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# ESA Support to Science Element (STSE) Cryosat+: Ocean Theme

## CP40 – Cryosat Plus 4 Oceans

ESA AO/1-6827/11/I-NB

### Mid Term Review – Executive Summary

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#### SUMMARY OF MODIFICATIONS

<b>Ed.</b>	<b>Date</b>	<b>Chapter</b>	<b>Modification</b>	<b>Author/s</b>
1.0	18/03/14		Document Issue 1	SatOC

# 1 Introduction to CP4O

Cryosat Plus for Oceans is a 24-month project, initiated by ESA<sup>1</sup>, supported by CNES, which will generate and evaluate new methods and products to support applications of Cryosat-2 data over the oceans, taking advantage of the new capabilities of the SIRAL SAR/SARin mode altimeter carried by Cryosat-2.

The CP4O project recently passed its Mid-Term Review at which the progress was assessed, and the plans for the second period re-evaluated and revised as necessary. This was an appropriate stage to invite experts to review key material and provide advice and recommendations on how to take this work forward.

## 2 Project Status and Requested Expert Group Input

A Group of Experts has been constituted by invitation and comprises:

Walter Smith - NOAA, USA  
Natalia Galin - NOAA/UCL, USA/UK  
Katharine Giles – UCL, UK (in memory, invited before her tragic accident)  
Keith Raney - 2kR-LLC, USA  
Laurent Phalippou –Thales Alenia Space, France  
Rob Cullen – ESA  
Xiaoli Deng - Newcastle Univ, AUS

At the Project Mid Point, the Expert Group were asked to review available outputs from two of the CP4O Work Packages:

**Work Package 2000 – “Preliminary Analysis of the State of the Art”**

**Work Package 4000 – “Product Development and Validation”**

The guidelines provided to the Expert Team are provided as an Appendix

## 3 Expert Group Findings

We are very grateful to the members of the Expert Group for spending time to review the various CP4O documents and providing detailed comments. The detailed comments have been analysed and a response provided against each with actions identified as appropriate<sup>2</sup>. In this document we provide a summary of the major recommendations.

### 3.1 Initial General Comments

The reviewers recognized the value of this work and the relevant expertise of the team to carry out this work:

- “The CP4O Project is ambitious, timely, and important. It is abundantly clear from the results presented at this mid-term benchmark that the SAR mode of ocean-viewing radar altimetry offers numerous advantages over conventional altimetry. The investigators who have been contributing to this endeavor are to be congratulated for their respective efforts, and are encouraged to continue working towards a major contribution.”
- “The team is extremely competent to analyse the existing data and propose algorithms and products.”

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<sup>1</sup> Under the Support To Science Element (STSE) of the Envelope Programme

<sup>2</sup> A detailed response is available separately in spreadsheet format.

- “efforts of the CP40 will directly contribute to near future satellite altimetry missions such as Sentinel-3 and Jason-CS”
- "This (project) is a crucial step for the team to successfully extend the CryoSat-2 to its complete data coverage over the whole earth surface"

## 3.2 Preliminary Analysis Report

### Overall Comments

The objective of the Preliminary Analysis Report was to provide “a comprehensive review of the state-of the art, relevant current initiatives, algorithms, models and EO-based products and datasets that are relevant in the context of the investigated theme of innovative ocean applications for CryoSat-2. In particular it reports on the state-of-the-art analysis of low and high-resolution open ocean altimetry, high-resolution polar ocean and coastal zone altimetry and high-resolution sea-floor altimetry.”

The reviewers agree that this document represents the state of the art for SAR altimetry as it was on the reference date of October 2012, and comment favourably on the significance of this report. Comments included:

- “This is a major document, and promises to be a significant milestone in the history of SAR-mode radar altimetry. Congratulations to the many contributors to this work, and to the editors who have managed to create a reasonably consistent whole out of what at one time must have been an assemblage of disparate parts.”
- " one of most significant contributions of CP40 from this report lies in that it tells Cryosat-2 users the status of existing data products, as well as corrections and applications conducted by the team. For example, it indicates that “the CryoSat-2 data products currently supplied by ESA for oceanographic applications, LRM L2 and SAR L2 are not useful and that SAR L1b is sub-optimal”
- “the report also shows the CP40 team’s strong confidence based upon the exceptional performance of CryoSat-2 over oceans through their detailed analyses.”

