First SAR altimeter tandem phase: a unique opportunity to better characterize open ocean SAR altimetry signals with unfocused and focused processing

OSTST 2019 - CHICAGO

P. Rieu[1], <u>T. Moreau</u>[1], M. Raynal[1], E. Cadier[1], P. Thibaut[1], F. Borde[2], C. Donlon[2], F. Boy[3], N. Picot[3], S. Clerc[4]

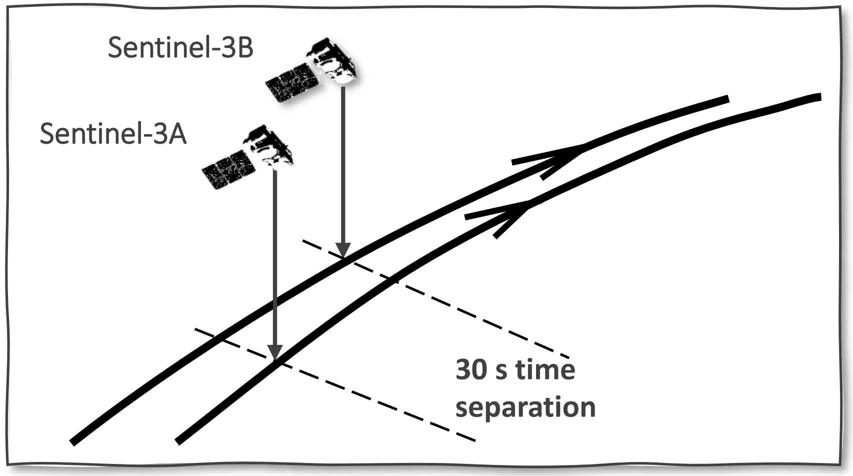
1 CLS, 2 ESA, 3 CNES, 4 ACRI

S3 Tandem For Climate

Multi sensor synergy study for Sentinel-3 C/D

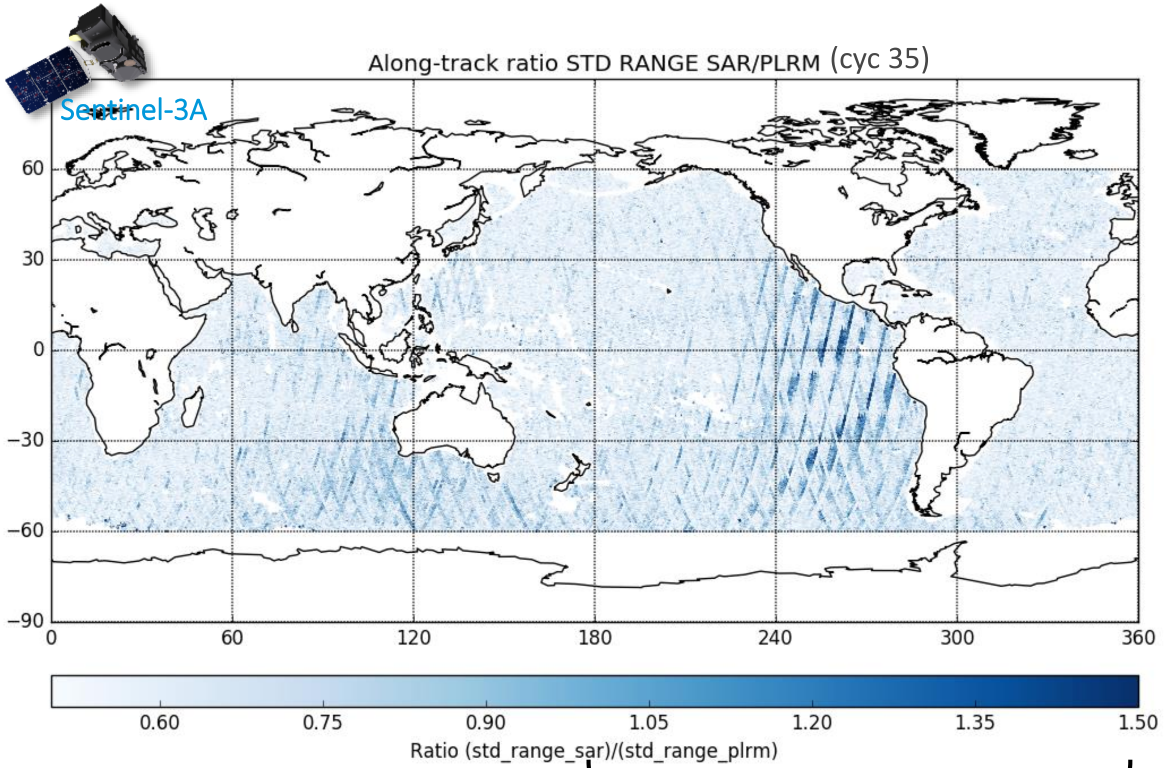
SENTINEL-3 TANDEM PHASE: CONTEXT & OBJECTIVES

- First SAR altimeter tandem phase. The first objective was to perform cross-calibration of the instruments, for producing homogeneous and unbiased time-series observations for climate records.

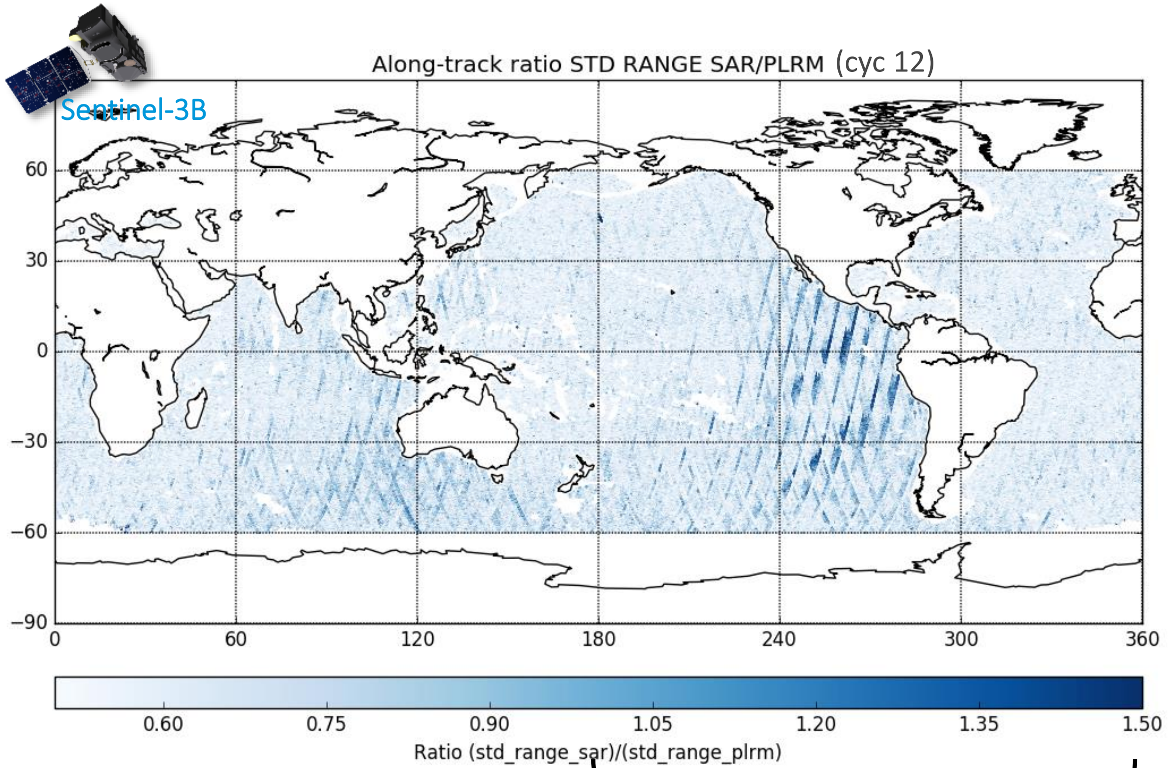


- It was also a unique opportunity to go further in the characterization of the SAR altimeter retrievals over ocean, by exploiting the combination of the two datasets and the time lag between them. **It was particularly interesting for going further in the investigations on swell impact.**

THE IMPACT OF SWELL ON SAR ALTIMETRY



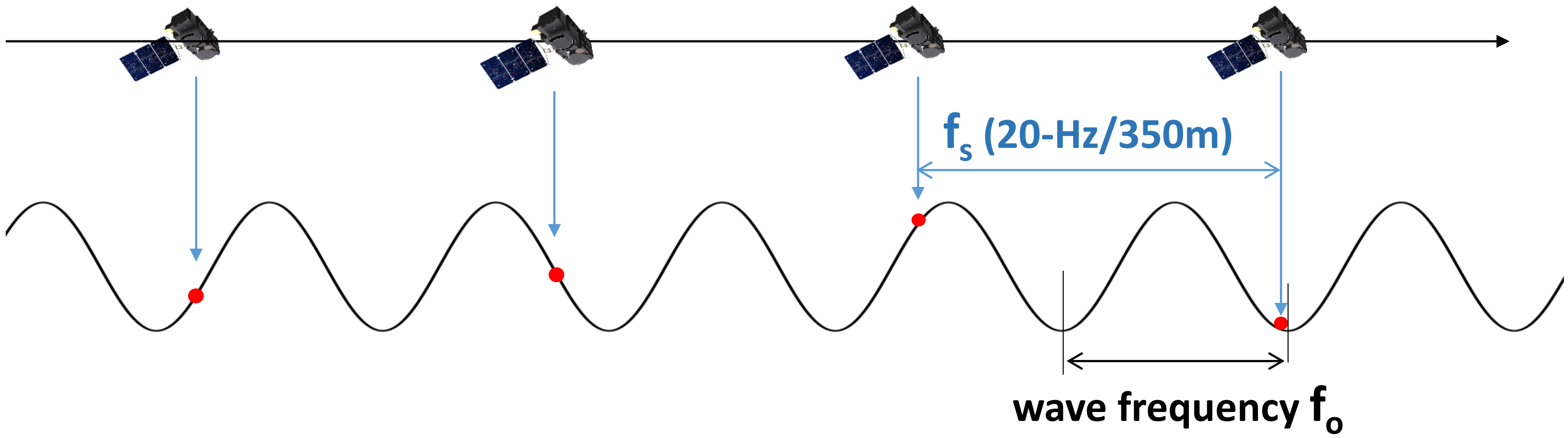
UF-SAR range std > PLRM range std



UF-SAR range std > PLRM range std

Same pattern / sea-state sensitivity observed with S3A and S3B UF-SAR data

LIMITATION OF THE UF-SAR PROCESSING TO RETRIEVE SWELL PROPERTIES



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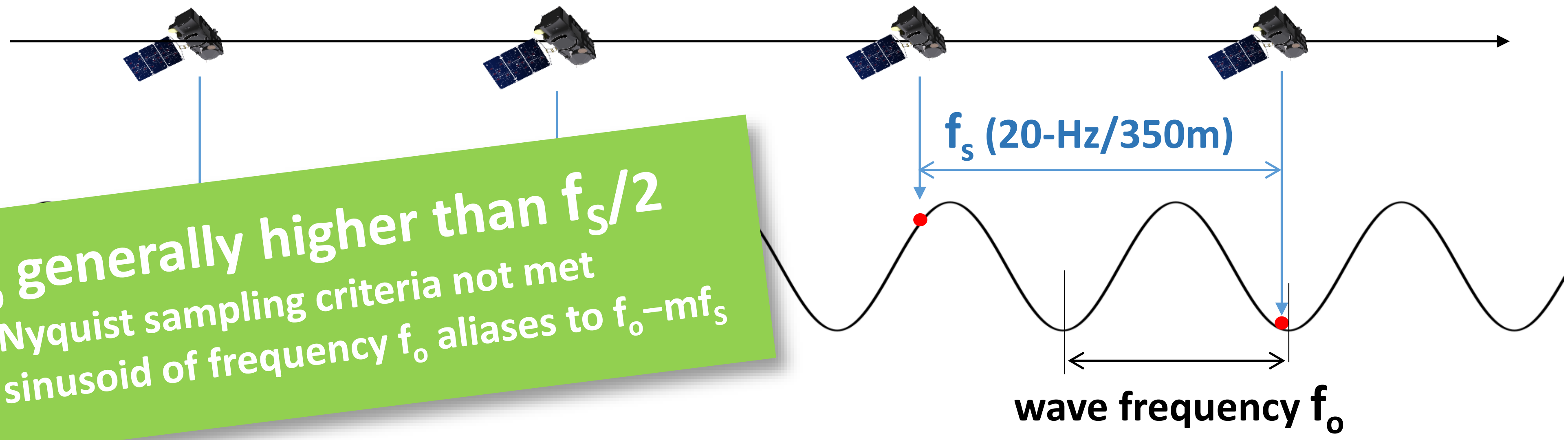


f_o generally higher than $f_S/2$

- Nyquist sampling criteria not met
- sinusoid of frequency f_o aliases to $f_o - mf_s$

- Aliasing effects contribute to:
  - 20-Hz range noise [Reale et al., 2018]
  - "red noise" signal on PSD [Raynal et al., OSTST 2018]

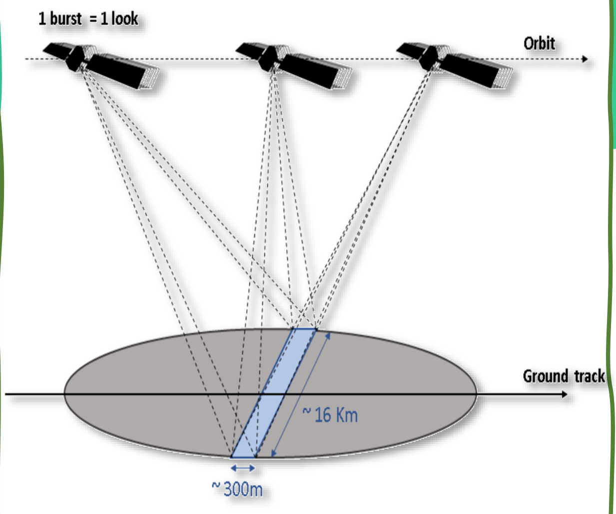
THE FULLY-FOCUSED SAR PROCESSING

- **Fully-Focused SAR [Egido & Smith, 2017]** offers high spatial resolution and allows high sampling rates, making it suitable for detecting swell-related SSH signals

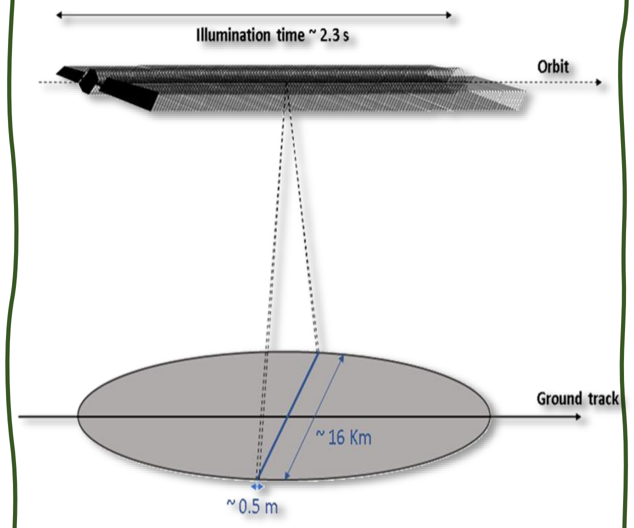
- **Frequency-domain focusing approach [Guccione et al., 2018]** to reduce computational time and **numerical retracking [Buchhaupt et al., 2018]** combined with azimuth PTR consistent with the FF-SAR processing are used

- Multilooking at 50 m (140 Hz) is performed

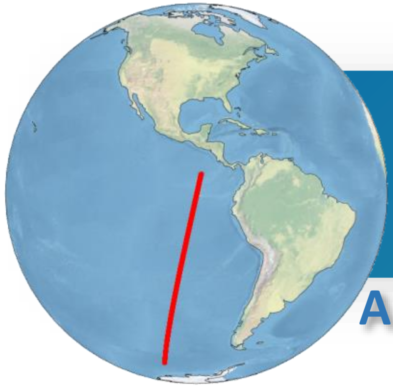
Unfocused SAR (SAR mode)
[Raney, 1998]



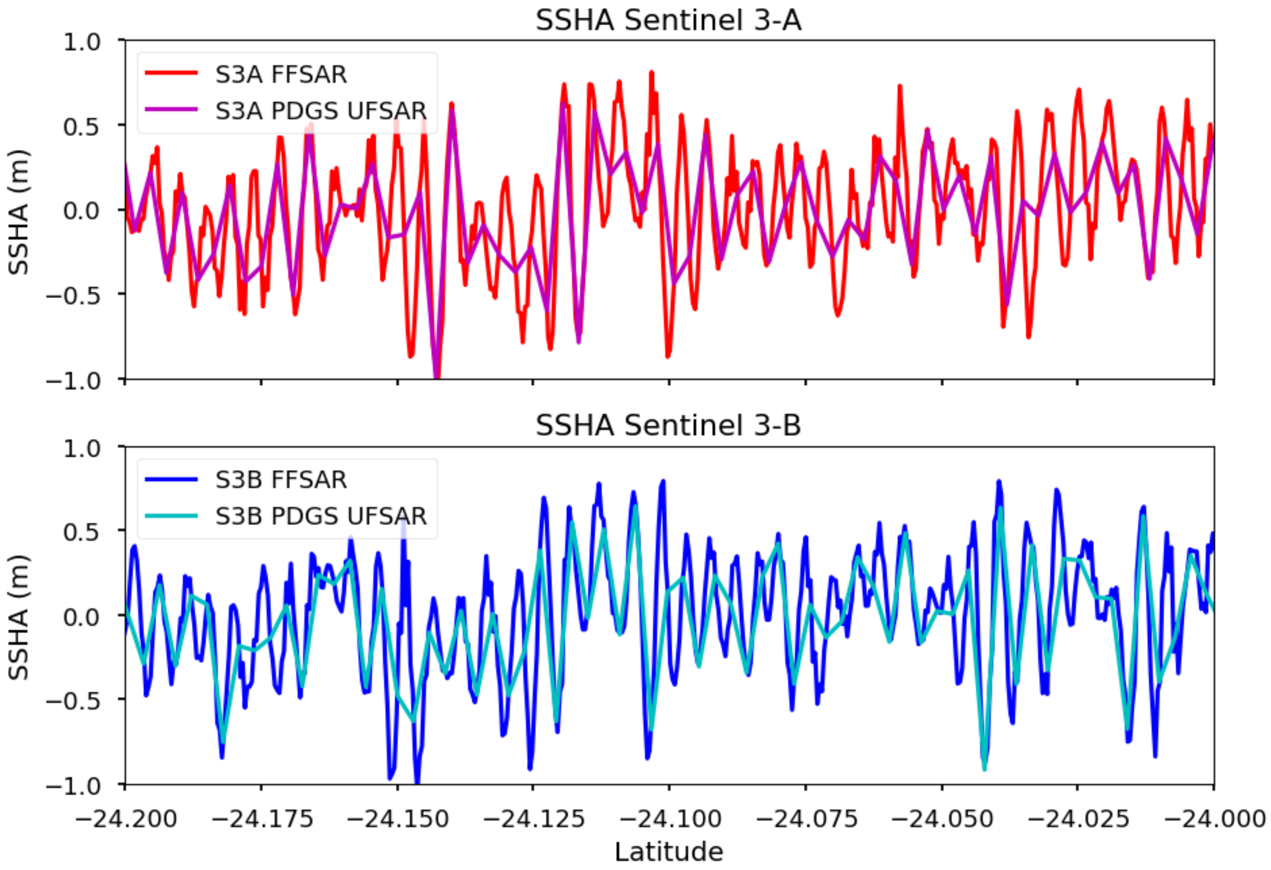
Fully-Focused SAR (FFSAR)
[Egido & Smith, 2017]

