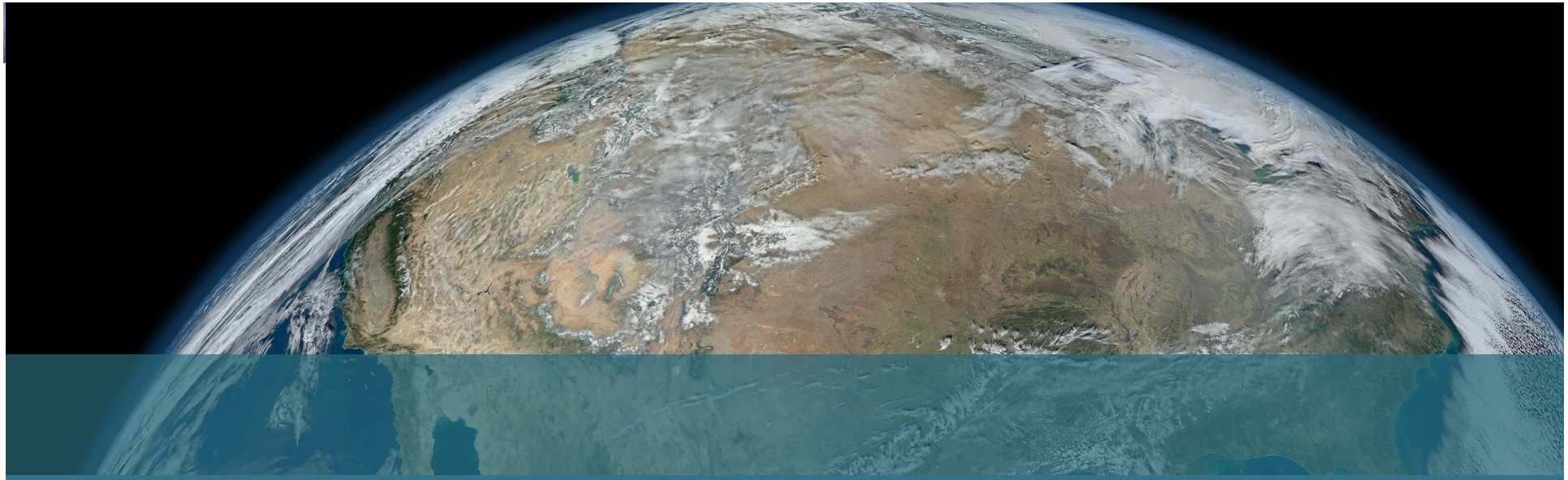


GOES-R Space Environment In-Situ Suite (SEISS)

- Solar and Galactic Proton Sensor (SGPS)
- Energetic Heavy Ion Sensor (EHIS)

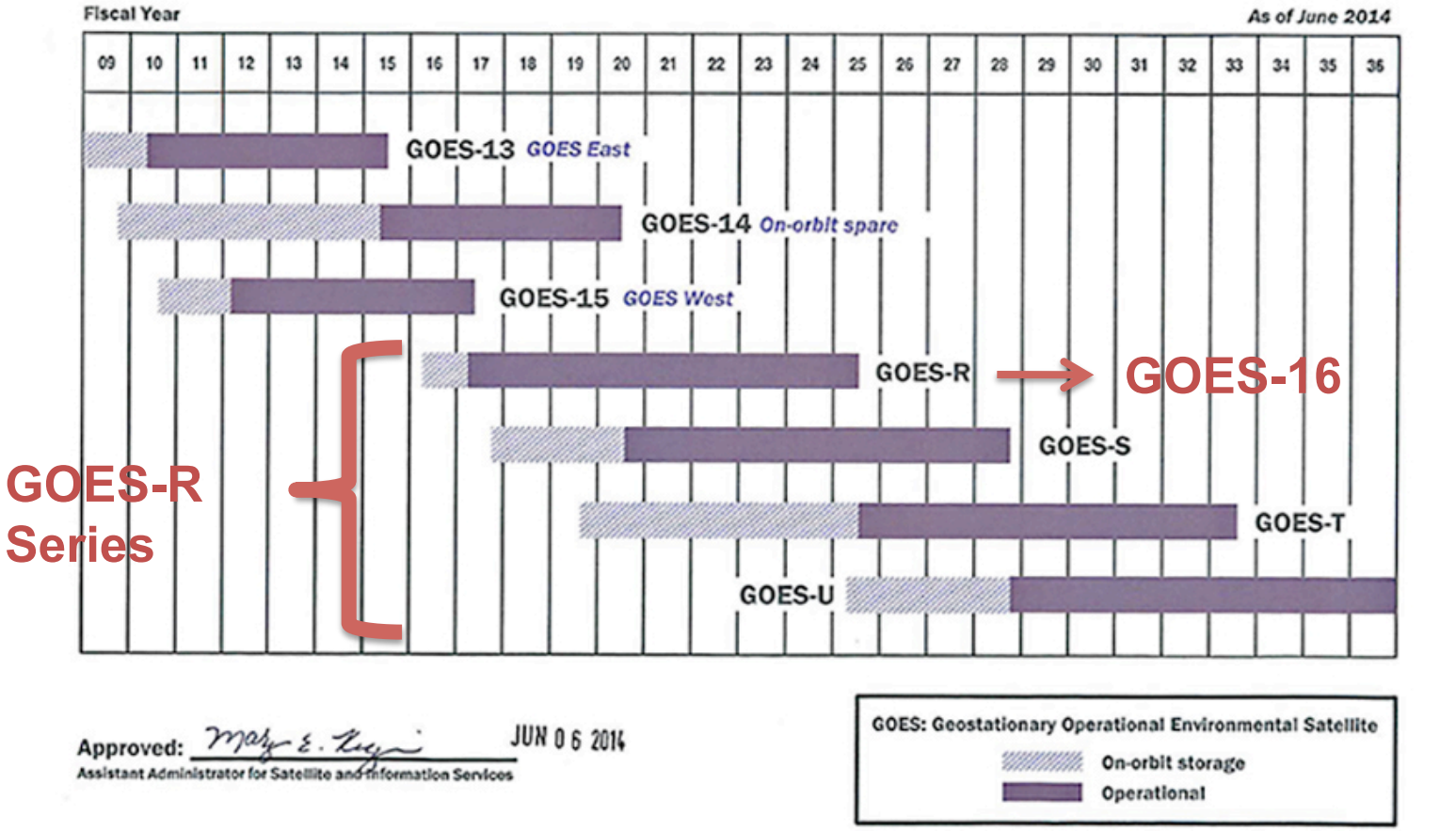
B. T. Kress, J. V. Rodriguez, and A. Boudouridis
NOAA's National Centers for Environmental Information, Boulder, CO

September 6, 2017

Outline

- Overview of current GOES and GOES-R missions
- SEISS SGPS and EHIS Overview
- Data products and use at SWPC
- SGPS response functions and cross instrument calibrations
- New data!
- Science supported by SEISS data

Continuity of GOES Mission



GOES-R Series Space Environment In-Situ Suite (SEISS): Solar and Galactic Cosmic Rays

Solar and Galactic Proton Sensor (SGPS)

- 2 Units, one looking East and one West
- 3 solid state telescopes on each unit
- 1 MeV-500 MeV protons in 13 differential channels, plus >500 MeV integral channel
- 4 MeV-500 MeV alphas in 12 energy bands (not processed)

