Mid-latitude HF radar workshop
October 24 (Mon), 2011
10:50-11:10

The Hokkaido HF radar observations of Pi2 pulsations in the near range echoes.

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Introduction

Pi2 pulsations (period: 40-150 s)

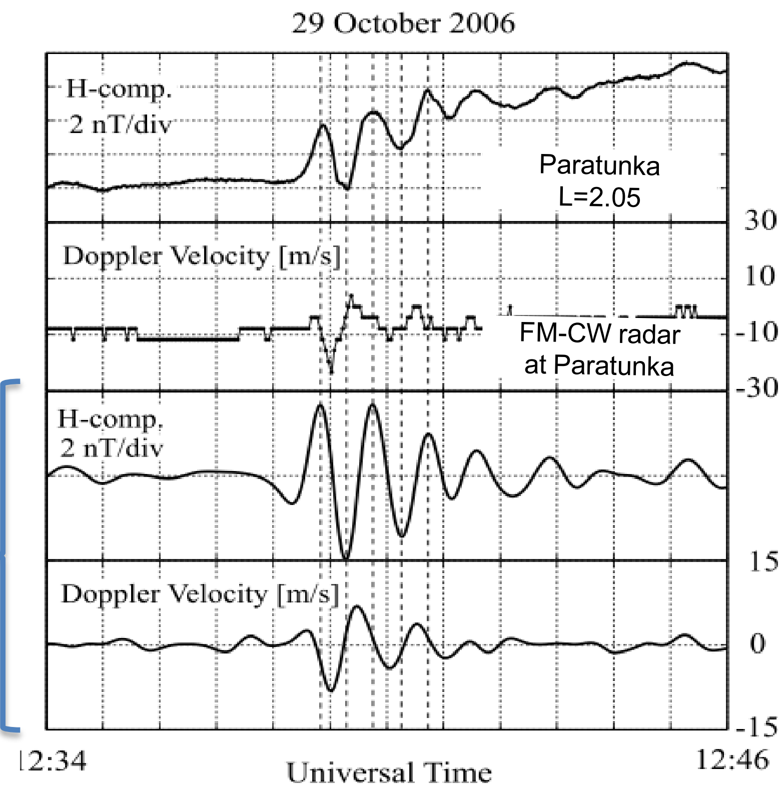
At substrom onsets, Pi2 pulsations were observed on the nightside over wide range of latitudes.

The mid- and low-latitude Pi2 pulsations

→They may occur through the fast mode waves propagating from the magnetosphere and subsequently being trapped between the plasmasphere and the ionosphere.

BPF applied

→The electric field characteristics of ionospheric Pi2 pulsations have not been investigated over the entire range of latitudes.



（*Ikeda et al*.,2010）

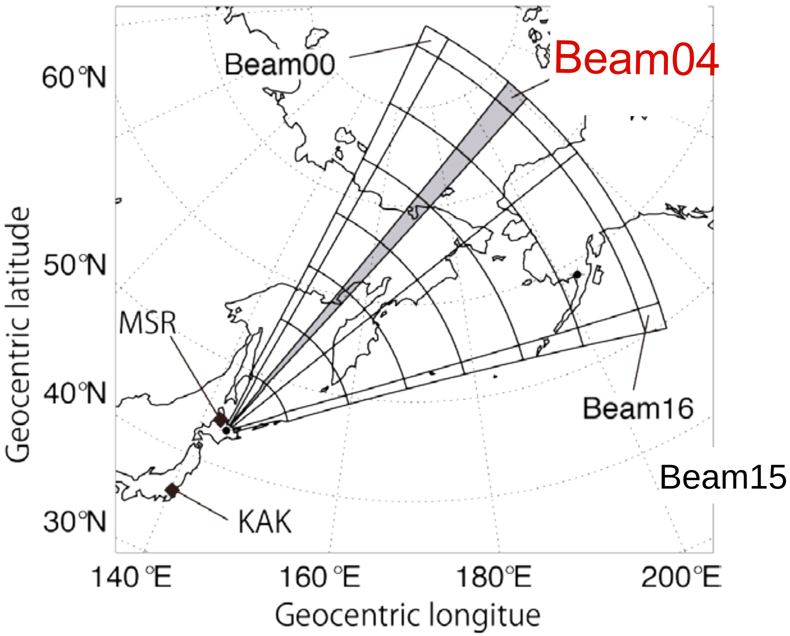
Mid- and low-latitude Pi2 pulsations in the ionospheric electric field

The radars detect electric field variations in the F-layer ionosphere.

･･･*Grant and Cole* [1992], *Marshall and Menk* [1999], *Ikeda et al*., [2010] We compared magnetic Pi2 pulsations on the mid-latitude ground stations to Doppler velocities observed by the Hokkaido HF radar.

The Hokkaido HF radar

- Location: 34.9° GMLAT, 211.6° GMLON
- In this study, we use Doppler velocity data of beam 4 sampled every 8 seconds (themisscan mode).
- The Hokkaido radar can observe Doppler velocities over a wide latitudinal range from 38° GMLAT to 80° GMLAT.

