SWIM ground-segment solution for retracking nadir echoes

Performance Analysis

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With support of all the SWIM Calval Team

LATMOS Ifremer METEO FRANCE CLS

Introduction

SWIM nadir is “almost” a conventional altimeter (Jason-2/3, SARAL/AltiKa, ...) but:

- It is not dedicated to ocean topography, **only wind and wave**
- It does not use MLE4 retracking but, the **adaptive retracking (CNES/CLS)**

Very innovative algorithm, developed by CNES/CLS and the result of many years of development.

For CFOSAT project, no constraint on the retracking algorithm choice, except for the **3h NRT latency.**

For the first time, in a ground segment!

Overview:

✓ **Evolution of retracking w.r.t. MLE4 and benefits**

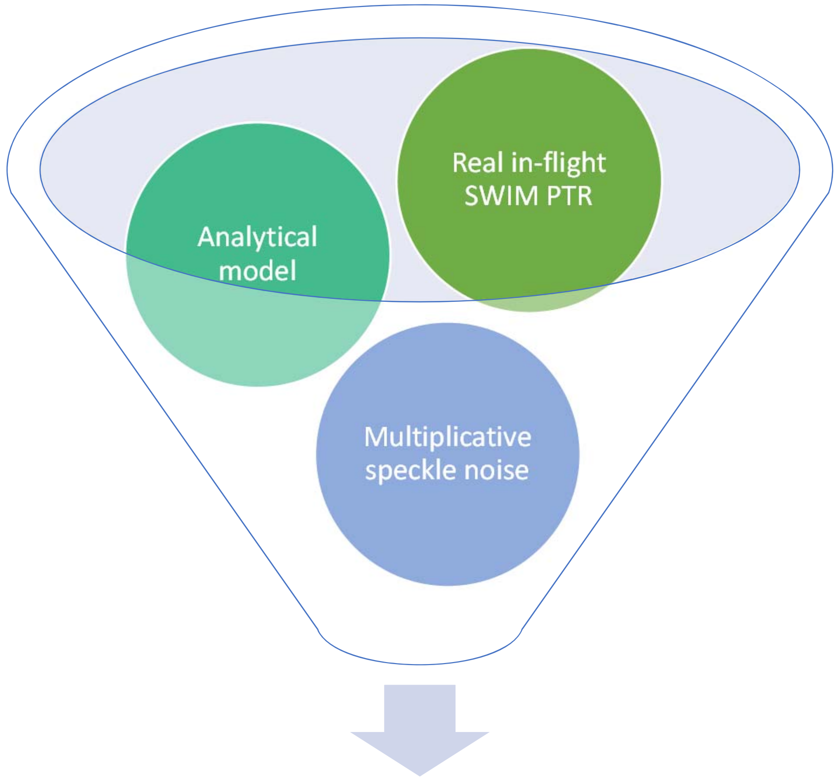
✓ **Comparison to models**

✓ **Comparisons to other missions**

Why such a retracking?

Use of simulations based on:

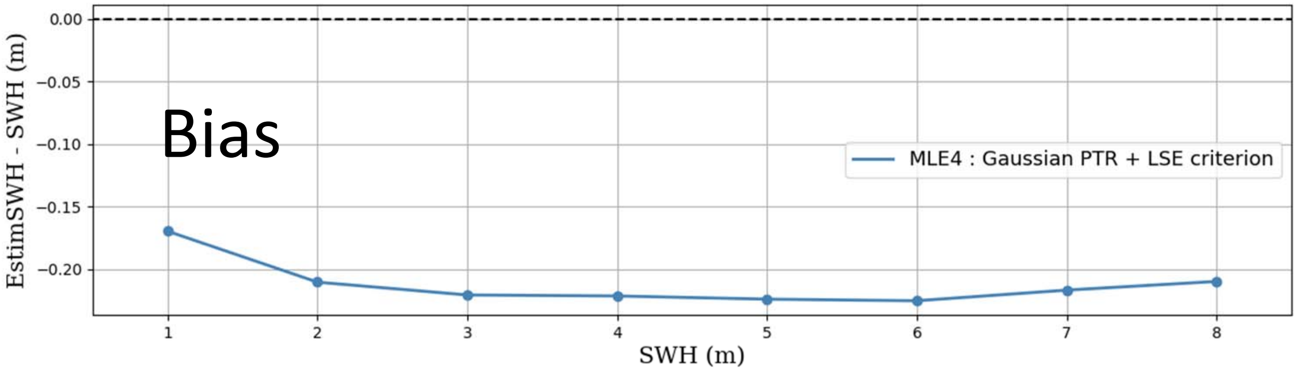
- Echoes generated with a analytical Model and a real in-flight SWIM PTR introduced numerically
- 10000 echoes generated for each SWH step (from 1m to 8m)
- A multiplicative speckle noise is applied : Gamma law with N=264
- Generated with typical CFOSAT parameters (altitude, antenna beam, ...)

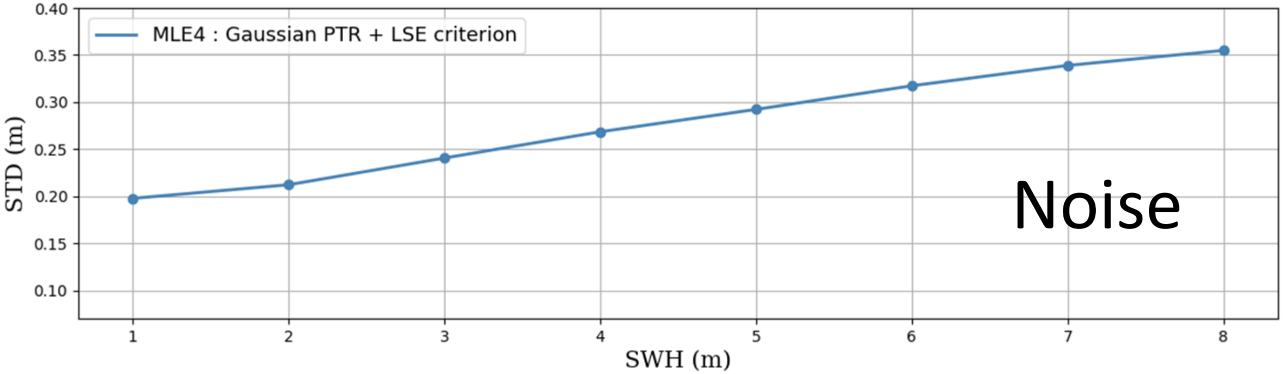


Generated with typical CFOSAT parameters (altitude, antenna beam, ...)

From the MLE4 to the Adaptive

Model	Likelihood criterion
Brown Model ()	Least-Square (degraded MLE)



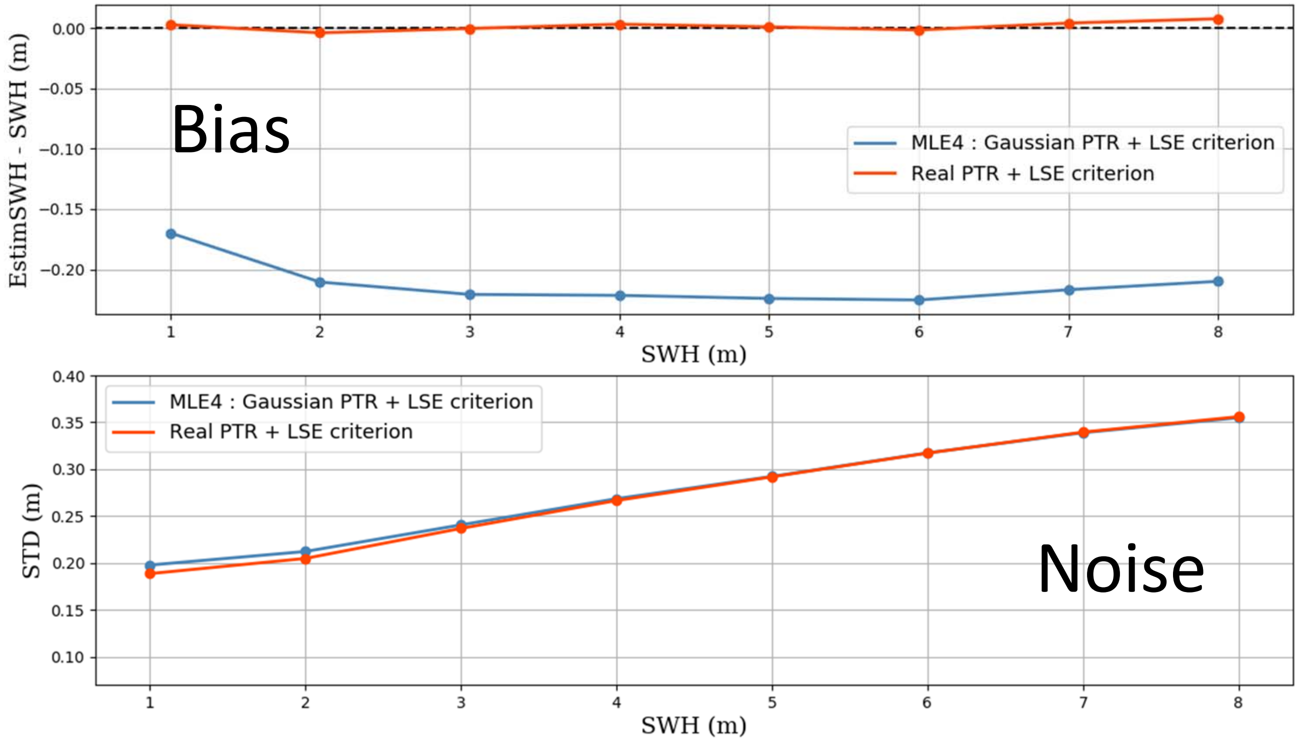


Configuration 1 : MLE4

- Gaussian PTR : Look-up tables needed
- Standard deviation between **20cm** and **35cm**

