Validation of CryoSat-2 Classical Altimetry Data over Ocean using a GOCE Geoid to compute Absolute Dynamic Topography

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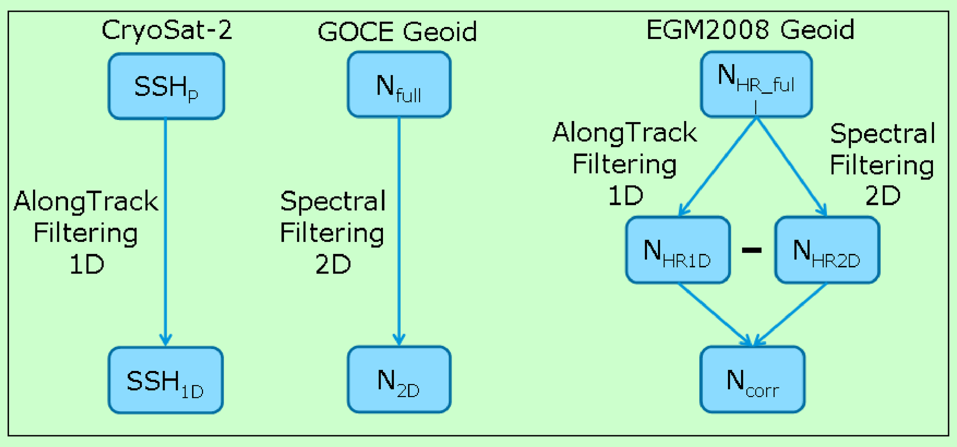
1 Along Track Approach:

Due to the arise of Geoids realisations of higher precision, it was decided to compute the Absolute Dynamic Topography (ADT) in a direct way using profiles along the altimeter passes and evaluate the obtained Sea Surface Height (SSH) measurements directly according formula (1).

$$ADT = SSH - N \quad (1)$$

With the geoid height N. To obtain spectral consistency filtering is an essential step in order to apply equation (1). Following W. Bosch [2] a Gausian Filter Kernel has been chosen for the 1D along track domain as well as for the 2D spectral domain because of its isotropic characteristics and its similar behaviour in the 1D and 2D domain. The kernel performs a low pass filtering and its size is the same in all steps. The filtering in the spectral domain was applied by using the workflow filter_shf of the GOCE User Toolbox (GUT) v2.0 [3]. The filter correction N_{corr}, which is necessary to overcome filter errors in areas with high variability in bathymetry, has been computed evaluating the ultra high resolution geoid EGM2008 [6] developed up to degree/order 2190. An example for the occurrence of the filter error can be a pass of the altimeter along a trench. Applying 1D along track filtering does not change the SSH measurements significantly. But applying 2D filtering so to say "lifts" the SSH measurements due to the higher surrounding areas. With shrinking size of the filter kernel the magnitude of the correction decreases.



As sketched in the above figure, the EGM2008 geoid has been evaluated along the passes of the altimeter on the one side at full resolution with subsequent 1D along track filtering to obtain N_{HR1D}, and on the other side after the 2D filtering in the spectral domain to obtain N_{HR2D}. The geoid heights N_{2D} derived from a GOCE geoid (in this case Time-Wise 2nd release solution [5]) were evaluated along the passes of the satellite after applying 2D spectral filtering. This leads from equation (1) to the full equation (2).

