RBSP-ECT and complementary datasets

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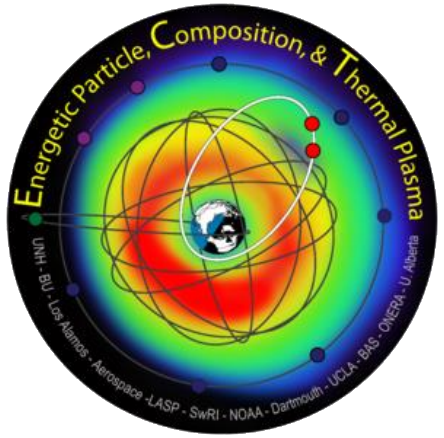
Overview

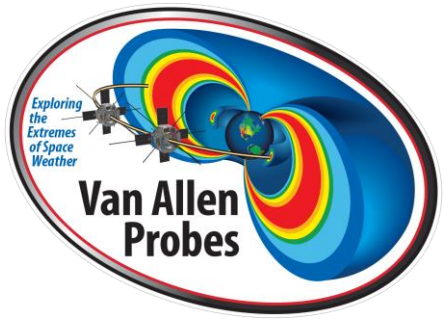
RBSP-ECT

- Unified data products for the ECT suite, combining electron measurements from HOPE, MagEIS and REPT
- Coverage for whole mission from 2012-2019
- **Complete electron spectra throughout the inner magnetosphere from 10s eV to 10s MeV**

REACH

- Set of 32 dosimeter payloads on IRIDIUM-Next
- Data is now publicly releasable
- Data coverage from 2017-2019, 2022-Present





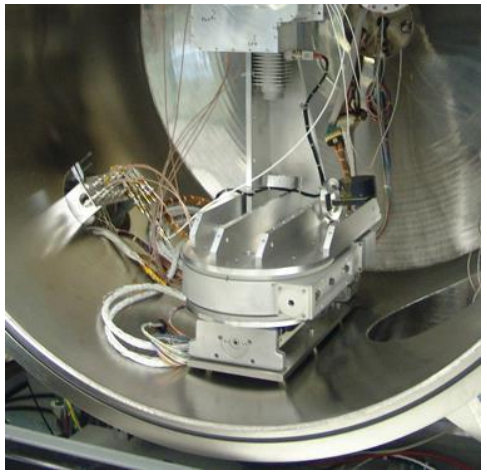
RBSP-ECT

Energetic Particle Composition and Thermal Plasma (ECT) Suite

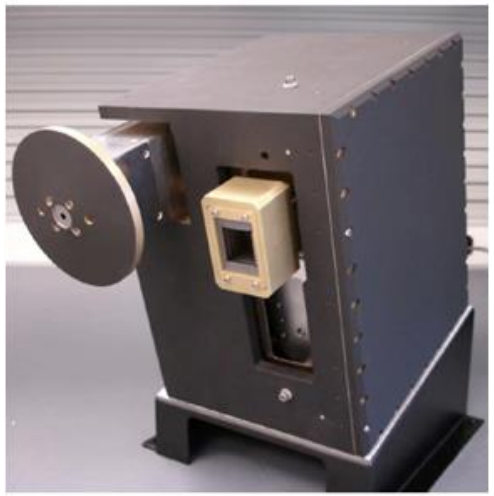
Instrumentation

- Van Allen Probes: 2 satellites in GTO orbit (Aug 2012 – Jul/Oct 2019)
- HOPE (Helium Oxygen Proton Electron Spectrometer)
  - *~10s eV – 50 keV electrons, ions*
- MagEIS (Magnetic Electron Ion Spectrometer)
  - *20 keV – 4 MeV electrons*
  - *60 keV – 20 MeV Protons*
- REPT (Relativistic Electron Proton Telescope)
  - *1.8 MeV – 20 MeV electrons*
  - *20 MeV – 2 GeV Protons*

HOPE

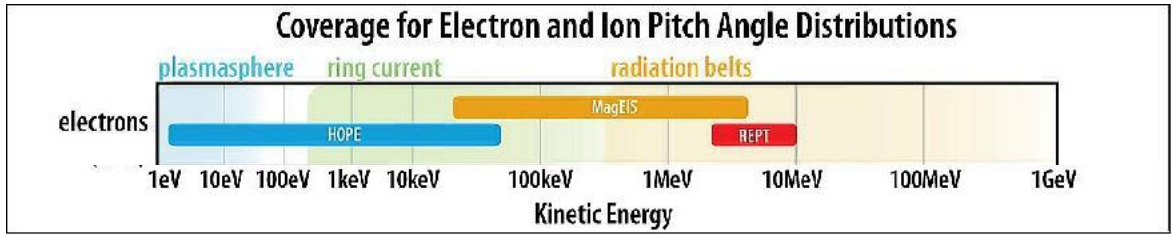


MagEIS



REPT

Image Credits: NASA



Mauk et al. (2012)

* Additional measurements of electrons/ions from RBSPICE (20 keV-1MeV) and protons from RPS (50-2000 MeV)

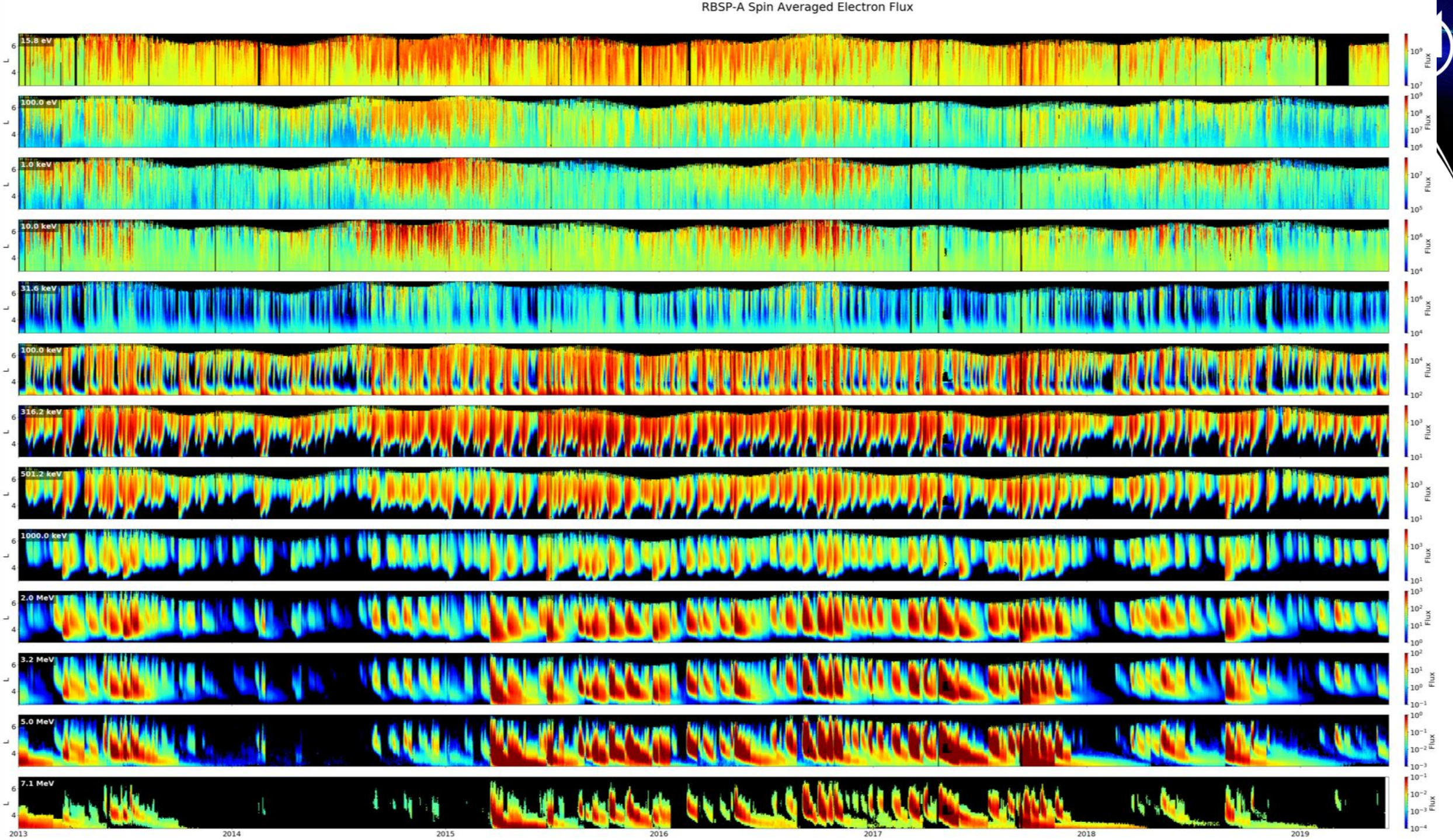
More than 7 years of electron spectra throughout the inner magnetosphere from 10s eV to 10s MeV

ECT

Combined Data Products

- Combine the HOPE, MagEIS, REPT electron data in one reliable, easy-to-use format
  - Removing low count, out-of-family channels
  - Providing data quality flags
  - Combined spectra (ex. FESA) and spline fit spectra (ex. FESA_FIT)
- Data products:
  - L2: Spin-Averaged Fluxes
  - L3: Pitch Angle Resolved Fluxes
- 3-minute averaged electron fluxes (label in middle of bin)
- The spin-averaged data product (L2) and Pitch angle resolved product (L3) is available for entire mission (2012-2019):
  - https://rbsp-ect.newmexicoconsortium.org/data_pub/rbspa/ECT/level2/
  - https://rbsp-ect.newmexicoconsortium.org/data_pub/rbspa/ECT/level3/
  - Accompanying paper in JGR:
    - https://doi.org/10.1029/2019JA026733 (L2)
    - https://doi.org/10.1029/2020JA028637 (L3)

