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What to Expect in AE9/AP9/SPM V1.50

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Changes in AE9/AP9 V1.5

- AP9 and AE9: new data from NASA's Van Allen Probes mission
- AP9: data added from Azur and TWINS 2
- AP9 and AE9: other revisions to flux maps (addressing gradients and other aspects of data set merging)
- Limited feature changes with this release—most significant will be changes to accumulators (next briefing)

satellite	orbit	time period	instrument	species	energy
Van Allen Probes A & B	GTO (800 x 30600 km, 10°)	Aug 2012 – Dec 2016	RPS (Relativistic Proton Spectrometer)	protons	>58 MeV -- ~2 GeV
			REPT (Relativistic Electron Proton Telescope)	protons	20 – 100 MeV
				electrons	1.5 – 30 MeV
			MagEIS	electrons	30 keV – 7 MeV
Azur	384 x 3145 km, 103°	Nov 1969 – Mar 1970	EI-88 telescope	protons	1.5 – 104 MeV
TWINS 2	Molniya (1000 x 39500 km, 63°)	Apr 2008 – Nov 2016	HiLET	protons	6 – 30 MeV

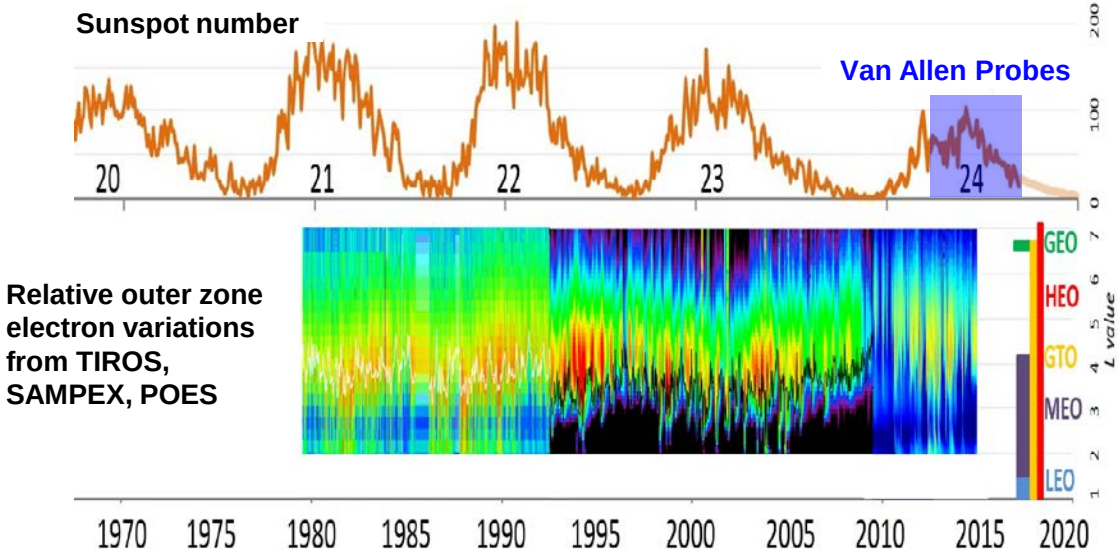
What AE9/AP9 does

- AE9/AP9 is a statistical climatological model
  - Its statistics address both measurement uncertainty and environment variability
- Most legacy models were static lookup tables of mean flux (compare to mean mode of AE9/AP9)

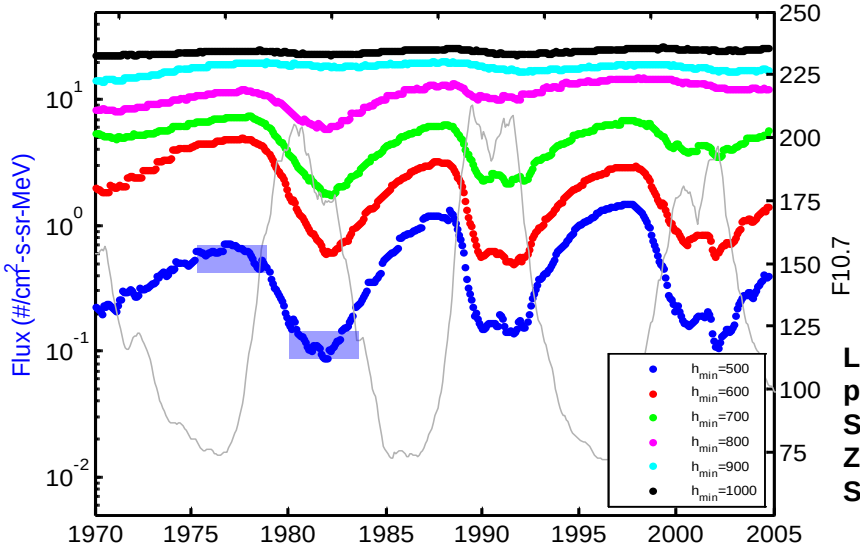
- Individual Monte Carlo scenarios in AE9/AP9 vary over time with perturbations reflecting both measurement uncertainty and climate variation
- Statistics from many MC scenarios thus give data-based confidence intervals

What AE9/AP9 doesn't do

- AE9/AP9 does not vary with solar cycle phase—instead, the confidence intervals span the range of solar cycle states
  - It won't provide results for a selected solar cycle state
  - It probably won't match a data set from a portion of a solar cycle
  - A given quality data set should lie within the range of AE9/AP9 statistics
- Legacy AE8/AP8 give a static answer for each of available activity levels—e.g. AP8 Min/Max



