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 (IPF2GDR_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)

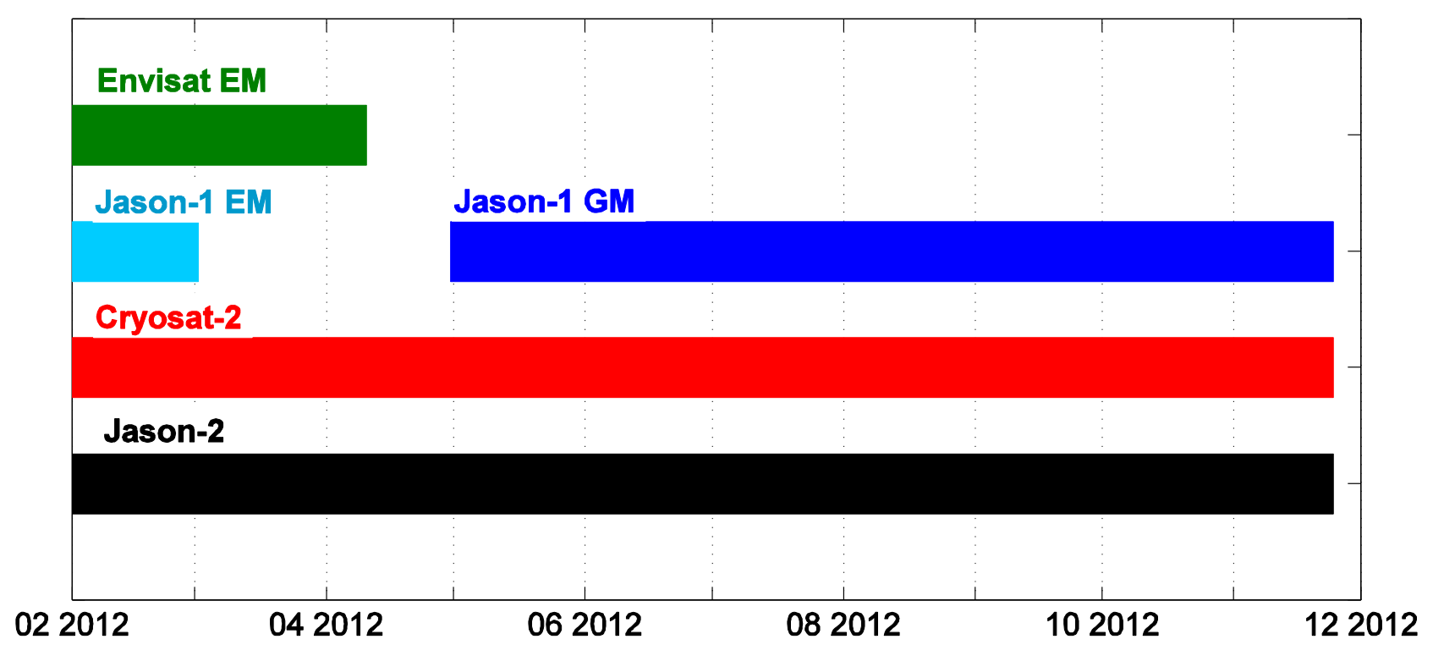

Fig. 1: Missions and time periods used for MMXO

Time period:
Feb. 2012 – Dec. 2012
Additional missions:
Jason-2 (GDR-D)
Jason-1 EM (extended mission, GDR-C)
Jason-1 GM (geodetic mission, GDR-C)
Envisat EM (extended mission, GDR-C)

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 expressed by short-term single- and dual-satellite crossover differences Δx_{ij} in all combinations. Together with consecutive radial errors δx_i they are minimized by a least squares adjustment, which includes a variance component estimate to achieve an objective relative weighting between different missions.

