

Auroral dynamics observed by the Syowa - Iceland conjugate observation

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Research Organization of Information and Systems (ROIS)

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Polar Environment Data Science Center (PEDSC)

(Concurrently)

National Institute of Polar Research (NIPR)

Space and Upper Atmospheric Sciences group

■ **Major area of research:**

Aurora physics, Magnetosphere physics

■ **Antarctic Experience:** Syowa Station

JARE-30 (winter), 44(winter), 50(winter, leader), 57(summer, leader)

(JARE: Japanese Antarctic Research Expedition)

■ **Arctic Experience:**

Iceland (23 times visit as the PI of the conjugate observation)

■ **Address:**

10-3, Midoricho, Tachikawa, Tokyo 190-8518, Japan

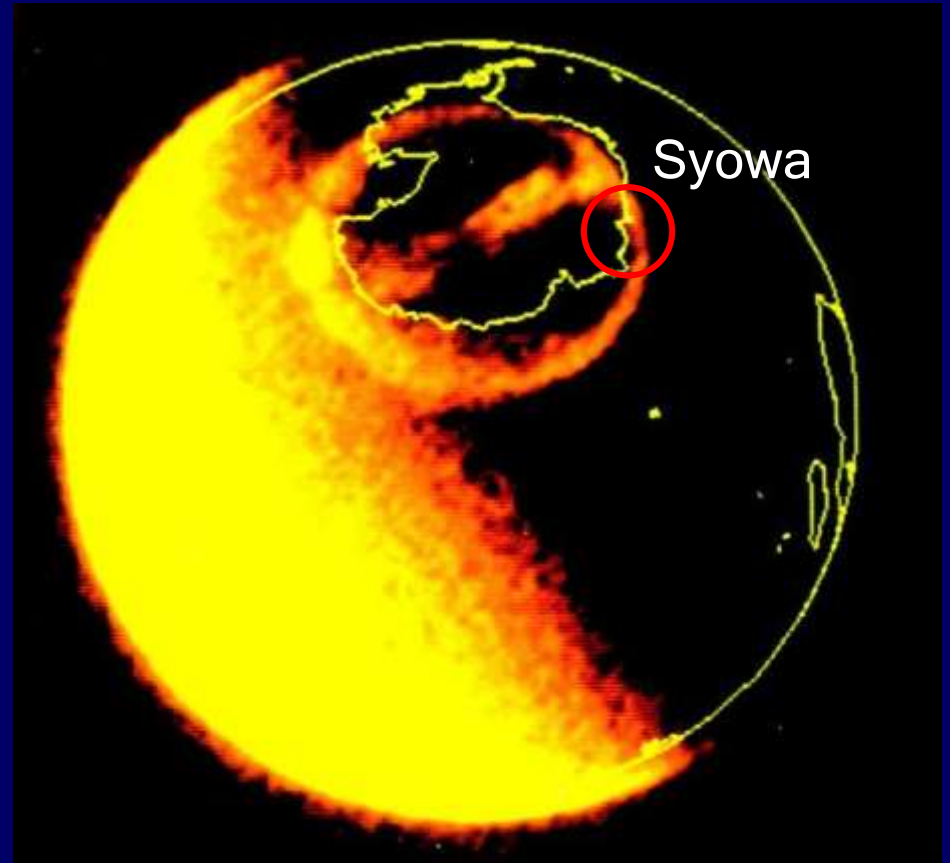
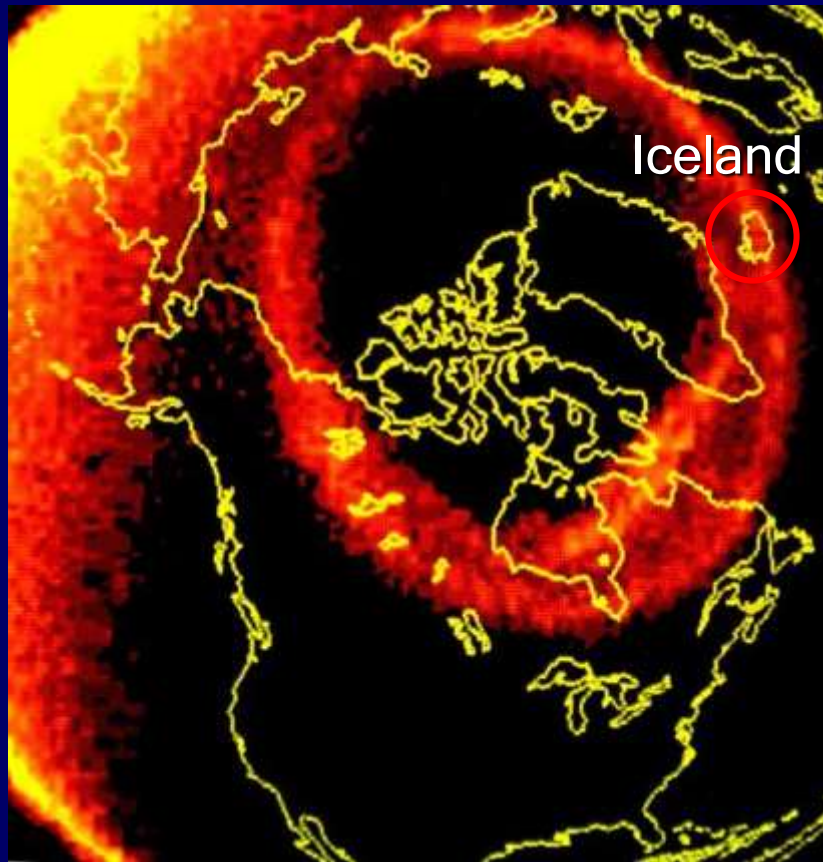
E-mail: kadokura@nipr.ac.jp



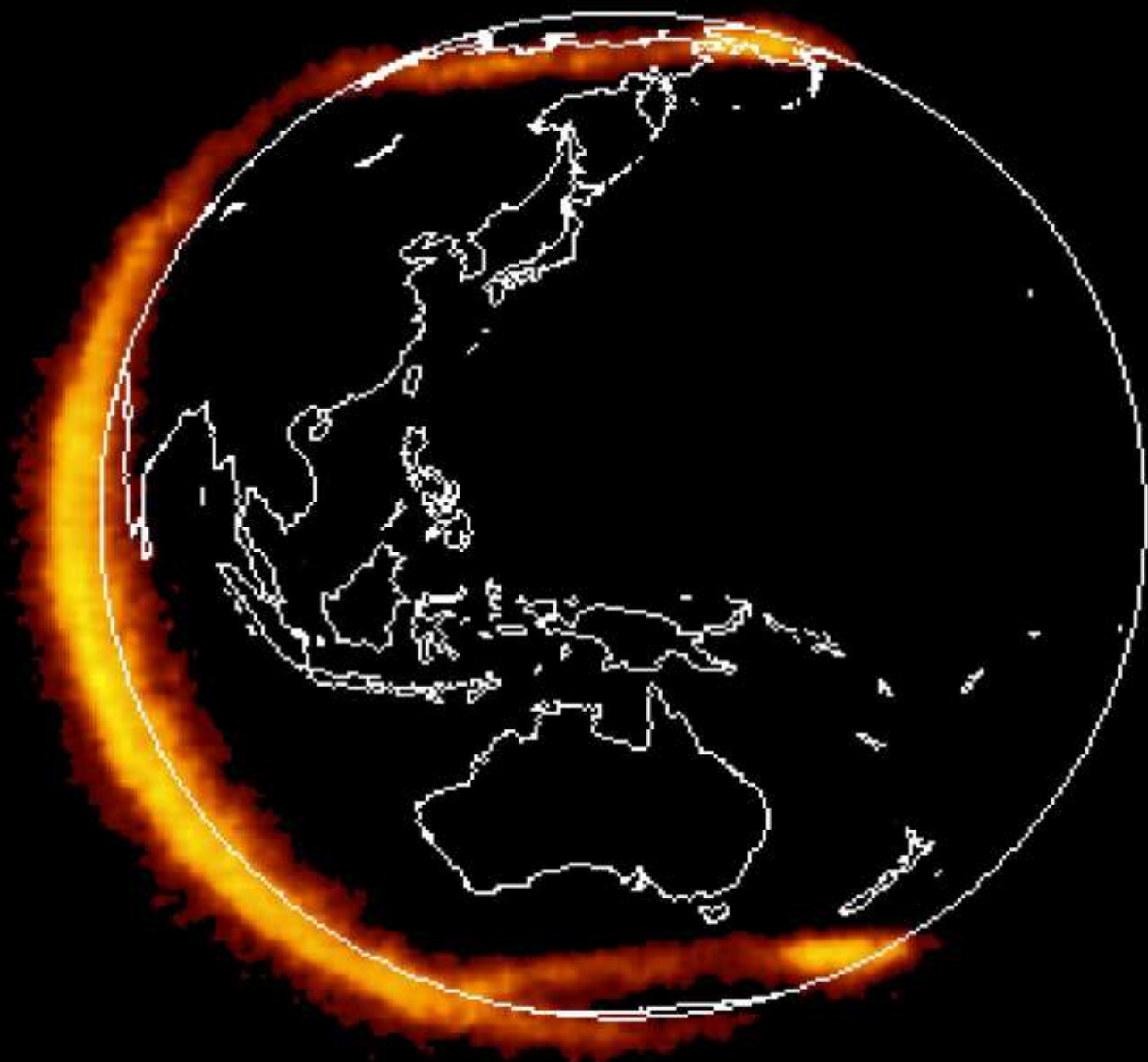
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 - ① conjugacy of substorm development

Auroral Oval observed by satellite imager

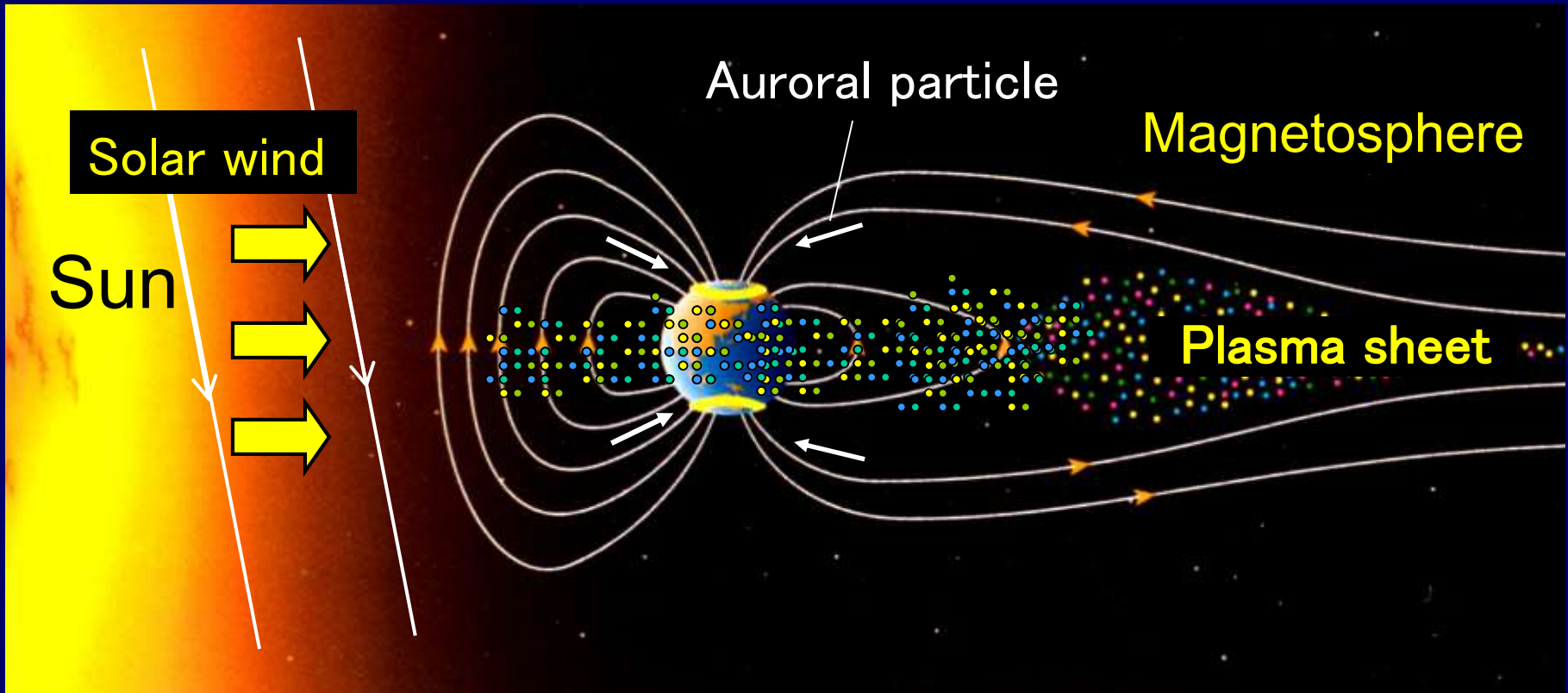


DE-1 satellite (NASA)

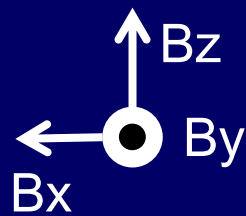


POLAR Satellite (Frank et al, 2003, JGR)

Aurora - Magnetosphere - Solar wind

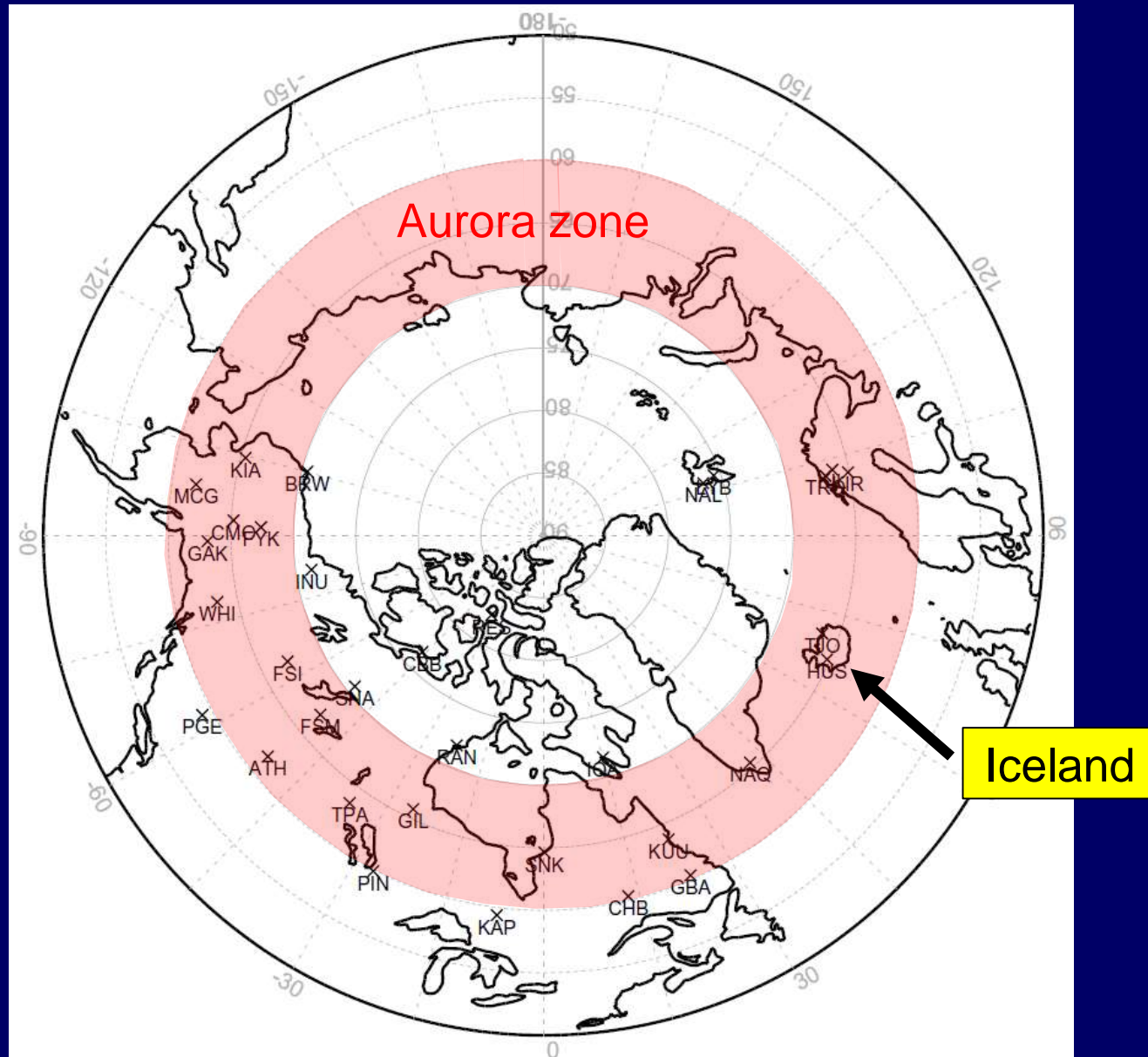


Interplanetary
Magnetic Field
(IMF)

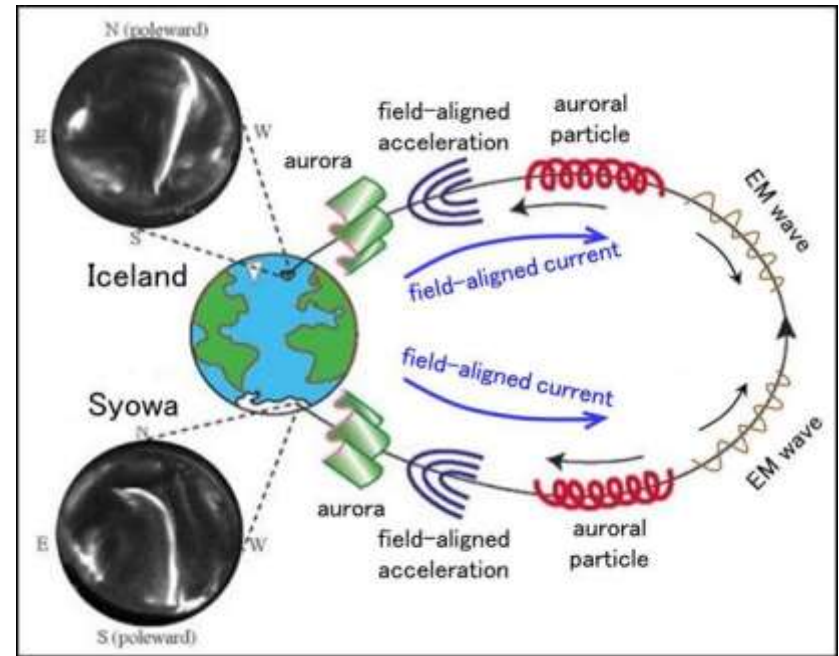


Iceland – Syowa Auroral Conjugate Observation

Mapping on Geomagnetic coordinates



Iceland-Syowa Auroral Conjugate Observation



Husafell (HUS)



Tjornes (TJO)



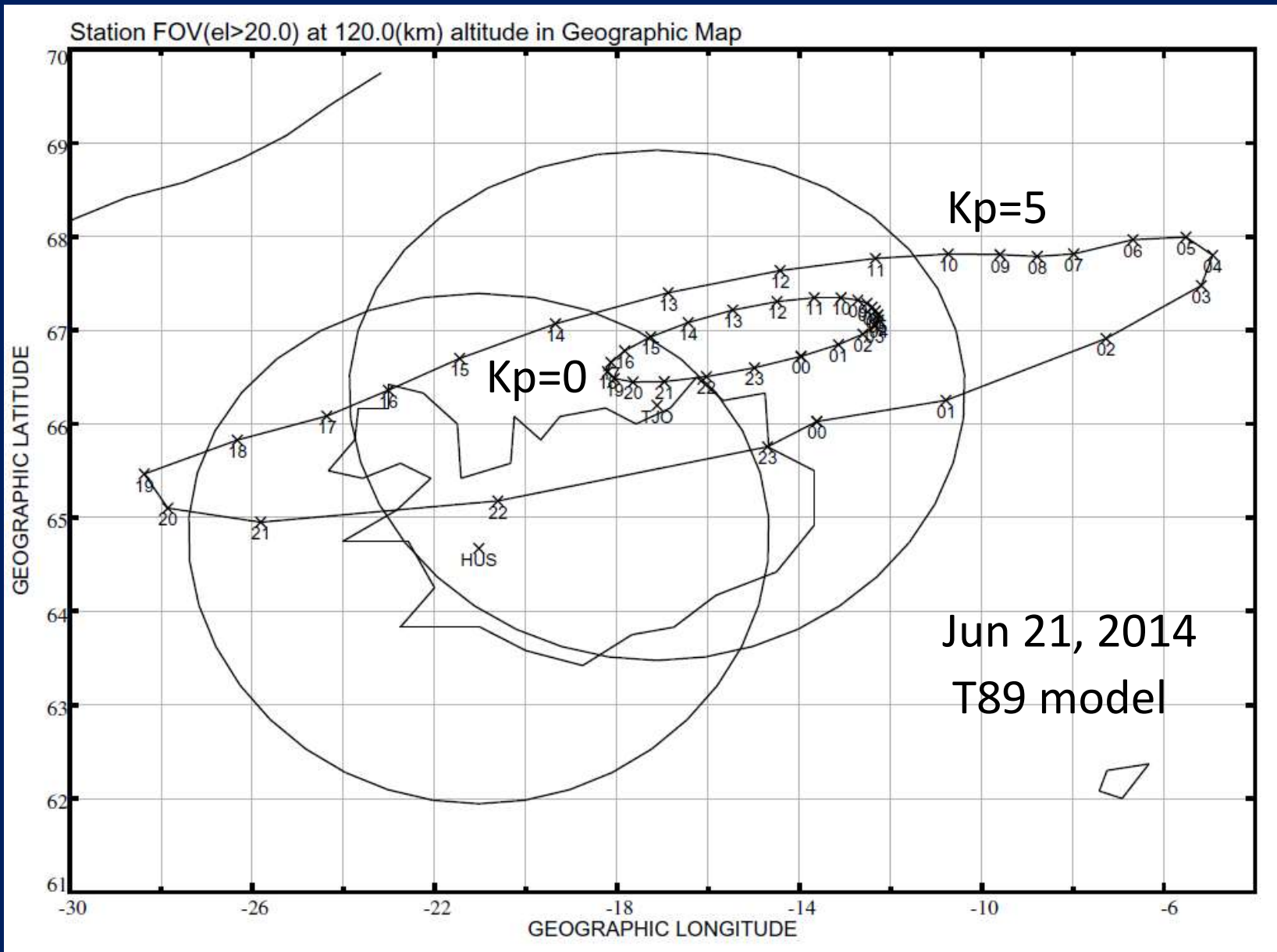
Syowa Station (SYO) in Antarctica

- Collaboration between University of Iceland and NIPR, Japan Since 1983.
- Observations of Auroral Phenomena have been carried out at two sites in Iceland, Husafell (Augastadir) and Tjornes (Manarbakki)

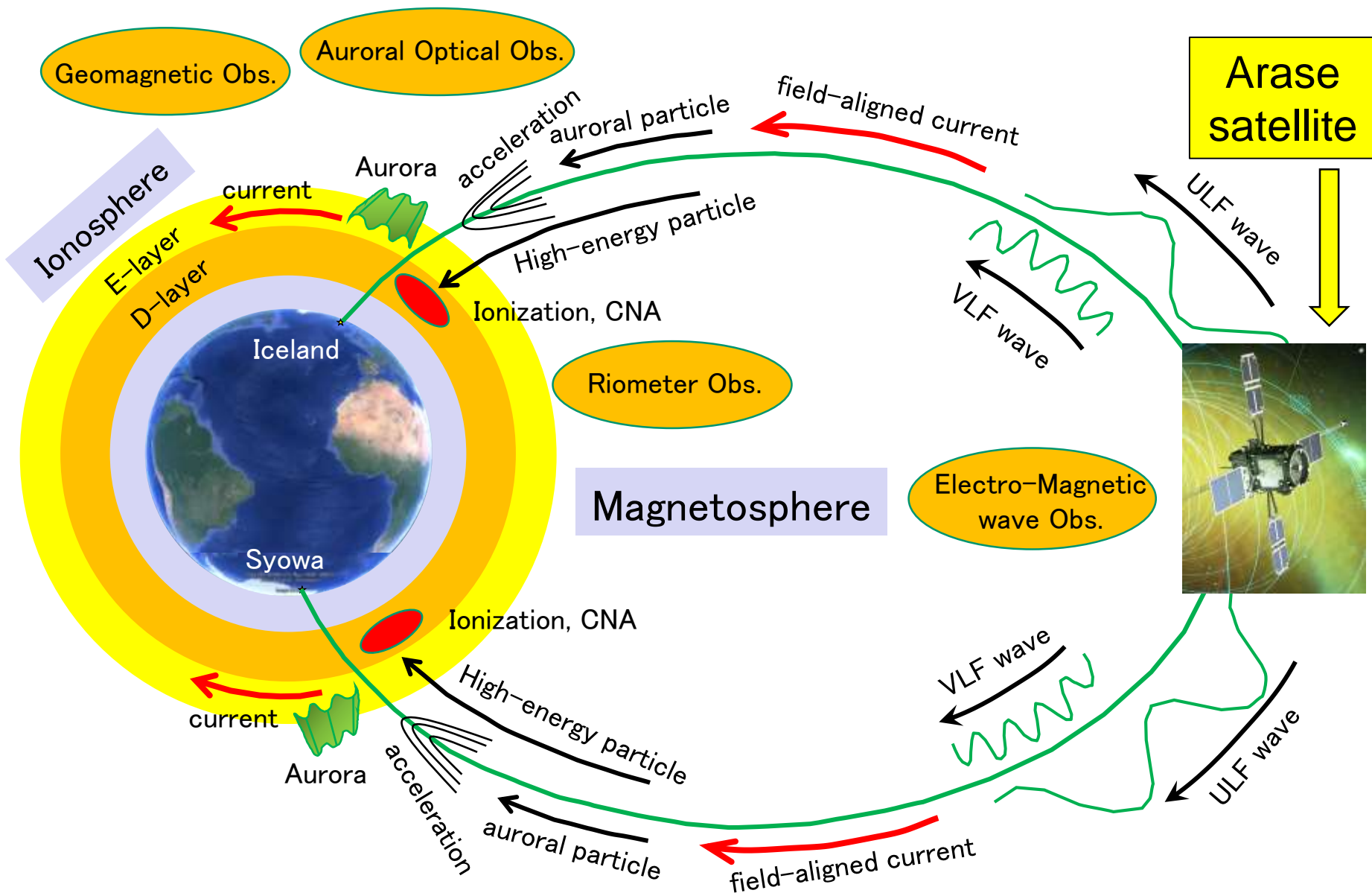
Conjugate point of Syowa Station in Iceland (IGRF)



