SuperDARNで観測されたPc5帯ULF波動のモード解析

Mode analysis of ULF waves in the Pc5 frequency range observed by SuperDARN

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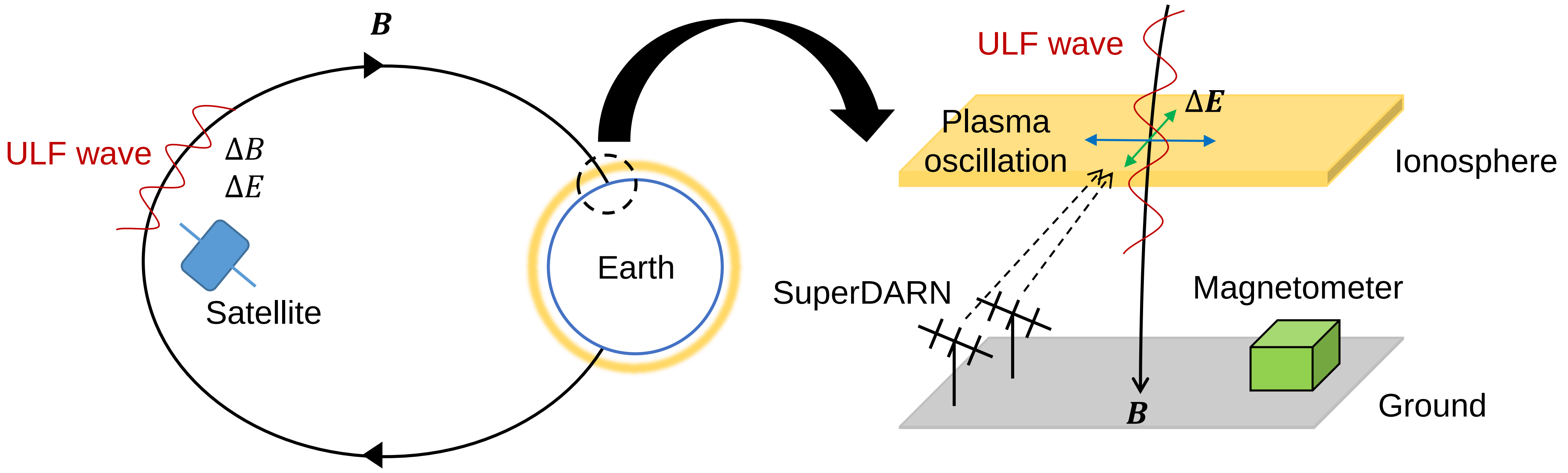
Introduction: ULF wave



◆Ultralow Frequency (ULF) waves are mainly driven in the magnetosphere.

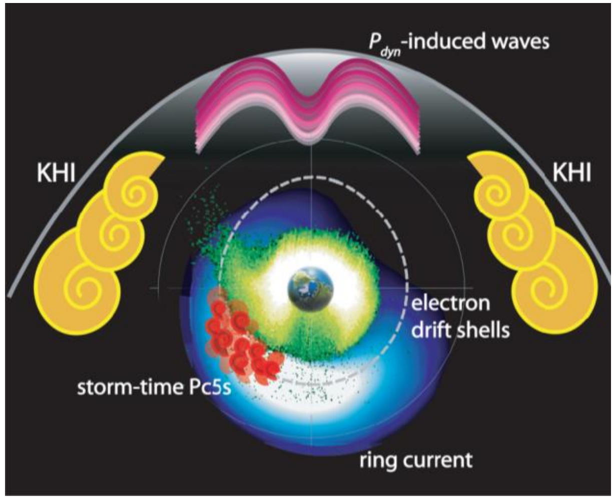
➢ Satellite data

◆ULF waves propagate along the earth's magnetic field lines and reach the ionosphere, causing perturbation of the ionospheric plasma motion and the magnetic field.

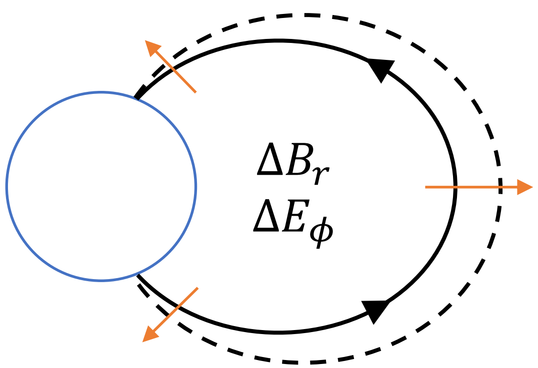
➢ SuperDARN / ground-based magnetometer data

