CryoSat Data Processing Concept

Prepared by: Lead Investigator

•
Centre for Polar Observation & Modelling
Department of Space & Climate Physics
University College London
Pearson Building, Gower St.
London WC1E 6BT
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Change Record

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1 Purpose of this document.

The main payload of CryoSat, the synthetic aperture, interferometric radar altimeter (SIRAL), is a new sensor. It will generate radar echoes from ice with a new observation technique, geometry and resolution. Experience of earlier missions informs us that optimising the scientific data processing will depend on detailed, post-launch experience.

One objective of the CryoSat Calibration, Validation and Retrieval Announcement of Opportunity (AO) is to invite teams or individuals to:

- Support the evaluation of the baseline, pre-launch retrieval algorithms,
- Recommend improved (or even different) algorithms to be implemented in a revision of the processing chain, and a reprocessing of the entire mission data.

The purpose of this document is to provide information to groups or individuals with an interest in this activity that will aid the focussing and planning of their activity. It contains an outline of the schedule and approach to the development of:

- Pre-launch, baseline processing algorithms,
- Post-launch, baseline processing algorithms,

together with an identification of:

- New processing algorithms whose optimisation requires particular post-launch attention.

Further information concerning the CryoSat mission is contained in other documents issued as part of the AO. These can be downloaded from the CryoSat website at http://www.esa.int/livingplanet/cryosat. Of particular relevance to this document are sections 7 and 8 of the CryoSat Mission and Data Description (MDD). These provide a description with illustrations of the baseline data products.

2 Approach to the baseline data processing and its post-launch reprocessing.

Over the past two decades, a body of experience in deriving land ice elevation from pulse-limited satellite radar altimeter echoes has built-up. This expertise is now being extended to deriving sea ice thickness. This experience informs to a considerable extent the calibration and validation concept of the CryoSat mission. On the other hand, the main payload of CryoSat, the synthetic-aperture, interferometric altimeter (SIRAL) is a new sensor. It will provide radar echoes from ice surfaces with a new observation geometry and resolution. The experience of previous, pulse-limited altimeter missions is that detailed optimisation of the retrievals will require post-launch investigations of the SIRAL measurements.

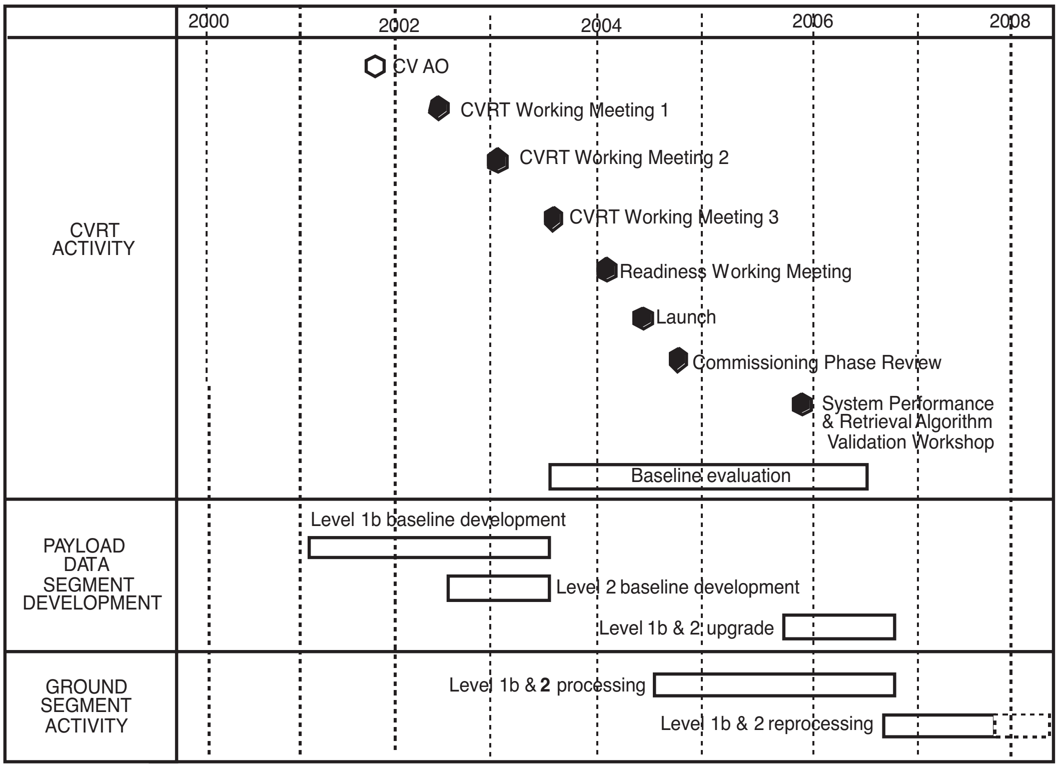

Fig. 1. The schedule of activities associated with the assessment and updating of the baseline (pre-launch) data processing algorithms. The figure shows (upper section) the schedule of the calibration, validation and retrieval team activities; the schedule of the development of the baseline algorithms and planned update activity (middle panel); and the data production by the ground segment (lower panel). The schedule shows the present mission planning; actual events are determined relative to the launch data.

