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New processing schemes enhancing SAR-mode ocean retrieval performance

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Abstract In SAR radar altimetry, the development strategy of the on-ground processing aimed at reducing the noise speckle of the measurements while retaining the high along-track resolution of the data. The actual Cryosat-2 and Sentinel-3 operating systems allow today to resolve Doppler bins with non-overlapping segments on the surface enabling to mitigate the contamination between adjacent Doppler bins. It is found however that the speckle noise reduction on the altimeter-derived parameters (range and wave height) is not as high as expected. In addition, some discrepancies between Pseudo-LRM and SAR-mode remain in low sea-state conditions, but also above 2m wave height in range (few cms) and swh (10 to 20 cm), and their difference depends on the significant wave height. In order to better exploit the capabilities of the SAR altimeter compared to those obtained with the actual ground processing, it is thus essential to develop alternative methods allowing a better processing that would take maximum advantage from the Doppler processing. This is of major interest for Sentinel-3 and Sentinel-6 missions, embarking both a SAR altimeter. This paper addresses the critical aspects of the actual SAR-mode processing and presents some innovative algorithms (developed/analyzed in R&D studies funded by CNES and ESA) that shall improve the SAR-mode data performances: describing their principle, benefits and drawbacks. The aim is also to determine whether the new processing schemes have a potential impact in operational use or not.

Stack analysis

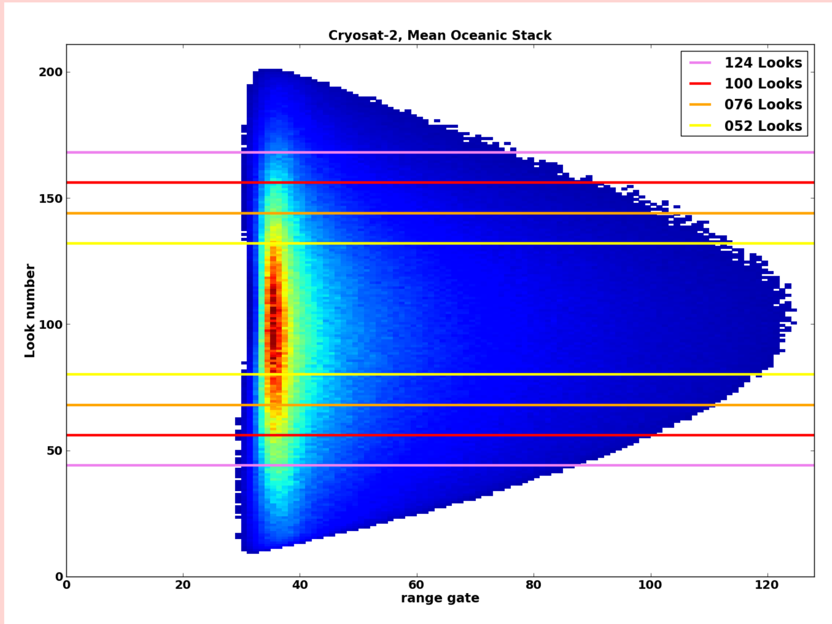
- No-degraded performances with 100 looks (even lower if no-mispointing)
- Similar 20-Hz noise levels (in range and SWH)
- No SLA bias and reduced SWH bias with P-LRM

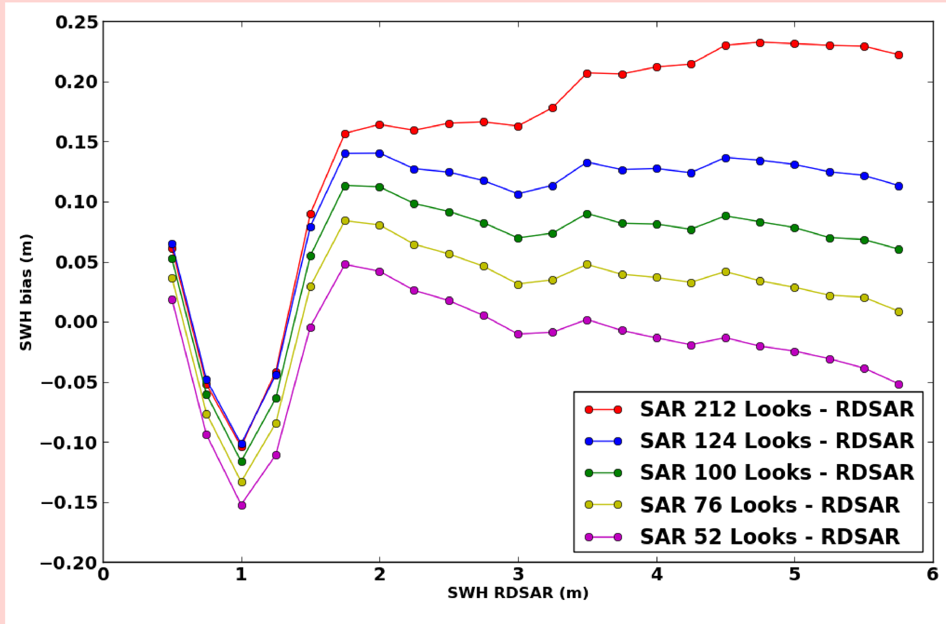
➔ By reducing the stack of beams (lower than the 2.5s stack -time duration) we might also improve the consistency between individual observations

