Wave attenuation in Arctic sea ice : a discussion of remote sensing capabilities

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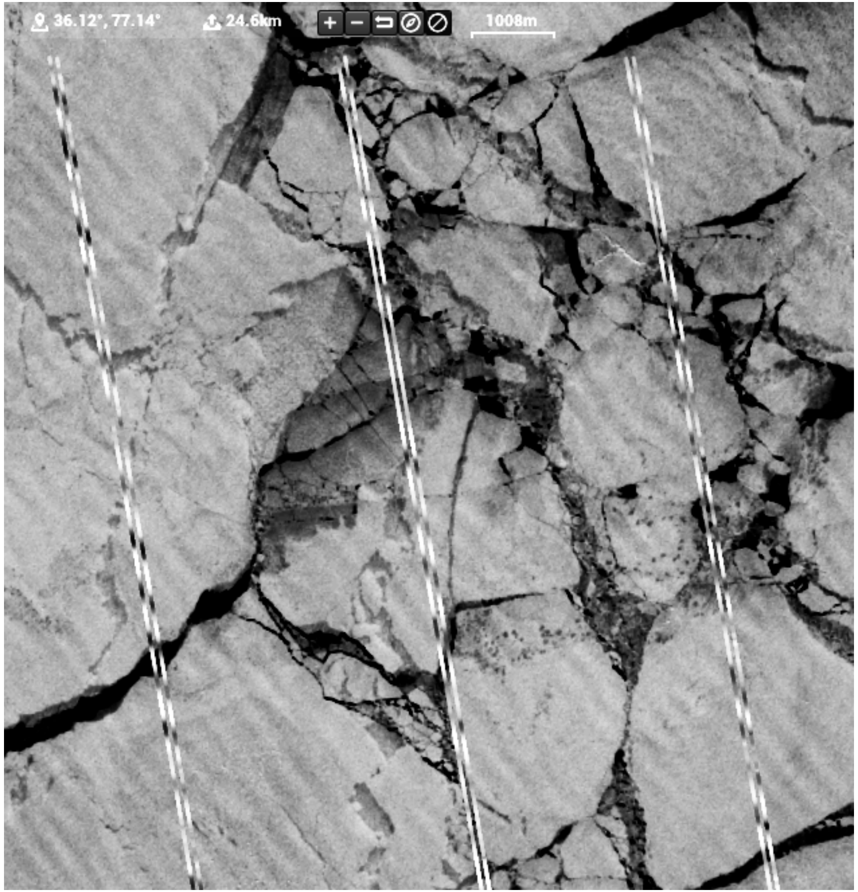
(in review with JGR-Oceans)



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1. Where we started

Wave-ice interactions

Pancakes and other water-ice mixtures (Rogers et al. 2016)

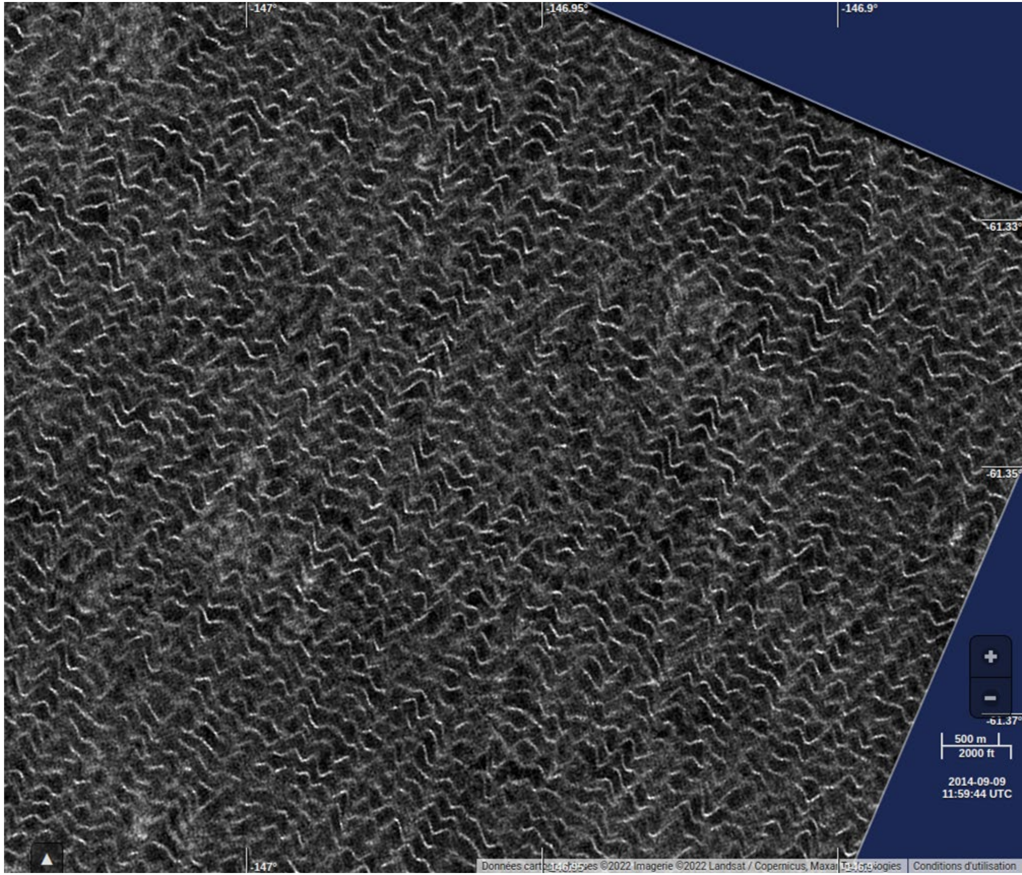
Effects of floe size & ice break-up on ice attenuation (Stopa et al. 2018, Ardhuin & al. 2020)

Remote sensing capabilities

SAR : Ardhuin et al. (2015, 2017 …)

IceSat-2: Horvat et al. (2020)

