Validation of Open-Sea CRYOSAT-2 Data in SAR Mode in the German Bight from 2010 to 2014

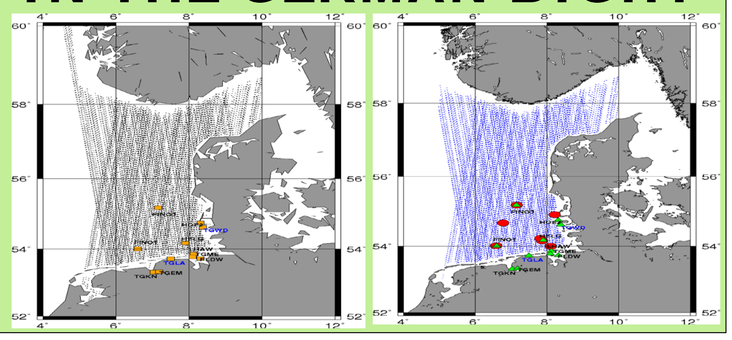
Salvatore Dinardo (SERCO/ESRIN), **Luciana Fenoglio-Marc** (TUD),**Remko Scharroo** (EUMETSAT), **Bruno Lucas** (DEIMOS/ESRIN), **Matthias Becker** (TUD), **Jerome Benveniste** (ESA)

Abstract

Altimetry Data acquired by the CryoSat-2 in SAR Mode in the time span 2010-2014 are processed and validated in the area of the German Bight at distance to coast larger than 10 kilometers (open sea points).
Instantaneous sea surface height (SSH), significant wave height (SWH) and wind speed (U10) from altimetry are compared to in-situ measurements at platforms, buoys and tide gauges and to results from an operational circulation model run by the German Federal Maritime and Hydrographic Agency (BSH). The in-situ network is maintained by the Waterway and Shipping Administration (WSV) and by the German Federal Institute of Hydrology (BFG, http://www.bafg.de). The relevant in-situ data are sea level, GPS coordinates and wave data. Wave and wind model data are compared to the SWH and Wind speed derived from altimetry.
The CryoSat-2 Data have been Delay-Doppler processed from the FBR (Full Bit Rate) Level 1A to Level 1B and subsequently re-tracked using the SAMOSA's SAR Echo Model and a fitting scheme based on Levenberg-Marquard Least Square Minimization Algorithm. Sea surface height, significant wave height and wind speed at 20 Hz and 1 Hz have been derived. The Delay-Doppler processing (L1B) and the re-tracking processing (L2) has been carried out by the EOP-SER Altimetry Team at ESA/ESRIN. Pseudo pulse-limited (PLRM) data derived from CryoSat-2 in SAR mode and provided via the RADS database are compared with parameters derived from the CryoSat-2 SAR Data to estimate possible biases and trends between SAR mode and LRM mode and tune up the SAR re-tracking scheme.
The ESRIN SAR data and the RADS PLRM data are now both provided at 20 Hz posting rate.
Look-up table (LUT) are used for SAR data to overcome the SAMOSA Model limitation due to the approximation of the instrument PTR Power Sinc with a Gaussian Curve. LUT are currently not used on RADS PLRM side.
A zero-padding operation prior to the range FFT is performed on RADS PLRM side and on ESRIN side to override waveform range aliasing.
The wind speed is derived using the same wind model used in Envisat mission and correcting for a small sigma nought bias (-3.04 dbW) to align CryoSat absolute backscattering to Envisat absolute backscattering.
On SAR and PLRM sides, the sigma nought is corrected for atmospheric attenuation and the altimeter wind speed are cross-compared against in situ measurements and models.
Performance metrics to measure the quality of the results, scatter plots, cross-correlations, standard deviations, regression slopes and biases between the in-situ and the CryoSat-derived measurements (SSH, SWH, U10) will be presented.
The wavenumber Spectrum of sea surface height, significant wave height and wind speed is computed either for the RADS PLRM dataset either for ESRIN SAR dataset for the North East Atlantic ocean region.
A very good agreement has been achieved between both PLRM and SAR processed altimeter and in-situ data for the SSH and SWH set.
In the comparison with two wave models, the best agreement is obtained with the regional LSM model of the Deutsche Wetterdienst (DWD).

