

→ NORTH-AMERICAN CRYOSAT SCIENCE MEETING AND GEODETIC MISSIONS WORKSHOP

ESA's ice Mission Explorer. Seven years in flights
dedicated to monitoring Earth's ice fields and beyond

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An assessment of sea ice retrievals from Fully-Focussed SAR altimetry

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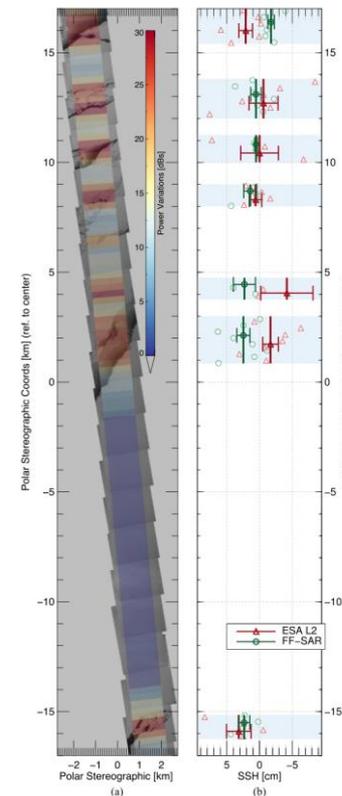
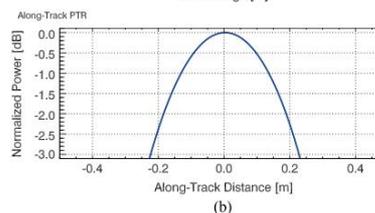
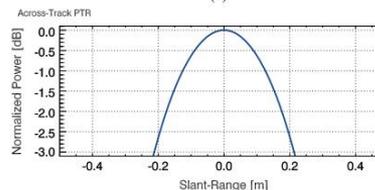
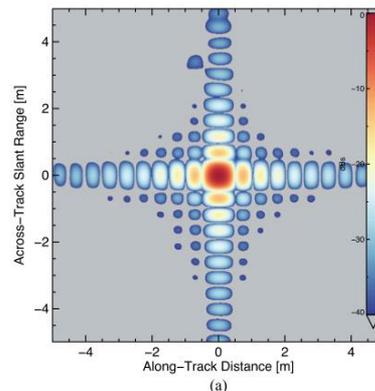
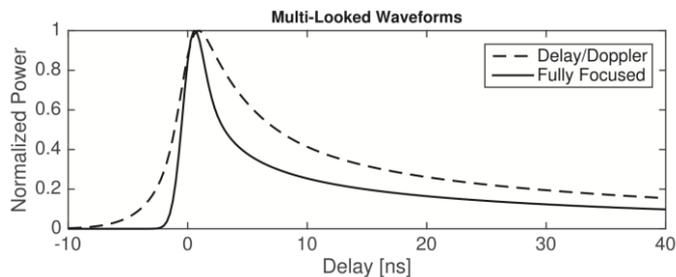


Talk structure

1. Brief recap of Alejandro and Walter's work
2. Why is FFSAR data particularly interesting for sea ice retrievals?
3. Data: 26th March 2014
4. Freeboard processing methodology
5. Along-track freeboard processing results
6. Some statistics
7. Conclusions

1. Recap

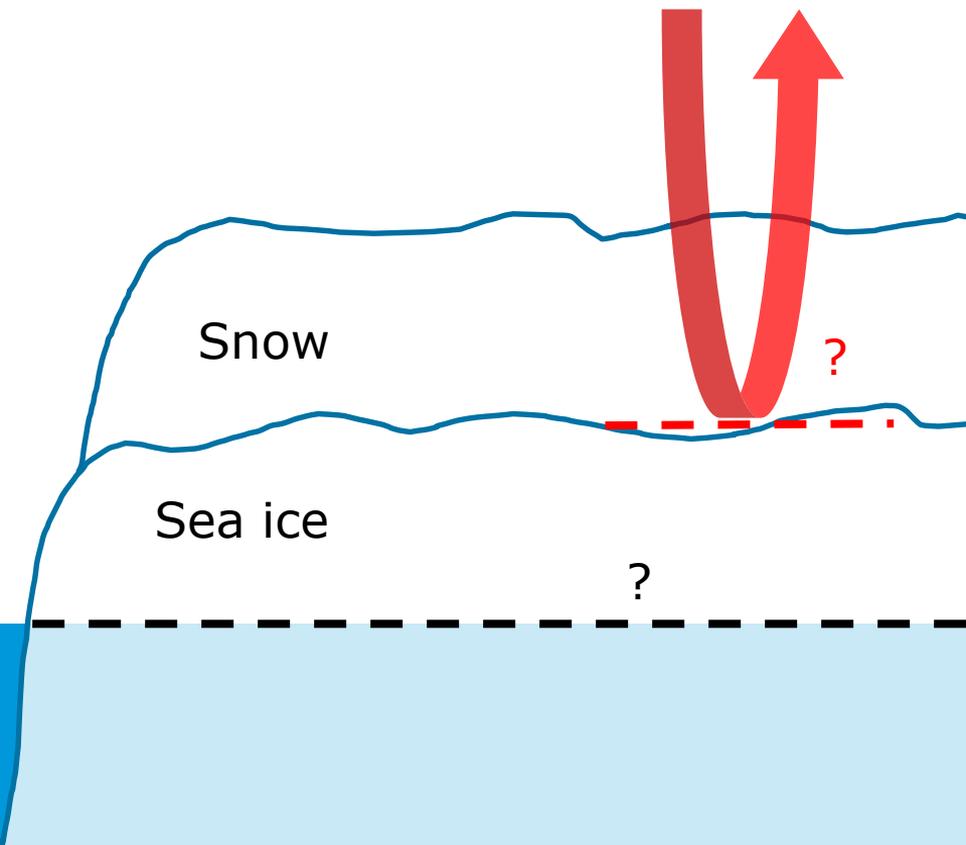
- FFSAR processing accounts for the phase evolution of scatterers, to perform an inter-burst coherent integration potentially during the entire illumination time of a scatterer on the surface
- Can achieve along track resolution of $\sim 50\text{cm}$
- Waveforms will tend to be sharper for flat surfaces



Figures: Egido & Smith (2017), "Fully Focused SAR Altimetry: Theory and Applications", *IEEE TGRS*, 55

2. Why is FFSAR interesting for sea ice retrievals?

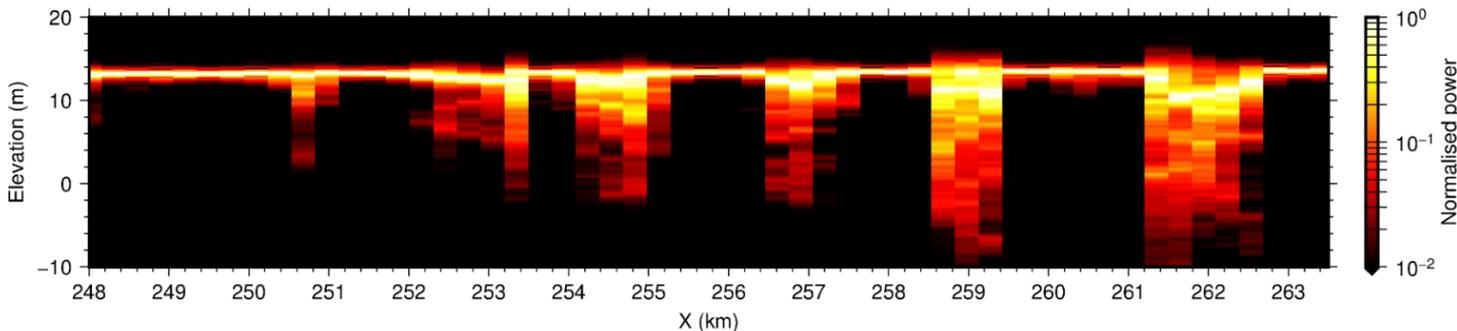
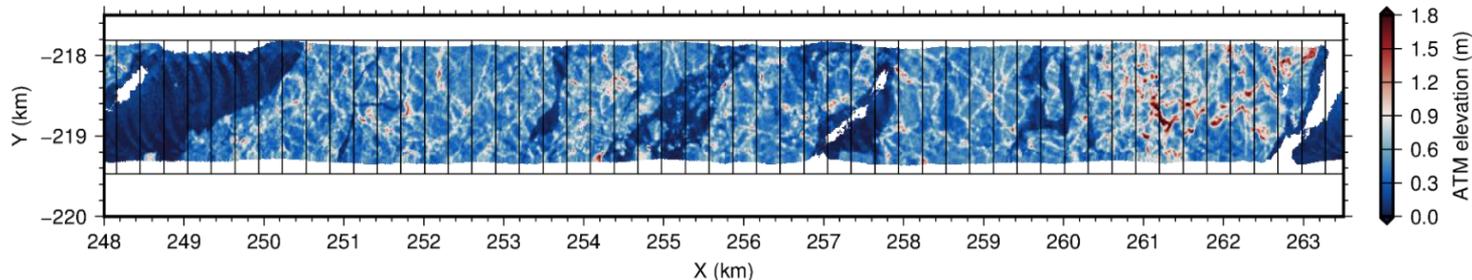
- Radar altimeter sea ice thickness uncertainty [Giles et al. (2007)]:
 - ~50% snow loading
 - ~40% freeboard measurement error
- Freeboard measurement error contributions:
 - Sea level interpolation
 - Sea level sampling
 - Noise
 - Penetration
- FFSAR data has potential to reduce freeboard and sea level uncertainty over sea ice



