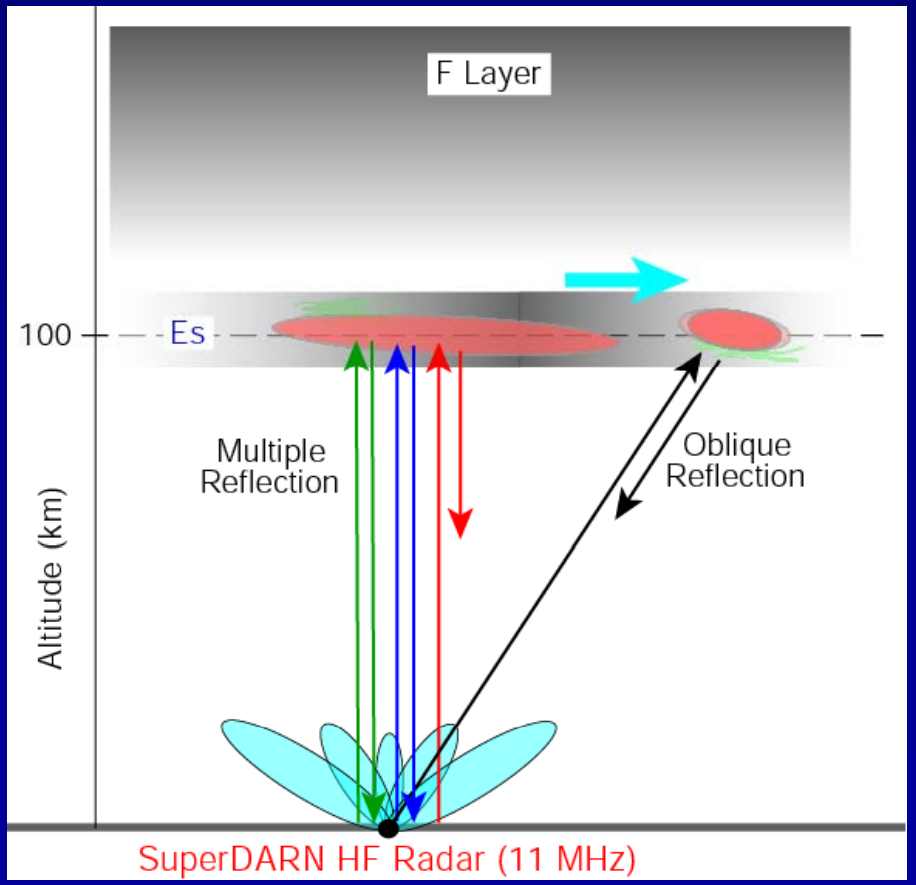
平成22年度 STEL研究集会「中緯度短波レーダー研究会」 名大 2011.1.31

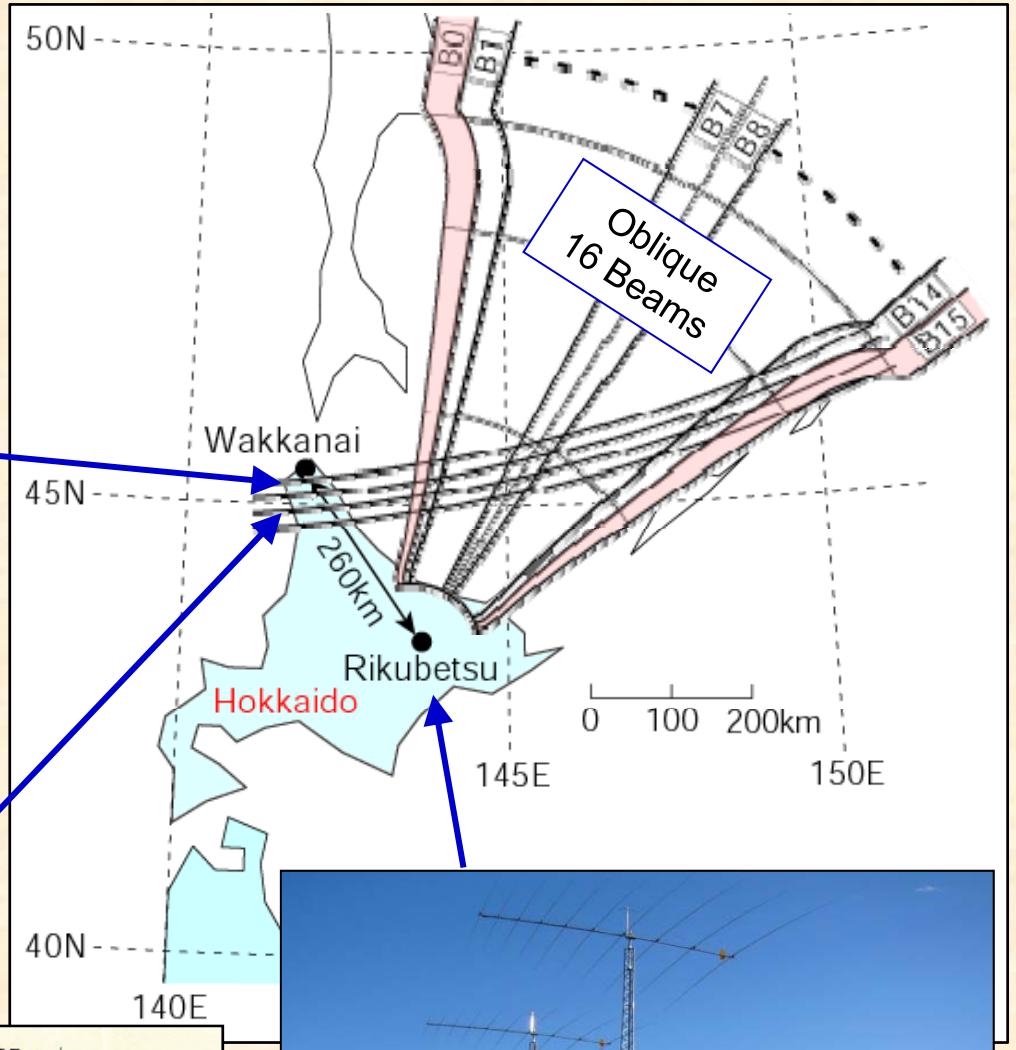
北海道-陸別 SuperDARN で初観測された夏季夕方の強い Es 層からの反射エコー

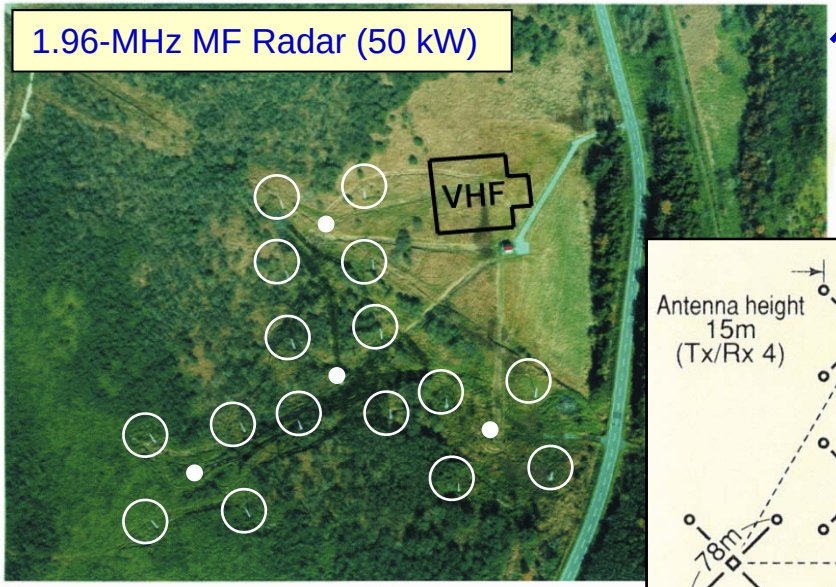
小川忠彦(NICT)、西谷 望(名大STE研)

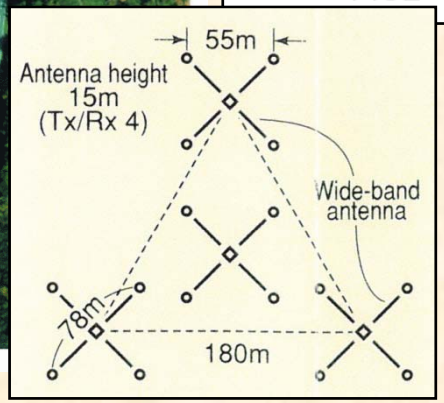
- HF radar echoes from strong Es
  - Multiple reflection from overhead Es cloud
  - Oblique reflection from away-moving Es cloud
- SuperDARN radar as a multibeam ionosonde