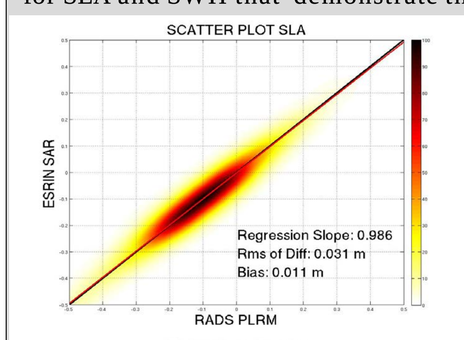
THE DATA SET: 4 YEARS IN THE GERMAN BIGHT

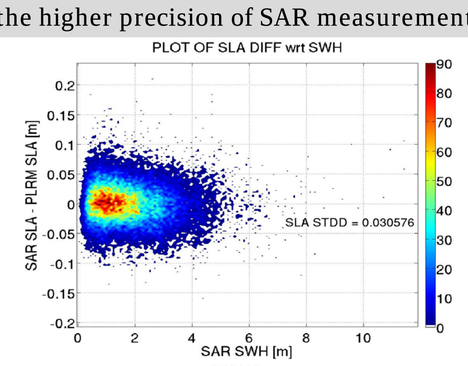
In this box, we show the German Bight's area and the CryoSat-2 passes used to carry out the inter-comparison exercises. Data from four year (2010-2014) have been analysed. The coastal zone data are ruled out from this study. This area has been selected because its low sea-state conditions are suitable to analyse the capability by radar altimetry to measure SWH in low sea state regimes.
In the plot you can see also the position of the in situ platforms.

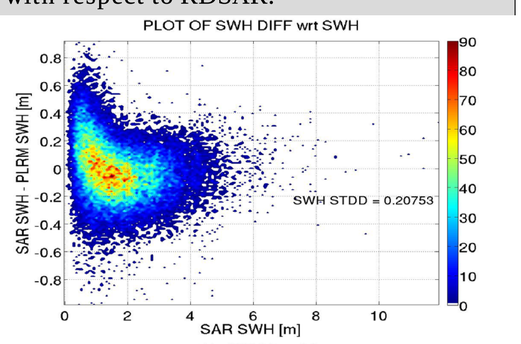


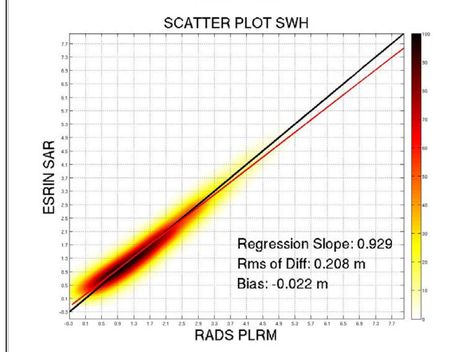
THE SAR-RDSAR CROSS-VALIDATION RESULTS

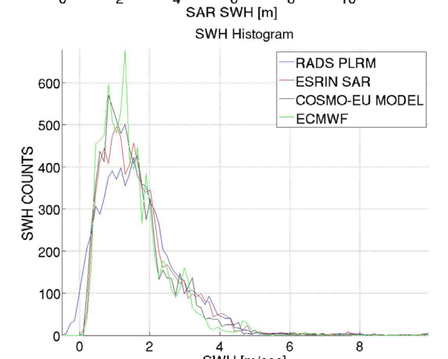
In this box, we present some plots that highlight the consistency between RDSAR measurement from RADS and ESRIN SAR measurements for SLA, SWH, U1o. The consistency is quite good between SAR and RDSAR and also against models (BSH and ECMWF) but we point out a possible inconsistency of RADS RDSAR SWH measurements for low SWH likely due to the missing application of PTR Look-Up table (LUT) on RADS side. Further, the performance curves (std vs. SWH) are shown for SLA and SWH that demonstrate the higher precision of SAR measurements with respect to RDSAR.