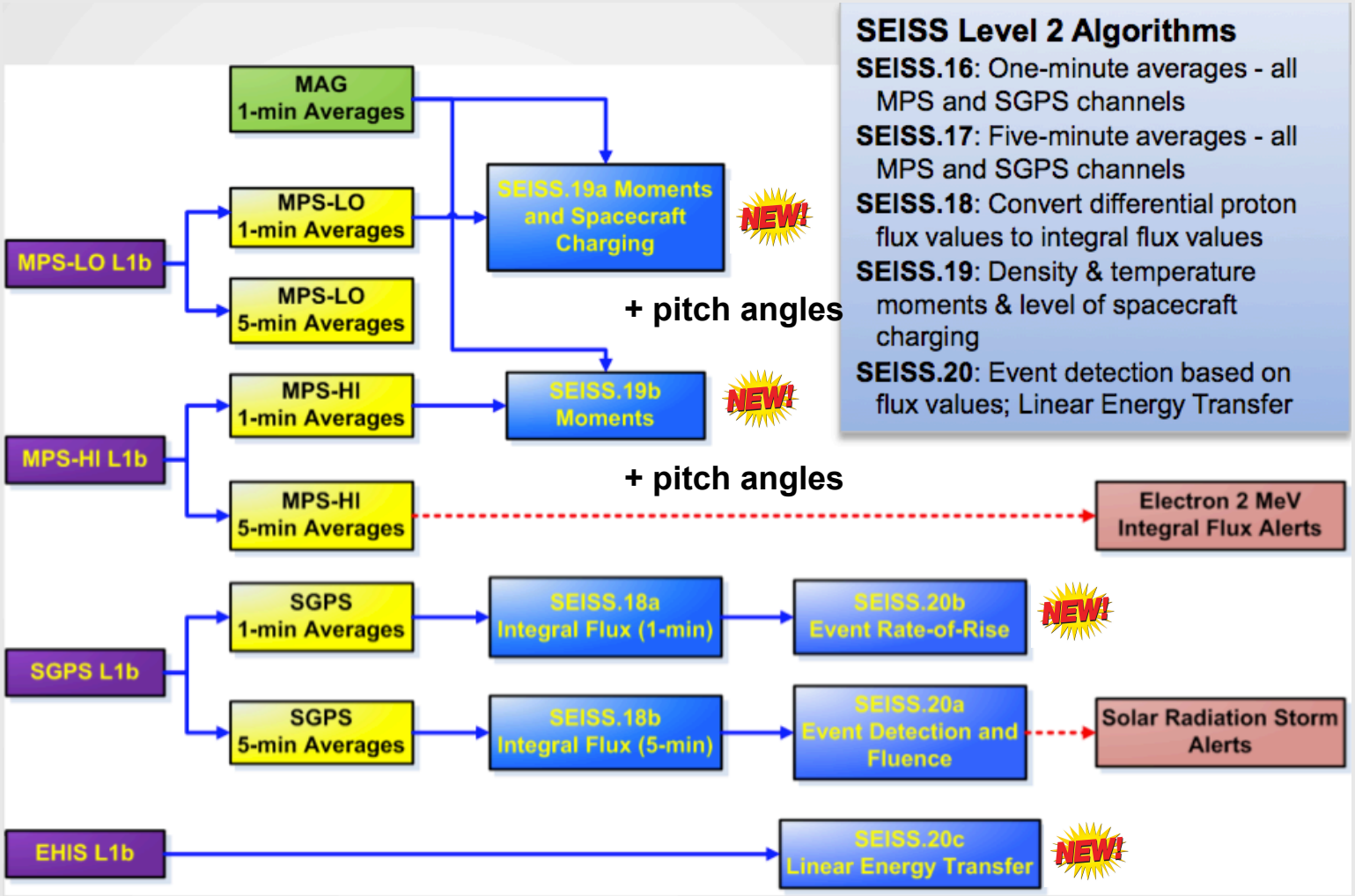
Energetic Heavy Ion Sensor (EHIS)

- 10-200 MeV/nucleon in 5 energy bands
- H, He, Z = 4-29 (Be-Cu), + CNO, Ne-S, Fe
- one look direction (radially outward)

SEISS sensors turned on Jan. 8th 2017

SEISS MPS designed, built, tested and calibrated by Assurance Technology Corporation

SEISS Level 1 and 2 Data Products



SGPS and EHIS Data Products

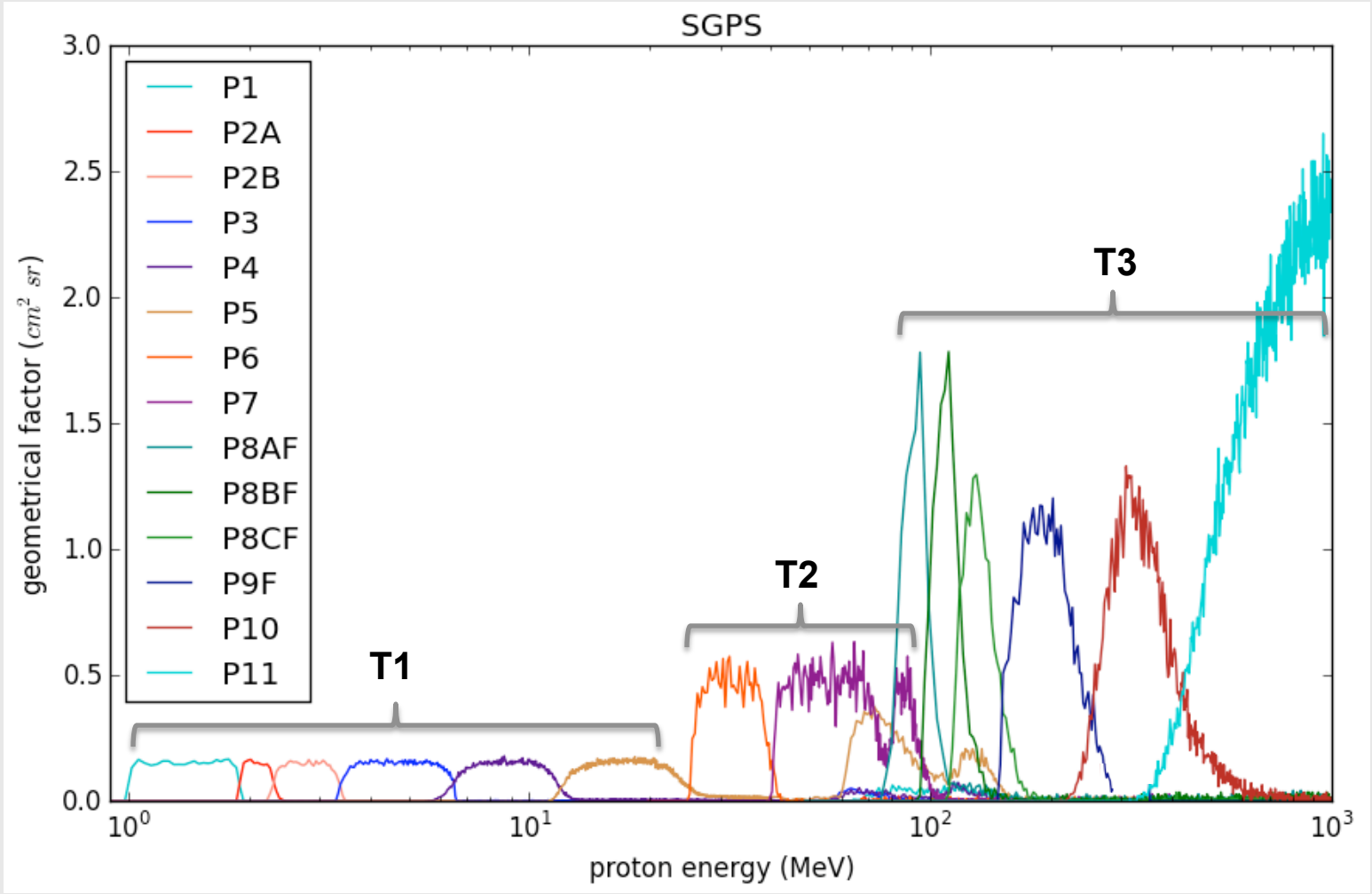
- Solar particle event detection -- Legacy
  - Solar Radiation Storm Scale detection, peak event fluxes, and event fluences.
  - Input: integral proton fluxes from13 differential and >500 MeV SGPS channels
- Rate of rise -- New
  - Estimates the rate-of-rise of 1-min SEP fluxes to predict when a solar particle event will reach different levels on the NOAA Solar Radiation Storm Scale.
  - Input: one minute cadence >10 MeV and >100 MeV integral fluxes from SGPS
- Linear energy transfer -- New
  - Transforms energy spectra measured by the Energetic Heavy Ion Sensor (EHIS) into linear energy transfer (LET) spectra
  - Input: EHIS L1b fluxes on a 5-min cadence.

