Evaluation of new CryoSat-2 measurements over the ocean

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1. Introduction

Why new products? CryoSat-2 is a huge asset to the oceanographic community, and the exploitation of its data over the ocean represents a welcome additional return for ESA's investment in the mission. The CryoSat Project has approved, in the frame of the CryoSat routine phase, the generation of additional **ocean products:** IOP (Interim Ocean Product) and GOP (Geophysical Ocean Product).

To enable their full exploitation by the scientific and operational oceanographic communities, these new ocean products now need to be thoroughly quality-controlled and validated.

Assessment and validation: The UK National Oceanography Centre (NOC) has been tasked with the scientific quality control and validation within the **CryOcean-QCV Project**. Here we show the results of a global assessment of the GOP sea surface height anomaly (SSHA) and significant wave height (SWH) in terms of measurement noise. We also present a global validation of the new GOP SSHAs and SWH against a variety of in situ observations such as tide gauges, buoys and Argo floats as well as against data from the Wavewatch III (WW3) model. In addition, we compare the performance of CryoSat-2 against that of Jason-2.

2. Data

We use the **new Level 2 GOP** data, which are delivered approximately 30 days after data acquisition and are available since April 2014. Our analysis is restricted to the period from 10th April 2014 to 30th June 2015. In GOP the SAR mode data are processed into pseudo low resolution mode (LRM) measurements (i.e., no complete SAR processing is implemented).

The 1Hz SSHA and SWH data from **Jason-2** are obtained from the RADS data base (http://rads.tudelft.nl/rads/rads.shtml).

Tide gauge data were obtained from the data archives of the British Oceanographic Data Centre (15 min) and the University of Hawaii Sea Level Center (60 min). The location of the tide gauge stations is shown in Figure 1.

The set of **T and S Argo profiles** used to derive steric heights were obtained from the EN4.1.1 data set (Good et al., 2013) made available by the Met Office Hadley Centre (http://hadobs.metoffice.com/en4/)

Hourly **buoy data** obtained from the National Data Buoy Center at http://www.ndbc.noaa.gov.

SWH data (hourly) from the **WW3 model** were obtained from the Pacific Islands Ocean Observing System (PacIOOS) at the University of Hawaii (http://oos.soest.hawaii.edu/erddap/griddap/NWW3_Global_Best.html).

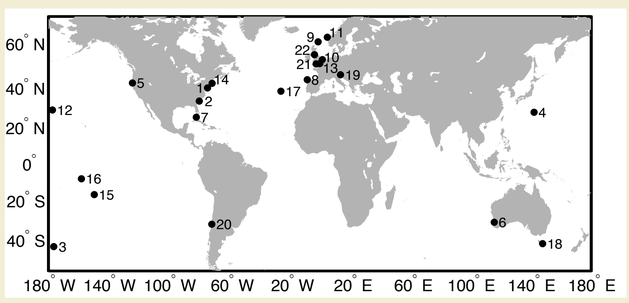

FIG 1. Location of the tide gauges used in the validation. Numbers correspond to stations shown in Table 1.

#	ρ C2	ρ J2	rms C2	rms J2	nrms C2	nrms J2
1	0.82	-	10.4	-	59.7	-
2	0.80	ns	10.2	8.1	74.4	80.5
3	0.92	0.88	4.6	4.9	41.7	52.6
4	0.83	0.87	5.4	5.1	63.5	57.7
5	ns	-	13.5	-	163.7	-
6	ns	-	11.6	-	142.2	-
7	0.53	-	8.0	-	154.9	-
8	0.87	-	6.4	-	50.6	-
9	0.84	0.78	9.1	8.2	65.7	73.1
10	0.84	0.84	12.8	11.7	71.2	64.4
11	0.89	0.97	8.3	6.8	48.0	25.9
12	0.68	0.47	6.4	8.0	103.3	112.8
13	0.45	0.51	19.1	14.8	151.3	109.6
14	0.80	-	8.4	-	65.4	-
15	0.60	0.79	5.0	5.6	103.9	110.2
16	0.62	0.64	5.8	3.7	82.3	61.7
17	0.67	ns	6.5	7.6	117.7	113.7
18	0.94	-	5.3	-	36.0	-
19	0.83	-	7.5	-	57.4	-
20	0.74	0.47	7.5	5.3	171.6	117.3
21	0.69	0.64	13.9	15.9	120.7	124.8
22	0.82	-	17.3	-	88.1	-

Table 1. Correlation, rms in cm, and normalized rms (nrms) between SSHAs and sea level from tide gauges for CryoSat-2 and Jason-2.

