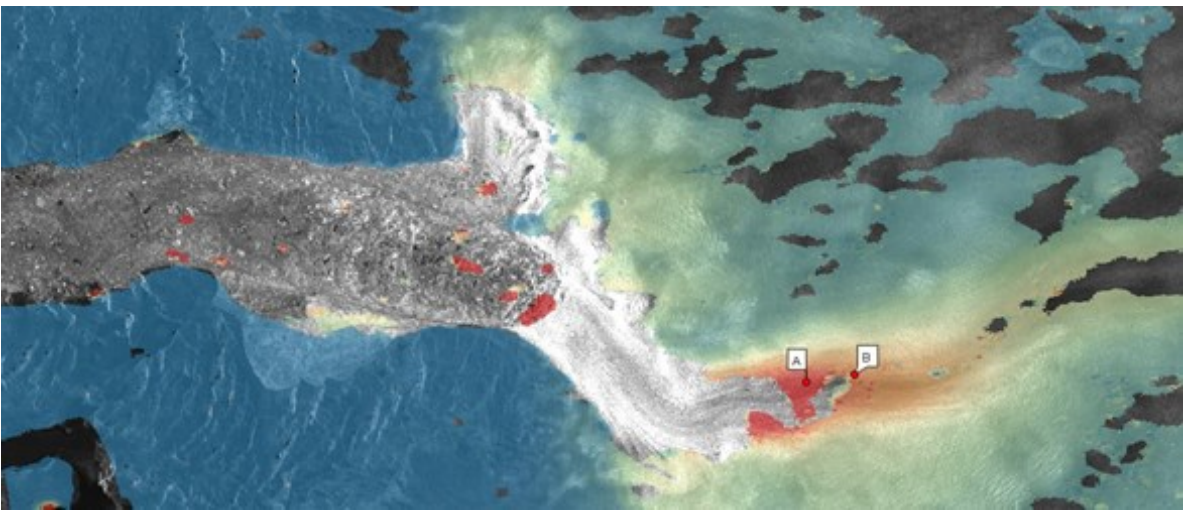
climate change initiative

→ ICE SHEETS NEWSLETTER

Issue n. 4 | May 2015



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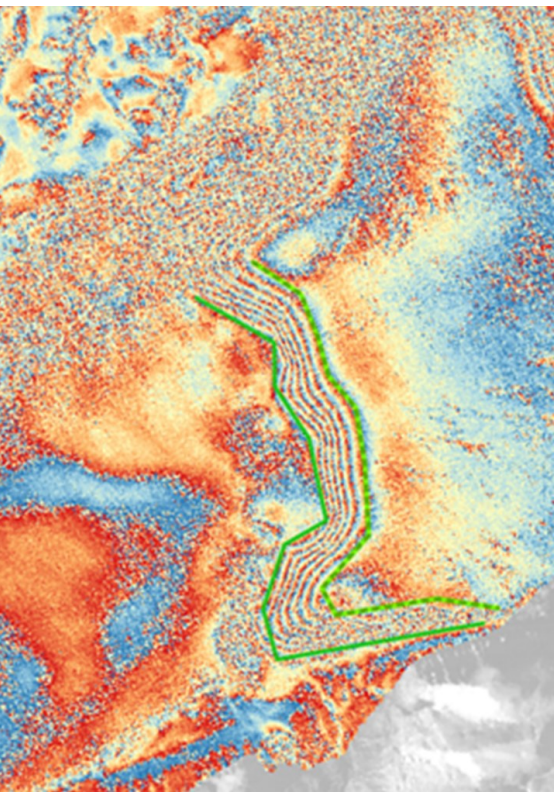

Ice Sheets CCI Project Releases Products

The **ESA Ice_Sheets_cci** project was initiated in 2012 to investigate essential climate variables related to changes in the Greenland ice sheet. The results are now available.

The ESA Climate Change Initiative (CCI) was initiated by the European Space Agency (ESA) to ensure a coordinated effort in producing long and reliable climate records, and to improve availability of data products derived from long-term space-based measurements. The CCI program currently includes 13 different sets of Essential Climate Variables (ECVs), defined by the Global Climate Observation System (GCOS).

In 2012, the **Ice_Sheets_cci** joined the CCI with the intention to provide high quality science and climate products for the Greenland ice sheet. The ice sheet ECV parameters provide a consistent, long term data set for climate modelling and sea level changes, based primarily on ESA satellite sensors. The data extend back in time to the first ERS measurements in 1991, and they provide continuity with future satellite missions such as those of the Sentinel programme.

The following Essential Climate Variable (ECV) parameters are tracked:

- **Surface Elevation Change (SEC),**
- **Ice Velocity (IV),**
- **Grounding Line Location (GLL),**
- **Calving Front Location (CFL).**

Products are available for download from

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

For further instructions on how to download the prototype products turn to page 9.

ABOVE: Processing of Ice Velocity (IV) data, (see page 2-4) **LEFT:** Detail from Grounding Line Location (GLL) product (see page 6). **BOTTOM:** CCI Ice Sheets partner logos.

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Ice Velocity (IV) Data products

Within phase one of the CCI Ice Sheets project, ice velocity maps have been generated by applying offset tracking techniques to both ERS-1/2, ENVISAT ASAR and ALOS PALSAR data.

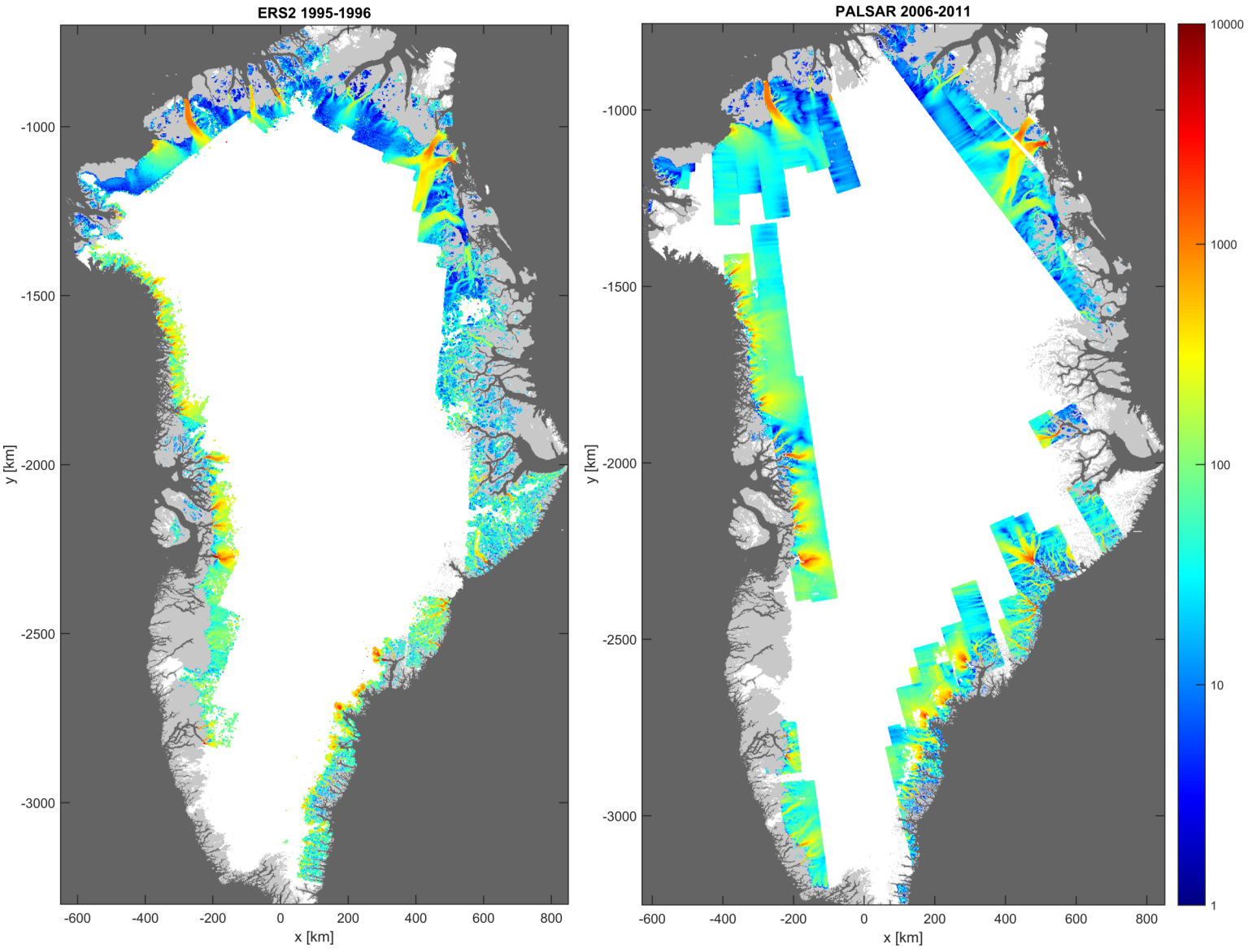
Large-scale maps have been generated covering:

