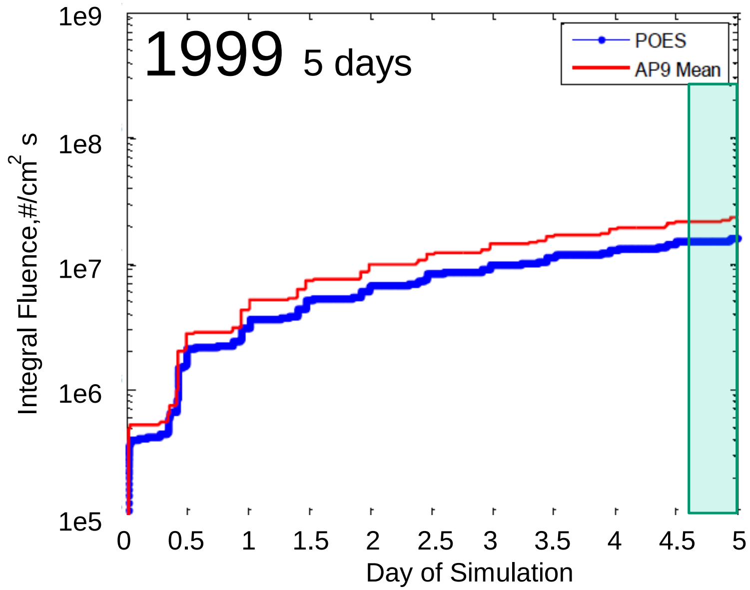


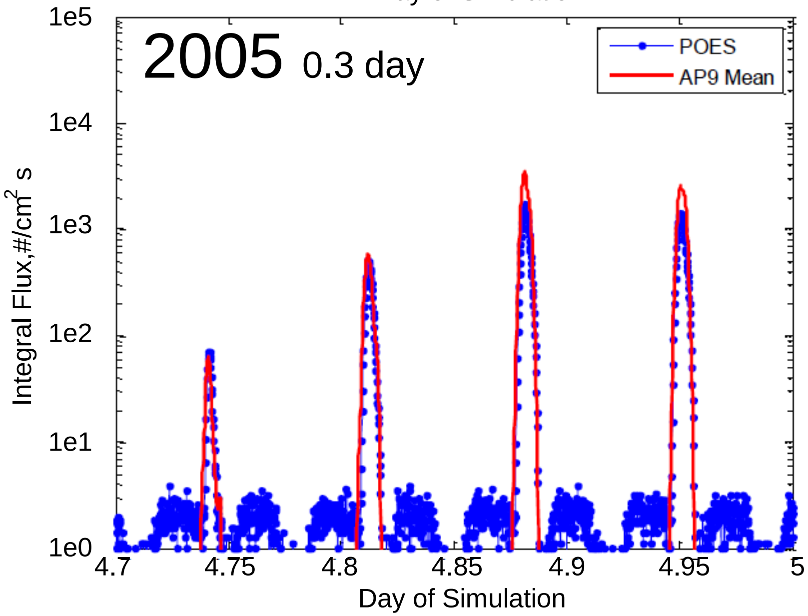


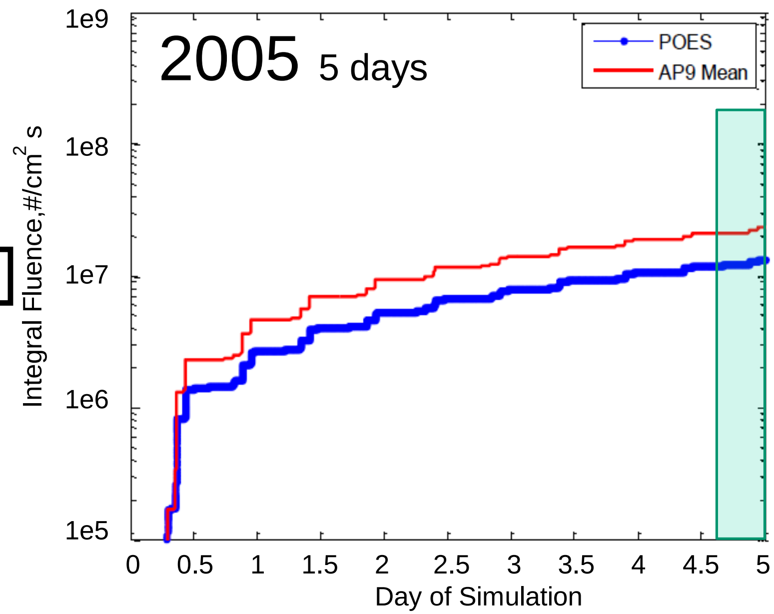
January 1999/2005 AP9 Validation, POES (part IV)

