



# Effects of Solar Energetic Particles and Radiation Belt Precipitation on the Middle Atmosphere and the Global Electric Circuit

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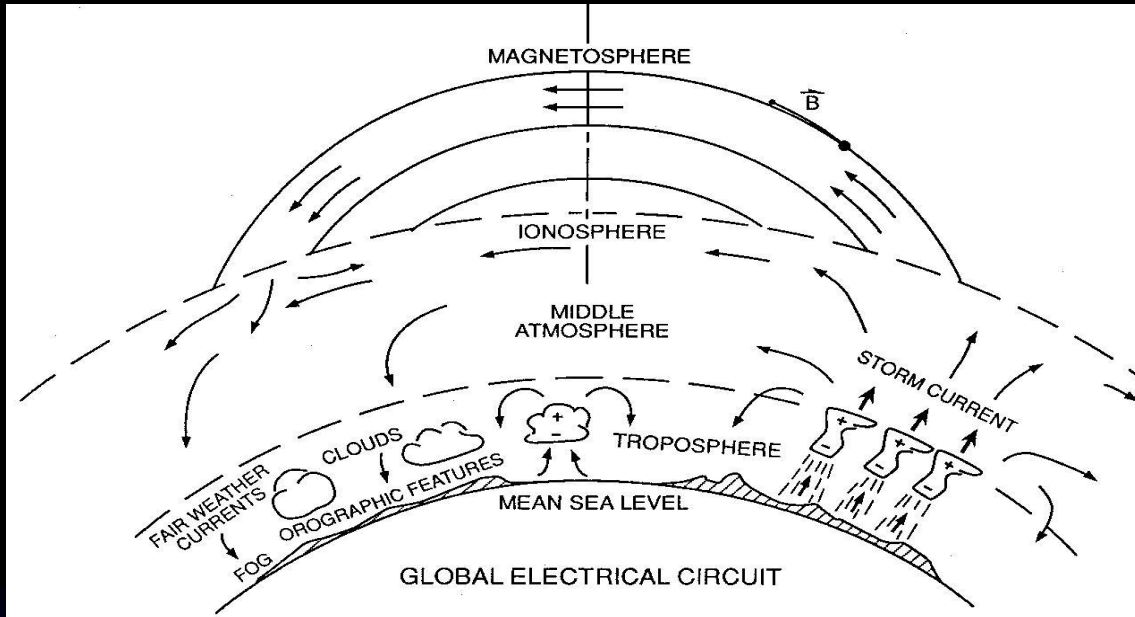


# Outline of Talk

- Introduction
- PPB Campaign
- Jan 27, 2003 Event
  - Conductivity perturbation
  - Pc1 event, Proton Precipitation
- MINIS Campaign
- Jan 20, 2005 SEP event
  - Vertical field response
  - Convection response



# Global Circuit



- Generators:
  - Tropospheric Thunderstorms
  - Cross-Polar Cap Potential
  - Quiet day Ionospheric Dynamo ( $S_q$ )
  - and other possible unknown sources
- Return Path Through Ionosphere, Fair Weather Atmosphere
- Model Rests on Very Meager Data Base

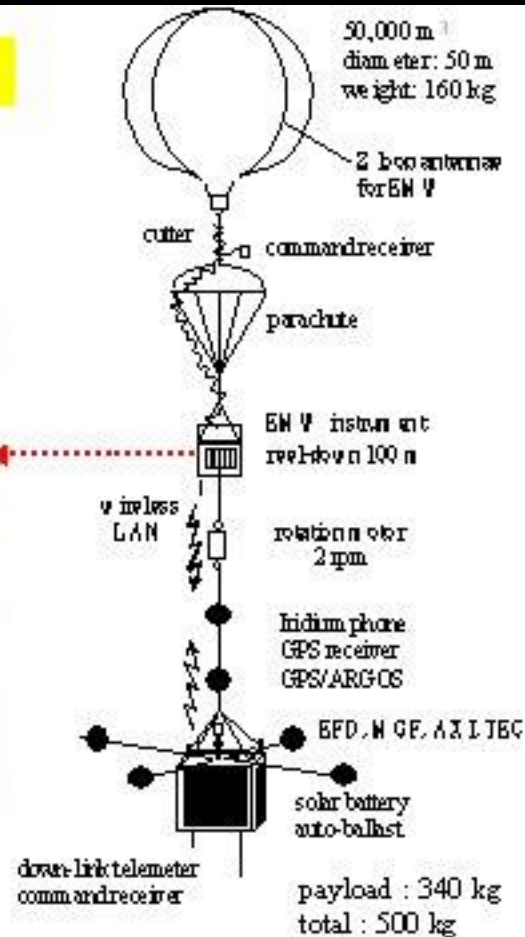
# Geophysics Balloon Cluster

## Flight configurations

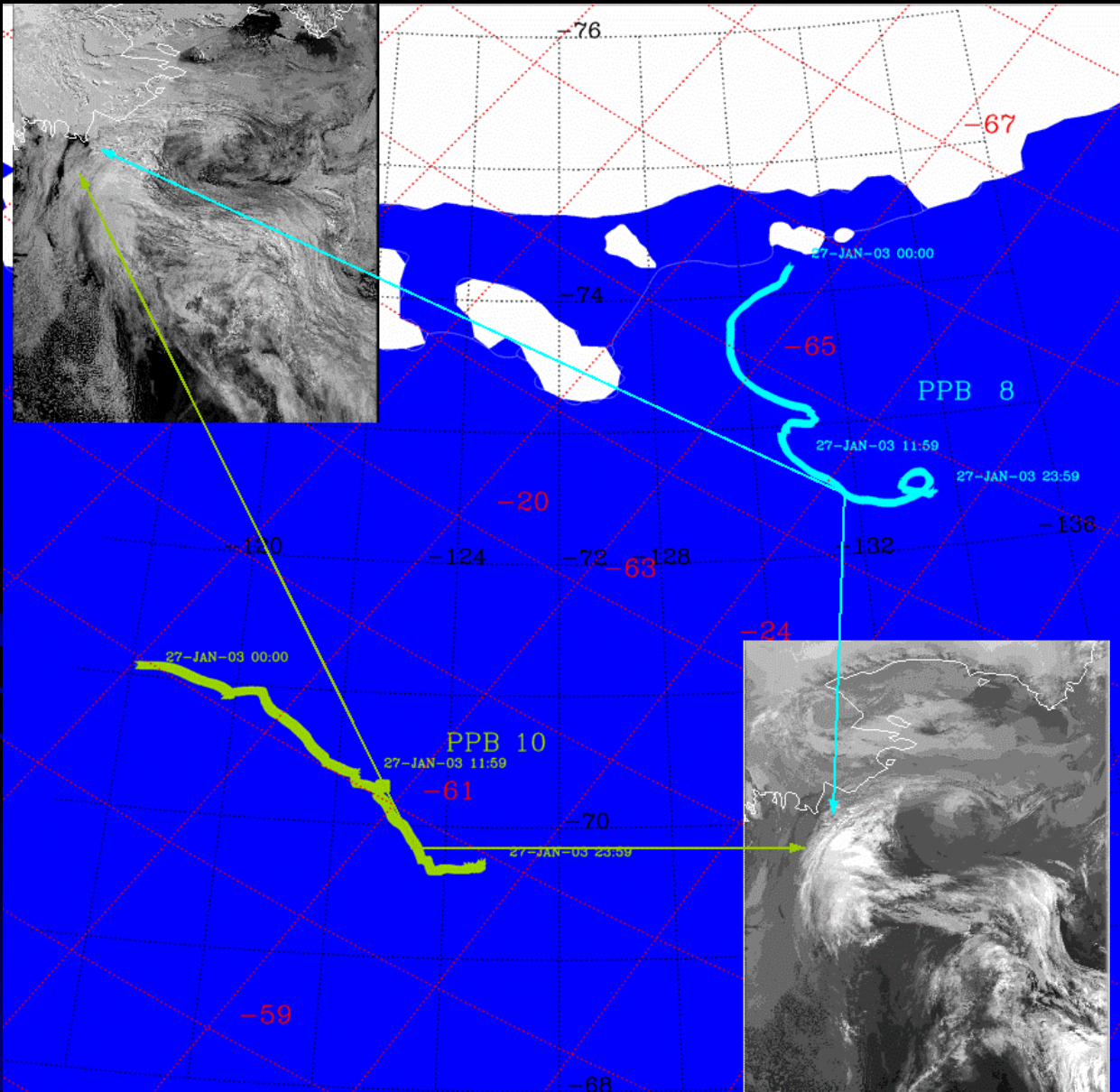
Altitude : 30-35 km  
No. of flight : 3 (Balloon Cluster)



