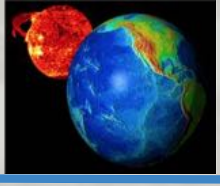


POES/Metop SEM-2 and NCEI National Centers for Environmental Information (NCEI)

R. J. Redmon

NOAA / NCEI / CCOG / Solar and Terrestrial Physics

SEESAW 2017
Boulder

Outline

POES and Metop Space Environment Monitor (SEM2)

- Status
- Near Future Plans
  - Metop-C Launch, Metop-A EOL
- Products and Activities

NCEI STP Broader View

- DSCOVR
- GOES
- Geomagnetism

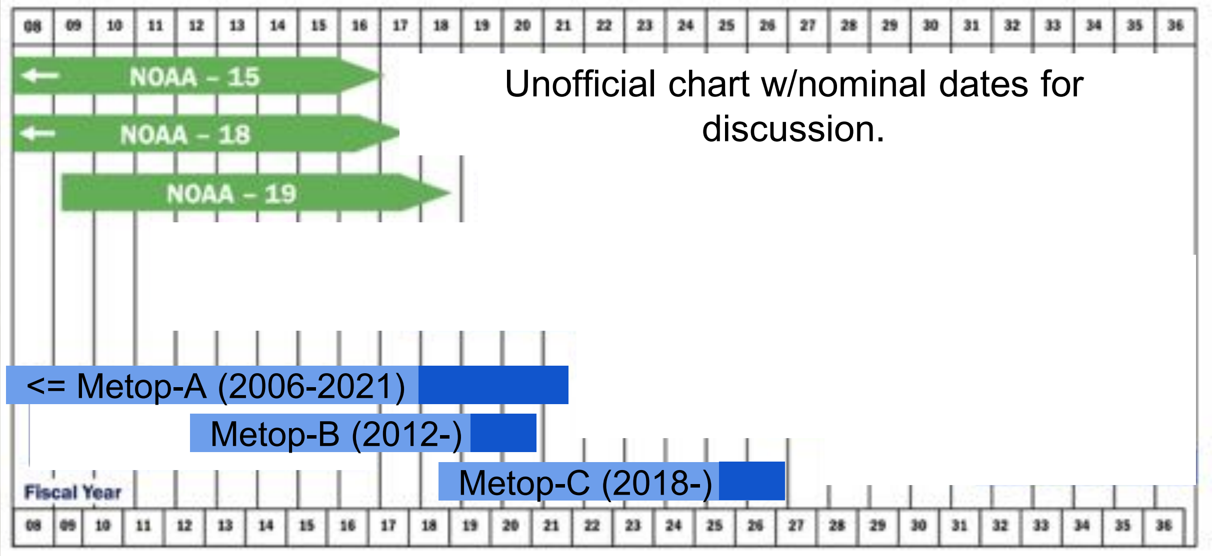
~~Continuity of LEO Measurements~~

An End of an Era (since 1978)

NOAA-19 (POES)
Launched: 08 Feb 2009

www.ngdc.noaa.gov/stp/satellite/poes/

- Current constellation:
  - N15, N18, N19, Metop-B, Metop-A
- Upcoming activities:
  - Metop-C Launch ~ October 2018
  - Metop-A End of Life ~ 2021



Adapted: nesdis.noaa.gov/content/our-satellites, eumetsat.int/website/home/Satellites/CurrentSatellites/Metop/

Status: NOAA-15-19, Metop-B,A

- Total Energy Detector (TED) (0.05-20 keV e-, i+, zenith and 30-off-zenith)
  - Metop-B e- and i+ detectors are showing signs of degradation.
  - Metop-A e- detectors are showing signs of degradation.
  - NOAA-18 detectors are degraded (biases are maxed).
  - NOAA-19 e- detectors are showing signs of degradation.
- Medium Energy Proton and Electron Detector (MEPED)
  - NOAA-15 MEPED proton directional detectors may be degraded (N15 vs N19).
  - Other MEPED and all “omni” appear nominal.
- Daily QC: https://satdat.ngdc.noaa.gov/sem/poes/data/processed/ngdc/uncorrected/full/2017/

S/C	Launch	LTAN	TED e-	TED i+	MEPED	omni
Metop-B	2012-09	9:30/21:30	2/3	3		
Metop-A	2006-10	9:30/21:30	6/7	5		
NOAA-15	1998-05	5:45/17:45	2	0		
NOAA-18	2005-05	5:53/17:53	7	7		
NOAA-19	2009-02	2:36/14:36	6/7	7		

*Analysis technique doesn’t properly characterize the “p-high 30deg” efficiency. Value is included for completeness but isn’t actionable.

