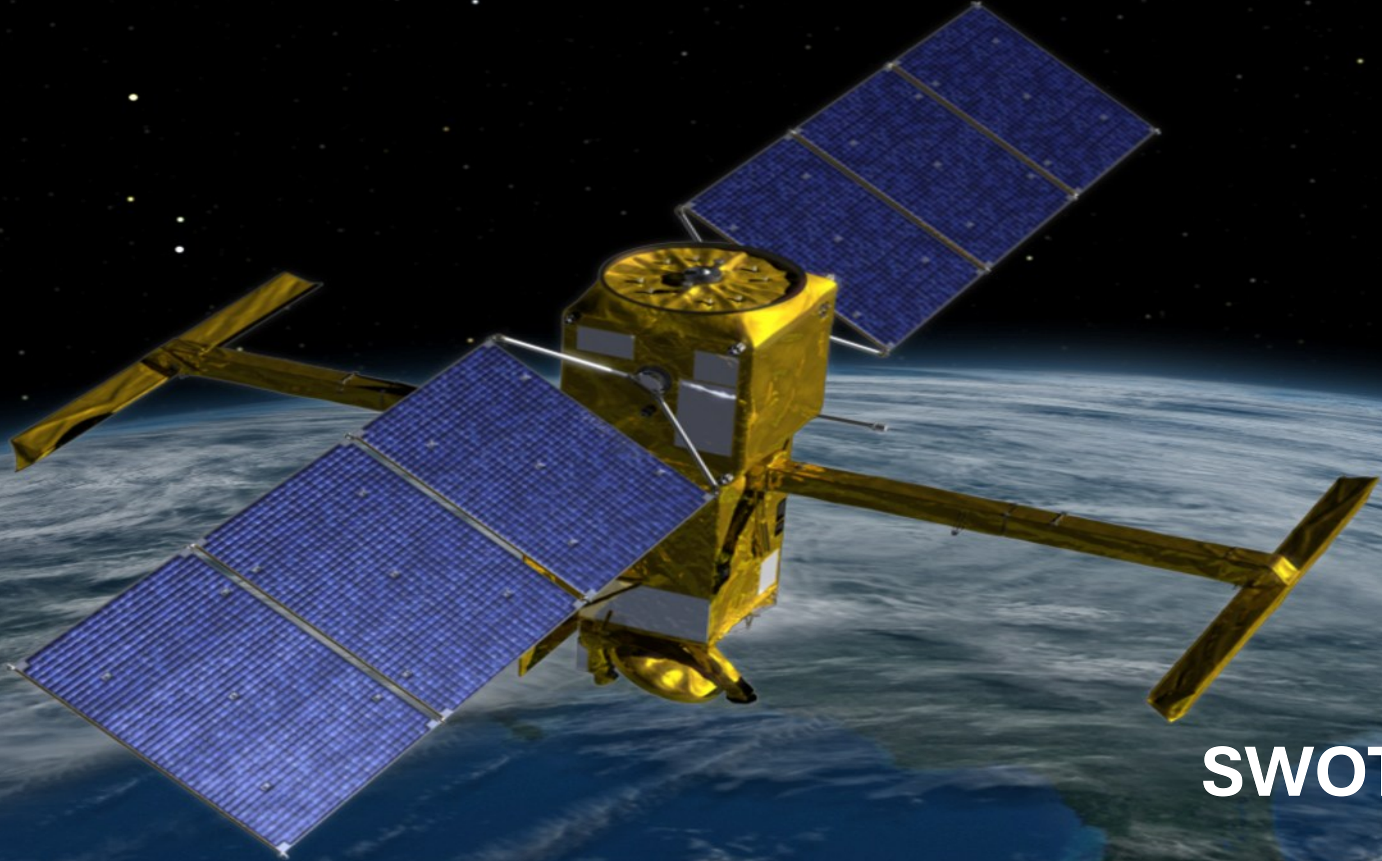
Sea State Bias: using KaRIn's wind speed and SWH estimates as inputs to the correction



October 15th, 2025

SWOT Science Team meeting

Beatriz Molero (CLS),

on behalf of the CNES/JPL algorithm team

Sea State Bias: using KaRIn's wind speed and SWH estimates as inputs to the correction

a **model** for the bias
on KaRIn's SSH measurement
given a sea state

SSB(SWH, U_{10}, ...?)

last presentation
by A. Bohe

knowledge
about the **sea state** that SWOT is flying over

SWH ? U_{10} ?
wave spectrum ?

this presentation

October 15th, 2025

SWOT Science Team meeting

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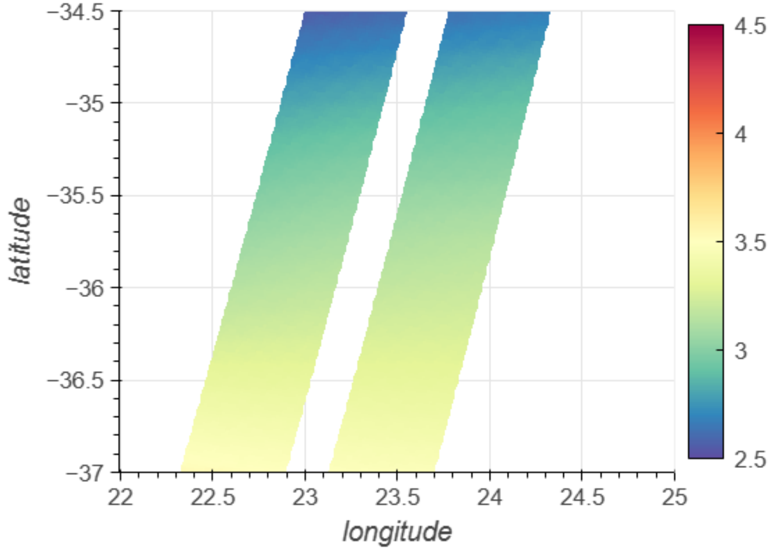
SSB: sea state inputs