From the MLE4 to the Adaptive

Model	Likelihood criterion
Brown Model () * **Real PTR**	Least-Square (degraded MLE)

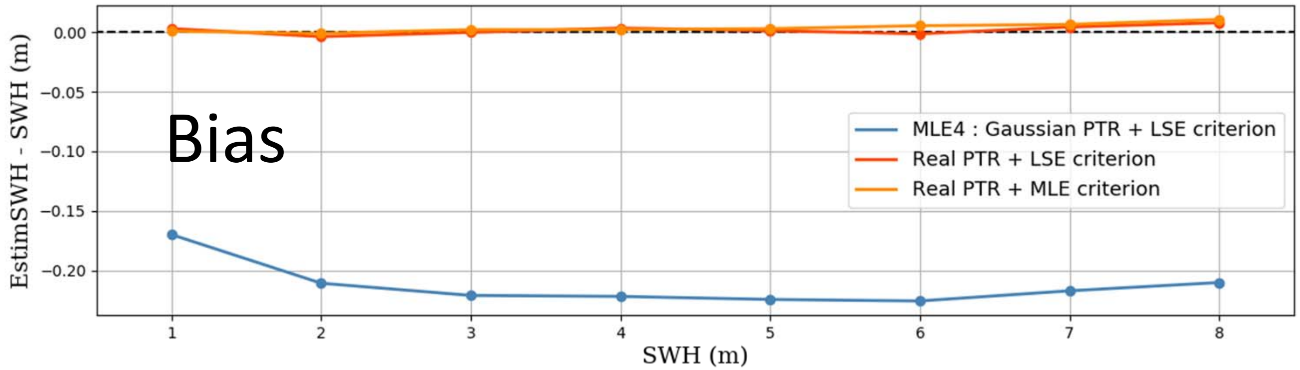


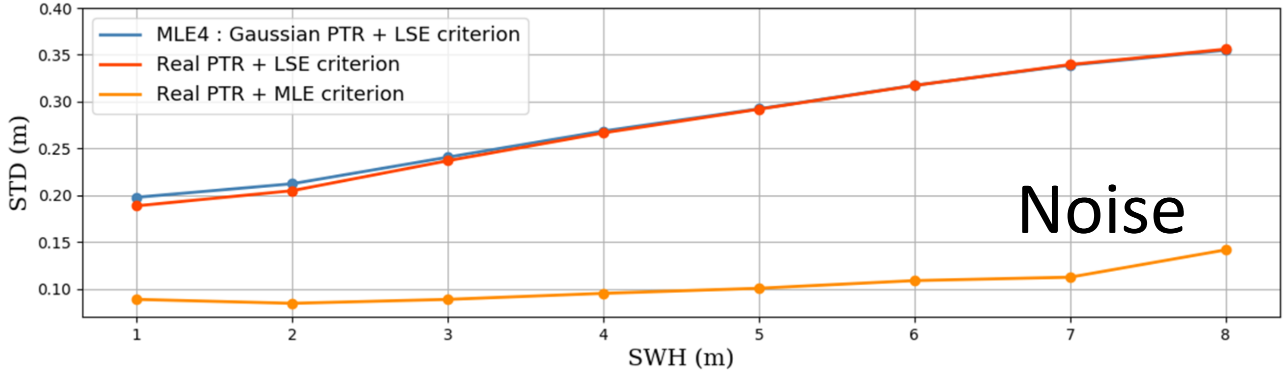
Configuration 2

- Real PTR introduced numerically : no need for Look-Up tables anymore
- Standard deviation between **20cm** and **35cm : similar to MLE4**

From the MLE4 to the Adaptive

Model	Likelihood criterion
Brown Model () * **Real PTR**	**Maximum Likelihood Estimator (MLE)**



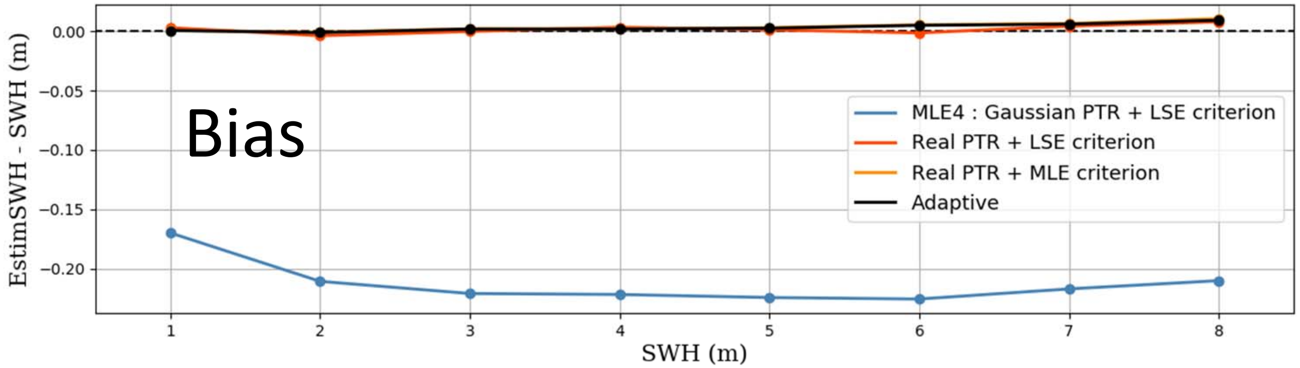


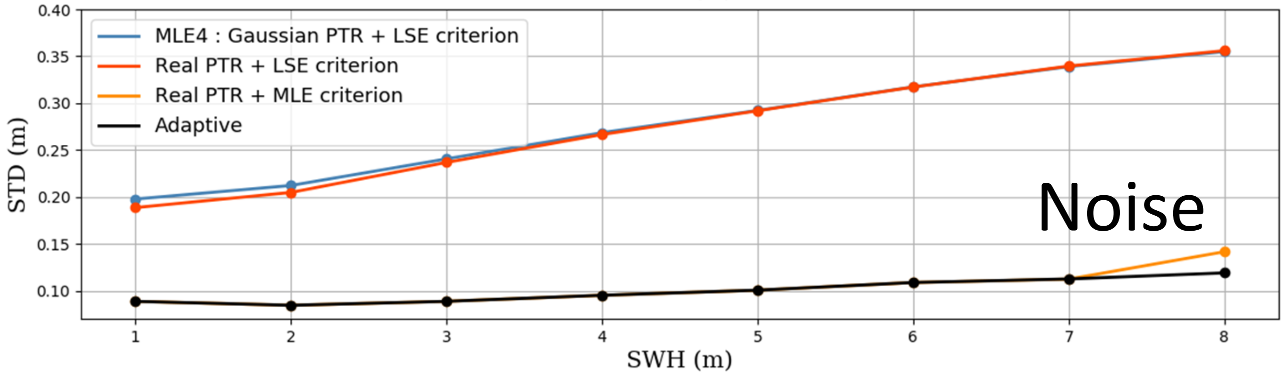
Configuration 3

- Real PTR introduced numerically : no need for Look-Up tables anymore
- Standard deviation between **8cm** and **15cm : 60% noise reduction**

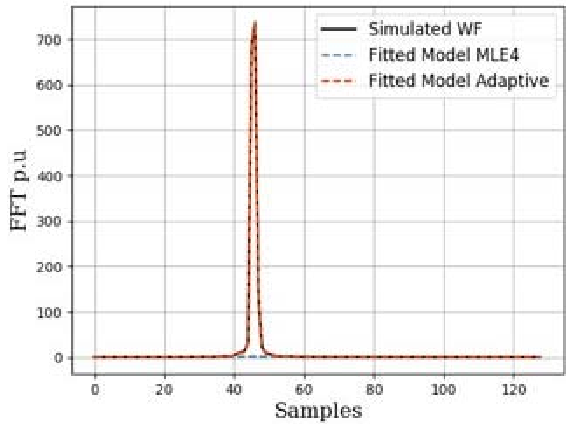
From the MLE4 to the Adaptive

Model	Likelihood criterion
Adaptive Model * Real PTR	**Maximum Likelihood Estimator (MLE)**