2. Why is FFSAR interesting for sea ice retrievals?

ESA Level-1b

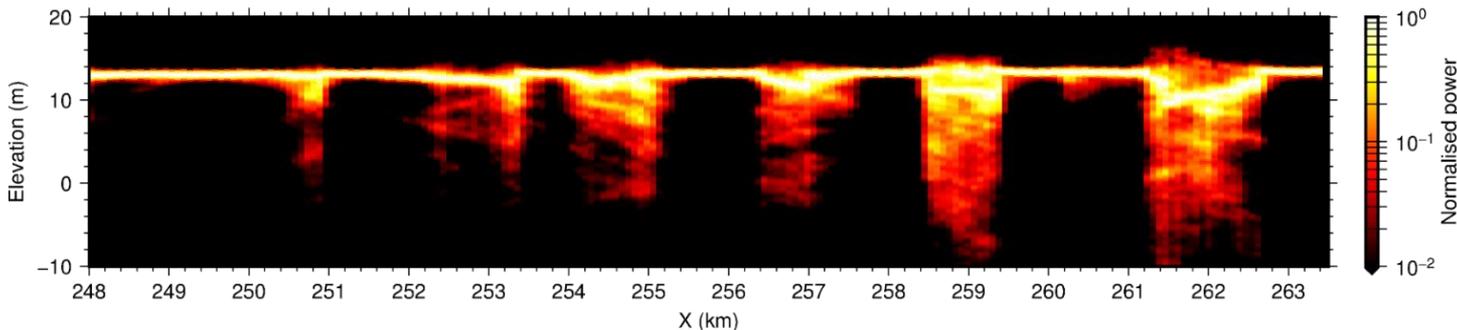
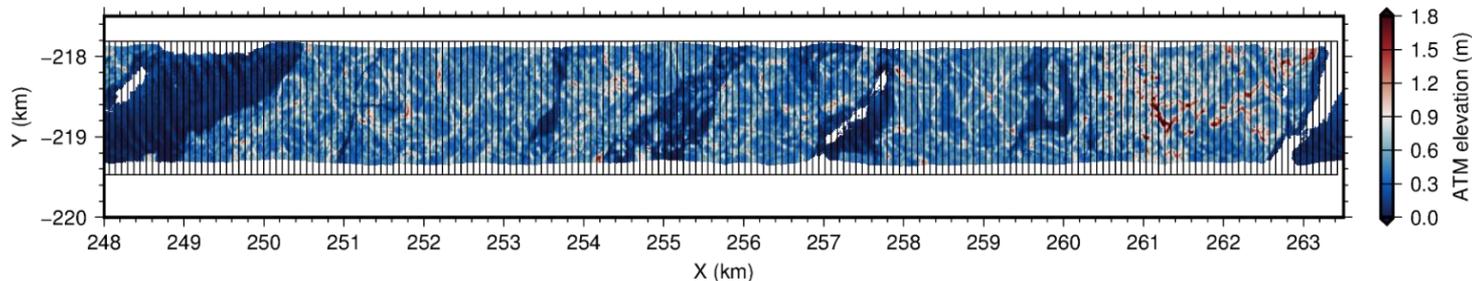
~300m
along track
sampling



2. Why is FFSAR interesting for sea ice retrievals?

FFSAR

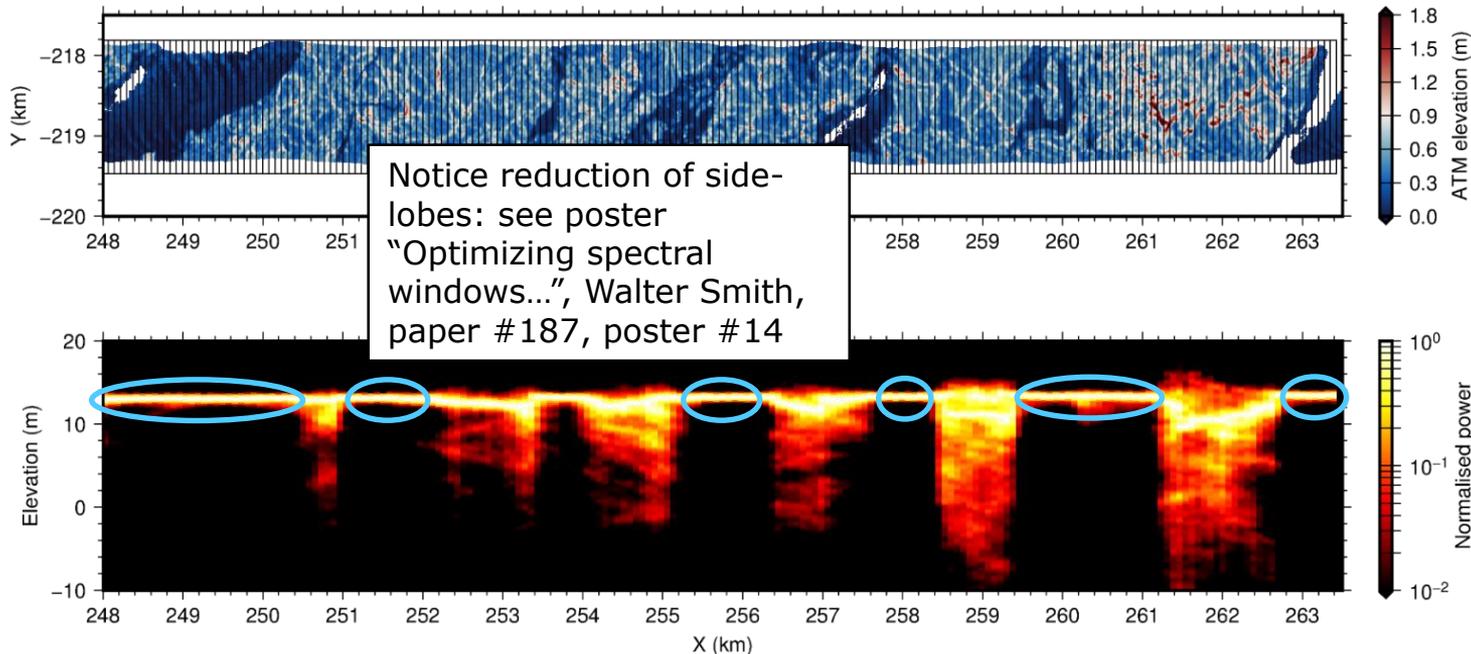
~80m
along track
sampling



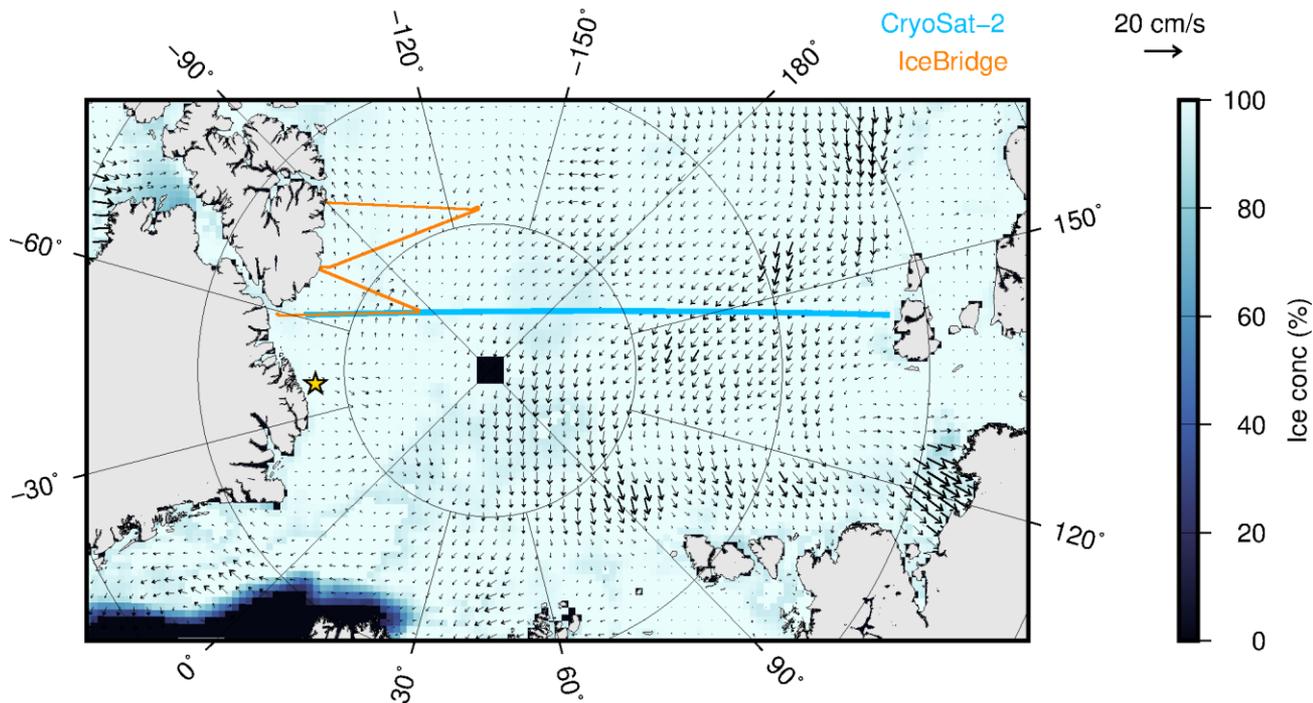
2. Why is FFSAR interesting for sea ice retrievals?

