Sea Ice Velocity Observed by HF Radar: Comparison with ADCP and Drifting Buoy Measurements

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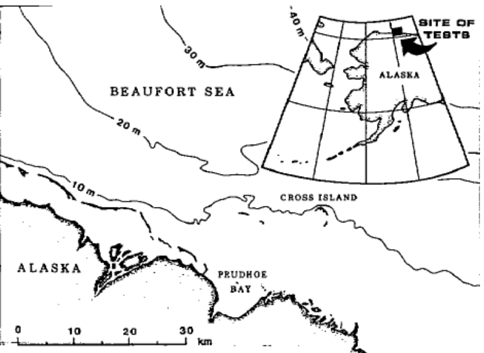
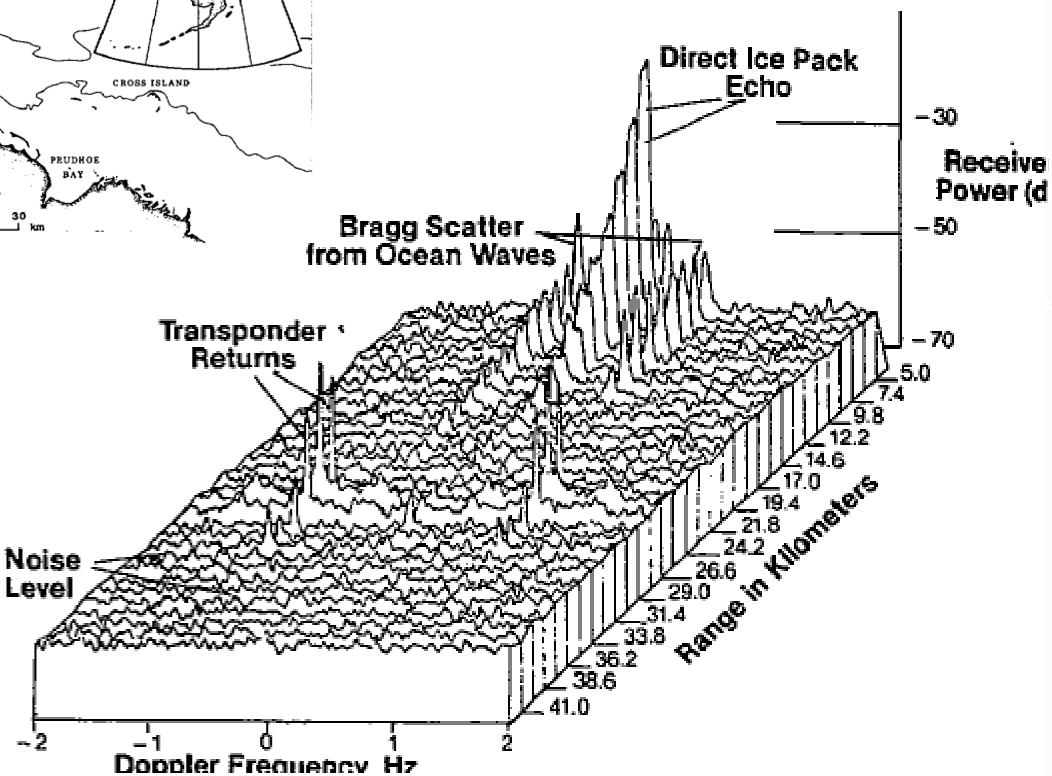
Review of HF radar sea ice measurement

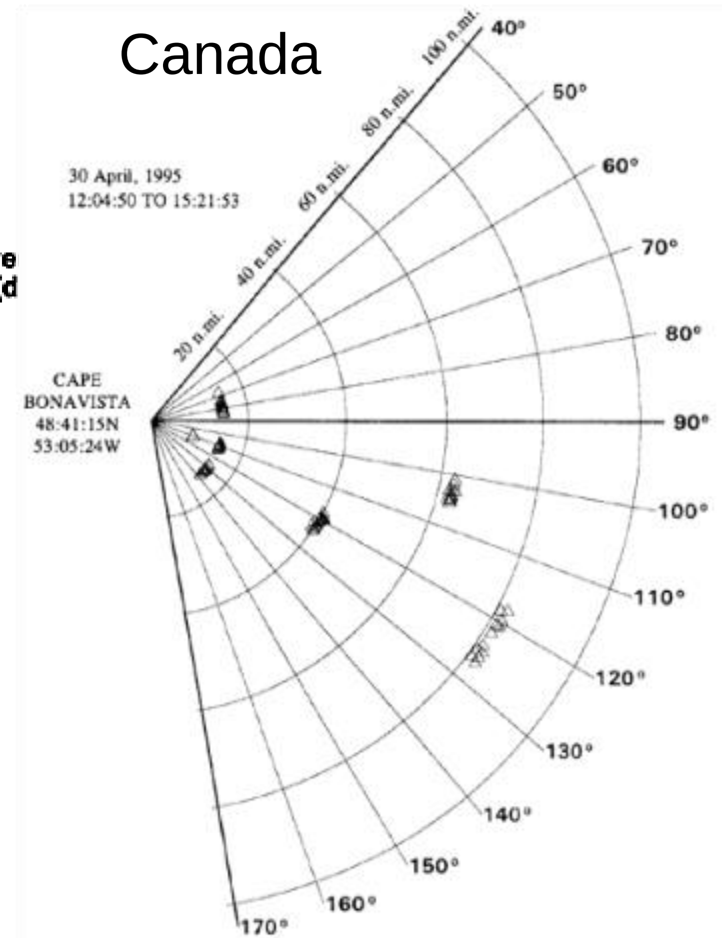
- HF radar has been used for pack ice and iceberg **detection** in past 30 years, but it is not completely developed due to NO velocity comparison in details.



Alaska, US

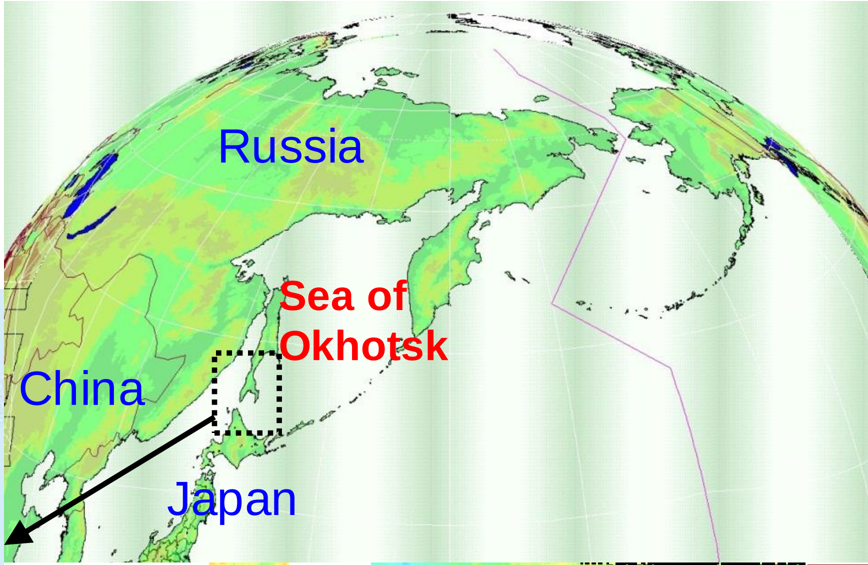


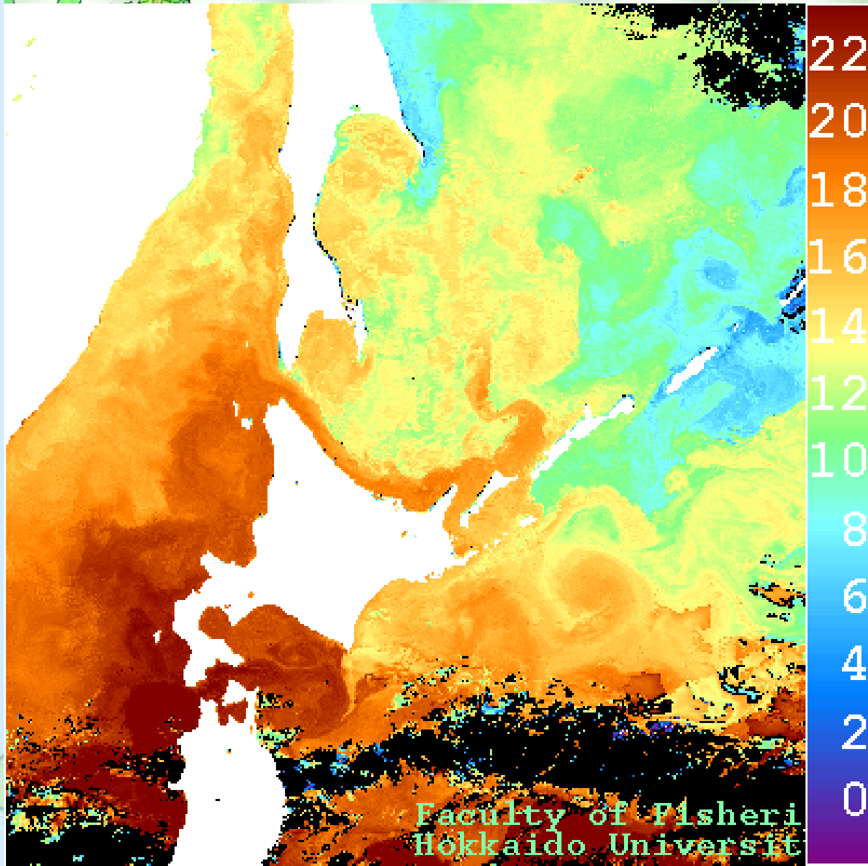
Canada



Lipa et al. (1977), Chan et al. (1997)

