Drift Ice Detection by HF radar off Mombetsu

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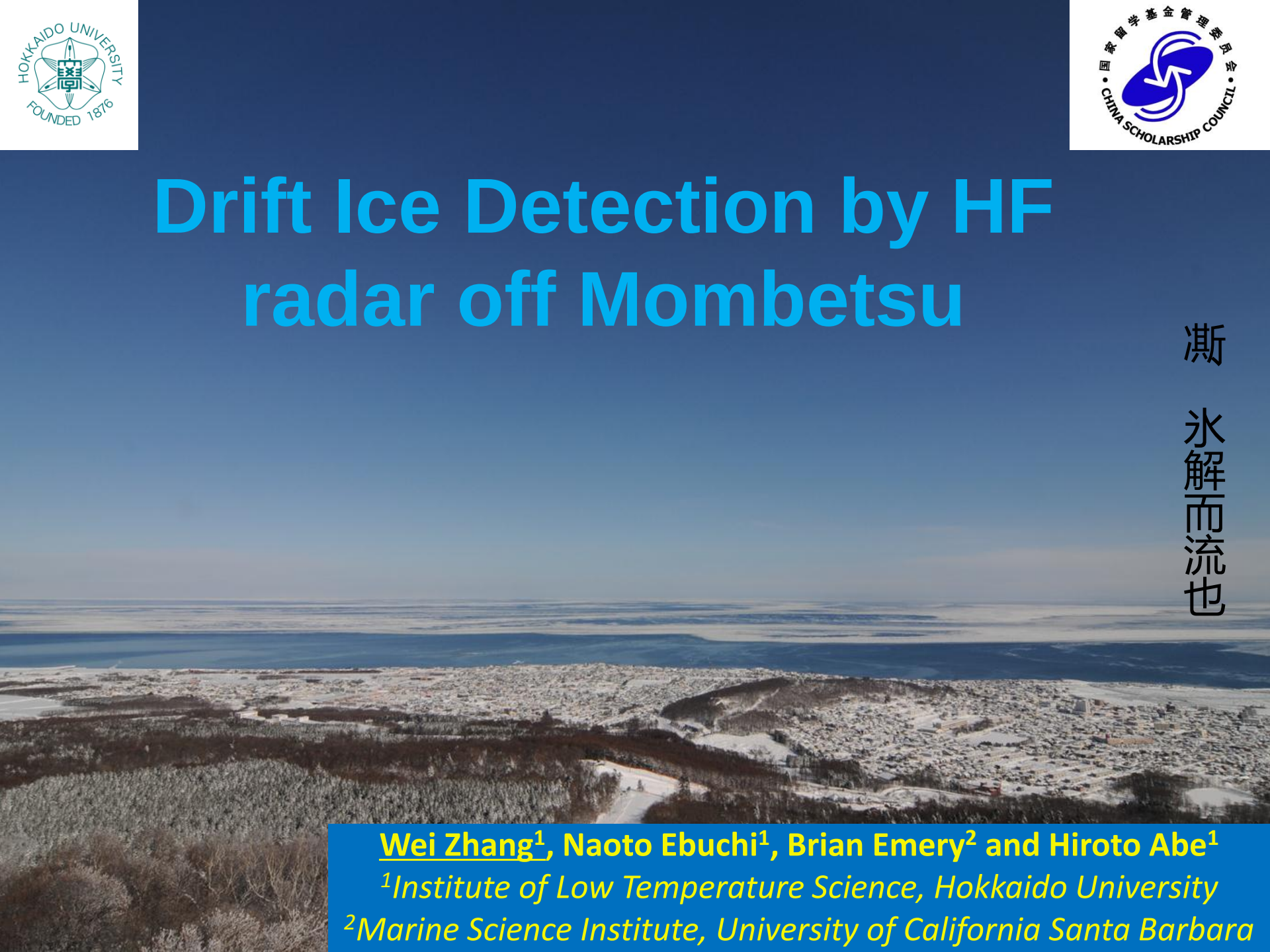

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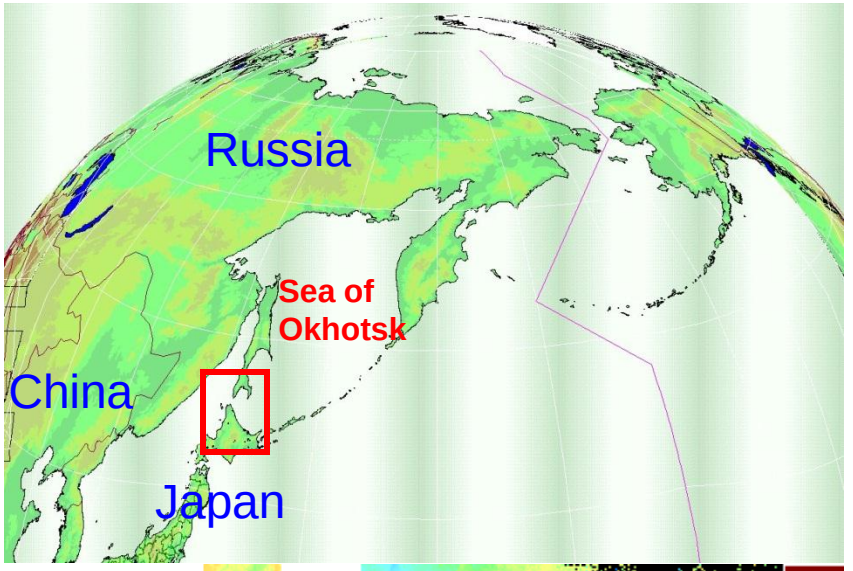
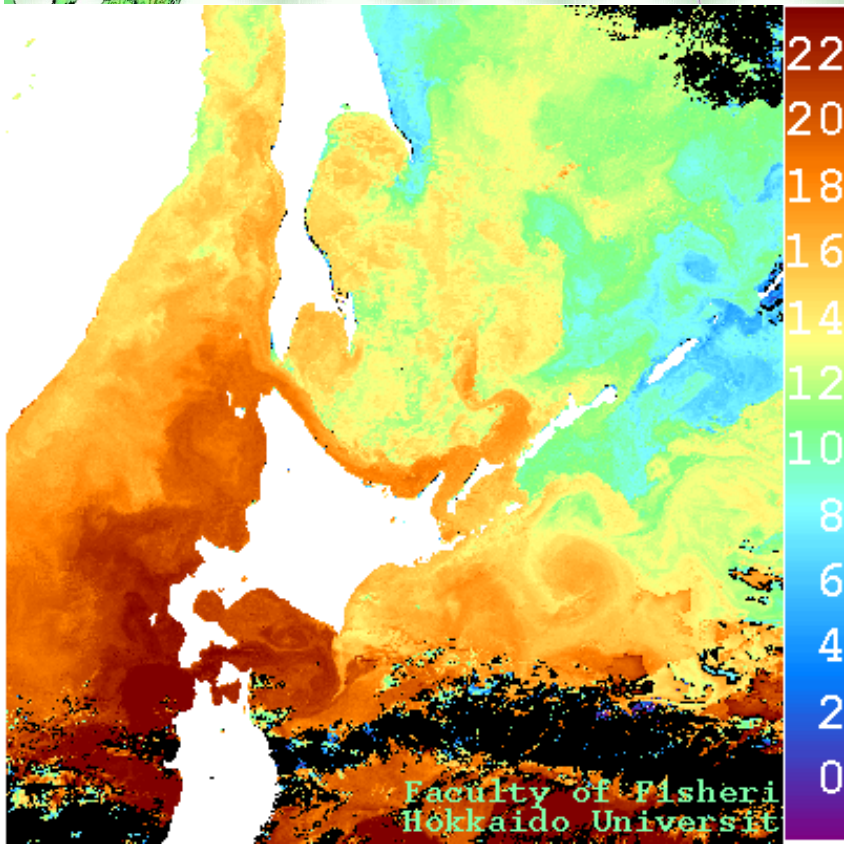
[2]Marine Science Institute, University of California Santa Barbara

