Lessons learned from Sentinel SARM missions in preparation of Jason-CS – Progress made

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Context

The presentation "Lessons learned from Sentinel SARM missions in preparation of Jason-CS" by Raynal et al. (OSTST 2019) reviewed the **SARM residual small errors** observed with respect to conventional altimetry :

Param	Error	Amplitude	Wavelength
Range & SWH	Swell impact (T02, Dir)	~several cm	<= 10 km
Range	Meridional wind speed effect	2 cm	>100 km
SWH	Wave height dependency	10/15 cm	>100 km
SWH	Swell dependency	5/10 cm	>100 km
SWH	waveform centering dependency	10 cm	> 100 km
Sigma0 / WS	Radial velocity dependency	0.1 dB / 30 cm/s	> 100 km
Range	Temporal drift	1 mm/y	> month
?	others	?	?

Context

The presentation “Lessons learned from Sentinel SARM missions in preparation of Jason-CS” by Raynal et al. (OSTST 2019) reviewed the SARM **residual small errors** observed with respect to conventional altimetry.

Investigations have been performed this year within the MPC framework to understand and correct these limitations.

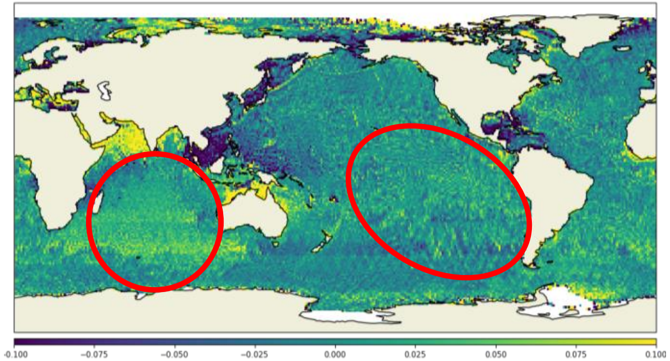
In these slides, we present the progress made in the understanding of Sentinel-3 processing. The following topics are addressed :

- SARM sensitivity to the echo centering
- SARM range drift (CNES/MPC activities)
- PLRM pulses alignment
- SARM SWH update in IPF SM2 V06.18

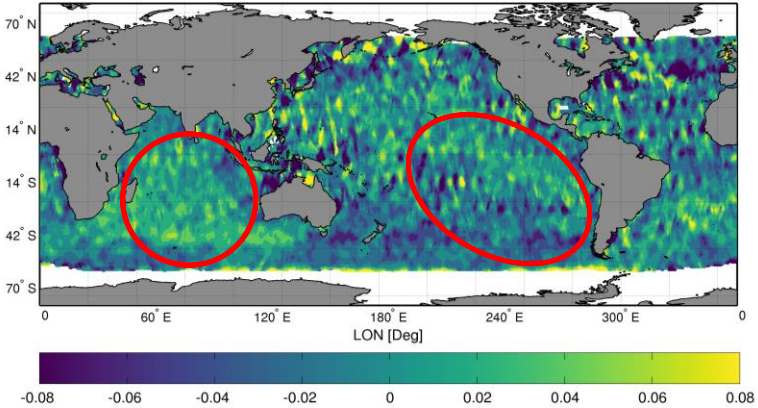
SARM sensitivity to the echo centering

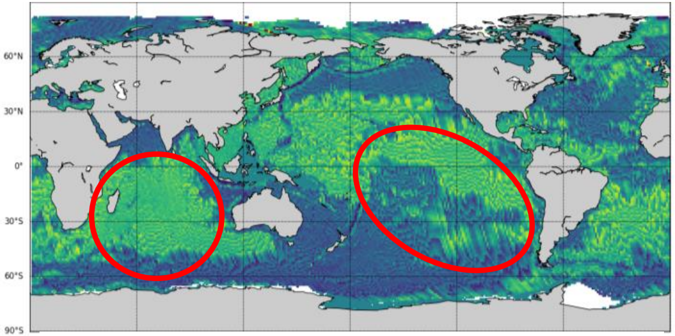
SARM sensitivity to the echo centering

(1) SWH SARM/PLRM difference for S3A OL : Ascending tracks grid – Descending tracks grid (m)



