2022 SuperDARN Research Meeting

Study of polarization and m-number characteristics of ULF waves in the Pc5 frequency range observed by SuperDARN radars

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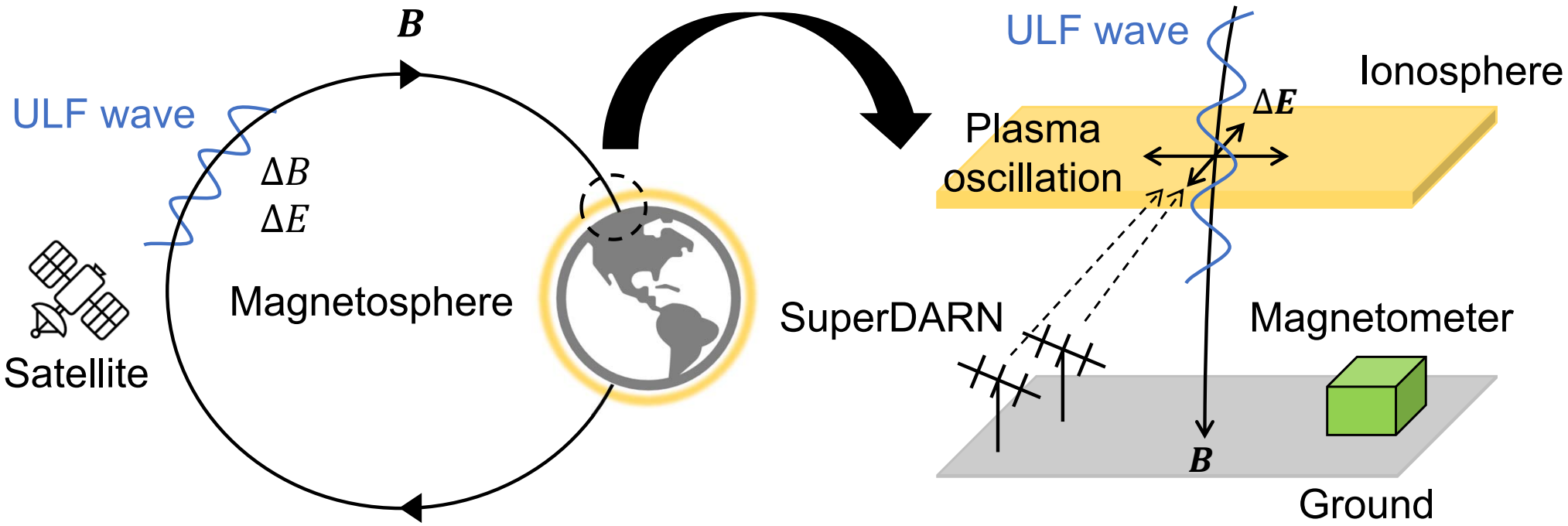
Introduction: ULF wave



◆Ultralow Frequency (ULF) waves are mainly excited 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

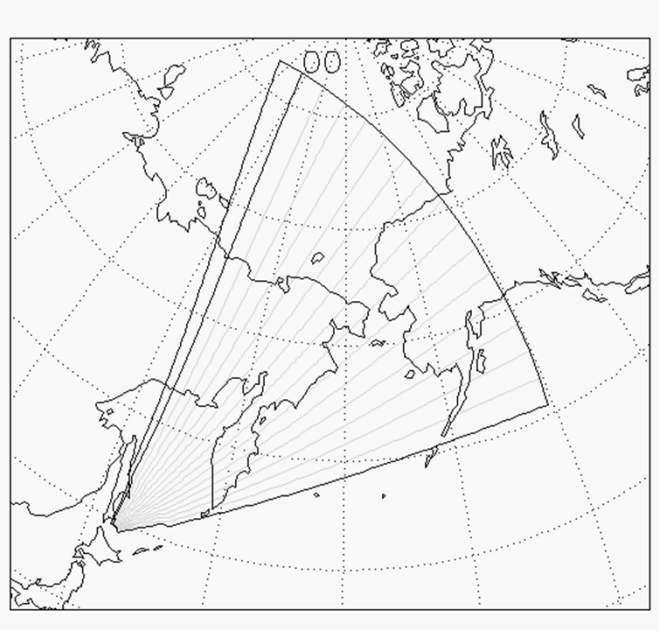
Introduction: Previous Research (Motivation)

