SWIM NRT products.
Focus on the nadir beam processing

C. Tourain[(1)], *C. Tison*[(1)], *T. Grelier*[(1)], *D. Hauser*[(2)], *L. Delaye*[(3)], *A. Jouzeau*[(4)], *P. Schippers*[(2)], *P. Castillan*[(1)]

(1) CNES, Toulouse, France

(2) LATMOS, CNRS, UVSQ, UPMC, Guyancourt, France

(3) ACRI, France

(4)CS-SI, Toulouse, France

OSTST 2016 –La Rochelle, November, 1-4, 2016

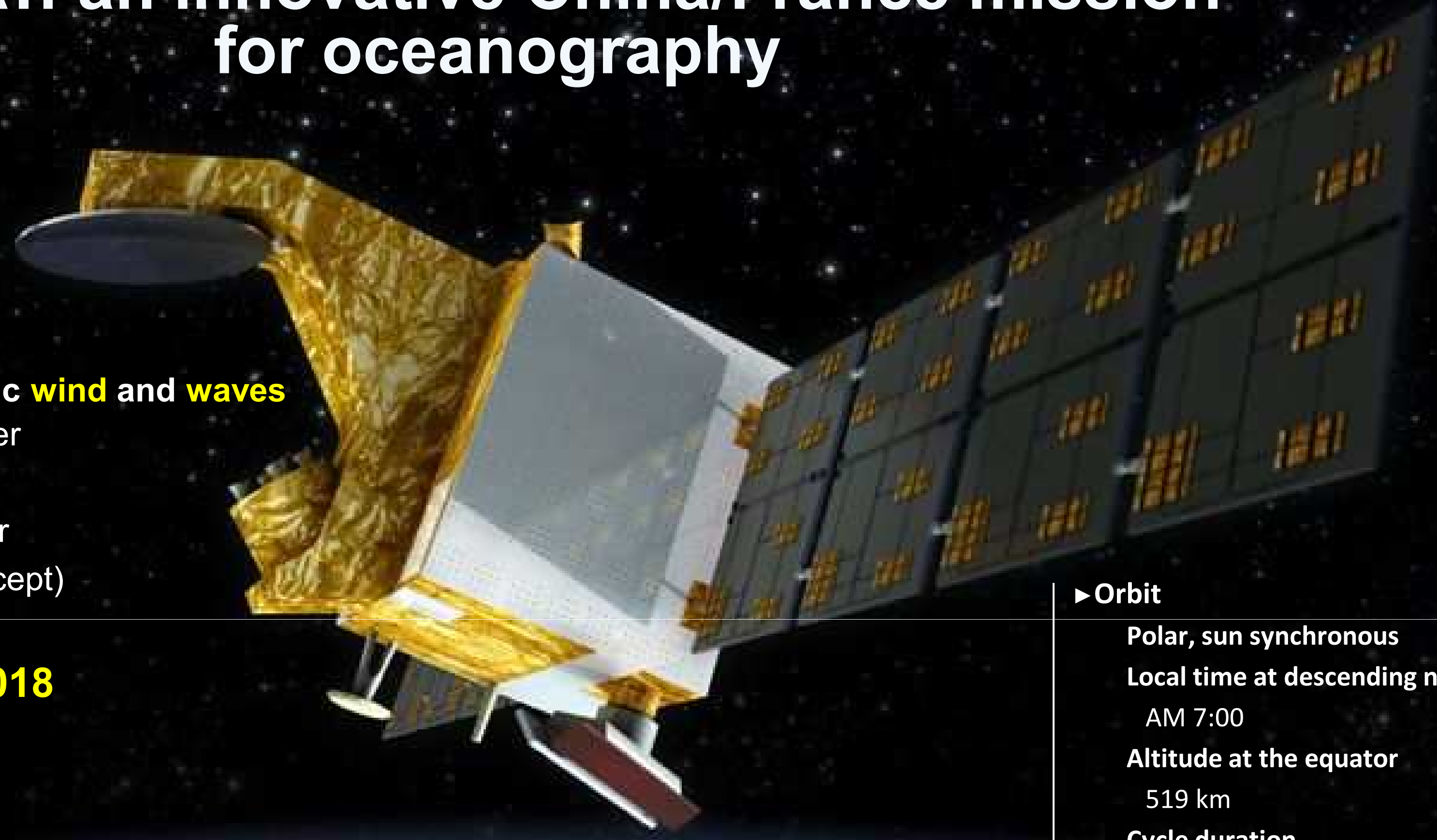
Overview of the talk

- Presentation of SWIM
  - ➔ CFOSAT mission
  - ➔ SWIM Concept
  - ➔ Instrument

- SWIM products :
  - ➔ Definition overview

- Focus on nadir processing
  - ➔ SWIM processing choices
  - ➔ Preliminary results