(2) SWH difference during tandem phase : SARM S3A in OL – SARM S3B in CL (m)





(3) Epoch on Ascending tracks (m)

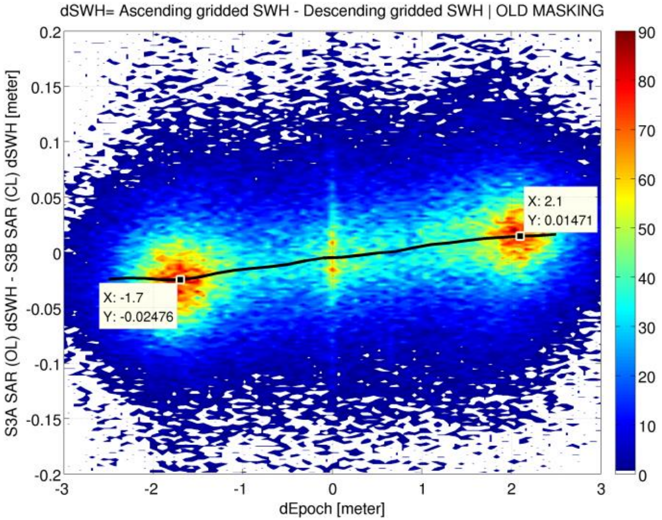
When SRAL operates in OL mode, SARM parameters show a **sensitivity to the echo centering** (epoch). It is visible here when comparing SWH SAR OL to P-LRM or SWH SAR OL to SAR CL during the tandem phase. See Raynal et al., OSTST 2019, effect is about few mm on range and few **cm** on SWH.

Note: with the S3 2020 reprocessing (using IPF SM2 V06.18), the correlation to the echo centering has been reduced for SARM SWH but are still visible (fig. 1) .

SARM sensitivity to the echo centering

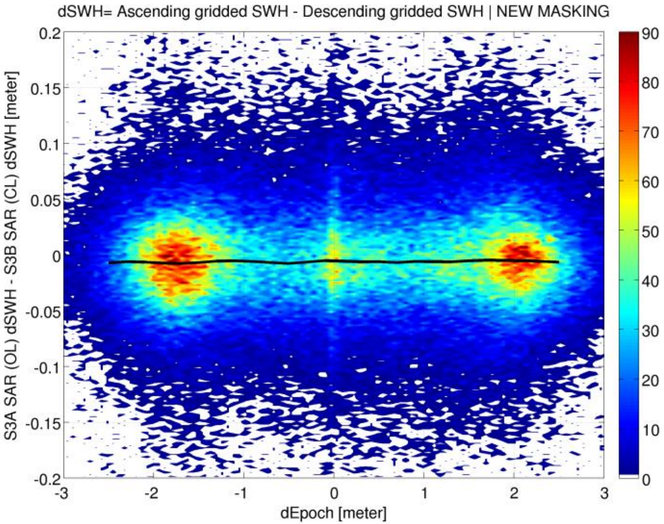
In OL mode, the waveform is moving within the tracking window (variations of the surface height above the reference surface (MSS) encoded in the OLTC). However, the zero-masking algorithm applied in S3 STM PDGS SAR (SAMOSA) retracking uses a **static mask** which does not allow to follow the vertical movement of the stack and lead to errors in the SRAL parameter estimations.

SARM SWH difference during tandem phase :
S3A in OL – S3B in CL
using static masking