- the margin of the Greenland ice sheet: winter 1995/1996
- the margin of the Greenland ice sheet: winters 2006-2011
- the Northern Drainage Basins: winter 1991/1992
- the Upernavik Glacier (time series)
- the Jakobshavn Glacier (time series)

The velocity maps are accompanied by quality maps, i.e. the estimated standard deviation of the velocities on a pixel basis.

The 1995/1996 map of the margin is based on ERS-1/2 data with a repeat cycle of 35 days and the 2006-2011 maps are based on ALOS PALSAR data with a repeat cycle of 46 days.

The maps have been generated by mosaicking and averaging all available acquisition pairs within the period. Consequently the maps are best interpreted as average ice velocities for the entire winter period, although the dispersed temporal coverage of the available acquisitions means that different parts of the maps may be based on different acquisitions within the period.



LEFT IV Map of margin from 1995/1996 ERS+1/2 data. The colour-scale is shared between the two plots. **RIGHT:** IV Map of margin from 2006-2011 ALOS PALSAR data.

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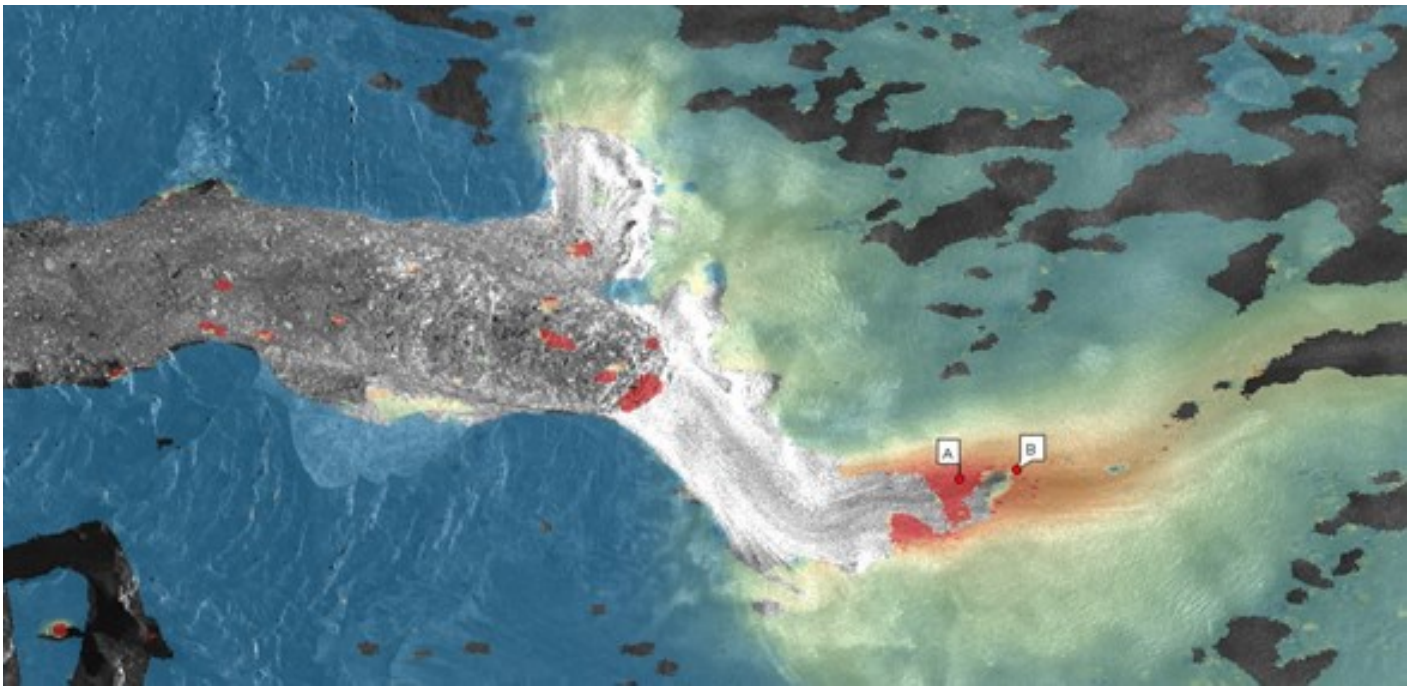
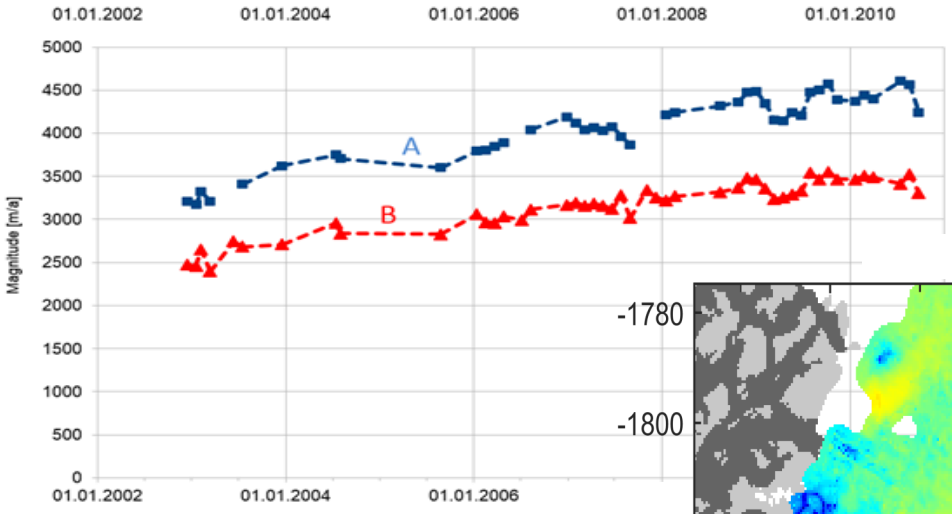
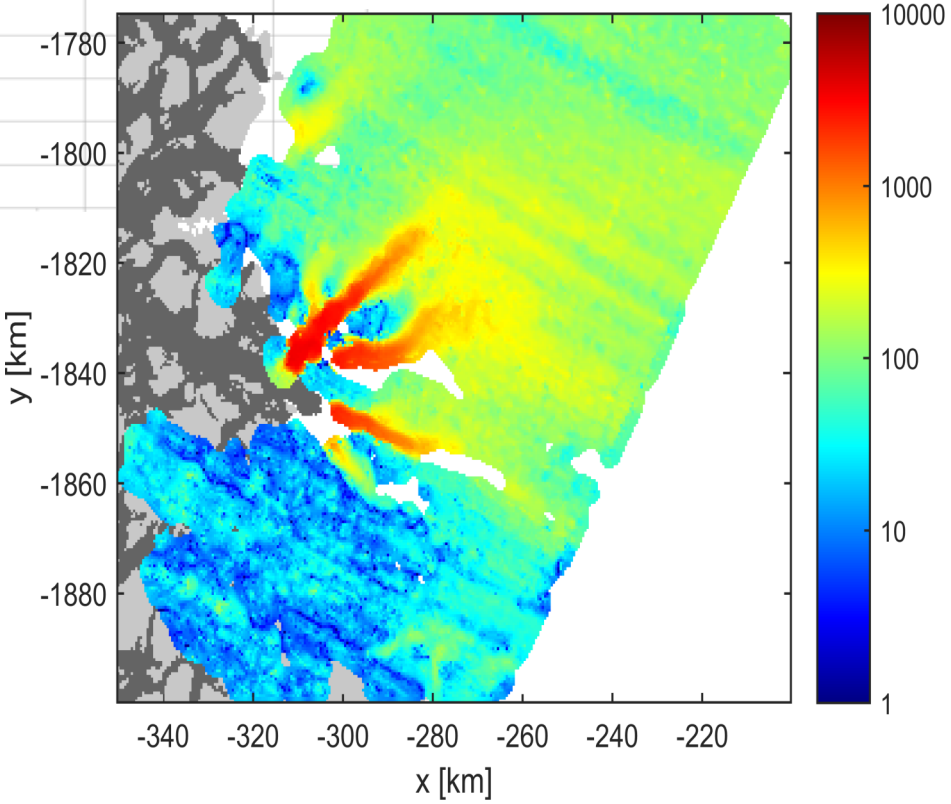




