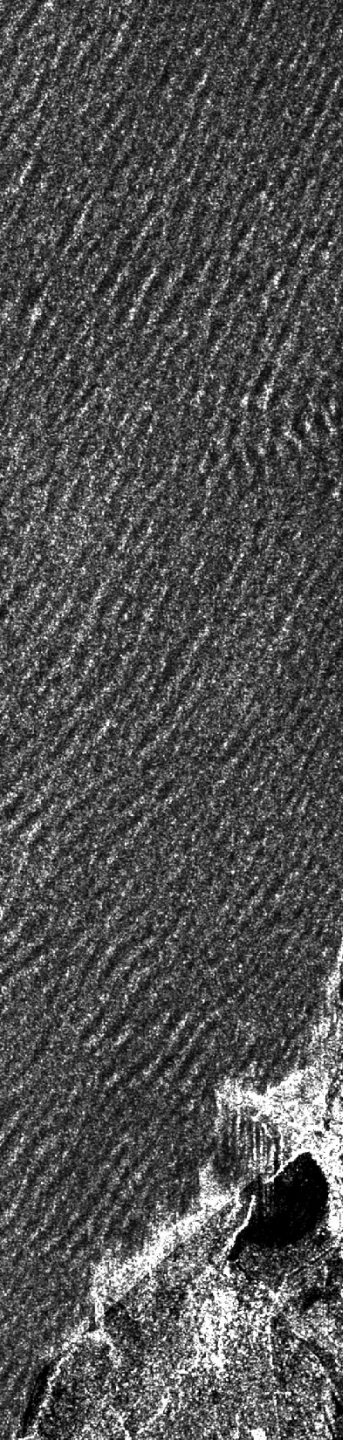

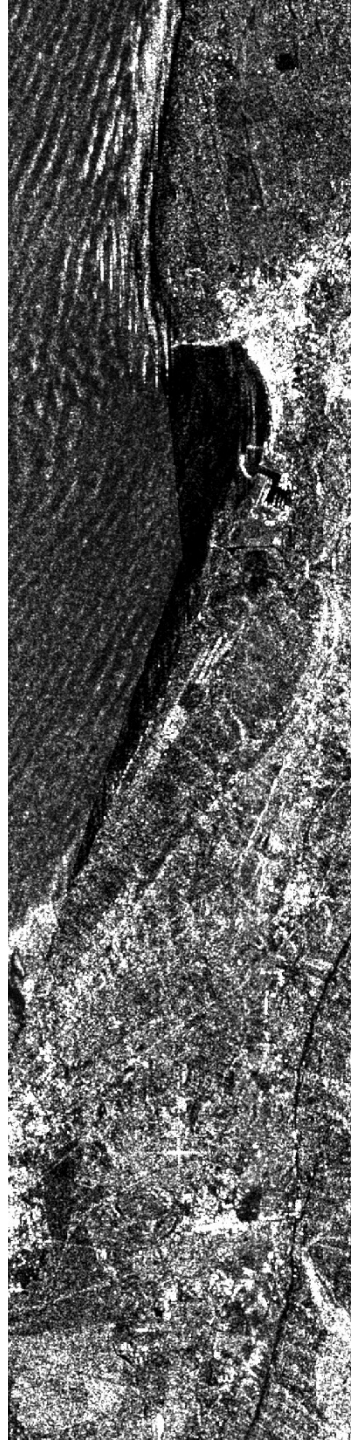

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CROSS-SPECTRAL ANALYSIS OF SAR ALTIMETRY WAVEFORM TAILS

08 November 2023

Partners

isardSAT

OceanDataLab

TU Delft Delft University of Technology

DLR Deutsches Zentrum für Luft- und Raumfahrt

LOPS

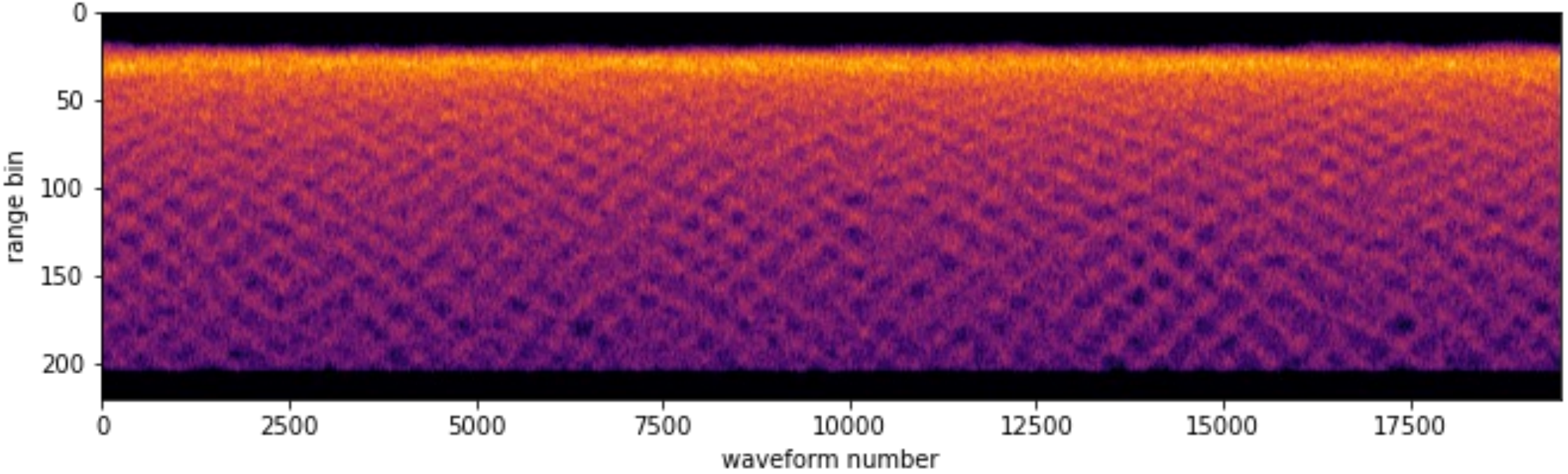
CLS SpaceTech RESEARCH CENTRE FOR SPATIAL INFORMATION

Politehnica University of Bucharest 200 1818

Funded by

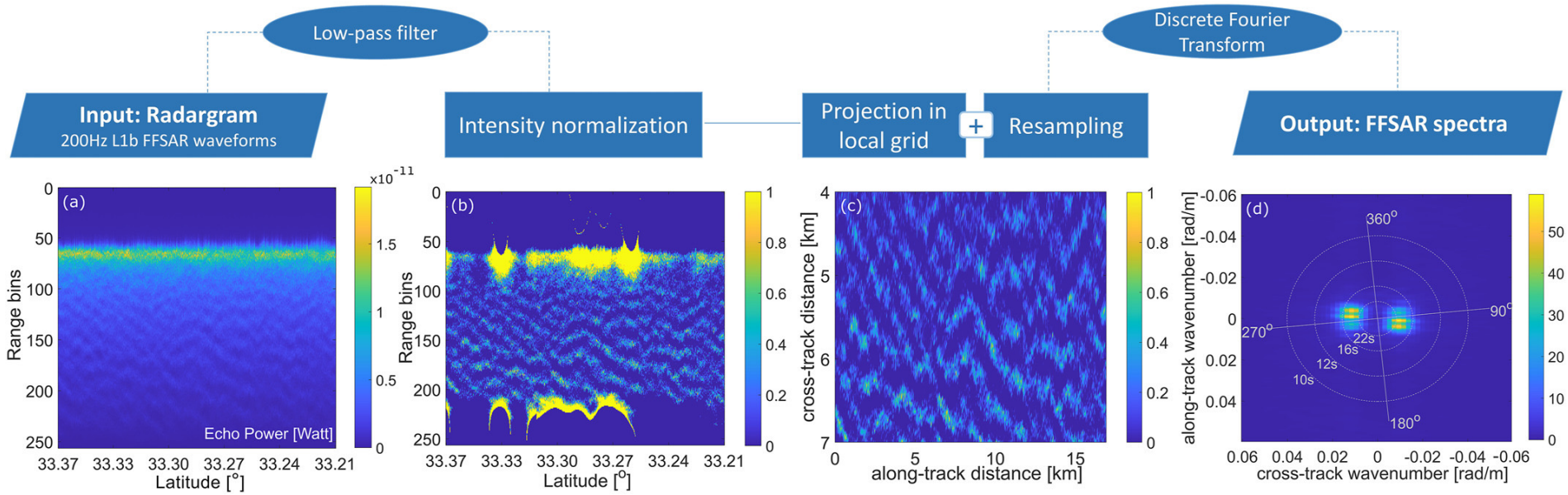
esa

Waveform tail backscatter modulations

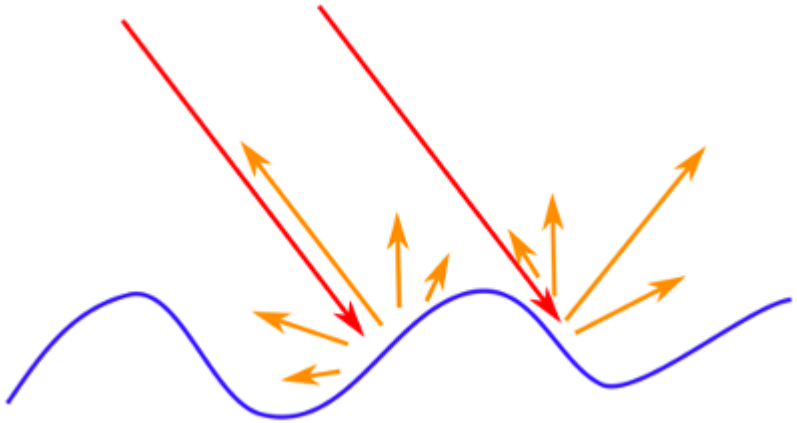


Altimetry SAR spectrum

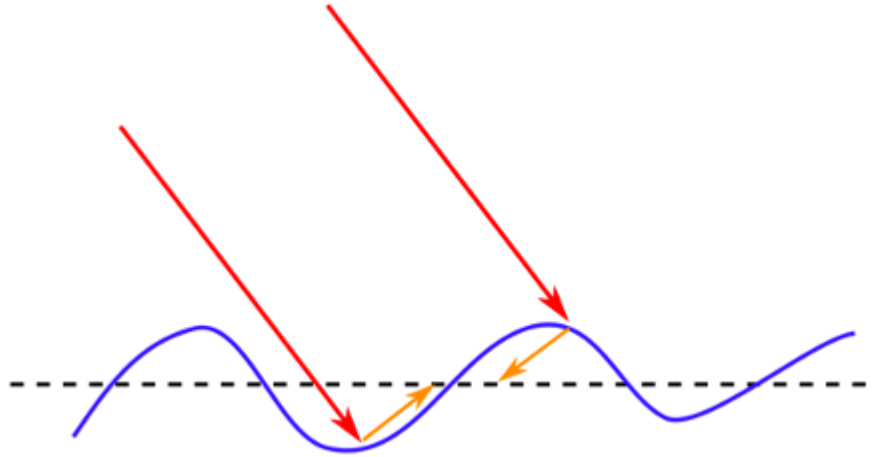
- Processing follows Altiparmaki et al. (2022).
- Correction for Earth's curvature.



