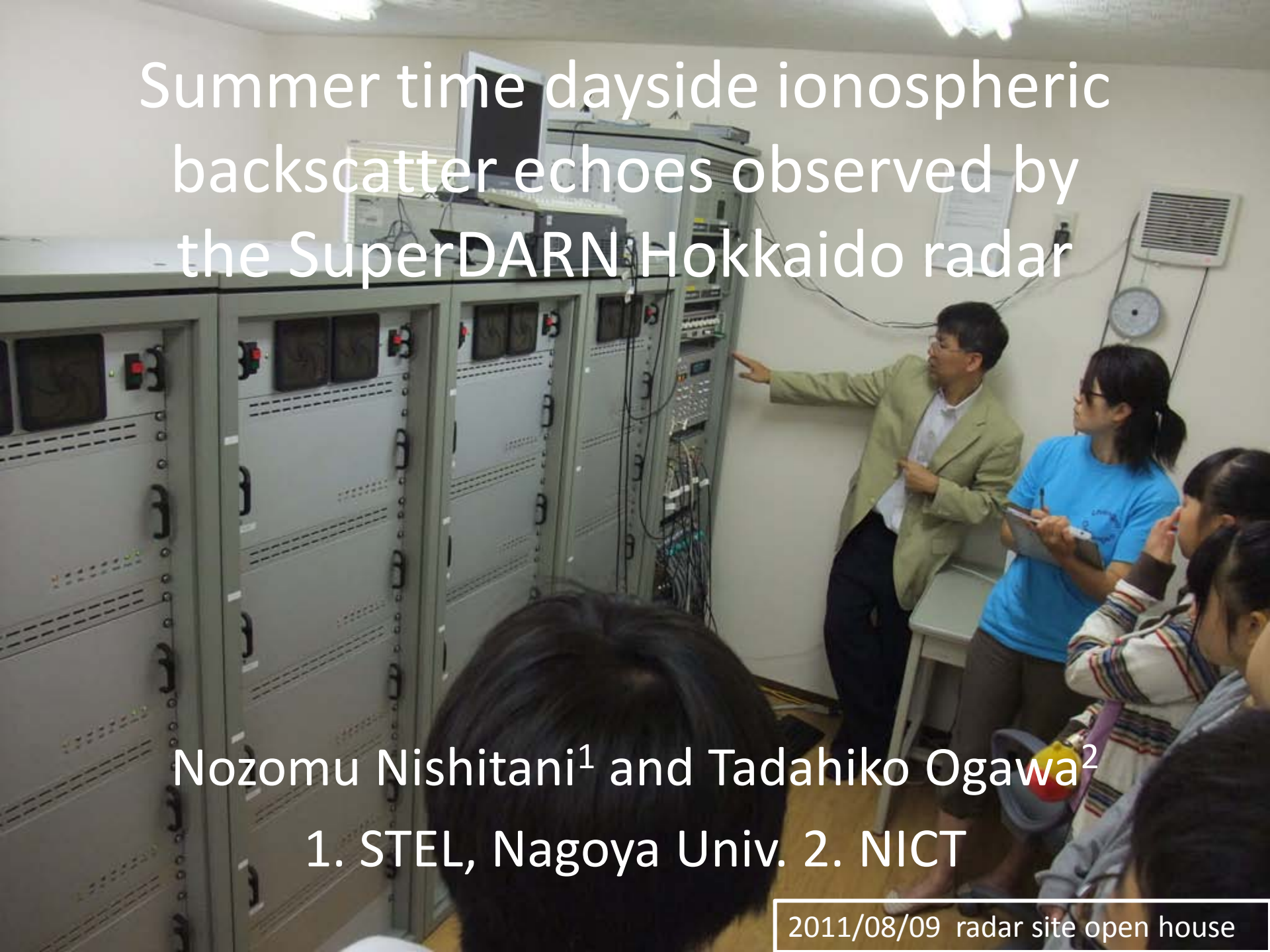
Summer time dayside ionospheric backscatter echoes observed by the SuperDARN Hokkaido radar



Nozomu Nishitani[1] and Tadahiko Ogawa[2]

1. STEL, Nagoya Univ. 2. NICT

2011/08/09 radar site open house

Ionospheric scatter and ground / sea scatter echoes

Modified from Ichihara et al. (2008)

•Ionospheric Scatter

Backscattered owing to Bragg scattering at ionospheric field-aligned irregularities (FAIs).

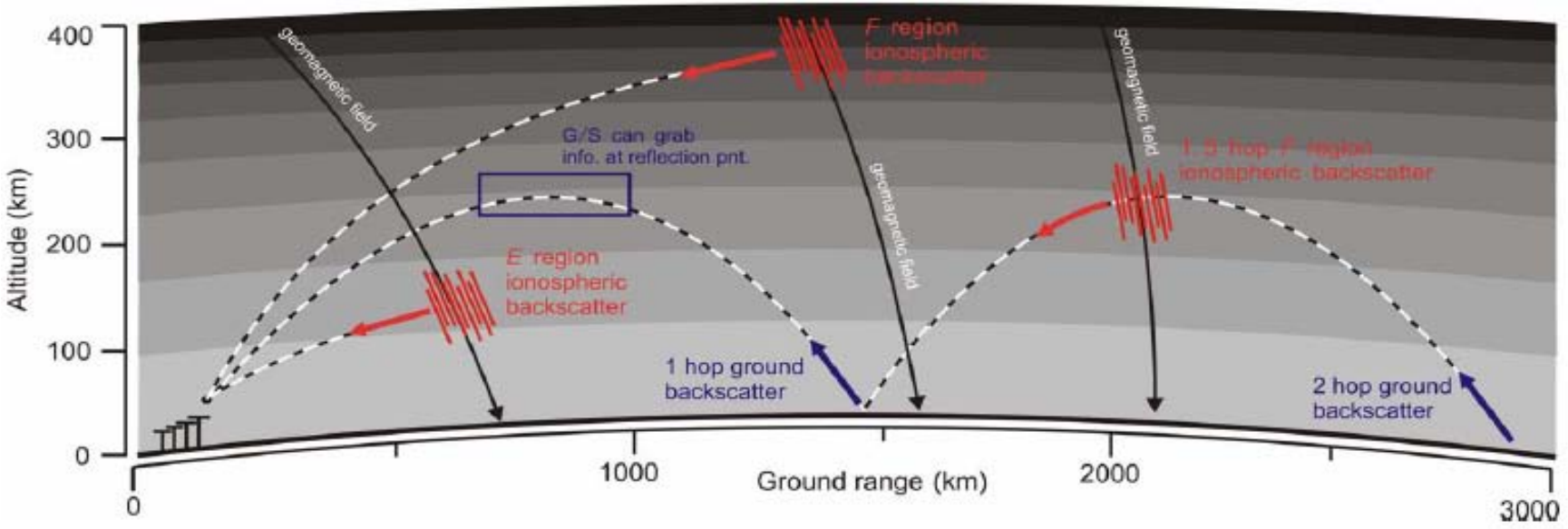
Line-of-sight ionospheric convection velocities can be obtained.

•Ground Scatter

Backscattered owing to irregularities at ground /sea surface.

Doppler speed is small (<50 m/s).

Upward / downward motion speed of the ionospheric structure can be obtained.



Ionospheric scatter and ground / sea scatter echoes

Hosokawa and Nishitani (2010, Radio Sci.) Hokkaido radar echo statistics (Apr '07)

