Study of Mesosphere Summer Echoes Observed by the SuperDARN Hokkaido HF Radar

SuperDARN北海道-陸別第一HFレーダーによって観測された夏季中間圏エコーに関する研究

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Atmosphere

What are PMSE/MSE?

Polar Mesosphere Summer Echoes (at polar region)
Mesosphere Summer Echoes (at midlatitudes)

Very low temperature
(below about 150 K)

Thermosphere

Mesopause (80-100 km)
→ the region where the temperature is lowest

90 km

Neutral temperature of the mesopause around the 85 km altitude occasionally goes below about 150 K.
※NLC (Noctilucent clouds) are also generated.

Mesosphere

Heavy charged ice aerosol particles are generated, which reduce electron diffusivity.

50 km

Stratosphere

Neutral air turbulence in combination with the reduced electron diffusivity leads to the creation of structures which backscatter radio waves (Rapp and Lübken, ACP, 2004).

10 km

Troposphere

HF radio wave

Hokkaido east HF radar

Earth's surface

previous studies related to PMSE/MSE

Polar region (PMSEs)

・Ogawa et al. (GRL, 2002): Event analysis using the HF radar

・Hosokawa et al. (GRL, 2005): Statistical analysis using the HF radar

・Bremer et al. (JGR, 2005): Statistical analysis using the VHF radar

Midlatitudes (MSEs)

・Zecha et al. (JGR, 2003): Statistical analysis using the VHF radar

・Ogawa et al. (JASTP, 2011): Event analysis using the VHF and MF radar

・Ogawa et al. (EPS, 2013): Event analysis using the HF radar

No statistical analysis of MSEs has been done at **midlatitudes** using HF radar!!

Characteristics of PMSE (previous studies)

Hosokawa et al. (2005, GRL)

・Statistical analysis at the polar region found that PMSE were observed frequently in summer daytime.

Purpose of study

By performing statistical analysis of MSEs,

・we understand the upper atmosphere dynamics near mesopause region (80 – 100 km heights) at midlatitudes.

・we determine the criteria for identifying MSEs at midlatitudes by the SuperDARN HF radar.

※This is the first statistical analysis of mesosphere summer echoes at midlatitudes using the SuperDARN Hokkaido east HF radar.

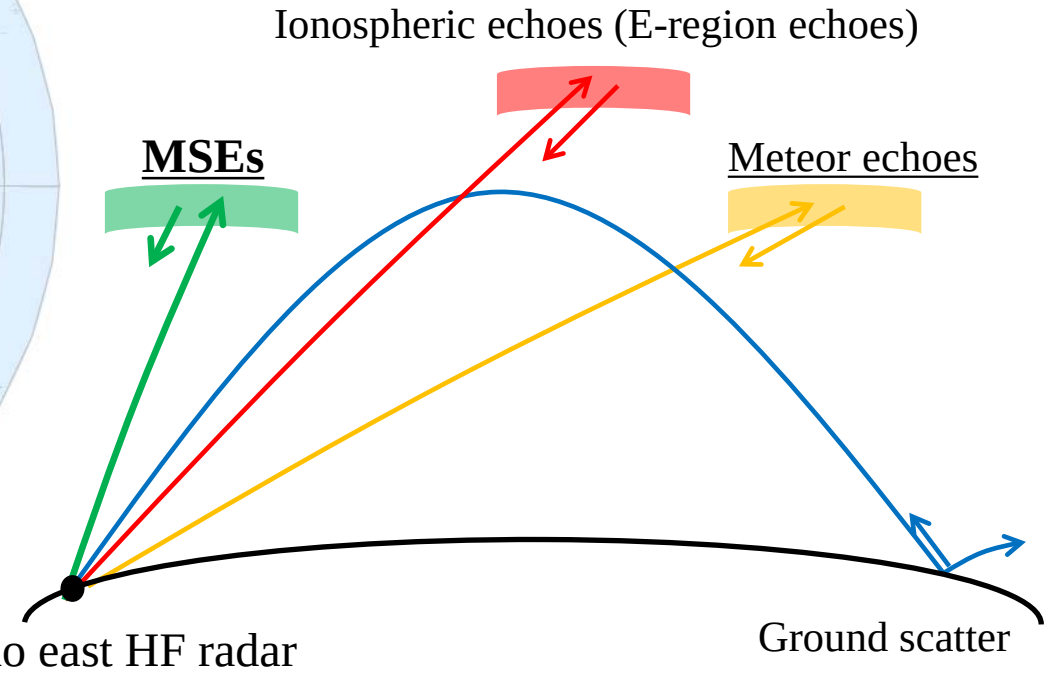
→ Hokkaido east radar is located at 43.5 degrees north latitude.

