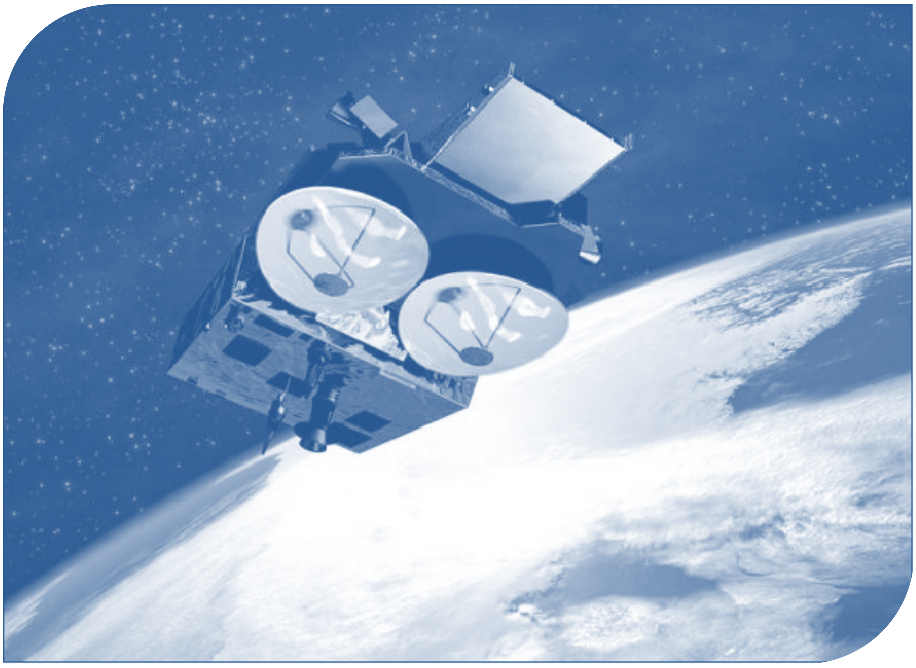
# 7TH CRYOSAT QUALITY WORKING GROUP FINAL REPORT



*This report has been compiled thanks to the inputs from IDEAS+ QC Team (Erica Webb, Ben Wright) and QWG#7 participants*

# MEETING HIGHLIGHTS AND CONCLUSION

- The 7th CryoSat Quality Working Group (QWG#7) was held in ESA ESRIN from Monday 26th November (afternoon) to Friday 28th November 2018 (morning).
- The QWG#7 was structured around 7 main sessions and involved 43 participants from different operational and research institutes including both CryoSat Expert Support Laboratory, QC and Val/Val teams, altimetry experts and multi-thematic scientists.
- The QWG#7 topics addressed both the data quality aspect of operational ice and ocean L1/L2 products, the results from Cal/Val Campaigns as well as the evolutions of core PDGS products and strategic implementation of future Cryo-TEMPO.
- The current operational CryoSat Ocean Processor (COP Baseline-C) status is nominal except minor issues mainly arisen from the migration to the NetCDF format:
    - Beside the new format migration, Ocean Baseline-C brings important improvements with respect to ocean Baseline-B, including the addition of Full Ocean SAR processing and the upgrade of key geophysical corrections.
    - Mode-dependent SSH biases have been however observed during the meeting and are under investigation.
    - In-depth analysis confirmed that baseline C NOP are performing well and can adequately replace the FDM after a 6-month overlap. It was agreed that FDM would be discontinued on **1st July 2019**.
- The current operational Ice processor (ice Baseline-C) status is nominal. The ice Baseline-D processor development is its final stage and will include a significant number of fixes and science algorithm evolutions with respect to the ice Baseline-C.
    - Beside the switch to netCDF format, QC checks of the 6-month Baseline-D TDS (pre-acceptance version vN1.0) and QWG presentations show significant quantitative and qualitative improvements with respect to Baseline-C.
    - Over the land ice the SARIn elevations show a slight improvement (roll angle issue fixed), whilst LRM is similar. The new surface type mask and slope model around Antarctica also shows better results.
    - Over the sea-ice SARIn freeboard is now computed whereas the SAR freeboard computation has been refined (less noisy and no more overestimated).
    - Over the ocean and inland water bodies: Baseline-D also shows welcome improvements. Baseline-D SAR data shows a large increase in the number of valid observations over inland water. Moreover, several presentations confirmed that the large biases previously observed over inland water have been removed.
- Based on the very positive Quality Control and Validation (QCV) of ice Baseline D TDS over multiple surfaces, the QWG **fully endorsed the implementation of the CryoSat Baseline-D into operations** (end of April 2019 after minor refinements).
- Main QCV Baseline D results will be part of a Community CryoSat QWG article.

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## REFERENCED DOCUMENTS

All the CryoSat QWG#7 presentations are available at:

**https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/cryosat/news/-/article/7th-cryosat-quality-working-group-meeting-presentations-now-online**


[RD1] Jerome Bouffard/Marco Meloni, Workshop introduction and logistics (CryoSat_QWG#7-Logistic-Info-V2)

[RD2] Tommaso Parrinello, CryoSat Mission Status (CryoSat QWG November 2018_Parrinello)

[RD3] Isabelle Dauvin, CryoSat Space Segment and Operations status summary (QWG#7-ESOC presentation)

[RD4] Stefano Badessi, CryoSat PDGS Status (Cryosat_QWG#7_PDGSv0.1)

[RD5] Sebastian Simonsen, CryoVEx, plans for 2019 and lesson learned from previous campaign (CryoVEx_CS2_QWG_SimonsenNov_2018)

[RD6] Jerome Bouffard, CryoSat Data Quality Status (Session1-CryoSat-QWG#7-Quality-BOUFFARD-V2)

[RD7] Erica Webb/Ben Wright, CryoSat Data quality control overview (IDEAS+ Operational Product Status_0.3)

[RD8] Michele Scagliola, SIRAL Calibration monitoring + Interferometer End-to-End calibration (SIRAL_CAL_20181126)

[RD9] Albert Garcia-Modejar, Transponder Calibration Results (isardSAT_CR2_TRP_results_20181127.pdf)

[RD10] Francesco Carriero, CryoSat Baseline-D Content and Status (QWG_ACS_Carriero.pptx)

[RD11] Erica Webb/Ben Wright, CryoSat Baseline-D TDS verification (IDEAS+ Ice Baseline-D TDS Verification_0.2.pdf)

[RD12] Luca Maestri, CryoSat L1b Baseline-D changes and assessment (Aresys_CS_IPF1_BaselineD_QWG_Frascati_V1_Maestri.pptx)

[RD13] David Brockley, L2 algorithm changes in Baseline-D and impact on Ice measurements (CS2_QWG_Nov18_BasD_L2_status.pdf)

[RD14] Marco Meloni, Cryosat L2 Baseline-D Quality assessment (QWG_Presentation-v1.pptx)

[RD15] Veit Helm, Comparison of Baseline C and D L1B and L2 products over ice sheets (ppt_helm_qwg_2018.pdf)

[RD16] Sebastian Simonsen, Validation of CryoSat-2 SARIn Data over Austfonna Ice Cap - a first look at Baseline- D (Austfonna_CS2_QWG_SimonsenNov_2018.pptx)

[RD17] Geoffrey Dawson, Baseline D SARIn swath data over Antarctica (CS2_DLS_swath.pptx)

[RD18] Stefan, Hendricks, Level-1b baseline-d data in the AWI sea ice processing chain (CS2QWG7-20181127-Hendricks.pptx)

[RD19] Sara Fleury, Sea Ice Thickness with baseline D (QWG_BASELINE_D.LEGOS.Fleury.20181127.pptx)

[RD20] Alessandro Di Bella, Improving phase difference in CS SARIn mode: impact on sea ice freeboard (QWG7-DiBella.pdf)

[RD21] Jean Tournadre, SARin swath data over icebergs (small and large) (CS2QWG7_tournadre.pdf)

[RD22] Sanggyun Lee, Comparison of the lead detection algorithm between Baseline C and D (CS2_meeting_2018_lee.pptx)

[RD23] Florent Garnier, Snow Depth with Baseline-C GOP PLRM (CS@QWG7-garnier.pdf)

[RD24] Michel Tsamados, CryoSat snow and sea ice thickness along track and gridded: lessons learned from Arctic+ and future directions (MichelTalk.pdf)

[RD25] Robert Ricker, Airborne evaluation of dual-band frequency satellite radar altimetry measurements over Arctic sea ice (rricker_QWG_CSN_Frascati_Nov2018.pdf)

[RD26] Karina Nielsen, level-1b and level 2 baseline-D evaluation for inland water (lakeKarina.pdf)

[RD27] Nicolas Bercher, Comparison of Baseline C and Baseline D L2 products for hydrology (2018-11-28_nbercher_CryoSat-2_QWG6_Baseline_D.pdf)

[RD28] Matthias Raynal, Assessment of the Cryosat-2 L2 products (baseline C) over ocean (QWG_C2_CalValOcean_BaselineC.pptx)

[RD29] Saleh Abdalla, Assessment of CryoSat-2 NRT Wind and Wave Data (Abdalla_CS_QWG_7_ESRIN_20181126-28.pptx)
[RD30] Chris Banks, Baseline C for CryoSat-2 Geophysical Ocean Products: some preliminary observations (noc_c2qwg_nov2018.pdf)

# CONTEXT AND MEETING SCOPE

The 7th CryoSat Quality Working Group (QWG#7) meeting was held from 26th to 28th November 2018 and hosted by the European Space Agency (ESA) at ESRIN in Frascati (Rome), Italy.

CryoSat QWG and validation experts attended the meeting to present and discuss their latest results about the CryoSat Ocean Processor Baseline-C and Ice Baseline-D Test Data Sets over the ice sheet and ice caps, Sea-Ice and Inland areas.

The 7th CryoSat Quality Working Group was structured around 7 main sessions (see detailed agenda in **Annex 3**):

- Session 01: Mission overview;
- Session 02: Operational Products QC & Calibration;
- Session 03: Introduction to Baseline-D;
- Session 04: CryoSat Data Quality over Land-Ice;
- Session 05: CryoSat Data Quality over Sea-Ice;
- Session 06: CryoSat Data Quality over ocean and inland water;
- Session 07: Summary and Recommendations.

Moreover, large time slots were dedicated to discussions and brainstorming.