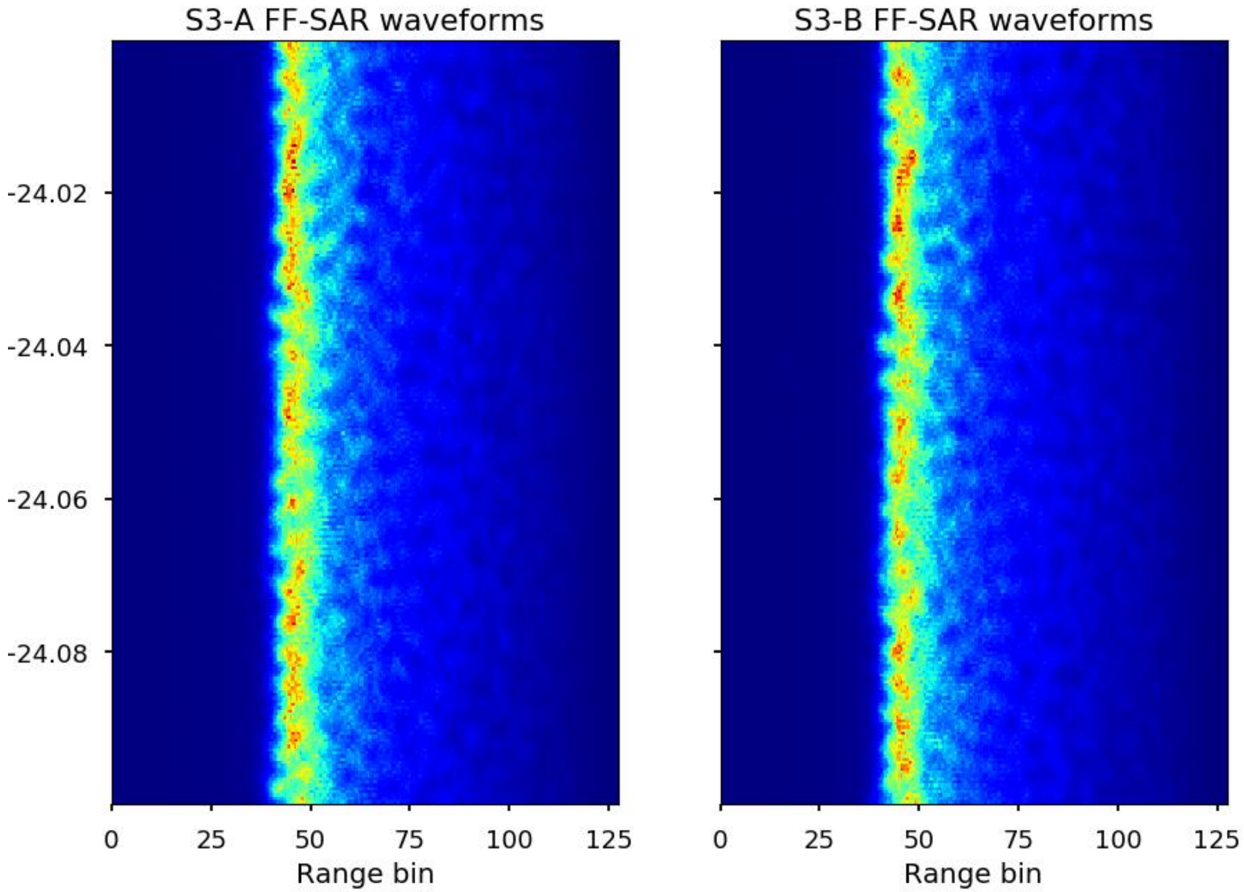


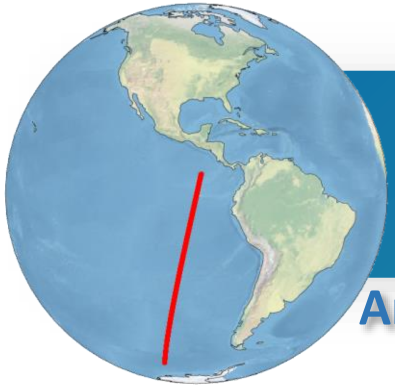
FIRST STUDY CASE : TEMPORAL ANALYSIS



Anticolinear swell

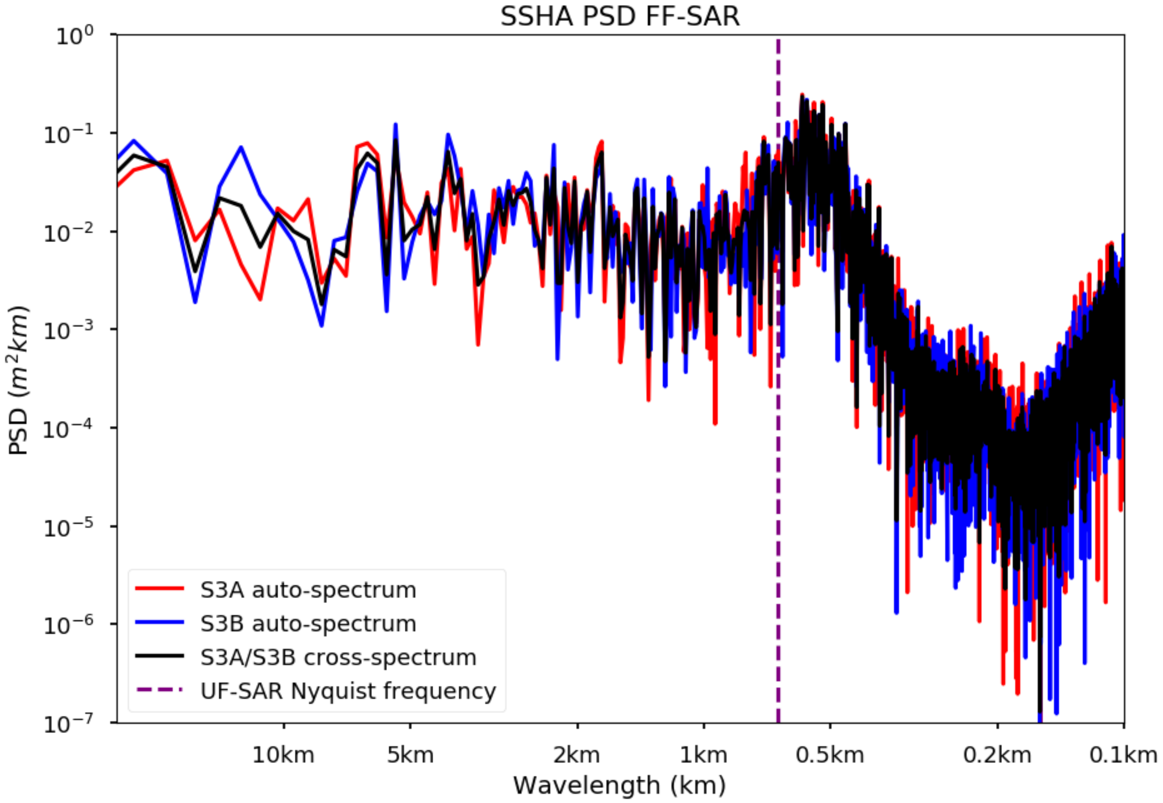


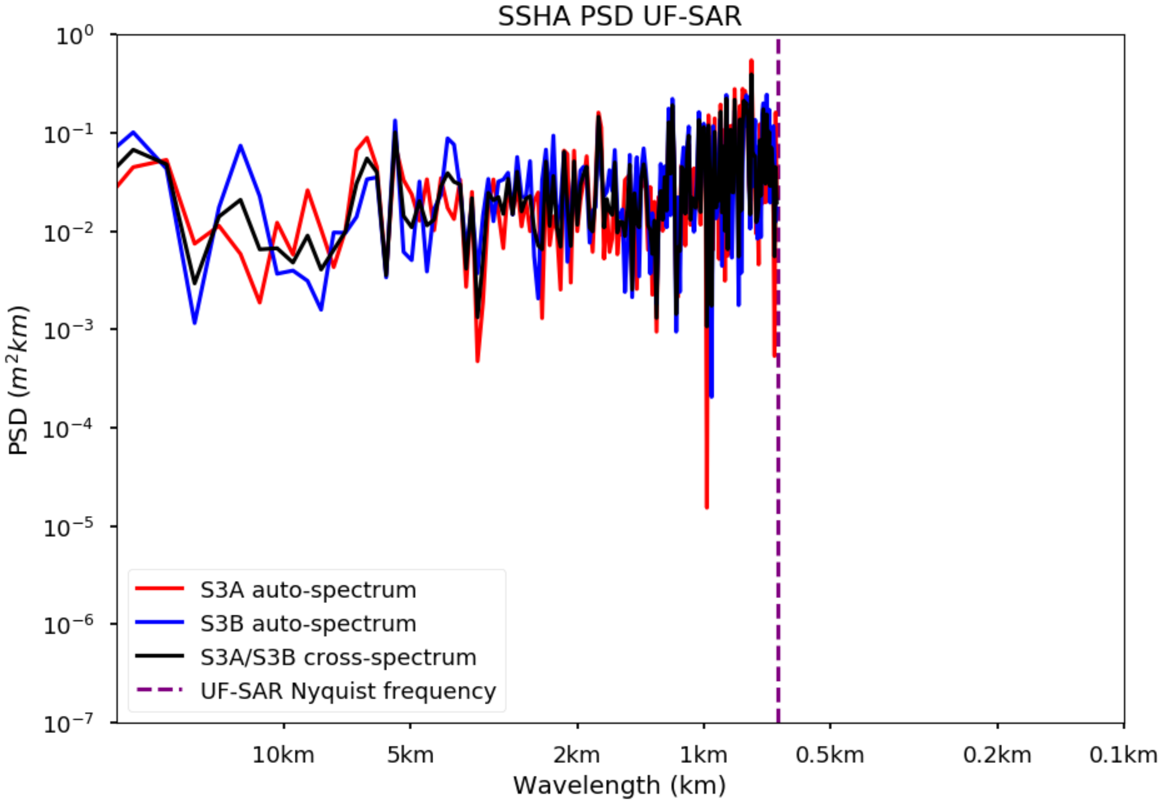




FIRST STUDY CASE : SPECTRAL DENSITY ANALYSIS

Anticolinear swell





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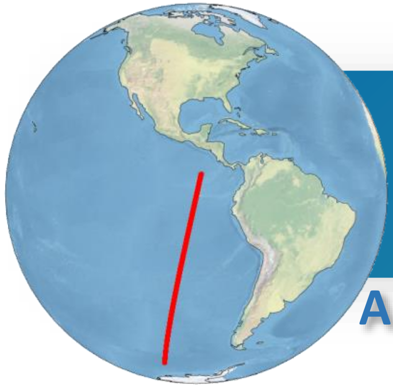

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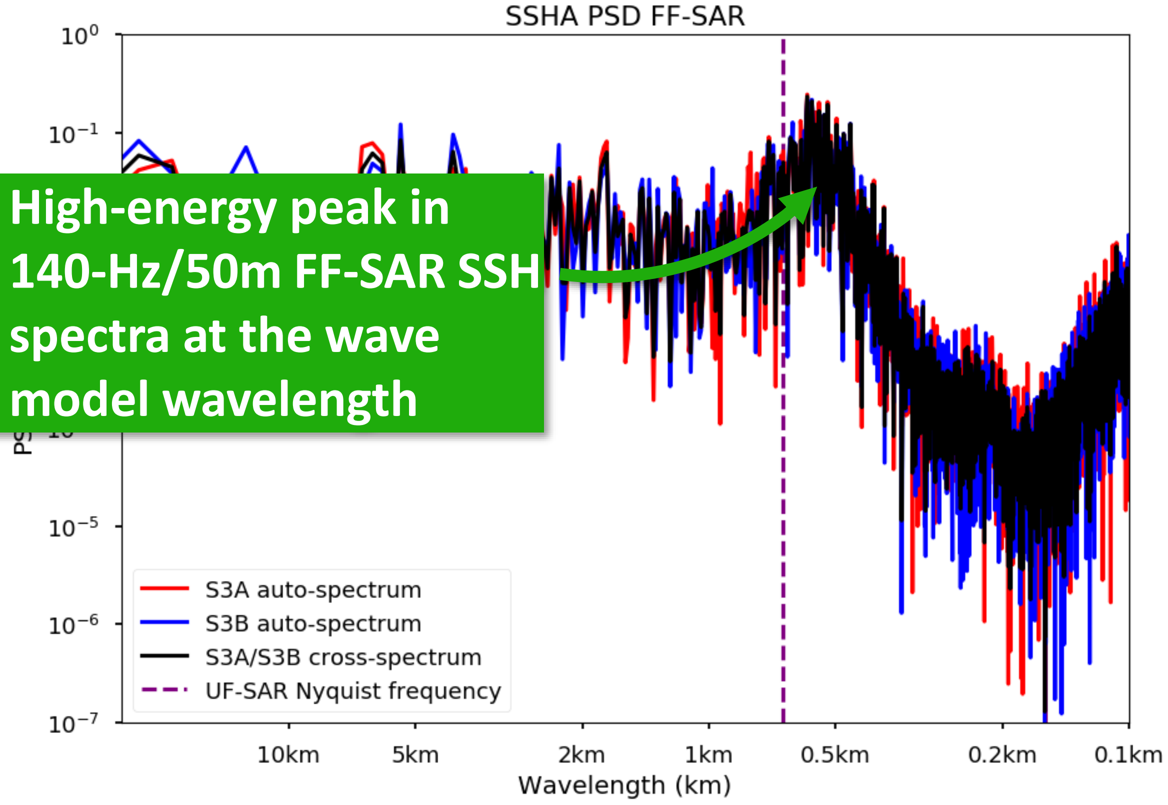

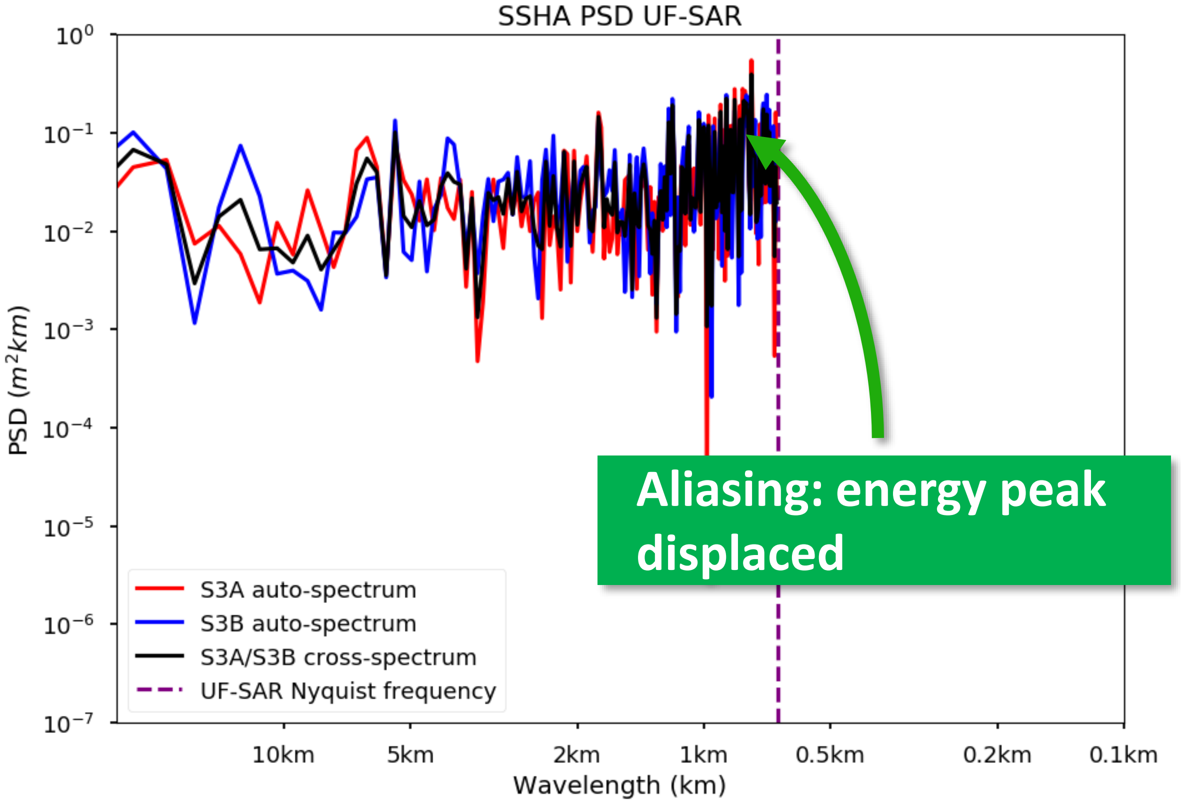

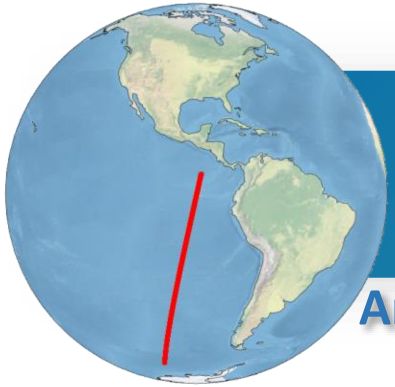

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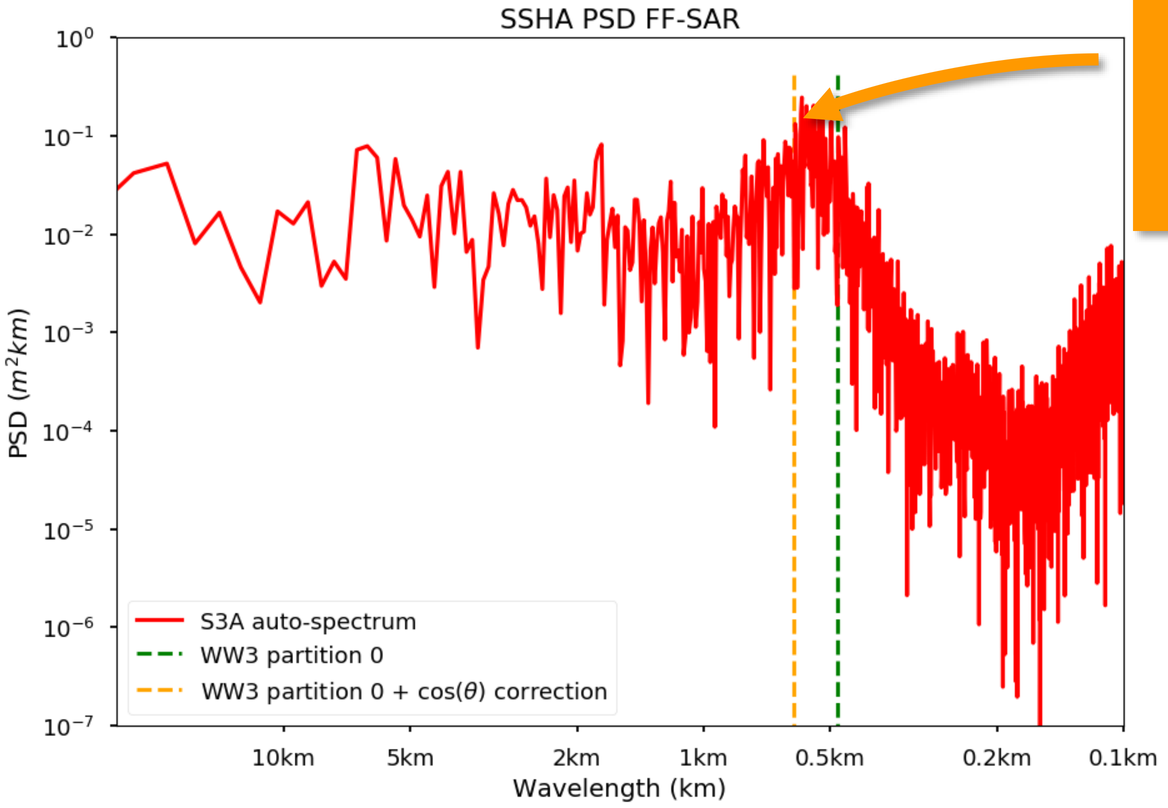
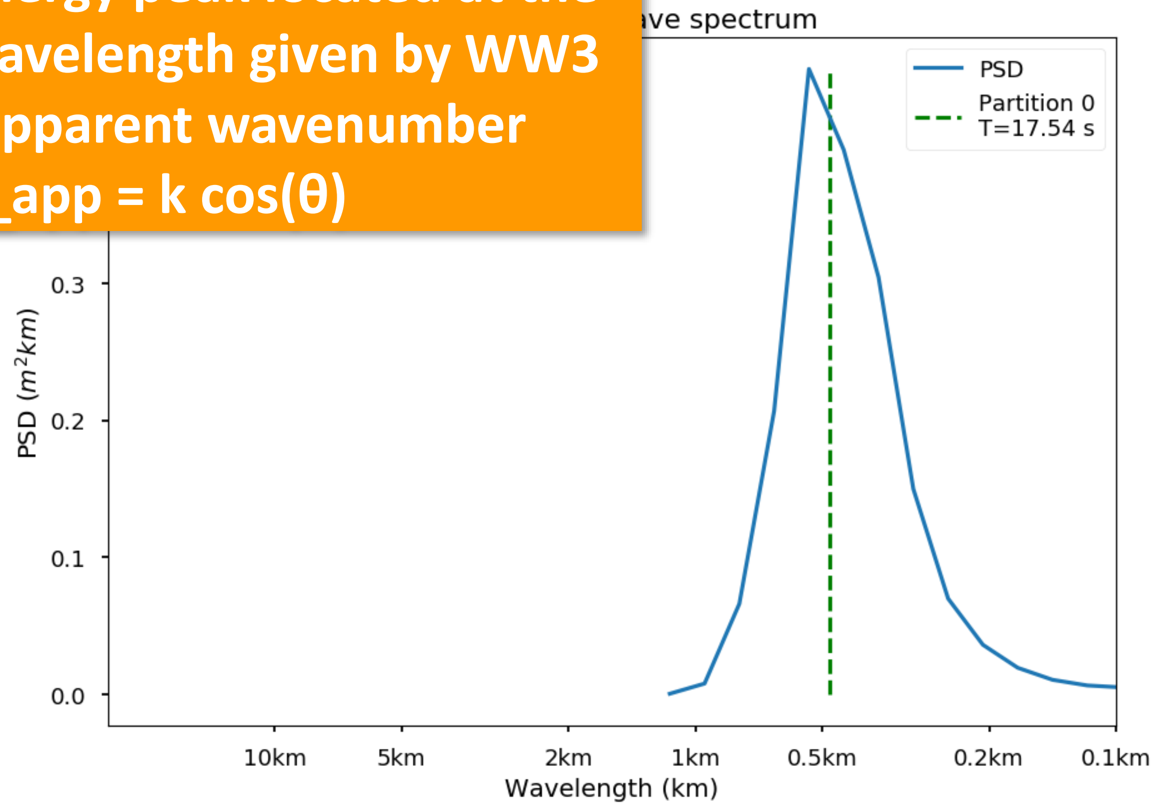
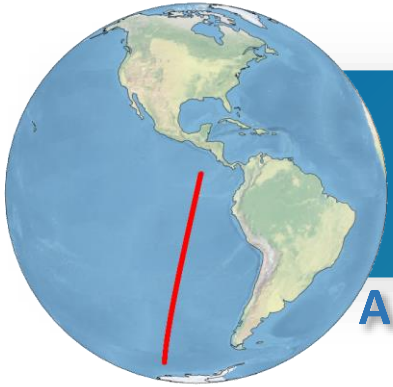


