

Statistical analysis and verification of mesospheric echoes using the SuperDARN Hokkaido HF radar

Taishi Tsuya

Nozomu Nishitani

Solar-Terrestrial Environment Laboratory, Nagoya University

Tadahiko Ogawa

National Institute of Information and Communications Technology

Introduction

About bachelor thesis (last year)

Target : near-range echoes (E-region ionospheric echoes, mesospheric echoes, meteor echoes)

Observation instrument : SuperDARN Hokkaido HF radar

Data used in the study

mode : longscan (First range: 120km, Range resolution: 15km)

time resolution : 1min

time span : December 2006 ~ January 2011

(※use only 15km resolution mode used → about 4days every month)

beam number : 1 (pointing magnetic north) to 14

frequency : 10.810MHz, 11.070MHz



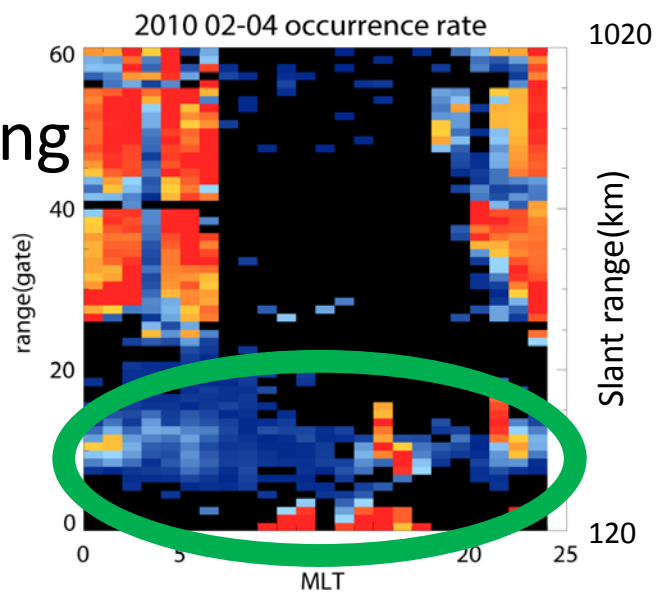
Statistical analysis of MLT and seasonal dependences of near-range echoes

Results of bachelor thesis

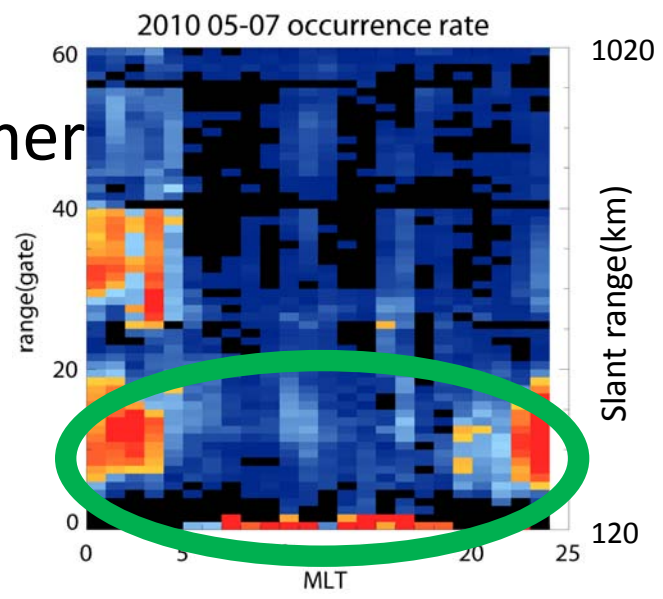
Introduction

beam1

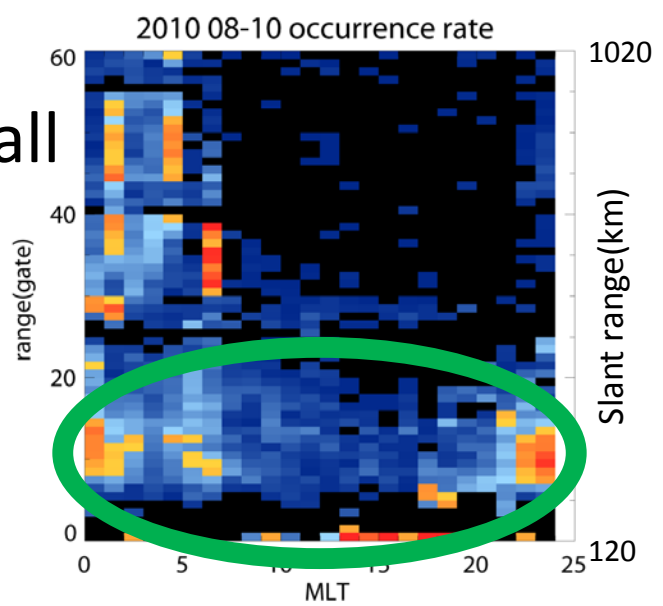
spring



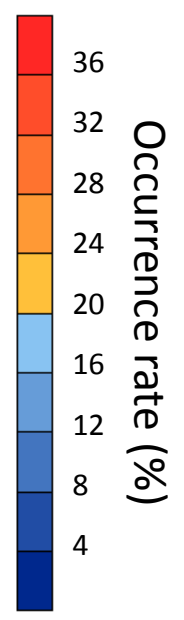
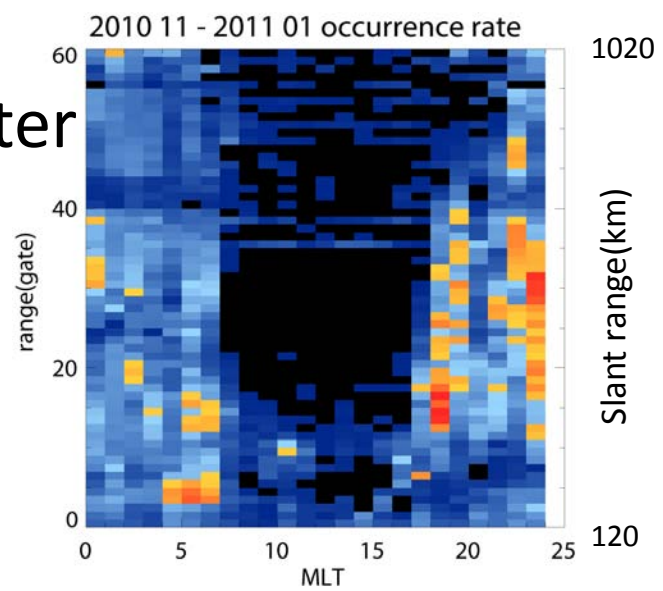
summer



