How might wind influence SWOT water surface retrievals?

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SWOT Lightning Talks

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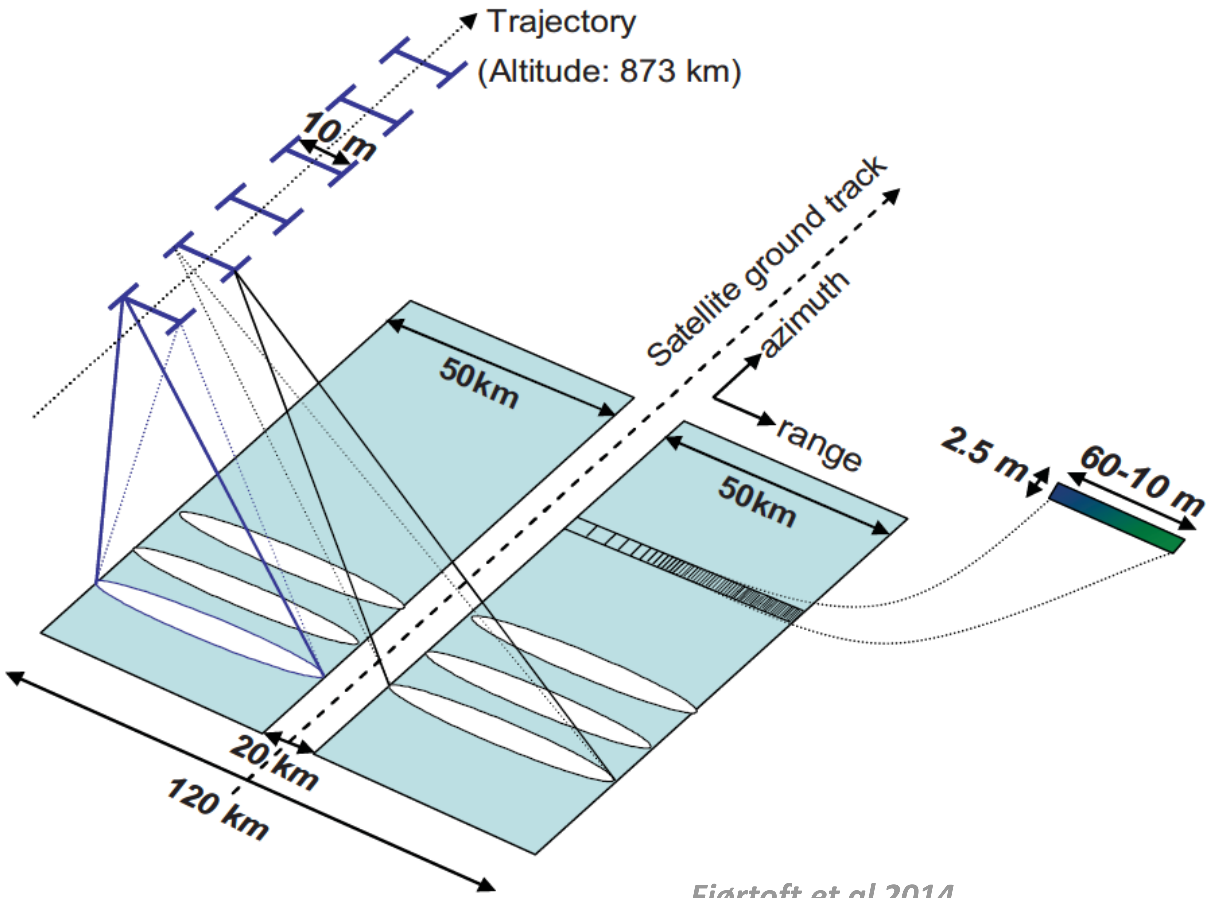
Background: The Surface Water and Ocean Topography (SWOT) Mission

For inland hydrology, SWOT will observe water surface elevation and water surface extent at a very high resolution (~10-70 m), additionally enabling long-term monitoring of floodplain changes.

