Report about

Retrieval of sea-ice volume (SIV) from SICCI-2 sea-ice thickness (SIT) data and combined OSI-450 and SICCI-2 sea-ice concentration (SIC) data – version v0.2, June 2018

by

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This is version v0.2 of this report issued together with the SIT and SIV data sets at the ICDC ESA-CCI-Projekt web page

Background

Sea-ice volume provides integral information about the sea-ice cover in the Polar hemispheres.

With the completion of the ESA SICCI-2 sea-ice thickness (SIT) data set based on satellite radar altimetry a time series of sea-ice volume = sea-ice thickness times sea-ice area can be derived for the period 2002 through 2017.

Data

We use daily gridded SICCI-2 project SIC sea-ice concentration climate data record (CDR) version v2.1 at 25 km grid resolution: http://dx.doi.org/10.5285/f17f146a31b14dfd960cde0874236ee5 and at 50 km grid resolution: http://dx.doi.org/10.5285/5f75fcb0c58740d99b07953797bc041e. This CDR is based on AMSR-E and AMSR2 data and therefore has an eight month data gap (October 2011 through July 2012). We fill the gap with the Eumetsat OSI-SAF OSI-450 SIC CDR at 25 km grid resolution: http://dx.doi.org/10.15770/EUM_SAF_OSI_0008 . This CDR is based on SSMIS data for the gap period.

We compute the monthly mean sea-ice concentrations from the above-mentioned CDRs.

We use monthly gridded SICCI-2 project SIT sea-ice thickness CDR version v2.0 at 25 km grid resolution (Arctic): Envisat: http://catalogue.ceda.ac.uk/uuid/f4c34f4f0f1d4d0da06d771f6972f180 , Cryosat-2: http://catalogue.ceda.ac.uk/uuid/ff79d140824f42dd92b204b4f1e9e7c2,

and at 50 km grid resolution (Antarctic):
Envisat: http://catalogue.ceda.ac.uk/uuid/b1f1ac03077b4aa784c5a413a2210bf5,
Cryosat-2: http://catalogue.ceda.ac.uk/uuid/48fc3d1e8ada405c8486ada522dae9e8.

All data sets are available on the EASE2 grid. For the Arctic the grid-cell area is 625 km², for the Antarctic the grid-cell area is 2500 km².

For the Arctic, SIT is available from 10/2002 through 03/2012 (Envisat) and from 11/2010 through 04/2017 (Cryosat-2) for winter months October through April. For the Antarctic, SIT is available from 06/2002 through 03/2012 (Envisat) and from 11/2010 through 04/2017 (Cryosat-2) year round.

Method

We compute the sea-ice volume SIV as: $V = I * A$ where V is volume, I is the true sea-ice thickness (not the grid-cell mean) and A is sea-ice area which is computed as $A = C * A_{grid}$ with sea-ice concentration C (as a fraction of grid cell area) and A_{grid} the grid cell area (see "Data").

We use a sea-ice concentration threshold of 60% (or 0.6) to compute A and hence V.

Both CDRs provide estimates of the uncertainty which allows us to also provide an estimate of the uncertainty of V. However, the uncertainty of the sea-ice thickness is so large that we would end up with uncertainties of V that would be so large that the seasonal variation in V would completely fall into the range of its uncertainty. As a preliminary solution we therefore scale the uncertainty proportional to the sea-ice thickness: $\sigma_I = 0.33 * I$. We compute the uncertainty in V, σ_V, as follows: $\sigma_V = \Sigma((\sigma_C * I)^2 + (C * \sigma_I)^2)$ with the total standard error in C: σ_C.

The SIT CDR might have data gaps where the SIC CDR indicates SIC > 60%. In order to avoid an under-estimation of V due to these gaps, which can be up to 10% in V, we interpolated the spatial gaps from nearby SIT values. A minimum of 5 SIT values is required for a box spanning 13 x 13 grid cells for the Arctic and 7 x 7 grid cells in the Antarctic; that is an area of ~ 350 km x 350 km.