fall



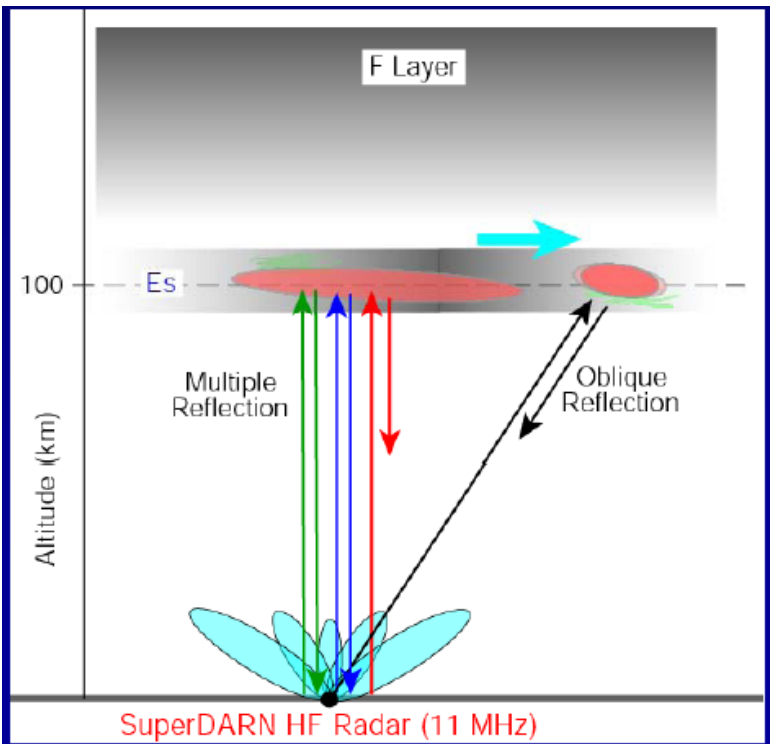
winter



Introduction

Point of interest

Echoes are observed at near-range (120-420 km) in spring, summer and fall.



Reference : T.Ogawa [2011],
Mid-latitude HF radar workshop

Because

- Sidelobe echoes are reflected just above the radar by Es .
- Mesospheric echoes

Research about
mesospheric echoes

Introduction

Point of interest

Very near range echoes observed in spring, summer and fall

Mesospheric echoes ?

Reasons to consider that they are mesospheric echoes

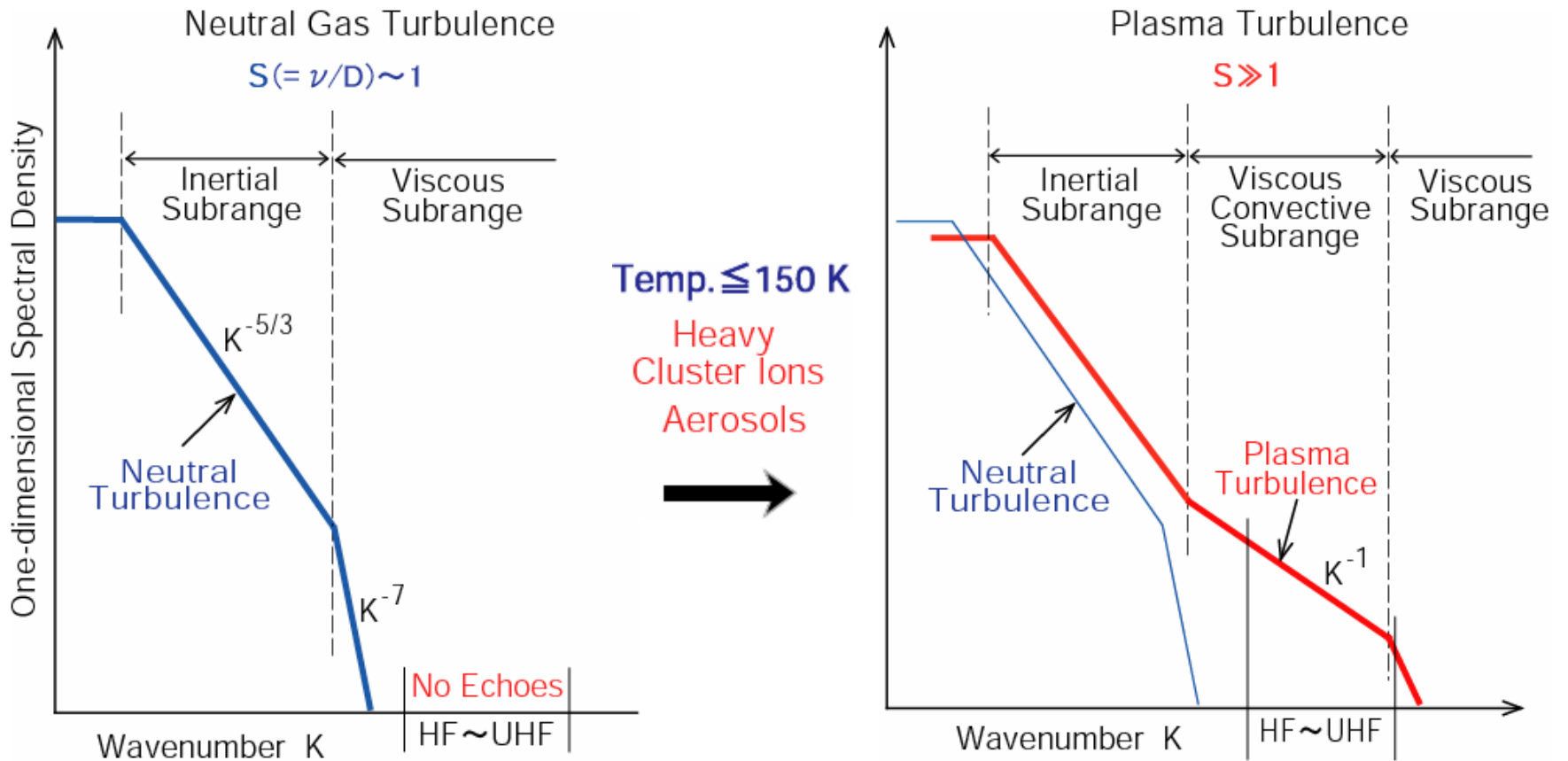
- i) frequently observed in spring, summer and fall
- ii) frequently observed around noon
- iii) having Doppler velocities toward the radar
- iv) observed for relatively long time span (>120min) at range 0 to 20