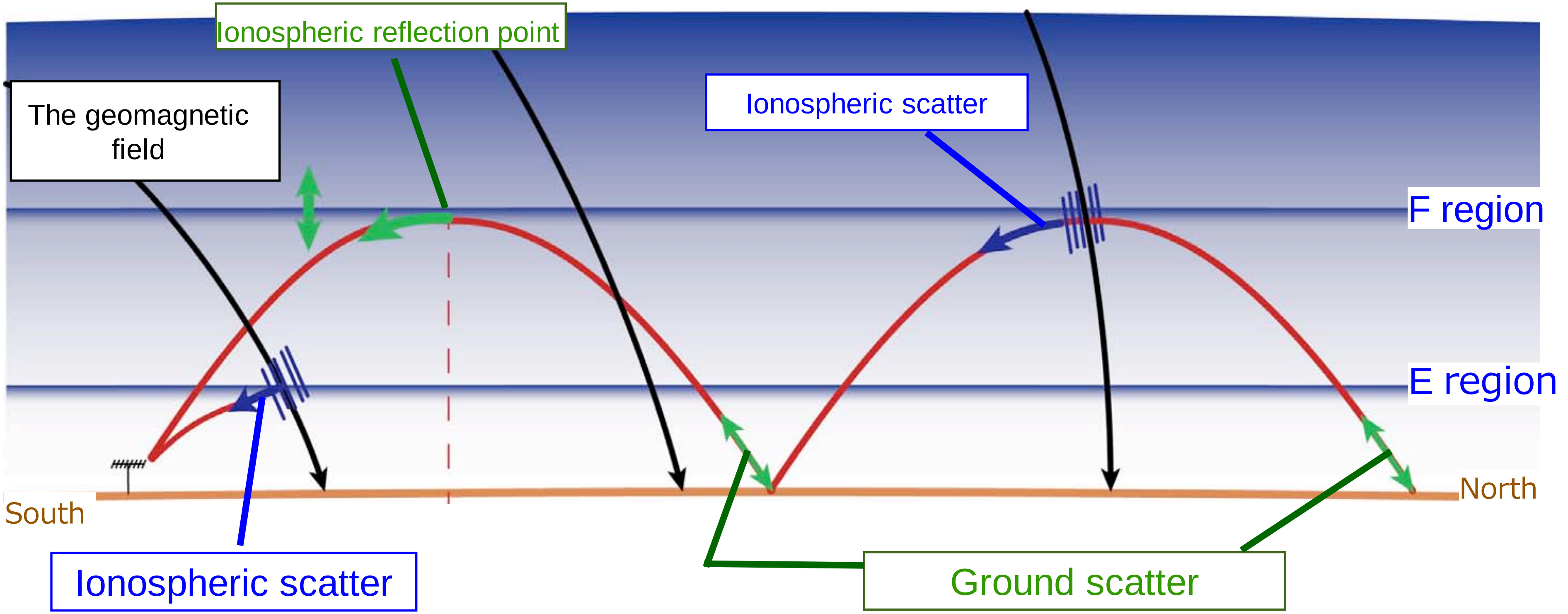


Ground magnetometer stations

- Moshiri (MSR): 37.6° GMLAT, 213.2° GMLON.
- Kakioka (KAK): 27.4° GMLAT, 209.2° GMLON.
- Magadan (STC): 52.1° GMLAT, 213.8° GMLON.
- St. Paratunka (PTK): 45.6° GMLAT, 221.1° GMLON

The fluxgate magnetometers sample data every 1 second.

The Ionospheric Scatter and Ground/sea Scatter



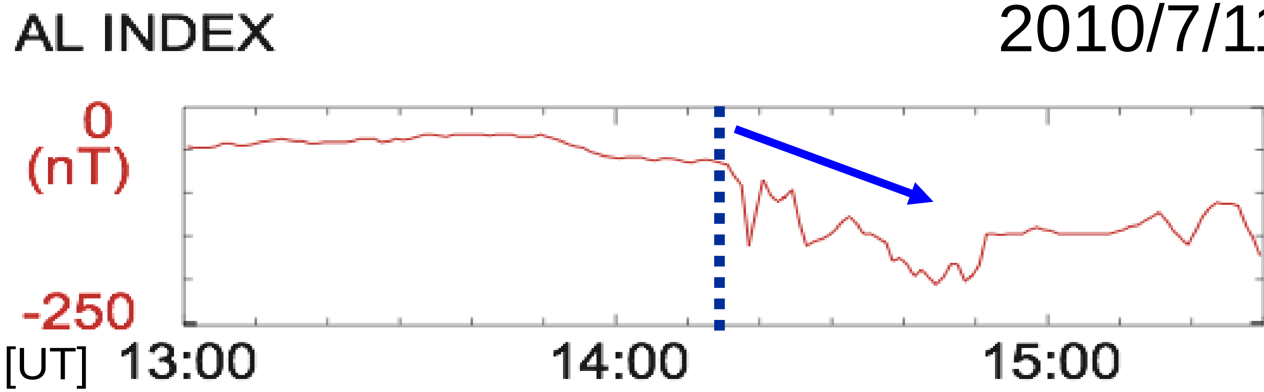
〇The ionospheric scatter occurs because of field-aligned electron density irregularities.
〇 Near-ranges scatter occurs from the E-region irregularities.

ULF waves might affect ground/sea scatter signals in the vicinity of the ionospheric reflection point.

We can estimate the electric field of the Pi2 pulsations in the ionosphere from the Doppler velocity observed by the HF radar.