HF Radar Sites

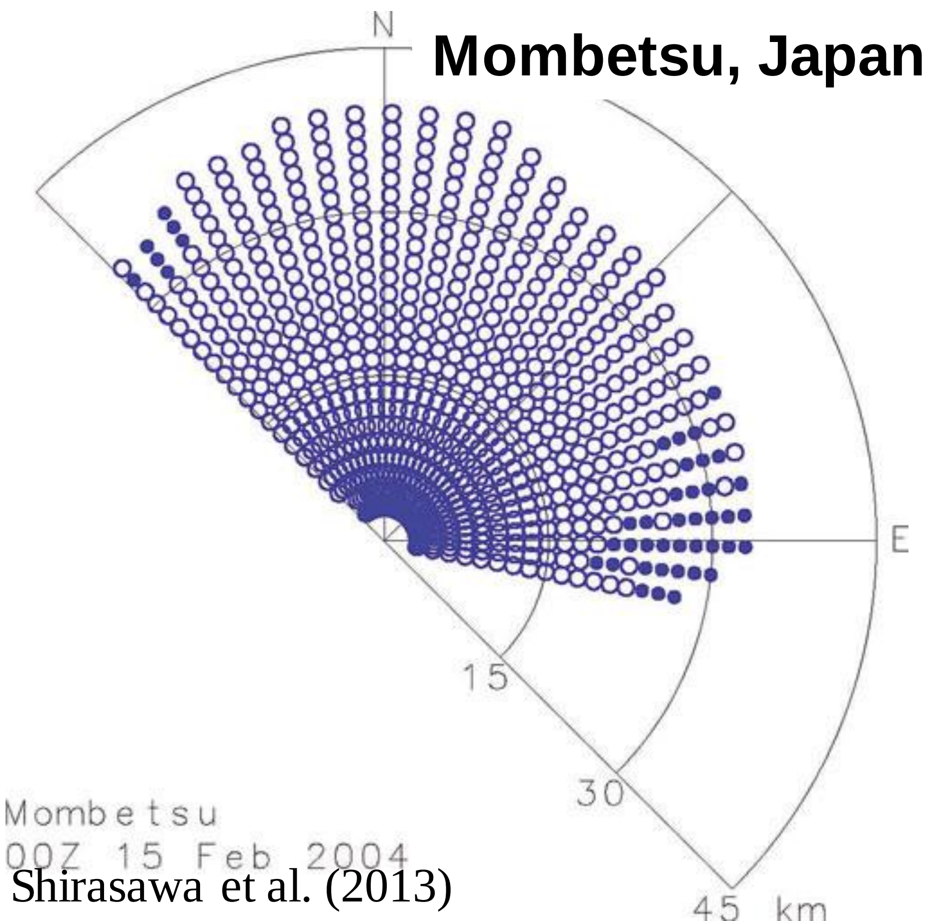


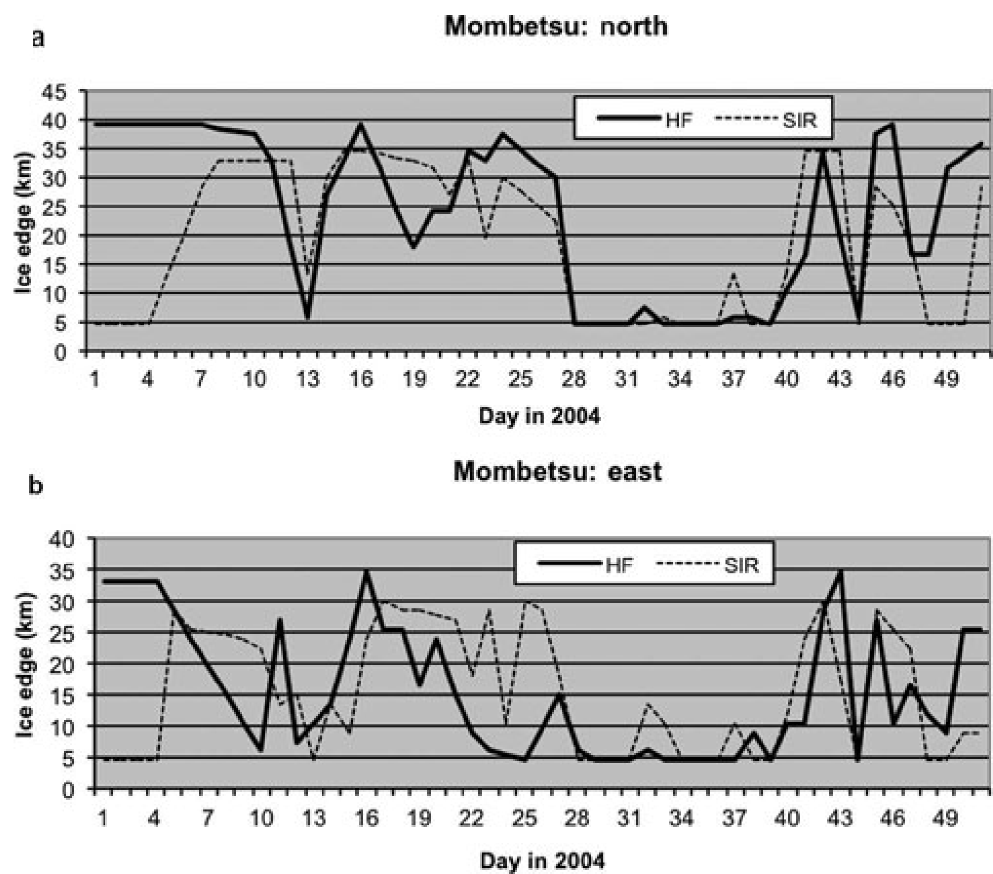


Previous Study of these radar for sea ice

- Shirasawa et al. (2013) used these radars to **indirectly** obtain sea ice **distribution**. HF radar provides surface currents data in open-water conditions, while areas with ‘no current’ can be identified as sea ice.

Mombetsu, Japan





Shirasawa et al. (2013)

Objective of This Study

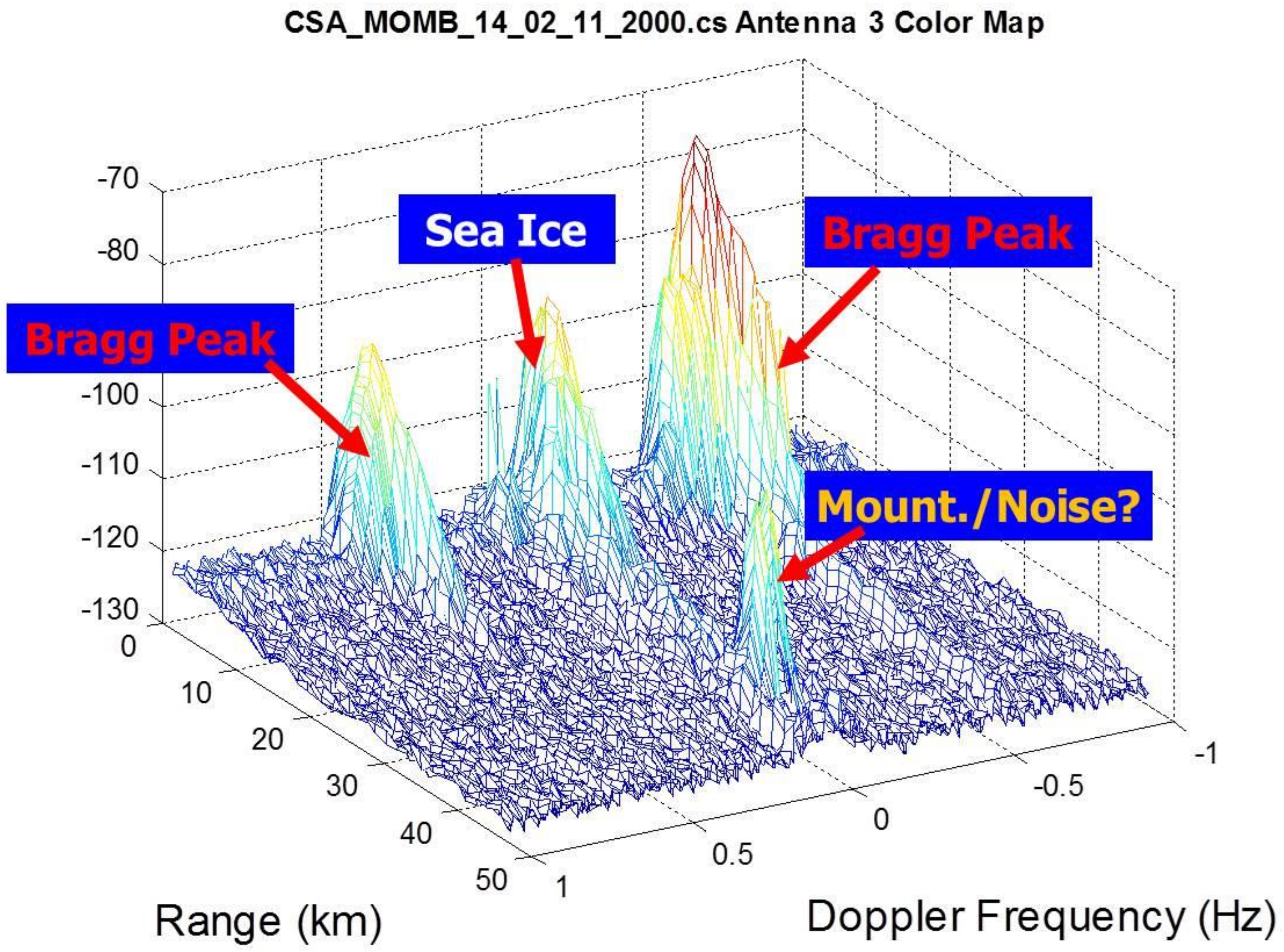
Investigate sea ice direct measurement by HF ocean radar.

- Try to extract sea ice signal from HF radar raw data, and derive sea ice radial velocity and direction; (reported in 2014)
- **Compare HF radar sea ice velocity with that from ADCP and drifting buoy;**
- Analyze sea ice observation by HF ocean radar.

CODAR SeaSonde Radar Station

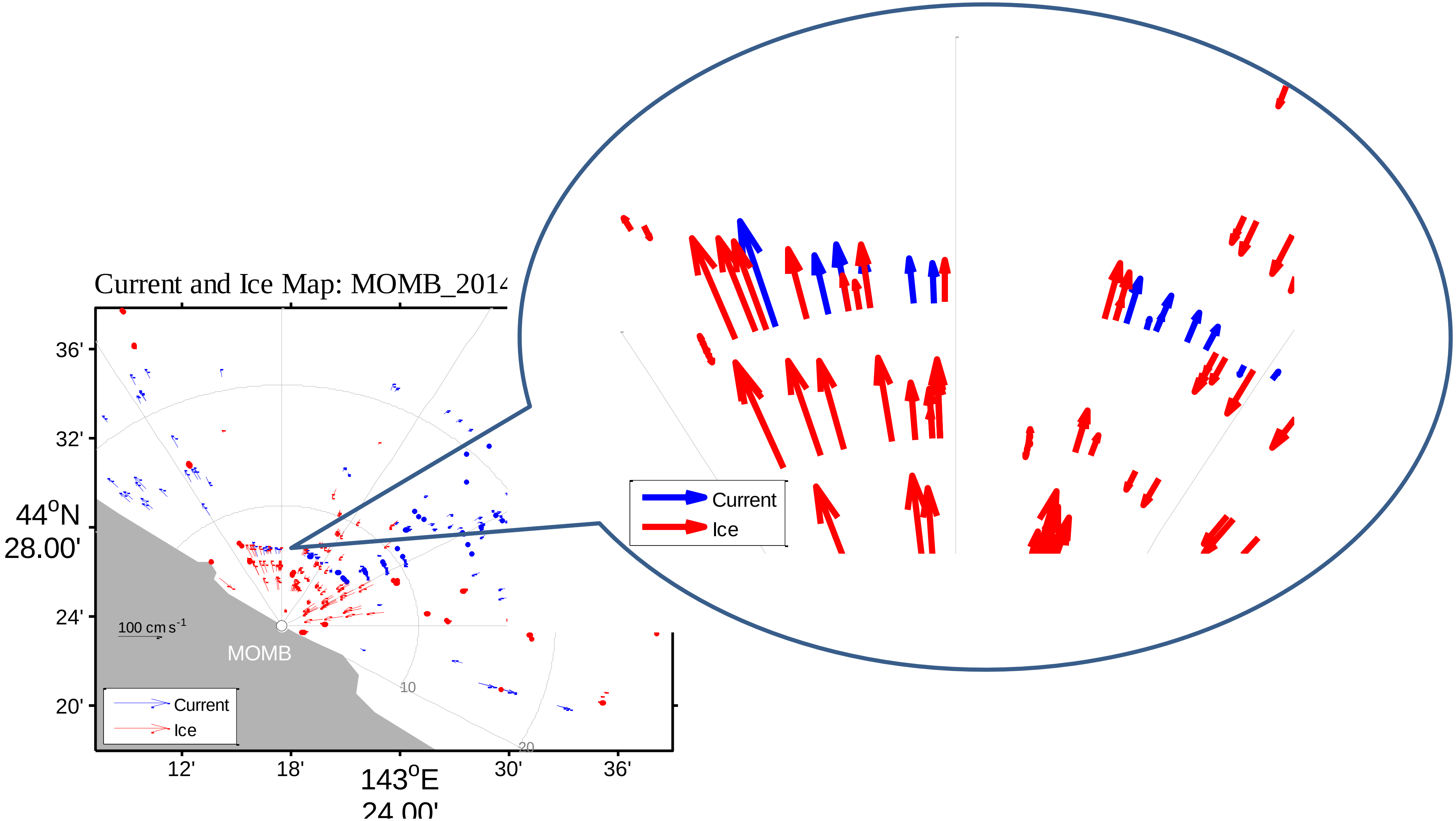
- Waveform: FMCW
- Center frequency: 24.56 MHz
- Detection range: 46.5 km
- Range resolution: 1.5 km
- Angular resolution: 5 deg.

