→ CLIMATE CHANGE INITIATIVE

Ice Sheets CCI Newsletter

Issue n. 2 | March 2013

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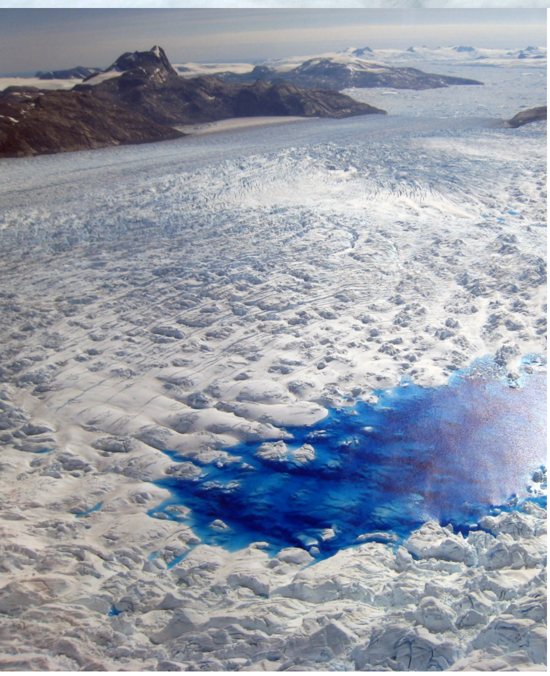

The Ice_Sheets_cci project concludes Round-Robin exercise, gears up for prototype product generation.

The **ESA Ice_Sheets_cci** project has concluded the Round-Robin exercise, and an initial batch of data production is expected for summer 2013.

The Ice_Sheets_cci has completed one year out of its three year duration. The has generated a lot of interest in the scientific community. ESA has confirmed that a follow-up project is planned. The project itself is also increasing in scope: CryoSat and Sentinel-1 data options are being considered, as well as user requirement elicitation for a similar project.

This second issue of the newsletter, timed to coincide CryoSat meeting, is dedicated to giving a taste of the results of the Round-Robin exercise. The full report is in the Product Validation and Algorithm Selection Report (PVASR) available from our webpage:

http://www.esa-icesheets-cci.org/.

ABOVE: Placement of a GPS stake on the Ice Sheet. Ice_Sheets_cci use data from GPS stakes for product validation [Photo: S. Andersen]. **LEFT:** Meltwater lakes form in the summer season. While beautiful, meltwater can speed up basal sliding by acting as a lubricant. [Photo: K. Scharrer]. **BOTTOM:** Project partner logos.

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Round-Robin Roundup: Overview

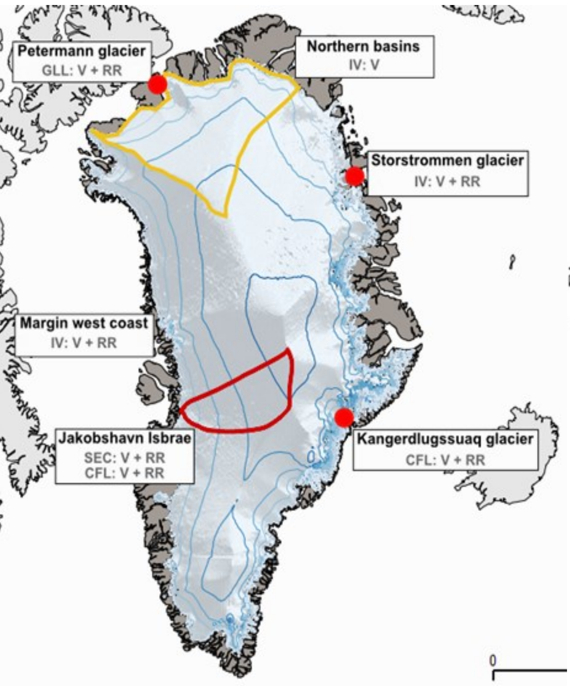
The Round-Robin exercise kicked off in August 2012, and the final submissions deadline was October. The results have been analysed and the final conclusions were presented in February 2013.

The main goal of the Round-robin experiments was to enable the comparison of various algorithms for the generation of ECV products, based on objective parameters including accuracy compared to reference data (e.g. GPS measurements), coverage, and processing effort. Based on their results, an effort has been made to identify the best performing algorithms. These algorithms will be used for generating the Essential Climate Variable products.