Reel-down mechanism and  
EMW instrument

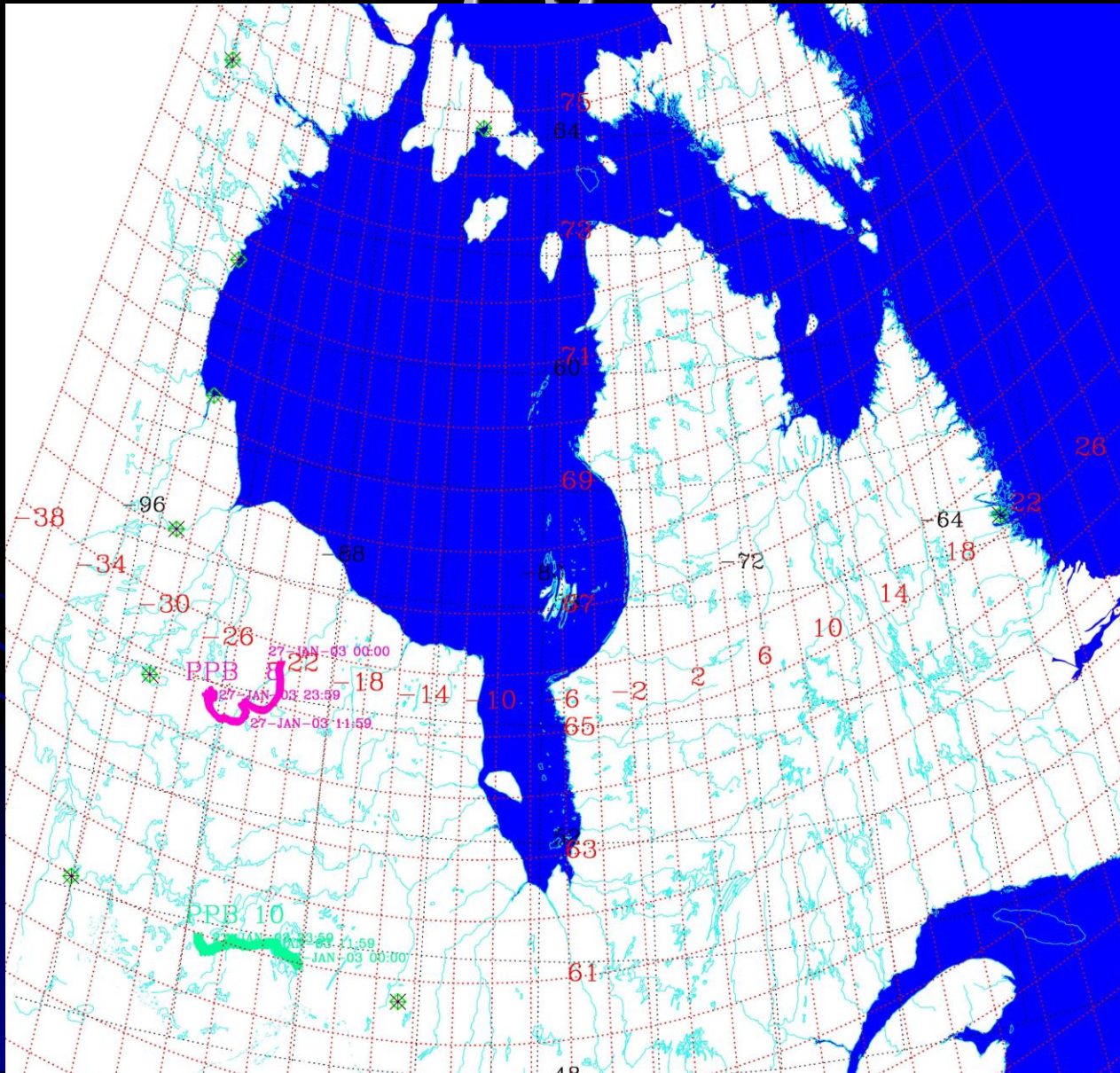


# Balloon Locations



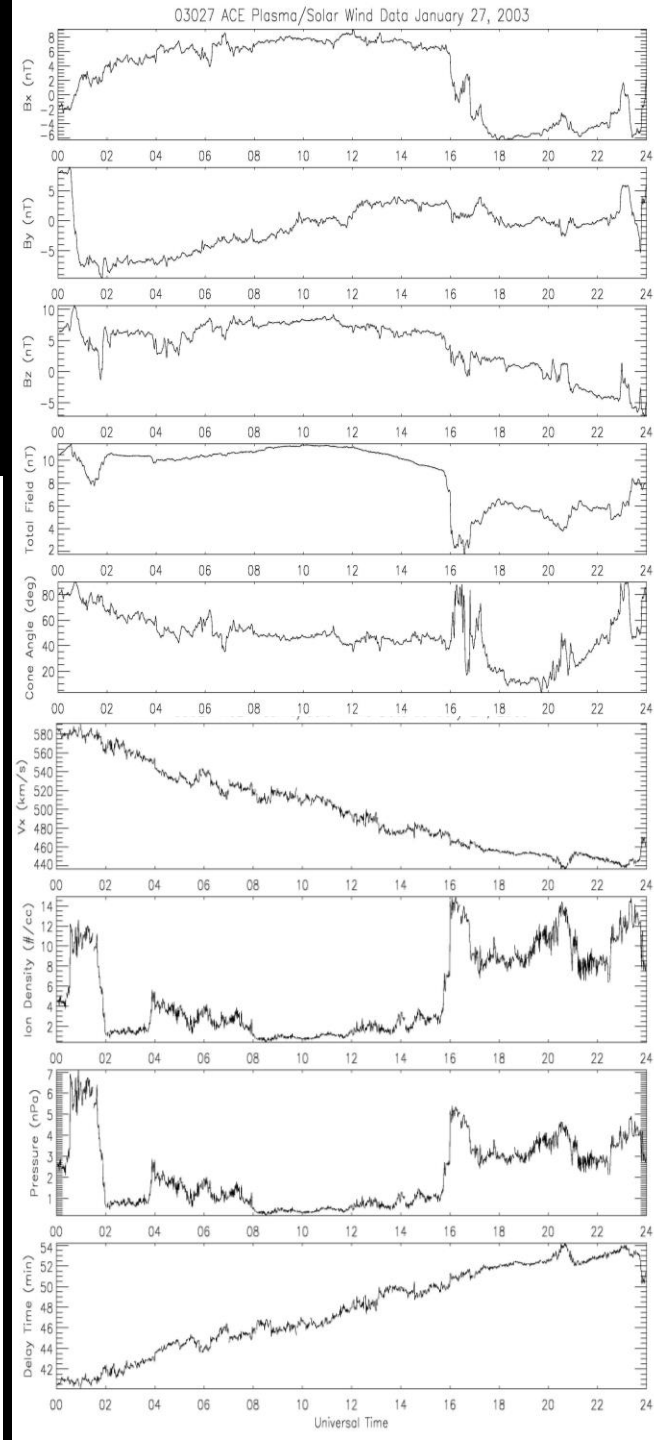
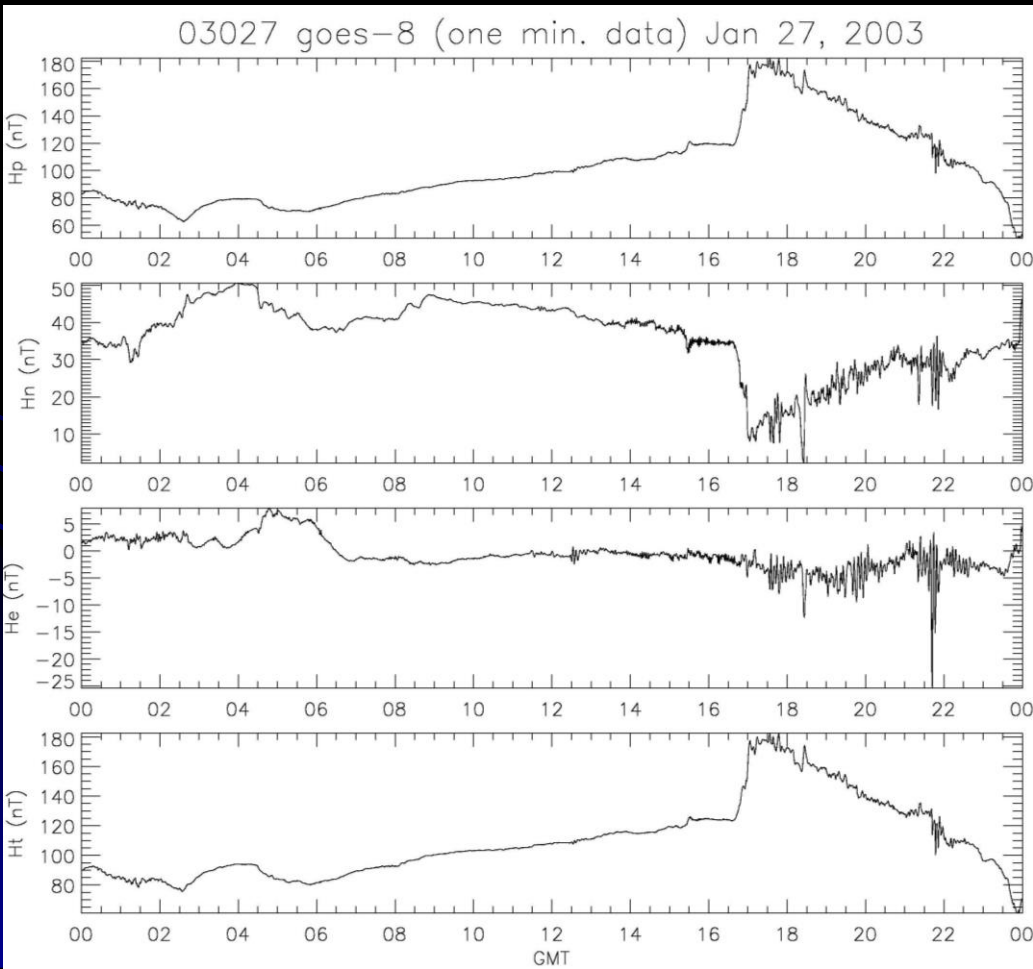
Range: 450 km

# Conjugate Paths





# Solar Wind, IMF, GOES



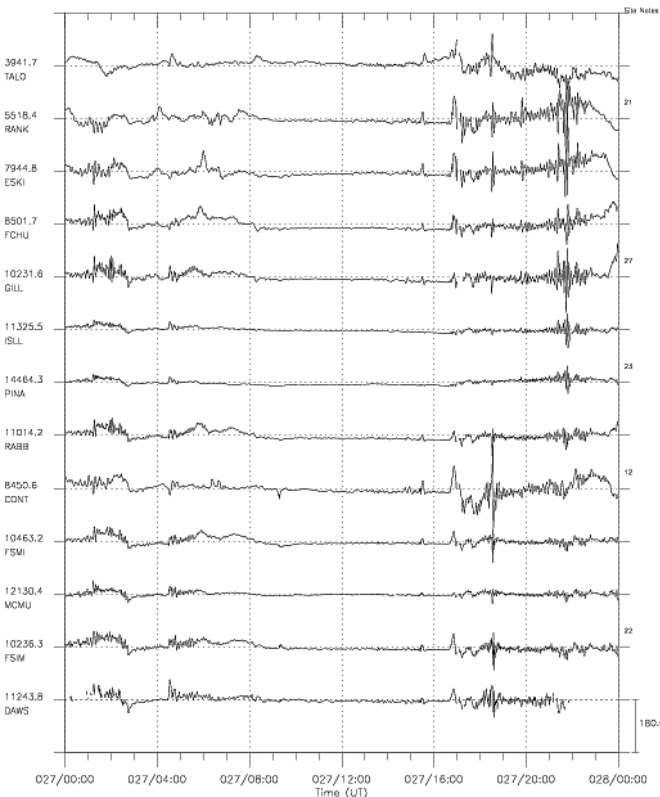


# Canopus Magnetometer Data

Start Time 2003/01/27(027) 00:00:00 UT DESPIKED ( $\Delta = 50.0$ )EDFL DATA

BASELINE: MEAN 27-00:00:00 TO 28-00:00:00

X

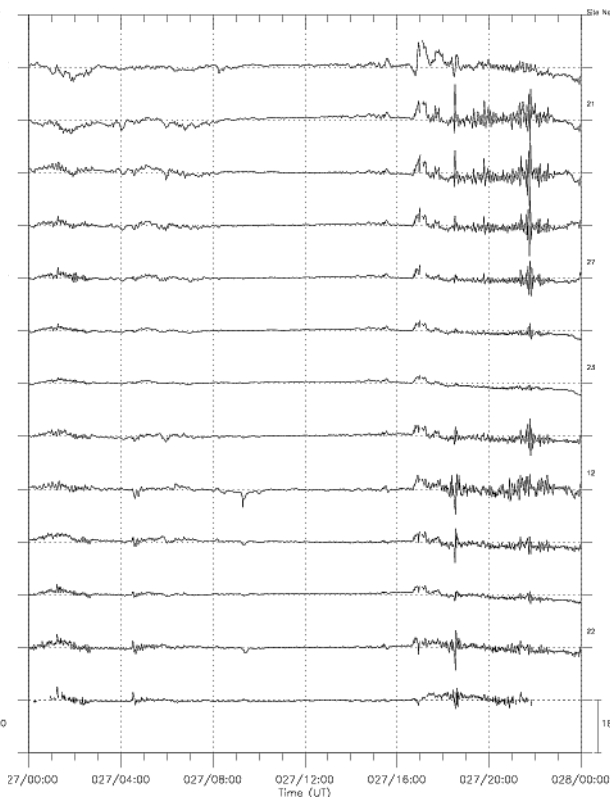


Plot Decimation = 9  
**CSA-ASC**

Start Time 2003/01/27(027) 00:00:00 UT DESPIKED ( $\Delta = 50.0$ )EDFL DATA

BASELINE: MEAN 27-00:00:00 TO 28-00:00:00

Y

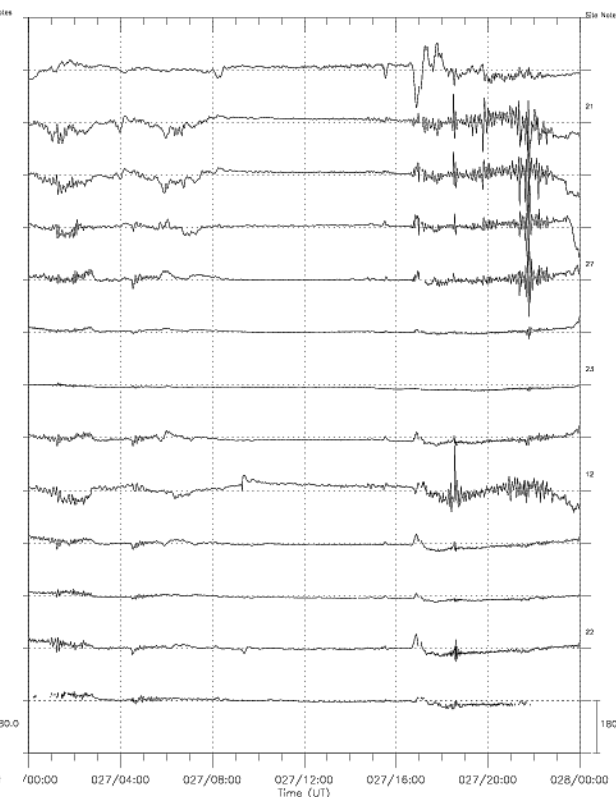


Plot Decimation = 9  
**CSA-ASC**

Start Time 2003/01/27(027) 00:00:00 UT DESPIKED ( $\Delta = 50.0$ )EDFL DATA

BASELINE: MEAN 27-00:00:00 TO 28-00:00:00

Z

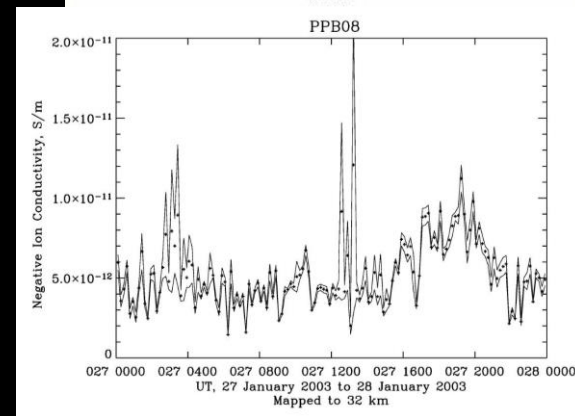
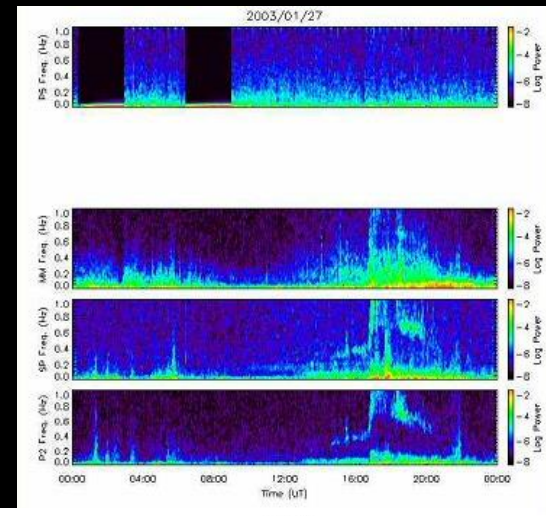
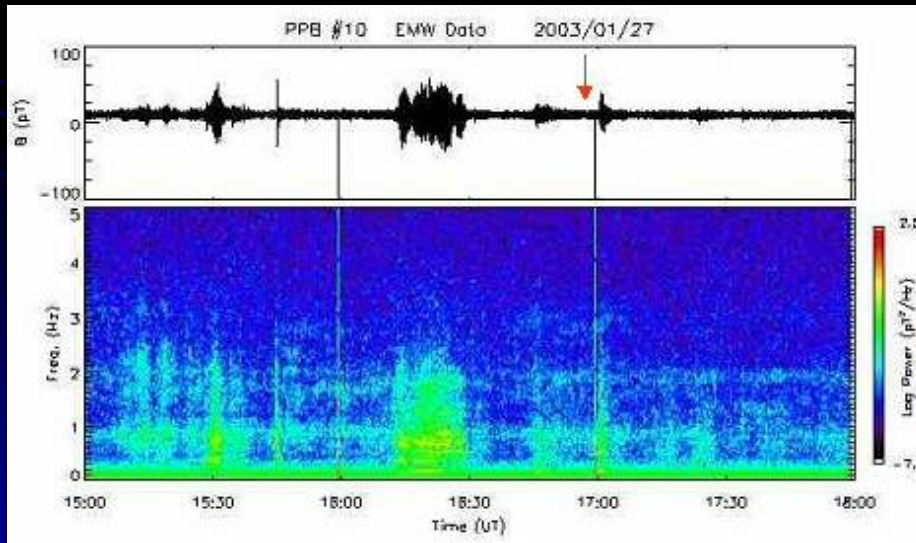