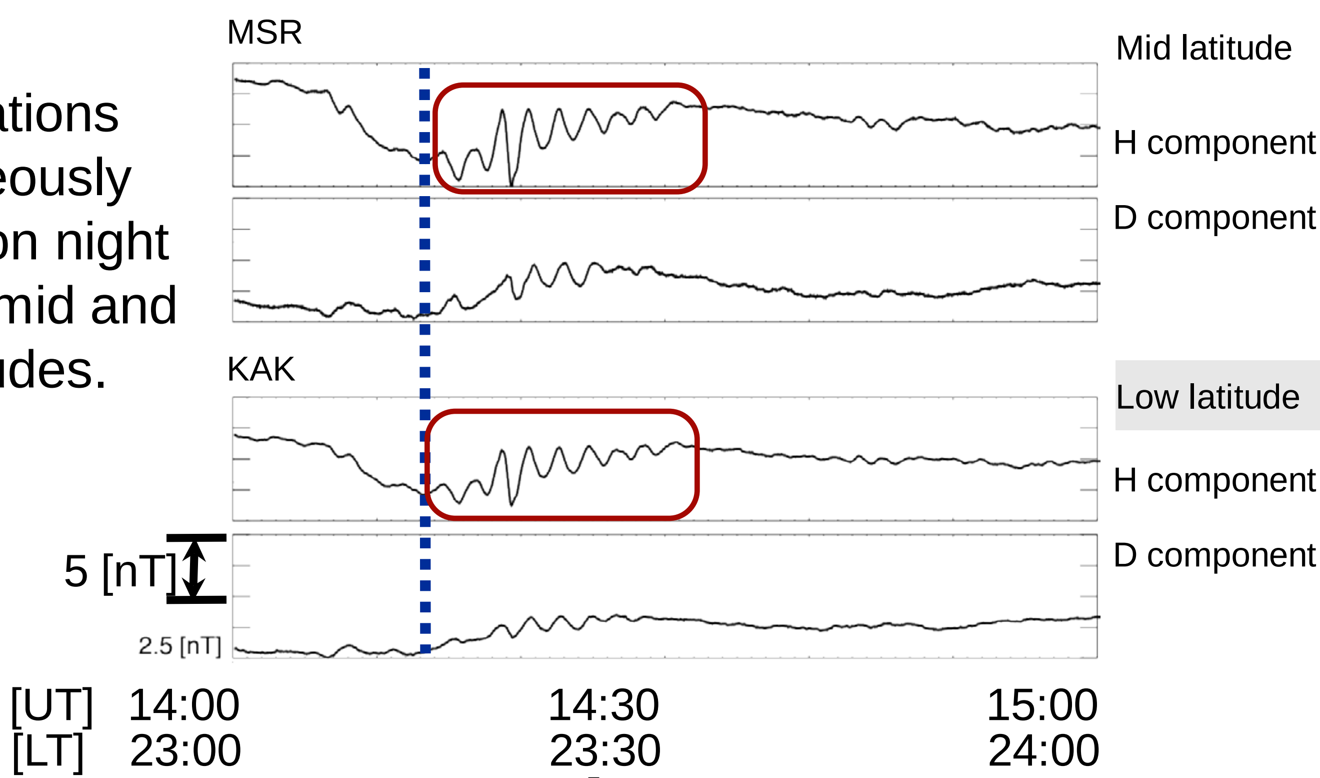
Substorm Signature

2010/7/11

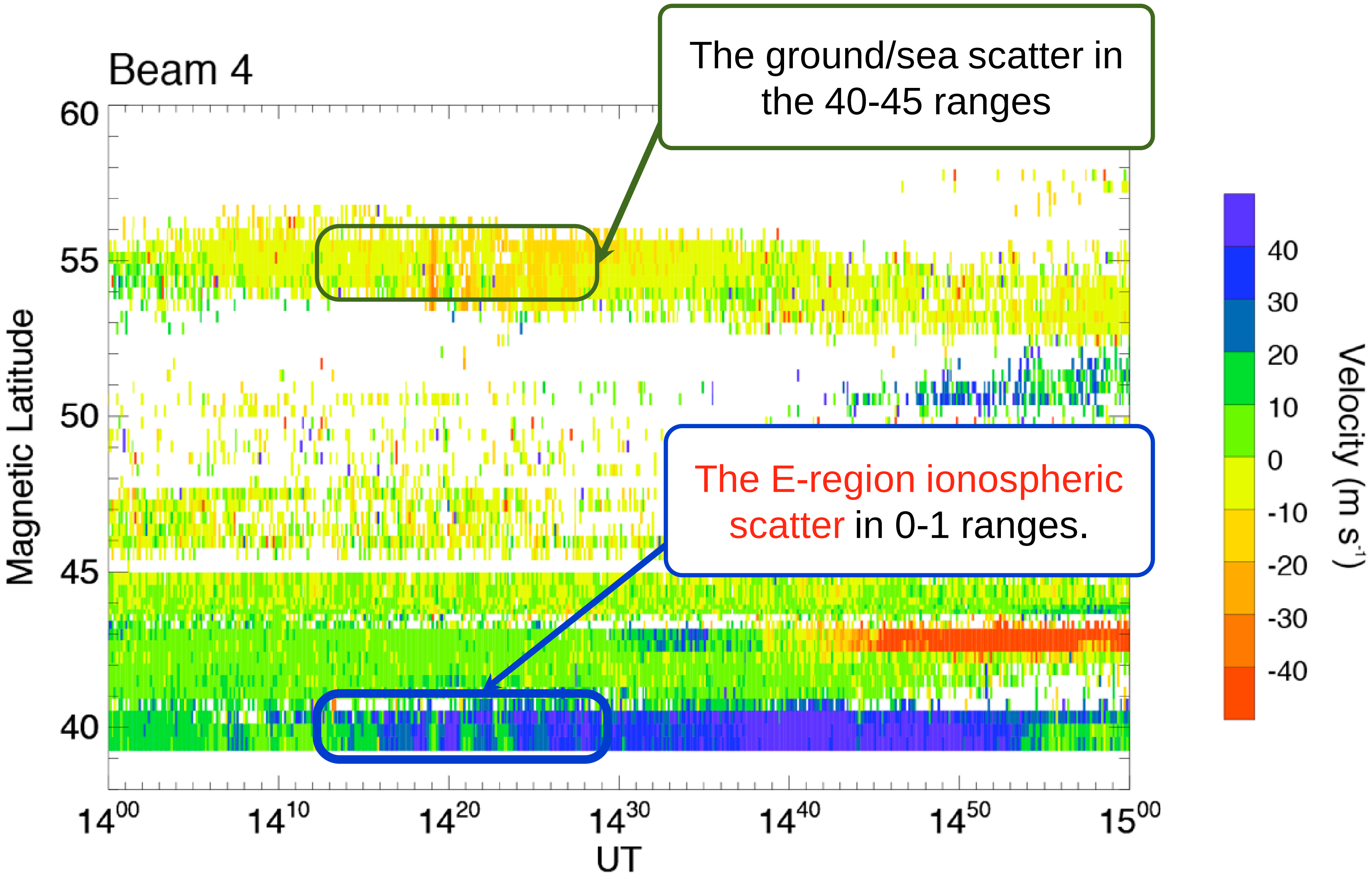


The AL index decreased around 14:15 UT