This recognition has been ‘built-in’ to the ground data processing development approach for CryoSat (Fig. 1). Prior to the satellite launch, a baseline data processing chain will be implemented within the CryoSat payload data segment (PDS). The design of this processing chain will be based on simulations of the scattering of the echo from land- and sea-ice surfaces. This activity was initiated in 2000 and will be completed by mid-2003. (This apparently early completion in comparison with the launch date of mid-2004 is related to the overall satellite and system test schedule). In mid 2003, detailed descriptions of the baseline retrieval algorithms will be available. Simulated data sets will be available to Calibration, Validation and Retrieval Team (CVRT) members.

In the period of the commissioning and science phases of the mission, the performance of these prototype algorithms will be assessed. It is anticipated that this assessment could benefit from interaction with other calibration and validation activities. It is intended that one function of the CVRT is to provide a forum for such interactions. The outcome of these activities will be consolidated at the System Performance and Retrieval Algorithm Validation Workshop, presently planned for launch plus 18 months. A main purpose of this workshop will be to recommend to the Agency optimal reprocessing algorithms with which to update the prototype processor. These optimised algorithms will then form the basis for a reprocessing of the mission data.

3 New processing algorithms requiring detailed research and evaluation.

While all the algorithm components of the CryoSat data processing chain require a validation activity, the retrievals associated with the new measurements of the SIRAL instrument require particular attention. The purpose of this section is to provide an overview of the CryoSat data processing chain, and to identify particular components that fall into this 'new' category. These are the algorithms that require the particular attention within the validation of the processing chain as a whole.

The first part of this section, section 3.1, provides an overview of the elements of the CryoSat ground processing chain and the associated products. It also introduces the terminology of data 'levels' and summarises their meaning in the context of the CryoSat mission[1]. More detailed breakdowns of the low-level and *1b* processor (section 3.2) and the level *2* processor (section 3.3) follow, with an outline of the main new aspects requiring post launch evaluation.

[1] The nature of CryoSat data does not fit perfectly with the standard definitions of satellite data 'levels', which are principally designed to describe imagery.