Model

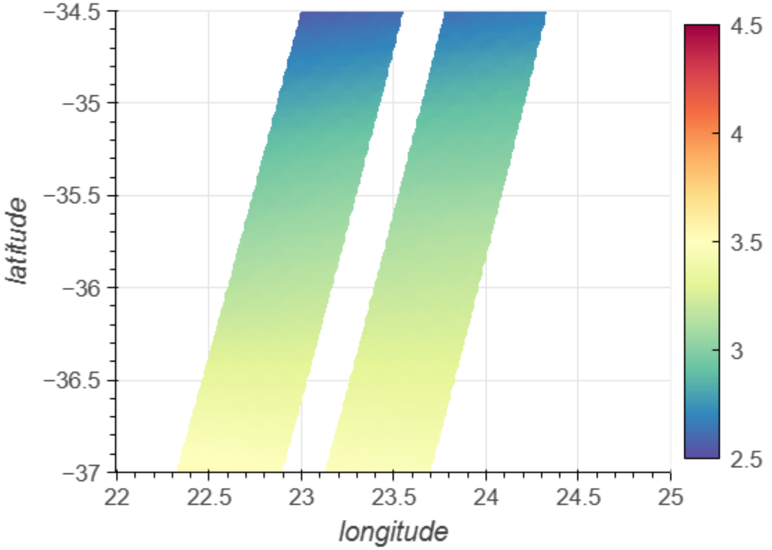


- Always available everywhere
- No noise
- But too smooth

sea_state_bias_cor_2

SSB: sea state inputs

Model



- Always available everywhere
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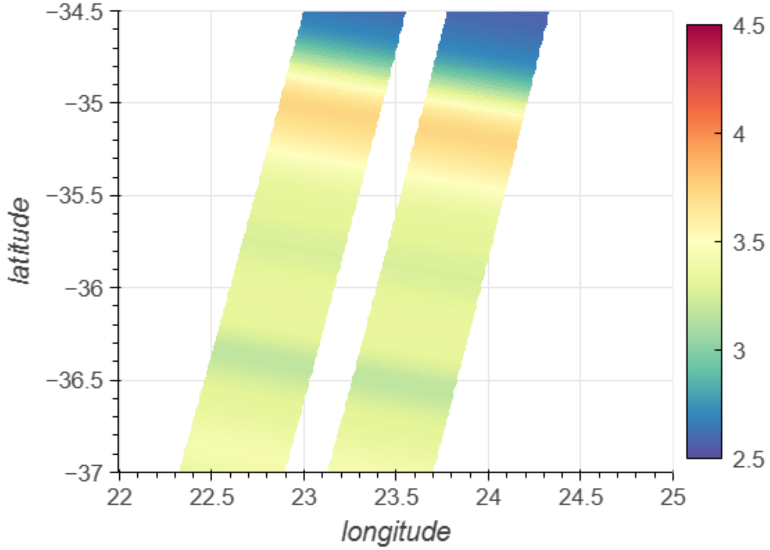
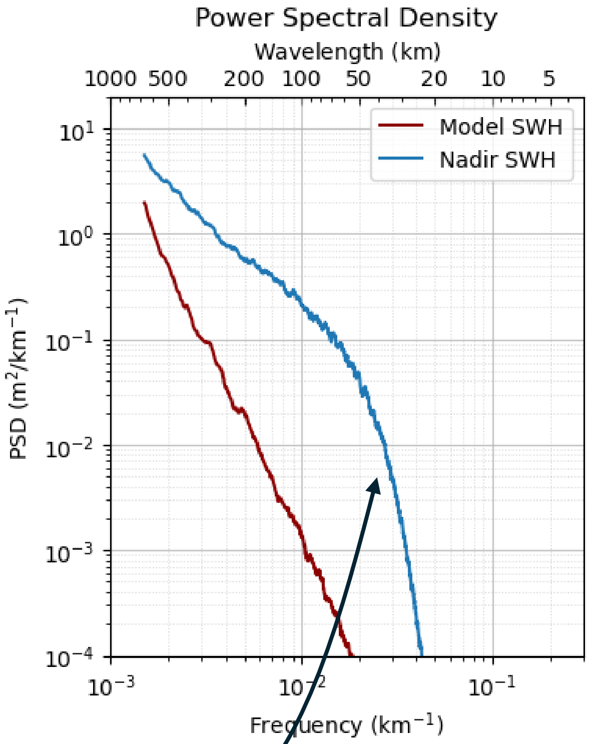
SWOT Nadir



- Better representation of **smaller wavelengths** than the model
- But **instrument noise** dominates at wavelengths < 70 km → filtered out for SSB estimation purposes
- **Spatial mismatch** with swath locations

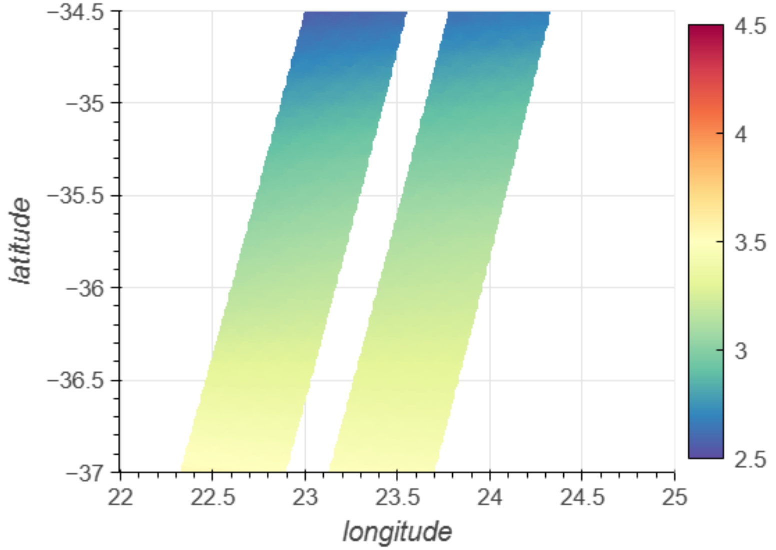


sea_state_bias_cor_2

sea_state_bias_cor_1

SSB: sea state inputs

Model



- Always available everywhere
- No noise
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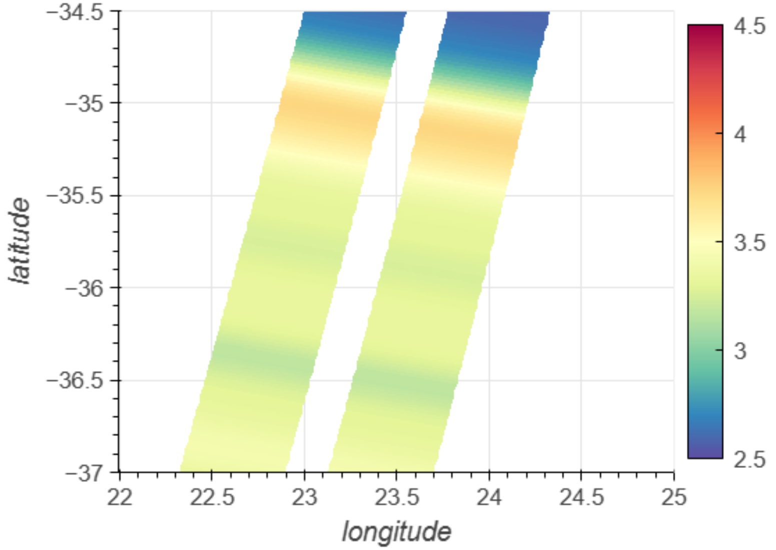
sea_state_bias_cor_2

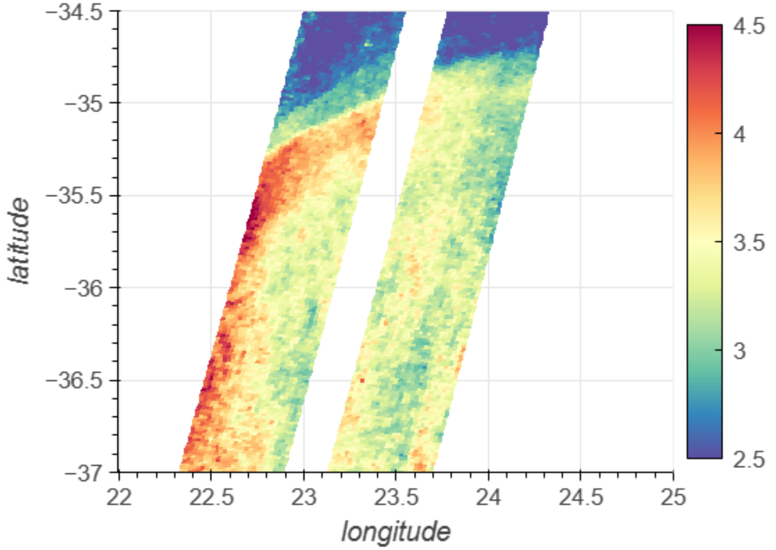
SWOT Nadir



- Better representation of **smaller wavelengths** than the model
- But **instrument noise** dominates at wavelengths < 70 km → filtered out for SSB estimation purposes
- **Spatial mismatch** with swath locations