It is important for the analysis of MSEs to understand the altitude distribution of neutral wind velocity.

→We estimate the altitude distribution of neutral wind velocity by using meteor echoes.

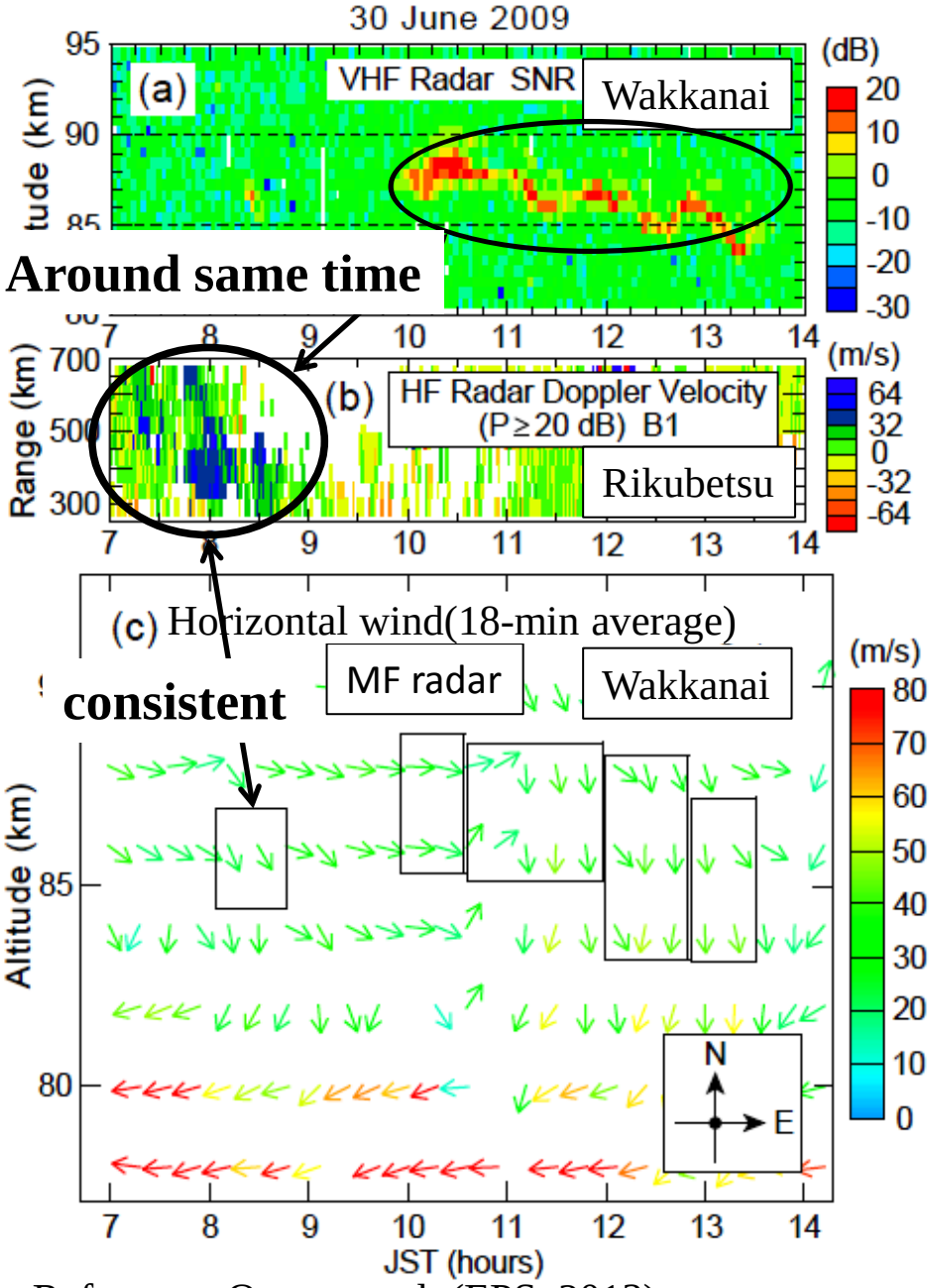
SuperDARN Hokkaido east HF radar
(Super Dual Auroral Radar Network)

・SuperDARN is HF band (8 – 20MHz) radar network.
・There are 22 radars in the northern and 11 radars in the southern hemisphere.
・Hokkaido east radar can observe lowest latitude region among the SuperDARN.
※Hokkaido east radar has been operating continuously since November 2006.
→This is suitable for statistical analysis of MSEs.



