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The AE9/AP9 Next Generation Radiation Specification Models – Progress Update

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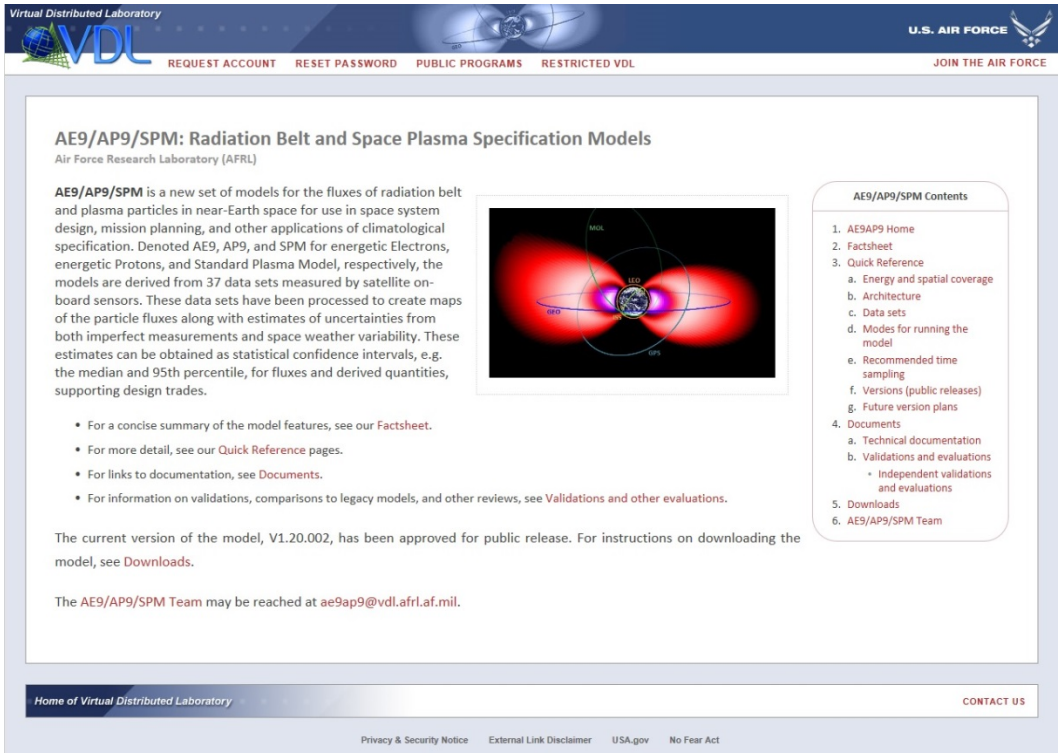
Outline

- **Version 1.20 – <u>Released</u>**
  - **Issues noted**
  - **Validation update**
- **Version 1.5 plans**
- **Version 2.0 plans**
- **Summary**

AE9/AP9 Website

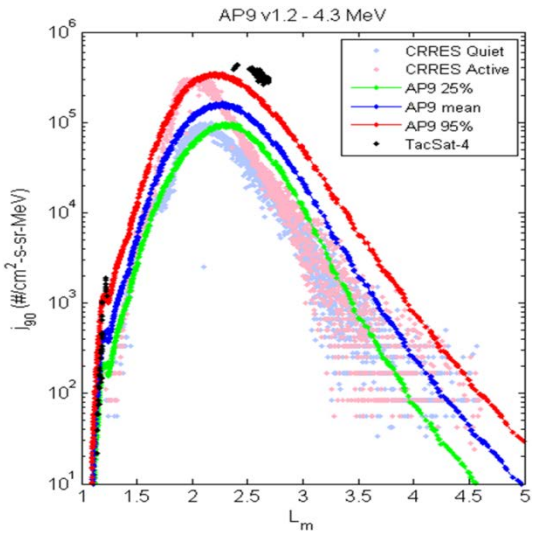
- We have launched a dedicated web site for the AE9/AP9 project hosted by AFRL's Virtual Distributed Laboratory: **https://www.vdl.afrl.af.mil/programs/ae9ap9**

- The latest version of the model may be downloaded from this site after creating an account
- Summaries and model documentation are also available (no account needed)
- Future news and releases will be announced through the website

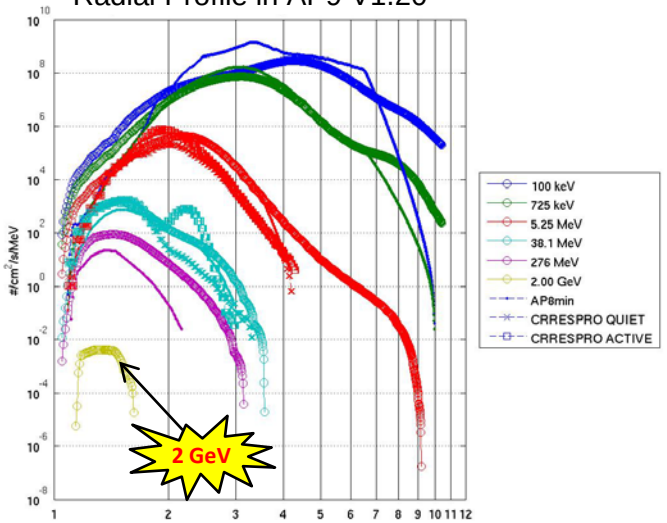


Version 1.20 – Database Updates

- **New data set (first new data to be added):**
  - **TacSat-4/CEASE proton data—captures new observations of elevated 1-10 MeV protons**
  - **Additional plasma data: THEMIS/ESA**
- **New electron templates**
  - **Improvements for inner zone electrons and for >3 MeV spectra**
- **New proton templates**
  - **Incorporate E/K/Φ and E/K/h_{min} profiles observed by RBSP/Relativistic Proton Spectrometer**
  - **Extend proton energies to 2 GeV**
- **Low altitude taper**
  - **Force fast fall-off of flux for h_{min} < 100 km.**
  - **Cleans up radial scalloping at altitudes below ~1000 km**



