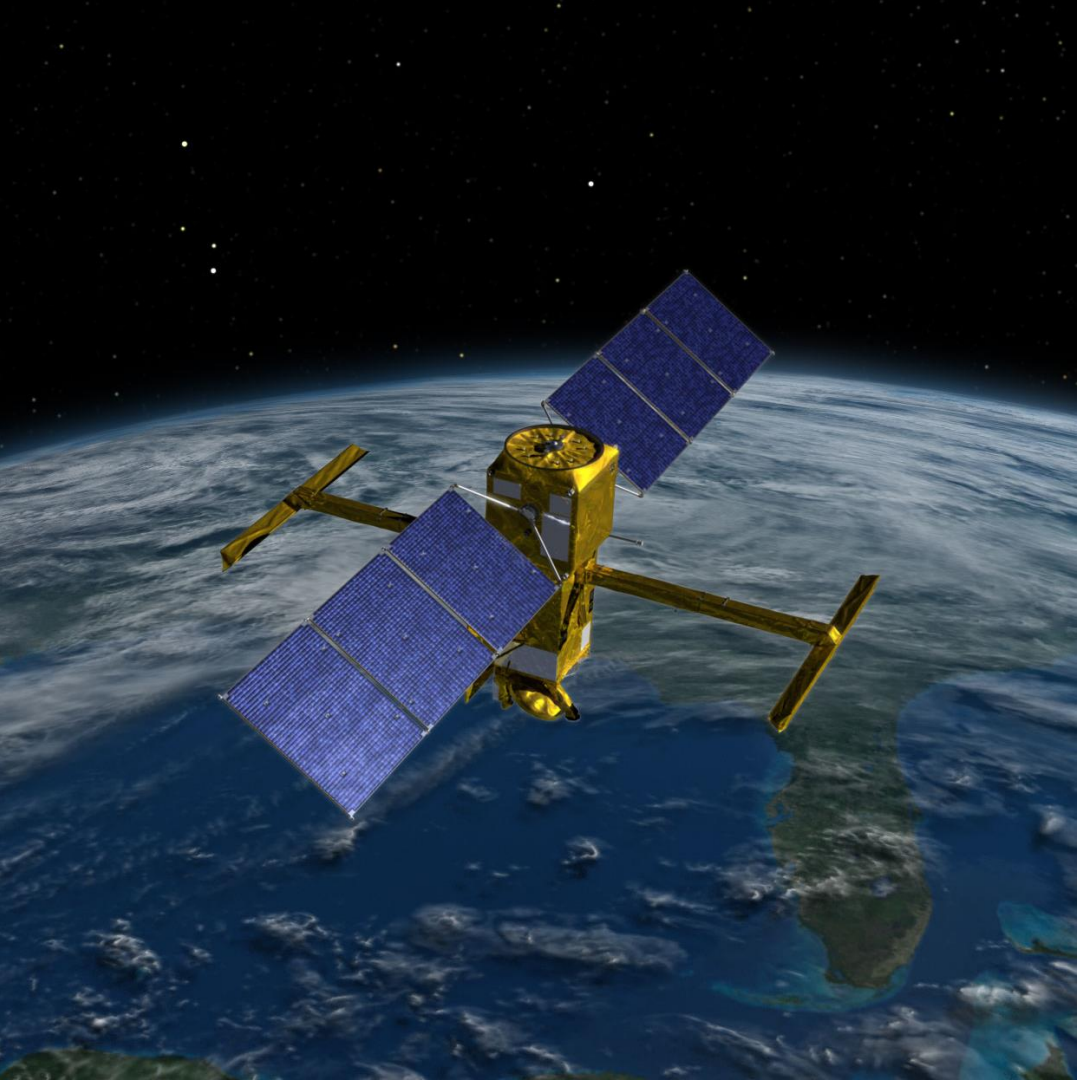

Surface Water Ocean Topography mission retrievals in the ice-covered ocean

Tom Armitage, Ron Kwok

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Jet Propulsion Laboratory
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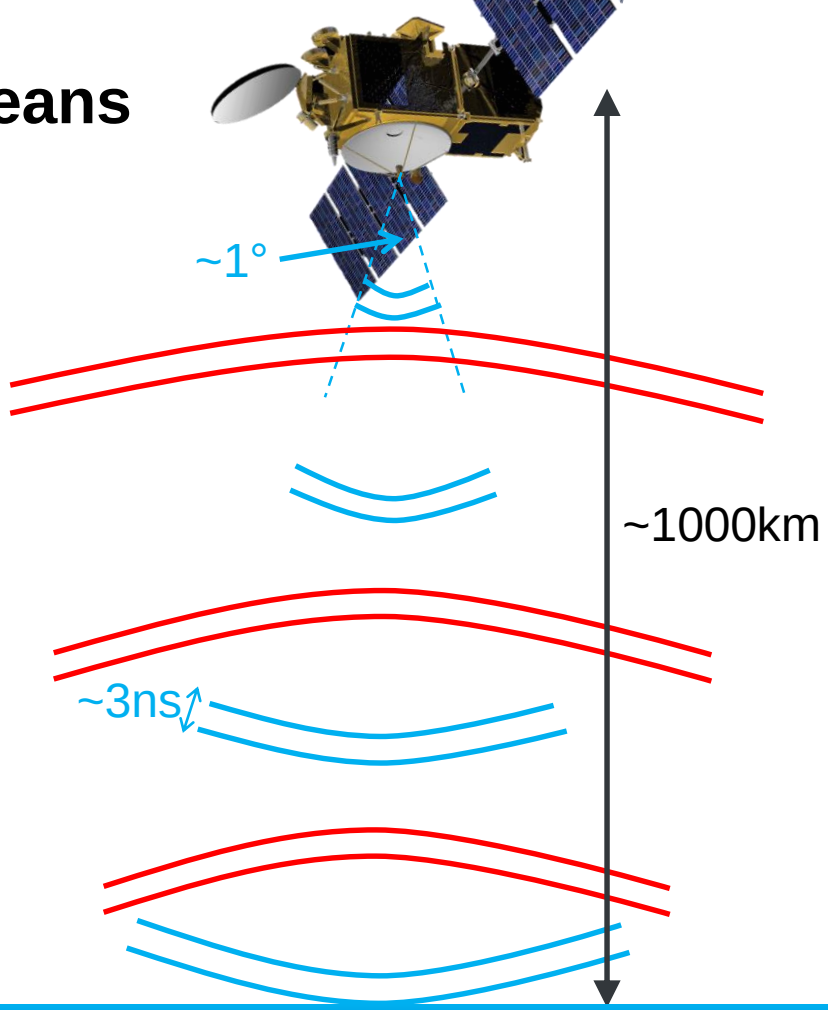
1. Radar altimetry in the polar oceans

1. Radar altimetry in the polar oceans

Conventional altimetry

- Satellite orbiting at ~1000km
- Emit radar pulses to surface
- Receive the reflected pulses and estimate the two-way travel time, convert to range
- Combine this with:
  - Satellite altitude
  - Geophysical corrections

→ Get sea surface height



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- Altimetry has proven a valuable tool for remote sensing of the polar oceans
  - Relies on distinguishing between sea ice and leads (cracks)
  - Estimate local sea level and ice elevation separately

