It’s Raining Ions and Electrons!

2016 ISR Group 5 Presentation

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30 Jul 2016

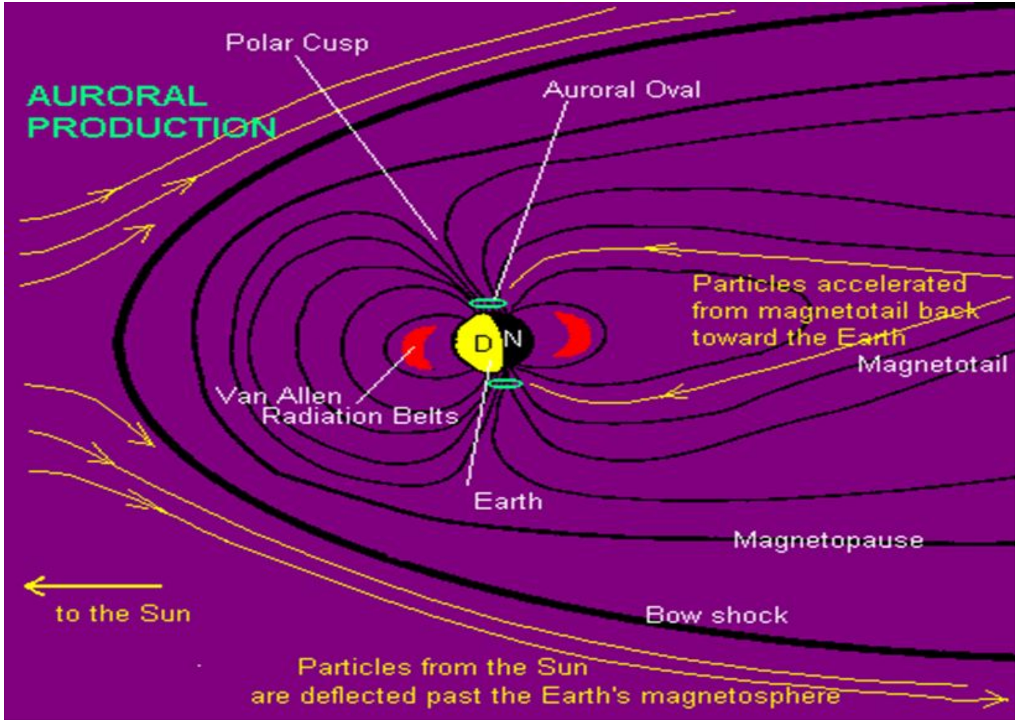
Experiment Goals

Goal: To observe potential electron precipitation.

Particle Precipitation

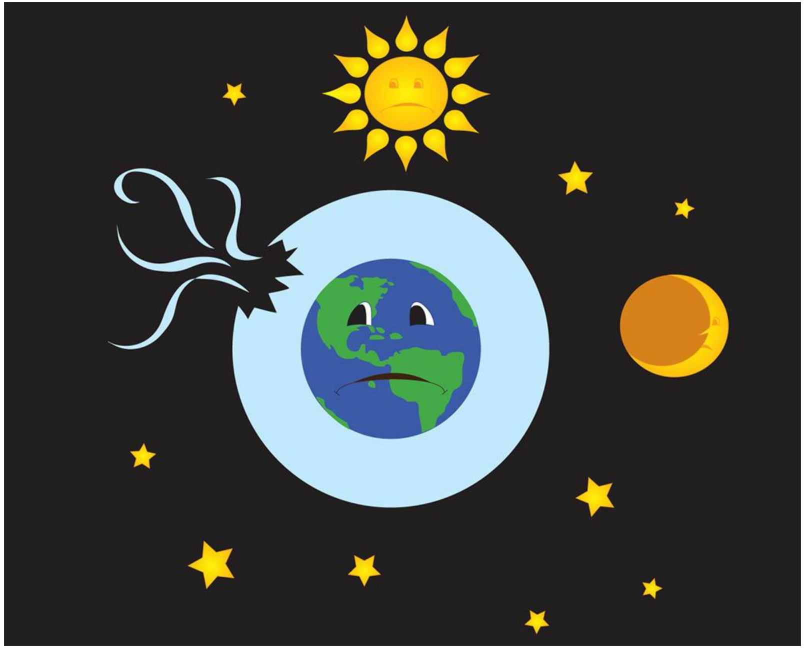
- Energetic particles precipitate into Earth's ionosphere when they enter the magnetosphere's loss cone.

- One common mechanism for nightside particle precipitation is through magnetic reconnection in the magnetotail.



Effects of the Energetic Particle Precipitation

- **Direct Effects:**
  Highly energetic particles produce NOx directly in the stratosphere. It is estimated that the EPP DE contributes up to 10% of the global annual source of stratospheric odd nitrogen.
- **Indirect Effects:**
  Occurs when low and medium energy particles produce NOx in the mesosphere and lower thermosphere. EPP-NOx can lead to the destruction of O3.

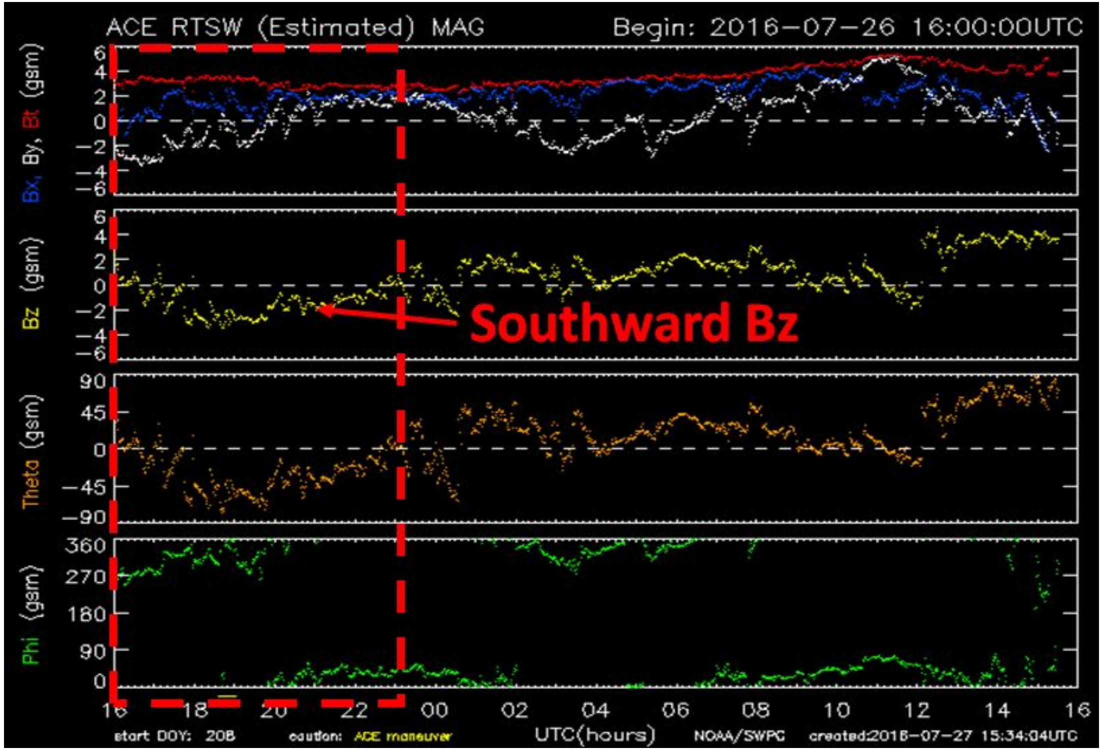


Geomagnetic Substorm

- A southward facing Bz component in the IMF allows a coupling between the solar wind and Earth's magnetosphere.

