CryoSat-2 IGDR SWH assessment – January 17, 2012

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SWH data from the CryoSat-2 IGDR data set recently produced and provided by the *NOAA Laboratory for Satellite Altimetry* (ftp://ibis.grdl.noaa.gov/pub/cs2igdr/) were validated using comparisons with collocated altimeter measurements from Jason-1, Jason-2 and ENVISAT RA-2.

Only the CryoSat-2 data for which the quality flag given in the product is equal to zero were selected. Nevertheless visual inspection of the along track SWH profiles reveals that from time to time erroneous spikes occur, with no a priori reasons. An example is shown in figure 1 for cycle 22, pass number 45.

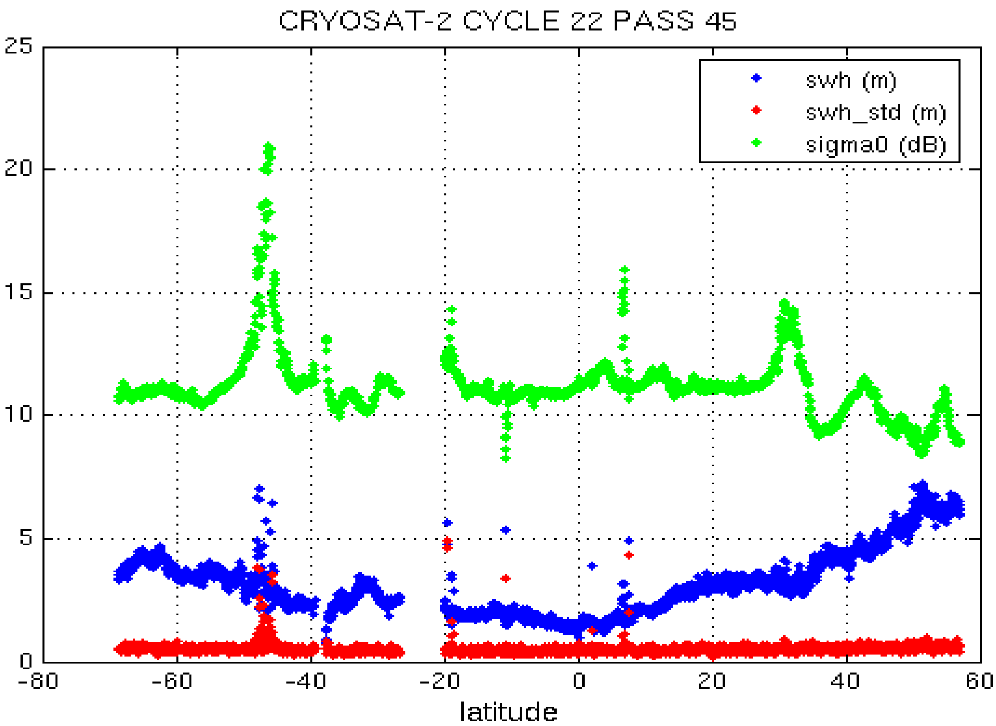

Fig 1: 1Hz SWH, SWH standard deviation and sigma0, for CryoSat-2 cycle 22 pass 45.

These spikes are often associated with enhancement of the corresponding 1 Hz SWH standard deviation (std). Plot in figure 2, of 1 Hz SWH std as a function of SWH (here over cycle 22) clearly shows two areas separated by the red line, defined as an upper threshold for the SWH std as a function of SWH. This was already observed for Jason1&2 (Queffeulou 2009). Estimating an upper threshold for SWH std is done (Queffeulou 2004) within the assumption that the distribution of the Logarithm of the std is much more Gaussian than the distribution of the std itself, the threshold was estimated, in the CryoSat-2 case, as exp{mean(Log(swh_std)) + 2x std(Log(swh_std))}, for each SWH class, 0.1 m wide, over the whole data set from cycle number 11 to 22. In practice, for eliminating such erroneous spikes, the real estimate of this threshold is tested for SWH less than 5 m; for SWH between 5 m and 8 m the threshold was estimated by a polynomial fit of the red line over this range; over 8 m a constant threshold (equal to 2.07 m) was applied.