FFSAR

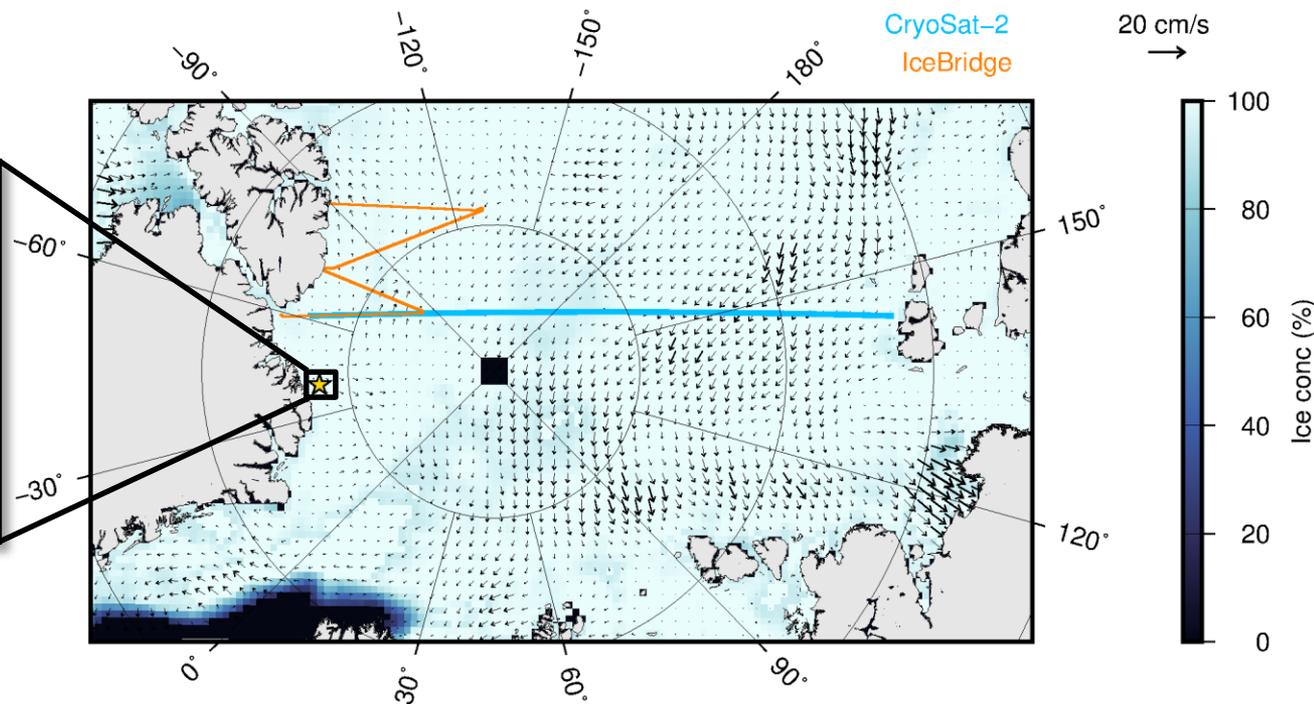
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along track
sampling



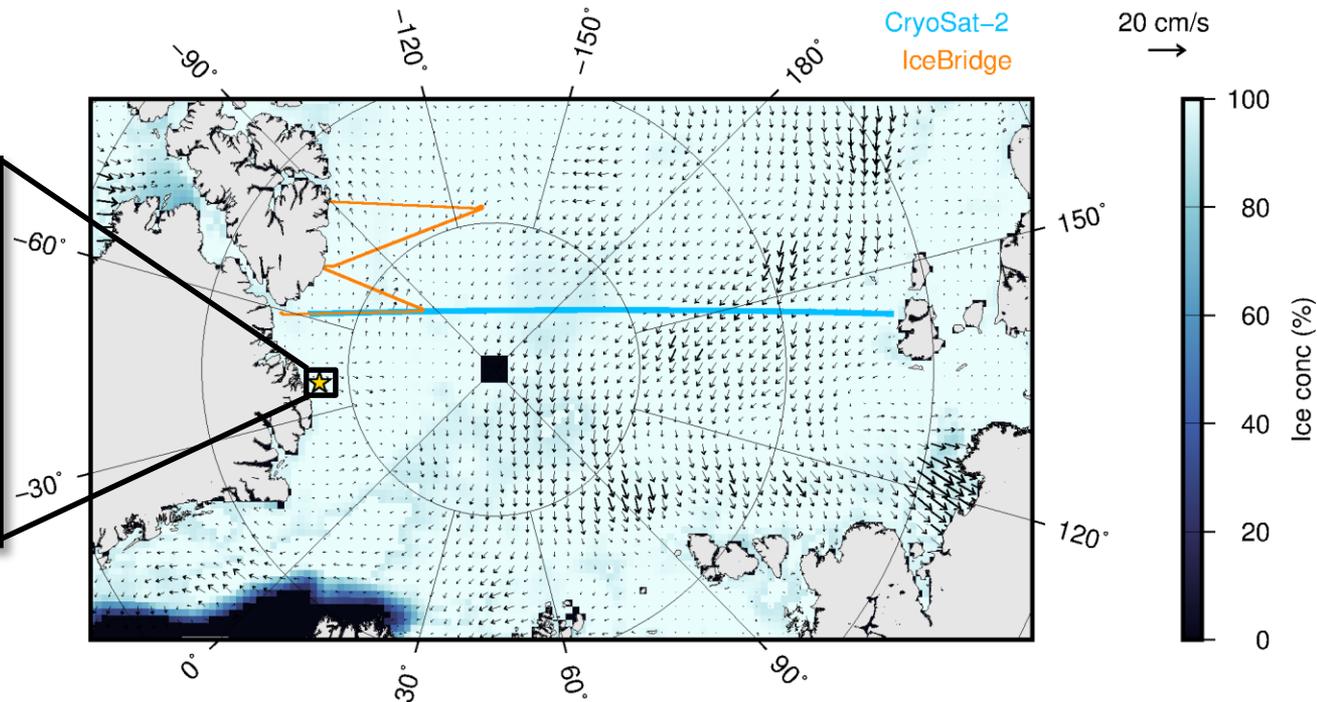
3. Data: 26th March 2014



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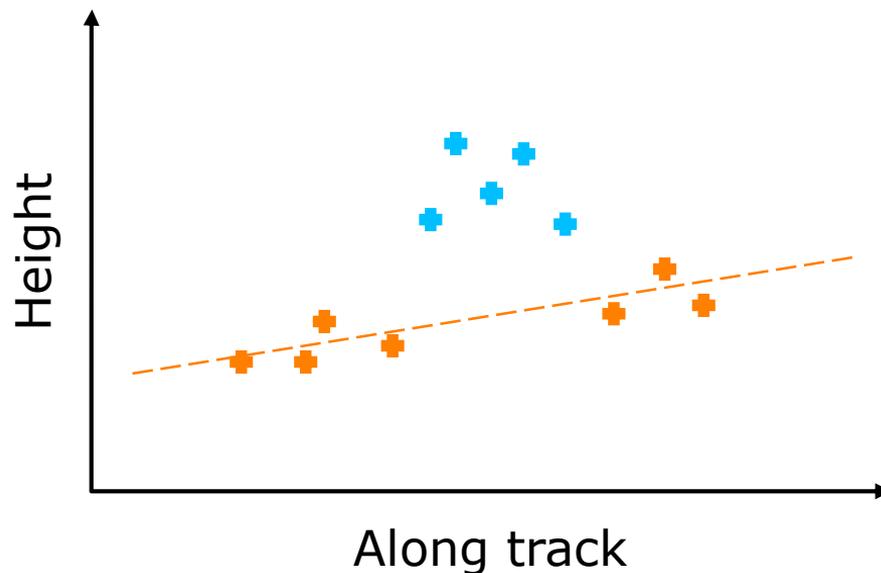