NOAA-NWS Space Weather Prediction Center Space Weather Scales

Solar Radiation Storms			Flux level of ≥ 10 MeV particles (ions)*	Number of events when flux level was met**
S 5	Extreme	Biological: unavoidable high radiation hazard to astronauts on EVA (extra-vehicular activity); passengers and crew in high-flying aircraft at high latitudes may be exposed to radiation risk. *** Satellite operations: satellites may be rendered useless, memory impacts can cause loss of control, may cause serious noise in image data, star-trackers may be unable to locate sources; permanent damage to solar panels possible. Other systems: complete blackout of HF (high frequency) communications possible through the polar regions, and position errors make navigation operations extremely difficult.	10^5	Fewer than 1 per cycle
S 4	Severe	Biological: unavoidable radiation hazard to astronauts on EVA; passengers and crew in high-flying aircraft at high latitudes may be exposed to radiation risk.*** Satellite operations: may experience memory device problems and noise on imaging systems; star-tracker problems may cause orientation problems, and solar panel efficiency can be degraded. Other systems: blackout of HF radio communications through the polar regions and increased navigation errors over several days are likely.	10^4	3 per cycle
S 3	Strong	Biological: radiation hazard avoidance recommended for astronauts on EVA; passengers and crew in high-flying aircraft at high latitudes may be exposed to radiation risk.*** Satellite operations: single-event upsets, noise in imaging systems, and slight reduction of efficiency in solar panel are likely. Other systems: degraded HF radio propagation through the polar regions and navigation position errors likely.	10^3	10 per cycle
S 2	Moderate	Biological: passengers and crew in high-flying aircraft at high latitudes may be exposed to elevated radiation risk.*** Satellite operations: infrequent single-event upsets possible. Other systems: effects on HF propagation through the polar regions, and navigation at polar cap locations possibly affected.	10^2	25 per cycle
S1	Minor	Biological: none. Satellite operations: none. Other systems: minor impacts on HF radio in the polar regions.	10	50 per cycle

- The NOAA Space Weather Scales communicate to the general public current and future space weather conditions and their possible effects on people and systems.
- Similar NOAA scales for **Geomagnetic Storms** and **Radio Blackouts,** plus >2 MeV radiation belt alert.
- Numbered levels, analogous to hurricanes, tornadoes, and earthquakes that convey severity.

SGPS Energy Passbands (GEANT)

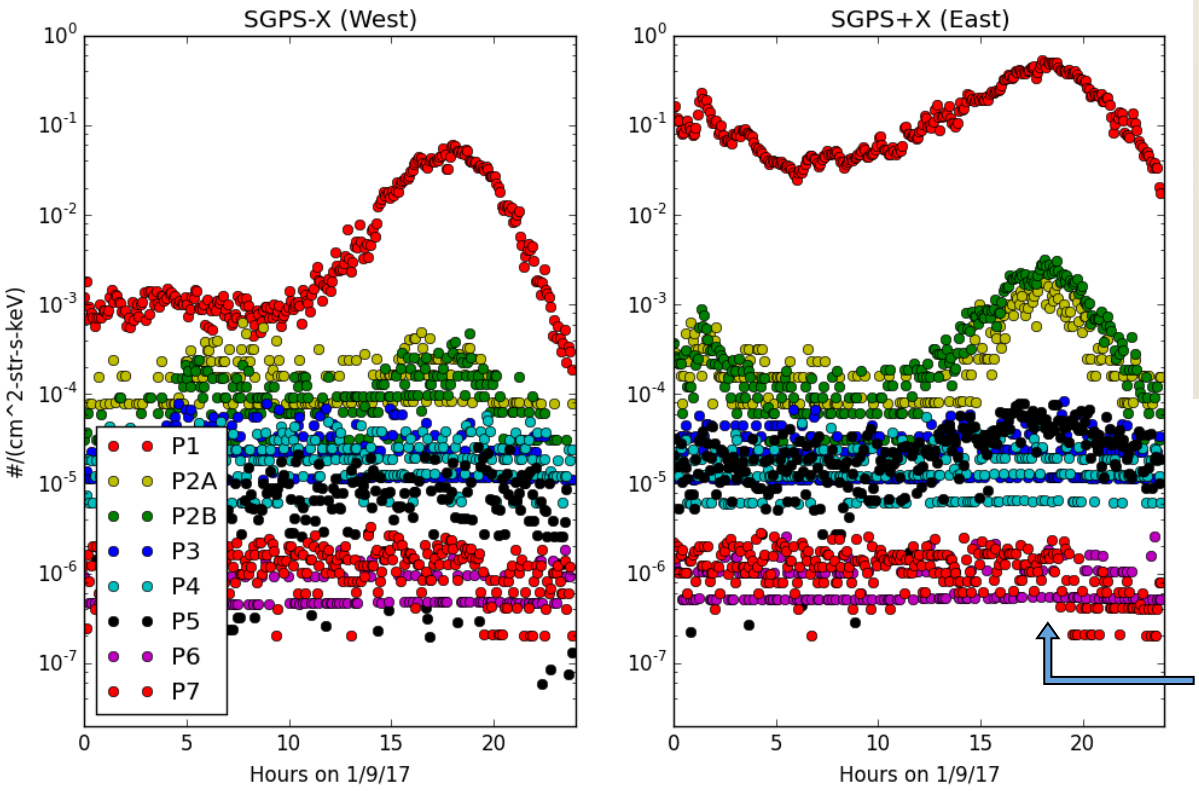


Post Launch Tests:
Solar Proton Channels Cross-Comparison

MPS-HI	SGPS (east and west facing units)	EHIS	EPEAD
P1 (80-115 keV)	P1 (1-1.9 MeV)	10.0-31.25 MeV	P1 (0.7–4.2 MeV)
P2 (115-165 keV)	P2A (1.9-2.3 MeV)	31.0-43.5 MeV	P2 (4.2–8.7 MeV)
P3 (165-235 keV)	P2B (2.3-3.4 MeV)	43.5-54.0 MeV	P3 (8.7–14.5 MeV)
P4 (235-340 keV)	P3 (3.4-6.5 MeV)	54.0-101.0 MeV	P3 (8.7–14.5 MeV)
P5 (340-500 keV)	P4 (6.5-12 MeV)	109.5-192.5 MeV	P4 (15–40 MeV)
P6 (500-700 keV)	P5 (12-25 MeV)		P5 (36–80 MeV)
P7 (700-1000 keV)	P6 (25-40 MeV)		P6 (80–180 MeV)
P8 (1000-1900 keV)	P7 (40-80 MeV)		
P9 (1900-3200 keV)	P8AF (83-99 MeV)		
P10 (3200-6500 keV)	P8BF (99-118 MeV)		
P11 (6500-10000 keV)	P8CF (118-150 MeV)		
	P9F (150-275 MeV)		
	P10 (275-500 MeV)		
	P11 (> 500 MeV)		

On-orbit cross-calibrations: SGPS -east and –west facing units, SGPS with EHIS above 10 MeV, SGPS with MPS-HI 1-10 MeV protons, and all GOES-R sensors with GOES 13-15 EPEAD.