Need to investigate whether they are mesospheric echoes or not

Introduction

Mesospheric echoes (Polar region, Summer)

Temperature at the mesopause becomes very low. (under 150 K)



Reference : T.Ogawa [2003], Mid-latitude HF radar workshop

Introduction

Results of previous study

- Mesospheric Echoes much observed at high latitude.
- Mesospheric Echoes sometimes observed at mid-latitude in recent years.
- Mesospheric Echoes observed in summer especially
- Mesospheric Echoes observed at daytime.

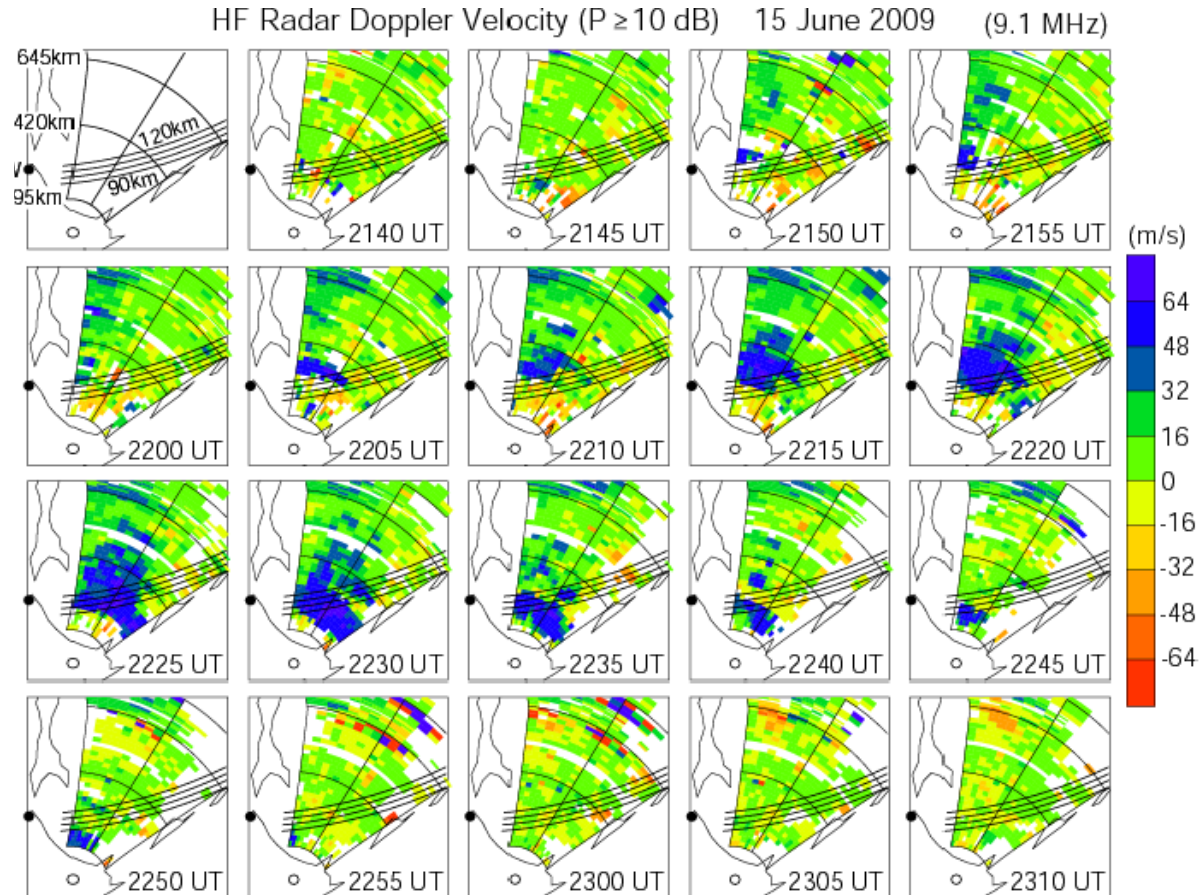
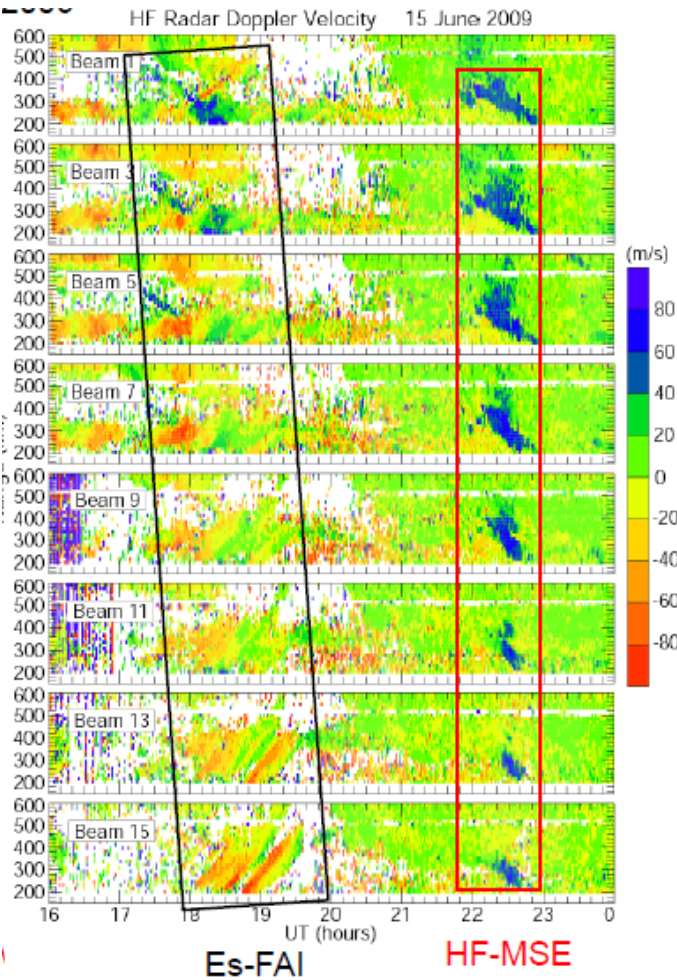
Purpose of study

