The High Latitude Geospace System

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CEDAR Grand Challenge Workshop, Final Report

The High-latitude Geospace System

Earth's magnetosphere, ionosphere, and thermosphere respond as a coherently integrated *system* to the impinging solar wind. This 'system science' view provides a path toward deeper understanding and improved prediction.

Nowhere is the systems approach more important than at polar latitudes, where solar wind power enters the geospace system through a cascade of processes that are challenging to capture observationally or through a single model.

Recent years have witnessed the rapid expansion of sensors deployed to the geomagnetic polar regions. These measurements are being supported by an increasingly sophisticated suite of models and space missions.

Efforts to reconcile these perspectives have called into question our understanding of four key areas:
1) energy transfer and dissipation in the geomagnetic polar regions
2) sources and impacts of instabilities and turbulence
3) role of extreme plasma gradients on magnetosphere-ionosphere coupling
4) mechanisms of high-latitude plasma escape.

Infrastructure Contributions

Improved sampling (coverage, density, capabilities)

Observational

- TREx - Donovan
- RISR - Varney, Gillies
- AMPERE - Anderson
- Aurorasaurus - Case, MacDonald
- Rocket Program - Clemens
- Antarctic infrastructure - Gerrard
- SWARM mission - Knudsen
- GNSS - Datta-Barua

Modeling

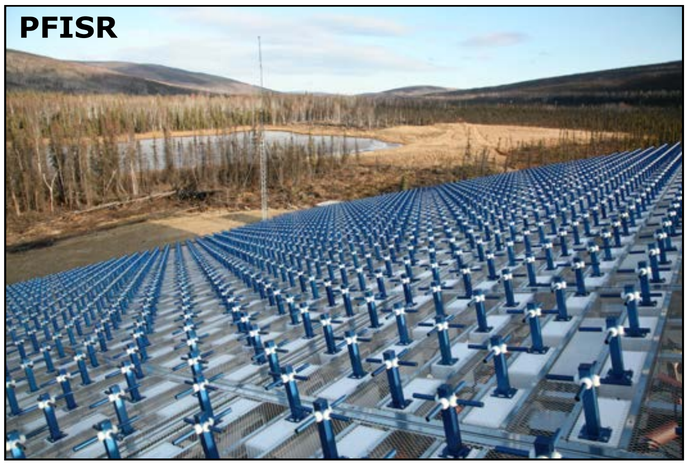
- Transport Modeling (GEMINI) - Zettergren
- Plasma Simulation - Oppenheim
- ISR Simulation (SimISR) - Swoboda
- I-T Modeling (GITM) - Ridley
- Assimilative modeling (AMIE-2) - McGranaghan
- Conductivity Estimation - Kaeppler

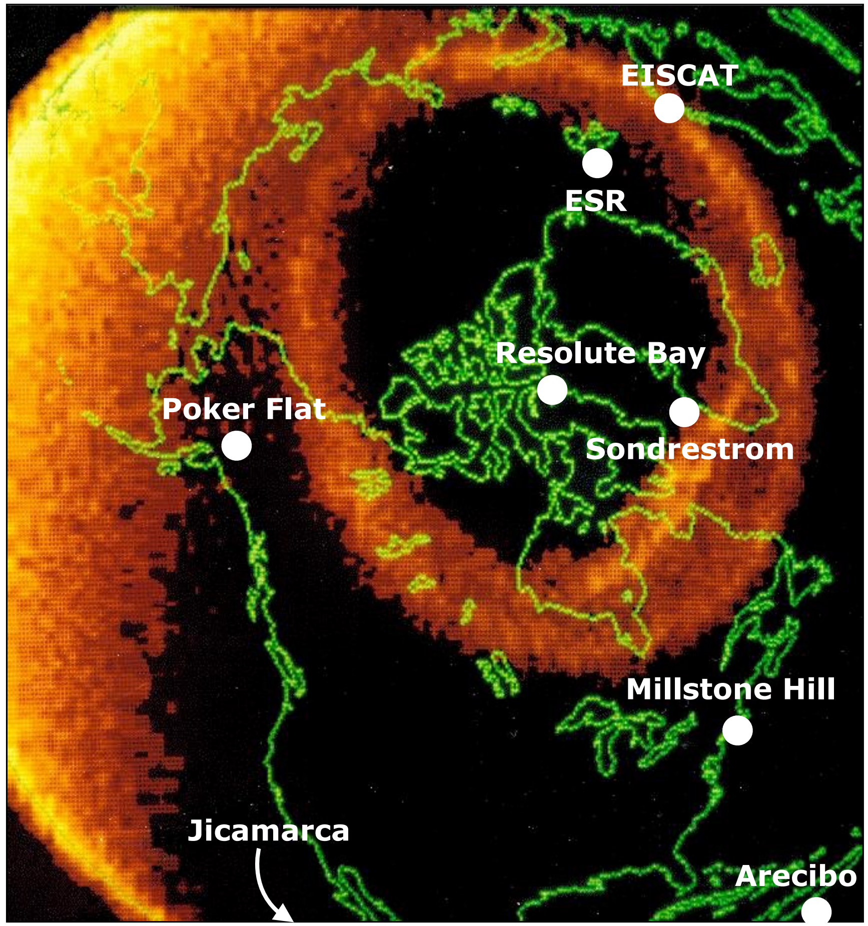
Science Contributions

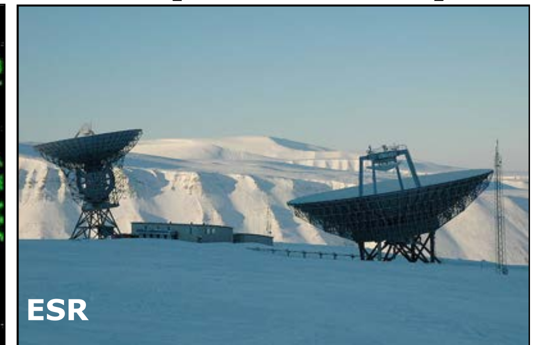
Use of models and intuition to reconcile measurements from different locations, times, platforms, sensors

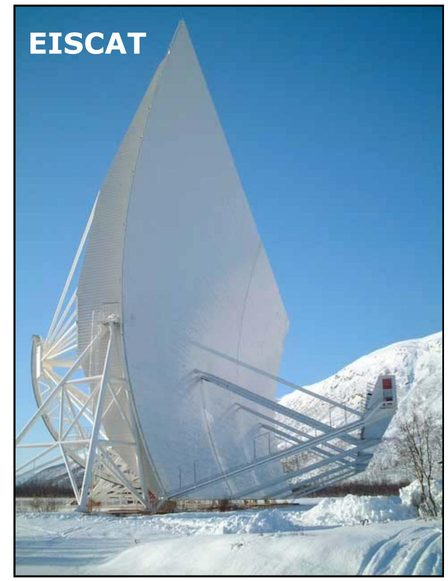
- Topside and Ion upflow - Burchill, Sojka, Varney
- Plasma patch dynamics - Y. Zou
- Auroral omega bands - J. Liu
- Reconnection - Perry, Dahlgren, Carlson, Semeter
- Polar electrodynamics - St.-Maurice
- Polar cap-aurora interaction - S. Zou, Nishimura, Lyons
- Flows and Joule Heating - Y. Huang, C. Huang, Horvath
- I-T and Neutral Dynamics - Wu, Lotko, C. Lee, Dhadly
- Substorm onset - Gallardo-Lacourt
- Polar cap potential saturation - Clauer
- Magnetotail processes - Sivadas

