I-T-M Research In Canada and Opportunities for Swarm

D. Knudsen and the Canadian EFI Science Team

Athabasca University

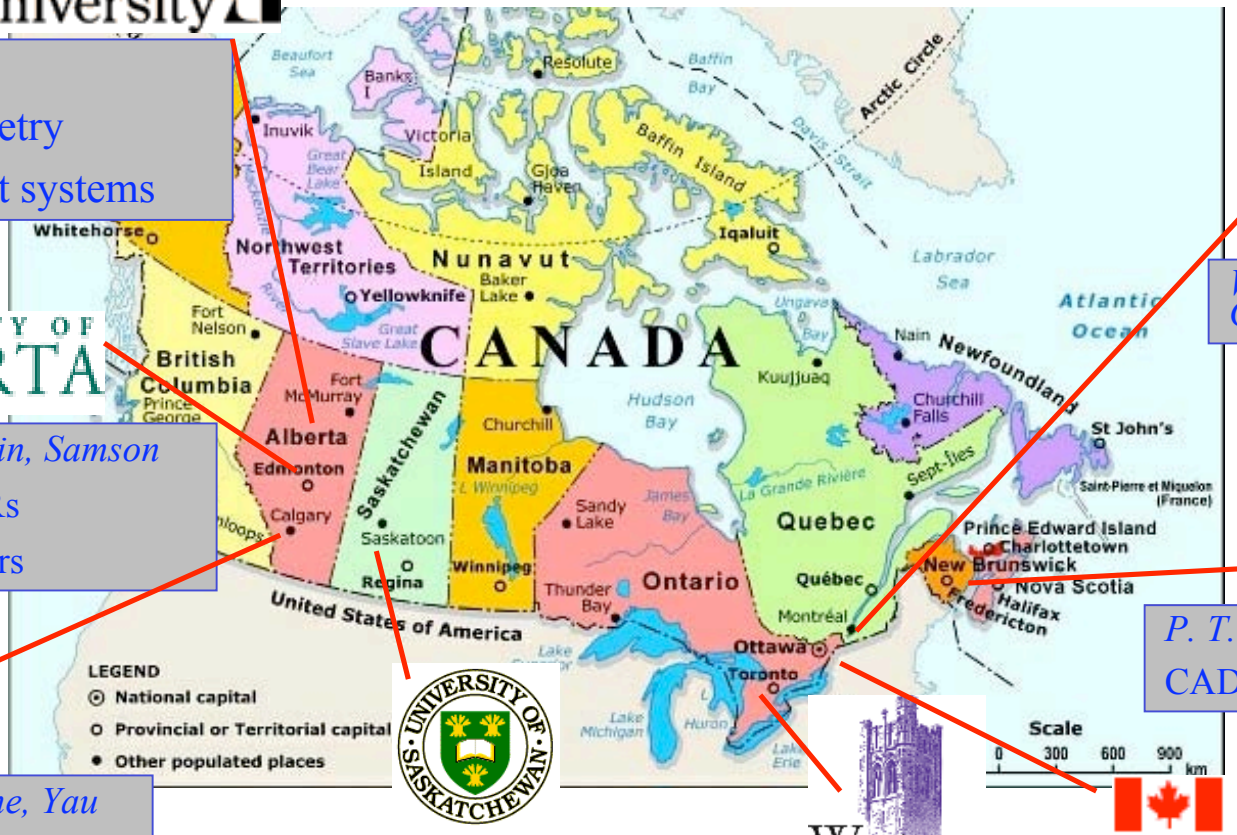
Conners
Ground magnetometry
Ionospheric current systems

UNIVERSITY OF ALBERTA

Fenrich, Mann, Rankin, Samson
MHD Modeling, FLRs
CGSM Magnetometers

UNIVERSITY OF CALGARY

Donovan, Knudsen, Skone, Yau
Space Flight Instrumentation
Ground-based Optics
GPS/GNSS



CSA ASC

W. Liu, J. Manuel, G. Gratton

UNB

P. T. Jayachandran
CADI Ionosondes

UNIVERSITY OF SASKATCHEWAN

Hussey, Kustov, McWilliams, Sofko, St. Maurice
SuperDARN and ISR Radars

Western

MacDougall
CADI Ionosondes

Natural Resources Canada

Boteler, Newitt
Space Weather, Regional modeling

Swarm Mission Science Objectives

Primary

- Core Dynamics and Geodynamo Processes
- Lithospheric Magnetisation
- 3-D Electrical Conductivity of the Mantle
- Magnetospheric and Ionospheric Current Systems

Must remove ionospheric δB

Secondary

- Ocean Circulation and its Magnetic Signature
- Magnetic Forcing of the Upper Atmosphere