Observed Range-Doppler Spectrum



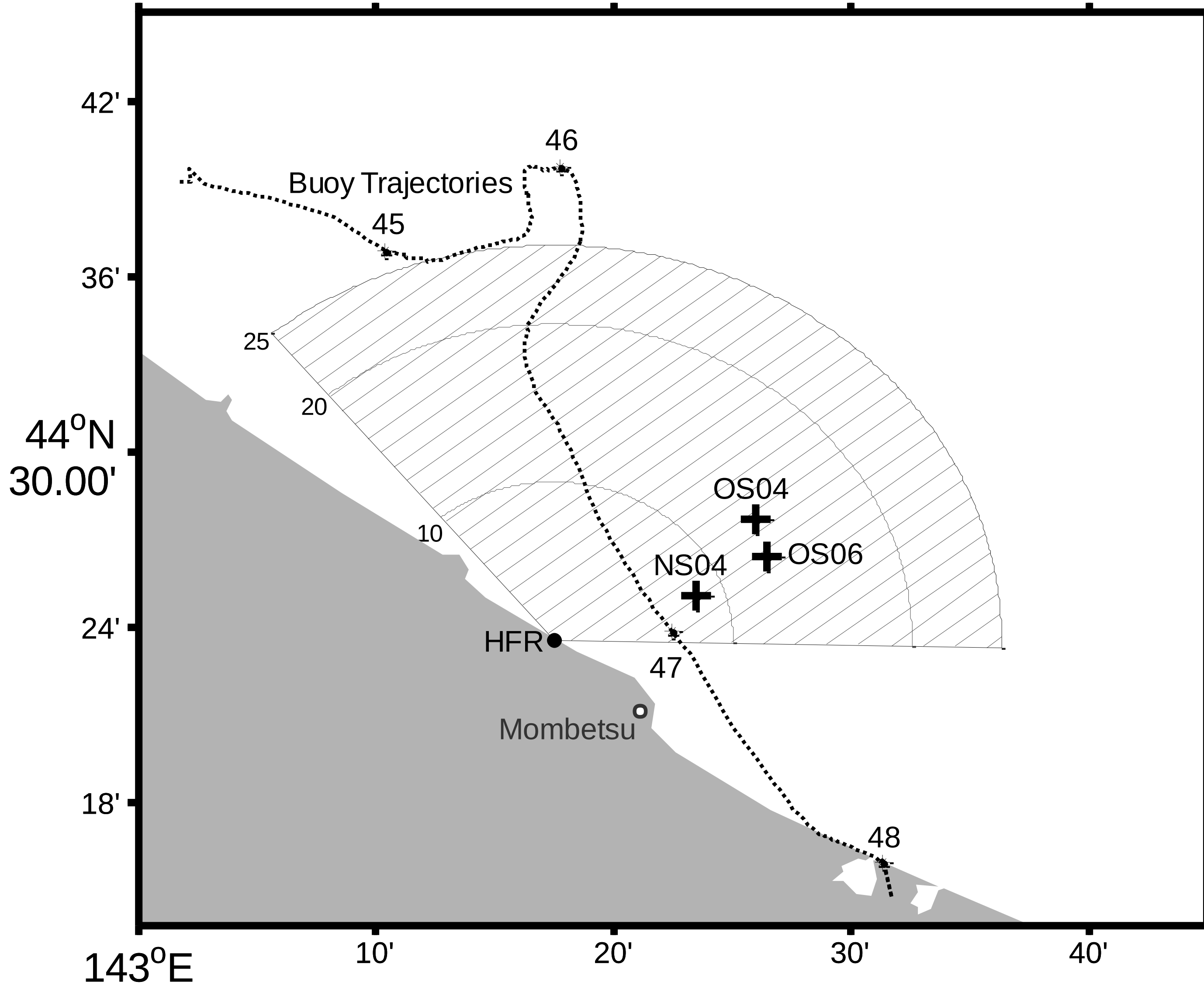
Signal scattered from sea ice is significantly strong.

Earlier Part of This Study (Reported in 2014)



Sea ice radial velocity is roughly **consistent** with nearby current radial velocity.

ADCPs & Drifting Buoy Measurements



ADCP Sea Ice Velocity

Error velocity:

$$v_{err} = w_{12} - w_{34}$$

$v_{err} \approx 0\ m/s$, sea ice

v_{err} noisy, open water

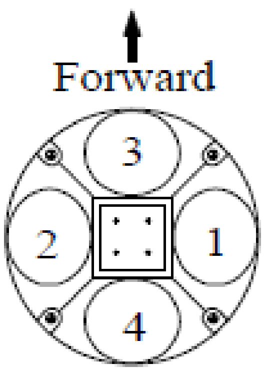
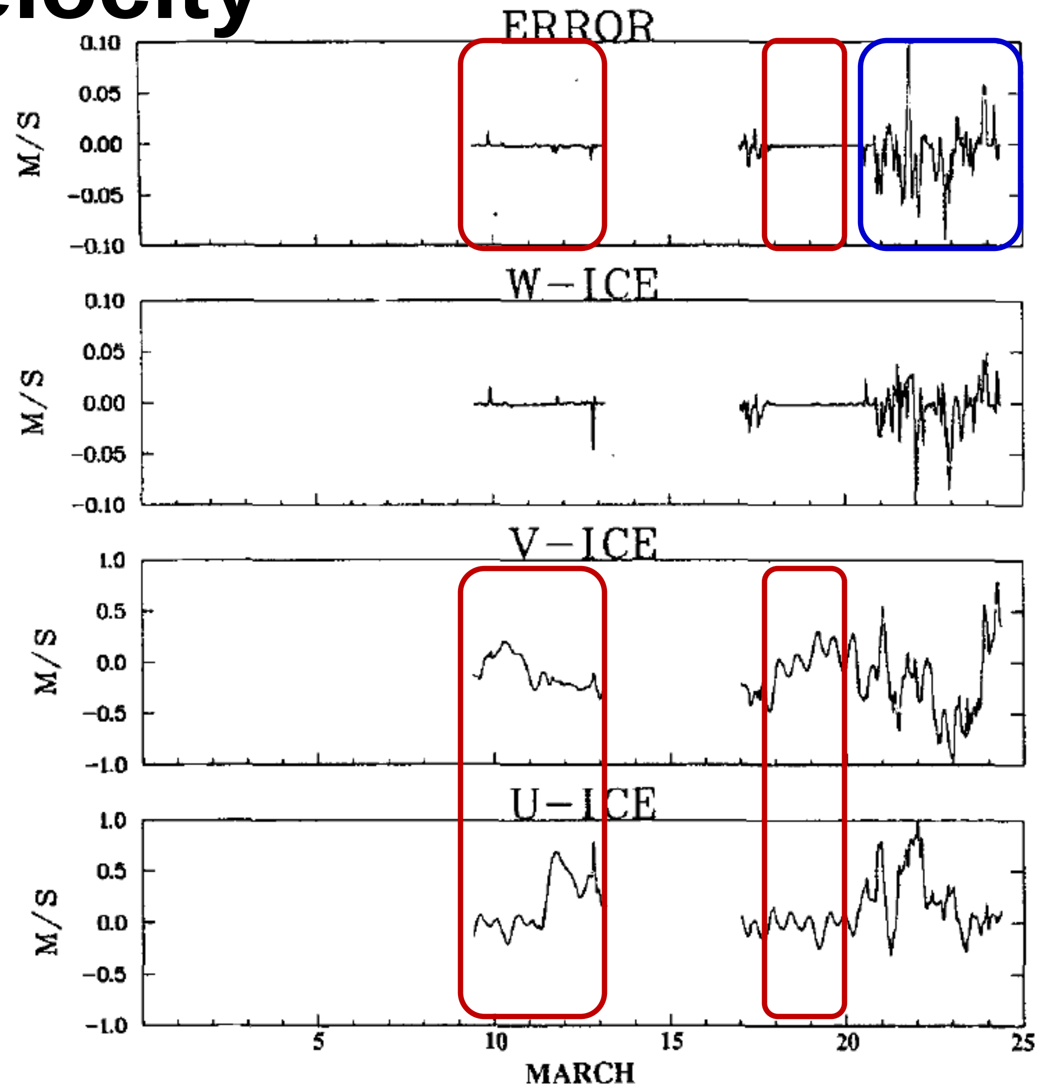


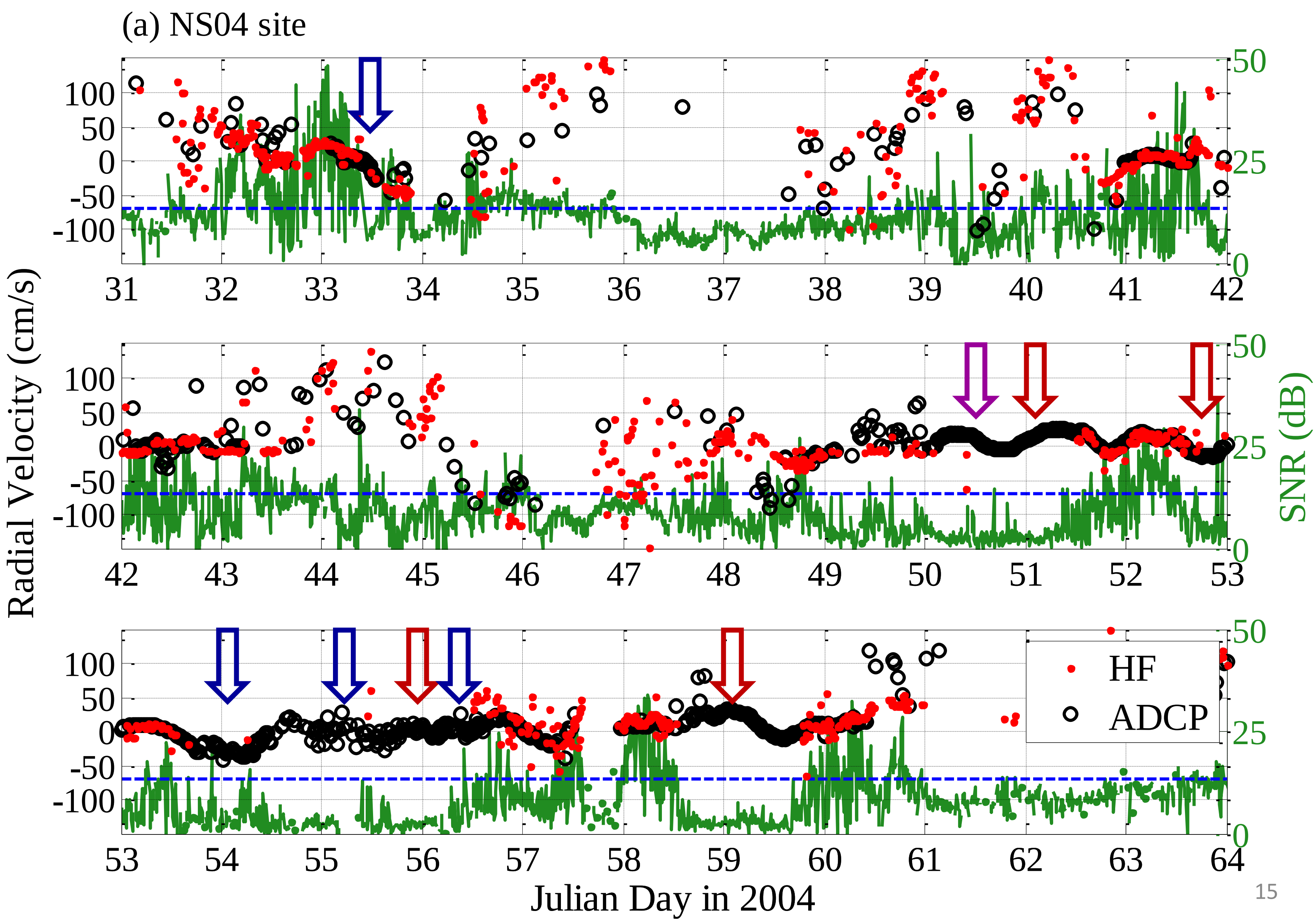
Figure 18. View facing an ADCP transducer. The layout is the same for both convex and concave transducers (see Figure 26).