First Full day of SGPS Data

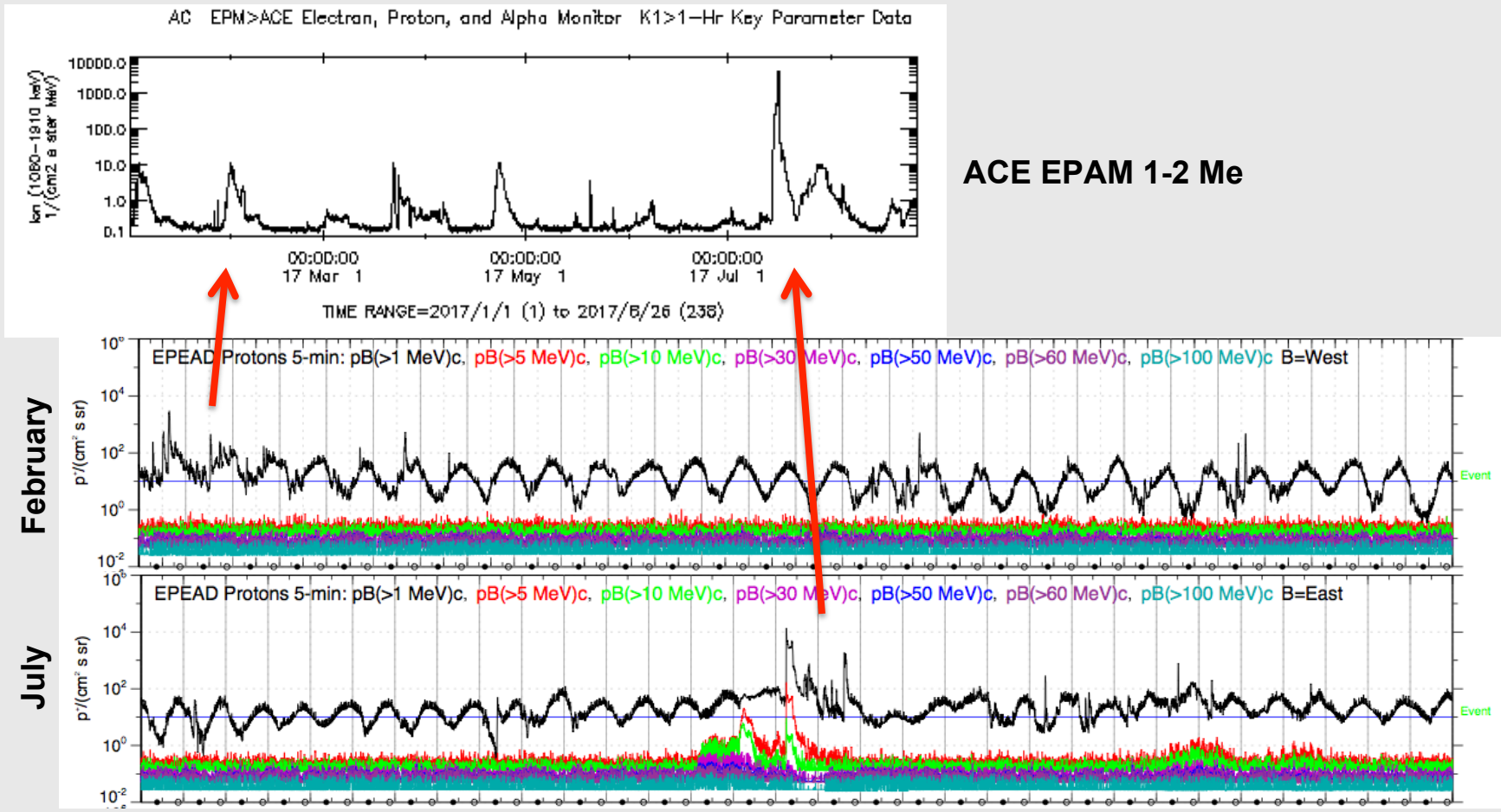


P1 (1-1.9 MeV)
P2A (1.9-2.3 MeV)
P2B (2.3-3.4 MeV)
P3 (3.4-6.5 MeV)
P4 (6.5-12 MeV)
P5 (12-25 MeV)
P6 (25-40 MeV)
P7 (40-80 MeV)

P7 D3-D1 rear entry removal circuit turned on

SGPS T1 and T2 5m averaged proton fluxes on 1/9/17. There is significant diurnal variation with a maximum near noon local-time and higher flux in general in the eastward facing detector.

Solar Energetic Particles (SEPs) in 2017



ACE EPAM 1-2 Me

Bottom two panels: GOES-13 integral fluxes from EPEAD

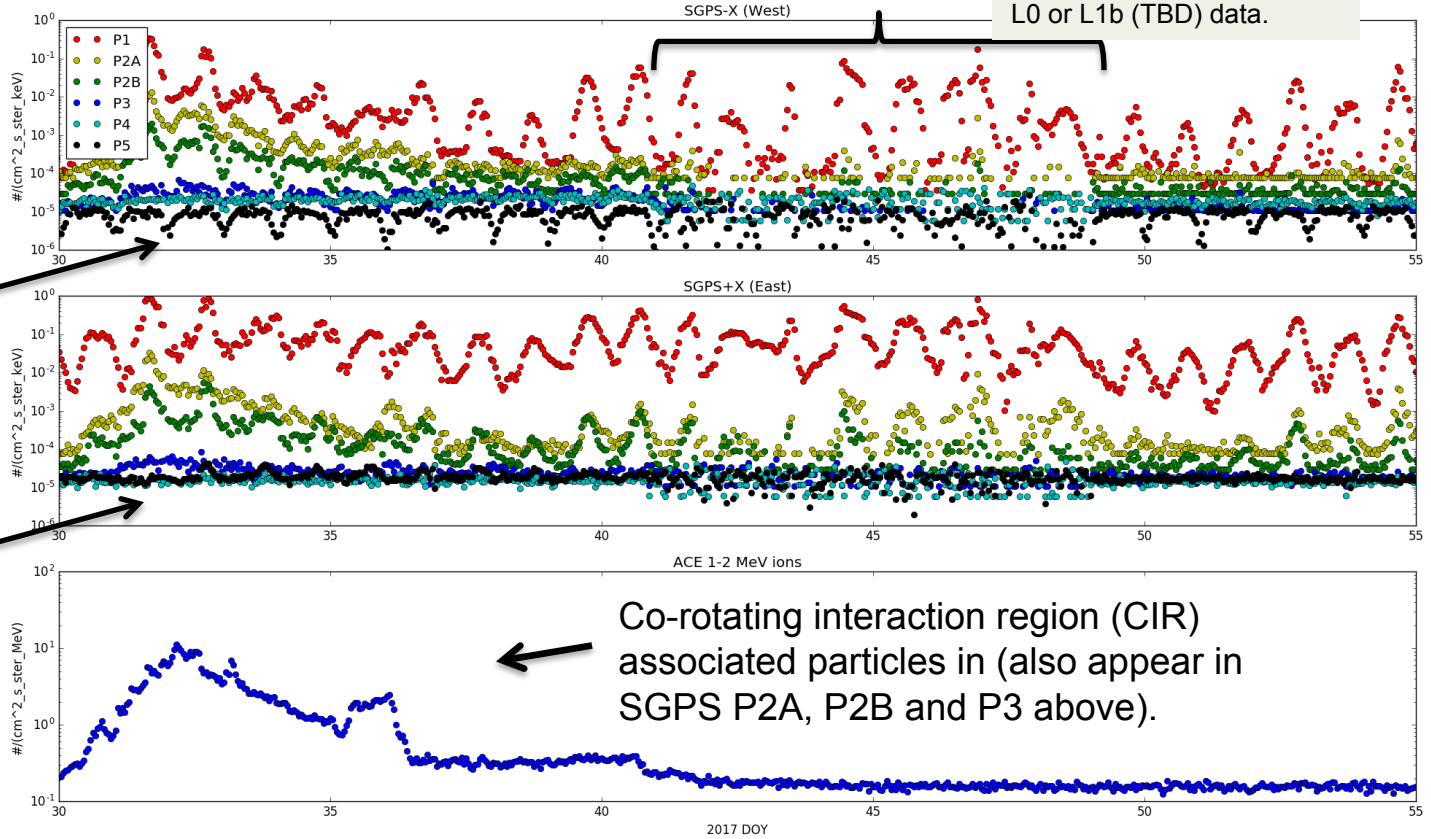
East and West facing SGPS T1 and ACE EPAM (interplanetary) data during Feb 2017

P1 (1-1.9 MeV)
P2A (1.9-2.3 MeV)
P2B (2.3-3.4 MeV)
P3 (3.4-6.5 MeV)
P4 (6.5-12 MeV)
P5 (12-25 MeV)

Periods of noisy or missing L0 or L1b (TBD) data.

