Sentinel-6 Poseidon-4 L1B simulator: end-to-end performance evaluation from model-based waveforms

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Abstract

Sentinel-6 mission objective is to provide high-precision measurements of global sea-level as continuation of the long-running Jason series of reference altimetry missions. In fact Sentinel 6 will fulfill the objectives of continuing the long term retrieval of global sea level rise/variability flying in the same orbit as its predecessors and monitoring oceans up to 66° latitude.
In the framework of the development studies for the Sentinel-6 Poseidon-4 and to support the on going performance analysis of the mission, a level 1B (L1B) simulator has been developed with the main objective to provide L1B data sets over periods longer than an orbit. The flexible design of the simulator also allows assisting with studies into concepts for other possible future radar altimeter missions.
This poster is presenting the architecture of the simulator as well as the first simulated data sets and a preliminary performance assessment.

Sentinel 6 (Jason-CS) Poseidon 4 Mission

Sentinel-6 main payload is a radar altimeter named POSEIDON-4, that will be the first altimeter able to operate in a continuous high-rate pulse mode, i.e. interleaved mode.

The advantages given by the interleaved mode are twofold:

- the number of single look waveforms that are gathered for each Surface Sample (SS) on ground is increased
- it allows the simultaneous production of low-resolution mode echoes on-board as well as the processing of high-resolution echoes on-ground.

Sentinel 6 (credits ESA)

Simulator objectives

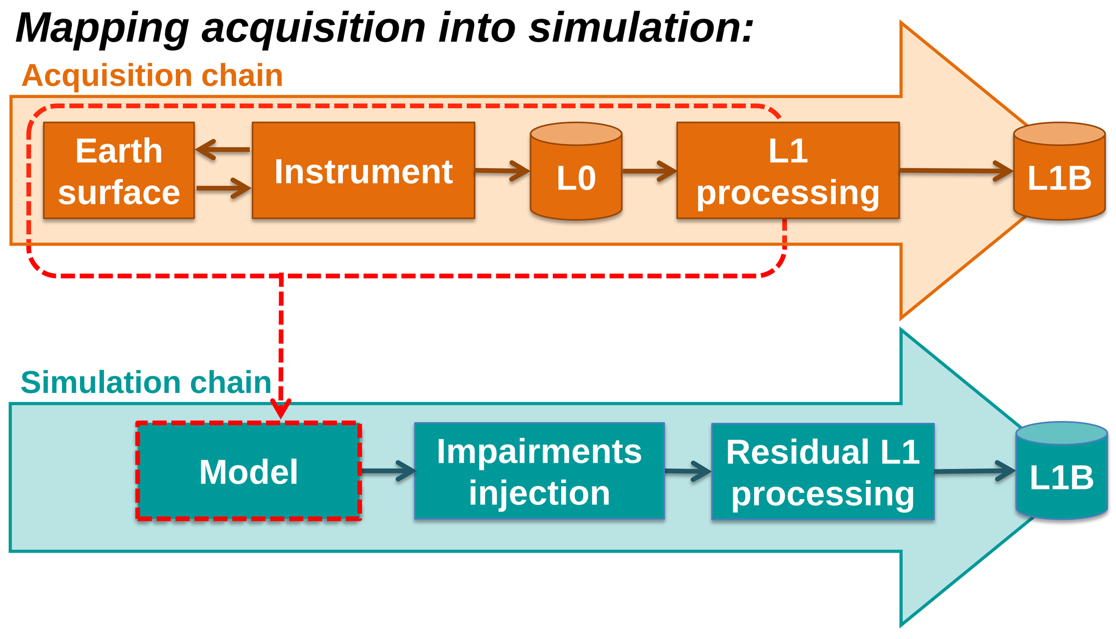
The main objectives of the POSEIDON-4 L1b Simulator are:

- Provide enough data to allow the assessment of some aspects of mission performance over longer periods than an orbit
- Provide long scale Level1B data sets

The Sentinel-6 L1B simulator main architectural features are:

1. **Model-based simulator:** theoretical waveform models are used to emulate part of the physical acquisition chain (e.g. the acquisition timeline, the instrument characteristics) and the interaction with the sea surface
2. **Full configurable, model-based impairments:** thermal noise and speckle contributions are added to the waveforms in order to emulate their impact on the output data; all impairments can be tuned and switched on/off by the user.
3. **On-ground L1 process:** L1 processing steps that are expected to have a direct impact on the quality of the L1B waveforms are replicated in the simulator;

