Low altitude measurements gaps--Particles (POES/DMSP)

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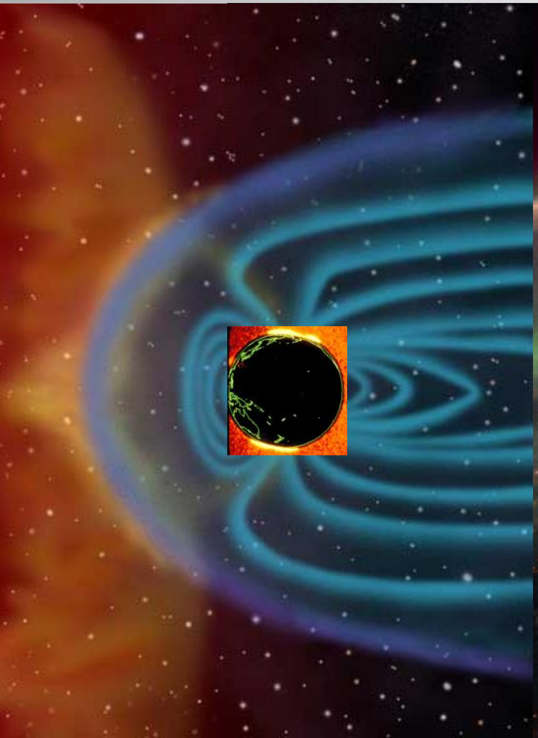
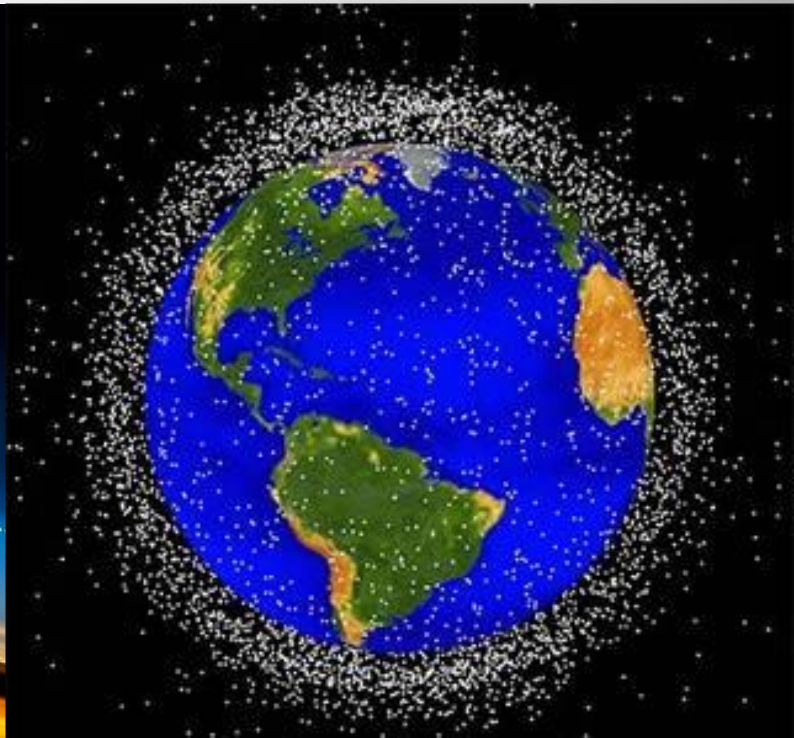
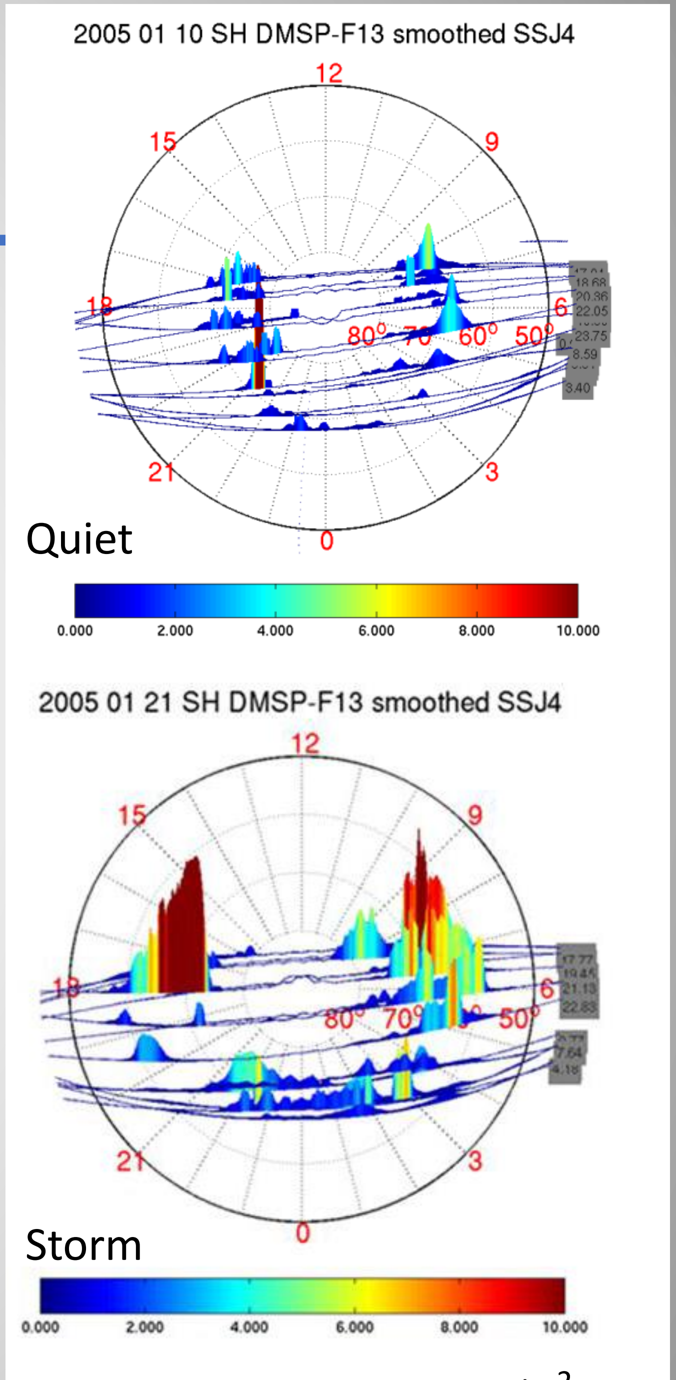