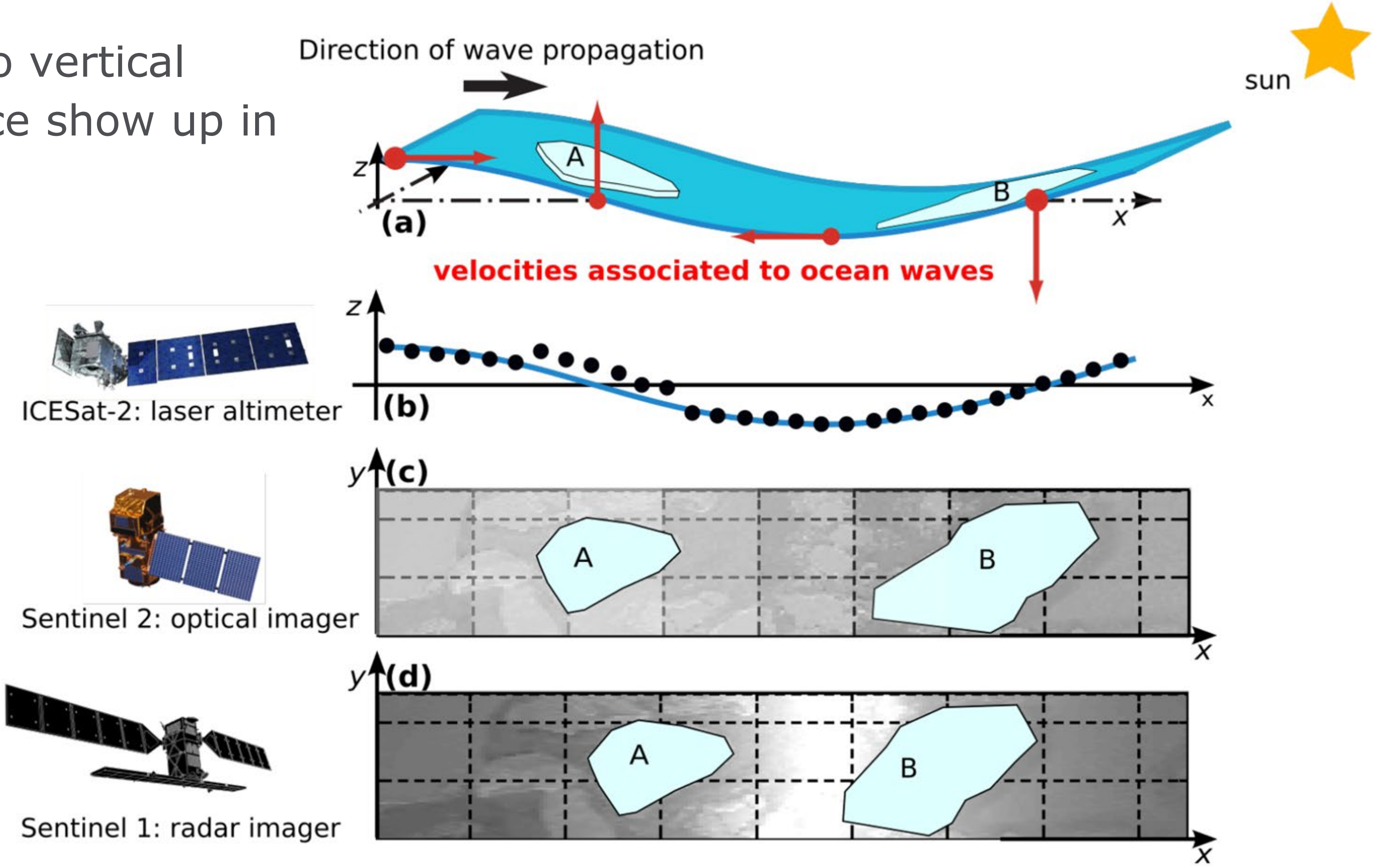
showed evidence of waves in sea ice



https://odl.bzh/ervLazPA

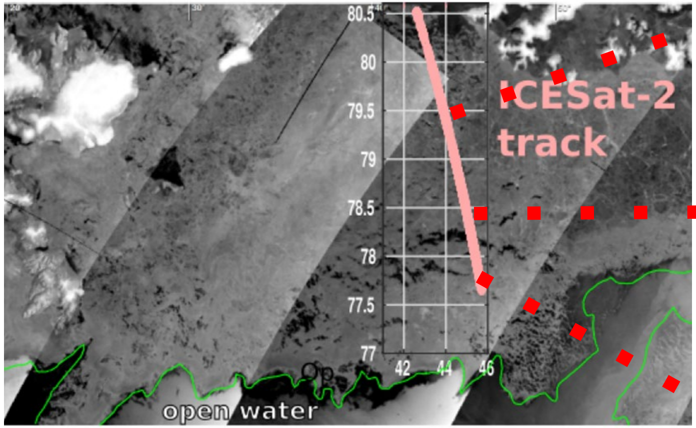
2. What can be observed

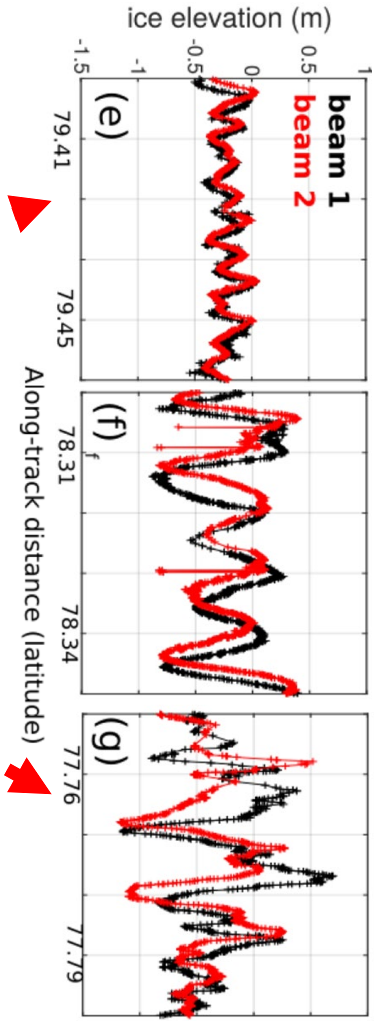
From « ice height » to vertical velocities: waves in ice show up in remote sensing data

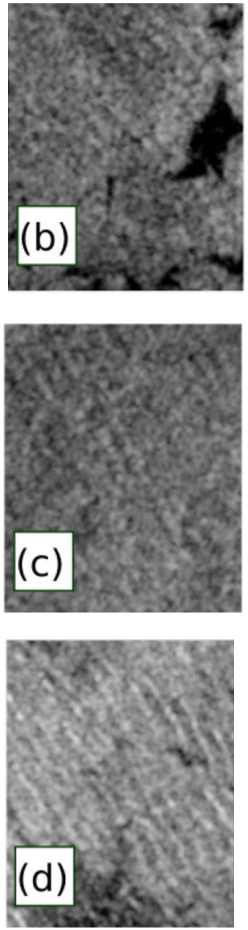


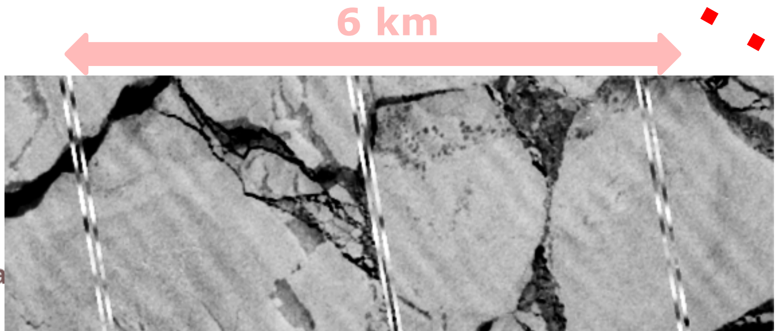
2. Wave parameters from ICESat-2

Signature in ICESat-2 lidar data
(Horvat et al. 2020)