Introduction: ULF wave modes

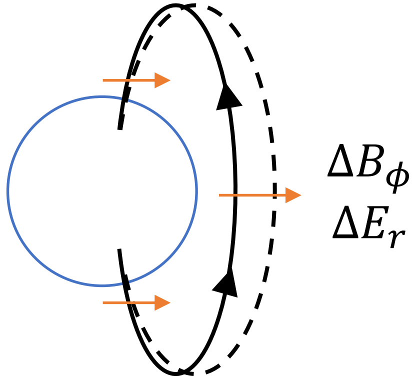
	Poloidal mode	Toroidal mode
Direction of ionospheric plasma oscillation	North-south perpendicular to the magnetic field lines	East-west
Primary driving source	◆ Internal source • Drift mirror instability • Drift-bounce resonance instability ◆ External source • Solar wind dynamic pressure variations • Kelvin-Helmholtz Instability	



[Ukhorskiy et al., 2009]



Poloidal mode

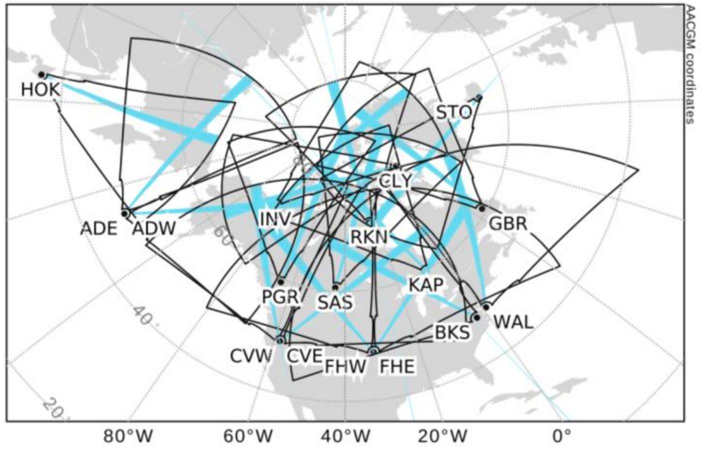


Toroidal mode

Motivation

◆Previous studies on ULF waves with SuperDARN

- Sakaguchi et al. (2012): MLAT 60-67˚
  - ➢The occurrence rate of Pc5 is higher on the night side than on the dayside.
- Shi et al. (2018): wide range of MLAT
  - ➢This paper analyzed Pc5 waves with high time resolution data and showed an MLAT/MLT distribution.
- Wharton et al. (2019): MLAT 60-76˚
  - ➢This paper suggested a driving source with a wide frequency band because the frequencies seen by the radar and the magnetometer are different.



[Shi et al., 2018]

- These studies analyzed ULF waves in a single line-of-sight direction.
- Few studies addressed occurrent characteristics depending on the wave mode.

Purpose

◆We analyze Pc5 waves with multiple line-of-sight beam data.

- Amplitude comparison → mode identification
- Phase comparison → m-number identification

◆Statistical analysis on geomagnetic latitude (MLAT) and local time (MLT) dependence of the Pc5 wave modes and m-number

➢Only the mode results are shown in this presentation.

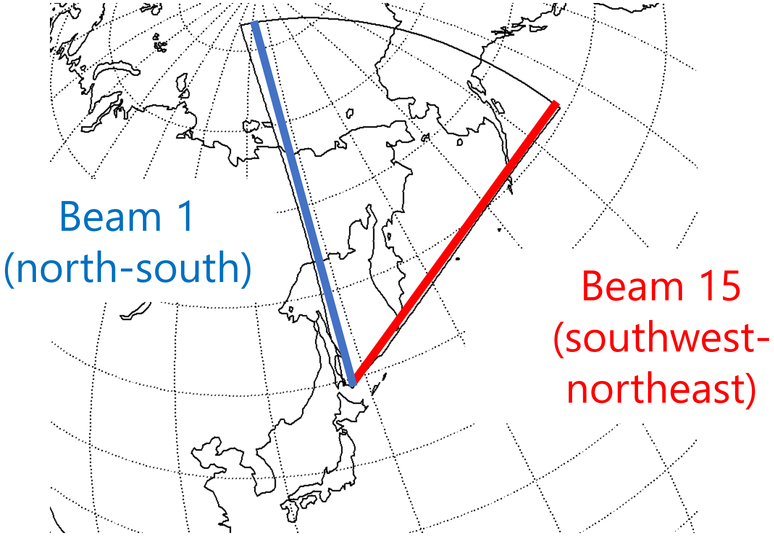
Instrumentation and Data

◆SuperDARN Hokkaido East Radar (HOK)

- FOV is covered with 16 beams and a line-of-sight plasma velocity is measured for each beam direction.
- Magnetic latitude range of FOV: ~40-80˚

◆We use only ionospheric backscatter echoes for this analysis.