Overview

- Particle-effects Traceability
- The Lineage of Low Energy Particle Measurements
  - & Measurement Limits
- Specification, Predictive & Lookback Capabilities
- **Examples of Gaps that Low Energy Particle Obs Can Fill**
- Opportunities



(Holden, 2012)

One day of particle energy deposition of DMSP F12

Particle Effects Traceability

Particle Energy

Supra-thermal (Soft)
30eV - 30 keV
(p+) & (e-)

Supra-thermal -Medium
30 keV - 10 MeV (p+)
30 keV - 1 MeV (e-)

Hard
10 MeV-250 MeV (p+)
1 MeV – 3 MeV (e-)

Flux

Particle Domain

Thermal Plasma & Auroral
< 200 keV

Sub-auroral
> 200 keV
Radiation

Energy Flux Divergence

Environmental Effects

Ionosphere
Increased Ion Density
Irregularities
Conductivity Variations

Neutral Atmosphere
Heat/Expand
Thermostat Effect

Spacecraft (S/C) Surface Charging

Increased Radiation Exposure for S/C
Deep Charging

Increased Radiation Exposure for Humans

D-Region Ionization
Radio Wave Absorption
Enhanced VLF Skywave

System Impacts

Auroral Radar/GNSS Communications (Comms) & Signal Disruption

Ground Induced Currents: Power Grid Disruptions

Regional Aviation Ionosphere Predictions

Orbital Drag Variations
Space Traffic Management
Debris tracking/removal

Spacecraft System Degradation
Anomalies/Failures

Sensor Interference
Performance Degradation

Human Health

Polar Radar/Comms Signal Disruption

Smead Aerospace
UNIVERSITY OF COLORADO BOULDER
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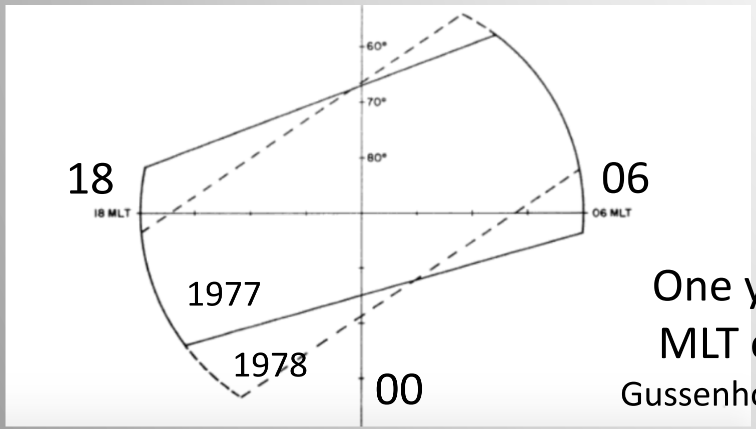
Previous Sources: W. Denig (NCEI) and T. Sotirelis (JHU/APL)

