Inclusion of the ocean's velocity variance into the sea-state-bias correction

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S6-MF and S3-NGT error budget

	Sentinel-6			Sentinel-3 NGT	
	Req.	Goal	Perf.	Req.	Goal
Orbit	1.5	1.0		1.0	0.8
Range noise	0.8	0.5		0.8	0.5
Ionosphere	0.5	0.3		0.3	0.3
Dry troposphere	0.7	0.5		0.5	0.5
Wet troposphere	1.0	0.8		0.7	0.7
SSB	2.0	1.0	**2.0***	1.5	1.0
SSH	***2.9***	***1.8***	***3.1***	***2.2***	***1.7***

Donlon et al. (2021), S3-NGT MRD

A recent study claims a lower number (Putnam et al. 2023).

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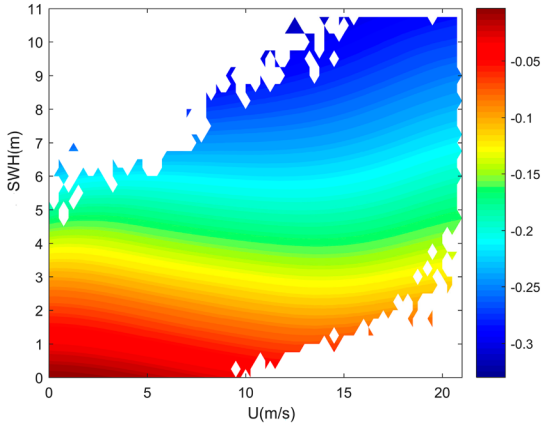
(Non-)Parametrized sea-state-bias models

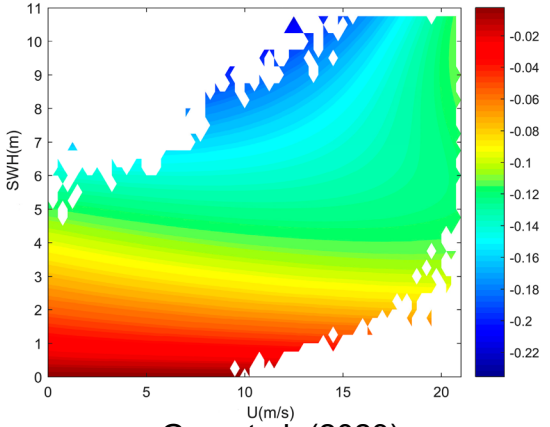
- Traditionally two parameter:
  - Parametric methods.
  - Non-parametric methods.

- Attempts to include model data:
  - Limited improvements.

- Attempts to use along-track derivatives/other observed parameters:
  - Limited improvements.