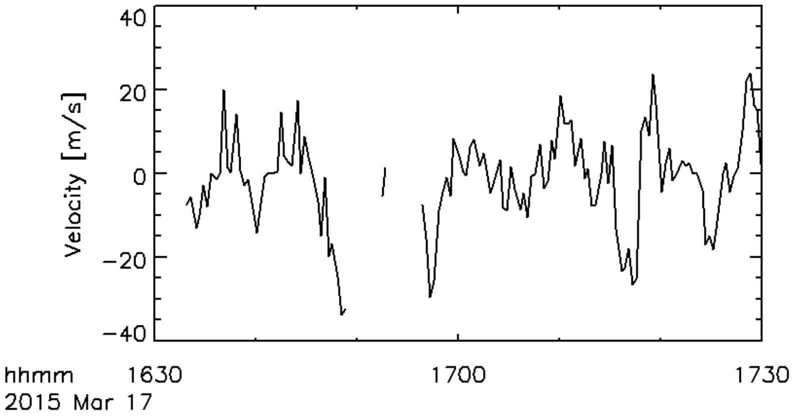
- Toroidal Pc5 waves cannot be found in ground/sea backscatter data.
- The results in this study are limited to the nighttime.



Method: Lomb-Scargle Periodogram

The Lomb-Scargle periodogram has a significant advantage in that it can easily be applied to unevenly sampled data with data gaps.

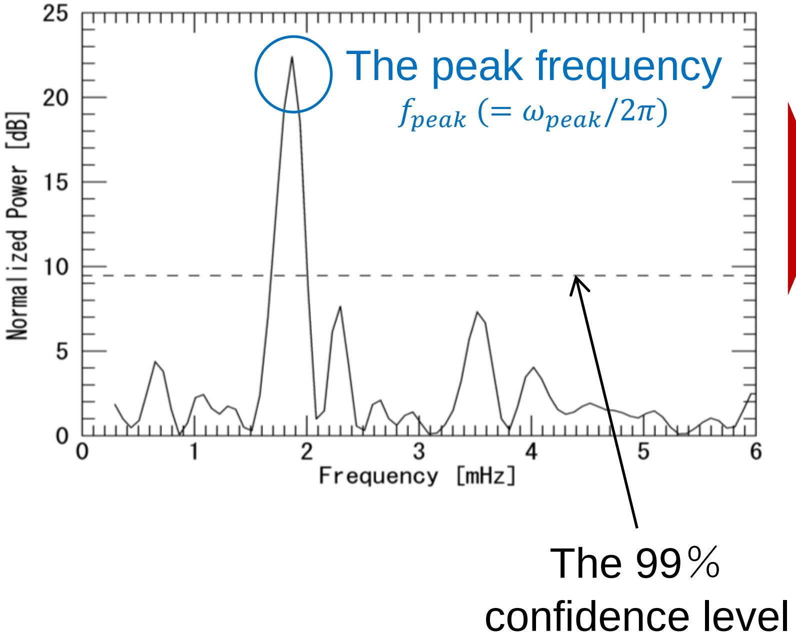
Median high-pass filtered ionospheric Doppler velocity data