Using data
・Frequency: 10.810 MHz, 11.070 MHz
・Spatial resolution: 15 km or 45 km, Time resolution: 1 min)
・Time span: Dec. 2006 – present (※Longscan mode is assigned 4 days a month.)

MSEs event (VHF radar, HF radar)



Reference: Ogawa et al. (EPS, 2013)

Characteristics of MSEs observed by the HF radar

- The echoes have velocity toward the radar (southward velocity).
- The echoes are observed at same ranges in all beams (not aligned along L-shell).

→The echoes having this characteristics are obviously not E-region echoes but MSEs.

Criteria for statistical analysis

1: 30dB < **Echo power**

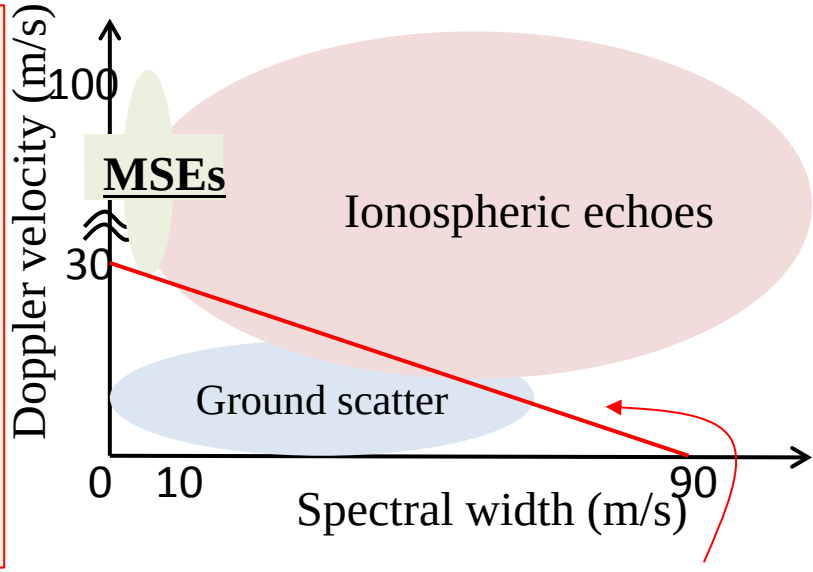
2: 0 < **Doppler velocity** < 100m/s

3: **Spectral width** < 10m/s

4: 3 min < **Duration time**

1,4→to distinguish from meteor echoes

2,3→to distinguish from E-region echoes



Criterion for ground scatter echoes

$$\text{Occurrence rate} = \frac{\text{Number of MSEs data}}{\text{Number of all data}} \times 100$$

※ Ground scatter echoes and artificial noises are excluded.

※ We don't consider the case that the mesospheric echoes are obscured by the E-region echoes.

・Criterion for ground scatter echoes

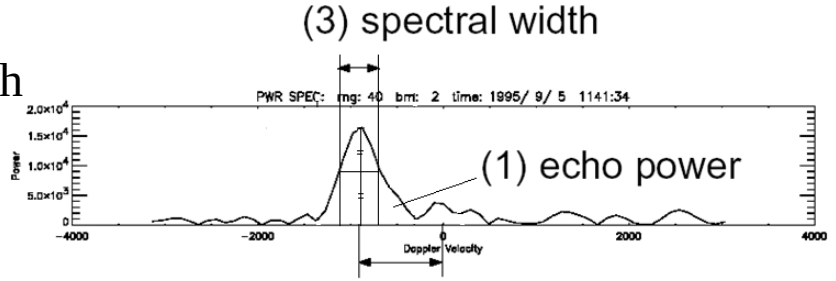
$$|\text{Doppler velocity}| \leqq 30[m/s] - \frac{1}{3} \times \text{Spectral width}$$

・Criteria for artificial noises

$|$ Doppler velocity $| \geqq 3500$[m/s]