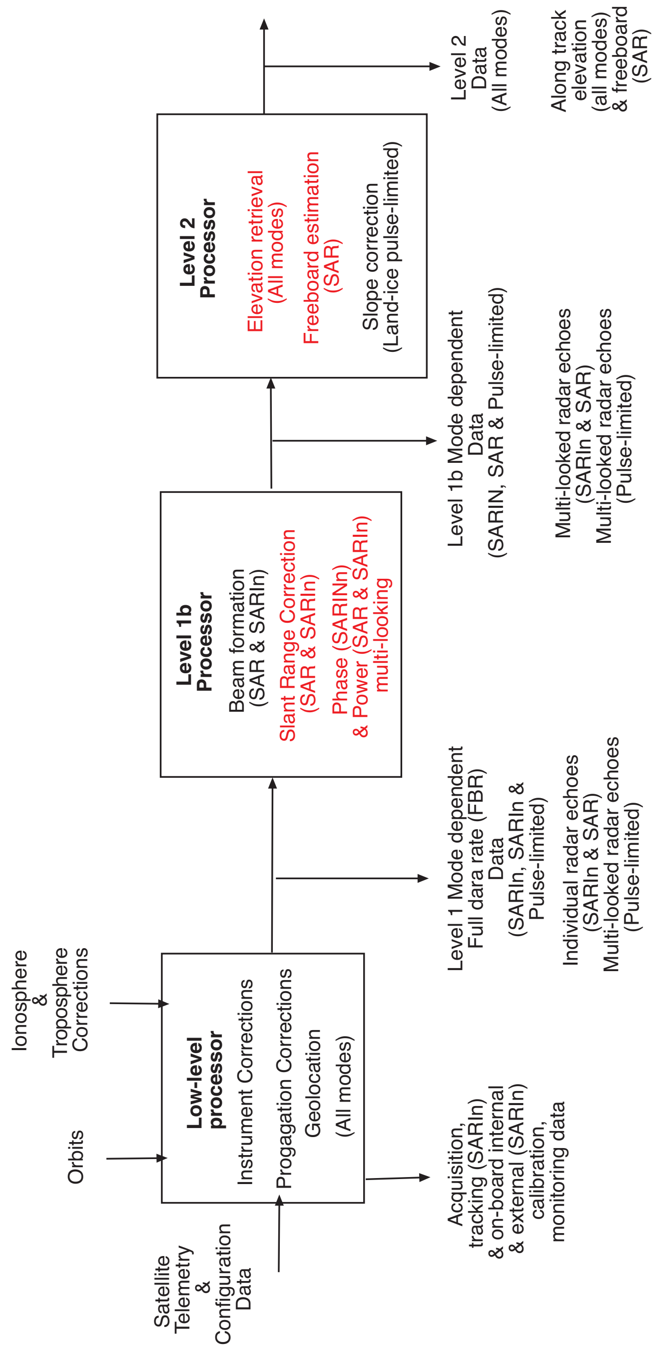

Fig. 2. The CryoSat low-level, level *1b* and level *2* processors and associated level *1* (FBR), level *1b* and level *2* data products. Shown in red are new processing algorithms whose optimisation requires research.

3.1 Low-level, level *1b* and level *2* processors and products.

A general overview of the CryoSat data processing chain and products is shown Fig. 2. There are essentially three sequential steps in the processing, each one generating one or more data products.

A 'low-level' processor is responsible for decoding the satellite telemetry, converting it to so-called 'engineering' units (Watts, seconds or counts, for example), and applying instrument corrections to the data. These corrections may be the result of pre-launch testing or of the on-board calibration measurements. On CryoSat this low-level processor will also geolocate the observations and calculate the ionosphere and atmosphere propagation corrections. The output of this stage of the processor is the so-called 'Level *1*' data. These data are also termed the 'full bit rate' (FBR) data.

For the interferometric mode (SARIn) and synthetic aperture (SAR) modes the FBR data contain the individual radar echoes ordered along-track according to their time of measurement; for the pulse-limited mode they contain the averaged (multi-looked) echoes. The FBR data are the 'highest level' data that contain the full information rate of the sensor. Products downstream of these data in the processing chain, this is no longer the case. This processor will also extract the radar tracking acquisition data, the radar tracking data in SAR and SARIn modes, and other parameters from the instrument telemetry that may be useful for instrument monitoring.

The main function for the 'level *1b*' processor is the calculation of the multi-looked echoes in the SAR & SARIn modes. This includes the pulse compression, synthetic beam formation, and power and (in SARIn mode) phase multi-looking. The output of this processing stage are multi-looked radar echoes, each one corresponding to a point on the surface, time-ordered along the satellite track. This processing stage has no action on the pulse-limited echoes – these are simply transferred from the FBR data to the level *1b* data.

The function of the 'level *2*' processor is the retrieval from the radar echoes of ice elevation and sea ice freeboard. The level *2* data consist of time-ordered along track values of these parameters in physical units (metres, for example).