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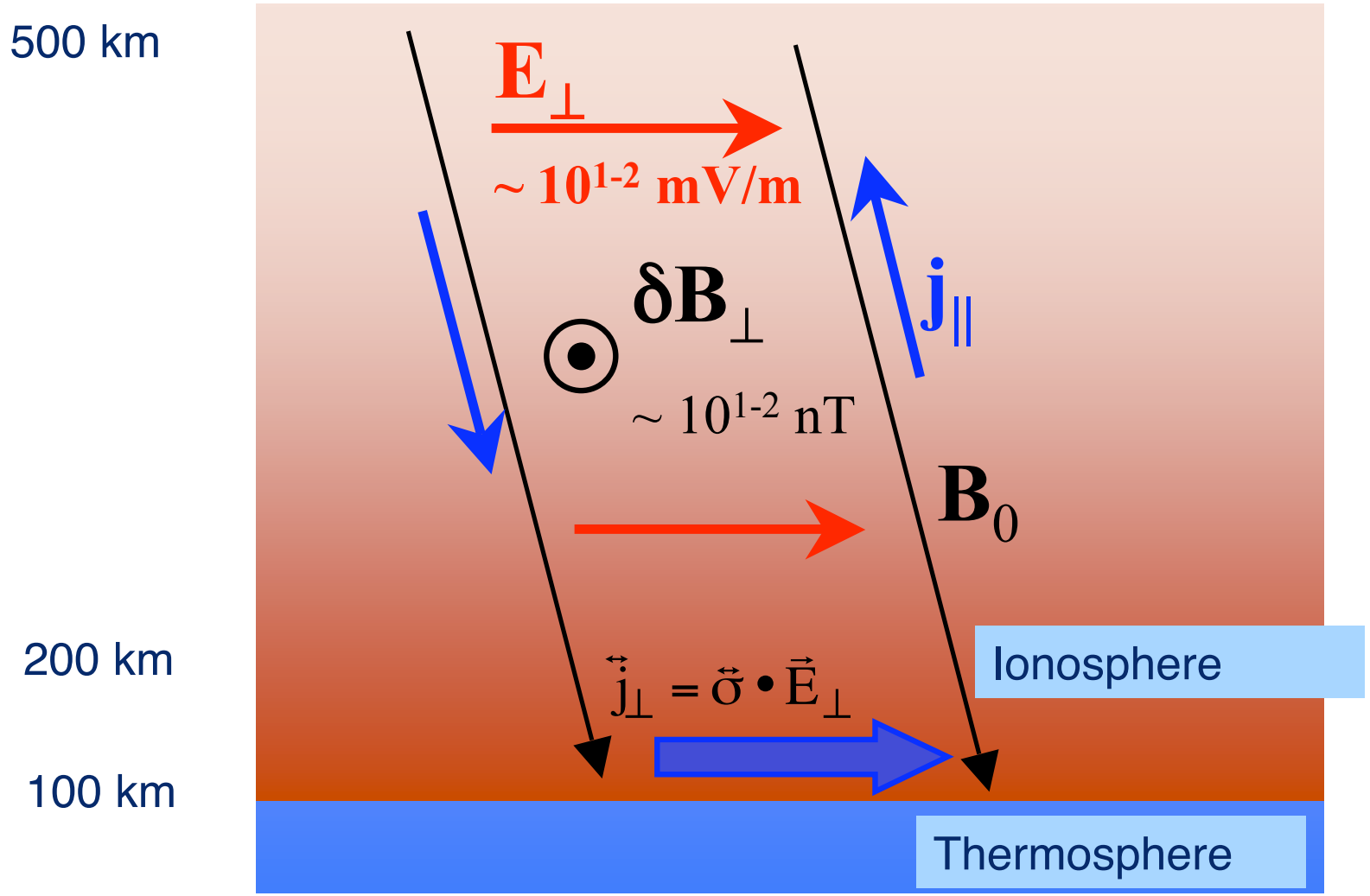
"One man's noise is another man's signal"

Ionospheric Current Systems



Relation Between **E** and **B** in the Ionosphere

$$\nabla x\vec{B} = \mu_0\vec{J} = \mu_0\vec{\vec{\sigma}} \bullet \vec{E}$$

$$\vec{\vec{\sigma}} = \begin{pmatrix} \sigma_p & \sigma_h & 0 \\ -\sigma_h & \sigma_p & 0 \\ 0 & 0 & \sigma_0 \end{pmatrix}$$

1-D:

$$j_x = \sigma_p E_x \qquad (1)$$

$$\nabla \bullet \vec{J} = 0 : \frac{\partial}{\partial x} j_x = -\frac{\partial}{\partial z} j_z \qquad (2)$$

$$\frac{1}{\mu_0}\frac{\partial}{\partial x}\delta B_y = j_z = -\frac{\partial}{\partial x}\int \sigma_P E_x dz \qquad (3)$$

$$\frac{\delta B_y}{\mu_0 E_x} = \int \sigma_p dz \qquad (4)$$

$$\frac{\mu_0 E_x}{\delta B_y} = \Sigma_p^{-1}$$

Sugiura [GRL, 877, 1984]

Relation Between **E** and **B** in the Ionosphere

$$\frac{\mu_0 E_x}{\delta B_y} = \Sigma_p^{-1}$$

Some exceptions:

1) Non-uniform **σ**

2) f > 0.1 Hz [*Knudsen et al., JGR*, p77, 1992]

3) $\boldsymbol{\lambda_\perp}$ **< ~2 km** [*Forget et al., JGR*, p1843, 1991]

Ways to estimate Σ_p:

1) Models for $\sigma(n_e, \nu, m_i, \mathbf{B})$
   - solar illumination
   - precipitation
   - collision frequencies
2) Incoherent-scatter radars + models
3) Ground-based cameras + models

Canadian GeoSpace Monitoring - CGSM

Ground-based observations of ionospheric electrodynamics

CGSM

10	Fluxgates (*Alberta*)
8	Induction Coils (*Alberta*)
26	Riometers (*Calgary*)
4	MSPs (*Calgary*)
10	ASIs (*Calgary*)
3-4	HF Radars (*Saskatchwan*)
6-8	CADIs (*Western Ontario*)