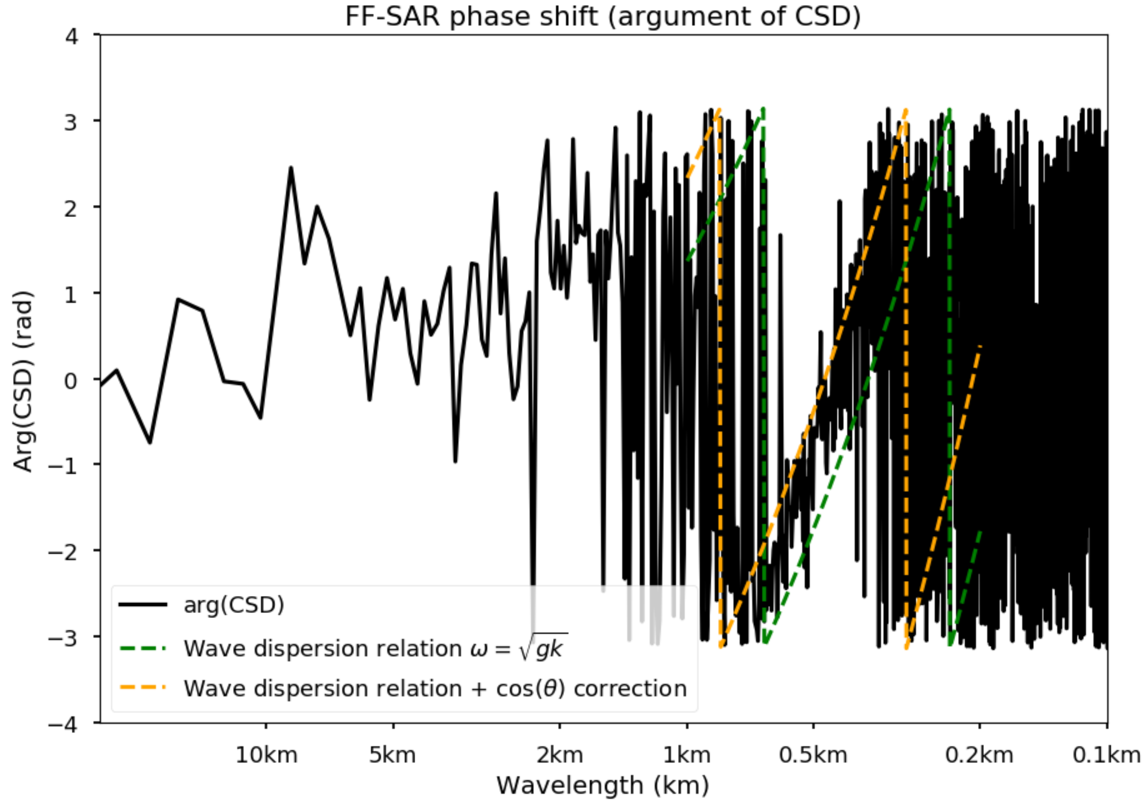
Energy peak located at the wavelength given by WW3 (apparent wavenumber k_app = k cos(θ))





FIRST STUDY CASE : PHASE SHIFT ANALYSIS

Anticolinear swell



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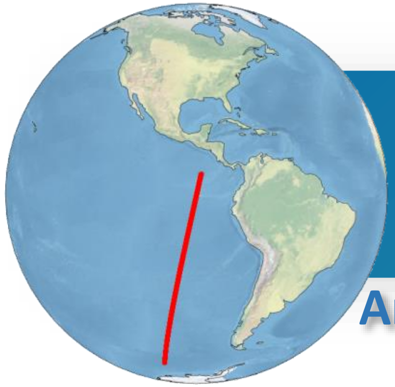

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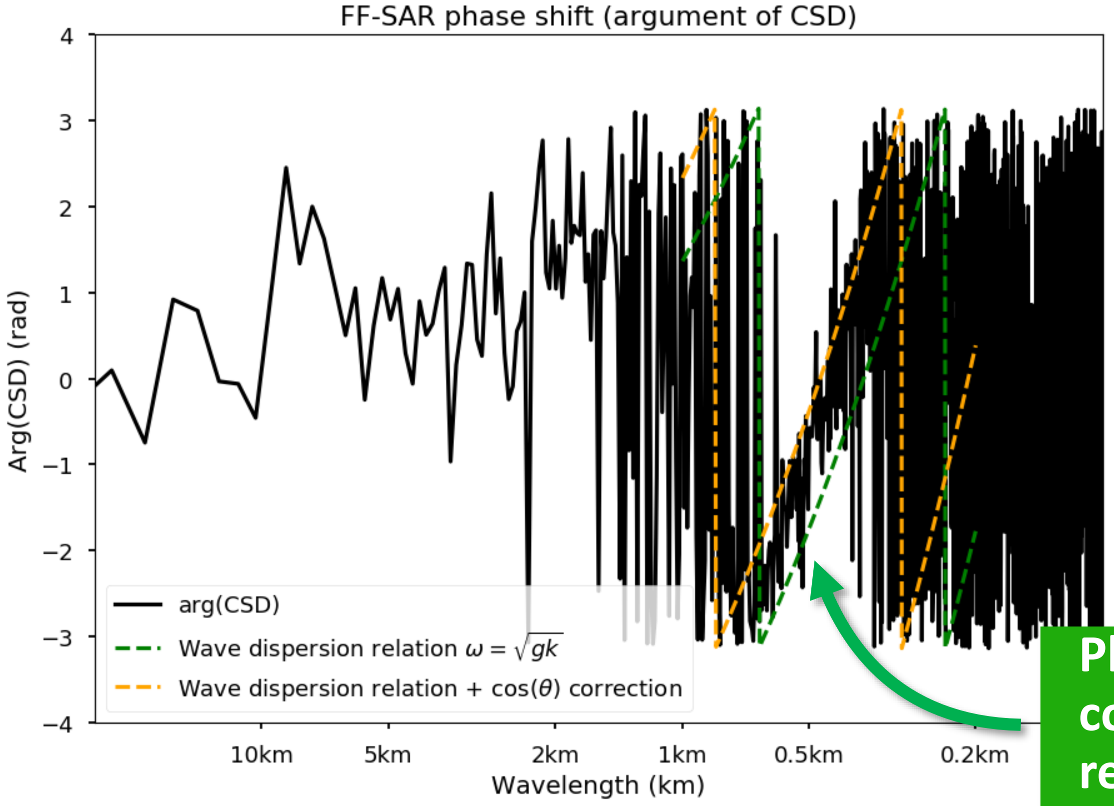

Phase shift between S3A and S3B consistent with the wave dispersion relation: $\Delta\Phi = \sqrt{gk}\Delta t$ at swell wavelength k and with a time lag Δt=30s

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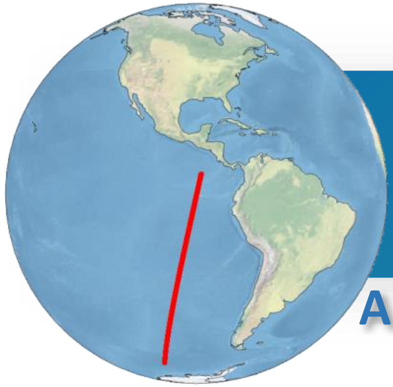

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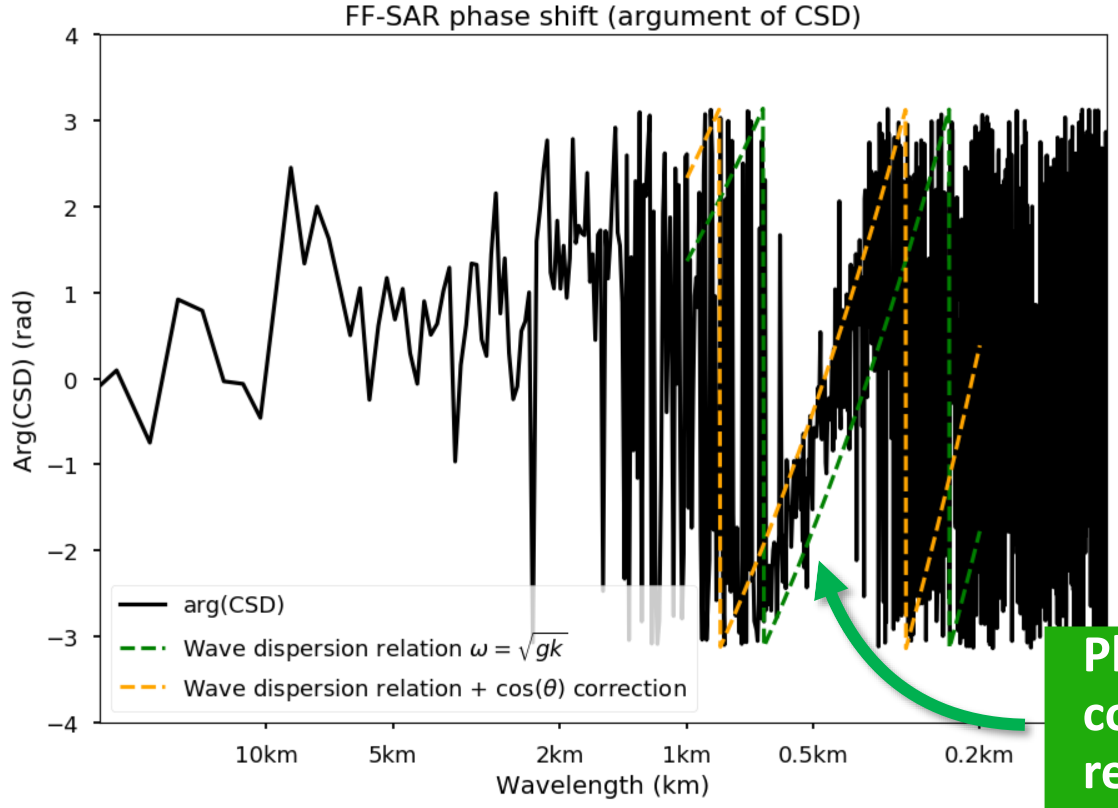

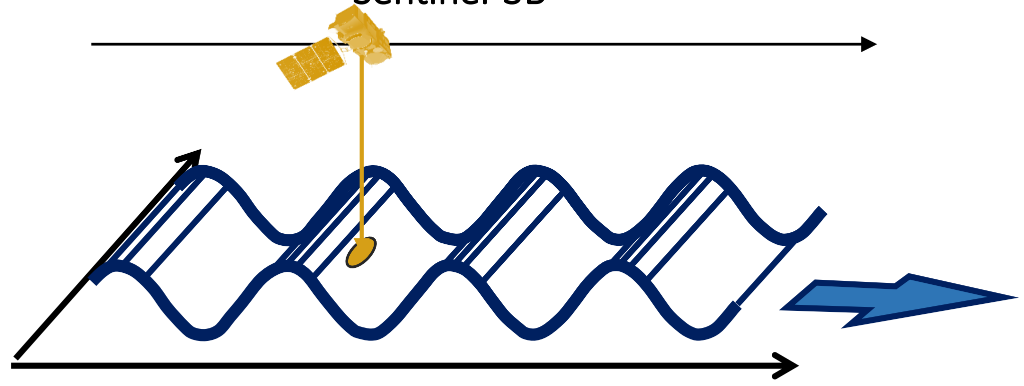

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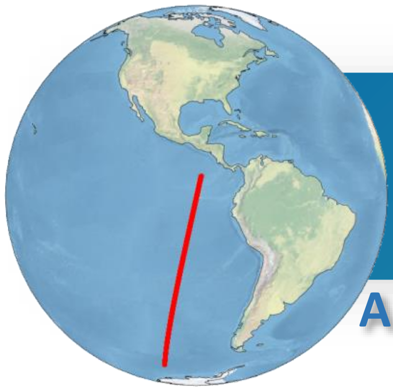

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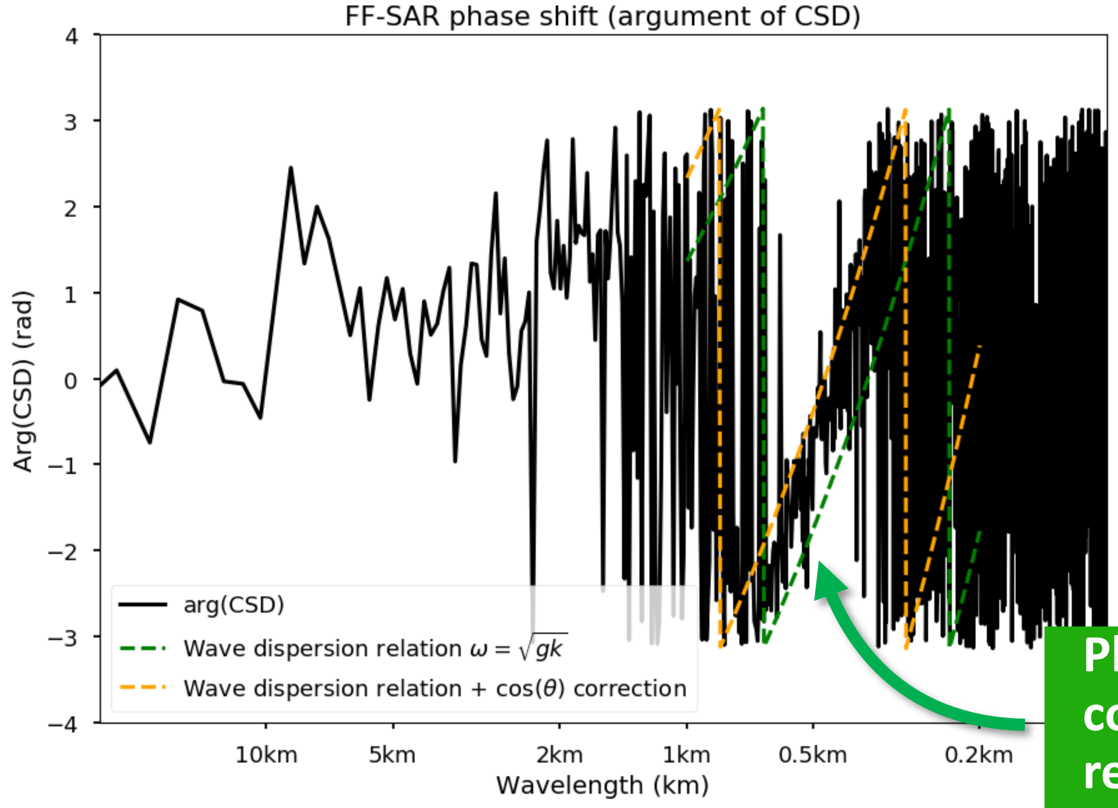

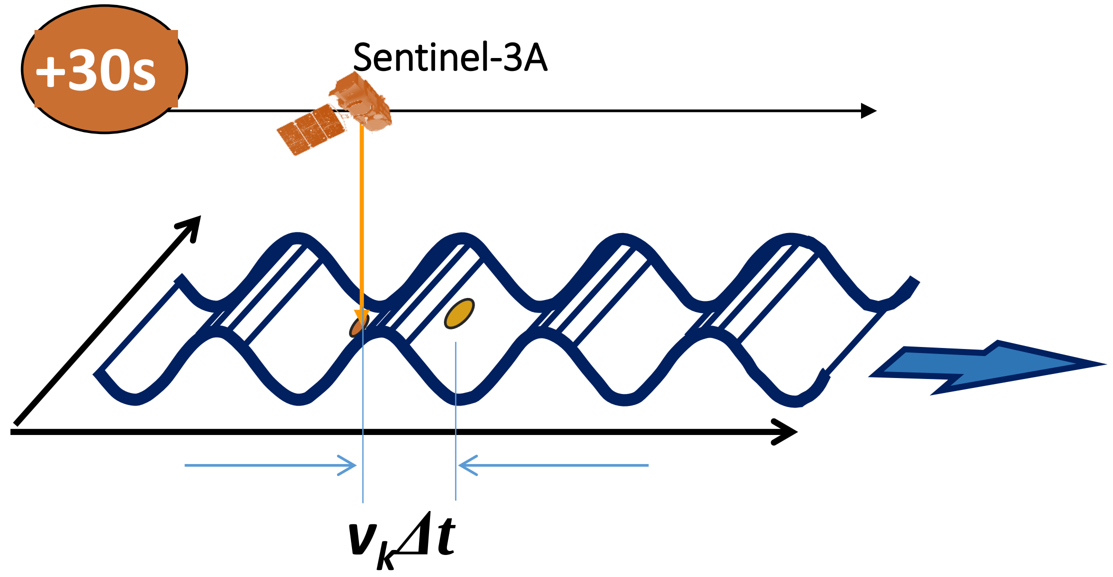

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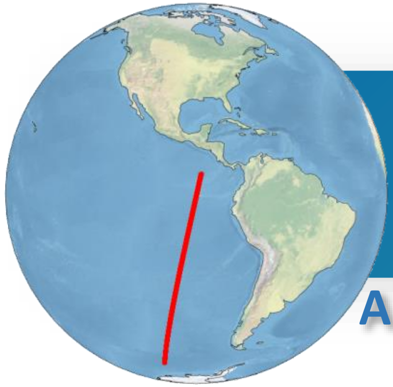

