Envisat GDR
Cross calibration Report

Cycle 039

11-07-2005 15-08-2005

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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 039 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 107. The main results for cycle 107 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 129 to 132. The main results for those cycles are reported in the Jason-1 Quality assessment report [3].

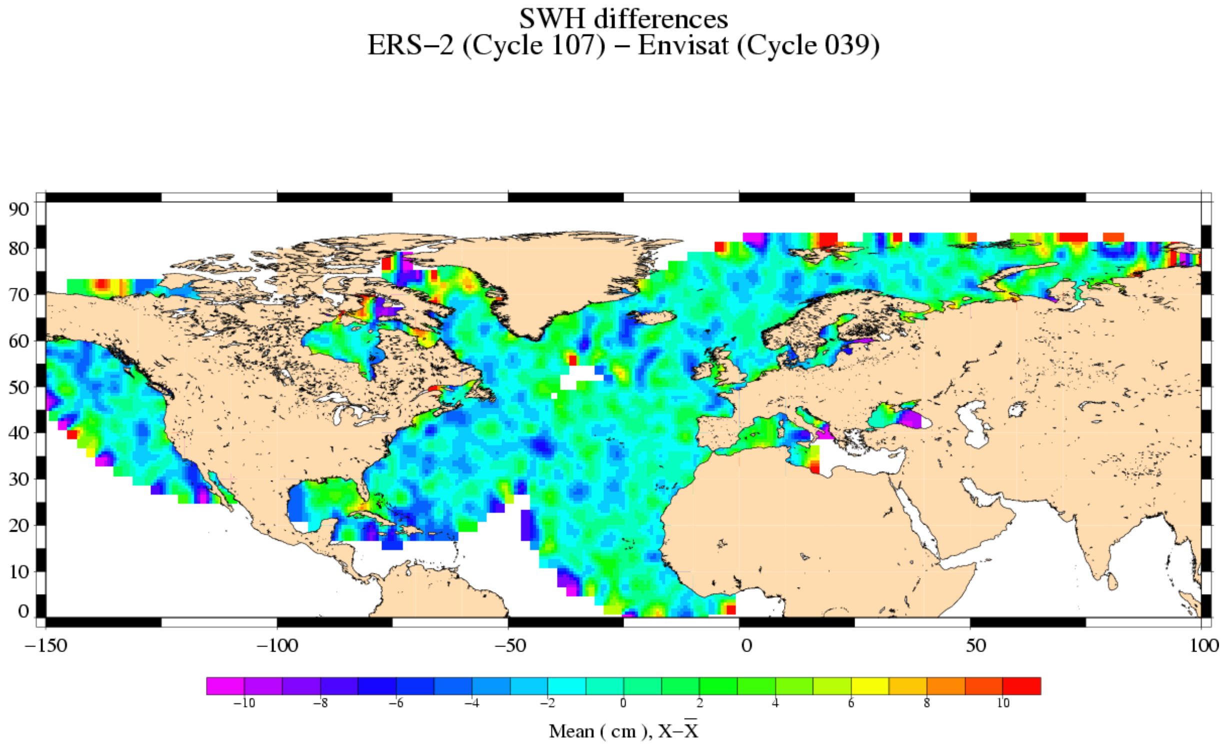
3 Cross Calibration with ERS-2

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 occured 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 039 data and data from ERS-2 OPR cycle 107 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

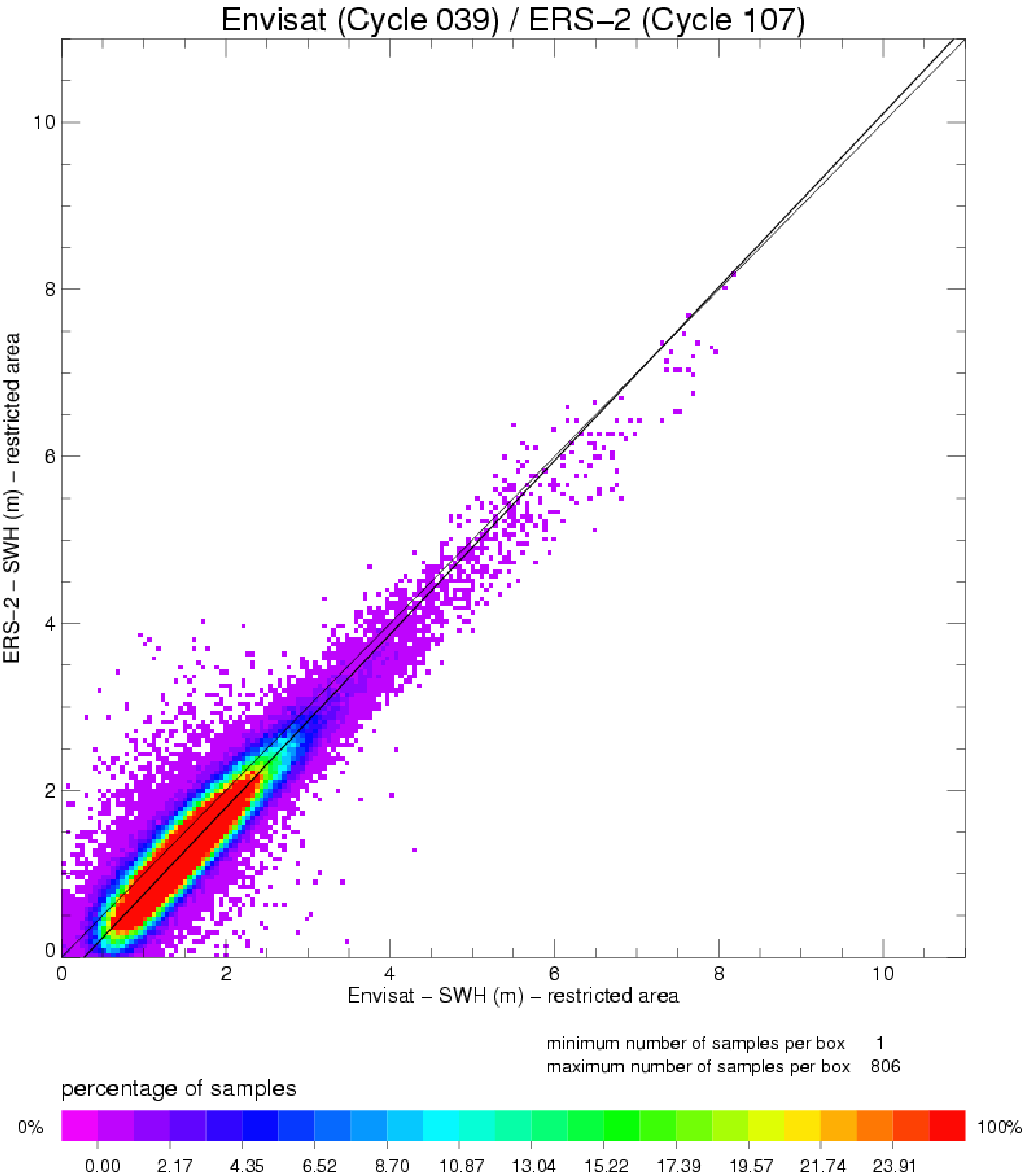
3.1.1 [ERS-2 - Envisat] Ku SWH differences

(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	190003	-0.23	0.25

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.



Statistics Y−X

mean = −0.22346
rms = 0.33464
std = 0.24910

Statistics Y,X

samples = 189530
covar = 0.37284
r = 0.92315

Linear regression

type: least rectangle

y = ax + b
a = 1.03926751
b = −0.28500681

Statistics X

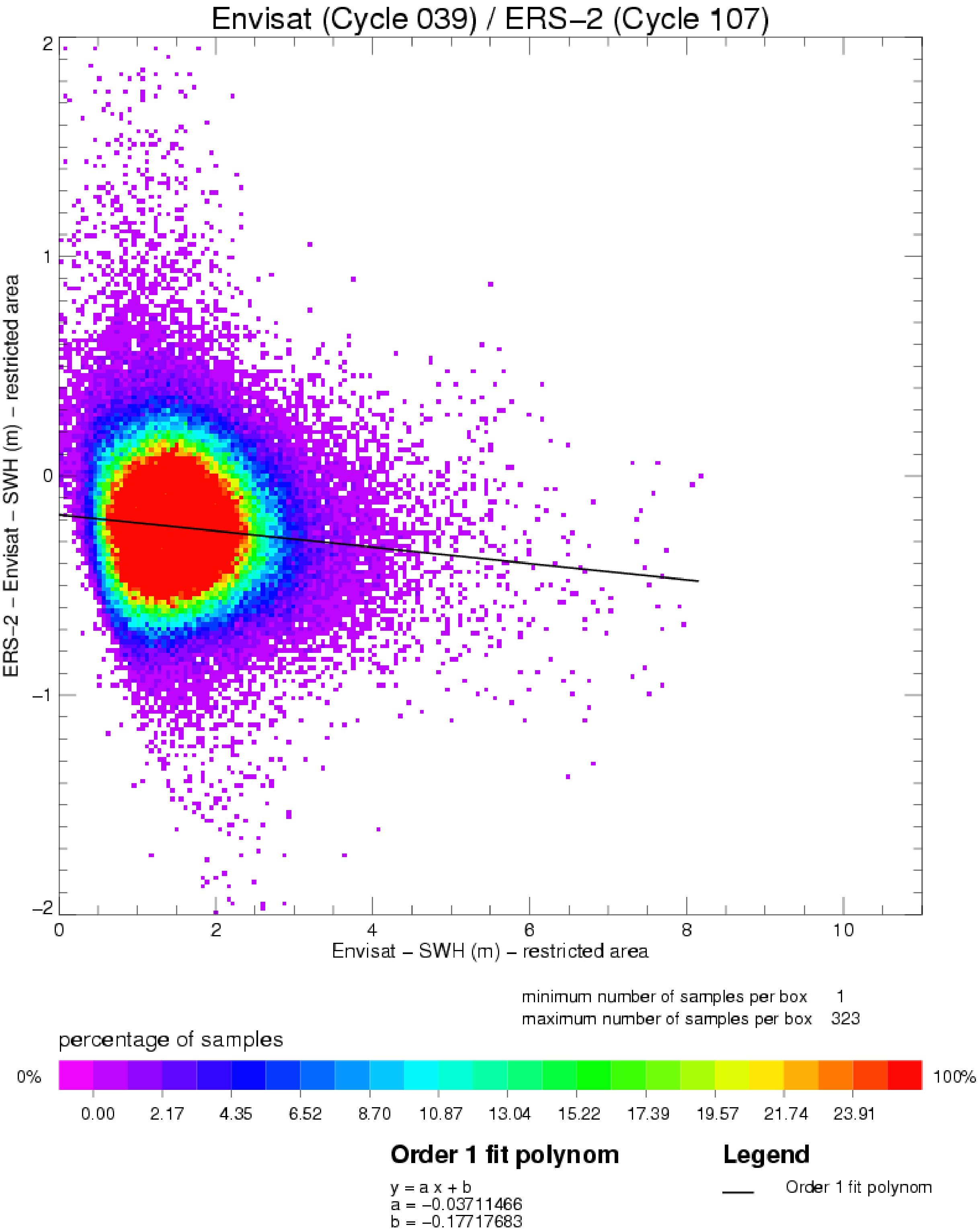
mean = 1.53892
rms = 1.66039
std = 0.62339

