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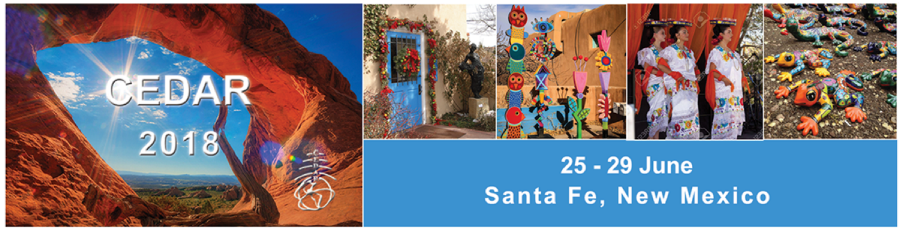
Polar region magnetometer review and future
- CEDAR Summer Workshop 2018

Zhonghua Xu, Michael Hartinger, Robert Clauer, Daniel Weimer

with contributions from M. Engebretson, E. Zesta, A. Gerrard, H. Kim, V. Eccles and others

This work supported by NSF PLR-1543364



Outline

- Overview of current magnetometer observations in polar regions
- Importance of magnetometer observations
- Future plans and ideas for collaboration

Overview of current magnetometer observations in polar regions

- What is a magnetometer?
- How many magnetometers?
- How to access data?

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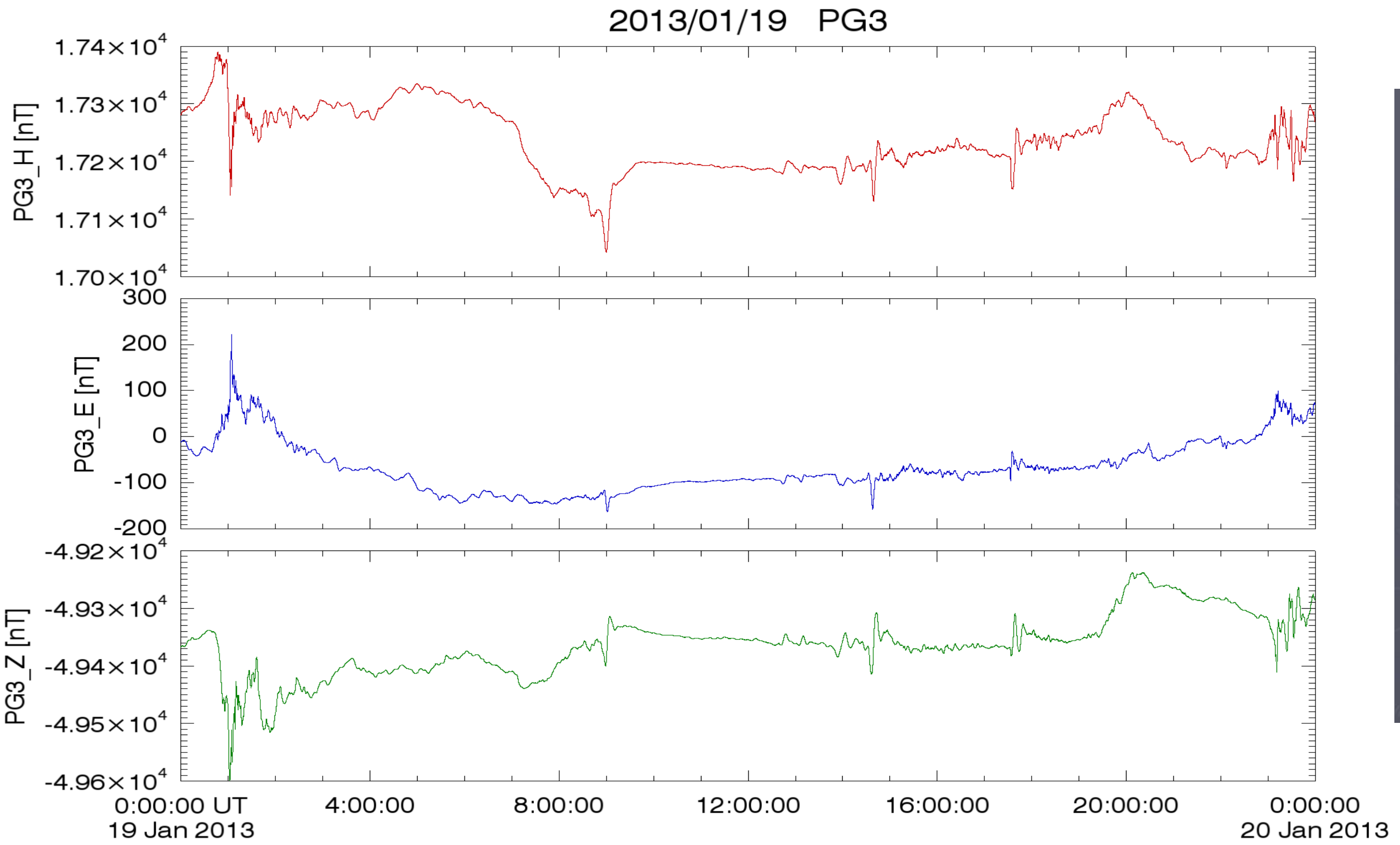
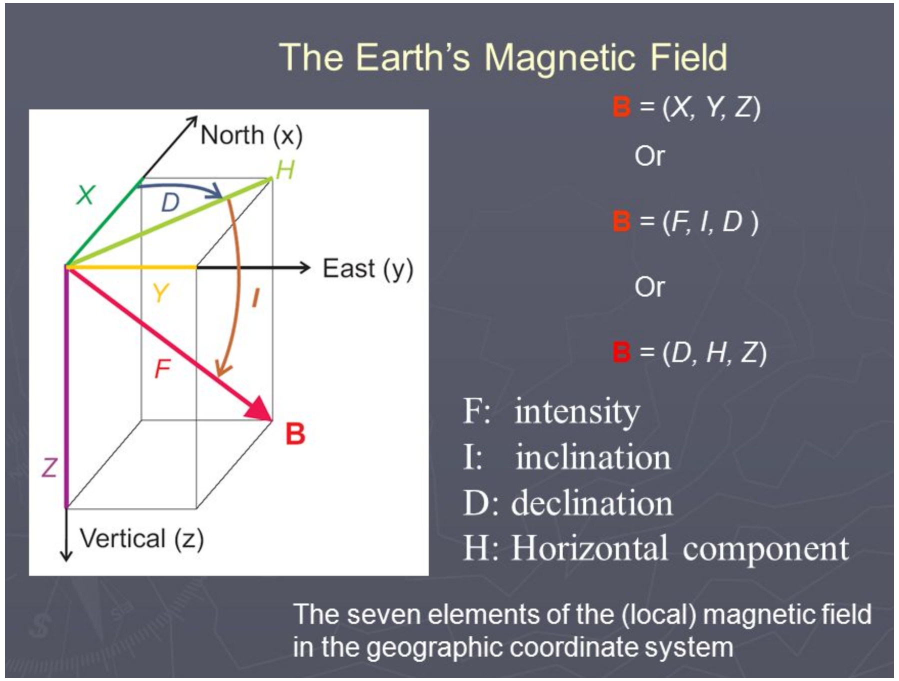
Autonomous Adaptive Low-Power Instrument Platform