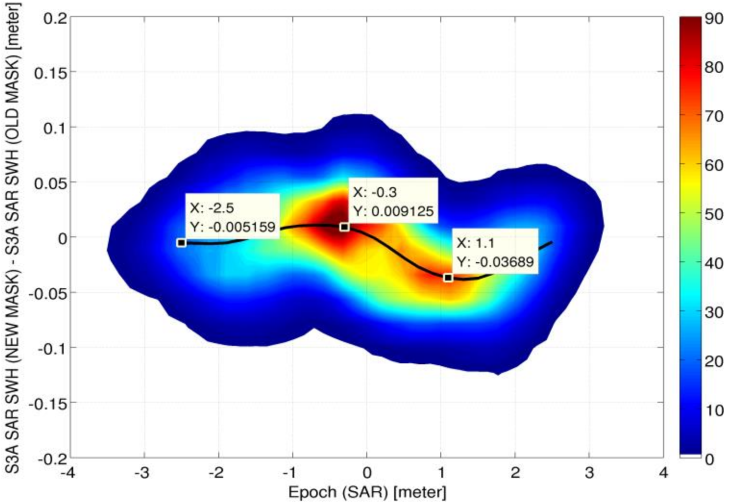


Recent study by Dinardo S. et al shows that the use of a **dynamic exact masking**, following the stack movement, allows to remove these errors.
Effect of the dynamic masking on SAR SWH is around 5 cm -> same error magnitude as observed from tandem phase

SARM SWH difference during tandem phase :
S3A in OL – S3B in CL
using dynamic masking