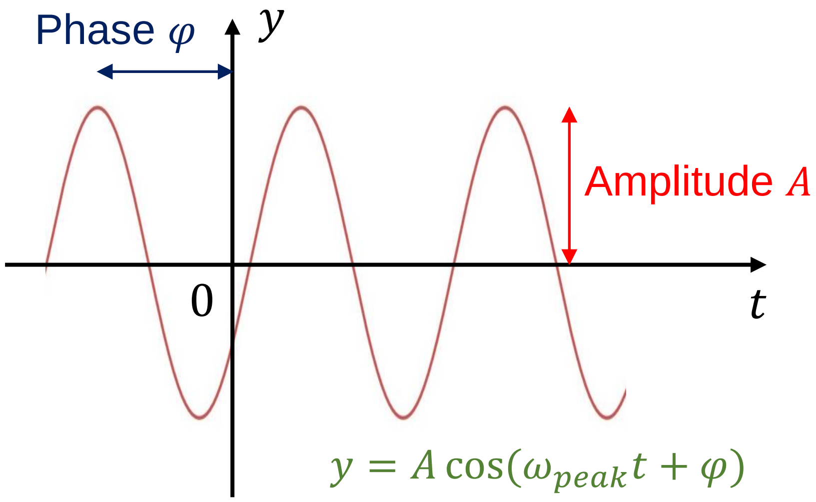


1-hr interval

incremented by 15 min iteratively

Lomb-Scargle Normalized Periodogram

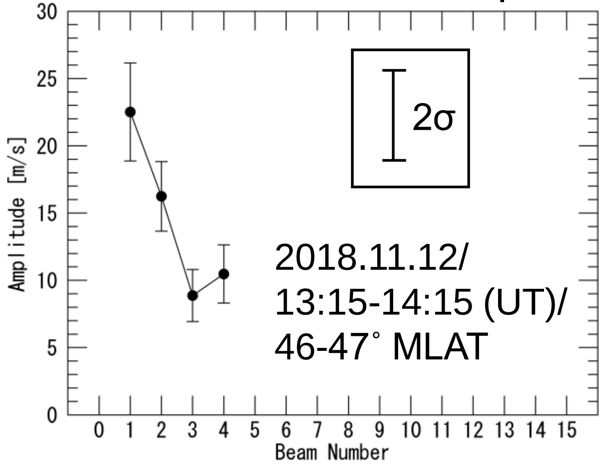




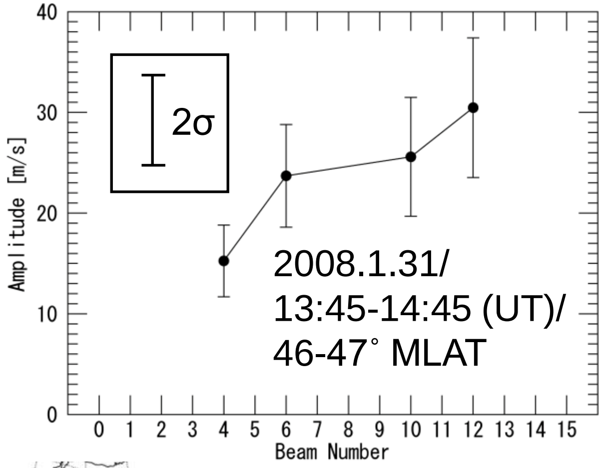
Method: Mode and M-number Identification

◆We identify the mode of Pc5 by comparing the amplitudes at the peak frequency among different beams at a fixed MLAT (1° interval), assuming that the Pc5 wave has a constant amplitude with the same mode over the observed longitudinal range.

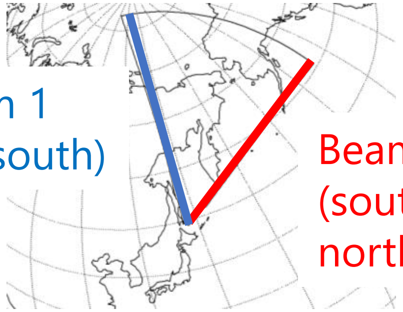
Poloidal mode wave amplitude



Toroidal mode wave amplitude

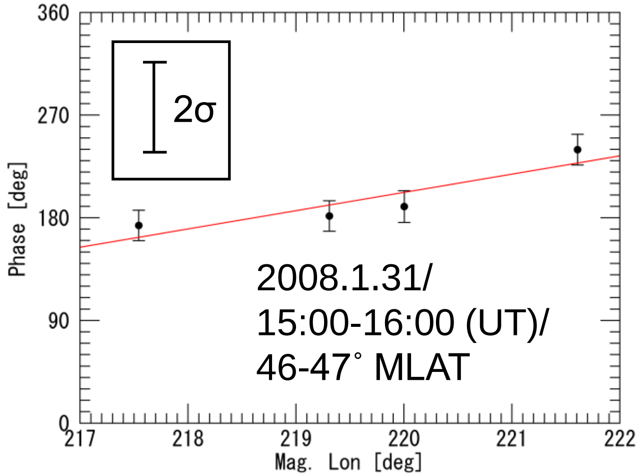


Beam 1
(north-south)



Beam 15
(southwest-
northeast)

◆We identify the m-number of Pc5 by comparing the phases among different geomagnetic longitudes at a fixed MLAT (1° interval).