ABOVE: IV Map of Jakobshavn glacier from ENVISAT ASAR 24 Feb 2010 to 31 Mar 2010.

LEFT: Time series of horizontal ice velocity at points A and B in the IV Jakobshavn plot (above).

BELOW: IV Map from the Upernavik Glacier time series showing January 1992.



The time series of the Upernavik glacier complex in West Greenland is based on ERS-1/2, ENVISAT ASAR and ALOS PALSAR data. Data from the period 1992 to 2011 have been processed. The ice velocity time series of Jakobshavn glacier is based on ENVISAT ASAR data with 35 days repeat acquisitions from 2002 to 2010. The frequency of maps varies with data availability.

In-situ GPS measurements overlapping in time and space were available for the margin of the Greenland ice sheet: winters 2006-2011 and the Upernavik time series and were used for validation. Results of the validation yield generally good agreement and may be seen in the Product Validation and Intercomparison Report (PVIR) document.

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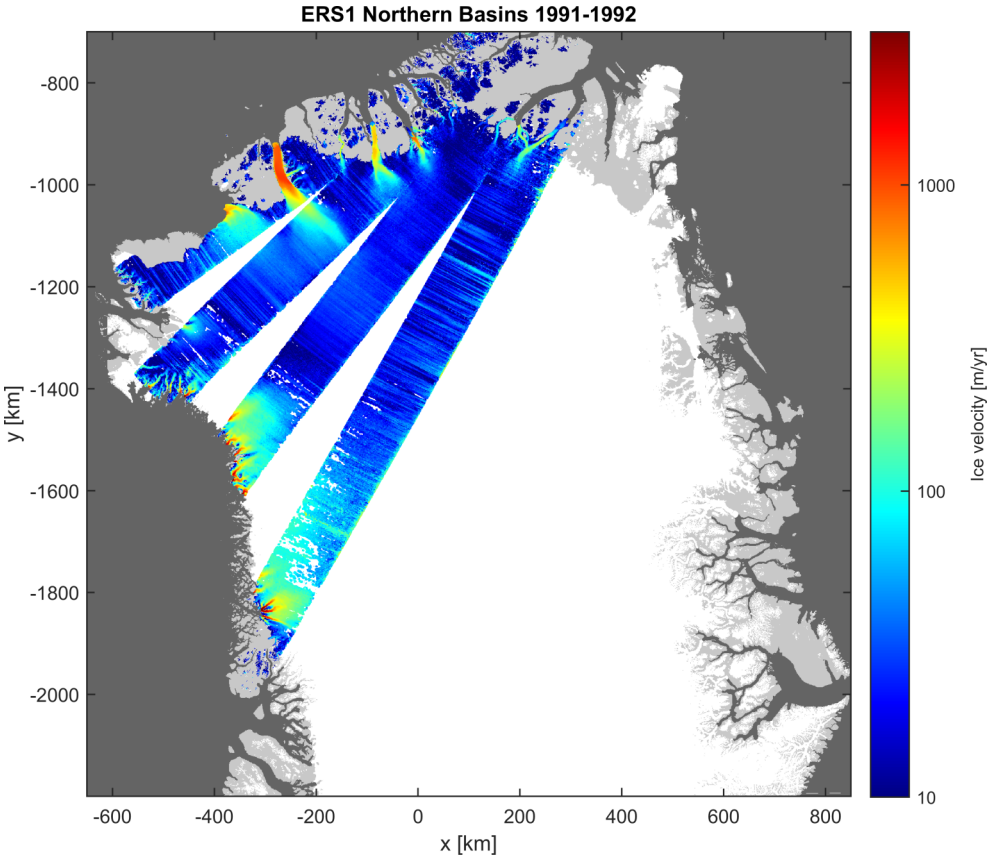
The map of the Northern Drainage Basins is based on ERS-1/2 data from the 3-days ice phase in 1991/1992. With a repeat cycle of 3 days, full coverage is not obtained, hence the finger pattern (right). In this case all available acquisition pairs have not been mosaicked and averaged, as the 3-days pairs have been excluded. Due to severe solar activity during the winter 1991/1992, the Northern Drainage Basin maps are highly affected by ionospheric interference, mainly apparent as streaks in the along-track velocity component. The 3-days pairs are excluded in order to increase the ratio of the true ice displacements to the apparent displacements induced by the ionosphere.

RIGHT: Northern drainage basins 1991-1992 from ERS-1. With a repeat cycle of 3 days, full coverage is not obtained, hence the finger pattern.



Surface Elevation Change (SEC) Data products

Twenty years of processed radar altimetry reveals a speed-up of thinning in the coastal areas of Greenland.

The SEC consortium has processed satellite radar altimetry data from the ERS-1, ERS-2 and Envisat satellites. The ERS-1 and ERS-2 data were provided following successful completion of the Reprocessed ESA ERS Altimetry (REAPER) project. The altimetry data were analysed using two different methods: the repeat-track method and the crossover method. These two were subsequently merged using kriging/collocation. The result is a dH/dt estimate for five-year intervals spanning the time frame 1992-2012.

Shown below are three such time periods as an example. The top row shows the change of the surface whilst the bottom row shows the associated errors. Errors are largest in coastal areas, where the altimeter struggles with steep topography. Errors are also large in between satellite tracks. Over flat terrain, the errors are lower.

For the first period, 1996-2000, some thickening can be seen in the northeast and the central south of the ice sheet. Thinning appears moderate.

For the second period, 2001-2005, pronounced thinning is visible in the west of the ice sheet. This is the location of the Jakobshavn Isbræ glacier which is known to be melting at an increased speed.

By the final period, 2006-2010, widespread thinning can also be observed along the northwest coast of Greenland. This area comprises in excess of twenty glaciers. In addition, parts of south-eastern Greenland also show an accelerated thinning signal. This area is home to the Helheim glacier, one of the largest outlet glaciers in SE Greenland. The signal in NE Greenland is more complex. An area of accelerated thinning, comprising the 79 Fjord and the Zachariæ Ice Stream, is located north of an area thickening. This thickening signal comes from the Storstrømmen glacier which experienced a large surge between 1978 and 1984 and which is thickening at present in response to this surge.

The SEC product represents a major advancement in our understanding of the behaviour of the Greenland Ice Sheet, providing an unprecedented level of detail reaching all the way to the margin of the ice sheet. The dH/dt estimates indicate that the surface of the Greenland Ice Sheet is thinning at increasing rates along large coastal areas. If this pattern of thinning persists, the associated ice melt will have a large effect on sea level rise in the 21st century. It is envisaged that the SEC product will be incorporated into ice sheet models used for predicting changes in polar areas.