**The scope of this document, is to summarize the main points discussed during the workshop and compile key user recommendations and feedbacks, which should be translated into future CryoSat-2 products and scientific activities.**

# 1. SESSION 1: MISSION OVERVIEW

**Jerome Bouffard (ESA)** first briefly introduced the 7th CryoSat QWG Meeting [RD1], which mainly focuses on the quality assessment of the Baseline-D Ice Test Data Set covering three different time periods (Sep-Nov 2013, Feb-Apr 2014 and April 2016 (only SARIn)) and made available to the QWG members several months prior the meeting. Aside from Baseline-D topics, the workshop also include discussion of the CryoSat mission status, the upcoming reprocessing campaigns and the future CryoSat Thematic Products.

**Tommaso Parrinello (ESA)** then presented the CryoSat mission status and the roadmap to the mission extension for 2020-2021 [RD2]. Review and evaluation of the mission started in October at the ACEO Meeting. New objectives were defined for the 2020 – 2021 extension, including swath processing, polar oceanography, operations and forecasts, long term records, cryosphere meteorology, Antarctic sea ice, River and lakes. In terms of the space segment, CryoSat is performing well. Battery EOL will be reached after 2025. The satellite has been consuming same amount of energy since launch. Temperature of the satellite is increasing, and is now approximately 4°C higher, which could be a sign of degradation, but is still within specification. The ground segment has evolved since the start of the mission but is functioning well with no major issues. The next evolution will be the thematic products. Overall, mission performance at the end of 2018 was close to 99%, well above the design specification. There are no technical limitations to continue the mission exploitation until the end of 2021. In terms of future science objectives, a number of new projects are planned to support the mission extension assessment criteria and new objectives. The new CryoSat thematic products will complement the existing products but will focus on particular issues and be aimed at thematic EO users. CryoSat user uptake, which is tracked through papers, citations, user registration etc. has increased by 700% since launch. CryoSat is contributing to 17 of the 25 living planet challenges. A recent study explores the attitude control of CryoSat for magnetic field studies. CryoSat CalVal campaigns have continued and now total 18 from 2002 – 2018. The MOSAIC campaign will take place 2019 – 2020 – an Arctic Drift expedition supported by international institutions. Now that ICESat-2 is in operation, CryoSat – ICESat-2 collaboration is anticipated. CryoSat altitude could be raised by a few hundred meters to match that of IceSat2, thereby increasing the number of coincident measurements Overall, CryoSat is in excellent shape and there are no technically limiting factors or programmatic constraints that would restrict the proposed 2-year extension. It has been discussed the reason of the 4 degrees in satellite temperature which is however due to the degradation of the satellite and it is within specification.

**Isabelle Dauvin (ESA)** presented a summary of the CryoSat Space Segment and Operations since the last QWG#6 [RD3]. Overall, the spacecraft is in good health, except for the PCDU DMS interface A which was switched off in 2013. There is about 30kg of fuel left, and all instruments are performing nominally. In 2016 an upgrade was implemented to the star tracker (STR) software to improve the attitude performance. Previously, the star tracker was losing attitude during high solar activity and the South Atlantic Anomaly (SAA). CCD annealing procedures are now performed periodically on all STR. There has been an observed improvement in overall performance and pointing rate since the 2016 SW patch. The maximum temperature of STR operation has improved and is now about 10°C higher than before. The update has also relaxed the limitations associated with the SSA. A number of special on-request SIRAL operations have been performed including roll manoeuvres for calibration, and the avoidance of manoeuvres during the CryoVex/ Karen campaign (Dec 2017 - Jan 2018). Unexpected anomalies were encountered on 02/06/2017 and 01/08/2018 when the SIRAL instrument entered Alarm mode. To avoid this issue in future an avoidance zone has been defined over Afghanistan. In June 2018 there was a small upset in the SIRAL power cycle. During the reporting period there were only two collision avoidance manoeuvres; the drastic reduction in number of warnings received since 2016 is due to the implementation of a new process purely based on probability risk. The number of orbit control manoeuvres has reduced due to a reduction in solar activity. Overall SIRAL instrument availability has remained high, with less than 30 hours lost per year since 2015. Routine spacecraft maintenance activities have been performed on the STR, battery and MMFU. The RCS subsystem remains under close monitoring. Since 2016 a slight increase in fuel consumption suggests a possible small leak. However, fuel consumption is still within specification and recovery actions are in place should leakage increase. In December 2017, the MMFU experienced a loss of storage capability. Recovery activities were executed and storage capabilities restored. Since August 2018, several MMFU events lead to small data gaps (< 10 packets). Recovery actions are in place should the situation degrade further, including a possible switch to MMFU-B. Airbus are in touch with the manufacturer to understand the root cause. Overall, a joint Airbus/ ESOC assessment of CryoSat health concluded that the satellite will be able to go through next extension without any major concern.

**Stefano Badessi (ESA)** presented a summary of the CryoSat PDGS, data availability and production completeness since the last QWG#6 [RD4]. An update on the Ocean Baseline-C reprocessing was also given. The number of products now generated for CryoSat is exceeding the original design of the PDGS. As a result, they have recently changed databases and how the system works, in order to improve PDGS performance and accommodate future baselines and updates. There are now an increased number of processing modes and cores, giving a higher processing power. 2015 experienced a high number of upset events, however these have now decreased drastically. Order processing errors have increased significantly with the introduction of NOP, IOP and GOP. These are expected to reduce with the installation of the next COP version. The Horus tool is used to perform detailed PDGS monitoring. Statistics from the last 6 months: generation 99.85 %, archiving 99.44 %, dissemination 99.73%. At the end of the year, anything missing is re-disseminated. The Ocean Baseline-C reprocessing campaign is starting at CNES to reprocess all GOP to Baseline-C. CNES will reprocess 1 month of data in 2 days, and the first 6 months of data are expected to be delivered just before Christmas. Data to be delivered in batches of 6 months. Upcoming activities include the Baseline-D TTO in Q2 2019, and the Ice Baseline-D reprocessing under DSI contract. PDGS will also undergo an operating system CentOS migration, and will take care to ensure no changes are introduced in computational results. The future CryoSat thematic products will be disseminated via PDGS. Finally, use of a second ground station, the Inuvik station, is proposed to give 100% coverage and allow near real time delivery for all orbits. Currently only 10 orbits are visible from Kiruna and 4 orbits are stored during the blind orbits.

**Sebastian Simonsen (DTU Space)** presented an overview of the ESA CryoVEx campaigns, results from recent campaigns and planned activities for 2019 [RD5]. The CryoVEx campaign aims to validate satellite altimeter missions and quantify sources of error over land and sea ice. A series of airborne radar, laser and in-situ campaigns are undertaken, using a variety of instruments and techniques. New instruments are also tested to support potential future satellite missions. Recent campaigns were undertaken in the Arctic in 2016 and 2017, and in the Antarctic in 2017/2018. In 2016 the KAREN instrument, a Ka-band altimeter, was added alongside the proven ASIRAS (Ku-band) system. The two instruments were used together to understand the snow condition and provide crucial information for CryoSat CalVal efforts. Campaigns also coordinate with operation Ice Bridge and CryoSat over flies. Planned future campaigns are reported in the presentation.

**Jerome Bouffard (ESA)** presented a review of data quality status after 8 years of operations and future planned updates [RD6]. This was followed by a review of the actions and recommendations from the CryoSat Science Expert Meeting (November 2017). CryoSat ice data quality is largely exceeding mission requirements, and is contributing to a wide range of applications, even civilian applications. Instrument and data quality status is nominal; some known data quality issues will be resolved at Baseline-D. Internal and external calibrations are nominal. The upcoming Ice Baseline-D will implement significant improvements, including improved signal to noise ratio, freeboard computation over SARIn, and the switch to NetCDF. It is expected that FDM processing will be discontinued following the implementation of NOP. The Baseline-D formal acceptance will take placed in December 2018, and reprocessing is planned for Q1 2019. CryoSat ocean data uptake is increasing, demonstrating its suitability for a range of ocean applications. In general, ocean product quality agrees with or even exceeds reference ocean missions. Since November 2017, COP Baseline-C allows full capability over the ocean as well as reduced noise through full SAR processing. Also included are a new tide model and a new wet tropospheric correction. Full mission reprocessing starting soon. The next steps are to further improve data quality, improve multi-mission harmonisation and implement new CryoSat Thematic products (CRYO-TEMPO). Currently the ESA PDGS cannot fulfil all the needs of the thematic end user. Existing L2 products cannot be aligned quickly enough with recent R&D outcomes and the implementation of new processing baselines is limited to every ~3 years. Therefore there is a need for new thematic products, ESA stamped products with traceable Quality Indicators (QI). Starting from the existing CryoSat L1B product, these thematic products will be developed and generated by coordinated groups of scientific experts. They will be generated outside the CryoSat PDGS but distributed via the PDGS. The proposed thematic products and suggested contents are:

1. Sea Ice CRYO-TEMPO – radar freeboard; sea ice concentration, snow depths and documented uncertainties.
2. Polar Sea CRYO-TEMPO – polar Absolute Dynamic Topography (ADT), polar Mean Dynamic Topography (MDT) and documented uncertainties.
3. Land Ice CRYO-TEMPO – swath elevation, POCA elevation, external DEM, and documented uncertainties.

4. Hydro CRYO-TEMPO – targeting specific rivers and lakes. Surface height, geoid model, and documented uncertainties.

The previous CryoSat Scientific Expert Meeting (CSEM) held in November 2017 aimed to provide recommendations for the improvement of CryoSat data products and from these define a roadmap for key CryoSat developments. Jerome Bouffard presented the output recommendations from this meeting and the current status of actions one year later (see presentation slides: Session1-CryoSat-QWG#7-Quality-BOUFFARD-V2). The complete list of recommendations and actions is reported in ANNEX 1.

In conclusion, CryoSat is exceeding the initial mission requirements. CryoSat data are used for wide range of multi-disciplinary applications beyond the original scope of the mission. The next step is to develop new CEOS QA4EO compliant CryoSat thematic products to be used by non-experts. It has been discussed if the retracking algorithms will be provided open source but ESA don't plan to make available full algorithms but will provide more information about how the data are processed.