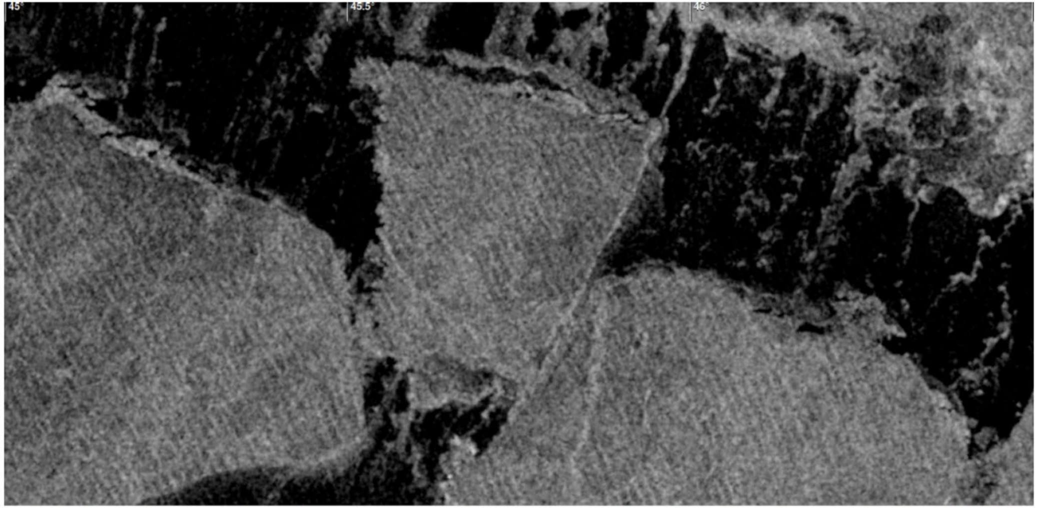
3. Wave spectra from S2

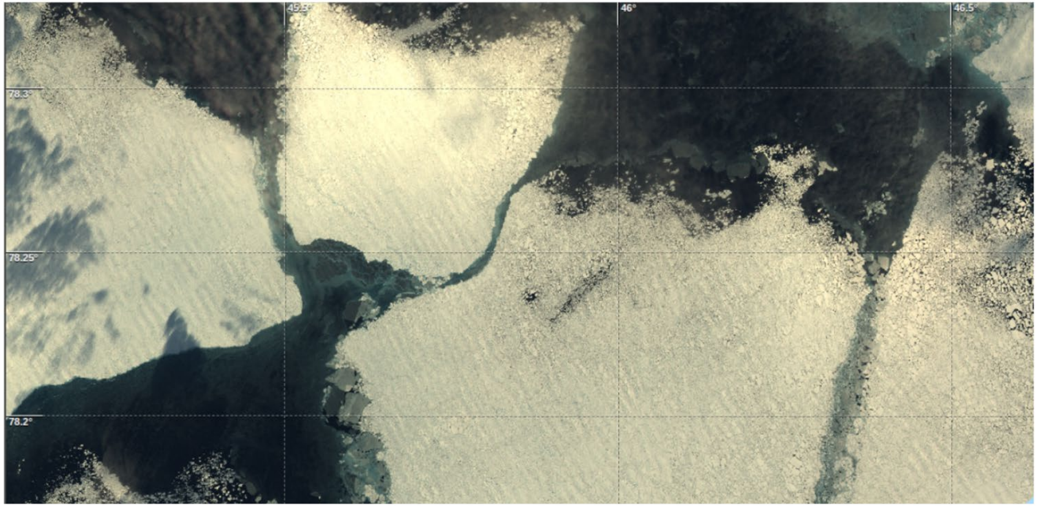
Optical imagery with grazing sun

$$\rho_{\mathrm{L1c}} = \rho_{\mathrm{true}} \frac{\cos(\theta_l)}{\cos(\theta_{\mathrm{Sun}})}$$

gives a MTF,

$$M = k \tan \theta_{\mathrm{Sun}} \cos(\phi_{\mathrm{Sun}} - \phi_w)$$





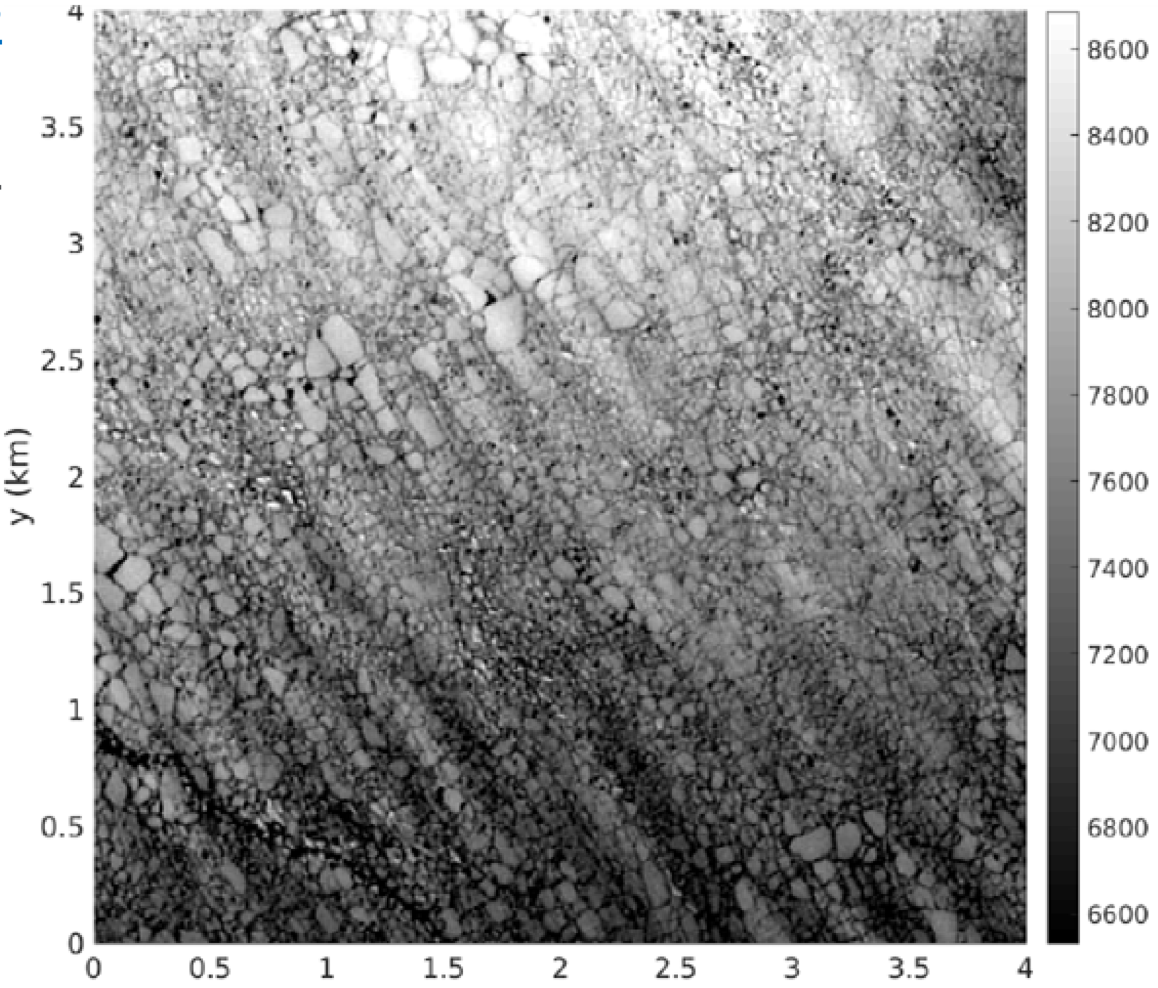
3. Wave spectra from S2

One minor issue:
water-ice edges (floes, leads) …

Here: 10 m resolution

NB: next generation S2 will
Have 5 m pixels!

we should correct MTF
for water fraction
(defined using threshold …)



