Rapid MeV Electron Precipitation Events and their Contribution to Radiation Belt Losses

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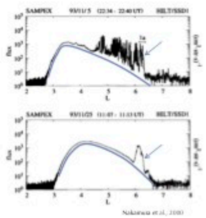
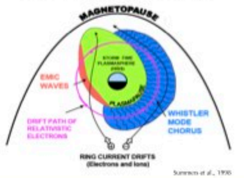
Background

- Radiation belt dynamics are controlled by a balance of acceleration and loss mechanisms
  - In order to fully quantify source processes, we must understand loss
  - One main loss mechanism is precipitation into the atmosphere via pitch angle scattering by EM waves (e.g. EMIC, Hiss, Chorus)
- Rapid enhancements of MeV electron fluxes are often measured by low earth orbit satellites on timescales ranging from <1 second to minutes
- Microbursts: <1 second bursts of electron precipitation
  - Occurrences peak from midnight – dawn, becoming more enhanced during active times
  - Pitch angle scattering by large amplitude whistler mode waves or Chorus at high latitudes or higher order resonance is believed to be one cause of MeV bursts (Lorentzen et al., 2001)
- Precipitation Bands: broader bands of precipitation, typically a few degrees in latitude, lasting 10s of seconds as measured at LEO
  - Occur most often on the afternoon and nightside, and are often seen in conjugate locations, persisting multiple orbits (Blake et al., 1996)
  - Potential source mechanisms include EMIC or electrostatic waves (Vampola, 1977; Thorne and Kennel, 1971)



Nakamura et al., 2000



Summers et al., 1998

Goal: to investigate the distributions of these rapid MeV electron precipitation events to better understand their source mechanisms and contributions to radiation belt losses

SAMPEX HILT Data

- We use 100 msec count rates from the HILT instrument on SAMPEX, in an 82° inclination orbit of ~500-600 km altitude
  - HILT: an array of 16 solid state detectors grouped into 4 rows of 4 detectors - SSD1, SSD2, SSD3, SSD4
  - Sensitive to >1 MeV electrons
  - ~60° field of view, geometric factor = ~15 cm² str per SSD row

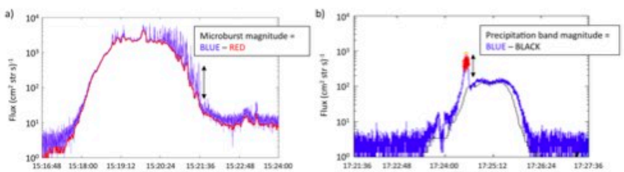
- Microburst detection criteria:

$$\frac{N - N_{ave}}{\sqrt{1 + N_{ave}}} > 10$$

(O'Brien et al., 2003)

N = 100ms count rate, and N_{ave} = average count rate over 500ms

- Precipitation Band detection criteria:
  - N_{100} > 4x baseline for ≥ 5 seconds
  - 10 second linear correlation coefficient between N_{100} and baseline <0.955

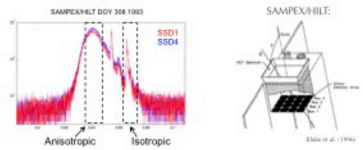


a) BLUE: 100 ms count rate
RED: Baseline - 10th percentile of 3 sec bins

b) BLUE: 100 ms count rate
RED: Band detections
BLACK: Baseline - 10th percentile of 20 sec bins

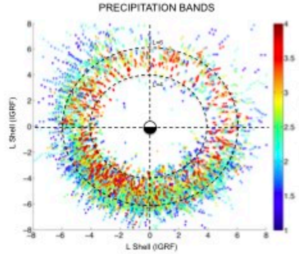
Pitch Angle and L-MLT Distributions

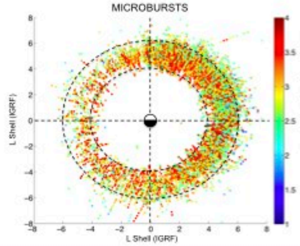
- Comparing relative count rates of HILT detector rows gives qualitative pitch angle information
- Microbursts and precipitation bands show more **isotropic** distributions, indicating a full loss cone



Blake et al. (1996)

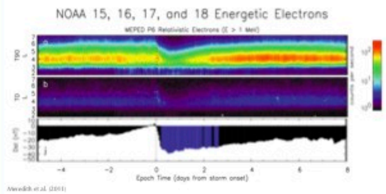
- L-MLT distributions and magnitudes of rapid precipitation features from 2003-2004



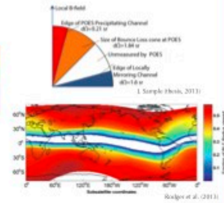


Storm-Time Distributions: Superposed Epoch Study

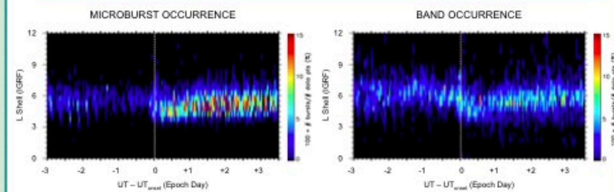
- 41 high speed stream (HSS) driven storms from 2003-2005 investigated (selected from Borovsky and Denton, 2009)
- Storms superposed at convection onset = 0 epoch
- Similar storm sets have been investigated by a number of others and show:
  - Main phase flux dropouts followed by rebuilding in late recovery
  - Magnetopause standoff distance remaining > ~8 R_E (Morley et al. 2010)
  - Little precipitation into the atmosphere, as measured by POES (Meredith et al. 2011)
- **What role do microbursts and precipitation bands play in these storm-time dynamics? Can SAMPEX/HILT, with its large field of view and high time resolution, provide more information regarding precipitation loss during HSSs?**

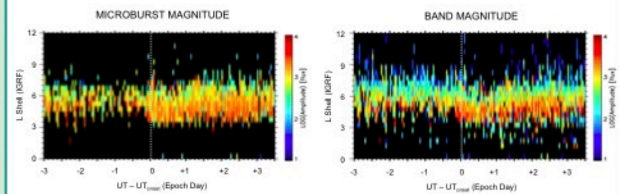


Meredith et al. (2011)



Rodger et al. (2013)





Summary

- Using SAMPEX HILT data we investigate the magnitudes and distributions of rapid precipitation enhancements at LEO on a variety of timescales – from <1 sec precipitation (microbursts) to longer duration (precipitation bands)
- Local time and radial distributions:
  - Microbursts occur primarily on the morning side, from ~2-12 MLT, while band occurrences show a strong enhancement around dusk/midnight, from ~15-24 MLT
  - Precipitation band magnitudes increase towards the inner edge of the outer radiation belt, ~ L of 4
- High speed stream driven storm distributions:
  - Microburst occurrence rates increase dramatically during the storm recovery phase, concurrent with the building back up of radiation belt fluxes. This is consistent with chorus waves as both a generator of microburst precipitation as well as a source of local acceleration of trapped electrons.
  - Precipitation band magnitudes increase during the main and early recovery phase. This suggests that MeV electron precipitation may play a role in main phase losses observed during HSSs, especially at lower L shells, and that this loss is not fully detected by the POES instruments alone.