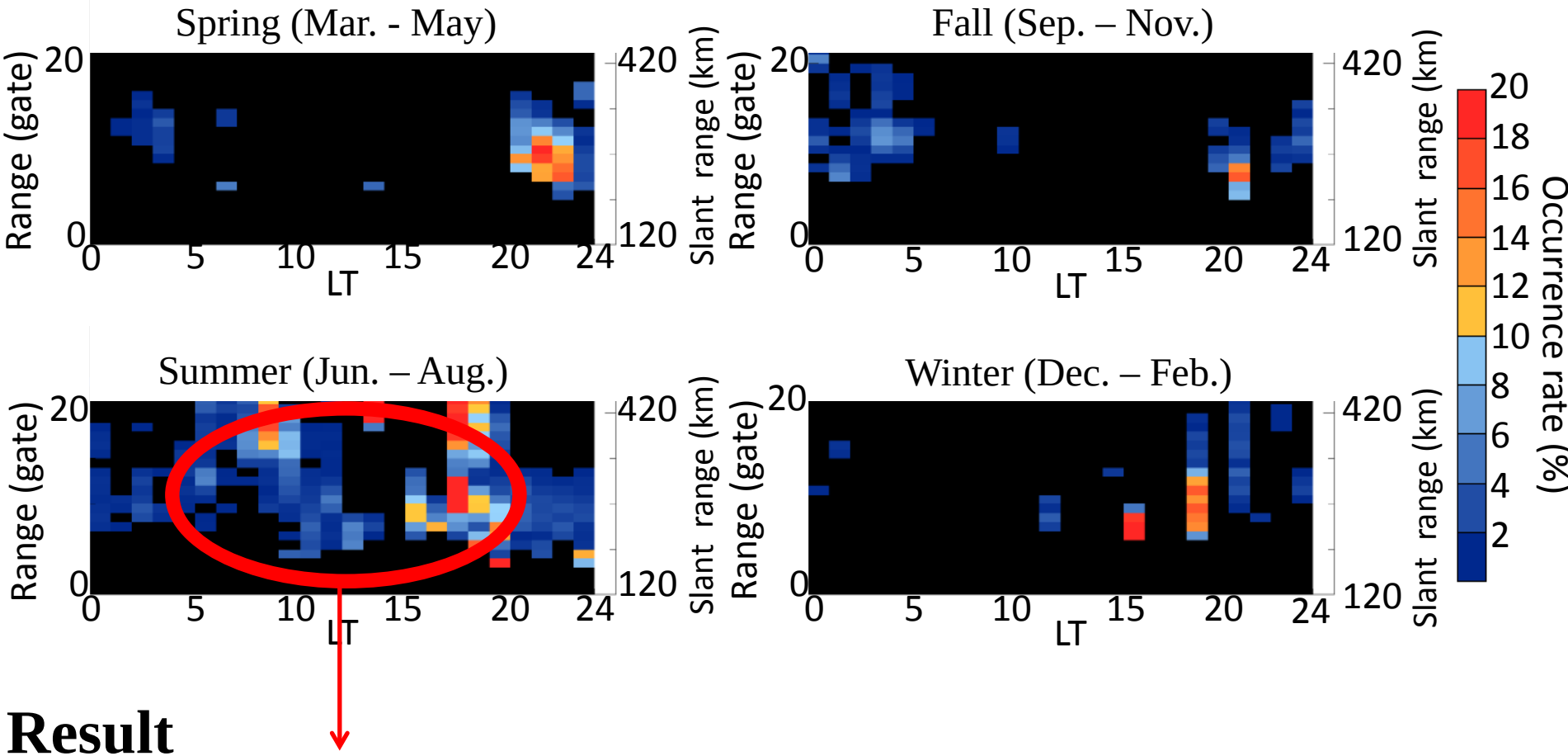
or

The amount of change of Doppler velocity $| \geqq 300$[m/s]



Reference: Tsutsui, BSc thesis (2008)

Occurrence rate of MSEs (Mar. 2010 – Feb. 2011)