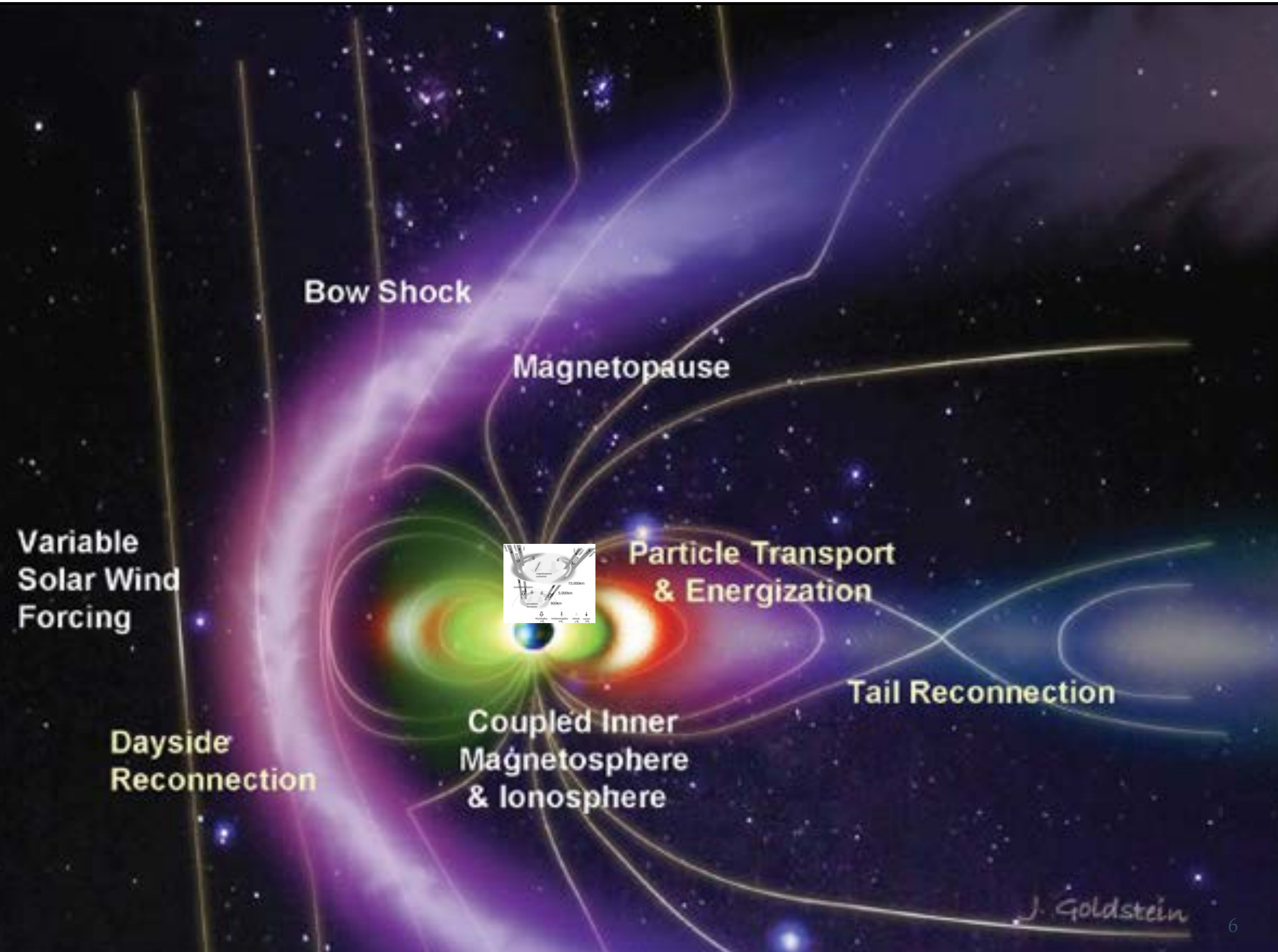
Incoherent Scatter Radar (ISR)



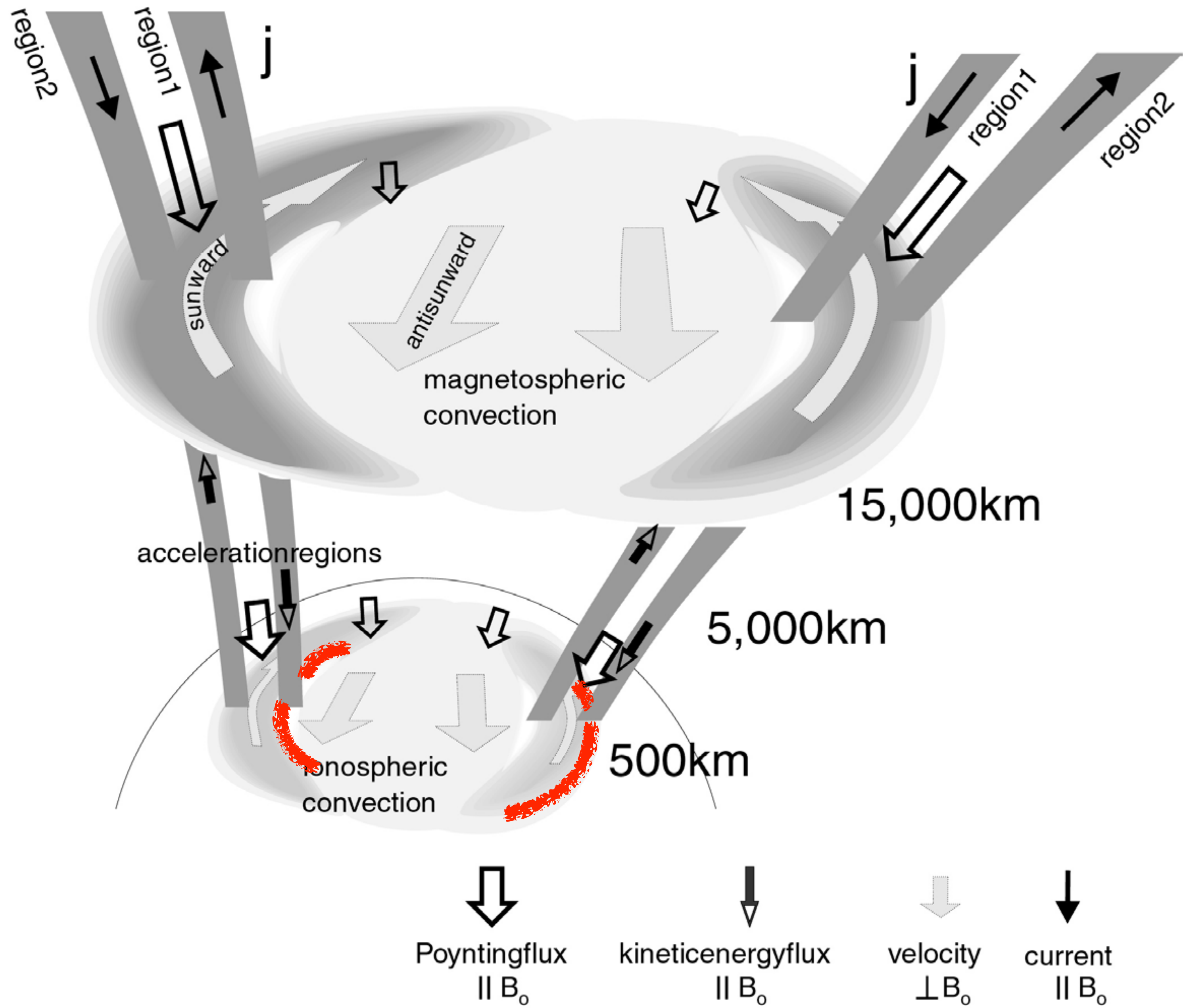






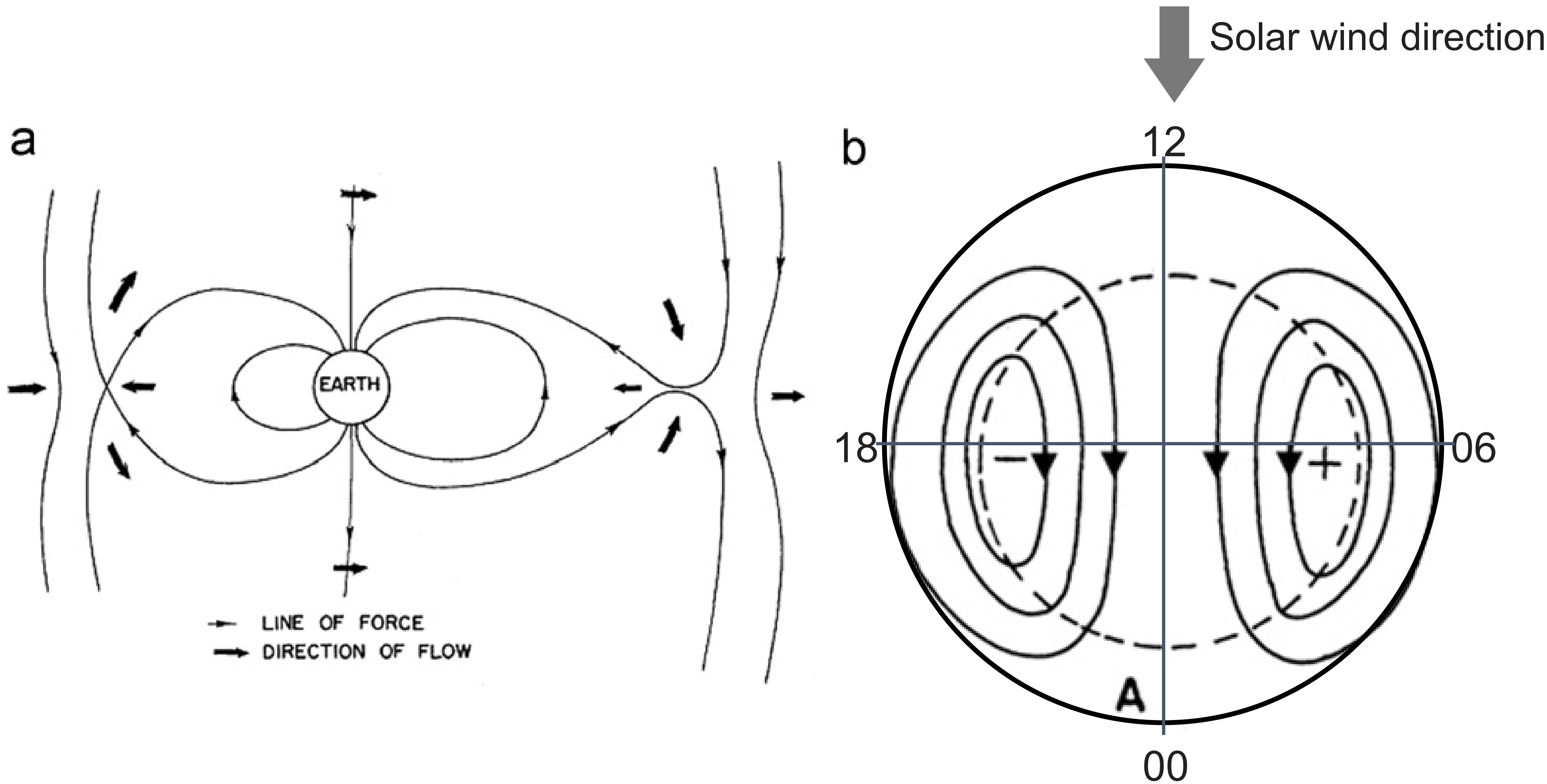

Bow Shock
Magnetopause
Variable
Solar Wind
Forcing
Particle Transport
& Energization
Tail Reconnection
Dayside
Reconnection
Coupled Inner
Magnetosphere
& Ionosphere
J. Goldstein