Mapping acquisition into simulation:



Simulation concept and results

Model based waveforms

Modified Wingham/Giles semi-analytical model [1]

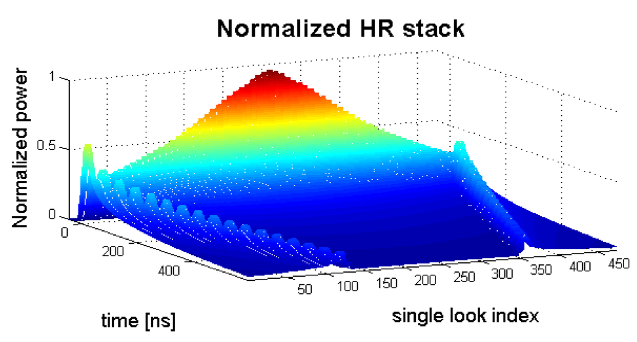
Amarouche analytical IR [2]

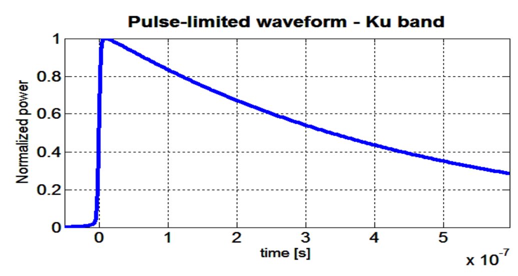
HR mode:

- Semi-analytical model by Wingham and Giles modified [1] to allow for greater accuracy even in presence of mispointing angles up to 0.4 degrees
- Single-look impulse response $X_k(\tau)$ (beam index k dependent) are numerically computed and stored in Look-Up Tables
- Single look waveforms referred to the same SS on ground are gathered in a stack and multilooked.

LR mode:

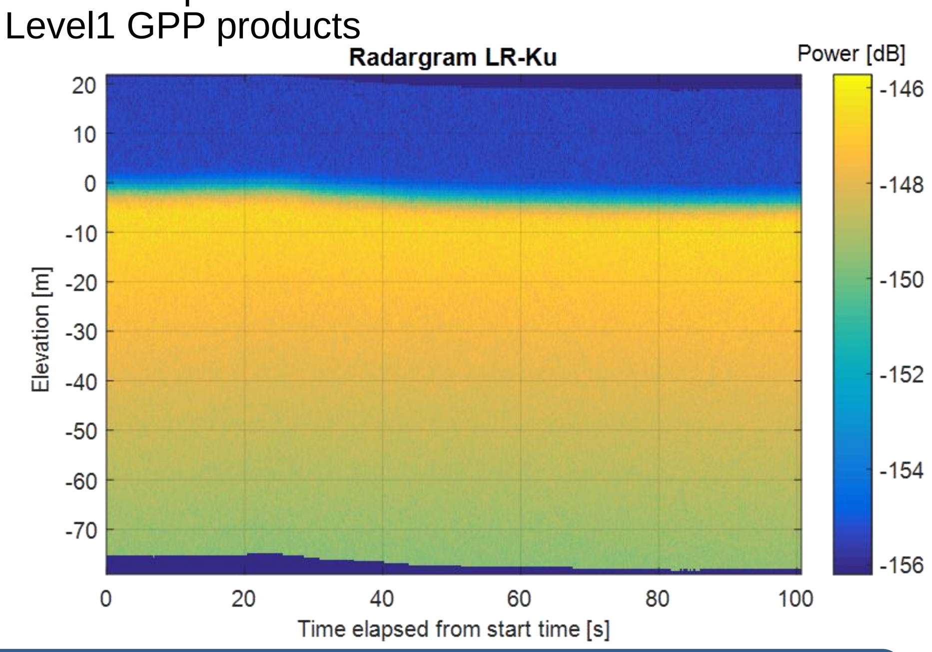
- Amarouche [2] analytical surface Impulse Response derived from the Brown model and considering a Bessel function developed to order 2 is used for LR C and LR Ku waveforms generation





L1B product:

- Simulated products have the same format as Sentinel-6 Level1 GPP products

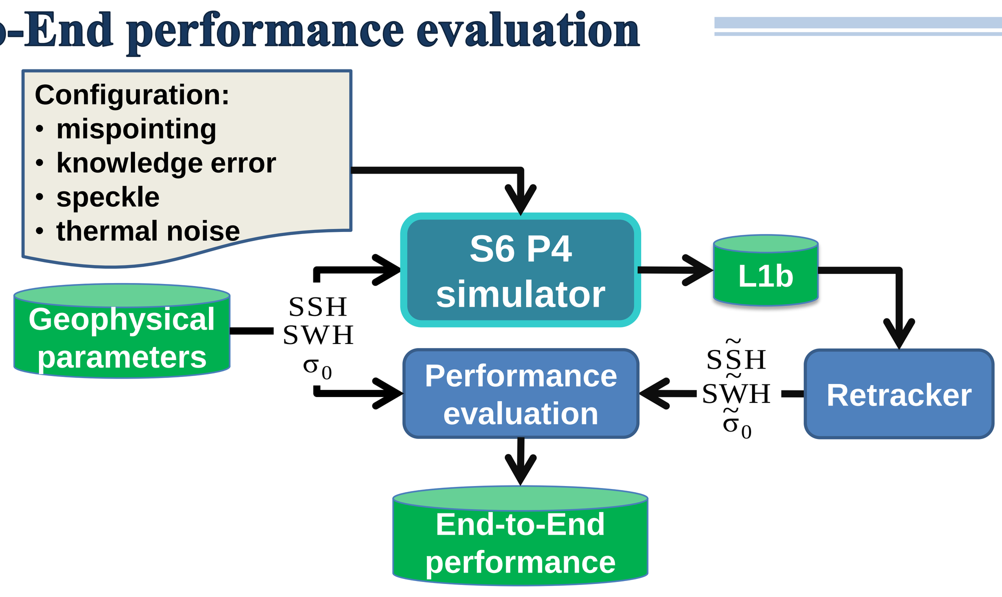


POSEIDON-4 L1b Simulator has been completely developed and can be used for performance evaluation

End-to-End performance evaluation

Performance can be evaluated from direct comparison of:

- geophysical parameters used as input to the Simulator
- geophysical parameters obtained by retracking Simulator L1B output product



Performance results

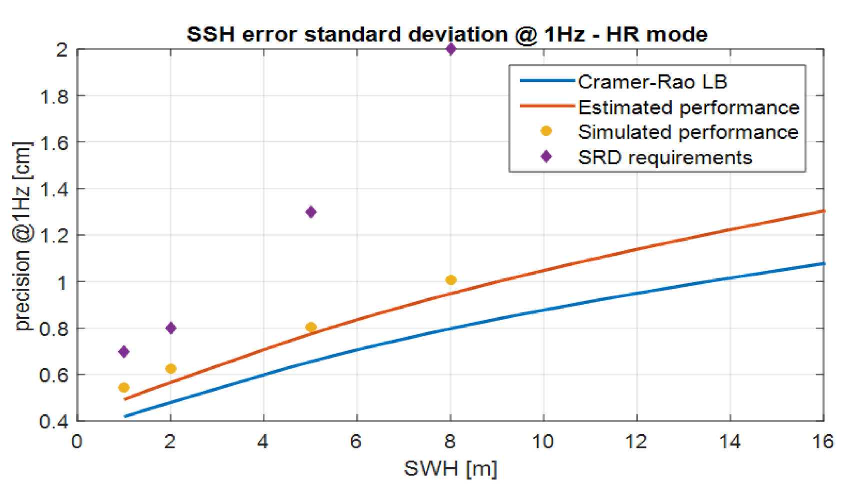
Simulation framework:

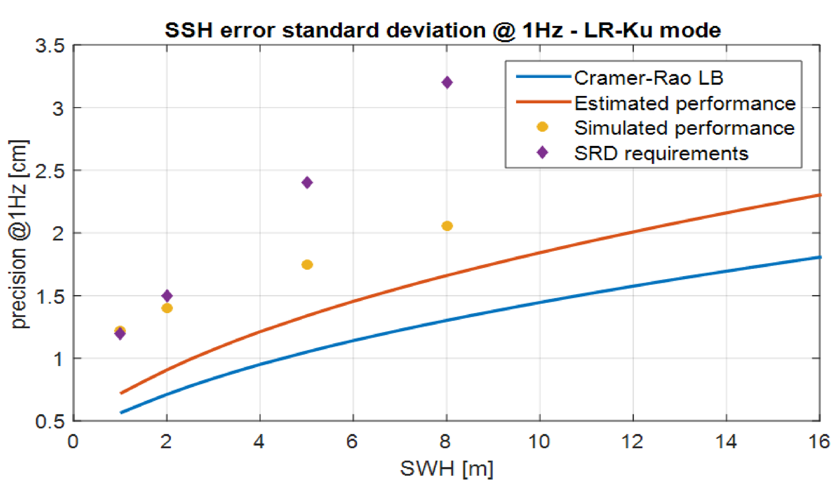
- 4 simulations(5 to 10 mins) with constant SWH = 1, 2, 5 ,8 m
- Constant Sigma0 = 11dB and SSH = 1m
- Worst cases SNR: 12 dB LR,18 dB HR
- Speckle injection applied
- No mispointing and no attitude knowledge error applied

