WP 3000
Doppler Stack Processing

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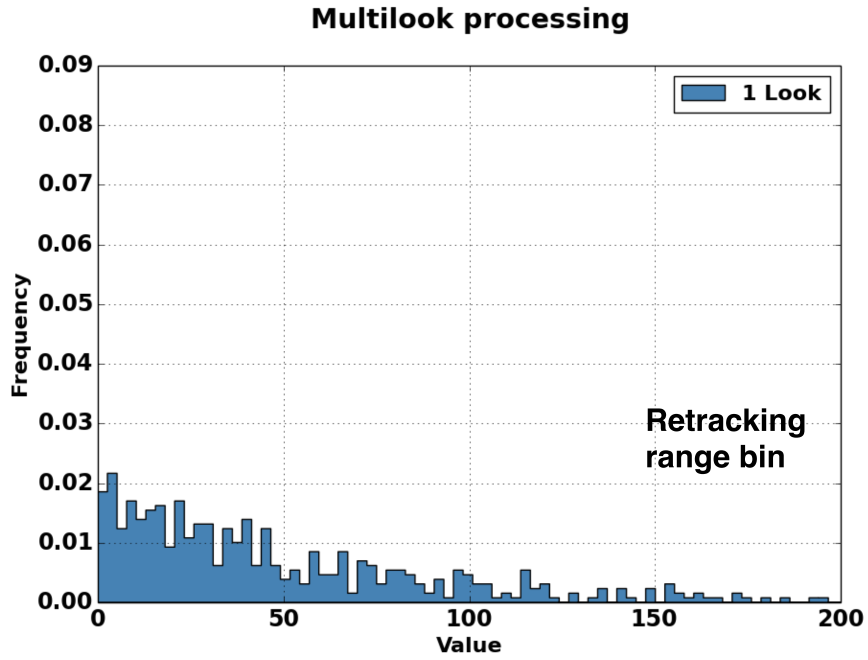
MULTILOOK PROCESSING

- **The multilook processing is used:**
  - To reduce the speckle noise
  - To obtain data compression

- **Single-look**
  - Probability distribution function has a exponential distribution

$$f(x;\lambda) = \lambda e^{-\lambda x}$$

  - Average value of the speckle amplitude = standard deviation

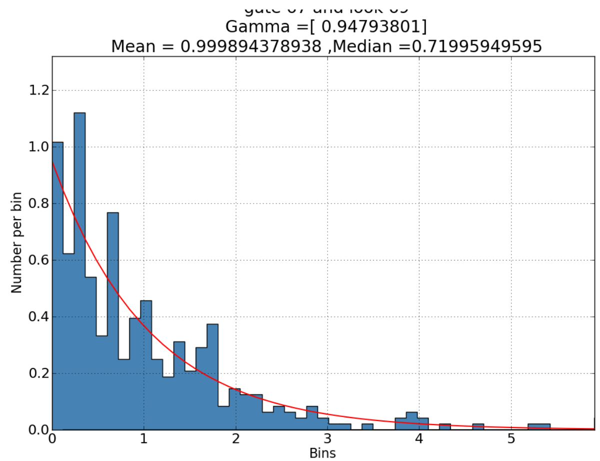


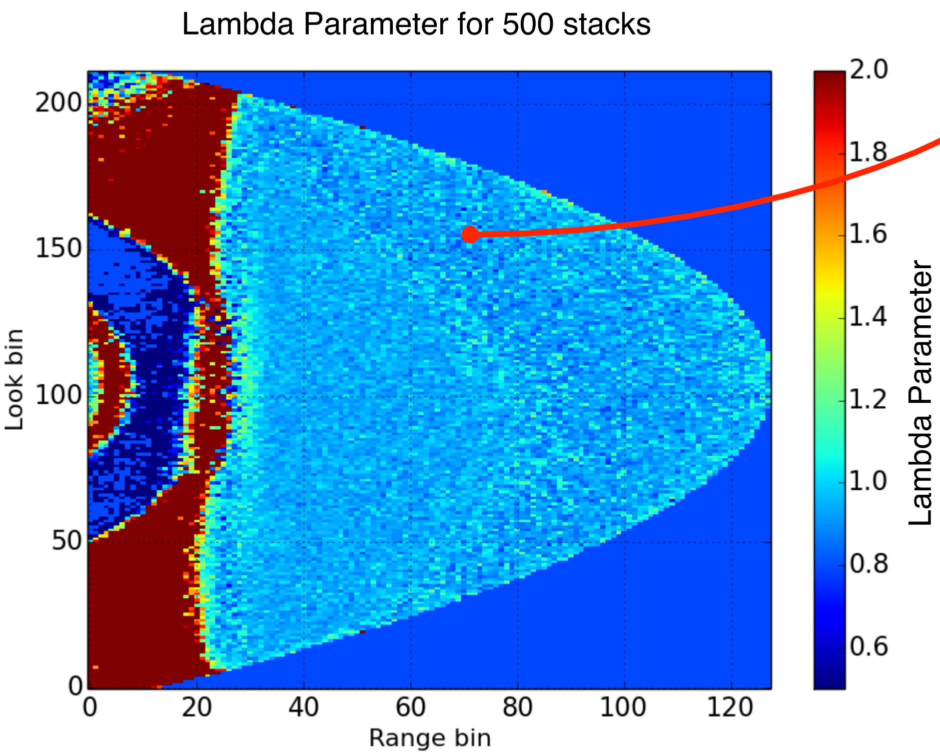
MULTILOOK PROCESSING

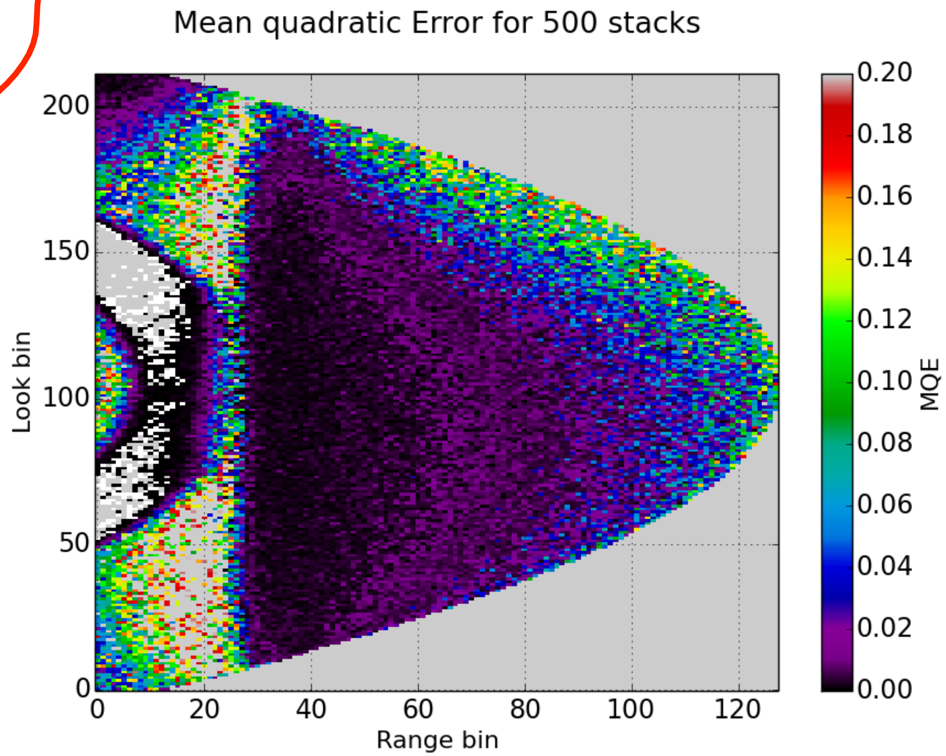
- Speckle noise law has been characterized with SIRAL data (from CPP) showing expected exponential distribution