sea_state_bias_cor_1

KaRIn swath



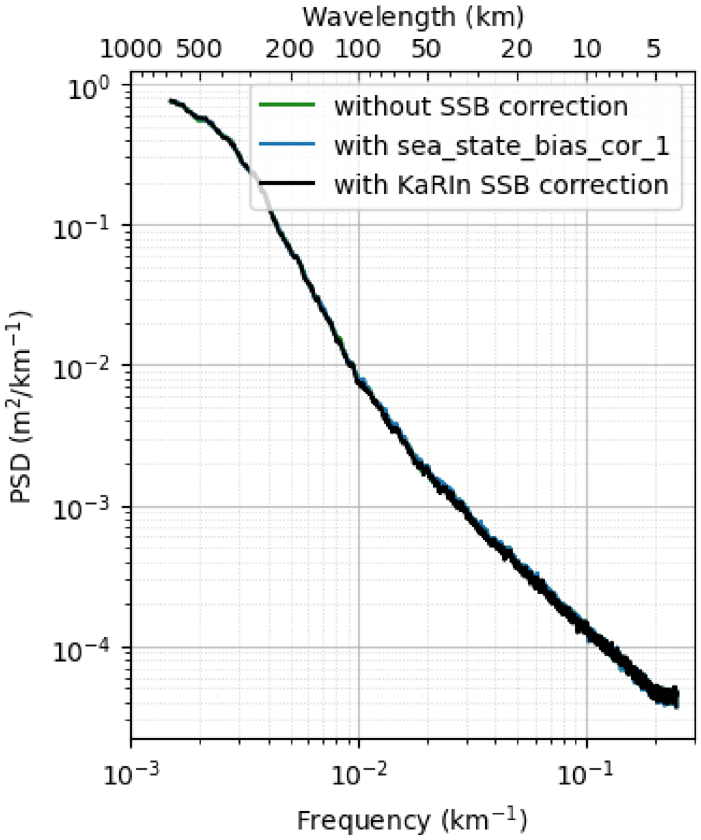
- **Perfect location**
- Represents **wavelengths below 70 km**
- But **instrument noise** is important, specially at far range → probably some filtering needed for SSB purposes

Can the SSB based on KaRIn sea state & wind inputs be better than current sea_state_bias_cor_1 ?

SSHA after *vs* before SSB correction

Along-track spectra of SSHA
before and after correction

at 10 km cross-track distance



SSHA after *vs* before SSB correction

Along-track spectra of SSHA
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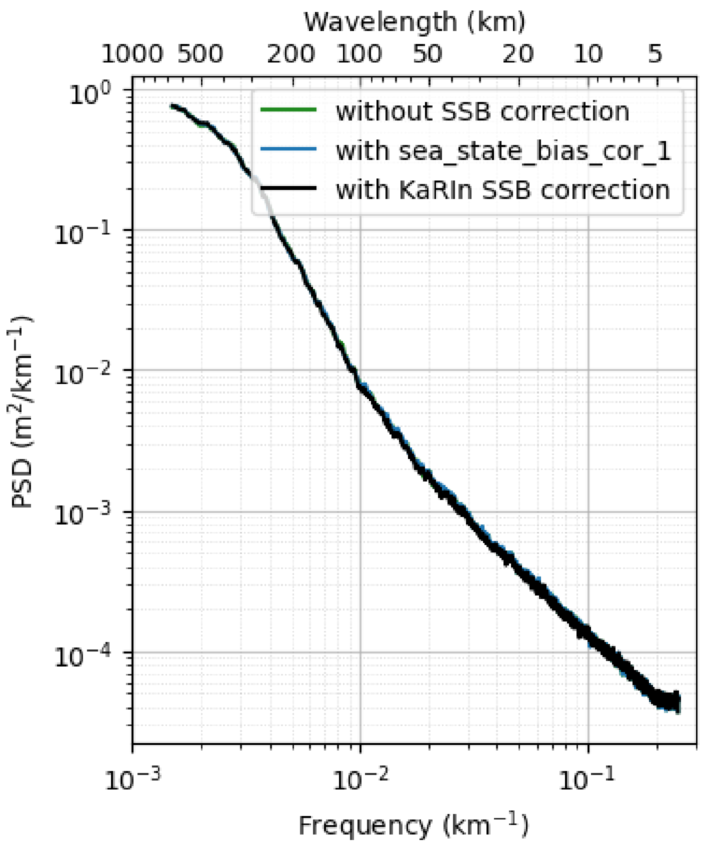
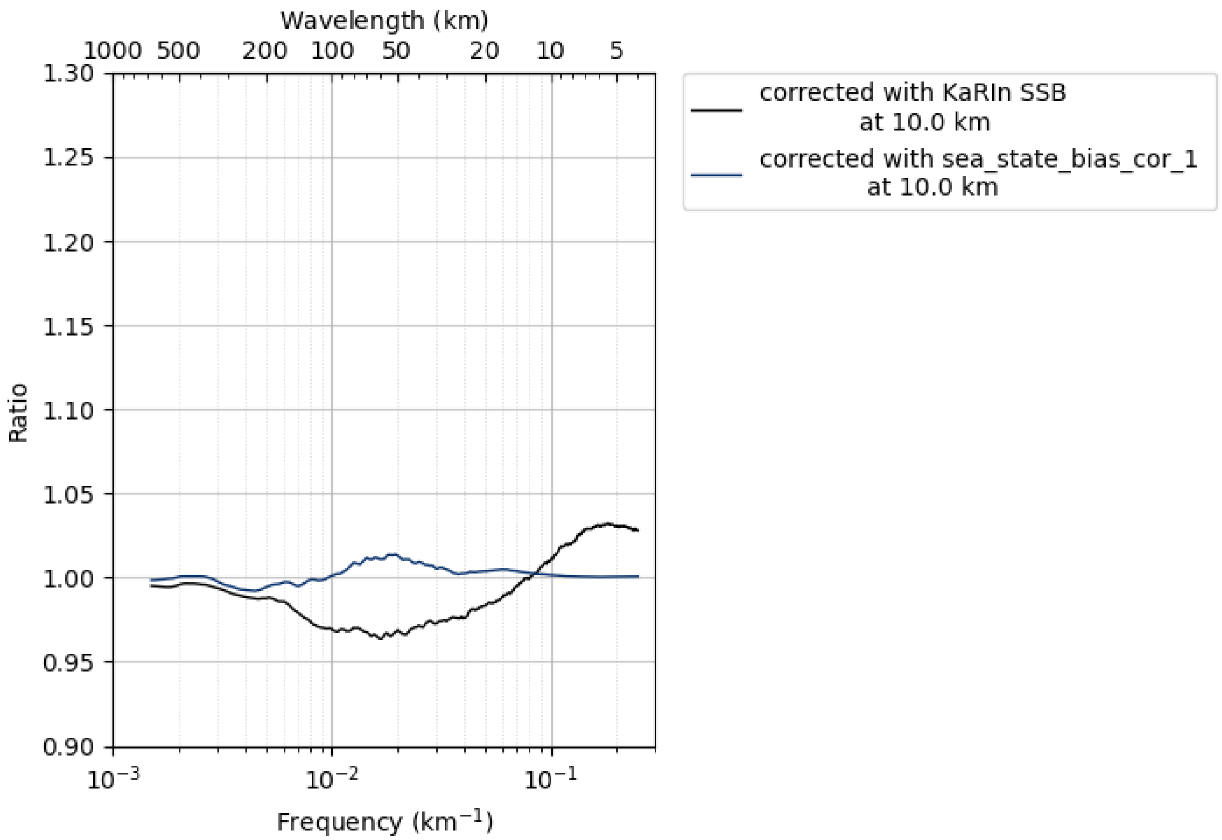
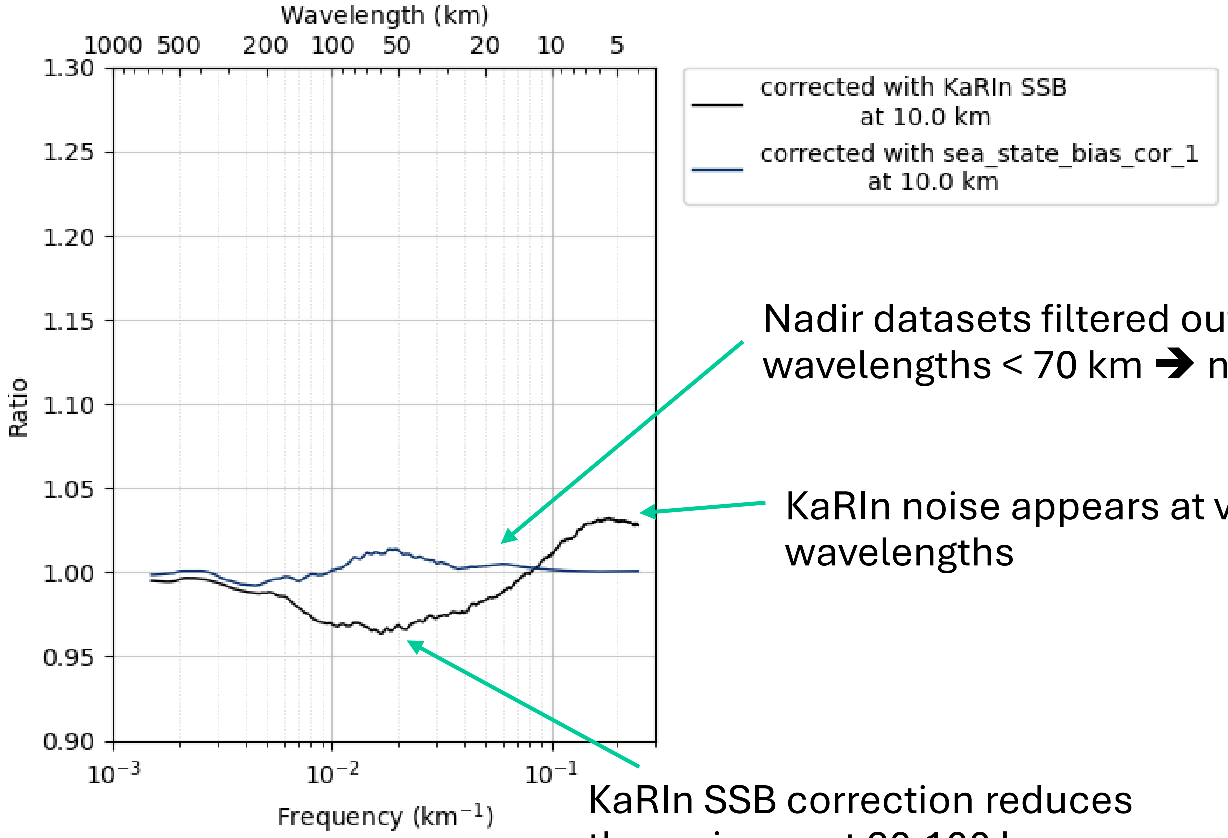