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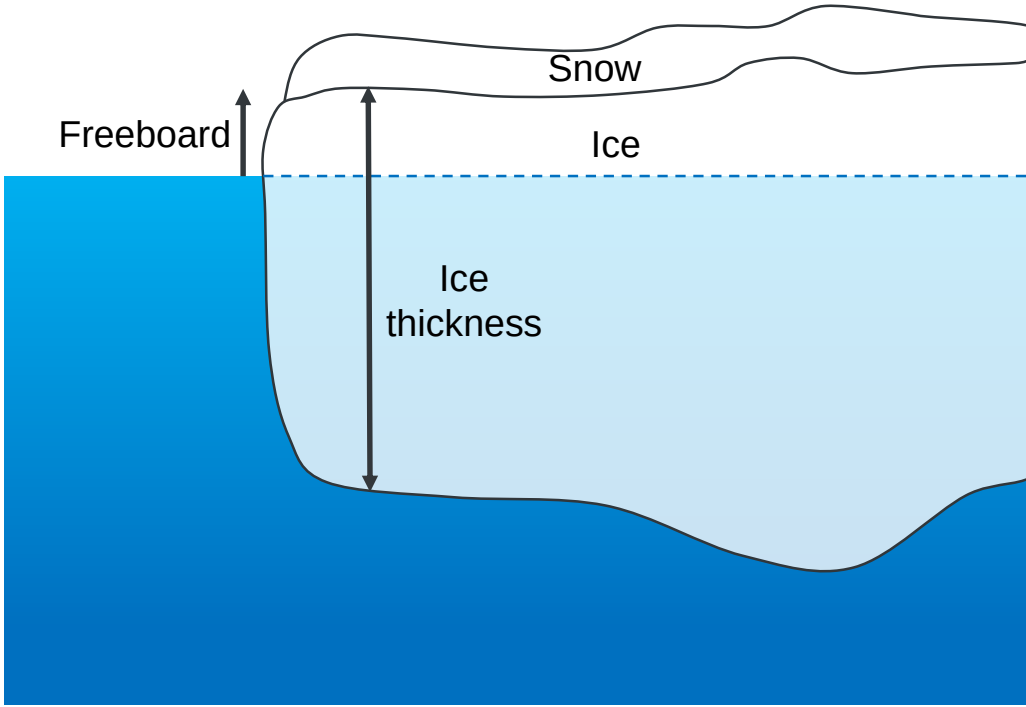

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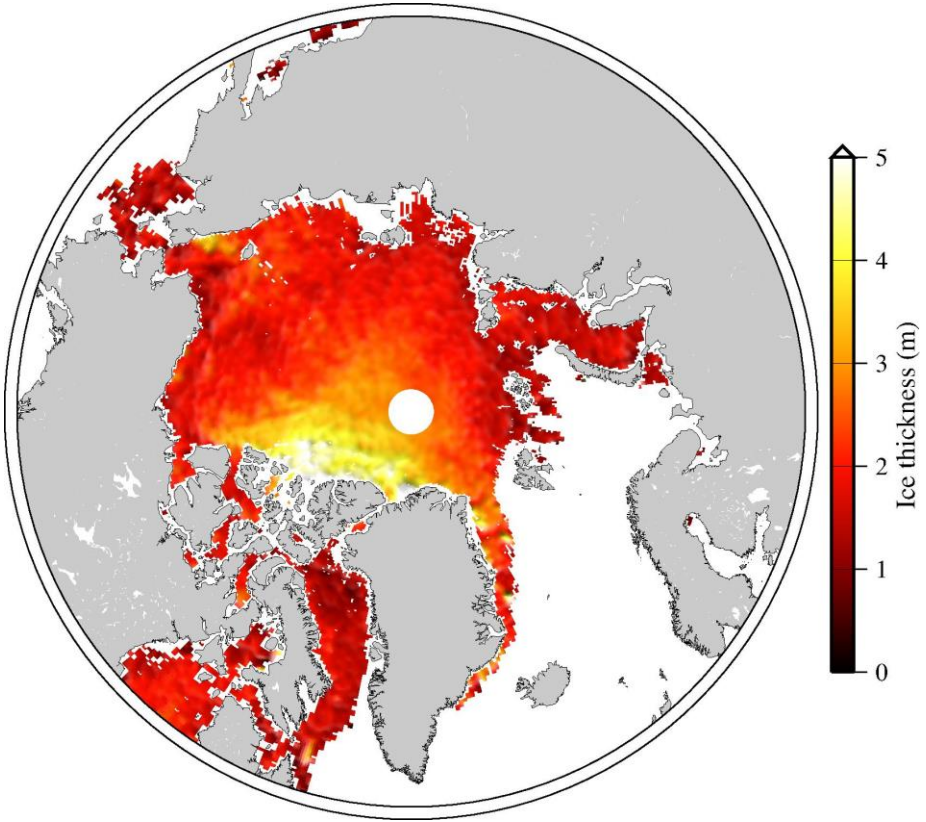

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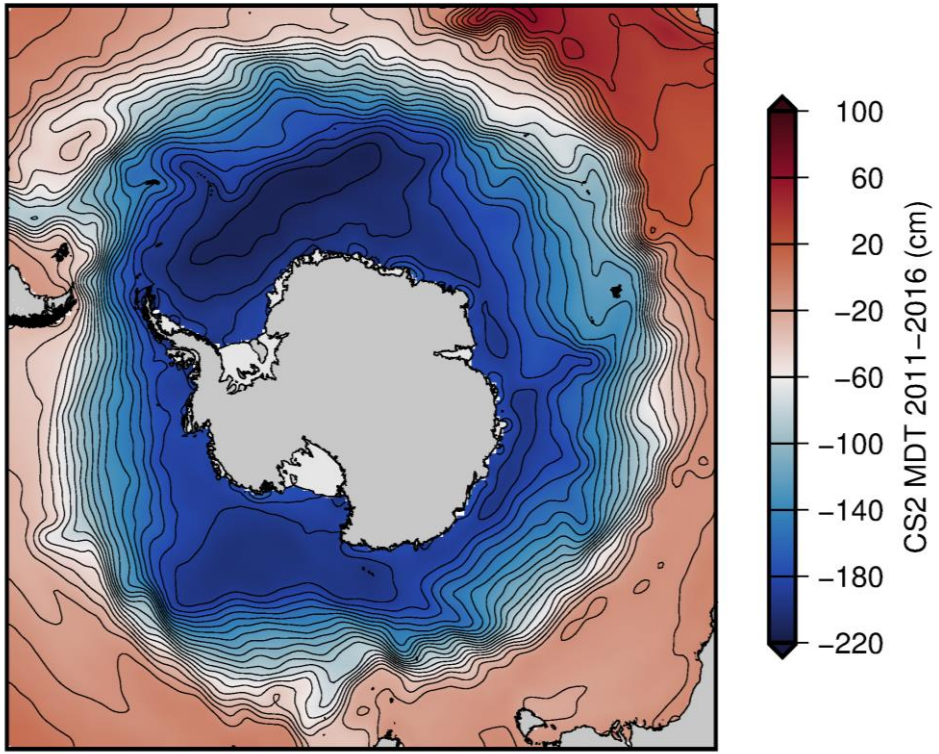
- Sea level in the ice-covered ocean