3. Data: 26th March 2014



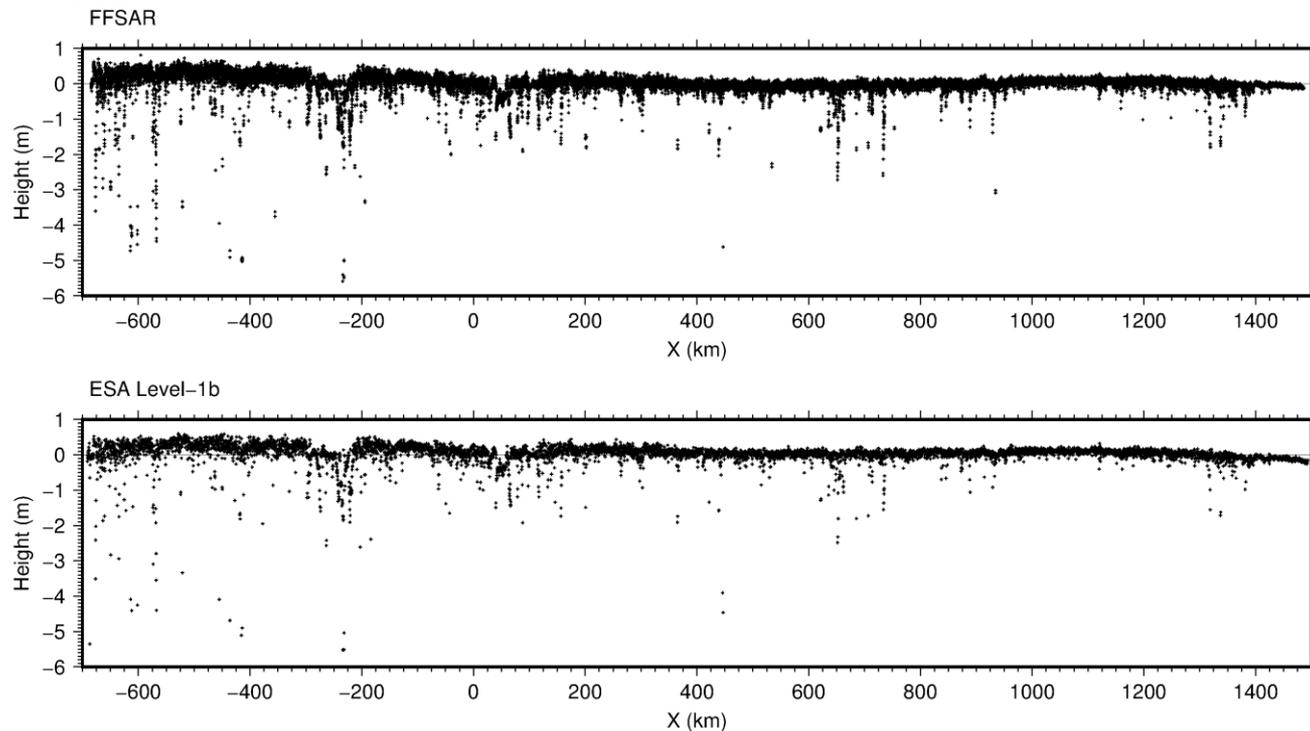
4. Methodology

- Apply **the exact same** (fairly simple) along track sea ice processing to ESA Level-1b and FFSAR data:
 - Identify specular/diffuse waveforms based on PP & leading edge width
 - Apply simple threshold retracker
 - Remove reference surface
 - Sea level interpolation based on specular waveforms
 - Freeboard = diffuse waveform elevation above interpolated sea level
- Can quantify differences/improvements from FFSAR



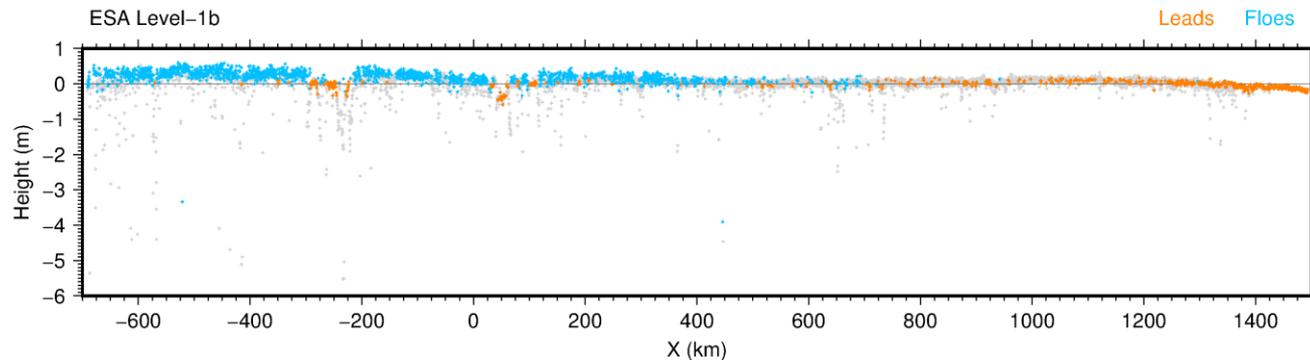
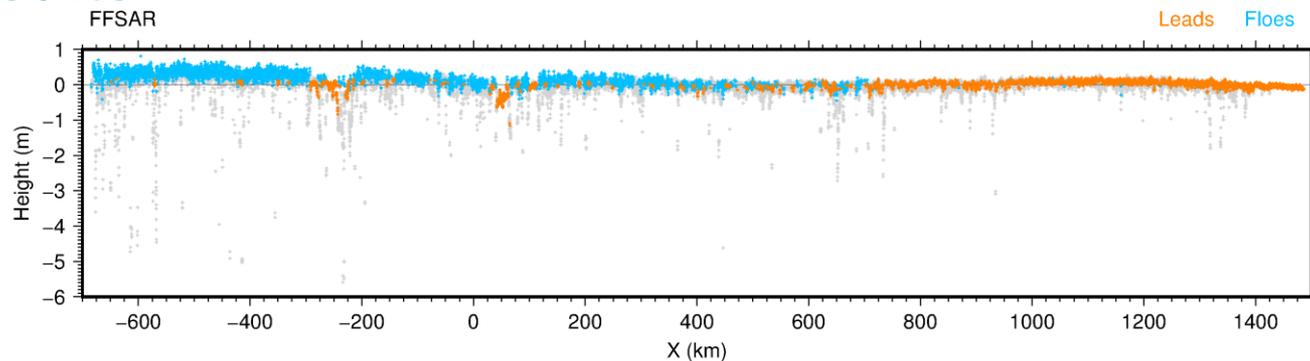
5. Along track results

