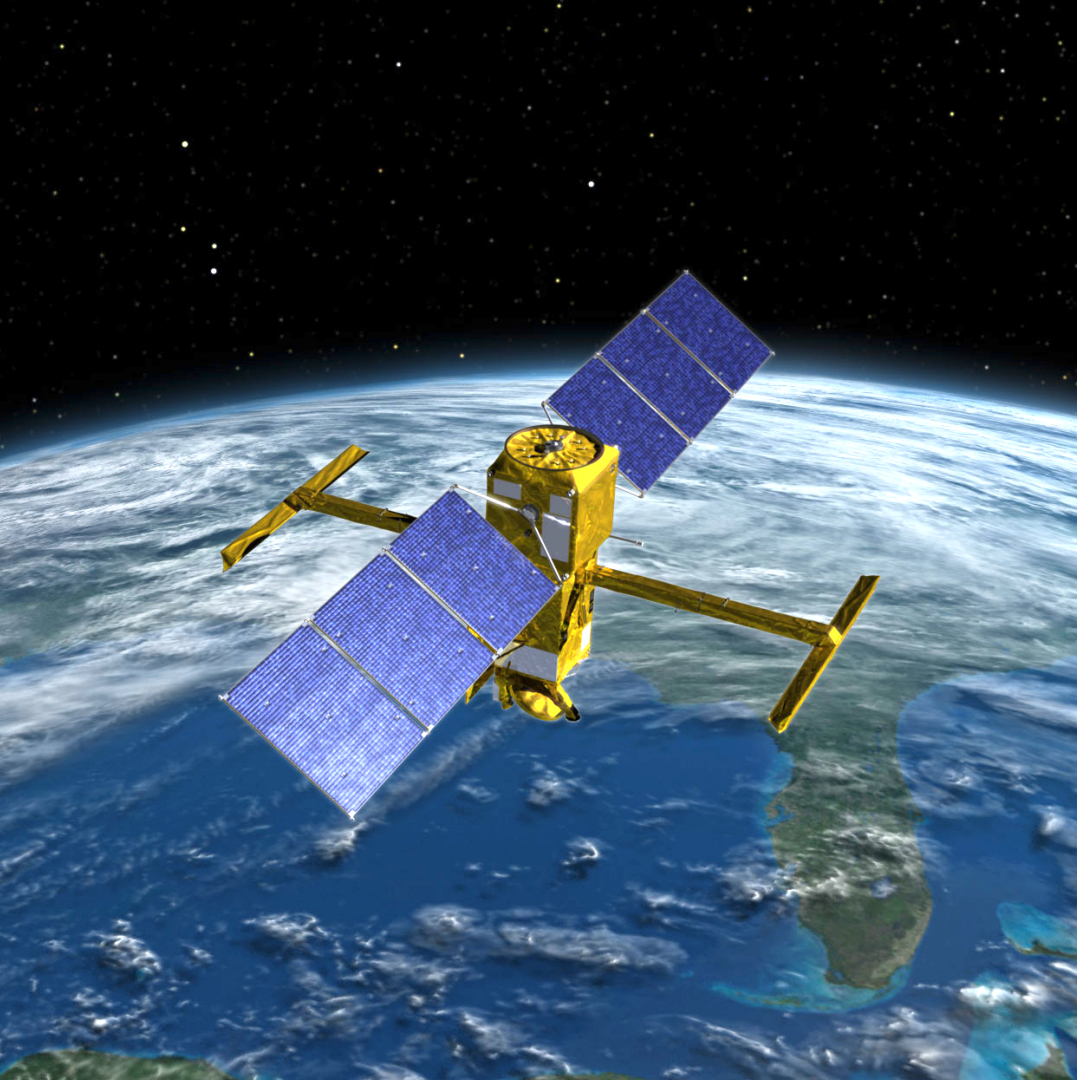

SWOT and the ice-covered polar oceans: An exploratory analysis

Tom Armitage, Ron Kwok

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1. Surface Water Ocean Topography mission

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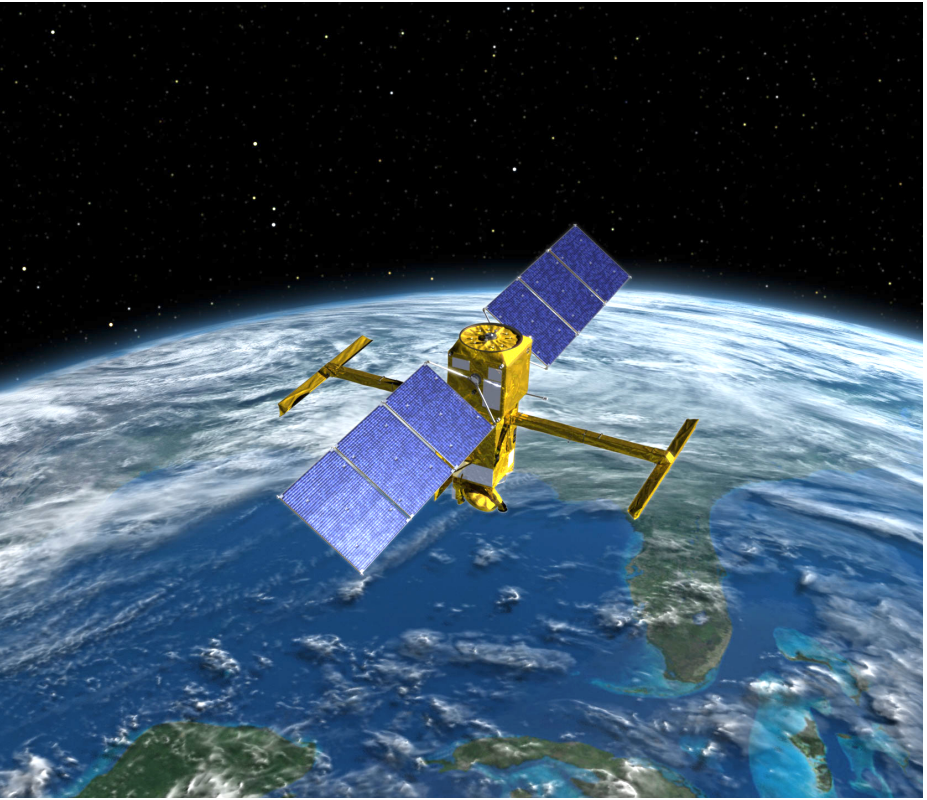
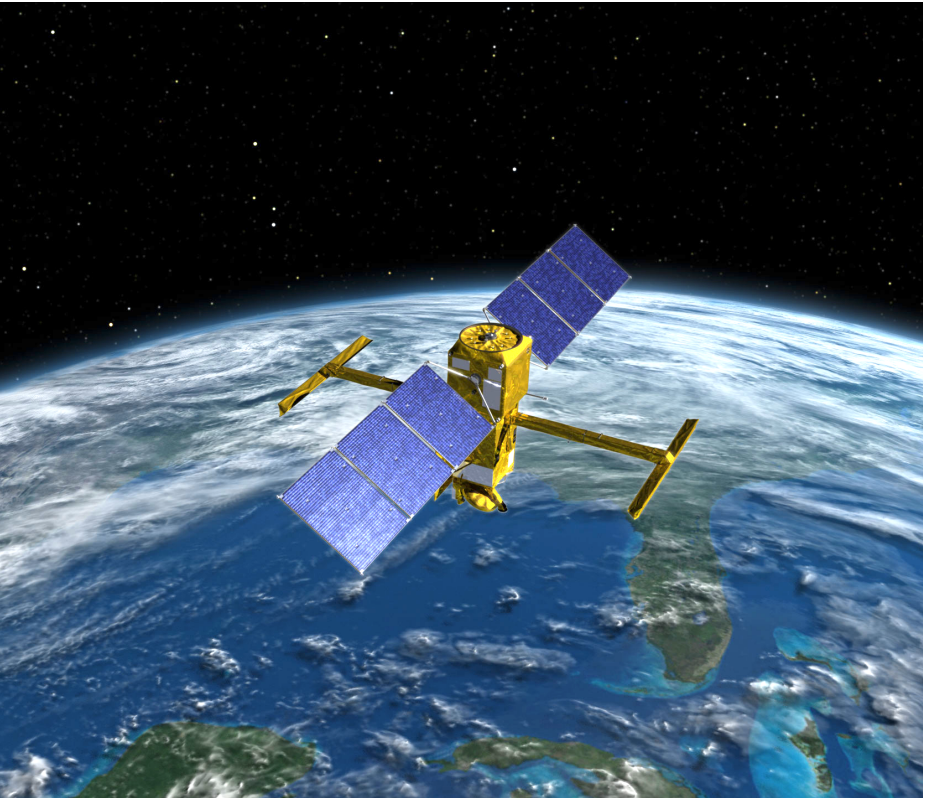


