Syowa - Iceland Conjugate Auroral Study - a Review

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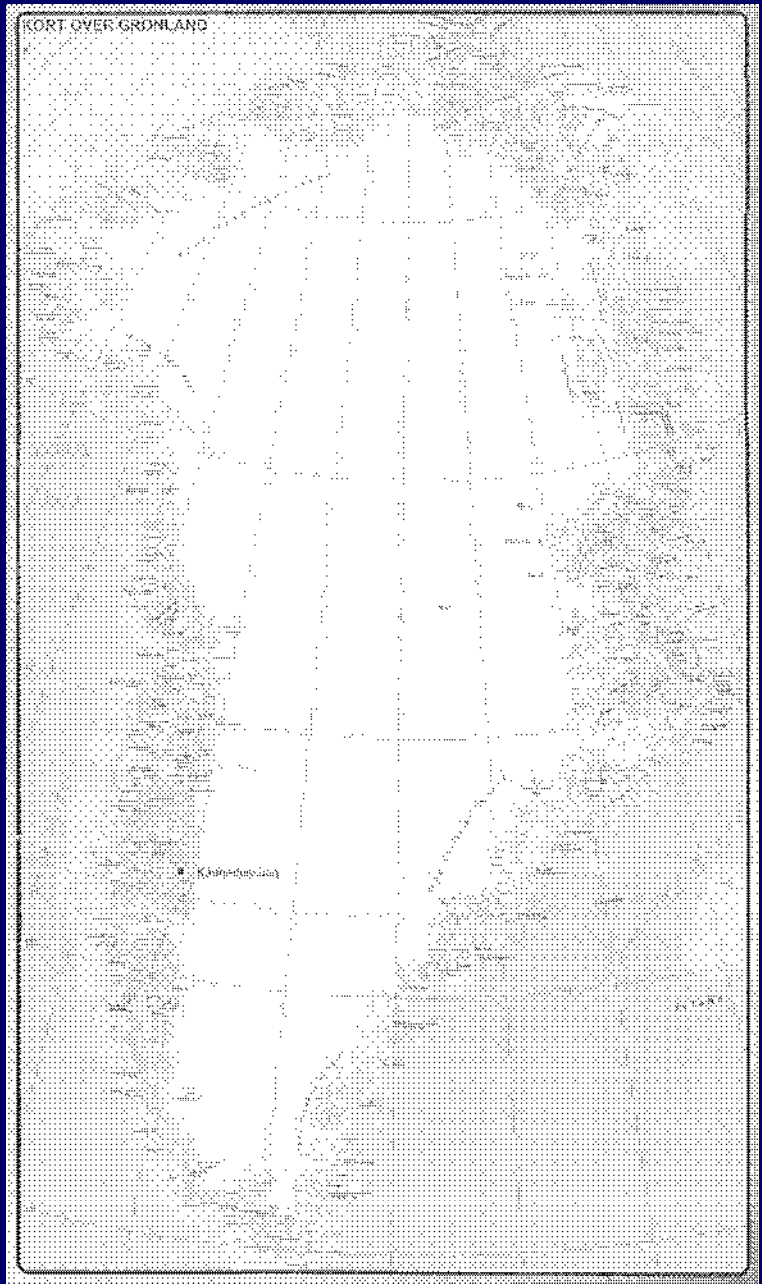
[4] *University of Iceland*

Greenland Space Sciences Symposium, May 4-9, 2007 at Kangerlussuaq



Transport in the Coupled Solar Wind - Geospace System Seen From a High-Latitude Vantage Point

The Greenland Space Science Symposium, to be held 4-9 May 2007 in Kangerlussuaq, Greenland, will strive to advance our understanding of solar-terrestrial interaction by focusing on old and new observations from very high latitudes, as well as related theory, modeling, and numerical simulations. The meeting will provide opportunity for presentations from, and coordination between, existing and planned networks of ground-based instruments and space probes. Modeling results indicating specific needs for additional data acquisition to address scientific issues and/or to validate models are also particularly relevant.

Greenland was selected as the symposium location to celebrate the rich history of Greenland as a base for scientific instruments providing a window into the geospace system. **The symposium is planned as part of the International Polar Year 2007-2008**.

Program Committee:

Jurgen Watermann (chair), Bob Clauer, Eric Donovan, Eigil Friis-Christensen
Christian Hanuise, Kirsti Kauristie, Jeff Thayer (co-chair), John Kelly, Lou Lanzerotti
Volodya Papitashvili, Todd Pedersen, Alan Rodger, Natsuo Sato, Bob Schunk
Susanne Vennerstrøm, Ray Walker, Allan Weatherwax

Greenland Space Sciences Symposium, May 4-9, 2007 at Kangerlussuaq

Invited Speakers - History And Outlook

Peter Banks	retired from The University of Michigan, USA
Richard Behnke	The National Science Foundation, USA
Asgeir Brekke	The University of Tromsø, Norway
Robert Clauer	Virginia Polytechnic Institute and State University, USA
Eigil Friis-Christensen	Danish National Space Center
Michael Hesse	National Aeronautics and Space Administration, USA
Bengt Hultqvist	Institute of Space Physics, Sweden
Torben S. Jørgensen	retired from The Danish Meteorological Institute
John D. Kelly	SRI International, USA
Hannu Koskinen	University of Helsinki
Knud Lassen	retired from The Danish Meteorological Institute
Alan Rodger	British Antarctic Survey, UK
Peter Stauning	The Danish Meteorological Institute

Invited Speakers - Technical Scientific Sessions

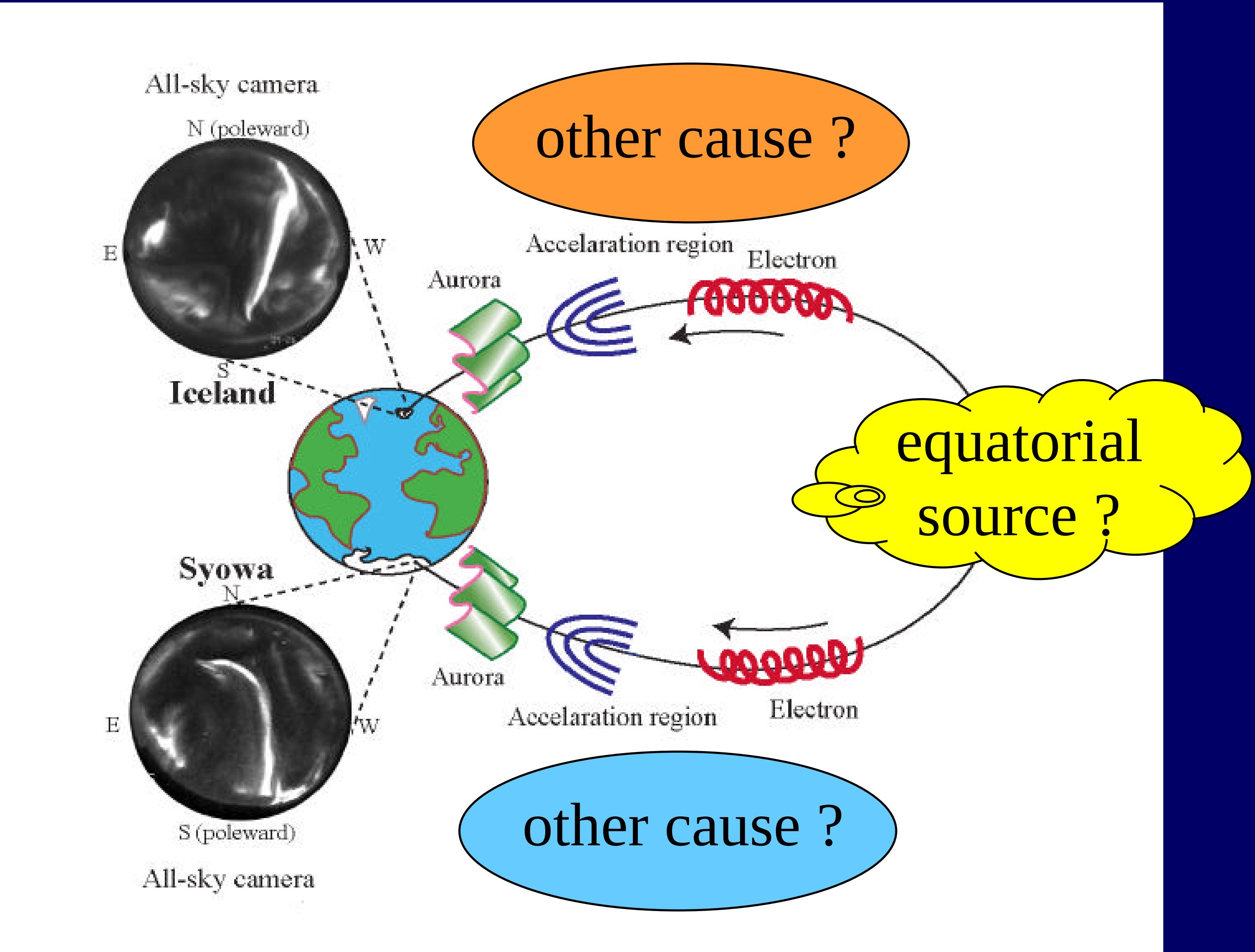
Irfan Azeem	Embry-Riddle Aeronautical University, USA
Joseph Borovsky	Los Alamos National Laboratory, USA
Mervyn P. Freeman	British Antarctic Survey, UK
Keisuke Hosokawa	The University of Electro-Communications, Japan
Umran S. Inan	Stanford University, USA
Akira Kadokura	National Institute of Polar Research, Japan
Hannu Koskinnen	The University of Helsinki, Finland
Mark Lester	The University of Leicester, UK
Gang Lu	NCAR, USA
Ian W. McCrea	Rutherford Appleton Laboratory, UK
David Murr	Dartmouth College, USA
Shin-Ichiro Oyama	Nagoya University, Japan
Scott Palo	The University of Colorado, USA
Frederic Pitout	The Grenoble Laboratory of Planetology, France
Robert W. Schunk	Utah State University, USA
Joshua Semeter	Boston University, USA
Peter Stauning	The Danish Meteorological Institute
Jean-Pierre St-Maurice	The University of Saskatchewan, Canada
Allan Weatherwax	Siena College, USA

Attendee : total 70

Outline of today's talk

- Previous works before our study.
- Geomag. features of Syowa - Iceland conjugate pair
- Brief review of our conjugate auroral studies so far
  - ☆ Conjugacy in MSP (Meridian Scanning Photometer) data
  - ☆ Morphology using ATV (All-sky TV) data
  - ☆ Conjugacy of Pulsating aurora
- Summary

Conjugate Observation



by Natsuo Sato

Conjugate Stations

Alaska
New Zealand

Geomagnetic mapping

Previous Study during IGY period

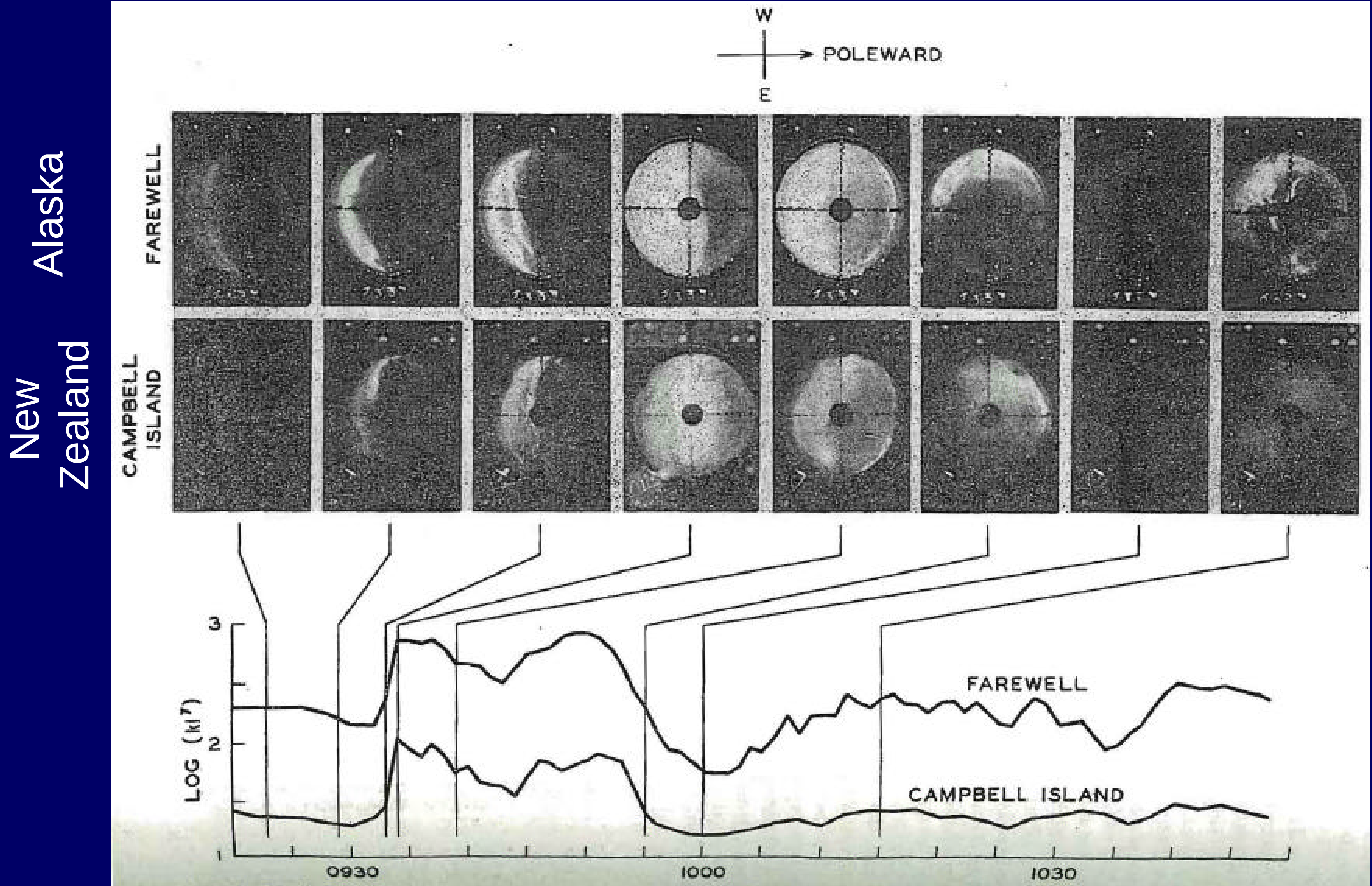


Fig. 3 Similar features of the auroras that appeared at Campbell Island and Farewell during universal day March 13, 1958.

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

Conjugate auroral study using the data during IGY period

In a later (unpublished) analysis of all-sky camera data obtained on six nights at a higher (70°) dp latitude (Reykjavik, Iceland, and Syowa, Antarctica), DeWitt noted considerably fewer similiarities in auroral features. *Wescott and Mather* [1964], using the same data, attempted to identify individual forms and trace their motion. Although the correlations of shape and intensity were not very good, Wescott and Mather had the impression that the conjugate positions of the two stations did not remain stationary and that apparent deviations of more than 400 km would have been necessary to reconcile some of the displays if they were magnetically conjugate. There was a tendency for the southern auroras to be located equatorward of the northern conjugate auroras, but the data did not permit them to determine whether a displacement in longitude might also be involved.

Syowa - Iceland conjugate All-sky data during IGY period

6 nights

Belon et al., JGR, 1969

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

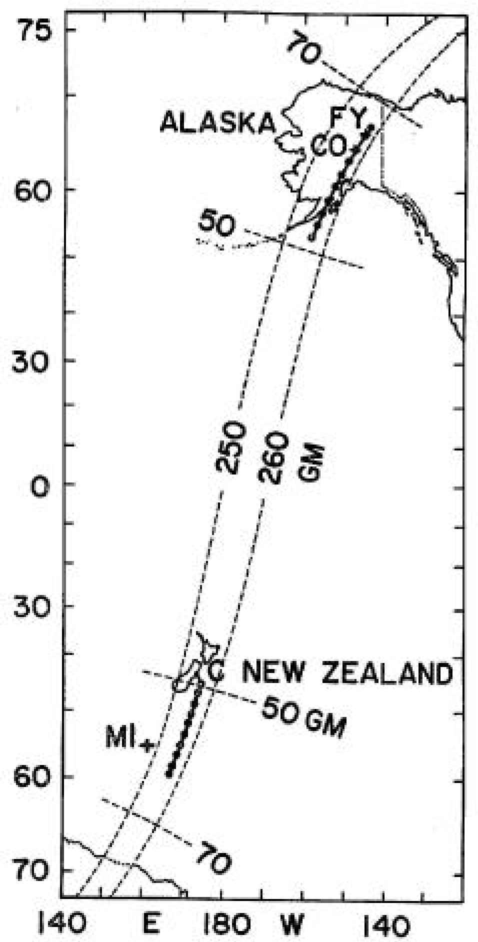


Fig. 1. Aircraft flight paths in northern and southern hemispheres. Corresponding solid circles indicate conjugate locations reached simultaneously.

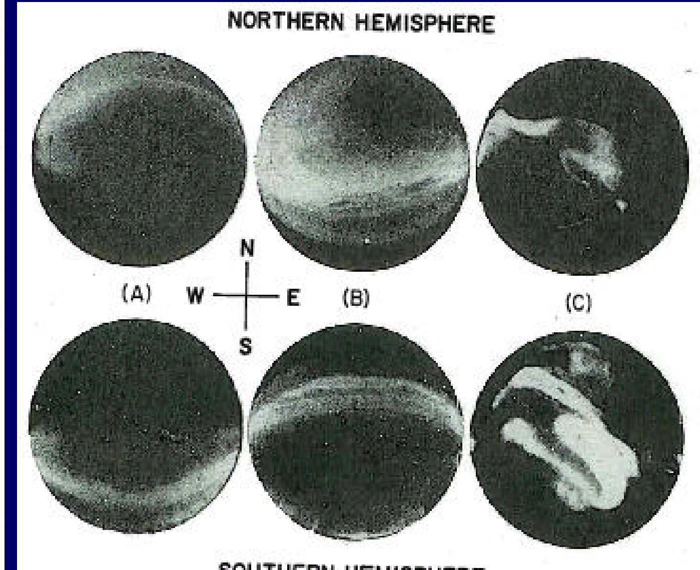


Plate 11a. Representative examples of conjugate all-sky photographs from March 1968 flights. Photograph pairs (A) to (F) represent increasing dp latitudes.

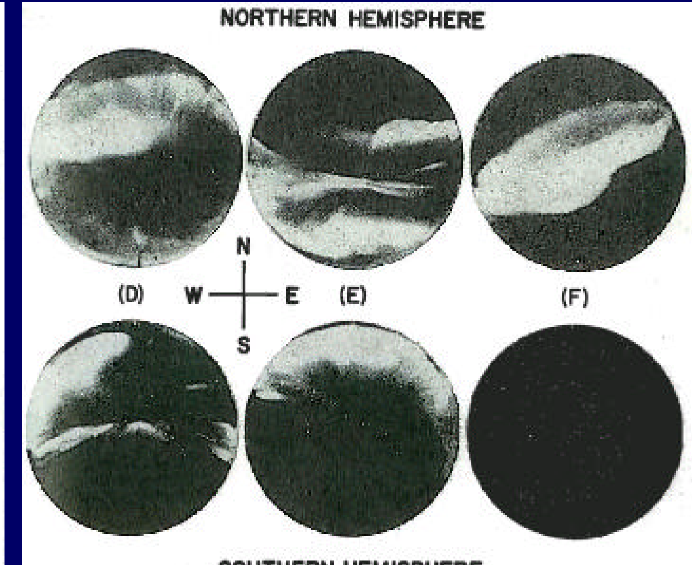
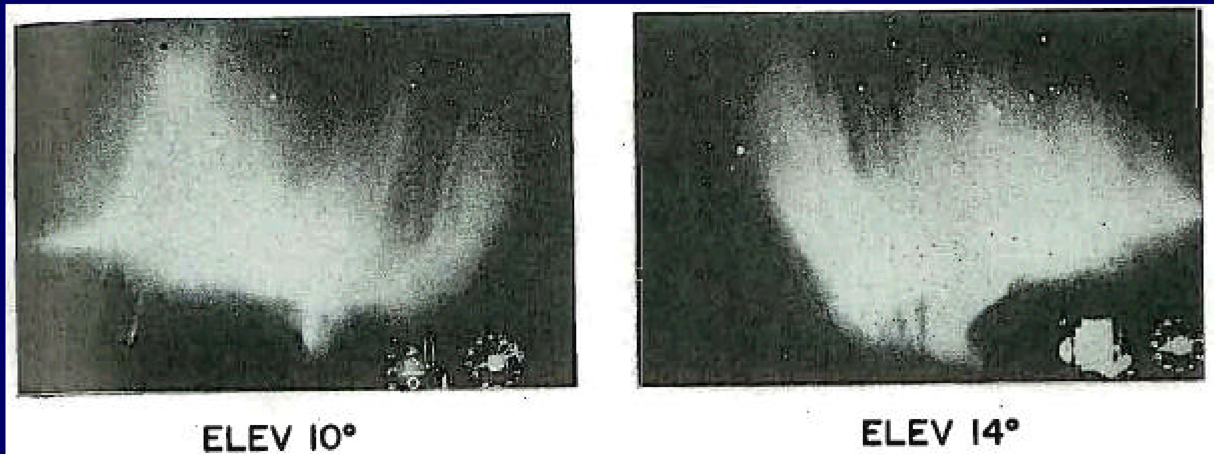


Plate 11b. Representative examples of conjugate all-sky photographs from March 1968 flights.

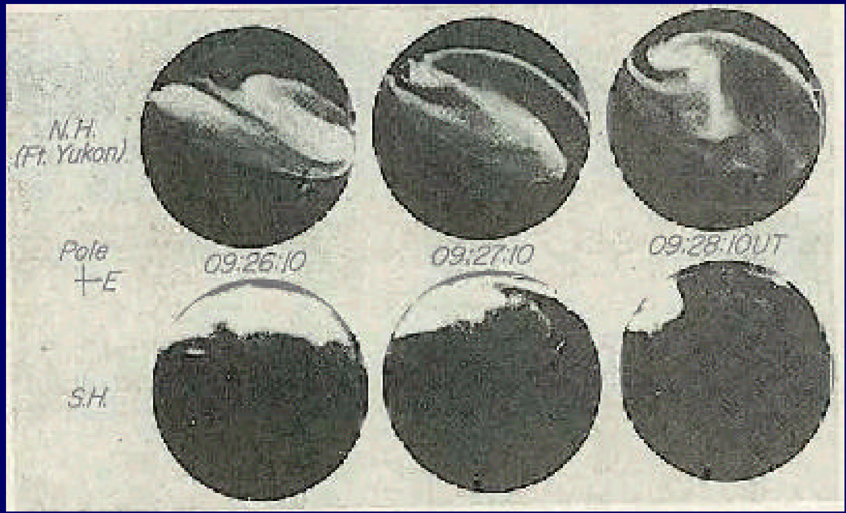


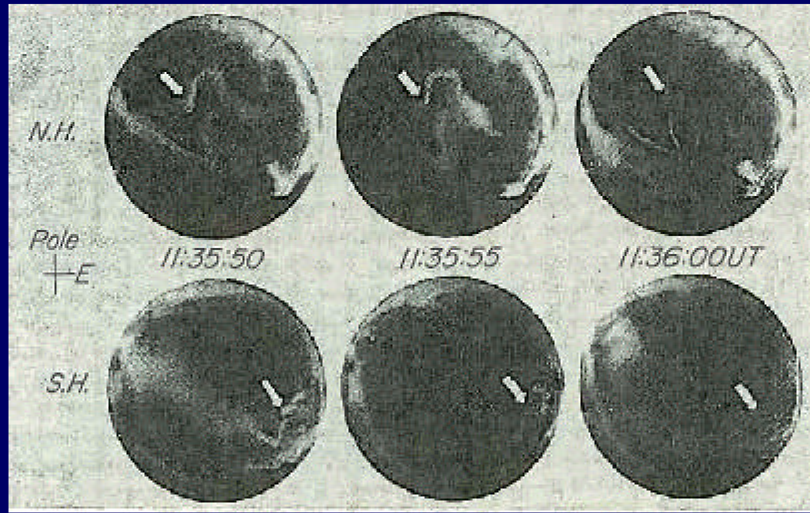
along 256° MM

Belon et al., JGR, 1969

Previous Study using the Jet Aircraft Flight

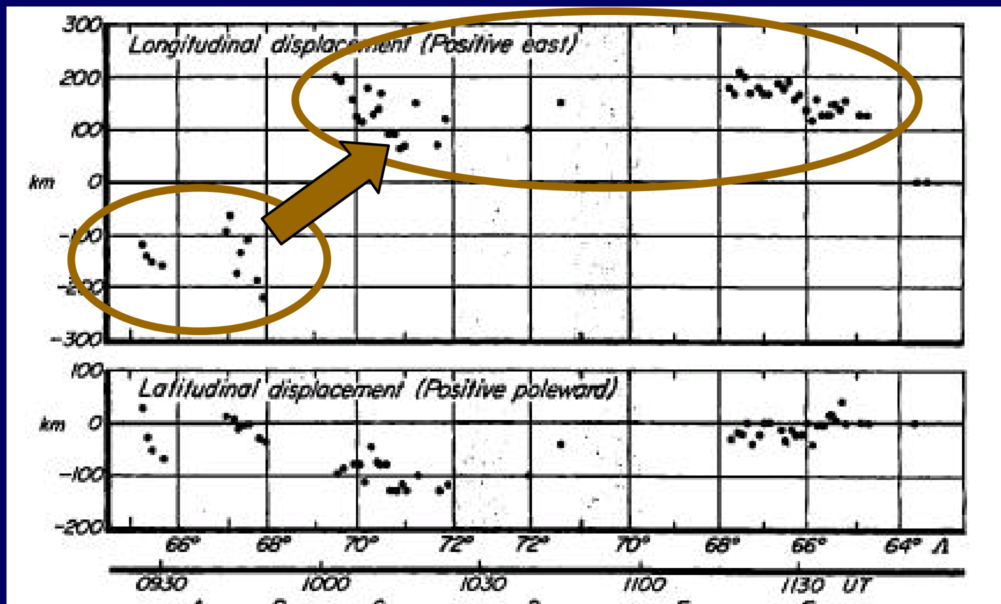
Motion of Conjugate Points during Substorm