Plot Decimation = 9  
**CSA-ASC**



# Wave Event

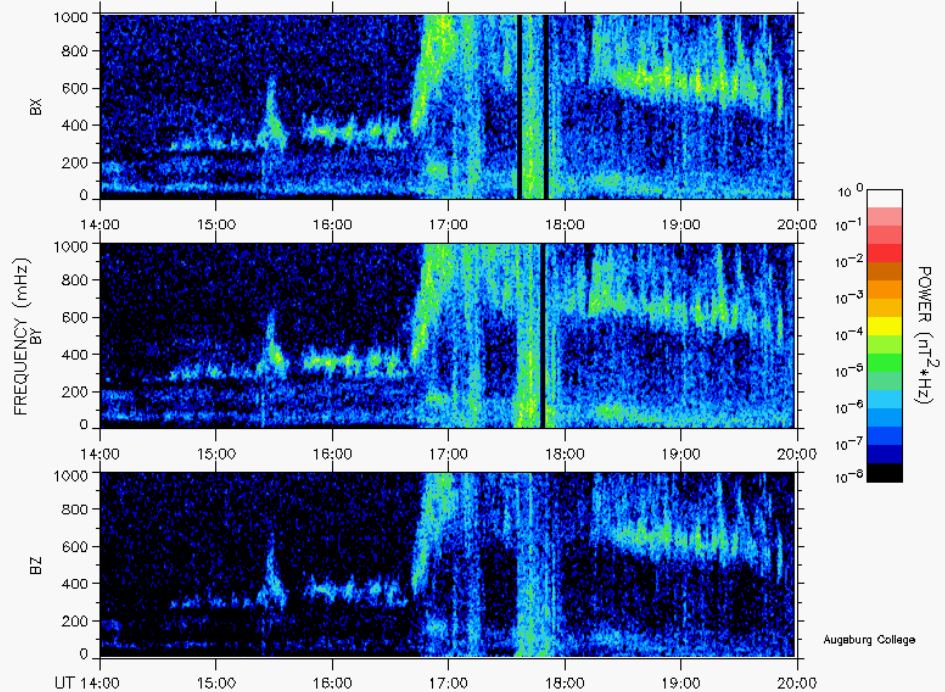
- $\sigma$  increase at one balloon appears to correlate with large scale ULF wave event



# Global Pc 1 Event

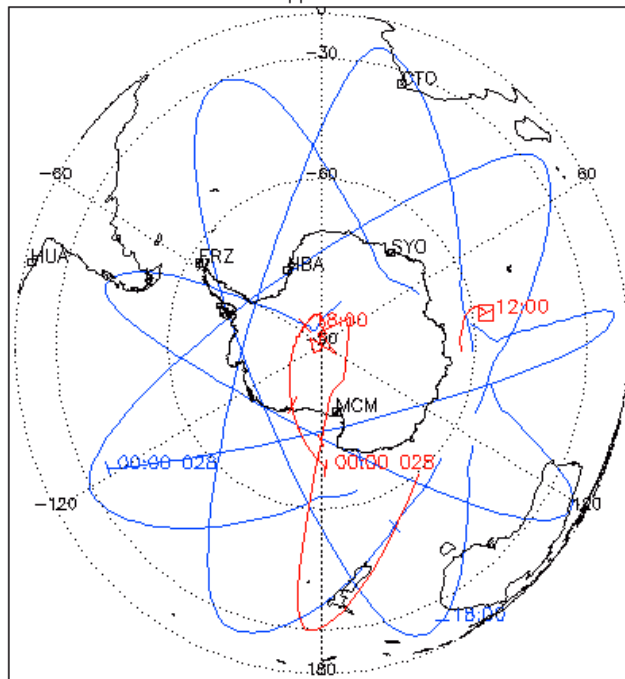
- Seen in both hemispheres
- Seen at P2, A80, A81, A84
- Polar
- S.Pole

South Pole YEARDAY = 03027 JAN 27, 2003

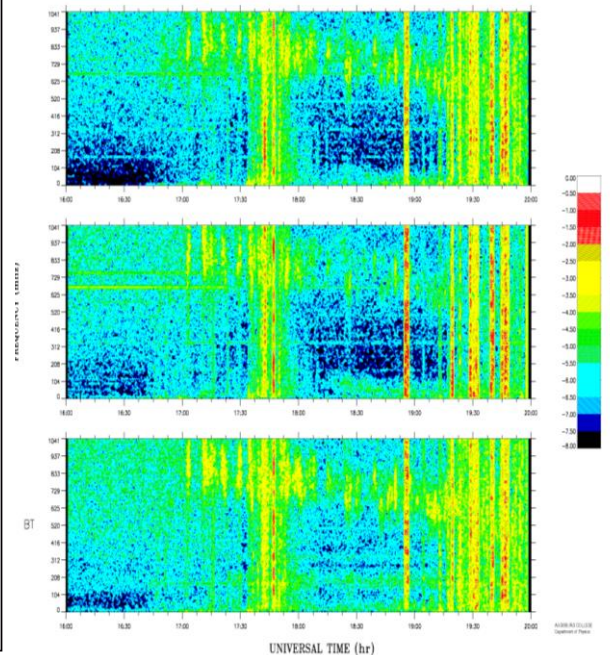


Augburg College

Mapped Plot

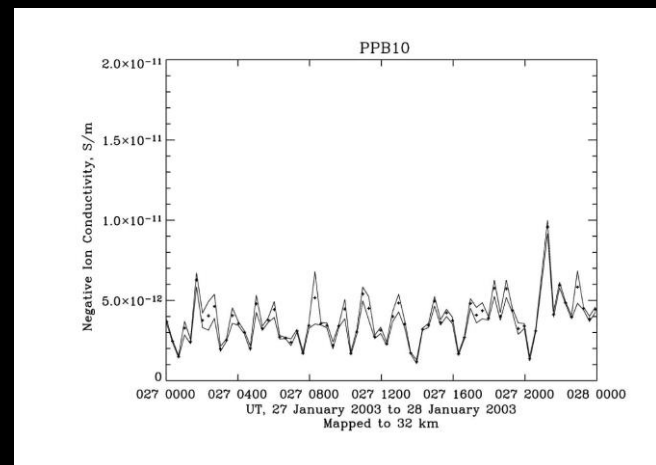
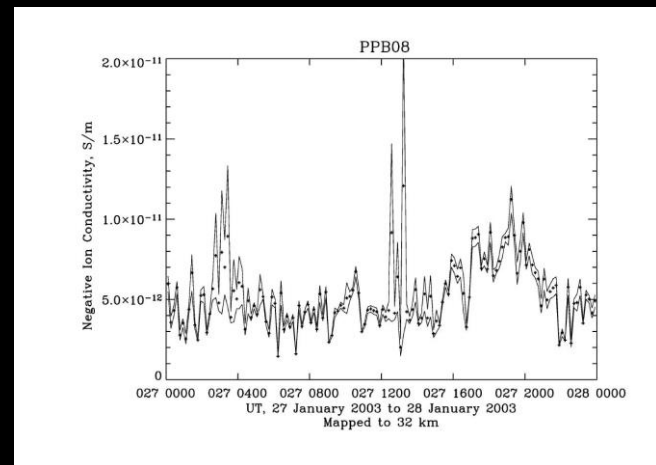
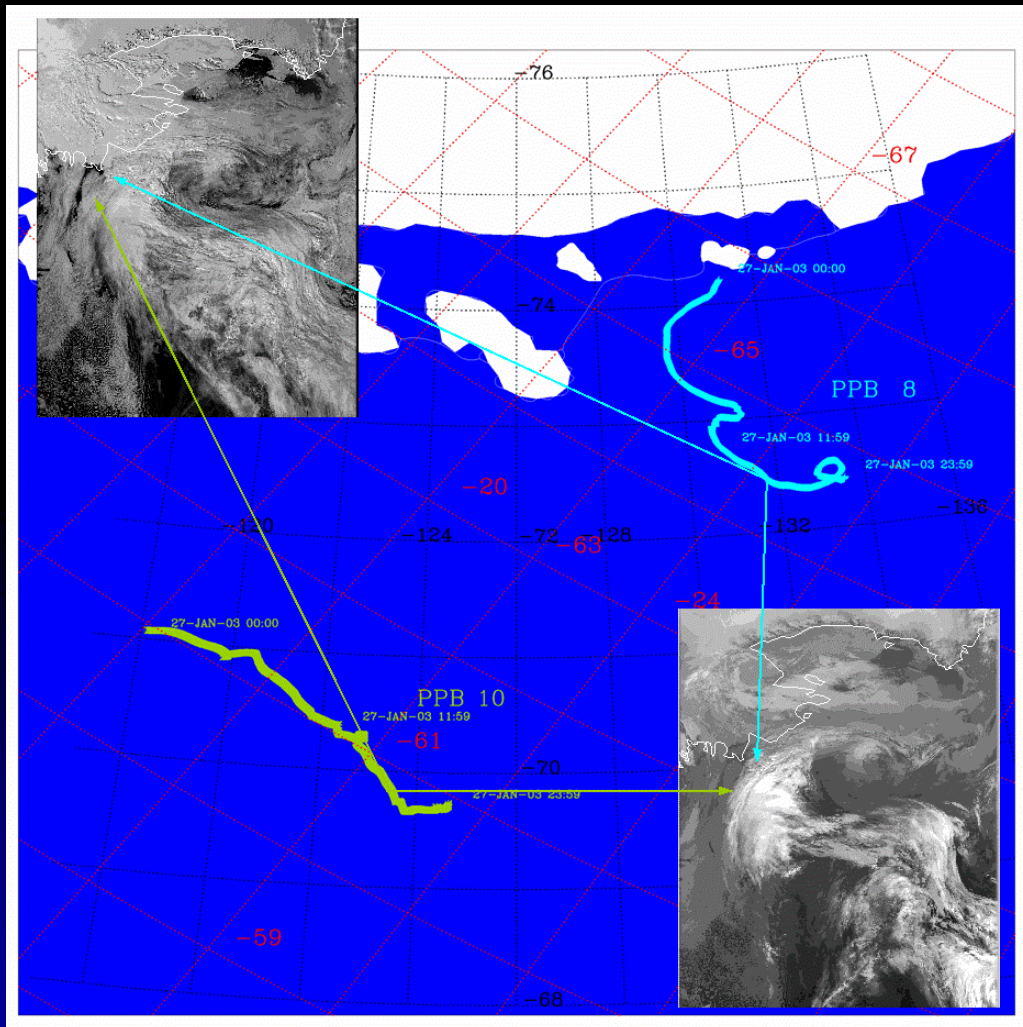