- Launch scheduled 2021
- Altitude ~890km; inclination 77.6°; ~21 day repeat orbit
- Primary mission
  - Measure sub-mesoscale (~10km resolution) ocean dynamic topography
  - Measure height of inland water bodies; lakes 250x250m^2, rivers 50-100m wide

1. Surface Water Ocean Topography mission

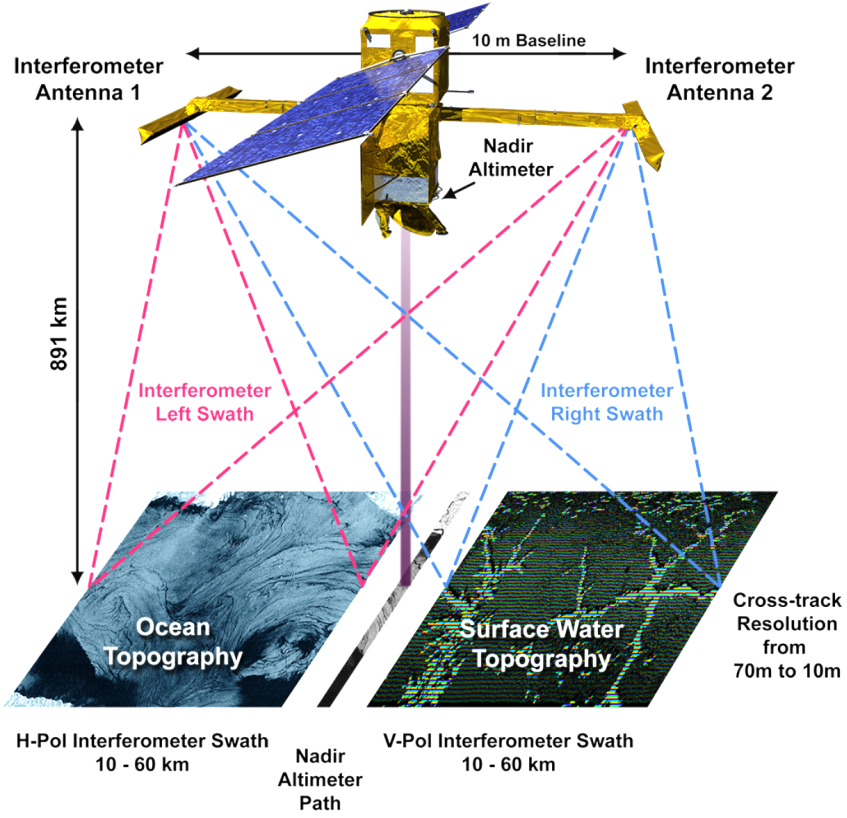


- Secondary mission objectives (i.e., within scope of mission design but don't drive mission requirements):
  - **Sea ice freeboard/thickness**
  - Ice sheet surface topography
  - Ocean tides
  - Ocean bathymetry
  - Tropical cyclone intensification
  - Sea level change

1. Surface Water Ocean Topography mission

Ka-band Radar Interferometer (KARIN):

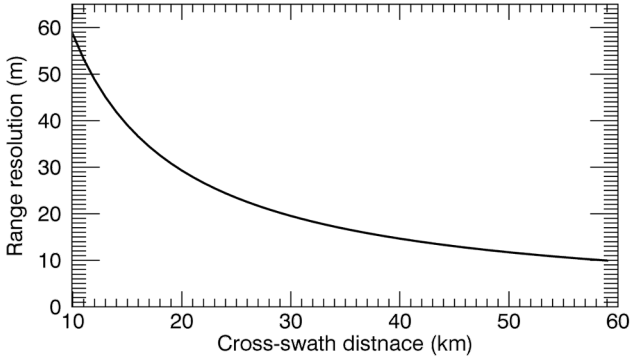
- 35.75GHz central frequency
- Bandwidth 200MHz (75cm free space range resolution)
- 5m antennas separated by 10m boom across-track
- Look angles ~0.6°–4.0°, two swaths 10–60km either side of nadir

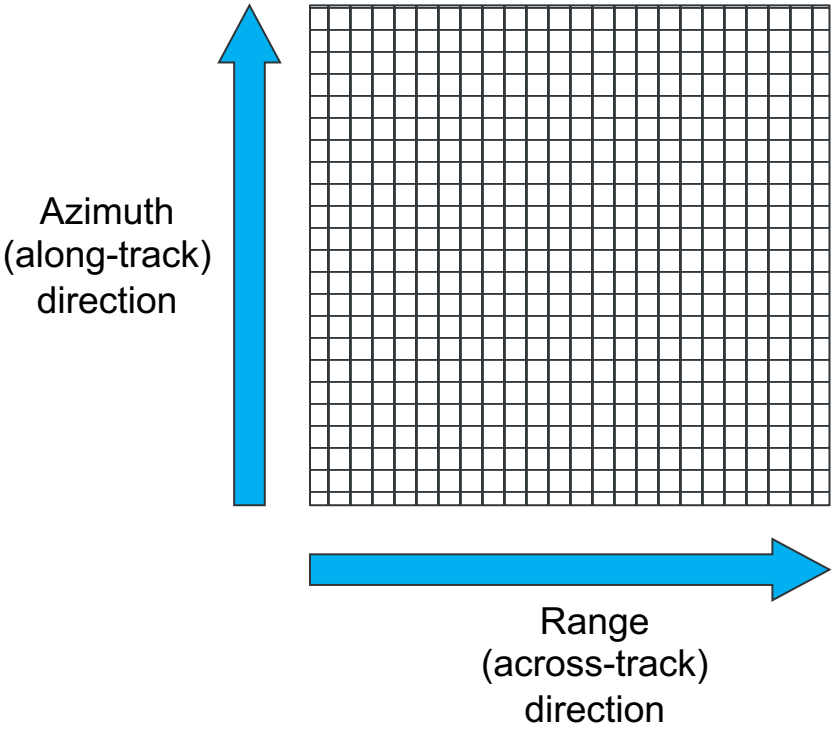


1. Surface Water Ocean Topography mission

Ka-band Radar Interferometer (KARIN):

- Resolution:
  - Azimuth: 5m
  - Range: ~60m (near-range) to ~10m (far-range)





