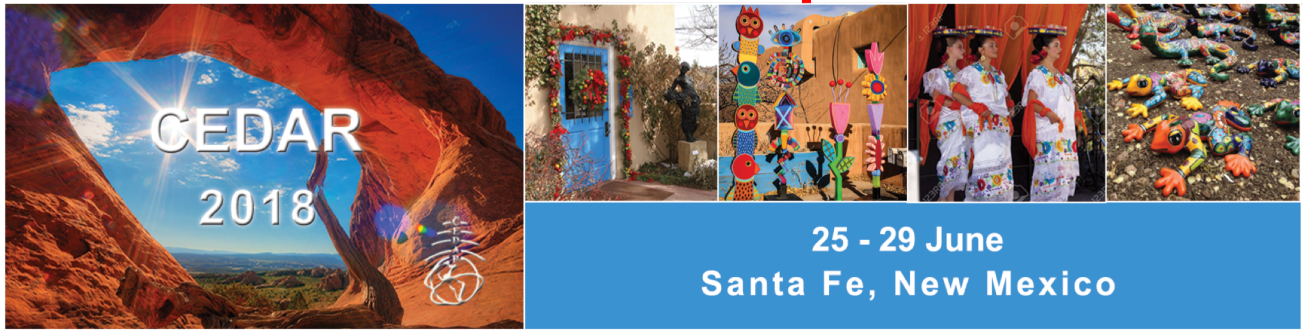
A comparison of the ground magnetic responses during the 2013 and 2015 St. Patrick’s Day geomagnetic storms

CEDAR Summer Workshop 2018-MITC-12



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Abstract

- The magnetosphere-ionosphere system response to extreme solar wind driving conditions depends on both the driving conditions and ionospheric conductivity. Since extreme driving conditions are rare, there are few opportunities to control for one parameter or another.
- The 2013 and 2015 St. Patrick's Day geomagnetic storms driven by coronal mass ejections (CME) provide one such opportunity. The two events occur during the same solar illumination conditions; in particular, both occur near equinox on the same day of the year leading to similar ionospheric conductivity profiles.
- Moreover, both CMEs arrive at the same time of day leading to similar observing conditions. We examine the ground magnetic response to each CME at a range of latitudes and in both the Northern and Southern Hemispheres, remote sensing several current systems. There are dramatic differences between the intensity, onset time and occurrence, duration, and spatial structure of the current systems in each case. For example, differing solar wind driving conditions lead to interhemispheric asymmetries in the high-latitude ground magnetic response during the 2015 storm; these **asymmetries** are not present in the 2013 storm.

Highlights

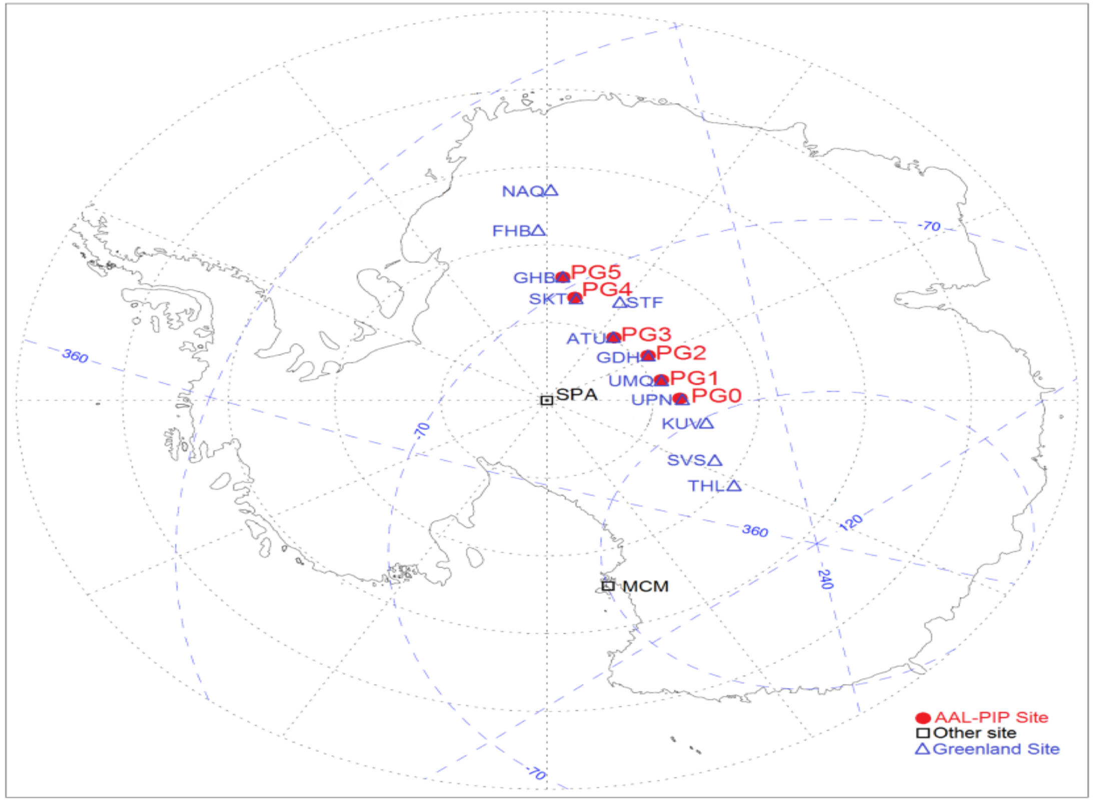
- To improve the understanding of the **storm time response** of **Magnetosphere-Ionosphere system**, with **ground-based magnetometer**.
- **Very rare opportunity**: 2013 and 2015 St. Patrick's Day
  1 Similar ionospheric conductivity in both hemispheres
  Same solar illumination conditions
  near equinox—March 17 in both years

  2 Similar UT time for CME arrivals
- **Dramatic differences**
  interhemispheric asymmetries in the high-latitude ground magnetic response during the **2015 storm**, including the intensity, onset time and occurrence, duration, and spatial structure, etc.

Instrumentation and Data

- **OMNI data** for showing CMEs, solar wind, Interplanetary Magnetic Field conditions.
- **Ground magnetometer** data from high latitude regions at inter-hemisphere **conjugate locations**.
- **Ground magnetometer** data from mid-low latitude regions almost evenly **distributed longitudinally** to provide 24MLT coverage.
- **SuperDARN** data/model are used to provide ionospheric convections background.