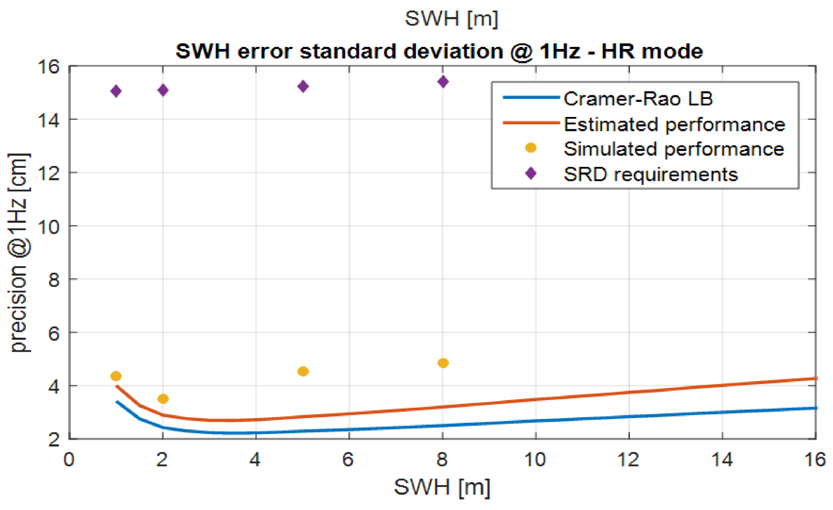
Performances evaluation:

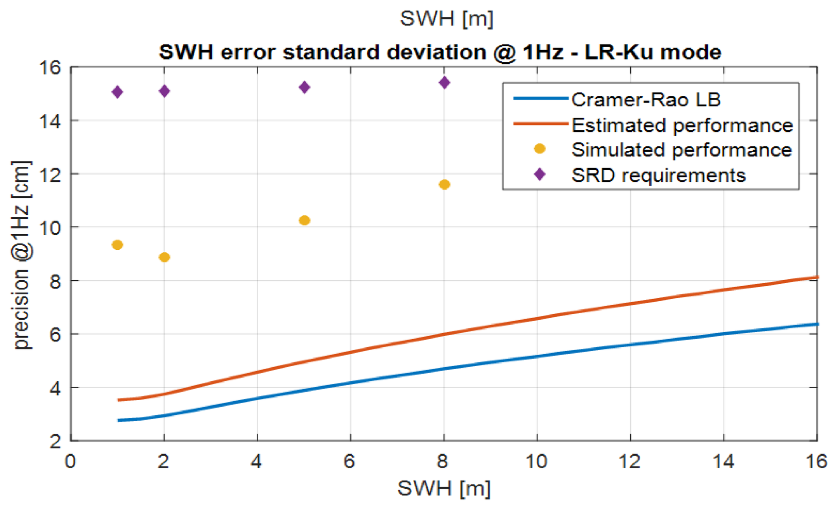
1Hz precision on SSH and SWH estimation has been evaluated from the geophysical parameters.