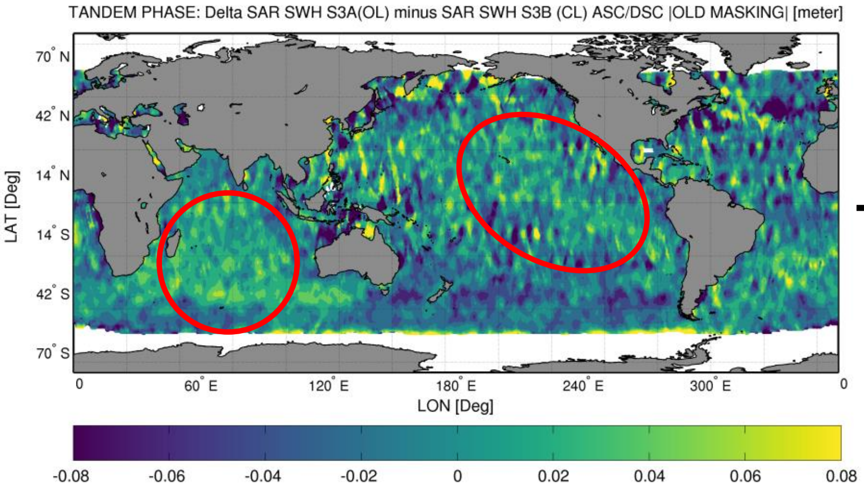


SARM SWH difference : using static masking minus using dynamic masking

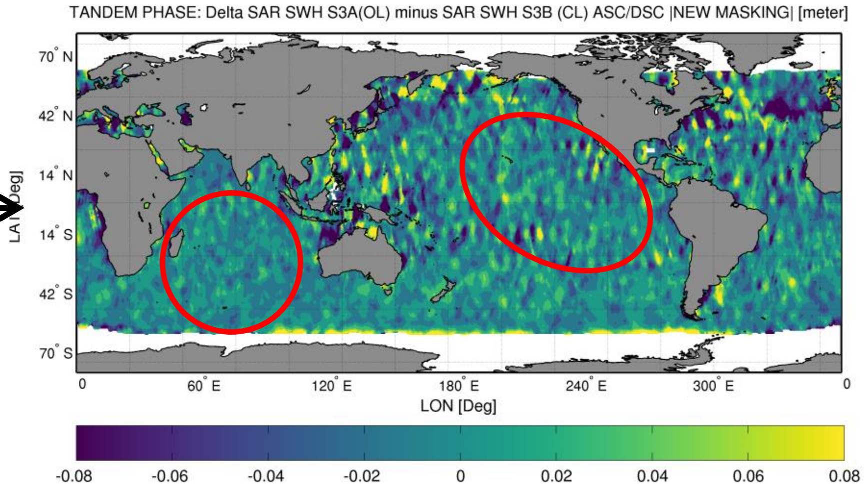


SARM sensitivity to the echo centering

Static Masking



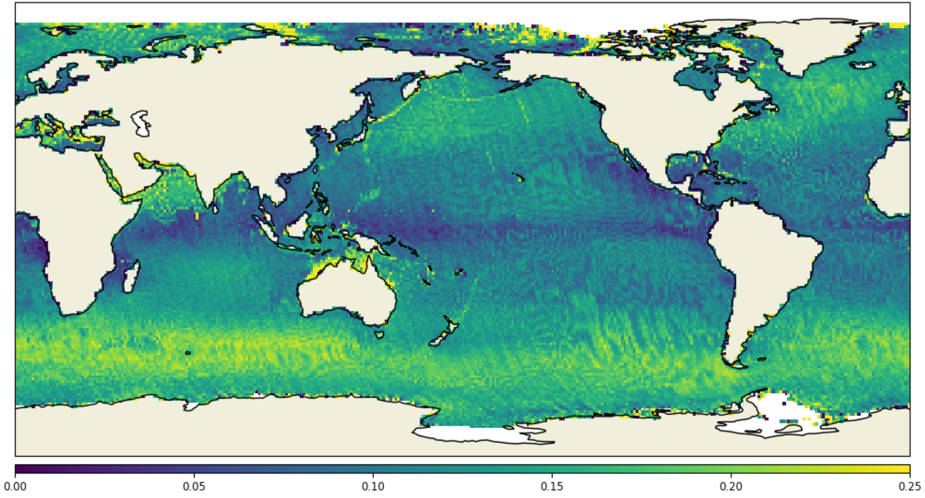
Dynamic Masking



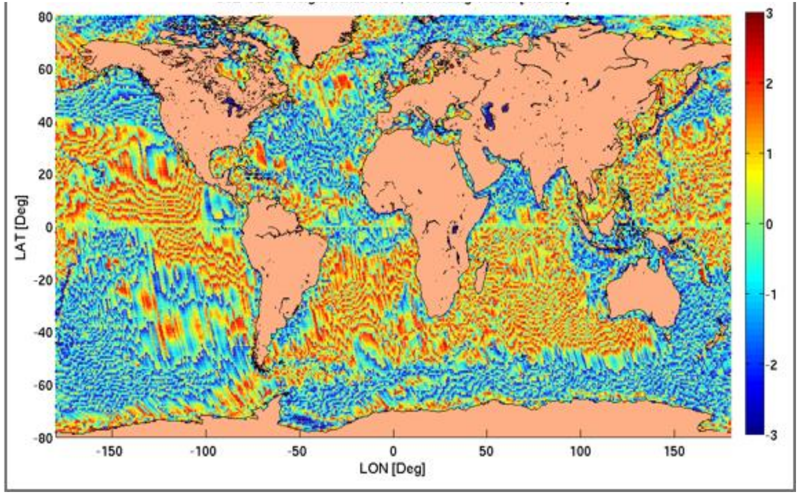
Dynamic masking removed the large-scale patterns correlated to the echo centering.

SARM sensitivity to the echo centering

SWH SARM/PLRM difference for S3A OL
Over ascending tracks (meter)



S3B OLTC height – MSS over ascending tracks (meter)



Dynamic masking has proven to correct SARM sensitivity to the echo centering at large scale.

However smaller scale sensitivity has also been detected with variation up to 10 cm, as shown on the maps here. The same sensitivity is observed for S3A and S3B.

The effect of the dynamic masking on these small scale variations is under testing.

SARM Range drift investigation and correction

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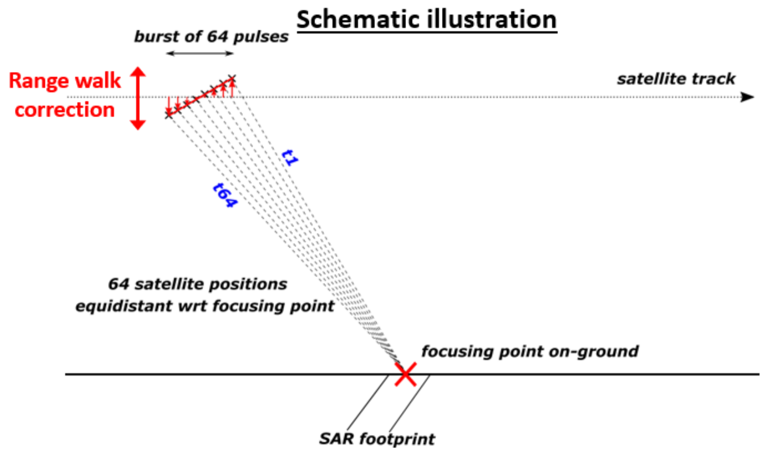
A significant drift has been detected on the S3A SAR GMSL trend: **about +1.3 mm/year** with an uncertainty of **0.4 mm/yr (68% CL)** *(Ablain et al. presentation OSTST 2020)* ➔ ***Understood***