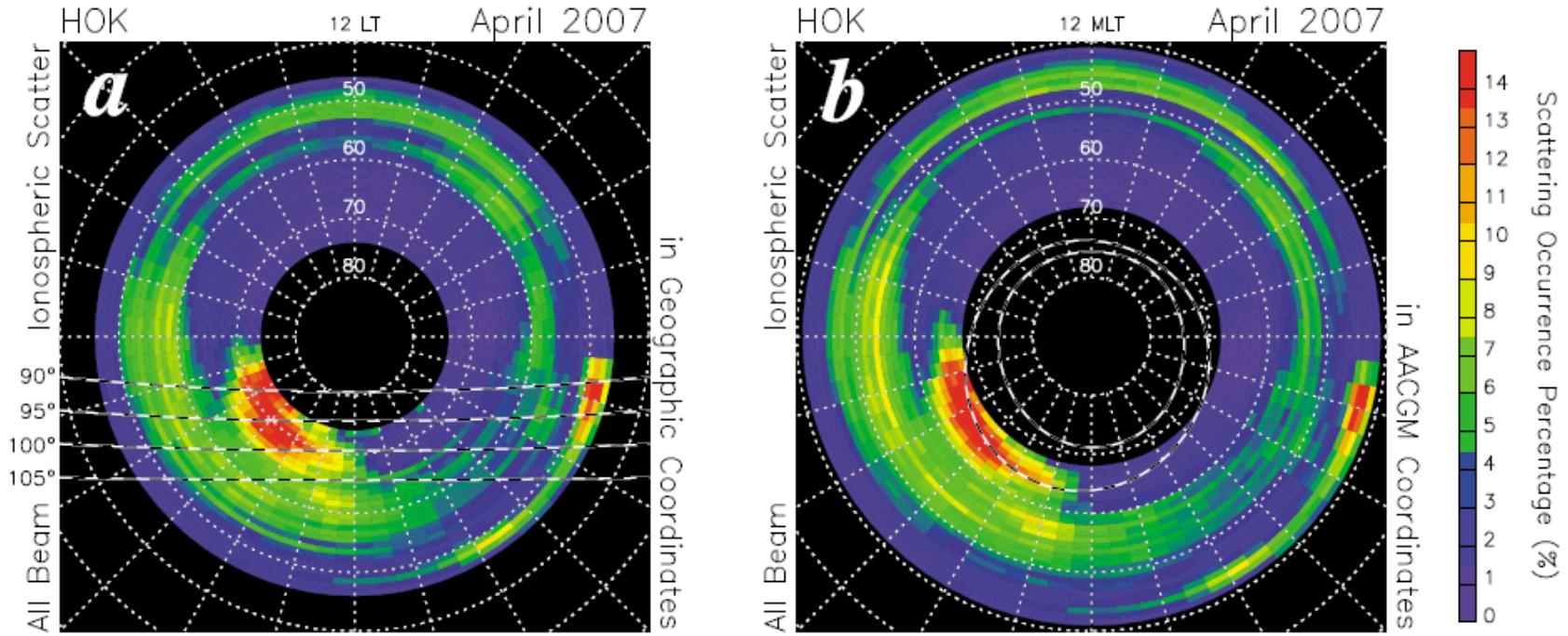


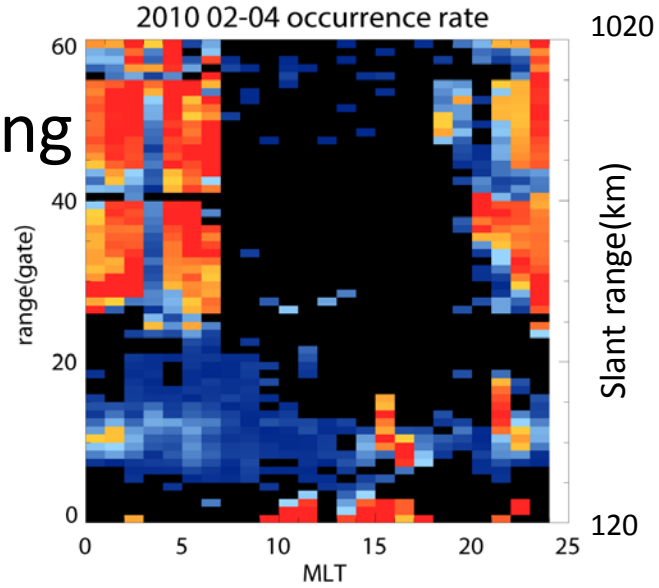
Figure 4. Distribution of scattering occurrence rate obtained from the Hokkaido radar observations in April 2007 (a) as mapped into the geographic coordinate system and (b) as mapped into the AACGM magnetic coordinate system. In Figure 4a, dashed lines represent a line of solar zenith angle of 90°, 95°, 100°, 105° at 15 April, respectively. In Figure 4b, two dashed circles indicate the equatorward and poleward edge of the auroral oval [*Feldstein and Starkov*, 1967] as modeled by *Holzworth and Meng* [1975] for $Q = 1$ (quiet conditions), respectively.

Near-range echoes

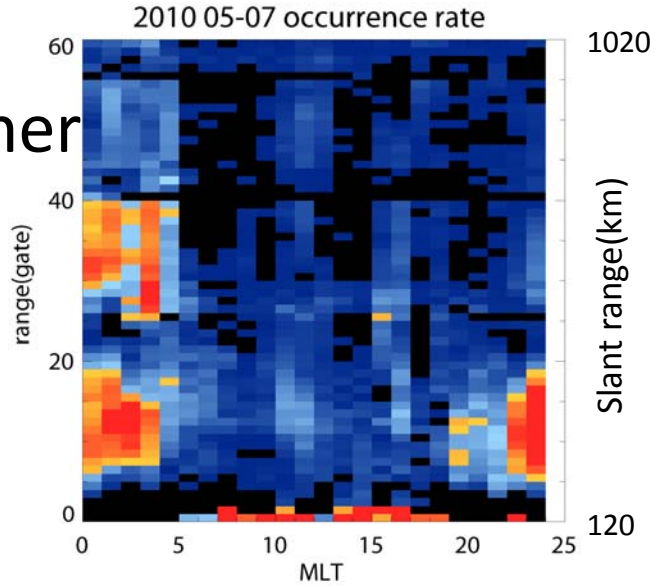
Tsuya (2011)

beam1

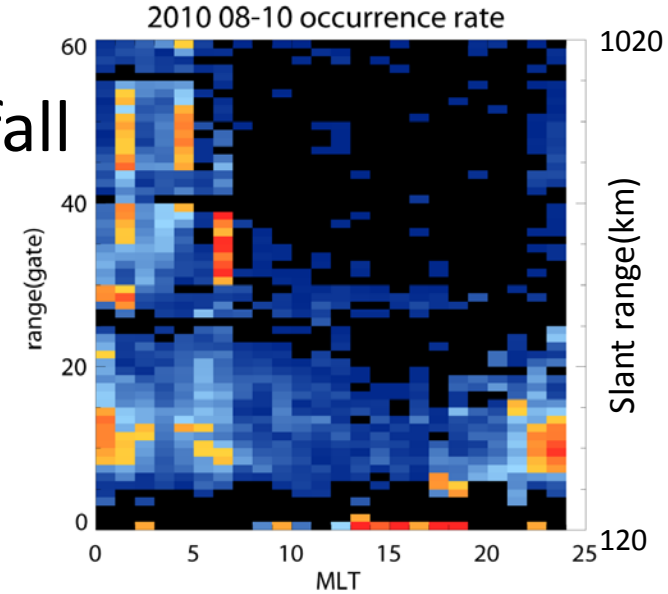
spring



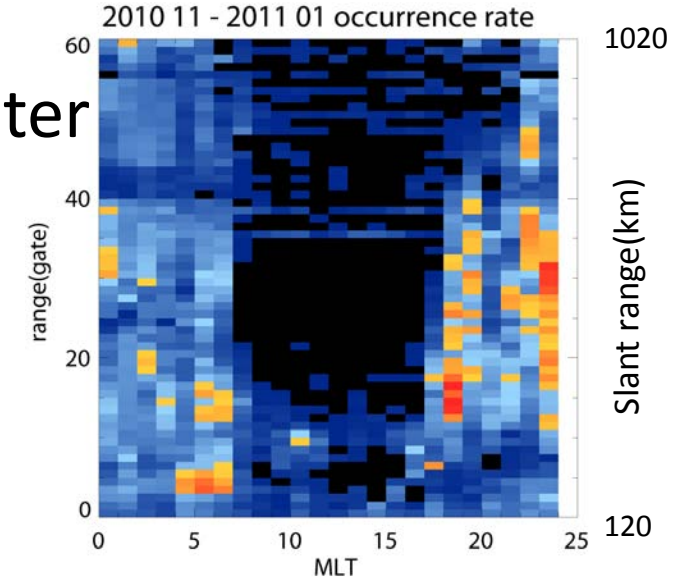
summer

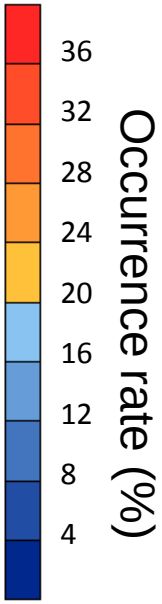


fall



winter





Yamamoto et al. (1992, JATP)