Ratio of spectra of SSHA $\dfrac{\text{after the correction}}{\text{before the correction}}$



SSHA after *vs* before SSB correction

Ratio of spectra of SSHA $\frac{\text{after the correction}}{\text{before the correction}}$



Nadir datasets filtered out at wavelengths < 70 km ➔ no correction

KaRIn noise appears at very short wavelengths

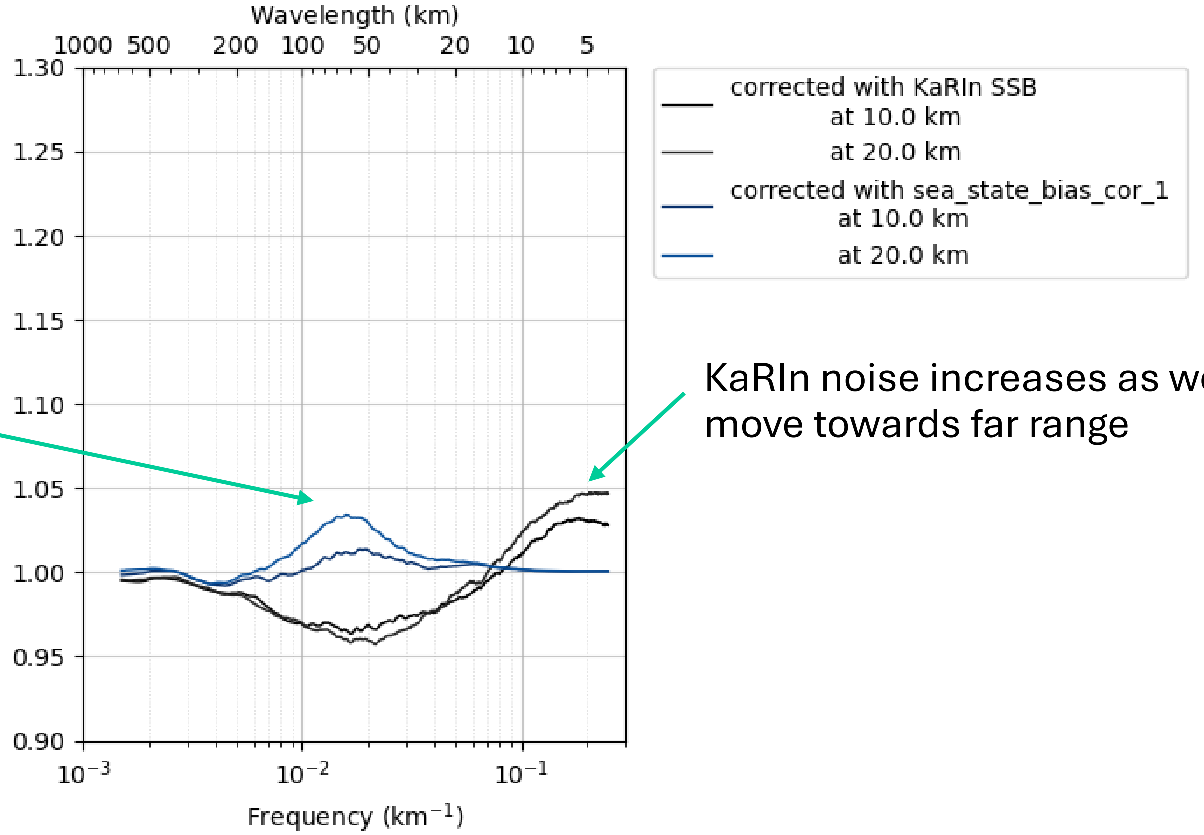
KaRIn SSB correction reduces the variance at 20-100 km

SSHA after *vs* before SSB correction

From near to far range…

Nadir SSB correction gets worse for 50 - 200 km wavelengths as we move away from nadir due to the **spatial mismatch** of nadir observations wrt KaRIn SSHA

Ratio of spectra of SSHA $\frac{\text{after the correction}}{\text{before the correction}}$

