Quantifying Rapid Energetic Electron Precipitation: Conjunction Studies Using New CubeSat and Balloon Measurements

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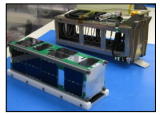
Overview

- Radiation belt dynamics are controlled by a balance of acceleration and loss mechanisms
  - In order to fully understand source processes, we must understand and quantify losses
  - One main loss mechanism is precipitation into the atmosphere via pitch angle scattering
  - Rapid precipitation is often observed at low altitude, but disentangling the spatial from temporal duration of events is difficult with single point measurements
- Conjunction studies using new measurements of MeV electron precipitation can help constrain the spatial and temporal extents of rapid precipitation events
- In this study, we examine:



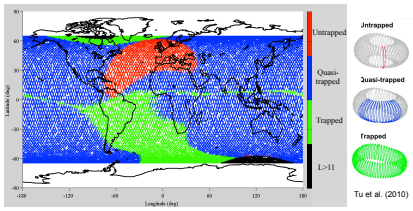
– Differential MeV electron measurements from the Colorado Student Space Weather Experiment (CSSWE) CubeSat, in a 65° inclination, 480 x 780 km orbit (Li et al., 2013)

– Bremsstrahlung x-rays produced by precipitating electrons and measured by balloons at ~35 km during the 2013 BARREL campaign (Millan 2011)

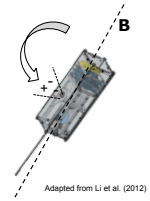
Using new conjunctive measurements, we estimate the spatial and temporal extent of MeV electron precipitation events to better quantify their contribution to radiation belt losses

CSSWE Measurements

- Relativistic Proton and Electron Telescope integrated little experiment (REPTile)
  - A miniaturization of the REPT instrument onboard NASA's Van Allen Probes (Baker et al., 2012)
  - 3 electron energy channels: 0.5-1.7 MeV, 1.7-3.3 MeV, > 3.3 MeV
  - 52° field of view, geometric factor = 0.52 cm² sr, boresight ~perpendicular to background magnetic field
  - Measures a combination of untrapped, quasi-trapped, and trapped particles

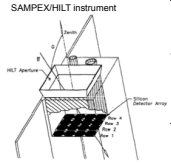


Tu et al. (2010)

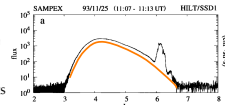


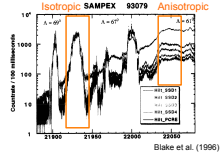
Adapted from Li et al. (2012)

- Previous observations from SAMPEX/HILT indicate that rapid enhancements measured at LEO, termed Precipitation Bands, contain a precipitating, rather than purely trapped, electron population



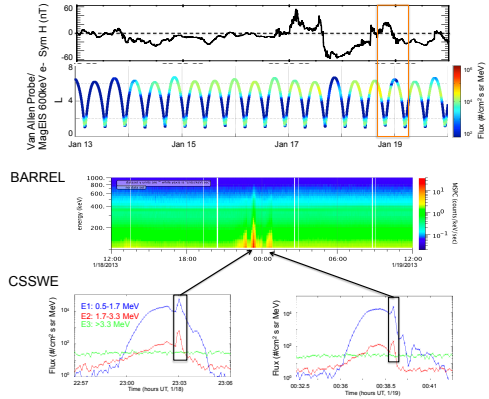
– Isotropization seen during rapid flux enhancements indicates a full loss cone and thus precipitation (Blake et al., 1996)
– Precipitation bands occur most often on the afternoon and nightside, and are often seen in conjugate locations, persisting multiple orbits (Blake et al., 1996)
– Band distributions suggest EMIC waves as a potential generation mechanism (Vampola 1971; Imhof et al., 1986)



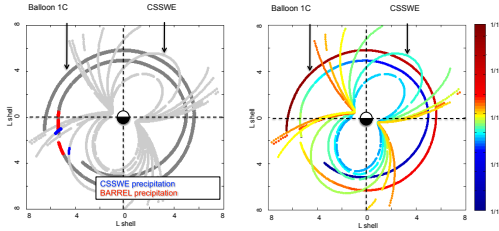


Event Study: January 18-19, 2013

- Large precipitation bands observed by the CSSWE CubeSat on January 18-19th, 2013, in conjunction with precipitation observed by one of the BARREL balloons