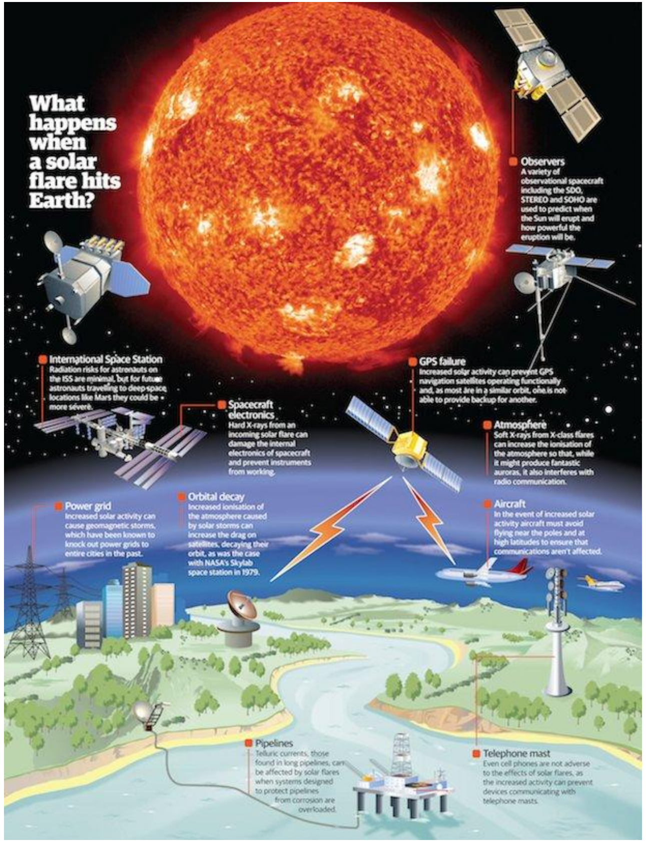
- Through this coupling the solar wind transfers energy to the magnetotail which can lead to reconnection in the tail.
- This initiates a substorm leading to particle precipitation in the ionosphere.

ACE Satellite Data



Effects of Space Weather on Earth

- International Space Station
- Spacecraft electronics
- Power grid
- Orbital decay
- GPS failure
- Atmosphere
- Aircraft
- Observers
- HF communications
- International shortwave broadcast

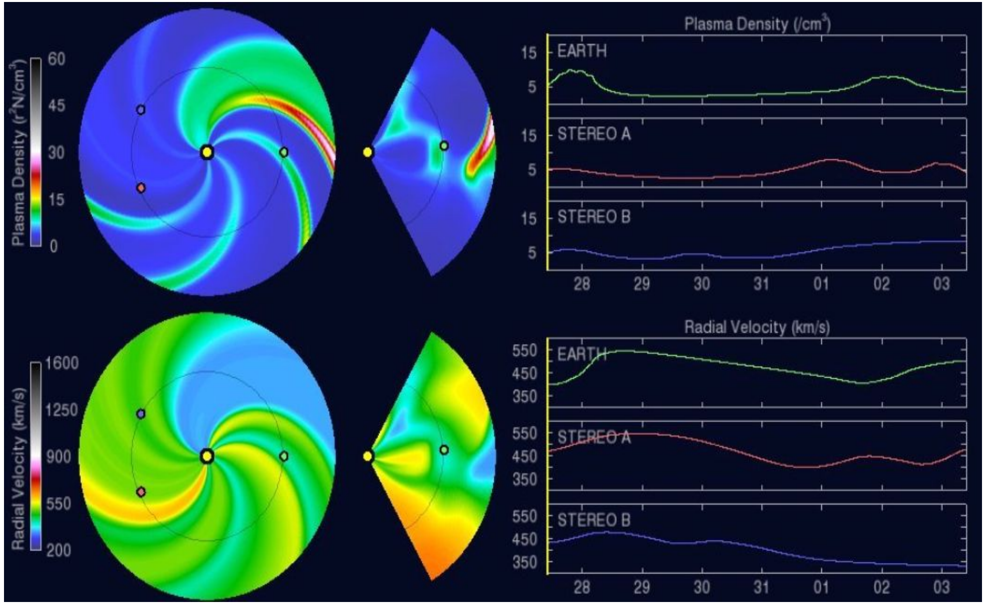


Importance of GPS

- Radar synchronization
- Automated vehicles
- Cartography
- Mobile communications
- General clock synchronization
- Disaster/Emergency services
- Tracking systems
- Aircraft tracking
- Mining
- Navigation
- Tectonics
- Power Grids

Precipitation Forecasting

- The Space Weather Forecast Office uses models to give 1-4 day advance warning of solar wind.
- A sudden change in solar wind momentum was predicted for 23:00 UTC on July 26th.

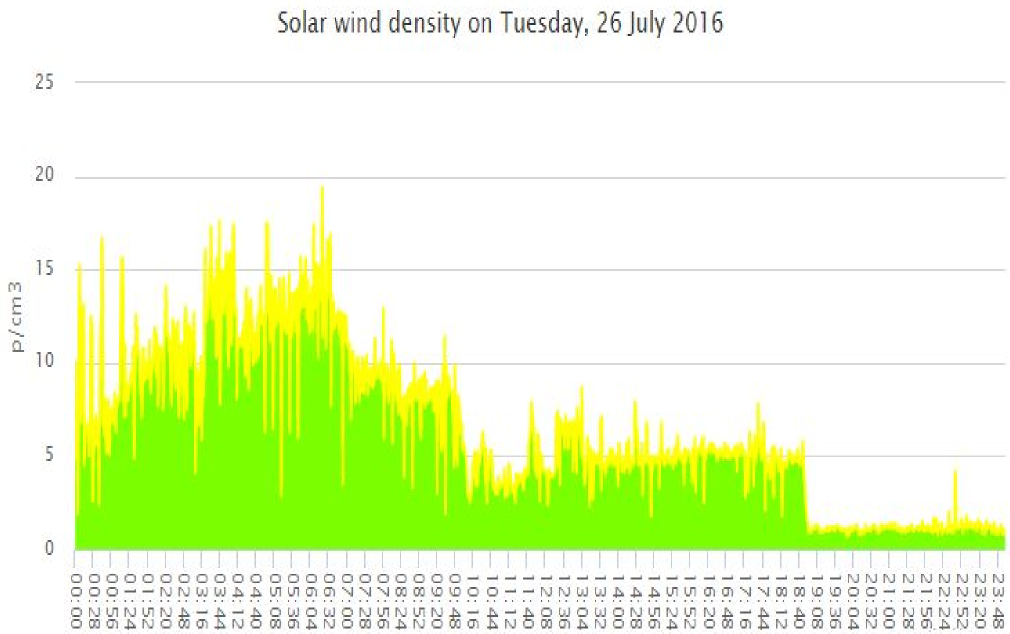


Shock in Solar Wind

- A sudden drop in solar wind density was observed ~2 hours prior to our observations.

- Adjusting for solar wind time of flight and dayside to nightside convection this new solar wind front should temporally align with our measurements.

- This observation confirms the predictions made by the Space Weather Forecast Office.