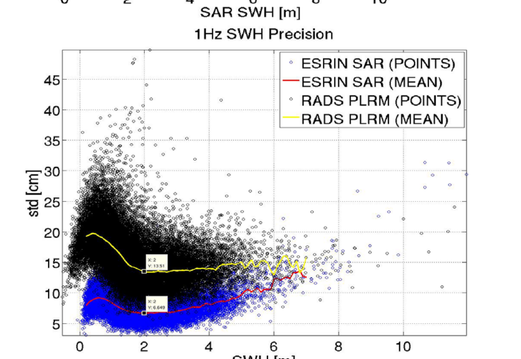


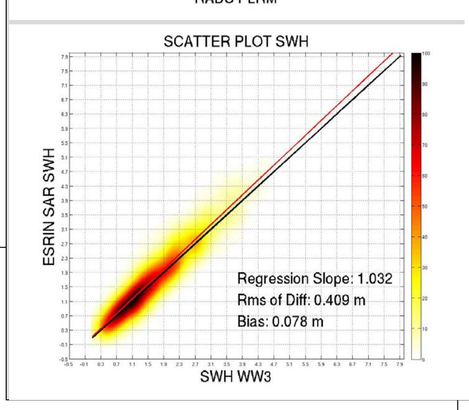


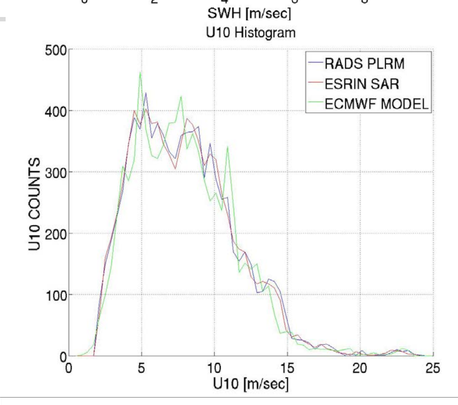


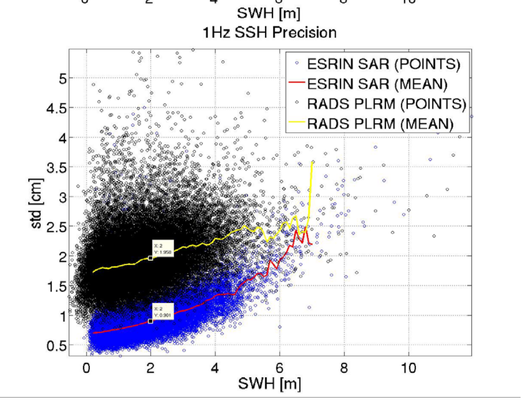






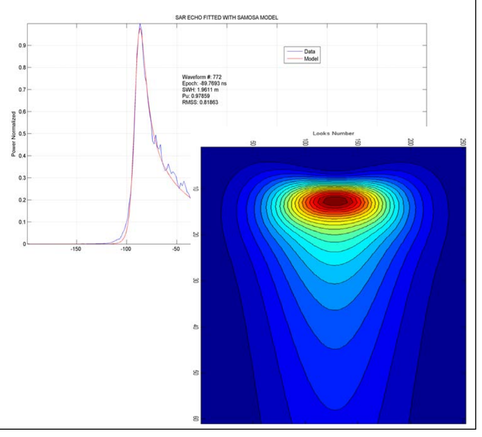






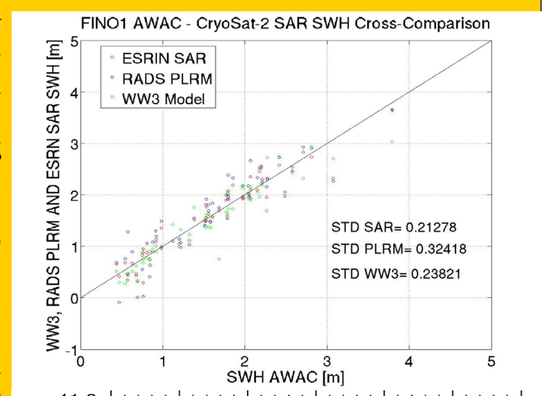
THE SAR AND RDSAR PROCESSING

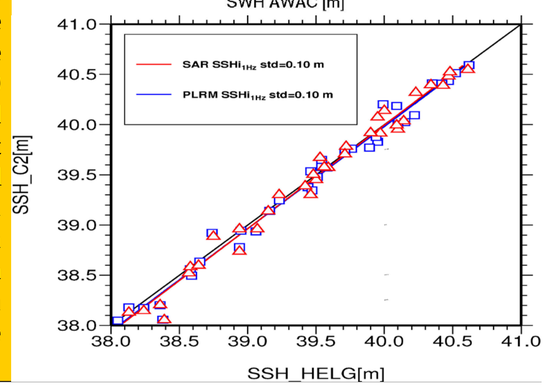
The Delay-Doppler processed SAR waveforms have been generated by the ESA-ESRIN EOP-SER Altimetry team starting from CryoSat-2 FBR (Full Bit Rate) data level (Dinardo et al., 2013). The SAR retracking procedure uses the SAMOSA2 SAR Waveform Analytical Model scheme based on the bounded Levenberg-Marquardt Least-Squares Estimation Algorithm (LEVMAR-LSE). The retracking processing consists of the estimation of the three parameters epoch , amplitude Pu 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 are from the Radar Altimetry Database System (RADS). The retracking procedure for the PLRM waveforms uses the Brown