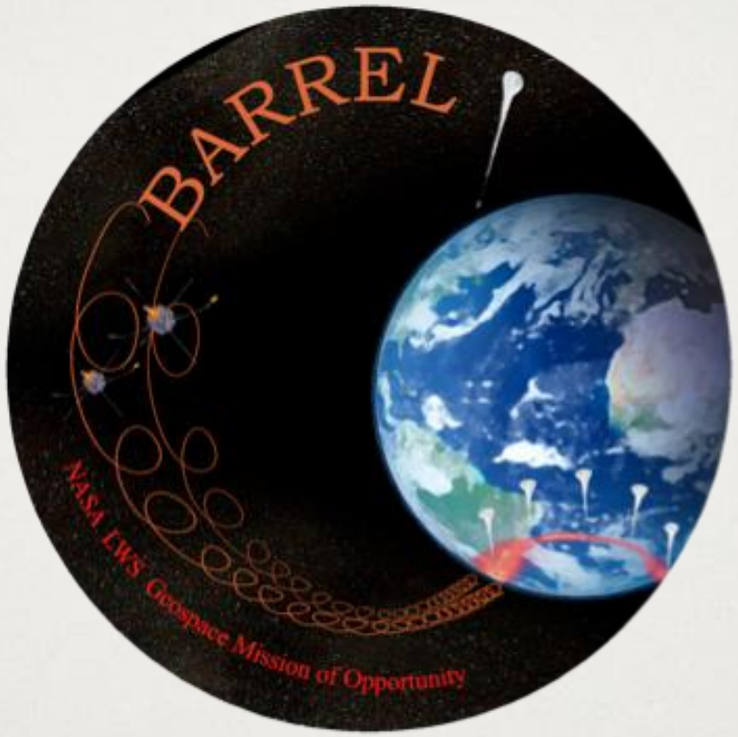


Balloon Array for RBSP Relativistic Electron Losses

BARREL TEAM

- Dartmouth College
  - Robyn Millan
  - Mary Hudson
  - David McGaw
  - Leslie Woodger
  - *Jessica Hewitt
  - Karl Yando
  - Brett Anderson
  - Nick Knezek
  - Julianna Scheimann

* Now at USAF Academy

- University of Washington
  - Michael McCarthy
  - Amanda Baker
- U. C. Berkeley
  - John Sample
  - Bob Lin
- U. C. Santa Cruz
  - David Smith
  - Max Comess
  - Andrew Liang
  - Warren Rexroad

BARREL Project Overview

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

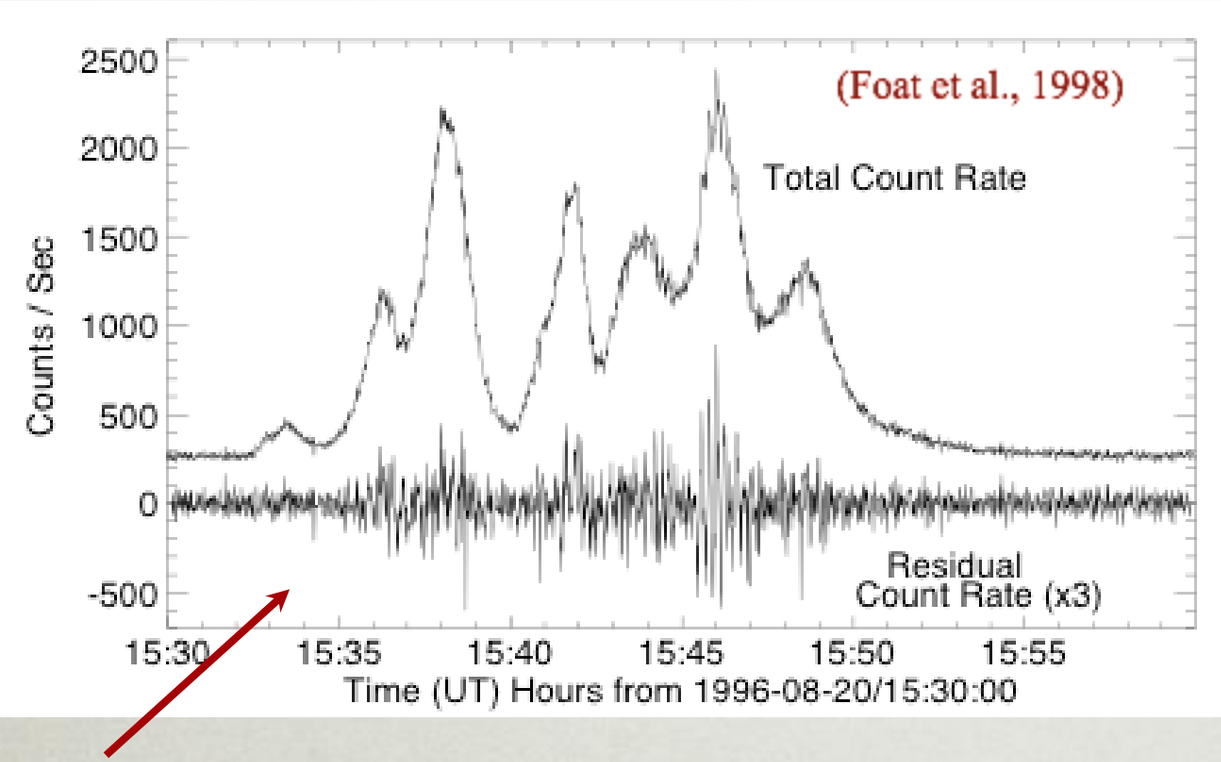
- Two Antarctic Science Campaigns during RBSP Mission
  - 20 small balloon payloads in each campaign in 2013 and 2014
  - Launched successively to set up slowly drifting array
  - Long duration balloon flights => 30 day campaign
  - >3000 hours of data in radiation belt region (L<7)
  - Launch sites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

Science Objectives

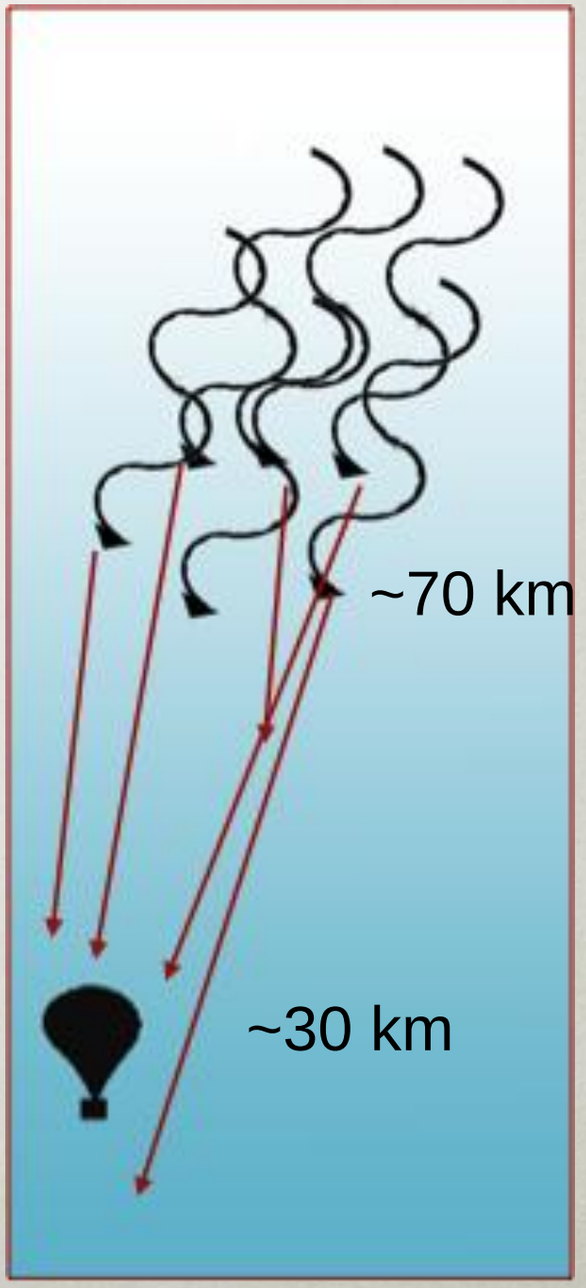
- Determine electron loss rate during specific relativistic electron events
  - Simultaneously measure precipitation over a wide range of magnetic local times.
- Directly test models of wave-particle interactions
  - Combine balloon measurements of precipitation with in situ RBSP measurements of plasma 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.