Wakkanai (Now Sarobetsu) Ionosonde







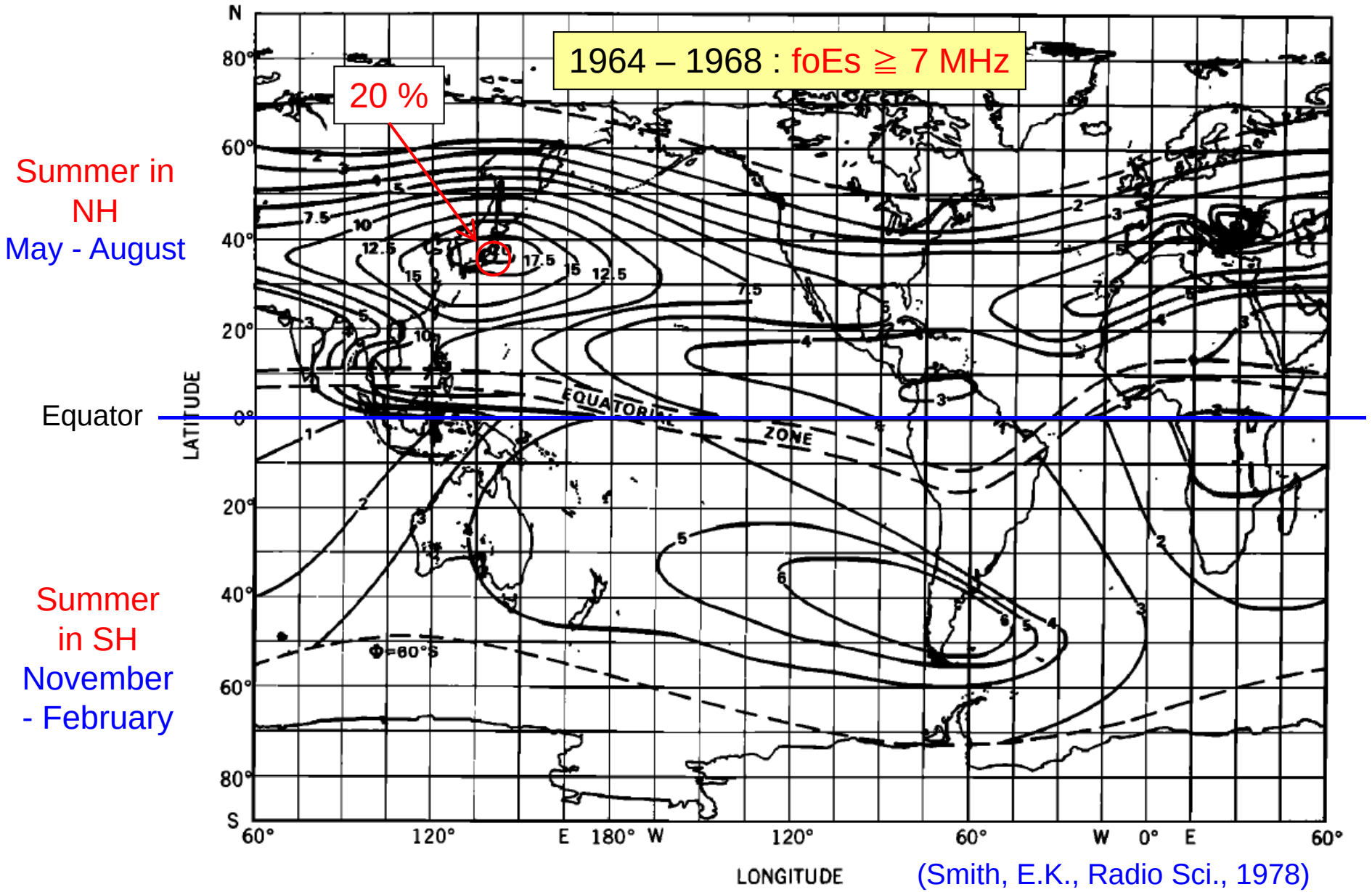
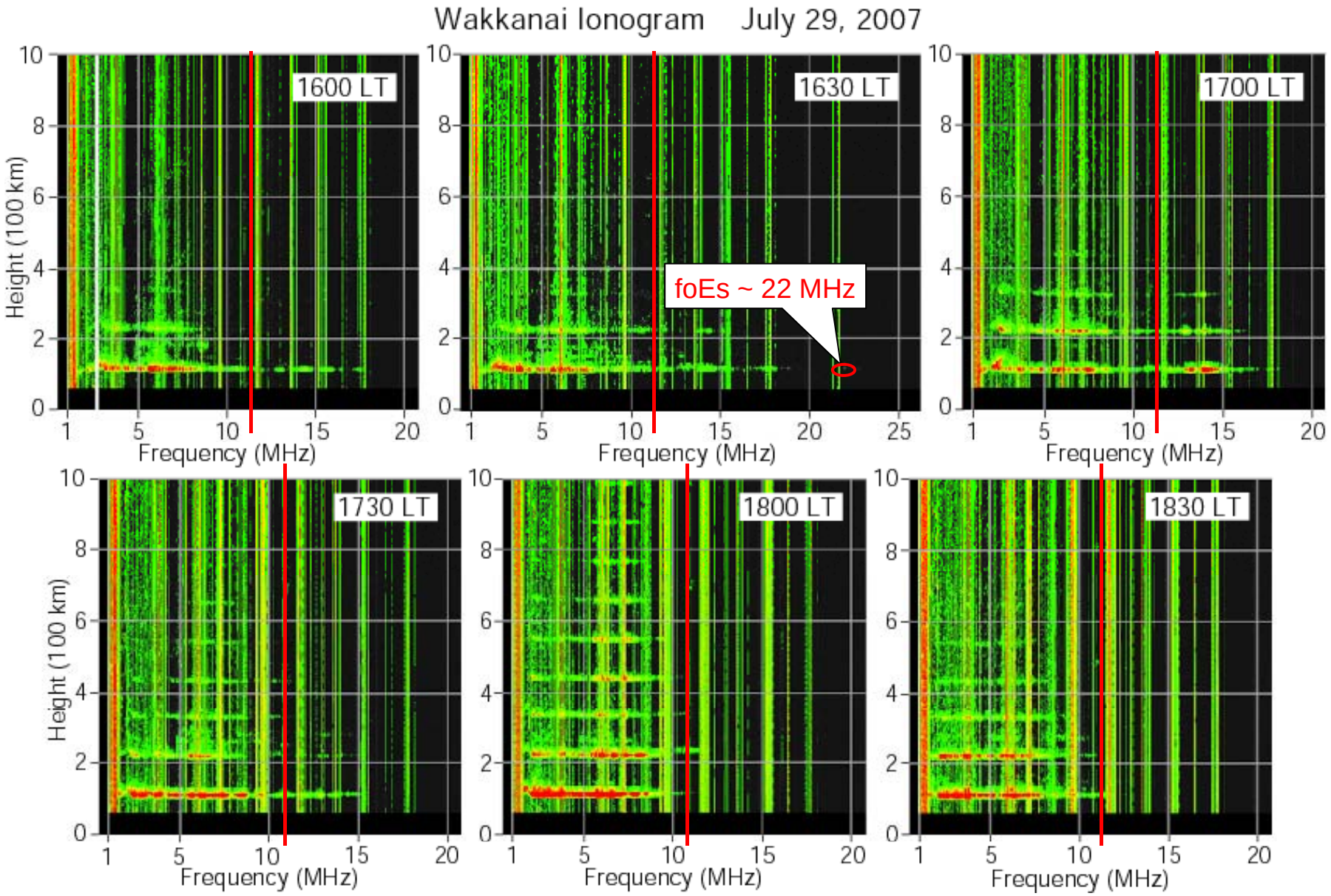


Fig. 2. Percentage of the time for which sporadic-E (f_oE_s) exceeds 7 MHz at vertical incidence in the temperate zone during "summer months" (summer months north of the equator are May–August, and south of the equator, November–February). The contours for $\phi = 60°$ north and south are geomagnetic (dipole) coordinates. The equatorial zone is ±5° in magnetic dip. Note that there is a discontinuity at the geographic equator.