Experiment Setup

Location: Tromso, Norway

Radar: EISCAT Tromso VHF IS Radar

Pointing: Zenith 90

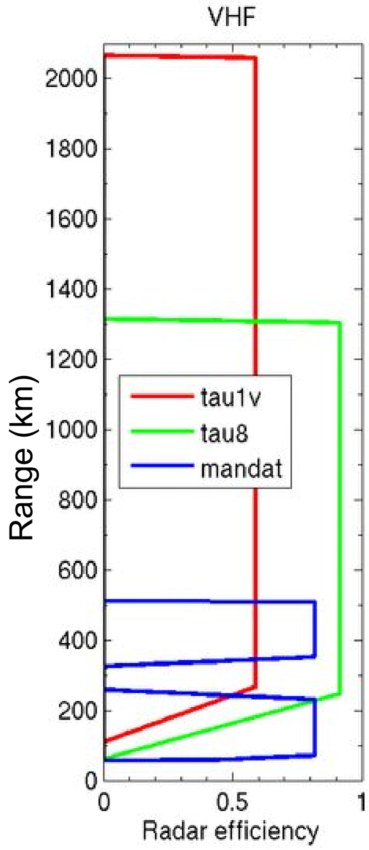
Pulse Pattern: Manda

Observation Time:
2016-07-26 20:37-22:29

Instrumentation: Engineering Facts

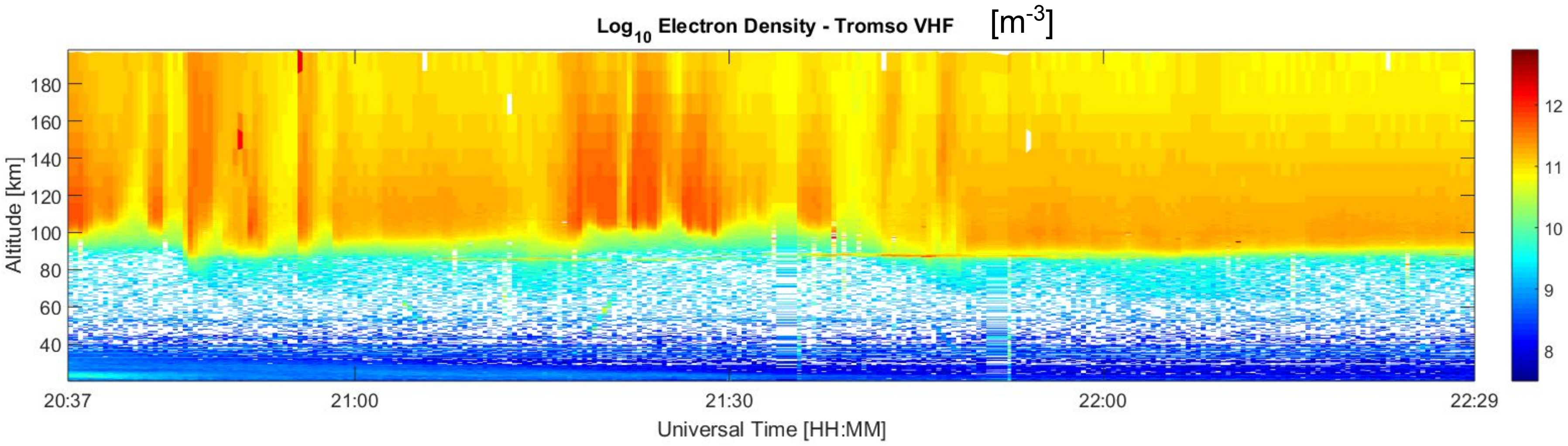
The MANDA sequence was selected for our experiment as it is designed for high elevation observation of the D (EF) region with high temporal resolution:

Pulses:	61 bit, 128 subcycles, alternating code
Sampling rate:	1.2 /µs
Range:	19 - 209 km
Time resolution:	4.8 s