After successful completion of Phase I of the CCI project, in Phase II new data sources will be incorporated into the SEC product such as Cryosat-2 and Sentinel-3.

TOP RIGHT: Mean 5-year surface elevation changes and their associated errors (**BOTTOM RIGHT**).

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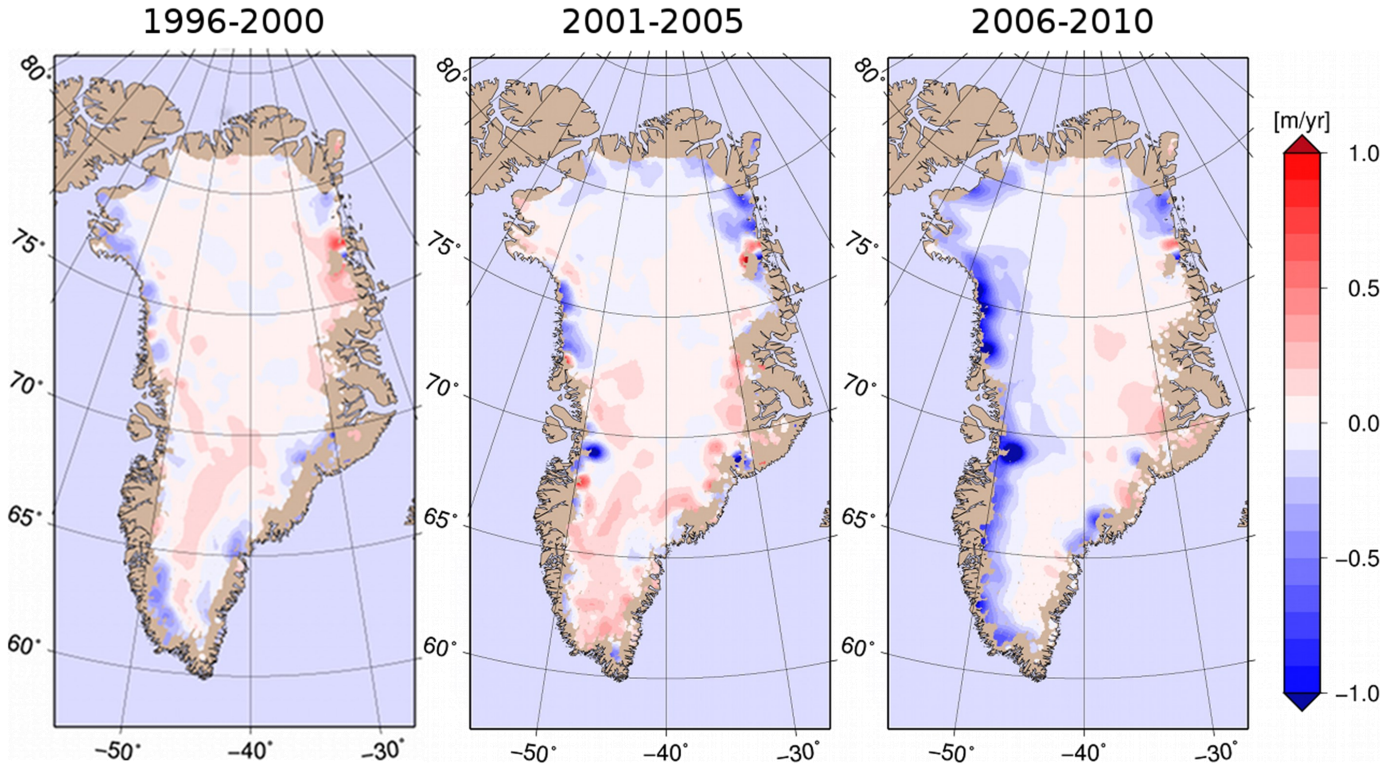
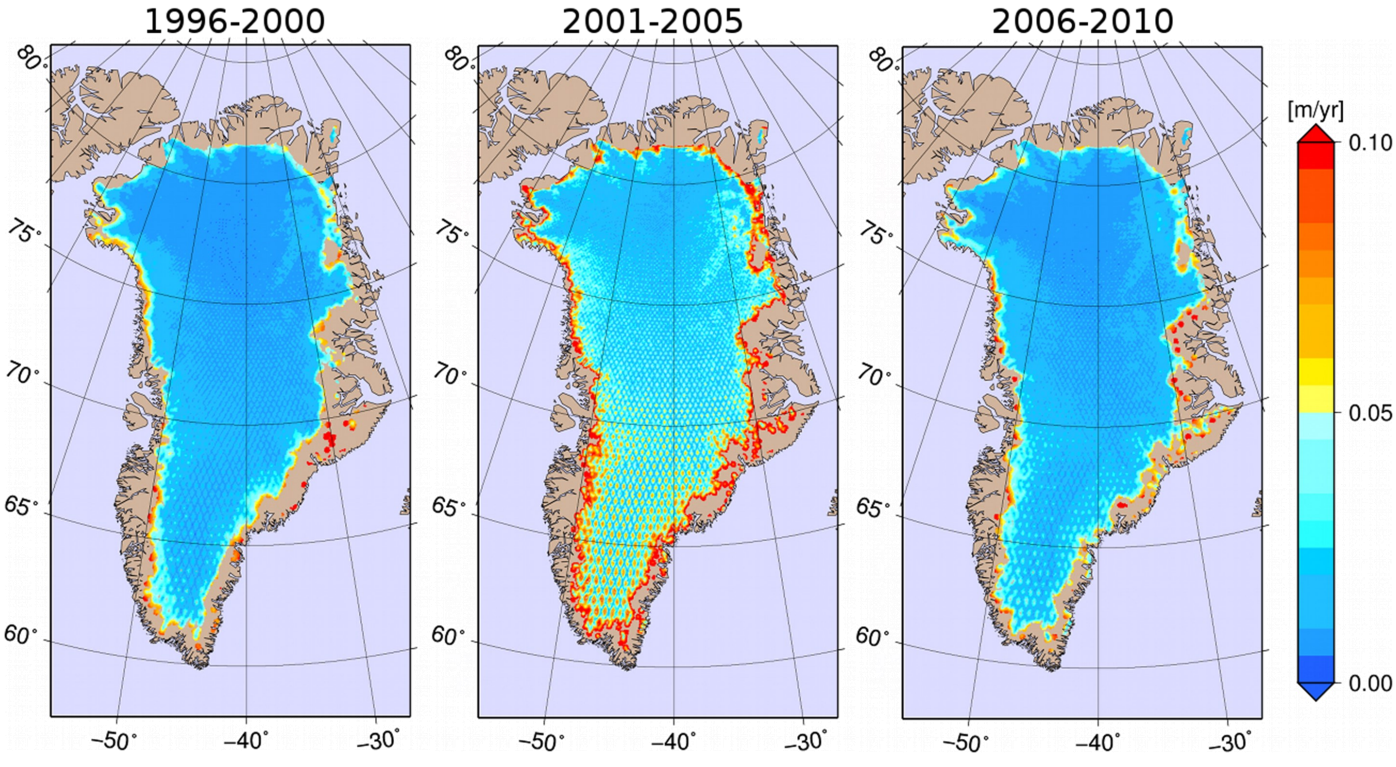
Mean 5-year surface elevation changes



Associated errors



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Seasonal and Interannual variations of the Calving Front of Greenland Outlet Glaciers

