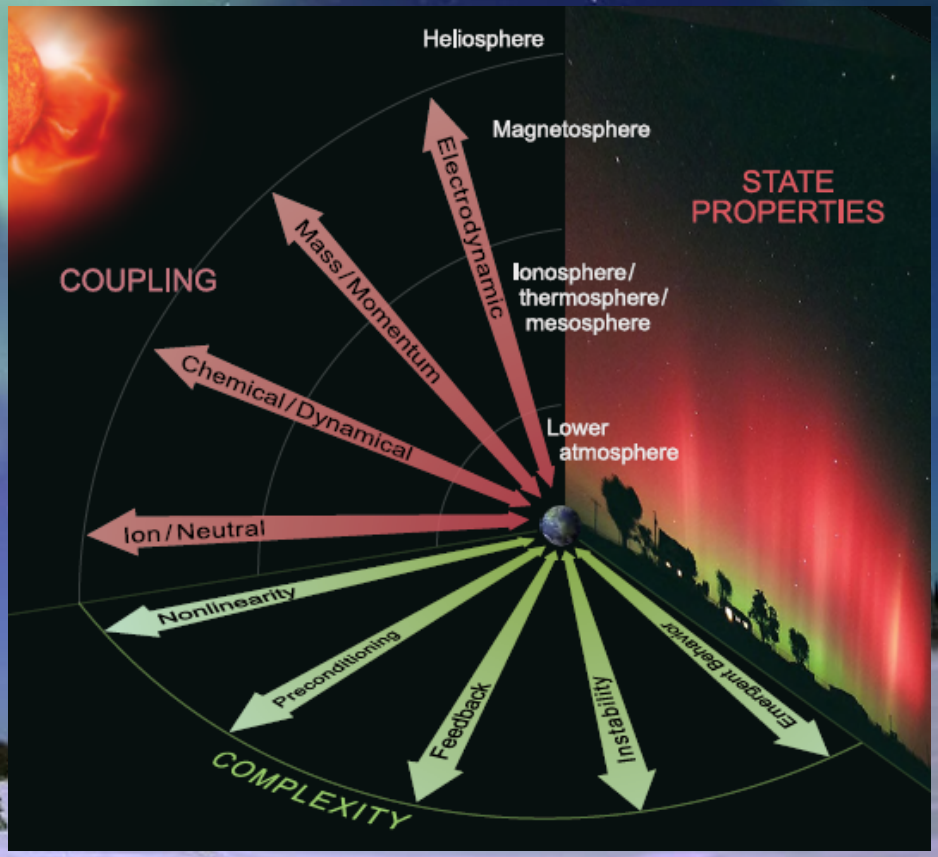
A Grand Vision for Studying the Coupled ITM System

Eric Donovan

Banff – August 3, 2012

The Systems Perspective



CEDAR: The New Dimension

CEDAR: "… understand the processes that govern the coupling, energetics, and dynamics of the upper atmosphere, and its linkages with the lower atmosphere, space, and the universe beyond…"

GEM: "… understand, explain and ultimately predict geospace system dynamics…"

SHINE: "… understanding of the processes by which energy in the form of B-fields and particles are produced by the Sun and/or accelerated in interplanetary space and on the mechanisms by which [they] are transported to the Earth..."

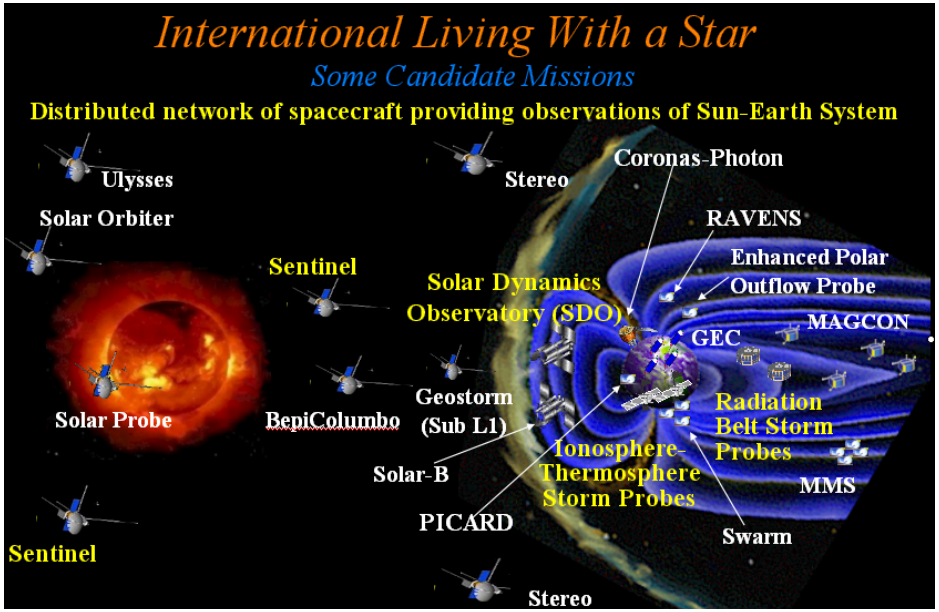
NASA 2009 Roadmap: "… understand the Sun and its Effects on Earth …"

CGSM: "… understand the transport of mass and energy across multiple scales throughout the entire solar system…" (2003); "To observe and understand geospace as a system." (2012)

GEMSIS: "… understanding energy and mass transport from the Sun to the Earth in the geospace environment."

Skynet

Solar Orbiter
Stereo
SOHO
Sentinel
Picard
Hinode
●
Solar Probe



System-level?
●
Geotail
Cluster
THEMIS
ePOP
RBSP & ERG
MMS
GOES
LANL

Skynet

Wind
ACE
Radiometers

THEMIS
MMS
Cluster

THEMIS/MMS
RBSPs/ERG
Cluster
GOES & LANL

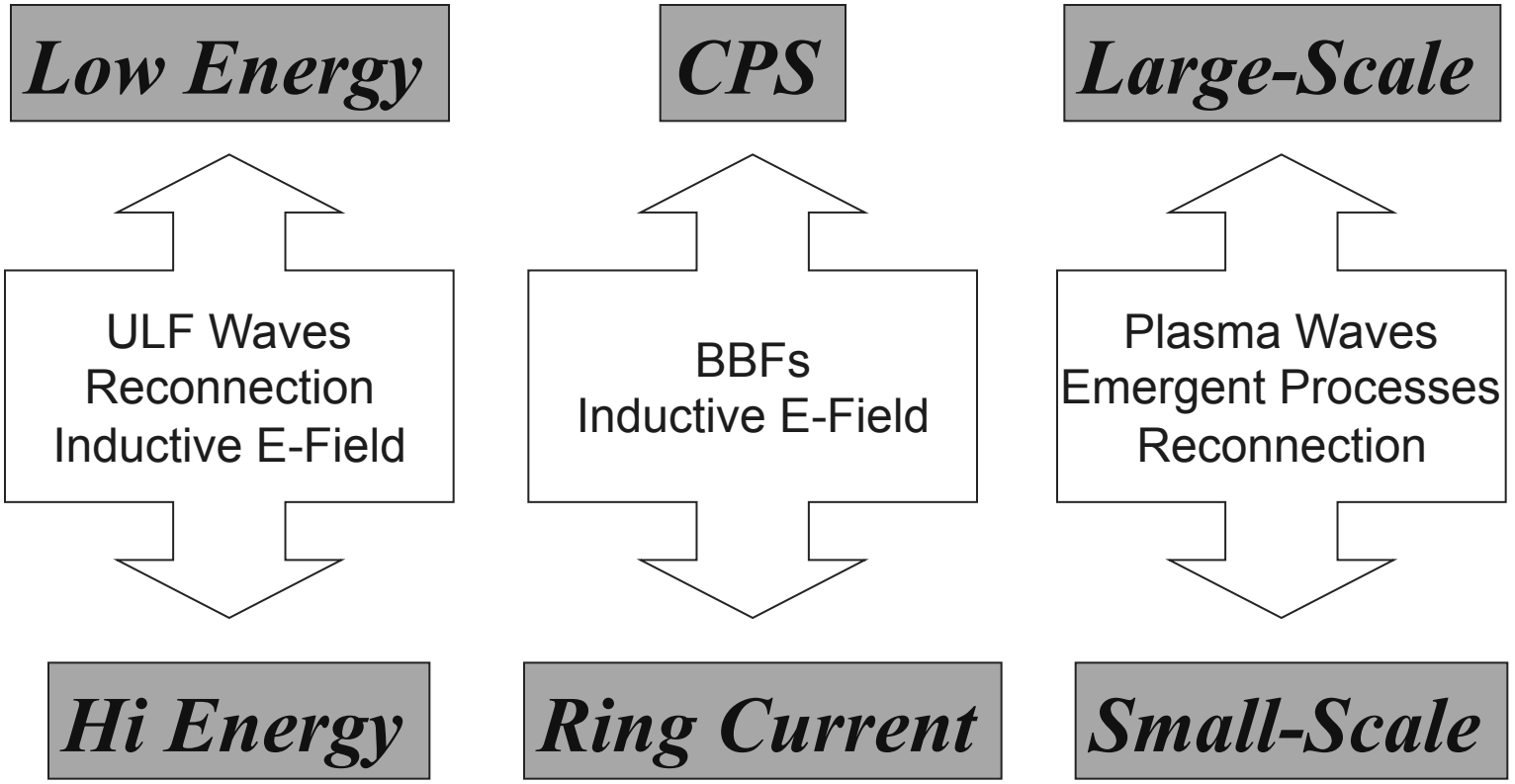
Ground-Based and Space-Based multi-scale observations

CGSM, AMISR, THEMIS-GBO, Swarm, RBSPs, etc, etc

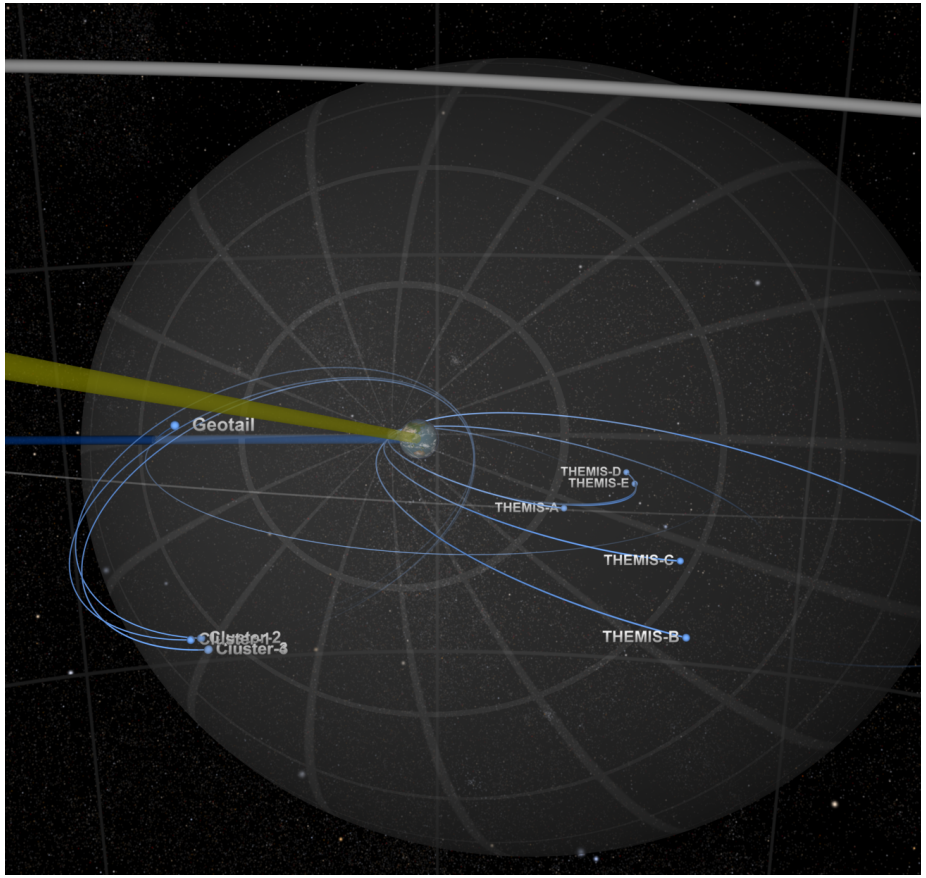
Solar Radiation
Energetic Particles
Solar Wind