Future Plans: Metop-C Launch

But first…

Past SEM Cal/Val Support from the *NOAA User Perspective**

- **POES and Metop-A** were supported by up to **2 FTEs** at NOAA/NWS/SWPC (Dave Evans and Sue Greer).
- **Metop-B** was supported by **1 FTE** at NOAA/NESDIS/NCEI (Janet Green).
- **Metop-C** - All POES and Metop SEM activities (5 spacecraft) are supported by approximately 0.10 FTE at NCEI (Rob Redmon).
  - As of August 2017, Rob Redmon has assumed the USG admin responsibilities of the NCEI Solar & Terrestrial Physics Chief as William Denig has retired (to Maine).
- NCEI is developing a tractable cal/val plan with hopes that NOAA/OPPA will fund it. We're also looking to leverage mutual collaborations with trusted parties (e.g. AFRL, Aerospace). If you would like access to pre-operational data, let us know.

Future Plans: Metop-C Launch

Calibration and Validation of SEM

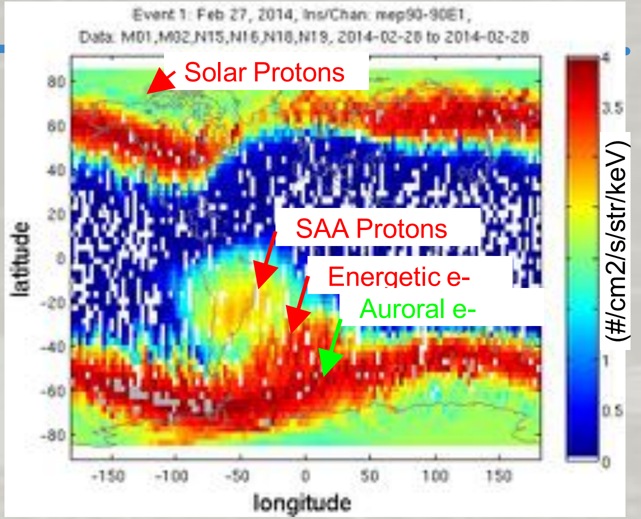
Basic plan: TED, MEPED, “omnis”:

- Synoptic maps w/ and w/o Metop-C.
- Assess penetrating radiation levels.

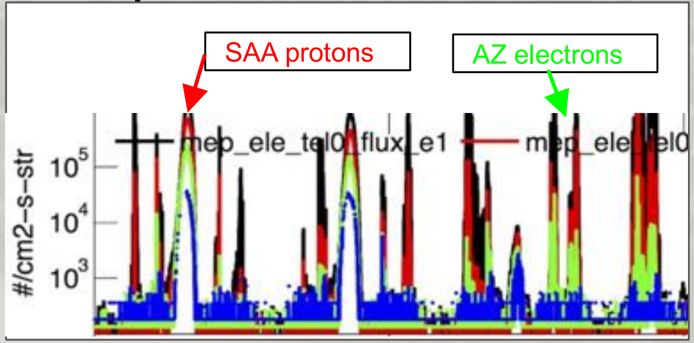
Keeping in mind:

- Many sources of both real geophysical and contam. signals.
- Existing (5) satellites are:
    - Different altitudes.
    - Degraded to some degree.
        - NOAA-18 and Metop-A TEDs.
        - NOAA-15 MEPED teles.

All TED > 30 keV electron flux



Metop-B MEPED >40 - >612 keV e-



Future Plans: Metop-A

Metop-A End of Life

- EOL ~ 2021
  - Driven by Search and Rescue (SARSAT).
- SEM EOL Tests
  - Pitch rotation through South Atlantic Anomaly
  - De-orbit - SEM will be one of the few sensors on during de-orbit.