Small WTS

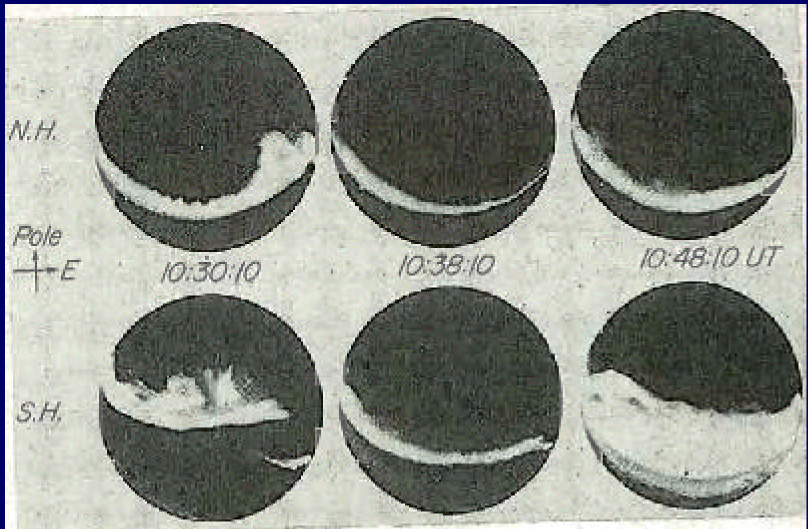
Pulsating Aurora

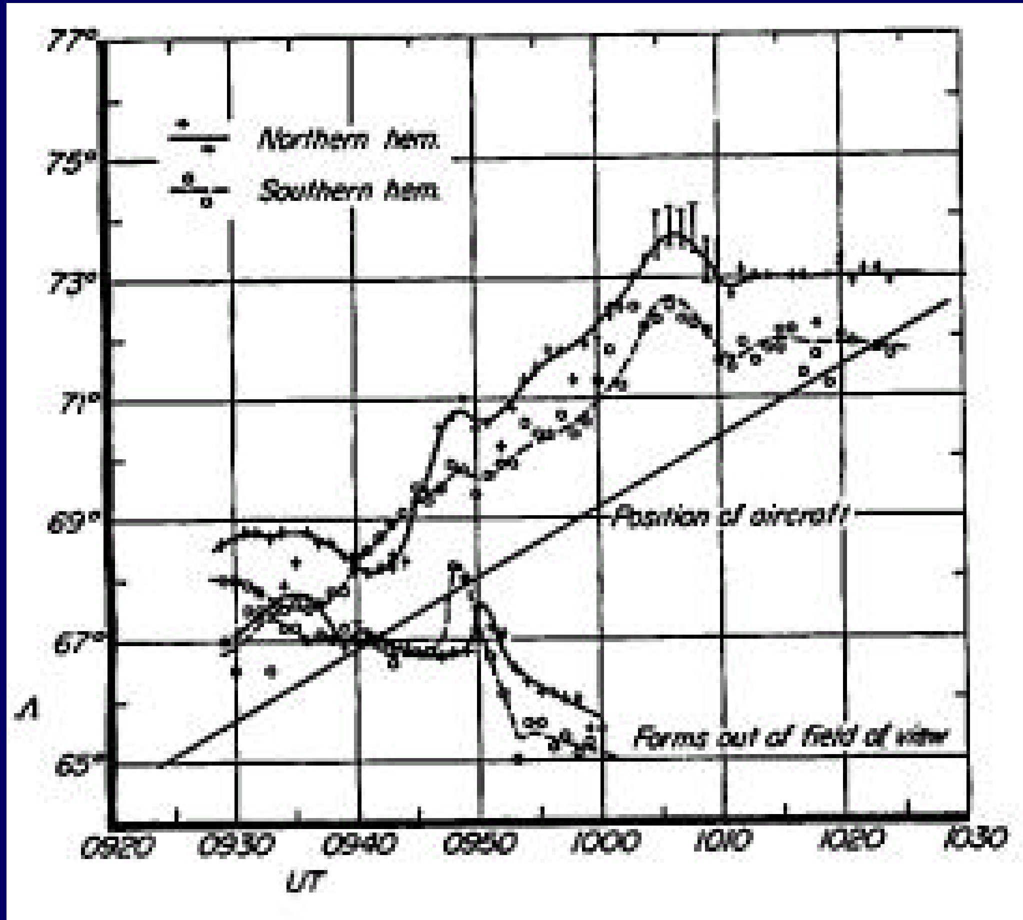


Stenbaek-Nielsen et al., JGR, 1972

Previous Study using the Jet Aircraft Flight

Time difference (～5 min) of the breakup start





Stenbaek-Nielsen et al., JGR, 1972

Previous Study using the Jet Aircraft Flight

Intensity difference N > S (x ∼ 1.3)

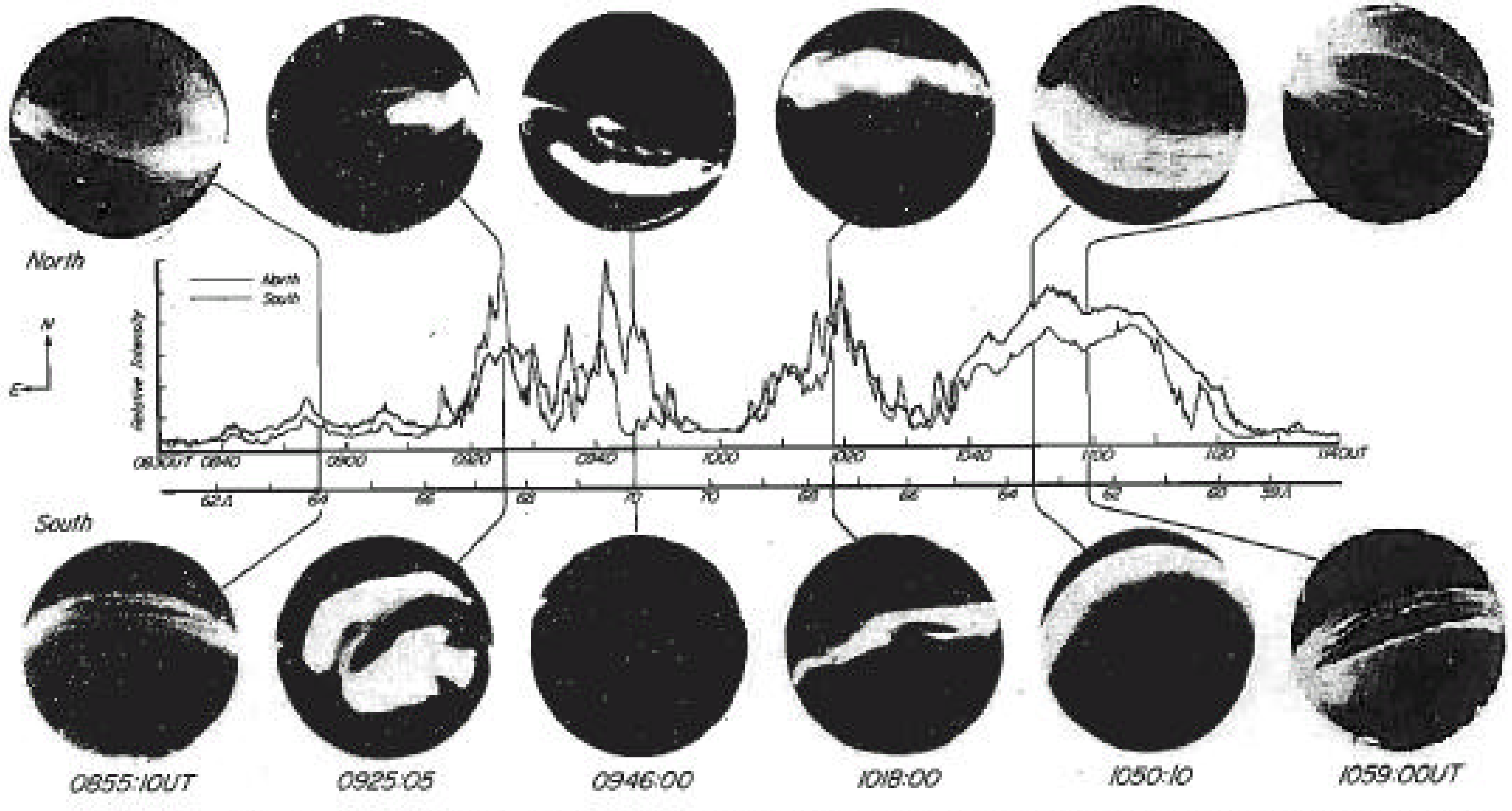


Fig. 2. March 29, 1968. Relative all-sky auroral intensities at conjugate areas along the

Stenbaek-Nielsen et al., JGR, 1973

Difference in B at conjugate points and Auroral Occurrence

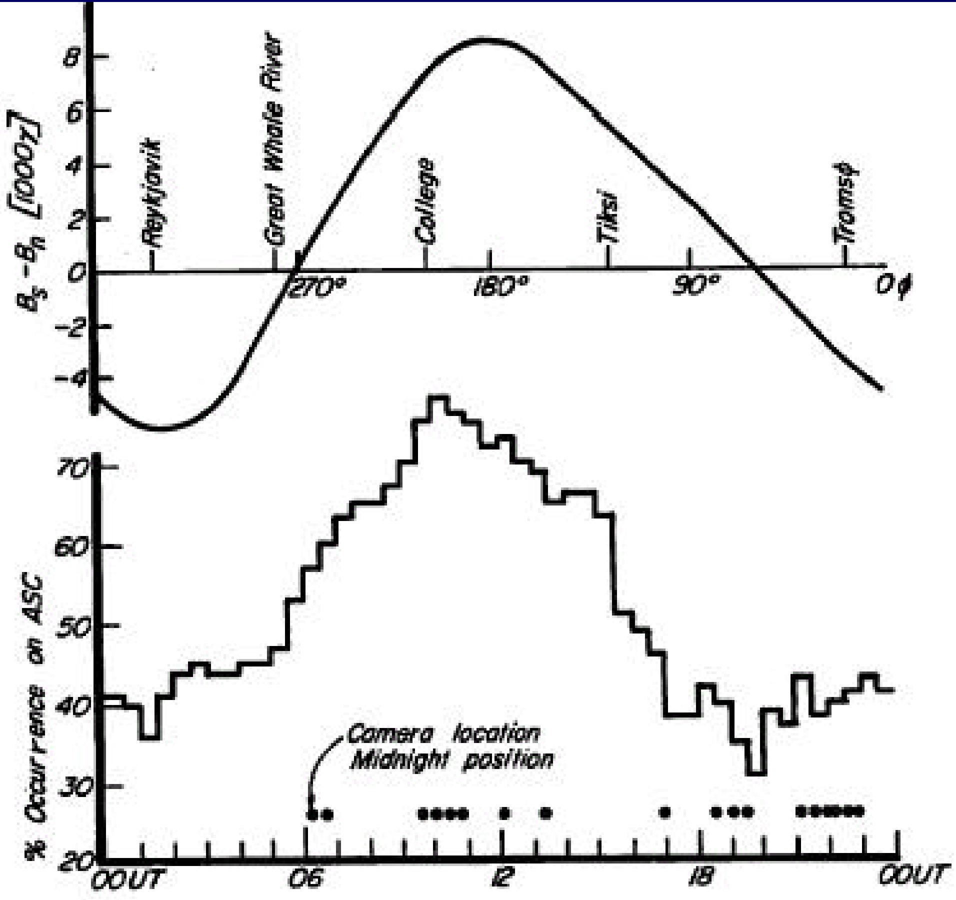


Fig. 1. Difference in magnetic field strength at 300 km at conjugate points along 65° invariant latitude. The lower plot gives per cent occurrence of aurora observed on all-sky camera data from auroral stations located between 64° and 70°N geomagnetic latitude. The data cover the period February 14 through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

Stenbaek-Nielsen et al., JGR, 1973

Theoretical Estimate of the Intensity Ratio

for Strong diffusion & Isotropic flux

$$\sin^2\alpha = B_0/B_m \qquad (1)$$

$$\alpha_N \cong (B_0/B_N)^{1/2} \quad \text{and} \quad \alpha_S \simeq (B_0/B_S)^{1/2} \qquad (2)$$

$$R(\alpha) = \alpha_N/\alpha_S \cong (B_S/B_N)^{1/2} \qquad (3)$$

The number of particles n_1 crossing the equatorial plane with pitch angles $< \alpha$ per unit time is then

$$n_1 = A_0 \cdot \pi \cdot j_1 \cdot \sin^2\alpha \simeq A_0 \pi j_1 \alpha^2 \qquad (4)$$

$$R_{1s} = n_{1N}/n_{1S} = B_S/B_N = 1.15 \qquad (5)$$

$$A_N B_N = A_S B_S \qquad (6)$$

Most auroras are in the form of thin sheets extending from horizon to horizon. The overall intensity ratio R_s will be equal to the ratio of the thicknesses of the auroral sheets t_N and t_S:

$$R_S = \frac{t_N}{t_S} = \left(\frac{A_N}{A_S}\right)^{1/2} = \left(\frac{B_S}{B_N}\right)^{1/2} = 1.07 \qquad (7)$$

If there is potential difference

$$W_N = W_0 + W_*/2$$
$$W_S = W_0 - W_*/2 \qquad (11)$$

$$\frac{B_0}{W_{\perp 0}} = \frac{B_N}{W_{\perp N}} = \frac{B_S}{W_{\perp S}} \qquad (12)$$

$$\sin^2\alpha_N = \frac{W_{\perp 0}}{W_0} = \frac{B_0}{B_N}\left(1 + \frac{W_*}{2W_0}\right)$$
$$\sin^2\alpha_S = \frac{W_{\perp 0}}{W_0} = \frac{B_0}{B_S}\left(1 - \frac{W_*}{2W_0}\right) \qquad (13)$$

$$R_* = \frac{n_N \cdot W_N}{n_S W_S} = \frac{B_S}{B_N}\left[\frac{1 + (W_*/2W_0)}{1 - (W_*/2W_0)}\right]^2$$
$$\approx \frac{B_S}{B_N}\left(1 + 2\frac{W_*}{W_0}\right) \qquad (14)$$

Stenbaek-Nielsen et al., JGR, 1973

Syowa-Iceland Conjugate Observation

✧ 1977～1978 : First campaign

IMS (International Magnetosphere Study) period

Only summer time; Husafell ～ Syowa

✧ From 1984 : Continuous observation

Collaboration with Iceland University

Husafell, Isafjordur, Tjornes

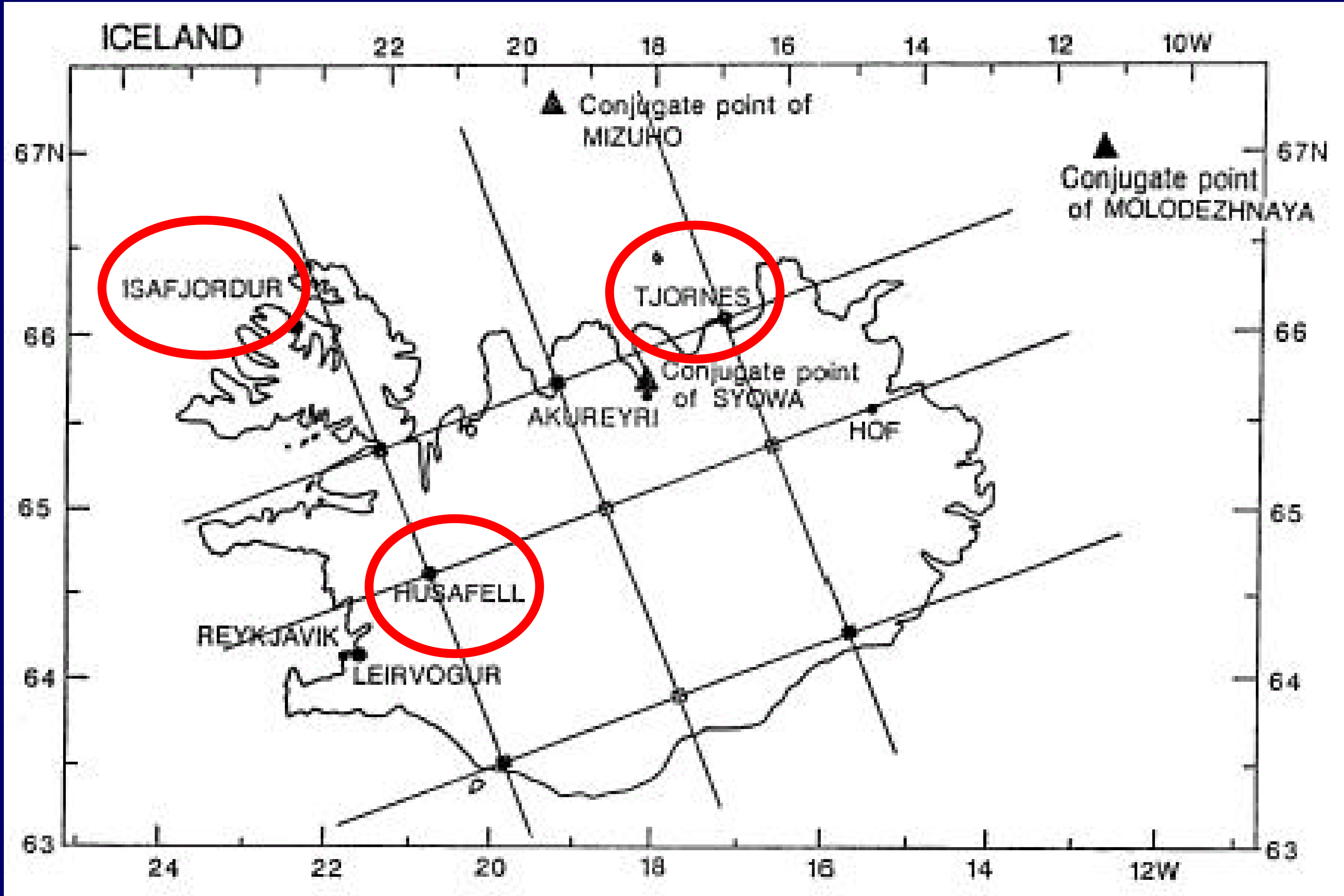
～ Syowa, Mizuho, Molodezhnaya

Instruments:

Fluxgate, Induction, Riometer, VLF, All-sky camera,
All-sky TV, Scanning photometer (H_β, 5577),
Fixed photometers (zenith, N30º, S30º)

Syowa-Iceland Conjugate Observation

Station distribution in 1984



Conjugate Stations

Husafell

Tjornes

Syowa

Block diagram of the Iceland system in 1984

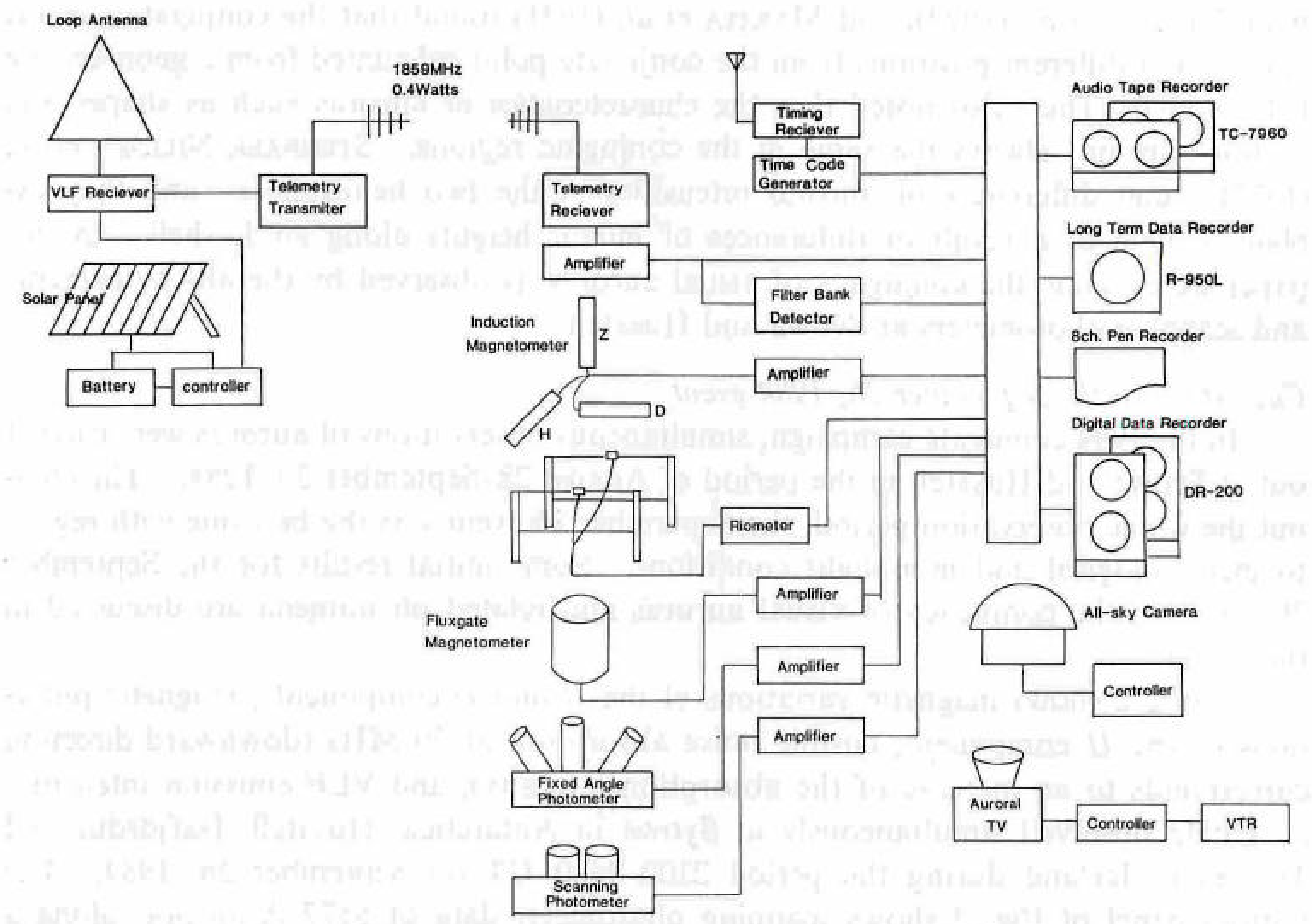


Fig. 1. A block diagram of the observation system at Husafell. The all-sky TV cameras, scanning and fixed direction photometers were set up in 1984; other equipment had been constructed in 1983.

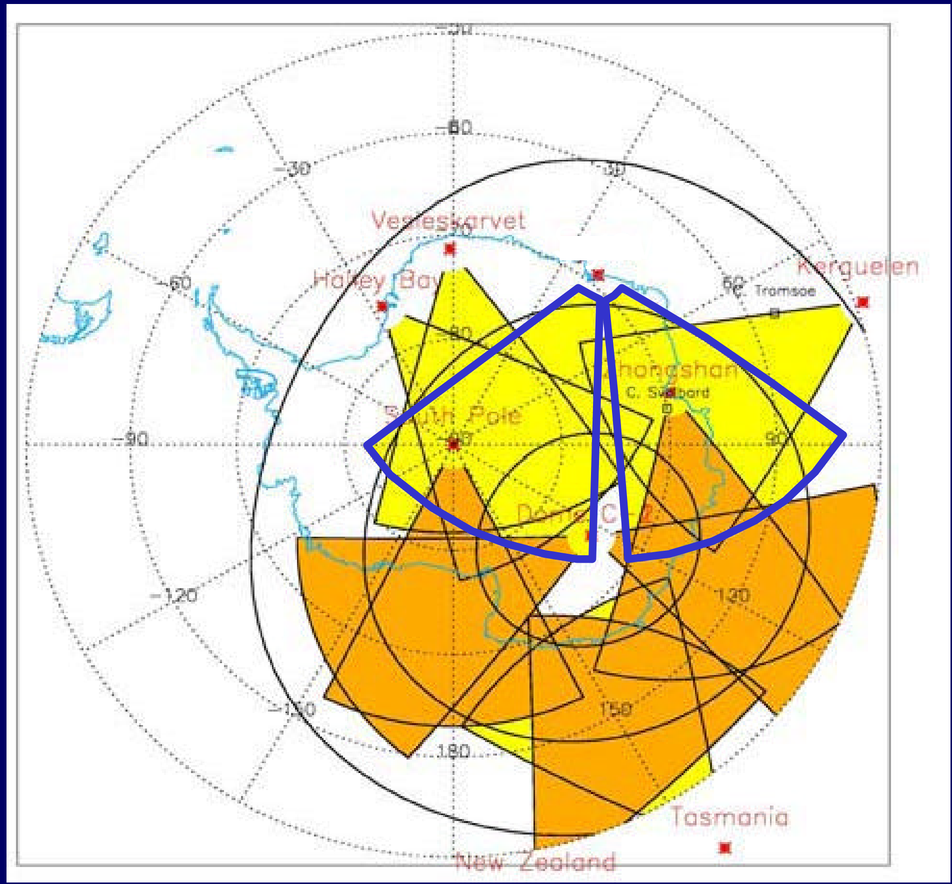
Instruments at conjugate stations at present

	SYO	HUS	TJR	AED
Fluxgate magnetometer	○	○	○	○
Induction magnetometer	○	○	○	○
VLF receiver	○	○	○	○
Riometer	○	○	○	○
Imaging Riometer	1992	1997	1990	
All-sky TV camera (night-viewer)	○	○	○	
All-sky monochromatic Imager	○	2005		
Meridian Scanning Photometer	○			
Fabry-Perot Imager	○			
SuperDARN radar	○		△	
MF-radar	○			
Ionosonde (NiCT)	○			
VHF Doppler radar (NiCT)	○			
FM/CW radar (NiCT)	○			