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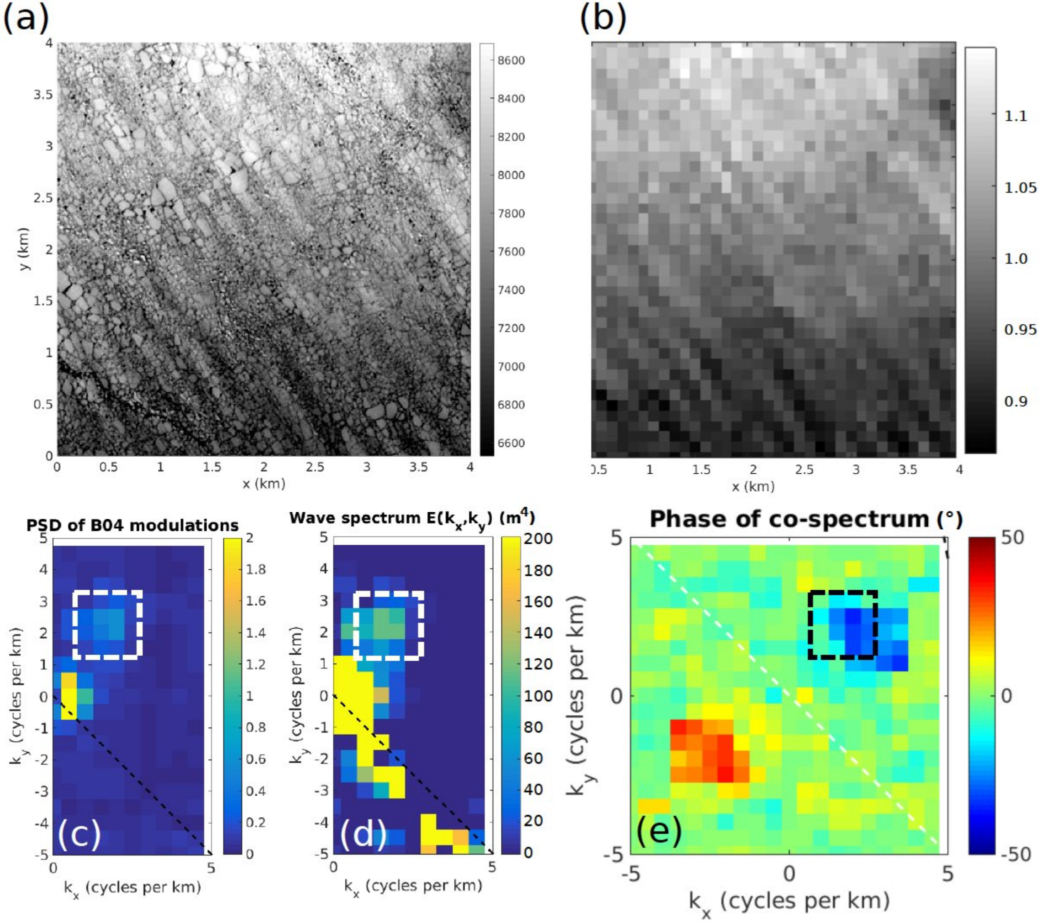
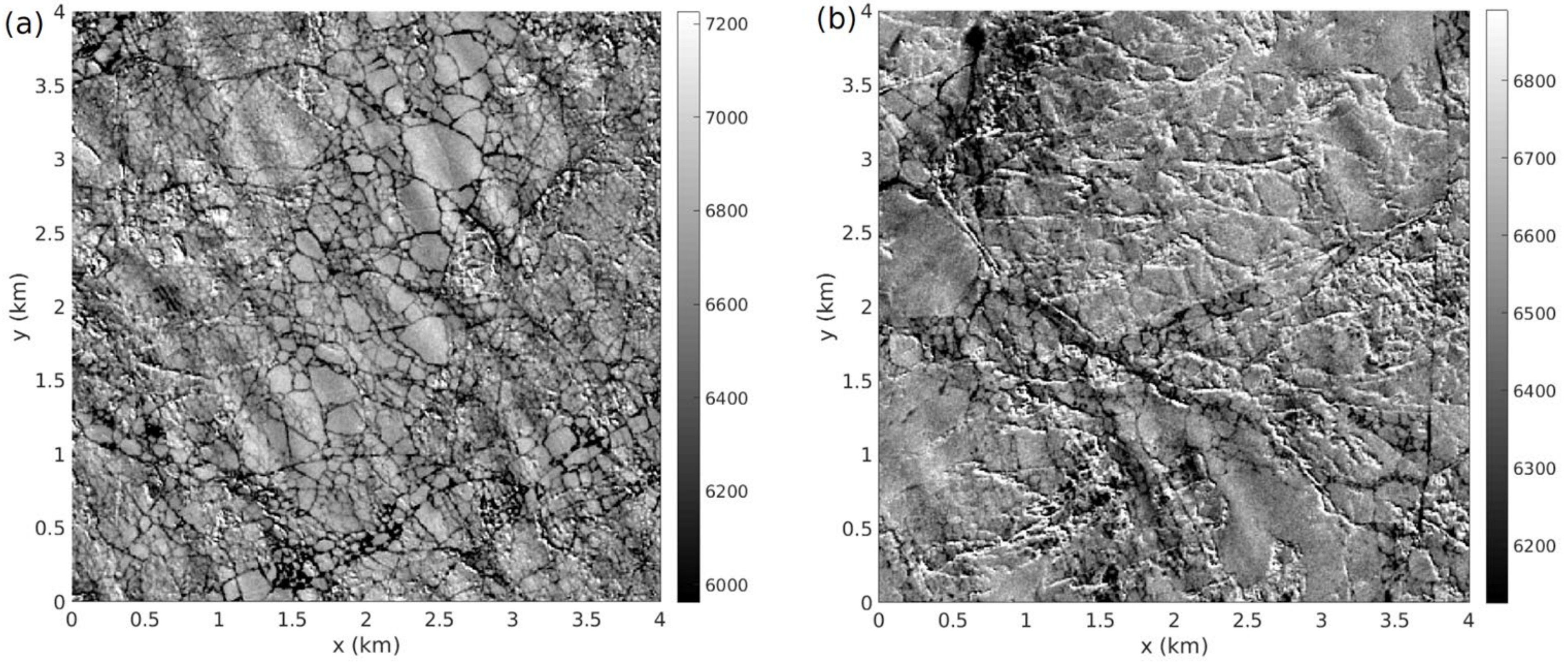
Which can be inverted to get
The wave spectrum E(kx,ky)

(NB: no 180° ambiguity thanks to cross-spectra of multiple bands, here B04-B02)



