Open-Sea CRYOSAT-2 Data in SAR and PLRM Mode in the South East Pacific and North East Atlantic

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Abstract

This work aims to generate, validate and analyse the altimetric geophysical parameters measured by the CryoSat-2 in SAR and PLRM Mode during one full year in the temporal interval 10/2012-10/2013 in the South East Pacific box and North East Atlantic box at distance to coast larger than 10 km (open-sea).
The reason to have both the aforesaid regions of interest is to make the analysis both in a very calm region (as the Pacific Ocean) and in very dynamic region with high seasonal variability (as the Atlantic Ocean).
The CryoSat-2 Data have been Delay-Doppler processed as from the FBR to Level 1B and subsequently re-tracked using the SAMOSA's SAR Echo Model (full solution) and a curve-fitting scheme based on Levenberg-Marquard Least Square Minimization Algorithm. The Delay-Doppler processing (L1B) and the re-tracking processing (L2) has been carried out by the EOP-SER Altimetry Team at ESA/ESRIN (GPOD Service).
In the open ocean analysis, Hamming function is not applied to the collected burst data. The zero-padding prior range-FFT is applied and an extended vertical swath window is used to mitigate the on board tracker shift errors.
In the SAR data processing the altimeter wind speed is derived using the wind model used for the Envisat mission and correcting for a little sigma nought bias to align CryoSat absolute backscattering to Envisat absolute backscattering.
Along with multilooked return waveform, also the RIP (Range Integrated Power) is built from the stack and fitted in order to retrieve significant geo-parameters (slope, mean square slope, skewness).
Finally, a sea state bias solution is built for the two areas of interest gridding the residuals elevation from mean sea level in the space SWH-Sigma Nought.
Sea surface height (SSH), sea level anomalies (SLA), significant wave height (SWH) and wind speed at 10 meter from sea surface (U10) at 20 Hz and 1 Hz are derived and cross-compared against PLRM L2 data, as generated by TU Darmstadt (TUDa).
TUDa L1b PLRM data are retracked both using a conventional Brown model with a Look up table (LUT) and a convolutional numerical model, without approximating the radar Point Target Response (PTR),. The numerical retracking in PLRM will allow to estimate possible biases and systematic trends between SAR mode and PLRM mode and to highlight any eventual imprecisions in the SAR re-tracking scheme.
Performance metrics and plots to measure the quality of the results (as scatter plots, cross-correlations, standard deviations, temporal monthly differences, regression slopes, performance curves, histograms and color-coded density plot) are built between the SAR/PLRM CryoSat-derived measurements or models.. For SLA the reference mean sea level surface is DTU13.
We compare both SAR and PLRM wave height and wind speed results with numerical models results. The low sea state conditions in the North East Atlantic are well suitable to assess the capability of the SAR Altimetry to accurately retrieve wave heights, also at the low end of the sea state spectrum.
Given the long time period of interest (one year) and long extension of the passes in the areas of interest, it will be possible to compute averaged wavenumber spectra of each of the retrieved geophysical parameters. This exercise will be mainly carried out in the South East Pacific region, whereas in the North East Atlantic we will attempt to assess any impact of seasonal phenomena (as swell fields) in the SAR data, making temporal monthly differences between SAR and PLRM wave heights.