3. Results

GOP noise statistics for the SSHA and SWH for May 2015

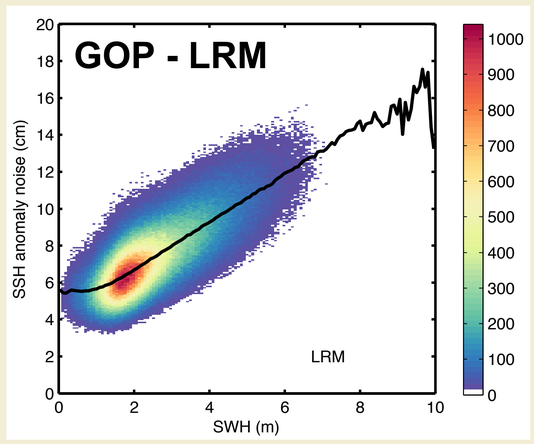

FIG 2. 2D histogram showing the 20 Hz SSHA noise from the GOP product as a function of SWH for LRM (left) and pseudo LRM (right) for May 2015. The black line denotes the median SSHA as a function of SWH. Note that GOP data are pseudo-LRM over the SAR mode areas.

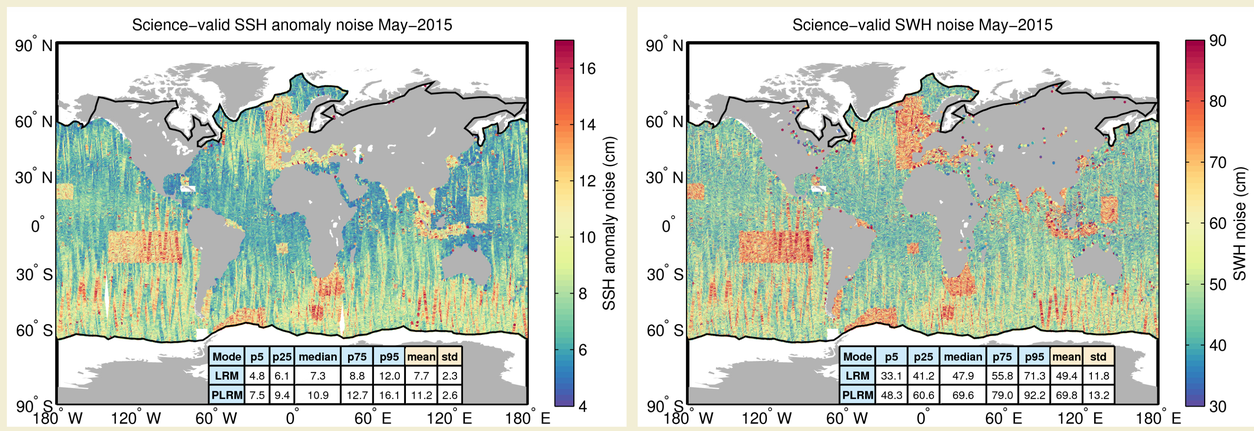

FIG 3. Geographical distribution of 20 Hz SSHA (left) and SWH (right) noise over oceans and lakes for May 2015. The black lines mark the outer limit of the Arctic and Antarctic polar regions.

Validation of GOP SSHAs against tide gauge data

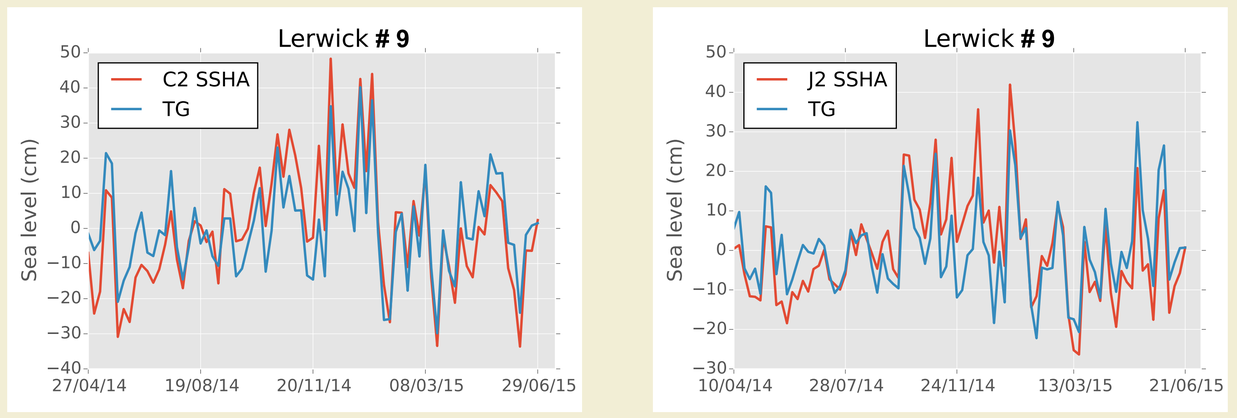

FIG 4. Comparison of SSHAs (red) from CryoSat-2 (left) and Jason-2 (right) with the sea level (blue) from the tide gauge record at Lerwick (# 9).