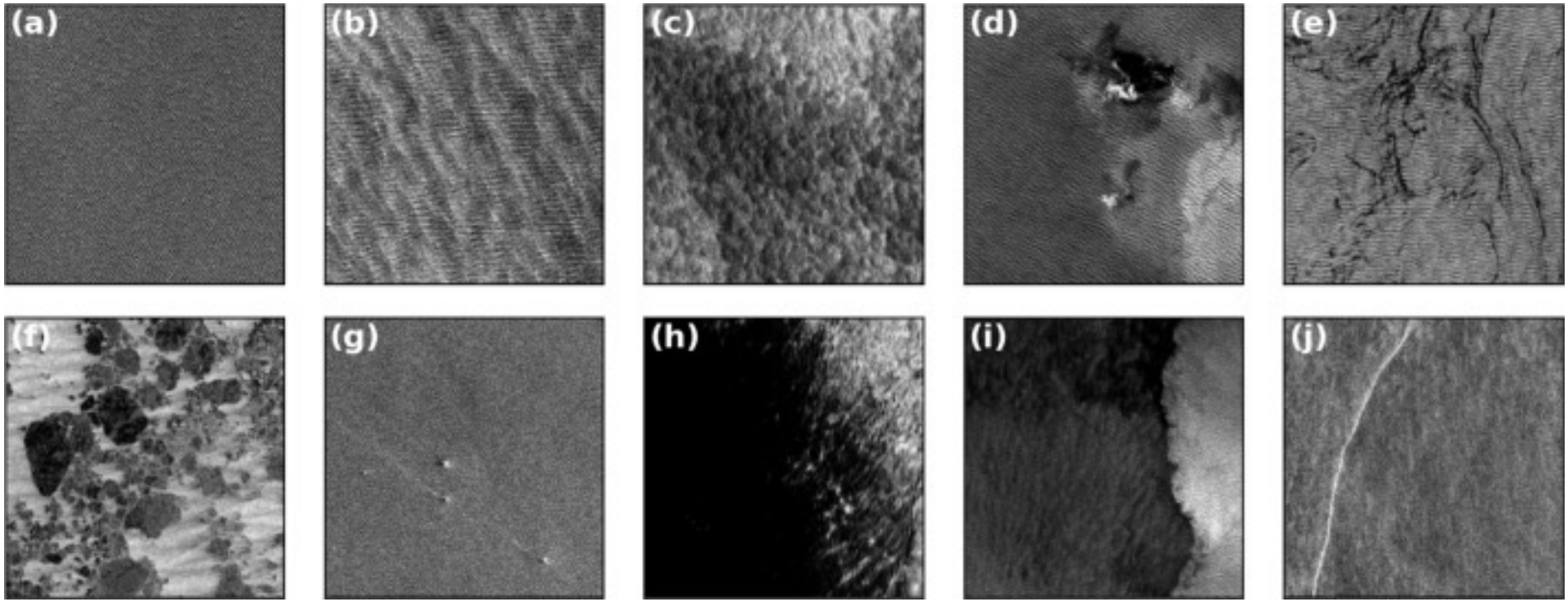
- Etc…





Guo et al. (2023)

A dynamic ocean….



Wang et al. (2018)

Responses are wavelength dependent!

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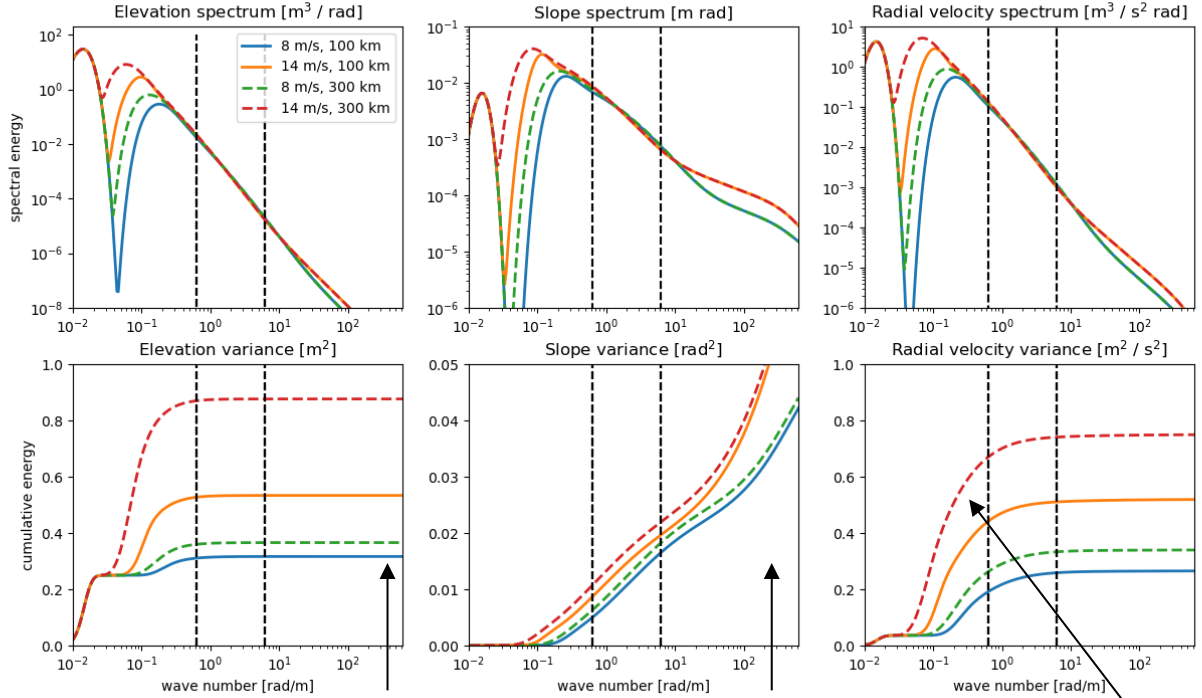
https://ovl.oceandatalab.com/