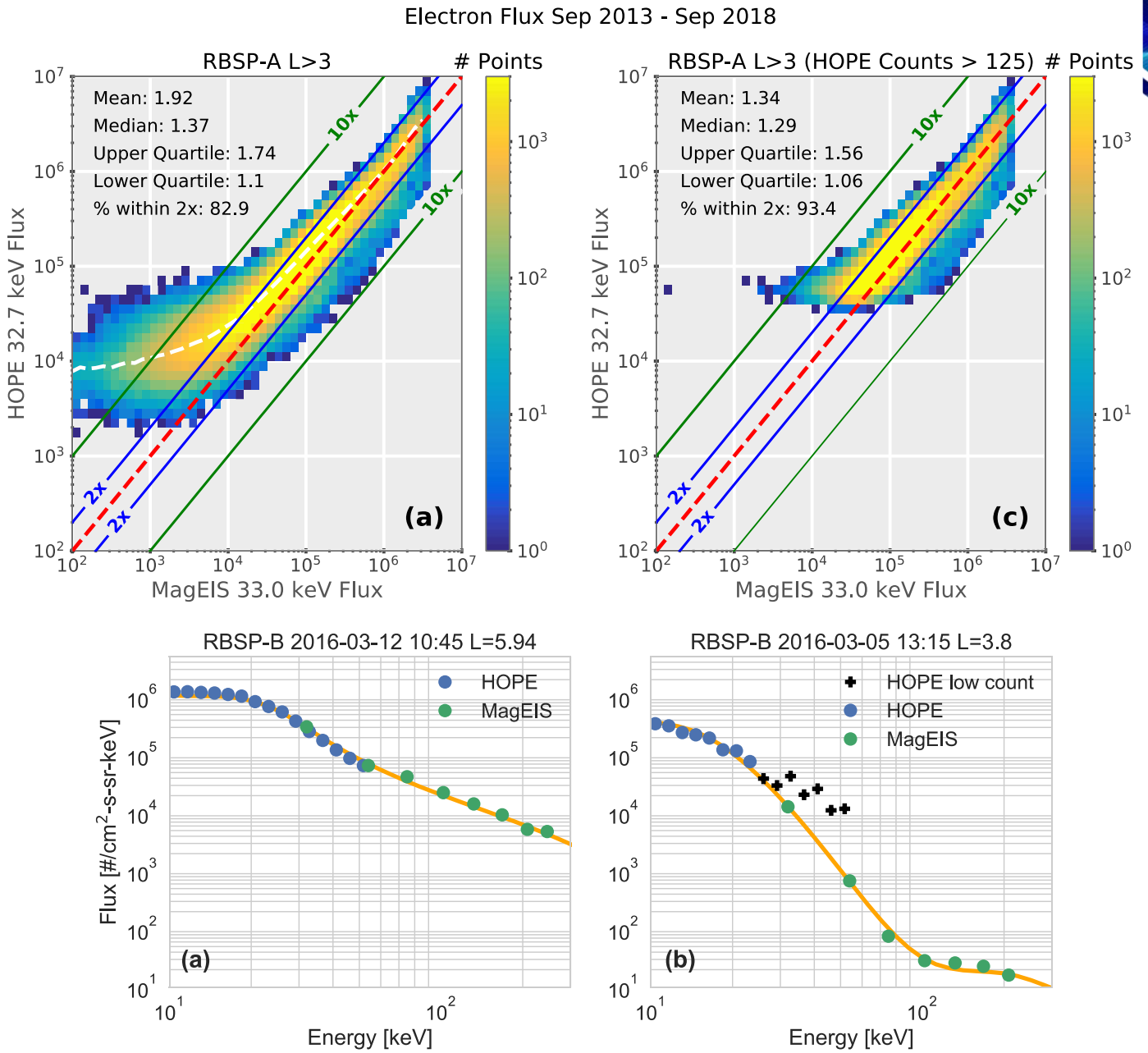
Future entryway into the ECT data


RBSP-A Spin Averaged Electron Flux
15.8 eV
100.0 eV
1.0 keV
10.0 keV
31.6 keV
100.0 keV
316.2 keV
501.2 keV
1000.0 keV
2.0 MeV
3.2 MeV
5.0 MeV
7.1 MeV
L
6
4
Flux
2013
2014
2015
2016
2017
2018
2019

HOPE-MagEIS

Spin-Averaged

- Comparison of HOPE/MagEIS 32/54 keV channels
- Remove times where HOPE has few counts (<125 in 3 minute window)
- When low count times removed, excellent agreement (92% within a factor of 2)
- Apply correction to HOPE (based on 32 keV ratio):
  - *Inner Zone (L < 2.5)*
  - *Days with large disagreement (efficiency correction)*

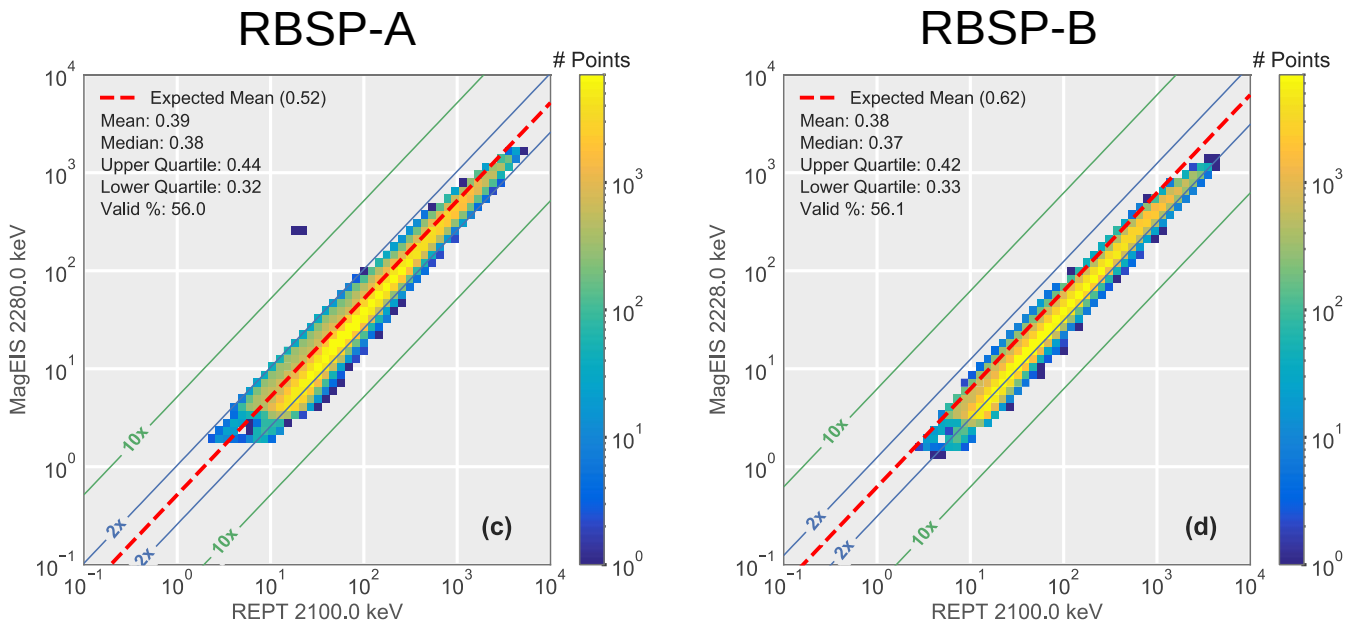


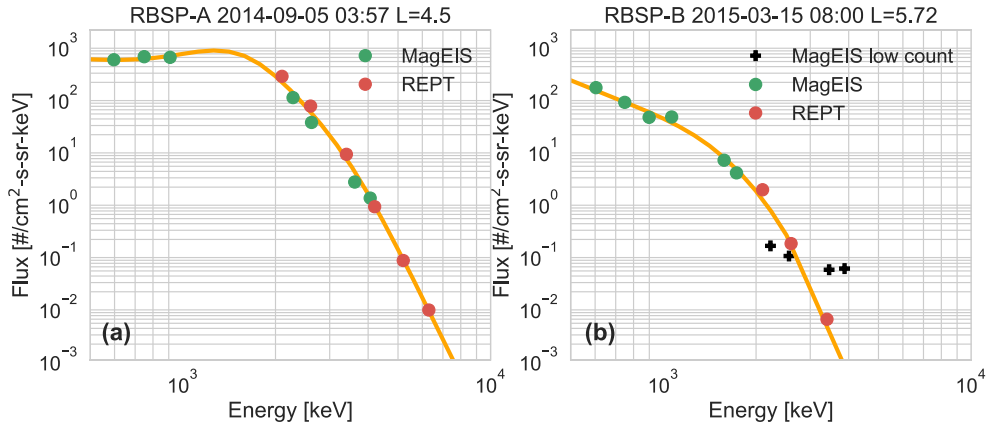
Boyd et al. (2019)

MagEIS-REPT

Spin-Averaged

- Comparison of MagEIS/REPT 2.1/2.6 MeV channels
- Removing low count times (estimated error > 75%), excellent agreement (92% within a factor of 2)
- 1.8 MeV REPT channel not included
  - *Factor of ~2.5 offset*
- MagEIS channels above 3 MeV not included
  - *Very few points with enough counts*





Boyd et al. (2019)