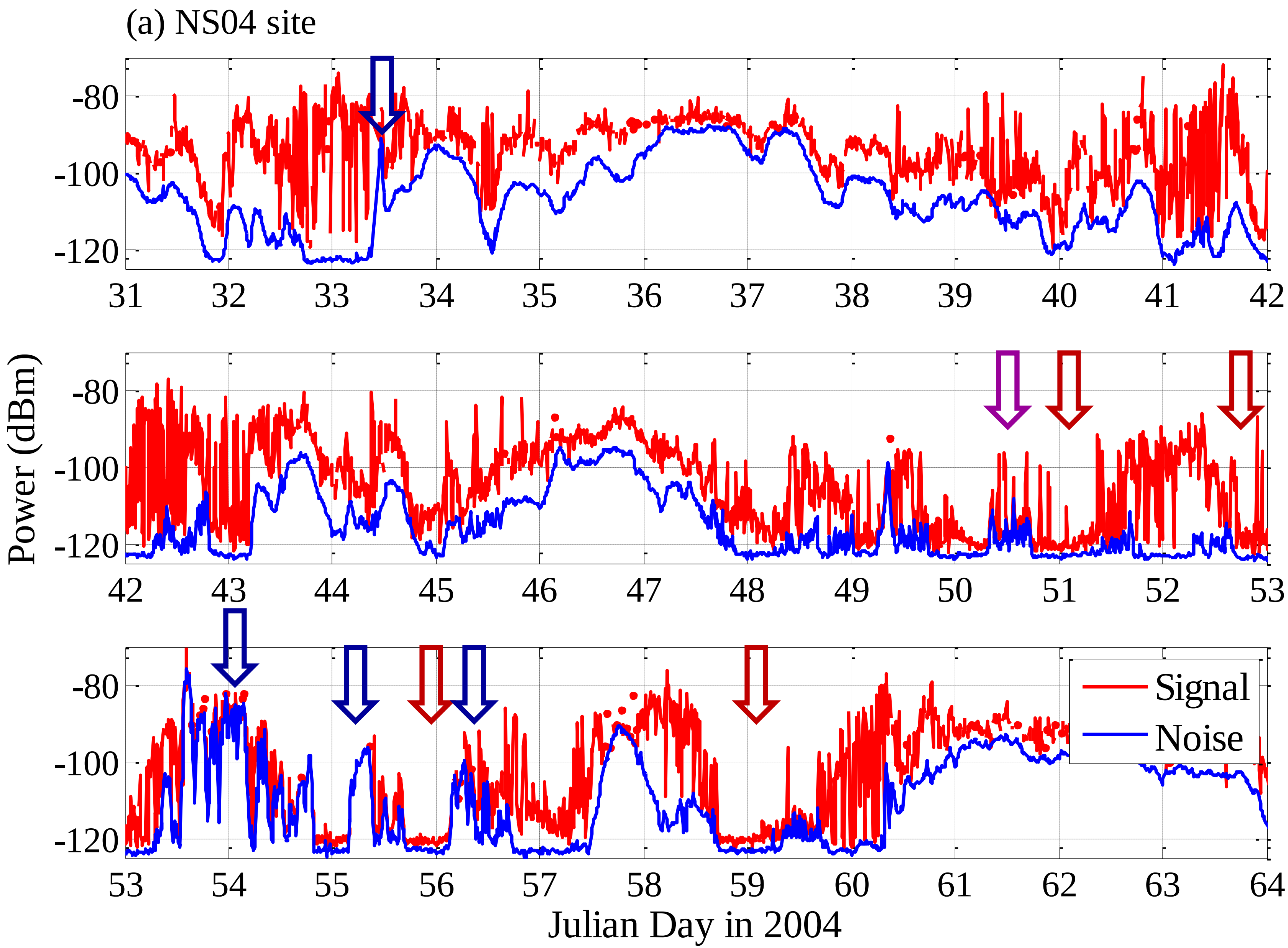
ADCP: $|v_{err}| \leq 1\ cm/s$

Belliveau et al. (1990)