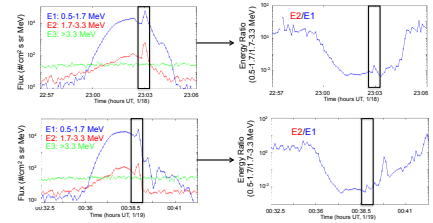


- Measurements mapped to the equatorial plane using T89, Kp=2:

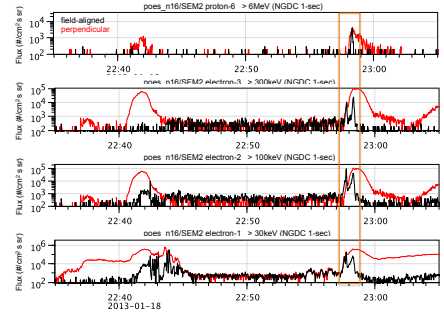


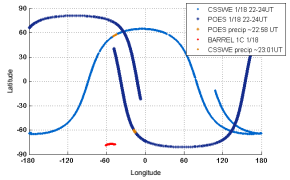
- The combination of balloon and CubeSat measurements constrain the region of precipitation in both space and time
- Next Step: use the measured magnitude and extent of the precipitation to quantify the total loss of MeV electrons during this event

- Energy spectrum of precipitation events:
  - Spectral hardening observed by CSSWE



- Additional conjunctions:
  - POES 16 measurements also indicate MeV electron precipitation in agreement with CSSWE and BARREL





- Next Steps:
  - Compare energy spectrum as observed by CSSWE, BARREL, and POES
  - Investigate additional conjunctive measurements (riometer data from Halley Bay, wave environment measured by GOES 13)

Summary

- On January 18-19th 2013, a large rapid increase in MeV electron precipitation was observed by the CSSWE CubeSat in conjunction the BARREL balloon array as well as POES satellites
  - The precipitation occurred across the dusk sector ~18-20 MLT, persisted for at least 2 hours, and maps to the edge of the outer radiation belt
- Combining new electron precipitation measurements from BARREL and CSSWE, we can:
  - Characterize the extent and duration of precipitation events
  - Investigate the energy spectrum of electron precipitation
  - Better quantify radiation belt losses due to rapid precipitation events

References

1. Baker, D., et al. "The Relativistic Electron-Proton Telescope (REPT) instrument on board the Radiation Belt Storm Probes (RBSP) spacecraft: characterization of Earth's radiation belt high-energy particle populations." Space Sci Rev, DOI 10.1007/s11214-012-9950-9 (2012). – 2. Blake, J. B., et al. "New high temporal and spatial resolution measurements by SAMPEX of the precipitation of relativistic electrons." Advances in Space Research 18.8 (1996): 171-186. – 3. Imhof, W. L., et al. "Relativistic electron and energetic ion precipitation spikes near the plasmapause." Journal of Geophysical Research: Space Physics (1978–2012) 91.A3 (1986): 3077-3088. – 4. Li, Xinlin, et al. "Small Mission Accomplished by Students—Big Impact on Space Weather Research." Space Weather (2013). – 5. Li, Xinlin, et al. "Colorado Student Space Weather Experiment: differential flux measurements of energetic particles in a highly inclined low Earth orbit." Geophys. Monogr. Ser., VOL. 199, 431 pp., doi:10.1029/GM199 (2012). – 6. Millan, R. M. "Understanding relativistic electron losses with BARREL." Journal of Atmospheric and Solar-Terrestrial Physics 73.11 (2011): 1425-1434. – 7. Nakamura, R., et al. "SAMPEX observations of precipitation bursts in the outer radiation belt." Journal of Geophysical Research: Space Physics (1978–2012) 105.A7 (2000): 15875-15885. – 8. Tu, Weichao, et al. "Quantification of the precipitation loss of radiation belt electrons observed by SAMPEX." Journal of Geophysical Research 115.A7 (2010): A07210. – 9. Vampola, Alfred L. "The effect of strong pitch angle scattering on the location of the outer-zone electron boundary as observed by low-altitude satellites. J. Geophys. Res. 82.16 (1977): 2289-2294.