1. Surface Water Ocean Topography mission

- Phase difference due to different path delay to each antenna:

$$\phi = \frac{2\pi}{\lambda}\Delta r$$

- Can write differential path delay as

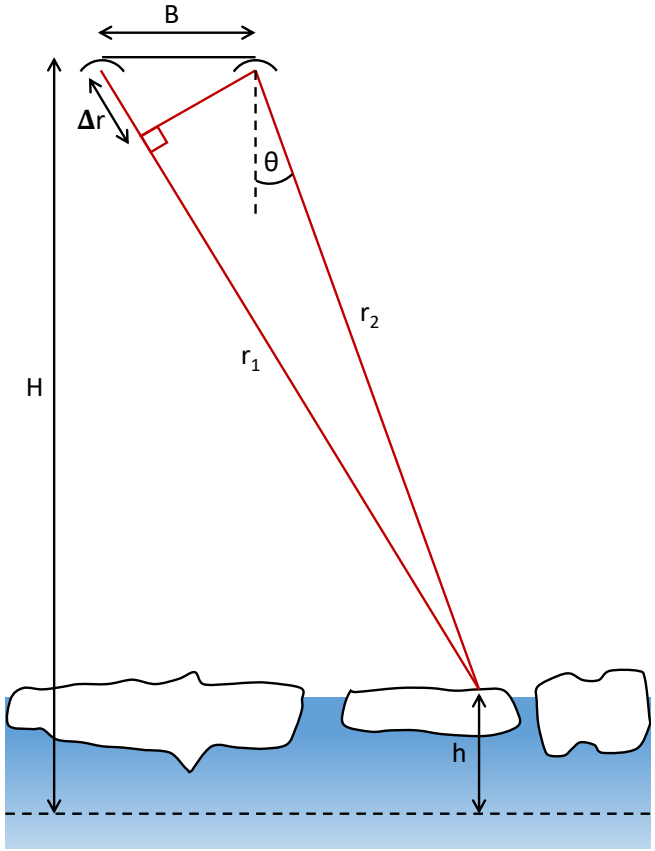
$$\Delta r = B \sin\theta$$

- Then the off-nadir angle is

$$\theta = \sin^{-1}\left(\frac{\phi}{B}\frac{\lambda}{2\pi}\right)$$

- And the height is

$$h = H - r_1 \cos\theta$$



2. SWOT in the ice-covered oceans

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Questions:

1. What are the Ka-band backscatter properties of sea ice and leads at small look angles?

2. Given this, what height retrieval performance can we expect?

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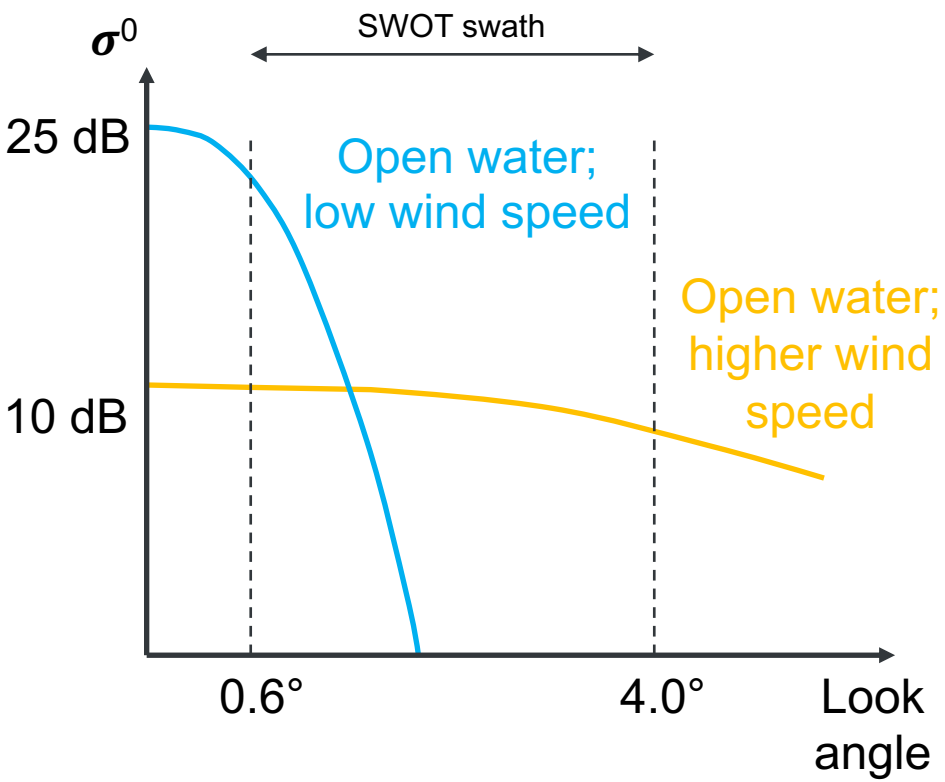
2. SWOT in the ice-covered oceans: Ka-band backscatter

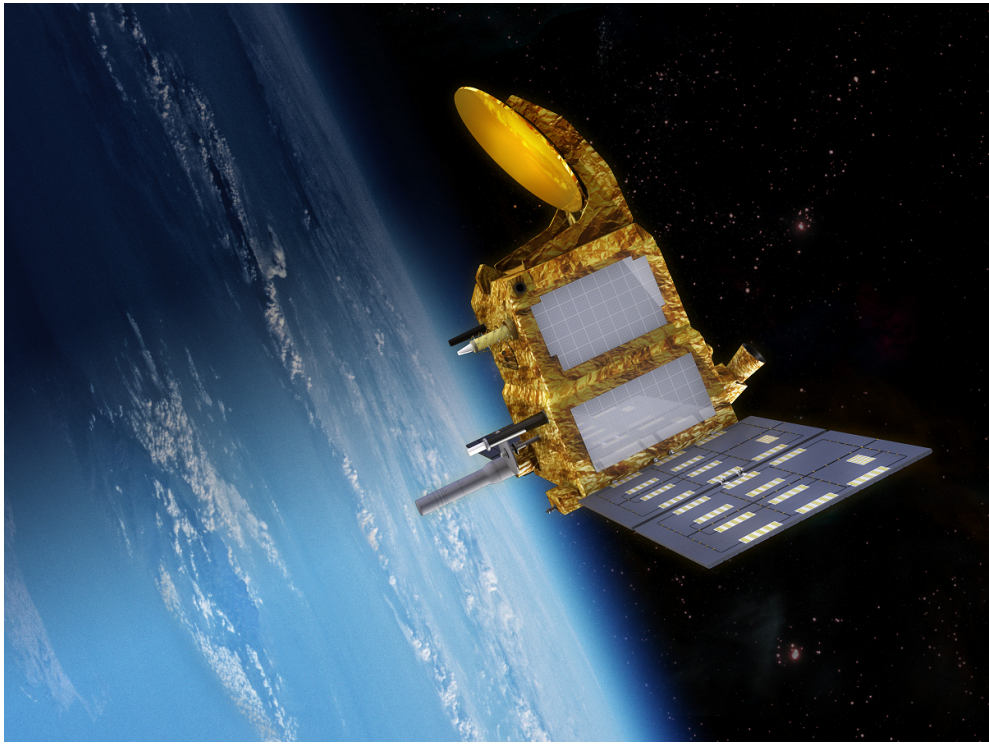
What might we expect to see?

- Leads:
  - Specular (mirror-like) near nadir
  - Ka-band highly sensitive to surface roughness (wavelength ~8mm)
- Sea ice:
  - ??