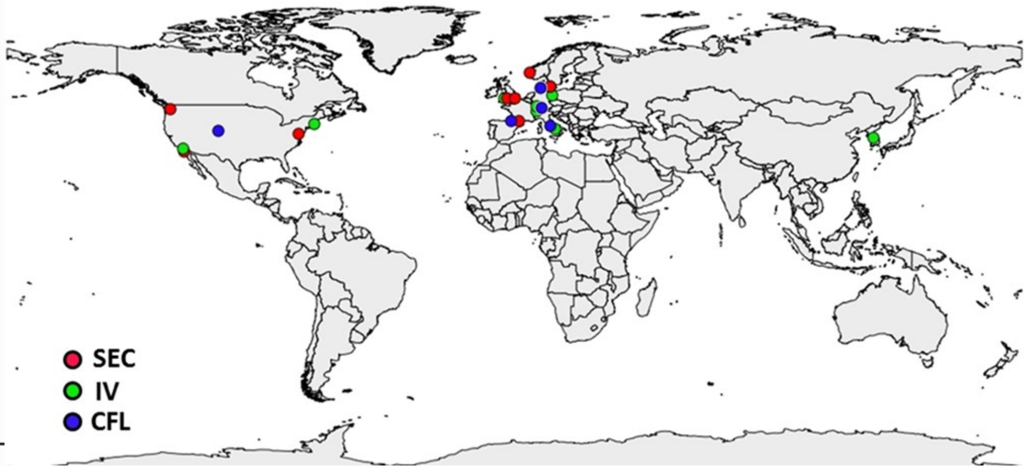
The Round-Robin exercise was announced on the home page of the Ice_Sheets_cci project **www.esa-icesheets-cci.org**, on the CRYO-LIST email list, and by personal invitation of 47 select scientists. A personal of invitation was clearly the most efficient, but it was important to make it possible for all Ice Sheet researchers to participate in the exercise.

As is indicated on the graphics on this page, a total of 22 submissions were received, distributed between SEC (7), IV (9), and CFL (6). The GLL parameter received no submissions, this is understood to be due to the experimental nature of this parameter. The Round-Robin submissions were anonymized and analyzed.

The contribution of Round-robin participants will is key to selecting an algorithm for an operational remote-sensing based ice sheet monitoring system, serving glaciological and climate research communities.



LEFT: The location of the Round-Robin sites. **BELOW:** Geographical location of Round-Robin participants.



Round-Robin Roundup: Surface Elevation Change (SEC)

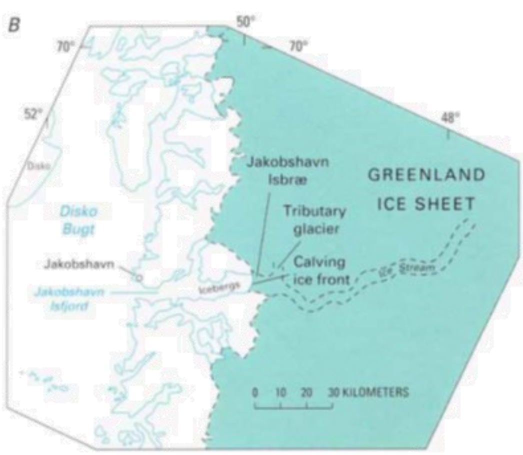
The large variety of the uploaded Round-robin results for satellite radar altimetry results allows for performing the validation activity of different repeat track altimetry algorithms for the elevation change product generation, based on the following components:

- A comparison of elevation change estimates derived from approximately temporally consistent airborne LIDAR and satellite altimeter data;
- A comparison of elevation changes derived from different sensors (i.e. radar vs. laser);
- A comparison of elevation changes derived from different algorithms (i.e. cross-overs vs. repeat-track).

The algorithm comparison and validation has been focused on the Jakobshavn Isbræ drainage basin.

Recommendations

From the intercomparisons of elevation change between methods, and the intercomparison of the different methods to an inde-



ABOVE: Jacobshavn Isbræ, location of the SEC Round-Robin site.