- 0.3 mm/year are due to the evolution of PTR shape in range direction (ageing of the instrument) not correctly accounted for in the MLE4 (PLRM) and SAMOSA DPM2.5 (SARM) retrackers *(JC.Poisson / S.Dinardo OSTST 2019).* Retrackers using the **real instrument PTR** allow to correct this effect (eg: adaptive retracker, see P. Thibaut et al. presentation in instrument processing session)

- About 1.3 mm/year are due to the evolution of PTR shape in azimuth direction (ageing of the instrument). A recent study **(see J. Aublanc et al. presentation in instrument processing session)** showed that the implementation of the **range walk correction** (Scagliola et al., 2019) allows to correct the range drift induced. Only the SARM is impacted.

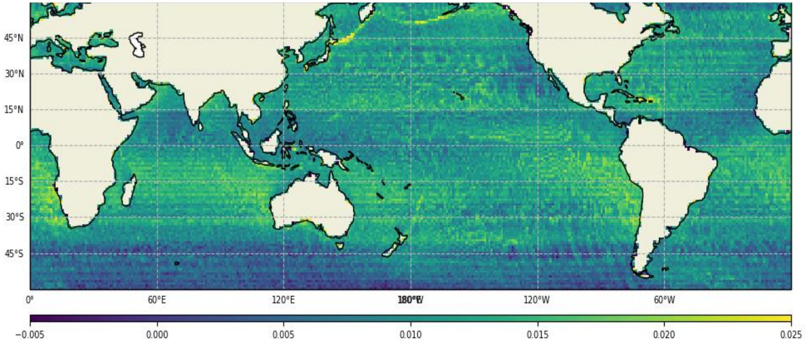


Objective of the range walk correction : *to compensate the range variation during the burst acquisition wrt focusing point.*

PLRM Pulses alignement

PLRM pulses alignement

SARM/PLRM Range difference on Ascending tracks (m)



Comparing SARM/PLRM range, **latitudinal effects** are observed. After investigation, J. Aublanc et al. has proved that part of the error comes from **PLRM** processing.

During the PLRM processing, the IPF performs on ground the alignments of the 256 individual pulses contained in a radar cycle. To generate PLRM waveforms it is necessary to

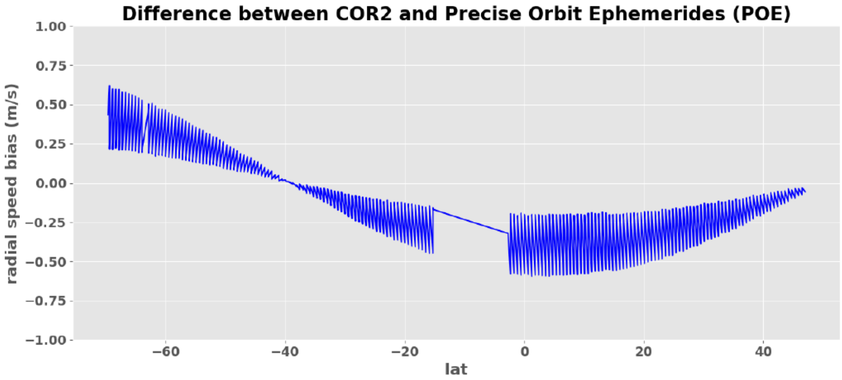
- Align the 64 pulses within bursts
- Align the 4 bursts together
- Adapt the PLRM tracker range to the measurement dating to position it at mid cycle (and the corresponding satellite altitude)

PLRM pulses alignement

Approximations in the PLRM pulses alignment have been detected :

