Towards a homogeneous reprocessing of historical missions: excellent performances of the Adaptive retracker applied to Jason-1 and ENVISAT

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Introduction

- ✓ Lots of effort during the last years to improve the **retracker**, i.e the **algorithm** allowing to retrieve the **geophysical parameters** from the echo waveform

- ✓ For conventional altimetry (LRM), the **Adaptive retracker** has been developed → major improvements compared to the baseline MLE3/MLE4

- ✓ Already applied on current missions with great performances (Jason-3, CFOSAT, …) but historical missions offer also lots of perspectives with more than 30 years of data !

- ✓ Essential for users to have the most **homogeneous** time series possible.

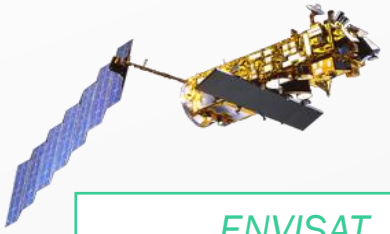
- ✓ In the frame of different projects, the Adaptive has been applied on **ENVISAT** and **Jason-1**
→ Not straightforward because of their instrumental specificities

Outline

1. The Adaptive Retracker

2. Application on ENVISAT (FDR4ALT)

- The ESA FDR4ALT reprocessing project
- PTR managment
- Results on open ocean SLA and waves



ENVISAT
May 2002-April 2012

3. Application on Jason-1 (GDR-F)

- The GDR-F reprocessing
- Compression/decompression of the echo
- Mispointing managment
- First results

Jason-1
Dec 2001-July 2013

4. Conclusions & Perspectives

The Adaptive Retracker

Physical retracker ensuring continuity for all surfaces (ocean, coastal, sea-ice,) thanks to the introduction of the pseudo-mss (mean square slope).

Real PTR of the instrument numerically introduced
→ Allows to take into account the instrumental ageing
→ Mandatory for long-term studies

Takes into account the real noise statistics by using a true MLE
→ Great noise reduction on all parameters

Algorithm developed in the frame of studies by CNES/CLS

Already presented multiple times at OSTST in the context of Jason-3

	MLE4	Adaptive
Geophysical parameters	Range, SWH, Sigma0, Pseudo-mispointing	Range, SWH, Sigma0, Pseudo-mss
PTR	Gaussian approximation : look-up tables needed	Real PTR introduced numerically
Likelihood criteria	Least-squared	True MLE

→ **Successfully applied on the Jason-3 ground segment in the context of the GDR-F reprocessing**

Benefits of the "Adaptive Retracking Solution" for the JASON-3 GDR-F Reprocessing Campaign doi: 10.1109/IGARSS47720.2021.9553647 [P. Thibaut et al.]

→ **Successfully applied on the SWIM ground segment.** Published in the context of the CFOSAT mission

Benefits of the Adaptive algorithm for retracking altimeter nadir echoes: results from simulations and CFOSAT/SWIM observation [Tourain et al.]

Application on ENVISAT : The FDR4ALT project

ESA Framework : Long Term Data Preservation Programme (LTDP+)

Reprocessing activity of **ERS-1**, **ERS-2**, **ENVISAT** Altimeter and Radiometer datasets : 23 years of data in total from 1991 to 2012

- ✓ Based on the best state-of-the-art algorithms and corrections
- ✓ Innovative level-1 and level-2P products

The objective is to serve the different communities involved in long term data exploitation for different Earth surfaces

Fundamental Data Records

L1B products containing all the ancilliary and instrumental data used to calibrate the instrument

Thematic Data Products

Level-2P, easy to use, validated products with uncertainties included

Ocean & Coastal Topography | Inland water | Land-Ice | Sea-Ice | Atmosphere | Ocean Waves

Find out more about the FDR4ALT project : Piras et.al, poster session

Application on ENVISAT : PTR management

One of the key aspect of the Adaptive model is the introduction of the real Point Target Response (PTR) numerically

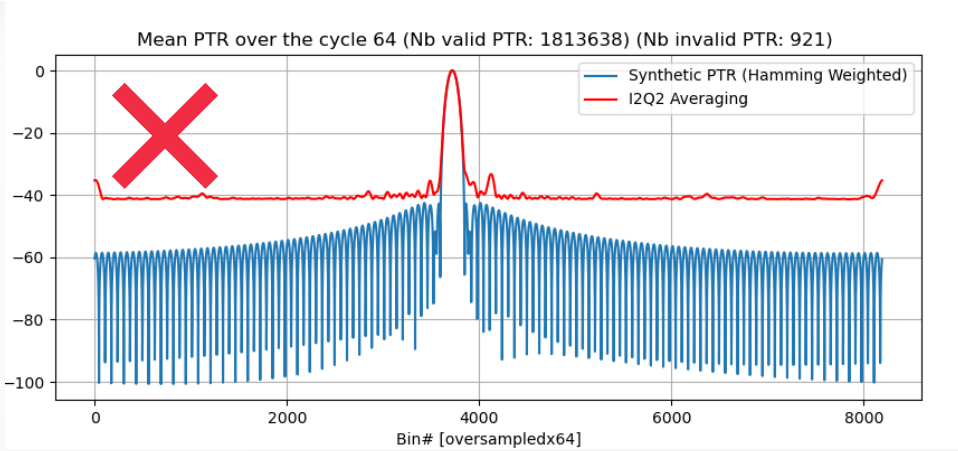
→ Mandatory for studying long-term trends & producing unbiased results (no LUTs).