CFOSAT: an innovative China/France mission for oceanography



Joint measurements of oceanic wind and waves

- **SWIM**: a wave scatterometer (new instrument)
- **SCAT**: a wind scatterometer (new fan beam concept)

Launch: mid-2018

►Orbit

Polar, sun synchronous

Local time at descending node

AM 7:00

Altitude at the equator

519 km

Cycle duration

13 days

Main Objectives

Measure on a global scale ocean surface wind and spectral properties ocean waves in order to:

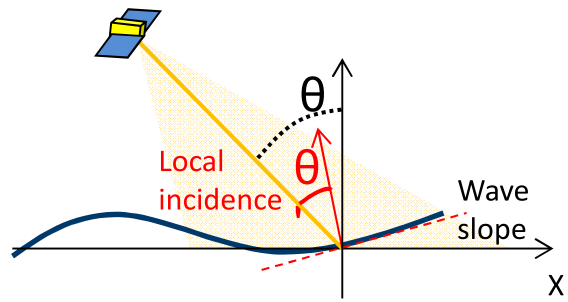
- **improve atmospheric, oceanic and wave forecast systems**
- **monitor sea-surface parameters for wind and wave climatology**
- **improve knowledge of surface waves**
- **improve the characterization of ocean/atmosphere coupling**

SWIM: Surface Wave Investigation Monitoring concept (1/2)

Wave scatterometer principle:

- ➢ Long waves create a tilting of the surface which modify local incidence
- → Introduce a modulation of the backscatter coefficient (σ) of the sea surface, as compared to a flat sea

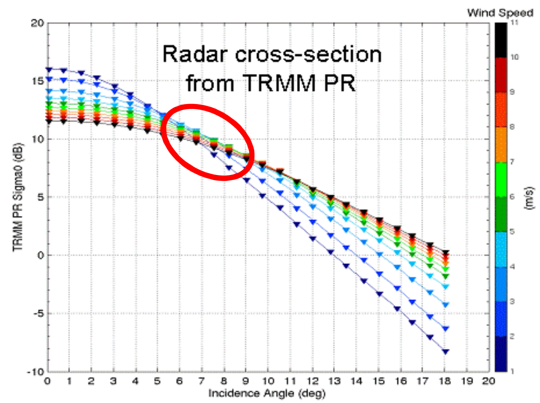
$$\frac{\delta\sigma}{\sigma} \propto wave\ slope$$



- ➢ Real aperture radar : integration of local modulations over antenna azimuth width

$$m(X,\phi) = \frac{\int G^2(\varphi)\frac{\delta\sigma}{\sigma}d\varphi}{\int G^2(\varphi)d\varphi}$$

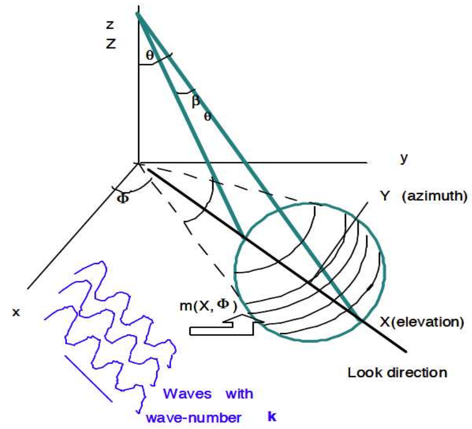
- ➢ For Ku Band, radar cross-section variations are quite insensitive to wind speed around 8°-incidence



SWIM: Surface Wave Investigation Monitoring concept (2/2)

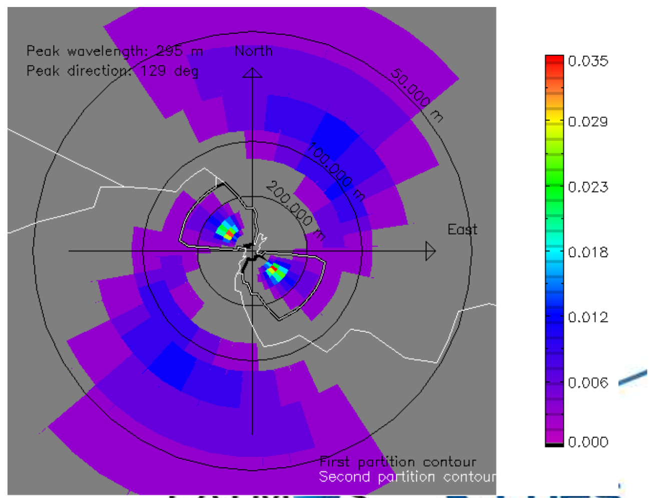
- Around 8°-incidence (Ku band) : Radar cross-section modulation spectrum is proportional to wave slope spectrum

$$P_m(k,\phi) = |FT(m(X,\phi)|^2 = \underbrace{\alpha(\theta)}_{\text{Mod. Transfer Function (MTF)}}\underbrace{F(k,\phi)}_{\text{Wave slope spectrum}}$$