- m≃16
- Eastward propagation

Case Results

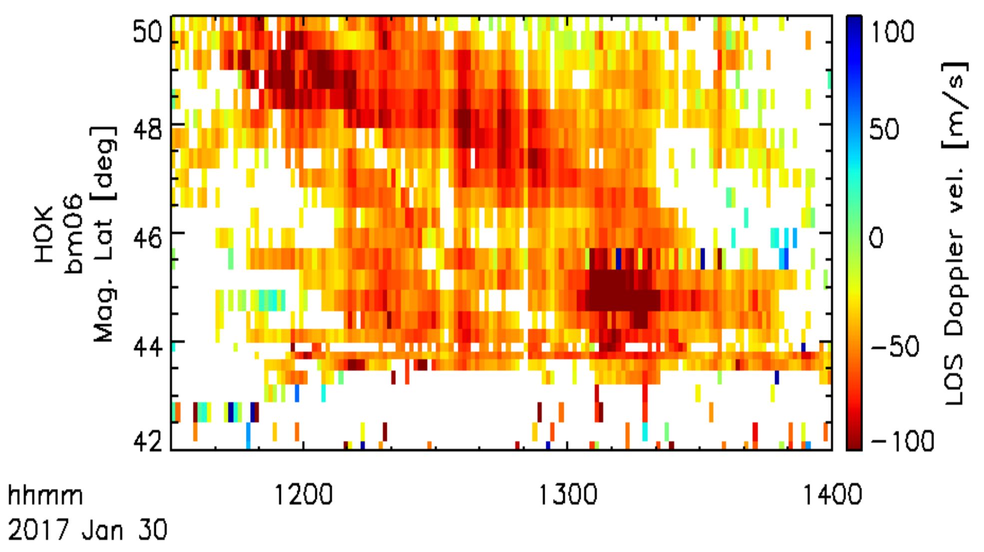
◆2017.1.30

◆The average peak frequency: ~2.0 mHz

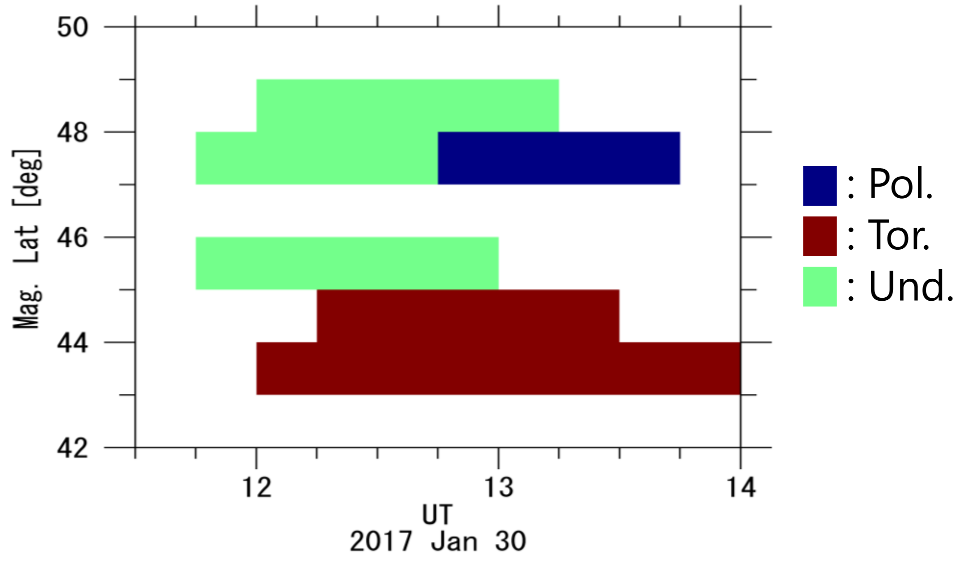
◆The results of the overlapping cells are average mode and m-number.