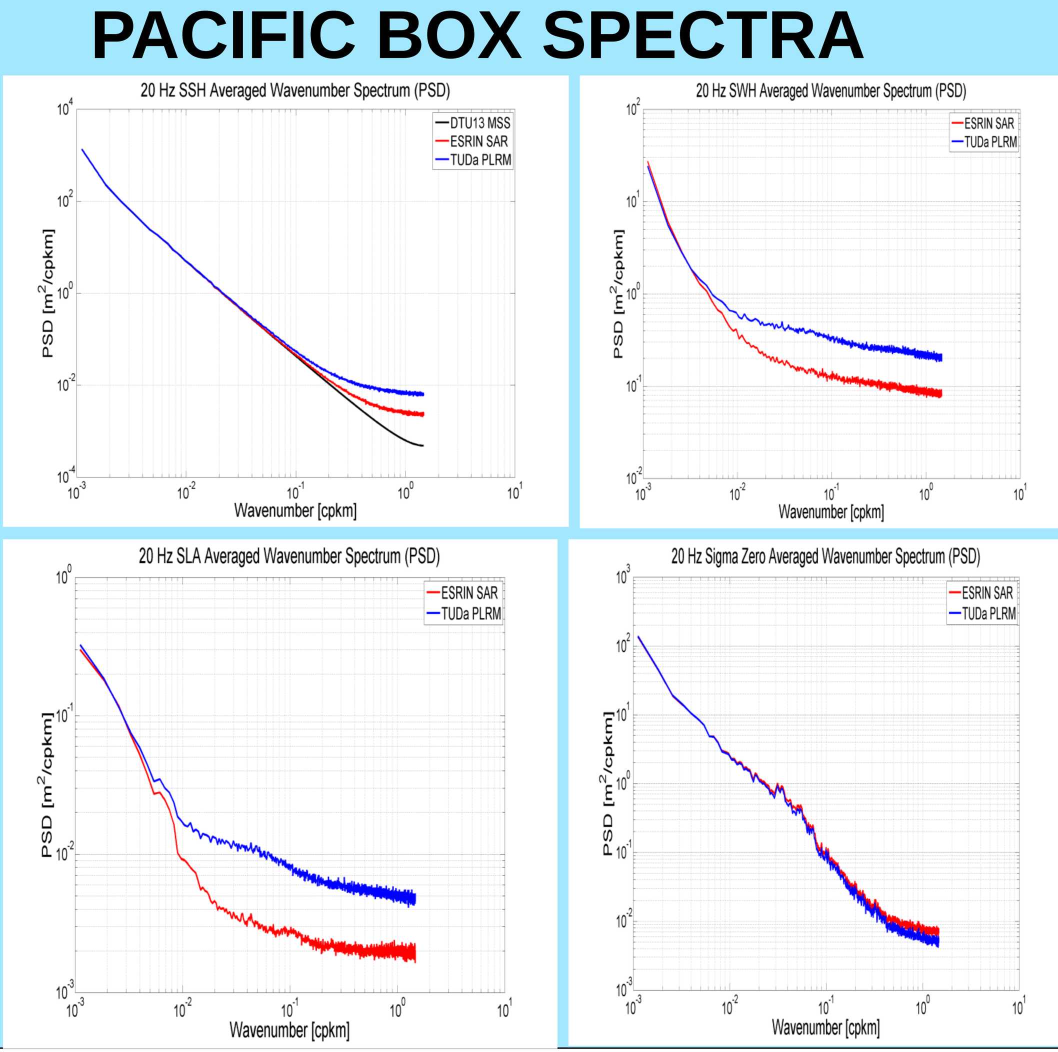
THE SAR AND PLRM PROCESSING

The SAR data at 20 Hz have been generated by the ESA-ESRIN EOP-SER Altimetry team starting from CryoSat-2 FBR (Full Bit Rate) data level with following options: Hamming Weighting **NO**, Zero-Padding **YES,** Extended window **YES**.
The SAR retracking scheme uses a bounded Levenberg-Marquardt Least-Squares Estimation Algorithm (LEVMAR-LSE) based on the **SAMOSA2 SAR Waveform Analytical Model**. The retracking processing consists of the estimation of the three parameters epoch, amplitude and SWH. Also the SAMOSA2 model uses a Gaussian approximation for the instrumental squared PTR. In order to mitigate the effect of this approximation, a dynamic value is extracted from a pre-calculated Look Up Table (LUT) function of SWH and ingested at runtime in the SAMOSA2 model. A zero-padding has also been applied during the SAR L1b processing, thus a more precise SWH estimation in SAR mode for low waves is expected.
The PLRM data at 20 Hz have been produced by TUDa in several flavours (using the Brown model with a LUT or a **numerical convolutional model**). The retracking scheme for the PLRM waveforms is an un-weighted Least Square Estimator derived from Maximum Likelihood Estimator. The three parameters epoch, amplitude, and slope of the leading edge are estimated.

