CryoSat-2 Interferometer Performance and Application to Mesoscale Observations of the Kuroshio Current

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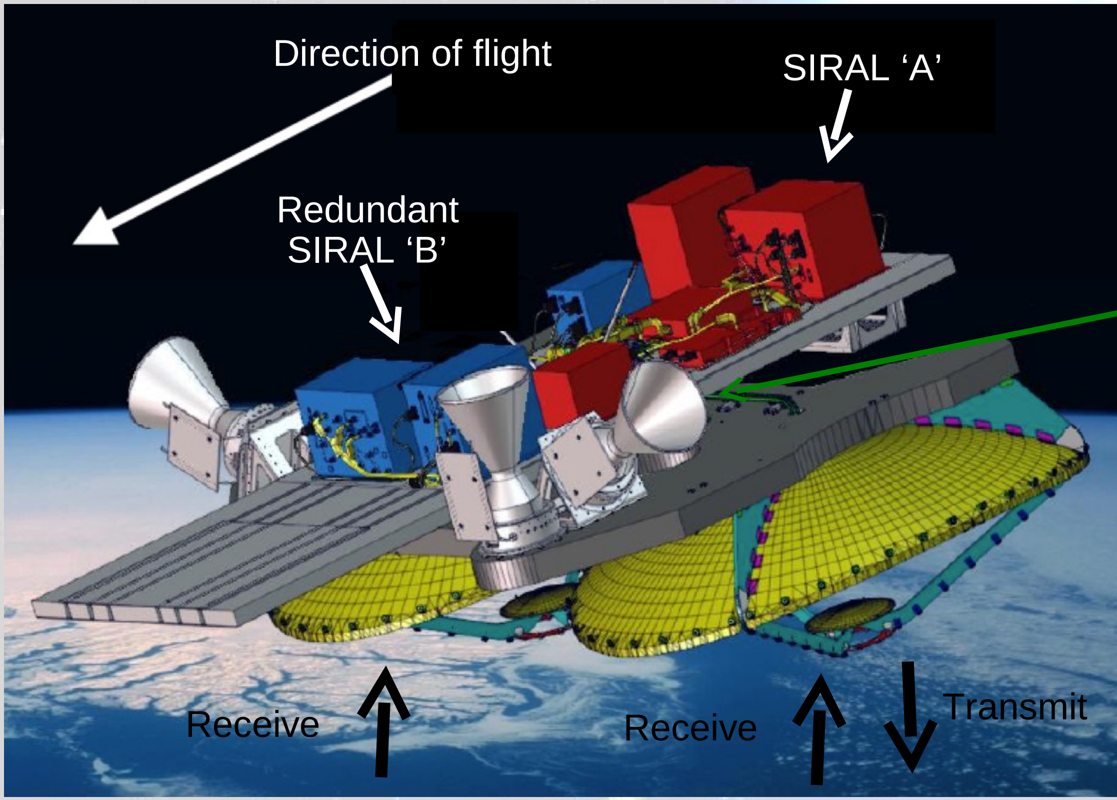
The CryoSat-2 Payload and Operating Modes.



- **"SARIN mode"**

  Illuminated area narrowed along-track by synthetic aperture processing & second receiving antenna forms an across-track interferometer. Star trackers determine baseline orientation.

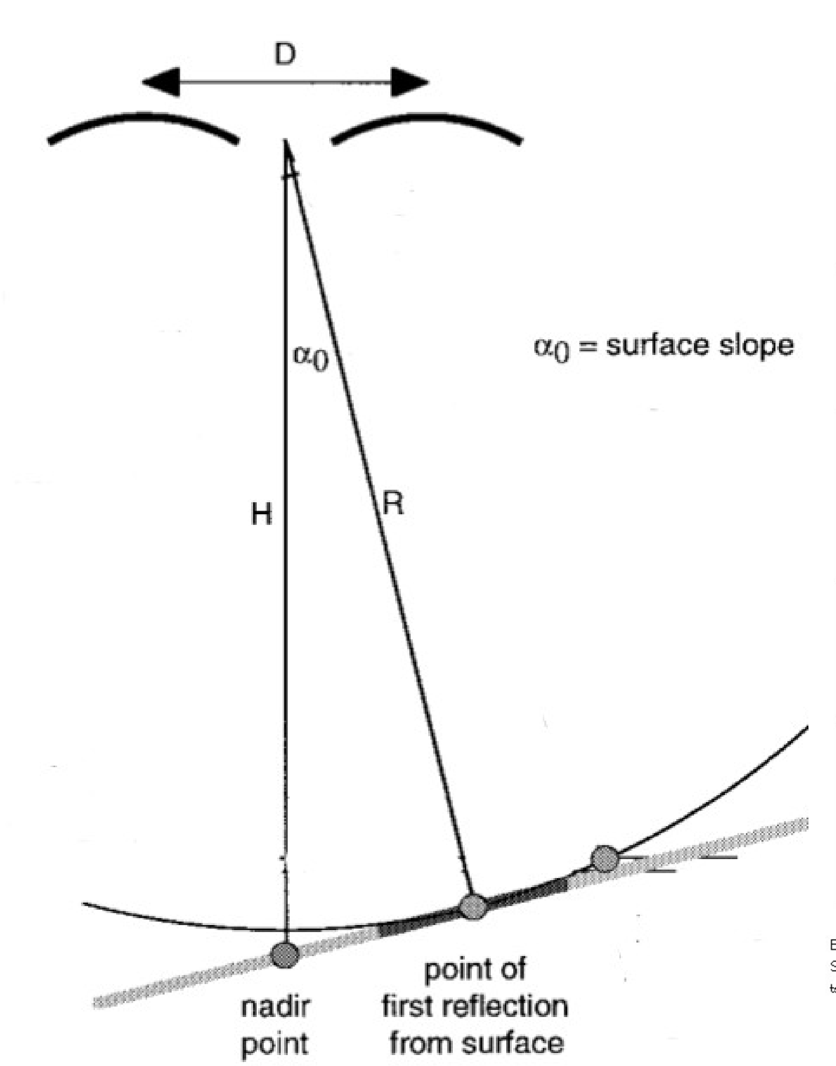
- "SAR mode" (SAR)