# 2. SESSION 2: OPERATIONAL PRODUCTS QC AND CALIBRATION

**Erica Webb (Telespazio)** presented the IDEAS+ QC team's data quality results from the last 12 months, covering data production completeness, and the quality of the operational Ice and Ocean products [RD7]. IDEAS+ continue to check data availability and confirm that all data is generated as expected. Over the last 12 months SIRAL data availability has been good with only 8 unplanned unavailability periods, and L0 data availability has remained above 99.5% throughout. Operational production completeness for the Ice processors remains very high with the total Offline and FDM completeness >99%. The Ocean processors have slightly lower overall production completeness largely due to a higher number of processing failures. NOP production experiences the highest number of processing failures, which should be addressed before FDM production is discontinued. IDEAS+ continued to perform routine daily QC on all CryoSat Ice and Ocean products. The current operational Ice and Ocean processors are both Baseline-C. The current quality status of the Ice processor is nominal, and there are only a small number of open issues, most of which will be resolved in the upcoming Baseline-D or will be irrelevant when FDM production is discontinued. The current operational ocean processor has a number of open issues, many of which have arisen from the migration to the new NetCDF and will be resolved in the next processor update. Currently the HDR files and global attributes section of the data files are incomplete preventing visibility of which auxiliary files have been used in processing. This and a number of other minor quality issues affecting the metadata will be resolved in the updated COP release (COP-IPF1v3.7 & IPF2v3.9). Quality issues affecting the science data will be postponed until a later COP update. COP-IPF1v3.7 & IPF2v3.9 has already been delivered, installed and tested at the reprocessing centre (CNES) and the PDS Reference Platform. The Ocean Baseline-C reprocessing campaign has just started and will reprocess all GOP data from the whole mission using this COP version.

**Michele Scagliola (Aresys)** presented the updated results from Aresys' SIRAL calibration monitoring and interferometer end-to-end calibration, as well as results from recent analysis of the antenna bench bending [RD8]. The CAL1 and CAL2 SAR corrections have remained stable over the past 12 months. The complex Cal1 corrections are largely stable with some variation as a function of the different phase corrections. The CAL4 phase difference correction shows the SIRAL dependence on temperature. Analysis of data acquired during the CryoSat roll campaigns is used to perform end-to-end interferometer calibration. The roll bias is decreasing at an approximately constant rate; at Baseline-D different roll biases will be applied in order to achieve the best performance of CryoSat. However, the end-to-end performance of the interferometer in terms of accuracy and precision is stable and within the mission requirements. Aresys have observed a possible bending of the antenna bench. The rigid bench is expected to undergo convex/ concave flexing when subject to a thermal gradient, and for this reason the antenna feeds are decoupled from the antenna bench. However, the star trackers are coupled with the antenna bench, and therefore antenna bench bending can affect the roll measured by the star trackers. However, this measured roll does not correspond to the real direction of the interferometer antenna.

STR1 and STR3 are on the same side of the bench, whilst STR2 is on the other side. The difference in roll measured from two star trackers on opposites sides of the bench is expected to the nearly zero. If the difference is greater than zero, this is due to antenna bench bending. Assuming the bending is symmetrical, and roll is only originating from the bending, the roll difference is equal to half the roll difference. Converting this to height gives 0.17mm (68% probability), or 1.25mm (99.7% probability). Further analysis is needed to fully understand the observations before any decisions are made to apply corrections to the roll.

**Albert Garcia Modejar (isardSAT)** presented an update of transponder calibration activities and results since 2016, based on the processing of transponder data from Svalbard and Crete [RD9]. The Svalbard transponder experienced two anomalies in early 2017 and late 2017 (20 and 6 passes were lost respectively). Range bias results from Svalbard show good agreement between SAR and SARIn (~4.1 cm), whilst for LRM this is lower (0.8 cm). Overall the range bias trend is small and the instrument is not drifting. By comparison, results from Crete show an average range bias of - 9 cm (a 13 cm bias difference and 4 cm noisier than Svalbard). In terms of datation, there is very good agreement between the Svalbard and Crete results. LRM presents a 2 millisecond bias, which is under investigation, possibly related to some Doppler correction which is currently not properly addressed. They need to check the datation equation in the IPF is correct. The SARIn interferometric phase accuracy and precision depend on star tracker being used to get the roll. The across-track results translated into a bias of 90 m of precision, 50 m of accuracy in the location computed. This bias could again be attributed to the bending of the antenna bench. The star trackers, developed by Airbus, have a single point of attachment which could be enhancing the bending; the use of two contact points would reduce the bending. Upcoming activities include a reprocessing activity for Baseline-D, error budget analysis to identify sources and understand them, a study of plate motion around transponder locations, generation of PLRM from SAR and SARIn and Pseudo-SAR from SARIn, and use of roll measurements from all star trackers available. More investigation about residual discrepancy between Svalbard and Crete ground segments is needed including the assessment if additional corrections are needed to account for the distance.

# 3. SESSION 3: INTRODUCTION TO BASELINE-D

**Teresa Geminale (ACS)** presented the current status of the Ice IPF development, and the expected changes and improvements which have been implemented in Baseline-D with respect to the current operational Baseline-C [RD10]. The Baseline-D pre-acceptance was held in July 2018, and since this ACS have been working to prepare the final delivery of the software. This final delivery will take into account additional new requests and fix additional minor issues identified during the analysis of the 6-month test data set generated with the pre-acceptance Baseline-D (see slides for full list of implemented changes). Regarding the Ocean processor, the current operational COP implemented the switch to netCDF. There are a number or minor open issues with this version, most of which are resolved in the latest COP IPF1v3.7 & COP IPF2v3.9. A few outstanding anomalies will be considered for fixing in a future COP update. In particular, CRYO-COP-33 reports a problem affecting NOP production. Occasionally NOP processing orders are failing when the systematic gaps in DOR_NAV coverage cannot be handled by the CFI. Further investigation is required.

**Erica Webb (Telesapzio)** presented the IDEAS+ QC results of the 6-month TDS generated with the new Ice Baseline-D processors at the miniPDS for testing and validation activities [RD11]. IDEAS+ performed QC of a 10-day sample of data to assess data quality and check for major anomalies. In summary, whilst data quality was good, a number of minor issues were identified. Many of these can be attributed to small mistakes and inconsistencies introduced to the products and documentation during the switch to netCDF. These include the mismatch of values between the HDR and netCDF files, and unexpected changes to the configuration of particular flags. Most of these will be resolved in the final Baseline-D release. IDEAS+ also performed a detailed review of the new Baseline-D product format specification documents and provided feedback to ACS on how these can be improved to make the documents more user friendly. It has been discussed why the HDR files are needed if the header information is already contained in the NetCDF data file. The HDR files have been maintained for heritage, and a number of ESA tools need these files to be present, for example for archiving. The HDR files also provide a way for users to check products before downloading them, and provides a good way to check products are consistent. It has been also discussed why there are a different number of products in the Baseline-C and Baseline-D data sets (e.g. for April 2014). This could be due to problems in the processing, since the Baseline-D dataset was generated at the MiniPDS, instead of the PDS.

**Luca Maestri (Aresys)** presented the main changes and improvements that have been implemented by Aresys into the new Baseline-D IPFs, in particular the STR processor and the SAR/ SARIn IPF1 [RD12]. Also, the results of product verification tests were presented. The Baseline-D Star Tracker processor (vN1.0) was delivered in October 2017, and implements a number of changes relative to the previous version (see slides for full list of implemented changes). In particular, the aberration correction flag was reversed in the Baseline-D configuration and different roll, pitch and yaw biases have been included for the different star tracker IDs. In order to assess the quality of the mispointing angles in the

STR_ATTREF, a test dataset was generated and made available online. 2 independent expert users provide validation of this STR_ATTREF dataset using swath processing. Whilst Baseline-C showed a positive roll bias, this is no longer visible in the new dataset, and the measurements are correctly centred on zero. The updated Baseline-D SAR/SARIn IPF1 (vN1.0) was delivered in May 2018, and implements a number of changes to fix anomalies and improve the products (see slides for full list of implemented changes). As requested by users the USO correction has now applied to the window delay directly by the IPF1. In Baseline-C the application was done by the users themselves. In Baseline-C there was an inconsistency between the L1B 20 Hz and 1 Hz heights; the 1 Hz waveform was lower than the 20 Hz waveform by about 5 m. It was confirmed that the 1 Hz waveforms are not correct since the satellite altitude and window delay do not refer to the same timestamp. The satellite altitude is taken from the centre of the 1 second averaging window, whilst the window delay is taken as the minimum. To realign the new values the window delay is now also taken from the middle of the window. After the change the heights are consistent to within 1 m. At Baseline-D new SAR/SARIn stack peakiness parameters have been added to the L1B products. These are useful to improve sea ice discrimination. Also the SARIn power scaling issue has now been resolved at Baseline-D; previously the power waveform was biased by a wrong scaling factor of 2. At Baseline-C, freeboard artefacts were observed at the boundaries of the SARIn patch when off-nadir range correction (ONC) information is used from the SARIn data. This issue only occurred at the beginning of the acquisition and is because the internal phase correction from the CAL4 packets is not being applied to the first 20 FBR samples. The solution was to change the ingestion algorithm to find the first CAL4 product and apply the same correction to the first 20 samples as the second 20 samples. Following the resolution of these issues, the Baseline-D L1B waveforms were verified to check for non-regression. No regression was observed in the L1B 20 Hz waveforms. Any differences observed in the L1B SAR 1 Hz waveform are expected due to the improvements made at Baseline-D. The observed changes in mispointing angles are expected due to updated star tracker processing. It has been discussed what happens to processing of the 1 Hz echoes when there are less than 20 Hz records. The 1 Hz records are not an average of the 20 Hz records; they are computed directly from the burst. If there are less that 20 Hz records, the 1 Hz is not computed.