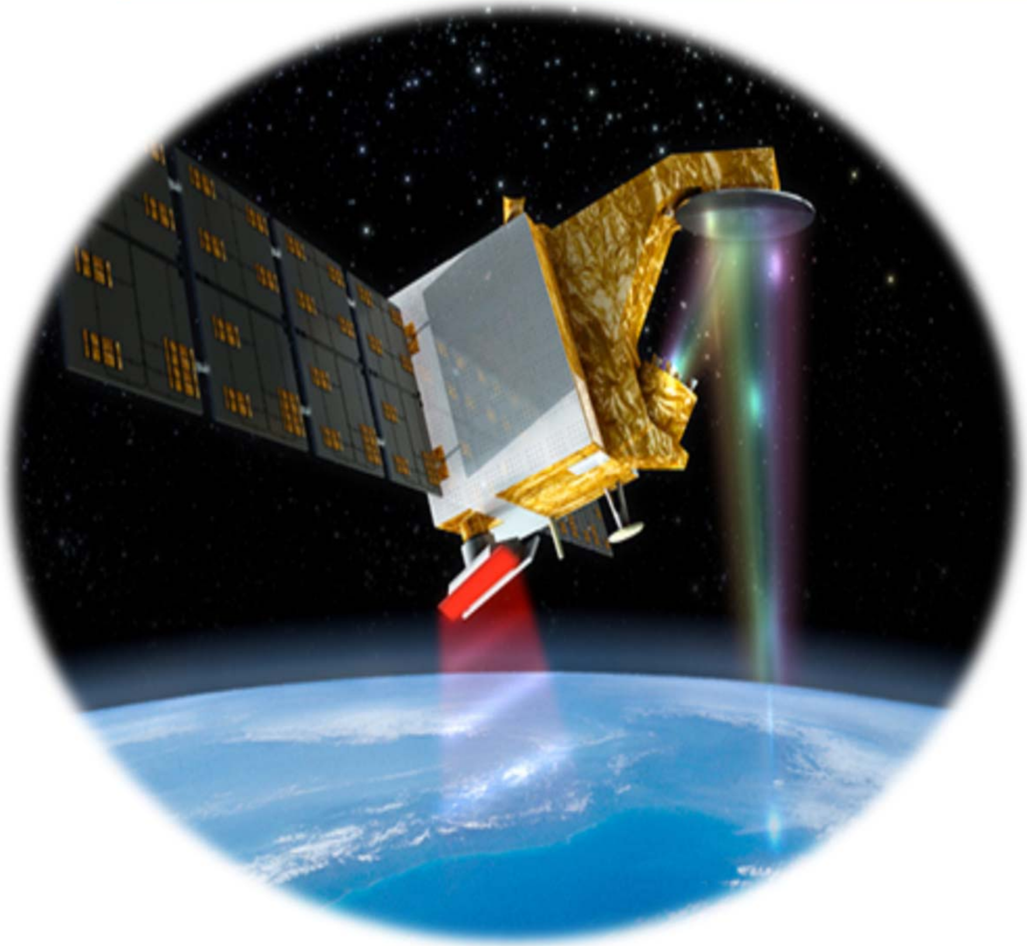


Configuration Adaptive



- Introduction of the roughness in the model to allow the retracking of non-oceanic surfaces (peaky echoes)

What about real data?



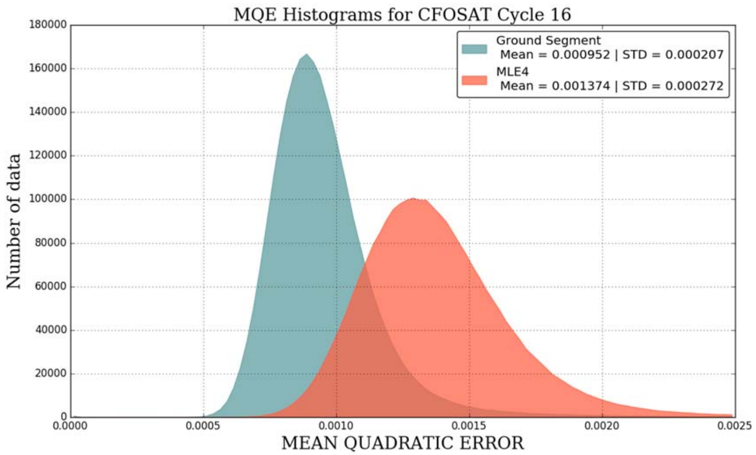
CFOSAT

- Adaptive = Official L2ANAD products on cycle 5 and cycle 16 of CFOSAT : nadir_swh_native, nadir_sigma0_native, nadir_mqe_native, ...

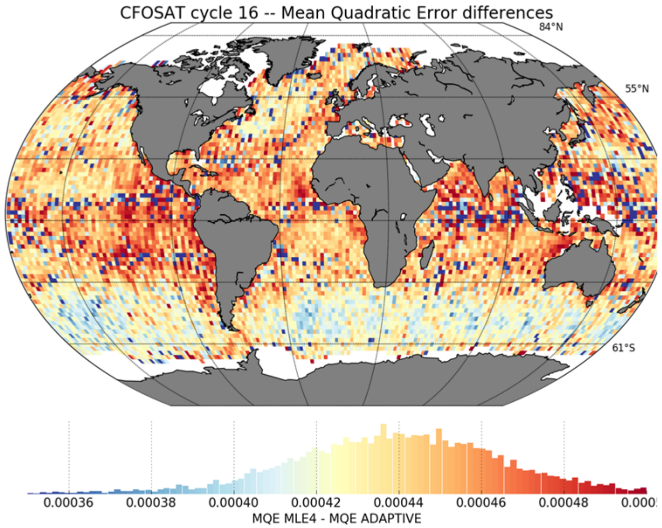
- MLE4 = Cycle 16 & Cycle 5 processed at CLS with an internal algorithm, based on the CNES Jason ground segment

Compared to current altimeters ground segment processing: Better Mean Quadratic error

MQE = Mean Quadratic Error, the quadratic difference between the **echo** and the **model** fitted to retrieve the geophysical parameters. Smaller is the MQE, better is the fit !



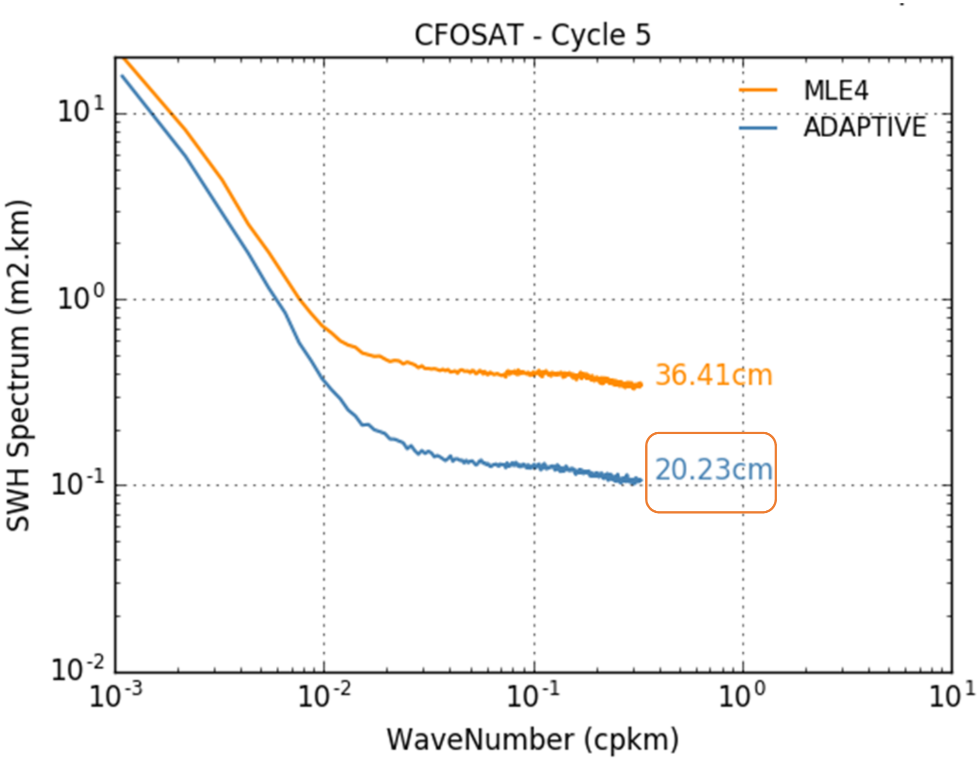
MQE Adaptive **better** than MLE4 in mean value and standard deviation



Difference always positive
MQE Adaptive < MQE MLE4 **everywhere**

The difference seems to be correlated to the rougness of the surface --> Coherent

Compared to current altimeters ground segment processing: Lower spectral noise level on SWH



Large scale bias on MLE4 (No Look Up Tables) reduced

CFOSAT **Ground segment** instrumental noise = **20.23 cm**

CFOSAT MLE4 instrumental noise = **36.41 cm**

45 % noise reduction w.r.t MLE4!

