CP4O

CryoSat Plus for Oceans

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D4.2 – Product Validation Report on the Improved Wet Tropospheric Correction for CryoSat-2

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1. Introduction

This document describes the validation activities performed by U.Porto in the scope of the CP4O project to the resulting product of the data combination algorithm (DComb) wet tropospheric correction (WTC), also developed by the same team.

Within this project two main independent validation tasks were performed to the improved WTC specifically developed for CryoSat-2 (CS-2): one by U.Porto in the scope of WP4000 – Product Development and Validation, described in this document, and one by CLS in the scope of WP5000 – Impact Assessment, reported on a separate delivery.

Since the DComb correction was computed globally, the assessment will also be performed globally and not for each separate project sub-theme (open ocean, polar ocean, and coastal zone). The validation performed by U.Porto comprises the following main topics:

- Along-track sea level anomalies (SLA) variance analysis: mean cycle values and collocated measurements;
- SLA analysis at cross-overs.

2. Overview

The validation of the DComb WTC presented in this document, complements the validation performed by CLS within WP5000. Both studies show that the DComb algorithm is an improvement over the WTC derived from the ECMWF operational model and provided along with CS-2 data. This study shows that DComb reduces the SLA variance both at collocated points and at crossovers by 1 to 2 cm^2 and that this improvement varies with time mainly depending on the coverage of the water vapour products from scanning imaging microwave radiometers (SI-MWR) and Global Navigation Satellite Systems (GNSS) stations.

In summary, the results show that for periods of good data coverage the improvement is remarkable and the overall improvement with respect to ECMWF operational model is evident.

3. Description of Cryosat-2 Products

For practical reasons the data used in most of the study were Jason-2 (J2) and CryoSat-2 (CS-2) data from the Radar Altimeter Database System (RADS). For this dataset (Dataset 1) the correction was computed and validated for the period of about 13 months that ranges from January 2012 to January 2013. In addition, the correction was also computed for the periods of July 2012 and January 2013 (Dataset 2) for data files provided by ESA. The latter dataset, more complete with respect to CS-2 acquisition modes than that retrieved from RADS, was selected to be provided for use in the independent validation task to be performed in WP5000.

RADS dataset

RADS provides CryoSat-2 data for all LRM points and most regions where the satellite is acquiring data in the SAR mode. In addition, as for all other satellites, RADS provides a large and harmonized set of orbits, mean sea surfaces, range and geophysical corrections, associated validation flags, and the “reference frame offset” (required to align all missions, when multi-mission data are required).

ESA files

Files were provided by ESA for the period from January 2011 to June 2013. ESA files contained only time, latitude, longitude, surface type and instrument mode. These files had to be pre-processed using the following steps:

- The sub-cycle and pass numbers according to RADS convention were introduced. These are required to run the DComb algorithm
- Some duplicated points were removed
- Only 1-Hz points were extracted (those for which the surface type and instrument mode were defined).
- The WTC from ECMWF operational model grids at 0.125°x0.125°spacing and 6 h time interval was interpolated for the time and location of each measurement

Validation files provided to CLS for use in WP5000

Two sets of files were provided to CLS for use in WP5000. Each set contains the WTC for Cryosat-2 sub-cycles 29 and 30 (July 2012) and sub-cycles 36 and 37 (January 2013). The sub-cycle numbers refer to the RADS numbering convention.

Dataset 1 – Computed for CryoSat-2 data points available in RADS. This includes all ocean points (Surface type=0) and the land points closest to the coast, up to a distance from coast of 50 km. This includes all LRM data and most of SAR mode data.

Dataset 2 – Computed for files provided by ESA, containing points for all surface types and all instrument modes.

All fields contained in Dataset 1, except for those related with the DComb WTC, were extracted from RADS. All files are provided at 1-Hz.

Two WTC data sets were generated because the RADS data are easier to handle and so were selected for the global scale validation, whilst a second dataset was needed for the specific coverage of the ESA dataset provided for the independent assessment by CLS. The coverage and precise time / location of data points differ between the RADS and ESA CS-2 altimeter datasets, so the same data could not be used for both evaluations.

Regarding the points for the LRM and SAR modes, the two datasets contain approximately the same points, although with different time and locations. The ESA dataset contains points for a few SAR mode regions which are not present in RADS, but there is also a very small number of track portions present in RADS which are not present in the ESA files.

The time interval between consecutive points in the ESA files is not constant. It can vary from 0.88 s to 0.94 s while in RADS the time interval is always ~0.94 s. To match the two data sets the time difference between TAI (Temps Atomique International) and UTC (Coordinated Universal Time) must be accounted for. Due to the fact that the time interval between the 1-Hz measurements is not the same, for a given epoch, the location of the corresponding points must be computed by interpolation. For a WTC comparison, the closest point in time can be used, provided that the time difference between the matching points is small enough, e.g. < 0.60 s.

The DComb WTC has been computed only for ocean points, therefore only these points should be used in the comparisons.