◆Studies of ULF waves observed in the ionosphere

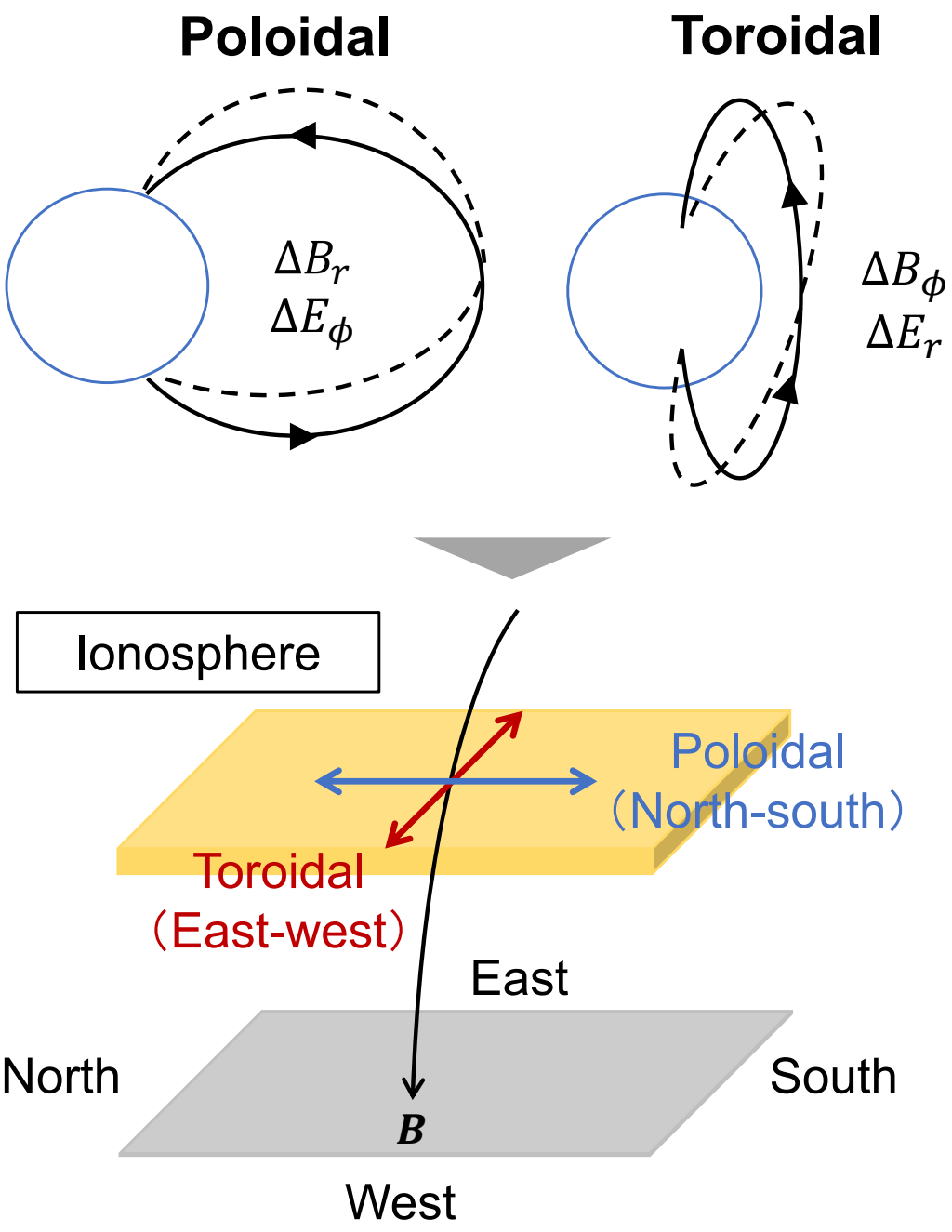
- Simple MLAT/MLT occurrence distribution is known from previous studies[e.g., Shi et al., 2018]
- More detailed distribution of MLAT/MLT occurrence, focusing on oscillation direction, etc., remains to be clarified.

◆Previous studies of ULF waves with SuperDARN have not explicitly combined observations in different beams.

- Can we analyze the oscillation direction based on the difference between beams?
- Are there any parameters that can be analyzed by taking advantage of SuperDARN 2D observation?

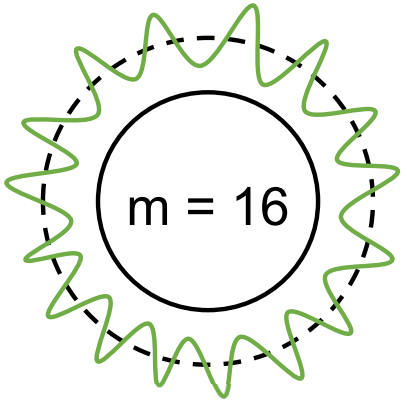


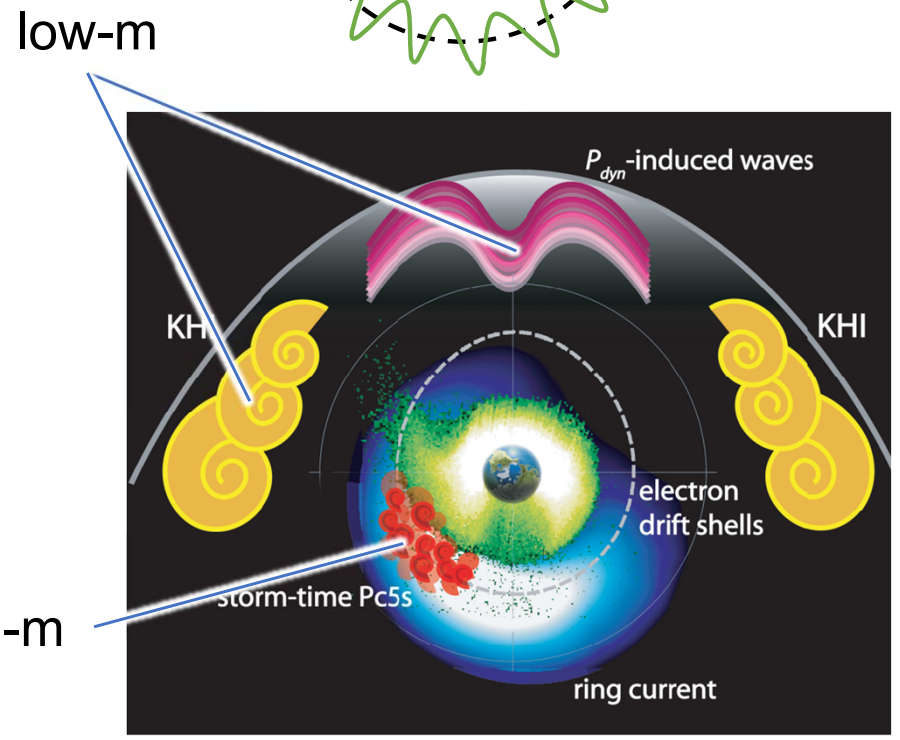
Introduction: Polarization (Oscillation Direction) and m-number



m-number

- azimuthal wave number
- help to understand driving sources





[Ukhorskiy et al., 2009]

Introduction: Purpose

◆Analysis of ULF waves observed in the ionosphere by combining multiple beam direction components of SuperDARN

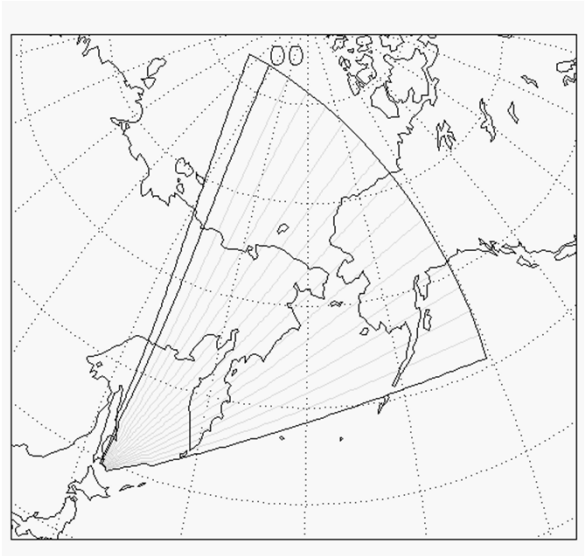
- Amplitude comparison ➢ polarization identification
- Phase comparison ➢ m-number identification
- Only Pc5 (1.7-6.7 mHz) wave analysis

