climate change initiative

→ SEA ICE NEWSLETTER

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Arctic sea ice north of Svalbard, consisting mainly of firstyear ice 1–2m thick. The iceberg is about 20 m long and 7-8 m deep. ©NERSC

In this issue:

Sea ice extent observed for more than three decades

Sea ice in the Polar seas is one of the most important climate change indicators. In the Arctic, sea ice extent has been reduced significantly in the last decades, especially in the summer season. This reduction has been documented from satellite passive microwave data collected systematically for more than three decades. In the CCI Sea Ice project new ice concentration data sets from Arctic and Antarctic have been produced from passive microwave data from SSM/I and AMSR-E . The ice concentration data sets are based on careful algorithm studies and systematic validation from a large number of sites in both the northern and southern seas.

In Phase 1 of the project (2012-2015), sea ice concentration (SIC) data sets have been calculated using the most accurate algorithm based on a detailed algorithm intercomparison study. This study has been used to select the optimal algorithm to produce SIC ECV data sets. Phase 1 has also included uncertainty estimation, providing error bars for SIC in every grid cell.

The SIC ECV data sets cover both the Arctic and Antarctic and consists of daily SSM/I-derived products from 1992–2008 and AMSR-E derived products from 2002-2011 (Fig. 1, next page). The SSM/I products are developed in collaboration with EUMETSAT OSI-SAF, which will be responsible for the long-term operational production of ice concentration data sets.

In Phase 2 (2015-2018) the SIC products will be improved by adding new features into the algorithm. Correction of brightness temperature will be done using a Radiative Transfer Model, tuned dynamically. The effect of land contamination, snow cover, melt conditions, and thin ice has been studied and will be included in next version of the algorithm.

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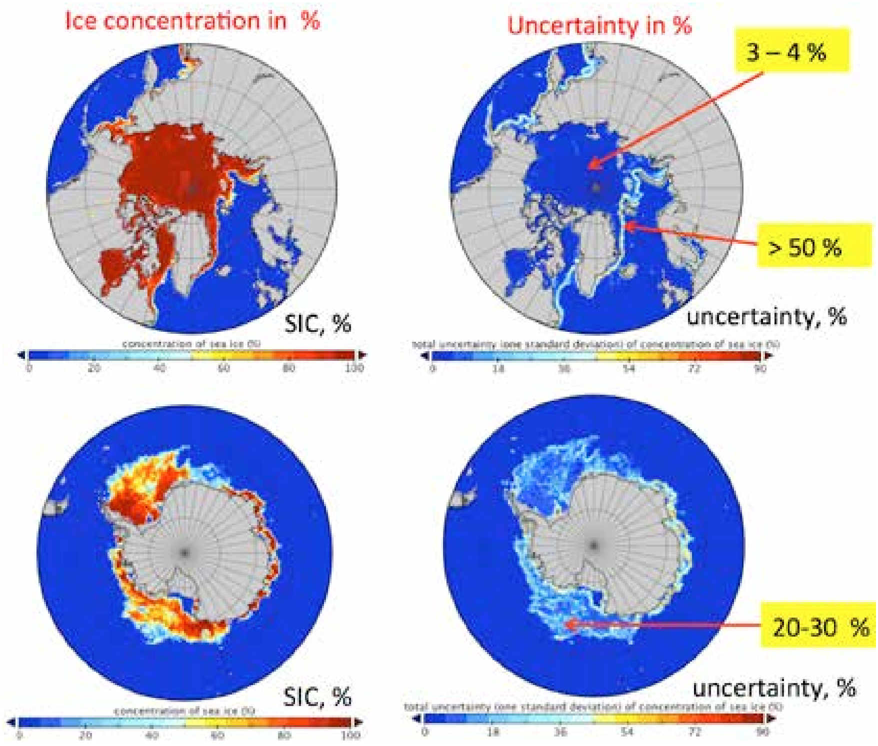
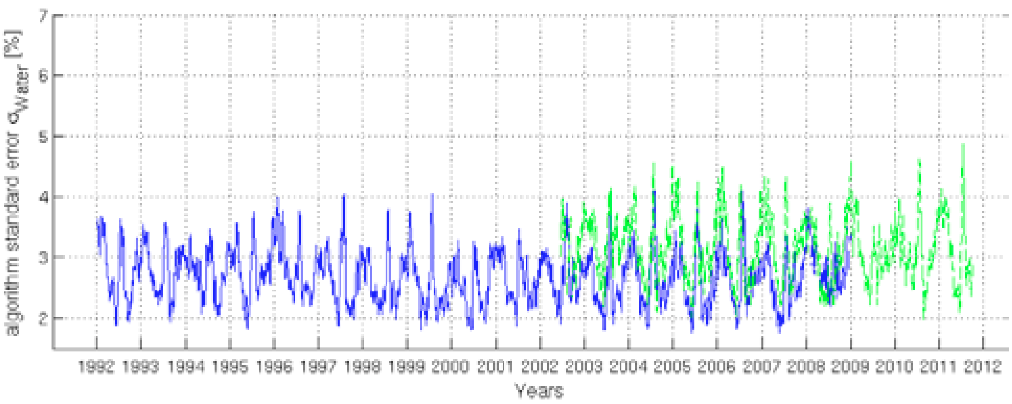