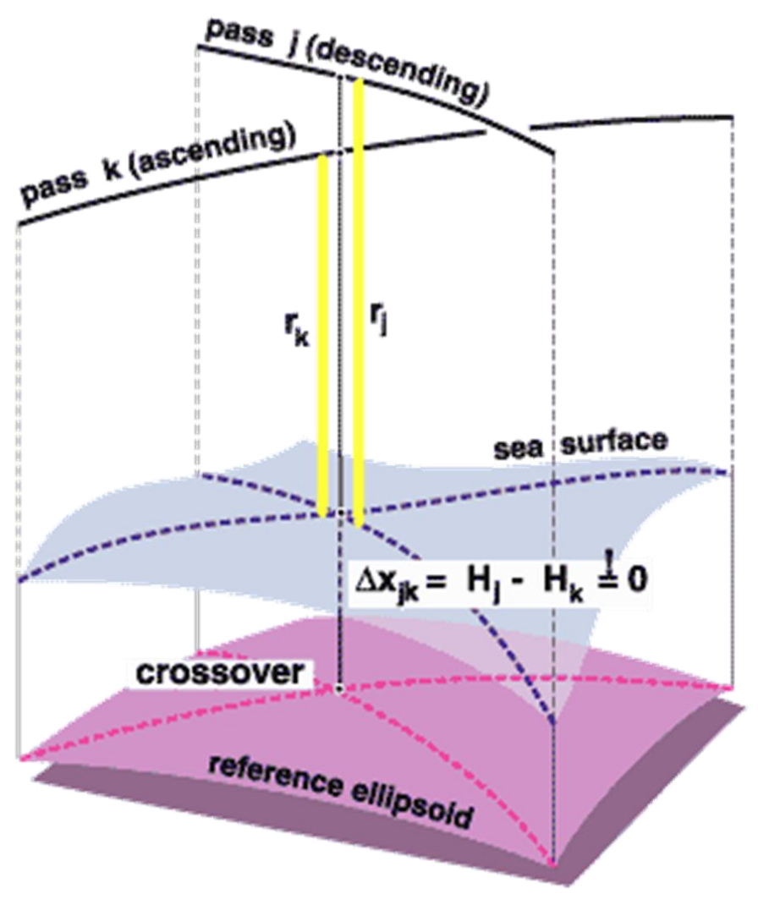

Fig. 2: Crossover differences

Main steps:

- Computation of single and dual-satellite crossover differences in all combinations
- Minimizing both $\Delta x_{jk} = x_j - x_k$ and $\delta x_i = x_{i+1} - x_i$ and estimation of radial errors x_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 Δr (per 10 day cycles)
  Mean differences in the center-of-origin realization Δx, Δy, Δz (10 day cycles)
  Global mean range bias for each mission (w.r.t. reference mission, i.e. Jason-2)

Radial Errors and its stochastic properties

In a first step only LRM over open ocean is used (for SAR and SARin see box below). The radial errors of Cryosat show an offset of -24.1 cm w.r.t. Jason-2 and a scatter of 1.3 cm (see Fig. 3a). Thus, Cryosat reaches the same quality level than other current altimeter missions (Tab.1).

	Mean radial error [cm]	# xovers
Jason-2	0.0 ± 1.1	443103
Cryosat	-24.1 ± 1.3	197127
Jason-1 EM	10.4 ± 1.6	42370
Jason-1 GM	10.9 ± 1.2	276650
Envisat EM	44.5 ± 1.2	65360

Tab.1 : Mean radial errors for all missions involved in MMXO

A frequency analysis of the time series of the radial errors of Cryosat (Fig. 3c) reveals only 3 Periods with amplitudes larger than 2 mm. The most significant period of 0.074 days represents the orbit revision period and is a first indication of slight geographically correlated errors. Smaller systematics can be seen with periods of 1 day, 0.5 days, and 30 days.