### Key Points

Key points for improving the document include:

- An additional objective for CPO was proposed “to identify lessons learned and design recommendations relevant for future radar altimeter missions”.
- Early in the PAR an objective was stated to provide an overview on how to process the Cryosat-2 data – but this does not seem to have been addressed later in the document. Later stages of the project should pick this up.
- It is essential that quantitative measures are applied when evaluating and comparing data products produced by different processing schemes. Too often qualitative assessments are provided – especially when comparing/evaluating SAR mode waveforms generated by different approaches, in both RDSAR and SAR processing.
- References must be provided for all sources.
- For the purpose of clarity there is a need to be more precise with terminology. Signal to Noise ratio is often used loosely in discussions and has a precise technical definition in radar engineering. Also a clear differentiation between different noise sources should be made.
- The document should emphasise the importance of optimizing the selection and use of the waveforms from a SAR-mode altimeter. Processing all 64 waveforms and weighting them equally is sub-optimum. Some approaches process only the middle 32, others apply a weighting to favour the central bins.

- Weighting (e.g. Hamming) is treated rather lightly and deserves a more complete treatment, including a discussion of the purpose for applying a window and evaluation of the different options.
- The document would benefit from a separate passage which discusses the requirement for over-sampling the waveform when the backscattering surface is near specular.

The issue is that the usual gate sampling of the waveform does not capture sufficiently the key features (i.e. leading edge, peak, trailing edge) of a “peaky” waveform that is returned from a specular surface. This important point was highlighted in a number of presentations made at the SAR Altimetry Expert Group Meeting, is recognized and detail will be added into the SAR. (See <http://www.satoc.eu/projects/CP40/meetings.html> for papers from the meeting).

- A substantive discussion of tracking/retracking, including concise definitions, would be helpful.
- There is a need for improvement of the section describing the different versions of the SAMOSA models, in particular clarifying the differences between different versions of the SAMOSA SAR echo model, the purpose behind the further developments, and on the details of specific implementations.
- The section describing the different RDSAR processing schemes does not fully address the problem caused by the Cryosat-2 SAR transmission scheme, a consequence of which is that any Cryosat-2 Pseudo LRM product, based only on 1Hz of SAR mode data will necessarily perform worse than the equivalent LRM mode as it includes fewer uncorrelated returns from the ocean surface.
- Some approaches to SAR processing were described whereby the range and azimuth response are treated as independent processes. One reviewer noted that this was physically incorrect.
- The contribution of NOAA to different aspects of the SAR and RDSAR processing schemes should be properly recognized.
- The Final section title promises some recommendations, but does not provide any.

There are in addition a number of minor detailed points identified by the Expert Team which have been catalogued in a spreadsheet which has been distributed to the report’s authors and will be addressed.

## Conclusion

The project team welcomes the endorsement of the PAR as representing the “State of Art”, and as being an important document in its own right. Once the document has been updated according to reviewers’ comments, it will be published on the project web-site and publicised through links in various media, including other ESA web pages and the ESA EO Newsletter.

## 3.3 Development and Validation Plan

### Key Points

The objective of the Development and Validation Plan is to provide a description of the activities that will develop and validate products for ocean applications under the 4 sub-themes of Open Ocean, Coastal Ocean, Polar Oceanography and Sea Floor Bathymetry.

The main issues identified by the Expert Team are summarised below:

- As identified in the PAR any validation must include quantitative measures, together with a clear methodology and objectives for a successful validation

- Importance of ensuring proper basis for comparisons of different processing schemes, use same source data, identify what aspect of processing is being evaluated.
- More details are required on the processing approaches to be used.
- RDSAR / Pseudo LRM processing teams should provide quantitative measures of their respective additive noise and speckle standard deviations, comparing those to a reference LRM data set.
- Details of the configuration used in SAR retrackerers (SAMOSA and CPP) should be specified.
- A tabular summary for each product (e.g. Table 2-2) would be helpful, together with a small map to identify the area of interest.
- Concern was expressed that existing validation methods may not be appropriate for high resolution SAR data, and that new methods must be developed. The validation section of the DVP does not provide enough detail to demonstrate that appropriate validation will take place.

### **Conclusion – Further Work**

It is clear there is some detail lacking in the Development and Validation Plan. The team will discuss with ESA whether to produce a second version of this document, or whether the points can be addressed in subsequent documentation (e.g. the Algorithm Theoretical Basis Documents and the Product Validation Reports).

No major concerns were expressed about the overall plans for WP4000, in terms of the specifications of the proposed LRM, Pseudo LRM and SAR products to be developed and validated under the four project themes. Thus no requirement to significantly alter the WP4000 Work Package was identified (for instance to drop some planned activities, or add new ones).

However, following subsequent discussions with the project team, and with Keith Raney it was agreed to drop the planned Starlab task to produce “RDSAR” products

However, some important technical issues were identified that each member of project team must take into account when developing and validating new data products within this work package. In particular in detail on the processing parameters is needed and a proper basis / methodology must be adopted for comparisons of different processing schemes and validating their outputs.