**Steve Baker (UCL/MSSL)** presented a summary of the changes implemented at Baseline-D with respect to Baseline-C, the impacts these changes have on the L2 results, and some suggestions of possible future improvements [RD13]. During their analysis, MSSL compared data from the 6-month Baseline-D test data set against operational Baseline-C products. The Baseline-D data set covered most of arctic winter season 2013/2014 and was generated with the pre-acceptance Baseline-D release. Baseline-D implements improvements to the SAR mode diffuse waveform retracker, which works for surfaces discriminated as unknown, so that fewer echoes will be rejected over inland water. The use of stack peakiness as a discrimination input helps to reject bad leads. Baseline-D also sees the activation of sea ice processing in SARIn mode, and the introduction of new slope models for Antarctica and Greenland in LRM (see slides for full list of implemented change). The MSSL QA has been updated for Baseline-D products, netCDF and a section has been added for sea ice parameters in SARIn mode. All cycles of the TDS have been updated.Analysis of the Baseline-D SARIn data for land ice shows a large decrease in crossover RMS over Greenland and Antarctica, compared to Baseline-C (from 0.9m down to 0.5m). There is only a small change in retracker corrections, and geocorrection changes are zero over land ice. These results give a good indication that the Baseline-D changes have not had negative impact in the waveform shape. Differences in the SARIn height measurements by up to +/-2 m can be attributed to the impact of phase and mispointing changes on the across-track correction of height. However these height changes are still small in the context of ice-sheet margin height variations. The 60 m bias in height over inland lakes observed in some products at Baseline-C, has now been corrected in Baseline-D. Looking at Baseline-D LRM data over land ice, the crossover results are mixed, and there is no clear improvement from the slope model change. The new slope model showed improvement directly against IceBridge data but over the interior it gives less improvement than expected. Comparisons with the Helm 2014 DEM show some improvements and some questions (the same DEM was used to create the slope model). The standard deviation is slightly improved for Antarctica, but slightly worse for Greenland. Since the Baseline-D ocean results show clear improvements, this points to the slope model rather than changes at L1B. It would be interesting to hear what other QWG members found. Improvement over the previous model was only expected to be small, so we could revert back to that if agreed with QWG. Land ice results will improve with other changes at Baseline-D. In terms of Baseline-D sea ice results, the activation of freeboard computation in SARIn has enabled the gaps in coastlines and the Wingham box to be filled. As expected, SARIn data show more noise. The previously observed "overdetection" of leads reported in Baseline-C data has been addressed by additional filtering based on stack peakiness. However, this overdetection was originally detected by comparison with lower resolution instruments and therefore overdetection might actually be the real picture. We need to be careful to separate these issues. Interpolated SSHA results are improved in Baseline-D SAR with respect to Baseline-C, and the Baseline-D SARIn now fills the previous gaps in SAR. An interpolation edge effect is present in both SAR and SARIn. To remove this would require splicing data together prior to processing. RMS error in most cases is reduced. Where higher this is probably due to infrequent leads in the dataset, where the ice is thicker. Freeboard results in Baseline-C seemed to be overestimated. At Baseline-D a bias correction was applied, and the improved discrimination and interpolated SSHA means that the distribution of results is tighter, scattering has been reduced and the tails have reduced. Freeboard retrieval characteristics in the SARIn box are equal to SAR areas nearby, however there is a slight edge effect at the mode boundaries.

**Marco Meloni (Serco c/o ESA)** presented results of analysis of the Baseline-D TDS and comparison with the Baseline-C products [RD14]. The Baseline-D Ice processors will hopefully be operational in spring 2019. Ocean results: Comparison of polar SSHA for SAR showed a mean difference of 0.05 m with respect to Baseline-C. This could be due to the MSS or retracking. Overall there is less variability in both polar plots. In the Arctic, the unusual pattern observed previously in September 2013 has now been removed in Baseline-D. In the Antarctic, high values at the edge of the sea ice have been removed in Baseline-D. Comparing the SSHA interpolation with height reveals a low variability particularly for the Antarctic. In general, smooth transitions are observed in SSHA, lead heights and freeboard over SAR/ SARIn boundaries. Sea ice results: The issue with peakiness values in Baseline-C SAR has now been resolved in Baseline-D. Peakiness values in SARIn are nominal, and the percentages of sea ice leads and floes are as expected. SAR mean freeboard values are lower in Baseline-D which meets the requirement. There is also less variability in both the Arctic and Antarctic. At Baseline-C there were 3 bumps in the waveform, whereas at Baseline-D there are only 2 bumps. It would be useful to analyse the Arctic and Antarctic separately. Differences between years could be due to sea ice thickness. SARn freeboard results from the Wingham box show less noise in Baseline-D than both the Arctic and Antarctic at Baseline-C. More discussion is needed to understand the noise and homogeneity. Perhaps the use of gridded data was not suitable for this spectral analysis. Land ice results: Analysis of height measurements over Antarctica showed good agreement with the DEM. Measurements over Greenland show very strange differences, of 10's of meters. Looking at the mask of continental ice, the LRM mask is similar between baselines, but in SARIn the mask is quite different for northern latitudes. Comparing common points, Antarctic and Arctic points are comparable and the differences are very small. LRM/SAR mode transitions over continental ice seem to be smooth. In summary, the Baseline-D quality is overall good. It has been discussed if phase information has been used in SARIn computation of sea ice but it has just been treated the same as SAR. It has been discussed a possible gap in data coverage in the Arctic north of Russia – the data is present in Baseline-C but missing in Baseline-D. This has been investigated and probably was an issue in the miniPDS production with respect to PDS.

# 4. SESSION 4: CRYOSAT DATA QUALITY OVER LAND ICE

**Veit Helm (AWI)** presented results of a comparison study between the Baseline-C and Baseline-D products over ice sheets [RD15]. Random tracks were compared between Baseline-C and Baseline-D to check important parameters.
Overall netcdf is easy to handle and Baseline-D shows good improvements with respect to Baseline-C. The surface type mask used at Baseline-D looks much better than the one used at Baseline-C. LRM retracker 1 results show a small but constant offset in sigma 0. LRM retracker 2 results show a 2 cm difference in range and also shows a constant offset in sigma 0. LRM ocean retracker also shows a small but constant offset in sigma 0. The offset in LRM height (st. dev difference 0.5 m) could be attributed to slope model change. However, the expected offset of using the new slope new would be 30 cm. Further investigation into a more suitable DEM/ slope model is needed. Swath processed results over the Ausfonna ice cap were compared to the TandemX DEM, and conformed that the Baseline-C issue in the east of the ice cap has now been resolved. Baseline-D swath processing results have a good centred normal distribution. Over Antarctica, the strange behaviour in Baseline-C has been resolved in Baseline-D. The previous difference between ascending and descending tracks is much better in Baseline-D. Crossover analysis revealed more bad data in Baseline-D, and some strange artefacts. This could be due to the incorrect application of flags for removing bad data. It has been discussed if the CryoSat DEM could be used as a slope model, but the latter is different from the DEM and it is not trivial to generate. It has been also asked if the results presented have been verified separately for each star tracker and if there is a bias between star trackers. The star tracker ATTREF is used in L1B products so you can't tell which star tracker was used. This information is not considered important for the average L1B user. In any case there is usually only one star tracker to choose from at any one time, due to platform constraints. The one selected on board is does not always give the best results in terms of biases. A static bias is applied to each star tracker. It has been discussed if plate motion could have an effect on the phase. 8.8mm/ year drift in elevation but this would be too small to influence phase.

**Sebastian Simonsen (DTU Space)** presented validation results of the CryoSat Baseline-D SARIn data over the Austfonna Ice Cap in Svalbard [RD16]. Validation was performed using CryoVex campaign data from 2003, 2011, 2012, 2014, 2016, 2017, where possible coincident with CryoSat orbits. The Austfonna ice cap is covered by SARIn mode and therefore echoes are received from the POCA, the highest point of the ice sheet, rather than the nadir. This can cause a relocation of up to 12 km off nadir due to the topography. By applying another retracker they can achieve a better estimate of the position on the ground. It is not only important to compare absolute height differences but also point of each on surface. Using 2016 CryoVex data they compared the results from 6 different retrackers. The most notable differences were at the far edge of the study area, where the ESA retracker points to echoes off ground track that others don't point to. Common nadir points were compared. In the highly crevassed zone, you would expect CryoSat, which only measures POCA, to show differences with the airborne lasers which measure at nadir and into the crevasses. See recently published paper for full results (Sorensen et al. 2018). As it has been observed by MSSL a 2 m offset between Baseline-C and Baseline-D, it has been asked if this has been observed also in this analysis. It has been shown a slight movement of the median by 20 cm, but has not observed the 2 m offset. The 2 m offset was observed at the edge of Greenland and Antarctica (only one track) and is likely to be the result of different pointing angles, different corrections for POCA and could depend on slope.

**Geoffrey Dawson (University of Bristol)** presented results of Baseline-D SARIn swath data over Antarctica [RD17]. Swath processing relies on an accurate measure of the roll of satellite, to avoid introducing height errors. A 0.006° error in roll would lead to a 73 m across track offset in geolocated return. This corresponds to a 1.3 m error in height for a 1° slope. At Baseline-C the roll values were incorrect due to an error in the star tracker data. Using a constant roll correction significantly improved results. The re-processed roll supplied for Baseline-C and the values in Baseline-D should be even better. The Baseline-C data showed a big difference between star tracker 1 and star tracker 3 roll values, possibly due to the antenna bench bending. Baseline-D and Baseline-C data (Feb – Apr 2014) were compared over the Siple Dome: point to point comparison using the closest swath data point from a different satellite pass (average distance between points is 19 m). Baseline-D results show a large improvement compared to the original Baseline-C results, and a slight improvement compared to the Baseline-C with reprocessed roll data.
In summary, Baseline-D data is easier to use, is performing well and new star tracker data leads to improved swath data.

# 5. SESSION 5: CRYOSAT DATA QUALITY OVER SEA ICE

**Stefan Hendriks (AWI)** presented results of recent activities to validate the L1B Baseline-D data using the AWI sea ice processing chain and to verify the consistency of sea ice parameters between Baseline-C and Baseline-D [RD18]. CryoSat data was processed using the AWI algorithm v2.1 (introduced in Autumn 2018). This version uses a merged Warren Climatology over the Arctic Ocean, and IUP Bremen AMSR2 over the remaining area. Other changes include the addition of a region flag and update of the MSS to DTU18.
Ice thickness results (April 2014) show very little difference between Baseline-C and Baseline-D. There is some scatter over the SARIn box and at margins of the sea ice. For all months studied, the difference in mean Arctic sea ice thickness is in the order of mm for LRM and SAR; SARIn differences are slightly greater. They observed a difference in the number of waveforms between the Baseline-C and Baseline-D data sets. There is a noticeable gap in Baseline-D data to the north of Svalbard (Kara/ Barents/ Greenland Sea), where fewer waveforms are available compared to Baseline-C (particularly in April 2014). A curved feature is persistent for all the months. This need to be checked.
In summary Baseline-D data generally shows good consistency with Baseline-C. The new file format is a good change, is faster and needs less coding.

**Sara Fleury (LEGOS)** presented results from the comparison of sea ice freeboard data in the Baseline-D L2 GDR, the Baseline-C L2 GDR, and freeboard data computed by LEGOS from both Baselines [RD19]. LEGOS freeboard values were computed from L1B data, using a 20km grid. In ESA Baseline-C there was a problem with the freeboard and values were about 12 cm too high. Compared to IceBridge, the LEGOS solution was much closer. The mean difference in ESA freeboard between Baseline-D and Baseline-C is about 10 cm. The mean difference in LEGO freeboard between Baseline-D and Baseline-C is zero. Different patterns in Arcric and Antarctic need to be investigated further. In general, the Baseline-D data is less noisy. The mean difference between ESA Baseline-D and LEGOS Baseline-D is 3 cm. Full in situ validation is needed. LEGOS is not yet able to compute freeboard for SARIn data; work ongoing.