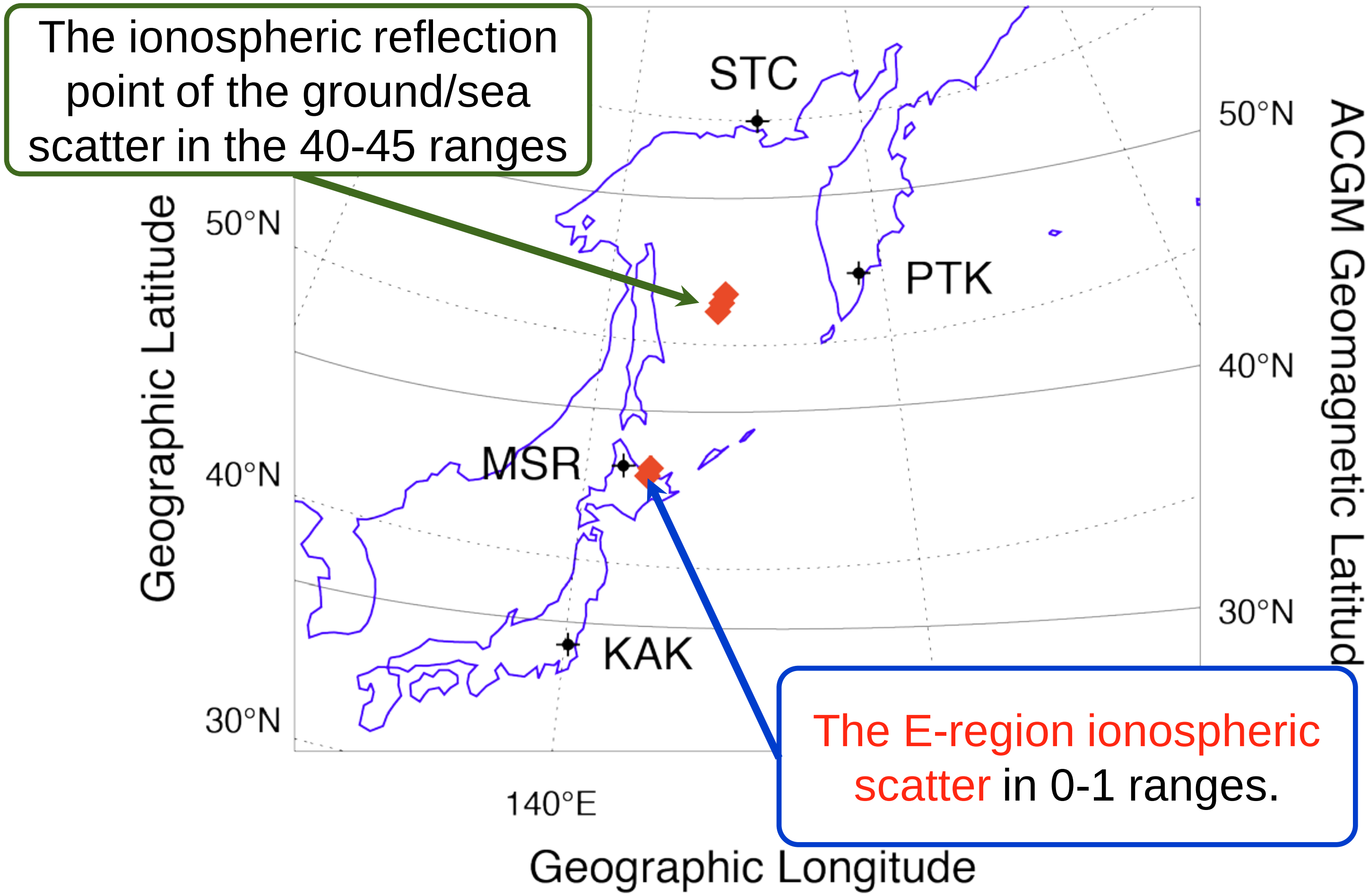
Pi2 pulsations simultaneously appeared on night side in the mid and low latitudes.