Relative outer zone electron variations from TIROS, SAMPEX, POES

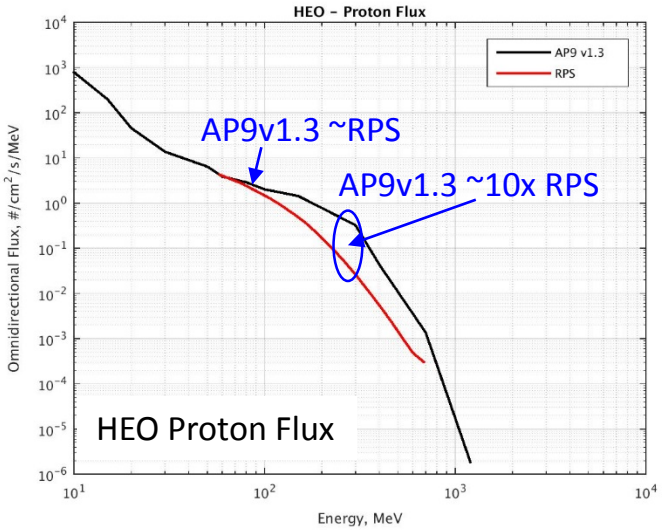


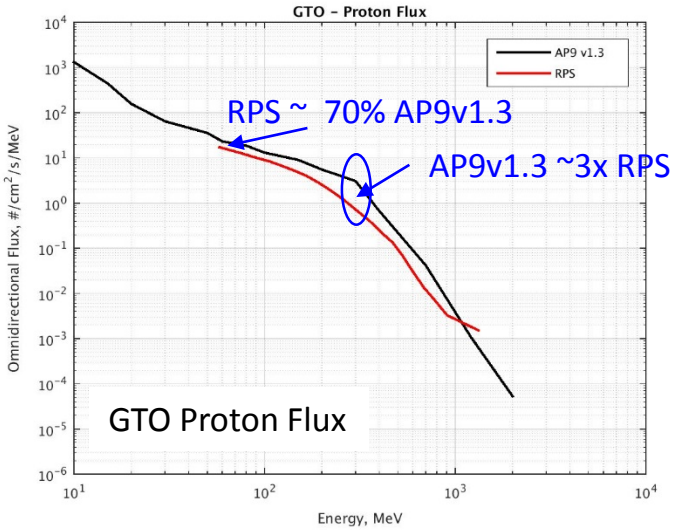
LEO 100 MeV protons from Selesnick Inner Zone Model (R. Selesnick, AFRL)

Issues and Limitations

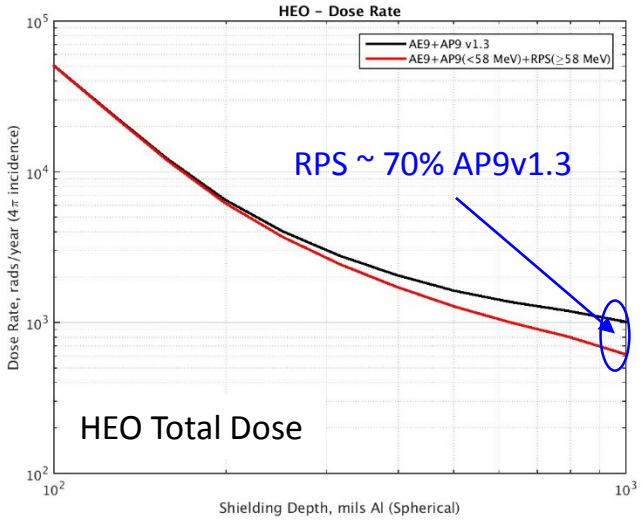
model/ regime	issue	expected improvements in V1.5
AP9 in LEO, inner zone	Large uncertainties for E>~100 MeV, leading to unrealistically large margins	Expected to be significantly addressed by including RPS data
AP9 and AE9 in LEO	Significant uncertainties in particle flux gradients for altitudes <800 km	Should be improved in V1.5 with additional data and with modified templates to address gradients in merged flux maps; further improvement should come with solar cycle dependence of LEO protons in V2.0
AP9 in LEO	Large uncertainties for E<20 MeV due to variability in satellite sensor data and sparse data coverage	Some improvement expected from inclusion of Azur and TWINS 2 data
AE9 in LEO, inner zone	Large uncertainties for all energies due to lack of observations uncontaminated by protons; Van Allen Probes have seen long periods with no electrons with E>700 keV, and past measurements are ambiguous	Unknown if state during Van Allen mission is temporary or nominal; addition of Van Allen data should reduce median
AE9 in GEO	Fluxes are higher than IGE-2006 despite both models using LANL data	May be a difference in LANL data set versions used or a difference in intercalibrations; will seek to resolve by V1.5
AE9 and AP9, all regimes	No solar cycle dependence, particularly relevant to LEO protons and outer zone electrons; statistics span solar cycle states but a particular state can't be queried	Will not be addressed in V1.5, although some data sets such as Azur should improve the range of solar cycle states represented; plan to address in V2.0 with solar cycle modulation of LEO protons and with the sample solar cycle