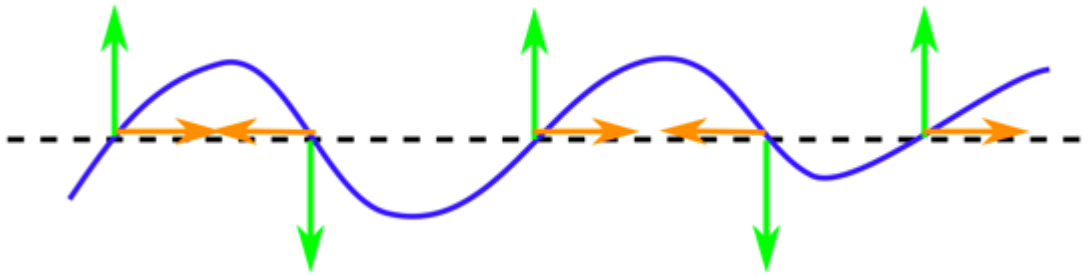
Modulation mechanisms



Tilt modulation

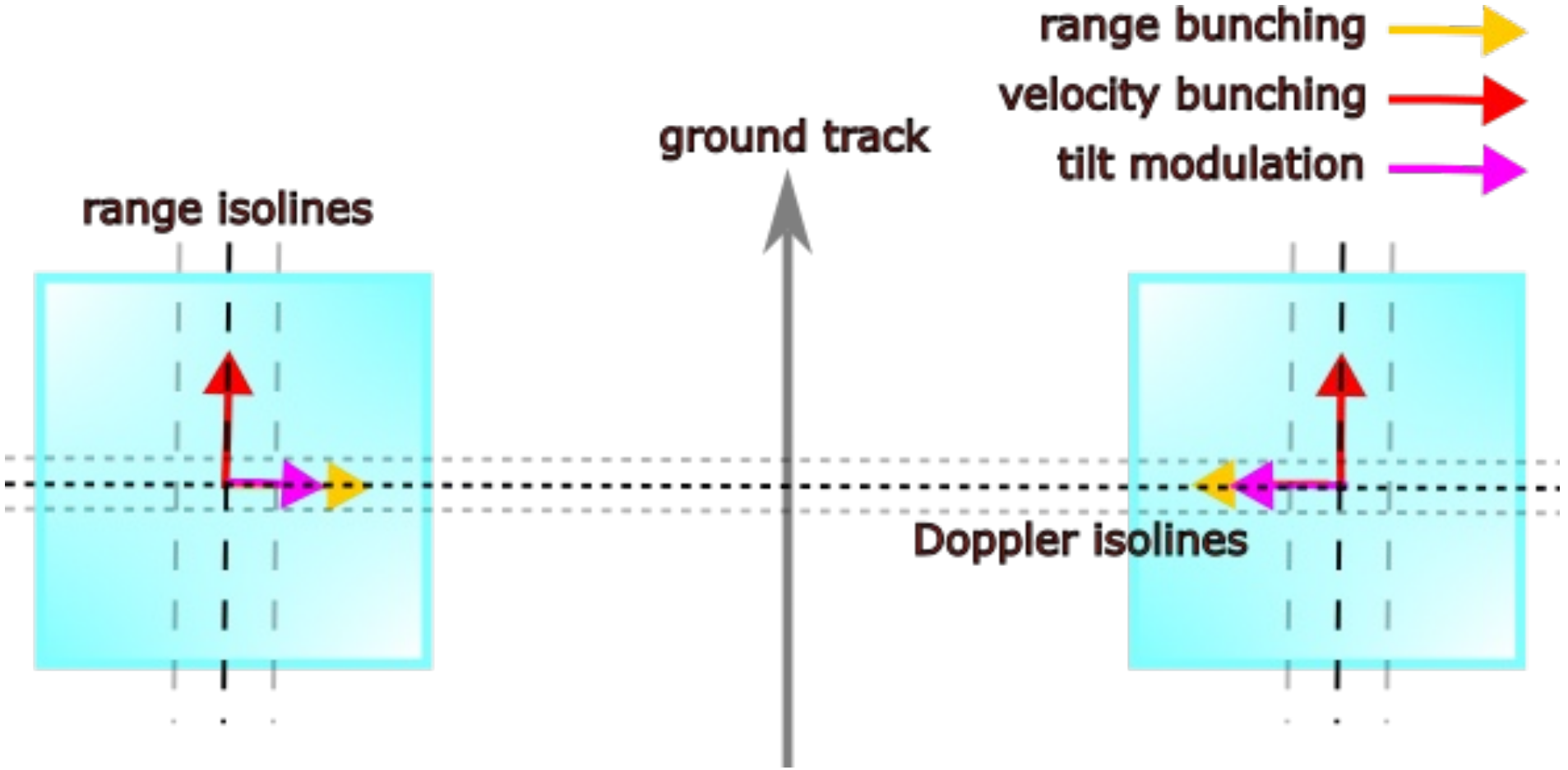


Range bunching



Velocity bunching

Zero-Doppler geometry



Closed-form model

Significant wave height

Velocity variance

Range bunching

Velocity bunching

Tilt modulation

$$P(k_x,k_y) = e^{-k_x^2\rho_{xx}(0,0)-k_y^2\rho_{yy}(0,0)-k_xk_y(\rho_{xy}(0,0)+\rho_{yx}(0,0))} \int\int e^{k_x^2\rho_{xx}+k_y^2\rho_{yy}+k_xk_y(\rho_{xy}+\rho_{yx})}(1+\rho_{II})e^{-i(k_xx+k_yy)}dxdy.$$

$$\rho_{ab} = \frac{1}{(2\pi)^2}\int\int \frac{1}{2}T_a(k_x,k_y)T_b^*(k_x,k_y)S(k_x,k_y) + \frac{1}{2}(T_a(-k_x,-k_y)T_b^*(-k_x,-k_y))^*S(-k_x,-k_y)dk_xdk_y$$

Transfer functions

$$\lambda_{ct} \propto \pi\sqrt{\rho_{xx}(0,0)} = \pi\sqrt{\frac{\sigma_e^2}{\tan^2(\theta)}} = \pi\frac{\mathrm{SWH}}{4\tan(\theta)}$$

$$\lambda_c \propto \pi\sqrt{\rho_{yy}(0,0)} = \pi\frac{R_t}{U}\sqrt{\sigma_v^2}$$

Fall-off ellipse!

$$T_y = -\frac{R_t}{U}(i\omega)$$

$$T_x = \frac{1}{\tan(\theta)}$$

$$T_I = -ik_x\frac{1}{\sigma_0}\frac{\delta\sigma_0}{\delta\theta}$$

Low incidence angles → highly non-linear range-shift behavior.
Closed-form not valid for nadir altimeters!!! Only ‘pedagogic’.

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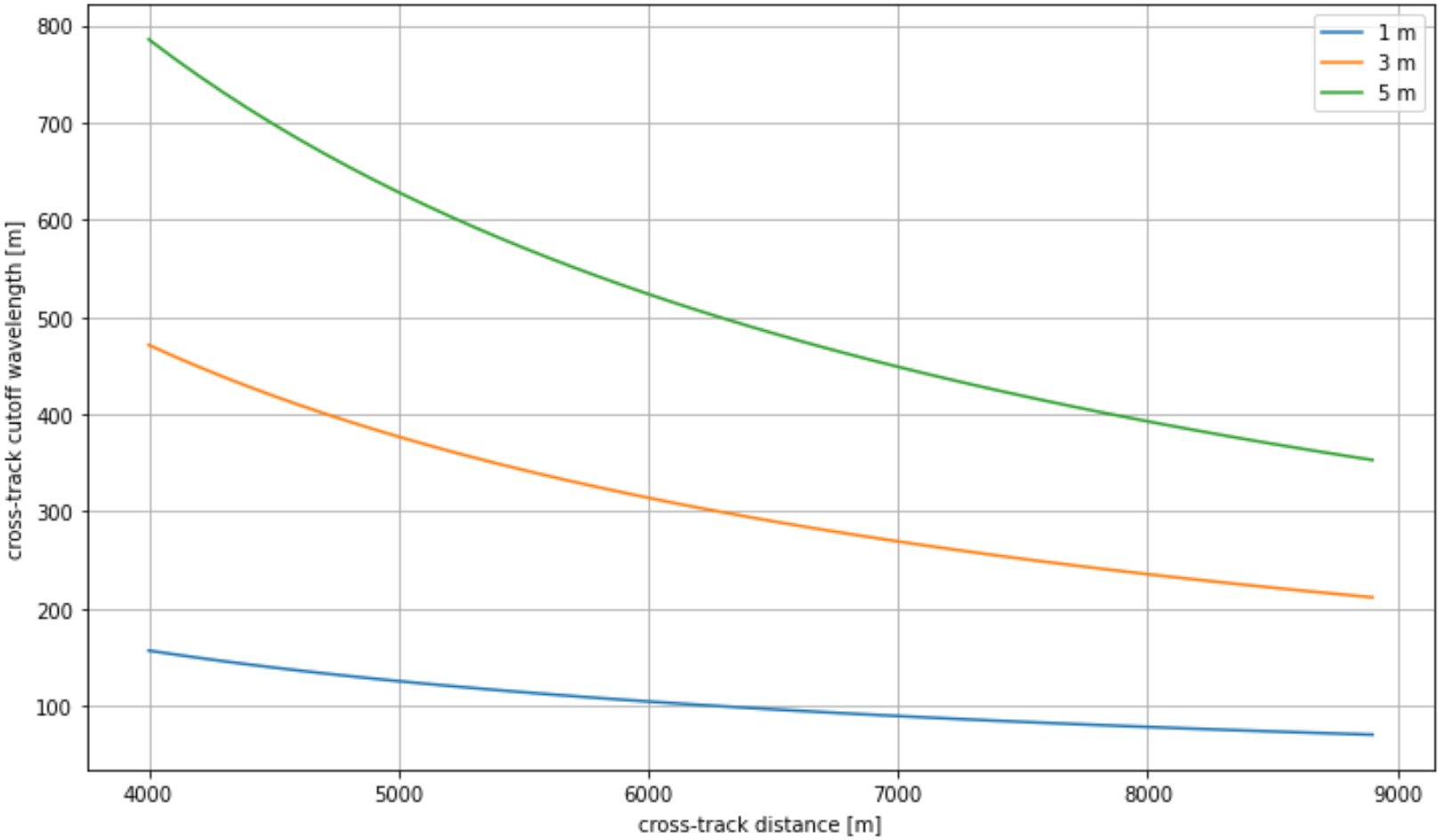
Cross-track resolution



