High latitude precipitation observation using PFISR (Poker Flat Incoherent Scatter Radar)

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[5]University of Southampton

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Section 1

Radar

Site Parameters

- Phased array Incoherent Scatter Radar located at Poker Flat, Alaska
- 65 N, 147 W
- Within the auroral zone (65 M-Lat)

PFISR

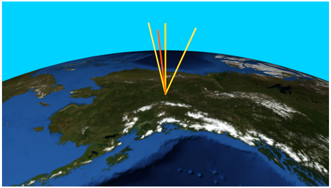
- Beam steering down to 30 $^{\circ}$
- Up to $2MW$ transmit power (500W * 4096 elements)
- 450 MHz
- Volumetric imaging of the ionosphere
- Velocity estimation (plasma AND neutral winds)

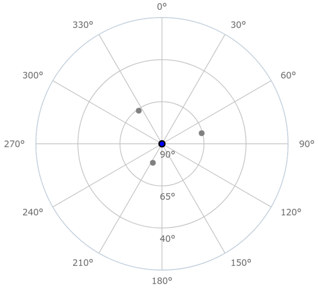
Pulse Mode: MSWinds26, D-region focus, E- and F-region context

- Barker Code
- Alternating Code
- Long Pulse
- 8/1/1 pulse split, respectively

Beams

- Up: 90 ° elev.
- Up-B: -154.3 ° az., 77.5 ° elev.
- ENE: -34.7 ° az., 66.1 ° elev.
- NNW: 75.0 ° az., 65.6 ° elev.

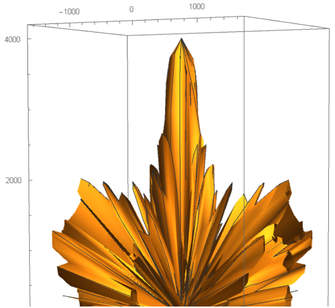




Barker Code: Most Sensitive Mode

- Sidelobe level -22.3 dB
- + + + + + - - + + - + - +
- Used to generate uncorrected electron density profile

Directivity Pattern



Section 2

Ionosphere

Neutral atmosphere

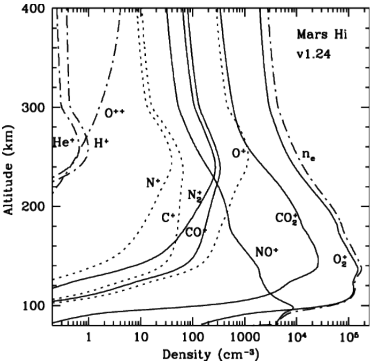
- Gravitational equilibrium
- Heavy molecules at low altitudes
- Light Atoms at high altitudes

Solar radiation heating the upper atmosphere

- Neutral ionization
- ion-electron pair creation

Ionosphere formation !

Atmosphere and ionosphere profile



Dawn ionosphere

Continuity equation :

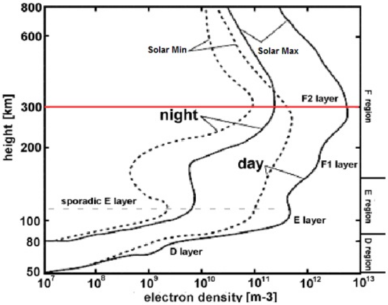
$$\frac{\partial n_{i,e}}{\partial t} + \nabla(\vec{u_{i,e}} n_{i,e}) = P_{i,e} - L_{i,e} \quad (1)$$