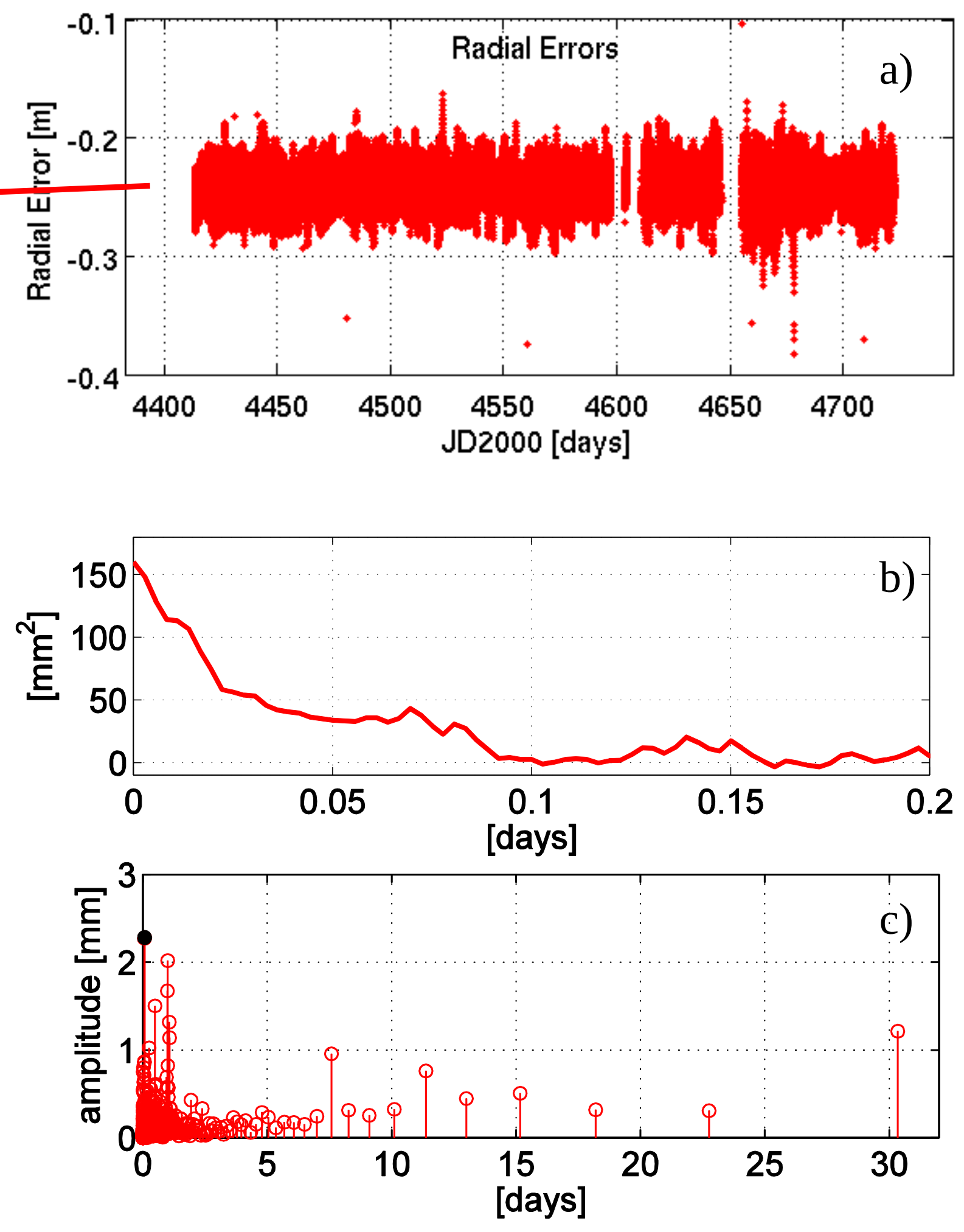

Fig. 3: Radial errors of Cryosat LRM and its stochastic properties. Plot a) radial errors, b) auto-covariance function and c) amplitude spectrum

Geographically correlated errors (GCE)

The radial errors can be used to compute GCE, i.e. error components having the same sign for ascending and descending passes. Most of these errors are due to uncertainties in the precise orbit determination (POD).

Fig. 4 shows the GCE for Cryosat (top) and Jason-2 (bottom). Both missions have large scale pattern with moderate amplitudes. Cryosat GCEs remain smaller than 2.5 cm. The RMS of ±4.0 mm is not as good as for Jason-2 but in the same order of magnitude than other missions (Jason-2: ±2.4 mm, Jason-1 GM: ±3.7 mm, Envisat EM: ±4.8 mm). Using a GDR-D standard orbit for Cryosat would probably improve these GCE.