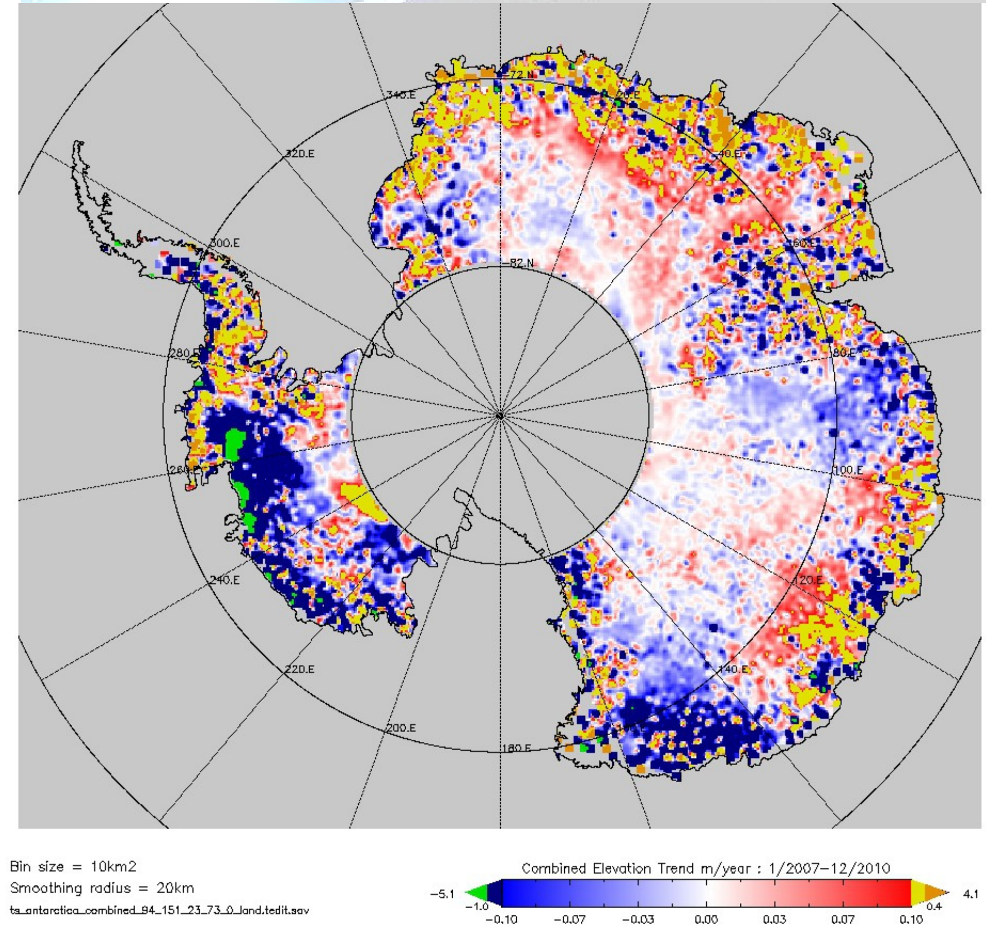
  Illuminated area narrowed along-track by synthetic aperture processing

- "Low resolution mode" (LRM)

  Conventional pulse-limited altimeter but with a slightly elliptical antenna

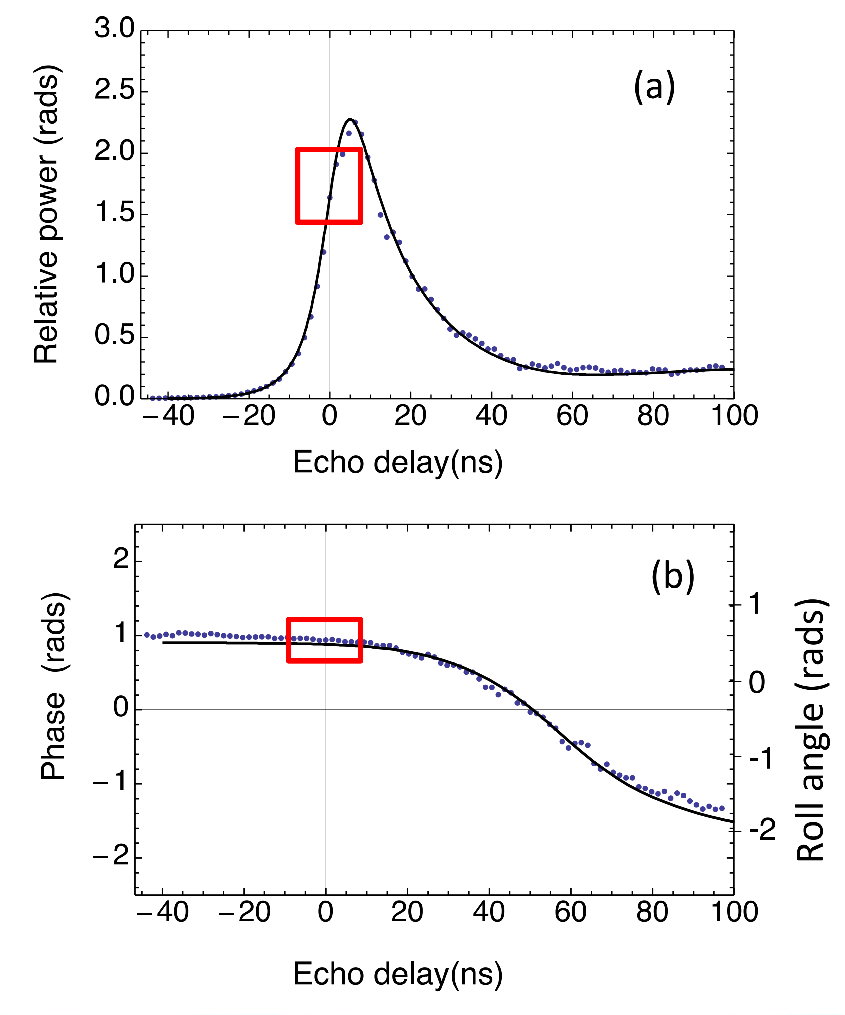
Filling in the omission areas in altimeter elevation retrieval