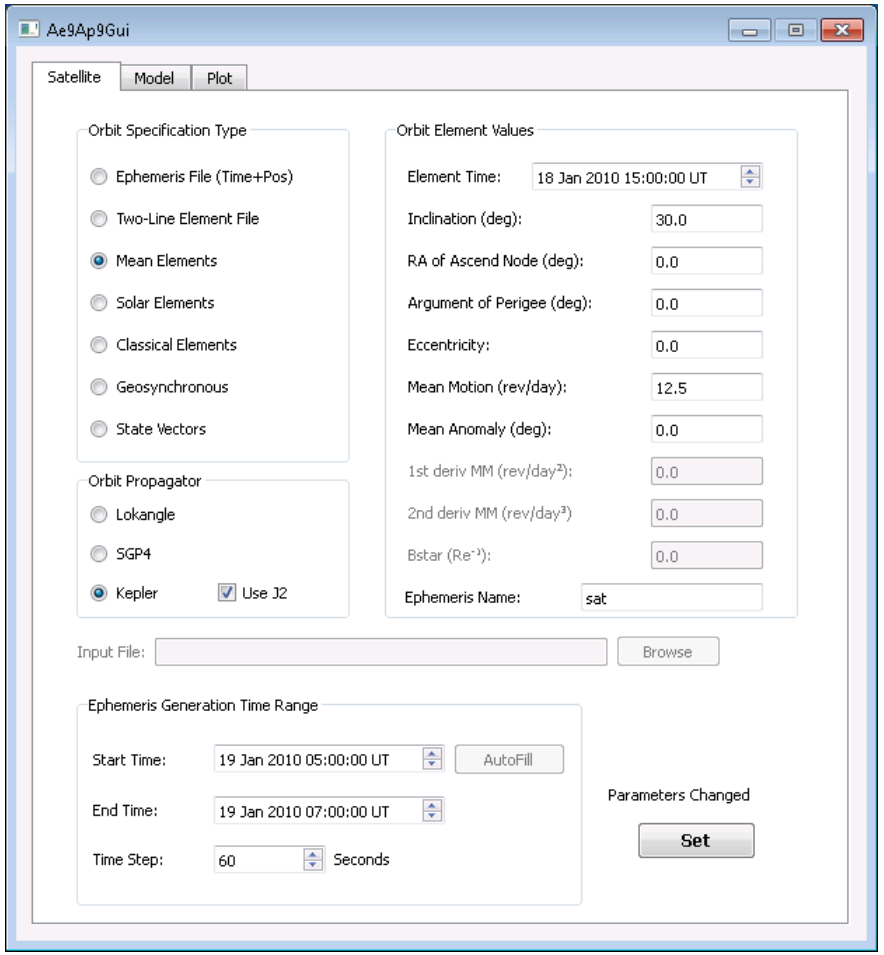
Radial Profile in AP9 V1.20



Radial Distance along +X MAG

Version 1.20 – Software Updates

- **Feature improvements**
  - **More options for orbit element input and coordinates**
  - **Third party developers guide (available now)**
  - **Pitch angle tool—make internal pitch angle calculations accessible to users**
  - **Easy extraction of adiabatic invariant coordinates**
  - **Improved error messages**



Issues Noted

Issues identified by D. Heynderickx in V1.05 *

model/ regime	issue	assessment
AP9 in LEO	SAA is too big/has wrong shape (fluxes do not fall off fast enough at SAA edges)	Known V1.05 issue, has been significantly addressed in V1.20
AP9 in LEO	Fluxes are higher than Azur data for E≤10 MeV; altitude gradients are different	Azur data is lower than other data sets, particularly S3-3 at these energies; don't yet know if this is climatological or instrumental
AP9 in LEO	Energy spectra is more like a power law, not an exponential as in AP8 and data sets	AP9 template spectra are exponential; spectra in given flux map bins may be power law or exponential; still investigating
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; still investigating

** Not a comprehensive list—these were selected as more significant issues, other reported issues will be checked as well*

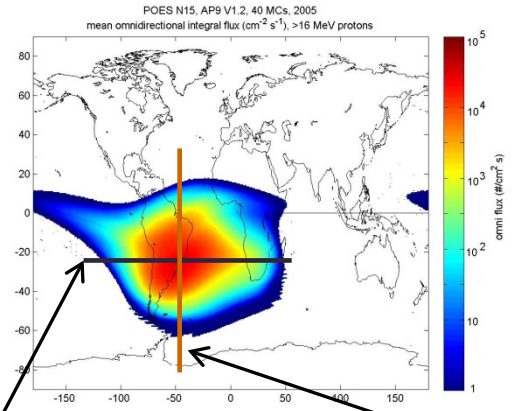
Issue identified by AE9/AP9 team in V1.05/V1.20

AP9 in LEO	Artifacts of localized high flux "stripes" near the SAA at low altitude (≤400 km)	Caused by K-Phi grid underlap of K-hmin grid; Fixed in V1.20.002