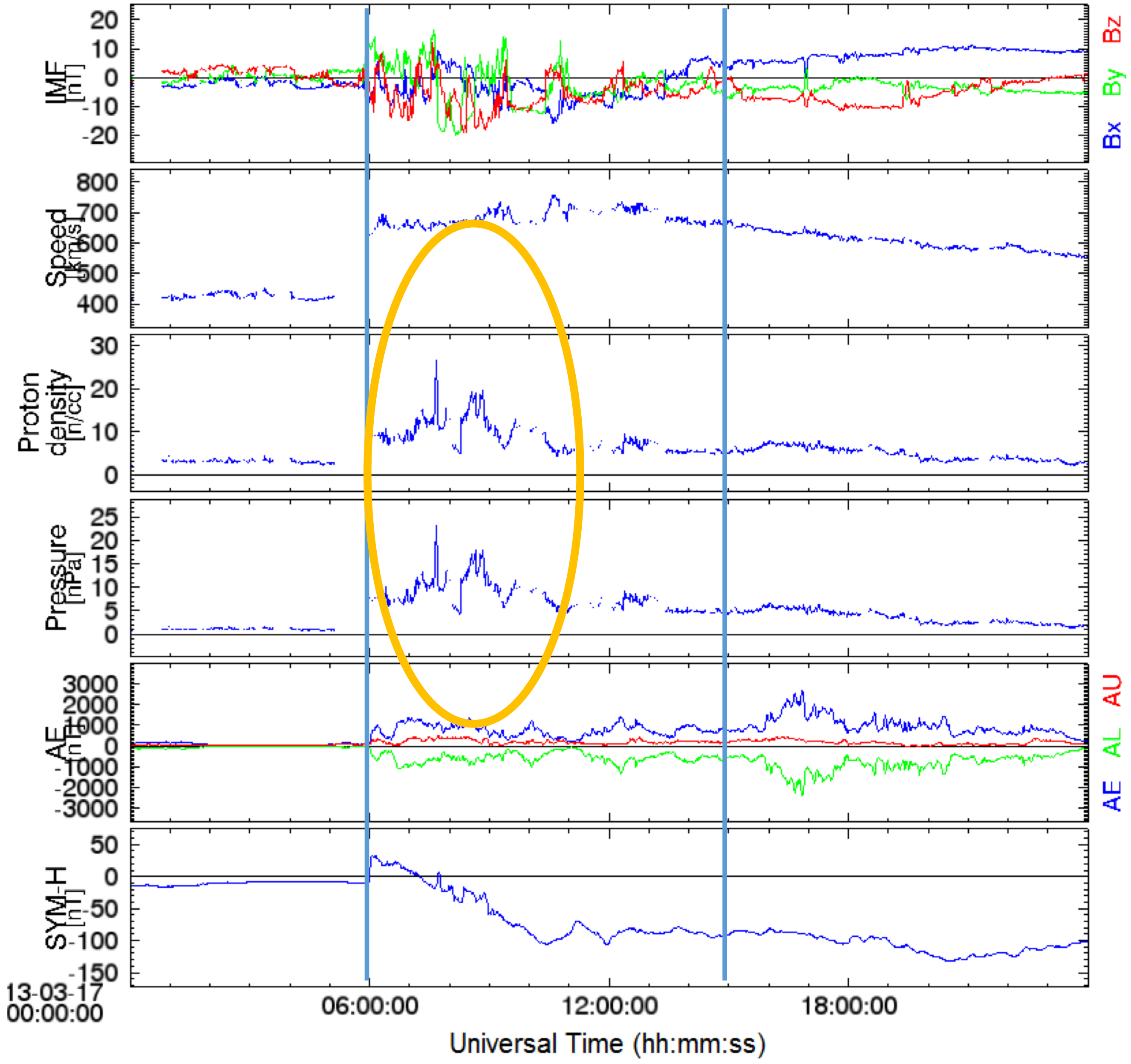
High Latitude Conjugate Array



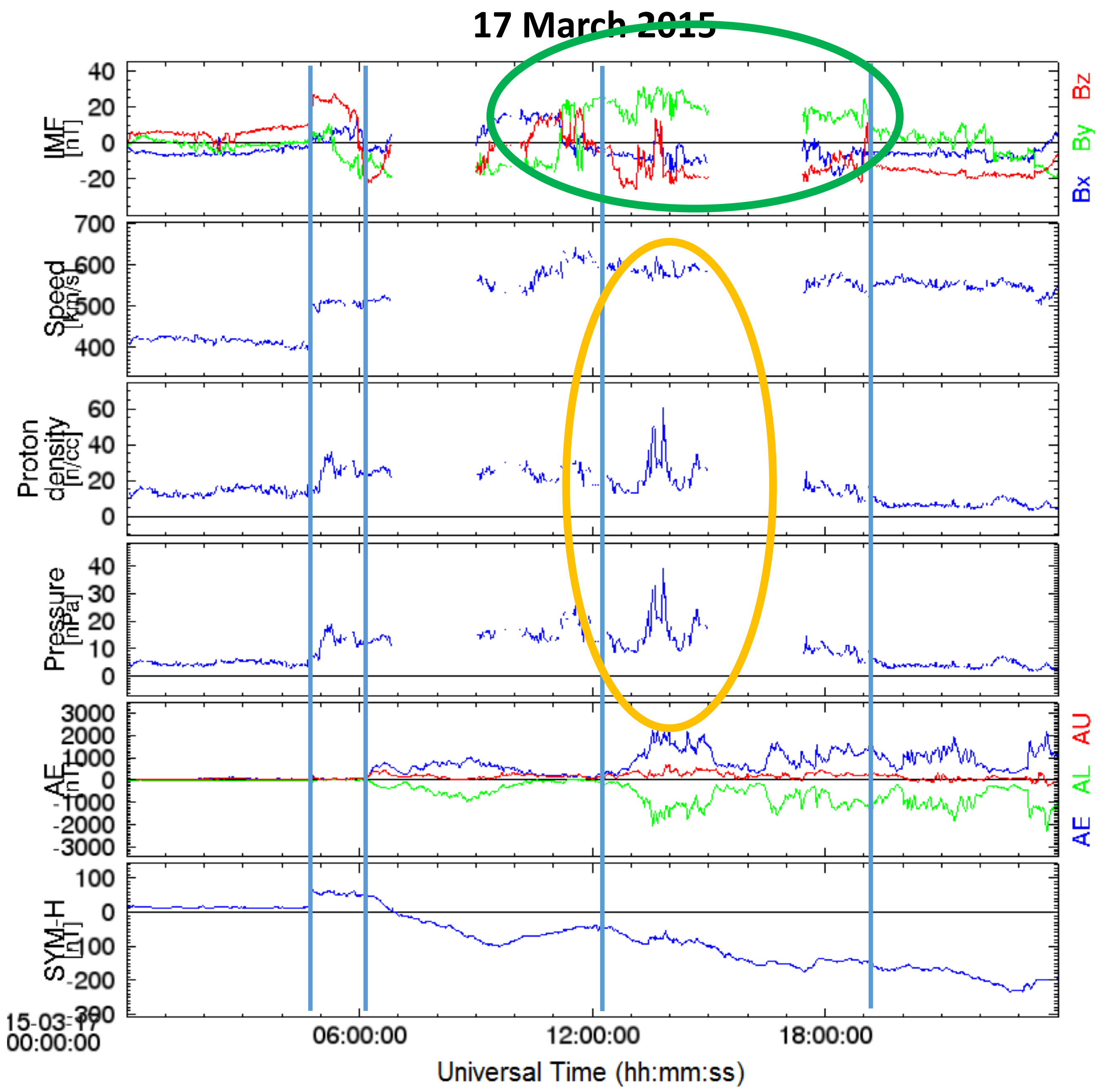
GREENLAND Site	Geog lat	Geog lon (E)	CGM LAT	CGM LON	Conj geog lat	Conj geog lon	Antarctic Conj site
Thule (THL)	77.47	290.77	84.40	27.48	-79.72	121.63	Vostok
Savissivik (SVS)	76.02	294.90	82.68	31.23	-81.20	116.23	
Kullorsuaq (KUV)	74.57	302.82	80.36	40.28	-82.25	99.40	AGO P4
Upernavik (UPN)	**72.78**	**303.85**	**78.57**	**38.71**	**-83.58**	**89.26**	**PG0**
Uunmannaq (UMQ)	**70.68**	**307.87**	**75.99**	**41.22**	**-84.50**	**77.20**	**PG1**
Qeqertarsuaq (GDH)	**69.25**	**306.47**	**74.82**	**38.15**	**-84.42**	**57.96**	**PG2**
Attu (ATU)	**67.93**	**306.43**	**73.54**	**37.09**	**-84.81**	**37.63**	**PG3**
Kangerlussuaq (STF)	67.02	309.28	72.14	39.96	-82.75	28.59	AGO P3
Maniitsoq (SKT)	**65.42**	**307.10**	**70.93**	**36.43**	**-83.32**	**12.97**	**PG4**
Nuuk (GHB)	**64.17**	**308.27**	**69.49**	**37.12**	**-81.95**	**5.67**	**PG5**
Paamiut (FHB)	62.00	310.32	66.92	38.43	-79.13	358.20	
Narsarquaq (NAQ)	61.16	314.56	65.23	42.61	-76.25	0.78	