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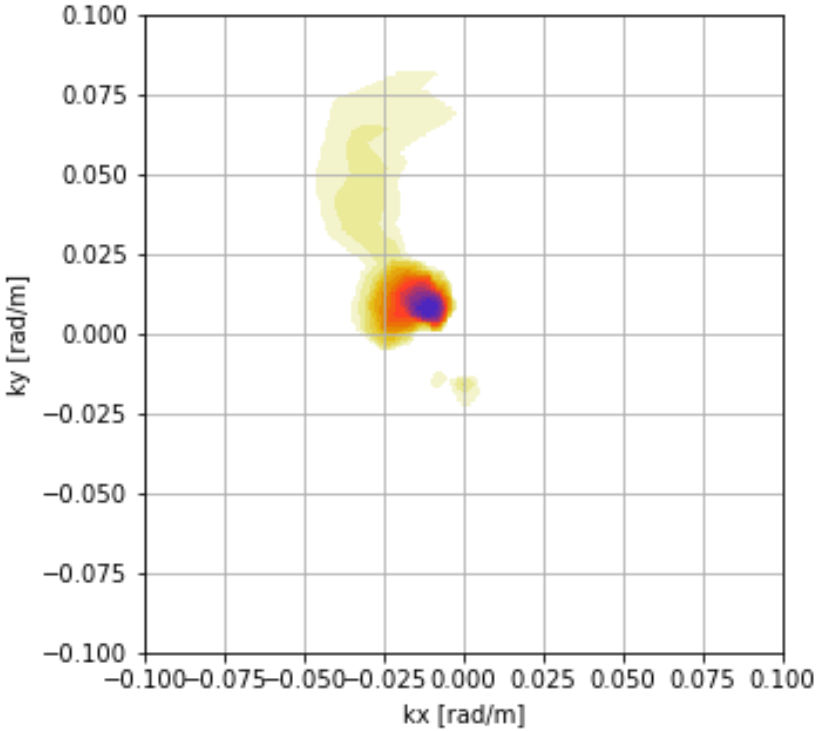
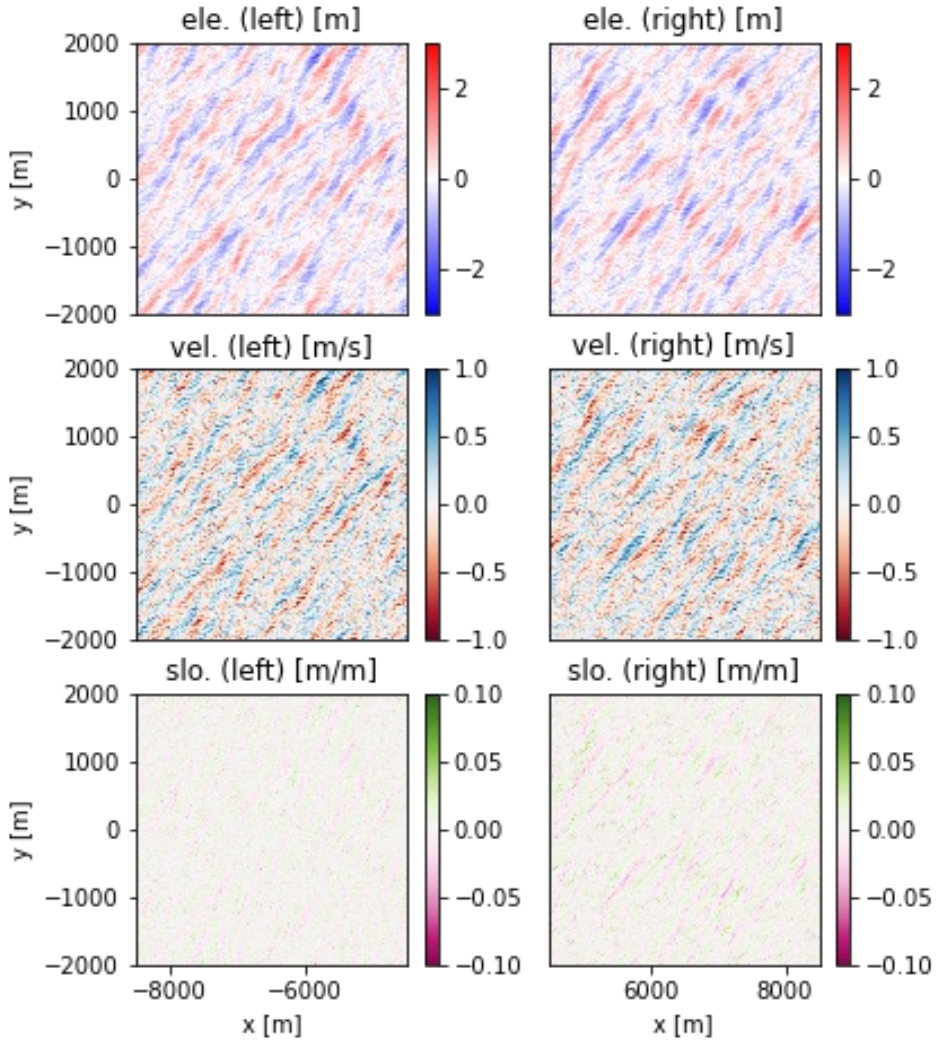
Numerical model





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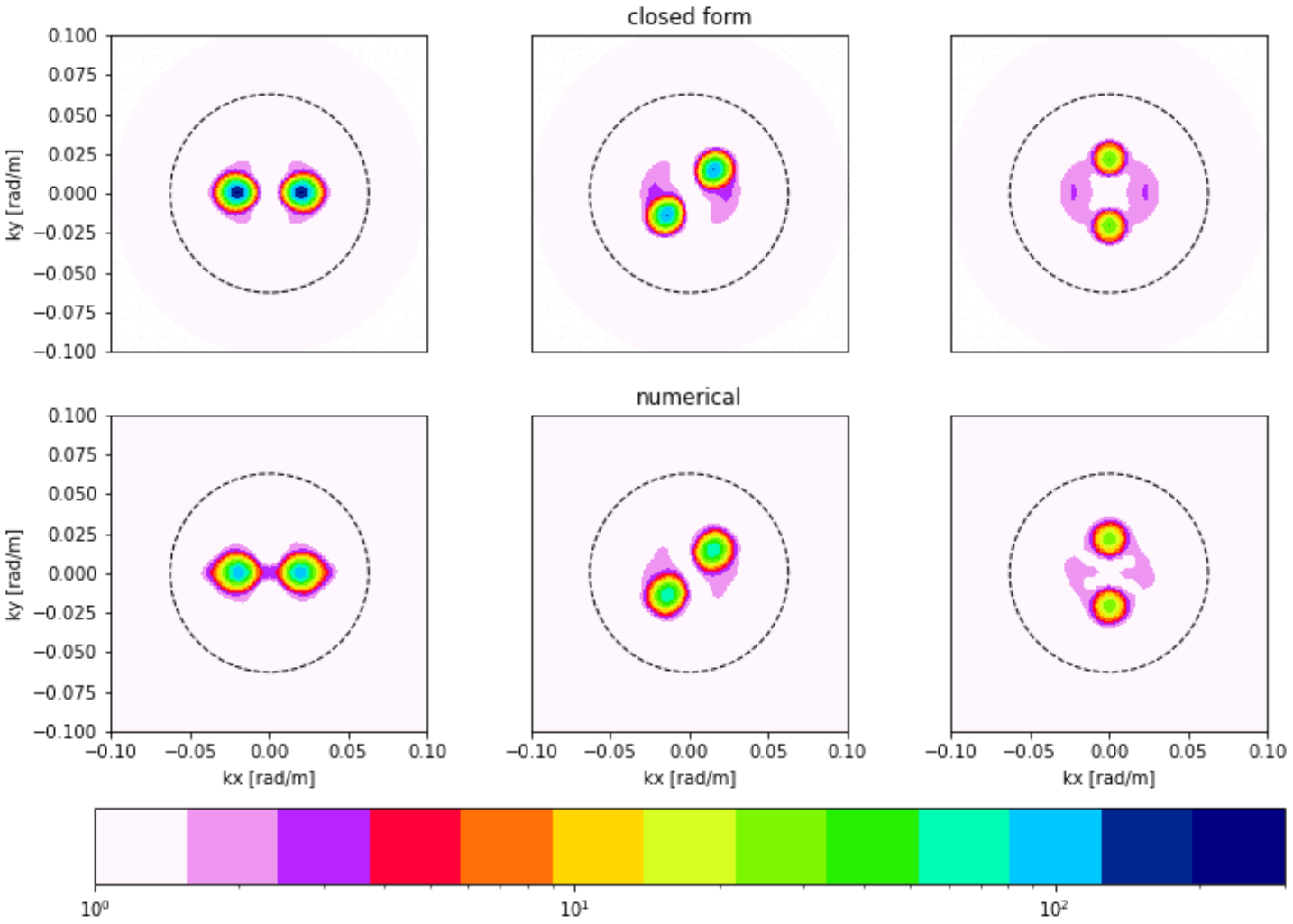
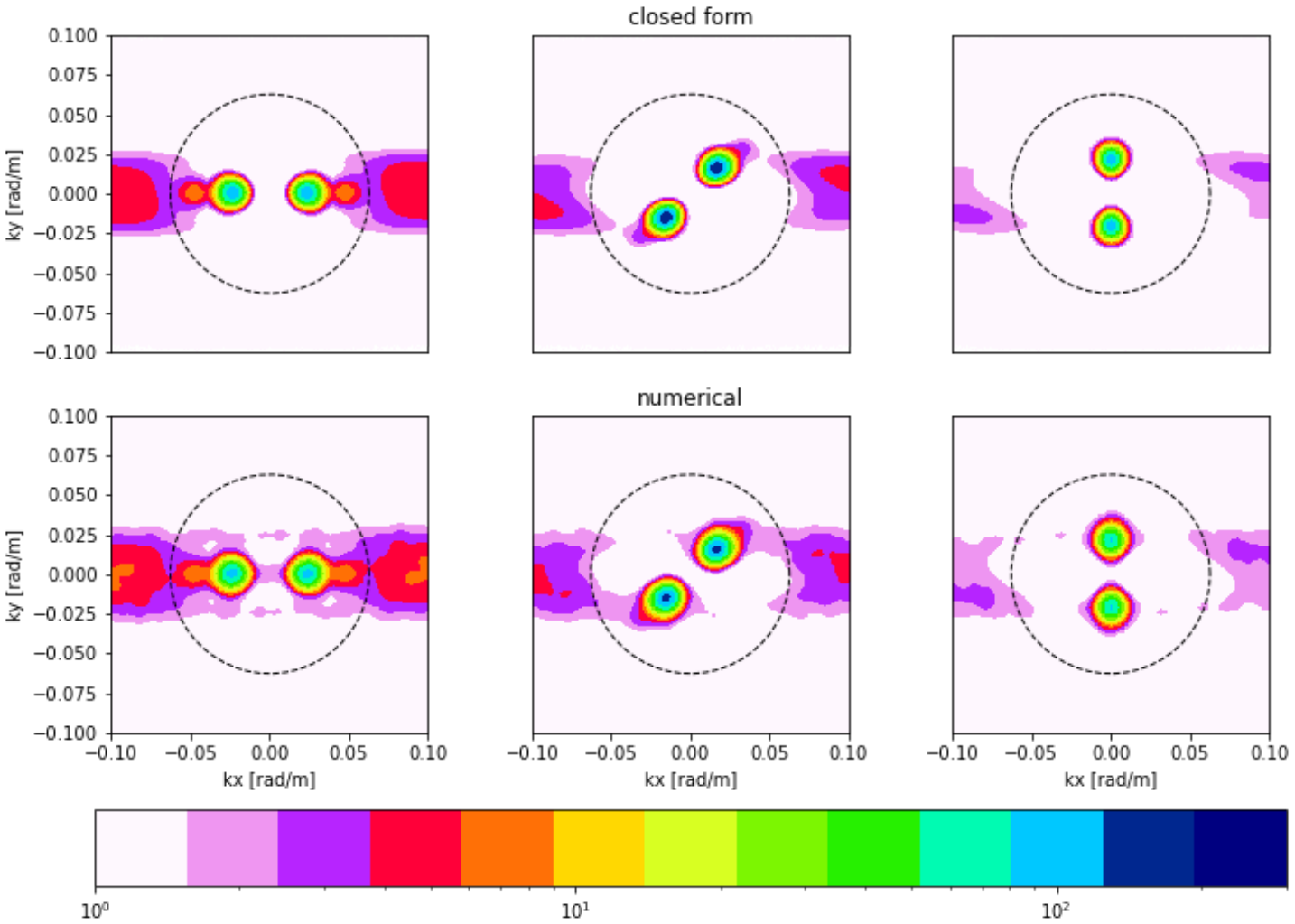
Numerical vs closed-form: nadir altimeter