Perform statistical analysis of MLT and seasonal dependences of mesospheric echoes at mid-latitude with SuperDARN Hokkaido HF radar.

Method of study

Mesosospheric echoes event

15, June, 2009



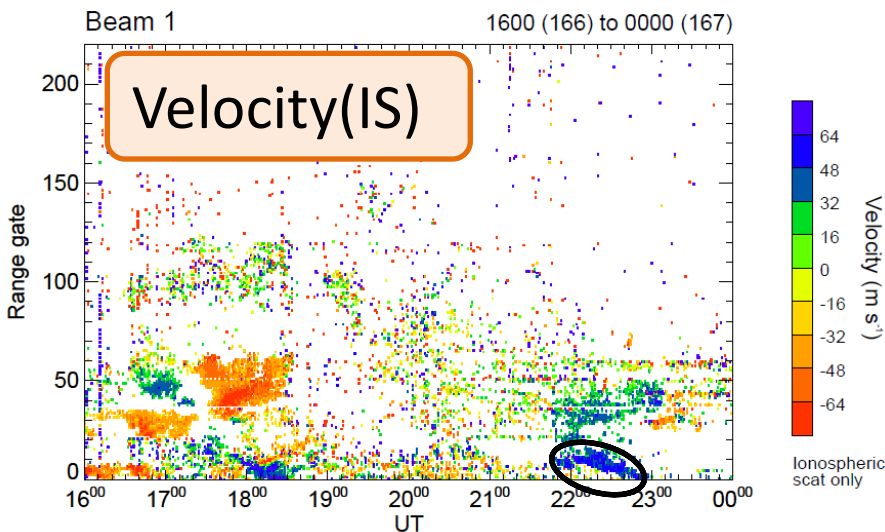
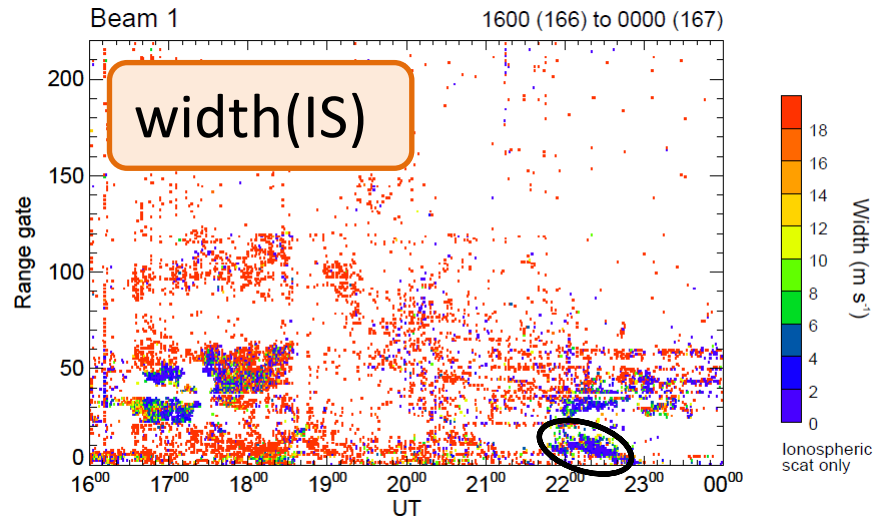
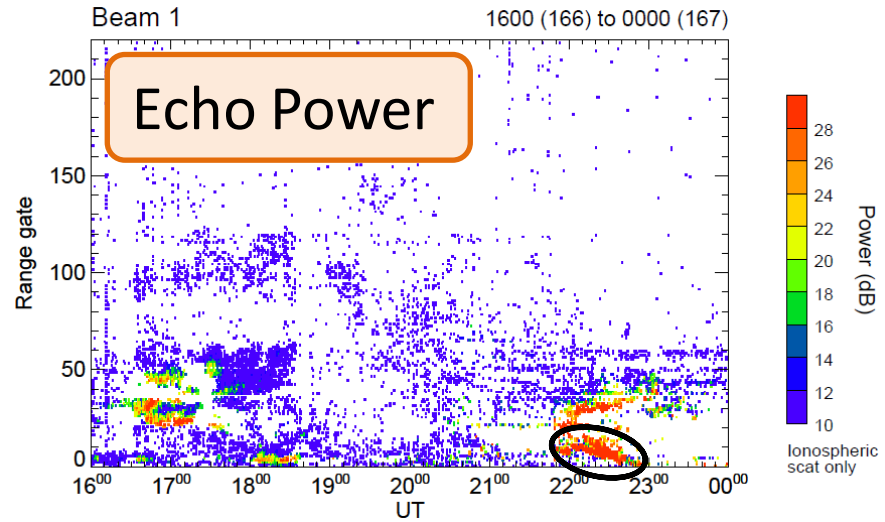
Reference : T.Ogawa [2011],
Mid-latitude HF radar workshop

Detailed research of this
event is at next slide.