2. SWOT in the ice-covered oceans: Ka-band backscatter

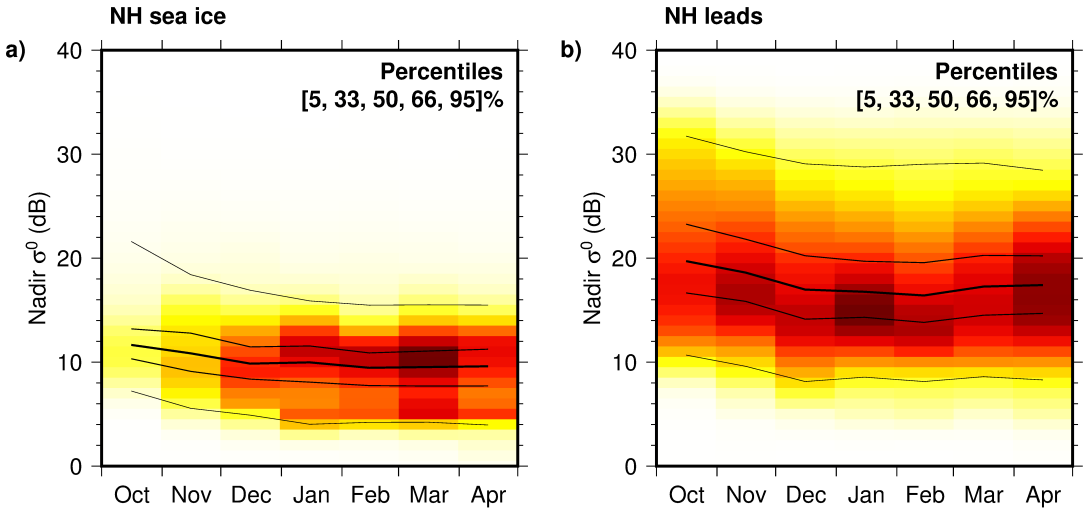
- Use data from AltiKa to constrain nadir backscatter
- Separate returns from leads/sea ice using
  - Pulse peakiness; σ^0
  - AMSR-2 sea ice concentration
- Look at σ^0 histograms for leads/sea ice during northern/southern hemisphere growth season



2. SWOT in the ice-covered oceans: Ka-band backscatter

Northern hemisphere

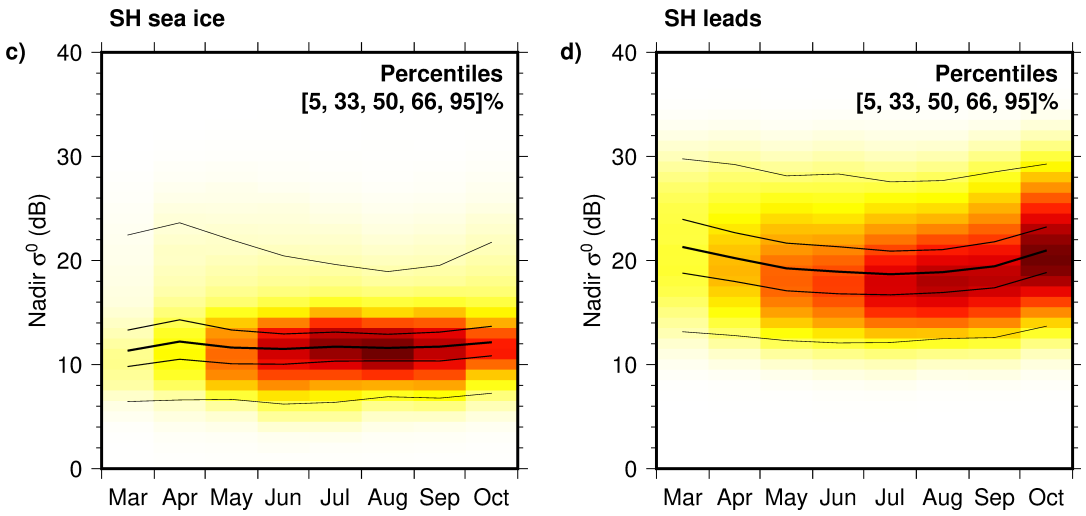
- Sea ice σ^0~10–12 dB (50th percentile)
- Leads σ^0~18–20 dB (50th percentile)
- Nadir backscatter fairly stable during the growth season



2. SWOT in the ice-covered oceans: Ka-band backscatter

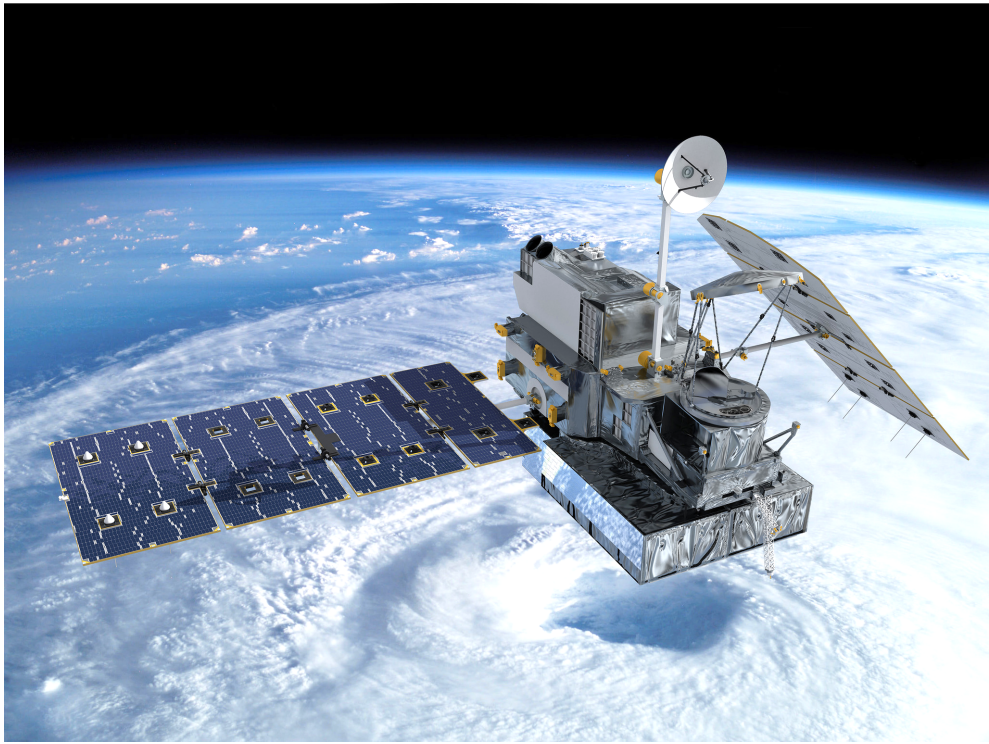
Southern hemisphere

- Sea ice σ^0~12 dB (50th percentile)
- Leads σ^0~20–22 dB (50th percentile)
- Nadir backscatter fairly stable during the growth season