Fluxgate magnetometer

Search coil (induction) magnetometer

Summary plots for inter-hemispheric comparisons: High resolution (1s) data





- Daily summary plots for individual fluxgate magnetometers already available on MIST website (http://mist.nianet.org)

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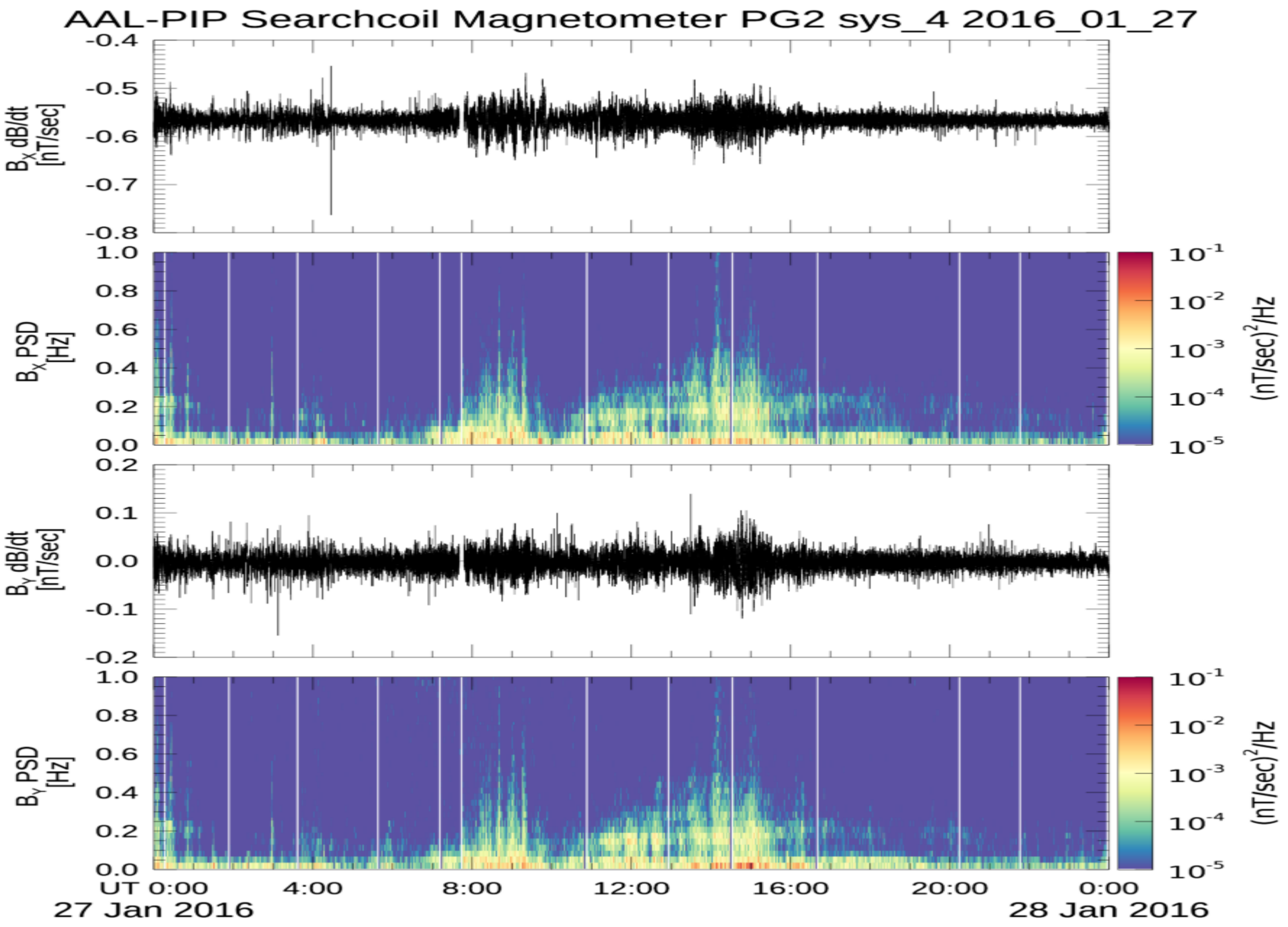
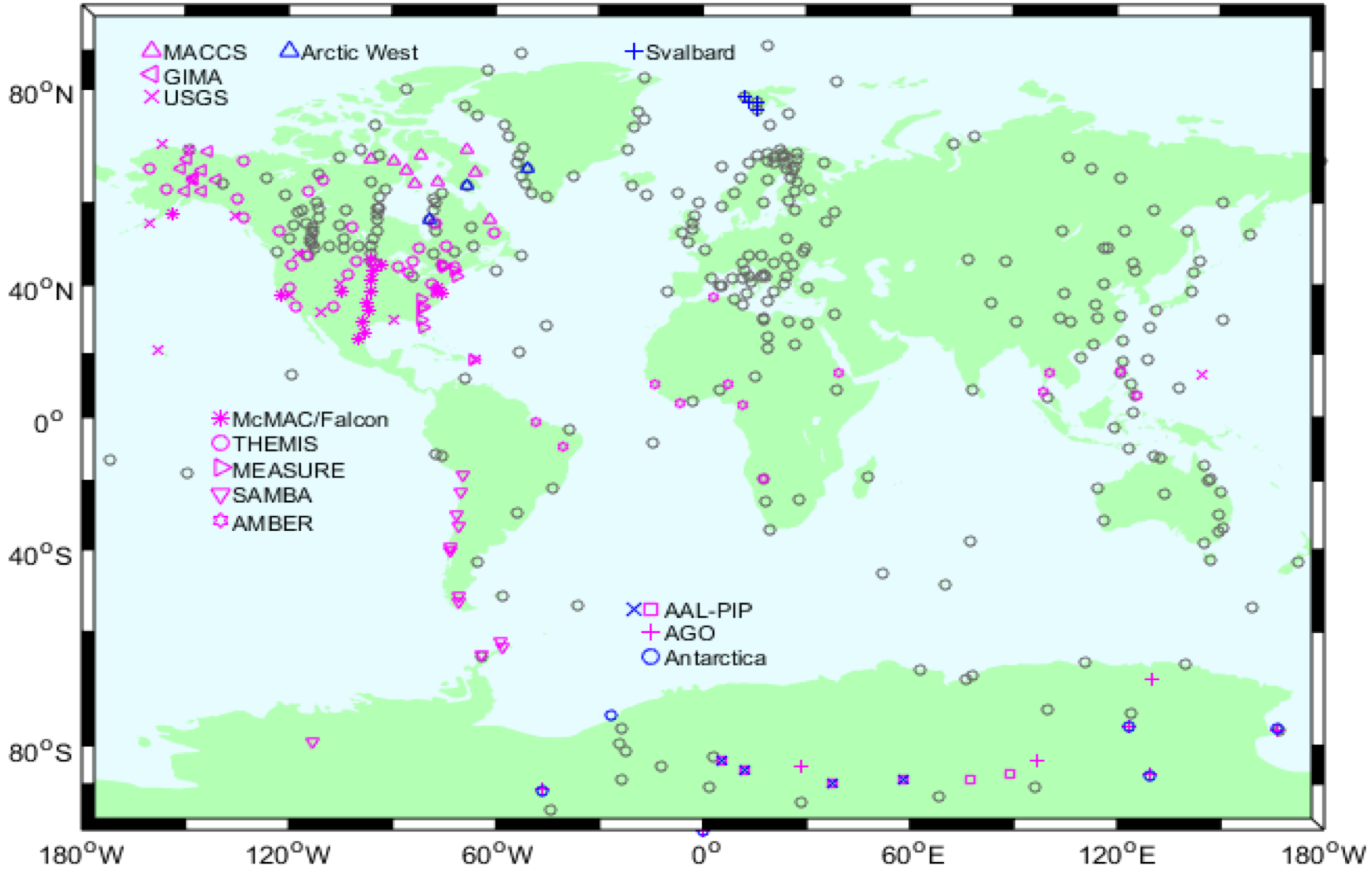
Summary plots: Induction Magnetometer



