



# Envisat GDR Cross calibration Report

**Cycle 038**

**06-06-2005 11-07-2005**

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## **1 Introduction. Document overview**

The purpose of this document is to report the major features of the cross-calibration between Envisat and the ERS-2 and Jason-1 missions. The document is associated with data dissemination on a cycle by cycle basis.

The objectives of this document are :

- To present the major useful cross-calibration results for the current cycle
- To report any change likely to impact the comparison between Envisat and other missions, from instrument status to software configuration

It is divided into the following topics:

**Cycle overview**

**Cross Calibration with ERS-2**

**Cross Calibration with Jason-1**

## 2 Cycle overview

Envisat cycle 038 has been produced with the IPF processing chain V4.54 and the CMA Reference Software V6.1\_01. The quality assessment report (Quality assessment report of ENVISAT cycles [1]) summarizes the major features of the data quality.

The cross-calibration with ERS-2 OPR2 version 6.5 from CERSAT centre has been performed with ERS-2 OPR cycle 106. The main results for cycle 106 are reported in the ERS-2 Quality assessment report [2]. All the necessary updates were performed on ERS-2 data to be homogeneous with the Envisat data set.

The cross-calibration with Jason-1 GDRs (CMA Reference Software V6.1) has been performed with Jason-1 GDRs cycles 125 to 129. The main results for those cycles are reported in the Jason-1 Quality assessment report [3].

### 3 Cross Calibration with ERS-2

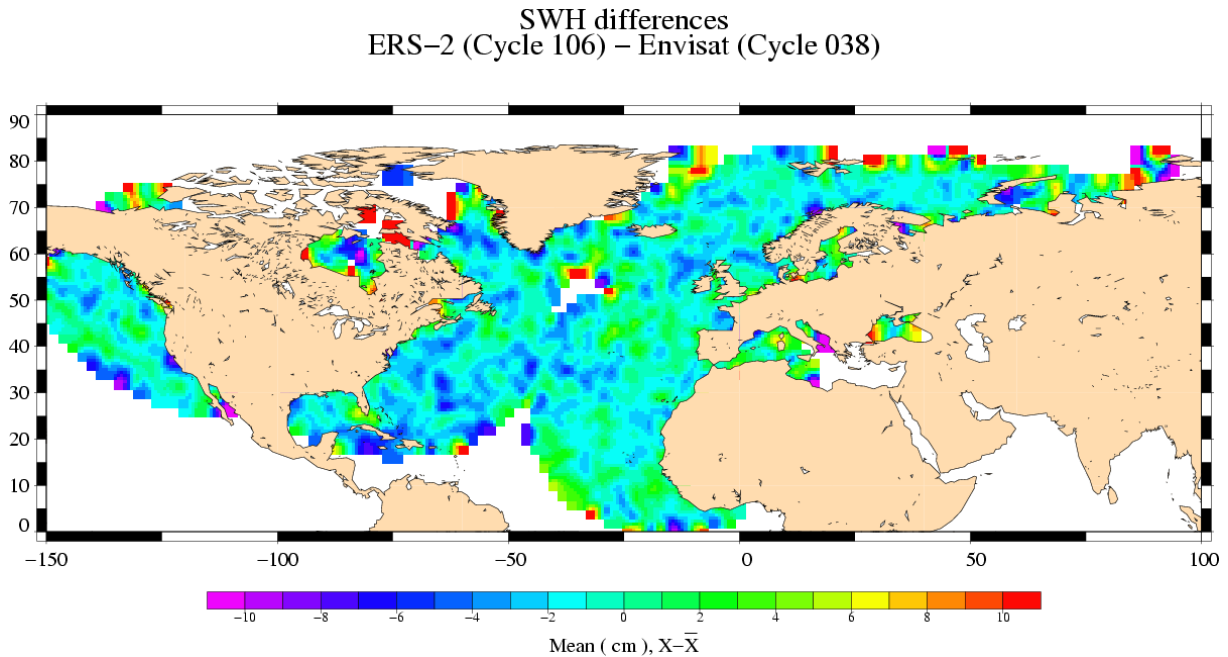
Envisat flies on the same ground track as ERS-2, about 30 minutes ahead. This section presents results that illustrate the difference with ERS-2.

A failure of the ERS-2 tape recorder occurred on 22 June 2003. The ERS-2 Low Rate mission continues within the visibility of ESA ground stations over Europe: North Atlantic, Arctic and western North America. Nevertheless, cross calibration with ERS-2 can be performed on this zone. Envisat cycle 038 data and data from ERS-2 OPR cycle 106 are collocated by repeat-track analysis in order to compare the main relevant parameters (SWH, SIGMA0, MWR, SSH). Note that no DGME-04 orbit files are available for this cycle, thus the DPAF orbit has been used.

#### 3.1 Cycle results

##### 3.1.1 [ERS-2 - Envisat] Ku SWH differences

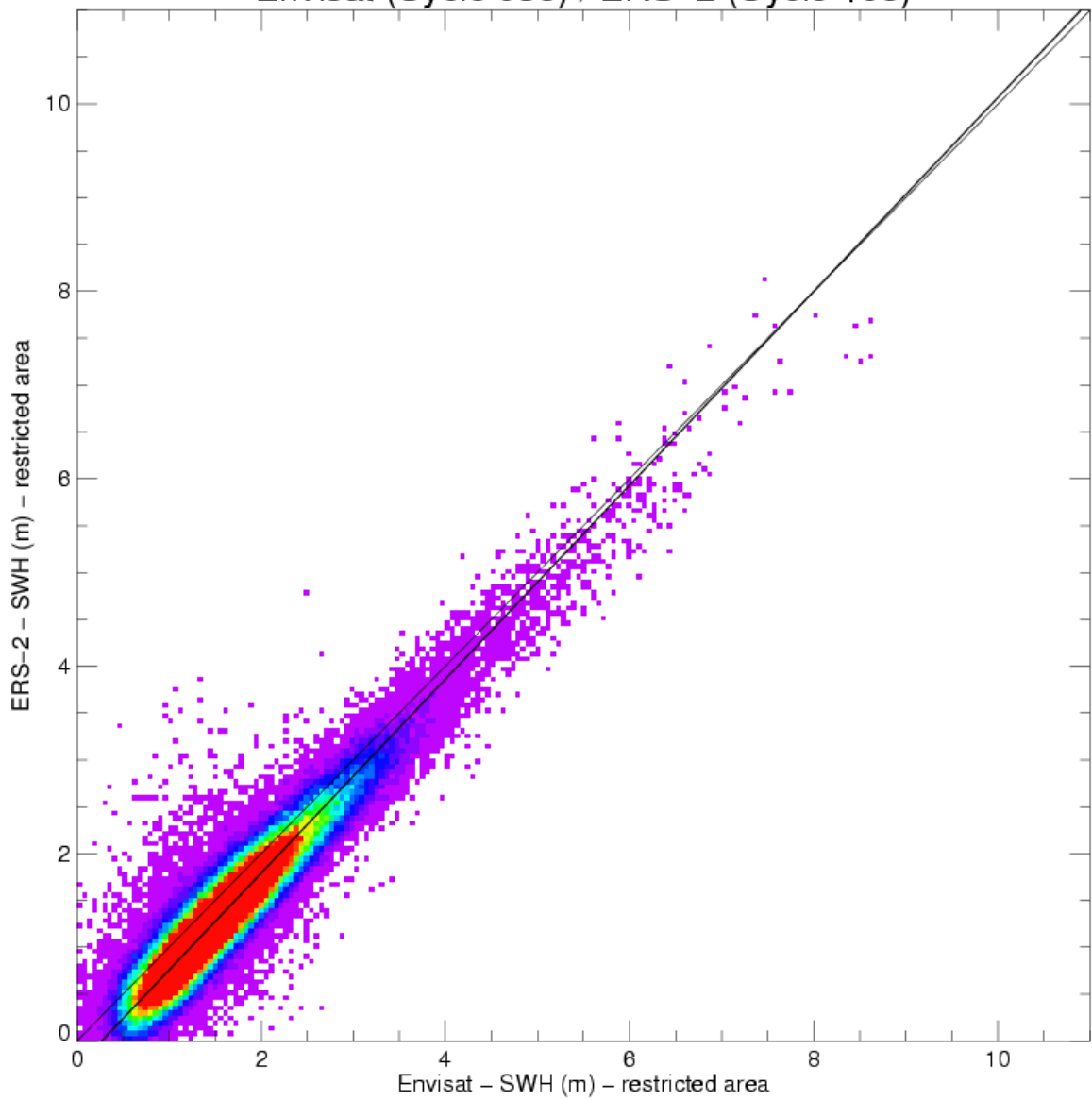
(ERS-2 - Envisat) Ku SWH differences are plotted on the following map (data are centered about the mean value).



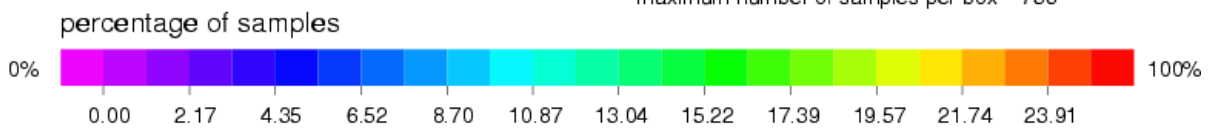
Analysis	Number	Mean (m)	Std. dev. (m)
E2-EN SWH	183327	-0.22	0.24

The Ku SWH values from ERS-2 and Envisat are compared in the next two charts, respectively, the scatter plot between ERS-2 and Envisat SWH values and a plot of (ERS-2 - Envisat) SWH differences as a function of SWH values.