On ENVISAT, the calibrations are **very noisy** and therefore need to be averaged before numerical convolution in the retracker.

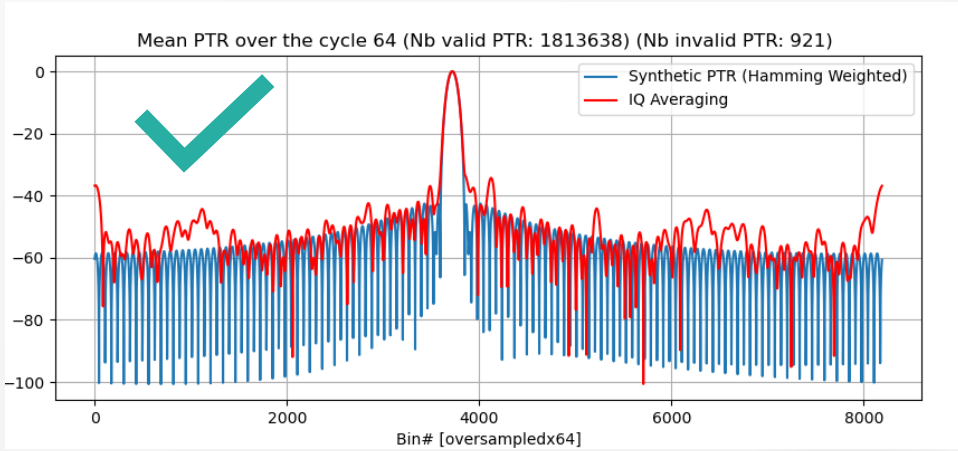
→ A classical averaging at **I2Q2 level** creates an **artifical plateau** and does not produce good results for the Adaptive

→ After investigations, PTR arrays were averaged at **I&Q level** (real and imaginary parts averaged before PTR reconstruction), allowing to recover secondary lobes with no introduction of artificial noise plateau

This PTR averaging was the key to have an optimal version of the Adaptive retracker



I2Q2 averaging



I&Q averaging

Application on ENVISAT : Status at OSTST

Algorithm tuned for other ENVISAT specificities : changing bandwidth, changing reference abscissa ✓

Adaptive part of a Round Robin exercise and selected for the Ocean & Coastal Topography TDP and Ocean Waves TDP ✓

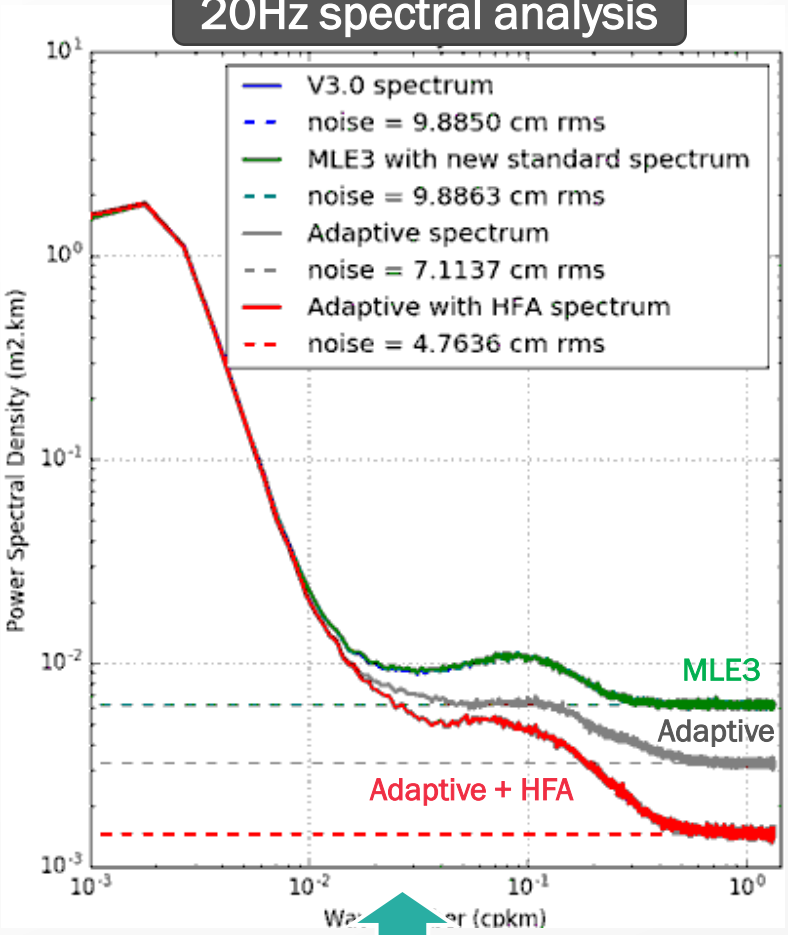
Dedicated Sea State Bias and High Frequency Adjustment (HFA) computed ✓