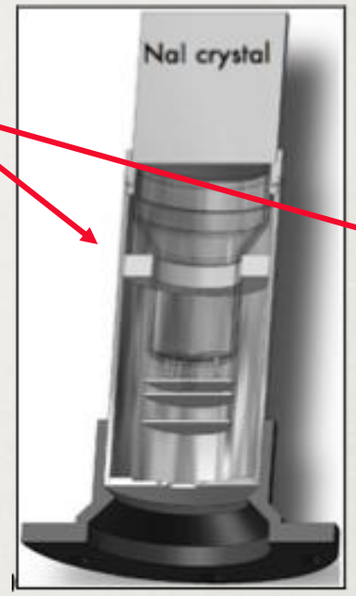
Balloon observations of MeV X-rays made in 1996 over Kiruna, Sweden

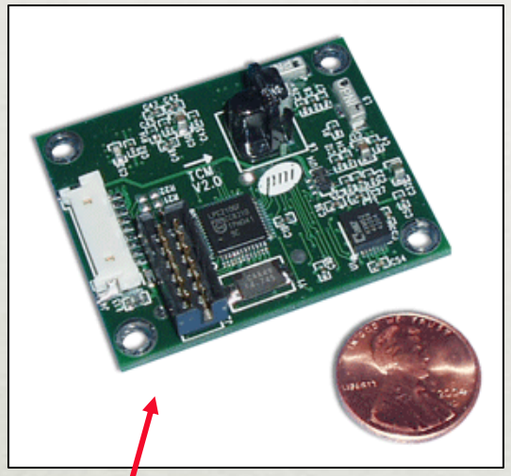


- The nearly-stationary balloon platform is complimentary to spacecraft observations

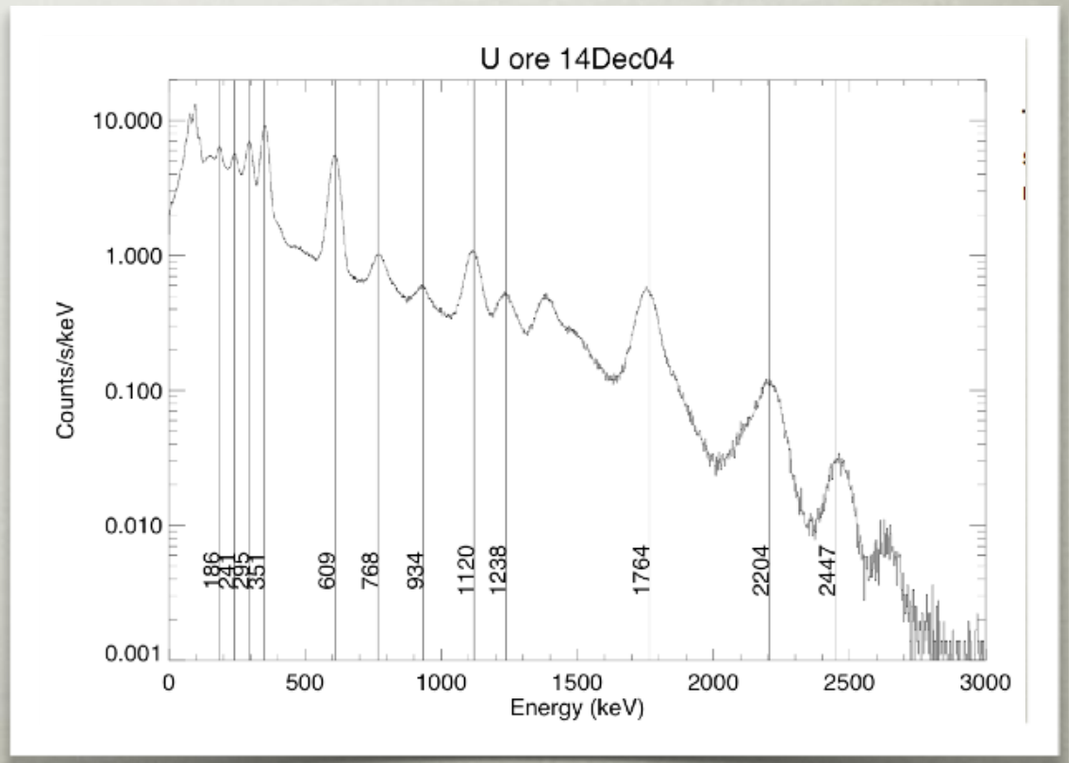
Science Instruments

- Primary Instrument: 3”x3” NaI scintillator
  - Energy range: 20 keV-7 MeV
  - Effective area: 16 cm^2 (photopeak)
  - Energy resolution ~10% at 1 MeV
  - Time resolution: 50 ms in 4 energy channels



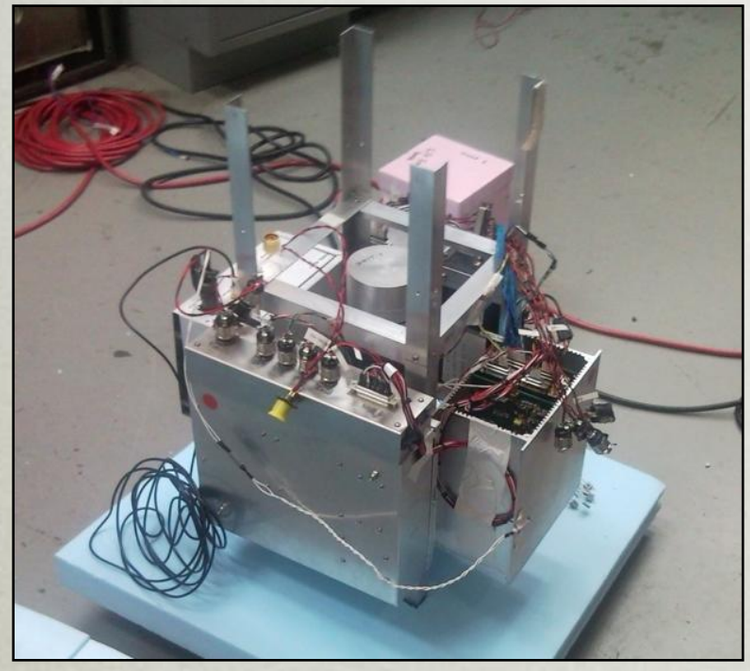


- Supporting science: DC Magnetometer
  - Horizontal and vertical magnetic field
  - Sensitivity ~10 nT
  - Goal is 1s time resolution