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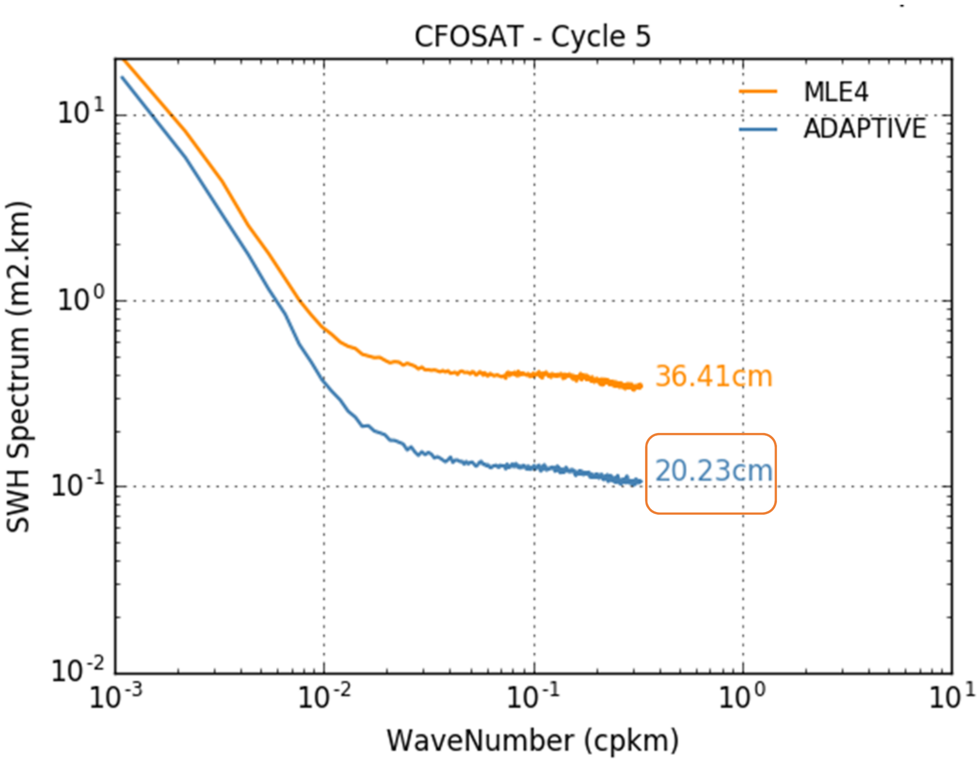

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CFOSAT **Ground segment** instrumental noise = **20.23 cm**
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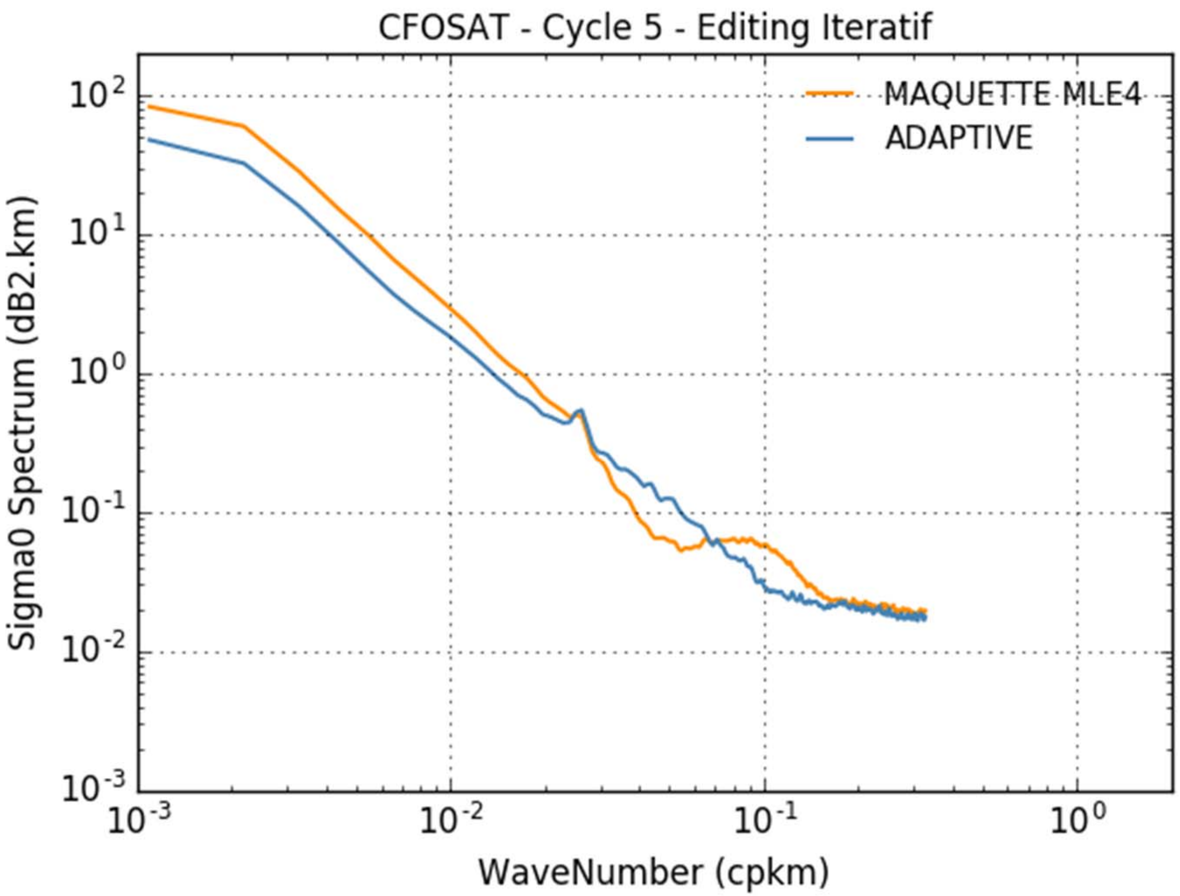
45 % noise reduction w.r.t MLE4!

J3 **Ground segment** instrumental noise = **51.68 cm**

60% noise reduction w.r.t. Jason-3 ground segment!

Thanks to higher PRF of CFOSAT and very good Instrumental SNR.

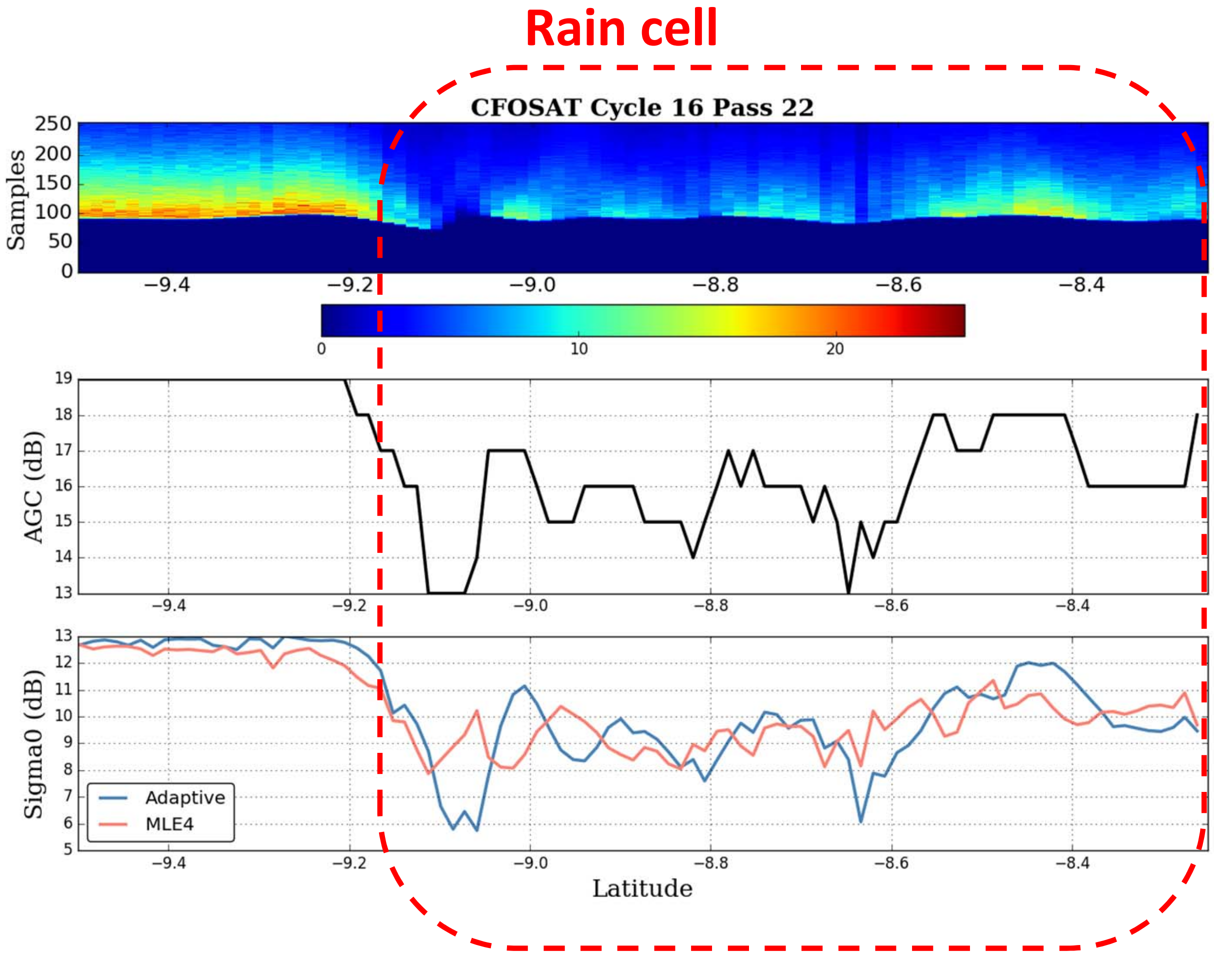
Compared to current altimeters ground segment processing: More relevant Sigma0 spectrum