Ionosphere as a projection of the magnetosphere



Vaivads, PhD dissertation

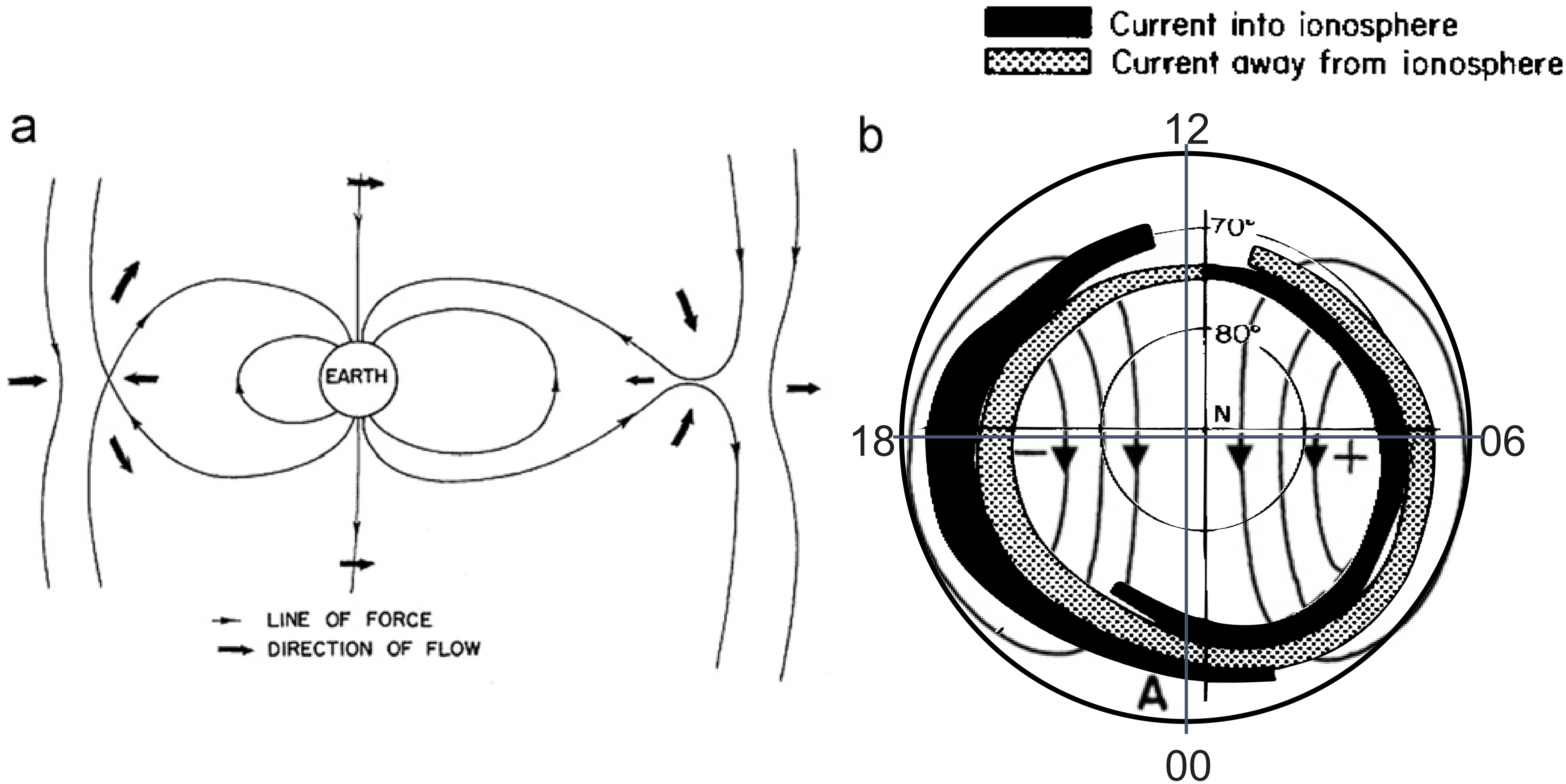
The Dungey Cycle



Reconnection is a dominant driver of magnetospheric convection

Dungey, 1961

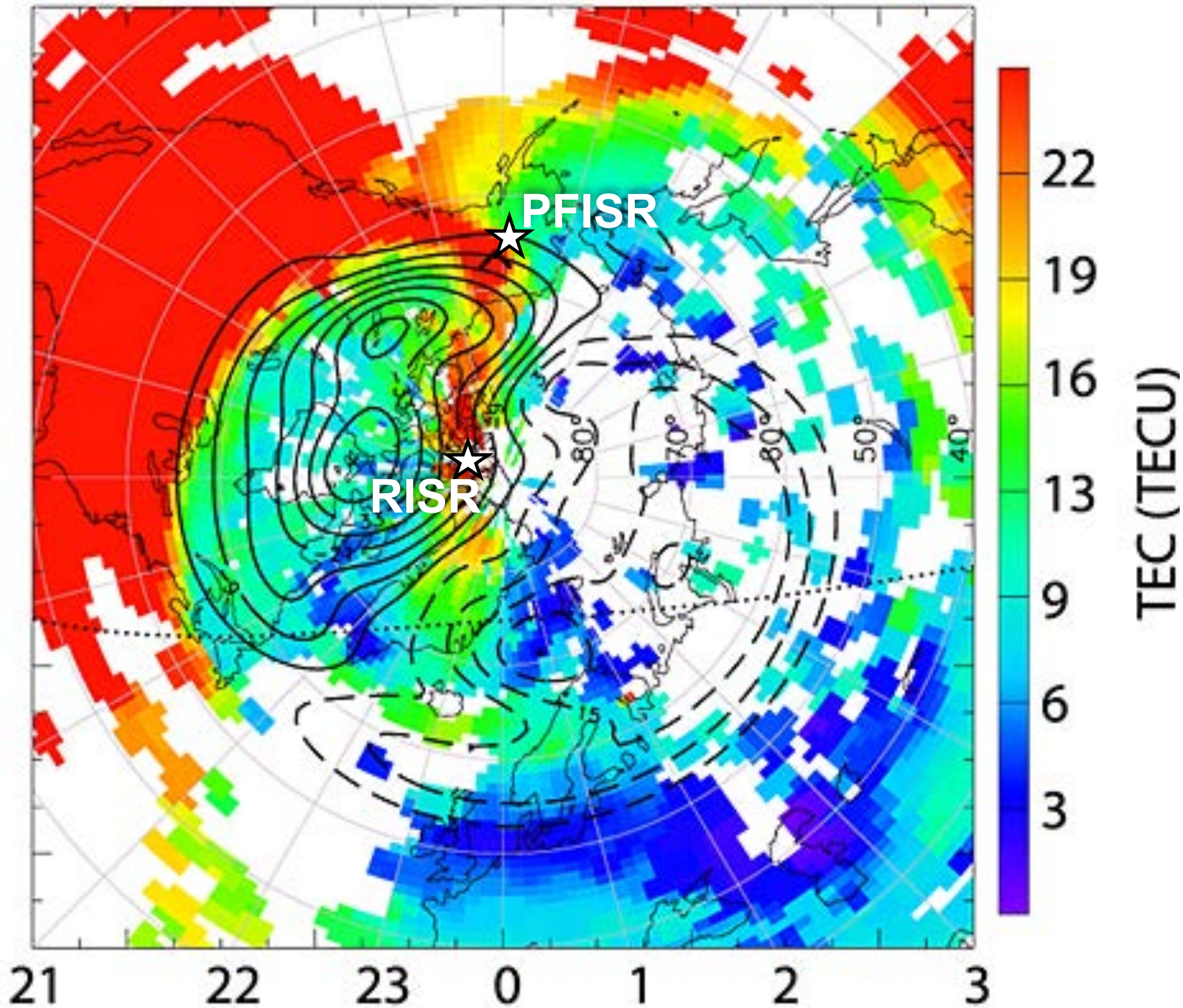
Birkeland currents



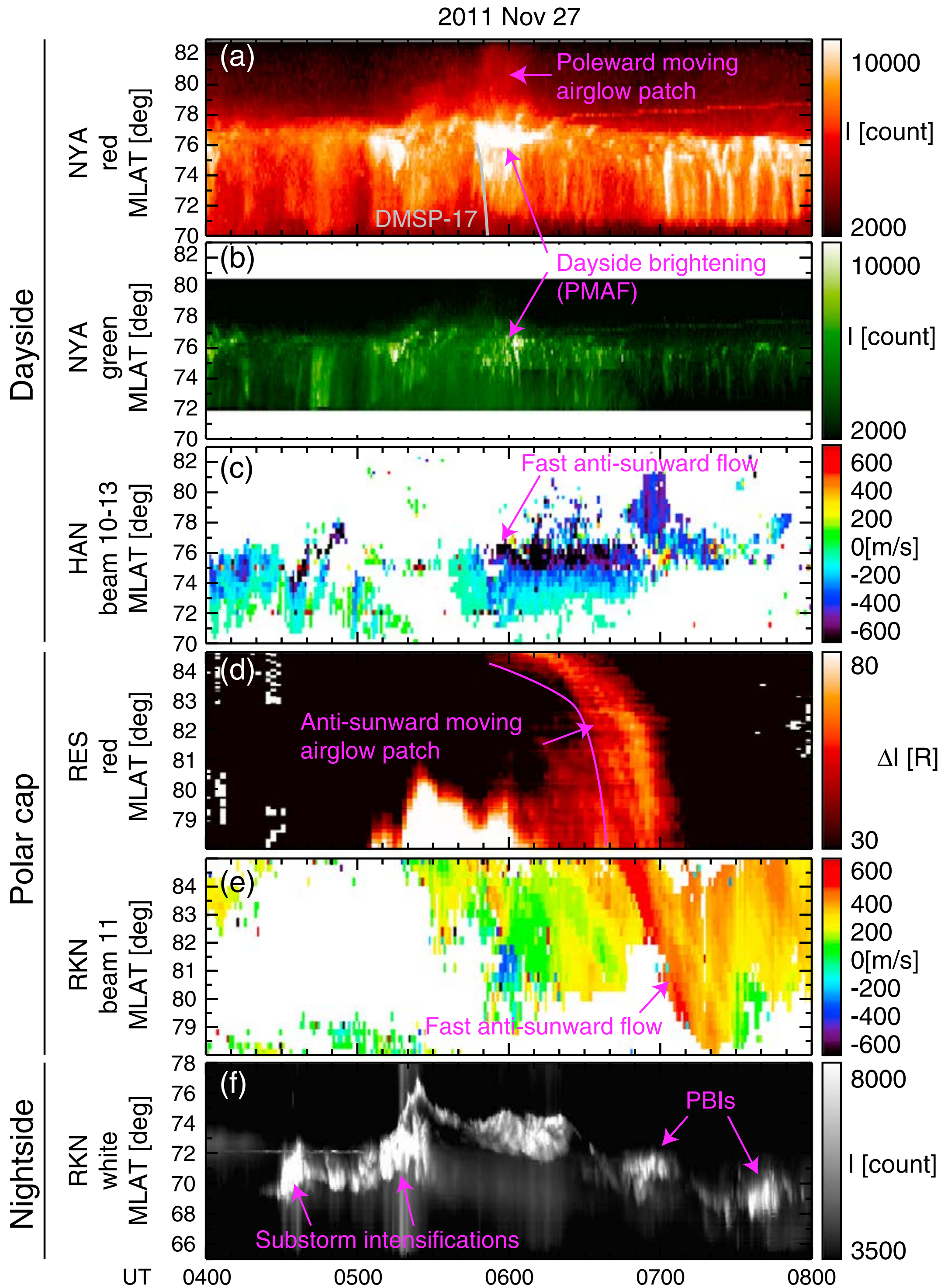
Electromotive force needed to drive convection

Ijima and Potemra, 1976

What we need: 1) Better coverage



S. Zou



Patch of enhanced plasma density moves poleward from dayside.

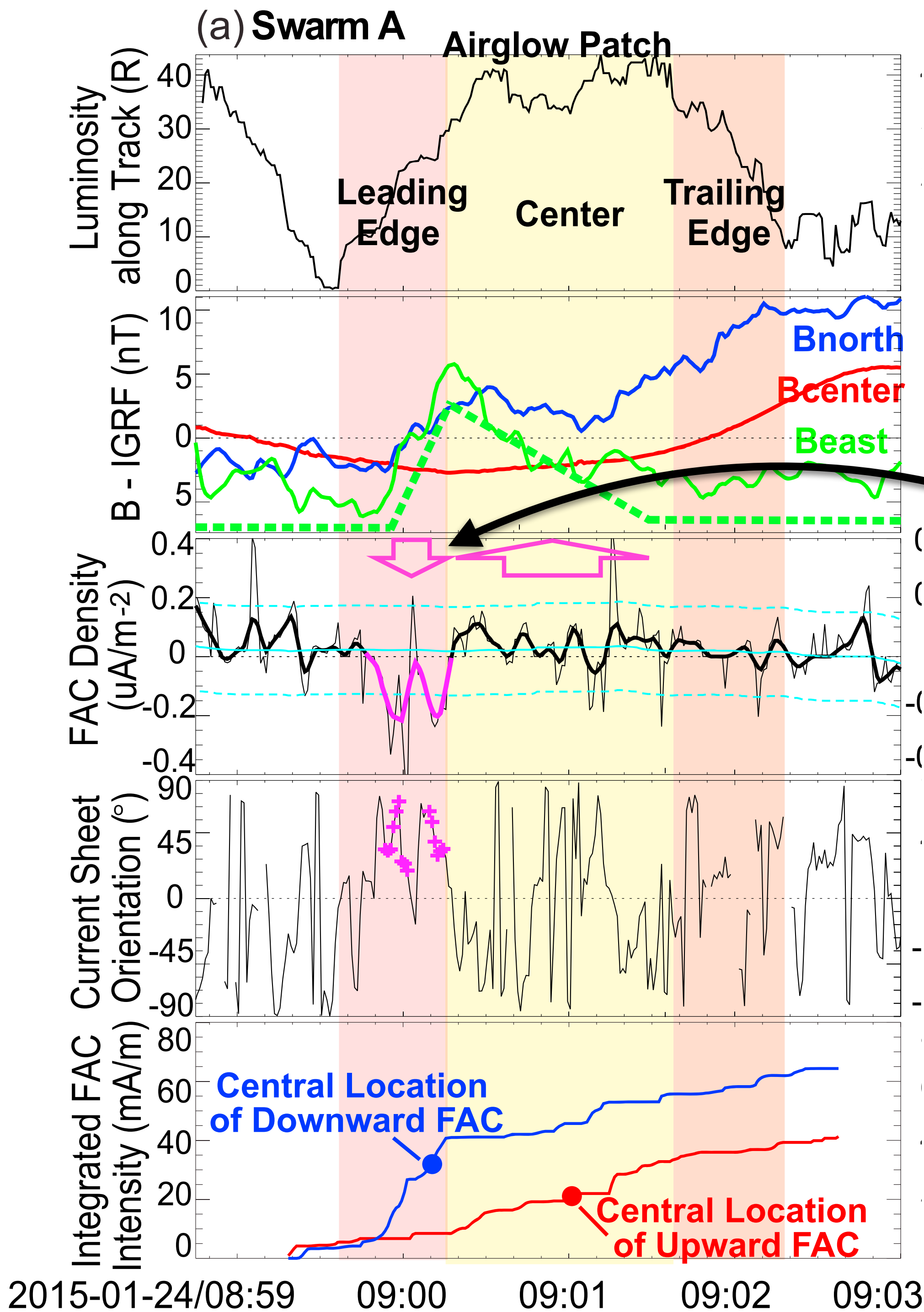
