Altimeter Mission End-To-End Simulators: Interesting tools to assess global performance and develop new algorithms for future missions

L. Amarouche[1], E. Obligis[1], F. Mercier[1], B. Picard[1], S. Jourdain[1], P. Dubois[1], P. Thibaut[1], M.L. Frery[1], A. Vernier[1], T. Moreau[1],N. Tran[1], N. Steunou[2], A. Mallet[2], C. Tison[2], N. Picot[2], J. Benveniste[3], C. Mavrocordatos[3], A. Houpert [4],

[1]*CLS, Toulouse, France, lamarouche@cls.fr*
[2]*CNES, Toulouse, France*
[3]*ESA, ESTEC, Netherland*
[4]*TAS, France*

Ocean Surface Topography Science Team Meeting, 27-28 September 2012, Venice, Italy,

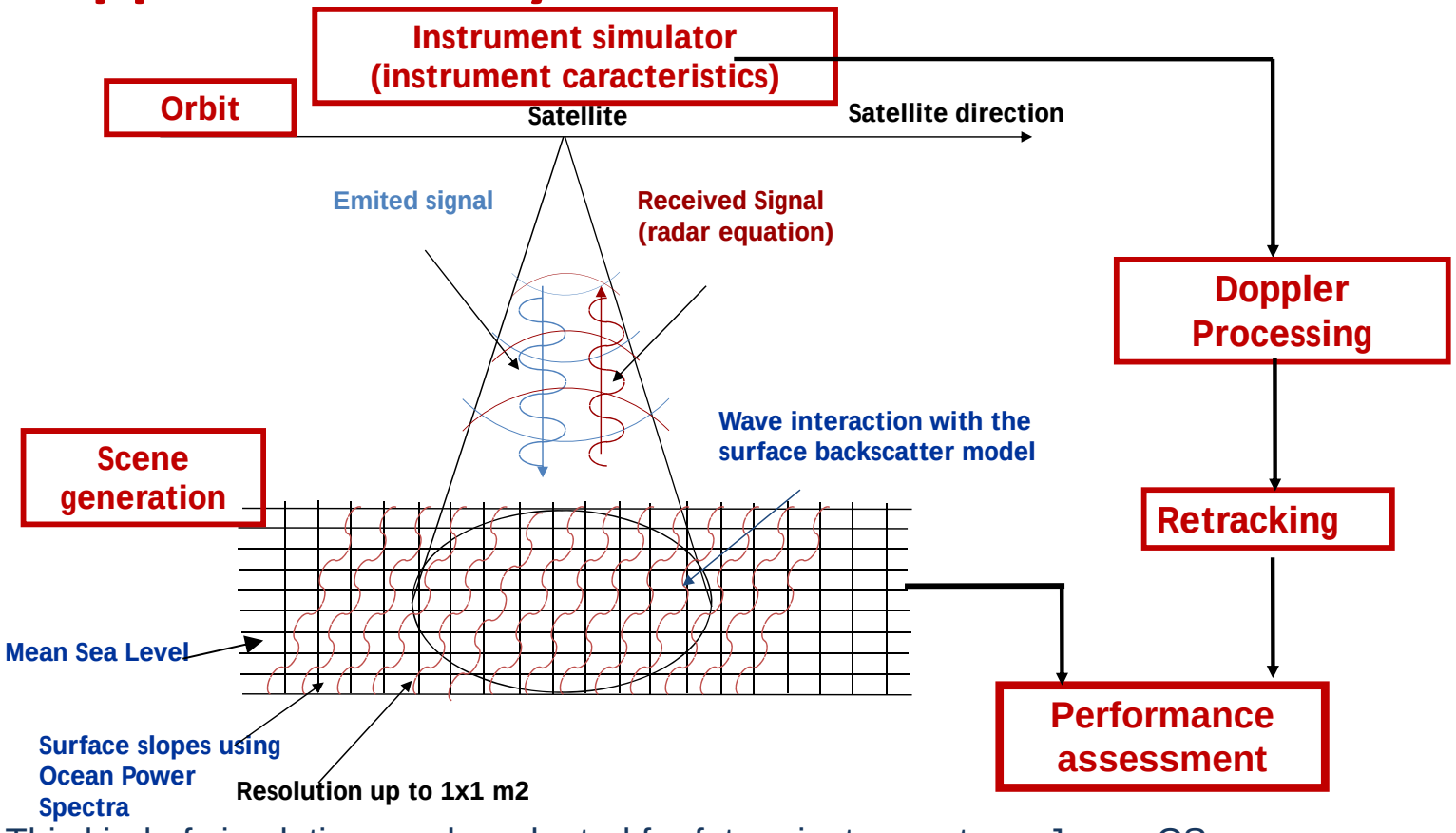
Introduction

In the last two decades, several simulation activities have been conducted by CLS (under either CNES, ESA or TAS funding) with the objectives to assess end-to-end mission performances, to develop and analyze new processing algorithms and also to assess the impact of physical phenomena (for eg. the Sea State Bias) or instrumental effects on the performance (for eg. The effect on the performance of the shape of Instrument Target Response, the instrument filter, the tracker design…). The first simulation studies focused on the ocean surface, but new analyzes were devoted to inland water or ice targets.