The correlation, root mean squared differences (rms), and normalized rms for all tide gauge stations are shown in Table 1 for both CryoSat-2 and Jason-2 (atmospheric effect included)

Validation of GOP SSHAs against steric height from Argo floats

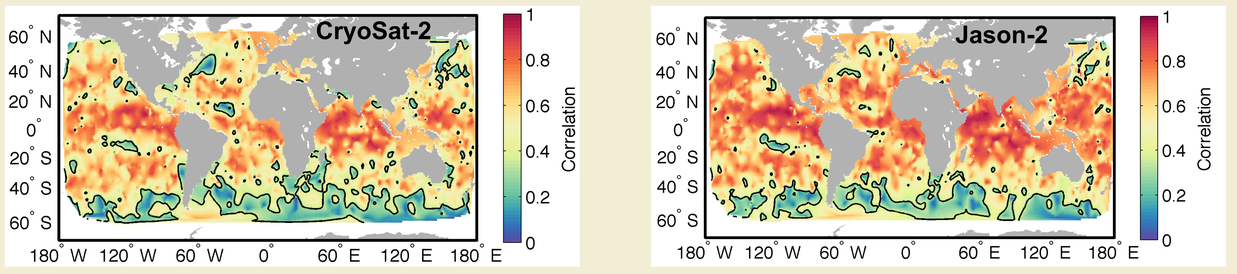

FIG 5. Correlation between SSHAs from CryoSat-2 (left) and Jason-2 (right) and the steric heights derived from Argo T/S profiles for the period April 2014 to June 2015. Black lines denote the 95% confidence level for the significance of the correlation.

Validation of GOP SWH

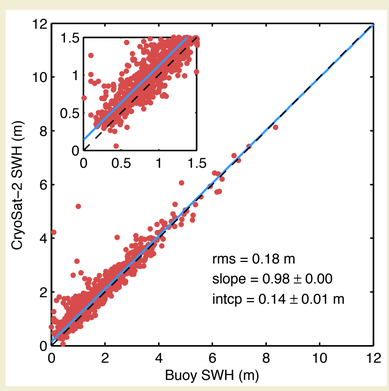

FIG 6. Validation of GOP SWH buoy data.

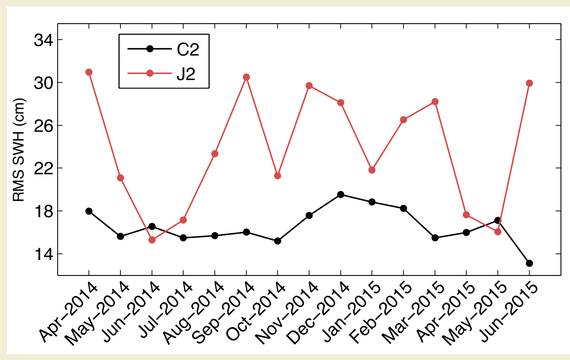

FIG 7. RMS derived from regressing altimetric SWH on the SWH from buoys for CryoSat-2 (black) and Jason-2 (red).

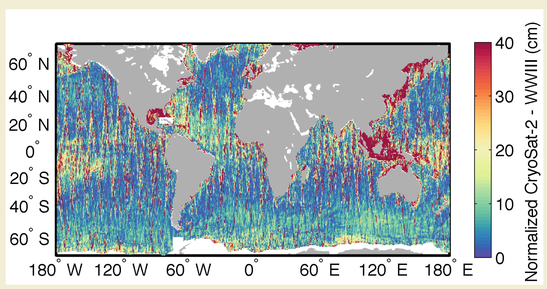

FIG 8. Spatial distribution of the normalized differences between the SWH from CryoSat-2 and that from the WW3 model (normalized by the SWH value from the WW3 model)

5. Conclusions

This study has provided a global assessment and validation of the new GOP SSHA and SWH from CryoSat-2, which has shown an excellent performance, comparable to that of other altimetry missions, demonstrating the potential applicability of the measurements acquired by CryoSat-2 over the ocean to a wide range of oceanographic problems and far beyond the sole framework of the cryosphere.

CryoSat-2 FDM, IOP and GOP products are available for registered users to access from the CryoSat dissemination server (ftp://science-pds.cryosat.esa.int). For any information regarding these products email eohelp@esa.int