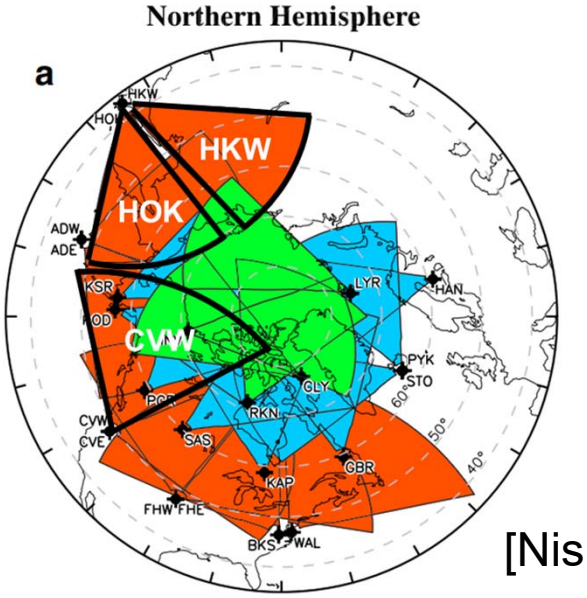
◆Statistical analysis of polarization and m-number of Pc5 waves observed in the ionosphere

Elucidation of the mechanism of Pc5 waves observed in the ionosphere

Method: Instrumentation

Super Dual Auroral Radar Network (SuperDARN) is ground-based HF radars that can measure the beam direction component of ionospheric plasma convection velocity.



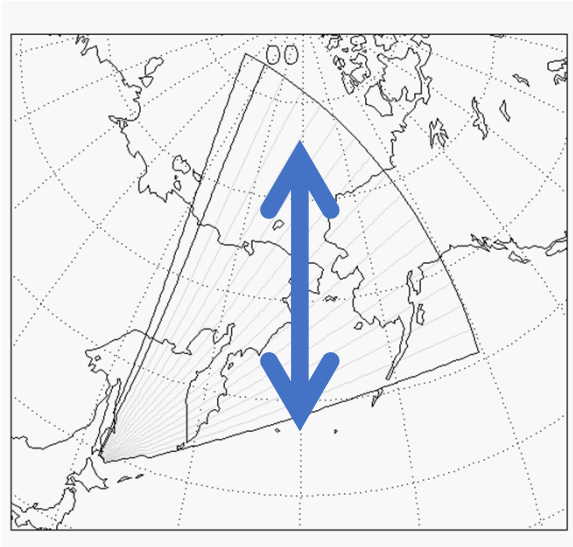


[Nishitani et al., 2019]

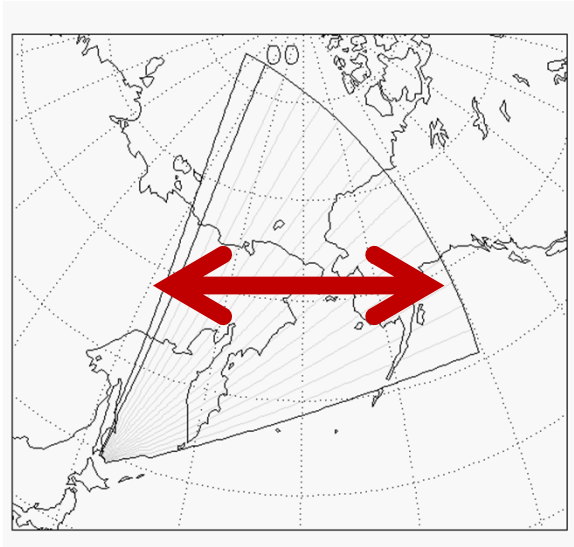
	Radar site	MLAT [°]	Analysis period
HOP	Hokkaido East (HOK)	36.76	2008-2020
HOP	Hokkaido West (HKW)	36.77	2015-2019
	Christmas Valley West (CVW)	49.50	2012-2018