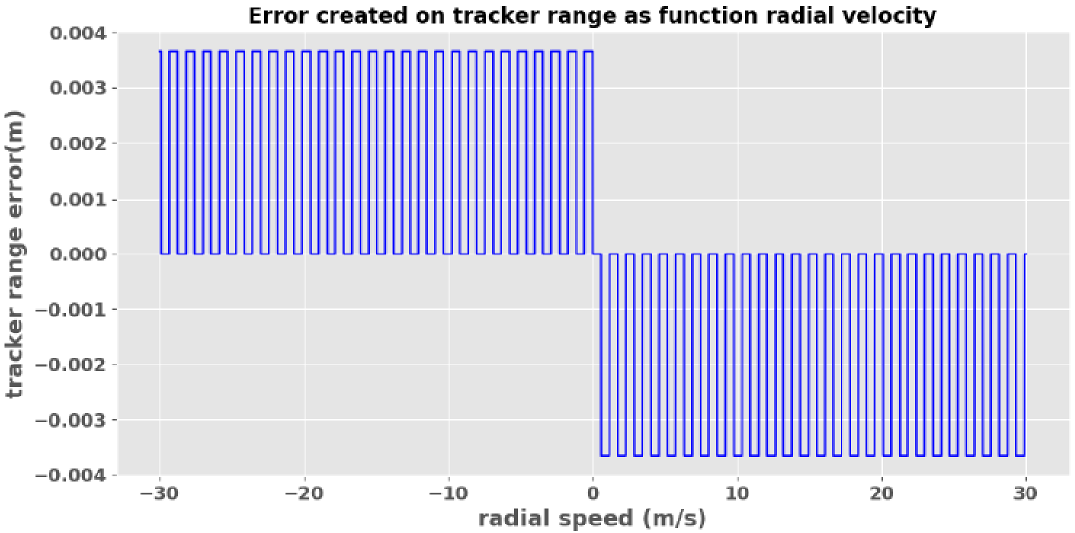
1. An accurate estimation of the satellite vertical velocity is mandatory to perform pulses alignment. In the IPF, the vertical velocity is estimated using COR2 value. Comparison to precise orbit highlights a **lack of accuracy of the on-board COR2** => Errors between [-0.5 : +0.5 m/s] in vertical velocity (see fig.).

2. A **mathematical truncation is applied to COR2**. It is mandatory for the IPF to derive the Coarse Altitude Instruction (CAI) applied by the altimeter (CAI being the burst tracker range). But, once the on-board CAI is computed, it is possible to recompute more accurate FAI to align pulses together (and cancel the effect of this mathematical truncation). => Errors between [-0.6 : 0 m/s] in vertical velocity



PLRM pulses alignement

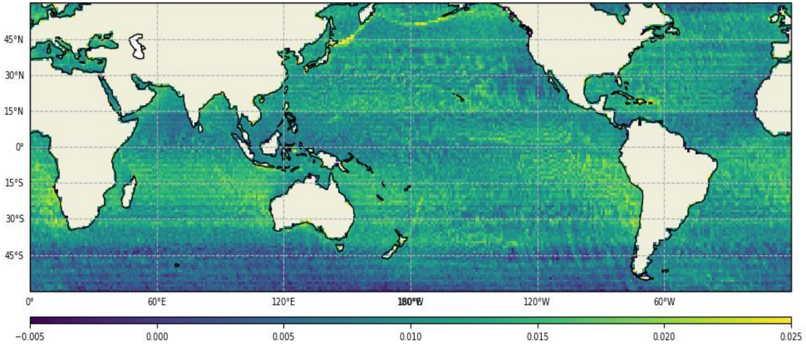
In addition, an **anomaly** was detected in the computation of the PLRM tracker range: a **mathematical truncation in the IPF PLRM tracker range approximation** has been spotted with no rational explanation. The error created on PLRM tracker range depends of the satellite vertical velocity (COR2).
SARM is not concerned.