# Envisat (Cycle 038) / ERS-2 (Cycle 106)



minimum number of samples per box 1  
 maximum number of samples per box 736



### Statistics Y-X

mean = -0.22132  
 rms = 0.32916  
 std = 0.24365

### Statistics Y,X

samples = 182954  
 covar = 0.41946  
 r = 0.93384

### Linear regression

type: least rectangle

$y = ax + b$   
 $a = 1.03476336$   
 $b = -0.27780660$

### Statistics X

mean = 1.59303  
 rms = 1.72390  
 std = 0.65885

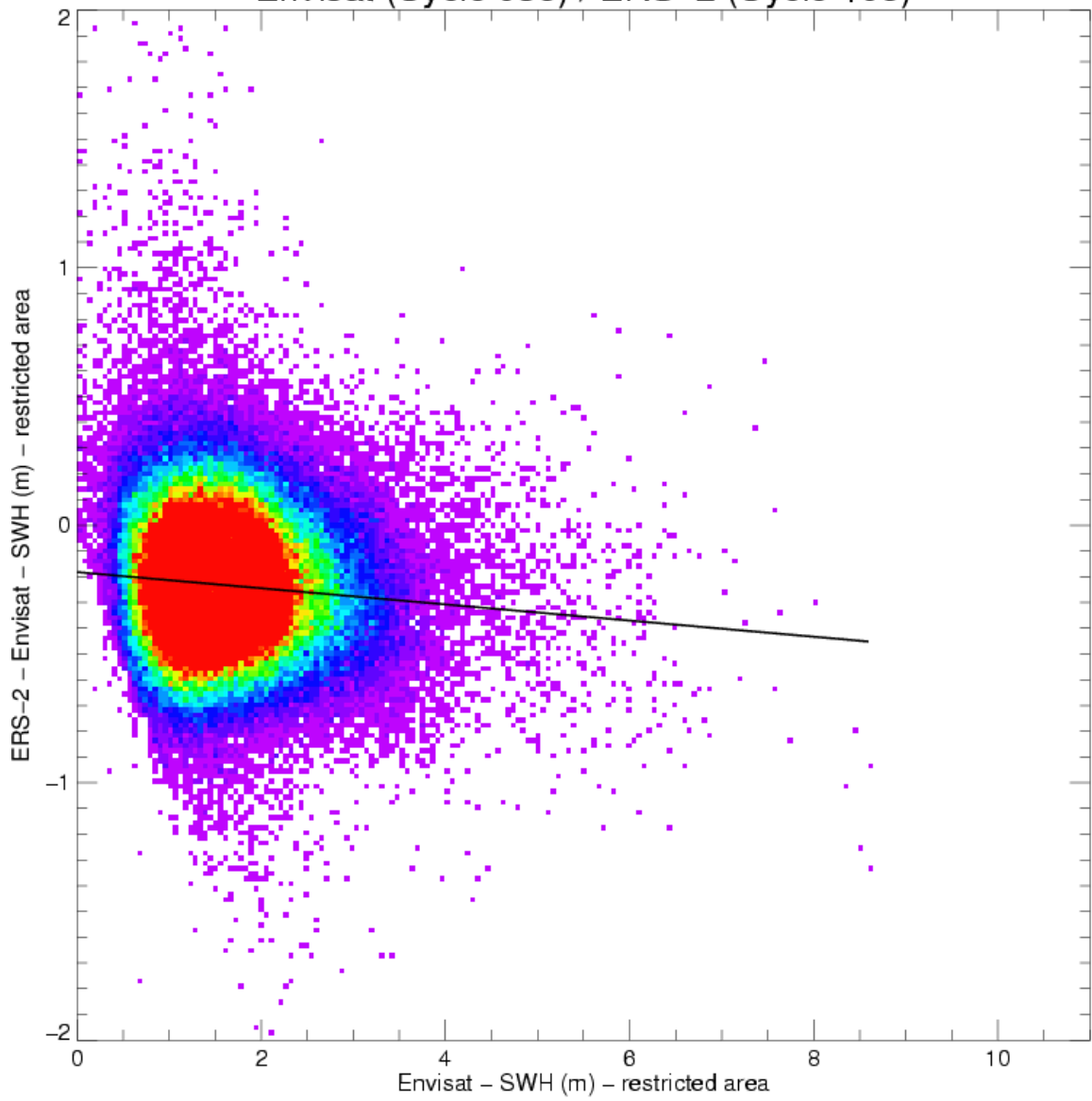
### Statistics Y

mean = 1.37060  
 rms = 1.53080  
 std = 0.68176

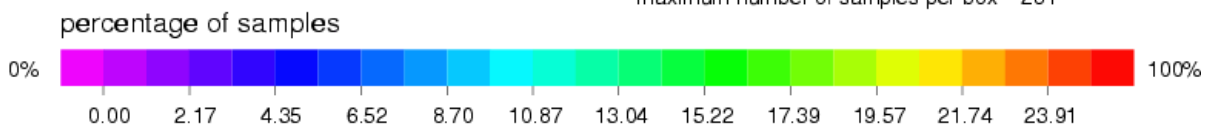
### Legend

— Linear regression  
 — Bisectrix

# Envisat (Cycle 038) / ERS-2 (Cycle 106)



minimum number of samples per box 1  
 maximum number of samples per box 281



### Order 1 fit polynomial

$$y = a x + b$$

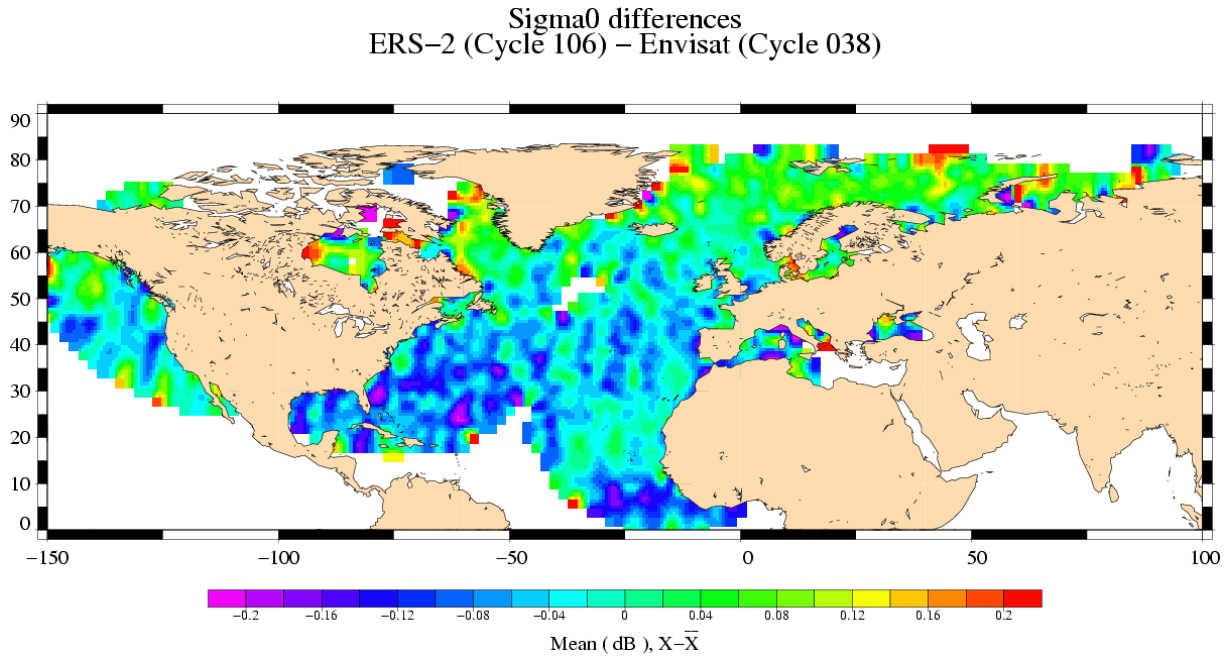
a = -0.03138500  
 b = -0.18198390

### Legend

— Order 1 fit polynomial

### 3.1.2 [ERS-2 - Envisat] Ku Sigma0 differences

(ERS-2 - Envisat) Ku SIGMA0 differences are plotted on the following map (data are centered about the mean value).

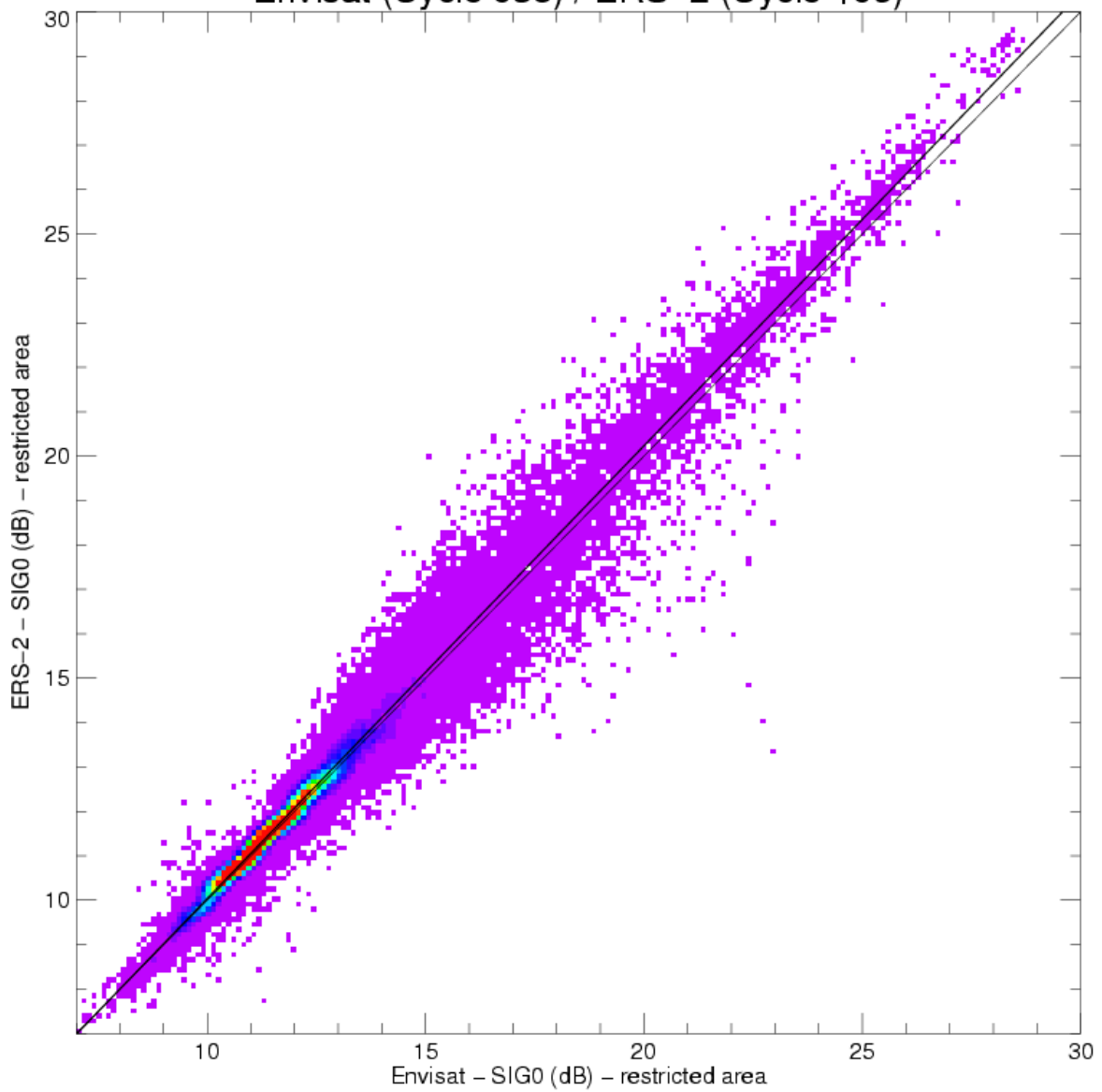


Analysis	Number	Mean (dB)	Std. dev. (dB)
E2-EN Sigma0	183327	0.07	0.32

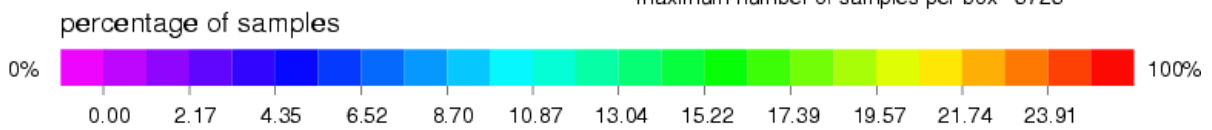
Wet areas appear because the ERS-2 atmospheric attenuation is incomplete (it only accounts for cloud liquid water path attenuation), contrary to the Envisat one. Note that the ERS-2 SIGMA0 has been corrected for a bias (+0.25 dB) as described in Dorandeu, 2000 [6].

The Ku SIGMA0 values from ERS-2 and Envisat are compared in the next two charts, respectively, the scatter plot between ERS-2 and Envisat SIGMA0 values and a plot of (ERS-2 - Envisat) SIGMA0 differences as a function of SIGMA0 values.

# Envisat (Cycle 038) / ERS-2 (Cycle 106)



minimum number of samples per box 1  
 maximum number of samples per box 3723



### Statistics Y-X

mean = 0.07259  
 rms = 0.33079  
 std = 0.32273

### Statistics Y,X

samples = 183327  
 covar = 3.42459  
 r = 0.98505

### Linear regression

type: least rectangle

$y = ax + b$   
 $a = 1.01927023$   
 $b = -0.15423587$

### Statistics X

mean = 11.78947  
 rms = 11.93325  
 std = 1.84684

### Statistics Y

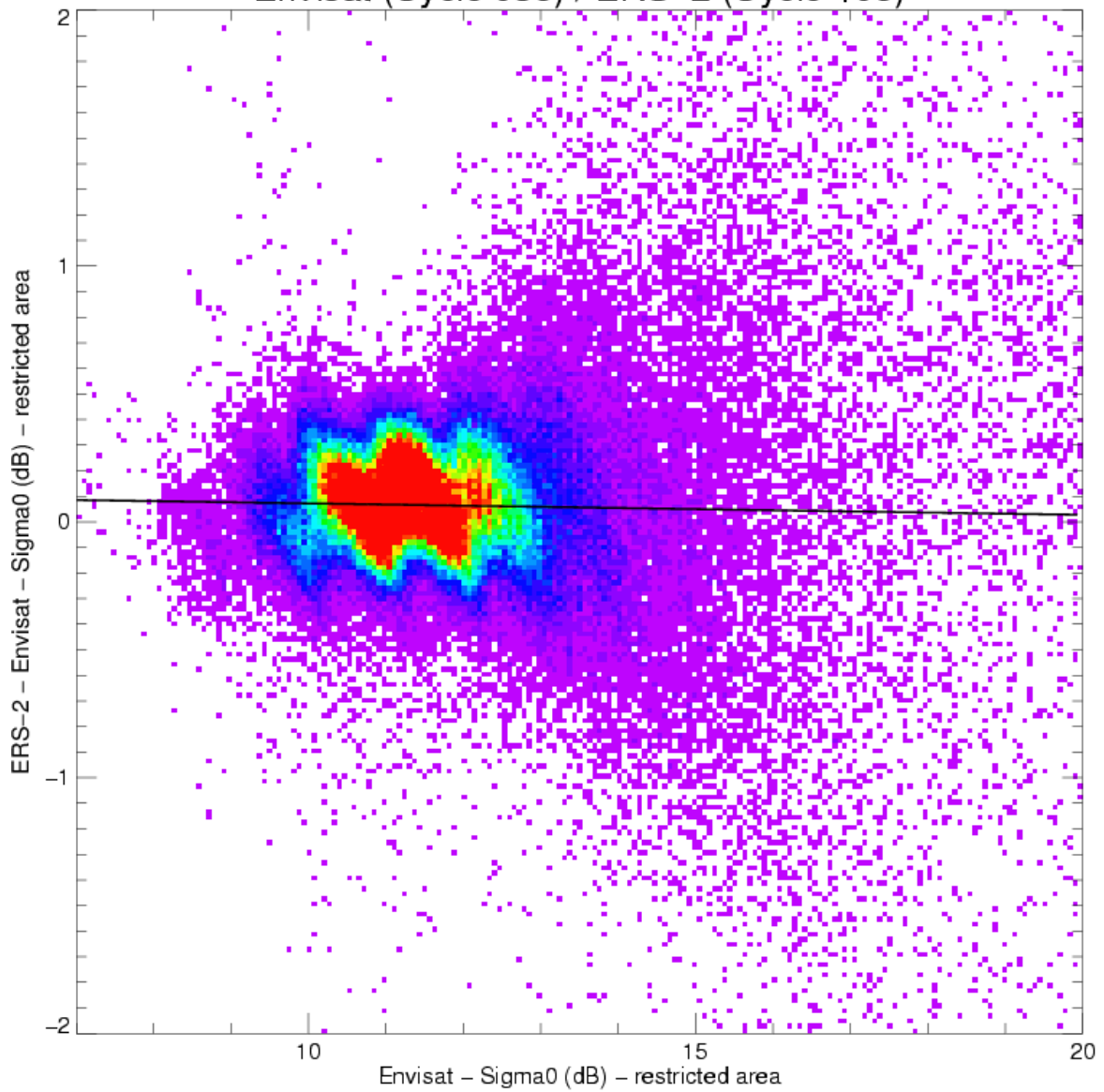
mean = 11.86242  
 rms = 12.01085  
 std = 1.88243