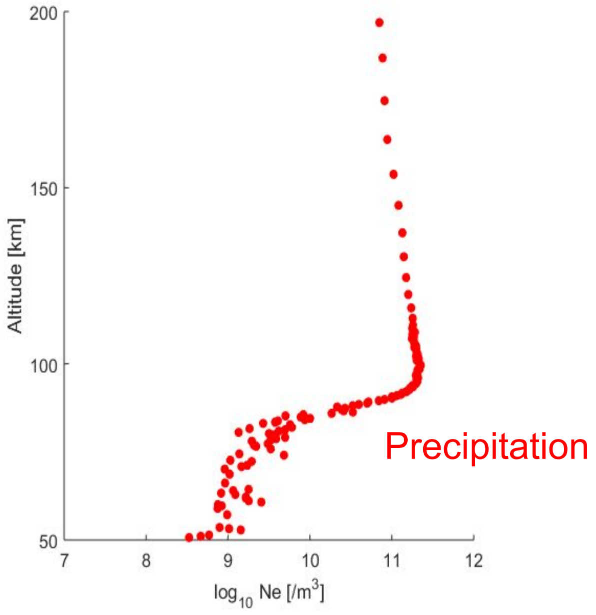
Experiment Observations

Precipitation observed using the Tromso VHF Radar

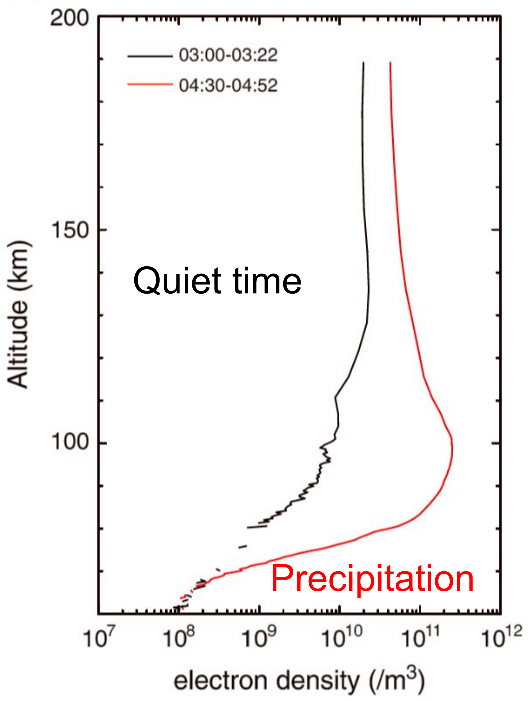


Particle Precipitation Energy Spectrum

Our measurement on
26 Jul 2016 22:06 UT

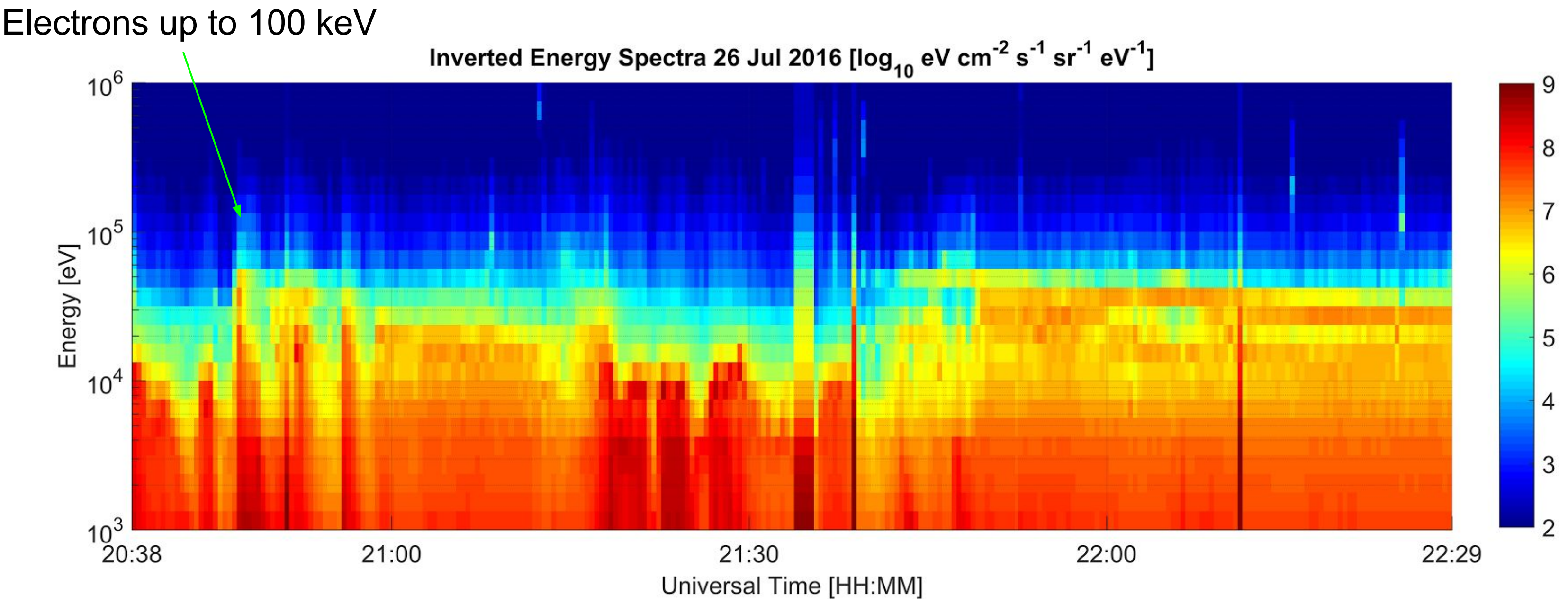


Miyoshi et al 2015
17 Nov 2012



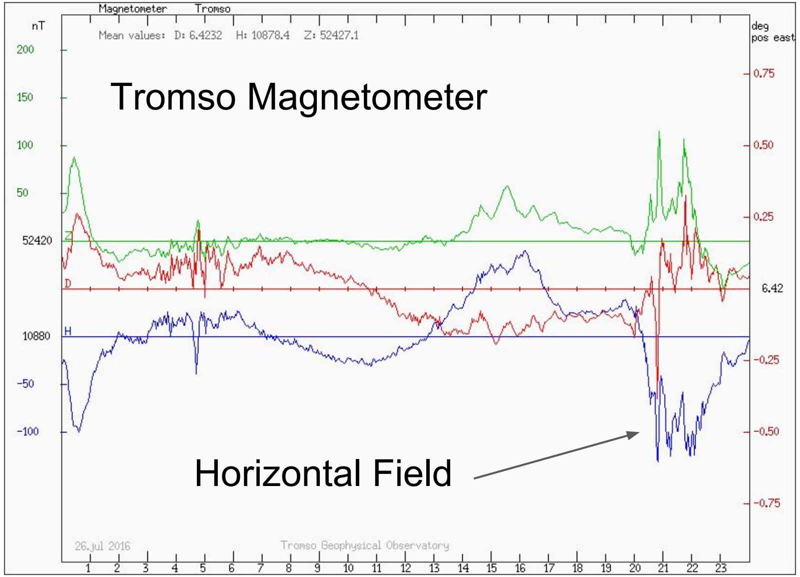
Particle Precipitation Energy Spectrum

- Color plot shows the estimated energy spectra of precipitating electrons
- Visible aurora generated by electrons of few keVs

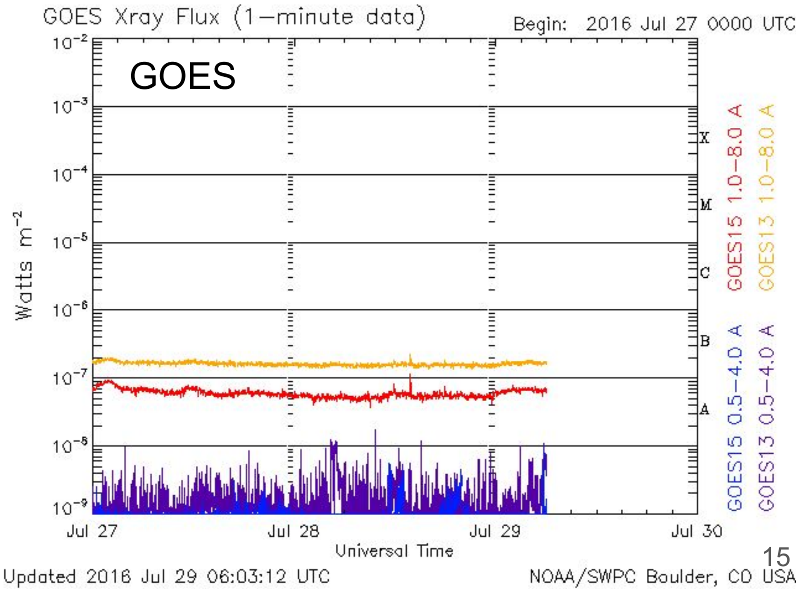


Magnetometer Evidence of Precipitation

Tromso magnetometer indicating abrupt change especially at high latitude stations (approx. 150 nT/10 minutes due to precipitation).