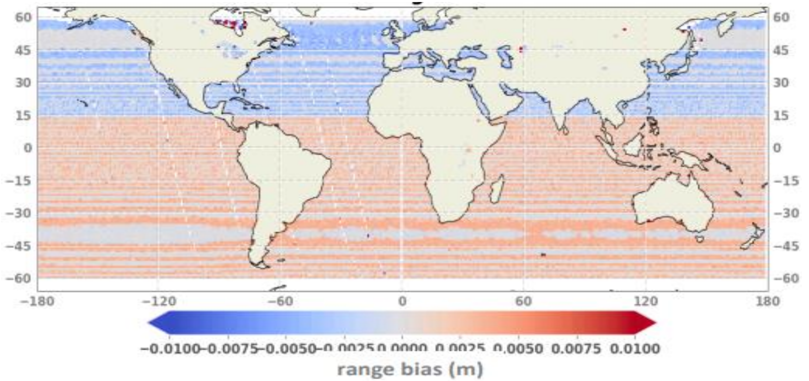
While the impacts created by vertical velocity inaccuracy remain relatively limited in the PLRM estimates (sub-mm bias in range, sub-cm bias in SWH), the **anomaly detected and removed in the PLRM tracker range can create errors of ~3.5mm in the PLRM range**.

PLRM pulses alignement

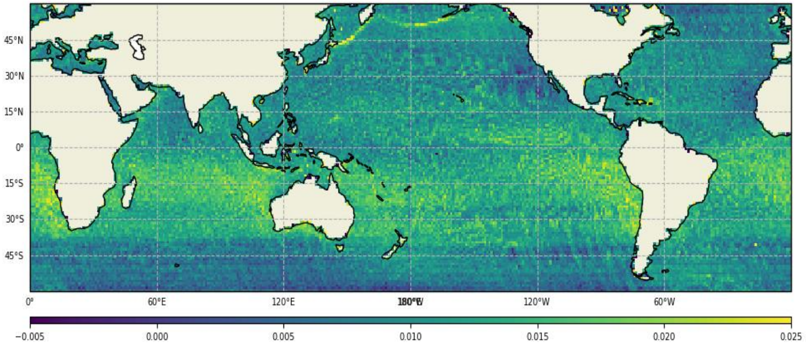
SARM/PLRM Range difference on Ascending tracks grid



Range bias between IPF and prototype on Ascending tracks



SARM/PLRM Range difference on Ascending tracks grid
After first guess correction



All approximations/anomalies have been corrected within an IPF prototype. Maps of the PLRM range bias between IPF and prototype show as expected latitudinal patterns with ~3mm amplitude, due to the correction of the tracker anomaly. The impact is predominant wrt the 2 other approximations corrected .

Applying this first guess correction maps to SARM/PLRM range maps shows a clear improvement (most latitudinal lines removed).

SARM SWH update in IPF SM2 V6.18

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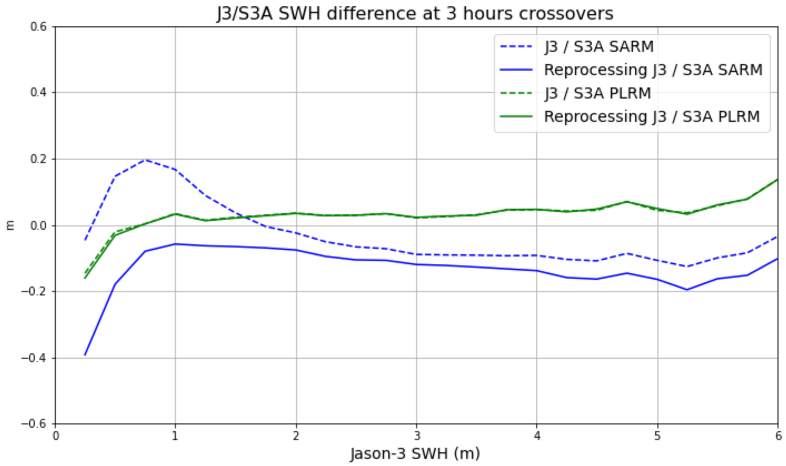
In the IPF SM2 V6.18, SAMOSA DPM 2.5 SWH fitting routine has been updated in order to improve low SARM SWH estimation. This IPF version has been used in the 2020 Sentinel-3 full mission reprocessing.