Ocean Radar in Mombetsu

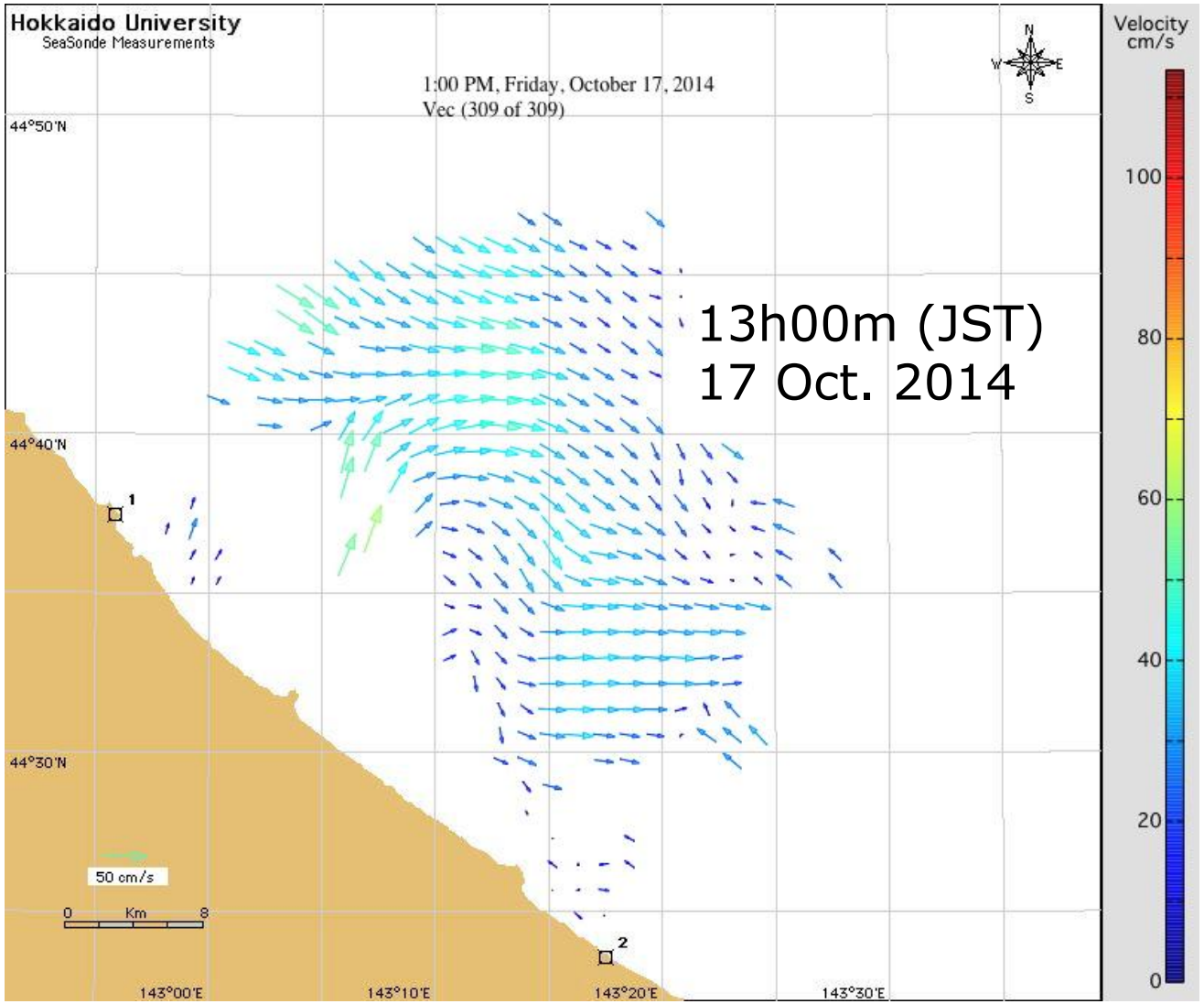




CODAR SeaSonde Radar Stations

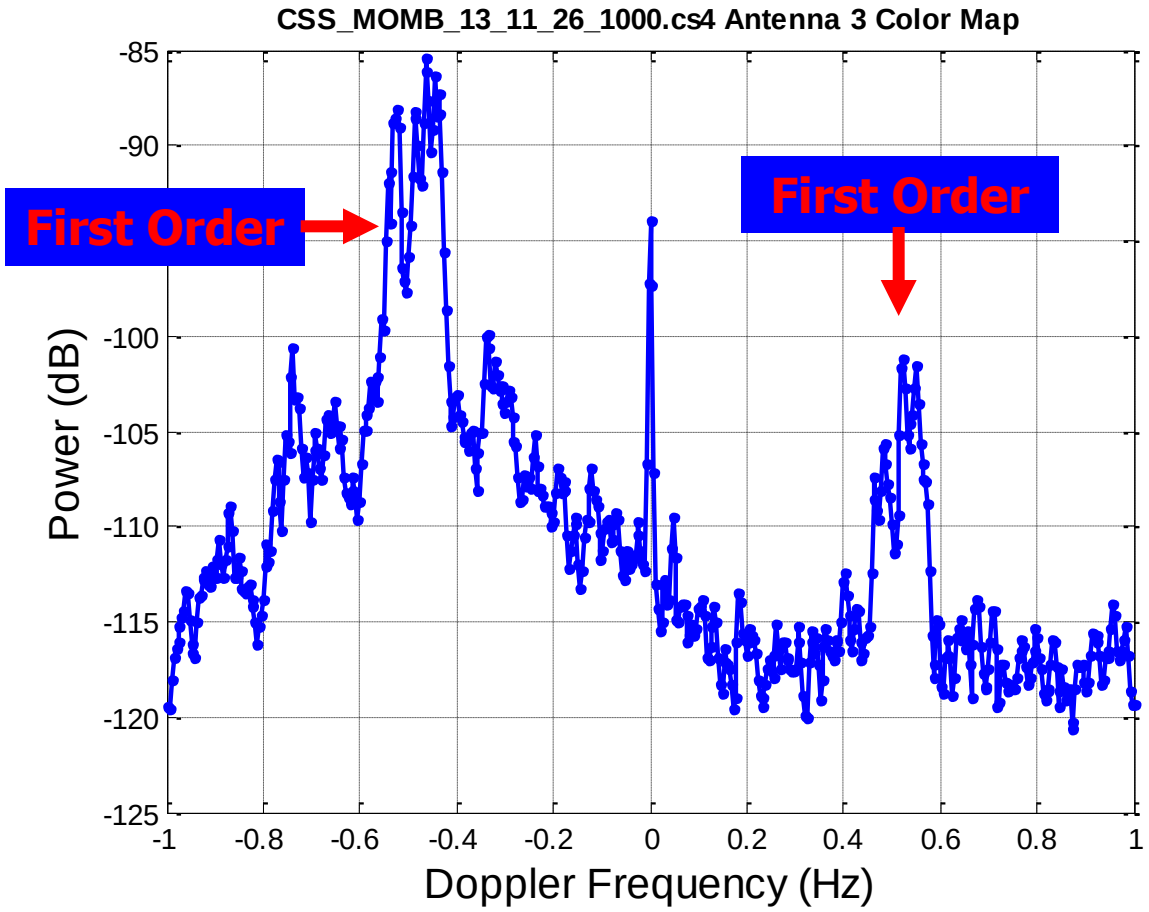
- Waveform : FMICW
- Center frequency: 24.5646 MHz
- Detection range: 46.5 km
- Range resolution: 1.5 km
- Azimuth resolution: 5 deg.

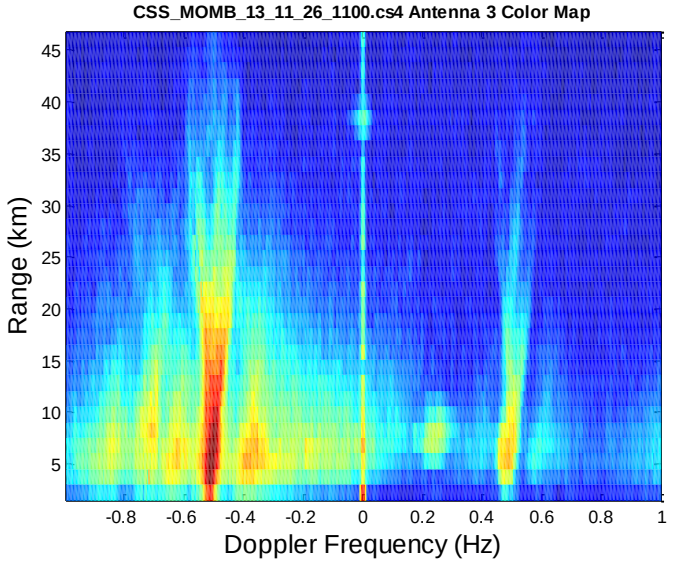
Example of Observed Snapshot



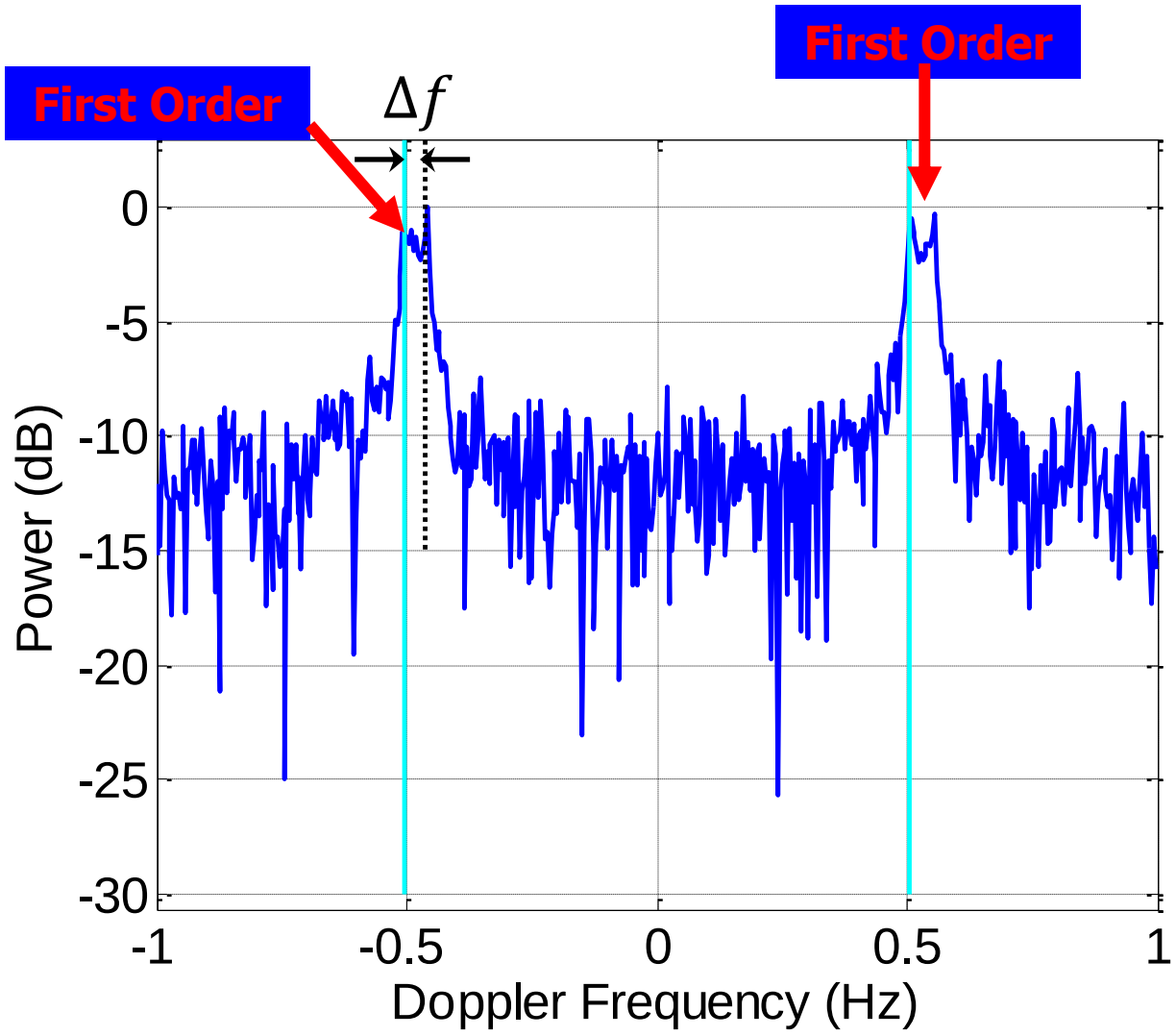
Real-time current maps are available from our web site.
http://wwwoc.lowtem.hokudai.ac.jp/hf-radar/index.html