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

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







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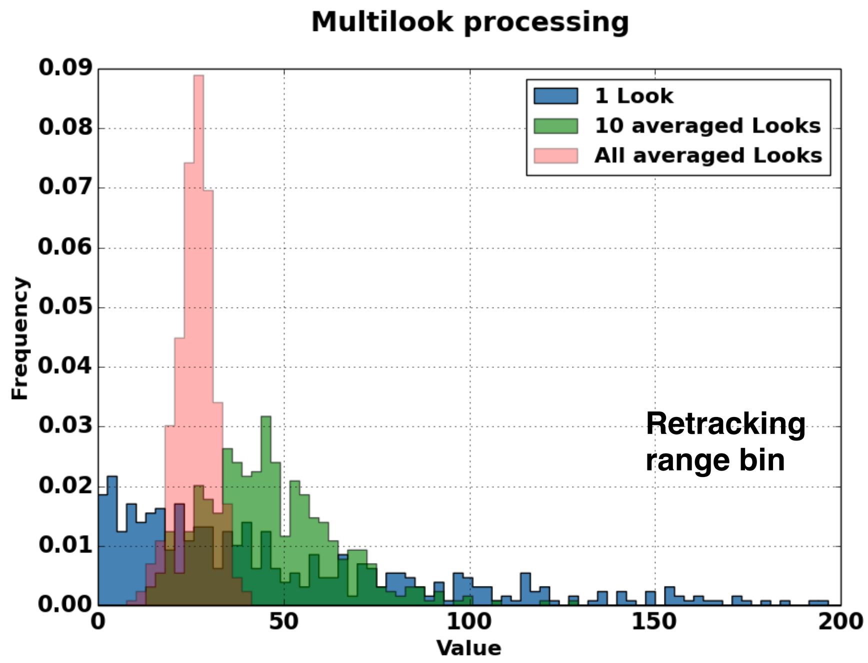
- **Multilooking**
  - Incoherent addition of independent looks of the same scene
  - For N-looks, the speckle amplitude has a gamma distribution

$$f(x;N;\lambda) = \frac{\lambda}{\Gamma(N)} e^{-\lambda x} x^{N-1}$$



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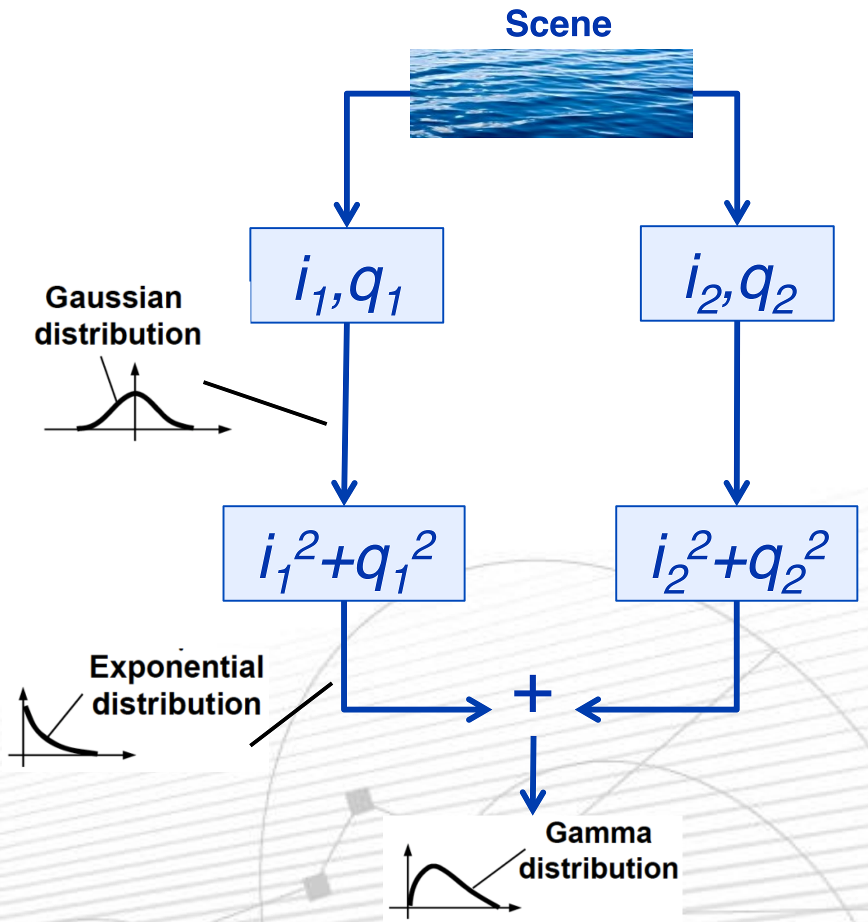
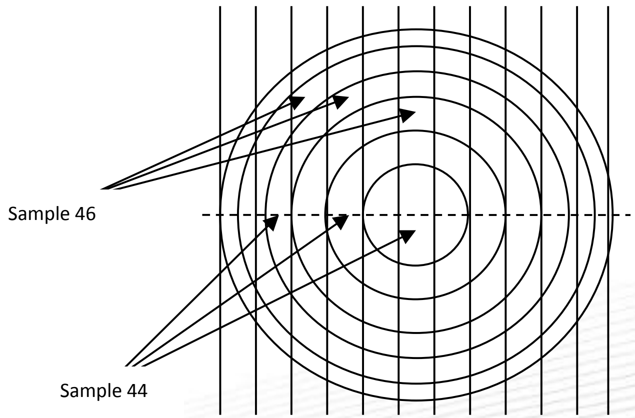
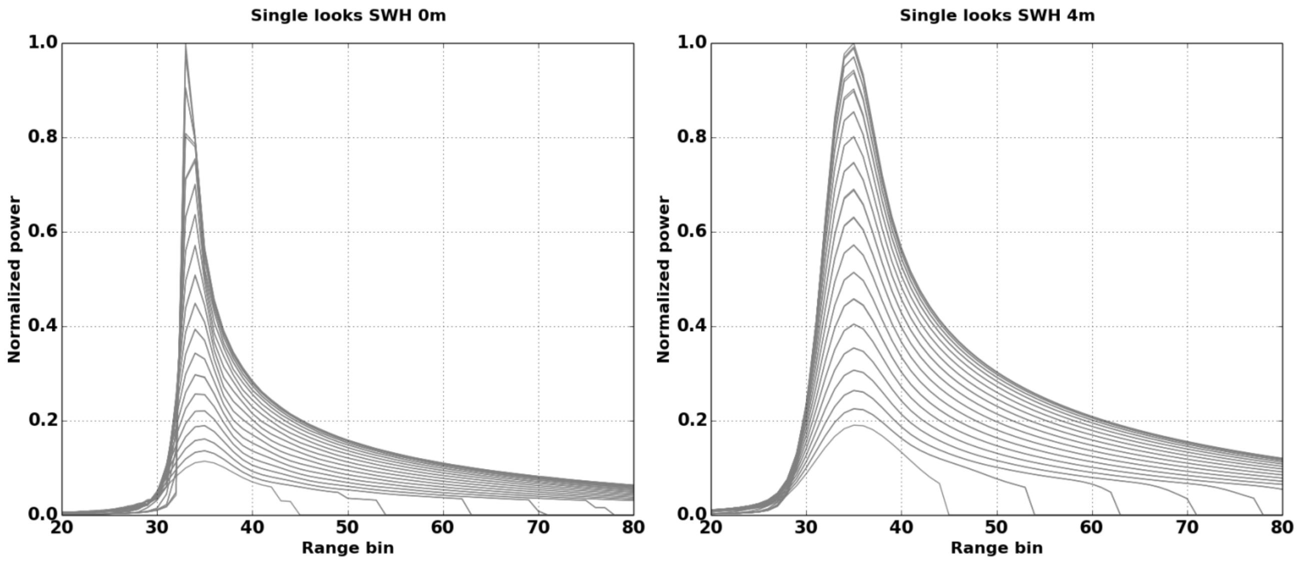