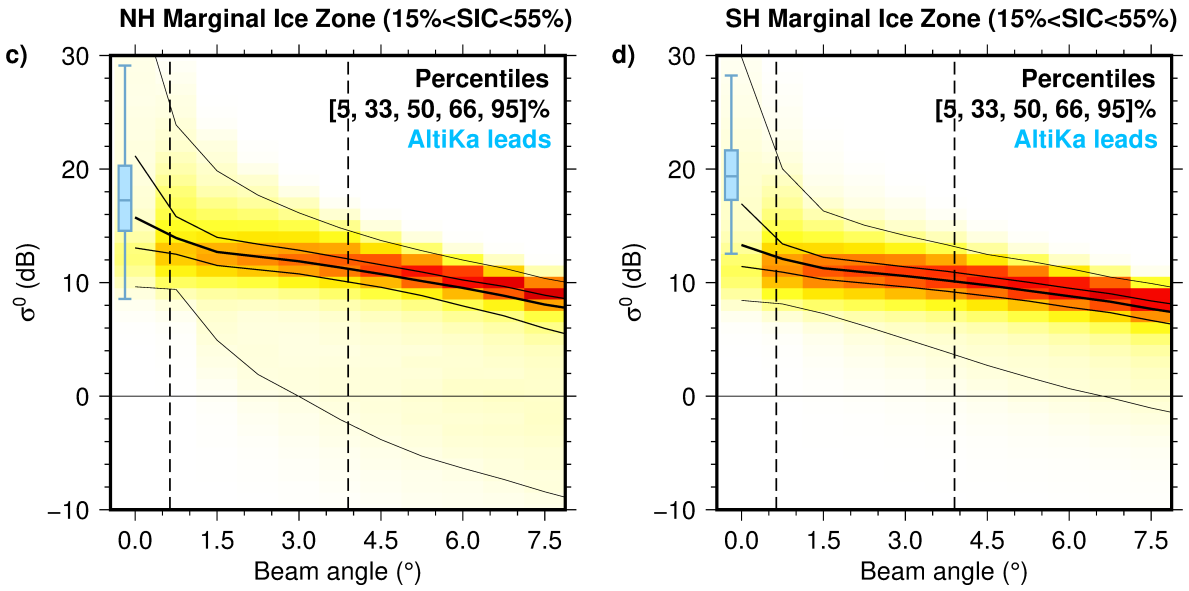
2. SWOT in the ice-covered oceans: Ka-band backscatter

- Use Ka-band phased array precipitation radar onboard the Global Precipitation Measurement observatory
- 25 beams spanning ±9°
- Covers up to 65°N/S
- Combine with daily AMSR sea ice concentration to look at backscatter as a function of angle and ice concentration



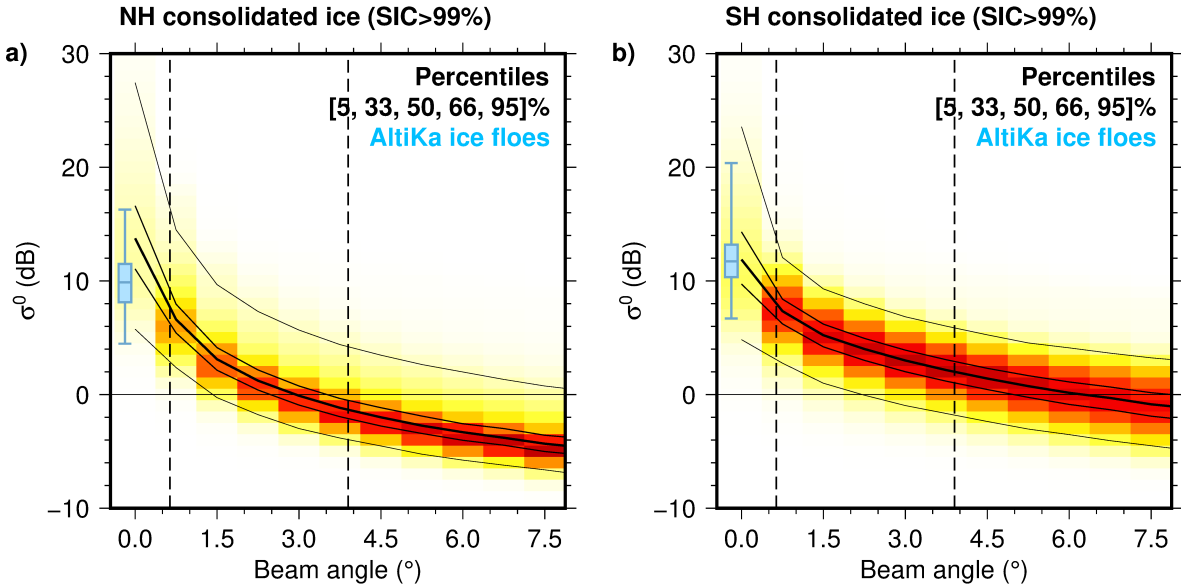
2. SWOT in the ice-covered oceans: Ka-band backscatter

- Marginal Ice Zone (MIZ) condition; sea ice concentration 15-55%
  - Water areas to dominate backscatter; dominated open ocean type scattering
  - Some evidence of specular backscatter as well, more so in northern hemisphere



2. SWOT in the ice-covered oceans: Ka-band backscatter

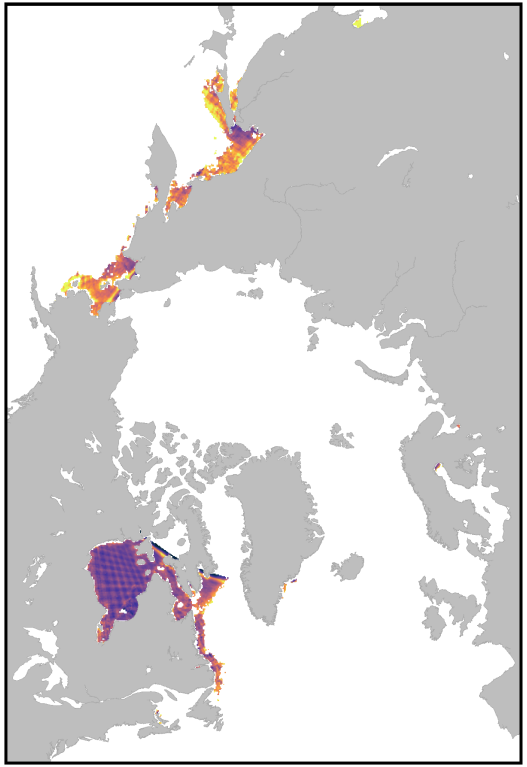
- Consolidated ice pack; sea ice concentration >99%
  - Faster drop off in σ^0 than open ocea
  - Decent match with AltiKa at nadir

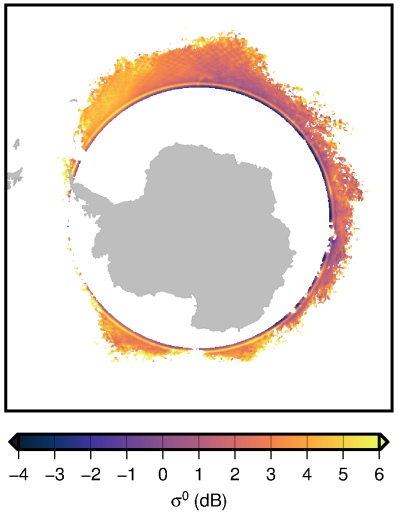


2. SWOT in the ice-covered oceans: Ka-band backscatter

Limitations of GPM KaPR:

- Latitudinal coverage
  - Only captures low-latitude sea ice
  - Surface melt
  - Fairly thin, flat, first year ice
- Footprint ~5km
  - Specular open water might be swamped by ice

