SC が励起する長周期ULF波動とその磁力線共鳴の可能性：SuperDARN Hokkaido East radar観測例

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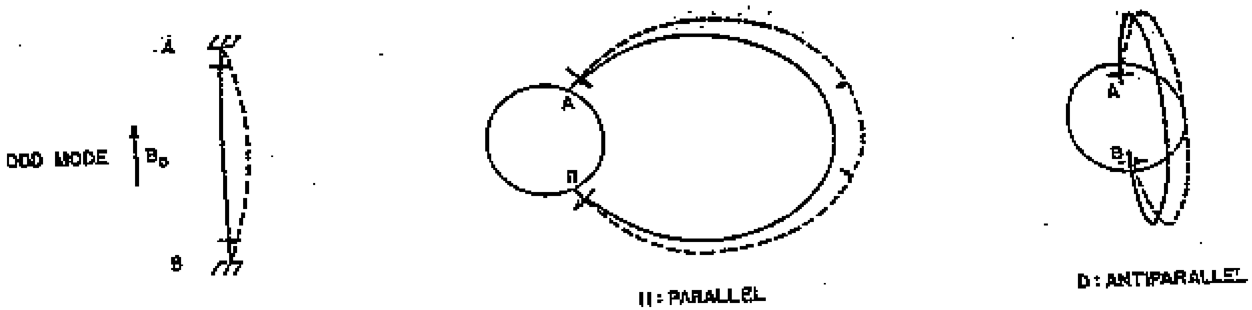
Outline:

- Background: Importance of identifying magnetospheric regions from the ground
- Geomagnetic pulsations caused by the field-line resonance (FLR)
- Case study (as shown in the above title)

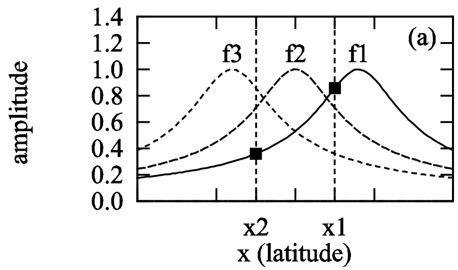
磁力線固有振動観測に基づくプラズマ圏密度推定

・地球起源の磁力線は固有振動する。



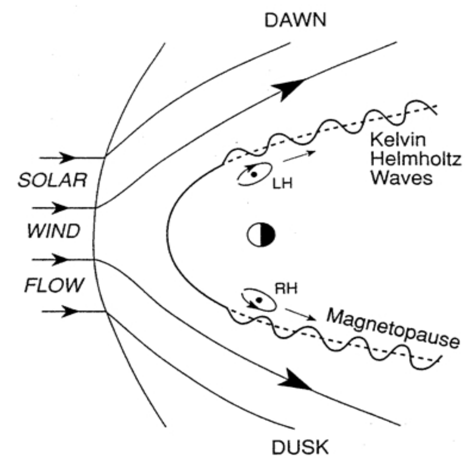
[Sugiura and Wilson, 1964]

・ギターの弦と同様に、「重い」磁力線ほどゆっくりと振動する。
→固有振動を地上観測し、その周波数から、磁力線に沿ってのプラズマ質量密度を推定可能である。

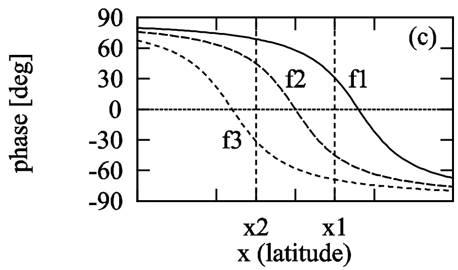


← 振幅の
緯度依存性

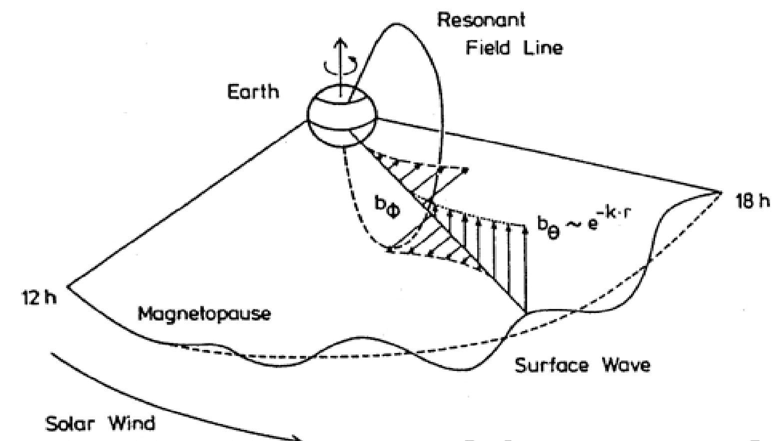
このパターンは Field-Line Resonance (FLR) によって作られる　[Southwood, 1974; Chen and Hasegawa, 1974]



[Hughes, 1994]



← 位相の
緯度依存性



[Glassmeier, 1995]

○What is (to be) seen by SuperDARN (review)

- As a result of FLR-driven pulsations, the ionospheric plasma should oscillate. The amplitude and phase of the oscillations are expected to follow the patterns predicted by the FLR theory.