- Daily summary plots for individual induction magnetometers already available on MIST website (http://mist.nianet.org)

Overview of current magnetometers in polar regions



Courtesy of V. Eccles and M. Engebretson

Conjugate Fluxgate magnetometer

PG5	5.71	-81.96	37.03	-69.51	Antartica	Virginia Tech
PG4	12.25	-83.34	36.17	-70.90	Antartica	Virginia Tech
PG3	37.62	-84.81	37.95	-73.43	Antartica	Virginia Tech
PG2	57.96	-84.42	39.07	-75.24	Antartica	Virginia Tech
PG1	77.20	-84.50	33.68	-76.55	Antartica	Virginia Tech
PG0	88.68	-83.67	38.35	-78.48	Antartica	Virginia Tech
ZHS	76.38	-69.37	96.59	-74.63	Zhongshan Station	Polar Research Institute of China
ZK1	77.98	-71.93	89.60	-76.23	ZK1	PRIC
ZK2	77.02	-74.58	79.22	-79.68	ZK2	PRIC
ZK3	76.96	-77.26	69.12	-77.54	ZK3	PRIC
DMA	77.54	-80.37	54.47	-77.81	Dome A	PRIC
DAV	77.97	-68.58	101.69	-74.77	Davis, Antarctica	Australian Antarctic Division
MAW	62.87	-67.60	91.42	-70.52	Mawson, Antarctica	AAD
CSY	110.53	-66.28	156.79	-8.74	Casey, Antarctica	AAD
MCQ	158.95	-54.50	-119.91	-64.48	Macquarie Island	AAD
P01	129.61	-83.86	17.33	-80.34	AGO P1	AGO
P02	-46.40	-85.70	19.70	-70.20	AGO P2	AGO
P03	28.60	-82.80	40.70	-72.20	AGO P3	AGO
P04	96.80	-82.00	42.20	-80.30	AGO P4	AGO
P05	123.52	-77.20	28.60	-87.10	AGO P5	AGO
SPA	0.00	-90.00	19.56	-74.19	South Pole Station	PENGUIN
MCM	166.70	-77.90	326.50	-80.00	McMurdo	PENGUIN
SBA	166.78	-77.85	326.66	-79.91	Scott Base	New Zealand
B03	291.88	-67.57	8.27	-53.14	m67-292	BAS
B11	336.58	-77.51	30.69	-63.96	m78-337	BAS
B12	335.88	-79.08	29.67	-65.15	m79-336	BAS
B14	337.74	-80.89	29.35	-66.70	m81-338	BAS
B16	347.06	-82.78	30.73	-68.71	m83-347	BAS
B18	336.14	-84.35	26.33	-69.45	m84-336	BAS
B19	2.06	-85.36	30.41	-71.39	m85-002	BAS
B21	28.41	-87.00	29.34	-73.53	m87-028	BAS
B22	68.17	-86.51	31.00	-75.62	m87-068	BAS
B23	316.13	-88.03	20.41	-72.34	m88-316	BAS
HAL	333.70	-75.60	29.80	-62.20	Halley Bay	BAS

THL	290.77	77.47	29.24	84.72	Qaanag	DTUSpace
SVS	294.90	76.02	32.87	83.00	Savissivik	DTUSpace
KUV	302.82	74.57	41.92	80.69	Kullorsuaq	DTUSpace
UPN	303.85	72.78	40.20	78.93	Upernavik	DTUSpace
UMQ	307.87	70.68	42.58	76.38	Uummannaq	DTUSpace
GDH	306.47	69.25	39.39	75.25	Godhavn	DTUSpace
ATU	306.43	67.93	38.19	73.99	Attu	DTUSpace
STF	309.28	67.02	40.87	72.64	Kangerlussuaq	DTUSpace
SKT	307.10	65.42	37.22	71.43	Maniitsoq	DTUSpace
GHB	308.27	64.17	37.85	69.98	Nuuk	DTUSpace
FHB	310.32	62.00	39.05	67.41	Paamiut	DTUSpace
NAQ	314.56	61.16	43.19	65.75	Narssarssuaq	DTUSpace
BFE	11.67	55.63	89.41	52.09	Brorfelde	DTUSpace
ROE	8.55	55.17	86.66	51.70	Rømø	DTUSpace
NAL	11.93	78.92	110.98	76.26	Ny Ålesund	Tromsø Geophysical Observatory
LYB	15.83	78.20	111.88	75.31	Longyearbyen	Tromsø Geophysical Observatory
HOP	25.01	76.51	115.01	73.12	Hopen	Tromsø Geophysical Observatory
BJN	19.00	74.50	107.76	71.52	Bjørnøya	Tromsø Geophysical Observatory
NOR	25.79	71.09	108.93	67.87	Nordkapp	Tromsø Geophysical Observatory
JAN	351.30	70.90	82.93	70.29	Jan Mayen	Tromsø Geophysical Observatory
SOR	22.22	70.54	106.08	67.40	Sørøya	Tromsø Geophysical Observatory
TRO	18.94	69.66	102.79	66.69	Tromsø	Tromsø Geophysical Observatory
AND	16.03	69.30	100.23	66.49	Andenes	Tromsø Geophysical Observatory
DON	12.50	66.11			Dønna	Tromsø Geophysical Observatory
RVK	10.99	64.95	93.18	62.28	Rørvik	Tromsø Geophysical Observatory
DOB	9.11	62.07	90.05	59.32	Dombås	Tromsø Geophysical Observatory
SOL	4.84	61.08	86.12	58.53	Solund	Tromsø Geophysical Observatory
KAR	5.24	59.21	85.55	56.43	Karmøy	Tromsø Geophysical Observatory
IQA	291.48	63.75	15.58	72.21	Iqaluit	CANMOS
LYR	15.83	78.20	111.03	75.64	Longyearbyen	TROMSOE, this from SuperMAG
YRS	11.90	78.90	110.07	76.38	Yellow River Station	PRIC
SOD	26.63	67.37	106.80	64.10	Sodankylä	Sodankylä Geophysical Observatory
KEV	27.02	69.75	108.70	66.50	Kevo	Sodankylä Geophysical Observatory
MUO	23.56	68.03	104.70	64.90	Muonio	Sodankylä Geophysical Observatory
OUJ	27.23	64.52	105.80	61.20	Oulujärvi	Sodankylä Geophysical Observatory

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Conjugate Search coil (induction) magnetometer