Statistics Y

mean = 1.31434
rms = 1.46535
std = 0.64787

Legend

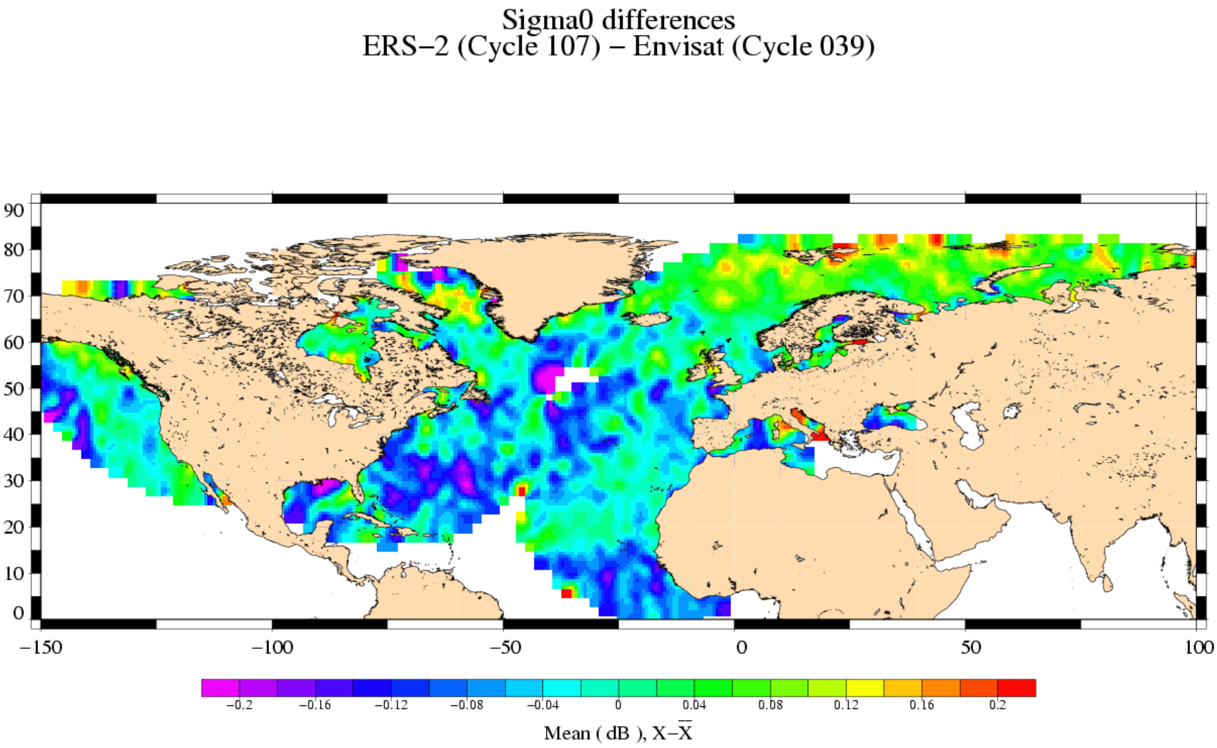
Linear regression
Bisectrix



Envisat (Cycle 039) / ERS−2 (Cycle 107)
ERS−2 − Envisat − SWH (m) − restricted area
Envisat − SWH (m) − restricted area
minimum number of samples per box 1
maximum number of samples per box 323
percentage of samples
0%
100%
0.00
2.17
4.35
6.52
8.70
10.87
13.04
15.22
17.39
19.57
21.74
23.91
Order 1 fit polynom
y = a x + b
a = −0.03711466
b = −0.17717683
Legend
Order 1 fit polynom

3.1.2 [ERS-2 - Envisat] Ku Sigma0 differences

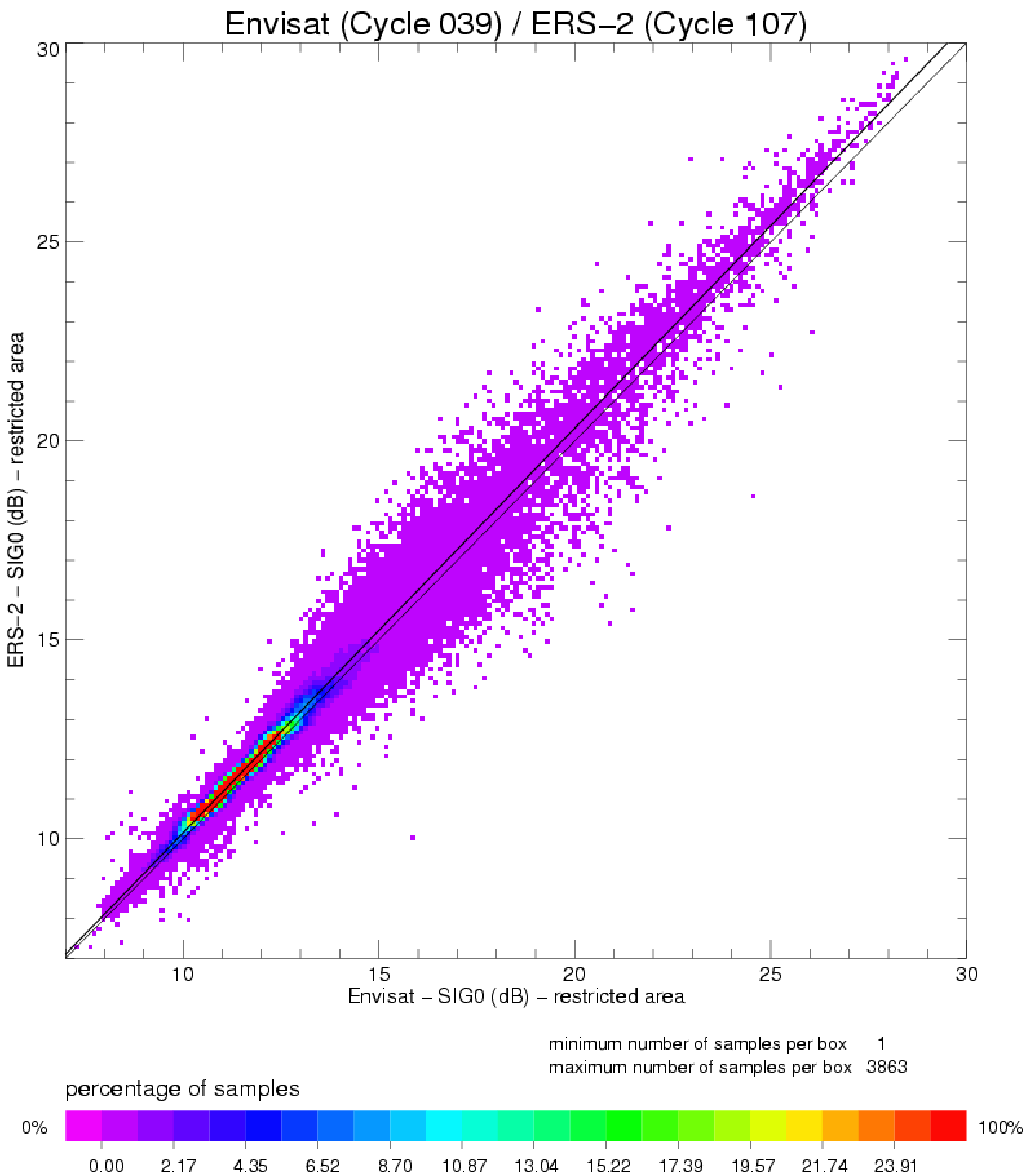
(ERS-2 - Envisat) Ku SIGMA0 differences are plotted on the following map (data are centered about the mean value).



Analysis	Number	Mean (dB)	Std. dev. (dB)
E2-EN Sigma0	190003	0.18	0.33

Wet areas appear because the ERS-2 atmospheric attenuation is uncomplete (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.



Statistics Y−X

mean = 0.18232
rms = 0.37724
std = 0.33025

Statistics Y,X

samples = 190003
covar = 3.60624
r = 0.98510

Linear regression

type: least rectangle

y = ax + b
a = 1.01735763
b = −0.02343214

Statistics X

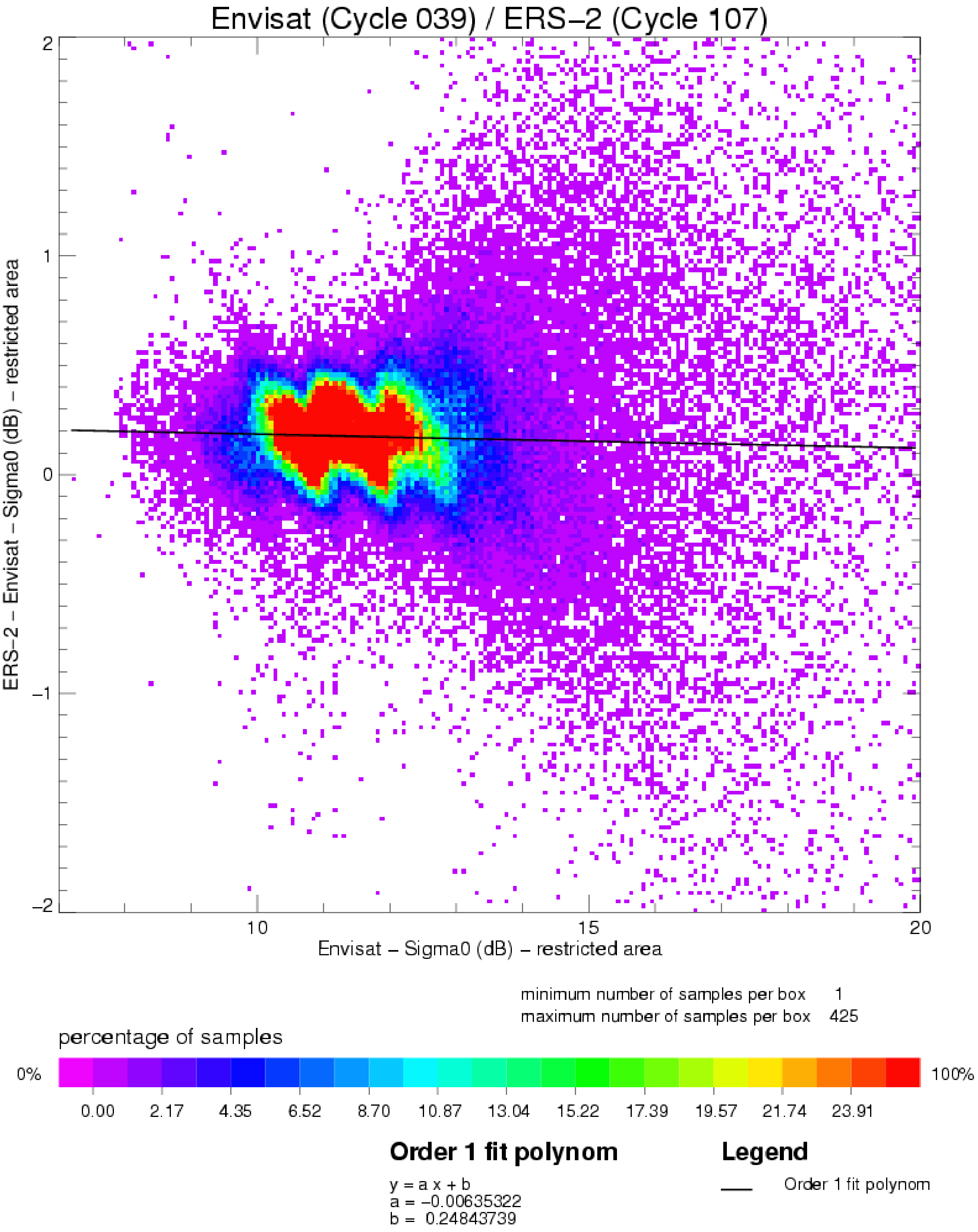
mean = 11.90593
rms = 12.05610
std = 1.89692

Statistics Y

mean = 12.08916
rms = 12.24222
std = 1.92985

Legend

Linear regression
Bisectrix

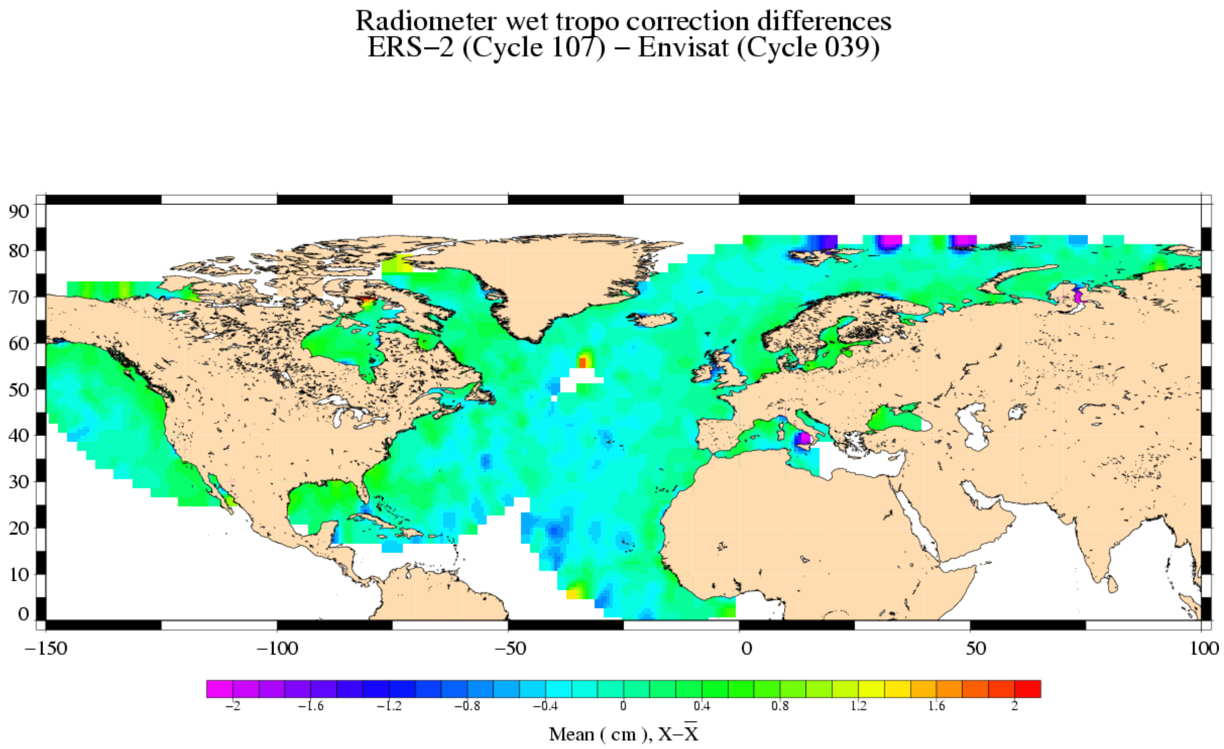


The particular features of the SIGMA0 differences mainly come from the shape of the ERS-2 histogram.