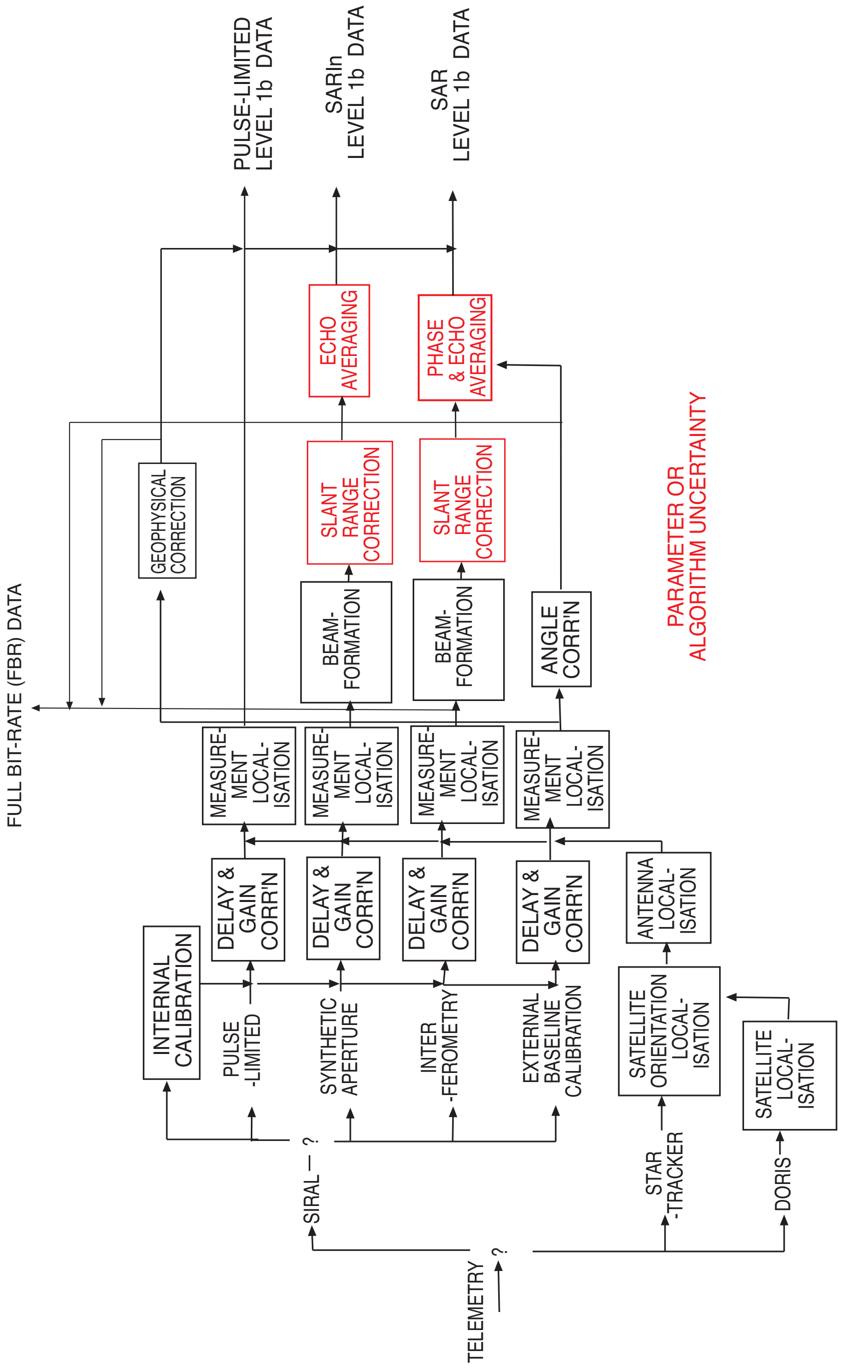

Fig. 3. The CryoSat low-level and level *1b* processors Shown in red are new processing algorithms whose optimisation requires research.

3.2 New algorithms in the low level and level *1b* processor.

A detailed breakdown of the low-level and level *1b* processor is shown in Fig. 3. The figure details in black processing steps that are well established through experience from, for example, the ERS and TOPEX/Poseidon missions. The figure also details in red those algorithms which are new and require detailed evaluation. The main aspects that require attention are the following:

• *Slant Range Correction*. This correction removes from the echo delay time the range associated with the 'slant range'. Its purpose is to align in delay time the echoes formed in each Doppler beam directed at a particular location on the ground. For a surface with known geometry (or very close to a known geometry) such as the ocean, this correction is straightforward. Over complex ice sheet topography it is not so clear what is an optimum correction to apply.

• *Echo Averaging.* In forming the multi-looked echo power (or phase), weights can be applied to each individual echo to reduce the noise in comparison with the signal in the multi-looked echo. There are many ways such weights could be derived and implemented. Secondly, synthetic aperture beam ambiguities will occur over surfaces whose gradients exceed (approximately) the real beam, half-power angle. Automated methods of identifying and tracking these ambiguities are required.

3.3 New algorithms in the level *2* processor.

A detailed breakdown of the level *2* processor is shown in Fig. 4. The figure details in black processing steps that are well established through experience from, for example, the ERS missions. The figure also details in green those algorithms which are new and require detailed evaluation. The main aspects that require attention in the cases of the land ice and sea ice are described respectively in section and section below.

3.3.1 New land ice retrievals.

Important new elements of the land ice processing are:

• *Elevation retrieval*. Elevation may be retrieved from the SARIn data in one of two ways depending on the geometry (see, for example, the simulations in the MRD). A great deal of the detail of these procedures is new. Examples are the automated determination of the geometry, and the determination through pulse-fitting of the first-arrival time and its associated phase.