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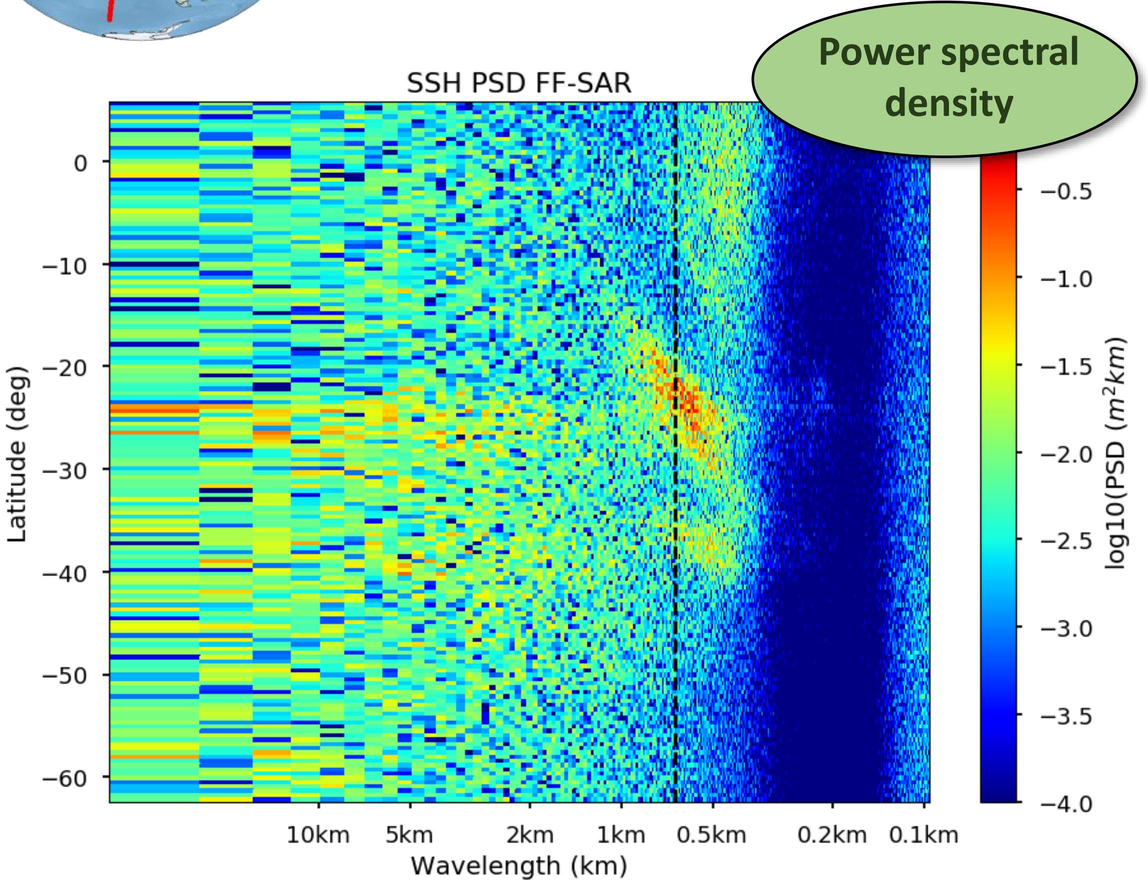

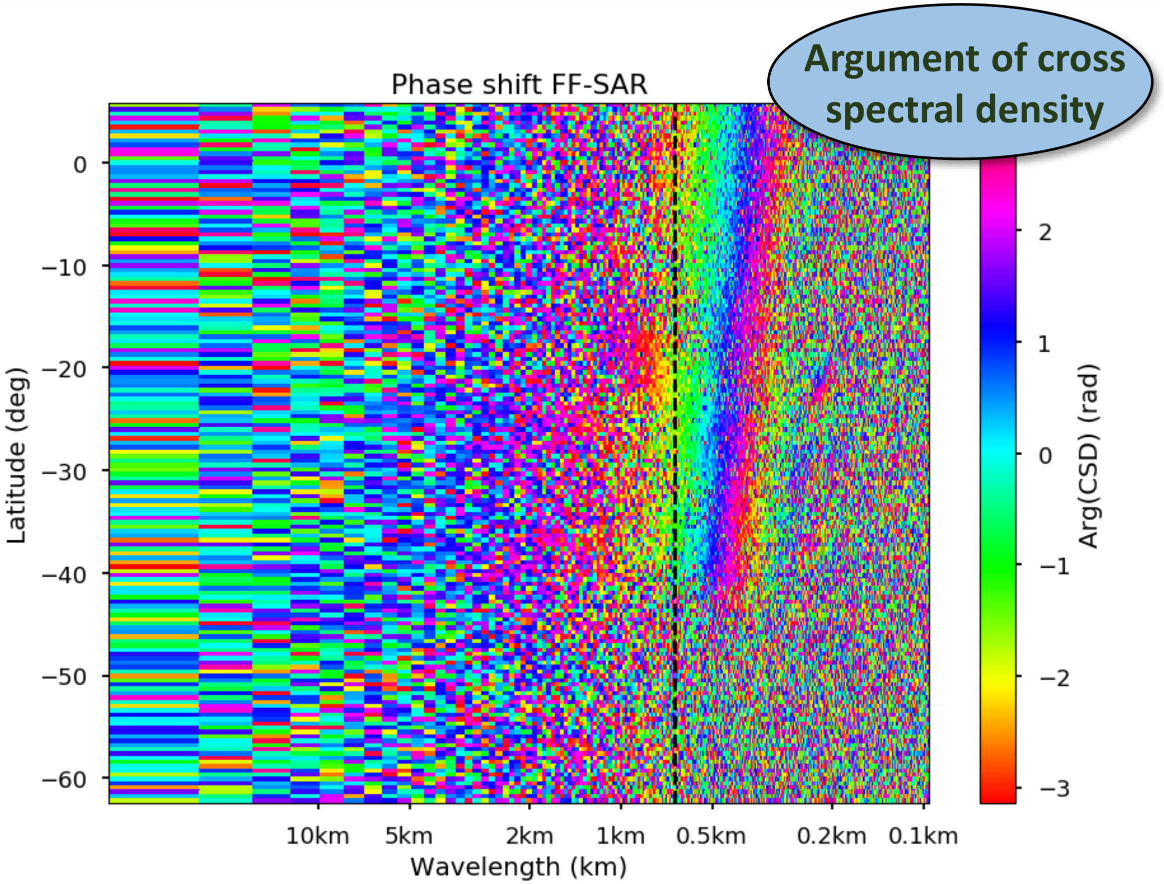

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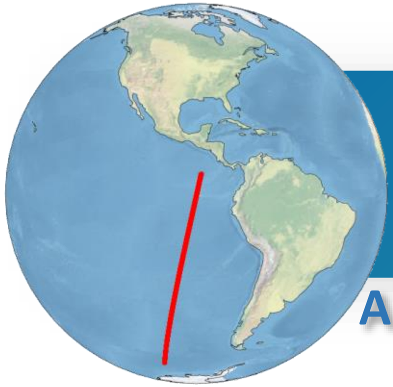
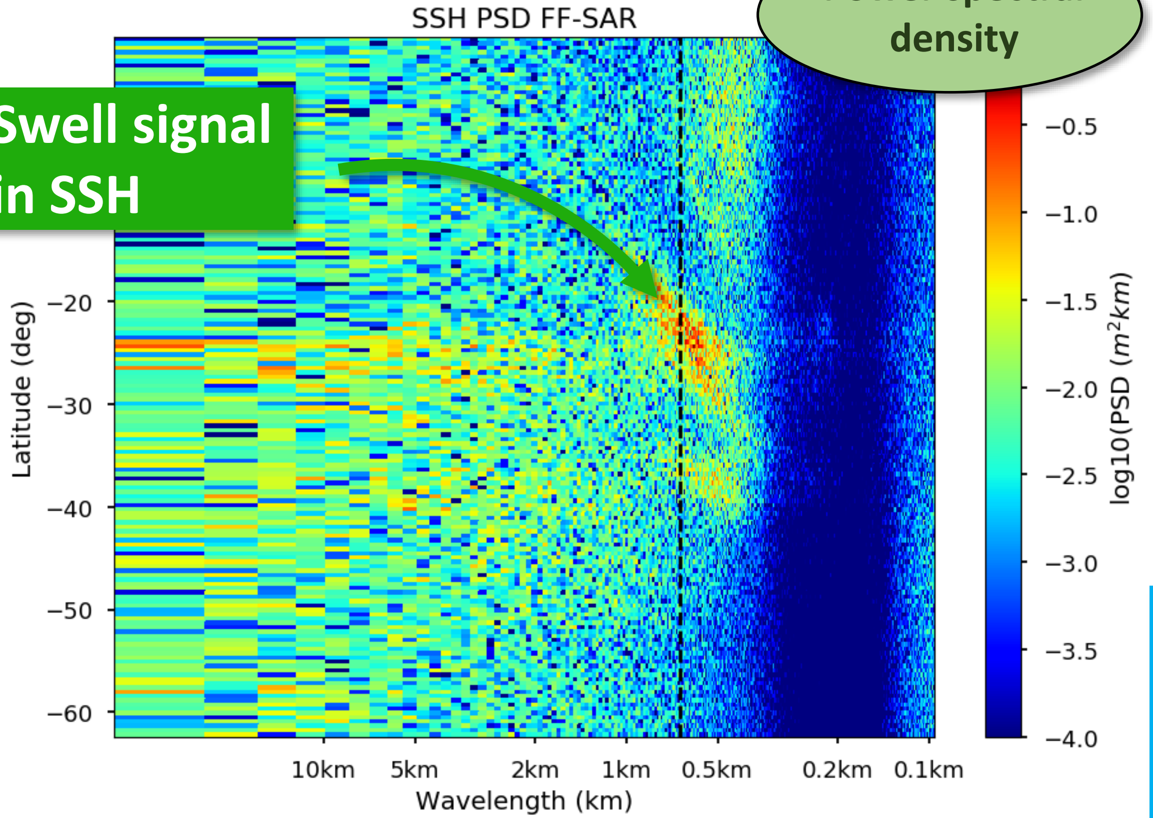


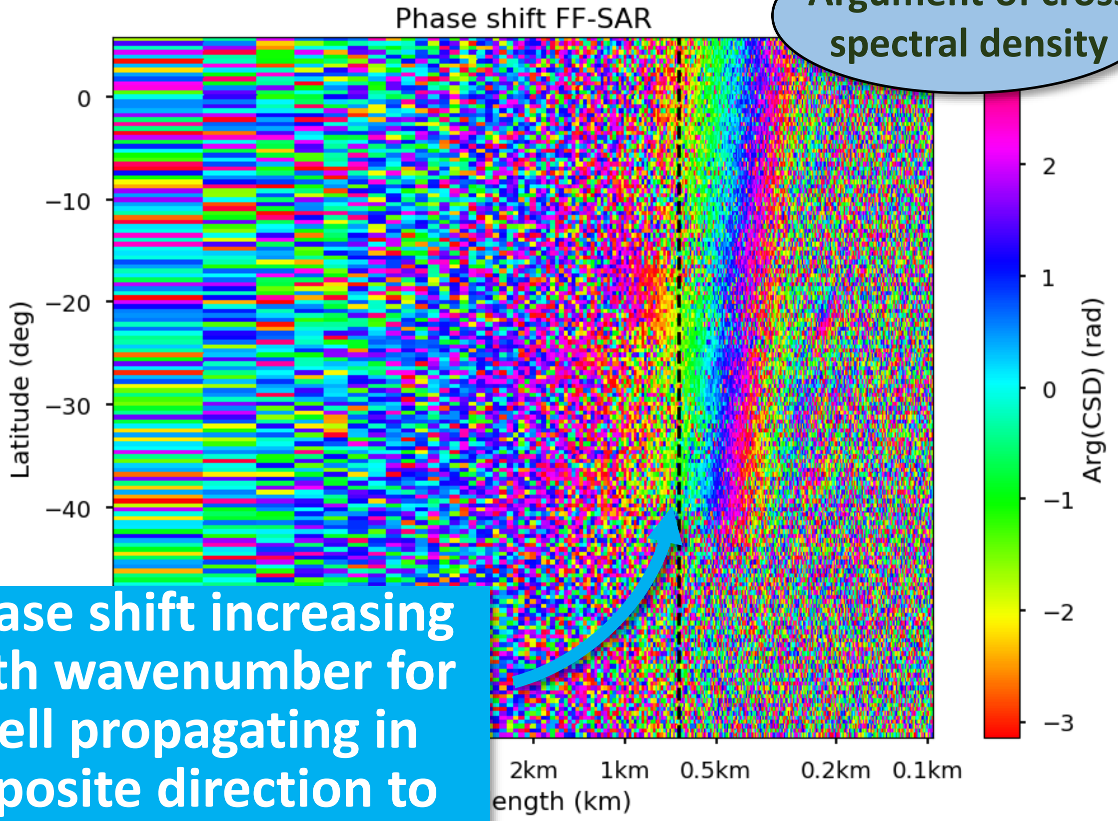
Anticolinear swell

Power spectral density

Swell signal in SSH



Argument of cross spectral density



Phase shift increasing with wavenumber for swell propagating in opposite direction to the satellite displacement

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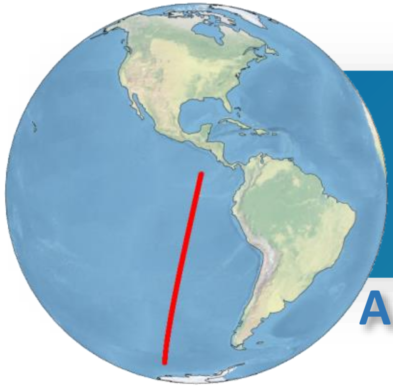
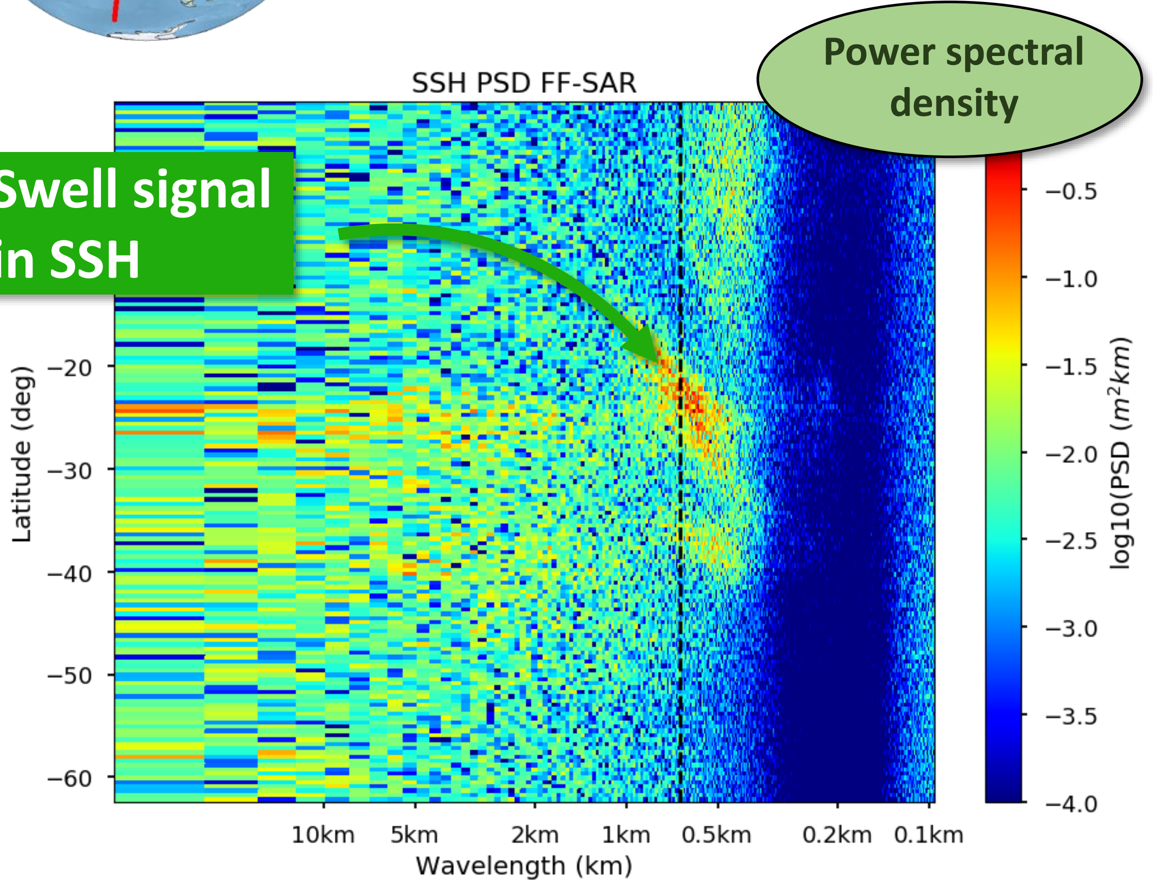
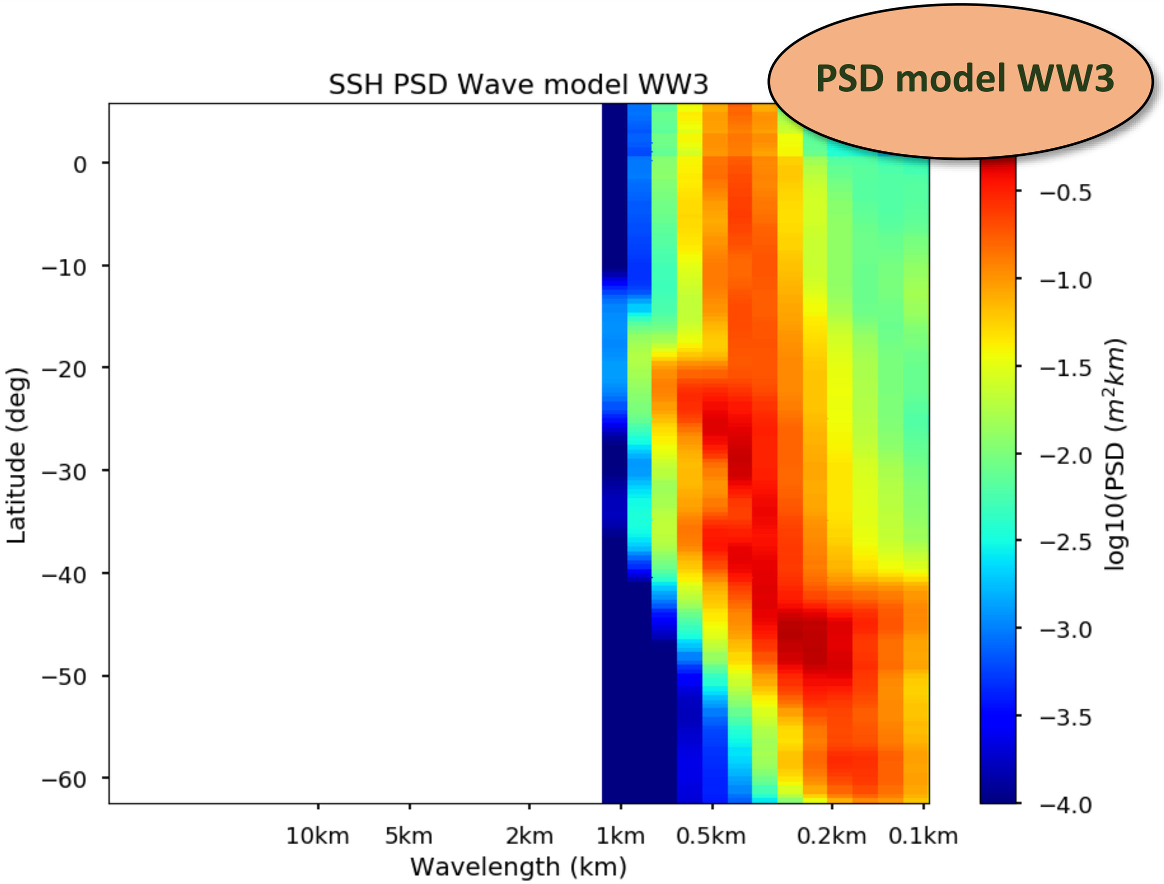
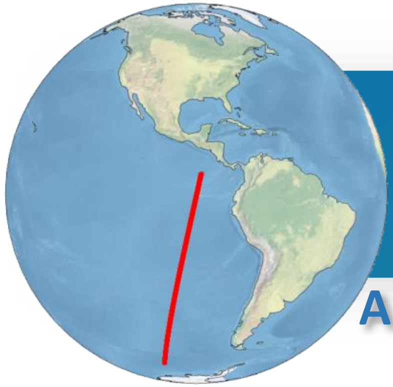