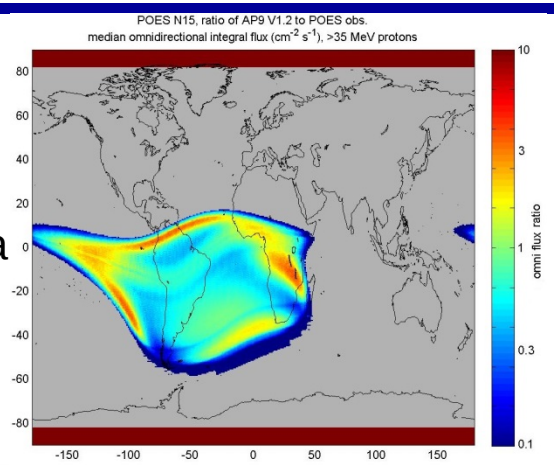
AP9 V1.20 Validation—SAA

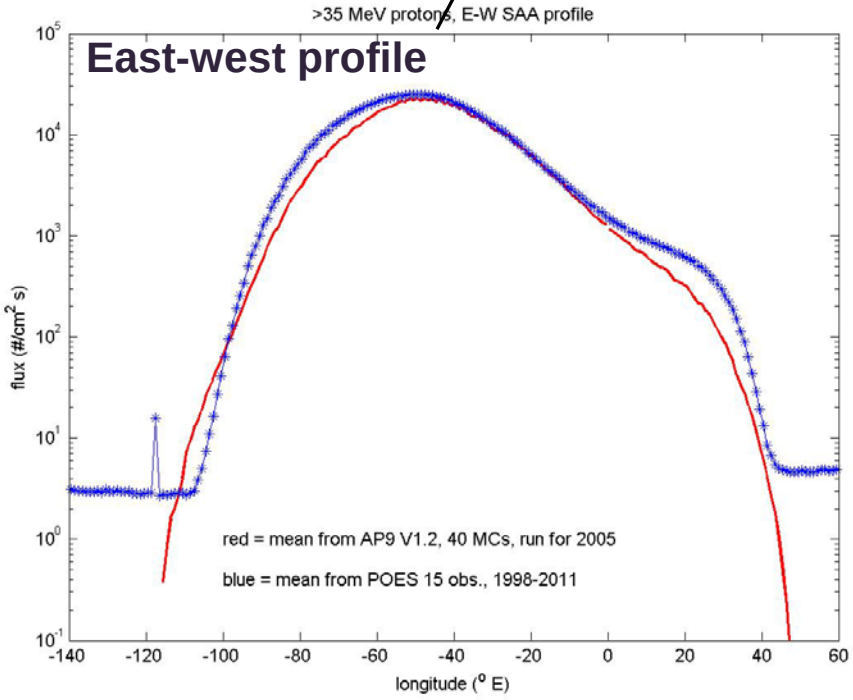
>35 MeV protons

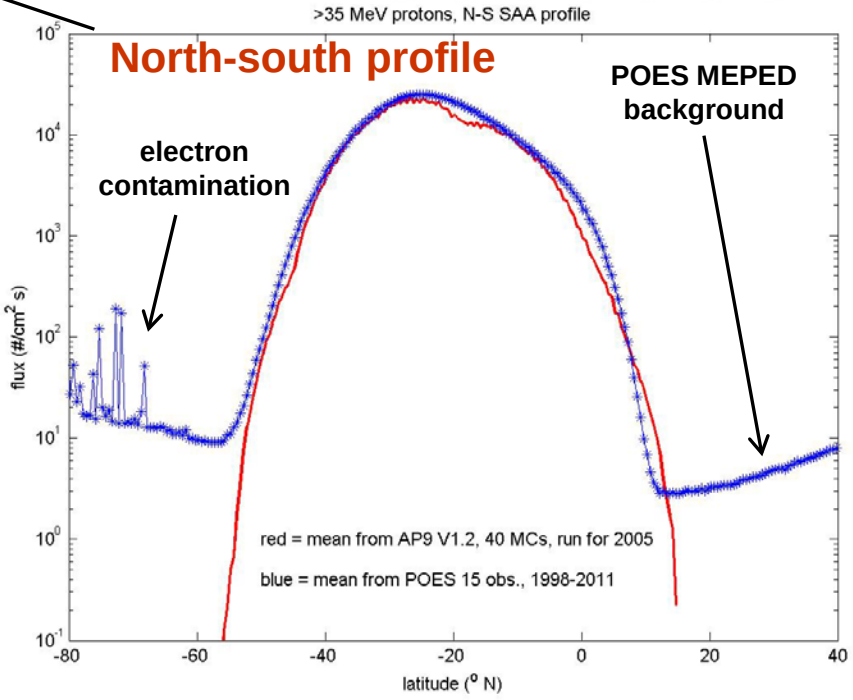
SAA flux profiles are improved in V1.20 as compared to POES observations