F10.7 Solar Flux Monitor (*NRC*)

FDAM/SSDP (*Alberta*)

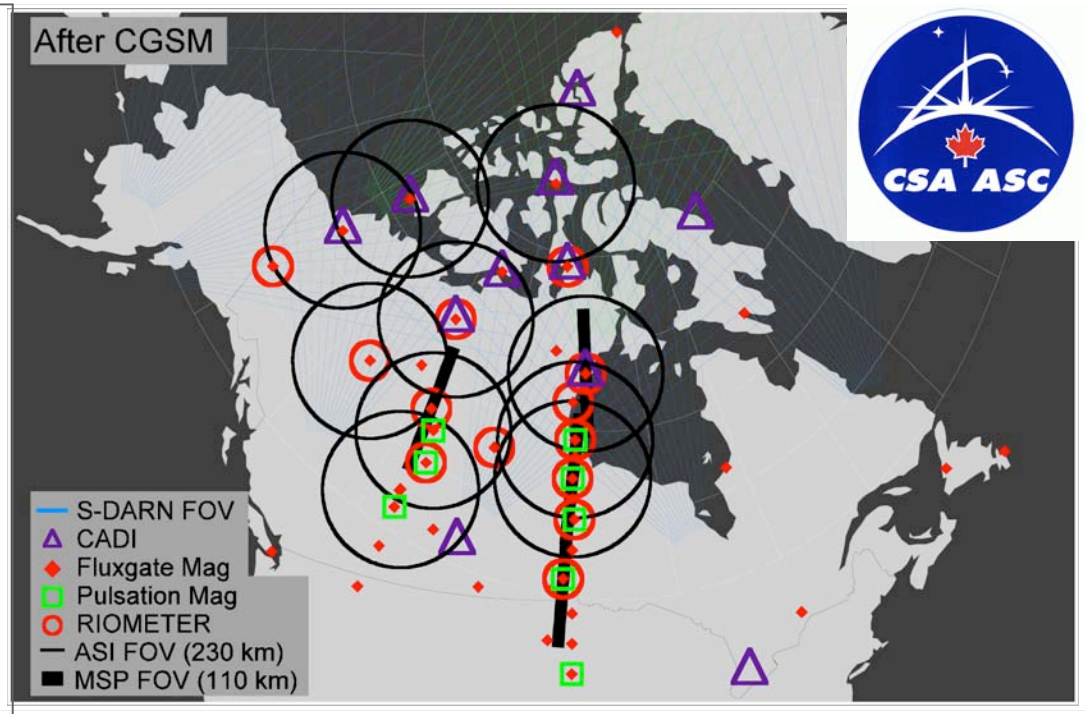
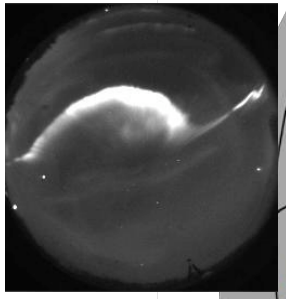
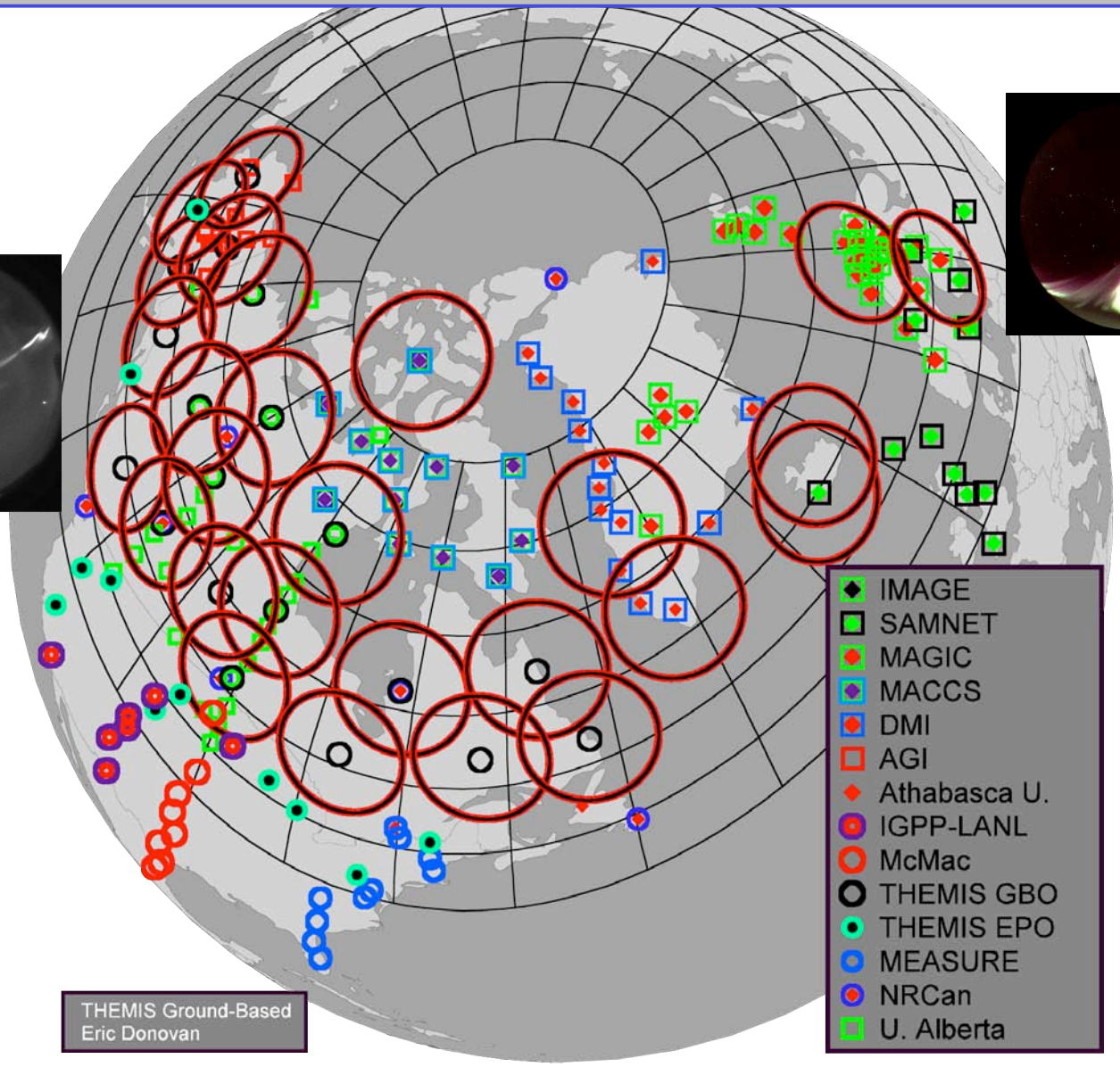