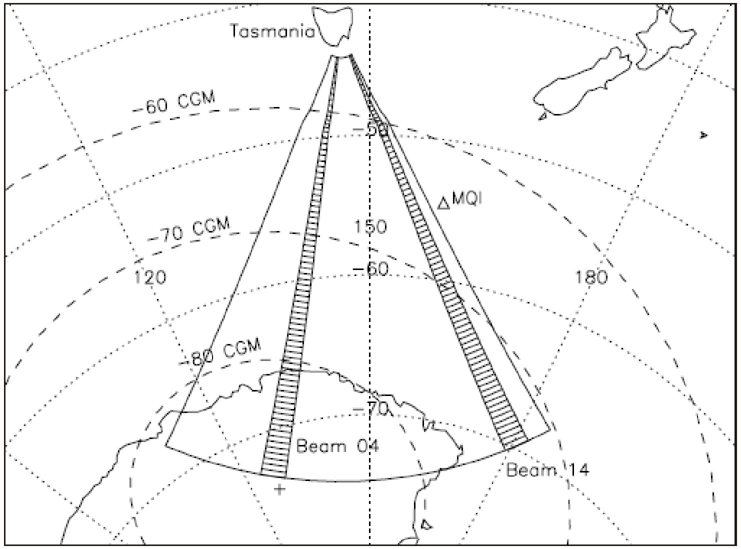
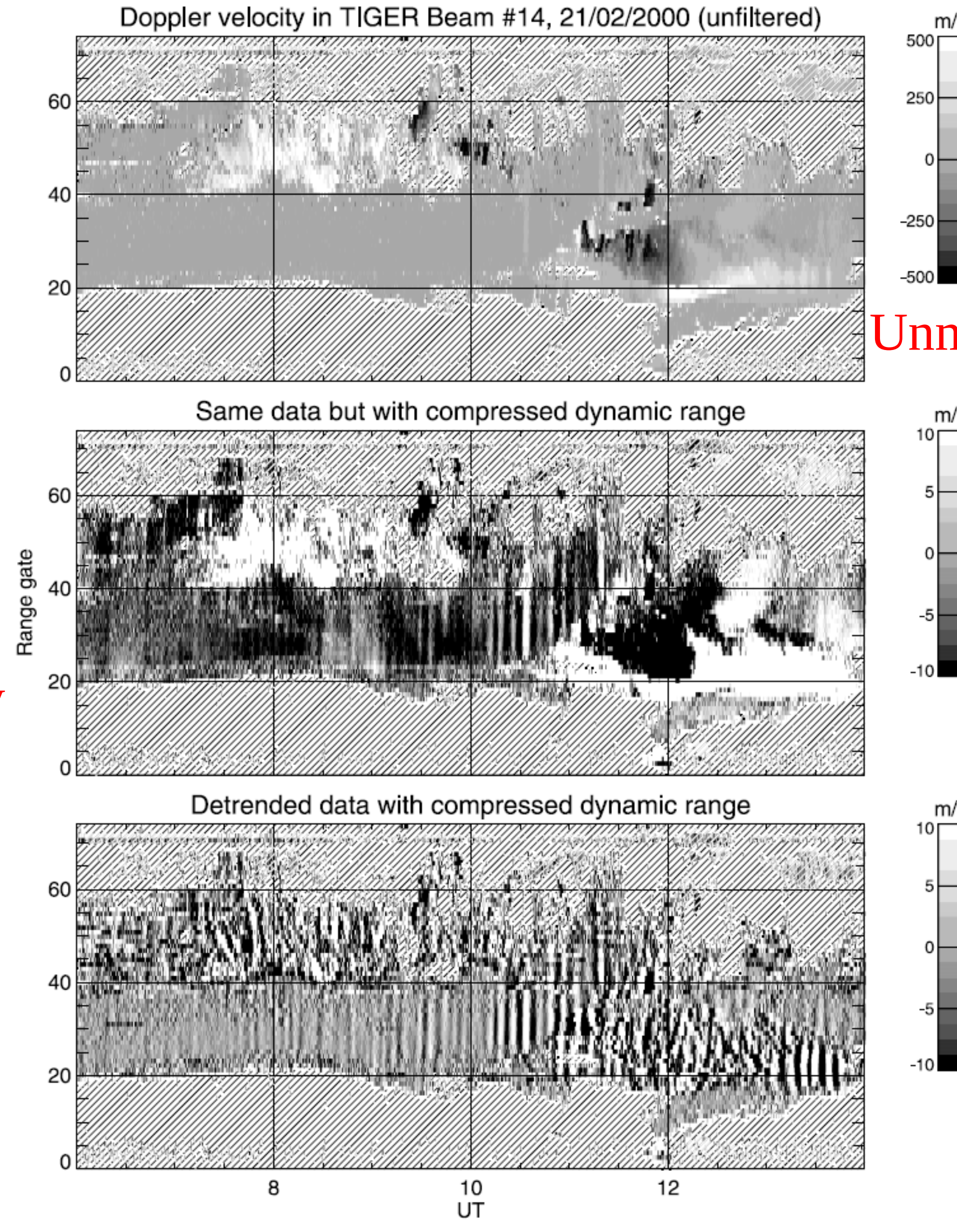


Figure 1. TIGER FOV in geographic coordinates. Triangle denotes Macquarie Island (MQI) magnetometer site.



Unmodified

Same data but with an artificially saturated amplitude scale

Trend is removed by using autoregressive smoothing (window size 600s).

[Ponomarenko et al., GRL, 2003]

Figure 2. Doppler velocity variations in beam 14 for 0600–1400 UT on February 21, 2000. Range-time cells with no valid data have diagonal shading. The top panel shows unmodified data obtained via FITACF procedure. The middle panel shows the same data but with an artificially saturated amplitude scale (±10 m/s). The bottom panel results from removing an autoregressive smoothing trend (window size 600 s) from the data and using the saturated amplitude scale.