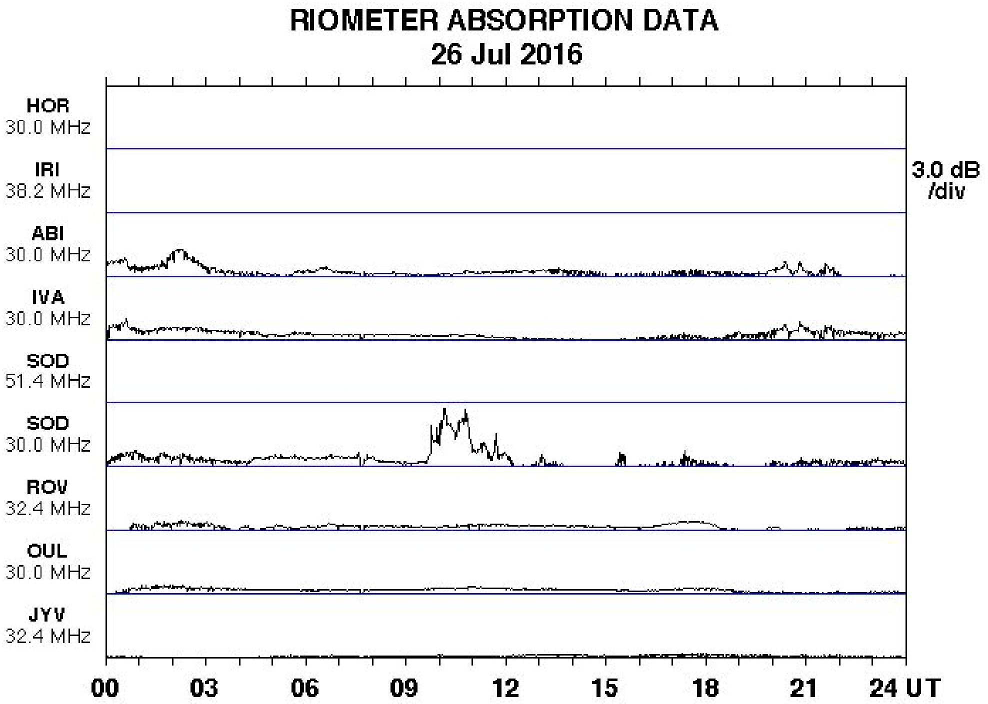
No solar x-ray event in GOES data



Riometer evidence

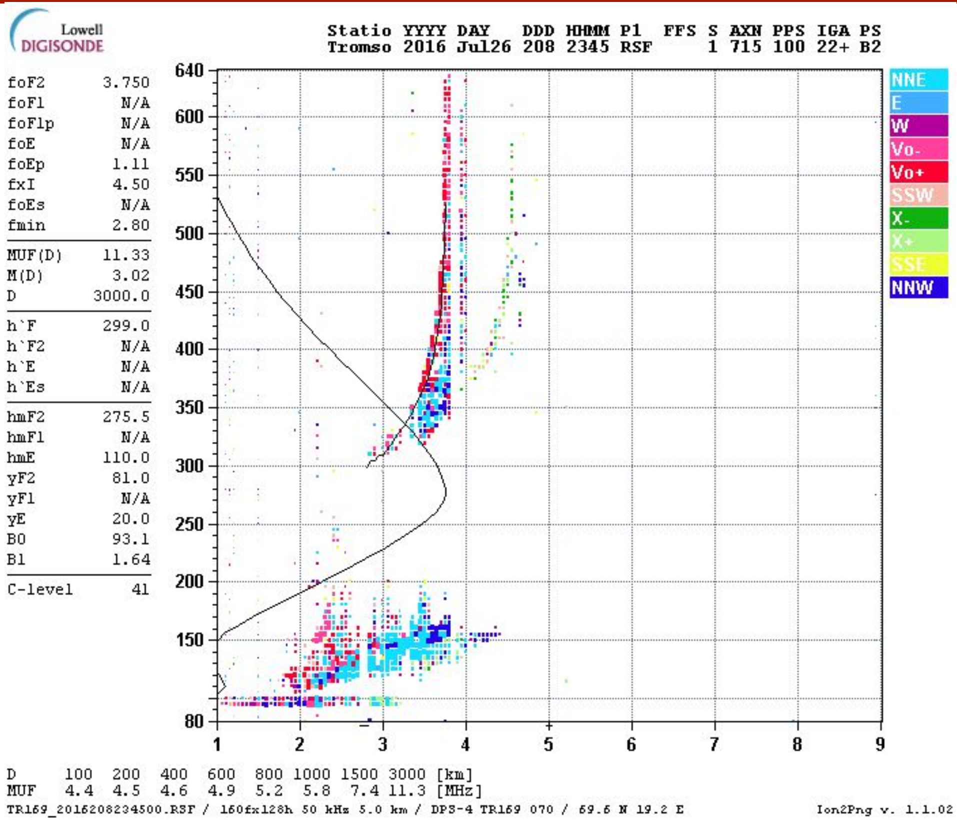
High-latitude Riometers at particularly at Abisko (30.0 MHz) and Ivalo (29.9 MHz) indicated an absorption of approximately 0.5 dB indicating ionisation of the D-layer.

Absorption commenced at the very beginning of experiment and lasted through the entire logging session.



Ionosonde evidence

D-layer absorption was also evident from the Tromsö vertical sounding Ionosonde with rapid disappearance E and F layers.



Syowa Antarctica Auroral Activity

2016/07/26 - 20:59’50”

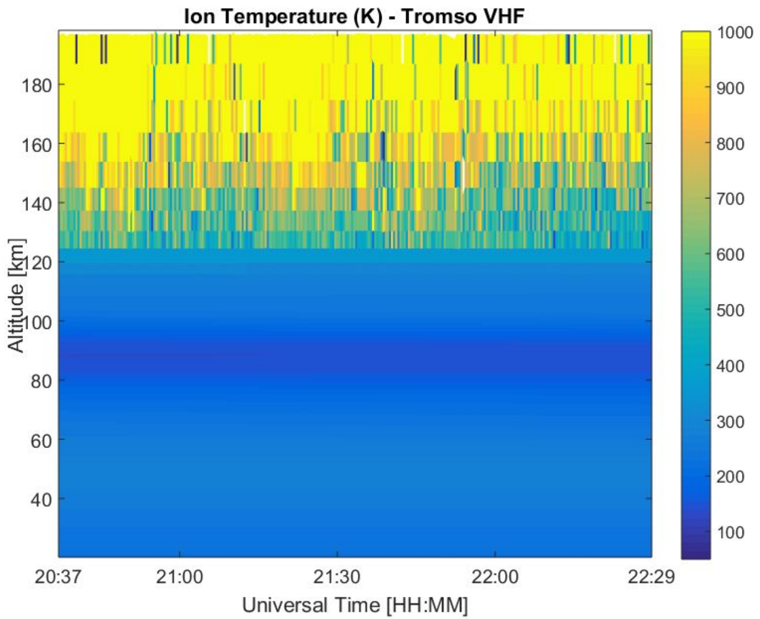
2016/07/26 - 21:15’56”

Syowa Antarctica Auroral Activity

Pulsating Aurora at Syowa towards the later part of experiment (older data unavailable).

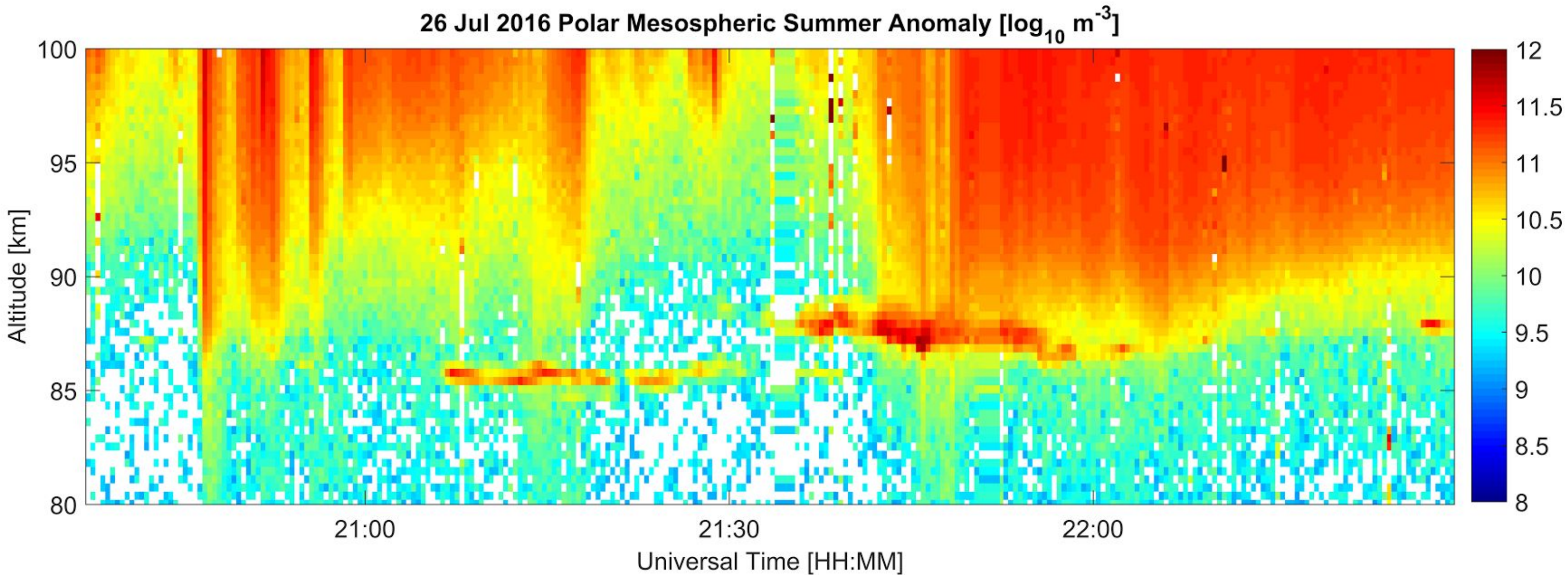
Polar Mesospheric Summer Echoes

The polar 80-90 kilometer region is the coldest place in the earth's atmosphere. Such low temperatures are related to the unique dynamical processes here. The water vapor can form ice particles in this extremely low temperature condition. These ice particles can become charged by electron and ion attachment.