model and an un-weighted Least Square Estimator derived from Maximum Likelihood Estimator. The three parameters epoch, amplitude, and slope of the leading edge are estimated.



IN-SITU VALIDATION RESULTS

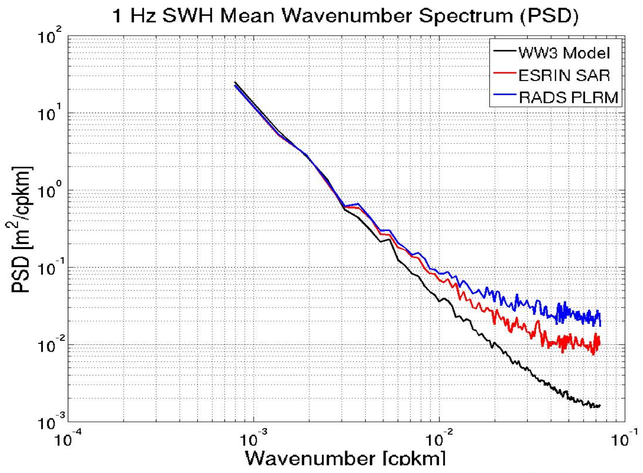
In this box, the SWH measured by RADS PLRM and ESRIN SAR are validated against in situ SWH data provided by FINO 1 AWAC .
The selection criteria are: space-lag between 10-40 km, time-lag 30 minutes.
The results highlight the more consistent behaviour of SAR SWH measurement with respect to RADS SWH.
Instead, the SSH in-situ comparison is performed at the tide gauge of Helgoland. Because of the CryoSat-2 long repeat cycle (369 days), the tracks are not co-located and hence the range measurement are affected by differential tidal dynamics and geoid characteristics. Anyhow, a std of 10 cm has been obtained in SAR mode, applying a SSB correction, between 10-20 km from Helgoland; also for PLRM the std is 10 cm.