Courtesy: A. Muir, CPOM/UCL

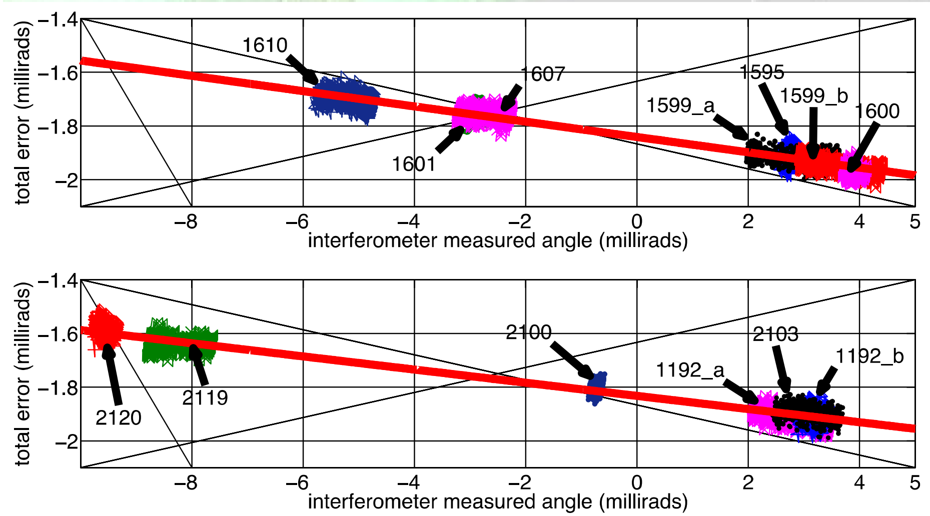
Estimating the interferometer angle



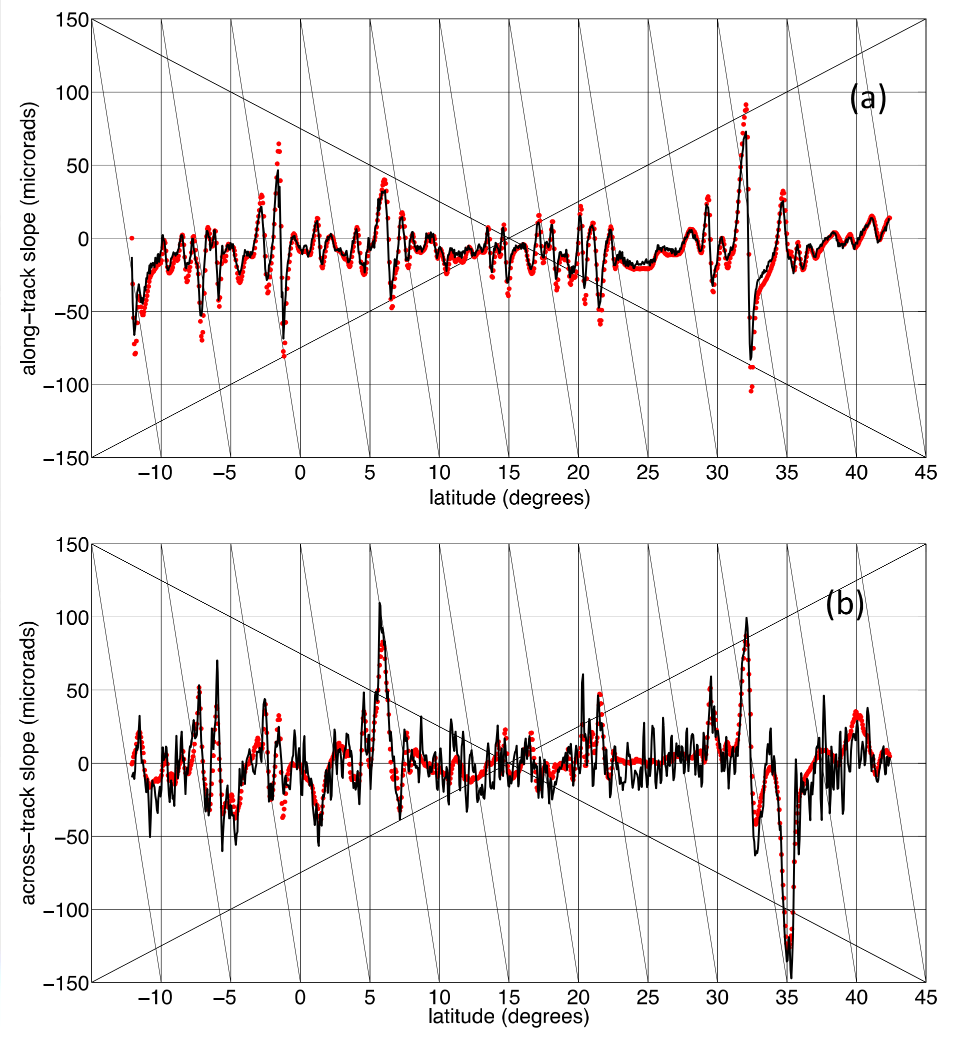
$$\sin(\theta) = Arg(\Psi(0)) / k_0 B + \phi_d$$

Measured scale factor:
0.973

Theoretical scale factor:
0.970



Achieved a precision of 25 microrads at 10km



First instantaneous ocean surface vector gradient!

Accuracy of 10 μrads at 1000km scales

If we fit a model to the data, can we reduce our noise to 10microrads?

	σ_r	$\sigma_r/\sqrt{(N_a-1)}$	$\bar{\varepsilon}_r$
SIRAL 'A'			
1595	20.4	0.6	3.4
1599_a	23.4	0.7	4.2
1599_b	20.0	0.8	-3.7
1600	22.6	1.2	-18.1
1601	20.5	0.6	3.1
1607	22.1	0.9	8.6
1610	21.6	0.8	-8.8
SIRAL 'B'			
1192_a	24.5	0.8	-16.0
1192_b	25.6	1.3	6.6
2100	19.1	0.7	13.4
2103	25.8	1.0	8.6
2119	22.8	0.9	-9.7
2120	25.0	1.0	2.7

The gridded nature of 2D SSH maps (AVISO / DUACS) can be misleading

Pulse-limited altimetry provides a 1D sea surface height (SSH) observation (along-track profiles ≠ not swath)

2D SSH fields (AVISO maps) are reconstructed using Objective Analysis (optimal interpolation) from 1D profiles

Illusion: homogeneous map with mesoscale observation

Reality: strongly anisotropic by nature

- Constrained by measurements where/when there are 1D profiles
- Constrained by correlation scales away from 1D profiles

Correlation scales are realistic (derived from observation) but only a statistical description of mesoscale signals ➔ not to be taken for granted

Courtesy: G. Dibarboure, CLS

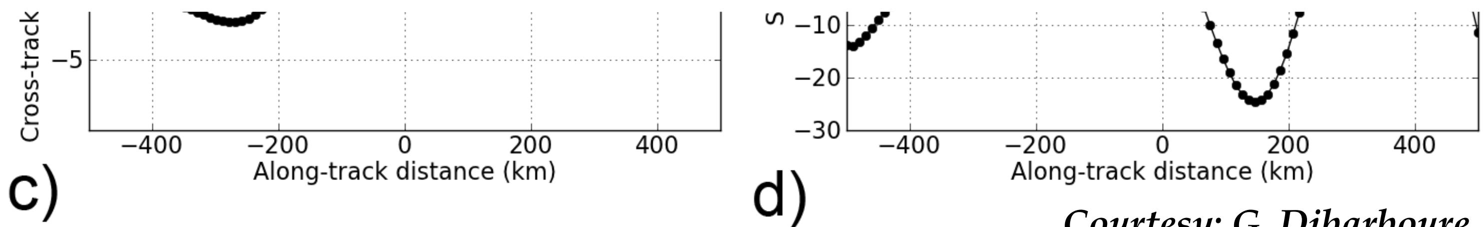
a) LRM sea surface height profile

b) SARin height & slope profile

Could the cross-track slope from an actual SARin instrument be used to enhance 2D SSH maps and to reduce the anisotropy ?

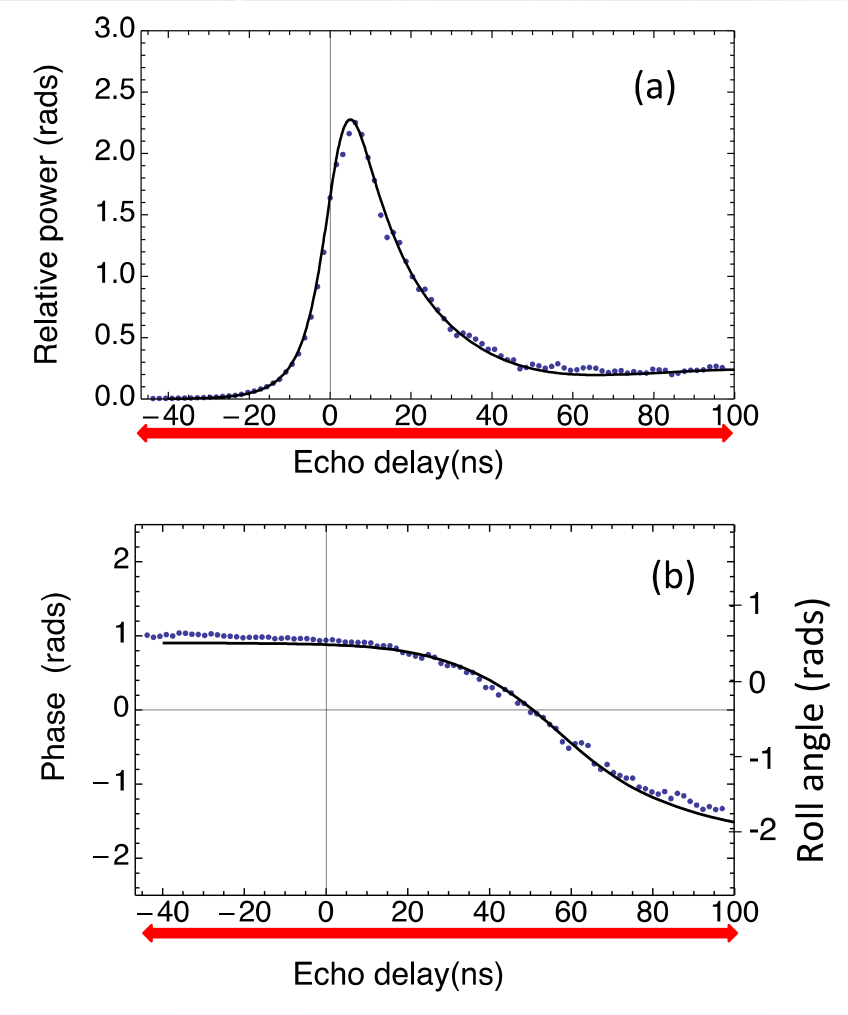
Short answer :