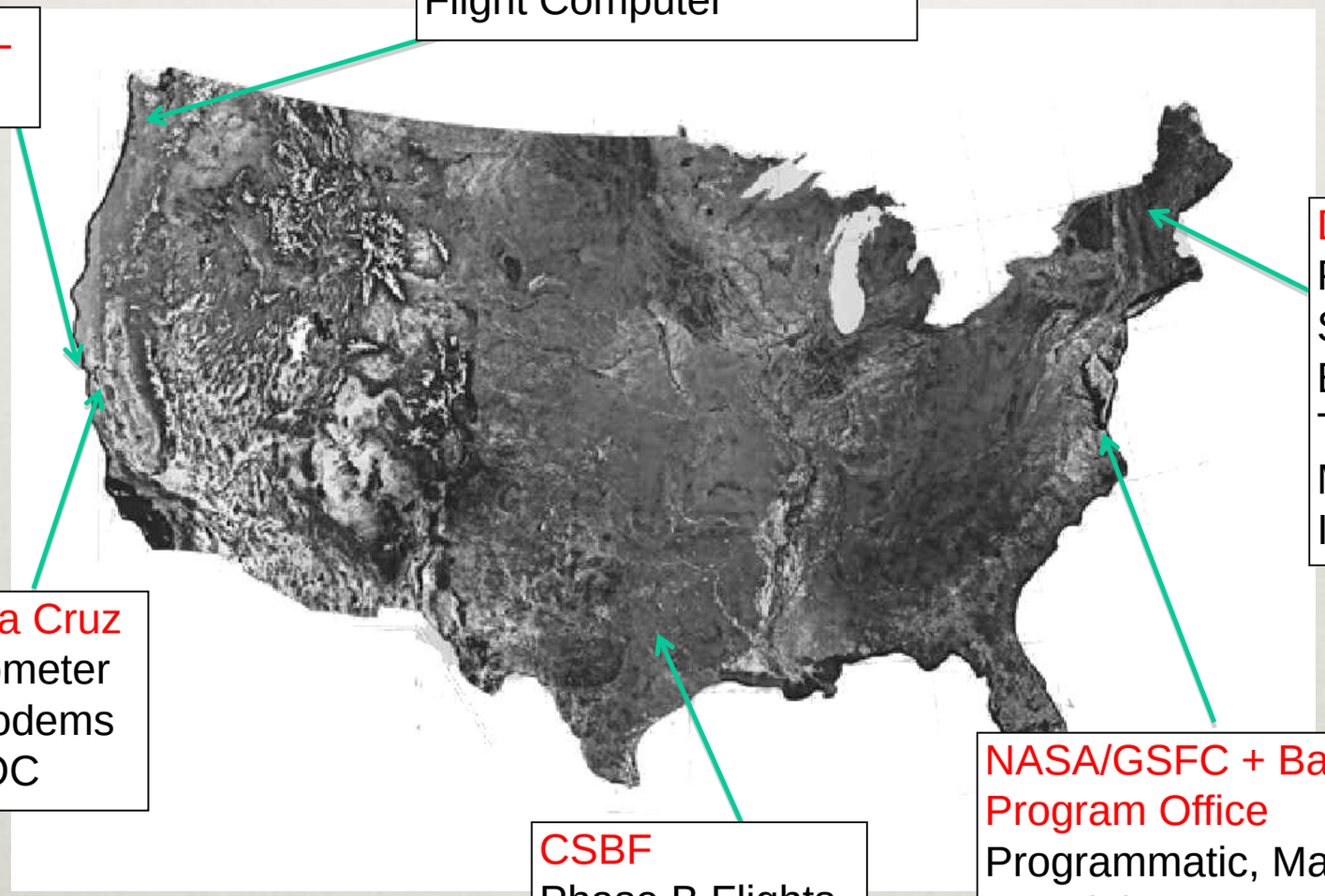
Payload Design

- 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

BARREL Instrument Teams



University of Washington
NaI Scintillator
Flight Computer

UC Berkeley-SSL
Power System

Dartmouth College
PI-Institution
Systems Engineering
Engineering Data
Terminate System
Mechanical, Harness
Integration & Test

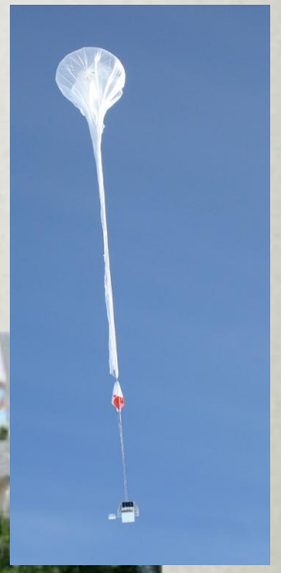
UC Santa Cruz
Magnetometer
Flight modems
MOC/SOC

CSBF
Phase B Flights
Launch Training

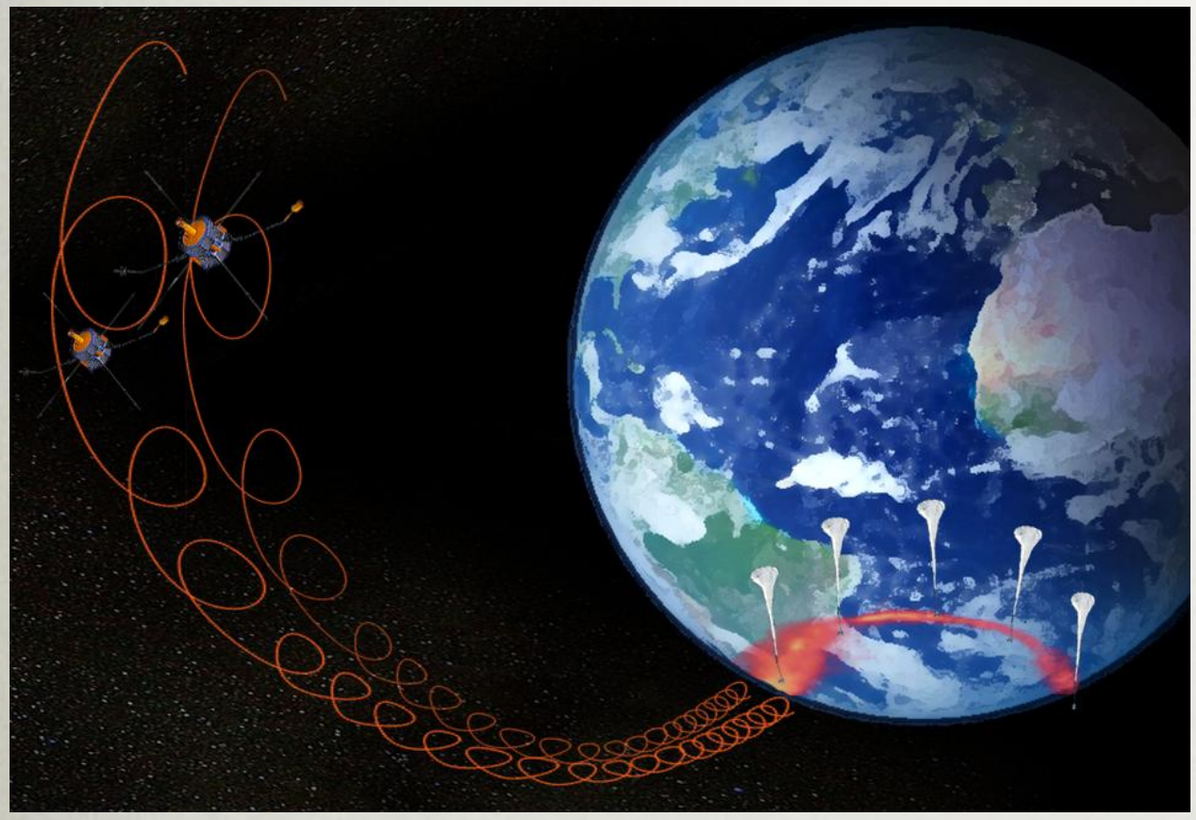
NASA/GSFC + Balloon Program Office
Programmatic, Management oversight