Observed Doppler Spectrum

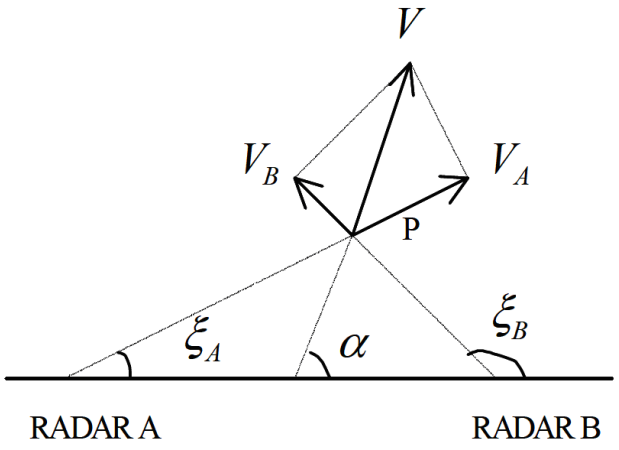




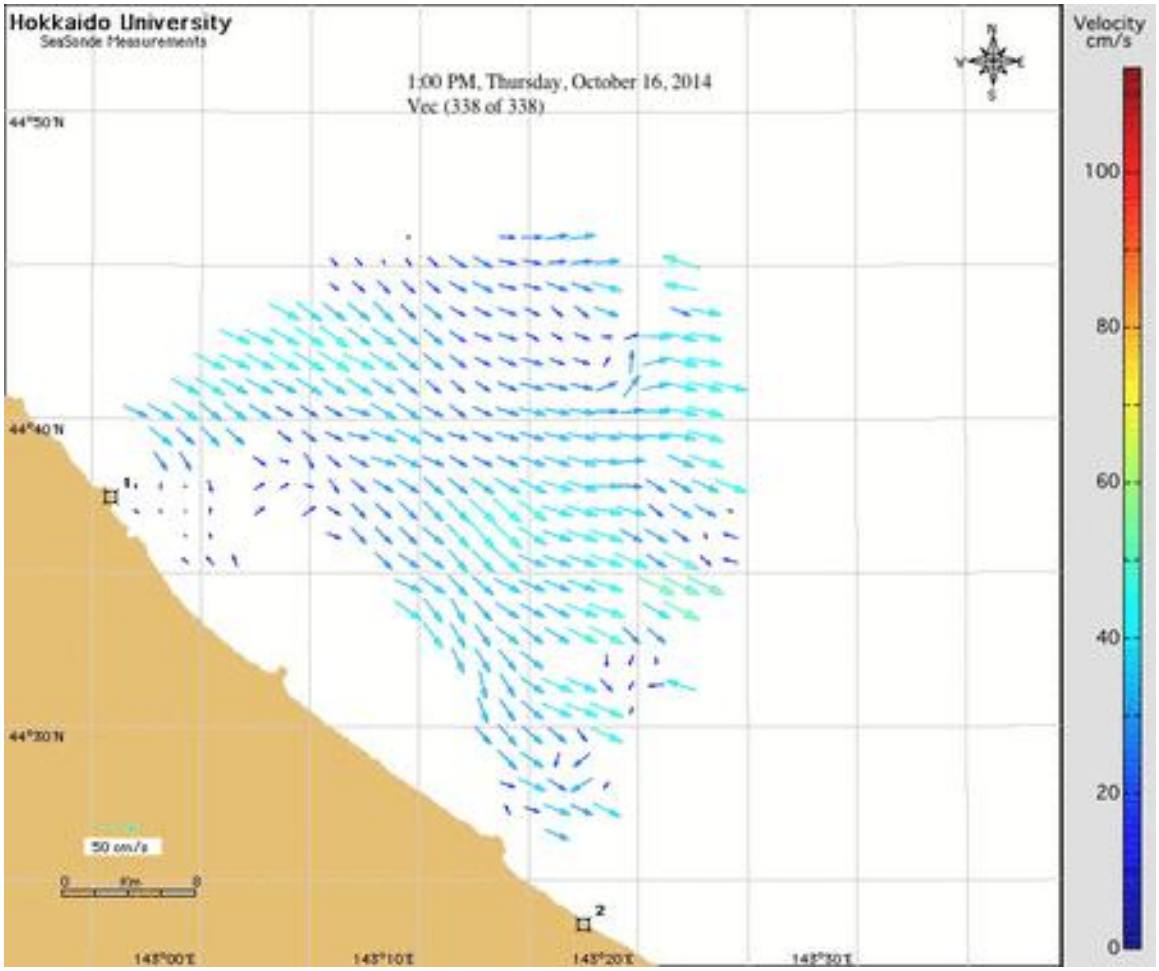
Current Information



Wind: Radial to radar
Bearing: -15° ~ 30°
Current SNR: 30 dB
Current Vel.: 0-30cm/s
Radar Freq.: 24.56MHz
Antenna:
Cross-loop Monopole

