Regional Sea Ice Outlook for the Central Arctic Basin

Assessment of CryoSat-2 Results

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Sea-ice thickness data from ESA's CryoSat-2 radar altimeter mission indicates a heterogeneous pattern of thickness change in April 2017 compared to previous years in the CryoSat observational period (2011-2016). CryoSat data from April is used as initialization for model forecasting activities (e.g. Kauker et al., 2015; contribution of Kauker et al. (AWI Consortium) to sea ice outlook) since it is considered the latest reliable data product before the onset of melt and snow metamorphism. We therefore assess the AWI Cryosat-2 data product (Ricker et al., 2014; Hendricks et al., 2016) and its results for spring 2017 in the central Arctic basin.

Thickness fields from April 2017, the average of previous years and the April 2017 anomaly defined as the difference between April 2017 and average thicknesses are displayed in Figure 1. Key features of the April 2017 CryoSat thickness anomaly are:

Below-average thicknesses (negative anomaly) in the

1. multi-year sea ice region north of the Canadian archipelago
2. Chukchi sea area
3. Shelf areas in the East Siberian and Laptev Sea (not landfast sea ice)

Above-average thicknesses (positive anomaly)

1. between the north pole and the Chukchi Sea
2. at the ice edge north of Spitsbergen
3. in localized anomalies close to the coasts of Greenland, the Canadian Archipelago and mainland Canada
4. in the landfast ice in the East Siberian Sea

The magnitude of the thickness anomalies is variable but generally below 1 meter. Their locations suggest that the 2011-2016 mean April thicknesses are strongly influenced on regional scale by extreme events in individual years of the comparably short CryoSat observational period. For one, the presence of thin first year ice in 2016 might have shifted the 2011-2016 thickness average in the Beaufort Sea below 2017 levels. Similarly, high thicknesses in the multi-year ice region north of the Canadian Archipelago in spring 2014 (not shown) very likely led to the 2017 negative anomaly.

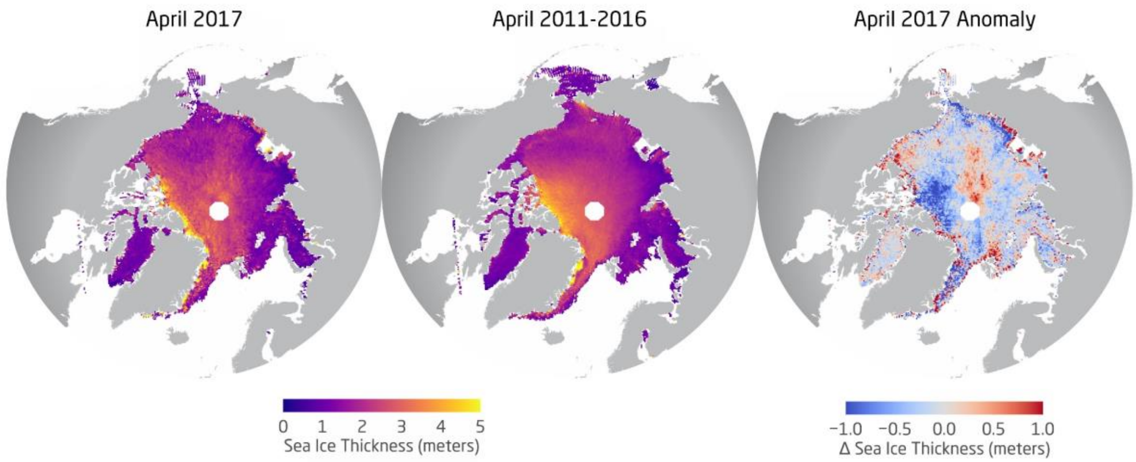

Figure 1. CryoSat sea-ice thickness maps from April 2017, April 2011-2016 average and the April 2017 sea-ice thickness anomaly. (Data source)

There are however two distinct features in the 2017 anomaly map that originate from the 2017 observations: 1) A negative anomaly in the Chukchi and East Siberian Sea north of the land fast ice zone, 2) a positive anomaly between the Chukchi Sea and the north pole and 3) a positive anomaly north of Spitsbergen. While the negative anomaly led to an already observed early sea ice retreat (see Regional Sea Ice Outlook for the Bering-Chukchi-Beaufort Seas by M. Druckenmiller in June 2017 Sea Ice Outlook), the two positive anomalies may add to the resilience against summer melt.