Chemical equilibrium

$$P_{i,e} - L_{i,e} = 0 \quad (2)$$

Dawn = No / Little Production
Expect Low electron density

Electron density profile



Energetic particle coming from the Sun

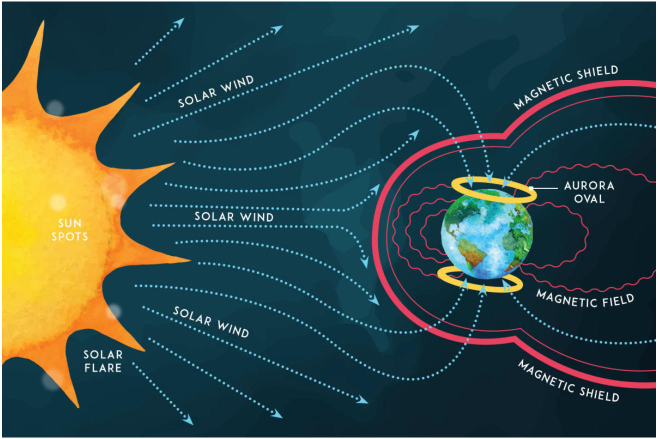


Figure: Magnetosphere-ionosphere coupling

Precipitation

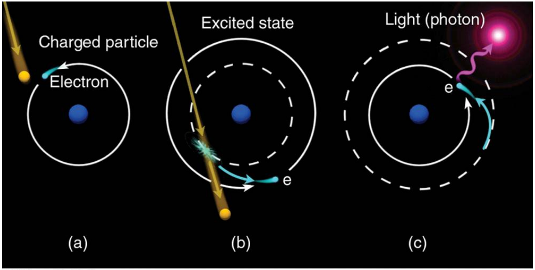


Figure: Neutral ionization through collision with energetic particles

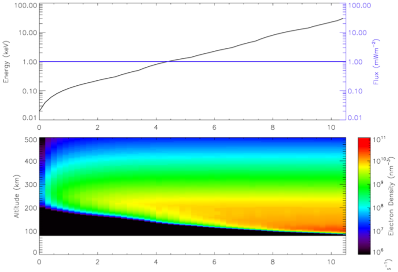
Each incident particles carry E eV (few keV)
Each particles create $\frac{E}{\Delta E}$ electron-ion pair ($\Delta E \approx 10$ eV)
If sufficient incident particles = enhanced electron density observable

Precipitation I

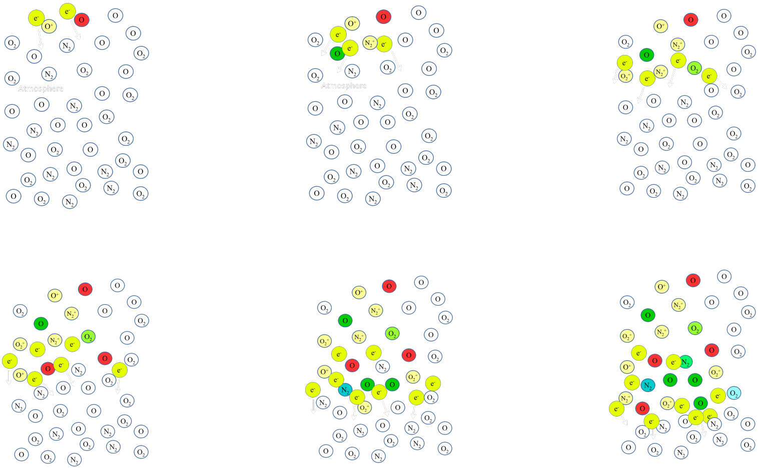
Higher energy particles penetrate further into the atmosphere

Electron density peak altitude descends as characteristic energy increases

This process can be modeled using electron transport and ion chemistry models



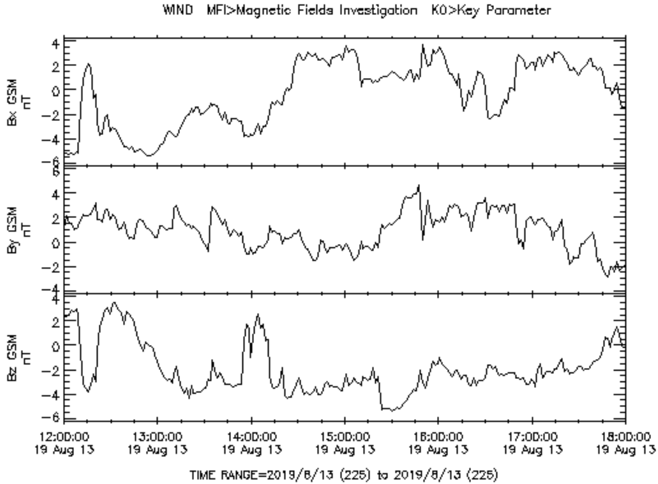
Precipitation II



Section 3

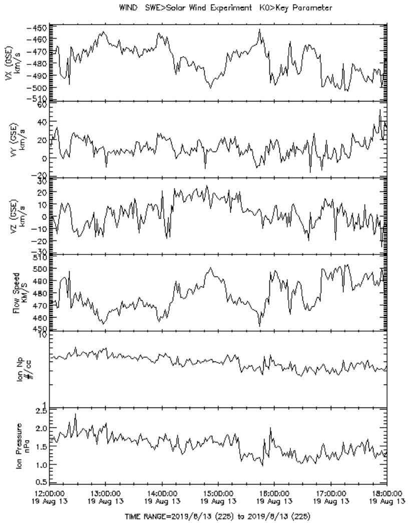
Geomagnetic Conditions

Solar Wind (IMF)