Polar YEARDAY = 03027 JAN 27, 2003



# Conductivity Perturbation

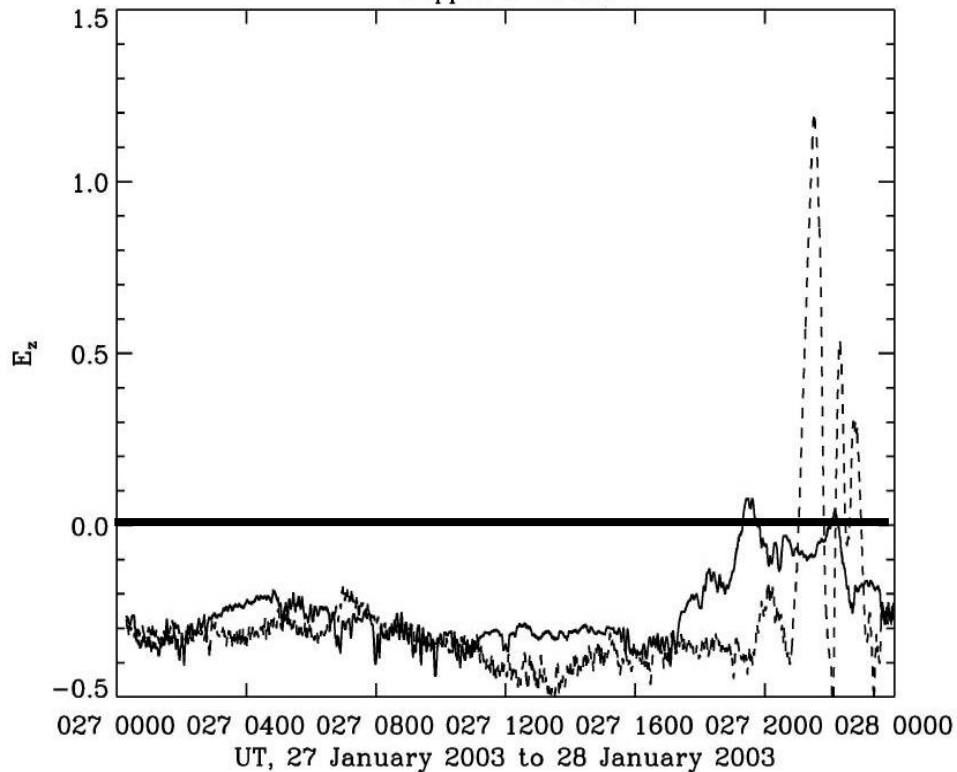
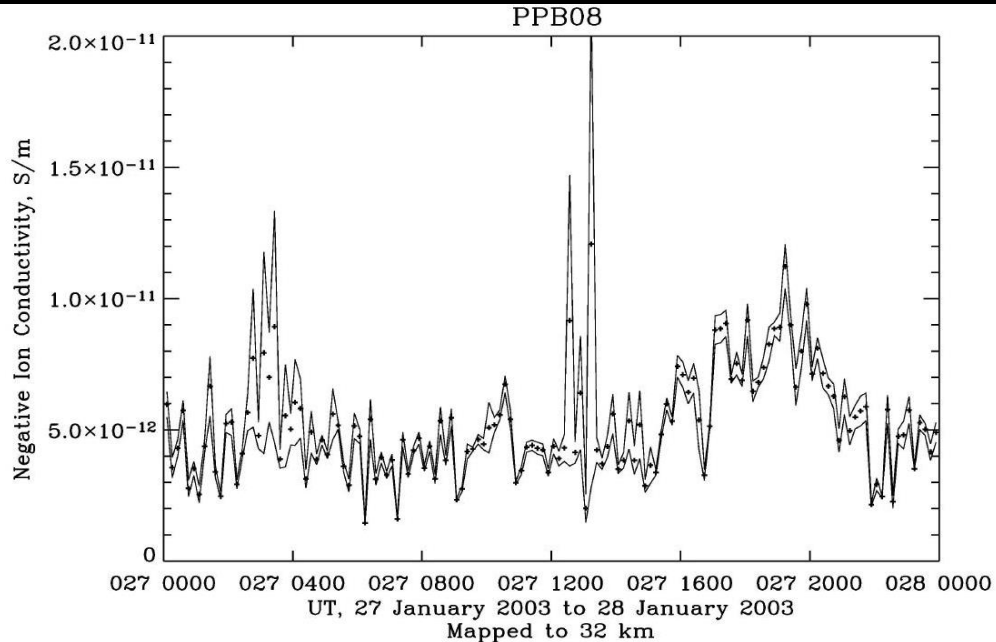
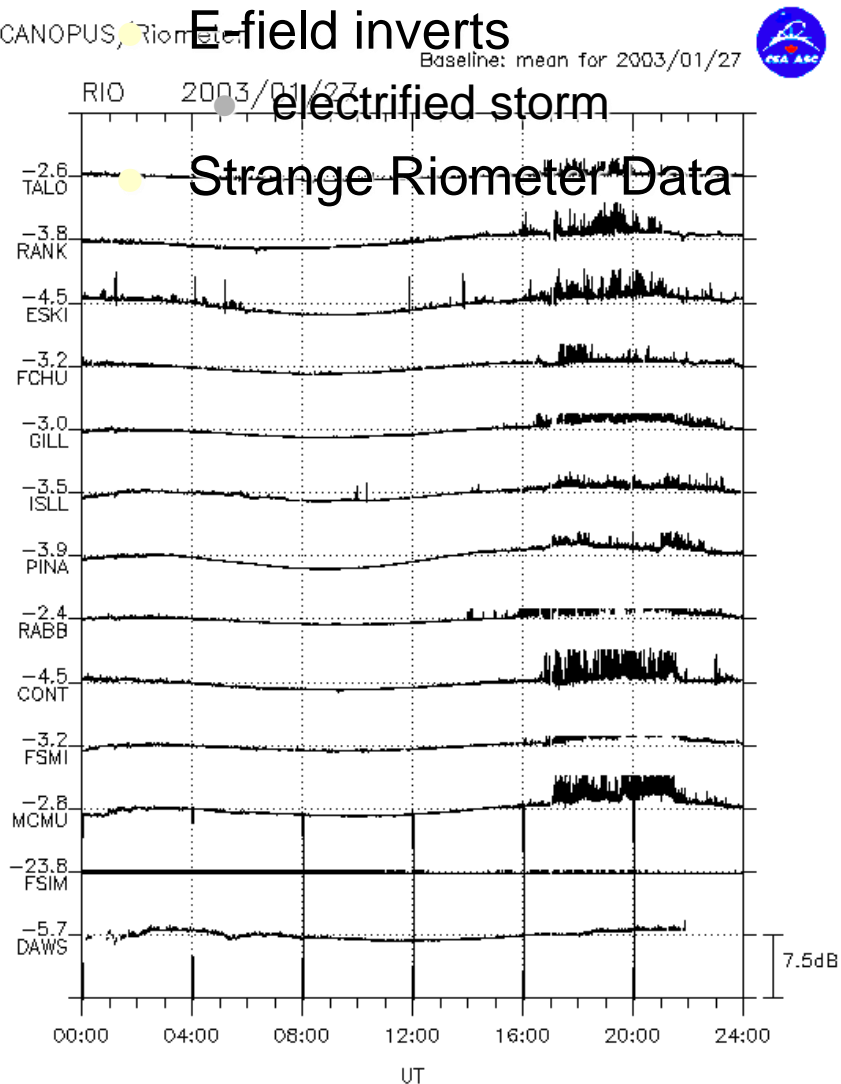
Range: 450 km





# Other Data

- No X-ray counts, but...



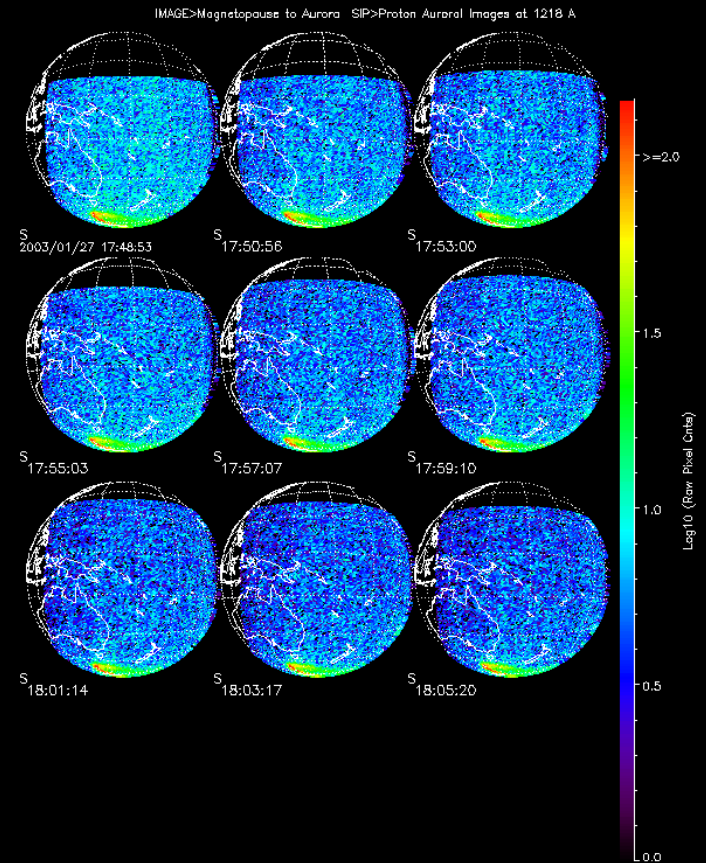
# Discussion

- What caused of the factor of  $2\sigma$  increase observed by PPB #8 on 27 January 2003? Electrons and X-rays ruled out by the absence of any X-ray counts in the on-board detector. Two ideas are: precipitating energetic protons, or the nearby tropospheric storm .

# Proton Evidence

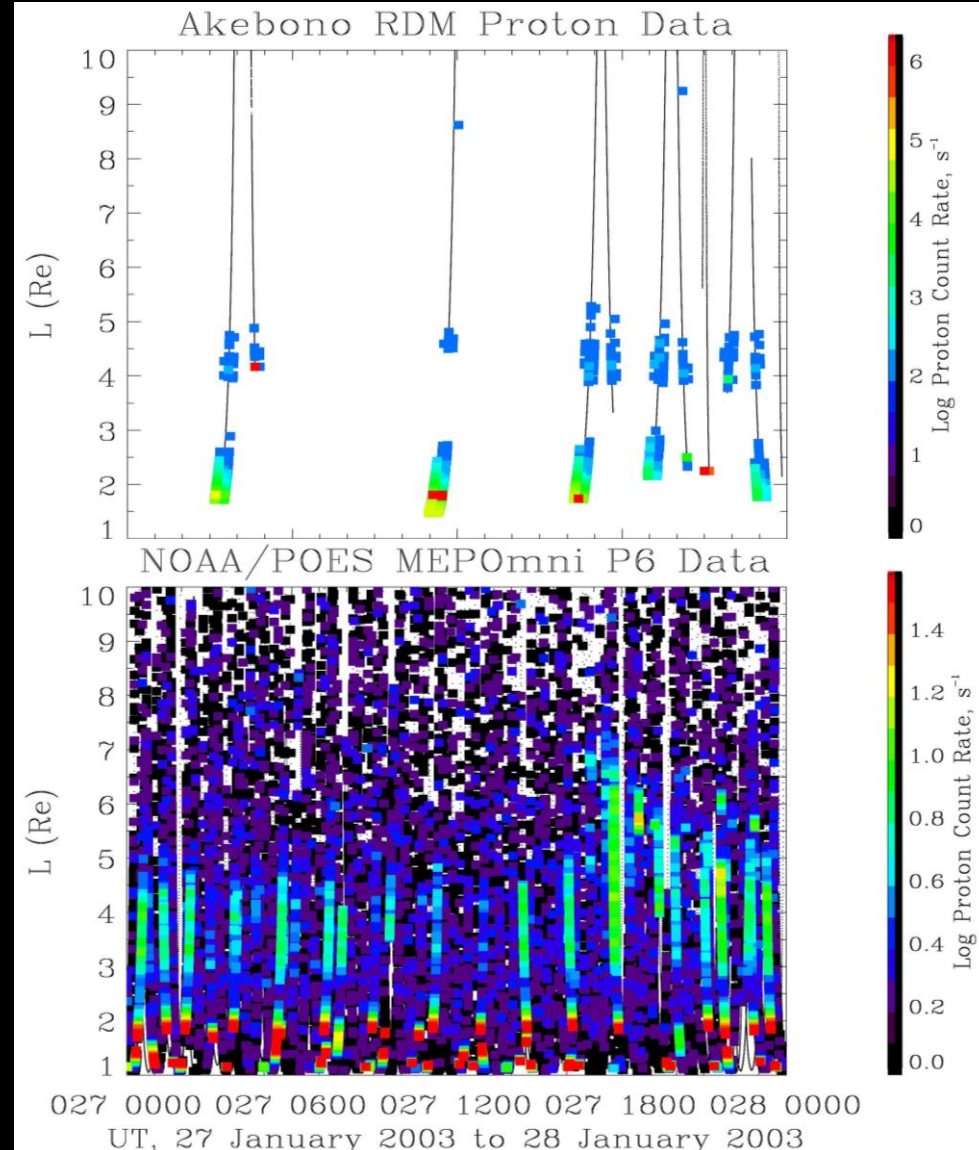
## IMAGE SIP Proton Auroral Images

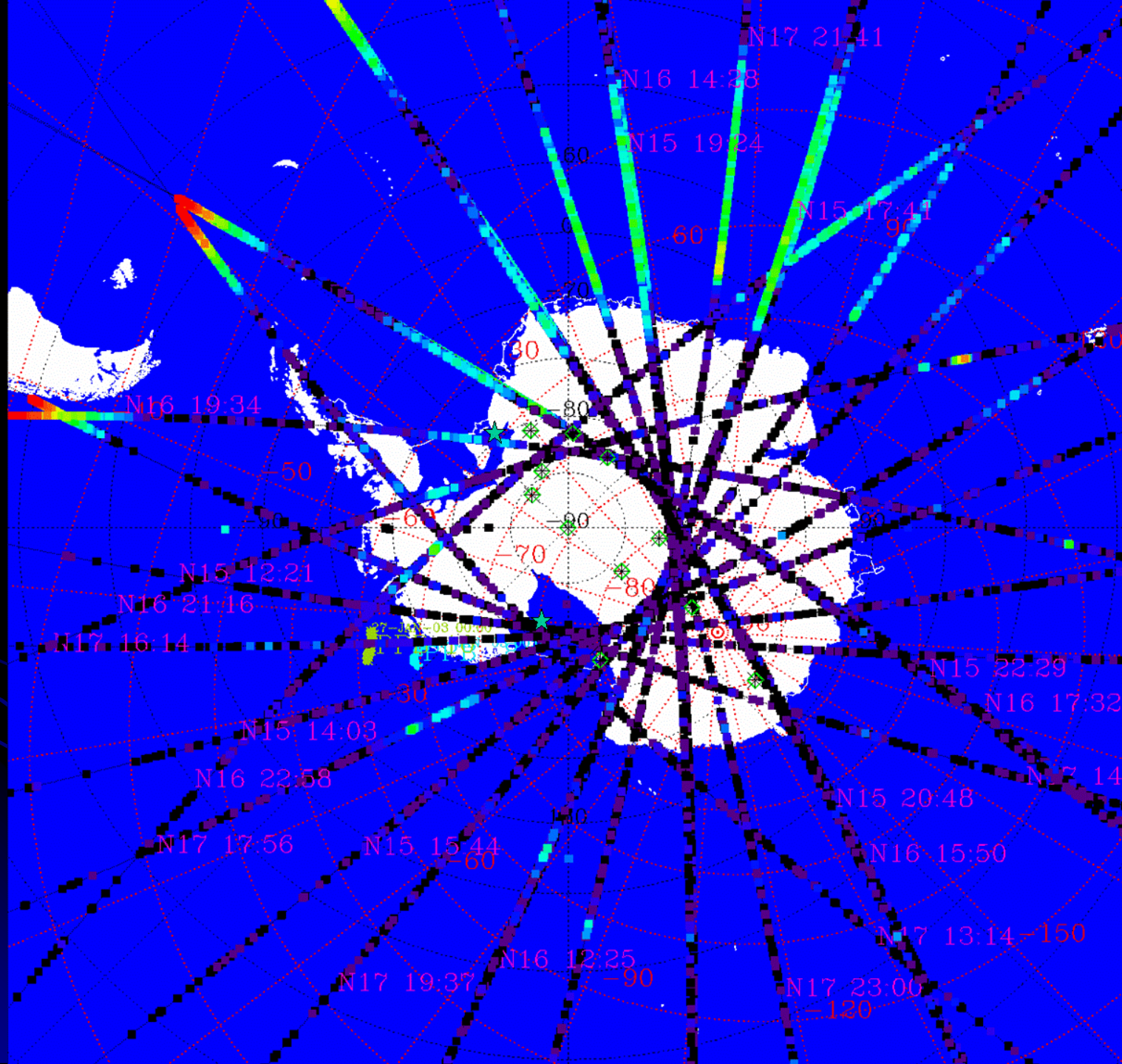
FUV proton auroral  
images from the IMAGE  
spacecraft for 17:48 to  
18:05 UT on 27 January  
2003.