IAGA	GLON	GLAT	MLON	MLAT	STATION-NAME	OPERATORS
PG5	5.71	-81.96	37.03	-69.51	Antartica	Virginia Tech
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P04	96.80	-82.00	42.20	-80.30	AGO P4	AGO
P05	123.52	-77.20	28.60	-87.10	AGO P5	AGO
P06	130.00	-69.50	215.20	-84.90	AGO P6	AGO
HAL	333.70	-75.60	29.80	-62.20	Halley Bay	BAS
MCM	166.70	-77.90	326.50	-80.00	McMurdo	PENGUIN
SPA	0.00	-90.00	19.56	-74.19	South Pole Station	PENGUIN
STF	309.28	67.02	40.87	72.64	Kangerlussuaq	DTUSpace
IQA	291.48	63.75	15.58	72.21	Iqaluit	CANMOS
BBG	14.12	78.09	110.30	75.40	Barentsburg	Sodankylä Geophysical Observatory
KIL	20.86	69.02	103.30	66.10	Kilpisjärvi	Sodankylä Geophysical Observatory
IVA	27.28	68.55	108.10	65.30	Ivalo	Sodankylä Geophysical Observatory
SOD	26.39	67.42	106.60	64.20	Sodankylä	Sodankylä Geophysical Observatory
ROV	25.94	66.78	105.90	63.60	Rovaniemi	Sodankylä Geophysical Observatory
OUL	25.90	65.08	104.90	61.80	Oulu	Sodankylä Geophysical Observatory
NUR	24.65	60.51	101.90	57.10	Nurmijärvi	Sodankylä Geophysical Observatory

ZHS	76.38	-69.37	96.59	-74.63	Zhongshan Station	PRIC
YRS	11.90	78.90	110.07	76.38	Yellow River Station	PRIC
DAV	77.97	-68.58	101.69	-74.77	Davis, Antarctica	AAD
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CSY	110.53	-66.28	156.79	-8.74	Casey, Antarctica	AAD
NAL	11.95	78.92	111.25	76.19	Ny Ålesund	UNH
LYR	15.82	78.20	112.08	75.25	Longyearbyen	UNH
HOR	15.47	76.97	109.16	74.23	Hornsund	UNH
BAB	14.23	78.07	110.37	75.35	Barentsburg(BBG for IAGA)	UNH
KAP	277.81	49.39	347.60	58.70	Kapuskasing (KAP), Canada	PWIN, VT??
NAN	298.30	56.50	14.80	65.80	Nain, NL, Canada	PWIN, Augsburg College
GAK	214.78	62.39	268.51	63.6	Gakona (GAK), Alaska	GI-UAF, UNH
JBS	164.20	74.60	223.50	70.25	Jang Bogo Station	Korean
VNA	351.70	70.40	81.12	69.59	Neumayer III Station	German

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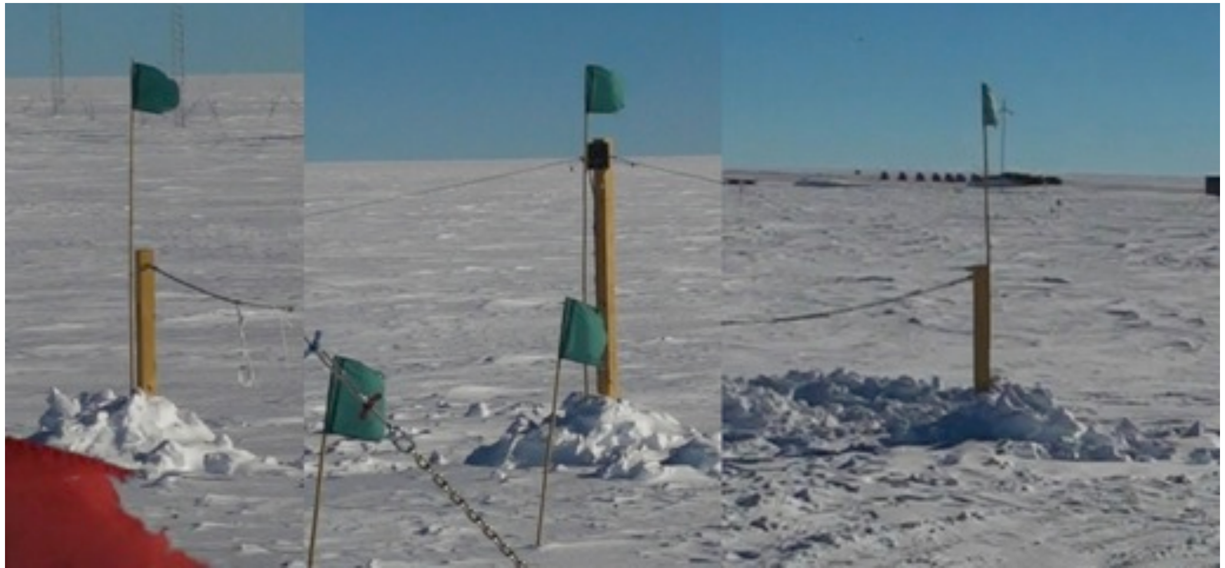

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Data Access

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- SPEDAS (Space Physics Environment Data Analysis Software) is a framework, written in IDL, to support loading, plotting, analysis, and integration of data from a number of space- and ground-based observatories, including THEMIS, MMS, GOES, ERG, IUGONET, and most data sets archived at CDAWeb., http://spedas.org/blog/),
- CDAWEB (Coordinated Data Analysis Web, Public data from current and past space physics missions, http://cdaweb.sci.gsfc.nasa.gov/index.html/),
- INTERMAGNET (International Real-time Magnetic Observatory Network), http://www.intermagnet.org/index-eng.php
- SuperMAG (http://supermag.jhuapl.edu)
- PI's own website, such as http://mist.nianet.org/

Data Access-MIST AAL-PIP Array http://mist.nianet.org/

- Fluxgate Magnetometer (1 Hz)
  - Virginia Tech MIST website (http://mist.nianet.org/)
  - THEMIS database (accessible via SPEDAS software and GUI)
  - NASA SPDF CDAWeb
  - SuperMAG (1 minute)
- Induction Magnetometer (10 Hz)
  - Virginia Tech MIST website
  - Contact us directly for special data requests
- CASES (GPS Receiver)
  - Virginia Tech MIST website
  - We're working on making data available on Madrigal database by end of summer
- HF experiment
  - available on Virginia Tech MIST website