…accompanied by a poleward moving auroral form (reconnection)

HF radar measures fast poleward flow channel

Measurements at geomagnetic pole show patch riding in a high speed flow field

On the nightside, flows appear to cause auroral intensifications along the auroral oval

Nishimura et al., 2014; Y. Zou et al., 2017



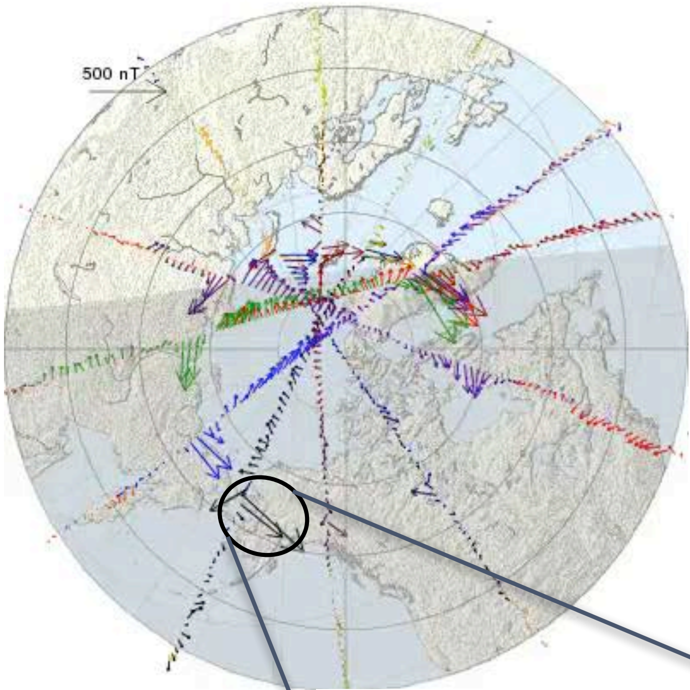
Conjugate measurements from SWARM satellite constellation suggests that anomalous flow channel is powered by enhanced field aligned currents.