### Legend

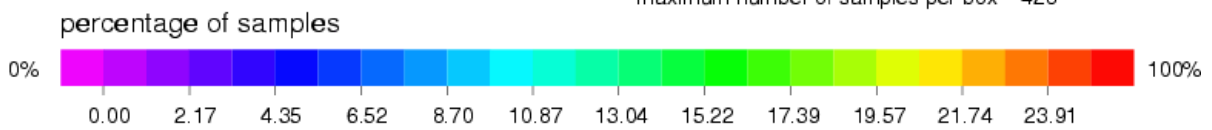
— Linear regression  
 — Bisectrix



## Envisat (Cycle 038) / ERS-2 (Cycle 106)



minimum number of samples per box 1  
 maximum number of samples per box 428



### Order 1 fit polynom

$$y = ax + b$$

$a = -0.00446700$   
 $b = 0.11665459$

### Legend

— Order 1 fit polynom

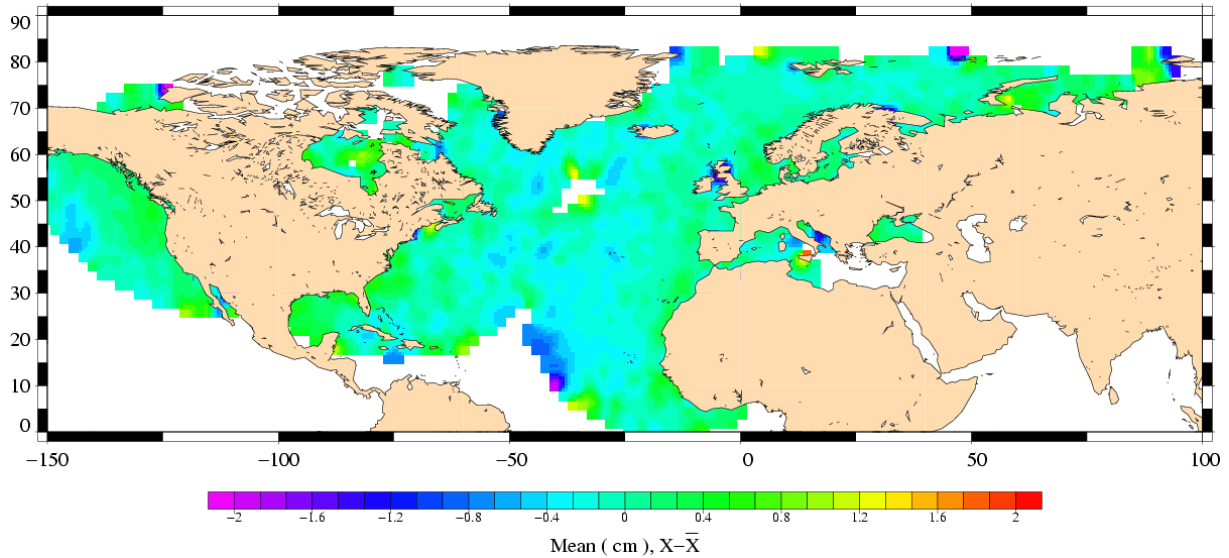
The particular features of the SIGMA0 differences mainly come from the shape of the ERS-2 histogram.

### 3.1.3 [ERS-2 - Envisat] radiometer wet troposphere correction differences

The ERS-2 radiometer correction is recomputed to correct for the gain drop and for the drift of the 24 GHz brightness temperature (Obligis et al., 2003 [4]).

(ERS-2 - Envisat) Radiometer wet troposphere correction differences are plotted on the following map (data are centered about the mean value).

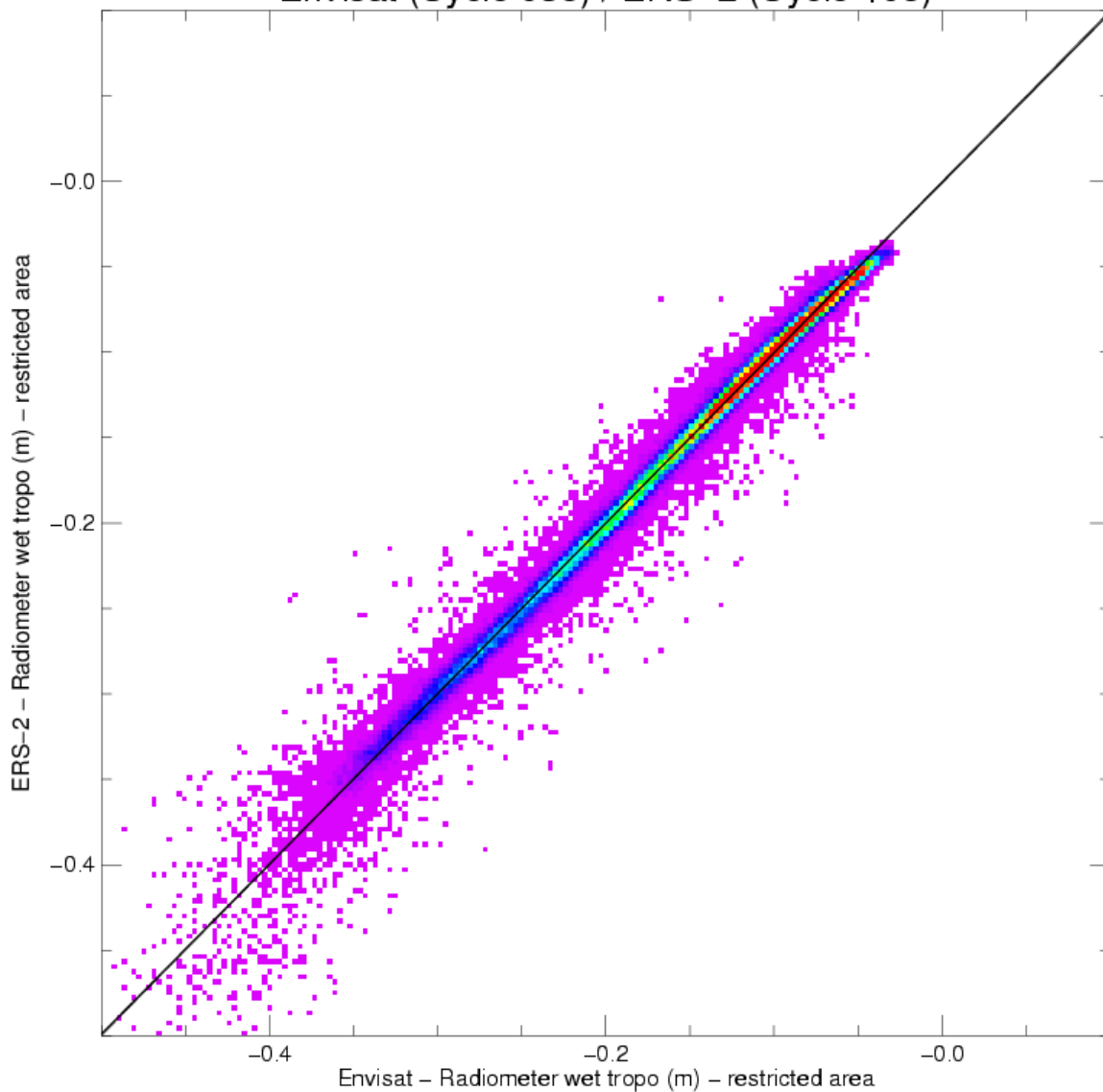
Radiometer wet tropo correction differences  
ERS-2 (Cycle 106) – Envisat (Cycle 038)



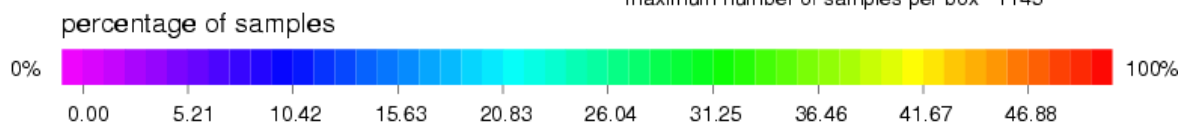
Analysis	Number	Mean (cm)	Std. dev. (cm)
E2-EN radiometer	183327	-0.03	0.69

The MWR wet troposphere corrections from ERS-2 and Envisat are compared in the next two charts, respectively, the scatter plot between ERS-2 and Envisat values and a plot of (ERS-2 - Envisat) differences as a function of MWR wet troposphere values.

# Envisat (Cycle 038) / ERS-2 (Cycle 106)



minimum number of samples per box 1  
maximum number of samples per box 1145



### Statistics Y-X

mean = -0.00025  
rms = 0.00699  
std = 0.00699

### Statistics Y,X

samples = 183326  
covar = 0.00611  
r = 0.99599

### Linear regression

type: least rectangle

$y = ax + b$   
a = 0.99620416  
b = -0.00083980

### Statistics X

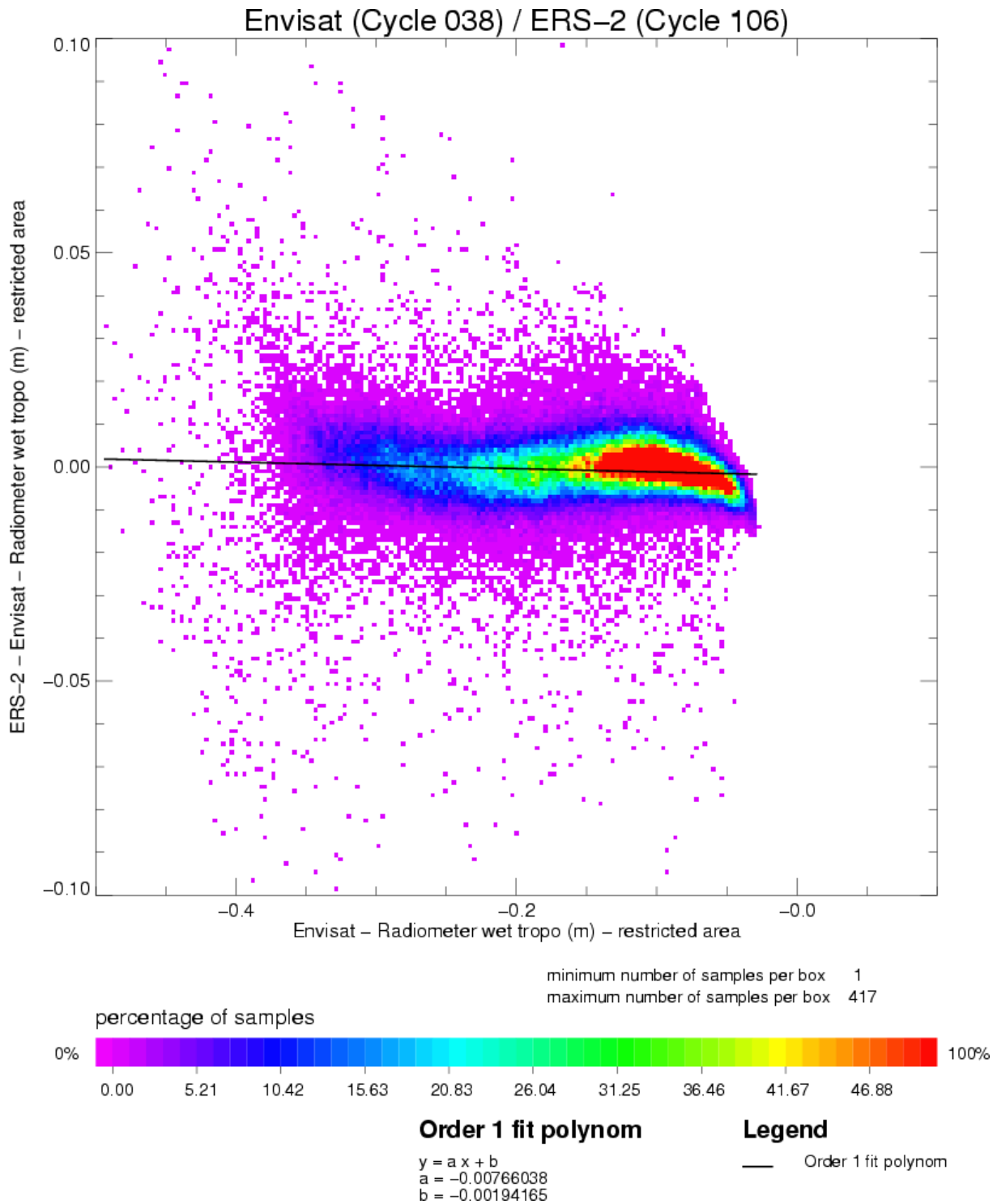
mean = -0.15413  
rms = 0.17295  
std = 0.07846