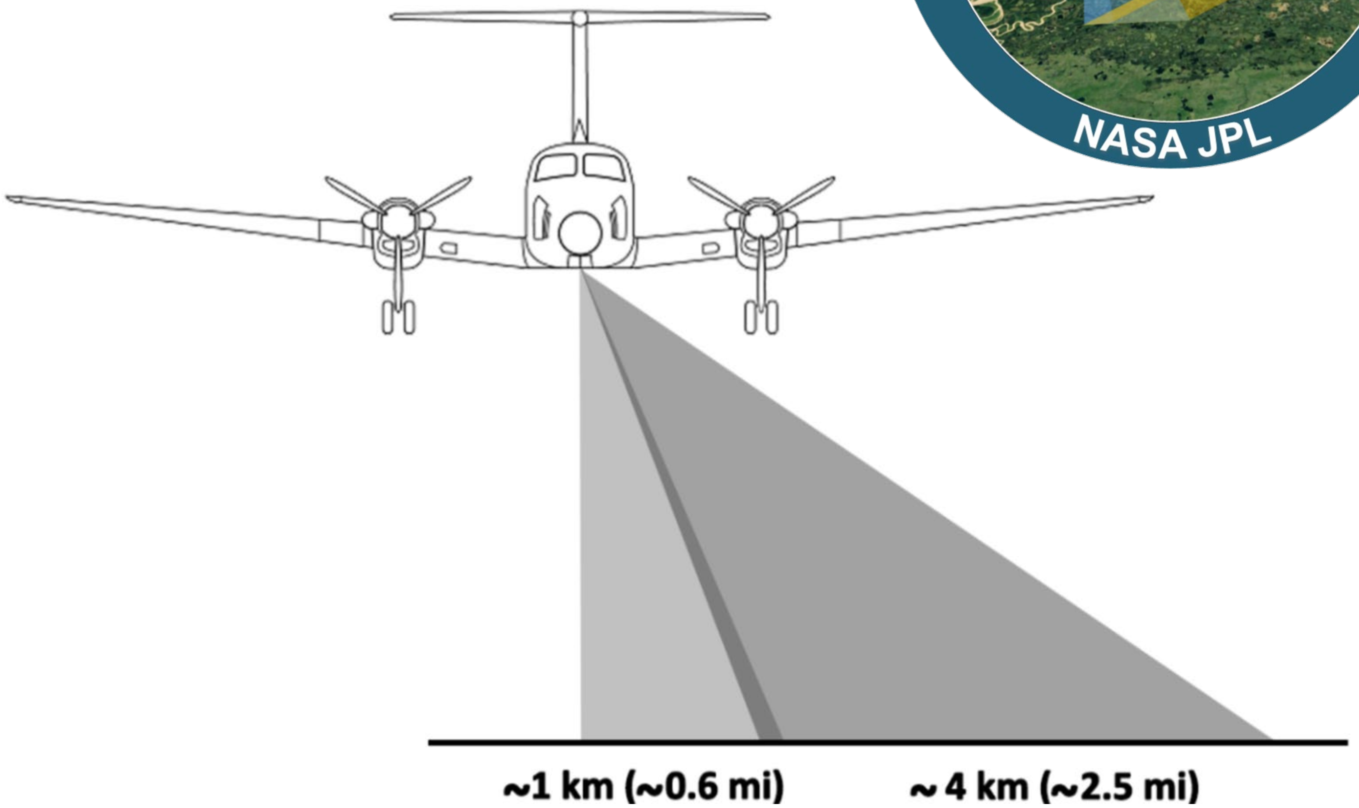


Fjørtoft et al 2014

Background: SWOT and AirSWOT

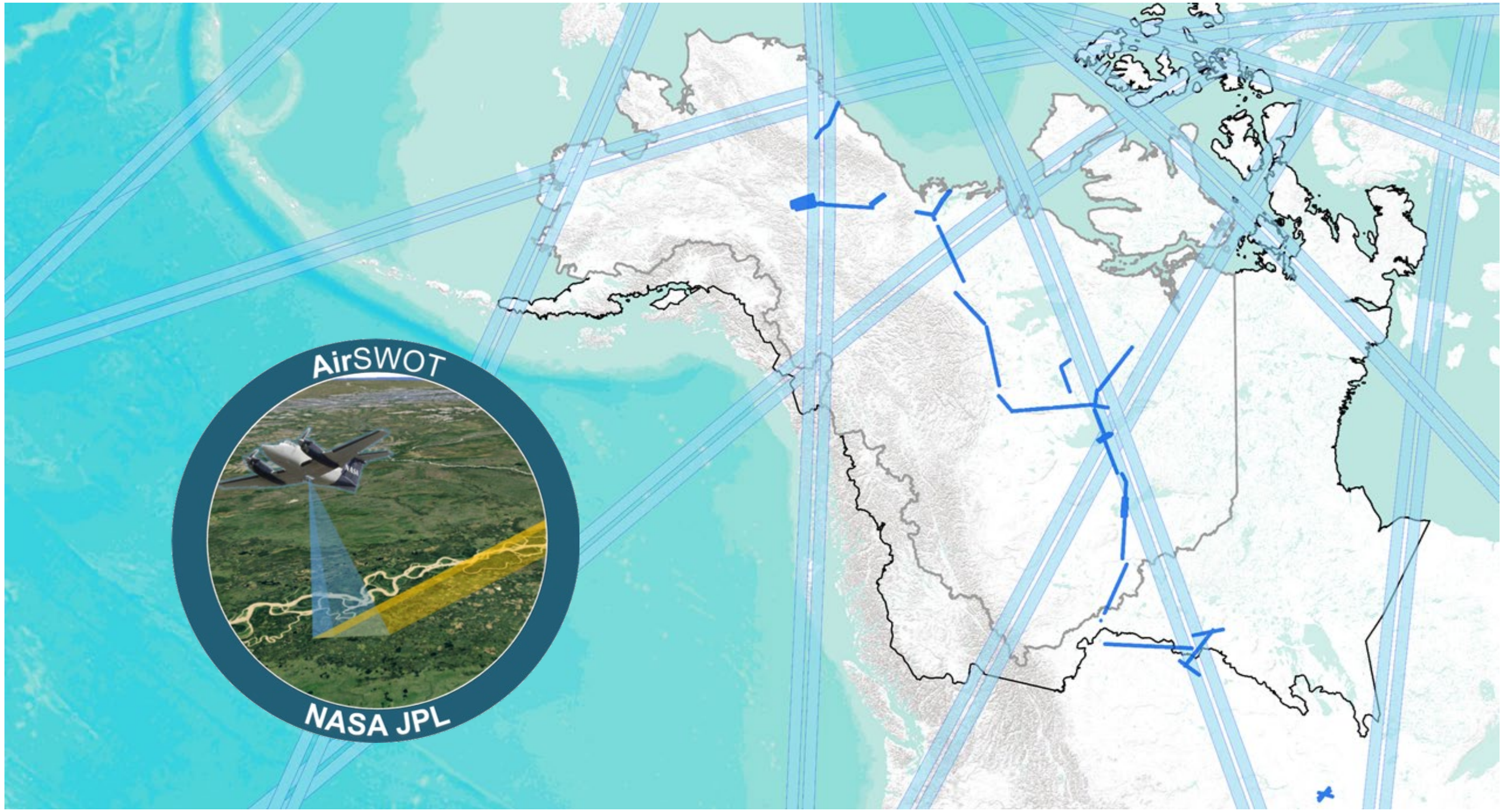
The SWOT satellite mission and its airborne complement, AirSWOT, use a high frequency **Ka-band radar** (35.7 GHz, 8.4 mm) and radar interferometric techniques to measure the elevation of surface water.

AirSWOT, flown throughout the US and Canada, can be used to help understand what SWOT observations might look like.



Background: AirSWOT ABoVE Flights 2017

In July and August 2017, Airborne-SWOT (AirSWOT) acquired data from over 130 flight lines averaging 45 km in length from Saskatoon, Canada to Yukon Flats, Alaska mapping a total area of 22,400km^2.



Fayne et al 2020 ERL

Background: Ka-band SAR Missions

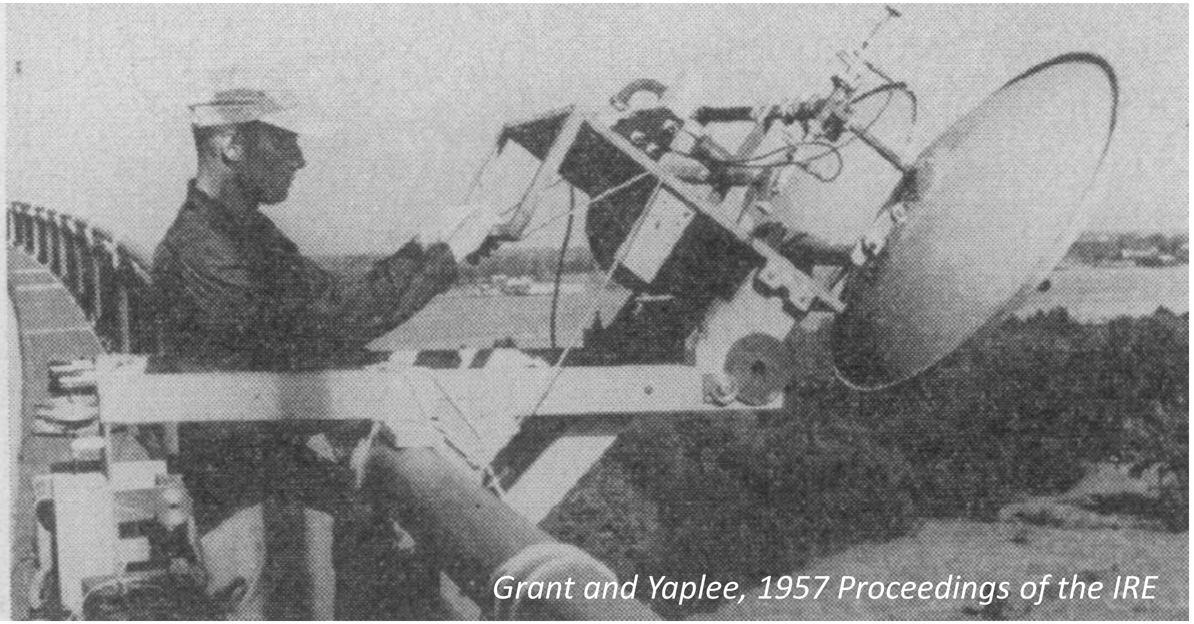
Because the Ka-band frequency has not historically been used for inland water mapping, scattering characteristics are not well understood for variations in surface cover.

Studying Ka-band scattering sensitivities and resultant InSAR elevations will not only support the primary objectives of the upcoming SWOT mission, but also support new Ka-band instruments and novel applications for SWOT data.

Ka-band scattering is a relatively unknown phenomenon

Ka-band has an 8mm wavelength, making it very (too) sensitive to surface features.

Longer wavelength radars such as C-, L-, and P- band have been more popular in recent decades.

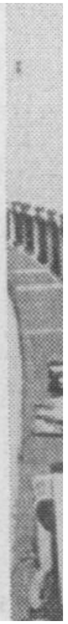


Grant and Yaplee, 1957 Proceedings of the IRE

Ka-band scattering is a relatively unknown phenomenon

Known:

Incidence-angle-dependent backscatter "drop-off" is expected for water.