Autonomous Adaptive Low Power Instrument Platforms (AALPIP)

17 March 2013

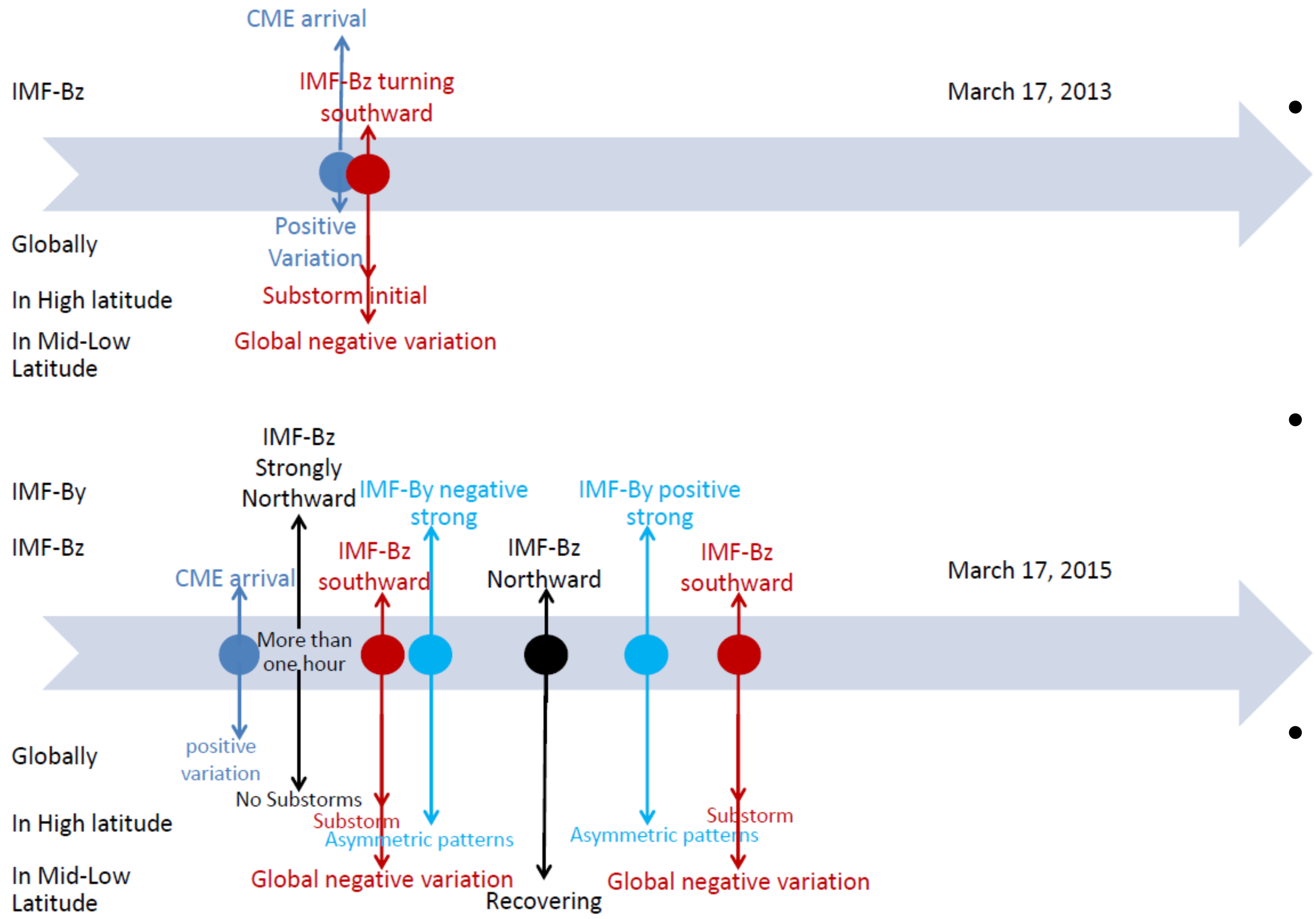


- In 2013, Bz is negative for most of the interval, By is small
- Solar wind speed ~650 km/s
- Dynamic pressure typically below 10 nPa