### Statistics Y

mean = -0.15439  
rms = 0.17304  
std = 0.07816

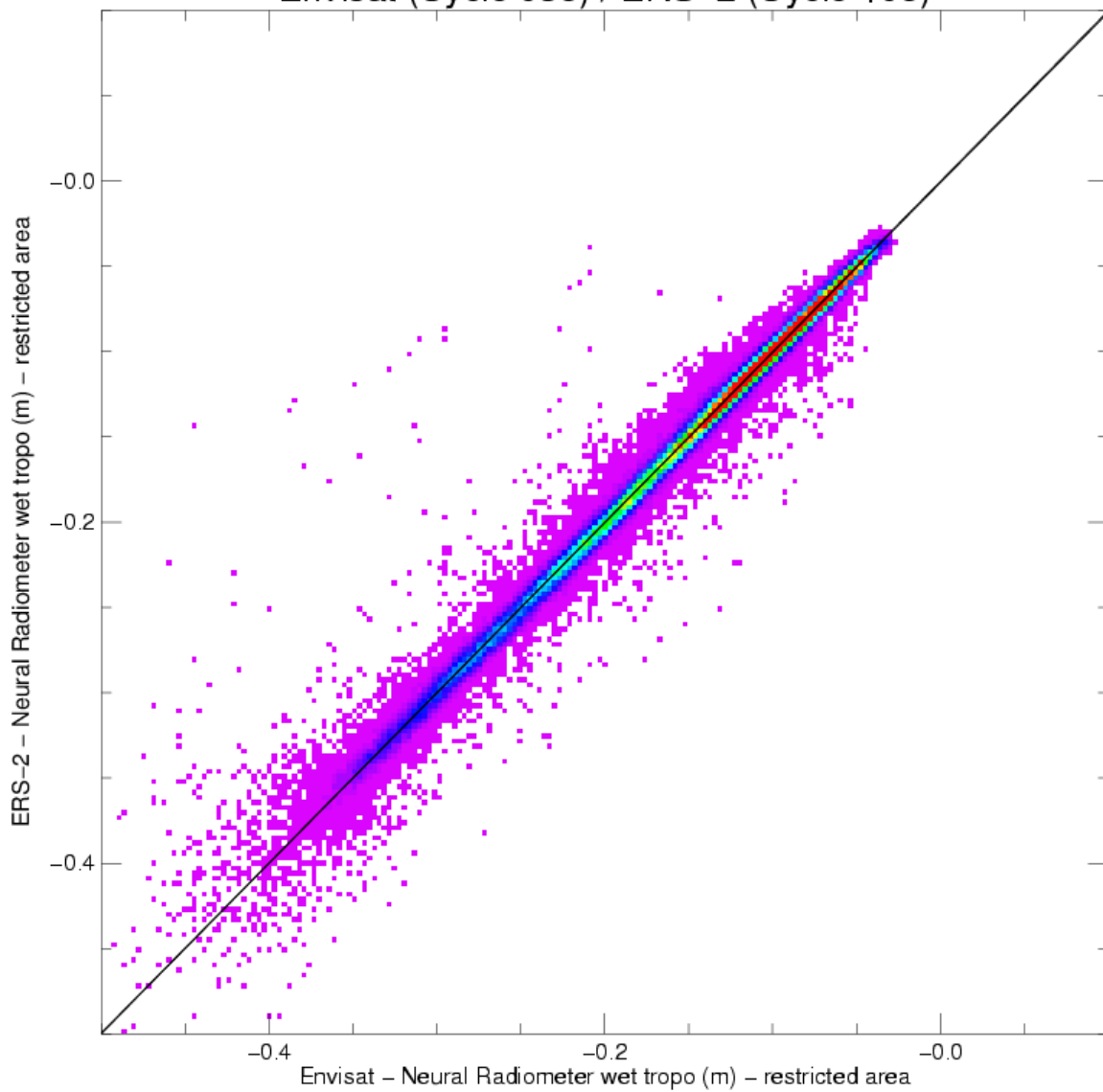
### Legend

— Linear regression  
— Bisectrix

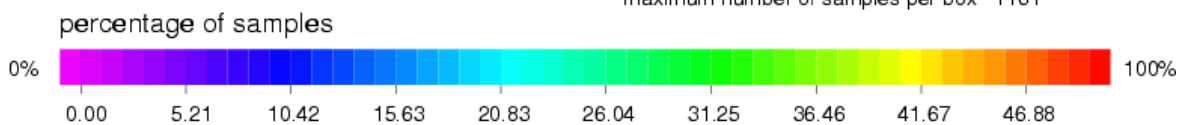


Note that the differences observed in dry conditions are mainly due to the ERS-2 algorithm. Indeed the next scatter plot shows the neural network ERS-2 MWR correction ([5]) and the Envisat one agree very well.

# Envisat (Cycle 038) / ERS-2 (Cycle 106)



minimum number of samples per box 1  
 maximum number of samples per box 1161



### Statistics Y-X

mean = -0.00041  
 rms = 0.00707  
 std = 0.00705

### Statistics Y,X

samples = 183326  
 covar = 0.00612  
 r = 0.99591

### Linear regression

type: least rectangle

$y = ax + b$   
 $a = 0.99765382$   
 $b = -0.00077616$

### Statistics X

mean = -0.15413  
 rms = 0.17295  
 std = 0.07846

### Statistics Y

mean = -0.15455  
 rms = 0.17324  
 std = 0.07827

### Legend

— Linear regression  
 — Bisectrix

### 3.1.4 [ERS-2 - Envisat] SSH differences

In order to compare SSH estimations from the two missions, ERS-2 OPRs have been updated with algorithms and corrections similar to Envisat.

The ERS-2 SSH is then computed as follows:

- + DPAF orbit (no DGME-04 orbit for this cycle)
- Range corrected for SPTR, USO, time tag bias [8]
- ECMWF wet tropospheric correction (rectangular grid)
- ECMWF dry tropospheric correction
- 3-parameter sea state bias [9]
- Inverted barometer correction with time varying reference pressure
- Total geocentric GOT00 ocean tide
- Geocentric pole tide height
- Solid earth tide height
- GIM ionospheric correction

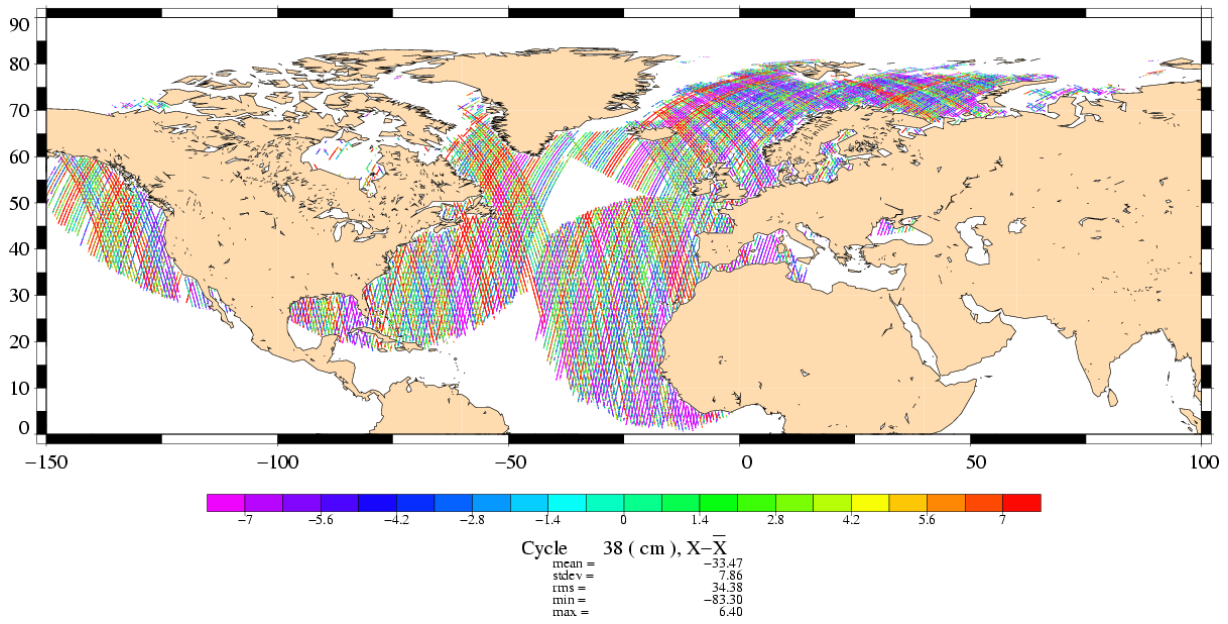
The SSH computed for Envisat is:

- + Orbit from the product
- Range from the product
- ECMWF wet tropospheric correction (rectangular grid)
- ECMWF dry tropospheric correction
- Non parametric SSB
- Inverted barometer correction with time varying reference pressure
- Total geocentric GOT00 ocean tide height
- Solid earth tide height
- GIM ionospheric correction

For Envisat, the only changes relative to the GDR product are ECMWF wet troposphere correction and GIM ionosphere correction.

(ERS-2 - Envisat) SSH differences are plotted on the following figure:

Corrected SLA (GIM iono, ECMWF (gaussian) wet tropo configuration)  
ERS-2 (Cycle 106) – Envisat (Cycle 038)



Analysis	Number	Mean (cm)	Std. dev. (cm)
E2-EN SLA	183327	-33.47	7.86

Some part of the along-track (ERS-2 - Envisat) SSH differences might be mainly due to ERS-2 residual orbit errors.

## 4 Cross Calibration with Jason-1

Jason-1 GDRs data (cycle 125 to 129) are used for this cross calibration. The parameters used to compute the sea surface height (SSH) for Envisat and Jason-1 are:

- radiometer wet troposphere correction
- ECMWF dry troposphere correction
- dual frequency ionospheric correction
- non parametric SSB
- inverse barometer with time varying pressure
- GOT00 ocean tide
- pole tide correction
- earth tide correction

Some comparisons were also performed using the ECMWF wet troposphere correction for both Envisat and Jason-1, to prevent possible discrepancies from radiometer corrections.

Several analyses were performed for this cross calibration study:

- comparison of altimeter and radiometer parameters
- comparison of Sea Level Anomalies relative to a Mean Sea Surface
- computation of a long wavelength error on Envisat
- comparison on a same time/space sampling

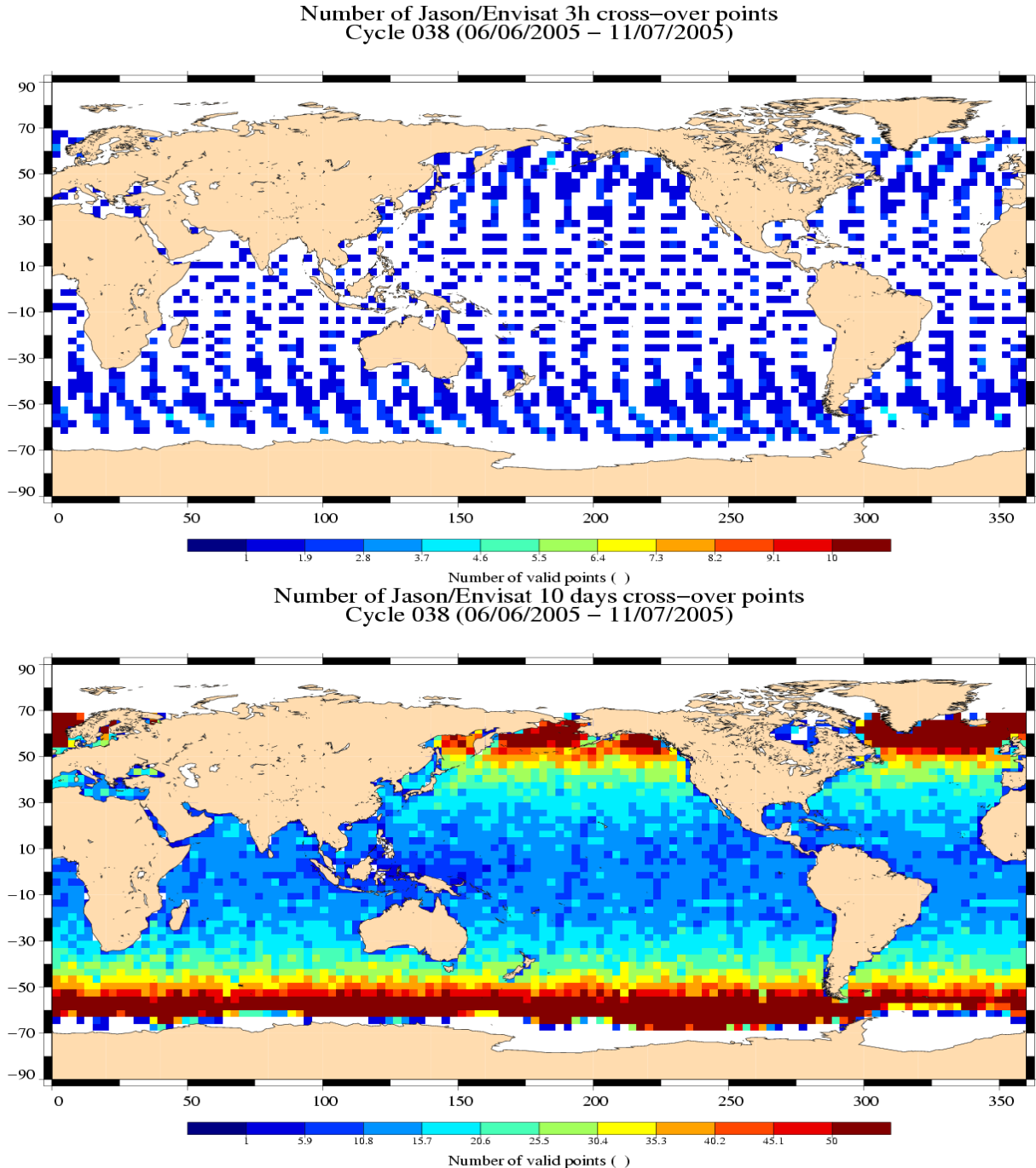
10 day crossovers are used to compare SSH estimations from Envisat and Jason-1 while shorter time lags (3 hours) are selected for altimeter and radiometer parameters.