BARREL Project Status

- 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

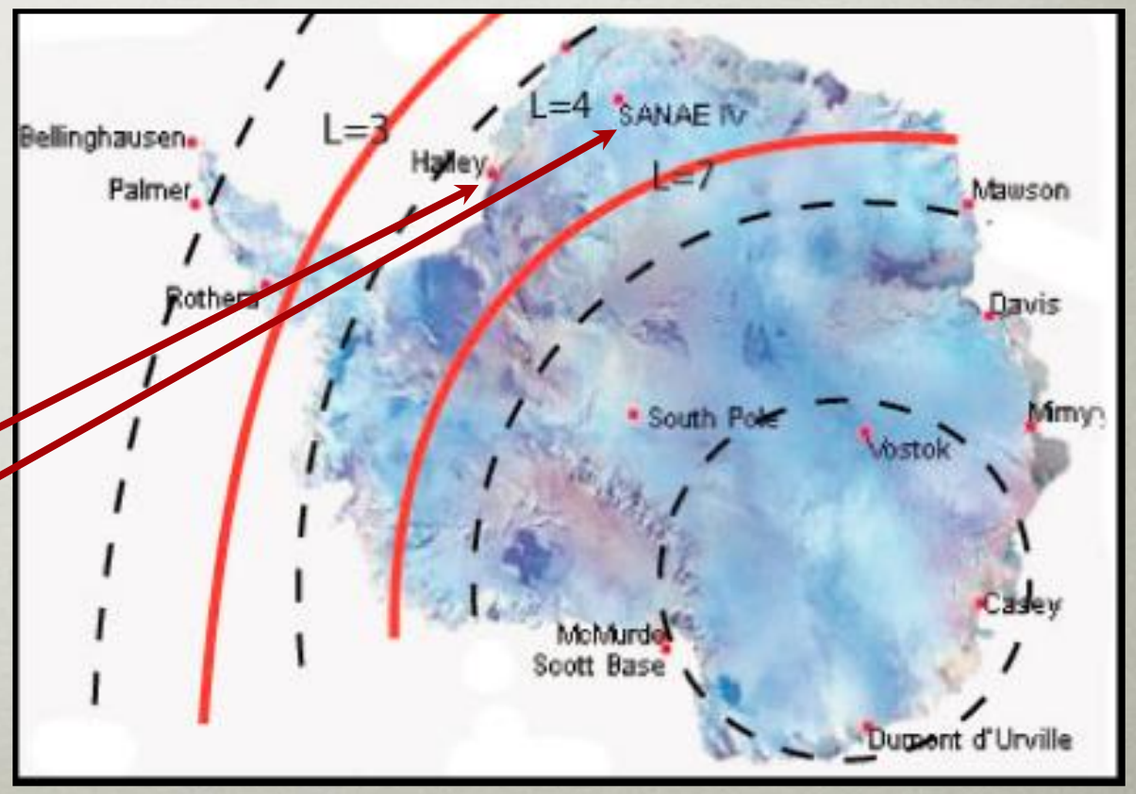


Platform - Balloon Array

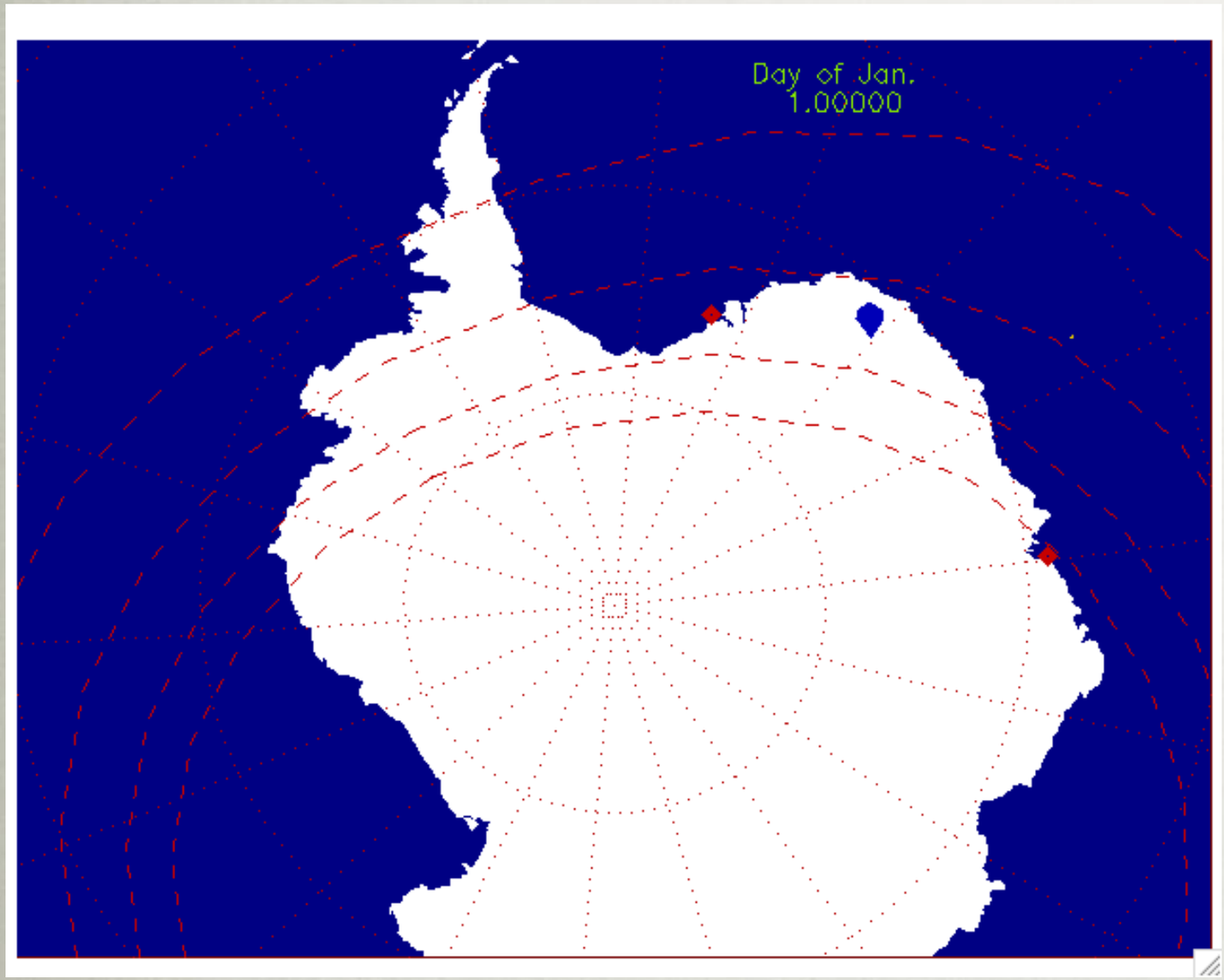


- BARREL uses an array of balloons to achieve its science
- 4-5 balloons aloft simultaneously
- separation 1-2 hours of MLT
- flight durations ~7 days
- 20 balloons per campaign