ESA and members of the project team have started to address this point, by publishing a Re-tracker configuration control Technical Note together with a benchmark data set, at:

[http://www.satoc.eu/projects/samosa/samosa\\_config.html](http://www.satoc.eu/projects/samosa/samosa_config.html)

## **3.4 Summary**

### **Conclusions**

The Expert Team has confirmed that the CP40 project is timely and important, and that the project team has the appropriate level of expertise to carry out the work.

It was confirmed that the Preliminary Analysis Report accurately represents the State of the Art for SAR altimetry as it was on the reference date of October 2012, and that this is an important document in its own right. Some corrections and additions to the document are required before it can be released and promoted.

The Development and Validation Plan lacks detail in some areas. No major changes to the overall approach in this part of the project were recommended, but attention to some specific aspects was recommended.

One reviewer identified “recurring themes” to be addressed by the time of the next review:

- Quantitative requirements should be established to assess performance of various processing schemes, and to compare products from the different Cryosat modes.
- The relatively poor performance of Pseudo LRM products, compared to LRM should be addressed.
- Appropriate and consistent terminology should be employed across all project documentation. It is essential to understand and accurately assign the contribution of error from different sources.

Preliminary effort to address this issue has been made by ESA through the publication online of a SAR processing Guidelines Technical Note, at:

(<http://www.satoc.eu/projects/CP4O/data.html>)

- The use of Look Up Tables at stages of processing can be appropriate, but care should be taken that they are not used to short cut investigations into the causes of undesirable, or not understood, features.
- More thought is needed into establishing the optimum approach to processing and combining waveforms from different Doppler bins.

### **Priorities for Further Investigation**

Some priorities for further investigation were identified by the experts, if not within CP4O, then through parallel studies. The project team will discuss with ESA how best to follow up on these recommendations, listed below:

- A more detailed investigation of the range / Doppler domain is needed. This would consider how many Doppler bins to include in waveform averaging, how exactly to carry out the range correction, and whether or not to apply weighting to favour waveforms closer to nadir, is at the heart of SAR processing, but has not yet been fully investigated.
- The issue of waveform blurring in response to higher spacecraft altitude rate is important. Implications range from determining constraints on acceptable orbit parameters for future missions to effective processing strategies designed to cope with the problem.
- It has long been the case that waveforms for low wave heights are under-sampled, meaning that accurate fitting of modeled waveforms is difficult and hence the accuracy of the retrieved geophysical parameters (range, wave height, backscatter) compromised. Further investigation in how to face this problem is recommended.
- An investigation into the impact of swell on the SAR mode performance is needed.
- More work could be done with SARIN over oceans, for instance to investigate whether useful estimates of across track slope could be derived.
- An investigation into auto-covariance of FBR echoes and stacks under different sea states, and characterization of the ocean surface (e.g. stack width, kurtosis, skewness) from stack data.
- The issue of the effect of mispointing on performance in SAR mode needs further investigation. This would develop a complete understanding of the impact of mispointing on the SAR echo shape and retracker retrieval of geophysical

parameters, It was also establish how best to account for this in an operational processing scheme, including how to generate an accurate mispointing angle from the available platform information.

- It was noted that the transmission scheme for Cryosat-2 SAR mode means that any Pseudo LRM product, based only on 1Hz of data, will necessarily perform worse than the equivalent LRM mode as it includes fewer uncorrelated returns from the ocean surface. Similar statistics can only be achieved by including data from a longer period and applying averaging. Thus equivalent performance is needed for continuity, RDSAR processing schemes for Cryosat-2 SAR data need to be modified.

Many of the open points raised by experts will be addressed under a number of ESA initiatives, including through additional work that could be supported under a Contract Change Notice to CP40 (under discussion), a new Cryosat + project ( Cryosat + Glaciers), and under the ESA SEOM (Scientific Exploitation of Operational Missions) Programme

*David Cotton, SatOC:*



## Appendix – Guidelines Provided to the Expert Team

### Introduction to CP40

Cryosat Plus for Oceans is a 24-month project, initiated by ESA<sup>3</sup>, supported by CNES, which will generate and evaluate new methods and products to support applications of Cryosat-2 data over the oceans, taking advantage of the new capabilities of the SIRAL SAR/SARin mode altimeter carried by Cryosat-2.

The CP40 project is now approaching its Mid-Term Review at which the progress will be assessed, and the plans for the second period re-evaluated and revised as necessary. This is an appropriate stage to invite experts to review key material and provide advice and recommendations on how to take this work forward.