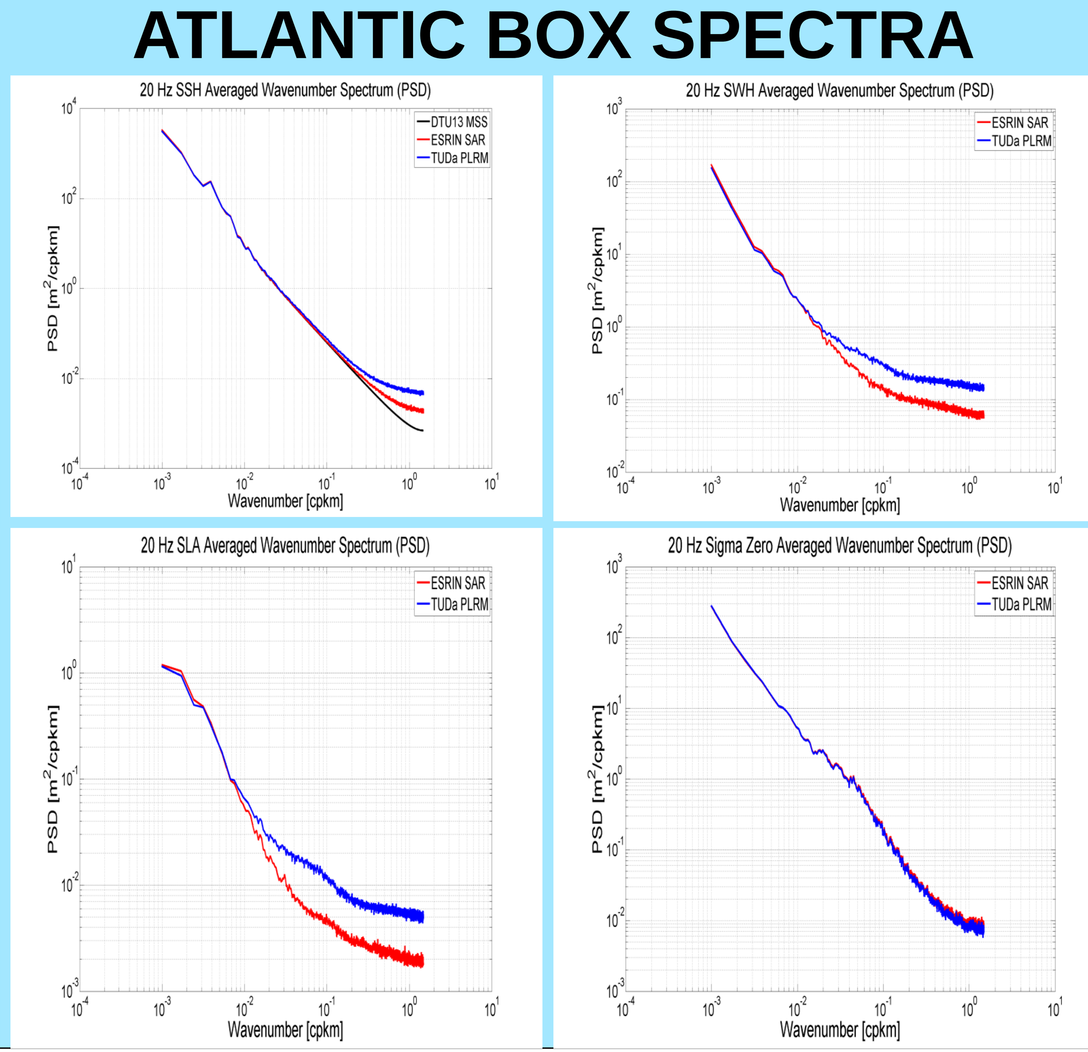
WAVE-NUMBER SPECTRA IN THE ATLANTIC AND PACIFIC BOX

In this box, we present the averaged wave-number spectra for the North-East Atlantic and South-East Pacific SAR region in the time frame 2012/10 and 2013/10 for SAR and PLRM dataset.
The spectra plots highlight the clear improvement, in term of measurement noise, provided by SAR mode with respect to TUDa PLRM for Sea Surface Height (SSH) and Wave Height (SWH). In black , as reference, we plot the Mean Sea Surface (DTU 13) for SSH spectrum. The sigma zero spectra are basically identical in SAR and PLRM mode.
In order to compute the spectra, an operation of data editing has been applied on TUDa PLRM data and on SAR data to rule out all the contaminated data (land, alga blooms, rain events, ships, etc.) .