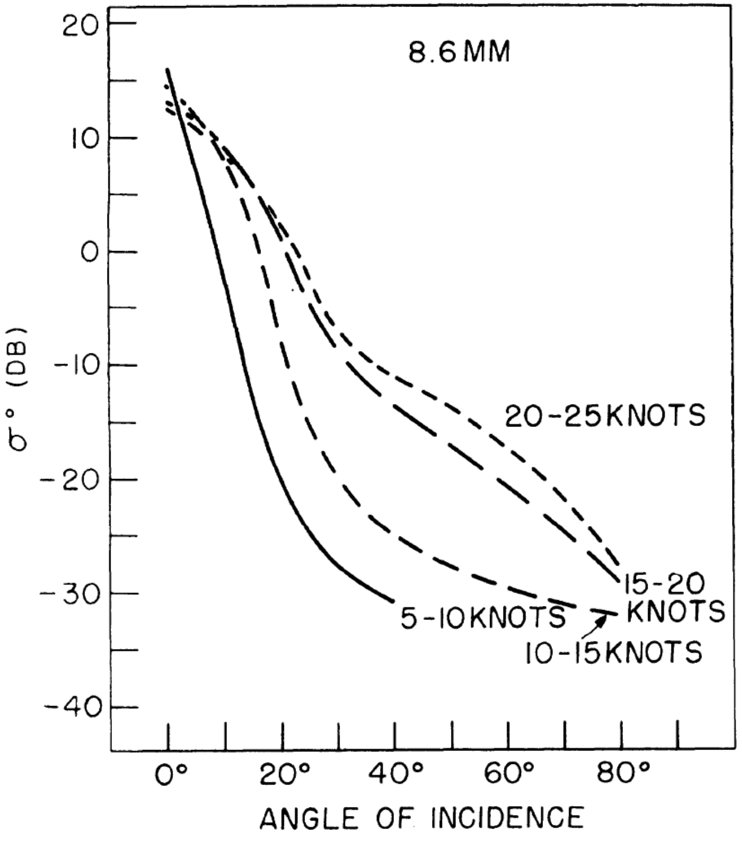
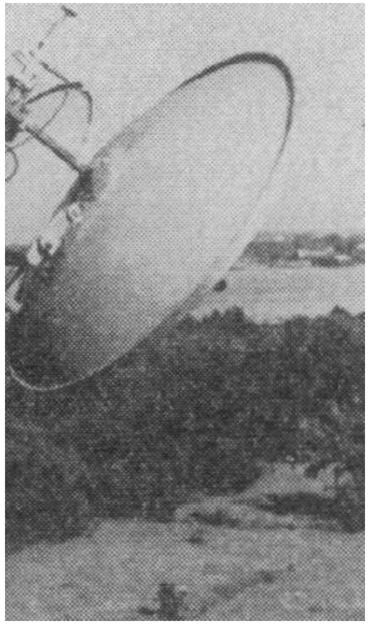


Fig. 4—σ° as a function of wind velocity, $\lambda = 8.6$ mm.



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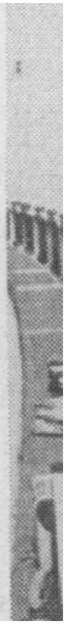
Wind speed influences the magnitude of Ka-band backscatter, especially at oblique angles.



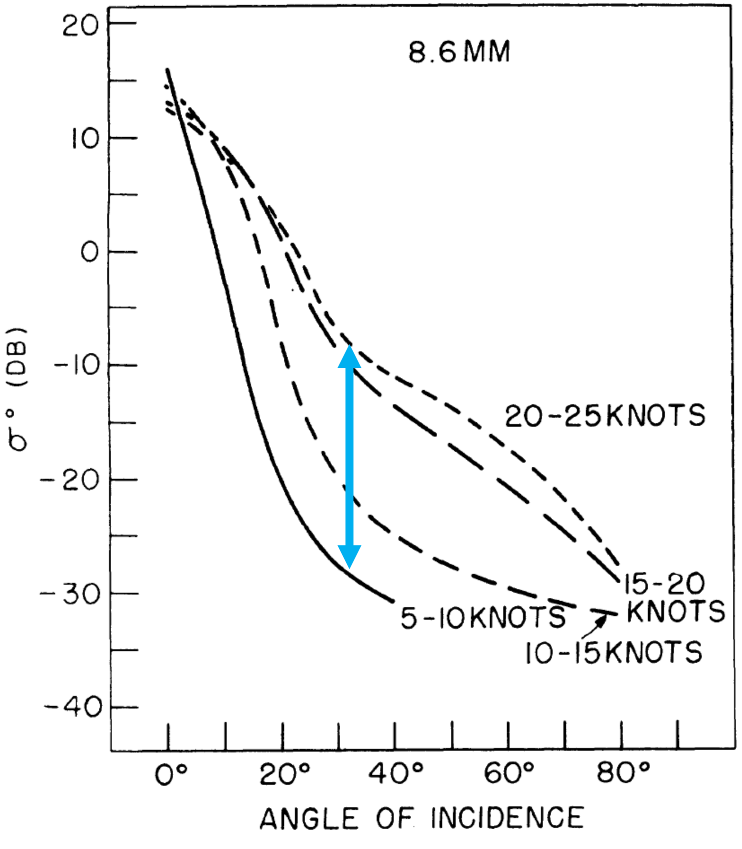
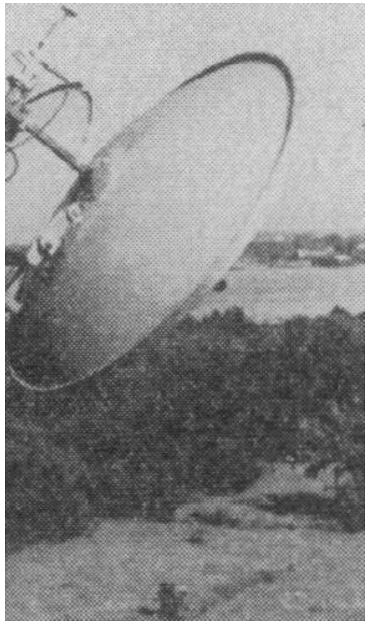


Fig. 4—σ^o as a function of wind velocity, $\lambda = 8.6$ mm.



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Many studies related to Ka-band wind speed and signal scattering come from the scatterometry community and are limited to oceanic studies or theoretical models.