Lineage & Limitations

- Late 1970's LEO polar spacecraft
- Low energy p+ and e- particle detectors
  - DMSP F2 (1977); NOAA POES-6 (1978)
  - ~100 min orbit period
- Slow drift of sun-synch orbit plane
- Produced ~ 200 satellite years of data
- Currently SEM-2 (MetOp) & SSJ/5 on DMSP



One year drift in MLT of DMSP F2
Gussenhoven et al., 1982

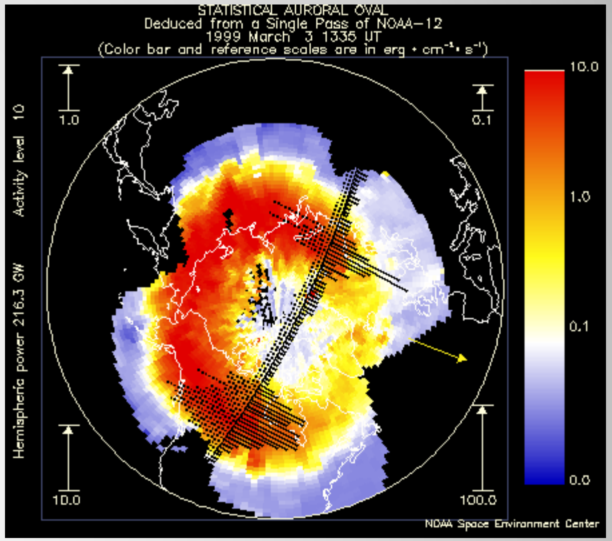
- Slow downlink over land only
- Limited local time measurements
- Detector degradation
- DMSP energy limit < 40 keV
- POES higher energy limits but wider channels
- Differing views of loss cone
- Rarely visited post noon/pre midnight
- Some high energy particle contamination
- Sensor degradation
- S/C and instruments exceeding lifetime
- No further POES or DMSP launches

Specification, Predictive & Lookback Capabilities

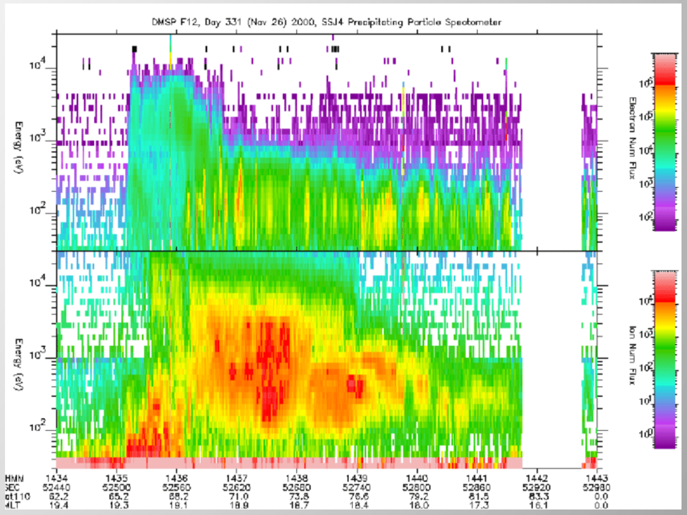
- Auroral Boundary Index
- Auroral Energy Deposition Estimates and Indices
- LEO Thermal-Plasma Charging Environment
- LEO Auroral Charging Environment
- Inferences about Magnetospheric State

- Climatological/Empirical Models Supporting All Above
  - DMSP provides > 100 satellite-years of archived data
  - NOAA POES & MetOp provide similar archive

- Post-Facto Anomaly Resolution
- Post-Facto Hundreds of Storm & Event Studies



NOAA-12 Hemispheric Power



DMSP F12 Proton Spectrogram (Lanchester et al. 2003)