$$ADT = SSH_{1D} - N_{2D} + N_{corr} \quad (2)$$

with

$$N_{corr} = N_{HR1D} - N_{HR2D} \quad (3)$$

2 Data used and data quality:

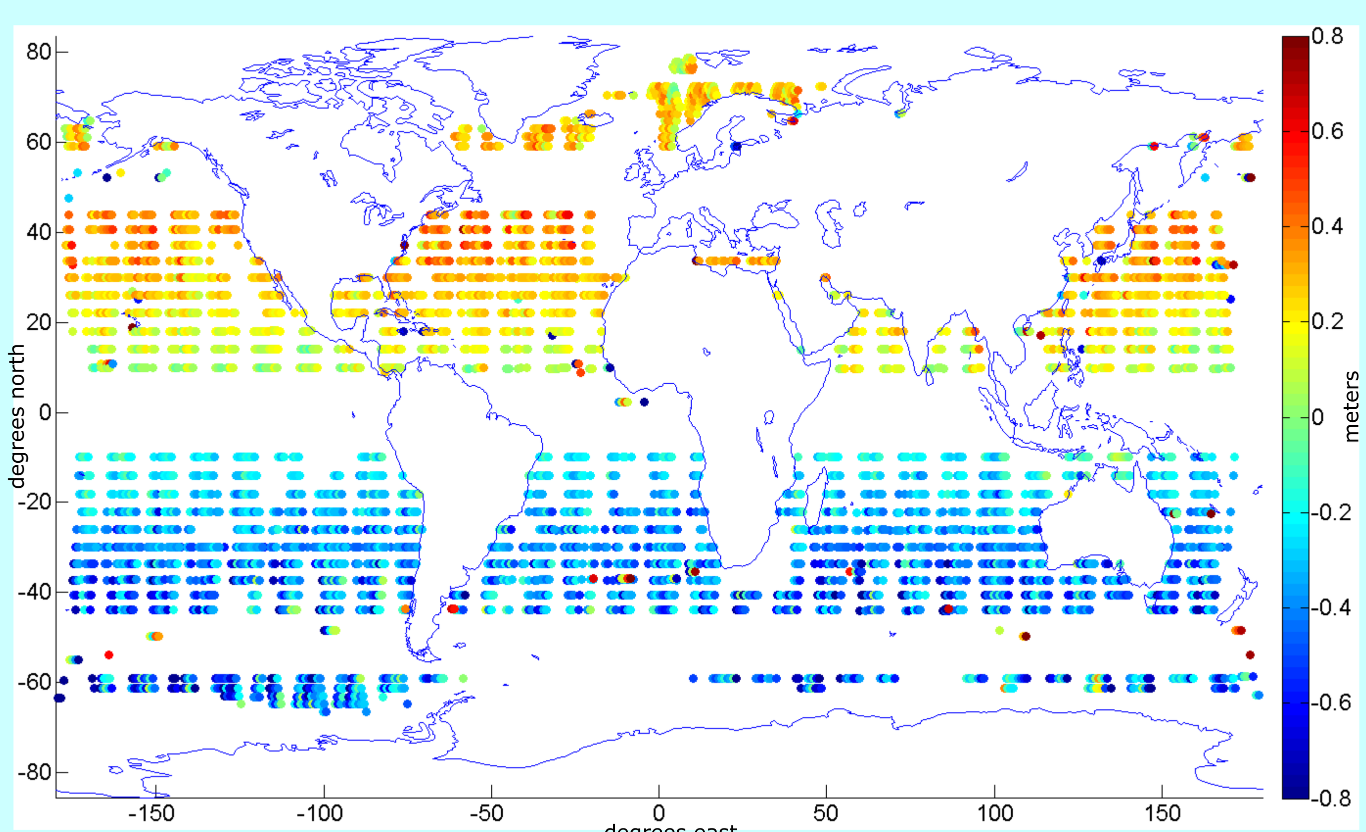
CryoSat-2: The altimetry data used is CryoSat-2 Level 2 Low Rate Mode (L2 LRM) of June 2011. From all the files disseminated from the server *science-pds.cryosat.esa.int* all measurements over Open Ocean were extracted for the further processing.

CryoSat-2 LRM data quality: 10% of the data acquired suffers from some deficits. The major factor is the absence of one or more corrections. The Sea State Bias (SSB) correction is not very reliable since up to 30% of the products hold invalid estimates for wind speed and wave height.