- Modulation is maximum when beam is aligned with wave propagation direction

- Directional wave spectrum available through a 360°-scan of the scene



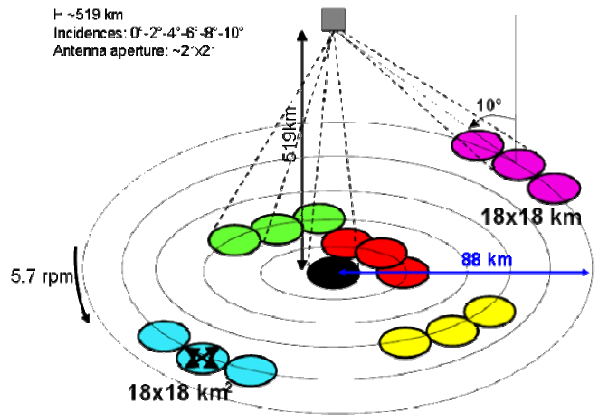
SWIM instrument

Ku-band real aperture radar

Six beams : 0°, 2°, 4°, 6°, 8°, 10°

- Sequential illuminations of the six beams

Rotating antenna (5.6 rpm)

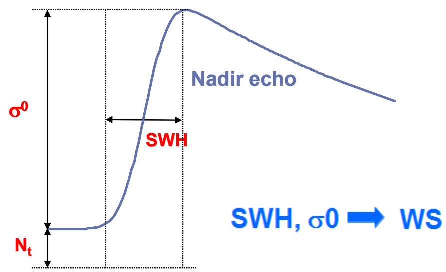


Alternate six beams illumination with 360° rotation

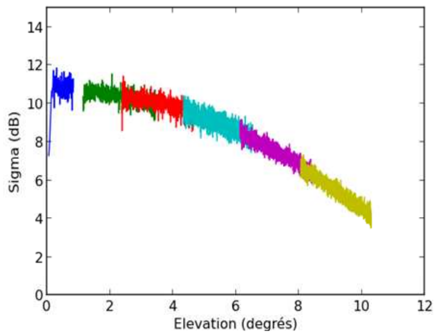
Geophysical products:

- Directional wave spectrum
  - 6°, 8°, 10° (spectrum beams)

- Nadir beam (0° beam)
  - Provide SWH, wind speed (inputs for Modulation Transfer Function)



- Complete σ_0 profile
  - 2°, 4° : complete σ_0 profile (0 to 10°)



SWIM NRT products

L0
Raw data (backscattered power versus range) @ 0, 2, 4, 6, 8, 10°

L1a
Calibrated waveform, geocoded @ 0, 2, 4, 6, 8, 10°
+ nadir waveform non calibrated, compensated for Instrument automatic gain

Nadir products (0°)

L2
- Hs, wind speed (ocean retracking)
- Ice and land properties (ICE 1 and ICE 2)

Wave products (6°, 8°, 10°)

L1b
- Modulation spectrum

L2
- Omnidirectional and 2-D wave spectra
- Partitioning and associated parameters (Hs, peak wave number and peak direction)

σ^0 products (0°, 2°, 4°, 6°, 8°, 10°)

L2
- σ^0 mean profiles versus incidence and azimuth

SWIM nadir product main technical choices (1/2)

SWIM is a wave observation instrument

- Optimization of retracking algorithm for SWH and sigma0 estimations

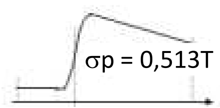
Choices made for on ground processing :

- similar to adaptive retracker

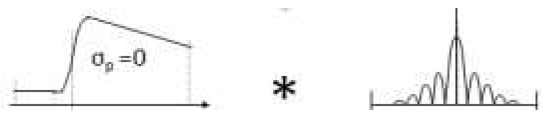
J.C. Poisson et al : New powerful Numerical Retracker (P. Thibault talk in Instrument processing session)

=> Ocean waveform retracking with 3 main innovations w.r.t operational altimetry

1. Numerical retracking: accounting for real point target response instead of a model



MLE4 modeled echo



Numerical modeled echo

» Suppression of Look Up Table

SWIM nadir product main technical choices (2/2)

2. adaptive model:

Brown model : - platform mispointing as an input
- estimation of the mean square slope parameter

$$S(t) = \frac{A\sigma_0}{2}\left[1 + erf\left(\frac{t - \tau - \frac{4c}{\Gamma h}\sigma_c^{\ 2}}{\sqrt{2}\sigma_c}\right)\right]\exp\left[-\frac{4c}{\Gamma h}\left(t - \tau - \frac{2c}{\Gamma h}\sigma_c^{\ 2}\right)\right] + N_t \qquad \Gamma = \frac{4.\gamma.mss}{4.mss.\cos 2\xi + \gamma}$$

Adaptive model expression (order 1, ξ=0° and skewness=0)

» Robust to sea ice echoes
» Improve sigma0 estimation

3. Nelder-Mead optimization algorithm:

» Allows to work with a real maximum likelihood criteria
» fully exploits the speckle noise statistics and thus improves the estimation performances

$$C = \frac{1}{Pu^2}\sum_{t=1}^{K}(y_t - S_t)^2$$

MLE4 convergence criteria (mean least square)

$$C = -Ln(L(y_1, ..., y_K)) = Cste + N\sum_{t=1}^{K}\frac{y_t}{S_t} - (N-1)\sum_{t=1}^{K} ln(y_t) + N\sum_{t=1}^{K} ln(S_t)$$

Nelder-Mead convergence criteria (maximum likelihood)

Preliminary results
Monte Carlo method simulation

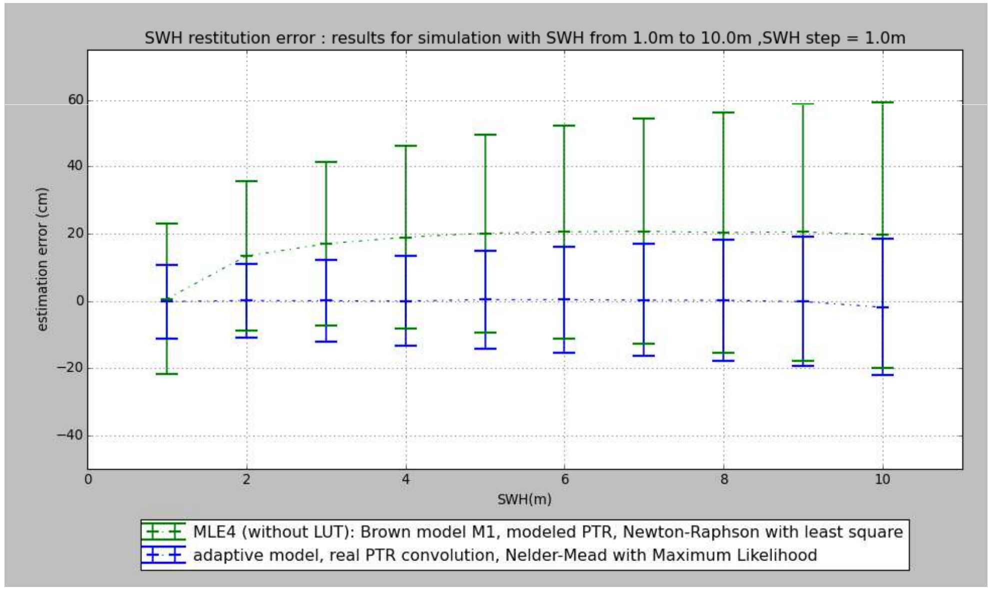
- Monte Carlo method simulation :

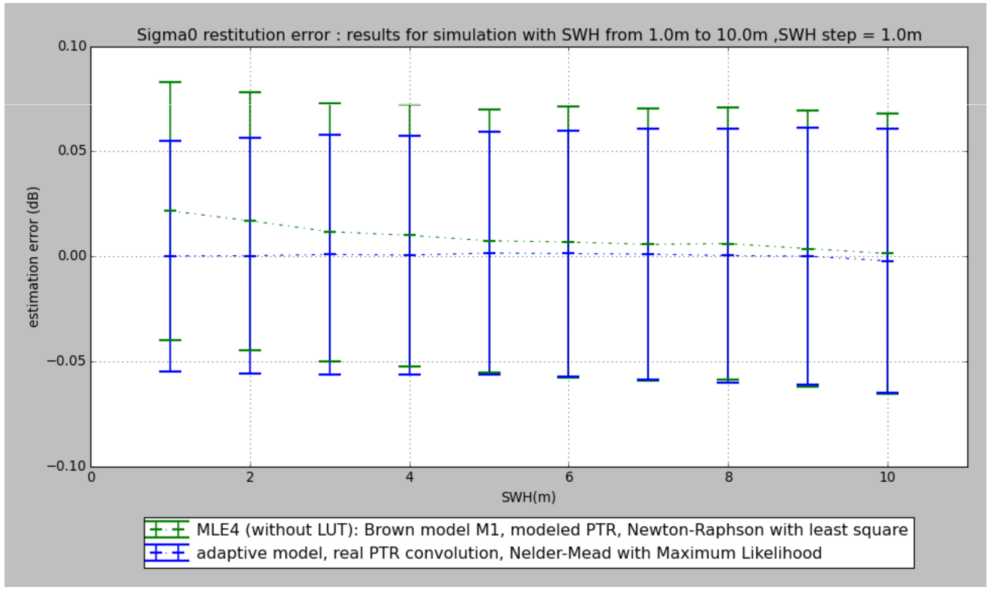
  Simulations of noised nadir waveform with Brown model (convolved with PTR)