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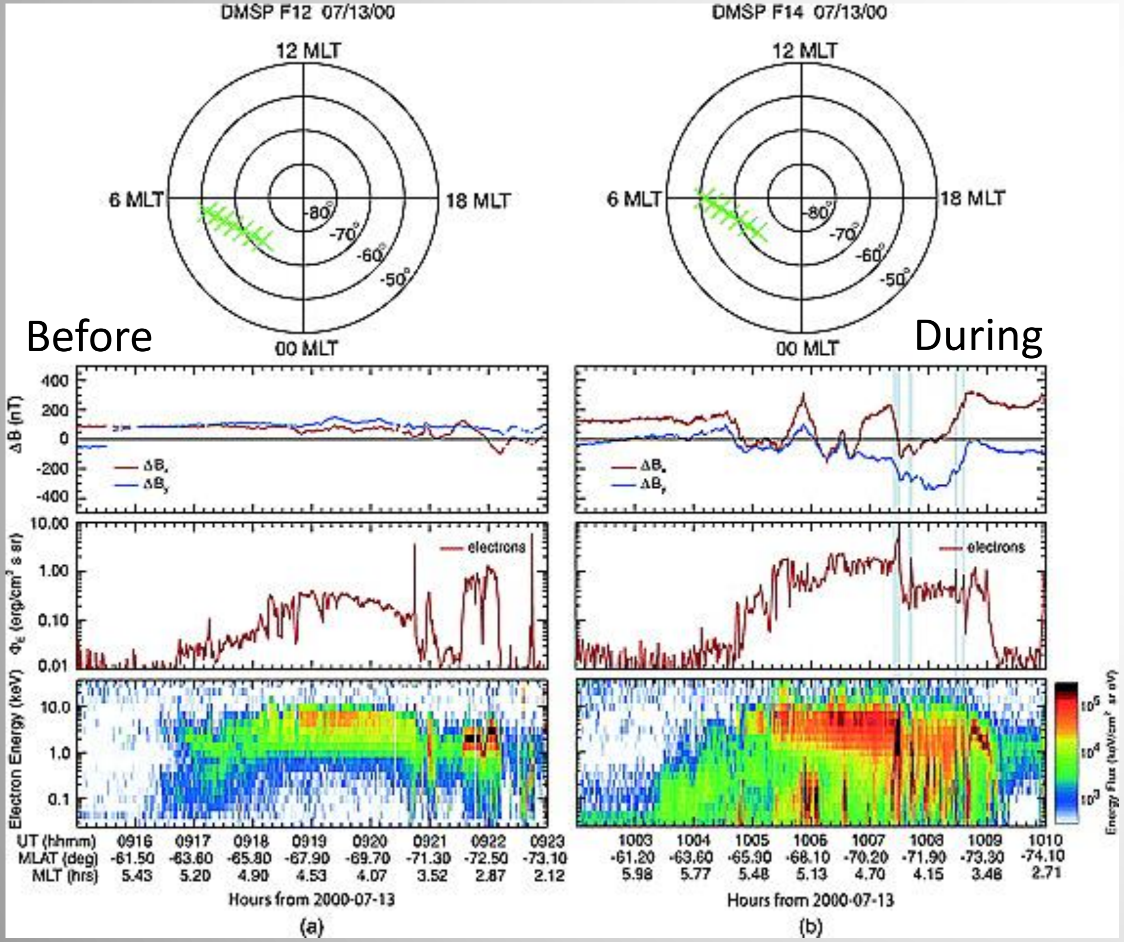
Gaps the Low Energy Particle Obs Can Fill (1)

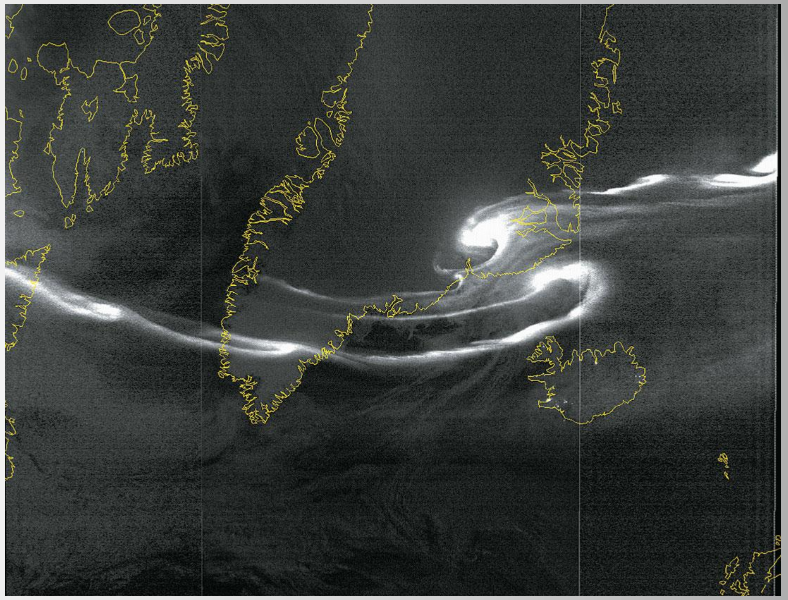
- Specification of particle spectra in shock aurora events
  - And more generally in all forms of aurora



DMSP and FAST measurements provided high and low altitude measurements of particle energy and fluxes as IP shock swept past Earth

Future studies should be merged with imagery to trace the dynamic response to IP shocks and resulting high-lat disturbances