Activity dependence: Daily variation of Conjugate point of Syowa



Syowa – Iceland Conjugate Observation for Auroral phenomena



ERG (Arase) satellite launched on 20 Dec., 2016

To study the inner magnetosphere, especially the Radiation Belts

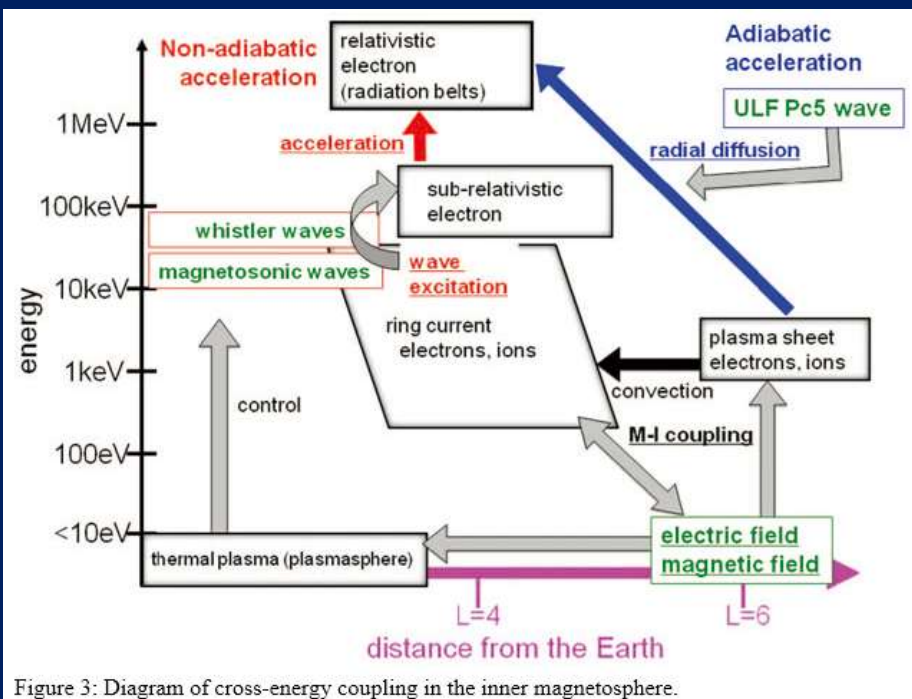
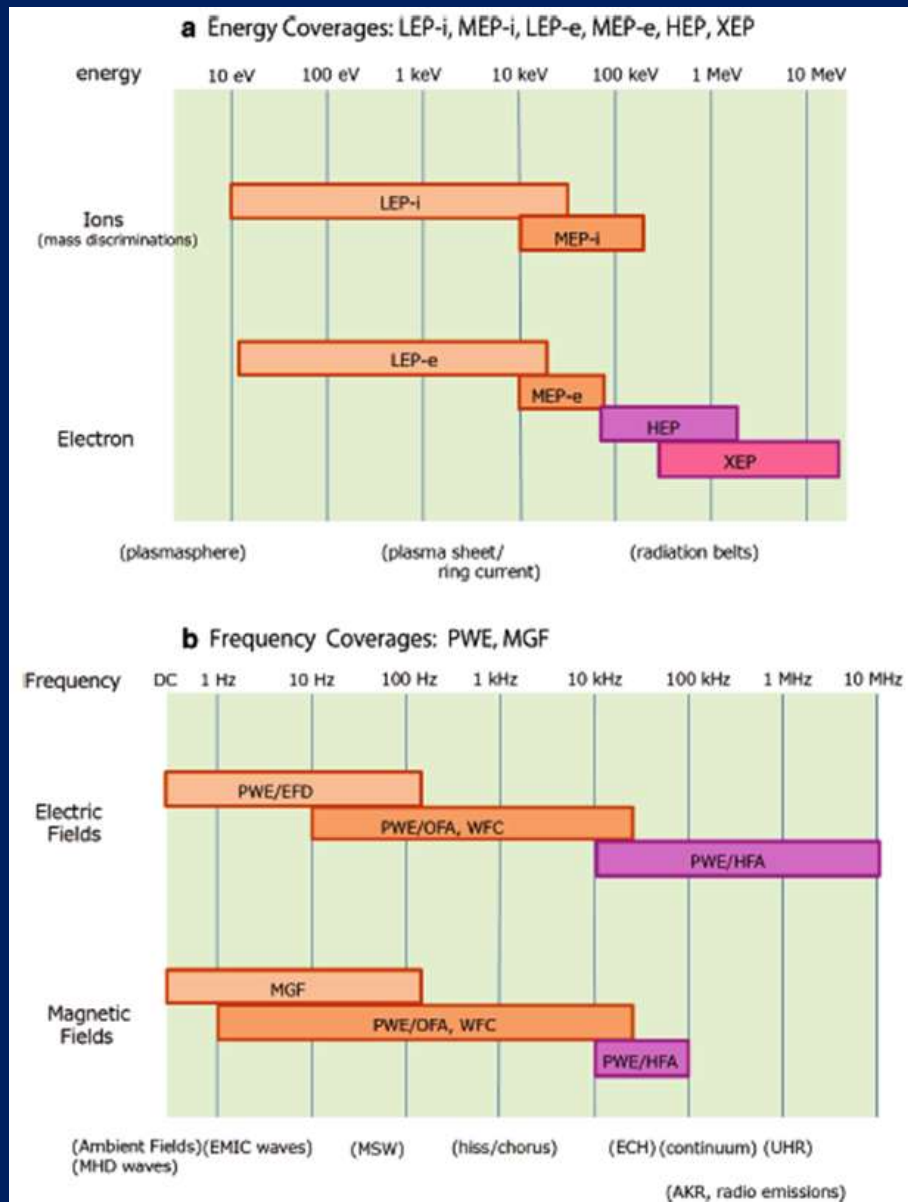
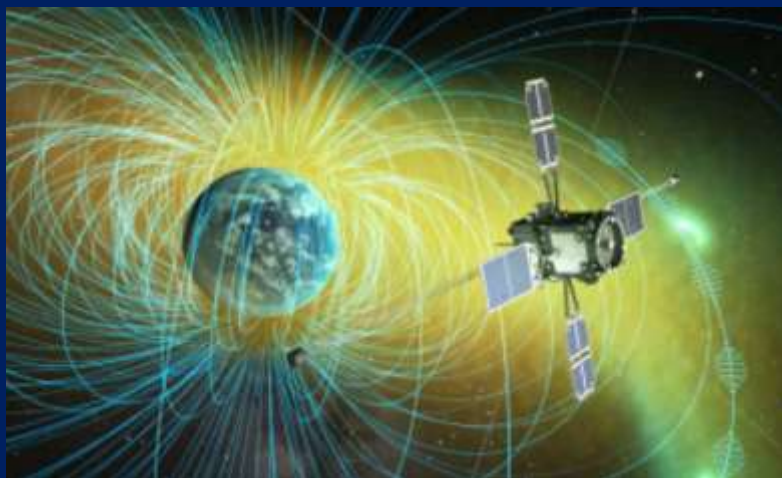
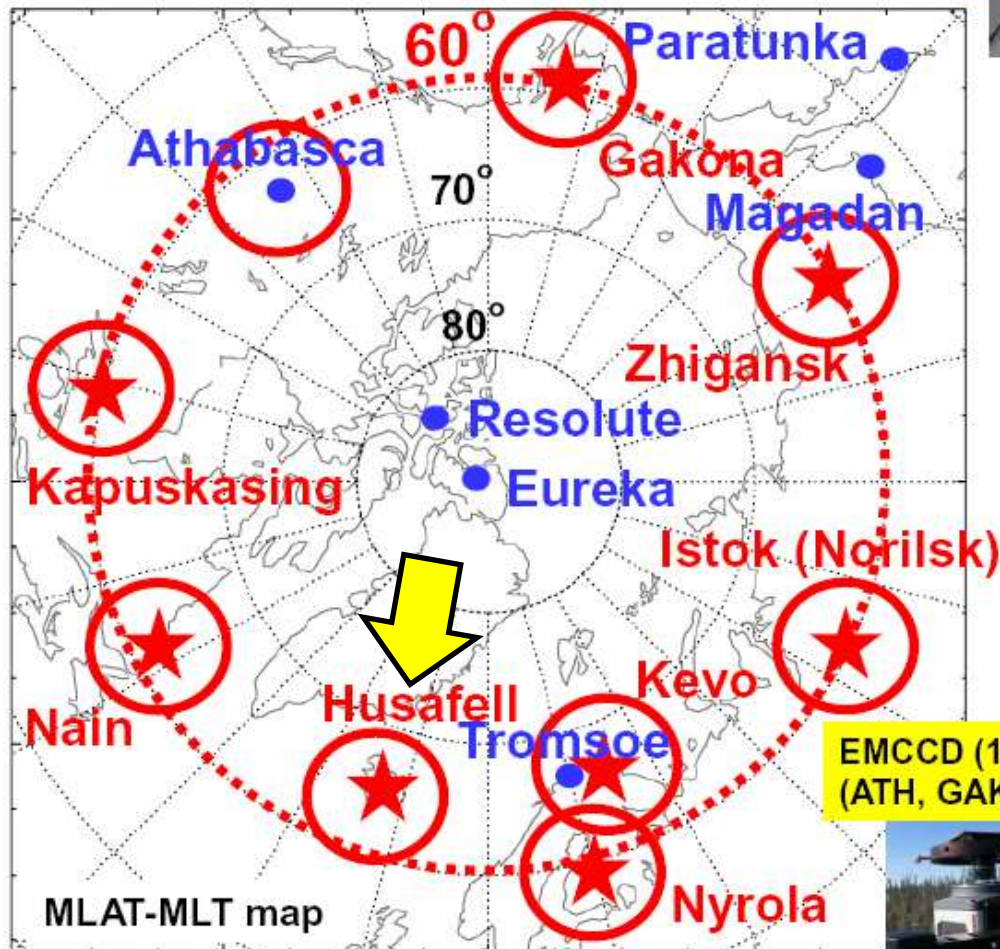


Figure 3: Diagram of cross-energy coupling in the inner magnetosphere.

PWING: ground-based observation network collaborating with Arase

Ground-based stations of the **PWING Project**.

● Existing sites ★ New sites

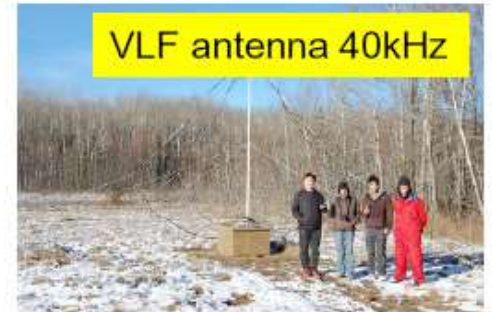


<http://www.isee.nagoya-u.ac.jp/dimr/PWING/>

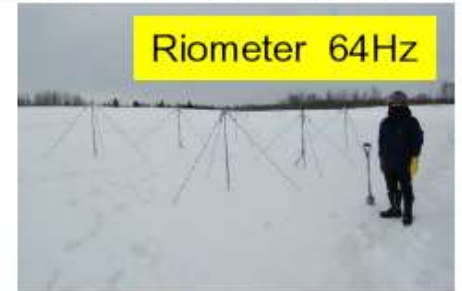
Induction magnetometer 64Hz



VLF antenna 40kHz



Riometer 64Hz



EMCCD (100Hz)
(ATH, GAK, KEV)



all-sky camera 1.5min



Shiokawa et al. *Earth, Planets and Space* (2017) 69:160
DOI 10.1186/s40623-017-0745-9

Instruments at conjugate stations

Instrument	SYO	HUS	TJO
Fluxgate magnetometer	○	○	○
Induction magnetometer	○	○	○
VLF receiver	○	○	
Riometer	○	○	○
Imaging Riometer	○	○	
All-sky High-speed Auroral Imager (100Hz)	○		○
All-sky TV camera	○	○	○
All-sky monochromatic Imager	○	○	
Proton Aurora Spectrograph	○		○
Meridian Scanning Photometer	○	○	
Atmospheric Electric Field detector	○	○	
MF Auroral radio emission		○	
Cosmic-ray observation (Be-7 sampler)		○	

Instruments at conjugate stations

Instrument	SYO	HUS	TJO
FM/CW radar type ionosonde (NiCT)	○		
GPS scintillation (NiCT)	○		
GNSS TEC (IGS:SYOG) (GSI)	○		
SuperDARN radars : Syowa-S, -E	○		
1-100Hz ELF wave observation : lightning	○		
Cosmic-ray Neutron monitor, Muon detector	○		
All-sky Airglow Imager : IR	○		
OH Airglow Spectrometer : temperature	○		
MF-radar : wind	○		
PANSY Atmospheric MST/IS radar : wind	○		

Auroral conjugacy: Previous study during IGY period

Alaska

New Zealand

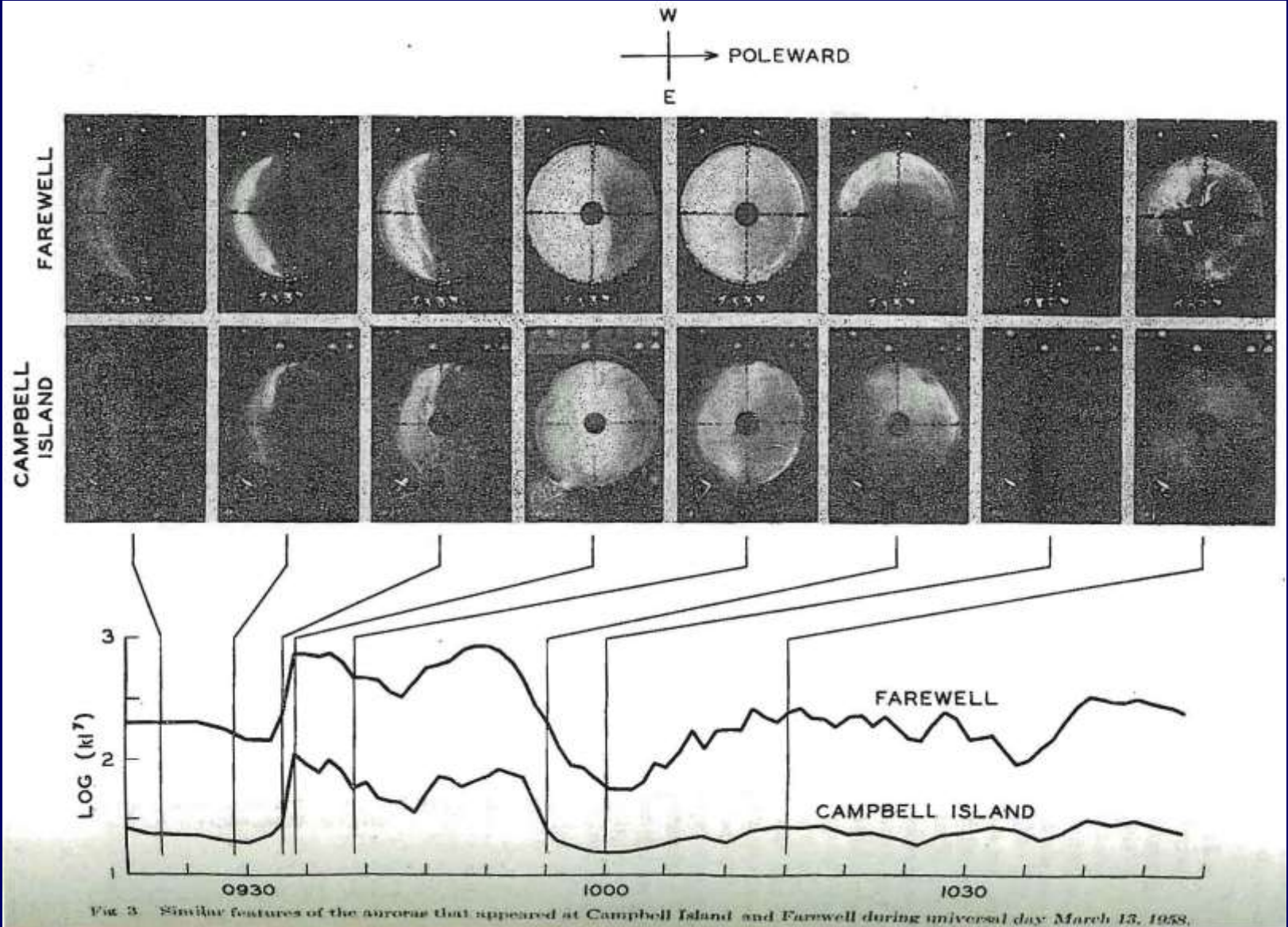
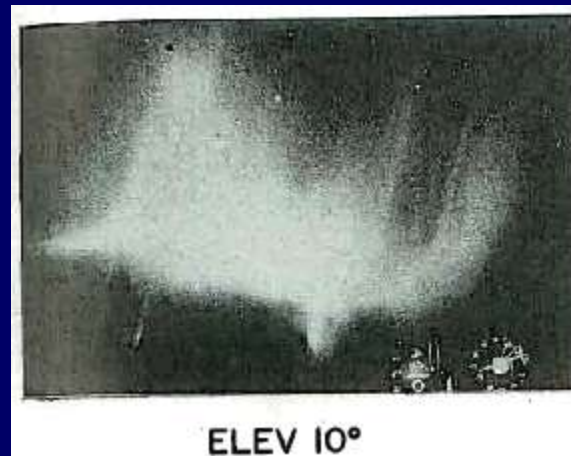
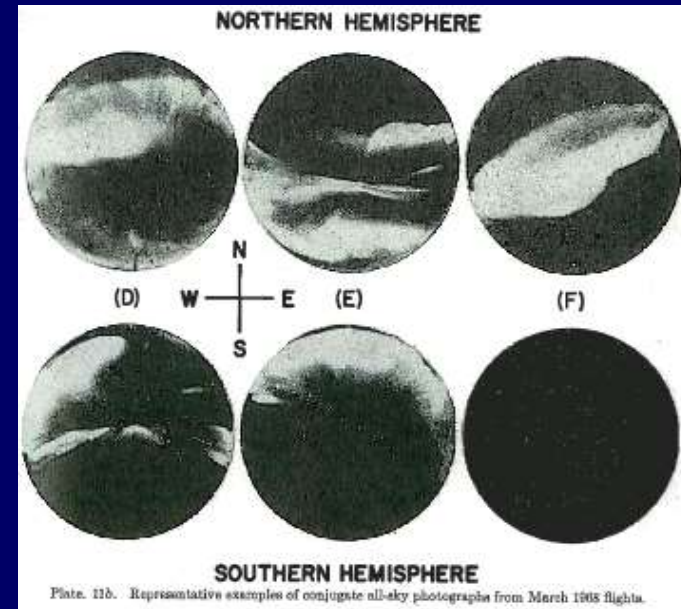
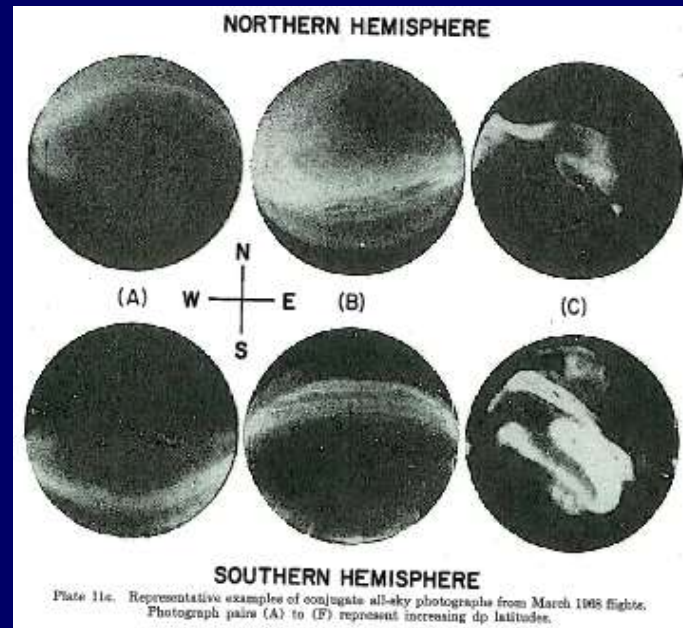
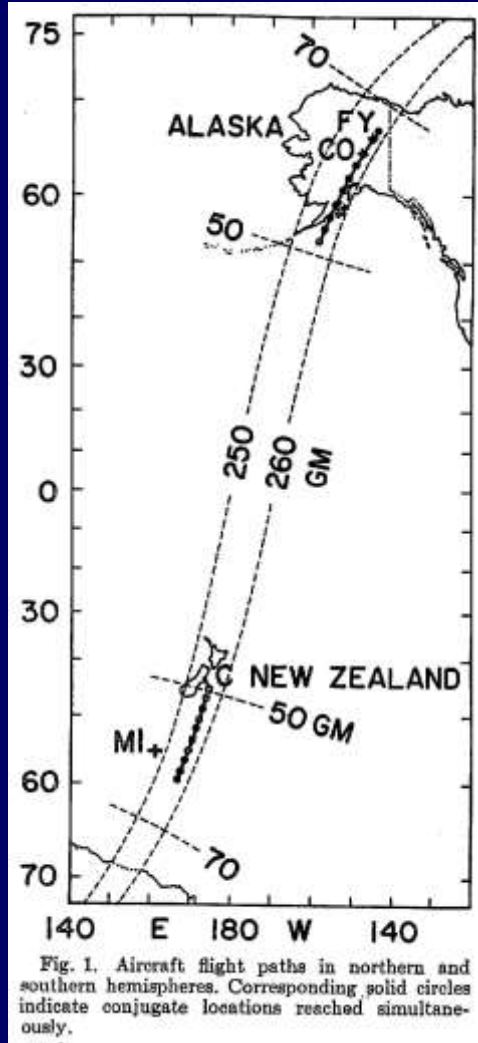


FIG. 3. Similar features of the aurorae that appeared at Campbell Island and Farewell during universal day March 13, 1958.

All-sky camera data on March 13, 1958 (DeWitt, JGR, 1962)

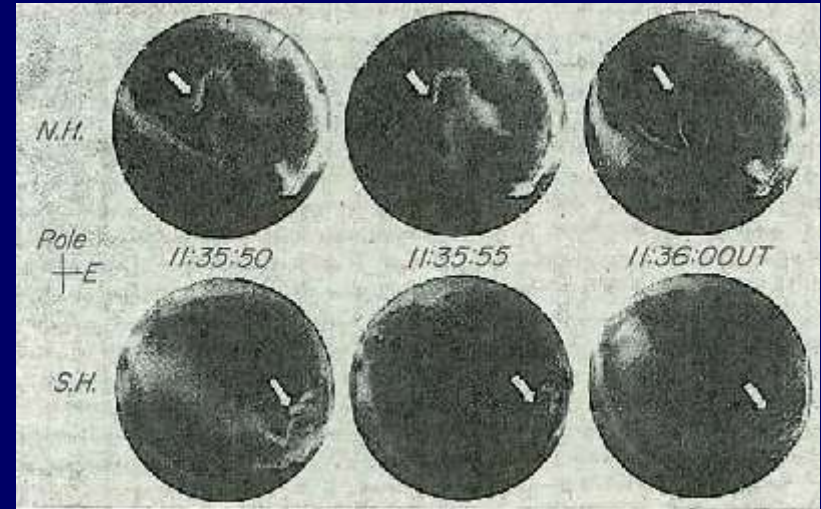
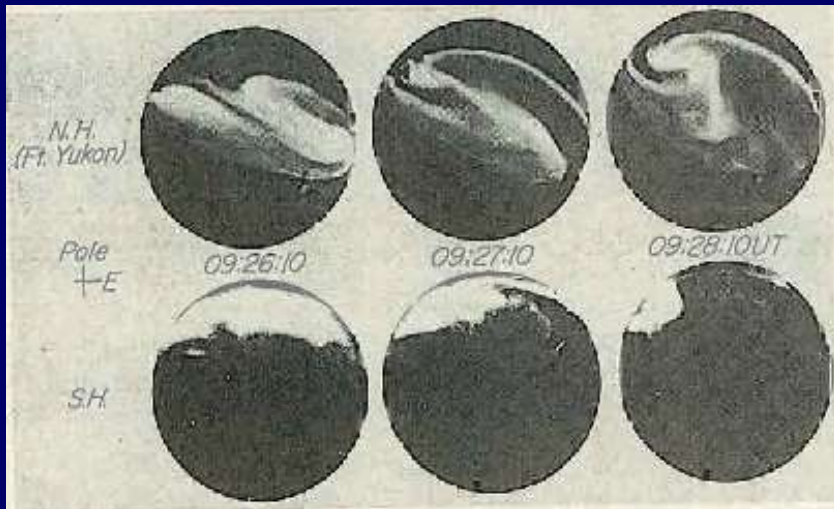
Previous Study using the Jet Aircraft Flight between Alaska - New Zealand during 1967~1971 (18 flights)



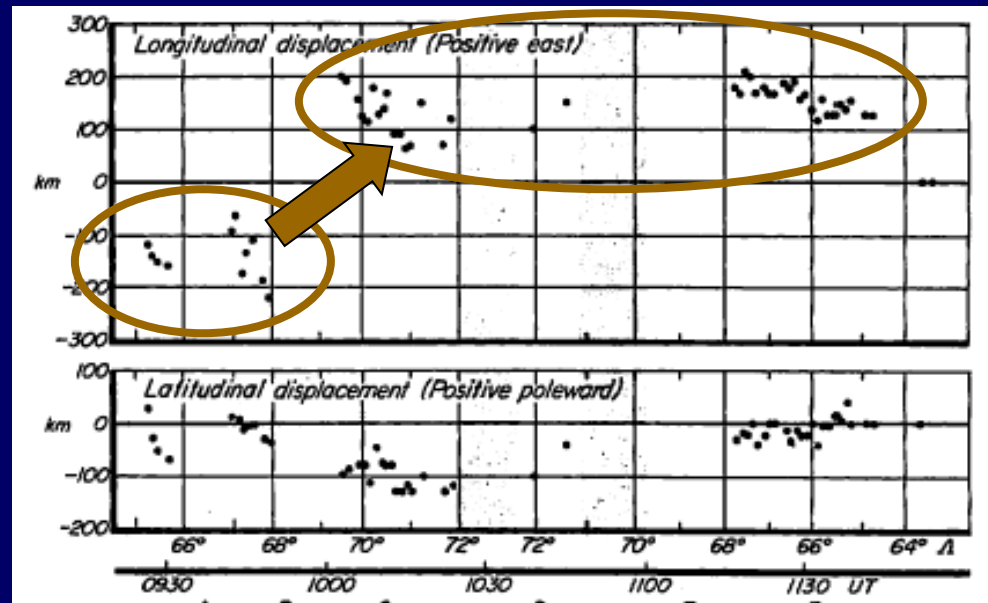
along 256° MM

Belon et al., JGR, 1969

Previous Study using the Jet Aircraft Flight Motion of Conjugate Points during Substorm



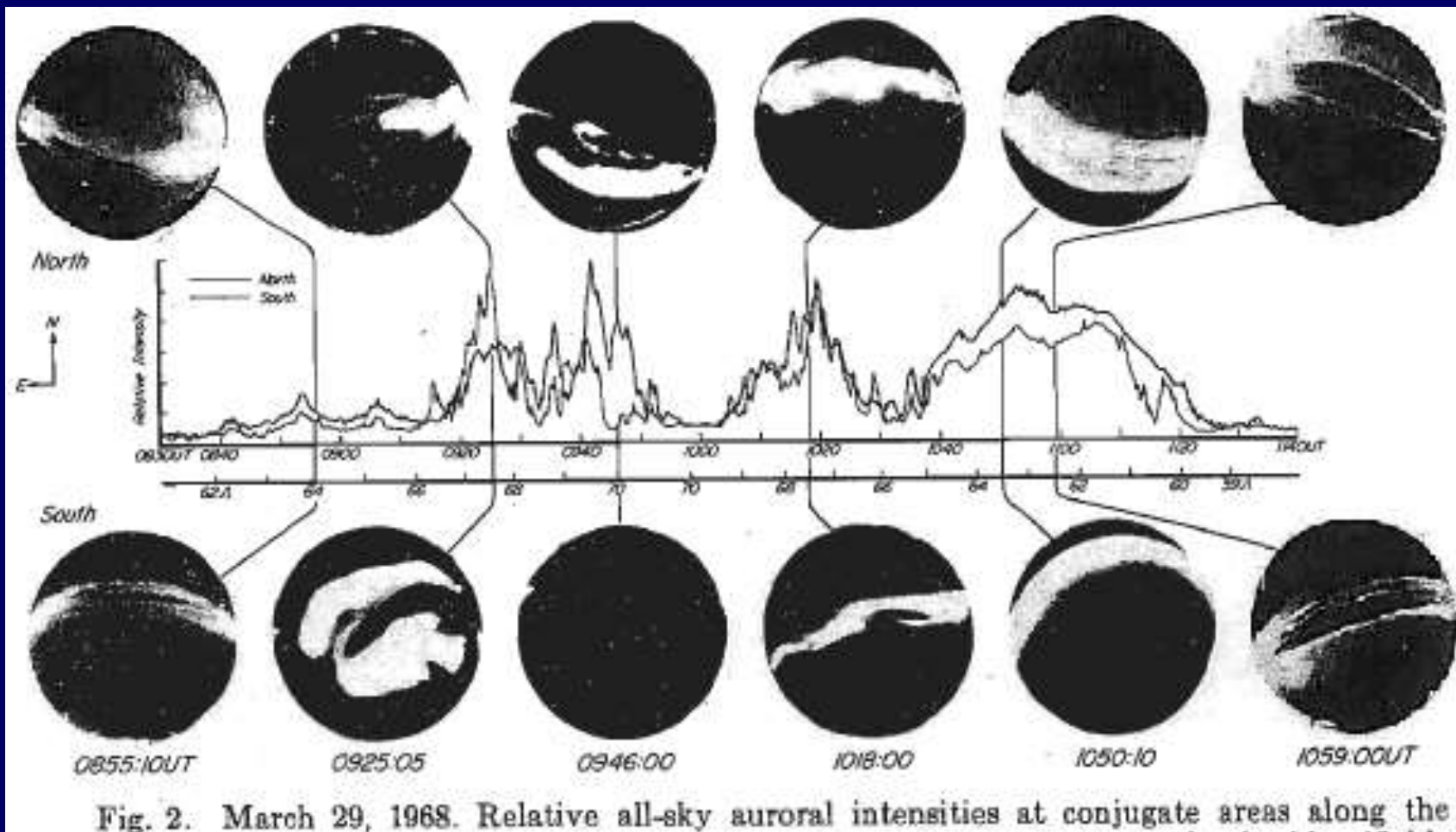
Small
WTS



Pulsating
Aurora

Previous Study using the Jet Aircraft Flight

Intensity difference $N > S$ ($x \sim 1.3$)



Stenbaek-Nielsen et al., JGR, 1973

Difference in B at conjugate points and Auroral Occurrence

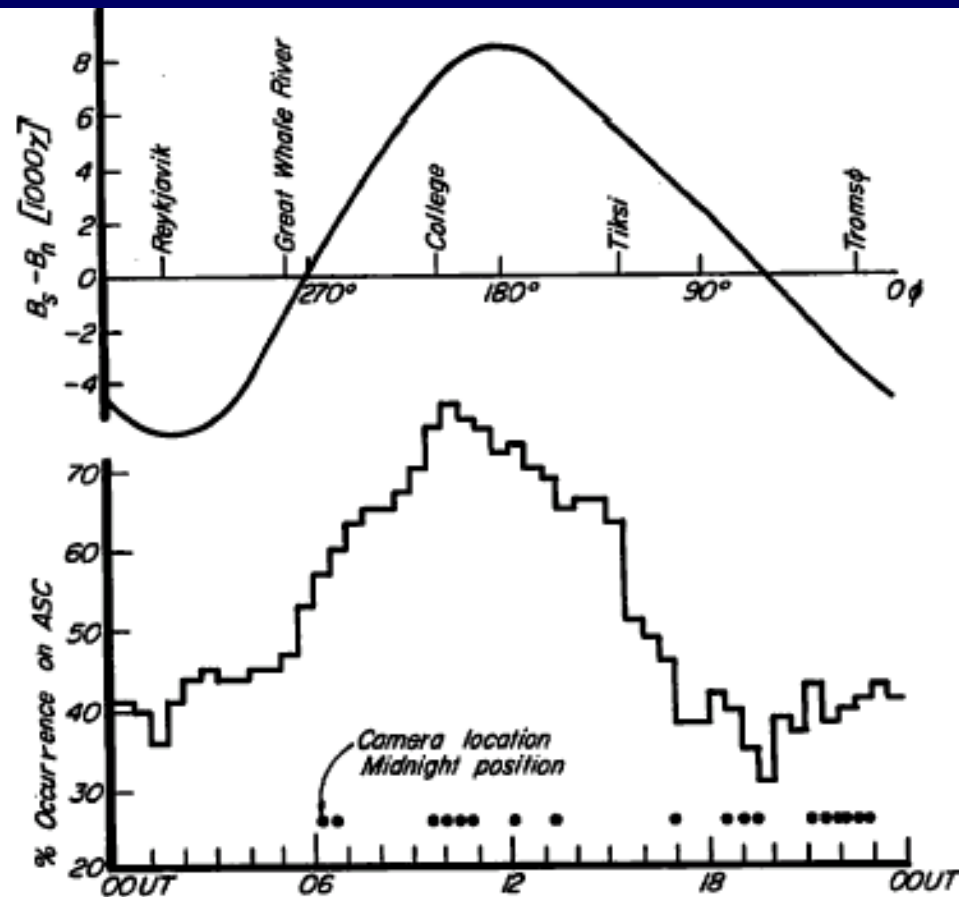


Fig. 1. Difference in magnetic field strength at 300 km at conjugate points along 65° invariant latitude. The lower plot gives per cent occurrence of aurora observed on all-sky camera data from auroral stations located between 64° and 70° N geomagnetic latitude. The data cover the period February 14 through March 9, 1958.