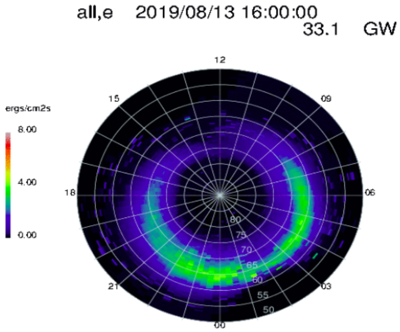
Please acknowledge data provider, R. Lepping at NASA/GSFC and CDAWeb when using these data.
Key Parameter and Survey data (labels K0,K1,K2) are preliminary browse data.

Solar Wind (Plasma)



- SW Flow speeds vary in magnitude by $\sim 50km/s$
- Pressure fluctuations are close to $1nPa$

Ovation Auroral Prediction



- AA-CGM derived MLTs for PFISR (16-18 UT): 4.5-6.9 MLT
- Ovation predicts slight electron flux enhancements in the local sector

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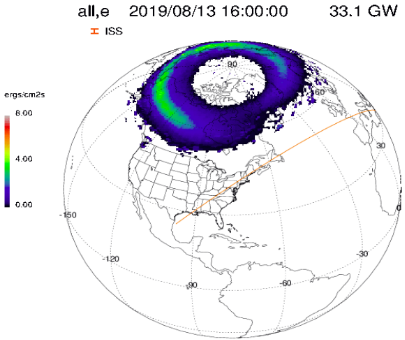

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Orbits

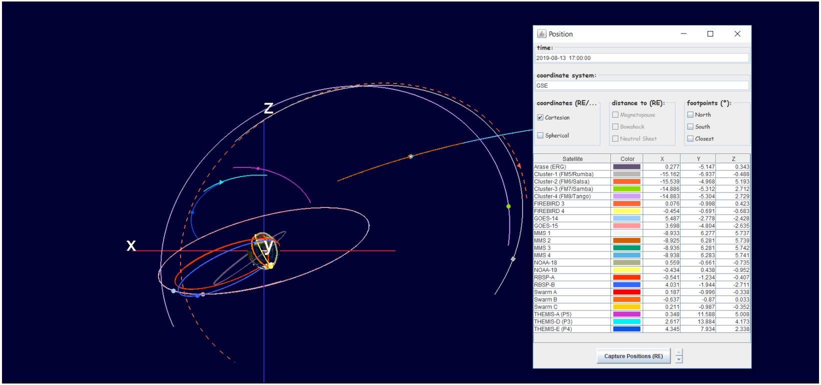
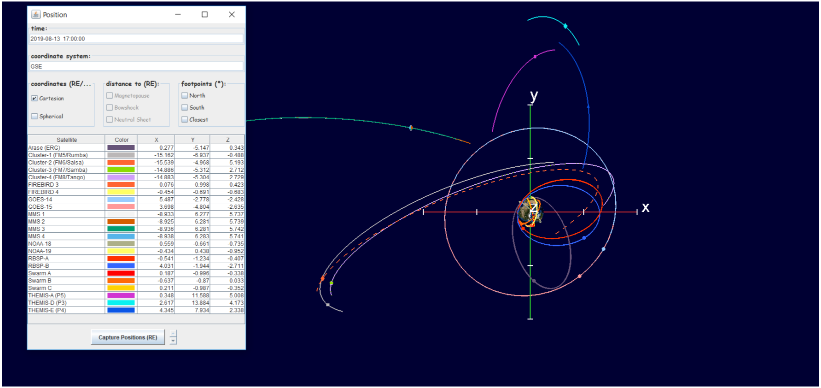


Figure: Orbits for selected satellite missions

Orbits



Satellite	Color	X	Y	Z
Arase (ERG)		0.277	-5.147	0.343
Cluster-1 (FM5/Rumba)		-15.162	-6.937	-0.488
Cluster-2 (FM6/Salsa)		-15.539	-4.968	5.193
Cluster-3 (FM7/Samba)		-14.886	-5.312	2.712
Cluster-4 (FM8/Tango)		-14.883	-5.304	2.729
FIREBIRD 3		0.076	-0.998	0.423
FIREBIRD 4		-0.454	-0.691	-0.683
GOES-14		5.487	-2.778	-2.428
GOES-15		3.698	-4.804	-2.635
MMS 1		-8.933	6.277	5.737
MMS 2		-8.925	6.281	5.739
MMS 3		-8.936	6.281	5.742
MMS 4		-8.938	6.283	5.741
NOAA-18		0.559	-0.661	-0.735
NOAA-19		-0.434	0.438	-0.952
RBSP-A		-0.541	-1.234	-0.407
RBSP-B		4.031	-1.944	-2.711
Swarm A		0.187	-0.996	-0.338
Swarm B		-0.637	-0.87	0.033
Swarm C		0.211	-0.987	-0.352
THEMIS-A (P5)		0.348	11.588	5.008
THEMIS-D (P3)		2.617	13.884	4.173
THEMIS-E (P4)		4.345	7.934	2.338