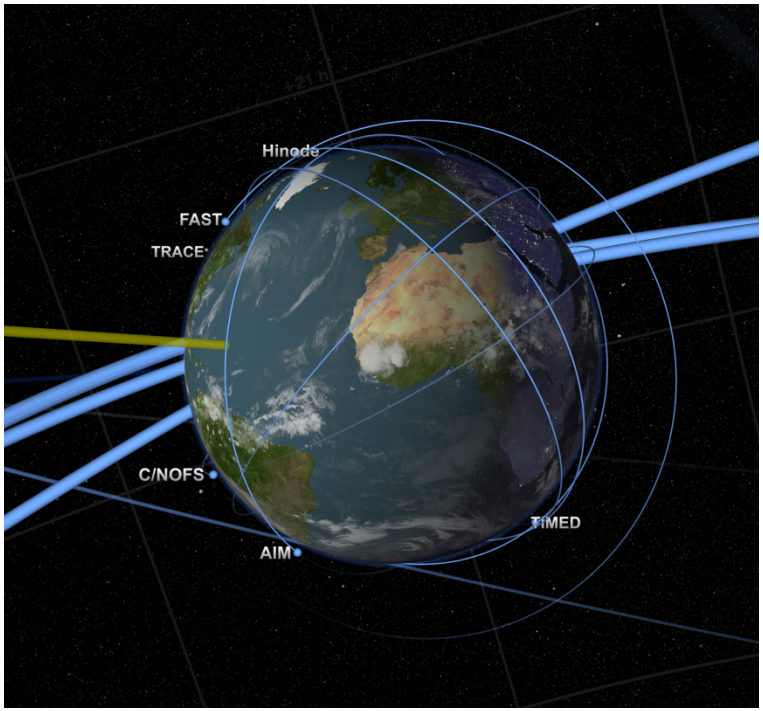
Auroral acceleration
WP Interactions
Reconnection
BBF
CD Instability
Injection
MHD Waves
Gravity Waves
Joule Heating
Sudden Impulse

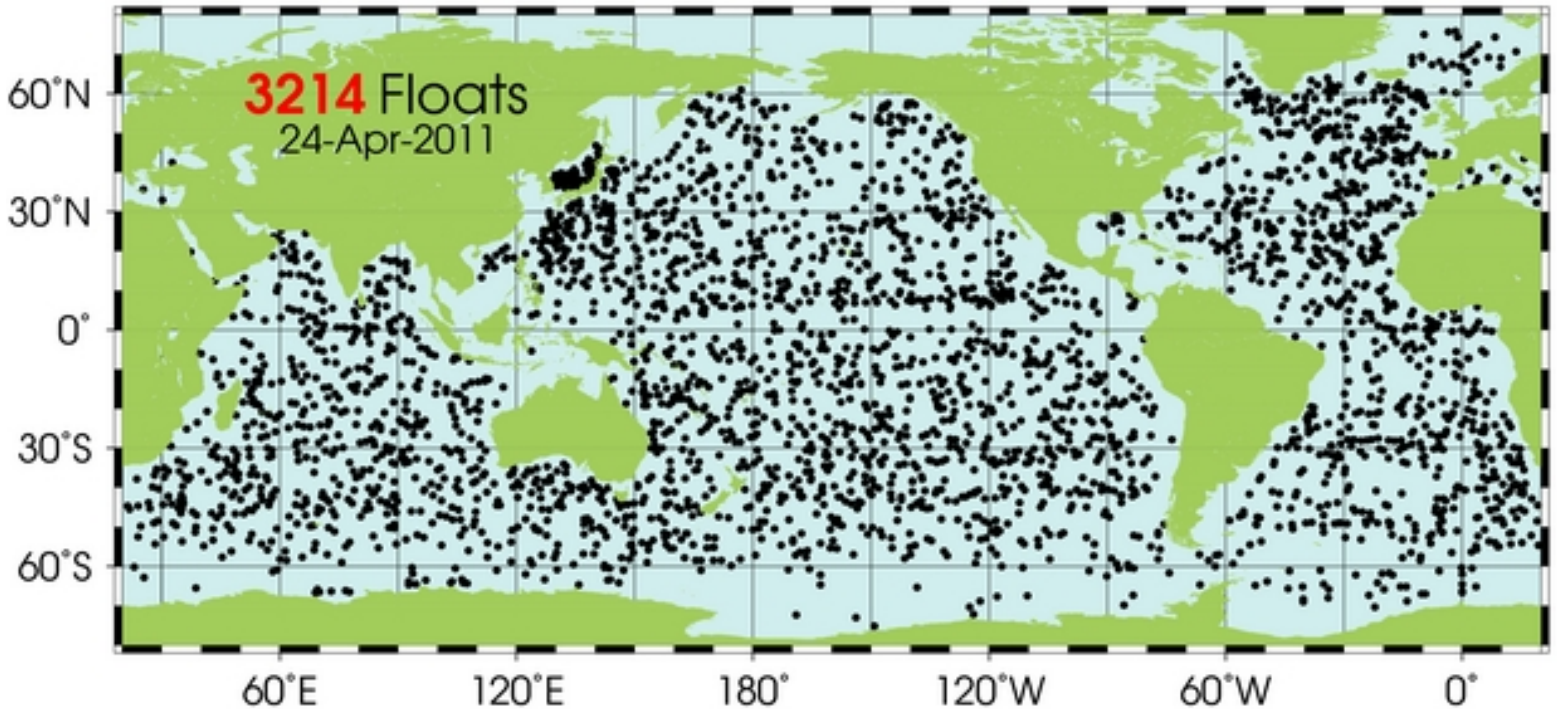
Plasmasphere
Thermosphere
Mesosphere
Ionosphere
Atmosphere
Ring Current
Plasma Sheet
Radiation Belt


Low Energy
CPS
Large-Scale
ULF Waves
Reconnection
Inductive E-Field
BBFs
Inductive E-Field
Plasma Waves
Emergent Processes
Reconnection
Hi Energy
Ring Current
Small-Scale

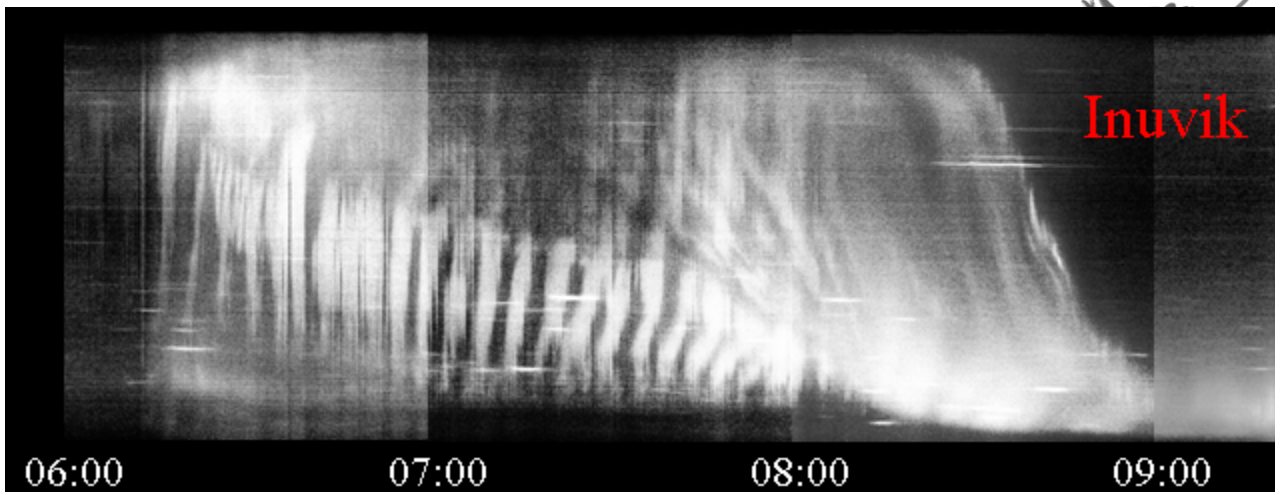
Skynet


Geotail
THEMIS-D
THEMIS-E
THEMIS-A
THEMIS-C
THEMIS-B
Cluster-2
Cluster-3


Hinode
FAST
TRACE
C/NOFS
TIMED
AIM

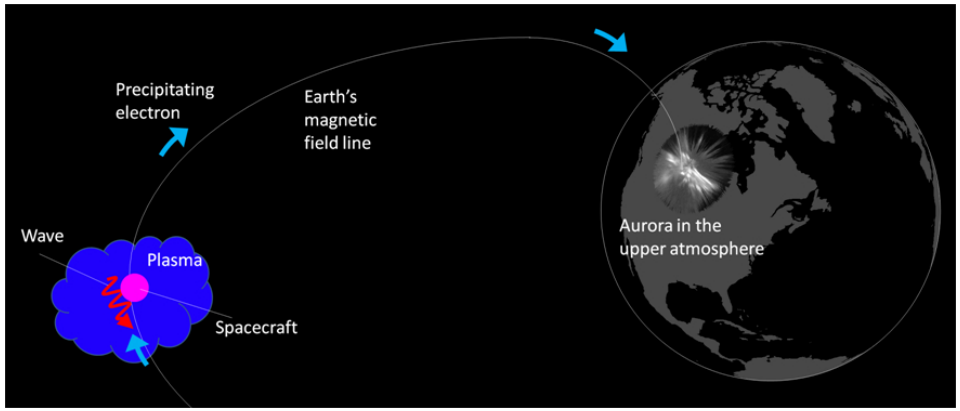


Quantifying the global distribution of auroral brightness, structure, type, e- characteristic energy and energy flux, and motion will be the Geospace equivalent of the ARGO observations… simple, not without problems, but by far our best and most complete way of tracking Geospace dynamics at the system level.

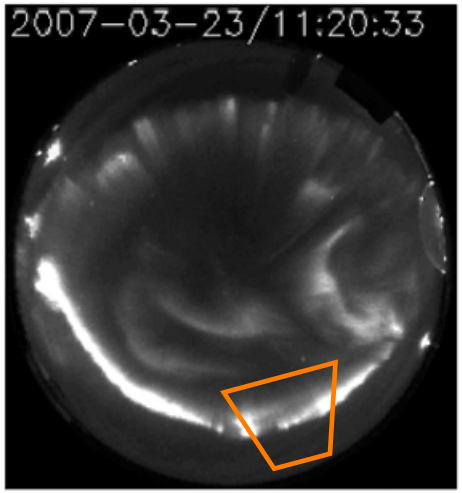


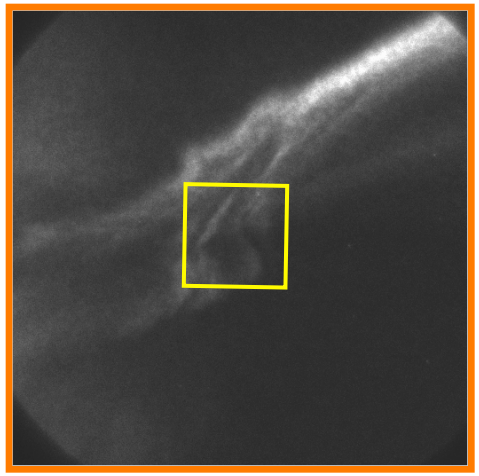
Use ionospheric observations as a way of remote sensing geospace as a whole, and also as a way of studying the ITM "at the system level".