Method: Polarization Identification

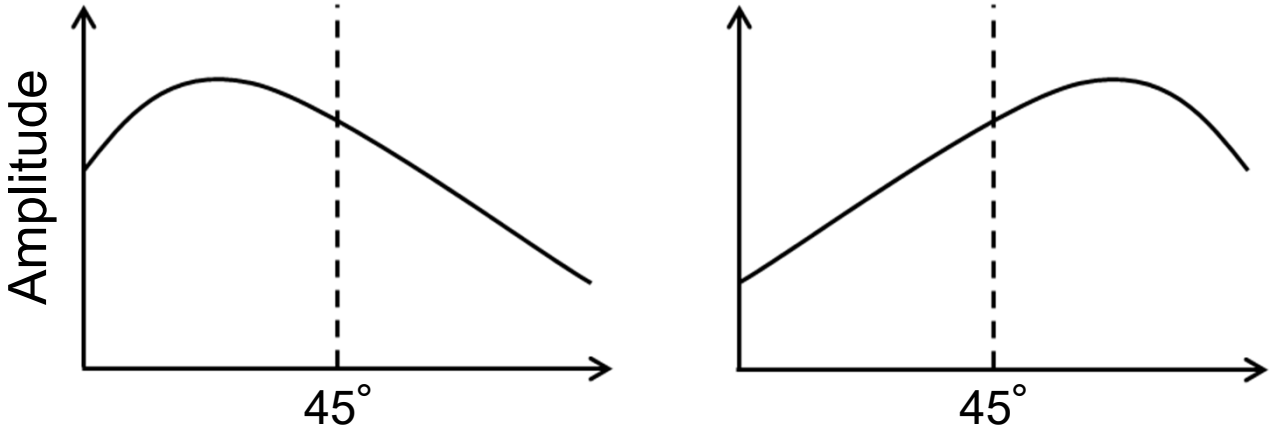
Poloidal



Toroidal

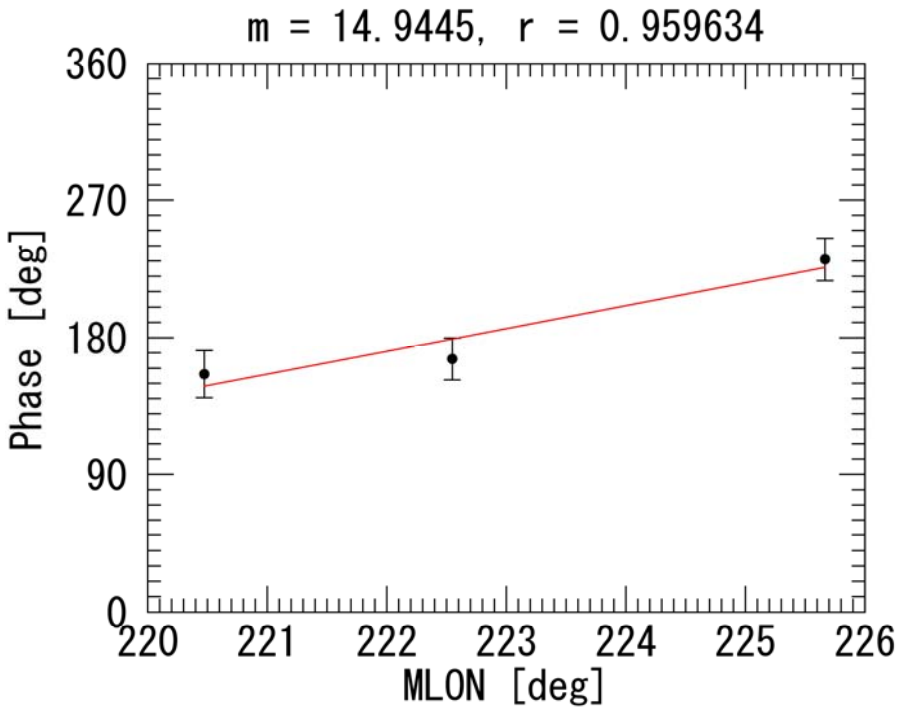


Theoretical curves were obtained by model calculations with varying parameters.



Determine the dominant component (poloidal or toroidal) by applying it to actual observations

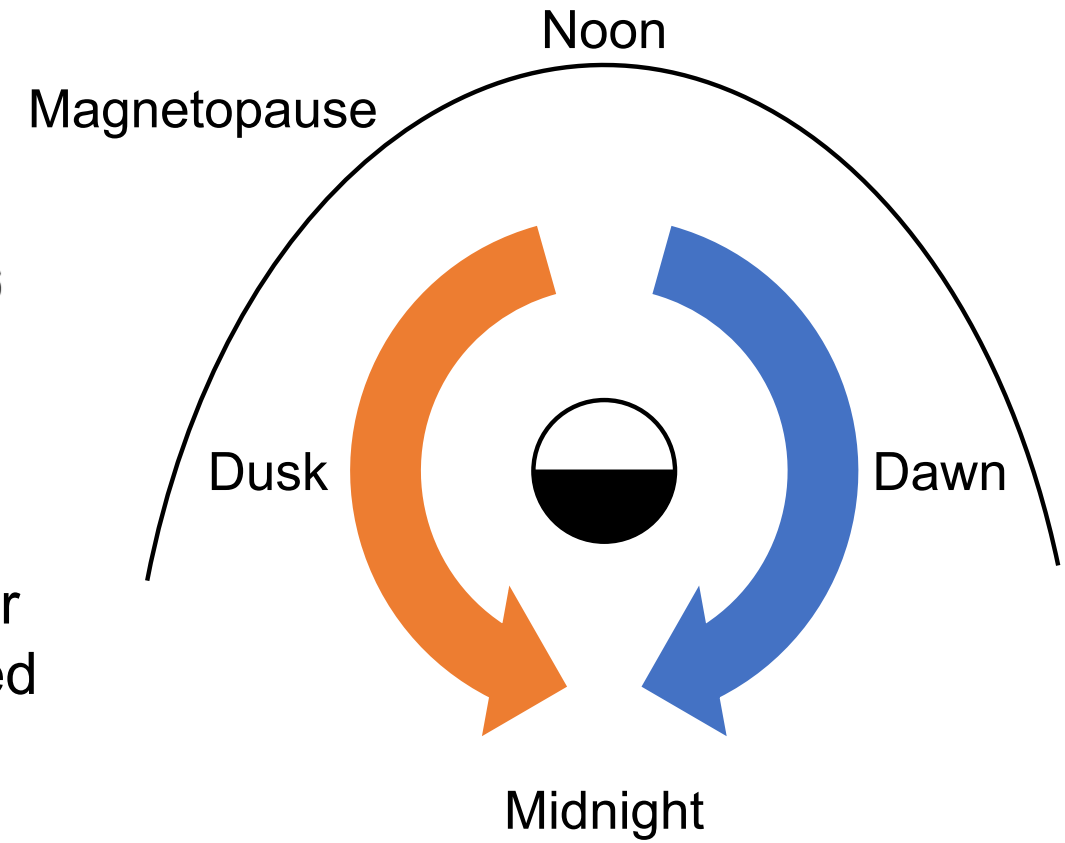
Method: m-number Identification



If the absolute value of the correlation coefficient is greater than 0.7, m-number is calculated from the slope.