Applied on the whole ENVISAT mission (10 years) using the CNES facilities (thanks to CNES for that !) ✓

Global validation with excellent results — On-going

Results on ENVISAT : Sea Level Anomaly

20Hz spectral analysis



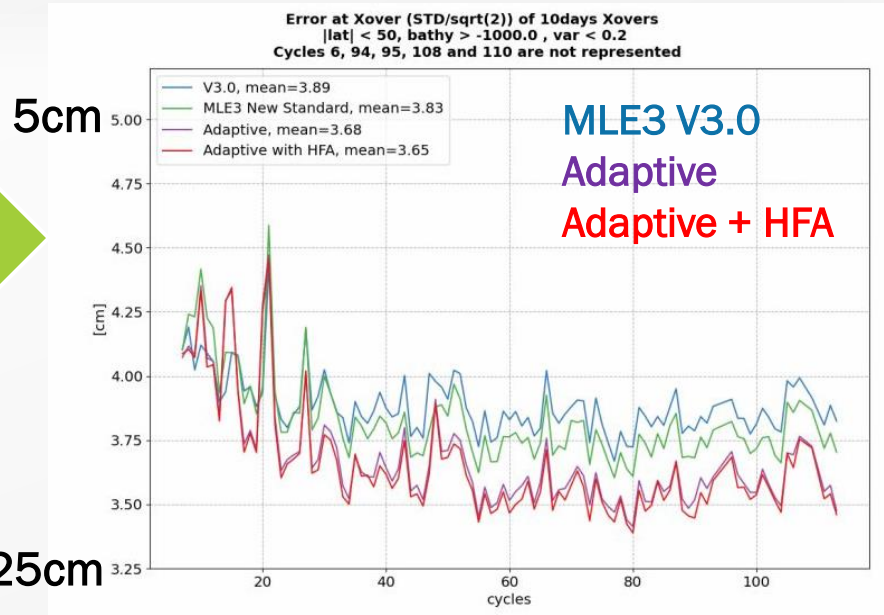
9.89 cm

7.11 cm

4.76 cm

~50% SLA noise reduction between V3.0 and FDR4ALT products !

Error deduced from SSH differences at 1Hz crossovers is significantly reduced, particularly using adaptive retracker outputs.