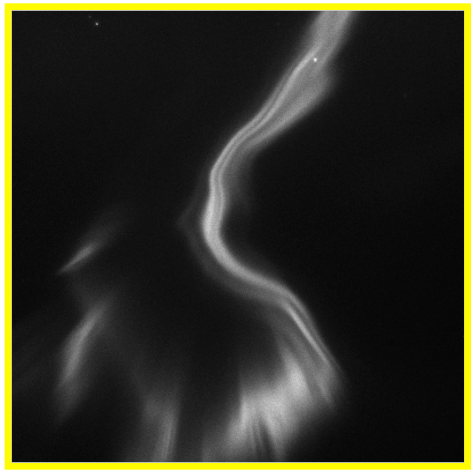
This approach capitalizes on synergy with space science satellites further out in space. The ionospheric remote sensing observations are much more than simply "context" for *in situ* observations.

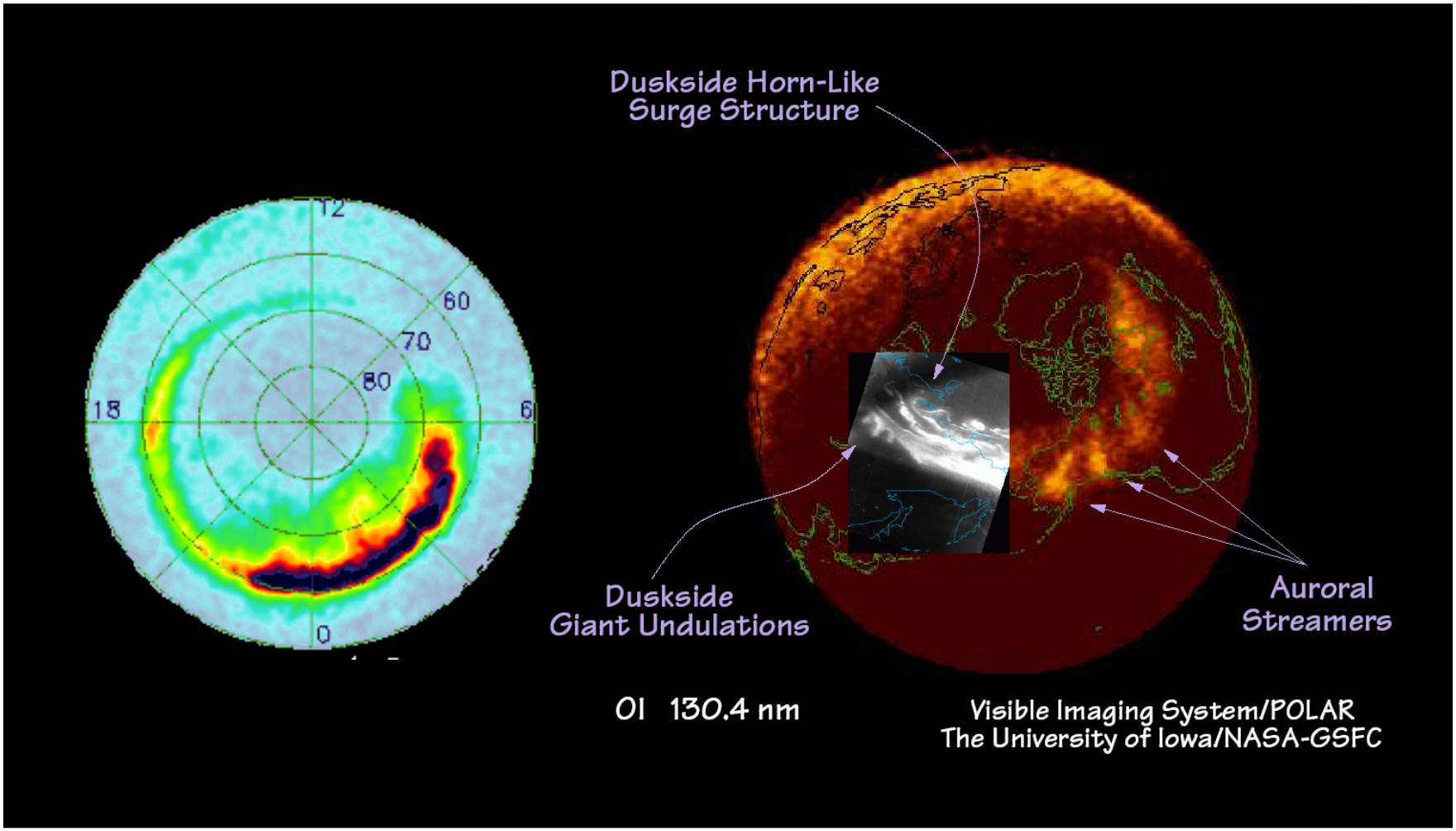


Courtesy: Toshi Nishimura

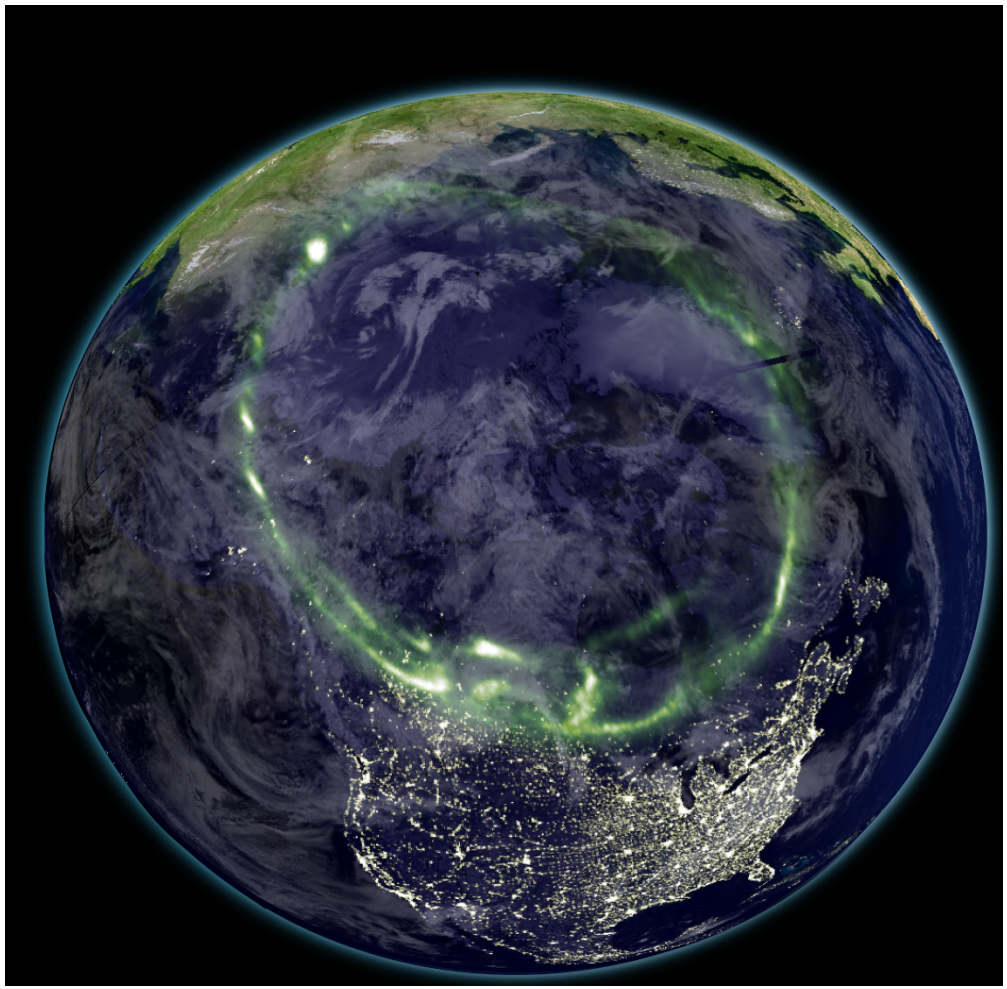

2007-03-23/11:20:33

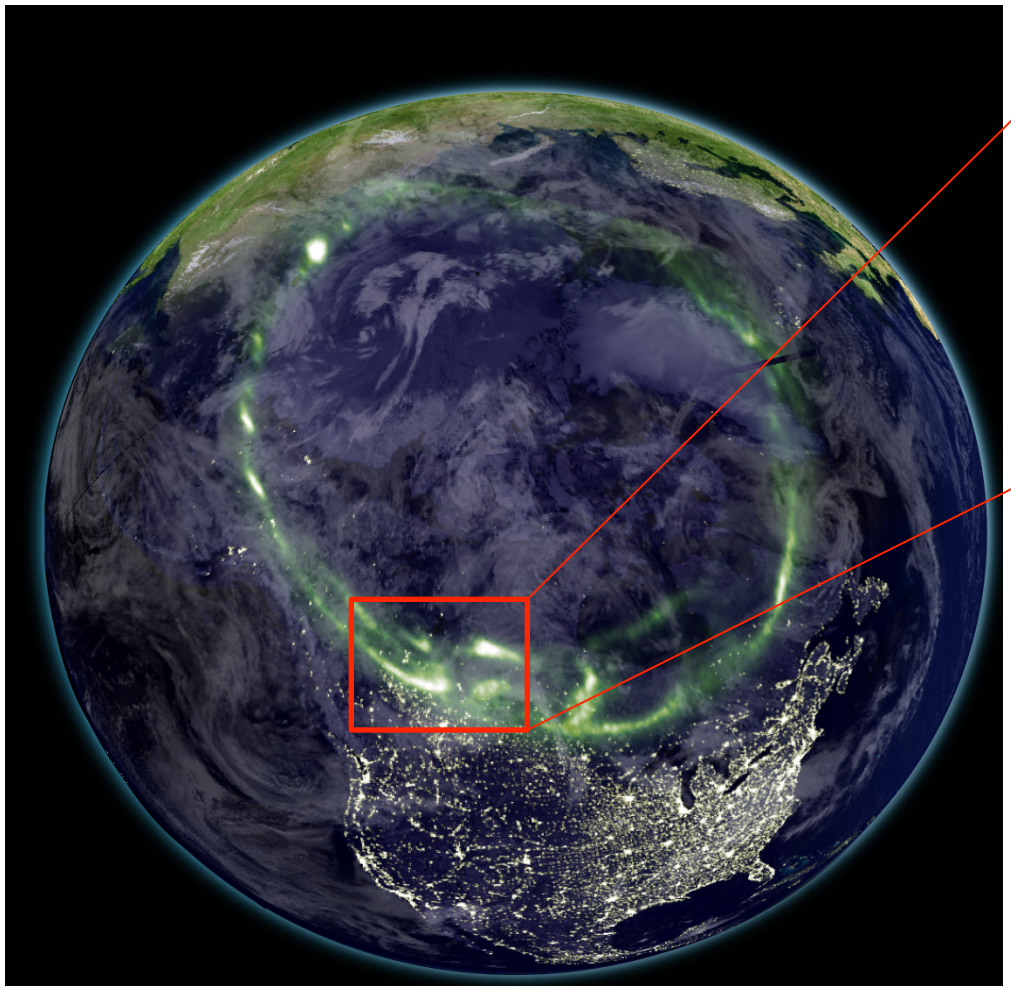




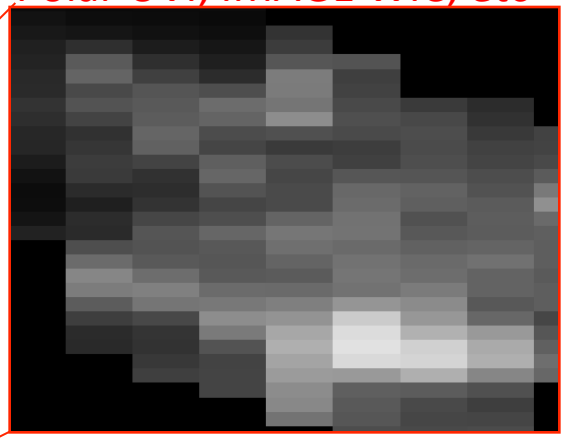

Duskside Horn-Like
Surge Structure
12
60
70
80
18
6
0
Duskside
Giant Undulations
Auroral
Streamers
01 130.4 nm
Visible Imaging System/POLAR
The University of Iowa/NASA-GSFC