Method of study

Mesospheric echoes event

15, June, 2009
(16UT-24UT)



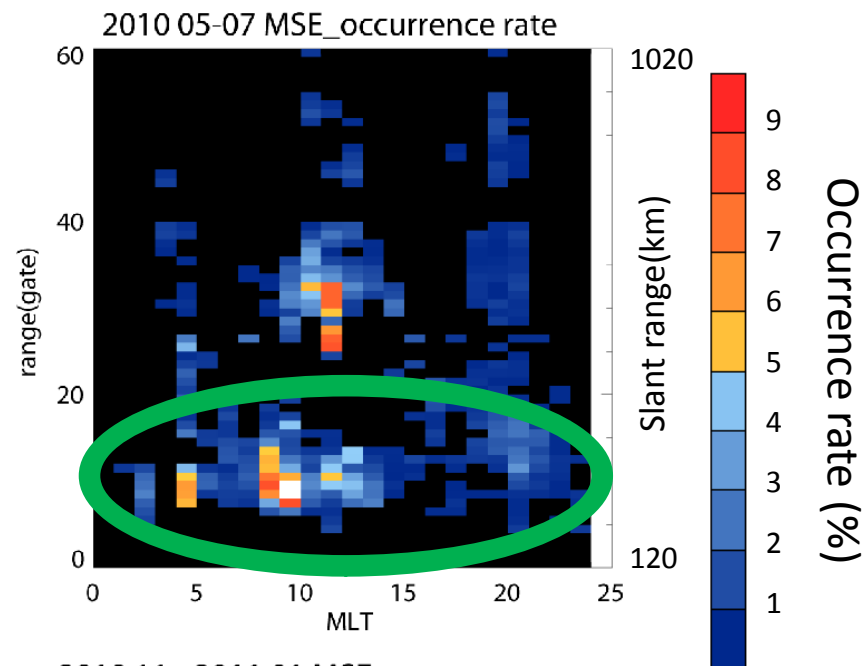
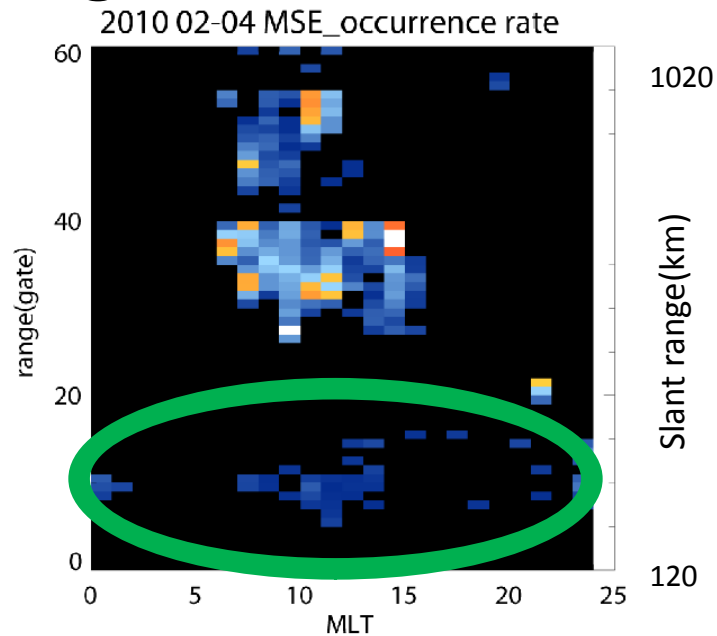
We set the Criteria for statistical analysis

- 1: Echo Power > 20dB
- 2: $0 < \text{Doppler velocity} < 160 \text{ m/s}$
- 3: spectral width < 10 m/s