SARM NOISE ISSUE

- **But the reduction of the noise level is not as high as expected (and lower than √N)** ***[Amarouche, meeting SAR, NOC, 2013]***
  - High inhomogeneity between Doppler bins (stack)
    - Along-track variation of the mean power waveforms from look to look due to antenna gain
    - Different mean shapes in range due to inaccurate migration corrections





SARM NOISE ISSUE

- **Equivalent (or effective) Number of Looks (ENL)**

  - Indicates the degree of averaging in the multilook echo
  - Good indicator of the speckle noise level

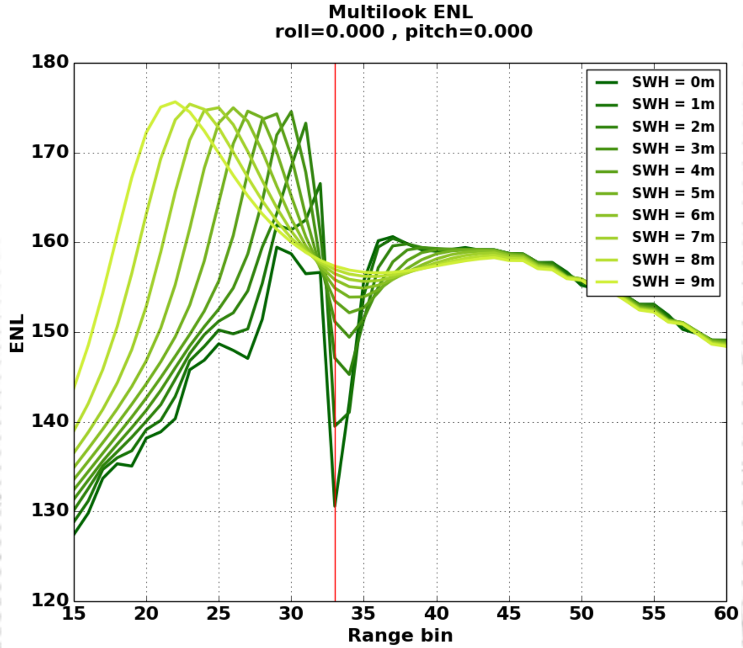
$$ENL = \left(\frac{a}{\sqrt{\nu}}\right)^2 = \frac{N}{1 + \frac{1}{N}\sum_{i=1}^{N}\left(\frac{\alpha_i}{a}\right)^2} = k.N$$

Number of looks

mean power variations within stacked beams

  - High speckle reduction for samples whose look-to-look discrepancies are low
  - Low speckle reduction for large variation of echo amplitude
  - Lowest values in the leading edge for low swh

    ➔ **increased noise level while retracking Doppler echoes at low wave height**

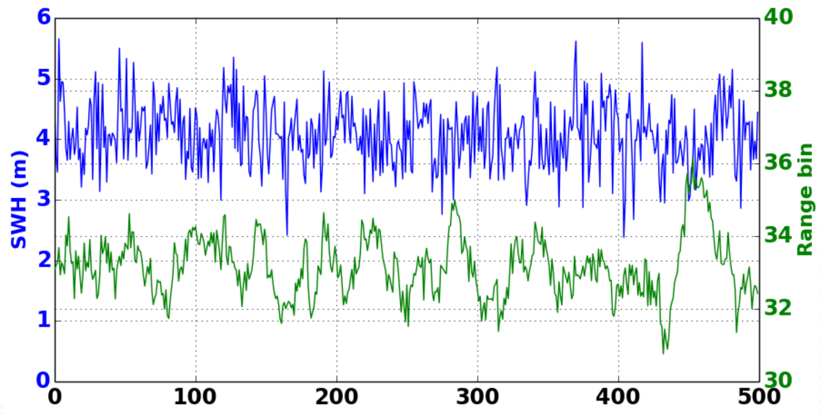


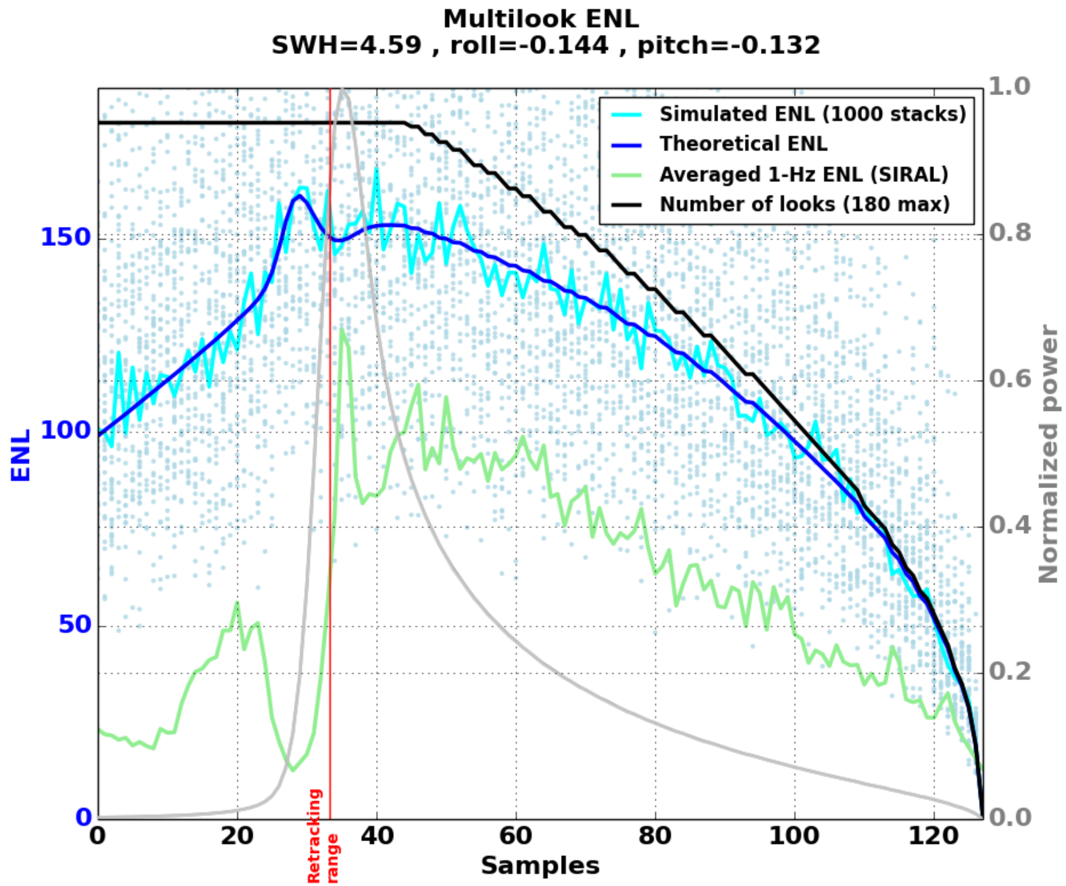
ENL for multilook echoes is lower than *N* and varies in range bins

In the Agulhas SAR-mode area

- **ENL** computed with **real data** (over 500 consecutive 20-Hz data) is **even lower**

  mostly due to the difficulty to gather data of homogeneous sea state and similar orbit parameters



