Balloon Array for RBSP
Relativistic Electron Losses
BARREL TEAM

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BARREL Project Overview

BARREL is a multiple-balloon experiment designed to study relativistic electron precipitation

- Two Antarctic Science Campaigns during RBSP Mission
  - 20 small balloon payloads in each campaign in 2013 and 2014
  - Launched successively to set up slowly drifting array
  - Long duration balloon flights => 30 day campaign
  - >3000 hours of data in radiation belt region (L<7)
  - Launch sites planned: Halley Bay and South African Antarctic station (SANAE)
Science Objectives

- Determine electron loss rate during specific relativistic electron events
  - Simultaneously measure precipitation over a wide range of magnetic local times.
- Directly test models of wave-particle interactions
  - Combine balloon measurements of precipitation with in situ RBSP measurements of plasma waves and particles
- Determine relative importance of different classes of precipitation
  - Occurrence probability maps in L-value and MLT
- Determine spatial extent and large-scale structure of precipitation.
  - Multi-point measurements provide large-scale coverage and resolve spatial-temporal ambiguity.
Balloon Observations of Loss

- Bremsstrahlung X-rays are produced as electrons collide with atmospheric neutrals.

Balloon observations of MeV X-rays made in 1996 over Kiruna, Sweden

- The nearly-stationary balloon platform is complimentary to spacecraft observations

(Foat et al., 1998)
Science Instruments

- Primary Instrument: 3”x3” NaI scintillator
  - Energy range: 20 keV-7 MeV
  - Effective area: 16 cm² (photopeak)
  - Energy resolution ~10% at 1 MeV
  - Time resolution: 50 ms in 4 energy channels

- Supporting science: DC Magnetometer
  - Horizontal and vertical magnetic field
  - Sensitivity ~10 nT
  - Goal is 1s time resolution
Payload Design

- **Supporting Instrumentation**
  - GPS time and position: Trimble Lassen SQ
  - Data Acquisition System
  - Telemetry: Iridium satellite network ~2kbps

- **Payload**
  - Suspended mass: 25 kg (payload ~20 kg)
  - Power: ~6W supplied by solar power system
  - Hand launched on 300,000 cu ft. balloon
Launched 4 prototype payloads from McMurdo in December 2009
Successful Confirmation Review in March 2010
Test flights in Nov. - Dec., 2010 to qualify solar panels
Completed TVAC, I&T of 2 payloads, Mission Readiness Review
BARREL uses an array of balloons to achieve its science:
- 4-5 balloons aloft simultaneously
- separation 1-2 hours of MLT
- flight durations ~7 days
- 20 balloons per campaign

Two launch sites:
- Halley Bay
- SANAE
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Information BARREL Provides

- Available near real-time (within 1 hour)
  - Balloon locations – where are measurements available?
  - Times of conjunctions with RBSP.
  - Quick-look plots (e.g. count rates, raw spectra)
  - Is there energetic precipitation at a given location and time?

- Data publicly available: Ascii, CDF, IDL save files
  - Fast Spectra: X-ray count rate in 4 energy channels at 50ms
  - Higher resolution 48 channel X-ray spectra every 4 seconds.
  - 256 channel X-ray spectra accumulated over 32 s (for calibration)

- Requiring more processing (bkngd subtraction; modeling response, etc.)
  - Flux and energy spectrum of precipitating electrons for specific events.
  - Spatial distribution of precipitation (maps)

- IDL software tools
  - For plotting data and balloon locations
  - Spectral analysis and inversion of X-ray spectrum, instrument response
BARREL with Other Missions

**Strengths of balloon-based measurements:**
- know definitively that what we’re seeing is precipitating electrons
- can separate temporal and spatial variations
- array provides multi-point measurements

**How can we best combine our data with other observations?**
- unique opportunity to measure precipitation, waves and particle distributions simultaneously
- compare precipitation rate with trapped flux
- map the location of precipitation to the equatorial plane
- quantitatively test wave-particle interaction theories
- comparison with riometer data - cross calibration of two methods
Spatial Variations

- Little is currently known about the spatial scale of energetic precipitation.
Flux Depletion Events

- Precipitation observed by POES during GOES dropout event
- Precipitation maps to distances inside geosynchronous satellites
- GOES sampling open drift paths for at least part of the time

(Millan et al., 2009; 2010)
Precipitation Mechanism?

SW Pdyn

UT on Jan 21, 2005

17:10 UT 18:44 UT

L~7
~1230 MLT

L~3.5
~1400 MLT

L~4
~1500 MLT

UT on Jan 21, 2005
Temporal Variations

Polar electric field shows ULF waves near same frequency as modulation for this event.

[Anderson and Milton, 1964]

[Foat et al., 1998]