## 4.1 Dual-crossover points

### 4.1.1 3-hour and 10-day crossover points location

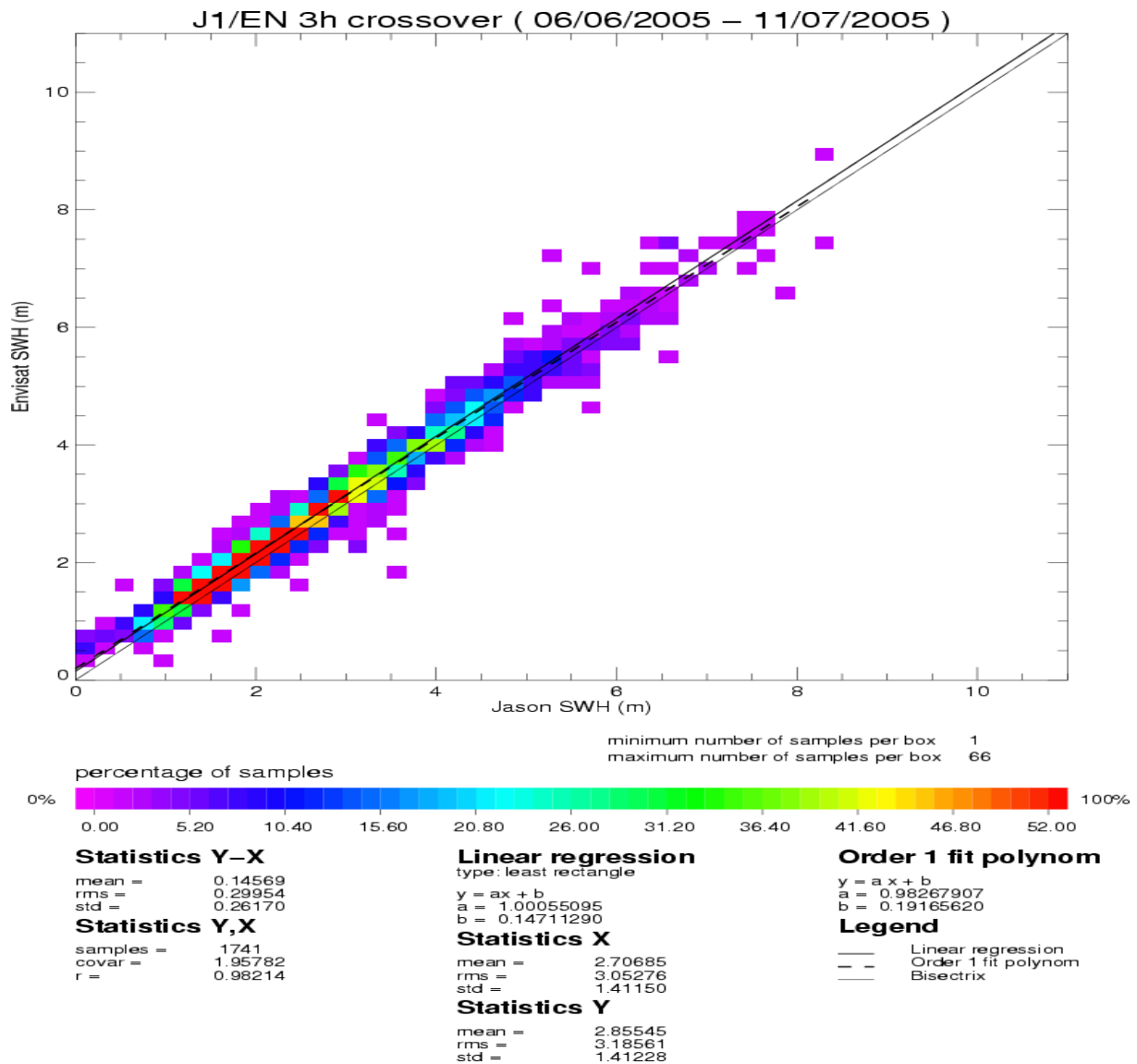
For Envisat Cycle 038 the location of crossover points with 3-hour and 10 day time lags between Envisat and Jason-1 are given on the following figures:



Most of the crossover points are located at high latitude. With 3-hour time lag there are only a few crossover points at mid and low latitudes. This geographical pattern is not constant for every Envisat cycle since Jason-1 is not sun-synchronous. When more Envisat data become available, (Jason-1/Envisat) comparisons will be performed over 12 Jason-1 cycle windows, so that the geographical sampling by Jason-1/Envisat crossovers will be constant.

### 4.1.2 [Envisat - Jason-1] Ku-band SWH differences

The scatter plot of crossover points with 3-hour time lag between Envisat and Jason-1 Ku-band SWH measurements is given on the following figure:

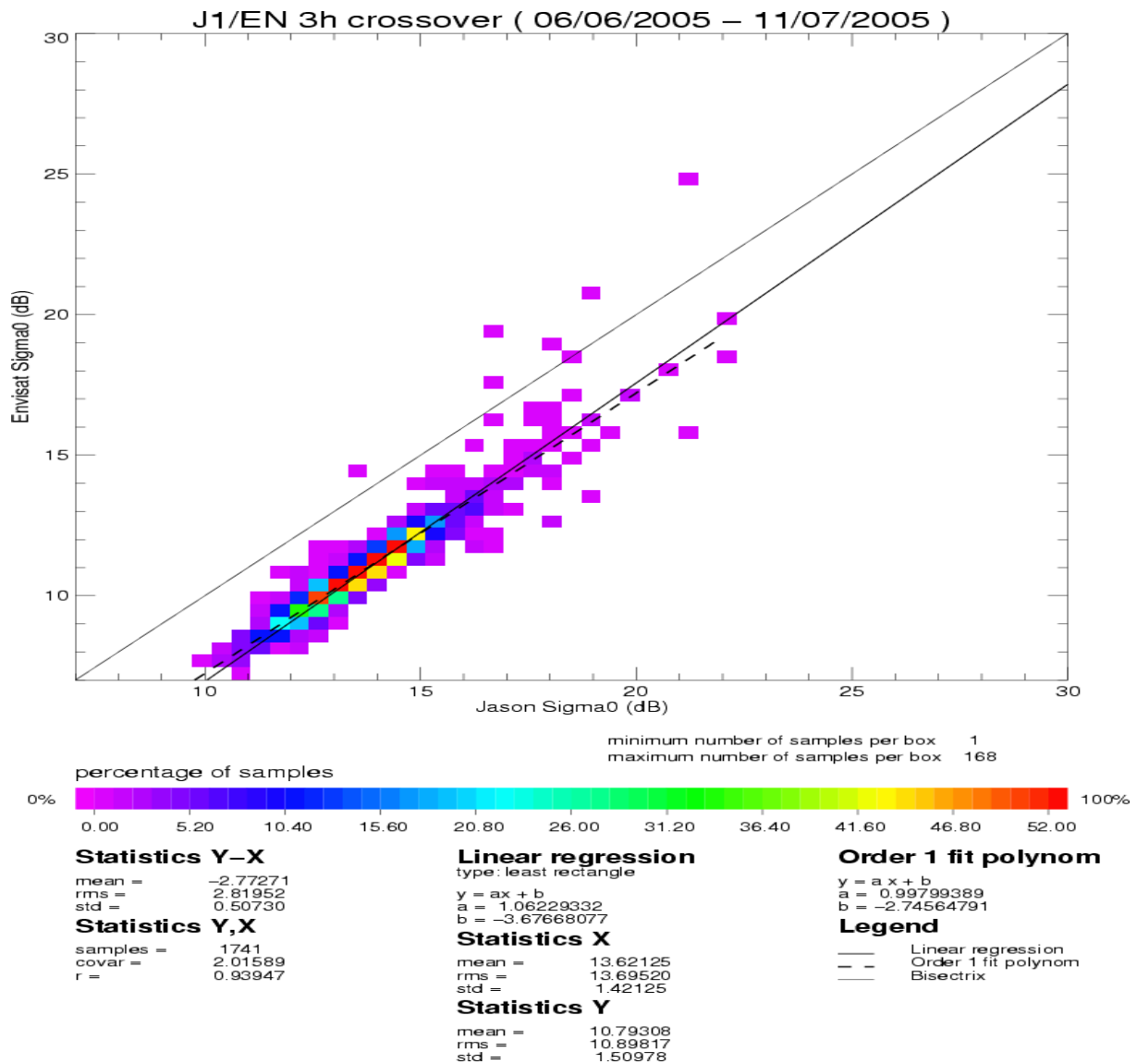


Analysis	Number	Mean (m)	Std. dev. (m)
EN-J1 SWH (m)	1741	0.15	0.25

There is a small bias between the two satellites: Envisat waves are slightly higher than Jason-1 ones.

### 4.1.3 [Envisat - Jason-1] Ku-band Sigma0 differences

The scatter plot of crossover points with 3-hour time lag between Envisat and Jason-1 Ku-band Sigma0 measurements is given on the following figure:

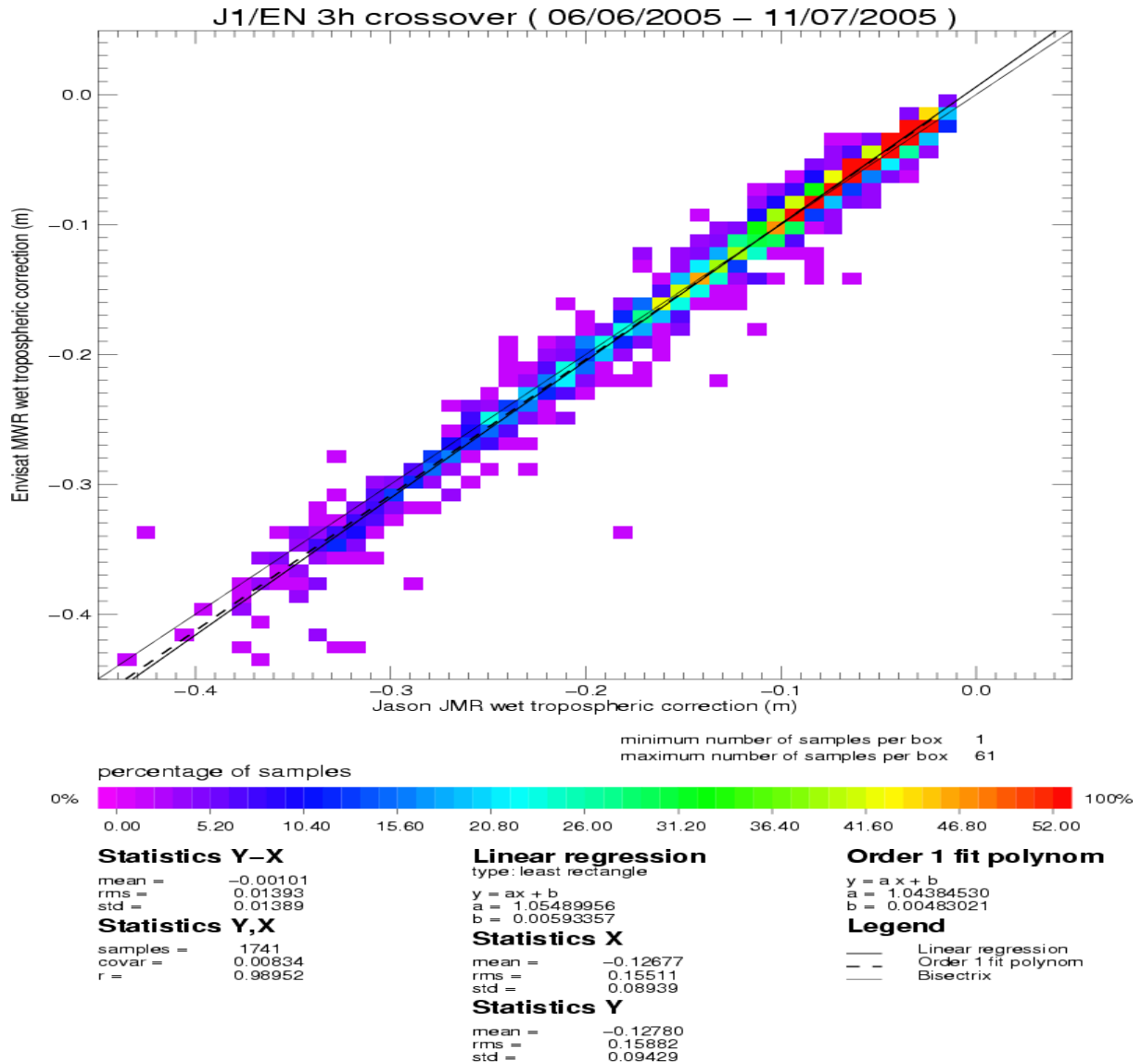


Analysis	Number	Mean (dB)	Std. dev. (dB)
EN-J1 Sigma0 (dB)	1741	-2.83	0.47

Jason-1 Ku-band sigma0 is 2.8 dB higher than Envisat. Envisat Ku-band sigma0 has been aligned on ERS-2 to satisfy the MWC wind model. Notice that Jason-1 Ku-band sigma0 is 2.3 dB higher than TOPEX. This difference is described in (Vincent et al., 2003 [10]).

#### 4.1.4 [Envisat - Jason-1] radiometer wet troposphere differences

The scatter plot of crossover points with 3-hour time lag between Envisat and Jason-1 radiometer wet troposphere correction is given on the following figure:



Analysis	Number	Mean (cm)	Std. dev. (cm)
EN-J1 radiometer wet troposphere correction (m)	1741	-0.09	1.35

Results are consistent over dry areas. There are not enough crossover points at low latitudes to comment the differences in wet areas.