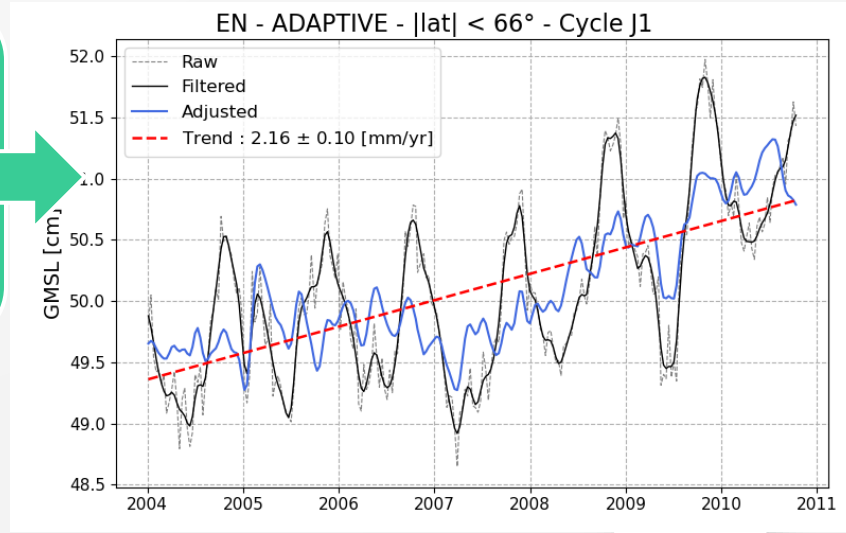
5cm

3.25cm

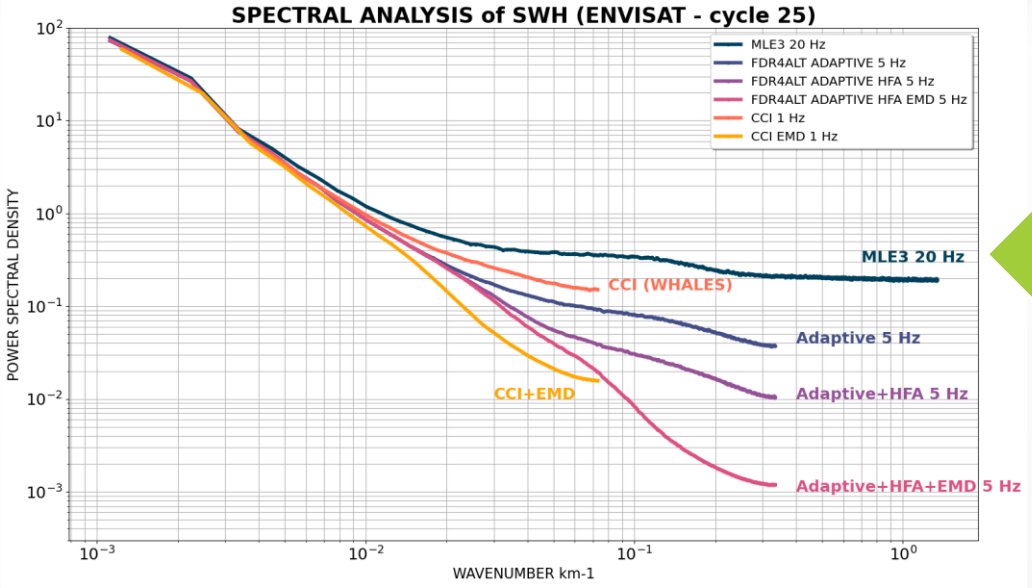
ENVISAT not a reference mission but the new GMSL is closer to Jason-1

V3.0 EN-J1 = 1mm/year

FDR4ALT EN-J1 = -0.52mm/year



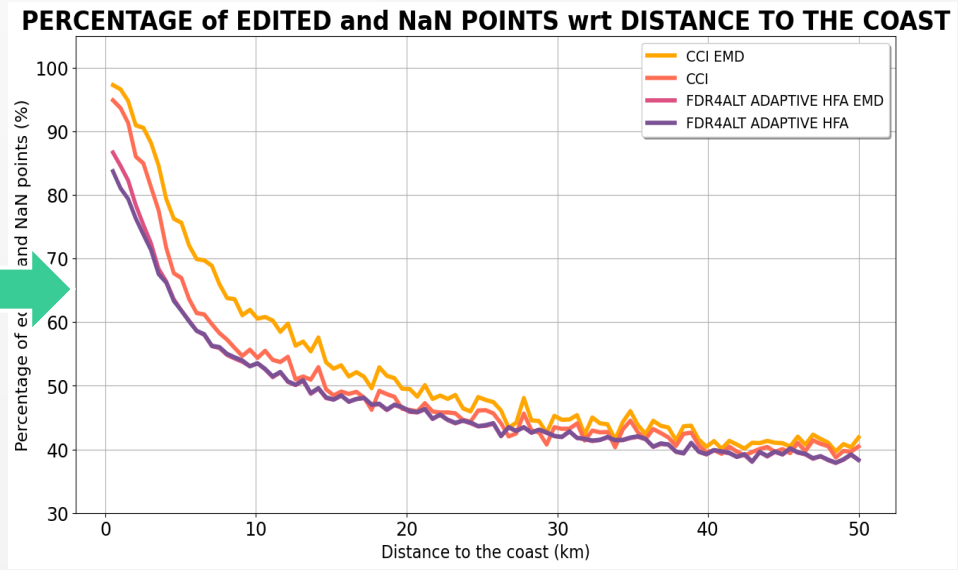
Results on ENVISAT : Ocean Waves



1000km 100km 10km 1km

Large SWH noise reduction thanks to the **Adaptive** allowing to provide SWH at 5Hz
Even better with **HFA** (Zaron et al., Tran et al.) that removes HF errors correlated to SLA

Better approach to the coast with respect to **CCI solutions (WHALES)** and **(WHALES +EMD)**



More information : *see Ollivier et al. talk in Application development for Operations session*

Application on Jason-1 : Jason GDR-F reprocessing

Jason missions are currently reprocessed with a new baseline that includes lots of improvements compared to the previous baseline, including **the Adaptive retracker** *(see dedicated presentation by F.Bignalet, OSTST 2020)*