Anticolinear swell





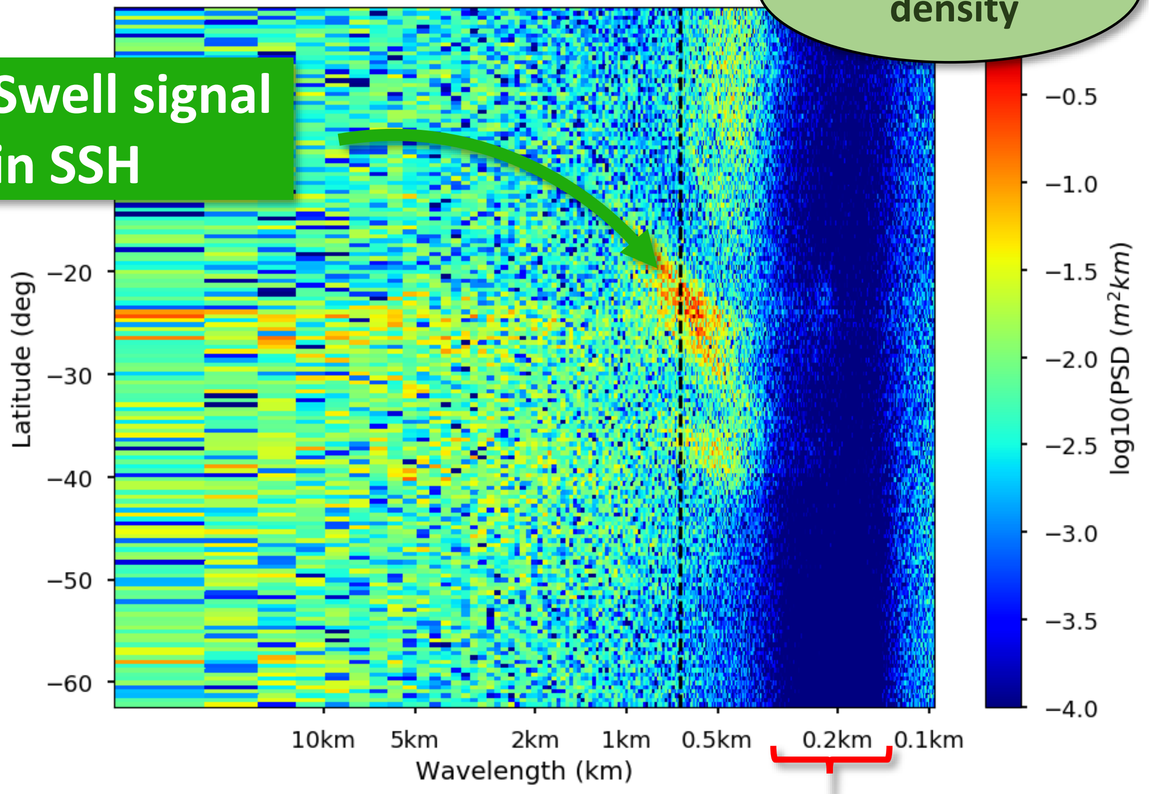


FIRST STUDY CASE : FF-SAR DATA SPECTRAL ANALYSIS

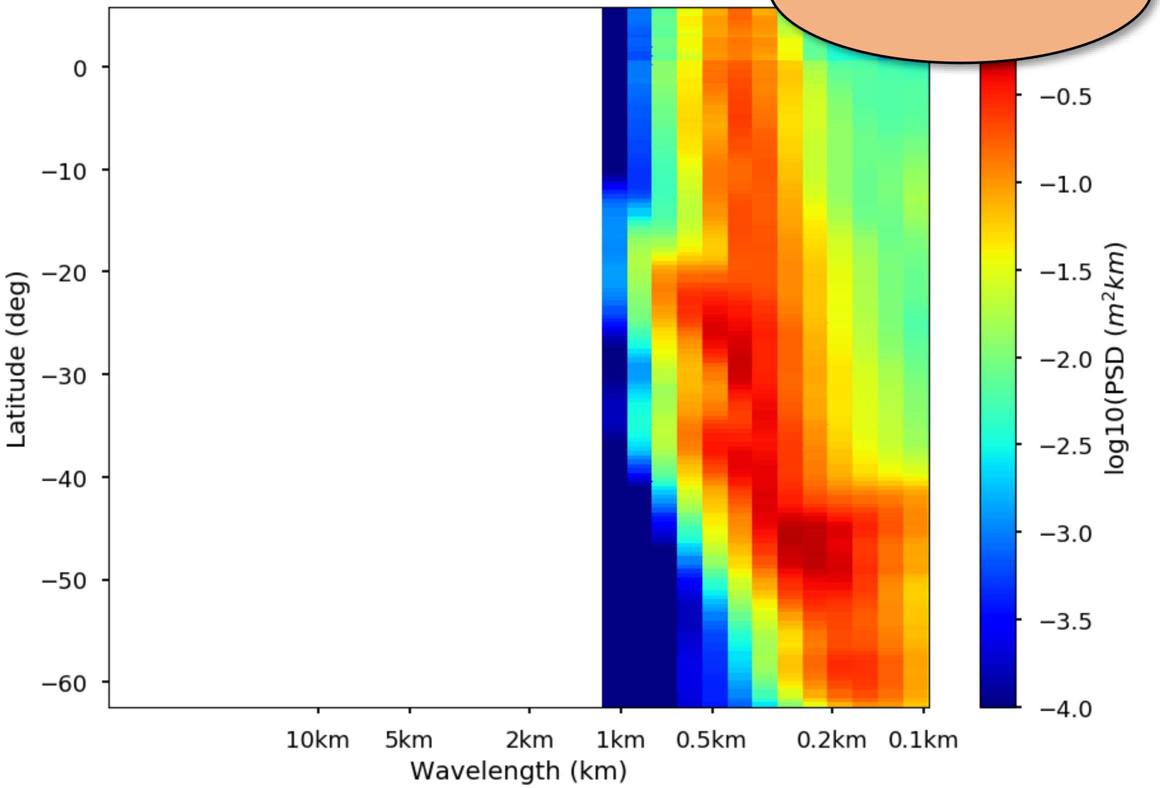
Anticolinear swell

Swell signal in SSH

Power spectral density



PSD model WW3



'Blind' band, probably due to spatial correlation (closed burst) – Not expected in Sentinel-6

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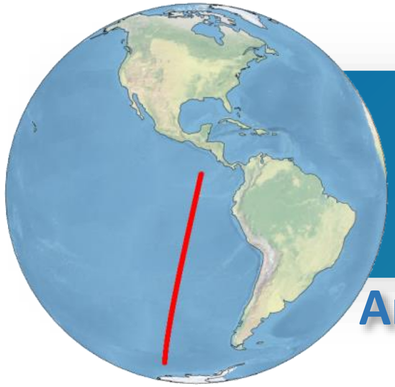
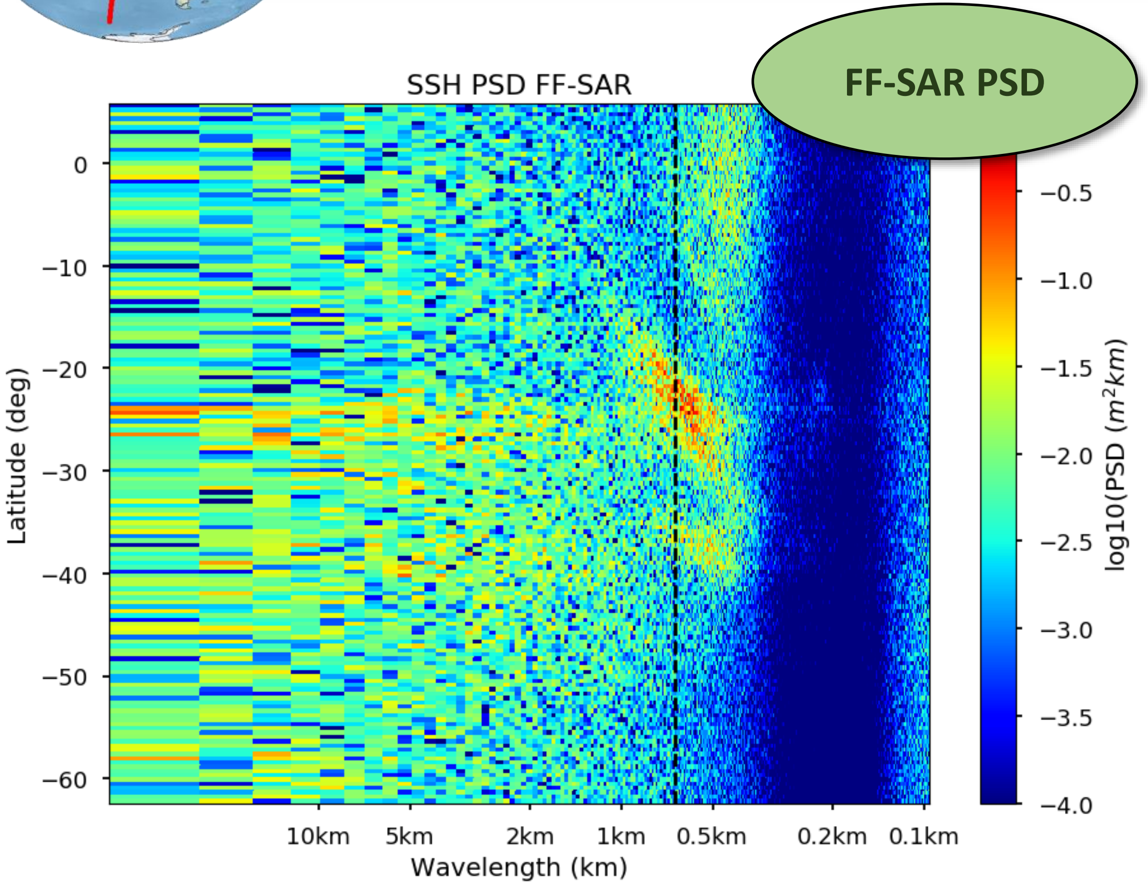
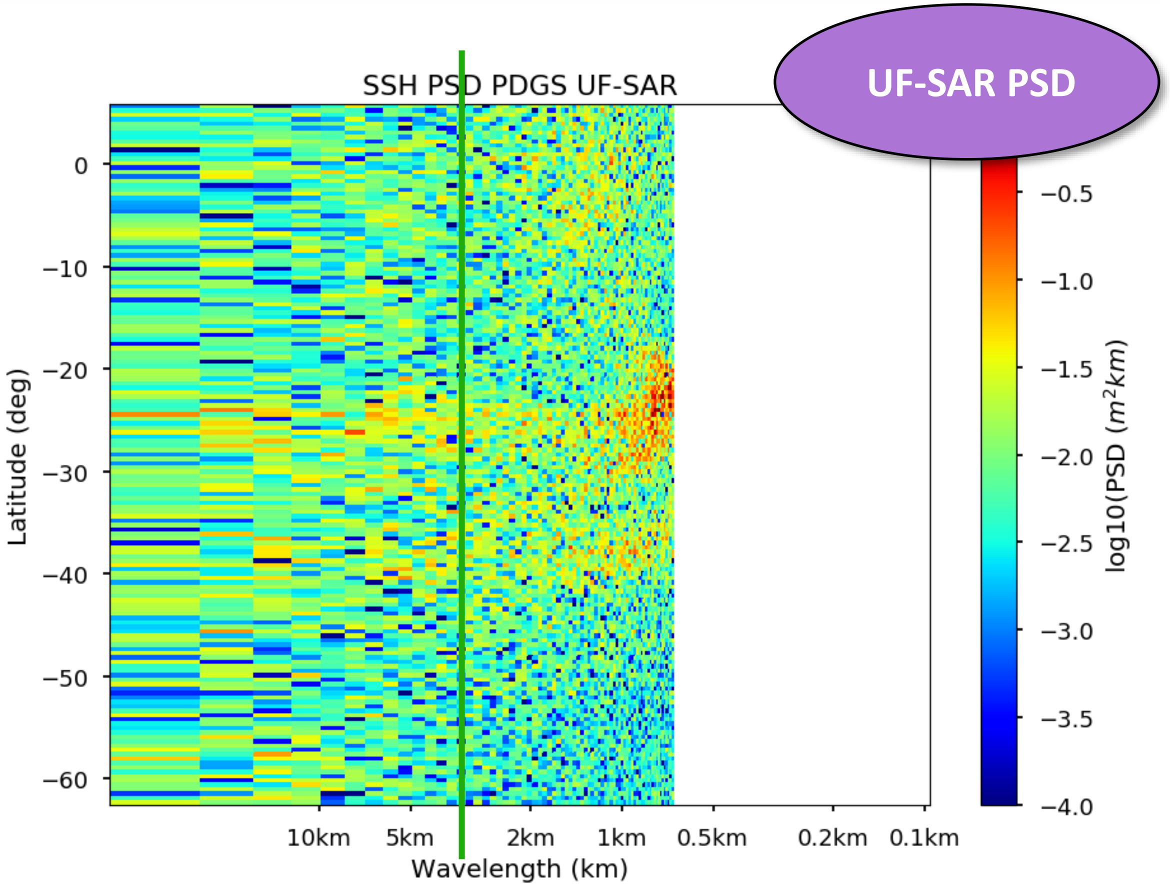


Anticolinear swell





Aliasing up to ~3 km

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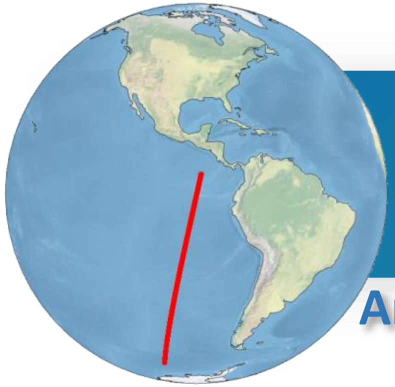
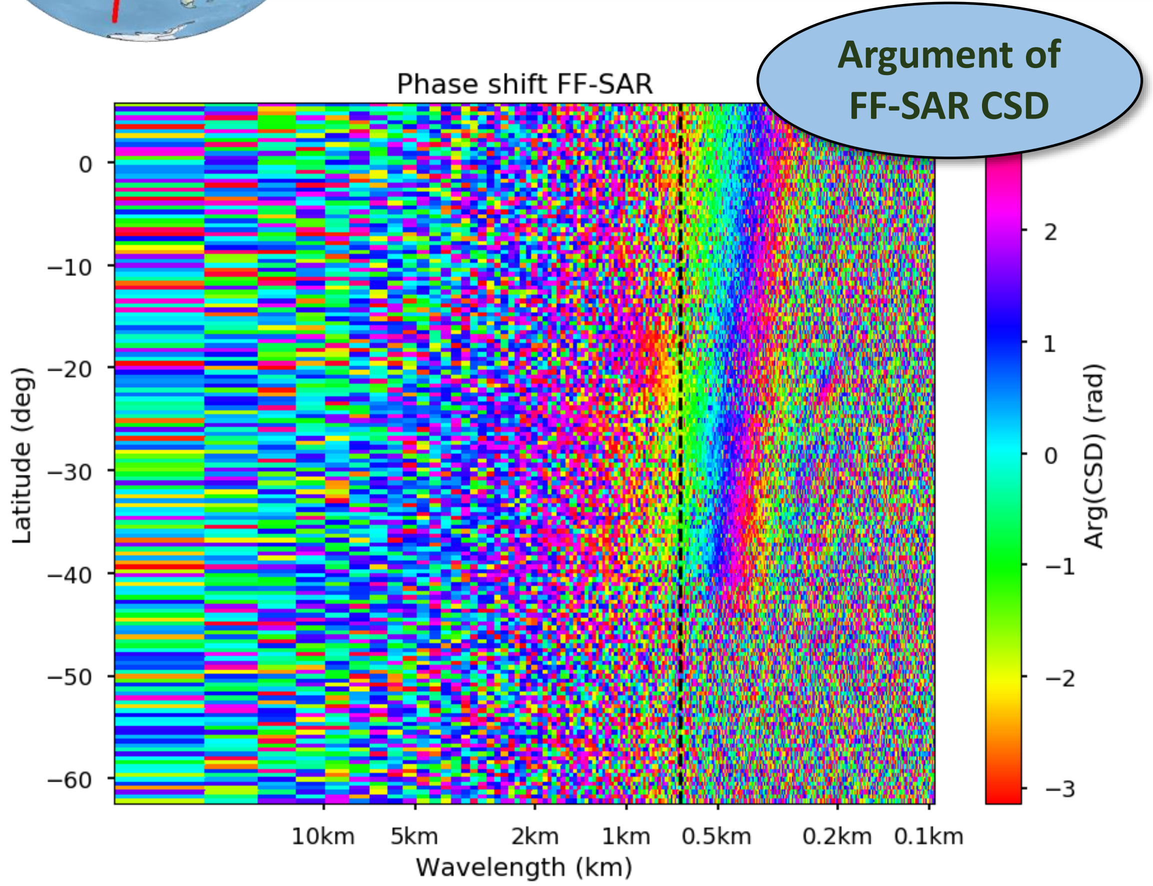
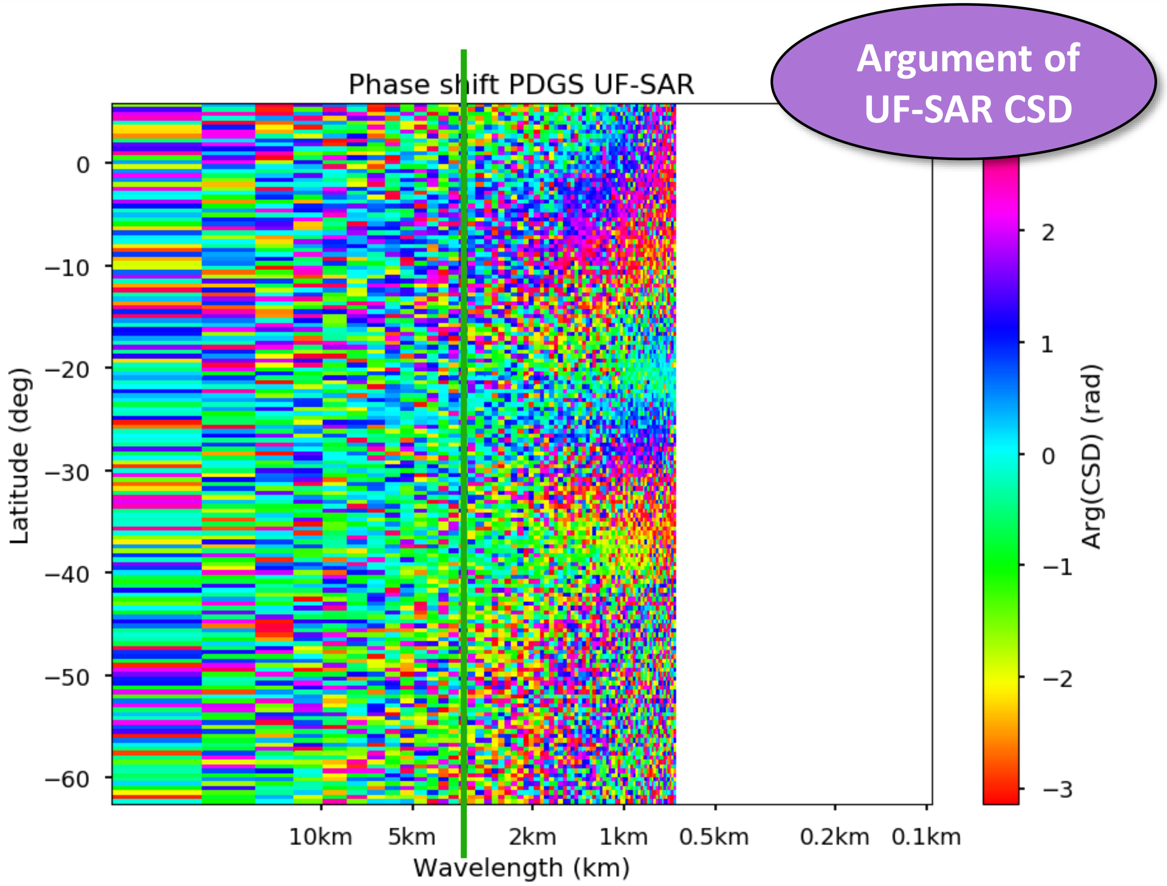