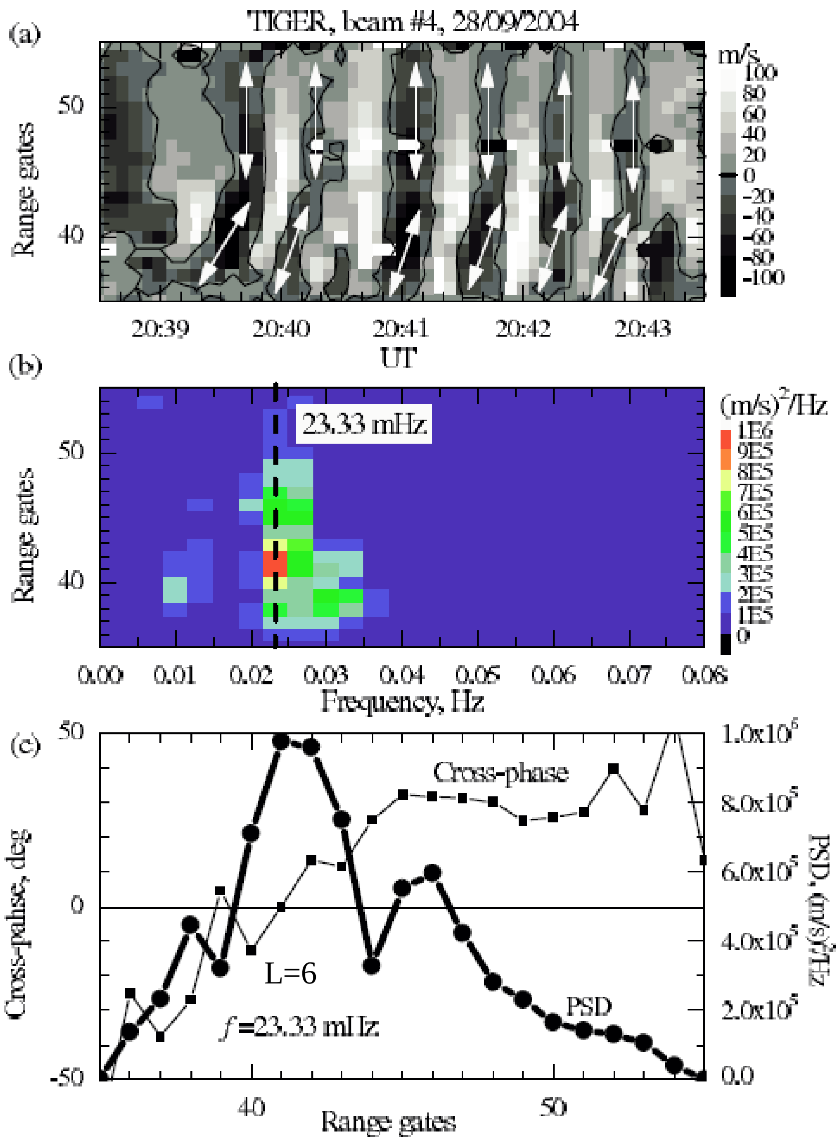


Fig. 5. Example of FLR-like variations in V_D over 20:38:30–20:43:30 UT. **(a)** Range-time dependence for V_D; white arrows show approximate alignment of the phase front. **(b)** Power spectral density; vertical dashed line corresponds to PSD maximum at 23.3 mHz. **(c)** Latitudinal profile of PSD and cross-phase at 23.3 mHz.

Range-time plot

Range-frequency plot of the phase-space density (PSD) of the wave (using all the data in the top panel)

Range-profile of PSD and the wave phase at the vertical line of the middle panel

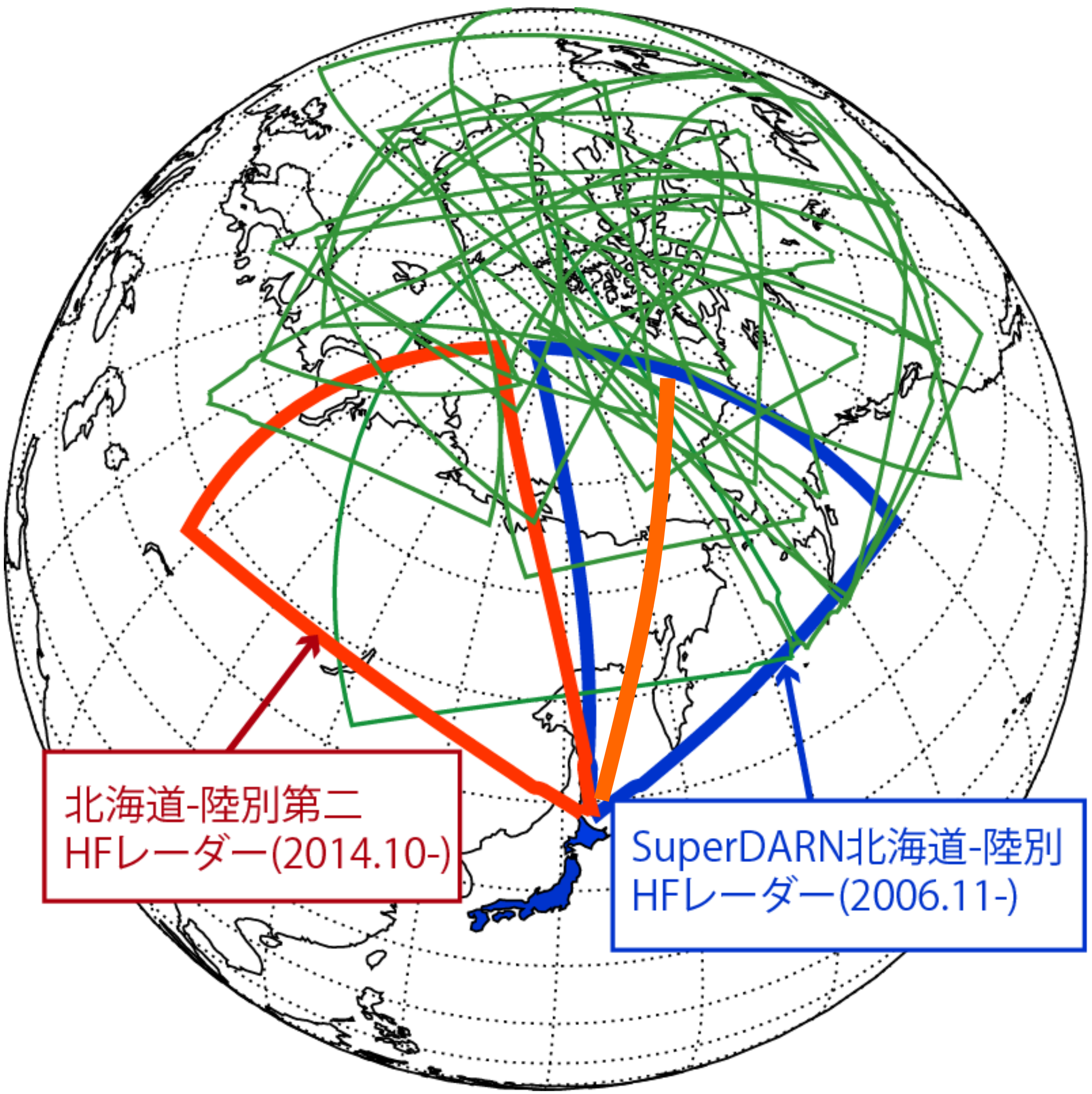
[Ponomarenko et al., ANGEO, 2005]

※ Points to note:

- So that sea-scattered signals show perturbations coherent with ULF waves, the part of the ionosphere which reflects the sea-scattered signals should oscillate in the vertical direction by the ULF waves.
  (⇔ Ionospheric echoes can show ionospheric plasma motions in the horizontal direction.)
- Toroidal-mode FLR waves do not move the ionosphere in the vertical direction, while
- Poloidal-mode FLR waves move the ionosphere in the vertical direction (because the ambient field lines are tilted in the north-south direction); thus,
- The observed FLR should be a poloidal-mode FLR (as is also stated by the authors of the paper).