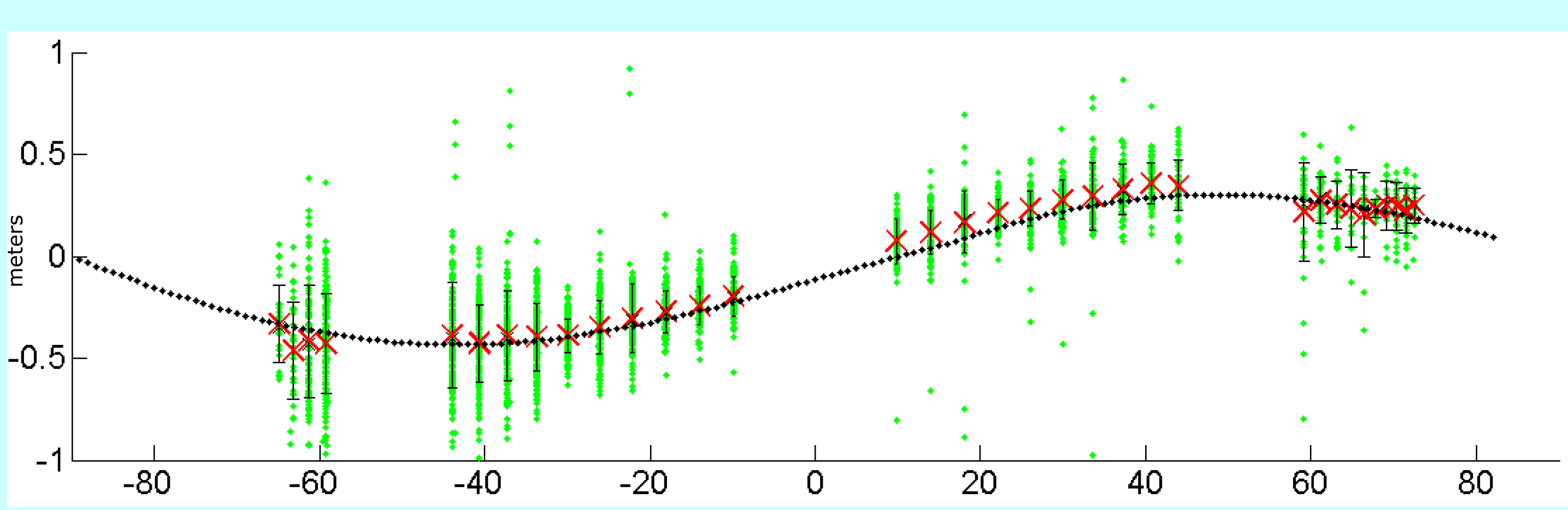
Geoids: The GOCE Time-Wise 2nd release geoid model as well as the EGM2008 geoid model were taken from the ICGEM website *http://icgem.gfz-potsdam.de/ICGEM/* and were processed using the ESA GOCE User Toolbox (GUT) [3].

3 Time Tag Bias and Cross Over Differences:

In order to estimate the Time Tag Bias (which was shown to be non-negligible in the measurements at the CryoSat Validation Workshop by M. Naeije [4]) cross-over differences over one month (June 2011) have been computed.



As the figure above shows, the computation was done globally over Open Ocean with a maximum time gap between two crossing tracks of 10 days. The colorbar next to the figure indicates the difference between ascending and descending track in meters. The total number of detected cross-over points is 3740.



The figure above shows the latitude dependent distribution of the differences from **ascending minus descending tracks** (green dots). The red crosses show the mean value for each bin, the error bars indicate the standard deviation of the corresponding mean value. The dotted black line shows the theoretical impact of a time **tag bias of 8.4 ms** with the orbit configuration of Cryosat-2. It is clearly visible that the theoretical values show very good agreement with the measured values. The Time Tag Bias is applied to the results shown in the following parts.

Introduction:

The ESA Earth Explorer mission CryoSat-2 provides a unique opportunity for exploring a broad variety of scientific applications in the fields of Geodesy and Oceanography. The quality assessment of CryoSat-2 data and in particular Low Rate Mode Level 2 (LRM L2) data is an essential step for a successful integration of the data products into operational usage and processing.

The investigations presented in this poster are divided into two parts; on the left side the **data quality analysis** and on the right side the **computation, use and validation of an corrected data product** in an oceanographic application.

After one year of data acquisition, the evolution of data quality is clearly visible. In this context a data quality analysis has been carried out, focusing on a cross-over difference analysis and the estimation of a present time tag bias as well as other parameters, such as consistency and availability of the product.

As a consequence of the present deficiencies in the delivered products, a correction was estimated and applied to the original product's data.