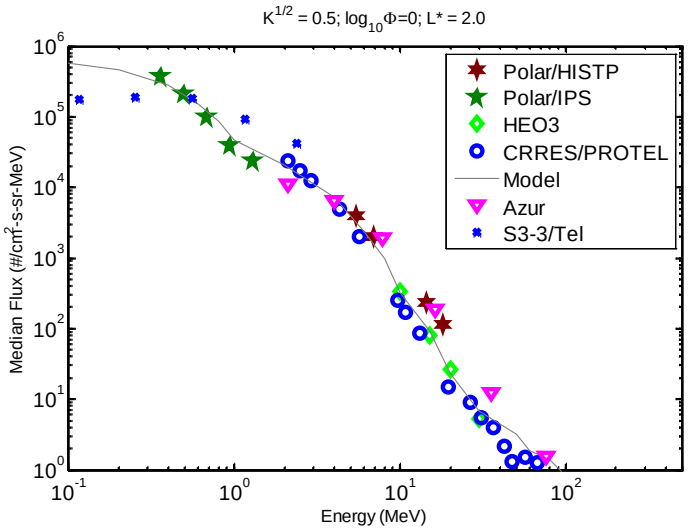
Ratio of AP9 V1.20 median to POES data



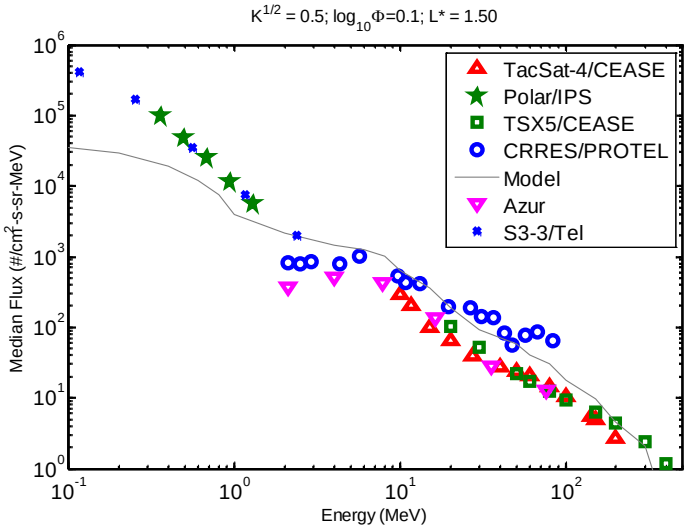


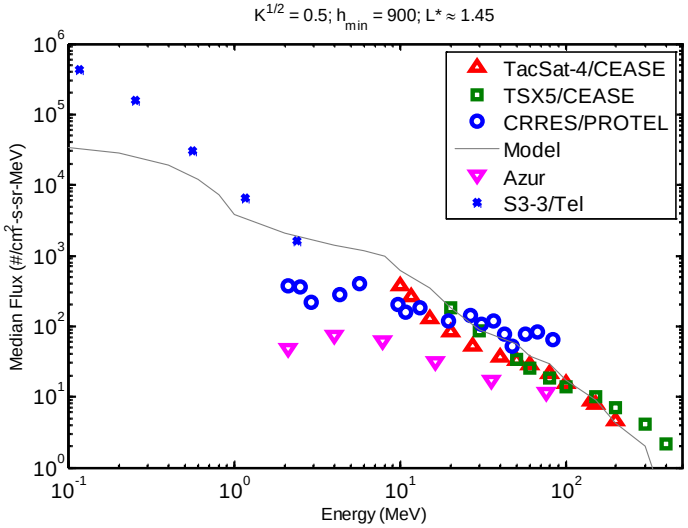


AP9 LEO Issue

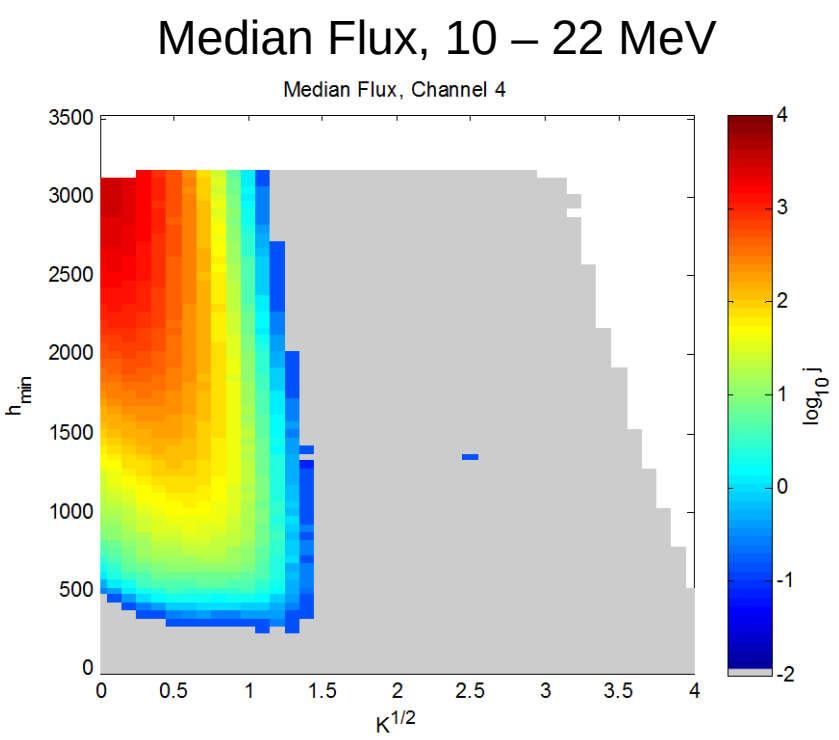


- **AP9 V1.20 combines many data sets: Polar, HEO, CRRES, S3-3**
- **S3-3, Polar not used in LEO**
- **AZUR data not used (yet)**
- **Depending on where you look, data sets agree or disagree**
- **Spread of data typically increases as L decreases**
- **The model typically splits the difference**