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

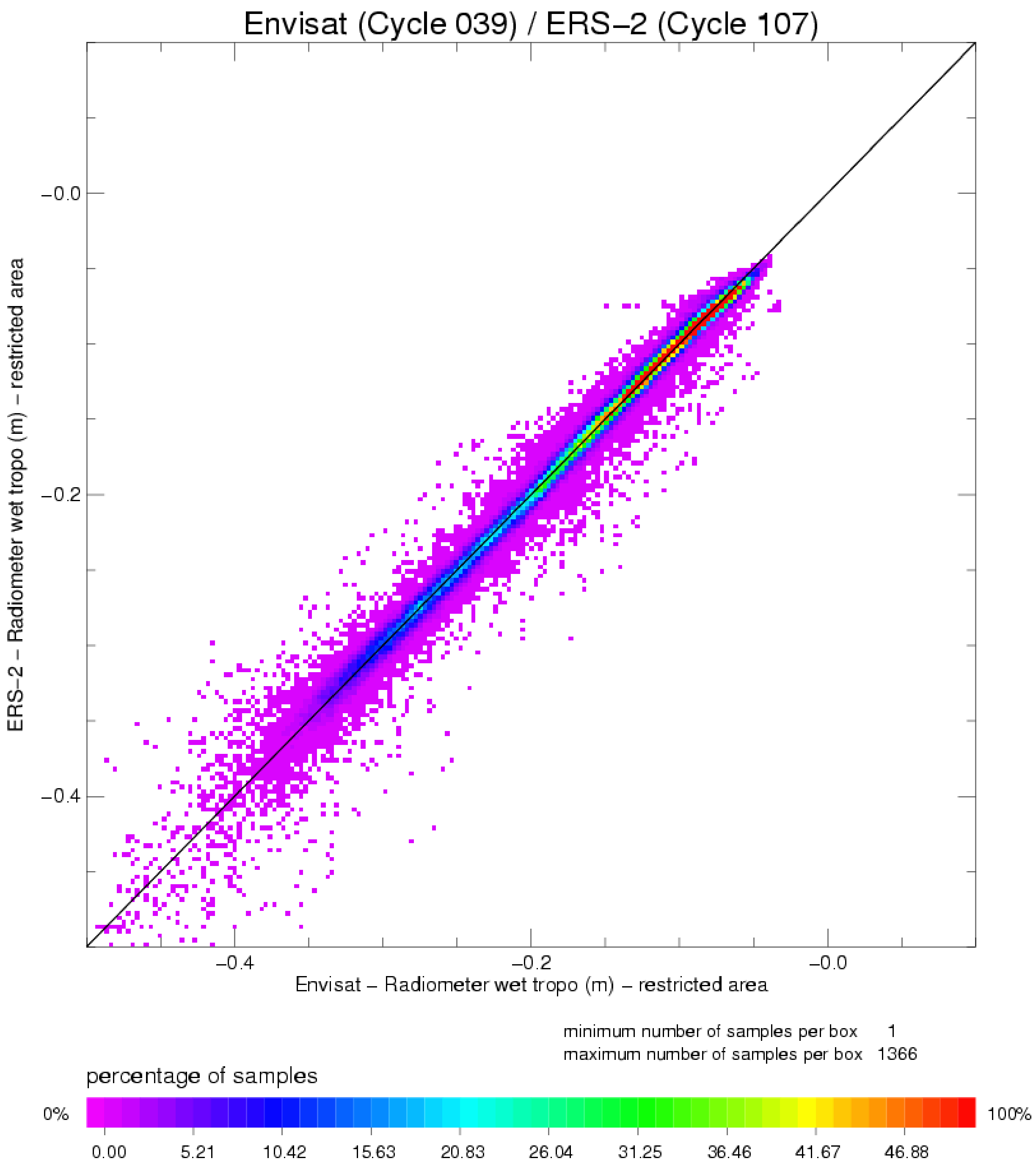
The ERS-2 radiometer correction is recomputed to correct for the gain drop and for the drift of the 24 GHz brightness temperature (Obligis et al., 2003 [4]).

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



Analysis	Number	Mean (cm)	Std. dev. (cm)
E2-EN radiometer	190003	0.02	0.68

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.



Statistics Y−X

mean = 0.00020
rms = 0.00689
std = 0.00689

Statistics Y,X

samples = 190002
covar = 0.00614
r = 0.99611

Linear regression

type: least rectangle

y = ax + b
a = 1.00079031
b = 0.00033138

Statistics X

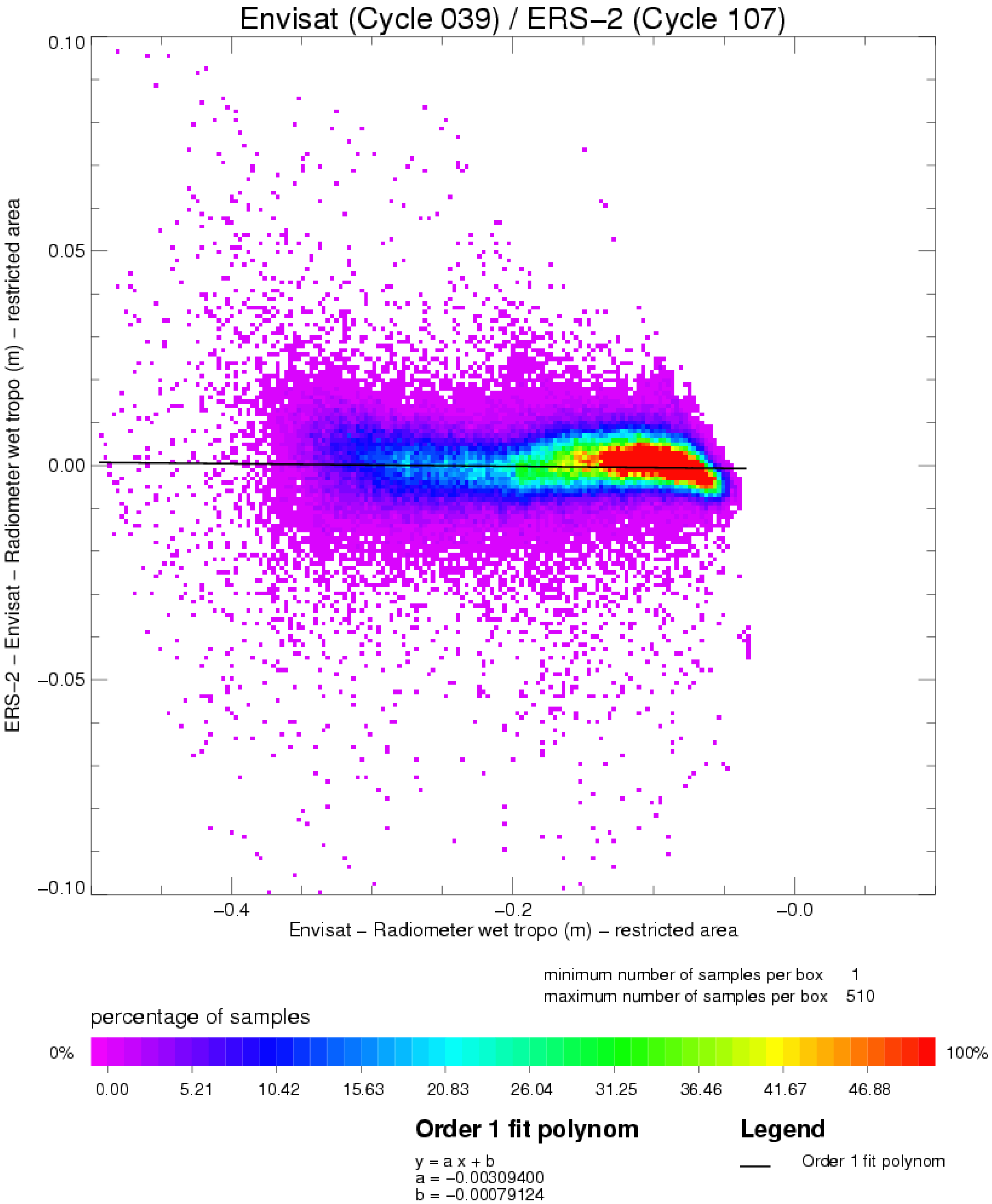
mean = −0.16085
rms = 0.17896
std = 0.07845

Statistics Y

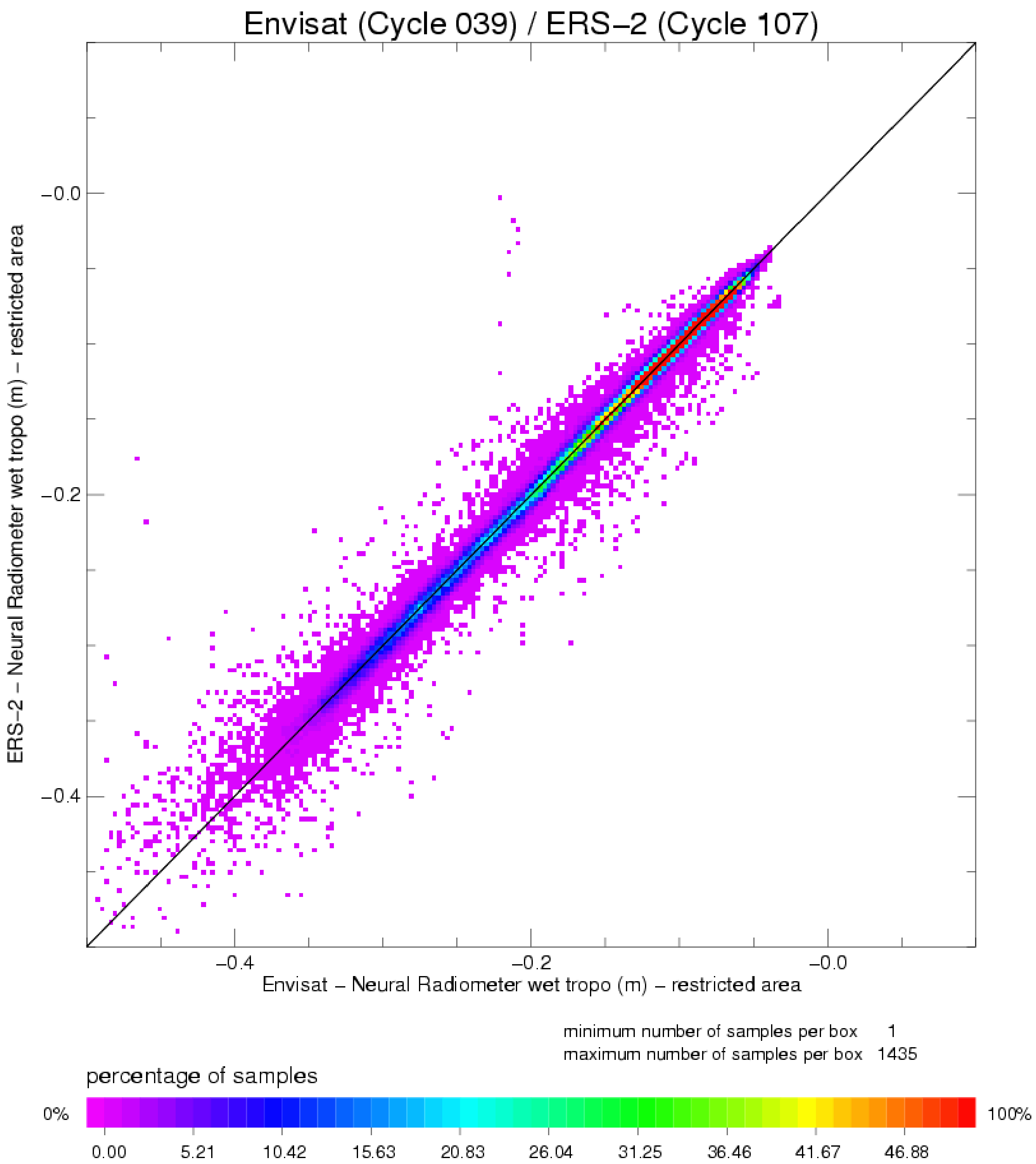
mean = −0.16064
rms = 0.17880
std = 0.07851

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.