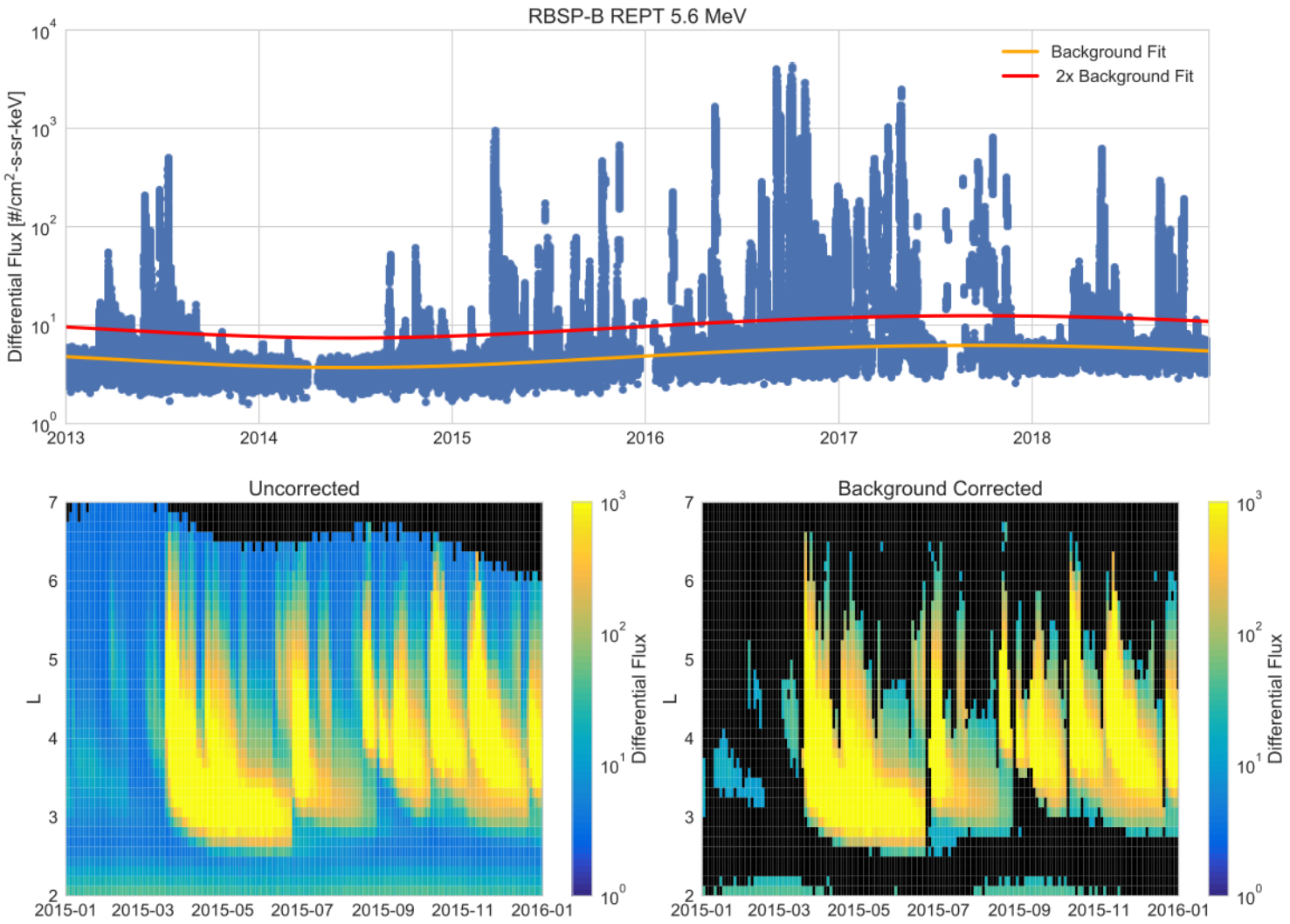
REPT Background

Spin-Averaged

- Outside of major enhancements, higher REPT channels (> 4 MeV) see background due in part to GCR
- To identify these times we apply a crude time-varying background fit:

$$E(t) = A + B\sin\frac{\pi t}{C} + D\sin\frac{\pi t}{C}$$

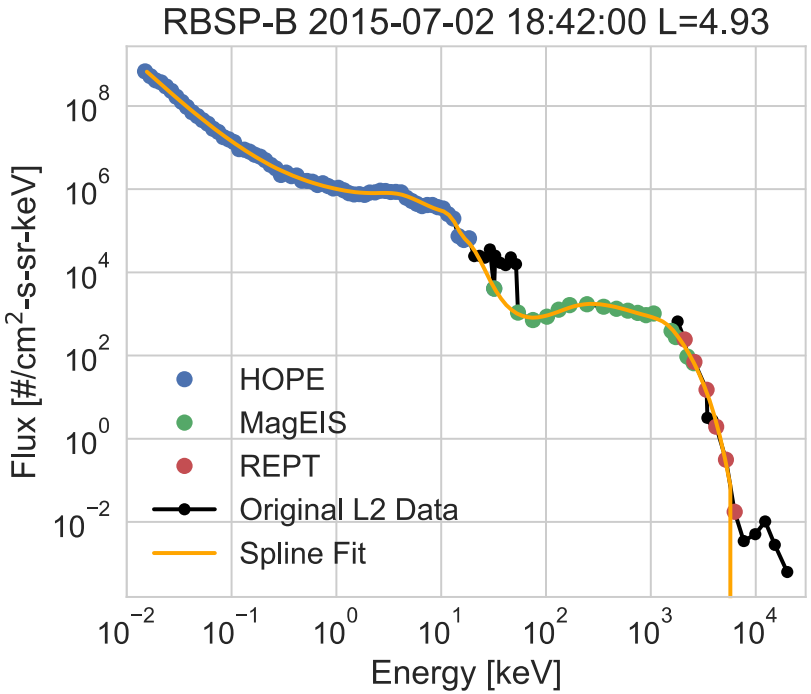
- Remove all times where flux < 2*fit
- At lower energy channels single count level is used

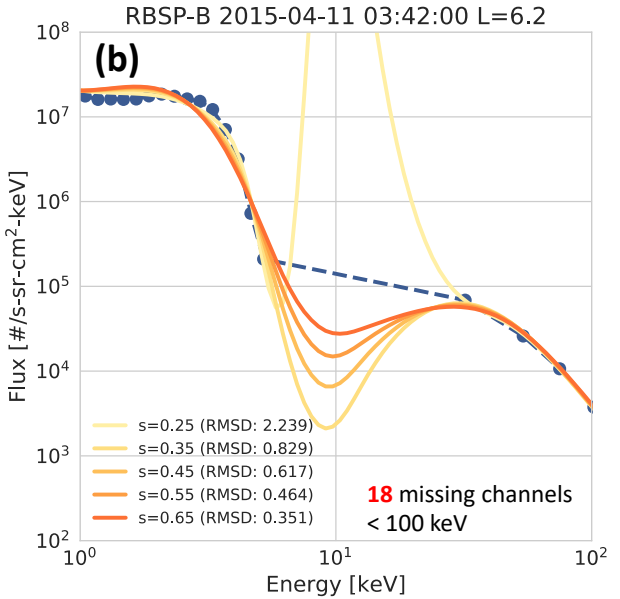


Boyd et al. (2019)

Spline Fitting

- Final step is a spline Fit of the combined spectra
- Output 127 log spaced energy channels
- Provide the knots and coefficients to allow user to reconstruct the fit
- Validation checks (increase smoothing or leave data gap in spline):
  - *Data gaps*
  - *Large 2nd derivative*
- Fit Quality Flag

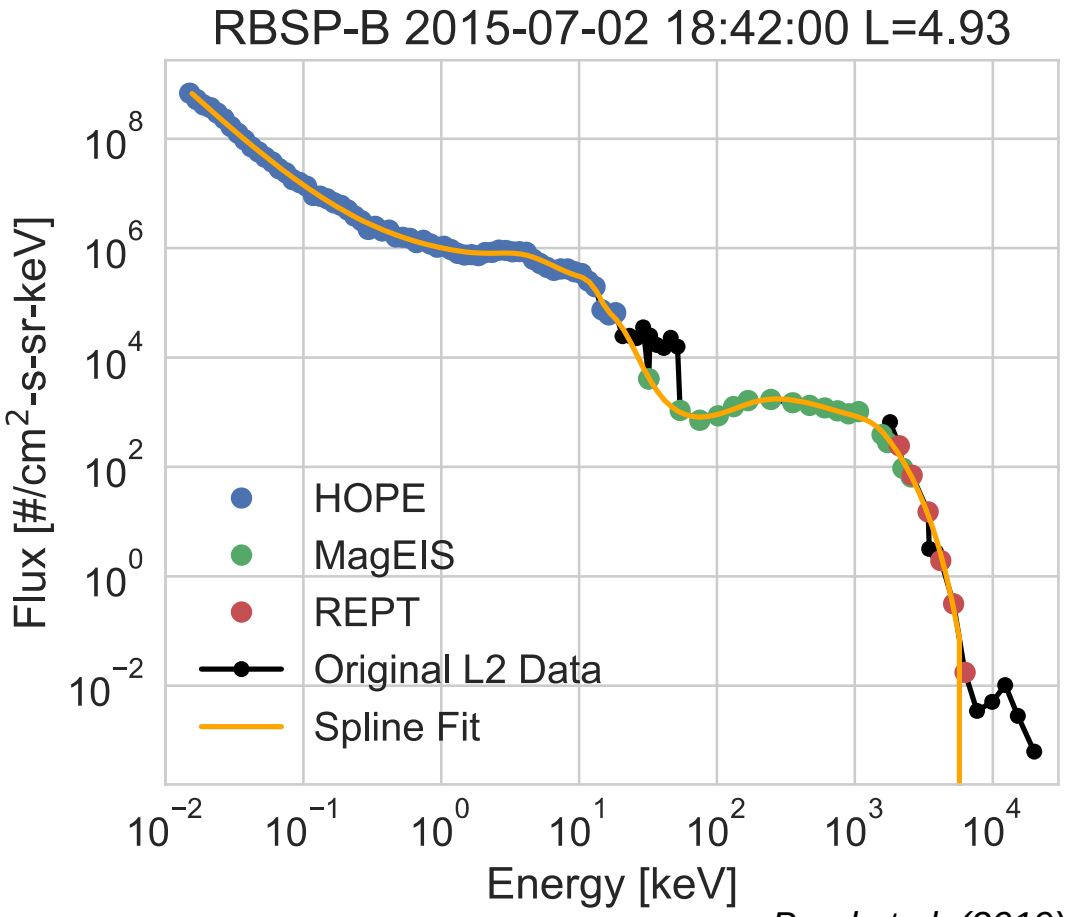




Boyd et al. (2019)