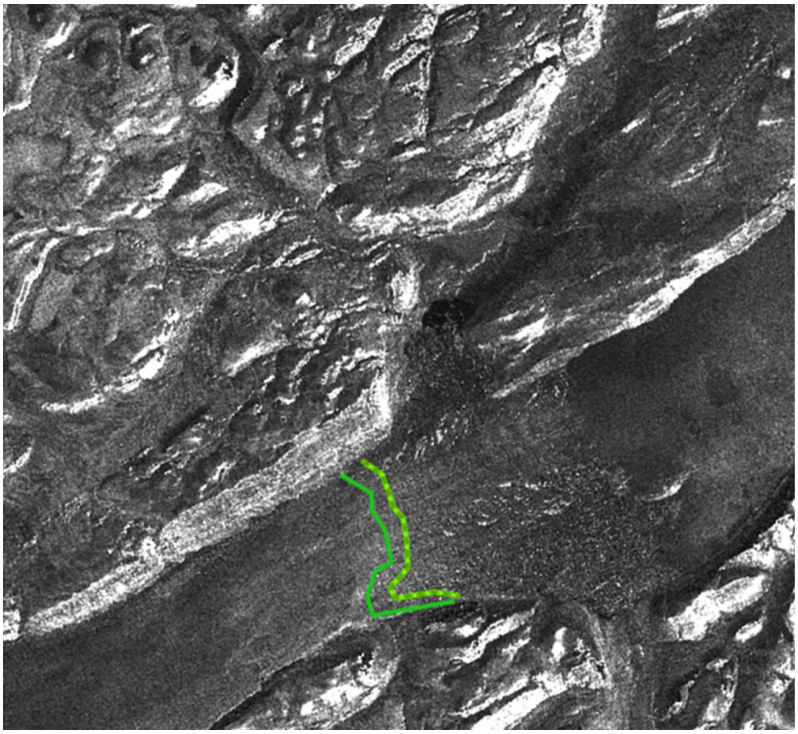
Time series of Calving front locations are used in modelling the ice dynamics of ice sheets, areal changes of out let glaciers. Long term trends in the CFL provides first insights into the mass balance of outlet glaciers.

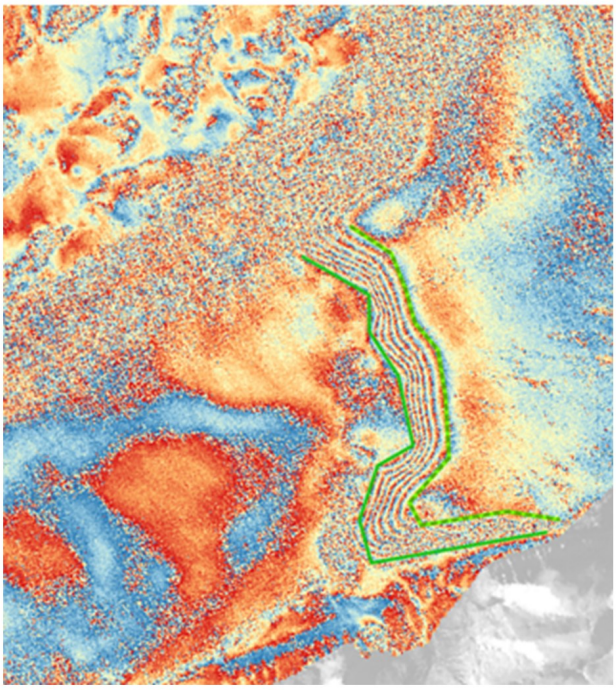
Within phase 1 of the ice sheet cci project we analysed time series of SAR data in order to monitor the interannual variation of 28 major tidewater glaciers of the Greenland ice sheet (preferable during summer). In addition, seasonal variations of the frontal position was mapped for 6 main outlet glaciers of the Greenland ice sheet. The main input data are SAR data acquired by ERS SAR and ENVISAT ASAR operating in Image Swath Mode, providing a time series from 1992 to 2010, depending on the SAR data availability. With the launch of Sentinel-1A in April 2014 a new era for monitoring ice sheets started. First CFL products from Sentinel-1A have been produced and included in the data package. Data gaps in the time series of CFL product result from missing SAR data.

The CFL production includes automatic extraction and geocoding of the SAR data covering the glacier termini and applies a manual delineation of the glacier front within a GIS system. The CFL product are stored as vectors in shape file format, and includes detailed metadata information on geographical coordinates and map projection, the SAR data used to generate the product. In addition, the material in front of the glacier terminus, which can be open water sea ice, sea ice melange, is annotated as it might affect the manual delineation accuracy of the frontal position.

Grounding Line Location

The location of the transition from grounded to floating ice (the grounding zone) of marine terminating glaciers and its temporal variation is of high interest for icesheet modelling, and for understanding the response to ice masses to changing oceanic and atmospheric boundary conditions. From Earth observation the grounding zone can be mapped only indirectly by observing ice surface features related to the position of the grounding line. Phase-1 of the ice sheet CCI project focussed on SAR interferometry for mapping the sea and landward limit of tidal deformation, which is related directly to the change from grounding to floating of the ice. The method requires repeat pass SAR data acquired within a short period of a few days only (e.g. ERS Tandem Phase with 1 days repeat acquisitions). Based on the formed double differenced interferograms the delineation of the sea and land-wards limit of the tidal deformation zone is carried out manually. The GLL products are stored as vector files in shape file format and included metadata information on used SAR images and processing system.





THIS PAGE: GLL product for Hagen Glacier. Amplitude image and interferogram (double differenced) from repeat pass ERS 1 and ERS-2 images acquired on 28/29 October 1995 and 16/17 March 1996.

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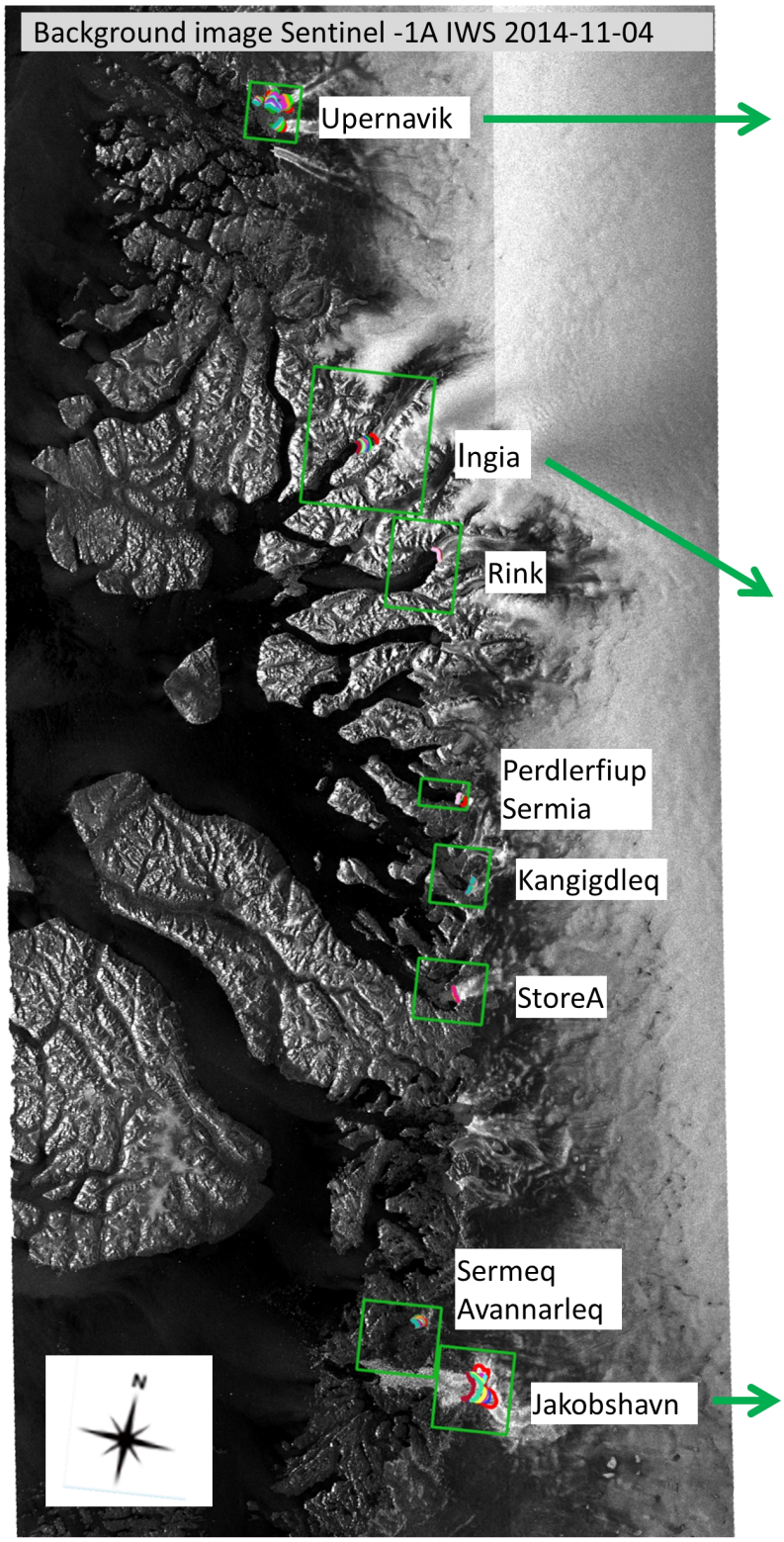