Pi2 Pulsations Simultaneously Detected in the Ground/sea and Ionospheric Echoes



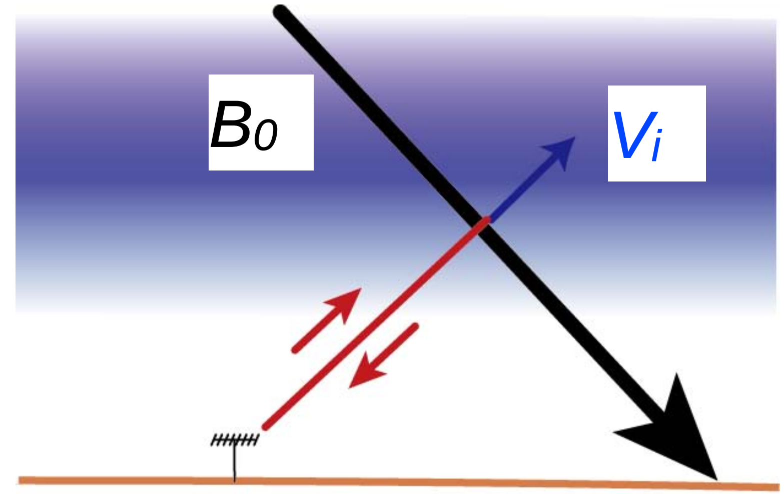
The Locations of Observations



The electric field estimated from the Doppler velocity

The ionospheric scatter

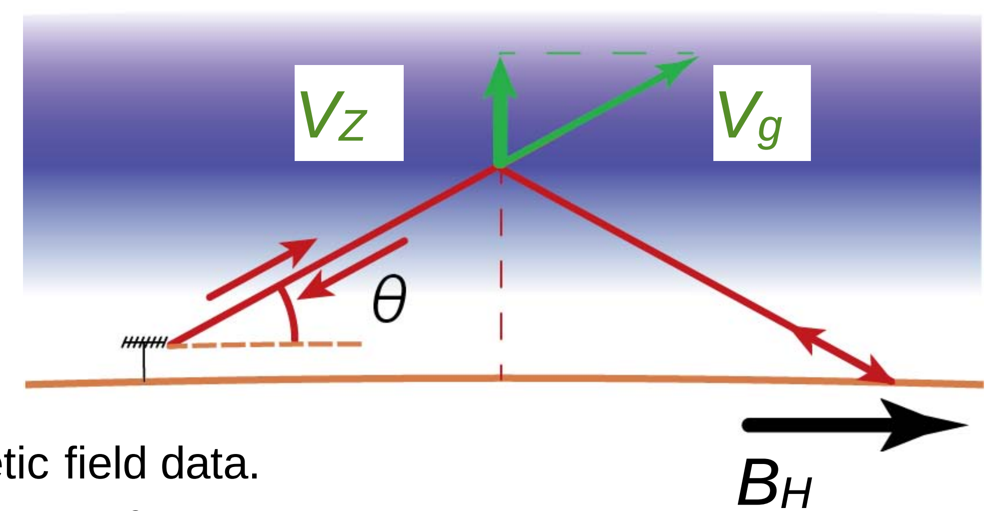
$$E_{\circledcirc}=V_iB_0$$



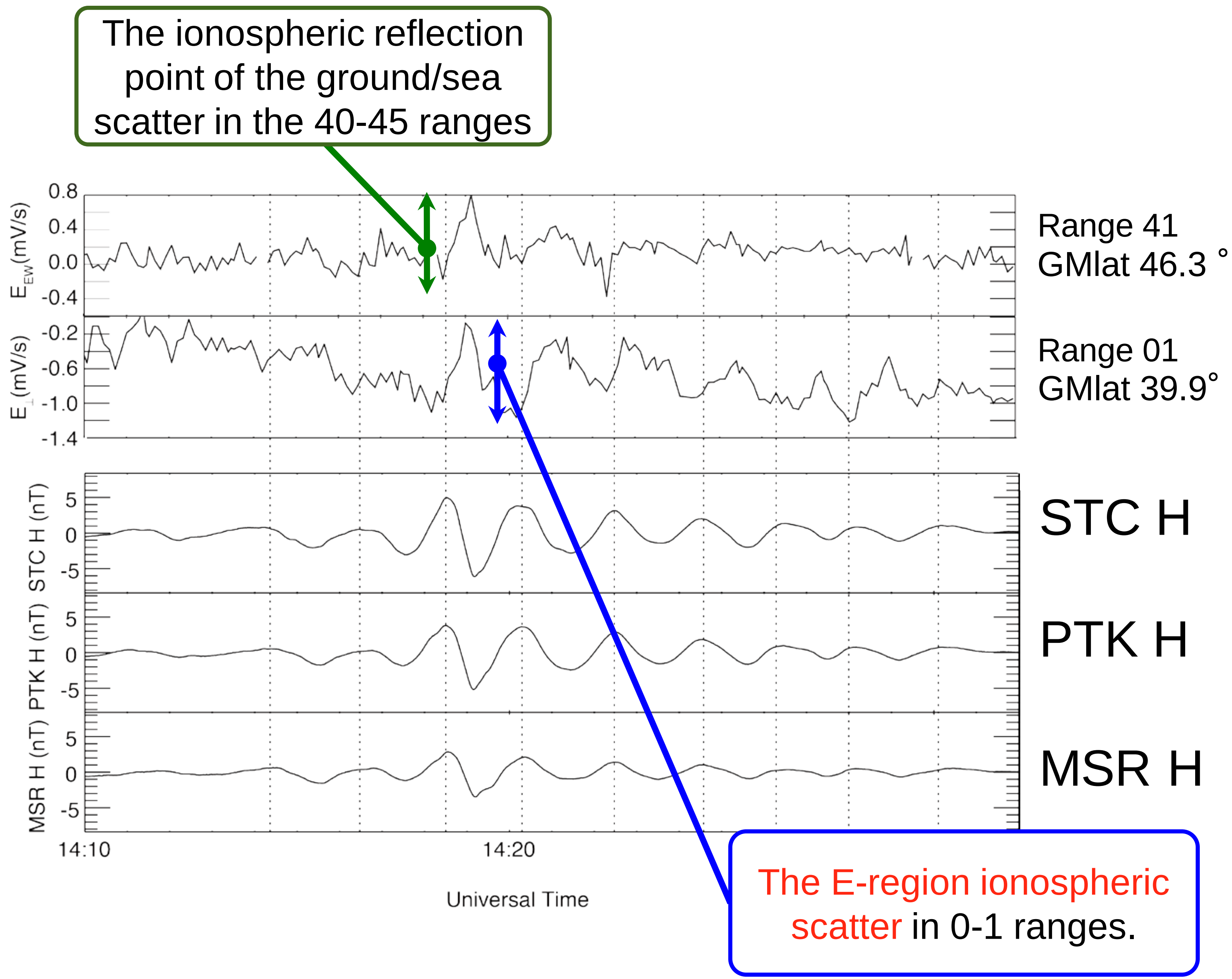
The sea/ground scatter

$$V_Z = (V_g \sin\theta)/2$$

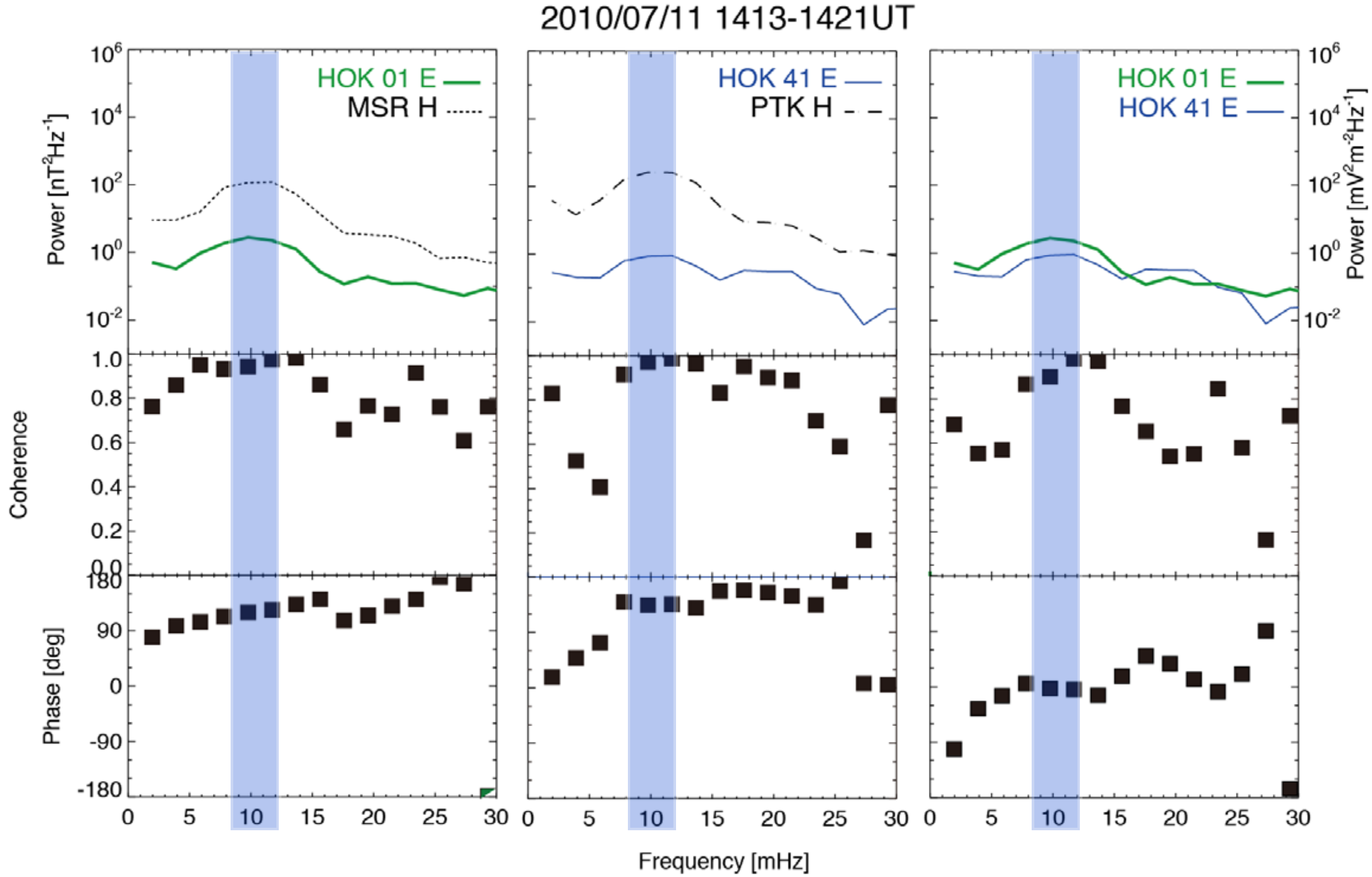
$$E_{EW}=V_ZB_H$$



We used IGRF model for the geomagnetic field data.


The ionospheric reflection point of the ground/sea scatter in the 40-45 ranges
Range 41
GMlat 46.3 °
Range 01
GMlat 39.9°
STC H
PTK H
MSR H
The E-region ionospheric scatter in 0-1 ranges.
0.8
0.4
0.0
-0.4
-0.2
-0.6
-1.0
-1.4
E_EW (mV/s)
E_⊥ (mV/s)
STC H (nT)
PTK H (nT)
MSR H (nT)
5
0
-5
14:10
14:20
Universal Time

Spectral Properties



- The power of velocities and H component from MSR and PTK had peak at 10 mHz.
- The H-E and E-E coherences were high (> 0.9) at 10 mHz.
- The electric field was in quadrature to H component at 10 mHz.
- Pi2 pulsation in the E region was in phase with that in the F region.

Theoretical Estimation 1

We theoretically estimated the ratio E/B for Alfvén and fast mode in a homogeneous medium according to the following equation [Pilipenko et al., 2008].

Alfvén mode

$$\left.\frac{E_x}{B_x^{(g)}}\right|_x = \frac{V_H}{\sin I}$$

→ ~4 × 10^6 [m/s]

- Σ_H~0.2 S estimated from IRI 2007 model
- sinI~0.9
- Z+h~300 km
- ω~0.06 s^{-1}

Fast mode

$$\left.\frac{E_y(z)}{B_x^{(g)}}\right|_x = -i\omega(z+h)$$

→ ~1.8 × 10^4 [m/s]

Observation shows that the ratio is ~6 × 10^4 [m/s] at peak frequency (10 mHz). It is much less than that for Alfvén mode but consistent with that for fast mode.