Why the velocity variance?



$$\left(\frac{H_s}{4}\right)^2$$

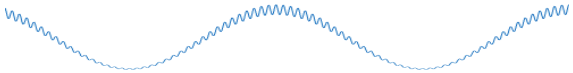
$$\sigma_0 \rightarrow U_{10}$$

Sensitive to long wind waves, but not to swell!

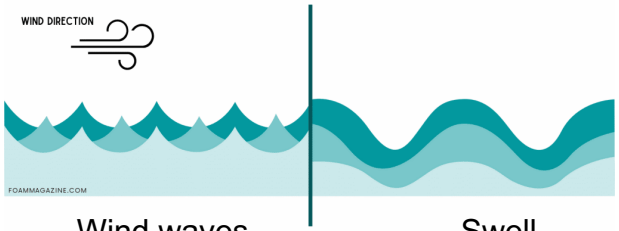
Hydrodynamic modulation

$$M^h(\mathbf{k},\mathbf{K}) = -\left(\frac{1-i\tau}{1+\tau^2}\right)\frac{k_1}{N(\mathbf{k})}\frac{\partial N(\mathbf{k})}{\partial k_1}$$

$$\tau = n\beta\omega/\Omega_{\mathrm{r}}$$ Hansen et al. (2012)



Non-linear wave shapes



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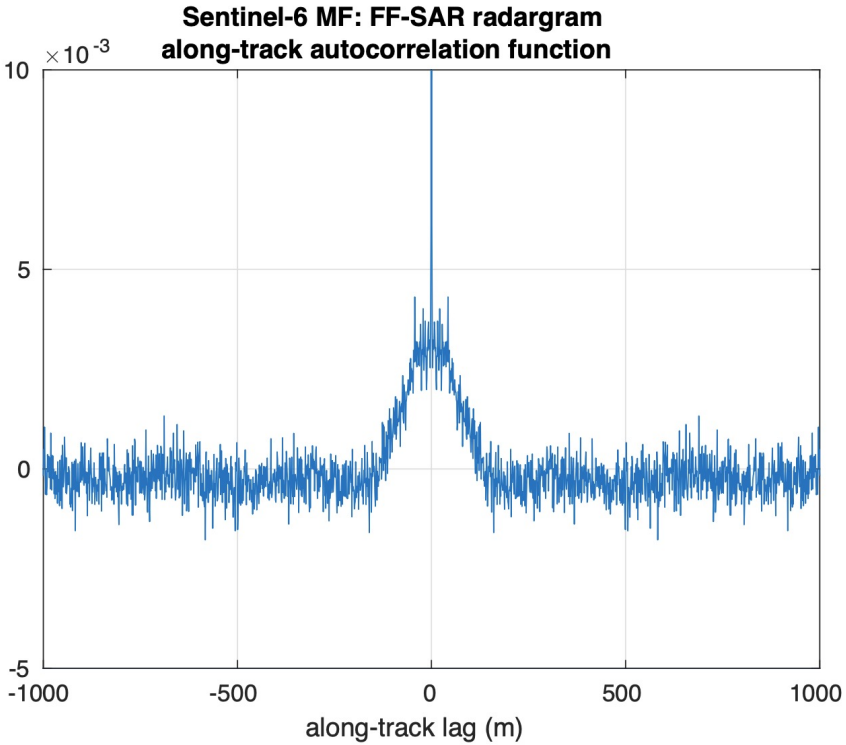
The along-track autocorrelation function