Such studies should be much easier to carry out, with clarity of results unaffected by observational limitations.

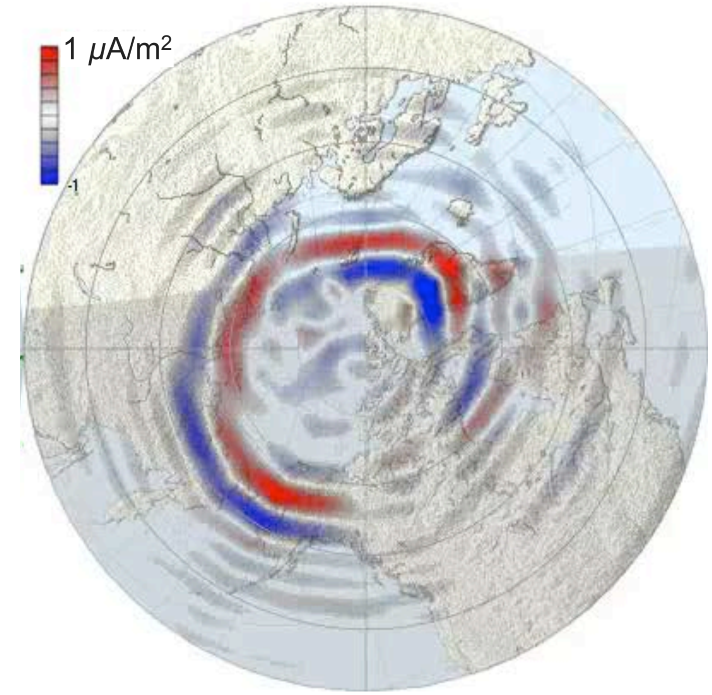
Y. Zou et al., 2017

What we need: 2) Multi-scale observations

01 Mar 2011 10:04:00 - 10:14:00 UT (north)



Spherical harmonic expansion



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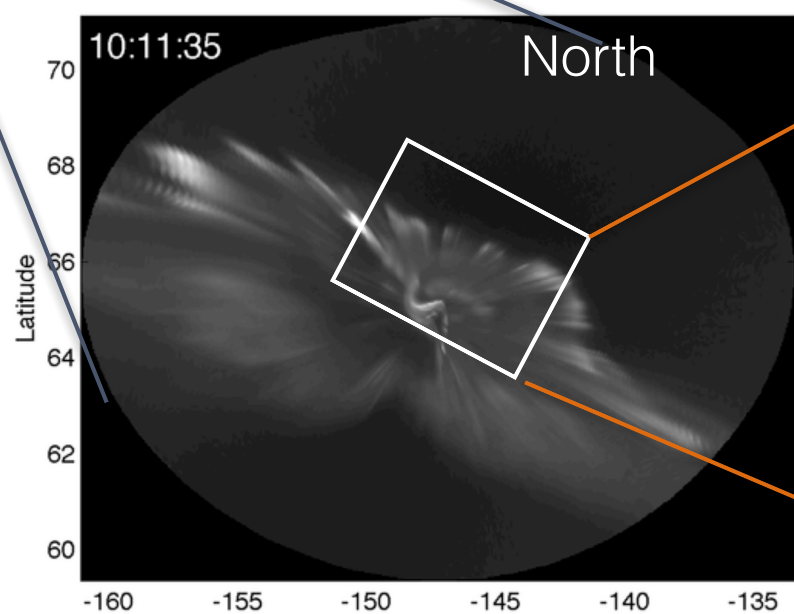
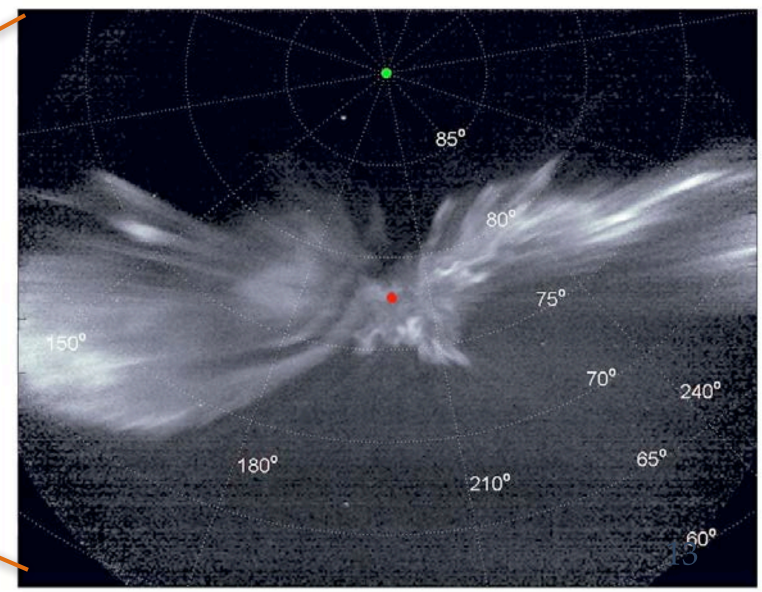
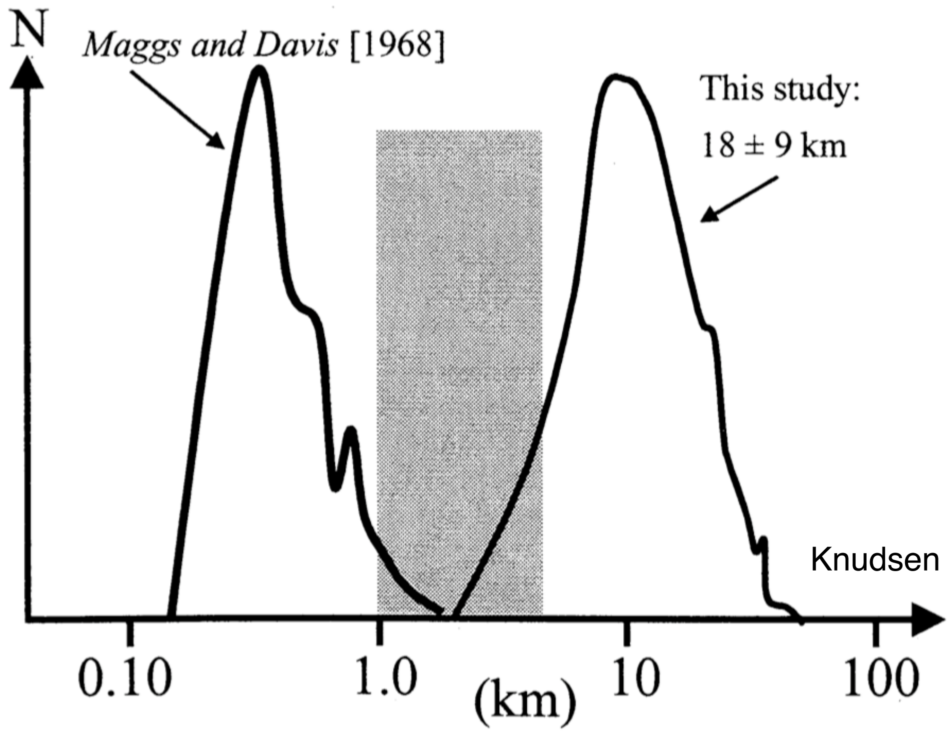