#### 4.1.5 [Envisat - Jason-1] SSH differences

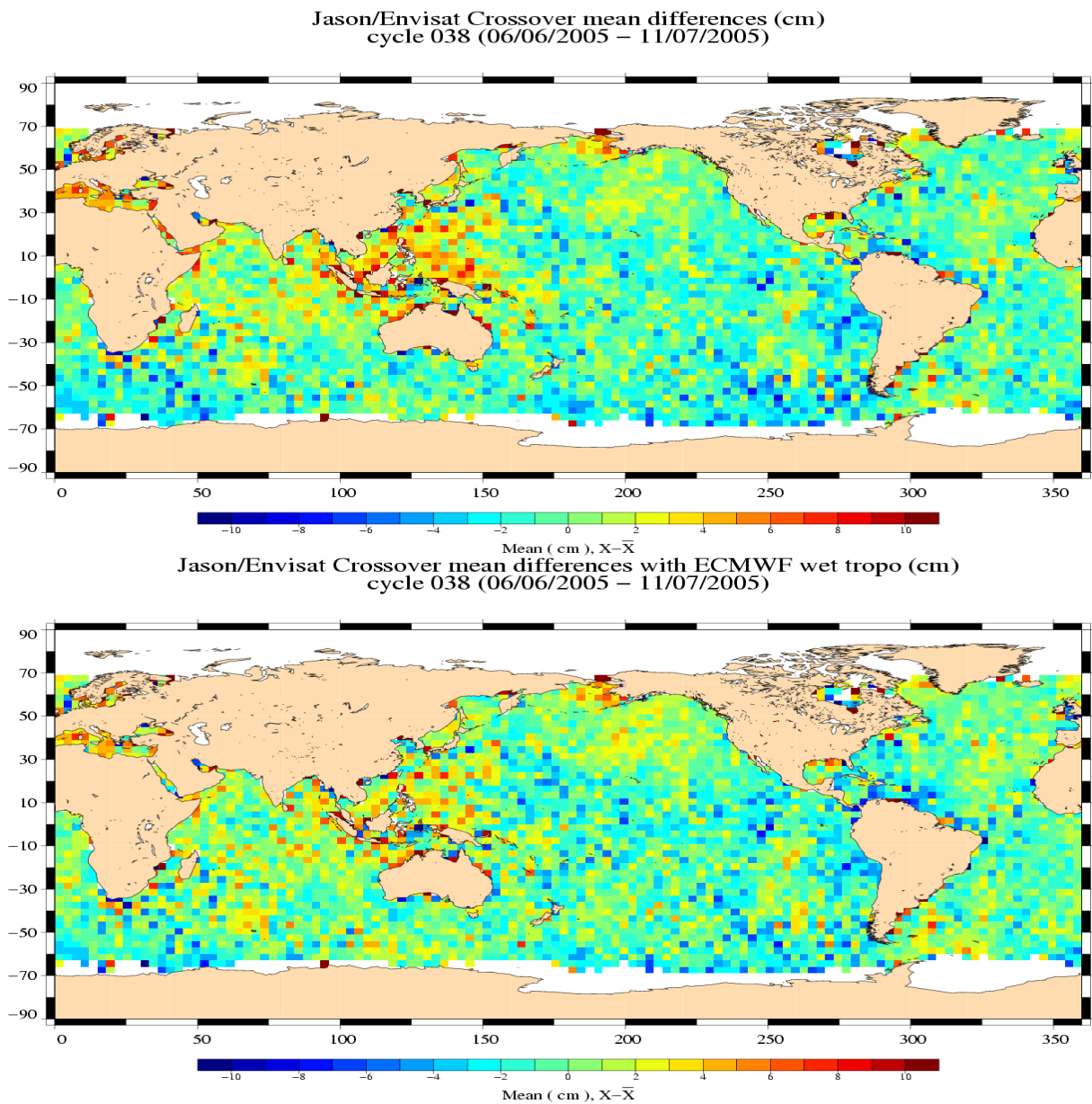
[Envisat - Jason-1] SSH differences at crossover points with 10 day time lag are computed in two configurations:

- using the radiometer wet troposphere correction
- using the ECMWF wet troposphere correction

When using a selection to remove shallow waters (1000 m), global statistics are:

Analysis	Number	Mean (cm)	Std. dev. (cm)
EN-J1 SSH	94451	26.71	7.55
EN-J1 SSH with ECMWF wet troposphere	94451	26.82	7.62

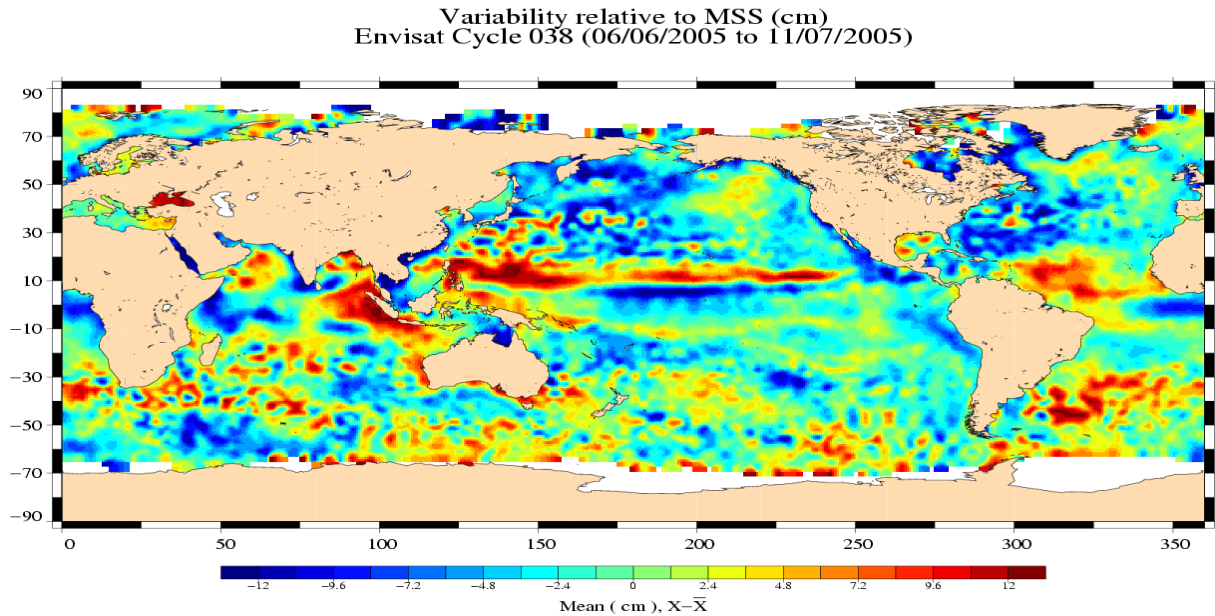
The differences are plotted on the following figure (data are centered about the mean value):



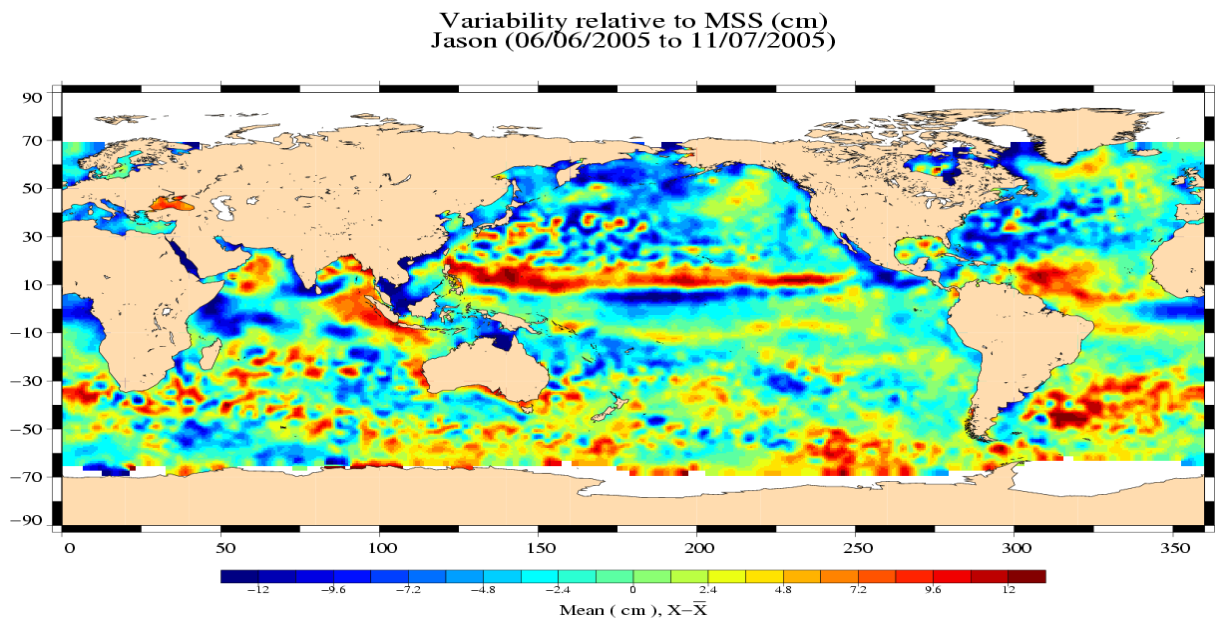
The two maps are very close. There are small scale [Envisat - Jason-1] differences in high variability areas, but also large scale differences in the Pacific ocean.

## 4.2 SLA Comparisons

Envisat and Jason-1 Sea Level anomalies relative to CLS01 Mean Sea Surface are computed. Global statistics are computed over deep ocean areas (1000 m) and low variability. In order to see fine features, maps are centered about the mean value.



Analysis	Number	Mean (cm)	Std. dev. (cm)
Envisat SLA	1201957	44.37	9.19



Analysis	Number	Mean (cm)	Std. dev. (cm)
Jason-1 SLA	1598870	17.35	9.38

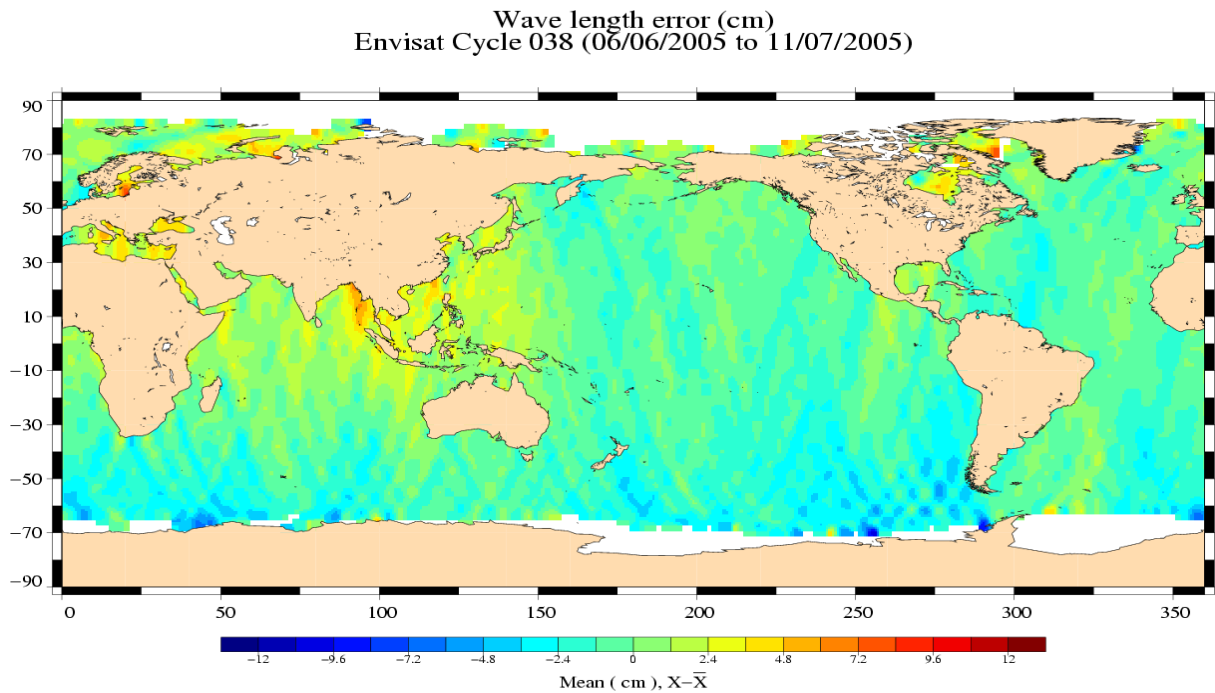
There is a very good correlation between the two maps. The SLA standard deviation for both Envisat and Jason-1 is about 9.5 cm. Differences are mainly due to the spatial and temporal

sampling of the ocean.

### 4.3 Long wavelength error reduction

#### 4.3.1 Long wavelength error

The Envisat long wavelength error has been computed by global minimization of (EN-J1) SSH differences. The method is described in (Le Traon et al., 1998 [11]). The map of the error is plotted on the following figure (data are centered about the mean value):



Analysis	Number	Mean (cm)	Std. dev. (cm)
Envisat lw error	1368981	27.25	2.70

The estimated long wavelength error has a small variance which confirms the good quality of the Envisat orbit.



### 4.3.2 Impact on crossover performances

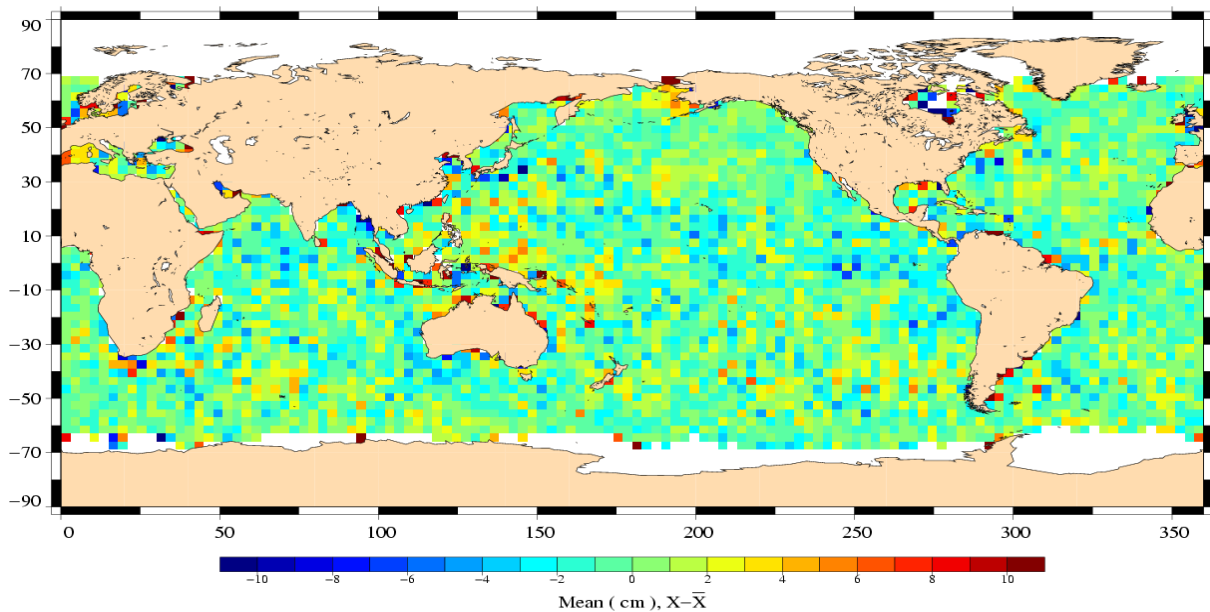
Global statistics for 35 days [Envisat - Envisat] and 10 days [Envisat - Jason-1] are only computed over deep ocean areas (1000 m) :