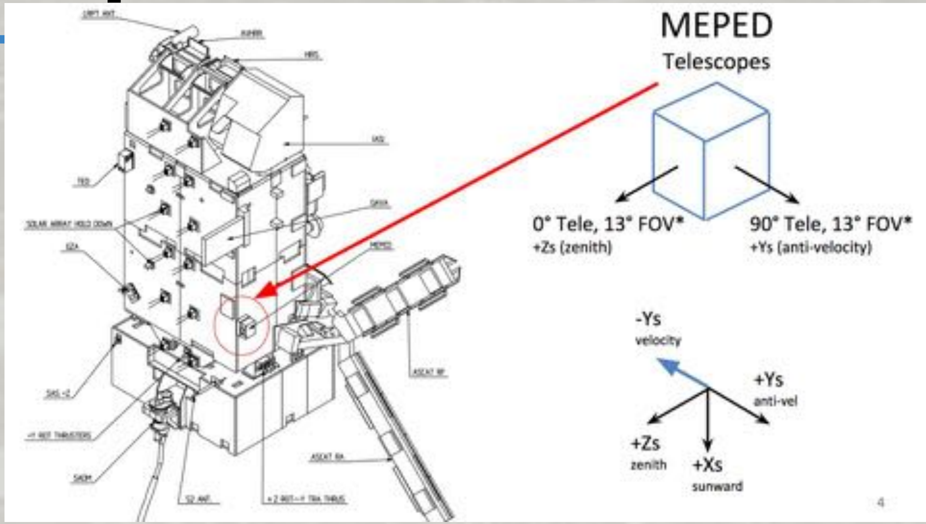


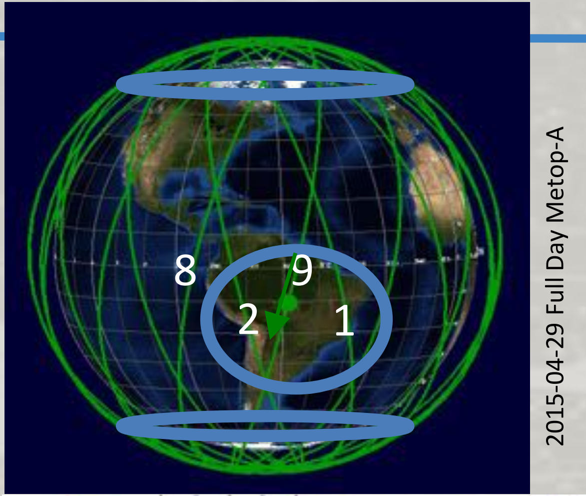
Figure above adapted from: ASTRIUM Ref: MO-IC-MMT-SE-0001: Figure 1.3.1/2a METOP “Back View of Satellite”.

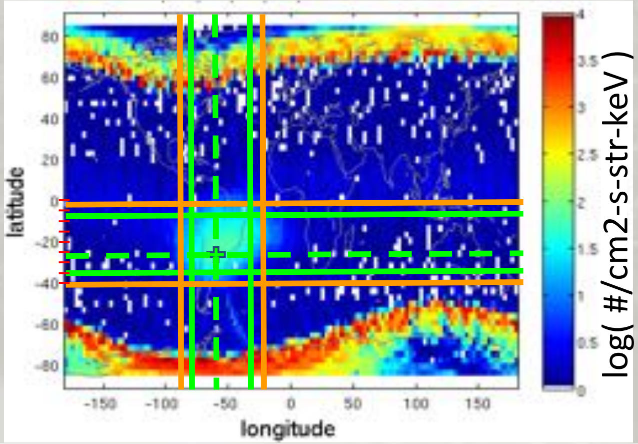
Left: Figure 13 (here) from ASTRIUM.

Metop-A End of Life

Metop-A EOL: SAA X-Cal

- MEPED telescope x-calibration.
- Pitch angle information through the SAA.
- Background:
  - Metop transits the SAA ~ 3-5/day.
  - The ACS will be paused s.t. attitude rotates in geographic frame.
  - There are many constraints and so far EUMETSAT is supportive.