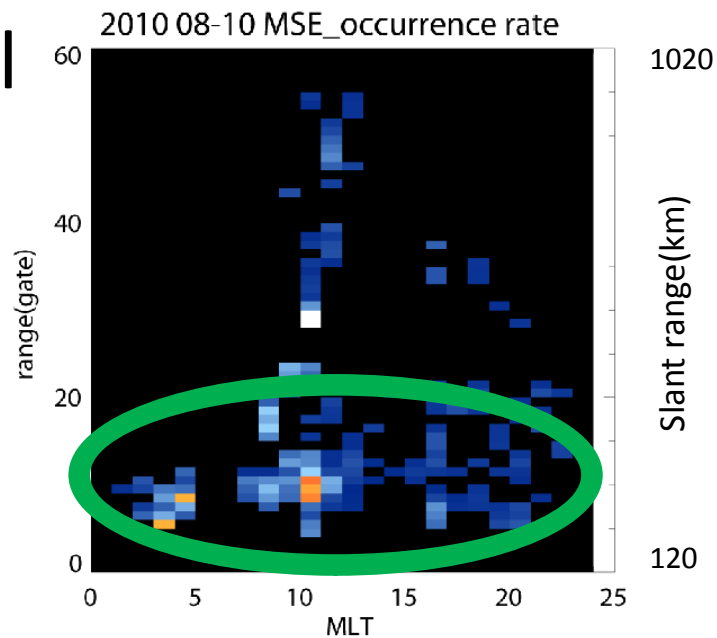
Results

Spring

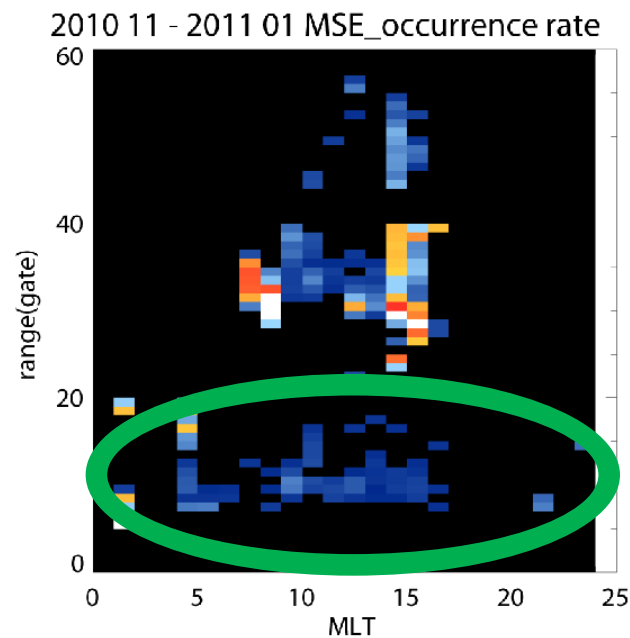
Summer



Fall



Winter



Result & Problem

Results

- Seasonal dependence
much observed in summer
- LT dependences
much observed at daytime

Results conform that of previous study.

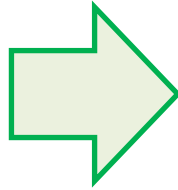
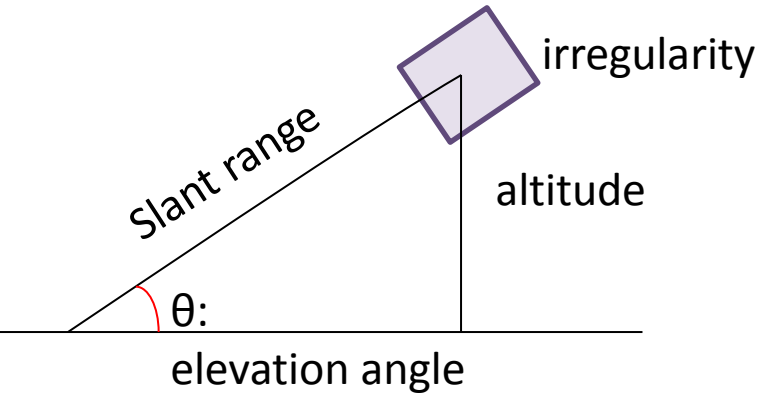
Problem(need to verify)

Make a comparison between events(Doppler velocity) observed with HF radar and wind velocity observed with MF radar in Wakkanai.

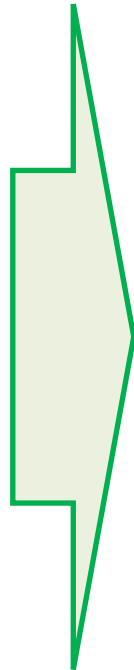
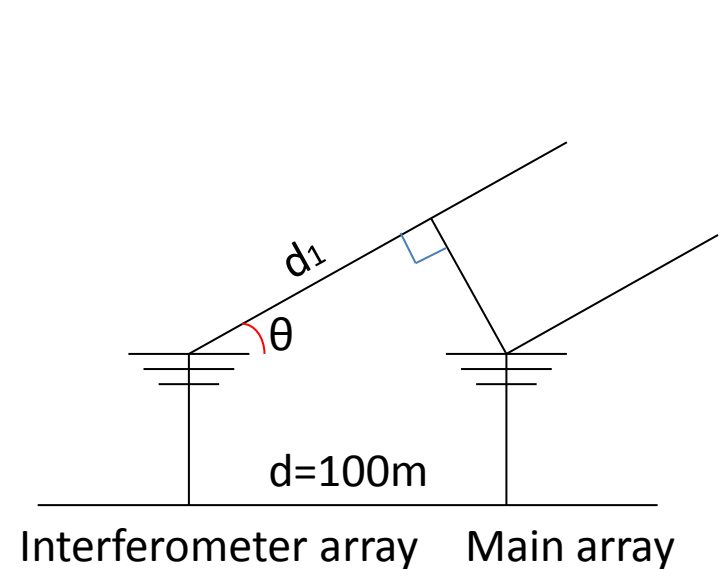
Use data of elevation angle to estimate the altitude of echoes.
→estimate how accurate mesospheric echoes are selected.