The AWI CryoSat-2 data product uses a modified snow depth climatology and thus the accuracy of sea-ice thickness will be degraded for actual snow conditions that deviate significantly from climatological values. We therefore use airborne data sets of total (snow + ice) thickness from the ESA CryoSat Validation Experiment (CryoVEx) and the AWI Polar Airborne Measurements and Arctic Regional Climate Model Simulation Project (PAMARCMIP) for a first assessment of CryoSat-2 result in April 2017 (see Figure 2). We added the snow depth climatology to the CryoSat sea-ice thickness for consistency with the airborne electromagnetic (AEM) total thickness results. The airborne data is projected on the CryoSat data grid and results from seven surveys between Fram Strait in late March to the Beaufort/Chukchi Sea areas in early April are compared to the April 2017 CryoSat monthly composite. Though we observe a significant but expected point-to-point scatter, we do not find an indication for an overall bias between the two retrievals. The respective mean total thicknesses only differs by 8 cm (CryoSat: 2.57m; AEM: 2.65m), a value well within the uncertainties of both methods. The available AEM thickness data is however regionally limited and does not extent into the central Arctic Ocean. Results from the NASA Operation Ice Bridge campaign in 2017 are not available at the time of this report but data from the extended flight program in the Eastern Arctic (Nathan Kurtz, NASA Operation IceBridge 2017 Arctic spring campaign: Final summary) may provide further inside into the positive CryoSat thickness anomaly.

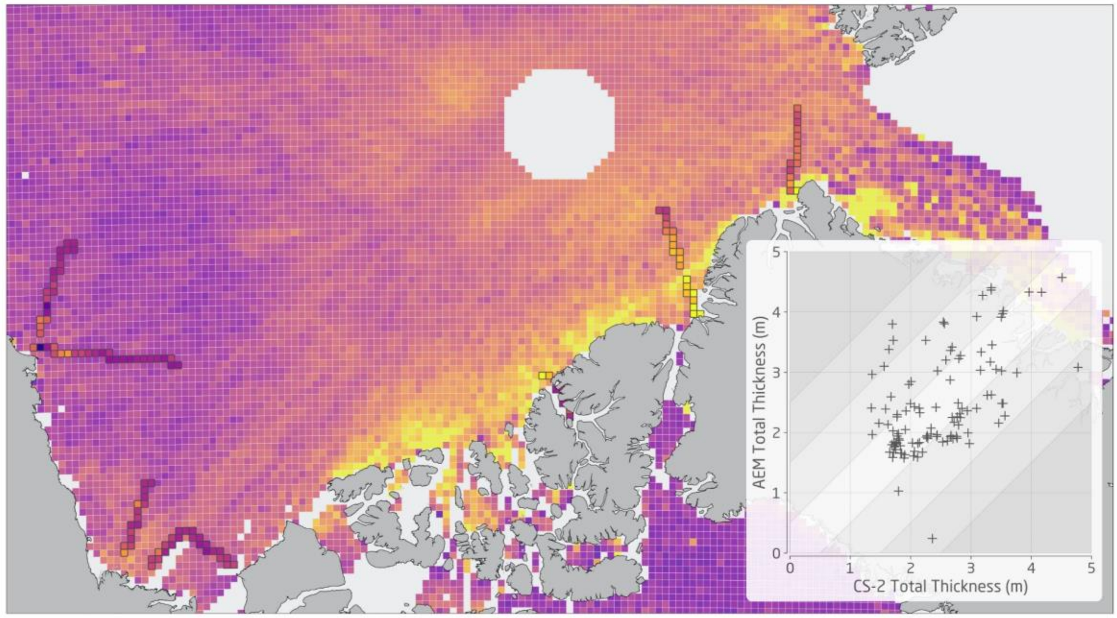

Figure 2. Initial validation of April 2017 CryoSat sea ice thickness fields with results from airborne electromagnetic induction sounding (highlighted grid cells) of late March/early April from the PAMARCMIP and CryoVEx fields campaigns. We added the modified snow depth climatology to the CryoSat thicknesses to ensure consistency with the airborne measurements of total (ice + snow) thickness.

We use the benchmark value of sea-ice volume in the central Arctic Basin to compare the 2016/2017 winter season in relation to previous years (see Figure 3.) The central Arctic Basin here is defined as the combination of the Central Arctic, Beaufort, Chukchi, E. Siberian and Laptev regions of the NSIDC regional mask. We have chosen to limit our analysis to this region (see map in Figure 3), to exclude areas where either the snow climatology is invalid or which are negatively affected by incomplete data coverage due and frequent data rejection rates of the sea-ice thickness retrieval algorithm. In addition, it is very likely that most of the remaining summer sea ice will have its origin in the selected source area.

The April 2017 sea-ice volume of 13.19 $\pm$ 1.15 (units in 1000 km^3) follows a continued decline for four years but only ranks as the 3rd lowest spring volume after April 2012 (13.14 $\pm$ 1.27) and 2013 (12.56 $\pm$ 1.21) in the AWI CryoSat data record. The difference between the three lowest volume estimates is within their respective uncertainties though.