Analysis	Number	Mean (cm)	Std. dev. (cm)
EN/EN SSH	36814	0.82	8.85
EN/EN SSH with orbit error	36814	0.18	8.08

Analysis	Number	Mean (cm)	Std. dev. (cm)
EN-J1 SSH	94451	26.71	7.55
EN-J1 SSH with orbit error	94451	0.05	6.96

The [Envisat - Jason-1] difference corrected for the estimate Envisat long wavelength error are plotted on the following figure (data are centered about the mean value):

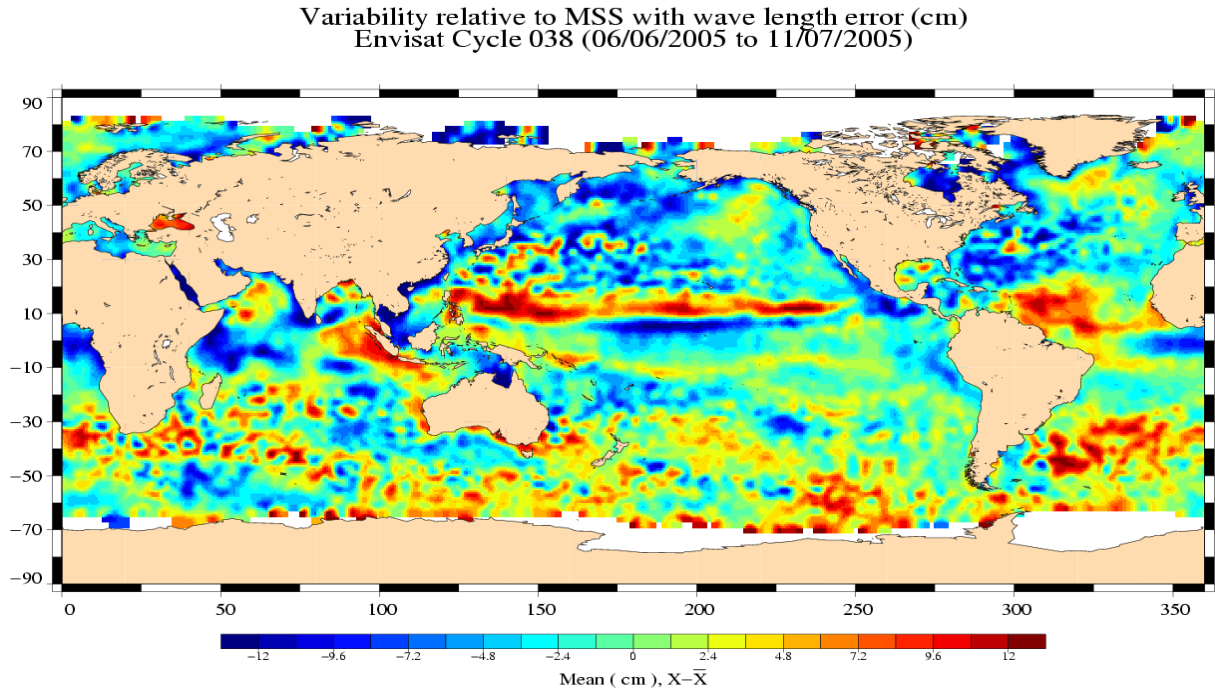
Jason/Envisat with LWE Crossover mean differences (cm)  
cycle 038 (06/06/2005 – 11/07/2005)



The large scale differences in the Pacific ocean are noticeably reduced.

### 4.3.3 Impact on SLA performance

Envisat Sea Level anomalies relative to CLS01 Mean Sea Surface using the long wavelength error are computed. Global statistics are computed using a selection to remove shallow waters (1000 m). Map is centered about the mean value.



Analysis	Number	Mean (cm)	Std. dev. (cm)
Envisat SLA	1201957	17.24	8.92

The slight impact on Envisat SLA variance shows that the Envisat long wavelength error is low.

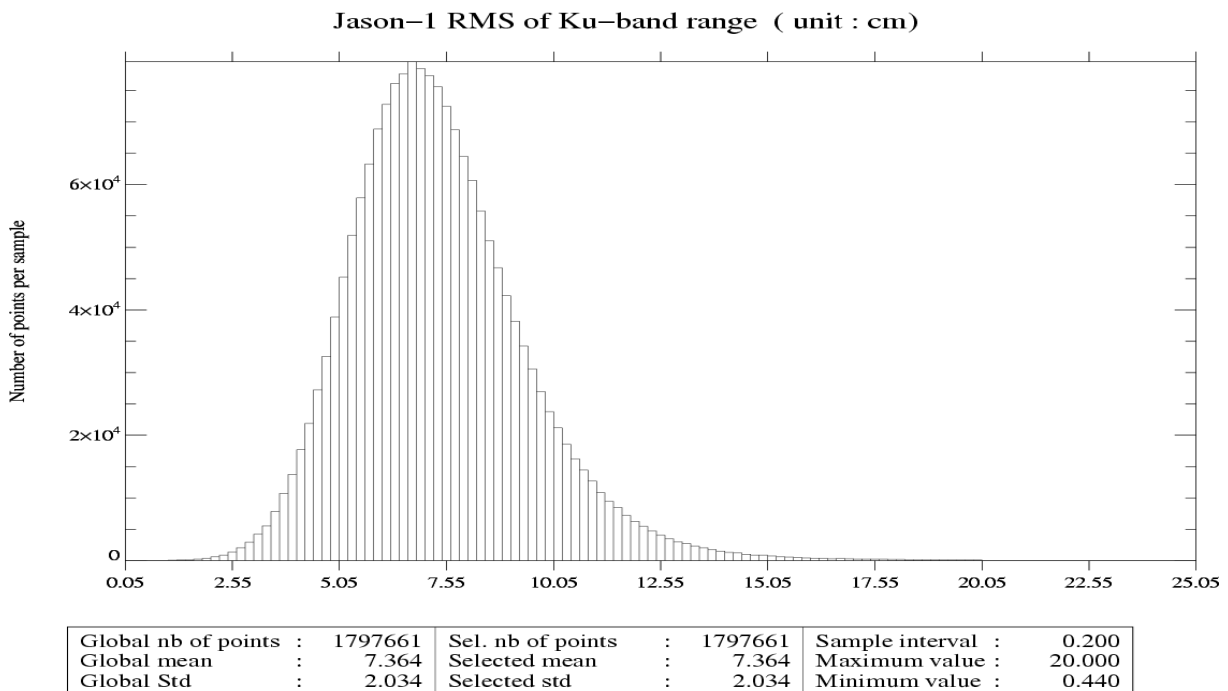
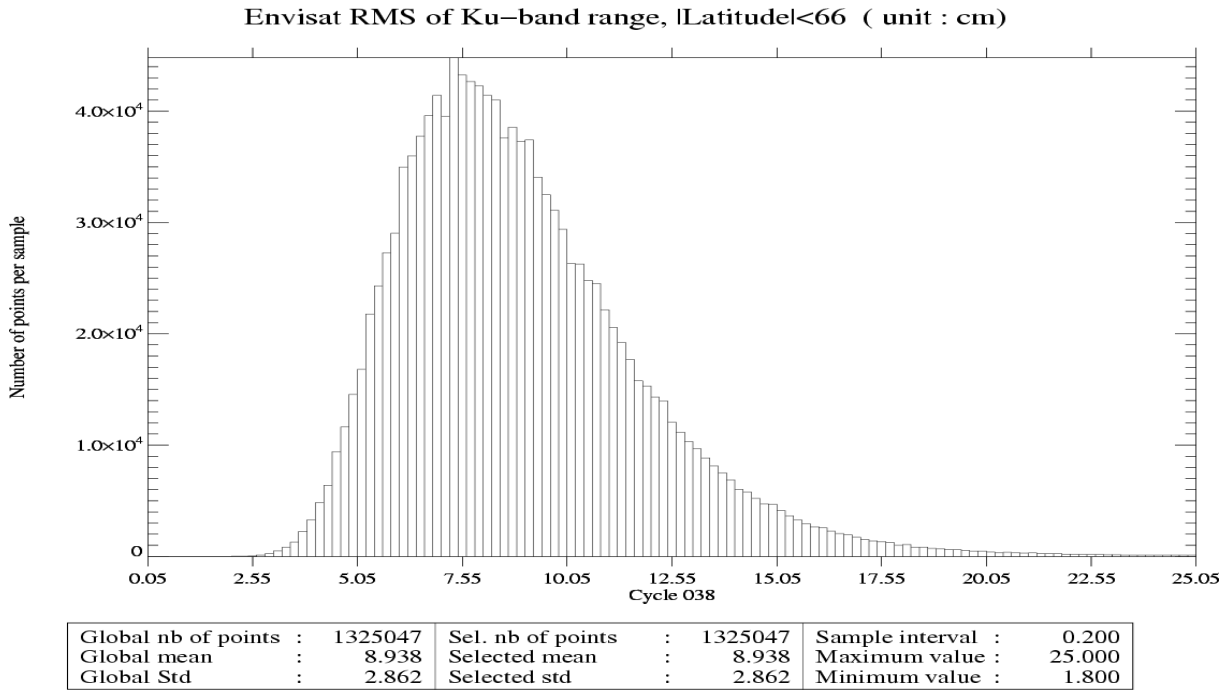
#### 4.4 Comparison on a same time/space sampling

Envisat and Jason-1 are now compared on a same time/space sampling:

- 35 day period
- $|\text{latitude}| < 66$

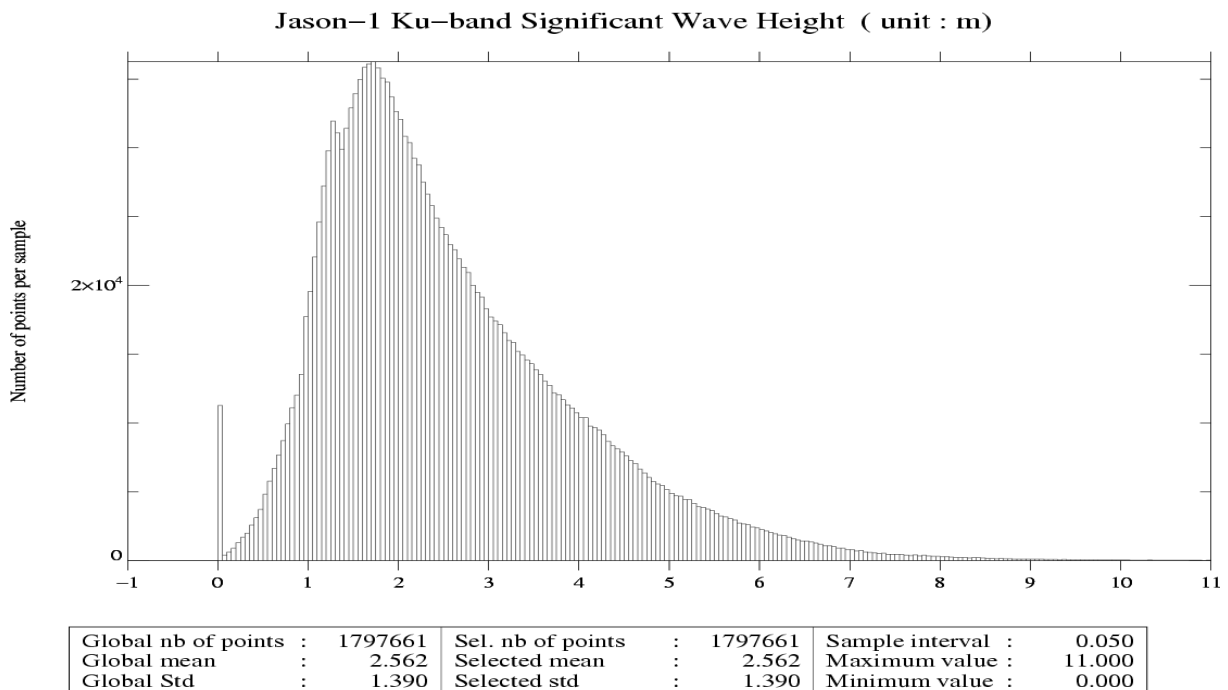
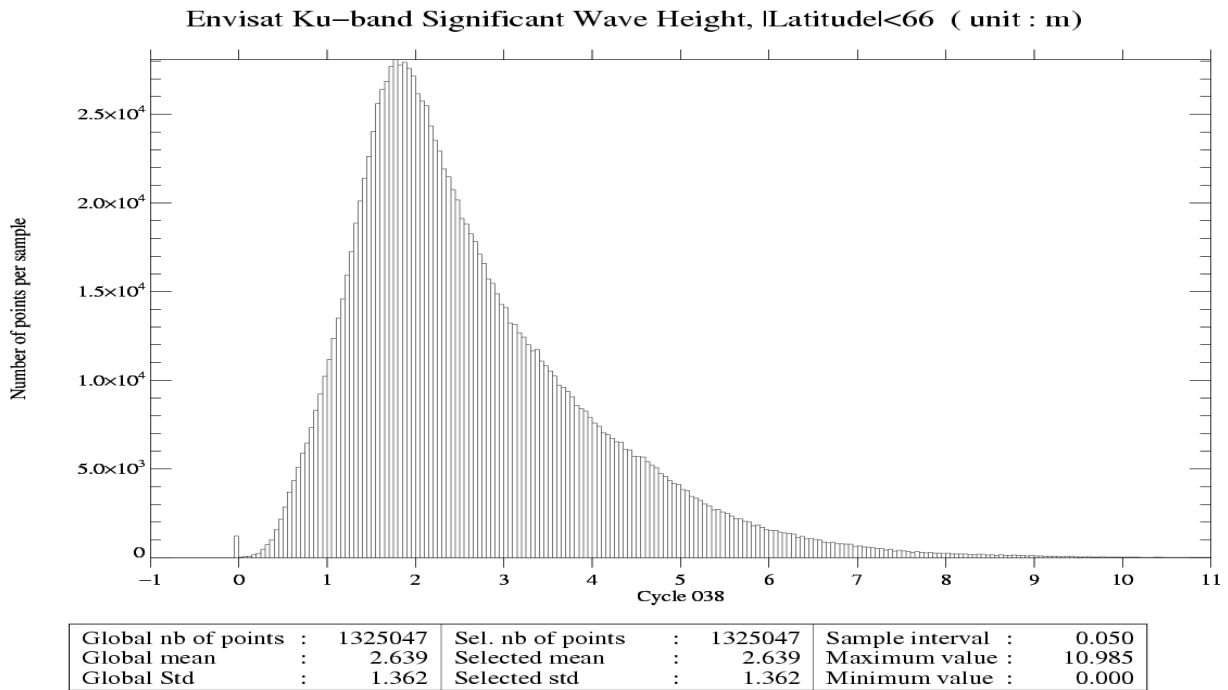
##### 4.4.1 Rms of Ku-band range statistics