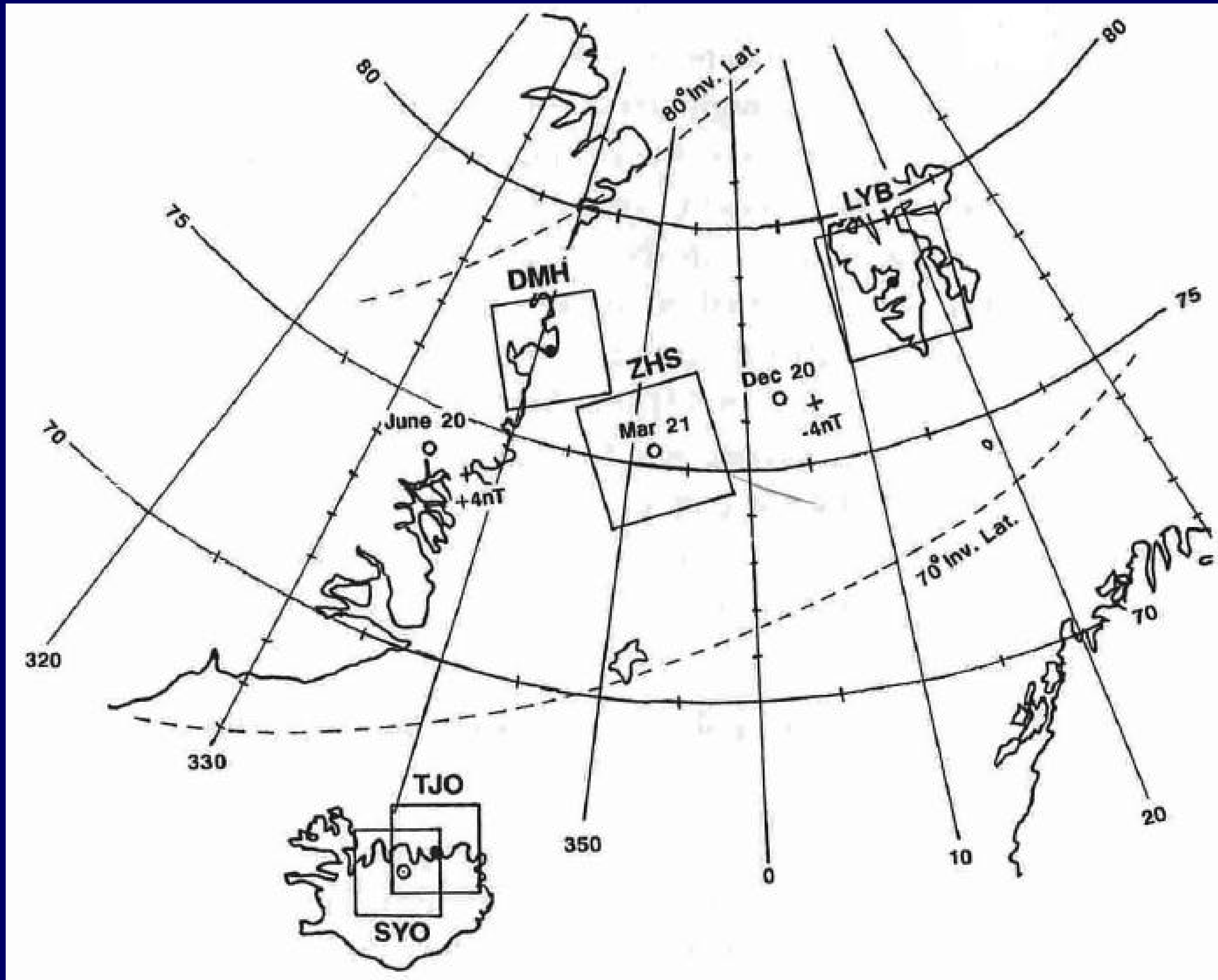
Conjugate Stations

Geomagnetic mapping

SuperDARN radar in both hemispheres

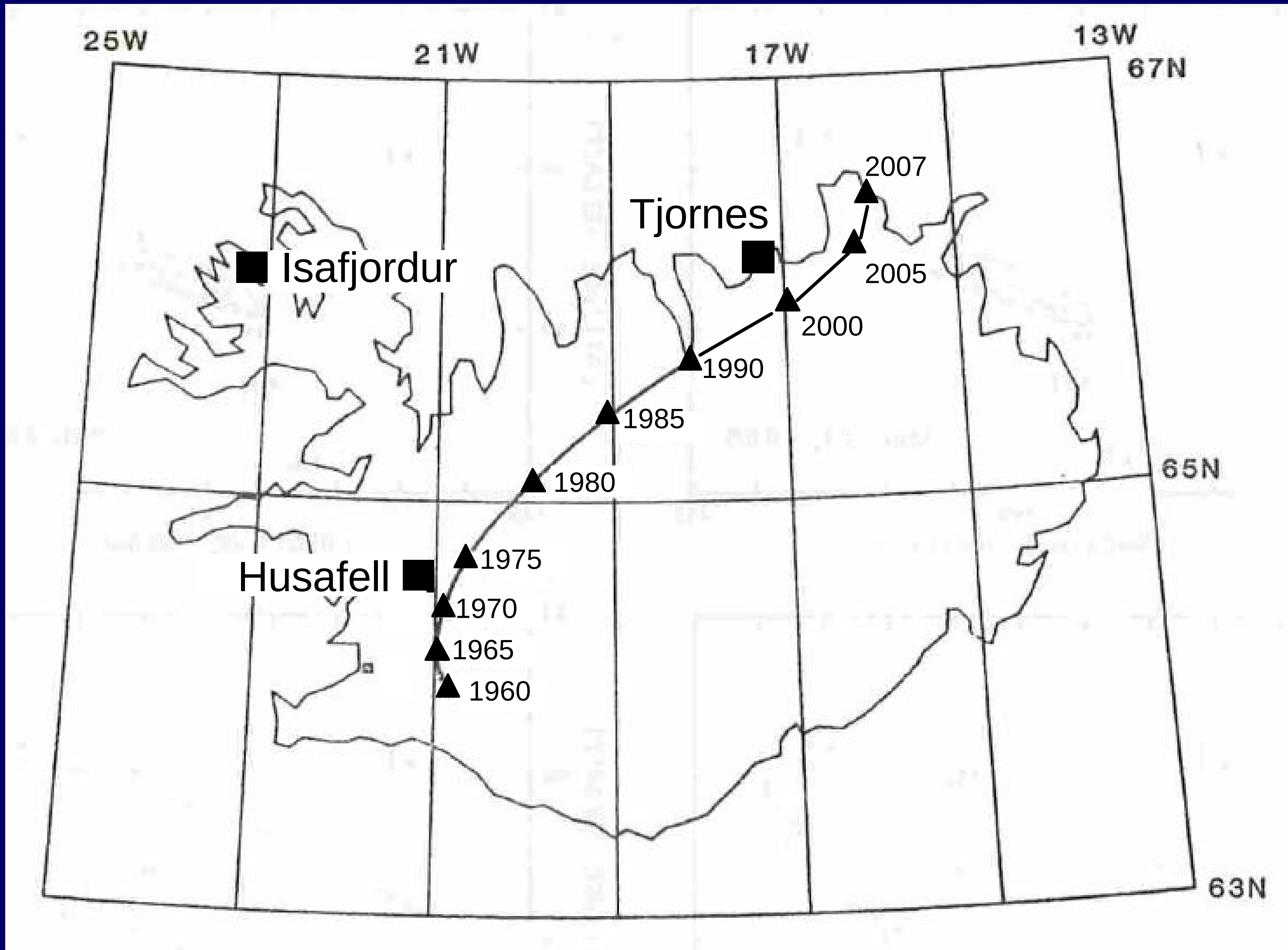


Imaging Riometer network



Yamagishi et al.,APUAR, 2000

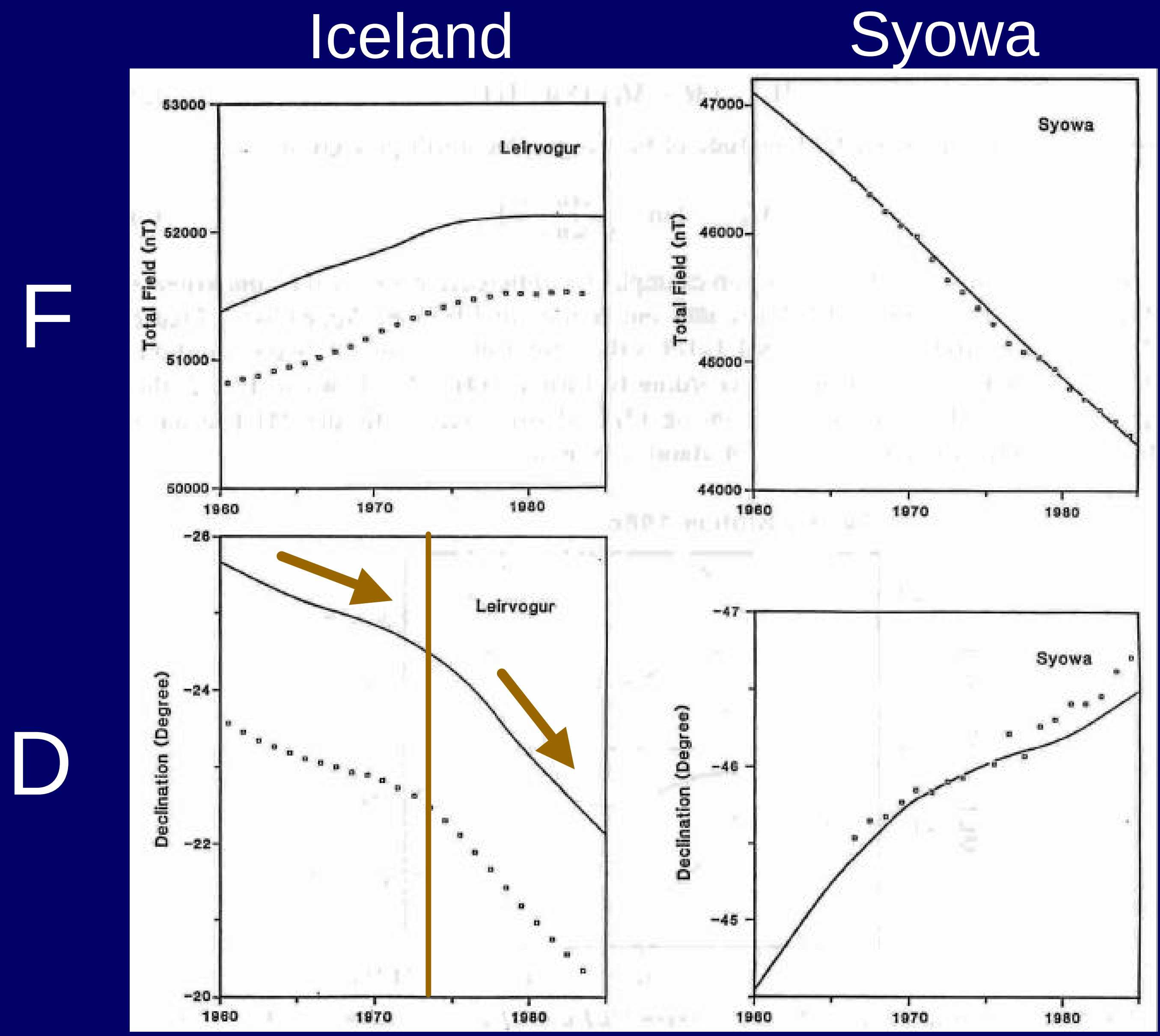
Secular variation of the conjugate point of Syowa



using IGRF

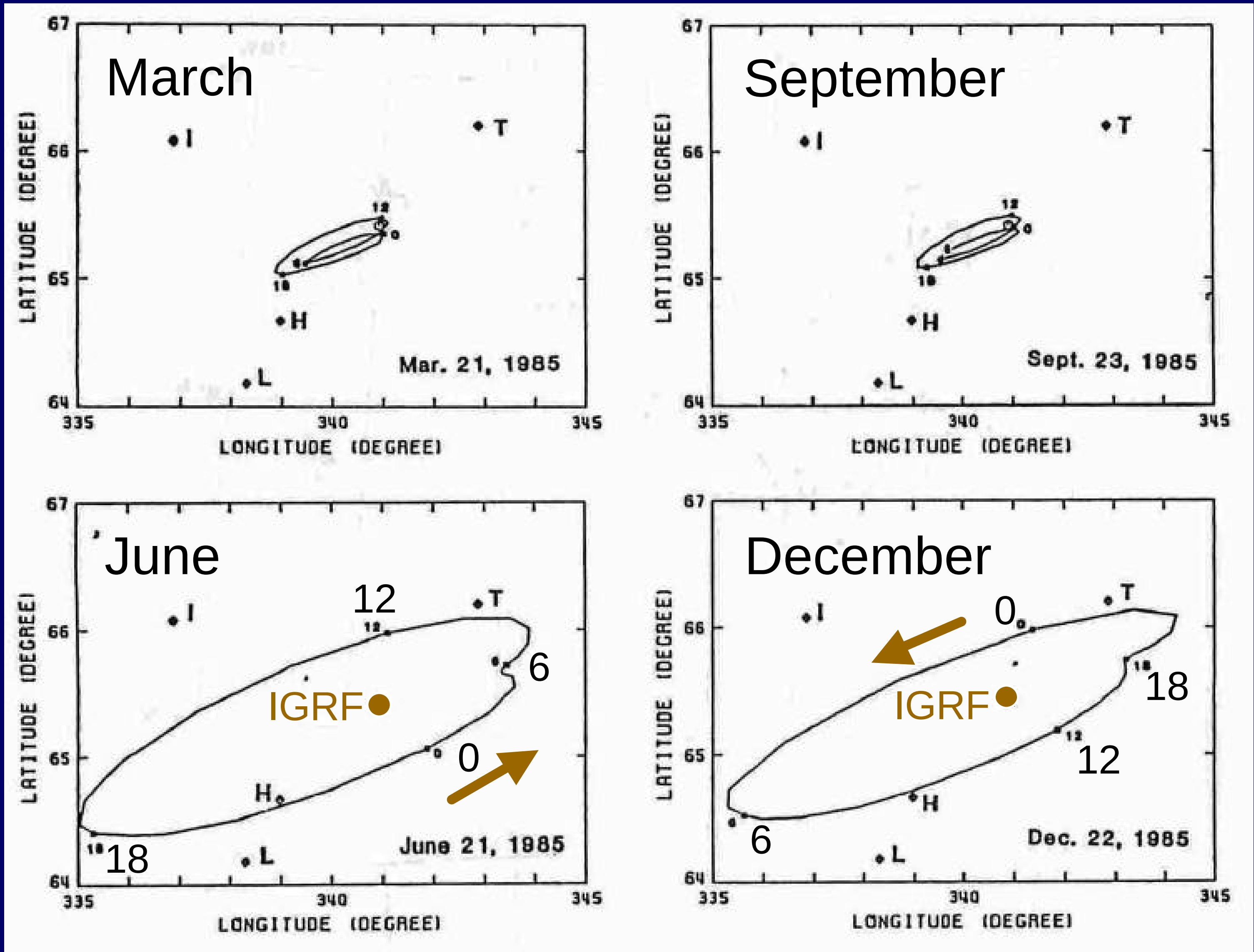
Ono, Memoirs of NIPR, 48, 1987

Secular variation of the magnetic field



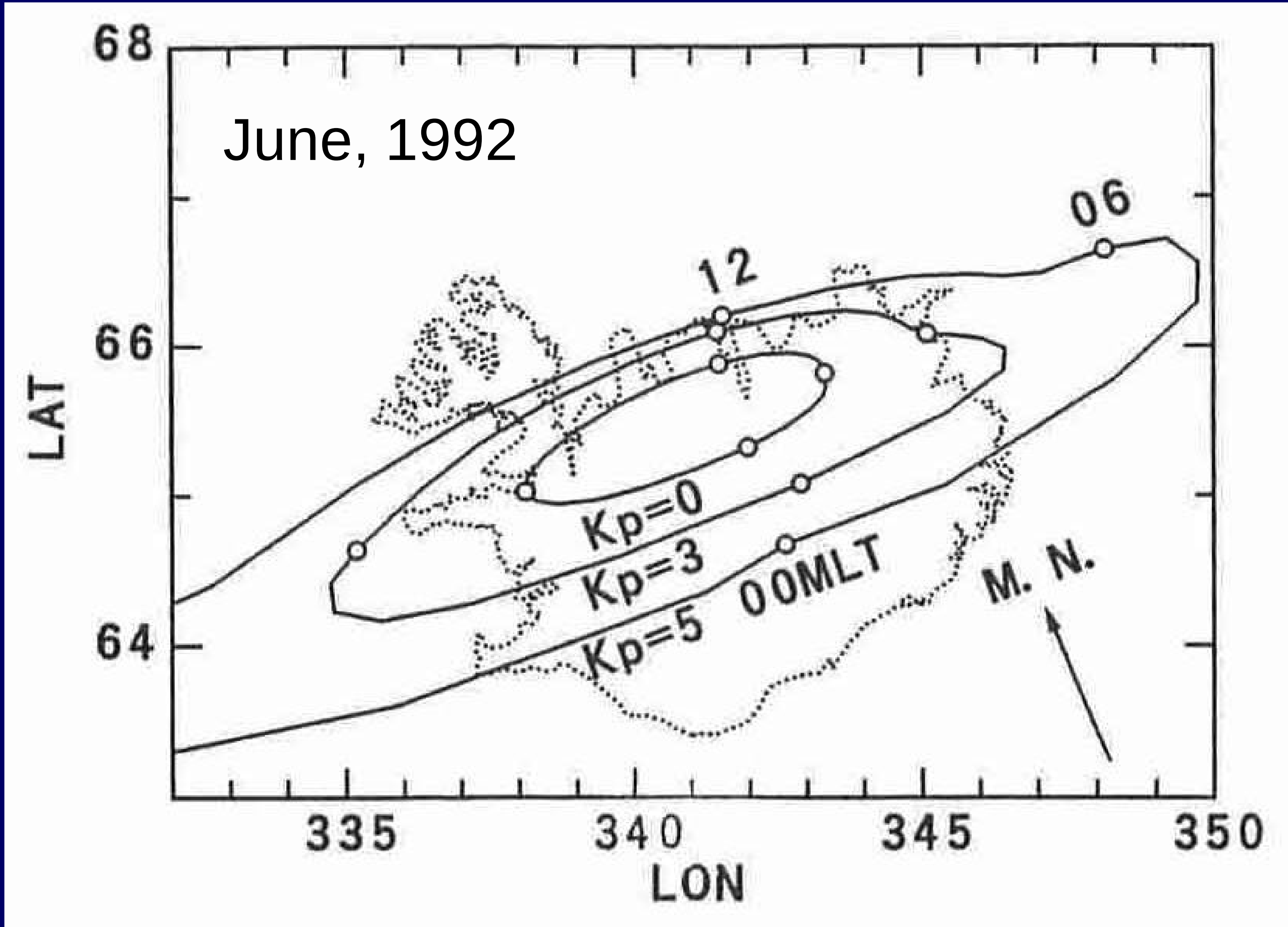
Ono, Memoirs of NIPR, 48, 1987

Seasonal & Daily variation of the conjugate point of Syowa



at 110 km using Tsyganenko and Usmanov (1982) *Ono (Memoirs of NIPR, 48, 1987)*

Activity dependence of the Daily variation



at 90 km using Tsyganenko (1989)

Fujita et al. (Antarc.Rec, 42, 1998)

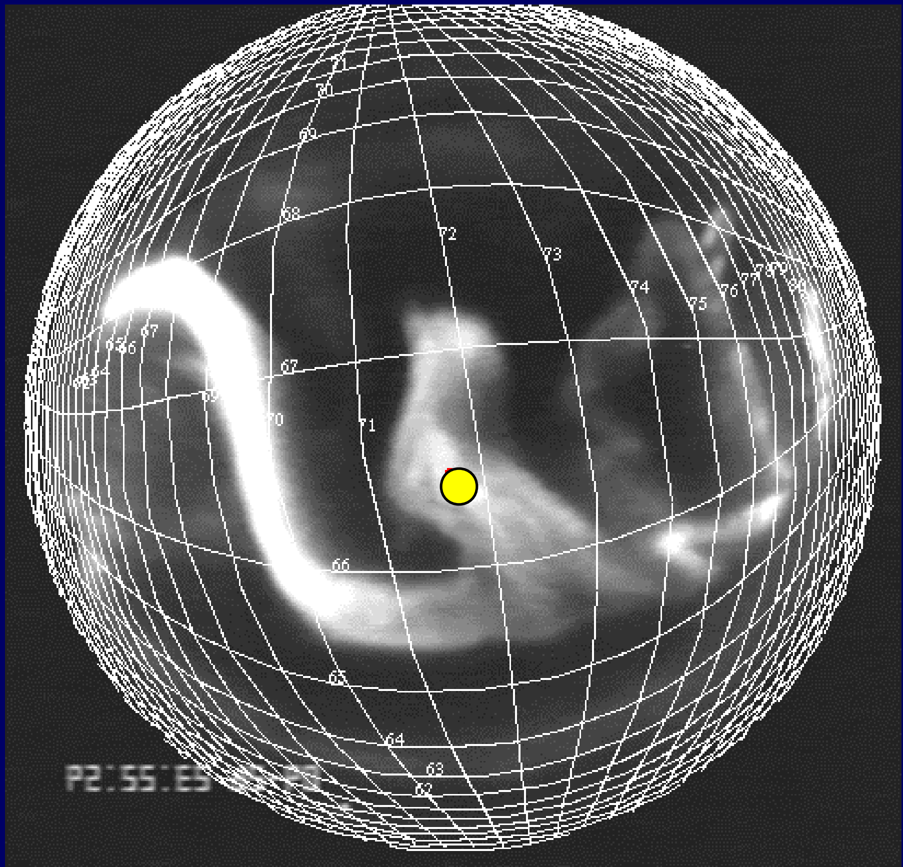
Geographic & Geomagnetic Parameters

1985.0 / 2007.0

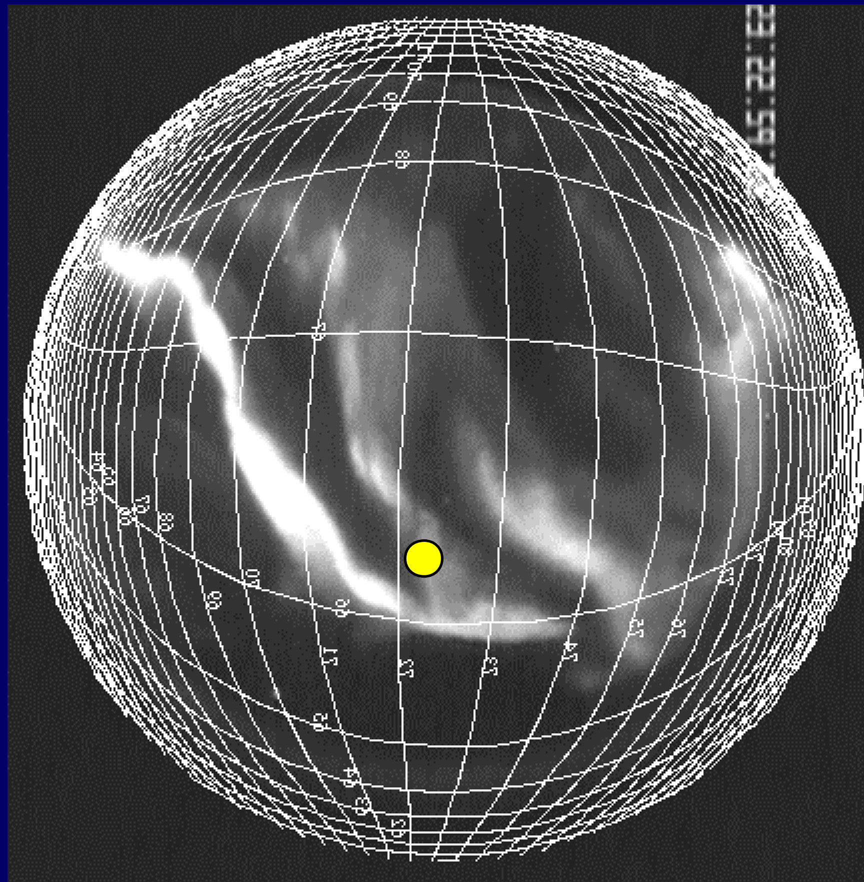
Station	Glat (deg)	Glon (deg)	Inv.lat (deg)	Mlon (deg)	MLT(hr) at 0 UT	L value	D (deg)	I (deg)	B (nT)	B_S/B_N
Syowa	-69.00	39.58	66.22 66.37	71.44 72.35	23.65 23.68	6.14 6.22	-46.50 -49.20	-64.70 -63.64	44365 43114	-
Isafjordur Aedey	66.08 66.09	-23.13 -22.65	67.65 66.99	68.81 66.69	23.48 23.30	6.92 6.54	-24.29 -18.27	76.83 76.77	52563 52775	0.84 0.82
Husafell	64.67	-21.03	65.87 65.28	69.36 67.04	23.52 23.33	5.99 5.72	-22.00 -16.58	75.93 75.87	52151 52410	0.85 0.82
Tjornes	66.20	-17.12	66.80 66.35	73.76 71.30	23.81 23.61	6.45 6.22	-20.29 -15.05	76.51 76.55	52145 52472	0.85 0.82

All-Sky Image and Geomagnetic mesh at 120 km altitude

TJORNES



SYOWA



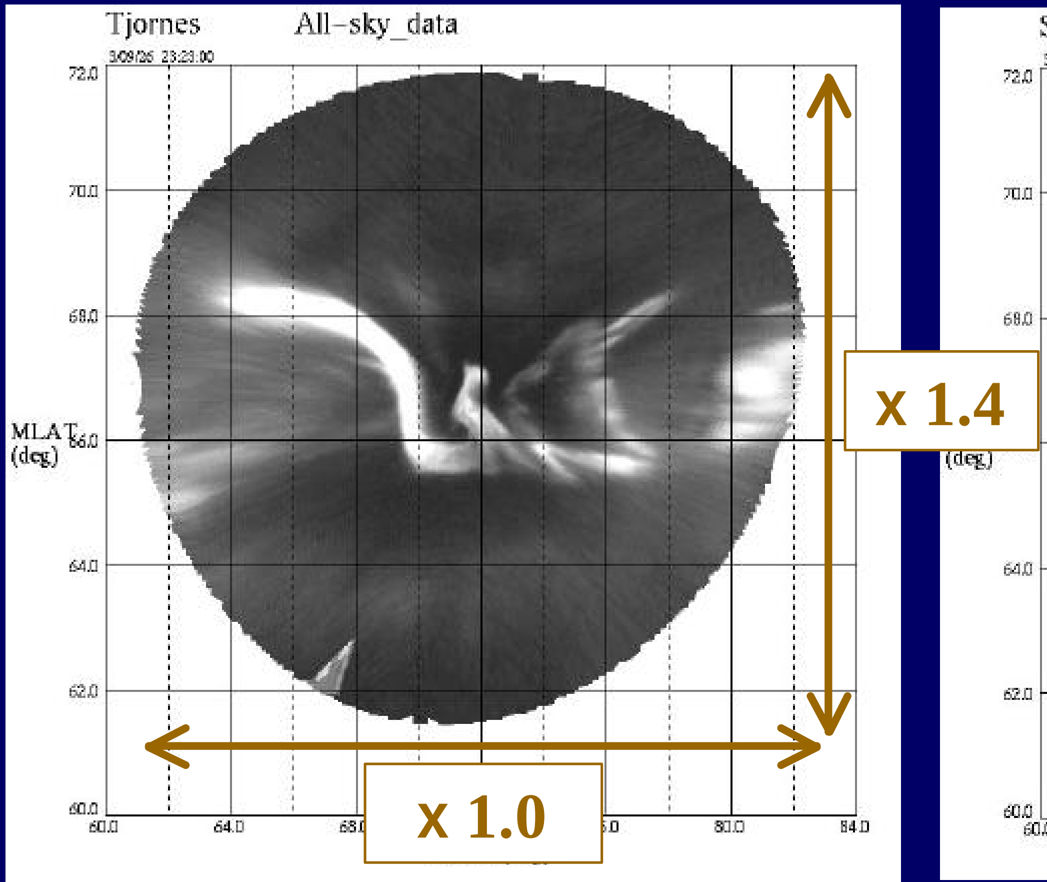
● Magnetic zenith

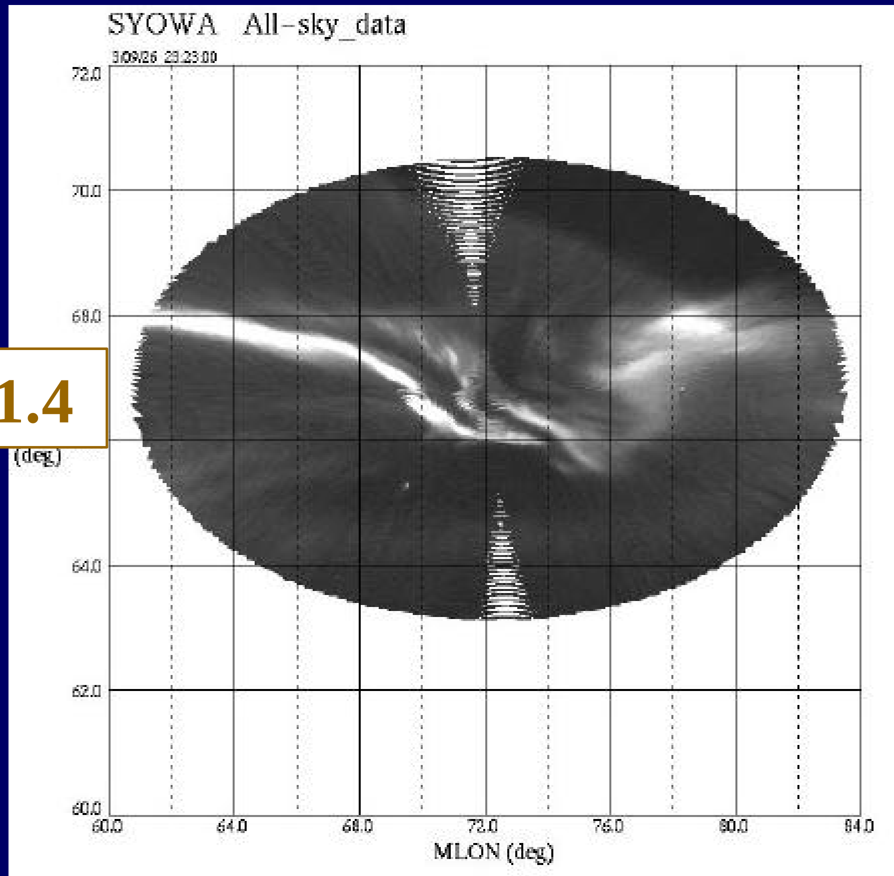
at 23:23:00 UT on Sep. 26, 2003

Difference in FOV on Geomagnetic plane

TJORNES

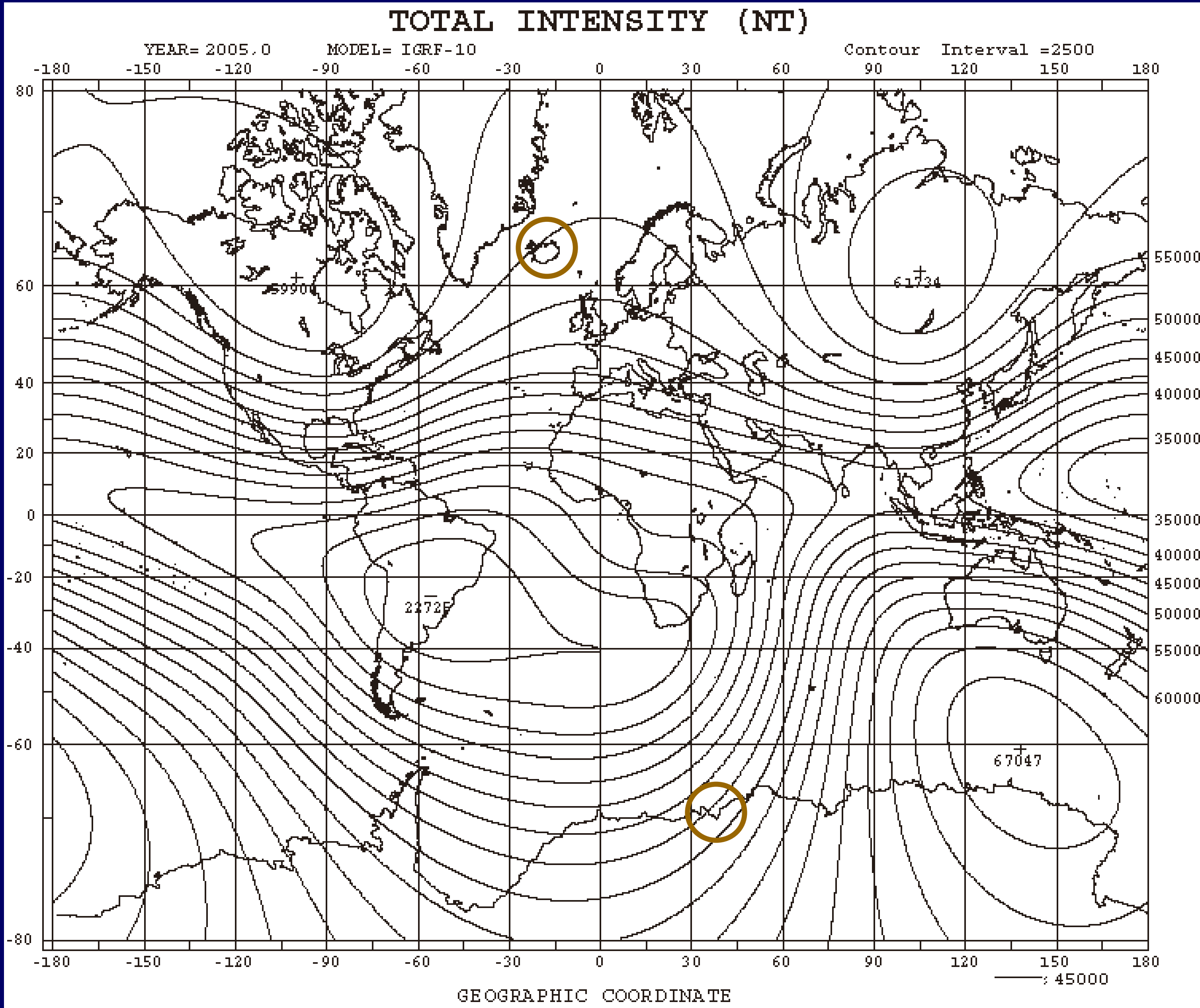
SYOWA





at 120km at 23:23:00 UT on Sep. 26, 2003 (elevation > 10°)