3. Wave spectra from S2 Other examples



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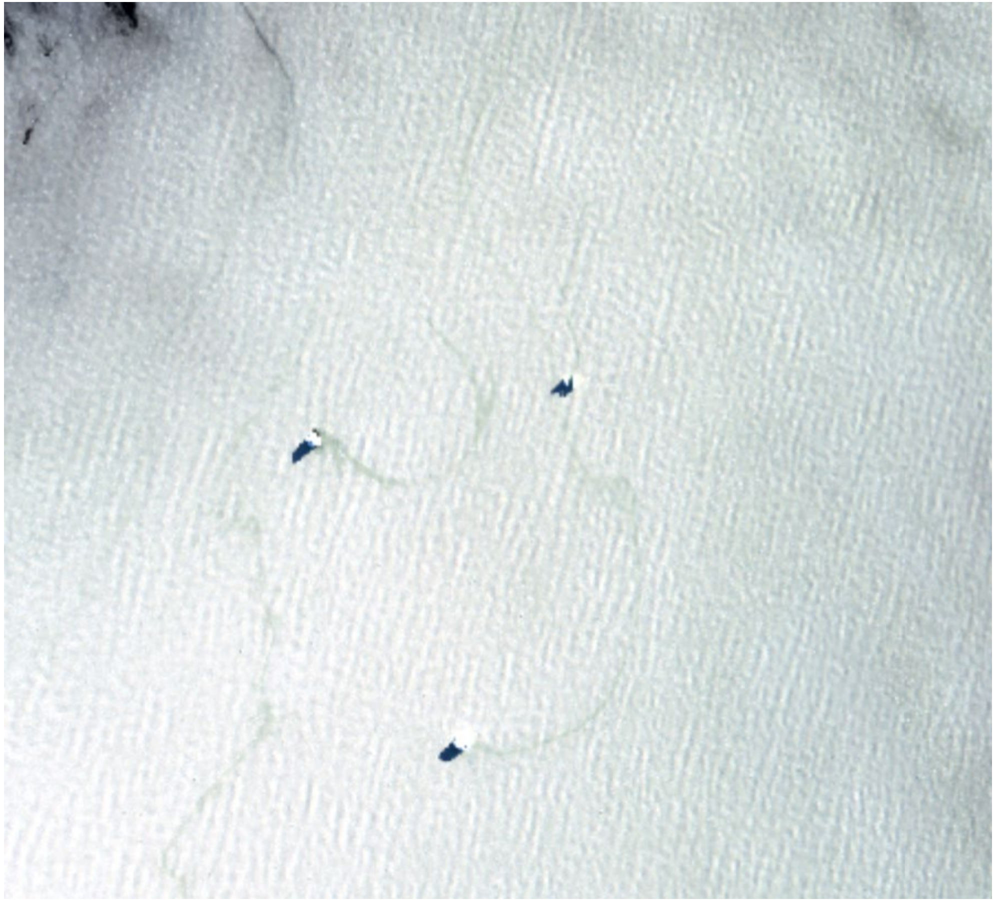
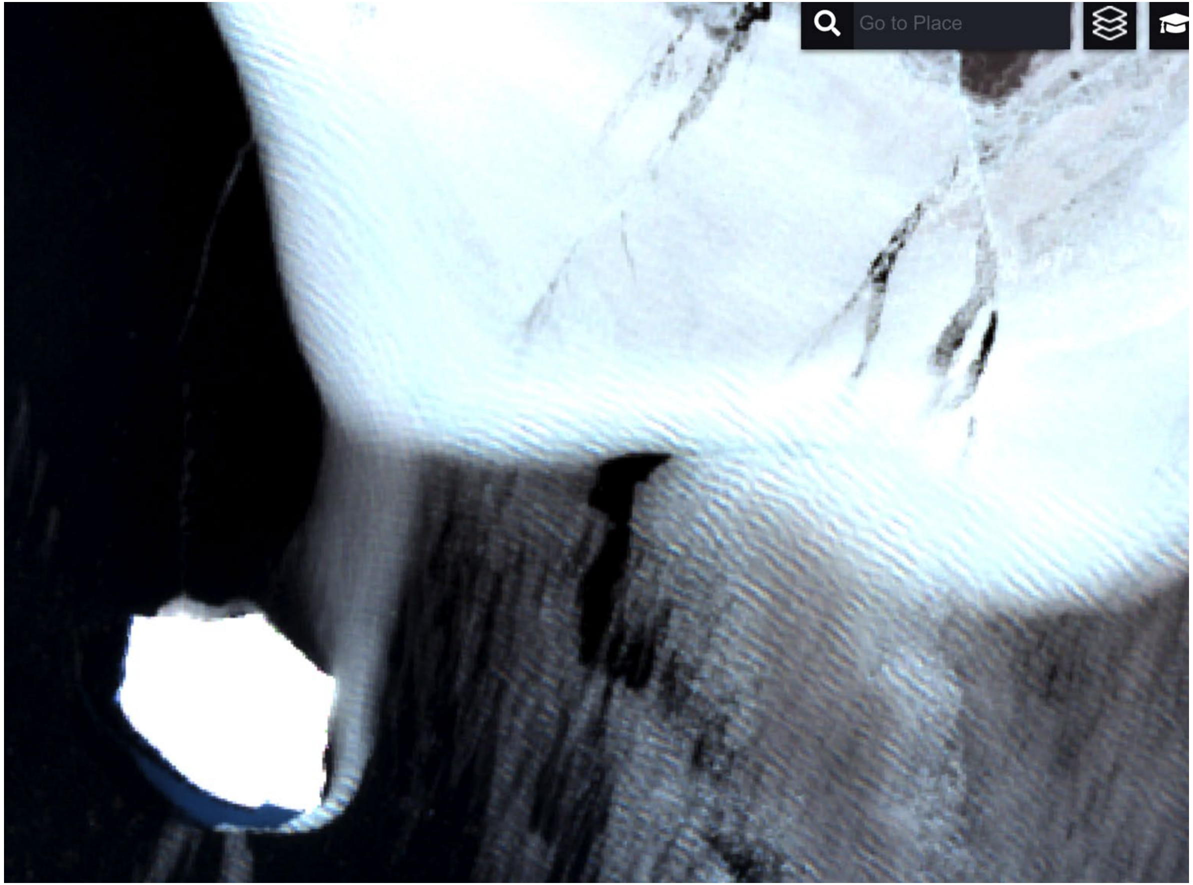


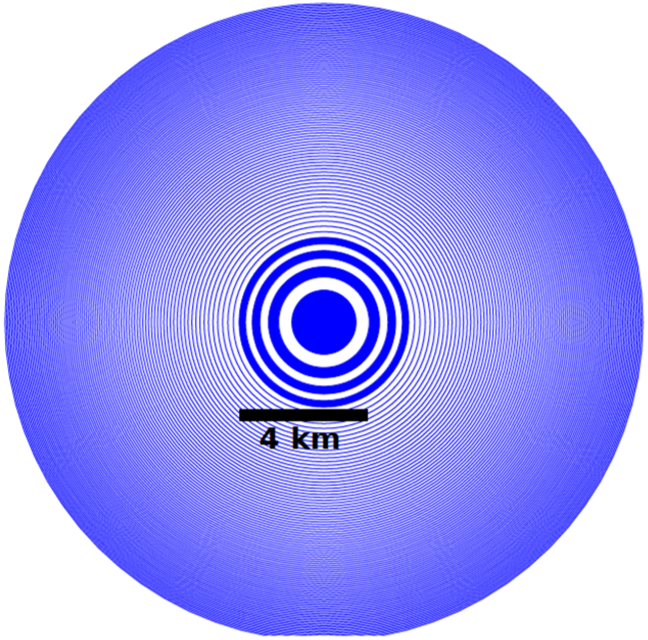
3. Wave spectra from S2 Other examples

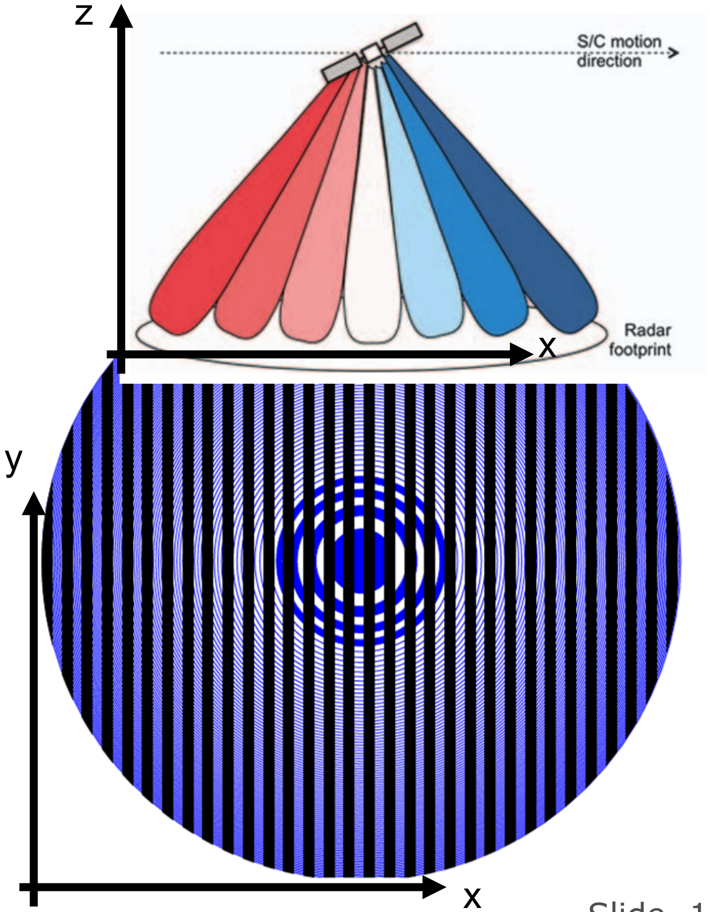


4. Wave signatures in S3 - FFSAR

Sentinel 3 L1b data: O(300 m) along-track res. dx

Going back to L1a: can do any dx !