  SWH from 1 to 10m,

  12000 simulations by SWH step

Restitution errors of SWIM retracking vs MLE4





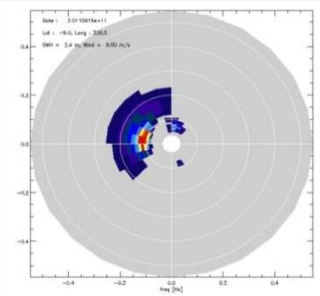
=> no LUT required,

=> noise estimation reduction : SWH 50% , sigma0 : 10%

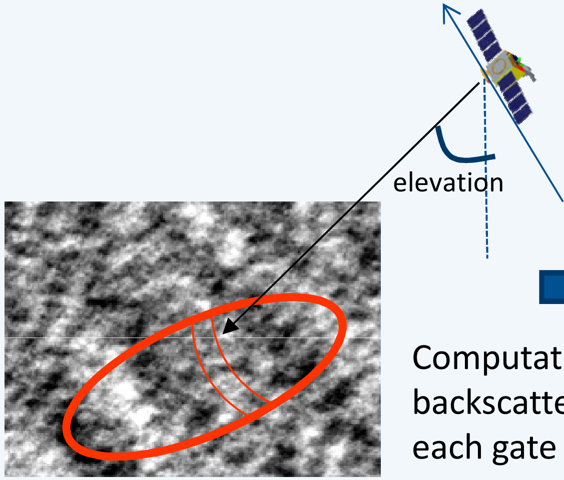
Preliminary results
SimuSWIM simulation results (1/2)

- SimuSWIM simulator :
  - » From surface description to signal simulation

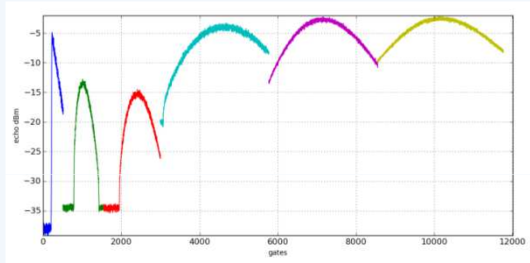
SimuSWIM



Generation of sea surfaces

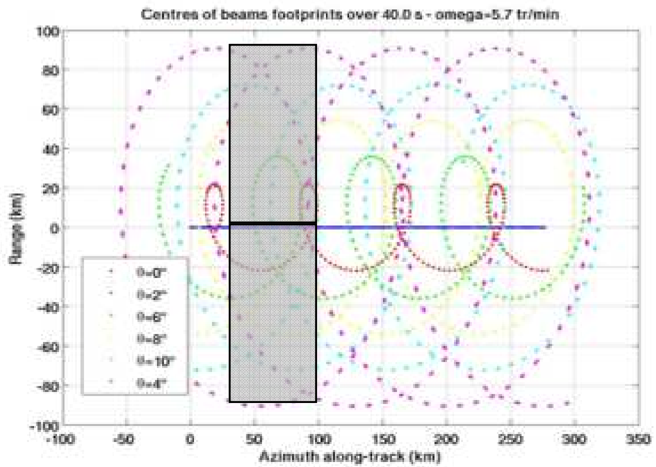


Computation of backscattered signal for each gate (GO model)



For each swath:
Inputs: wave models
(MF_WAM, WAM)

- Box definition:
  - » Resolution cell to have a full 360° azimuth coverage
  - » 70km along satellite track
  - » 180km across track (±90km)