Wakkanai Ionogram

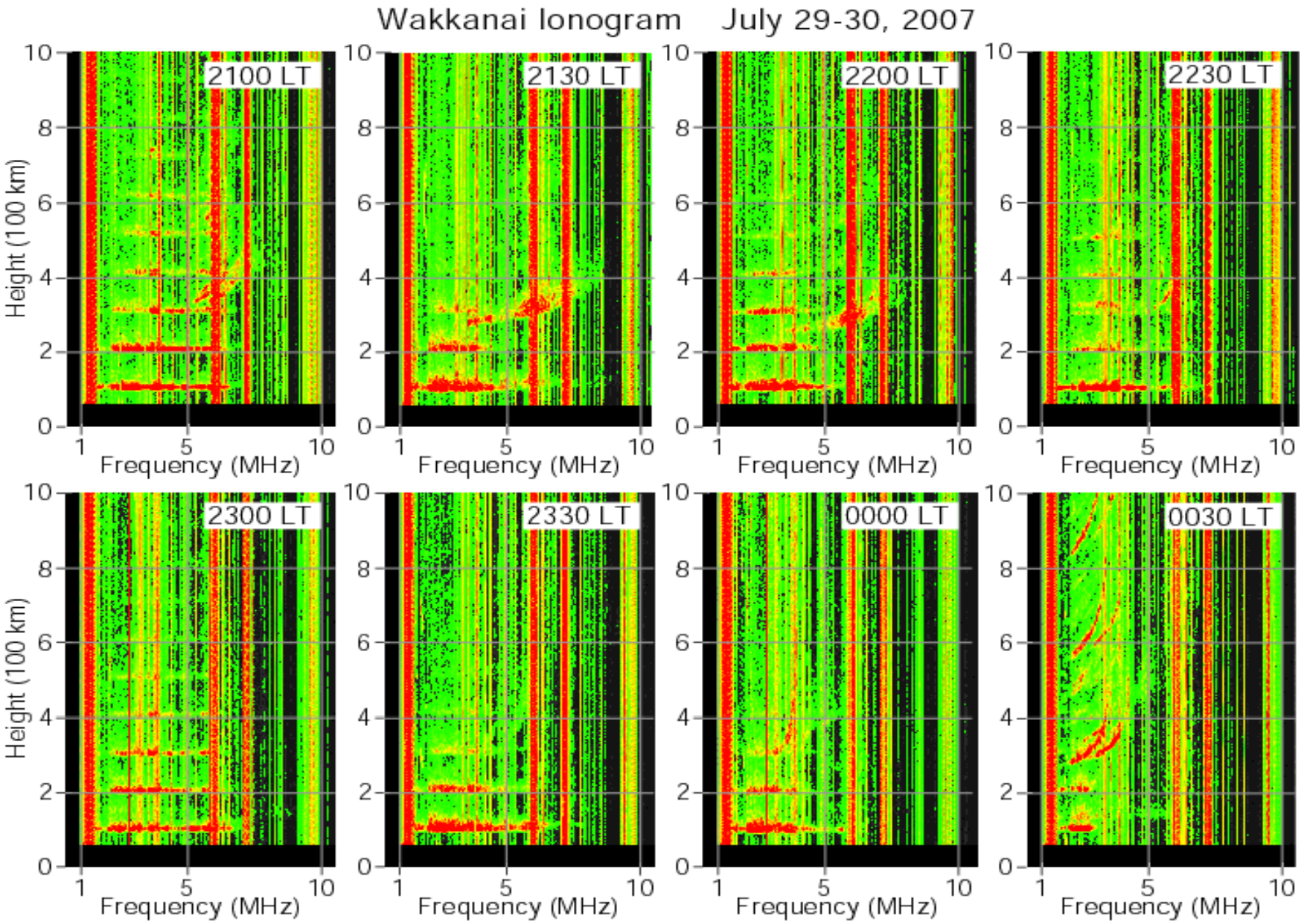
Multi-reflection From Strong Es in the Summer Evening



SuperDARN Freq. ~11 MHz < foEs

Wakkanai Ionogram

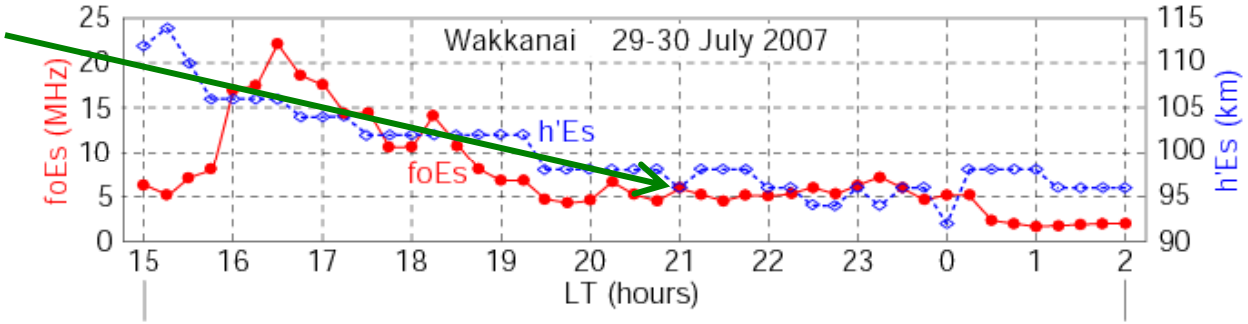
Multi-reflection From Es in the Summer Night