Periodic drops in P5 flux in SGPS-X

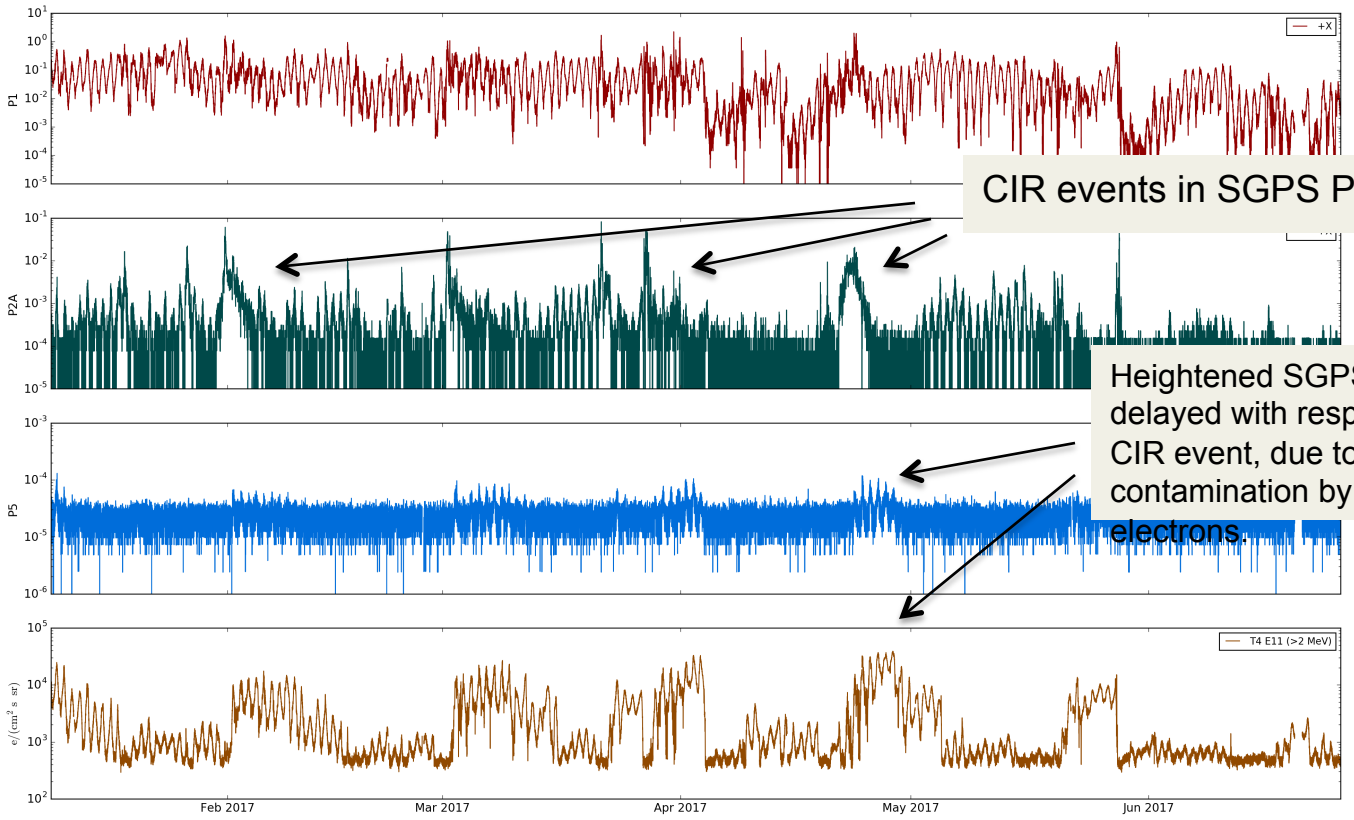
Small diurnal variations in P5, delayed with respect to start of CIR event.



Co-rotating interaction region (CIR) associated particles in (also appear in SGPS P2A, P2B and P3 above).

Top 2 panels: SGPS -X (west) and +X (east) T1 one hour averaged L1b fluxes during Feb 2017.
Bottom: ACE EPAM 1-2 MeV ions, showing CIR particles, associated with solar wind high-speed streams.

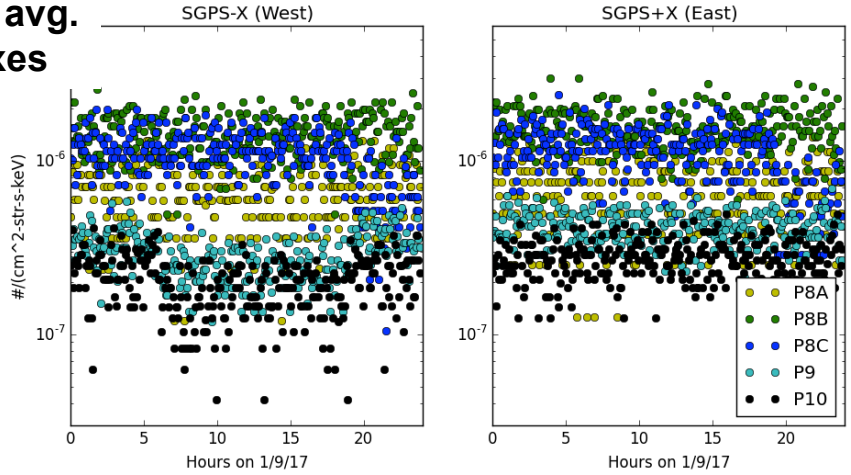
SGPS P5 contamination by electrons



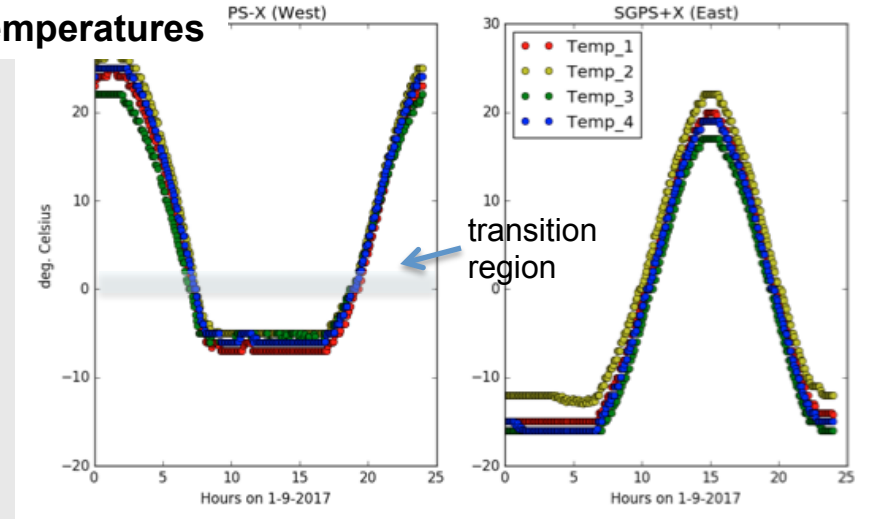
Top 3 panels: SGPS +X (east) P1, P2A, and P5 fluxes during Jan-June 2017. **Bottom:** MPS-HI E11 (>2MeV) showing enhanced radiation belt electron fluxes associated with CIR events.