- Two launch sites:
- Halley Bay
- SANAE

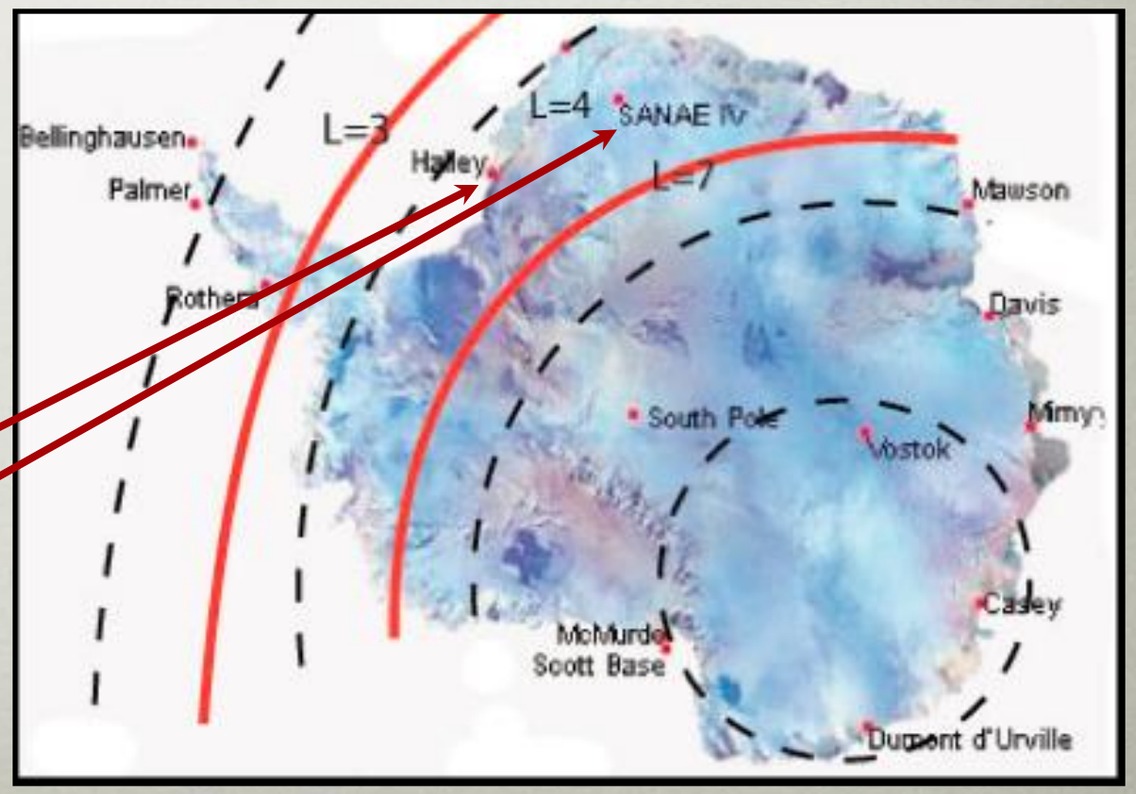


Platform - Balloon Array



- 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



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 (bkgnd subtraction; modeling response, e**
  - 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

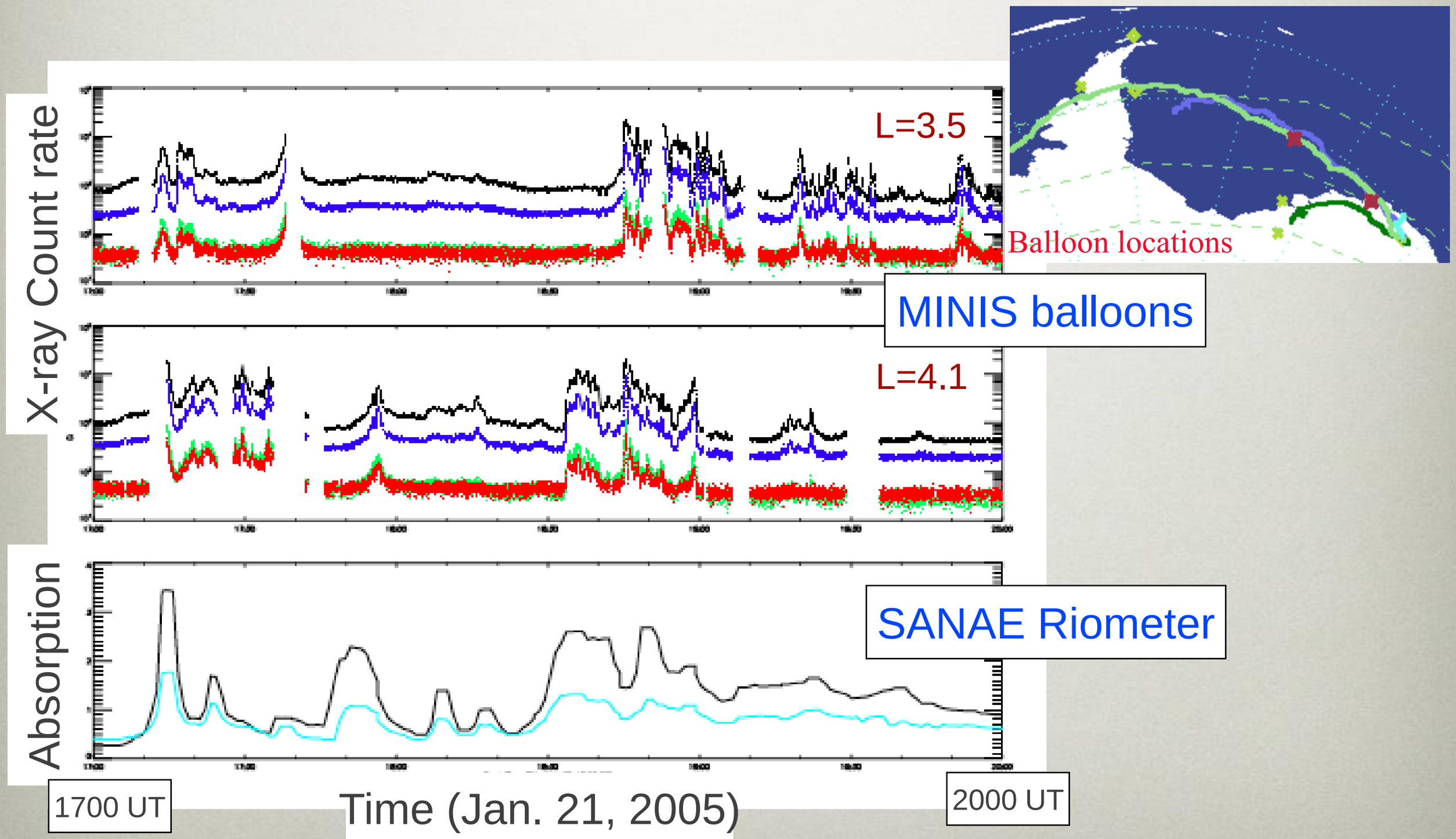
How can we best combine our data with other observations?