Jason-3
Poseidon-3B
Reprocessing completed
Adaptive available

Adaptive was initially developed for Jason-3

Jason-2
Poseidon-3
Reprocessing on-going

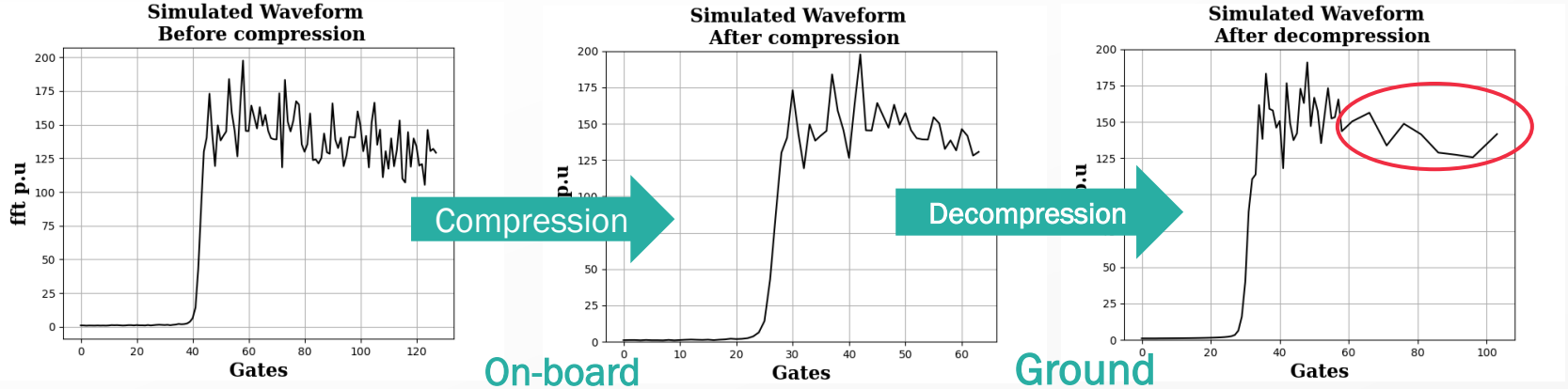
POS3B = twin brother of POS3 : Adaptive is directly applicable on Jason-2

Jason-1
Poseidon-2
Adaptive planned for 2023

POS2 : some specificities related to the instrument must be considered

Application on Jason-1 : Compression/Decompression

Data rate constraints on Jason-1 : waveform was compressed/decompressed



128 samples 64 samples 128 samples

Changes the noise statistics on the **trailing edge**

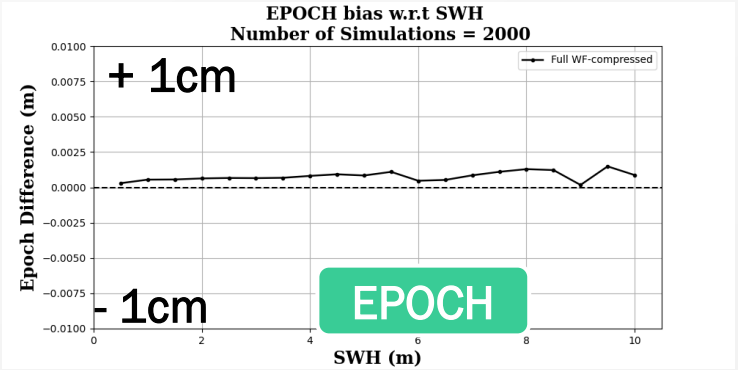
→ The Adaptive takes into account the noise statistics (ENL)

→ What are the impacts on the Adaptive ?

Simulations

The impact of the compression/decompression is negligible on the geophysical outputs (Range, SWH, Sigma0, Gamma)

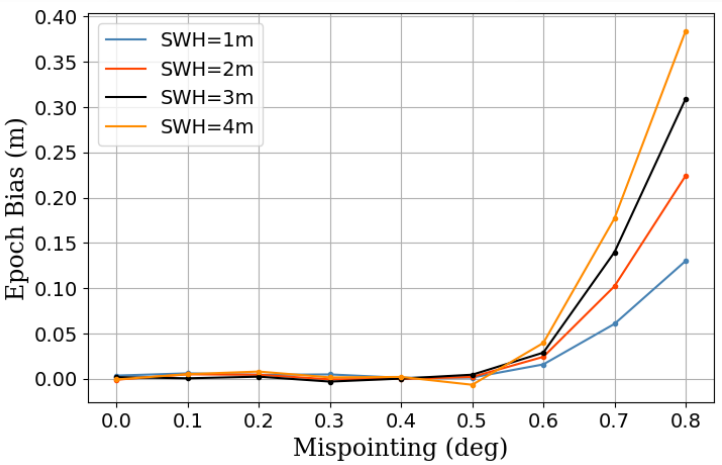
→ **The Adaptive can be applied as such on Jason-1 echoes (no change on the likelihood function)**