Verification

Elevation angle



$$altitude = slantrange \times \sin(elev)$$



$$\Delta\phi = \frac{d'}{\lambda} \times 2\pi - 2n\pi$$

$$\Leftrightarrow d' = \frac{\lambda}{2\pi} \Delta\phi + n\lambda$$

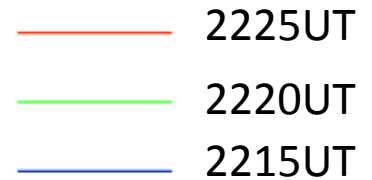
$$d' = 2d_1 = 2d \cos(elev)$$

$$\Rightarrow elev = \arccos\left(\frac{d'}{2d}\right)$$

$\Delta\phi$: phase difference
 d' : path difference

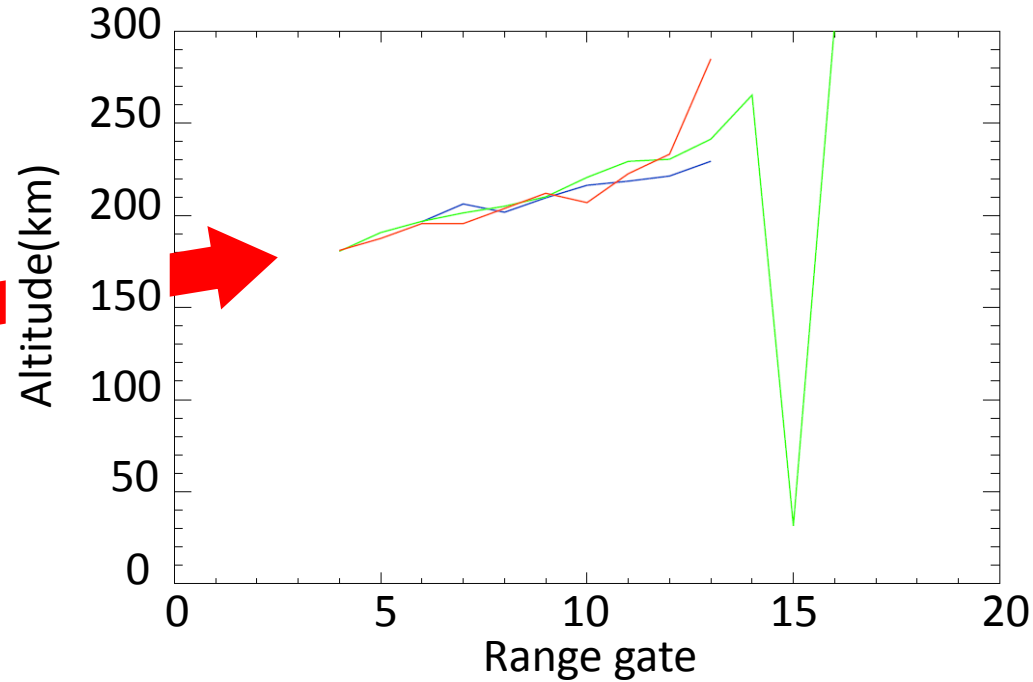
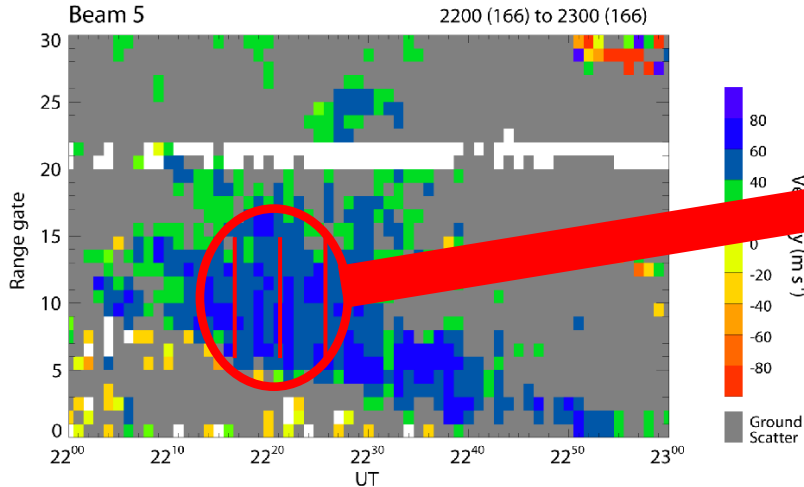
Verification

Elevation angle



SUPERDARN PARAMETER PLOT
Hokkaido: vel

15 Jun 2009⁽¹⁶⁶⁾
unknown scan mode (-151)



- When there are mesospheric echoes (time: 2215-2225UT, range: 5-15), the altitude are higher for farther ranges.
- In addition, the altitude are totally higher than mesopause.
- this is caused by radar hardware offset?

Verification

Radar Hardware offset

- SuperDARN Hokkaido HF radar measures phase difference between main and interferometer arrays.
- The radar does not measure elevation angle directly. Instead, we need to calculate this parameter from phase difference between arrays.