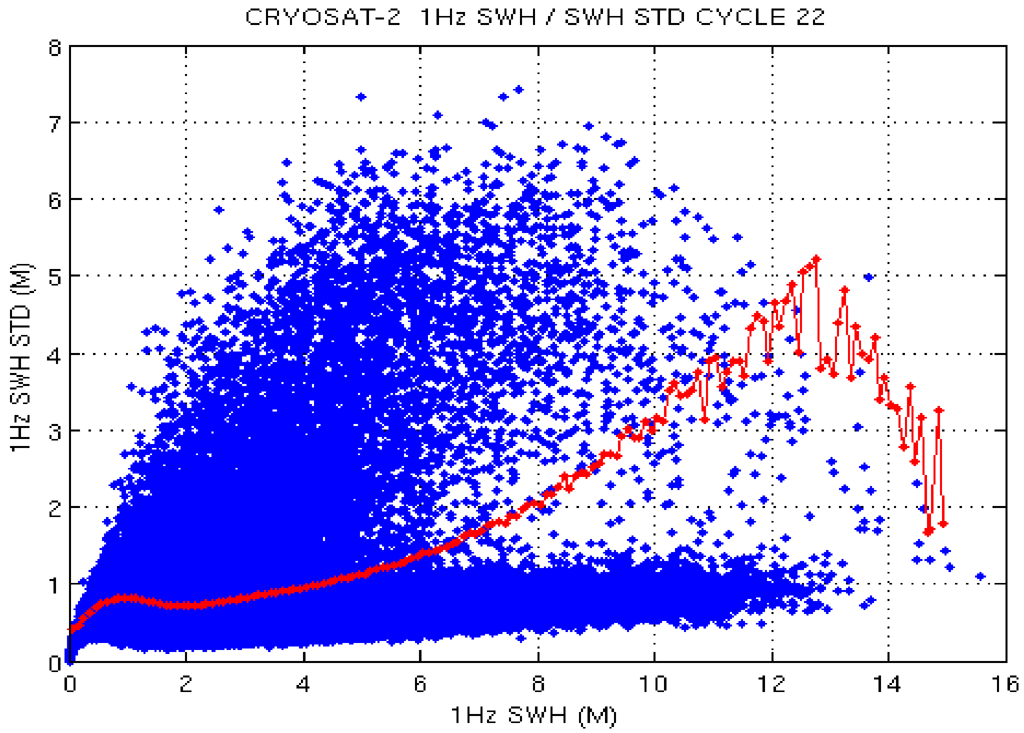

Fig 2: plot of 1Hz SWH and SWH std for cycle 22. Red line is the estimated upper threshold over 0.1 m wide SWH classes, for data from cycle 11 to 22.

Percentage of data over the threshold is shown in Figure 3. It is less than 4% for SWH under 7 m, but is high at high SWH. For Jason-1 or Jason-2 this percentage was less than 1%. The present threshold might be too low and could be increased in the future.