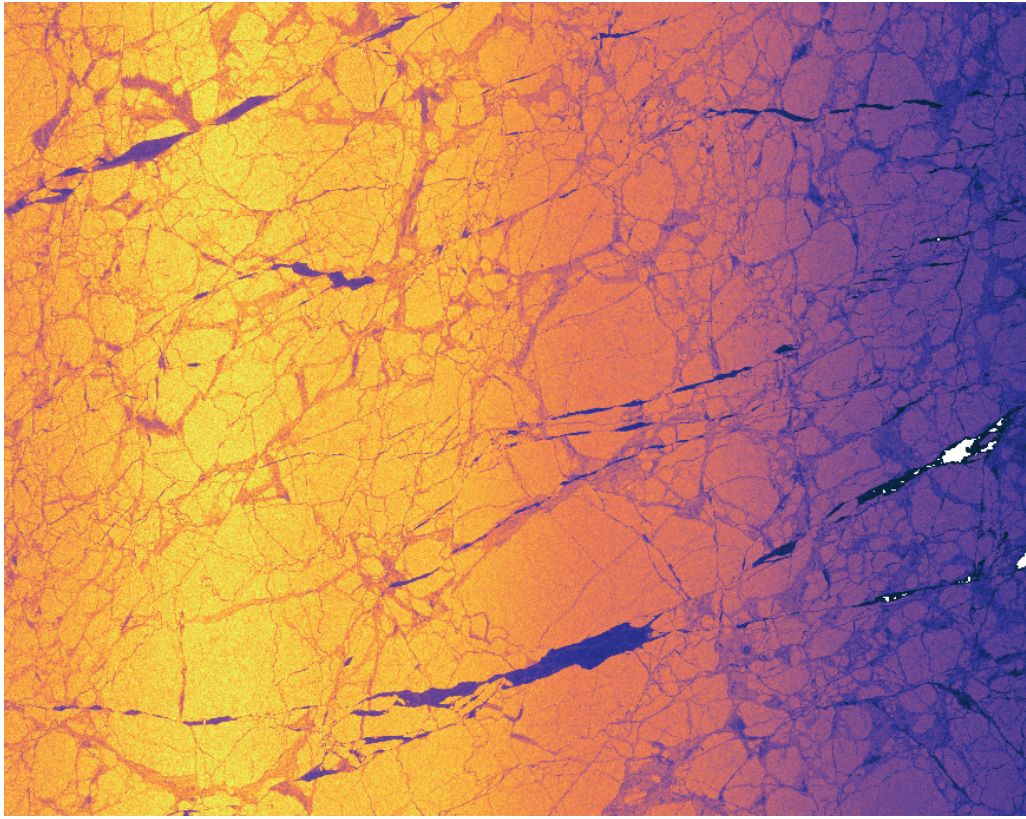




2. SWOT in the ice-covered oceans: Ka-band backscatter

Airborne data?

- GLISTIN
- AirSWOT



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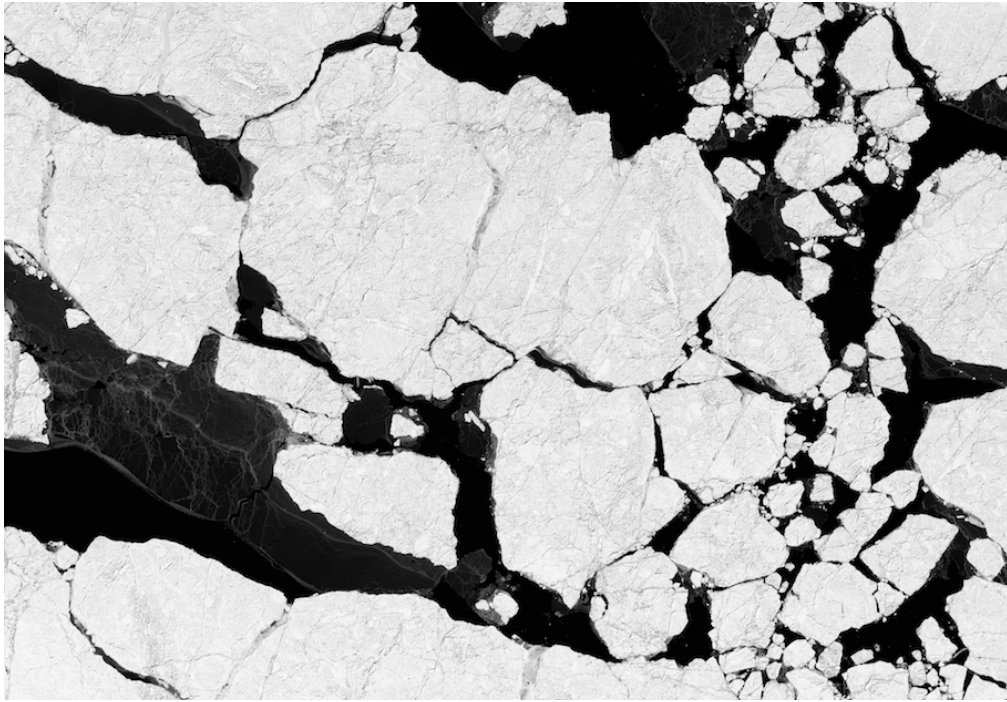
- Adapt the SWOT Hydrology Simulator
- Simulates expected SWOT performance
- Produces L1b products based on
  - SWOT projected orbit
  - SWOT radar parameters
  - An input elevation model
  - Surface type mask
  - Profiles of backscatter with angle for each surface type



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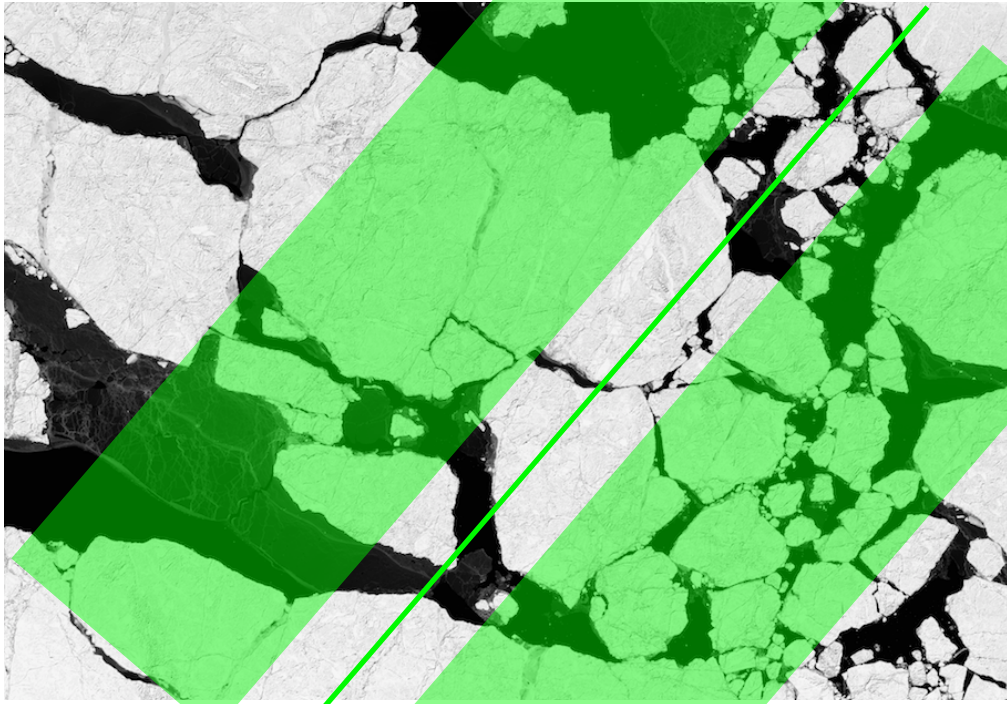

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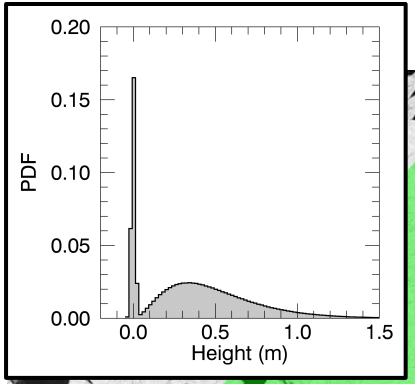