- MLE4 : Artificial bump due to the **correlation** between the Sigma0 and the other parameters of the model
- Adaptive model deccorelates the Sigma0 from the trailing edge

--> Real physical Sigma0, no bump

Compared to current altimeters ground segment processing: More precise rain cell detection

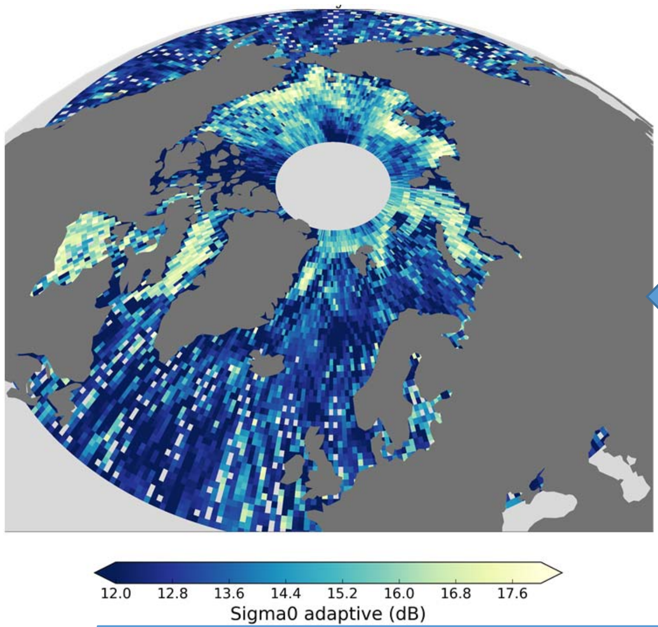


- Rain event : characterized by less backscattered power, lower AGC values.
- Sigma0 adaptive : follows the AGC variations whereas the Sigma0 MLE4 **does not**.
- Sigma0 adaptive more physical, able to detect special events such as **rain cells** or **blooms**

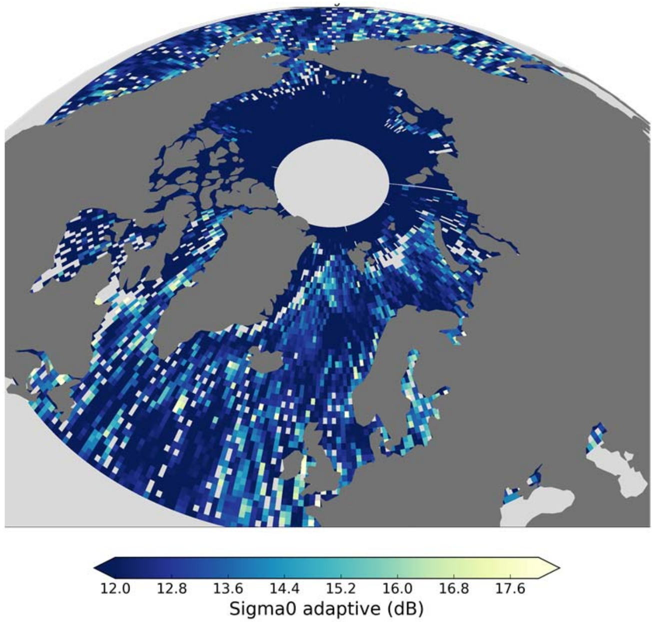
Compared to current altimeters ground segment processing: Relevant Sea Ice detection

Sea-ice = reflective surface, echoes are more "peaky" than ocean-type echoes

Adaptive Cycle 16



MLE4 Cycle 16

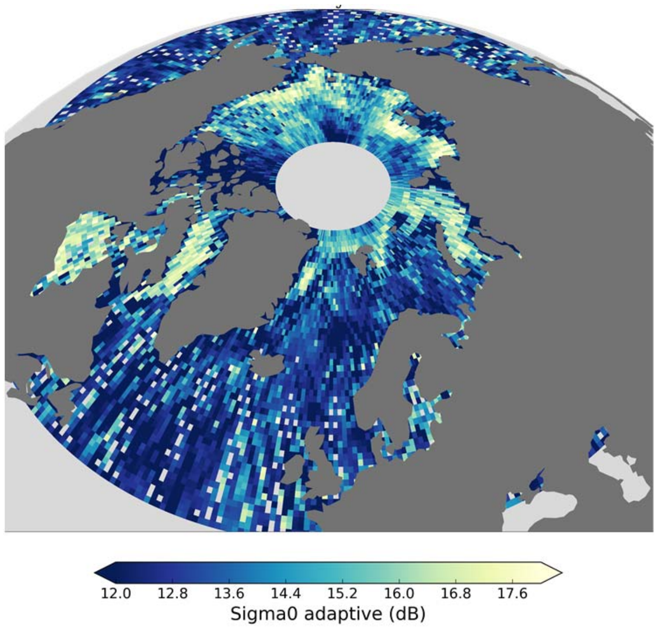


Adaptive = Fits very well peaky echoes thanks to the **roughness** introduced in its model --> Physical Sigma0, higher on sea-ice than ocean

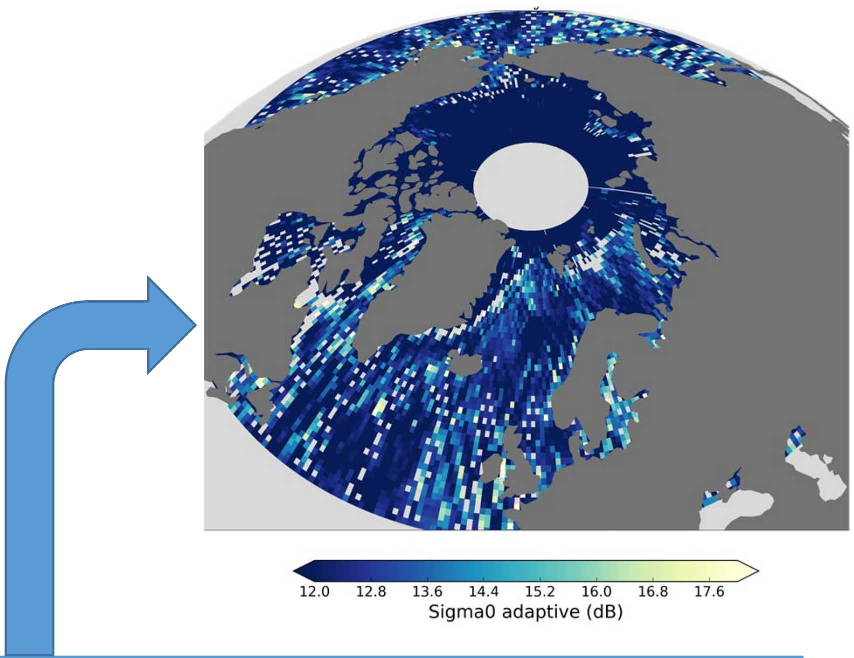
Compared to current altimeters ground segment processing: Relevant Sea Ice detection