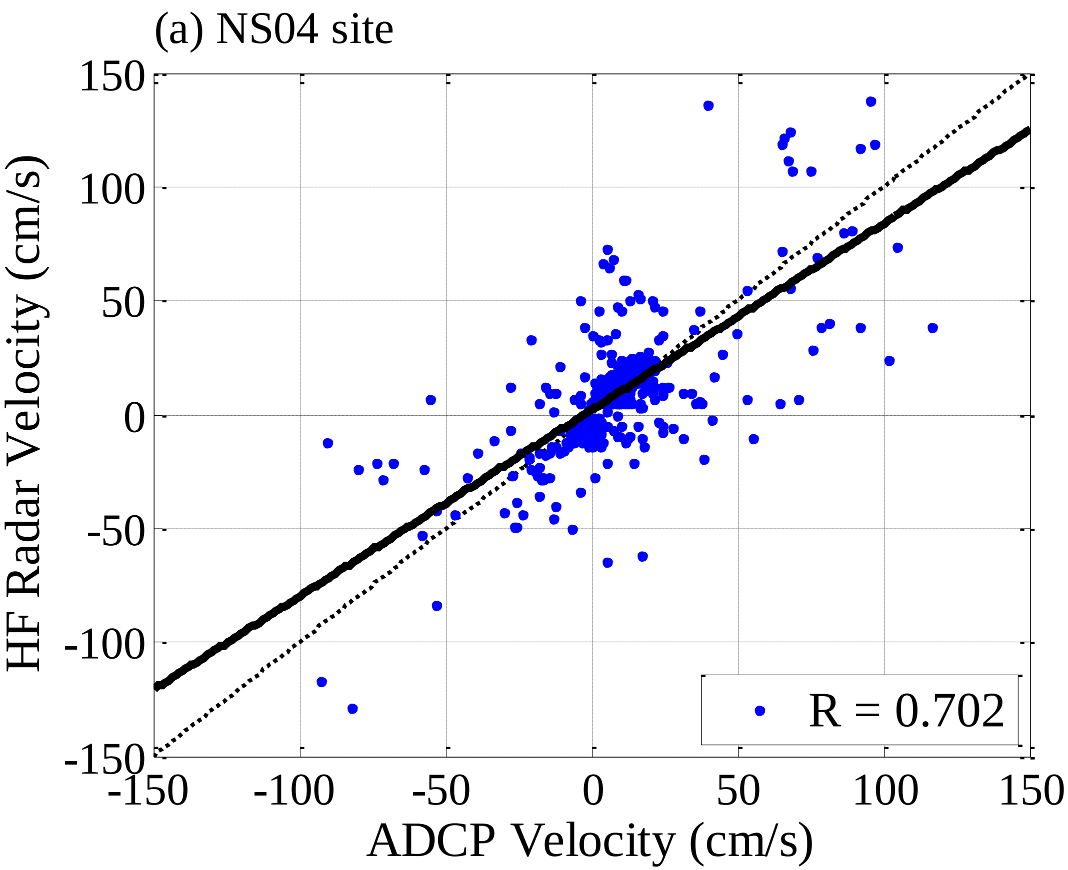
Sea Ice Velocity Comparison at NS04



Radar Signal and Noise Floor at NS04



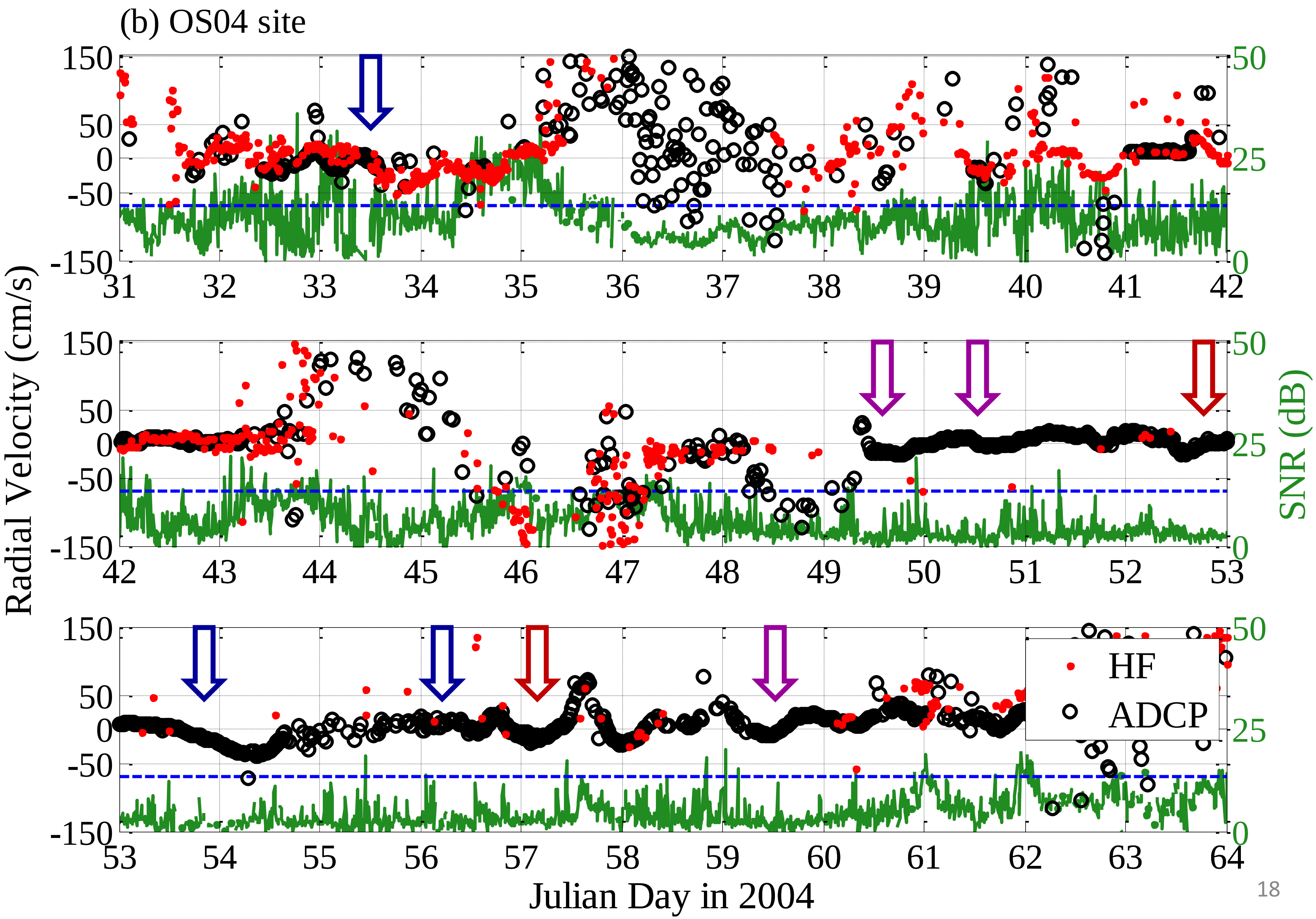
Sea Ice Velocity Comparison at NS04



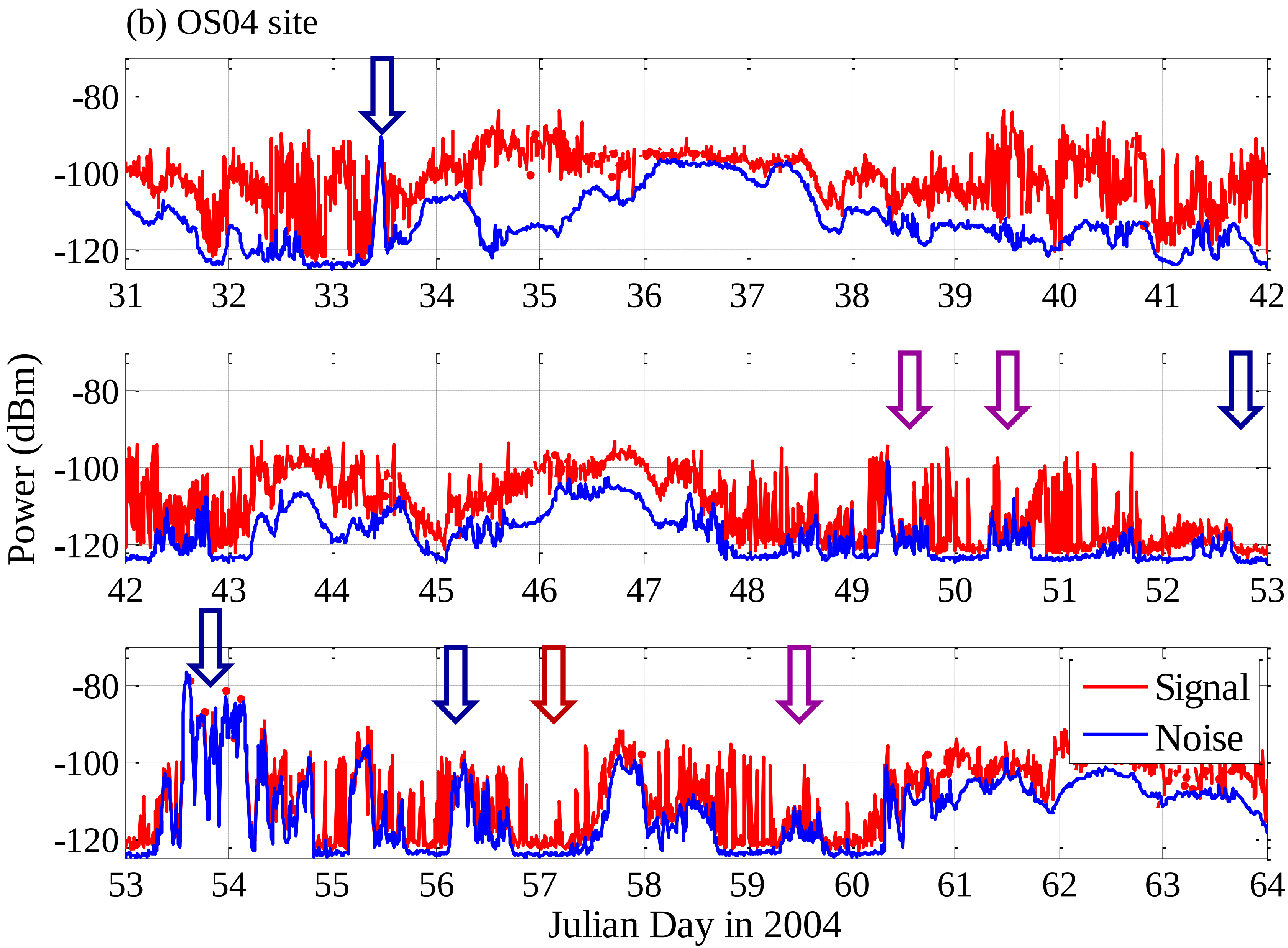
Bias (HF-ADCP)	0.4 cm/s
RMSD	20.7 cm/s
Correlation Coefficient	0.702
Slope	0.82

Sea ice velocities from ADCP and HF radar are high **consistent**.