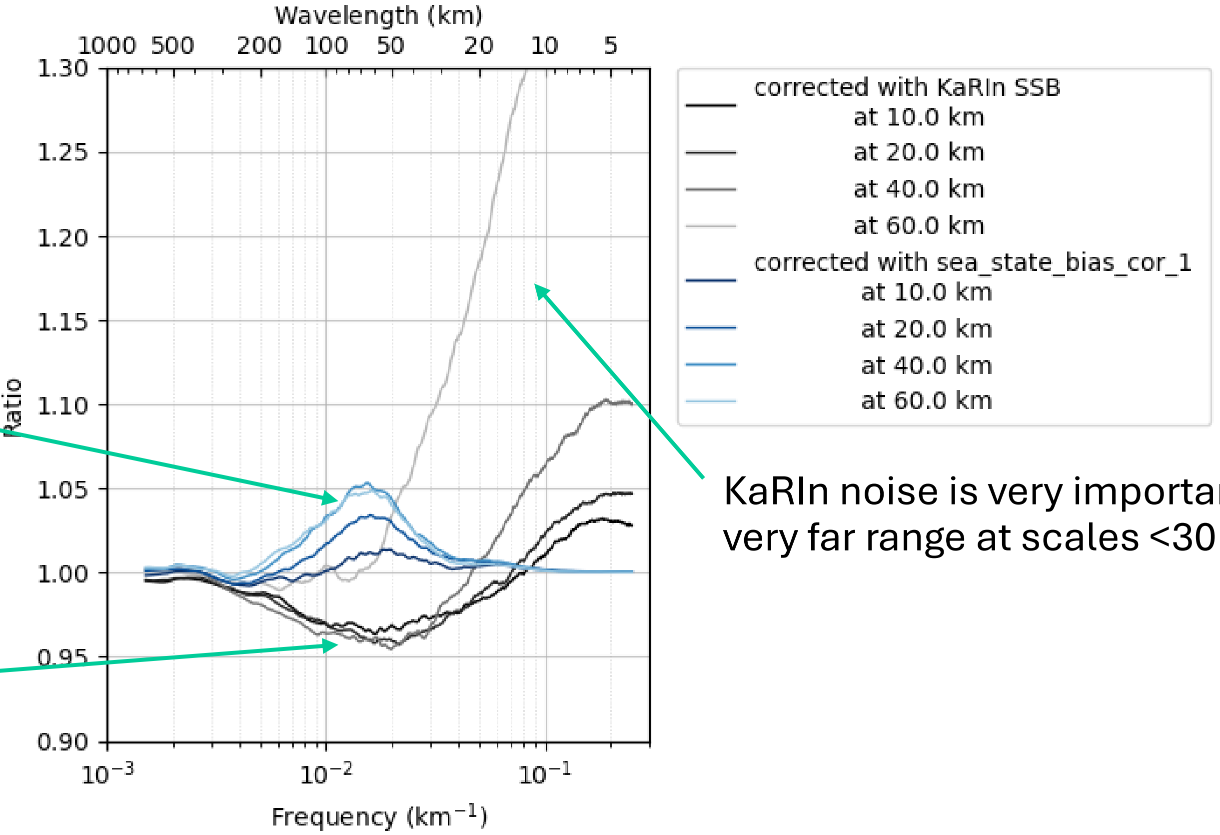


KaRIn noise increases as we move towards far range

SSHA after *vs* before SSB correction

From near to far range…

Ratio of spectra of SSHA $\frac{\text{after the correction}}{\text{before the correction}}$



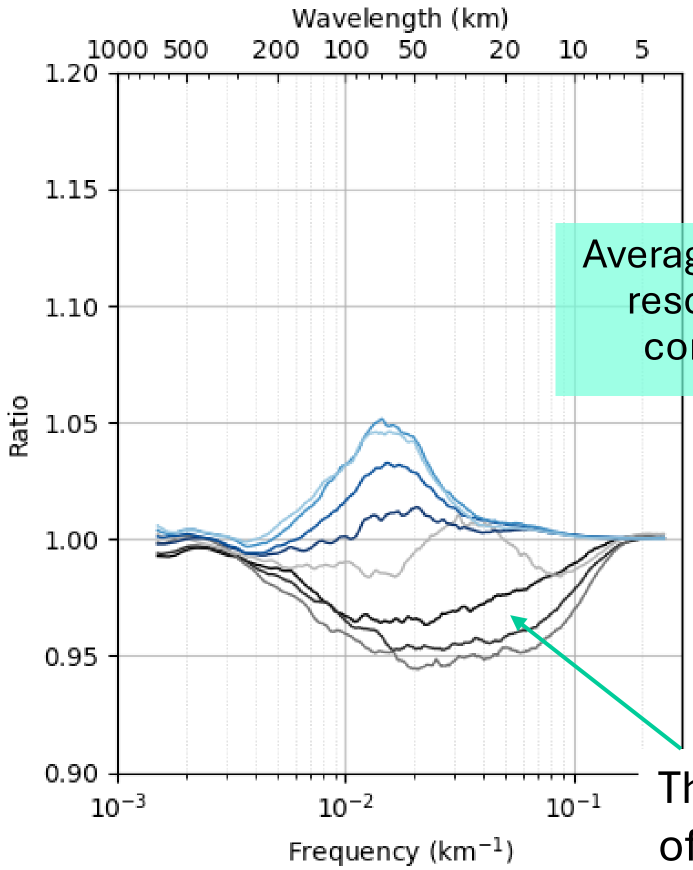
Nadir SSB correction gets worse for 50 - 200 km wavelengths as we move away from nadir due to the **spatial mismatch** of nadir observations wrt KaRIn SSHA

KaRIn SSB is better than nadir for 50 - 200 km wavelengths

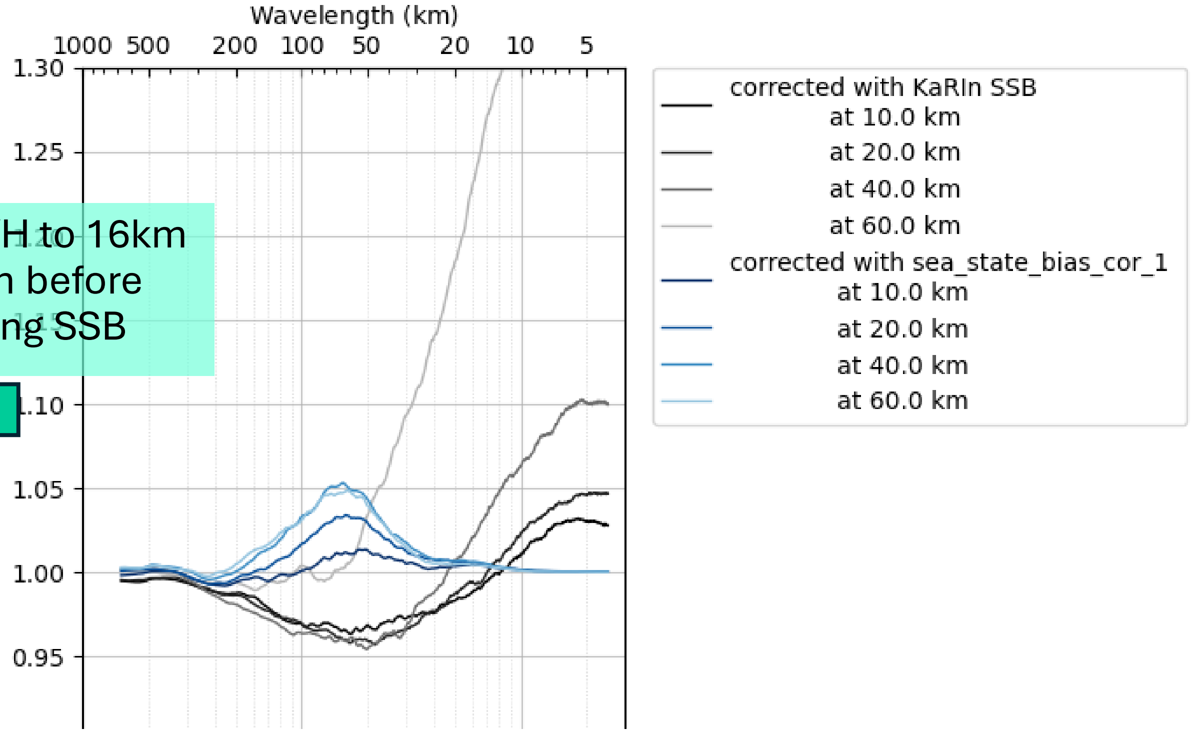
KaRIn noise is very important at very far range at scales <30 km

Averaging SWH to reduce KaRIn SSB noise

Ratio of spectra of SSHA $\frac{\text{after the correction}}{\text{before the correction}}$