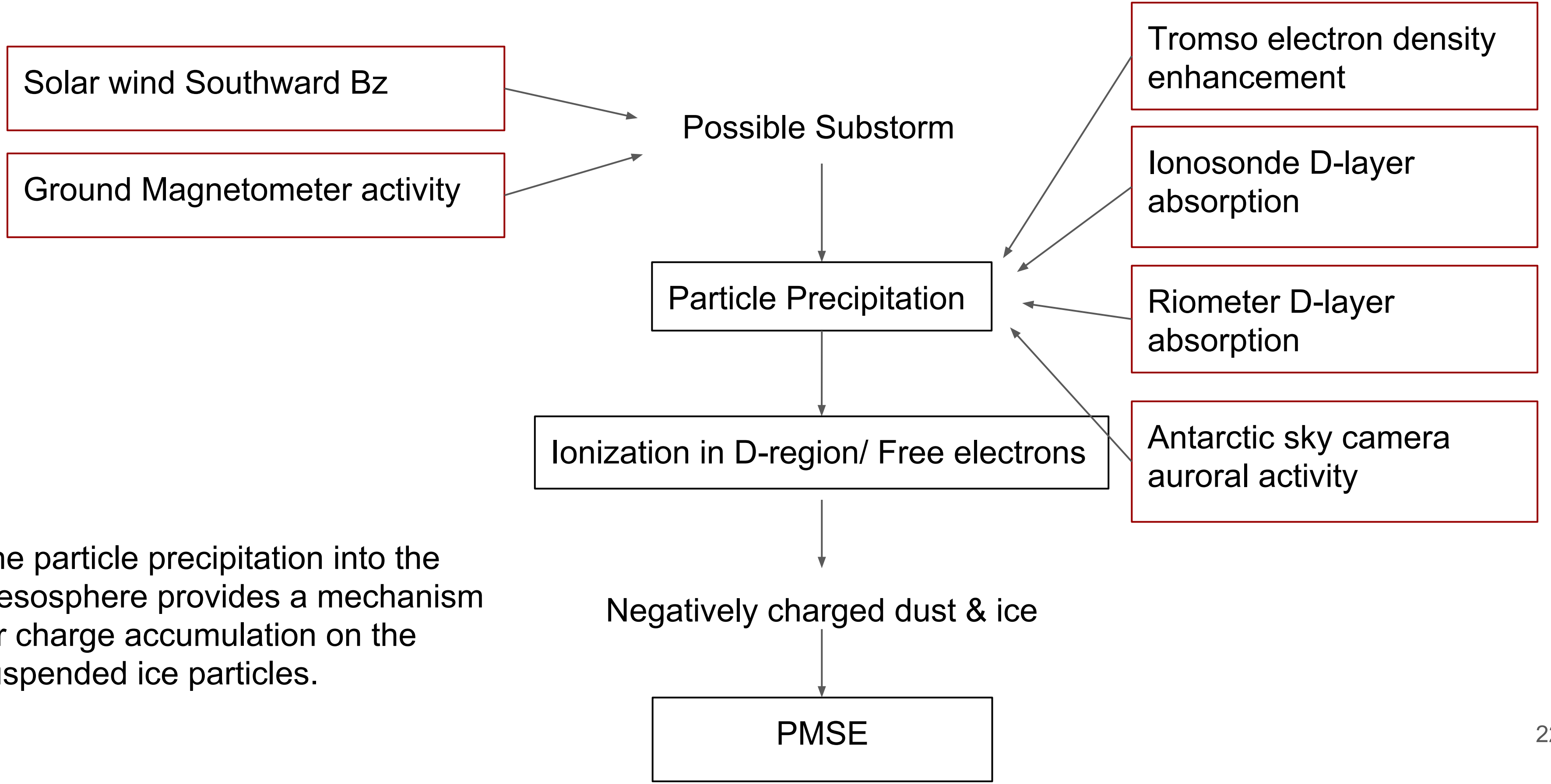


Polar Mesospheric Summer Echoes

PMSE is a strong radar backscatter associated with the charged ice particles in the mesosphere.



Discussion



The particle precipitation into the mesosphere provides a mechanism for charge accumulation on the suspended ice particles.

Conclusions

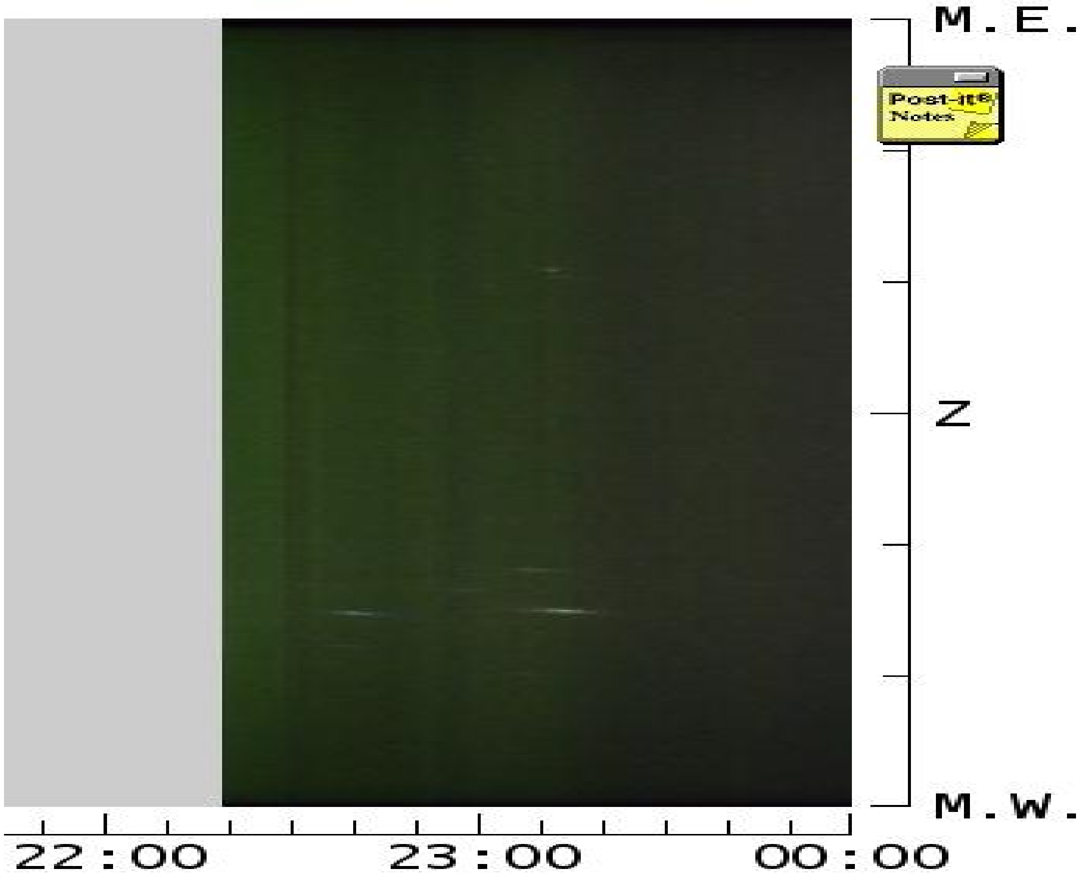
- We observed precipitation event up to 100 keV electrons before midnight UTC

- During this precipitation activity a PMSE event was also observed.