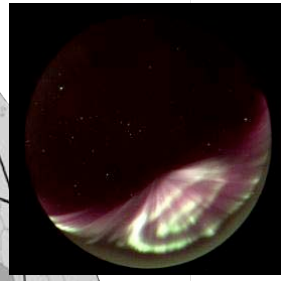
Figure: Eric Donovan

Ground-based networks relevant to Swarm



UC Berkeley
U Calgary

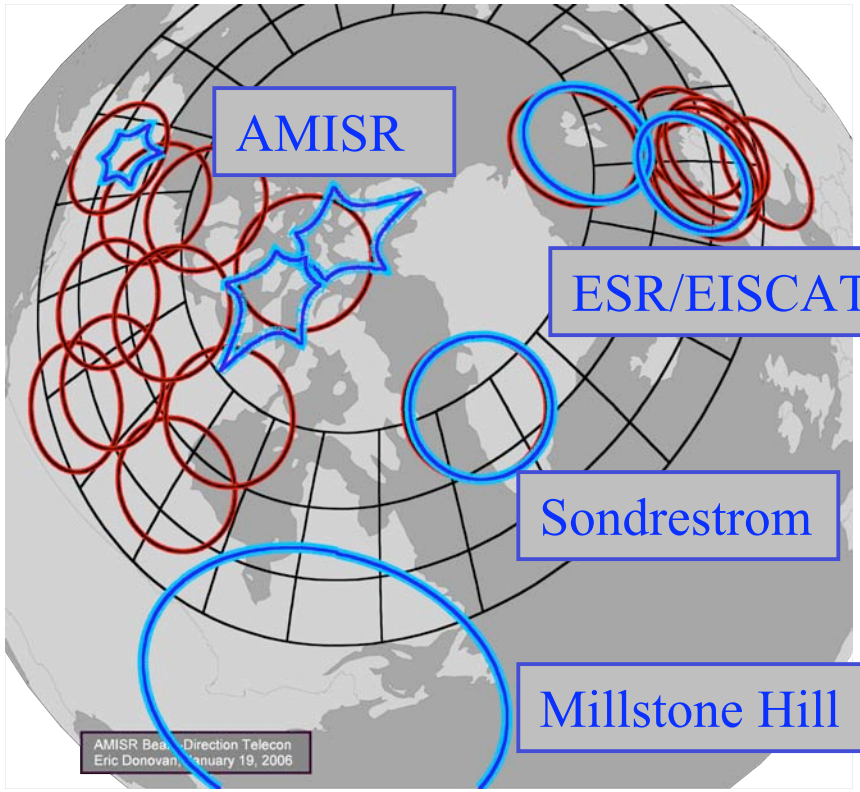




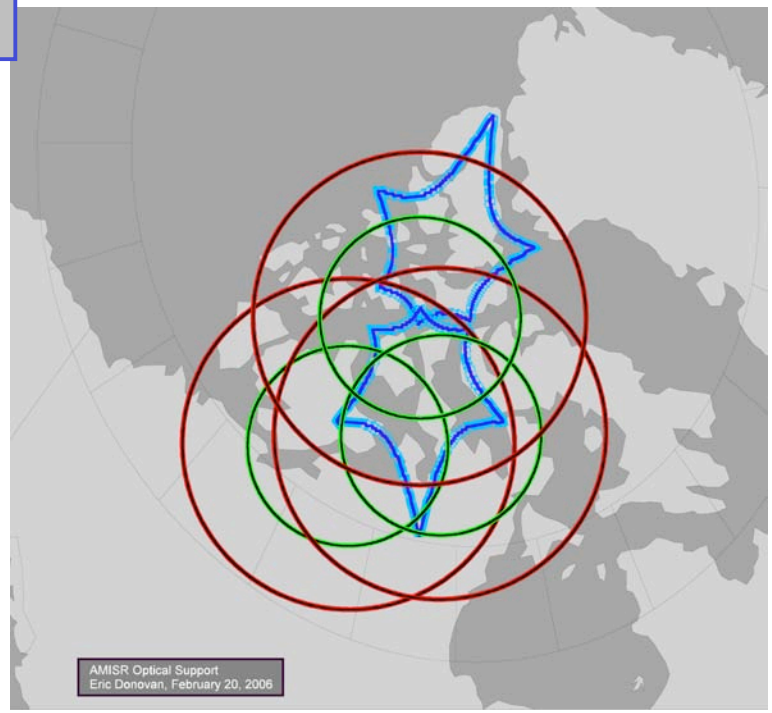
U Calgary
U Saskatchewan
EISCAT
U Tromso
FMI
DMI
SRI
Astronomy North
Lancaster U