Sea-ice = reflective surface, echoes are more "peaky" than ocean-type echoes

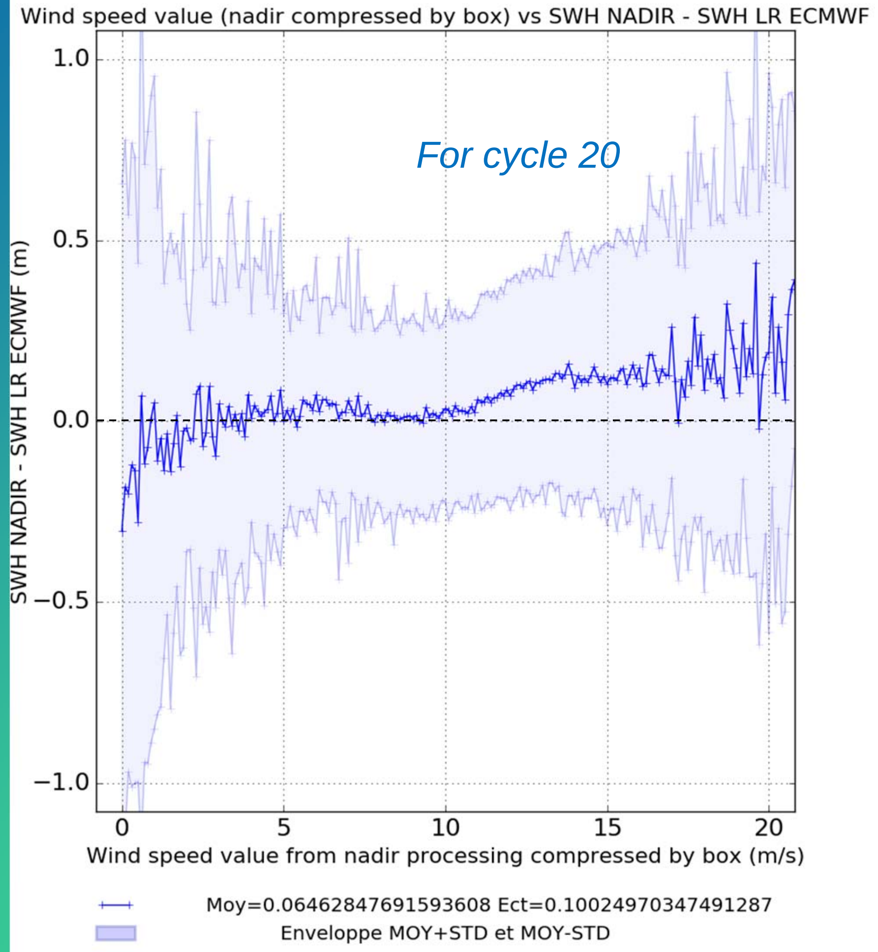
Adaptive Cycle 16



MLE4 Cycle 16



MLE4 = Fits very poorly peaky echoes because the model is made only for ocean
--> non-physical Sigma0, not exploitable at all on sea-ice

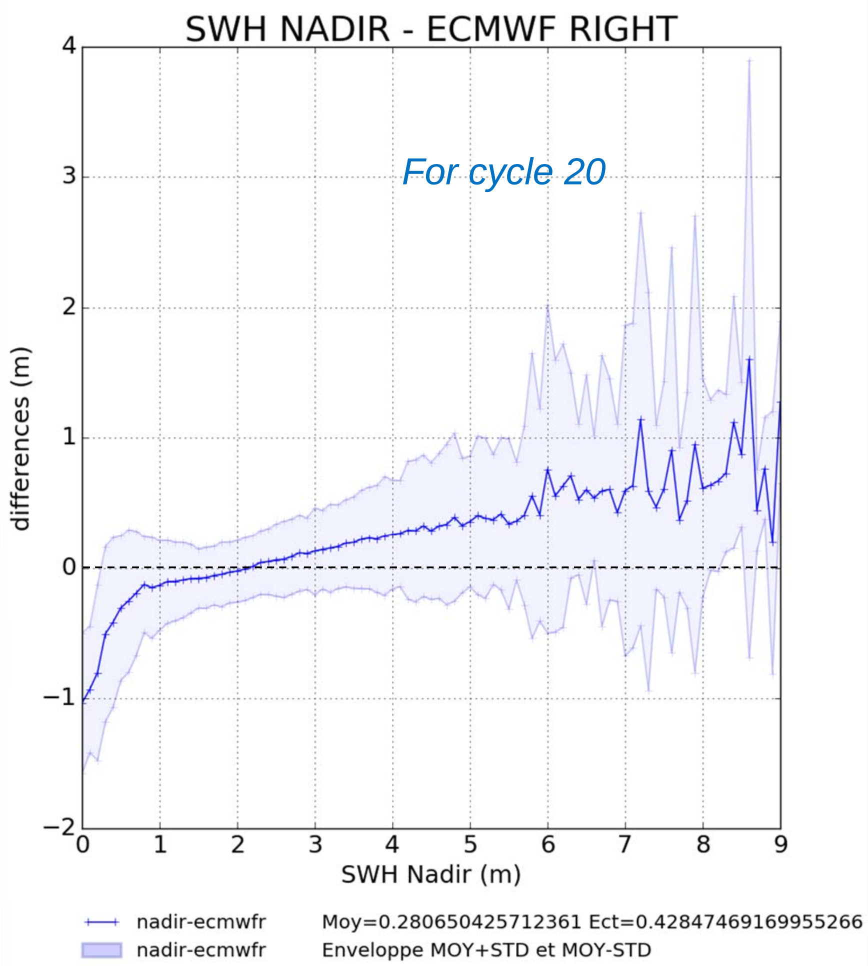


Comparison to models: SWH

SWIM retrieved SWH behavior close to ECMWF
(similar results based on MF WAM model) (see Lotfi Aaouf talk):

- Mean bias observed over 6 months : ~1 cm
- Bias repartition over the globe : no abnormal pattern
- Very weak wind dependency

← SWH (nadir – ECMWF) vs wind nadir



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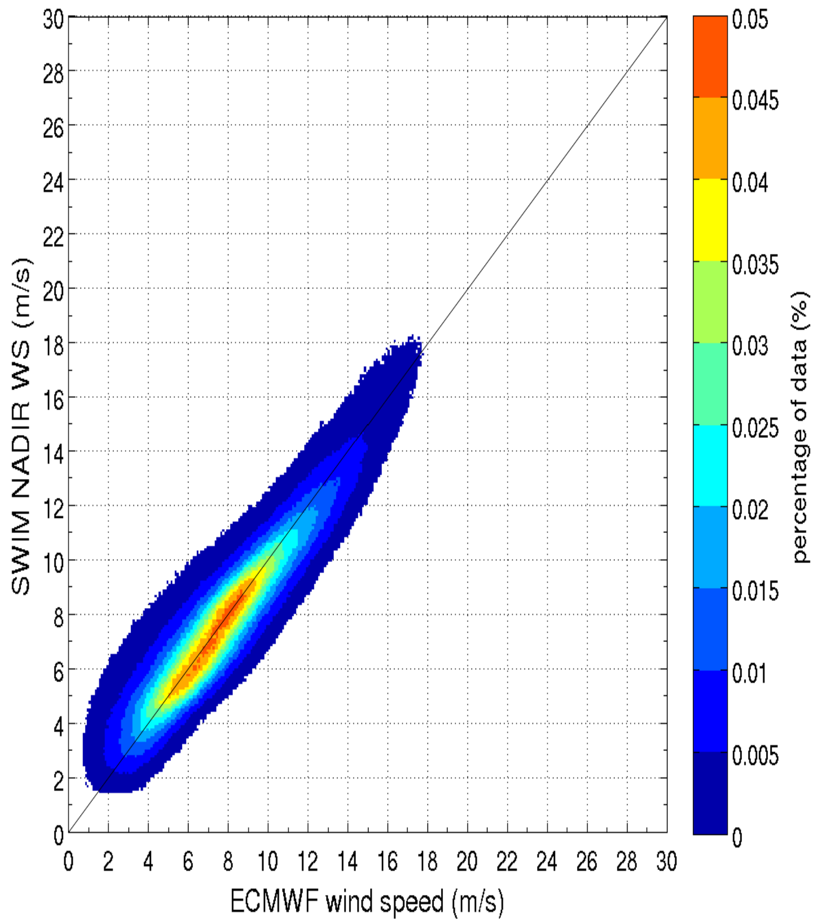
- Mean bias observed over 6 months : ~1 cm
- Bias repartition over the globe : no abnormal pattern
- Very weak wind dependency
- Light linear wave dependency (less than 1cm at 2m)

← SWH (nadir – ECMWF) vs SWH nadir



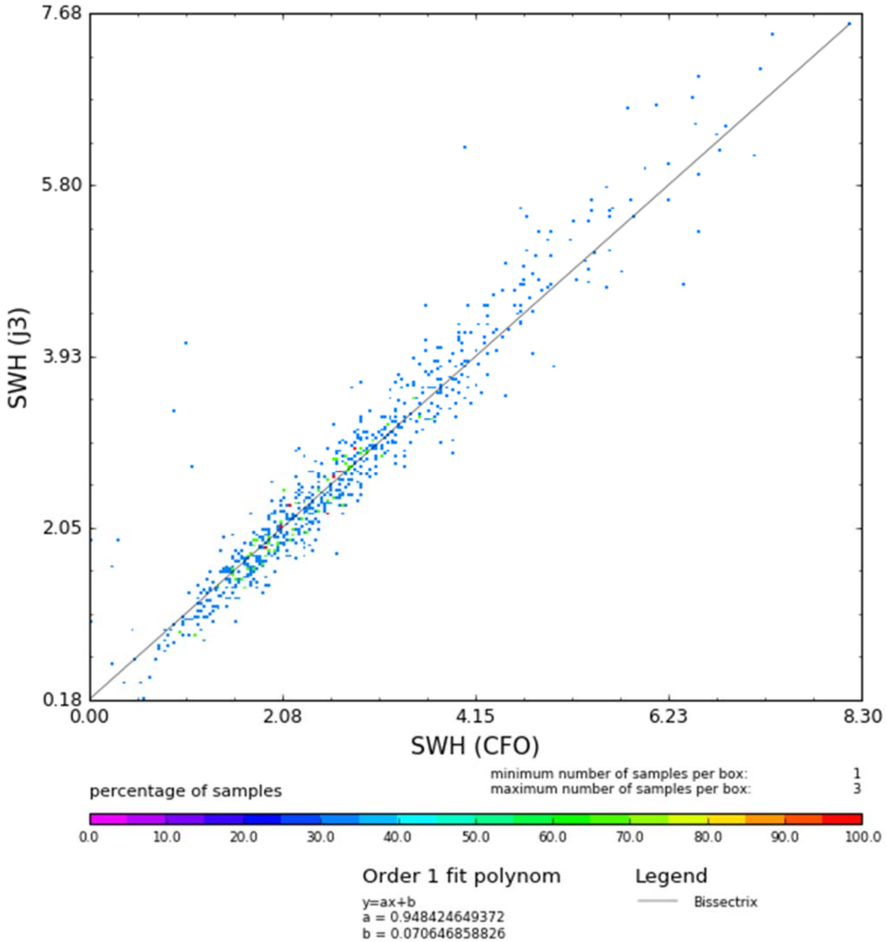
Comparison to models: wind

Derived from Sigma0
In SWIM nadir product, based on Collard's algorithm [2005]
First parametrization: Jason based

- Very good agreement even with the first parametrization!

