# VALIDATION OF (SENTINEL-3* and) JASON-3 ALTIMETER WAVE HEIGHT MEASUREMENTS

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* Sentinel-3 data were not collected in time for the present study. Only Jason-3 validation results are presented.

Jason-3 was launched on January 17, 2016 and first IGDR (GDR) were available for validation in March (September).The eighteen first cycles are analyzed for test and validation, covering the 6-month period from February 12 (cycle 0, pass 117) to August 3, 2016 (end of cycle number 17).

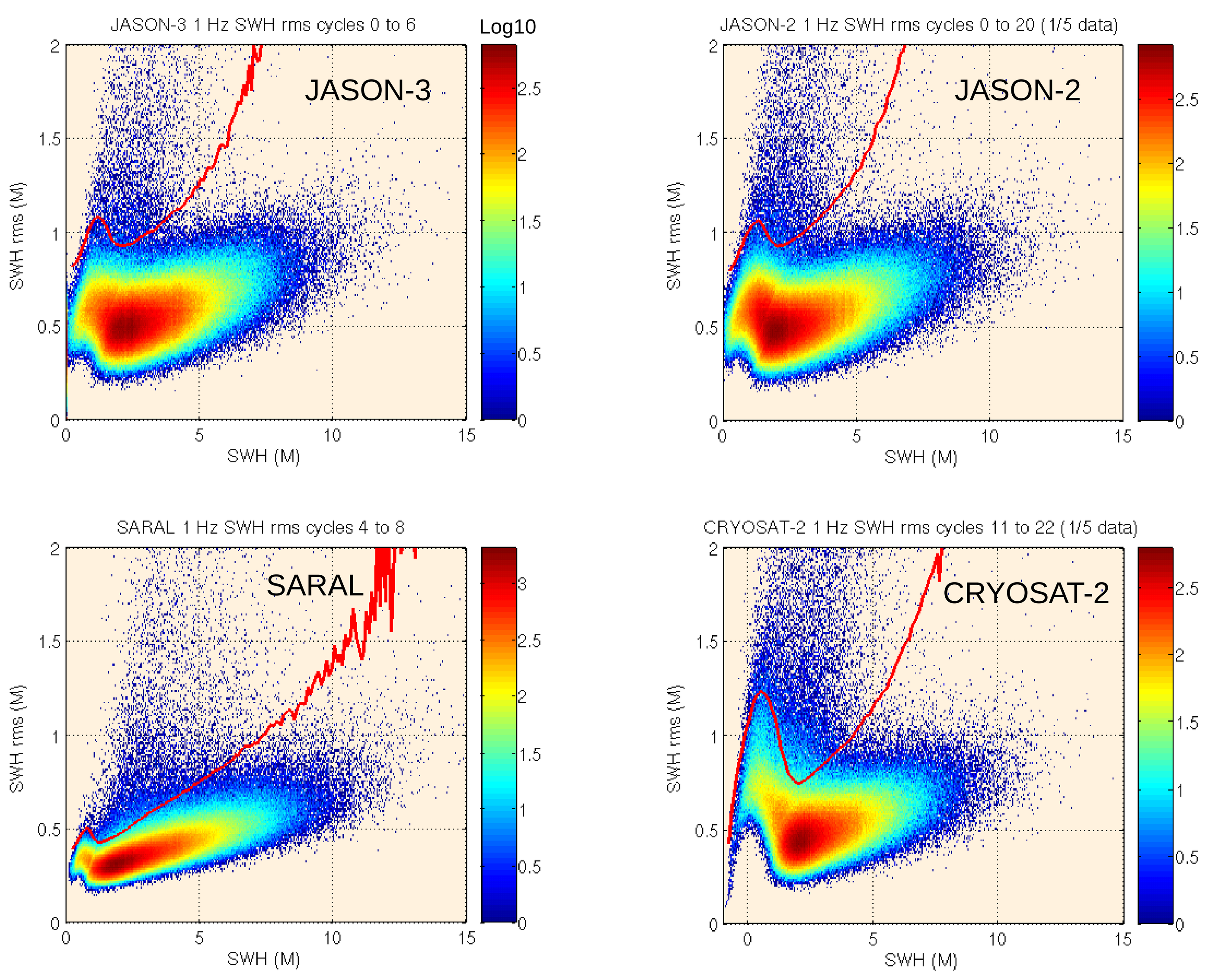
A first idea of the quality of the Jason-3 significant wave height (SWH) measurement is given by the shape of the joint distribution of the 1 Hz SWH value (mean value over 1 s) and the associated standard deviation (SWH RMS). Comparison with other altimeters indicates a good quality of the data, very close to the JASON-2 behaviour.