# Proton Evidence

- Energetic proton count rates from the RDM detector on Akebono and the >16 MeV channel from the POES/MEPOmni detector on NOAA-15, -16 and -17 plotted in an L-shell vs. UT spectrogram format for 27 January 2003.**







# Proton Summary

- An *MeV* proton event was seen in the outer belt at the right time/place
- IMAGE FUV proton aurora images show arc near balloon location.
- Event was initiated by SI and IMF orientation change
- Pc1 waves with  $f$  near equatorial  $f_{c,H}$  were seen with same time envelope as  $\sigma$  bump.

# Jan 27, 2003 Conclusion

- It appears to us that precipitating energetic protons are the leading candidate explanation.
- This conclusion points to the fact that MeV protons sometimes contribute to the post-noon proton hotspot.
- Major reasons are the better temporal agreement and the lack of known mechanism for the storm explanation.
- The observation of an electrified extra-tropical cyclone at this latitude is unusual and significant.

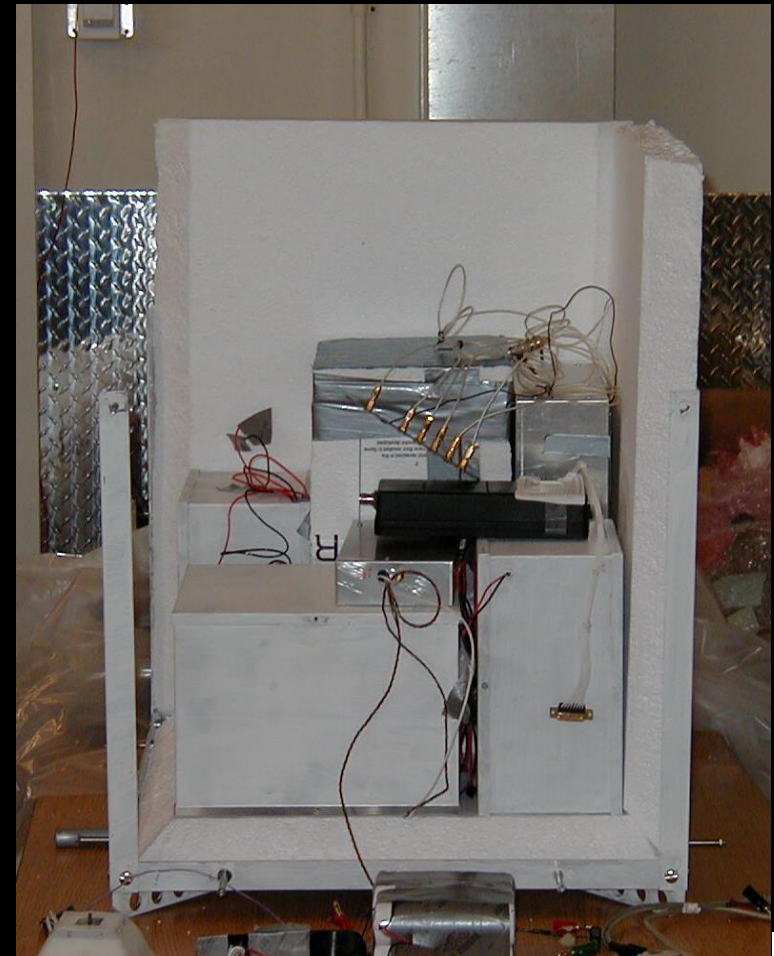
# MINIS: The Balloon Flights

- Small, hand-launched balloons
  - 300,000 ft<sup>3</sup>
  - 70 lb payload
  - 8 day flights
  - 35 km (115,000 ft) float altitude



# MINIS: The Instruments

- X ray scintillation counter
  - Detailed, broad energy spectrum
  - 10 MeV maximum
- Electric field, 3 axis
- Magnetic field, 3 axis
  - Dc-0.5hz, both fields
- VLF wave power (1-30 kHz)
  - One axis each electric and magnetic field
- Ambient temperature



# MINIS: The Place

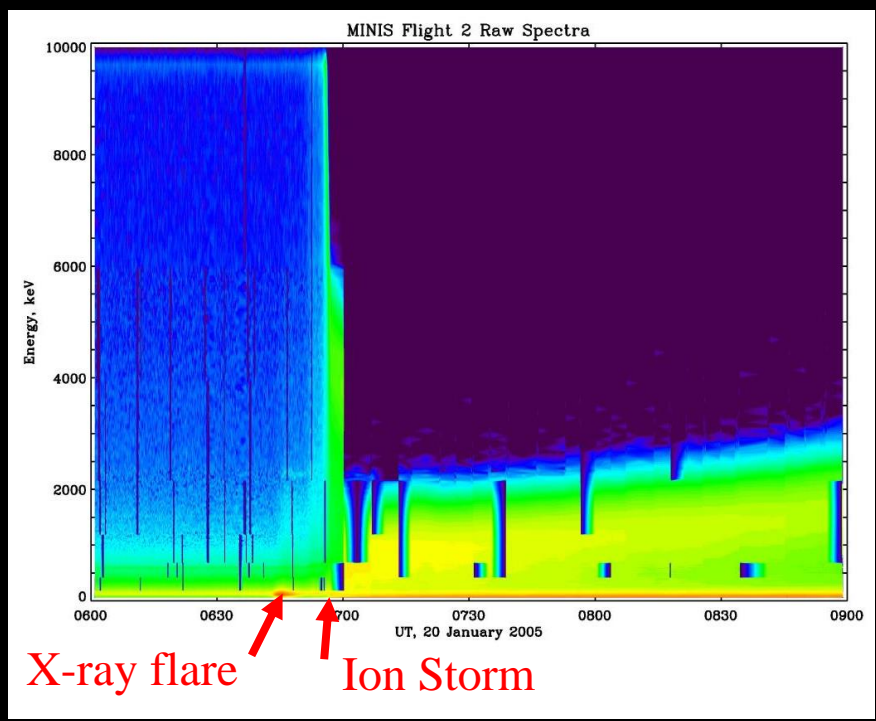
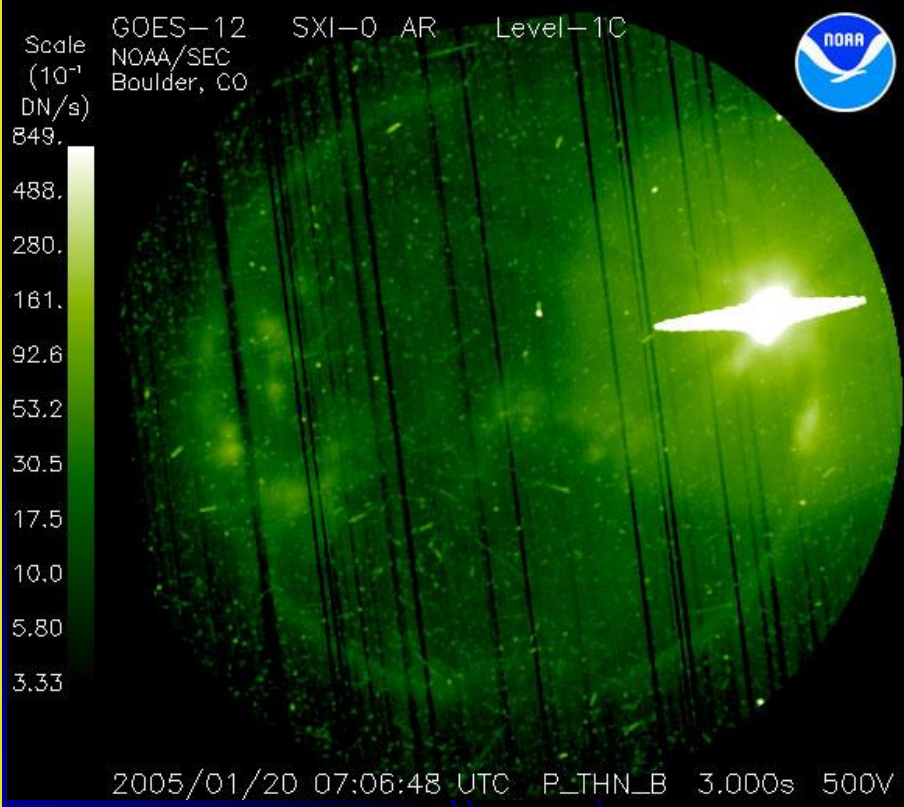
- SANAE





# Class X7.1 Flare, 20 Jan 2005

Mo Dy Begin Max End Reg# Lat CMD X-class  
 Jan 20 0227 0636 0701 0726 N14 W61 X 7.1 Ion Storm, Ground Level Enhancement



Raw X-ray spectra from 2S for the interval 0600-0900 UT on 20 Jan 2005, showing details of the flare onset.





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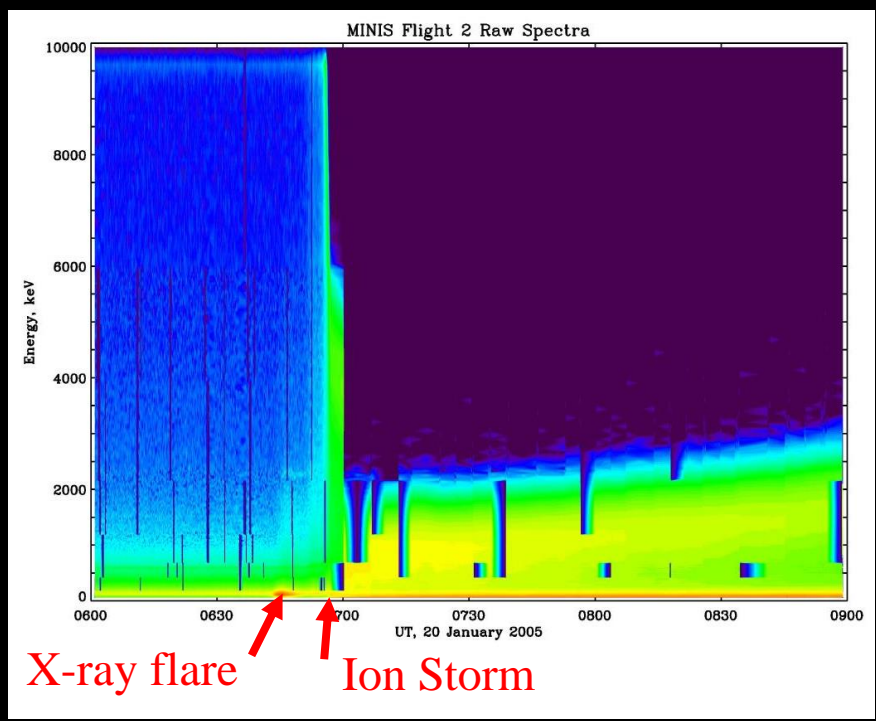
Scale (10<sup>-1</sup> DN/s)  
 849.  
 488.  
 280.  
 161.  
 92.6  
 53.2  
 30.5  
 17.5  
 10.0  
 5.80  
 3.33

GOES 15  
 NOAA/SEL  
 Boulder, CO

NOAA

Flare X-rays were detected by the balloon at the same time RHESSI sees main high energy portion of flare.

Counting rates jump rapidly about 15 min after x-ray flare, saturating detector and creating severe dead-time effects.



Raw X-ray spectra from 2S for the interval 0600-0900 UT on 20 Jan 2005, showing details of the flare onset.