- Slight under-estimation for WS above 8 m/s
- Over-estimation for WS below 8 m/s
- Some SWH remaining impact on SWIM nadir WS values below 8 m/s

Comparison with other altimeters at 3h crossovers SWH



Statistics performed on differences at crossovers:

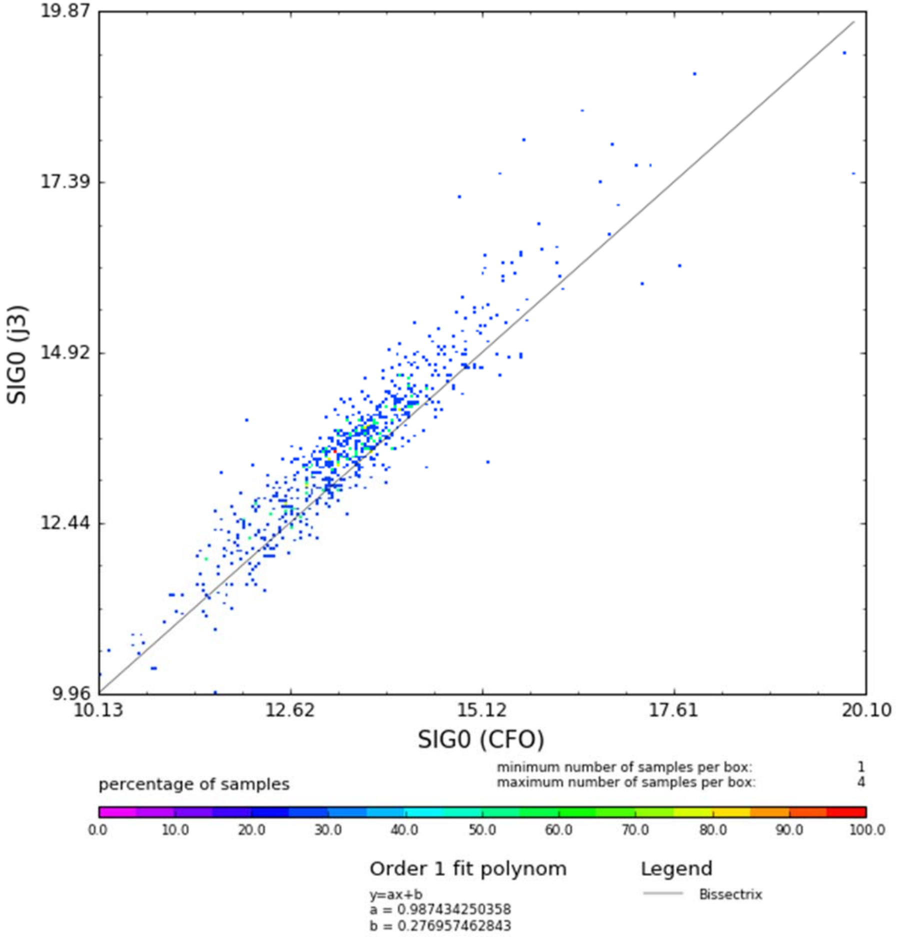
- Possible with Jason-3, AltiKa, Cryosat-2
- No possible crossovers with Sentinel-3 and HY2B

SWH	CFO - J3	CFO -AL
Mean bias	-6cm	0,1cm
Std	35cm	35cm

Very good and stable consistency,

No geographical patterns.

Comparison with other altimeters at 3h crossovers Sig0



Statistics performed on differences at crossovers:

- Possible with Jason-3, AltiKa, Cryosat-2
- No possible crossovers with Sentinel-3 and HY2B

Sig0	CFO - J3	CFO -AL
Mean bias	0,12dB	-2,7dB
Std	0,4dB	0,5dB

Very good and stable consistency,

Differences of interaction of Ku/Ka band with surface (rugosity and SST), see Vandemark et al. 2016

Conclusion

The CFOSAT SWIM ground segment retracking , so called the adaptive shows excellent results and improvements w.r.t. MLE4 retracking:

- **Very small noise on SWH**
- **Very relevant Sigma0 information including over Sea Ice and rain/bloom events**
- **Good consistency of Wind and wave estimation with reference to models and other nadir missions**

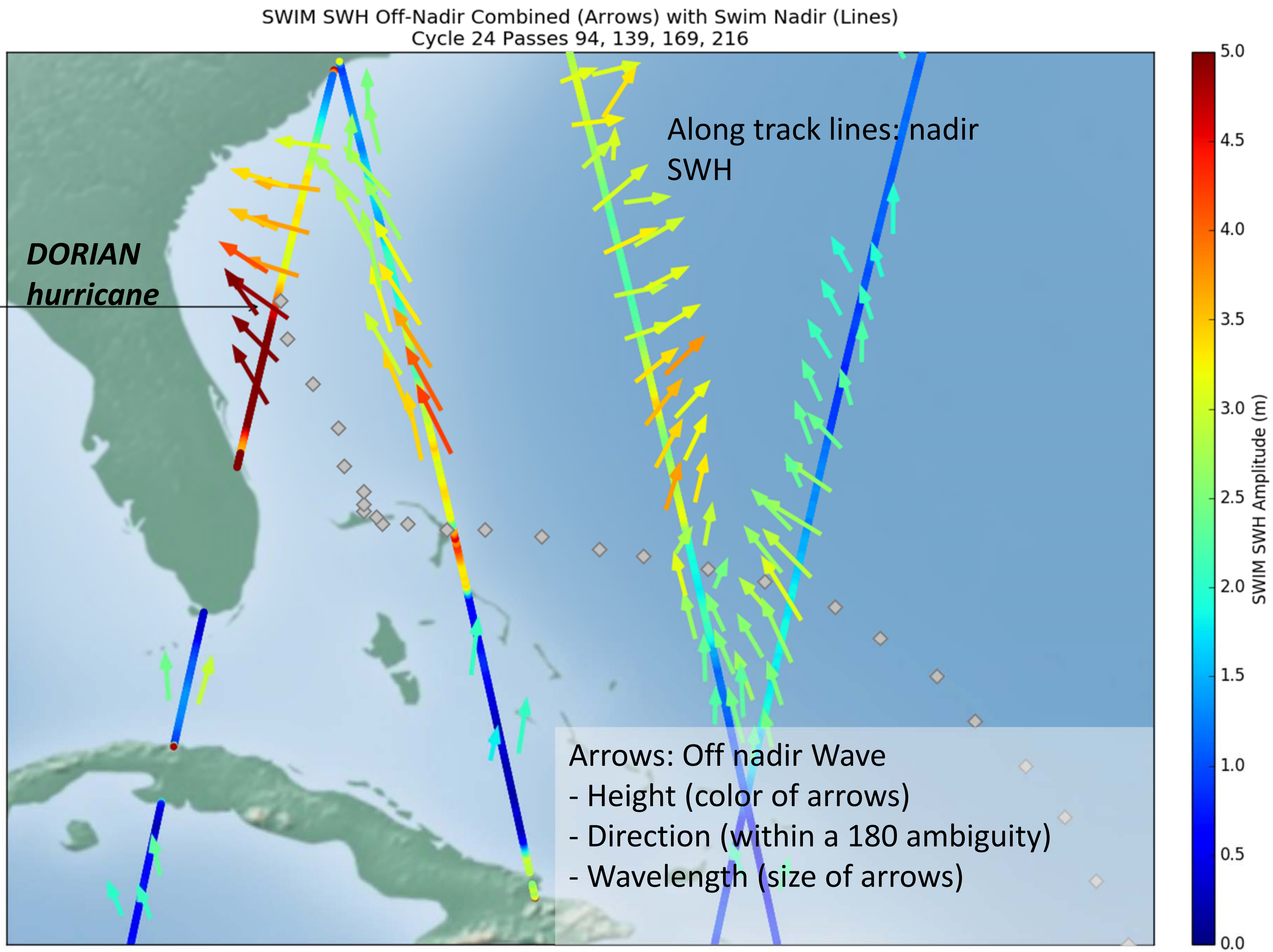
Complient with a NRT 3h product delivery

The nadir processing is optimized regarding wind and wave parametrers.