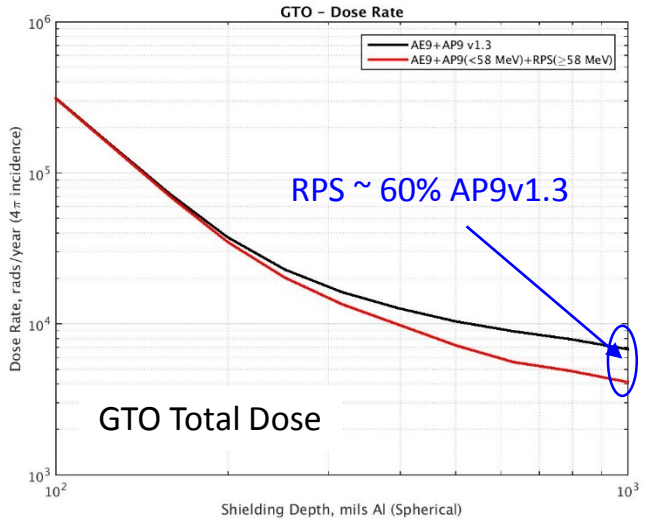
RPS at HEO and GTO



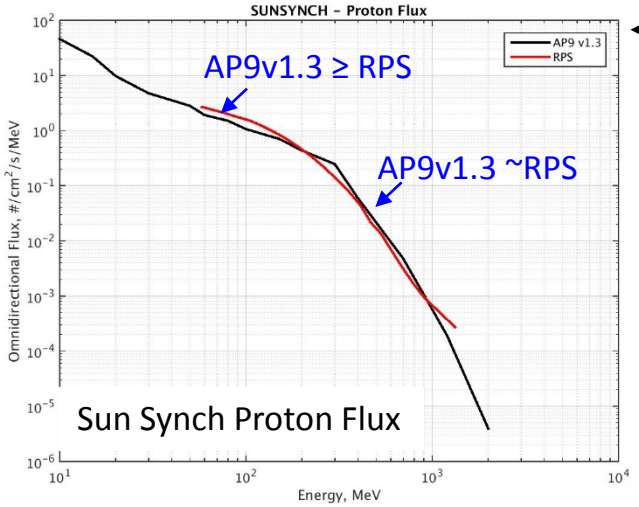


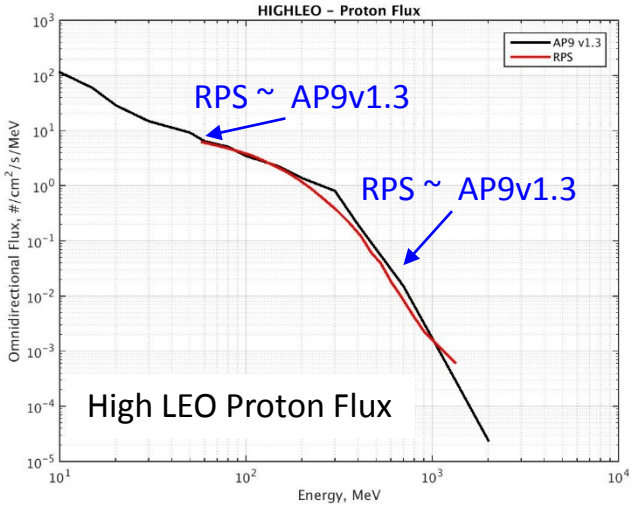
- HEO and GTO show large discrepancies at >200 MeV
- RPS is lower than AP9 by ~10x
- Relatively better agreement at 60-100 MeV seems to determine dose outcome at thick depths (~1 inch)



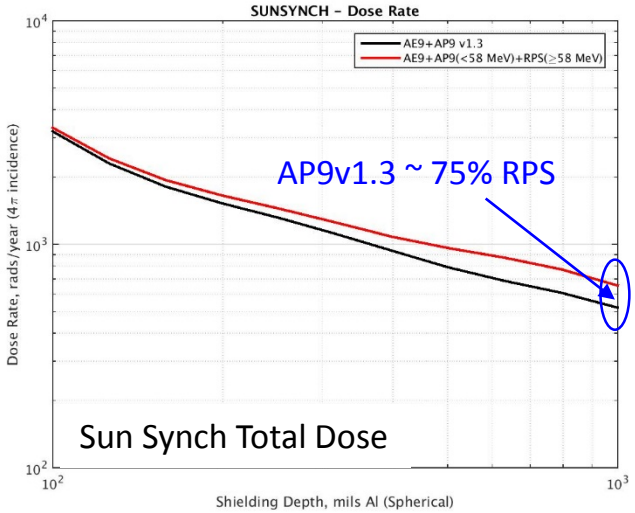


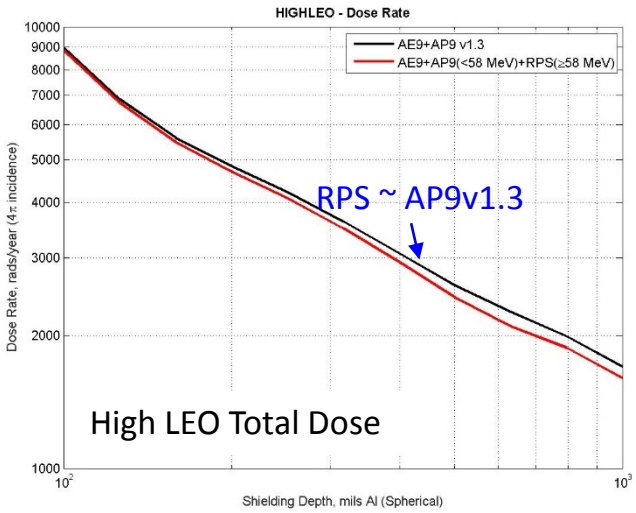
RPS at LEO





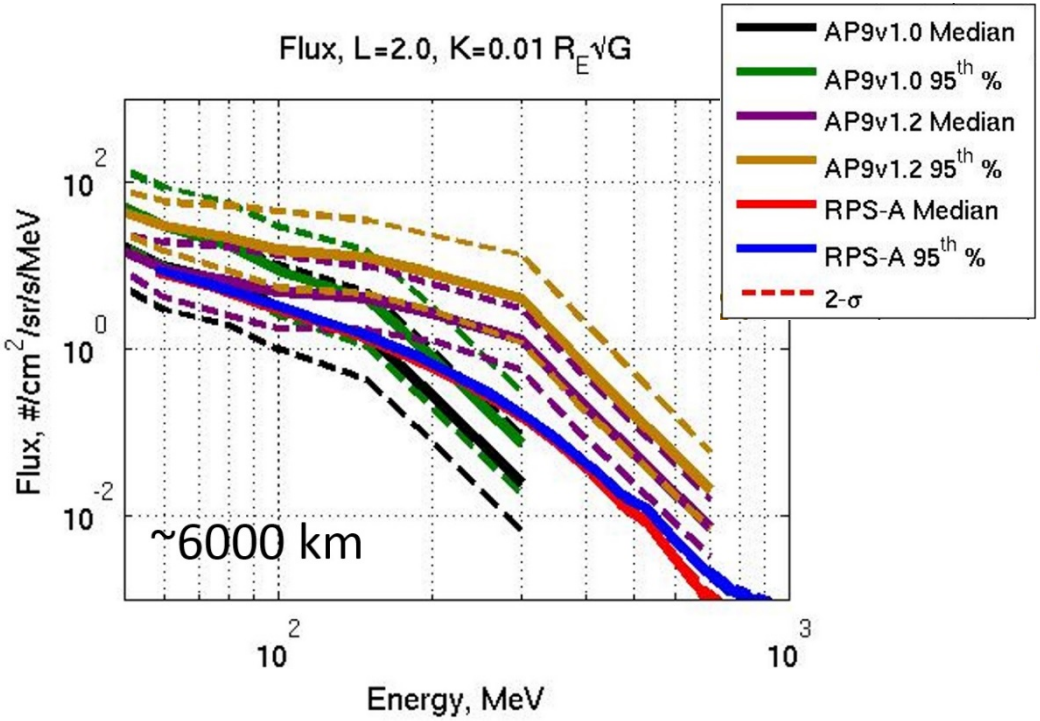
- **For Sun Synch LEO (800 km)**
  - RPS flux is slightly higher than AP9 up to 200 MeV
  - AP9 dose is about 25% less than RPS