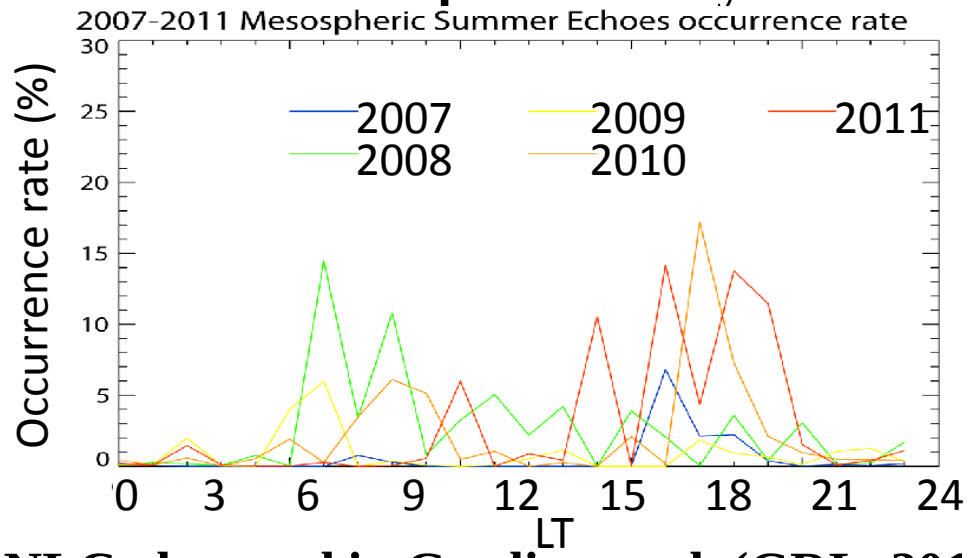


Result

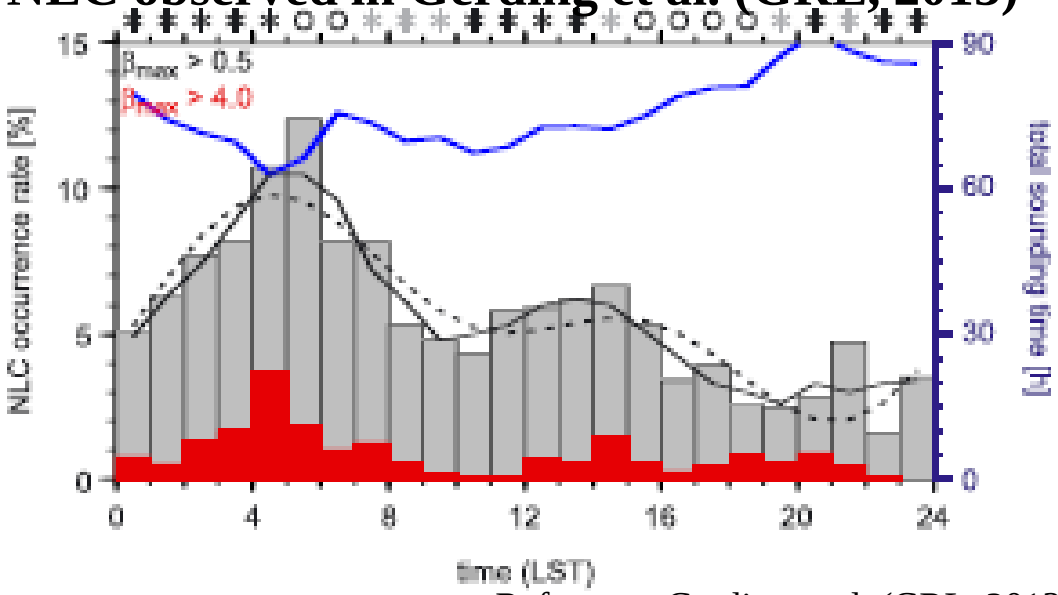
Seasonal dependence

- MSEs are observed frequently in summer daytime.
- This is similar to the result of statistical analysis of PMSE at the polar region [Hosokawa et al. (2005, GRL)].

MSEs observed in present study



NLC observed in Gerding et al. (GRL, 2013)



Reference: Gerding et al. (GRL, 2013)

Peak time and peak value

- Occurrence rate of MSEs has peak value at morning and evening.
- Peak value of occurrence rate is about 15 %.

Result

LT dependence

- This is similar to the result of NLC observed by the lidar at mid-latitudes (54 degree) [Gerding et al. (2013, GRL)].

Seasonal and LT dependence are similar to the result of PMSE and NLC.

The echoes identified in this study are **likely to be MSEs**.