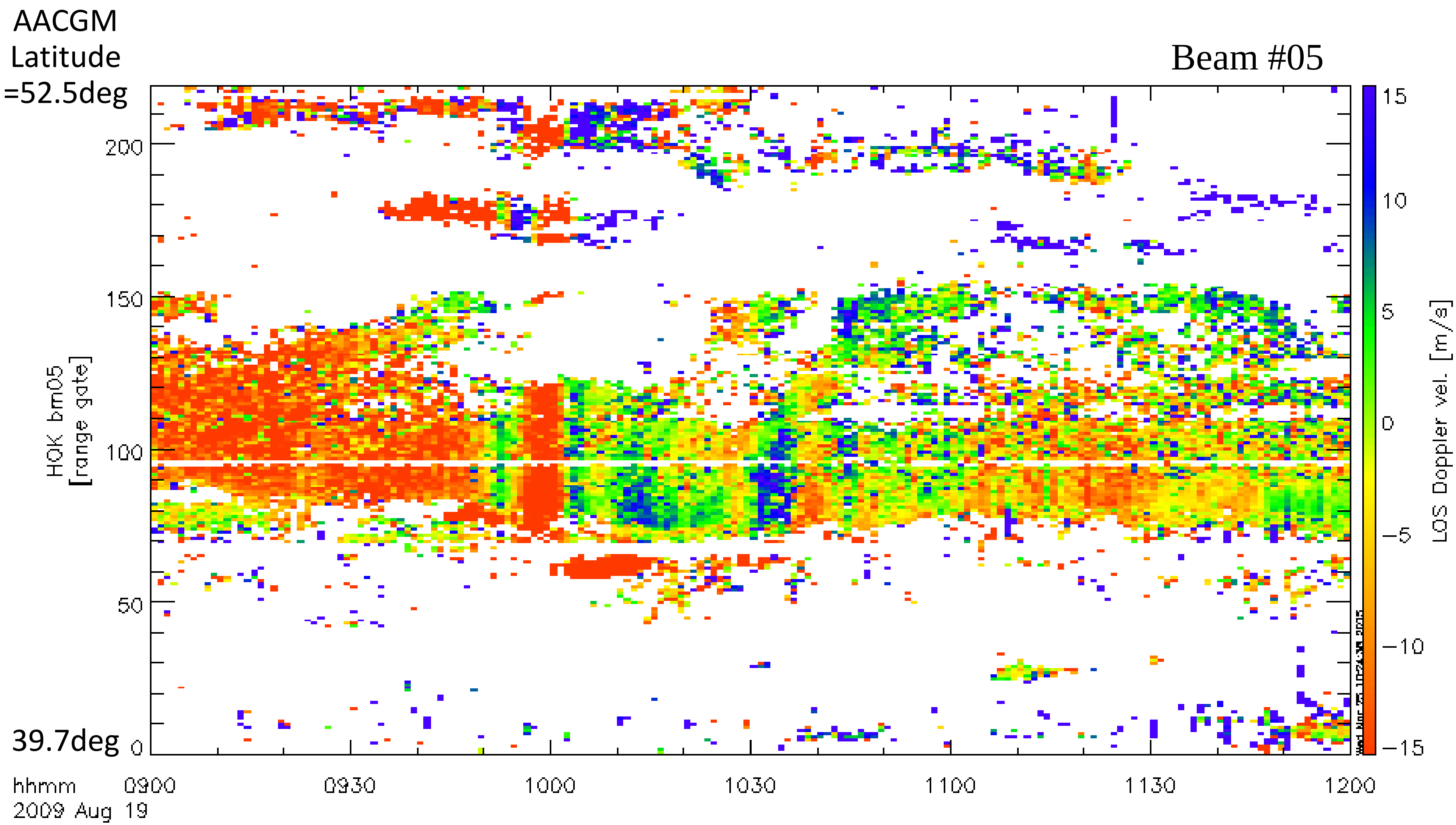
Here we report a possible SC-triggered waves including FLR effects, observed by the SuperDARN Hokkaido East radar.