MU-radar observation of E-region echoes

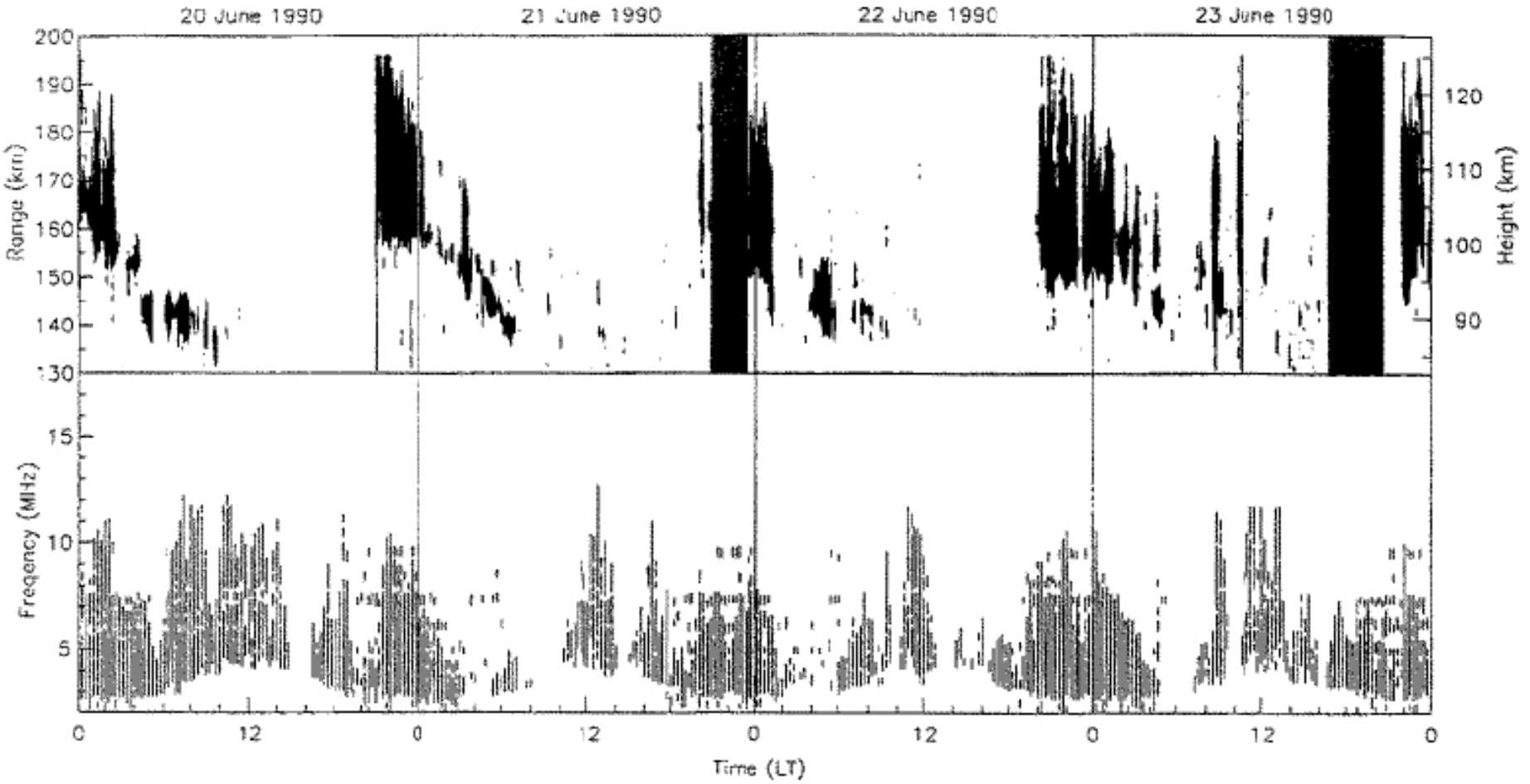
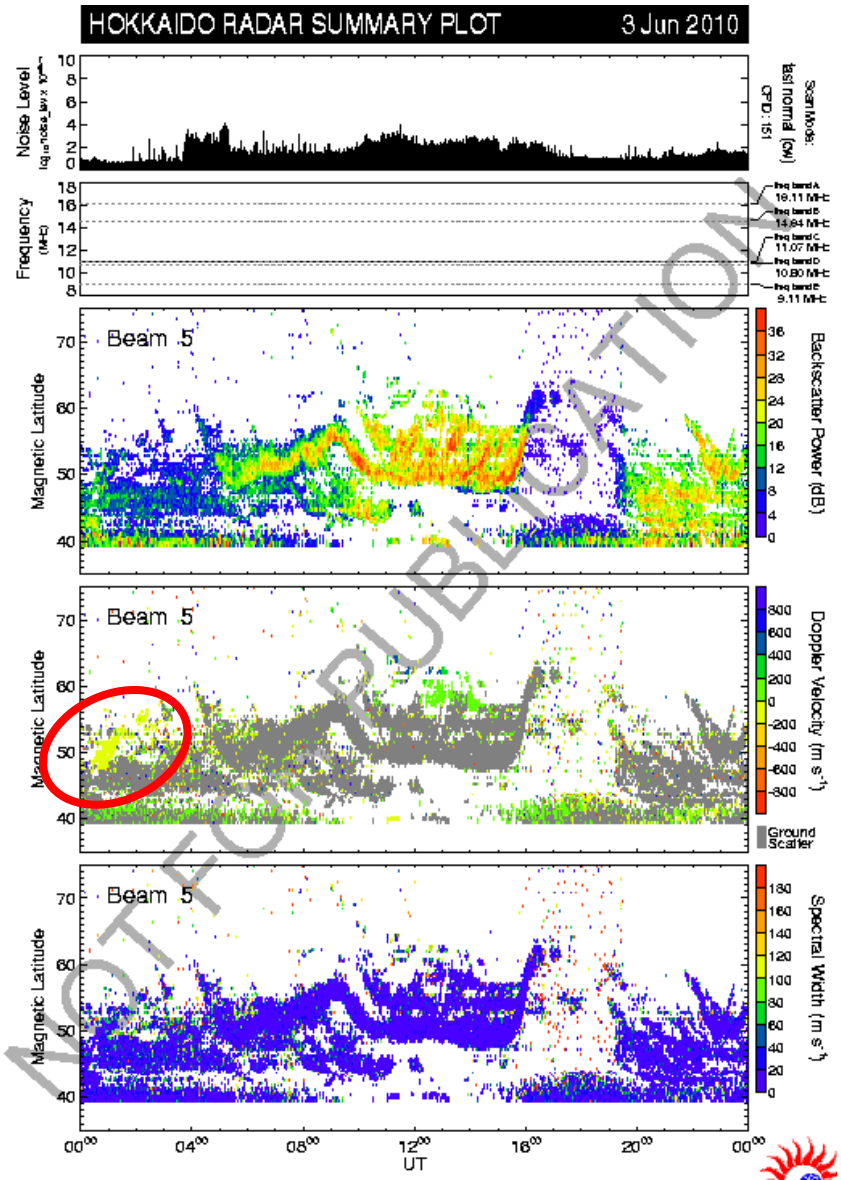
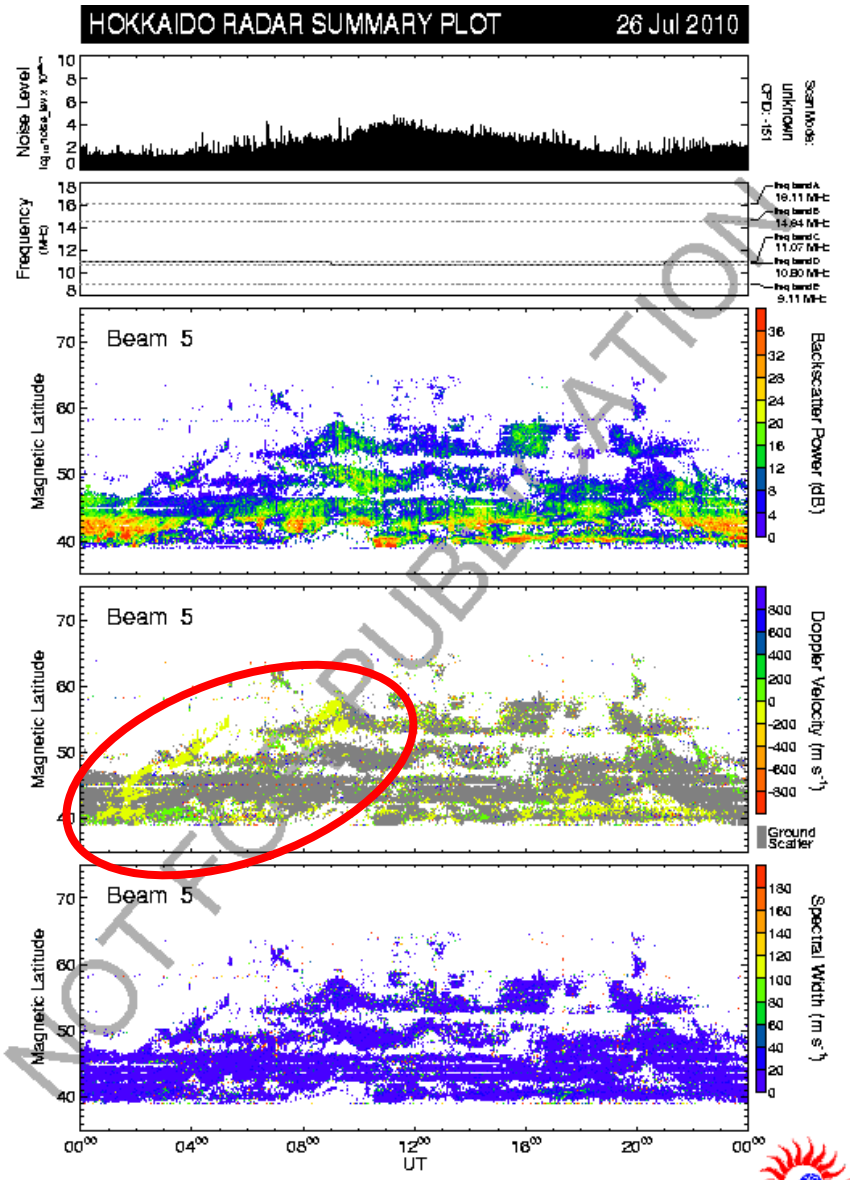


Fig. 4. Upper panel shows the time–height distribution of irregularity echoes with the signal-to-noise ratio above 0 dB which were observed during 20–23 June 1990. No operation of the MU radar was made during the periods of the hatched area. Lower panel shows the frequency range at which the ionosonde at Shigaraki detected echoes in the virtual heights of 90–130 km.