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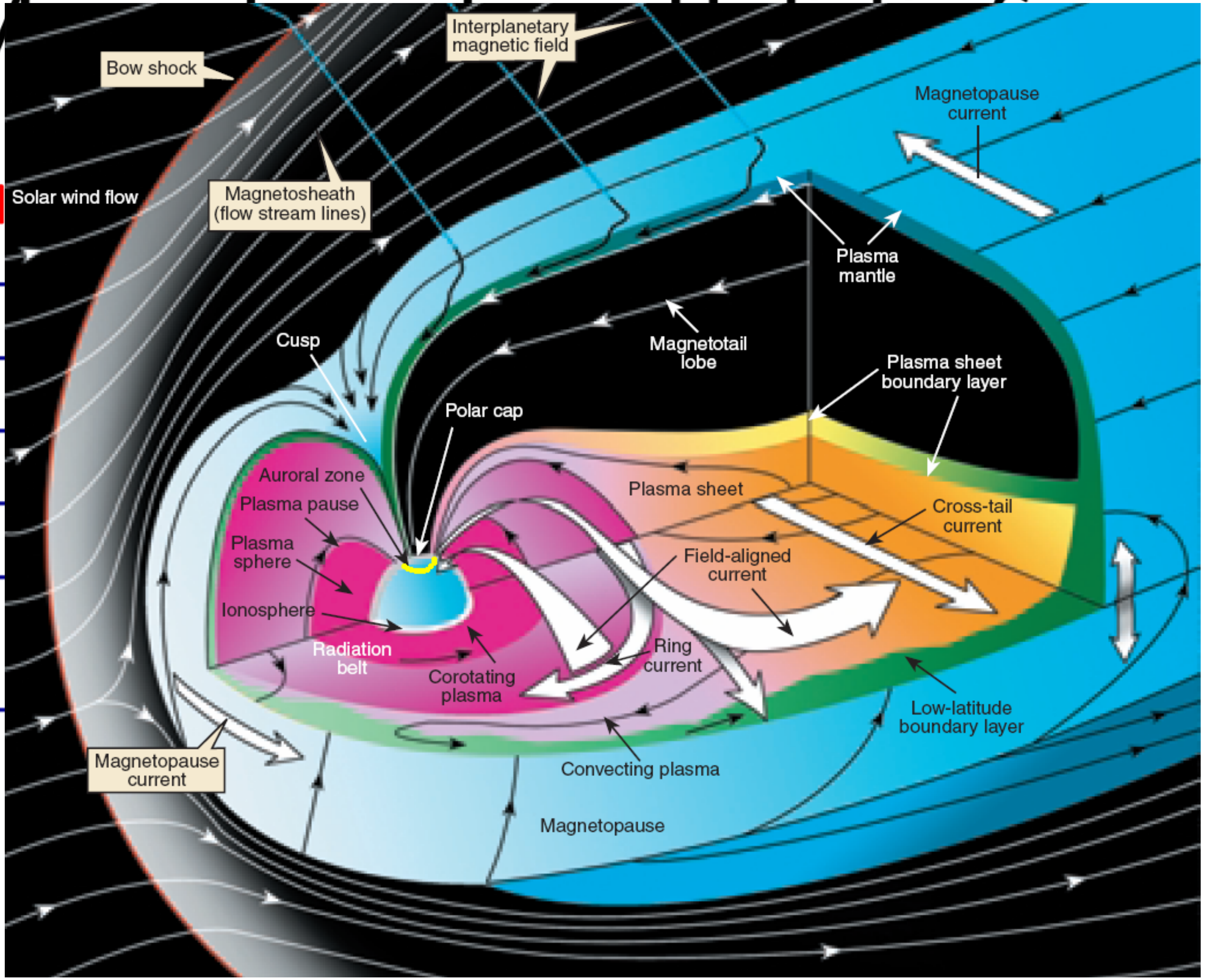
The Future of Work
Navigating the New Arctic
Multi-messenger Astrophysics
The Quantum Leap
Understanding the Rules of Life
Mid-scale Research Infrastructure
NSF 2026
Growing Convergence Research
NSF INCLUDES

coverage.