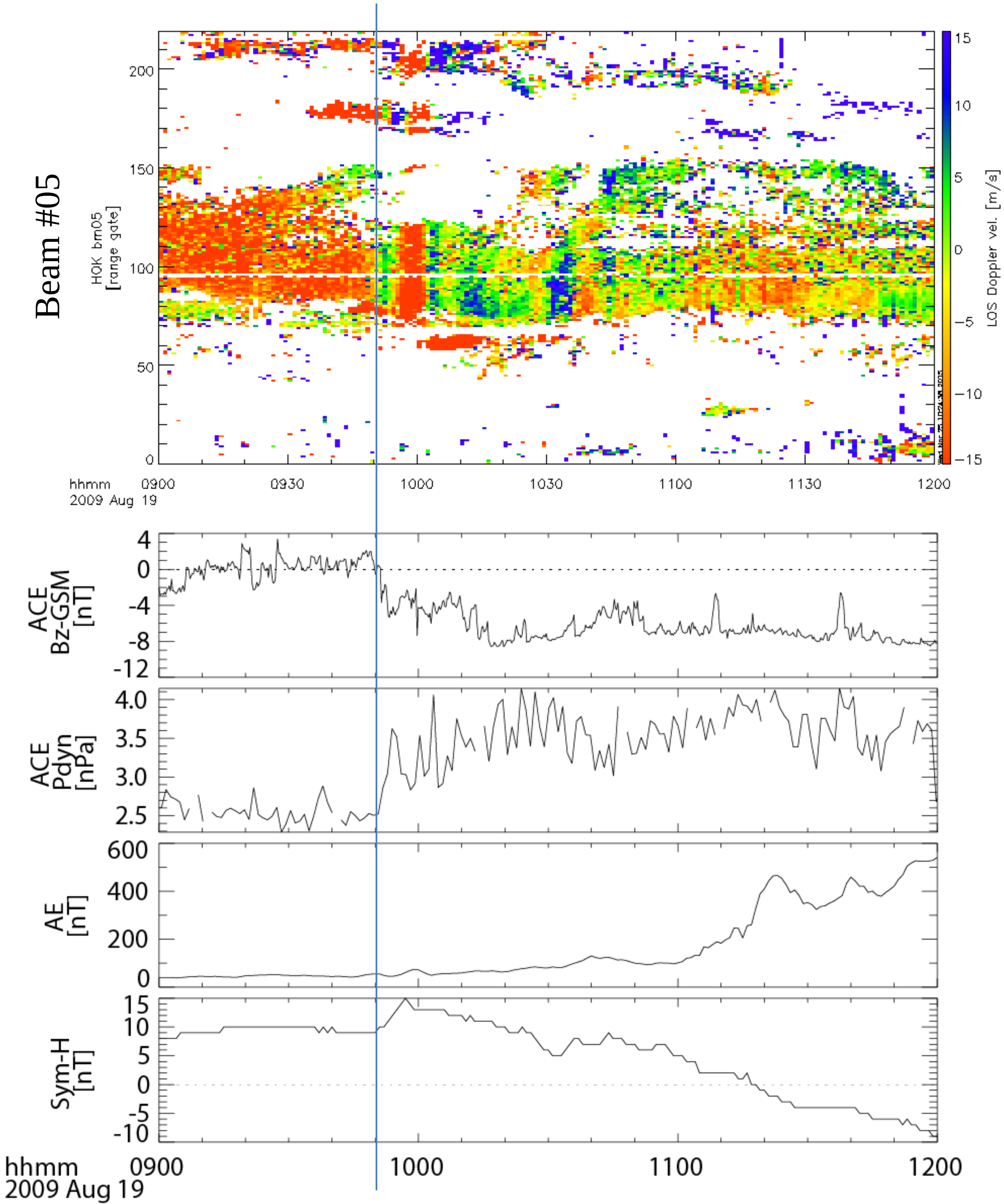
SuperDARN radar network



(http://center.stelab.nagoya-u.ac.jp/hokkaido/site1/press_release/img/20141115/img1.png)

ULF pulsations identified in the ground-scattered echoes received by the SuperDARN Hokkaido East radar

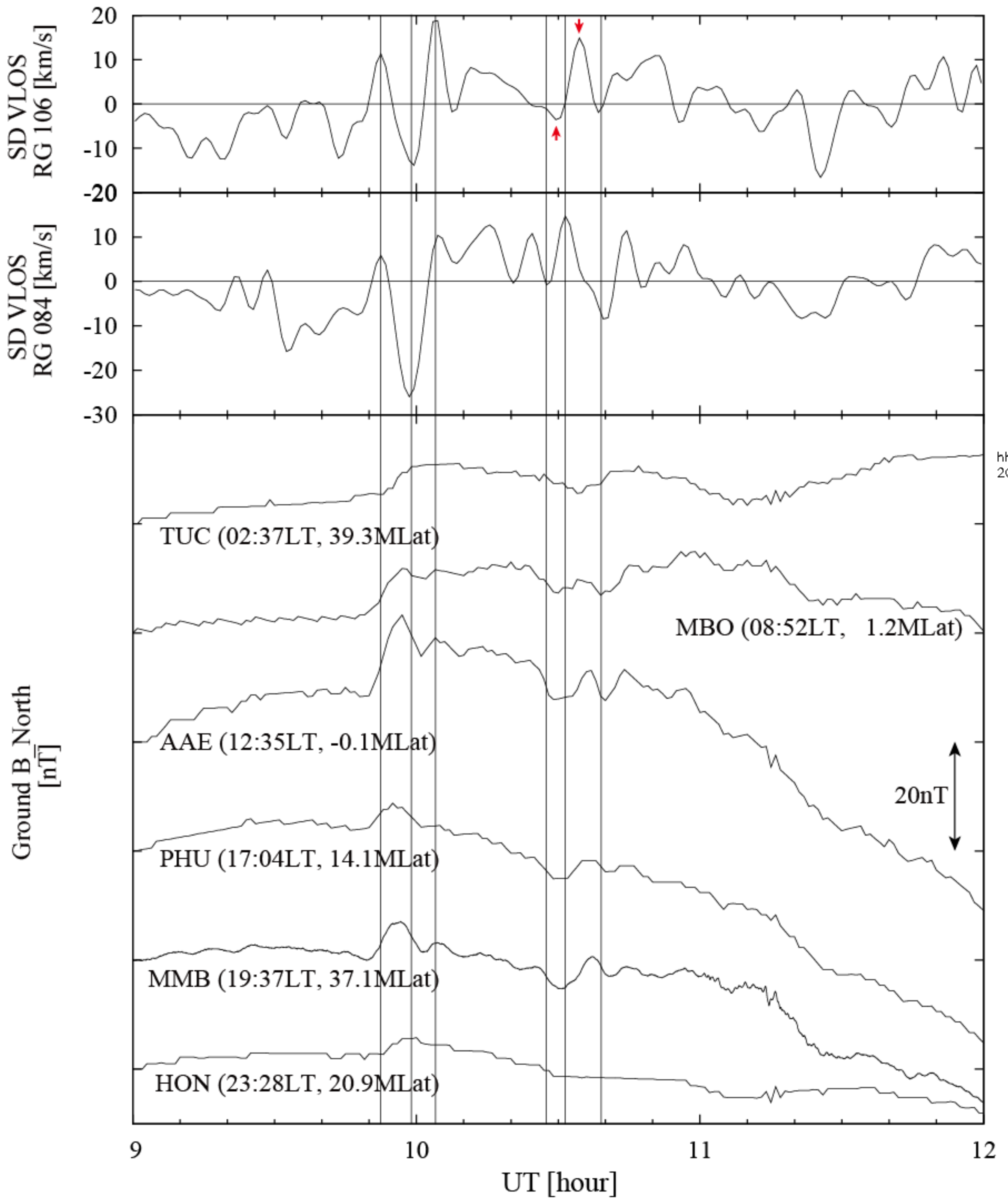


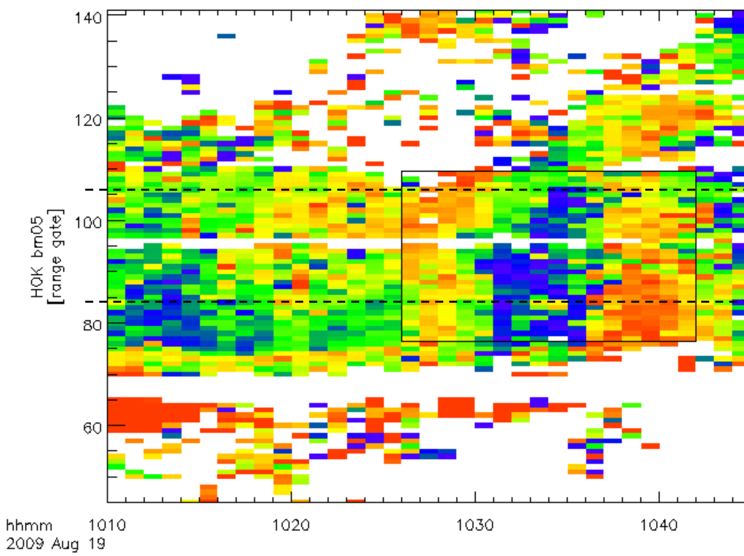


Solar wind propagation lag from ACE to the Earth = 44 minutes in the left panel.