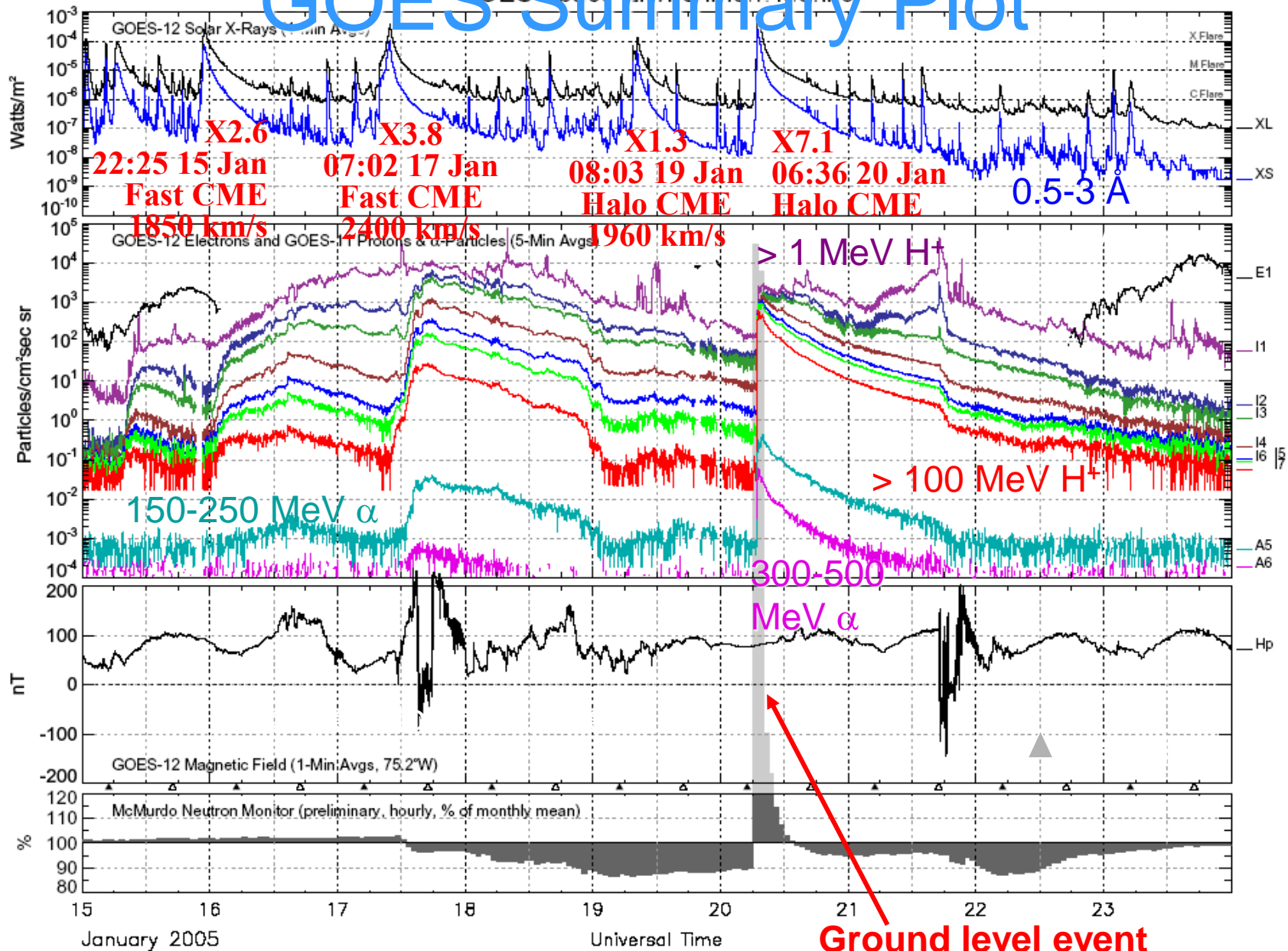
2005/01/20 07:06:48 UTC P\_THN\_LB 3.000s 500V





# GOES Space Environment Monitor

## GOES Summary Plot



Ground level event



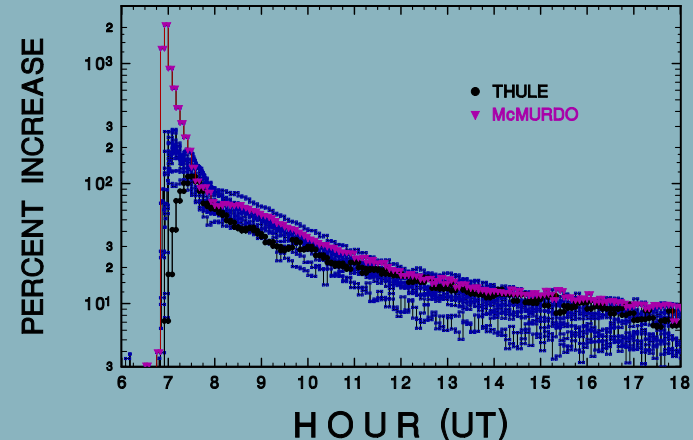


# Ground Level Event

- Observed neutron monitor increases for GLE 69.
- Top: Polar stations with cutoff rigidity  $< 1$  GV.
- Bottom: Stations with cutoff rigidity  $> 1$  GV.
- (Highest Rigidity displayed: *Hermanus*,  $R_c = 4.4$  GV,  $\sim 7\%$ )
- (Highest Rigidity recorded: *Athens*,  $R_c = 8.4$  GV,  $\sim 2\%$ )

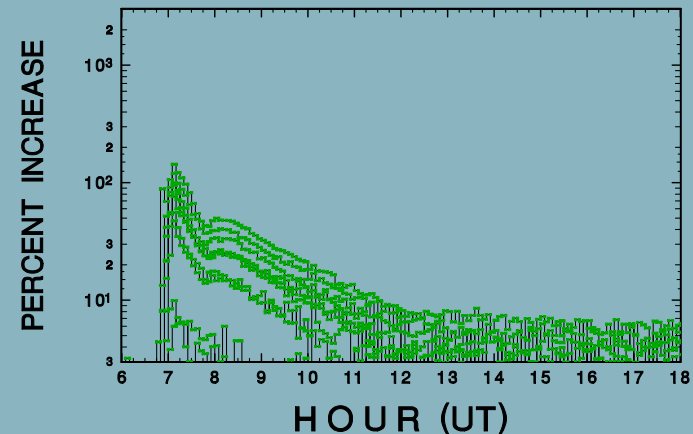
20 JANUARY 2005

GLE 69 ( $R_c < 1$  GV)



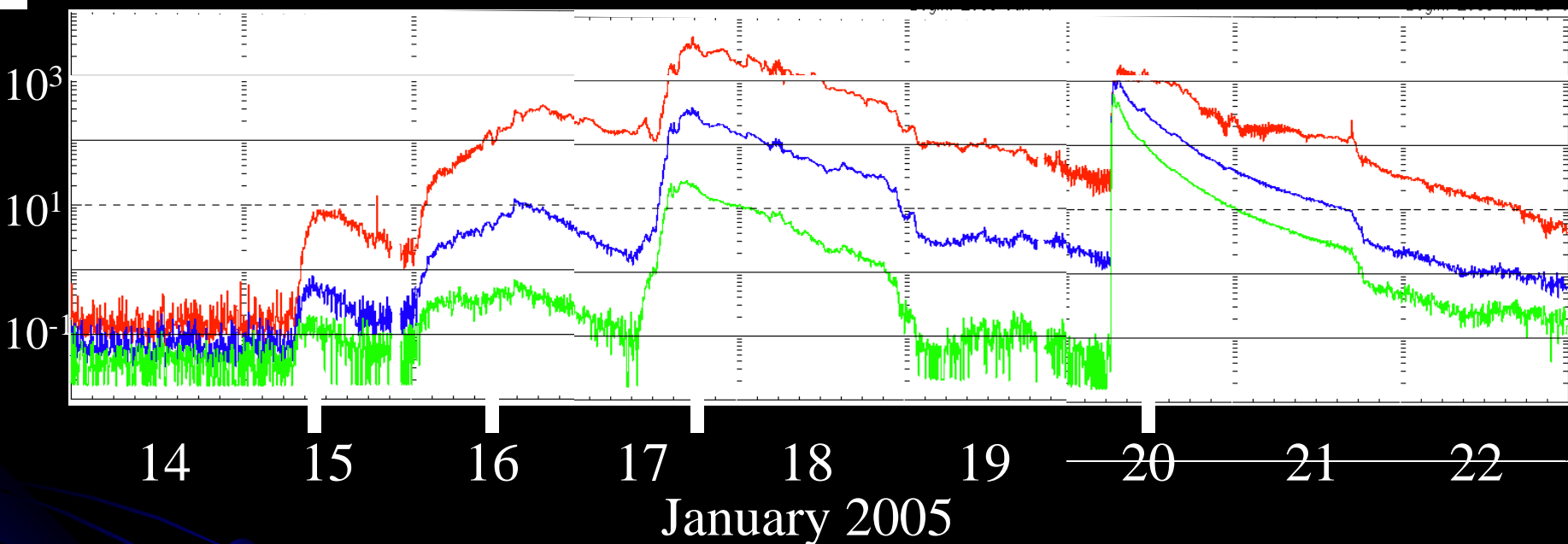
20 JANUARY 2005

GLE 69 ( $R_c > 1$  GV)



# Proton Flux Measurements by GOES 11

(Particles  $\text{cm}^{-2} \text{s}^{-1} \text{sr}^{-1}$ )



**>10 MeV**

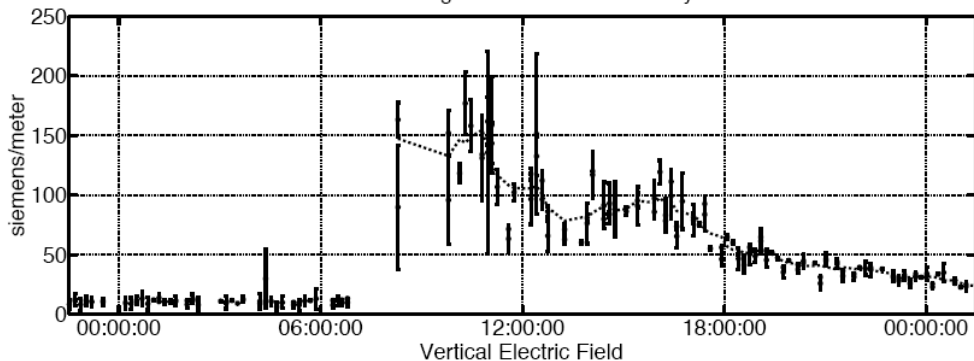
**>50 MeV**

**>100 MeV**

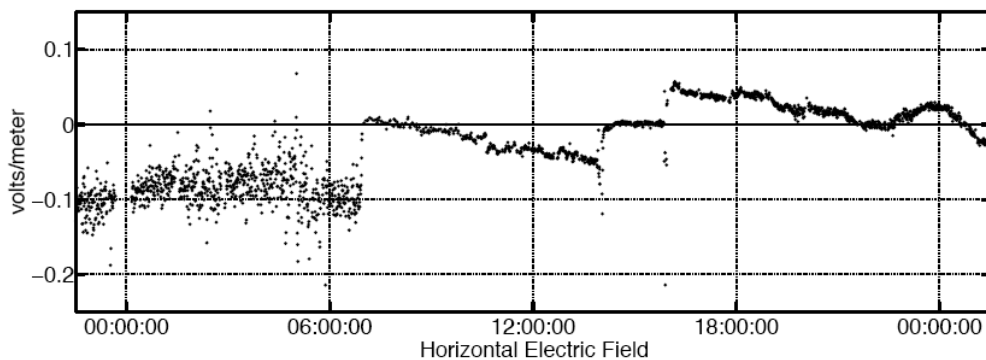
Four separate solar proton events in time period.