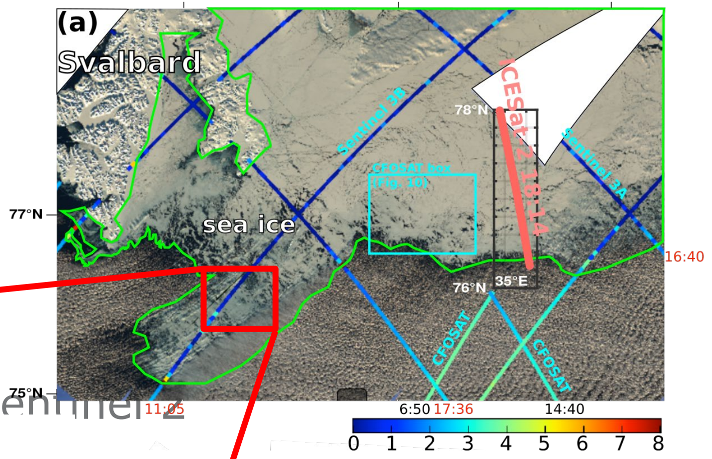


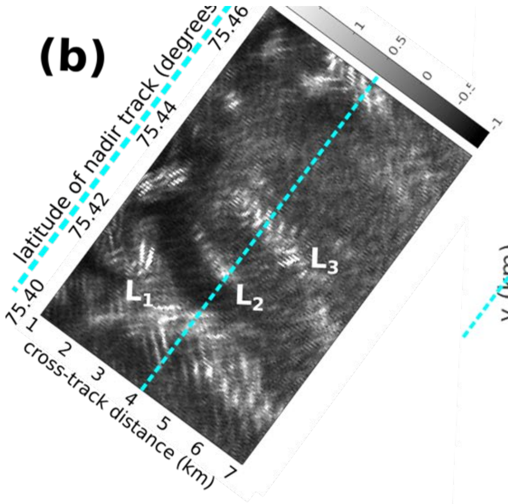


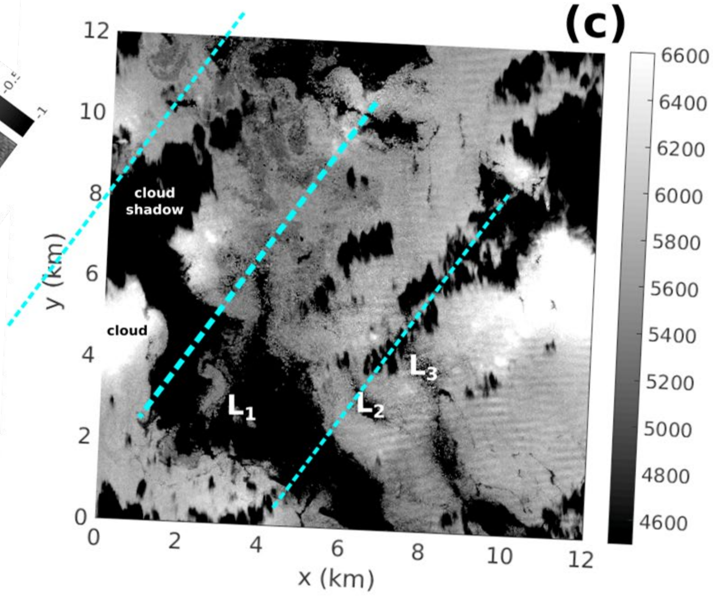
4. Wave signatures in S3 - FFSAR

Look at the same swell-in-ice event …

Sentinel 3–FFSAR







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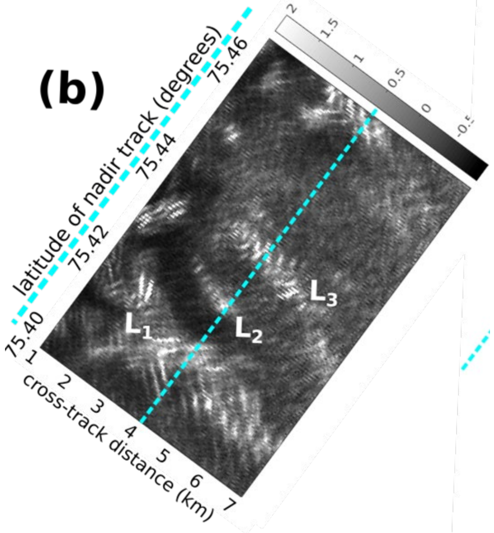
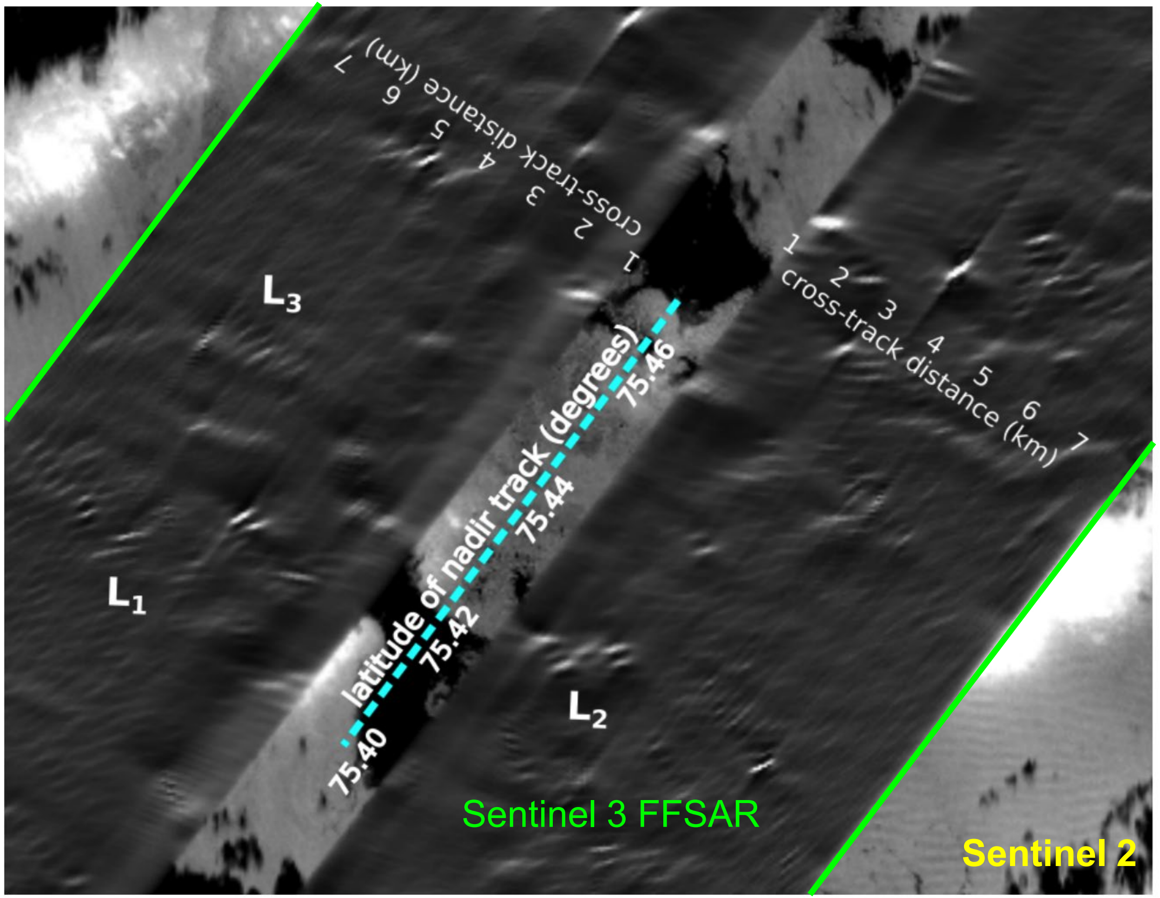
Look at the same swell-in-ice ev