The correction is provided in NetCDF files with the fields listed below.

List of provided fields

Cycle	sub-cycle number according to RADS convention
Pass	pass number according to RADS convention
Tisec	time in seconds since 2000-01-01 00:00:00 (UTC) – on Dataset 1
Tisec	time in seconds since 2000-01-01 00:00:00 (TAI) – on Dataset 2, as in original ESA files
MJD	Modified Julian Date (UTC)
Latitude	Latitude (degrees north)
Longitude	Longitude (degrees east)
wet_ECMWF	WTC from the ECMWF operational model (metres)
wet_DComb	WTC from the DComb algorithm (metres)
formal_error	formal error of the wet_DComb estimate (metres)
Surface_type	0=open ocean, 1=enclosed seas and lakes, 2=continental ice, 3=land
N_obs	total number of observations used
flag_GNSS	1 if GNSS observations were used
flag_ECMWF	1 if ECMWF operational model was used
flag_SI-MWR	1 if SI-MWR observations were used

4. Description of Experimental Datasets

4.1 Cryosat-2 Data

These were already described in section 3.

4.2 Independent Data Sources

Apart from CS-2 data, in the validation task J2 data were also used from RADS as described in section 3.

5. Validation Activities

The DComb wet tropospheric correction has been computed for J2 cycles 128-168, covering the period from January 2012 to January 2013. For this dataset the following main analyses were performed:

- Analysis of SLA along-track variance difference.
- Analysis of SLA variance difference at crossovers

5.1 Validation Results for Jason-2

A. Analysis of SLA along-track variance difference.

Figures 1 to 4 show the results for the J2 SLA variance analysis, when using different WTC: global values for each cycle (Figure 1 and Figure 2) and at collocated along-track points (Figure 3 and Figure 4).

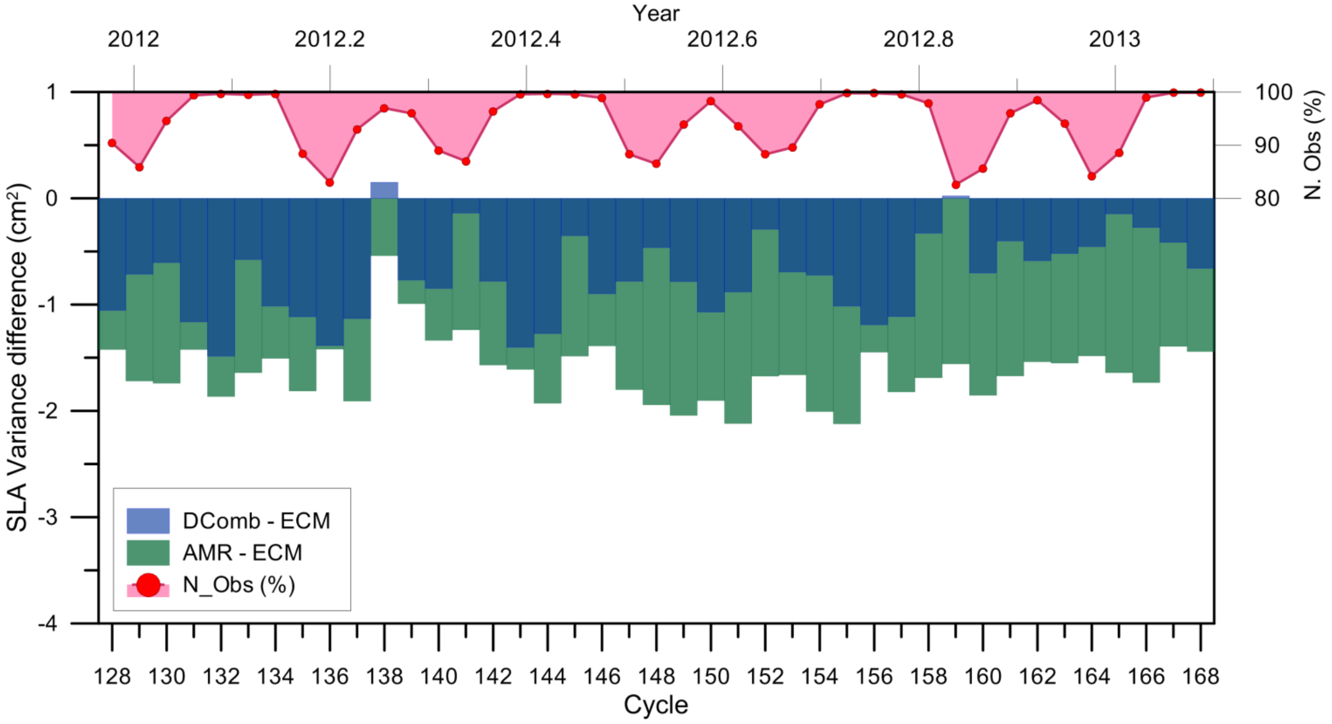

Figure 1 - SLA variance differences (cm^2), for each J2 cycle and different WTC computations: between DComb and ECMWF Operational (blue) and between AMR and ECMWF Operational (green), using all points. The top plot shows the percentage of measurements with observations of any type (GNSS or SI-MWR).