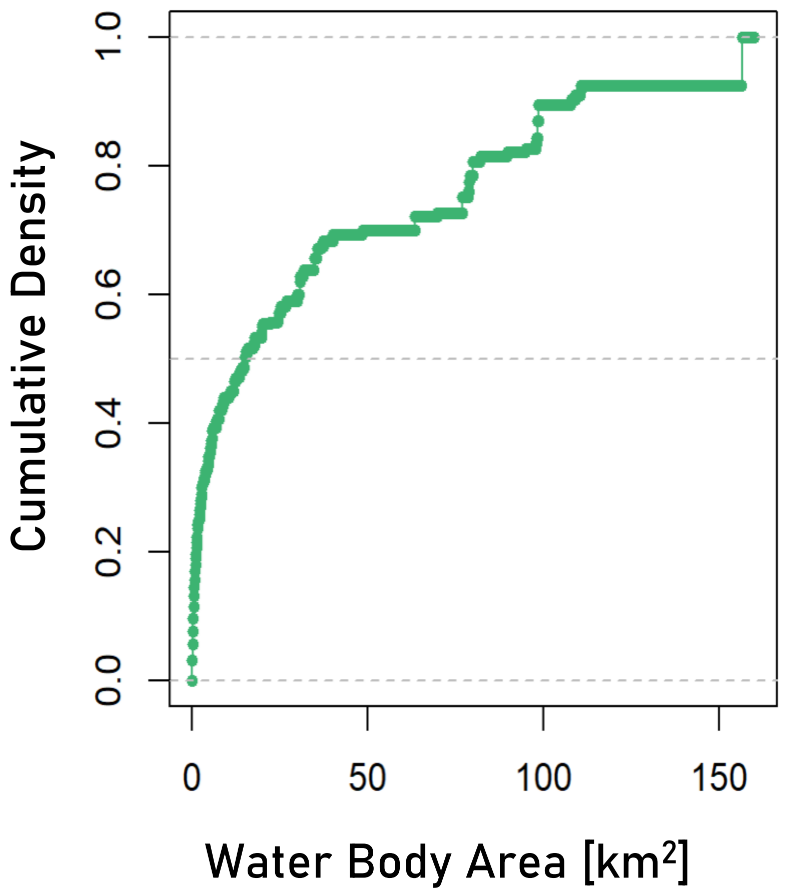
Few have studied behavior over inland water bodies using observations; these studies use coarse resolution data (5-12km resolution points), limiting examinations to large water bodies >25 km^2.

Wind speed has the potential to increase or decrease returned signal magnitudes, reducing the ability to produce coherent images and accurate elevations from InSAR.

Distribution of AirSWOT Observations

50% of water features examined in this study are smaller than 15 km².

20% of water features are smaller than 1 km².



The AirSWOT observations are evenly distributed over all wind speeds. There is no bias in observations from any incidence angle.

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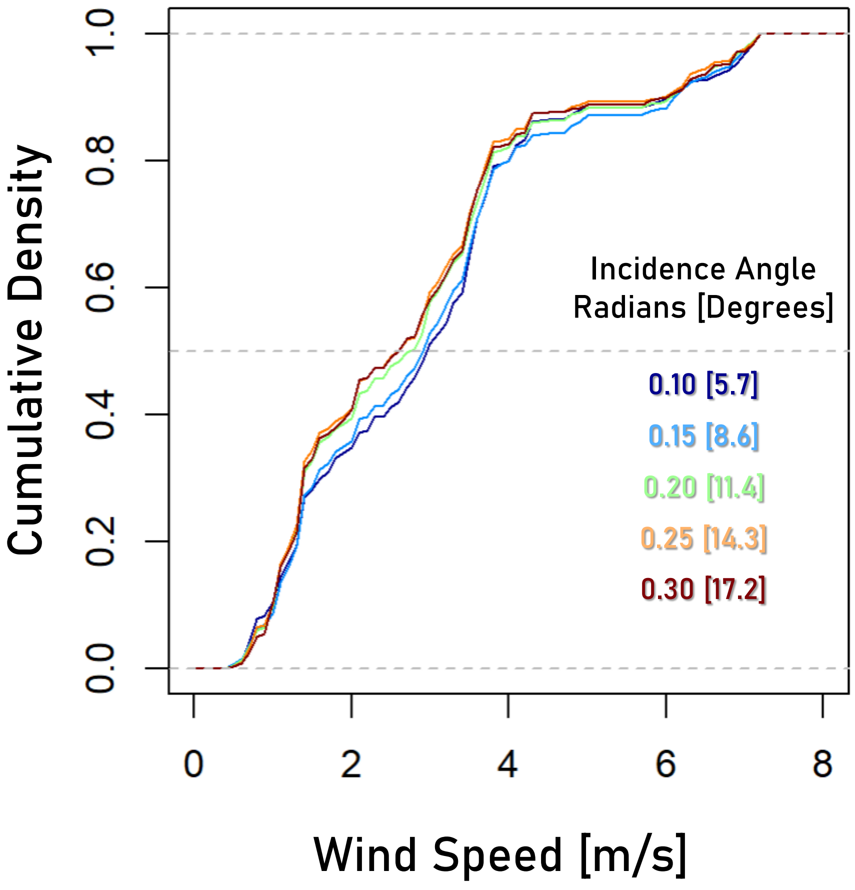


Research Questions

How do wind-driven waves in *small inland* water bodies influence Ka-band scattering?

Whereas previous studies were limited to studying water bodies greater than 25 km^2, 50% of the water bodies examined in this study are smaller than 15 km^2, and 20% of water bodies are smaller than 1 km^2.

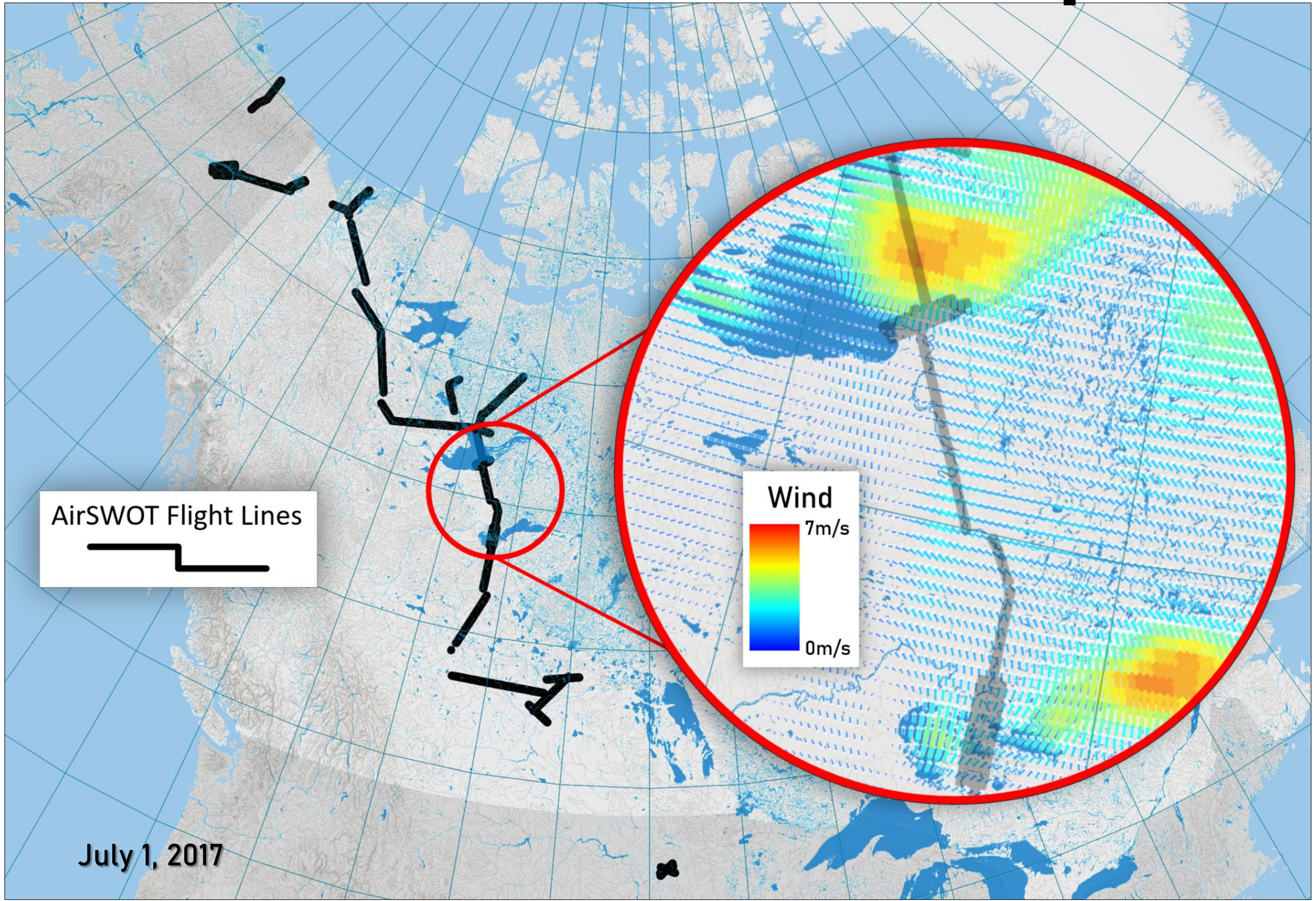
Approach:

Examine the 2D scattering phenomenon of Ka-band data from AirSWOT for over 10,000 inland water bodies across Canada and Alaska.