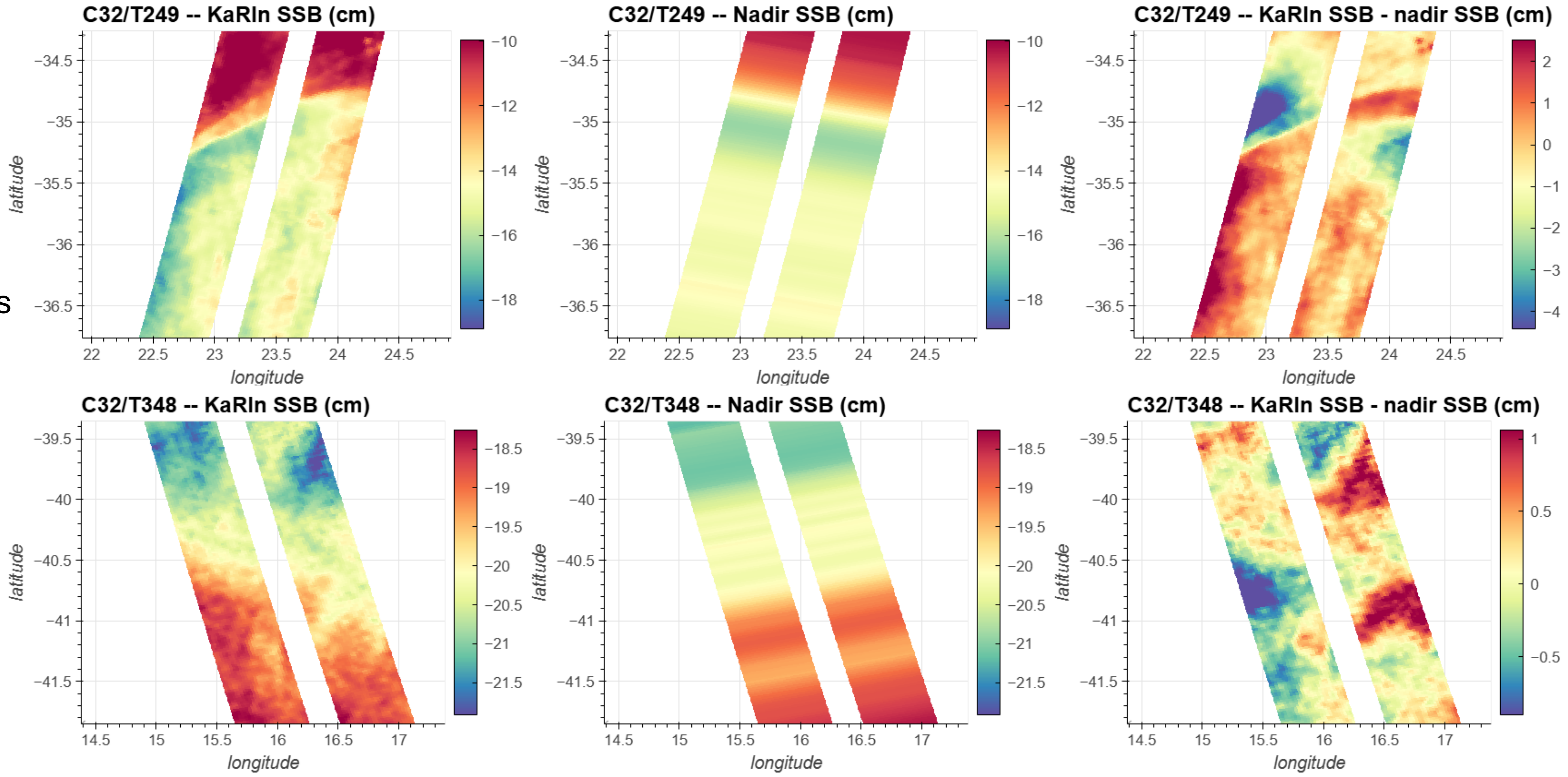
Average SWH to 16km resolution before computing SSB



The 2D averaging of SWH effectively mitigates a large portion of the noise and allows to have an effective KaRIn SSB correction for wavelengths between 10-300 km

Nice examples

KaRIn improves the spatial representation of the SSB correction

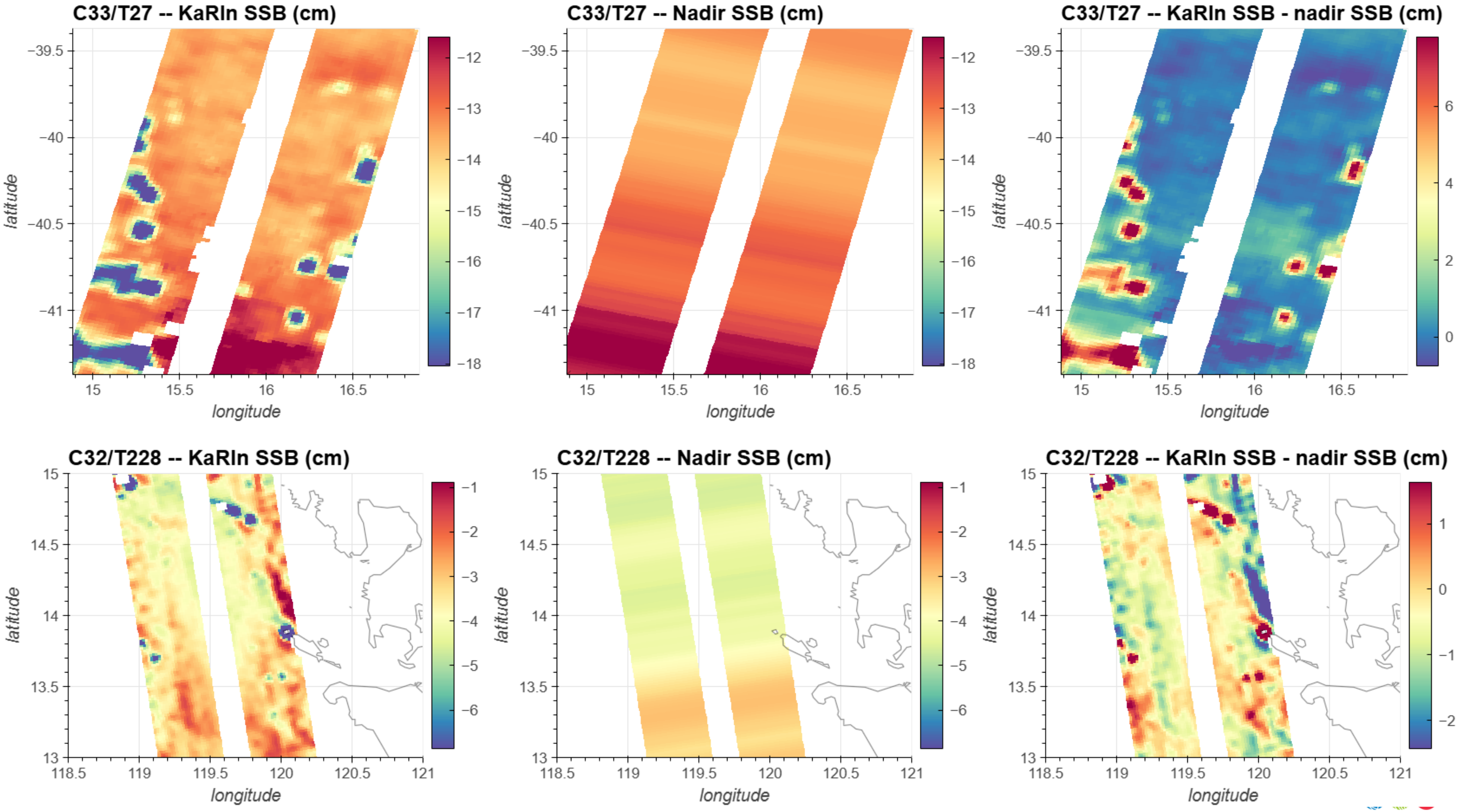


Current limitations

Rain in KaRIn SWH

Editing algorithms under investigation (see poster by B. Picard & A. Colin, *« The effects of rain on a Ka-band swath altimeter: lessons learned from the SWOT mission”*