E_x : the wave electric field in the North-South component on the ground.
$B^{(g)}_x$: the wave magnetic field in the North-South component on the ground
$V_H = (\mu_0 \Sigma_H)^{-1}$: Ionospheric velositiy
I : Inclination of the magnetic field.
E_y (z): the wave electric field in the East-West component on the ground.
h : The altitude of a thin conductive layer.
z : Altitude from a conductive layer.

Theoretical Estimation: the Parameter p

For the highly-conductive ground, the ratio of the North-South magnetic field on the ground ($B_x^{(g)}$) to the compressional fast mode wave from the magnetosphere (B_x) is

$$\frac{B_x}{B_x^{(g)}} = 1 - ip, \qquad p = \frac{\omega h}{V_c}.$$

$V_c = (\mu_0 \Sigma_c)^{-1}$: Ionospheric velocity determined by the Cowling ionospheric conductance ($\Sigma_c = \Sigma_p + \Sigma_H^2/\Sigma_p$).
ω: angular velocity of the wave

- $|p| \sim 1$: the ionosphere partially screens the incident wave from the magnetic field.
- $|p| \ll 1$: the incident fast mode wave from the magnetosphere is transmitted through the ionosphere.

- $\Sigma_p \sim 0.3$ S
- $\Sigma_H \sim 0.2$ S
- $\omega \sim 0.06$ s^{-1}

→ $p \sim 3 \times 10^{-3}$

The fast mode wave propagating from magnetosphere may be completely transmitted through the ionosphere and reflect at the earth surface.

Statistical analysis：Near-range Events Selection

Events were identified to investigate the E/B ratio, E-B cross phase, and p parameter property of Pi2 pulsations in the near-range echoes. The time interval from November 2007 to December 2010 was considered. The following procedures were used.

First step: The substorm onsets were identified from the AL index.

① The standard deviation of the AL index for the 20-min time interval before t is less than 50nT.
② The AL index decreased by the larger than 100 nT during 20 minutes after t.

Second step: Pi2 pulsations are identified on MSR. ⇒ 51 events

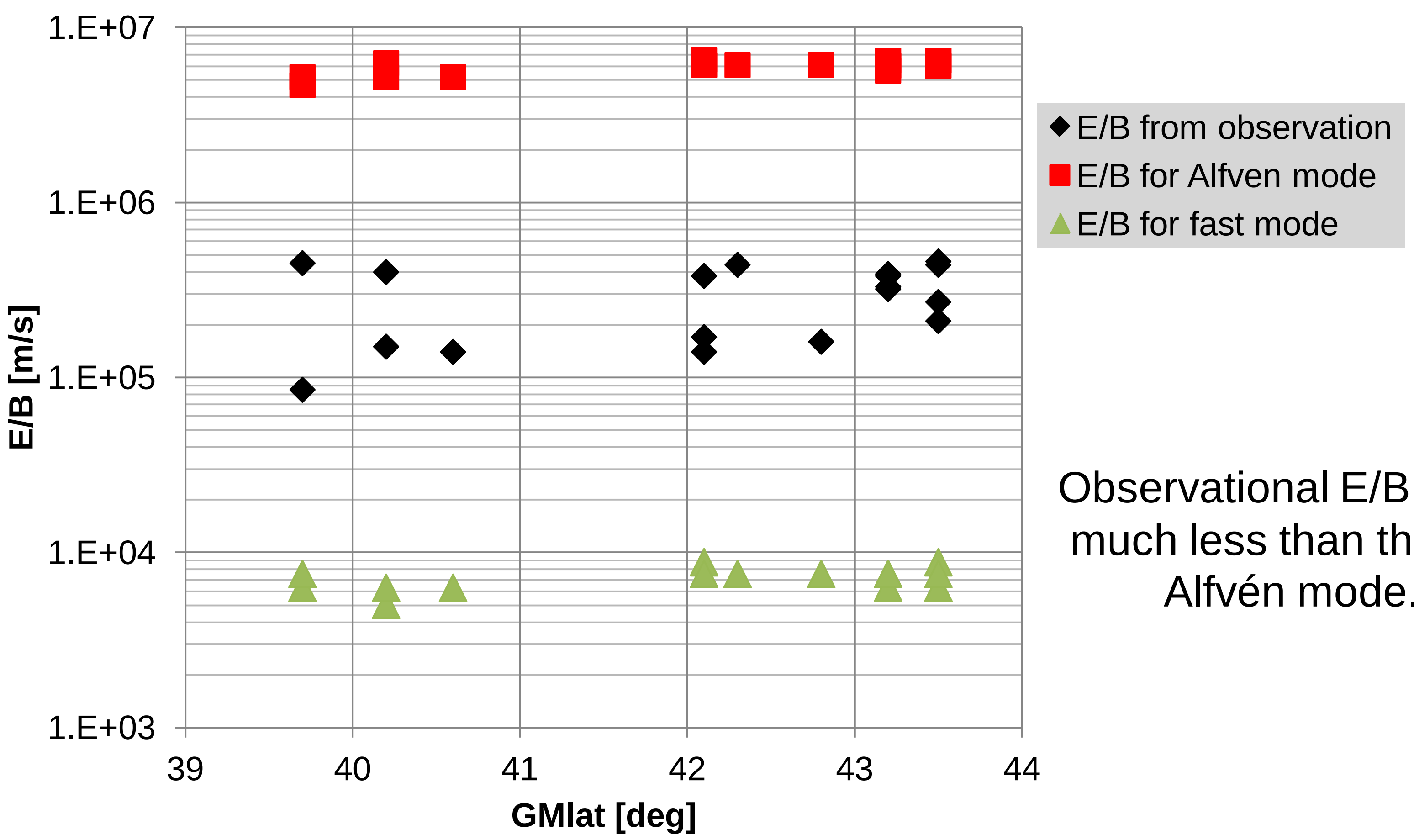
①MSR was located on the night side (2000-0400MLT).
②The amplitude of Pi2 pulsations is greater than 1 nT.