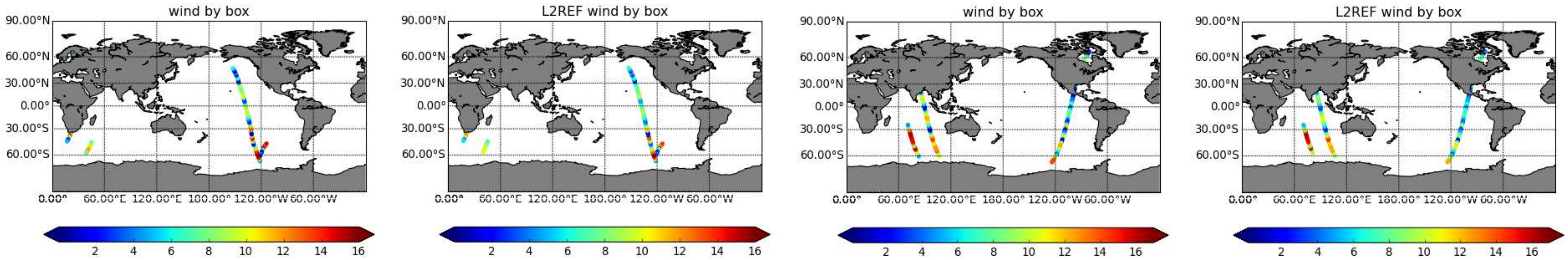
Preliminary results
SimuSWIM simulation results (2/2)

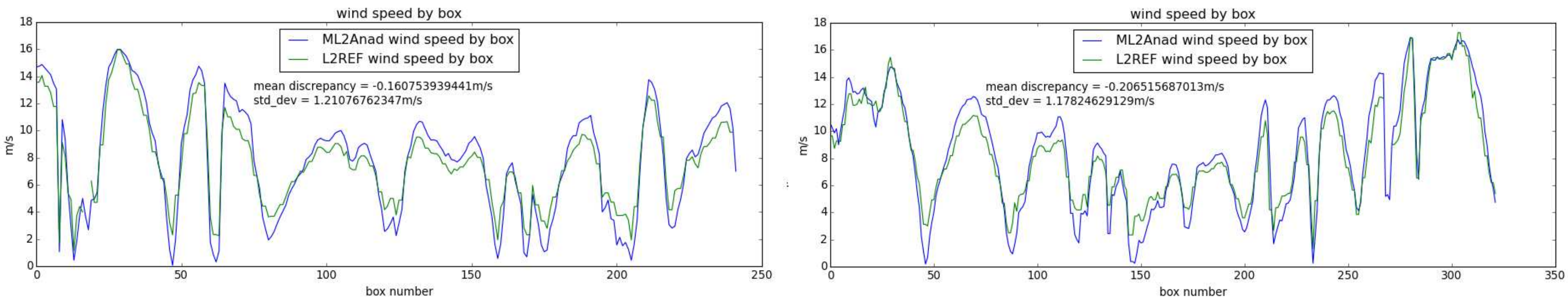
- Parameter estimation results

Comparison on box averaged data

SWIM retracking outputs

Vs. Reference L2REF: integration over each box of wave model (input of SimuSWIM)





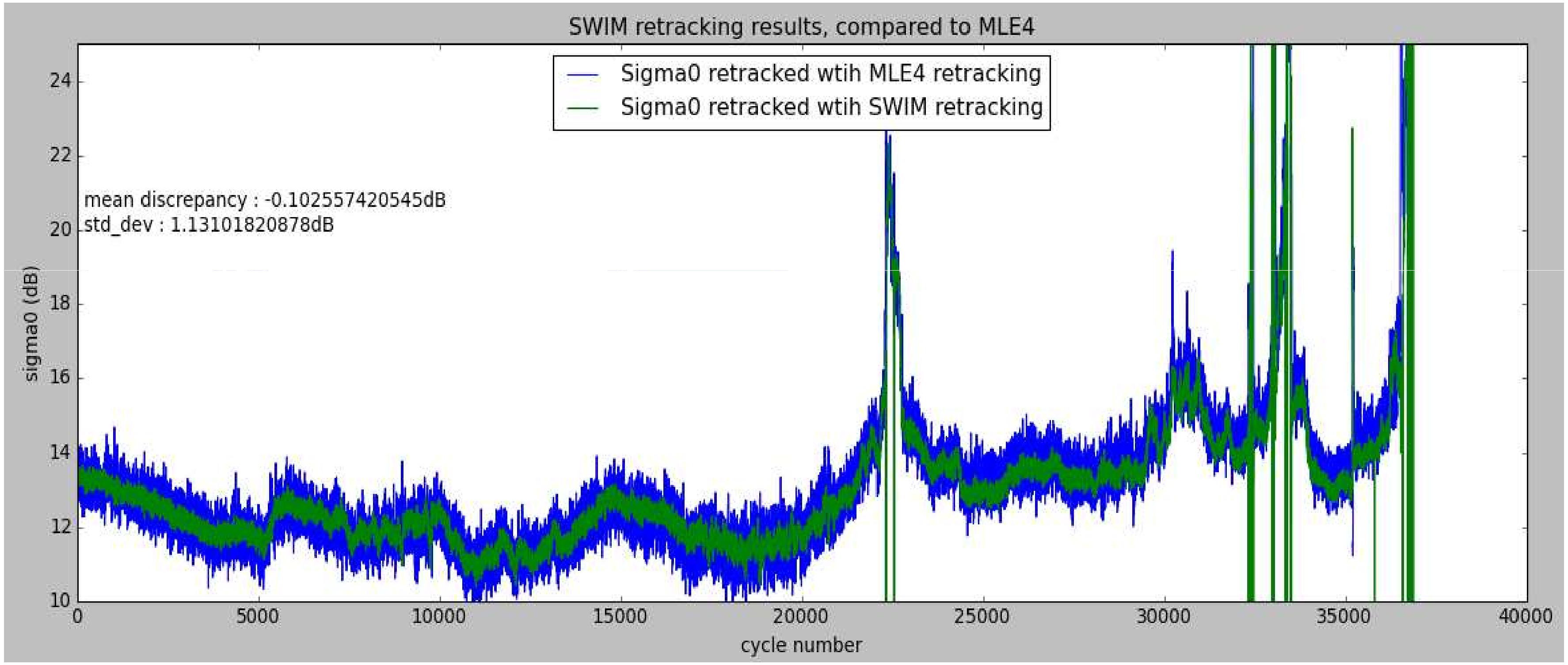
SWH : First results compliant with the specification, bias to be explained (simulation effect?)