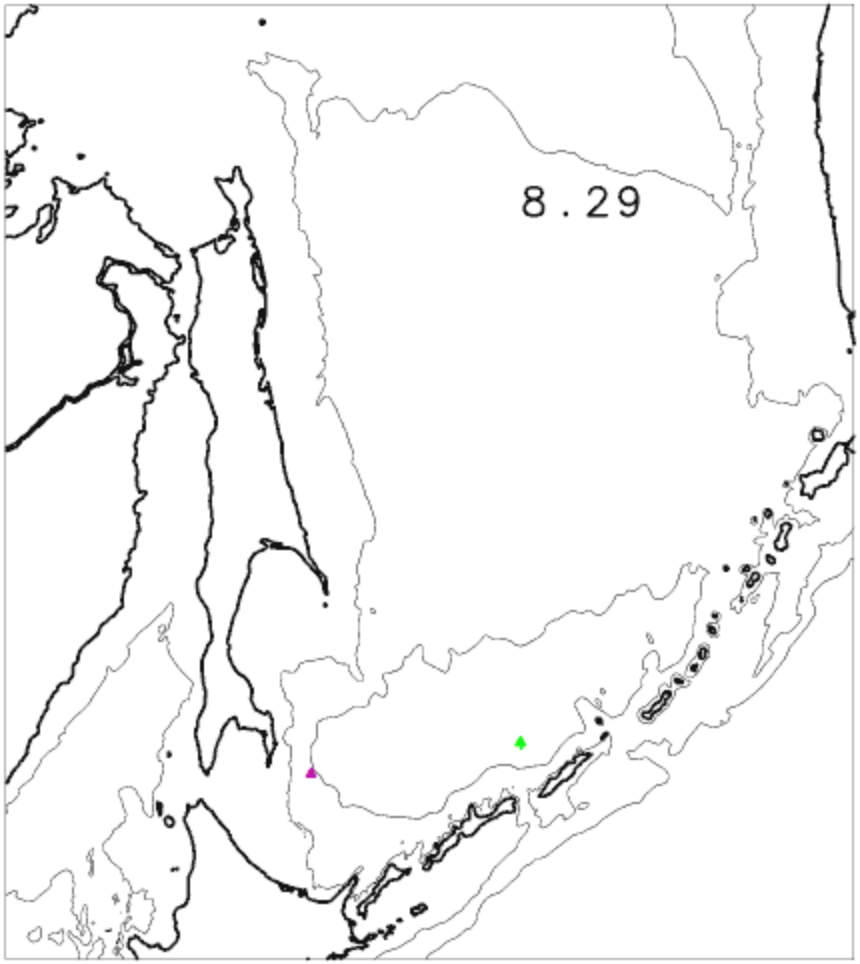


Hourly Surface Current Fields



HF ocean radar clearly capture the current variation

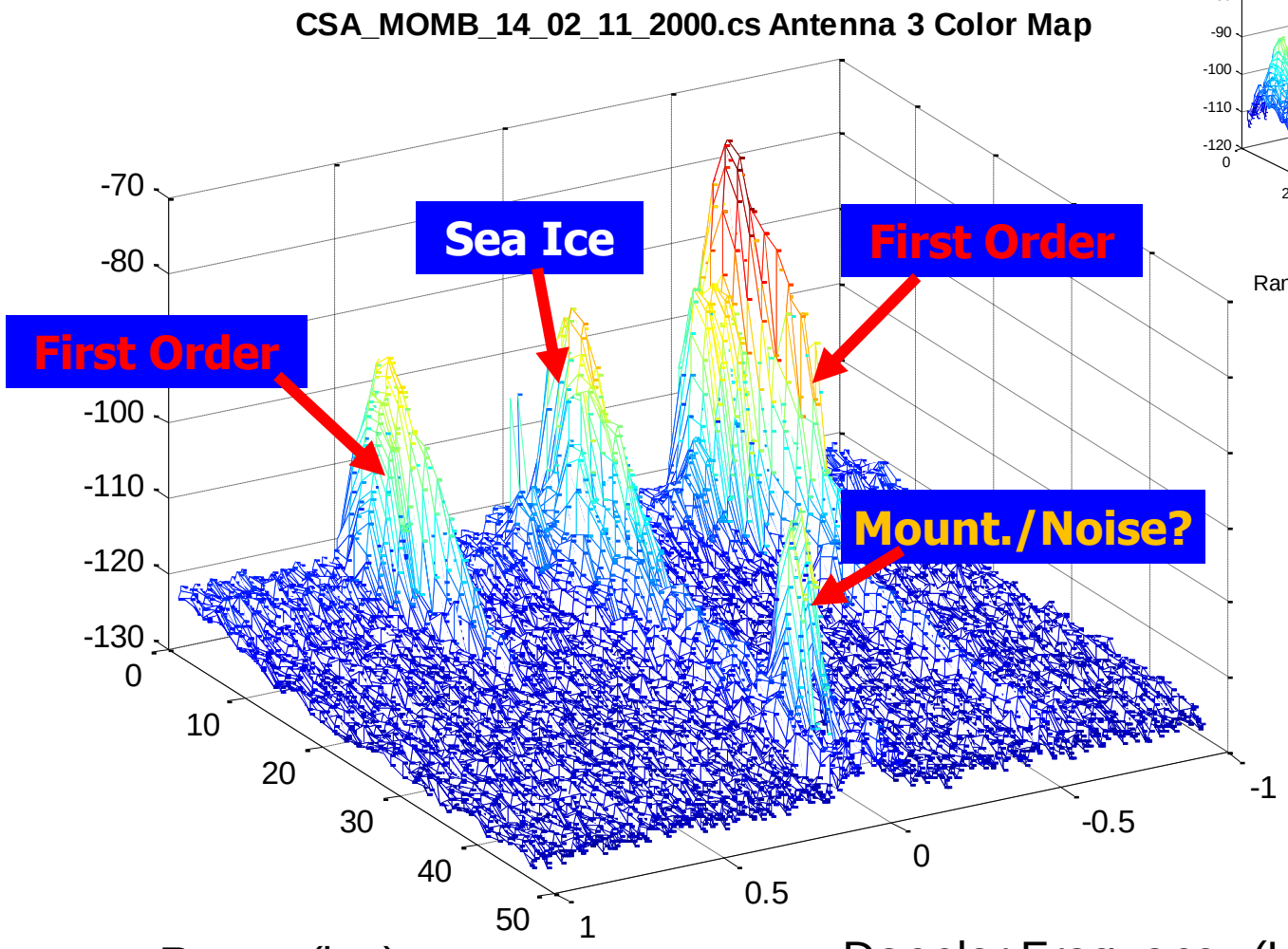
Drift Ice off Mombetsu

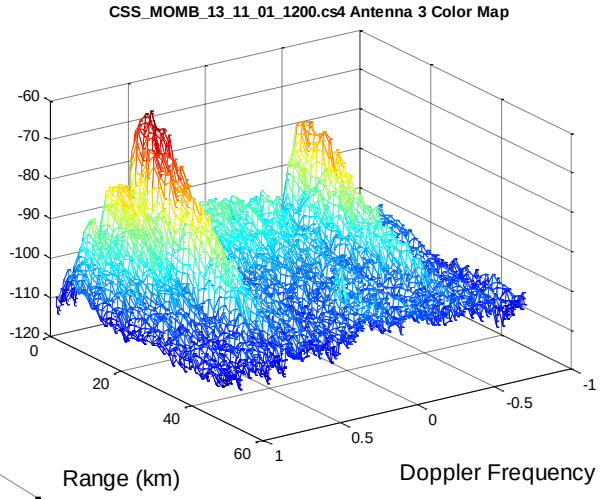


Surface current circulation by drift buoy

www.lowtem.hokudai.ac.jp

Observed Range-Doppler Spectrum



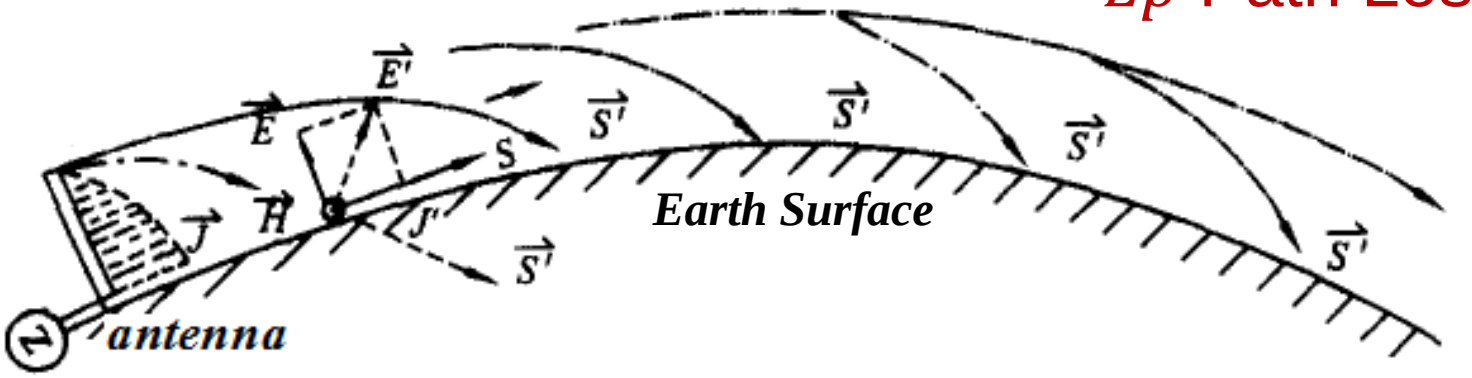


Radar Equation

Description of the relationship of transmitted power, received power and the range

$$P_r = \frac{P_t G_t G_r \sigma \lambda^2}{(4\pi)^3 d^4 L_p^2}$$

P_r Received Power
P_t Transmitted Power
G_t Transmitted Gain
G_r Received Gain
σ Radar Cross Section
d Detected Range
λ Radio Wavelength
Lp Path Loss



Radar Cross Section

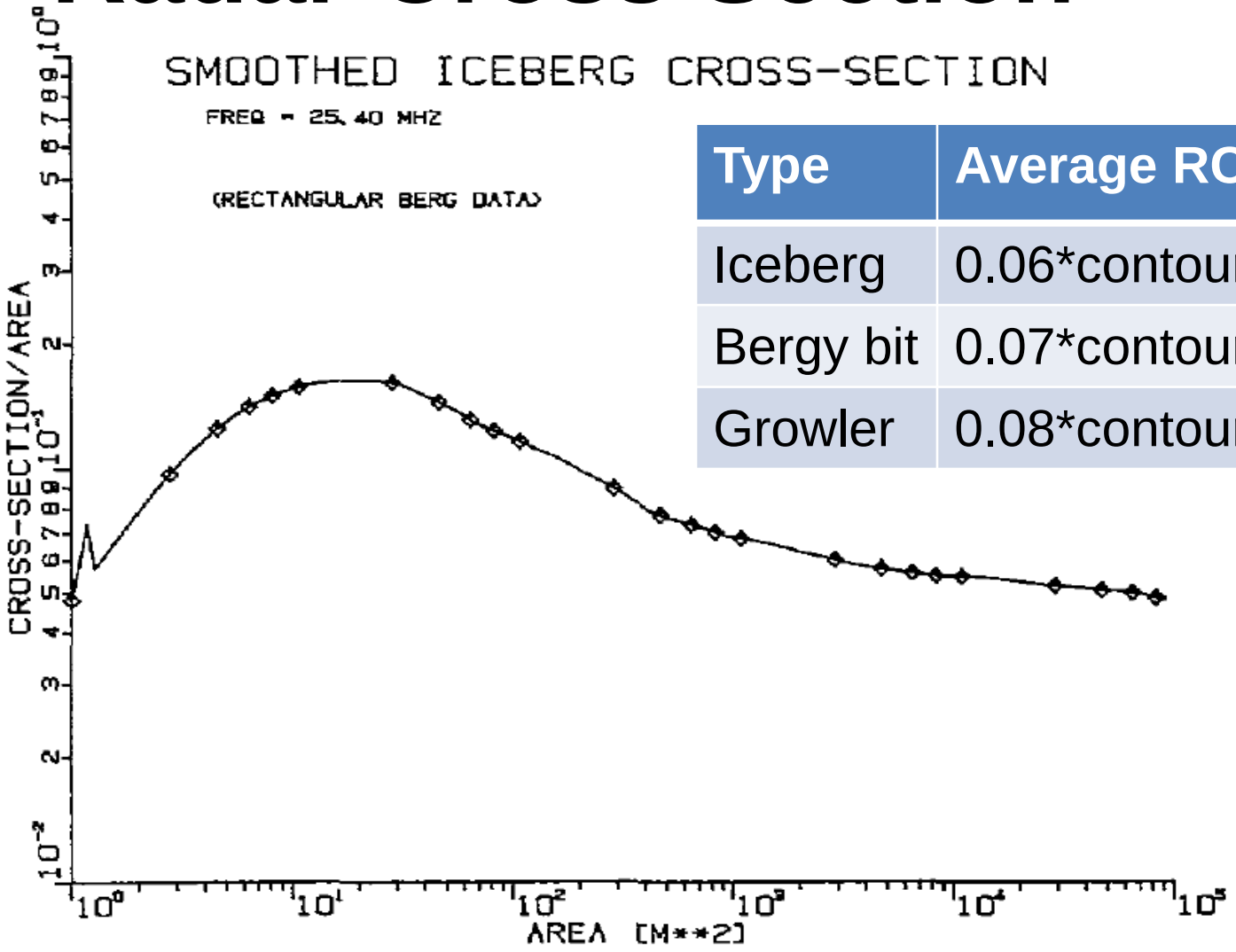


Fig. 4. Smoothed iceberg cross section at 25.40 MHz averaged over different aspect ratios (shape independent).

Type	Average RCS	Freq.
Iceberg	0.06*contour area	2-30 MHz
Bergy bit	0.07*contour area	5-30 MHz
Growler	0.08*contour area	20-30MHz

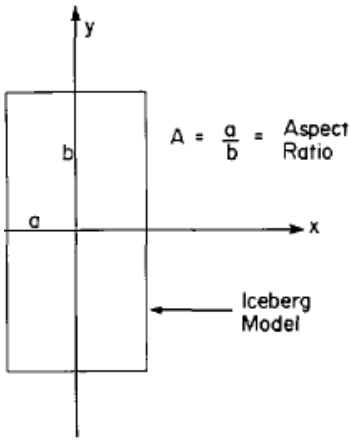


Fig. 3. Definition of aspect ratio for iceberg cross-section calculations.