PACIFIC BOX SPECTRA



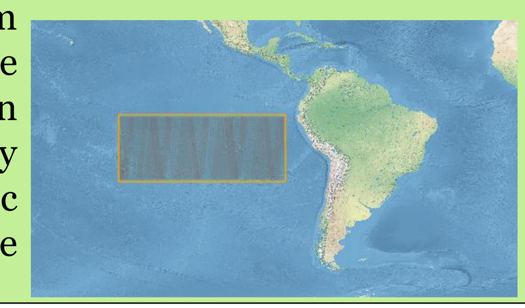
ATLANTIC BOX SPECTRA



THE DATA SET: 1 YEAR IN THE PACIFIC AND ATLANTIC BOX

In this box, we show the chosen area of interest and the CryoSat-2 passes used to carry out the inter-comparison exercises. Data from one year (10/2012-10/2013) have been analysed. The coastal zone data are ruled out from this study. This areas has been selected in order to analyze the performance of the instrument either in a very cal m region (Pacific box) either in a very dynamic region (Atlantic box) where all the SWH regimes (very low and very high) are encountered

South-East Pacific

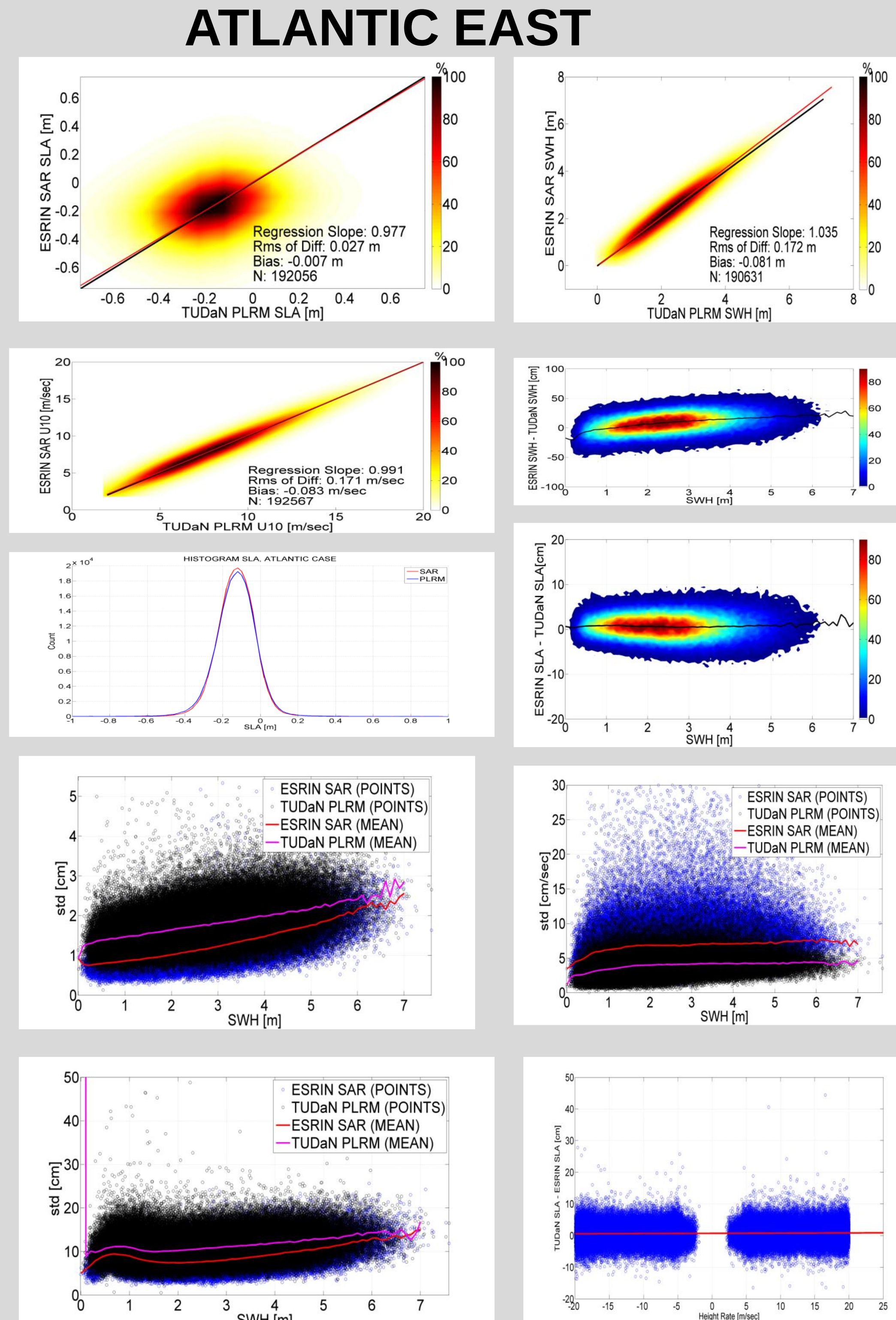


North-East Atlantic

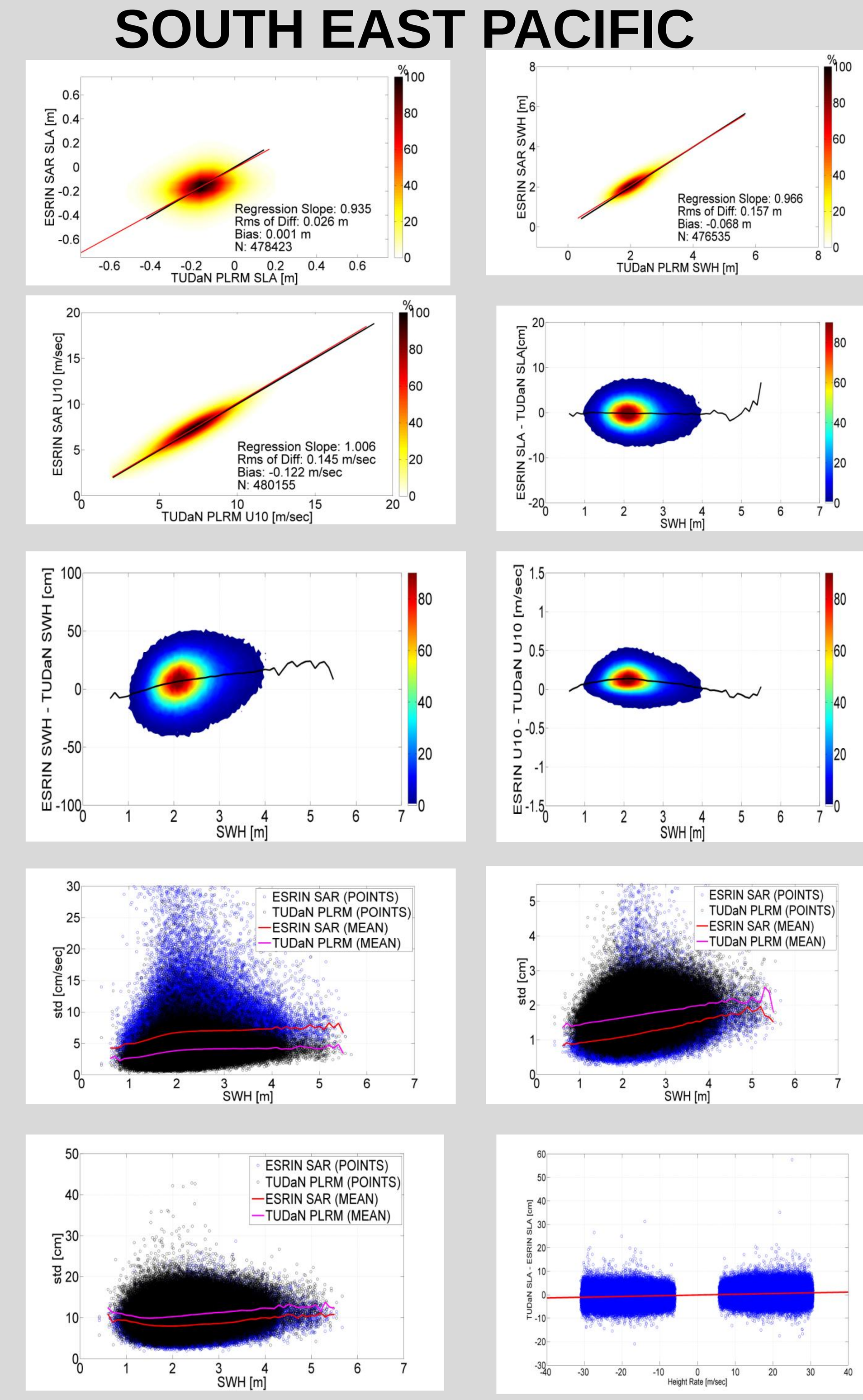
THE SAR-PLRM CROSS-VALIDATION RESULTS

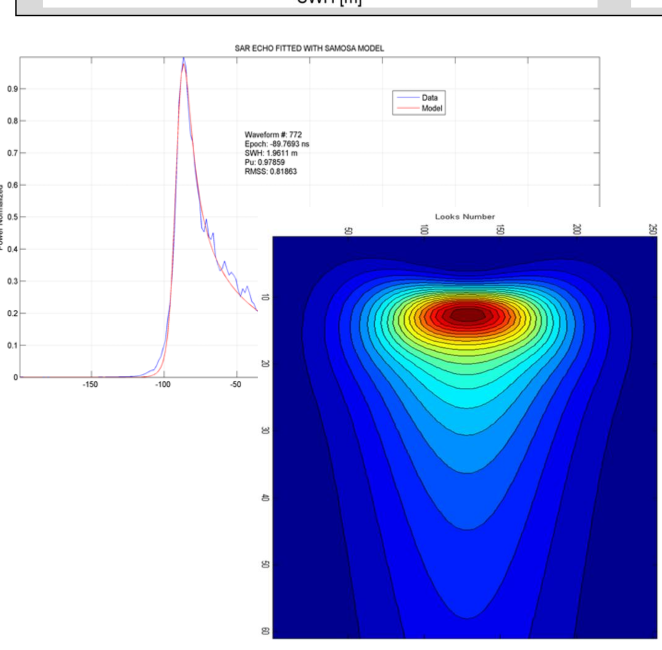
In this box, we present some plots that highlight the consistency between PLRM measurement (numerical convolutional model) from TUDa and GPOD SAR measurements for SLA, SWH, U10. The consistency is quite good between SAR and PLRM even for low SWH (see scatterplots and histograms). Further, the performance curves (std vs. SWH) are shown for SLA and SWH that demonstrate the higher precision of SAR measurements with respect to PLRM.