$$\lambda_c = 2\pi\sqrt{\frac{R^2}{V^2}\sigma_v^2 + d.c.}$$

Schulz-Stellenfleth et al. (2002)

$$\min(acf - \exp\left(-\frac{\pi^2 l^2}{\lambda_c^2}\right))$$

Kerbaol et al. (1998)

In Sentinel-1 OSW algorithm used to estimate the wave age!

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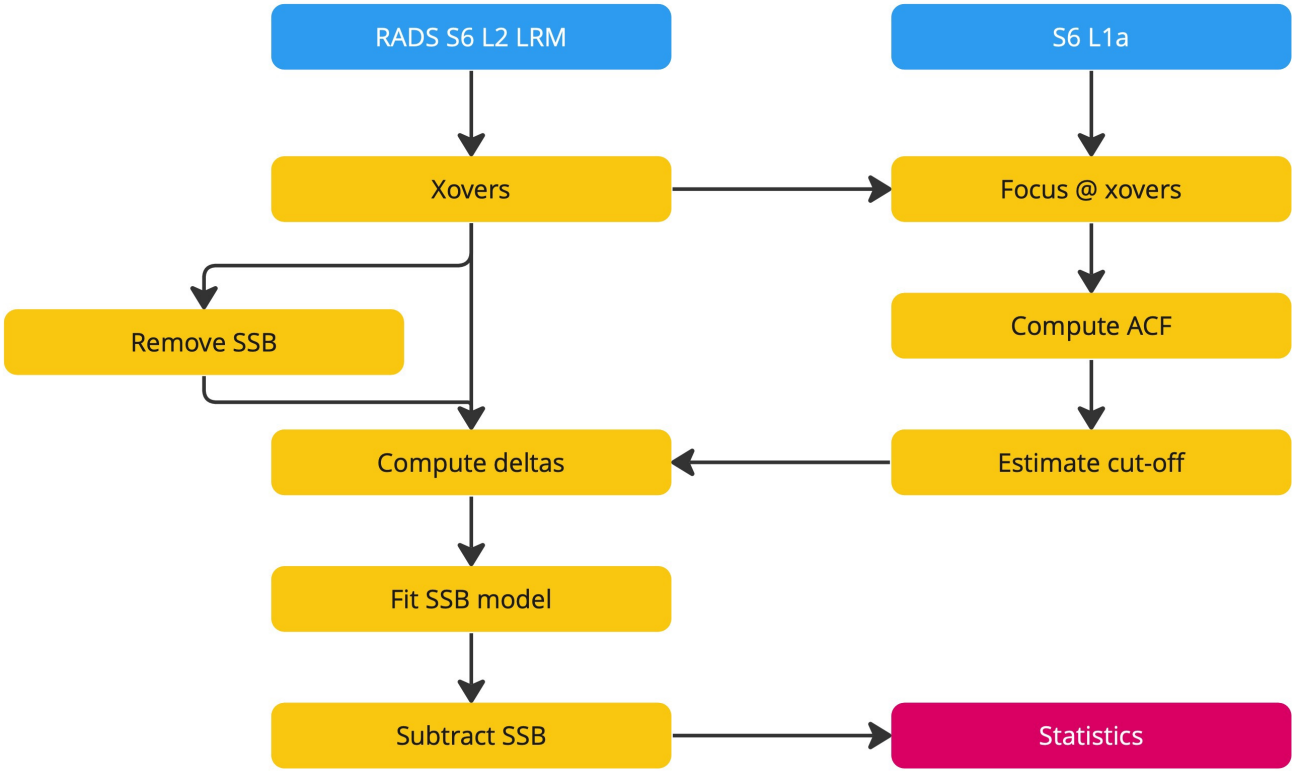
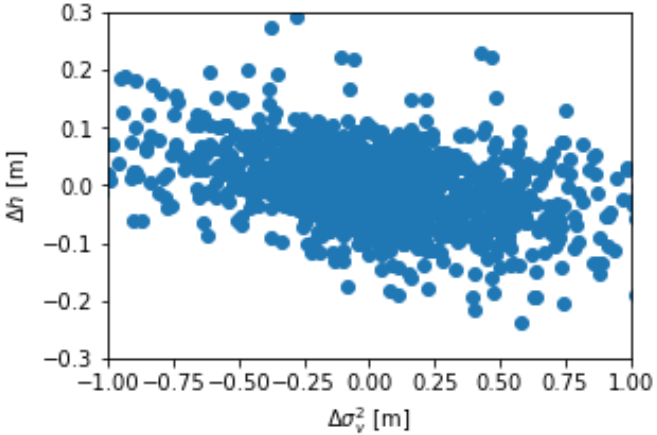
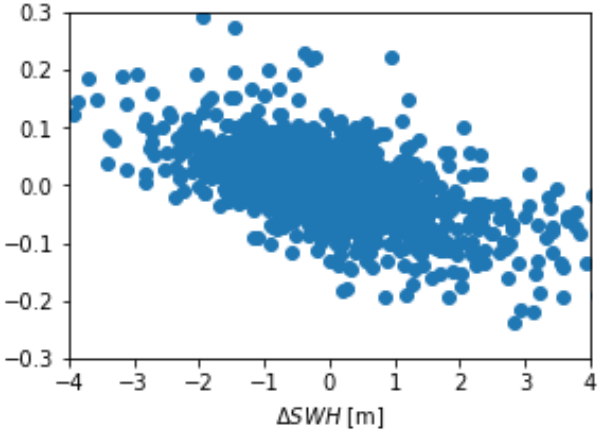
Methodology