Auroral conjugacy: Satellite imager observation

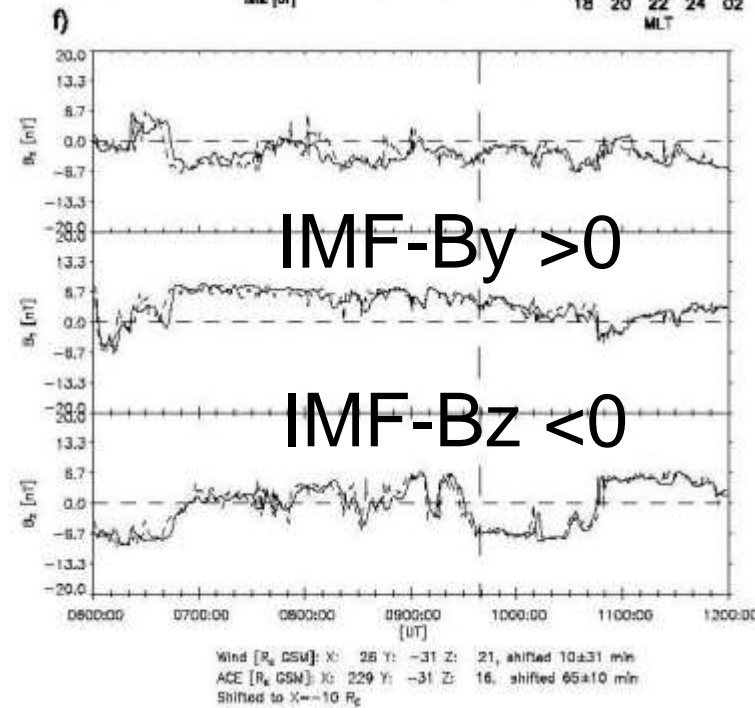
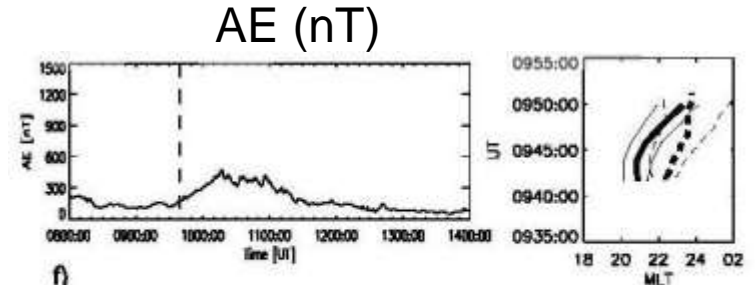
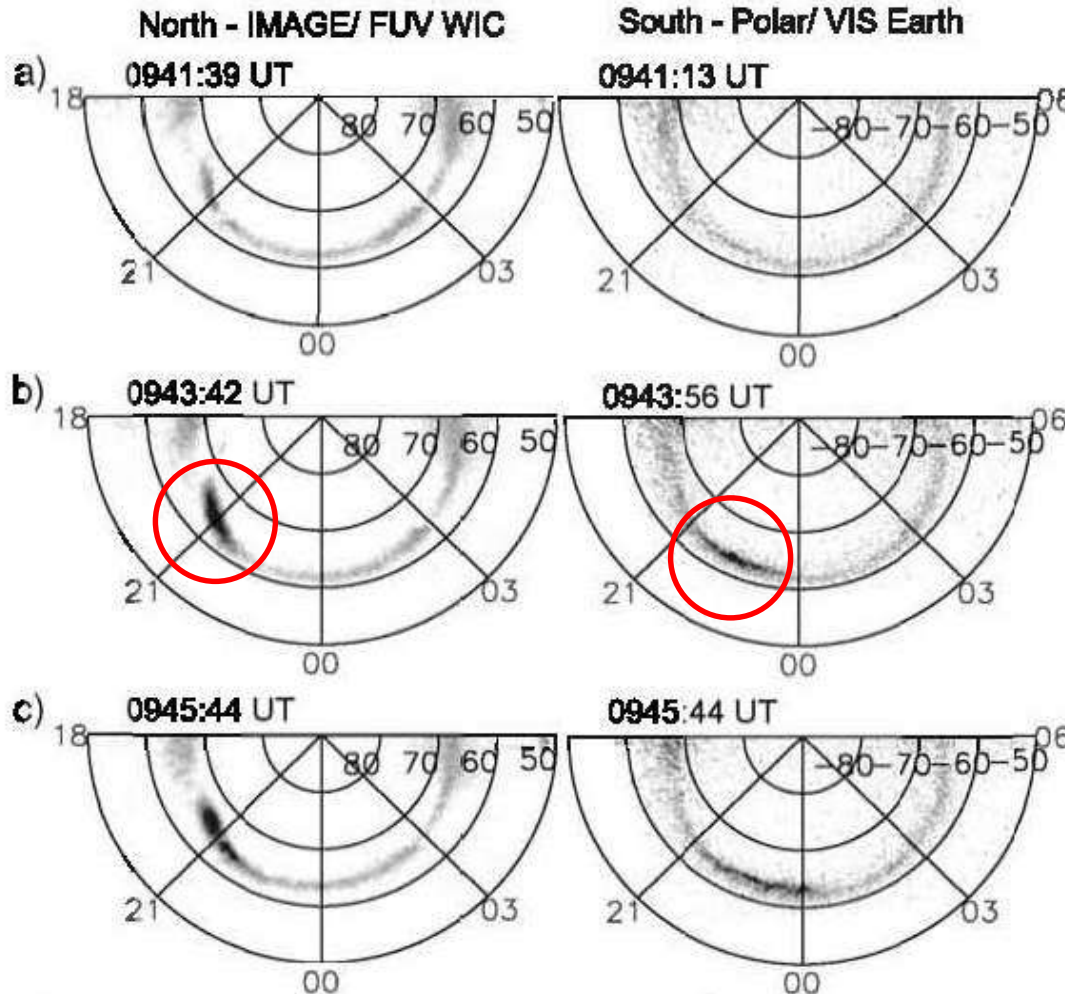
IMF external control of the conjugate auroral location

North

September 13, 2001

South

Østgaard, et al. (JGR, 2004)



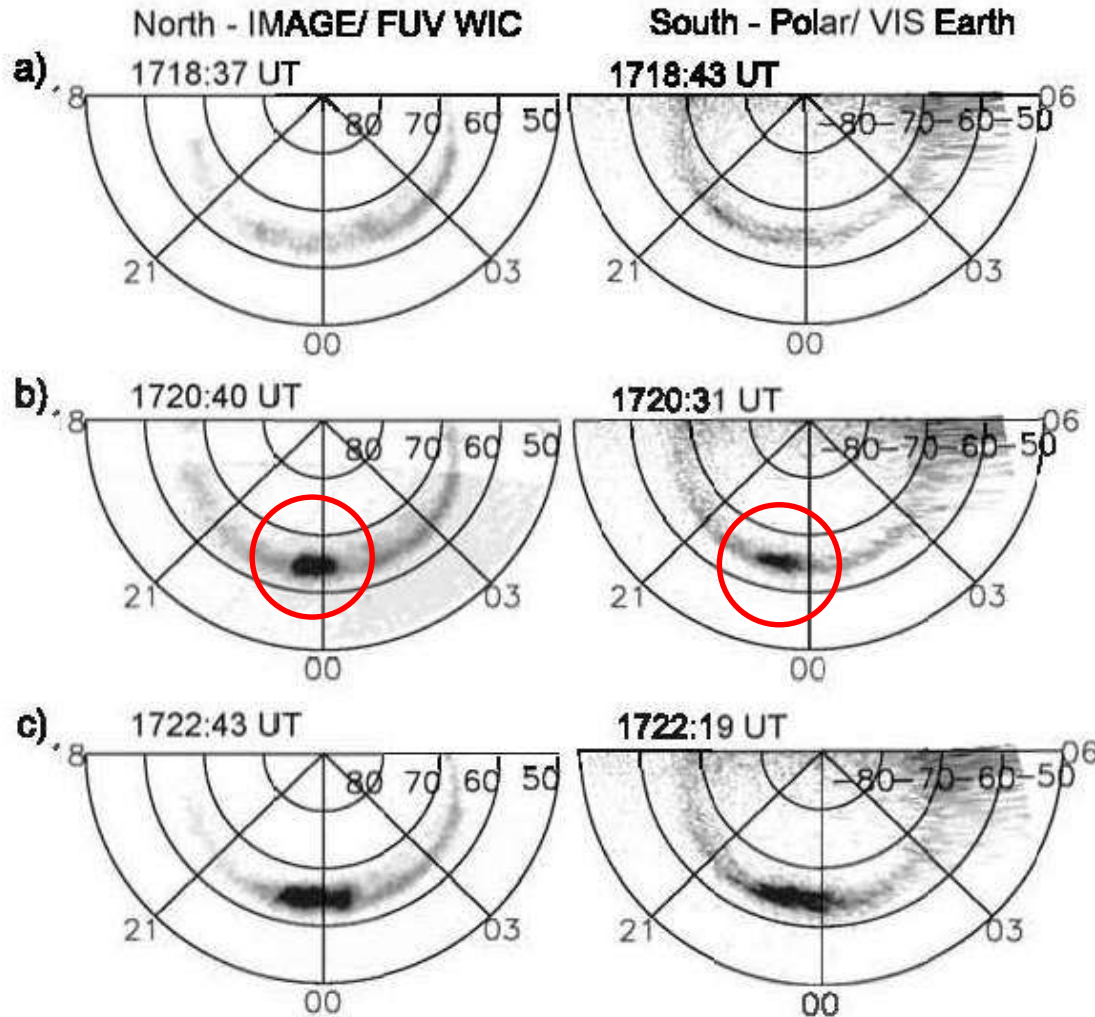
Auroral conjugacy: Satellite imager observation

IMF external control of the conjugate auroral location

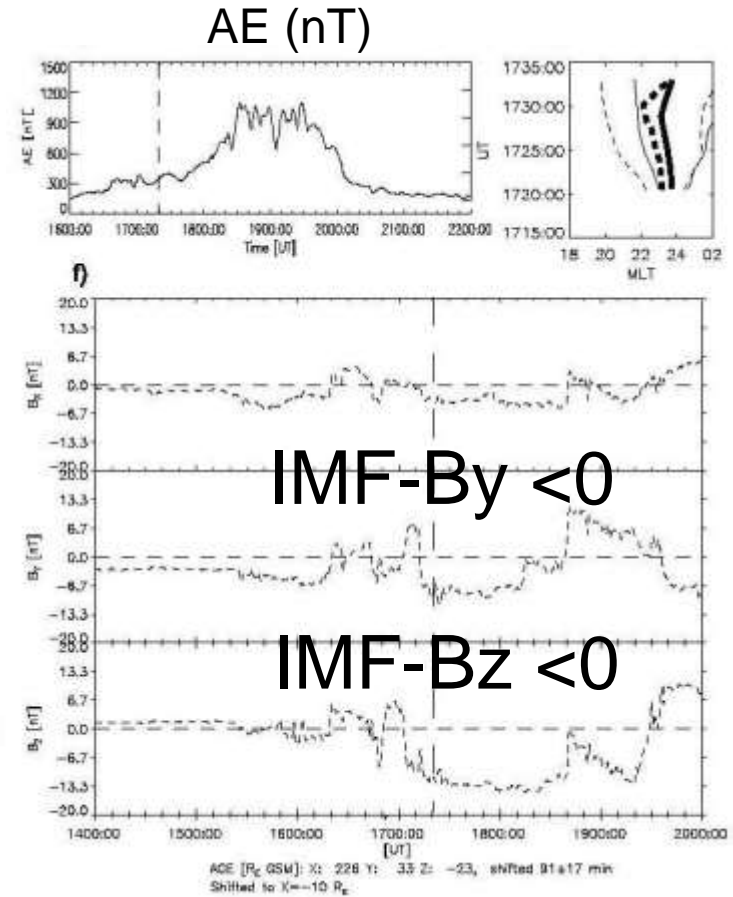
North

November 15, 2001

South

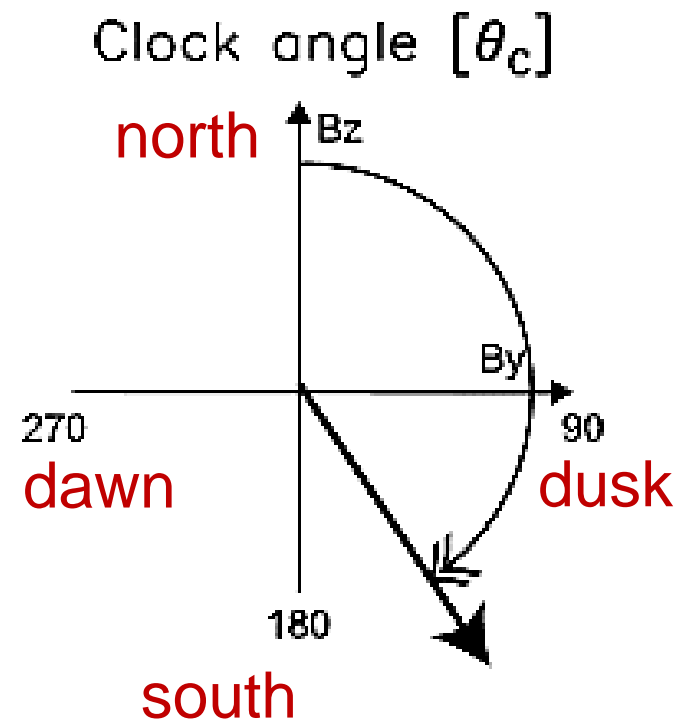
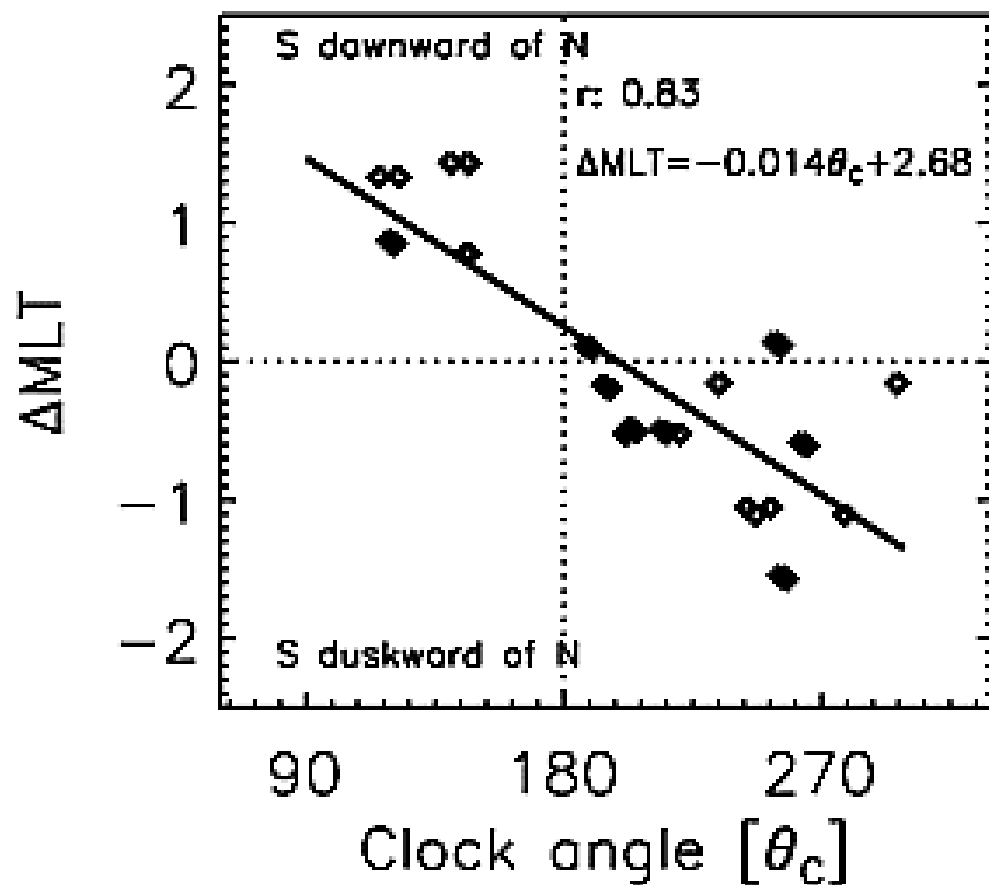


Østgaard, et al. (JGR, 2004)

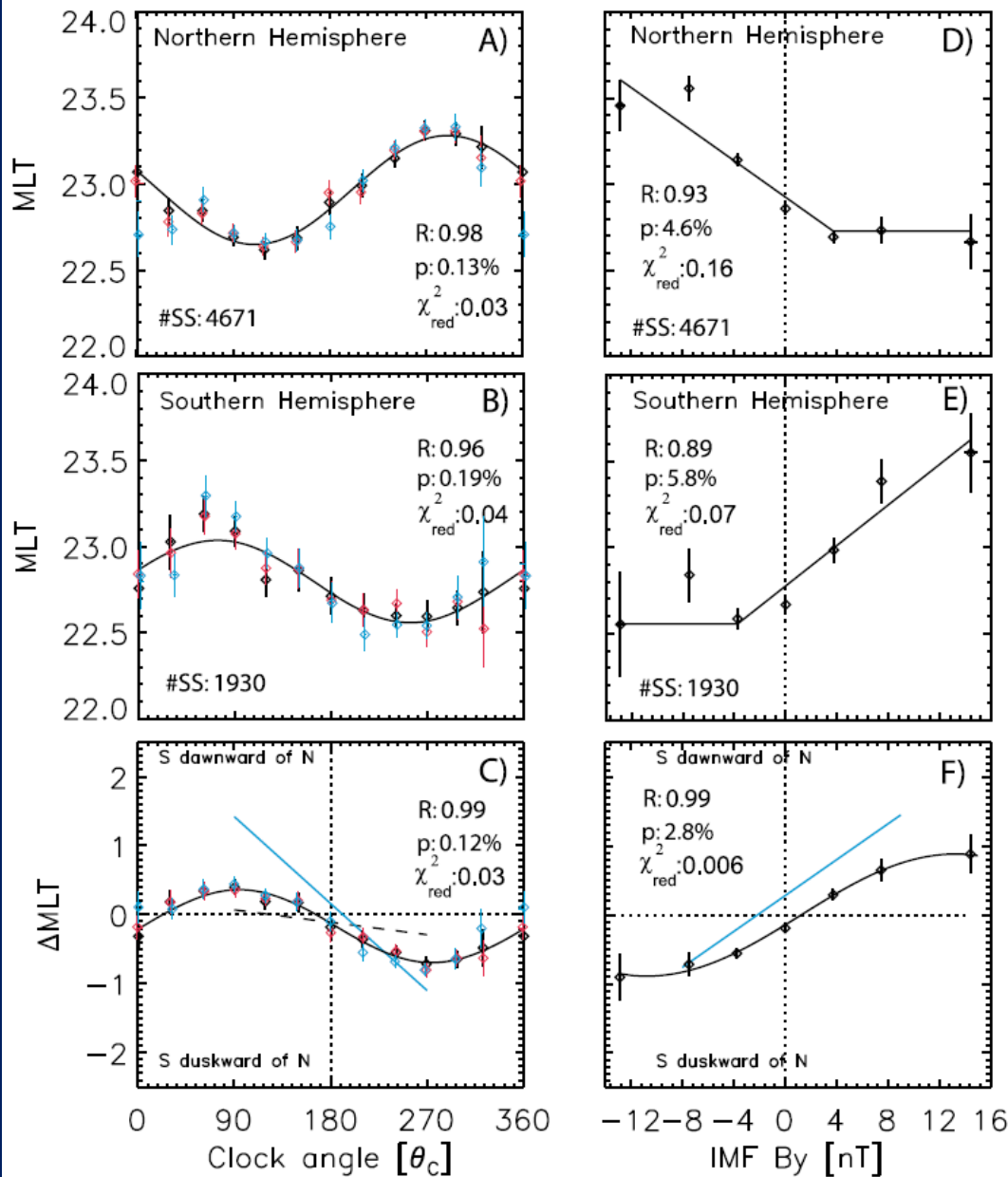


IMF external control of the conjugate auroral location

Østgaard, et al. (JGR, 2004)



IMF control of the conjugate auroral location



Independent Substroms
 Polar UVI : 2539
 IMAGE FUV : 4192

$$MLT_n = 0.32 \times \sin(\theta_c - 201) + 22.9,$$

$$MLT_s = 0.24 \times \sin(\theta_c + 16.3) + 22.8$$

$$\Delta MLT (MLT_s - MLT_n) =$$

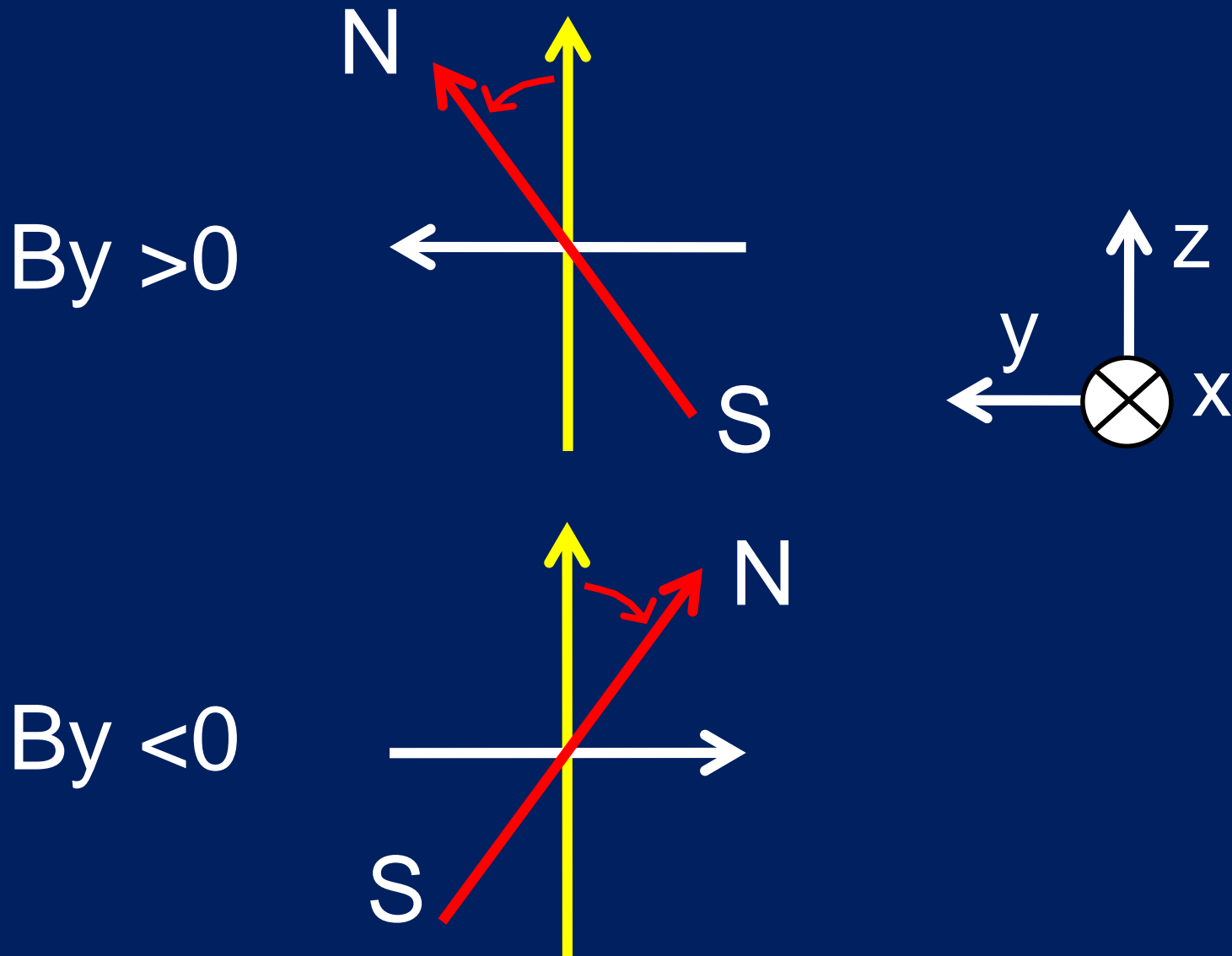
$$0.53 \times \sin(\theta_c - 4.8) - 0.17$$



0.73 (if $B > 5\text{nT}$)

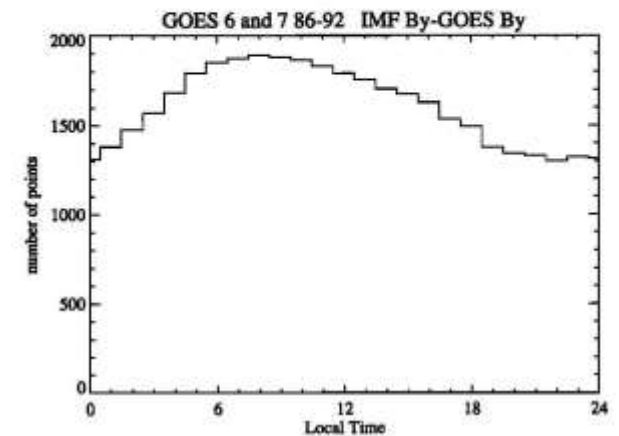
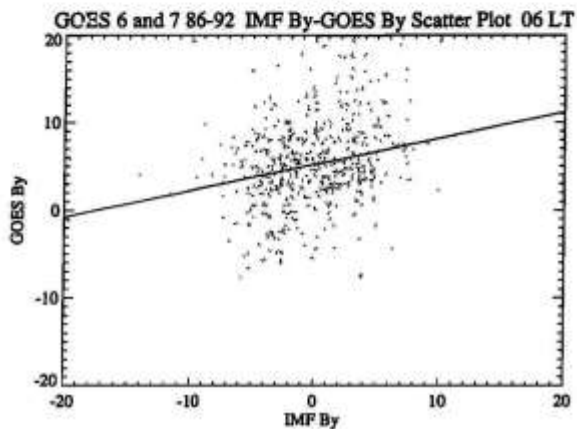
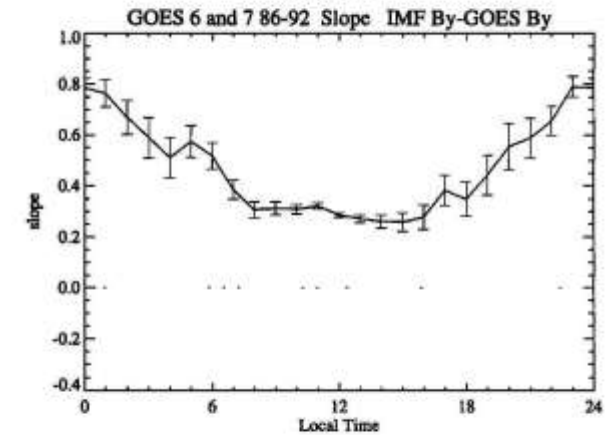
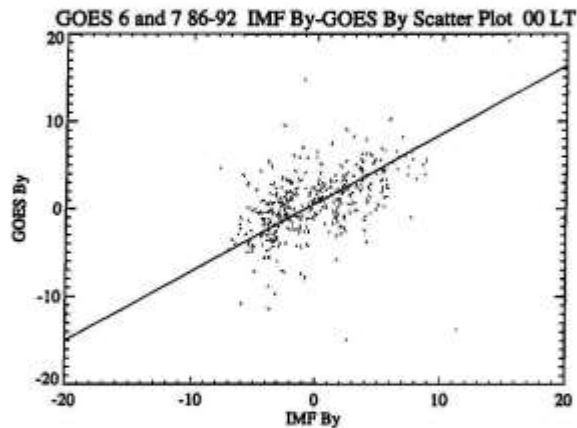
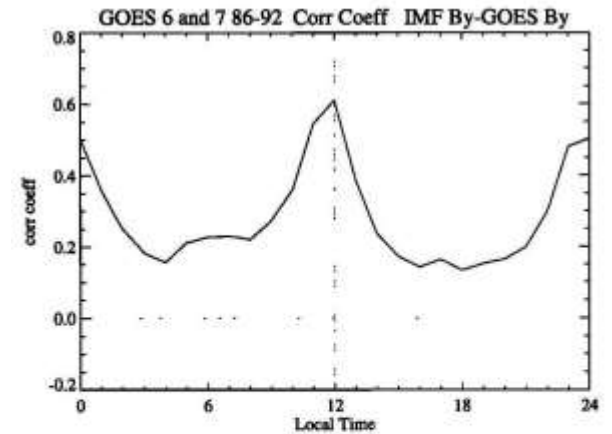
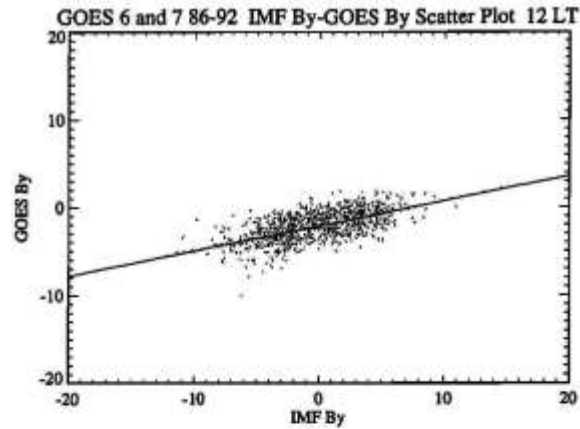
Østgaard, et al.
 (GRL, 2011)

Footprint location change due to B_y entry



IMF- B_y entry into near earth region

Wing, et al.
(GRL, 1995)



IMF- B_y entry into near earth region

Tenfjord,
et al.
(JGR,2017)