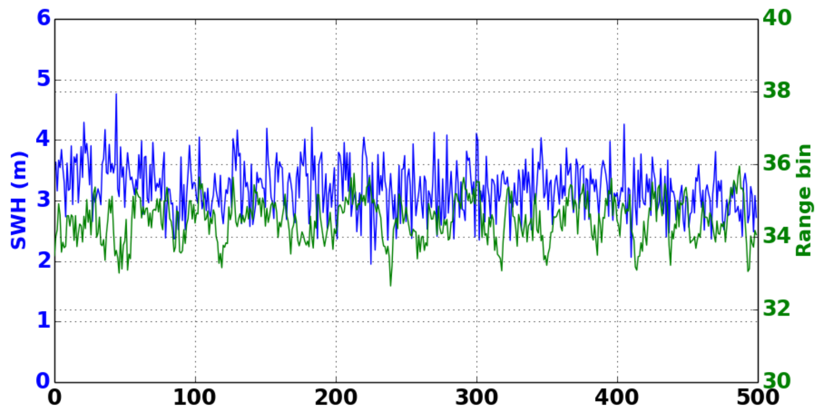


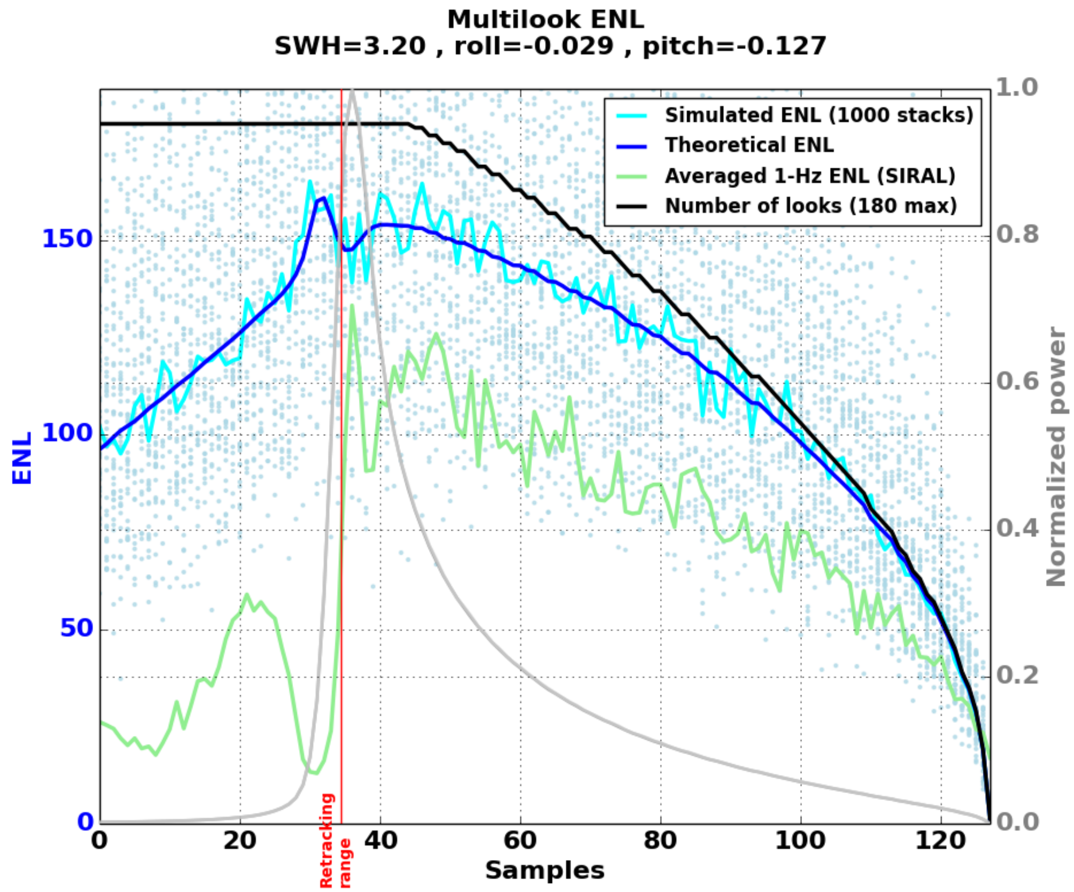
SARM NOISE ISSUE

In the Pacific SAR-mode area

- **ENL** computed with **real data** (over 500 consecutive 20-Hz data) is **even lower**

  A better homogeneity in sea state and orbit parameters improve the computed ENL





SARM NOISE ISSUE

- New L1b processing methodologies are currently being developed
  - new multi-look methodology [Ray et al., 2014],
  - antenna pattern compensation [Scagliola et al., 2014; Dinardo et al., 2015], stack beam weighting)

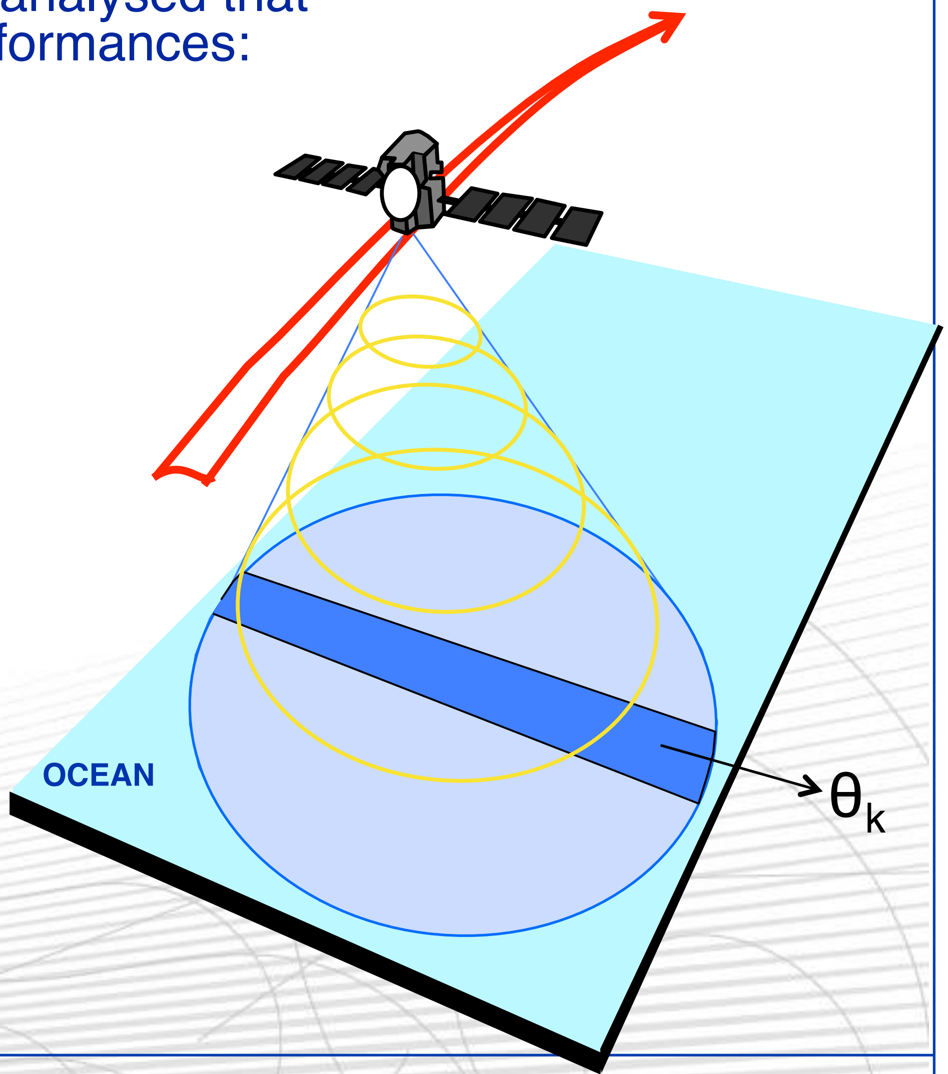
  aiming at giving equal weight to all waveforms in the stack