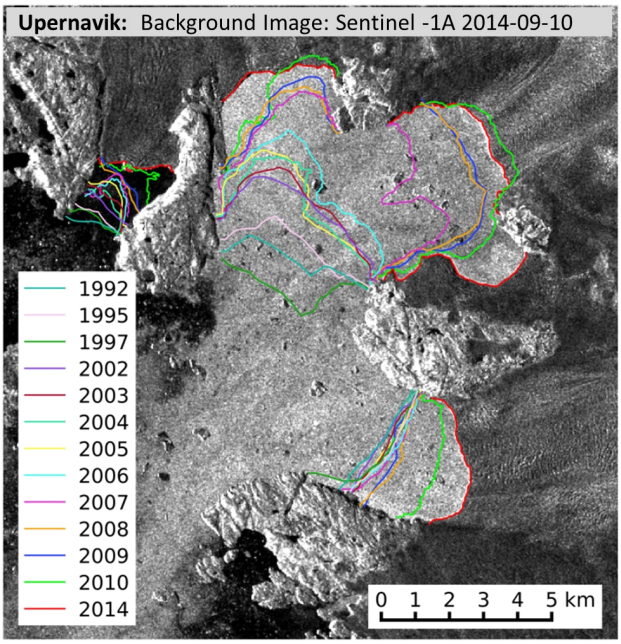

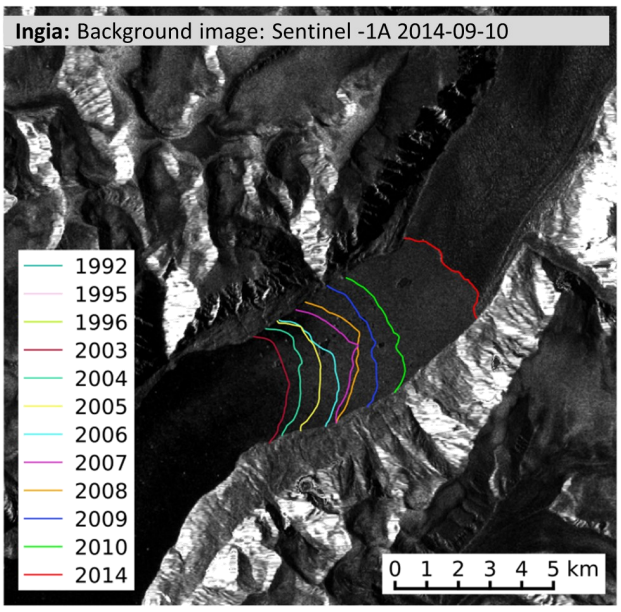

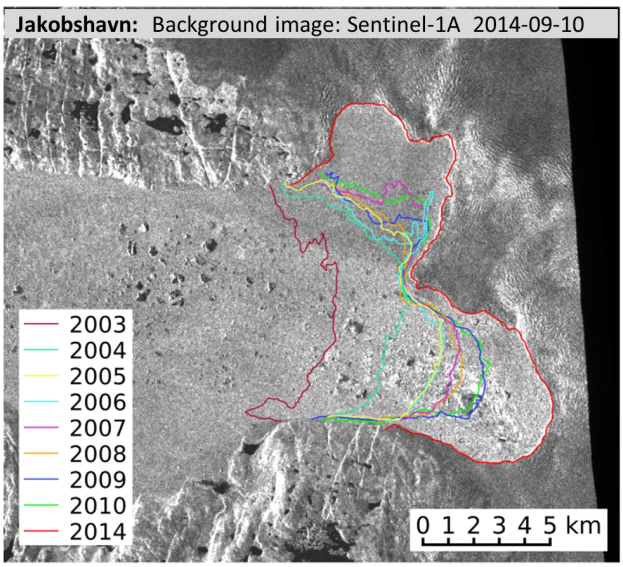

THIS PAGE: Time series of calving front locations of outlet glaciers in West Greenland, and detailed view to selected glaciers. The CFLs are based on ERS, ENVISAT and Sentinel-1 SAR images. CFLs are colour coded according to the legend. The CFLs are overlaid on the amplitude image of Sentinel-1A TOPS IWS, acquired on 10.9. 2014.

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The Ice_Sheets_cci Consortium

Our project team consists of the following partners from Austria, Denmark, Norway, and the United Kingdom.

- **Technical University of Denmark, National Space Institute**
  Scientific lead; Ice Velocity (IV) processor development lead; Surface Elevation Change (SEC) processor development.
- **The Danish Meteorological Institute (DMI)**
  End user representative of the modelling community.
- **ENVironmental Earth Observation IT GmbH (ENVEO)**
  Calving Front Location (CFL) processor development lead; Grounding Line Locatino (GLL) processor development lead; system engineering; scientific system development lead.
- **The Geological Survey of Denmark and Greenland (GEUS)**
  Product validation lead.
- **The Nansen Environmental Remote Sensing Center (NERSC)**
  Surface Elevation Change (SEC) processor development.
- **The Niels Bohr Institute (NBI)**
  User requirements lead; modelling community member.
- **Science [&] Technology AS (S[&]T)**
  Technical project management; system engineering lead; system development lead.
- **University of Leeds (UL), School of Earth and Environment**
  Surface Elevation Change (SEC) processor development lead. system development; product generation.