Dayside ionospheric scatter echoes (2010)





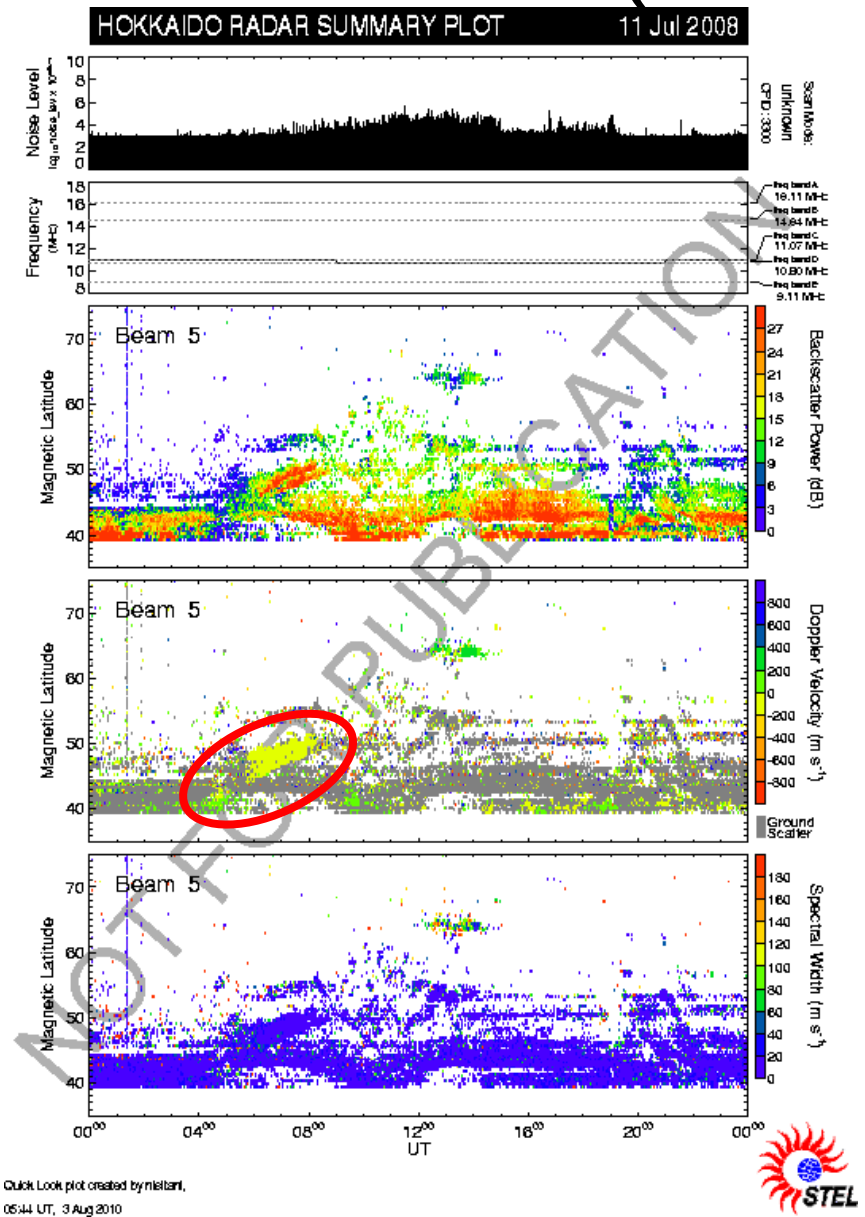
Quick Look plot created by nielitant,
22:28 UT, 2 Aug 2010

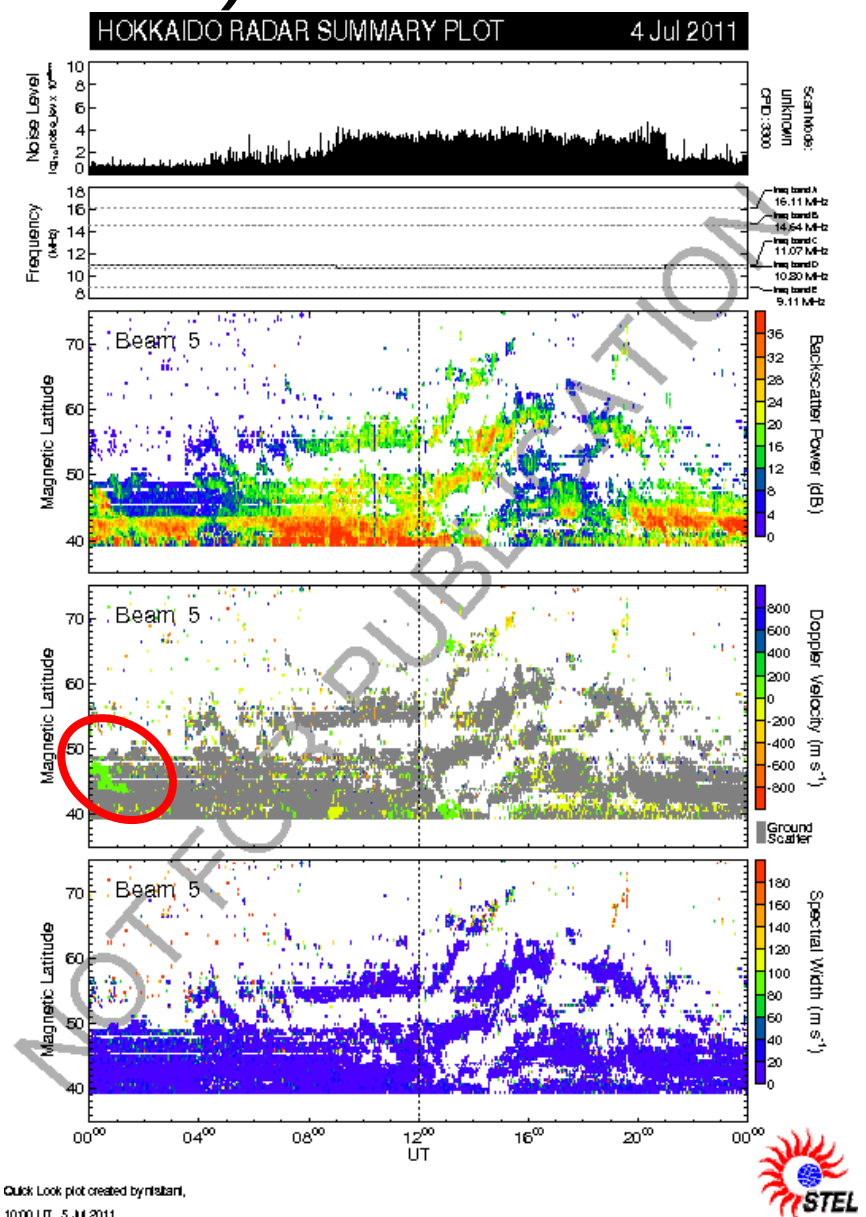
STEL

Quick Look plot created by nielitant,
23:03 UT, 2 Aug 2010

STEL

Dayside ionospheric scatter echoes (2008/ 2011)





Dayside ionospheric scatter: event selection

- Classified as ionospheric scatter echoes by fitacf
- Dayside echoes (22 – 08 UT)
- Coherent (not scattered as meteor echoes)
- Duration > 1 hr
- Range span > 2 degs
- Echo power > 10 dB

Events selected

2007
05/07 06-07
05/13 04-08
05/31 05-09
06/24 00-04
07/01 04-05
07/02 01-02
07/05 07-08
07/11 06-08
07/12 04-05
07/23 03-04
07/25 06-07