Figure: Orbits for selected satellite missions

Section 4

Observations

Precipitation Observations

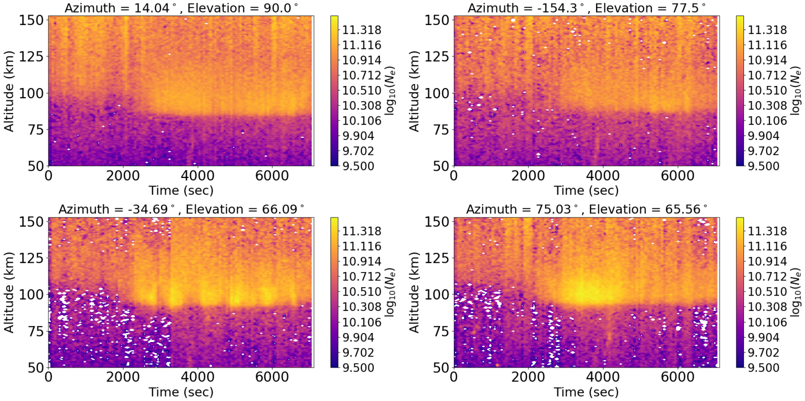


Figure: Electron Density Plots

Tromsø

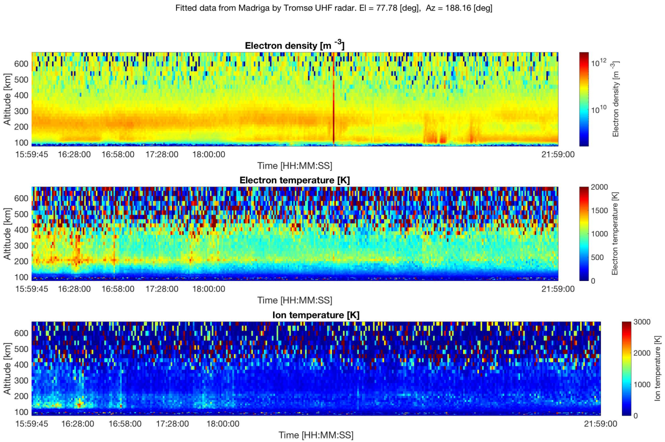


Figure: Ionosphere observation at Tromsø

ULF Waves

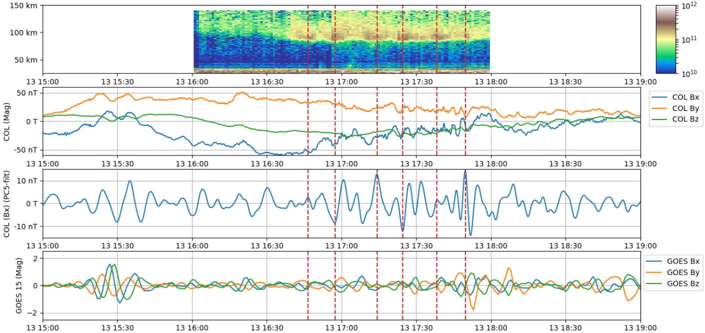
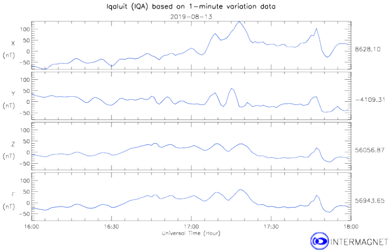
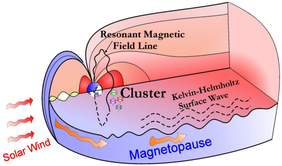


Figure: ULF waves in the PC5 range ($\sim 1.6mHz / \sim 10min$) modulating precipitation seen in the Northward facing beam of PFISR.