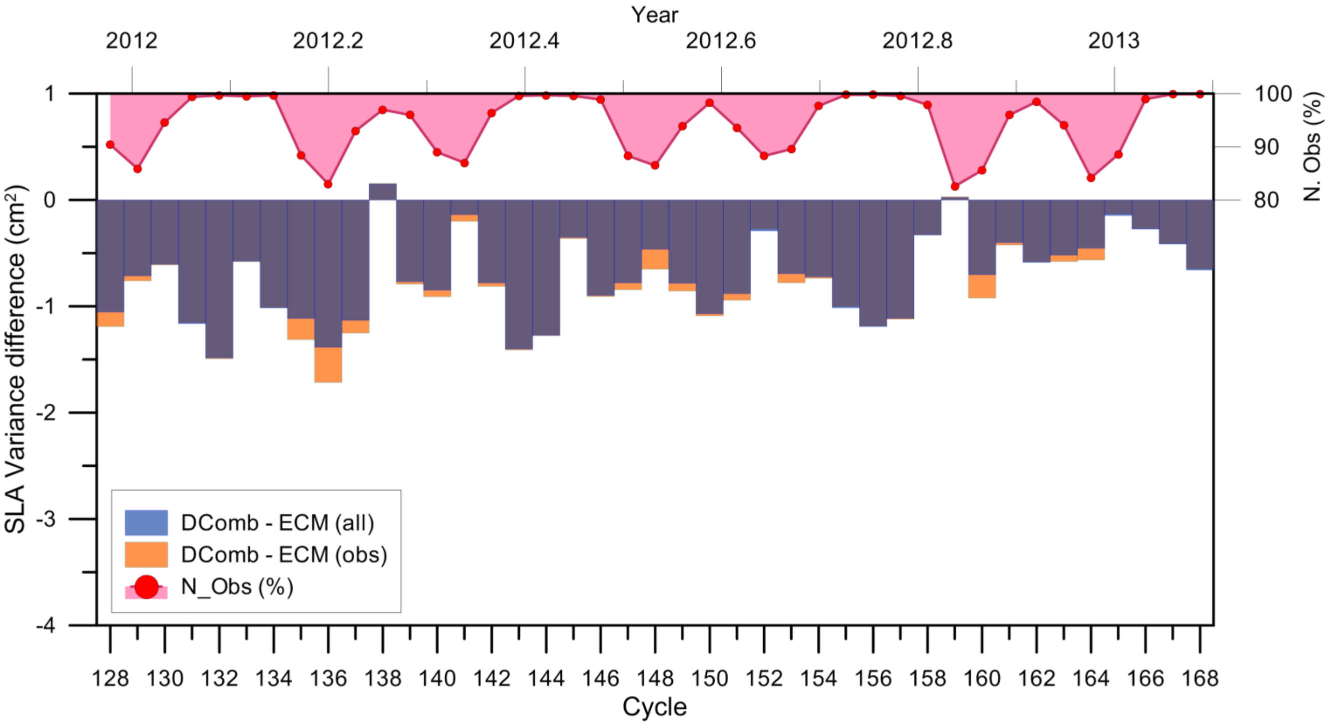

Figure 2 - SLA variance differences (cm^2), for each J2 cycle and different WTC computations: between DComb and ECMWF Operational, using all points (blue) and only points for which either GNSS or SI-MWR observations were available (orange). The top plot shows the percentage of measurements with observations of any type (GNSS or SI-MWR).