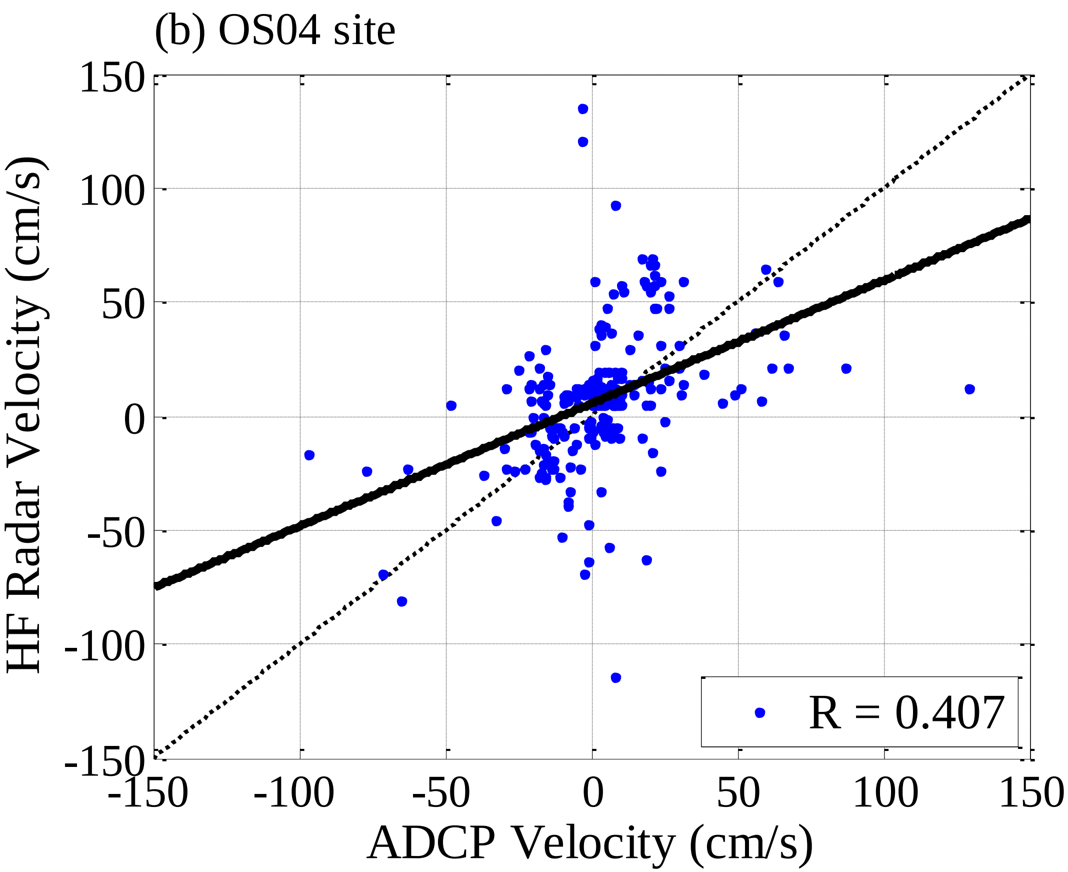
Sea Ice Velocity Time Series at OS04



Radar Signal and Noise Floor at OS04



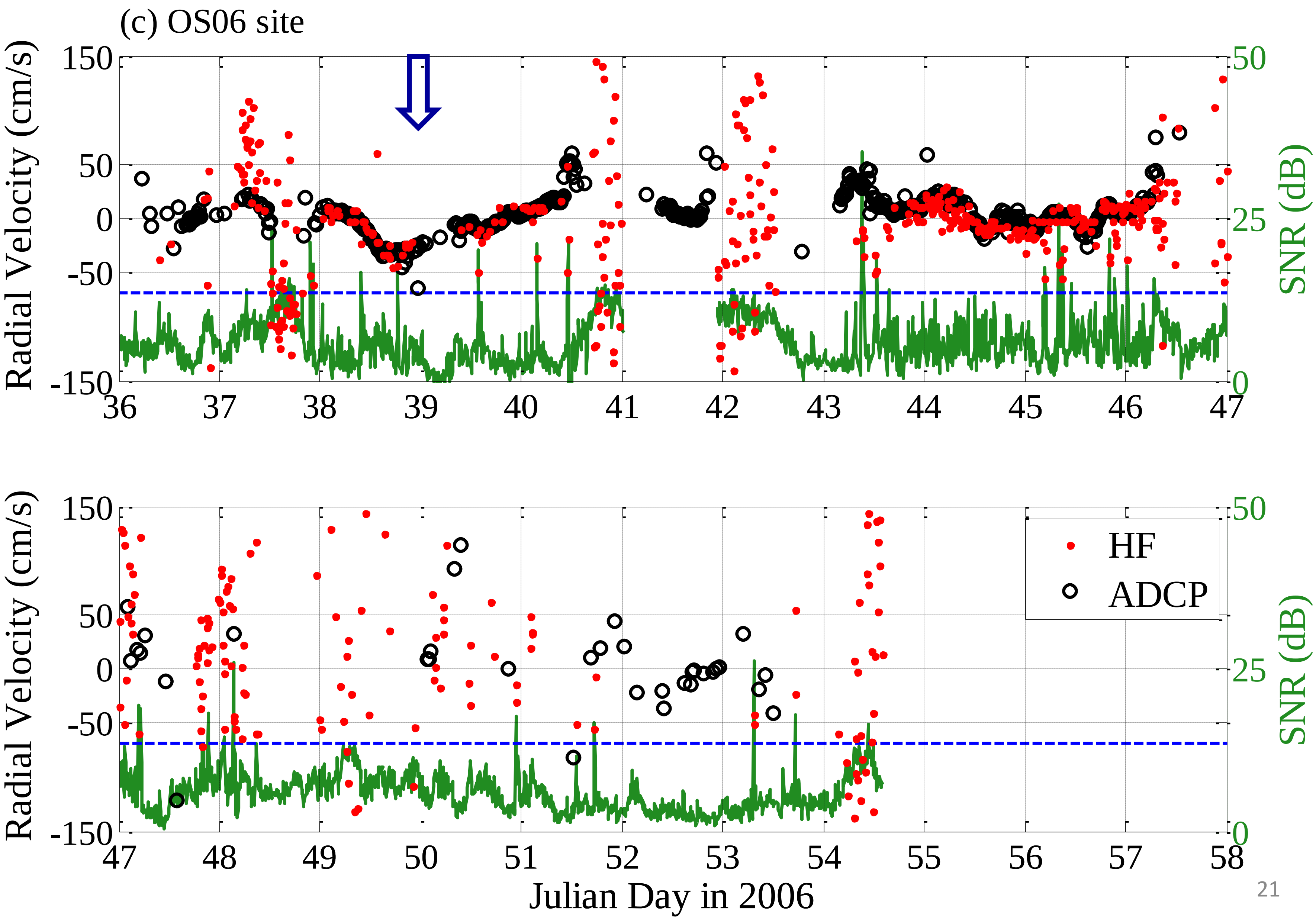
Sea Ice Velocity Comparison at OS04



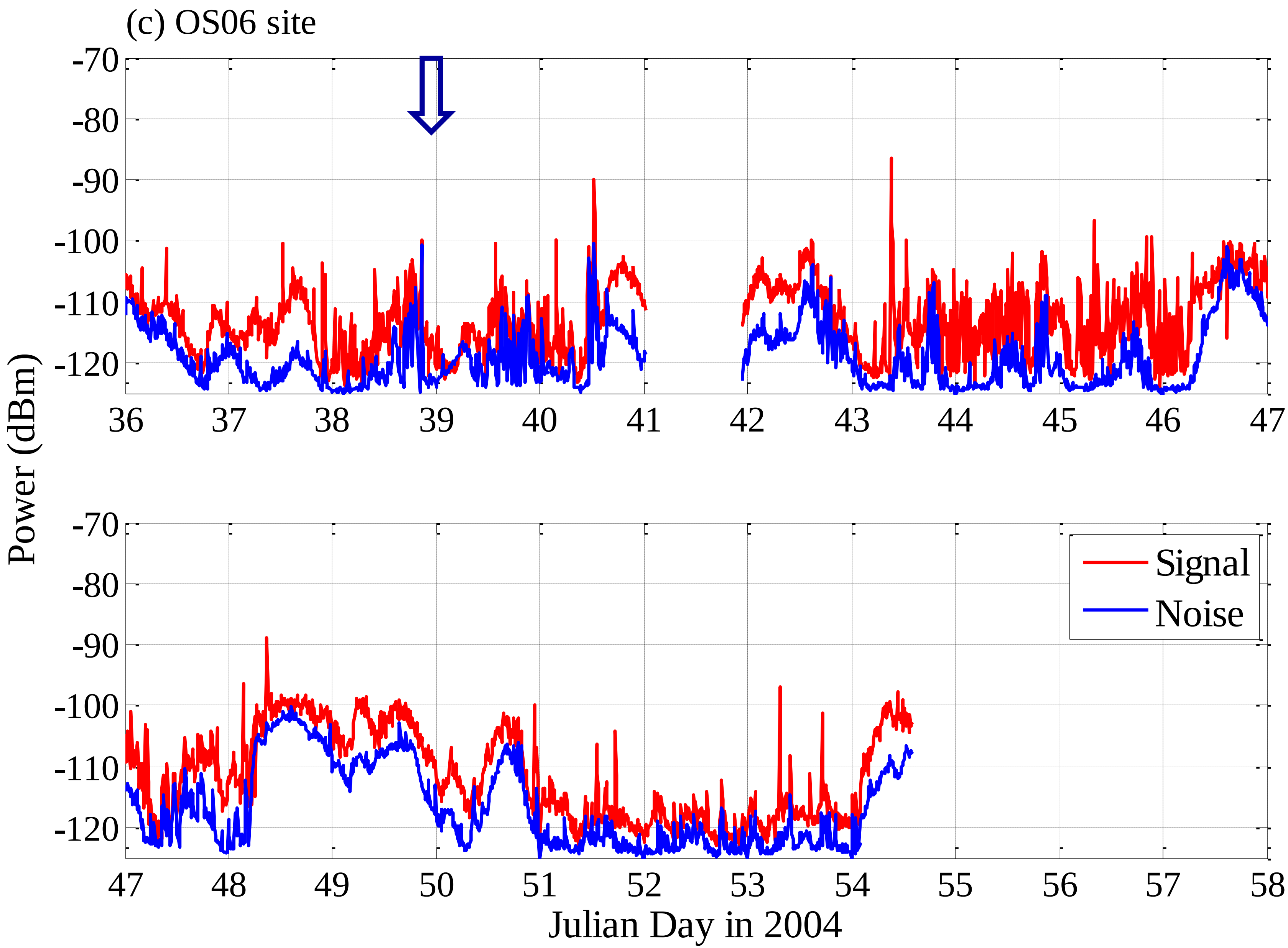
Bias (HF-ADCP)	4.2 cm/s
RMSD	28.4 cm/s
Correlation Coefficient	0.407
Slope	0.54

Sea ice velocities from ADCP and HF radar are **NOT** high consistent.

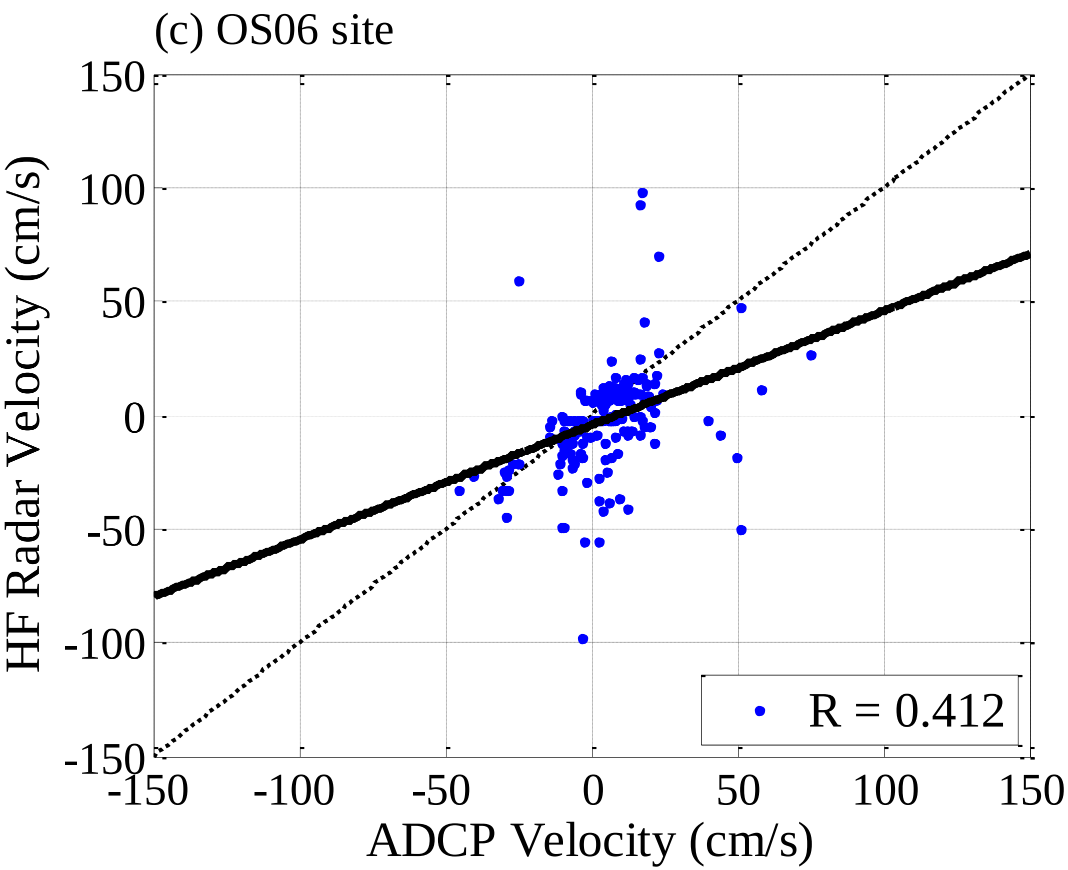
Sea Ice Velocity Time Series at OS06



Radar Signal and Noise Floor at OS06



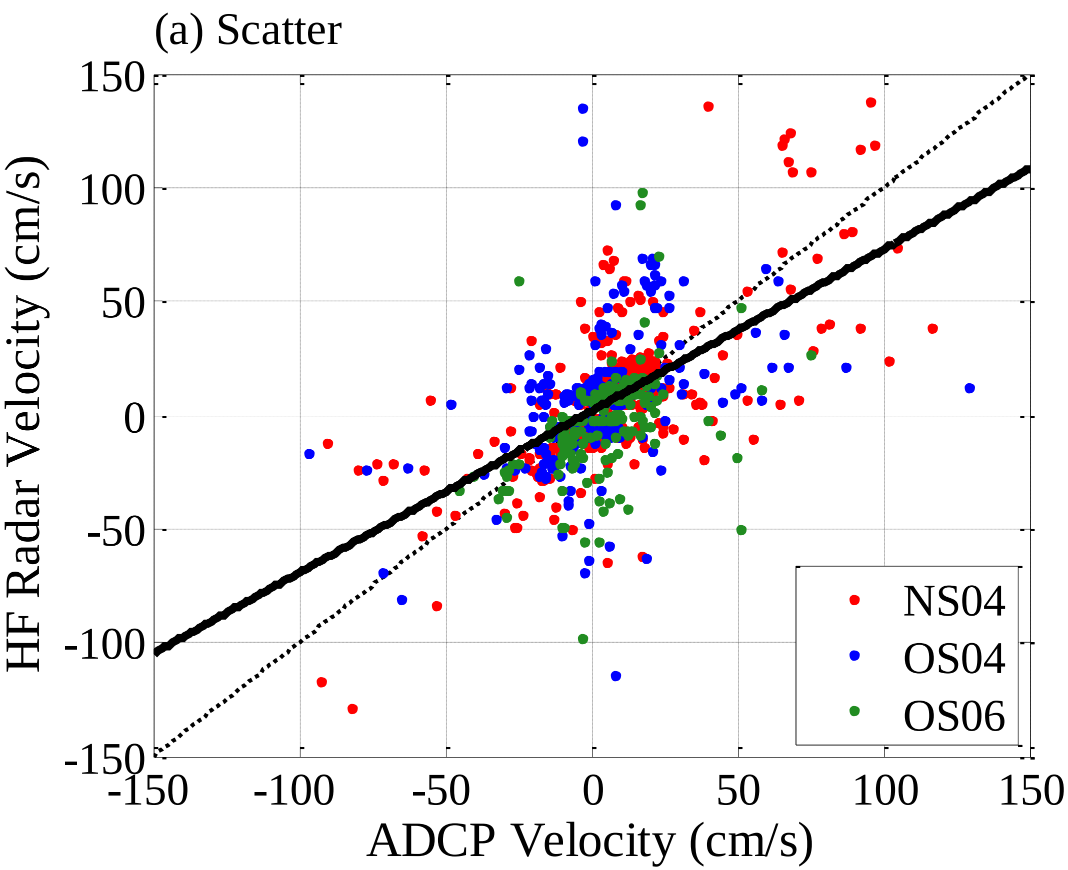
Sea Ice Velocity Comparison at OS06



Bias (HF-ADCP)	-6.5 cm/s
RMSD	22.4 cm/s
Correlation Coefficient	0.412
Slope	0.50

Sea ice velocities from ADCP and HF radar are **NOT** high consistent.