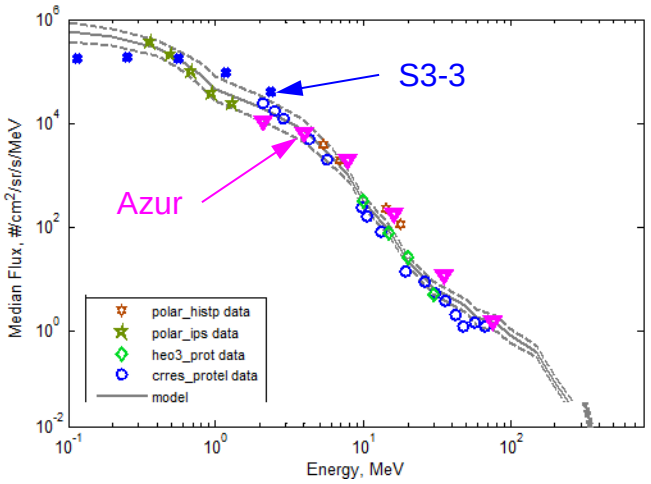
Azur Proton Data



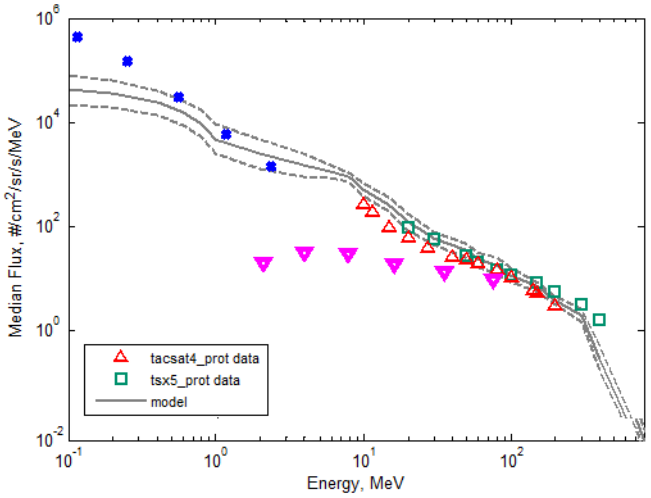
- Azur data provided by ESA
- High quality data set; 1.5 – 104 MeV in 6 channels
- Data will be incorporated in AP9 V1.50
- Data also being used to develop templates for future versions

AP9 Validation in LEO

$K^{1/2}$=0.6; L ≈ 2.0



$K^{1/2}$=0.5; L ≈ 1.4



- Review by ESA showed discrepancies among AP9, AP8, and data (including Azur)
- Extensive review by team:
  - We trust data currently in AP9
  - AP9 model accurately represents these data sets
  - We also trust Azur data
  - Most likely explanation: Azur and S3-3 represent two different geophysical states
  - We expect that inclusion of Azur data will decrease AP9 fluxes and increase error bars
  - Need to explain discrepancies and natural variability

Spectral Shapes: AP8 & Older Data

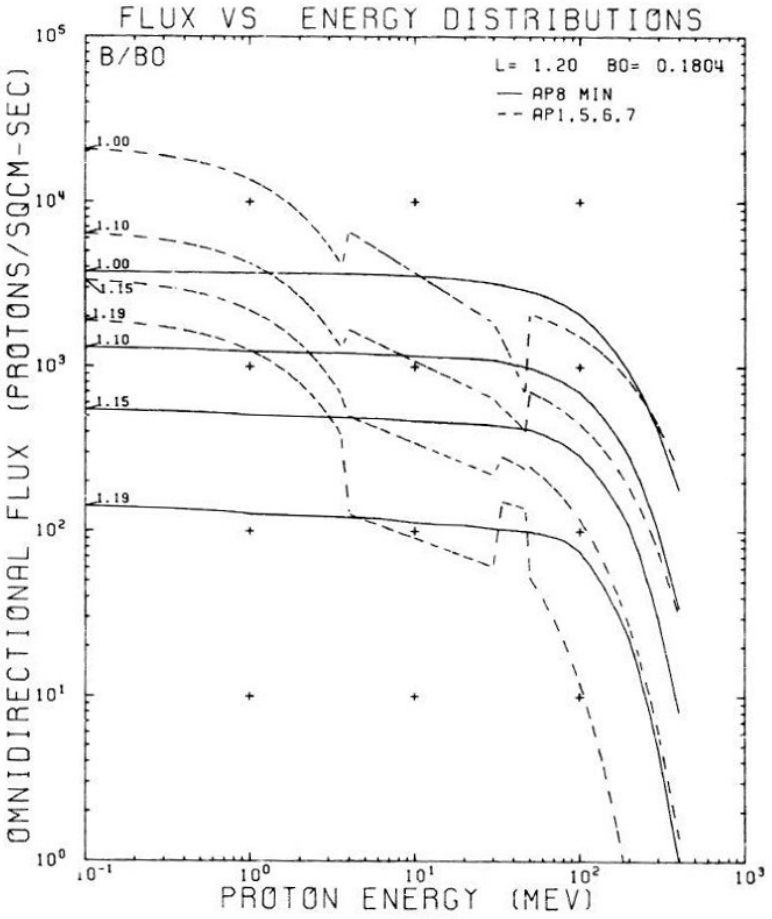
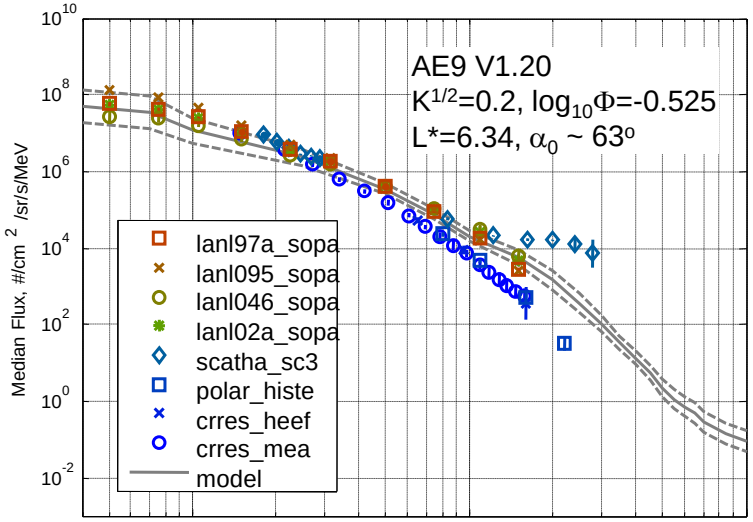