There is no significant difference in the realization of the center-of-origin visible between Cryosat and Jason-2. The mean offsets are:

$\Delta x = -1.5 \pm 2.1$ mm
$\Delta y = -0.9 \pm 1.9$ mm
$\Delta z = 0.9 \pm 4.0$ mm

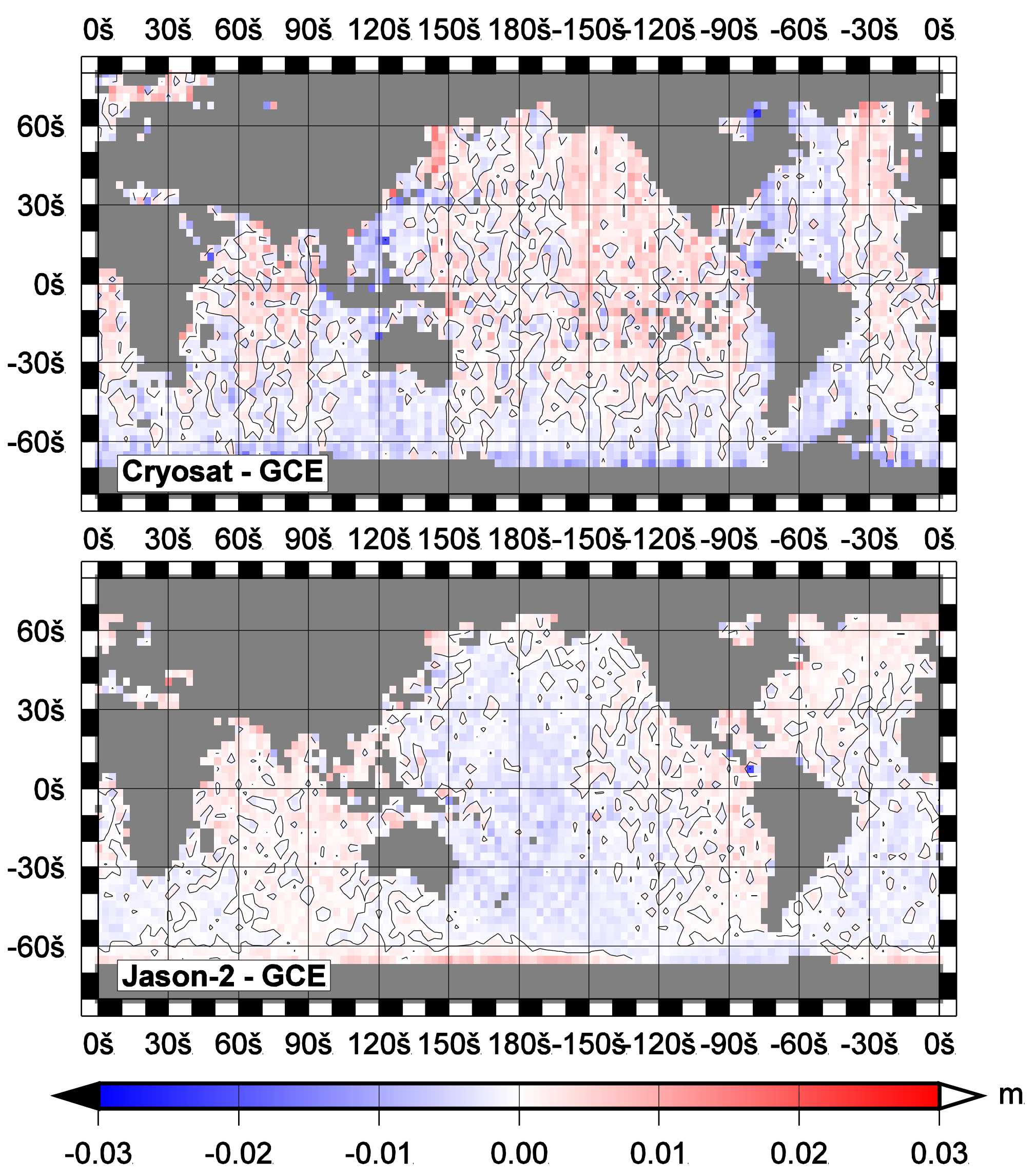

Fig.4: GCE for Cryosat (top) and Jason-2 (bottom)

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 clearly distinguishable by their different mean offsets to Jason-2. This is also visible in the range bias estimated in the MMXO:

The radial errors for SAR and SARin are larger than for LRM with a mean of 1.2 m and a scatter of 15.8 cm (only within +/- 60° latitude)

- The high scatter is partly due to a lack of valid SSB correction.
- The offset is different for SAR and SARin and changing with time.