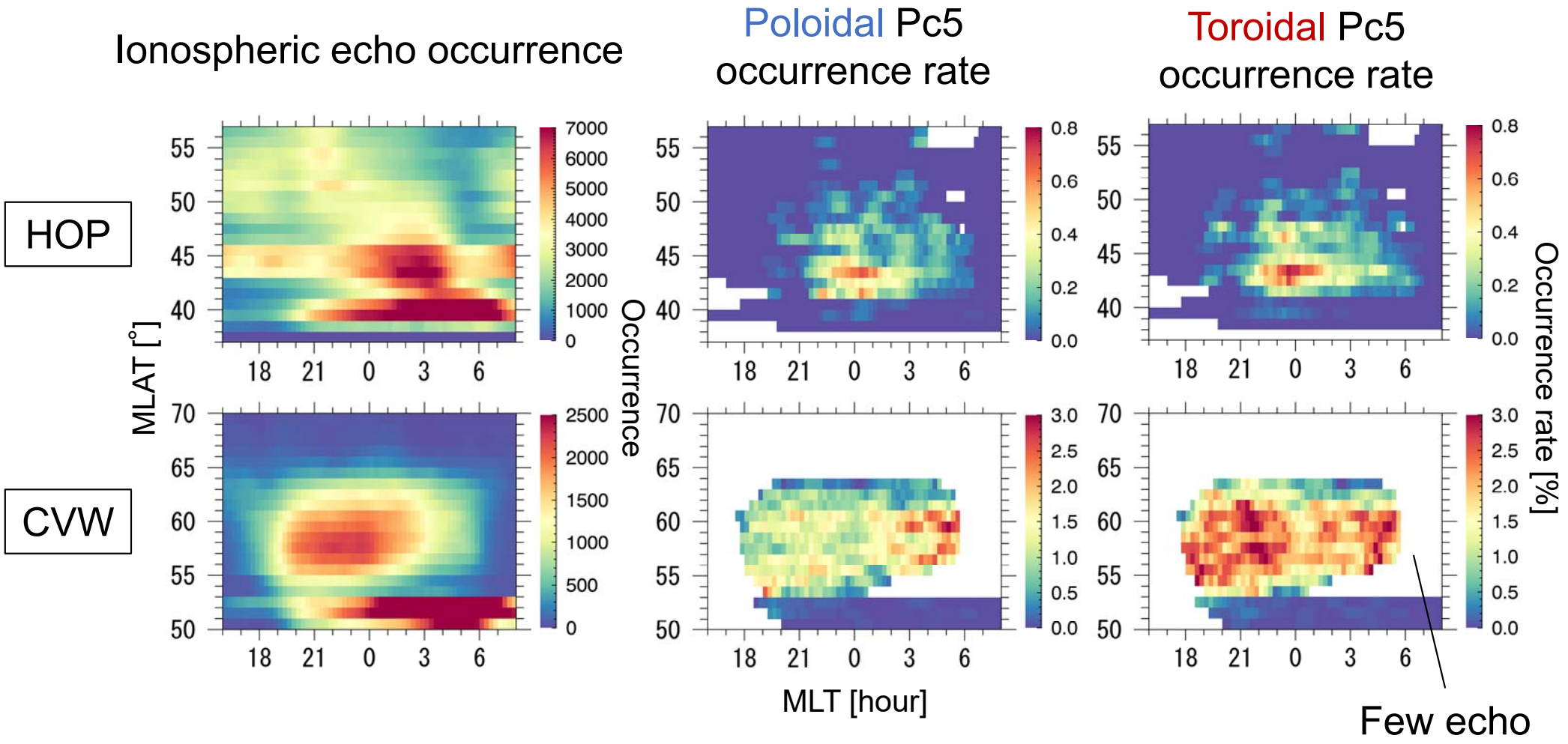
◆ Longitudinal Propagation

- m > 0: eastward propagation
- m < 0: westward propagation



Result: Polarization

- HOP：72（HOK、2008-2020）＋87（HKW、2015-2019）＝**159** events
- CVW：**533** events（2012-2020）

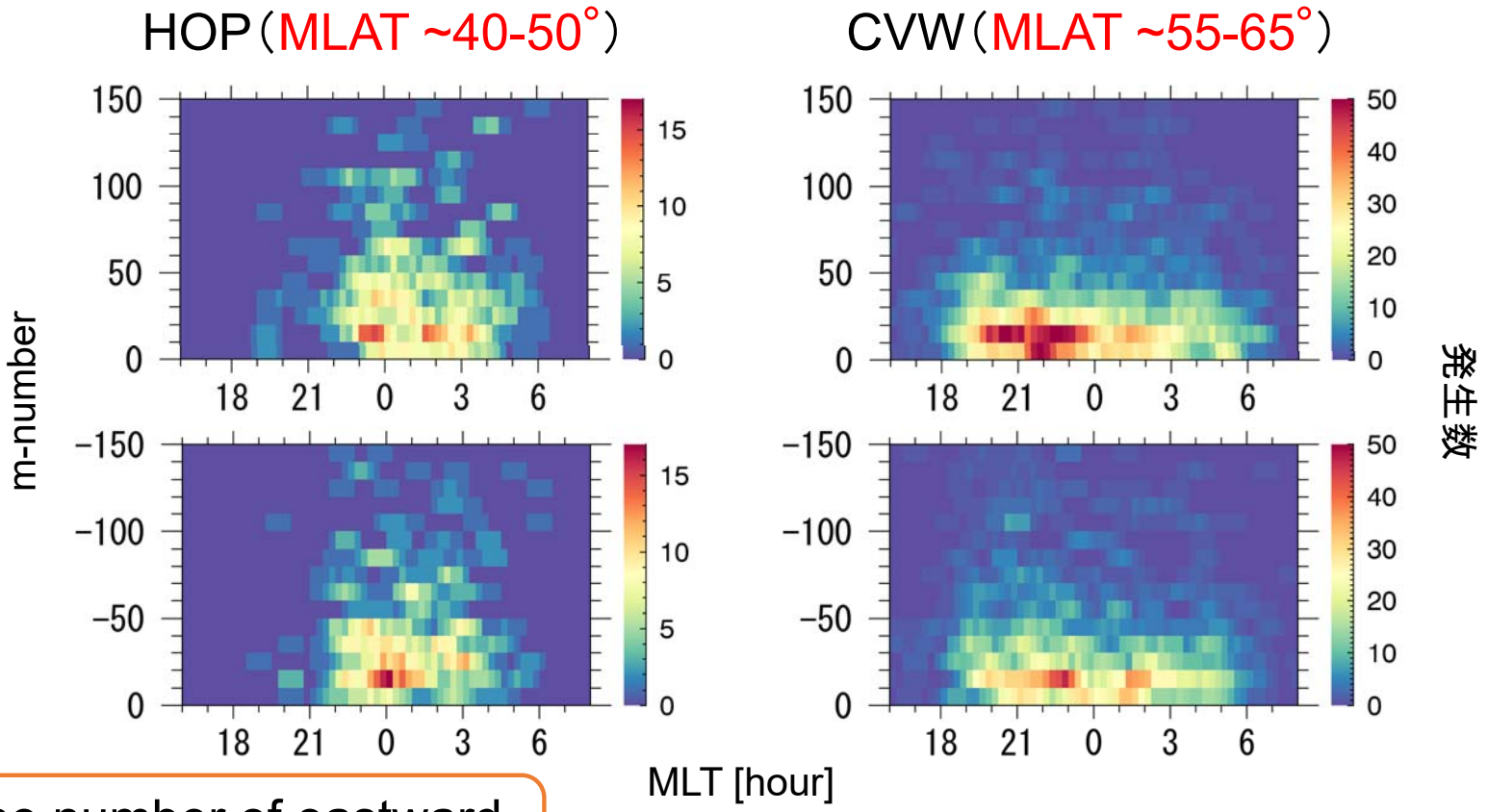


Toroidal waves occurred more frequently than poloidal waves.