1. All elevation w.r.t geoid



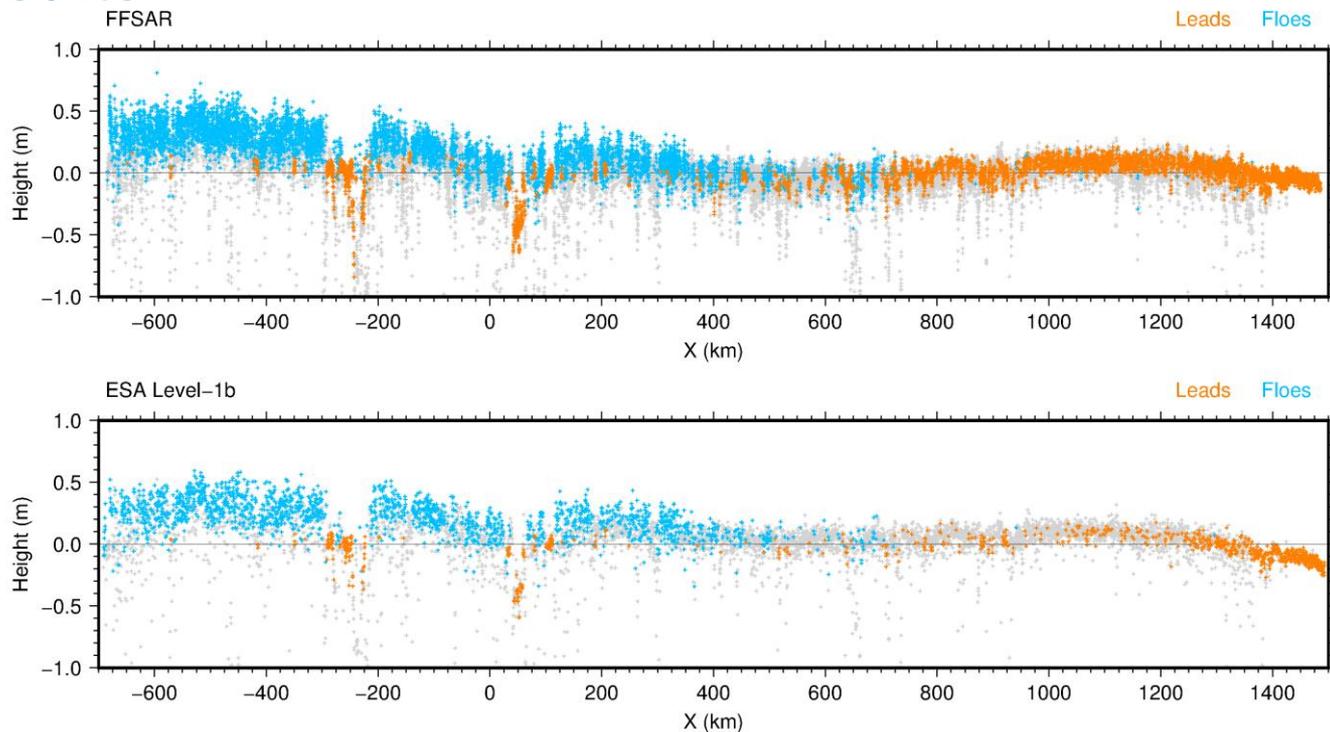
5. Along track results

1. All elevation w.r.t geoid
2. Waveform discrimination
 - Orange: lead
 - Blue: floe



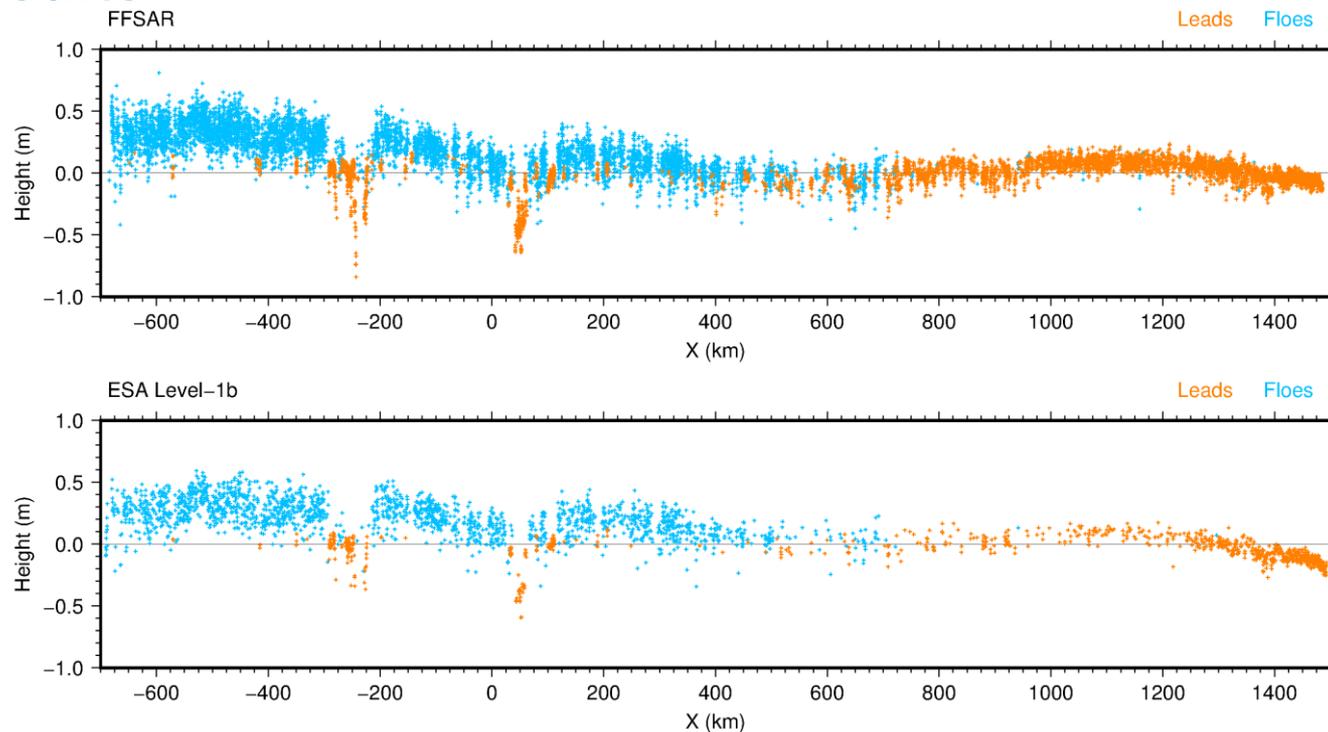
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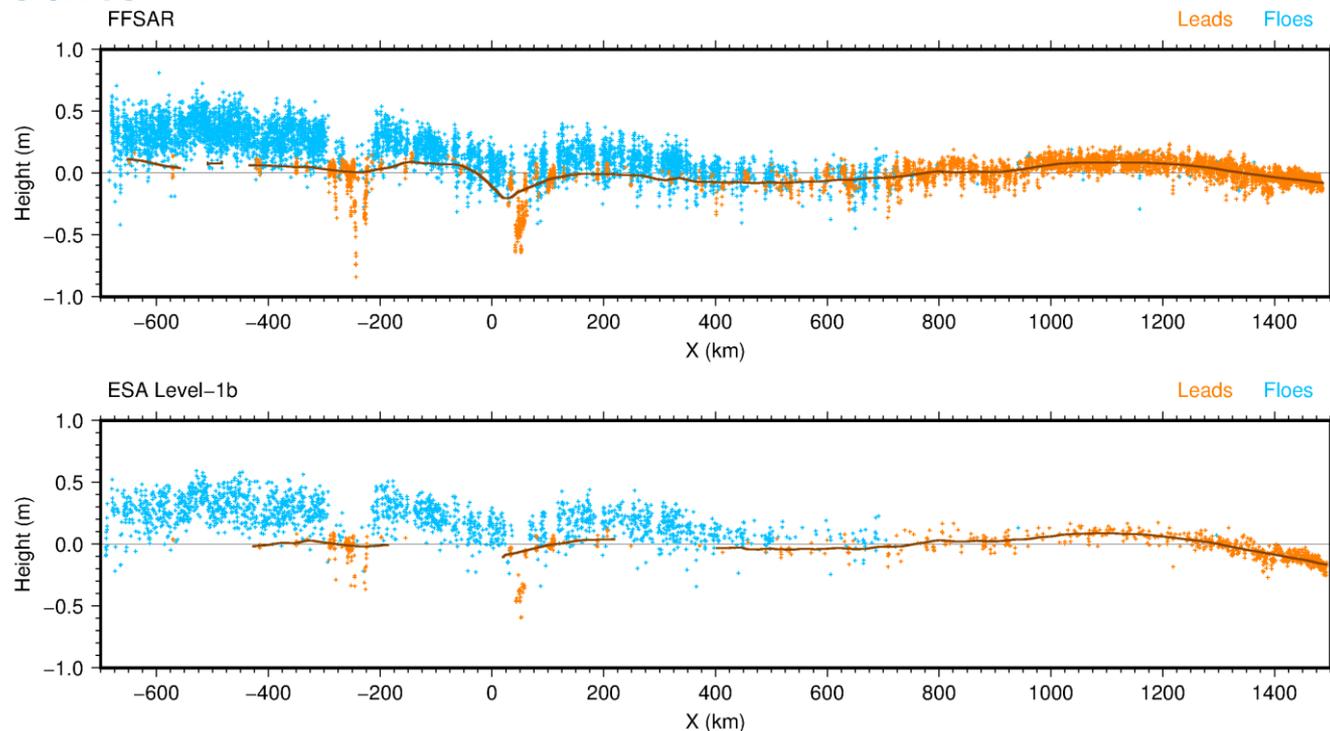
5. Along track results

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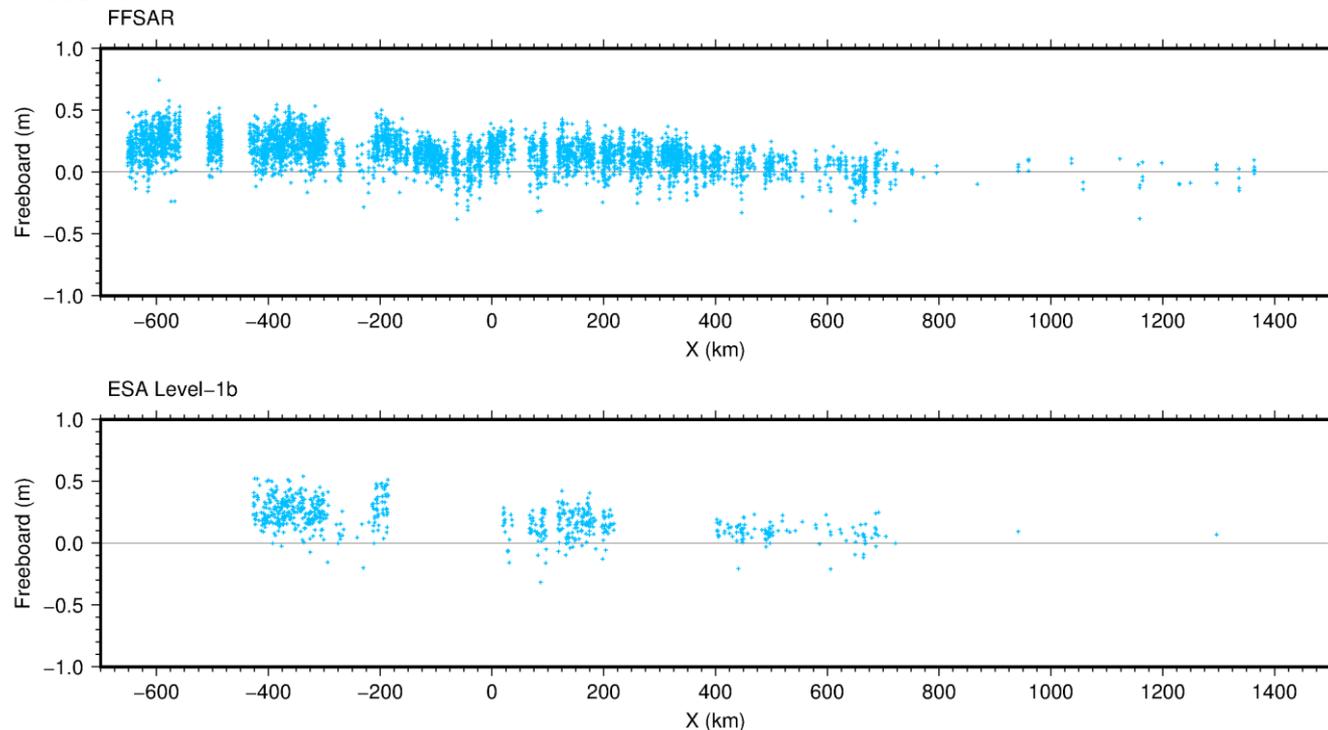
5. Along track results