(We have estimated the propagation lag for all the ACE data in the 44 minutes preceding 09:50UT

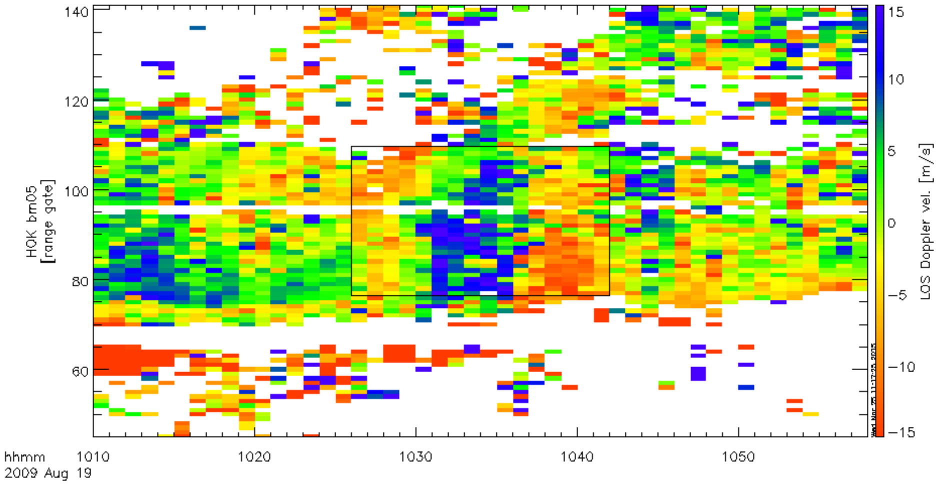
→ The lags' 1-σ range is 40~342 min (median =120 min)





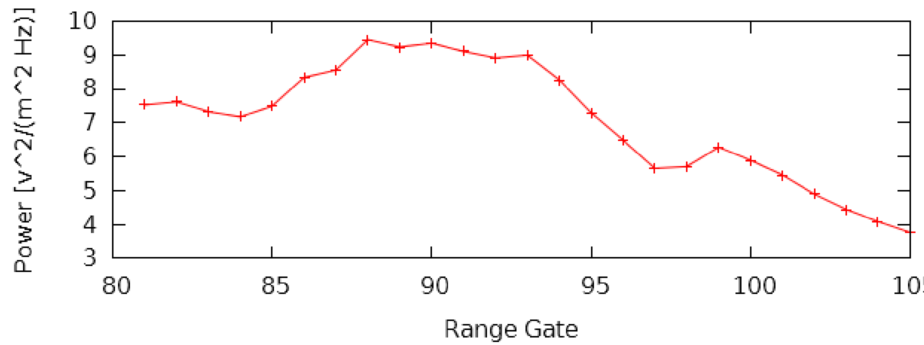
The local times shown in the left legends are those at 10:00UT.

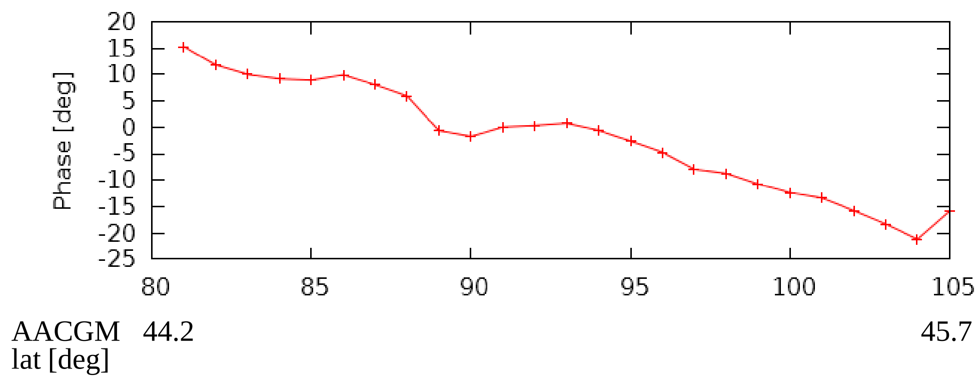
▪FFT analysis of the data of Range Gate 77-109 in 10:26-10:42 UT



FFT Power (top) and Phase (bottom) as functions of latitude (Range Gates (RG)) at f = 1.04±0.52 [mHz] or T = 11〜16〜32 [min]

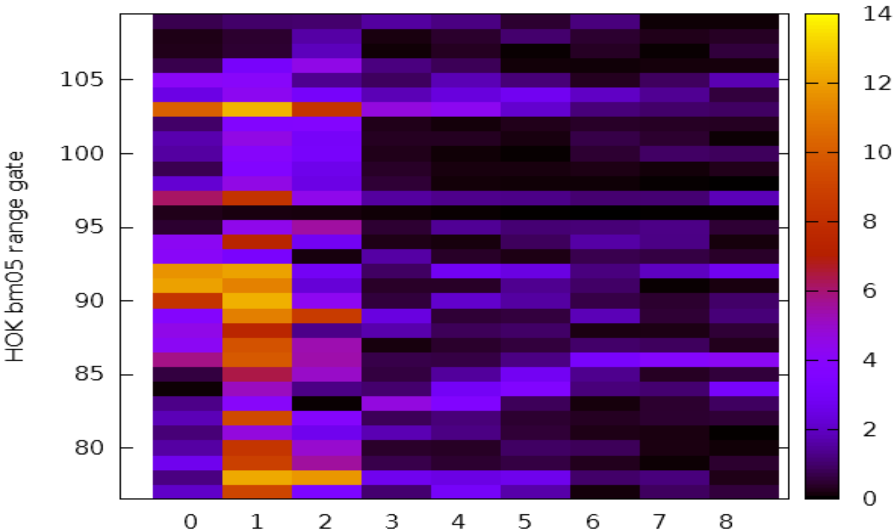
(Nine RGs are moving averaged)