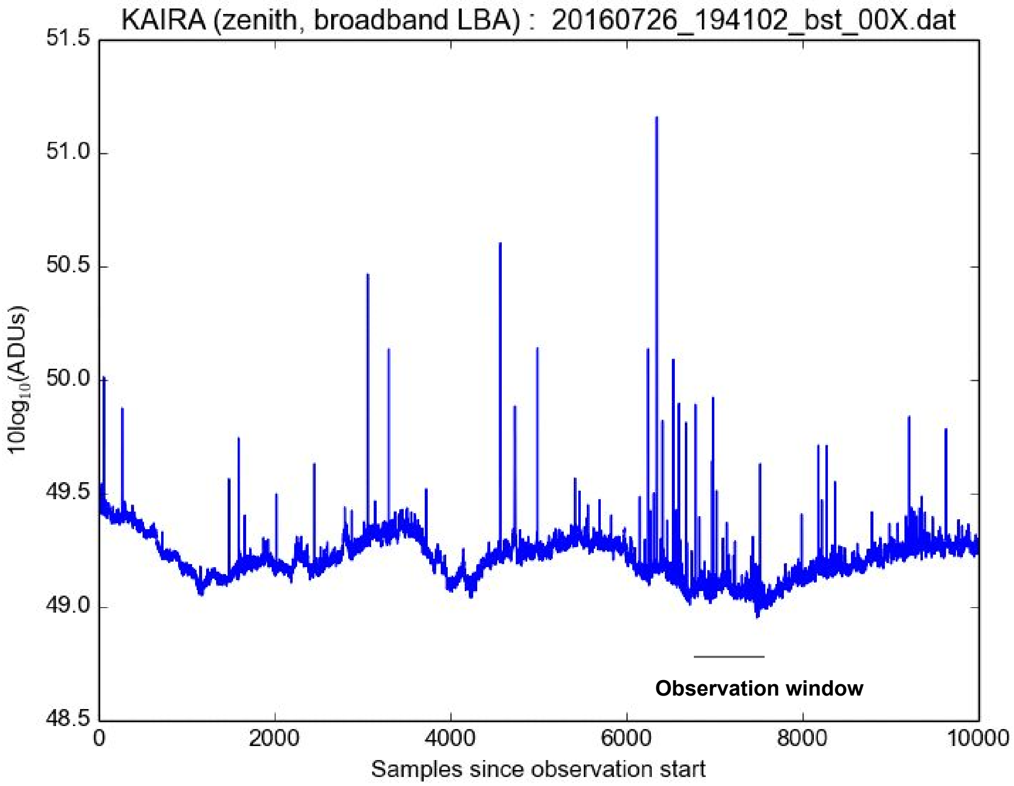
Questions

Syowa Antarctica Auroral Activity

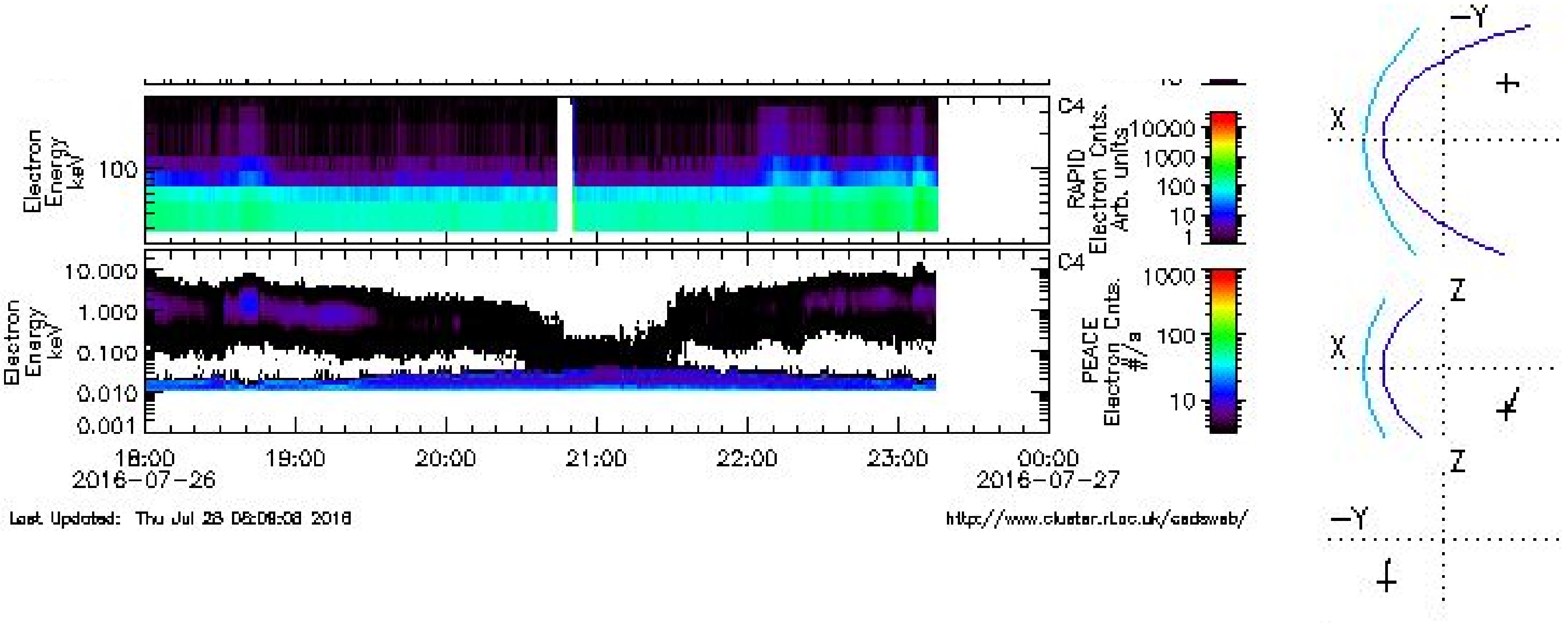
Syowa NW-Keogram indicating Pulsating Aurora