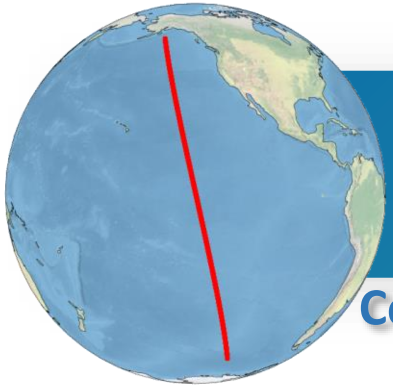
Anticolinear swell



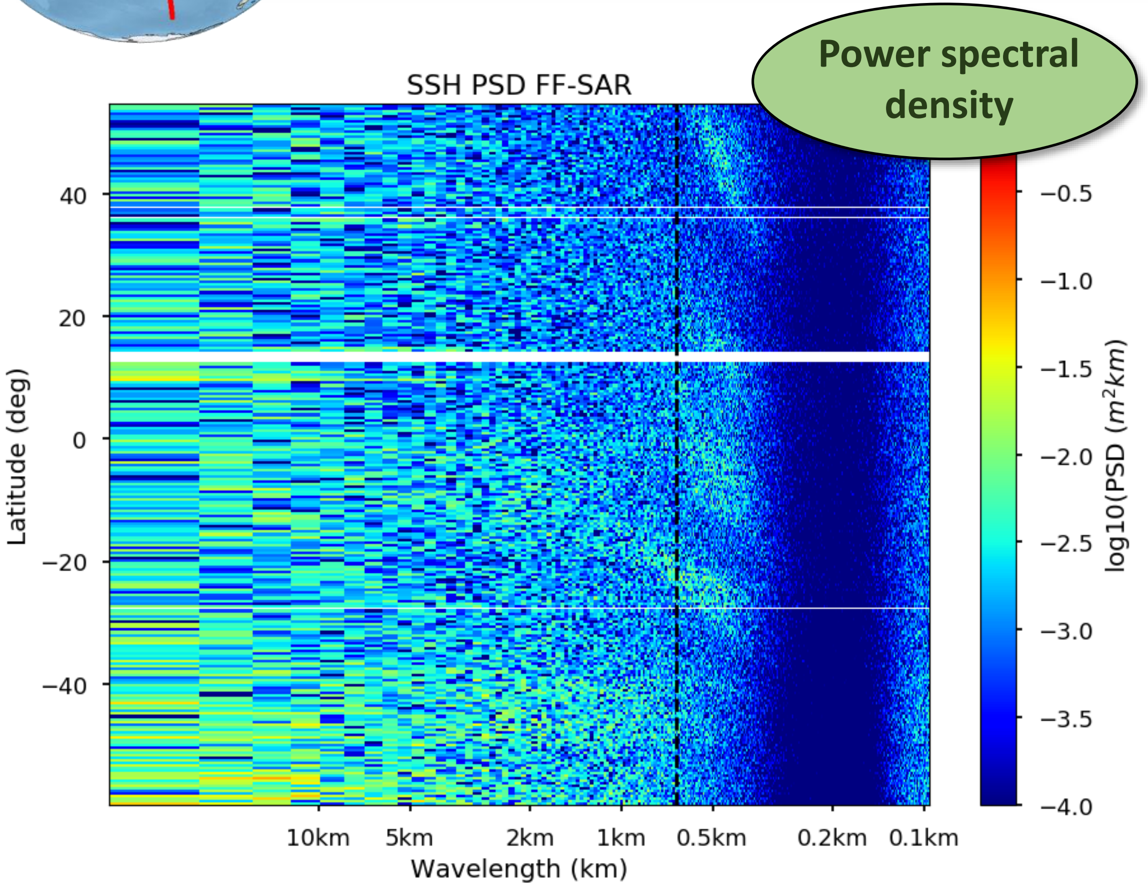


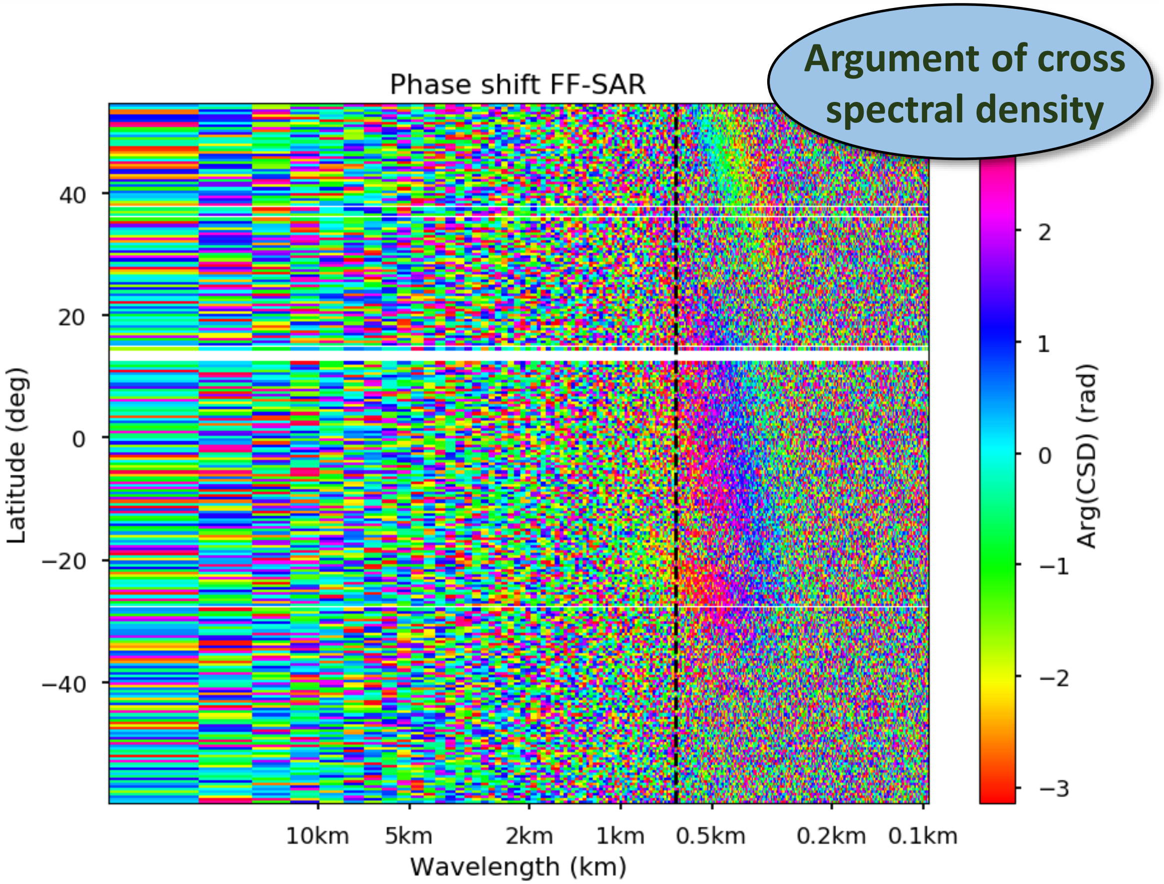
Aliasing up to ~3 km

SECOND STUDY CASE : FF-SAR DATA SPECTRAL ANALYSIS



Colinear swell





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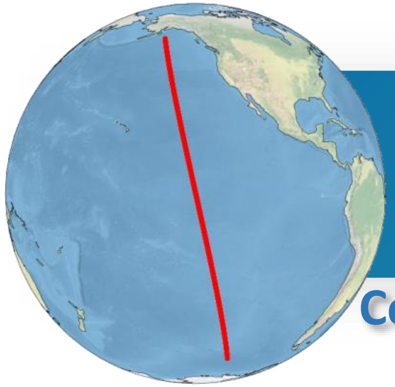

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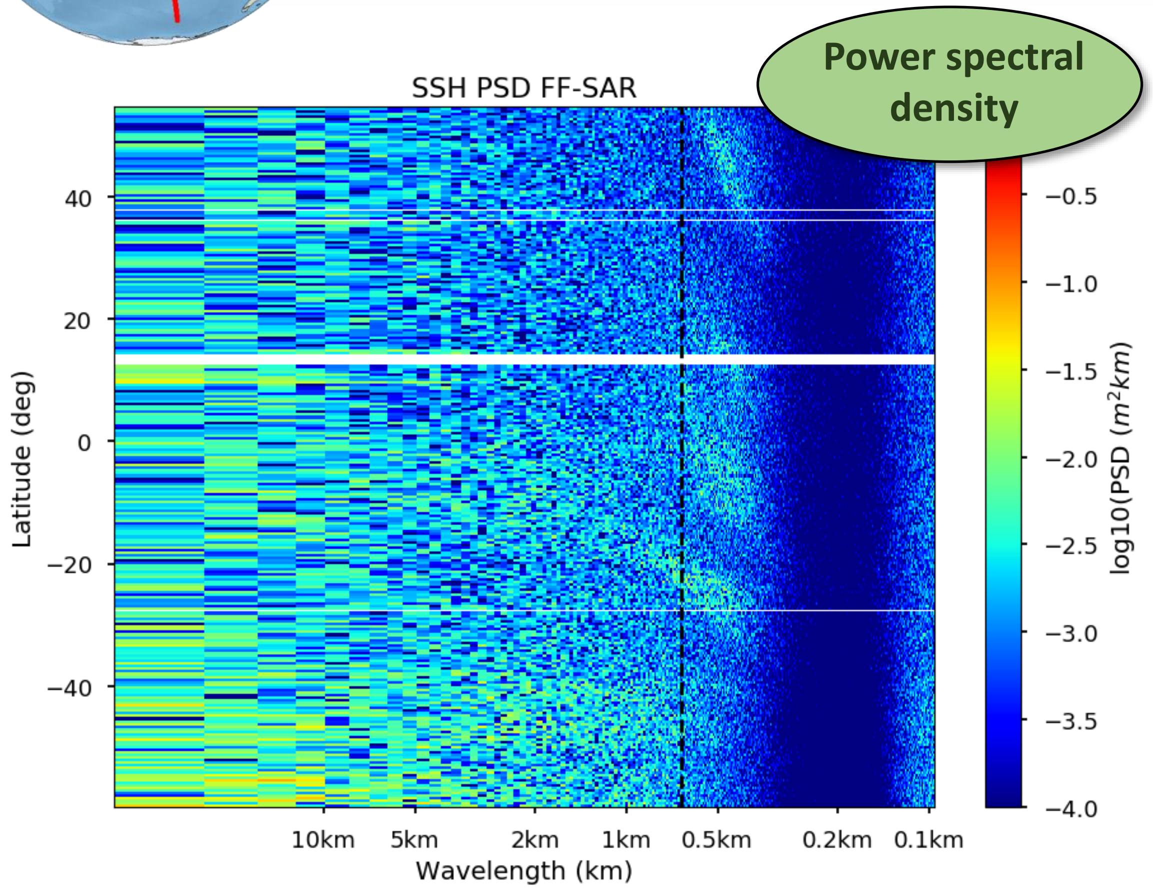
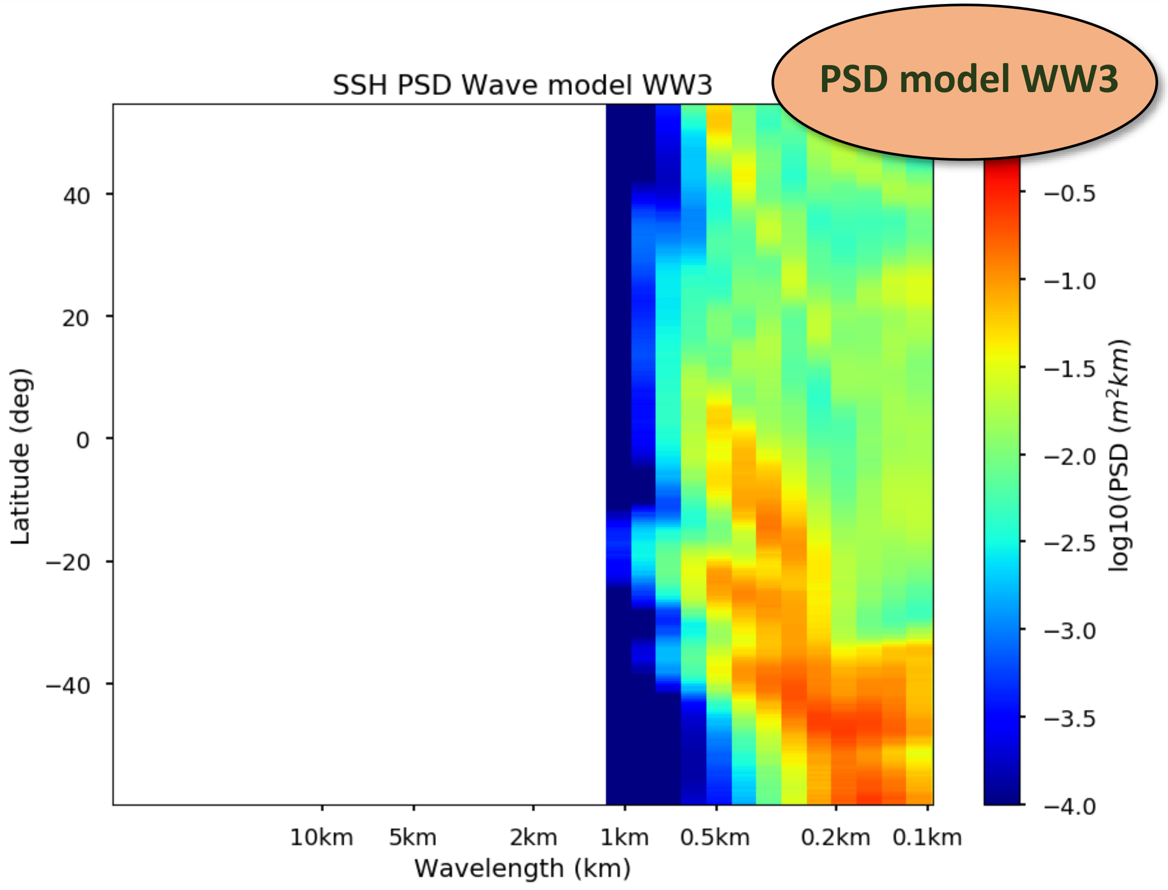
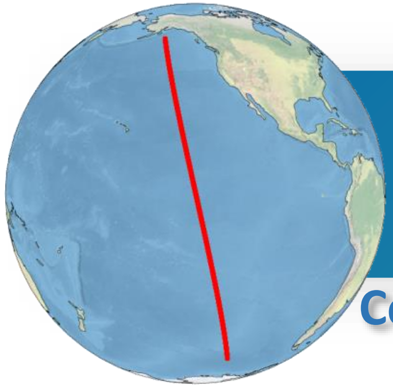