2008
05/06 07-08
05/22 05-07
06/05 03-05
06/07 05-07
06/09 03-04
06/10 08-09
06/13 04-05
06/26 04-05
06/28 02-08 *
07/03 08-09
07/09 06-07
07/11 06-09 *
07/14 08-09
07/21 05-09 *
07/23 06-09
08/10 07-08
08/21 08-09

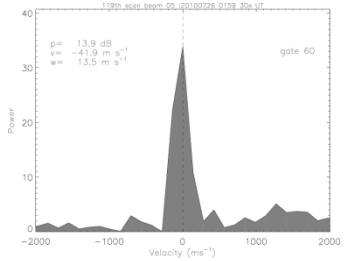
2009
05/24 06-09
05/26 05-07
06/18 00-04
06/18 08-09
07/04 07-09
07/13 04-06
07/30 05-08
(freq. scan)
08/22 05-07

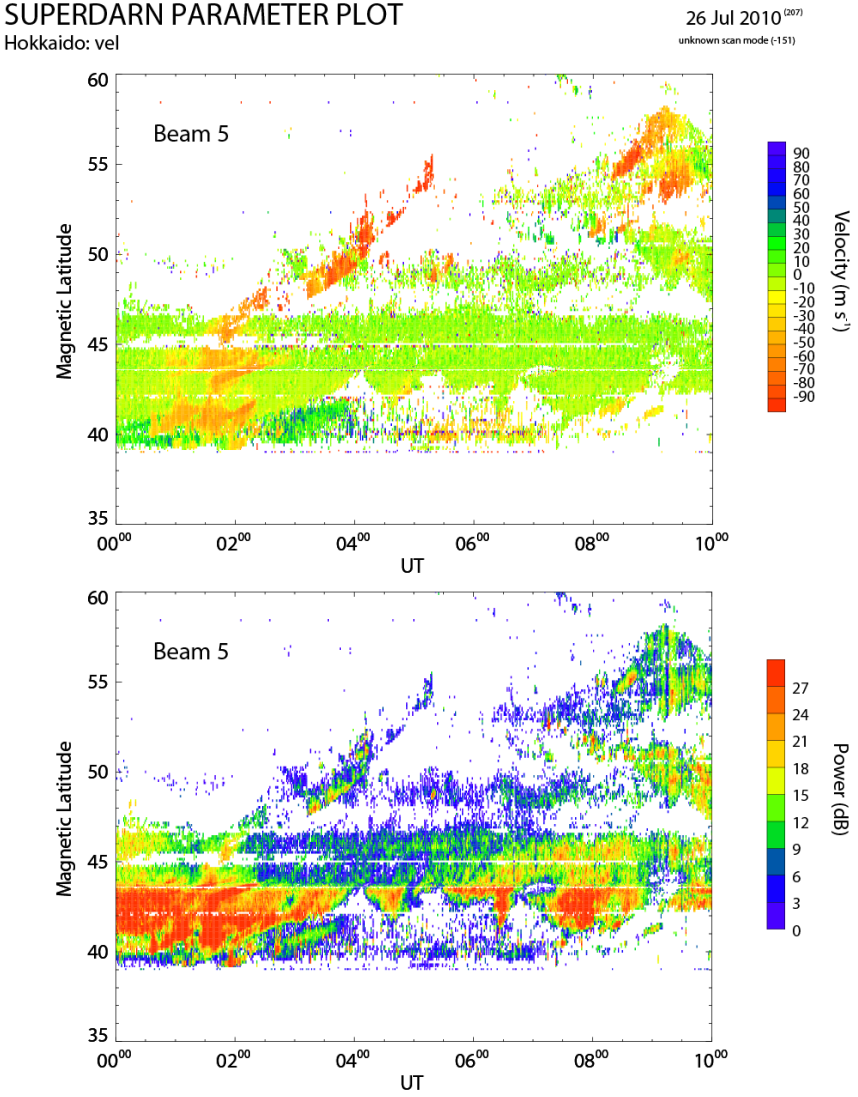
2010
05/07 03-05
(freq. scan)
05/22 00-06
06/03 00-03 *
06/04 08-09
06/09 08-09
06/14 06-07
06/18 05-09 *
06/20 07-08
06/21 08-09
(freq. scan)
07/01 03-06 *
07/08 02-04
07/20 05-08 *
(freq. scan)
07/21 05-07 *
07/26 01-09 *
07/27 08-09
(freq. scan)

2011
05/27 04-05
06/07 00-02 *
06/14 01-02
06/29 00-02
07/04 00-02 *
07/15 07-08
07/17 05-06
07/27 07-08
07/29 06-08
08/04 07-09

Total: 61 events
Season: May to Aug
*: echoes extending to far (> 1000 km) ranges

Unusual echoes in the summer dayside region





- Appears in the summer dayside region
- Strips of echoes with velocity of up to about 100 m/s and spectral width < 10 m/s.
- Not directly associated with geomagnetic activity or mesospheric echoes.
  - E-region echoes?
  - F-region echoes?
  - Mesospheric echoes?

Origin of echoes

F-region echoes?

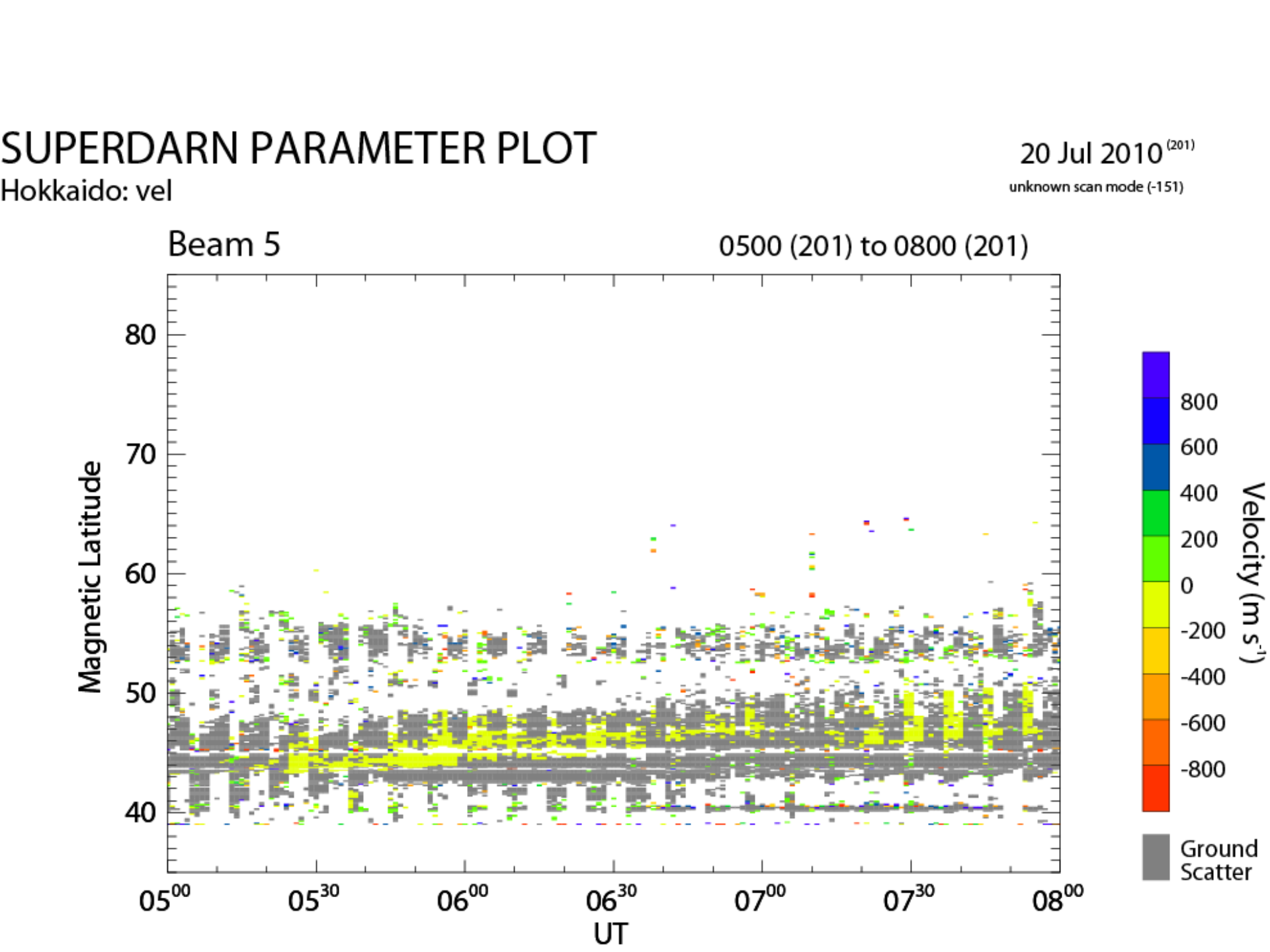
- Probably not.
  - “No echo has been observed during daytime”: Fukao et al., Turbulent Upwelling of the Mid-Latitude Ionosphere 1. Observational Results by the MU Radar, JGR, 1991.