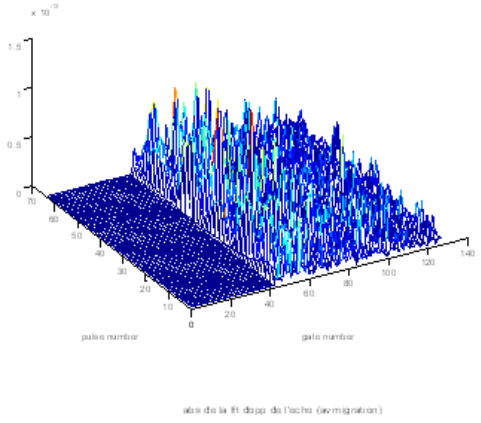
The methodology has been successfully used for conventional altimeters (Jason 1/2 and Envisat/RA-2 instruments), Doppler altimeters (CryoSAT and Sentinel-3), Wide Swath interferometric altimeters (WSOA and SWOT configurations) and radiometers (SARAL/AltiKa, Sentinel-3). CLS has also participated in the development of the SWIM simulator (on board CFOSAT mission).

This paper will provide an overview of such end-to-end simulators and their main application studies.

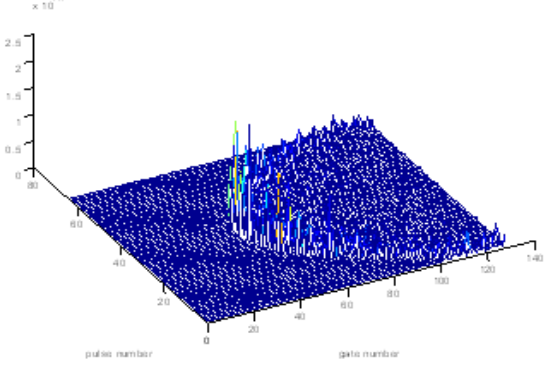
Doppler Altimetry Simulation



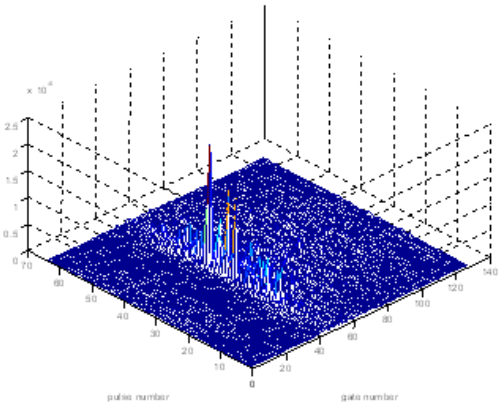
Before Doppler processing



Doppler processing



slant range corrections



This kind of simulation can be adapted for future instruments as Jason-CS

This principle has been used in the development of the End-to-End Simulator of Sentinel-3 SRAL instrument. See the poster of L. Amarouche et al. **« Sentinel-3 Surface Topography Mission: System Performance Simulator and Ground Prototype Processor and Topography Expertise”** presented in the 20 years of Progress in Radar Altimetry Symposium.