1. All elevation w.r.t geoid
2. Waveform discrimination
 - Orange: lead
 - Blue: floe
3. Sea level interpolation
 - Iterative Linear interpolation of leads in 150km window
 - 25km boxcar smoothing



5. Along track results

1. All elevation w.r.t geoid
2. Waveform discrimination
 - Orange: lead
 - Blue: floe
3. Sea level interpolation
 - Iterative Linear interpolation of leads in 150km window
 - 25km boxcar smoothing
4. Extract freeboard

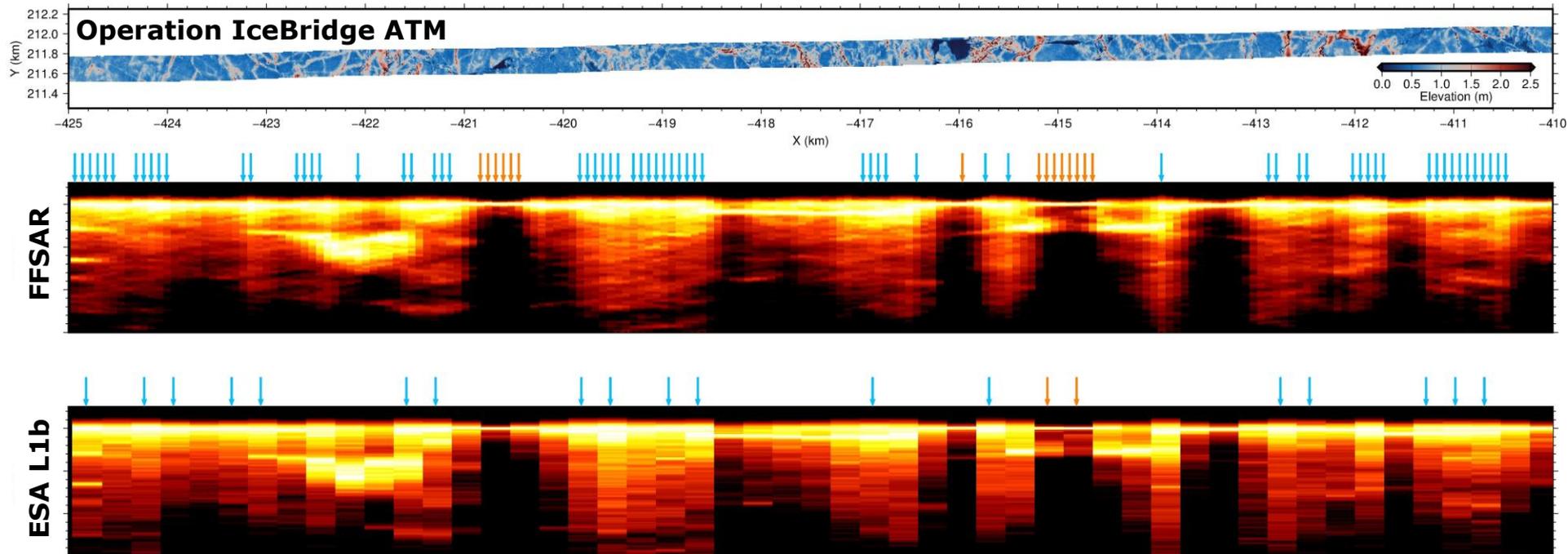


5. Along track results

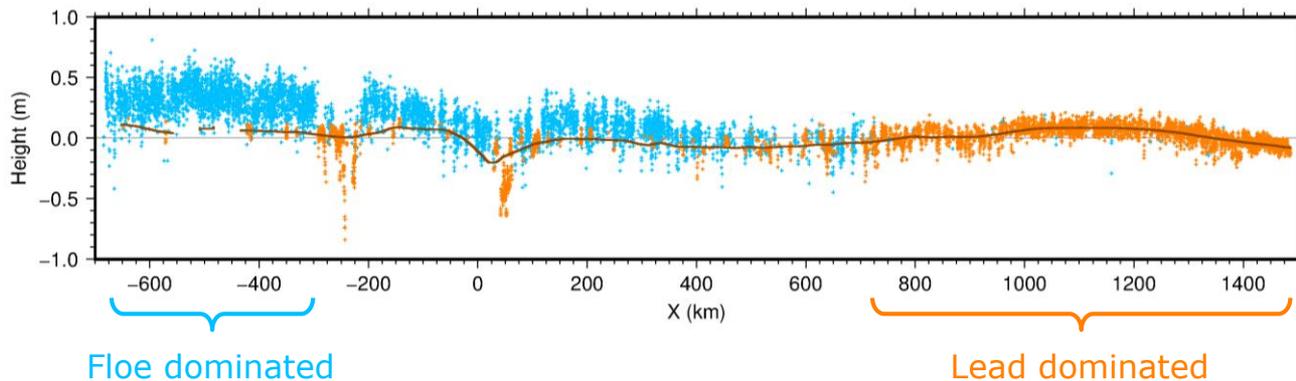
1. Get 6.4x more lead elevation estimates*
 - ~4x increase from 80m along track resolution (4 estimates per ESA L1b detected lead)
 - FFSAR also detecting *more individual leads*
2. Get 3.2x more floe elevation estimates*
 - Increase from 80m along track sampling
3. Get 7.2x more freeboard estimates*
 - Better along track coverage due to more leads