E-region ionospheric echoes?

- Possibly yes, but not really consistent with the previous observations.
  - “Although the sporadic-Elayer is very active in the daytime, we could not find irregularity echoes in the afternoon, implying that the irregularities may be dumped by the high conductivity in the daytime E-region.”: Yamamoto et al., JATP, 1992.

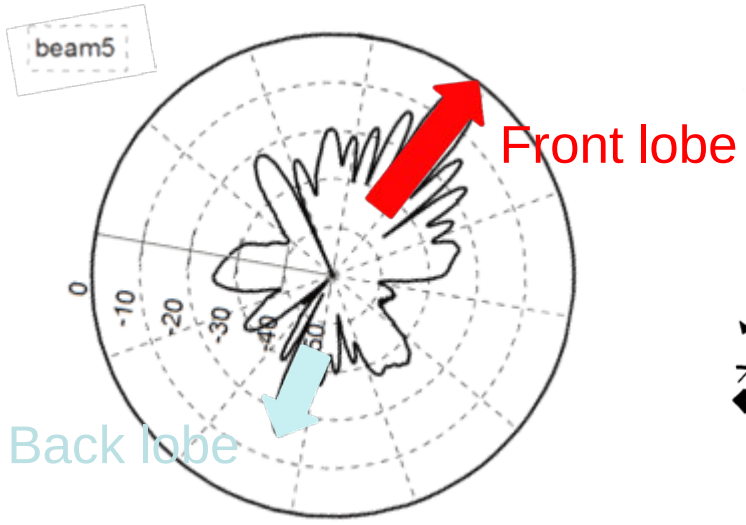
Ground / sea scatter?

- No, because
  - The Doppler velocities goes up to 100 m/s
  - There is almost no radar frequency dependence of the echo ranges


SUPERDARN PARAMETER PLOT
Hokkaido: vel
20 Jul 2010 (201)
unknown scan mode (-151)
Beam 5
0500 (201) to 0800 (201)
Magnetic Latitude
80
70
60
50
40
05^00
05^30
06^00
06^30
07^00
07^30
08^00
UT
800
600
400
200
0
-200
-400
-600
-800
Velocity (m s^-1)
Ground Scatter

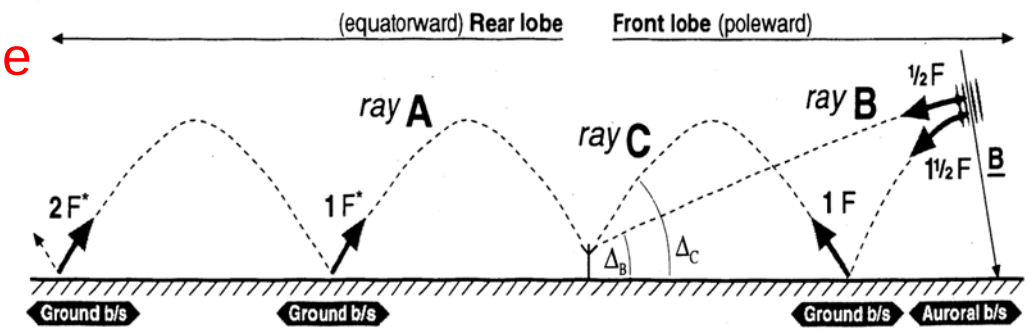
Backlobe echoes?

Radar beam pattern issue



Beam5 horizontal beam pattern

Modified from Ichihara et al. (2008)



Frontlobe and backlobe echoes

[*Milan et al.,1998*]

SuperDARN Hokkaido radar antenna system has backlobe.

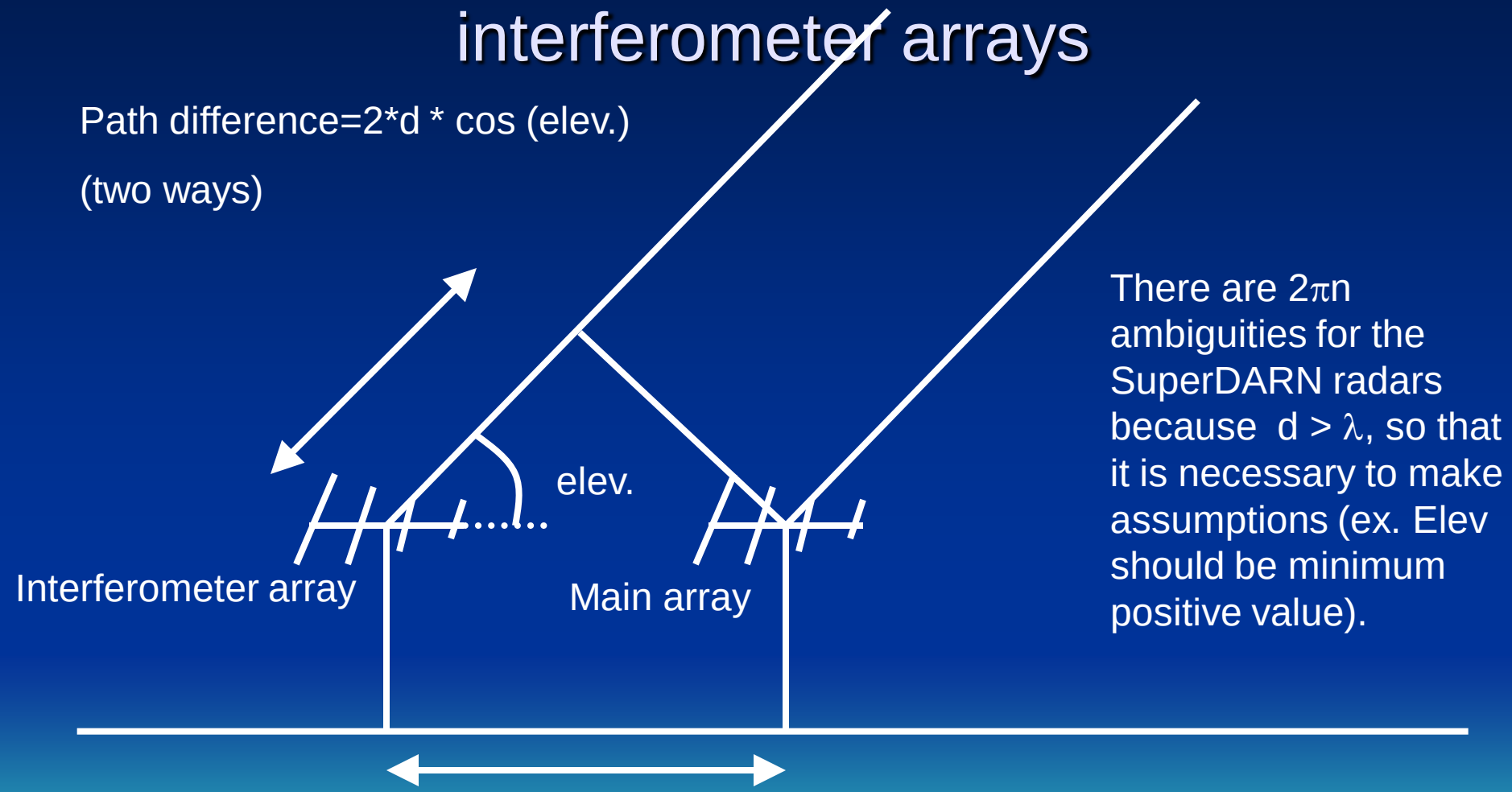
It is possible that the echoes observed actually come from behind the radar

Elevation angle can tell the difference[*Milan et al., 1997*]

Calculation of elevation angle from the phase difference between main and interferometer arrays

Path difference=2*d * cos (elev.)