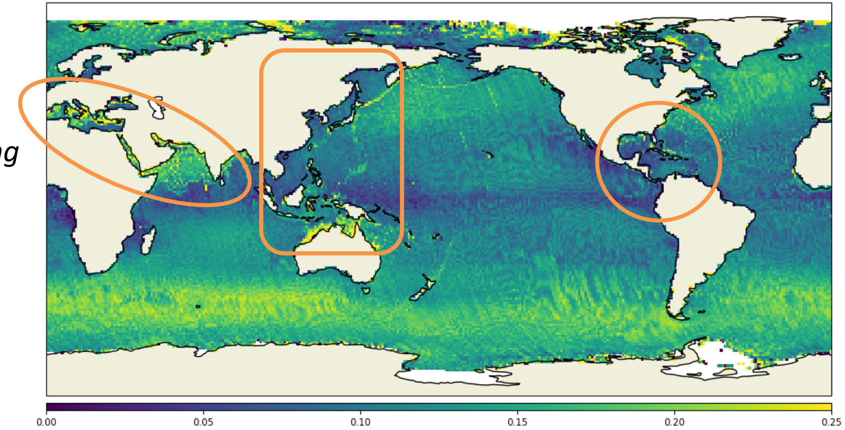
Comparing reprocessing dataset to previous dataset, we observed:

- A global bias of + 8cm on SARM SWH between the two datasets
- Low and negative SARM SWH now possible.
- A reduction of the dependency to low wave (see blue solid line on the figure)

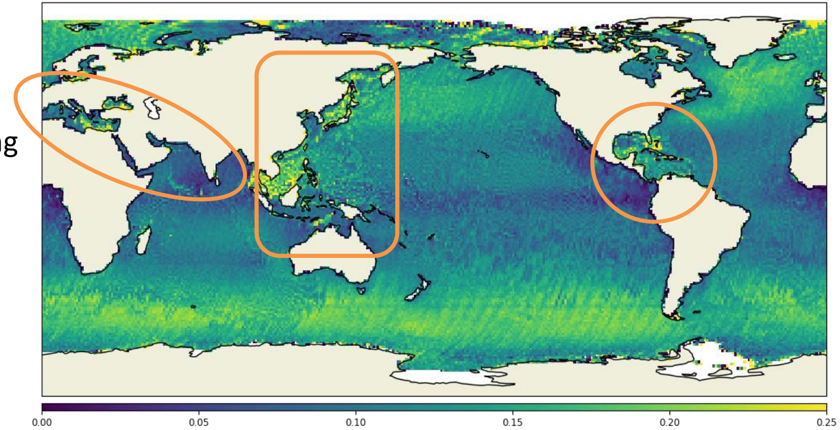


SARM SWH update in IPF SM2 V6.18

Ascending tracks



Descending tracks



SARM/PLRM SWH difference (m)

Previous slide shows an improvement in SARM SWH estimation for low wave heights at global scale.
However, abnormal difference between ascending and descending tracks in low SWH areas are observed. This was not the case before the reprocessing (before SAR fitting routine update).

It is normal to have higher differences in zones of low SWH as PLRM SWH minimum value is 0.5m and SARM SWH can now be negative. But different patterns between ascending and descending tracks are not expected.

→ **Under investigation**

Conclusion

Significant progress have been made this year in the understanding of Sentinel-3 SARM and PLRM processings:

- ✓ The SARM range drift origins have been identified and corrections have been determined.
- ✓ The origin of SARM sensitivity to echo centering at large scale has also been clarified and a
- ✓ Approximations and errors in the P-LRM processing have been detected ➔ reduce partially the SARM/PLRM range difference geographical (latitudinal effect)

Conclusion

Summary of the SARM residual small errors observed with respect to conventional altimetry

Param	Error	Amplitude	Wavelength
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✓ SWH	waveform centering dependency	10 cm	> 100 km **Understood**
Sigma0 / WS	Radial velocity dependency	0.1 dB / 30 cm/s	> 100 km
✓ Range	Temporal drift	1 mm/y	> month **Understood**
Range	Latitudinal effect in SARM/PLRM difference	~3 mm	> 100km **Reduced after PLRM correction**
?	others	?	?