Statistics Y−X

mean = −0.00006
rms = 0.00670
std = 0.00670

Statistics Y,X

samples = 190002
covar = 0.00613
r = 0.99632

Linear regression

type: least rectangle

y = ax + b
a = 1.00009241
b = −0.00004921

Statistics X

mean = −0.16085
rms = 0.17896
std = 0.07845

Statistics Y

mean = −0.16091
rms = 0.17902
std = 0.07846

Legend

—— Linear regression
—— Bisectrix

3.1.4 [ERS-2 - Envisat] SSH differences

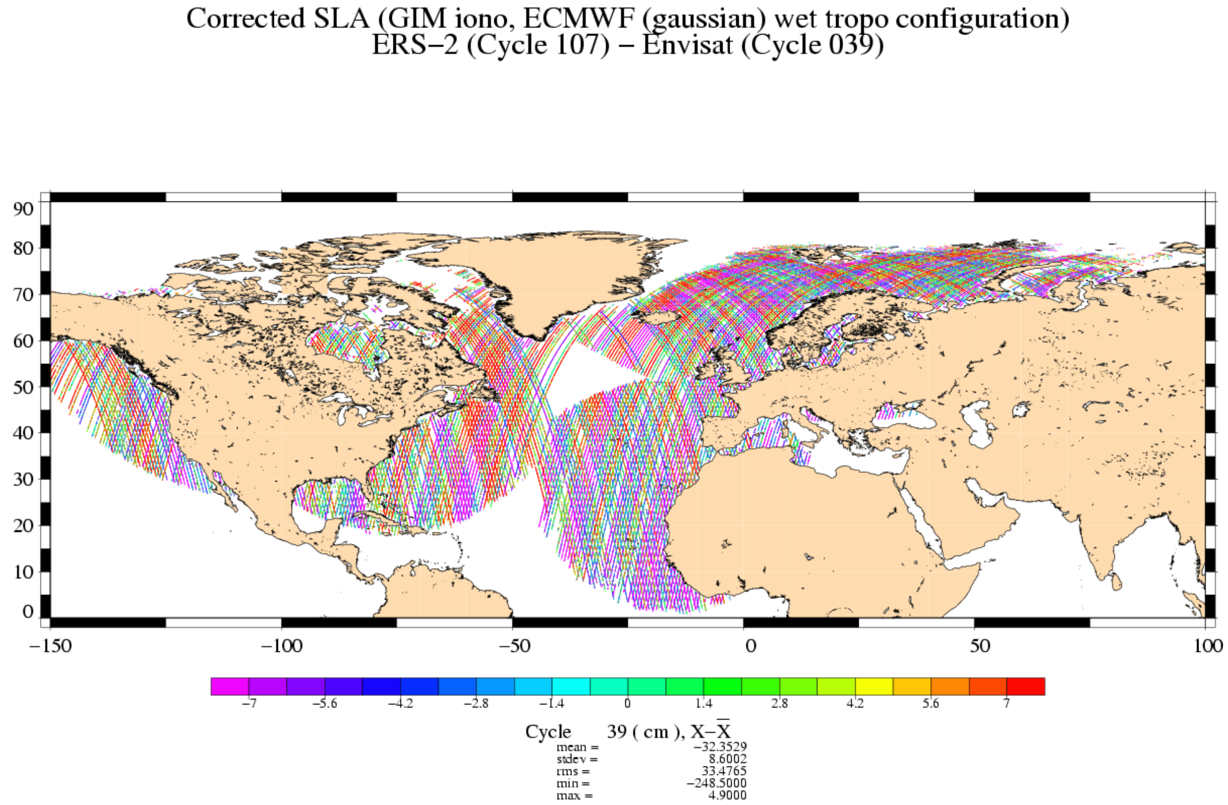
In order to compare SSH estimations from the two missions, ERS-2 OPRs have been updated with algorithms and corrections similar to Envisat.

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:



Analysis	Number	Mean (cm)	Std. dev. (cm)
E2-EN SLA	190003	-32.36	8.60

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 129 to 132) 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 parameric 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.

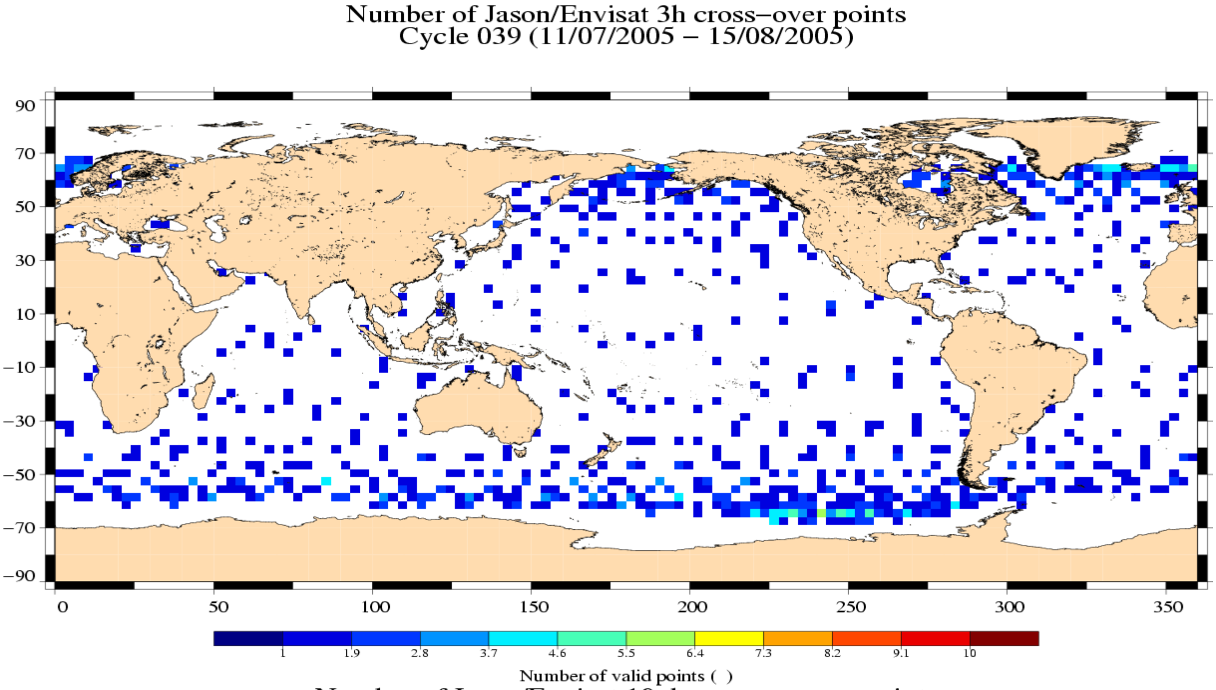
Several analyses were performed for this cross calibration study:
- comparison of altimeter and radiometer parameters
- comparison of Sea Level Anomalies relative to a Mean Sea Surface
- computation of a long wavelength error on Envisat
- comparison on a same time/space sampling

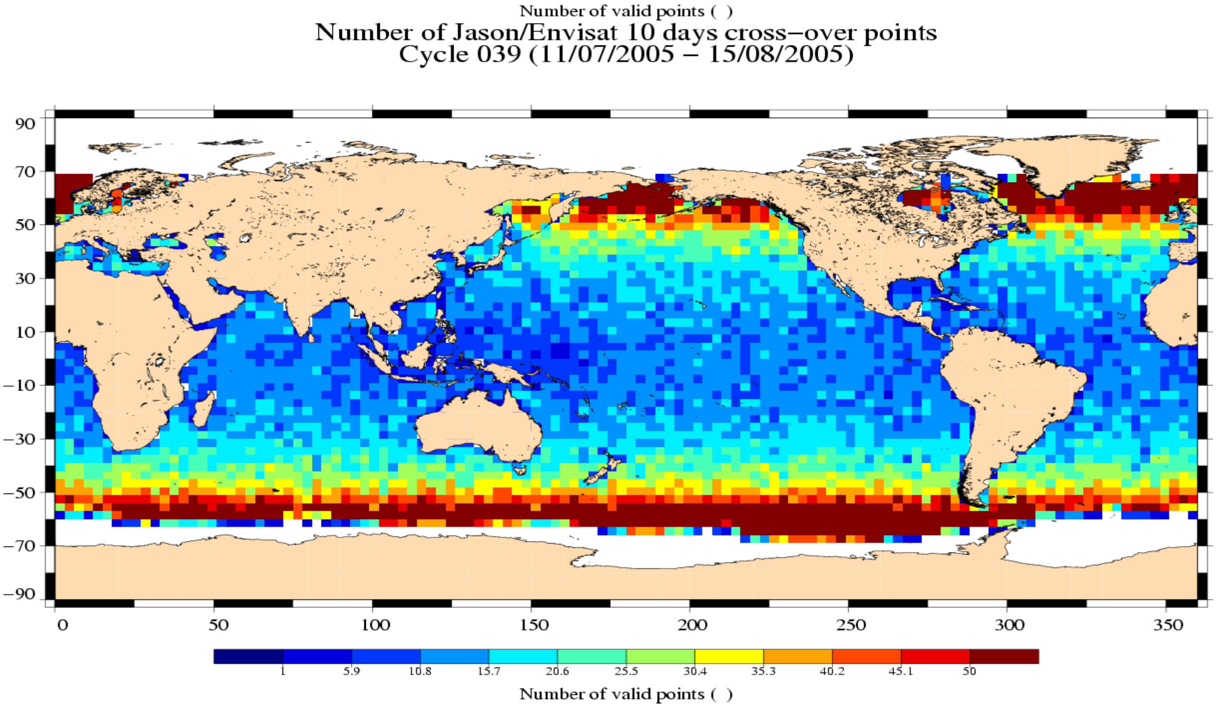
10 day crossovers are used to compare SSH estimations from Envisat and Jason-1 while shorter time lags (3 hours) are selected for altimeter and radiometer parameters.

4.1 Dual-crossover points

4.1.1 3-hour and 10-day crossover points location

For Envisat Cycle 039 the location of crossover points with 3-hour and 10 day time lags between Envisat and Jason-1 are given on the following figures:

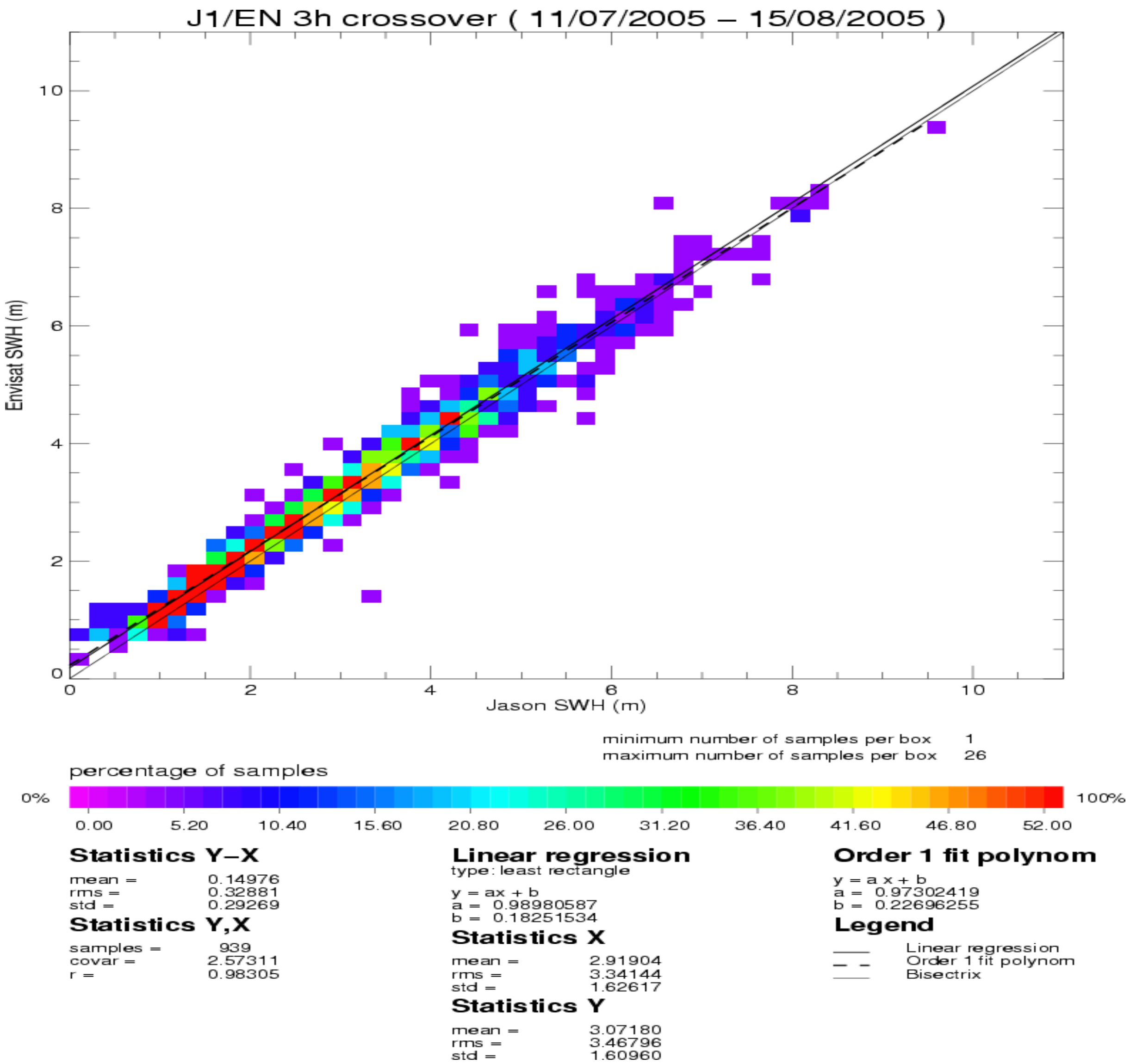




Most of the crossover points are located at high latitude. With 3-hour time lag there are only a few crossover points at mid and low latitudes. This geographical pattern is not constant for every Envisat cycle since Jason-1 is not sun-synchronous. When more Envisat data become available, (Jason-1/Envisat) 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:

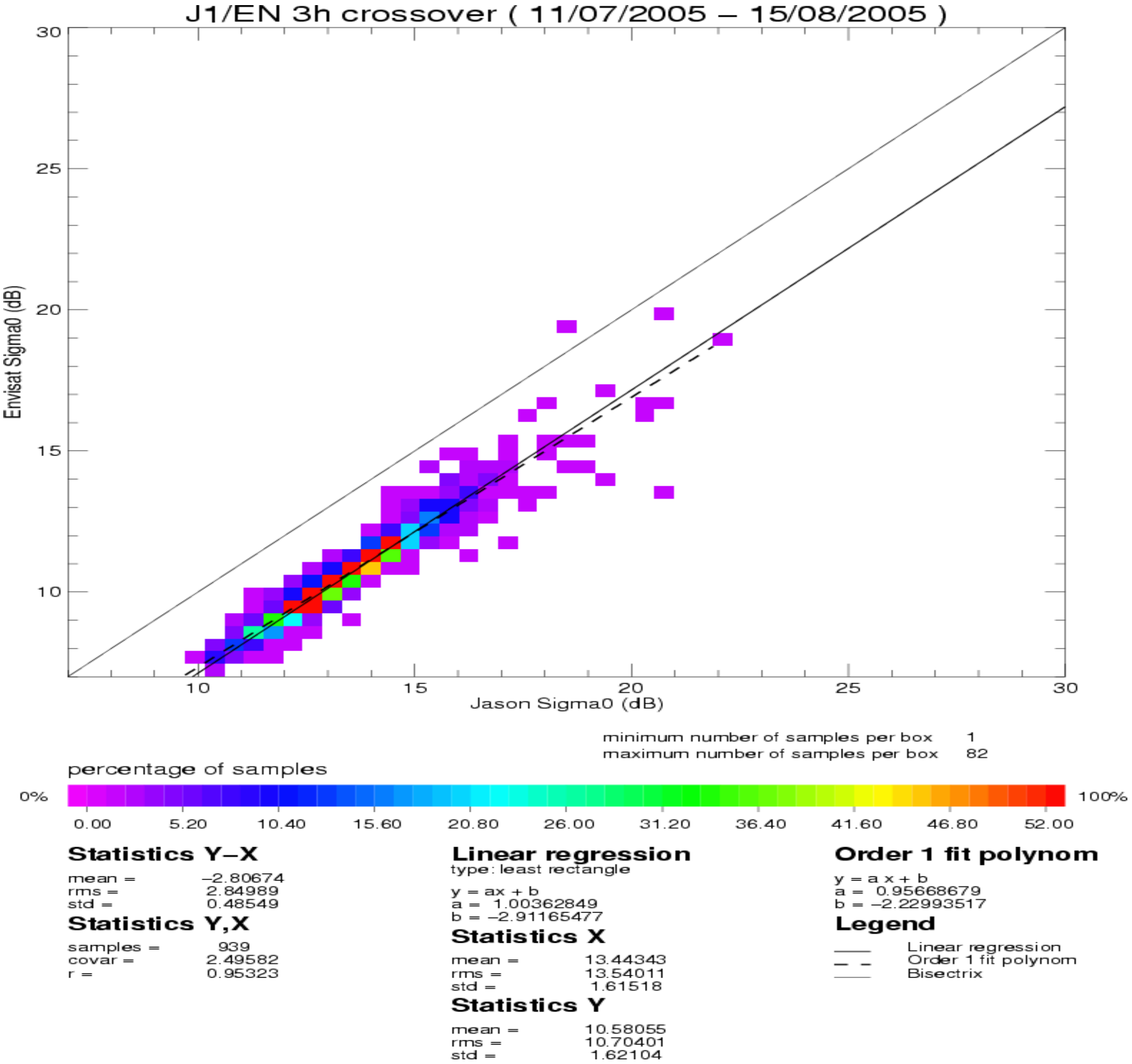


Analysis	Number	Mean (m)	Std. dev. (m)
EN-J1 SWH (m)	939	0.15	0.28

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:

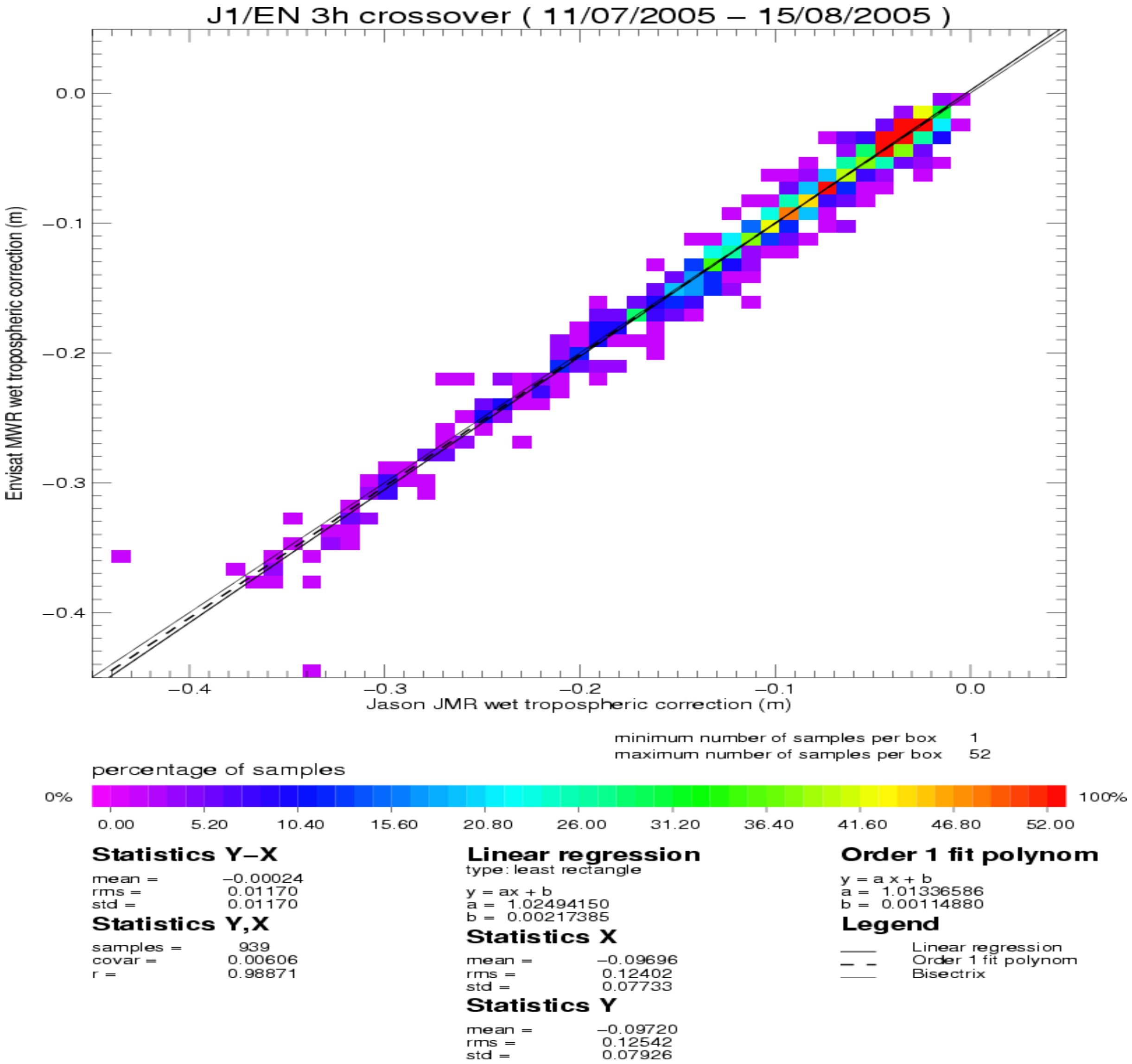


Analysis	Number	Mean (dB)	Std. dev. (dB)
EN-J1 Sigma0 (dB)	939	-2.86	0.46

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)	939	-0.02	1.10

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

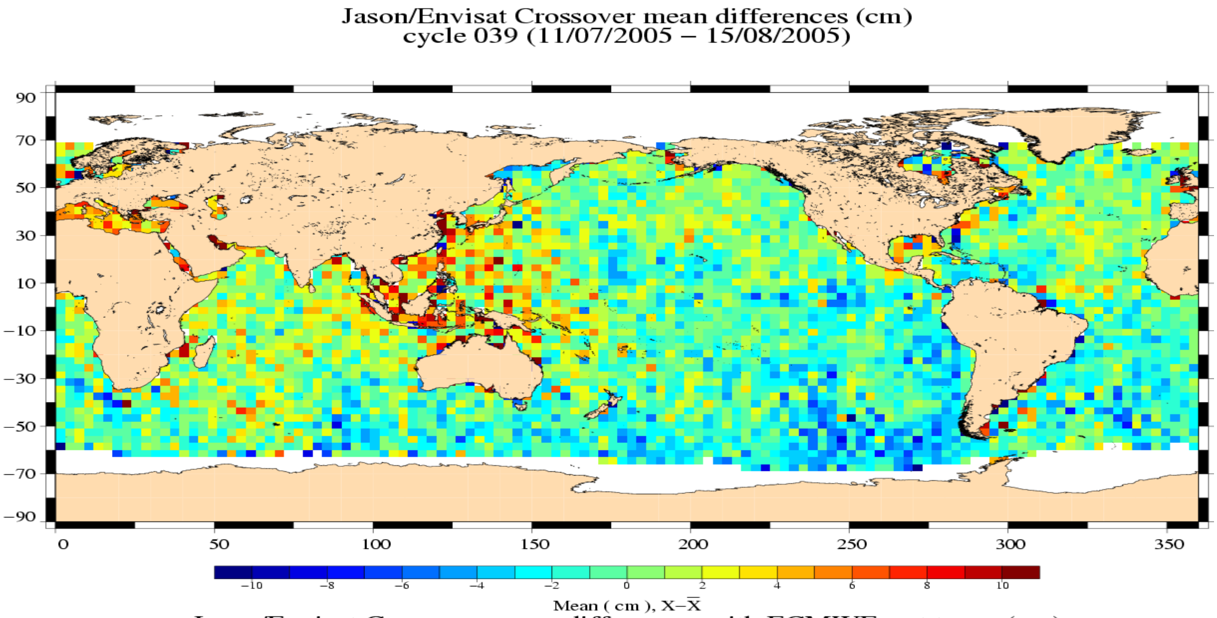
4.1.5 [Envisat - Jason-1] SSH differences