This kind of simulator has been successfully used for the development of new retracking techniques for Doppler Altimetry. See the poster of T. Moreau et al. **“Doppler Altimeter Data over Ocean, Processing strategy and associated Performance”** presented in the 20 years of Progress in Radar Altimetry Symposium.

Radiometers Simulation Principle

Instrument simulator instrument characteristics to derive counts and physical temperatures

ISP, NavAtt

Orbit (CFI)

Satellite direction

Satellite

Simulations in the expected configuration

Incidence angle
Frequency
Polarization
Active (s0) or passive (TB)
Antenna pattern

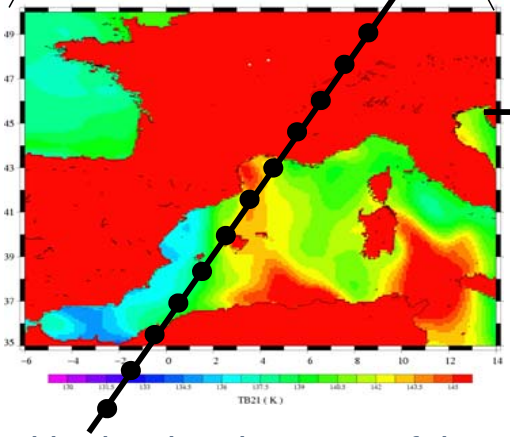
Instrument Module Principle

- For each pixel, convolution of the TBs maps by the antenna pattern to get the measured TBs
- Use of instrumental characteristics (reflector, horn, switch, receiver gain…) and physical temperatures to build the equivalent measured counts
- Organization at **I**nstrument **S**ource **P**aquet format

Ground processing L0/L1b GPP

Ground processing L2

Scene generation



TBs Maps

Performance assessment

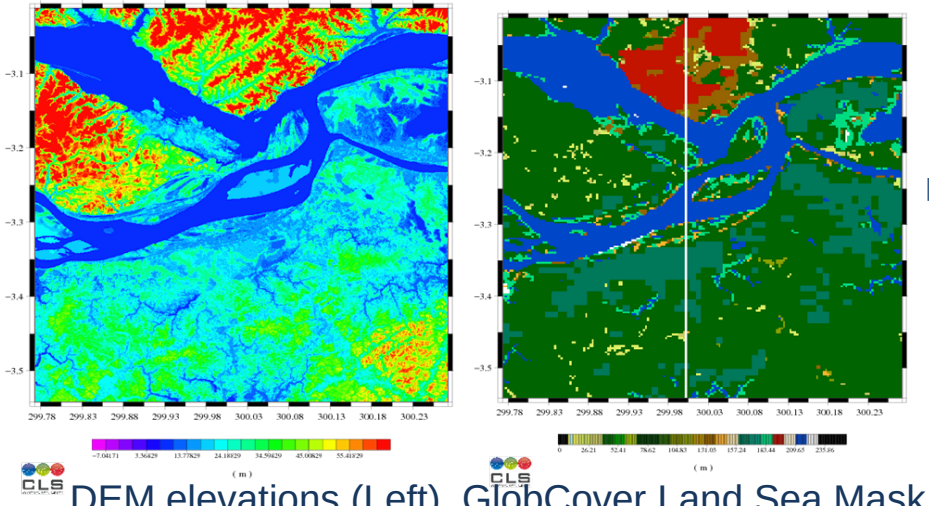
- Wet tropospheric correction
- Water vapor content
- Cloud liquid water content
- Atmospheric attenuation of the altimeter $\sigma 0$

This principle has been used in the development of the End-to-End Simulator of Sentinel-3 MWR instrument. See the poster of L. Amarouche et al. **« Sentinel-3 Surface Topography Mission: System Performance Simulator and Ground Prototype Processor and Topography Expertise".**