It will constitute :

- **A fully reliable reference** to validate the off-nadir information.
- A useful information potentially usable as an **input to constrain some off nadir ground segment processings**
- An aditionnal nadir mission available for **assimilation in WeatherForcast models, see:**
    - ***next talk Lotfi Aouf, Meteo-France***
    - ***Alice Dalphinet, Meteo-France poster***

Back ups



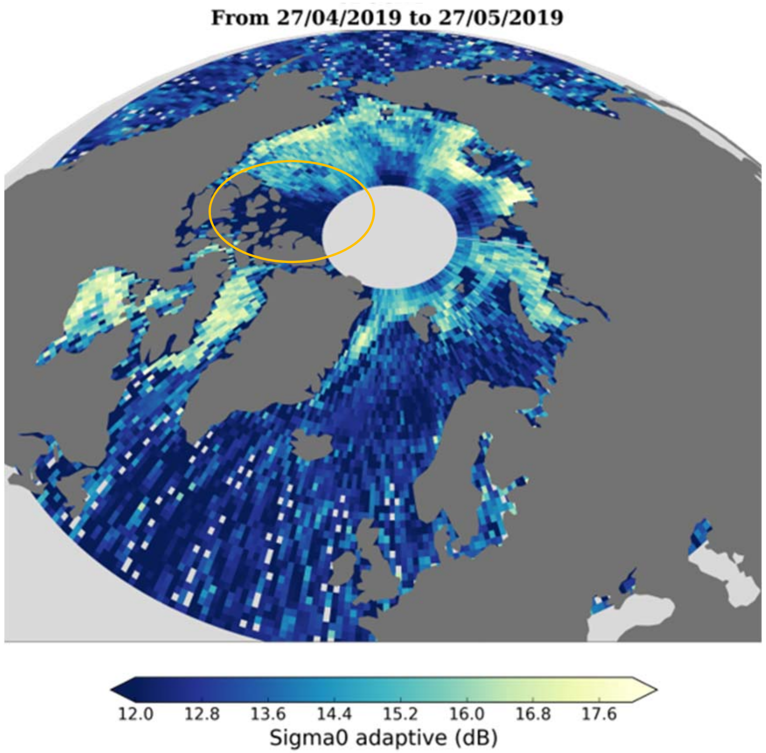
谢谢

Merci !

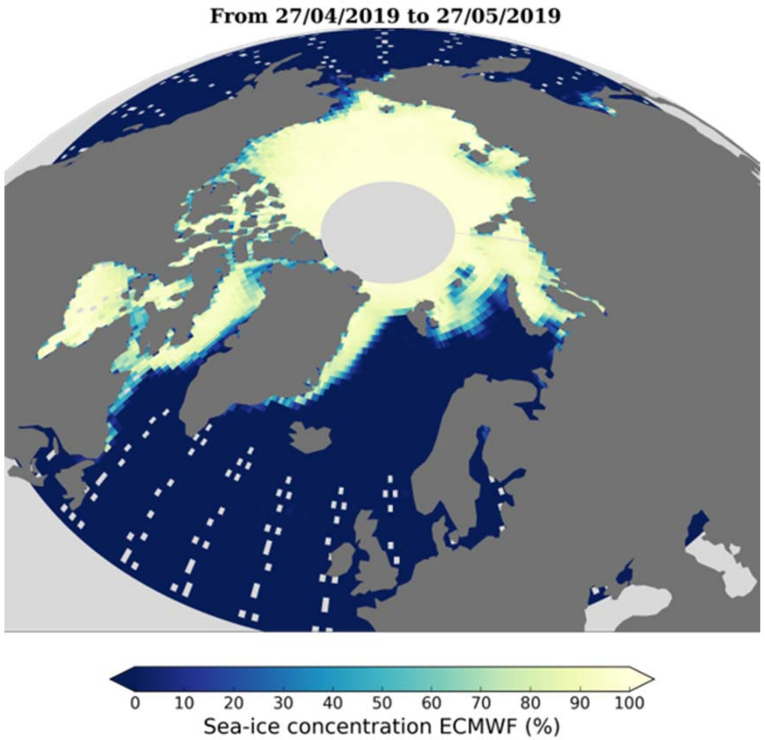
Thank you !

Sigma0 Adaptive on sea-ice regions : comparison with ECMWF

Adaptive on 30 days



ECMWF Sea-Ice concentration



- Very good correlation with the sea-ice extent
- Sigma0 shows typical Arctic patterns such as multi-year patch with a higher roughness

What about real data?

CFOSAT

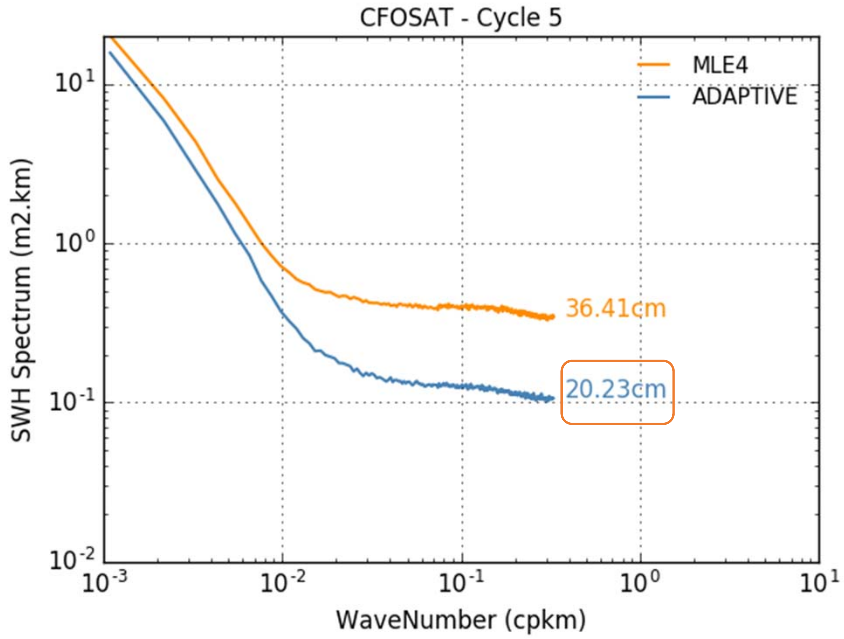
- Adaptive = Official L2ANAD products on cycle 5 and cycle 16 of CFOSAT : nadir_swh_native, nadir_sigma0_native, nadir_mqe_native, ...
- MLE4 = Cycle 16 & Cycle 5 processed at CLS with an internal algorithm, based on the CNES Jason ground segment

Jason-3

- Adaptive = data from an enhanced HR database (for experts) developped in the frame of a CNES/CLS project.
- MLE4 = official L2 SGDR products from CNES ground segment.

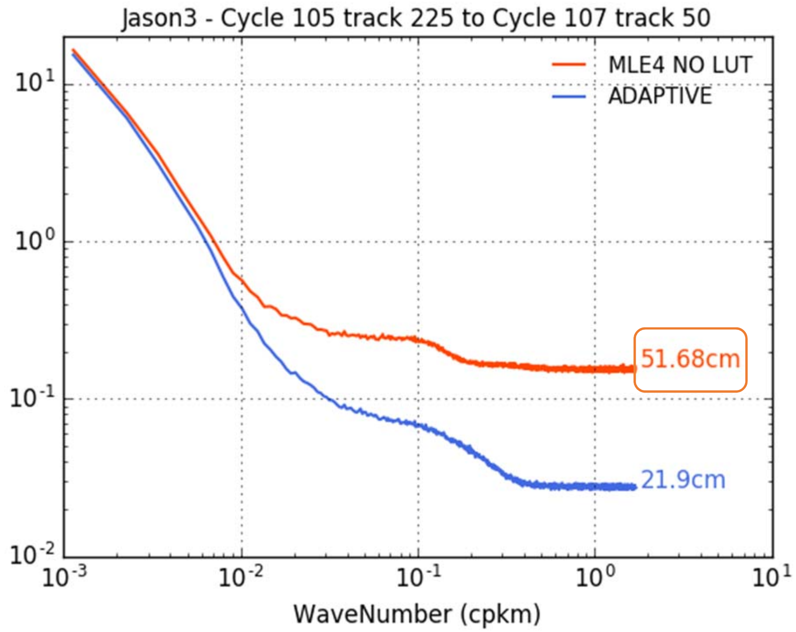
Compared to current altimeters ground segment processing: Lower spectral noise level on SWH

CFOSAT **Ground segment** instrumental noise = **20.23 cm**
MLE4 instrumental noise = **36.41 cm**



45 % noise reduction with Adaptive

Jason-3 **Ground segment** instrumental noise = **51.68 cm**
Adaptive instrumental noise = **21.9 cm**



58% noise reduction with Adaptive

(Less than J3 but totally normal because the MLE4 noise is lower (number of indivual pulses > J3))