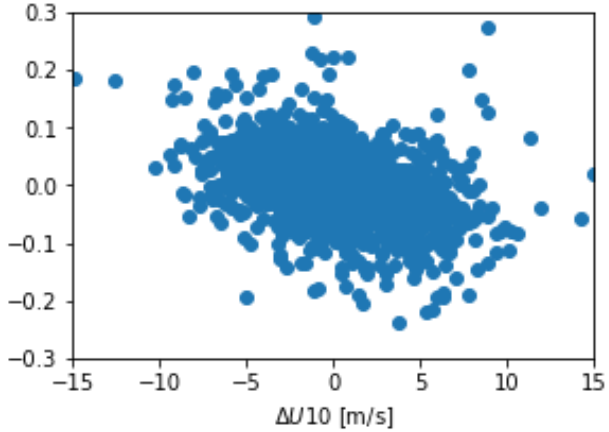


Note: we compute an SSB for LRM using FF-SAR-derived quantities!

ACF results

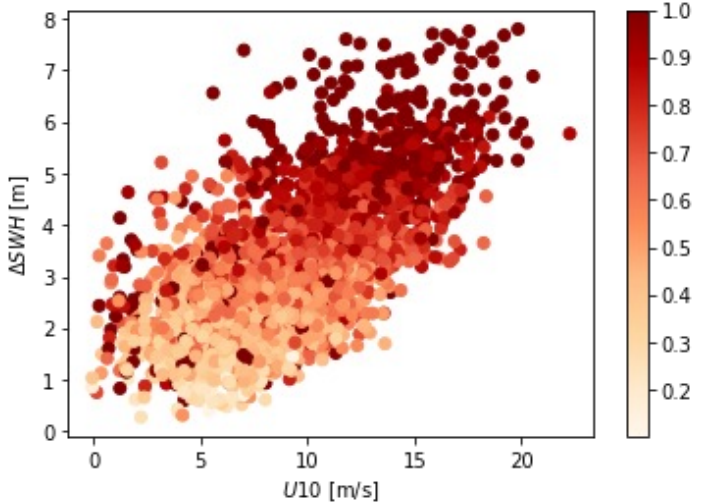






	Est. Unc. [cm]
SSB3	2.0
SSB4	2.0
SSB4 + velocity variance	1.9-2.0