What's in the data files

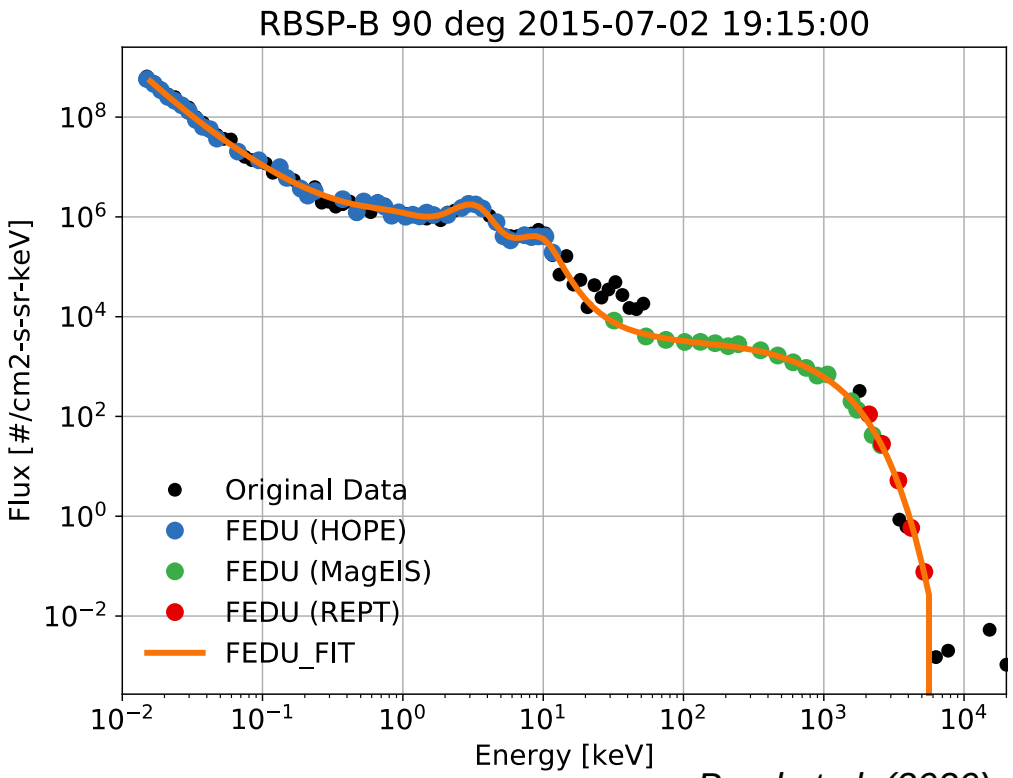
- Combined Flux Spectra
  - *FESA (102 energies)*
  - *Data Quality Flags (FESA_Quality)*
- Spline Fit Spectra
  - *FESA_FIT (127 energies)*
  - *Data quality flags (FESA_FIT_Quality)*
- Support Data
  - *Magnetic Ephemeris*
  - *Spline Coefficients and Knots*



Boyd et al. (2019)

Pitch Angle Resolved Data Product

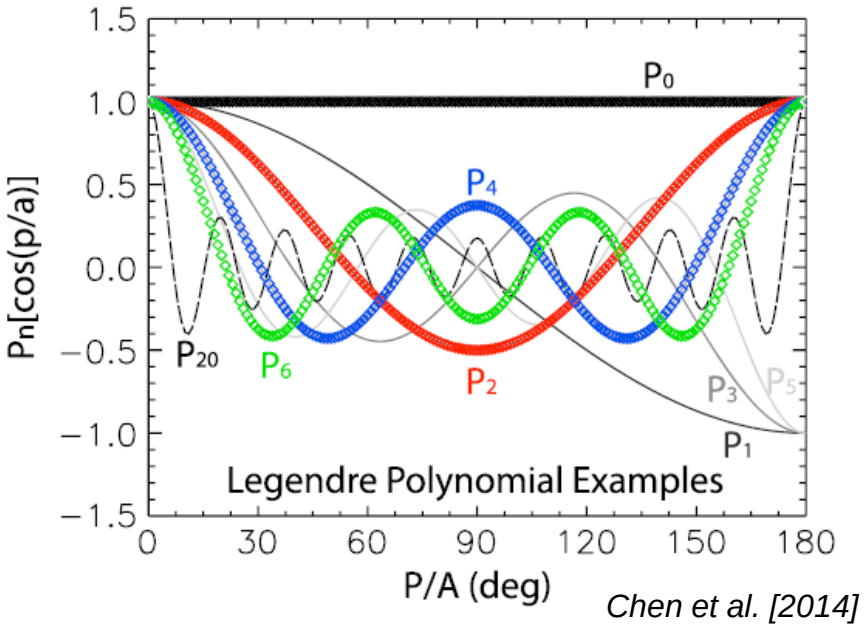
- Follow same basic methodology as L2
  - *HOPE*
    - Remove low count channels
    - Correction factor based on ratio at 90 degrees
  - *MagEIS*
    - HIGH channels where FEDU_ERROR < 75
  - *REPT*
    - Same background correction (if spin-averaged below background all PA bins are set to 0)
- Each of the instruments have different pitch angle bins, so need to fit angular distributions output at 35 pitch angles (5,10,15…170, 175)
- Calculate omnidirectional flux (FEDO, FEDO_FIT) and equatorial flux (FEDU_Eq)



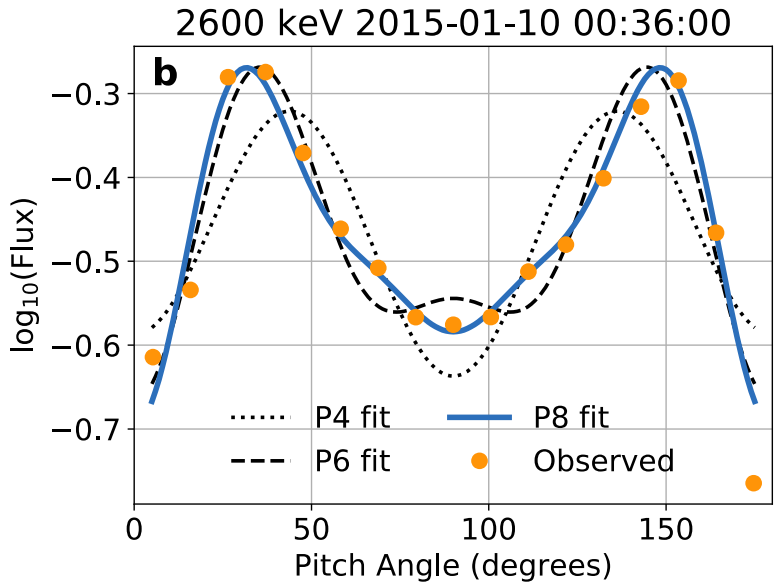
Boyd et al. (2020)

Pitch Angle Fits

- Legendre Polynomials with log10(flux)
- Most fits only use even terms
- Estimate symmetry (determine whether to include odd coefficients):
  - *Mean ratio of 1st/last 4 PA pairs (e.g. 8º/172º)*
  - *If < 0.75 or <1.3 include odd coefficients, otherwise only the even*
- Each PA is fit using same spline routine
- FEDU_FIT (127 energies, 35 pitch angles)



Chen et al. [2014]



Boyd et al. (2020)

Caveats

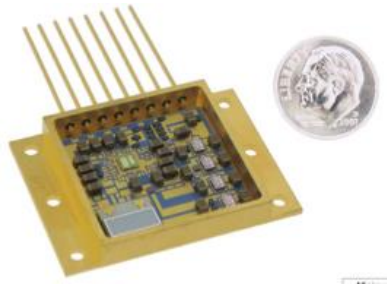
- The combined products will be updated as final instrument data is available
- Inner Zone (L < 2.5)
  - *All fluxes above 1 MeV are not included (this does not mean these are always 0)*
- Early Mission (before Sept 2013)
  - *Changing instrument modes/energy channels can lead to unexpected results*
- Pitch Angle shapes in FEDU_FIT can be inconsistent
- **Use the data quality flags!**