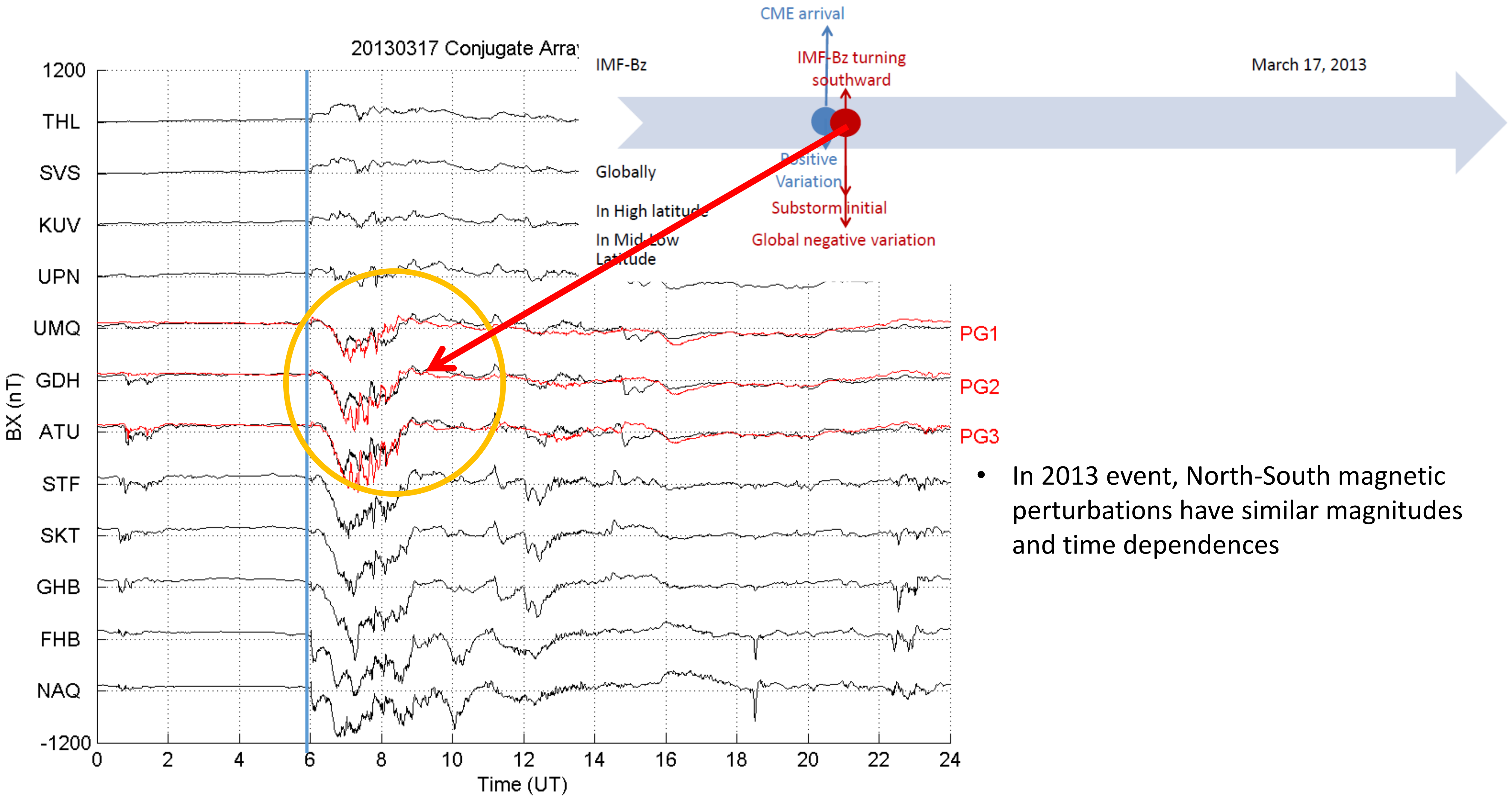


- In 2015, Bz is positive and negative during different periods but magnitude is typically larger than in 2013, By is very large during some intervals
- Solar wind speed ~600 km/s
- Dynamic pressure exceeds 10 nPa for some periods
- 2015 storm is more intense than 2013 based on Sym-H

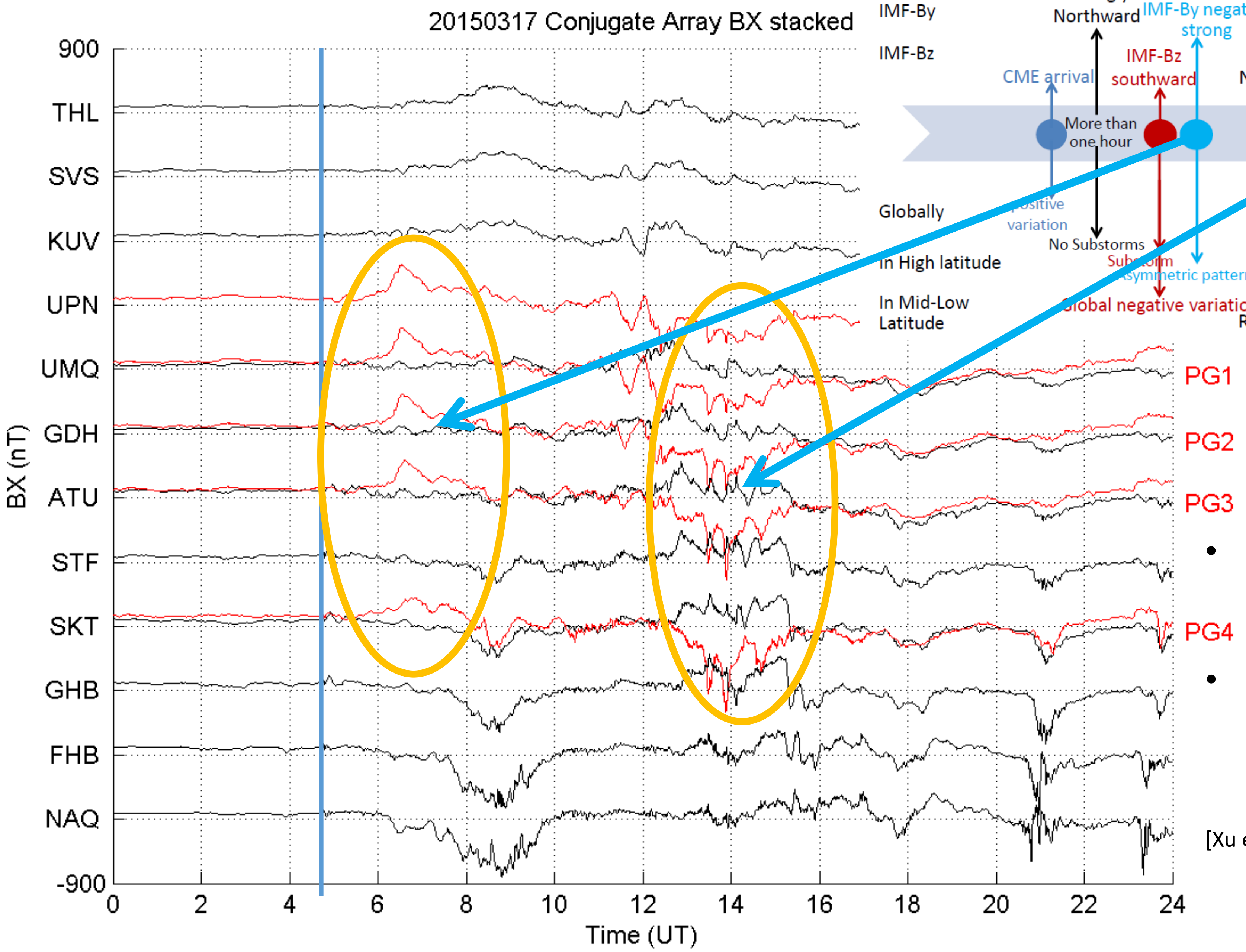
17 March 2013/2015 storms: unique opportunities to test effect of solar wind driving on ground magnetic response