SSB-VV - (no SWH)	2.5-2.7

Very limited improvement!



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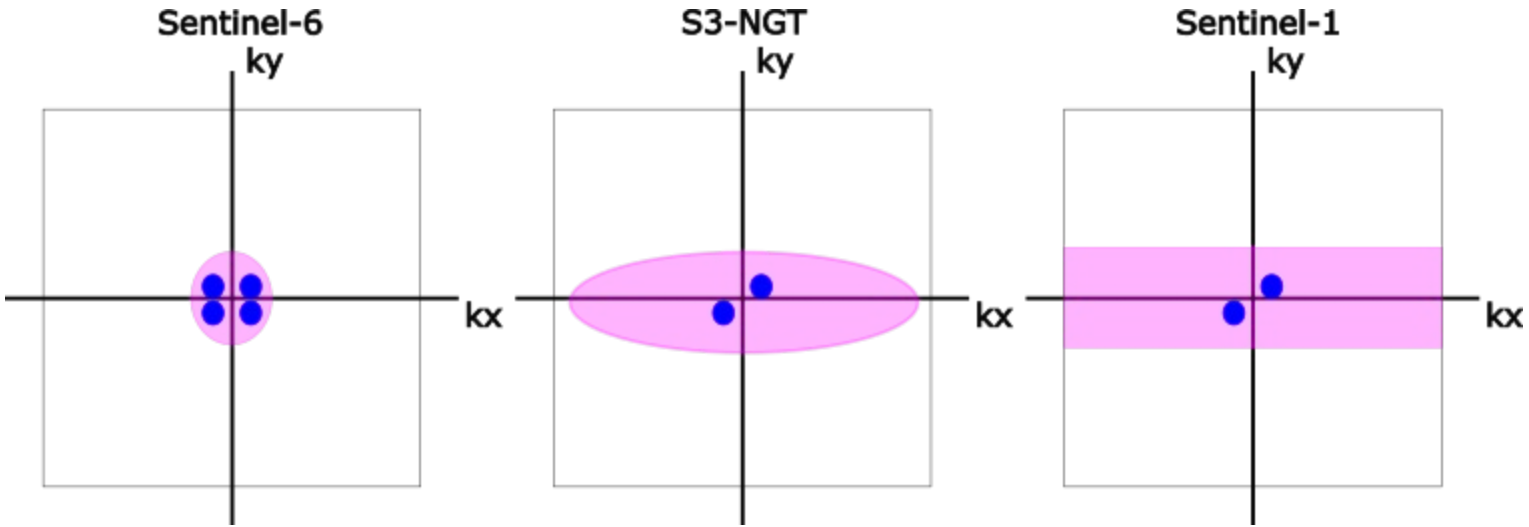
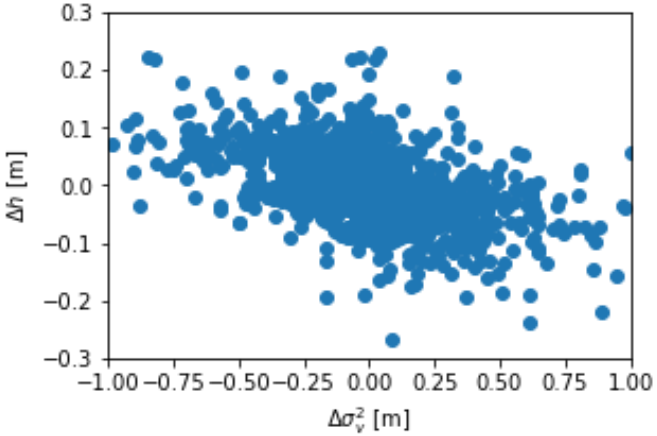
Fitting issues: a limited cross-track resolution