Figure 1. Sea ice concentration in the Arctic (upper figures) and Antarctic (lower figure) on 01 January 2008 from AMSR-E data (left) and uncertainty per grid cell of the ice concentration data from the same day (right). Note that uncertainty is highest in the ice edge region, while it is low (< 4 %) in the interior of the ice pack. In summer, the uncertainty is higher because snow properties are more variable and sea ice concentration varies more on sub-grid scale.



The uncertainties in the ice concentration estimates are provided per pixel for each day and can be shown as a map (Fig. 1). The overall uncertainty can be represented as a time series of the algorithm standard error for the SSM/I-derived data (1992-2008) and the AMSR-E- derived data (2002-2012), as shown in Fig. 2. The uncertainty estimate is in the range 2 – 4 % for ice concentration of 0%.

EUMETSAT OSISAF and ESA CCI will join forces in Phase 2 in order to produce an improved data set with the best possible accuracy. In 2016 the next version of a full reprocessed SIC ECV will be provided, where the total period of passive microwave satellite data from 1978 to present will be included.

OSISAF also produces near-realtime SIC data for daily monitoring of the ice cover in both Arctic and Antarctic. The time series of ice concentration are used to derive ice extent and ice area to monitor and quantify the annual variability and the long-term trends with uncertainty estimation.

A user group of about 30 people have tested the SIC ECV products from Phase 1 in various applications: validation of climate models and sea ice models, in testing of assimilation, and trends in the sea ice cover. The SIC ECV data set is assessed to be the best quality data set available so far. This is based on the algorithm intercomparison study and the provision of uncertainty estimates for each daily data set.

Figure 2: Time series of uncertainty of the SIC data sets (in %) derived from SSM/I and AMSR-E data during Phase 1. The uncertainty is expressed as an algorithm standard deviation over open water.nearly constant throughout the year because they are in controlled orbits.

Sea ice freeboard and thickness from radar altimetry

It was demonstrated during the 1990s that sea ice thickness can be derived from radar altimetry (Laxon et al., 2003). The concept is that very precise elevation measurements of the sea ice freeboard can be used to calculate the average thickness over a certain area. In Phase 1, the CCI Sea Ice project has used the concept to estimate freeboard and calculate ice thickness in the Arctic for the Envisat period (2002–2012). In Phase 2 the project will include ERS (1993-2002) and CryoSat (2010-2015) in order to provide two decades of freeboard and thickness data in both Arctic and Antarctic.

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The freeboard and ice thickness products cover the Arctic areas up to 81.5 N due to the inclination of ENVISAT. The products are monthly mean for the winter months (October to March) in 100 km grid cells (Fig. 3 and 4). The freeboard is calculated from the difference in elevation between echoes from ice floes and open water. An important assumption is that the radar signals penetrate the snow cover on top of the ice during the winter months.

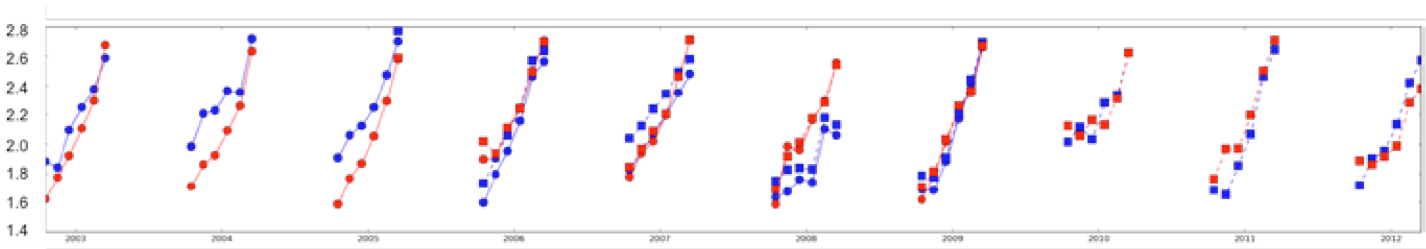

Figure 3. Timeseries of ice thickness (m) in the Arctic for the winter months October 2003 to March 2012 retrieved from Envisat radar altimeter data. The blue dots represent thickness in the western sector (10-180W) and red dots are for the eastern sector (0-180E). Circles are retrievals using multiyear data from Ifremer, while squares are retrievals using multiyear maps from OSISAF.