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pendent surface change data set from airborne LIDAR data (IceBridge data supplemented with CryoVEx and Danish PROMICE ice sheet monitoring flights), the comparisons of the Round-Robin experiment in the Jakobshavn Isbræ drainage sector of the Greenland Ice Sheet can be summarized:

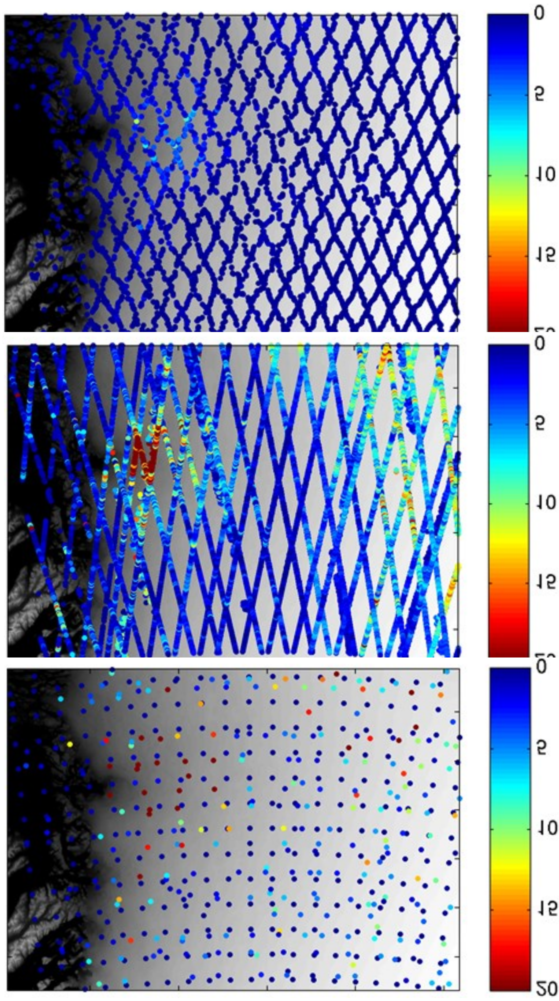
SEC resolution is the best from repeat-track algorithms, and generally better for the limited-footprint laser altimetry (ICESat) than for radar altimetry (Envisat). However, the comparisons have shown, that Envisat data have the potential to map height changes even on the relatively narrow fast-flowing ice stream of Jakobshavn Isbræ. This therefore shows the potential of the upcoming Sentinel-3 radar altimetry mission to provide reliable SEC estimates nearly all the way from the interior ice sheet to the ice margin.

The SEC accuracy is superior using the cross-over method, at the price of limited resolution. This method is therefore less suitable to monitor changes in height associated with changes in glacier and ice stream flow velocities, but more suitable for estimating drainage basin-scale overall elevation changes.

We therefore propose for the practical implementation in the Ice Sheets CCI project to implement a combined cross-over and repeat-track methodology. In practice two separate methods would be implemented, both on ice-sheet wide scales: a cross-over method implementation, with pre-defined cross-over points tailored to the specific missions (Envisat, CryoSat, Sentinel, IceSat-2), and a repeat-track method implementation, employing cross-track estimation for obtaining dense along-track SEC values, which could over time be improved as more and more detailed ice sheet heights are accumulated. As algorithms for this are already implemented for other applications among the CCI project partners, major adaption, tuning and optimization efforts will be necessary for implanting a truly operational and transparent system setup, including the application of state-of-the-art radar slope correction and backscatter corrections.

A special challenge in making a contemporary CryoSat SEC data set, bridging the gap between Envisat and Sentinel-3, comes from the (nearly) non-repeat orbits, the understanding accuracy and performance of the interferometry SAR altimetry performance, as well as the quality of the applied slope corrections in the interior of the Ice Sheet.
The results from the parallel application of independent cross-over and repeat-track algorithms would subsequently be combined into a consolidated, interpolated SEC grid product, using optimal gridding procedures taking into account the specific error estimates of the individual estimation points.

In the longer term, the two separate estimation methods could likely be combined into a single "hybrid" estimation method. This would however require a significant amount of research.



ABOVE: Signal-to-noise ratios found by dividing dH/dt by the corresponding errors. This is done for both the repeat-track resultsand the cross-track results. **Top:** Repeat-track, Envisat only; **Middle:** Repeat-track, ICESat only; **Bottom:** Cross-track, both Envisat and ICESat.

Round-Robin Roundup: Ice Velocity (IV)

The IV Round-robin exercise consisted in 4 different Tasks and was carried out by 9 external and 3 internal participants, listed in Table 4.1. The different tasks were related to the different measurement techniques envisaged in the project, namely DInSAR (Task 1), MAI (Task 2) and offset-tracking (Tasks 3 and 4). The response rate is considered exceptionally good, since almost all foremost groups took part in the exercise and several participants were willing to carry out more than one task.