Only for 2-···structures in strong currents



Courtesy: G. Dibarboure, CLS

Fitting the interferometer angle



$$\sin(\theta) = Arg(\Psi(0)) / k_0 B$$

CROSS-PRODUCT IMPULSE RESPONSE

$$X(\tau) \sim \frac{\lambda^2 G_0^2 D_0 c \sigma^0}{32\pi^2 h^3 \eta} \sum_{k=-\frac{(N_b-1)}{2}}^{\frac{(N_b-1)}{2}} H\left(\tau + \frac{\eta h \xi_k^2}{c}\right)$$

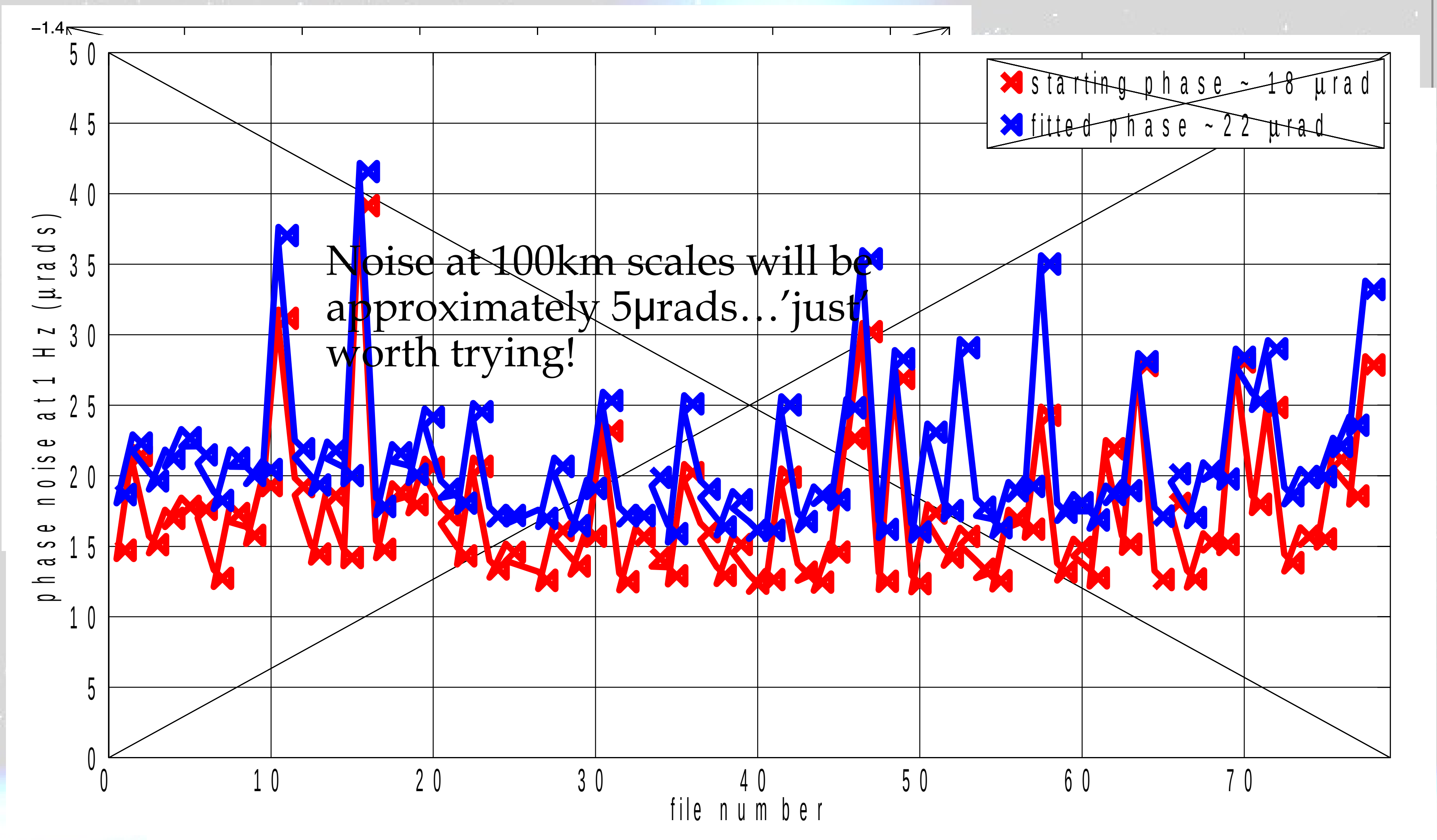
$$\cdot \int_0^{2\pi} d\vartheta \, d(\rho\cos\vartheta - \xi_k)\, e^{ik_0 B(\rho\sin\vartheta - \chi - (\beta/\eta))}$$

$$\cdot \exp\left[-2\left(\frac{(\rho\cos\vartheta - \mu - (\varsigma/\eta))^2}{\gamma_1^2} + \frac{(\rho\sin\vartheta - \chi - \beta/\eta)^2}{\gamma_2^2}\right)\right]$$