- Poloidal & Toroidal → Undefined
- Toroidal & Undefined → Toroidal

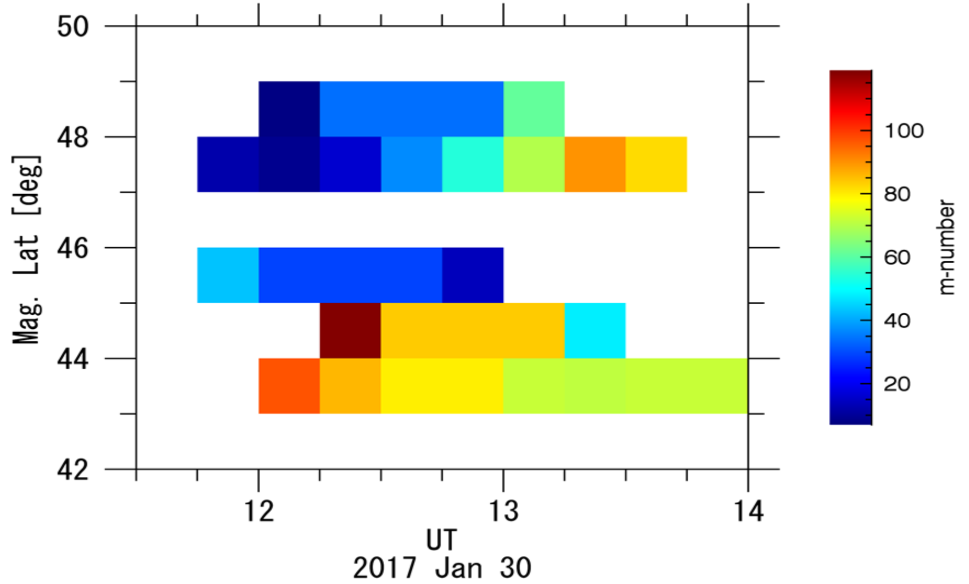
Range-Time-Intensity plot



The Pc5 wave mode results



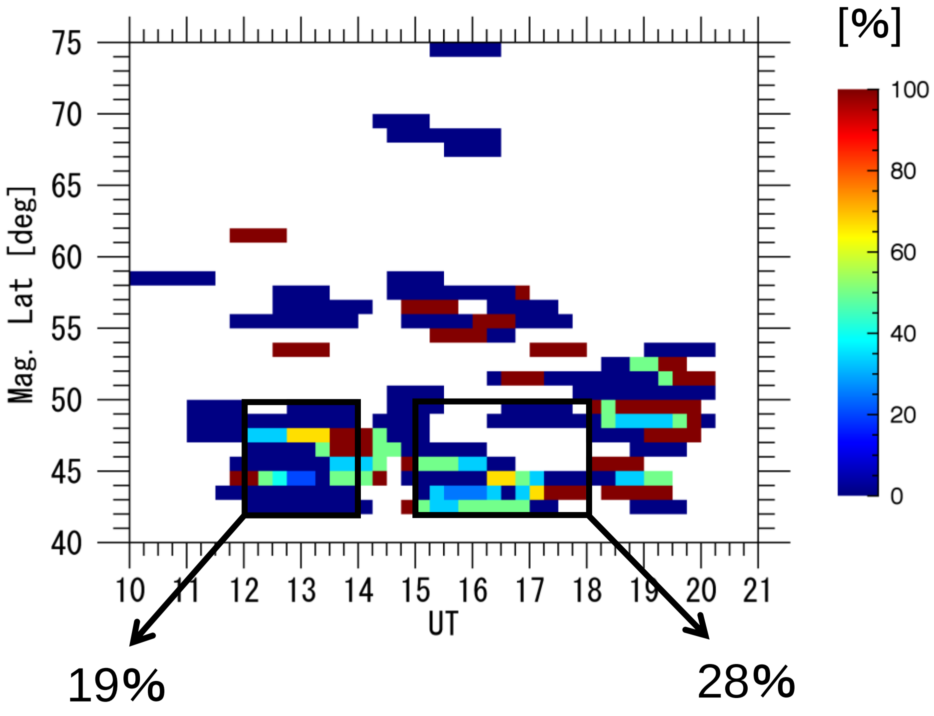
The Pc5 wave m-number results



Statistical Results

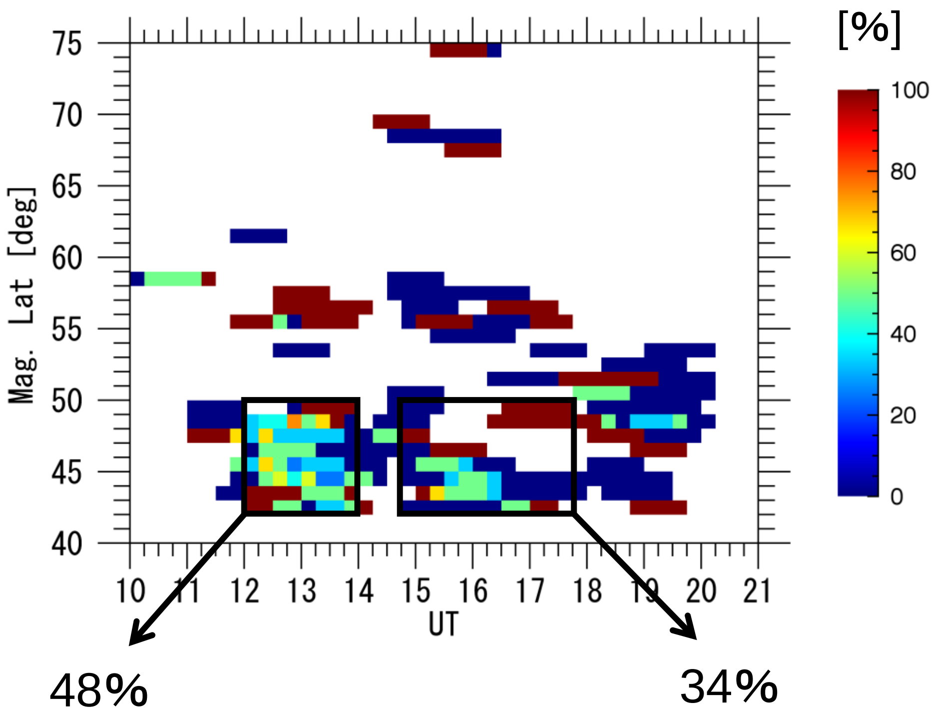
◆Analysis period: 2011-2020 (32 events)