Figure 144. AP8MIN and AP-1, -5, -6, and -7 Flux vs Energy Comparison Plot for L = 1.20 R_E

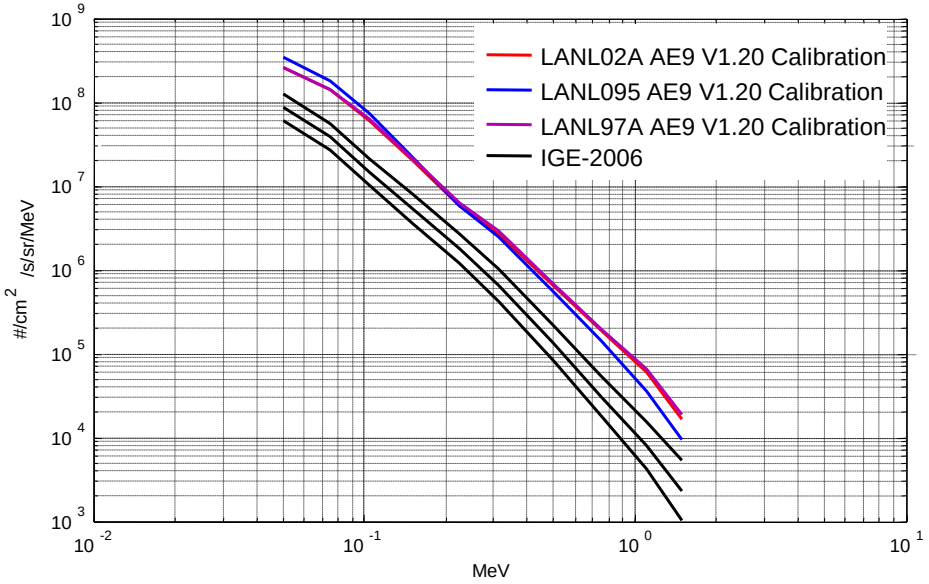
- **This plot from the AP8 report shows the evolution of model spectra at L = 1.2.**
- **Note that these are integral, omnidirectional fluxes.**
- **Early model AP-5 did have higher fluxes at lower energies.**
  - **AP-5 covered 0.1 – 4 MeV, assumed an exponential spectral shape (in integral flux).**
- **Relay 1 (1963) measured 3 MeV fluxes about 9 x Azur (1970) at L ≈ 1.7.**
- **Vette probably modified the shape based on Injun 5 and Azur.**
- **This illustrates the uncertainty and difficulty in developing global models including many data sets and a large energy range.**

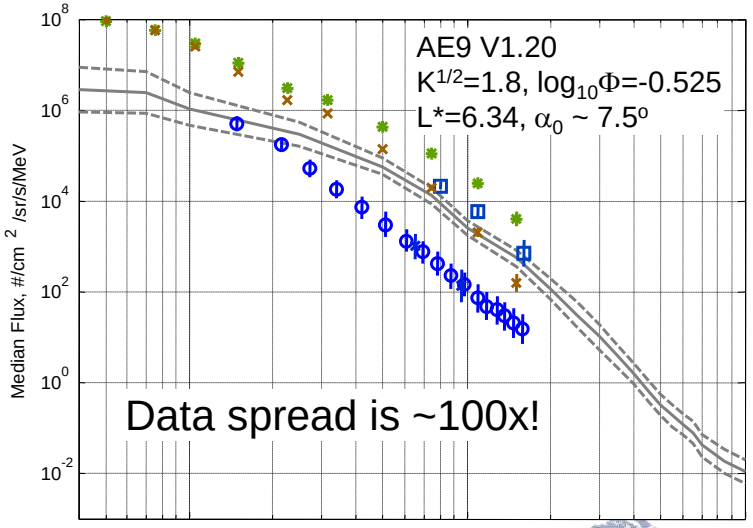
AE9 GEO Issue

- **AE9 is higher than IGE at GEO, looks like AE8**
- **One-year average of AE9 V1.20 calibrated LANL data are often well above IGE for same year**
- **All data were calibrated to CRRES MEA and HEEF**
- **In some K/L bins data spread is 100x across large energy range (typically larger K, lower pitch angle)**
- **It is not a simple calibration issue**