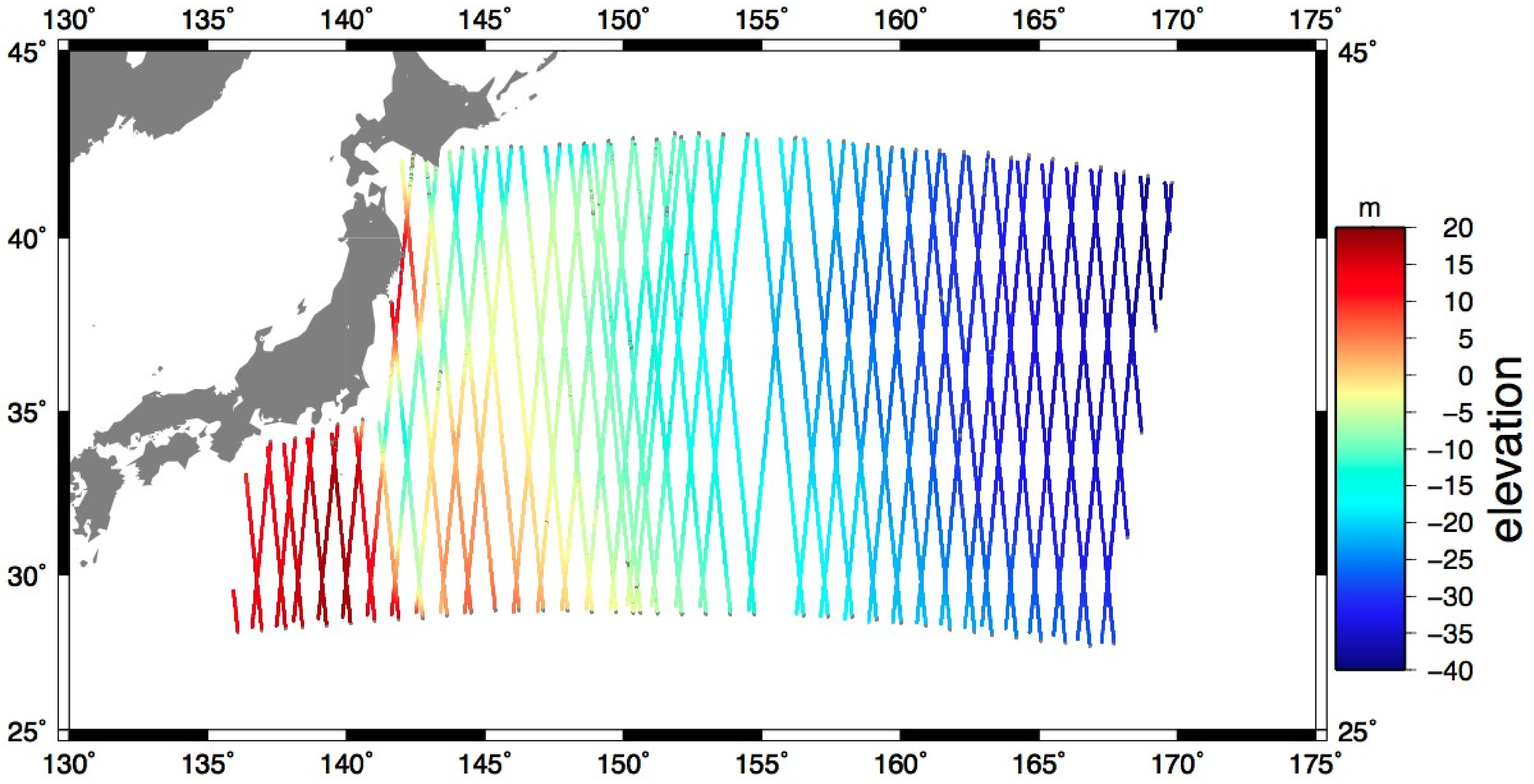
Numerical approximation to the cross-product:

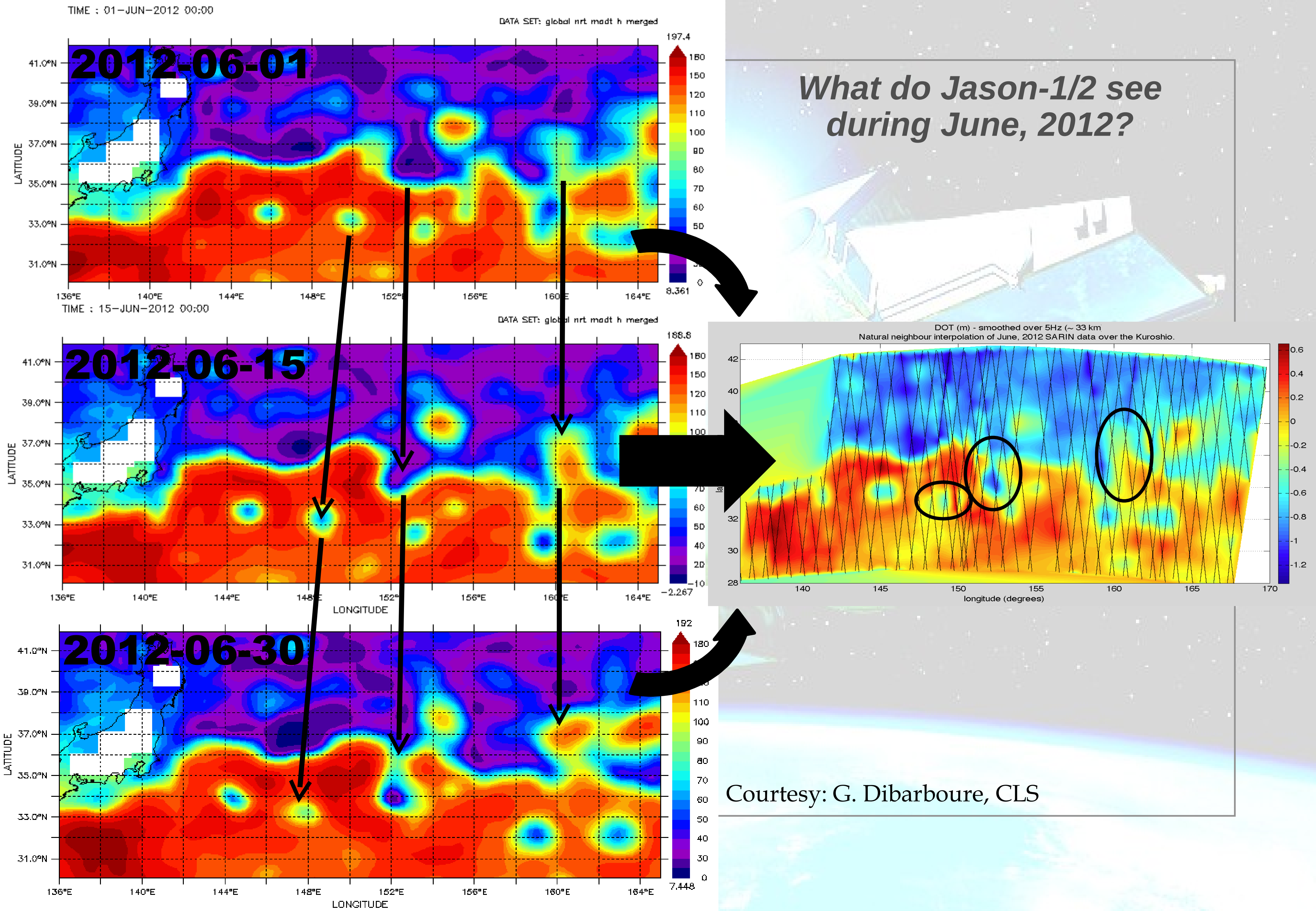
$$X(\sigma^0, \theta, SWH; \tau)$$

The bias versus noise trade-off



SARIN data over the Kuroshio region, June, 2012

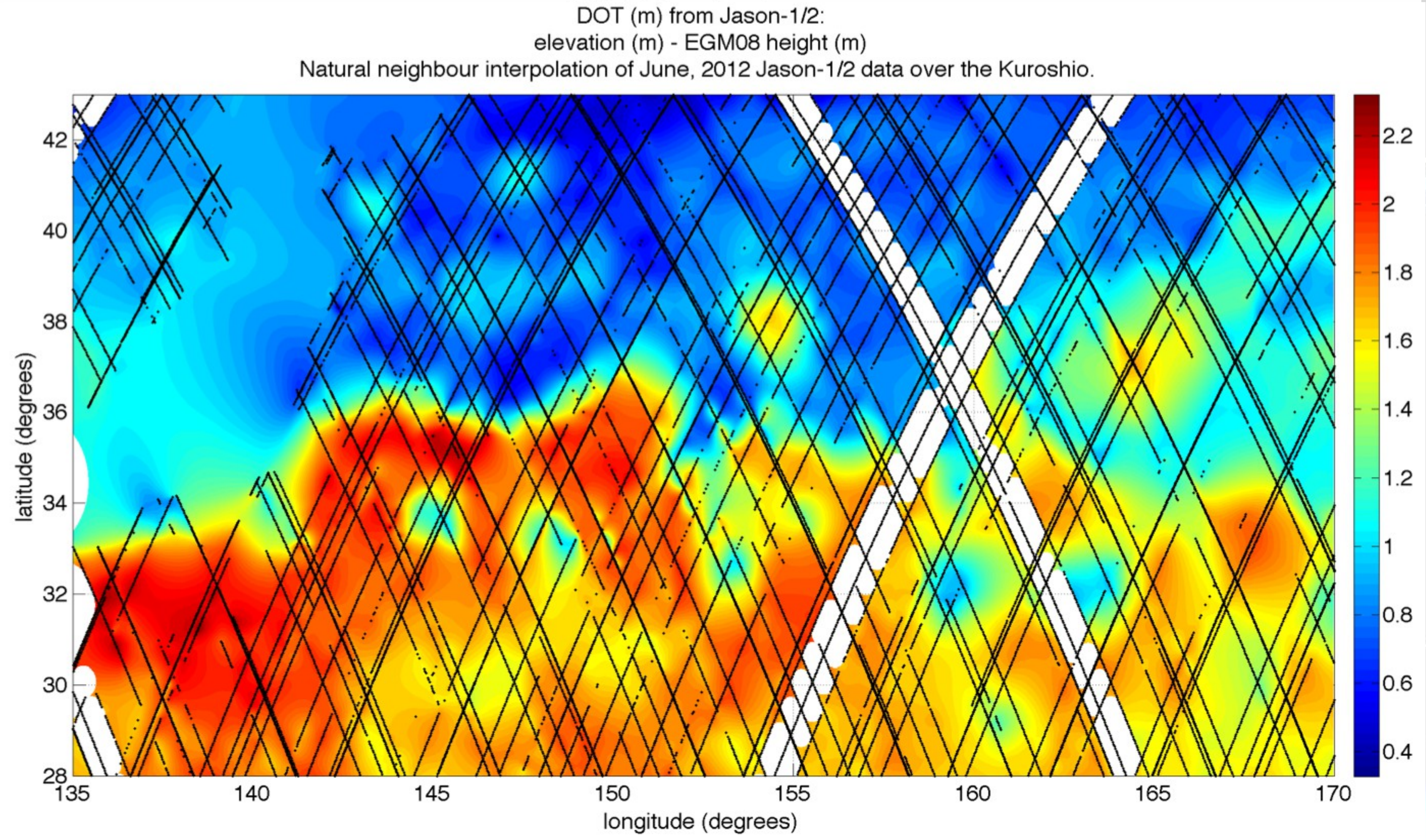




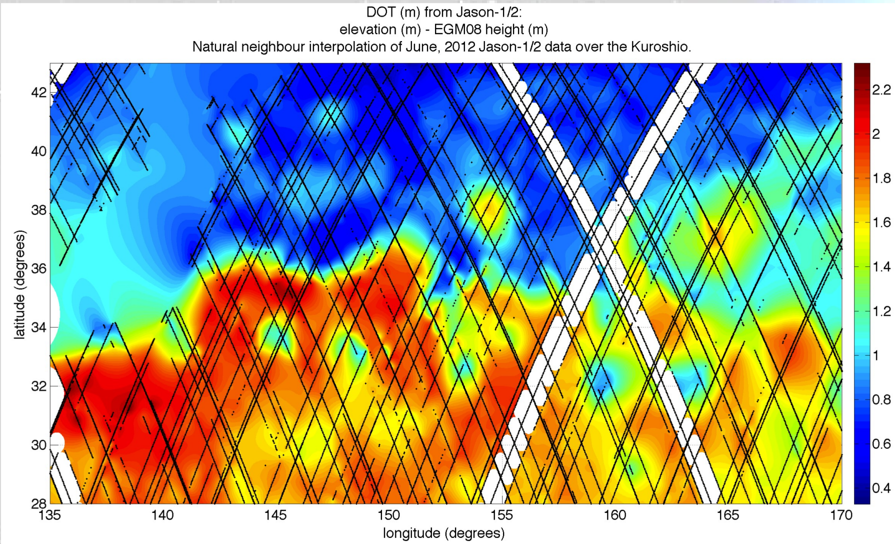
What do Jason-1/2 see during June, 2012?