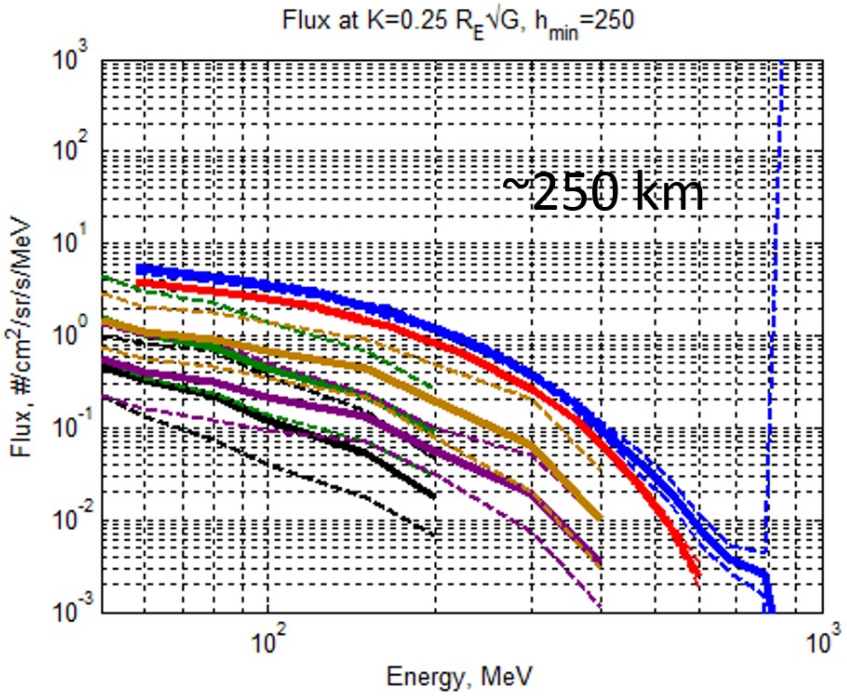




- **For High LEO (1000 km x 60º) RPS and AP9 are in good agreement for flux and dose**

RPS Energy Spectra at MEO, LEO



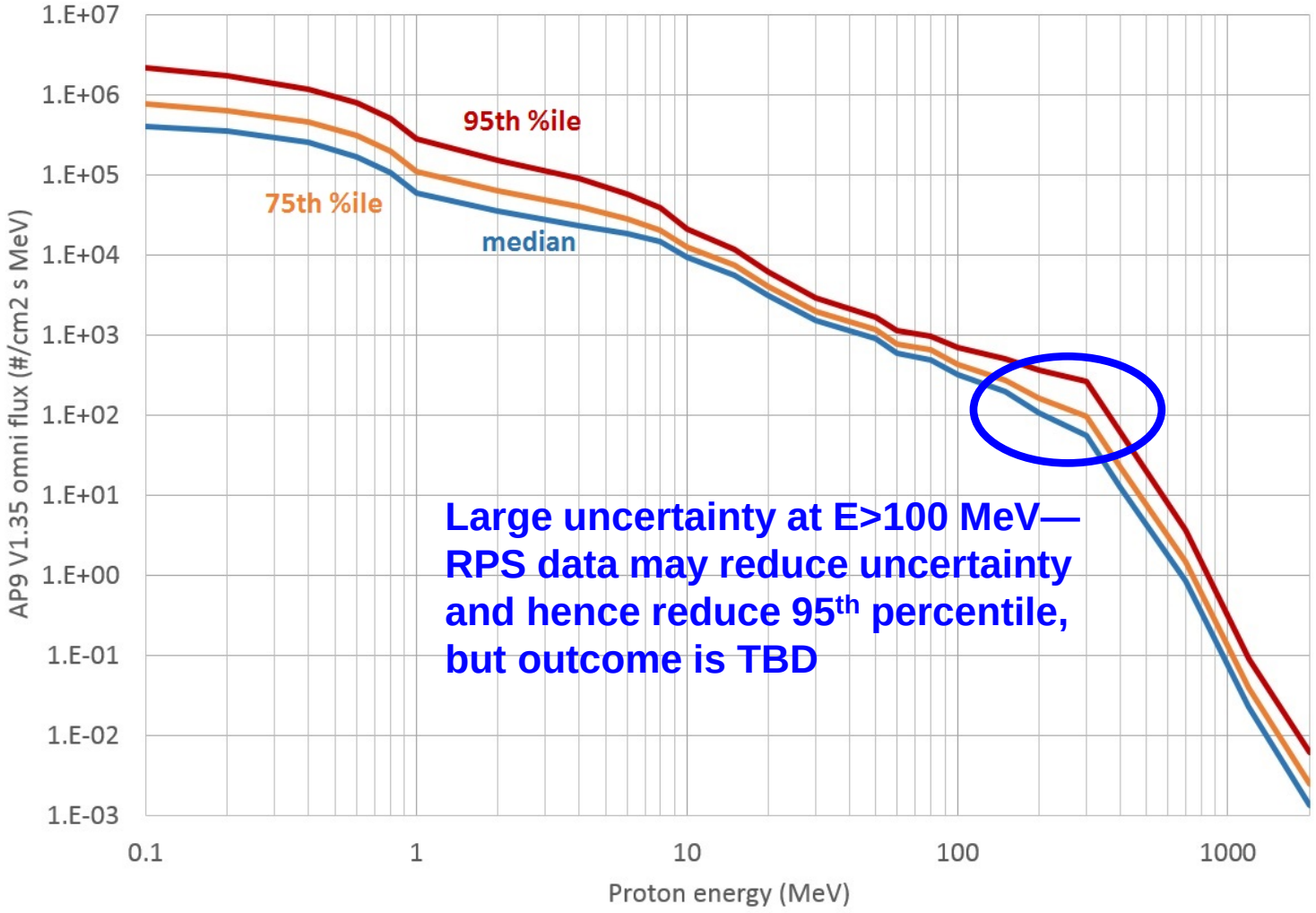


- Four energy spectra are shown for particles near the magnetic equator at different altitudes
- RPS data are in BLUE
- AP9v1.0 curves are in BLACK and GREEN
- AP9v1.2 curves are in PURPLE and BROWN
- RPS are nearly always lower than AP9v1.0 and AP9v1.2
- AP9v1.5 will likely be lower in some MEO locations, higher in lowest altitude LEO locations