- Same oceanic signal content (from spectra analysis)

From the actual processing/retracking scheme, outer looks have more likely no impact on SAR performances (notably range)

➔ How to take advantage from these contributions ?





SAR-mode noise issue

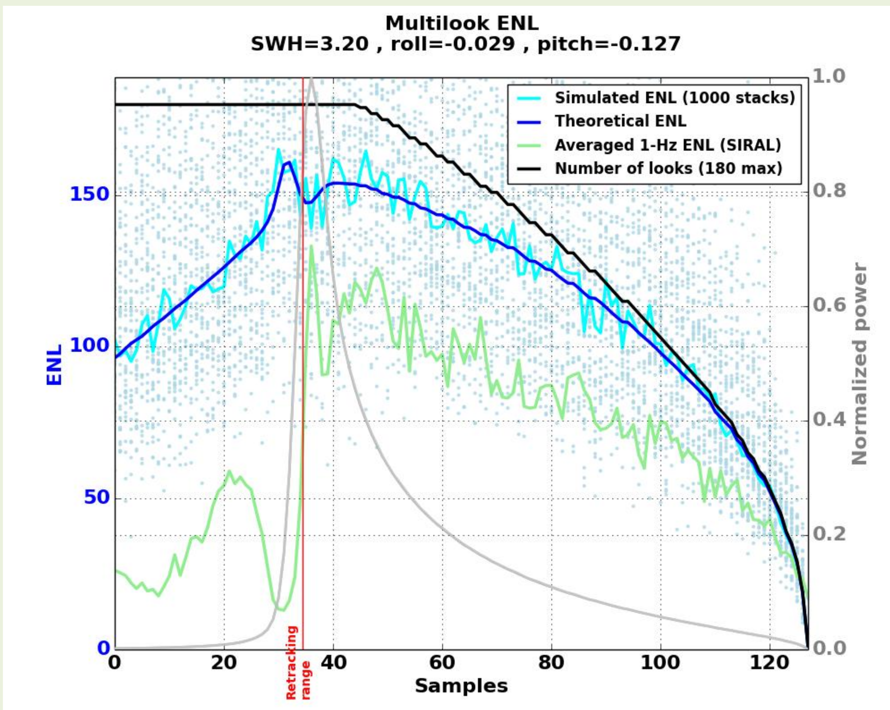
In a stack, the contributing Doppler beams to the final averaged waveform have different mean shapes and different amplitude values related to the looking angle of measurement. The off-nadir beams of lowest amplitudes thus contribute very little to the noise reduction, as well as to the geophysical parameter estimates. As computed theoretically by Amarouche [2013], the effective number of looks (ENL) that are ultimately involved in the noise mitigation process is lower than the number of beams and varies in range bins and wave height.

$$ENL = \left(\frac{a}{\sqrt{v}}\right)^2 = \frac{N}{1+\frac{1}{N}\sum_{i=1}^{N}\left(\frac{\alpha_i}{a}\right)^2} = k.N$$