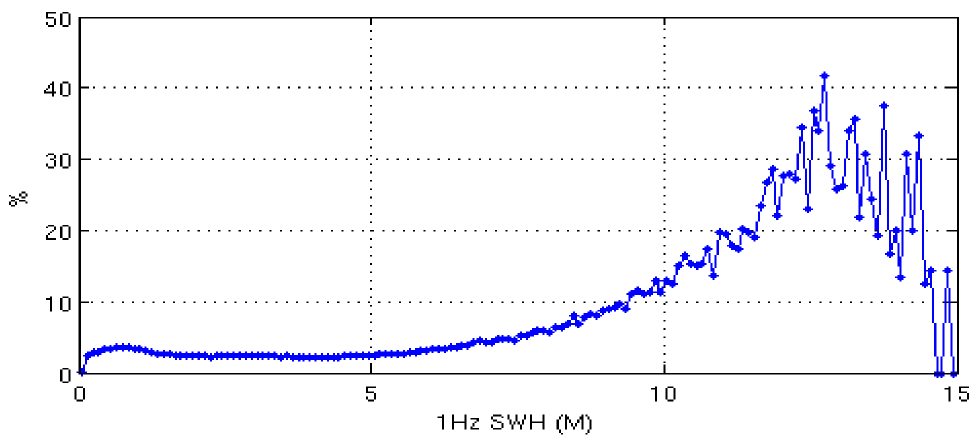

Fig 3: percentage of data over the 1Hz SWH std upper threshold, cycle 11 to 22.

As for Jason-1 and Jason-2, many (not all) of the spike events are associated with sigma0 blooms - high values of the backscatter coefficient (figures 1 and 4); in these cases the altimeter waveforms (for Jason) are very peaky, typical of quasi-specular reflection, leading to erroneous fit of theoretical altimeter waveform. Sigma0 distributions are shown in figure 4 for data over and under the threshold, respectively. Note that negative values of sigma0 exist in the data set, and are not considered here.

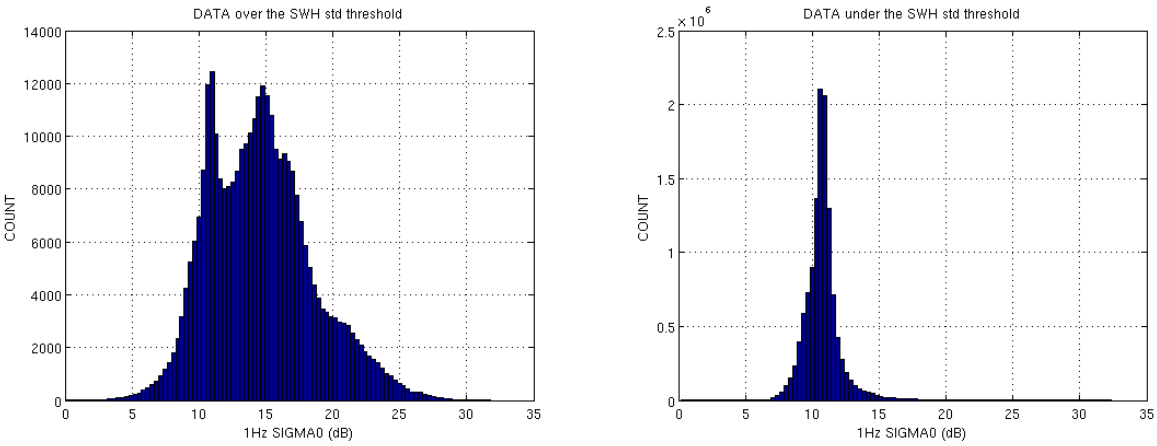

Fig 4: sigma0 histograms for data (cycle11 to 22) over (left) and under (right) the swh std threshold.

Once the threshold test performed, the CryoSat-2 data were then processed as in Queffeulou and Croizé-Fillon 2011 for Jason-1 Jason-2 and ENVISAT, to eliminate remaining outliers spikes (land, ice contamination...). The resulting data set was then collocated with GDR swh data from Jason-1, Jason-2 and ENVISAT, extracted from the Ifremer altimeter data base. Collocated crossing points are selected when the time difference is less than one hour, and the distance less than 10 km. Then the data are averaged along track over 50 km, 25 km each side of the crossing point, for each of the altimeters, before comparison. Only data for which all the 1Hz along track measurements over the 50 km are valid, corresponding to 7 measurements for CryoSat-2 or ENVISAT and 9 for Jason.