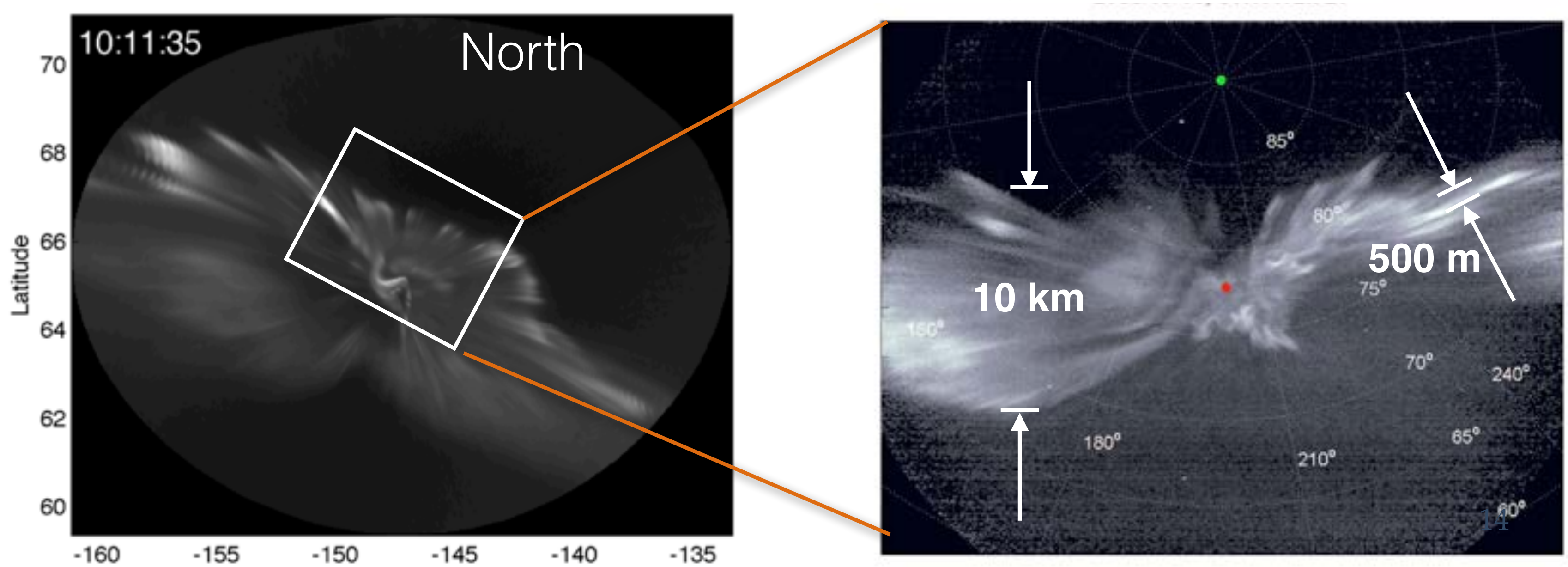


What we need: 2) Multi-scale observations

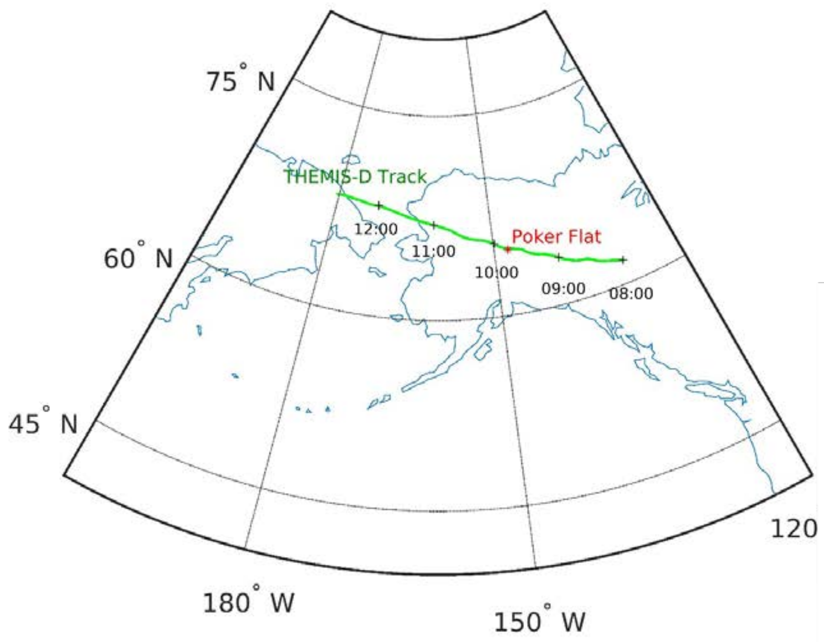
There is not a continuum of scales in the magnetosphere-ionosphere system.   Rather, the physics changes abruptly as we cross specific parameter regimes.