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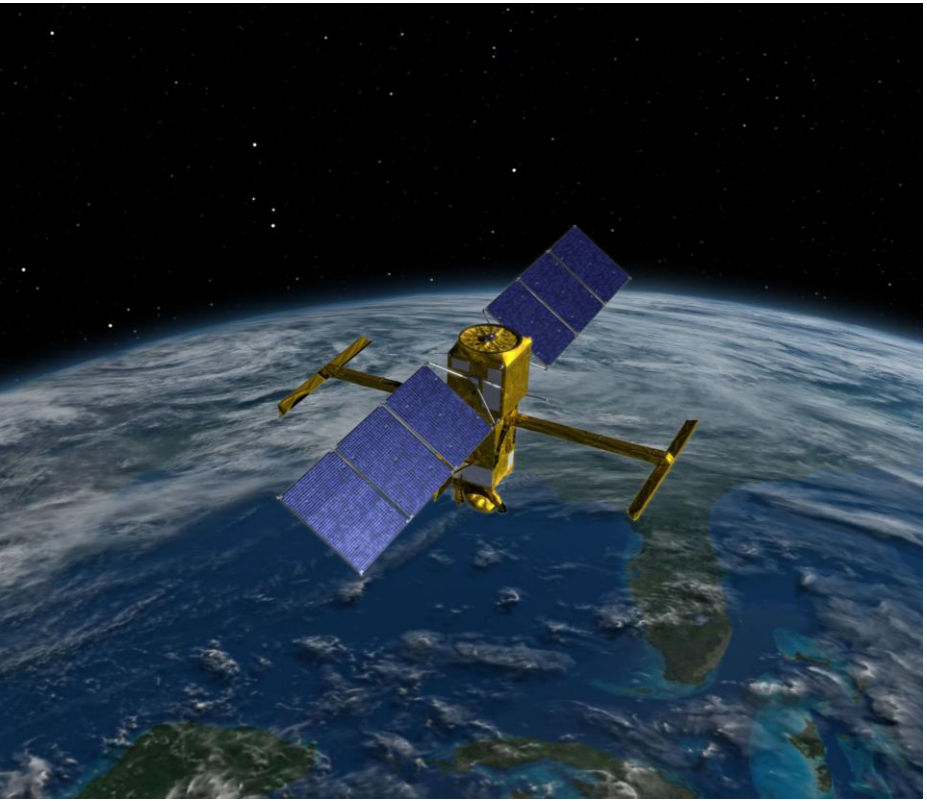
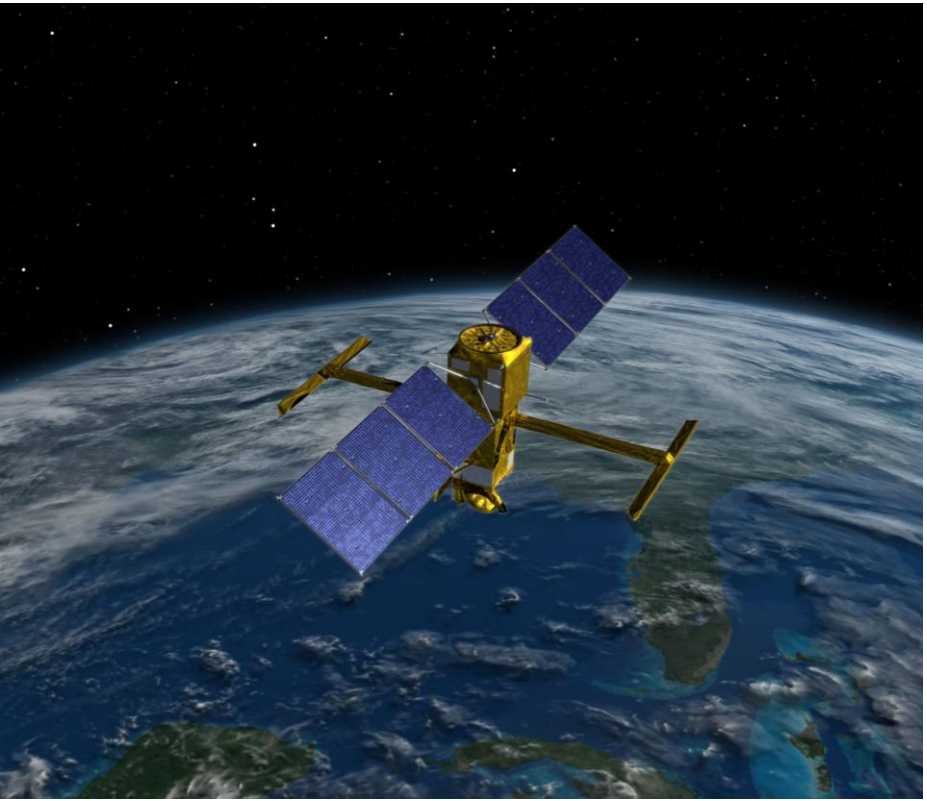


- Launch scheduled 2021
- Altitude ~890; inclination 77.6°; ~21 day repeat orbit
- Primary mission
  - Measure sub-mesoscale (~10km resolution) ocean dynamic topography
  - Measure height of inland water bodies; lakes 250x250m^2, rivers 50-100m wide

2. Surface Water Ocean Topography mission

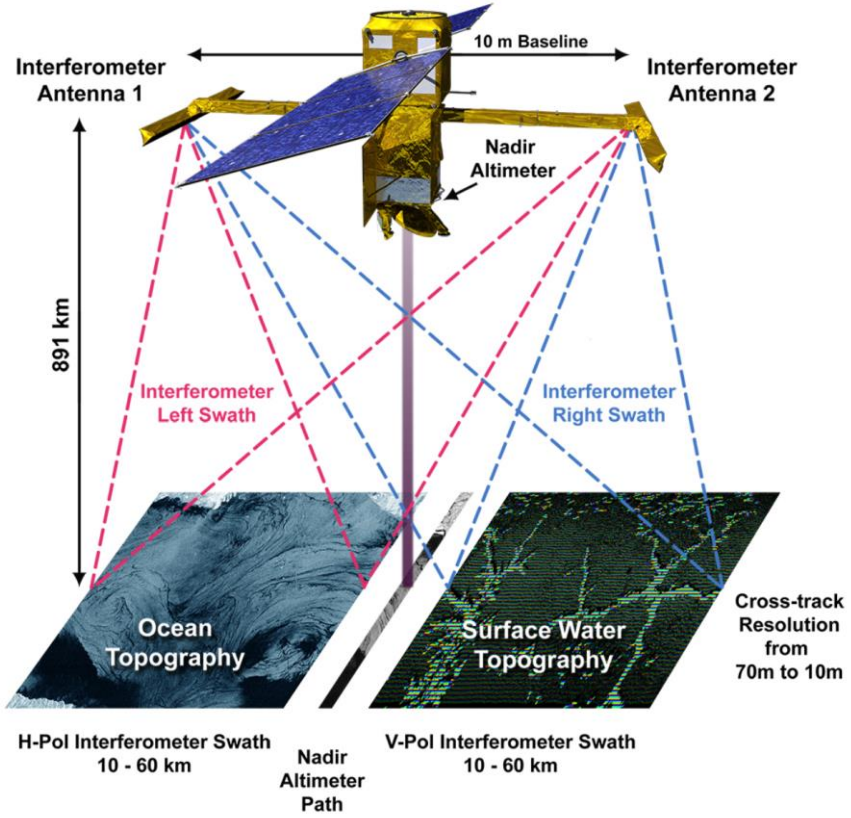


- Secondary mission objectives (i.e., within scope of mission design but don't drive mission requirements):
  - **Sea ice freeboard/thickness**
  - Ice sheet surface topography
  - Ocean tides
  - Ocean bathymetry
  - Tropical cyclone intensification
  - Sea level change

2. Surface Water Ocean Topography mission

Ka-band Radar Interferometer (KARIN):

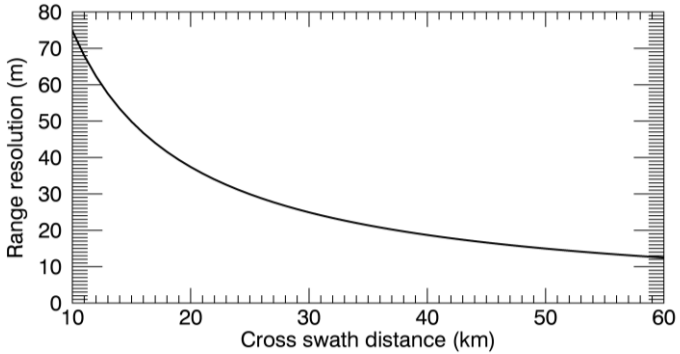
- 35.75GHz central frequency
- Bandwidth 200MHz (75cm free space range resolution)
- 5m antennas separated by 10m boom across-track
- Look angles ~0.6°–4.0°, two swaths 10–60km either side of nadir