Sentinel 3–FFSAR -> unfolding





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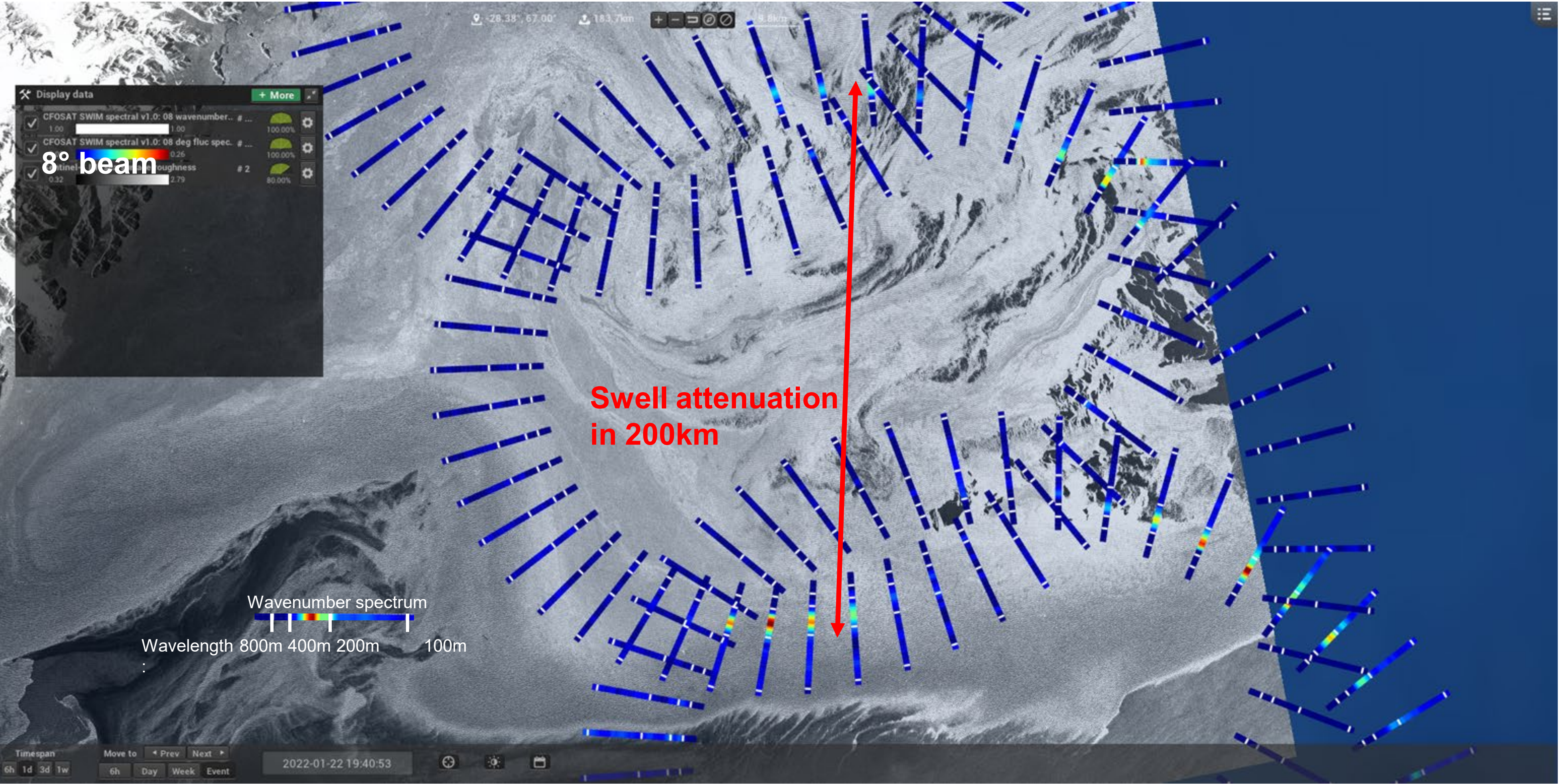
5. Last sensor: CFOSAT's SWIM instrument



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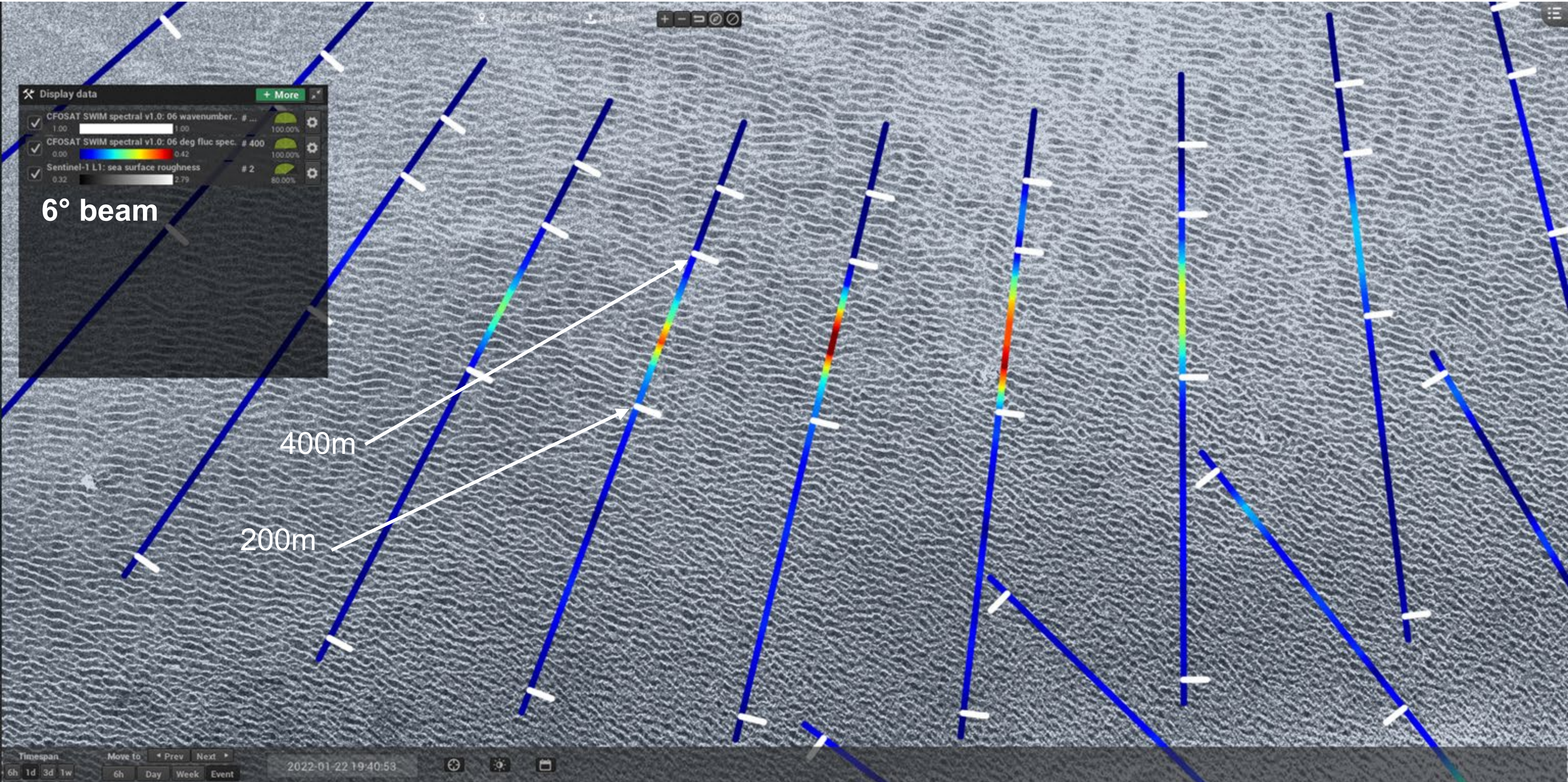
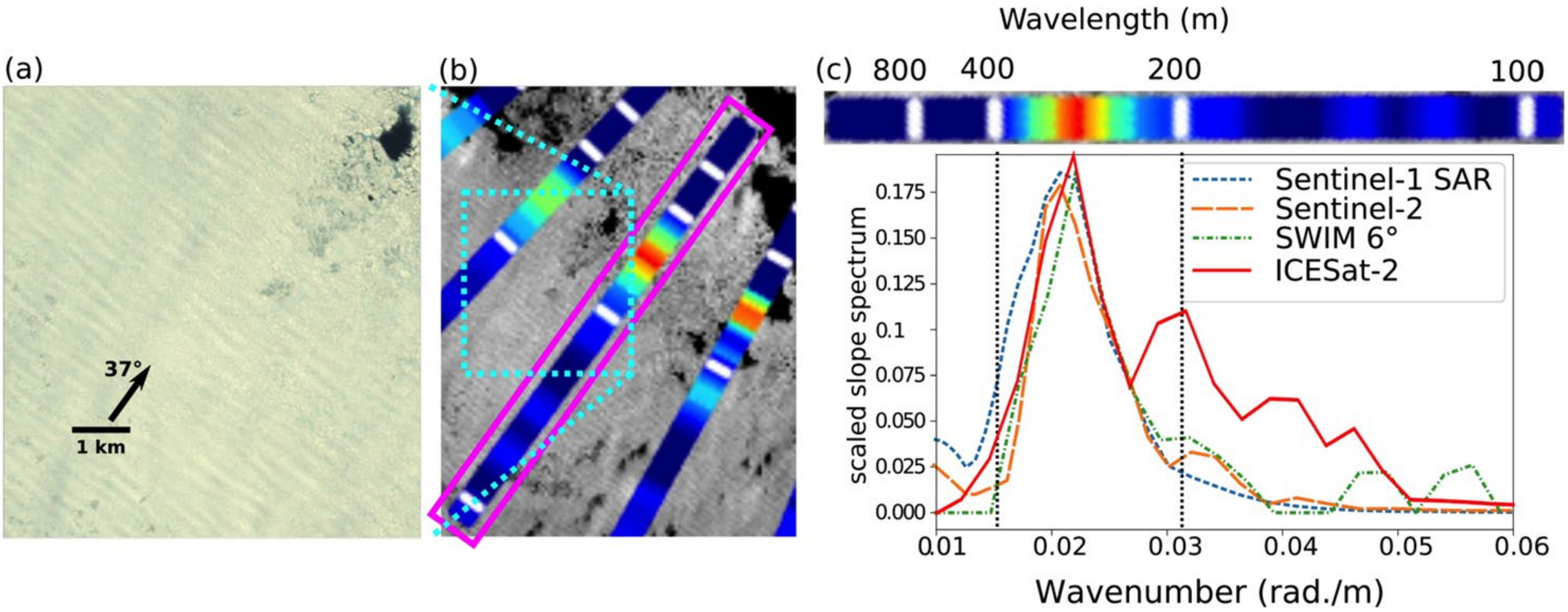