A second validation step consists in comparing along-track 1 Hz collocated measurements from JASON-3 and JASON-2. During the commissioning phase JASON-3 is following JASON-2 on the same track about 80 s after, so that the sea state sensed by the two altimeters should be the same at a given geographical location.

A last test is performed comparing JASON_3 measurements at crossing tracks with other in-flight altimeters: SARAL and CRYOSAT-2. SARAL and CRYOSAT-2 SWH data are issued from the Ifremer merge altimeter SWH data base available at ftp://ftp.ifremer.fr/ifremer/cersat/products/swath/altimeters/waves (Queffeulou and Croizé-Fillon 2016).
Comparison results are also given for the Ku band backscatter coefficient (sigma0) measurements and associated estimated surface wind speed.

Conclusions of this validation study are: 1) the JASON-3 SWH measurement accuracy is very similar to the JASON-2 accuracy, and is in good agreement with SARAL (which is more accurate) and CRYOSAT-2; 2) JASON-3 GDR Ku sigma0 has been adjusted to match JASON-2 sigma0., and exhibits some bias relative to CRYOSAT-2, resulting in significant differences in wind speed estimates. More generally, further improvements are needed for homogenization of long-term sigma0 calibration and wind speed algorithms.

## SWH / SWH-RMS DISTRIBUTIONS




In a first step the JASON-3 SWH data (IGDR) was tested using the following criteria : surface_type<2 & swh_ku>0 & swh_numval_ku>18. Then the 1 Hz SWH RMS was analysed as a function of SWH.

SWH RMS can be considered as a good indicator of the quality of the SWH measurement. It can be used to discard erroneous SWH measurements, due to land contamination, sigma0 blooms and strong rain attenuation. The rms level depends also on SWH, due to both instrument and geophysical sea surface height variability (at the wave height scale). For a given narrow SWH bin range the distribution of the rms is not Gaussian, but the distribution of the logarithm is generally more Gaussian. This property can be used to estimate a maximum threshold value for the logarithm of SWH rms as the sum of the mean value and twice or thrice the standard deviation- this factor is adjusted empirically for each altimeter. From that, a maximum threshold is then estimated for the SWH rms itself (red curves), above which the data is set as erroneous. This technique used for the data base, was applied to JASON-3. In pratice the RMS threshold is applied for SWH up to 8 m, and then the threshold is set to a constant value.