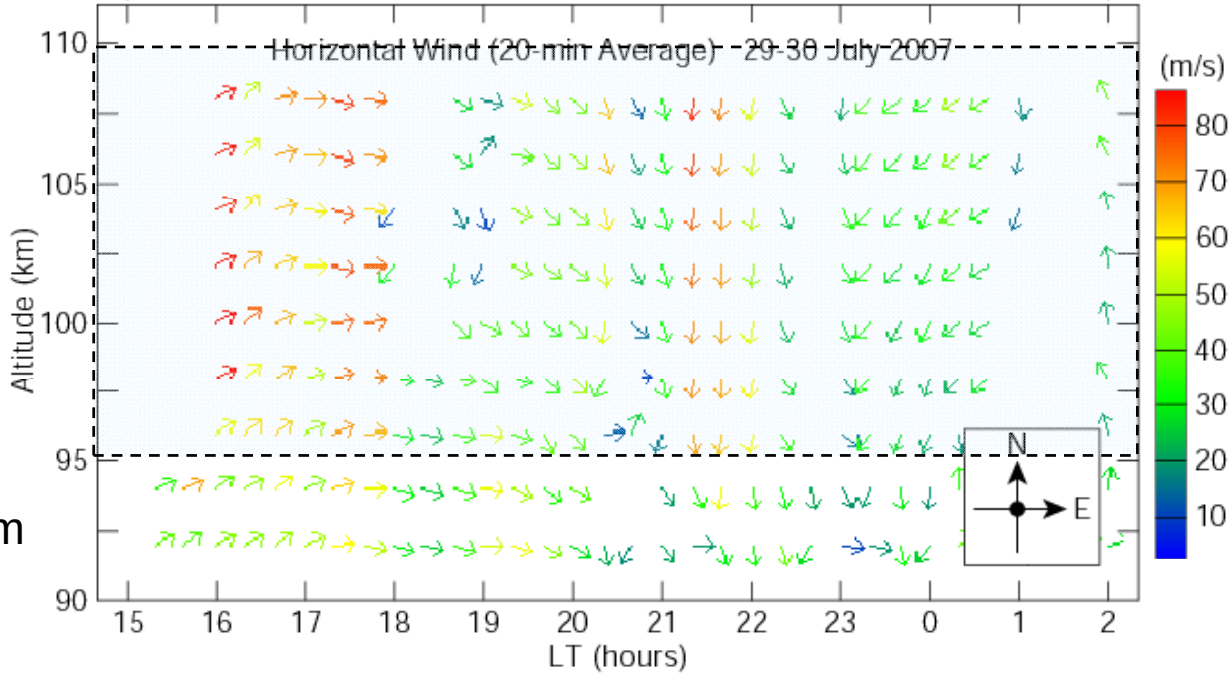
SuperDARN Freq. ~11 MHz > foEs

h'Es (2 km / h)
Semidiurnal Tide

foEs & h'Es

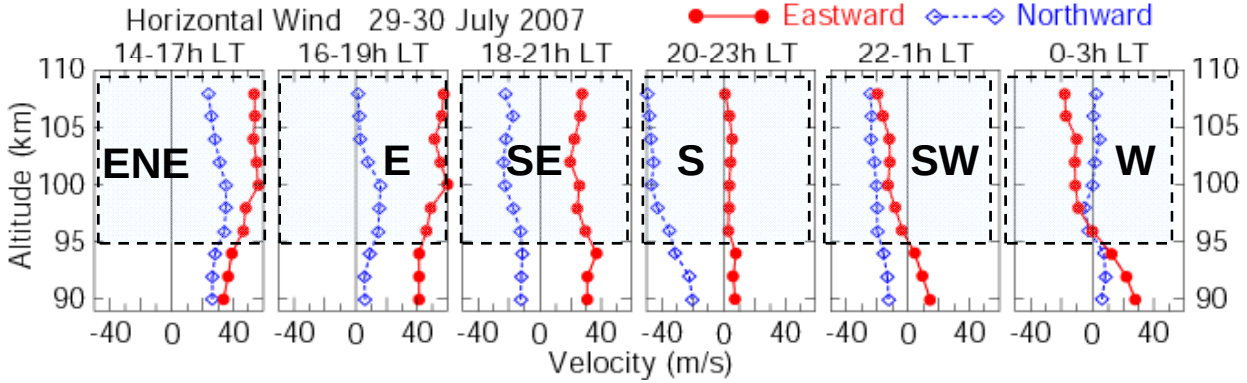


Horizontal wind observed with the Wakkanai MF radar



Wind direction at 95-110 km rotates clockwise with time due to semi-diurnal tide

Horizontal wind averaged over 3 hrs

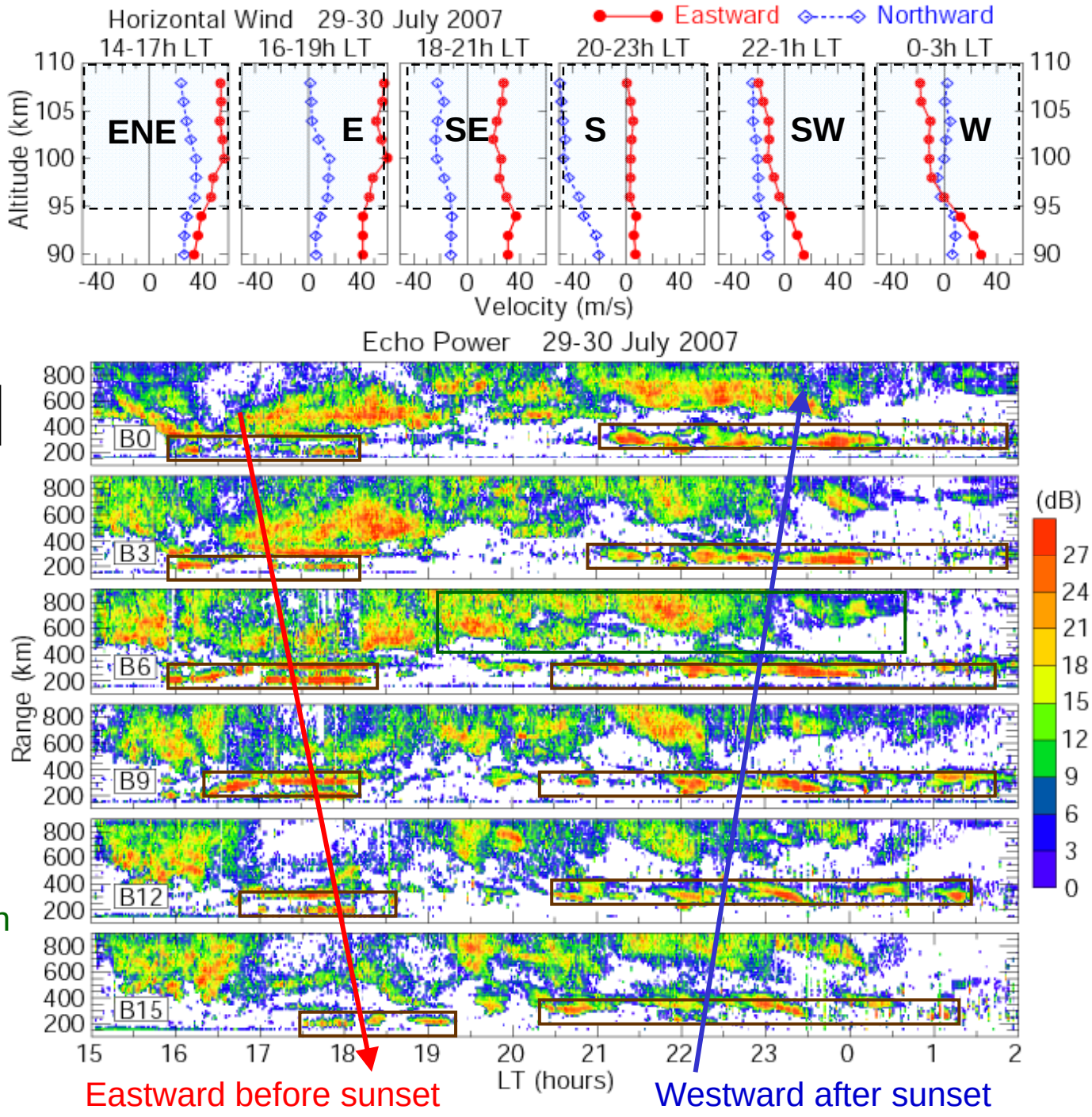


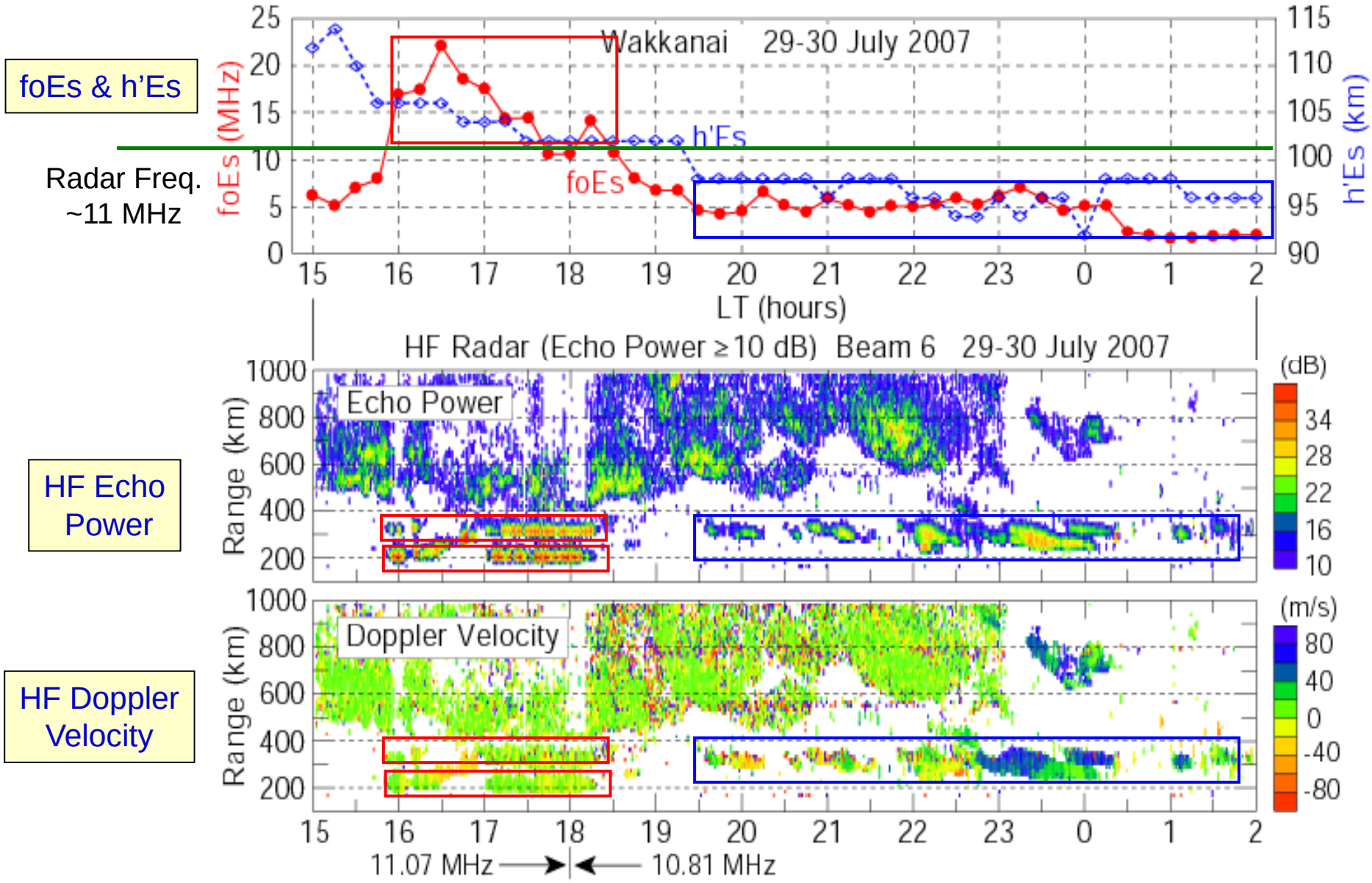
Wakkanai
Horizontal Wind

HF Echo Power

Es echo regions below 400 km range move with neutral wind (semi-diurnal tide) at 95-110 km

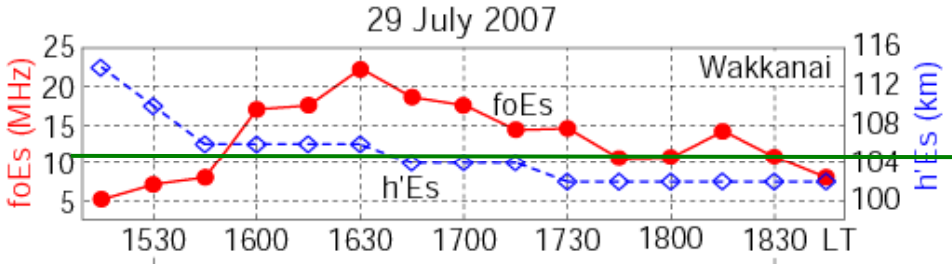
Nighttime Es echoes are connected with echoes from MSTID in the F-region beyond 400 km range