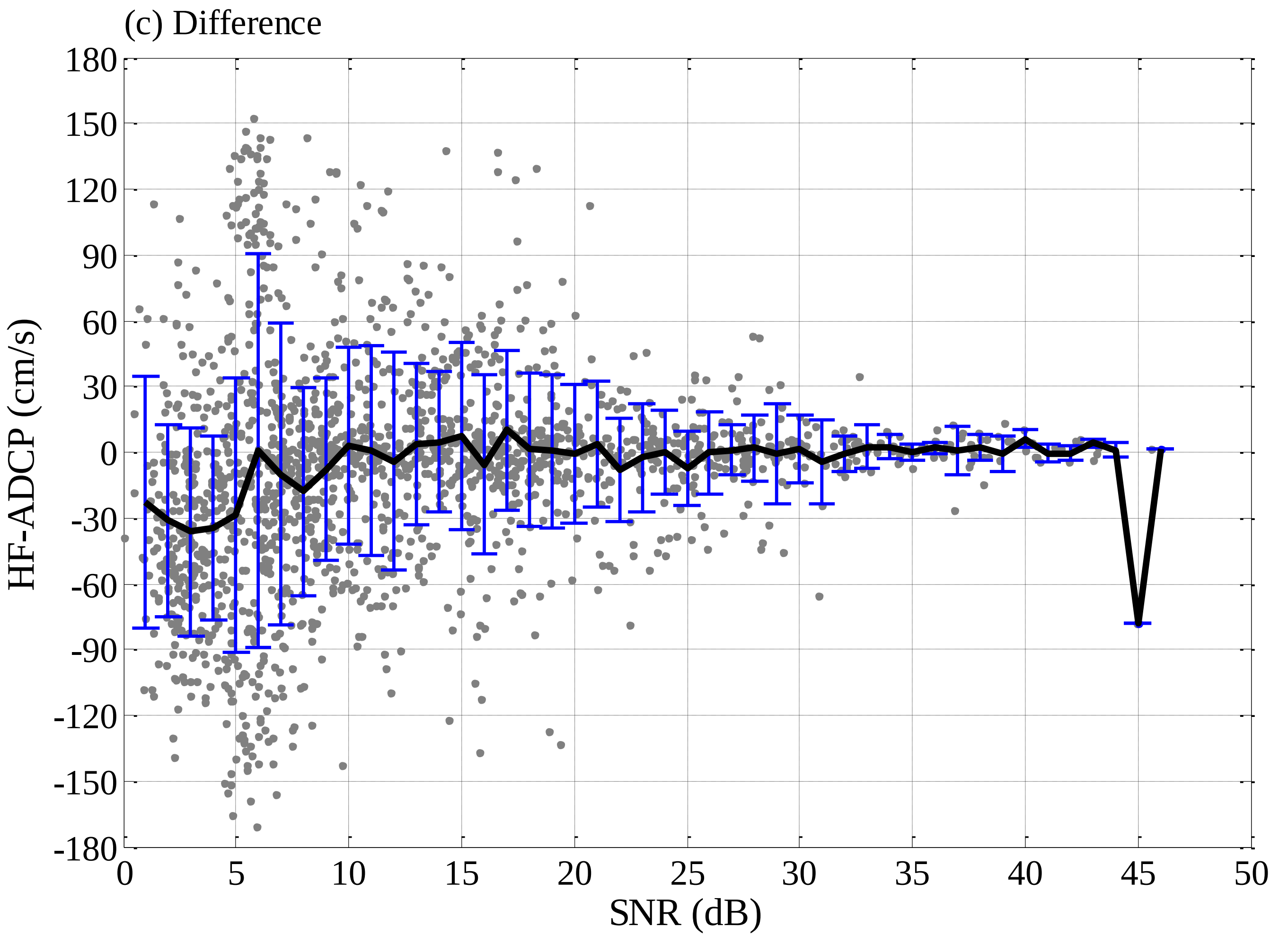
Total Comparison with ADCPs



Bias (HF-ADCP)	0.1 cm/s
RMSD	23.5 cm/s
Correlation Coefficient	0.575
Slope	0.71

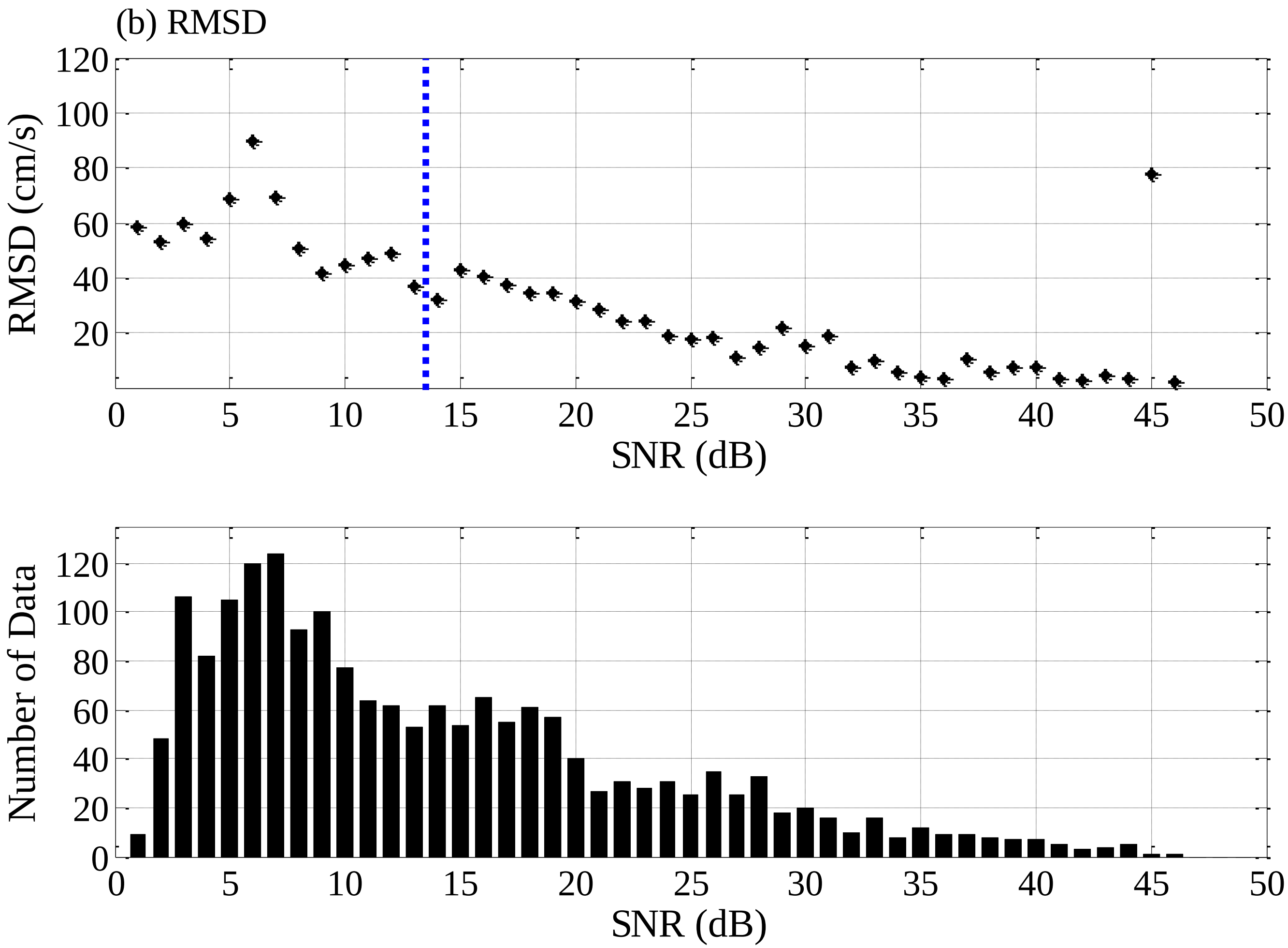
Sea ice velocities from ADCPs and HF radar are roughly consistent.

Total Velocity Difference on SNR



Sea ice velocity difference trend decrease when SNR increases.

Total RMSD along with SNR

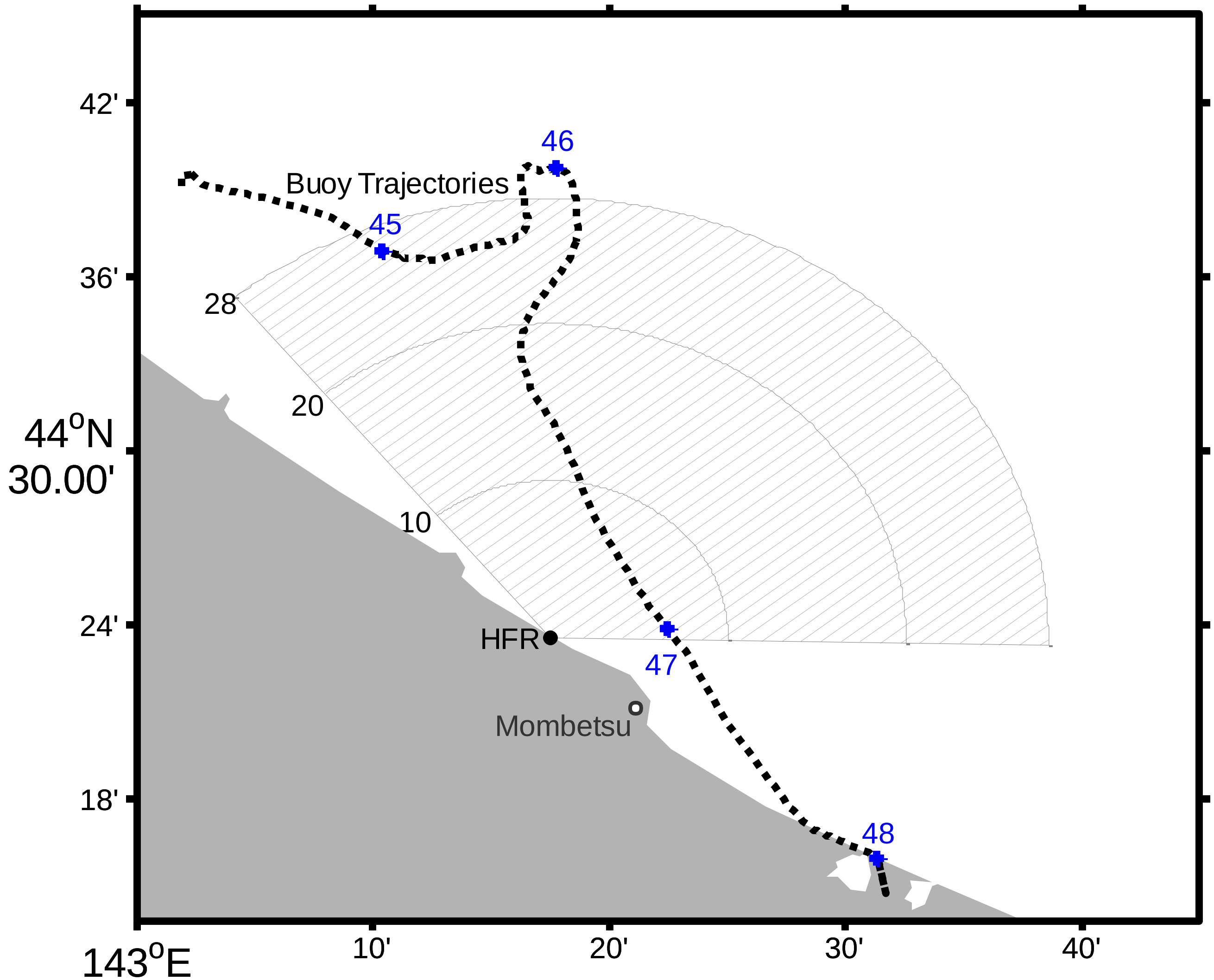


Sea ice velocities Root Mean Square Difference decrease when SNR increases.

10
GUARD

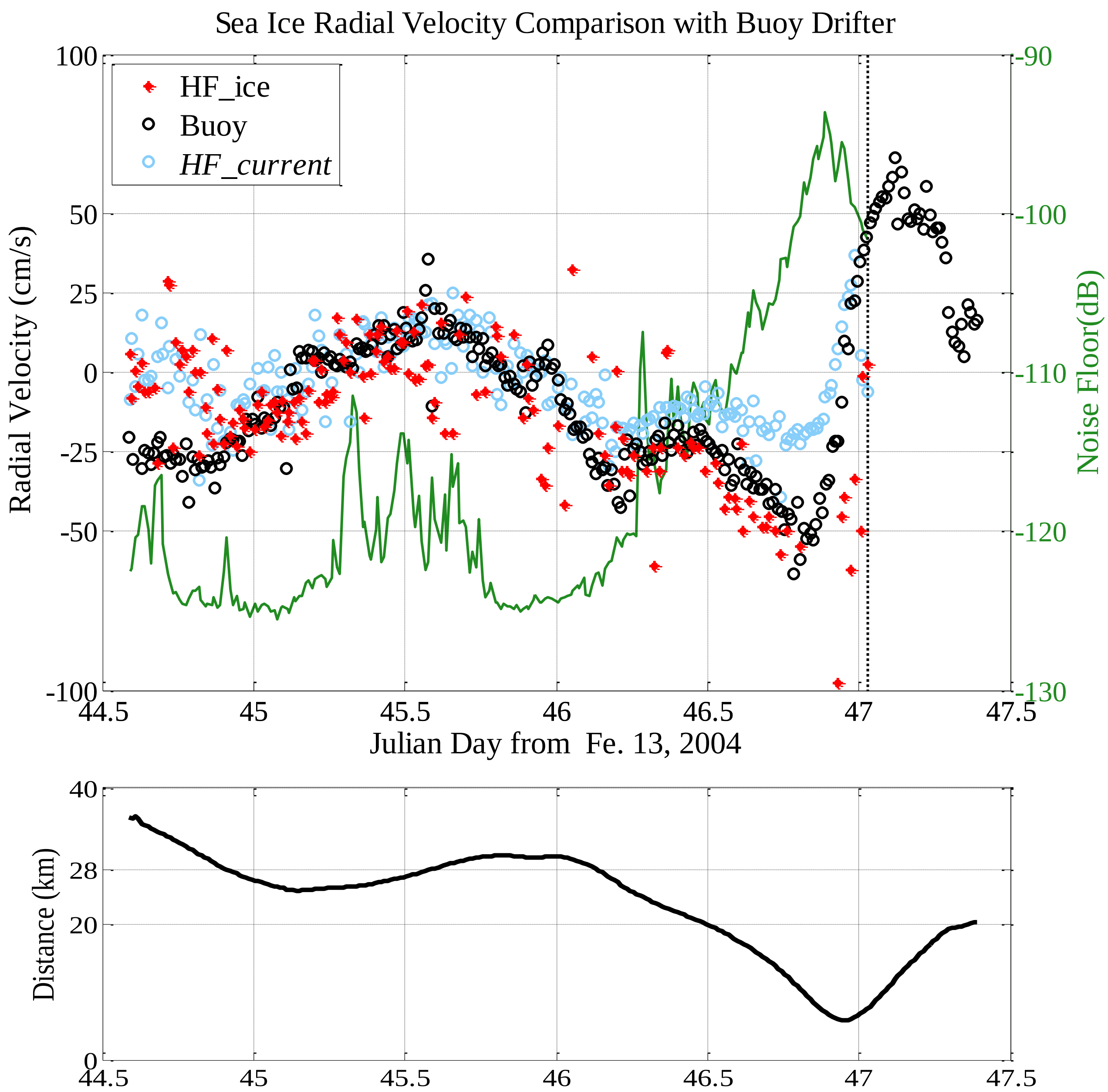
N44°56'43.7" E143°17'18.4"
2004/ 2/ 7 11:34pm