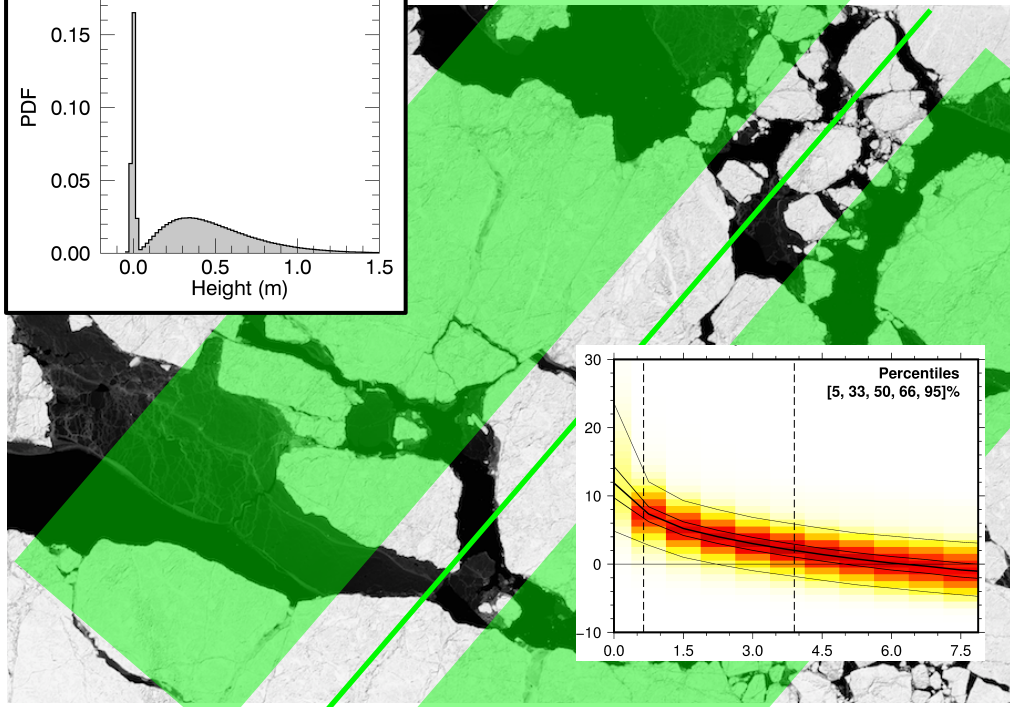

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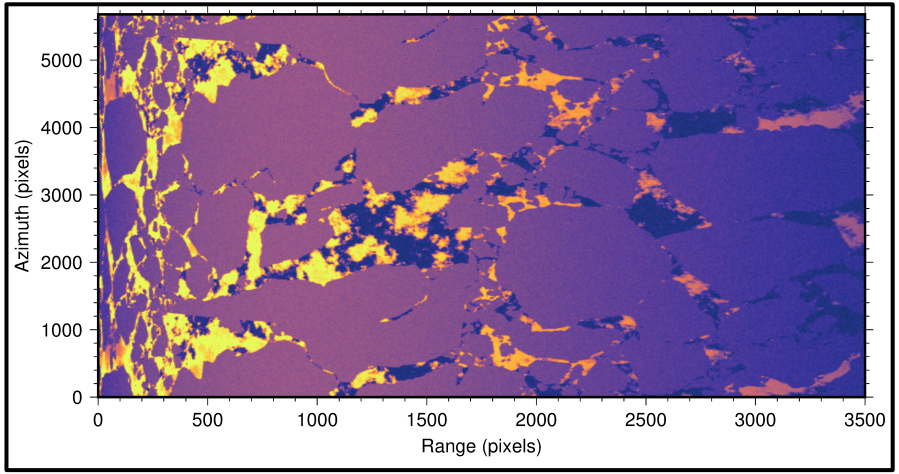

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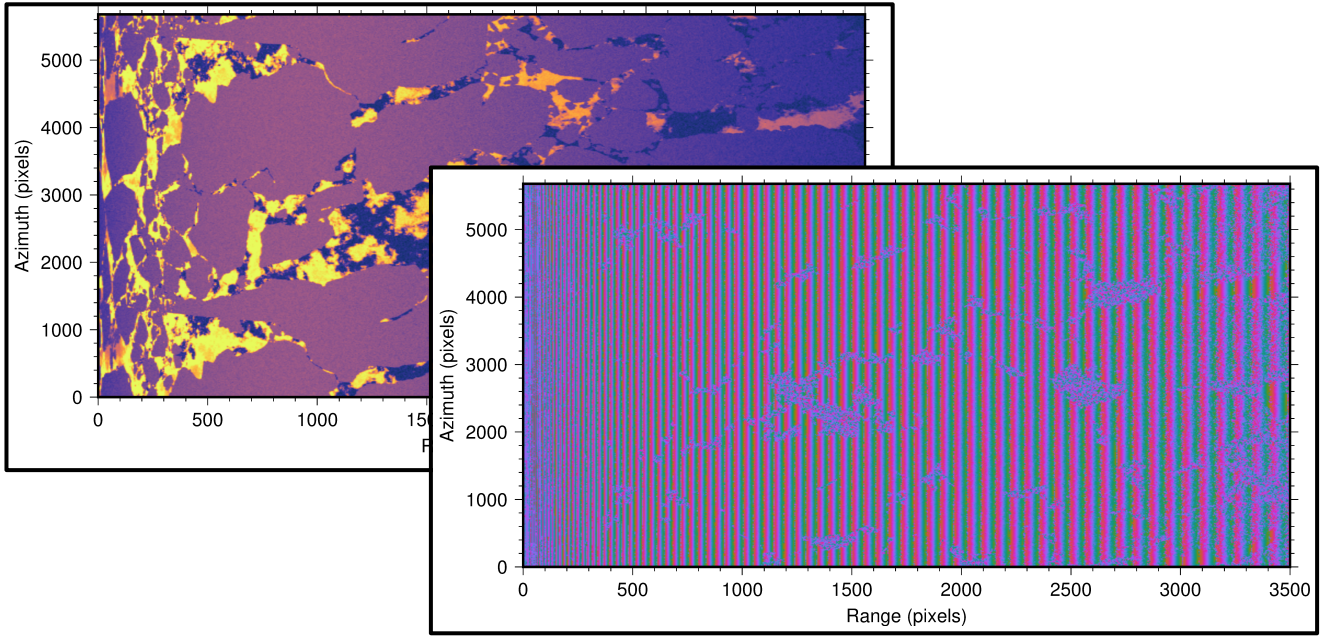