Wind speed : good results, wind calculation parameters to be adjusted in flight (Jason parameters for this processing)

Preliminary results
Performance on Jason-3 data

SWIM retracking performance on Jason-3 20Hz data (compared to MLE4):

» Cycle 11, track 1



» SWH: as expected noise reduction of 50%

» Sigma0: noise reduction of 40%

Conclusion
SWIM interest for OSTST:

- A new space-borne scatterometer for accurate **directional wave spectrum** characterization.
  - Great source of information for understanding of interaction of sea states in altimeter measurements.

- Joint measurements with wind scatterometer.
  - Strong potential for wind calculation algorithms validation.

- Nadir processing : Innovative algorithms implemented in ground segment.
  - Promising preliminary results, operational assessment

Simulation data open to scientists on AVISO+ since July 12th 2016

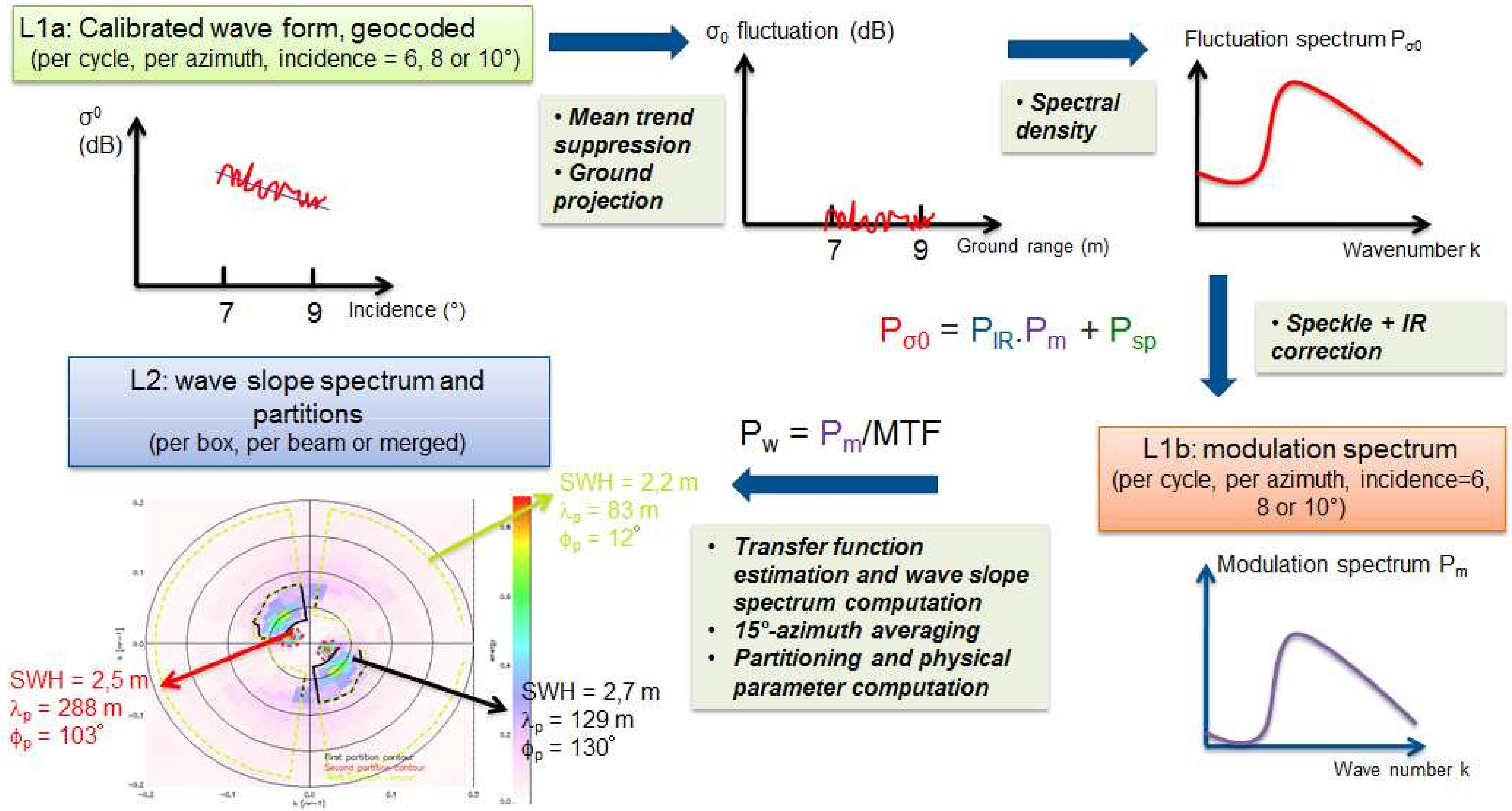
http://www.aviso.altimetry.fr/fr/missions/missions-futures/cfosat.html