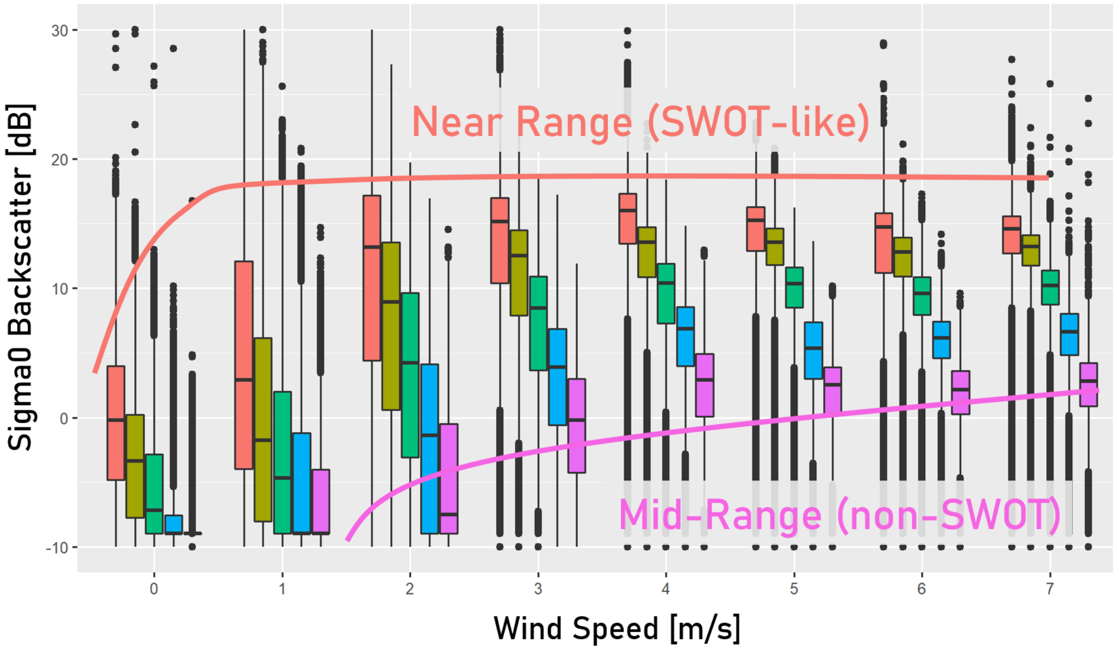
- Produce moderate resolution wind speed data (5 km)
- Compare wind speed with radar backscatter and coherence

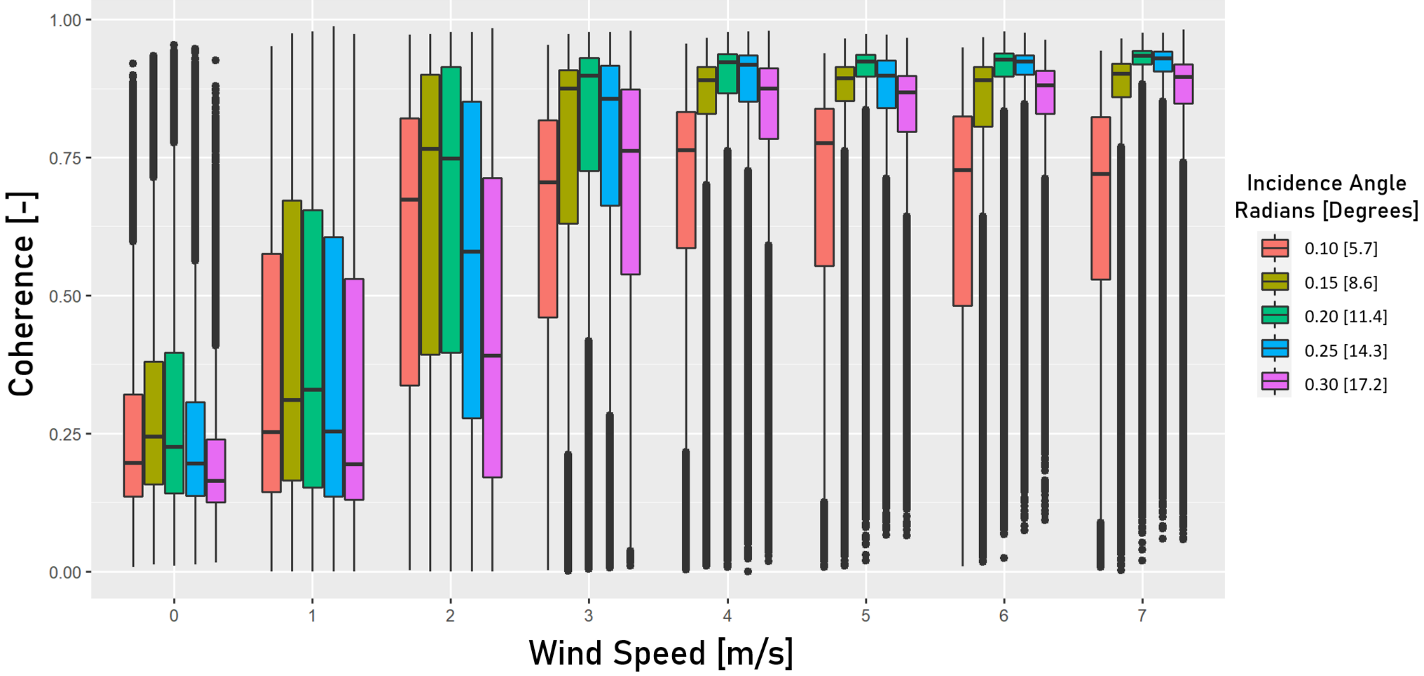
Results: Produce Moderate Resolution Wind Speed

10 km gridded hourly wind speeds are interpolated to a 5 km grid using ECMWF ERA5 and in-situ stations