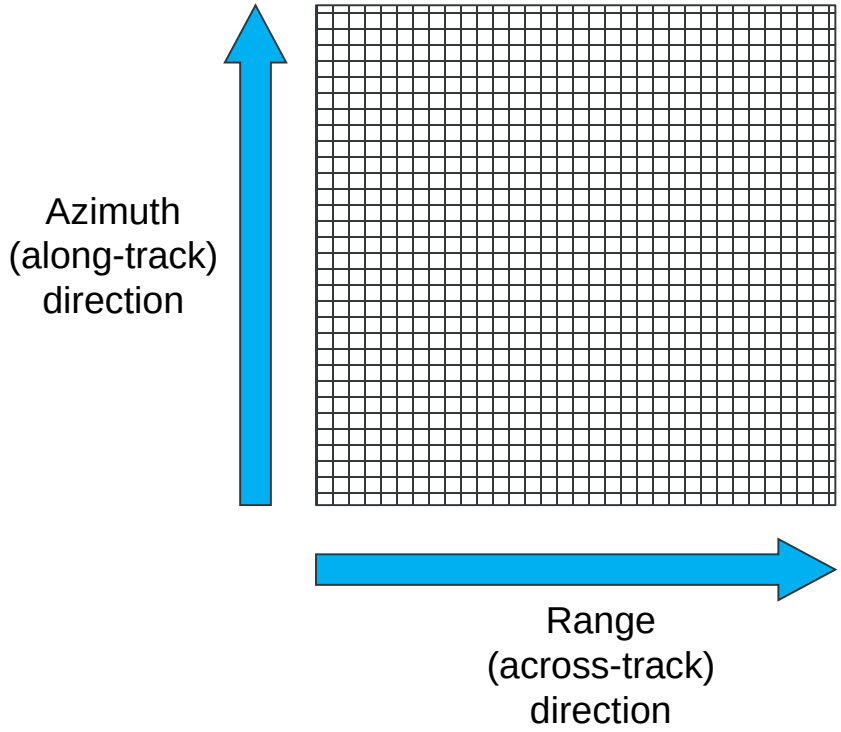


2. Surface Water Ocean Topography mission

Ka-band Radar Interferometer (KARIN):

- Resolution:
  - Azimuth: 5m
  - Range: ~70m (near-range) to ~10m (far-range)





2. 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

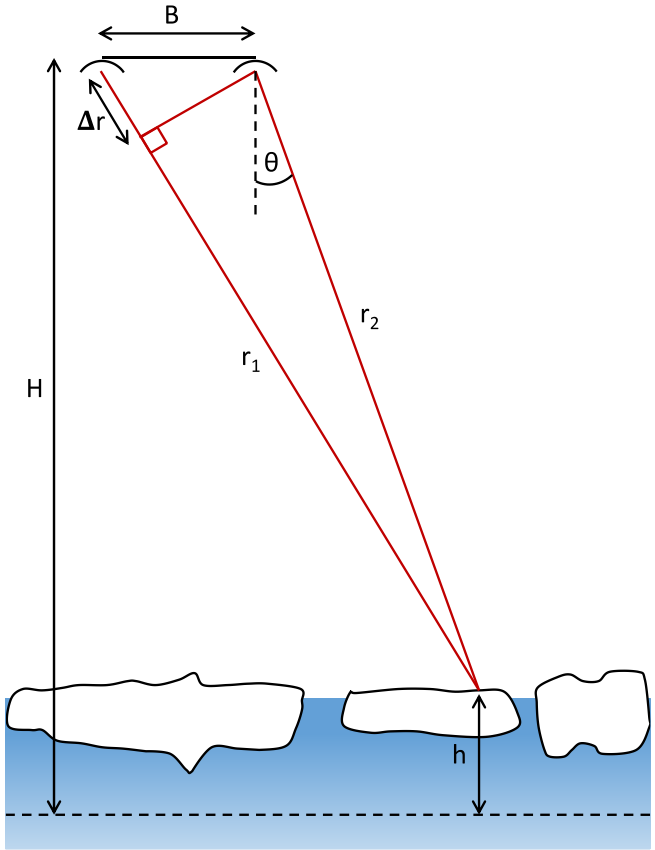
$$\Delta r = B \sin\theta$$

- Then the off-nadir angle is

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

- And the height is

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



3. SWOT in the ice-covered oceans

3. SWOT in the ice-covered oceans

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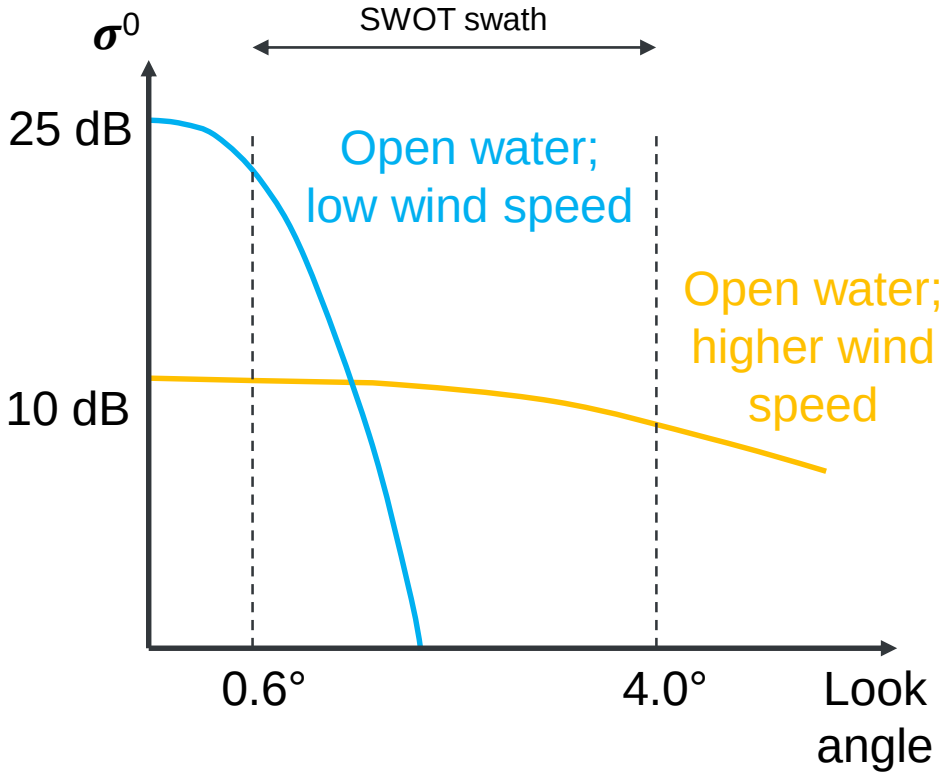
3. SWOT in the ice-covered oceans: Ka-band backscatter

What might we expect to see?