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

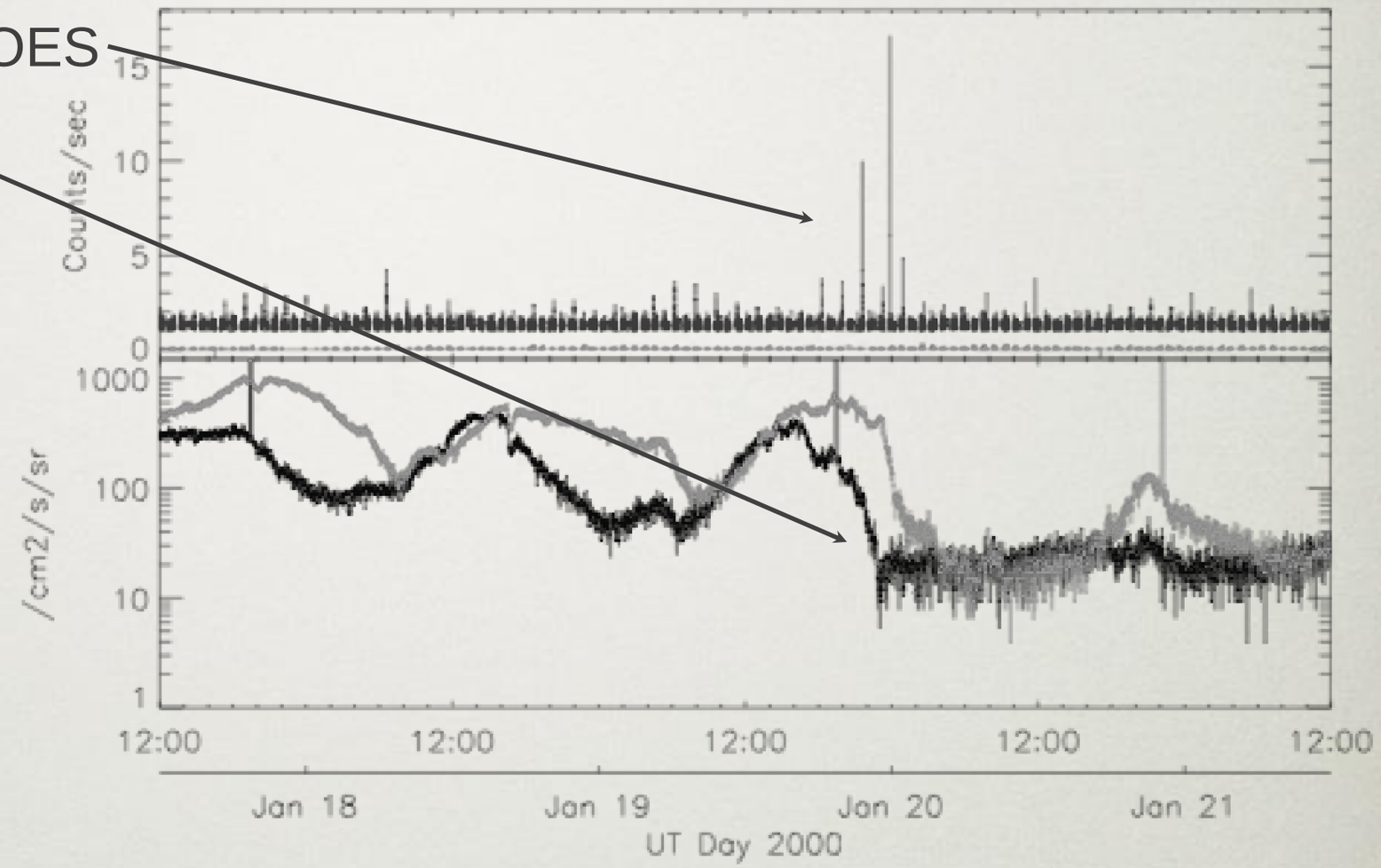
Spatial Variations

- Little is currently known about the spatial scale of energetic precipitation

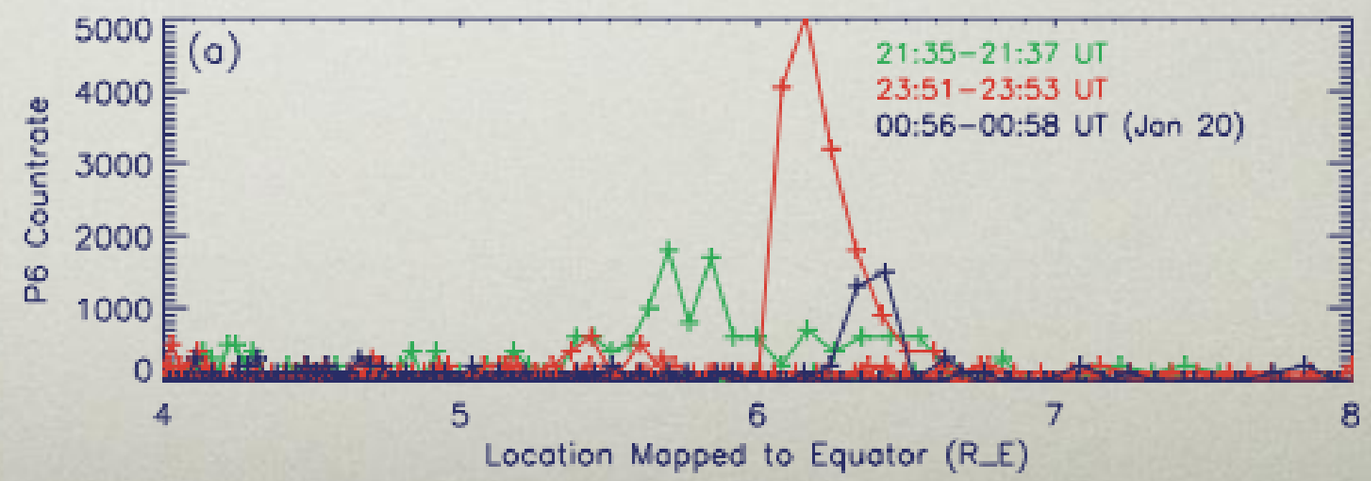


Flux Depletion Events

- Precipitation observed by POES during GOES dropout event