5. Last sensor: CFOSAT's SWIM instrument

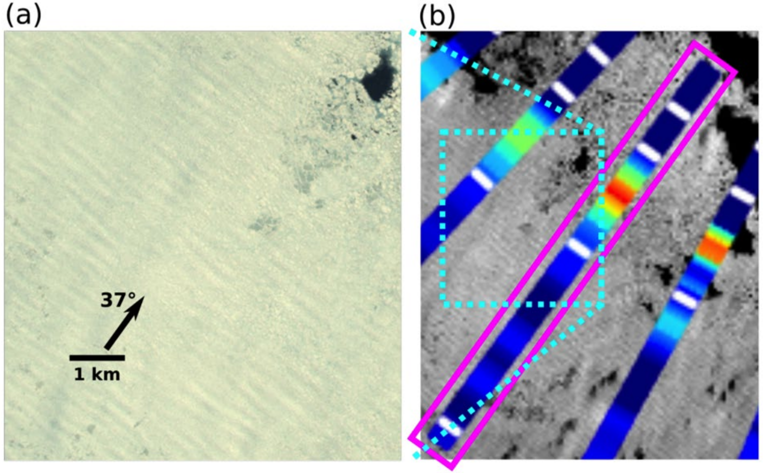
In this case modulations are averaged over O(20 km)

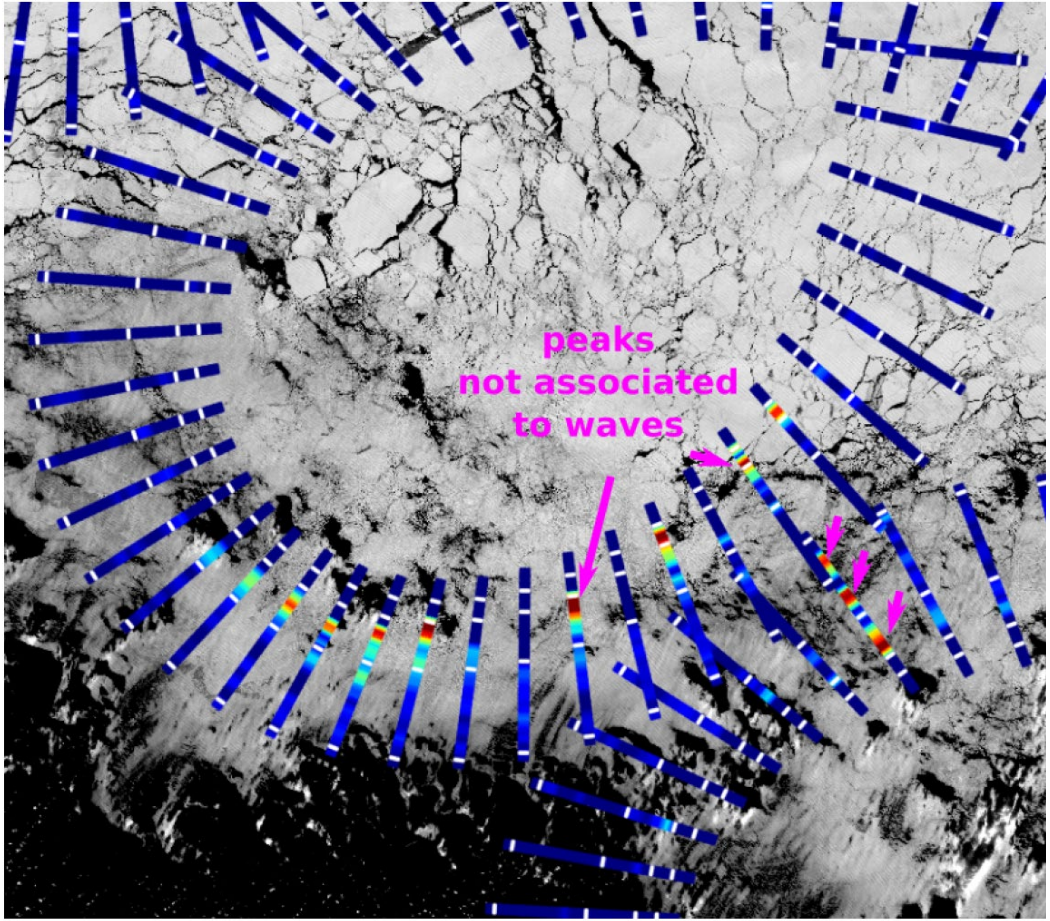


5. Last sensor: CFOSAT's SWIM instrument

But … Ice features can also give modulations!

Hard to discriminate without a real image of the surface …





Conclusions

All radar and optical systems that can resolve waves in sea ice but,

- Transformation from wave elevation to measurements can be non-linear

- Ice features may produce errors in wave parameter retrievals

- These errors are more easily detected in high resolution imagery