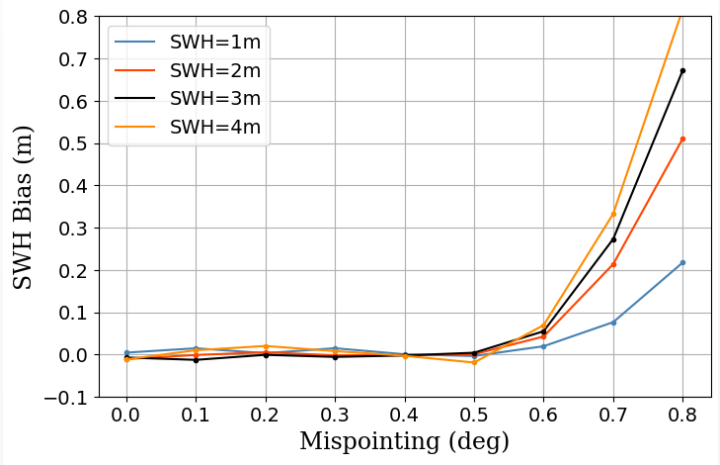


+ idem for SWH, Sigma0 and Gamma

Application on Jason-1 : Platform Mispointing issues

- ✓ Jason-1 had multiple periods of strong **mispointing**
- ✓ The mispointing is an input of the Adaptive RTK but not estimated (ξ^2=0 for Jason-3 and Jason-2)
- ✓ Platform mispointing not available → **Which solutions for the Adaptive algorithm ?**
- ✓ **What are the impacts of real mispointing on the Adaptive outputs ?**





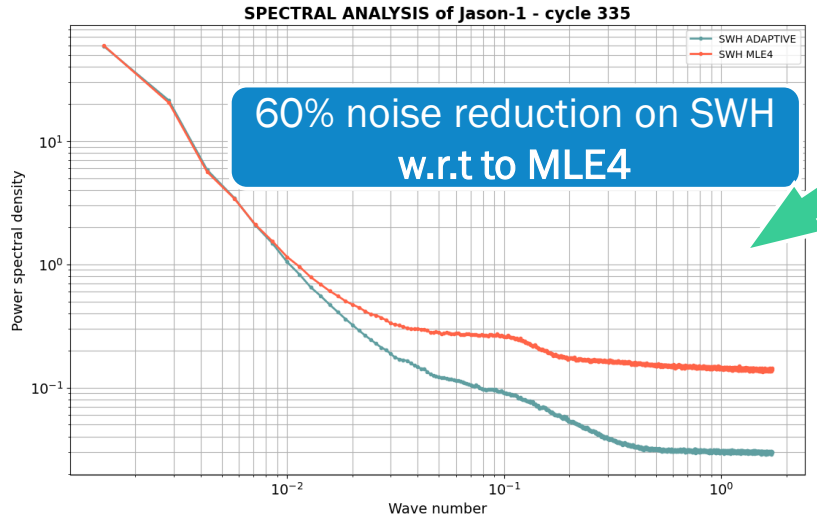
The Adaptive has been applied on simulated **mispointed** echoes

Thanks to the **gamma** parameter that absorbs part of the mispointing, the Adaptive reacts **very well** to mispointing. Impacts on range/SWH are visible only for **mispointing > 0.5 deg (0.2 deg²)**

Different solutions are currently being tested to handle Jason-1 high-mispointing periods (introduction of a filtered MLE4 mispointing, data flagging)....

→ **The Adaptive behaves already very well for mispointing < 0.5 deg (large majority of the dataset)**