Differential InSAR (Task 1)

The Round-Robin exercise did not provide any specific algorithmic recommendation for this family of techniques. It rather stressed the sensitivity of the latter to the phase unwrapping step. The results of Group 1 are on one hand alarming, since they show that even in the case of a highly coherent dataset with a short temporal baseline, very significant errors may be introduced. On the other hand, the error predictions associated to Group 1's result showed that, at least to a certain degree, a simple error prediction approach can be effective in flagging such situations.

Multi-Aperture InSAR (Task 2)

The Round-Robin exercise provided a quantitative example of ionospheric propagation effects on the performance of the MAI techniques. These results are to our best knowledge not reported in literature, and are therefore very interesting. A recommendation would be of course to develop a method of general applicability to mitigate these effects. Among the Round-Robin participants, the only mitigation approach, which was indeed partially effective, required several operator- and dataset-dependent steps (e.g. determining the orientation of the streaks).

Offset Tracking (Tasks 3 and 4)

The Round-Robin exercise provided very interesting results, in the sense that a much higher variability than expected was observed between the delivered products and

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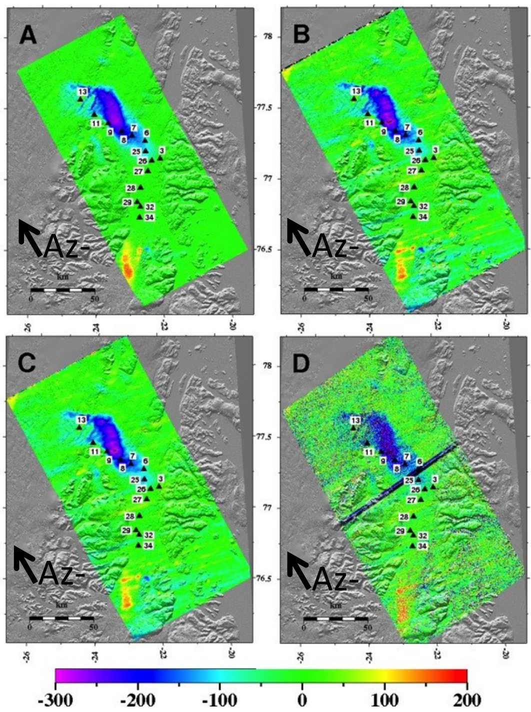
with respect to the GPS measurements, however only partial indications concerning algorithmic aspects can be derived.

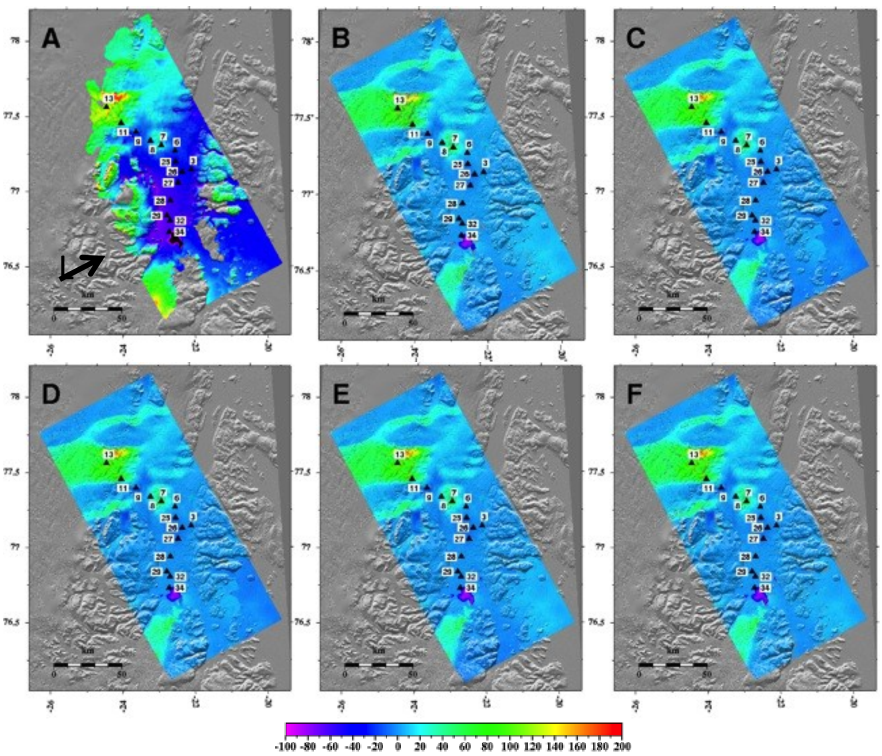
Prefiltering was applied in the form of a high-pass filter only by Group 2 in both Task 3 and Task 4. In the form of multi-looking, it was applied by Group 2 and by Group 7 for fast-moving areas only. Since most matches are due to common features, both for Task 3 and for Task 4, prefiltering is expected to be beneficial. There may be two indirect indications of this: the low error variance of Group 2's results in both Task 3 and Task 4; the high coverage of Group 7 in fast moving areas (although validation data is not available to verify the accuracy of this coverage).