Zhou et al., 2003

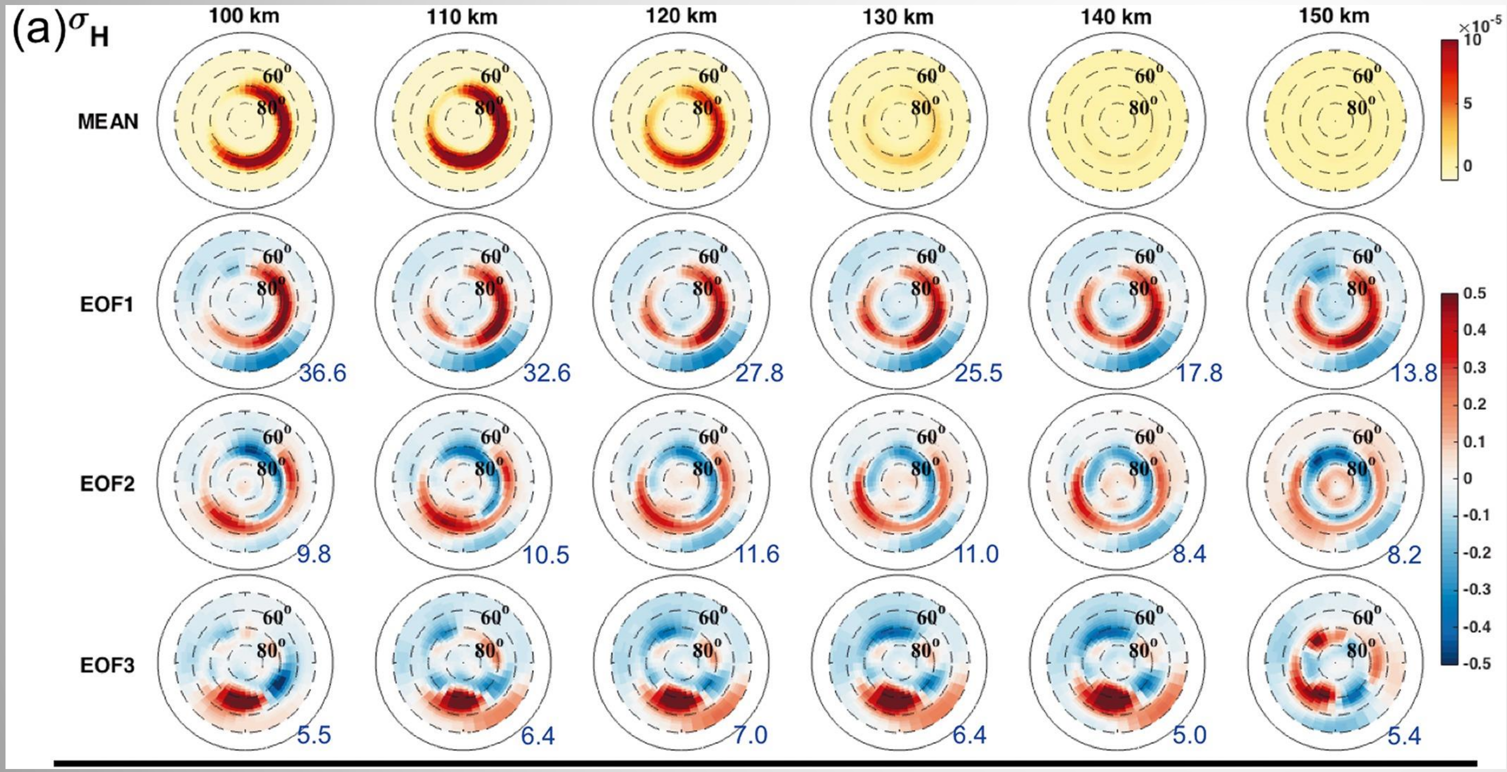


DMSP discrete aurora, 2004

Describe elements of energy input into the ITM system

Gaps the Low Energy Particle Obs Can Fill (2)

- Near Real Time Specification of Hemispheric Conductivity (3-D)
  - Three dimensional version of Auroral boundaries and energy deposition



Primary modes of Hall conductivity at 6 altitudes

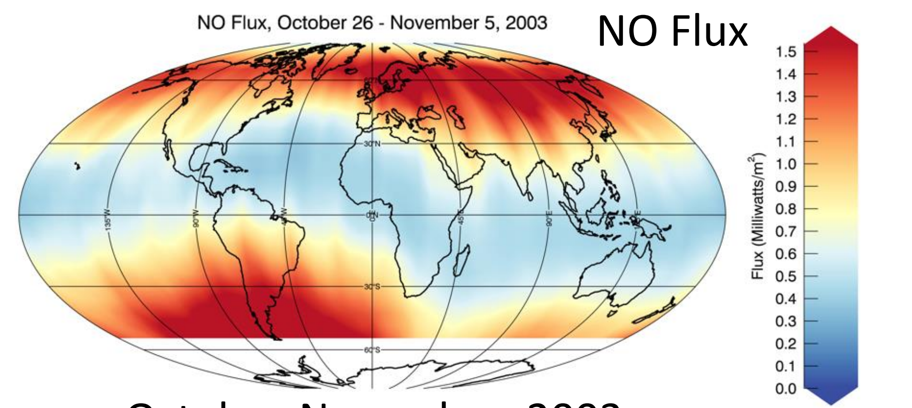
McGranaghan et al., 2016

- Millions of DMSP spectra reprocessed with GLOW code to yield primary modes of spatial variability.
- As new observations become available, an optimally interpolated pattern of conductivity in 3-D could be reconstructed in NRT.
- With data from higher energy detectors could extend this type of analysis to effects deeper in the atmosphere