Results: Backscatter and Coherence Sensitivity to Wind Speed by incidence





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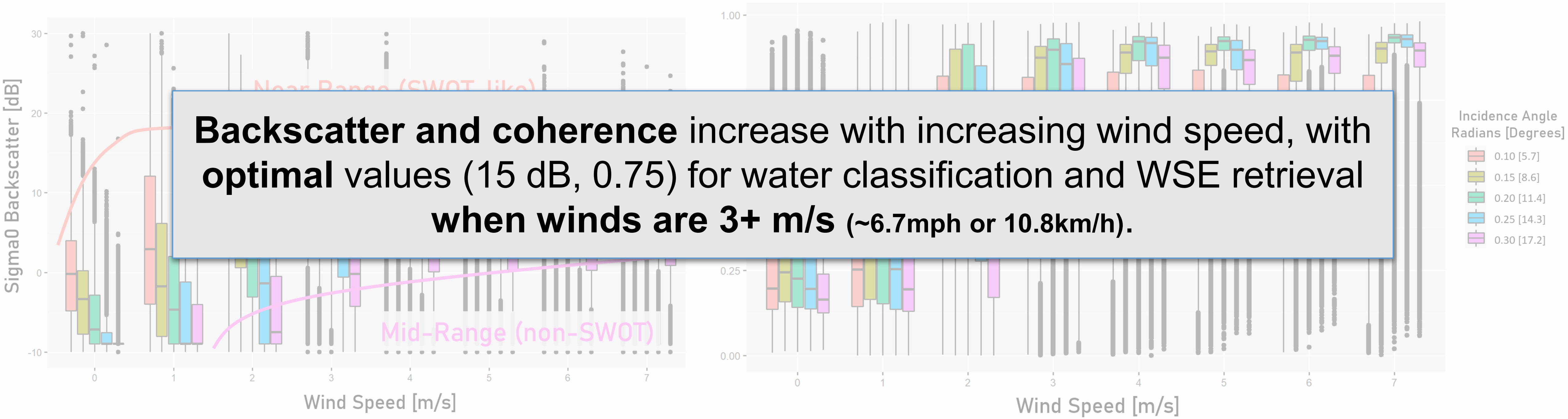
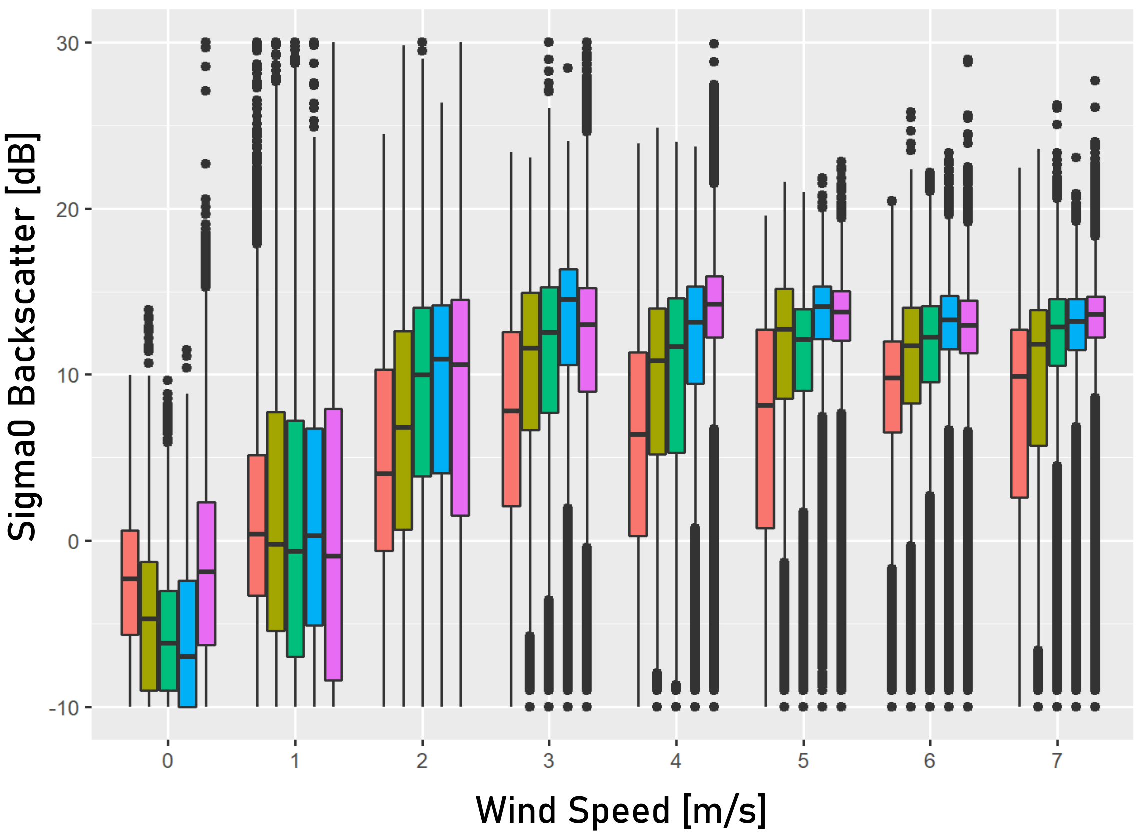
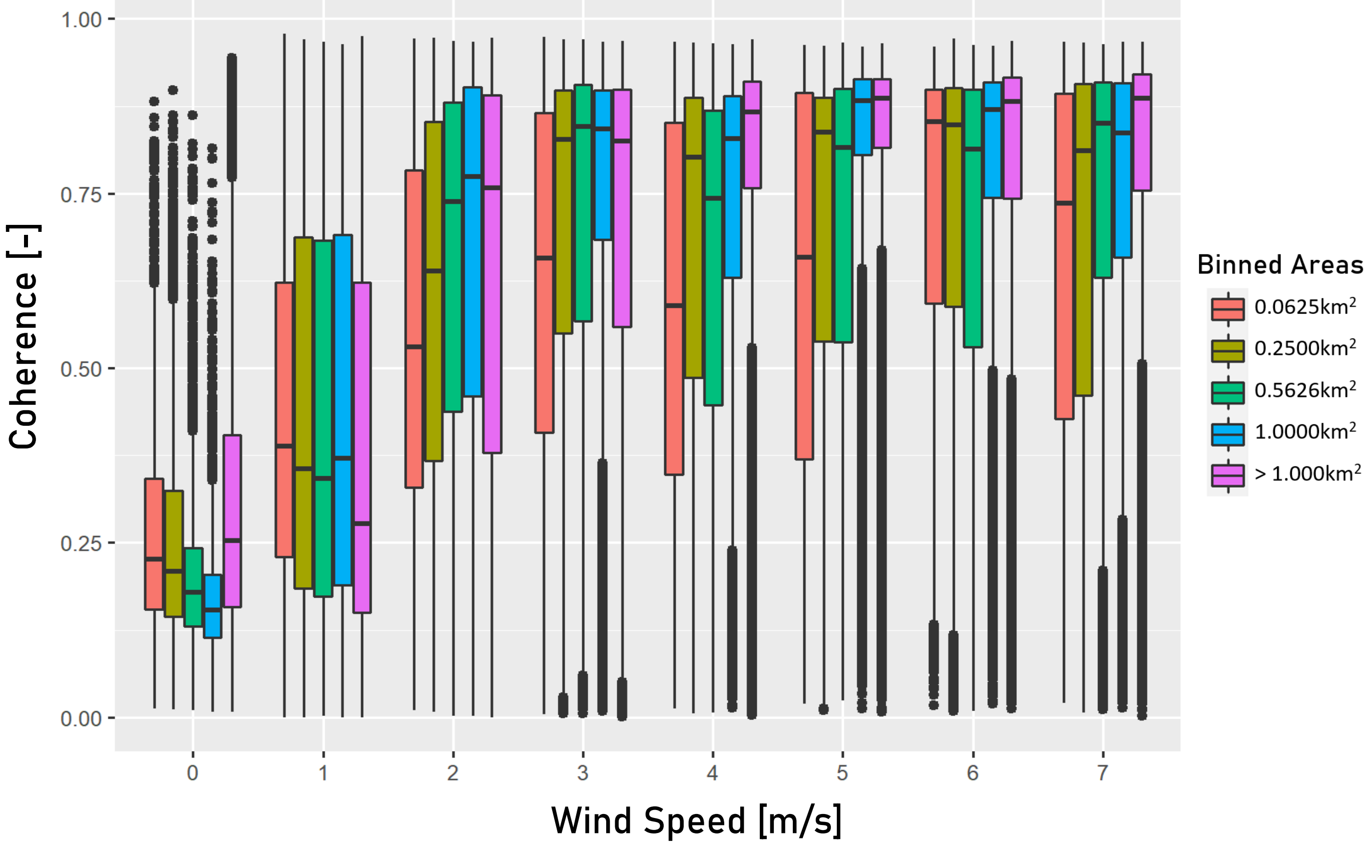