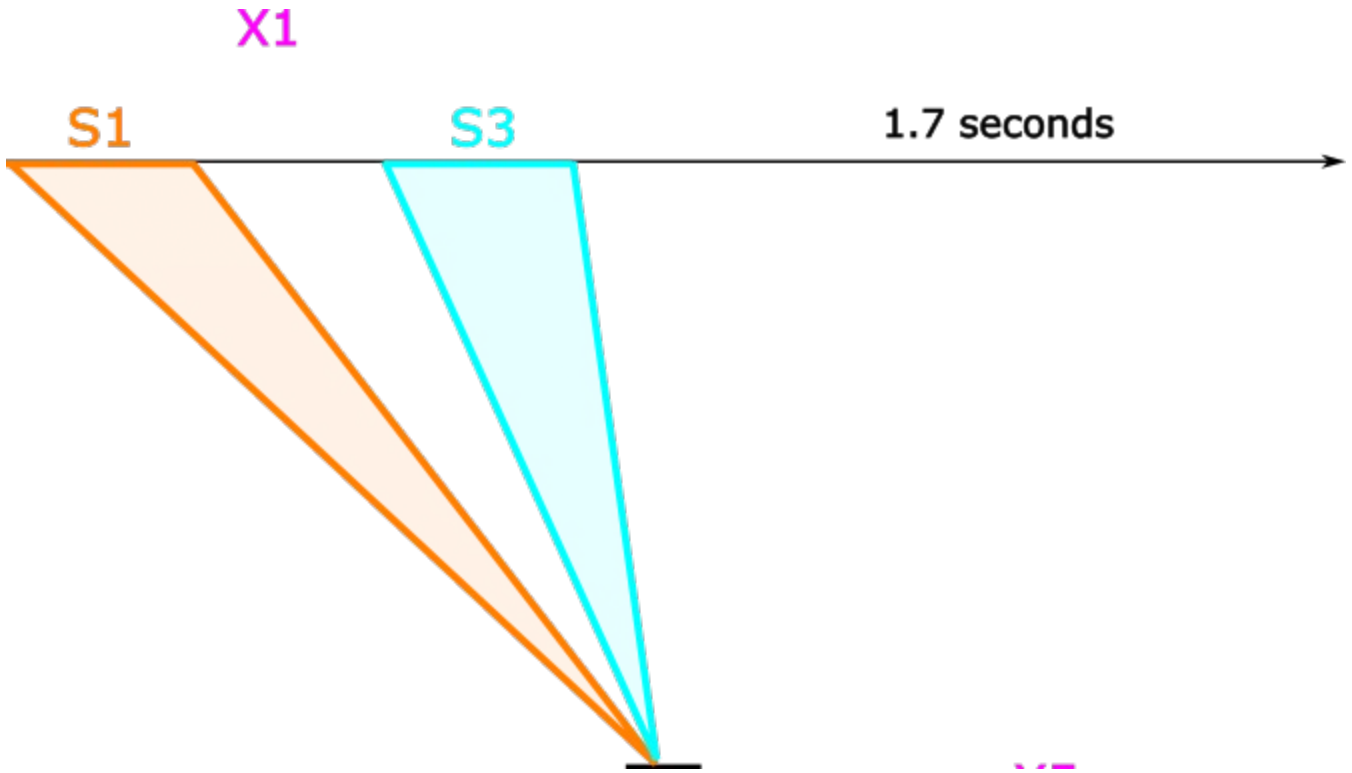


Right side of the ground track only.

Numerical vs closed-form: swath altimeter



Sublooking



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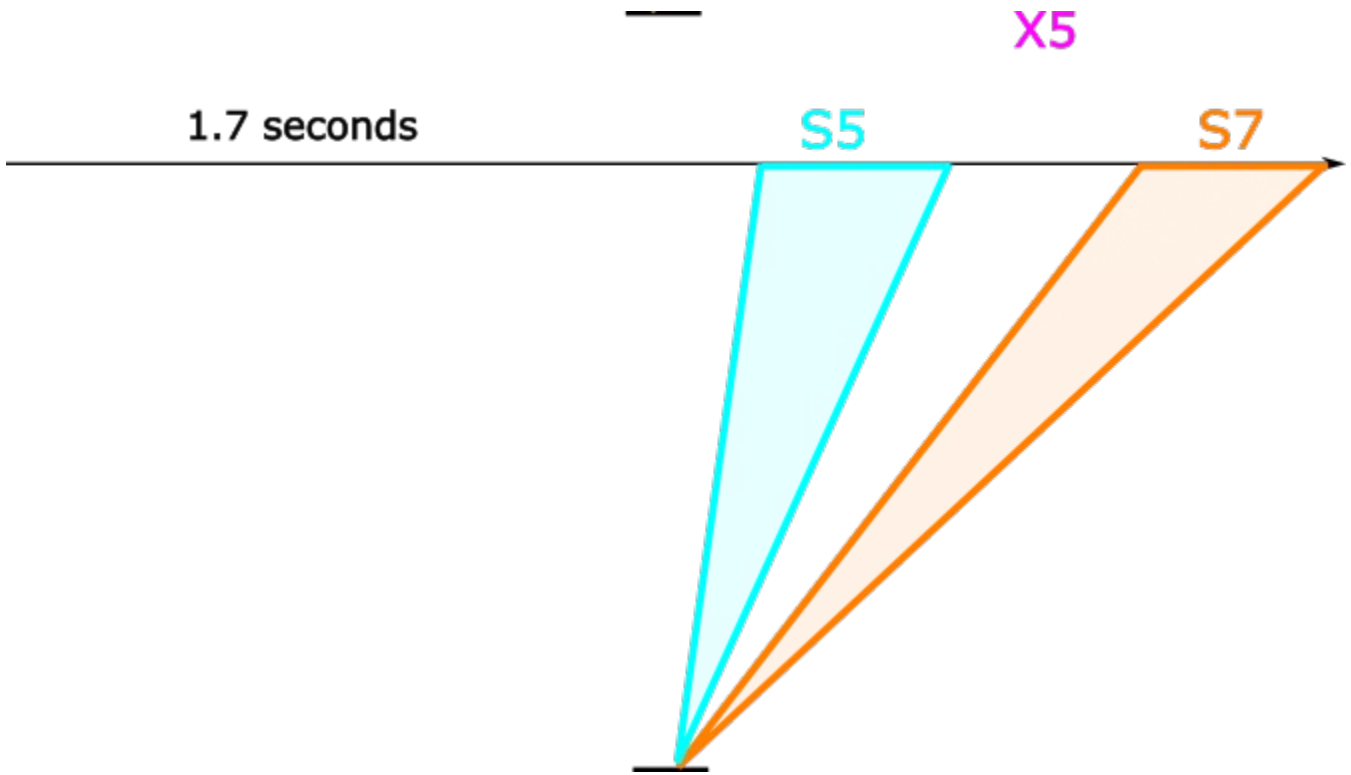
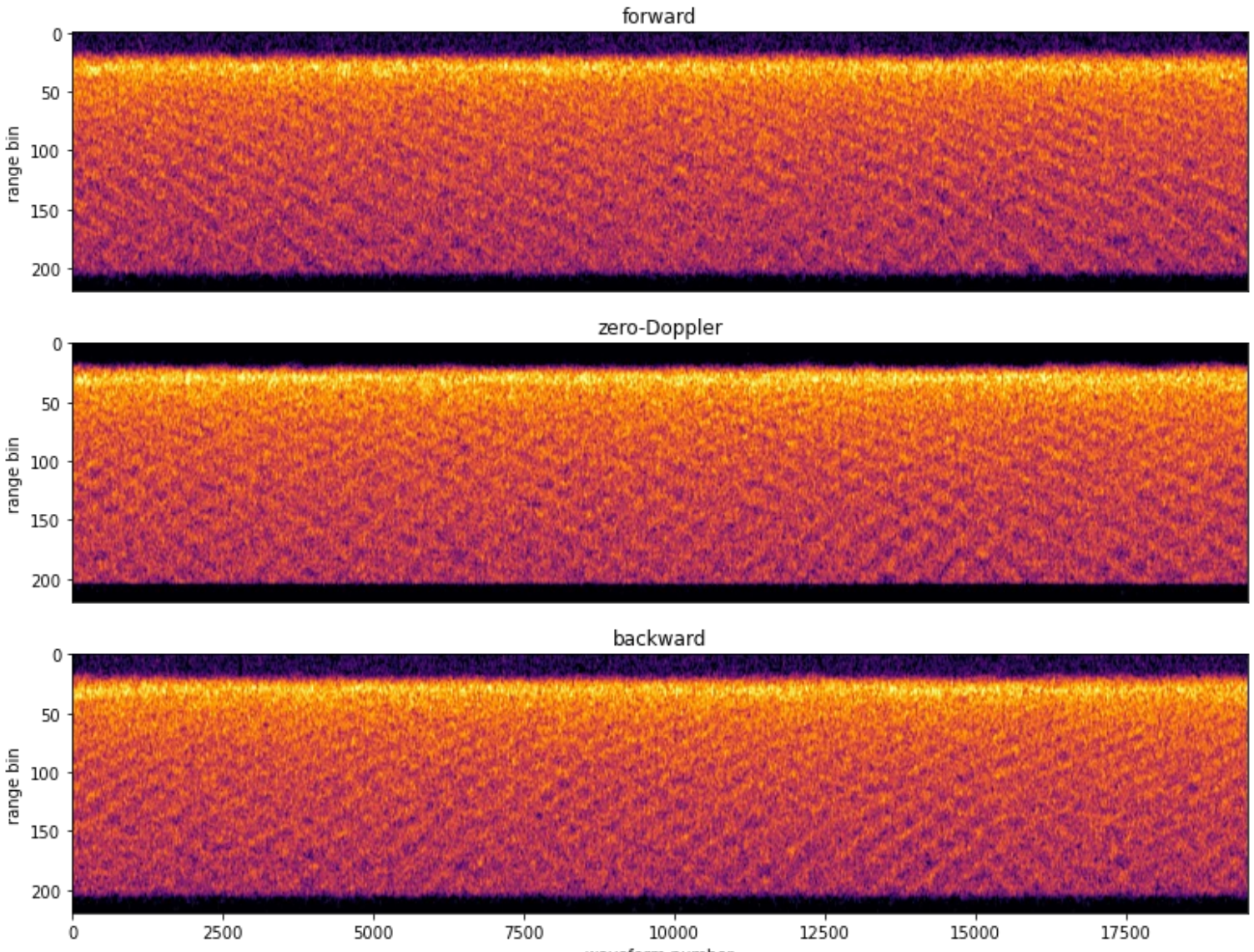
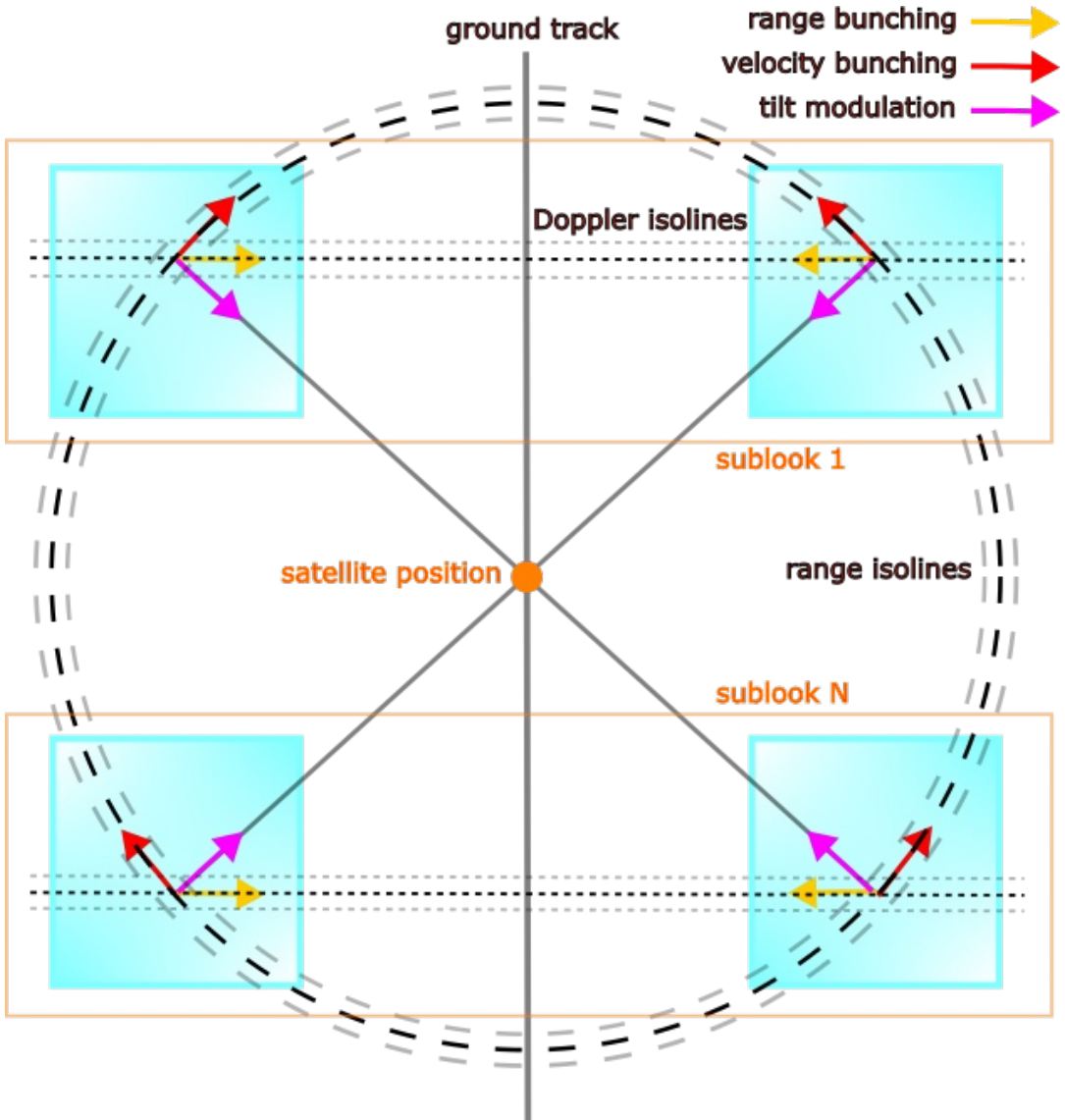
Sublooking