Describe elements of energy input into the ITM system in 3-D

Gaps the Low Energy Particle Obs Can Fill (3)

- Thermospheric damping driven by Nitric Oxide (NO) 'thermostat'

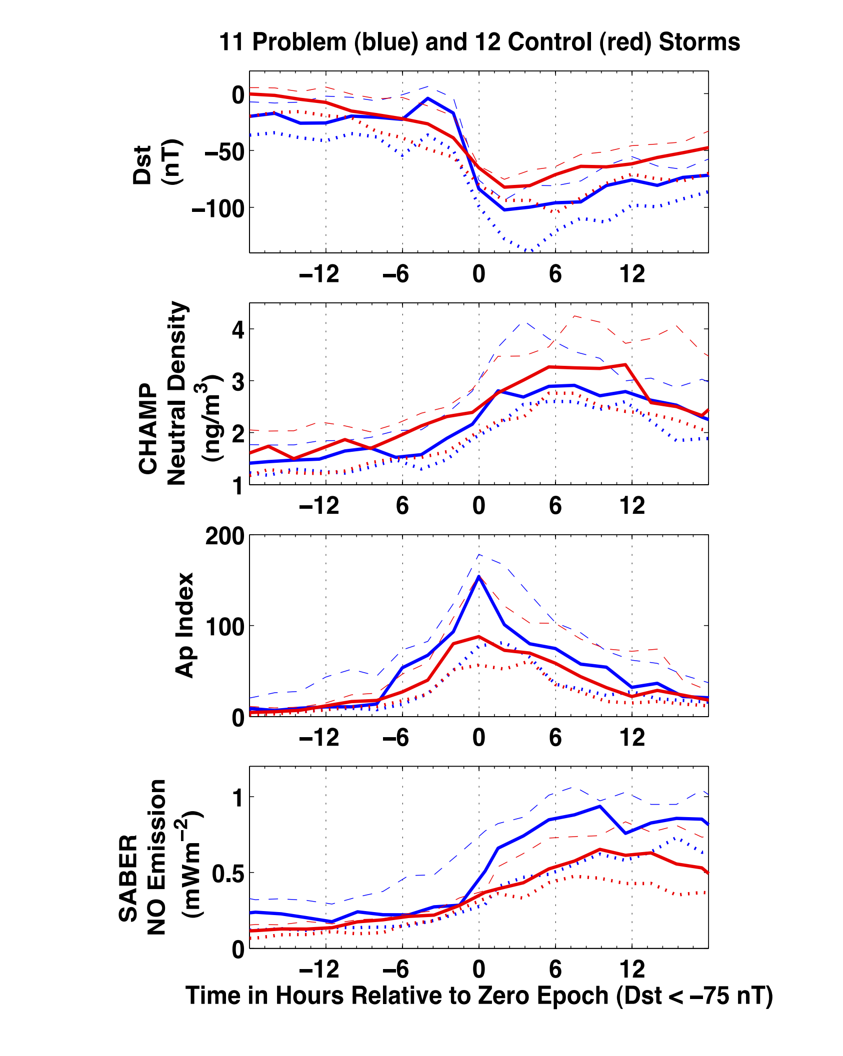


October-November 2003

Courtesy. M. Mlynczak

- Enhanced soft electron flux at high altitudes may alter thermospheric dynamics (Huang and Burke 2004)

- Severe geomagnetic storms with excess low energy particles fluxes measured by DMSP showed a density recovery twice as fast as fast as more moderate storms. (D. M. Oliveira personal communication)