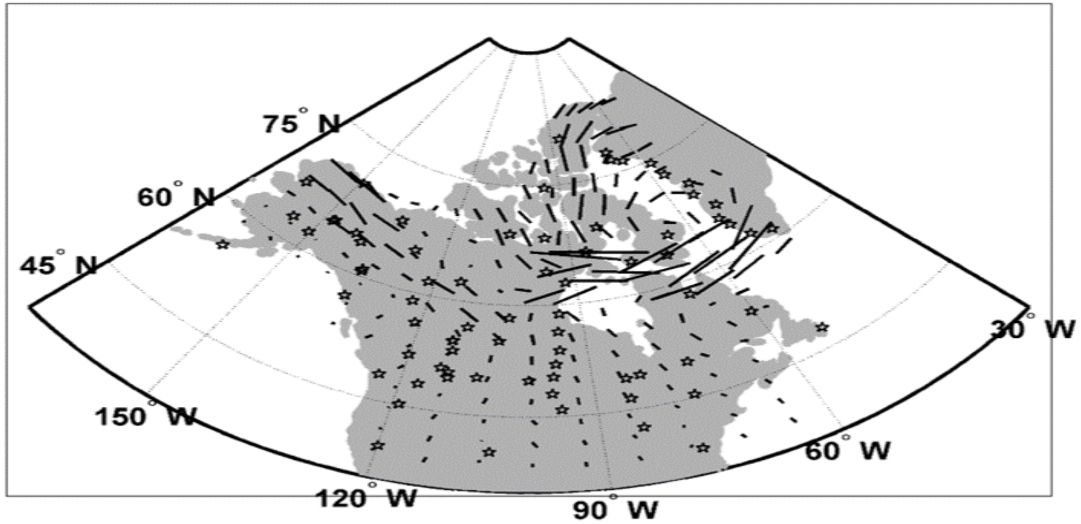


Courtesy of V. Eccles and M. Engebretson

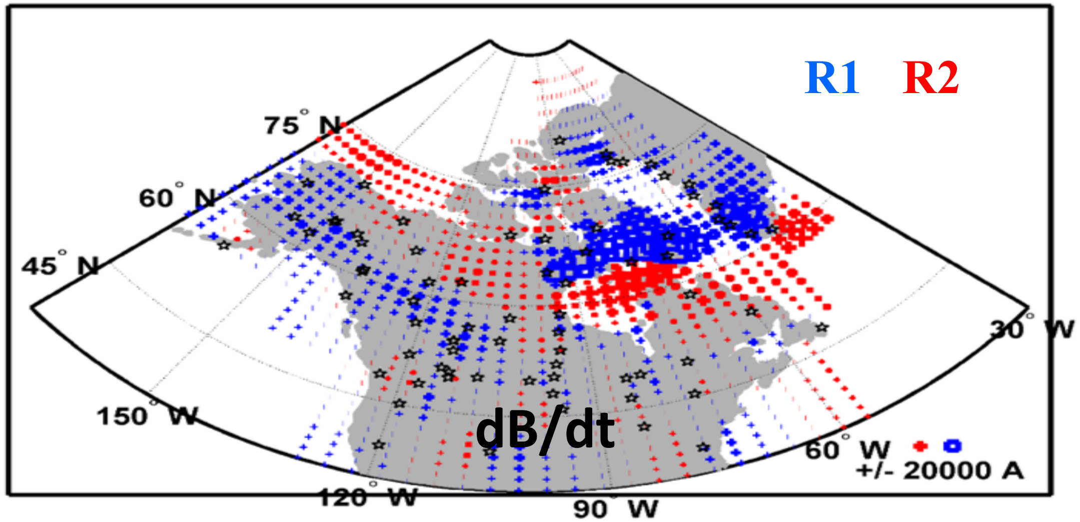
MESO-scale

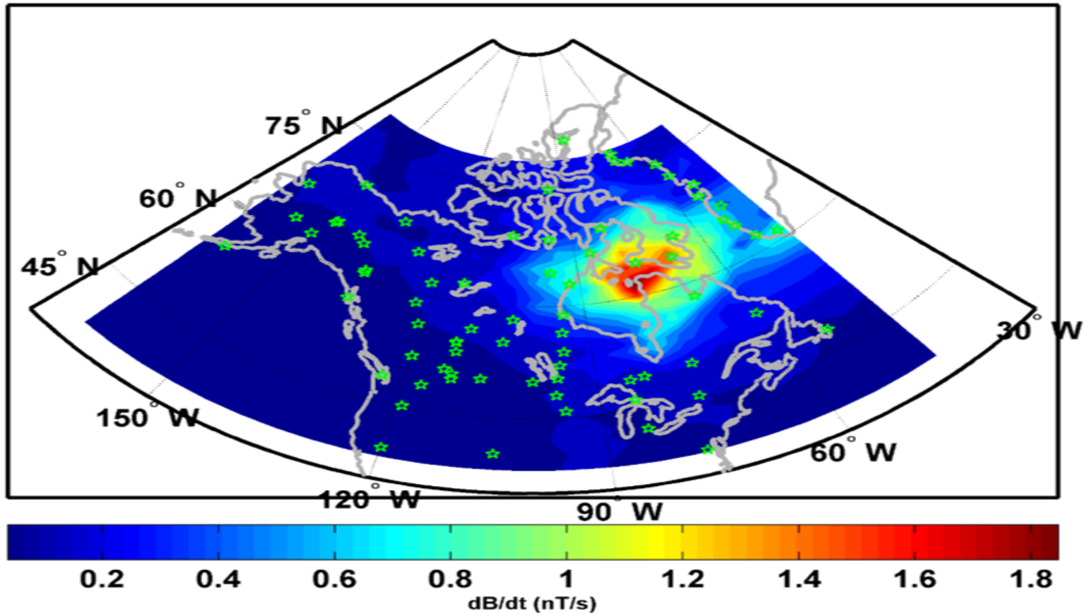
currents (100’s-1000’s km) and other phenomena in cusp/auroral zone

Equivalent Ionospheric Currents



Inferred Field-aligned Currents





<u>Superposed epoch analysis of 21 nighttime magnetic impulse events</u> observed at Cape Dorset (MACCS) between 0230 and 0330 UT, from mid-2014 through 2016.

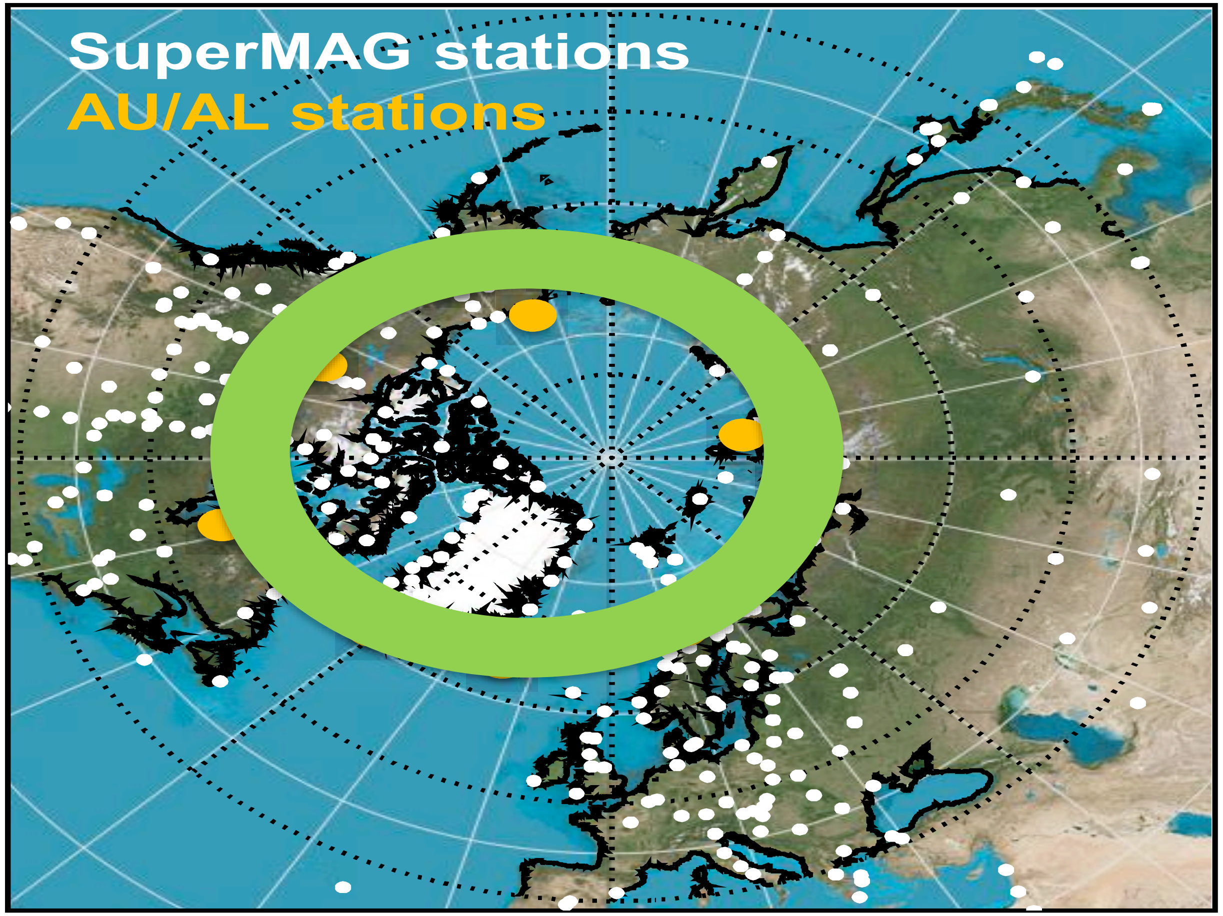
<u>>> Nighttime MIEs are highly localized</u>

-- **Weygand, 2018**

Courtesy of M. Engebretson

MESO-scale

Using many more stations worldwide provides
-- better timing of substorm onsets
-- better measures of amplitude
-- better knowledge of location