**Alessandro Di Bella (DTU Space)** presented the results of recent activities to improve the phase difference In Baseline-D, and the benefits this can bring for the determination of sea ice freeboard in SARin [RD20]. SARIn has the potential to improve the determination of sea ice measurements. Most waveforms retrieved over sea ice have a combination of diffuse and peaky returns, due to the mix of sea ice and leads. The Off Nadir Correction (ONC) can be used to correct for the range overestimation caused by the strong reflection from off-nadir leads. To do this the L1B SAR/ SARIn waveforms are classified, retracked, and the height and SHA are computed. The ONC from the phase is applied to the SSA before computing the freeboard. The phase difference is used to correct the freeboard but doesn't change the average scatter off track but reduces the uncertainty. Analysis of results revealed a problem with the processing of SARIn Baseline-C data when the phase information was combined. They performed analysis of the SARIn and found a discontinuity in the stack phase difference between the $19^{th}$ and $20^{th}$ burst. It was discovered that the CAL4 packet is not applied to the first 19 bursts. Aresys developed a solution to this problem and a patch to apply the CAL4 to the first 19 bursts. This patch has been included in the upcoming Baseline-D release. When the Baseline-C SARIn is patched with CAL4 it no longer shows problems/ discontinuities.

Overall the percentage of negative freeboard values is reduced in Baseline-D. At L2 the surface height and backscatter measurements are comparable. The patch developed to fix this issue will benefit the sea ice community and other users of small areas of SARIn, e.g. inland lakes.

**Jean Tournadre (Ifremer)** presented the results of recent activities to use SARIn swath processing for the study of icebergs [RD21]. Iceberg detection from SAR imagery can be quite difficult. Using altimetry, icebergs can be detected in the noise part of the altimeter waveform, by the appearance of a small peak of energy before the main sea surface (the iceberg acts like a transponder). A detection algorithm has been developed to detect a parabolic signal in the waveform. This only works in open water. The parabolic signal in LRM reduces to a bright spot in SAR, which can be used to detect even very small icebergs. The area of the iceberg can be estimated from the backscatter. SARIn can be used to estimate the area and freeboard of an iceberg. The phase difference can be used to compute the off nadir angle, which can be used to determine the elevation of the iceberg. SARIn also allows detection of icebergs in areas of sea ice, however the noise level is significantly higher. They currently experience a problem with the sea ice edge, which creates spurious effects. They tracked the A68 iceberg from July 2017 to January 2018 using S1 images. There is a high density of CryoSat tracks over the iceberg which allows high resolution of freeboard elevation to be derived. Using 100 CryoSat passes they performed swath processing over iceberg. Some crevasses show up much clearer in the CryoSat backscatter than in optical MODIS data. Swatch processing can achieve up to 2 0m across track resolution. In conclusion, swath processing is the perfect tool to analyse icebergs but a robust procedure is needed. Swatch processing can produce very high-resolution elevation data for small and large icebergs, which is important for following the evolution of icebergs. It has been discussed how quickly icebergs can be detected and if it can be performed in near real time, and if it could be easily added to standard processing. The limiting factor is the availability of data; the processing is very fast. CLS are already providing this in their service. In addition, there has been a 4% increase in icebergs around Greenland in last 10 years. Iceberg melting introduces iron to ocean which is essential for primary production, therefore, it is important to study iceberg distribution.

**Sanggyun Lee (UCL)** presented results of a study comparing the lead classification between Baseline-C and Baseline-D data [RD22]. The lead classification algorithm is related to shape of waveform. There are only very minor differences between Baseline-C and Baseline-D waveforms. A spectral mixture algorithm often used in hyperspectral analysis was applied to the CryoSat waveform of CS2 to give a waveform mixture algorithm. Lead and ice fractions were used to identify leads and ice, and thresholds were calibrated. Same results were observed between Baseline-C and Baseline-D. Baseline-C and Baseline-D products have subtle differences in geolocation information. Not sure how many products this affects. As a result, the waveforms have different shapes which causes them to be classified differently. Baseline-D products may have been processed with slightly different orbit files, resulting in slightly different time information and slightly different waveforms. The shift appears to be constant. This is possibly with the JO generation arising from the different environment (Baseline-D test products were generated at MiniPDS). ESA to reprocess products and provide them for comparison.

**Florent Garnier (LEGOS)** presented results from a recent study comparing snow depth observations from Ka-band SARAL and Ku-band CryoSat [RD23]. Snow depth measurements are important for sea ice calculations, and uncertainty can be responsible for 30-100% of the error in sea ice thickness estimates. Generally snow depth is poorly known. Sea ice thickness calculations currently use the Warren-99 climatology model which is constricted with in situ data from 1957-1990. The penetration difference between Ka-band frequency (SARAL) and Ku-band frequency (CryoSat) can be used to estimate snow depth. To do this we need to take into account the different footprint sizes of CryoSat LRM, SAR and SARIn. To calculate snow depth requires equivalent size footprints. Arctic satellite observations from 2013 – 2017 were used to generate snow depth maps. These have been validated with in situ data from operation IceBridge. The correlation between altimeter snow depth is better than using the Warren model. Similarly snow depth maps were generated for the Antarctic; but currently only October has been processed. There is a lack of in situ data for Antarctica for validation. In situ measurements from the ASPect campaign (1980 -2004) may not be representative as boats probably didn't go where the ice was thick. A SAR/SARIn PLRM product is essential to compare snow depth from Ka/Ku-band retrieval method. Initial testing has been performed using PLRM from the CryoSat Baseline-C GOP. Work is ongoing. SARIn mode seems to increase coastal snow depth representation. This needs to be validated.

**Michel Tsamados (UCL)** presented results of the ARCTIC+ Snow and ARCTIC+ Ice studies [RD24]. Snow is a very important parameter in models and is the largest source of uncertainty for radar sea ice thickness retrievals. Ku-band radar doesn't penetrate right to snow-ice interface and depending on the snow thickness sometimes there is no penetration at all. There are also biases due to the topography of the sea ice, snow ice thickness, snagging effects, salinity effects etc. LASER has a smaller footprint but doesn't penetrate the snow and the same biases are present. Similar biases are present for KAREN, ASIRAS, ATM. Two satellites are used together to determine dual-altimeter snow thickness (DuST). For example, Envisat vs ICESat (2003-2009), CryoSat vs Altika (2010-2018). This method appears to underestimate the snow and sea ice thickness. Snow on drifting sea ice (SNODSI) data appears to overestimate snow and sea ice thickness. The new snow products were used in NEMO/LIM and CICE models, and the results show differences of up to 1500km$^3$ after the initialisation in Feb/March 2014. They compared the gridded and along-track thickness products from different groups, and saw a consistent spread between different products, and consistent interannual variations. There is more spread over the first year ice and mixed (first year ice and multi-year ice).

**Robert Ricker (AWI)** presented results of recent activities to validate dual-band satellite radar altimetry measurements over the Arctic with collocated airborne datasets [RD25].
3 validation datasets were used (CryoVEx/ Ka-band, PAMARCIMP-2017, and operation IceBridge). On the 24th March 2017 they had collocated ice data measurements from KAREN, ASIRAS, operation IceBridge, and AWI. Along track processing of surface height was performed by selecting leads manually or by amplitude (ASIRAS/KAREN). SSH between leads is estimated by interpolation between leads. ASIRAS, KAREN (using the same thresholds) and ALS waveforms were compared over different ice types. Whilst laser scanners represent the surface of the snow, for radar scanners this is still open to debate and depends on surface type. Over a thick snow layer on multi-year ice KAREN freeboard exceeds ASIRAS by 19 cm. It is assumed that KAREN represents close to the surface of the

snow, whilst ASRIAS represents the ice surface. Over a thin snow layer on first year ice, KAREN and ASIRAS are similar. The difference between KAREN and ASRIAS freeboard does not seem to represent the full snow depth (~ 28 cm). The Analysis of the CryoSat/ Altika snow depth (LEGOS) products correlates well with operation IceBridge snow depth over first year ice but seems to underestimate high snow depths (>30 cm).
Future recommendation is to performed further investigation of KAREN and ASIRAS waveform characteristics.

# 6. SESSION 6: CRYOSAT DATA QUALITY OVER OCEAN AND INLAND WATER

**Karina Nielsen (DTU)** presented results of recent activities to evaluate along-track water levels from the Baseline-D products over study areas in Sweden and the Tibetan Plateau, where there are a large concentration of lakes [RD26]. The study of small lakes is challenging due to the inhomogeneity of the surface within the footprint and the high risk of signal contamination from land. The study used Baseline-C and Baseline-D SAR data from September to November 2013, and also compared this with DTU solutions. For the Sweden study area, from Baseline-C to Baseline-D the standard deviation of water levels was significantly reduced. DTU processing with Baseline-D data also showed a reduction. Overall Baseline-D SAR shows a higher percentage of good measurements and looks very promising. For the Tibetan plateau study area L2 SARIn data was used. Many of the lakes have outliers several hundred meters off. From Baseline-C to Baseline-D there is a small reduction in standard deviation. In terms of the percentage of good observations, the change is less noticeable. Ascending and descending tracks over Namco lake were used to map missing geoid signal around the late. The topography around the lake is so steep that it takes the altimeter a while to adjust to the water surface.

**Nicolas Bercher (Along-Track)** presented validation results of the SAR Baseline-D products for hydrological applications. Comparisons were also made with data from previous Baselines [RD27]. CryoSat is valuable mission for studying rivers, offering both SAR and SARIn modes. CryoSat has a long repeat period, therefore new approaches have been developed to derive time series over river water levels. SARIn measurement density is so high over rivers and can be used to derive accurate river profiles. This study looked at SAR over the Amazon. Baseline-D SAR measurements (Feb 2014) were compared to previous studies with Jason-2, SARAL an in situ water measurements. CryoSat data compares well to the in situ water level measurements. CryoSat L2 Baseline-C data showed a large number of outliers and a ghost profile 20 m below the water elevation. At Baseline-C each mode has it's own bias, which was too complex to work with. Instead a systematic bias was applied to some of the points. In Baseline-D, the outliers are mostly removed and the profile is much improved. It has been asked if hydrologists prefer SAR or SARIn mode over rivers and lakes. This depends on the user. SARIn appears to be performing a bit better than SAR over rivers. In 2012 a section of the mask over the Amazon was switched to SAR for testing and comparison with SARIn. We need to accelerate the update of SAR mode for hydrology. S3 has SAR over rivers. For lake users, generally SAR is better. However, in areas of high topography, SARIn is better. The range window is larger in SARIn but it has 4 times more noise. It has been discussed what would be an ideal new mission for hydrologist. The ideal new mission would operate the SAR mode we have now but with interferometric capabilities and the window size we have now in SAR. Receiving from 2 antennas you can have interferometry but without the noise from SAR. Open loop tracking allows you to look directly at a target. Unfortunately, there is no hydrology mission planned for ESA/ Europe except SWATH. Despite this, the UN Sustainable Development Goal #6 is to ensure freshwater for everyone on the planet by 2030. The hydrology community need to demonstrate that fully focused SAR is better for rivers. It would give far more measurements and requires a lot of CPU. Fully focused measurements are pretty noisy and would need to be smoothed.