(please contact cedric.tourain@cnes.fr for more information)

Thank you for your attention!

BACKUP

SWIM NRT products
Wave products

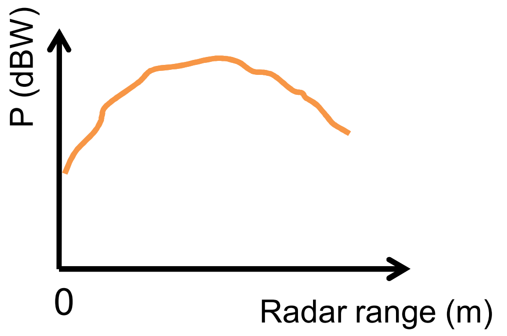


Requirements :

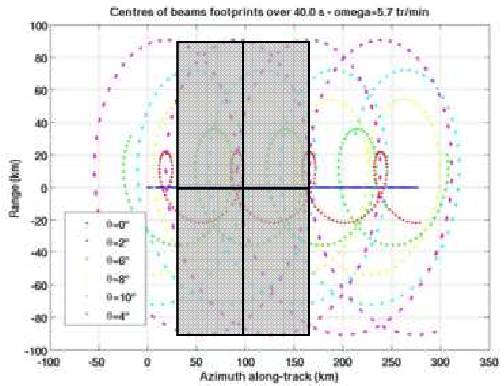
λ	$\frac{\delta\lambda}{\lambda}$	ϕ	*Spectral peak power*	*Resolution cell*
70 – 500 m	10%	15°	20%	70x90 km²

SWIM NRT products
σ^0 profile

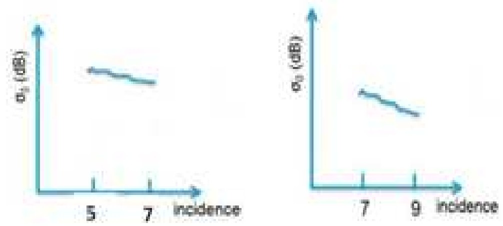
L0: non calibrated wave form (per cycle, incidence, azimuth)



- ***σ^0 estimate from radar equation***
- ***Geocoding***

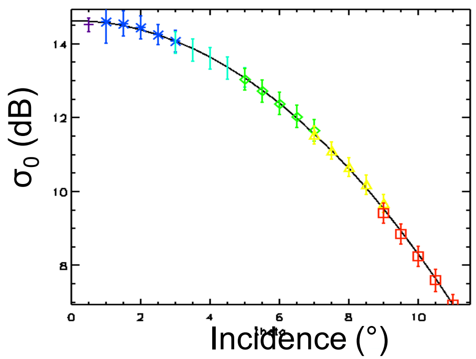


L1a: Calibrated wave form, geocoded (per cycle, incidence, azimuth)



- ***Combining incidences within boxes***

L2: Normalized radar cross-section profiles
From 0° to 11° (per 15°-azimuth range) at a scale of 70 x 90 km and associated radiometric accuracy



Requirements :

σ_0	$\Delta\sigma_0^{i,j}$
1 dB	0.1 dB