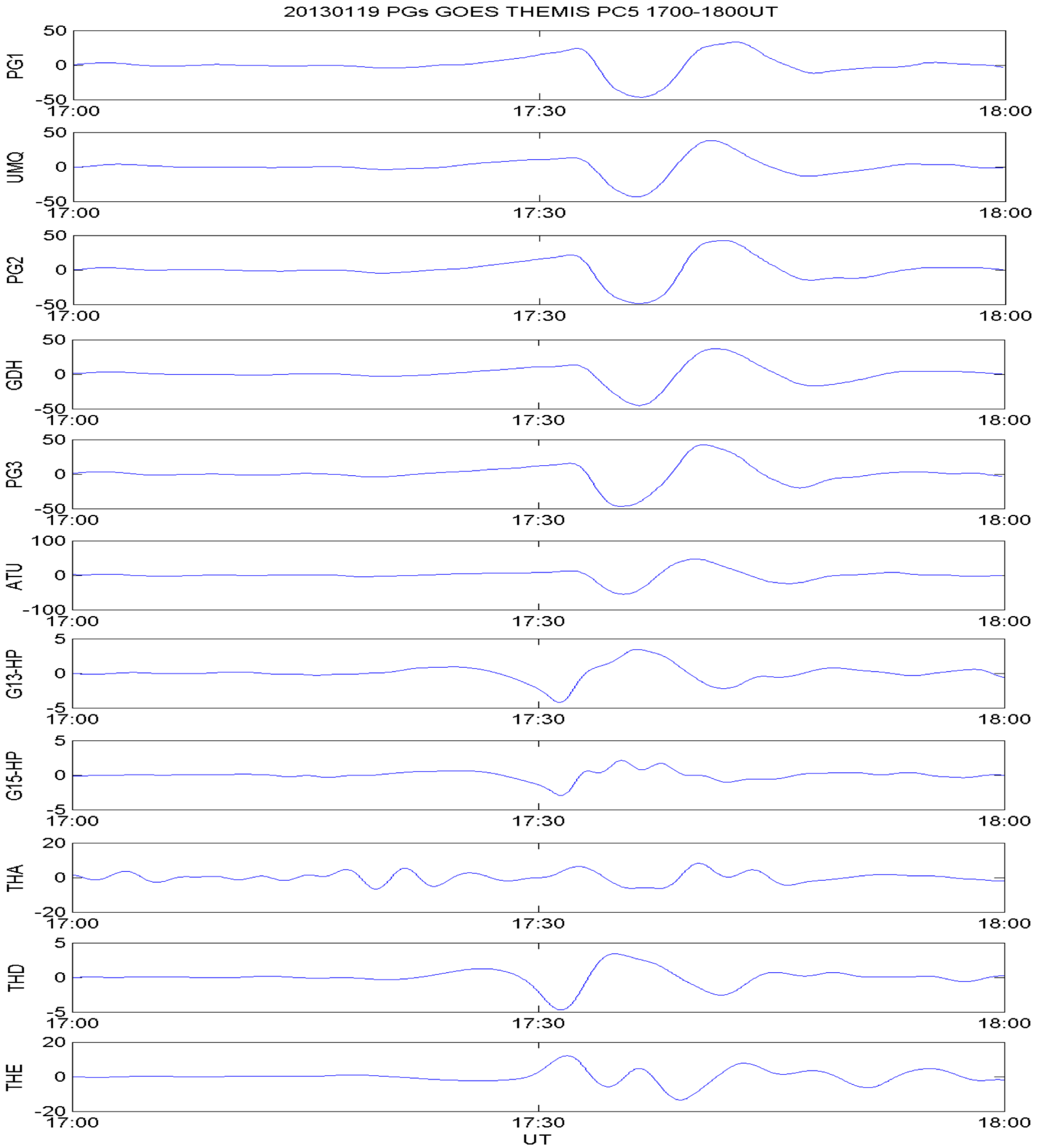


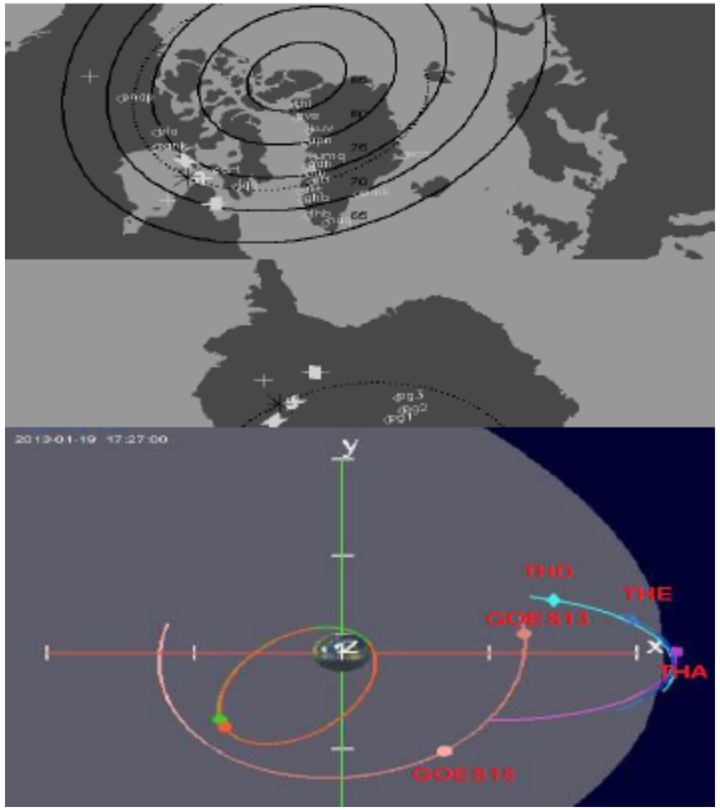
SuperMAG AL (SML) uses >100 latitudinally scattered stations.

Courtesy of M. Engebretson

Future plans and ideas for collaboration

- Current plans
  Inter-hemisphere, Satellite - ground-based conjunction
  2D conjugate comparisons including Svalbard
  Extensions to array through collaboration
- Community input?
  Ideas for collaboration
  Data sharing
  Deploying new instrumentation





Similar pulsations are found in filtered THEMIS-D, GOES 13, 15, and ground magnetometer observations.

The arrival times and number of pulsations seen at different stations and satellites support that the conjugate pulsations are related to the Sudden Impulse (SI) dayside transient event.

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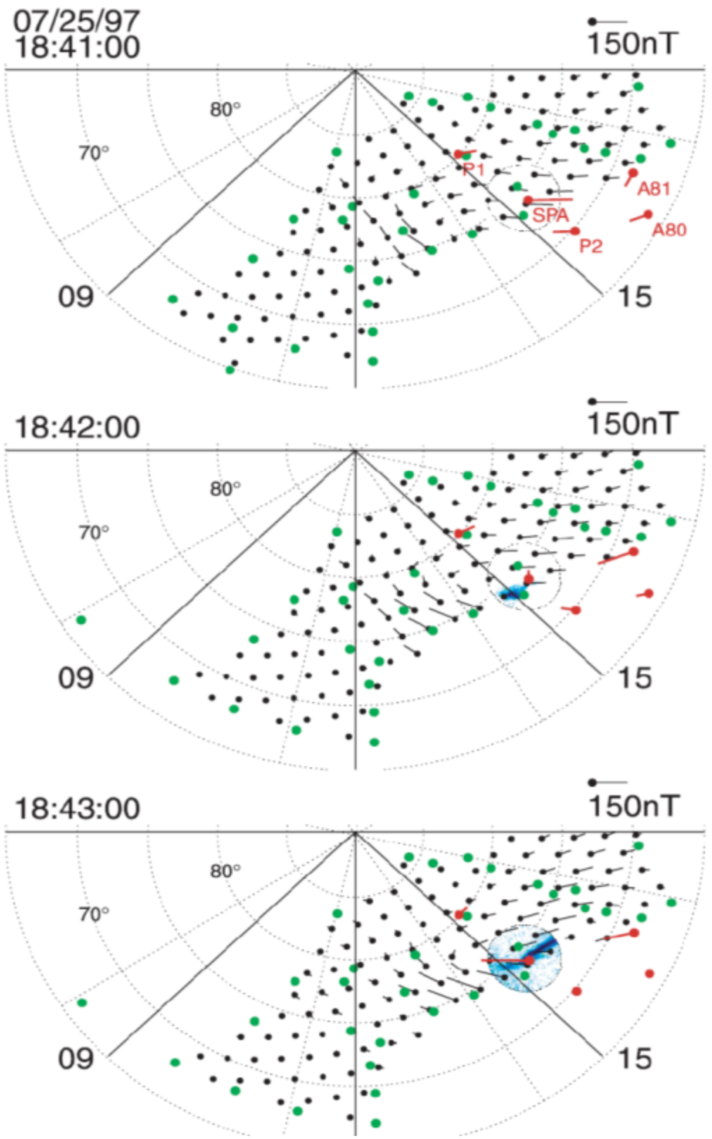
2D current system time evolution in both hemispheres