Occurrence rates of Poloidal mode Pc5 waves
(only ionospheric backscatter echoes)



MLT ≃ UT + 9

Occurrence rates of Toroidal mode Pc5 waves
(only ionospheric backscatter echoes)



The occurrence rate of toroidal mode Pc5 waves is higher than that of poloidal mode during 21-23 MLT and during 0-3 MLT in the range of 42-50˚ MLAT.

Discussion

Comparison with Liu et al. (2009)

◆Liu et al. (2009) used electric and magnetic field measurements from the THEMIS satellite.

◆From Figure 7 of Liu et al. (2009), we can see that the occurrence rate of toroidal mode Pc5 waves is higher than that of poloidal mode during 21-23 MLT and 0-3 MLT, in agreement with our results.

◆Caution

- Target magnetic latitude
  - ➢Liu et al. (2009): L>~5 (MLAT>~63.4˚)
  - ➢Our study: 42-50˚ MLAT
- Our statistical results in the target latitude region of Liu et al. (2009) have few data points.

Fig. 1

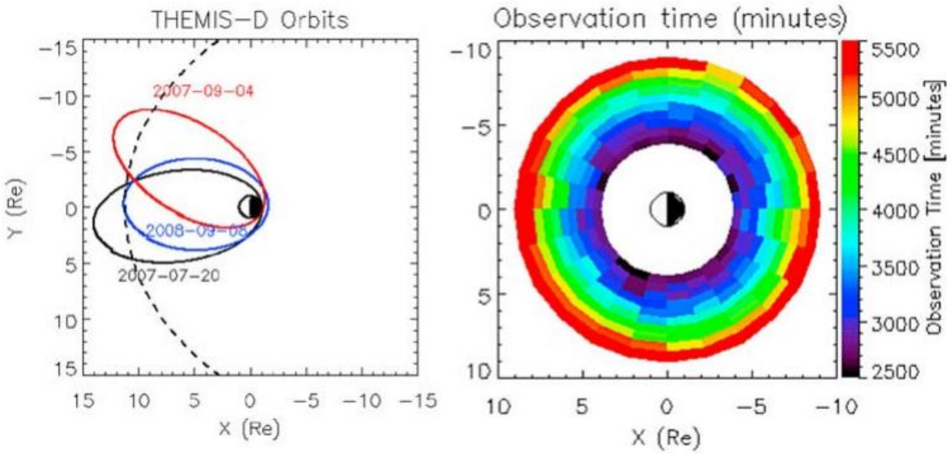
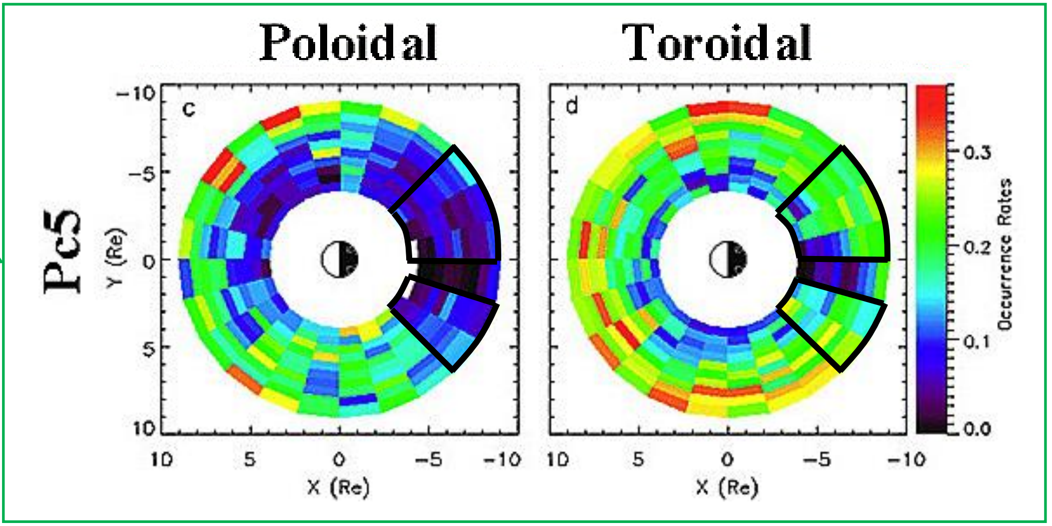