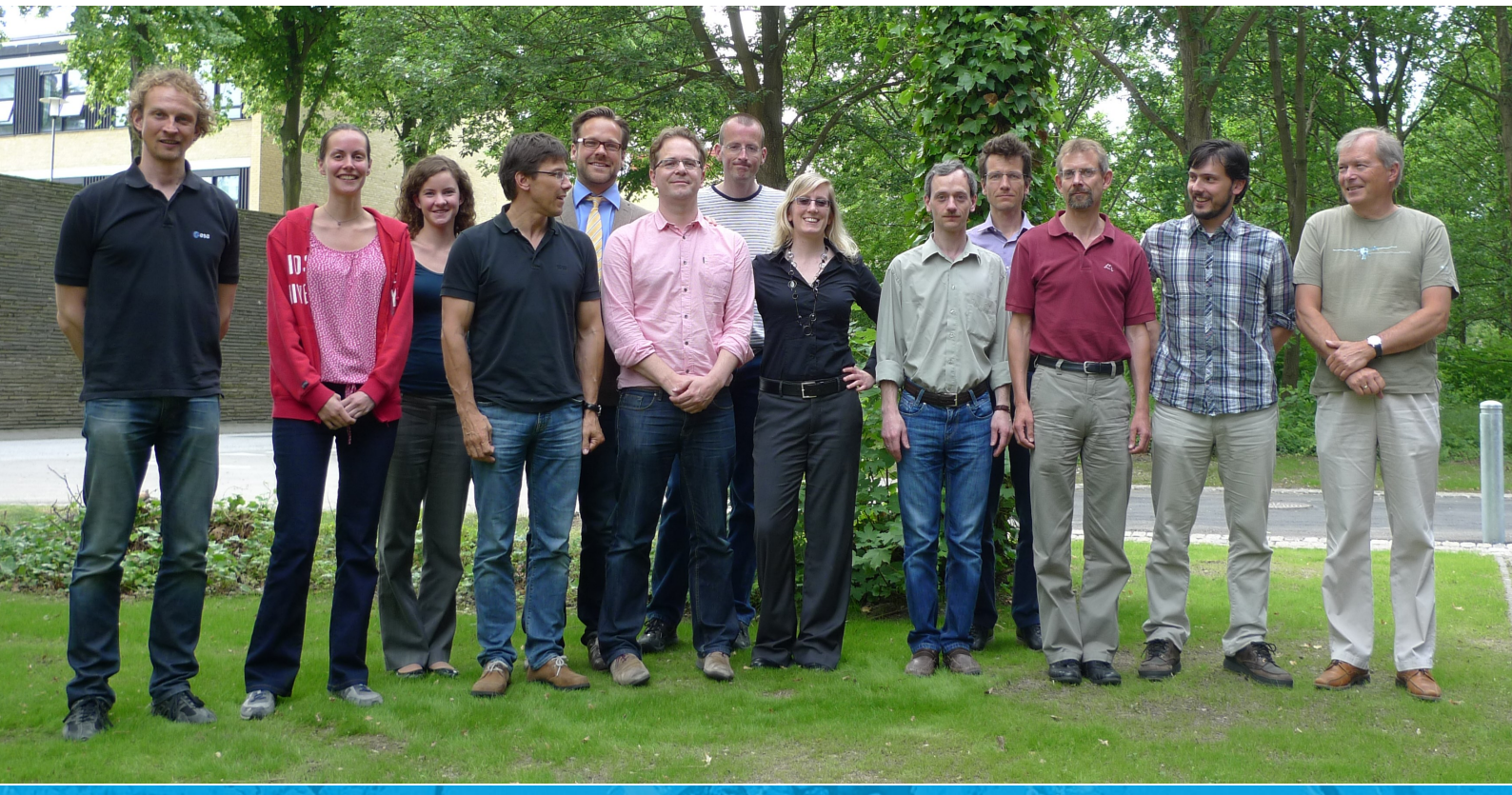
The Climate Research Group (CRG)

The Climate Research Group is a panel of experts invited to be part of the project as external reviewers and advisors.

The main role of the Climate Research Group is to review documentation produced by the consortium, assess requirements and corresponding product specifications, and to a limited degree take part in science meetings within the Climate Change Initiative (CCI) framework. The CRG consists of the following experts:

- **Dr. Andreas Ahlstrøm (CRG Lead)**,
  The Geological Survey of Denmark and Greenland (GEUS);
- **Dr. Gudfinna Adalsgeirsdottir**,
  University of Iceland, Reykjavik;
- **Prof. Dr. Michiel van den Broeke**,
  University of Utrecht;
- **Prof. Jon-Ove Hagen**,
  University of Oslo (UiO);
- **Dr. Ian Howat**,
  Byrd Polar Research Center, Ohio State University;
- **Dr. Heikki Järvinen**,
  Finnish Meteorological Institute (FMI);
- **Dr. Ian Joughin**,
  Polar Science Center, APL, University of Washington.

BELOW: Ice_Sheets_cci at the leafy DTU campus. From the left: M. Engdahl (ESA), J. Levinsen (DTU), A. Hogg (ESA), T. Nagler (ENVEO), D. Evensberget (S[&]T), A. Shepherd (UL), M. Kamstra (S[&]T), C. Aas (S[&]T), K. Khvorostovsky (NERSC), M. Hetzenecker (ENVEO), J. Dall (DTU), J. Boncori (DTU), R. Forsberg (DTU) [Photo M. Engdahl].



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Download the CCI Ice Sheets Products

The CCI Ice Sheet data products are on-line. To download the data, please go to **http://products.esa-icesheets-cci.org/** and follow these steps:

Fill in the simplified registration form by clicking on 'register', then enter the following information about yourself:

- Your name in the following form: Firstname.Lastname,
- your organisation, and
- your email address.

Choose your password and click 'Register'. Click 'log in' and provide (again) your name on the form Firstname.Lastname, and the password you previously picked. The SEC, IV, CFL and GLL data products may now be downloaded.

Download our data products!

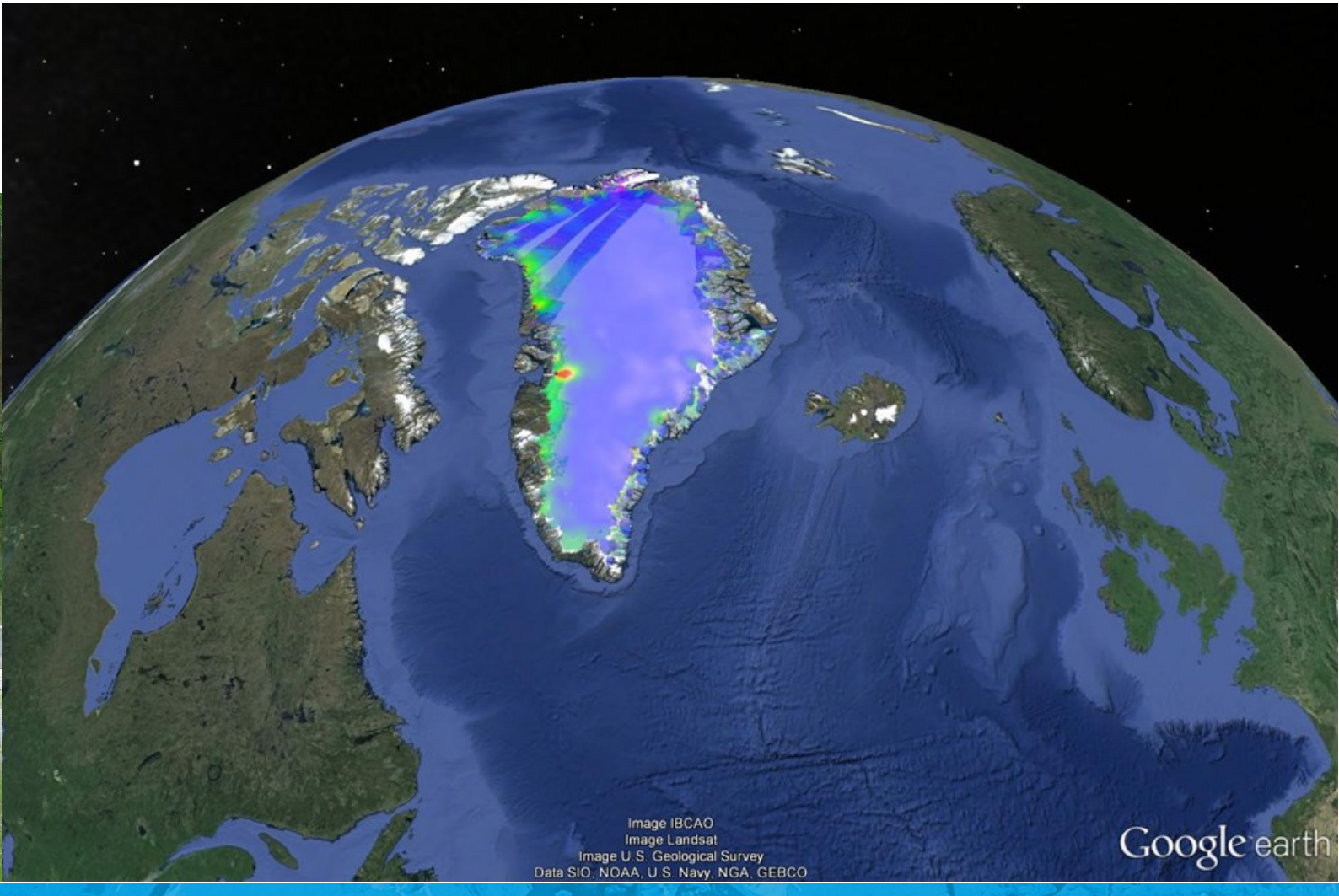
Data Product Visualization in Google Earth

A visualisation of the Ice_Sheets_cci data products has been made in Google Earth and is available for viewing and download at **http://www.esa-icesheets-cci.org/**

In the visualisation, Surface Elevation Change (SEC) data and Ice Velocity (IV) data are shown as partly transparent overlays. Calving Front Location (CFL) data is show as polygons. The user may navigate and zoom using the relatively familiar Google Earth interface. The Google Earth application must be installed to view the file.