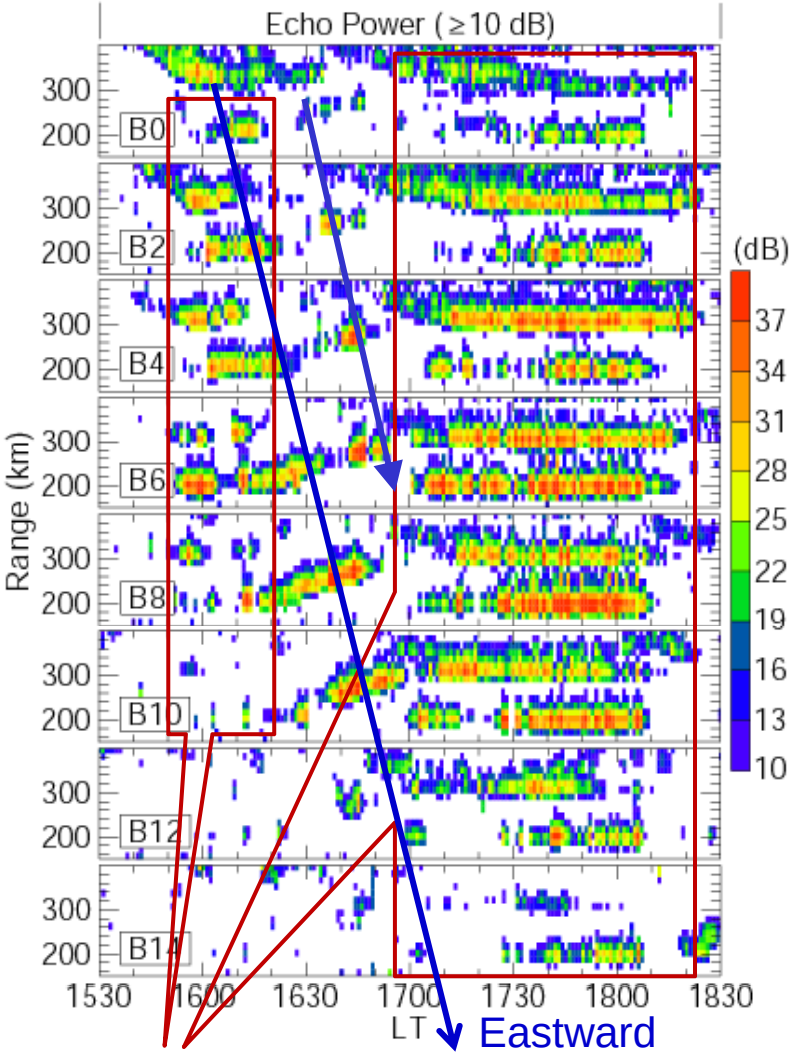
Multi-reflection from strong Es (foEs ≧ 10 MHz)

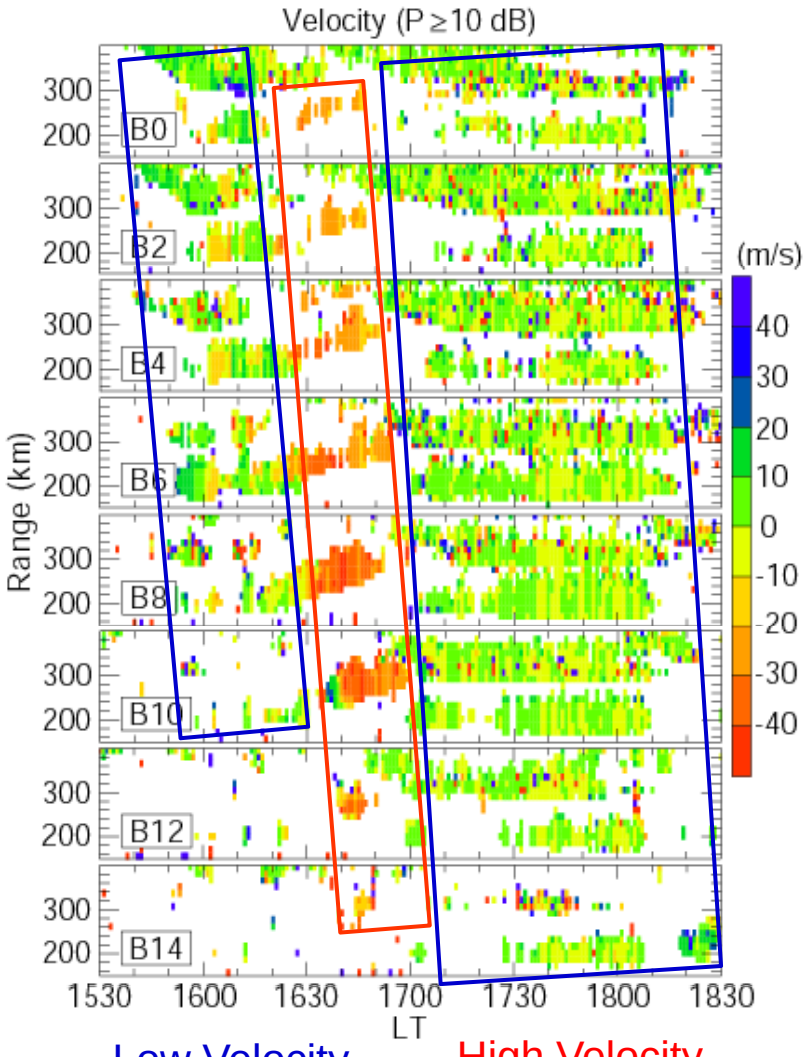
Coherent echoes from weak Es (foEs ≦ 7 MHz)