Metop-A End of Life

Metop-A EOL: De-Orbit

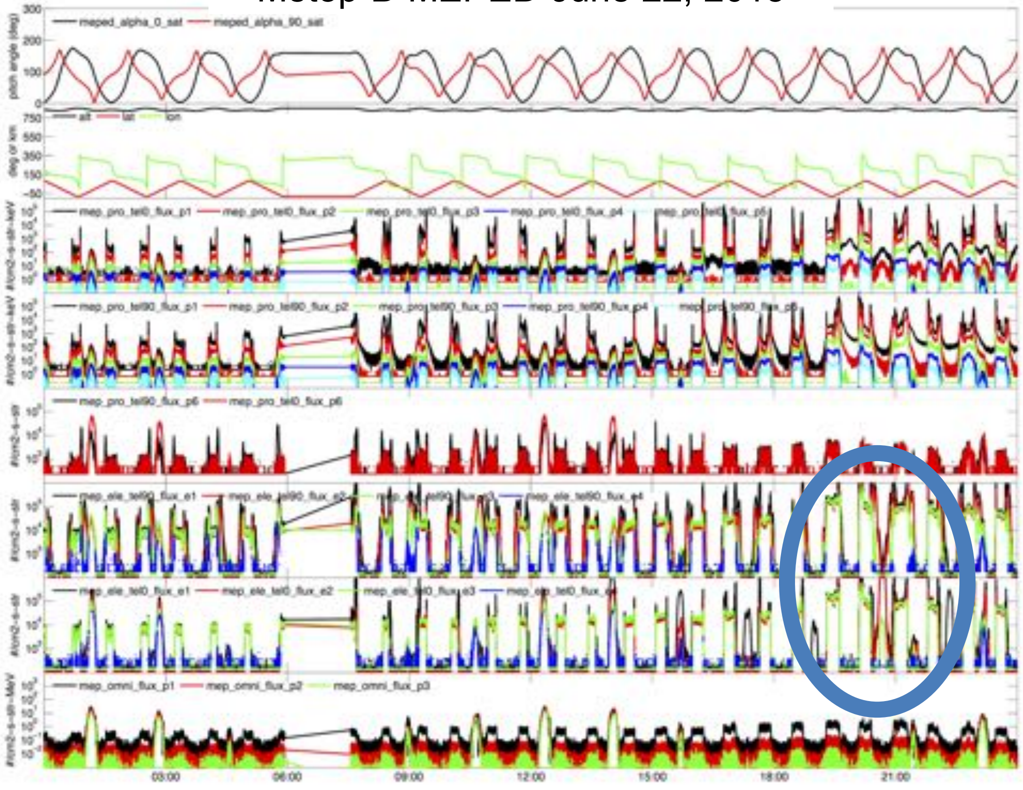
- Observations of low-altitude charged particles are sparse.
- Short 6 day test:
  - Circular 820 km to elliptical ~ 722x525 km.
  - We'll continue to encourage extensions.
- Potential Benefits:
  - Additional data for model development (e.g. AE/AP).
  - Lifetime inter-cal w/POES/Metop and potentially comparisons to other non POES/Metop LEO obs such as SAMPEX/LICA (e.g. Sandanger et al. 2015; Peck et al. 2015; Mazur et al. 1998).
  - Studies of the interactions of energetic precipitating particles with the atmosphere (e.g. Randall et al. 2007).
  - Thruster (hydrazine) interactions with the local plasma.

POES/Metop Products Current

Full resolution day files 2-second

- Raw and cal. fluxes
  - New GFs MEPED
- TED: 0.05-20 keV e-, i+, tele: zenith and 30-off-zenith
- MEPED: tele: zenith, wake
  - e-(4): >40 to >612 keV
  - i+(6): 115 to >6423 keV
- Detector pitch angles
- Omni: 25, 50, 100 MeV
- Uncertainties
- Ephemeris
- Where? NCEI, CDAWeb

Metop-B MEPED June 22, 2015



POES/Metop Products Current

Belt Indices

Derived Radiation Belt Indices

- Daily median vs satellite lifetime
- 22 Indices / day / satellite
  - Missing Metop-B
- Total, Inner, Slot, Outer
  - L-shell boundaries
- Lots of ideas for improvement.
- We use these for satellite anomaly basic situational awareness.
  - See also, O'Brien et al. [2011, 2012]

```
Total Belt Index
Inner Belt Index
Slot Belt Index
Outer Belt Index

****************
SEM-2 Sensor Numbers
****************
0 >30 keV Electrons (0 deg detector)
1 >30 keV Electrons (90 deg detector)
2 >100 keV Electrons (0 deg detector)
3 >100 keV Electrons (90 deg detector)
4 >300 keV Electrons (0 deg detector)
5 >300 keV Electrons (90 deg detector)
6 30-80 keV Protons (0 deg detector)
7 30-80 keV Protons (90 deg detector)
8 80-250 keV Protons (0 deg detector)
9 80-250 keV Protons (90 deg detector)
10 250-250 keV Protons (0 deg detector)
11 250-250 keV Protons (90 deg detector)
12 800-2500 keV Protons (0 deg detector)
13 800-2500 keV Protons (90 deg detector)
14 2500-6900 keV Protons (0 deg detector)
15 2500-6900 keV Protons (90 deg detector)
16 >6.9 MeV Protons (0 deg detector)
17 >6.9 MeV Protons (90 deg detector)
18 16-70 MeV Protons (Omnidirectional)
19 35-70 MeV Protons (Omnidirectional)
20 70-235 MeV Protons (Omnidirectional)
21 140-275 MeV Protons (Omnidirectional)
```