To get more support that they are MSEs, we need to obtain information of the altitude distribution of neutral winds, by analyzing meteor echo data observed by the radar.

Meteor echoes

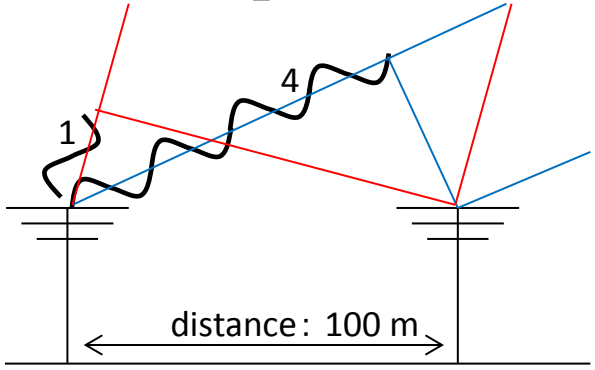
Meteor echoes are the echoes backscattered from meteor trails.
Meteor trails are formed around 70 -110 km altitude and travel with neutral wind.

Analysis of meteor echoes make it possible to obtain neutral wind distribution.

Hokkaido east radar has the range and phase hardware offset caused by various factors.
→We have not determined the altitude of MSEs and meteor echoes.
(※We are trying to estimate the hardware offset.)

We compare relatively the altitude of MSEs with that of meteor echoes.

Relative comparison altitude between meteor echoes and MSEs



$$\Delta\phi = \frac{L}{\lambda} \times 2\pi - 2\underline{n}\pi \Leftrightarrow L = \frac{\lambda}{2\pi}\Delta\phi + \underline{n}\lambda$$

$$L = d\cos(elev) \Rightarrow elev = \arccos\left(\frac{\lambda}{d}\left(\frac{\Delta\phi}{2\pi} + \underline{n}\right)\right)$$

$$altitude = slant\ range \times \sin(elev)$$

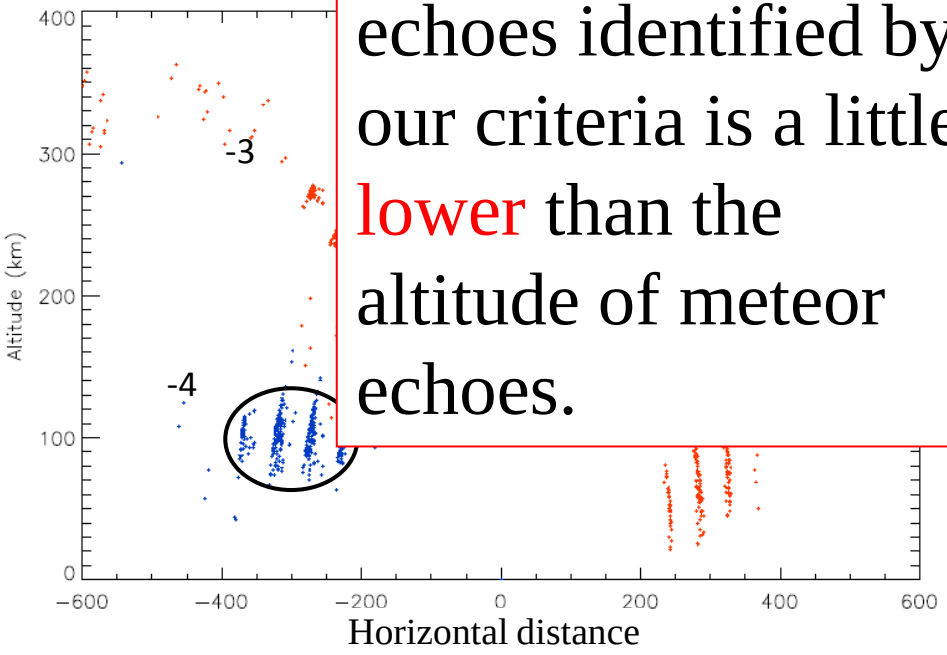
Δφ : phase difference (**observation value**)
L : channel difference

