Performance of ESA Cryosat-2 GDR data over open ocean

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Motivation
Although not part of the basic mission objectives the Cryosat-2 data acquired over ocean has already shown its suitability and value for a variety of ocean applications. Especially, the combination of this data with other altimeter systems is challenging to enhance the temporal and spatial resolution of sea surface height measurements. The majority of altimeter users presumably apply the official ESA Level 2 GDR product. Hence, the quality of this product and its consistency with other altimeter missions such as Jason-1/2 and Envisat is of particular interest.

Data: ESA Level 2 GDR, Baseline B
All results presented here are based on the official ESA Level 2 GDR product, Baseline B (IPFGDR_2A/2.4). The data is provided in files containing all measurements from one full orbit. Thus, measurements coming from LRM, SAR, and SARIn mode are combined and provided in the same format.

In order to use the Cryosat data together with other missions, the following steps have been applied to the data:
• Range has been reconstructed from given elevations and orbit heights.
• Own geophysical corrections have been used in order to be as much consistent as possible to other data sets.
• L2 LRM time tag bias of 4.5 ms has been applied (see ESA, 2012).
• SSB set to ZERO for SAR and SARIn data (no valid SSB given in the data set).

Method: Multi-Mission Crossover Analysis (MMXO)
The Multi-Mission Crossover analysis (MMXO) takes advantage of the high redundancy provided by a multiple surveying of the sea surface through contemporaneous altimeter missions. The redundancy is exploited by short-term single- and dual-satellite crossover differences $\Delta i$, in all combinations. Together with consecutive radial errors $\delta_i$, they are minimized by a least squares adjustment, which includes a variance component estimate to achieve an objective relative weighting between different missions.

Main steps:
• Computation of single and dual-satellite crossover differences in all combinations
• Minimizing both $\Delta x = x_{ij} - x_i$ and $\Delta y = y_{ij} - y_i$ and estimation of radial errors $\delta_i$ at all crossover points
• Output: Time series of radial errors for each mission
  Empirical auto-covariance functions of the radial errors
  Geographically correlated errors (GCE) Mean range bias $\Delta r$ (per 10 day cycles)
  Mean differences in the center-of-origin realization $\Delta x$, $\Delta y$, $\Delta z$ (10 day cycles)
  Global mean range bias for each mission (w.r.t. reference mission, i.e. Jason-2)

Consistency between measurement modes (LRM, SAR, SARIn)
The measurements form different modes show clear offsets between each other. This becomes apparent in the crossover differences between Cryosat and Jason-2. In Fig. 5 the regions with different modes are nicely combined with other altimeter missions and used for ocean applications, when taking into account some important points:
• The 1 Hz time is referring to the first of the 20 Hz measurements and not to the origin realization
• Various time tag bias of 4.5 ms exists.
• No valid SSB corrections for SAR and SARIn are included in the data.
• A significant LRM range bias of 24.1 cm w.r.t. Jason-2 has to be taken into account.
• Even if the “combined” Cryosat L2 GDR product is easy to handle, the different range offsets require a separate treatment of the different measurement modes, as they show significant offsets between each other.

References:
Dettmering D., Bosch W.: Multi-Mission Crossover Analysis. Merging 20 years of Altimeter Data into One Consistent Long-term Data Record. ESA Publication SP-713, 2012

Fig. 1 Missions and time periods used for MMXO
Fig. 2: Crossover differences
Fig. 3: Radial errors of Cryosat LRM and its stochastic properties. Plot a) radial errors, b) auto-covariance function and c) amplitude spectrum
Fig. 4: GCE for Cryosat (top) and Jason-2 (bottom)
Fig. 5: Crossover differences between Cryosat Cycle 34 and Jason-2 in [m]

Conclusions
Although not part of the basic mission objectives, the Cryosat L2 GDR data can be nicely combined with other altimeter missions and used for ocean applications, when taking into account some important points:
• The 1 Hz time is referring to the first of the 20 Hz measurements and not to the mean of the time frame.
• A significant time-tag bias of 4.5 ms exists.
• A significant LRM range bias of 24.1 cm w.r.t. Jason-2 has to be taken into account.
• Even if the “combined” Cryosat L2 GDR product is easy to handle, the different range offsets require a separate treatment of the different measurement modes, as they show significant offsets between each other.

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