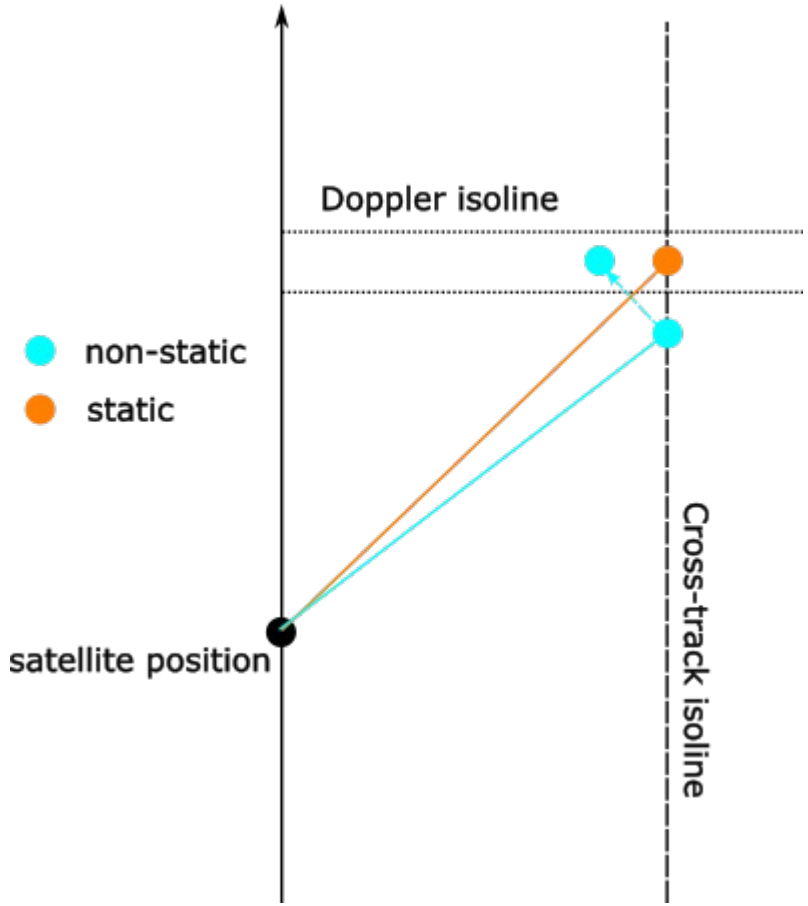


Cutting the Doppler spectrum



Non-zero-Doppler geometry





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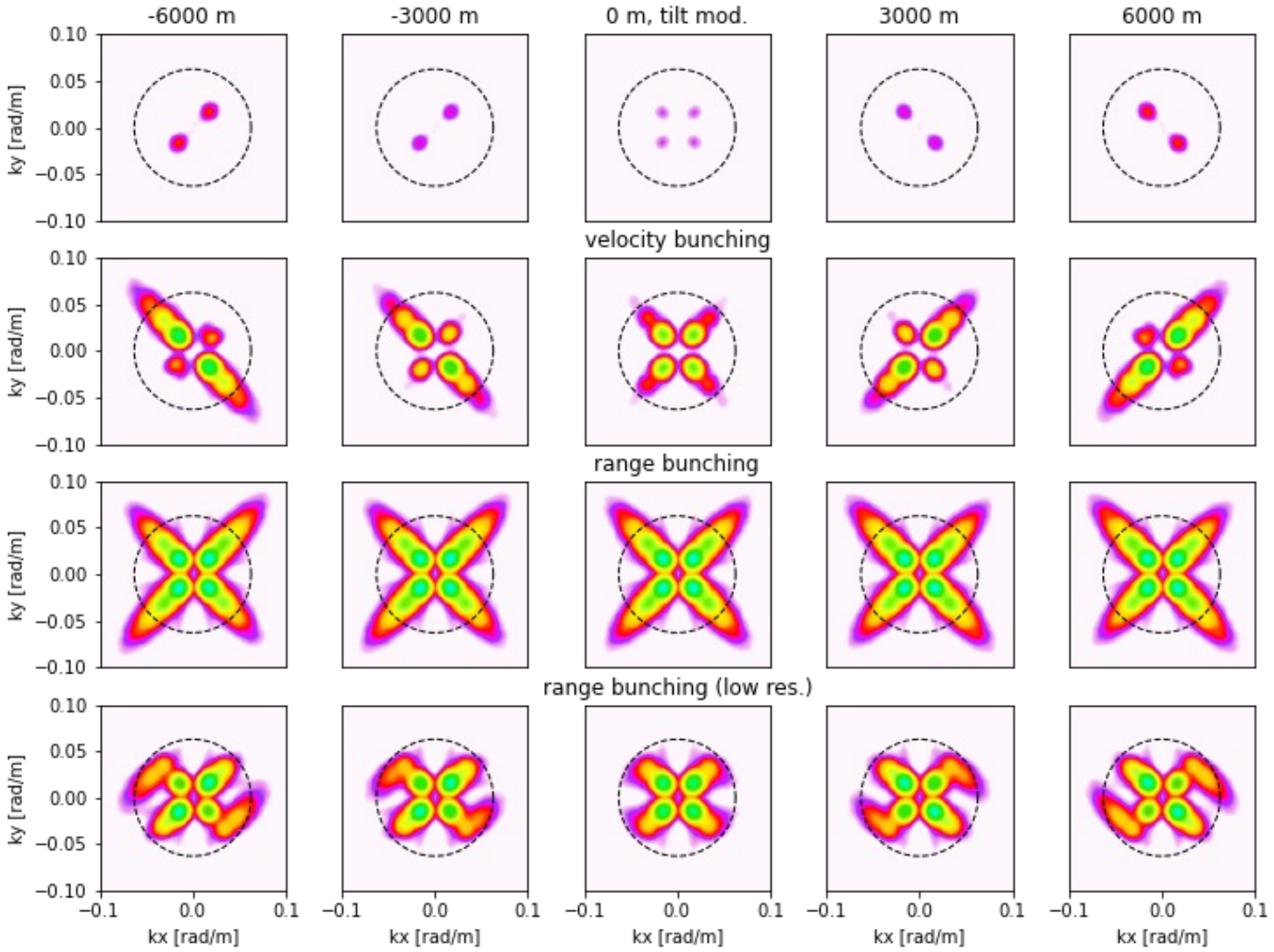
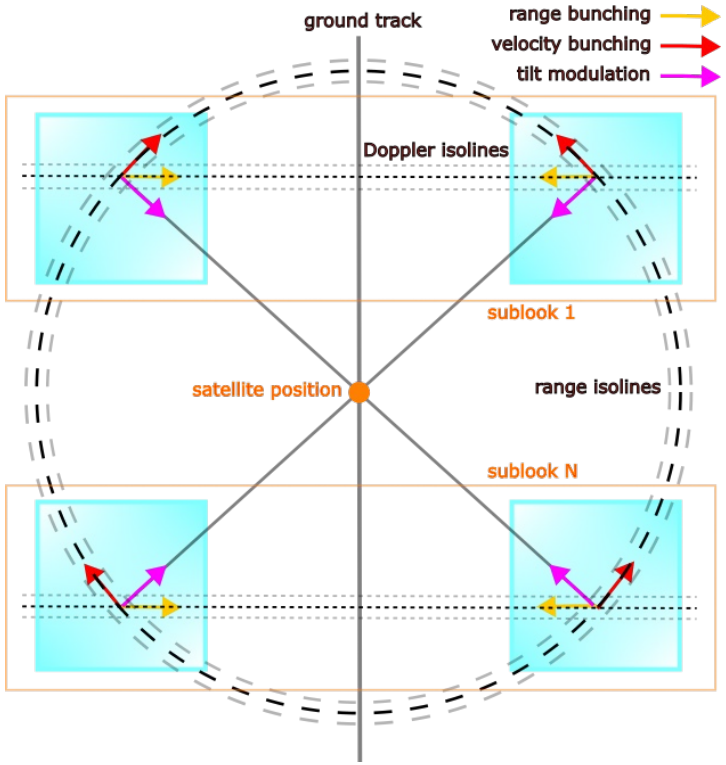
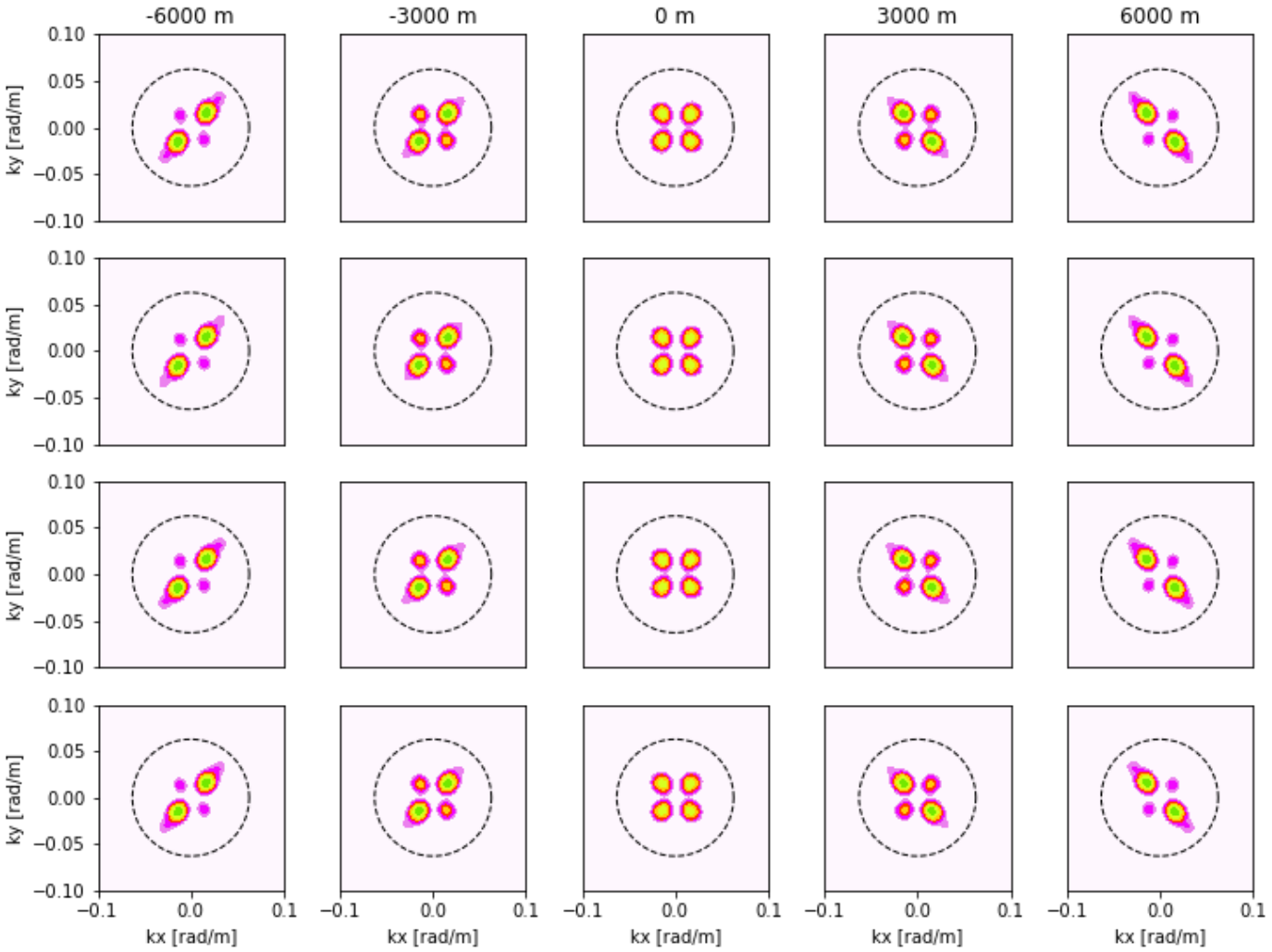
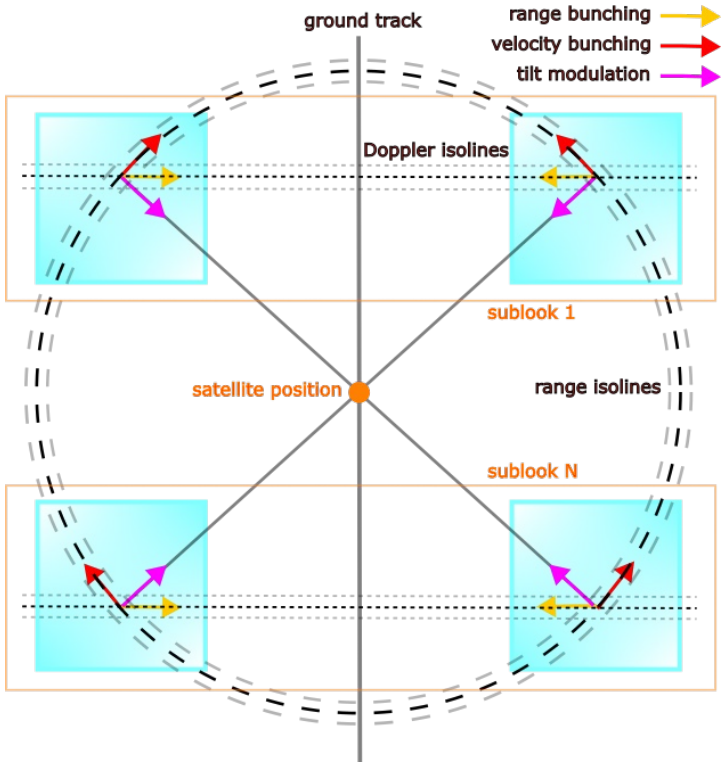
Individual contributions