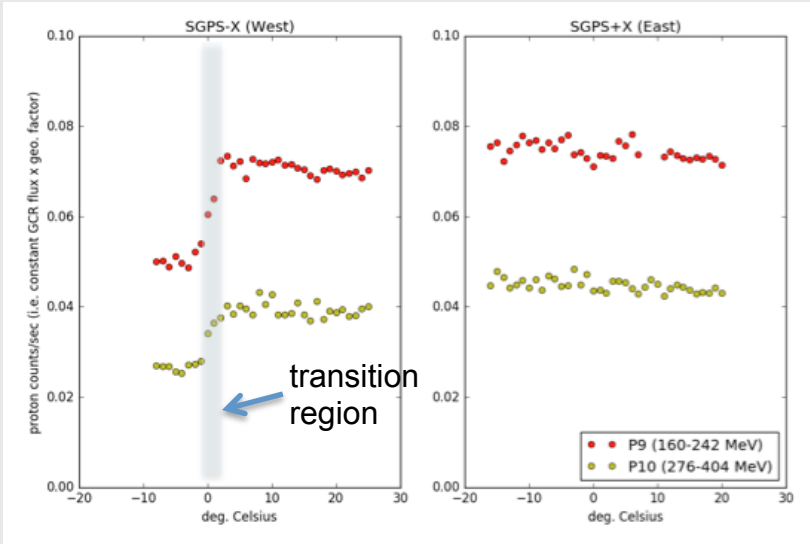
SGPS-X (west) temperature dependence

5m avg. fluxes



Temperatures

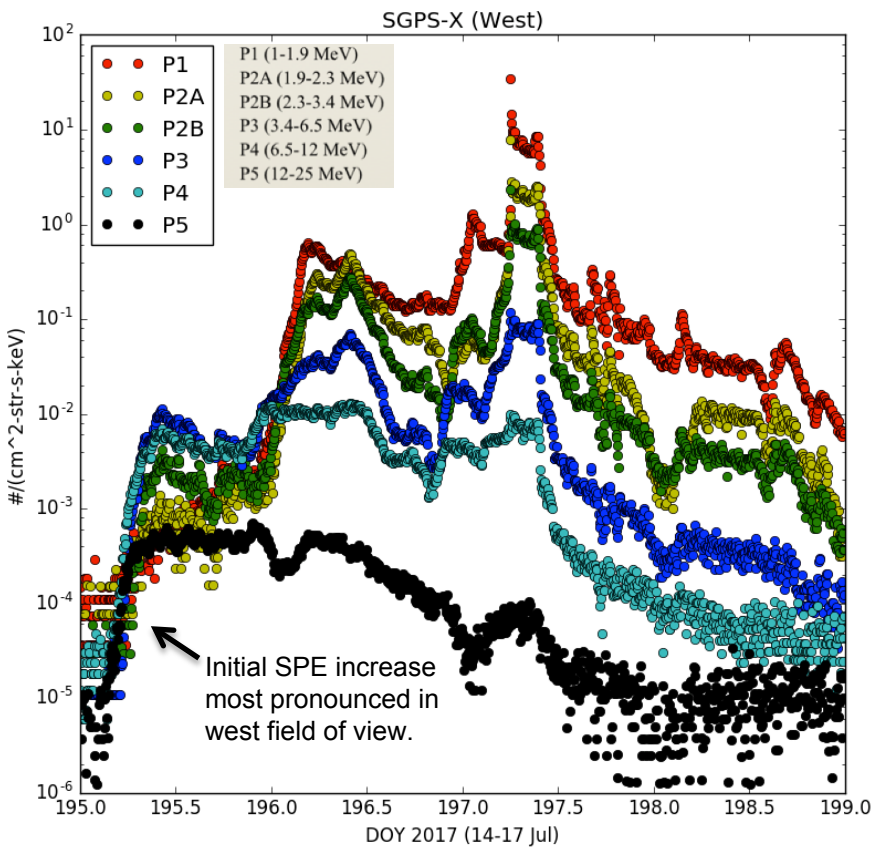


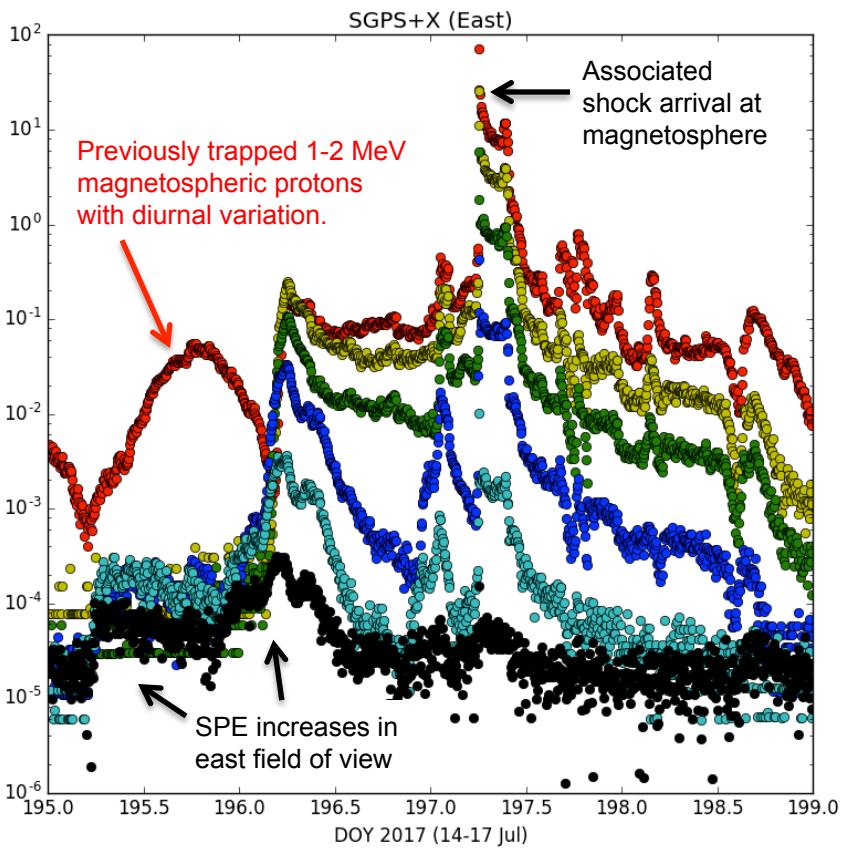


22 day averages of counts/sec in 1 deg. temperature bins between -20° and +30° C. If we assume a constant GCR flux, the plots show the channel geometric factors times a multiplicative constant (GCR flux) versus temperature.

Here, P9 and P10 are shown as examples. There is also significant temperature dependence in response of P11, P5 and possibly P1-P3 channels.