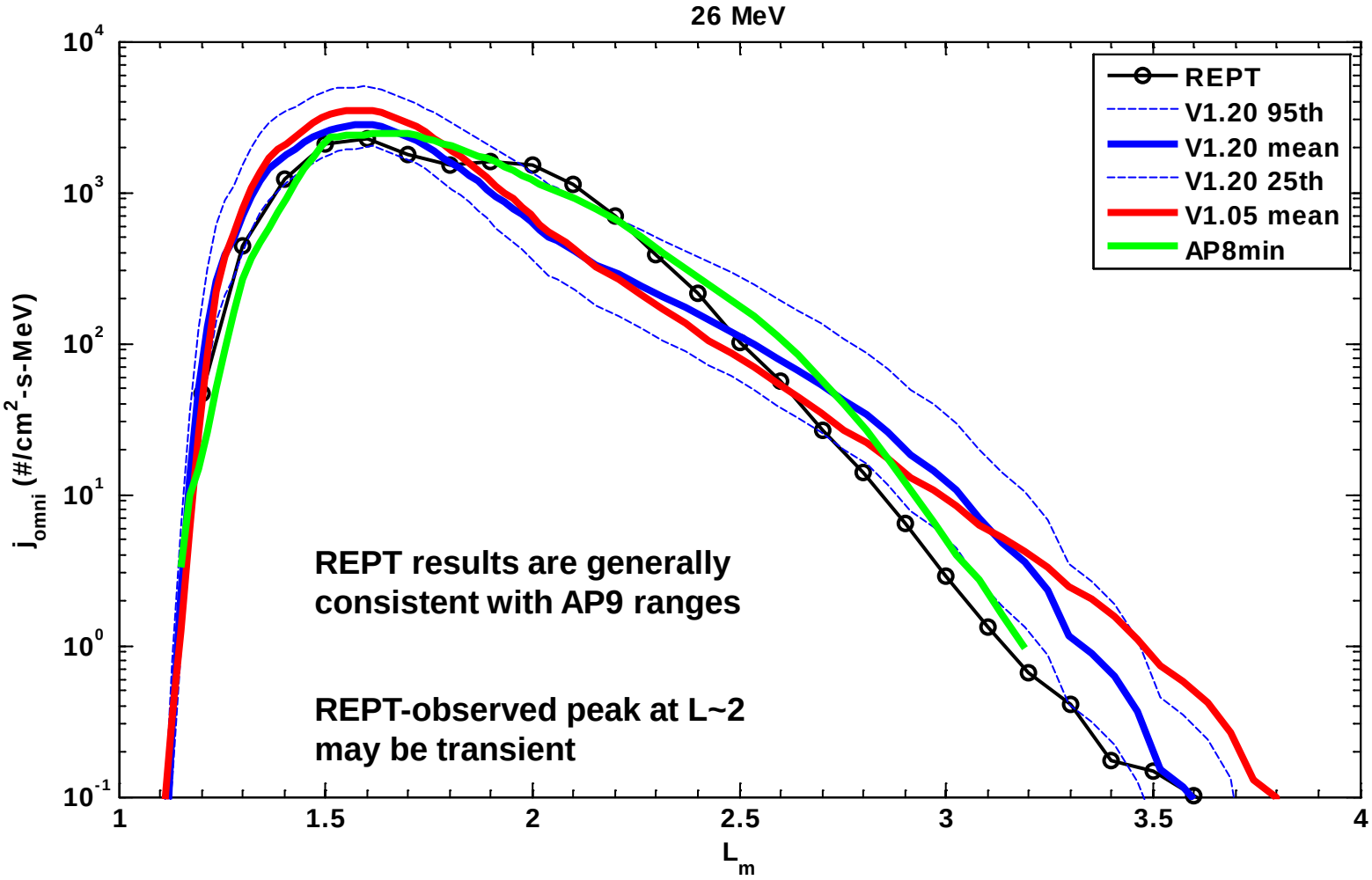
RPS Summary

- The addition of RPS data to AP9 v1.5 will change the inner zone >58 MeV
- High altitude orbits traversing the inner zone will see lower fluxes (particularly at >100 MeV) but only slightly less dose
- However, LEO fluxes <1000 km will go up, especially at very low altitudes (100 km)
- Changes in proton fluxes at ~60 MeV from AP9 v1.3 to RPS will dominate the changes in the dose depth curve
- Dose depth curve changes will be modest: ±30-40% at ~1 inch
- Model uncertainties and dynamics will drop substantially (see backups), possibly bringing down the 95% confidence level doses by larger amounts (TBD)