Figure: Eric Donovan

Incoherent Scatter Radars

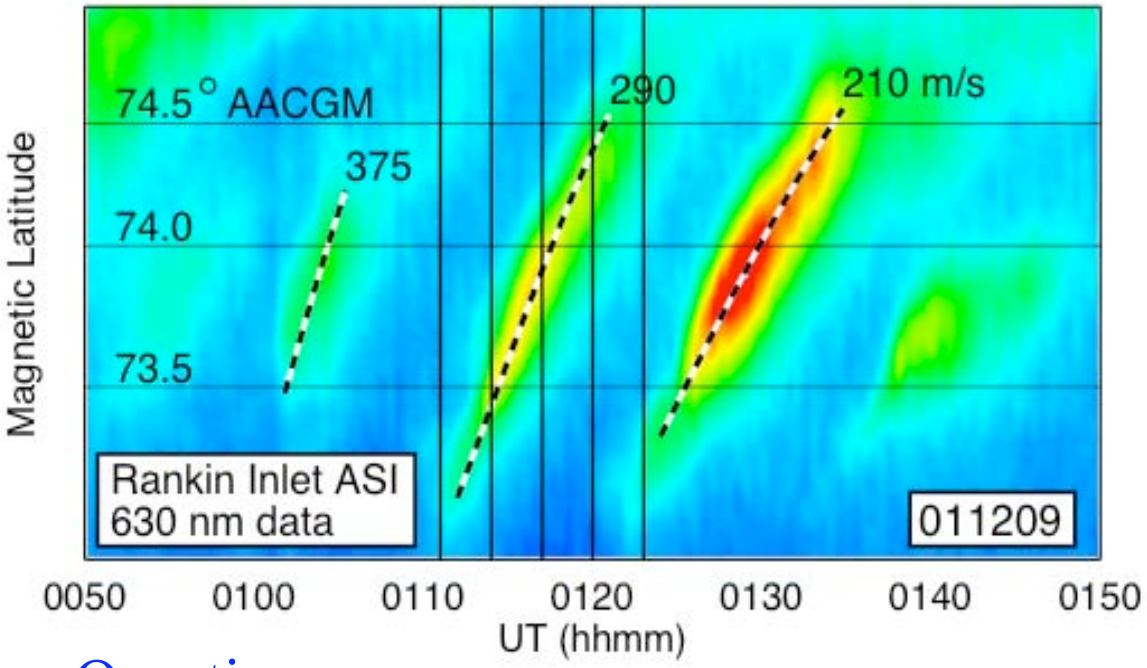


- $n_e(z)$, $\mathbf{v}_i(z)$, $T_i(z)$, $T_e(z)$, others



Figures: Eric Donovan

Science Theme 1: Auroral arc electrodynamics

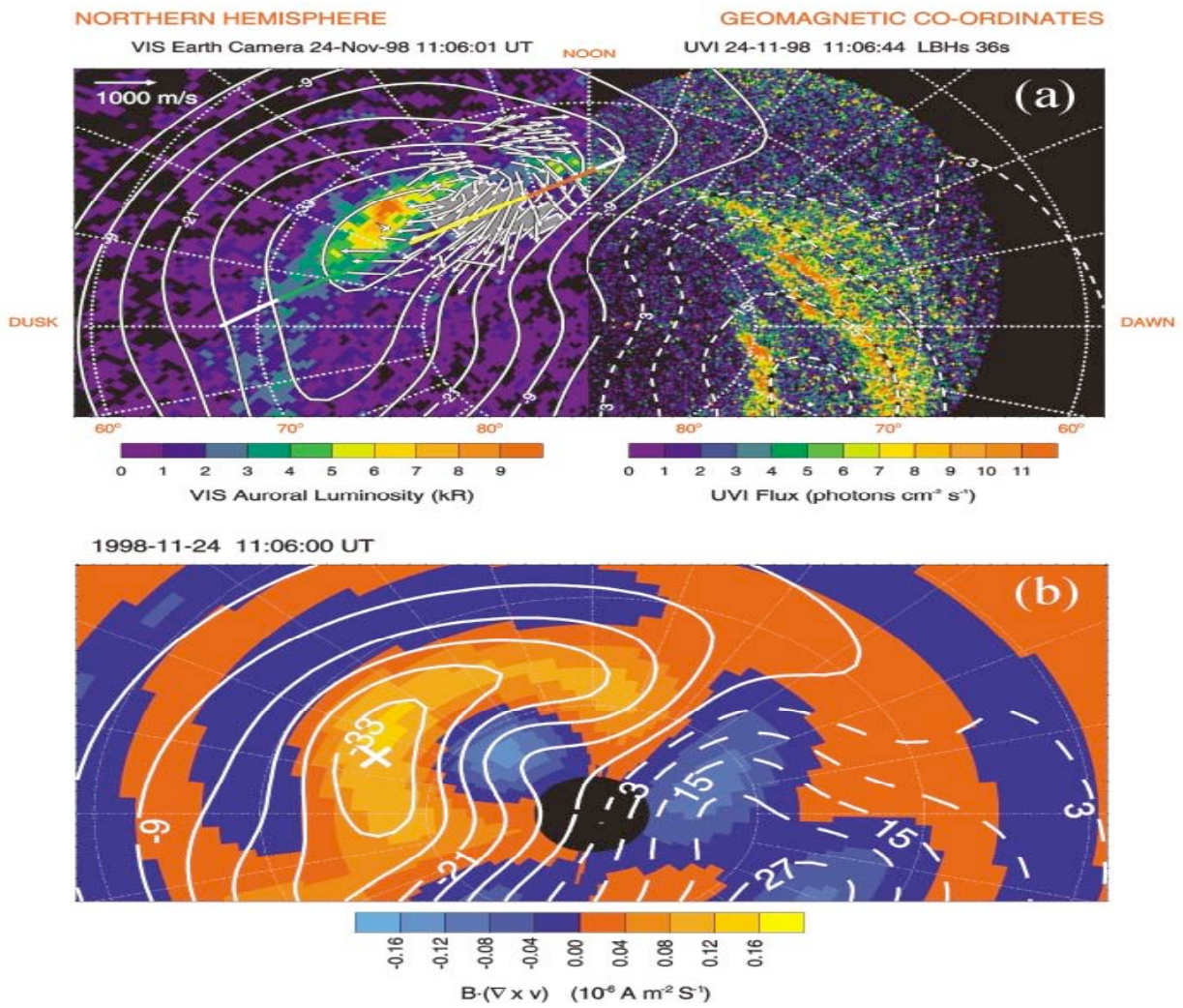


Rankin et al. [2003]

Questions:

- Role of MHD waves and resonances