**For this individual pass*

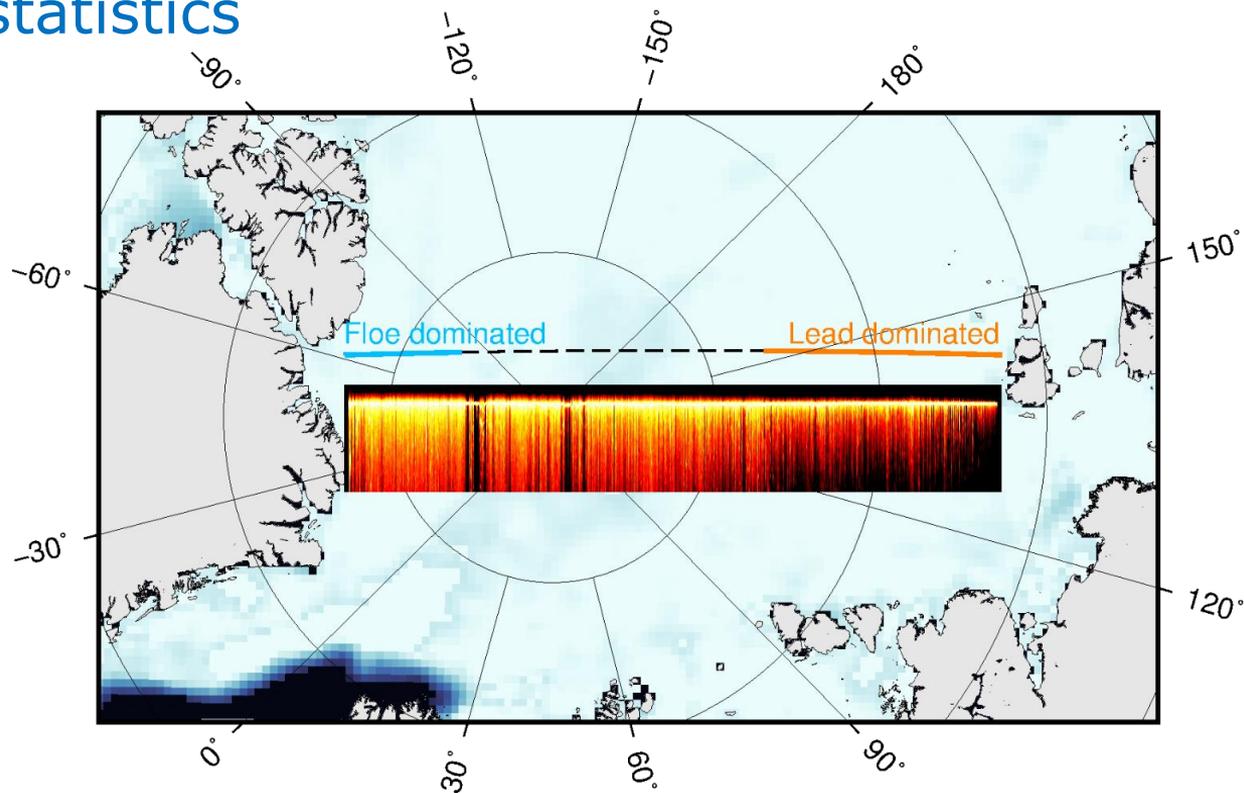
5. Along track results



6. Some statistics

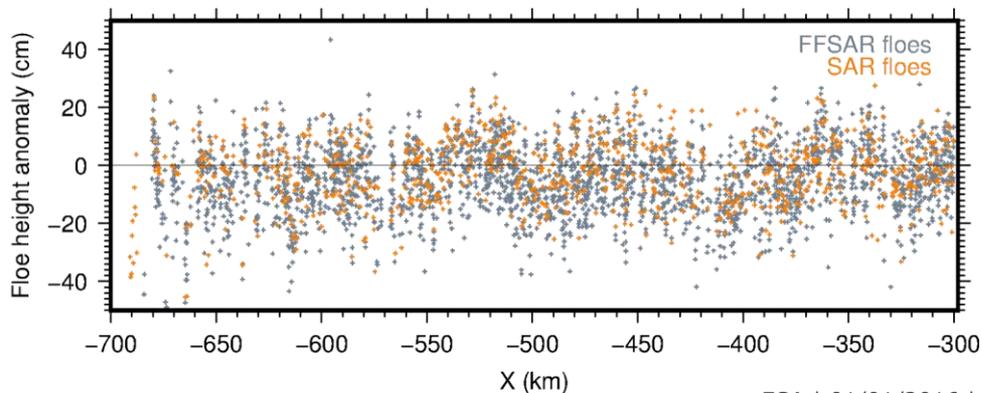
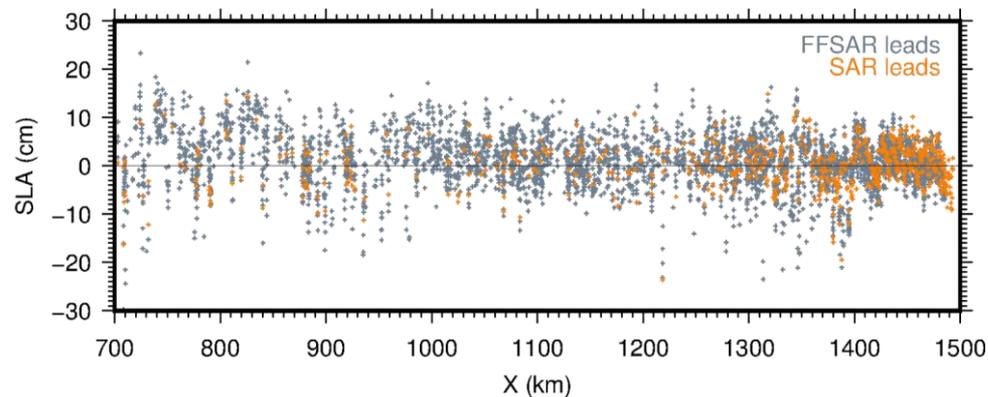


6. Some statistics

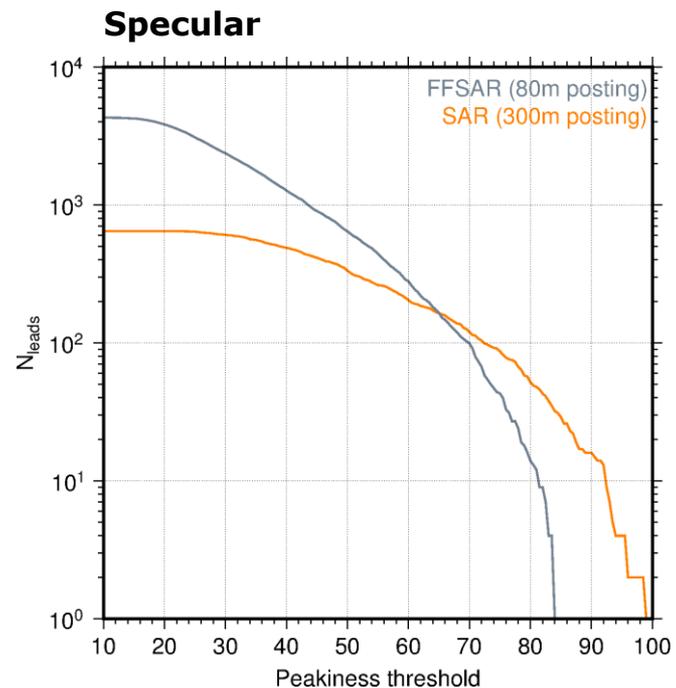
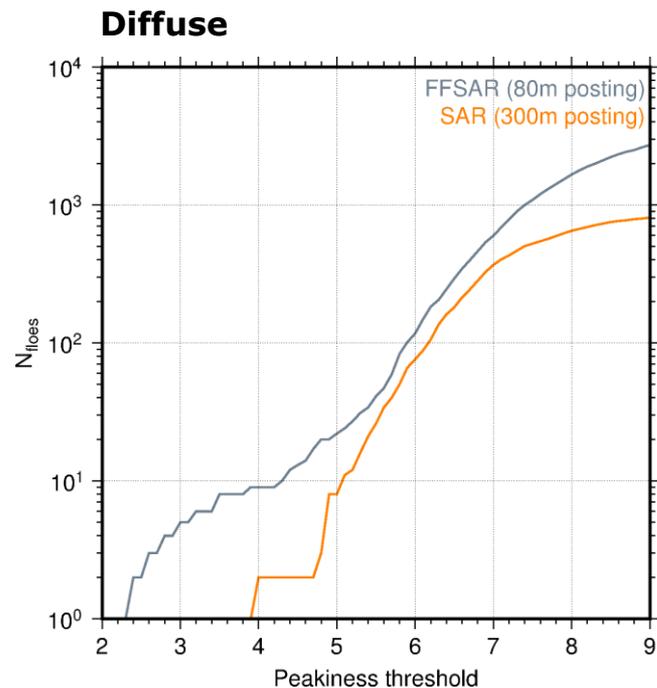


6. Some statistics

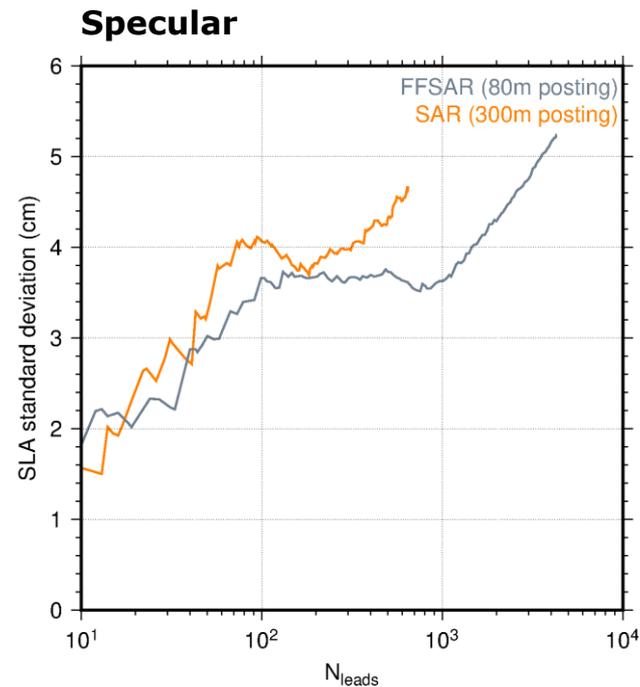
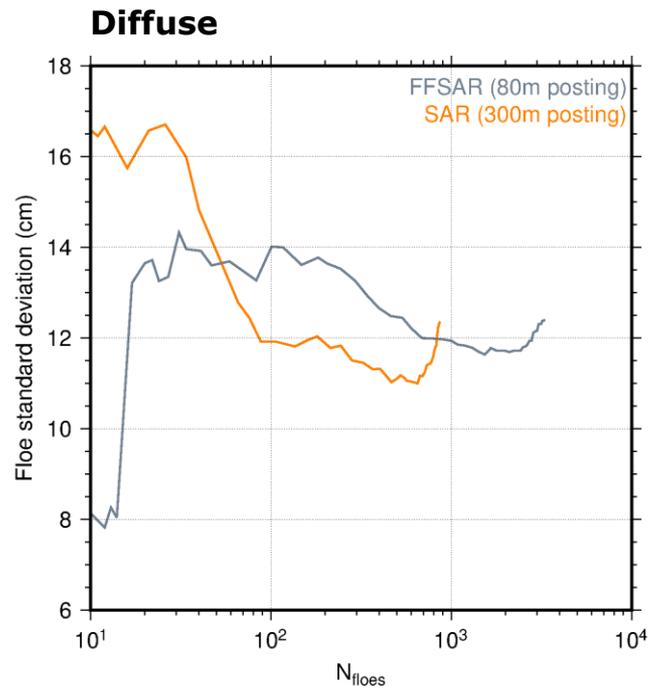
- Remove along track height variations
- Look at:
 - Number of waveforms vs. filtering
 - Height standard deviation vs. number of waveforms
 - Height standard error vs. number of waveforms
- Along track statistics