- We propose a new solution: **individual Doppler beams retracker** to optimise the speckle reduction with no beams weighting
- **Alternative SAR processing method to be tested, implemented and assessed**

INDIVIDUAL DOPPLER BEAMS RETRACKER

Moreau et al., OSTST, 2015

- An alternative processing method will be analysed that is expected to further improve SARM performances:



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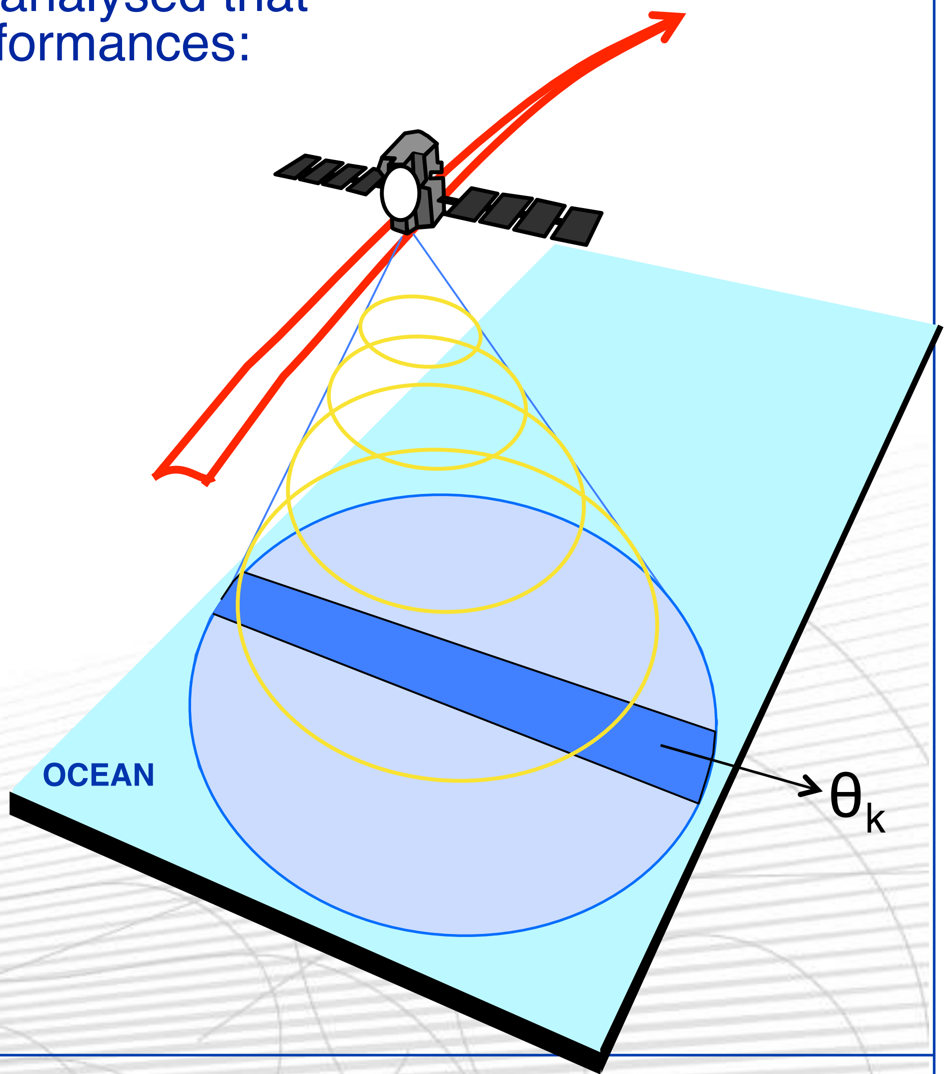
  - To process each individual look



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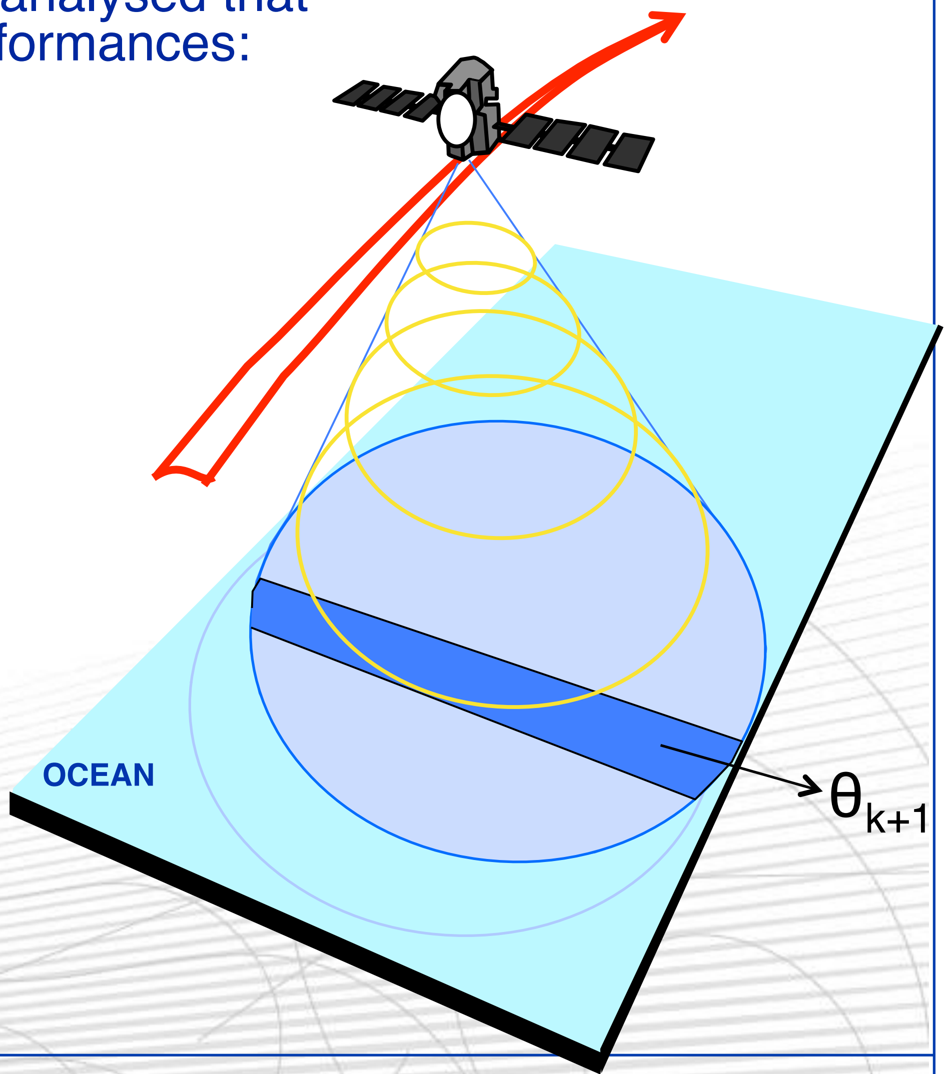