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

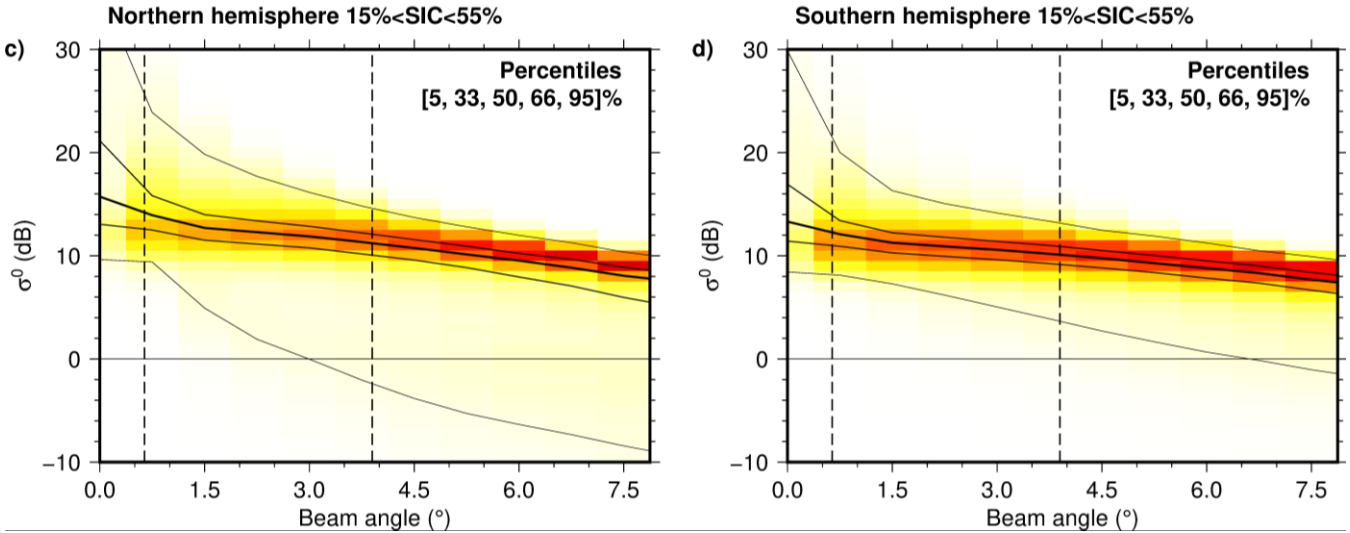


3. SWOT in the ice-covered oceans: Ka-band backscatter

- Used 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

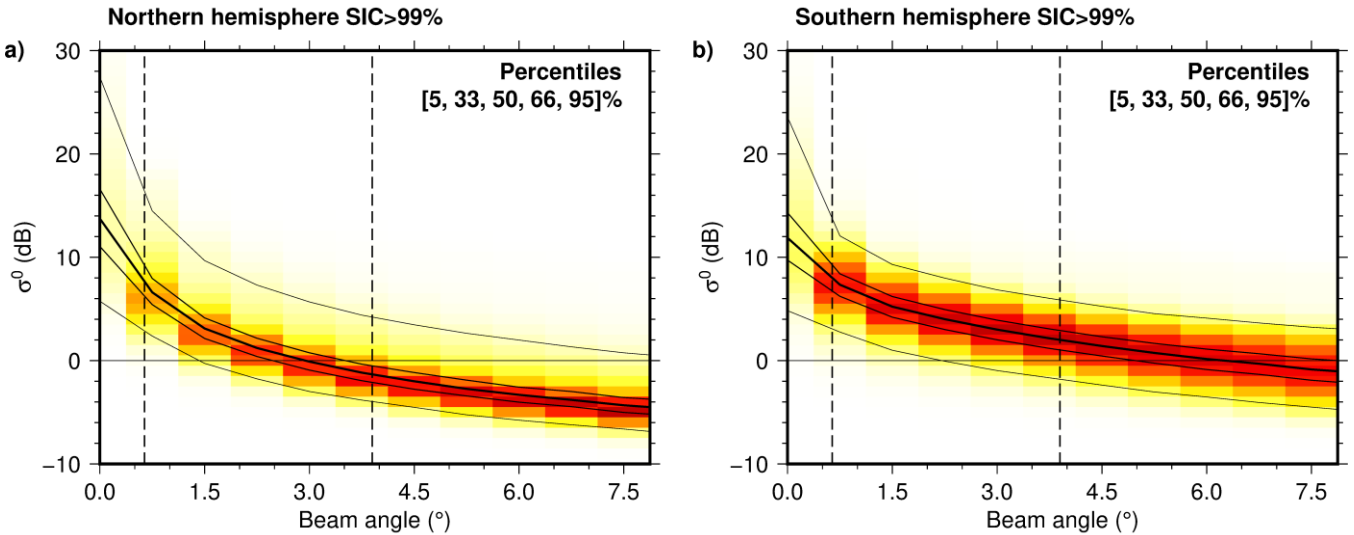
3. SWOT in the ice-covered oceans: Ka-band backscatter

- 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



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

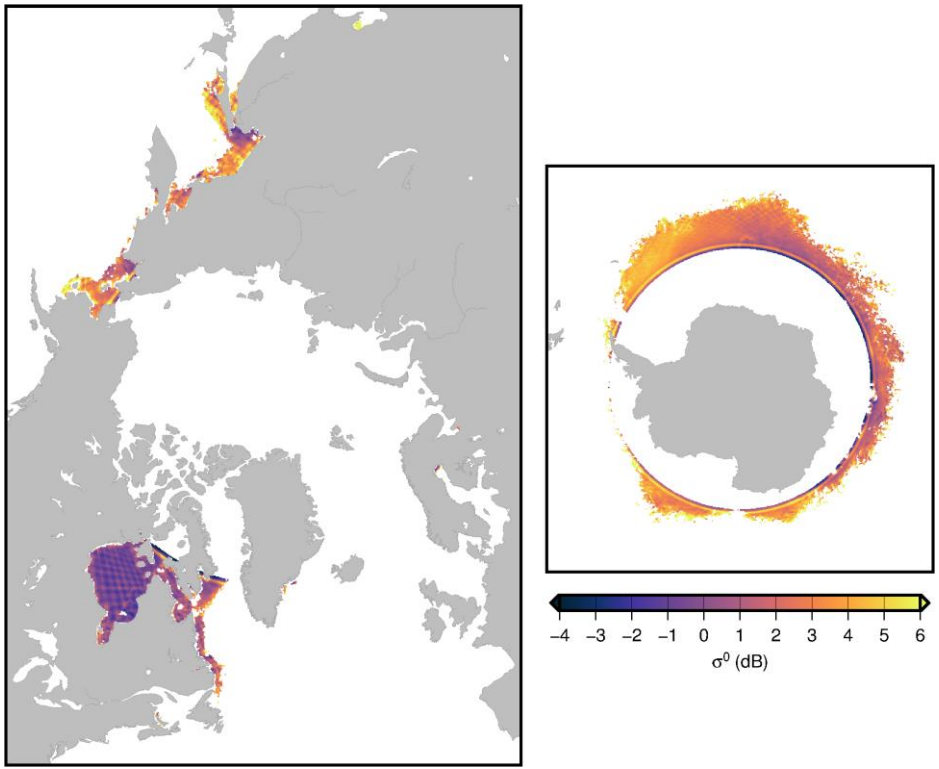
- Consolidated ice pack; sea ice concentration >99%
  - Faster drop off in σ^0 than open ocean



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

Limitations of GPM KaPR:

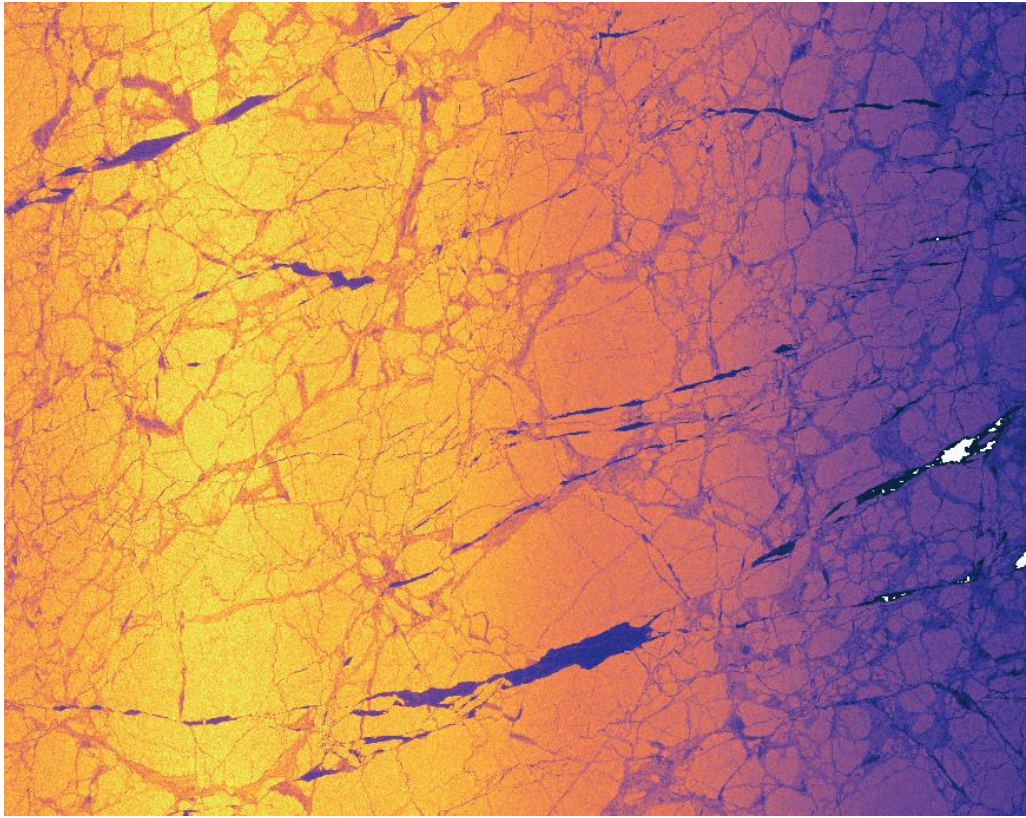
- Latitudinal coverage
  - Only captures low-latitude sea ice
  - Surface melt
  - Fairly thin, flat, first year ice
- Footprint ~5km
  - Specular open water might be swamped by ice



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

Other data:

- GLISTIN
- AirSWOT



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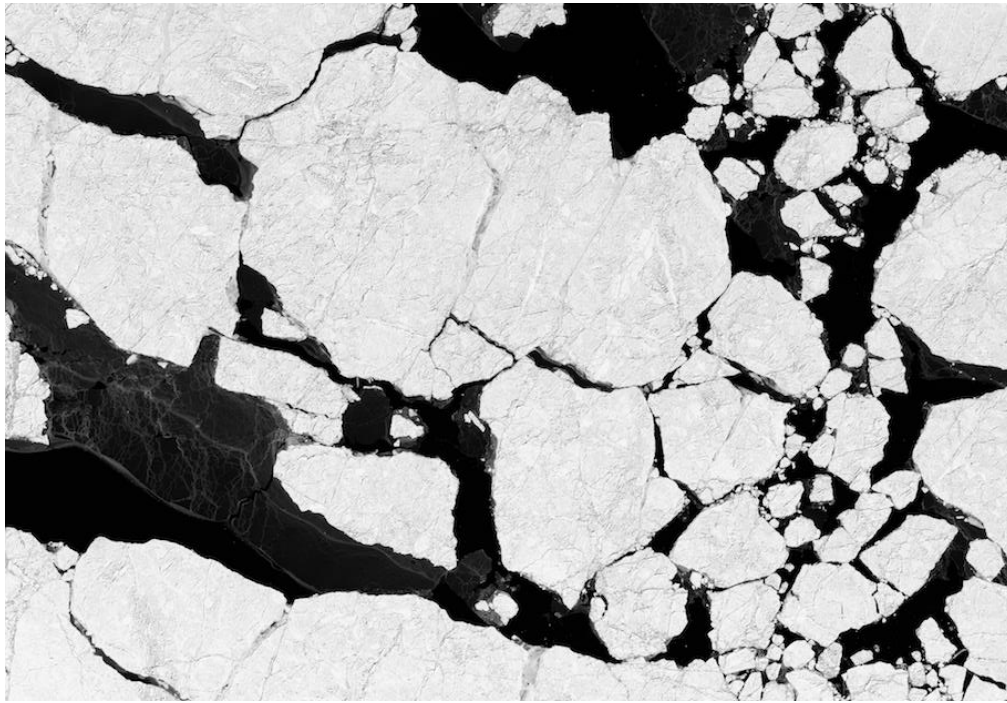
- Adapt the SWOT Hydrology Simulator
- Simulates expected SWOT performance
- Produces L1b products based on
  - SWOT projected orbit
  - SWOT radar parameters
  - An input elevation model
  - Surface type mask
  - Profiles of backscatter with angle for each surface type



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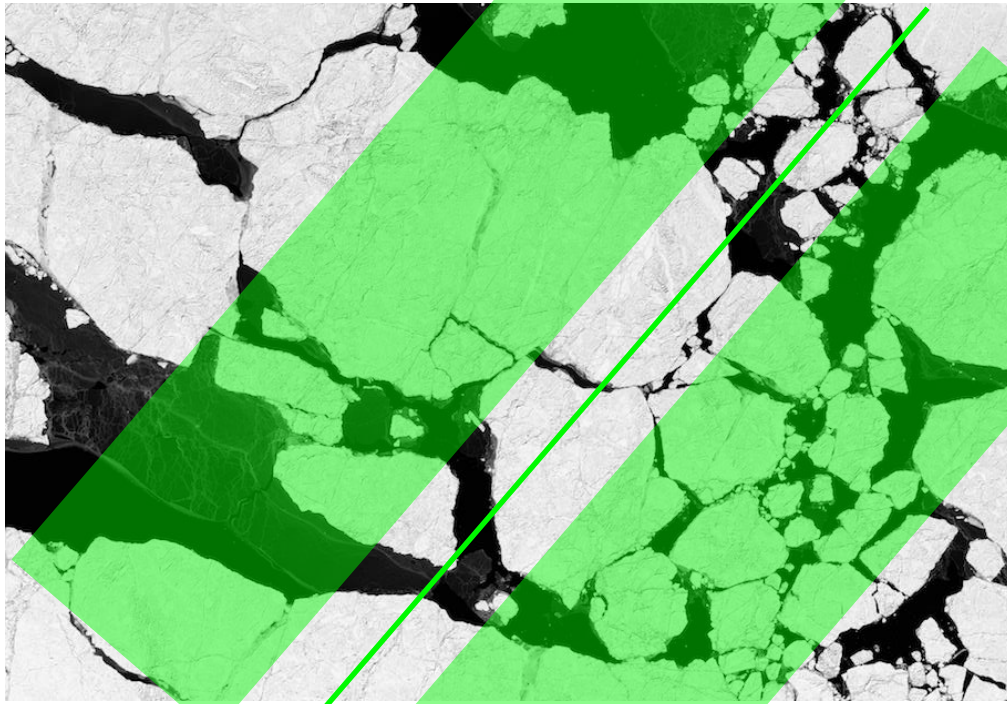

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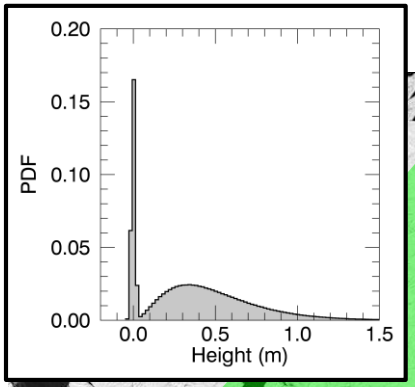