This is not a problem of Cryosat measurements but of Level 2 preprocessing.

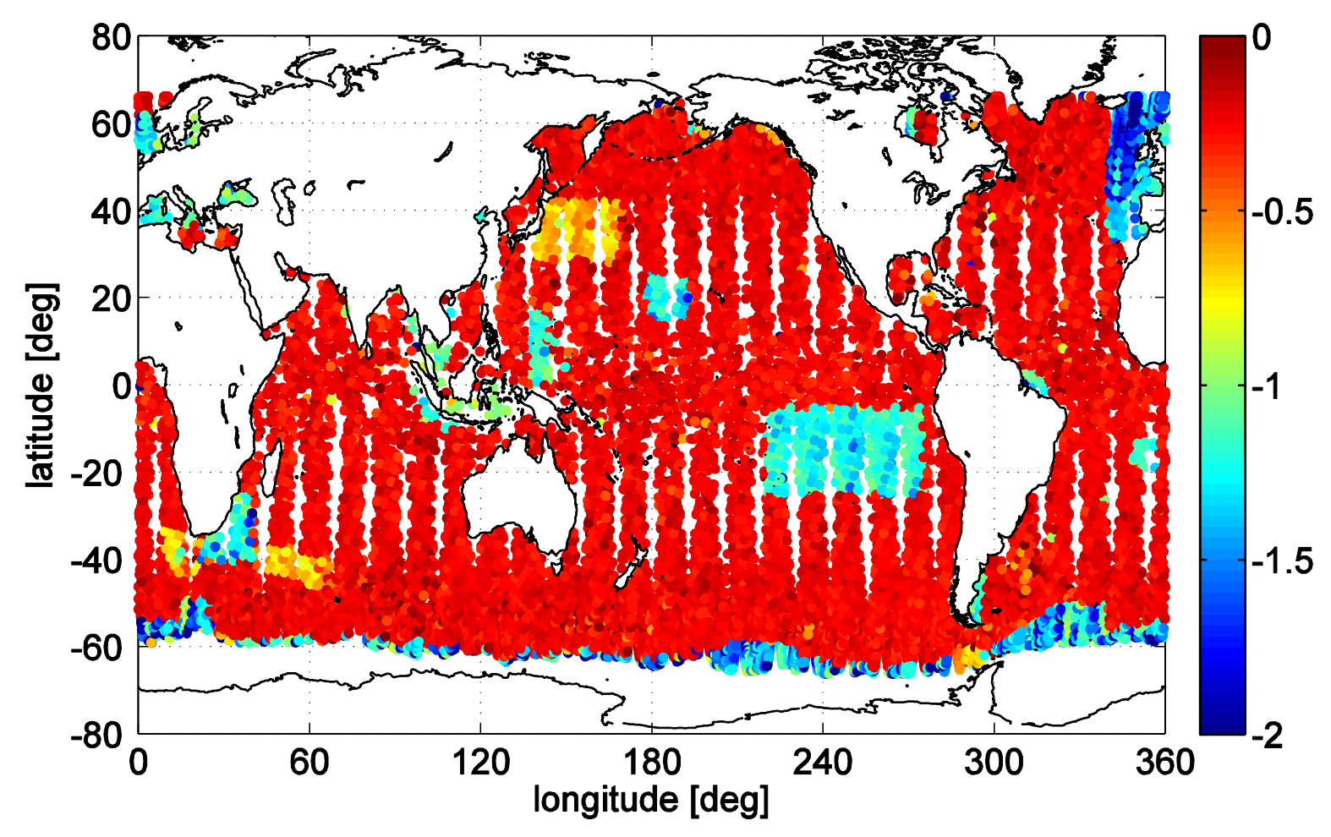

Fig. 5: Crossover differences between Cryosat Cycle 34 and Jason-2 in [m]

Conclusion

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 given 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.
- 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 measurements modes, as they show significant offsets between each other.

References:
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