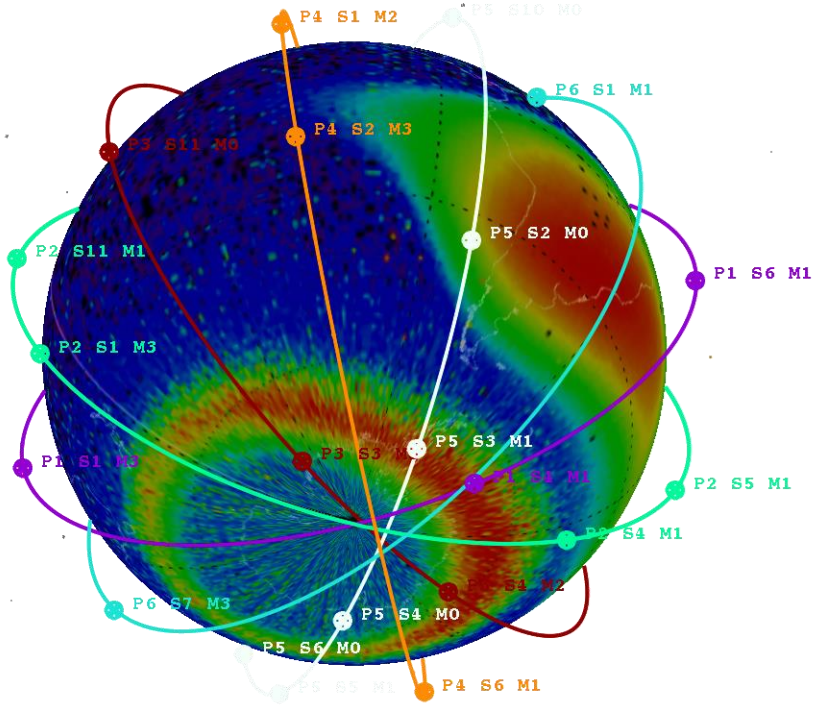
REACH

Overview

Responsive Environmental Assessment Commercially Hosted constellation

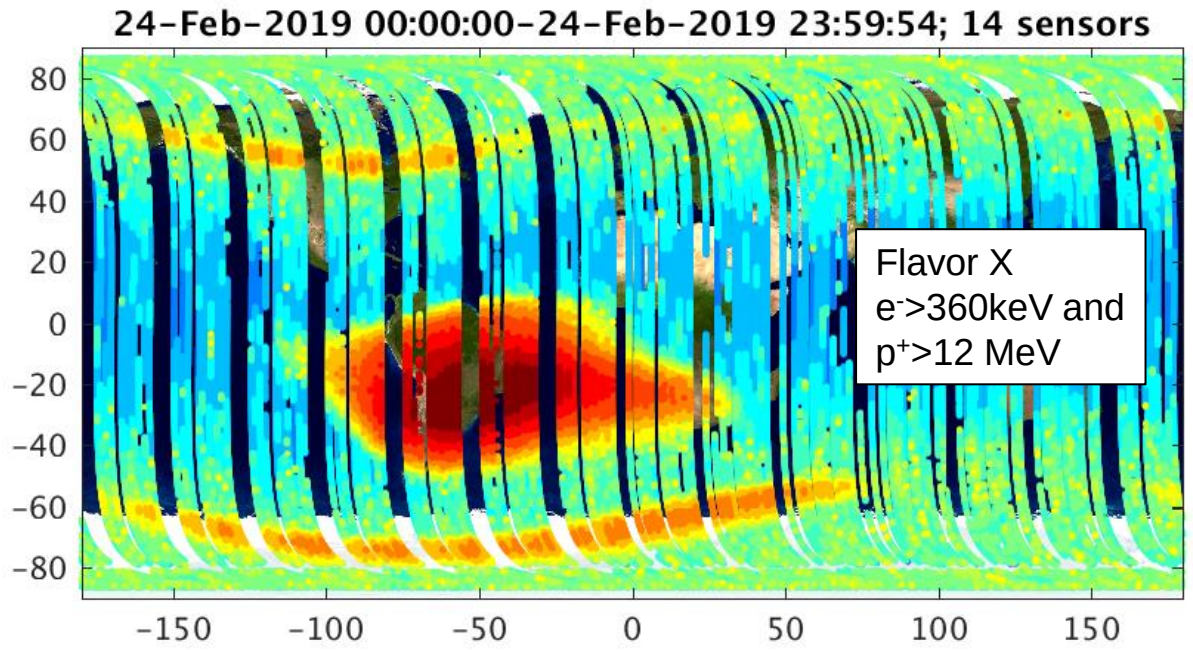
- REACH is a hosted space weather payload on the Iridium-Next constellation in LEO (780 km)
- 32 REACH payload in 6 orbital planes
  - Each payload has 2 micro-dosimeters – 64 total sensors
  - 6 different “flavors” each cover different energy range for electrons and protons
- Offers unprecedented temporal coverage of the LEO radiation environment
- First 2.5 years of REACH data (2017-2019) available on Zenodo: 10.5281/zenodo.5988170
- As of October 2022, receiving new data in real time
  - Sensors healthy, all continue to perform well
  - Data is publicaly releasable, pushed real time into unified data library (UDL)

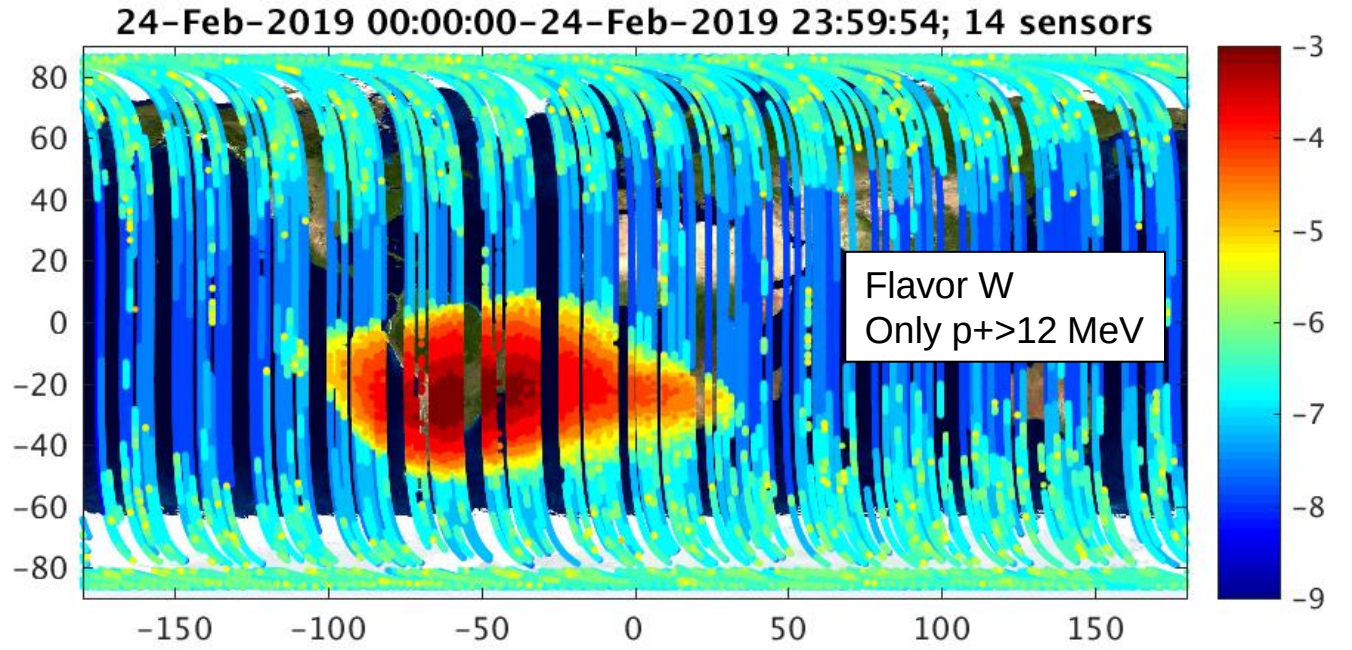




REACH Constellation

REACH has 6 shielding thicknesses/electronic thresholds: we call them flavors





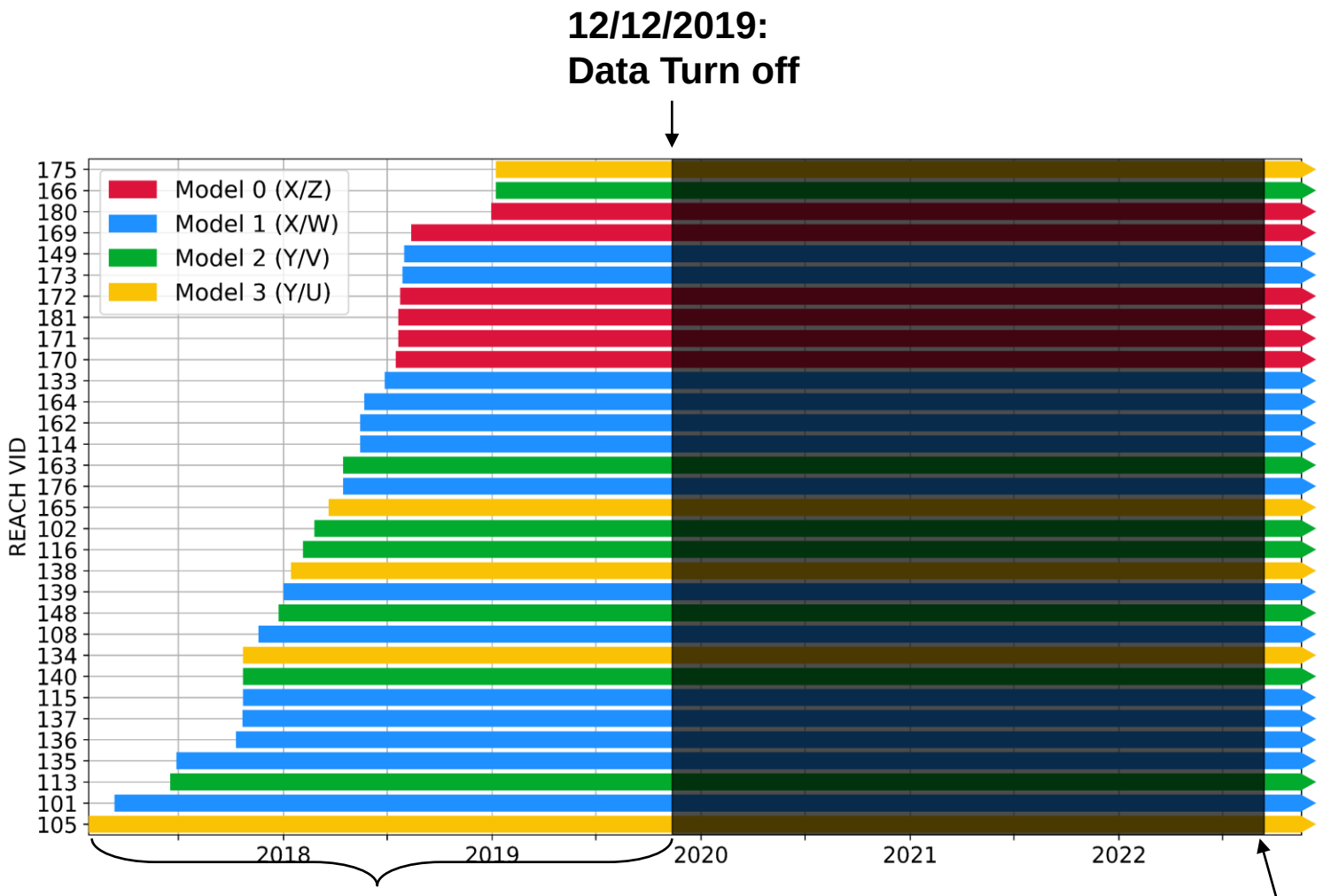
Dose rate in log10(rad/sec) from 14 individual sensors taken over 24 Feb 2019, southbound passes only

Flavor	Electrons	Protons	# Satellites
U	>4.97 MeV	>57 MeV	5
V	>3.41 MeV	>47 MeV	7
W	-	>12 MeV	14
X	>360 keV	>12 MeV	20
Y	>1.6 MeV	>31 MeV	12
Z	>50 keV	>200 keV	6

With 14 equivalent sensors in LEO measuring all the time, this is an unprecedented orbital coverage