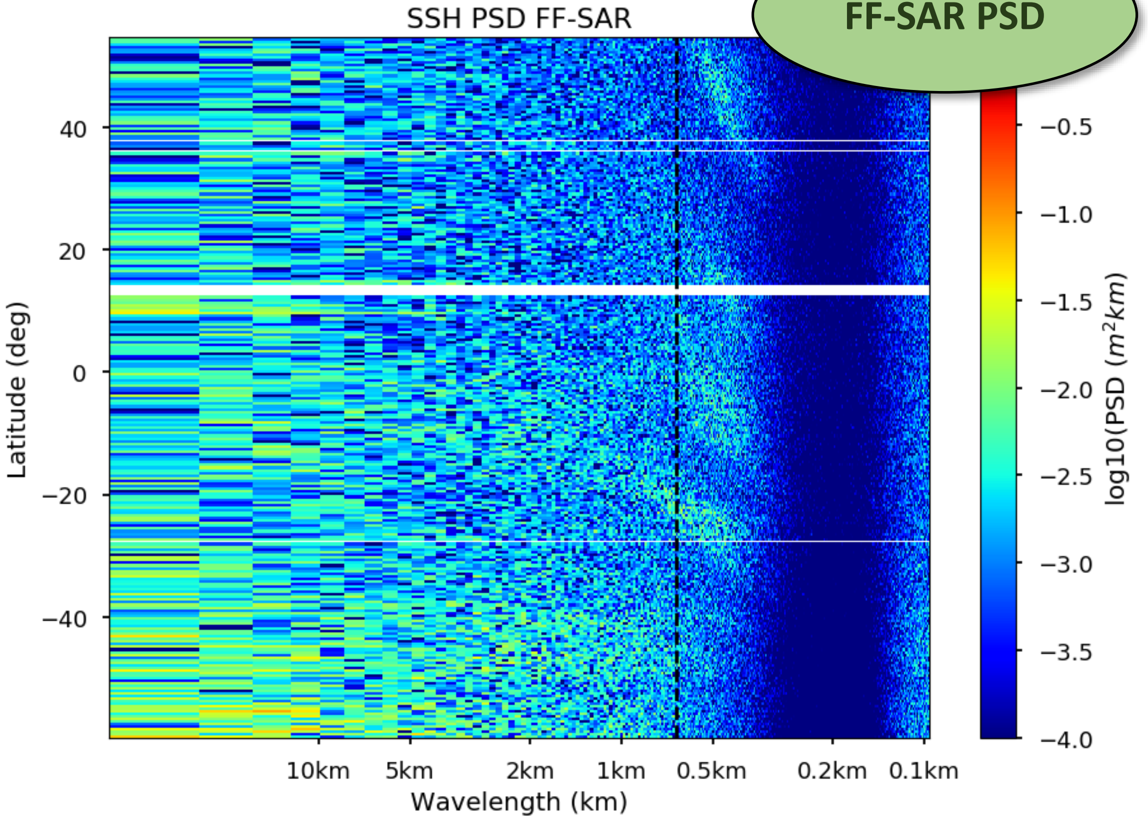




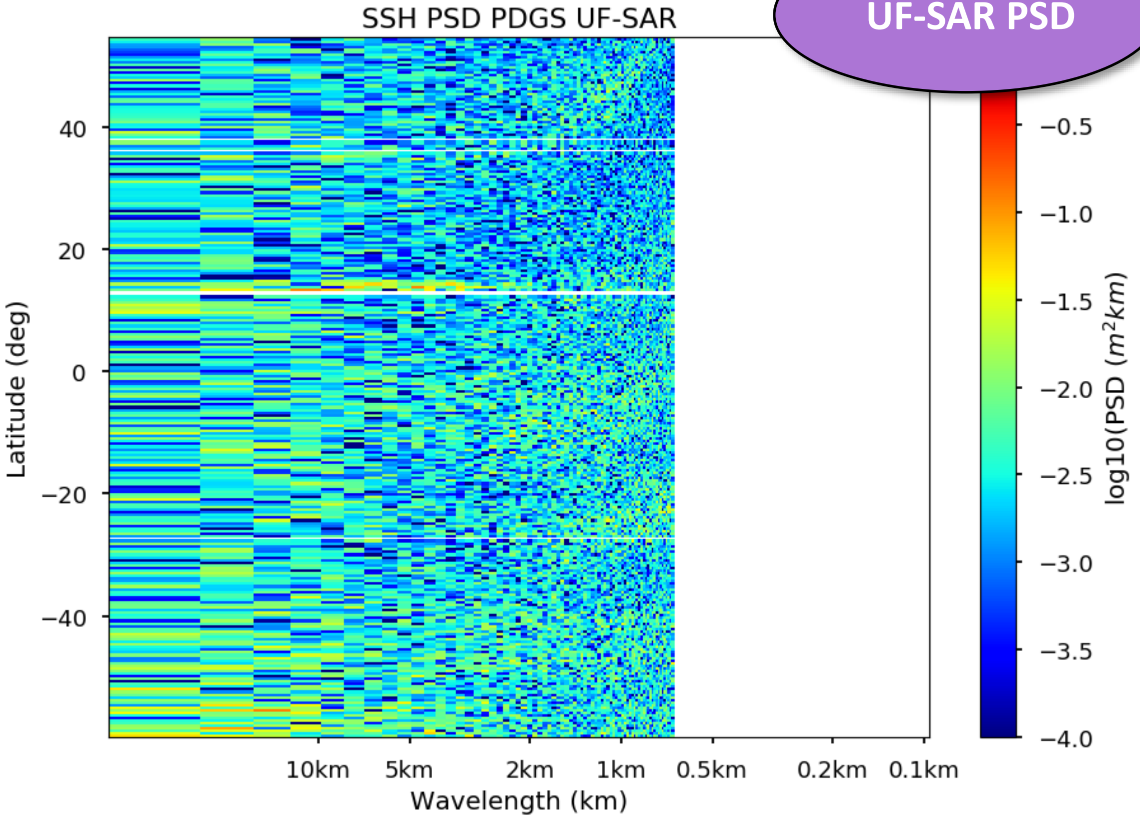
SECOND STUDY CASE : UF-SAR DATA SPECTRAL ANALYSIS

Colinear swell

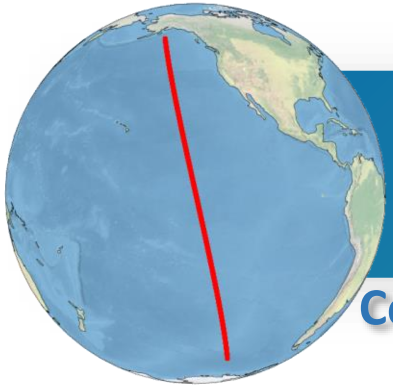
FF-SAR PSD



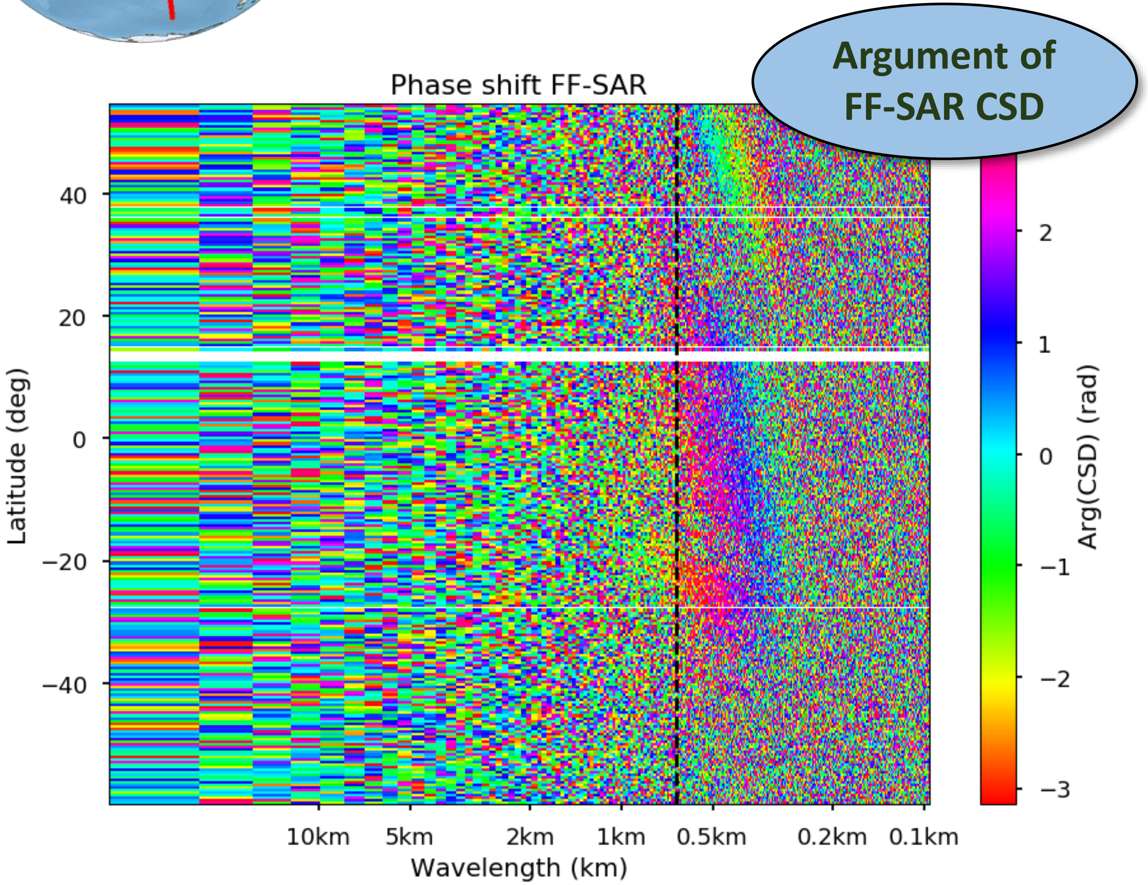
UF-SAR PSD

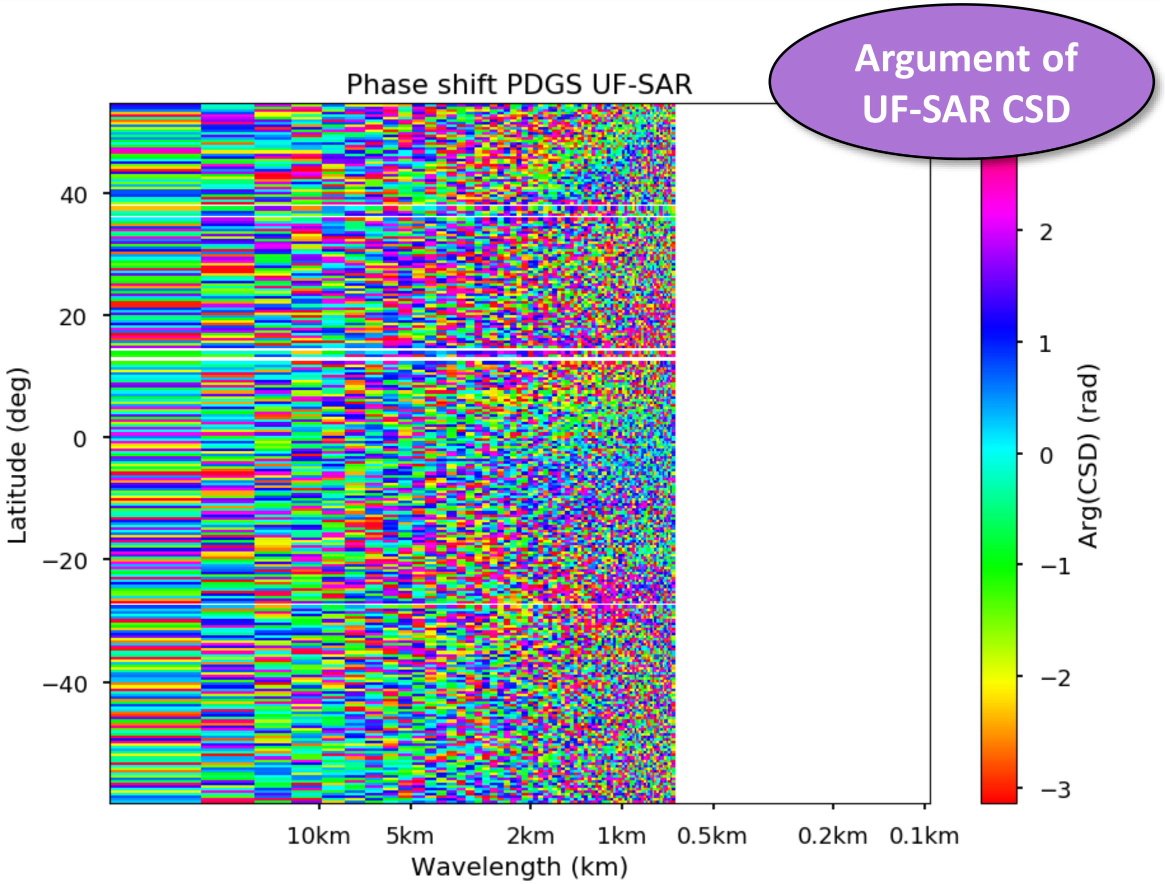


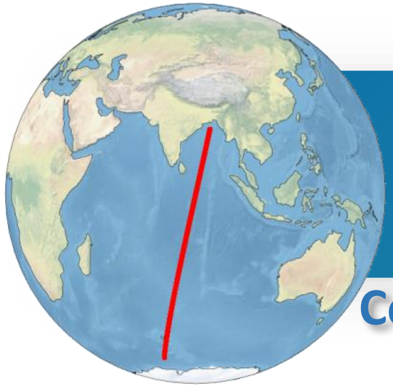
SECOND STUDY CASE : UF-SAR DATA SPECTRAL ANALYSIS



Colinear swell

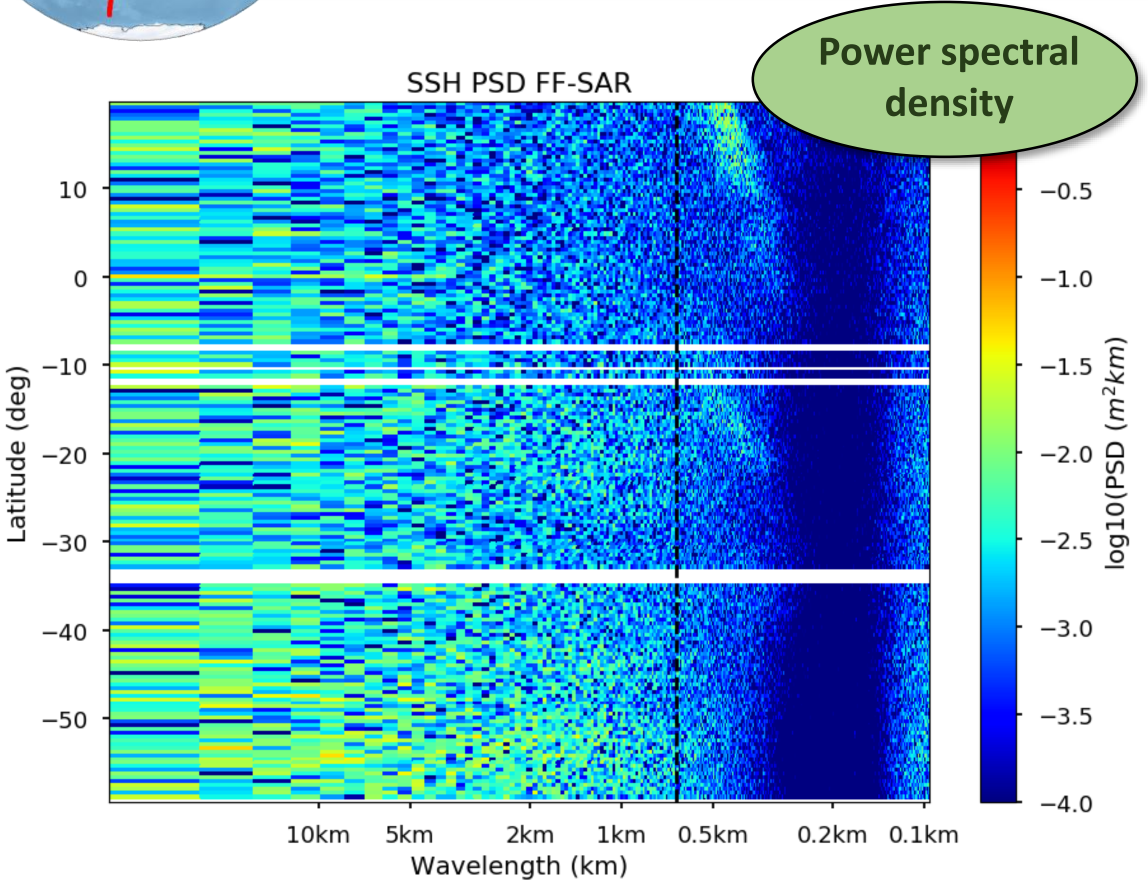


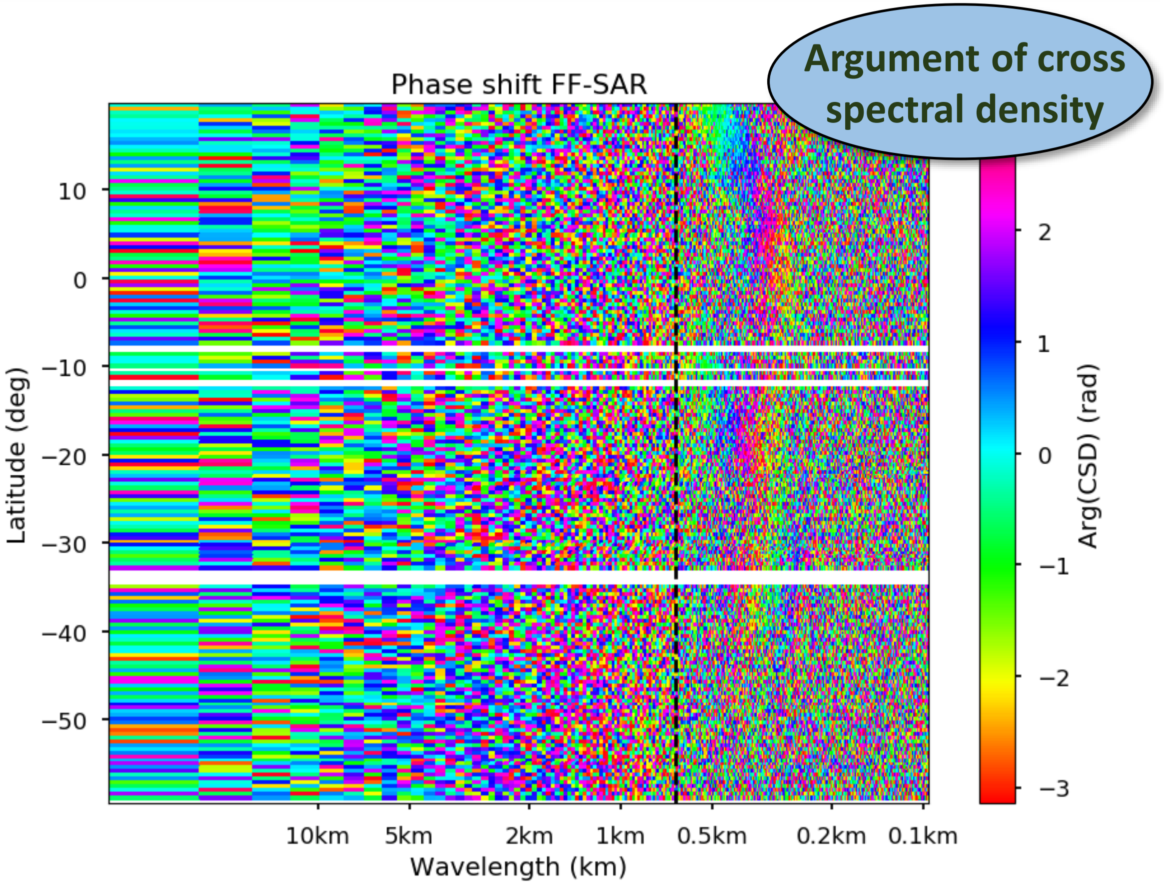


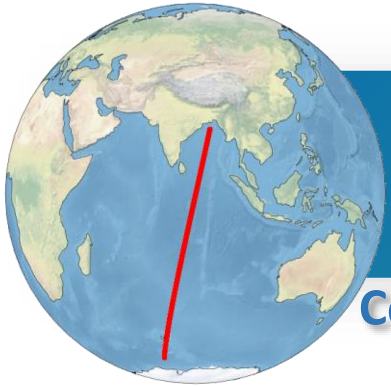


THIRD STUDY CASE : FF-SAR DATA SPECTRAL ANALYSIS

Colinear swell



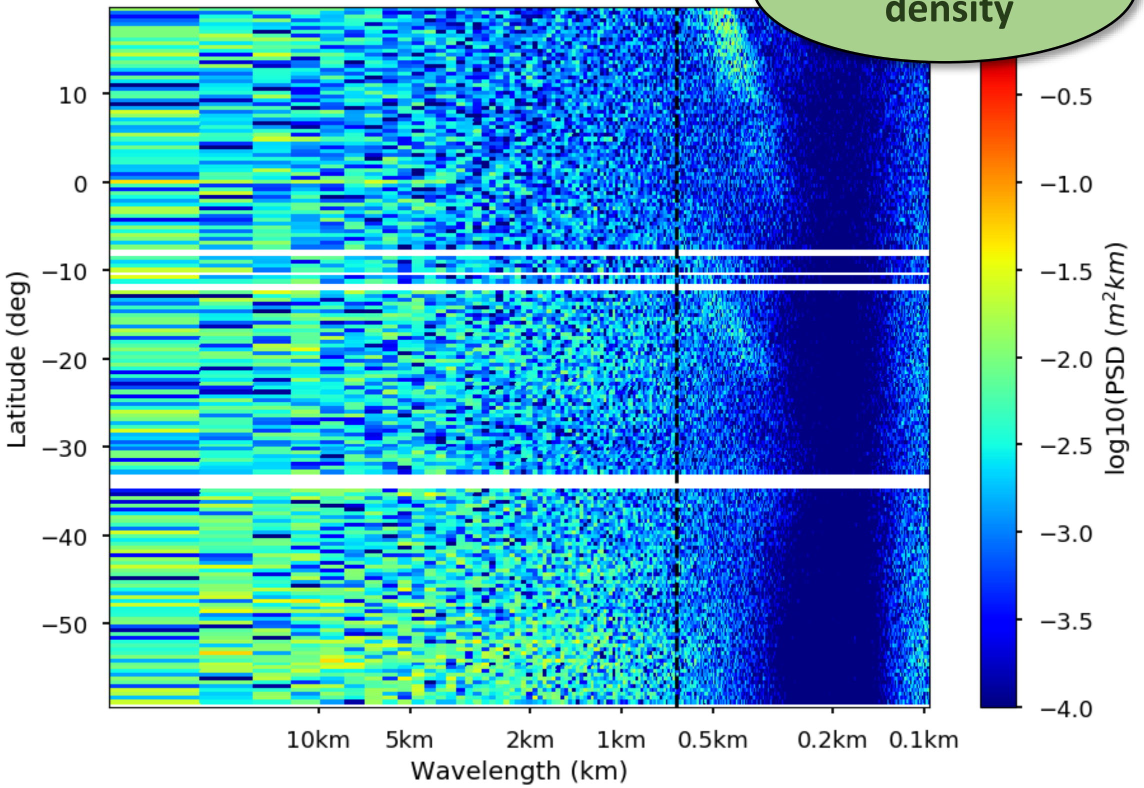




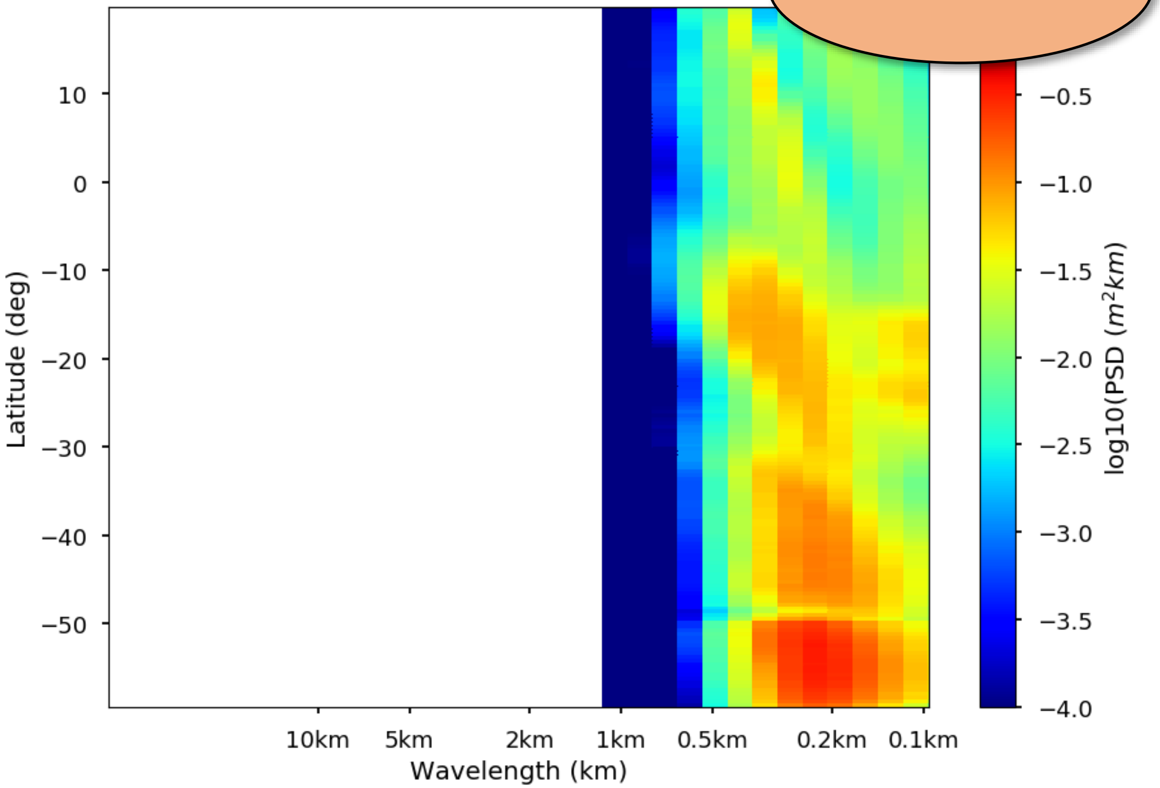
THIRD STUDY CASE : FF-SAR DATA SPECTRAL ANALYSIS

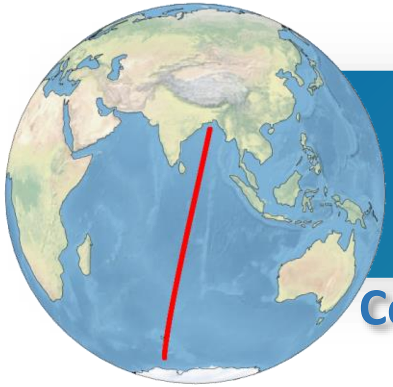
Colinear swell

Power spectral density



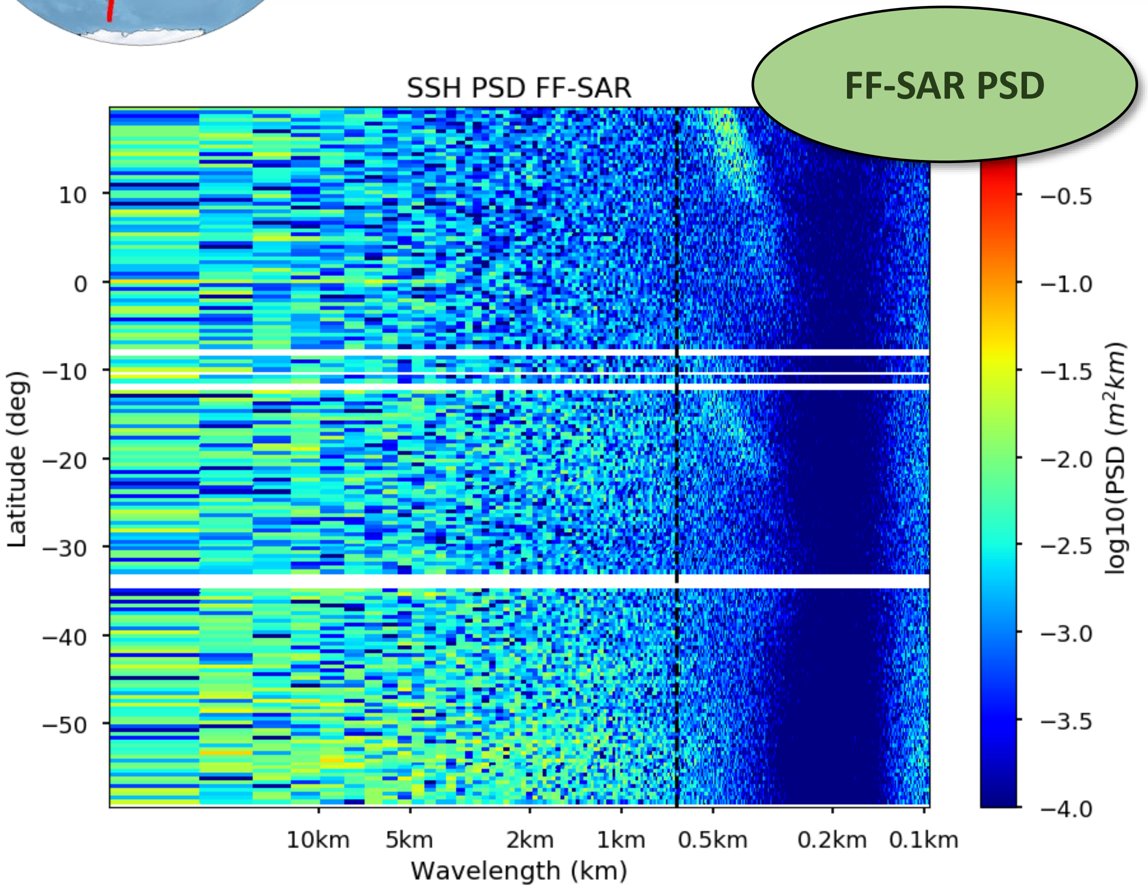
PSD model WW3

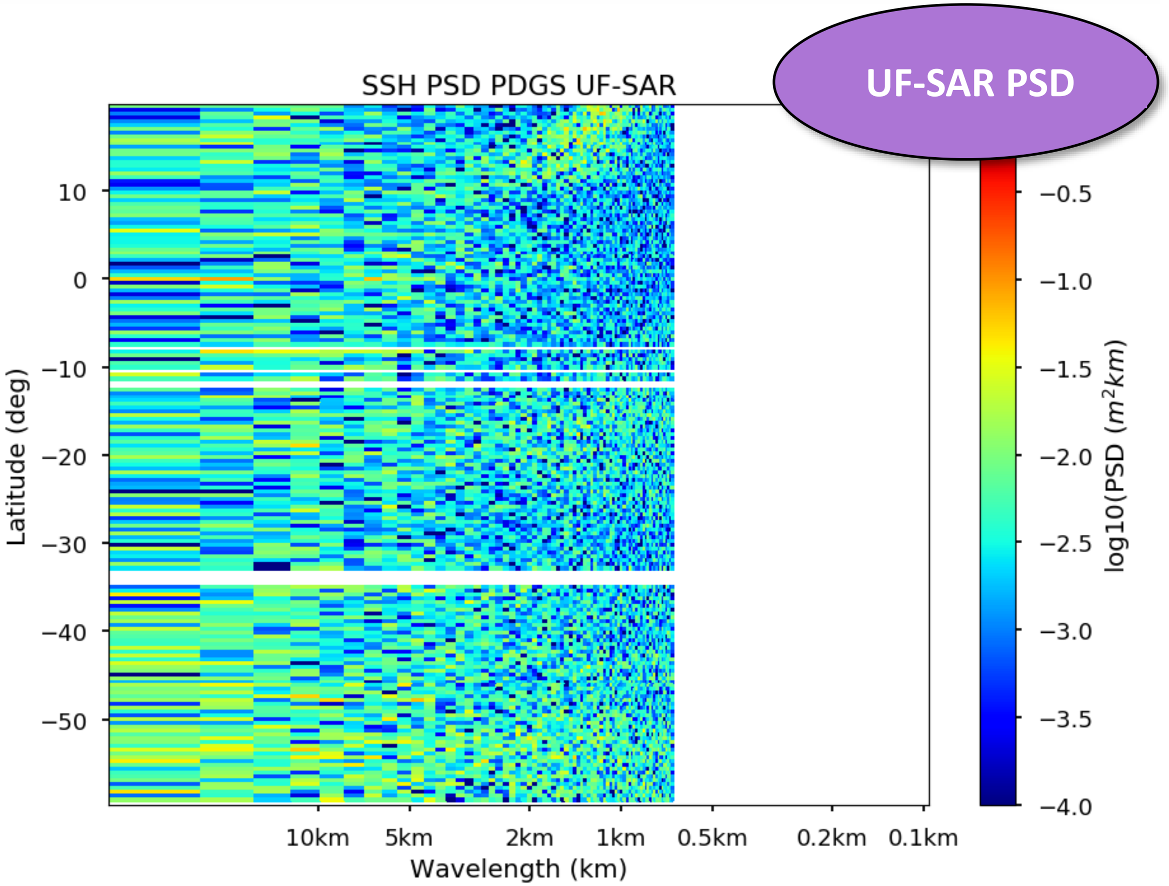


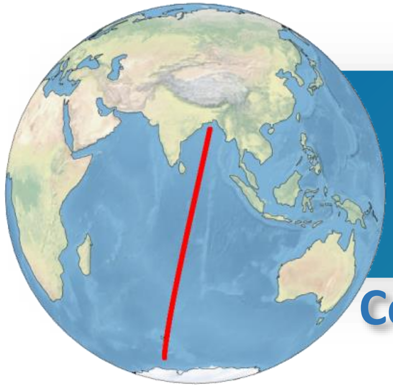


THIRD STUDY CASE : UF-SAR DATA SPECTRAL ANALYSIS

Colinear swell







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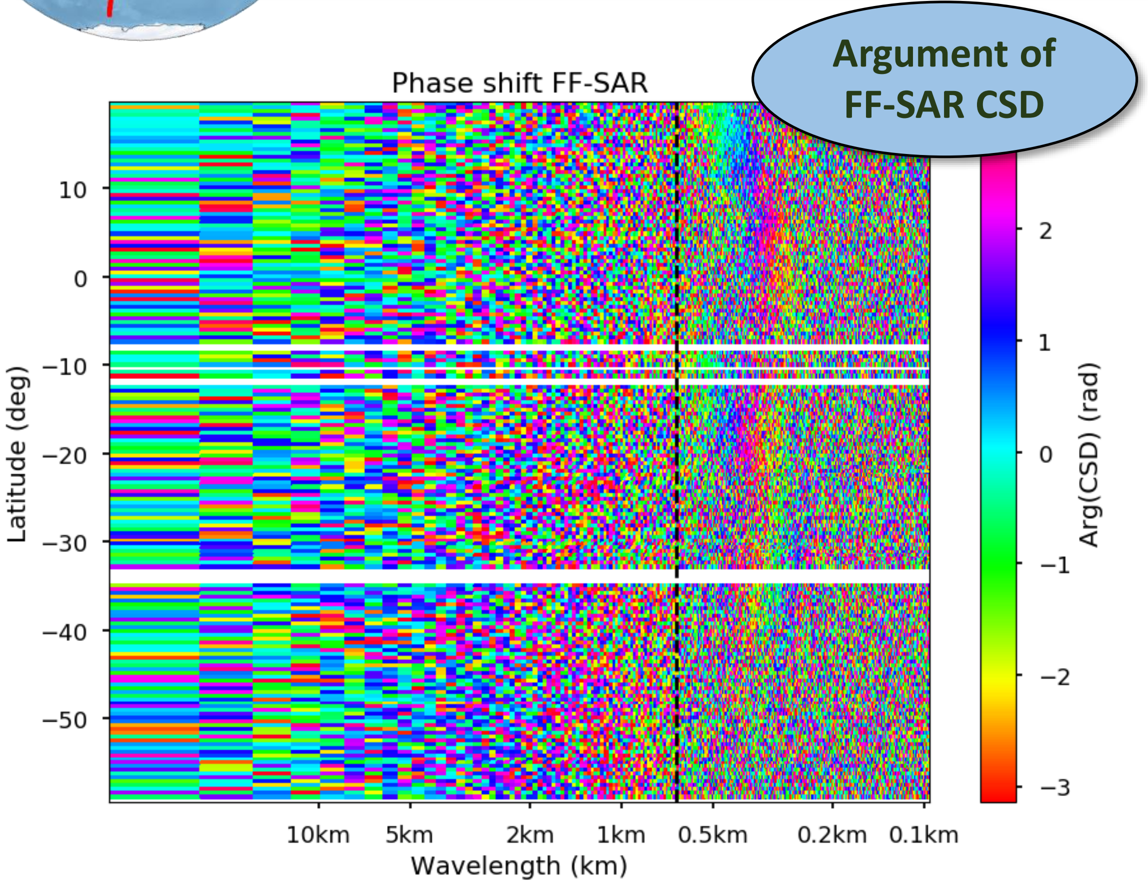
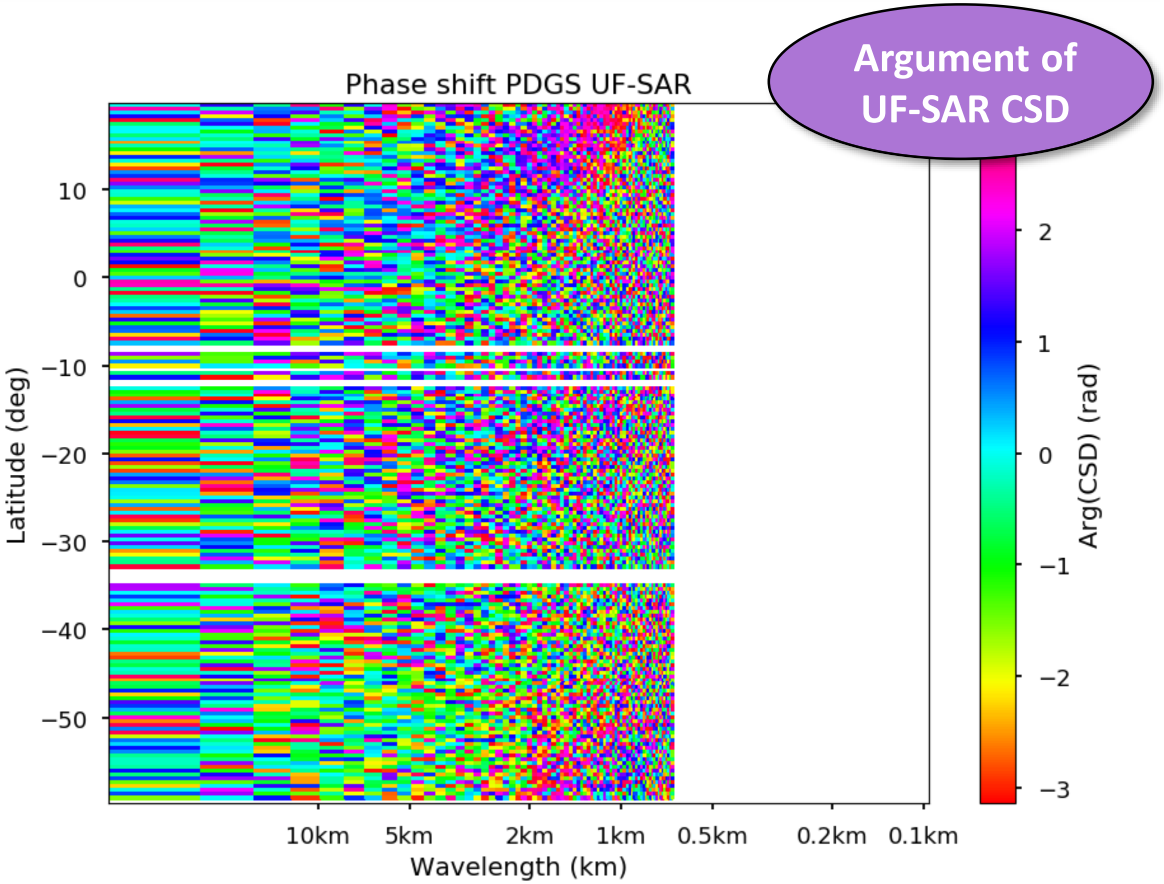