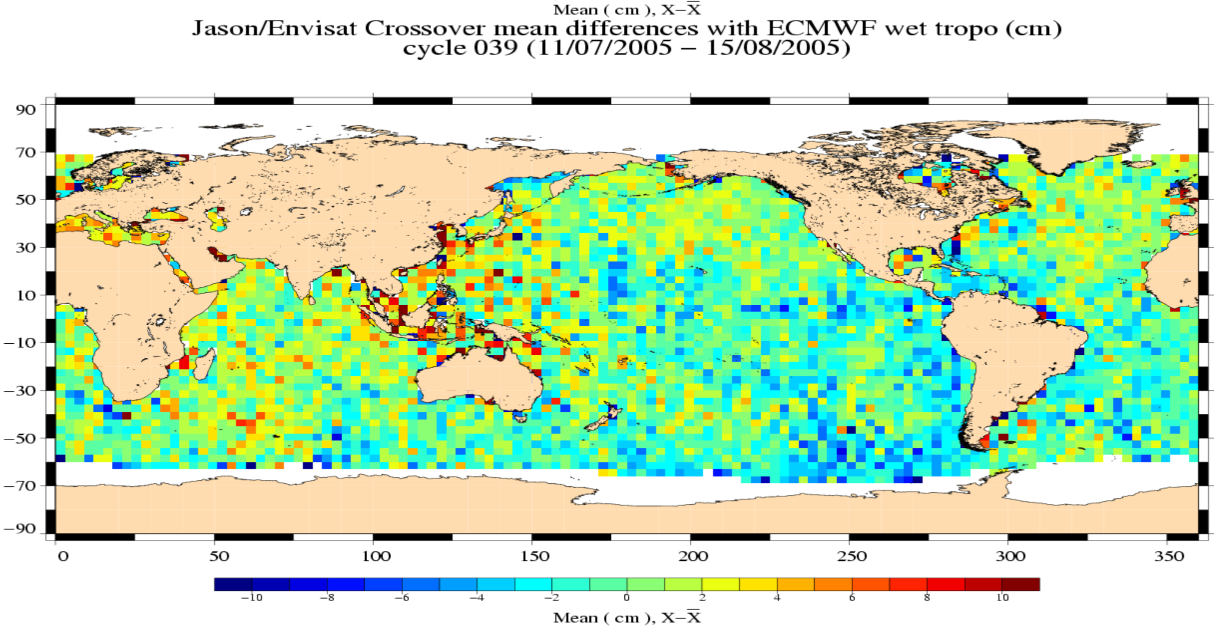
[Envisat - Jason-1] SSH differences at crossover points with 10 day time lag are computed in two configurations:
- using the radiometer wet troposphere correction
- using the ECMWF wet troposphere correction

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

Analysis	Number	Mean (cm)	Std. dev. (cm)
EN-J1 SSH	83606	27.29	7.97
EN-J1 SSH with ECMWF wet troposphere	83606	27.30	8.04

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

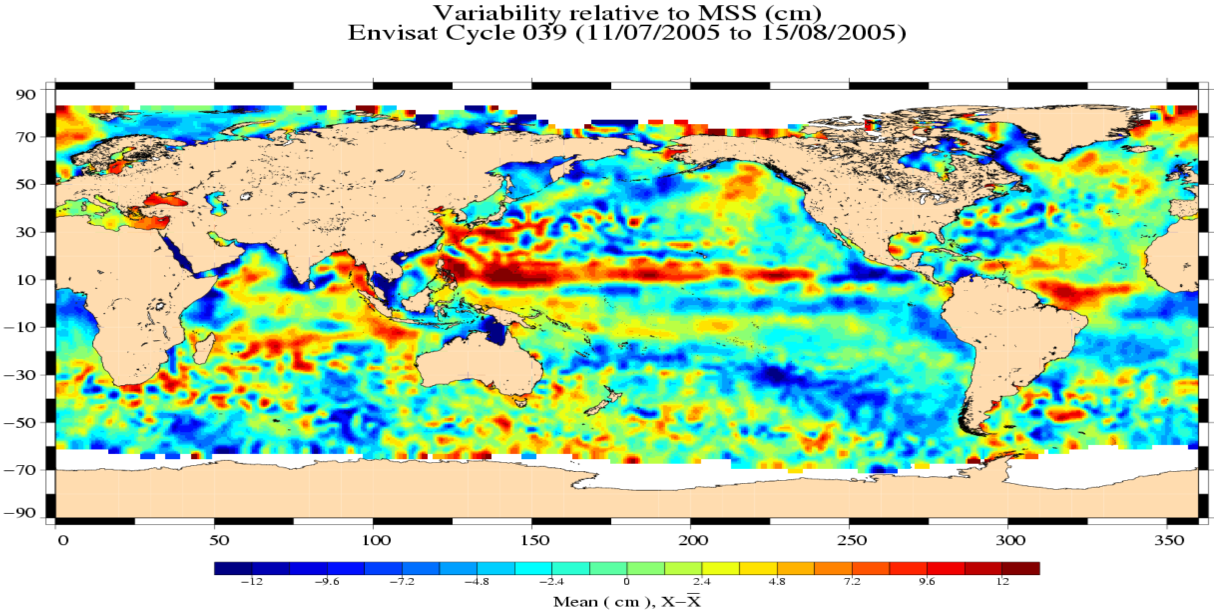




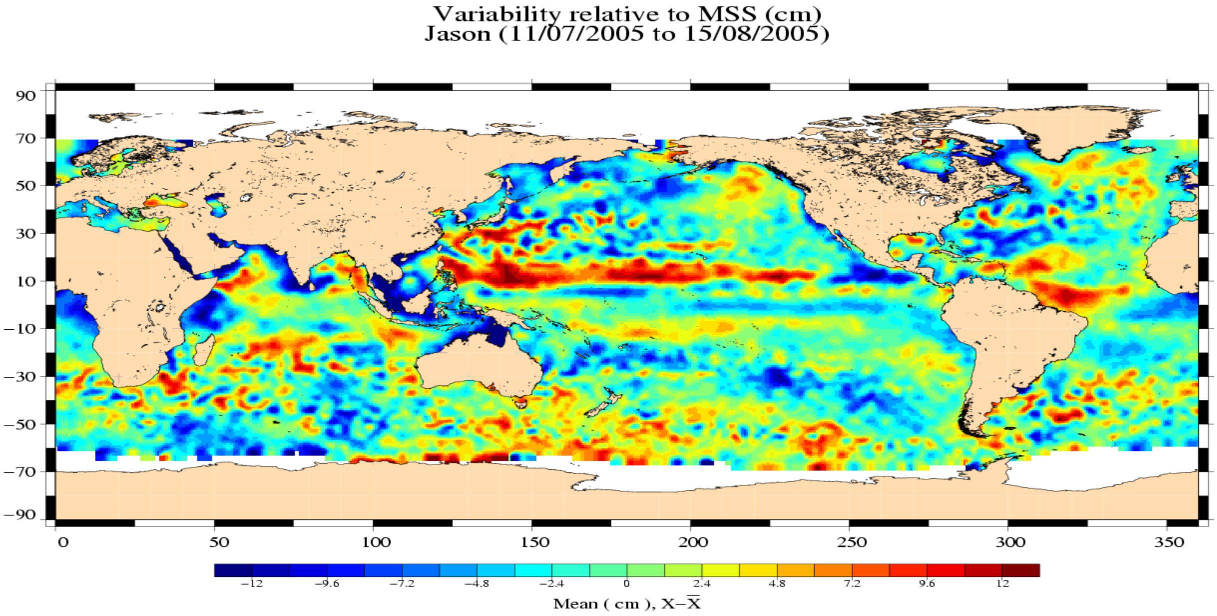
The two maps are very close. There are small scale [Envisat - Jason-1] differences in high variability areas, but also large scale differences in the Pacific ocean.

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	1142000	45.03	9.09



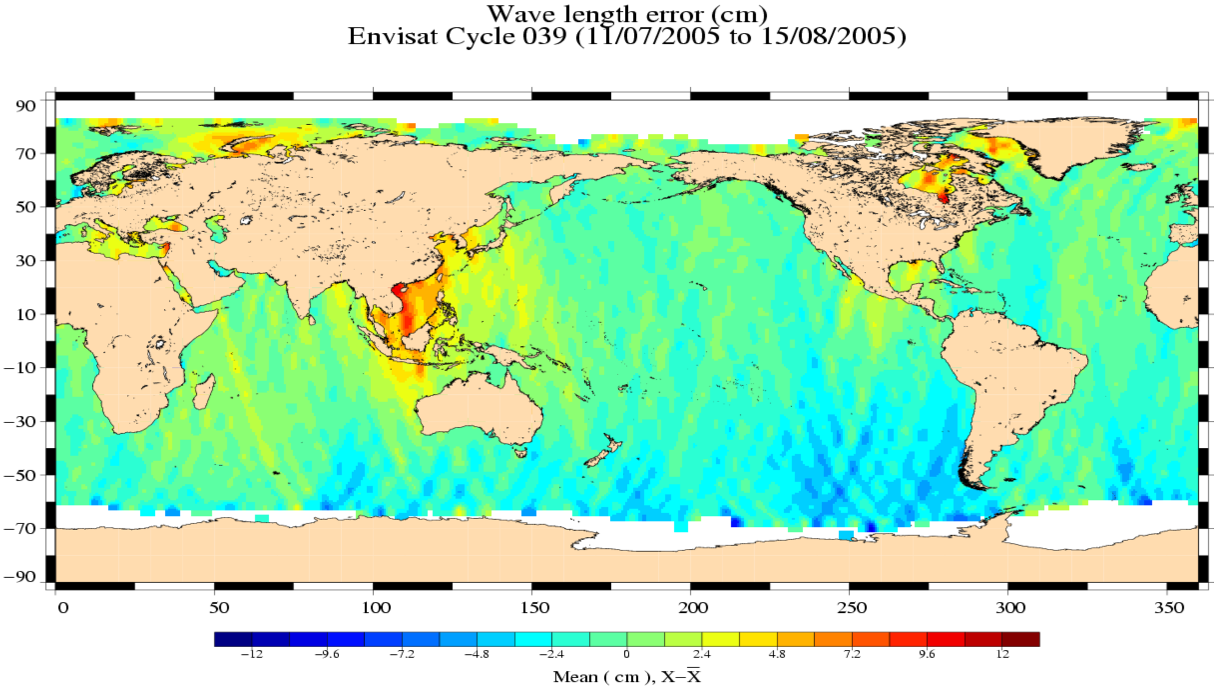
Analysis	Number	Mean (cm)	Std. dev. (cm)
Jason-1 SLA	1547118	17.25	9.25

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 wavelentgth 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	1324582	28.00	3.18

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

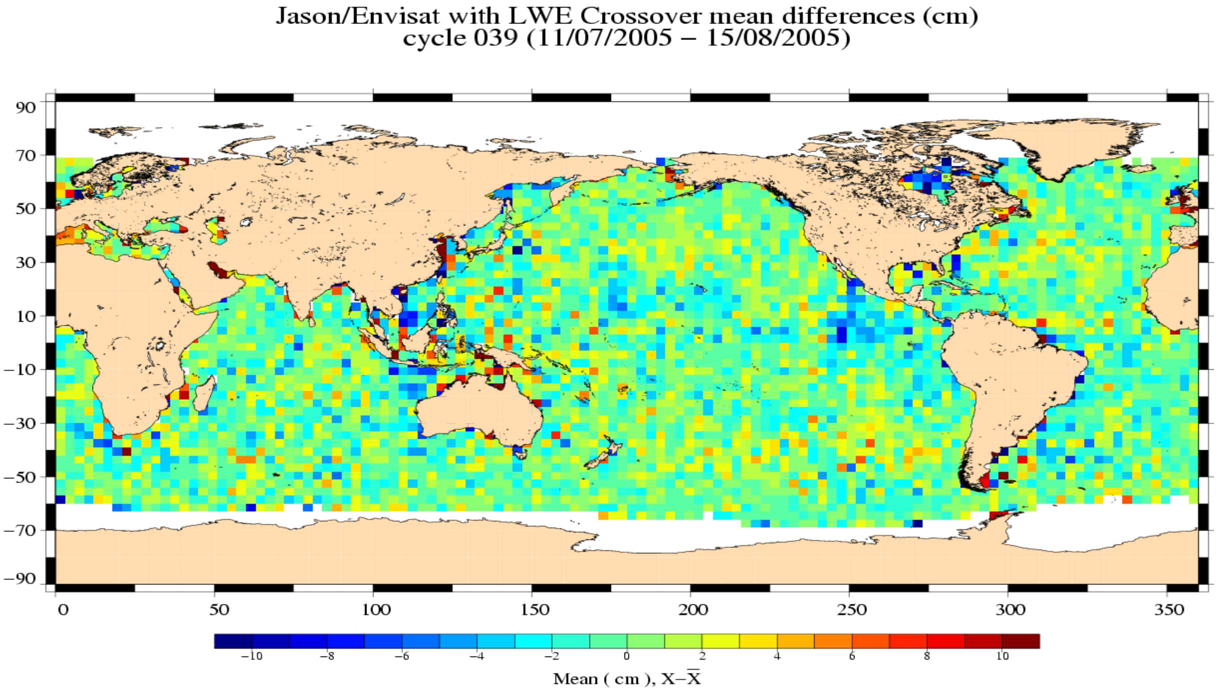
4.3.2 Impact on crossover performances

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	33436	1.30	8.79
EN/EN SSH with orbit error	33436	-0.03	7.96