Figures, Walsh et al. (1986); Table, Haykin et al. (1994)

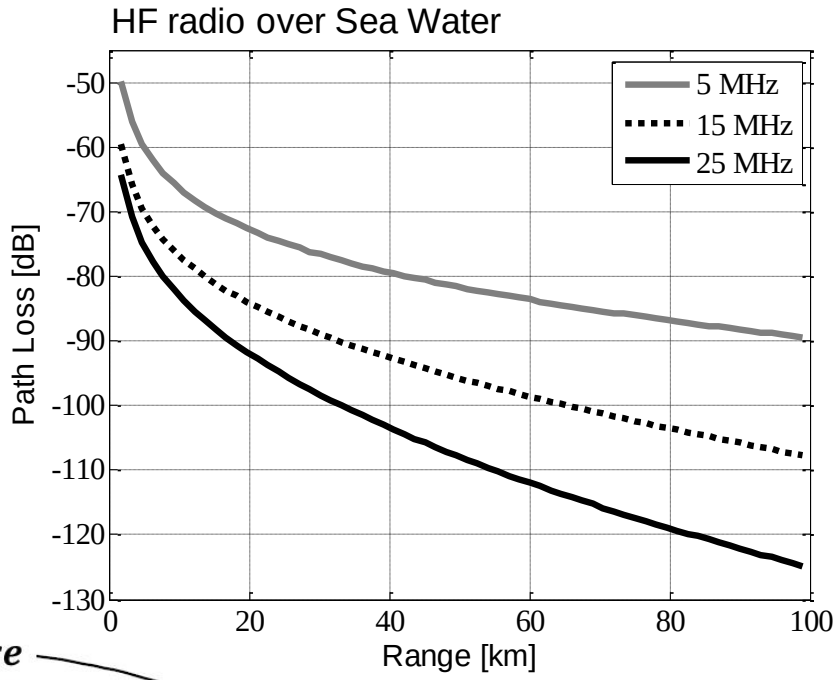
Radio Path Loss Simulation

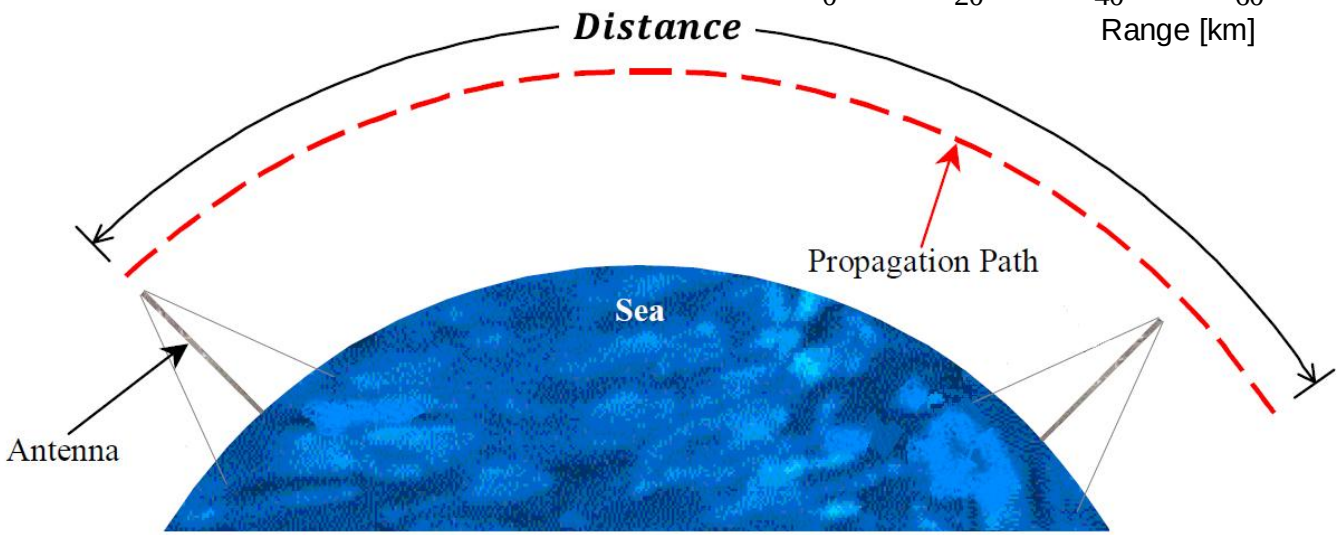
$$L_p(d) = 10log_{10}\left(\frac{P_r}{P_t}\right)$$

$$L_p(d) = 142 + 20\log(f_{MHz}) + 20\log(E_{\mu v/m})$$

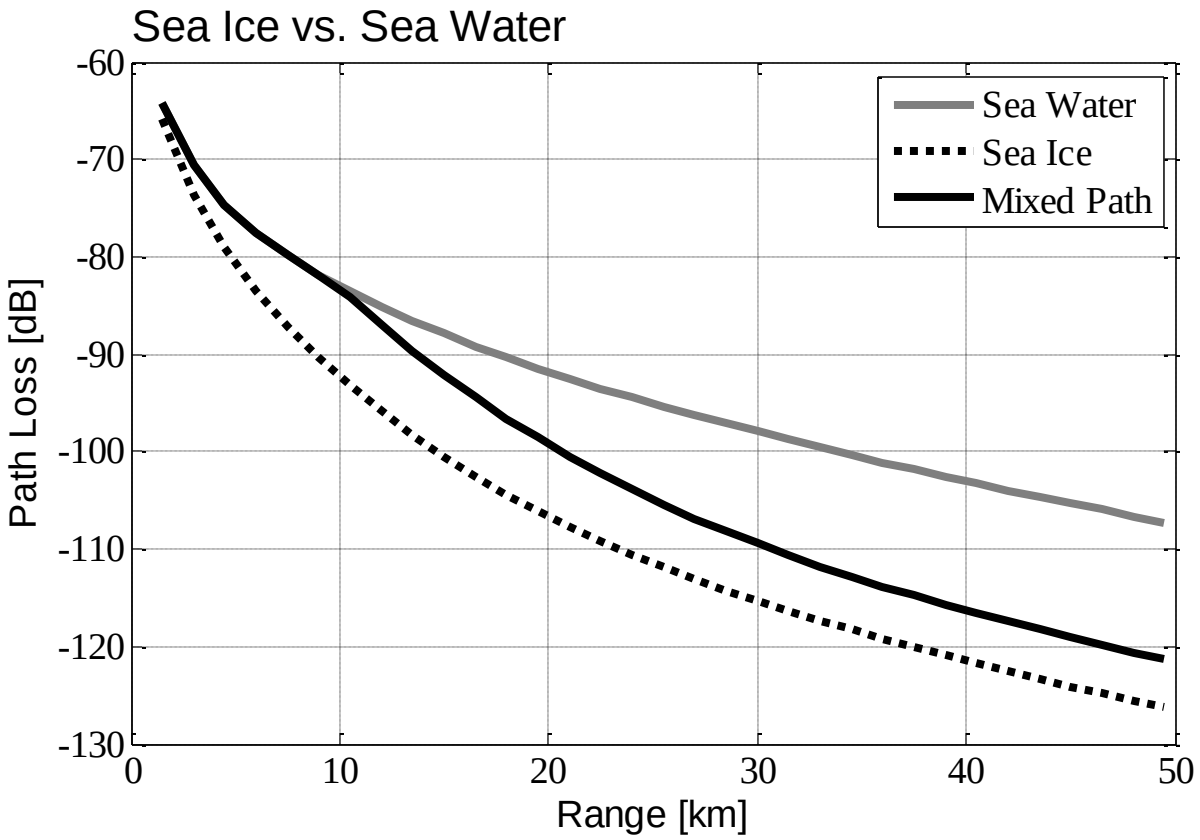
$E_{\mu v/m}$ Electrical field strength

f_{MHz} Radio frequency in MHz





Mixed Path Loss Simulation



f_0 = 24.5646 MHz

Sea Water:

σ_w = 5 S/m

$\varepsilon_w/\varepsilon_0$ = 80

Sea Ice:

σ_i = 1 S/m

$\varepsilon_i/\varepsilon_0$ = 6

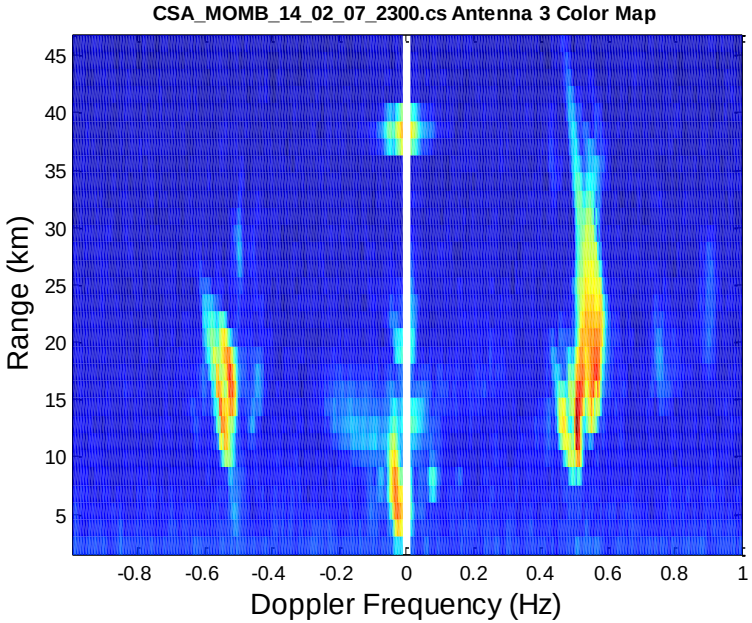
Mixed Path:

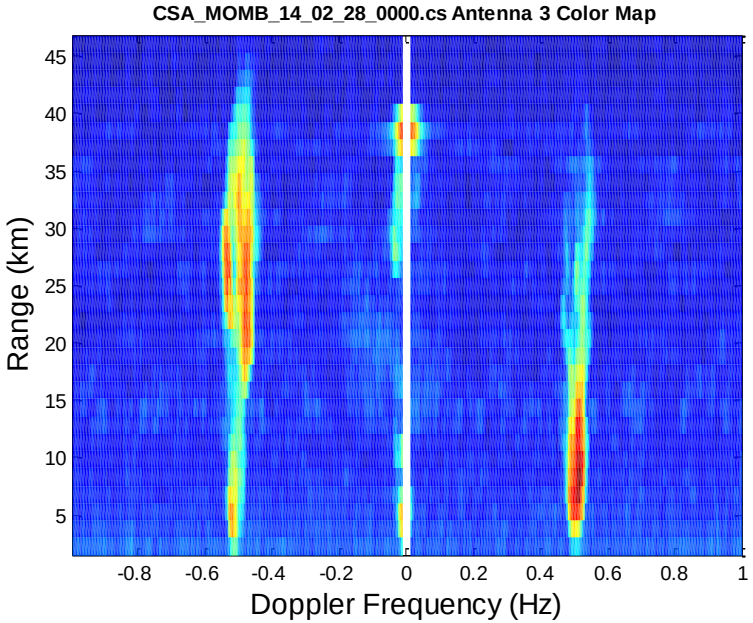
Sea Water: 10 Km

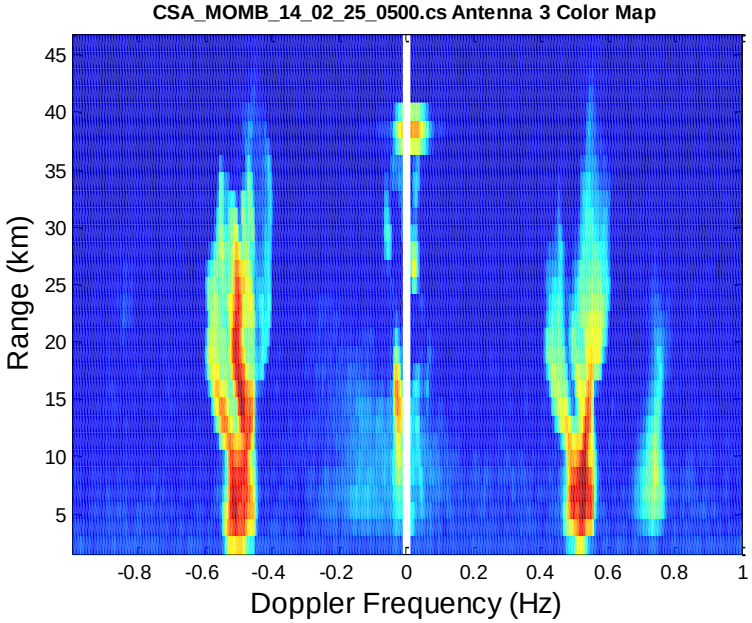
Sea Ice : 40 Km

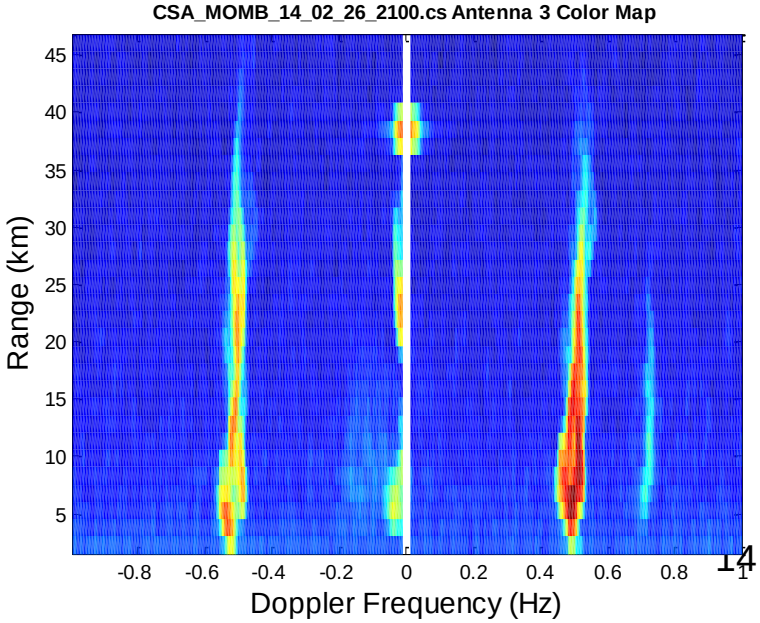
The HF radio wave over sea ice decrease **faster** than over sea water.