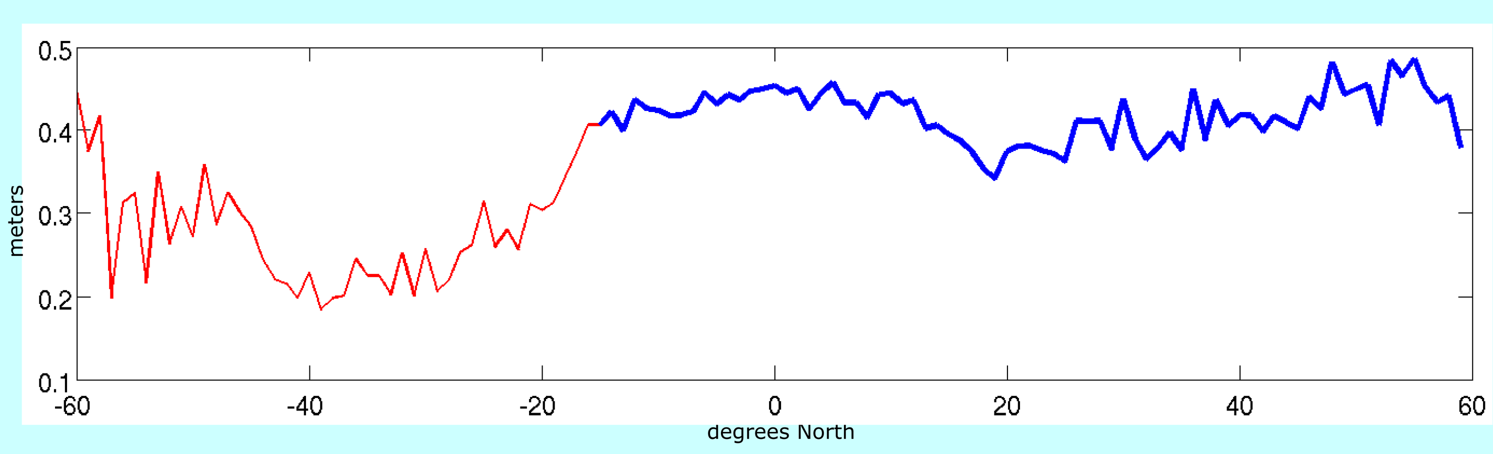
To prove the feasibility of this enhancement and of the along track approach using CryoSat-2 and GOCE data, a case study demonstrates the performance of Absolute Dynamic Topography (ADT) results in an oceanic region.

For the ADT computation in the along track approach, geoid heights derived from the GOCE time-wise geoid model are used. The spatial resolution of the ADT is 100 km. A validation of the CryoSat-2/GOCE ADT results, with an independently derived ADT, shows the performance of the ADT solution obtained.

4 Validation of CryoSat/GOCE ADT against independent ADT:

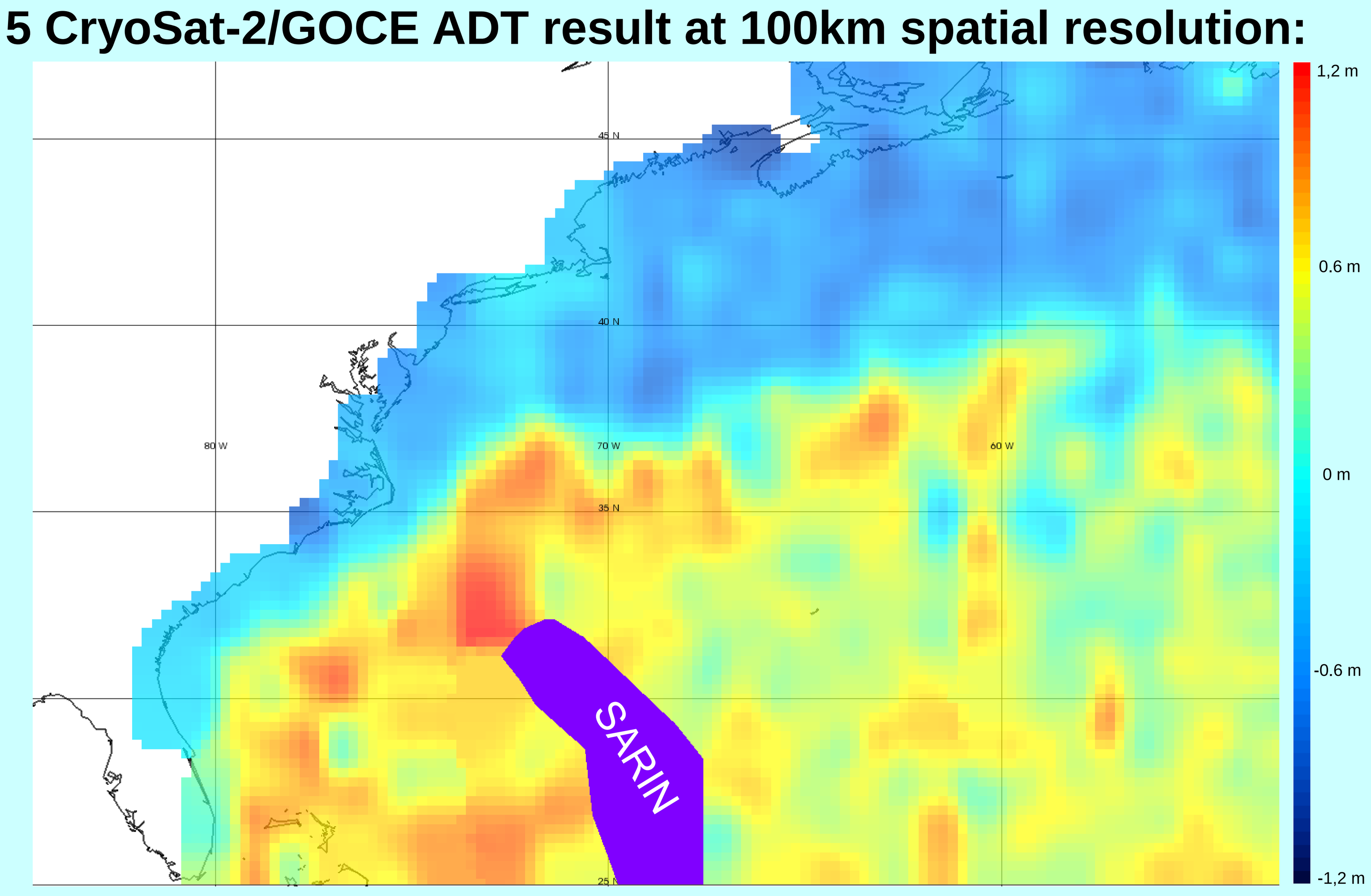
The independent ADT estimates used for comparison reasons were produced by Ssalto/Duacs and distributed by Aviso, with support from CNES [7]. They are provided on daily basis from a multi-mission (Jason-1, Jason-2 and Envisat RA2) altimetry dataset on a ¼ degree global grid. For the comparison the Aviso results were interpolated along the CryoSat-2 passes from the Aviso grid closest in time.