The collocated data set spread over the following time periods, within cycles 11 to 22 of CryoSat-2 :

-Jason-1: January 28 – November 18, 2011
-Jason-2: January28 – November 23, 2011
-ENVISAT: February 27 – August 18, 2011

Figure 5 shows the scatter-plots comparing the 50 km averaged collocated data with Jason-1, Jason-2 and ENVISAT, from top to bottom, for GDR (left) and corrected Jason-1, Jason-2 and ENVISAT GDR (right). Jason-1, Jason-2 and ENVISAT SWH are corrected according to Queffeulou and Croizé-Fillon 2011 :

For Jason-1: $swh\_cor = 1.0211 \times swh + 0.0139$
For Jason-2: $swh\_cor = 1.0149 \times swh + 0.0277$
For ENVISAT:
$swh\_cor = 1.0095 \times swh + 0.0192$; for $swh > 3.41$ m
$swh\_cor = 0.4358 + 0.5693 \times swh + 0.1650 \times swh^2 - 0.0210 \times swh^3$; for $swh \leq 3.41$ m

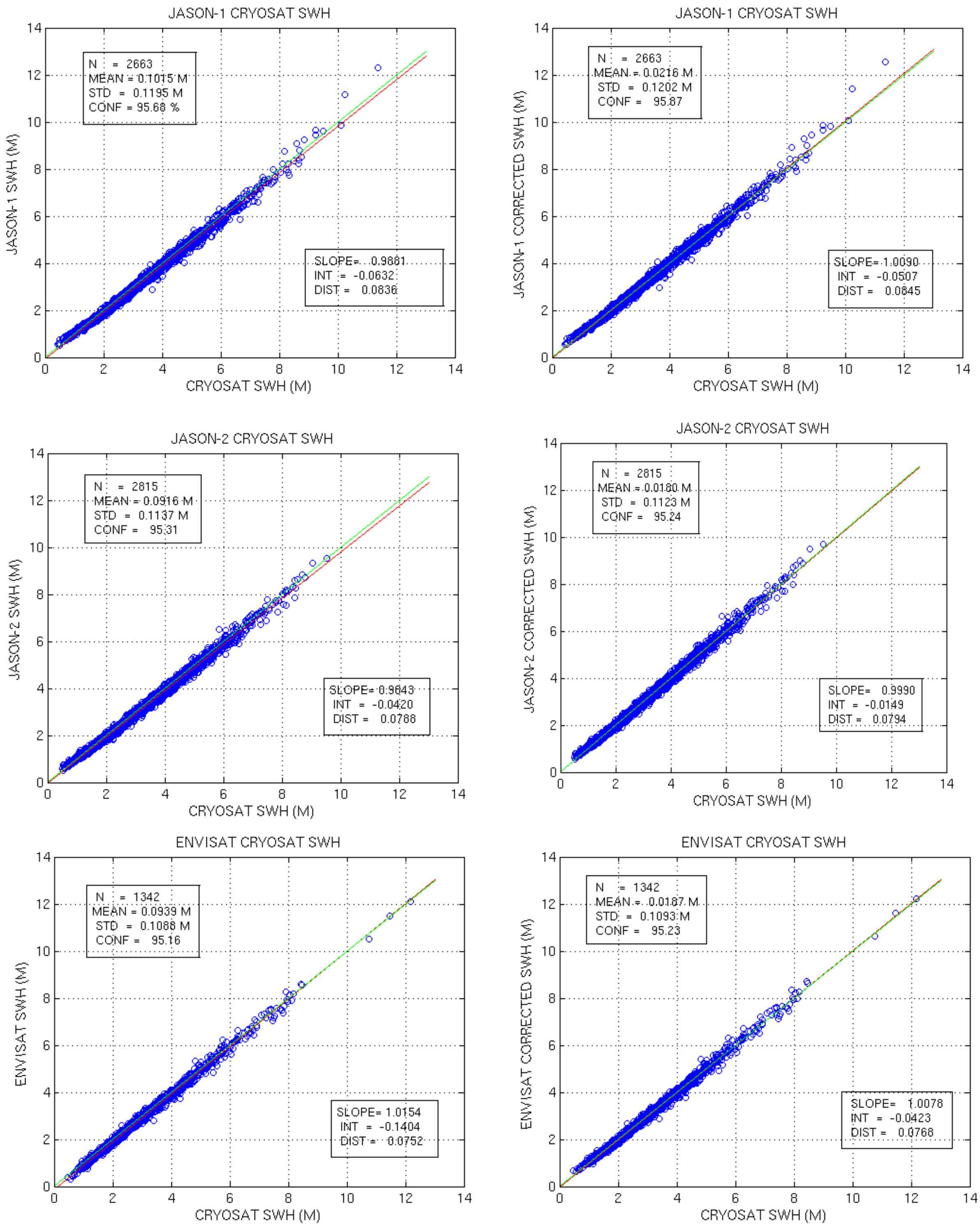

Fig 5: scatter-plots comparing collocated SWH measurements from CryoSat-2, and Jason-1 (top), Jason-2 (middle) and ENVISAT (bottom) GDR (left) and corrected GDR (right).

Results relatively to the 3 altimeters are very good. A better consistency is observed when using the Jason-1, Jason-2 and ENVISAT corrected data: the CryoSat-2 SWH mean bias is about 2 cm relative to Jason-1, Jason-2 and ENVISAT, with corresponding standard deviations of differences about 11 – 12 cm. Note that for the 1 Hz collocated data (not shown here) the mean bias is the same (1 cm to 2 cm), with a larger standard deviation of differences (24 cm) certainly due to the 1 hour maximum time difference between the 1Hz measurements.

A zoom on the low SWH part of the plots (not shown) indicates a consistent negative non linear bias of CryoSat-2 at low SWH, confirmed in figure 6.