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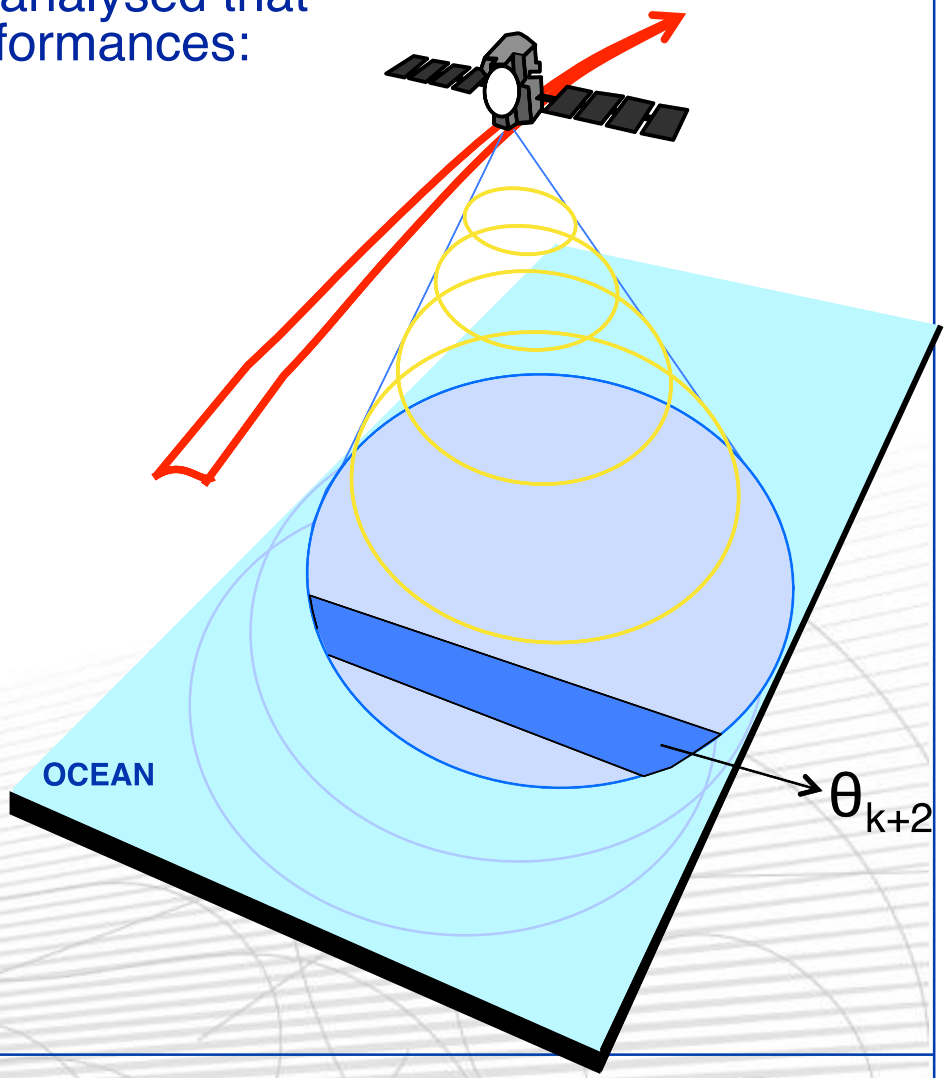

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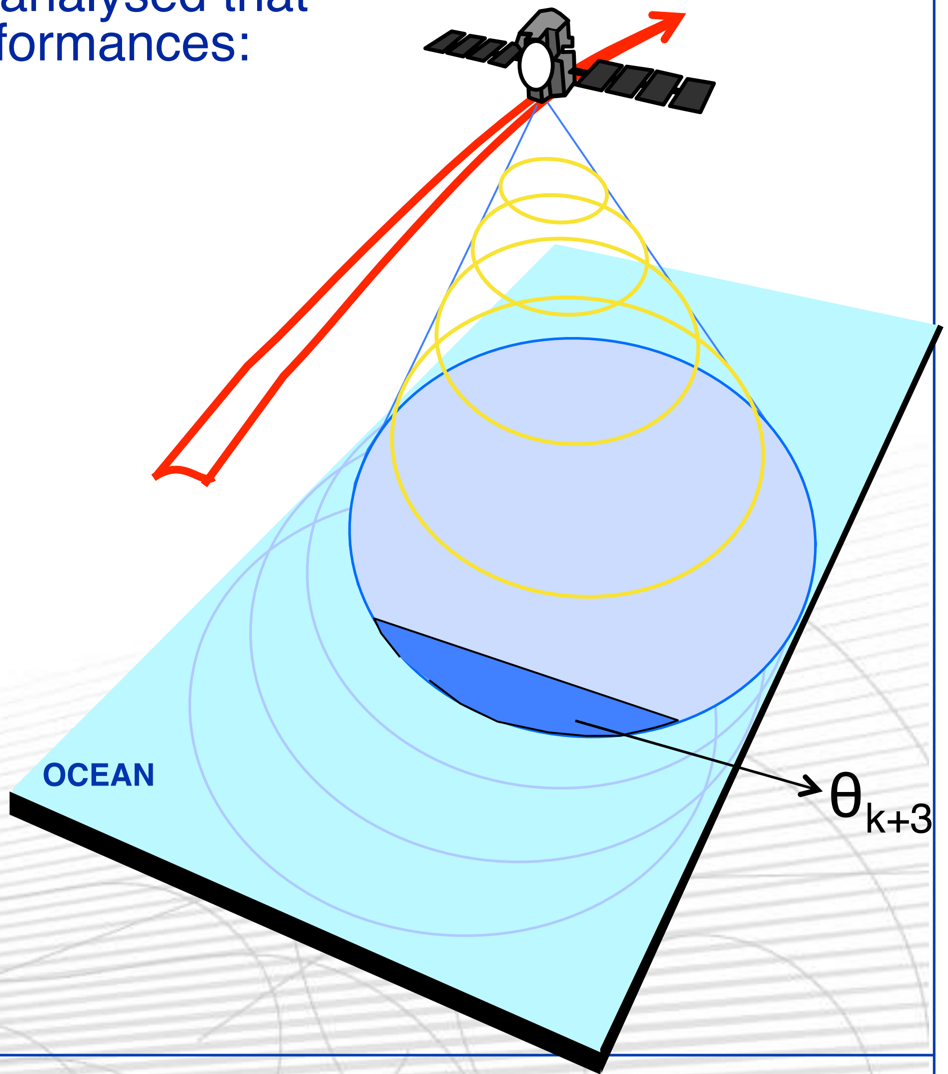
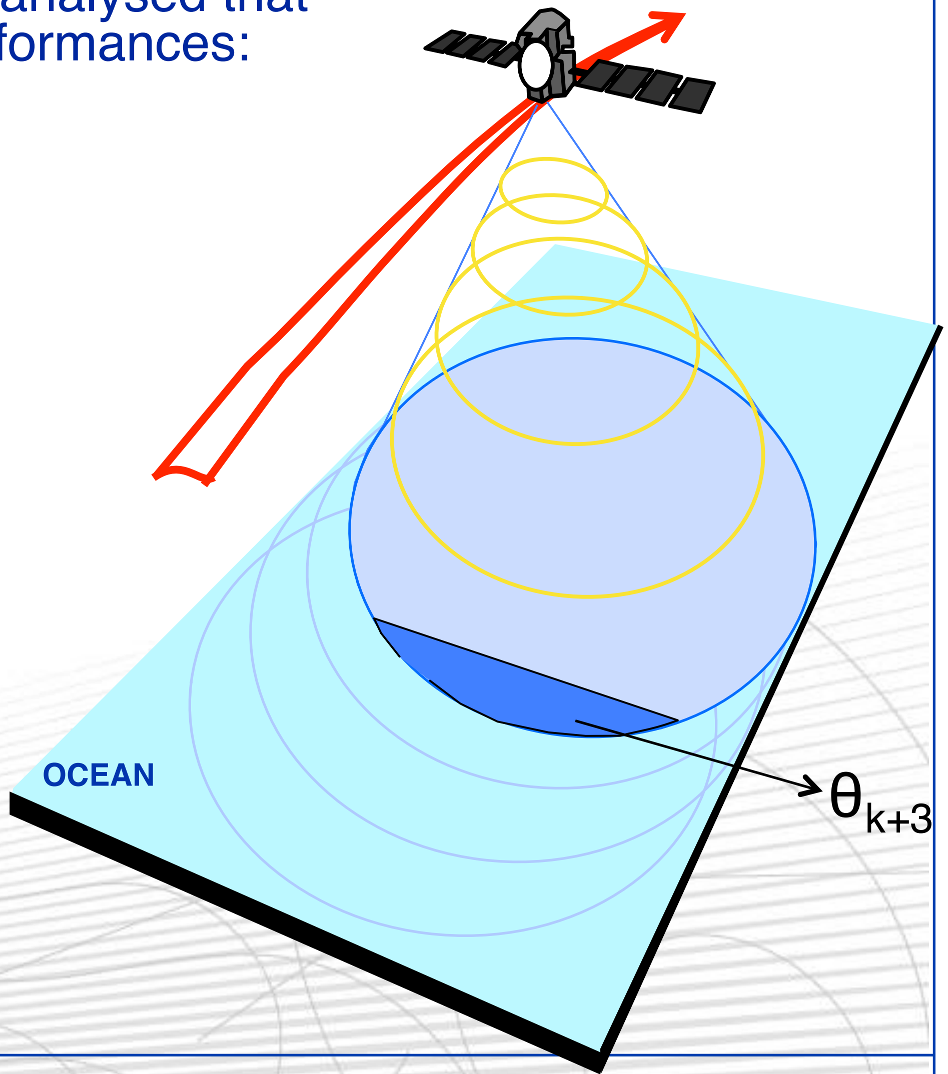