Difference in B & ∇B



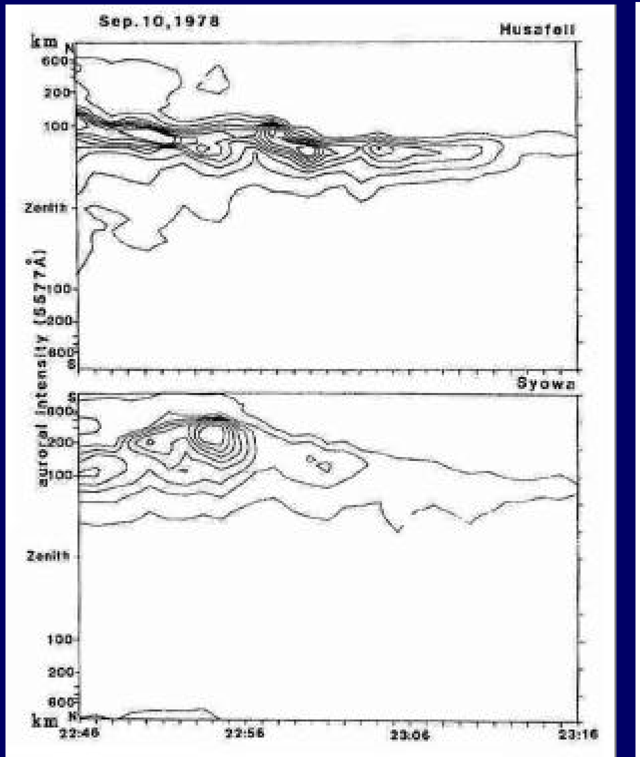
Syowa-Iceland Conjugate Study

Published refereed papers : 136

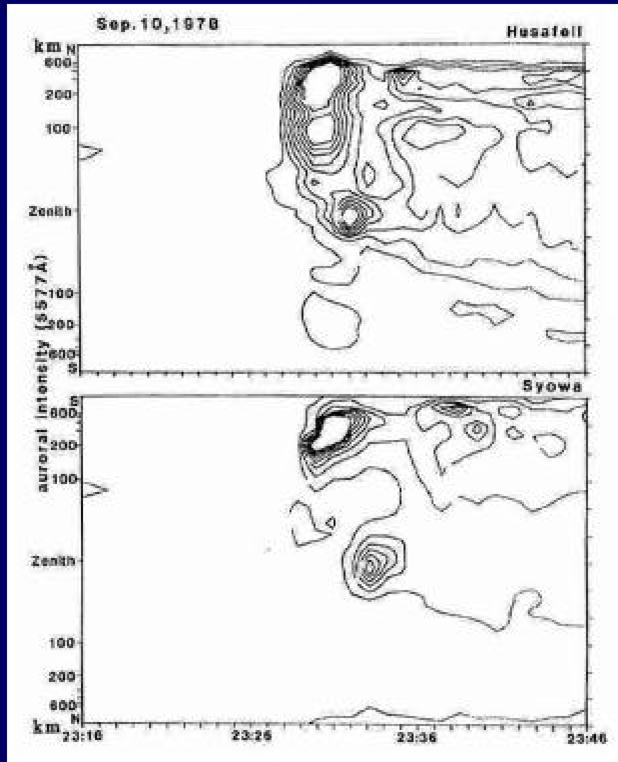
- Magnetic Pulsation : 38
- ELF/VLF wave : 26
- Aurora : 23
- Project report, introduction : 13
- SuperDARN : 13
- Magnetic DC variation : 7
- Imaging Riometer (IRIO) : 7
- Balloon : 5
- CNA : 2
- Satellite : 2

Conjugacy in MSP data

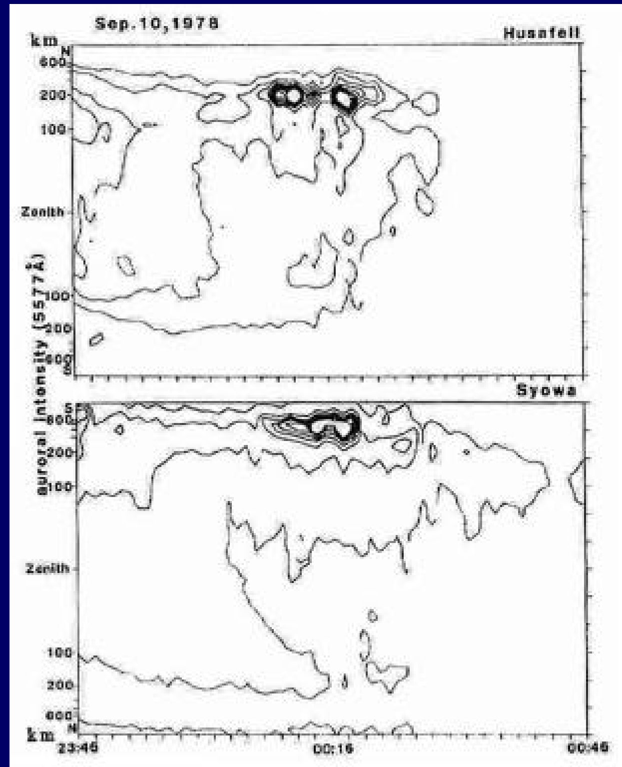
Pre-breakup



Breakup



Post-Breakup



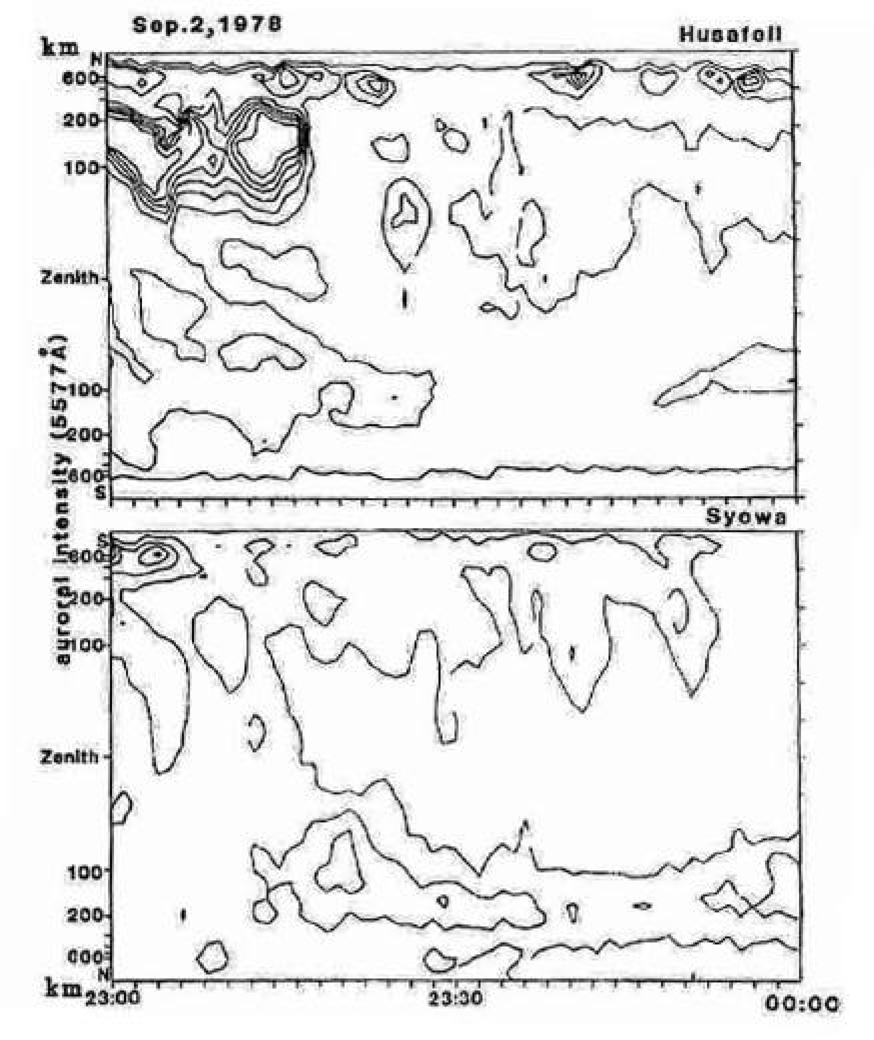
557.7 nm

Similar as a whole.
However, small scale variation is frequently different.

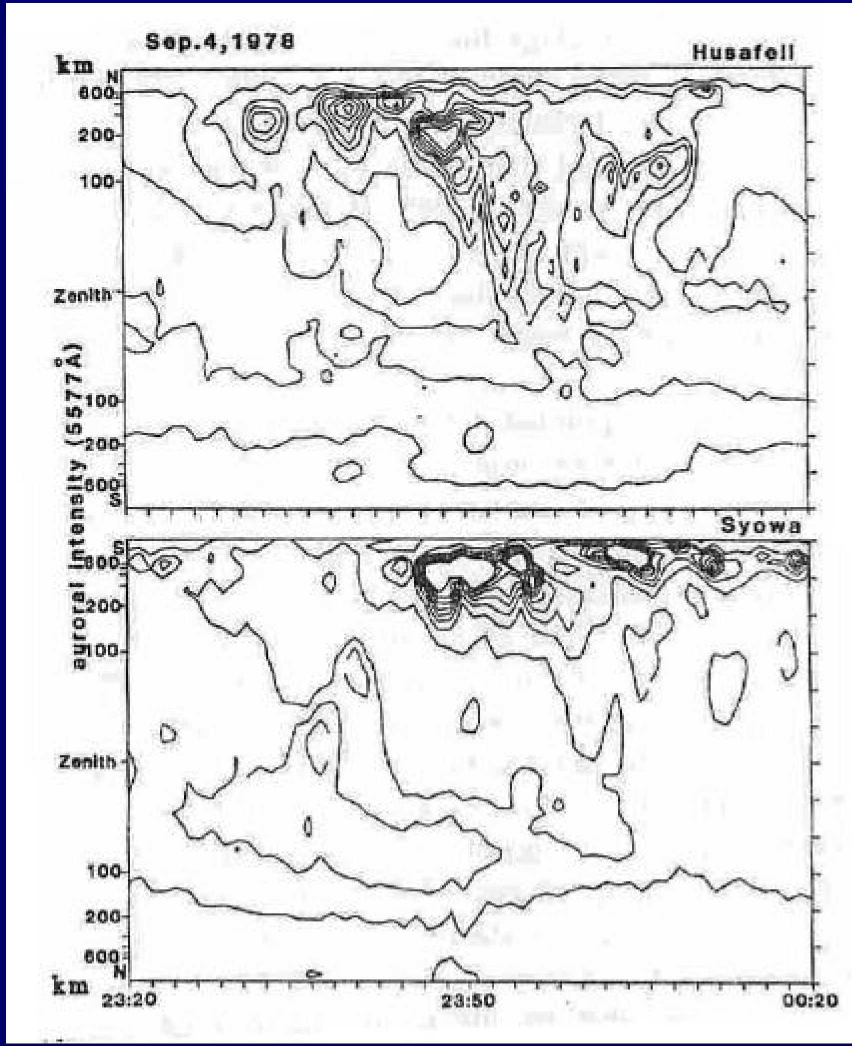
Makita et al. (Memoirs of NIPR,18, 1981)

Non-conjugacy in MSP data

Recovery Phase



During positive ΔH

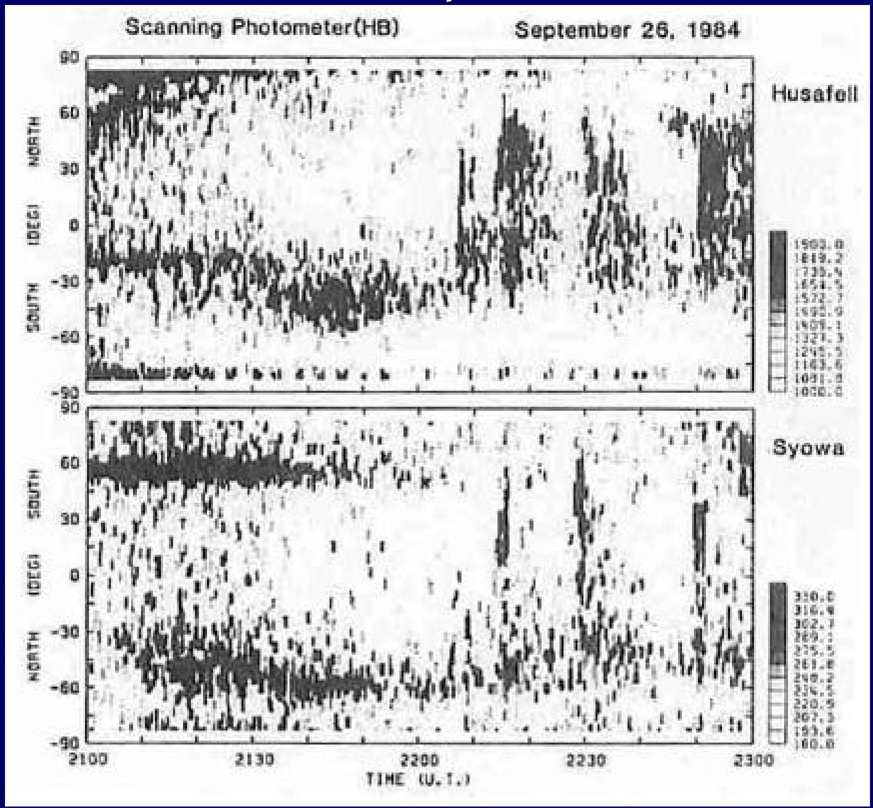


557.7 nm

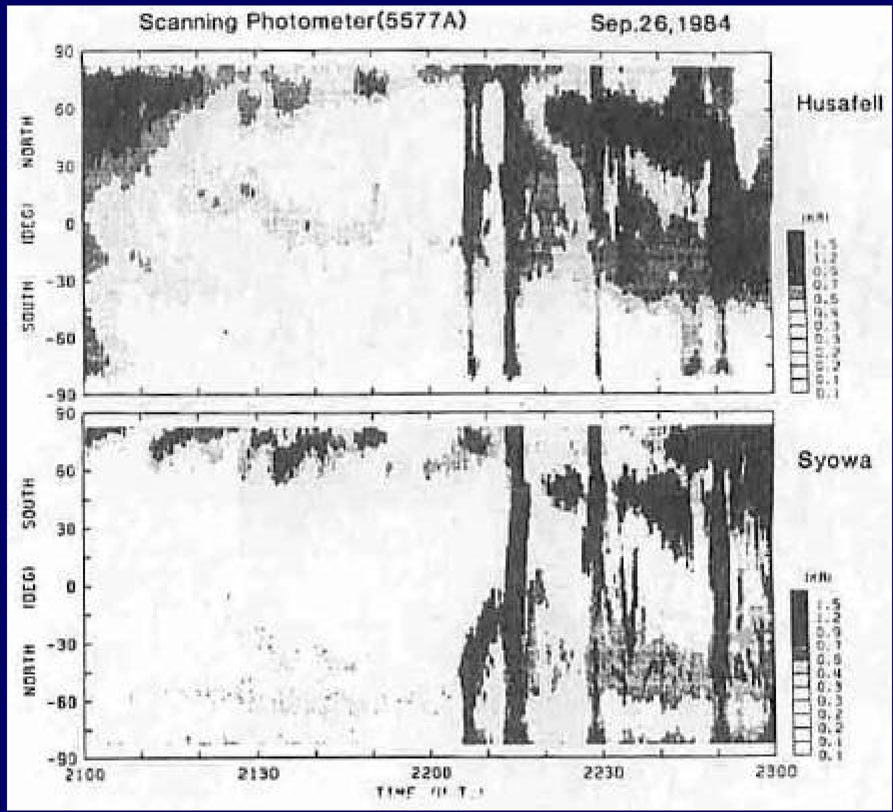
Makita et al. (Memoirs of NIPR,18, 1981)

Comparison between Proton and Electron aurora

H_β



557.7 nm (OI)

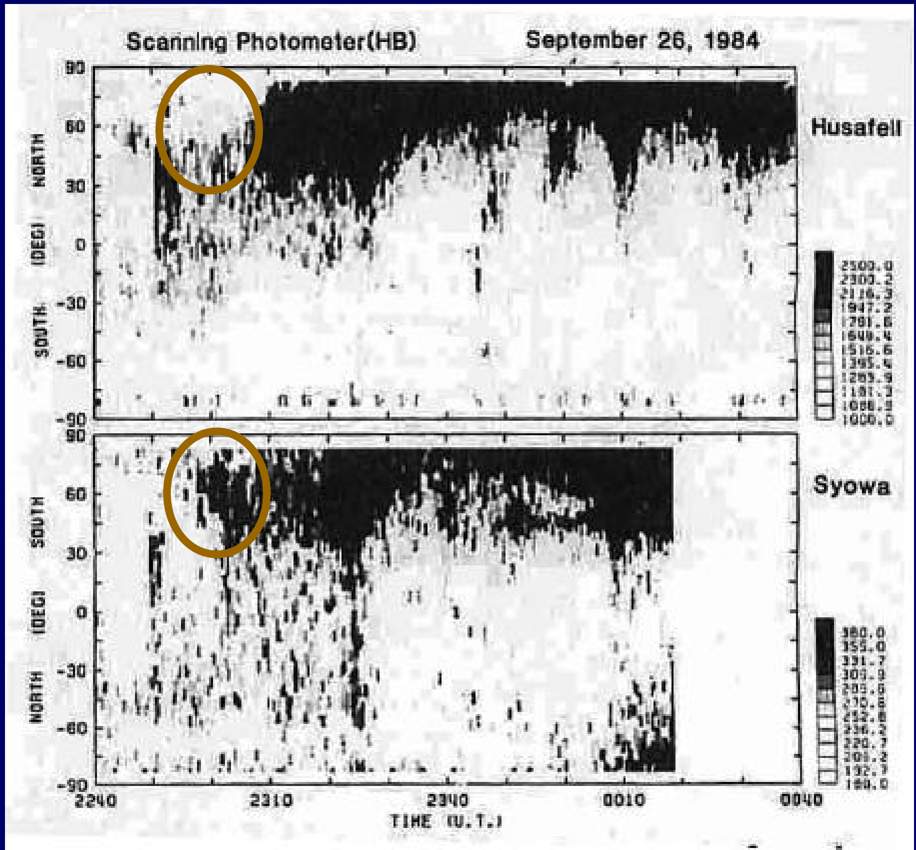


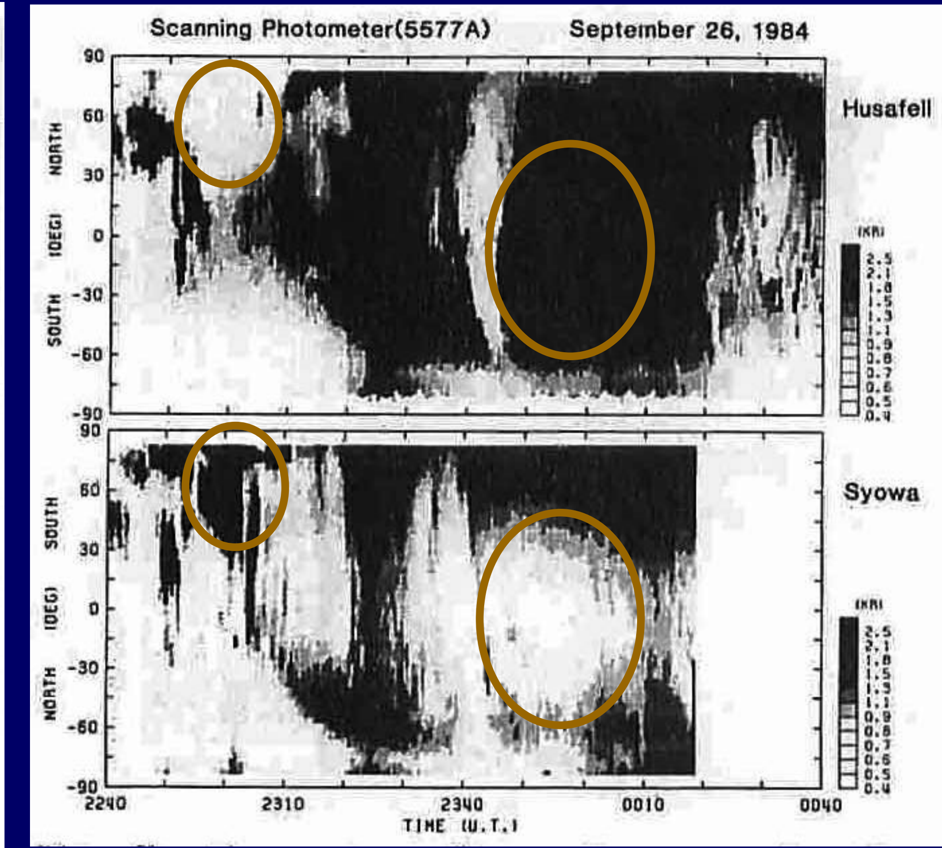
At the breakup phase, H_β at HUS is higher than at SYO.

Sato et al. (GRL,13, 1986)

Comparison between Proton and Electron aurora

H_β 557.7 nm (OI)



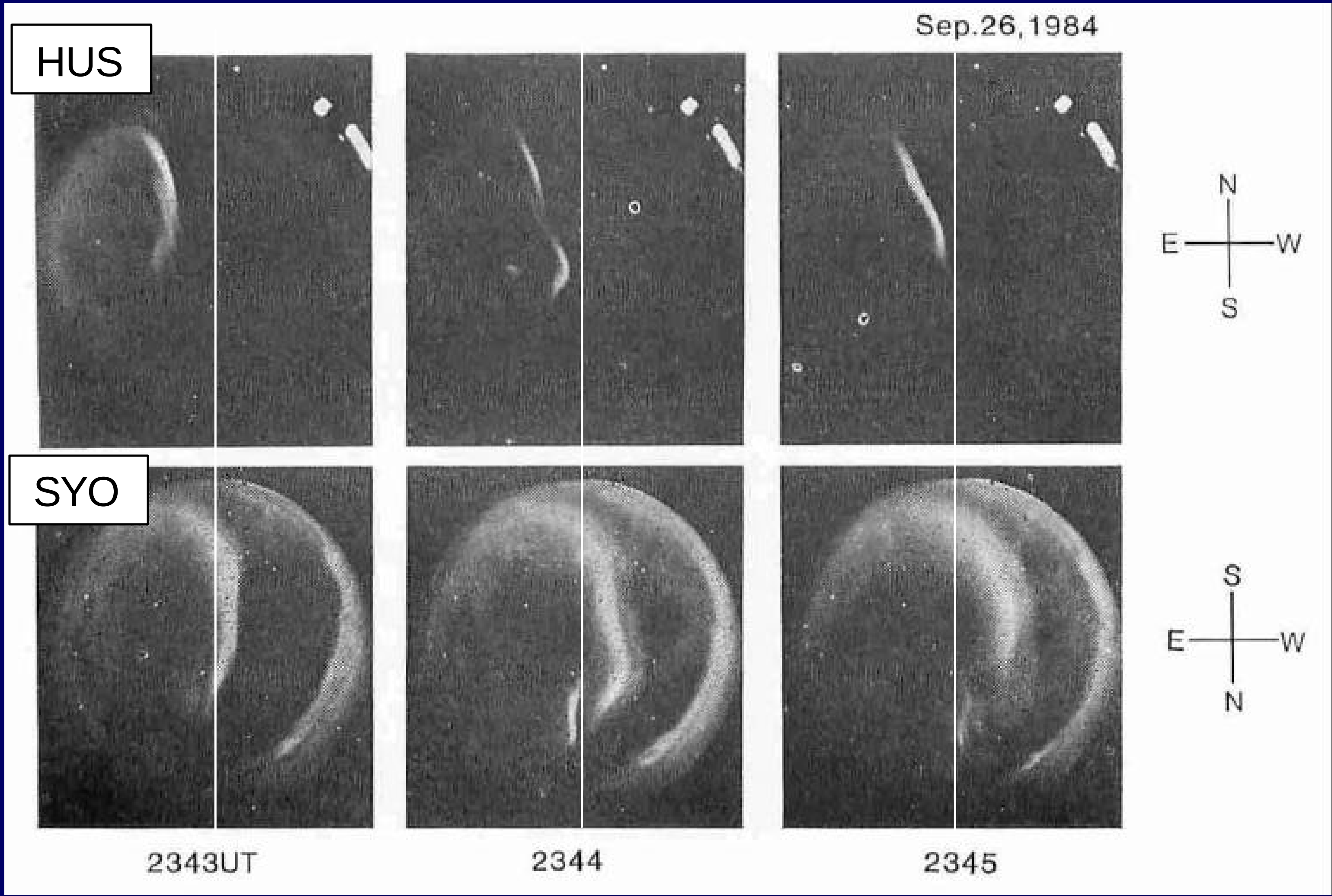


During expansion phase, poleward H_β is enhanced.
Equatorward H_β is diminished within the pulsating auroral region.