Ice thickness is calculated from freeboard by assuming that the ice is in hydrostatic equilibrium with water. The calculation requires reliable estimates of snow and ice density as well as snow depth.

The recent decline of multiyear ice has been shown to change the snow thicknesses in the Arctic. The snow depth on first year ice is approximately 50% of that given by the Warren et al. climatology, and some of the recent publications use Warren climatology modified over first year ice. It is not clear the Warren climatology, modified or not, is representative for the situation today. The snow climatology therefore needs to be further investigated in Phase 2.

A significant thickness bias was found in the Phase 1 validation. This was tracked to stem from ice density values used. In Fig. 3 the thickness retrievals use firstyear-multiyear classification to provide variable ice density and snow depth across the Arctic.

In Phase 2 the sea ice freeboard and thickness products will be further validated against other types of data obtained from in situ and airborne sensors, which observe different ice thickness parameters. In particular, the effect of snow and ice properties will be clarified in order to reduce the uncertainty in the thickness retrievals.

In the Antarctic, the sea ice characteristics are different from the Arctic, because the ice cover is more dominated by firstyear ice and a thicker snow cover. Radar altimeter data from Envisat and CryoSat-2 have been used to retrieve and compare freeboard for the overlapping period 2010-2012. The results show that there is good consistency between Envisat and CryoSat-2 (Fig. 5) freeboard estimates. This is an encouraging result suggesting that it is possible to construct a multi-mission freeboard time series. To calculate thickness from freeboard, however, is not straightforward due to the snow conditions in the Southern seas. We lack reliable snow thickness estimates and it is doubtful if the radar signal actually penetrates through the snow cover over ice in the Antarctic waters, as shown by comparison with IceSat laser altimetry. The study will be continued in Phase 2.

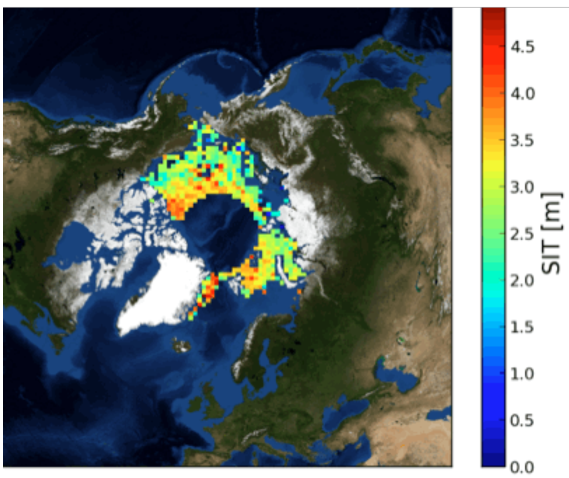

Figure 4. Map of monthly mean ice thickness for the Arctic in March 2004 based on Envisat radar altimeter data.

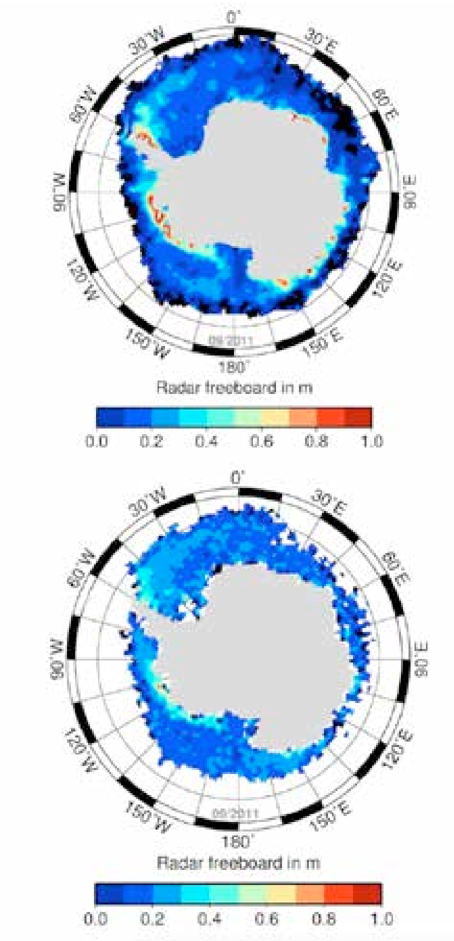

Figure 5. Freeboard in Antarctica derived from the radar altimeter on CryoSat-2 (upper figure) and Envisat (lower figure) for late winter when ice extent is at the maximum (September 2011).

References:

Laxon, S., N. Peacock, and D. Smith (2003), High interannual variability of sea-ice thickness in the Arctic region, Nature, 425, 947–950.

Warren, S. G.,et al.,(1999), Snow depth on Arctic sea ice, J. Clim., 12, 1814-1829.