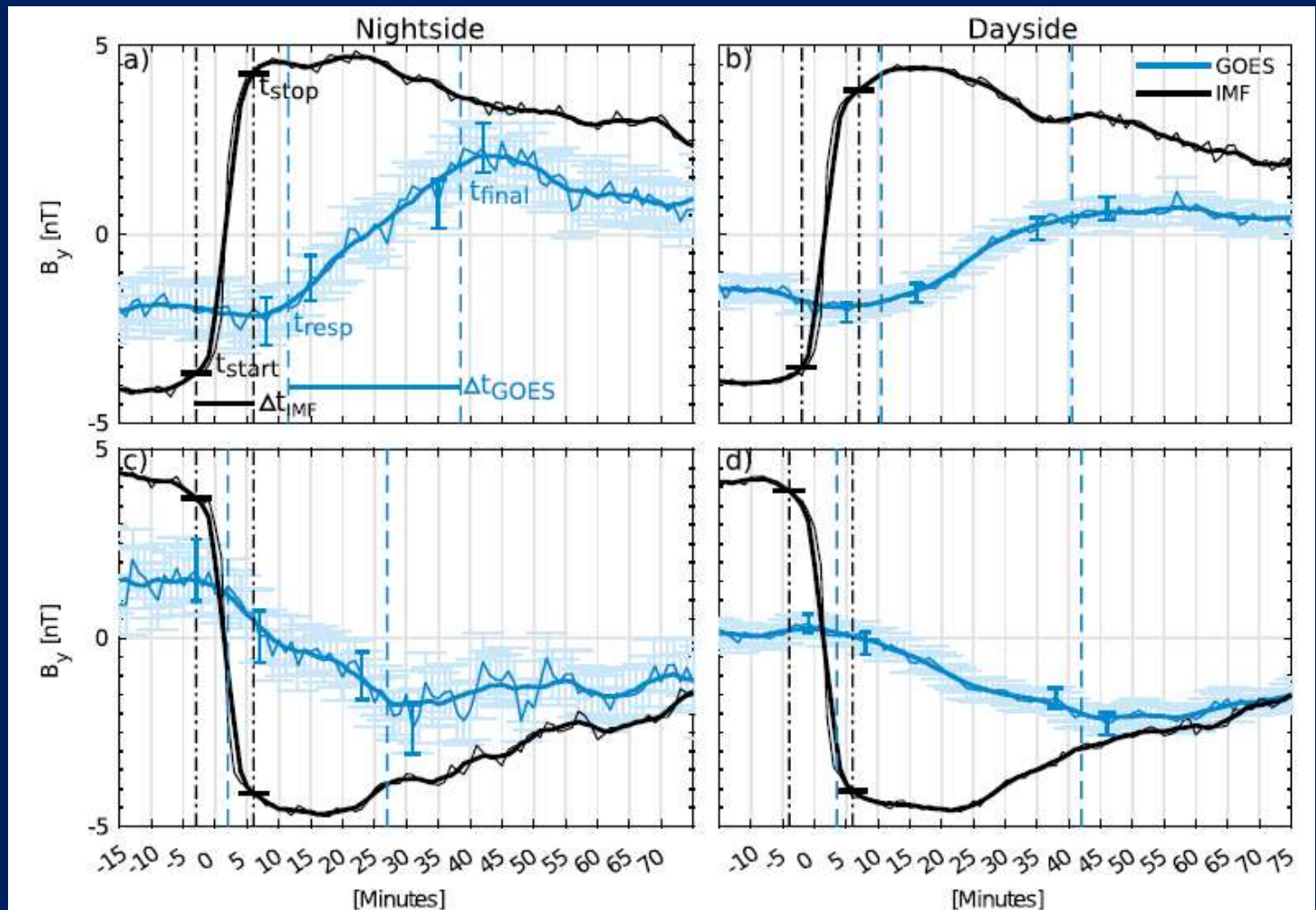
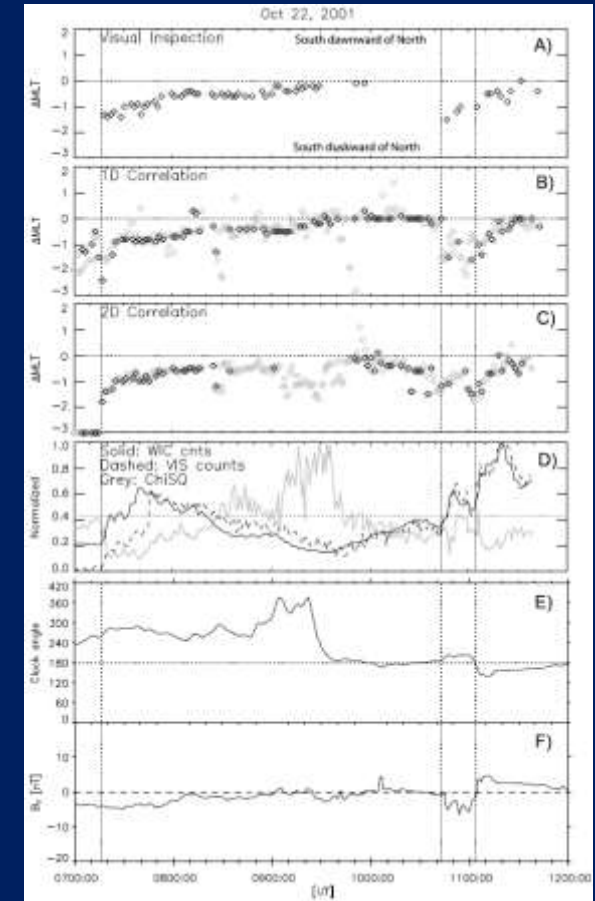
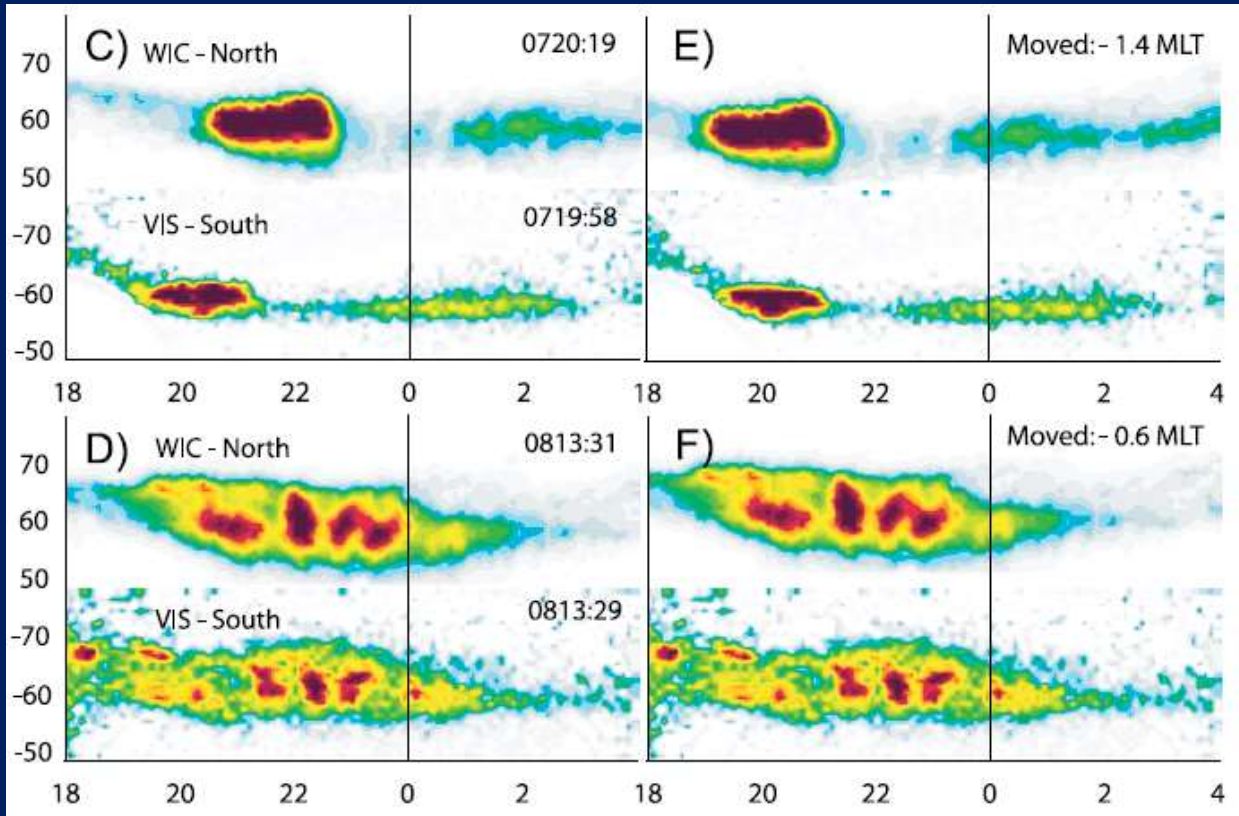


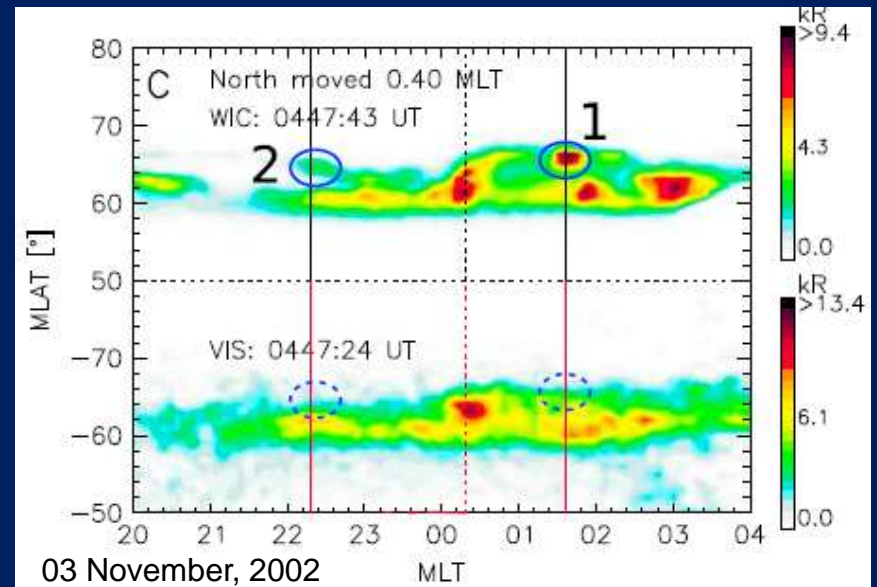
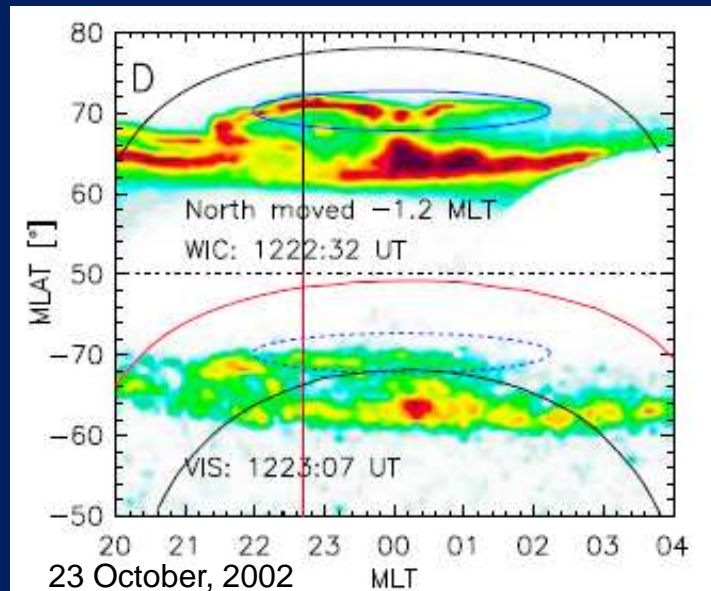
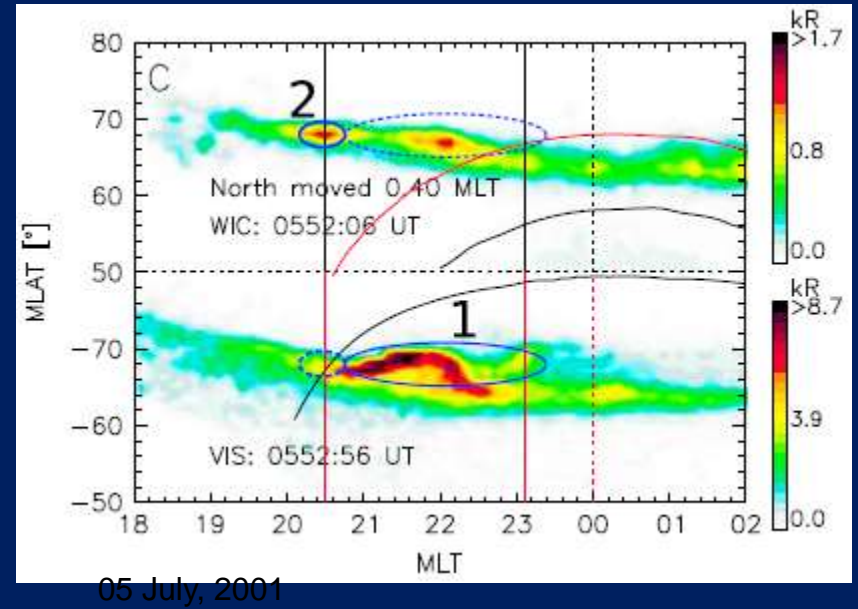
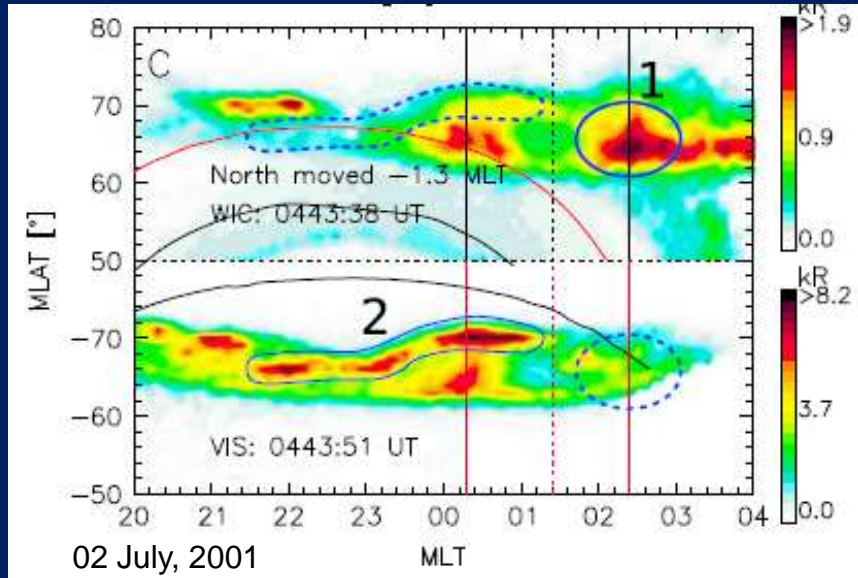
Figure 6. IMF B_y (black) and GOES B_y correspond to (a, b) Figure 4 and (c, d) Figure 5 but are smoothed using a moving average with 10 min step length. The black vertical dash-dotted lines show the defined t_{start} , the time when IMF B_y begins to reverse, and t_{stop} indicates the time when IMF B_y ends its rotation. The blue vertical dashed lines show the defined GOES response and the GOES final time. The uncertainty in GOES B_y represents the standard error of the mean. See text for details and Table 1 for values.

Evolution of the auroral displacement during substorm



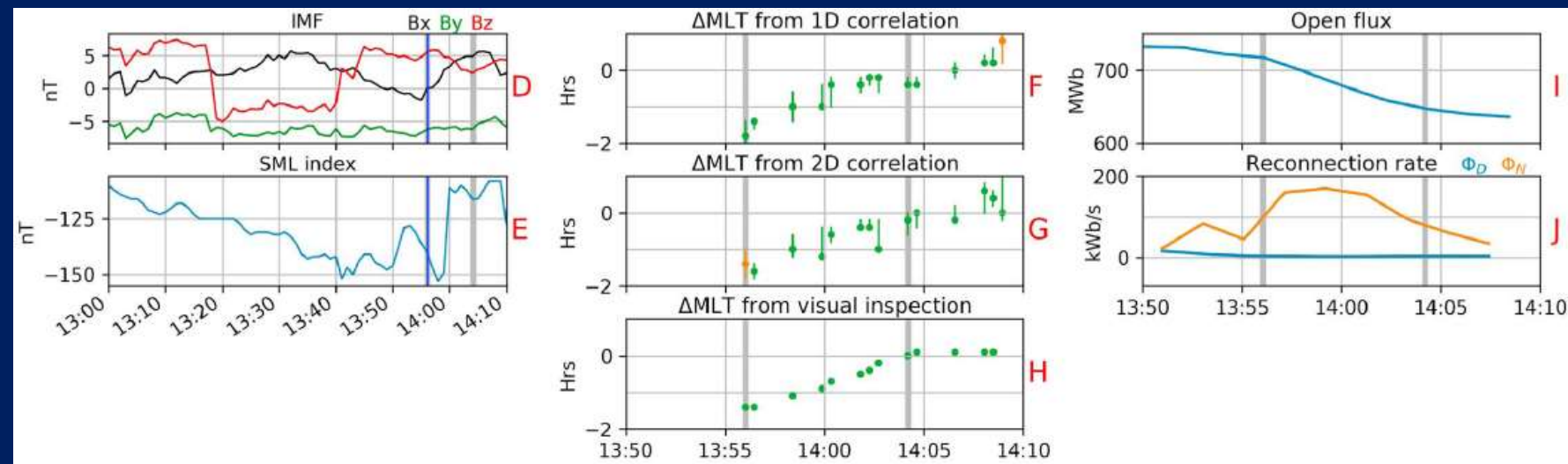
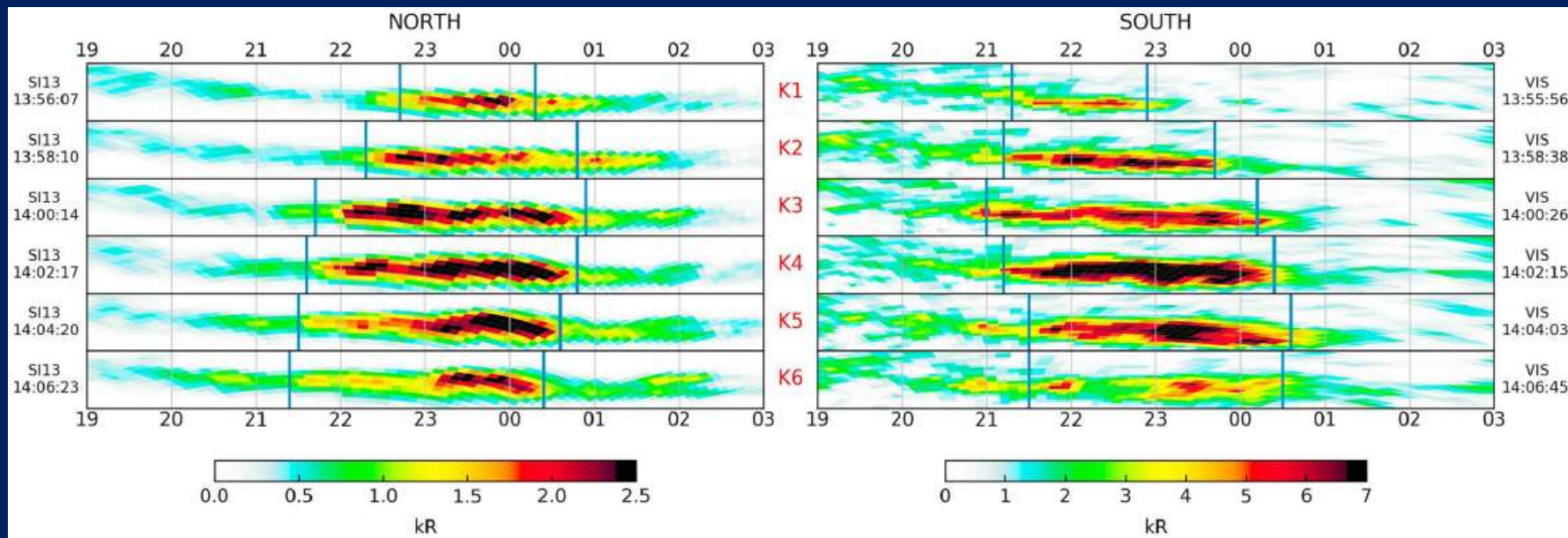
Østgaard, et al. (GRL, 2011)

Non-conjugacy of the nightside aurora



Reistad, et al. (JGR, 2013)

Evolution of the auroral displacement during substorm

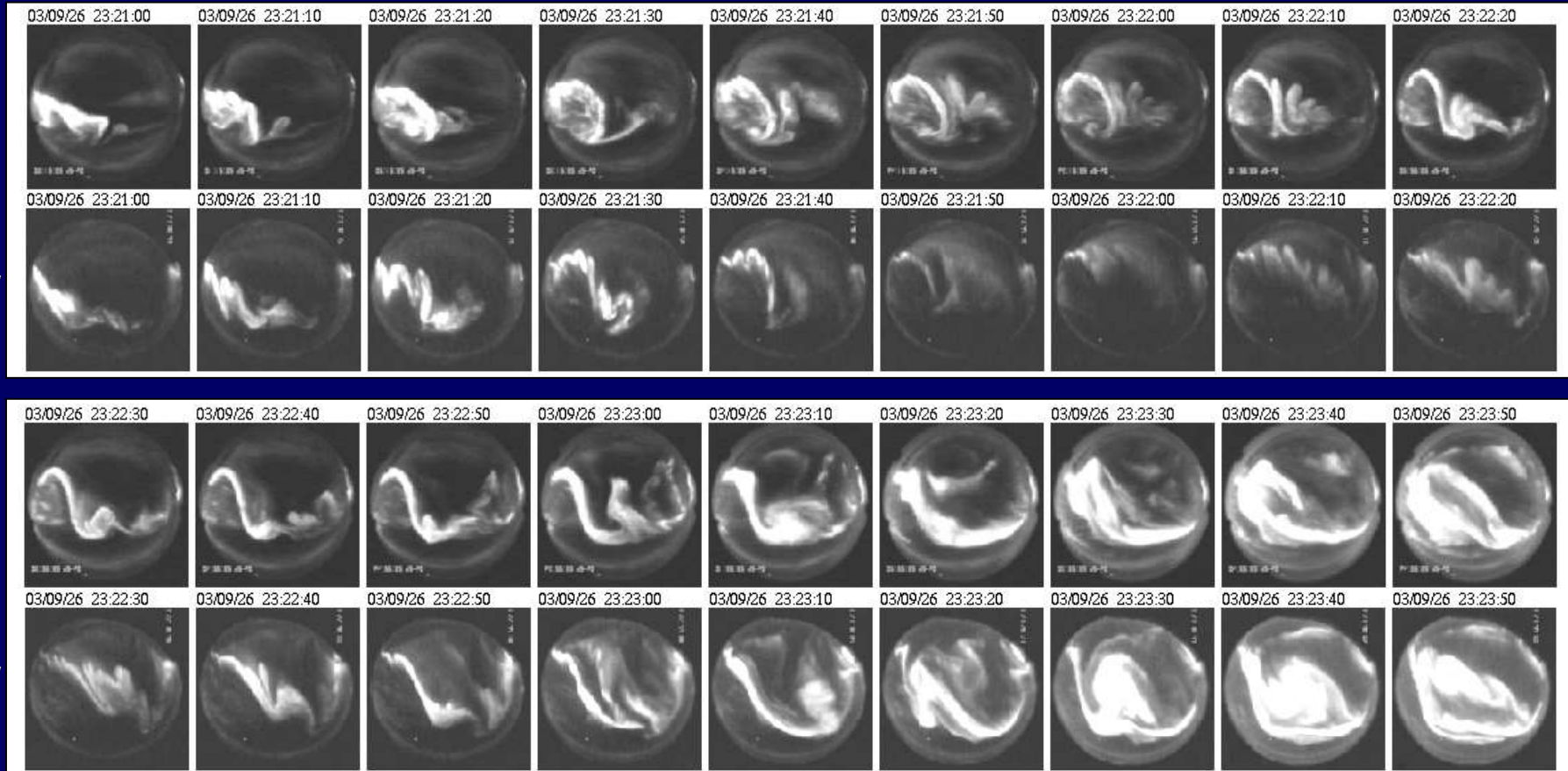


Ohma, et al. (JGR, 2018)

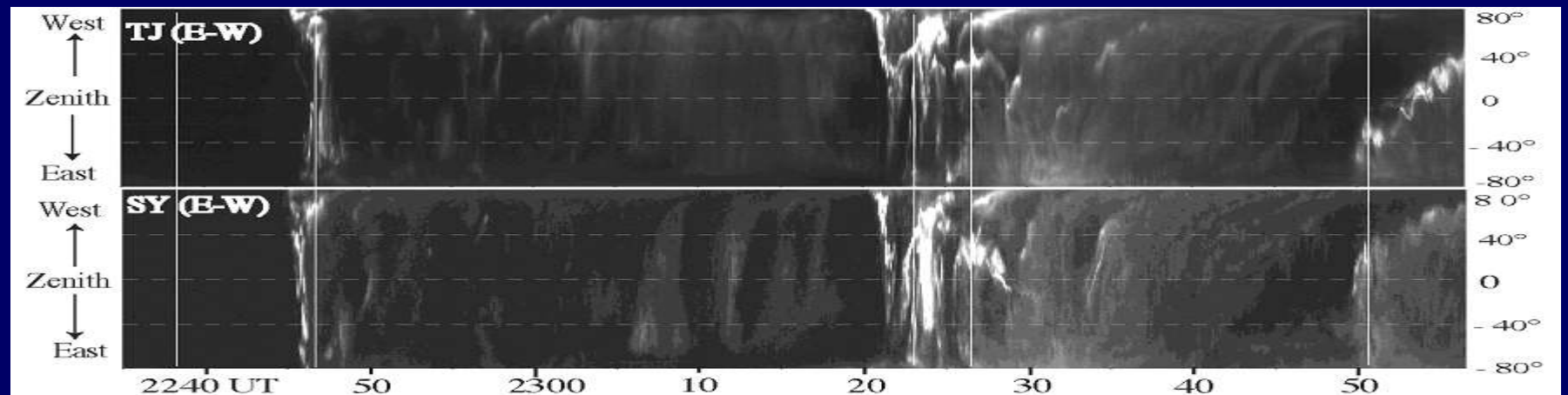
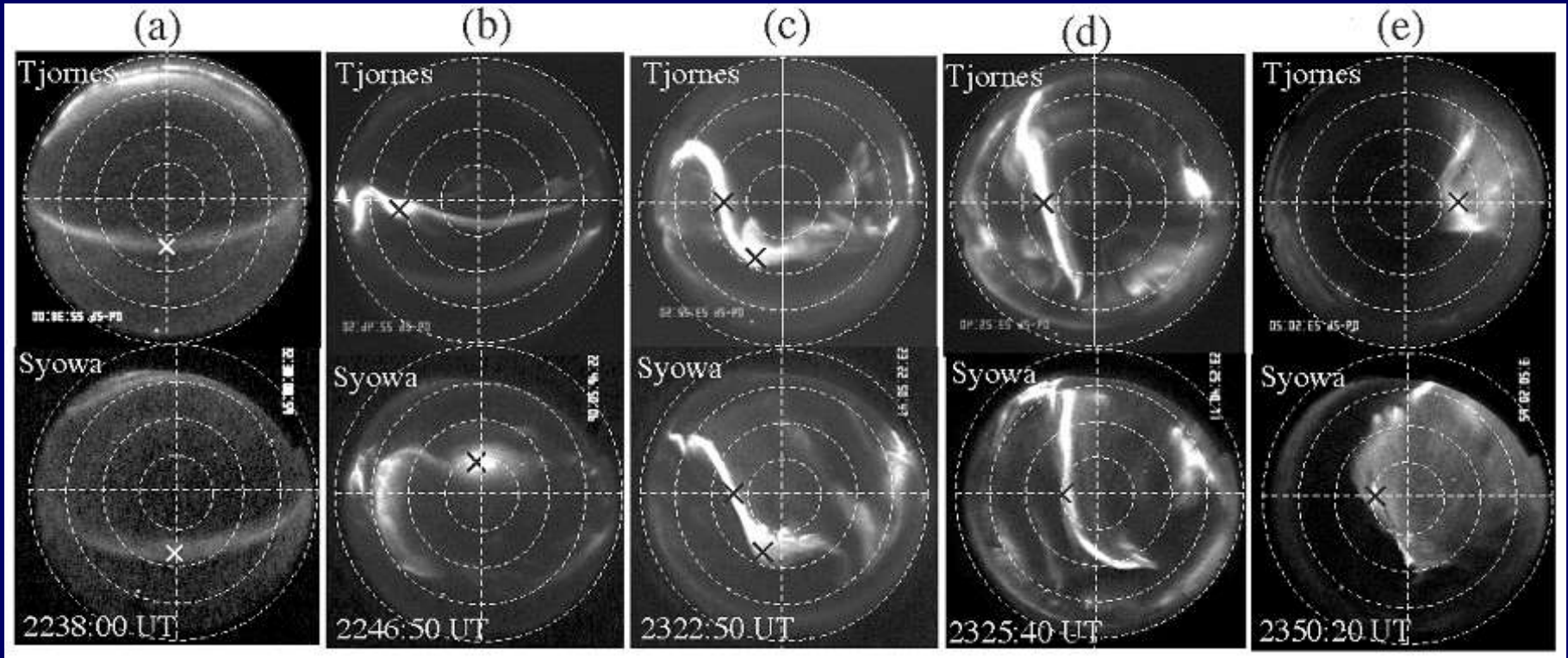
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Event on Sep. 26, 2003