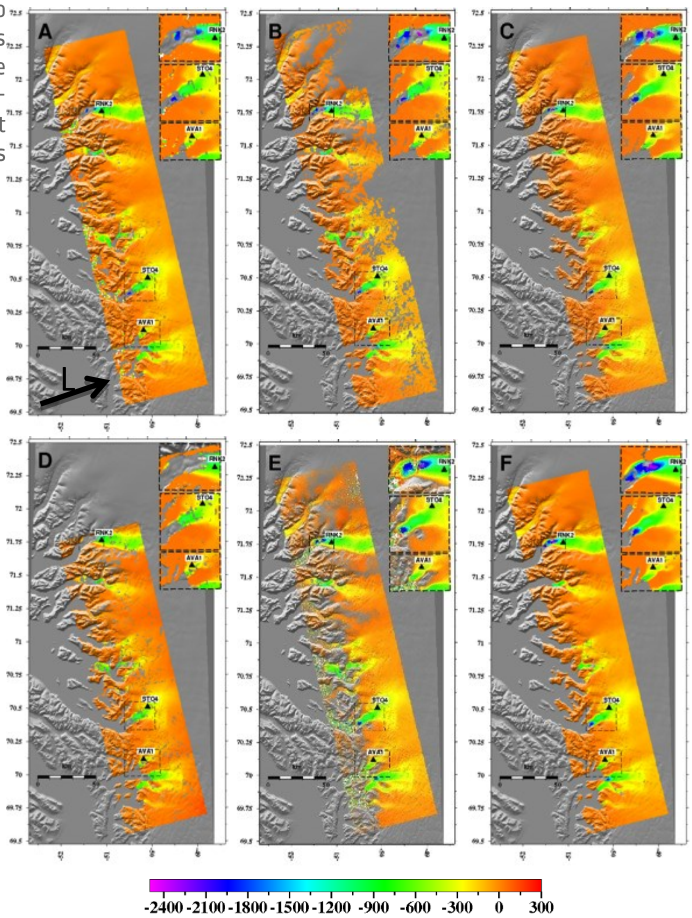
Very different values were selected for the cross-correlation window sizes and postings by different groups. These impact on accuracy and processing time. The latter could not be compared due to lack of info provided in the feedback forms concerning processing times and machine information. One aspect concerns the posting size in relation to the cross-correlation window size. In particular the results of Task 3 seem to indicate that there is no clear advantage in choosing a very fine posting size in relation to the cross-correlation window size, since for instance Groups 1 and 6, who apply a three times coarser posting in each dimension compared to other groups, perform well with respect to the GPS measurements. Another aspect is related to the advantage of an adaptive approach, capable of adapting the window size to the feature/speckle pattern to be tracked. The approach applied by Group 7 for Task 4 is very interesting and might be partly responsible for the remarkable coverage of Group 7 with respect to other groups.

Different culling procedures were applied. Robust results were obtained by a combination of cross-correlation quality parameter thresholding, local statistics analyses and thresholding based on the maximum expected velocity. Use of a sea-ice mask is recommendable, since prior to delivery to a user, slant-range and azimuth offset would typically be converted to Cartesian velocity components, under the surface parallel flow assumption, which makes no sense for sea ice that is subject to tidal effects.

Concerning baseline calibration, Task 4 confirms that this aspect can become one of the main error sources, even close to the ice margin, when data strips of a few hundreds of km are considered. An automated procedure for Ground Control Point selection on bedrock outcrops is recommended as well as the use of a baseline error model, rather than a simple low order polynomial offset model.