Backscatter and coherence increase with increasing wind speed, with **optimal** values (15 dB, 0.75) for water classification and WSE retrieval **when winds are 3+ m/s (~6.7mph or 10.8km/h).**

Results: Backscatter and Coherence Sensitivity to Wind Speed by area





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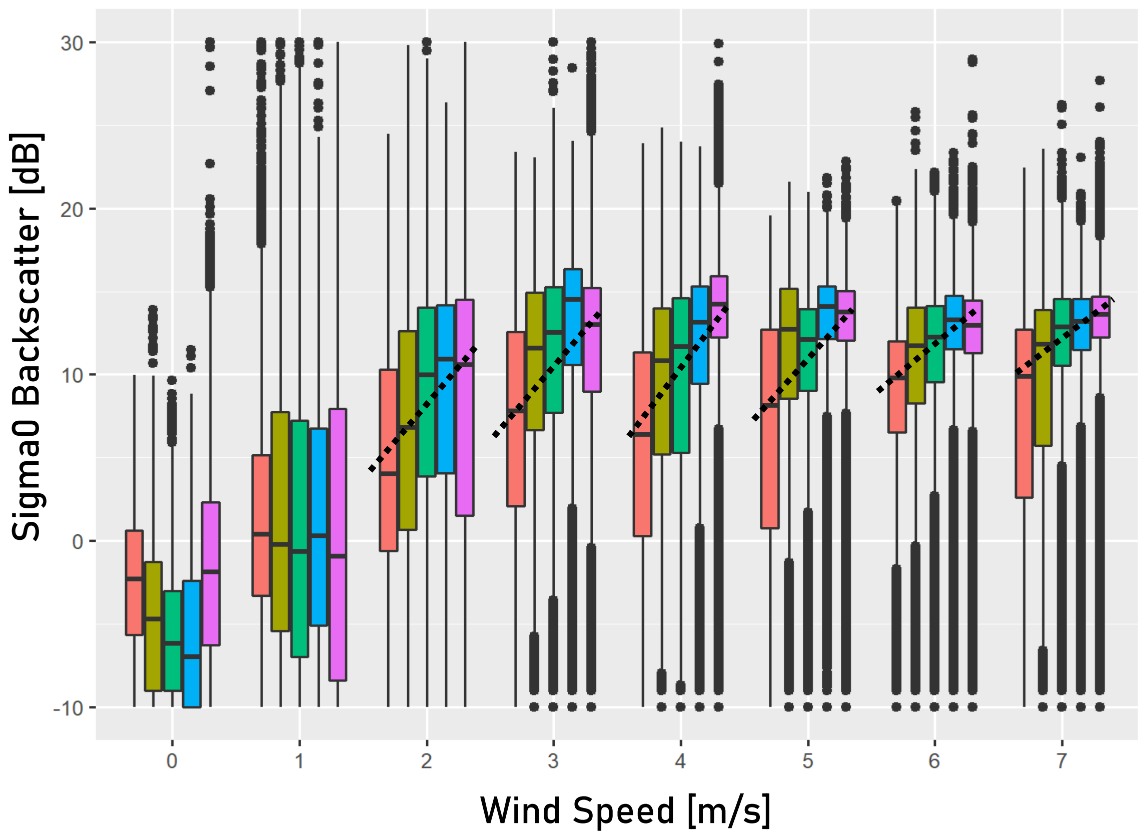