Drifting Buoy Trace in 2004

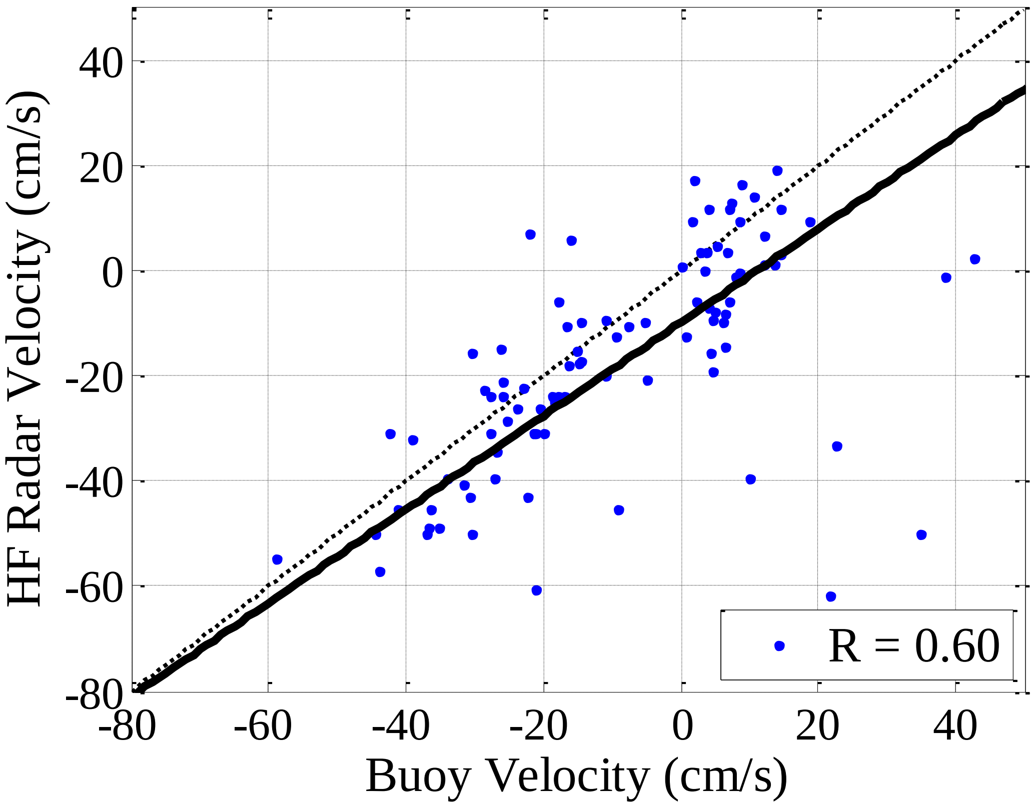


$$v_i = \frac{loc(x_{i+1}, y_{i+1}) - loc(x_i, y_i)}{\Delta t}$$

Sea Ice Velocity Time Series



Sea Ice Velocity Comparison for Buoy

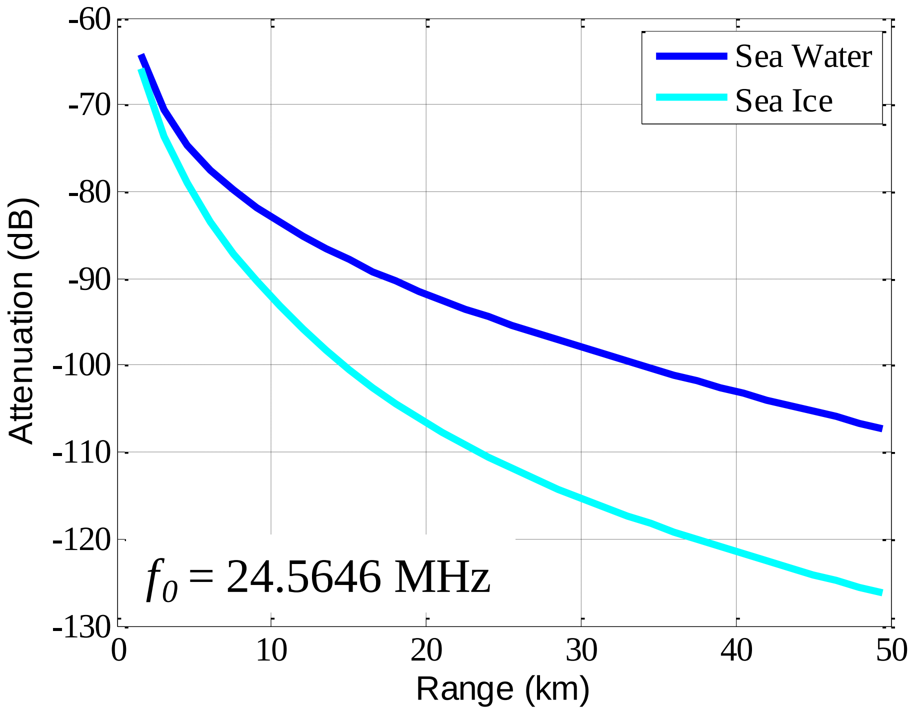


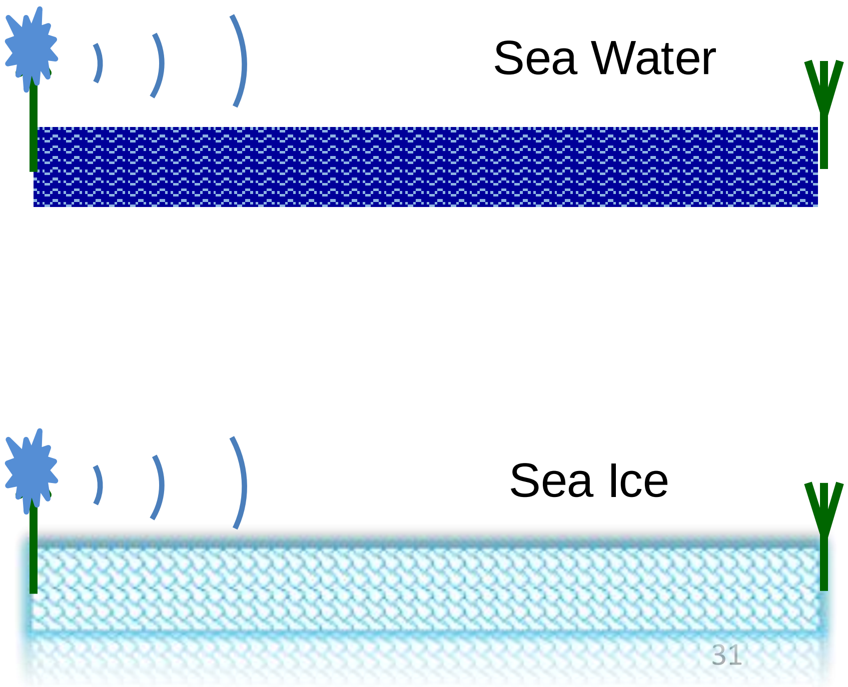
Bias (HF-Buoy)	-8.7 cm/s
RMSD	20.9 cm/s
Correlation Coefficient	0.6
Slope	0.89

Sea ice velocities from HF radar and drifting buoy are **consistent**.

Missing Data (1)

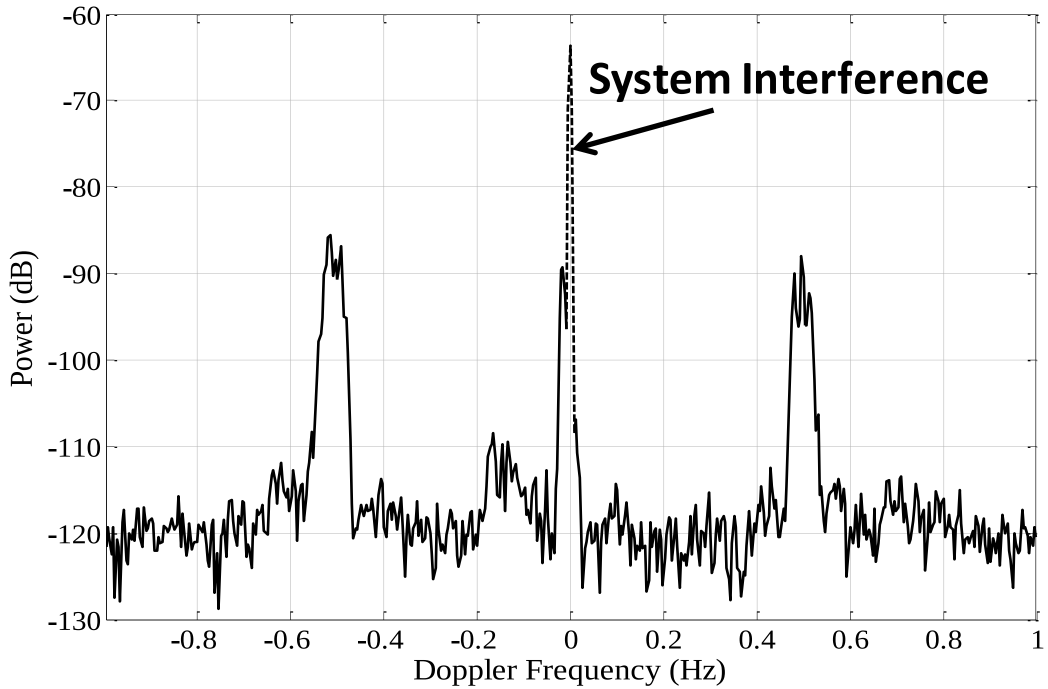
- Signal is too weak to be recognized from noise.
  - Strong Radio Frequency Interference (noise floor) masks sea ice signal,
  - Sea ice is too thin/small to scatter distinct signal,
  - Signal attenuates over sea ice rapidly.





Missing Data (2)

- Signal contaminated by HF ocean radar system interference.
- Signals is assumed to be no more than 2 at each Doppler point due to MUSIC algorithm.



Interferenced Velocity:
-3 cm/s < V_i < 3 cm/s

MUSIC algorithm: Antenna system with 3 sensors estimates no more than two signals at one Doppler point.

Summary

- HF ocean radar can observe sea ice motion, and obtain bearing angle and radial velocity.
- In nearshore, sea ice drift velocities obtained from HF ocean radar are consistent with that from ADCP and drifting buoy. The correlation is about 0.7 and 0.6, respectively, and the RMSD is about 21 cm/s.
- Low SNR induces inaccurate or missing data of sea ice measurement. It is mainly caused by RFI greatly increasing noise floor.

謝謝聆聽

Thank you for your Attention

本研究纯属胡诌，如有雷同，不一定巧合！