Sato et al. (GRL,13, 1986)

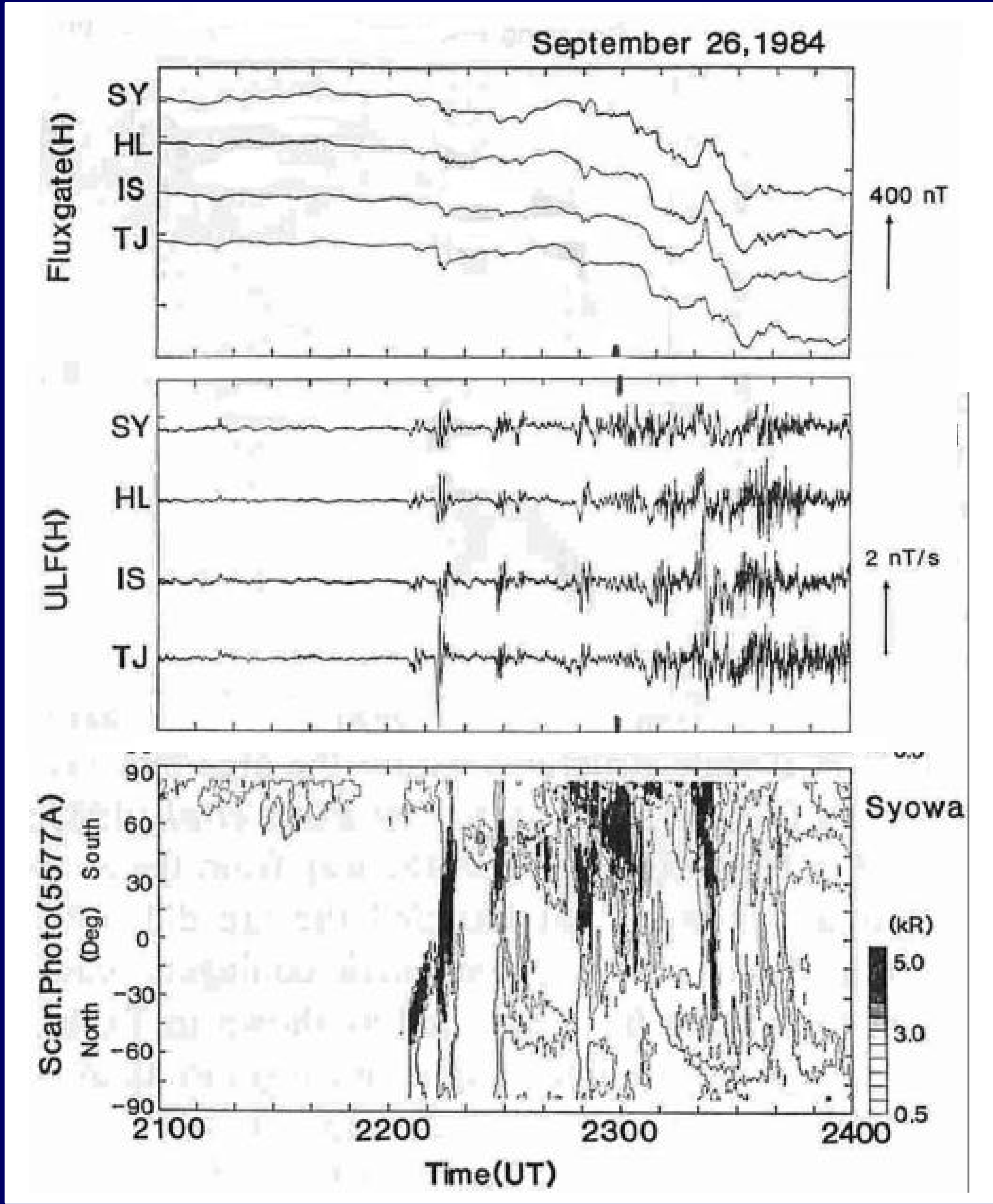
Non-conjugacy in MSP does not mean real non-conjugacy

Sato et al. (Memoir of NIPR,48, 1987)



Longitudinal displacement of the westward drifting N-S aurora

MSP and Magnetic variation



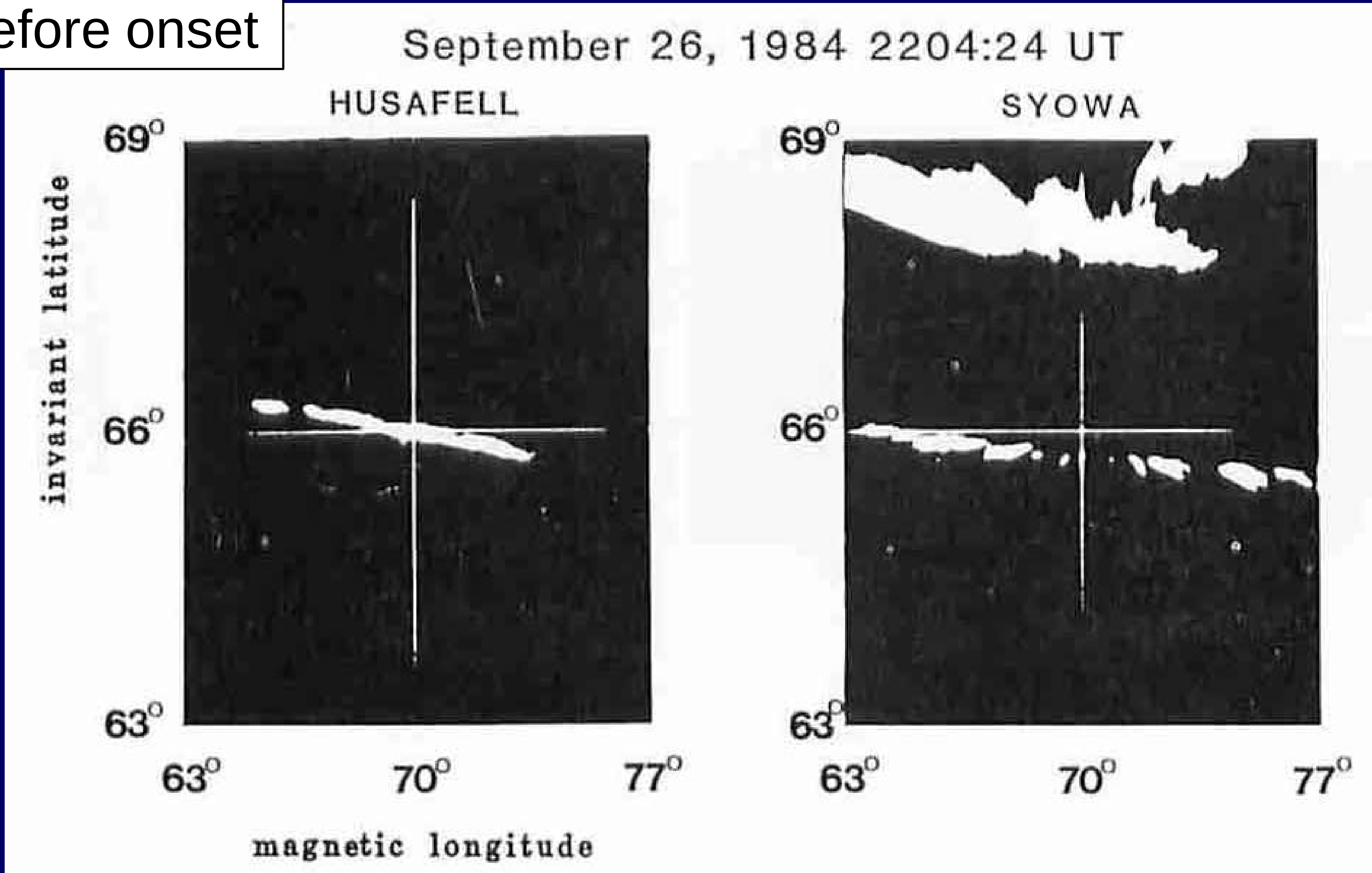
Pi2, Pi1B, Pi1C, Westward electrojet, Counter electrojet

All are very similar, and well correspond to auroral variation

Sato et al.
(Memoir of NIPR,48, 1987)

Morphology Study using ATV (All-sky TV) data

Before onset

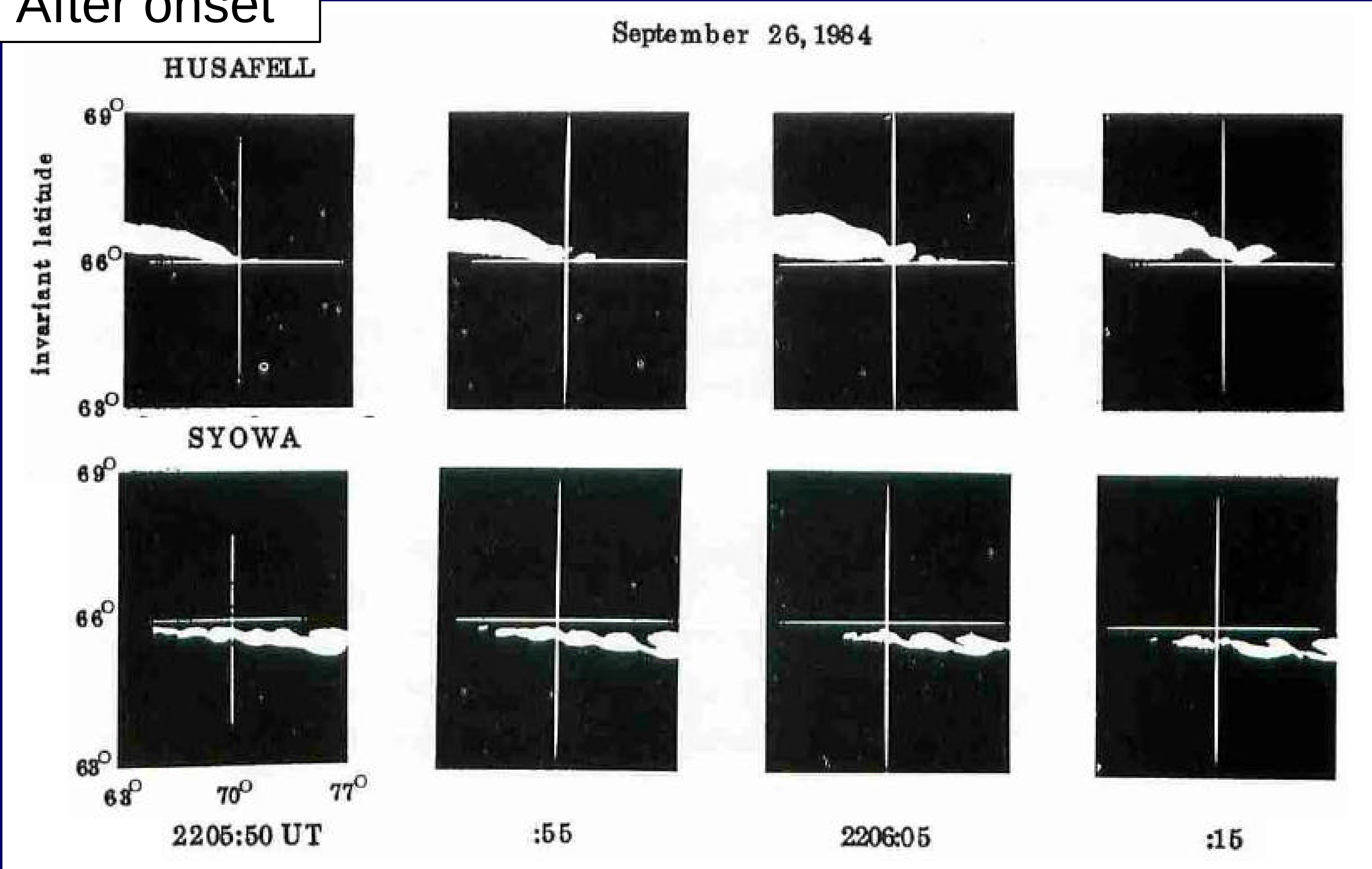


Large scale similar, Small scale dissimilar
HUS: homogeneous, SYO: ray structure & curls

Fujii et al. (Memoir of NIPR,48, 1987)

Similarity and Dissimilarity

After onset



Eastward motion similar, Vortex (fold) scale dissimilar : HUS > SYO & Longitudinal displacement

Fujii et al. (Memoir of NIPR,48, 1987)

Conjugacy and Non-conjugacy of small breakup

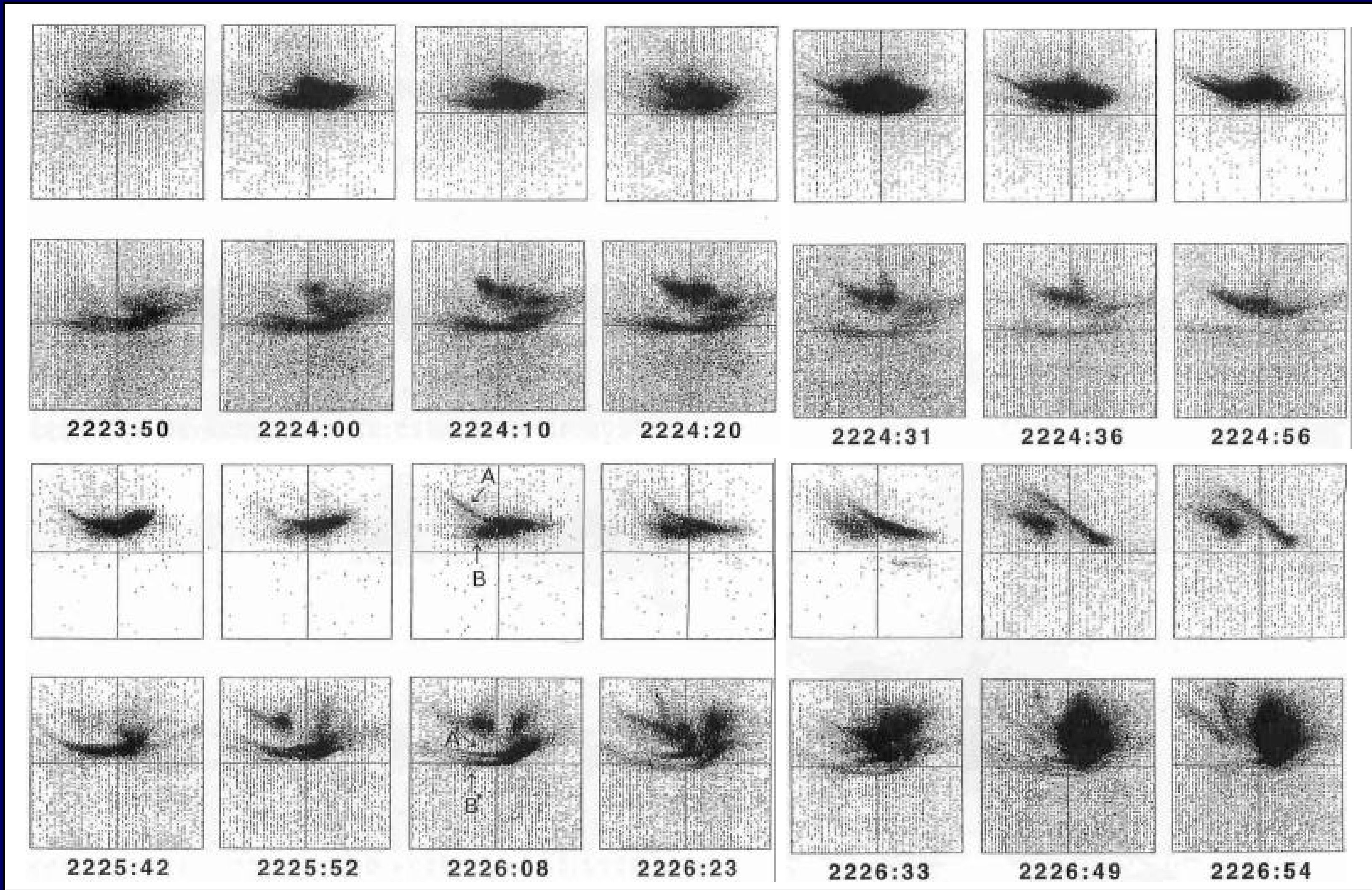
Sep. 12, 1988 *Sato et al. (JGR, 103, 1998)*

HUS

SYO

HUS

SYO



Non-conjugate auroral breakup. Breakup started earlier at Syowa.....

But … seems a little subjective … ?

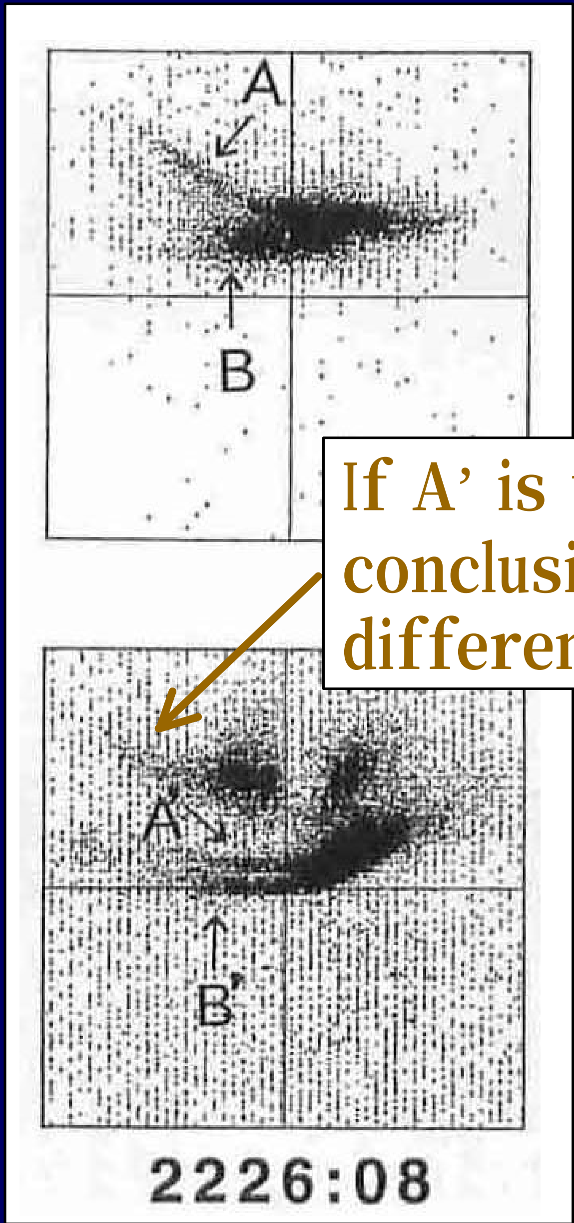
Non-conjugate breakup ?

Sato et al. (JGR, 103, 1998)

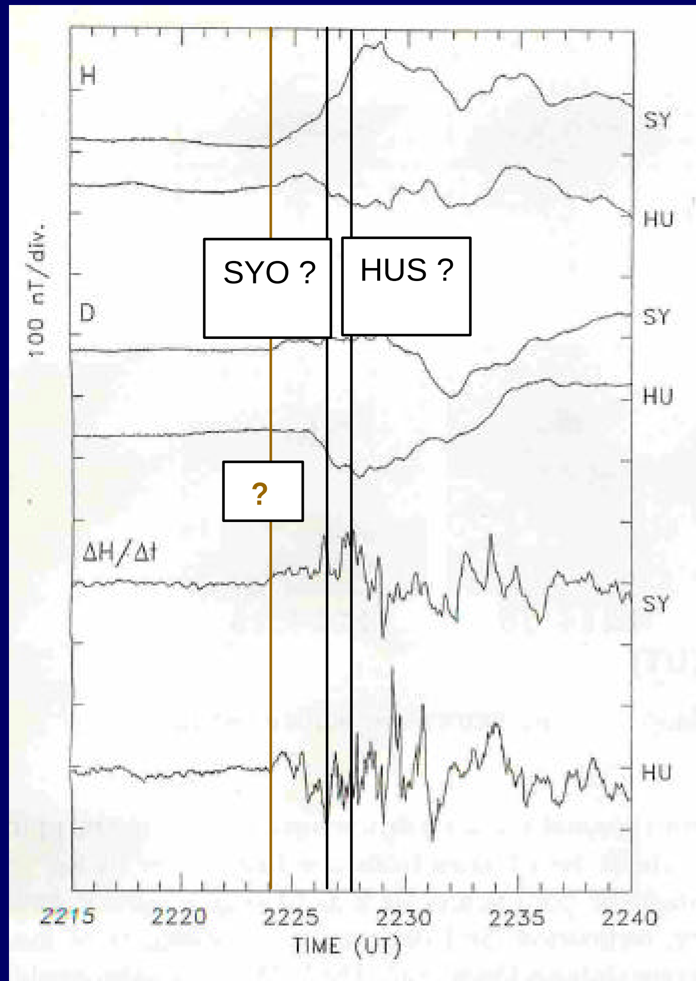
and, breakup time definition is a little delicate problem ....

HUS

SYO

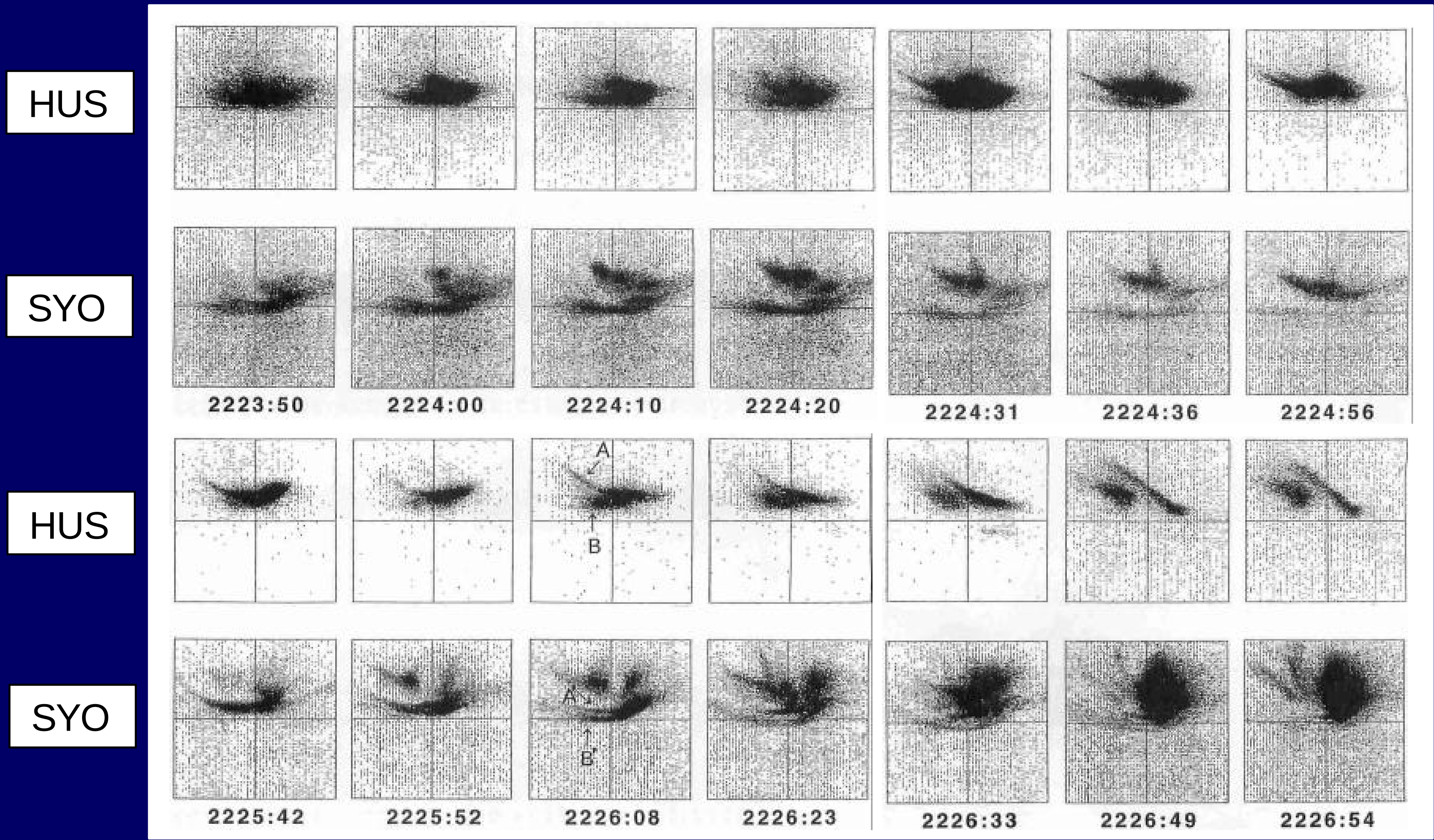


If A' is this part, conclusion becomes different.......