Third step : the events are identified in the Doppler velocities.

① The frequency of MSR Pi2 pulsations is same as that of the Doppler velocities.
② The coherence between H and V was greater than 0.8.
③ A maximum range of 10 were used.

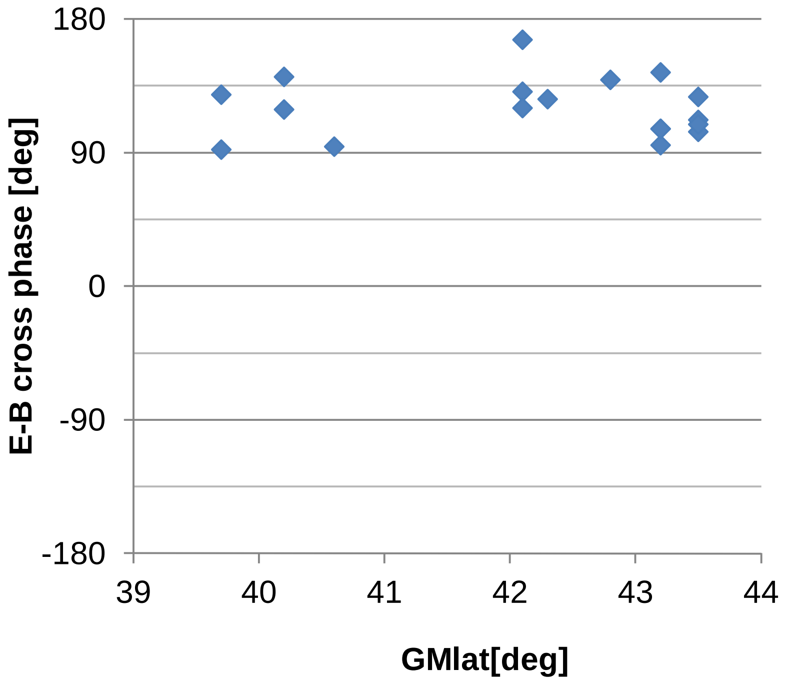
15 events were identified from the near-range echoes.

The Latitudinal Distribution of E/B

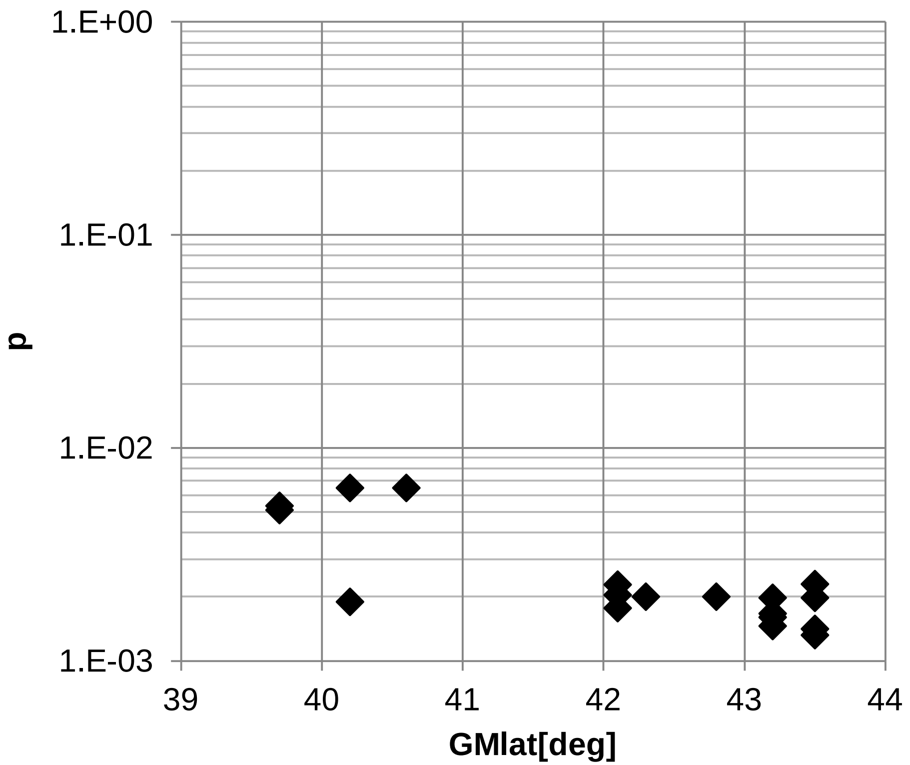


Observational E/B were much less than that for Alfvén mode.

The Latitudinal Distribution of the E-B Cross Phase and the Parameter p



The E-B cross phases were greater than 90° and less than 180°.



In all cases, p parameter is much less than 1

Summary and Conclusion

On July 11, 2010, the Hokkaido radar observed the ionospheric echo from the E region at 39.5° -39.9° geomagnetic latitudes and the ground/sea echo from the F region at 46.3° -47.0 ° Geomagnetic latitudes.

- The periods of the electric field variation estimated from Doppler velocity were similar to those of mid-latitude Pi2 pulsations on the ground.
- The electric field estimated from Doppler velocity was in quadrate to Pi2 pulsations in the H component on the ground.
- The E/B ratio at 10 mHz was ~6×10^4 [m/s], which was much less than E/B for Alfvén mode and consistent with E/B for fast mode according to theoretical estimate (*Pilipenko et al.*, 2008).
- The p parameter was ~3×10^{-3}, which indicates that the incident fast mode wave propagating from magnetosphere reflects not from ionosphere but from the ground.

Statistical property of Pi2 in the near-range echoes.

- The E/B ratio was much less than that for incident Alfvén wave.
- The electric field variations estimated from near-range echoes had phase difference to the ground H component.
- The p parameter is much less than 1.