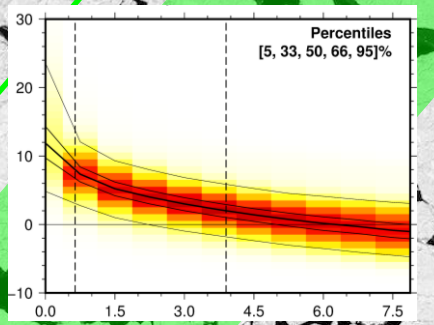

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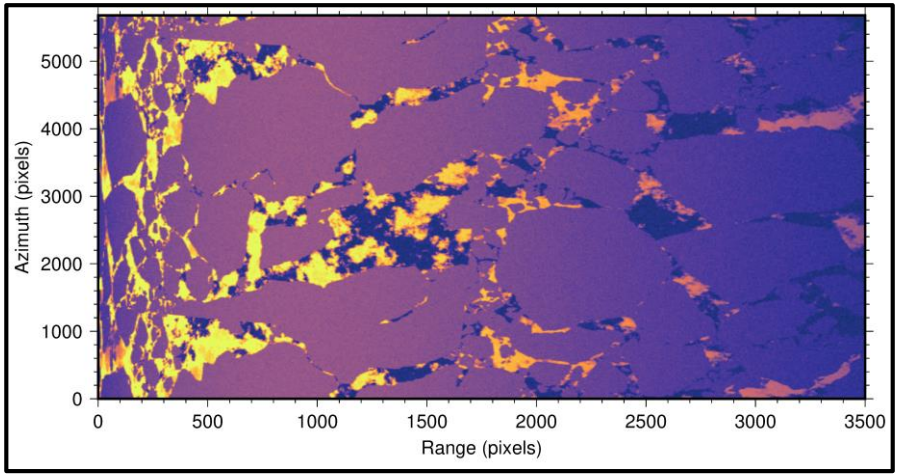

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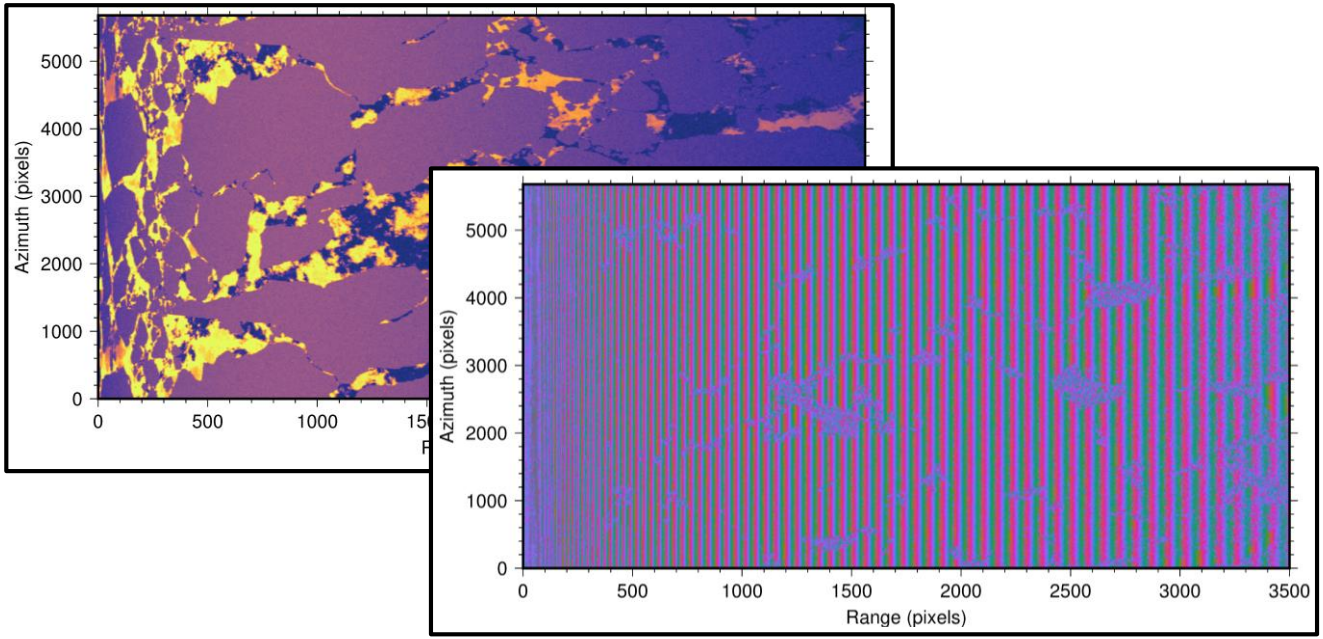

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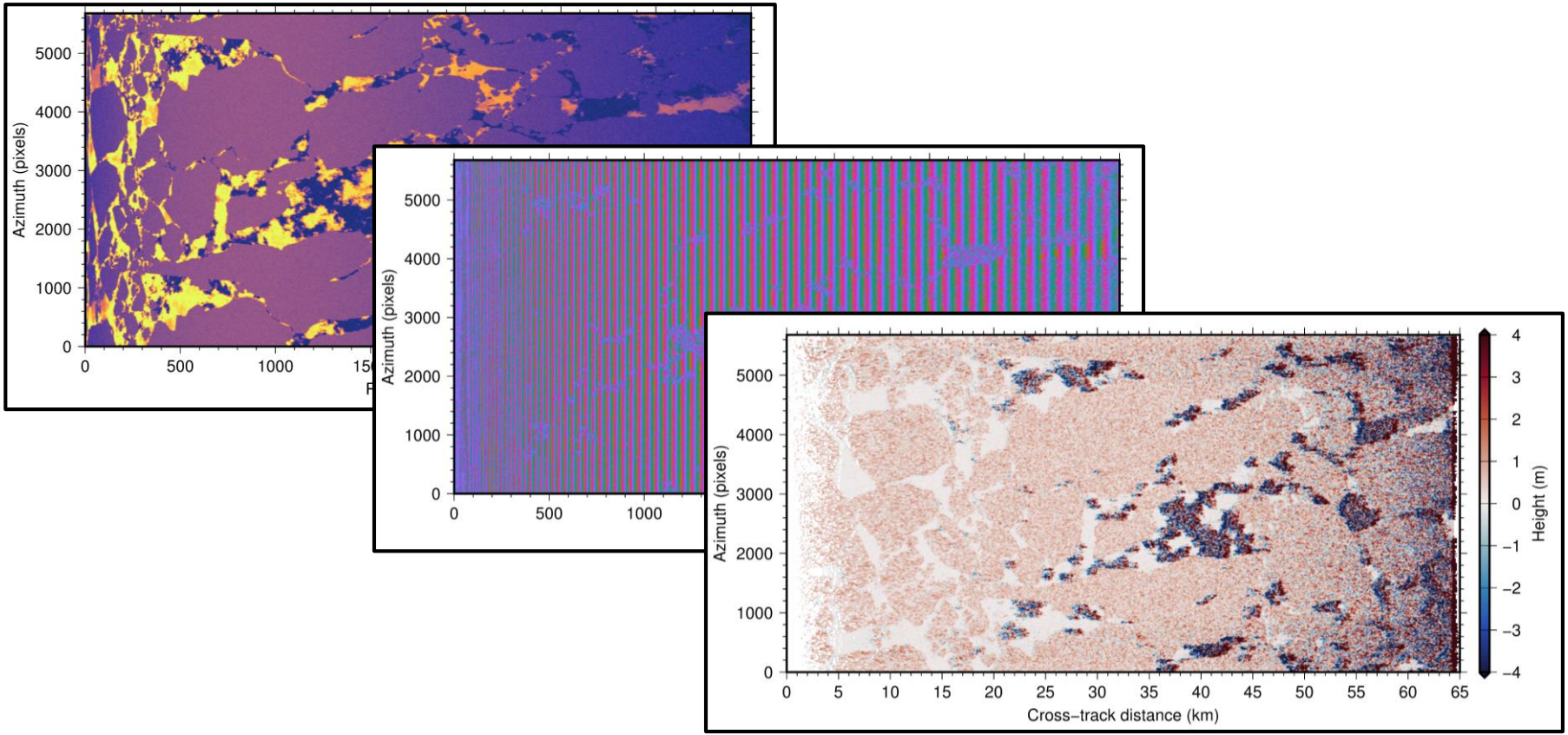