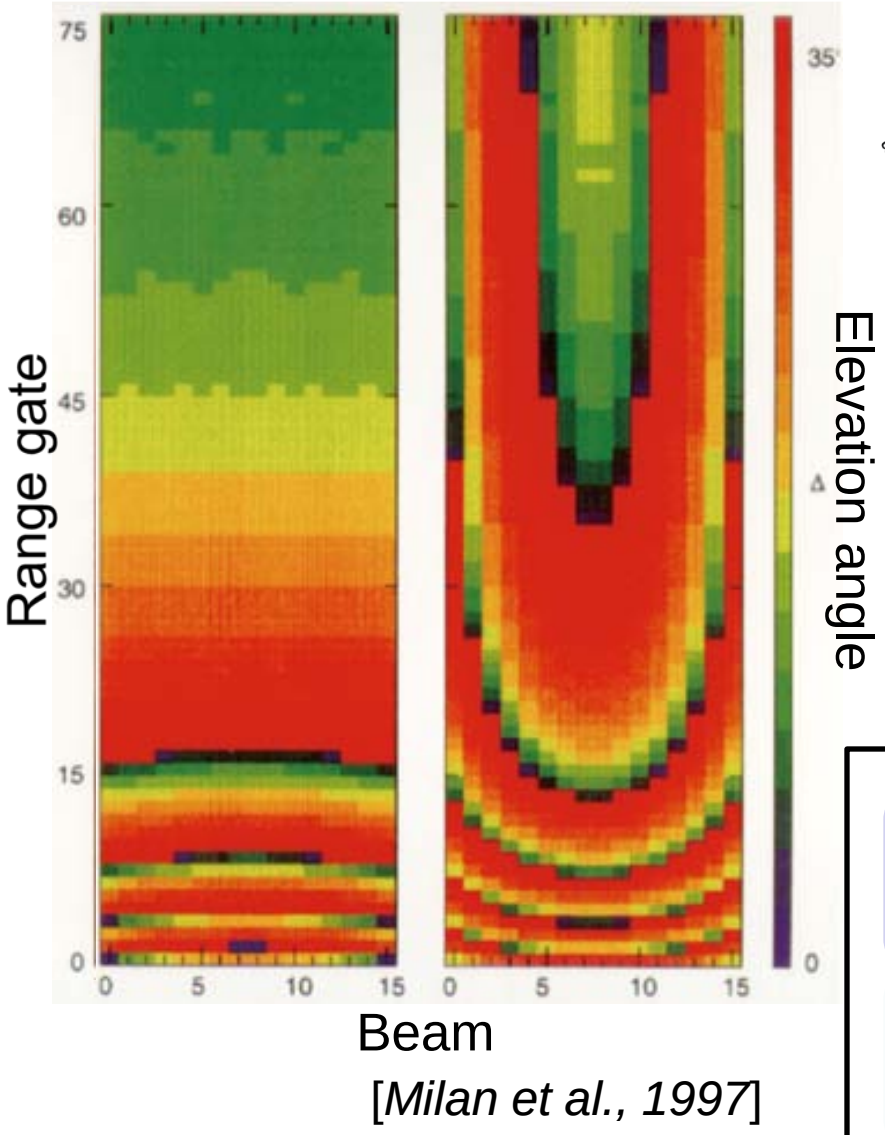
(two ways)



There are $2\pi n$ ambiguities for the SuperDARN radars because $d > \lambda$, so that it is necessary to make assumptions (ex. Elev should be minimum positive value).

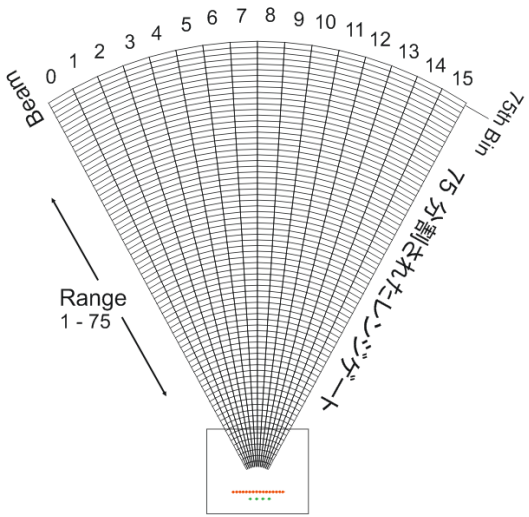
Elevation angle can distinguish frontlobe and backlobe

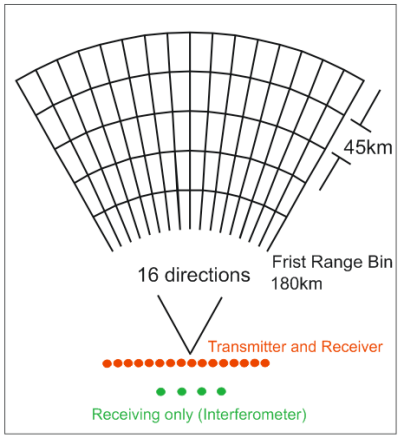
Frontlobe Backlobe



[*Milan et al., 1997*]

Modified from Ichihara et al. (2008)





Elevation angle

-If it is actually frontlobe
Elev shows horizontal structure.

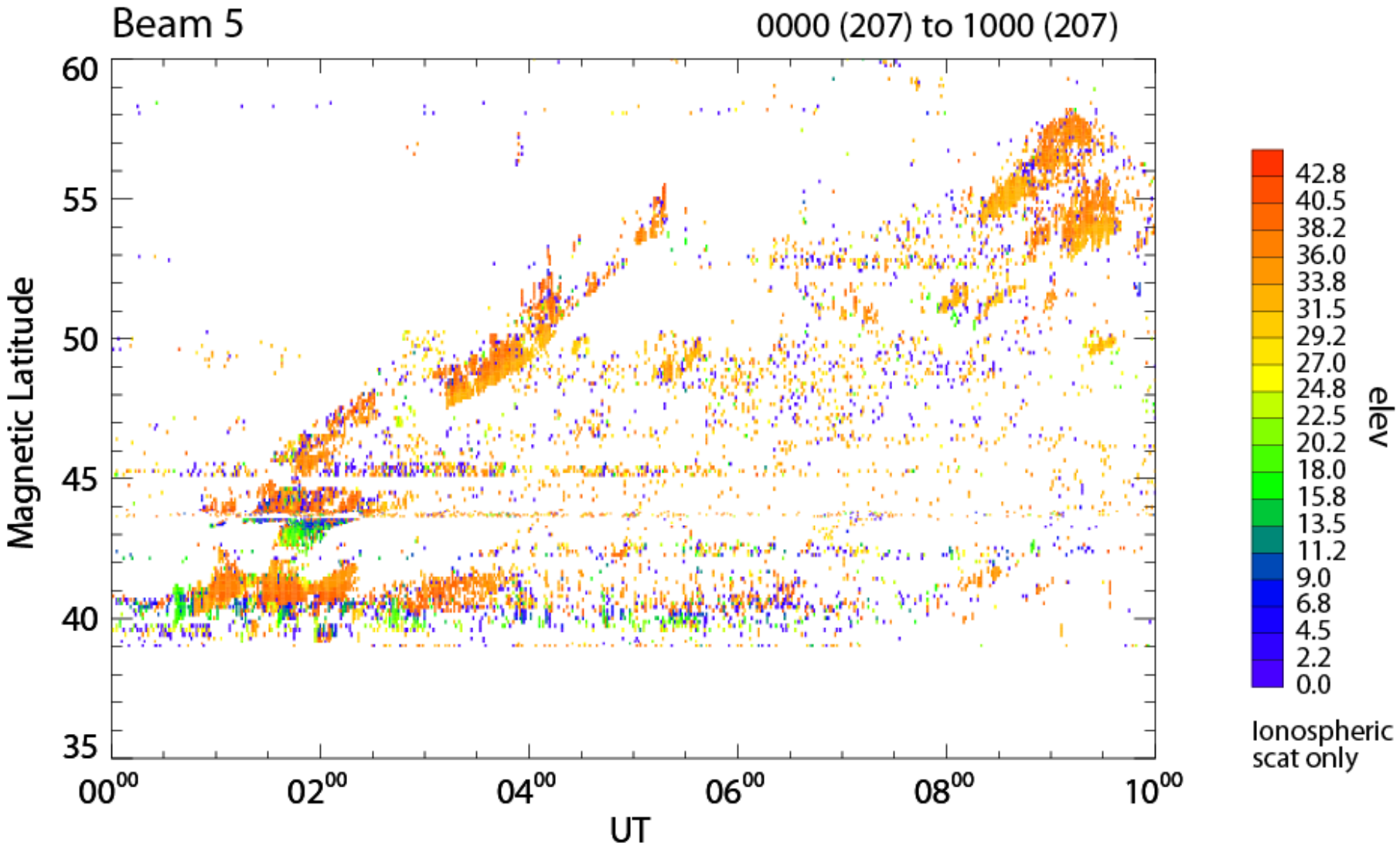
-If it is backlobe
Elev shows ellipsoidal structure.