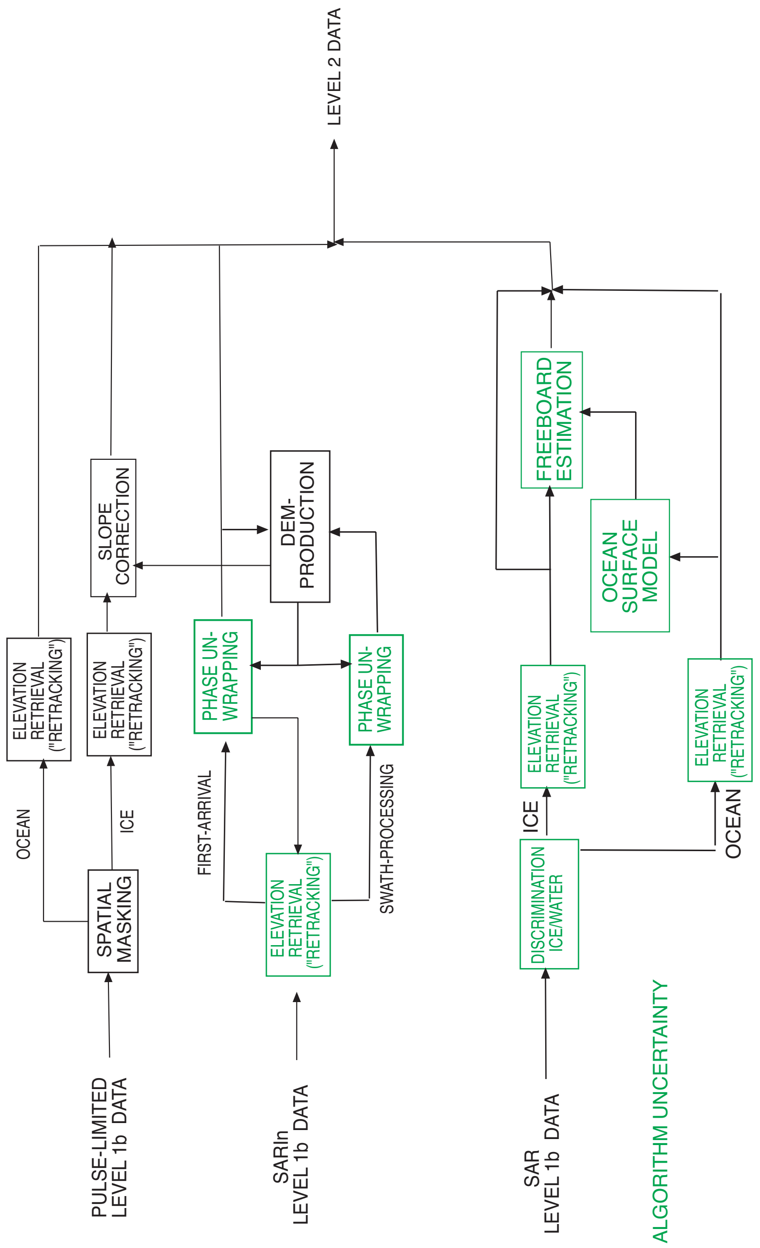

Fig. 4. The CryoSat level *2* processor. Shown in green are new processing algorithms whose optimisation requires research.

• *Phase unwrapping*. The phase measured by the SIRAL interferometer will phase-wrap if the across track direction of the echo exceeds (approximately) the real beam, half-power angle (see, for example, the simulations in the MRD). Automated detection and correction of the phase wrapping is required. This may involve the use of a digital elevation model of the ice sheets, determined from historical measurements (ERS, for example) and, with time, the CryoSat measurements themselves.

3.3.2 New sea ice retrievals.

Important new elements of the sea ice processing are:

• *Ice/water discrimination.* The discrimination of pulse-limited echoes scattered from ice and water has been done on the basis of the scattered power and the shape of the echo as a function of delay time. In the SAR mode, the shape of the echo is substantially independent of the surface, and the equivalent information is the distribution of power between the synthetic beams. This information needs to be parameterised and used as a basis of discrimination.

• *Elevation retrieval.* The retrieval of ice or water from the SAR mode echoes is essentially similar to the corresponding pulse-limited procedure. Nonetheless, in detail the echo shape as a function of delay time is quite different, and a new ‘generation’ of retrieval (‘retracker’) design is required.

•*Freeboard estimation.* The determination of the freeboard is in principle straightforward: it is simply the difference between an ice elevation and the ocean surface. However, as discussed in the CVC, the errors depend a great deal on how the ocean surface is modelled. There are many aspects requiring research concerning the generation of this modelled surface and its updating throughout the mission lifetime.