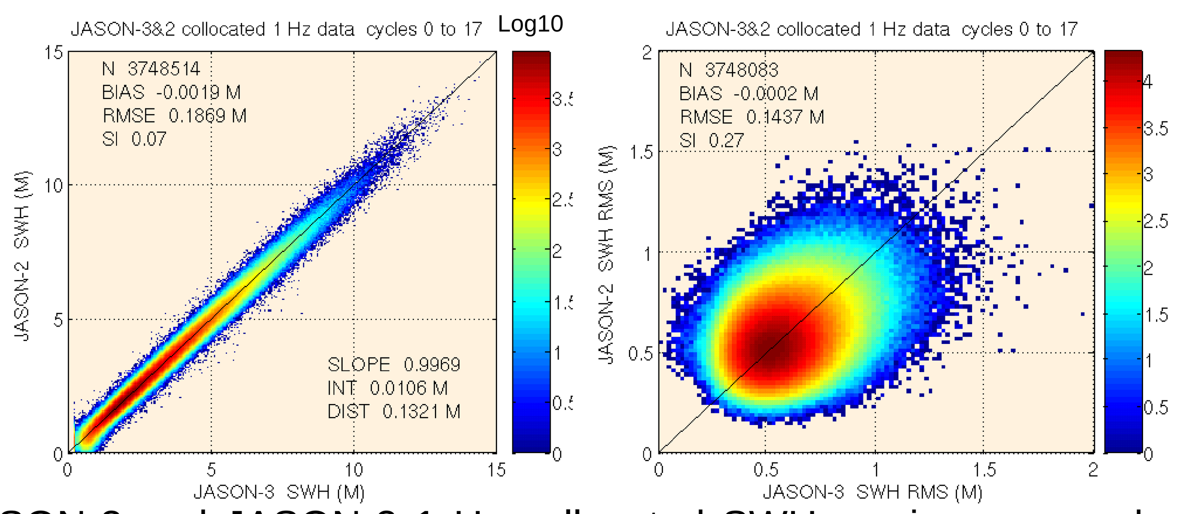
Density plots of SWH /SWH RMS are shown for JASON-3, JASON-2, SARAL and CRYOSAT-2. Color scale is log10(n).

On each plot, three patterns can be distinguished. The main one in the global axis of the distribution,indicates that the rms increases with SWH. A secondary pattern consists in large, scattered, rms values, above the red curve, for SWH range about 1-9 m, extending up to 9 m RMS well beyond the upper limit of the plots. Most data of this second pattern correspond to along-track, almost isolated, erroneous spikes. A third pattern in the bottom left side of the plots, shows a specific non-linear behaviour of the rms at very low sea state, in the first 1.5 m SWH range. This feature, observed on all altimeters , may be due to the waveform processing.

The plots are very similar for JASON-3 and JASON-2. CRYOSAT-2 exhibits large non-linear feature at low SWH. The lowest RMS is clearly observed on SARAL, providing very accurate SWH measurements (Sepulveda et al 2015).

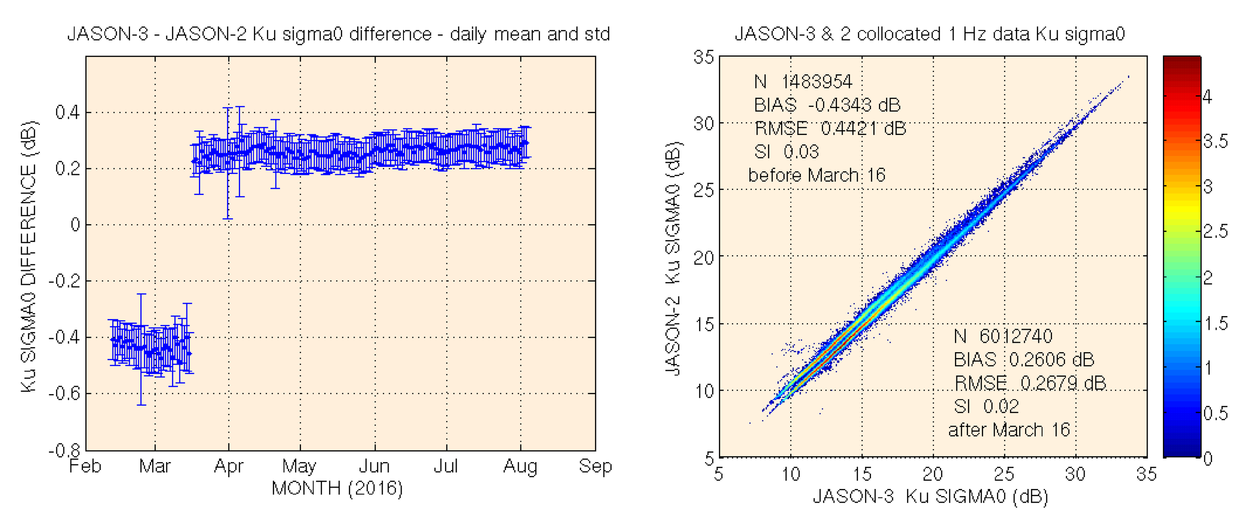
## COMPARISON of ALONG-TRACK JASON-3 and JASON-2 MEASUREMENTS

### SWH




JASON-3 and JASON-2 1 Hz collocated SWH are in very good agreement (SWH RMS test applied). The regression line is close to the perfect one. The bias is less than 2 mm and the rms is about 19 cm. The right plot shows a symmetrical distribution of the SWH RMS for JASON-3 and JASON-2. The large pattern is due to the dependence of SWH RMS on SWH.