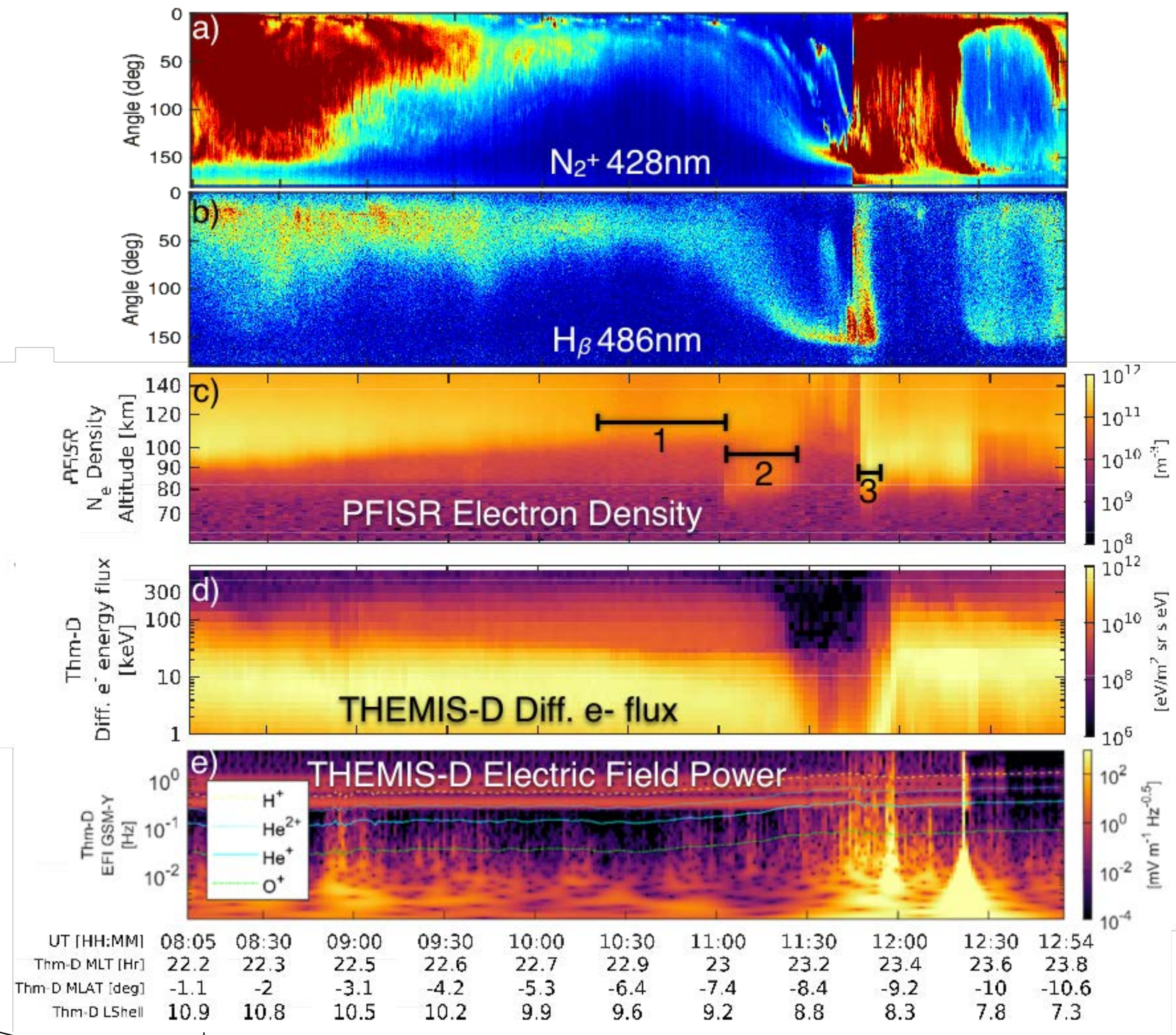


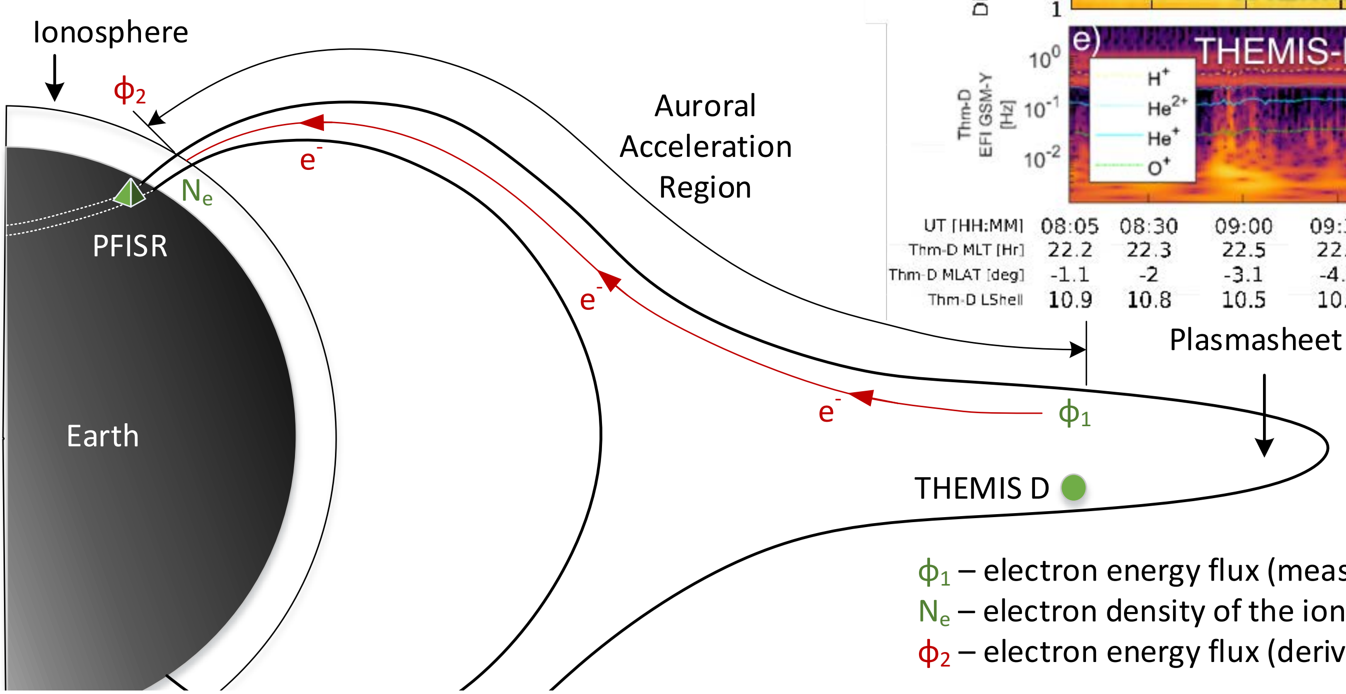
Knudsen et al., 2001



What we need: 3) Collaborative measurements from ground and space







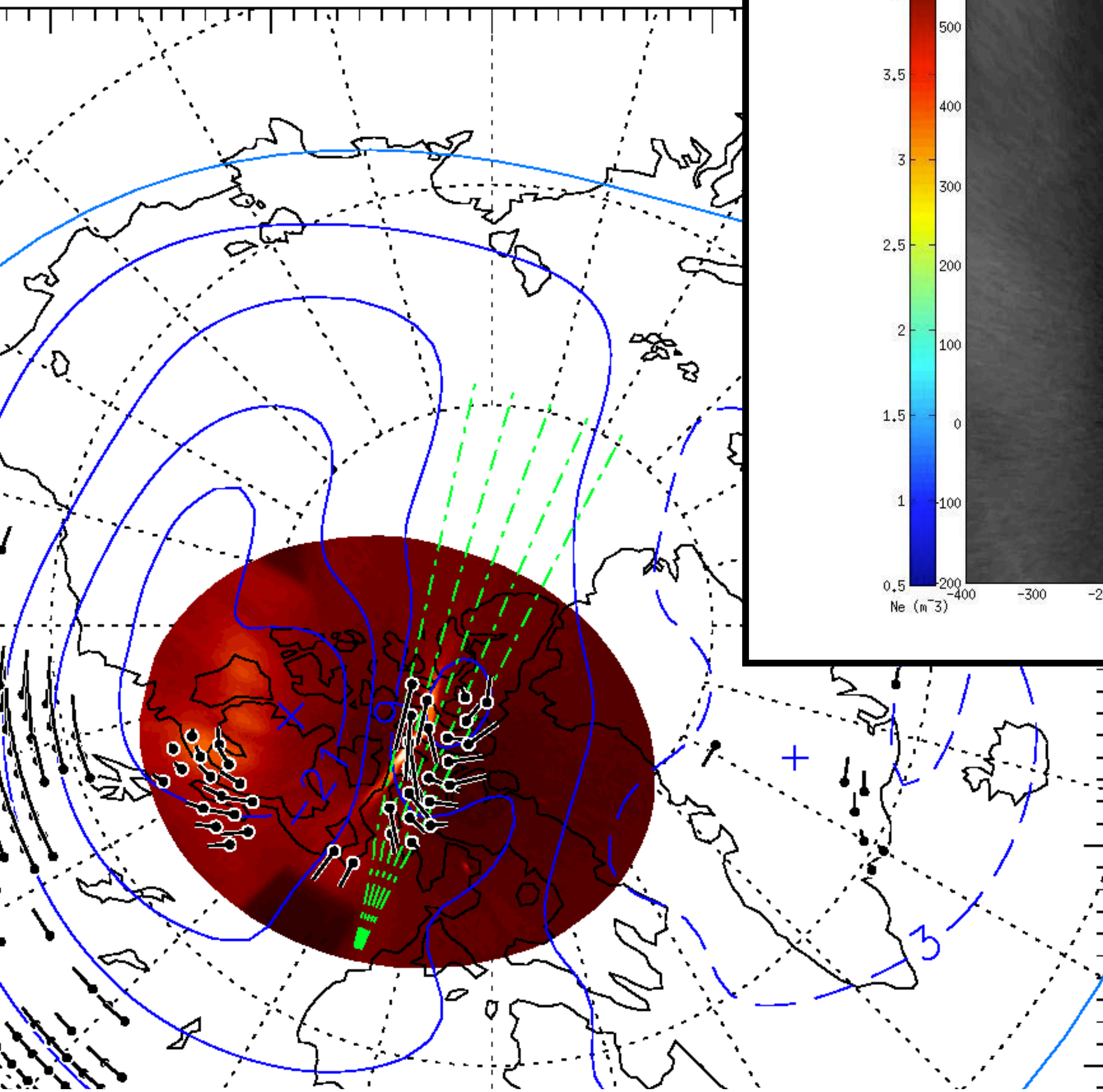
ϕ_1 – electron energy flux (measured by THEMIS D)

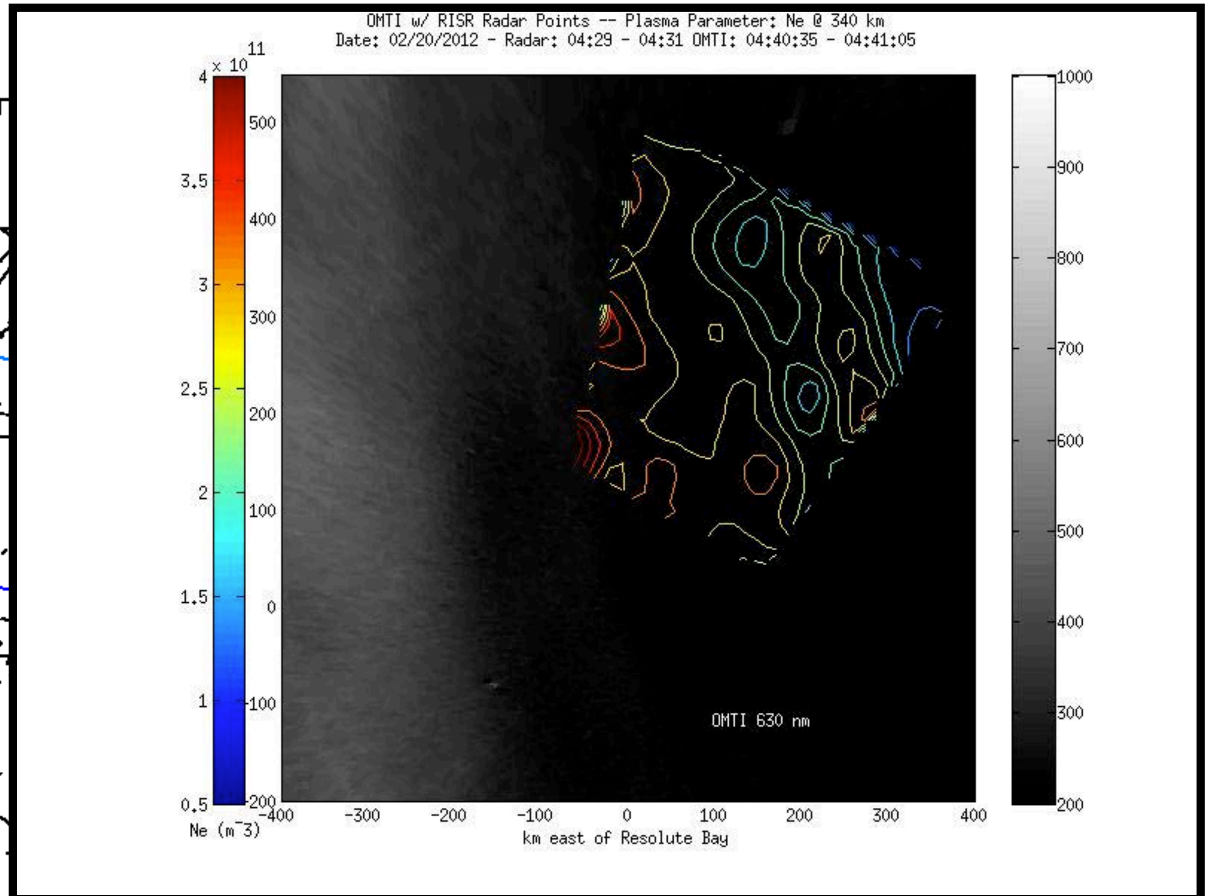
N_e – electron density of the ionosphere (measured by PFISR)

ϕ_2 – electron energy flux (derived from N_e)