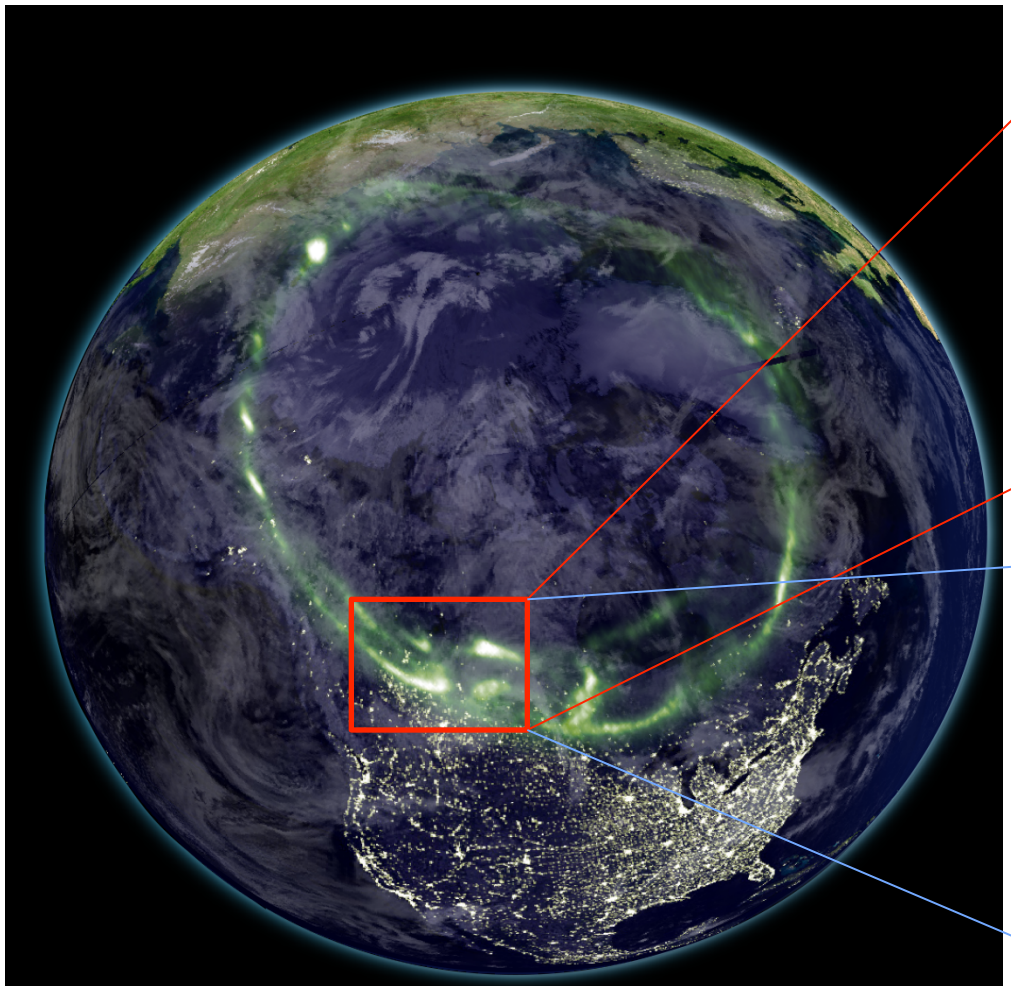
Skynet



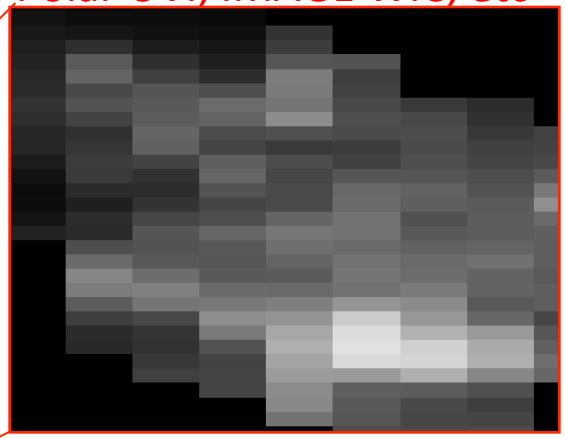


Polar UVI, IMAGE WIC, etc

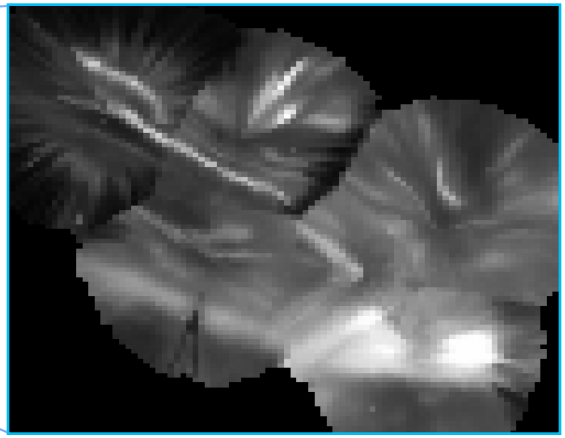




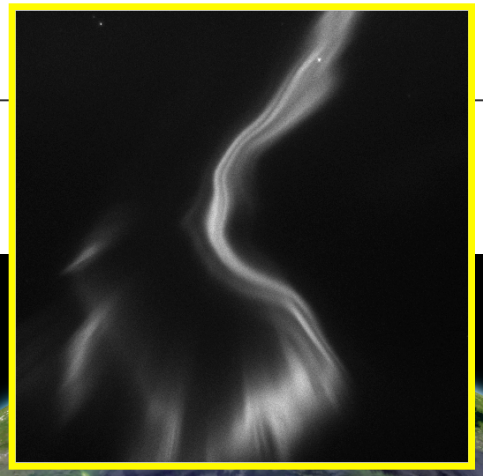
Polar UVI, IMAGE WIC, etc

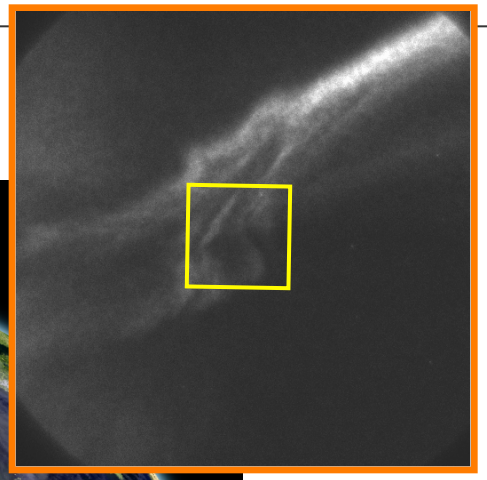


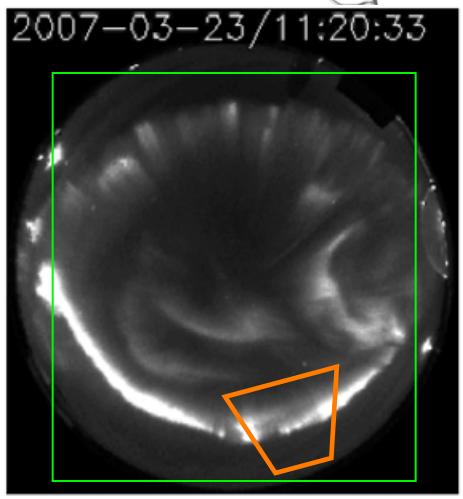
THEMIS-ASI*

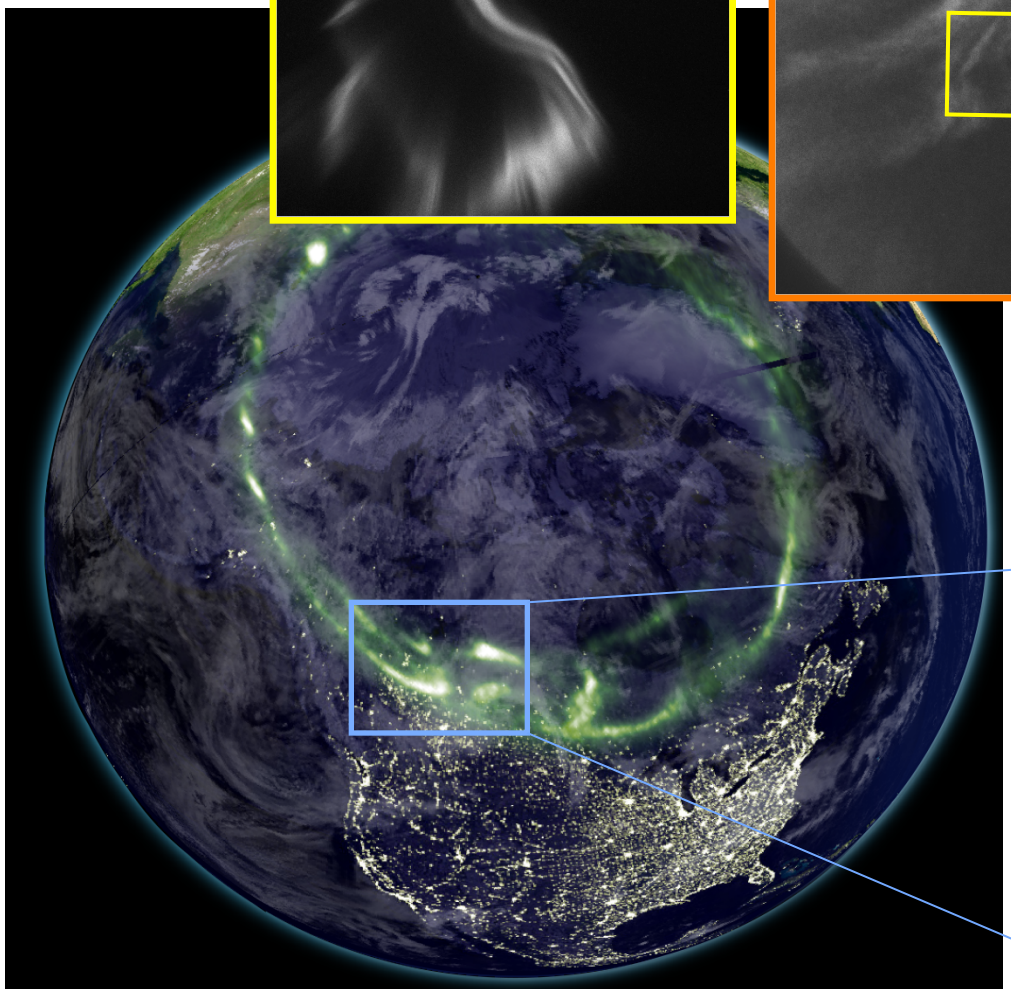


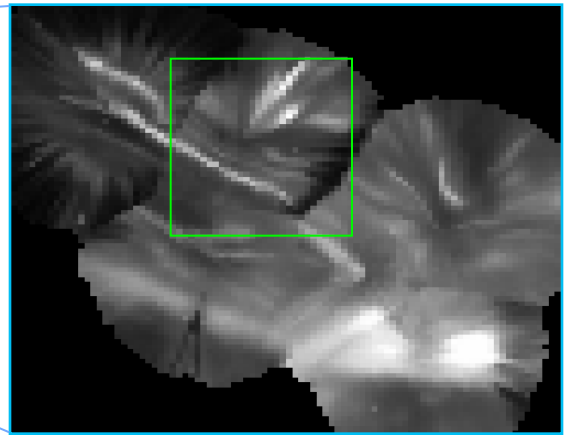
Skynet

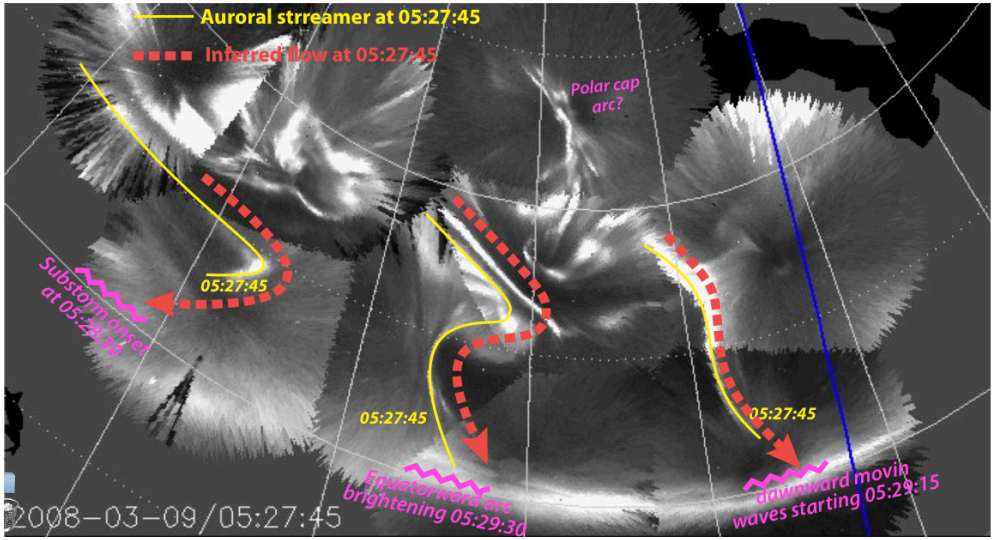


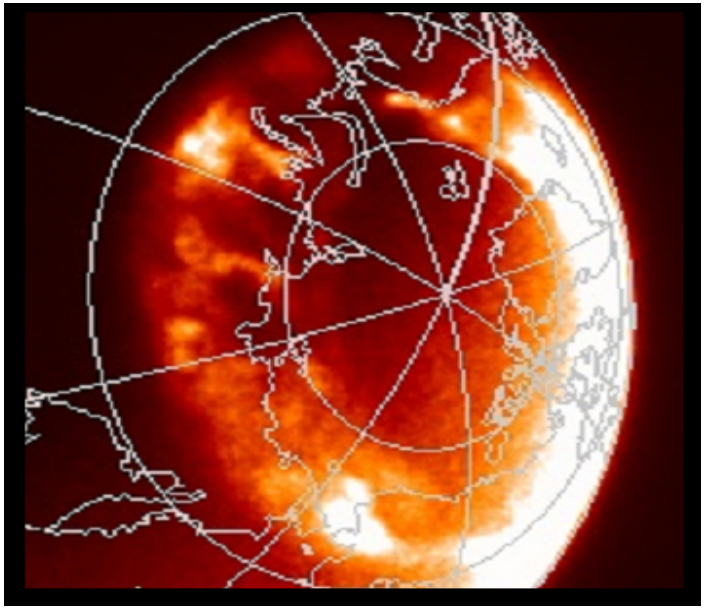









Auroral strreamer at 05:27:45
Inferred flow at 05:27:45
Polar cap arc?
05:27:45
Substorm onset at 05:28:30
05:27:45
05:27:45
Equatorward arc brightening 05:29:30
dawnward movin
waves starting 05:29:15
2008-03-09/05:27:45



Making Connections Across Scales in Geospace

To address important outstanding "mission level" questions in geospace science, we need to recognize that there is an imbalance *at the highest (e.g. programmatic) level* in the way we approach our research.

We spend billions of dollars on experiments that measure plasma properties at a few (well chosen) points (MMS, ISRs).

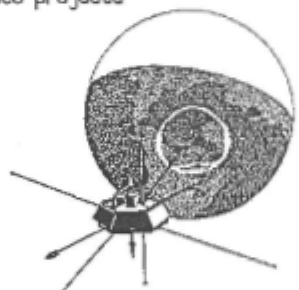
We spend hundreds of millions of dollars on experiments that provide a global view (UV, ENA, SuperDARN, SuperMAG) and there are **none** right now or for the foreseeable future.

We spend millions of dollars (THEMIS-ASI, CGSM, MIRACLE, etc) on observations that bridge the gap between small scales and global scales.

We need to (1) spend hundreds of millions of dollars for global imaging from space and (2) spend hundreds of millions of dollars to bridge the gap in scales between small and global.