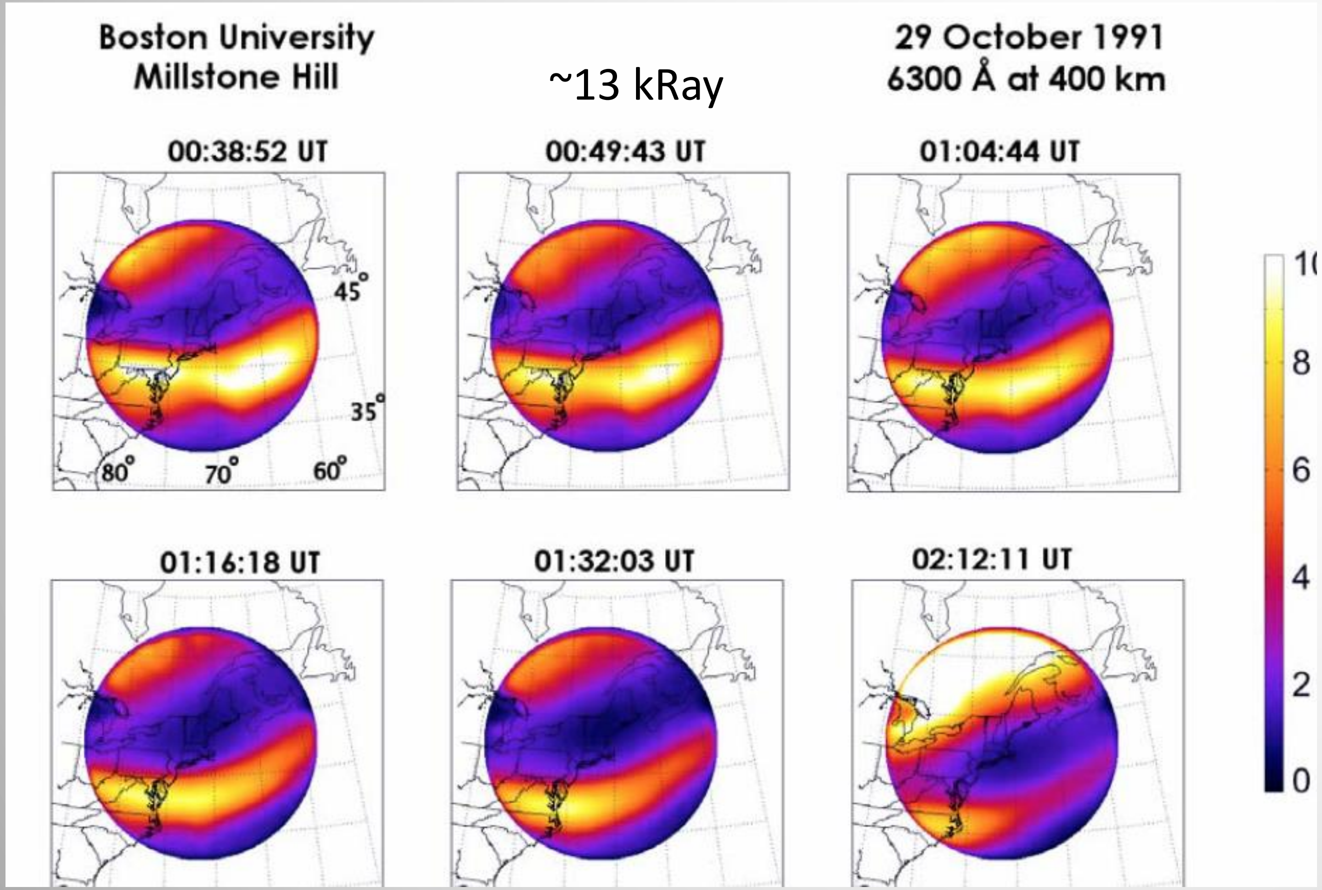
Knipp et al. (2013)

- Low energy electron and ion flux show dramatic enhancement ahead of these 'thermostat' storms

Describe elements of energy input into and emission from the IT system. Improve forecasting of neutral density in severe storms

Gaps the Low Energy Particle Obs Can Fill (4)

- Excess low-energy protons from ring current = Great Red Aurora?
  - Stable Aurora Red Arc from RC-plasmasheet interaction driven by 10-30 KeV ions



- Energetic RC ions collide with cold electrons and ions along the plasmapause to generate a geomagnetic-flux tube-aligned heat flux into the ionosphere. The heated ionospheric electrons collide with O atoms to generate spectrally pure 630.0 nm emission.