Radar Freq.
~11 MHz

Very narrow
Spectral widths

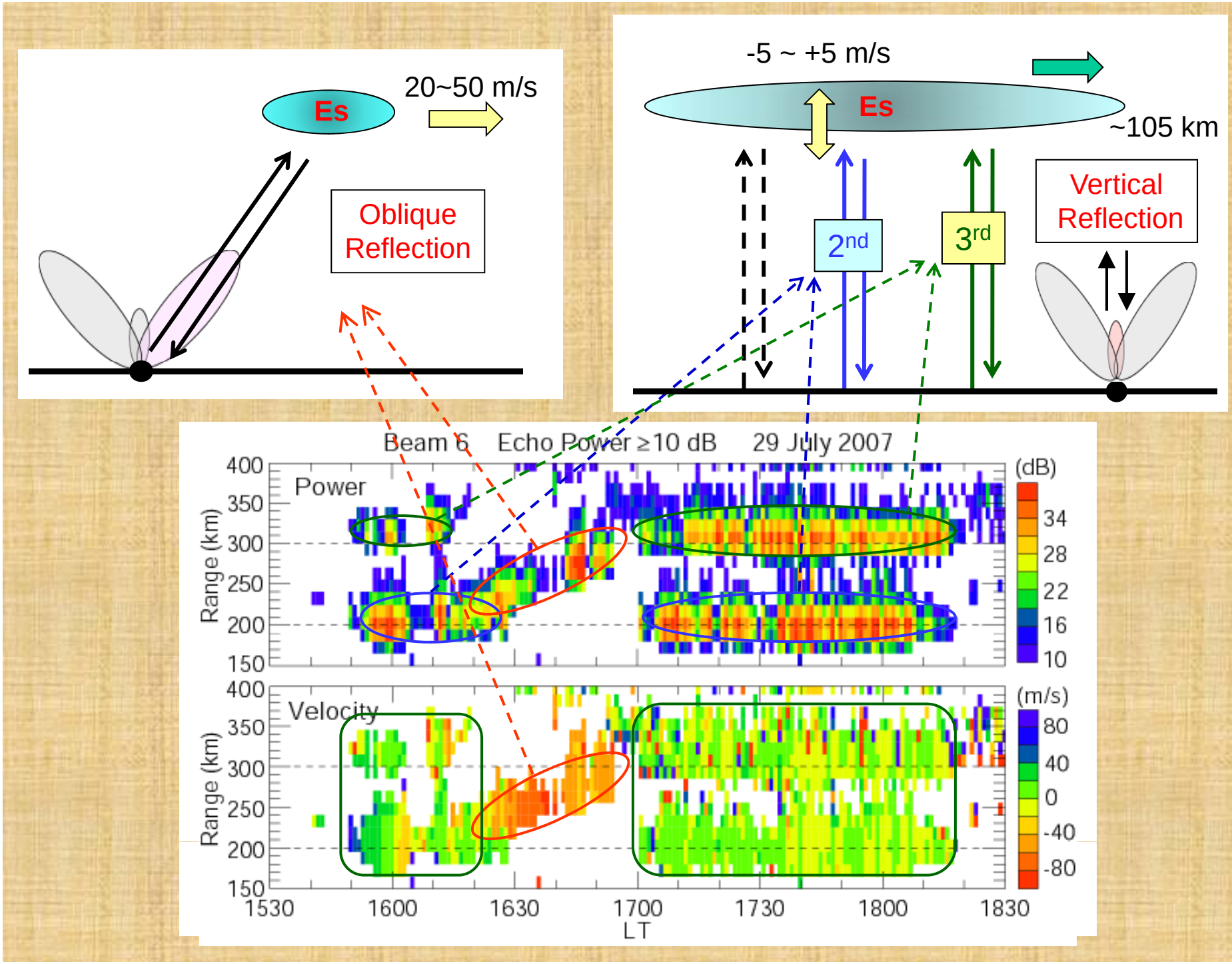




Echoes appear at ranges of 195-210
and 300-315 km on all the beams

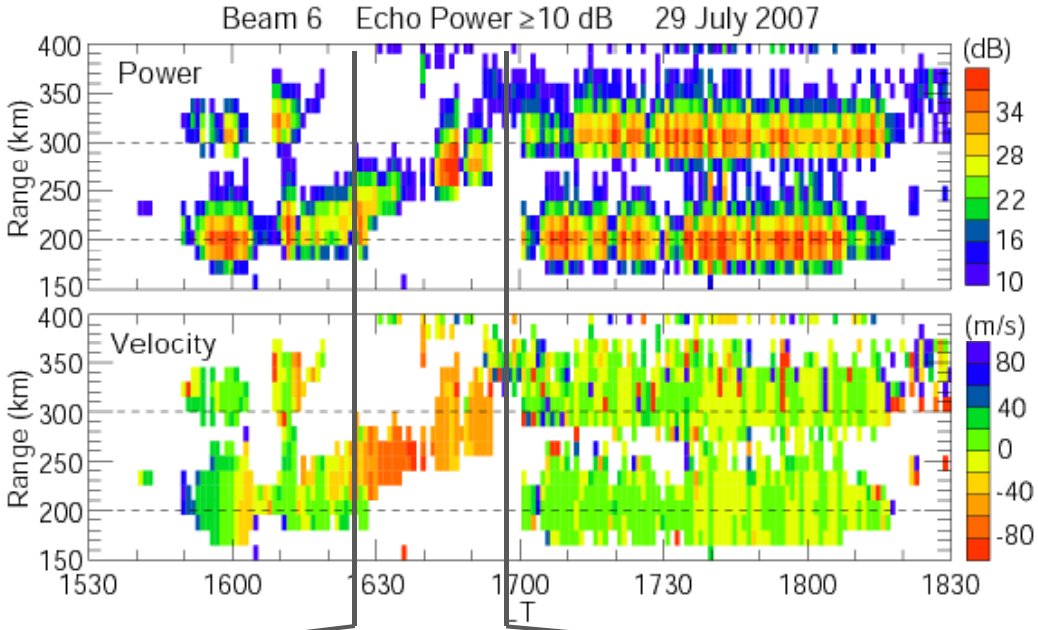
Low Velocity
(+5 ～ -5 m/s)

High Velocity
(+20 ～+50 m/s)


Es
20~50 m/s
Oblique
Reflection
-5 ~ +5 m/s
Es
~105 km
2nd
3rd
Vertical
Reflection
Beam 6 Echo Power ≥10 dB 29 July 2007
Power
Range (km)
400
350
300
250
200
150
(dB)
34
28
22
16
10
Velocity
(m/s)
80
40
0
-40
-80
1530
1600
1630
1700
1730
1800
1830
LT