Sea water/Mixed path Example

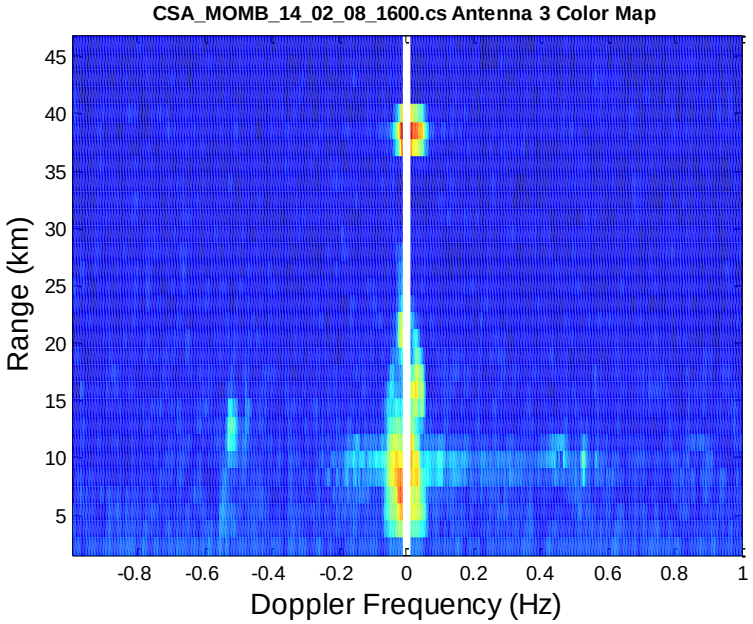


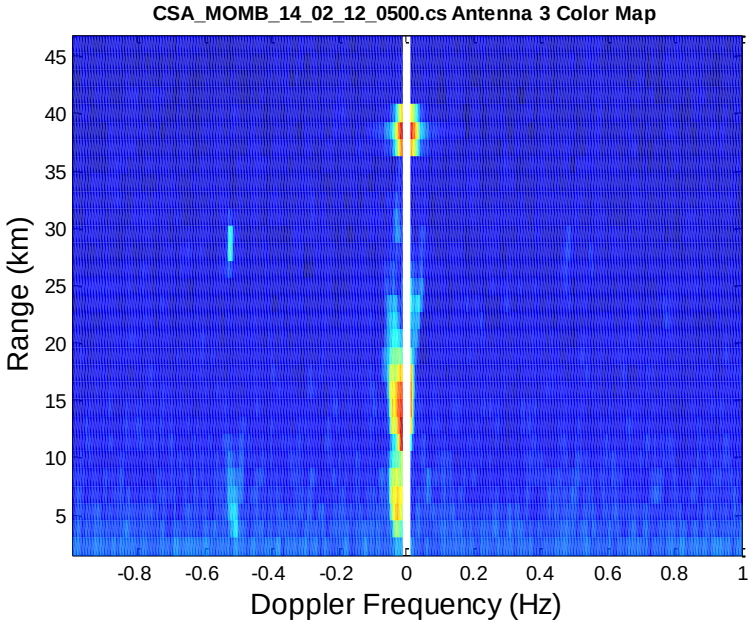


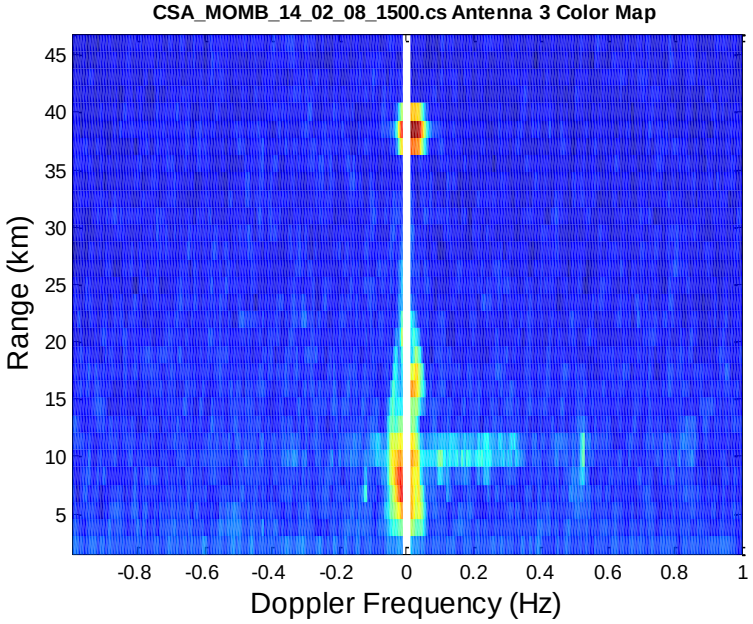


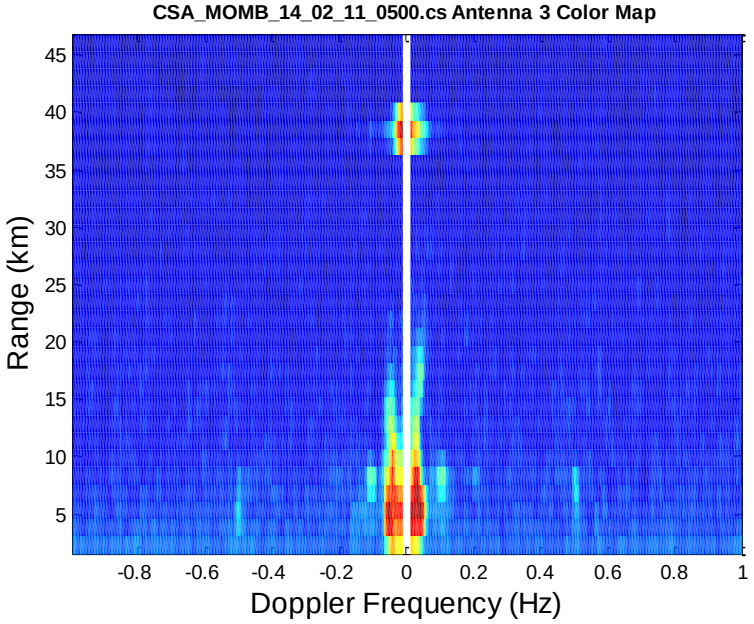


Sea Ice Path Example



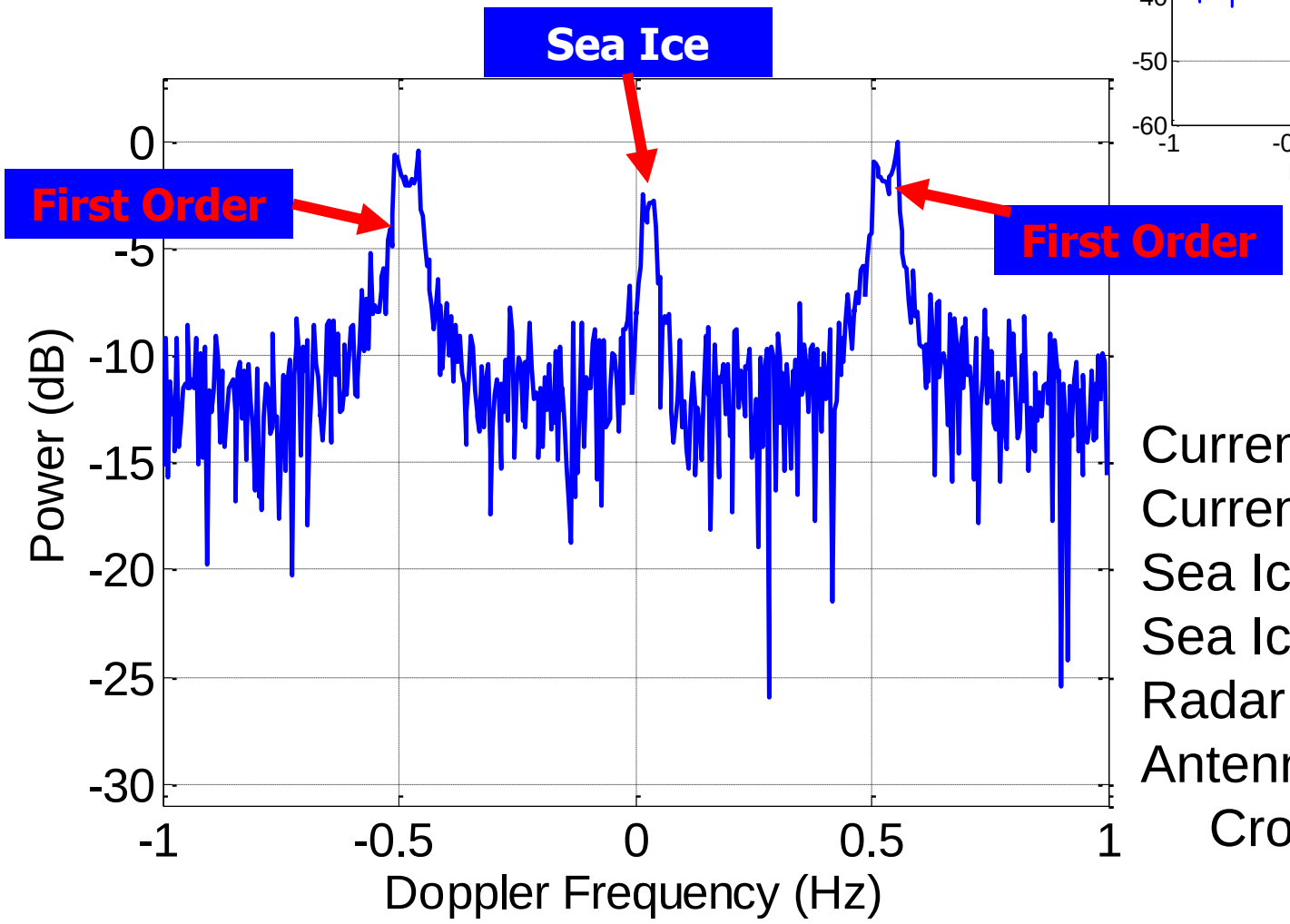


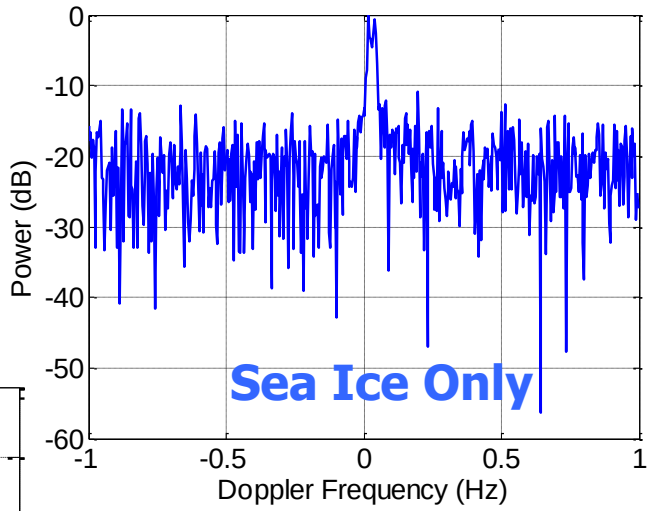




Doppler Simulation

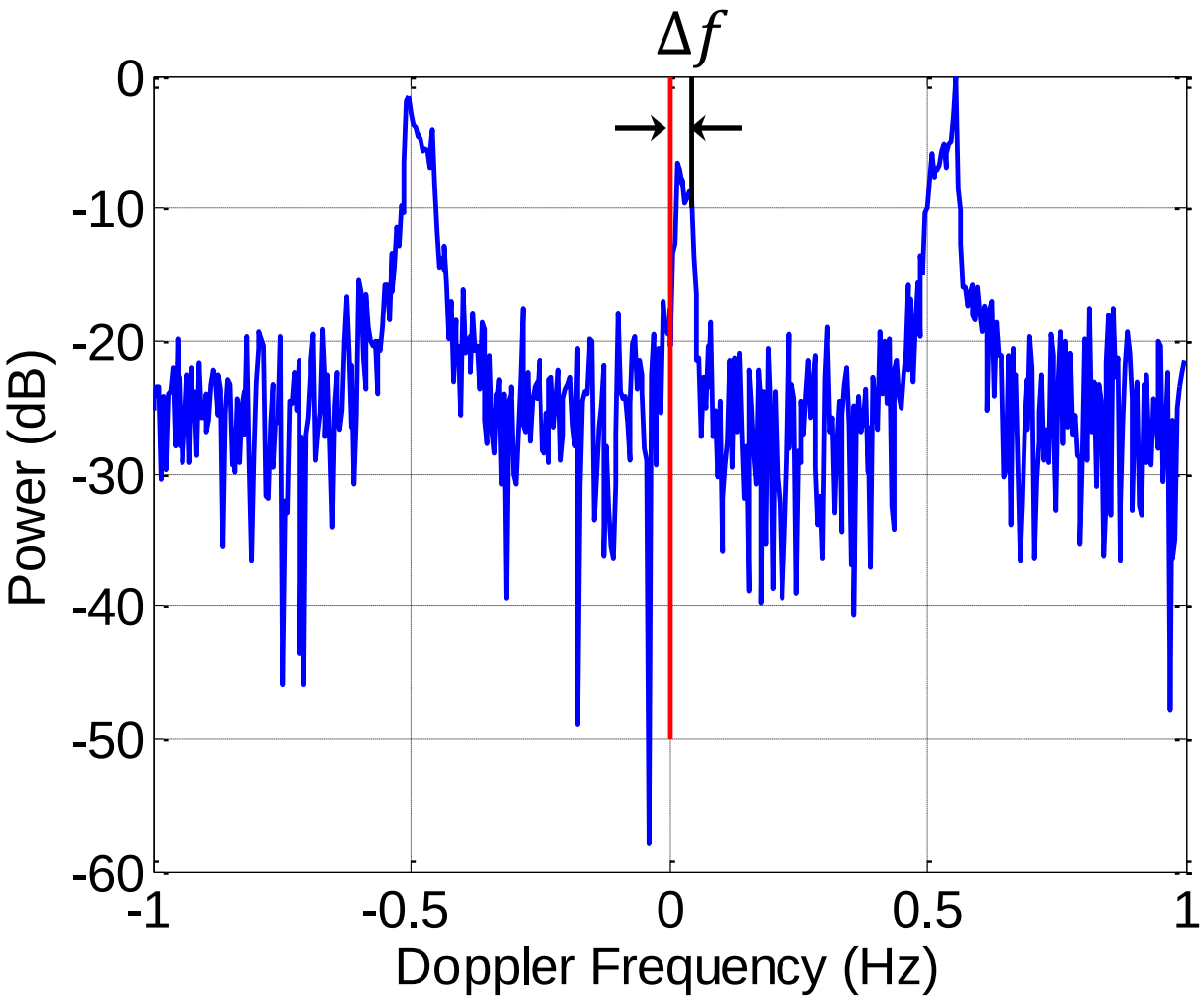
Sea Ice with Current





Current SNR: 30 dB
Current Vel.: 0-30cm/s
Sea Ice SNR: 15 dB
Sea Ice Vel.: 10-25cm/s
Radar Freq.: 24.56MHz
Antenna:
Cross-loop Monopole

Radial Velocity



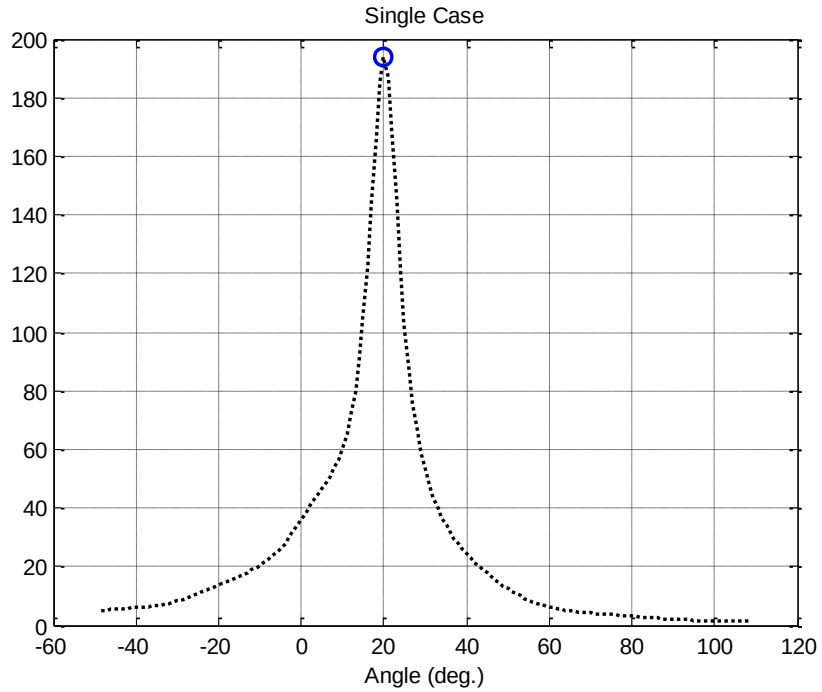
Target Radial Velocity

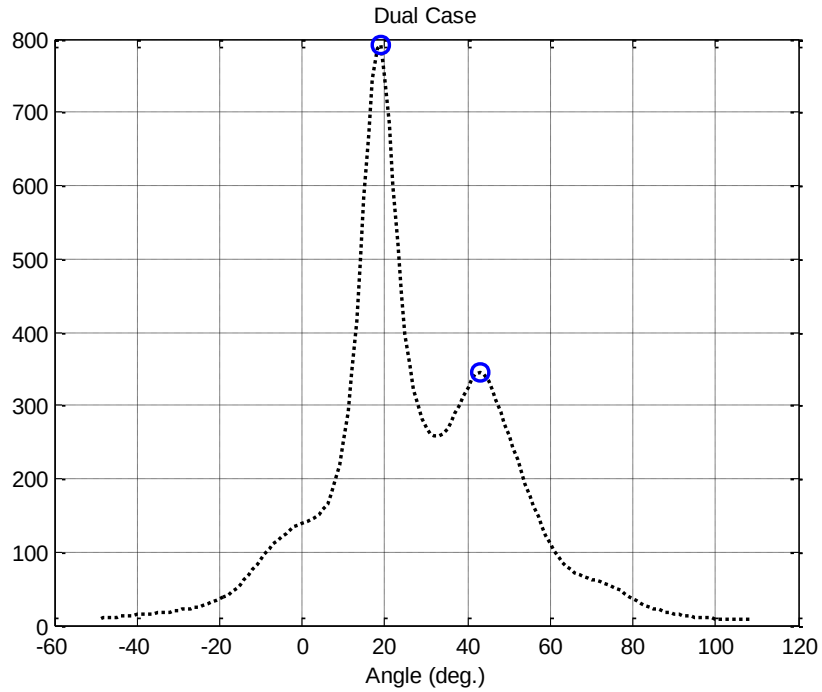
$$\frac{2V_r}{c} = \frac{\Delta f}{f_0}$$