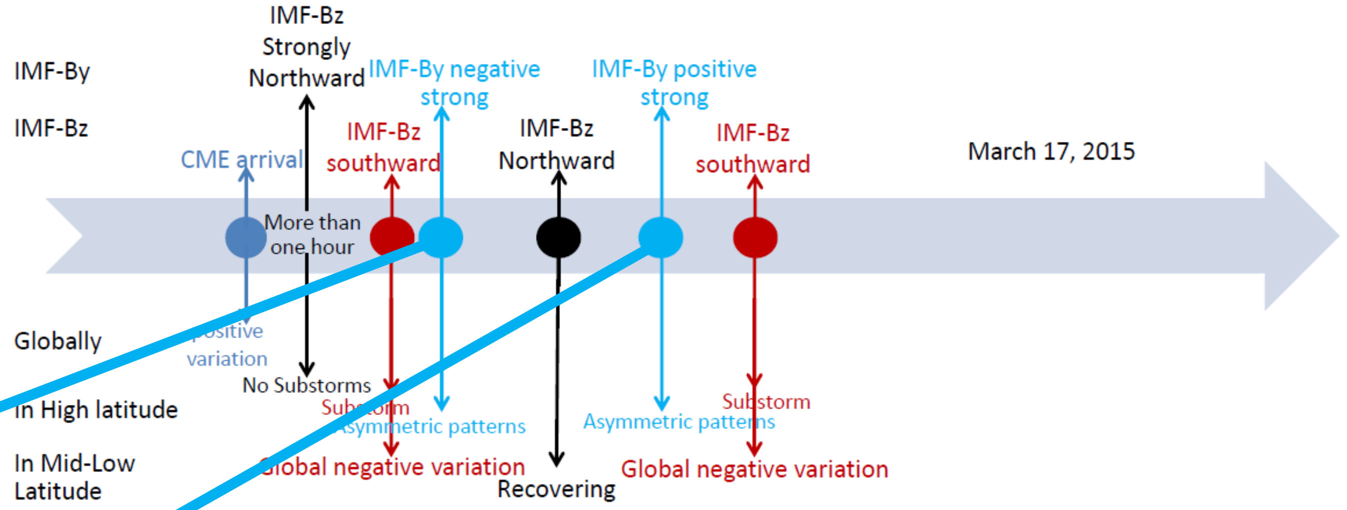


- The 2013 and 2015 St. Patrick's Day storms are ideal for examining sources of asymmetries in the ground magnetic response
- Different solar wind driving conditions, similar solar illumination (near equinox conditions on March 17) and magnetometer LT
- Results from Xu et al., [2017], JGR special issue on these storms



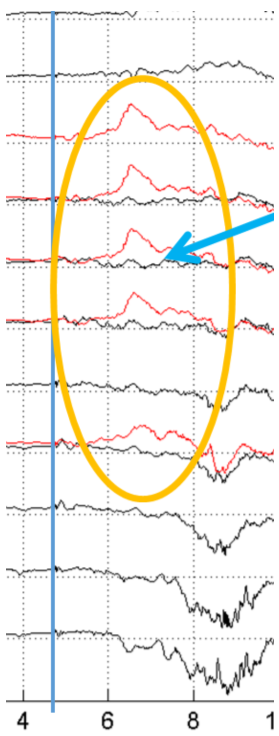
- In 2013 event, North-South magnetic perturbations have similar magnitudes and time dependences