The monthly increase in sea-ice volume over the 2016/2017 winter shows a similar pattern to previous years. The largest increase in all years occurs between October and November, followed by a more variable contribution to the final volume by the following months. The volume increase in the last winter (+7.38) is comparable to earlier winters

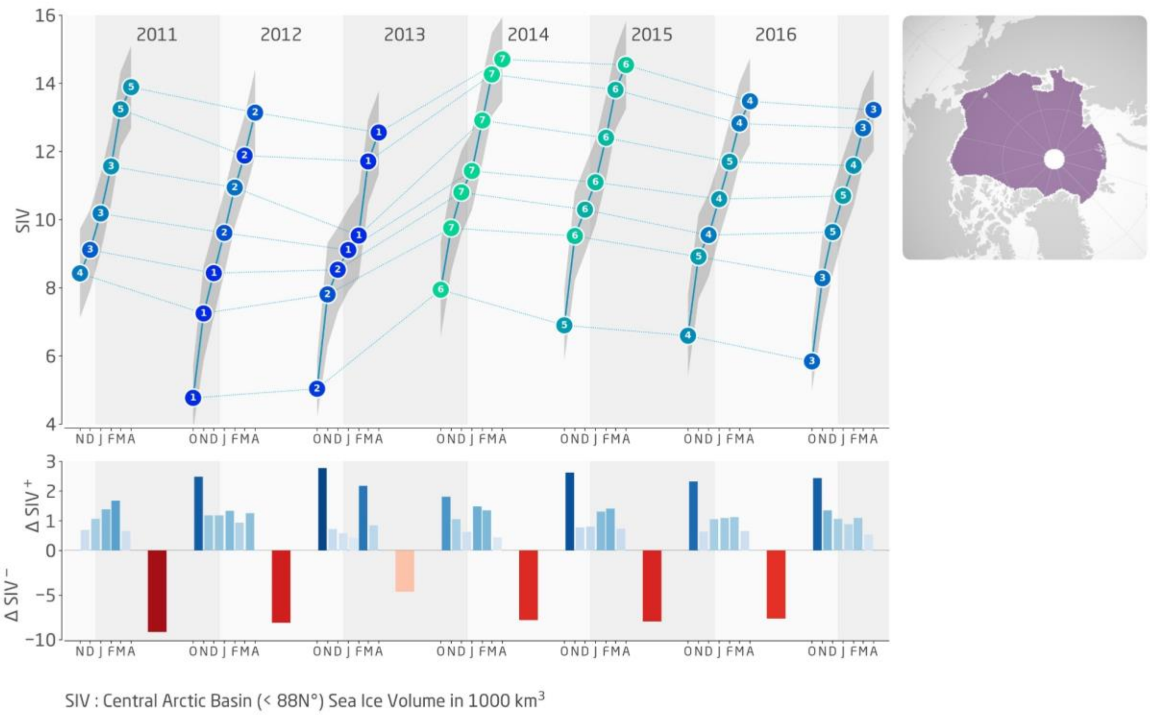

Figure 3. (upper left) Monthly time series of sea-ice volume from CryoSat measurements in the Central Arctic Basin (see map on the right). Number in the markers indicate the ranking of each month with respect to the lowest value. (lower left) Monthly volume increase (ΔSIV^{+}) for the winter month (October-April) and volume loss (ΔSIV^{-}) of all summer month (May-September).

(min: +6.76 in 2013/2014, max: +8.36 in 2011/2012), which seems questionable at first sight, given the very mild winter measured by cumulative freezing degree days (National Snow and Ice Data Center, Sea Ice Analysis, July 5, 2017). In addition, the winter season of 2012/2013 with very low increase in volume between November and February followed by a large increase back to normal values suggest that the impact of ice surface properties on CryoSat results during the deep winter needs further investigations. We therefore do not make an assertion whether the early volume increase in the last winter or the positive thickness anomaly in the central Arctic is caused by a bias in the CryoSat data due to the warm winter or the result of dynamic and thermodynamic processes.

Supplementary Information to AWI CryoSat-2 data product

The surface type classification of the AWI CryoSat-2 data product (version 1.2) is partially based on sea ice concentration (OSI-401-b) from Ocean and Sea Ice Satellite Application Facility (OSI SAF). The data mask of this product has changed in summer 2016 with a less restrictive land mask. While this is an improvement, it must be taken into account for comparing sea ice thickness results before and after the mask change. The mask applied to the volume computation in Figure 3 however does exclude affected grid points.

Data Access

The AWI Cryosat-2 data product is available as netCDF files via the webportal data.meereisportal.de or ftp service:

> ftp://data.meereisportal.de/altim/sea_ice/product/north/cryosat2/cs2awi-012/
> user: altim
> passwort: altim

References

Hendricks, S., Ricker, R. and Helm, V. (2016): User Guide - AWI CryoSat-2 Sea Ice Thickness Data Product (v1.2), http://epic.awi.de/41242/

Kauker, F., Kaminski, T., Ricker, R., Toudal-Pedersen, L., Dybkjaer, G., Melsheimer, C., Eastwood, S., Sumata, H., Karcher, M., and Gerdes, R.: Seasonal sea ice predictions for the Arctic based on assimilation of remotely sensed observations, The Cryosphere Discuss., 9, 5521-5554, https://doi.org/10.5194/tcd-9-5521-2015, 2015.

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