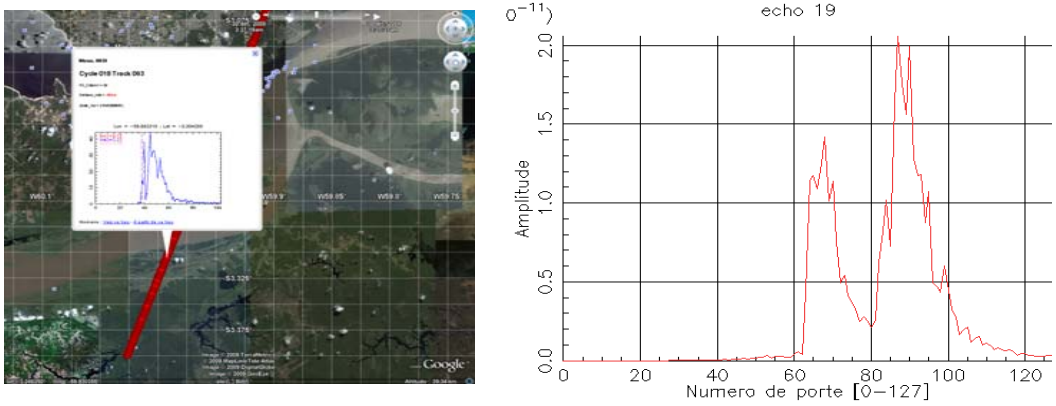
Other radiometer simulators have also been developed by CLS for CNES:

- End-to-end Simulator of AltiKa Radiometer
- Simulators of SAHIR and MADRAS on-board Megha-Tropiques Mission

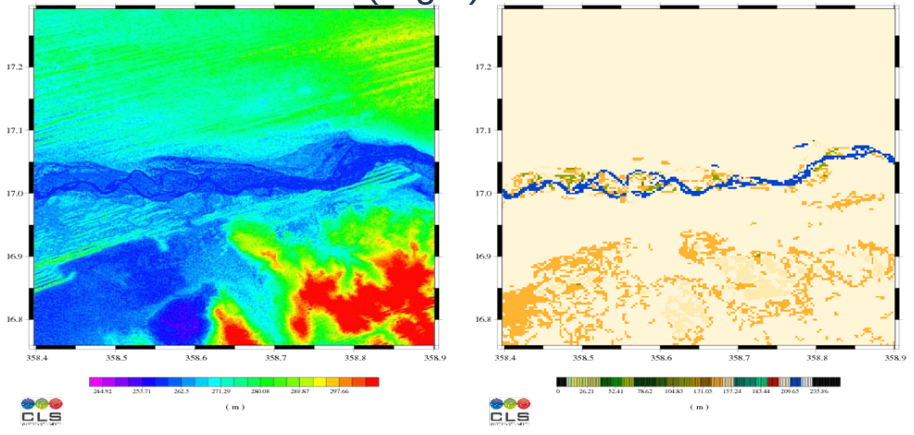
Simulations over inland water areas



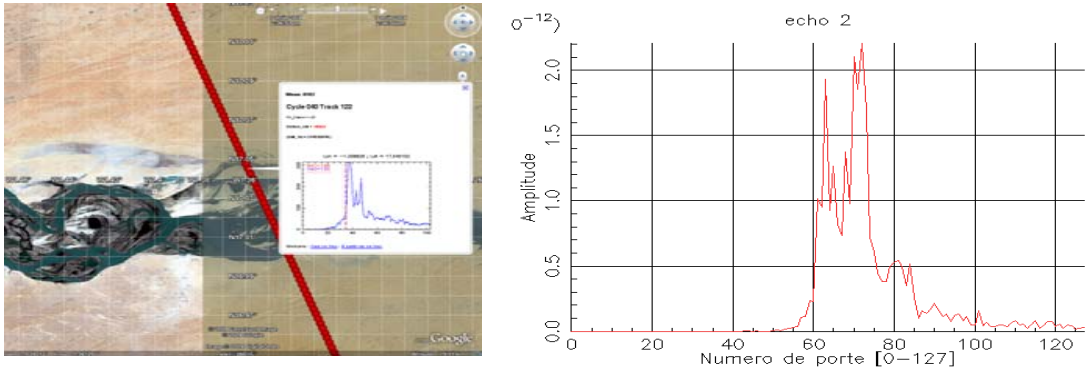
DEM elevations (Left), GlobCover Land Sea Mask Class (Right) in the Amazon