ATLANTIC EAST



SOUTH EAST PACIFIC

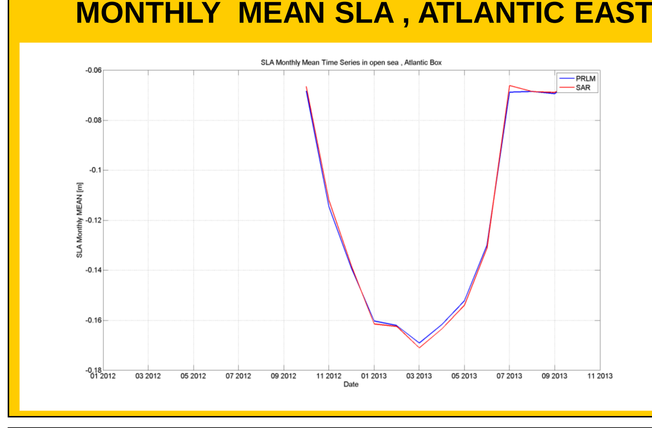




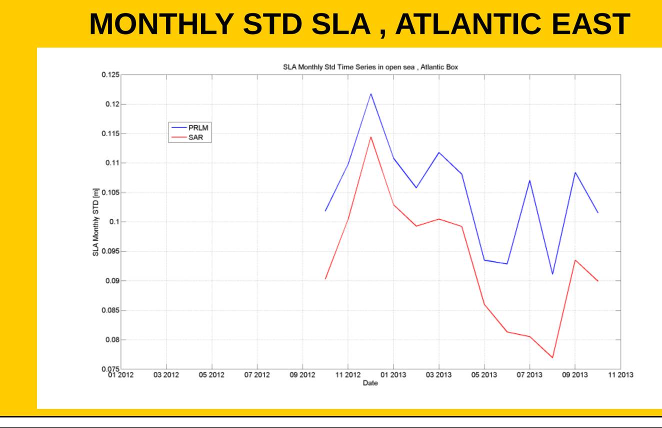
MEAN MONTHLY SEA CYCLE

In this box, we present the **monthly mean** of the sea level and **monthly std** of the sea level anomaly. We can conclude that two modes measure exactly the same sea cycle but SAR with higher precision (lower std) than PLRM.

MONTHLY MEAN SLA , ATLANTIC EAST

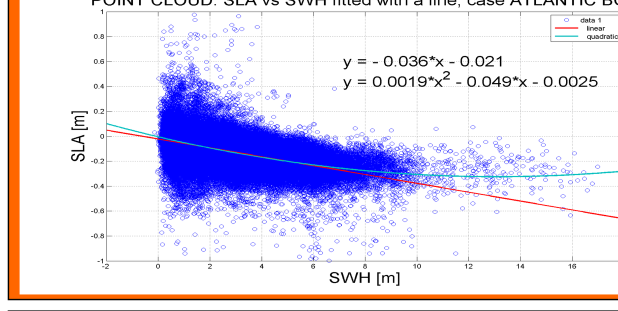


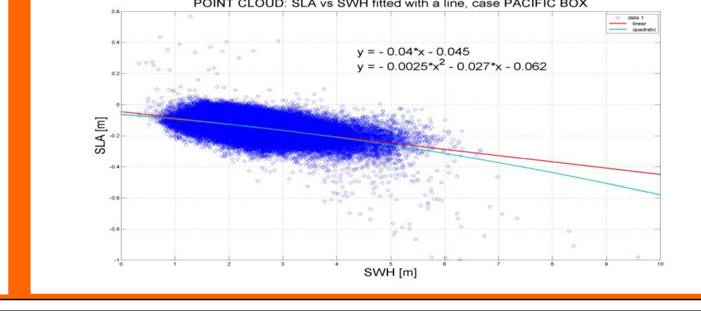
MONTHLY STD SLA , ATLANTIC EAST



SEA STATE BIAS

In this box, we plotted the SLA vs. SWH and we fitted the point cloud with a line for the Pacific and Atlantic data. We see that the line slope is around 4% of SWH but, indeed, it would be better to have ,as SSB solution, a quadratic curve instead of a linear relationship.





CONCLUSIONS

We conclude that the new SAR altimetry technique brings a clear improvement for the measurement of the open ocean topography and sea state; the regional cross-validation analysis in open sea has proven the good consistency between TUDa PLRM (numerical solution) and the GPOD SAR data in the period 2012/10-2013/10. There is no significant bias in SSH, SWH and wind speed derived from both techniques. **The two techniques SAR and PLRM measure also the same monthly sea cycle but SAR measure it with higher precision.** A first-approximation of Sea State bias solution seems to be 4% of SWH. Thanks to the performance curve and wavenumber spectra, we confirm definitively that the precision of SSH and SWH is improved with respect to TUDa PLRM processing whereas sigma nought has equivalent statistics between SAR and PLRM. We postpone to a further study the analysis of RIP and the issue of swell identification. For further information, please contact:
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