AP9 V1.3 Energy Spectra at 3000 km Equatorial

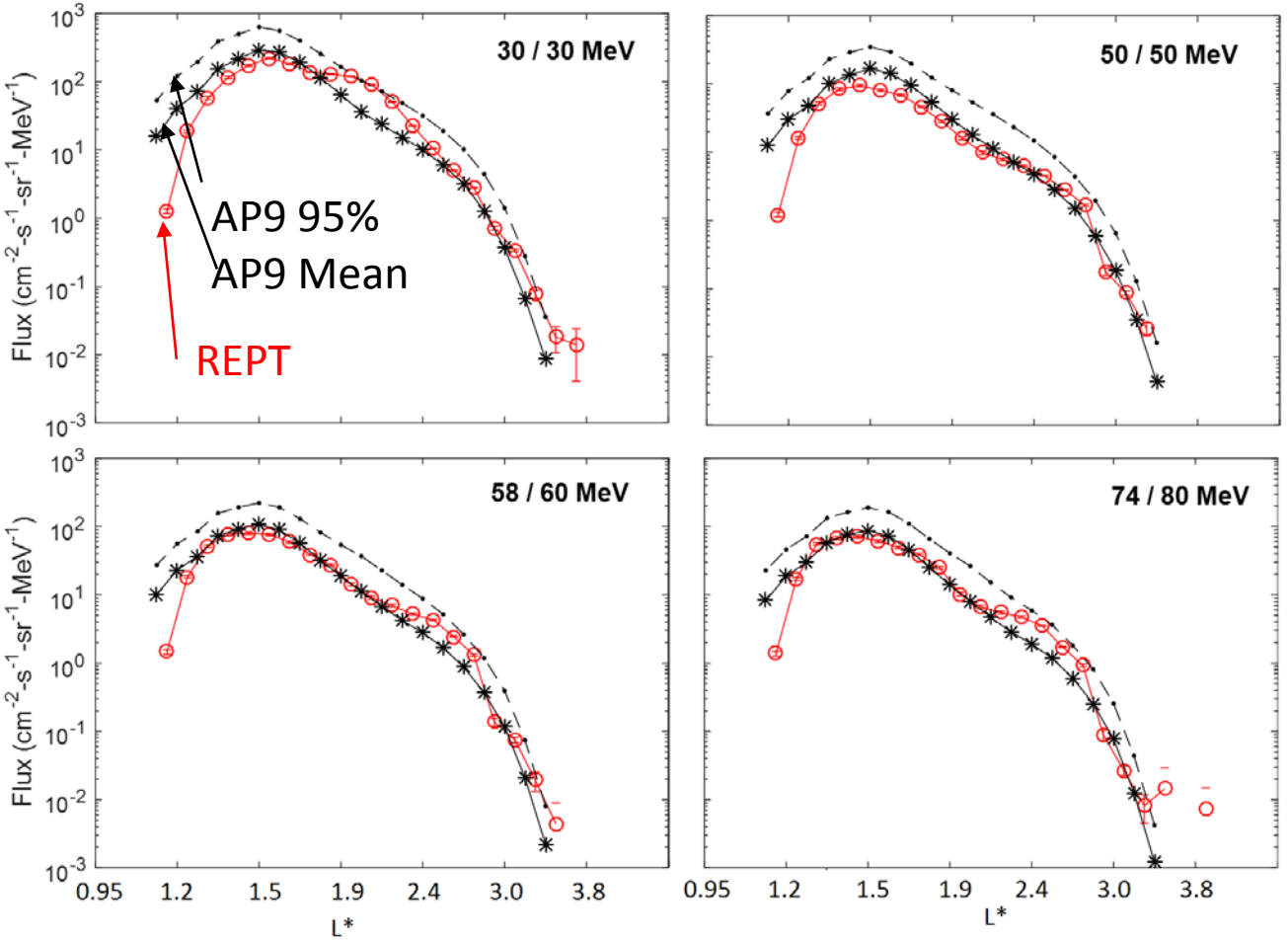


REPT Protons (26 MeV)



REPT Protons (30-80 MeV)

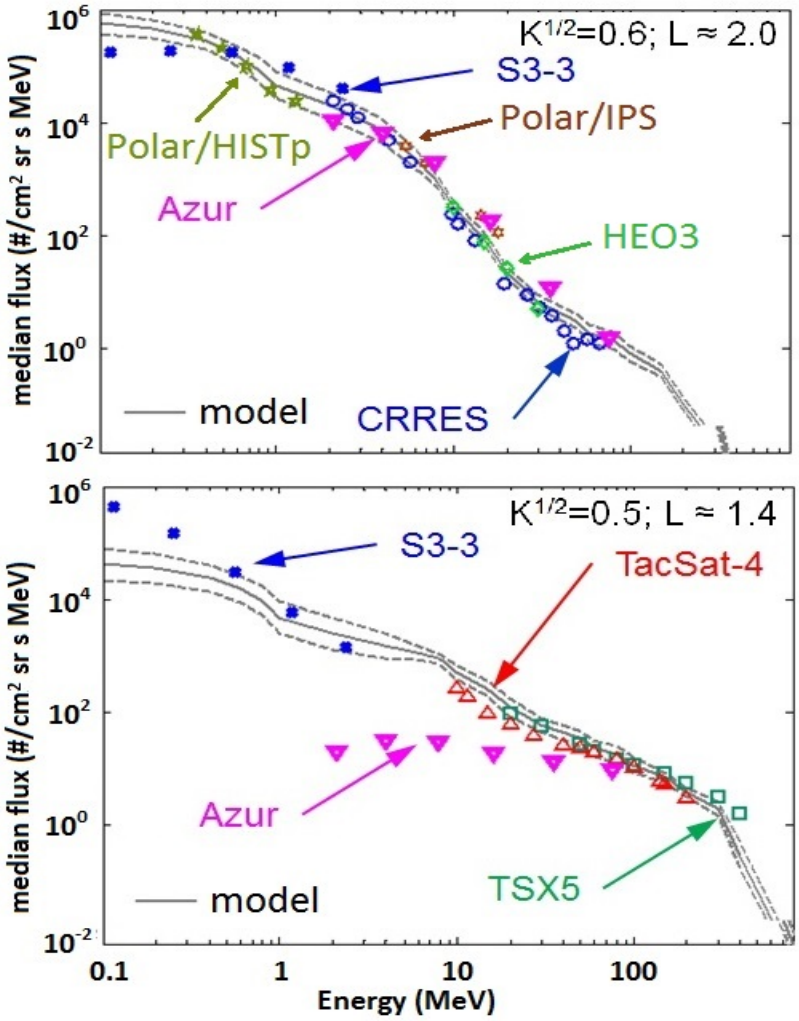
Jan 2015 (no SPE)



Possible transient peaks in REPT data at L*=1.9-2.5

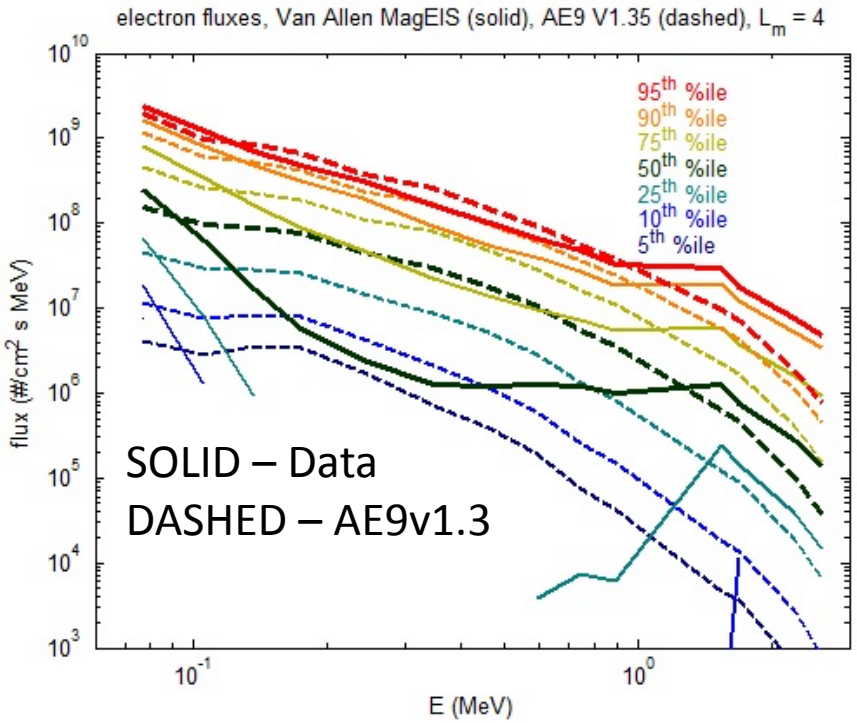
REPT results generally consistent with AP9 V1.3