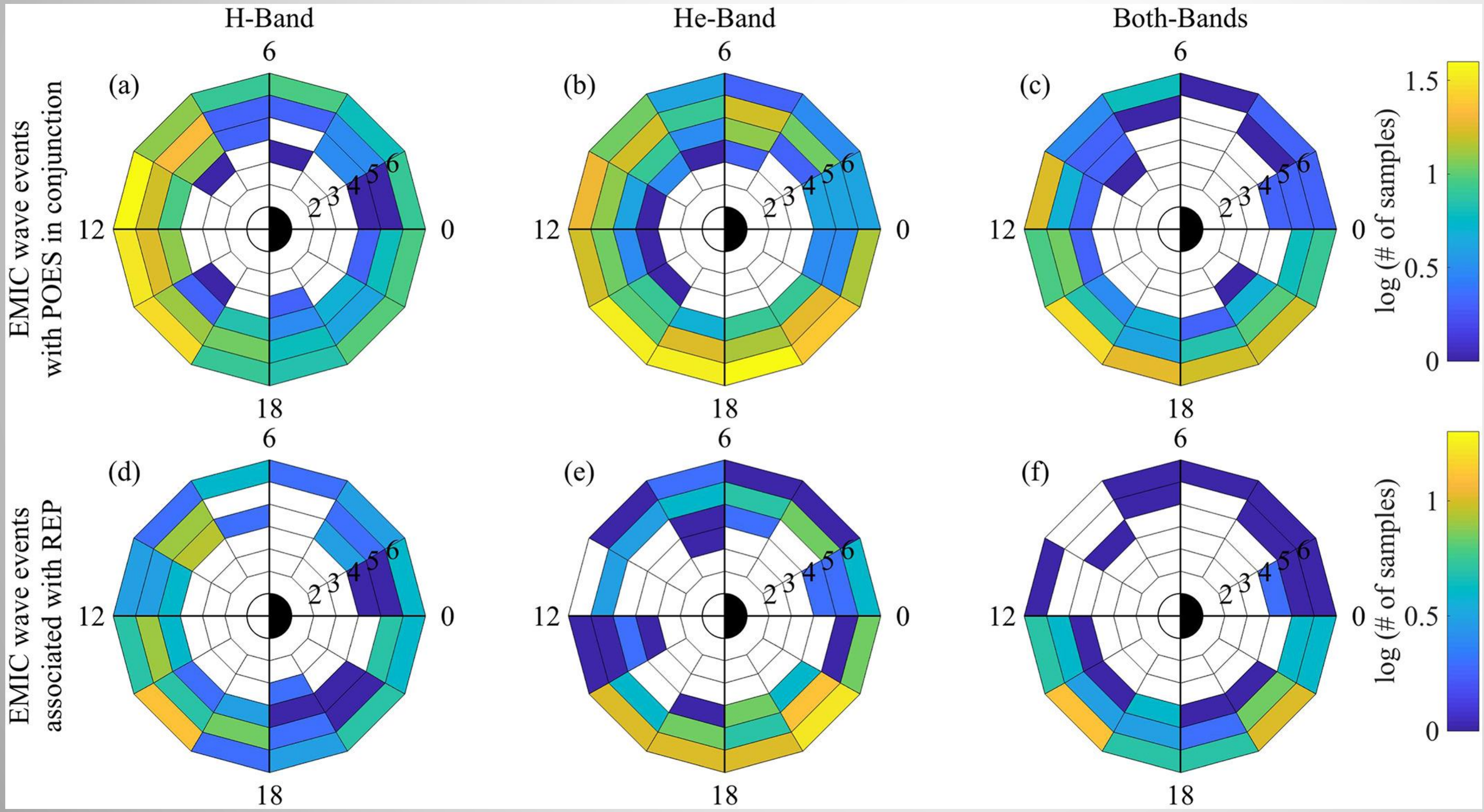
- Roots of Great Red Aurora?
- Important measurements provided by DMSP

Describe characteristics of extreme MIT interactions

Baumgardner et al. 2008 and Mendillo & Wroten, 2019

Gaps the Low Energy Particle Obs Can Fill (5)

- Remote sensing of radiation belt particle populations as well as losses
  - Coincidence of EMIC wave events and Relativistic Energetic Particle events



Qin et al., JGR 2018, 2020

- POES and Van Allen Probes provide information on source regions for REPs
- Future studies like these will not be possible without good POES coverage and Van Allen Probe follow-on

Describe elements of radiation belt dynamics in tandem with follow-on radiation belt mission

Particle Effects Traceability Including Model Verification

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Opportunities for Revived LEO Low Energy Particle Observations

- Specification of auroral energy deposition and boundaries
- In situ sensing to describe elements of energy input into the ITM system; 2- and 3-D
- In situ sensing for predicting/understanding conductance changes
- In situ monitoring auroral and other precipitation effects on s/c charging
- In situ monitoring of particles associated with Great Red Aurora of superstorms
- Remote sensing of radiation belt particle populations as well as losses
- Particle precipitation both at rad belt and lower energies for space effects on middle atmosphere
- Low altitude and high inclination SEP monitoring - important for aircraft with polar routes, PC absorption events etc
- Without regular monitoring of low energy particles in high-inclination orbits, our ability to monitor and ultimately model and predict the space environment and the upper atmospheric evolution is hampered.
- We are also deprived of the opportunity to include measurements of this type in future assimilative models and model verification.

Considerations:

- Cubesats, Disaggregated platforms, Commercial hosting on constellations,
- Better orbit plane coverage, mix of in situ and imagery
- Candidate for OSSE

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