CANOPUS

An automatic ground-based instrumentation array to support space projects



Scientific Objectives and System Description

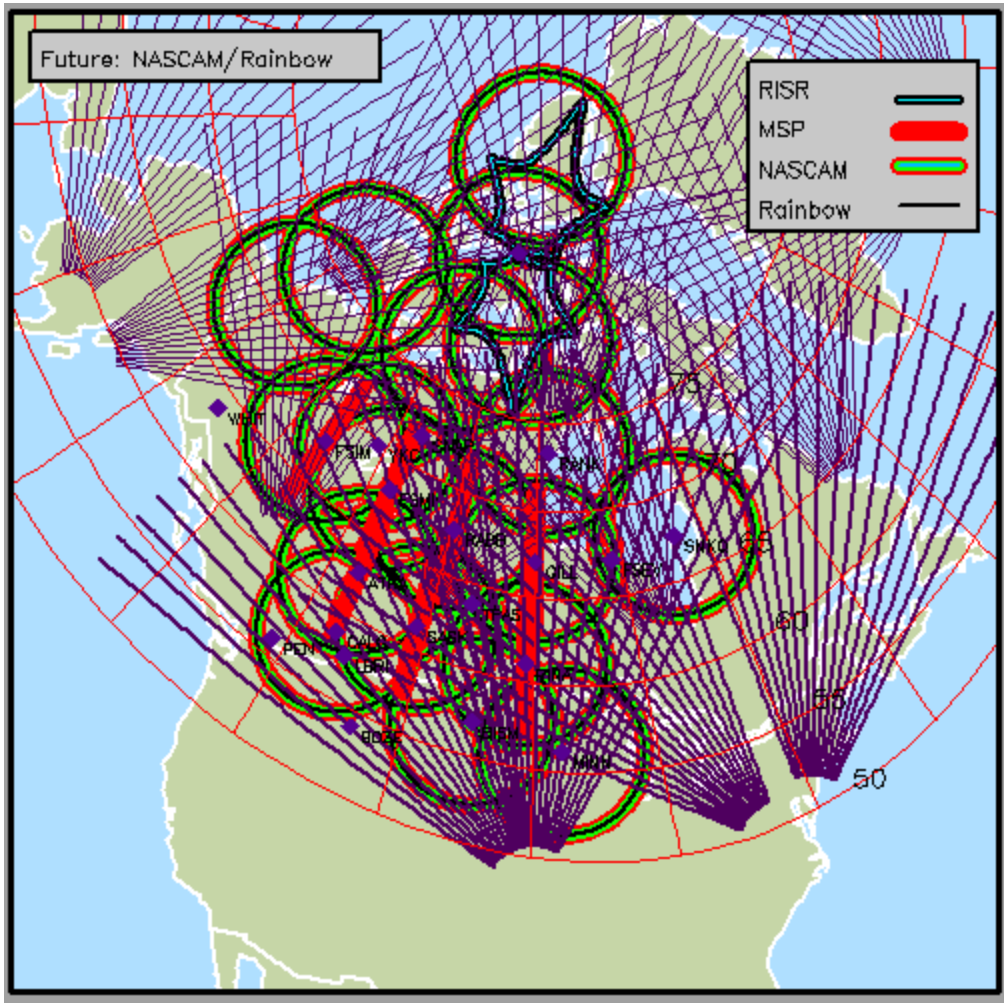
Prepared by the CANOPUS Science Team

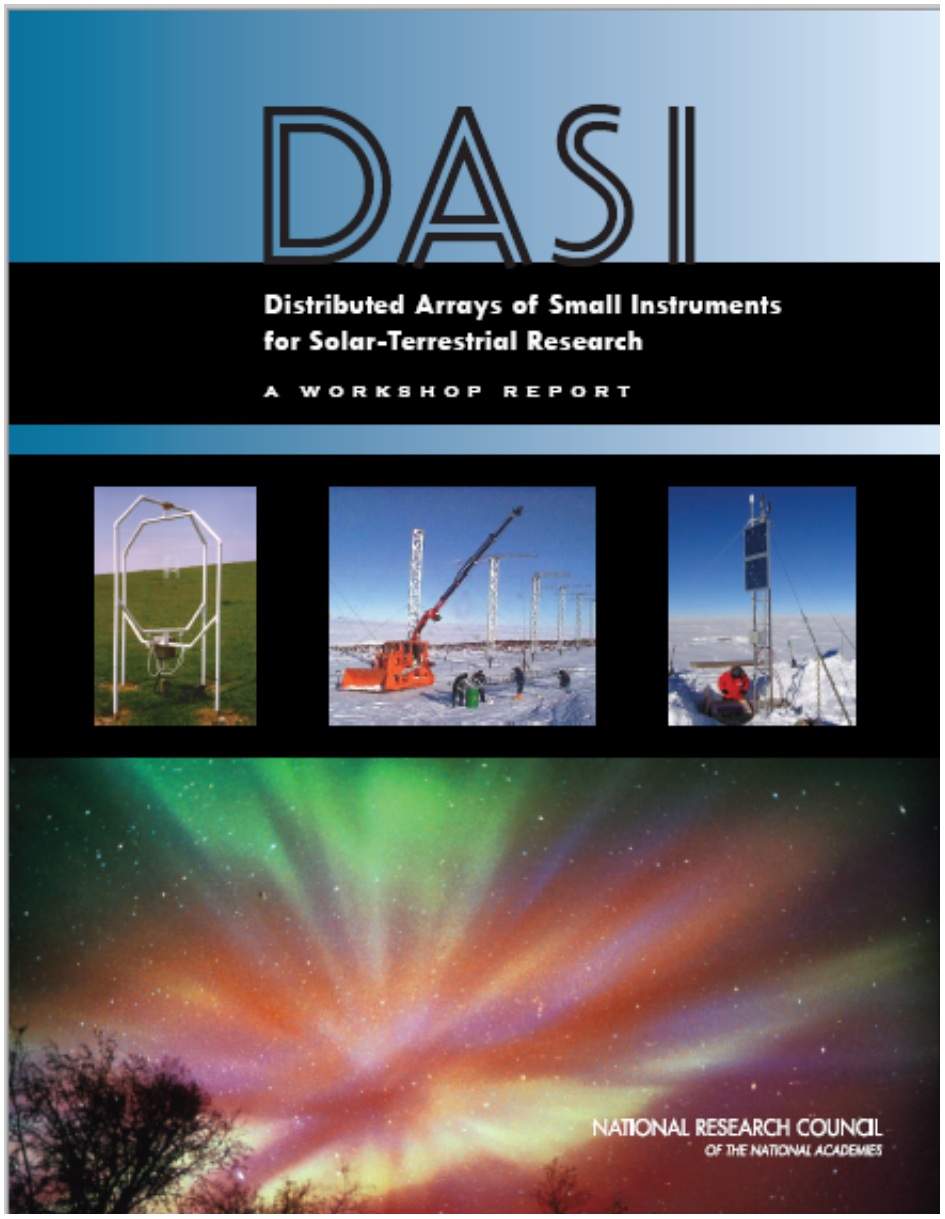
January 1986

Table 1 CANOPUS Stations

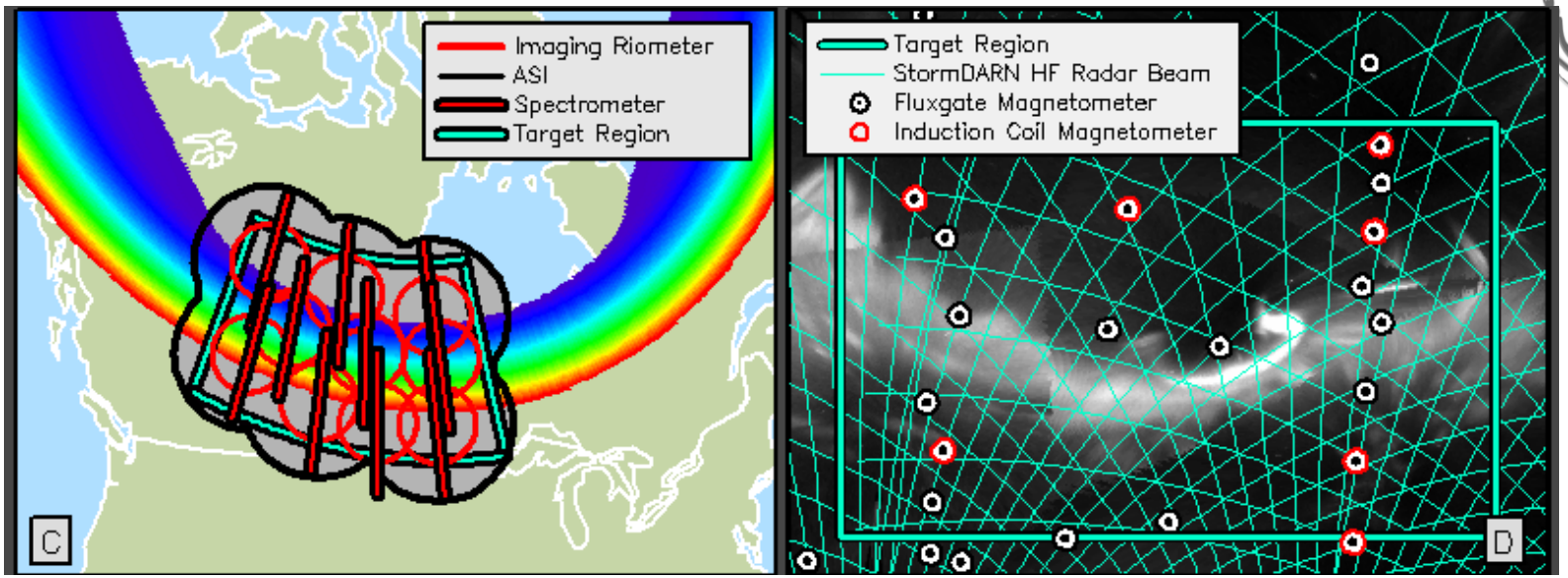
MAP ID	Station	Geographic Coordinates Lat.	Long.	Geomagnetic Latitude EDFL	INV	Site + Instruments
DA	Dawson City	64 04	139 25	67.30	68.42	M
SI	Fort Simpson	61 52	121 23	67.49	67.61	M
CL	Contwoyto L.	65 45	111 14	72.46	73.62	M
FS	Fort Smith	60 01	111 55	65.58	67.05	M,P
MC	Fort McMurray	56 44	111 23	63.29	64.79	M
RA	Rabbit L.	58 12	103 40	65.31	67.67	M
RI	Rankin Inlet	62 49	92 07	70.38	73.54	M,P
EP	Eskimo Point	61 06	94 03	68.63	71.77	M
CM	Churchill	58 44	94 06	66.31	69.57	M,I
BA	Back	57 40	94 04	65.18	68.49	M
GI	Gillam	56 22	94 42	63.87	67.18	M,P,I
IL	Island L.	53 51	94 40	61.38	64.75	M
PI	Pinawa	50 09	95 53	57.68	60.95	M,P