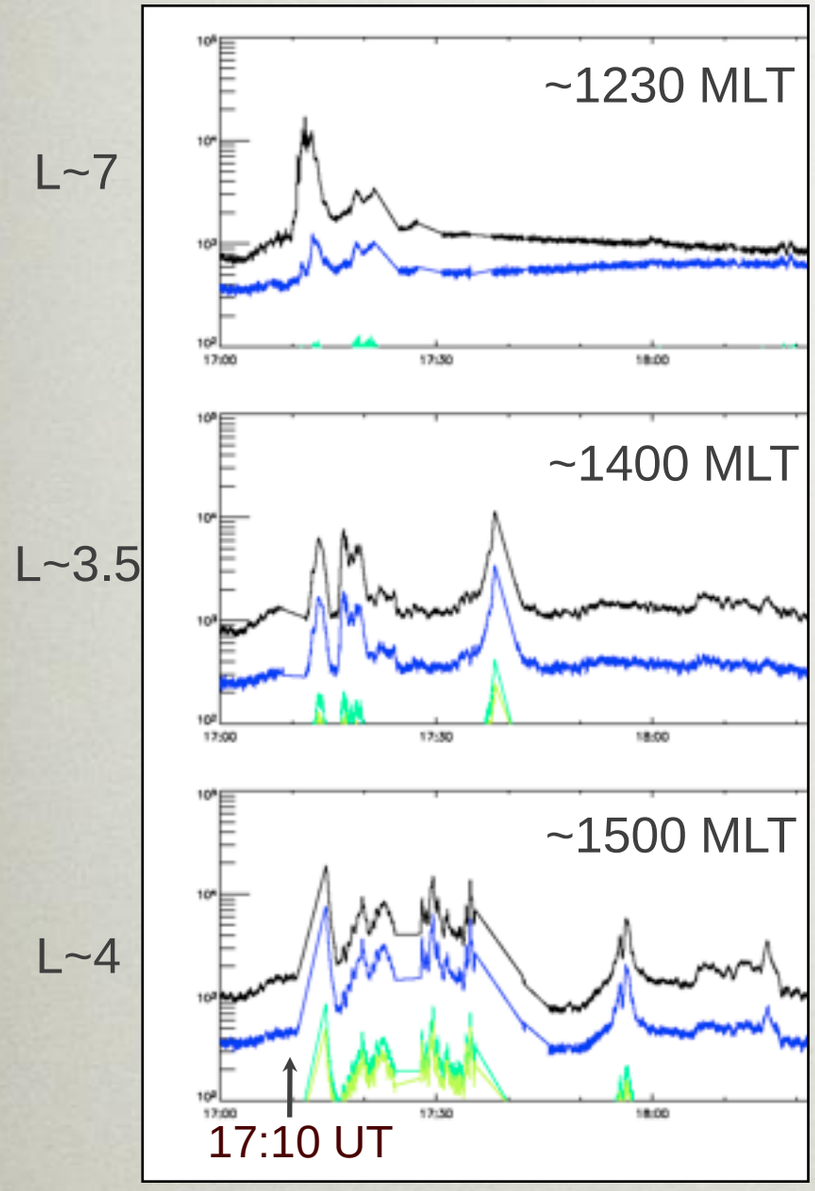


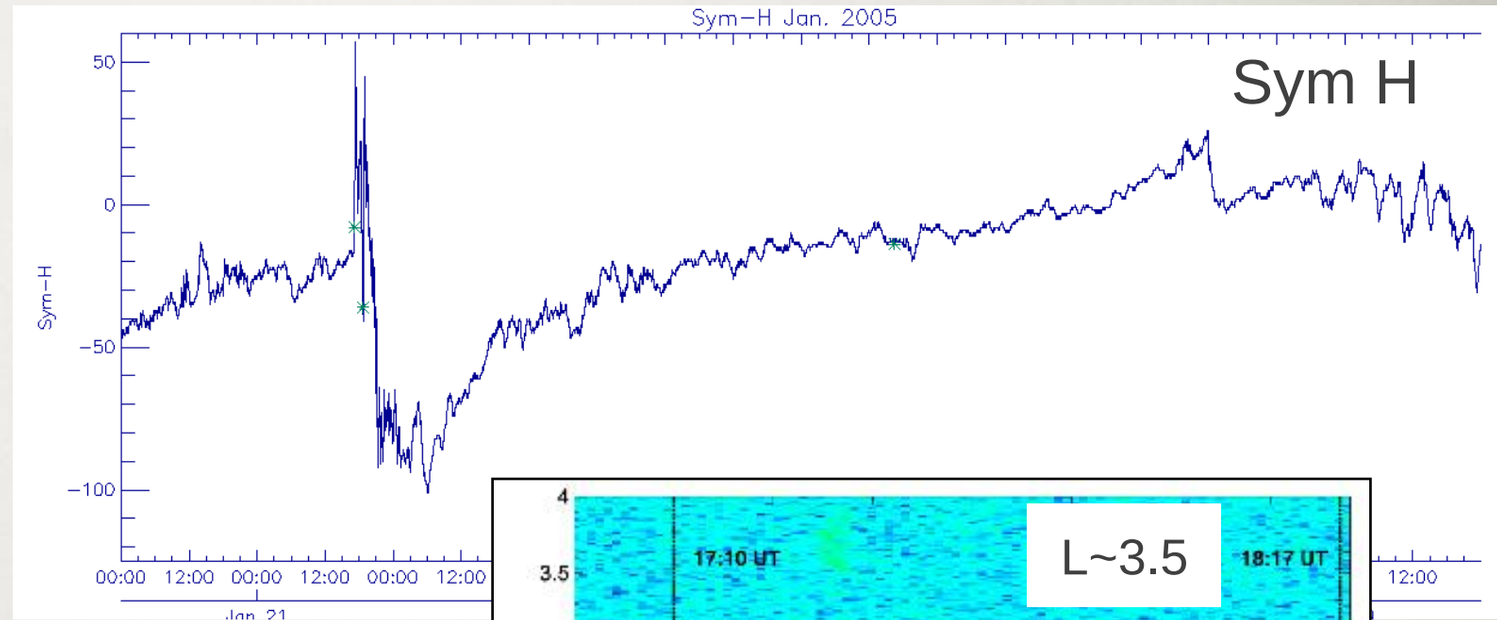
- Precipitation maps to distances inside geosynchronous satellites
- GOES sampling open drift paths for at least part of the time

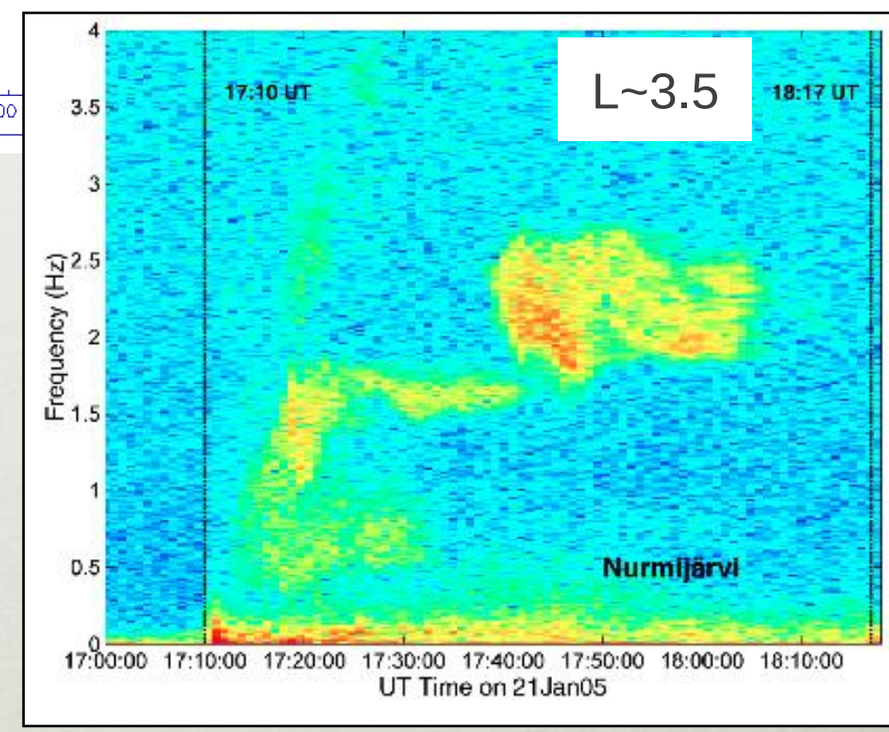


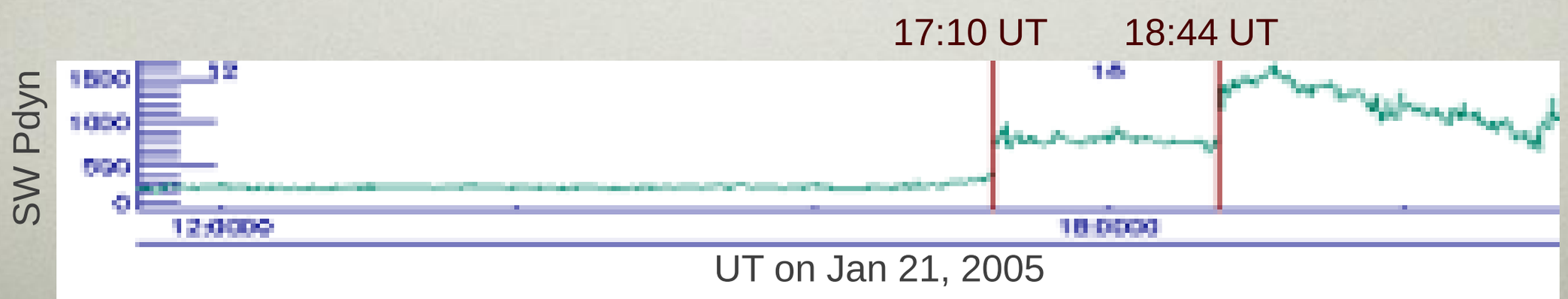
(Millan et al., 2009; 2010)

Precipitation Mechanism?