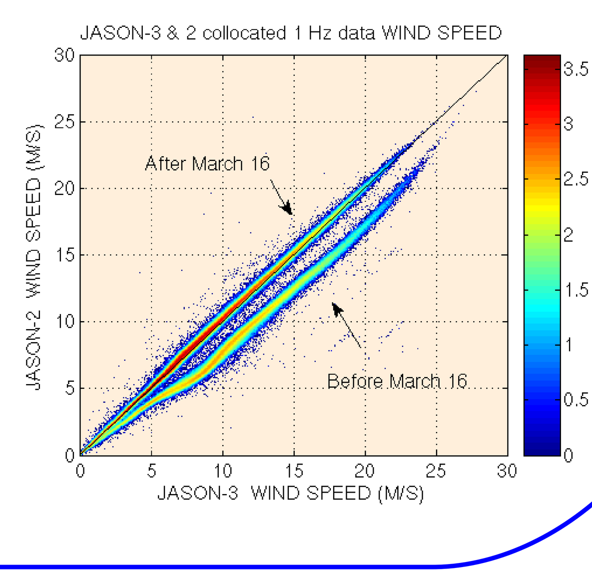
### SIGMA0



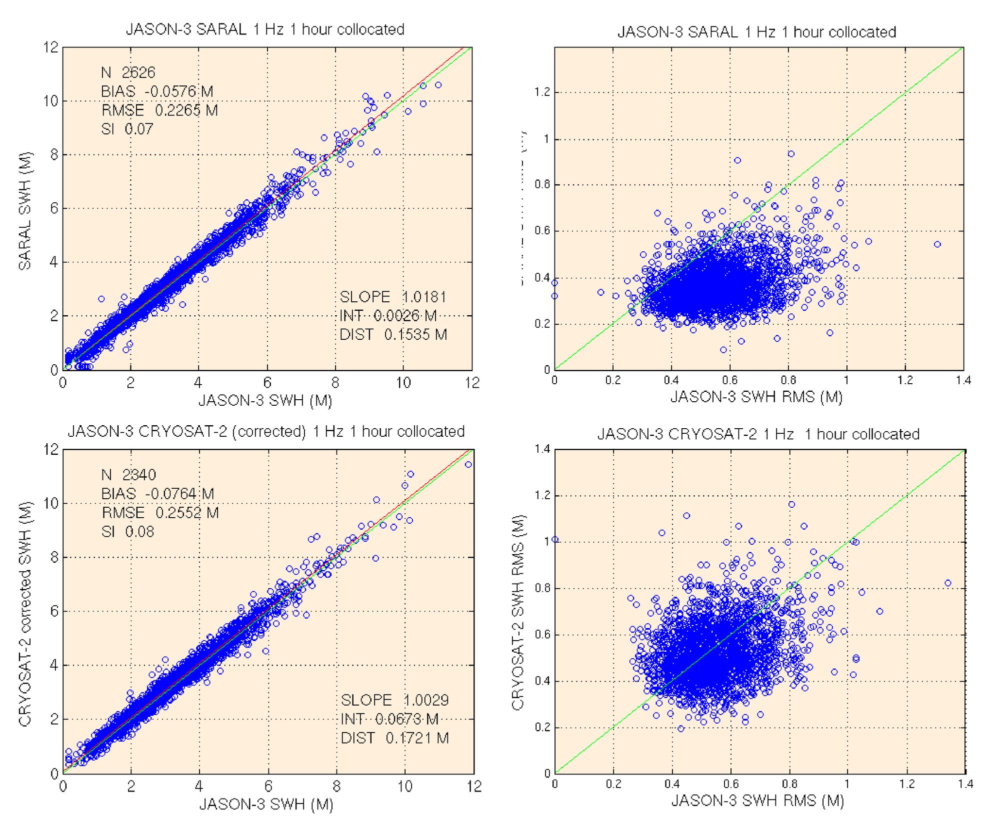

Plot of the daily mean value and standard deviation of sigma0 differences at collocated points (left, above) shows that an offset about +0.69 dB was applied to JASON-3 after March 16. Consequently two distinct patterns are observed on the density plot (right), with a bias about -0.43 dB and +0.26 dB before and after March 16, respectively.

### WIND SPEED

Due to the sigma0 offset two branches are also clearly observed on the wind speed density plot comparing JASON-3 and JASON-2 (right). The agreement with JASON-2 is much