https://satdat.ngdc.noaa.gov/sem/poes/data/belt_indices/

NCEI's Satellite Anomaly Activities

- Creation of a public anomaly database originally championed by Joe Allen (STP chief 1981-1995) [Data access (last updated 1993)]
- Current support is adhoc as staff are available to contribute
  - Recent support to NOAA: DSCOVR, GOES, POES; US partners: EUMETSAT; Commercial (e.g. Galaxy 15)
  - E.g. sample reports, documentation; Loto'aniu et al. [2015], Redmon et al. [2016 (SCTC) and 2017 (IEEE)]
- NCEI's attempt to promote a Satellite Anomaly Initiative:
  - Currently unsupported, even though it would fit well with OSTP's Space Weather Action Plan (SWAP) and pending formalization of anomaly support by NOAA to EUMETSAT and others.

NOAA-18 Mission Lifetime >800keV Flux and Accumulated Charge

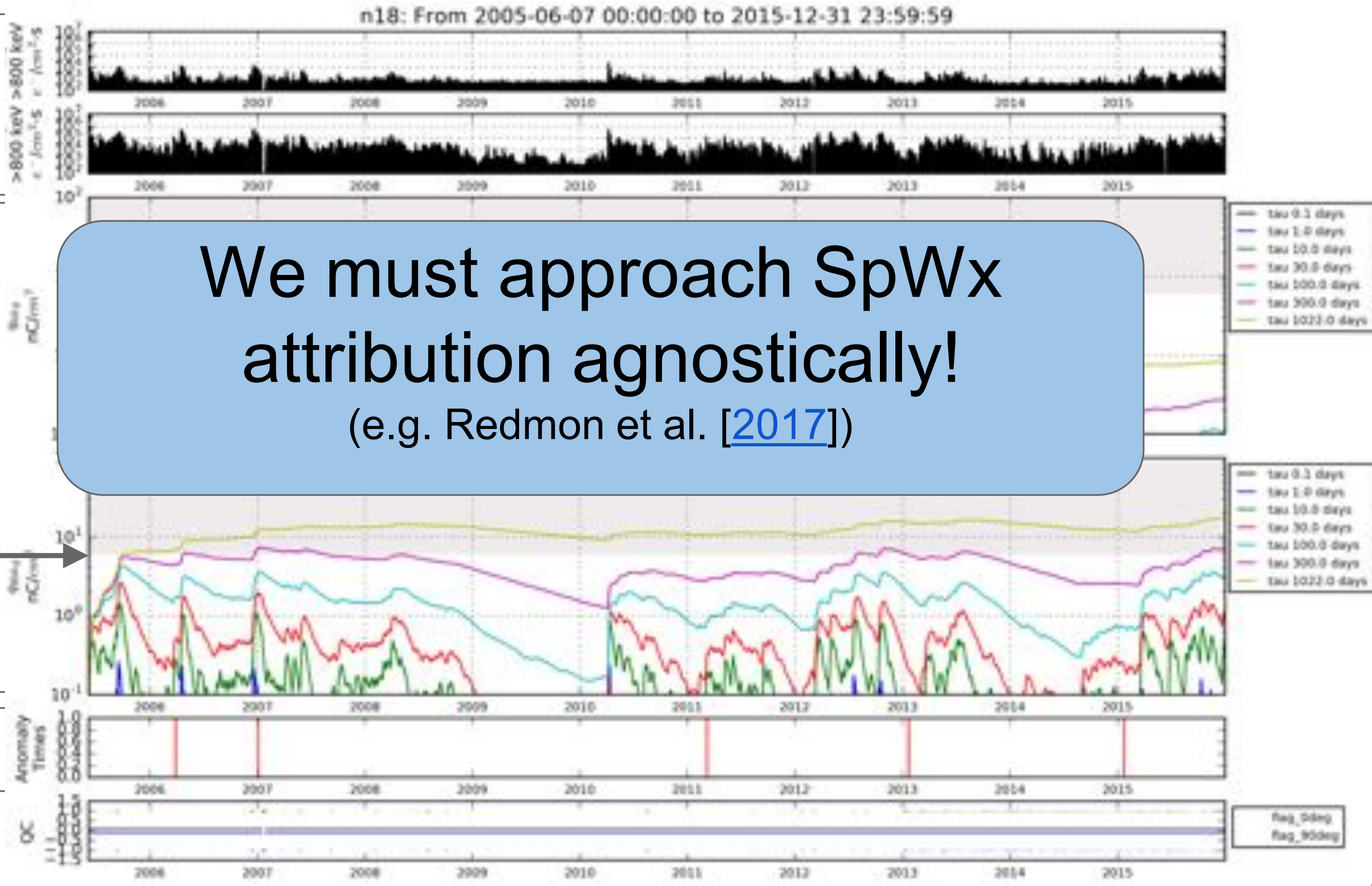
Observed >800keV e- number flux

Estimated accumulated charge nC/cm2

6 nC/cm2

6-20nC/cm2 captures most materials in space (*Bodeau et al. [2010]*).

BVR Anomaly Times



We must approach SpWx attribution agnostically!

(e.g. Redmon et al. [2017])

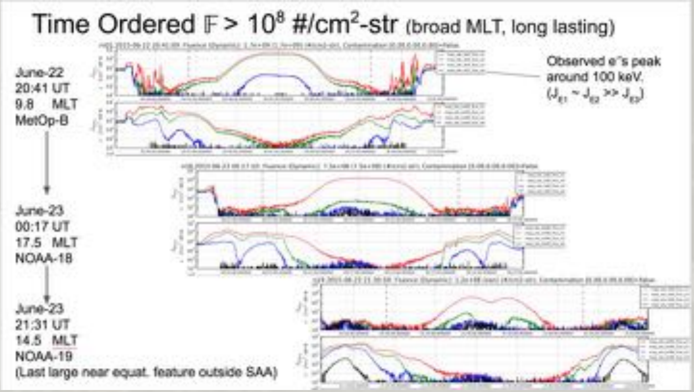
Adapted from Redmon et al. [2017].

Research efforts and New Products

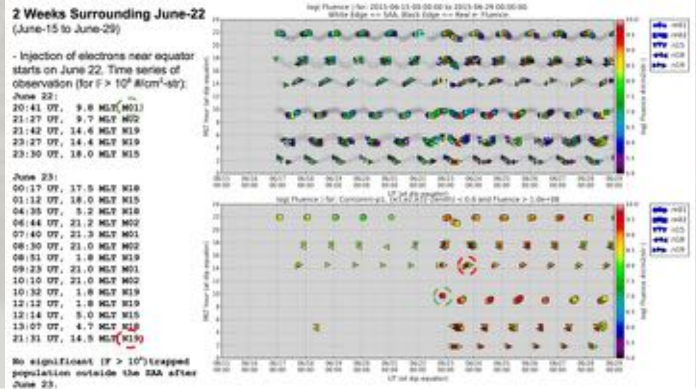
Metop-B MHS anomaly inspired studying June-22 event as it was unfolding.

- Injected ~100 keV electrons observed at the equator (L~1.1)
- Across all MLT.
- Persist for ~24 hours globally.
- Persist for months in the SAA.
  - After dealing with proton contamination of MEPED electron detectors.
- Confirmed with MAGEIS.
- Future improvement to MEPED e-