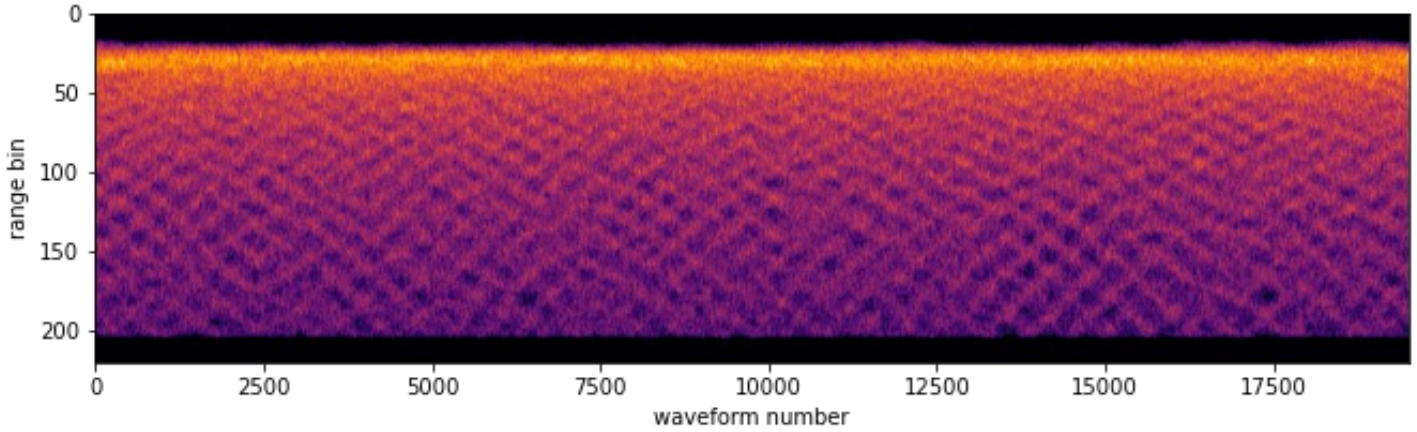


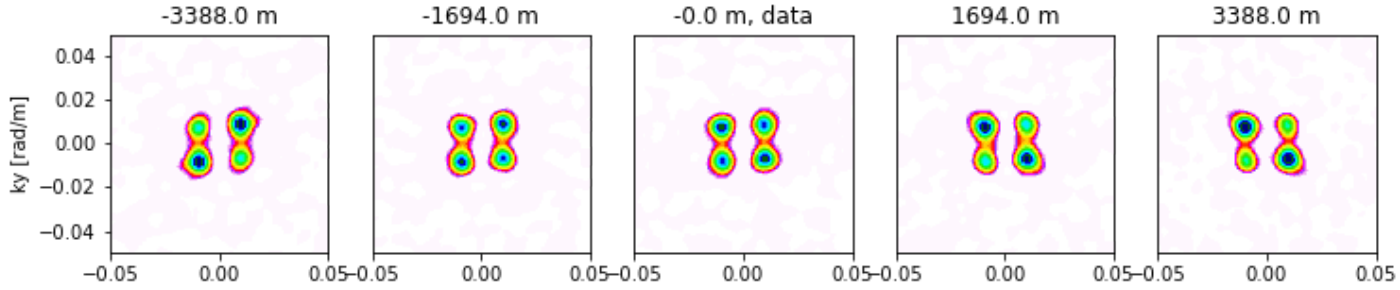
Wind sea

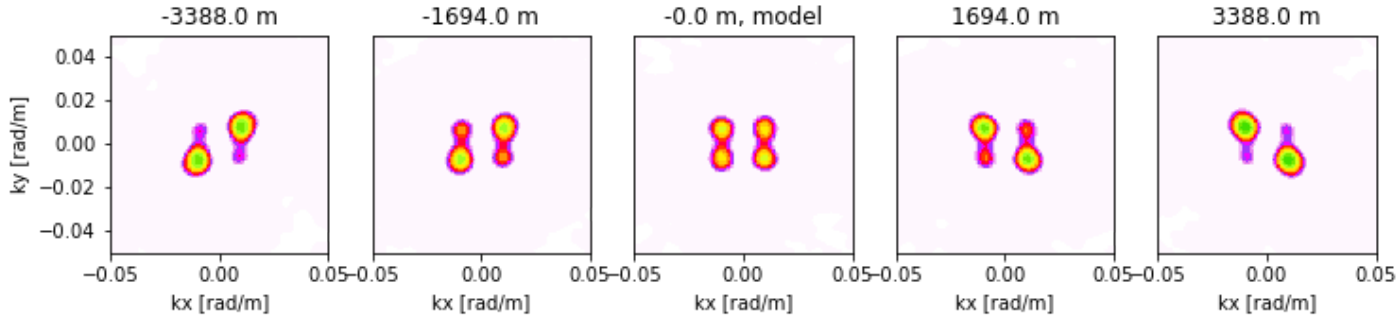

-6000 m
-3000 m
0 m
3000 m
6000 m
ky [rad/m]
kx [rad/m]
0.10
0.05
0.00
−0.05
−0.10
−0.1
0.0
0.1


ground track
range bunching
velocity bunching
tilt modulation
Doppler isolines
sublook 1
satellite position
range isolines
sublook N