TOP RIGHT: MAI Azimuth maps (Task 2) resampled to a common geometry. **BOTTOM LEFT:** DInSaR Slant-range maps (Task 1) resampled to a common geometry. **BOTTOM RIGHT:** Offset Tracking Slant-range maps (Task 4) resampled to a common geometry.

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Round-Robin Roundup: Calving Front Location (CFL)

The Round-Robin experiment for CFL was conducted at Jakobshavn glacier at the West coast, and Kangerlussuaq glacier at the East coast of Greenland.

SAR amplitude images from different satellites (Envisat, ERS-2) and from different image modes: ENVISAT-ASAR IS2/ERS-2, with 20 m pixel size, and ENVISAT-ASAR wide swath mode, with 75 m pixel size were selected for the Round-robin experiment. All data were terrain-corrected and geocoded to the same reference DEMs, and made available in GEOTIFF format in order to be easily readable into many GIS environments.

Participants were asked to extract the calving front positions from the provided SAR images for several outlets in the two test regions .

A main criterion for selecting the SAR scenes for the Round-Robin experiment was the potential of the sensor/product for ECV production as well as an identical acquisition time compared to the available SPOT-5 validation data. Further, scenes of ascending and descending orbits were selected, due to the different layover/shadow characteristics that can affect the appearance of the calving cliff in the corresponding SAR image.

Results

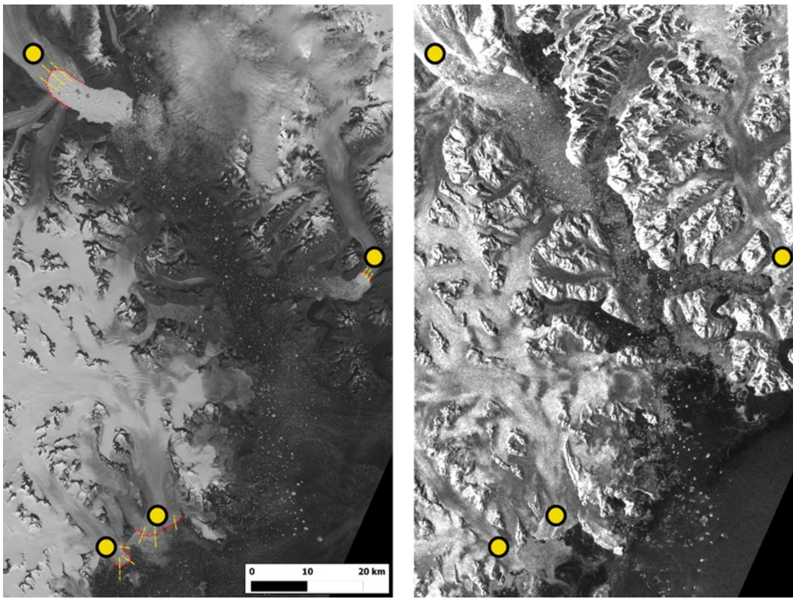
To date, no automatic method of picking CFL from SAR images has been reported in the scientific literature and this is reflected by the Round-Robin contributions. All participants manually digitized the termini locations in a GIS environment. The calving front locations extracted by the Round-Robin participants were compared to a reference data derived from SPOT-5 data acquired at the same time or only few days apart (0 to 8 days) compared to the SAR images. We defined calving front cross-section profiles for every glacier (2 to 4 according to glacier width) and measured the distances between the termini positions provided by the participants relative to the position of the corresponding reference SPOT-5 vector

Extracting the calving front position of a marine terminating glacier from SAR is not an easy task. Generally, the errors we found in the Round-Robin contributions are about an order of magnitude higher than expected. However, it has to be mentioned that we deliberately selected some poor data and chose difficult circumstances in order to cover the full range of potential scenarios Interestingly, the errors seem to be more or less independent from the resolution of the dataset and settle at 5.05 pixels for the SAR scenes with 20 m resolution and 4.13 pixels for the 75 m ASAR wide swath data.

Semi-automatic procedures might support the detection of the CFL in the future, but this is still under development.