The histograms of Envisat and Jason-1 Rms of Ku-band range are given on the following figures:



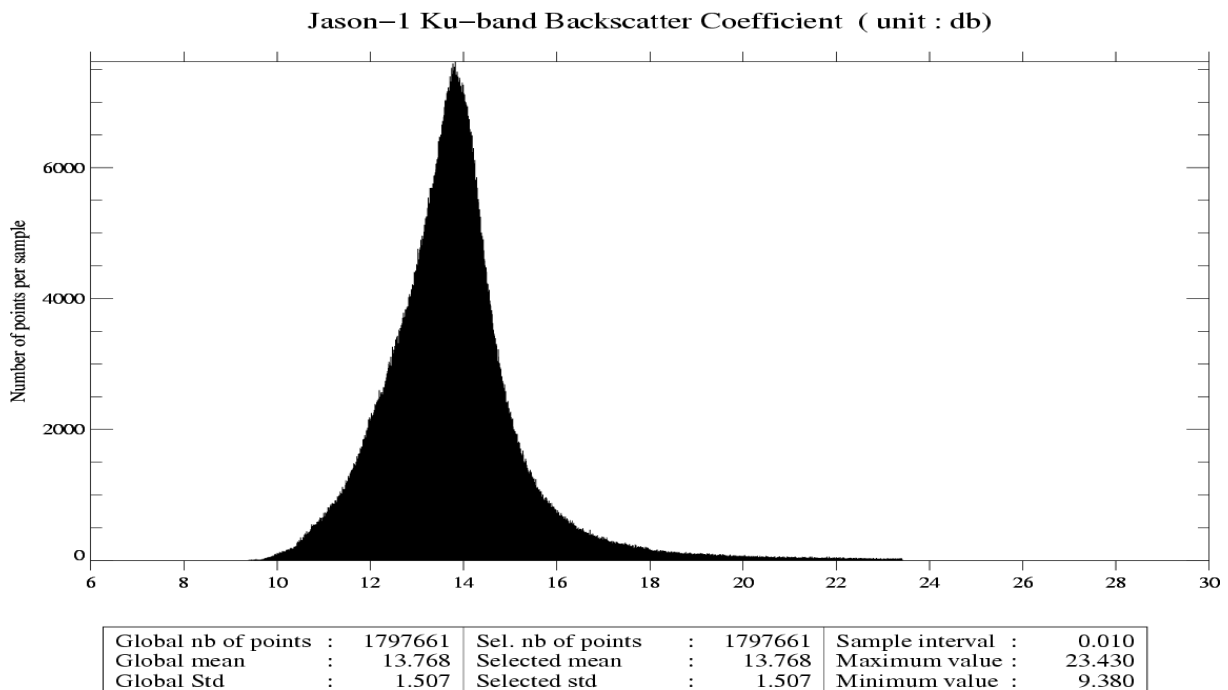
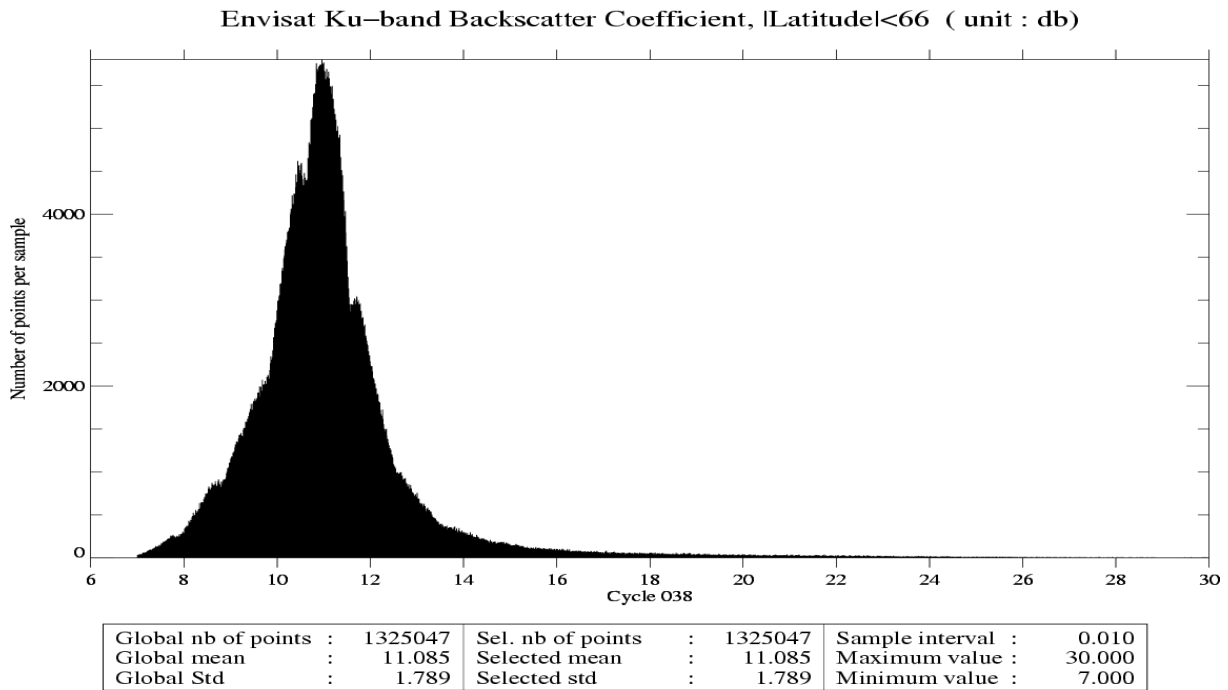
#### 4.4.2 Ku-band SWH statistics

The histograms of Envisat and Jason-1 Ku-band SWH are given on the following figures:



### 4.4.3 Ku-band Sigma0 statistics

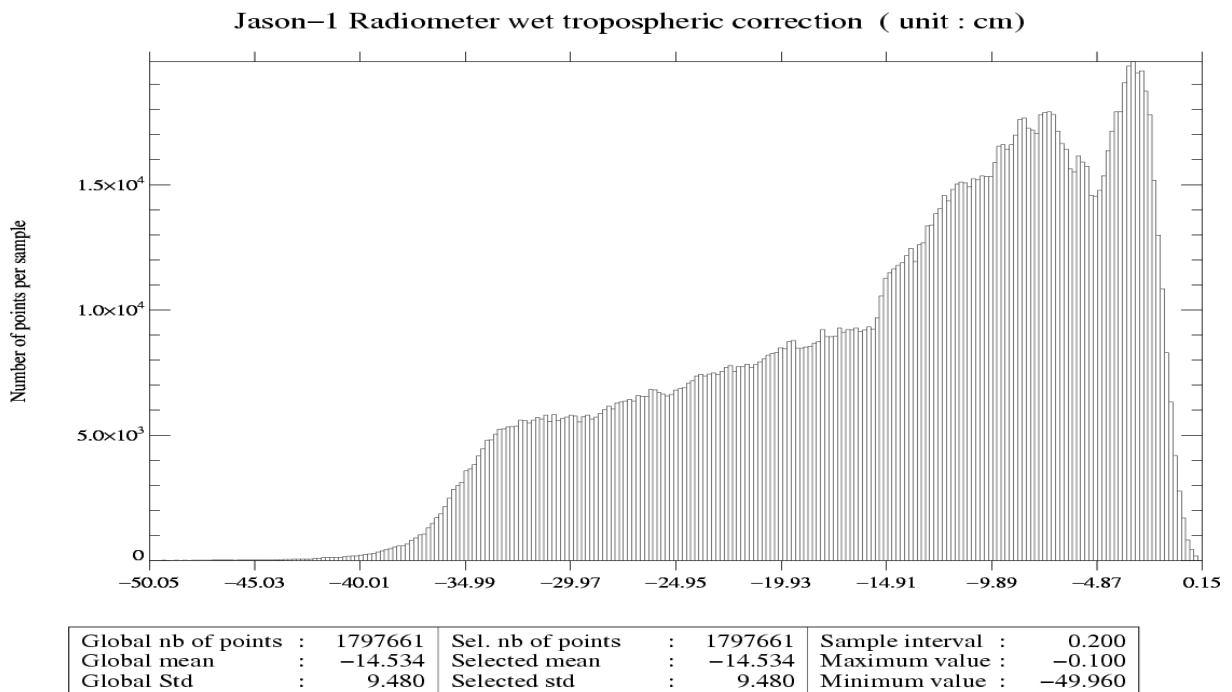
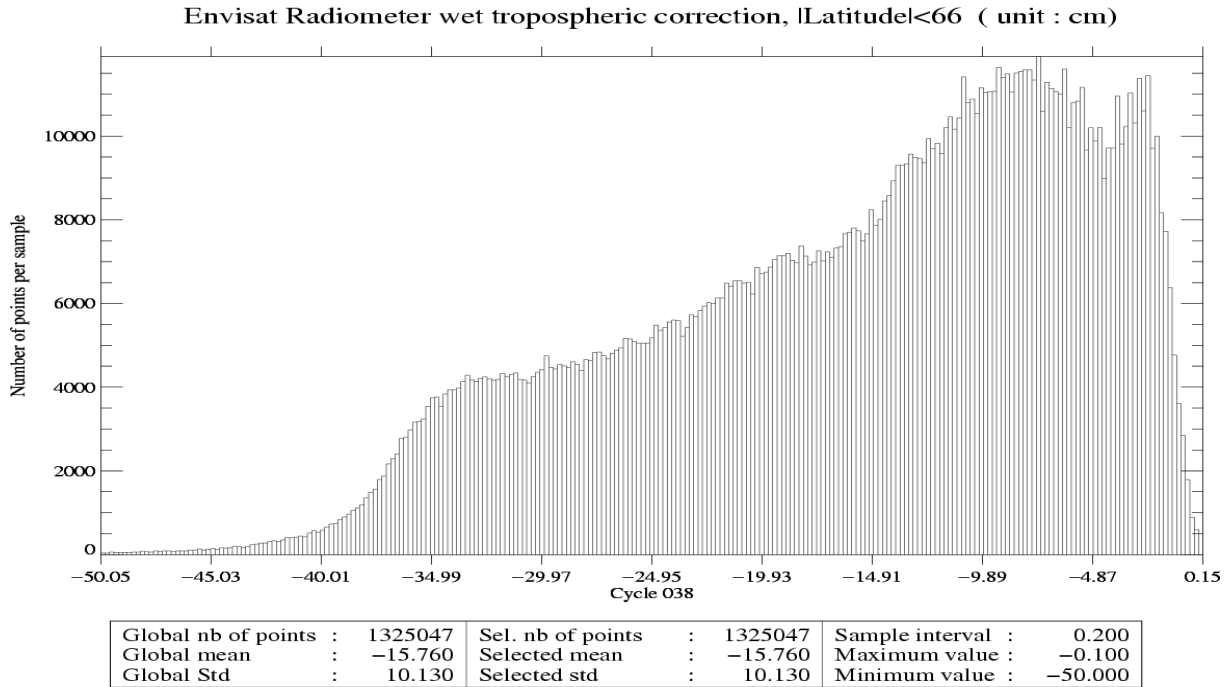
The histograms of Ku-band Sigma0 for Envisat and Jason-1 are given on the following figures:



The general shape of the Envisat histogram is not significantly different from the one obtained at global scale.

#### 4.4.4 Troposphere statistics

The histograms of Envisat and Jason-1 radiometer wet troposphere correction are given on the following figures:



#### 4.4.5 SSH crossover performances

10-day crossover points are computed for both Jason-1 and Envisat. Global statistics of SSH differences at crossovers are computed using a selection to remove shallow waters (1000 m):

Analysis	Number	Mean (cm)	Std. dev. (cm)
EN/EN SSH	16985	0.96	7.38

Analysis	Number	Mean (cm)	Std. dev. (cm)
J1/J1 SSH	19457	0.39	7.42

Using an additional selection to remove areas of high ocean variability and high latitudes (> 50 deg) leads to:

Analysis	Number	Mean (cm)	Std. dev. (cm)
EN/EN SSH	10968	0.83	6.43

Analysis	Number	Mean (cm)	Std. dev. (cm)
J1/J1 SSH	9395	0.54	6.50

#### 4.4.6 SLA relative to MSS

Envisat and Jason-1 Sea Level anomalies relative to CLS01 Mean Sea Surface are computed. Global statistics are computed removing shallow waters (1000 m) and areas of high ocean variability (20 cm).

Analysis	Number	Mean (cm)	Std. dev. (cm)
Envisat SLA	1217708	44.33	10.23

Analysis	Number	Mean (cm)	Std. dev. (cm)
Jason-1 SLA	1598870	17.35	9.38

These results show comparable performances in terms of SLA variability (standard deviation), and also confirm the crossover estimation of the (Envisat-Jason-1) bias.



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