- Relation to large-scale plasma convection
- Current return to the magnetosphere
- Energy dissipation/Poynting flux

Science Theme 2: Large-scale convection and FACs



Kathryn McWilliams, Univ Saskatchewan

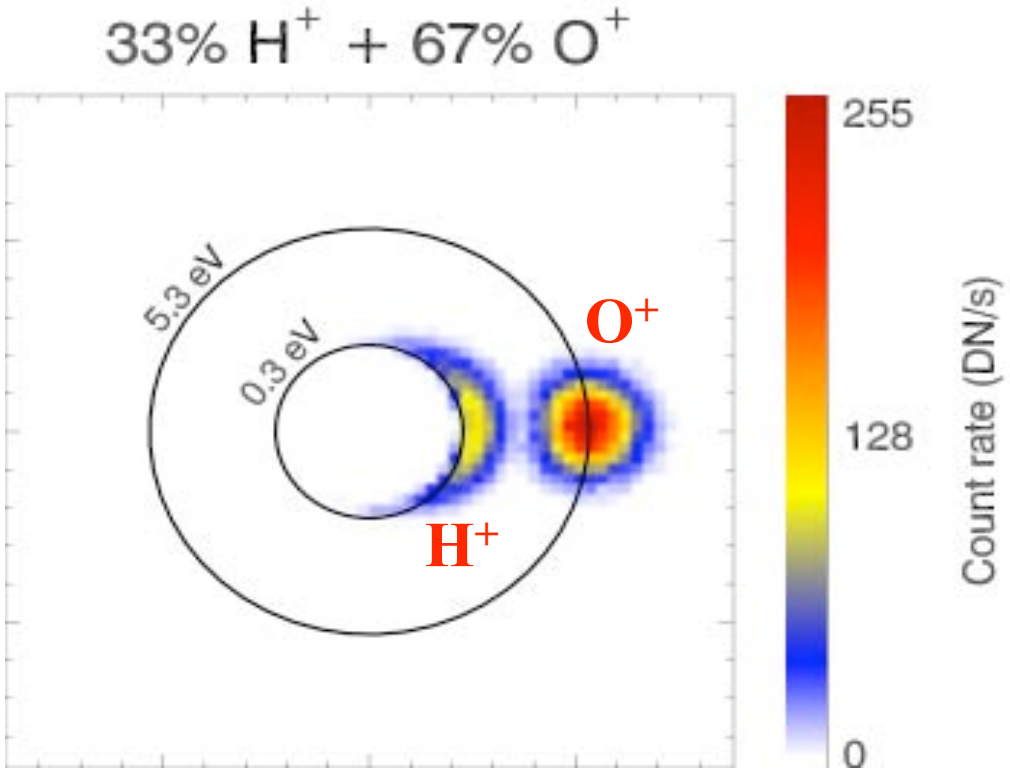
Science Theme 3: Ion Heating and Outflow

Sub-orbital velocity.