Conjugacy of small breakup

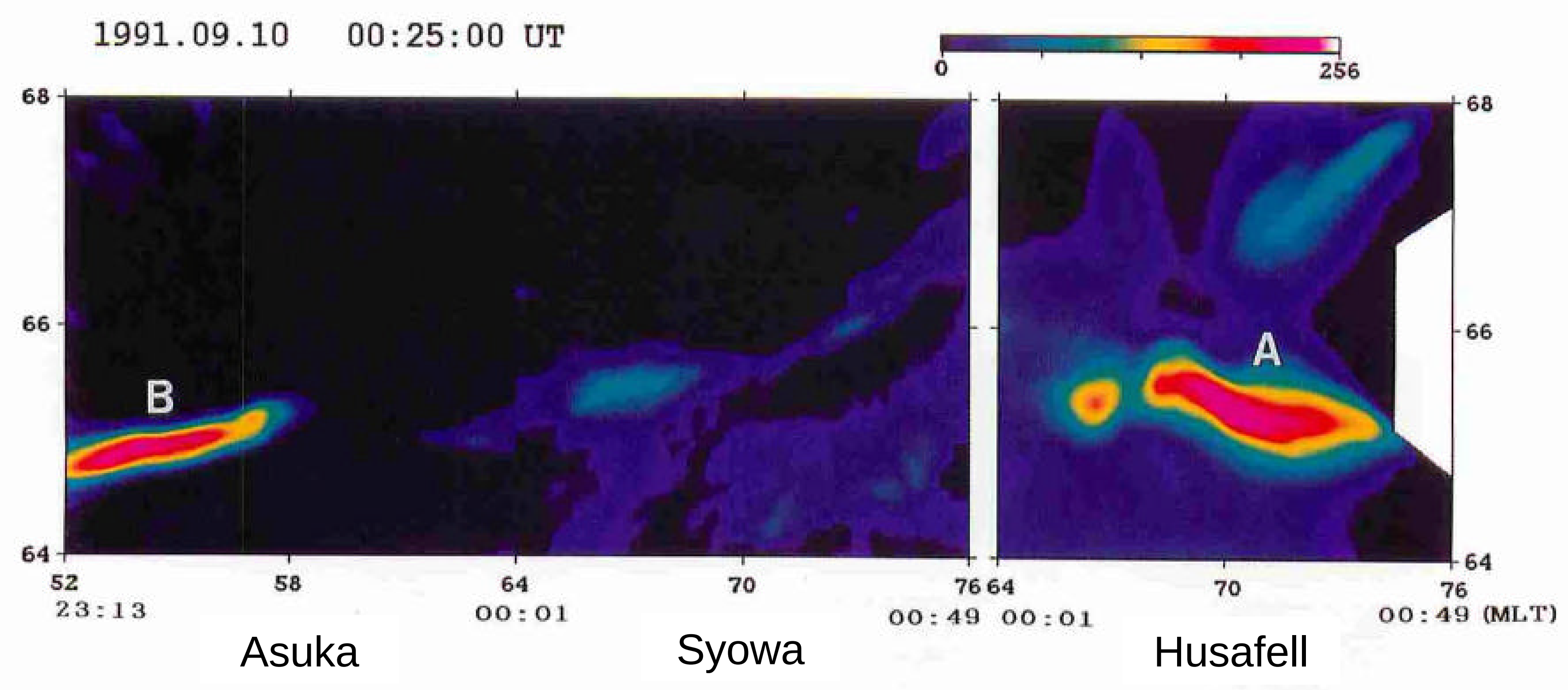
Sep. 12, 1988 Geographic coordinate



Latitudinal scale is different, larger than the difference in B & ∇B

Sato et al. (JGR, 103, 1998)

Large longitudinal displacement



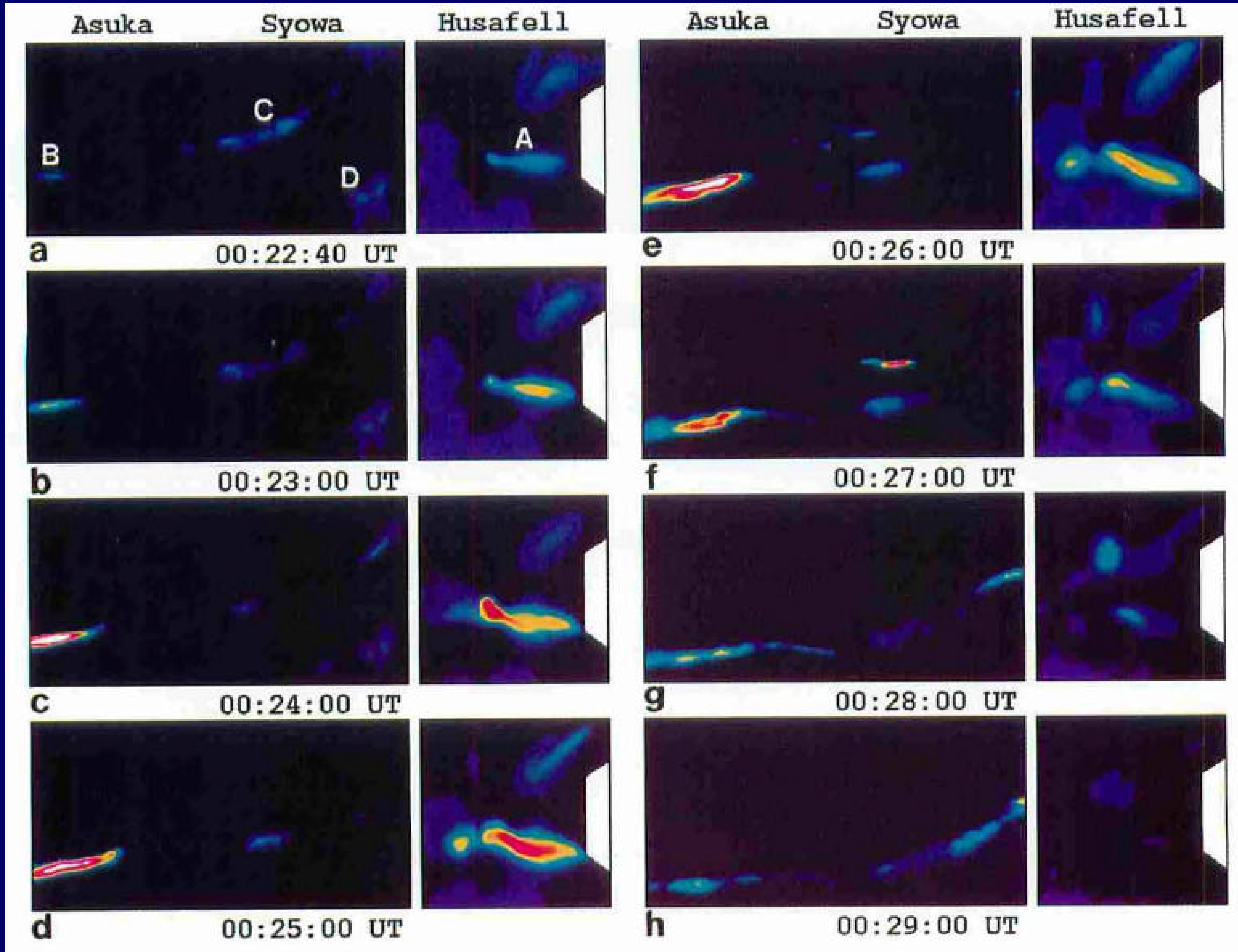
Large displacement : ～1 hr

During recovery phase of large substorm

Minatoya et al. (JGG, 48, 1996)

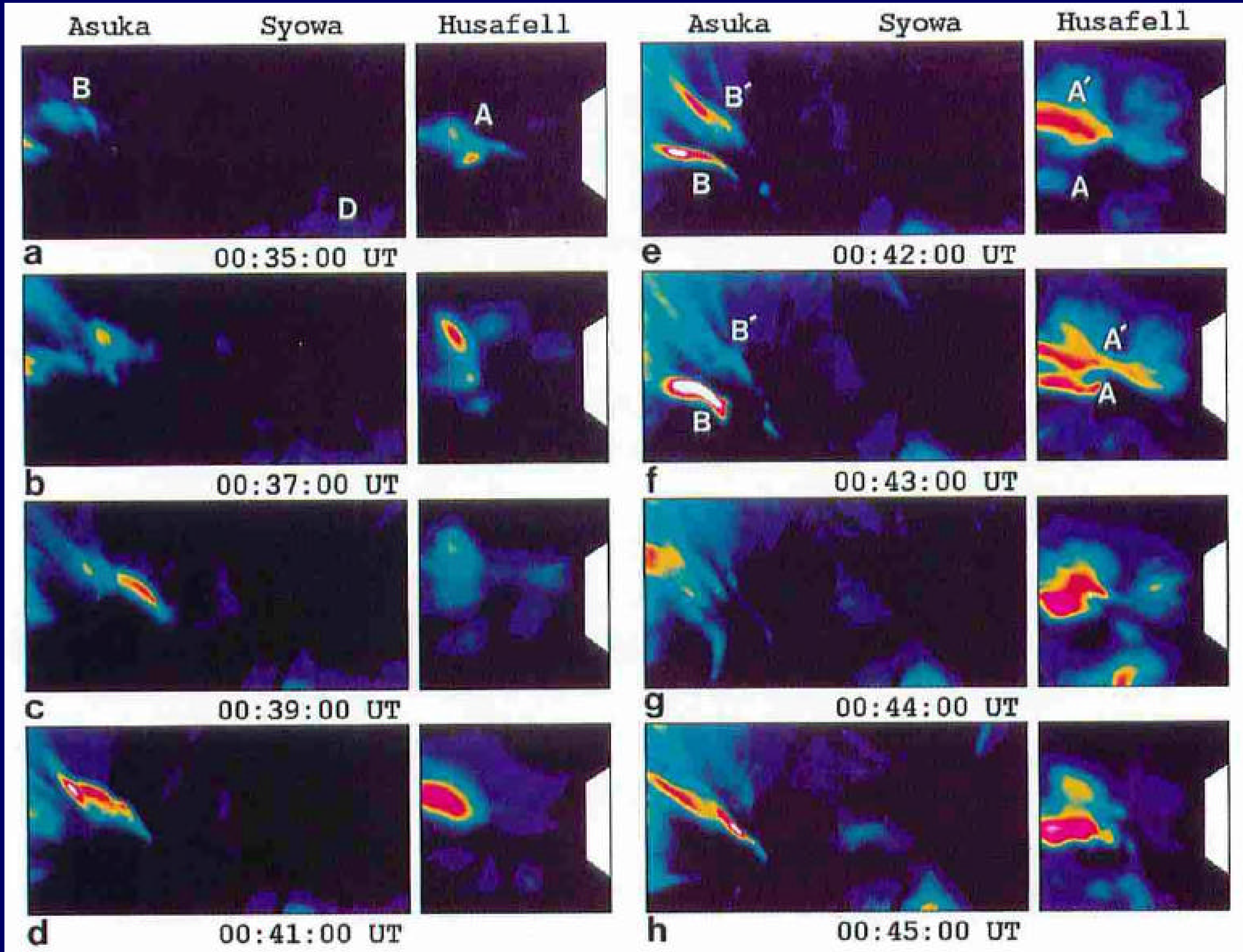
Large longitudinal displacement

Minatoya et al. (JGG, 48, 1996)



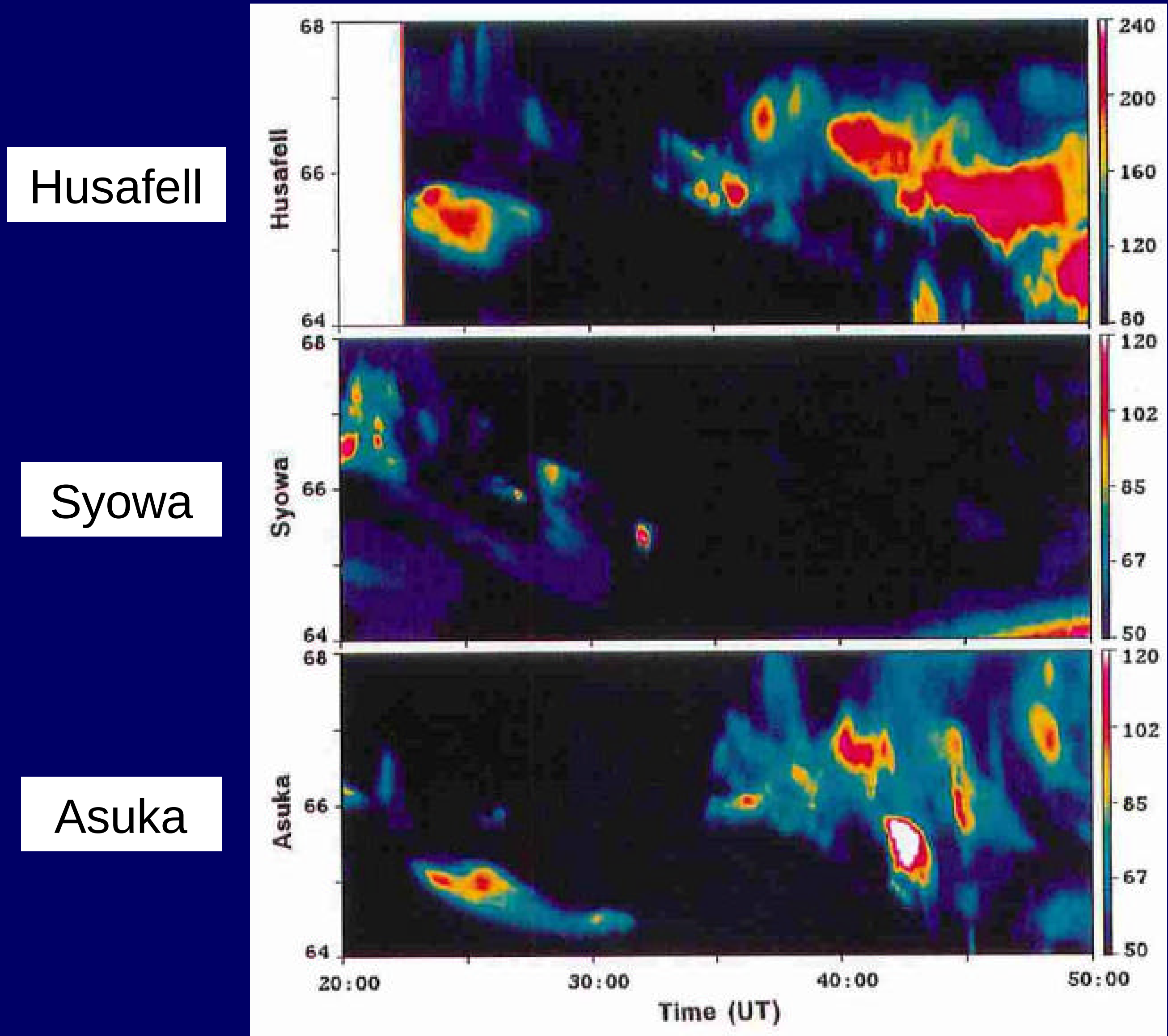
Large longitudinal displacement

Minatoya et al. (JGG, 48, 1996)



Large longitudinal displacement

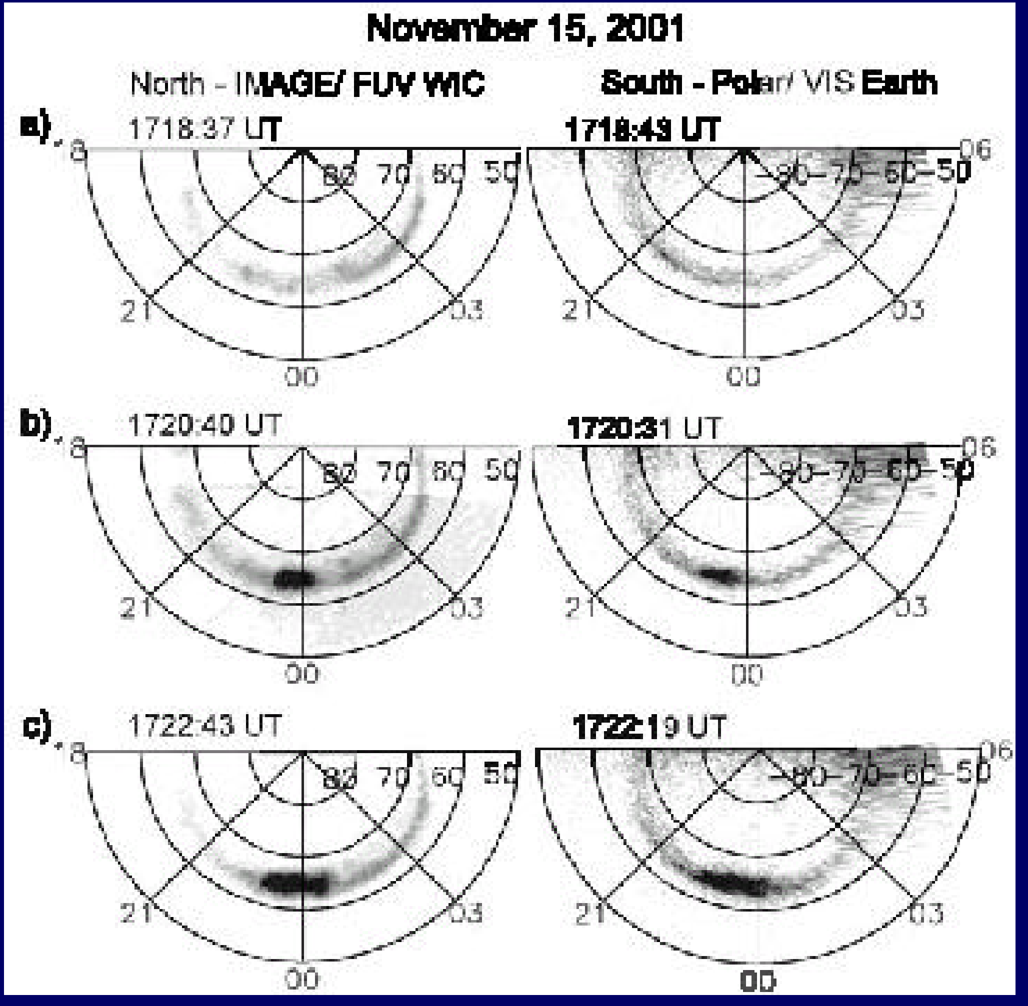
Keogram Sep. 10, 1991

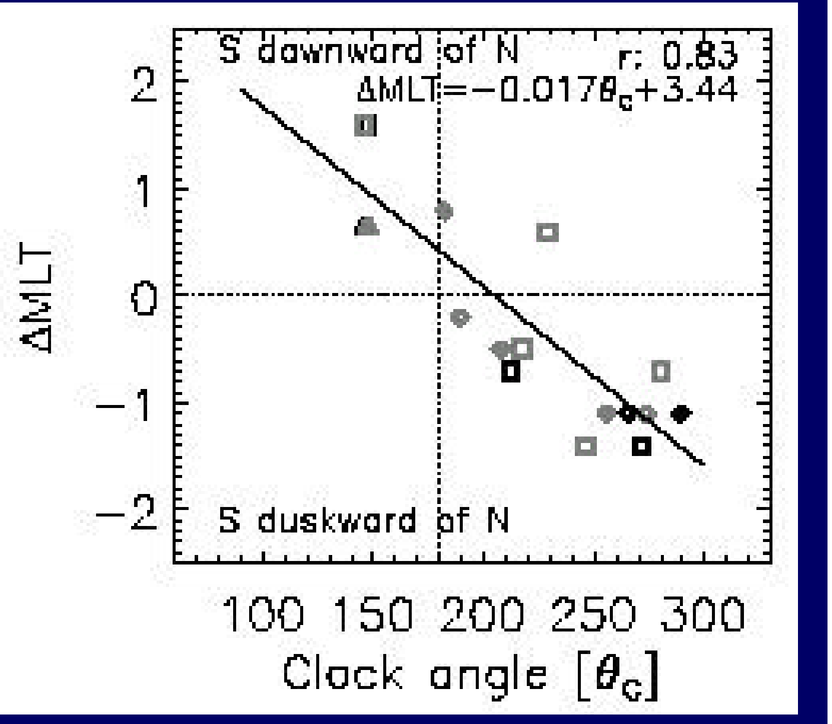


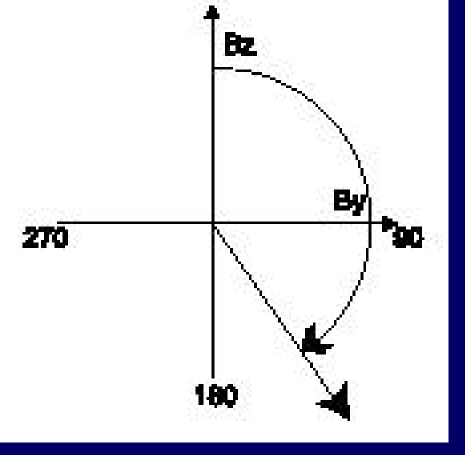
Minatoya et al.
(JGG, 48, 1996)

Longitudinal displacement depending on the IMF clock angle

Østgaard et al. (JGR, 2004)

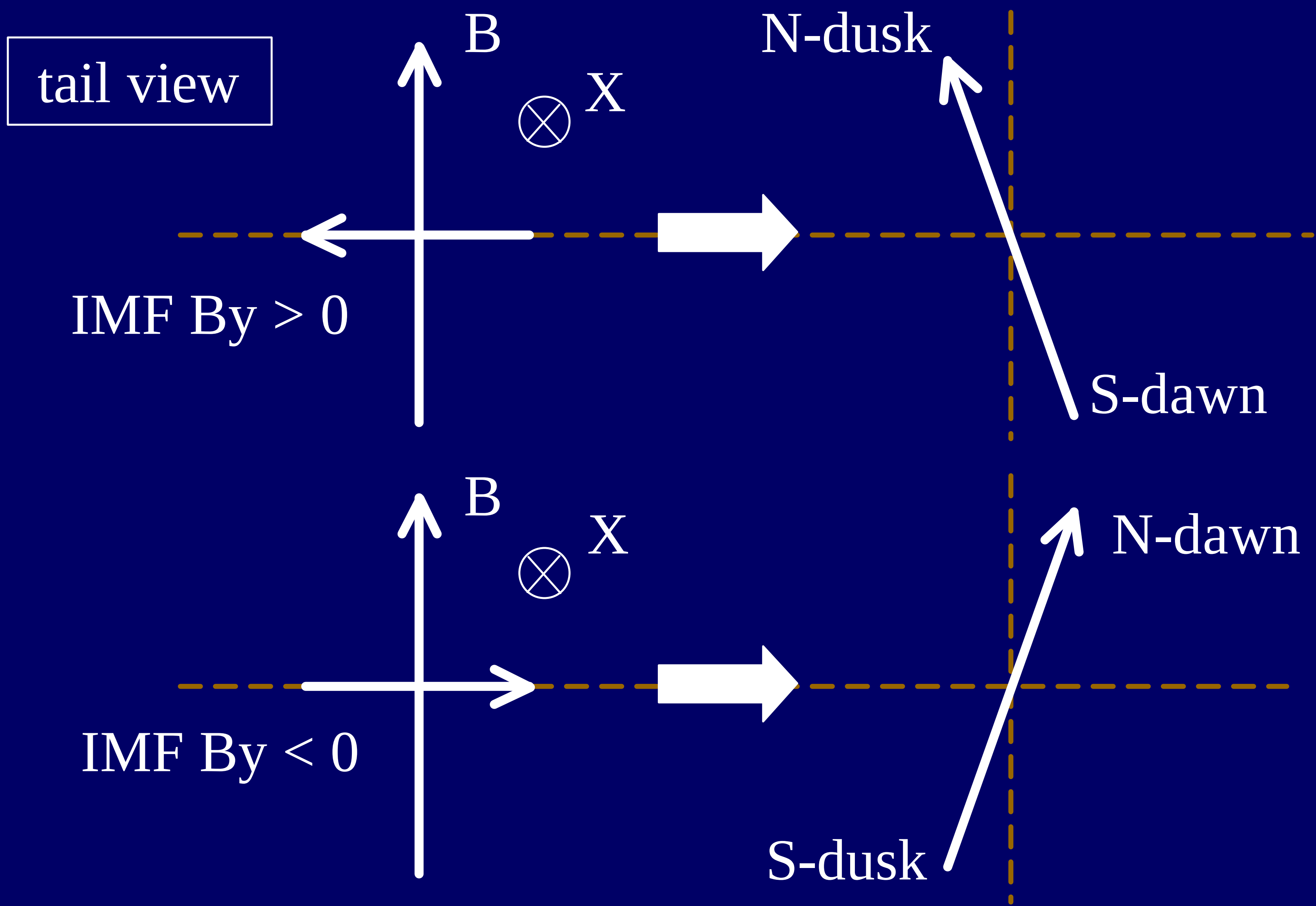




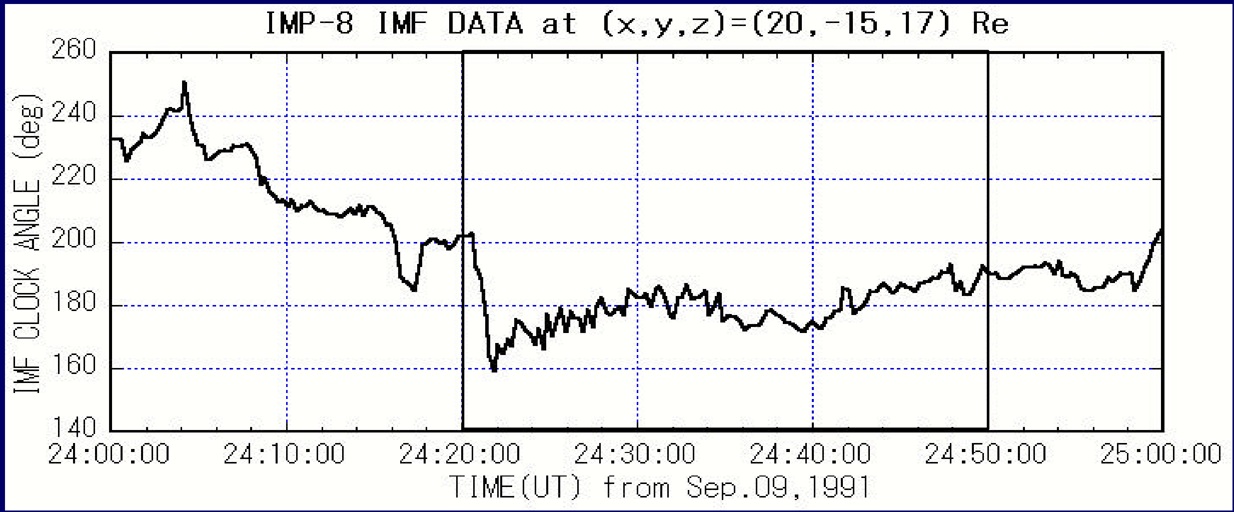


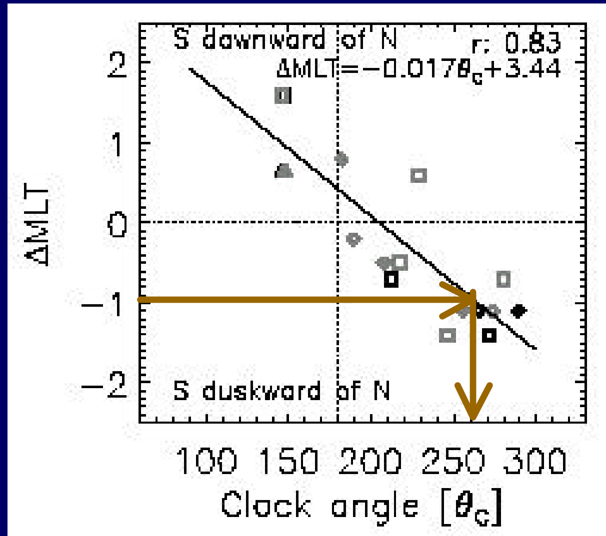
IMF By < 0, Bz < 0

Longitudinal displacement depending on the IMF clock angle



Large longitudinal displacement due to IMF ?