HF Echo Power

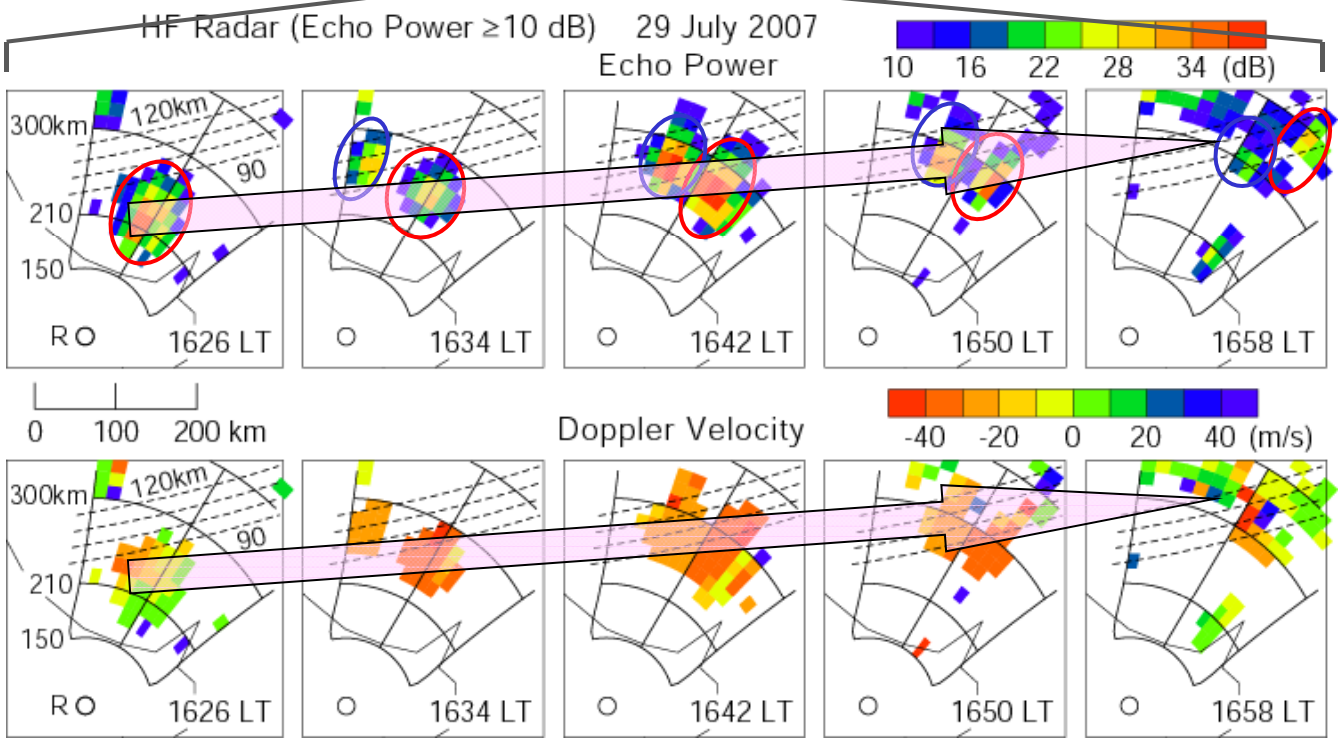
HF Doppler Velocity

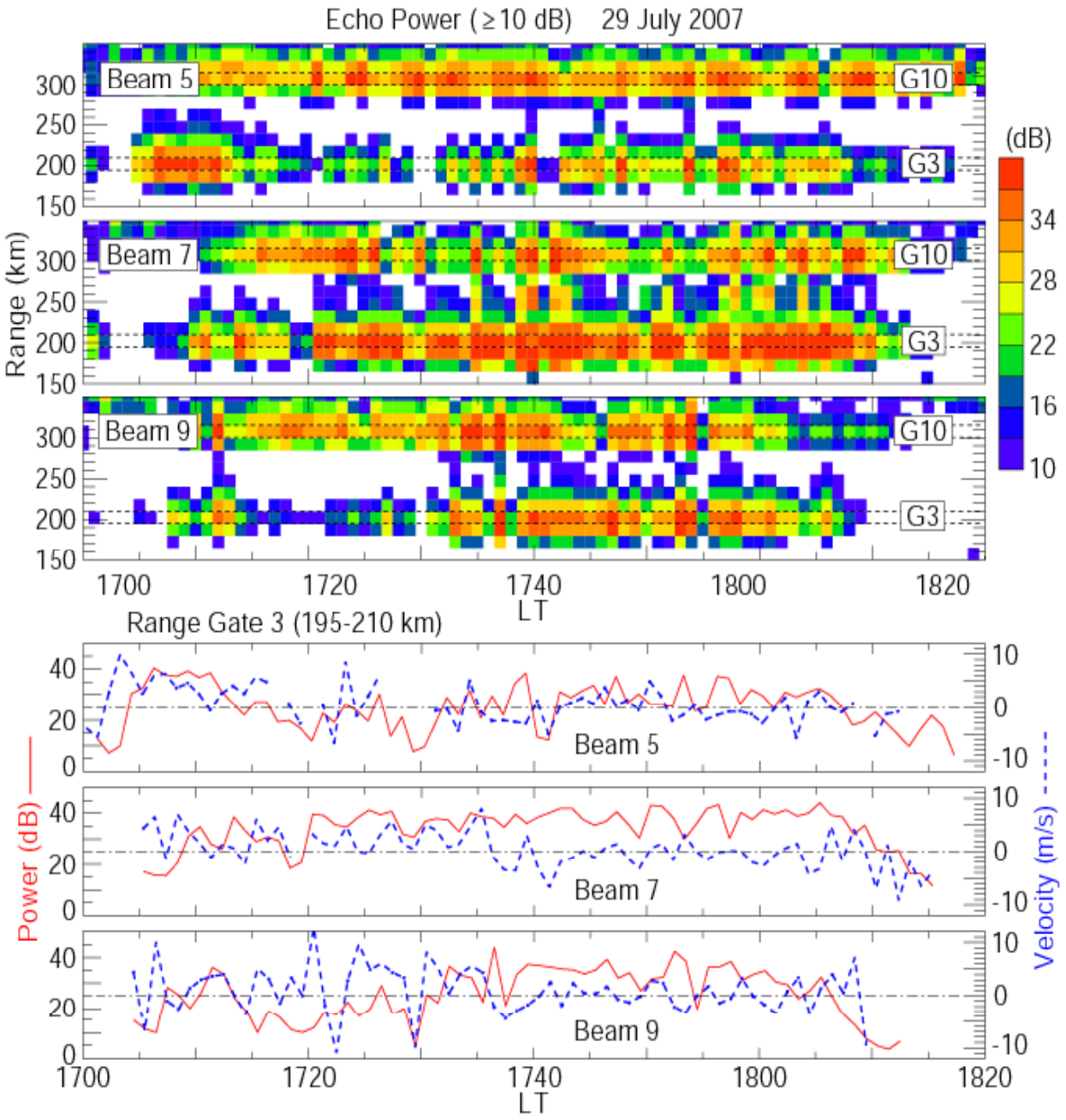


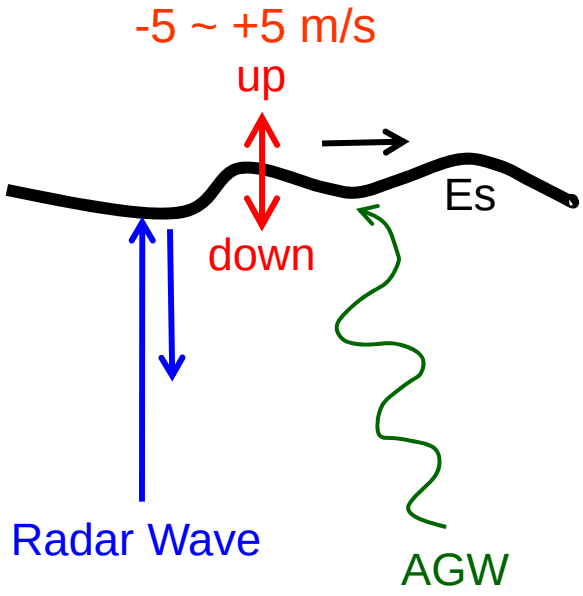
Two-dimensional Map of Echo Power

Es clouds move toward ENE at 20~50 m/s with neutral wind

Two-dimensional Map of Doppler Velocity

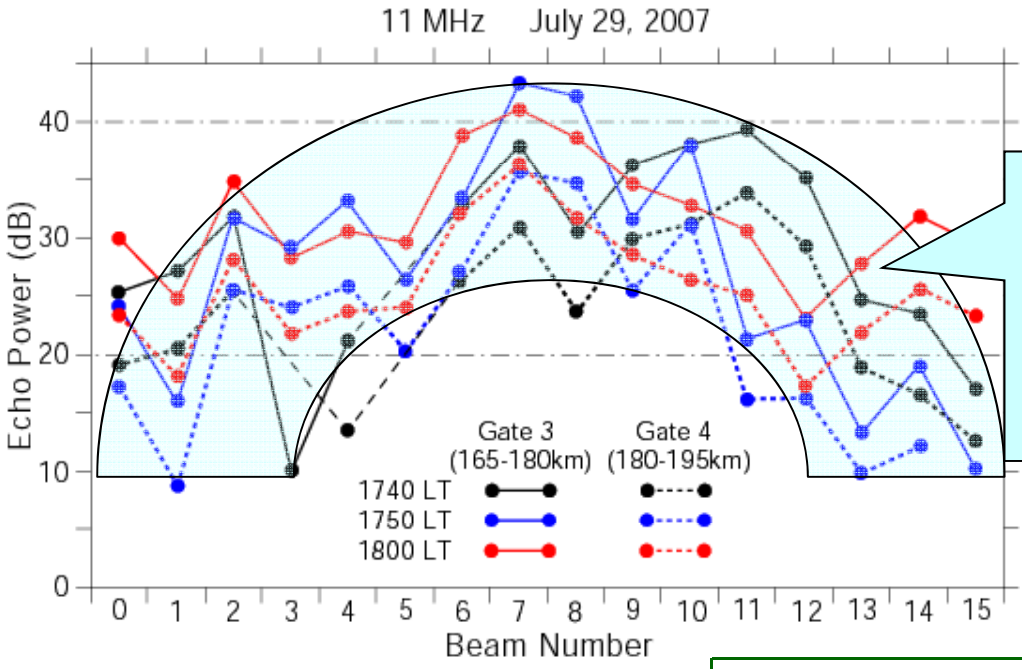






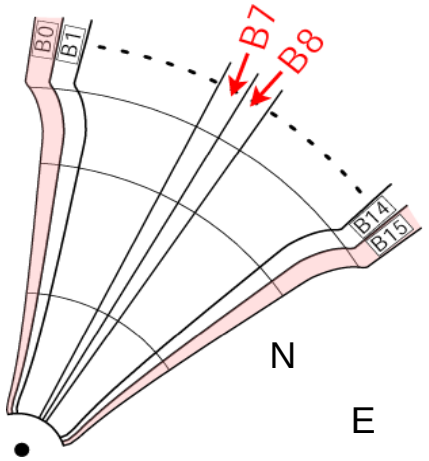
Spatiotemporal variation of echo power and Doppler velocity (-5 ~ +5 m/s) with periods of 5 ~ 20 min due to short-period atmospheric gravity waves from below