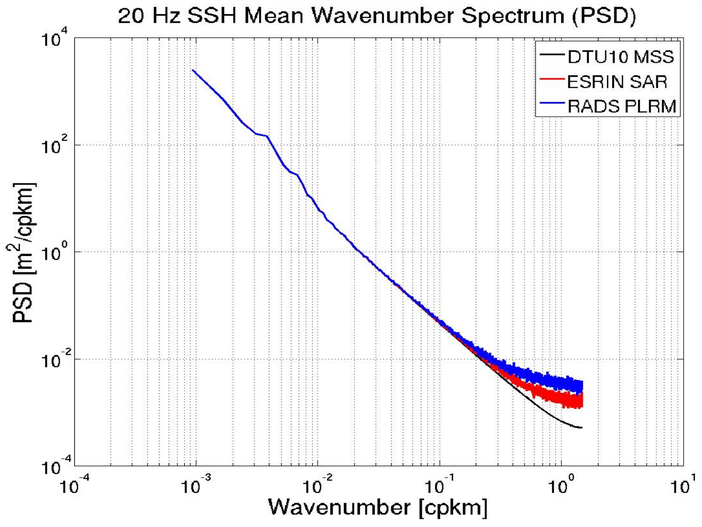


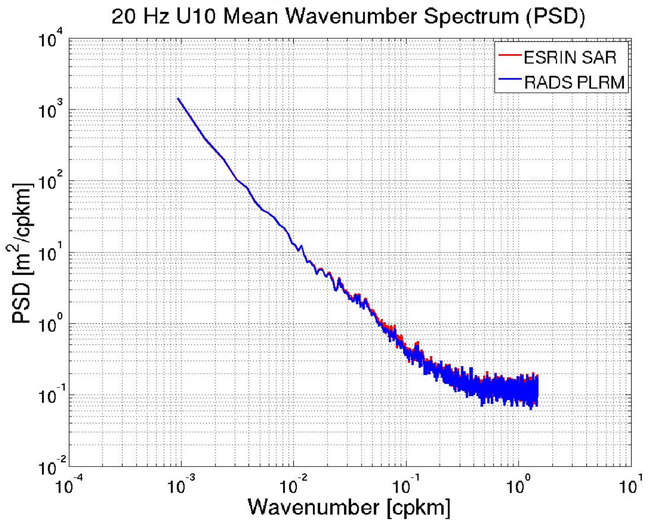


WAVE-NUMBER SPECTRA IN THE ATLANTIC OCEAN

In this box, we present the averaged wave-number spectra for the North-East Atlantic SAR region in the months 2012/07 and 2013/01 for SAR and RDSAR dataset.
The spectra plots highlight the clear improvement, in term of measurement noise, provided by SAR mode with respect to RADS PLRM for Sea Surface Height (SSH) and Wave Height (SWH). In black , as reference, we plot the Mean Sea Surface (DTU 10) for SSH spectrum and the WW3 model for SWH spectrum.
The wind speed (U10) spectra are basically identical in SAR and PLRM mode.
In order to compute the spectra, an operation of data editing has been applied on RADS PLRM data and on SAR data to rule out all the contaminated data (land, alga blooms, rain events, ships, etc.) .







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 RADS PLRM and the ESRIN SAR data in the period 20110-20124.
There is no significant bias in SSH, SWH and wind speed derived from both techniques.
The in-situ analysis shows the improved behavior of the SAR satellite altimetry data for SSH and SWH.
We reached as well the clear evidence that it is possible to carry out very precise wind speed measurements also in SAR mode.
Thanks to the performance curve and wavenumber spectra, we confirm that the precision of SSH and SWH is improved by a factor around 2 with respect to RADS PLRM processing.
For further information, please contact:
salvatore.dinardo@esa.int, fenoglio@psg.tu-darmstadt.de

esa serco deimos ENGENHARIA TECHNISCHE UNIVERSITÄT DARMSTADT