Low L~1.1 electrons injected ~100 keV

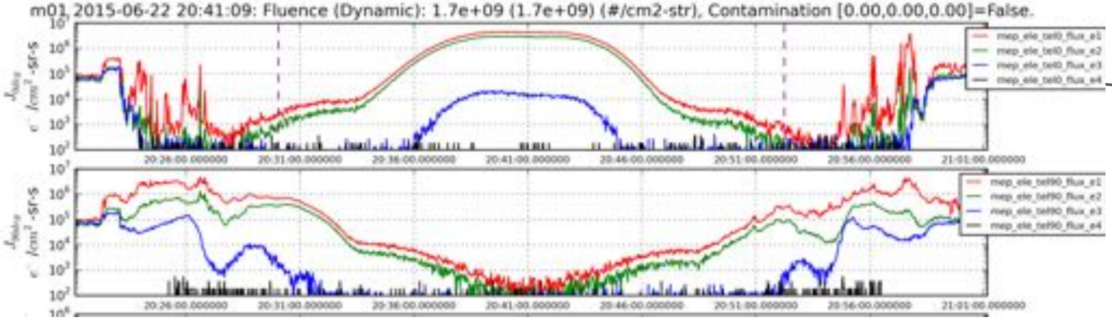


Population persists for months



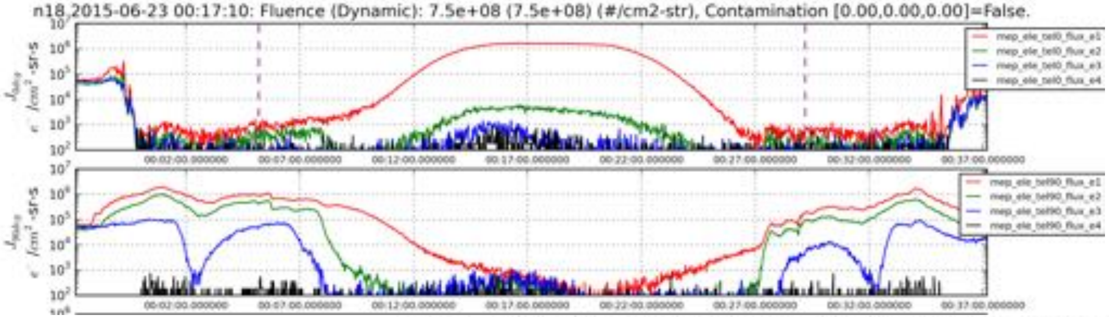
Time Ordered $\mathbb{F} > 10^8$ #/cm^2-str (broad MLT, long lasting)

June-22
20:41 UT
9.8 MLT
Metop-B

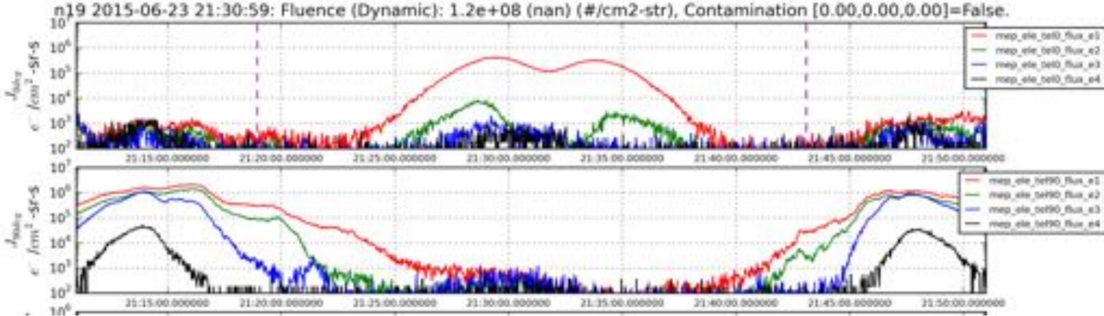


Observed e^-'s peak around 100 keV. ($J_{E1} \sim J_{E2} >> J_{E3}$)

June-23
00:17 UT
17.5 MLT
NOAA-18



June-23
21:31 UT
14.5 MLT
NOAA-19
(Last large near equat. feature outside SAA)