INDIVIDUAL DOPPLER BEAMS RETRACKER

- An alternative processing method will be analysed that is expected to further improve SARM performances:
  - To process each individual look
  - Then "average" their estimates θ_k
    $\theta = 1/L\ \Sigma(..\ +\theta_k+\theta_{k+1}+\theta_{k+2}+\theta_{k+3})$



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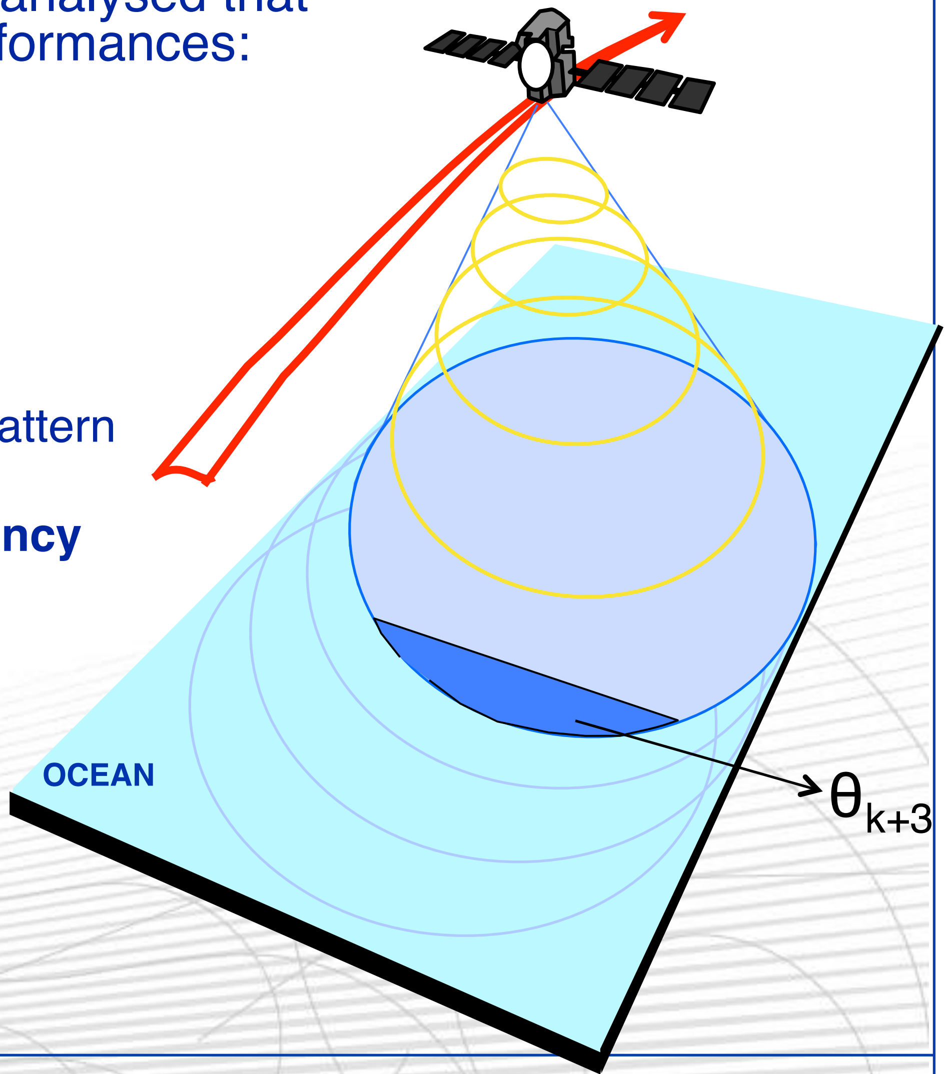
  ➔ Making all Doppler beams with equal contribution to the noise reduction

  - 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)



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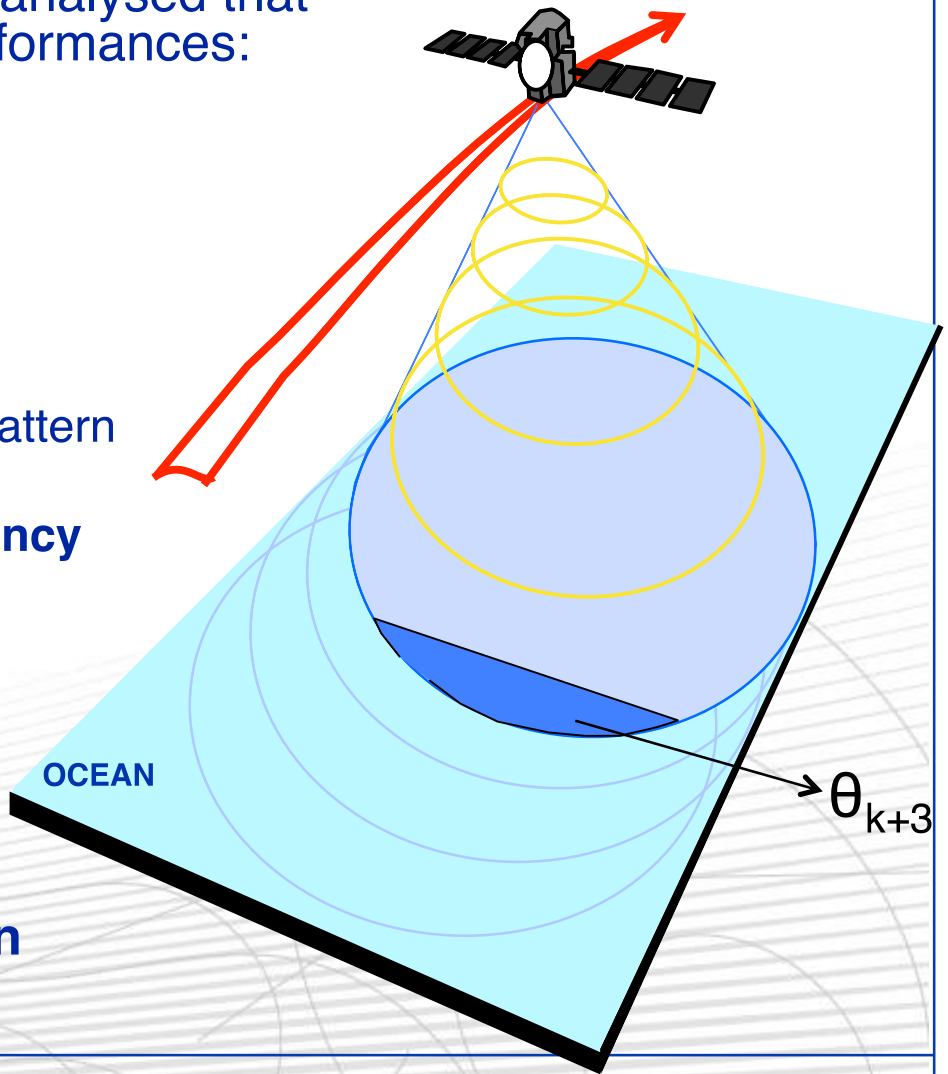
  ➔ **Making all Doppler beams with equal contribution to the noise reduction**
  - With no beams weighting (e.g., antenna pattern compensation, stack beam weighting)