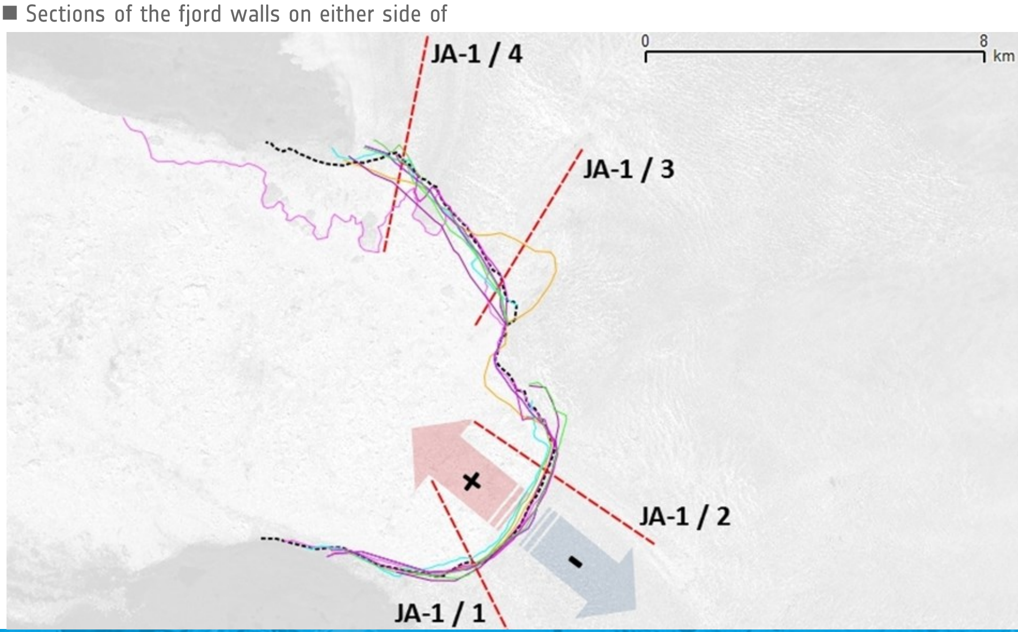
For the manual extraction of calving front positions we define a set of guidelines for the ECV production based on the results of the Round-Robin experiments that will help to increase quality and accuracy of the product:

- Digitisation should be performed by an experienced operator only.
- High resolution SAR data (e.g. ERS-1/2, ENVISAT-ASAR image mode) are preferable.
- Poor data should be rejected without CFL extraction.
- Sections of the fjord walls on either side of a calving front should be included in the digitisation that can be used for relative quality assessment.
- Data should be projected to the local UTM zone in order get quadratic pixels and therefore minimize any distortion.



ABOVE: The outlet glaciers selected for the CFL experiment in the Kangerdlugssuaq region (yellow dots). The left panel shows an example of the SPOT-5 validation data (© Astrium, CNES), the right panel an ENVISAT-ASAR wide swath image acquired on 11/10/2007.

BELOW: Results for Jakobshavn glacier with the profiles used for data analysis and comparison. The dashed black line indicates the corresponding reference CFL vector all results are relatively measured to (positive [+] and negative [-] shifts).



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Round-Robin Roundup: Grounding Line Location (GLL)

The Round-Robin experiment on grounding line location was conducted at Petermann glacier. The site was selected as it is one of the largest outlet glaciers in North

Greenland with a permanent floating ice tongue and therefore with a pronounced grounding line. Another criterion for selecting this outlet is the availability of published results that can be reproduced using the same input data.

In-situ measurements of the tidal flexure require a network of GPS stations, which is not available at Petermann glacier. However, InSAR provides an excellent tool for directly observing the tidal motion of a marine terminating outlet glacier and the main goal of this Round-Robin experiment was the comparison of extracted grounding zones provided by Round-Robin participants. However, no external results were received. Therefore, we performed a qualitative comparison with published results of Rignot that we tried to reproduce using the same input data. The SAR datasets consist of two SAR data triplets with a 3-day temporal separation (04+07+10/02/1992 and 25+28+02/02-03/1992) that allows formation of differential interferograms for separating the tidal flexure at Petermann glacier.

It has to be mentioned that Rignot additionally applied an elastic beam model and tidal predictions in order to derive the actual grounding line. However, InSAR can only deliver the surface expression of the so-called grounding zone (upper and lower limit of tidally induced flexure) without additional modeling and assumptions. No additional modeling efforts will be undertaken within the Ice_Sheets_cci project, and therefore only the upper and lower limit of tidally induced flexure will be delivered in the ECV product. Despite the difference in the final parameter (grounding line vs. upper and lower limit of tidal flexure) the qualitative comparison of the Ice_Sheets_cci consortium results with the grounding line position published by Rignot (1996) shows a good agreement.