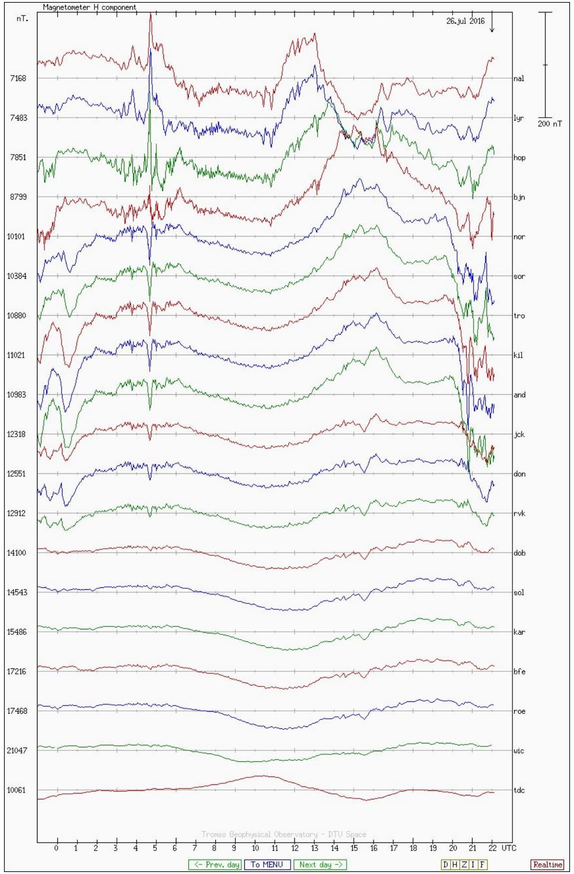
Uncorrected KAIRA Riometer Data



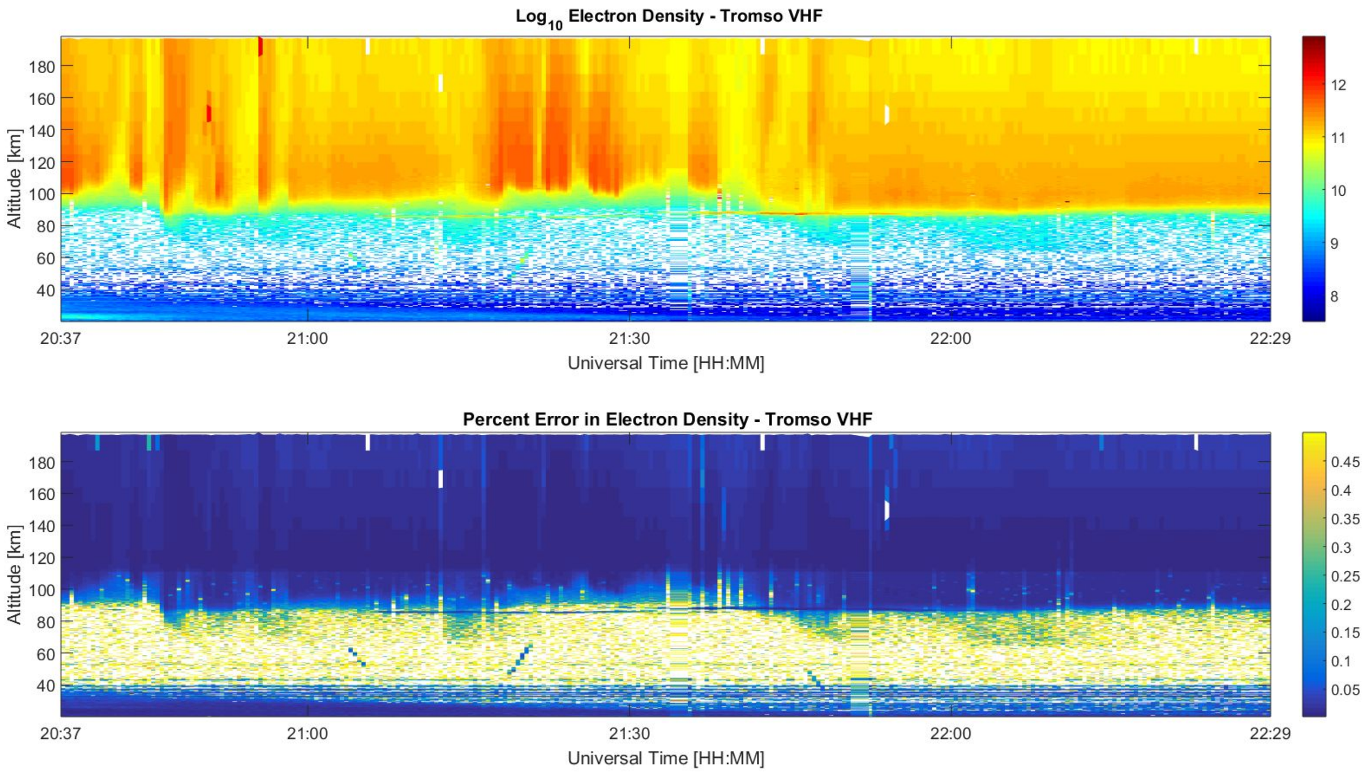
Cluster Satellite Data



Norwegian Magnetometer Chain

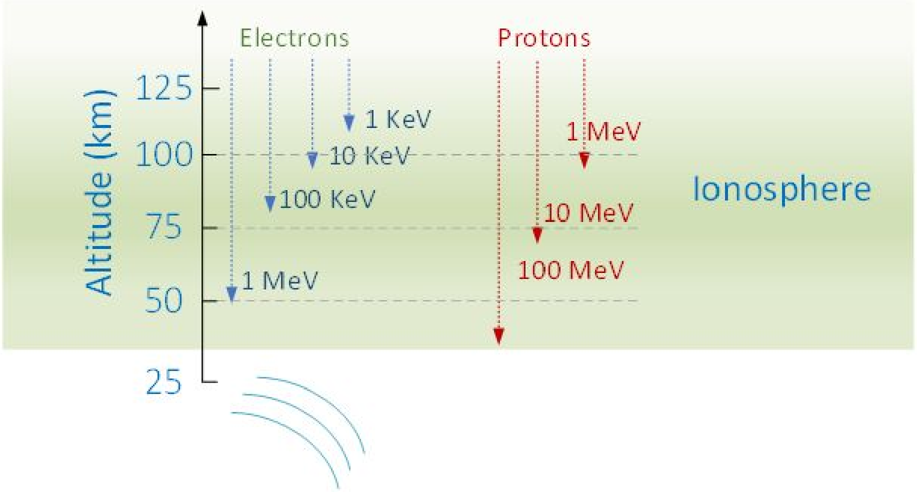


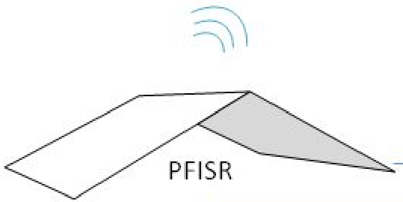
Experiment Observations



Tromsø Technical Characteristics (VHF)

Transmit frequency	222.8 - 225.4 MHz
Peak power	1.6 MW (single klystron)
Max duty cycle	12.5 % (^200 kW avg.)
Pulse length	1 - 2000 μs
Antenna size	120x40m(4 x (30mx40m))
Antenna gain	46 dBi
Antenna beamwidth	Whole antenna 0.6 deg ES, 1.7 deg NS, half antenna 1.2 deg EW, 1.7 NS
System temperature,Tsys	250 - 350 K
Antenna type	Offset parabolic cylinder
Feed system	Feed line
Polarization	Circular





Estimating Energy Spectra (Inversion)

$$\phi(E,t) = inv[A]\underbrace{\left(\frac{dN_e}{dt} + \alpha_{eff}N_e^2\right)}_{q(z,t)}$$

$\phi(E,t)$ Precipitating electron flux

$N_e(z,t)$ Ionosphere Electron density

α_{eff} Effective recombination coefficient

$q(z,t)$ Production rate

$[A]$ Production rate per electron flux

Blue – Model
Green – Measured
Red – Unknown

Altitude profile of ionosphere electron density $N_e(z)$ → Invert $[A]$ → Precipitating electron energy Spectra $\phi(E)$

We can measure precipitating electron energy spectra by inverting altitude profiles of ionosphere electron density.