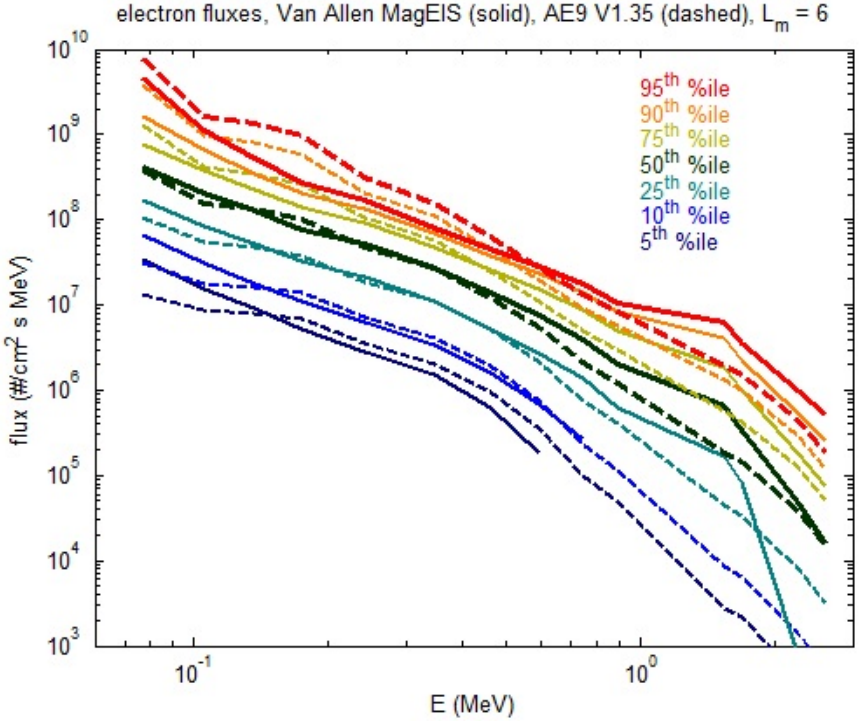
Azur Protons



- Review by ESA showed discrepancies among AP9, AP8, and data (including Azur)
- We extensively reviewed this issue, concluding:
  - Data currently in AP9 are reliable
  - AP9 model accurately represents these data sets
  - Azur data are also reliable
  - Most likely explanation: Azur represents a different climatological state than other data
  - Azur is ~4 months of data near solar max—used in developing AP8 MAX
  - We expect that inclusion of Azur data will decrease AP9 fluxes and increase error bars

MagEIS electrons



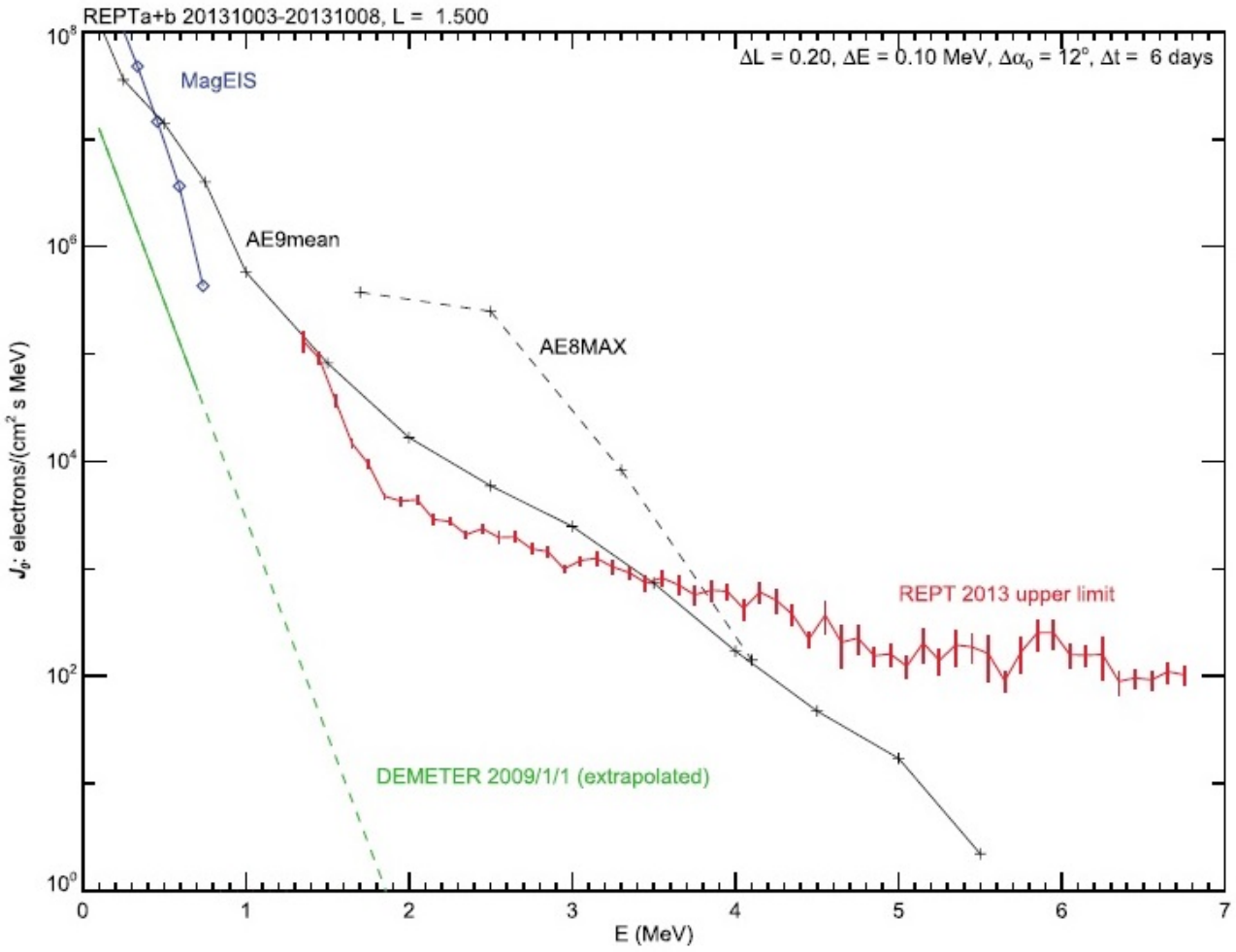


- At largest L values (L~6), MagEIS climatology is similar to AE9
- MagEIS fluxes are lower at L~4 for E=100s of keV
  - This is likely due to lower-than-average activity state during Van Allen mission
- Impact of MagEIS data on AE9 is TBD due to complexities of merging electron data sets