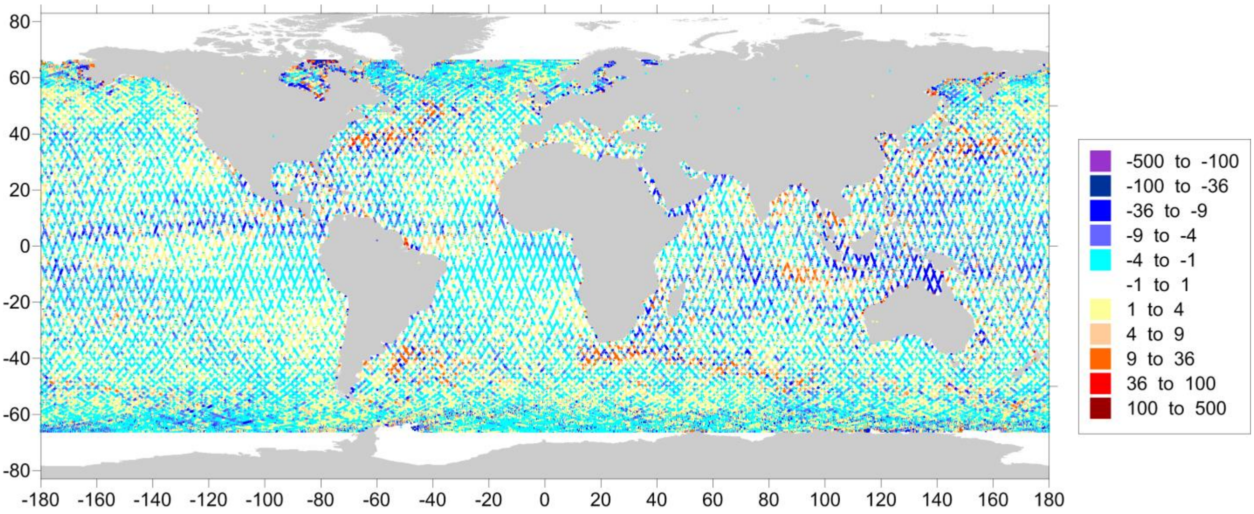

Figure 3 - SLA variance differences at along-track collocated points (cm^2), between DComb and ECMWF Operational model WTC computations, for the period covered by J2 cycles 128-168.

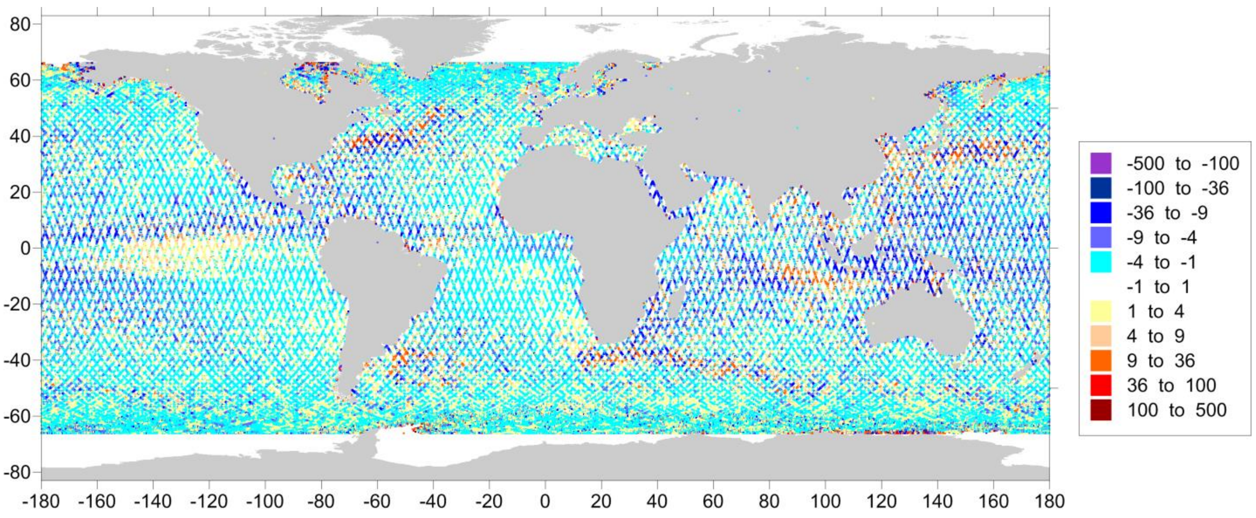

Figure 4 - SLA variance differences (cm^2), between AMR and ECMWF Operational model WTC computation, for the period covered by J2 cycles 128-168.

B. Analysis of SLA variance difference at crossovers

Figures 5 to 7 show the results for the J2 SLA variance analysis at crossover points.