**Matthias Raynal (CLS)** presented results from a data quality assessment of the Baseline-C Ocean products, available in operations since November 2017 [RD28]. The main evolutions introduced to the Baseline-C Ocean products were the addition of SAR processing, and pseudo-SARIn processing. LRM and PLRM were not supposed to change between Baseline-B and Baseline-C, however there is a ~400 us time tag bias in LRM, and ~200 us in PLRM. This could have arisen from the correction of the COR2 computation. CMEMS raised questions about a 2 cm bias between LRM and PLRM around the pacific SAR box. CryoSat and Jason SLA biases are consistent. A bias of 1.5 /2 cm is observed between LRM and PLRM data, but they can't say whether it is temporal or geographical. This could be dependent on track orientation if pseudo time tag biases are not applied, or SWH. In terms of SAR data the proposed improvements are observed in the Baseline-C products. SAR range noise is lower than for LRM and pLRM, which is unexpected due to the longer range window. Comparing PLRM and SAR reveals different patterns on ascending and descending tracks. There is a slight dependency with respect to SWH and with respect to radial velocity. There is a good transition over SAR pacific box, and no significant bias observed. However, differences are observed between ascending and descending passes ~ 5-10 cm magnitude, which could be due to the effect of SWH or radial velocity. In conclusion, the Ocean Baseline-C brings important improvements with respect to Baseline-B including the addition of SAR processing and the upgrade of some geophysical corrections, which leads to improved spatial and temporal resolutions. Upgrade of the MSS model improves he observation of small-scale geodetic structures.

**Salah Abdallah (ECMWF)** presented results of a study to compare wind and wave parameters from L2 FDM and L2 NOP (LRM, SAR, SARIn), and ultimately assess whether NOP a good replacement for FDM [RD29]. The parameters chosen for analysis were windspeed, backscatter and significant wave height. Parameters from the products were also validated against the ECMWF model, in-situ measurements and measurements from other altimeters. L2 NOPM and FDM wind speed: NOPM shows small underestimates in with respect to the ECMWF model, and more outliers than usual. FDM has slightly more data points, but the correlation is slightly worse, and instead FDM overestimates compared to the model. Overall the correlation is better in NOPM. NOPM compared to buoy measurements again shows a slight underestimation. Comparing global plots of NOPM wind speed and ECMWF model wind speed reveals only very small differences. The high differences around the southern ocean are probably model problems. L2 NOPM and FDM SWH: NOPM shows very good correlation with ECMWF model. FDM shows a higher bias and a higher standard deviation difference. Overall NOPM is an improvement compared to FDM. Comparison with buoy measurements shows the same results. L2 NOPR wind speed: Compared to the model NOPR shows a few issues: a small patch of data with very different values, some bias compared to NOPM and a slightly lower correlation. A negative bias dominates almost everywhere except for a few positive patches. L2 NOPR SWH: Compared to the model NOPR shows a slight overestimation, however the correlation is largely good. This is confirmed by in situ measurements. The global plots show some differences over the Southern Ocean, but these are likely to be model problems. Again, there are high differences in standard deviation over the Southern Ocean L2 NOPN wind speed: Compared to the model NOPN slightly underestimates at low values, and overestimates at high values. The buoy measurements show a similar picture. L2 NOPN SWH: NOPN overestimates everywhere and there is a non-linear behaviour between NOPN and the model, which is not as good as expected. The overestimation increases with wave height. Buoys give the same picture but less pronounced. Comparing CryoSat wind speeds against other altimeter: NOPM and NOPR are close, but FDM and NOPN are too high. There is a noticeable change in NOPN in March and mid-June 2018. Regarding SWH: NOPM and NOPR are good, but FDM and NOPN are again too high. In conclusion, the NOP products are performing better than FDM overall. NOPM and NOPR are good. NOPN wind speed is good but SWH is not as good as expected. The changes in behaviour observed in March and mid-June 2018 could be related to a model updated. It has been discussed if the SAR boxes could be creating a bias. Saleh confirms that he needs to double check.

**Chris Banks (NOC)** presented preliminary results from the validation of the Baseline-C GOP [RD30]. Operationally NOC perform QC and validation of all ocean products, and generate daily and monthly reports.
Analysis of the probability distribution function (PDF) of SSHA from Baseline-C GOP (Sept 2018) shows a slight offset compared to Jason-3 and RADS. Separating the results by mode, the SARIn data values sit slightly below the average, before jumping above the average in June 2018.
SWH from Baseline-C GOP (Sept 2018) shows unrealistic values around the edge of Antarctica. Otherwise the global SWH PDF is in good agreement compared to Jason-3 and RADS. SARIn data again has a lower mean SWH than the other modes.
Wind speed from Baseline-C GOP (Sept 2018) shows unusually low values over the Southern Ocean. However then PDF is in very good agreement with Jason-3.
In summary, the move to netCDF has been a good improvement. The CryoSat ocean product complement well the ocean altimetry record from repeat-orbit missions. Investigation is ongoing into the unusual SAR and SARIn observations.
It has been discussed if the wind speed observations could be showing boundary layer effects around the edge of sea ice. Perhaps, but a closer look at the quality flags is required to understand if there is bad data to be discarded.

# 7. GENERAL CONCLUSIONS

In conclusion, validation activities presented at this QWG confirm that the new Baseline-D Ice processors show significant improvements with respect to Baseline-C. The large 7-month test data set made available to expert CryoSat users was very instrumental for in-depth quality -assessment. Scientists from all different research domains welcome the switch to CF-compliant netCDF-4, a much more convenient and easier format to use compared to the former EE. The Baseline-D algorithms show significant improvements over all kinds of surfaces. Most notably, freeboard appears to be less noisy, no longer overestimated over the Arctic area and discontinuity issues are fixed at the SAR/SARIn interfaces. For land ice, the main improvements are the roll error improvement, and the improved surface type mask. Inland water users reported strong improvements and a reduction in measurement outliers. Overall, there were no critical issues observed by the QWG and only a number of minor issues to be considered in the final Baseline-D release. The QWG fully endorsed the implementation of the Baseline-D into operations. Validation activities performed on the ocean products confirmed that Baseline-C is performing better than Baseline-B. The quality of geophysical parameters has improved and some previous issues have been resolved. Analysis confirmed that NOP are performing well and can adequately replace FDM. Future evolutions and improvements are to be considered for new the CRYO-TEMPO products. The proposed thematic products are: Sea Ice, Polar Sea, Land and Hydro. These products will provide the opportunity for including innovating algorithms outside of the core PDGS development cycle, allowing them to evolve quickly and be more adaptable to changes.

# 8. SUMMARY OF RECOMMENDATIONS

The following table compile most of recommendations expressed by the CryoSat QWG#7 participants which will be considered for future evolutions of the CryoSat L1 and/or L2 Ice and Ocean baselines and in the implementation of the new CryoSat CRYO-TEMPO products.

| Recommendation | Title |
|---|---|
| **Session 2 – Operational Products QC & Calibration** | |
| QWG#7 - REC1 | Further Investigate the possible bending of the antenna bench, in order to derive a correction. It will be interesting to know if the residual error is only spatial dependent or also time dependent. |
| QWG#7 - REC2 | Further investigate the transponder results and prepare of an updated Technical Note on the CryoSat biases. |
| QWG#7 - REC3 | Add the retracker flags for SARIn during routine QC checks. |
| **Session 3 – Introduction to Baseline-D** | |
| QWG#7 - REC4 | CRYO-COP-33 reports a problem with the handling of the DOR_NAV in NOP processing. This issue should be verified and fixed before Baseline-D is put into operations. |
| QWG#7 - REC5 | Minor issues identified in Baseline-D products to be addressed in the final Baseline-D release. |
| QWG#7 - REC6 | Review and update of Baseline-D documentation to make it more user friendly. QWG attendees are invited to send comments and remarks to Marco Meloni. |
| QWG#7 - REC7 | Check the continental mask used in Baseline-D |
| QWG#7 - REC8 | Check the slope model used in Baseline-D. |
| QWG#7 - REC9 | Request for the provision of accurate dynamic snow corrections for sea ice, ideally snow depth and density, instead of modelled data, in order to calculate snow loading and propagation delay. This should be considered for the Arctic sea ice CRYO-TEMPO products. |
| QWG#7 - REC10 | Further improvement and refinement of sea ice processing methods, including the use of phase information in SARIn mode and the interpolation of SSHA across SAR/ SARIn boundaries. |
| QWG#7 - REC11 | Implement an alternative and improved slope model. |
| QWG#7 - REC12 | Further improve the product format, such as flagging to make products easier to use, and flags relevant to certain user-focused parameters. Additionally, the recipe needed to use the flags should be added to product format specification documents. |

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| QWG#7 - REC13 | Include additional/ replacement retrackers to be recommended by specific communities, e.g. inland water which currently does not have its own retracker. |
| **Session 4 – CryoSat Data Quality over Land-Ice** | |
| QWG#7 - REC14 | Further test and verify of the new slope model:<br>• Antarctica: REMA + global TanDEM-X<br>• Greenland: GIMP, ArcticDEM, global TanDEM-X |
| QWG#7 - REC15 | Assess the effect of the new DEM on the SARIn height difference flag (x-track angle error flag). |
| QWG#7 - REC16 | Add a new field to the product containing the height difference compared to the DEM. However, MSSL warn that since this value is not POCA, it may not be so useful. |
| QWG#7 - REC17 | Use the new DEM in the SARIn chain for unwrapping. |
| QWG#7 - REC18 | Add another ice retracker in SARIn. This would add an additional set of range and POCA locations in the L2 and L2I. |
| QWG#7 - REC19 | Add the range integrated power to the ice products. This is important for various surface types. |
| QWG#7 - REC20 | Use an updated DEM. This is not possible for Baseline-D but could be considered for CRYO-TEMPO. |
| QWG#7 - REC21 | The descriptions for the Inverse Barometric Correction and Dynamic Atmospheric Correction need to be checked to ensure they are consistent. |
| QWG#7 - REC22 | Perform a validation campaign to study PLRM and SARIn over an ice cap (e.g. Austfonna), Devon or Greenland to capture diverse snow zones. |
| QWG#7 - REC23 | The priority variables for a future CRYO-TEMPO product are: latitude, longitude, elevation, sigma0, and LE. A consistent retracker should be used for all modes. |
| **Session 5 - CryoSat Data Quality over Sea-Ice** | |
| QWG#7 - REC24 | Further investigate to understand what is causing the massive difference in freeboard between Baseline-C and Baseline-D. |
| QWG#7 - REC25 | Add missing latitude and longitude (lat_cor_01/ lat_cor_01) at L1B |
| QWG#7 - REC26 | Investigate data gap spotted in the Barents Sea. |
| QWG#7 - REC27 | Introduce small SAR patches in Antarctic for experimenting and to prepare a future mission. |