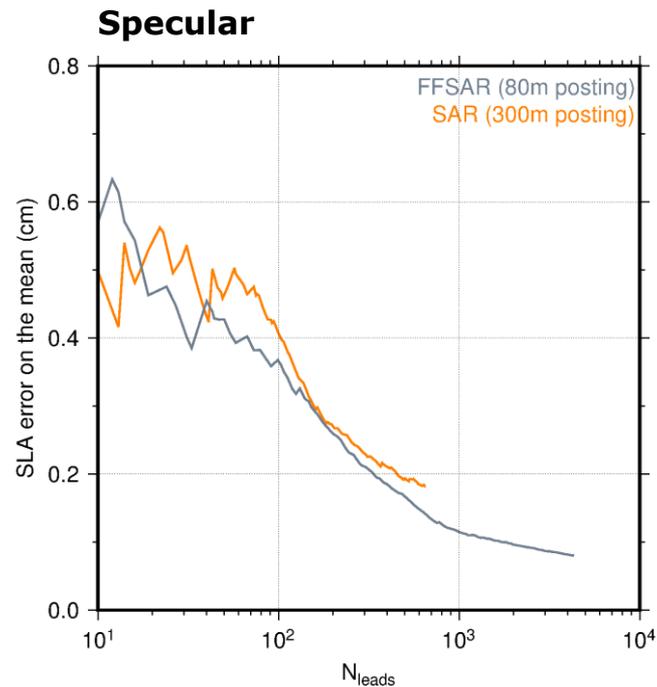
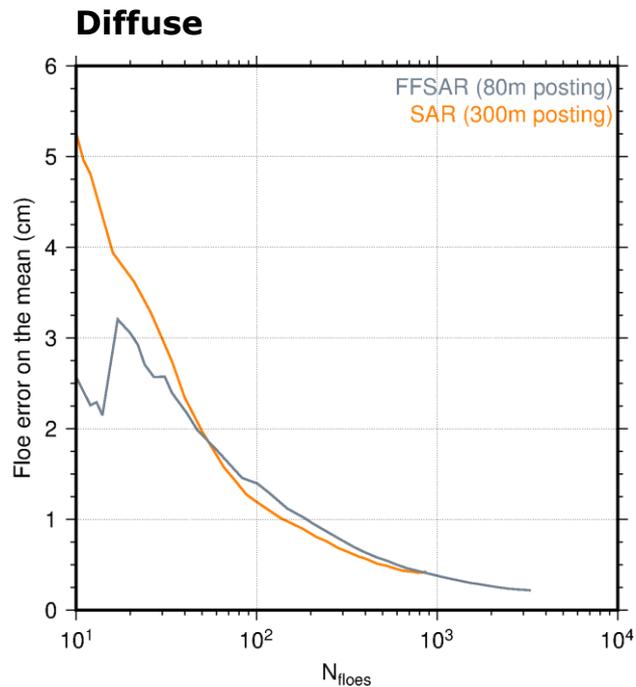
6. Some statistics: Number of waveforms



6. Some statistics: Height standard deviation



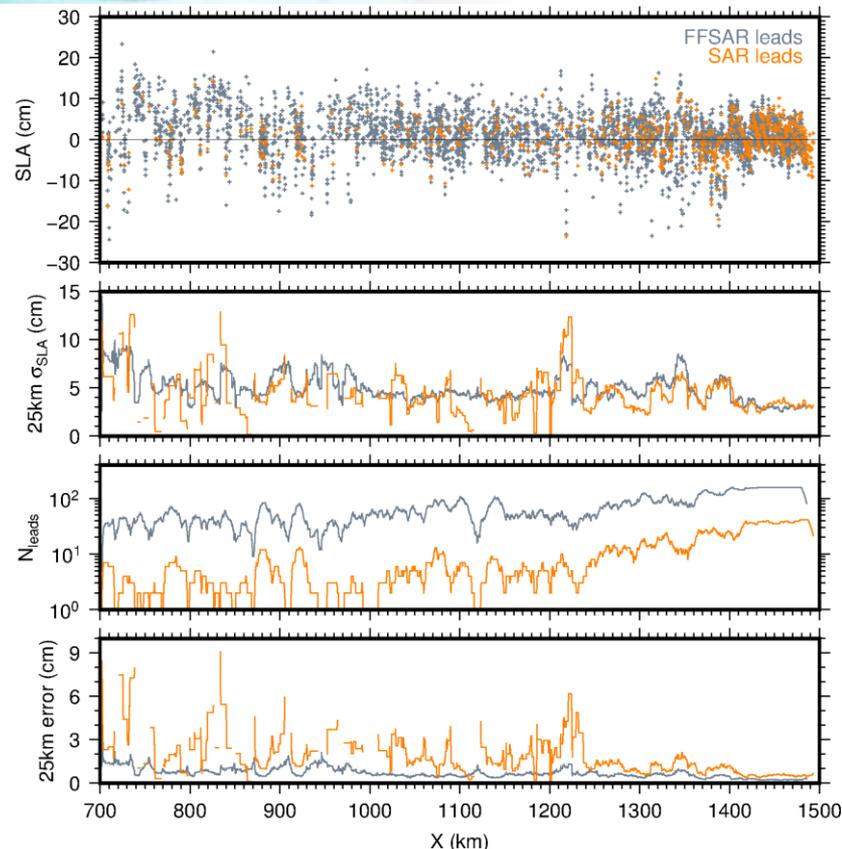
6. Some statistics: Height standard error



6. Some statistics: Along track statistics

Leads

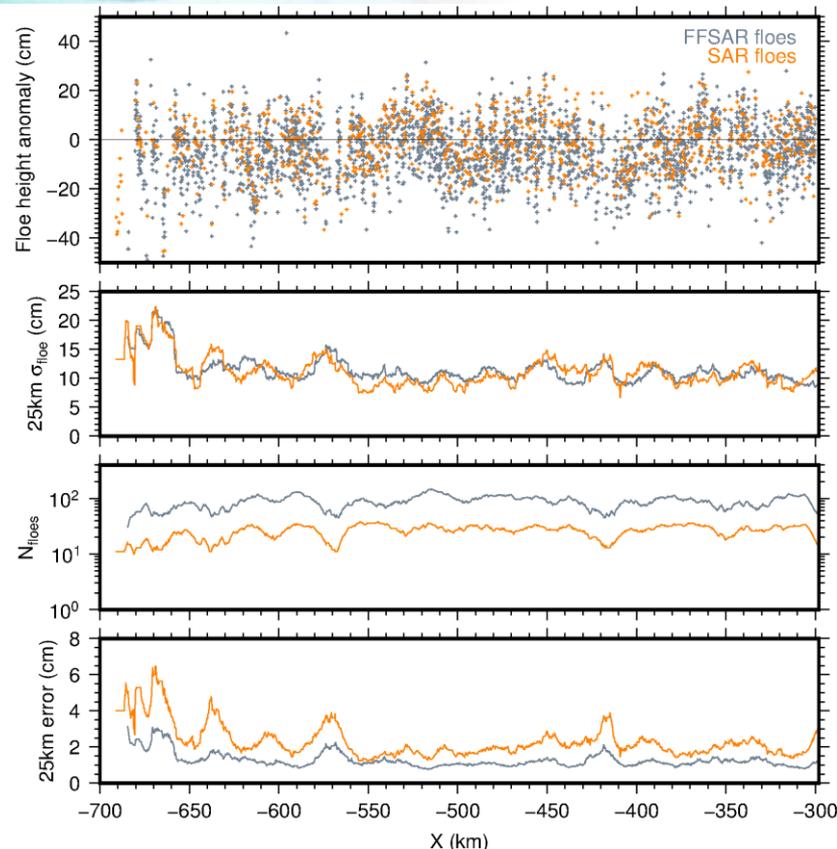
- Similar 25km height standard deviation ($\sim 5\text{cm}$)
- More lead waveforms in FFSAR data
- FFSAR has lower along track height standard error
 - $\sim 3\text{cm}$ for ESA L1b
 - $\sim 1\text{cm}$ for FFSAR



6. Some statistics: Along track statistics

Floes

- Similar 25km height standard deviation (~ 10 - 15 cm)
- More lead waveforms in FFSAR data
- FFSAR has lower along track height standard error
 - ~ 1 - 2 cm for ESA L1b
 - ~ 2 - 4 cm for FFSAR



7. Conclusions

- Over sea ice FFSAR data shows similar precision to ESA L1b, **but at 80m posting rate**
- FFSAR data is **great** for sea level and freeboard retrievals over ice-covered oceans
 - 80m along track resolution = 4x along track sampling rate = ~4 lead/floe elevation estimates per ESA L1b lead/floe elevation estimate
 - But FFSAR actually resolves *more individual leads* for the same processing/filtering parameters = better sampling of sea level along track = better polar oceanography
 - More sea level tie points = better sea level interpolation = better along track freeboard coverage

Any Questions?

Contact

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 @twkarmitage

References

Egido & Smith (2017), "Fully Focussed SAR Altimetry: Theory and Applications", *IEEE TGRS*, 55

Giles et al. (2007), "Combined airborne laser and radar altimeter measurements over the Fram Strait in May 2002", *Remote Sens. Environ.*, 111