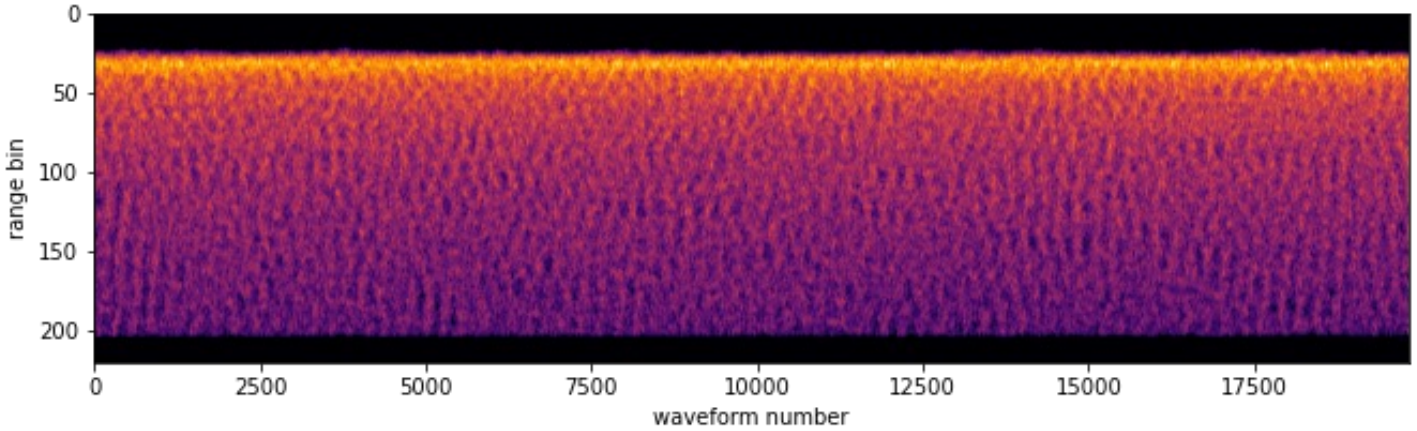
Real data vs the model

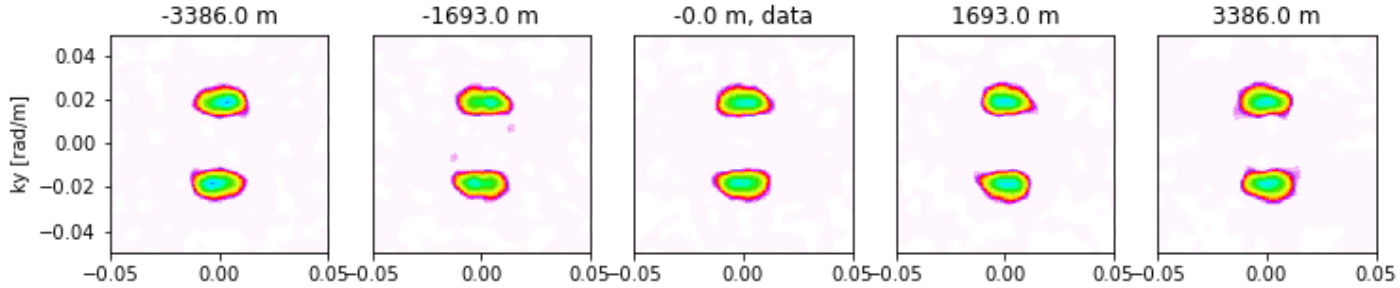


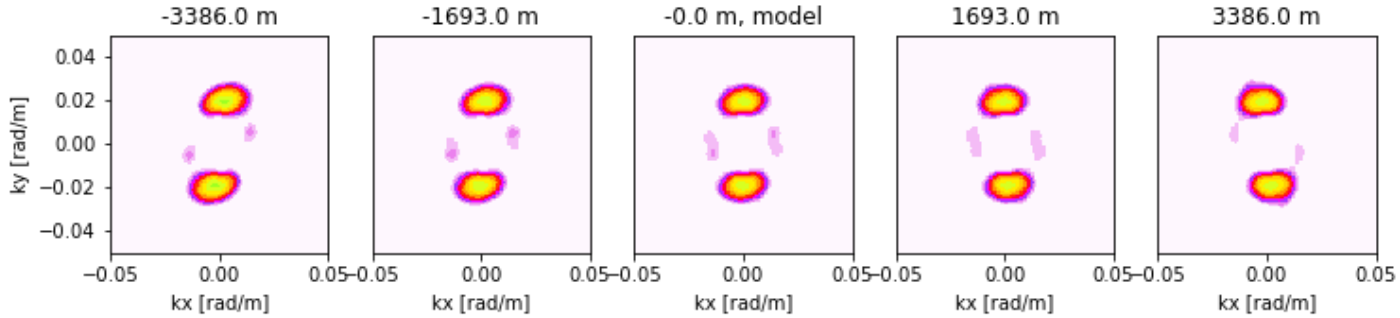




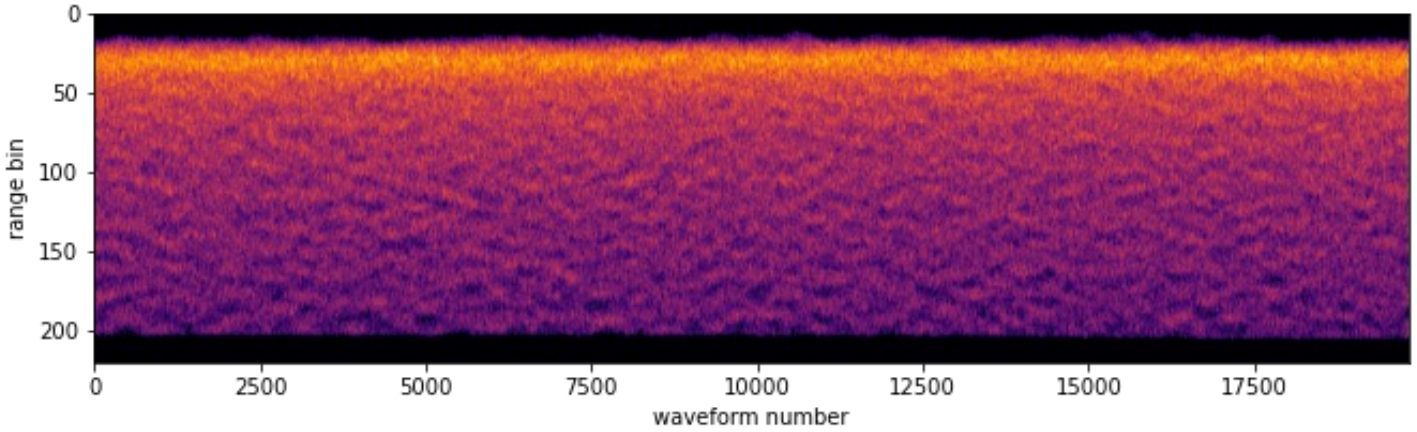
Along-track swell

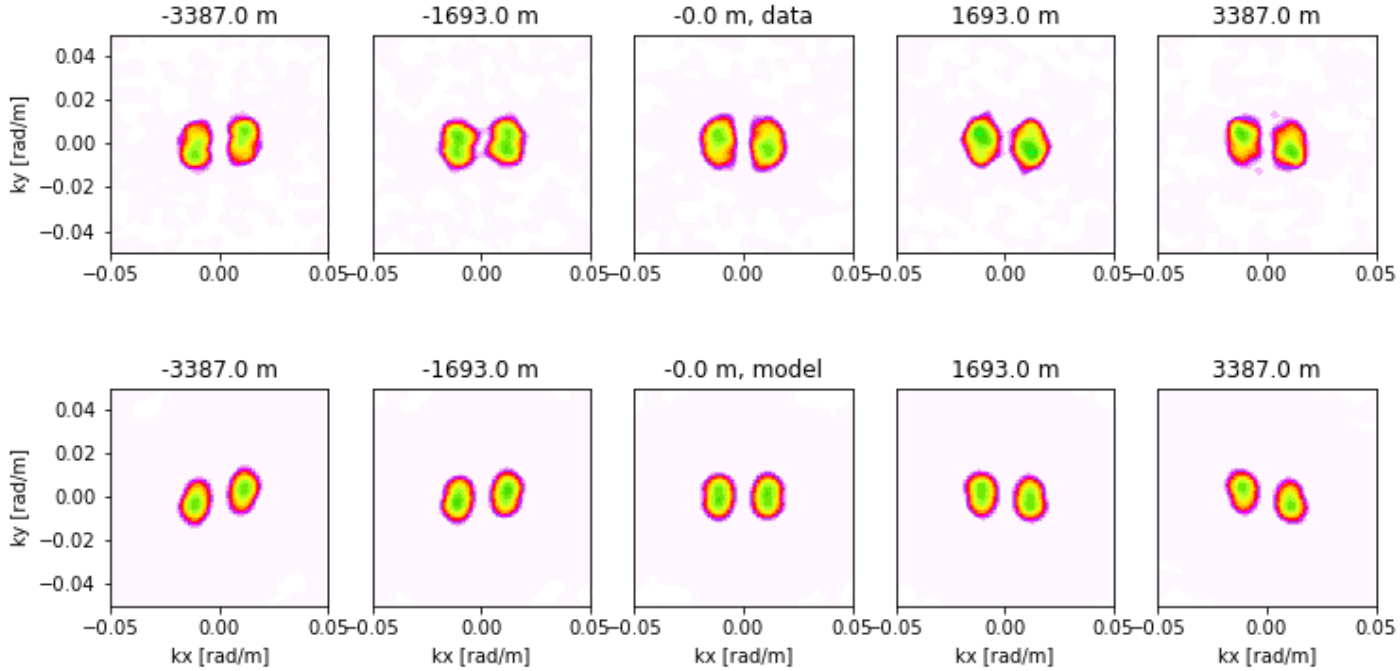




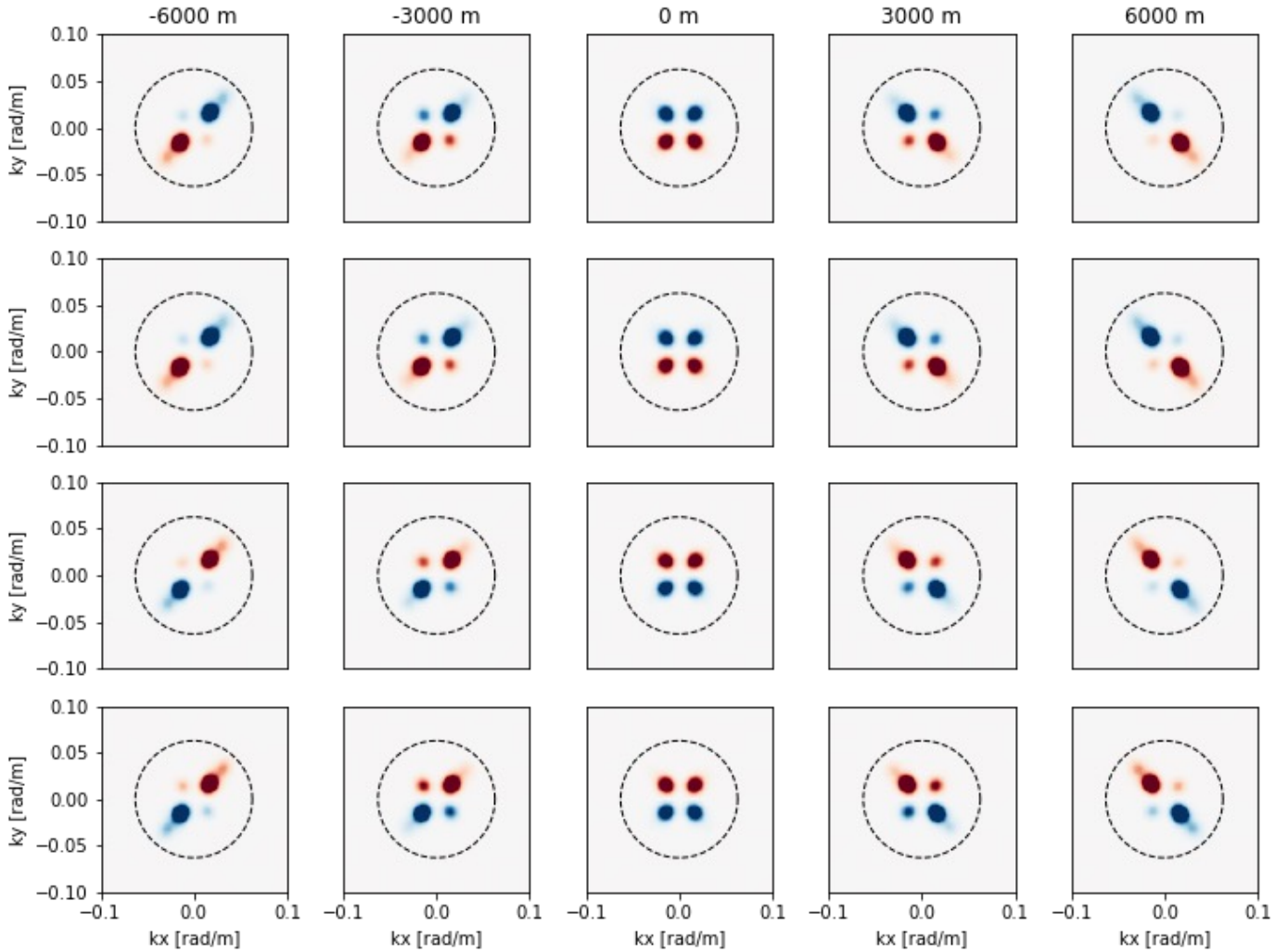


Across-track swell

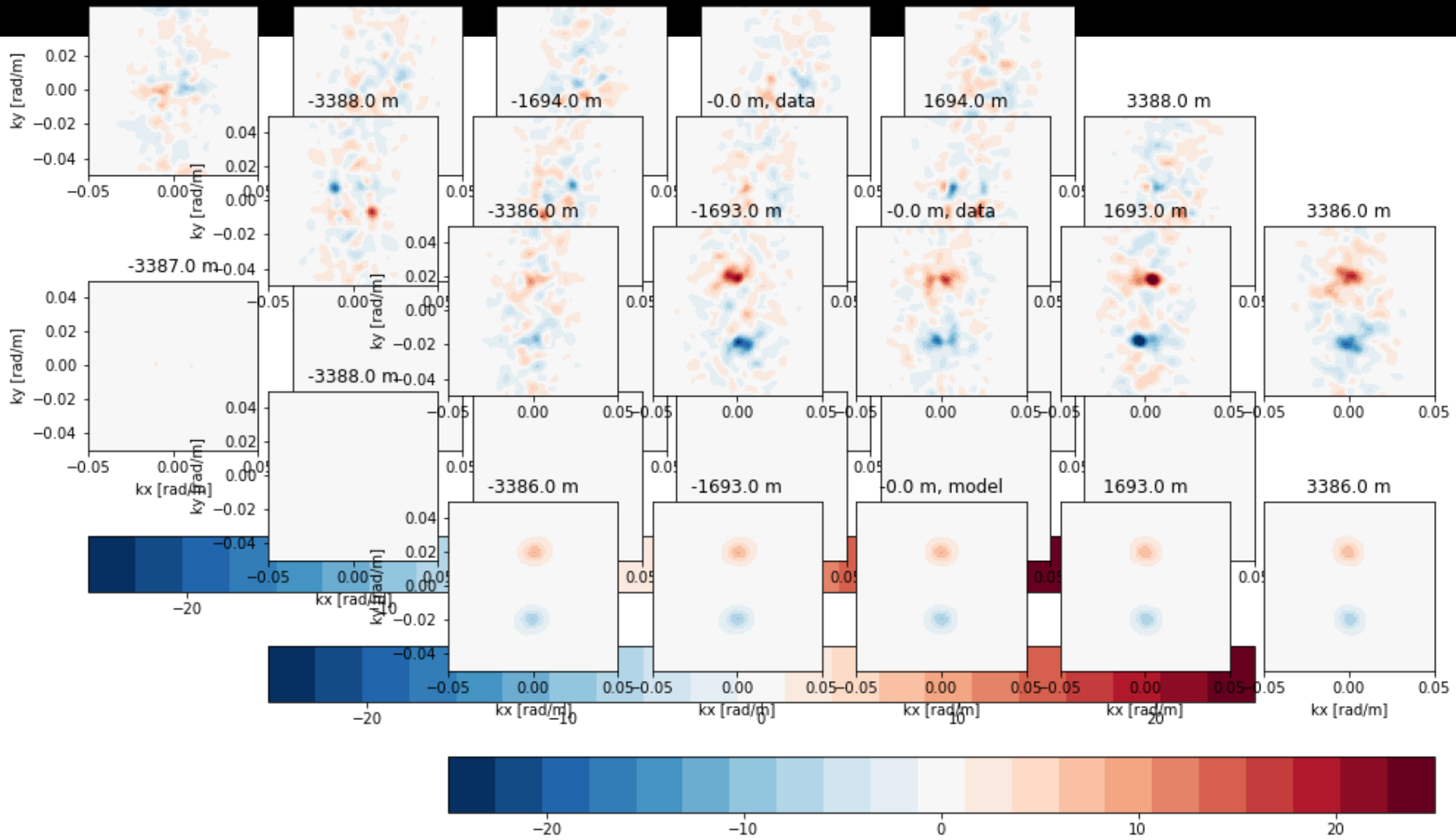




Imaginary values



Imaginary values



Summary

- A numerical model is able to reproduce SAR altimetry spectra.
- A closed-form solution is invalid at small incident angles.