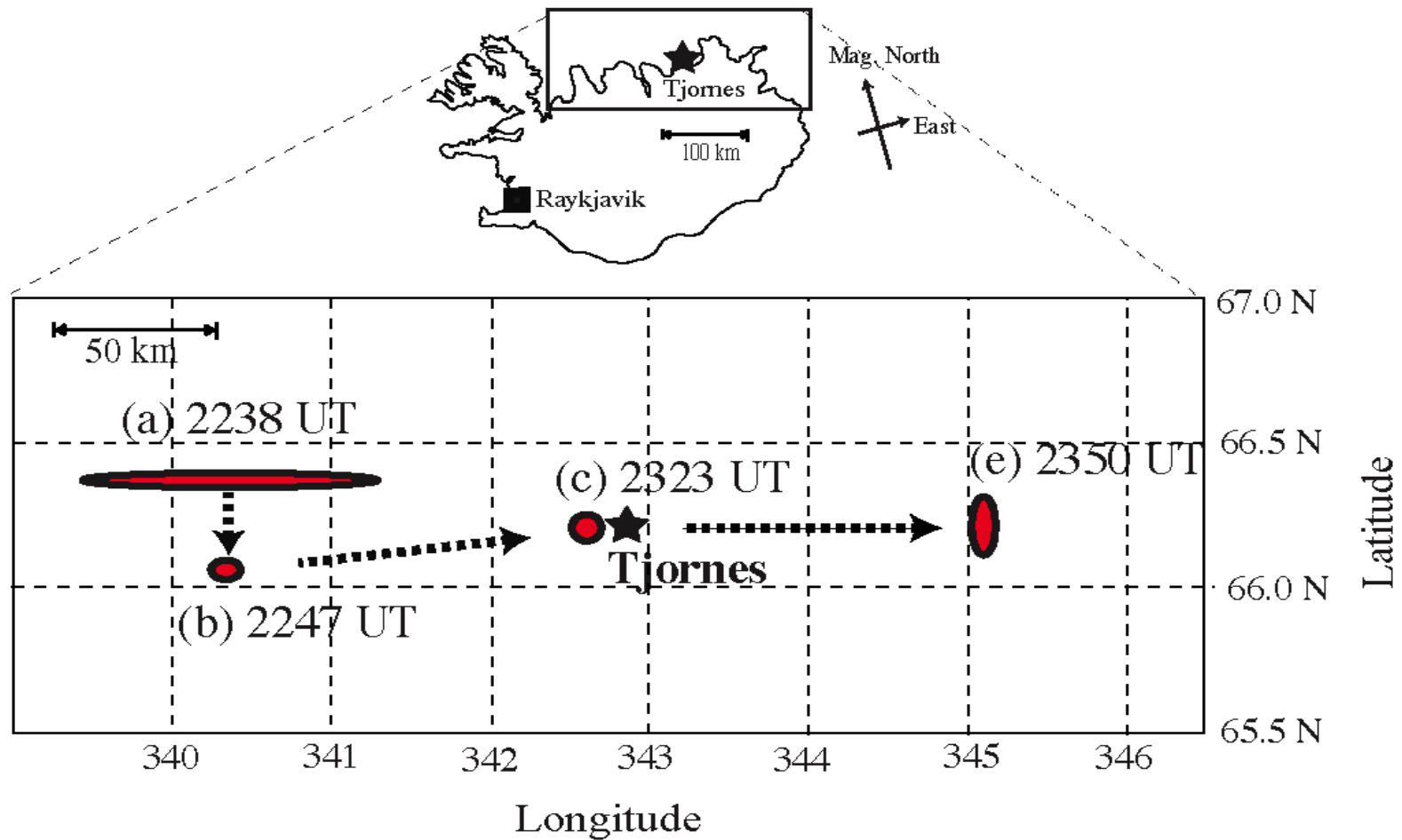


Event on Sep. 26, 2003



Tracing the movement of conjugate point

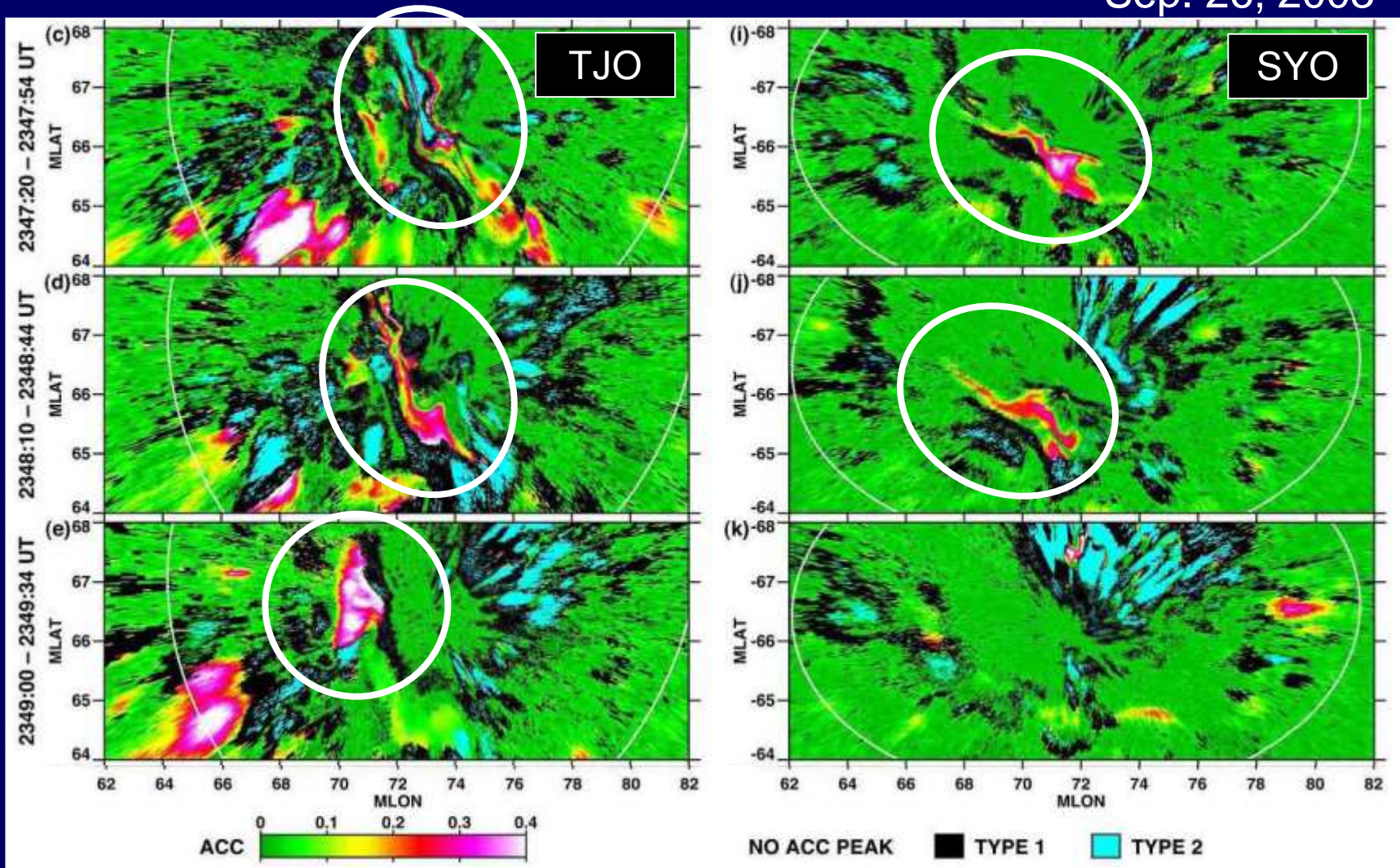
Event on Sep. 26, 2003



Conjugacy of Pulsating Aurora

Auto-correlation coefficient

Sep. 26, 2003



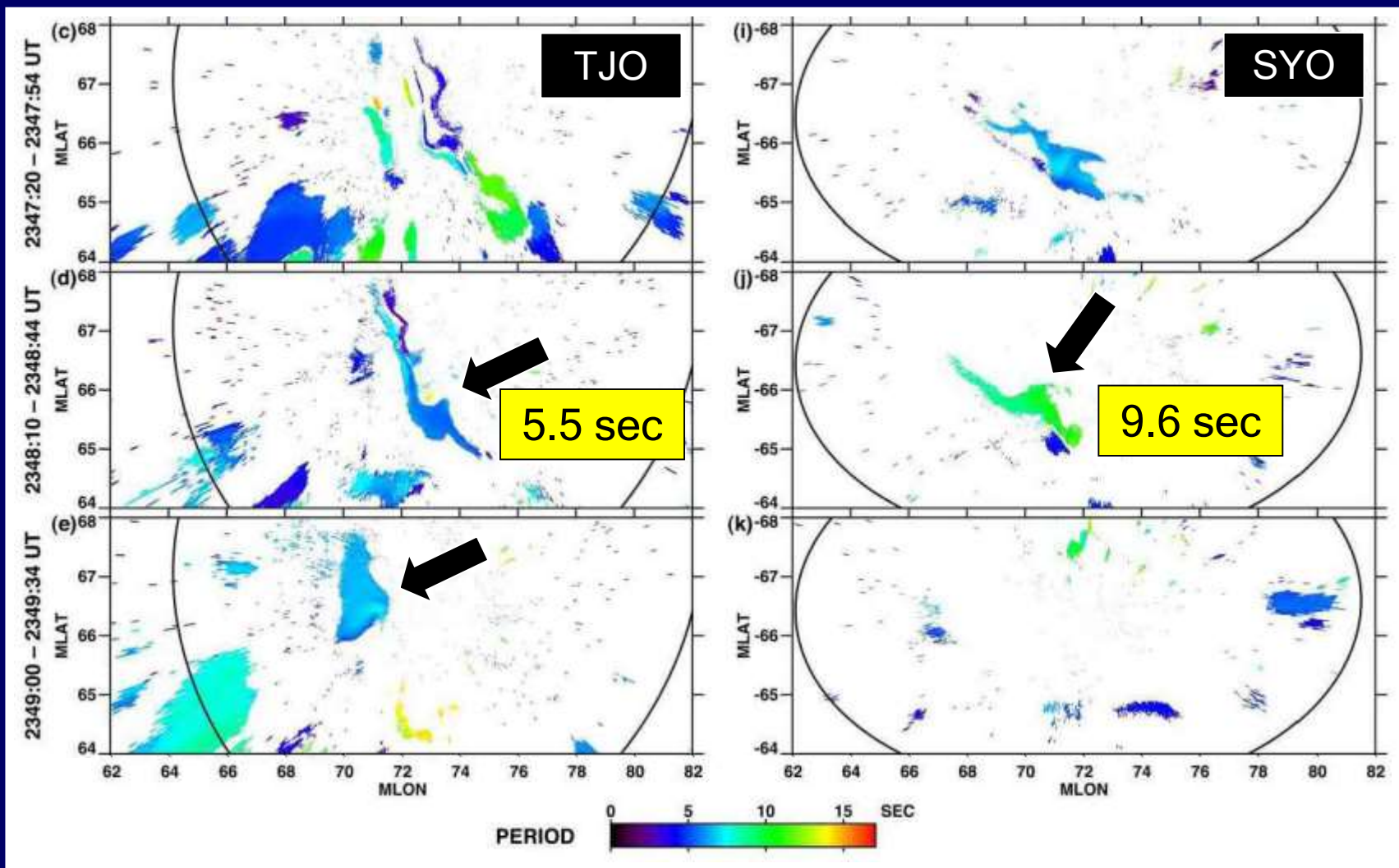
Shape & location are similar.
Sometimes high periodicity differently appears.

Watanabe et al.
(*GRL*, 2007)

Conjugacy of Pulsating Aurora

Period ($R > 0.1$)

Sep. 26, 2003



Shape is similar, but period is different.
Some appear only one hemisphere.

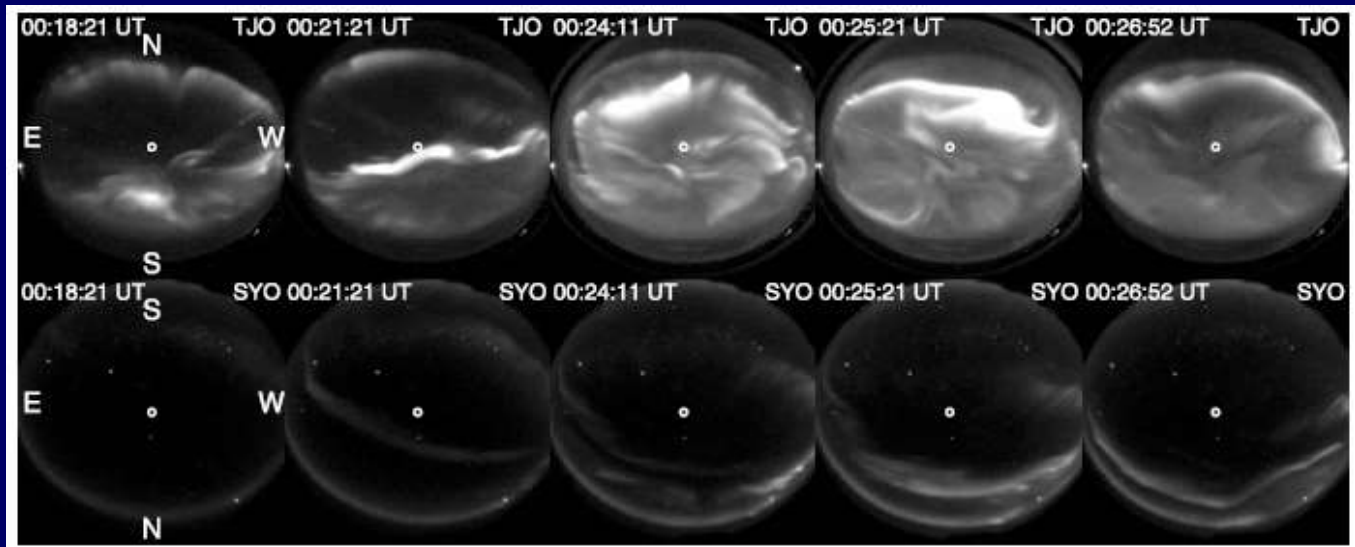
Watanabe et al.
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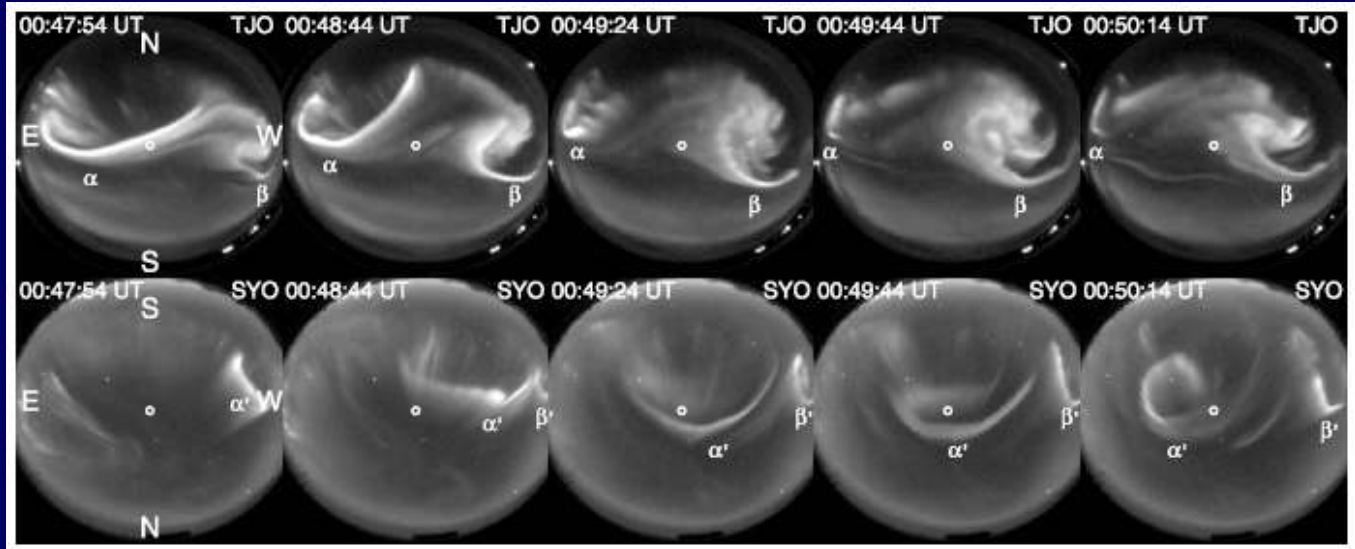
Event on Sep. 21, 2009

Tjornes



Syowa

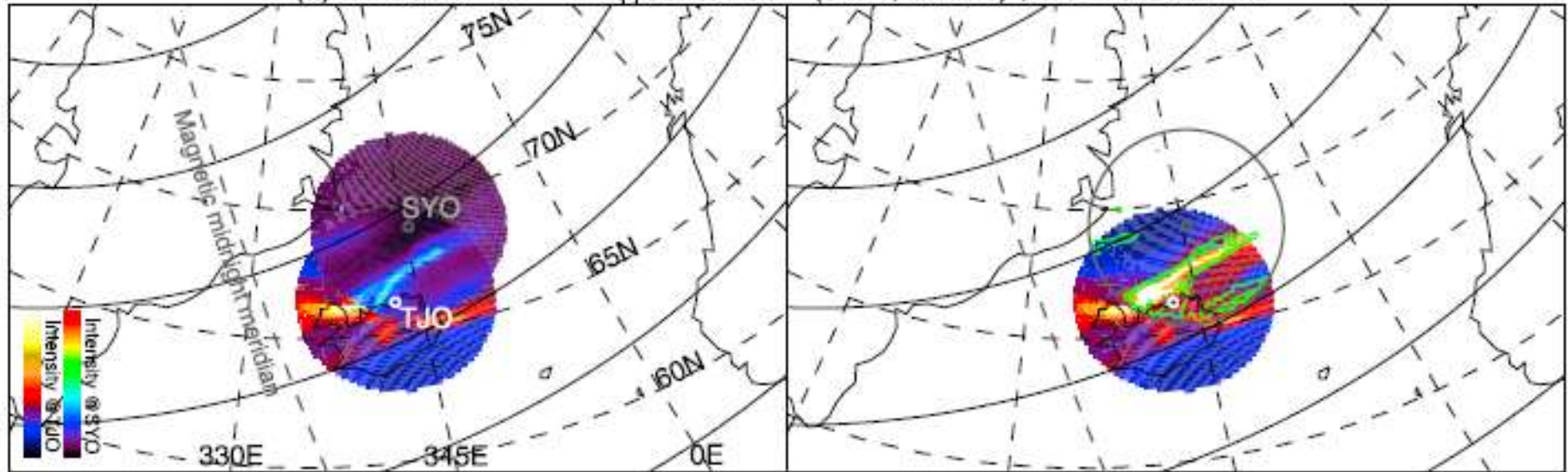
Tjornes



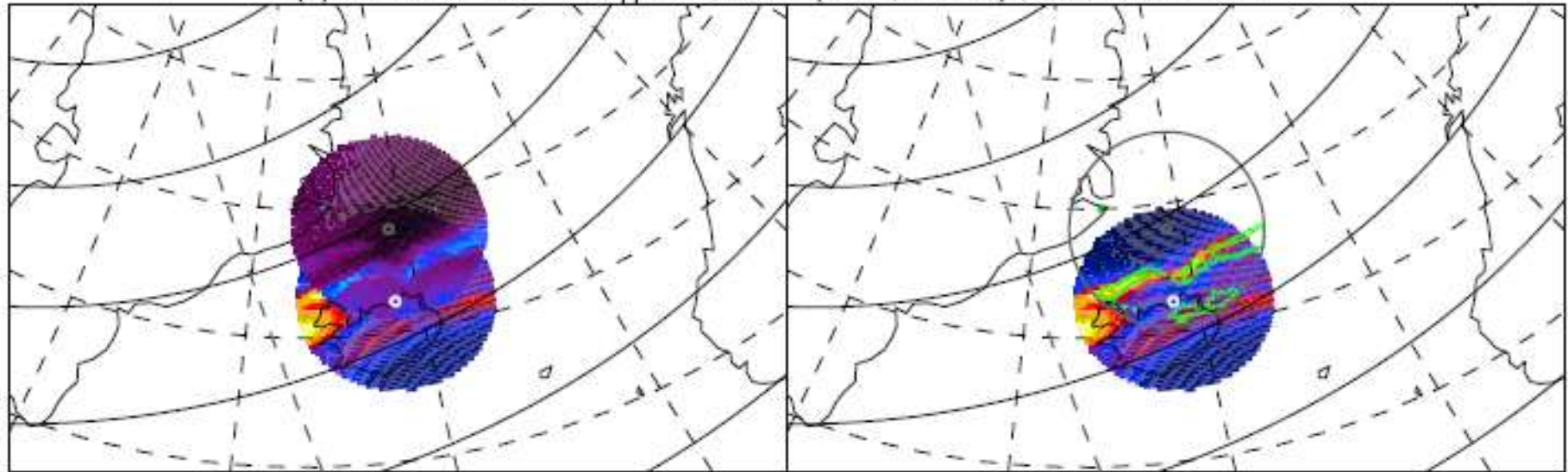
Syowa

Event on Sep. 21, 2009

(a) 00:25:21 UT N_{FP} of SYO = (69.0, 345.4) , RD= 328.8 km

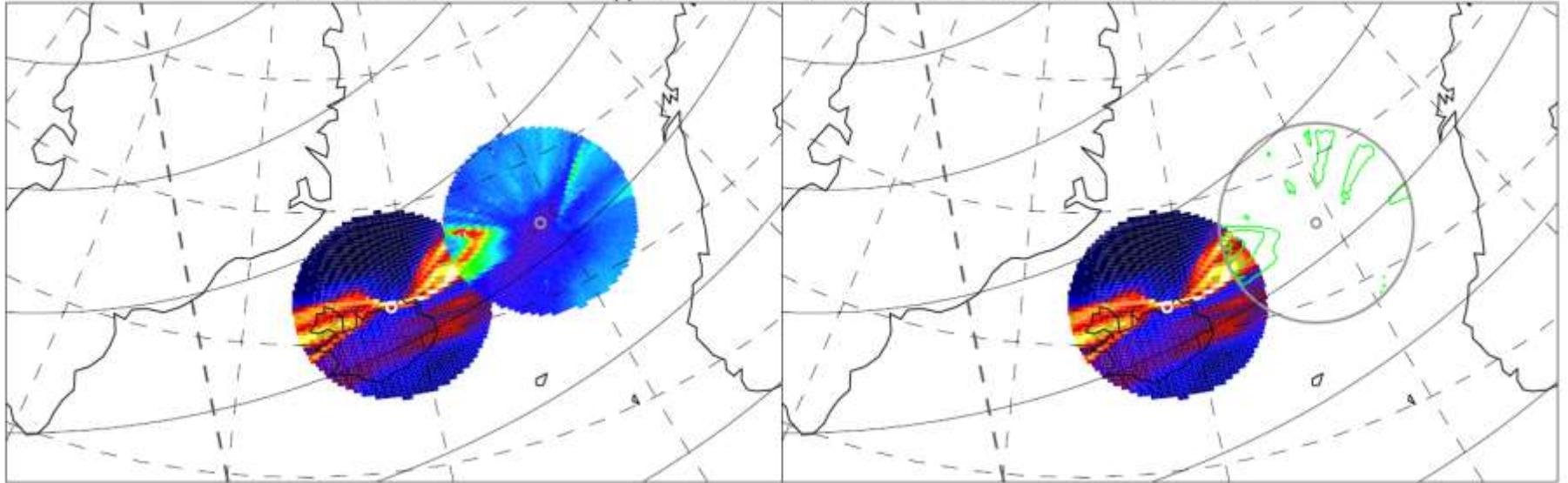


(b) 00:26:52 UT N_{FP} of SYO = (69.0, 343.4) , RD= 312.1 km

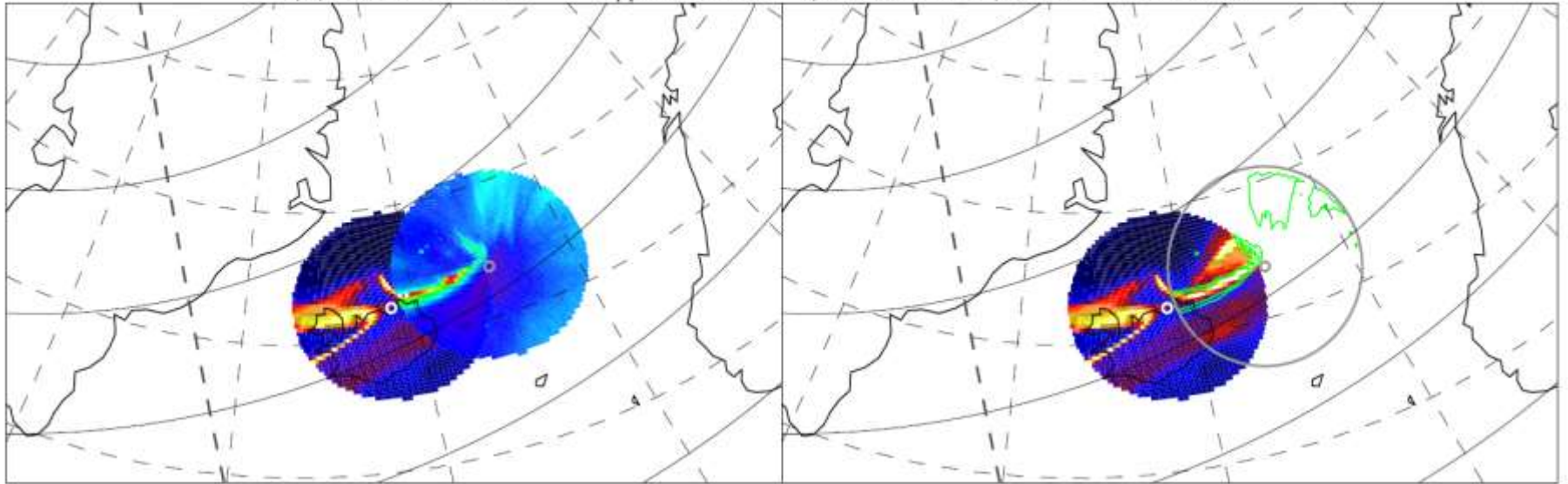


Event on Sep. 21, 2009

(c) 00:47:54 UT N_{FP} of SYO = (67.7, 358.4) , RD= 693.1 km



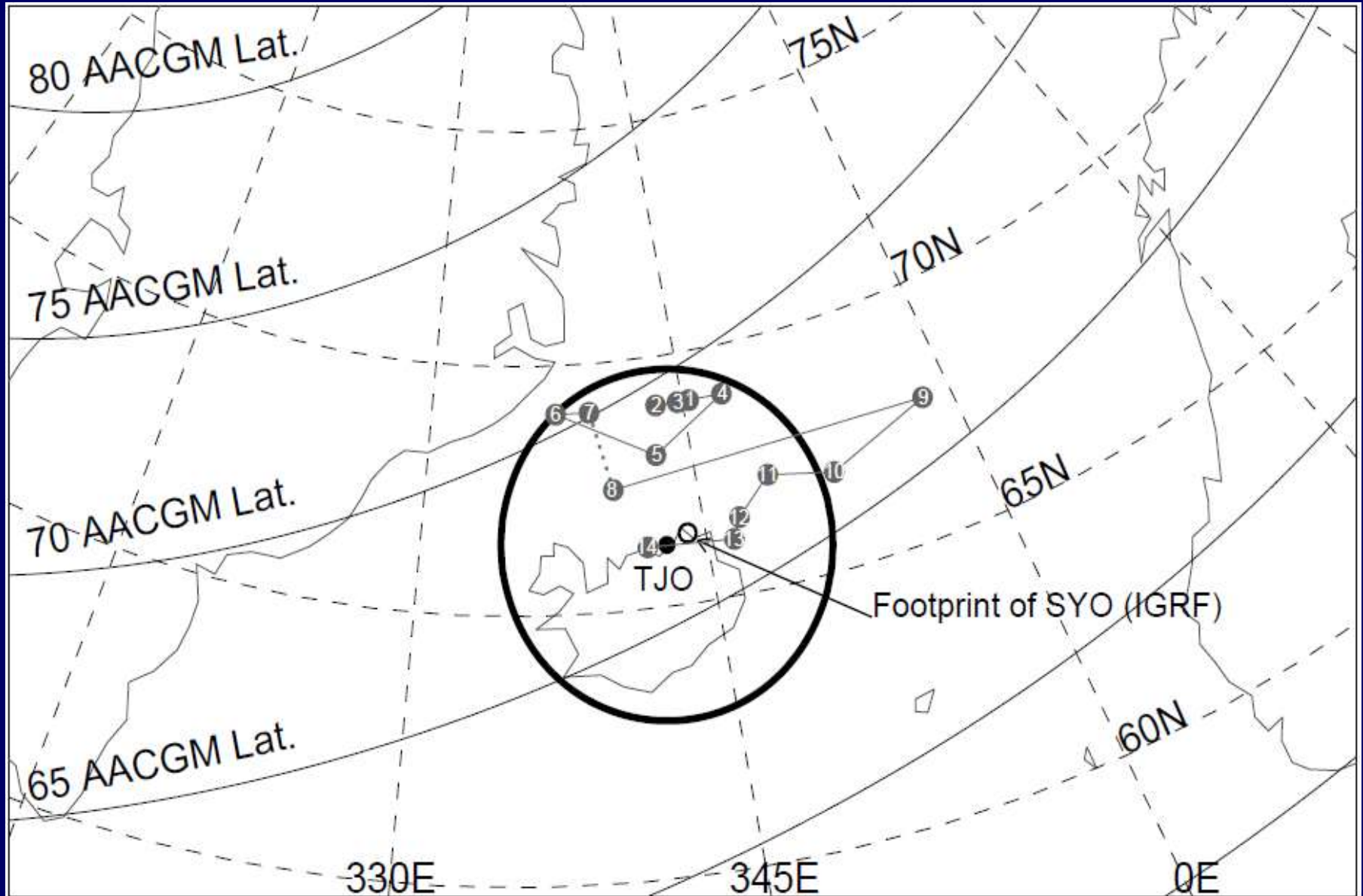
(d) 00:48:44 UT N_{FP} of SYO = (66.9, 352.4) , RD= 427.1 km