> 140 MeV



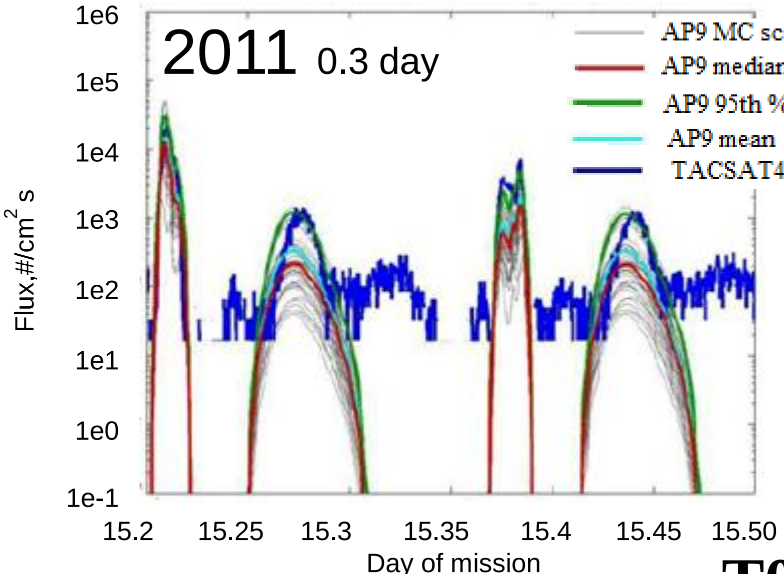


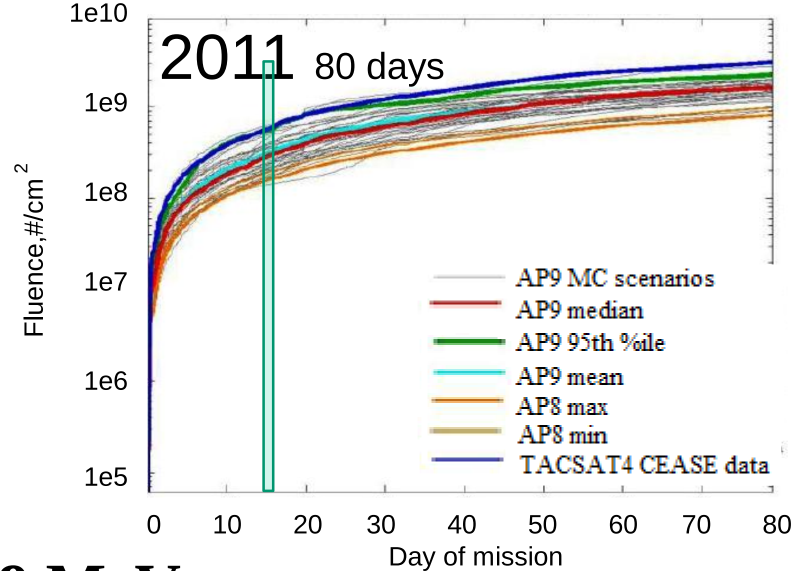




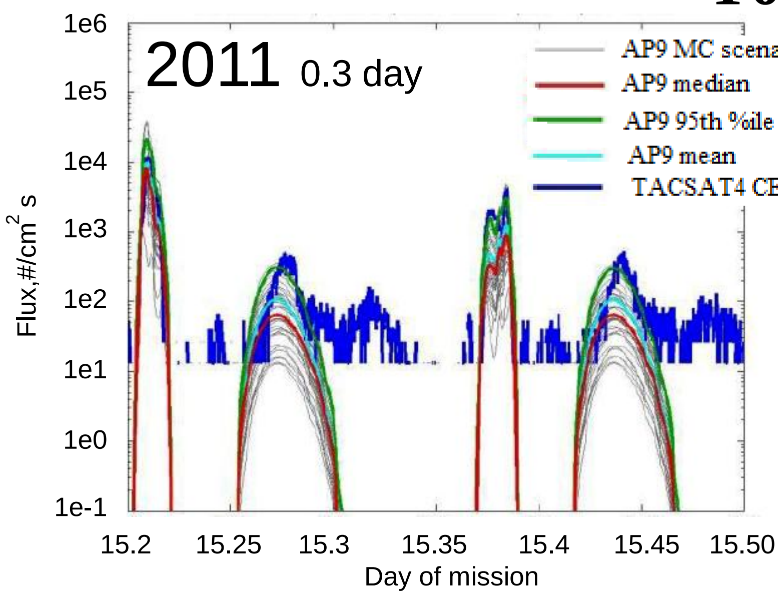
October 2011 AP9 Validation, TACSAT4 (part V)

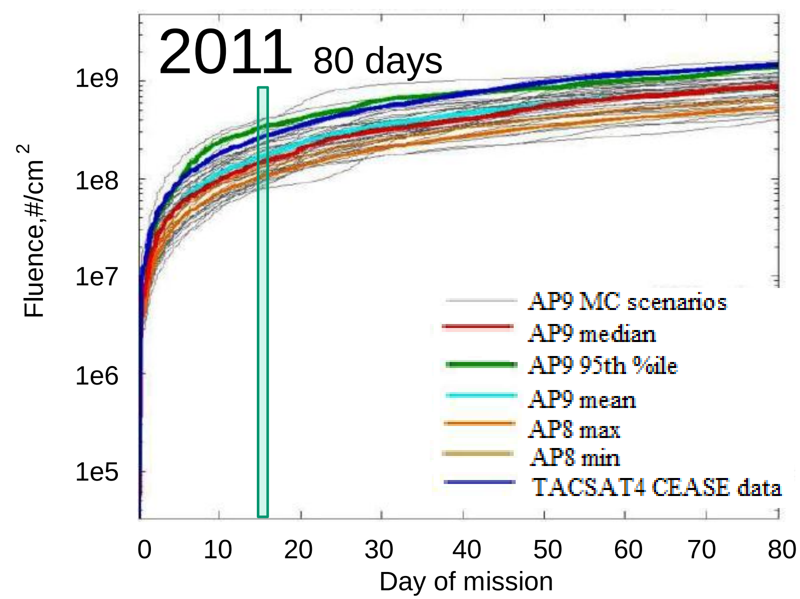
T09 > 43.7 MeV





T08 > 71.9 MeV





AP9 (PM/MC) Run Times

Transit Trajectory - Crew1out to 50,000 km			123 orbit positions
	Perturbed Mean	Monte Carlo	
10	1.763	2.005	
50	4.532	5.585	
100	7.77	10.063	
250	17.652	23.28	
500	35.757	47.814	
999	66.618	89.445	

1 Day - ISS Orbit			1440 orbit positions
	Perturbed Mean	Monte Carlo	
10	16.092	17.269	
50	41.857	45.414	
100	73.495	80.682	
250	168.289	186.369	
500	327.021	362.435	
999	643.048	714.52	

Summary and Current/Future Works

- Using IRENE (SPENVIS) version of AE9/AP/SPM, I discussed:
  I. Deficiencies of AE8/AP8 model
  II. Plans for implementing AE9/AP9 model on SPENVIS-4 and SPENVIS-NG
  III. Statistical capabilities of AP9 model in **PM** and **MC** modes
  IV. For ISS, verification among AP8, AP9 and CRRES-proton models
  V. Validation of AP9 model using POES and TACSAT4 satellites measurements

- Current version (1.20, July 2014) not available on SPENVIS yet
  I. Updated flux maps for electrons/protons
  II. Partial inclusion of data from Van Allen twin satellites to:
     I. Study GeV protons using relativistic proton spectrometer (RPS) measurements
     II. Separate temporal/spatial anomalies

- On going work to release Version 2 of AE9/AP9/SPM (2015 ???)