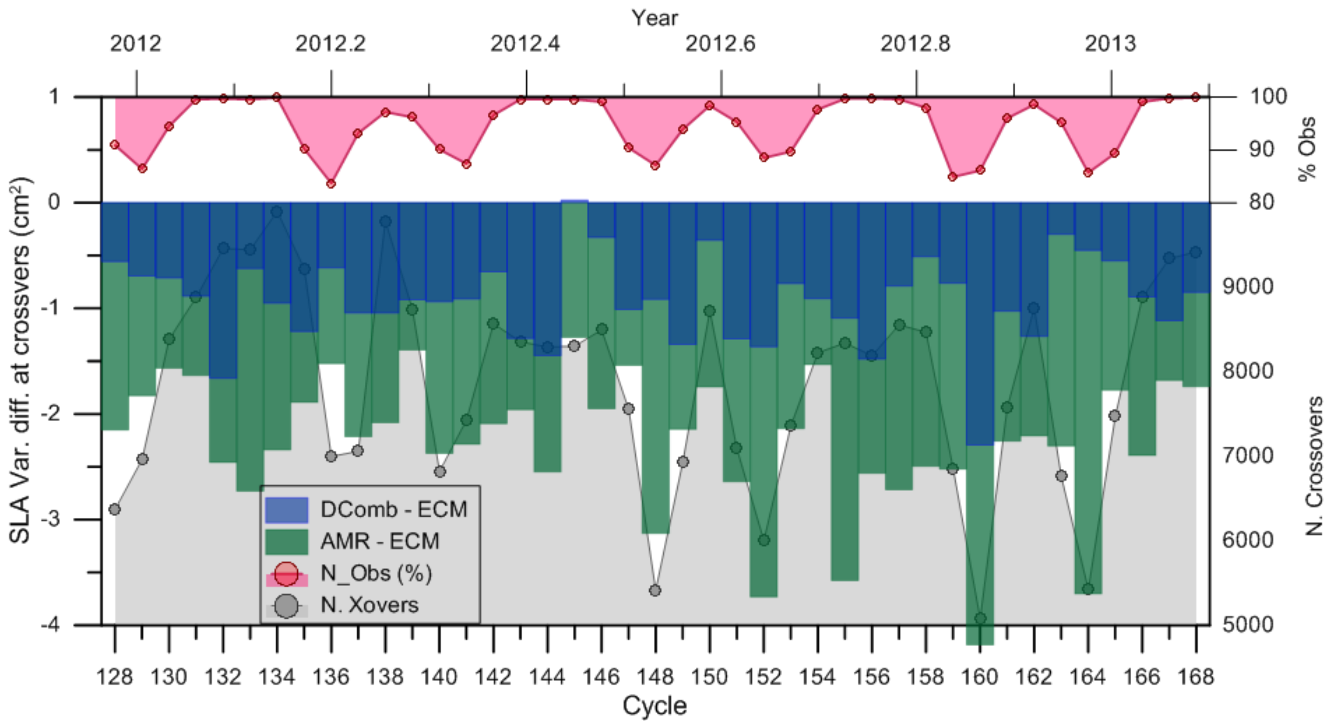

Figure 5 - SLA variance difference at crossovers (cm^2), for each J2 cycle and different WTC computations: between DComb and ECMWF Operational model (blue) and between AMR and ECMWF Operational model (green). The top plot shows the percentage of measurements with observations of any type (GNSS or SI-MWR). The grey dots represent the number of crossovers.

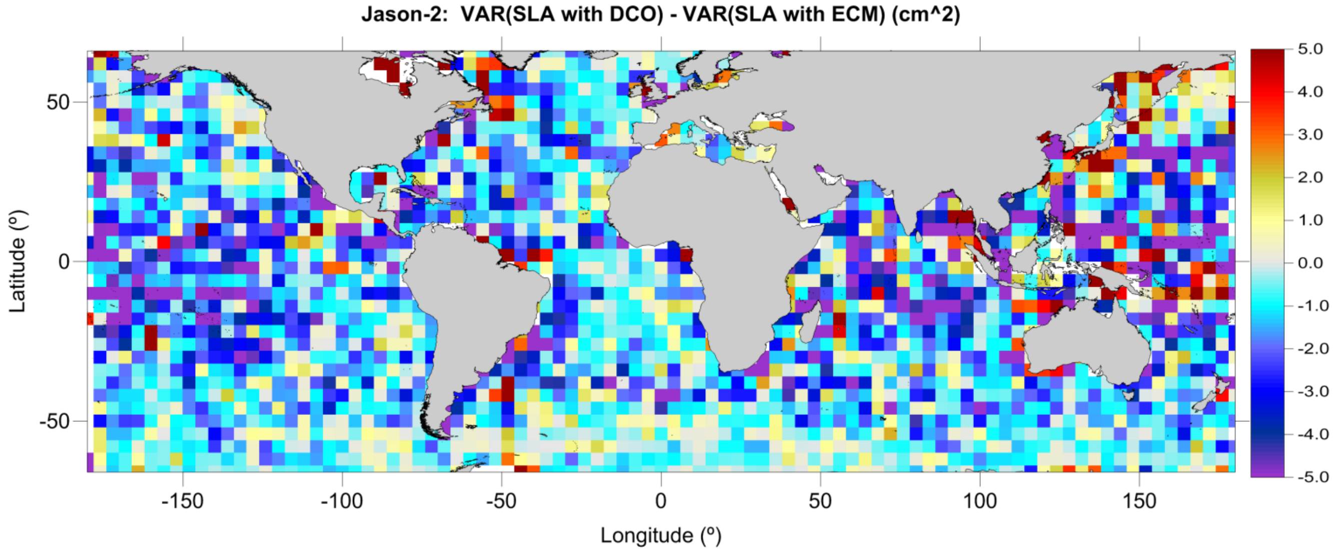

Figure 6 - SLA variance differences at crossovers (cm^2), between DComb and ECMWF Operational model WTC computations, for the period covered by J2 cycles 128-168.