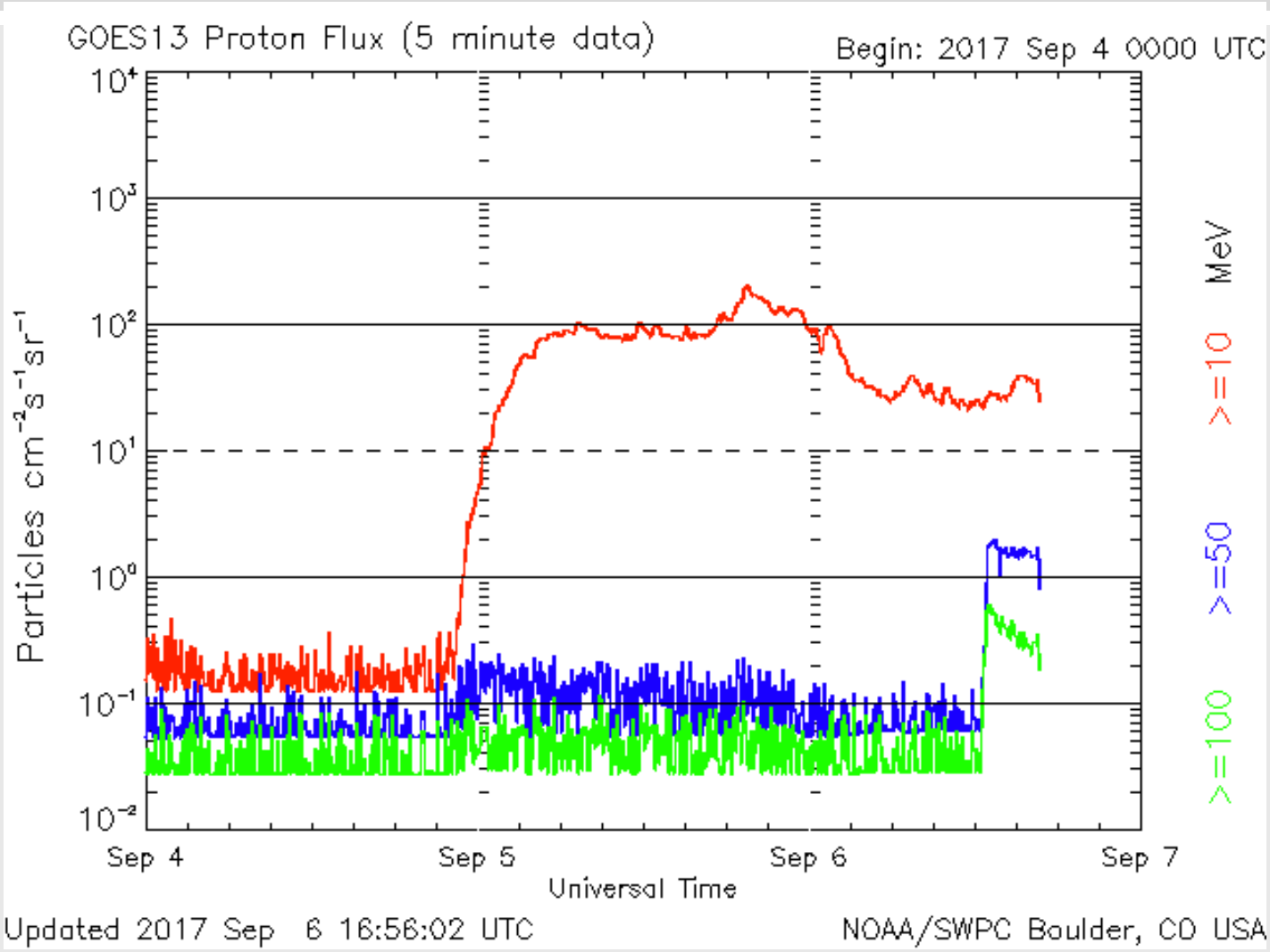
14-17 July 2017 SPE in SGPS T1





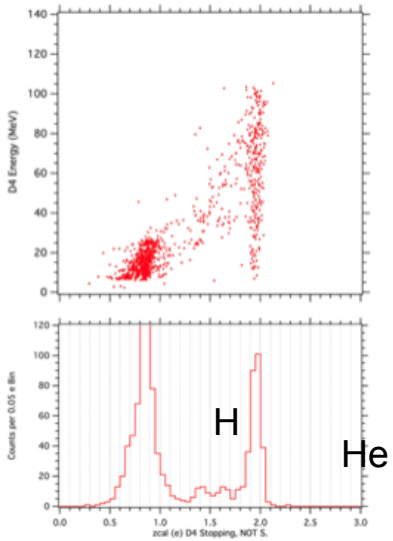
14-17 July 2017 solar particle event (SPE) 5m averaged fluxes in SGPS T1 (1-25 MeV). This event had a small response in T2 fluxes (25-80 MeV), and no discernable response in T3 fluxes (80 to >500 MeV).

4-?? September 2017 SEP event

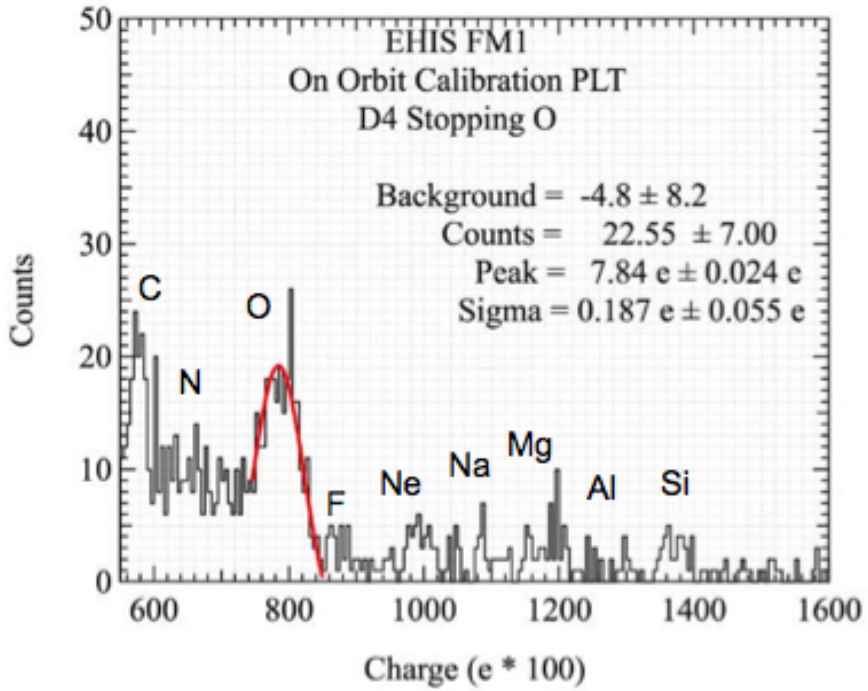


Histograms of H, He, and heavy ion counts from EHIS on-orbit calibration

LEFT: Proton Peak Is Off The Top Of The Chart At ~750



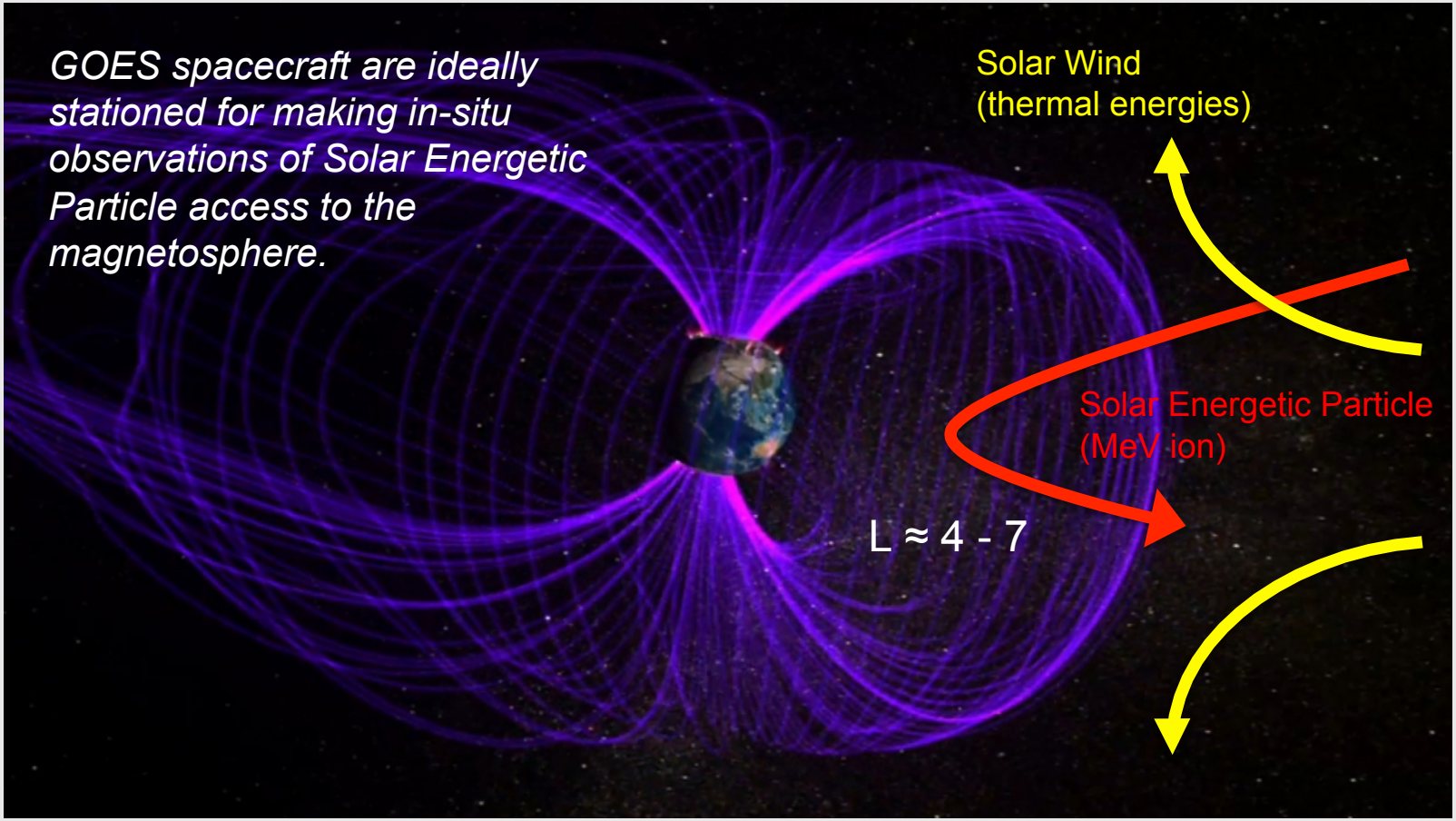
* Key simplifying assumptions put peaks at 0.7e For Protons, 1.4e For Deuterium, 1.6e For Helium-3, and at 2.0e For Helium-4, where the data lie.