NI	Nipiwan	53 25	104 02	60.51	62.90	R
RL	Red L.	60 54	93 28	58.51	61.98	R

MM = Magnetometer, riometer, tellurics (MARIA)
P = Meridian scanning photometer (MSPA)
I = All Sky Imager (ASI)
R = Bistatic Auroral Radar (BARS)


Future: NASCAM/Rainbow
RISR
MSP
NASCAM
Rainbow
80
70
60
50


DASI
Distributed Arrays of Small Instruments
for Solar-Terrestrial Research
A WORKSHOP REPORT
NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

Skynet

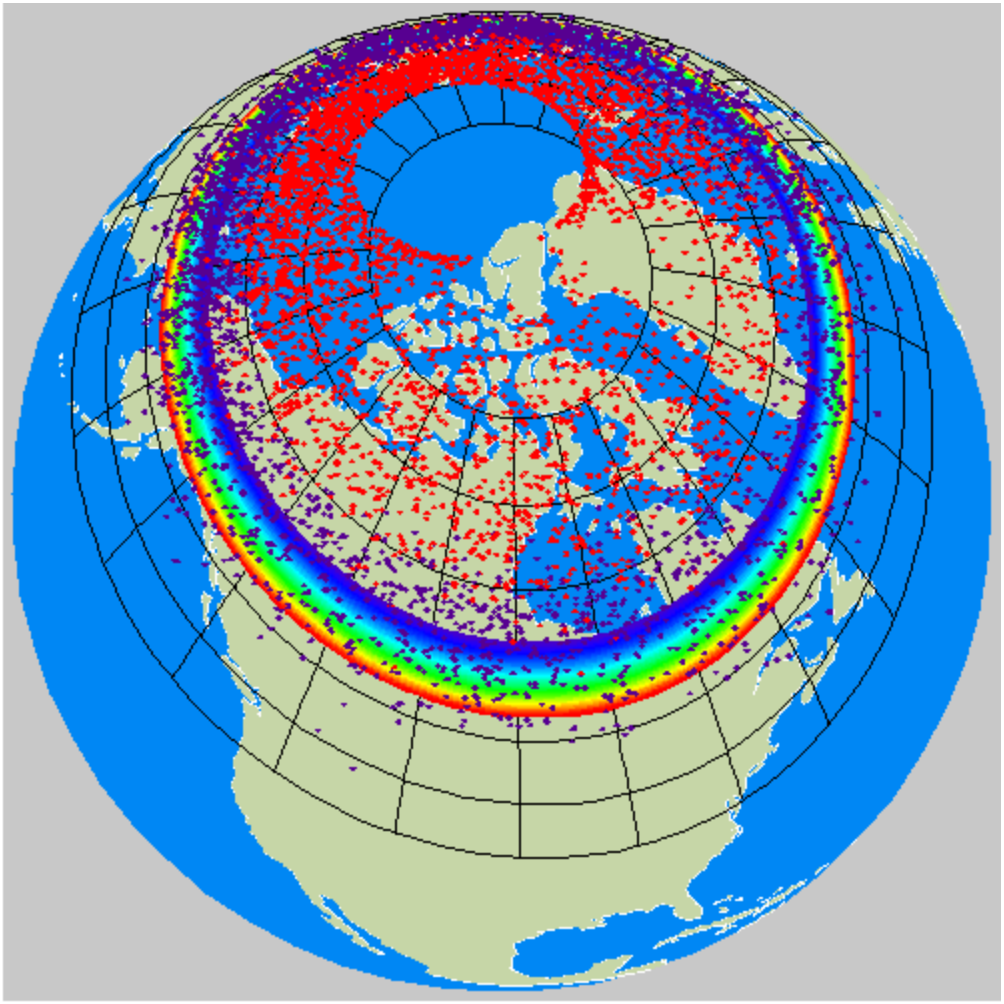


Add instruments to achieve <u>comprehensive</u> observations of precipitation, waves, convection, and B (current) across this target region with large enough coverage to e.g. bracket streamers and their consequences or to place the beginning of DEI in the context of other mesoscale processes (beads, streamers, pulsations, "wedgelets", etc..)

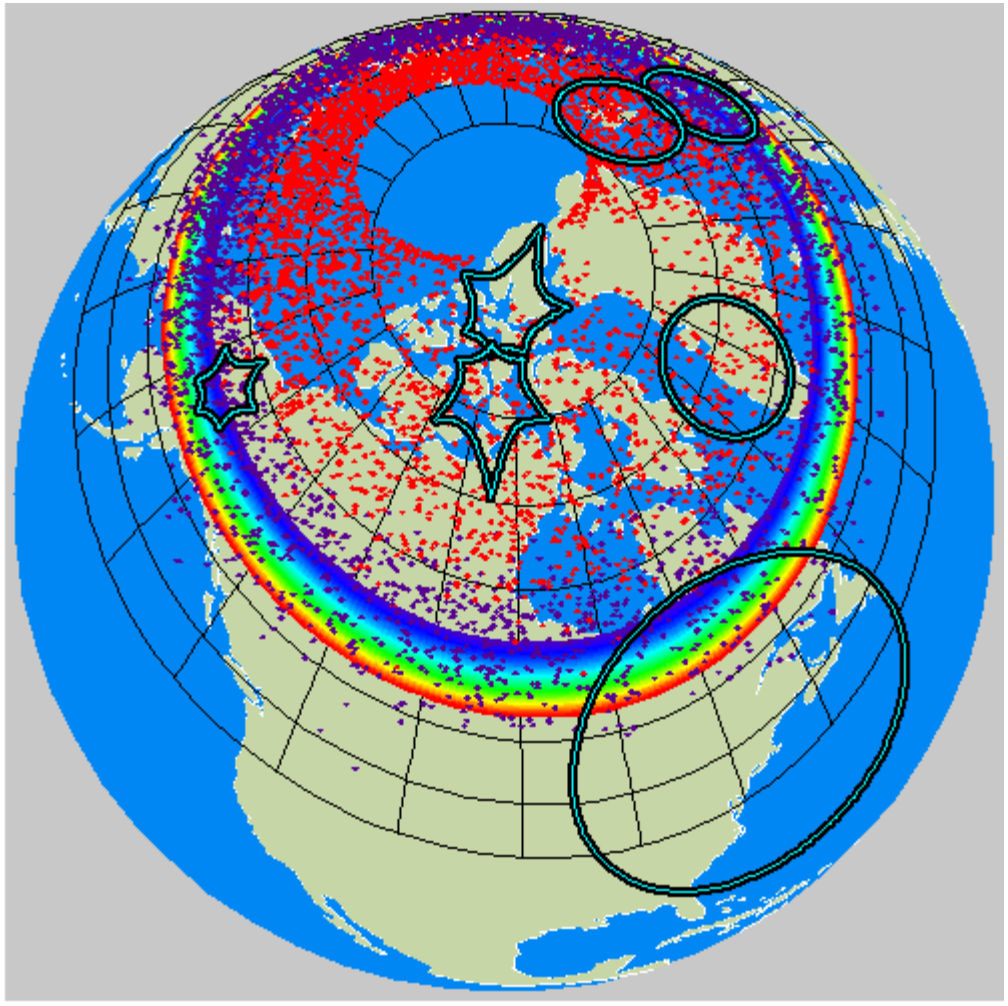
1 Hz Imaging riometers (6 app. + 4 prop.)
Meridian Imaging Spectrographs (10 second)
30 Hz/ 10 Hz white-light/greenline ASIs