# X 7.1/2b Solar Proton Flare at 0636

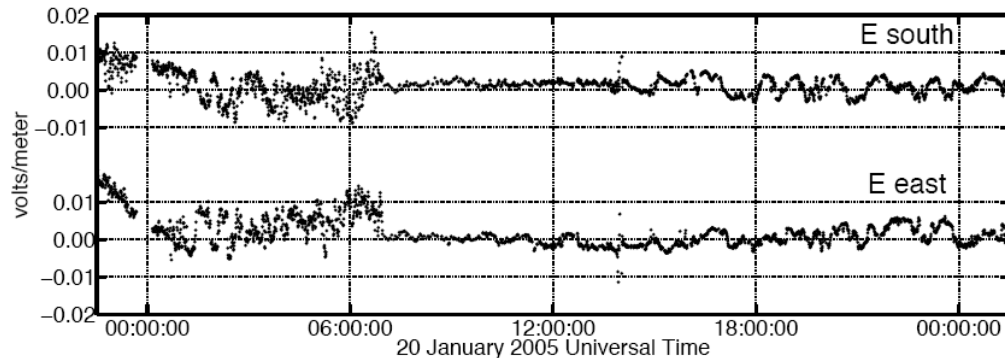
MINIS Flight 2 South – Conductivity



Vertical Electric Field

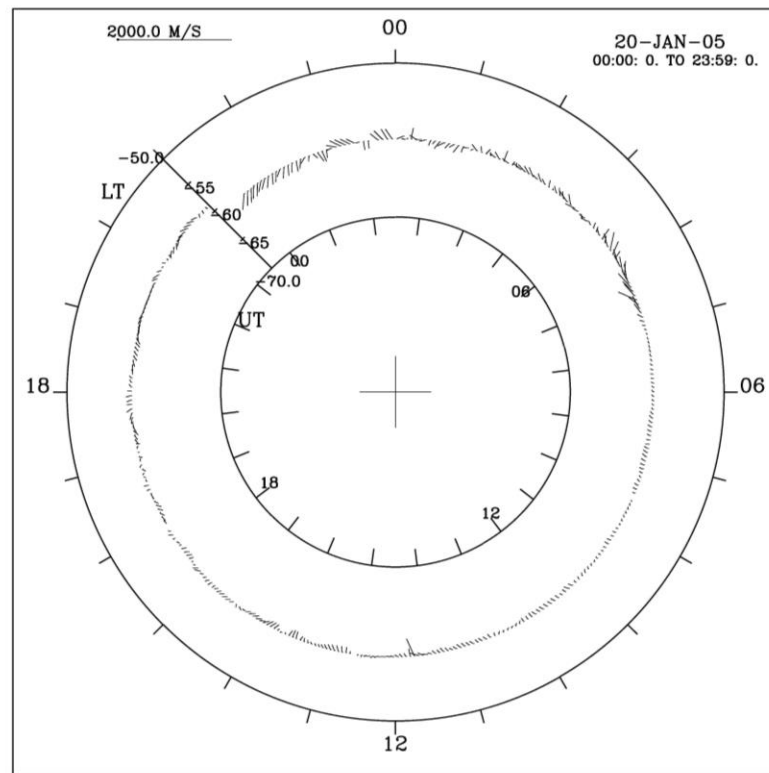


Horizontal Electric Field

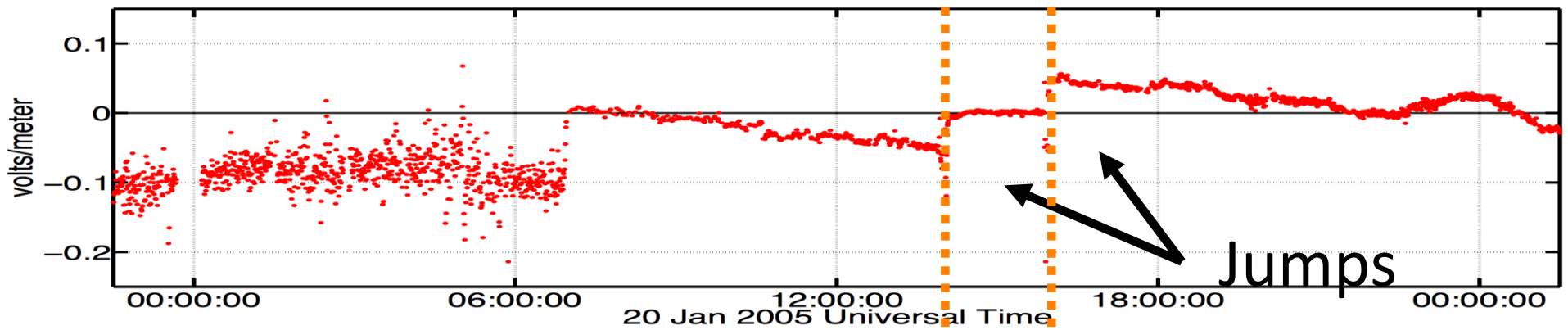


20 January 2005 Universal Time

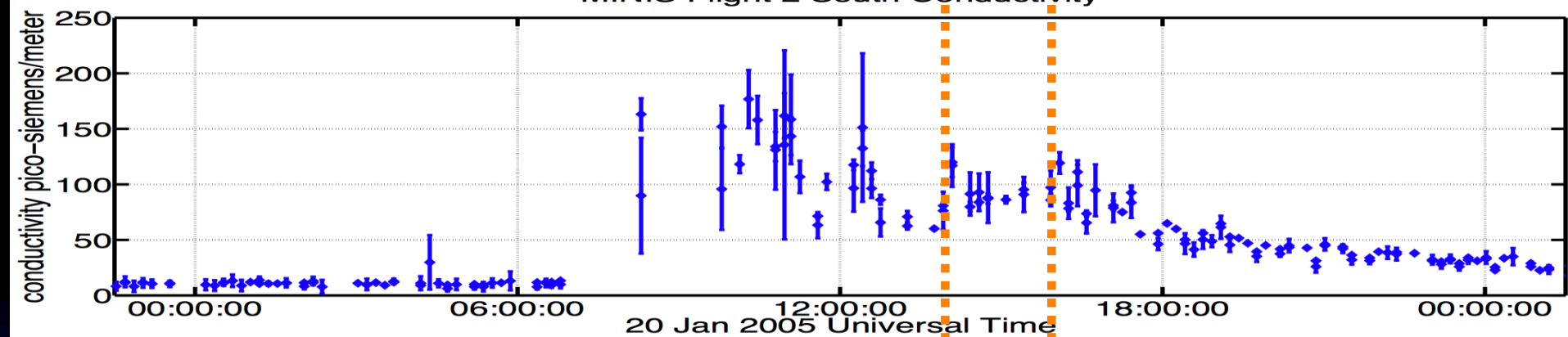
MINIS FLIGHT 2S



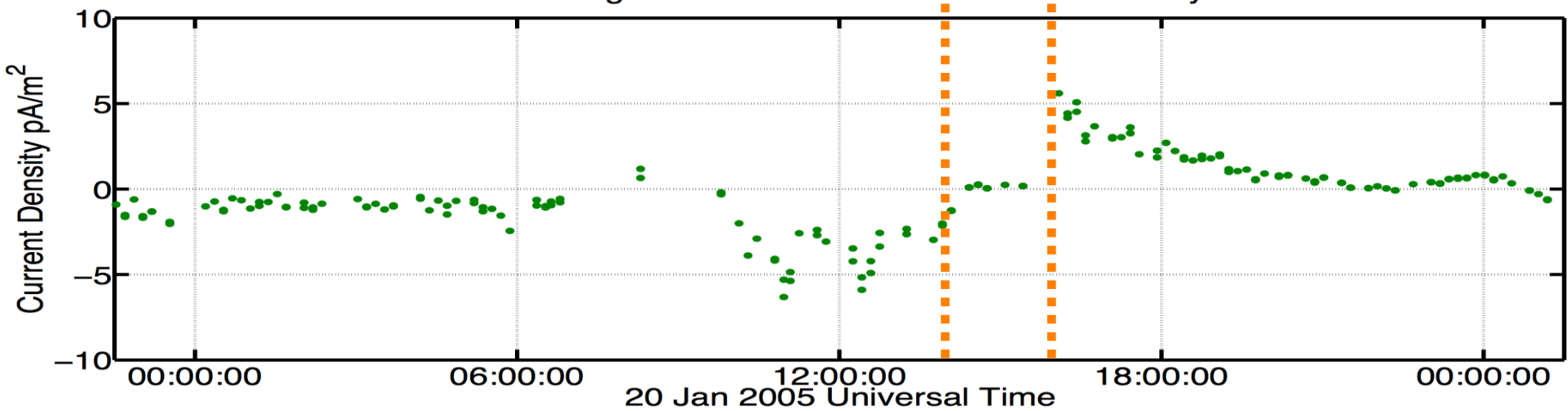
MINIS Flight 2 South Vertical Electric Field