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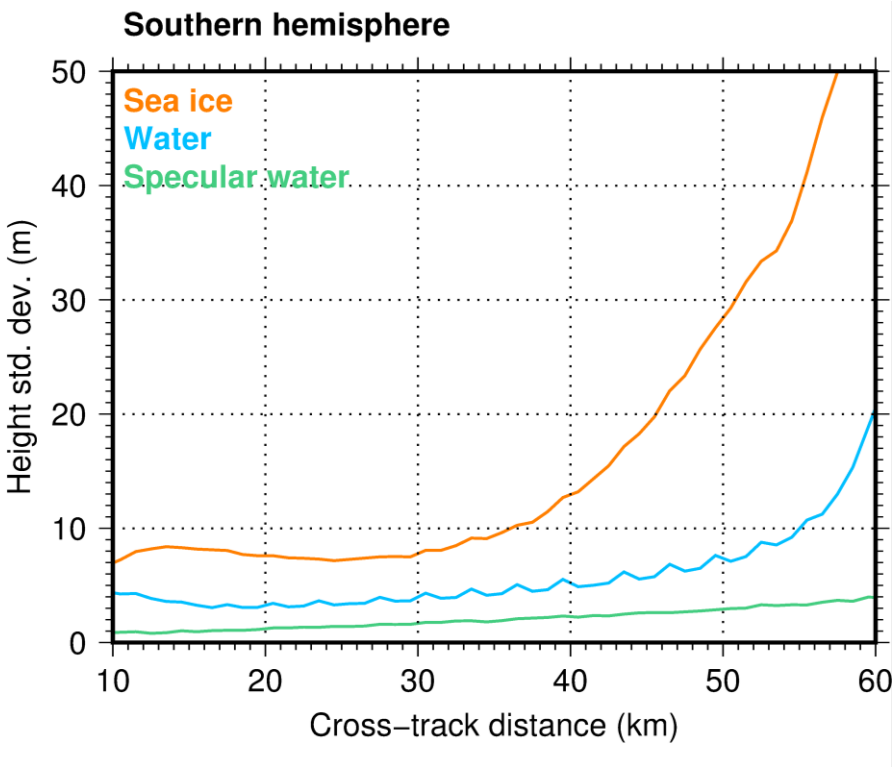
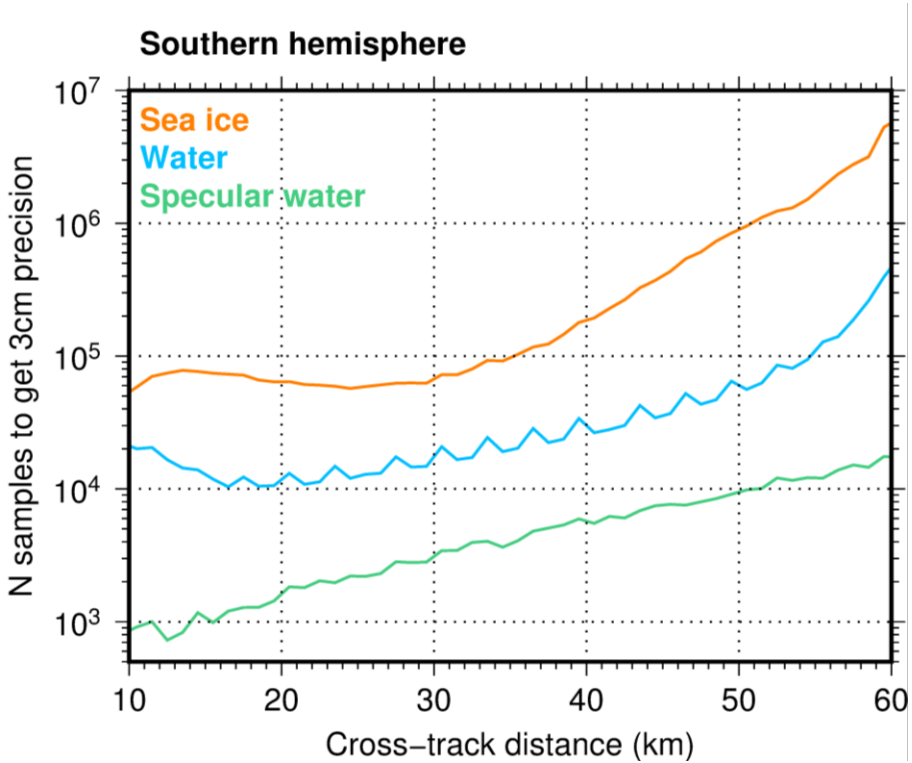
  - Phase uncertainty increases linearly with look angle



3. 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 ~500x500 m^2 (3cm precision)
  - Sea ice ~3x3 km^2 (3cm precision)



4. SWOT: Science in the ice-covered oceans

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What might SWOT deliver beyond nadir altimetry?

- 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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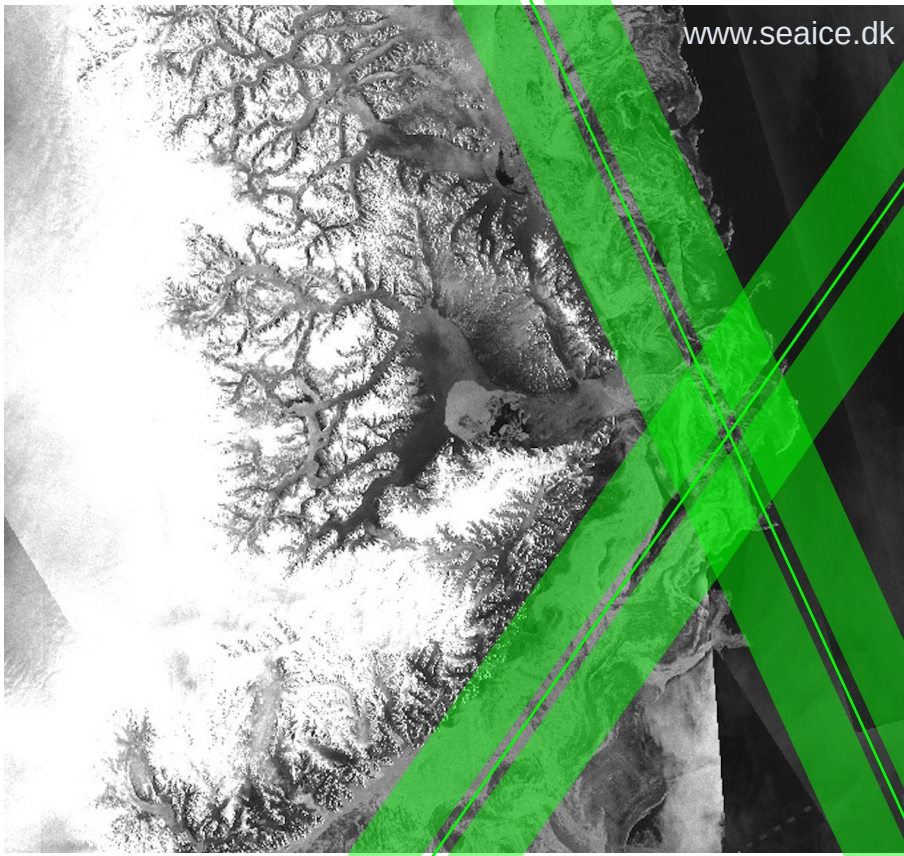

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