Such time variation is also discernible in horizontal neutral winds



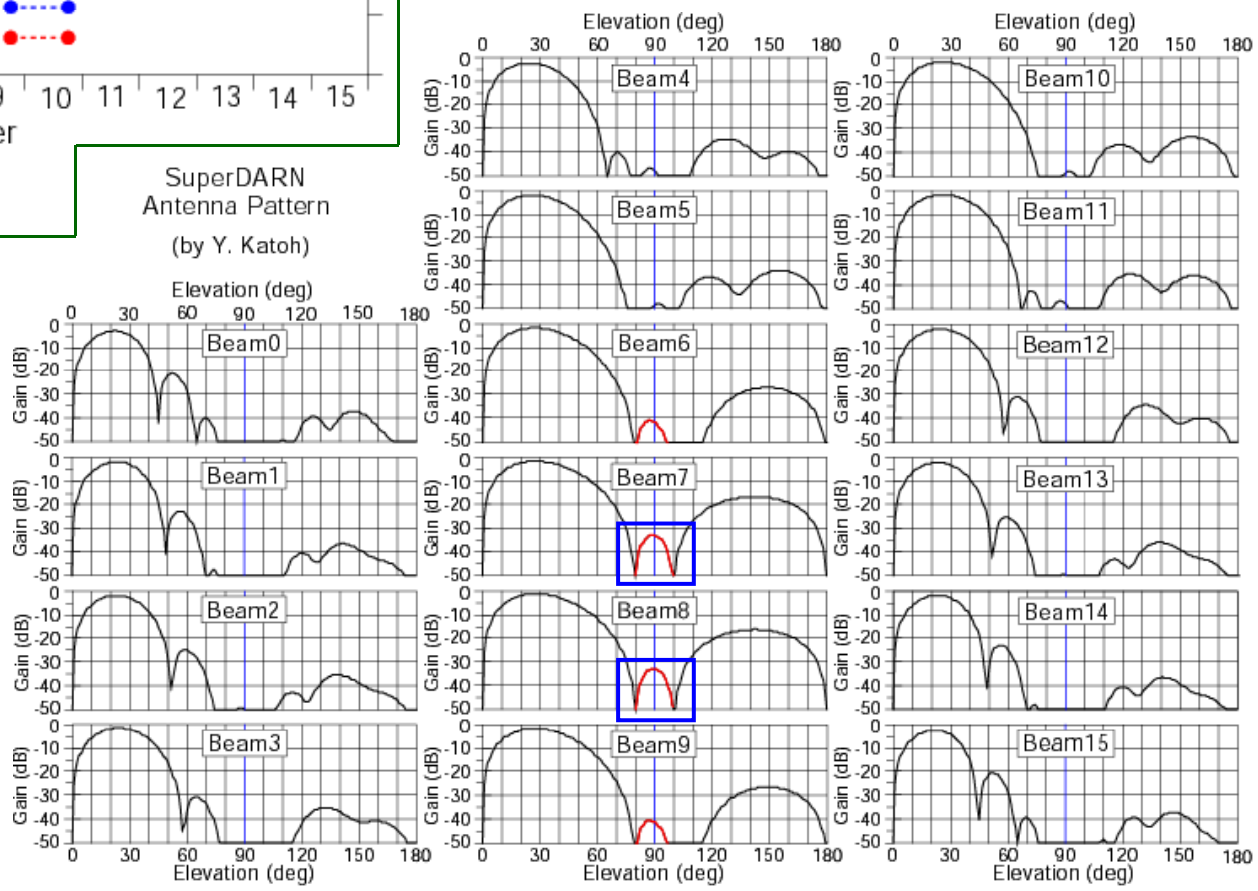
Echo Power vs Beam Number

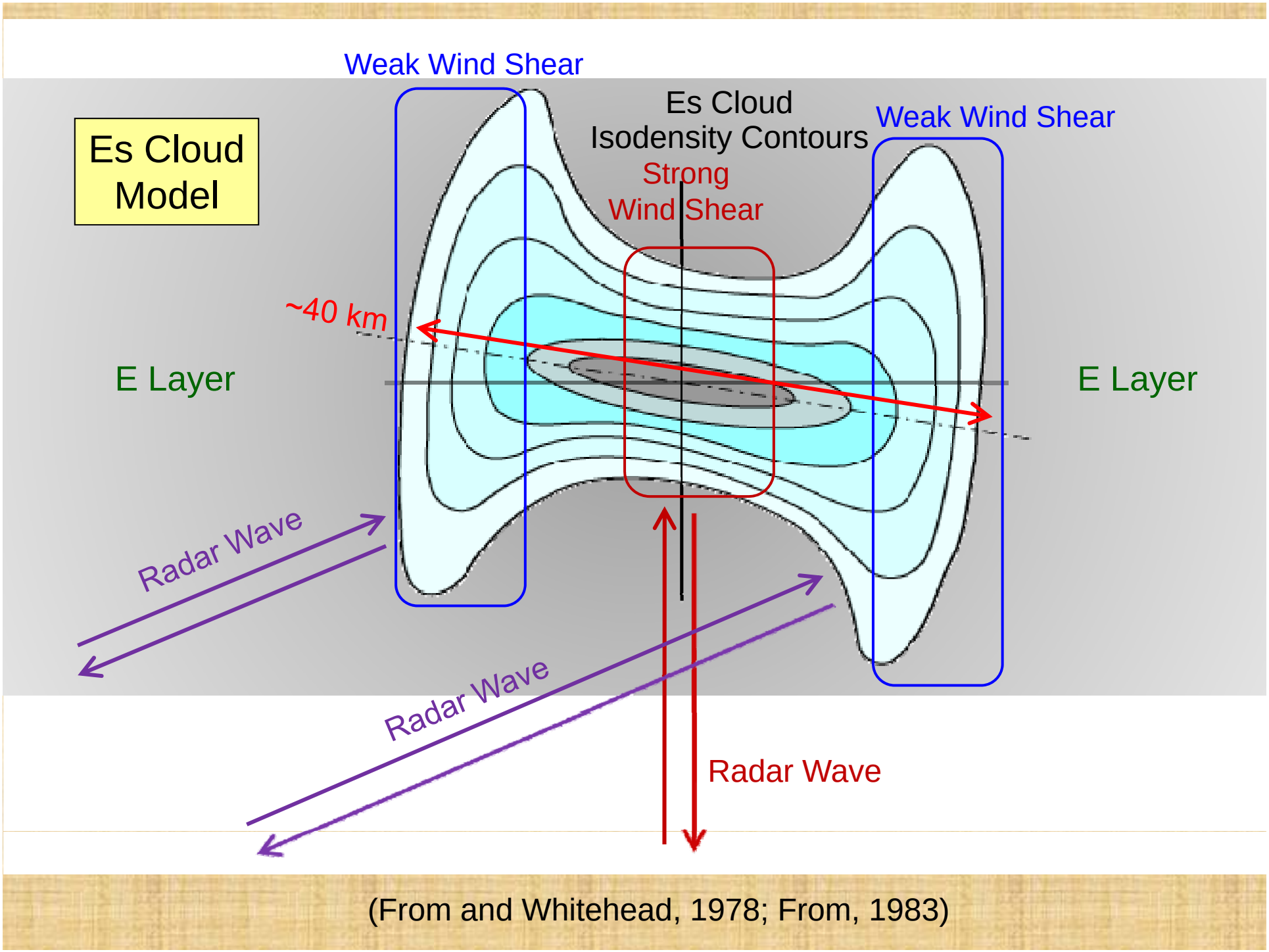
Power is strongest on beams 7 and 8, in line with a beam number dependency of simulated vertical antenna gain pattern



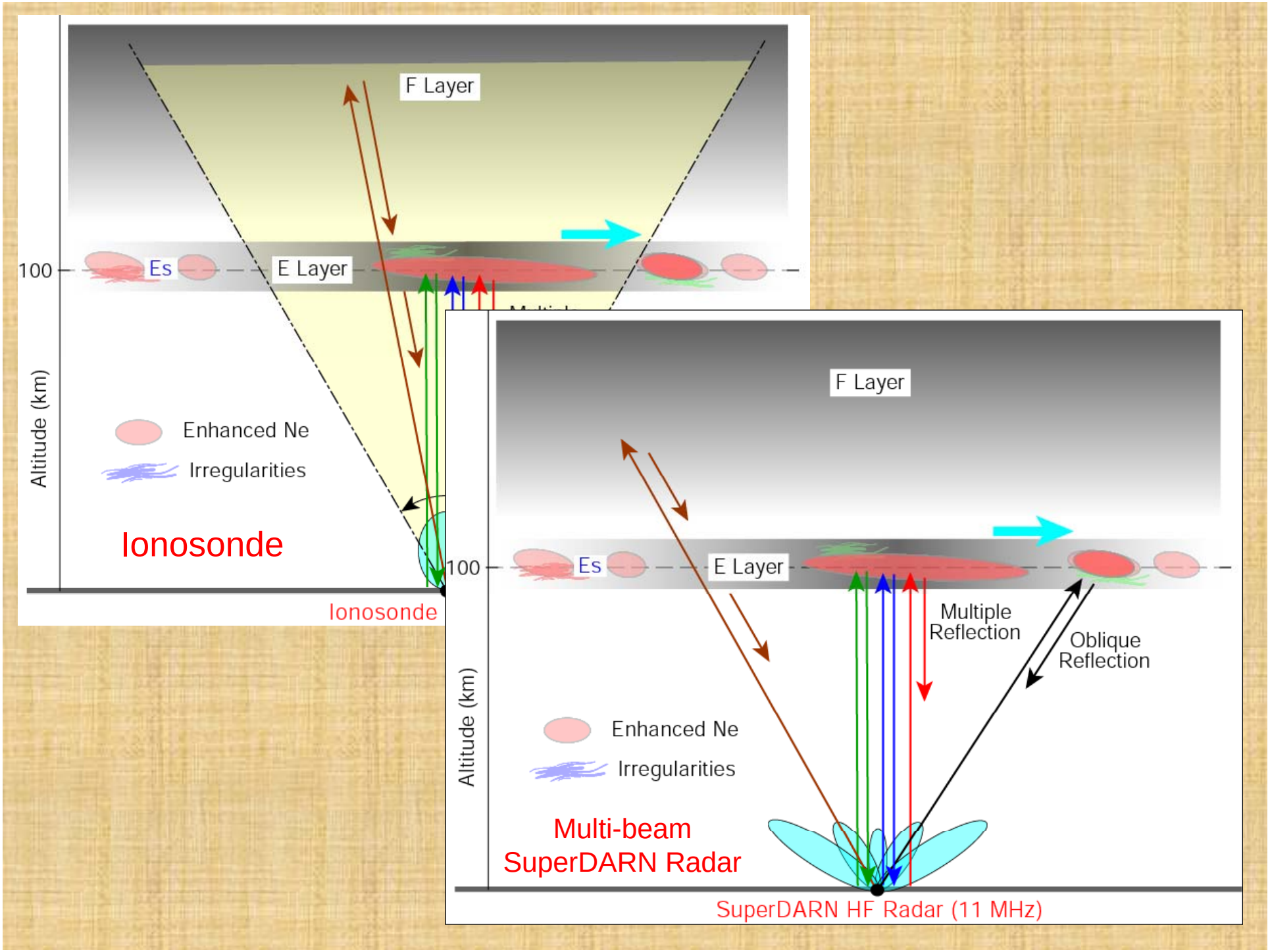
Beam Pattern of Each Beam (Beams 0, 1, 2, … , 14, 15) in the Vertical Plane (Frequency = 10.1 MHz)

Antenna gain has a maximum at an elevation angle of about 30^{o}, and is very low in the vertical with a maximum on central beams 7 and 8





(From and Whitehead, 1978; From, 1983)


F Layer
Es
E Layer
100
Altitude (km)
Enhanced Ne
Irregularities
Ionosonde
Ionosonde
F Layer
Es
E Layer
100
Multiple
Reflection
Oblique
Reflection
Altitude (km)
Enhanced Ne
Irregularities
Multi-beam
SuperDARN Radar
SuperDARN HF Radar (11 MHz)

まとめ

・SuperDARNで、夏季夕方の非常に強い Es からの反射エコーと、Esの水平面内運動を初観測

→ SuperDARNがマルチビームアイオノゾンデとして機能

・稚内を経て東に移動した頭上 Es パッチによる多重鉛直反射エコーを、主ローブでなく、低いゲインを有する鉛直向きのサイドローブで観測。

・鉛直反射のエコー強度とドップラー速度（-5～+5 m/s）は5～20分の周期で変動

→ 下層からの AGW が Es を変調

・レーダーサイトから遠ざかる Es パッチからの斜め反射エコーを主ローブで観測。パッチの東への移動（約 50 m/s）は Es 高度の中性風の向きや速度と一致

・北海道SuperDARNは中緯度Es層ダイナミクスの解明に貢献できる