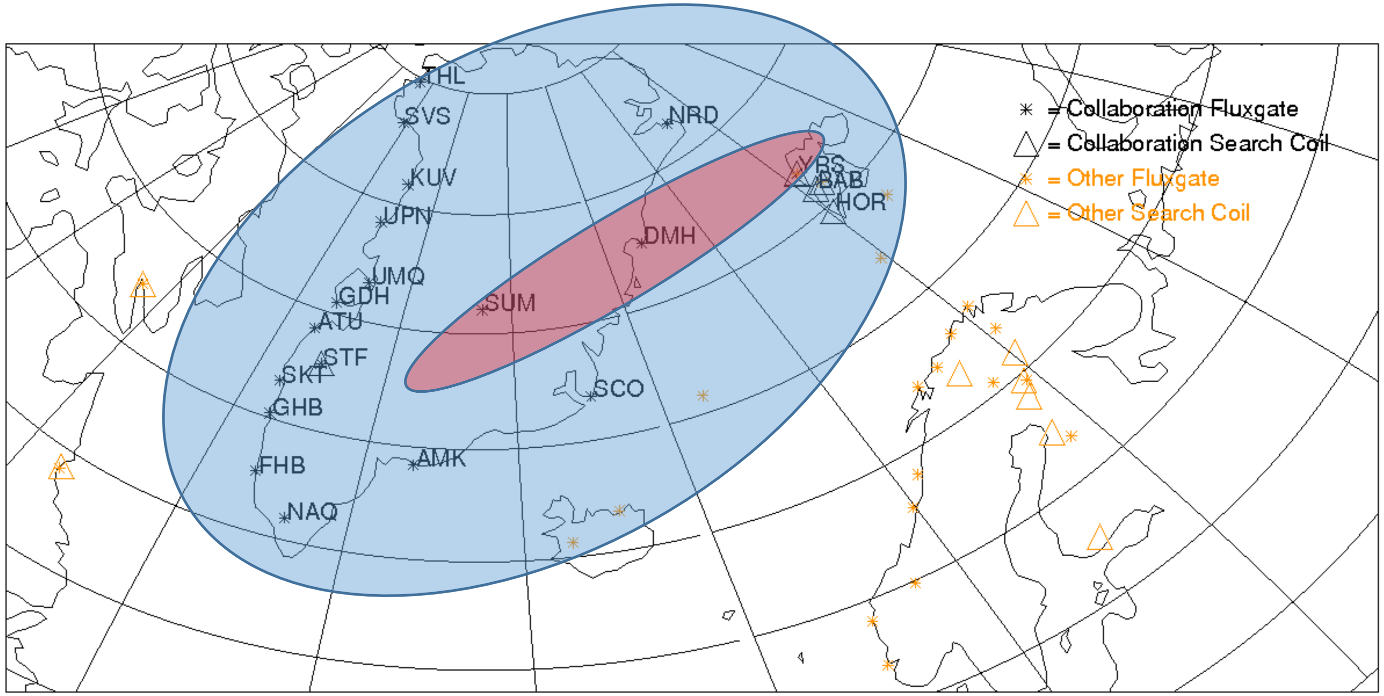
- With 2D arrays (e.g., IMAGE) in both hemispheres, it would be possible to resolve temporal and spatial evolution of transient current systems, such as Hot Flow Anomalies

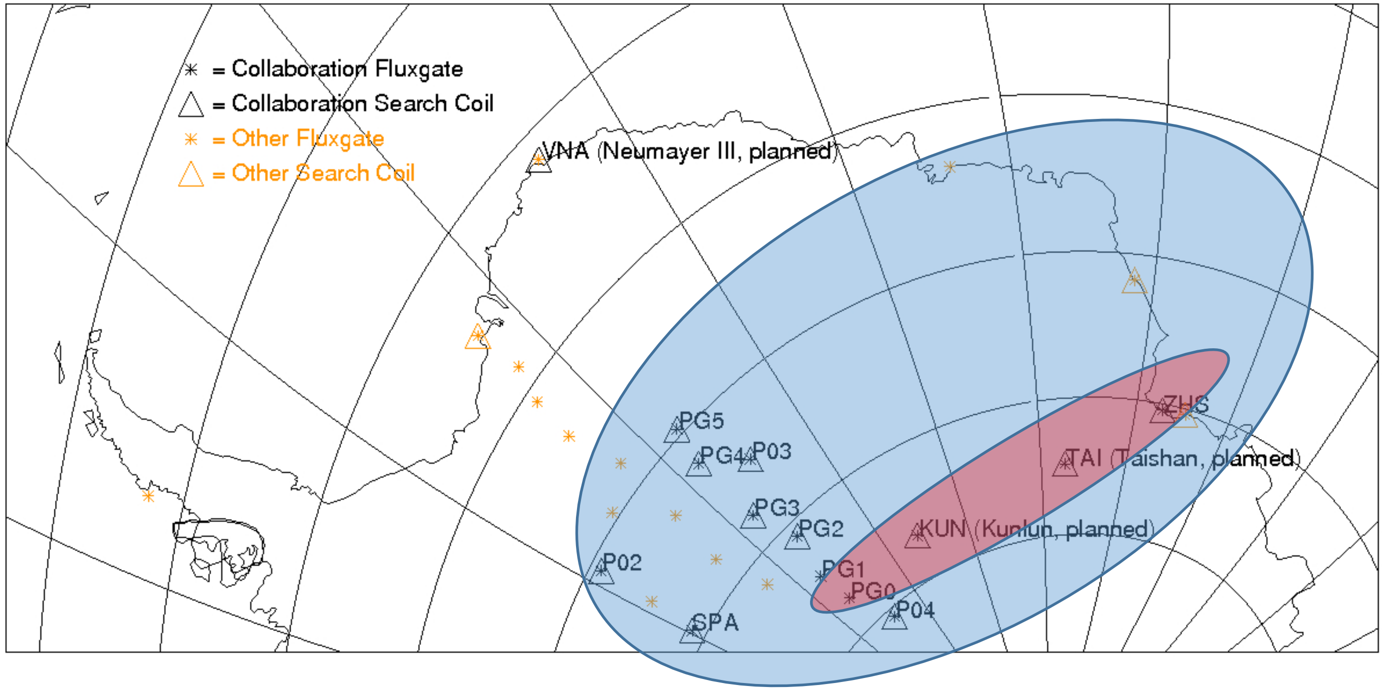


Murr et al., [2002]

Future Plans

- Deploy new instruments at existing and new locations
  - If current NSF proposal to work with PRIC is selected, extend chain to cover a wider range of longitudes conjugate (IGRF) to regions near East Coast of Greenland and Svalbard
  - Submit NSF renewal proposal in 2020
  - Extend chain, if possible, through international collaboration
  - Feedback on most important locations and instruments





Community input?

- Ideas for collaboration

  Observations: Lidar TIFe Layer, Satellites, SuperDARN, GPS

  Models: AMIE, SAM, and others

  Weygand et. al, JGR 2012 (Comparison between SuperDARN flow vectors and equivalent ionospheric currents from ground magnetometer arrays)
- Data sharing and Higher level data product
- Deploying newer and better instrumentation