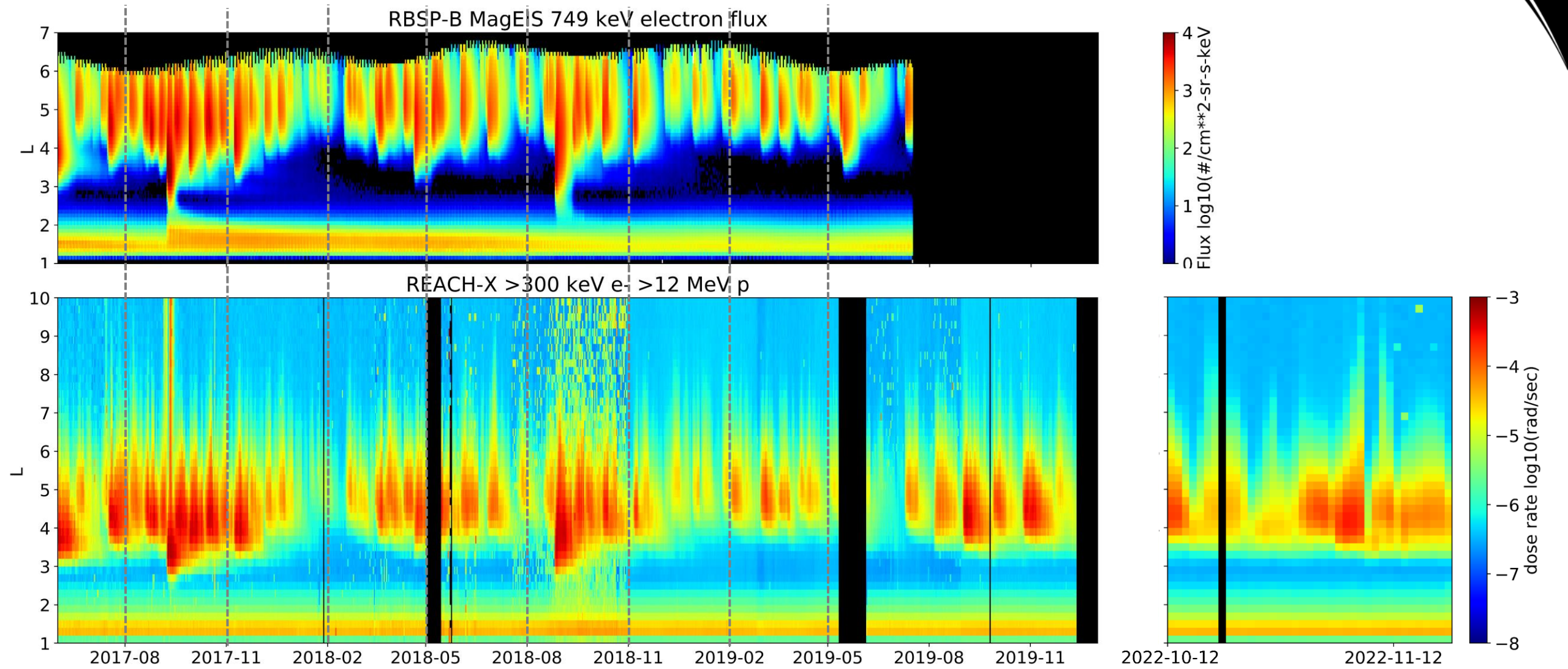
Current Status

- REACH data from 2017-Dec 2019
  - *Data archived on zenodo:* 10.5281/zenodo.5988170
    - Documentation
    - csv files of 5-second average dose, fluxes
- Data turned back on 10/12/2022
  - *Realtime data from all REACH payloads*
  - *Analysis shows all payloads healthy and performing well*