- Simulated performance (yellow dot)
- Cramer-Rao (CR) lower bound (blue line)
- Estimated performance (orange line) derived from CR considering impairments
- System Requirement Document requirements









- Very good agreement between estimated and simulated performances for HR mode
- For LR-Ku simulated performance are in line with SRD requirements but higher than estimated performance

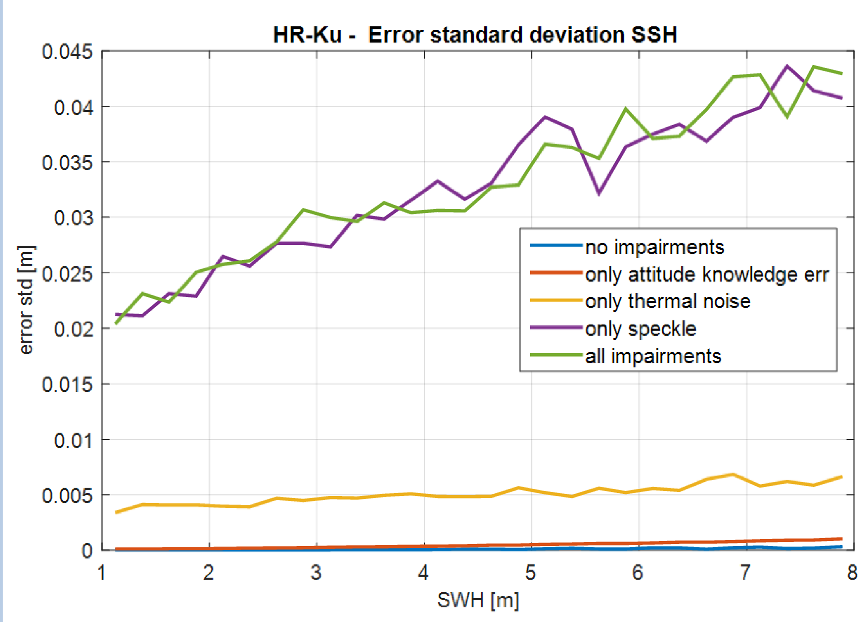
Sensitivity analysis

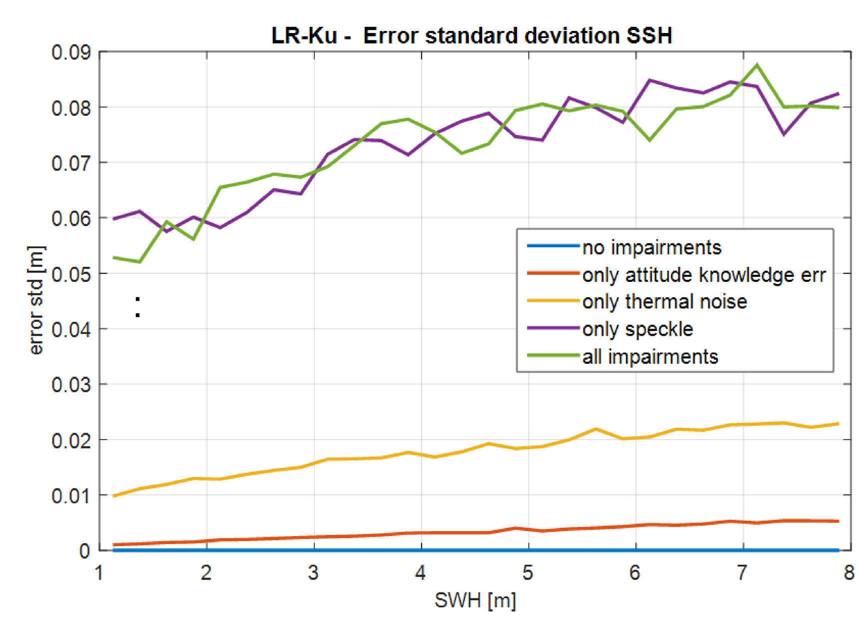
Simulation framework:

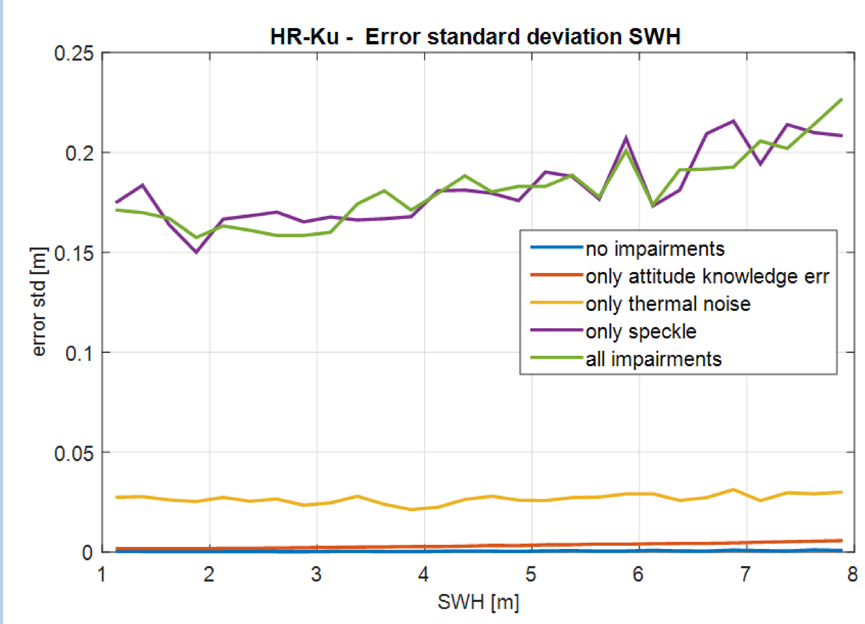
- 5 simulations (5 min) with linearly increasing SWH from 1 to 8 m, and constant Sigma0 = 11dB and SSH = 1m
- One-by-one impairments injection application in worst-case configuration:
  1. No impairments
  2. Only mispointing knowledge error (total error = 0.13 deg)
  3. Only thermal noise (SNR =11.2 dB LR-Ku, 18 dB HR)
  4. Only speckle injection (according to theoretically estimated ENL)
  5. All impairments applied

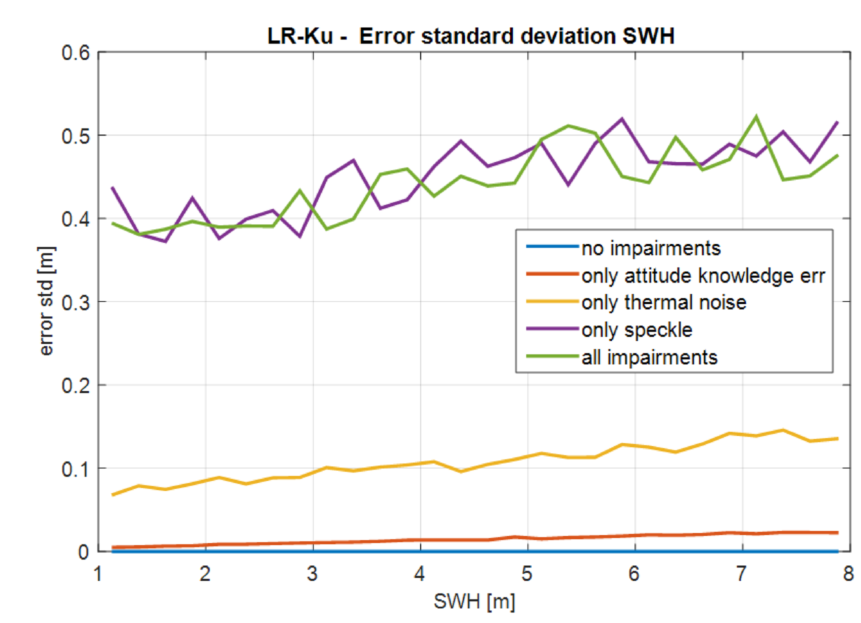
Performances evaluation:

RMSE on SSH and SWH have been evaluated for HR and LR modes with a binning approach .









- The most relevant contribution to the deterioration of the performance is in all cases provided by speckle
- For HR mode, the worst-case contribution of all impairments still allows for a SSH RMSE < 4.5 cm and a SWH RMSE < 25 cm
- For LR-Ku waveforms, the worst-case contribution of all impairments allows for a SSH RMSE < 9 cm and a SWH RMSE < 0.5 m

Conclusion

- The proposed simulator allows for Sentinel-6 Poseidon-4 end-to-end mission performance evaluation by providing long scale Level1B data sets
- A preliminary performance analysis of the simulator shows good results, in line with all requirements and in the same order of magnitude as expected performances from other studies
- The flexibility of the adopted models allows to monitor the impact of different impairments

References

[1] Recchia, Scagliola, Giudici, Kuschnerus: An Accurate Semianalytical Waveform Model for Mispointed SAR Interferometric Altimeters, *IEEE Geoscience and Remote Sensing Letters 14 (9), 1537-1541*

[2] Amarouche, L., P. Thibaut, O. Z. Zanife, J.-P. Dumont, N. Steunou, & P. Vincent, 2003: Improving the Jason-1 ground retracking to cope with attitude effects. *Marine Geodesy, Special Issue on Jason-1 Calibration/Validation, Part 2*

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