Recommendations
Only InSAR processing will be considered for GLL retrieval within the Ice_Sheets_cci project. The InSAR processing steps for retrieving the grounding line are similar to the method that has been tested and validated in the Round-robin experiment on IV.

Outreach, Conferences, and Publications

Outreach and community interaction is an important element of the Climate Change Initiative; we consider such activities very important to the **Ice_Sheets_cci** team.

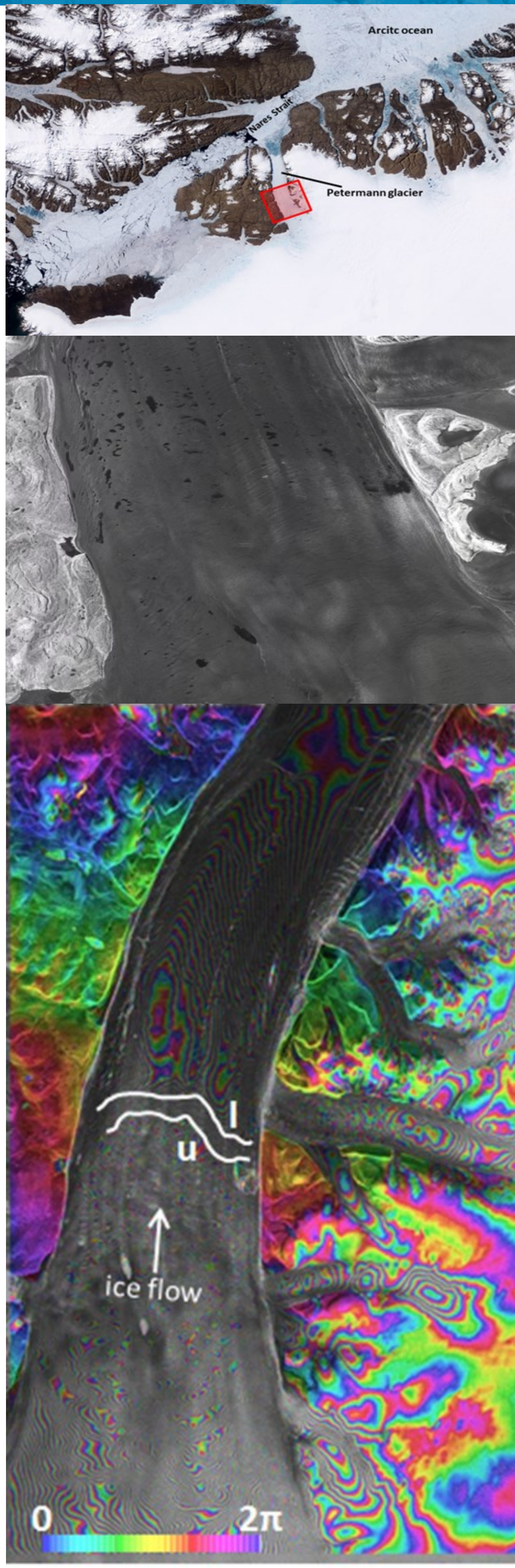
Since the project kick-off in January 2012 we have presented the project and the result of the user survey at the following conferences and workshops around Europe:

- **European Geosciences Union (EGU)**, Vienna, 23-26 April 2012: (C. Hvidberg and A. Shepherd).
- **Planet under Pressure**, London, 26-29 March 2012 (A. Shepherd)
- **Ice2Sea Open Forum**, Amsterdam, February 2012 (R. Forsberg and C. Hvidberg)

Our team will also appear as co-authors in a new cross-CCI paper submitted to the following journal:

- **Bulletin of the American Meteorological Society**: "The ESA climate change initiative: satellite data records for essential climate variables" (under review).

Our website **www.esa-icesheets-cci.org** will always contain the latest project news, status updates, newsletter, and official documents.
The **Ice_Sheets_cci** newsletter will be published twice a year.



TOP: Overview of the Round-Robin site Petermann glacier from MODIS, 05/07/2003 (© NASA) with the red bounding box indicating the footprint of the TanDEM-X scene shown on the center panel. **CENTER:** The TanDEM-X scene covers the area where the grounding line is expected to be. **BOTTOM:** Interferogram with the extracted upper and lower limit of tidal flexure at Petermann glacier.

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