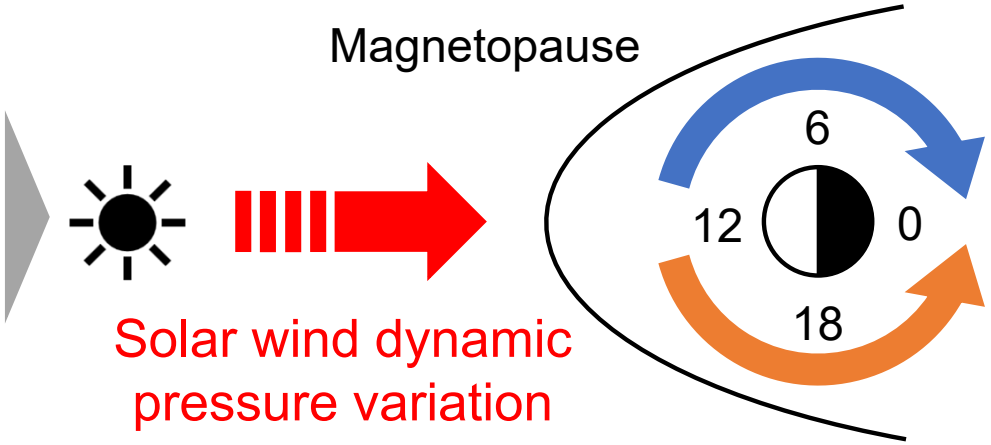
Result: m-number (Consideration of drive source)

Eastward propagation
(m > 0)

Westward propagation
(m < 0)

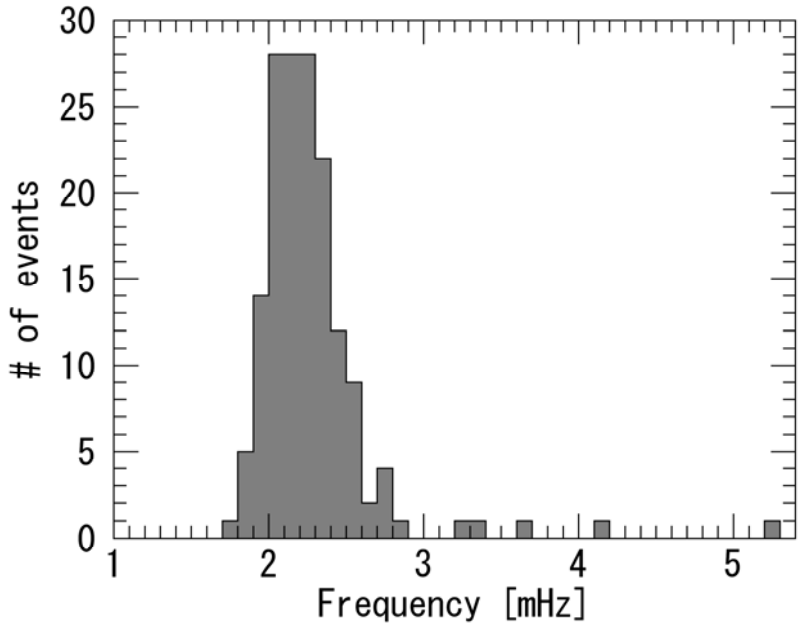


- In HOP data, the number of eastward and westward propagating waves is about the same around midnight.
- In CVW data, eastward propagation is more frequent from evening to midnight.
- No latitudinal dependence is seen in |m| (mode: 10-20).

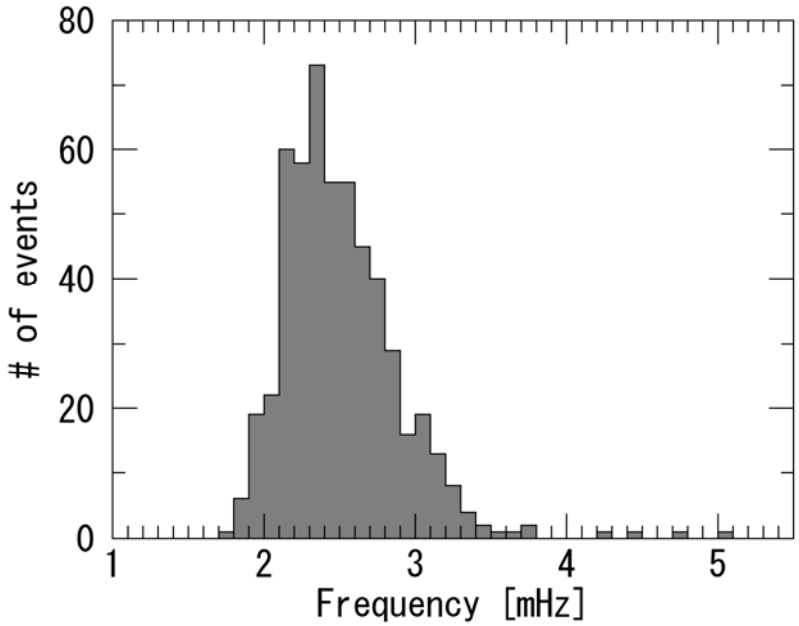


Result: Frequency (Verification of FLR)

HOP（MLAT ~40-50°）



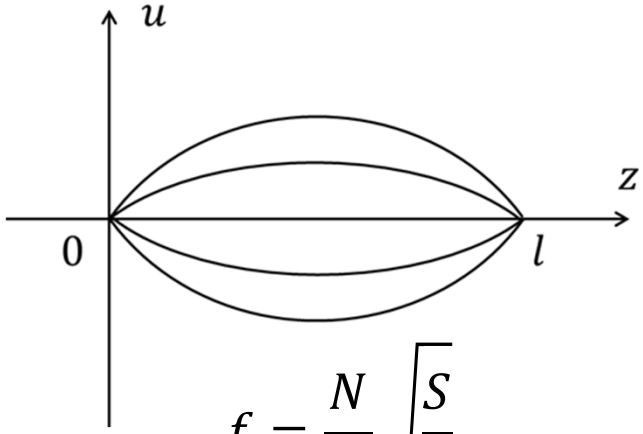
CVW（MLAT ~55-65°）



◆There is no magnetic latitudinal dependence of frequency.