Application on Jason-1 : Results on cycle 335

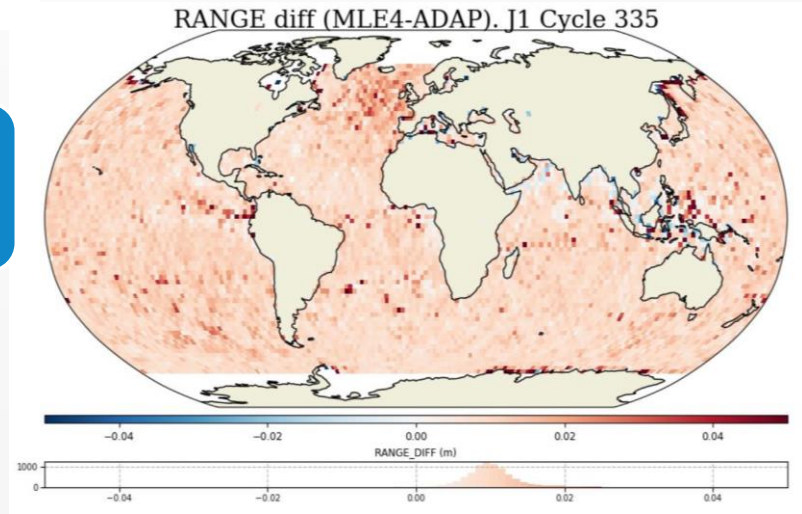


60% noise reduction on SWH **w.r.t to MLE4**

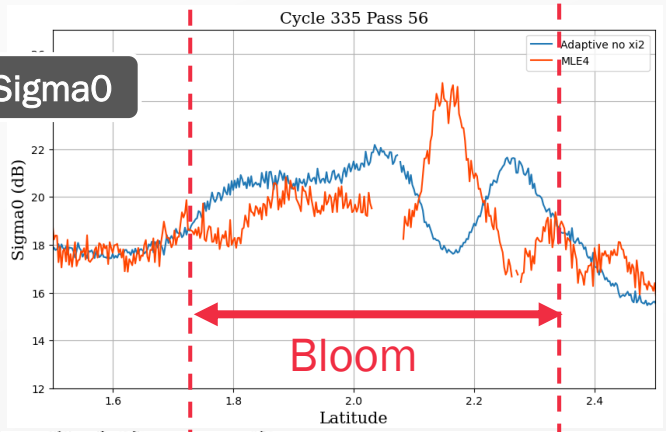
Excellent performances, comparable to Jason-3

Physical Sigma0 on bloom, rains, internal waves ...

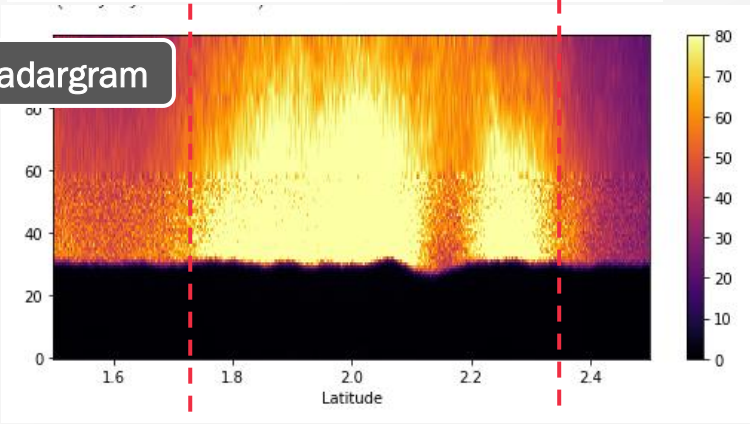
Unbiased estimations of geophysical parameters (no LUTs needed)



Sigma0



Radargram



... and more !!!!

Conclusions & Perspectives (1/2)

→ The major benefits of the **Adaptive** retracker have already been demonstrated and pusblished (Jason-3 and CFOSAT).

→ It now has been successfully applied to two historical missions with **excellent performances.**

ENVISAT (FDR4ALT)

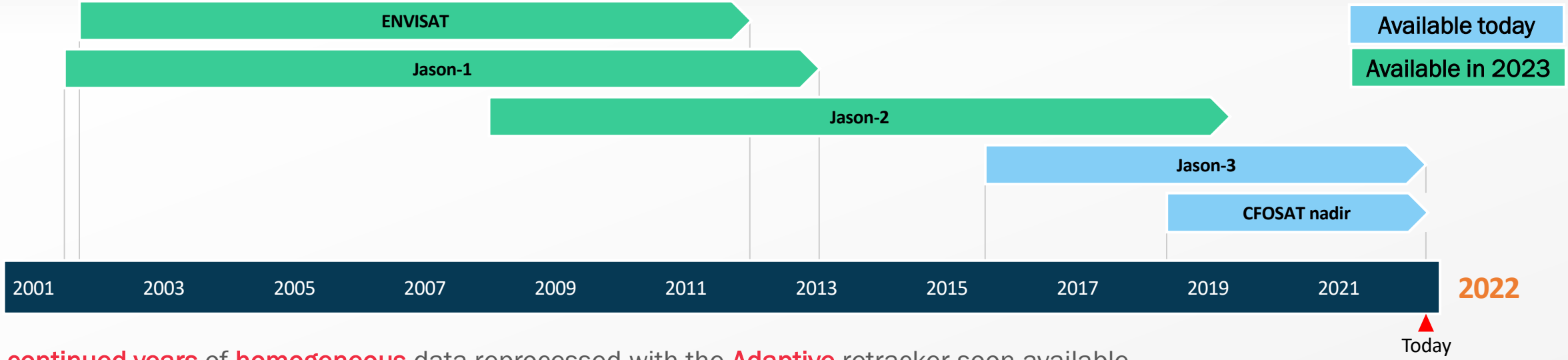
- ✓ Adaptive has been applied thanks to a new averaging method for the PTR.
- ✓ Whole time series have already been reprocessed
- ✓ Fully validated on ocean : performances are excellent
- ✓ Official products will be released ~March 2023

A test dataset is available to any users, contact fpiras@groupcls.com or visit the www.fdr4alt.org

Jason-1 (GDR-F)