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

- Beams alignment before multilooking can be disrupted by inaccurate COR2 command (computed on-board)

  ➔ **Tracker range alignment is not applied herein (only distance migration correction) mitigating possible errors**

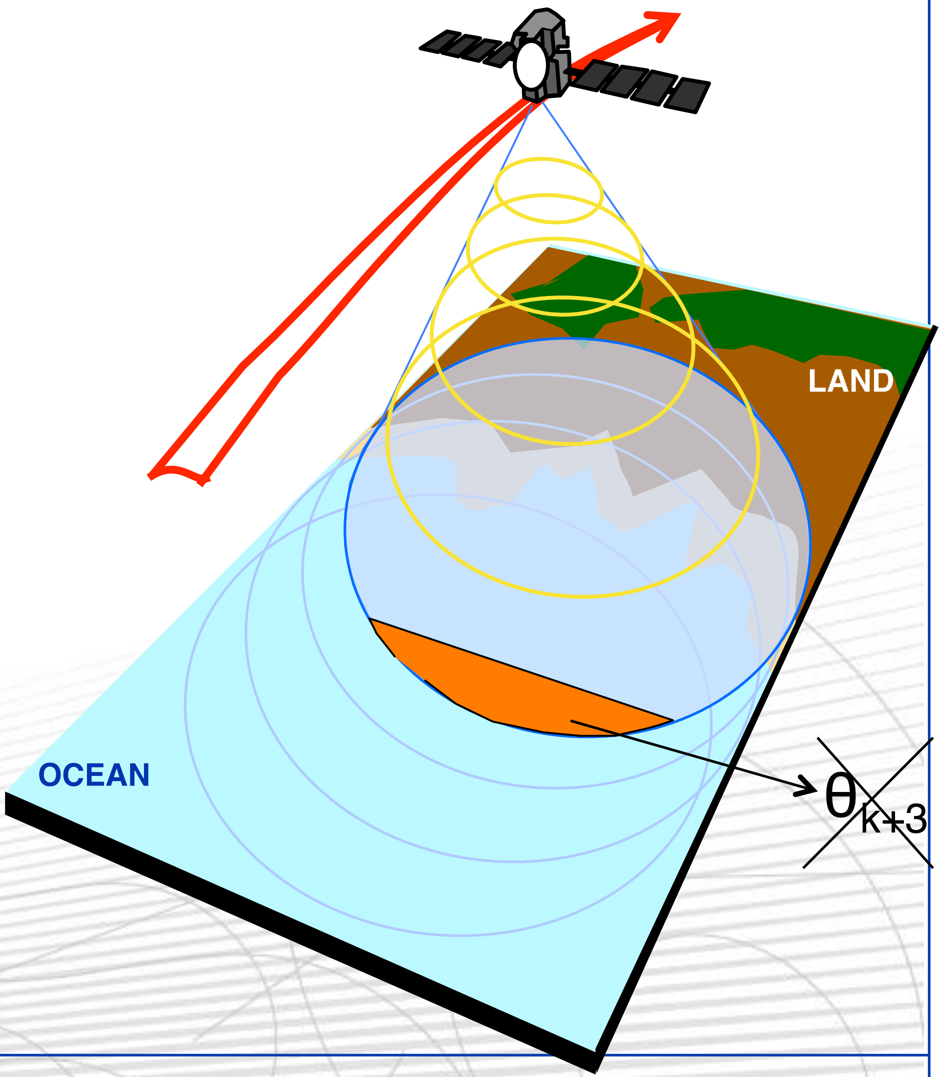


INDIVIDUAL DOPPLER BEAMS RETRACKER

- No valuable data for tracks perpendicular to the coast line at distance < 2-3km despite its high along-track resolution

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

$$\theta = 1/L\ \Sigma(..\ +\theta_k+\theta_{k+1}+\theta_{k+2}+\cancel{\theta_{k+3}})$$



INDIVIDUAL DOPPLER BEAMS RETRACKER

- **Speckle *x* is a multiplicative noise of exponential distribution**
  Power return echo $y_t = S_t x$ (with S_t the model)
- The density of an exponential law:
  $$f(x) = e^{-x} \mathrm{I}_{\Re^+} \text{ , giving } \qquad f(y_t) = e^{-\frac{y_t}{S_t}} \frac{1}{S_t} \mathrm{I}_{\Re^+}$$
- The log-likelihood function estimator algorithm
  $$\mathrm{Ln}(f(y_1,..,y_K)) = \mathrm{Ln}\left(\prod_{t=1}^{K} f(y_t)\right) = \mathrm{Cste} - N\sum_{t=1}^{K}\frac{y_t}{S_t} - \sum_{t=1}^{K}\mathrm{Ln}(S_t)$$
- To find the maximum of the log-likelihood, we calculate the derivatives of the log wrt parameters and set it to zero
  $$\frac{\partial Ln(f(y_1,..,y_k))}{\partial \theta_m} = 0 \quad \Rightarrow \quad \sum_{t=1}^{K} \frac{\partial S_t}{\partial \theta_m}\left[\frac{y_t - S_t}{S_t^2}\right] = 0$$
- **Same criteria as found for the conventional Newton-Raphson algorithm (MLE)** and for Levenberg-Marquardt method (TBC) to solve the system and infer geophysical parameters

➔ No change foreseen in the iterative estimation method even if the likelihood function is different (any bias?)

WP3000 Synthesis and Risks/Recommendations

Task

- Test to be done with CPP data and the associated SAR model
- Adapt and tune the retracking algorithm based on the SAMOSA model (v2.5 ?) to retrack individual looks done in WP4000
- Implement modifications to the S-3 processing scheme, and generate L1B test data sets phase 2 of the open ocean and coastal zone.

➔ The new method(s) shall allow a better processing to take maximum advantage from the Doppler processing (improving the SARM capabilities)

Deliverables

- Product Specification Document D2.3
- Source Code of Prototyped Algorithms (initial and updated) D2.10
- Software/Problem Management Tool D2.11
- Updated POCCD
- Updated ATBD(s) D1.3
- L1B Test Data Set for Phase 2

Risks (N/A)

Recommendations

- Close collaboration with WP4000 team for the development of the associated retracker (L1B to L2) processing

REFERENCES

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