Østgaard et al. (JGR, 2004)

Observed displacement is larger than the clock angle effect.

for 1 hr

θc = 261 deg

September 26, 2003 event :

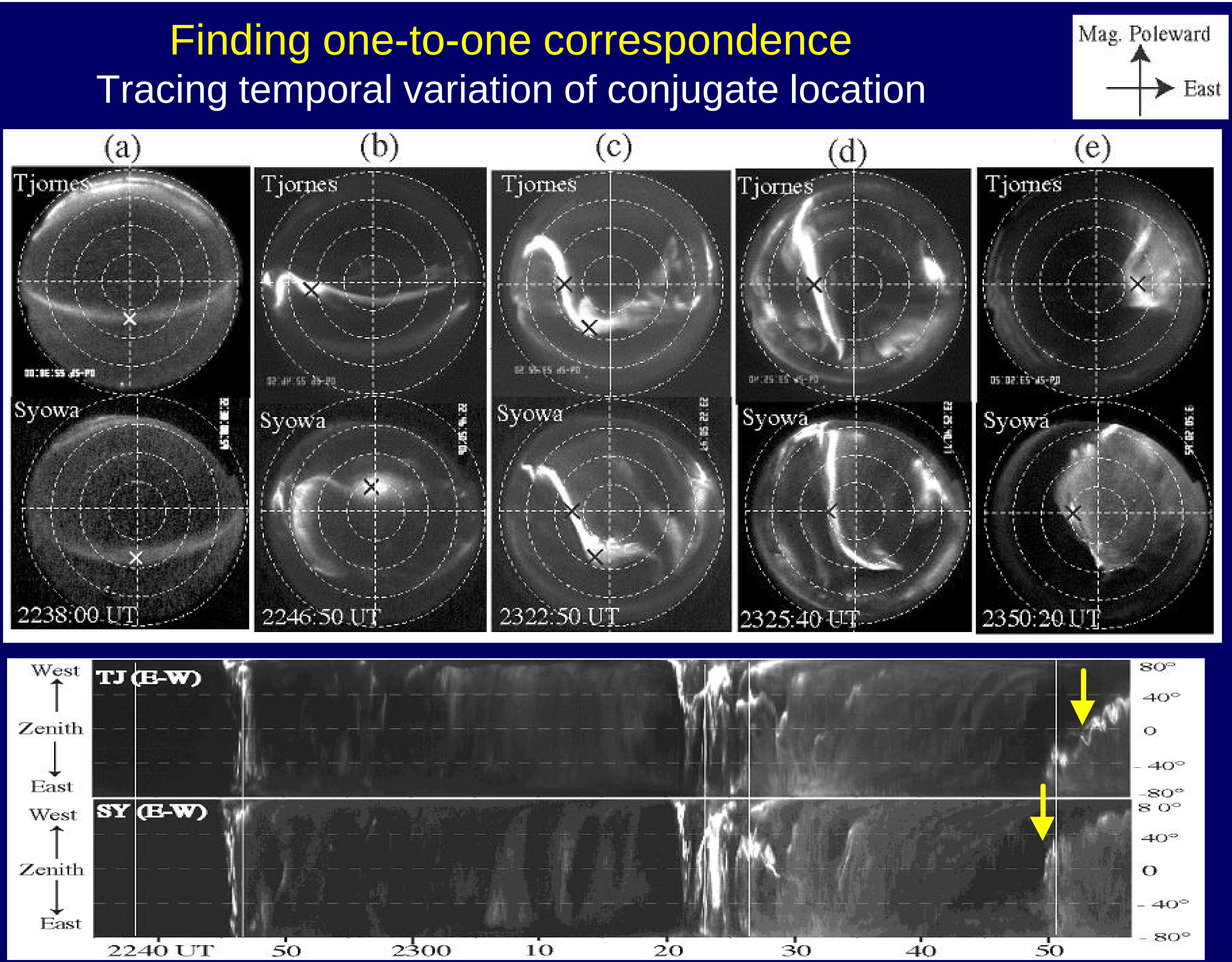
The best conjugate event in the 22 year history

Iceland (Tjornes) SYOWA

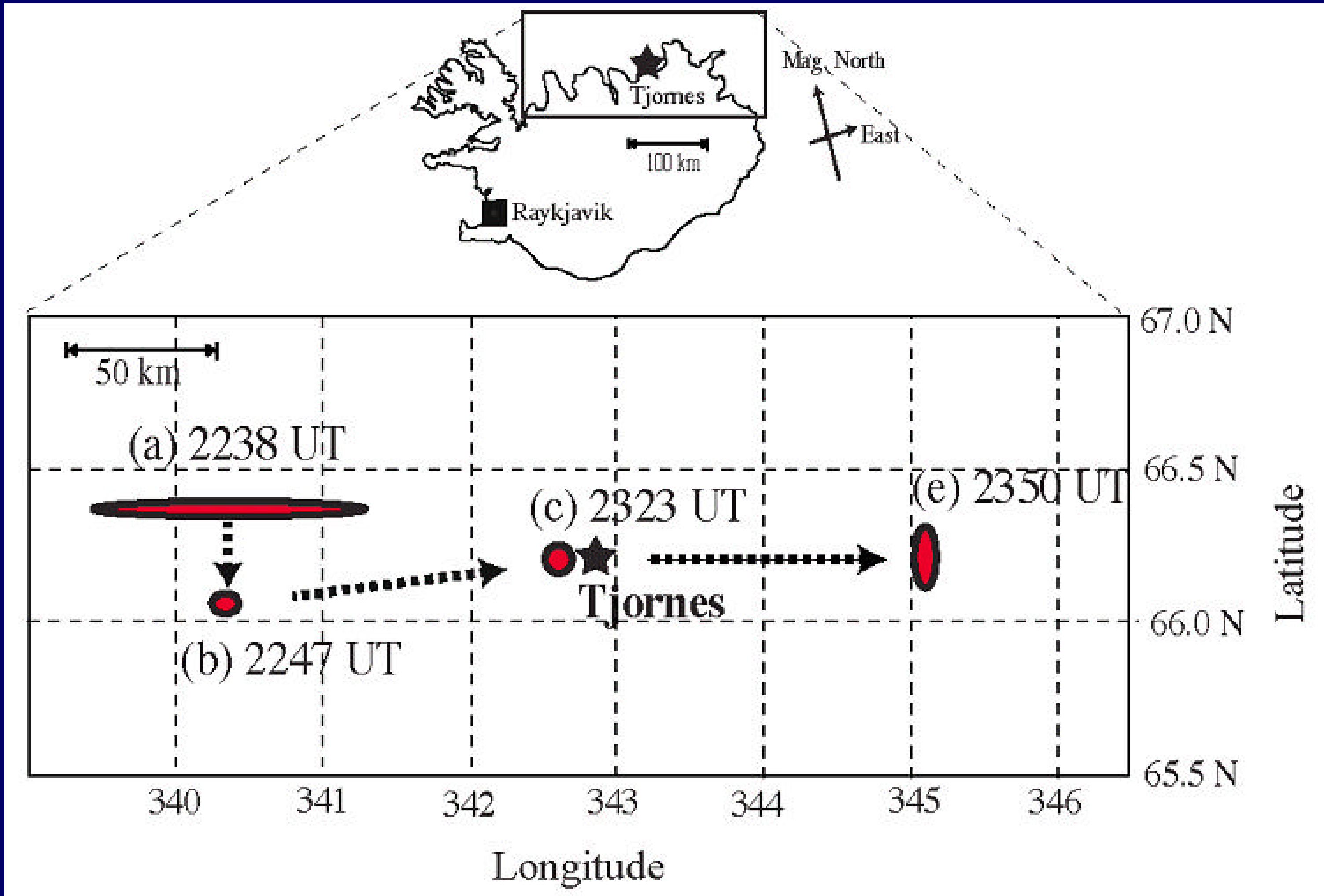
Sato et al. (GRL, 32, 2005)

Finding one-to-one correspondence

Tracing temporal variation of conjugate location



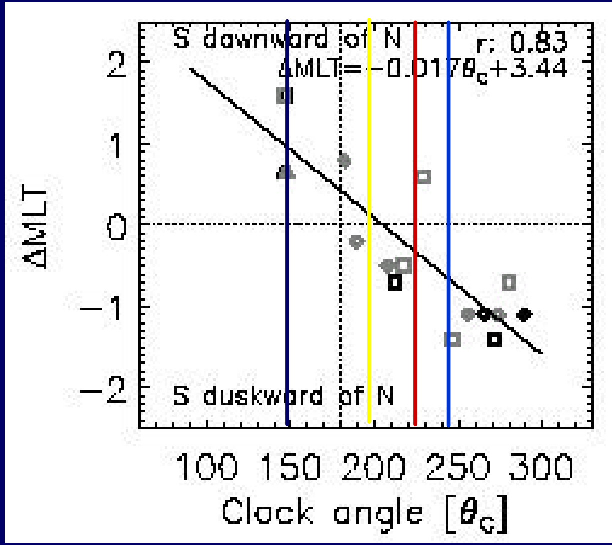
Tracing temporal variation of conjugate location of Syowa



Sato et al. (GRL, 32, 2005)

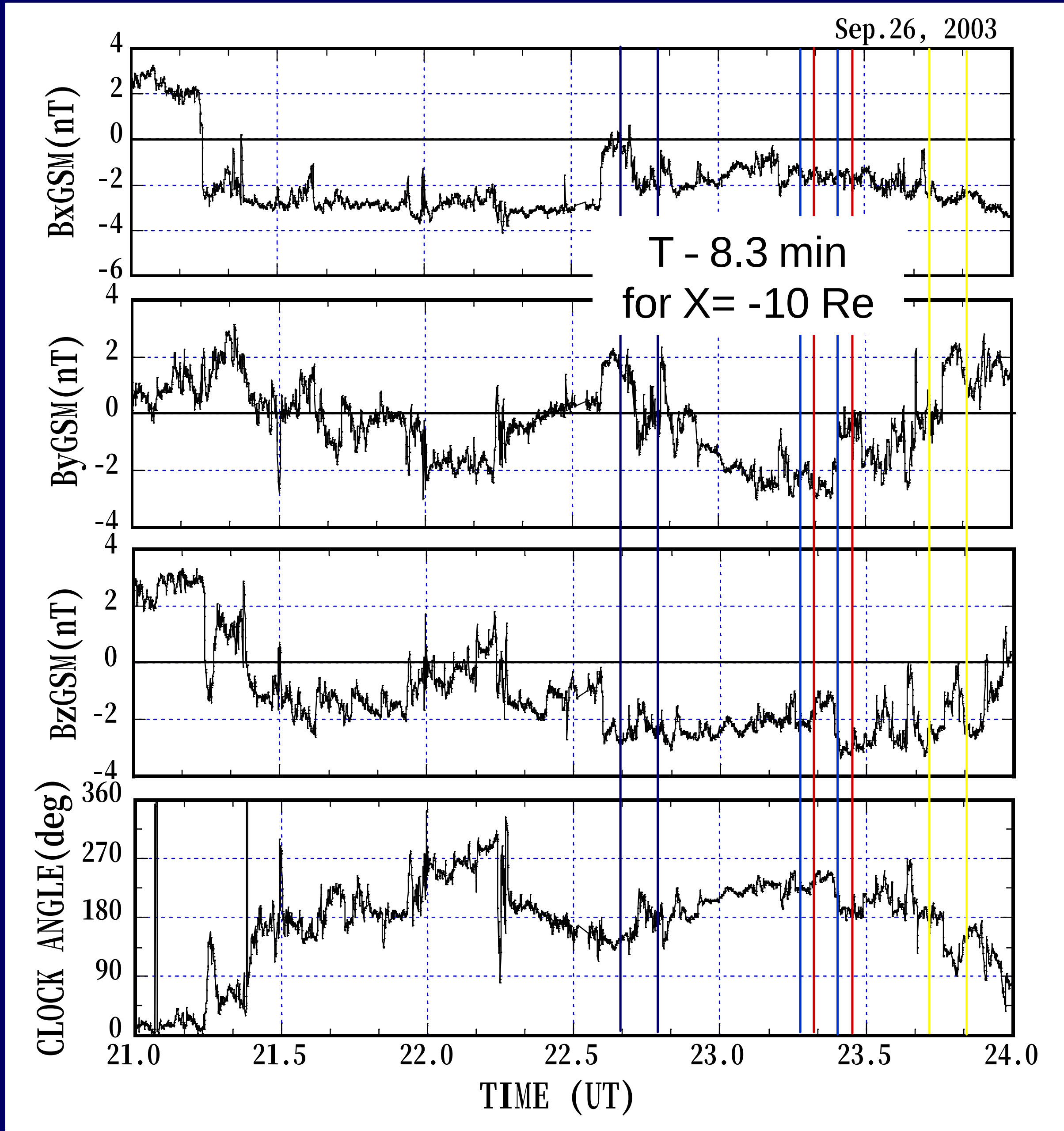
Clear displacement appears during recovery phase.

IMF data
Geotail



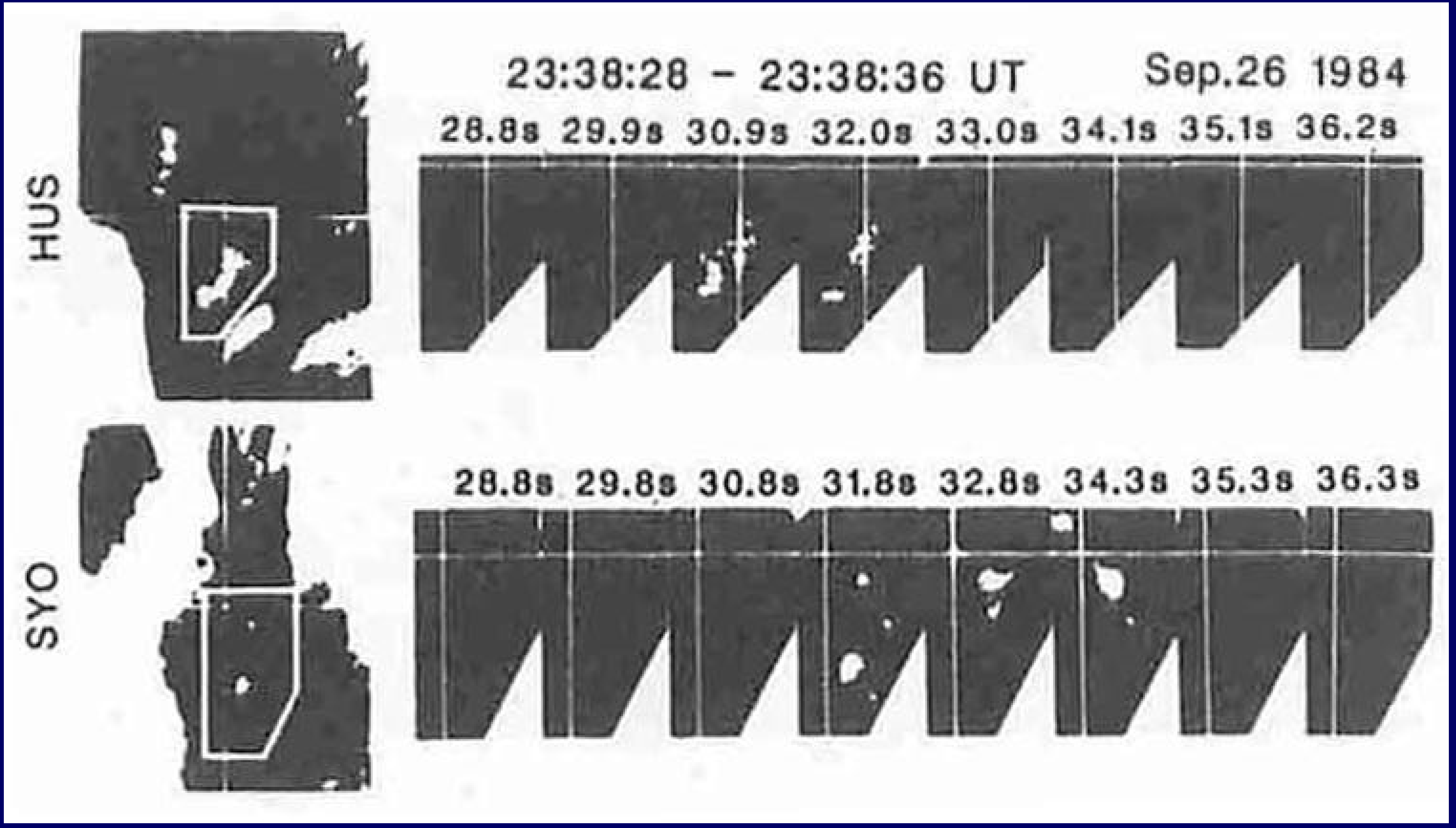
Østgaard et al. (JGR, 2004)

(X, Y, Z)gsm = (29.0～28.6, 11.1～12.5, 2.4～1.9) Re
ACE Vsw ～ 500 km/s



Conjugacy of Pulsating Aurora

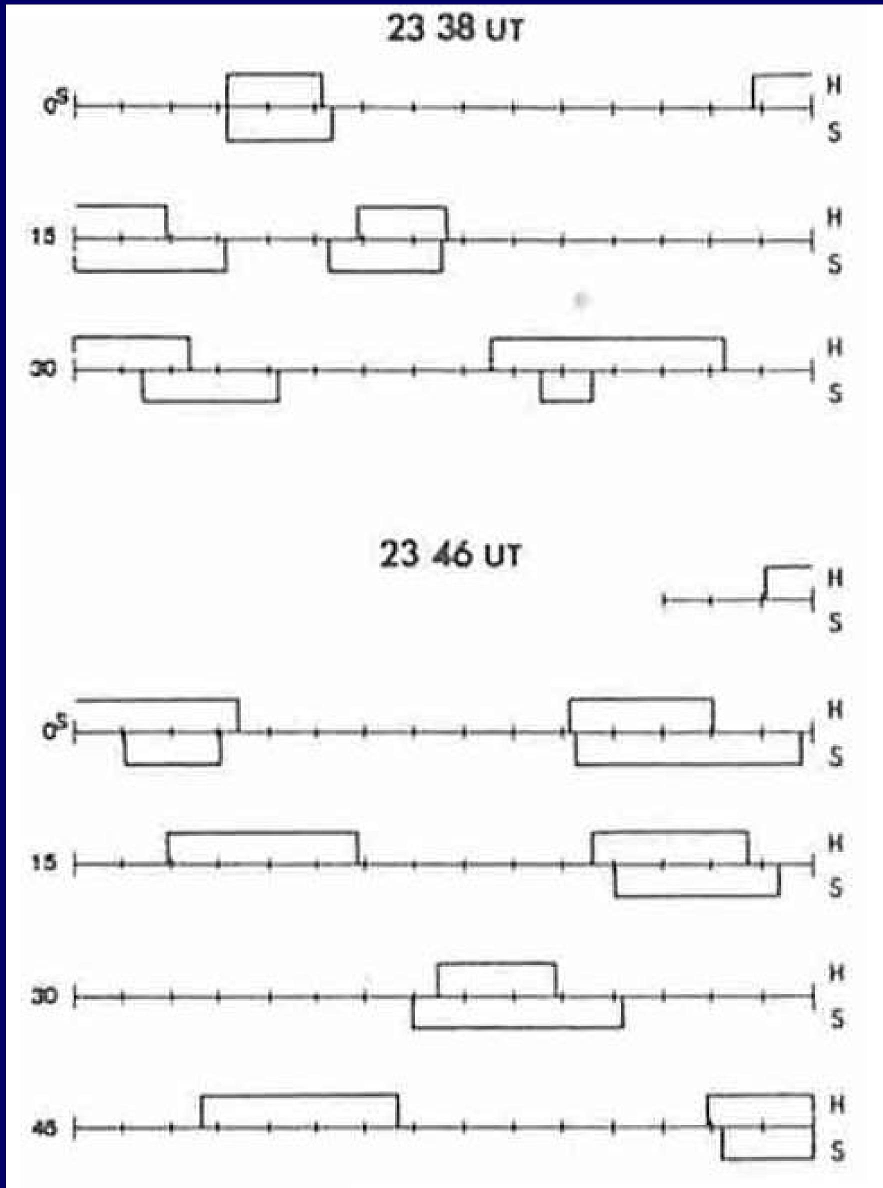
Patchy Type



Fujii et al. (GRL, 14, 1987)

Conjugacy of Pulsating Aurora

Patchy Type

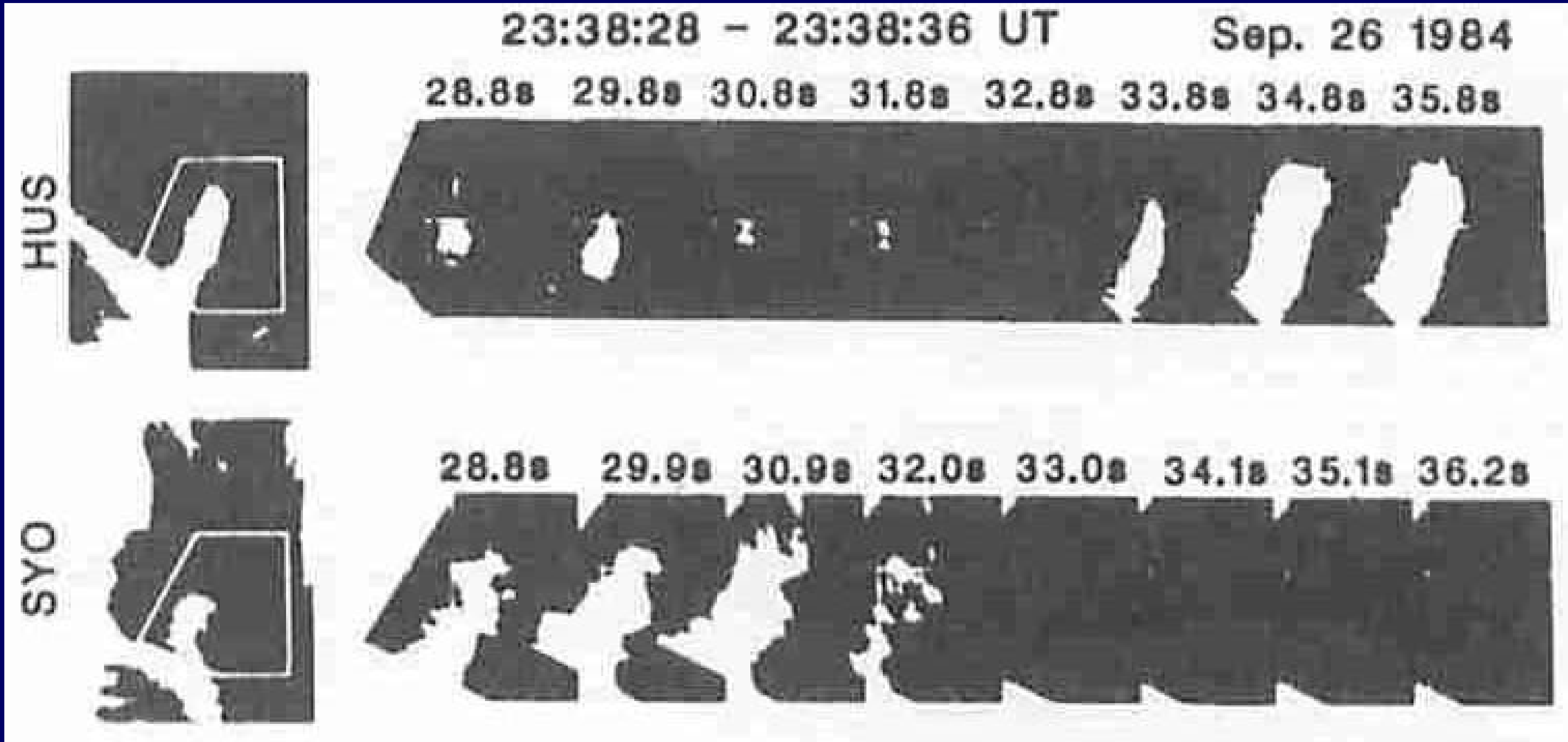


Appears almost simultaneously in phase

Fujii et al.
(GRL, 14, 1987)

Conjugacy of Pulsating Aurora

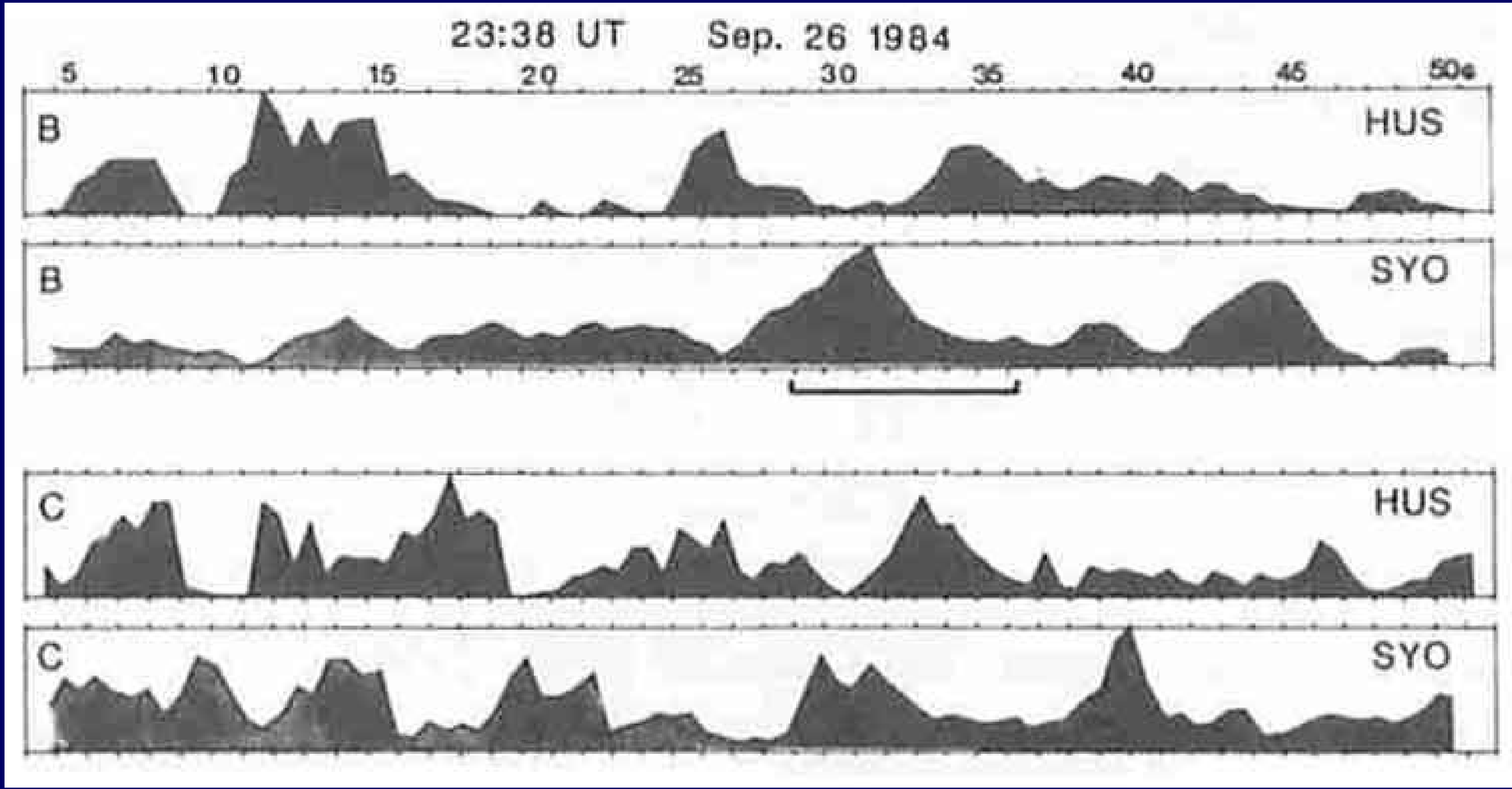
Expansion Type



Fujii et al. (GRL, 14, 1987)