Science Applications

Radiation Belt Monitoring



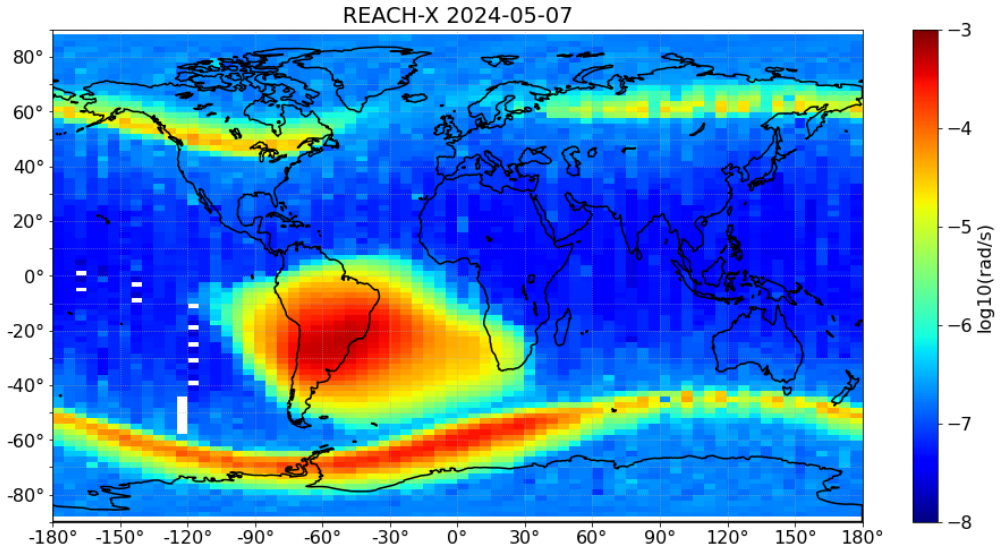
REACH Maps

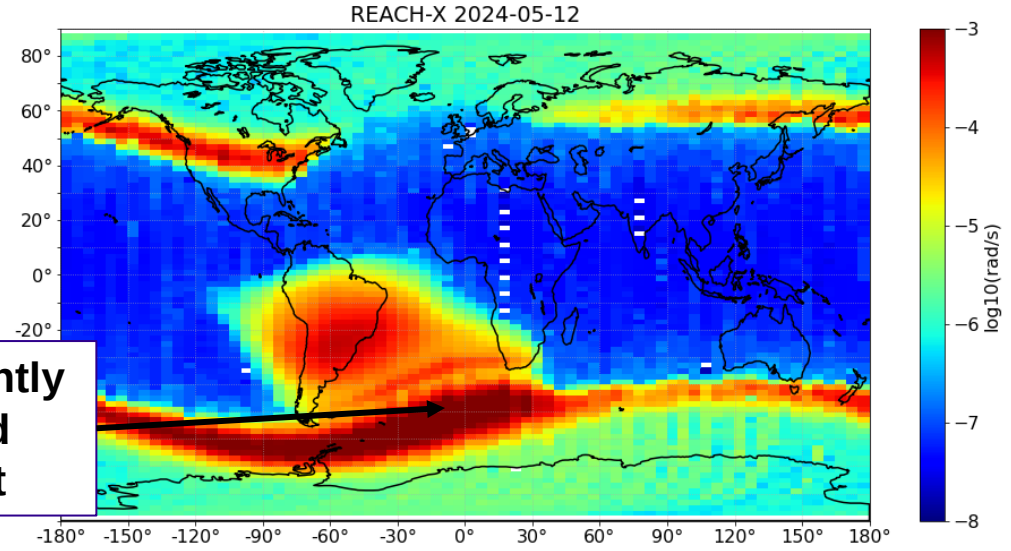
May 2024 Storm

Pre-Storm

Stormtime

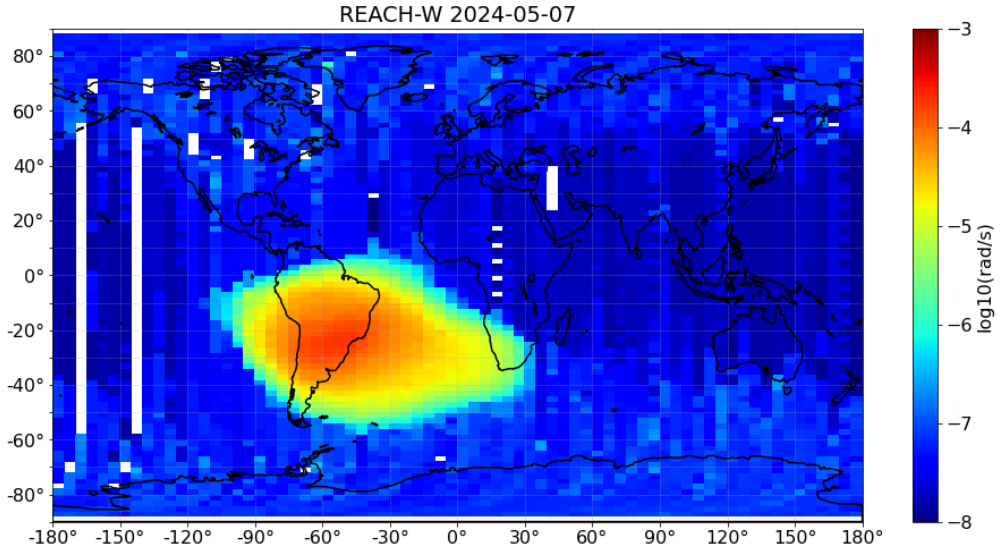
X: >300 keV electrons, >12 MeV protons

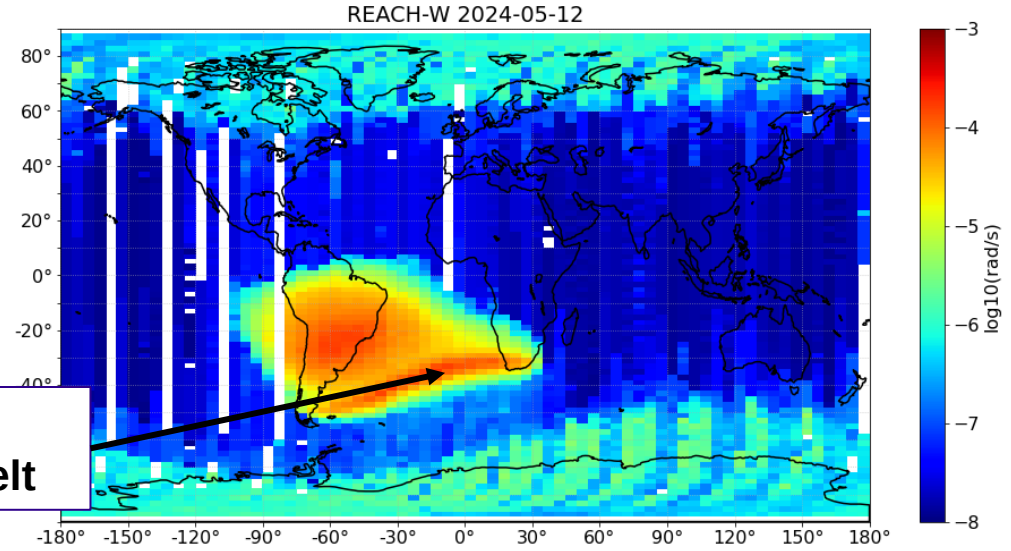




Significantly enhanced outer belt

W: >12 MeV protons





Transient Proton Belt

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REACH

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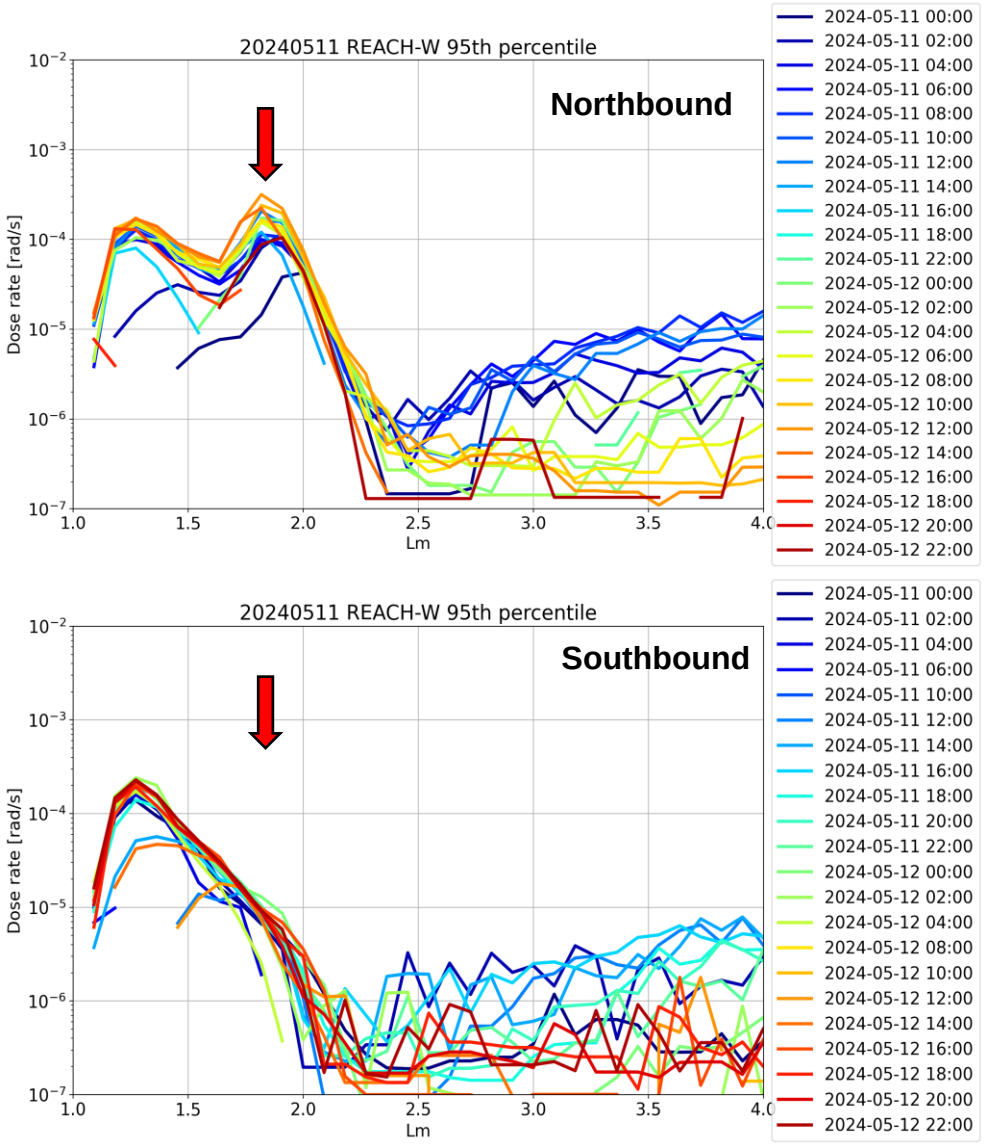
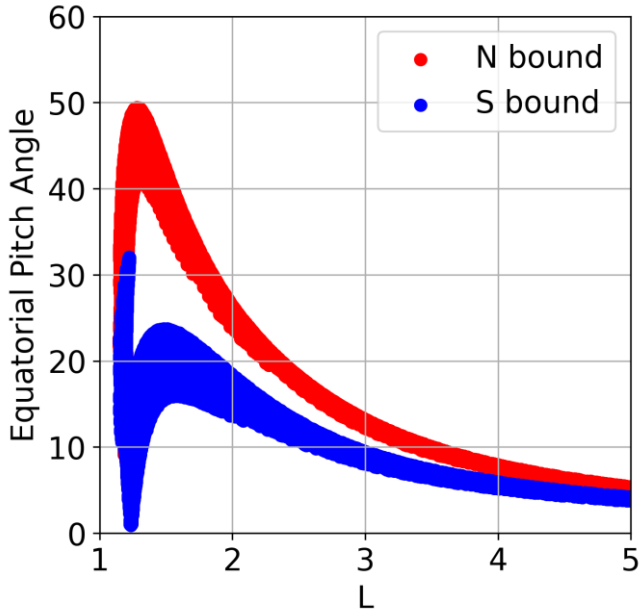
Backup

Proton Observations

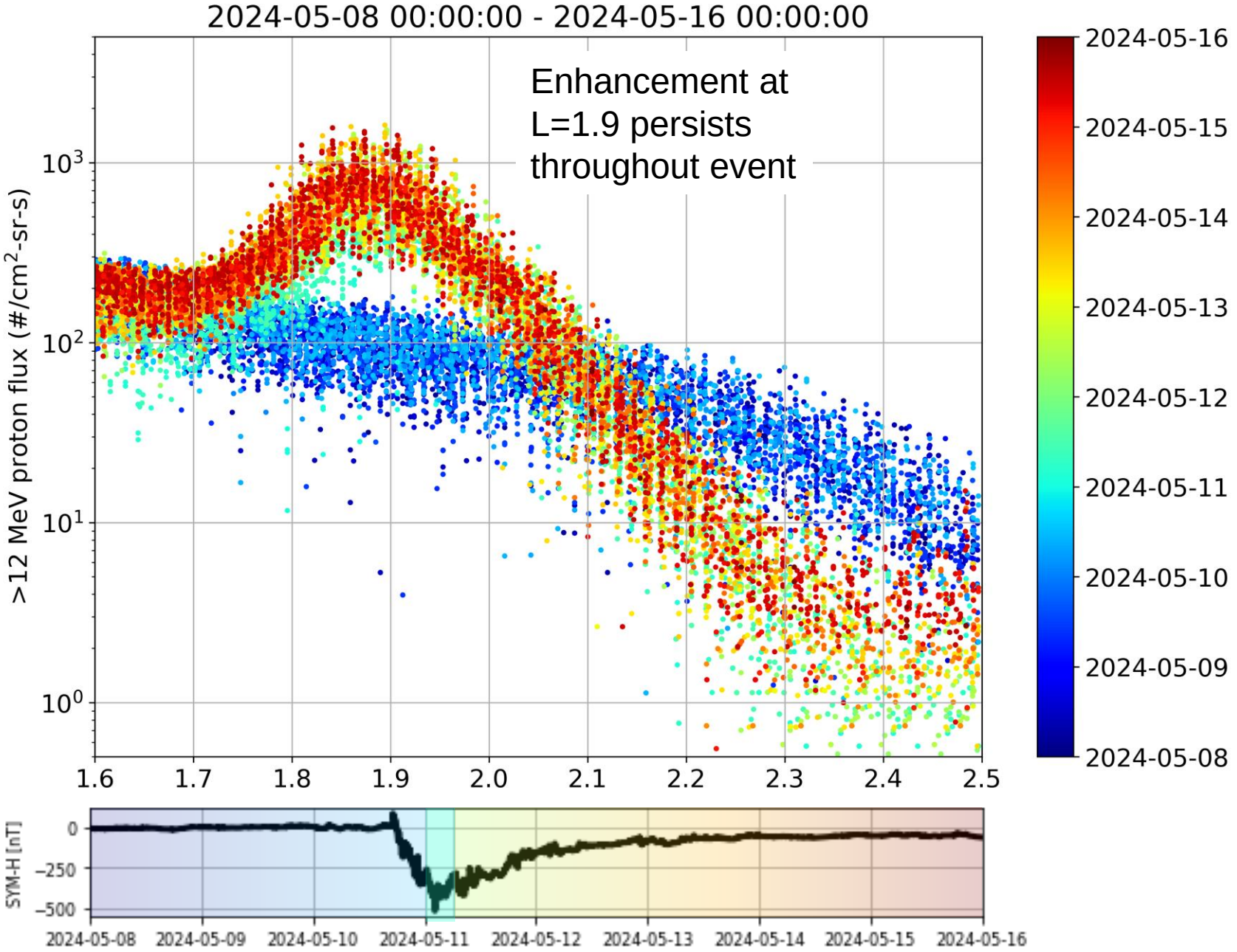
May 2024 Storm



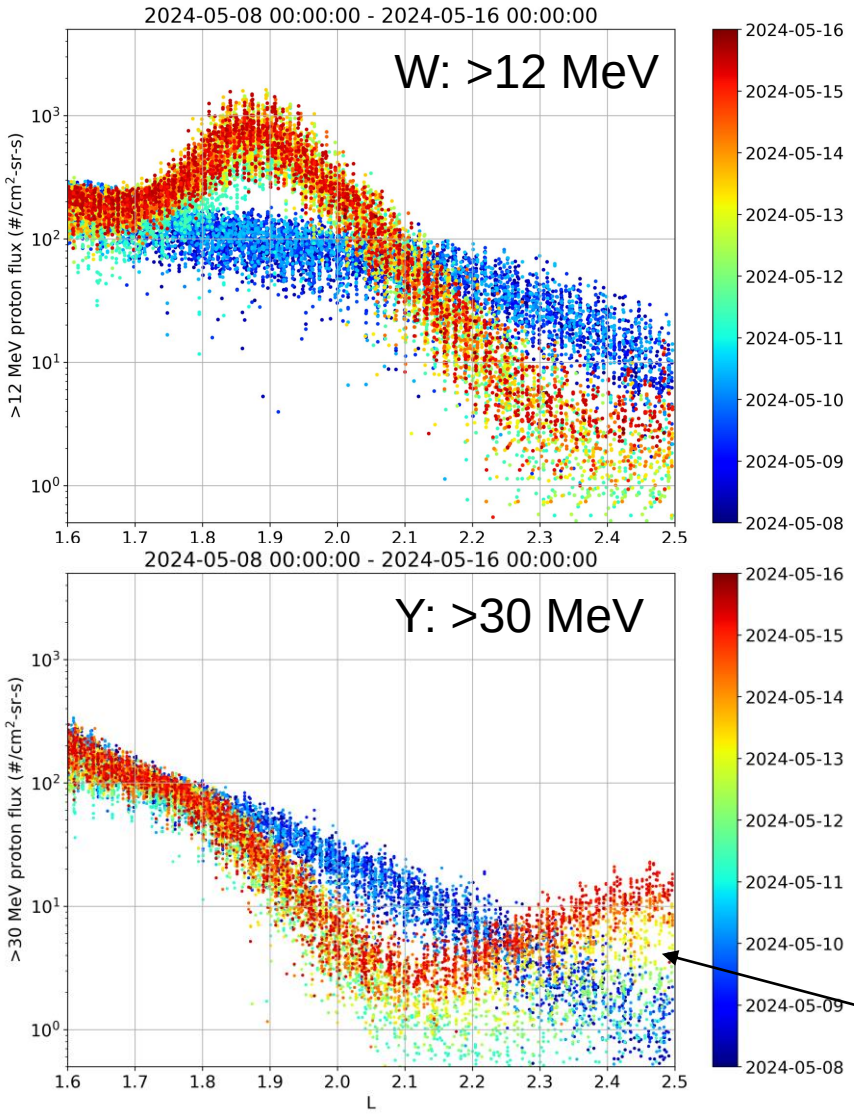
- A new transient Proton Belt, similar in magnitude to the SAA is only observed during northbound passes
- For REACH, northbound passes correspond to pitch angles closer to 90 degrees