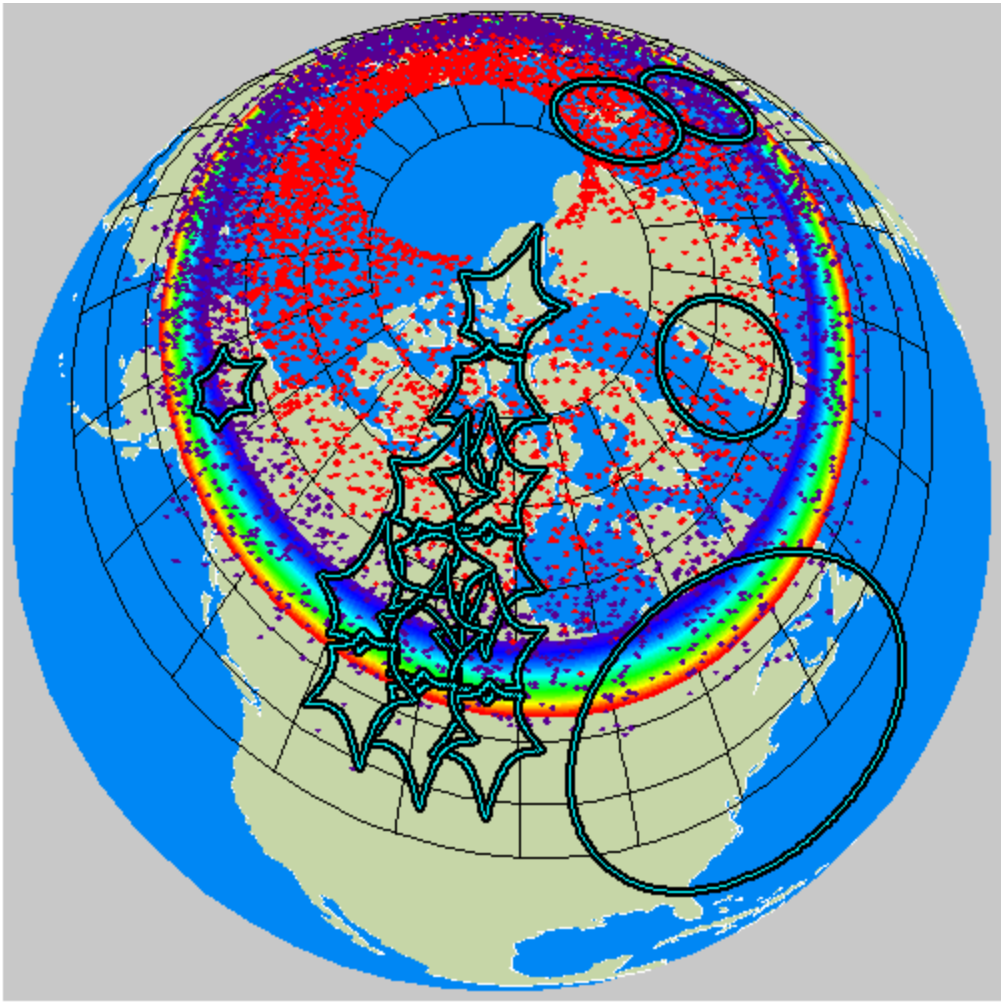
THEMIS ASIs
StormDARN
Redline ASIs
Induction Coils
VLF Receivers
Fluxgates

Skynet



North American and European ISRs Now

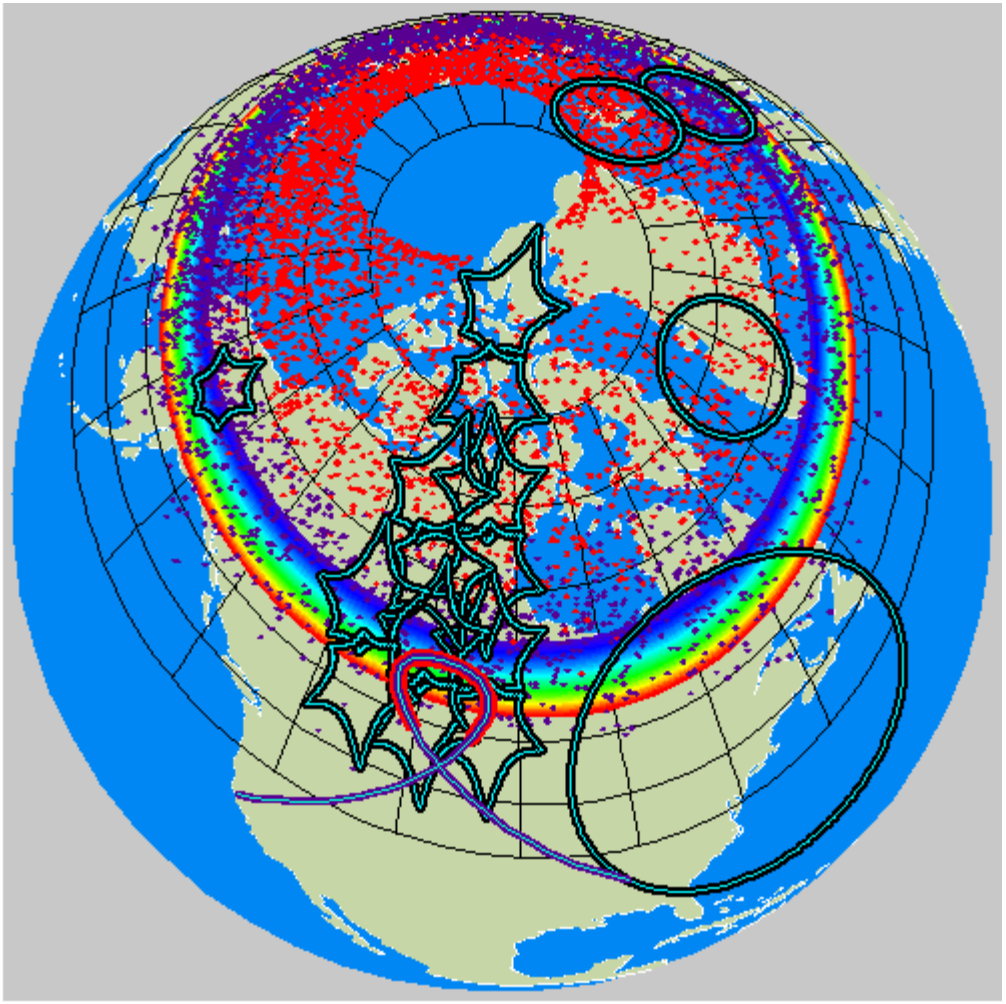




ISR-Net: 10 or more ISRs

One could envision other ISR-Nets such as equatorial, Africa, etc….

This ISR-Net couples strongly to existing instrumentation, NASA, CSA, JAXA etc. missions and the space weather interests of Canada and the US.

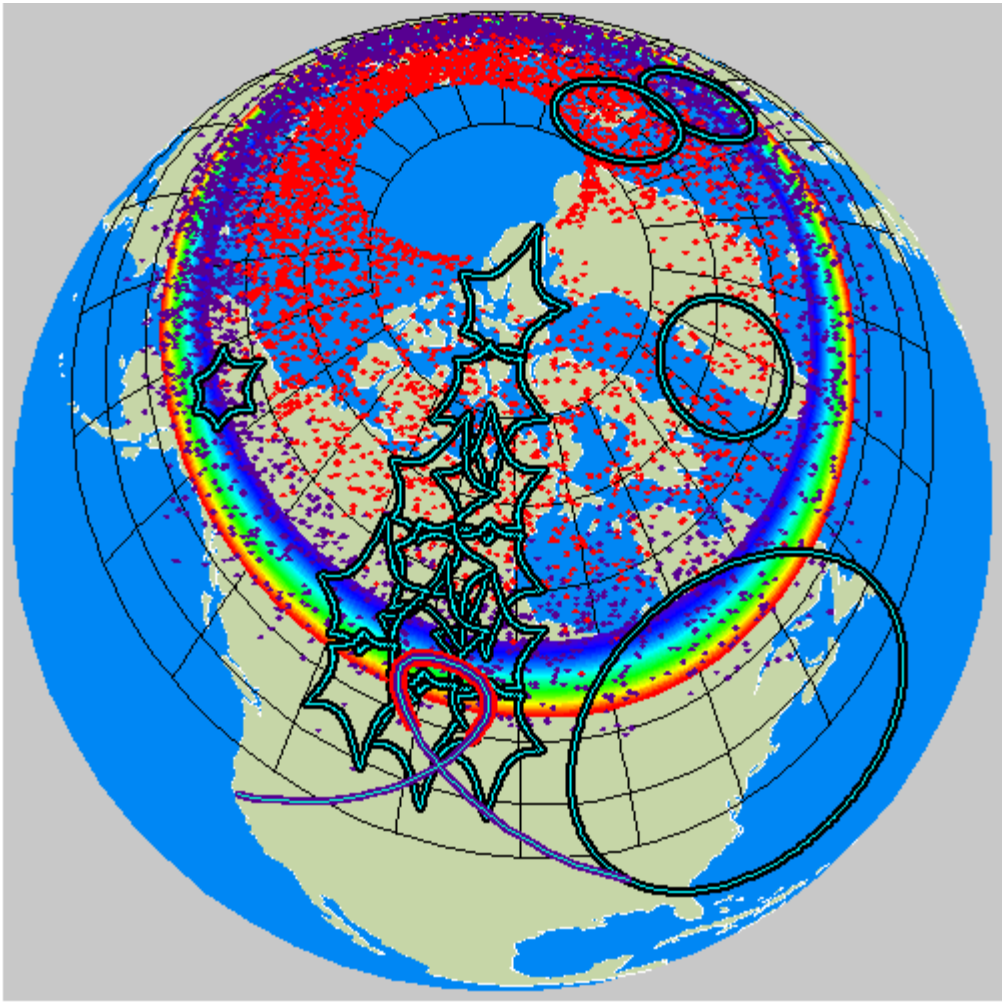


ISR-Net: 10 or more ISRs

Enables all of:

- Complexity
- Cross-Scale Coupling
- Driving From Below
- Driving From Above

Requires development of Sensor Web, Stream Computing, and Data Mining technologies.