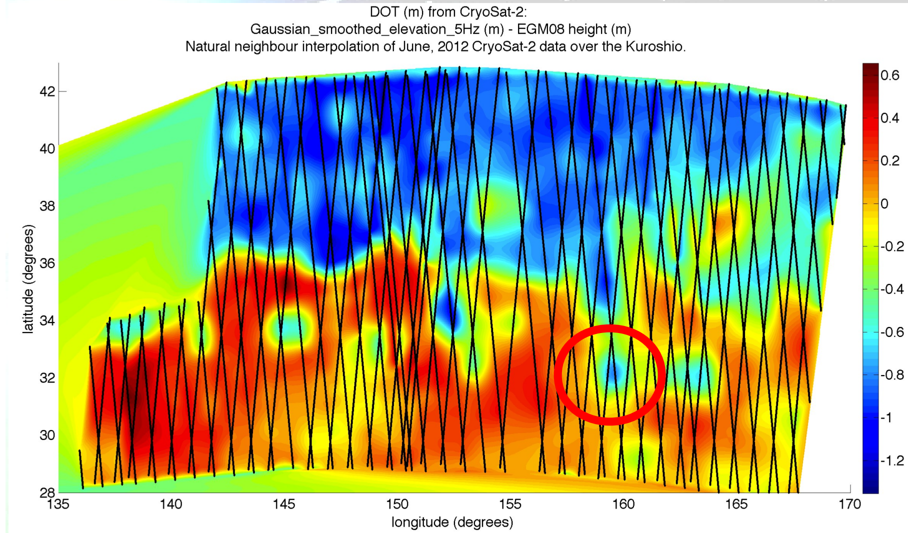
Courtesy: G. Dibarboure, CLS

1. Can CryoSat-2 see dynamic topography?



2. Comparing JS-1/2 and CryoSat-2 data with the same interpolation scheme…

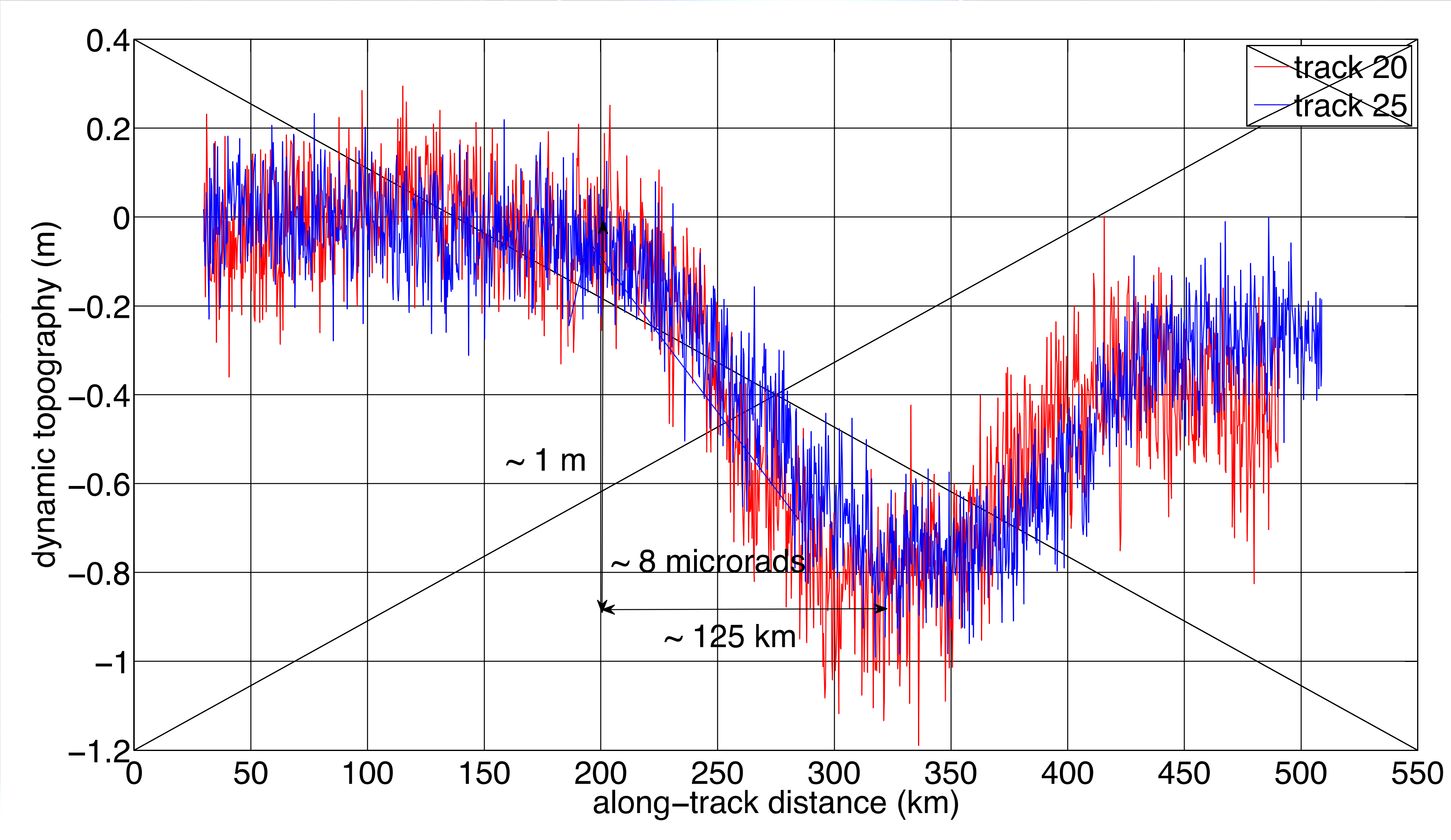




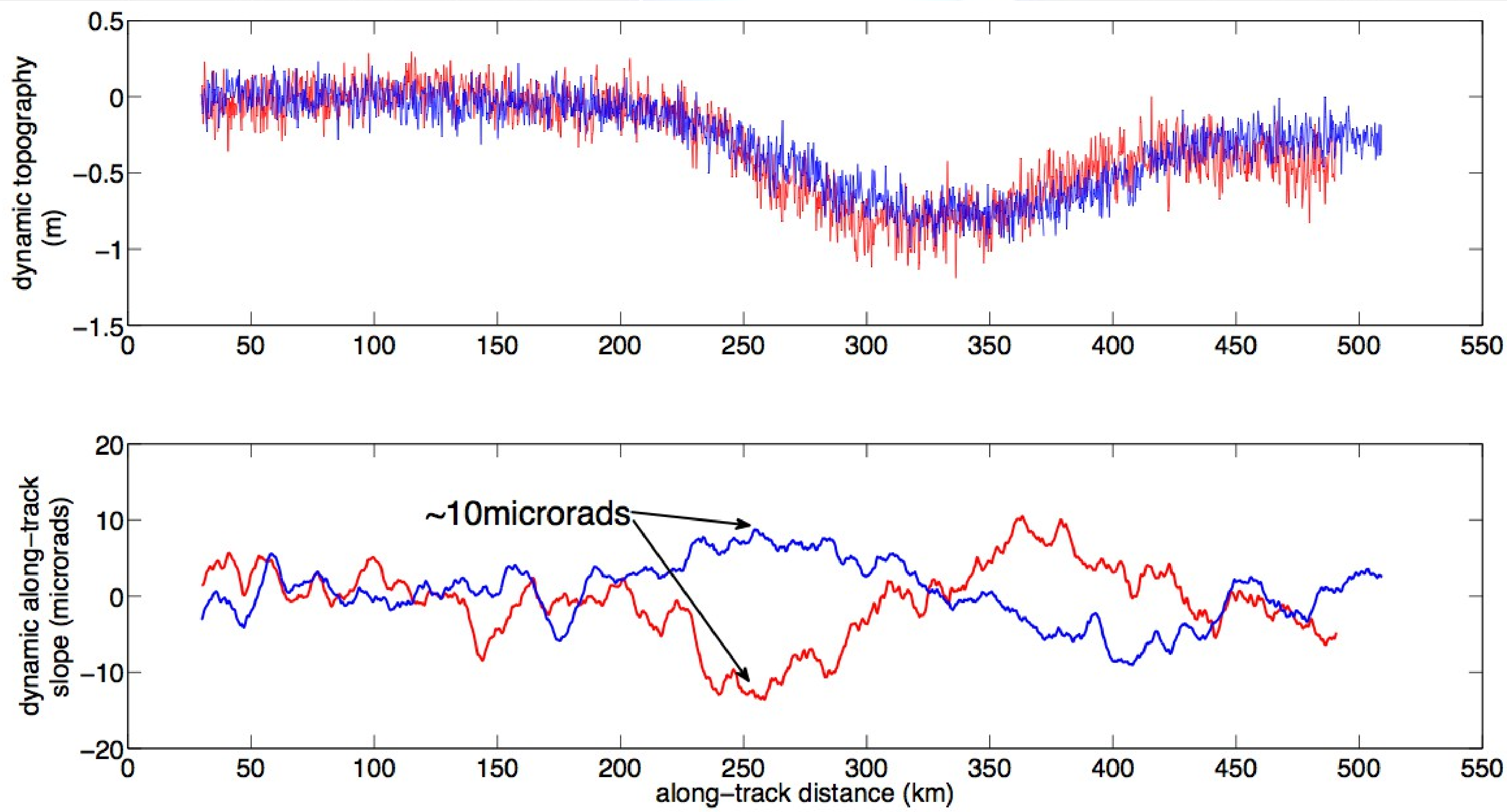
meters	CryoSat-2	Jason-1/2	differences
mean	-0.31	1.28	
stdDev	0.10	0.07	
minimum	-1.35	0.33	1.68
maximum	0.66	2.32	1.66
range	**2.01**	**1.99**	**0.0179**