Conjugacy of Pulsating Aurora

Expansion Type

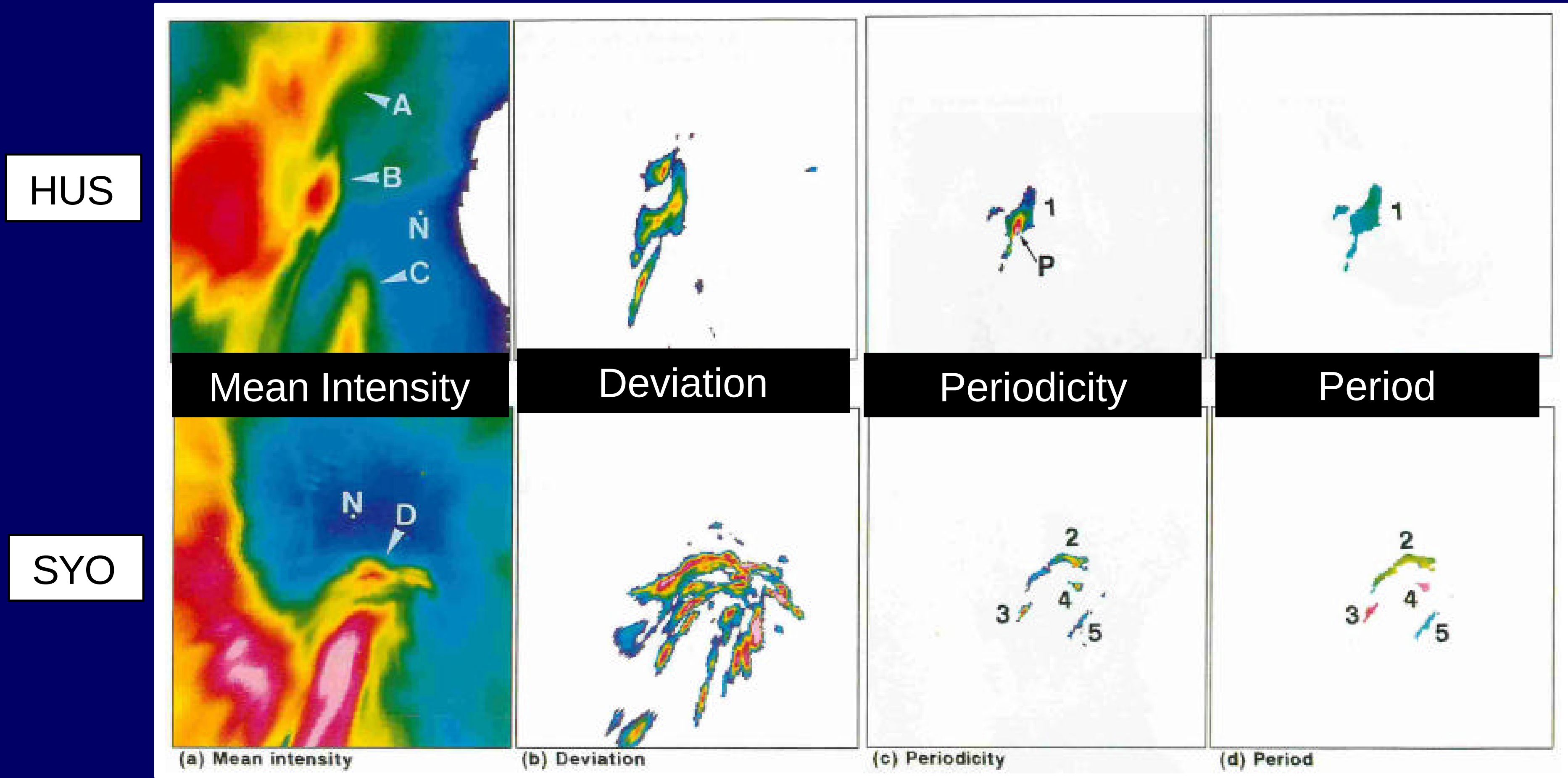


Often appears almost out of phase

Fujii et al. (GRL, 14, 1987)

Conjugacy of Pulsating Aurora

Minatoya et al. (JGG, 47, 1995)



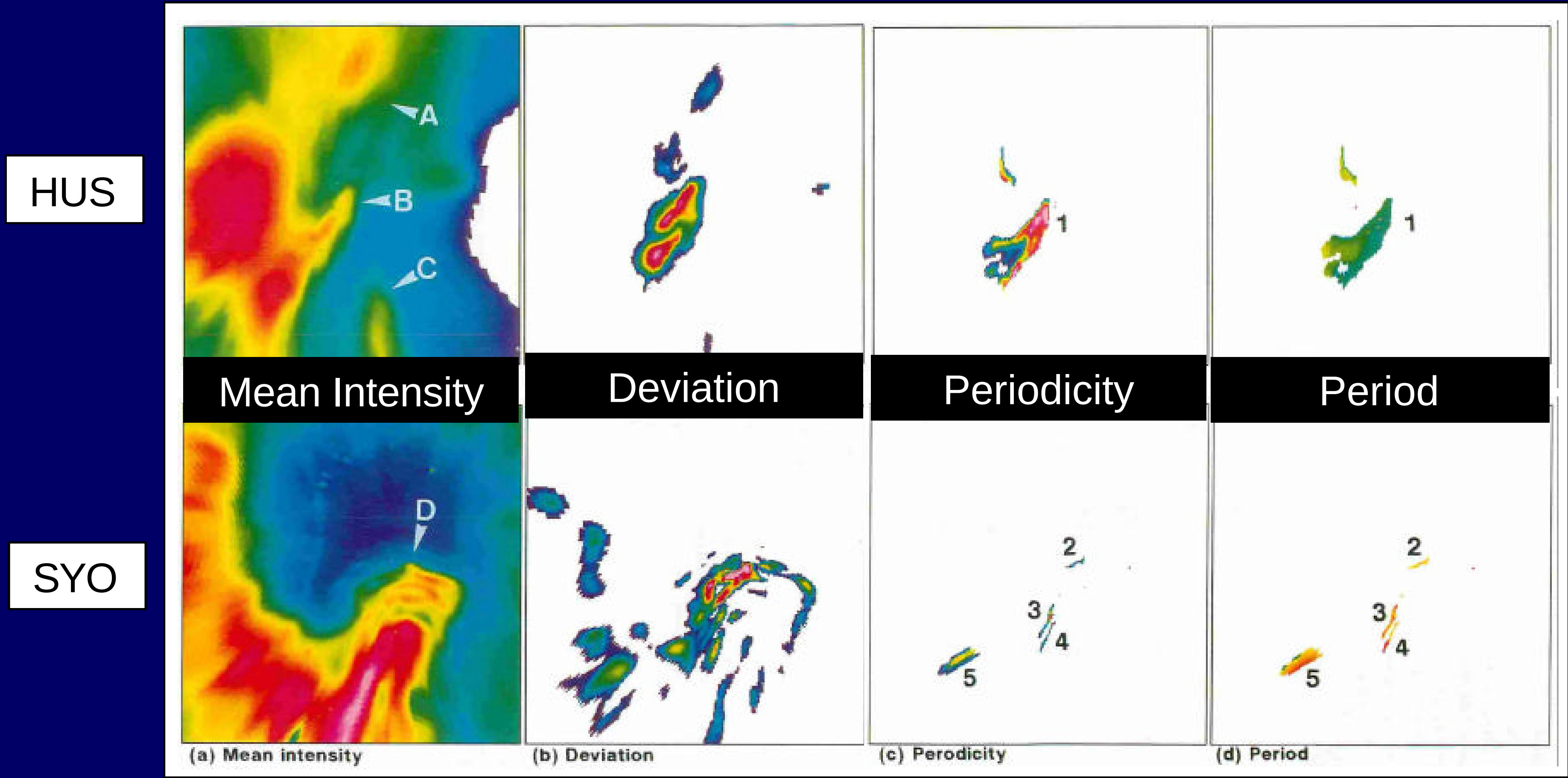
Correlation is poor in every aspect ;
spatial pattern, periodicity, period

Date: 91.9.9
Time: 22:54:40 - 22:55:00 UT

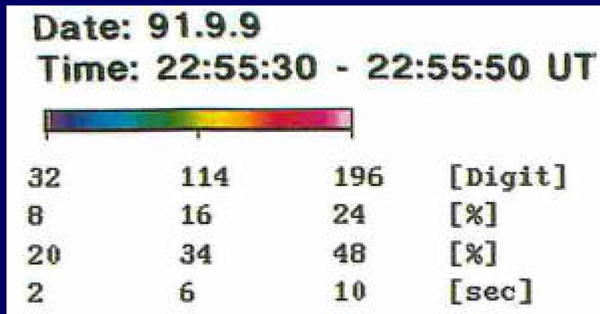
32	114	196	[Digit]
8	12	16	[%]
20	34	48	[%]
2	6	10	[sec]

Conjugacy of Pulsating Aurora

Minatoya et al. (JGG, 47, 1995)

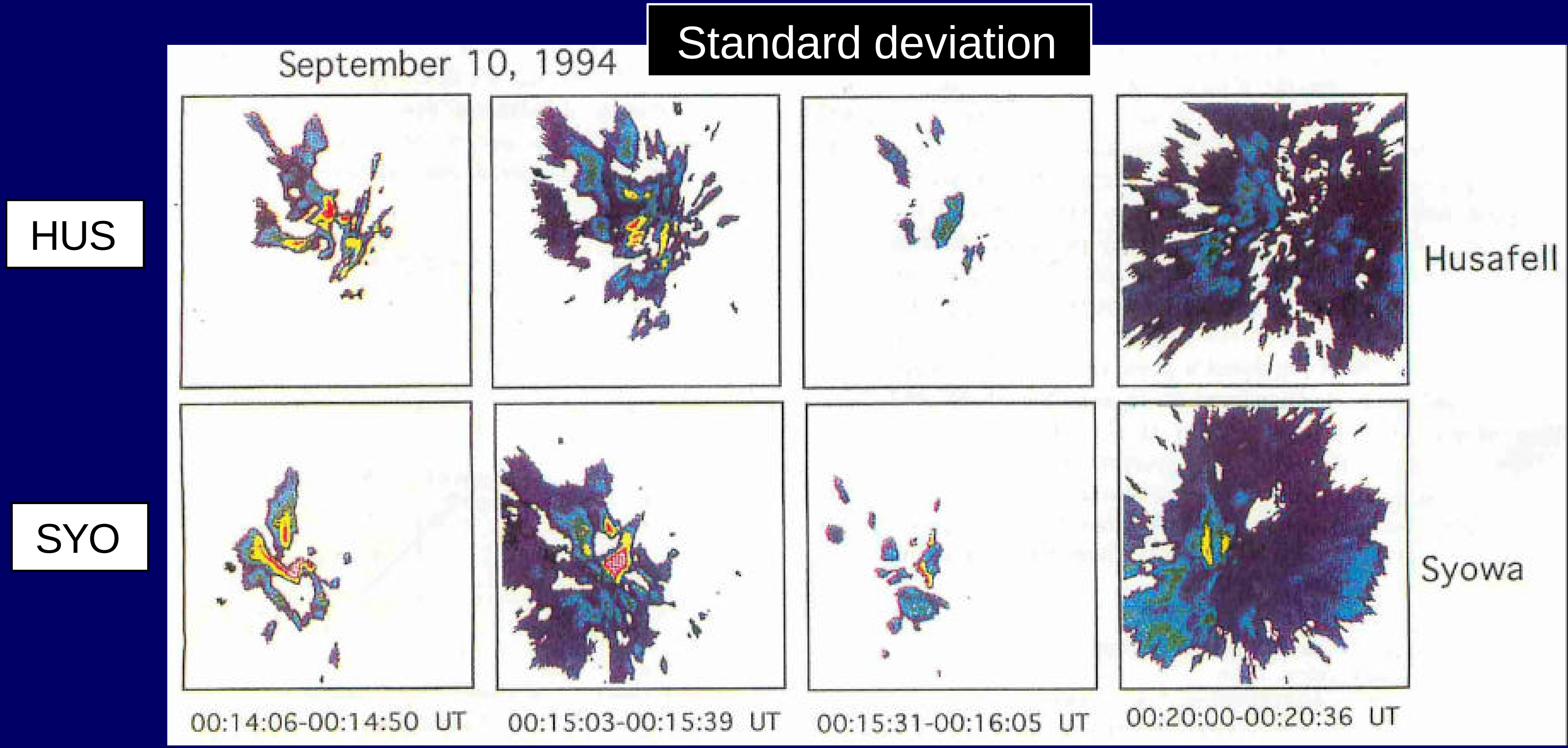


Correlation is poor in every aspect ;
spatial pattern, periodicity, period



Conjugacy of Pulsating Aurora

Sato et al. (GRL, 25, 1998)

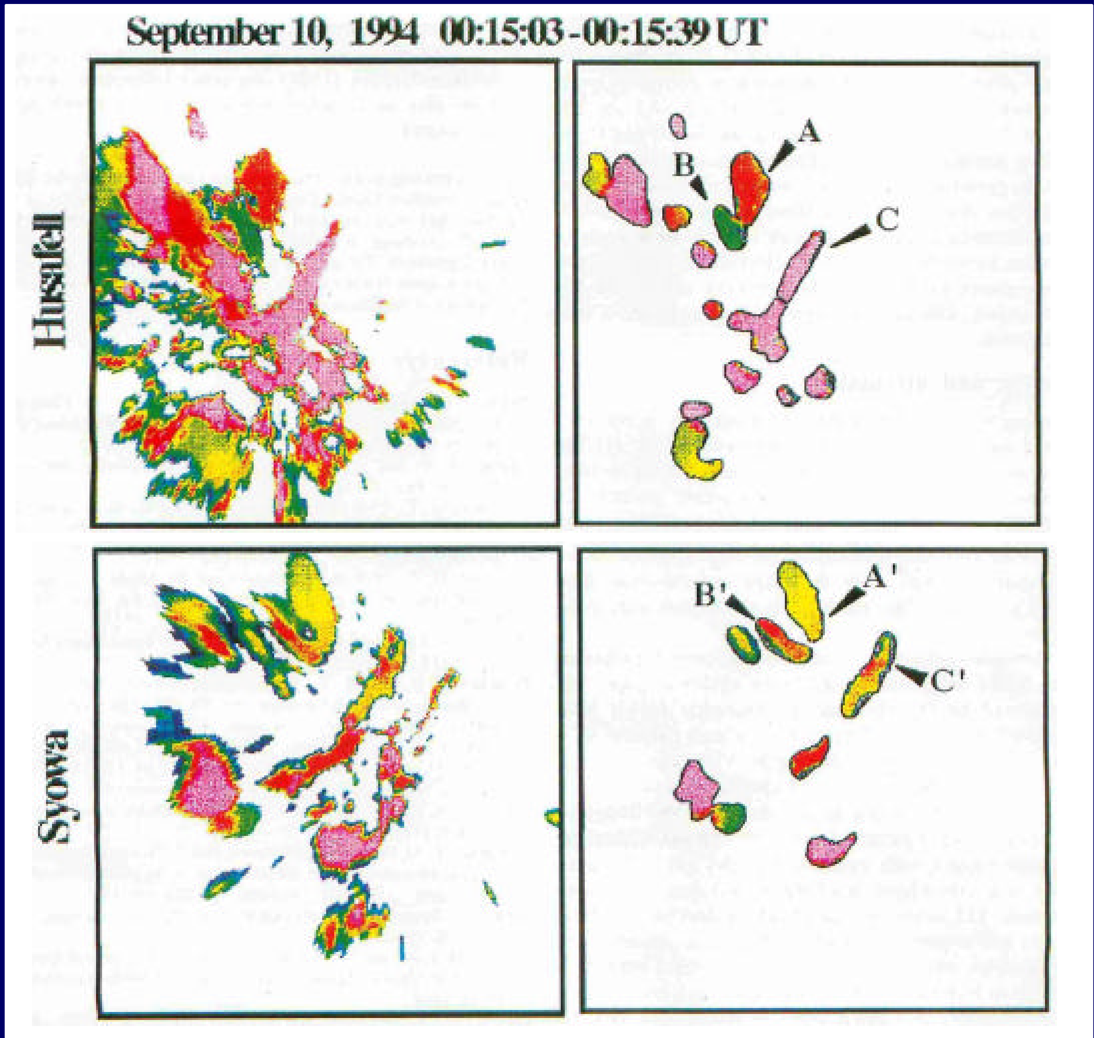


Overall variations are similar.
But, correspondence of each patch is unclear.

Conjugacy of Pulsating Aurora

HUS

SYO



Period

Sato et al.
(GRL, 25, 1998)

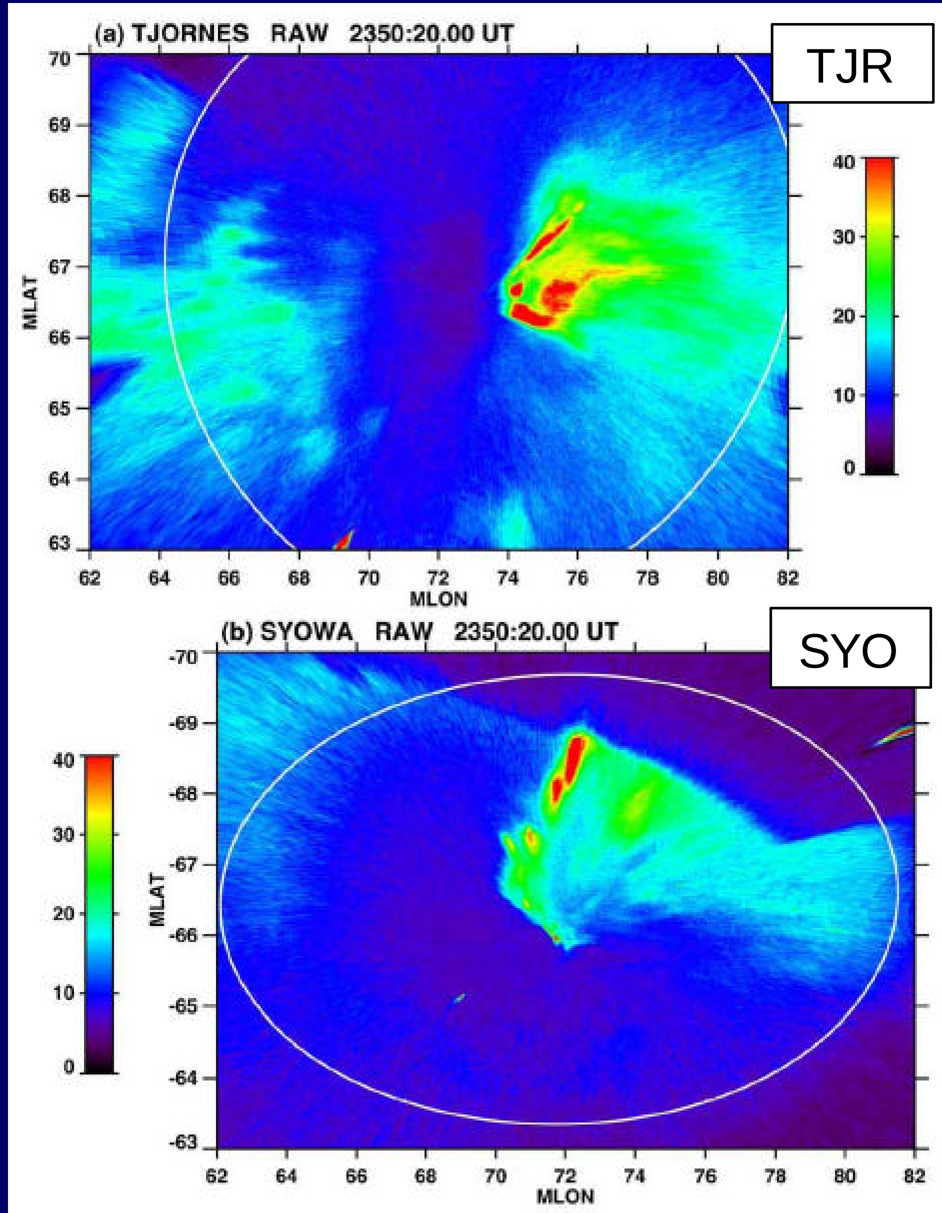
Even if the patch shape and type are similar, period is different.

Conjugacy of Pulsating Aurora

Watanabe et al.
(GRL, 2007, submitted)

Event on Sep. 26, 2003

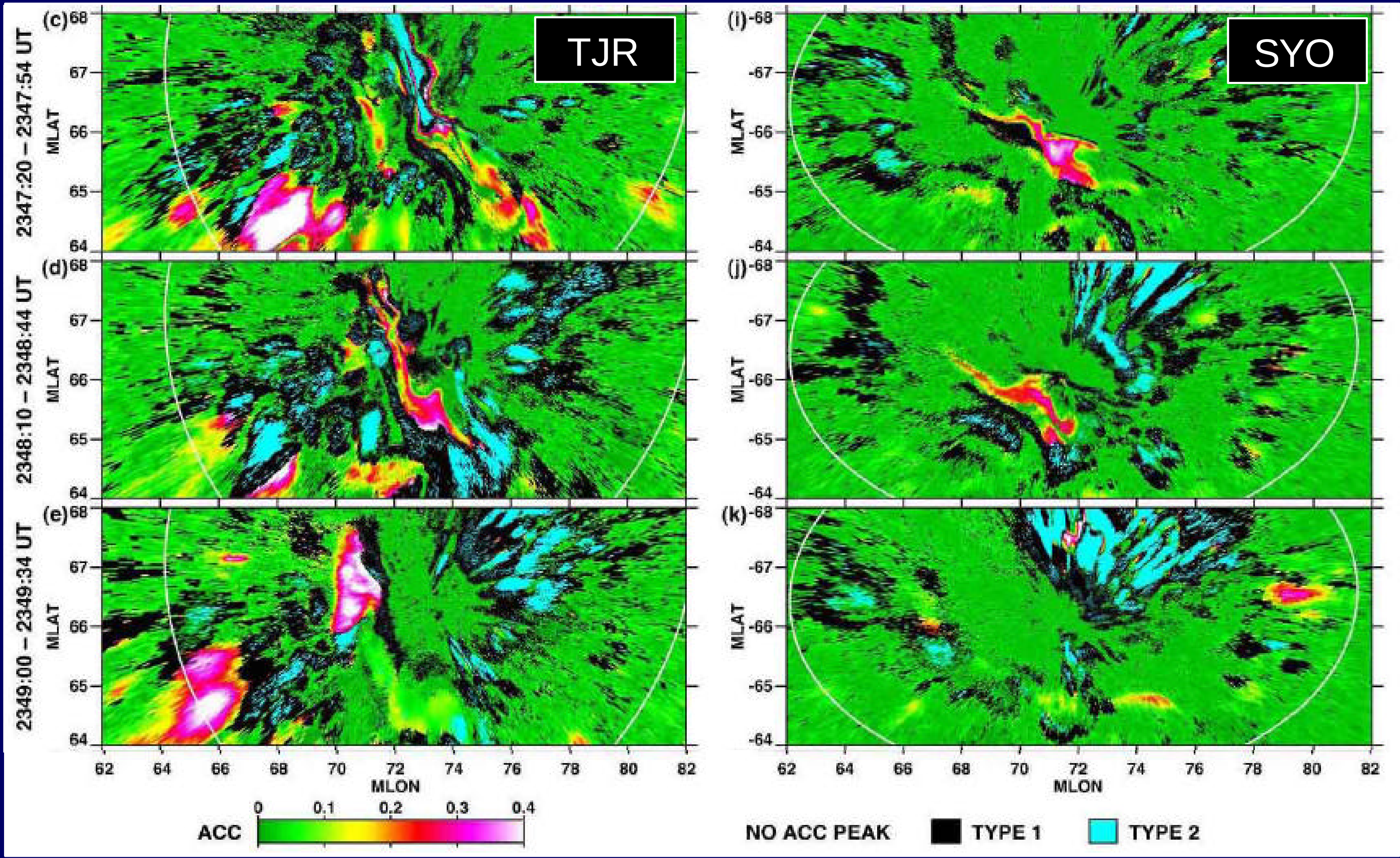
Overall structure is displaced longitudinally about 3.6 deg.



Conjugacy of Pulsating Aurora

Auto-correlation coefficient

Sep. 26, 2003



Shape & location are similar.

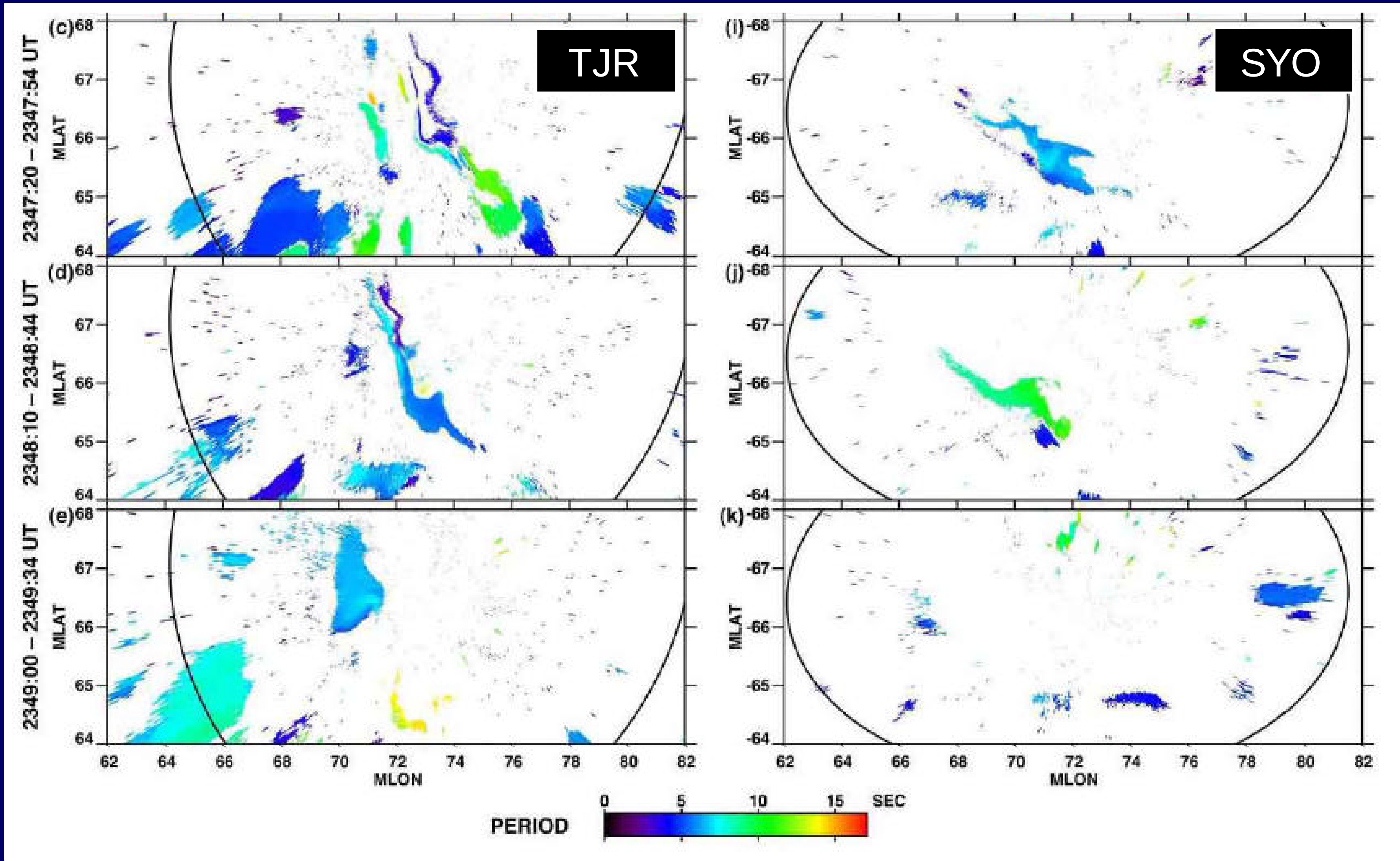
Sometimes high periodicity differently appears.

Watanabe et al.
(GRL, 2007, submitted)

Conjugacy of Pulsating Aurora

Period

Sep. 26, 2003



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

Watanabe et al.
(GRL, 2007, submitted)

Summary

- Large scale conjugate, small scale non-conjugate, is frequently observed.
- Large longitudinal displacement beyond the clock angle effect, is observed during recovery phase.
- Latitudinal scale difference beyond the difference in B and ∇B, is observed at a small breakup.
- As for the pulsating aurora, even if the shape and type are similar, other features (periodicity, period) are frequently dissimilar.
  Sometimes, patch appears only one hemisphere.

Summary

- Such dissimilarity or non-conjugacy should be caused by some processes between the equatorial plane and ionosphere.

  Difference in $E_{||}$?
  Difference in Field-Aligned Current intensity ?
  Where is the source region for the pulsating auroral modulation ?

- To solve these problems, simultaneous multi-point observation along a same field line is essential.
  But .....