Tracing the movement of conjugate point

Event on Sep. 21, 2009

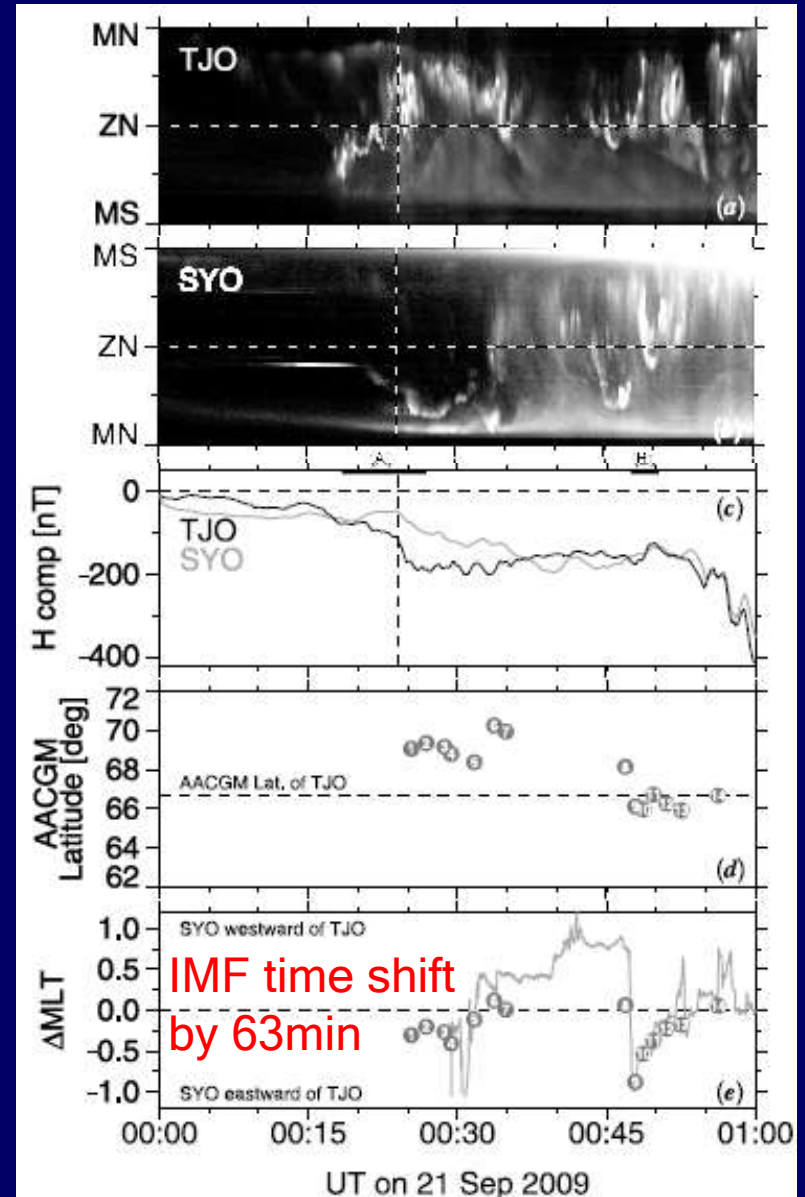
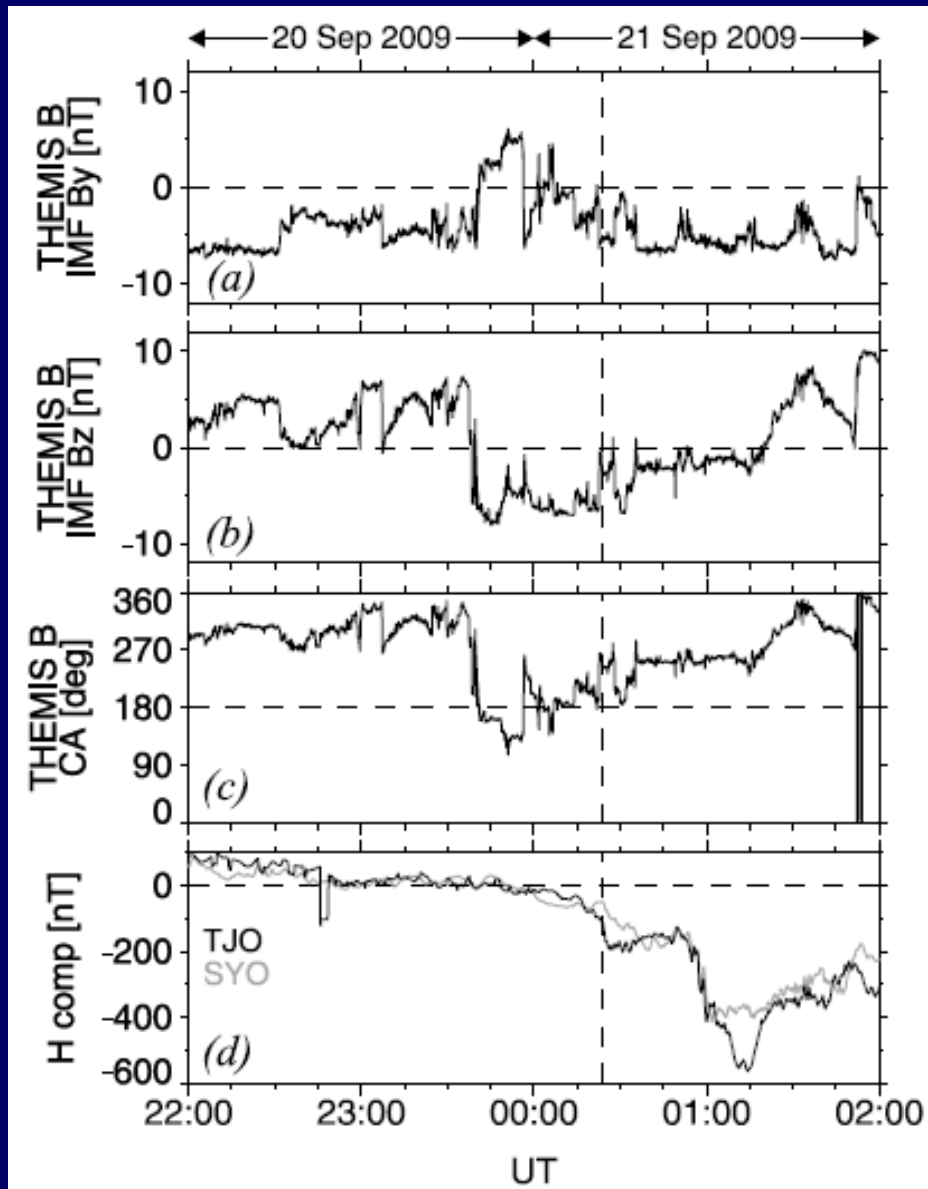
Motoba, et al. (2010, JGR)



Relationship with the IMF variation

Event on Sep. 21, 2009

Motoba, et al. (2010, JGR)

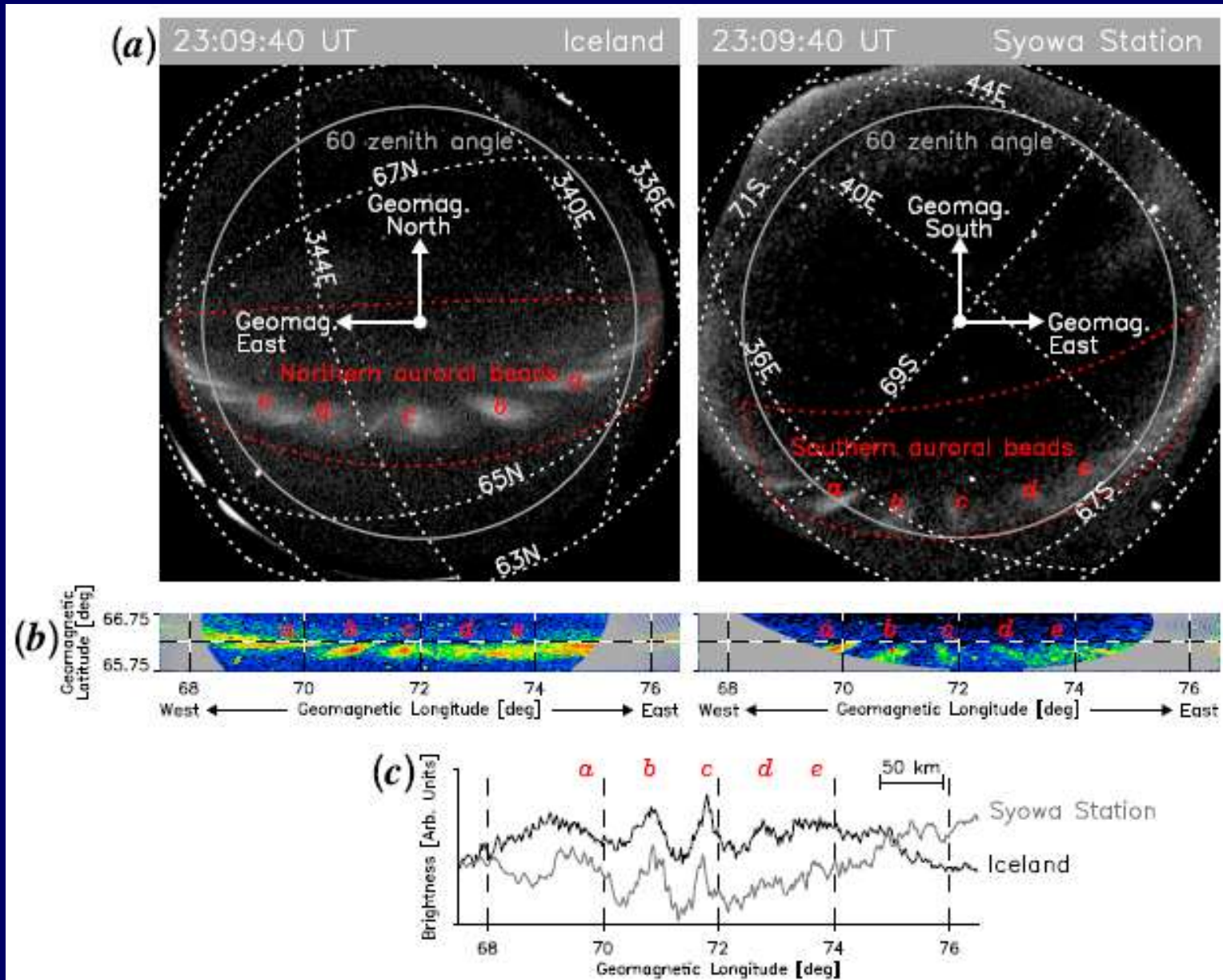


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 - ① conjugacy of substorm development

Conjugacy of Auroral beads

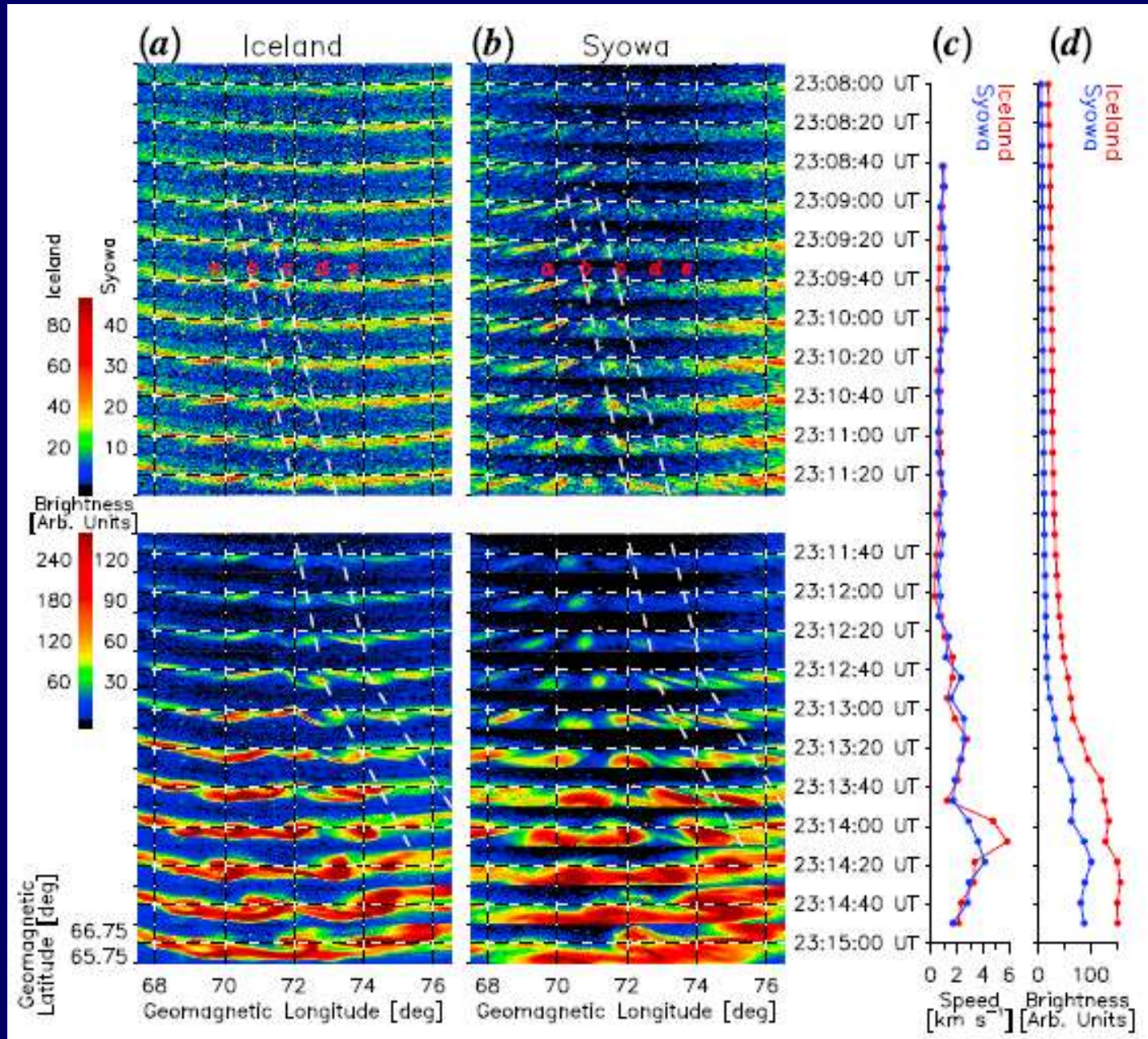
Sep. 30, 2011



Motoba, et al. (2012, GRL)

Conjugacy of Auroral beads

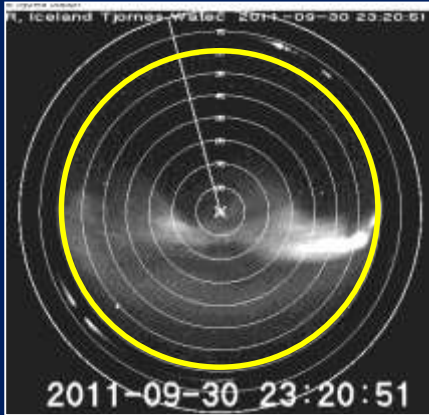
Sep. 30, 2011



Conjugacy of intensity variation

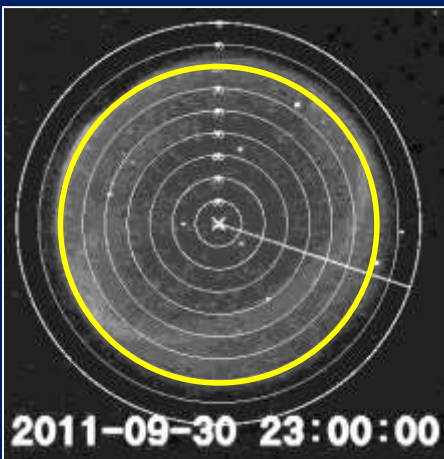
Sep.30, 2011

TJO



SYO

EL>20deg

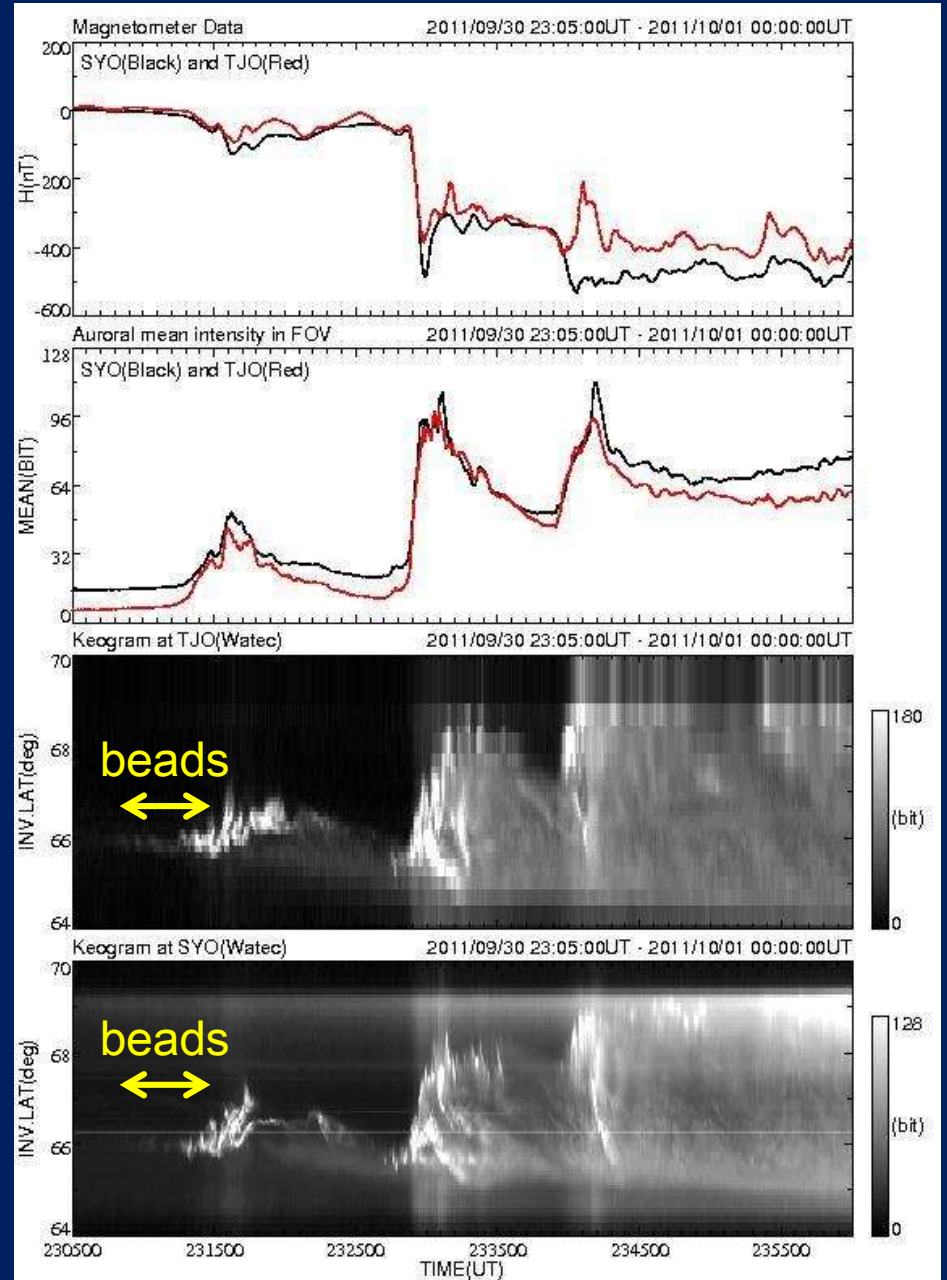


H(nT)

FOVint
(bit)

TJO

SYO



Conjugacy of Magnetic pulsation

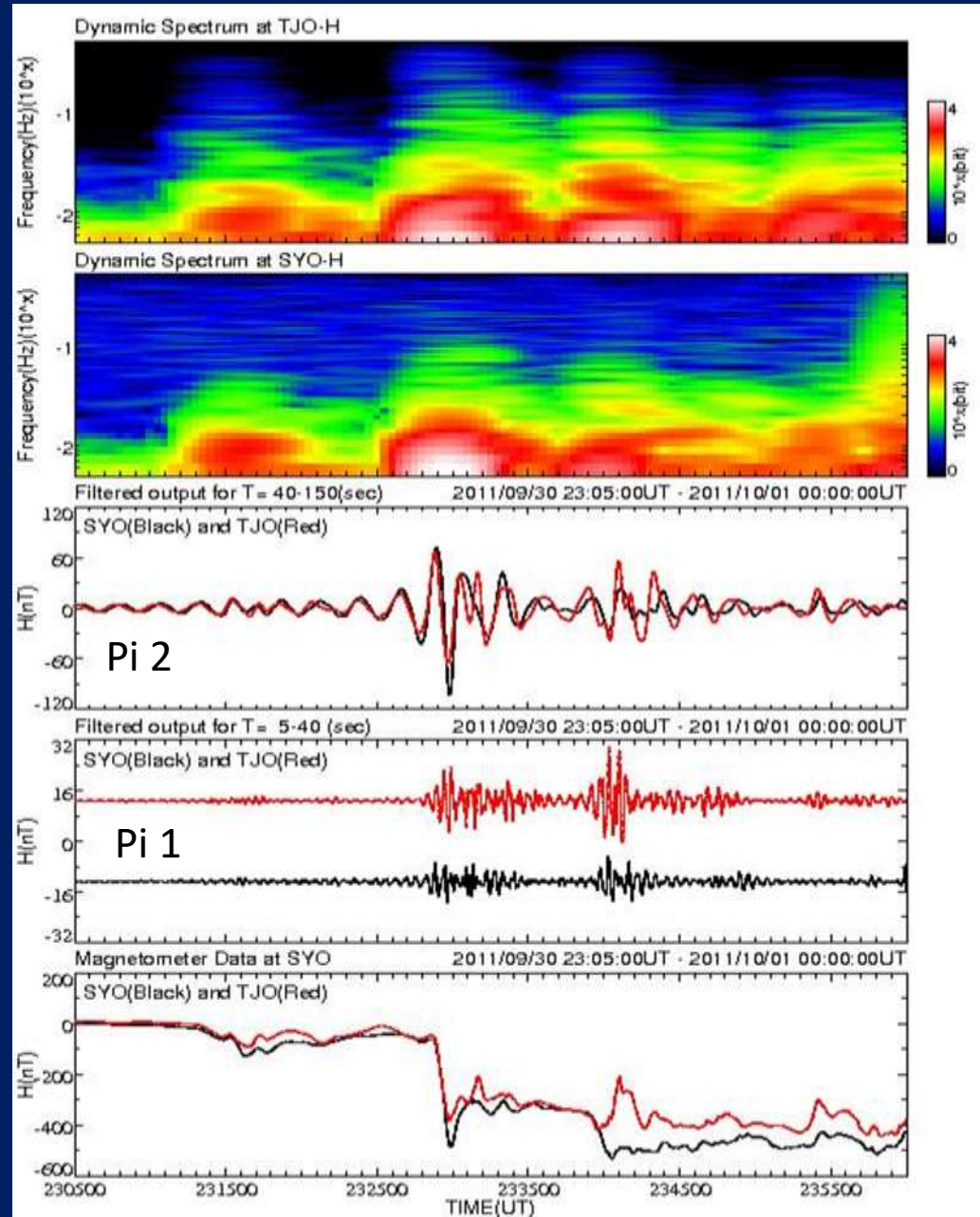
TJO-H
Hspectrum

SYO-H
spectrum

Filtered
40-150sec

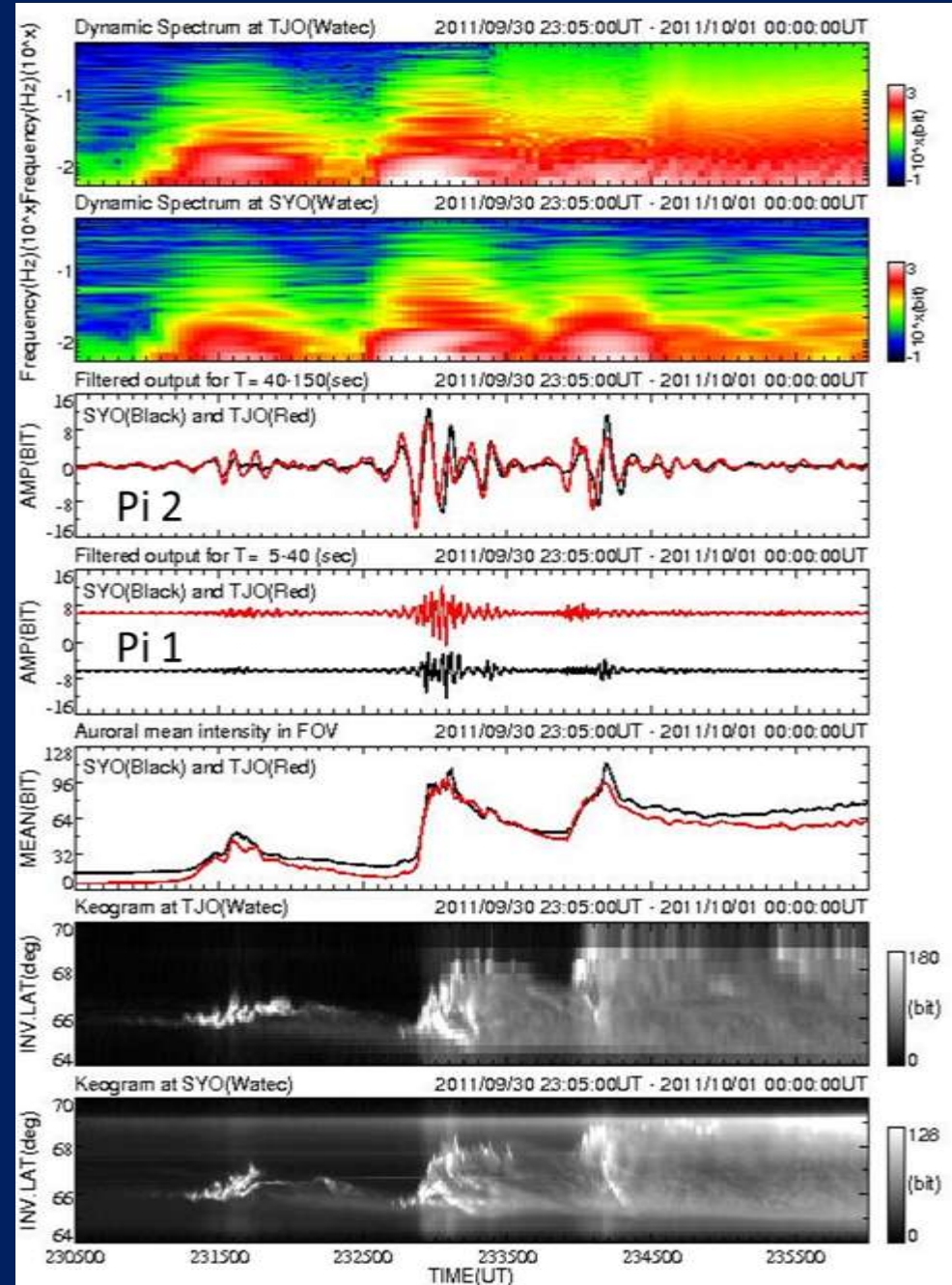
Filtered
5-40sec

H(nT)



Conjugacy of Auroral intensity pulsation

TJO
FOVint
spectrum
SYO
FOVint
spectrum
FOVint
Filtered
40-150sec
FOVint
Filtered
5-40sec
FOVint
TJO
SYO



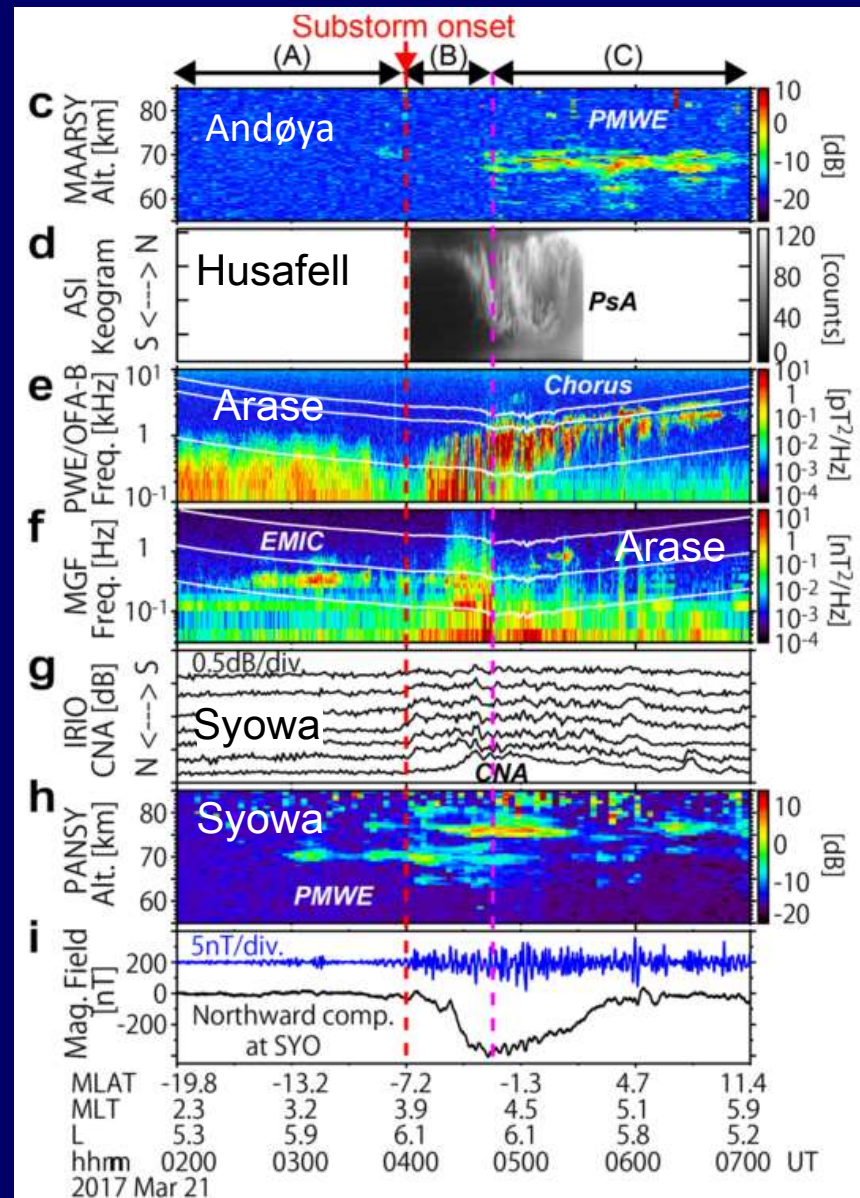
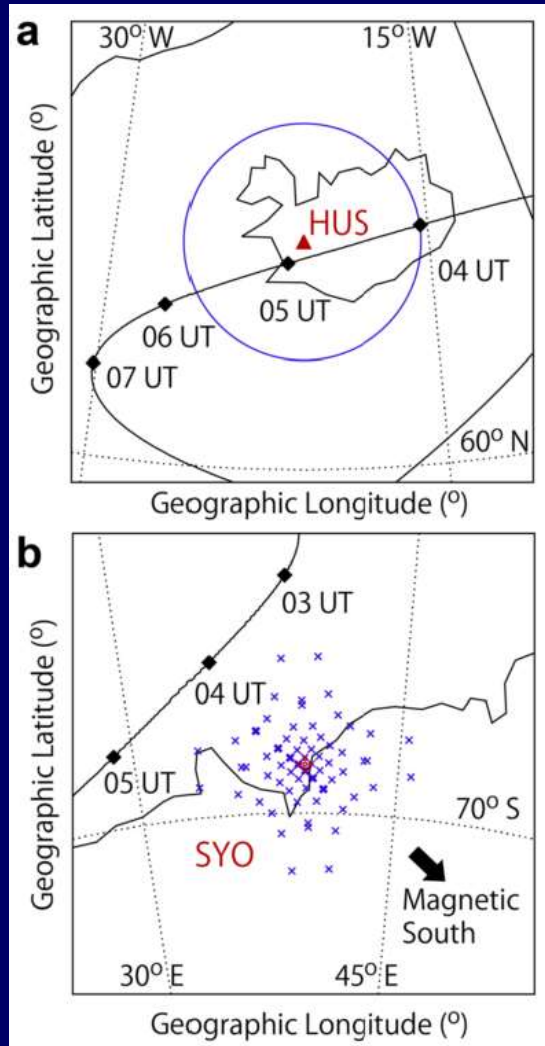
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Iceland-Syowa-Arase conjugate event on 21 March, 2017