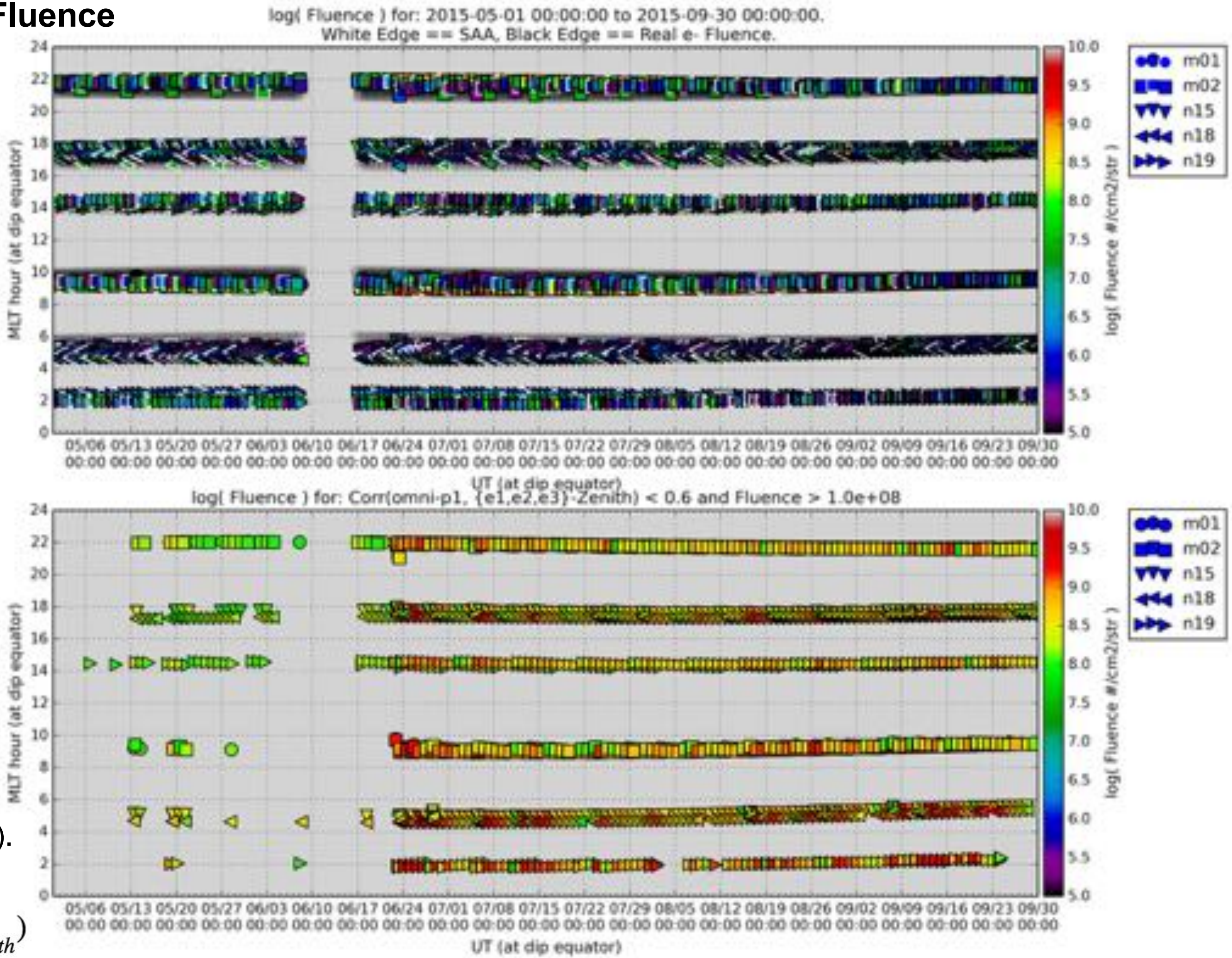
5 Months of MEPED E1-Zenith Fluence

- E1 is **>40 keV** electrons
  - E1-0 ≡ E1-zenith
    - Trapped at equator.

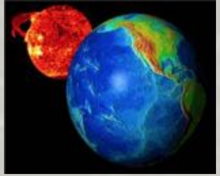
- Top Panel
  - Fluence $\mathbb{F}_{E1} \in (10^5, 10^{10})$ #/cm²-str
  - Shows all significant fluences.
  - Fluence < colorbar = shadowed.

- Bottom Panel
  - Fluence $\mathbb{F} \in (10^8, 10^{10})$ #/cm²-str
  - Fluence when uncorrelated with omni-p1 ($\rho < 0.6$) to avoid focusing on SAA proton contamination.
  - These electrons are:
    - *Occasionally* evident pre-storm (inside SAA above proton contam. due to deeper magnetospheric view at POES altitude).
    - Injected ~ mid June-22
    - Clearly evident at all MLT
    - Persist long after storm period (inside SAA; same deeper view reason).
- Fluence calc'd using zenith telescope:

$$F = \sum_{MLat=-40}^{40} \Delta t \cdot j_N(e^- > 40keV, \Omega_{0^0, zenith})$$



Outline Continued



POES and Metop Space Environm... (SEM2)

- Status
- Near Future Plans
  - Metop-C Launch
- Products and A...

NCEI ST... View

- D...
- G...
- Ge...netism

This section was trimmed to save space for sharing. Materials are available on request

Questions?

"No one trusts a model except the [person] who wrote it; Everyone trusts an observation except the [person] who made it."

- Harlow Shapley

Notes and References

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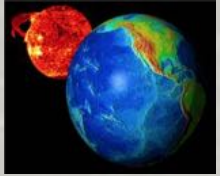

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