The CryoSat-2 data used for this external validation was taken from a test area in the Pacific Ocean ranging from 140° to 150° West and from 60° South to 60° North. The area covers Open Ocean only and Land Contamination is not present. The covering measurement mode is LRM only.



The figure above shows the mean difference between the CryoSat-2/GOCE ADT and the Aviso ADT against latitude in 1-degree bins. The result shows very good agreement between the two entities. Especially between 15° South and 60° North (in blue) the results match very well with an **offset of 42 cm** and a **standard deviation of 3,1 cm**.

5 CryoSat-2/GOCE ADT result at 100km spatial resolution:



The figure above shows an CryoSat/GOCE derived ADT in the North Atlantic Region. The purple part is covered with SARIN mode measurements and not with LRM. The spatial resolution of the original data is 100km. With the along track approach explained above, profiles along the CryoSat-2 passes are obtained. For the figure a Loess extrapolation was performed using the ESA Basic Altimetry Radar Toolbox (BRAT) on a ¼ degree grid.

Conclusions & Way Forward:

The results of the ADT computation using CryoSat-2 Pulse Limited Altimeter data and the GOCE Time-Wise 2nd release Geoid model are in very high agreement with the AVISO ADT results obtained from a multi mission daily processing.

A broader validation of the CryoSat-2 mission is currently ongoing. In this context the validation against Jason-2 and other altimeters is under preparation to detect e.g. a bias between the missions.

Another aspect will be the assessment of the quality & performance of all corrections coming with the original product. This will be done in an international context.

References:

[1] Bosch W. & Savcenko R. (2010). On estimating the dynamic ocean topography - a profile approach. In: Mertikas (Ed.) Gravity, Geoid and Earth Observation. IAG Symposia, Springer, Vol. 135.
[2] CryoSat Mission and Data Description CS-RPESA-SY-0059 Issue 3 02.01.2007 http://esamultimedia.esa.int/docs/Cryosat/Mission_and_Data_Descrip.pdf
[3] GUT User Guide and Algorithm Descriptions ESA-GUT-AD-001 Version 2.0 09.03.2011 http://earth.esa.int/gut/documents/GUT_UserGuide.pdf
[4] Naeije M. et al (2011). Calibration and Validation of CryoSat-2 Low Resolution Mode Data. In: Proceedings of the CryoSat Validation Workshop, 1 - 3 February 2011, Frascati, Italy, ESA SP-693.
[5] Pail R. et al (2011). GOCE-only gravity field model derived from 8 months of GOCE data. In: Proceedings of the 4th International GOCE User Workshop, 31 March - 1 April 2011, Munich, Germany, ESA SP-696.
[6] Pavlis N.K. et al (2008). An Earth Gravitational Model to Degree 2160: EGM2008. Presented at the 2008 General Assembly of the European Geosciences Union, Vienna, Austria, April 13-18, 2008.
[7] SSALTO/DUACS User Handbook: (M)SLA and (M)ADT Near-Real Time and Delayed Time Products CLS-DOS-NT-06-034 - Issue 2.4 29.03.2011 http://www.aviso.oceanobs.com/fileadmin/documents/data/tools/hdbk_duacs.pdf

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