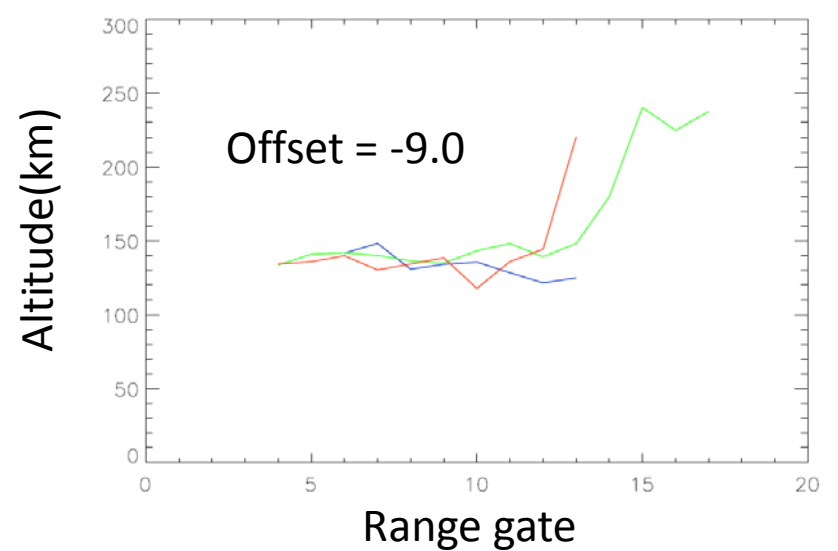
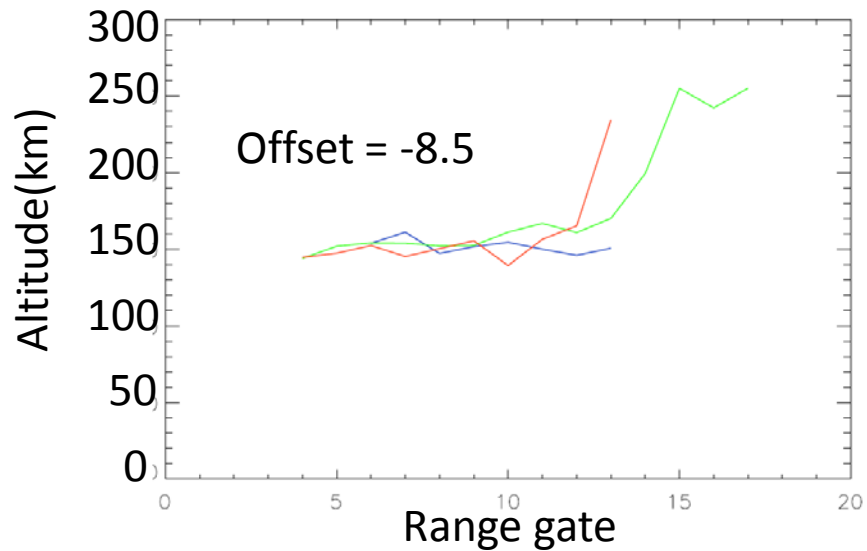
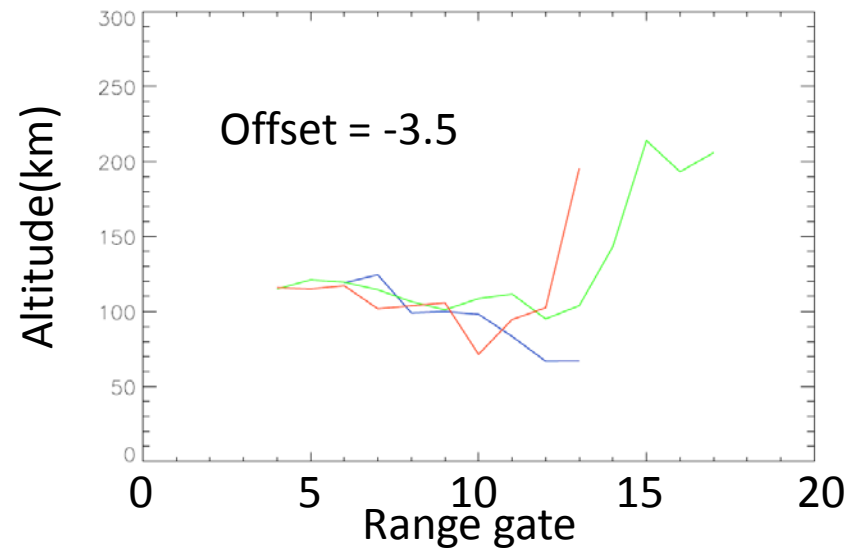
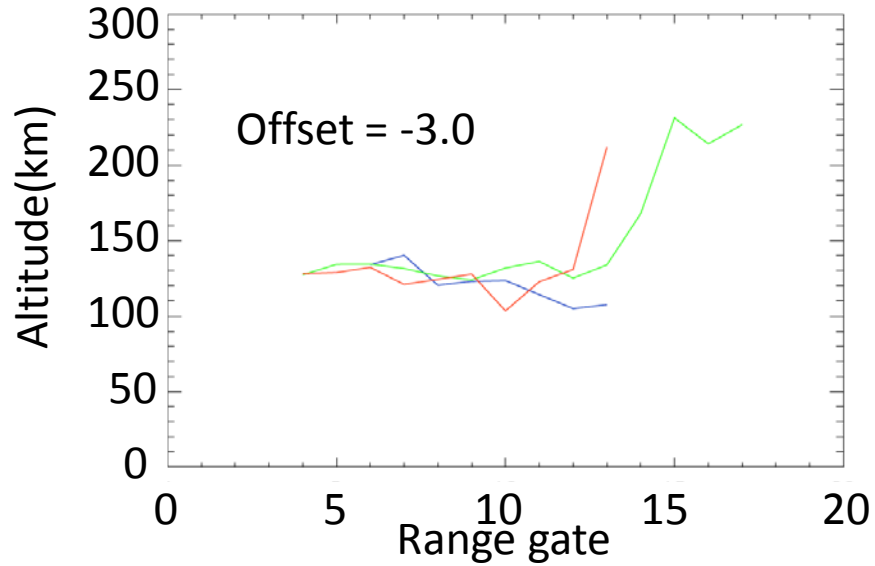
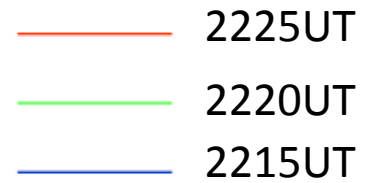
- Phase difference values obtained by the SuperDARN Hokkaido HF radar might contain radar hardware offset.
→ We need to estimate this offset

Methods for estimating the radar hardware offset

- We utilize the mesospheric echo events to find the suitable offset so that the echo altitudes remain in the vicinity of mesopause, by iteration technique.

Verification

altitude of several offset



Verification

Results of estimating radar hardware offset

When offset is -3.5 degrees, obtained altitudes reach lowest values (regarded as best estimated value).

However, the obtained altitude are not low enough with this offset (mesopause is 85-95km) .

Future works

Investigate why obtained altitude is not low enough.

Summary

We perform statistical analysis of MLT and seasonal dependences of mesospheric echoes at mid-latitude with SuperDARN Hokkaido HF radar. The preliminary results confirm the past studies' results.

We estimate the radar hardware offset of the main – interferometer array phase difference.

- -3.5 degrees seems to be the most plausible value.
- However, the obtained altitude are not low enough with this offset (mesopause is 85-95km) We need to investigate the reason for this.

Further investigation of elevation angle data and comparison with wind velocities observed with MF radar in Wakkanai are necessary to investigate detailed characteristics of mesospheric echoes.