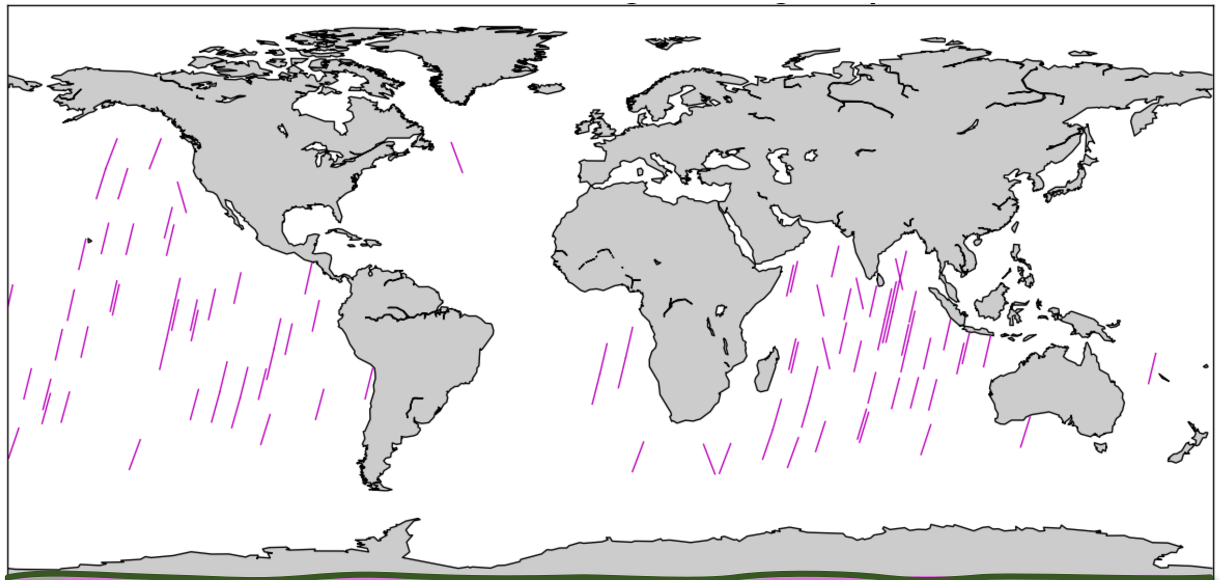
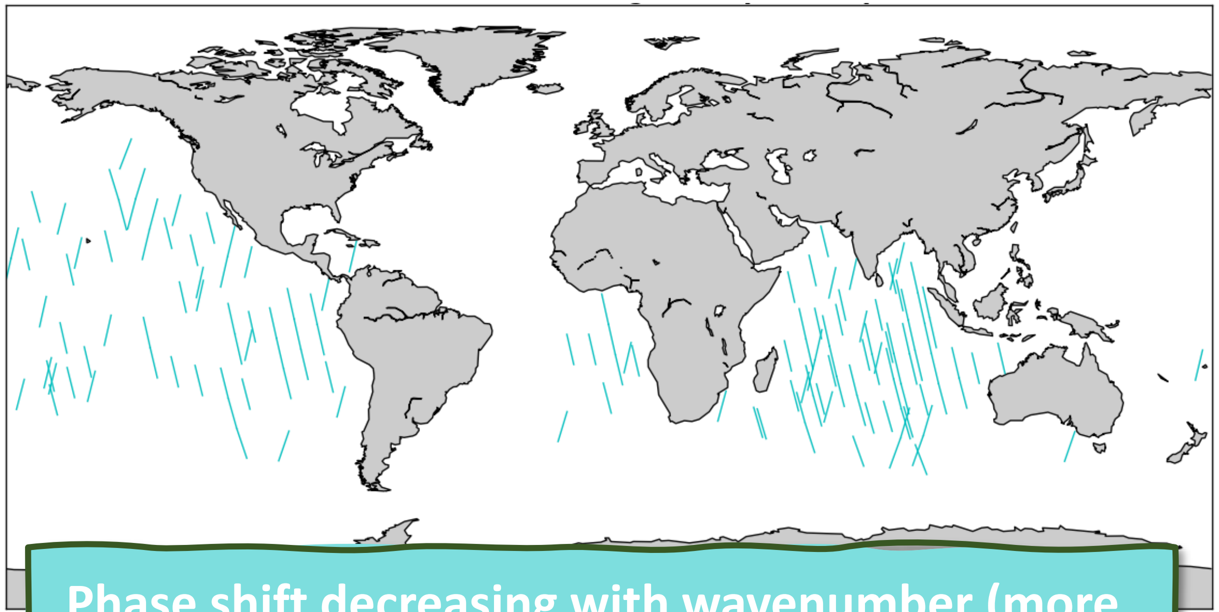




SPECTRAL ANALYSIS OF S3A/B UF-SAR ALTIMETER DATA



Phase shift increasing with wavenumber for swells anticolinear with the satellite flight direction



Phase shift decreasing with wavenumber (more likely observed) for swells colinear with satellite flight direction

Rieu et al., « Better insight of unfocused-SAR altimetry sensitivity to long-ocean waves using Sentinel-3 data in tandem phase», in preparation

CONCLUSION

Exploitation of S3 tandem phase provides a better insight of SAR-mode sensitivity to long ocean waves

- Confirming past findings (UF-SAR noise level and bias, and dependencies to sea state parameters)
- Cross-correlation of S3A and S3B UF-SAR data reveals signals linked to long ocean waves
- Techniques with higher spatial sampling and resolution (e.g FFSAR) help recovering (in some cases) the swell signal period (except the «blind band»)
- Phase difference allows to go a bit further in our understanding of UF-SAR sensitivity to swell, and identify the swell-related signals in the global SSH spectrum. Direction of the swell (colinear or anticolinear) can be determined.