Number of looks

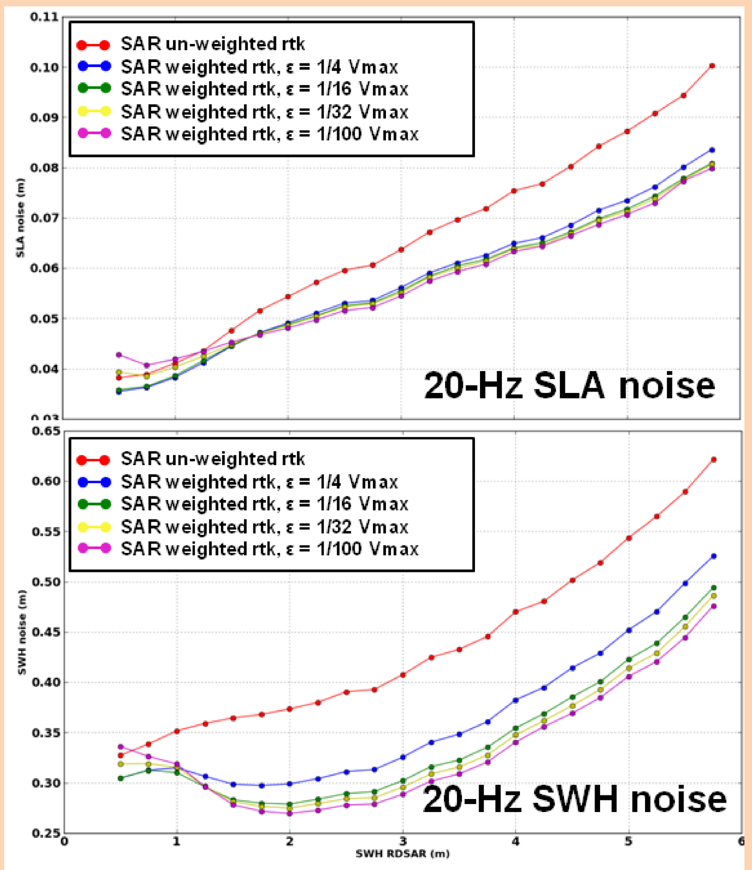
mean power variations within stacked beams

ENL computed with real data (over 500 consecutive 20-Hz data in Pacific SAR-mode area) is even lower due to inconsistent sea state between data.



Optimized SAR-mode retracking

A weighted MLE3 retracking gives more importance to portions of the waveform with low power that originate from outer beams (toe)



➔ No significant bias

➔ 20-Hz noise reduction (SWH @2m)
- SLA 10%
- SWH 20%
- Sigma0 25%

➔ Same oceanic signal content (from spectra analysis)

➔ A likehood estimator weighted in Doppler beams would even provide more improvements

Alternative SAR-mode processing (SCOOP ESA project)

Individual Doppler beams retracker method:

- To process each individual look with adapted retracking accounting for the noise law characteristic of single beams
- Then "average" their estimates θ_k

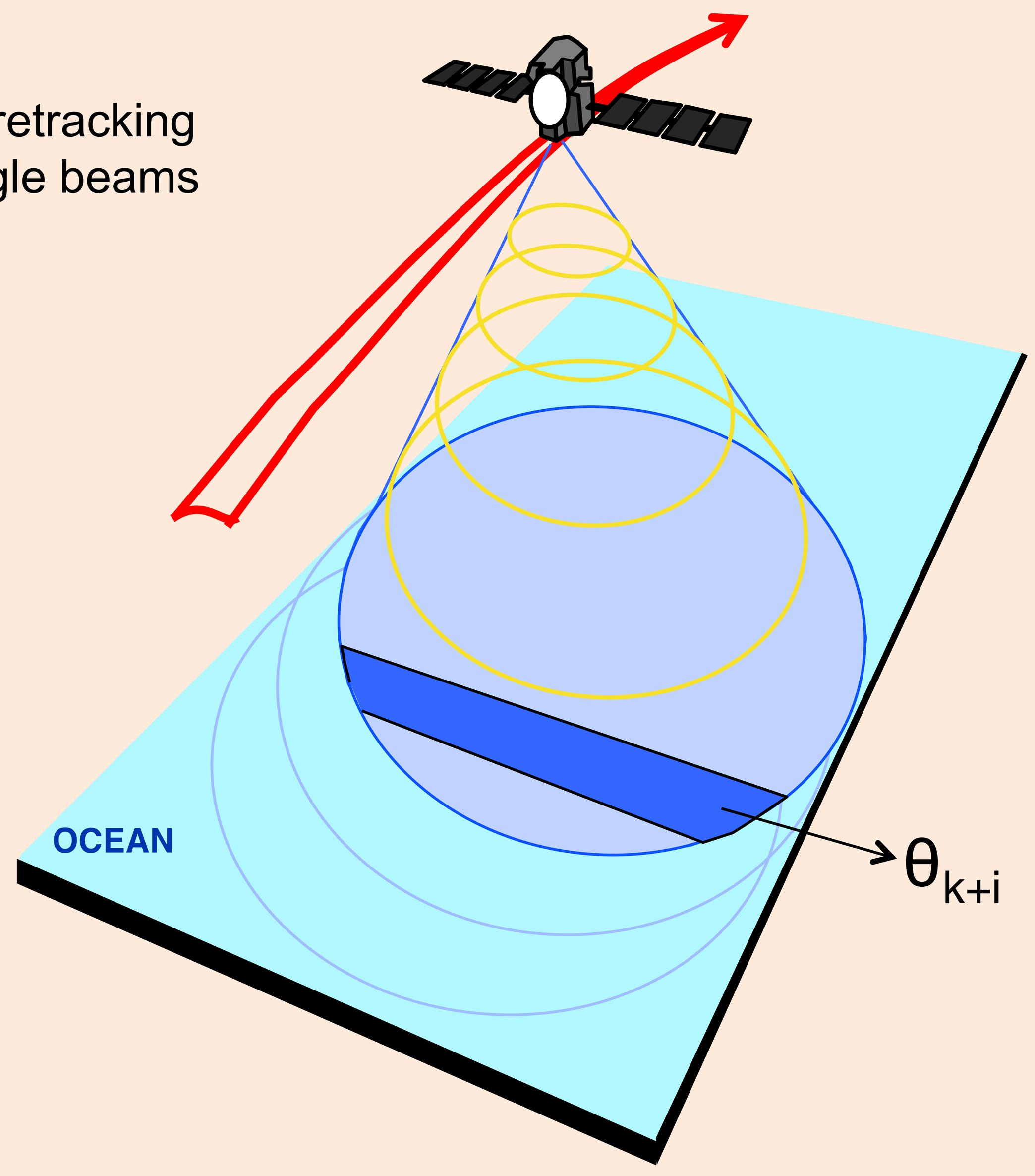
$$\theta = 1/L\ \Sigma(..+\theta_k+\theta_{k+1}+\theta_{k+2}+..)$$