better for the branch after March 16. But further investigation on sigma0 calibration is needed, as confirmed by the comparisons with SARAL and CRYOSAT-2 (right panel).

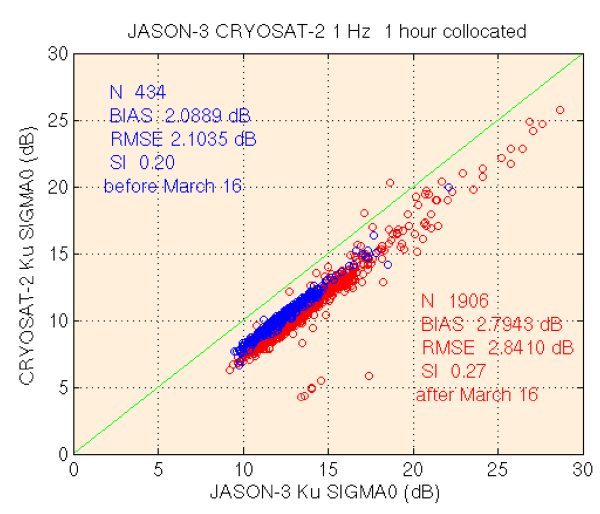



## COMPARISON at CROSSING LOCATIONS with SARAL and CRYOSAT-2

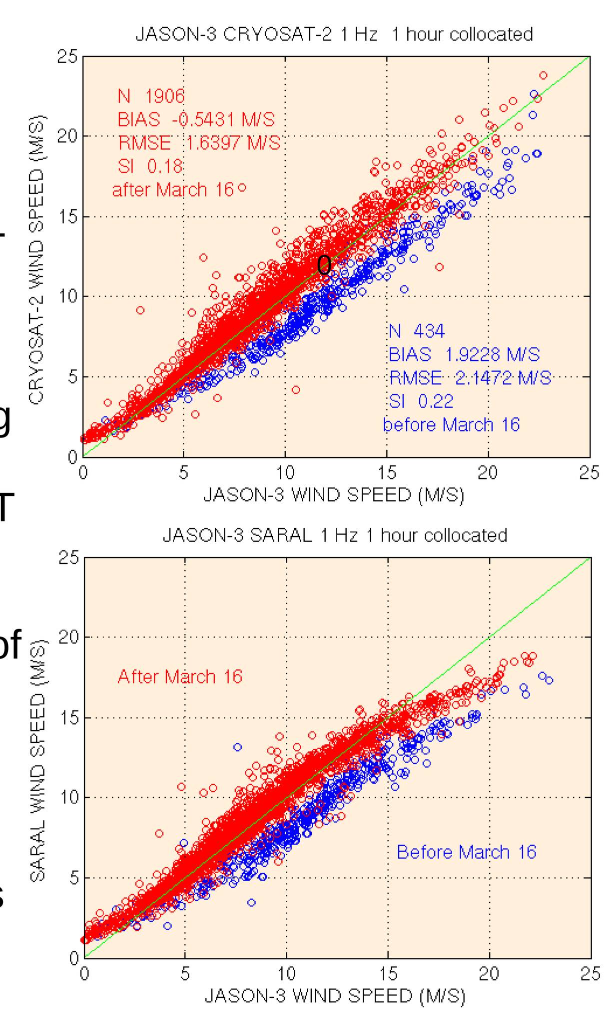



Comparisons with SARAL and CRYOSAT-2 show a good agreement for SWH (left plots). The bias is about 6-8 cm and rmse about 23-25 cm, for 1 Hz collocated cells, within a 1 hour wide time window. When averaging both altimeters over 50 km, along-track, the rmse reduces to very low values, about 12-14 cm.