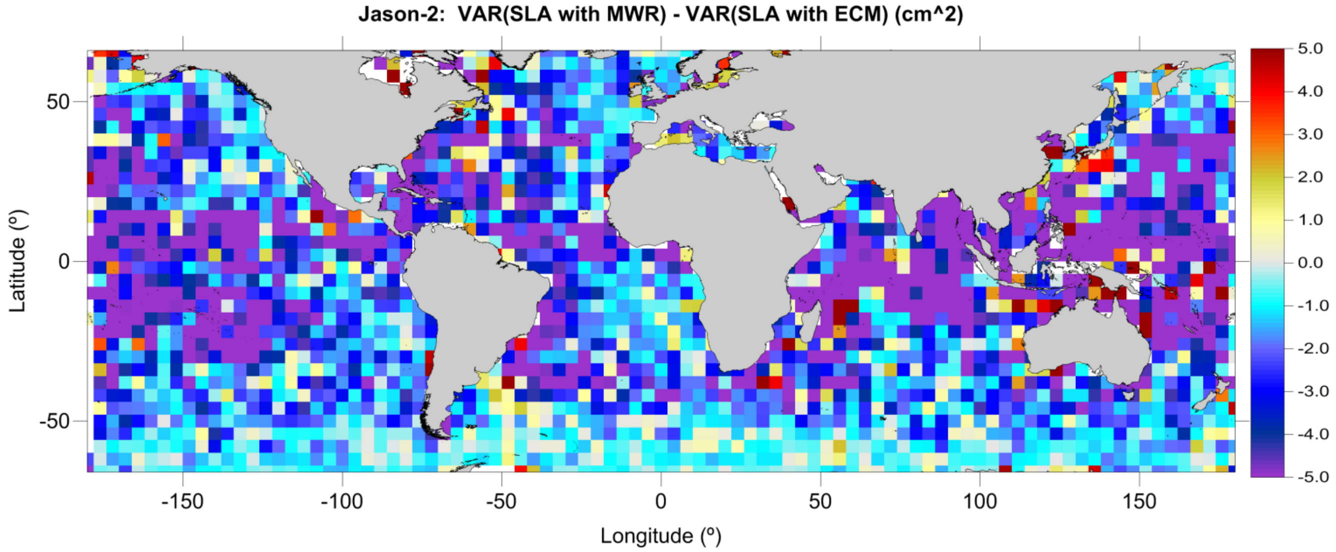

Figure 7 - SLA variance differences at crossovers (cm^2), between AMR and ECMWF Operational model WTC computations, for the period covered by J2 cycles 128-168.

Results show that although AMR provides the best results in terms of SLA variance reduction with respect to the ECMWF operational model, the DComb algorithm consistently reduces the SLA variance with respect to the model by about 1 to 2 cm^2. This improvement varies from cycle to cycle, mainly depending on the data coverage. As expected, when only the points for which WTC observations (GNSS or SI-MWR) are available are used, the improvement is slightly larger.

5.2 Validation Results for CryoSat-2

A. Analysis of SLA along-track variance difference.

Figure 8 shows the results for the CS-2 SLA variance analysis, global values for each cycle.