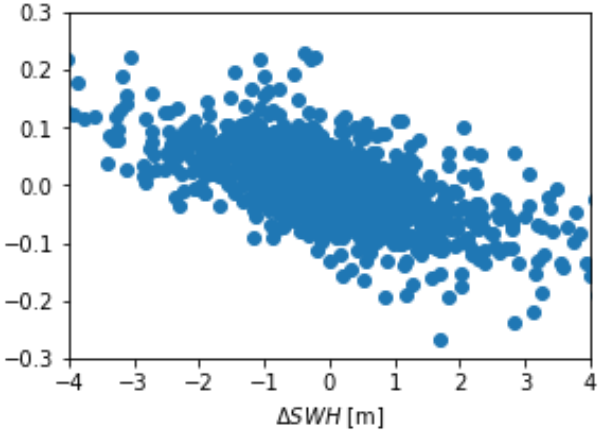


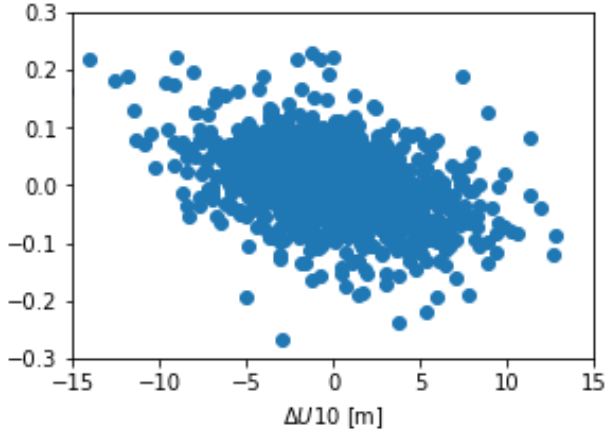
Remember: along-track acf is the mean in kx and the iDFT in ky!

Other issues: bright scatterers, fronts, etc.

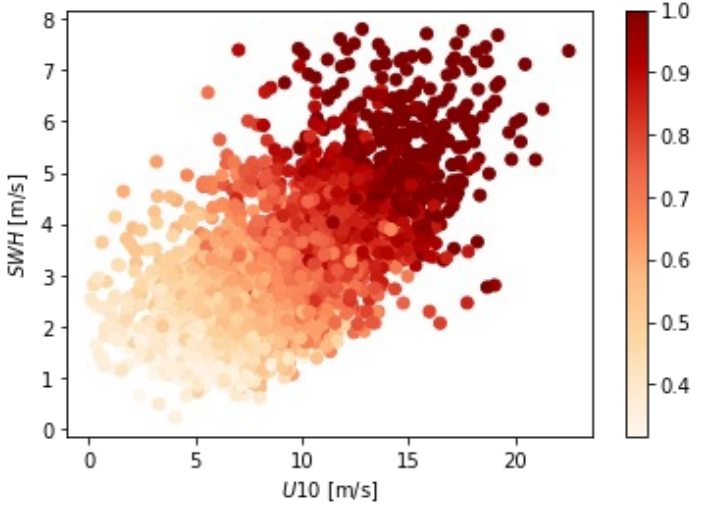
Model results







	Est. Unc. [cm]
SSB3	2.0
SSB4	2.0
SSB4 + model VV	1.9-2.0
SSB-SWHm	2.3-2.4
SSB-VVm	2.3-2.5



Model based SSB not bad, use for SWOT?