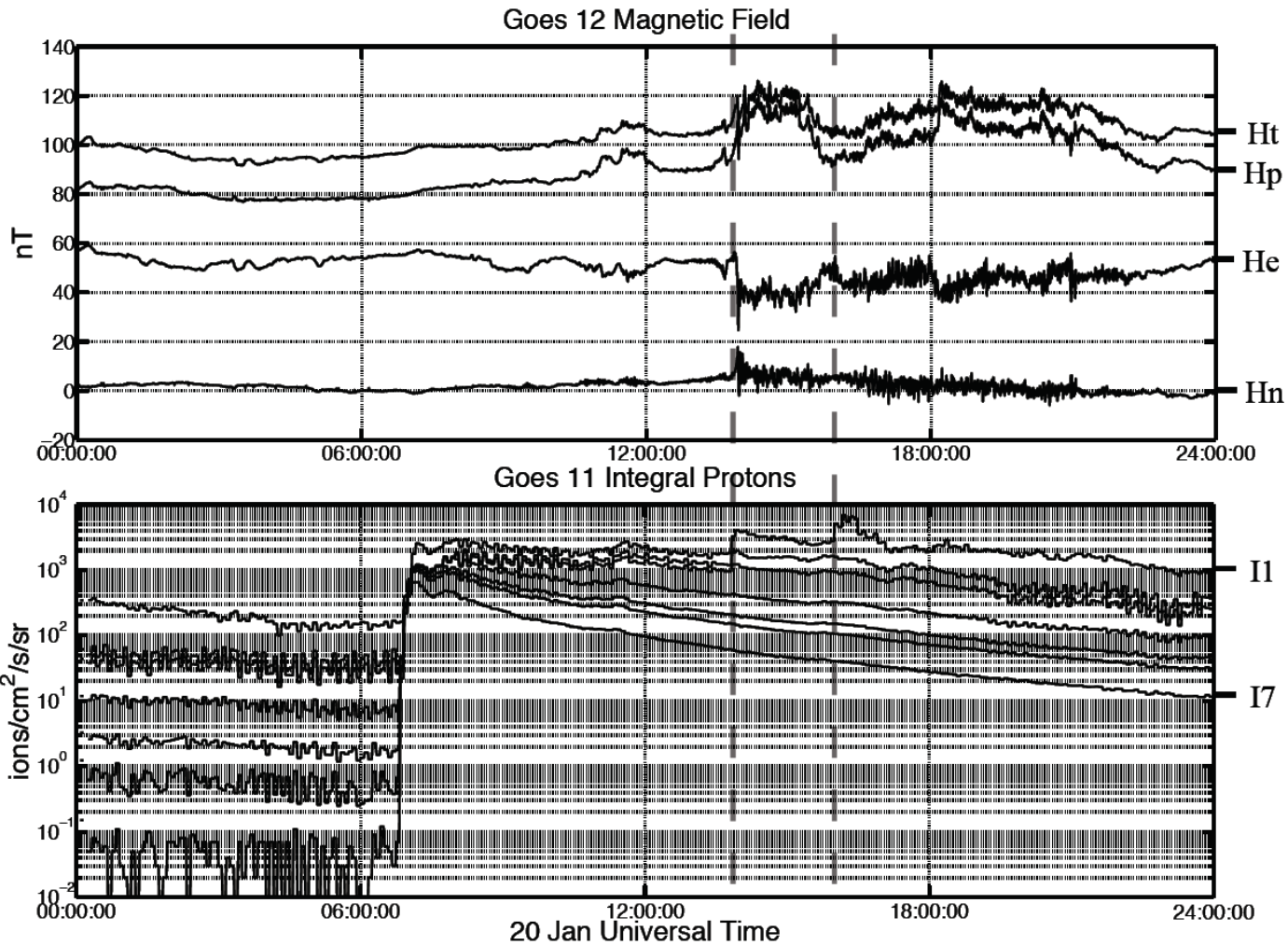
MINIS Flight 2 South Conductivity



MINIS Flight 2 South Calculated Current Density

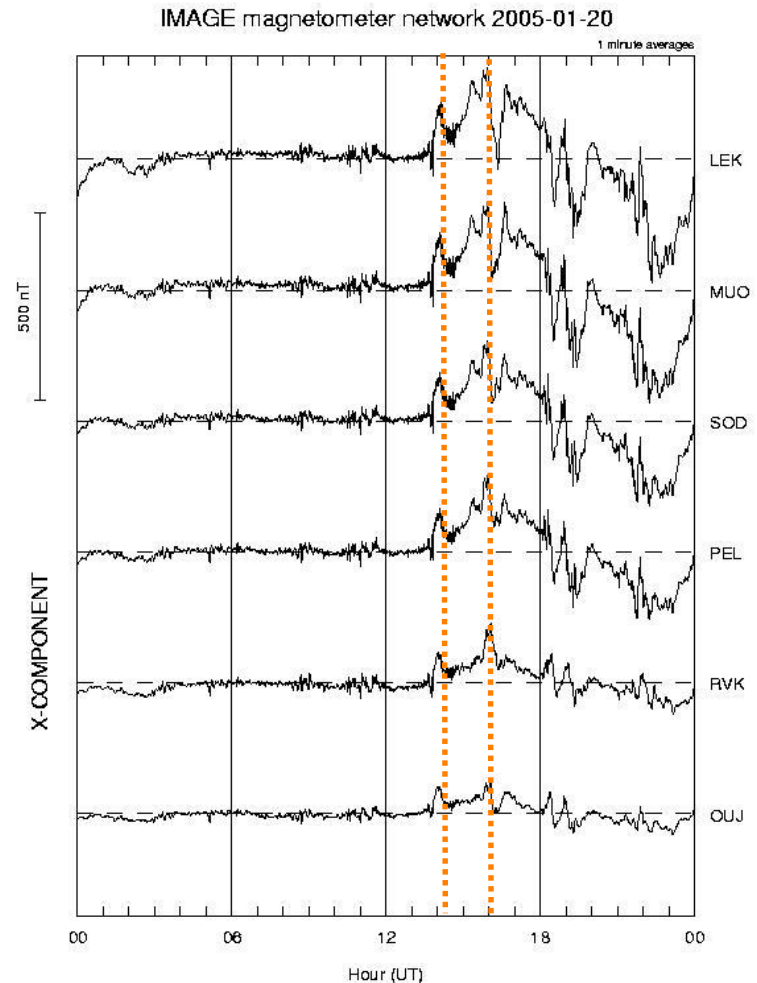


# Jumps Followed By Proton Peaks

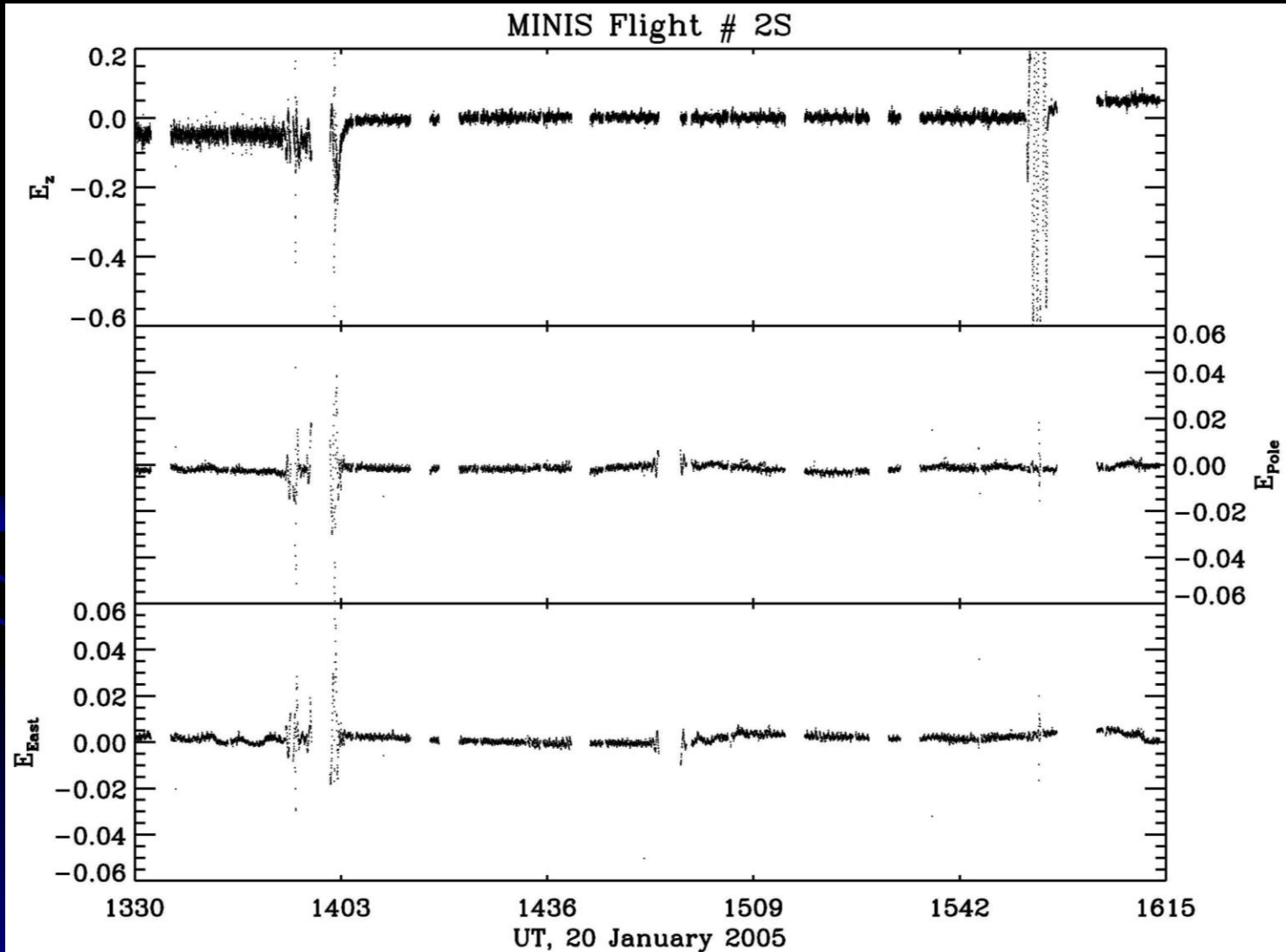


# Global Current Flows

- Each Jump preceded by  $\Delta B_x > 0$  spike in auroral zone

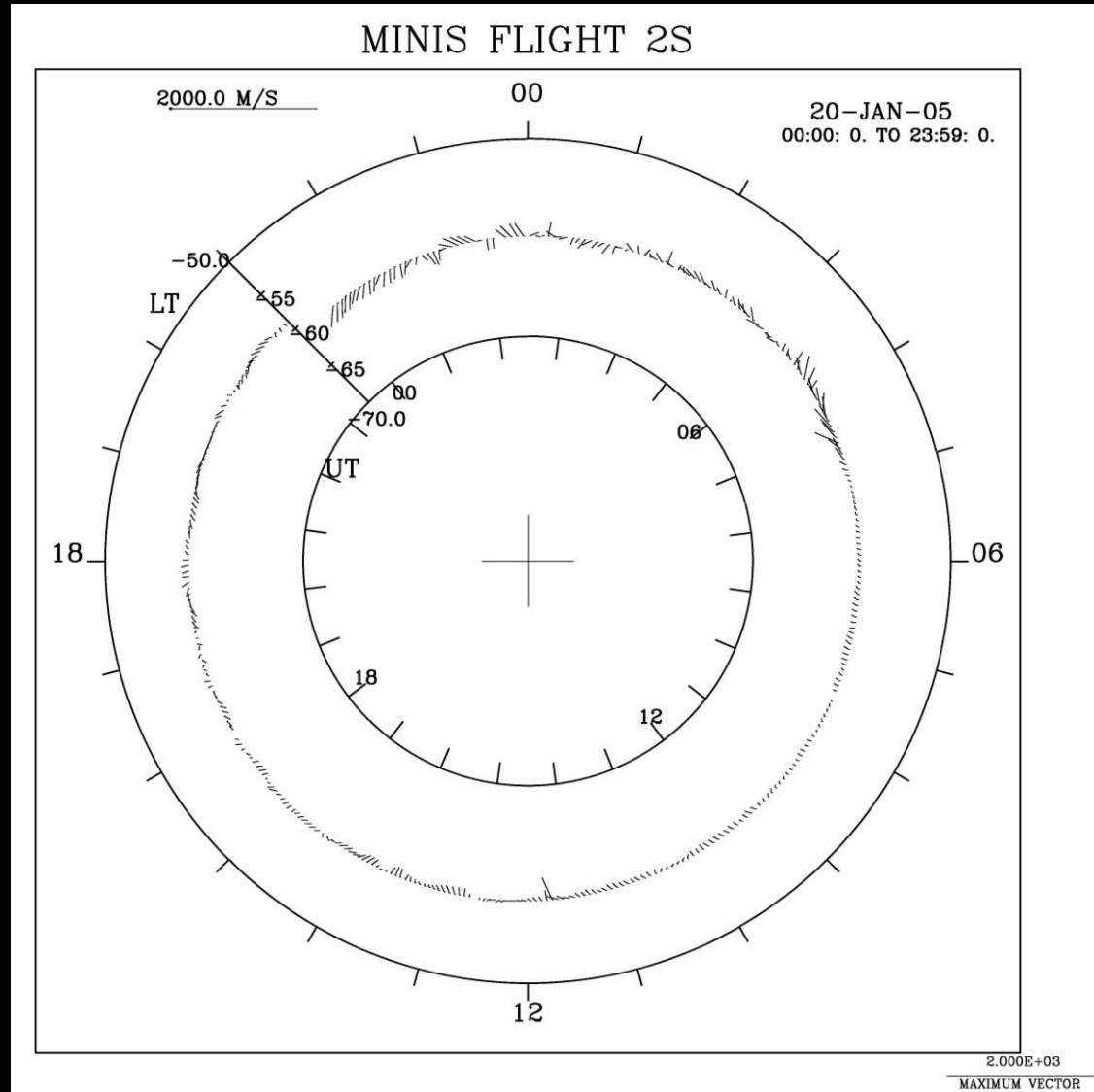


# Details of the Electric field



# Horizontal Electric Field

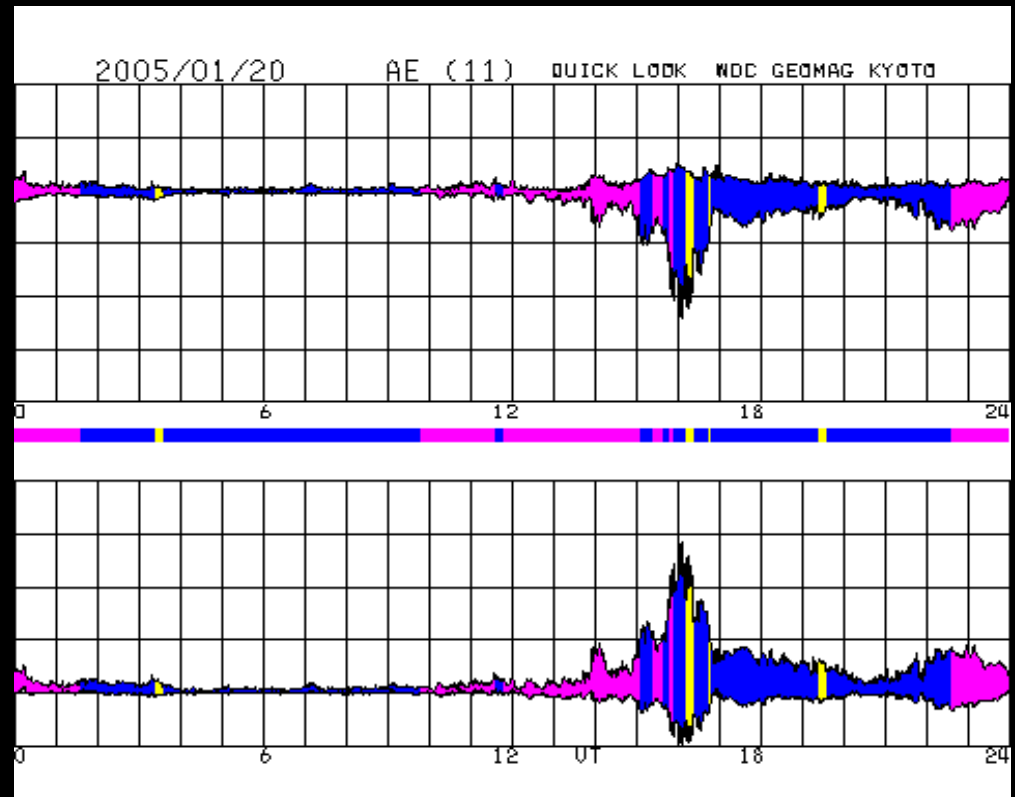
- Convection disappears at the time of the SEP event





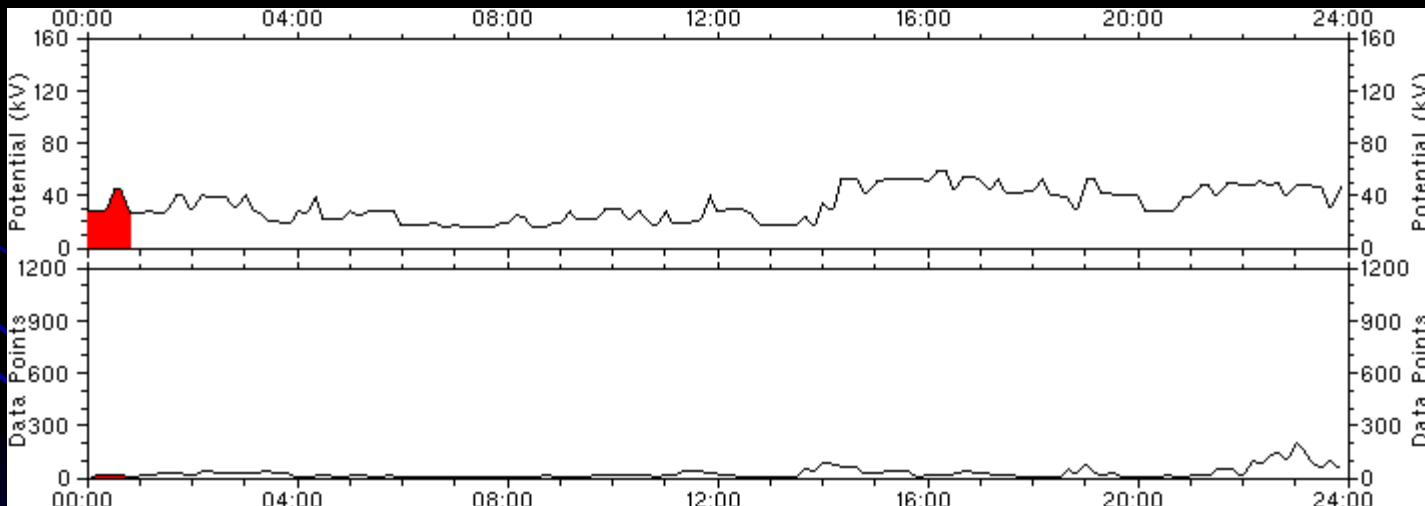
# Magnetic Activity

- Magnetic activity already low
- Absent for 6 hours following flare



# SuperDarn Summary

- Potential estimate was Model not Data Driven
- Data Points  $\sim 0$  for 2 Hours after flare



# Conclusions

- Solar protons strongly affect global circuit.
- Changes of stratospheric conductivity
- Major changes in vertical field
- Short out the magnetosphere?
- Stay tuned. Exciting results pending!