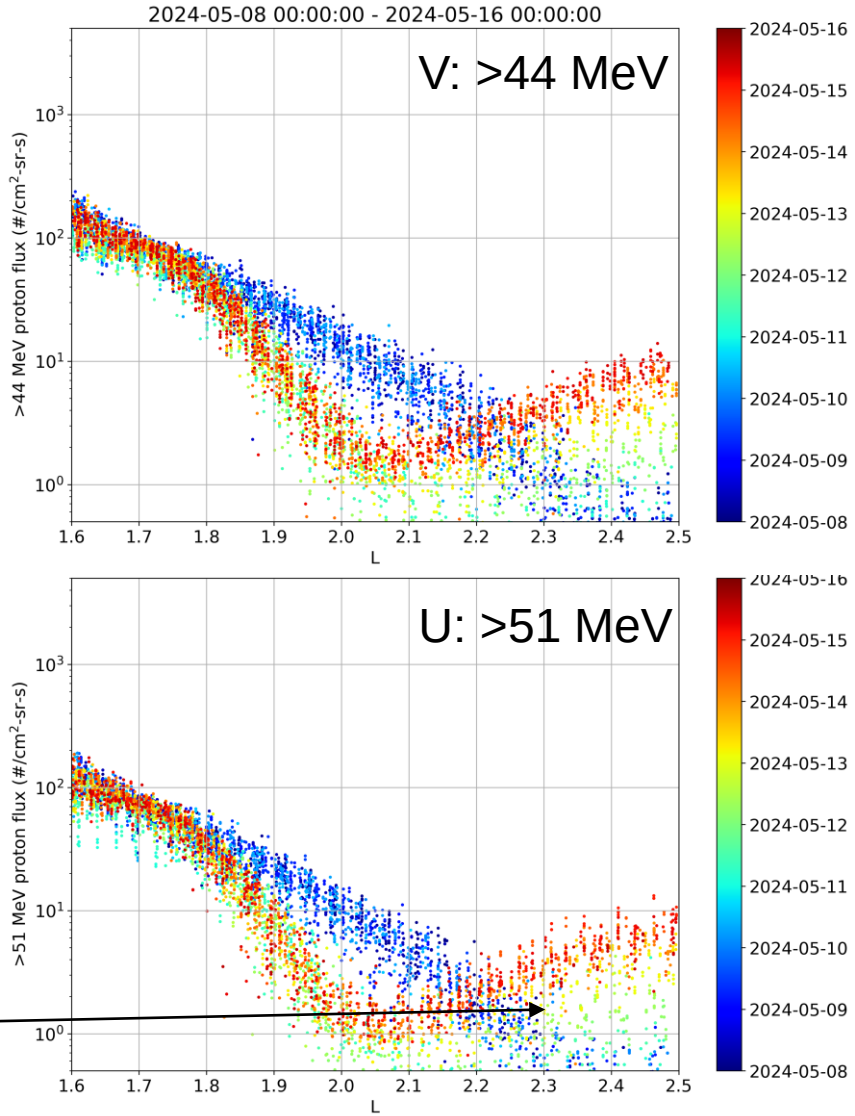


Proton Observations



Energy Dependence

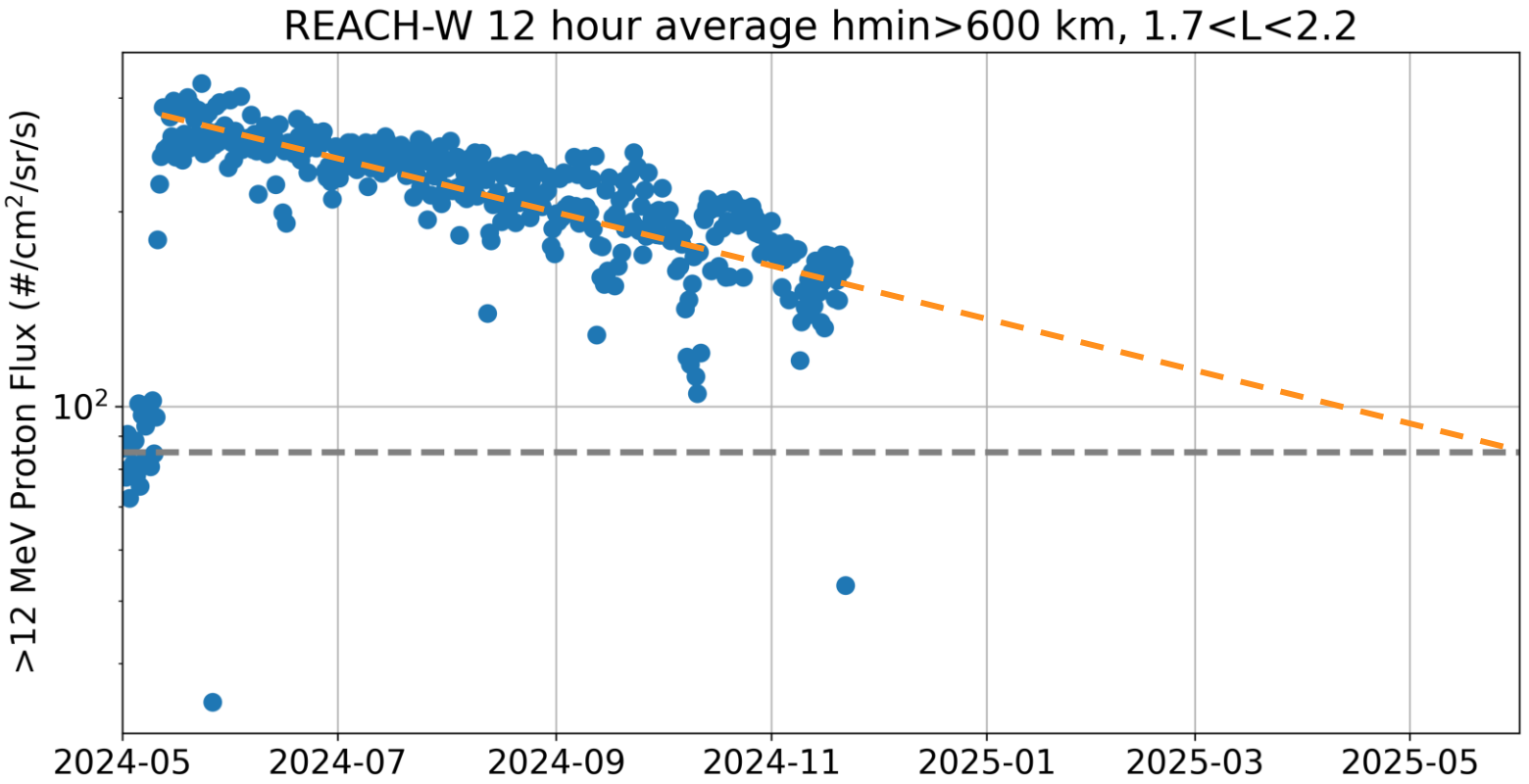


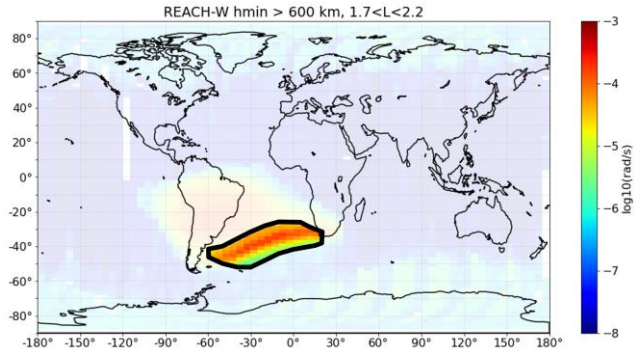


Transient proton belt at L=1.9 is limited to ~12-30 MeV

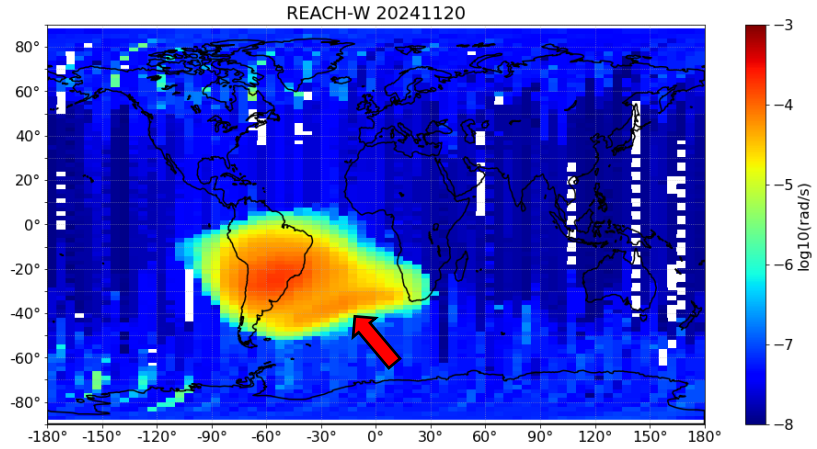
Observations of >2 MeV electrons

Long term observations





Region with h_{min} > 600 km and 1.7<L<2.2



- Transient belt is still observable 6 months after storm
- Decay rate suggest belt will remain above pre-storm levels for ~1 year


Thank you