3. Yes, CryoSat-2 can see dynamic topography. Now, let's pick a 'mesoscale' feature and zoom in…

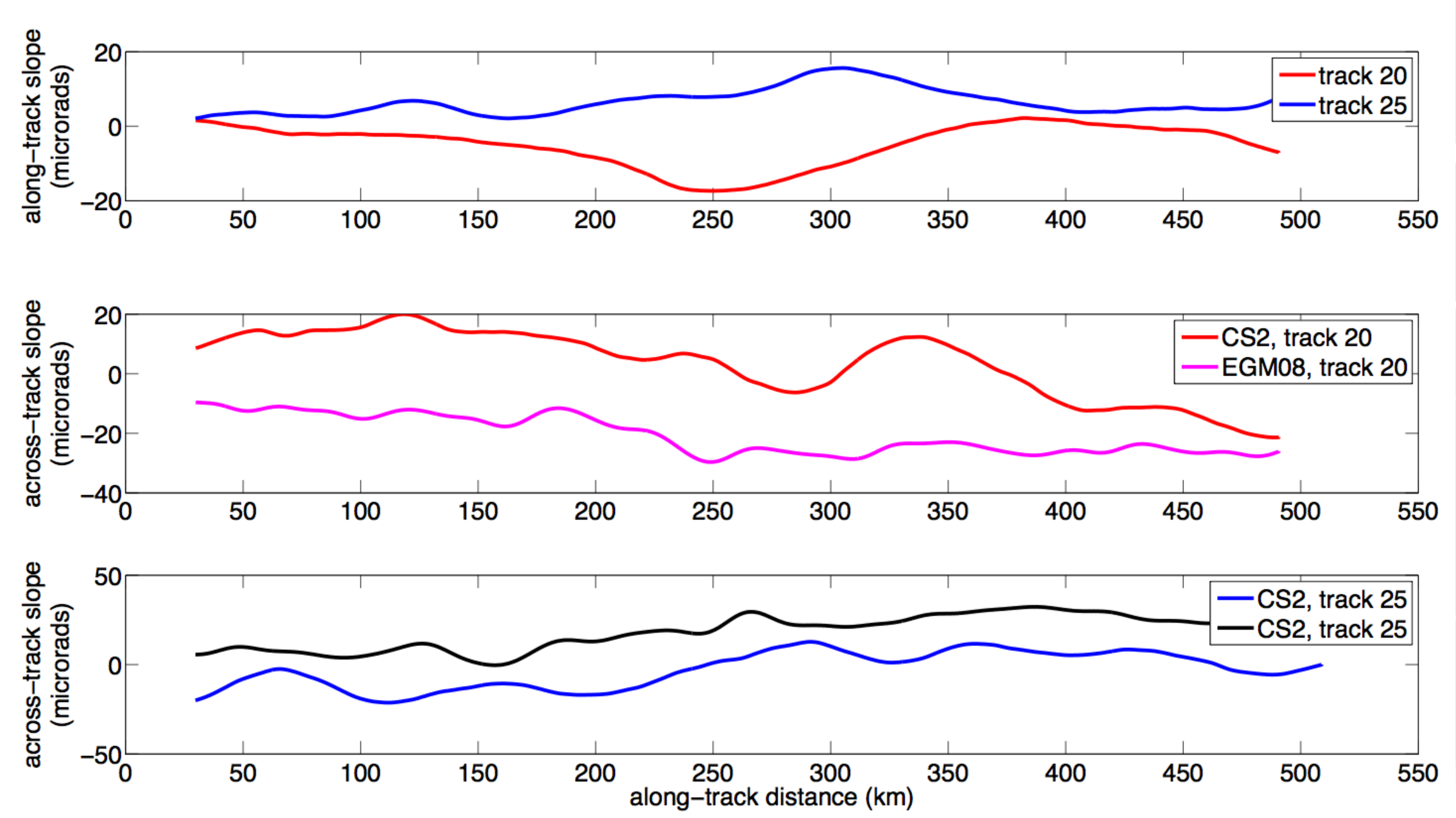
4. What does the feature look like along-track?



4. What does the feature look like in along-track slope?



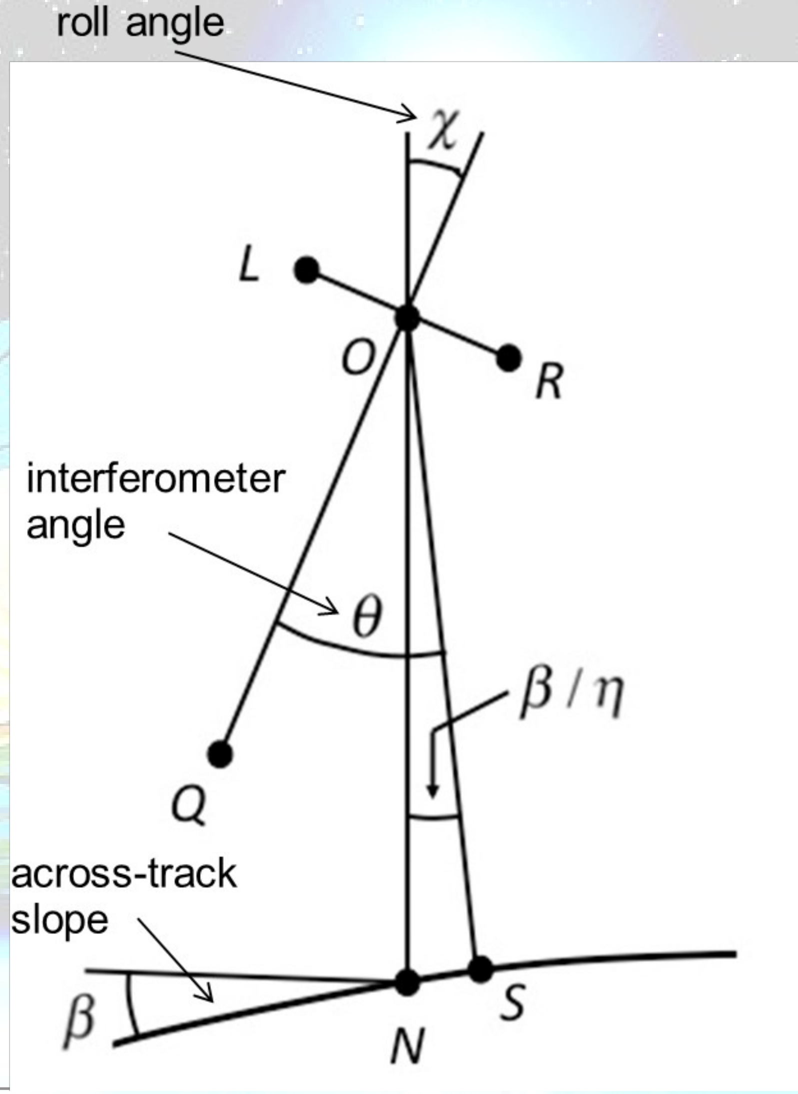
4. What does the feature look like in ACROSS-TRACK slope?



Summary

- We have developed and demonstrated the use of a numerical model to fit the SARIN cross-product.
- Unfortunately, while the model eliminates the biases in the fitted parameters, the noise on the phase-difference increases.
- We anticipate that the phase noise will be of the order of 5 μrads at scales of 100 km. Consequently, we have **hope** of detecting mesoscale features.
- Currently, we haven't been able to conclusively demonstrate the presence of mesoscale features in the across-track slope. BUT we've only just started looking.
- We have to understand the biases in the CS2 across-track slope.
- We have to look the spectrums of the across-track slope from EGM08 and CS2. Perhaps EGM08 is missing some higher frequency components.
- We have to perform a large-scale quantitative comparison to Jason-1/2 to really understand the capacity of this instrument to detect and measure mesoscale features.

The basic viewing geometry



$$\theta \approx \chi + \beta / \eta + \varepsilon$$