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Sea ice drift

In addition to sea ice concentration and sea ice thickness, the most requested sea ice climate variable is sea ice drift (also known as sea ice motion). The climate community is in need for long-term, consistent, error-characterized time-series to evaluate model simulations and to supplement sea-ice drift data observed with ice buoys.

None of the existing sea ice drift datasets can be considered to be optimal for climate research. They are either not global, not up-dated, or not made into proper Climate Data Records (e.g. Rampal et al. 2011; Olason and Notz, 2014). The existing datasets also lack uncertainty information based on error propagation.

In Phase 2 an algorithm intercomparison exercise will be performed using a Round-Robin Data Package (RRDP) that co-locates satellite data with trajectories of buoys drifting with the ice. The satellite data will include both low-resolution data (passive microwave, scatterometer, etc.) and SAR data. The RRDP will enable an evaluation of existing as well as new algorithms in an unbiased and open manner, and the goal is to select the optimal algorithm for production of a sea ice drift ECV and estimate the uncertainties. The results will be published in refereed journals and be presented at workshops and conferences to ensure scientific quality and involvement of the EO and modelling communities. Implementation of a sea ice drift ECV is planned after Phase 2.

References

Notz, D., F. A. Haumann, H. Haak, J. H. Jungclaus, and J. Marotzke (2013), Arctic sea-ice evolution as modeled by Max Planck Institute for meteorology's Earth system model, JAMES, 5, 173–194, doi:10.1002/jame.20016.

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Rampal, P., J. Weiss, C. Dubois, and J.-M. Campin (2011), IPCC climate models do not capture Arctic sea ice drift acceleration: Consequences in terms of projected sea ice thinning and decline, J. Geophys. Res., 116, C00D07, doi:10.1029/2011JC007110.

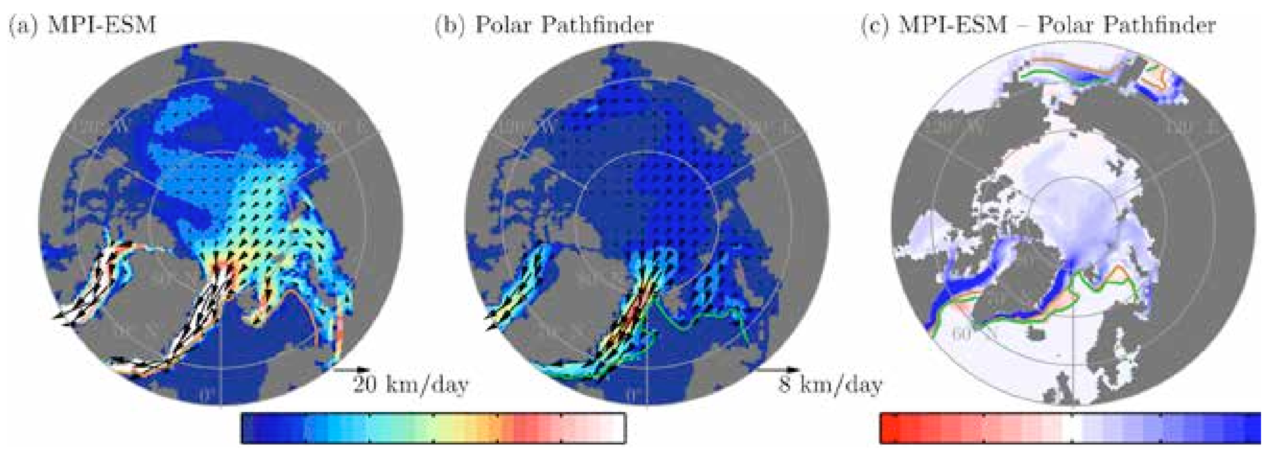

Figure 6. Comparison between mean modeled and observed March Arctic sea-ice drift vectors and drift speeds in the period 1979 to 2005: (a) simulated MPI-ESM-LR data; (b) satellite-derived Polar Pathfinder data; and (c) simulated minus satellite-derived drift speed data. (Notz et al., 2013).

Expected achievements in Phase 2

The CCI Sea Ice project will provide: 1) a consistent time series of ice concentration data for the Arctic and Antarctic based on passive microwave data obtained from a series of satellites from 1979 to present. This work will be done in collaboration with Eumetsat OSISAF. 2) a consistent time series of sea ice thickness from radar altimeter data in Arctic and Antarctic regions from 1993 onwards. There will be one full reprocessing of the ice concentration and ice thickness data sets during Phase 2. In addition, sea ice drift algorithms will be assessed and intercompared in preparation for a future sea ice drift ECV reprocessing, including uncertainties. The ECV data will be disseminated to a wider group users who will provide feedback and assessment of the data.

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