Fig. 7



[Liu et al., 2009]

Conclusions

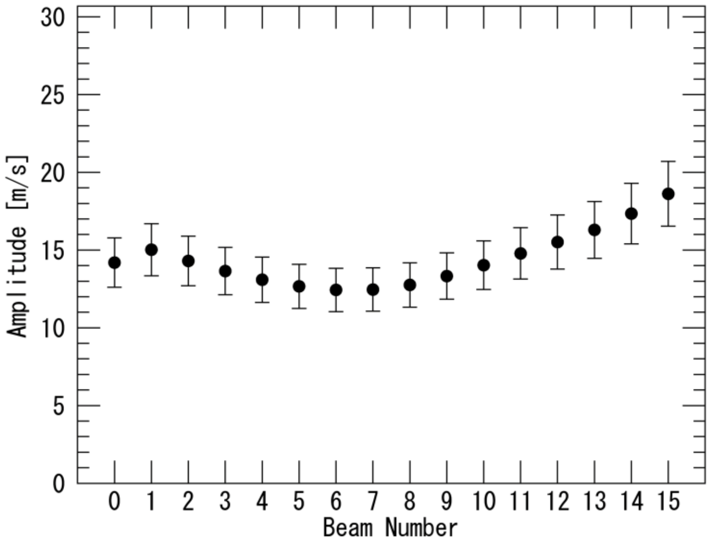
◆The occurrence rate of toroidal mode Pc5 waves is higher than that of poloidal mode during 21-23 MLT and during 0-3 MLT in the range of 42-50˚ MLAT, in agreement with the statistical MLT results of Liu et al. (2009).

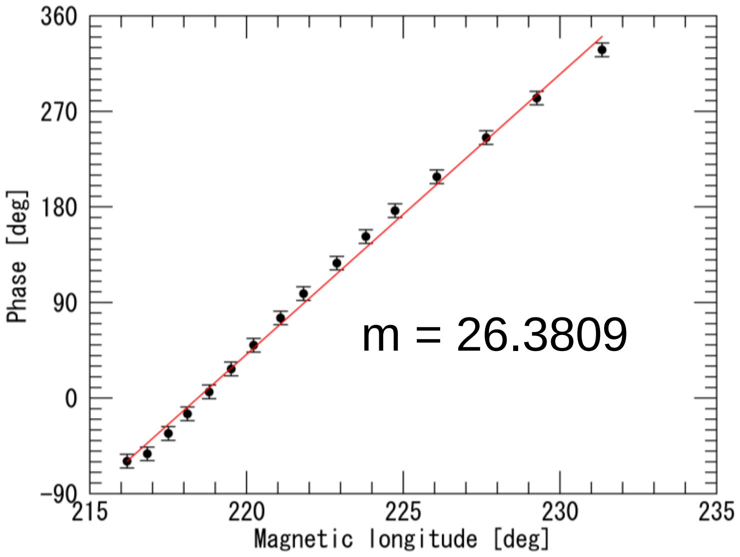
◆To the best of our knowledge, it is the first study on the MLAT and MLT dependences of the Pc5 wave modes in the midlatitude region with SuperDARN.

Future Work

◆We started simulating the amplitude and phase of the Doppler velocity at each beam using the modeled mode-coupled Pc5 waves with various parameters such as the poloidal/toroidal wave amplitude ratio and m-number.

Parameters
- Frequency: 2.0 mHz
- Poloidal wave amplitude: 15 m/s
- Toroidal wave amplitude: 30 m/s
- Phase difference: 120°
- M-number: 20
- Magnetic latitude: 45-46°





Undefined mode in this study

We discussed the error.

◆We are evaluating our statistical analysis results by comparing with the model simulation results.