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| QWG#7 - REC28 | Add tidal corrections to LRM. |
| QWG#7 - REC29 | UCL observed a slight shift in the along-track position of some Baseline-D products compared to Baseline-C. The shift is not systematic and should be investigated. |
| QWG#7 - REC30 | Investigate potential data gap/ fewer waveforms in Kara/ Barents/ Greenland Sea |
| QWG#7 - REC31 | Several global attributes are integers whereas floats would be more appropriate and the conversion must be guessed, e.g. open_ocean_percent |
| QWG#7 - REC32 | Add a distance to coast variable, similar to the S3 product |
| QWG#7 - REC33 | Add PLRM waveforms to the LRM products |
| QWG#7 - REC34 | Add SAR/SARIn PLRM product in the ice baselines. |
| QWG#7 - REC35 | Further research is needed to better understand light and snow/ ice interactions |
| QWG#7 - REC36 | Further research is needed to attribute biases in the freeboard retrieval |
| **Session 6 – CryoSat Data Quality over Ocean and Inland Water** | |
| QWG#7 - REC37 | Introduce open-loop retrackers to guide retracking over complex surfaces. |
| QWG#7 - REC38 | The ideal new hydrology mission would operate the SAR mode we have now but with interferometric capabilities and the window size we have now in SAR. Receiving from 2 antennas you can have interferometry but without the noise from SAR. Open loop tracking allows you to look directly at a target. |
| QWG#7 - REC39 | The time_01 are time_poca_20_ku are not synchronised any more in Baseline-D. This breaks the old assumption that there are 20 x time_poca_20_ku records in 1 x time_01. This is more complex to handle in processing. Synchronise time fields again. |
| QWG#7 - REC40 | There is no longer an alt_20 field, but instead the user has to interpolate satellite orbit to recompute his own elevations heights. Add this field back in. |
| QWG#7 - REC41 | Include OCOG retracker in SAR and SARIn products. |
| QWG#7 - REC42 | Add cycle and track numbers in the product filenames, as this helps to process data faster. This is not possible to change for the Baseline-D IPF but could be considered for the thematic products. |
| QWG#7 - REC43 | Investigate possible time-tag bias (400 micro seconds in LRM; 200 microseconds in pLRM) and if confirmed, information should be provided to users to correct for them. |
| **Conclusions - General** | |
| QWG#7 - REC44 | Organize CRYO-TEMPO user forum in 2019 |
| QWG#7 - REC45 | Prepare and contribute to the CRYO-TEMPO evolution |

## ANNEX 1 RECOMMENDATIONS FROM THE LAST CSEM

The CryoSat team organized a meeting (Scientific Expert Meeting (CSEM)), held at ESA/ESRIN on 07-08 November 2017, inviting scientists with the objective to listen to their view and collect innovative ideas for future products, targeting new geophysical parameters, processing algorithms, operational applications, data assimilation and multi-mission synergy. The new Cryo-TEMPO products paradigm, improvements of the core PDGS L1 and L2 products and potential changes to the actual CryoSat Mode Mask and orbit have been also discussed. All the details are reported in the following website:

**https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/cryosat/news/-/article/cryosat-scientific-expert-meeting-presentations-and-summary-report**

The QWG#7 was the occasion to make detailed point on the status of the recommendations compiled during the CSEM meeting, with their follow on one year after. The table below reports in colour code the status of each recommendation and its status update.

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| Recommendation implemented |
| On going implementation |
| No more applicable or not implemented |

| Rec | Description | Update this QWG |
|---|---|---|
| *Sea Ice* | | |
| 1 | Implement future ice Baseline changes out of the Arctic winter season (October- April) and not done in the middle of a month. | *Based on this recommendation, the Baseline D TTO is postponed to April -May 2019. The full mission reprocessing should start on January.* |
| 2 | Activate a new sea-ice SARin box where the density of leads is high. | *There is currently no consensus from the sea ice community. Most of the literature shows that for CryoSat SAR mode is better over sea-ice. Knowledge gained from existing SARIn data would be a key step in planning a future mission that could perform interferometry over a higher proportion of the mode mask.* |
| 3 | Publish on the CryoSat webpage an animation of the mode mask change evolutions since the beginning of the mission. | *Generation of the mask on-going, to be published by March 2019.* |
| 4 | Better document the origin of geophysical parameters and scientific algorithms | *An updated Baseline-D product handbook has been made available to CSEM experts for comments / suggestions. The updated MSSL L2* |

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| | used within the L2 PDGS sea ice processing chain. | *DSD is nearing completion. It is ESA's intention to publish a TN based on this document.* |
| 5 | Improve the Lead/Floe classification algorithm as there seem to be too many leads in the current ESA Baseline-C sea-ice products | *Incorporating the stack peakiness into the discrimination has resulted in the rejection of records previously incorrectly classified as leads (9% down to 7.5%). This also resulted in a minor improvement in the interpolated MSS.* |
| 6 | Improve the Freeboard retrieval technique as the ESA Baseline-C freeboard seems to be overestimated | *Updates made to the technique specified by CPOM. Experimentally derived bias correction added which reduces freeboard. More detailed results to be presented by MSSL and ESA (MM).* |
| 7 | Provide freeboard from SARIn mode in L2 sea ice products. This would require identifying new SARin areas where the density of leads is high. | *Freeboard computation now Implemented in the Ice Baseline-D. The second part of this recommendation is linked to recommendation 2.* |
| 8 | Provide an uncertainty parameter associated with the freeboard computation in the L2 products. | *This has not been implemented in the Ice Baseline-D PDGS product but could be considered for inclusion in the future CRYO-TEMPO sea ice products.* |
| 9 | Provide alternative freeboard values from physical-like retrackers in L2 products. | *This has not been implemented in Baseline-D. Multiple freeboard values in the core PDGS product could confuse users. It would be better to perform a study to find the best retracker and implement that in future CRYO-TEMPO sea ice products.* |
| 10 | Provide up to date important corrections for freeboard retrieval (DAC, Ocean Tides, MSS...) in the L2 products. | *All of these corrections are currently provided in the L2 product. The correction values are provided via an ESA CFI. Inclusion of up-to-date correction could be implemented in the future CRYO-TEMPO sea ice products.* |
| 11 | Provide the non-corrected ranges and not just the corrected surface height values in the L2 products. | *The non-corrected range is part of the Baseline-D product.* |
| 12 | Implement consistent sea ice processing strategies across all ESA Missions. | *Coordination effort at ESA Level (eg Sentinel-3 SI product "à la CryoSat" in future L2 baseline, Dec 2018). The CRYO-TEMPO concept (content/ format) will be adapted to past ESA missions (FDR4Alt) and to the Sentinel ones (TBD & endorsed in Sentinel User forum).* |
| 13 | Provide the stack-derived Range Integrated Power (RIP) and the corresponding | *RIP derived metrics could be added to the beam behaviour parameters but this is not recommended since it would roughly double the* |

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| | RIP characteristics within the L1B. | *size of the L1B SAR/SARin product. The added information is not (at least at this moment) exploited by the standard L2 processing chains and could be useful only for expert users. The alternative solution is to go ahead in Baseline-E with the generation of a new L1BS (stack) product which would contain the whole stack.* |
| 14 | Generation of new CryoSat sea ice thematic products which shall:<br>Target the sea-ice scientists (simple NetCDF products, ≤ 5 meaningful parameters)<br>Use PDGS L1 products as inputs<br>Include both the L2 PDGS and optimized freeboards (with uncertainty parameters)<br>Quickly evolve and reflect the most recent scientific outcomes<br>Be regional (Arctic and Antarctic) and provide the data in such a way that specific areas can be easily extracted from a user friendly interface. | *Arctic CRYO-TEMPO sea ice ITT expected Q1/Q2 2019. Antarctic CRYO-TEMPO sea ice ITT expected end-2020 or 2021.* |
| *Land Ice* | | |
| 15 | Better document the origin of geophysical parameters and scientific algorithm used within the L2 PDGS land ice processing, as well as more information on data limitations and effects of Baseline changes. | *An updated Baseline-D product handbook has been made available to CSEM experts for comments / suggestions. The updated MSSL L2 DSD is nearing completion. It is ESA's intention to publish a TN based on this document.* |
| 16 | Not change massively the Mode Mask over ice sheets. SAR patches could be useful for the analysis of crossover Antarctica pattern and for covering high latitude regions (not reach by Sentinel-3), but only if 20Hz PLRM is provided at the same time. | *Since the last CSEM no massive mode mask changes have been implemented. 20Hz PLRM is not provided in the ice products. There have been no user requests received for SAR patches over Antarctic crossovers.* |
| 17 | Improve the on-board | *There has been no progress on this topic* |

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| | retracker for steep margins in order to avoid data loss | |
| 18 | Use swath product to calibrate / solve small remaining attitude ambiguity in the L2 products. | *This requires a study to be commissioned. The use of CRYO-TEMPO land ice swath data could be used for this purpose.* |
| 19 | Provide the coherence, the power and additional retracker (e.g. TFMRA) in the L2 products. | *Coherence at retracking point is output in the L2I product. Extra retrackers could be added as needed but it would be better to find the "best retracker" from R&D and implement that in future CRYO-TEMPO land ice products.* |
| 20 | Aside from existing ESA PDGS products, the CSEM participants support the concepts of:<br>A new CryoSat swath product (to include latitude, longitude, coherence, power…) | *CRYO-TEMPO land ice swath activity to be started soon. Antarctica and Greenland CRYO-TEMPO products are expected to be in production in Q2 2019. Swath CRYO-TEMPO products for glaciers, ice caps and Patagonia are expected in Q2 2020 (TBC).* |
| 21 | A new CryoSat POCA Land-Ice thematic product. | *CRYO-TEMPO POCA land ice ITT expected in Q1/Q2 2019.* |
| *Ocean* | | |
| 22 | Use the most recent GDR-E orbit standards and the SAMOSA V2.5 retracker. | *Not yet discussed or implemented but could be taken on-board for future COP Baselines and/or Ocean CRYO-TEMPO products.* |
| 23 | Maximise SAR & SARin acquisitions on complex geodetic regions for marine geodesy application and minimise SARin acquisitions for operational oceanography (CMEMS). | *New mode mask under internal discussion and testing, including new ocean SAR/SARIN areas.* |
| 24 | Shift CryoSat ground tracks by 4km in longitude to increase the weight of CryoSat data into operational oceanography systems. | *On-going discussion to change the CryoSat orbit to allow synchronized measurements with ICESat-2. As a side effect, this might be also beneficial for ocean sampling.* |
| 25 | Generation of a new CryoSat Polar Ocean thematic product (priority#1) | *Arctic Ocean CRYO-TEMPO ITT on Q1/Q2 2019. Antarctic Ocean CRYO-TEMPO ITT planned for end 2020 or 2021.* |
| | A new CryoSat Coastal Ocean Thematic product (priority#2, content TBD) | *Not yet discussed or implemented but should benefit from future planned ESA R&D on the Topic (JB).* |
| *Rivers & Lakes* | | |