➔ Making all Doppler beams with equal contribution to the noise reduction with no beams weighting (e.g., antenna pattern compensation, stack beam weighting)

➔ Enabling to assess the model consistency (checking any discrepancies between nadir/off-nadir look estimates)

➔ Tracker range alignment is not applied mitigating possible errors due to inaccurate COR2 command (computed on-board)

➔ To edit inconsistent looks still contaminated by land / calm sea (or disrupted by possible on-board tracking error)

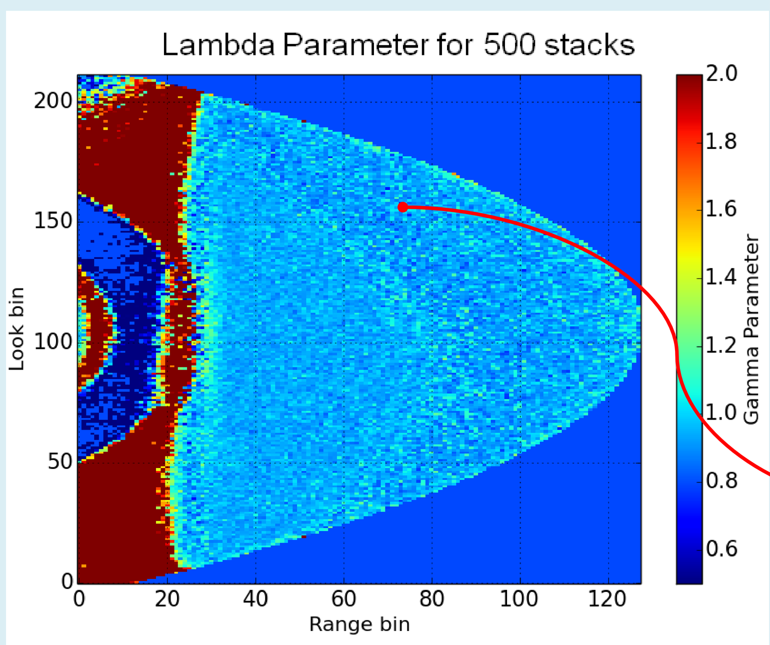


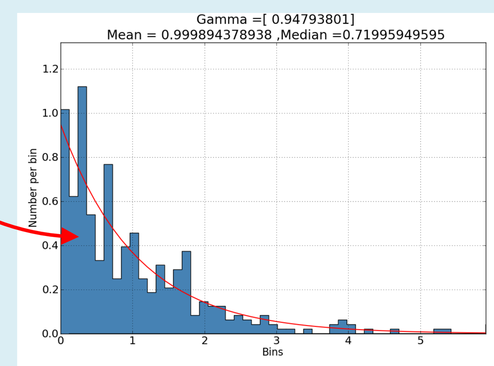
Speckle noise law characterization

Speckle noise law has been characterized with CPP data showing expected exponential distribution

$$f(x,\lambda) = \lambda e^{-\lambda x} \quad \text{with } \lambda=1$$

➔ Same speckle characteristics after Doppler processing as for individual conventional altimetry pulses





Further analysis, test, implementation and assessment are on-going...

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