Arase-ground first campaign

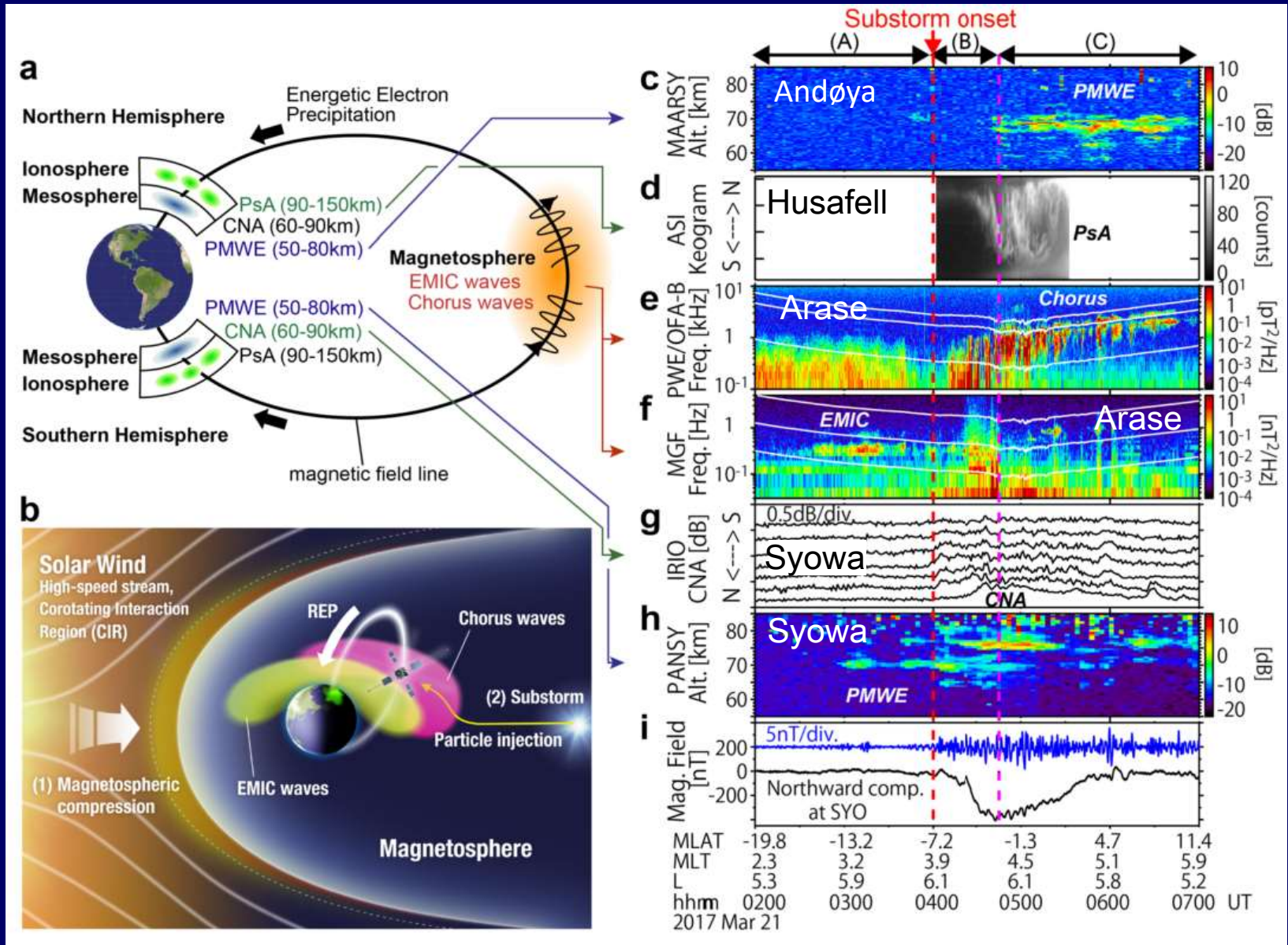
Arase footprint trajectory



Tanaka, et al., 2019, JGR, <https://doi.org/10.1029/2019JA026891>

Direct Comparison Between Magnetospheric Plasma Waves and Polar Mesosphere Winter Echoes in Both Hemispheres

Iceland-Syowa-Arase conjugate event on 21 March, 2017



Tanaka, et al., 2019, JGR, <https://doi.org/10.1029/2019JA026891>

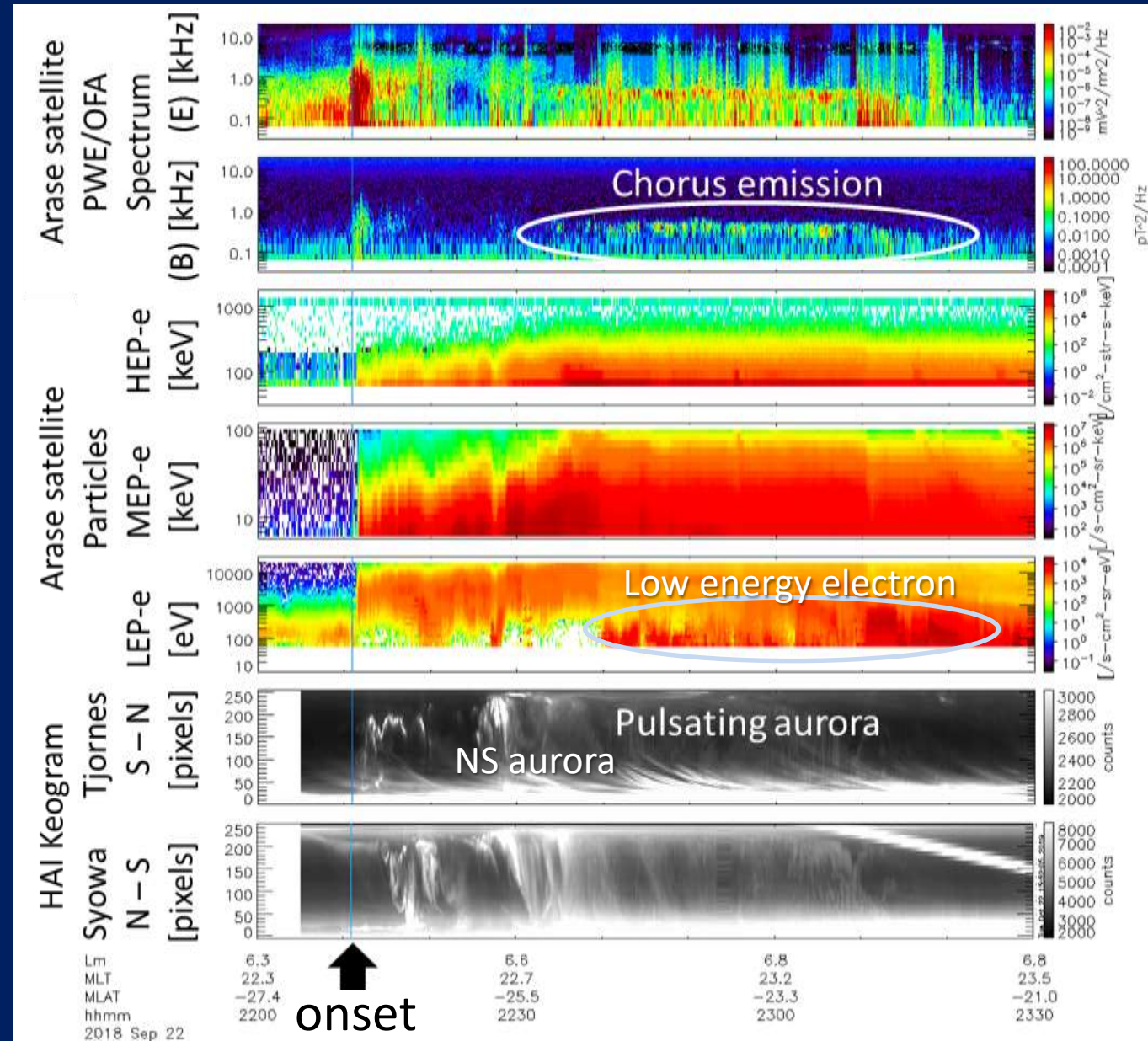
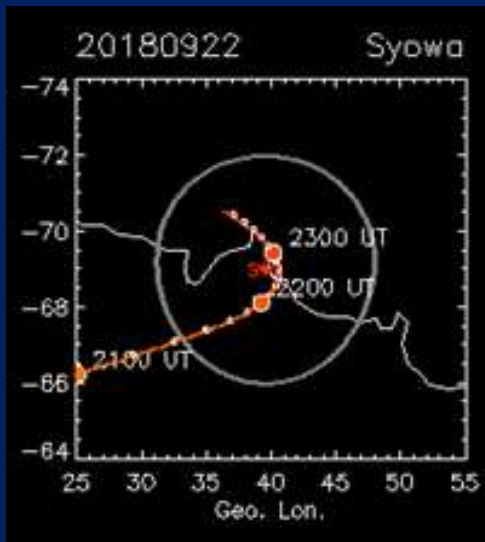
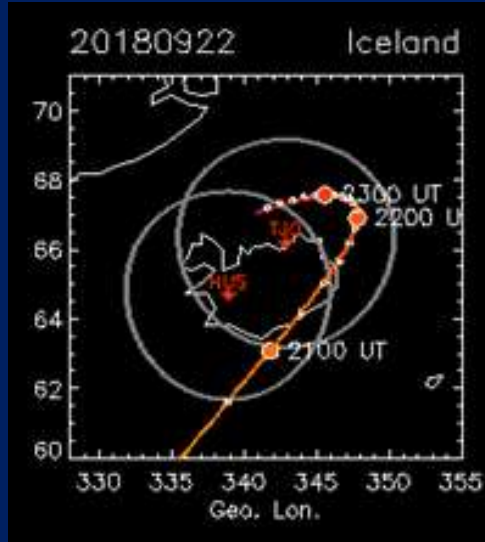
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Iceland-Syowa-Ararse conjugate event on Sep. 22, 2018

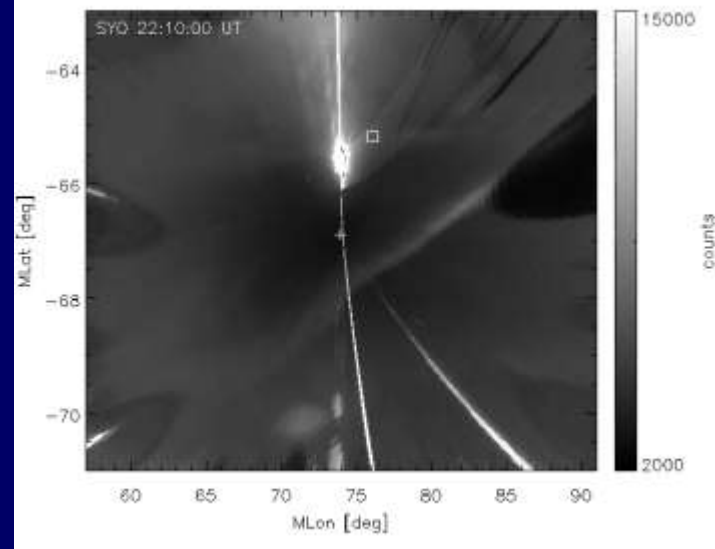
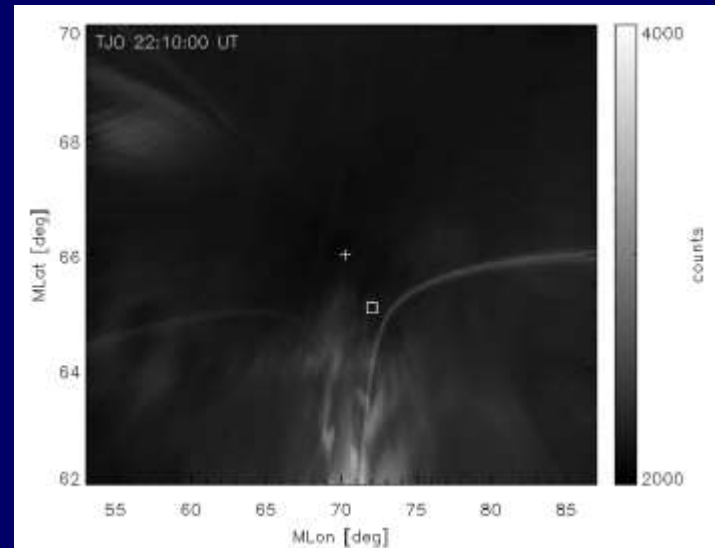
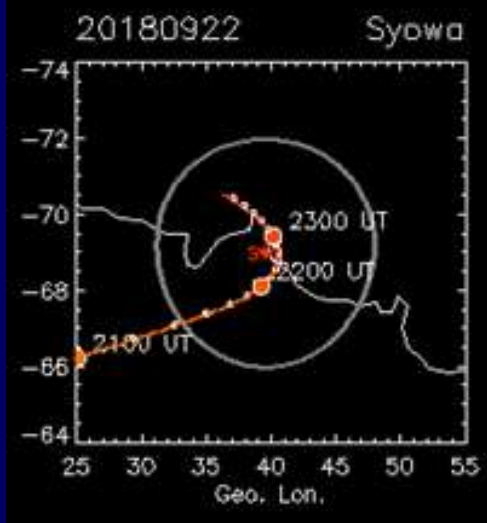
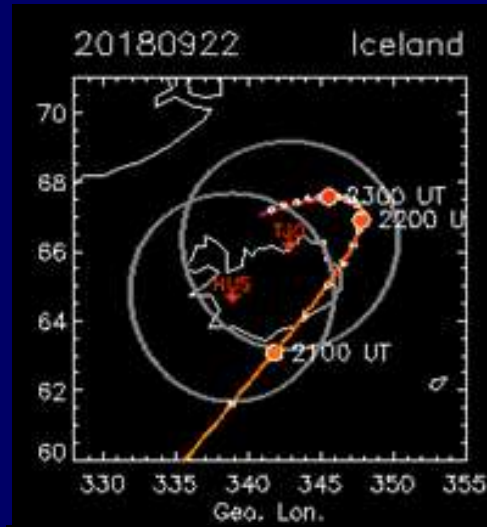
Ararse footprint trajectory



Event on Sep. 22, 2018 with Arase satellite

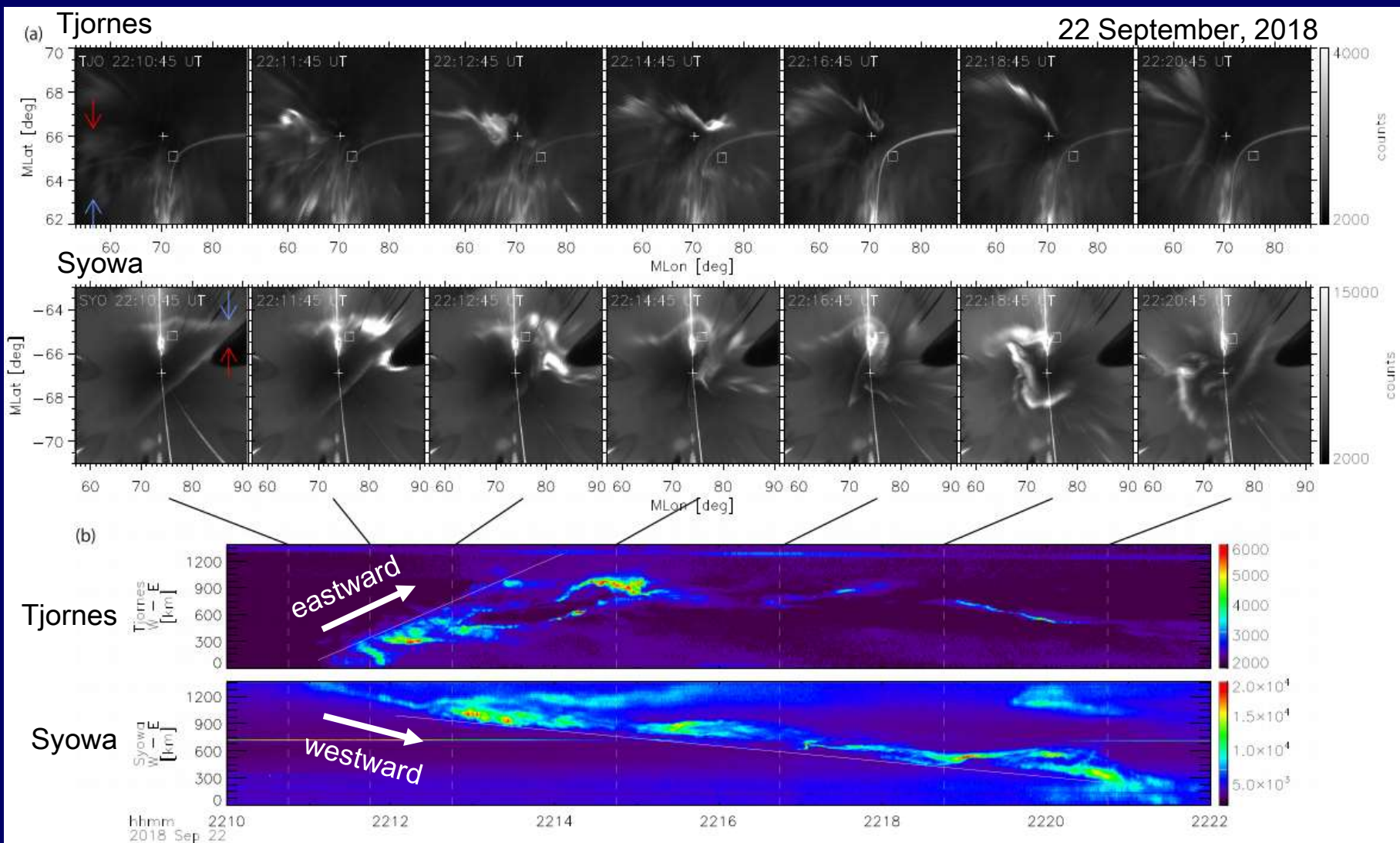
Different azimuthal development of breakup surge

Arase footprint trajectory



Event on Sep. 22, 2018 with Arase satellite

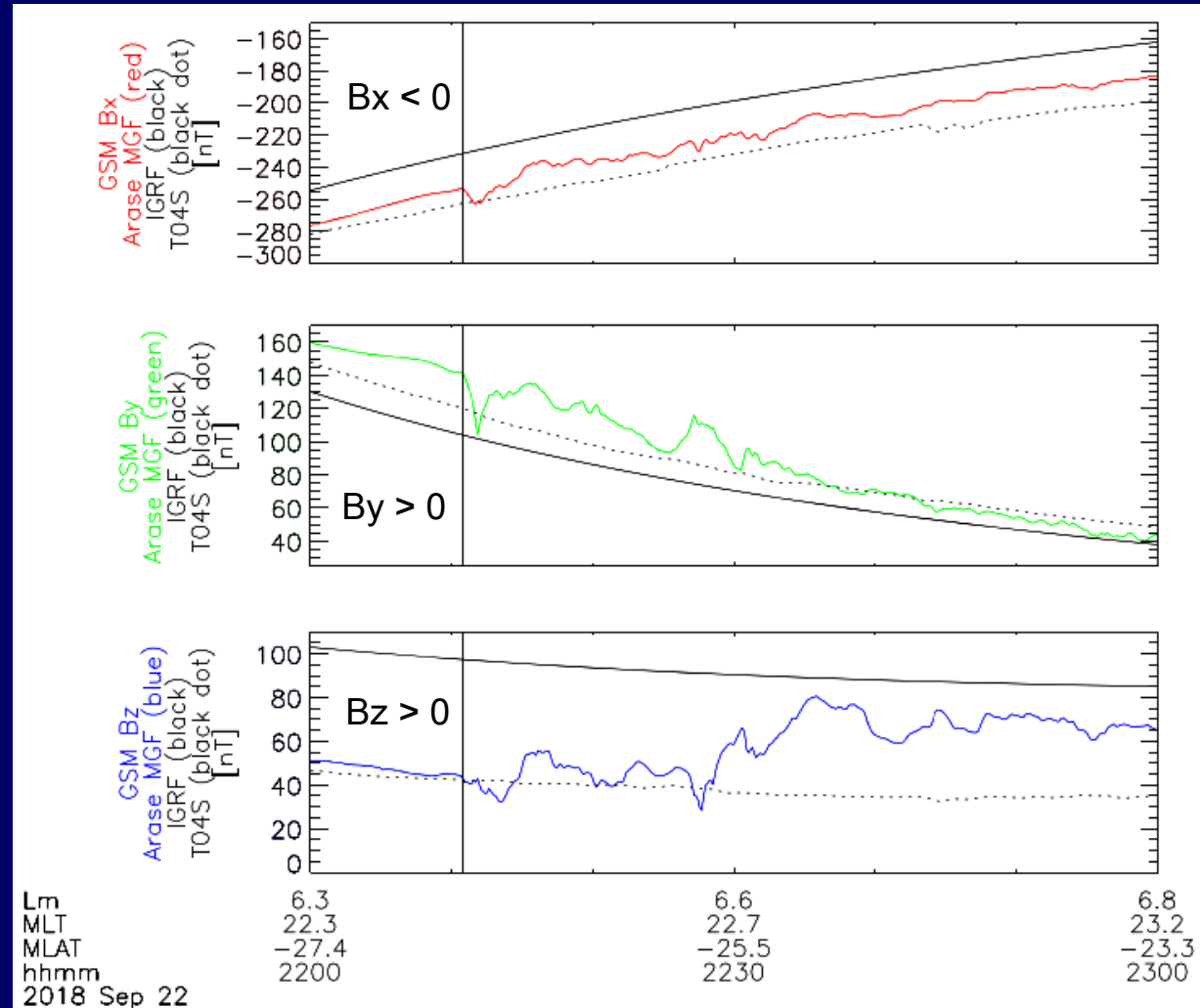
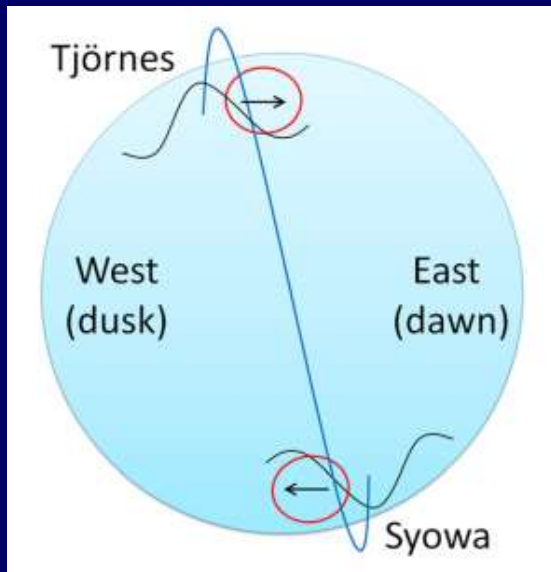
Different azimuthal development of breakup surge



Event on Sep. 22, 2018 with Arase satellite

Different azimuthal development of breakup surge

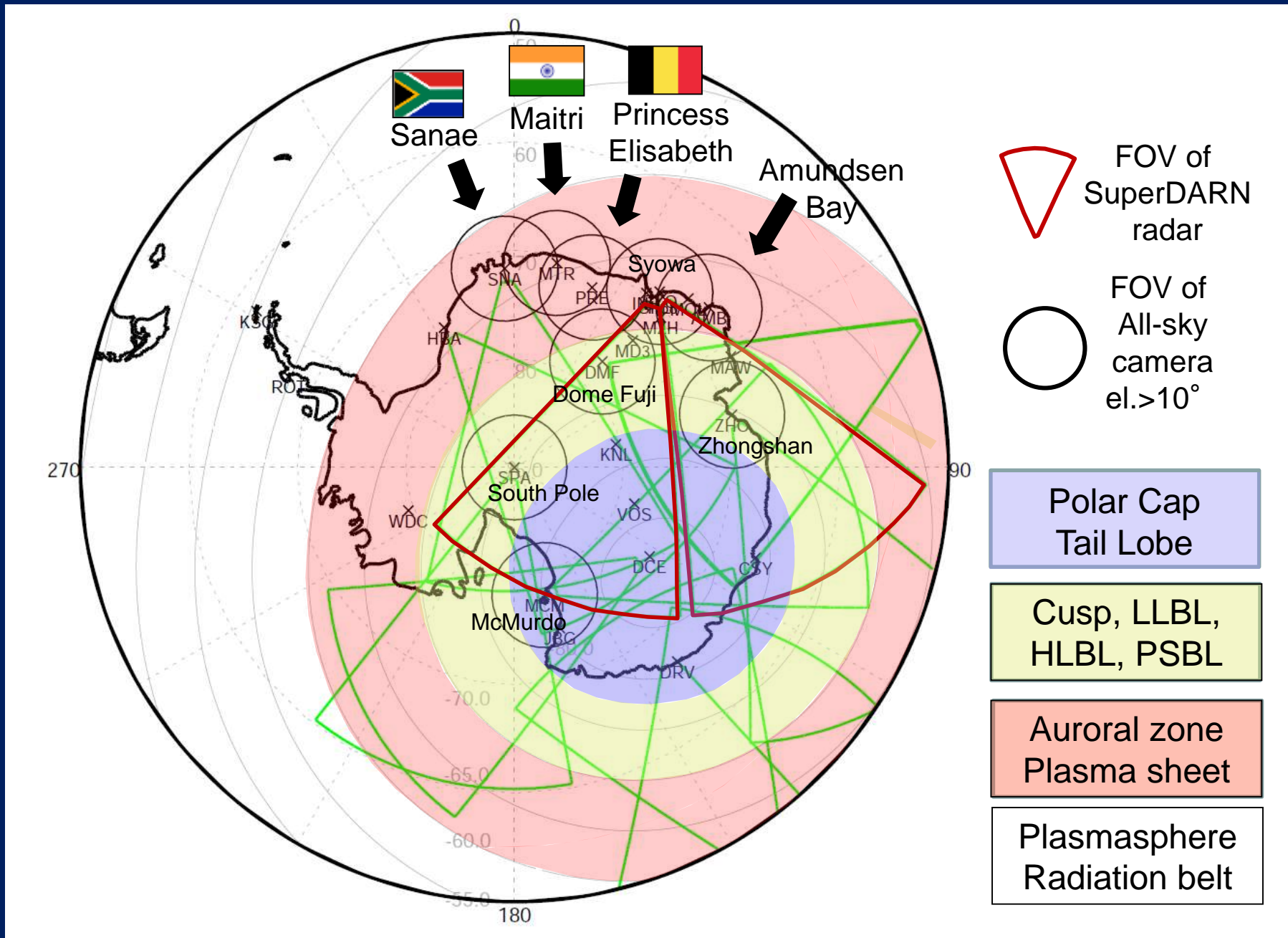
Arase MGF data



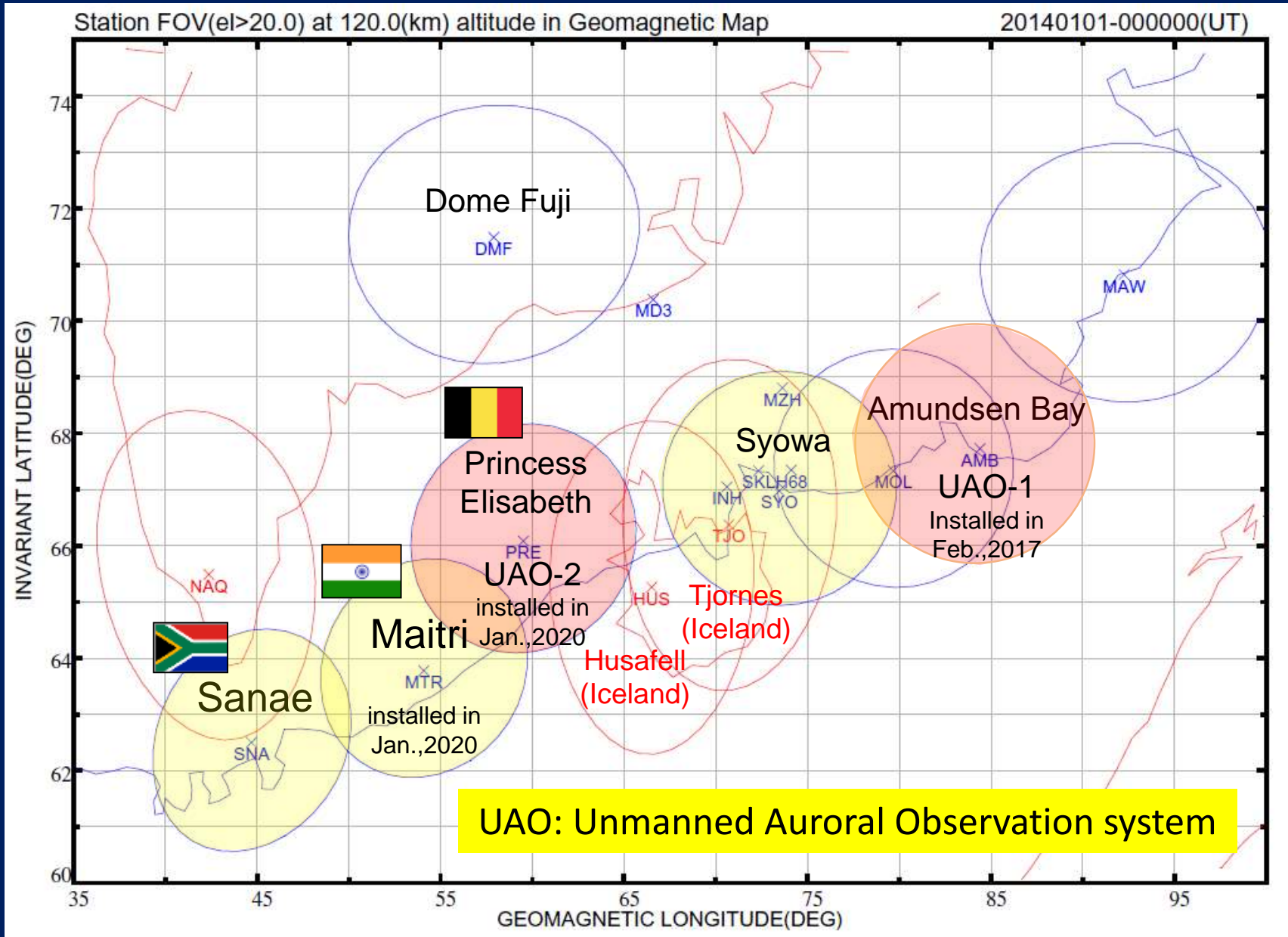
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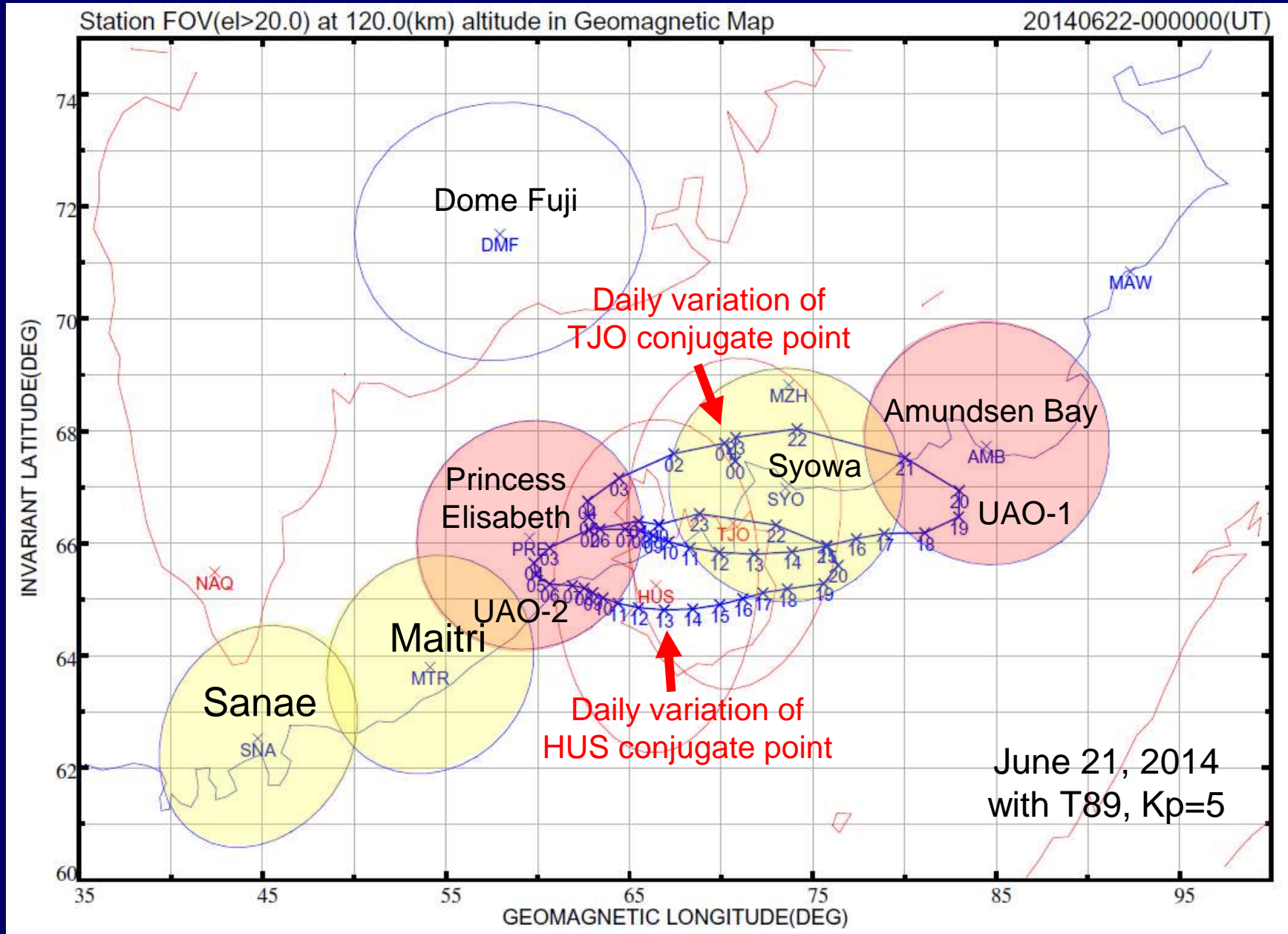
Antarctic Auroral Observation network using unmanned system