Sivadas et al., 2016

What we need: 4) Creative experimental techniques

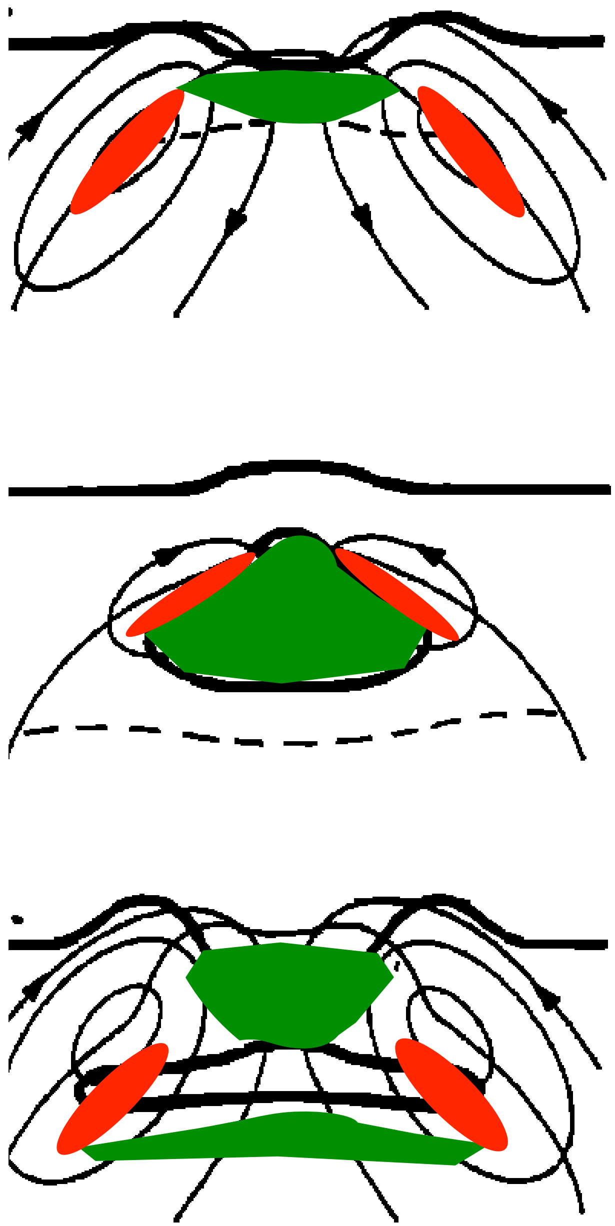




Complex interaction between plasma patch and the auroral boundary
Unresolved effect of high-latitude (lobe) reconnection.

Perry et al., 2016

What we need: 4) Creative experimental techniques



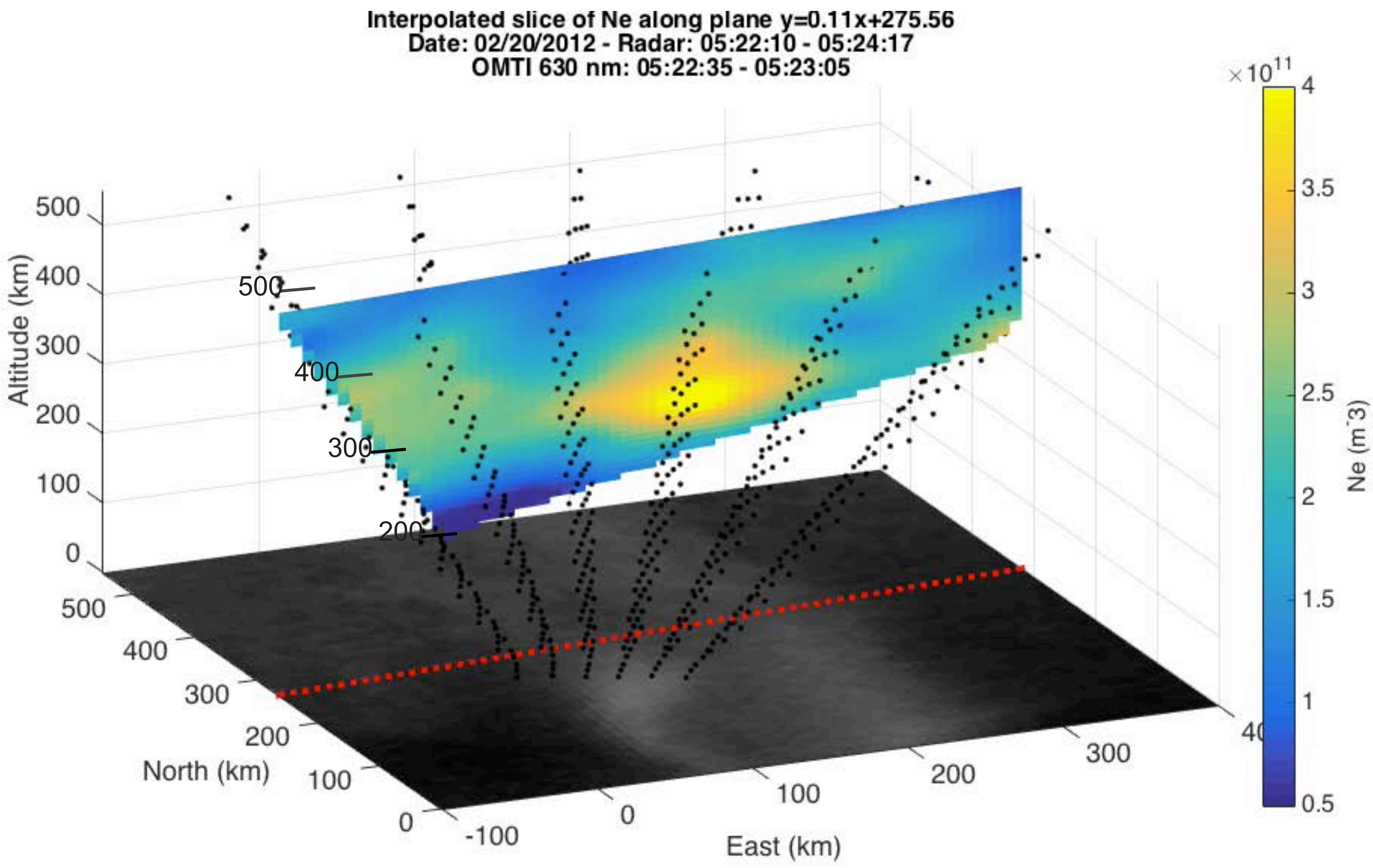
E-region arc

F-region patch

Temporal scales, spatial scales, and flow complexities associated with this physics has not been established.

Cowley, Carlson, Lockwood

What we need: 4) Creative experimental techniques



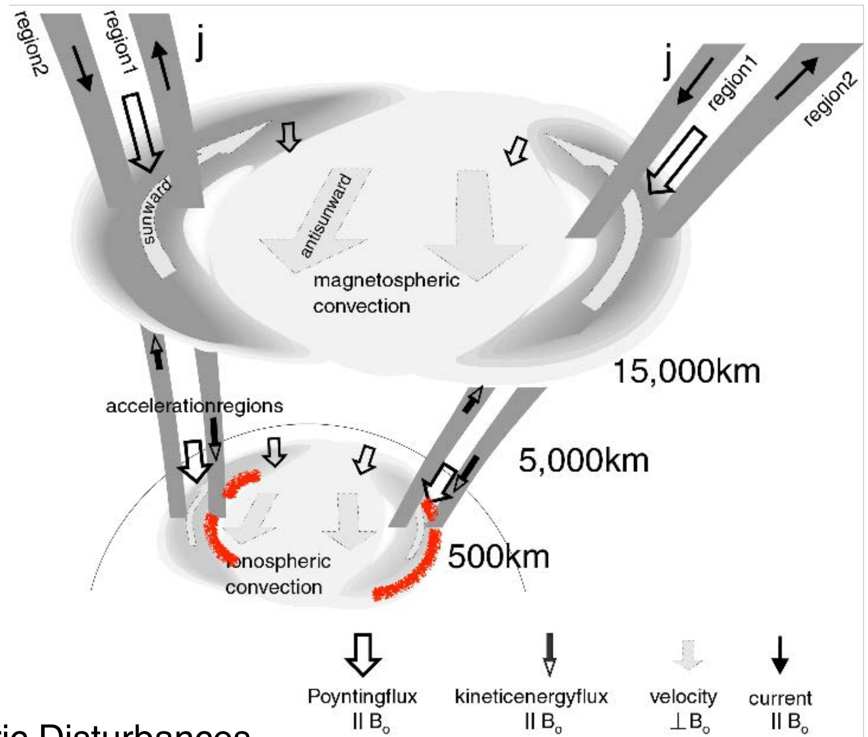
What we need

1) Better coverage

2) Multi-scale observations and multi-scale modeling

3) Collaborative measurements from ground and space

4) Creative experimental techniques



Join us for further further discussion:

Monday 1600-1800: A. Space Weather Observation Network I: Ionospheric Disturbances

Tuesday 10-12: B: Space Weather Observation Network I: Ionospheric Disturbances

Tuesday 13:30-15:30: A: Space Weather Observation Network II: Thermospheric Expansion

Wednesday 13:30-15:30. B: Space Weather Observation Network II: Thermospheric Expansion