### Project Status and Requested Expert Group Input

A Group of Experts has been constituted by invitation and comprises:

Walter Smith - NOAA, USA  
Natalia Galin - NOAA/UCL, USA/UK  
Katharine Giles – UCL, UK (in memory, invited before her tragic accident)  
Keith Raney - 2kR-LLC, USA  
Laurent Phalippou –Thales Alenia Space, France  
Rob Cullen – ESA  
Xiaoli Deng -Newcastle Univ, AUS

We are asking the Expert Group to review two of the CP40 Work Packages:

#### Work Package 2000 – “Preliminary Analysis of the State of the Art”

This Work Package provides a review of the state of the art for SAR altimetry and Cryosat -2 products and an overview of plans for developing and validating new products in WP4000 of the project. WP2000 is now almost completed, pending the final compilation of some material and the provision, review and acceptance of the two deliverables, the “Preliminary Analysis Report” (D2.1), and the “Development and Validation Plan” (D2.2).

#### Work Package 4000 – “Product Development and Validation”

Within this activity the CP40 team is developing and validating test products under the following themes:

- Low Rate Mode, Open Ocean
- SAR mode and “RDSAR” mode – Open Ocean
- SAR mode – Coastal Ocean
- SARIN mode – Coastal Ocean
- SAR mode – Polar Ocean
- SAR mode – Sea Floor Topography.

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<sup>3</sup> Under the Support To Science Element (STSE) of the Envelope Programme

This work package started early in 2013 and is due to complete in November 2013. For each products, two documents will be produced: An “Algorithm and Theoretical Basis Document”, and a “Product Validation Report”. At this stage draft documents for some of the themes will be available. For some themes the work is not yet at a sufficiently mature stage for review.

*Please note that the intended approach for this Work Package is for separate organisations to develop, evaluate and iterate their own processing schemes independently. At the end of this Work Package each organisation will then produce a validation data set, produced according to some agreed specifications, which will be used as input to the next stage. These validation data sets will then be inter-compared and assessed for their capability to provide improved oceanographic measurements.*

### Material for Review

To support the review we will provide the complete deliverables for WP2000: D2.1 and D2.2, and draft deliverables for selected activities within WP4000. In addition some of the presentations in the SAR Altimetry Expert Workshop will include results from this work.

Table 1 lists the WP2000 and WP4000 activities and deliverables. We will only be asking for a review for which draft documents are available, marked with an ‘X’. Where there will be a relevant presentation in the SAR Altimetry Expert Workshop, this is indicated in the last column.

These presentations will be made available for download in pdf format at:

<http://www.satoc.eu/projects/CP4O/MidTermReview.html>

*Table 1 CP40 deliverables / reports to be reviewed by the Expert Group*

Activity	Who	Documents to be Reviewed		Relevant Presentation at MTR
		Preliminary Analysis Review	Development & Validation Plan	
<b>WP2000</b>				
Preliminary Analysis of the State of the Art	TU Delft	X	X	
<b>WP4000 – Product Development and Validation</b>		<b>Draft ATBD</b>	<b>Draft PVR</b>	
LRM for Open Ocean (RADS)	TU Delft			Naeije
SAR for Open Ocean / SAMOSA retracker	Starlab/NOC			Gommenginger et al.
SAR for Open Ocean / CLS, CNES re-tracker	CLS	X	X	Moreau
RDSAR for Open Ocean CNES/CLS SAR reduction algorithm	CLS	X	X	Moreau
SAR for Coastal Ocean	NOC			Gommenginger et al.
SAR for Sea Floor Mapping	DTU Space			Andersen
SAR for Polar Ocean	DTU Space			Andersen & Stenseng

SARIN for Coastal Ocean	isardSAT			Garcia
Wet tropo Corrections	U Porto	X (provided as a single document)		Fernandes
Ionospheric Corrections	Noveltis	X	X	Cancel
Regional Tides	Noveltis	X	X	Cancel
Other Geophys corrections	TU Delft			Naeije

### Requested Expert Group Input

We are requesting an expert scientific review on the approach taken, and for recommendations on how best to take the work in CP4O forward. We are not asking the experts to contribute to the formal process of accepting or rejecting the deliverables. To support these aims we suggest that the experts could consider the following questions:

#### WP2000

- Does the “Preliminary Analysis Report” (D2.1) provide a complete analysis of the state of the art for SAR altimetry as it was on the reference date of October 2012?
- Are there any clear gaps or inaccuracies?
- Does the Development and Validation Plan (D2.2) provide a clear definition of the products to be developed and the approach to be taken?

#### WP4000

For each of the activities / products listed in the table above

- Is the theoretical basis sound?
- Is the source data set and processing approach sensible?
- Is the time period and geographical extent of the demonstration data set appropriate?
- Are the validation technique and data sets suitable?

#### General Questions

- Do you have any changes to suggest in the products being developed and the validation approach being applied (bearing in mind finite resources of project)?
- Are there any potentially important products / applications not being covered?

Please note that we will welcome any expressions of interest in collaborating more closely with the project, for example in confronting output data and discussions on theoretical and empirical approaches.

*David Cotton, SatOC:*

*Jérôme Benveniste, ESRIN:*

*CP4O Project Manager*

*ESA Scientific Officer for CP4O*