The data is temporal in nature. Different time intervals may be set and an animation of the data evolution in time can also be viewed.

BELOW: Visualization of SEC and IV data in Google Earth. Of note is the Jakobshavn glacier area (in red) where the Ice Velocity and the Surface Elevation Change are both large.



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Outreach, Conferences, and Publications

Scientific publications and outreach activities are important elements of the Climate Change Initiative. This is a list of papers and papers in preparation based on Ice_Sheets_cci results:

R. Forsberg, L. S. Sørensen, J. Levinsen, D. Evensberget, M. Kamstra, S. B. Andersen, J. Dall, A. Kusk, C. Hvidberg, K. Khvorostovsky, T. Nagler, K. Scharrer, A. Shepherd, F. Ticconi. "Ice_Sheets_cci: Essential Climate Variables for the Greenland Ice Sheet" ESA-Clic Earth Observation and Cryosphere Science, Frascati, November 2012.

J. Levinsen, K. Khvorostovsky, F. Ticconi. "Validation and inter-comparison of surface elevation changes derived from altimetry over the Jakobshavn Isbræ drainage basin, Greenland – Round Robin results from ESA's Ice_Sheets_cci" European Geosciences Union (EGU) meeting. Vienna, April 2013.

F. Ticconi, J. Levinsen, K. Khvorostovsky, R. Forsberg, A. Shepherd. "Preliminary Results of the Ice_Sheets_cci Round Robin Activity on the Estimation of Surface Elevation Changes" IGARSS. Melbourne, July 2013.

Levinsen, J. F. "ESA Ice Sheets CCI: Derivation of the optimal method for surface elevation change detection of the Greenland Ice Sheet – Round Robin results" International Journal of Remote Sensing.

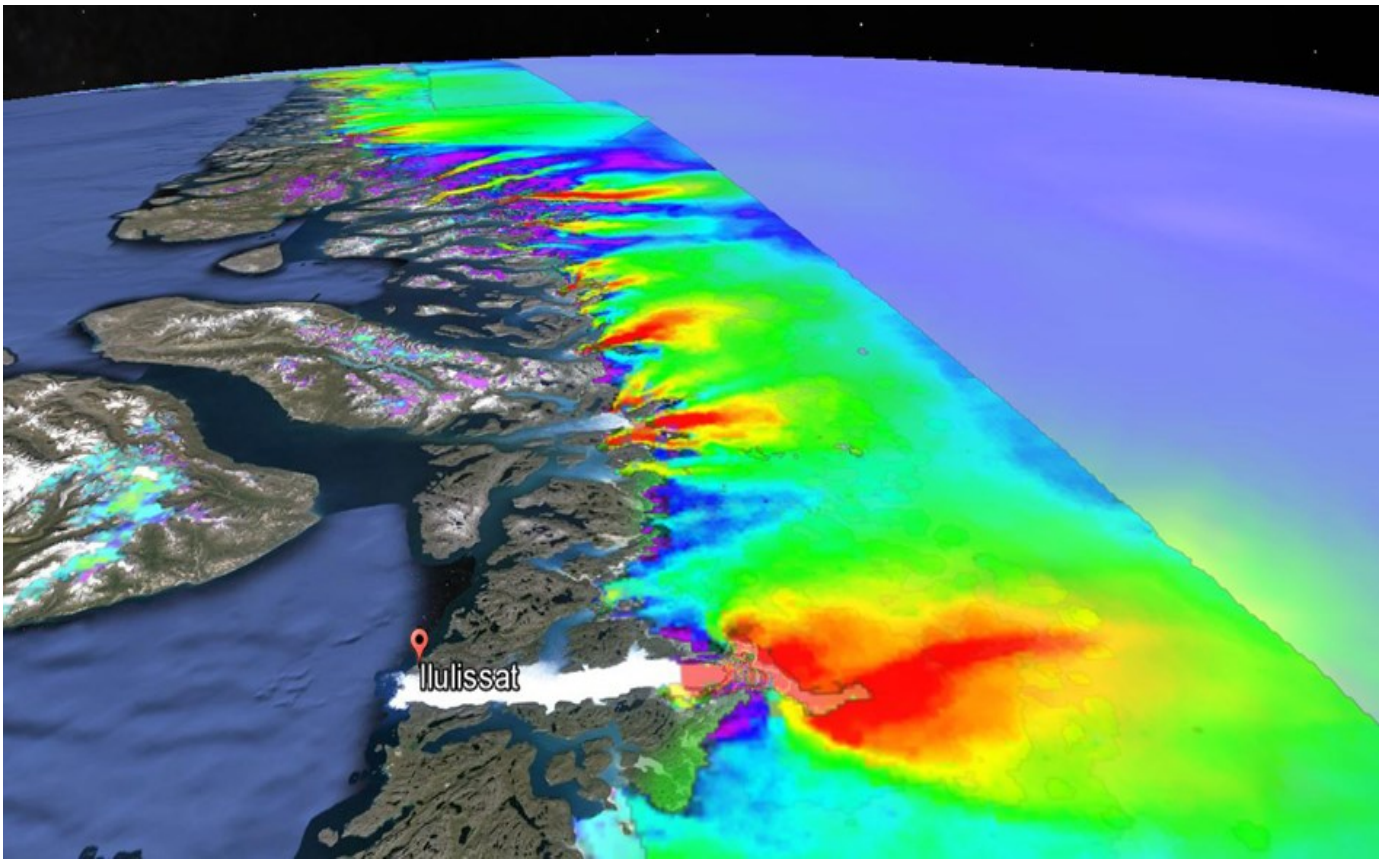
Sørensen, Louise Sandberg; Simonsen, Sebastian Bjerregaard; Meister, Rakia; Forsberg, René; Fredenslund Levinsen, Joanna; Flament, Thomas. "Envisat-derived elevation changes of the Greenland ice sheet, and a comparison with ICESat results in the accumulation area" Remote Sensing of Environment, Vol. 160, 2015, p. 56-62.

J. Nilsson, P. Vallelonga, S.B. Simonsen, L.S. Sørensen, R. Forsberg, D. Dahl-Jensen, M. Hirabayashi, K. Goto-Azuma, C.S. Hvidberg, H.A. Kjær, and K. Satow (2015): "Greenland 2012 melt event effects on CryoSat-2 radar altimetry" GRL in press.

R. Forsberg, L. Sørensen, J. Levinsen, J. Nilsson: "Mass loss of Greenland from GRACE, IceSat and CryoSat". Proceedings of the CryoSat Workshop, Dresden, March 2013. ESA Special Publication 717 paper S6-4.

J. Dall, A. Kusk, U. Nielsen, J.P.M. Boncori, "Ice velocity mapping using TOPS SAR data and offset tracking", FRINGE 2015 workshop, Frascati, March 2015.

BELOW: Ilulissat (site of the next project meeting) and nearby ice streams. Ice Velocity magnitude data is displayed along the margin. In the interior Surface Elevation Change data is displayed. CLF delineations are visible at the Jakobshavn Glacier east of Ilulissat.



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