◆<u>Field Line Resonance (FLR)</u>

- Standing Alfvén wave
- Inverse correlation between length of magnetic field lines (MLAT) and frequency



$$f = \frac{N}{2l}\sqrt{\frac{S}{\rho}}$$

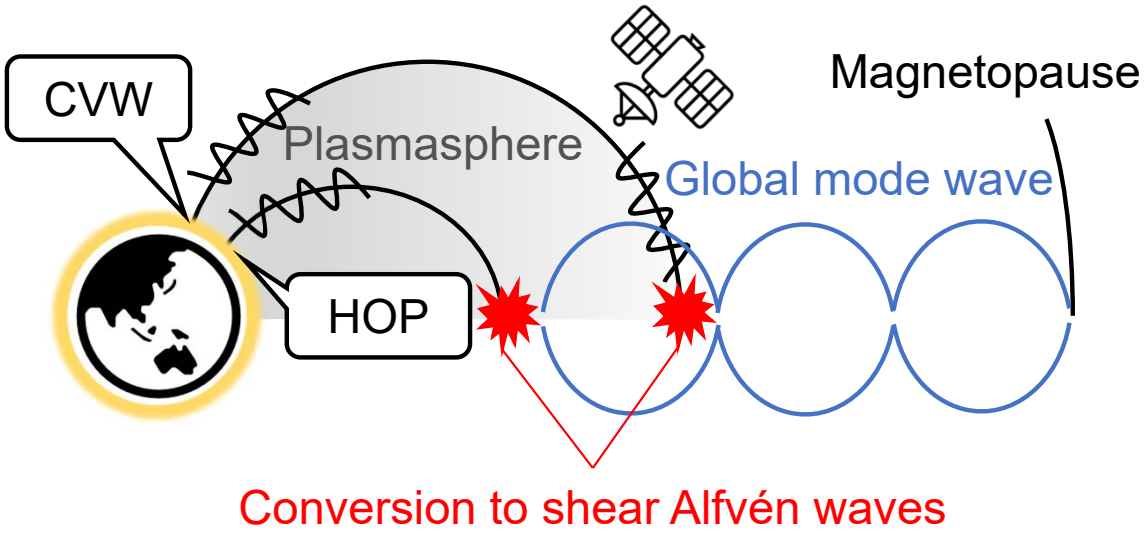
FLR is unlikely.

Discussion: Excitation Mechanism

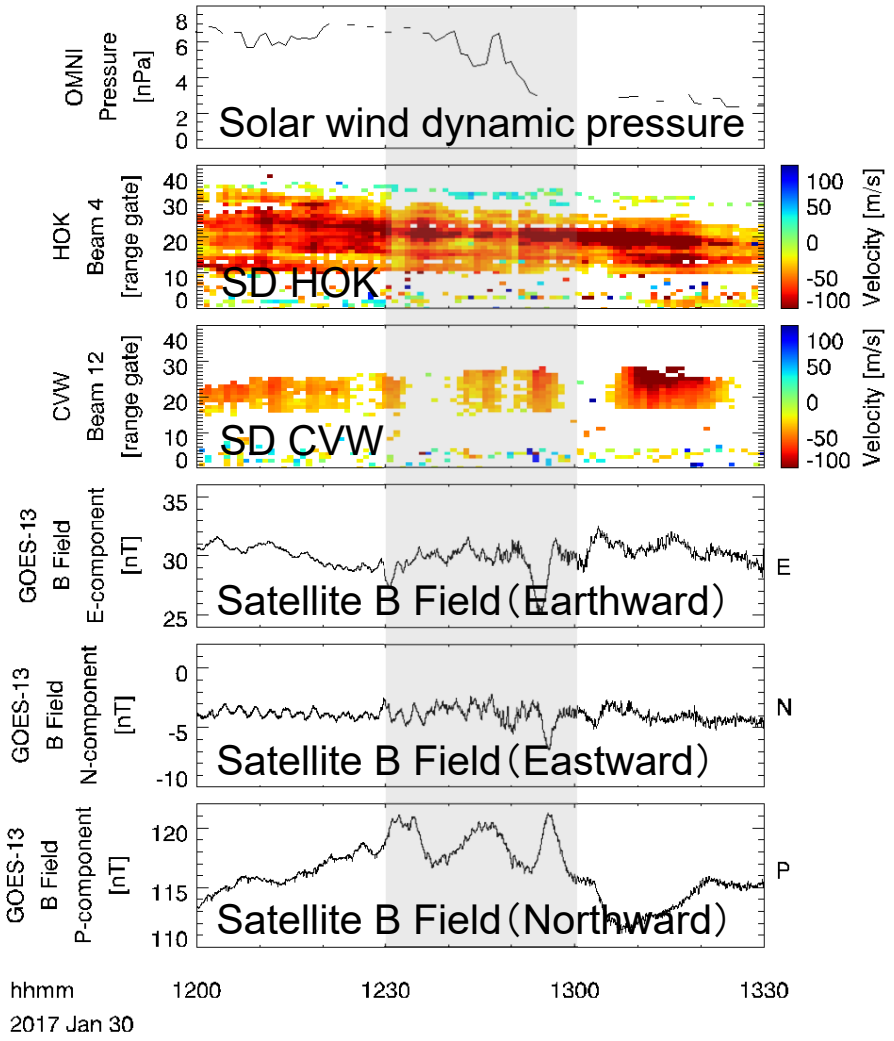
Global (cavity/waveguide) mode wave

- Solar wind dynamic pressure variations cause global Pc5 compressional oscillations in the magnetosphere.