Right plots compare the SWH RMS of JASON-3 and CRYOSAT-2 (bottom), and SARAL (top). Symmetrical distribution is observed relative to CRYOSAT-2, while SWH RMS is larger for JASON-3 relative to SARAL.



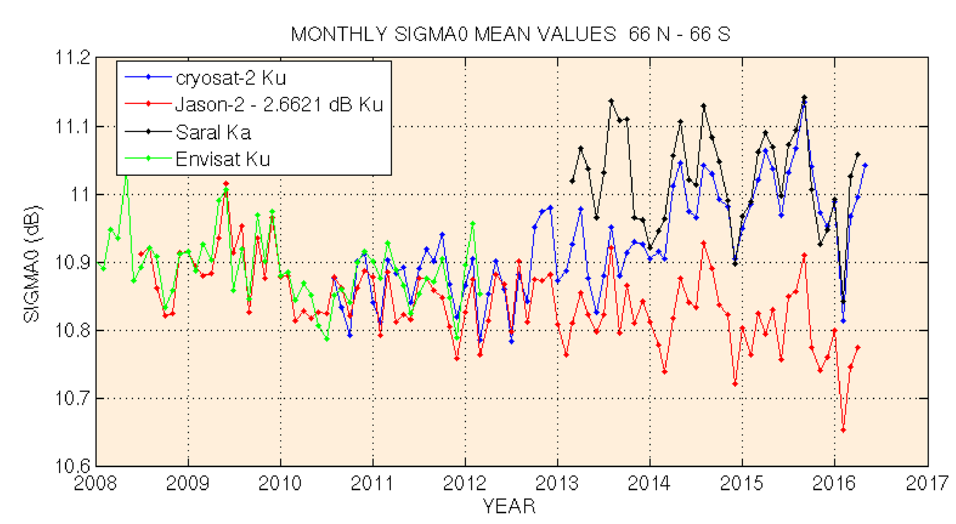

Left plot comparing JASON_3 and CRYOSAT_2 sigma0 shows the JASON-3 sigma0 offset. After March 16 the bias is +2.79 dB from which could be subtracted 2.77 dB (offset applied to JASON-2 GDR sigma0 before computing wind speed).
Wind speed comparisons with CRYOSAT and SARAL (right plots) confirm that further improvements are needed for sigma0 calibration and homogenization of wind speed algorithms (cf hereunder).




### Altimeter long term sigma0 drift

Plot of monthly sigma0 mean values over the global ocean (for latitudes between 66 N and 66 S) shows a good agreement between the altimeters up to mid year 2012.

After that time CRYOSAT-2 sigma0 (in blue) is observed to increase, while JASON-2 (in red) exhibits some slight decreasing trend.




REFERENCES
Queffeulou, P. and D. Croizé-Fillon, 2016. Glogal altimeter SWH data set, September 2016, Technical report , Ifremer. ftp://ftp.ifremer.fr/ifremer/cersat/products/swath/altimeters/waves/documentation/altimeter_wave_merge__11.3.pdf
Sepulveda, H. H., P. Queffeulou and F. Ardhuin. Assessment of SARAL AltiKa wave height measurements relative to buoy, Jason-2 and Cryosat-2 data. Marine Geodesy, 38 (S1),449-465, doi: 10.1080/01490419.2014.1000470. 2015.
Calibrated, merged, along-track altimeter SWH data (daily files) are available at ftp://ftp.ifremer.fr/ifremer/cersat/products/swath/altimeters/waves
Monthly gridded merged altimeter SWH data are available at ftp://ftp.ifremer.fr/ifremer/cersat/products/gridded/altimeters/waves