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| 26 | Develop a dedicated inland water product based on study that compares the water level from various retrackers over different targets. | *Not yet discussed or implemented but recommendation considered to define planned ESA R&D on the Topic (JB) could be taken on-board for future hydro CRYO-TEMPO, see [Rec.33].* |
| 27 | Update regularly the global water mask. | |
| 28 | Increase the number of inland SARin boxes, as Sentinel-3 data is available and provides SAR Altimeter data globally. | |
| 29 | Invest in improving the retrieval of small "wet" targets level. | |
| 30 | Process data at 80 Hz, since it will provide an opportunity to extend the limit of targets that can be observed by radar altimetry. | |
| 31 | Have an easier access to validation data, and also provide some dedicated ESA funding for validation data and campaigns. | |
| 32 | Make effort for 1) integrating satellite and in situ measurements 2) on the possibility to maintain the in situ monitoring network and 3) for providing the access and dissemination of altimetry datasets ready to be used by the hydrological community. | |
| 33 | Generate CryoSat River & Lake thematic products which shall:<br>Be based on the heritage of previous ESA –EOPS R&D activities<br>Target a large hydrology community (simple NetCDF products)<br>Contain at least Time, Lat, | *Future CRYO-TEMPO hydro ITT (date TBD/TBC)* |

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| | Long, Height/WGS84, (Height 2, Height3), Geoid model and the Error (Height/Flag)<br>Contain river discharge & lake volume parameters<br>Quickly evolve and reflect the most recent scientific outcomes. Be easily extracted from a user-friendly interface. | |

## ANNEX 2 LIST OF CryoSat QWG#7 PARTICIPANTS

| | |
|---|---|
| Stefan Hendricks | Alfred Wegener Institute |
| Karina Nielsen | DTU |
| Sara Fleury | LEGOS |
| Jérôme Bouffard | ESA |
| Malcolm Davidson | ESA |
| Nicolas Bercher | Along-Track S.A.S. |
| Antoine Laforge | LEGOS |
| Stéphanie Urien | CLS |
| Matthias Raynal | CLS |
| Pierre Thibaut | CLS |
| Marco Restano | SERCO c/o ESA |
| Michele Scagliola | Aresys |
| Luca Maestri | Aresys |
| Marco Fornari | ESTEC |
| Alessandro Di Bella | DTU Space |
| Sebastian Simonsen | DTU Space |
| Geoffrey Dawson | University of Bristol |
| Chris Banks | NOC |
| Jean Tournadre | Ifremer |
| Erica Webb | Telespazio |
| Ben Wright | Telespazio |
| Sanggyun Lee | UCL |
| David Brockley | UCL-MSSL |
| Steve Baker | UCL-MSSL |
| Francesco Carriero | ACS |
| Saleh Abdalla | ECMWF |
| Isobel Lawrence | UCL |
| Teresa Geminale | ACS |
| Michel Tsamados | UCL |
| Veit Helm | AWI |
| Robert Ricker | AWI |
| Florent Garnier | LEGOS |
| Jérôme Benveniste | ESA |

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|---|---|
| Julia Gaudelli | UCL-MSSL |
| Mònica Roca i Aparici | isardSAT |
| Albert Garcia-Mondéjar | isardSAT |
| Isabelle Dauvin | ESA/ESOC |
| Tommaso Parrinello | ESA/ESRIN |
| Marco Meloni | SERCO c/o ESA |
| Pierre Femenias | ESA/ESRIN |
| Vittorio Torroni | SERCO |
| Stefano Badessi | ESA/ESRIN |

# ANNEX 3 CRYOSAT QWG#7 MEETING AGENDA

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|---|---|---|---|
| **Day 1** | **Monday 26/11/2018** | | |
| | | **Location: Room Magellan (ESA-ESRIN, Building 1)** | |
| | | **Session 1: Mission overview** | **Co-chairs: Tommaso Parrinello Jerome Bouffard** |
| 14:00 | 14:10 | Workshop introduction and logistics | Jerome Bouffard / Marco Meloni |
| 14:10 | 14:30 | CryoSat Mission Status | Tommaso Parrinello |
| 14:30 | 14:50 | CryoSat Space Segment and Operations status summary | Isabelle Dauvin |
| 14:50 | 15:10 | CryoSat PDGS Status | Stefano Badessi |
| 15:10 | 15:30 | CryoVEx, plans for 2019 and lesson learned from previous campaigns | Sebastian Simonsen |
| **15:30** | **16:00** | **Coffee break** | |
| 16:00 | 16:20 | CryoSat Data Quality Status | Jerome Bouffard |
| 16:20 | 16:40 | Review of Action Items and Recommendations from the 2017 CryoSat Scientific Expert Meeting | Jerome Bouffard |
| | | **Session 2: Operational Products QC & Calibration** | **Chair: Marco Fornari** |
| 16:40 | 17:00 | CryoSat Data quality control overview | Erica Webb / Ben Wright |
| 17:00 | 17:20 | SIRAL Calibration monitoring + Interferometer End-to-End calibration | Michele Scagliola |
| ***17:20*** | ***17:50*** | ***Discussion*** | |

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| **Day 2** | **Tuesday 27/11/2018** | | |
| | | **Location: Room Magellan (ESA-ESRIN, Building 1)** | |
| | | **Session 3: Introduction to Baseline-D** | **Chair: Marco Meloni** |
| 08:40 | 09:00 | Transponder Calibration Results | Albert Garcia-Mondéjar |
| 09:00 | 09:20 | CryoSat Baseline-D Content and Status | Francesco Carriero |
| 09:20 | 09:40 | CryoSat Baseline-D TDS verification | Erica Webb / Ben Wright |
| 09:40 | 10:00 | CryoSat L1b Baseline-D changes and assessment | Luca Maestri |

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| 10:00 | 10:20 | L2 algorithm changes in Baseline-D and impact on Ice measurements | David Brockley |
| 10:20 | 10:40 | Cryosat L2 Baseline-D Quality assessment | Marco Meloni |
| **10:40** | **11:10** | **Coffee break** | |
| | | **Session 4: CryoSat Data Quality over Land-Ice** | **Chair: Veit Helm** |
| 11:10 | 11:30 | Validation of CryoSat-2 SARIn Data over Austfonna Ice Cap - a first look at Baseline D | Sebastian Simonsen |
| 11:30 | 11:50 | Baseline D SARIn swath data over Antarctica | Geoffrey Dawson |
| 11:50 | 12:10 | Comparison of Baseline C and D L1B and L2 products over ice sheets | Veit Helm |
| ***12:10*** | ***12:40*** | ***Discussion*** | |
| **12:40** | **14:00** | **Lunch break** | |
| | | **Session 5: CryoSat Data Quality over Sea-Ice** | **Chair: Michel Tsamados** |
| 14:00 | 14:20 | Level-1b baseline-d data in the AWI sea ice processing chain | Stefan Hendricks |
| 14:20 | 14:40 | Baseline D checks with imagery over sea-ice | Pierre Fabry |
| 14:40 | 15:00 | Sea Ice Thickness with baseline D | Sara Fleury |
| 15:00 | 15:20 | Improving phase difference in CS SARIn mode: impact on sea ice freeboard | Alessandro Di Bella |
| **15:20** | **15:50** | **Coffee break** | |
| 15:50 | 16:10 | SARin swath data over icebergs (small and large) | Jean Tournadre |
| 16:10 | 16:30 | Comparison of the lead detection algorithm between Baseline C and D | Sanggyun Lee |
| 16:30 | 16:50 | Snow Depth with Baseline-C GOP PLRM | Florent Garnier |
| 16:50 | 17:10 | CryoSat snow and sea ice thickness along track and gridded: lessons learned from Arctic+ and future directions | Michel Tsamados |
| 17:10 | 17:30 | Airborne evaluation of dual-band frequency satellite radar altimetry measurements over Arctic sea ice | Robert Ricker |
| ***17:30*** | ***18:00*** | ***Discussion*** | |

| Day 3 | Wednesday 28/11/2018 | | |
|---|---|---|---|
| | | **Location: Room Magellan (ESA-ESRIN, Building 1)** | |
| | | **Session 6: CryoSat Data Quality over ocean and inland water** | **Co-Chairs: Marco Restano Jerome Benveniste** |
| 09:00 | 09:20 | level-1b and level 2 baseline-D evaluation for inland water | Karina Nielsen |
| 09:20 | 09:40 | Comparison of Baseline C and Baseline D L2 products for hydrology | Nicolas Bercher |
| 09:40 | 10:00 | Assessment of the Cryosat-2 L2 products (baseline C) over ocean | Matthias Raynal |
| 10:00 | 10:20 | Baseline C for CryoSat-2 Geophysical Ocean Products: some preliminary observations | Chris Banks |
| 10:20 | 10:40 | Assessment of CryoSat-2 NRT Wind and Wave Data | Saleh Abdalla |
| **10:40** | **11:00** | **Coffee break** | |
| ***11:00*** | ***11:30*** | ***Discussion*** | |
| | | **Session 7: Summary and Recommendations** | **Co-Chairs: Jerome Bouffard & Marco Meloni** |
| 11:30 | 11:40 | Session 2 Summary and Recommendations | Marco Fornari |
| 11:40 | 11:50 | Session 3 Summary and Recommendations | Marco Meloni |
| 11:50 | 12:00 | Session 4 Summary and Recommendations | Veit Helm |
| 12:00 | 12:10 | Session 5 Summary and Recommendations | Michel Tsamados |
| 12:10 | 12:20 | Session 6 Summary and Recommendations | Jerome Benveniste |
| ***12:20*** | ***12:30*** | ***Final Conclusions and Meeting Closure*** | ***Jerome Bouffard*** |