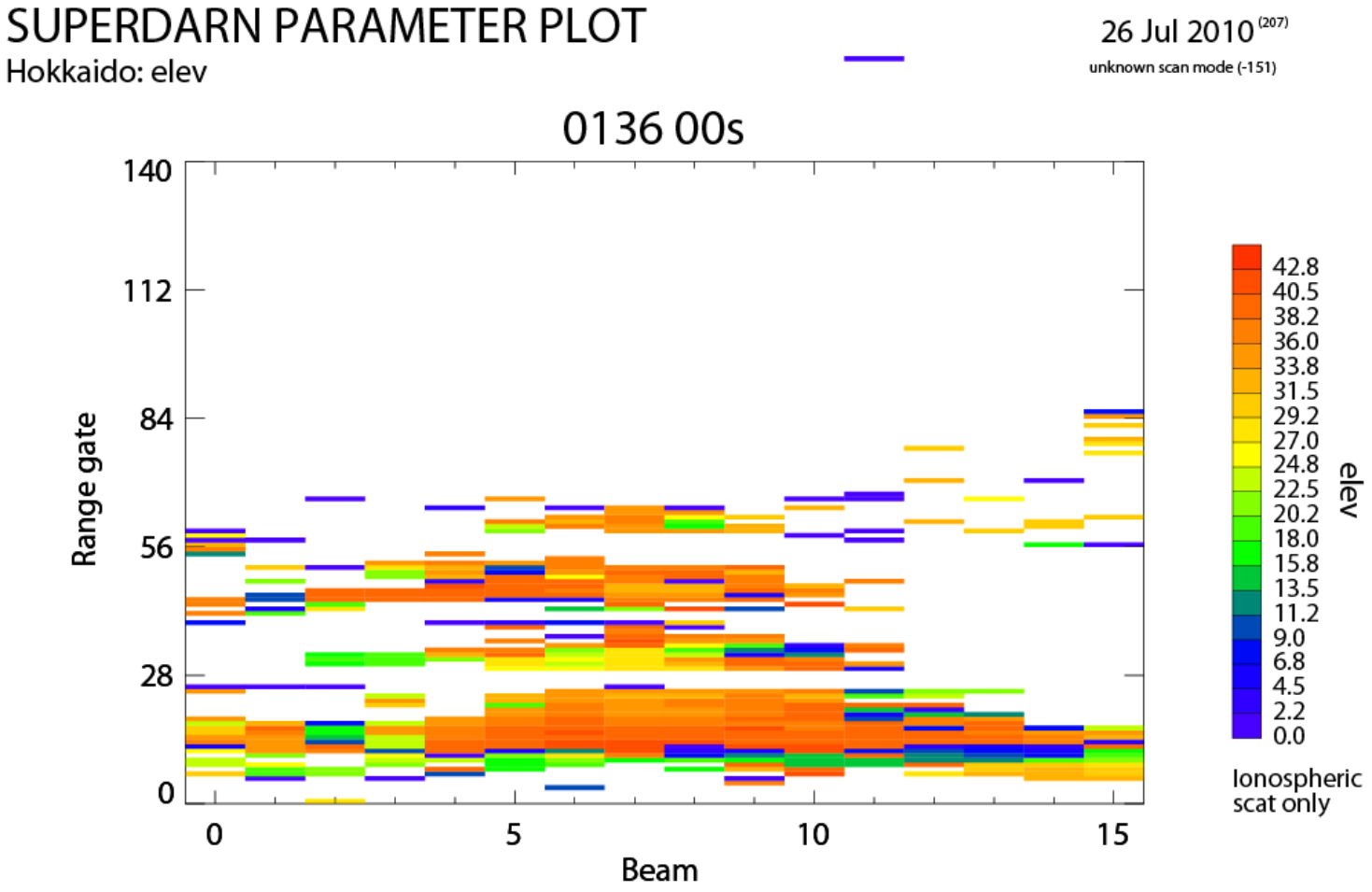
SUPERDARN PARAMETER PLOT

Hokkaido: elev

26 Jul 2010 (207)

unknown scan mode (-151)



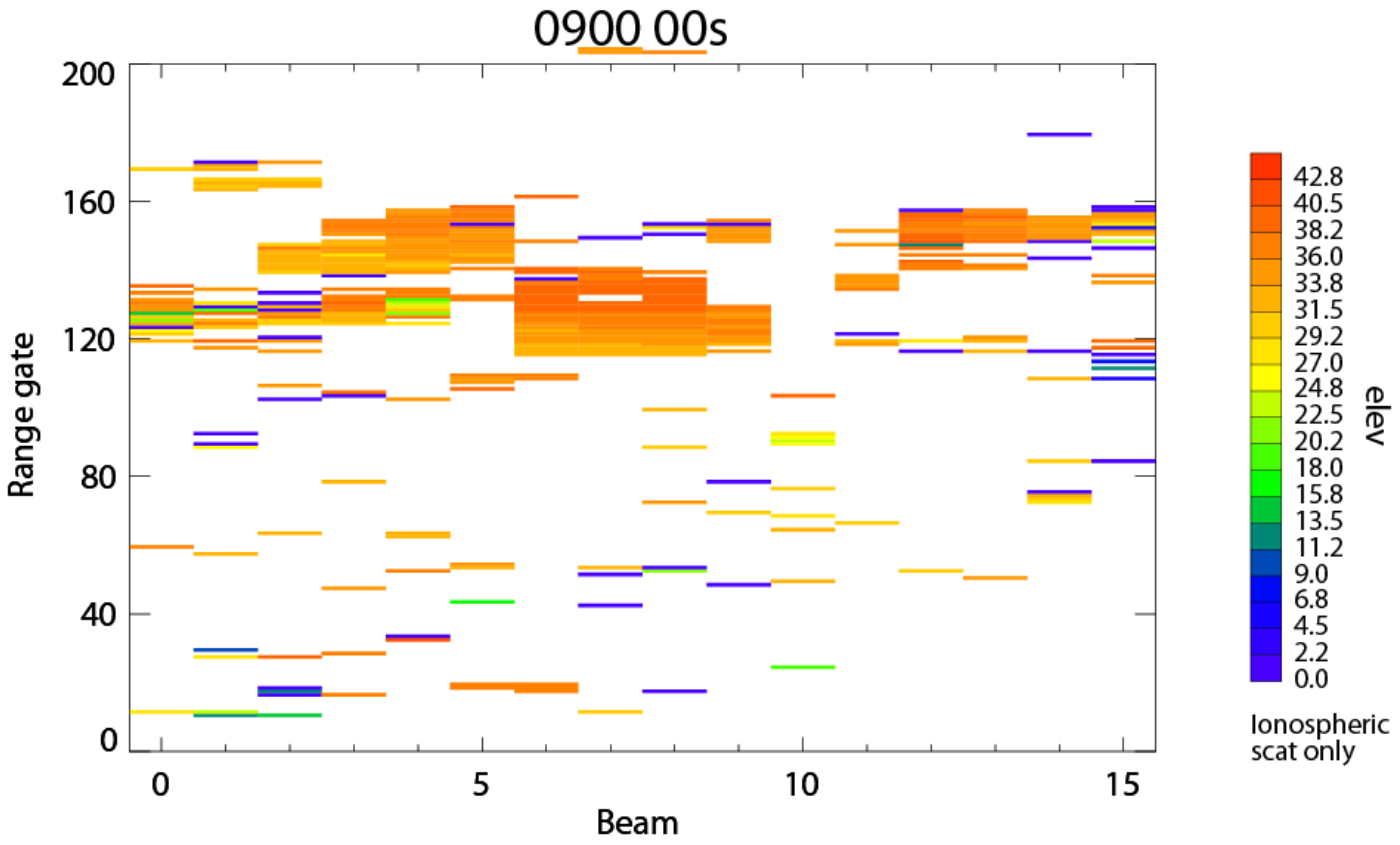

SUPERDARN PARAMETER PLOT
Hokkaido: elev
26 Jul 2010 (207)
unknown scan mode (-151)
0136 00s
140
112
84
56
28
0
Range gate
0
5
10
15
Beam
42.8
40.5
38.2
36.0
33.8
31.5
29.2
27.0
24.8
22.5
20.2
18.0
15.8
13.5
11.2
9.0
6.8
4.5
2.2
0.0
elev
Ionospheric
scat only

SUPERDARN PARAMETER PLOT

Hokkaido: elev

26 Jul 2010 (207)

unknown scan mode (-151)



Summary: summer-time dayside ionospheric scatter echoes

- Dayside mid-latitude Ionospheric scatter echoes are often observed in summer.
- They are NOT ground / sea scatter echoes.
- They are probably NOT F-region echoes.
- They might possibly be E-region echoes but not really consistent with previous observations.
- They are NOT mesospheric echoes as can be inferred from the comparison with Wakkanai VHF radar data.
- Some of them (but not all) are backlobe echoes coming from behind the radar.
- Most of them have poleward Doppler velocities, with their structures moving mostly poleward (but it may backlobe echoes, corresponding to echoes moving equatorward).

Unsolved questions

- What are the origin of these echoes?
- What are the origin of these high Doppler velocities corresponding to E ~ 5 mV/m?
- Are they related to TID structures?
- Why are they not observed with MU radar?

Future studies

- Comparison with Wakkanai ionosonde to identify relation with sporadic E.