Analysis	Number	Mean (cm)	Std. dev. (cm)
EN-J1 SSH	83606	27.29	7.97
EN-J1 SSH with orbit error	83606	0.01	7.26

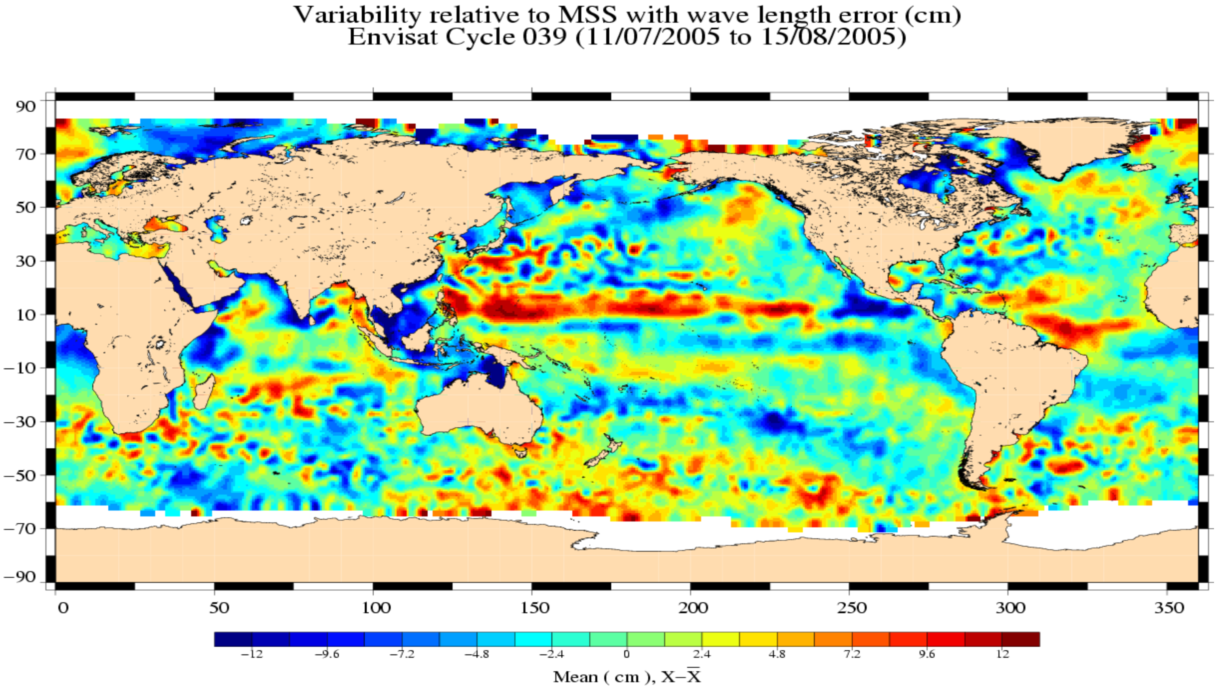
The [Envisat - Jason-1] difference corrected for the estimate Envisat long wavelength error are plotted on the following figure (data are centered about the mean value):



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	1142000	17.25	8.75

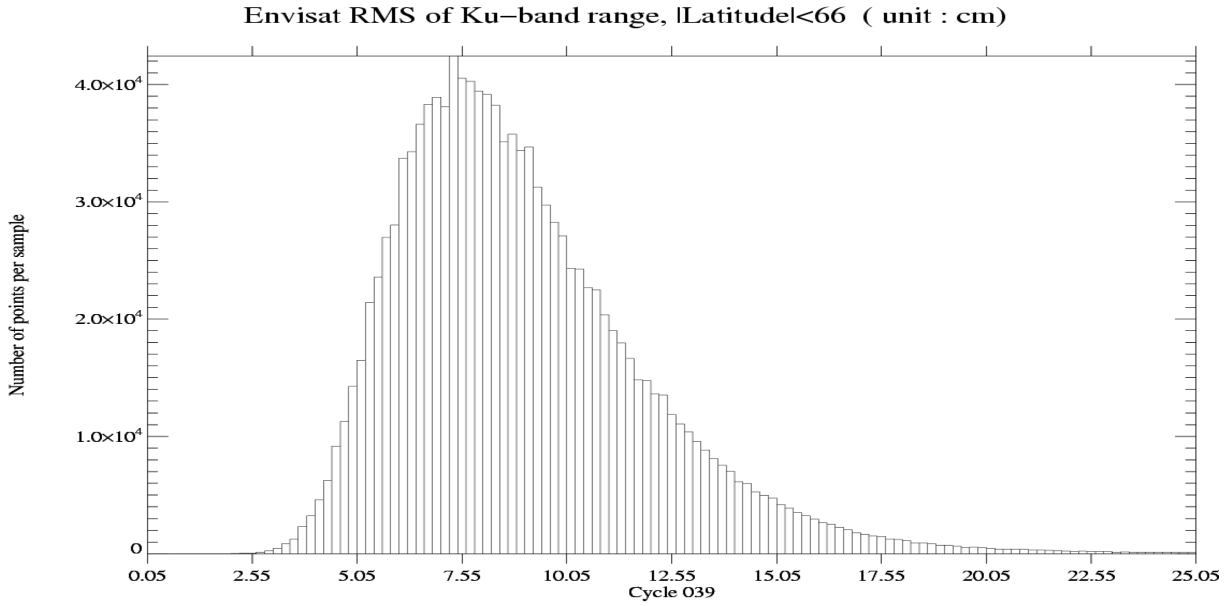
The slight impact on Envisat SLA variance shows that the Envisat long wavelength error is low.

4.4 Comparison on a same time/space sampling

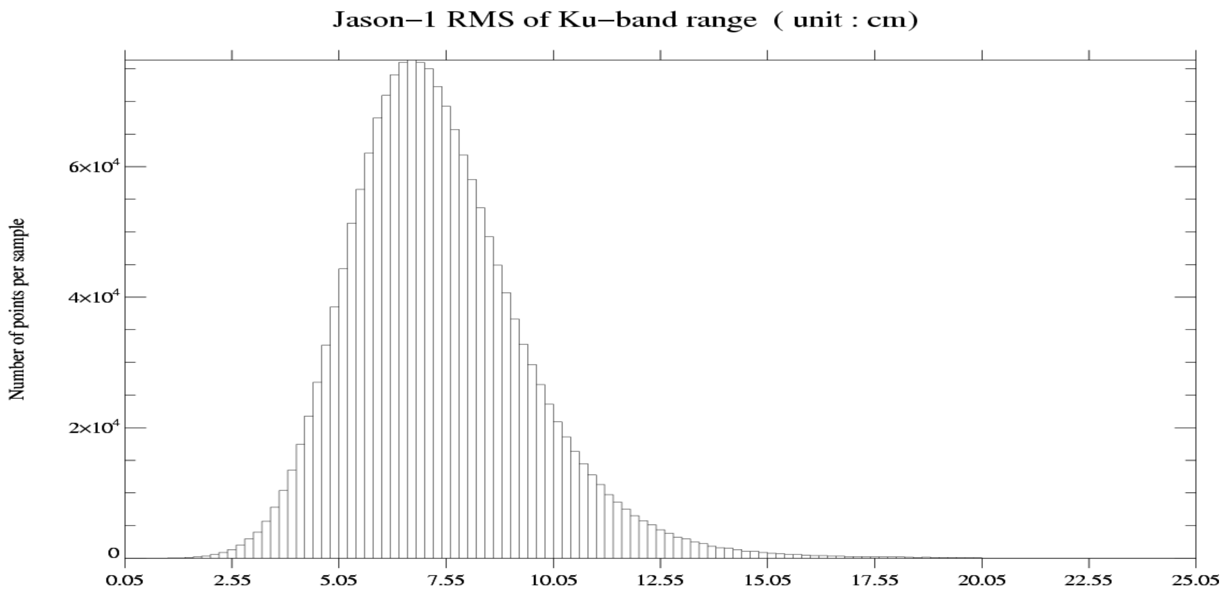
Envisat and Jason-1 are now compared on a same time/space sampling:
- 35 day period
- |latitude| < 66

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:



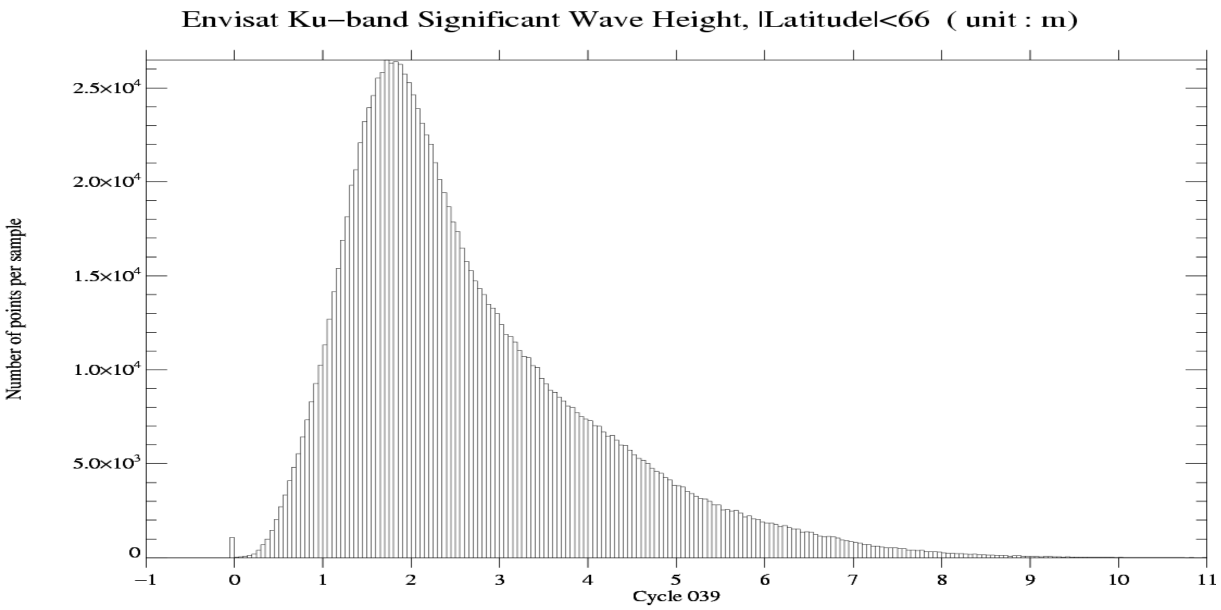
Global nb of points	:	1262047	Sel. nb of points	:	1262047	Sample interval	:	0.200
Global mean	:	8.973	Selected mean	:	8.973	Maximum value	:	25.000
Global Std	:	2.940	Selected std	:	2.940	Minimum value	:	1.900



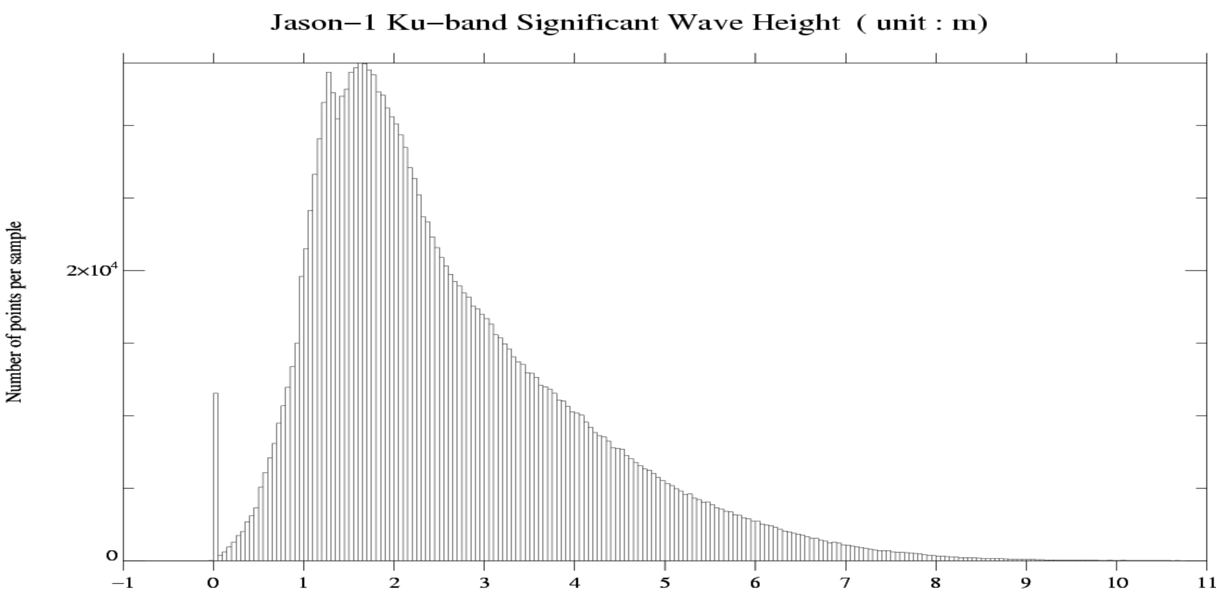
Global nb of points	:	1755033	Sel. nb of points	:	1755033	Sample interval	:	0.200
Global mean	:	7.380	Selected mean	:	7.380	Maximum value	:	20.000
Global Std	:	2.071	Selected std	:	2.071	Minimum value	:	0.390