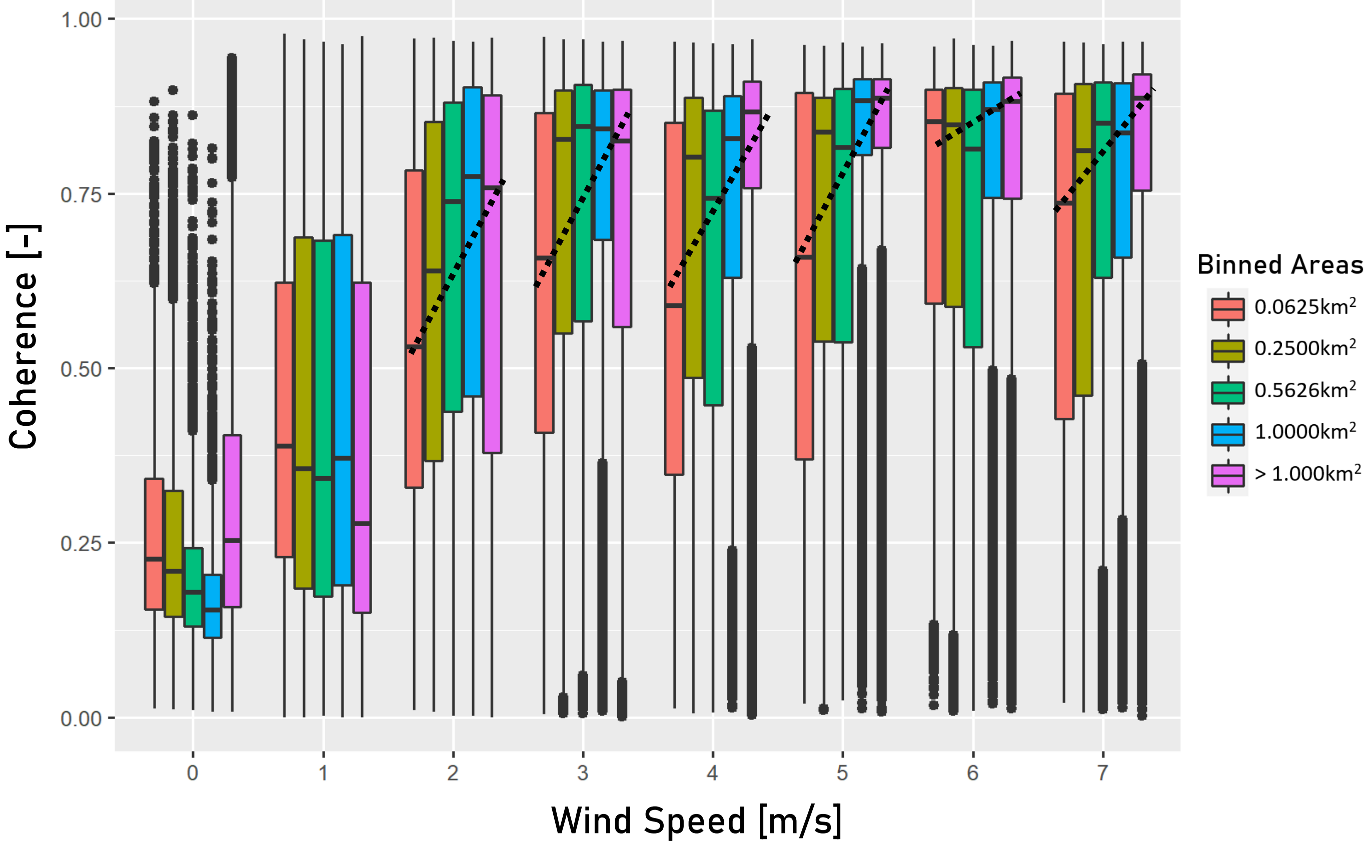

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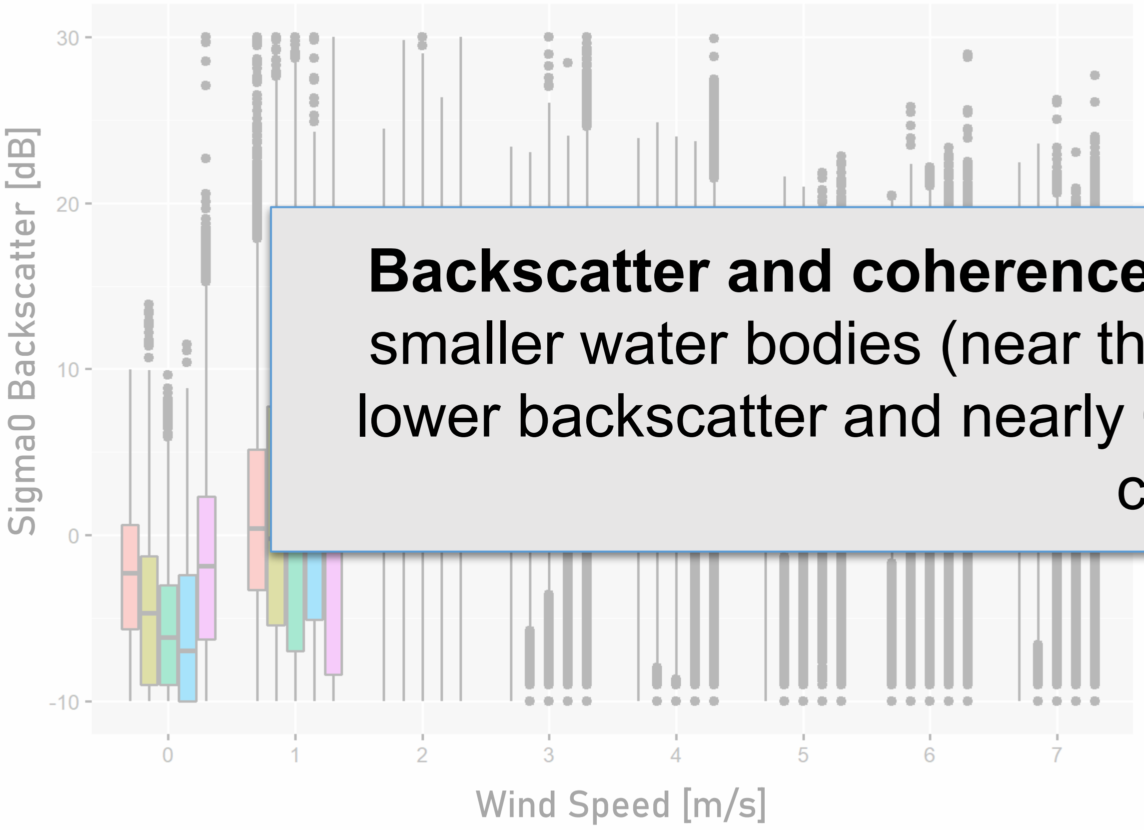
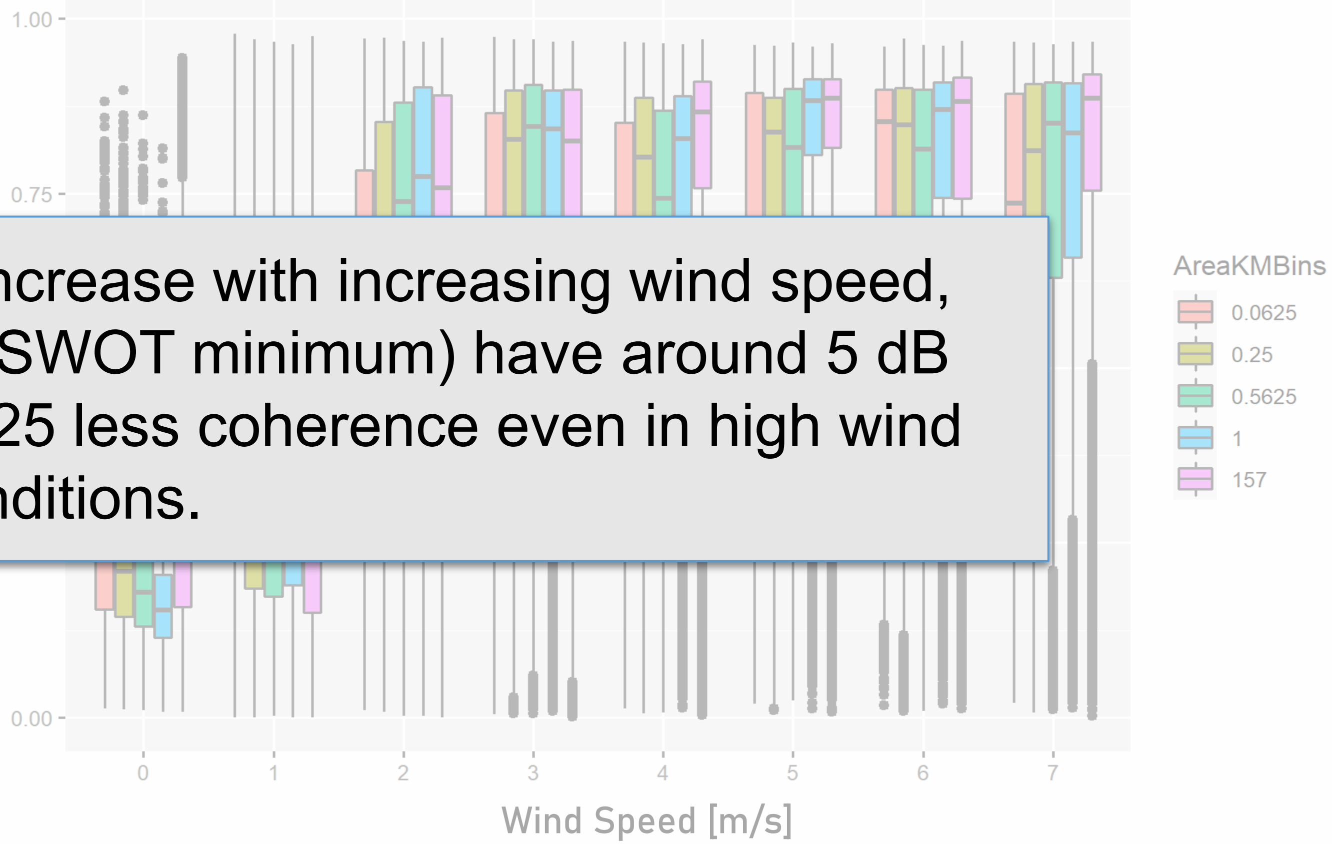


Backscatter and coherence increase with increasing wind speed, smaller water bodies (near the SWOT minimum) have around 5 dB lower backscatter and nearly 0.25 less coherence even in high wind conditions.



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Research Answers

How do wind-driven waves in *small inland* water bodies influence Ka-band scattering?

Wind speeds 3 m/s and greater produce water surface roughness leading to high Ka-band backscattering and high coherence **(higher quality observations!)**.

Small water features (<1 km^2) may have lower scattering (up to 5 dB), and lower coherence (up to 0.25), even under high wind conditions **(lower quality observations!)**.

Implications

- Low wind conditions and small water bodies should expect to produce lower backscatter and coherence values, leading to reduced measurement accuracy
- Average global wind speeds are around 3 m/s (and increasing); ***on average***, wind speeds should be high enough to produce accurate measurements
- Future analyses examining inland water wind for small lakes can support local-scale hydro-climatological assessments for wind and evaporation modeling

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