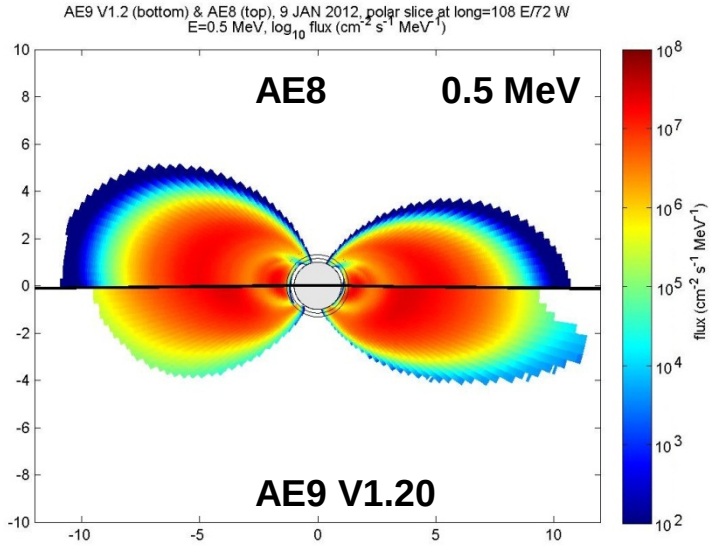


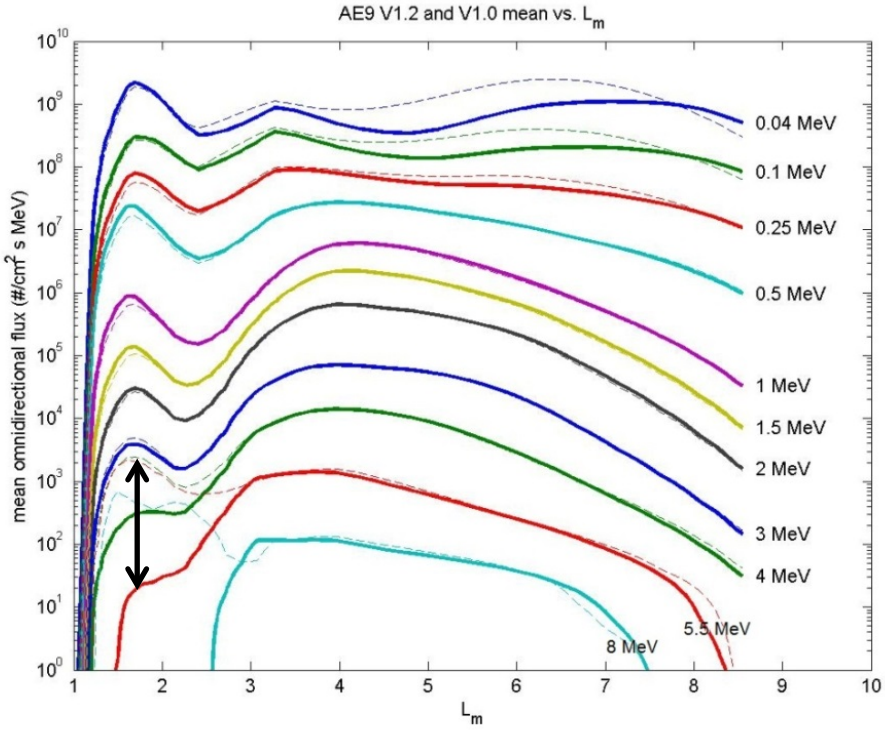
LANL and IGE for Year 2003





AE9 V1.20 Model Comparison



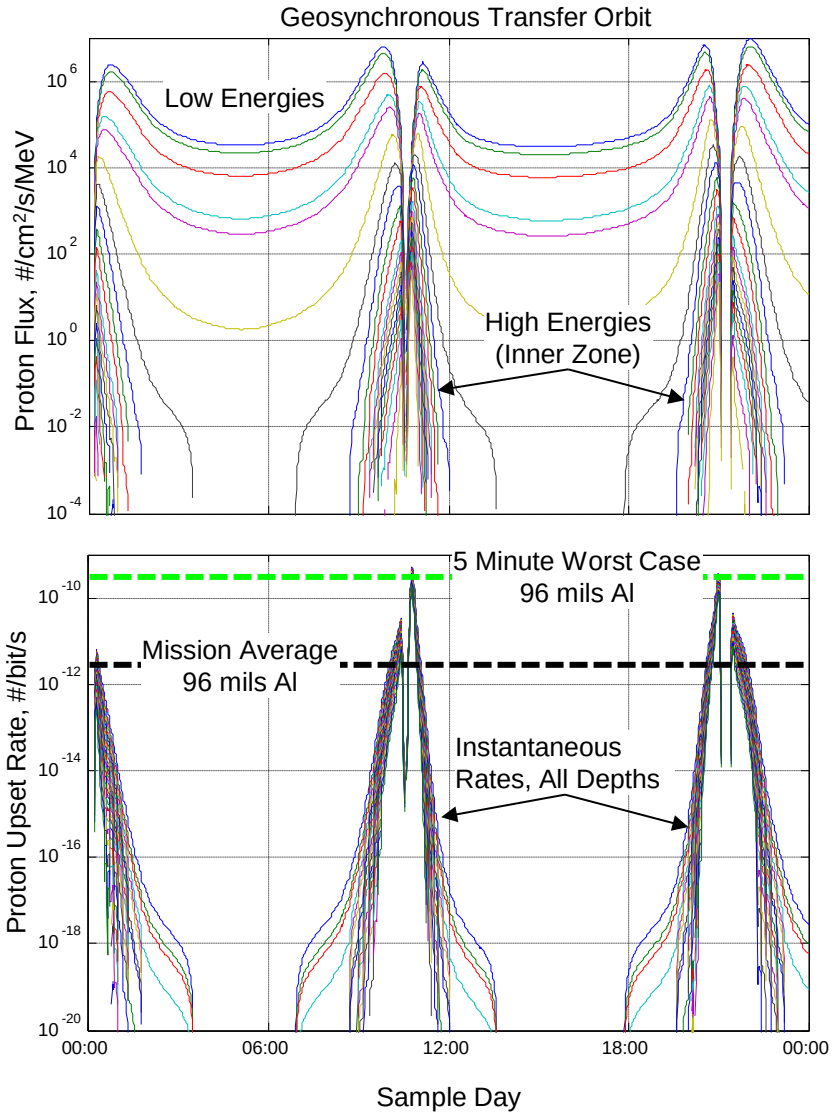


- **Inner zone electrons at E>3 MeV are lower in V1.20 than V1.00**
  - **Result is more consistent with Van Allen Probe results**