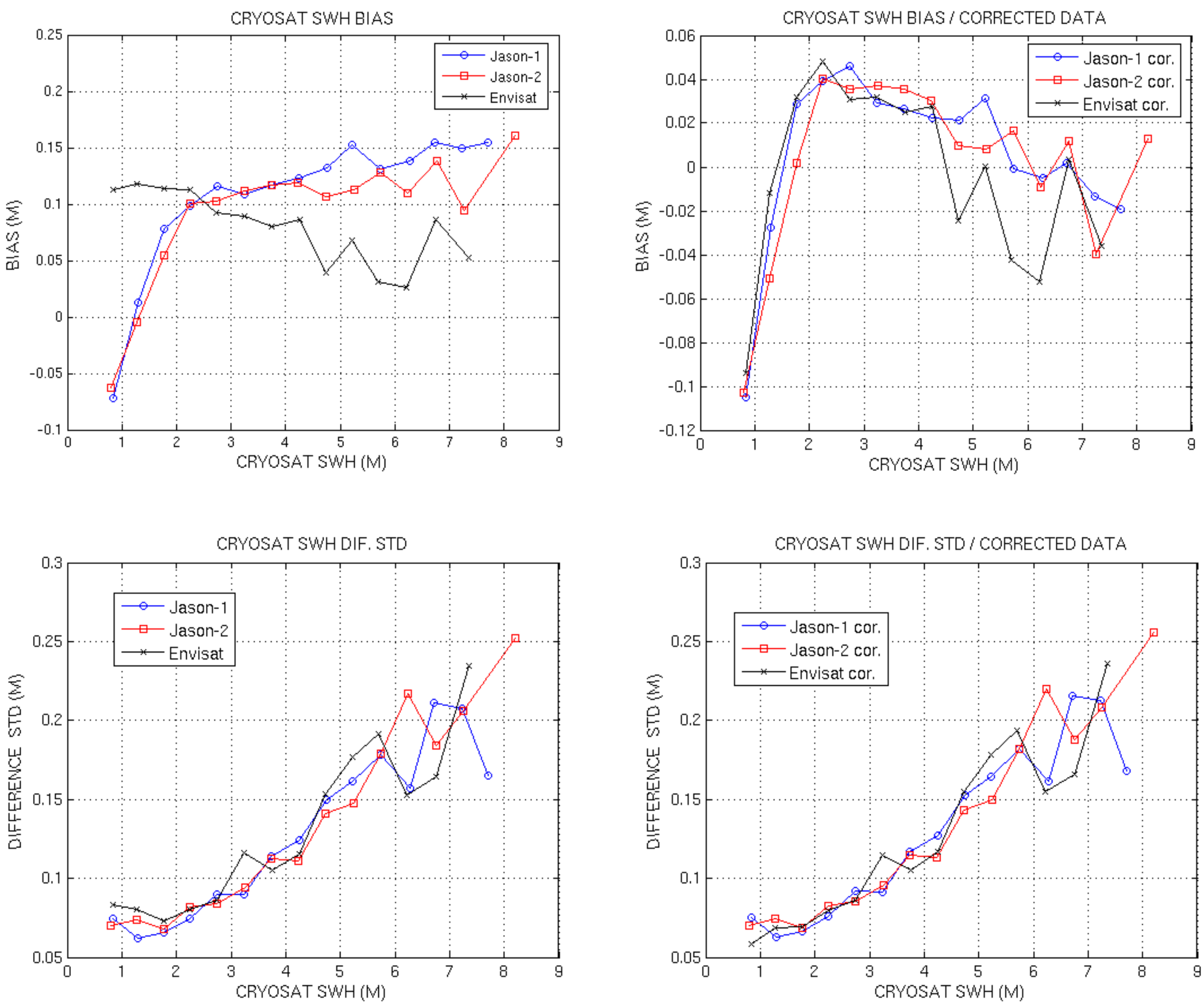

Fig 6: CryoSat-2 SWH bias (top) and SWH difference standard deviation (bottom) as a function of SWH, relative to Jason-1, Jason-2 and ENVISAT GDR (left) and corrected GDR (right) SWH.

Figure 6 shows the CryoSat-2 SWH bias and SWH difference standard deviation as a function of SWH. For the GDR data the bias behaviour is almost the same relative to Jason-1 and Jason-2, but not relative to ENVISAT (top, left). However, once the GDR are corrected (top, right) the behaviour of the CryoSat-2 SWH bias is very consistent relatively to the 3 altimeters: a negative bias up to -10 cm is observed for SWH less than 1.5 m; a positive bias, less than 4 cm is observed over the SWH range 1.5 m – 7 m. Indeed the observed differences for ENVISAT in top left are due to the non-linear behaviour of the ENVISAT SWH (version 2.1) as indicated by the above correction relation, and in Queffeulou and Croizé-Fillon 2011. These results are also a good validation for the proposed corrections for Jason-1, Jason-2 and ENVISAT GDR SWH. The standard deviation of differences (bottom) increases almost linearly from 6 cm to 20-25 cm.

CONCLUSION

CryoSat-2 IGDR SWH measurements are shown to be in close agreement with Jason-1, Jason-2 and ENVISAT GDR data. The agreement is better (particularly relative to ENVISAT) when the GDRs are corrected (mean SWH bias about 2 cm, standard deviation of differences about 12 cm, with identified variation with SWH range, for 50 km along track averaged collocated data), which furthermore confirms the validity of the proposed corrections for Jason-1, Jason-2 and ENVISAT.

Taking into account the global value of the quality flag, CryoSat-2 data were selected when the flag is equal to zero. Nevertheless some remaining spurious values of SWH are observed, associated with relatively high values of the corresponding 1Hz SWH standard deviation, and also, for many cases, associated with sigma0 blooms. It could be of interest to examine particularly the waveforms in such events. A threshold has been estimated to discard such data events. Presently this threshold might be a little bit too low, inducing to reject too much values as a function of SWH range.

REFERENCES

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