REPT Inner Zone Electrons

- Electron spectra at L=1.5 at the equator (from Li et al, 2015, JGR, A020777)

- REPT upper bounds on inner zone electrons in red (likely proton contamination)
- REPT bounds for E~1-3 MeV are lower than AE9 V1.2 mean
- Unknown if current state is typical (note that solar cycle 24 is the weakest of the space age)
- More recent MagEIS results report elevated electrons at E~1-2 MeV



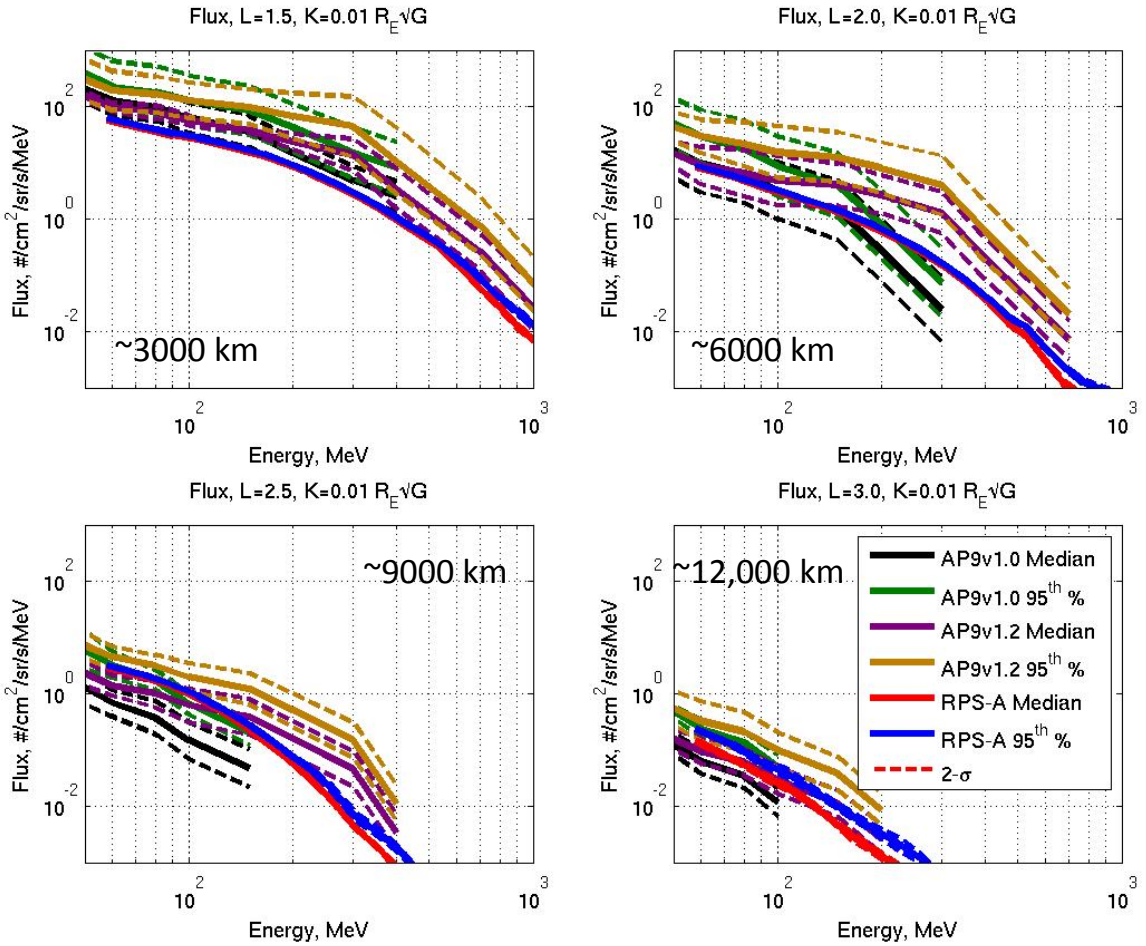
Summary

- **AE9/AP9 V1.5 will add new electron and proton data sets from Van Allen Probes, plus new proton data sets from Azur and TWINS 2**
- **Preliminary comparisons of new data to the existing model are presented as an indication of what changes may result:**
  - At E>100 MeV, RPS data will likely lead to lower HEO fluxes, higher LEO fluxes, and possibly lower 95th percentile confidence levels (from reduced uncertainty)
  - RPS data-based changes to dose depth curve will likely be modest, e.g. 30-40% at 1 inch Al
  - REPT data will likely produce little change for protons 25-100 MeV
  - Azur data may slightly lower the median and expand confidence limits for LEO protons of E<20 MeV
  - REPT electron data may lower median electron fluxes in the inner zone for E>0.7 MeV
  - MagEIS electron data impact is TBD
- **Ultimately, changes will reflect both the inclusion of the new data as well as the information they bring to bear on aspects of the data-to-flux map merging process**

Backups

RPS Energy Spectra at MEO

- Four energy spectra are shown for particles near the magnetic equator at different altitudes
- RPS data are in BLUE
- AP9v1.0 curves are in BLACK and GREEN
- AP9v1.2 curves are in PURPLE and BROWN
- RPS are nearly always lower than AP9v1.0 and AP9v1.2
- We expect AP9v1.5 will be lower by ~10x in many places



RPS Energy Spectra at LEO

- Four energy spectra are shown for particles in the South Atlantic Anomaly
- RPS data are in BLUE
- AP9v1.0 curves are in BLACK and GREEN
- AP9v1.2 curves are in PURPLE and BROWN
- The model is slightly high for ~1000 km
- As the altitude goes lower, RPS data are progressively higher than the model