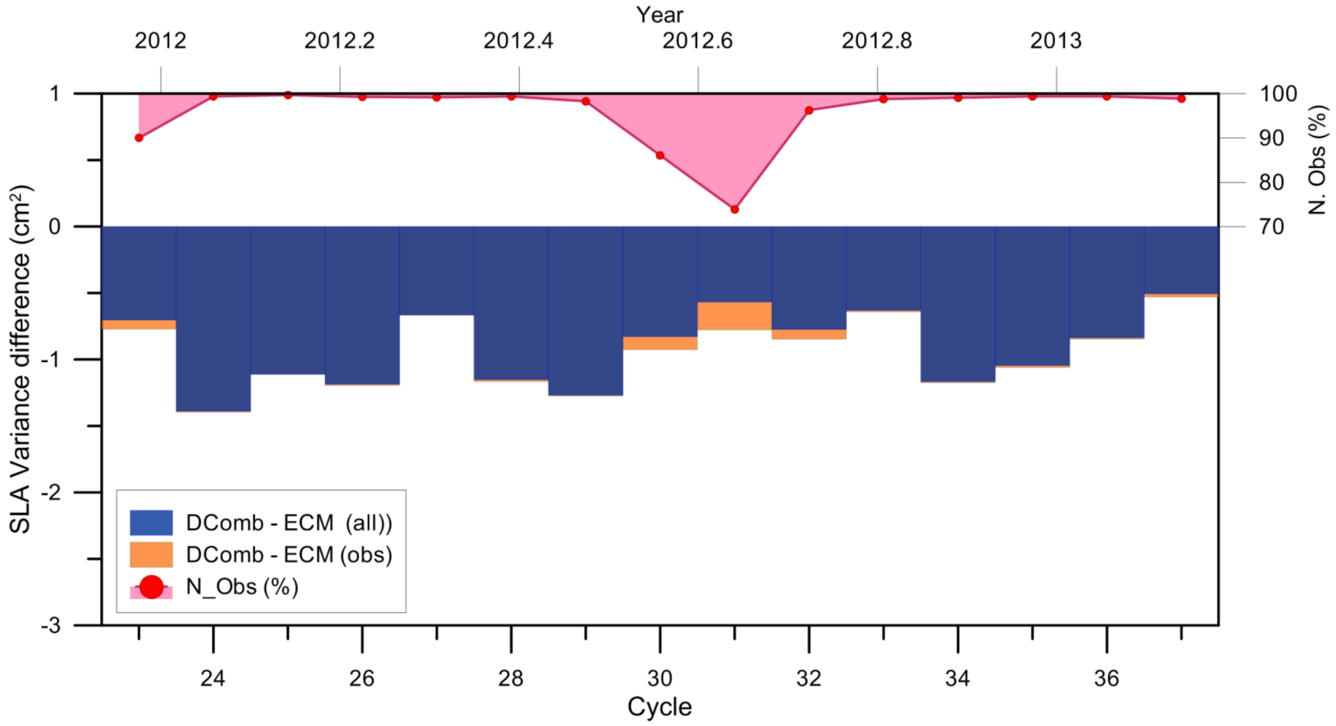

Figure 8 - SLA variance differences (cm^2), for each CS-2 cycle and different WTC computations: between DComb and ECMWF Operational model, using all points (blue) and only points for which either GNSS or SI-MWR observations were available (orange). The top plot shows the percentage of measurements with observations of any type (GNSS or SI-MWR).

B. Analysis of SLA variance difference at crossovers.

Figures 9 and 10 show the results for the CS-2 SLA variance analysis at crossover points.

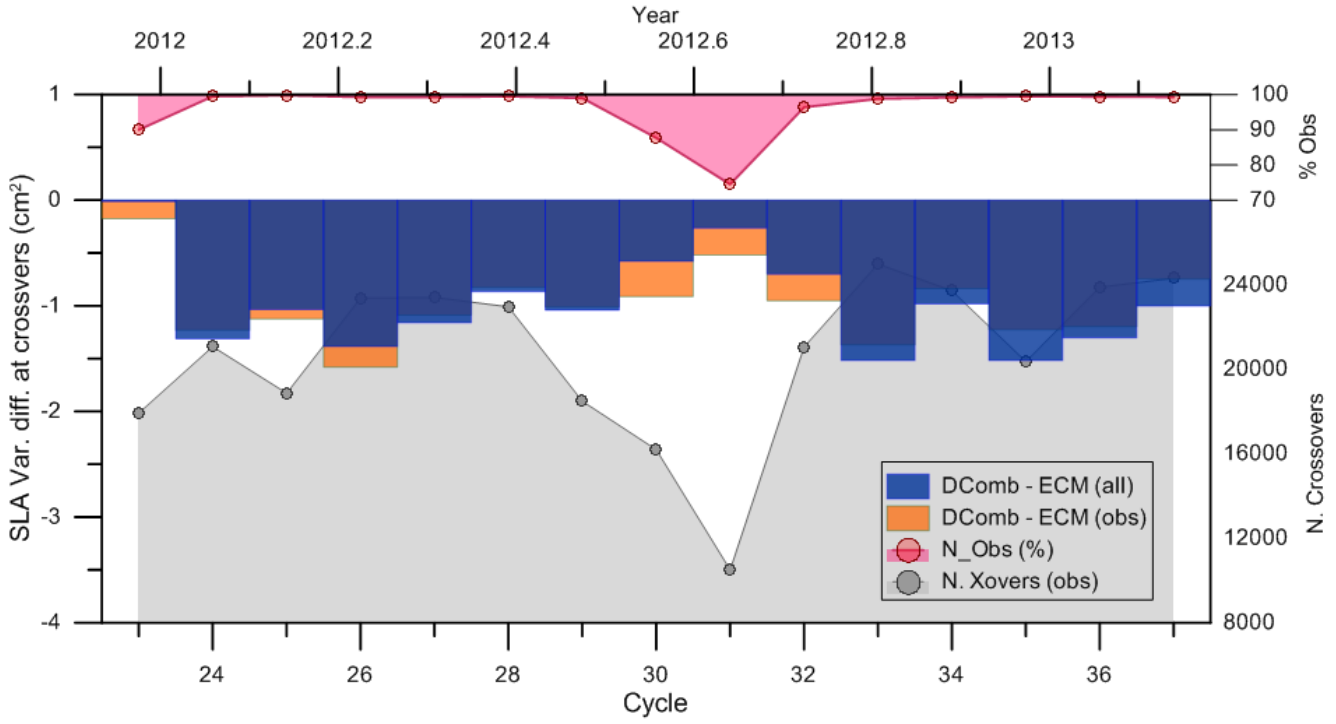

Figure 9 - SLA variance difference at crossovers (cm^2), for each CS-2 cycle and different WTC computations: between DComb and ECMWF Operational model, using all points (blue) and only points for which either GNSS or SI-MWR observations were available (orange). The top plot shows the percentage of measurements with observations of any type (GNSS or SI-MWR). The grey dots represent the number of crossovers.