Residual instrumental errors in KaRIn SWH (check presentation A. Bohe on SWH)

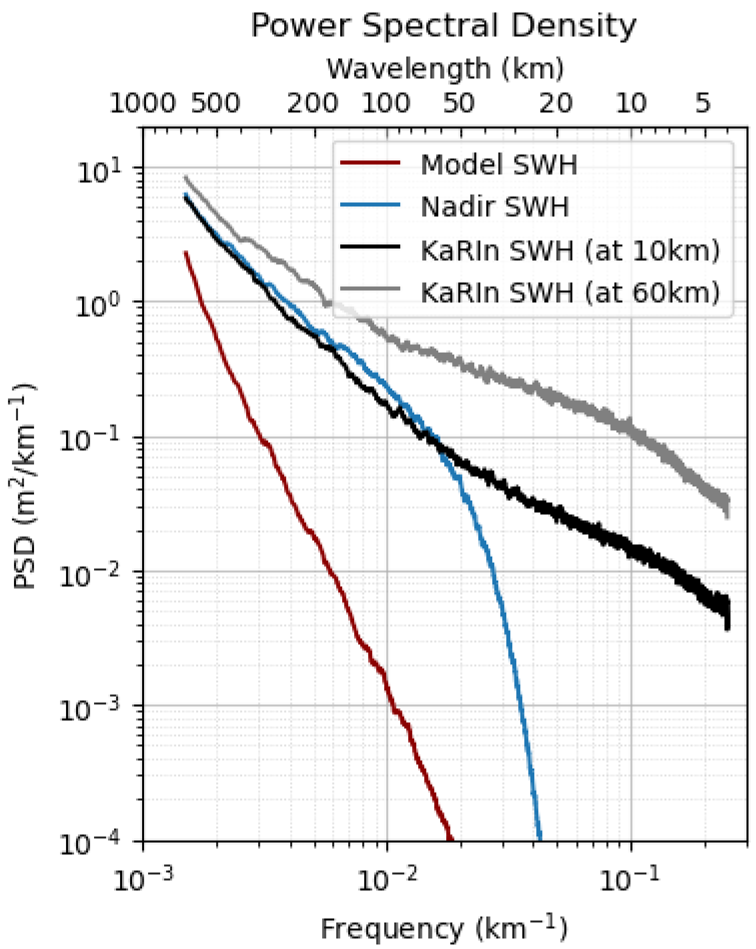


Conclusions

- Nadir SSB correction (**sea_state_bias_cor_1**): degrades performance at scales < 300 km , probably due to the spatial mismatch wrt swath locations (it corrects SSHA with the wrong phase)
- **KaRIn-based SSB** is very promising: allows to resolve smaller scales and get rid of spatial mismatch errors
- Locally, will present gaps in rainy conditions (but that's why we have a model-based SSB dataset) and instrument artifacts under some conditions (see A. Bohé presentation on SWH)
- Investigations on KaRIn SSB will continue, with a special emphasis on SWH flagging and refinement
- In a global perspective, it performs better than nadir-based SSB: it reduces SSHA variance at scales < 300 km