4.4.2 Ku-band SWH statistics

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



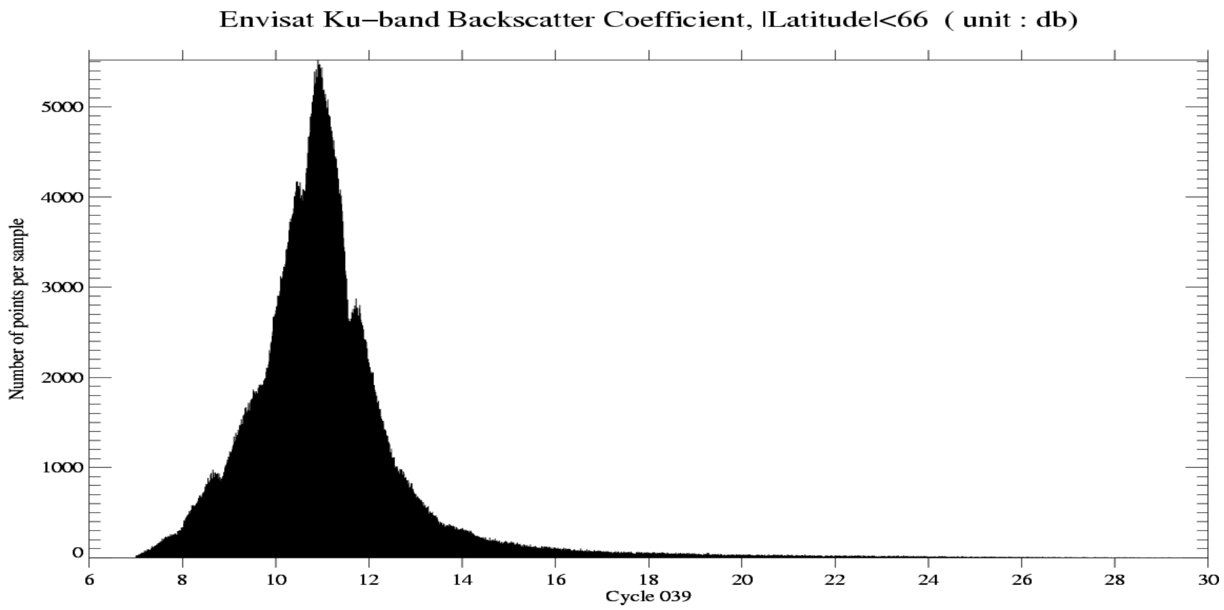
Global nb of points	:	1262047	Sel. nb of points	:	1262047	Sample interval	:	0.050
Global mean	:	2.660	Selected mean	:	2.660	Maximum value	:	10.998
Global Std	:	1.424	Selected std	:	1.424	Minimum value	:	0.000



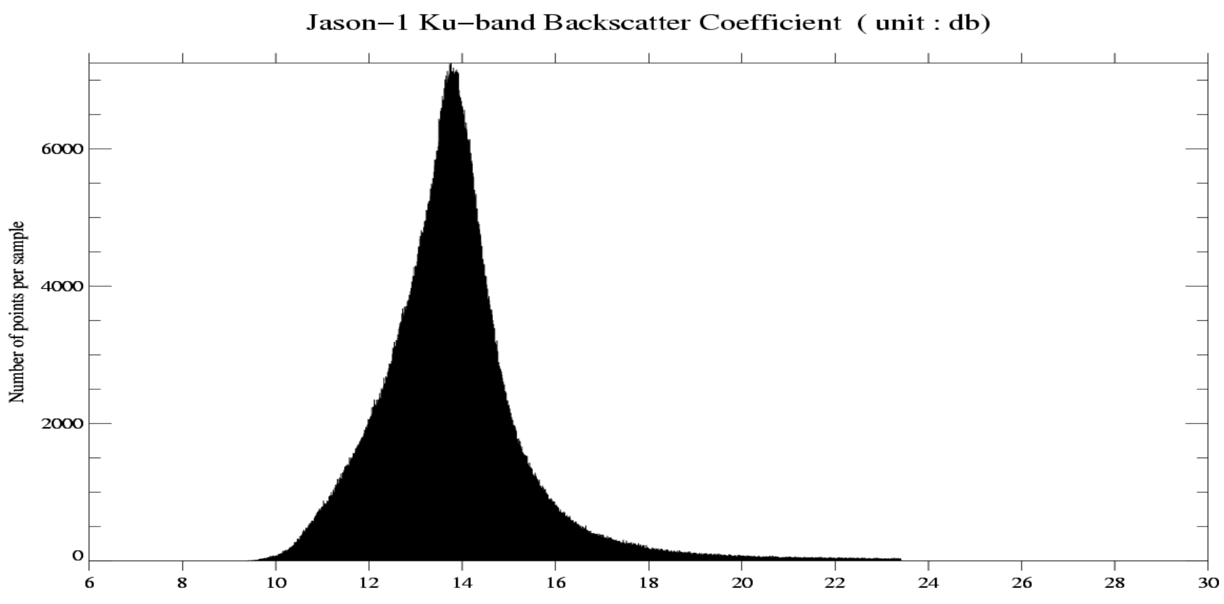
Global nb of points	:	1755033	Sel. nb of points	:	1755033	Sample interval	:	0.050
Global mean	:	2.582	Selected mean	:	2.582	Maximum value	:	10.955
Global Std	:	1.461	Selected std	:	1.461	Minimum value	:	0.000

4.4.3 Ku-band Sigma0 statistics

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



Global nb of points	:	1262047	Sel. nb of points	:	1262047	Sample interval	:	0.010
Global mean	:	11.104	Selected mean	:	11.104	Maximum value	:	29.850
Global Std	:	1.869	Selected std	:	1.869	Minimum value	:	7.000

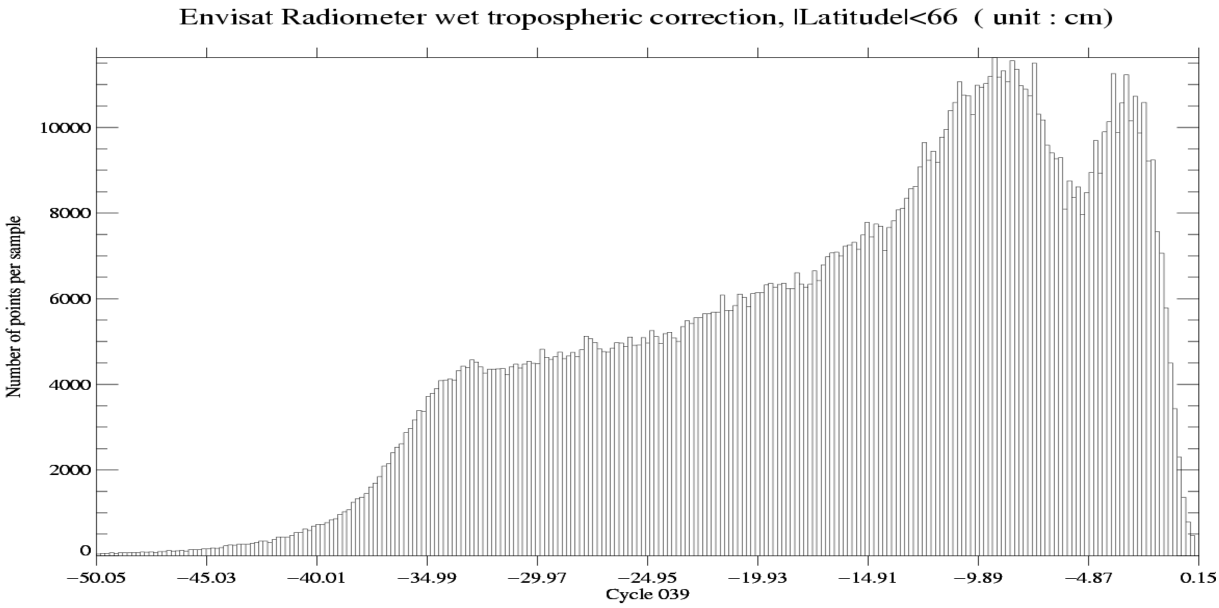


Global nb of points	:	1755033	Sel. nb of points	:	1755033	Sample interval	:	0.010
Global mean	:	13.791	Selected mean	:	13.791	Maximum value	:	23.430
Global Std	:	1.570	Selected std	:	1.570	Minimum value	:	9.380

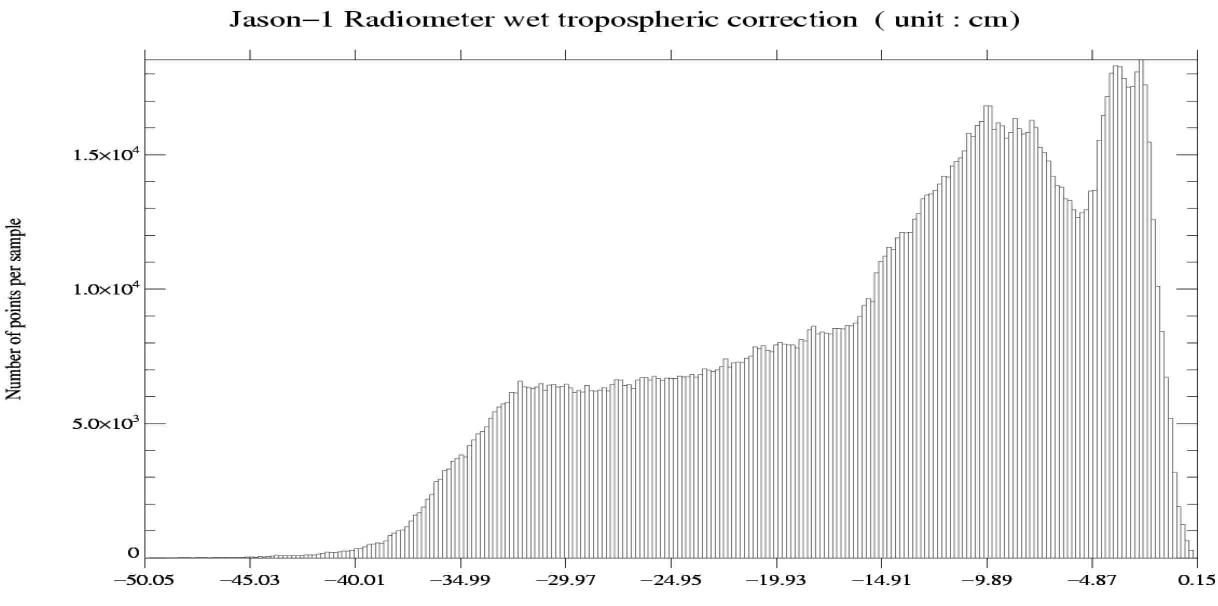
The general shape of the Envisat histogram is not significantly different from the one obtained at global scale.

4.4.4 Troposphere statistics

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



Global nb of points	:	1262047	Sel. nb of points	:	1262047	Sample interval	:	0.200
Global mean	:	−16.087	Selected mean	:	−16.087	Maximum value	:	−0.100
Global Std	:	10.318	Selected std	:	10.318	Minimum value	:	−50.000



Global nb of points	:	1755033	Sel. nb of points	:	1755033	Sample interval	:	0.200
Global mean	:	−15.020	Selected mean	:	−15.020	Maximum value	:	−0.100
Global Std	:	9.786	Selected std	:	9.786	Minimum value	:	−49.950

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	15336	1.44	7.40

Analysis	Number	Mean (cm)	Std. dev. (cm)
J1/J1 SSH	18082	-0.41	7.80

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	10298	1.42	6.38

Analysis	Number	Mean (cm)	Std. dev. (cm)
J1/J1 SSH	9370	-0.03	6.68

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	1155701	44.99	10.03

Analysis	Number	Mean (cm)	Std. dev. (cm)
Jason-1 SLA	1547118	17.25	9.25

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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