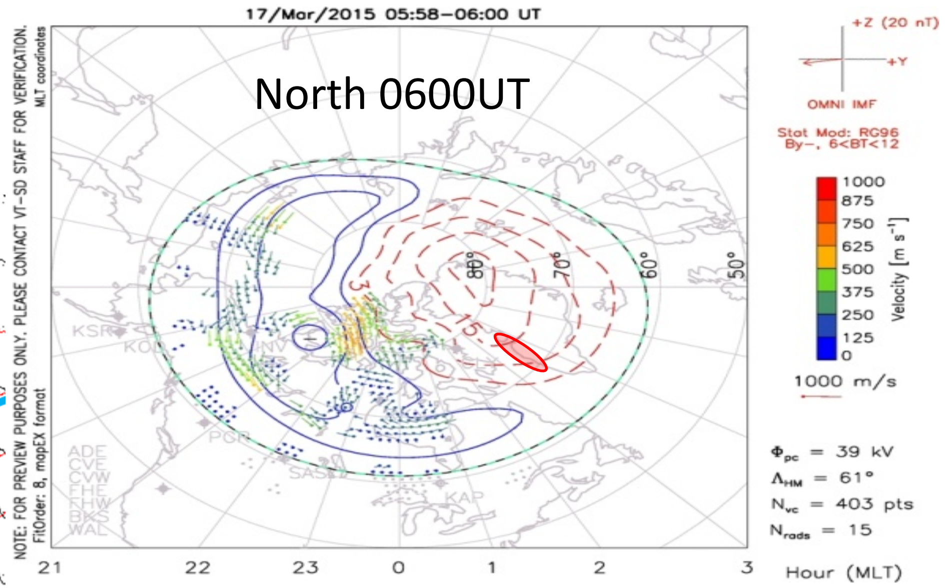


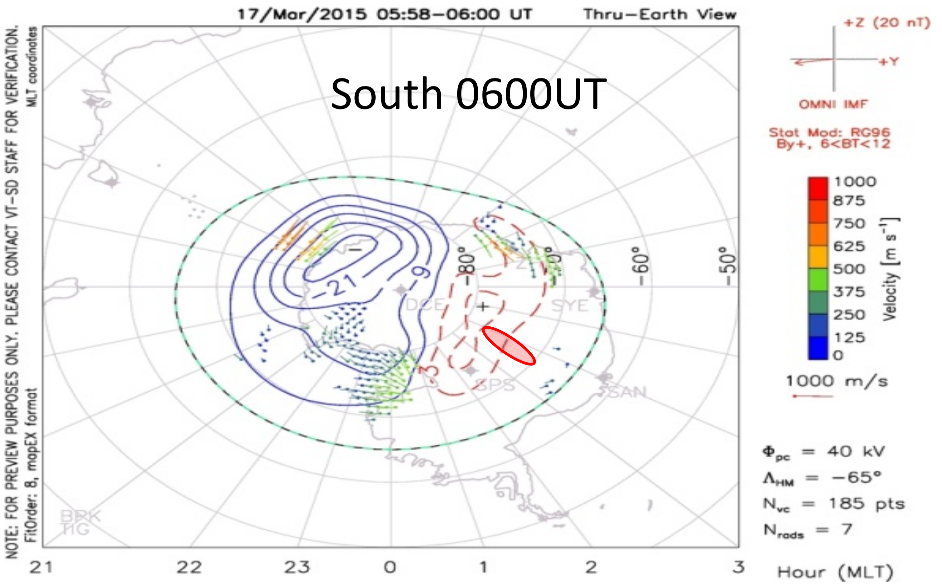


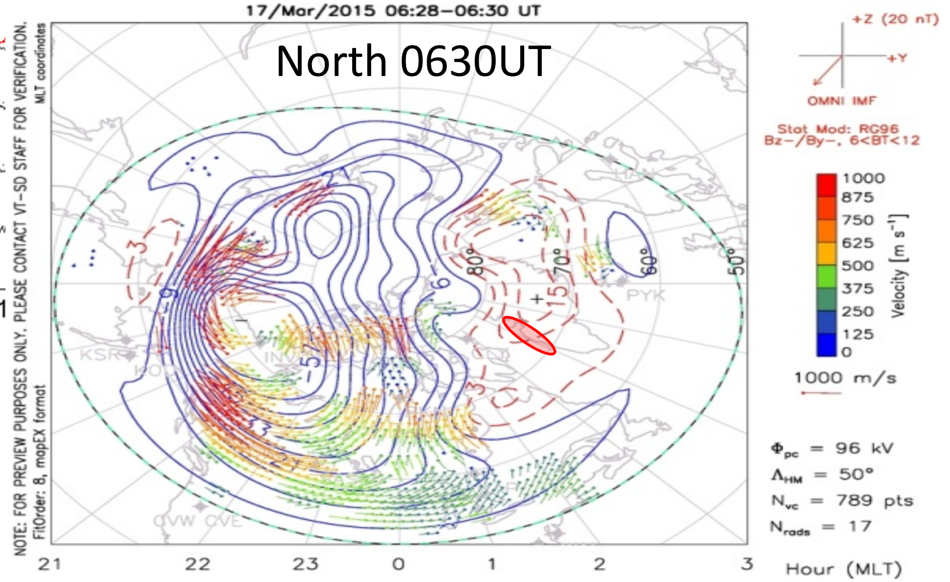
- In 2015 event, North-South magnetic perturbations have different magnitudes and time dependences
- There's a correspondence with solar wind driving conditions

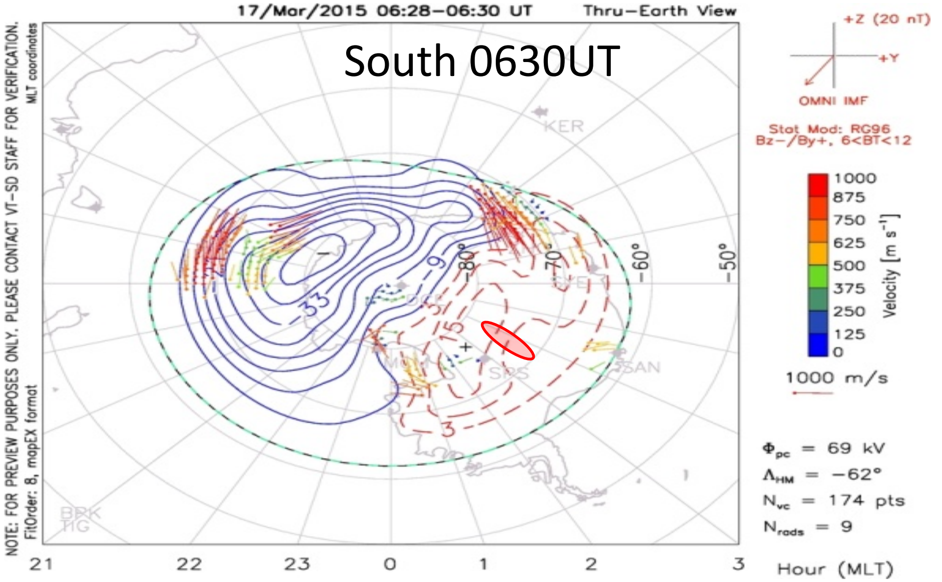
[Xu et al., 2017]