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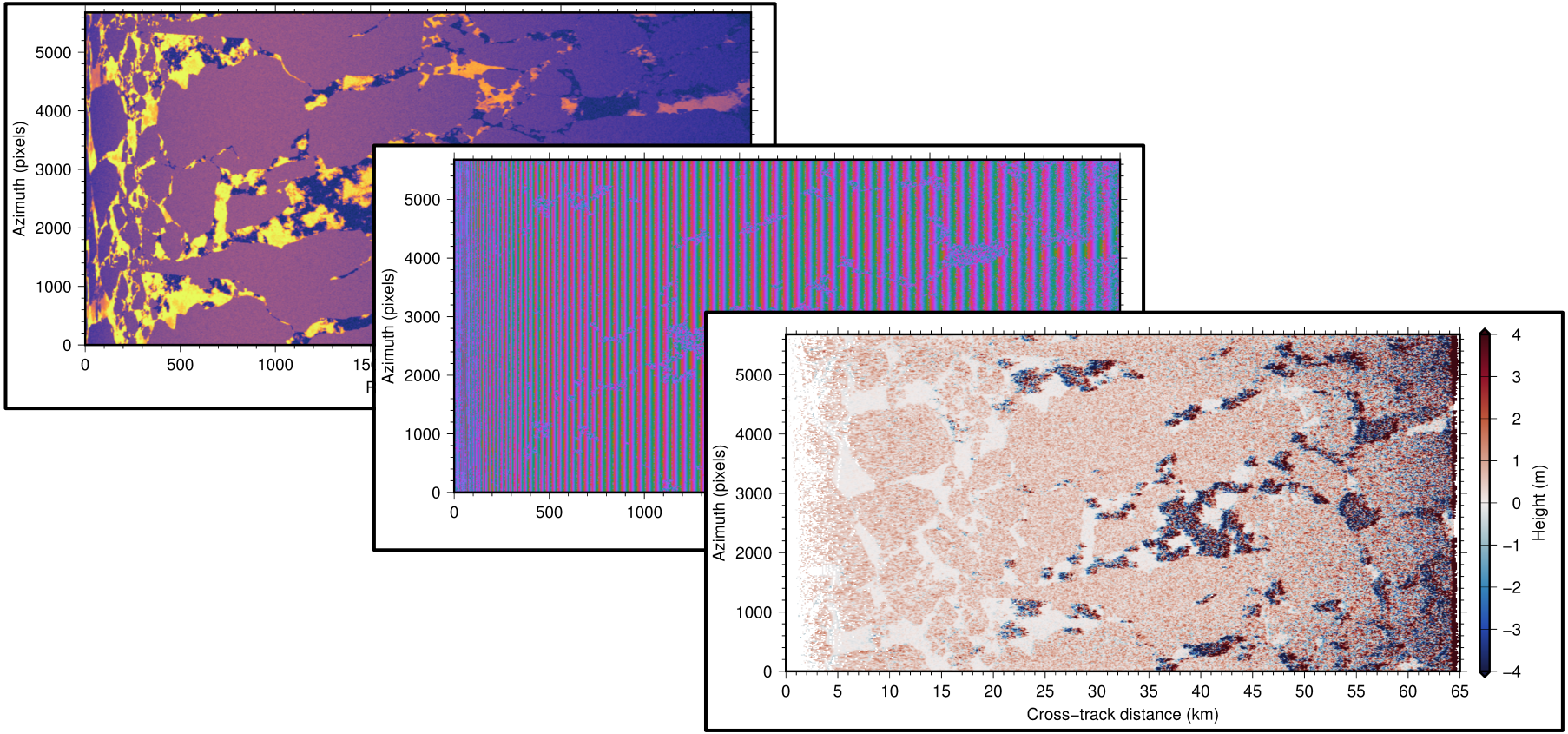

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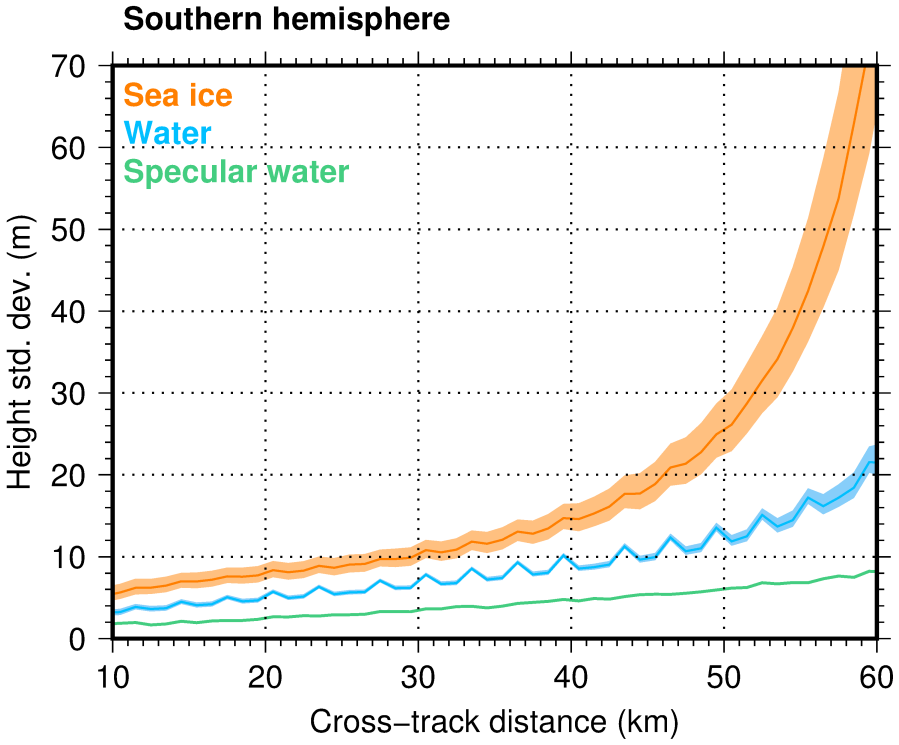
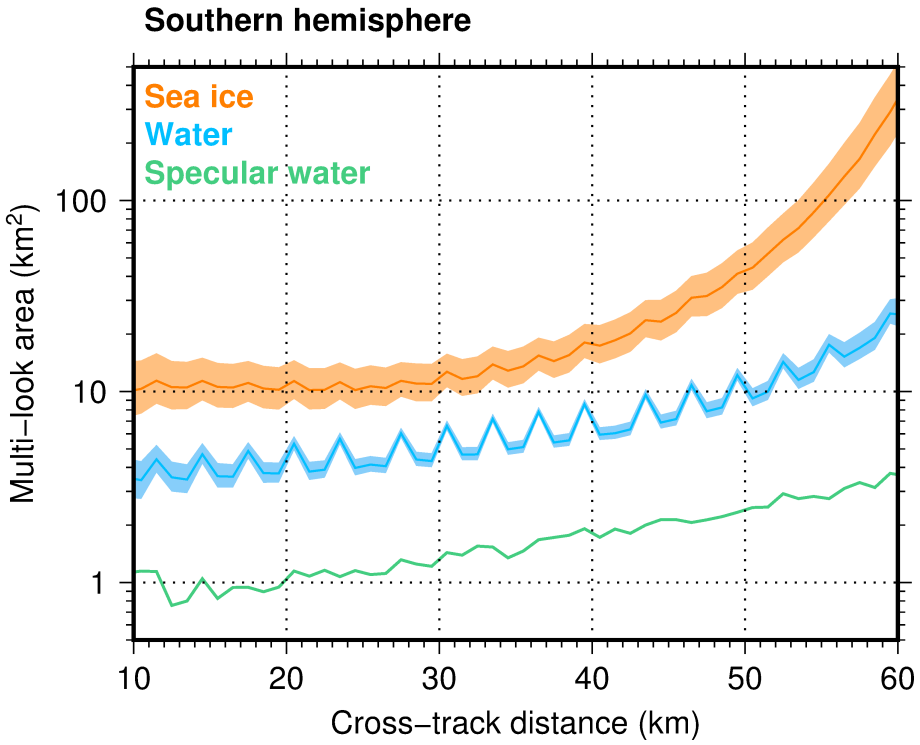


2. SWOT in the ice-covered oceans: simulated retrievals

- Height uncertainty increases across the swath due to
  - Decreasing σ^0
  - Antenna pattern
  - Phase uncertainty increases linearly with look angle
- Number of pixels to average a function of look angle
  - Specular water average ~1–2 km^2 (3cm precision)
  - Sea ice ~10–40 km^2 (3cm precision)



3. SWOT: Science in the ice-covered oceans

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<u>What might SWOT deliver beyond nadir altimetry?</u>

- Two-dimensional ice thickness
- Swath provides much better coverage/faster repeat
- Two-dimensional currents, particularly interesting in MIZ, eddy-ice dynamics
- Synergies: CS-2/IS-2/NISAR

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