- ✓ Impact of the compression/decompression of the echoes is negligible for the Adaptive.
- ✓ Only periods of severemispointing can impact the Adaptive performances : studies on-going to choose the optimal version of the algorithm
- ✓ Preliminary performances are excellent
- ✓ Application on the whole Jason-1 period is planned for 2023

Conclusions & Perspectives (2/2)



- **20 continued years** of **homogeneous** data reprocessed with the **Adaptive** retracker soon available
- **Huge perspectives on different thematics** :
  - ✓ **Global Mean Sea Level** studies that need long datasets (Jason = reference missions)
  - ✓ **Polar Sea Level Anomaly** and **sea-ice freeboard** estimation thanks to ENVISAT
  - ✓ **Ocean waves** : Huge potential of the Adaptive 5Hz (integration planned in Copernicus Marine Service: Wave TAC)
  - ✓ **Internal waves** : the Adaptive detects very well internal waves signatures, as opposed to MLE4 (Magalhães et al, in preparation, S6-JTEX)

... and more !!!!

- Applicable to other current/future missions : S6 LRM, S3 LRM, SWOT nadir, CRISTAL, S3NG ...
- CPU time : Faster version of the algorithm developped and under validation (cf A.Mangilli talk)

Thank you

☺

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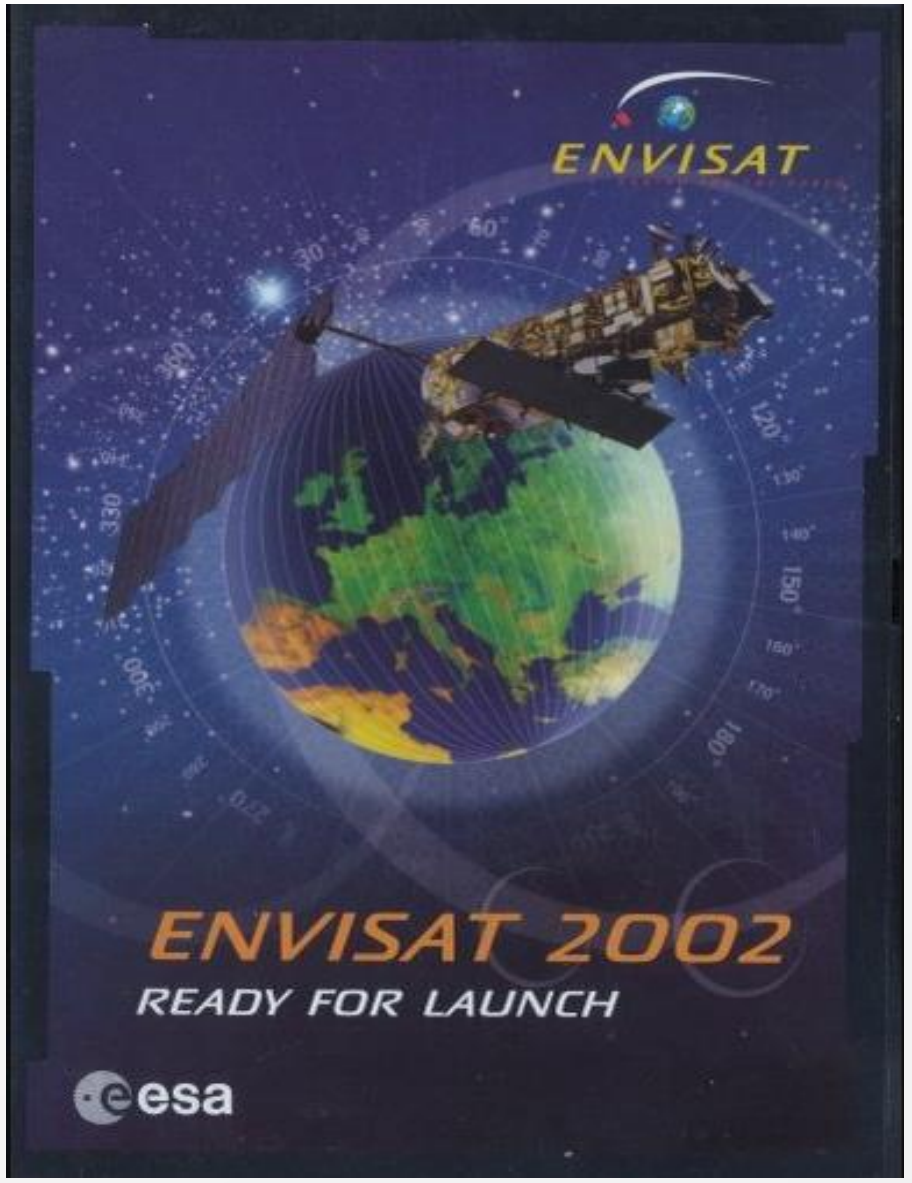

CLS