Simulated Waveform (Right) against real one (Left), Track 63 of Jason-2



DEM elevations (Left), GlobCover Land Sea Mask Class (Right) Over Niger River



Simulated Waveform (Right) against real one (Left), Track 122 of Jason2

Simulations in the Ku band conventionnal altimetry have been used to understand the processes involved in the waveform interaction in order to develop retracking algorithms.
Other studies have been performed for the same areas but by applying Ka band altimeter configurations (AltiKa) or Doppler Altimeters (Sentinel-3).

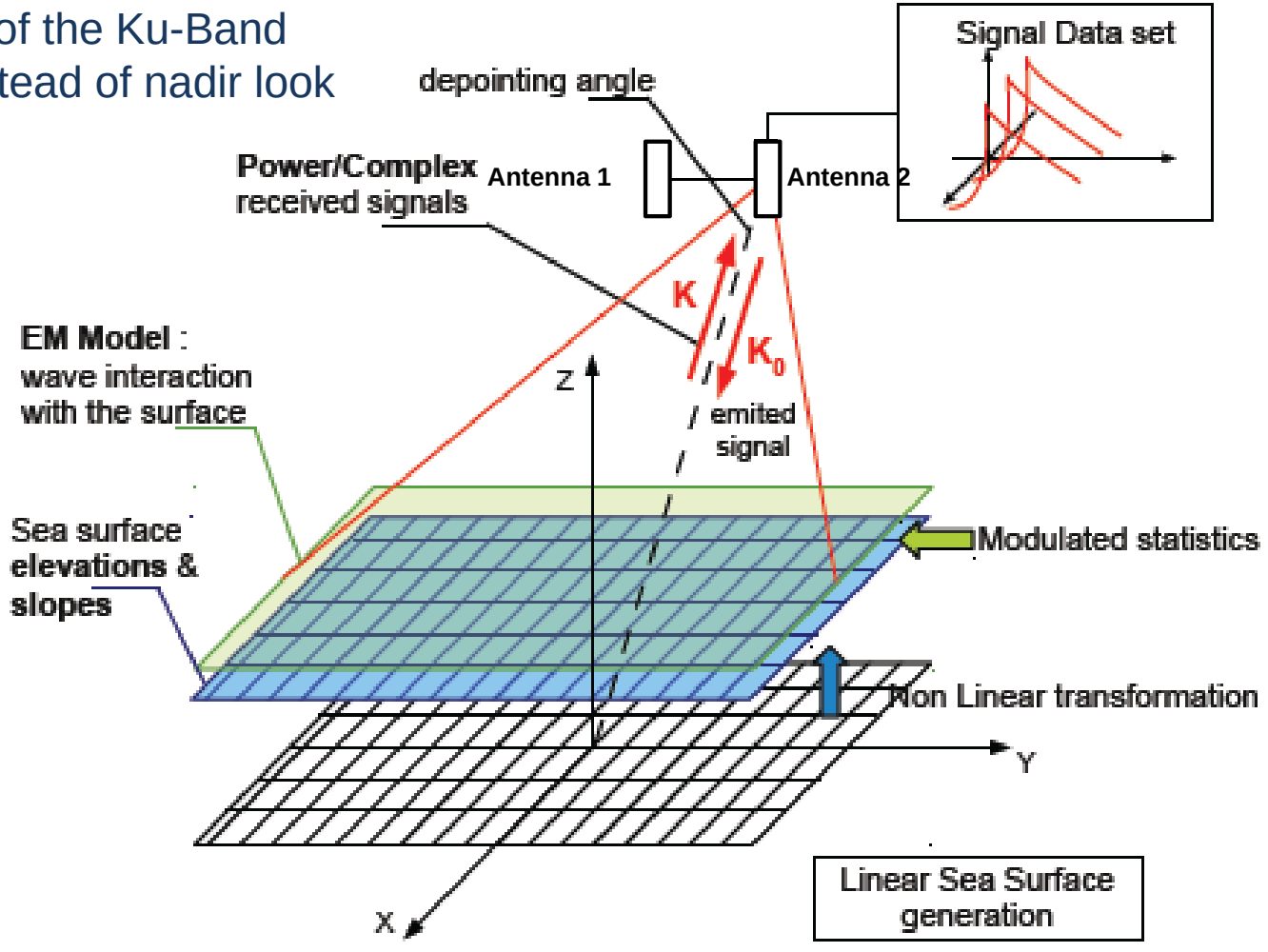
AltiKa and SWOT configurations: Analysis of the SSB for Ka band