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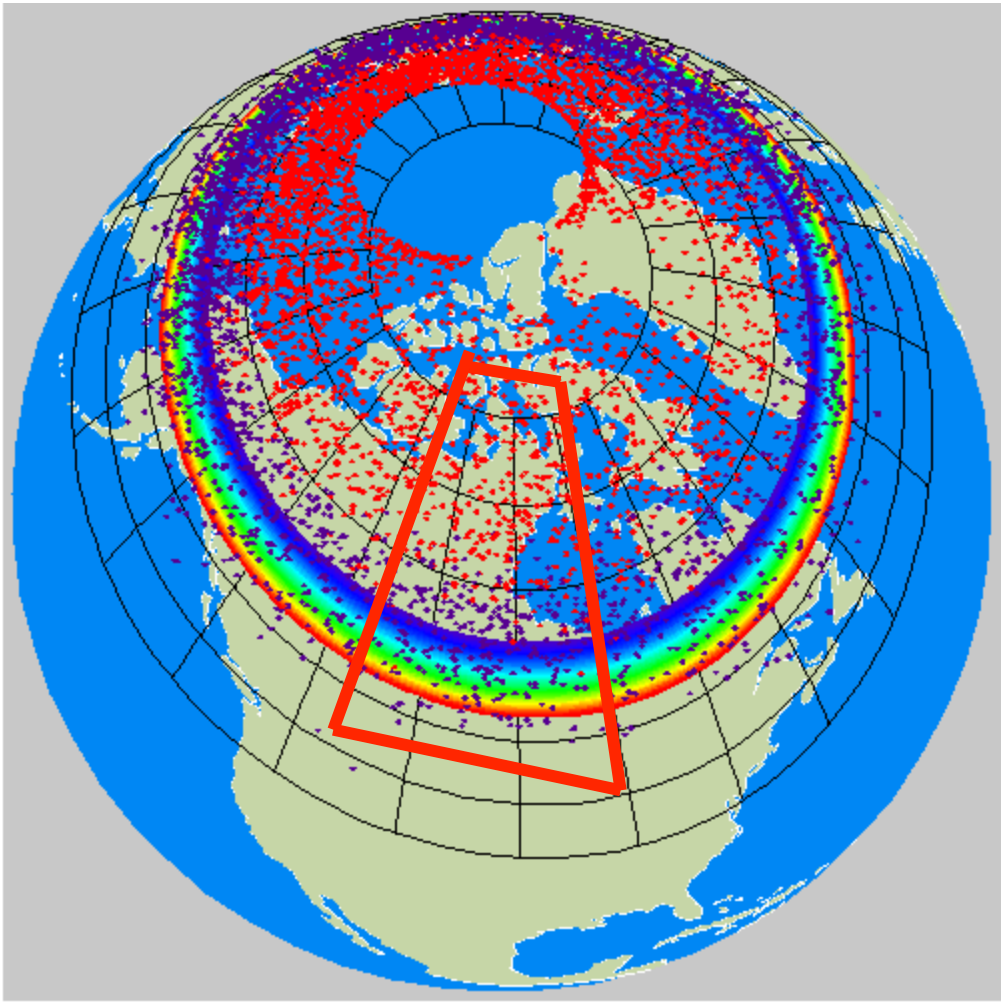
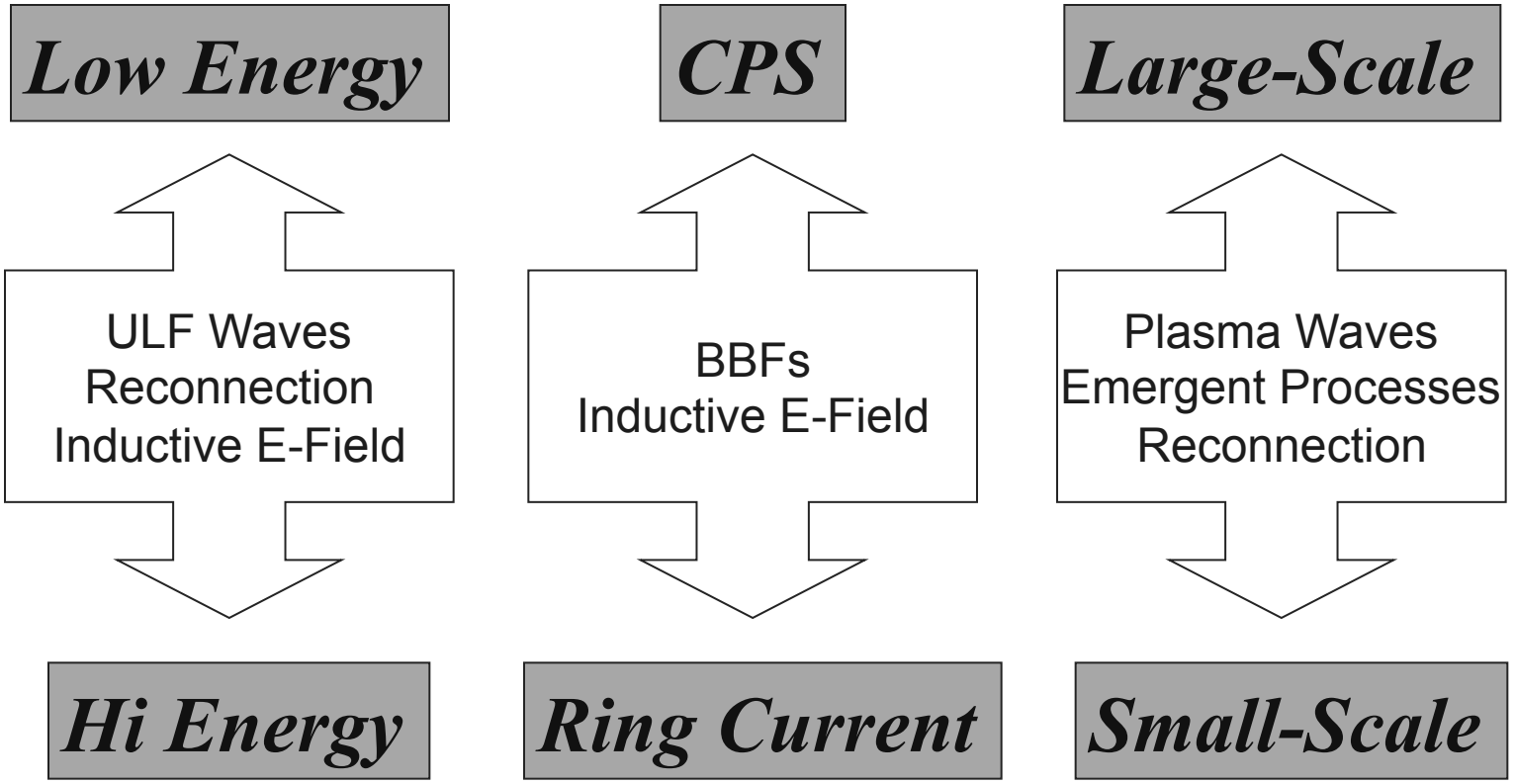


Specify some high-level science objectives

Determine the extent and location to be “imaged”

Identify the parameters, resolutions, cadence, duration etc necessary to enable science closure


Low Energy
CPS
Large-Scale
ULF Waves
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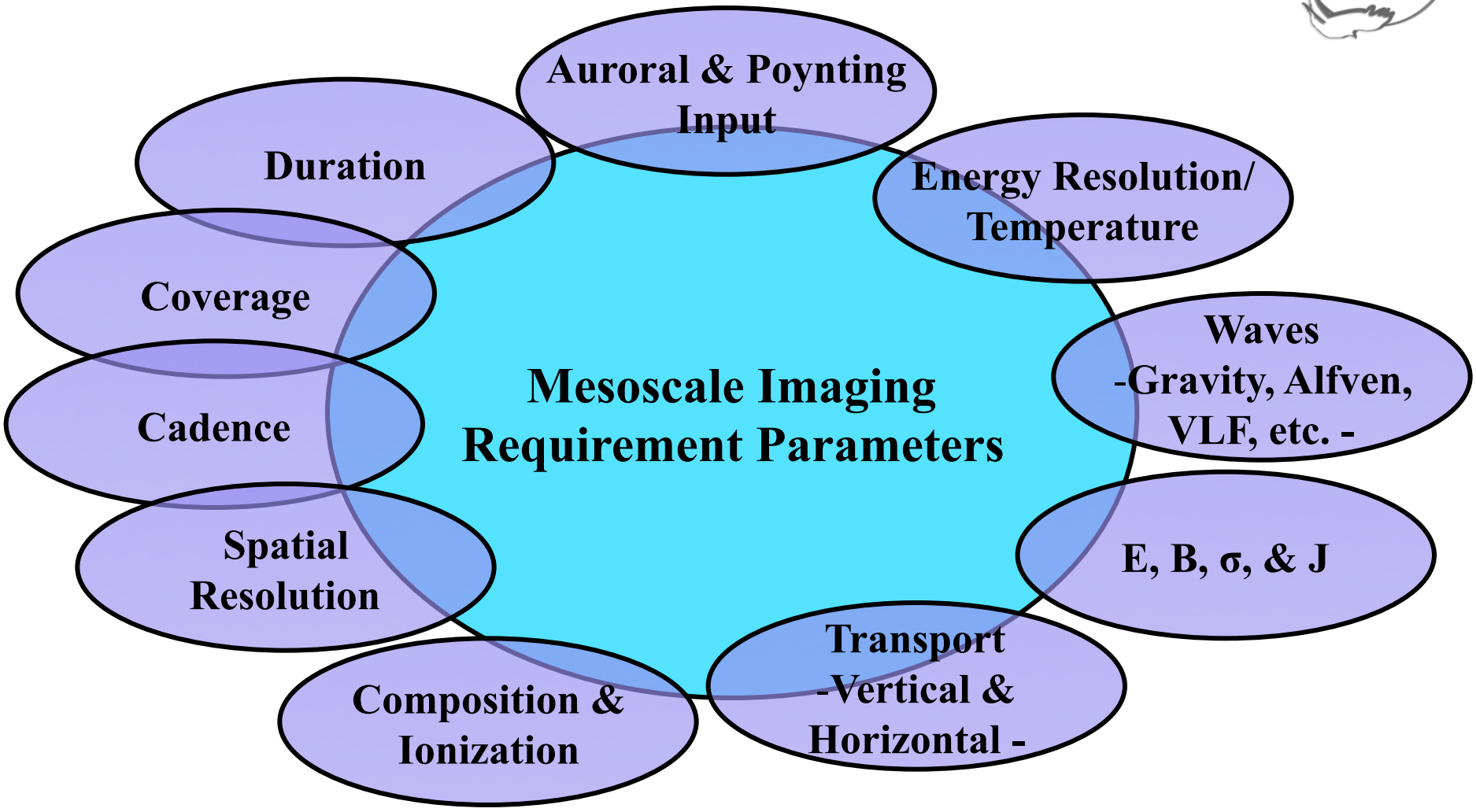
Hi Energy
Ring Current
Small-Scale


Auroral & Poynting Input
Duration
Energy Resolution/ Temperature
Coverage
Waves -Gravity, Alfven, VLF, etc. -
Cadence
Mesoscale Imaging Requirement Parameters
Spatial Resolution
E, B, σ, & J
Transport -Vertical & Horizontal -
Composition & Ionization

A "Mission-Level" Ground-Based Geospace Initiative

Be bold – imagine that we can do this if we develop the right vision (the right "mission level" questions), establish the right partnerships, and innovate technologically.

At $350M, this ground-based geospace project would be similar to the Canadian-led Ocean Tracking Network ($350M), the NSF MREFC funded Ocean Observing Initiative (>$200M), and would enable profound steps forward scientifically.

Done right, the science and applied payoff would exceed that of a typical NASA Explorer class mission.