1. Global mode waves are excited by solar wind dynamic pressure variations
2. Conversion to shear Alfvén waves
3. Propagation to the ionosphere



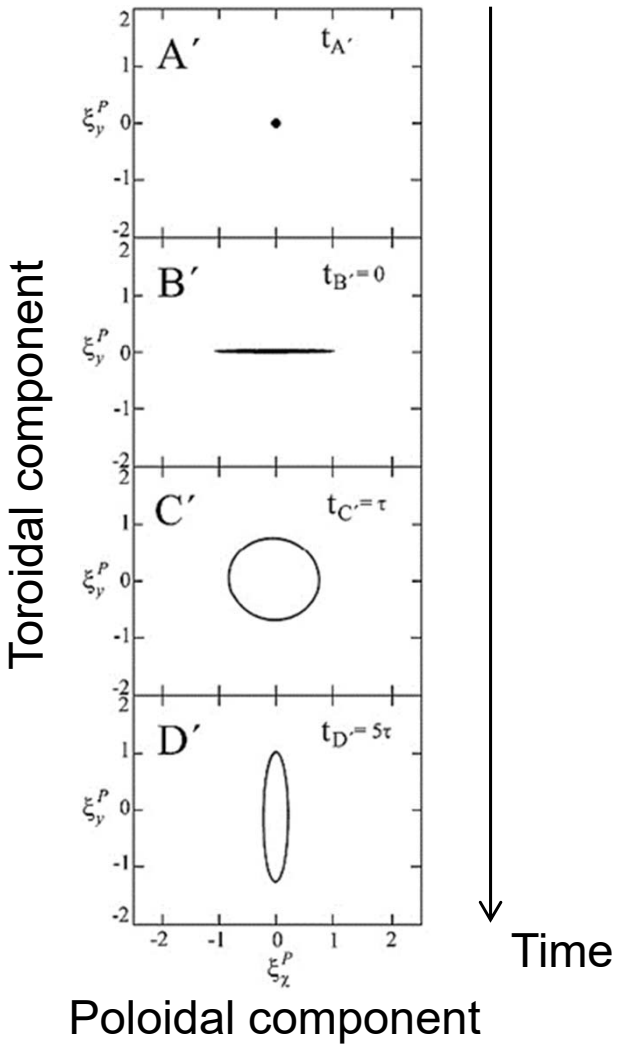
Example of global Pc5 observation

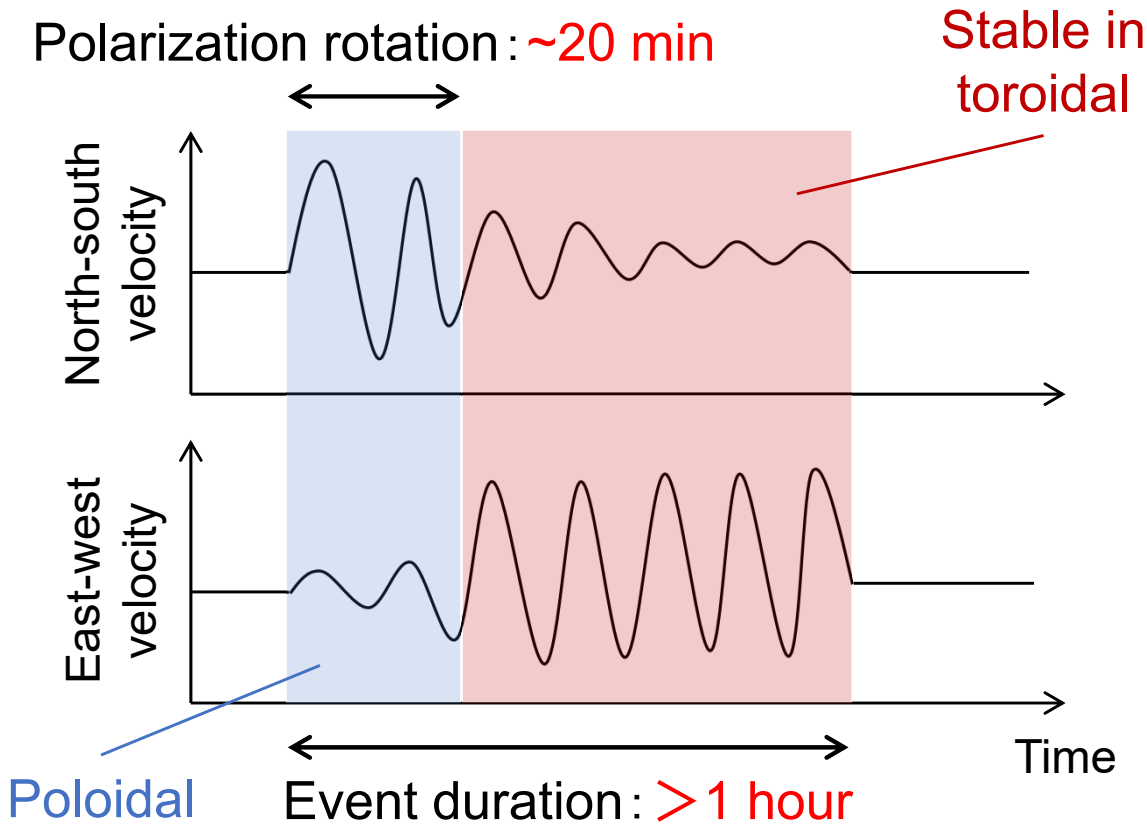


Discussion: Polarization

Polarization rotation : Poloidal waves are converted to toroidal waves over time.

Numerical simulation
[Mann & Wright, 1995]





Oscillation direction statistics would be expected to show that toroidal waves are observed more frequently than poloidal waves.

Conclusions

We identified the polarization and m-number of Pc5 waves observed in the ionosphere with SuperDARN and investigated their statistical characteristics.

- Toroidal waves occurred more frequently than poloidal waves.
  - As for the Pc5 waves observed in this study, which lasted for several hours, the toroidal waves had a longer duration than the poloidal waves due to polarization rotation, and statistics suggest that the toroidal waves were observed more frequently.

- No latitudinal dependence of m-number and longitudinal propagation characteristics suggest the solar wind dynamic pressure variations as the driving source.
- Since no latitudinal dependence of frequency was seen, it is unlikely to be related to FLR.
  - Pc5 waves observed in the mid-latitude (MLAT ~40-65°) ionosphere are presumed to be associated with the global mode waves rather than typical FLR.