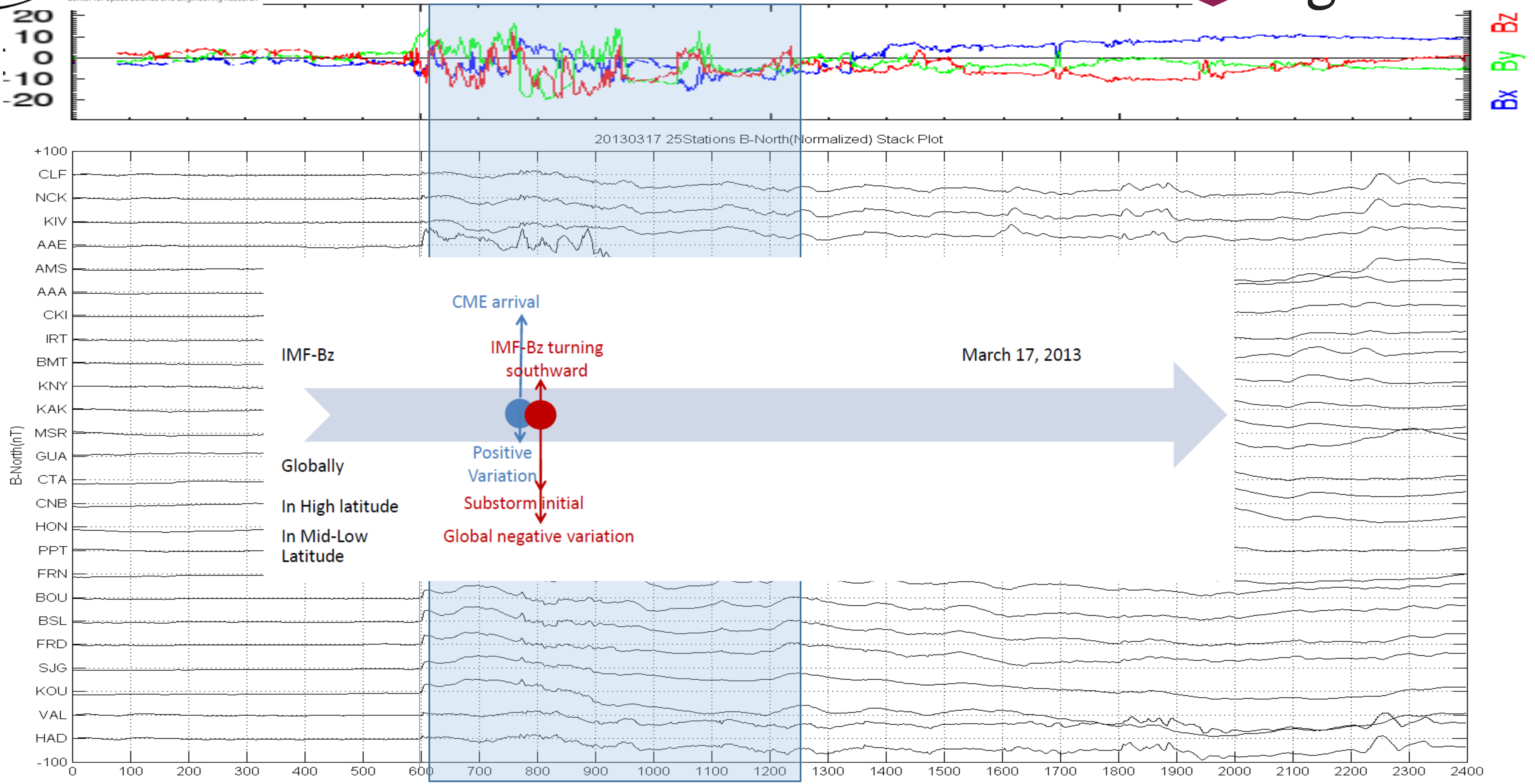






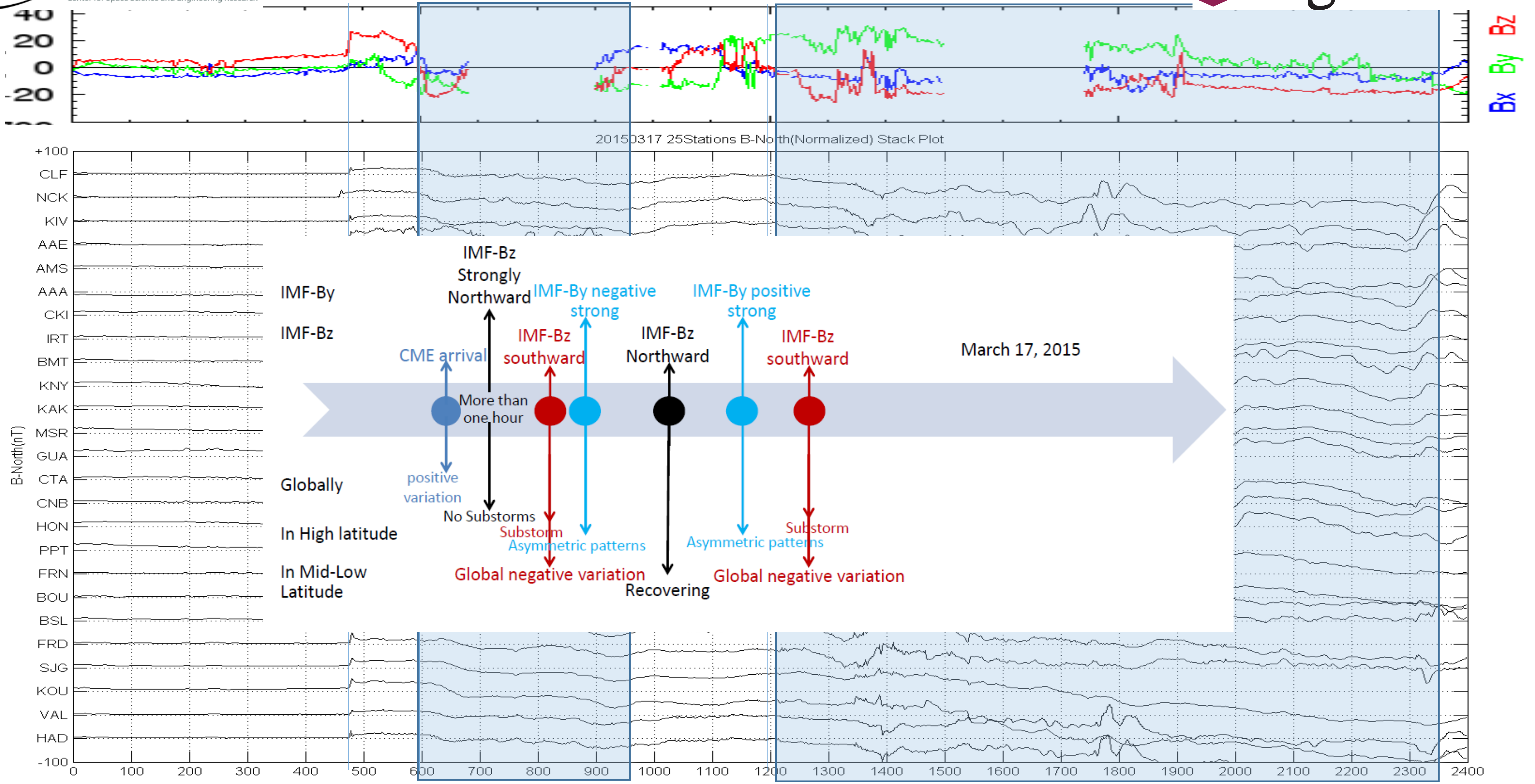


showingthe location of the array

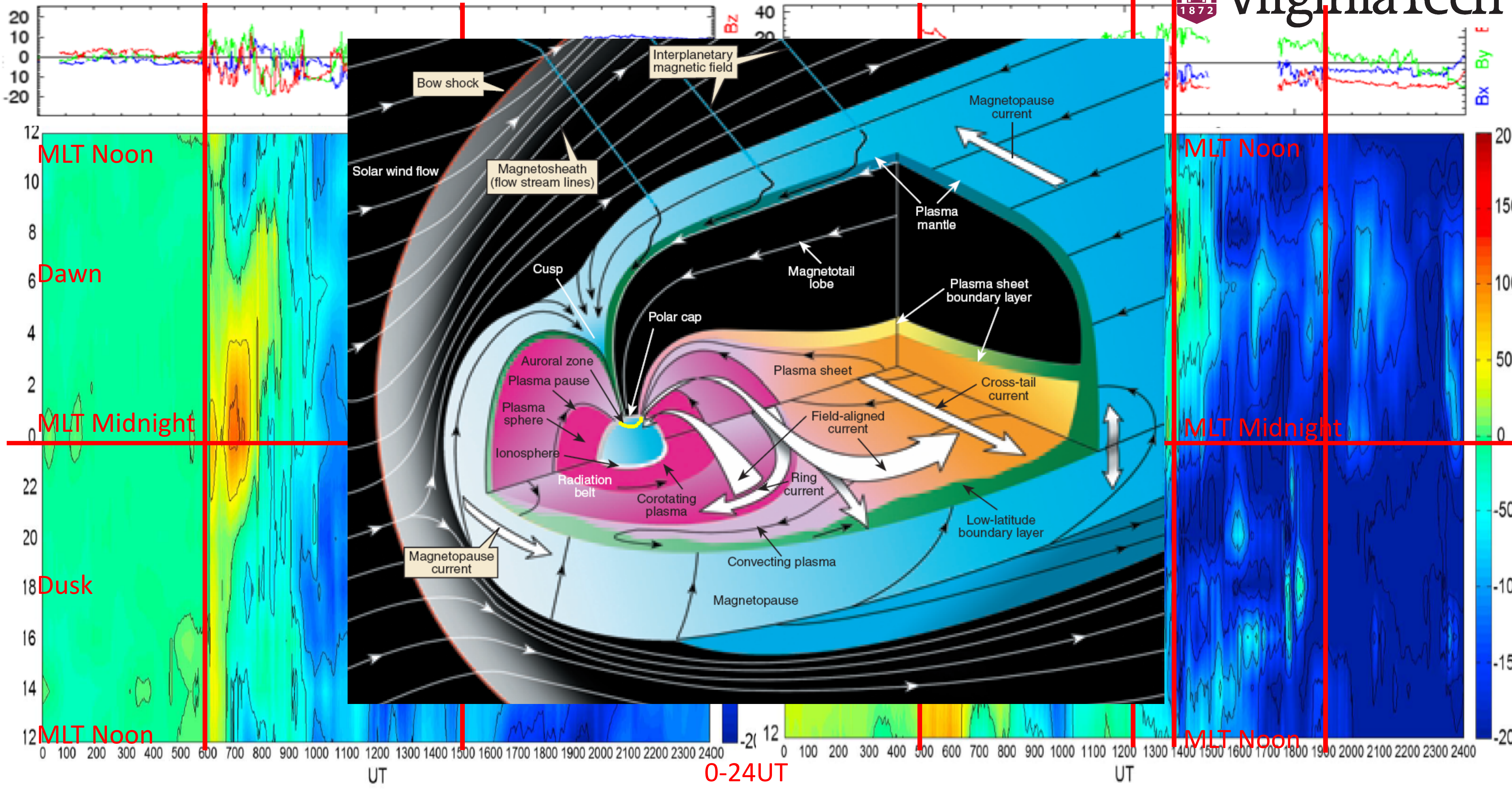

20130317 25Stations B-North(Normalized) Stack Plot
Bz
By
Bx
B-North(nT)
CLF
NCK
KIV
AAE
AMS
AAA
CKI
IRT
BMT
KNY
KAK
MSR
GUA
CTA
CNB
HON
PPT
FRN
BOU
BSL
FRD
SJG
KOU
VAL
HAD
CME arrival
IMF-Bz turning southward
IMF-Bz
March 17, 2013
Positive Variation
Globally
In High latitude
Substorm initial
In Mid-Low Latitude
Global negative variation

Space @ Virginia Tech
Center for Space Science and Engineering Research

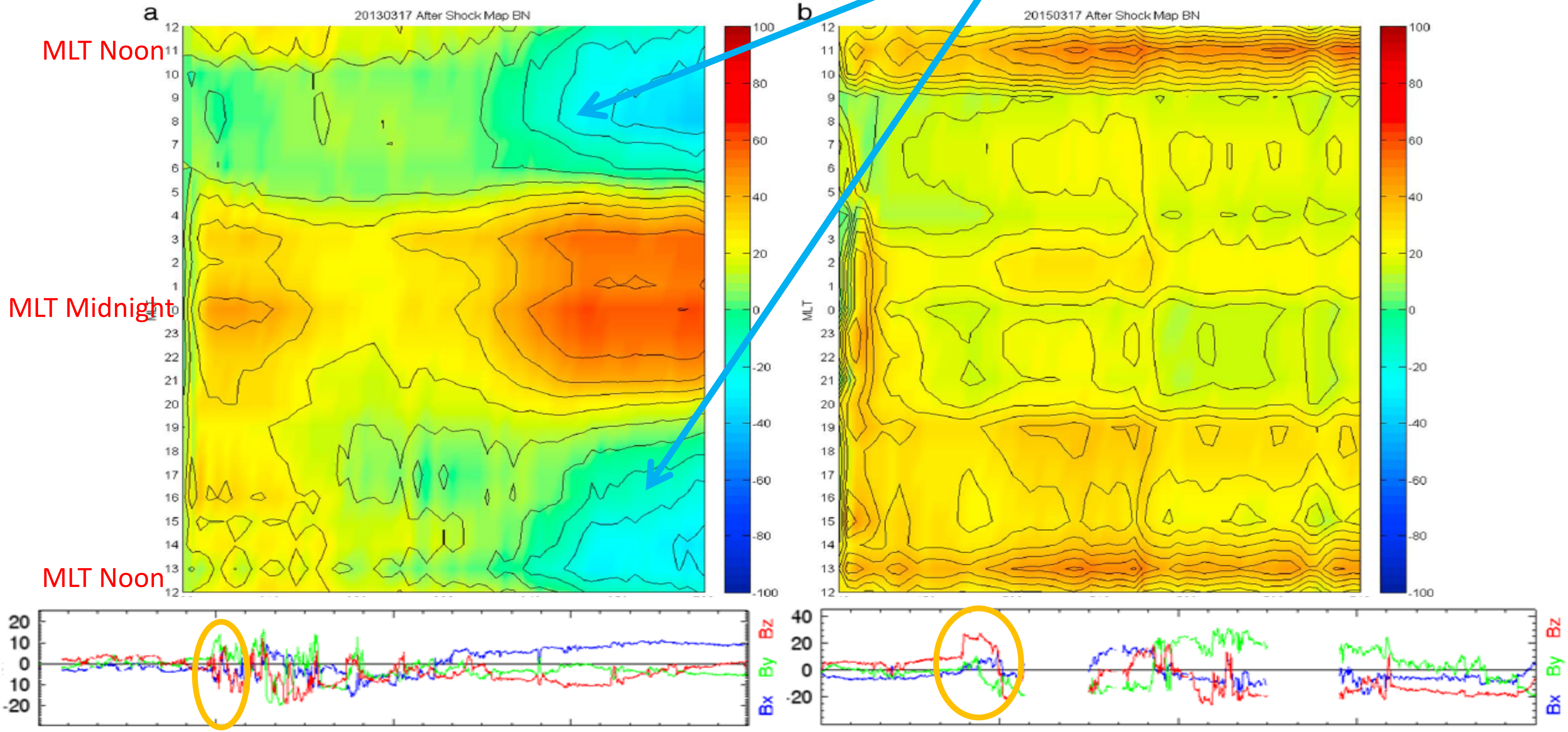
VirginiaTech 1872



VirginiaTech



Rapidly the ring current intensifies in 2013 event (blue color) in contrast to the 2015 event (no blue seen in b), due to IMF Bz.



Summary and discussion

- **Differing MI system responses attributed primarily to differing solar wind driving conditions**

  High latitude conjugate stations:
  1. Conjugate condition changes due to IMF configuration changes;
  Similar to Ganushkina et al., [2013], we traced magnetic field lines from empirical models (IGRF+Tsyganenko [2002]) between hemispheres to estimate magnetic field distortions
  The magnetic field in the 2015 event was significantly distorted from IGRF. It was much stronger than in 2013, consistent with asymmetric ground responses seen in 2015 but not 2013.

  Mid-low latitude global stations:
  1. Magnetopause (Chapman-Ferraro) currents
  2. Response to ring currents and partial ring currents.
  3. Some tail/Substorm Current Wedge/DP1 currents effect near MLT-midnight.

- **With networks of ground magnetometers, it may be possible to determine the timescale for nightside/dawn current systems which respond to changes in IMF By.** Modeling work is needed to determine which solar wind conditions contributed most strongly to these distortions, and whether other factors contributed to the asymmetric ground magnetic response (e.g., substorm current systems leading to more disturbed conditions at high latitudes, Tanskanen et al., [2002])