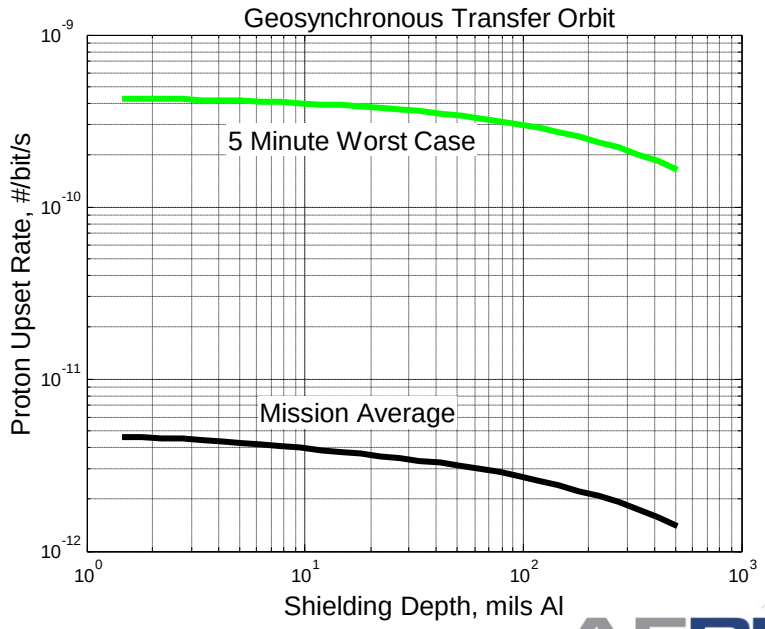
Version 1.5

- **New data:**
  - **Protons: Azur, Van Allen/MagEIS & REPT**
  - **Electrons: DEMETER/IDP, Van Allen/MagEIS & REPT**
  - **Plasma: SCATHA/SC8, AMPTE/CCE-CHEM**
- **New features**
  - **Introduce kernel-based methods for fast dose/effects calculations**
  - **Fix flux-to-fluence calculations to cover variable time steps—supports optimizing time steps for shorter run times**
  - **Capability for parallelization across scenarios—improves run times (may be available sooner as an interim release, V1.25)**
  - **IGRF update (if new coefficients are available in time)**
  - **Allow selection of time period for calculation of fluence—supports different time periods for different effects**
- **International collaborators on board—with new model name: IRENE**
  - **International Radiation Environment Near Earth**

Kernel-Based Effects Calculation



- User provides Weibull or Bendel Parameters and desired shielding depths
- Utility computes "kernel" that transforms proton flux to SEE rate behind shielding (CSDA degraded)
- SEE rates computed from AP9 proton fluxes:
  - Instantaneous rate
  - Mission average rate
  - Worst case rate on desired timescale



Version 2.0

- **Major feature changes:**
  - **Sample solar cycle—introduces a full solar cycle reanalysis as a flythrough option**
  - **New module frameworks for e.g. plasma species correlations, SPM stitching with AE9/AP9, auroral electrons, additional coordinates for MLT variation in SPM**
  - **AP9 improvements: solar cycle variation in LEO, east-west effect**
  - **Incorporate untrapped solar protons with statistics**
  - **Parallelization capability for runs on clusters—needed to speed up long runs**
  - **Mac OSX build?**
- **New data**
  - **Van Allen/MagEIS & REPT protons and electrons**
  - **PAMELA protons—addresses high energy proton spectra**
  - **Other international data sets: possibilities include Cluster/RAPID-IIMS, ESA SREMs, CORONAS, NINA, Akebono/EXOS-D, SAC-C, Jason2**
- **Subsequent releases will include new data**
  - **DSX/SWx, ERG**

Summary

- AE9/AP9 improves upon AE8/AP8 to address modern space system design needs
  - More coverage in energy, time & location for trapped energetic particles & plasma
  - Includes estimates of instrument error & space weather statistical fluctuations
  - Designed to be updateable as new data sets become available
- Version 1.20 is now available to the public
- Review paper published in Space Science Reviews: http://link.springer.com/article/10.1007/s11214-013-9964-y
- Updates are in the works
  - Improvements to the user utilities (no change to underlying environments)
  - Improvements to the model environments (new data)
  - Additional capabilities (new features, new models)
- For future versions, collaborative development is the goal
  - Being proposed as part of new ISO standard
  - Discussions have begun on collaboration with international partners
  - We have benefitted already from discussions with colleagues in Europe

Points of Contact

- **Comments, questions, etc. are welcome and encouraged!**
- **Please send feedback, requests for model or documentation, etc., to (copy all):**
  - **Bob Johnston, Air Force Research Laboratory, AFRL.RVBXR.AE9.AP9.Org.Mbx@us.af.mil**
  - **Paul O'Brien, Aerospace Corporation, paul.obrien@aero.org**
  - **Gregory Ginet, MIT Lincoln Laboratory, gregory.ginet@ll.mit.edu**
- **Information available on NASA SET website:**

  http://lws-set.gsfc.nasa.gov/radiation_model_user_forum.html
- **V1.20 code public release is expected in Oct-Nov 2014**
  - **To be available at AFRL's Virtual Distributed Laboratory website, https://www.vdl.afrl.af.mil/**
  - **In the meantime for V1.05 contact Gregory Ginet, MIT Lincoln Laboratory, gregory.ginet@ll.mit.edu**

Thank You