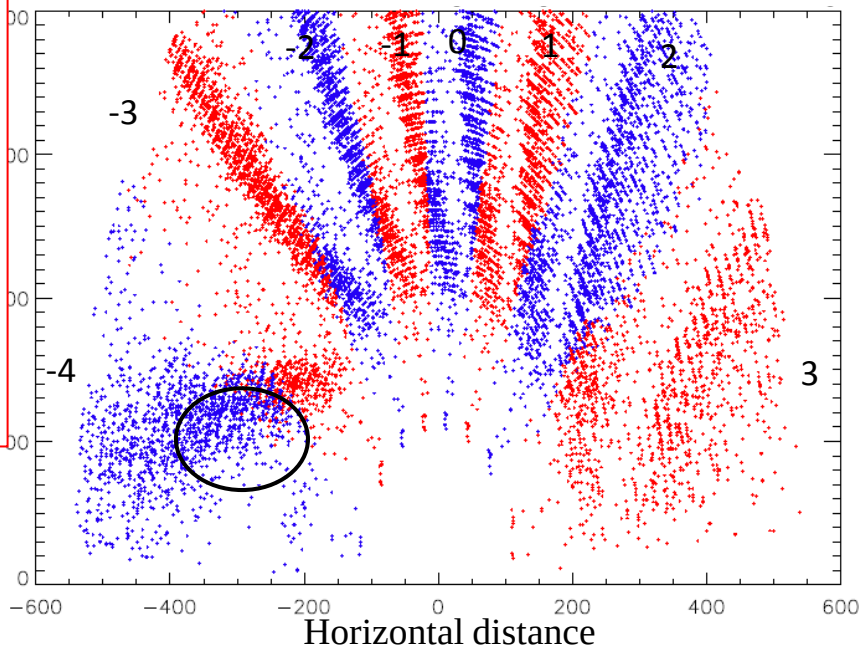
Result

The altitude of the echoes identified by our criteria is a little lower than the altitude of meteor echoes.

Range offset: 0 gate

Meteor echoes

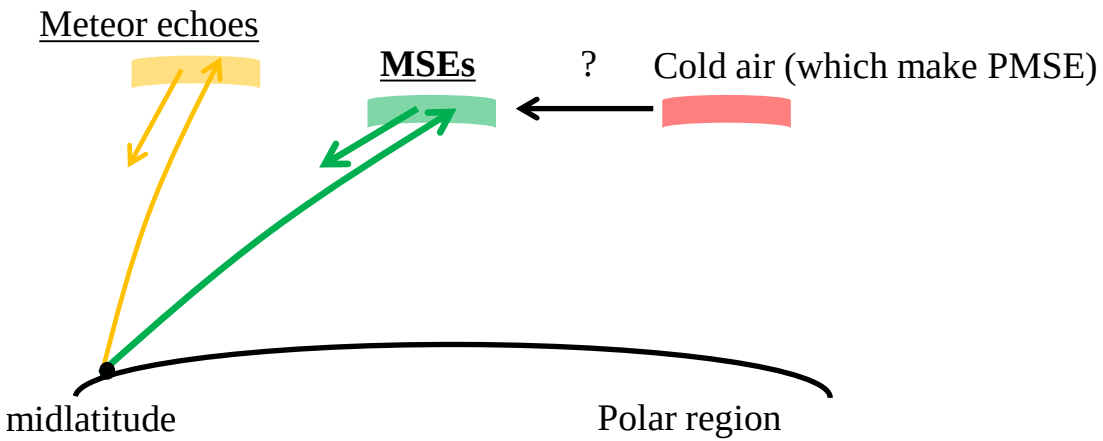




Discussion

According to the results, it is suggested that the echoes identified by our criteria are likely to be **MSEs**.

In this study, we pick up echoes with southward Doppler velocity to see the effect of transportation of cold air from higher latitude.
→At least these echoes have characteristics to fit into following scenario.
※**The region with very low temperature at summer mesopause in the polar region generates PMSEs, which are transported to midlatitudes.**



Summary

・We analyzed MSEs statistically using our criteria and it is found that MSEs are observed frequently in summer daytime.

・We compared the altitude of MSEs and that of meteor echoes and it is found that the altitude of MSEs is lower than that of meteor echoes.

→ The echoes identified by our criteria are likely to be the MSEs.

It is suggested that the region with very low temperature are to be found at mesopause in the midlatitude. (The region with very low temperature at summer mesopause in the polar region generates PMSEs, which are transported to midlatitudes?)

Future tasks

・To improve the estimation of hard ware offset by using meteor echoes.

・To identify the altitude distribution of MSEs and meteor echoes.

・To observe simultaneously MSEs and neutral wind by the Hokkaido west radar and MF radar.