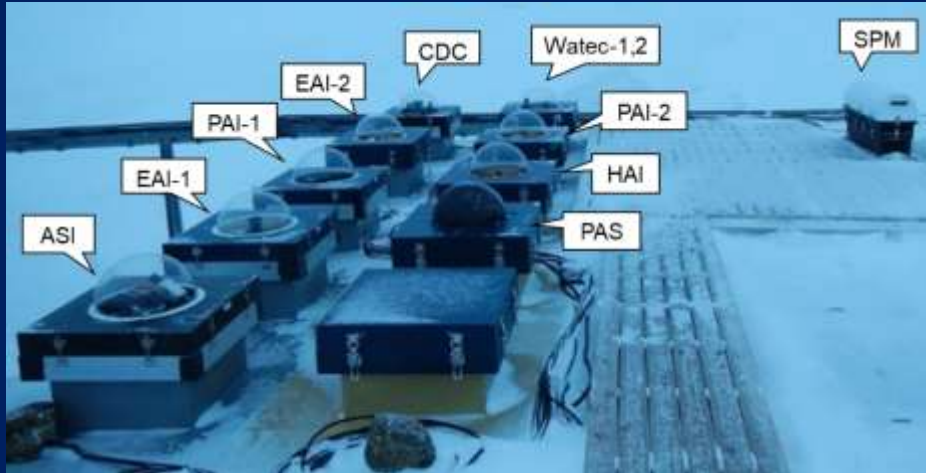
Antarctic Auroral Observation network using unmanned system with conjugate stations



Antarctic large area observation network



Auroral instruments at Syowa Station



UAO-1 at Amundsen Bay



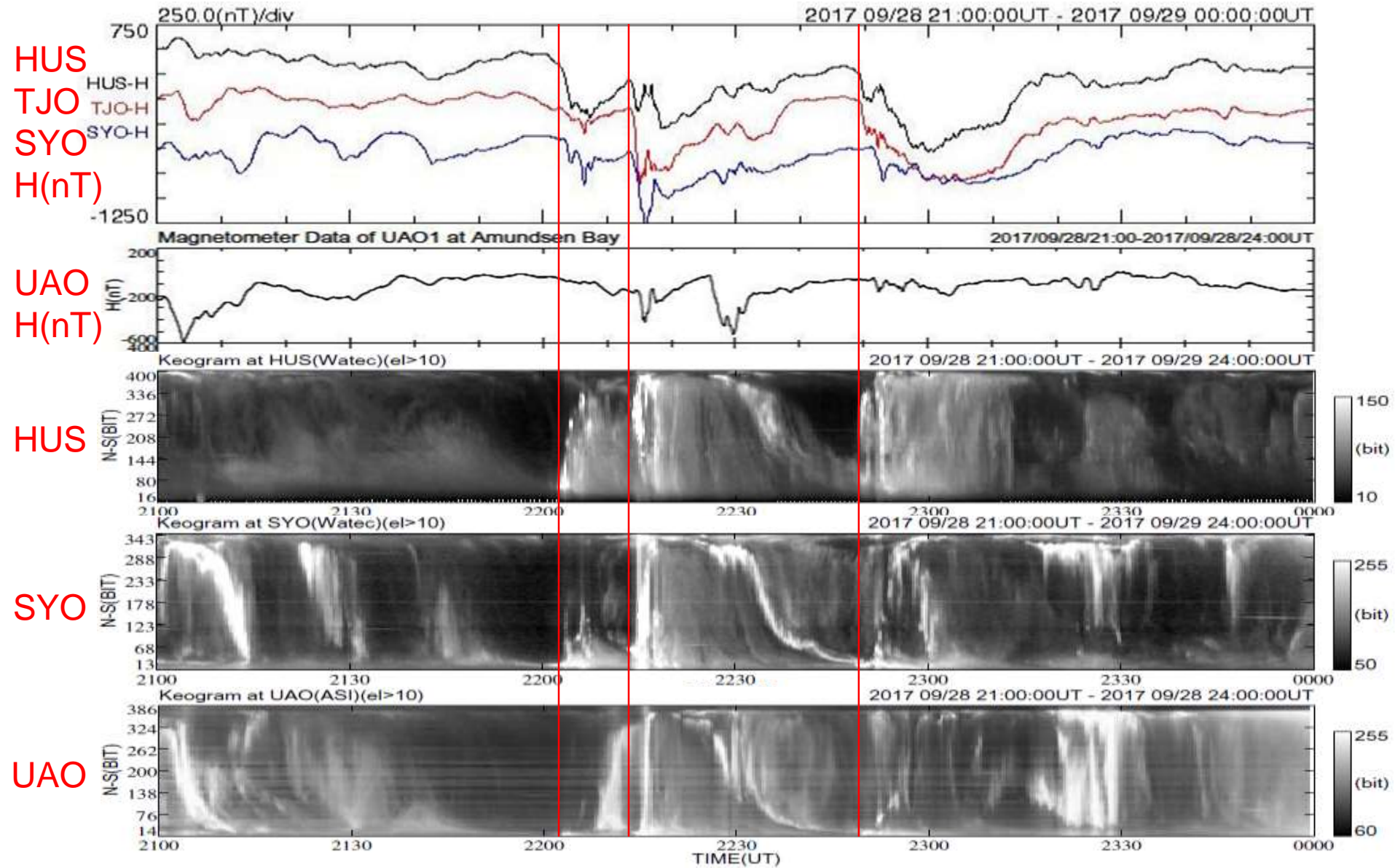
AIS (Auroral Imager System) at Maitri Station



UAO-2 at Princess Elisabeth Antarctica Station

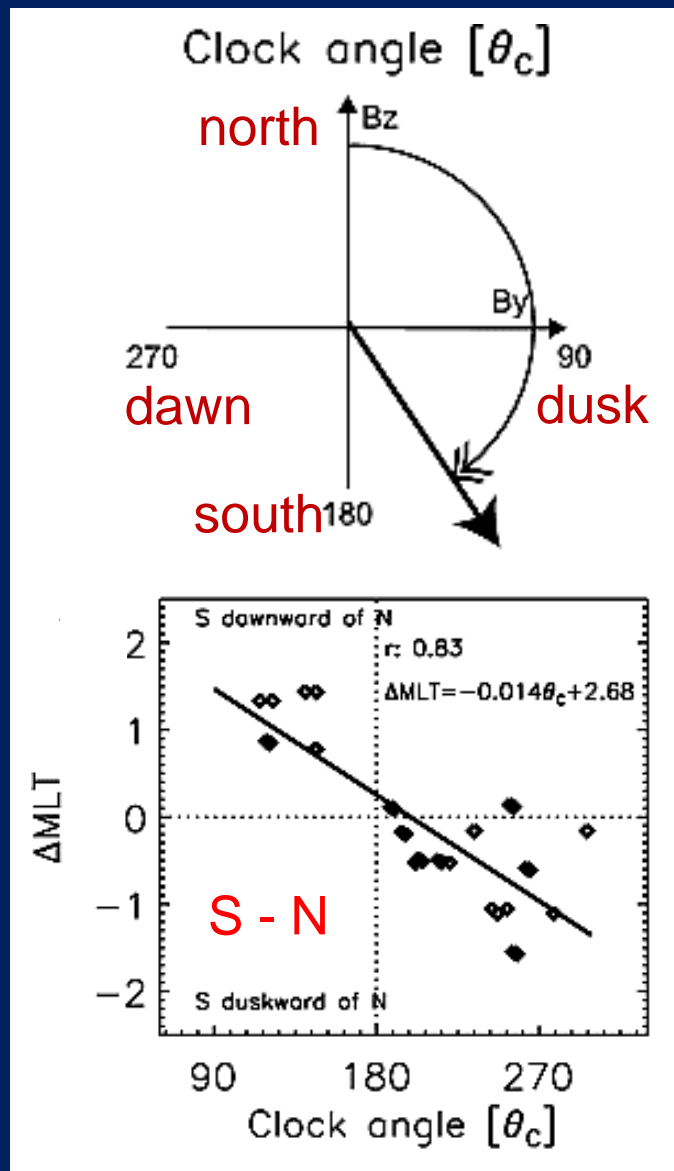
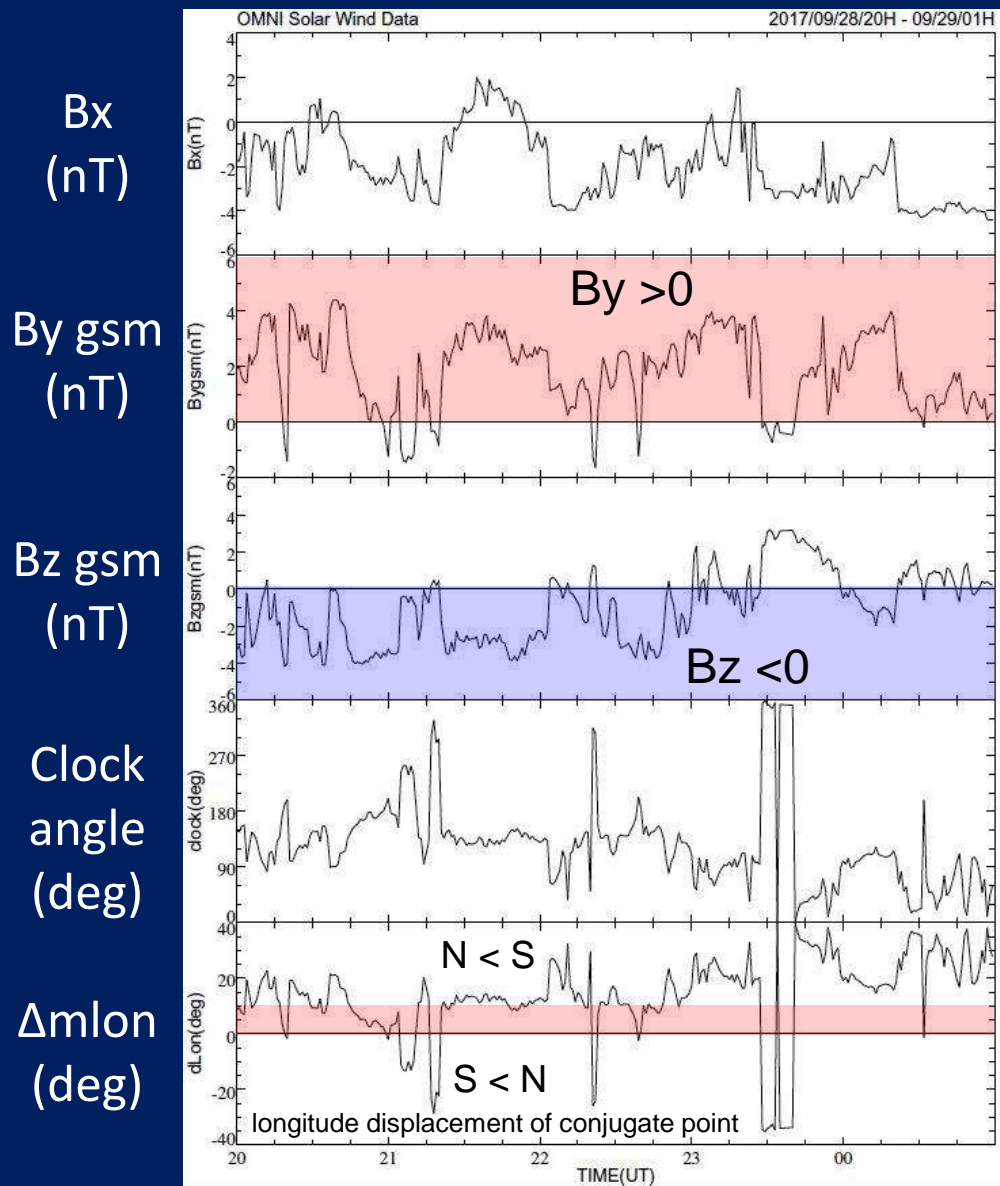


Syowa, UAO-1 – Iceland Conjugate event on Sep. 28, 2017



Syowa, UAO – Iceland Conjugate event on Sep. 28, 2017

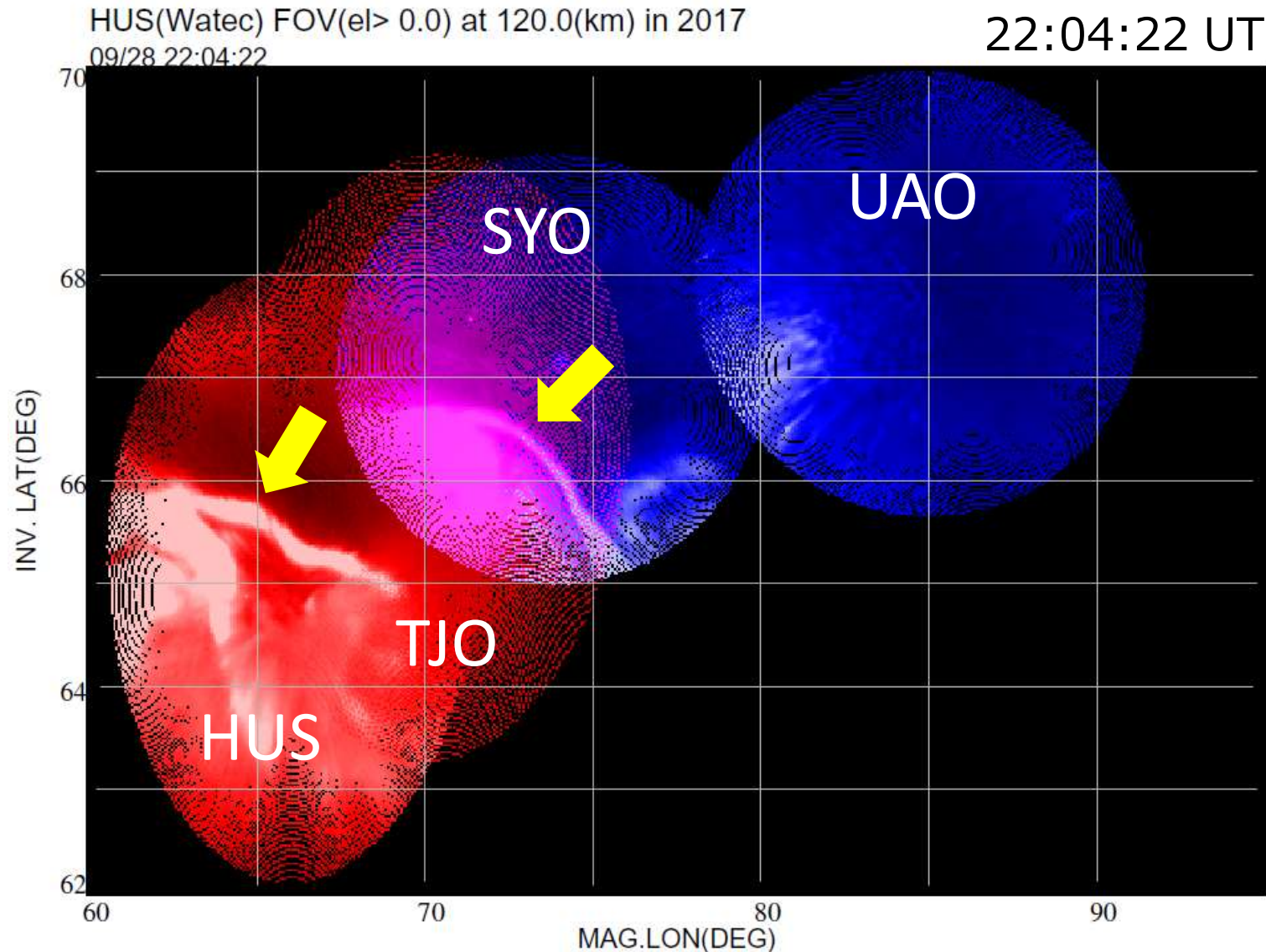
OMNI IMF data



Østgaard, et al. (JGR, 2004)

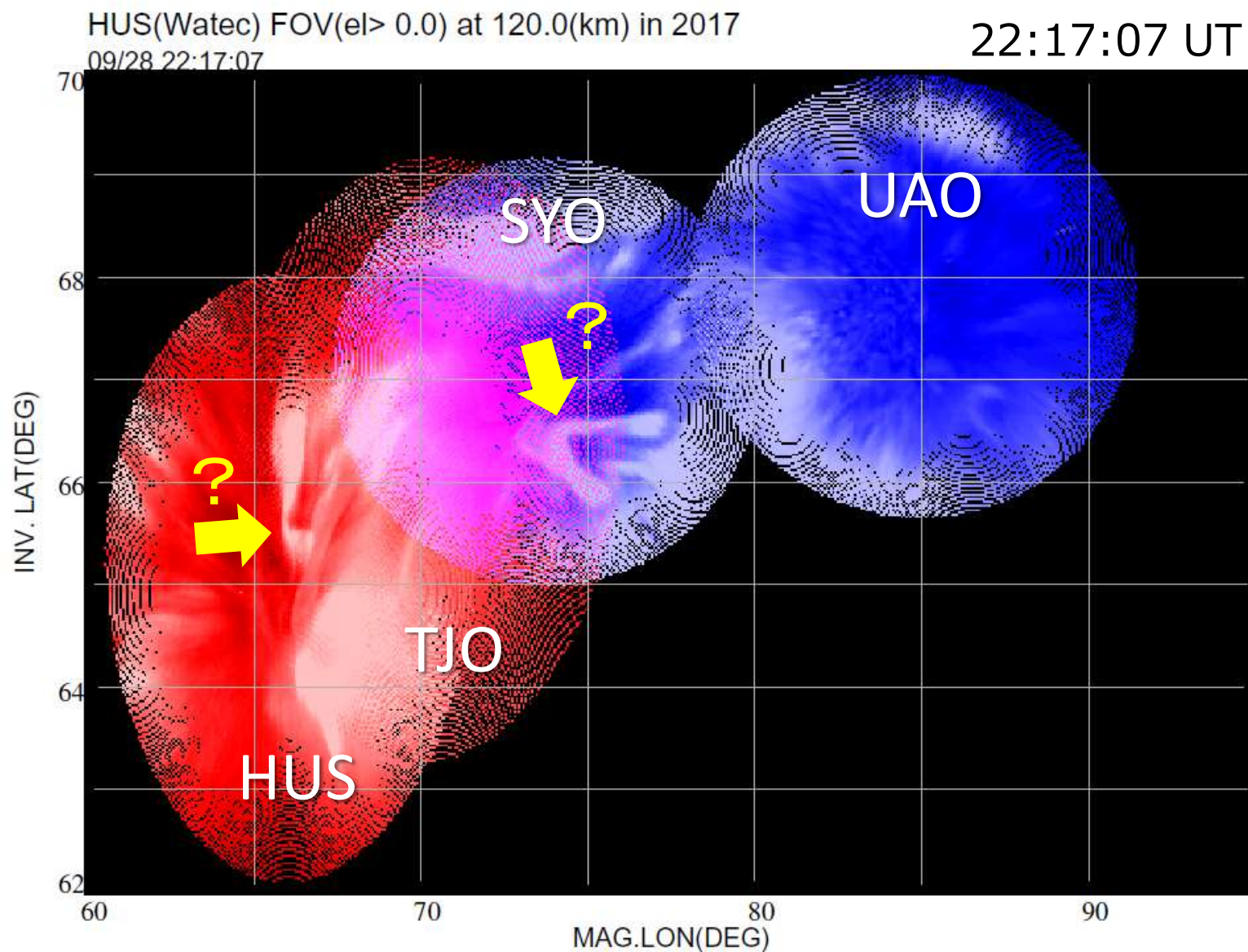
Syowa, UAO – Iceland Conjugate event on Sep. 28, 2017

Longitudinal & latitudinal displacement: 1st stage of first expansion



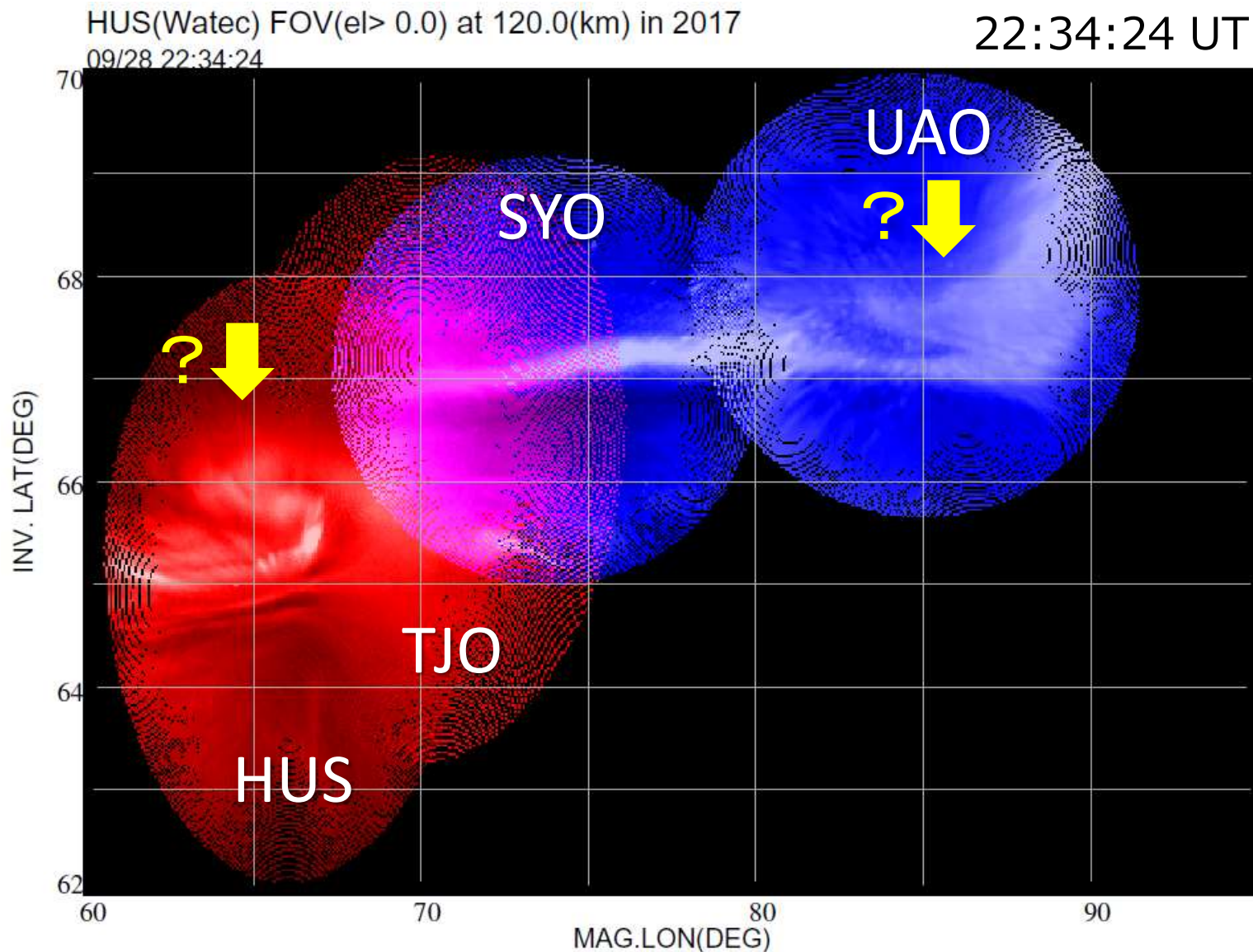
Syowa, UAO – Iceland Conjugate event on Sep. 28, 2017

Longitudinal displacement & Rotation (?) : 2nd stage of first expansion

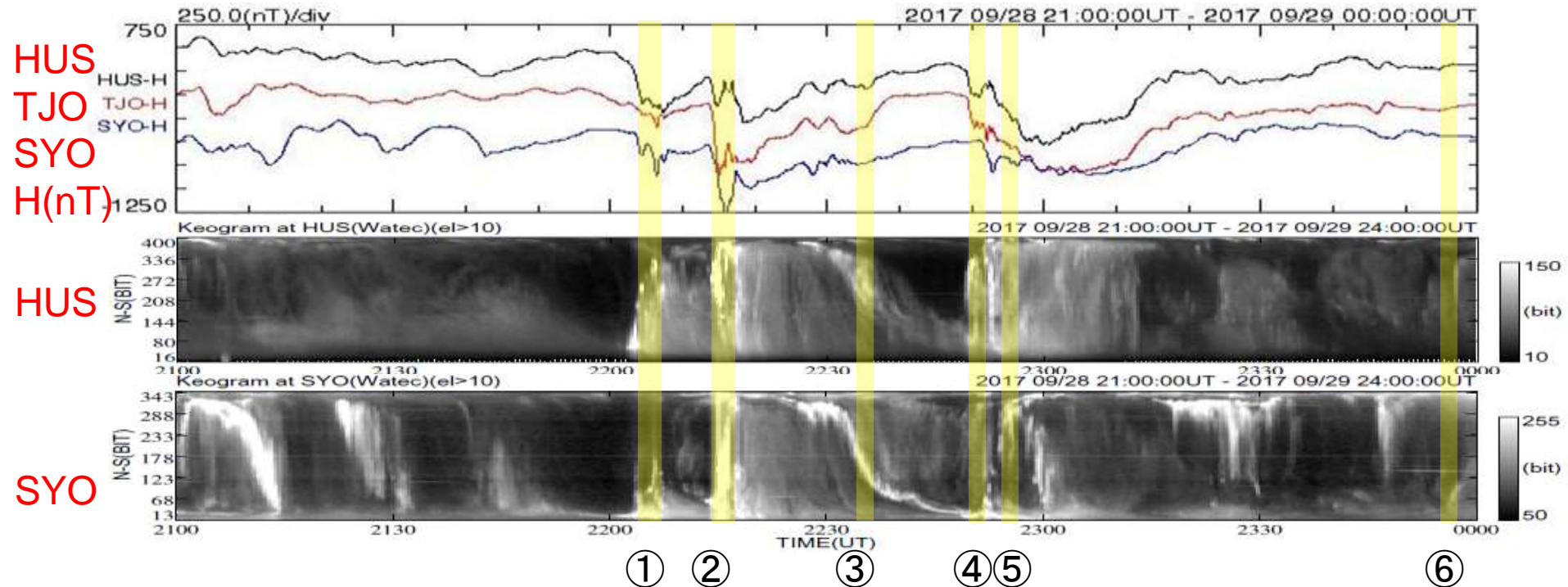


Syowa, UAO – Iceland Conjugate event on Sep. 28, 2017

Large Longitudinal displacement (?) : recovery of first expansion



Summary : Conjugate event on Sep. 28, 2017



- ① Lon(S-N): 8 deg, Lat(S-N): 0.8 deg
- ② Lon(S-N): 8 deg, Lat(S-N):
PE is rapid in N than S, CCW rotation in N than S
- ③ Lon(S-N): 20 deg, Lat(S-N): 2 deg
- ④ Lat(S-N): -1.0 deg, PE is rapid in N than S
- ⑤ N: pulsating aurora, S: discrete aurora
- ⑥ Lon(S-N): 6 deg, Lat(S-N): 0.2deg