PLT Success Criteria met: collect a minimum of 50 counts of each major elemental species, H, He, C, N, O, Ne, Mg, Si and Fe In each of 5 energy bands and verify that results (ZCAL And Alpha-Kappa) are in-family to pre-flight ground calibrations, and/or models.

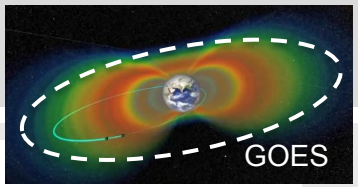
From: Post Launch Test Report For The GOES-R Space Environment In-Situ Suite (SEISS) Initial EHIS On-Orbit-Calibration, SEISS-TR-SY121-11, Final

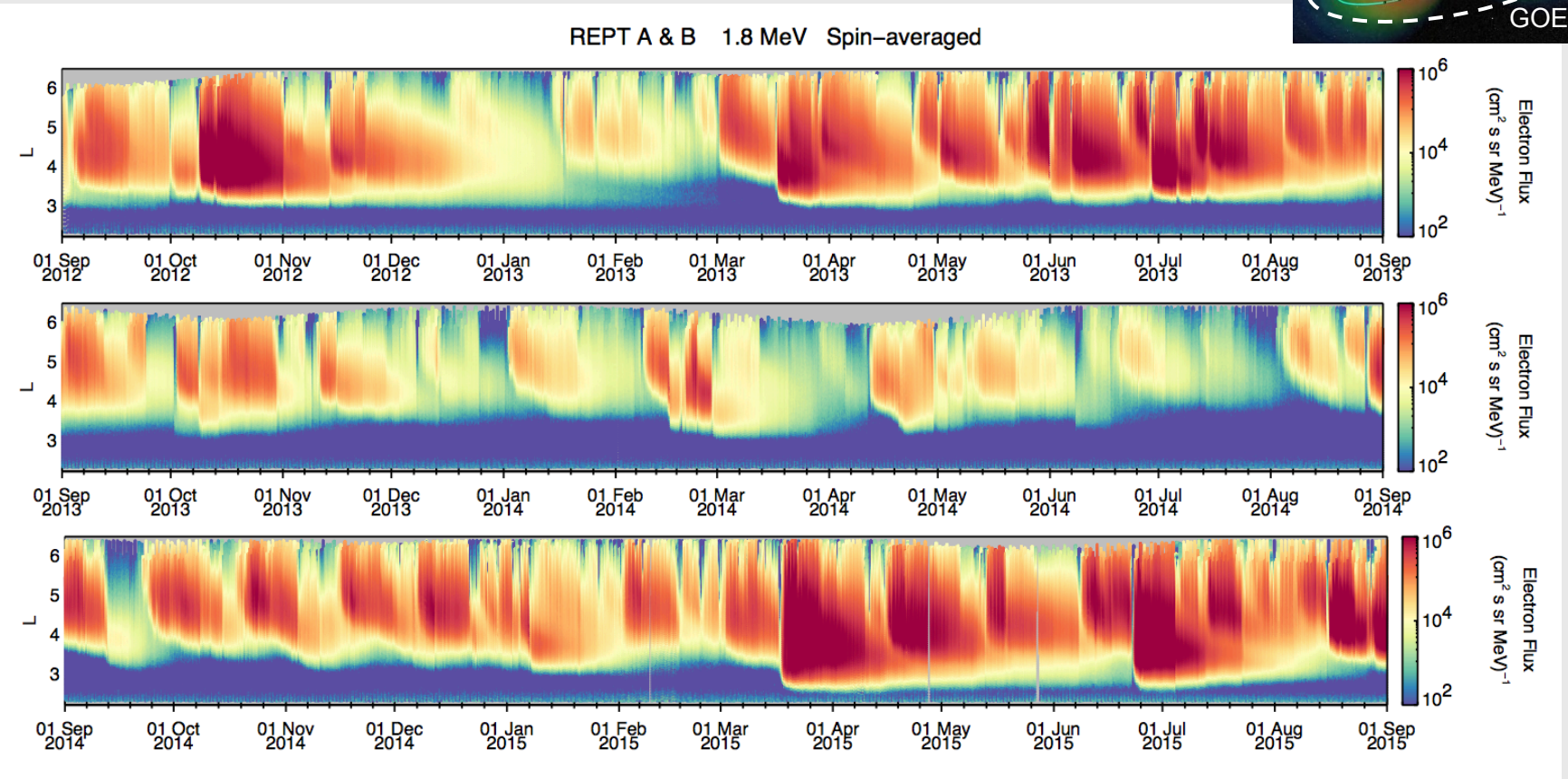
Science Supported by GOES Energetic Particle Observations



During quiet conditions, Solar Energetic Particles are magnetically shielded inside of L ~ 4 (L is distance in Earth radii of dipole field line, in equatorial plane)., Outside of L ~ 7, the Solar Energetic Particle flux is the same as in interplanetary space.

In-situ observations of source population for Earth's outer radiation belts





Van Allen Relativistic Electron Proton Telescope (REPT) spin averaged 1.8 MeV electron flux [From Dan Baker's RBSP-MMS Slides]. In-situ observations of source population for Earth's outer radiation belts

Summary

- The SEISS instrument was launched on-board GOES-16 on Nov 19. Sensors were turned on on Jan 8th.
- Measurement of 30 eV to 30 keV particles by SEISS MPS-LO and heavy ions by EHIS are new capabilities not previously flown on the GOES system. SEISS also has improved energy and pitch angle resolution above 800 MeV.
- The new GOES instrumentation will support the following new products
  - Densities, temperature, and spacecraft frame charging levels
  - Linear Energy Transfer from EHIS heavy ions
  - First-principals space weather modeling and prediction at SWPC
- GOES spacecraft are ideally stationed for making in-situ observations of
  - solar and galactic cosmic ray access to the Earth's magnetosphere
  - source populations for the Earth's ring current and outer radiation belts