Global ULF Observations





- ULF waves are observed in ground magnetic response at MLTs across North America.
- Long period PC5 waves are often the result of pressure fluctuations in SW
- Day side PC5 waves could be cavity mode resonances (standing fast mode waves), or KHI generated TCVs

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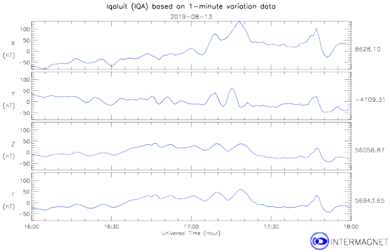

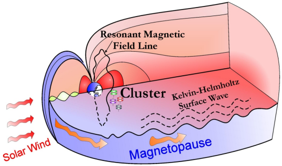

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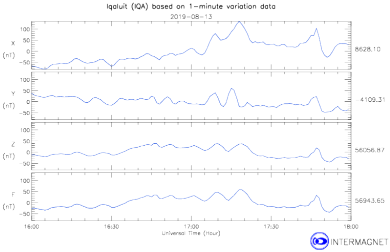

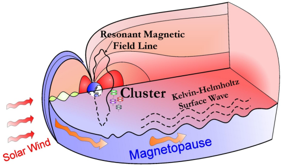

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THEMIS

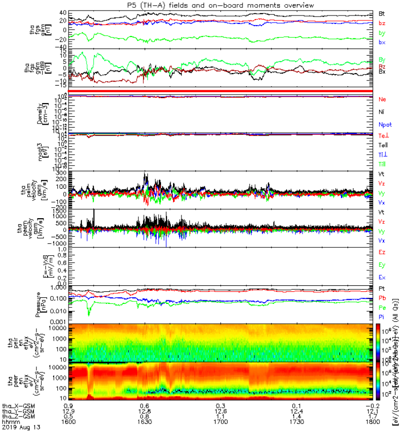

Figure: THEMIS

- THEMIS (A,D,E) are located on the dusk side, with THE closest towards noon
- Slight enhancements in plasma pressure and electron/ion energy flux occur coincidentally with dayside ULF wave events (seen in THE)

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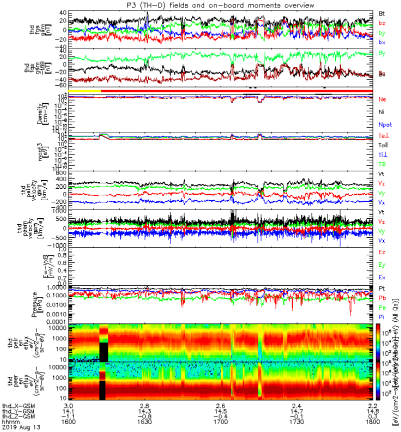

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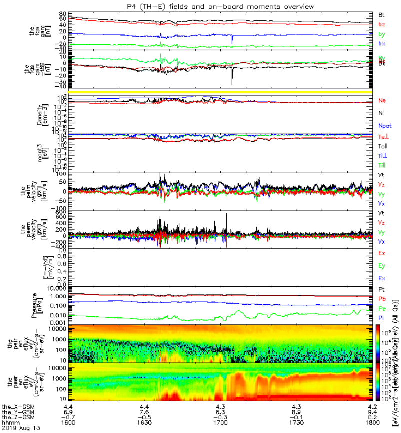

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Electron Energy and Flux

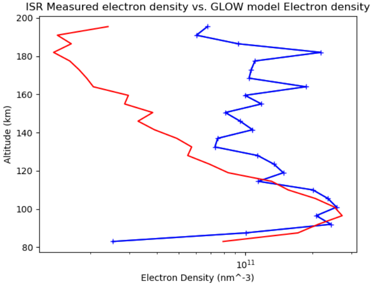

Figure: Foward modeled electron density profile. Measured (blue), Modeled (red).

- Can infer precipitation characteristics from N_e profile inversion (alternating code, 10min integration, field-aligned!)
- Use a forward model of electron transport, ionisation and recombination.
- In this case used a simple version of the GLOW model, with only NO^+ and O_2^+ ions (abundent in E-region)
- Best fit parameters: $E_0 = 11.1$ keV, $F_0 = 6.8$ mW/m^2

Section 5

Conclusion

Summary

- D/E/F observations of the ionosphere via MSWinds26.v03 mode at PFISR
- Looking for precipitation event
- Found a precipitation event
- Also found ULF wave density modulation!
- Evidence of cavity mode resonance? Magnetopause KHI?
- Inferred precipitation characteristics from electron density profiles
- Further opportunity for study (Arase, DMSP, Ground Mags)

It's Over!

Questions?