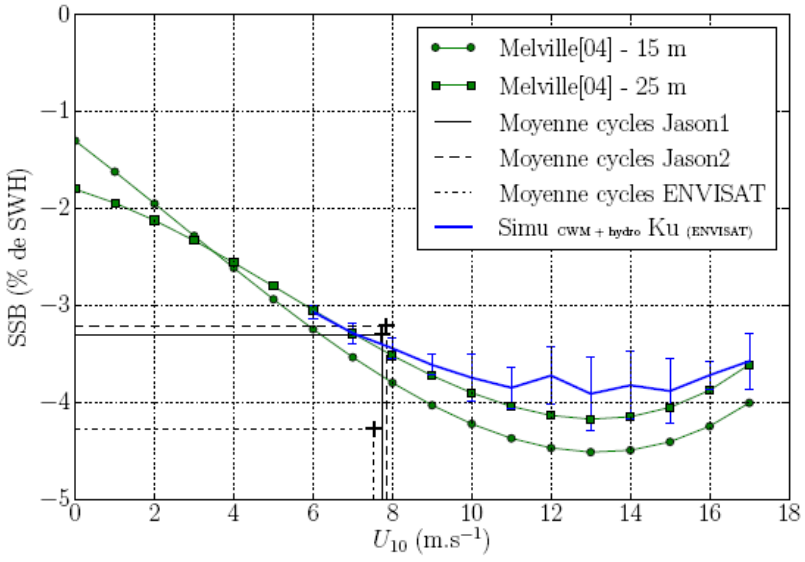
One of the applications of the End-to-end simulators is the analysis of the effect of the Sea State Bias on the geophysical estimates. For this kind of analysis, the sea surface simulation has a particular attention in addition to the simulation of the instrument caracteristics, configuration and processing. From the configurations used and validated for conventional altimetry for Ku band we included the following evolutions:

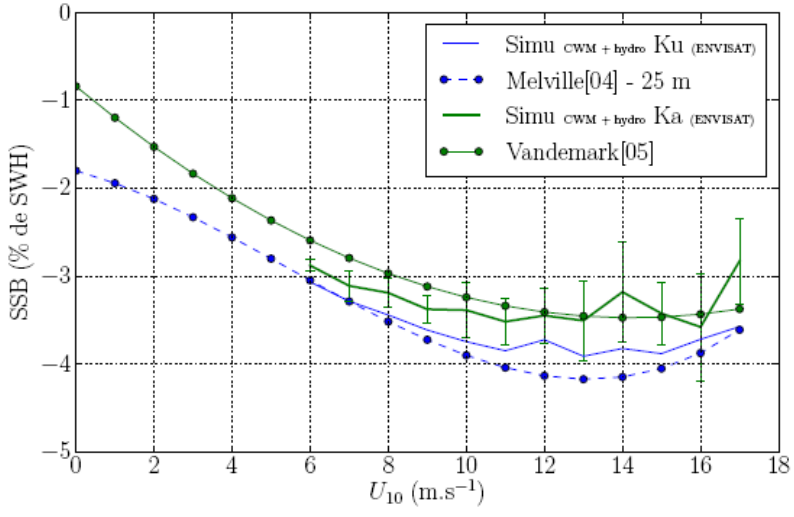
- The use of the EM Ka-Band instead of the Ku-Band
- The slight despointing look-angle instead of nadir look
- The along track Doppler processing
- Addtion of a second antenna
- Interferometric processing

For the ocean surface simulation, the effects and the properties of the Sea State that contribute to the formation of the signal that have been simulated are:

- The Tilt modulation
- The Hydrodynamic modulation
- Long wave motion



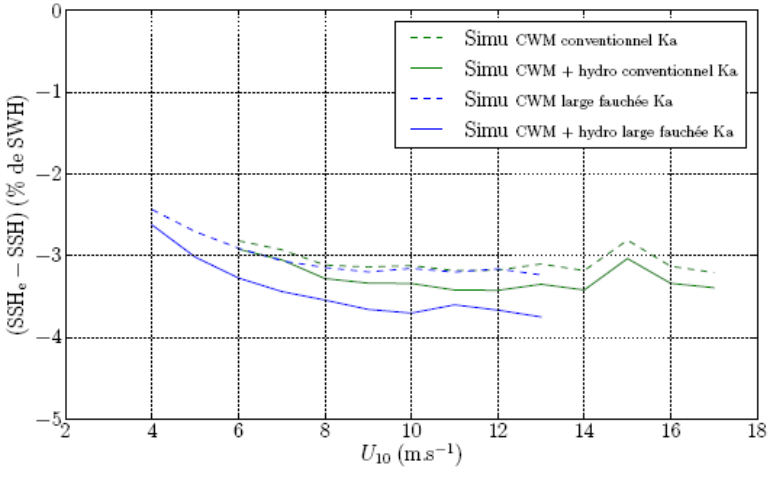




The simulations have been first applied to Ku band conventional altimetry and showed very good agreement with Jason-2 observations (see the figure in the left).

Using AltiKa caracteristics, the simulation gave an estimation of the Sea State Bias for this future mission. The SSB in AltiKa has the same behaviour as for Ku band versus the wind speed and significant wave height but its magnitude is lower than for Ku band (see the figure on the bottom left side).

Finally, the analysis for SWOT configuration showed that the SSB has the same order of magnitude as for AltiKa but variations with the incidence angle have been observed (see the figure below).

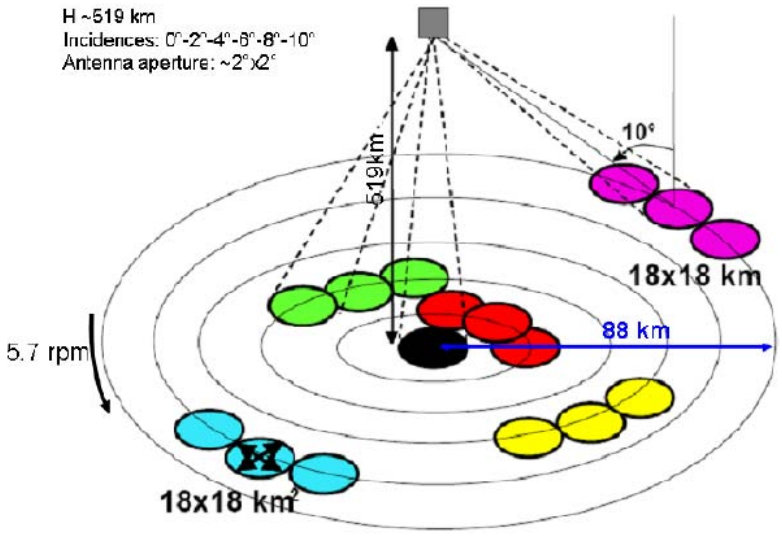


Reference

P. Dubois et al., « Design of a multi-configuration altimeter simulator for the study of the impact of the wind Sea State », In press in IEEE Geoscience and Remote Sensing.