V_r : Ice radial velocity
Δf : Ice Doppler shift
f_0 : Radar frequency
c : light speed

Direction Finding

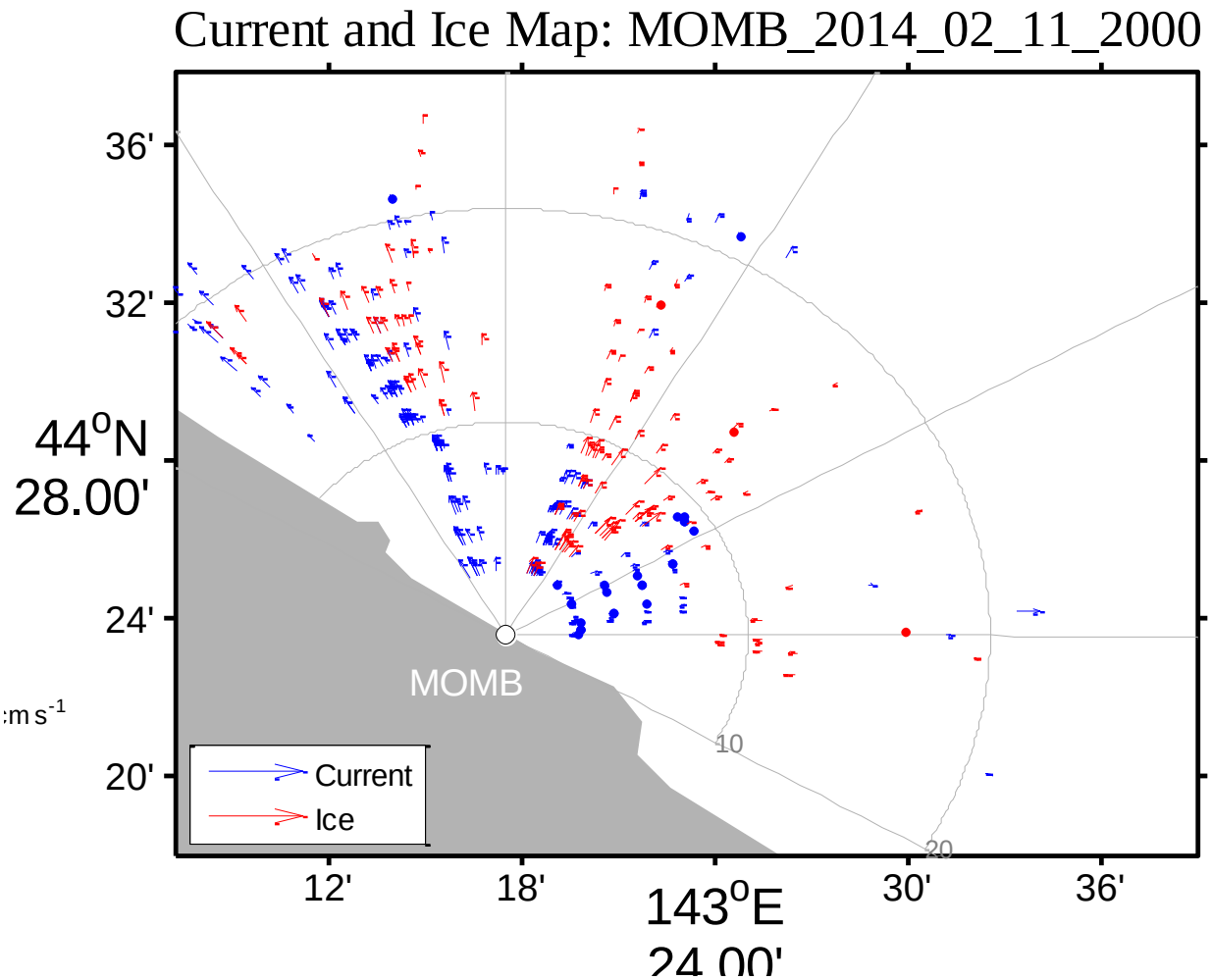
MUSIC (**MU**ltiple **SI**gnal **C**lassification) algorithm





1. Assumed no more than two azimuth angles at one sea ice Doppler point;
2. Angle numbers are determined by signal and noise powers.

Current and drift Ice Radial Velocity Map



Drift ice velocity is roughly consistent with nearby current.

Application of Ice Radial Velocity

Relationship of Wind, Ice and Current:

$$v_{dif} = v_{ice} - \bar{v}_{cur}$$

$$v_{dif} = \alpha cos\theta U + \alpha sin\theta V$$

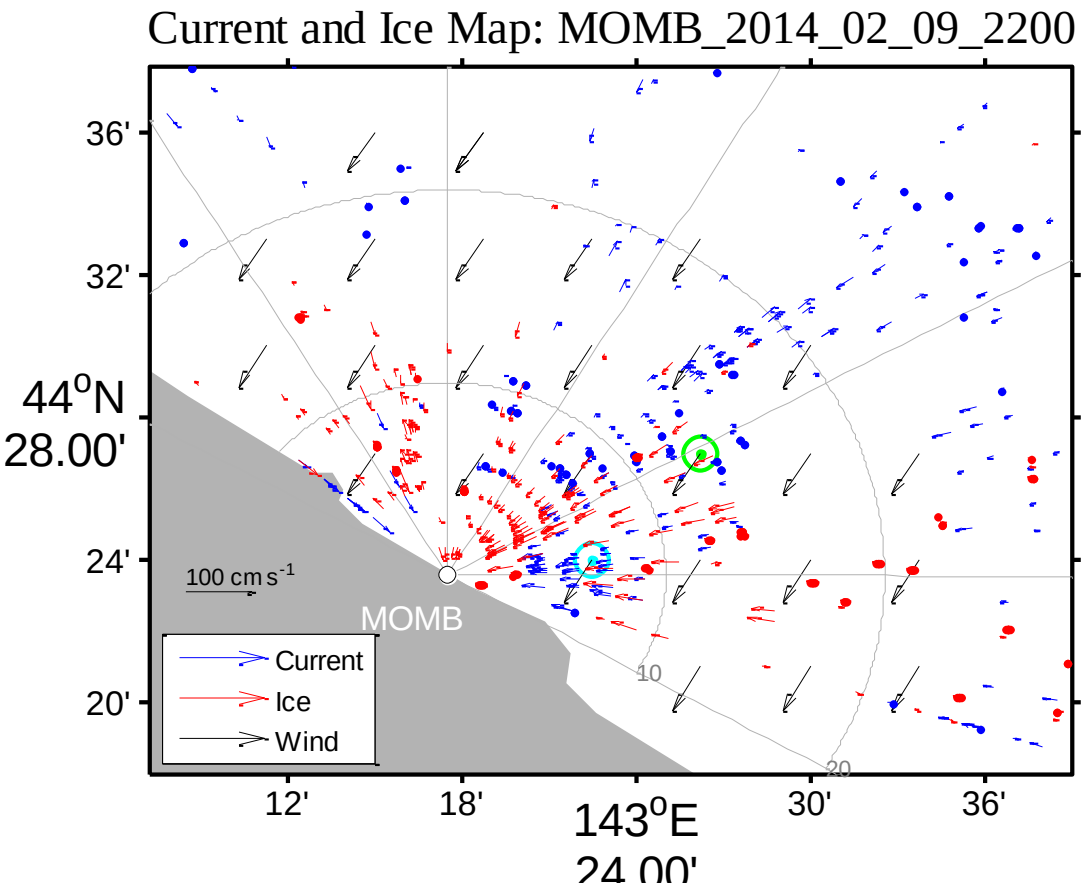
Least Square Method

v_{ice} ice radial velocity
$\bar{v}_{cur}$ average radial current velocity
α speed ratio
θ turning angle
$W(U,V)$ wind vector

$$f(\alpha,\theta) = \min_{(\alpha,\theta)}[v_{dif} - \alpha cos\theta U - \alpha sin\theta V\ ]$$

Usually, the wind to ice speed ratio is 2%.

Wind to Ice Drift Parameter



Green
Distance : 13.5 Km
Turning angle: 51°
Speed ratio: 2 %
Data points: 120

Cyan
Distance : 6 Km
Turning angle: 54°
Speed ratio: 1.43%
Data points: 204

Wind to ice drift parameters are reasonable by using ice and current radial data from HF ocean radar.

Summary

- **HF ocean can detect drift ice, and obtain bearing angle and radial velocity.**
- **Generally, drift ice detection range by HF ocean radar is about 20 Km**
- **Wind to ice drift parameters calculated from sea ice and current HF ocean radar are reasonable, and turning angle is about 50 degree, speed ratio is 1.4% ~ 2%.**

Citation Reference

- **Walsh et al. (1986), Remote sensing of icebergs by ground-wave Doppler radar.**
- **Haykin et al. (1994), [M] Remote Sensing of Sea Ice and Icebergs.**