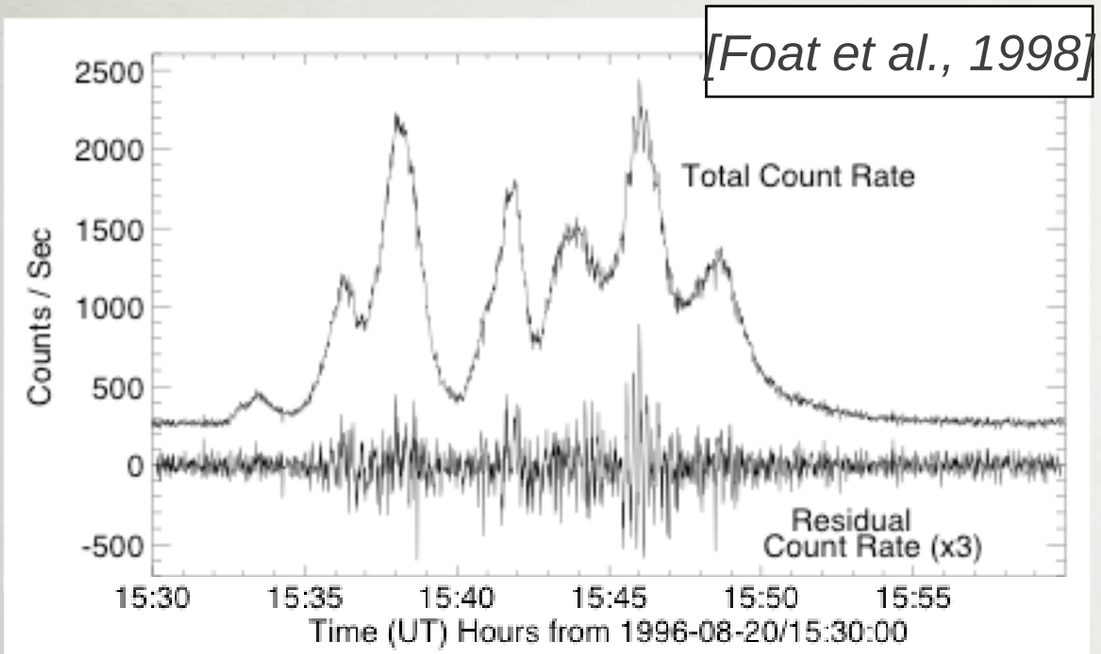




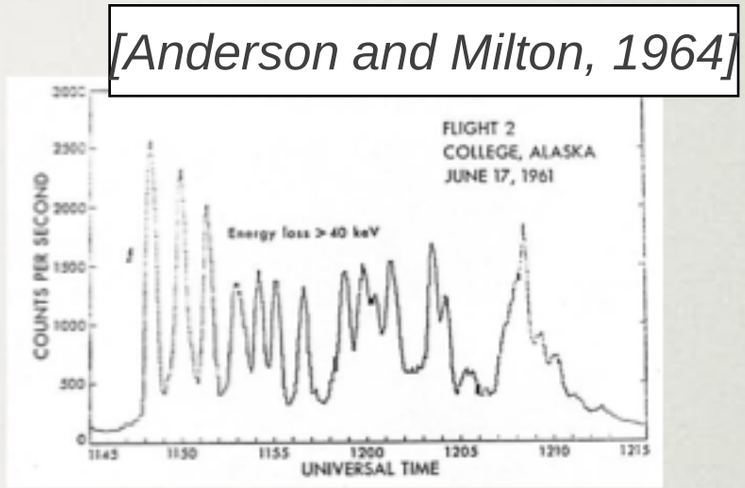


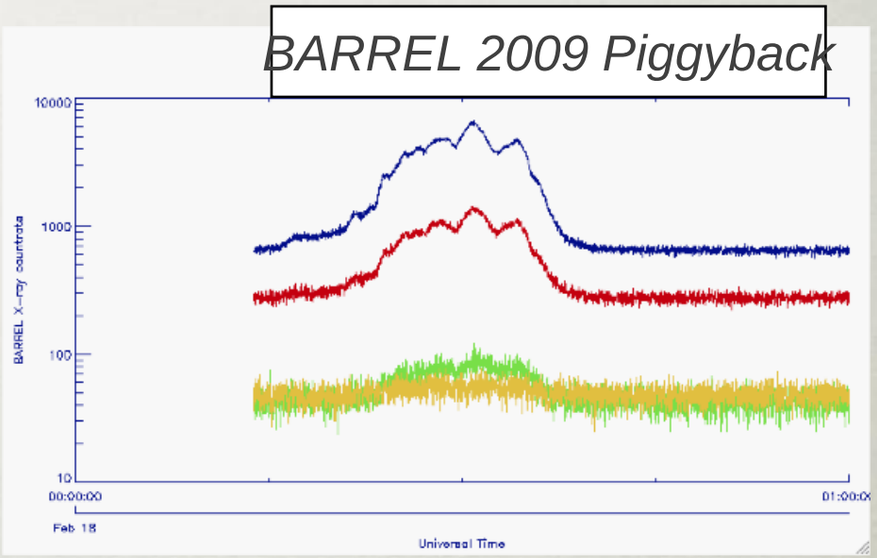
Temporal Variations

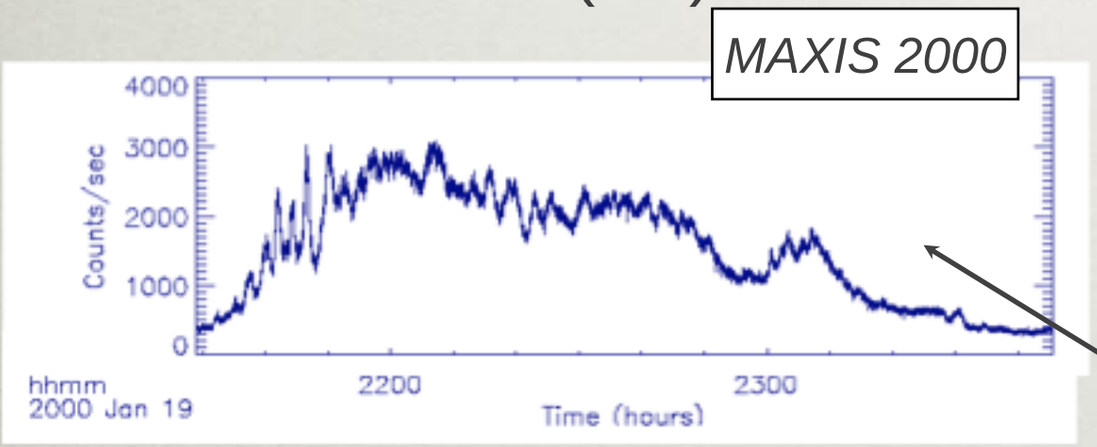
X-ray Countrate

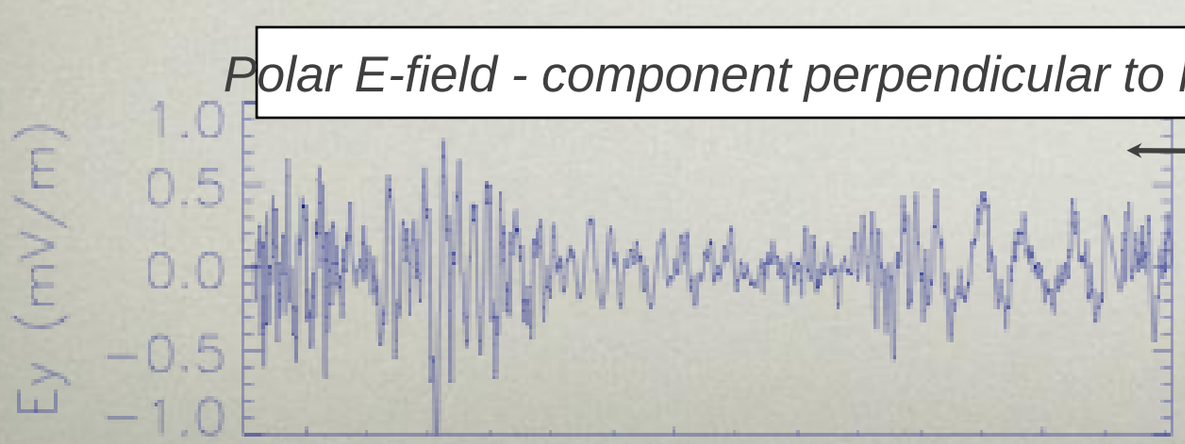


Time (UT)









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