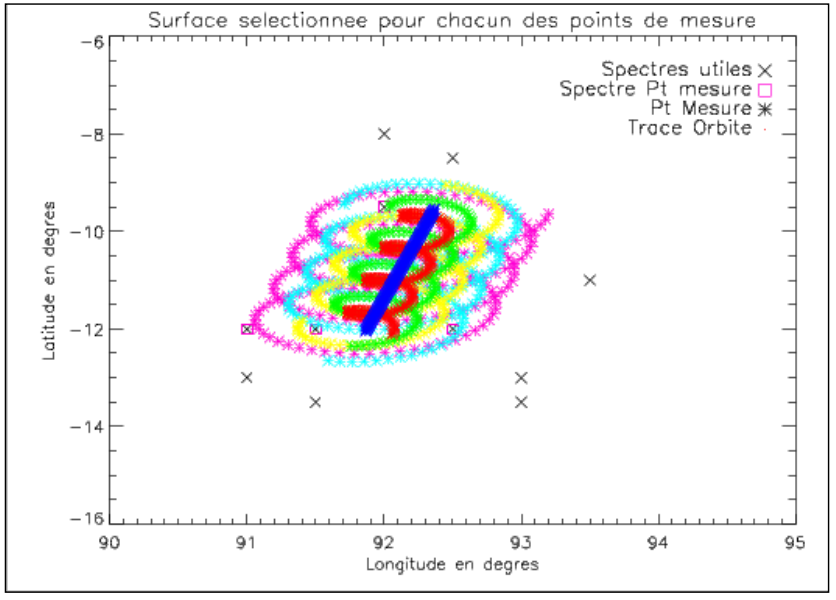
P. Dubois, « Impact de l'état de la mer sur la mesure d'élévation des futurs instruments altimétriques », PHD thesis 2011.

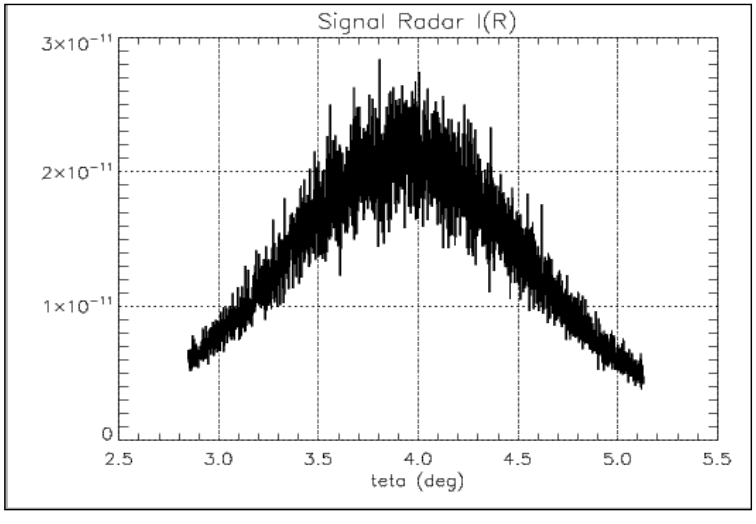
Case of SWIM instrument onboard CFOSAT mission



Overview of SWIM sequential illumination from its 6 beams. From C. Tison et al. (CNES document 2010)

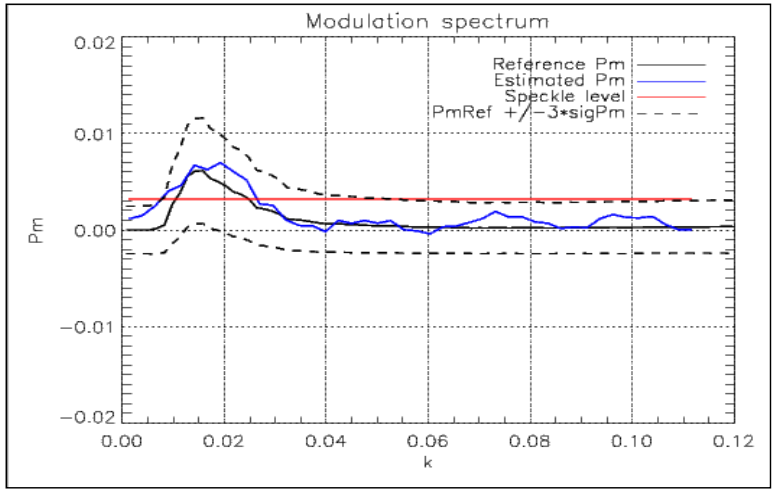
Measurements locations for the 6 beams of SWIM





Radar Signal obtained by the simulator

Application of inversion techniques



Surface Modulation Spectrum: Comparison between the theoretical and the estimated ocean spectra.