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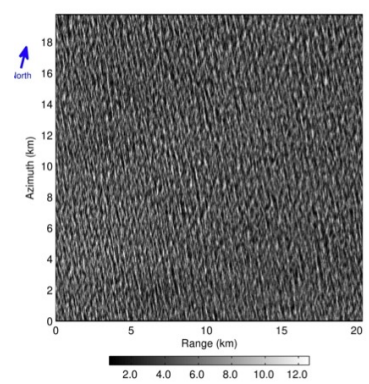
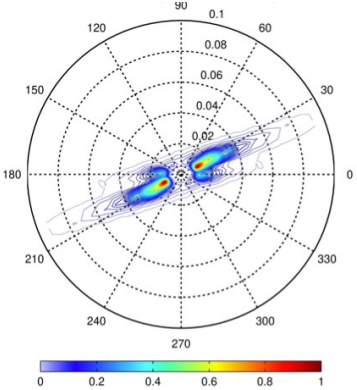
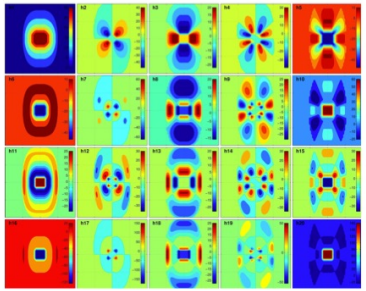
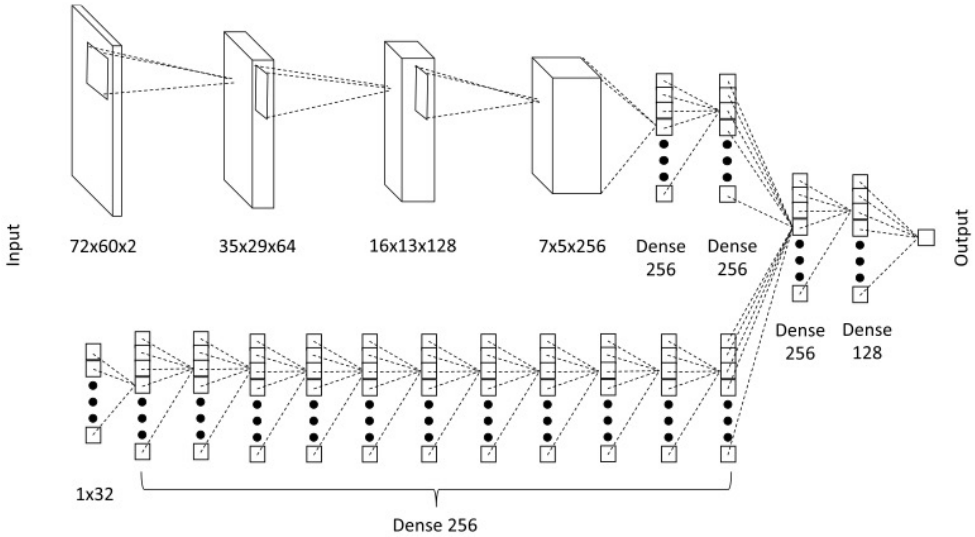
A way forward: cross-spectra and higher-order stats









Figures from Quach et al. (2019)

SWH from SAR images: 0.3-0.4 m uncertainty.
Direction, wave periods,…. (Pleskachevsky et al. 2022).

Use similar approaches for nadir-altimeter SSB!

Summary

- Including velocity variance has limited impact on SSB:
  - The ACF method is not robust enough.
  - The model data is not accurate enough.

- For swath altimeters:
  - Model data might help to reduce the SSB uncertainty.
  - ACF method on S3-NGT spectra probably yields better results.
  - How good is SWOT/S3-NGT SWH from coherence?

- Looking forward:
  - Use machine-learning approaches on focused SAR altimetry spectra, waveform parameters (e.g. intensity statistics) and geophysical parameter noise statistics.