- A non-zero-Doppler geometry is likely the cause for Altiparmaki's left-right differences.
- Sublooking might help to retrieve more accurate swell data.

- Swell mean wavelength and energy can be retrieved within the cut-off.
- Direction? Imaginary values are noisy and poorly understood.

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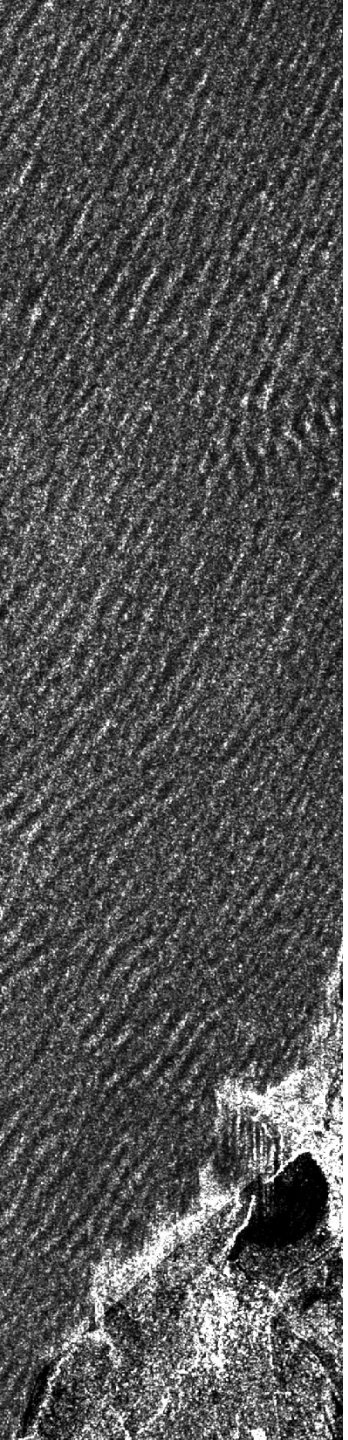

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Thanks!

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