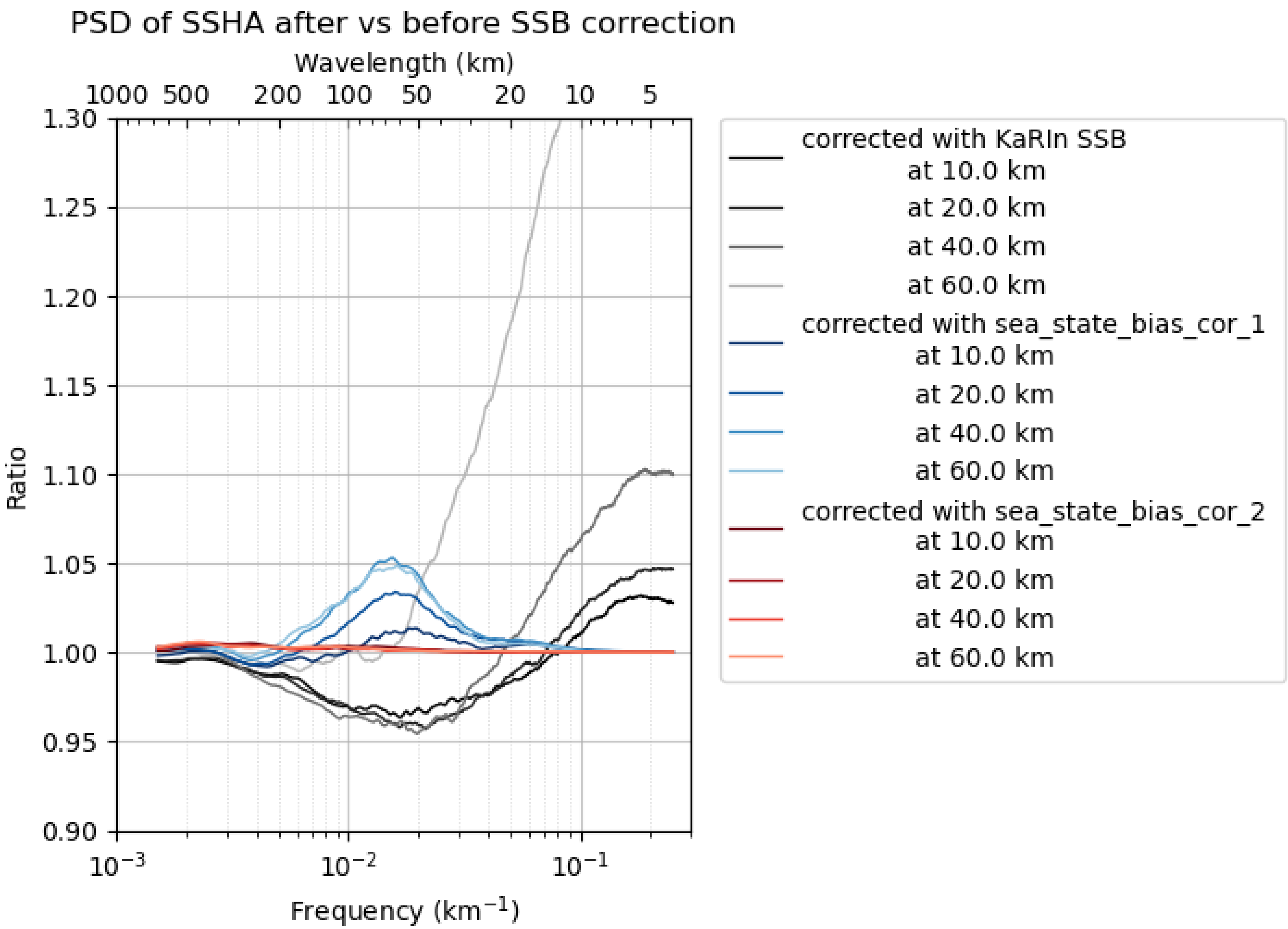
Backup slides

SWH

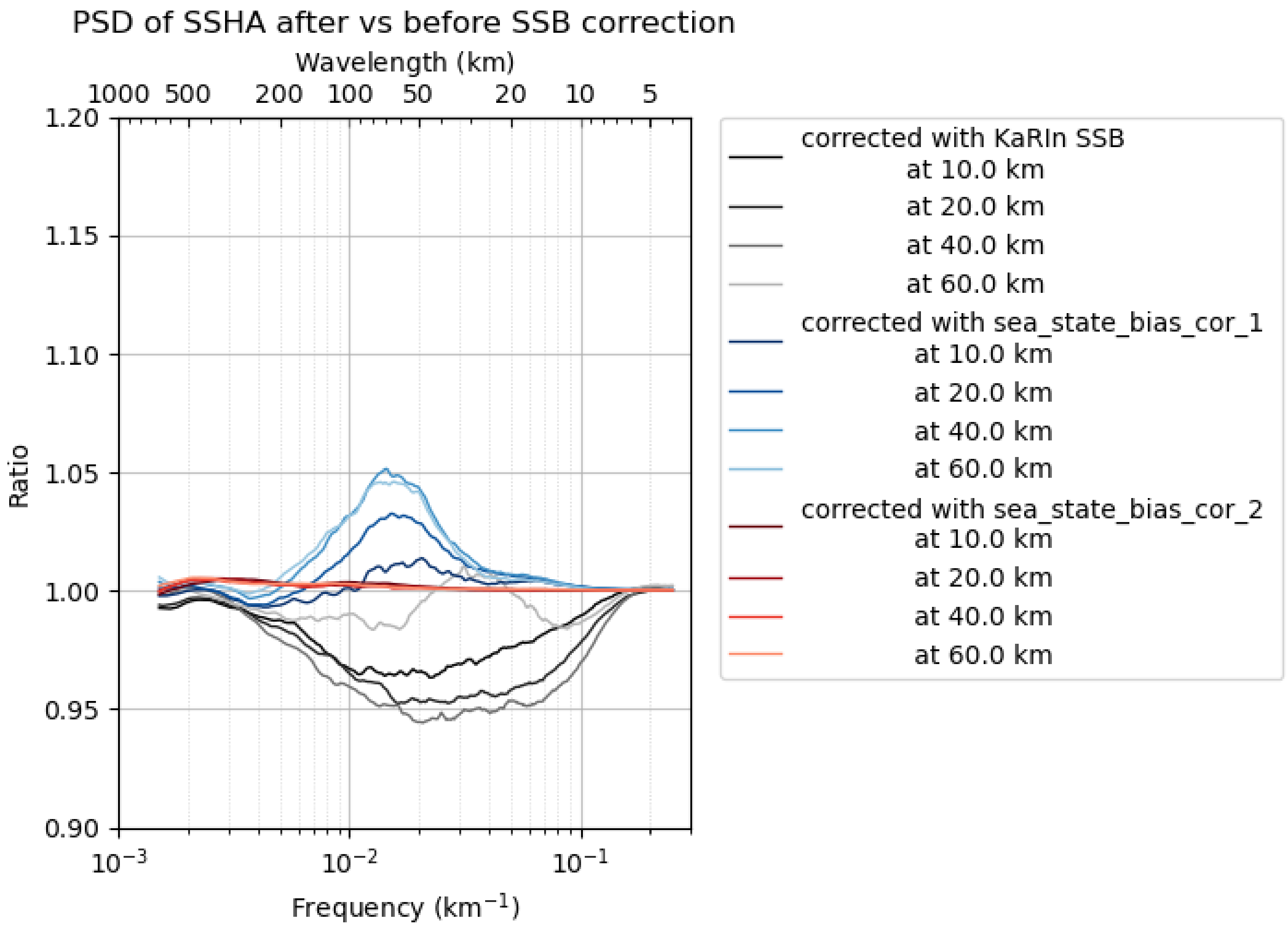


Power Spectral Density
Wavelength (km)
1000 500 200 100 50 20 10 5
Model SWH
Nadir SWH
KaRIn SWH (at 10km)
KaRIn SWH (at 60km)
PSD (m^2/km^{-1})
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-3} 10^{-2} 10^{-1}
Frequency (km^{-1})

Ratios


PSD of SSHA after vs before SSB correction
Wavelength (km)
1000
500
200
100
50
20
10
5
1.30
1.25
1.20
1.15
1.10
1.05
1.00
0.95
0.90
Ratio
10−3
10−2
10−1
Frequency (km−1)
corrected with KaRIn SSB
at 10.0 km
at 20.0 km
at 40.0 km
at 60.0 km
corrected with sea_state_bias_cor_1
at 10.0 km
at 20.0 km
at 40.0 km
at 60.0 km
corrected with sea_state_bias_cor_2
at 10.0 km
at 20.0 km
at 40.0 km
at 60.0 km

Ratios after avg at 16 km



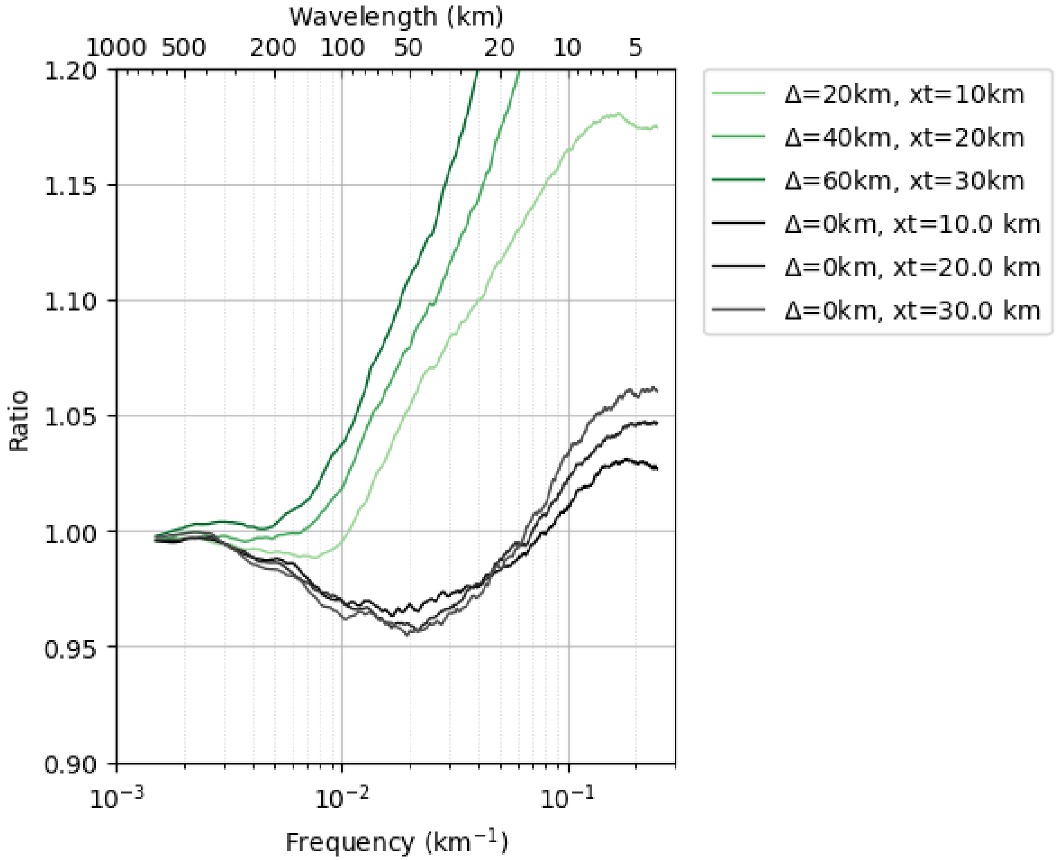
Effect of spatial mismatch on variance ratios

SSHA at cross-track distance ***xt*** corrected with a SSB computed at a ***xt-Δ*** distance

vs

SSHA at cross-track distance ***xt*** corrected with SSB at the same location

SWH not averaged



SWH averaged at 8km resolution