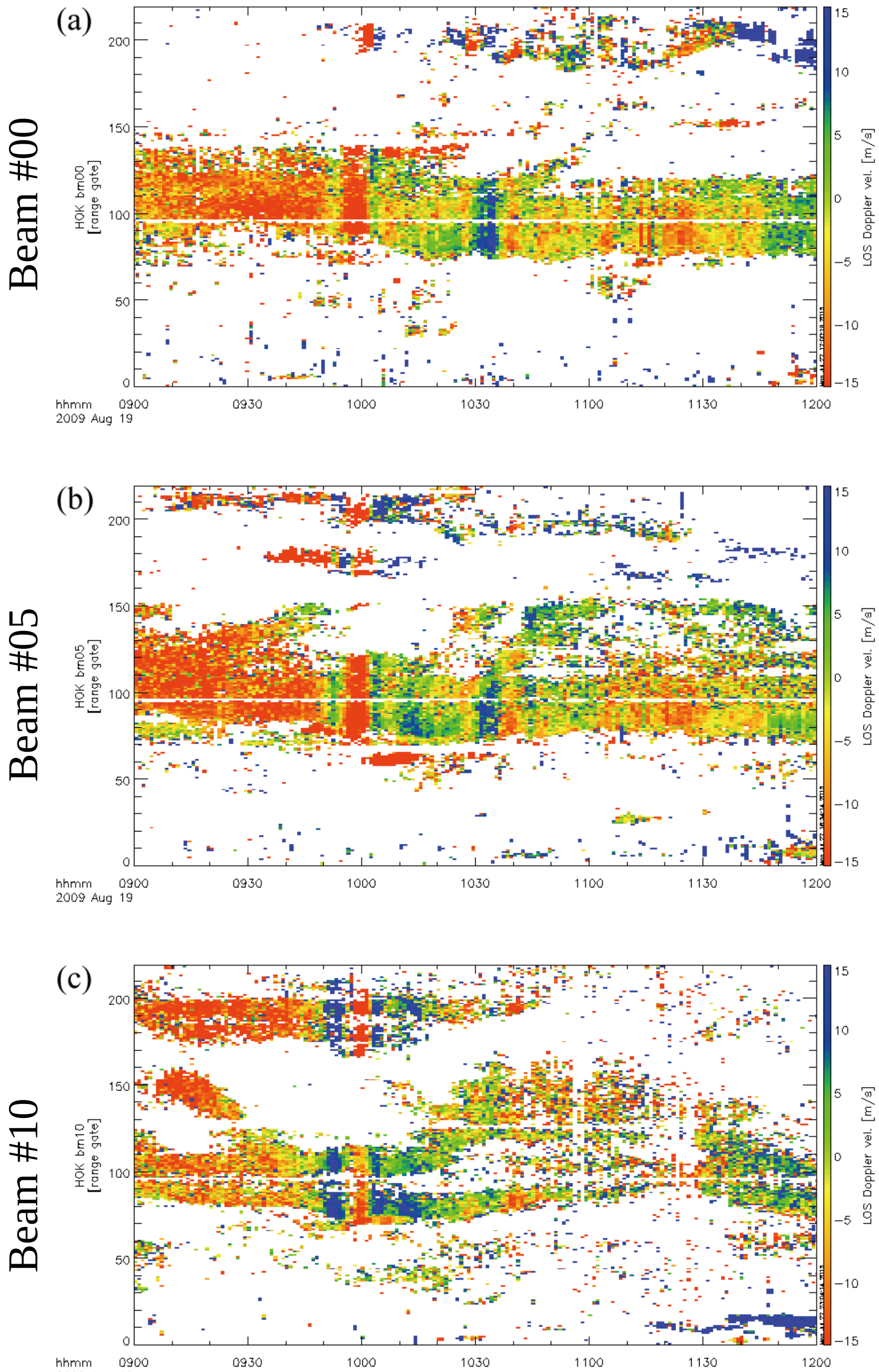
Range Gate

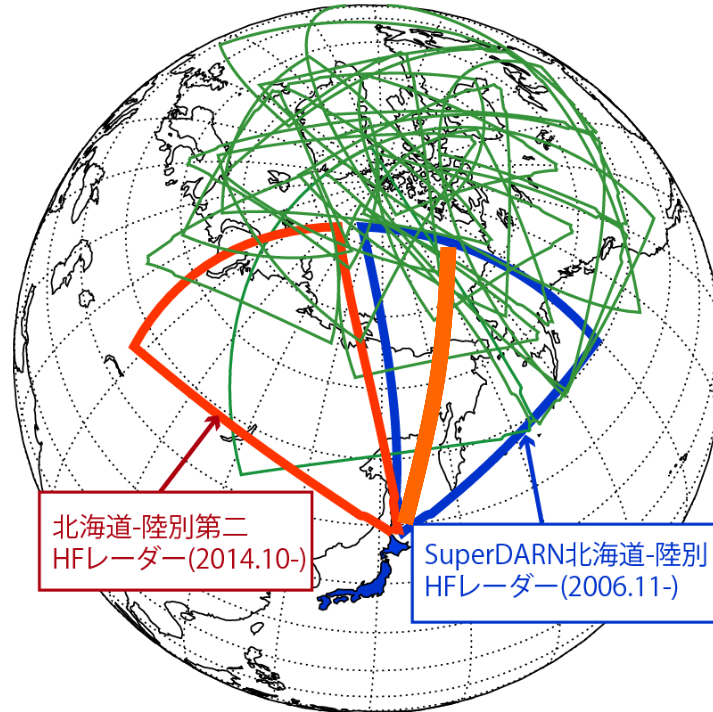
FFT Power

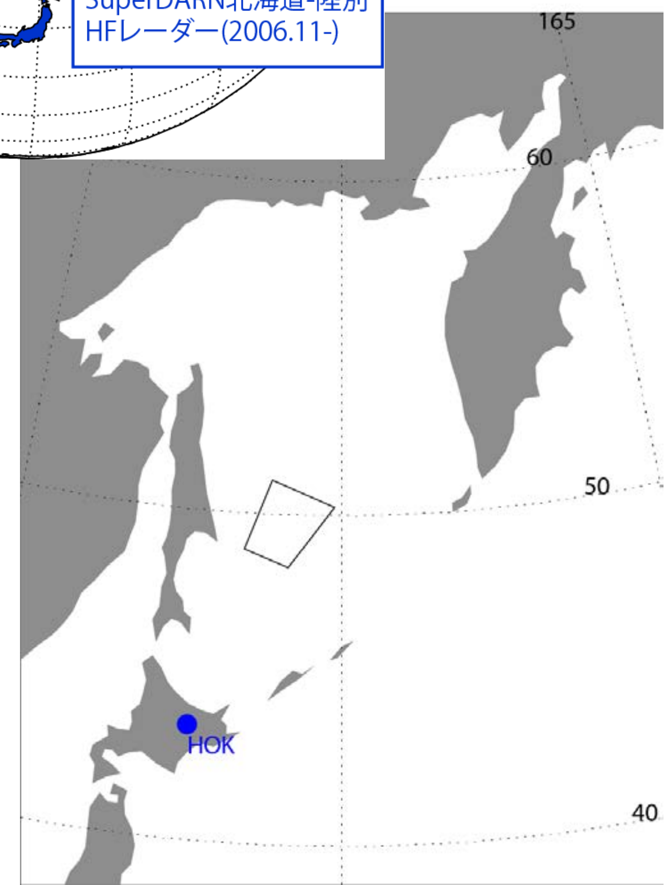


Frequency [mHz]

→ By using the method of *Schulz* [1996], the ion density at L=2.0 (corresponding to RG=91) is estimated to be 9×10^5 [amu/cc].

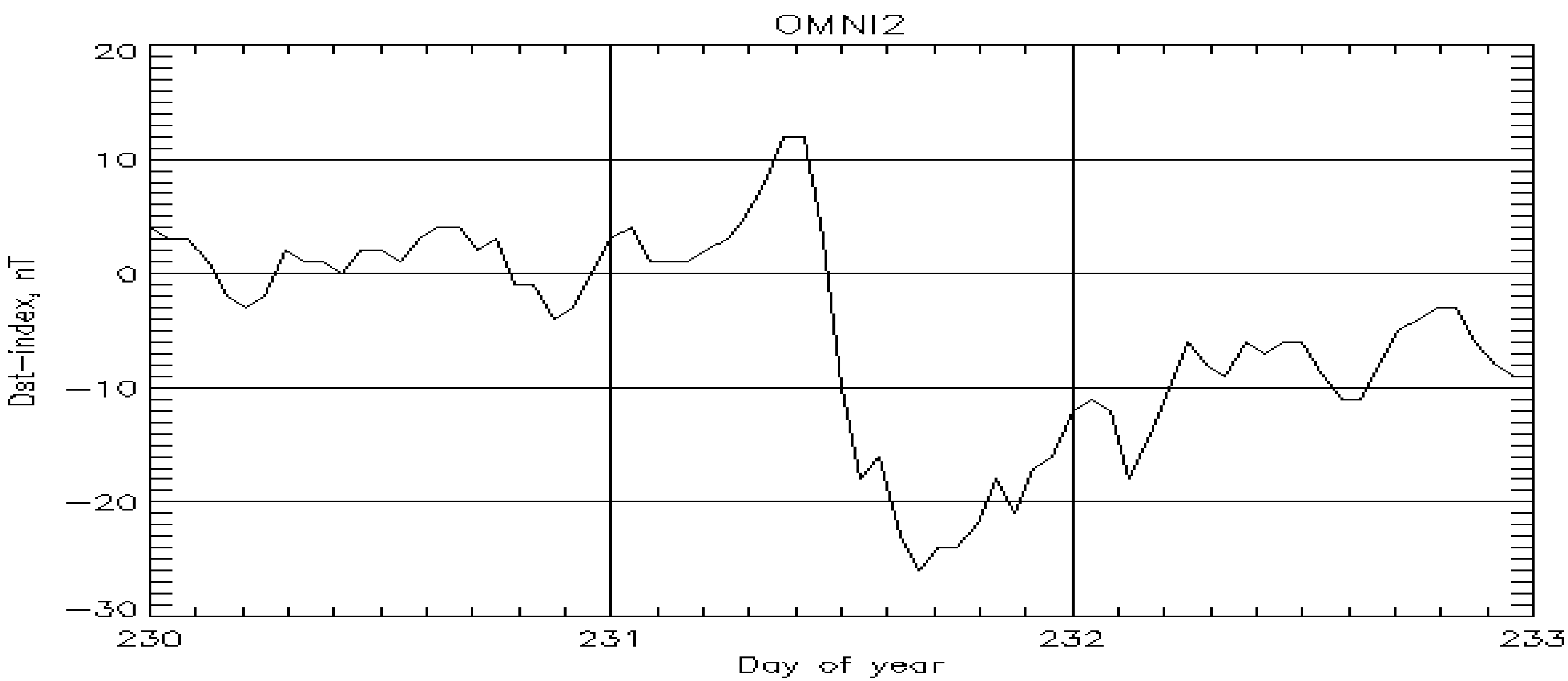

(a)
Beam #00
HOK bm00 [range gate]
LOS Doppler vel. [m/s]
(b)
Beam #05
HOK bm05 [range gate]
LOS Doppler vel. [m/s]
(c)
Beam #10
HOK bm10 [range gate]
LOS Doppler vel. [m/s]
hhmm 0900 0930 1000 1030 1100 1130 1200
2009 Aug 19


北海道-陸別第二
HFレーダー(2014.10-)
SuperDARN北海道-陸別
HFレーダー(2006.11-)


165
60
50
40
HOK

Possible causes of the high density

- The observed waves were quarter waves [Obana et al., 2008, 2015]. The event took place around 19:30UT, but the north/south Pedersen conductance ratio was fairly large (3.7), enabling the possible occurrence of quarter waves. If so, the density estimate becomes 2×10^5 [amu/cc], much smaller than the 9×10^5 [amu/cc] for the case of the usual fundamental-mode waves.
- Ionospheric O+ outflow caused by the SC [Kale et al., 2009]
- Ionospheric O+ outflow caused by the storm [Takasaki et al., 2006]



Summary

- The wavy perturbations in Vlos of the SuperDARN Hokkaido East radar's Beam #5 had the features of FLR.
- Since the Beam #5 is roughly parallel to the north-south direction, it is likely that this FLR was a poloidal-mode FLR.
- It is possible that this FLR was triggered by an SC which started at 09:50UT, followed by enhancements in |Vlos| simultaneously observed at many Range Gates starting 09:50UT.
- Beams #2 through #6 showed more-or-less similar features (not shown).

- It is important to statistically analyze similar events.

END