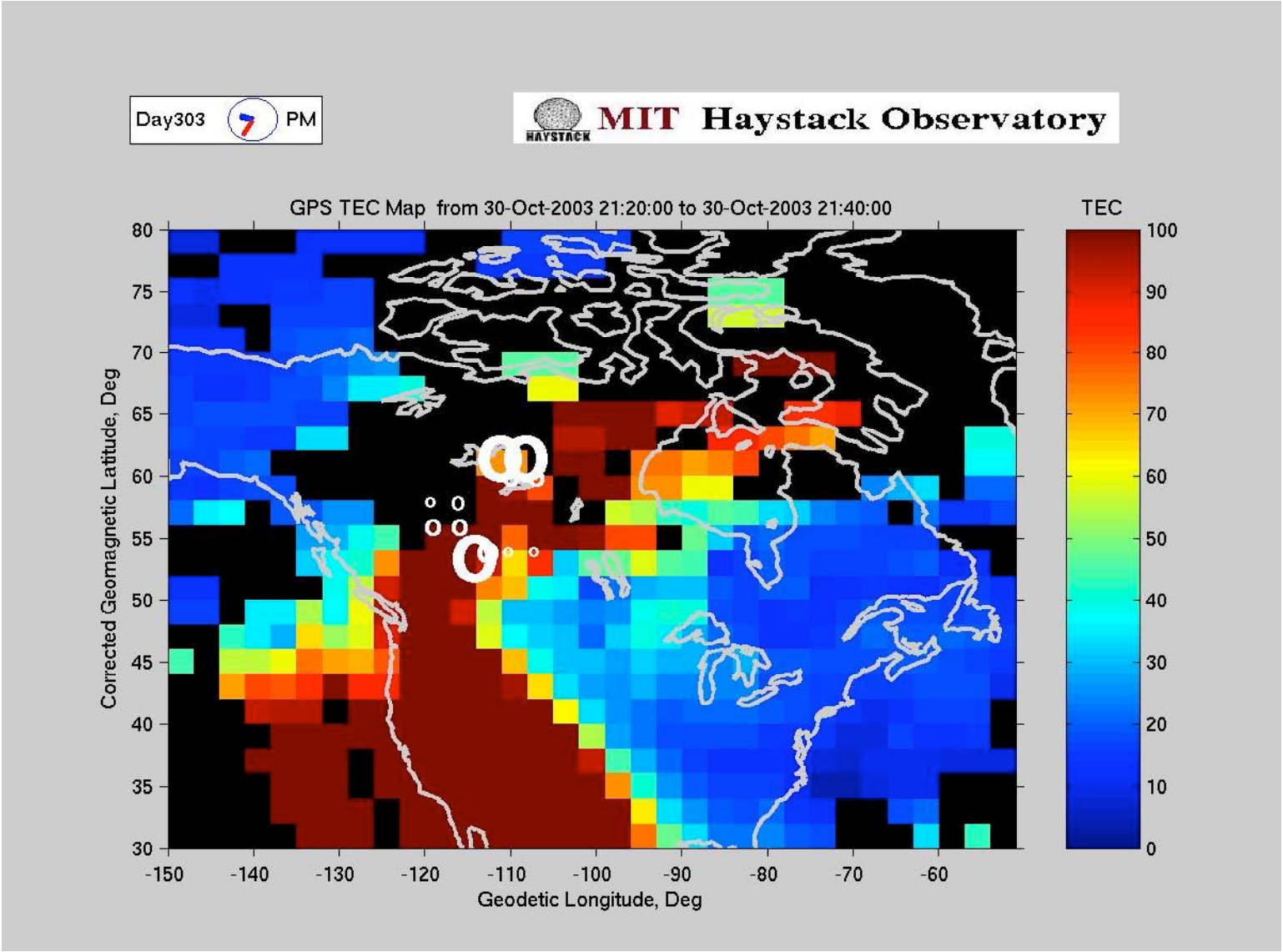
See:

http://www.isr.ucalgary.ca/sp/projects/geodesic/mpg/SII_alfven_waves.mpg

Orbital velocity:

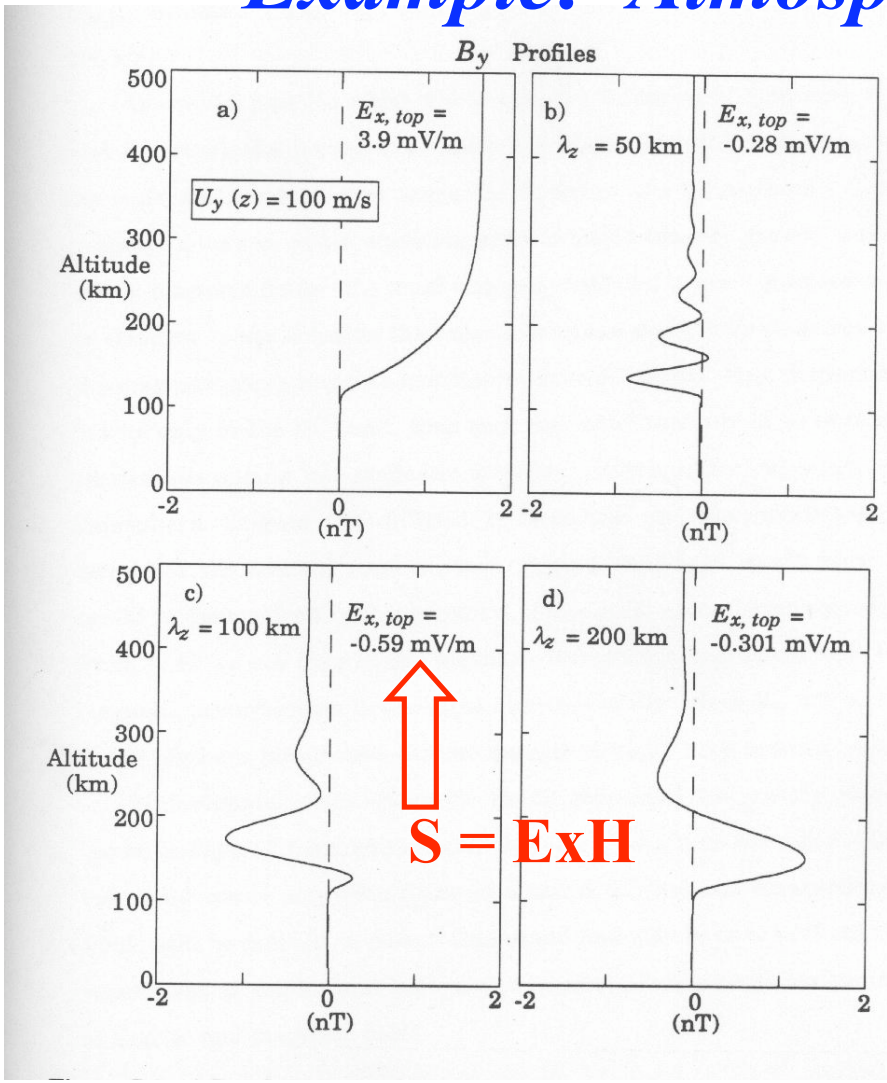


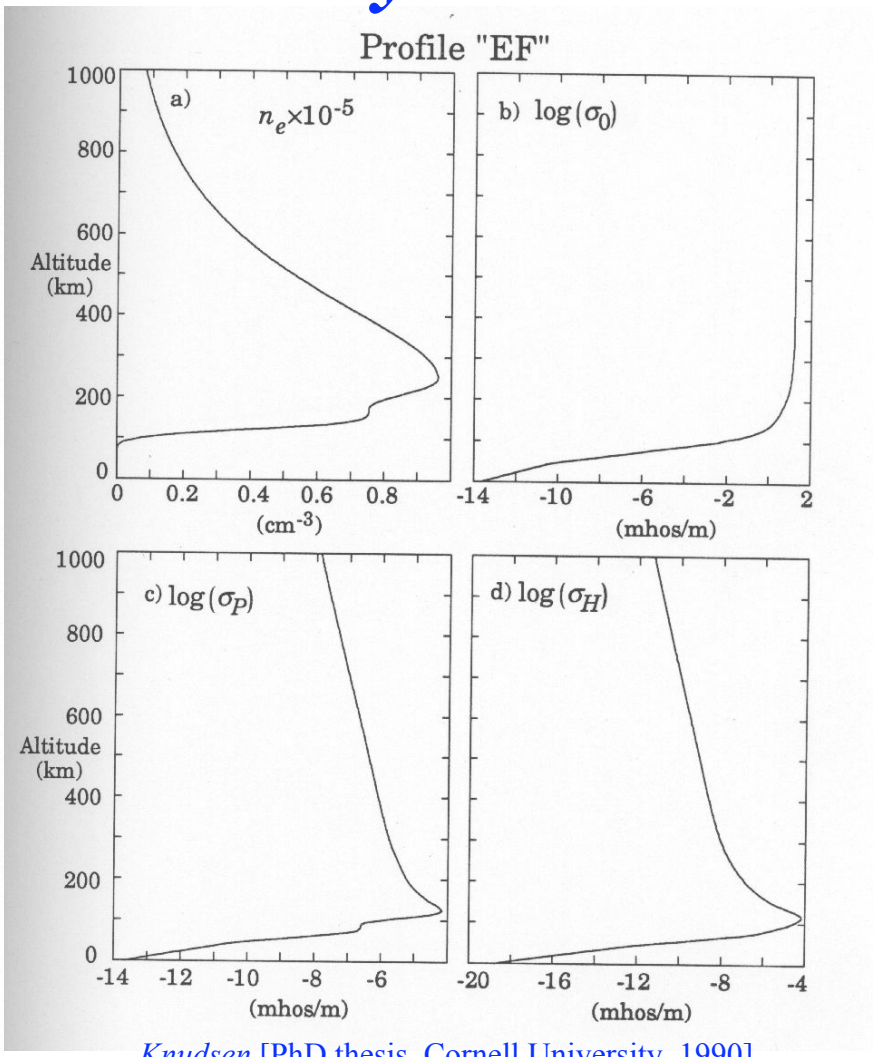
Science Theme 4: Plasma structuring and instabilities



Science Theme 5: I-T Coupling

Example: Atmospheric Gravity Waves





Knudsen [PhD thesis, Cornell University, 1990]

Summary

The Canadian Space Environment research program will contribute to and benefit immensely from Swarm

- 8 scientific research centers in universities and government will be actively involved Swarm-related research.
- Canada is home to the world's most extensive high-latitude array of ground-based magnetometers, cameras and radars.
- In-situ instrumentation (CEFI) will characterize ion drift velocity, ion temperature, electric fields, plasma density, ion composition, and ion distribution functions.
- T_e and spacecraft potential will be measured in collaboration with the Swedish Institute for Space Physics, Uppsala.

⇒ See poster #2