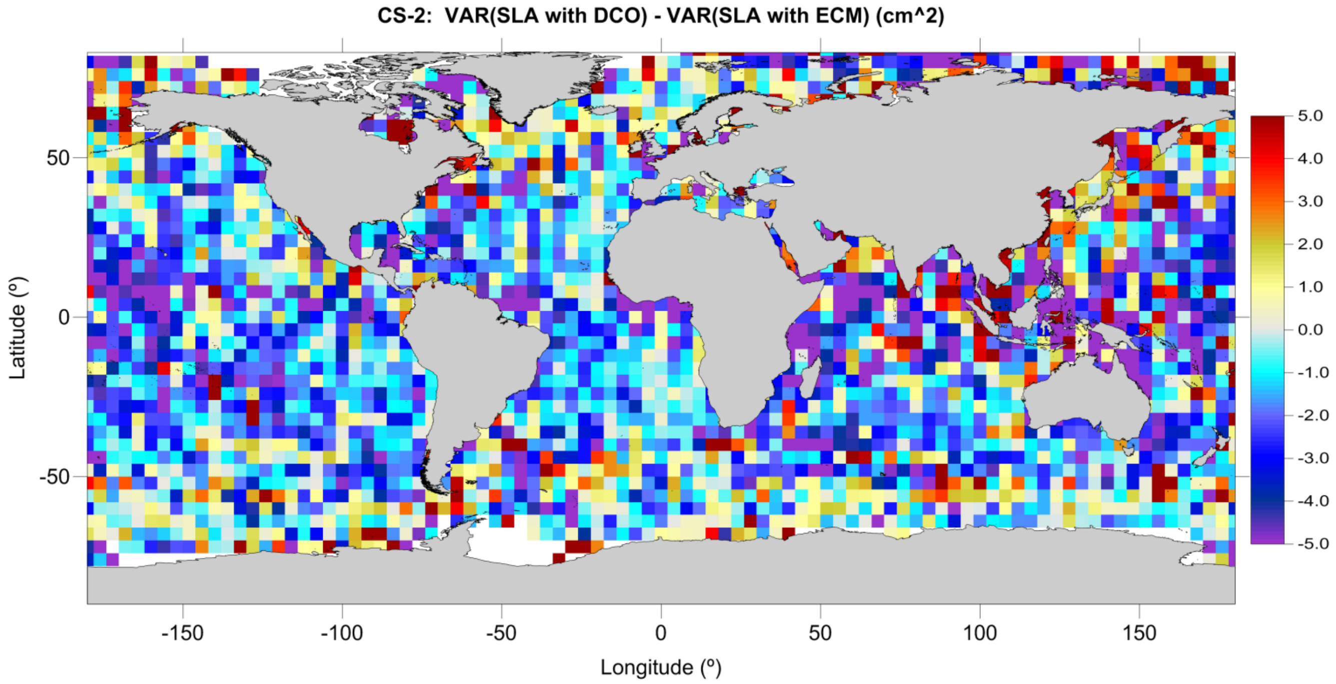

Figure 10 - SLA variance differences at crossovers (cm^2), between DComb and ECMWF Operational model WTC computations, for the period covered by CS-2 cycles 23-37.

Results for CS-2 are very similar to those for J2, i.e. the DComb algorithm consistently reduces the SLA variance with respect to the model by about 1 to 2 cm^2. This improvement varies from cycle to cycle, mainly depending on the SI-MWR and GNSS data coverage.

5.3 Additional future analysis

Within the time frame of this project, up to the date of the writing of the present document, it was not possible to perform a thorough quantitative analysis of the performance of the algorithm in the coastal regions, in particular the influence of the GNSS data. However, detailed graphical analysis similar to the one presented in Figure 10 in D4.1 – Algorithm Theoretical Basis Document, has been performed for various J2 and CS-2 cycles, showing a clear influence of the GNSS data in the WTC estimation in the costal regions.

In the validation report performed by CLS for Dataset 2, mentioned in section 3, it was found that this impact is difficult to assess on global analysis and that alternative diagnostics need to be adopted for this purpose, possibly by selecting only the regions of influence of these data. This complementary aspect of the validation of the DComb algorithm will be the next subject of investigation.

6. References

D4.1 – Algorithm Theoretical Basis Document on the Improved Wet Tropospheric Correction for CryoSat-2

7. Abbreviations and Acronyms

AMR	Advanced Microwave Radiometer
ATBD	Algorithm Theoretical Basis Document
CS-2	CryoSat-2
DComb	data combination (algorithm)
ECMWF	European Centre for Medium-Range Weather Forecasts
ESA	European Space Agency
GNSS	Global Navigation Satellite Systems
J2	Jason-2
LRM	Low Resolution Mode
MJD	Modified Julian Date
MWR	microwave radiometers
RADS	Radar Altimeter Database System
SAR	Synthetic Aperture Radar
SI-MWR	Scanning Imager MWR
SLA	sea level anomaly
TAI	Temps Atomique International
U.Porto	University of Porto
UTC	Coordinated Universal Time
WTC	wet tropospheric correction

8. Acknowledgements

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