The SICCI-2 sea-ice thickness retrieval uses the Warren et al. (1999) snow-depth climatology for snow depth and snow density. Because this climatology is only valid over the Arctic Ocean but not in the peripheral seas like the Hudson Bay or Barents Sea, or the Canadian Arctic Archipelago, we limit the computation of the sea-ice volume to the sector "Arctic Ocean". The grid cells belonging to this sector are derived from the Arctic sector mask provided originally by NSIDC on polar-stereographic grid and modified by NSIDC (personal communication, W. Meier and S. Steward, NSIDC, 2018).

Finally, and most crucially, for the Arctic for both sensors exist a large circular area centered at the Pole where no observations are made due to the satellites' orbit inclination. This does not apply to the Antarctic. We fill this hole by interpolation. This region of no observations begins at ~81.5°N for Envisat and at ~88.5°N for Cryosat-2. For Cryosat-2 we compute the mean SIC and mean SIT of the ring north of 87.0°N (Figures 1 and 2); for Envisat we compute the mean SIC and mean SIT of the ring north of 81.0°N (Figures 3 and 4).

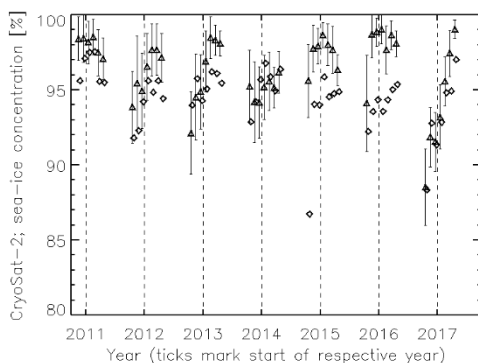

Figure 1: Mean sea-ice concentration of the area north of 87°N used for the sea-ice volume based on Cryosat-2 sea-ice thickness data (triangles); diamonds show the mean sea-ice concentration obtained for the ring 81.0°N to 81.5°N used to continue the Envisat-based sea-ice volume time series (see text).
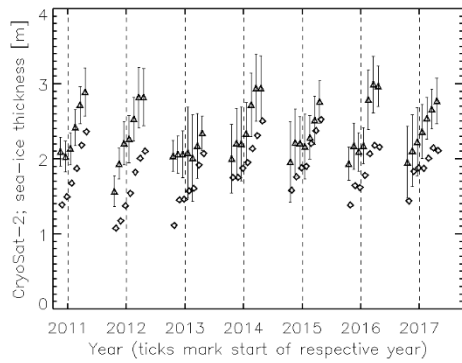
Figure 2: As figure 1 but showing the mean Cryosat-2 sea-ice thickness for the area north of 87.0°N (triangles) and the ring 81.0°N to 81.5°N (diamonds).
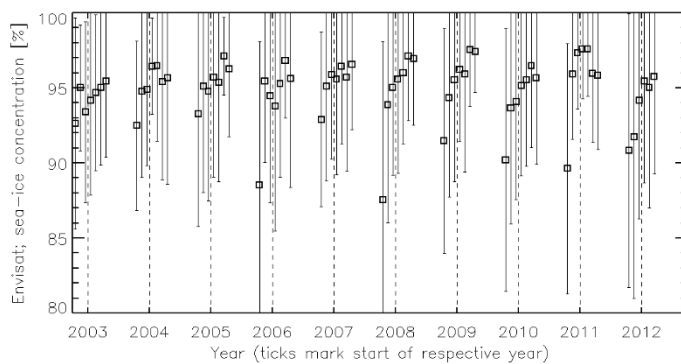

Figure 3: Mean sea-ice concentration of the ring area between 81.0°N and 81.5°N used for the sea-ice volume based on Envisat sea-ice thickness data.
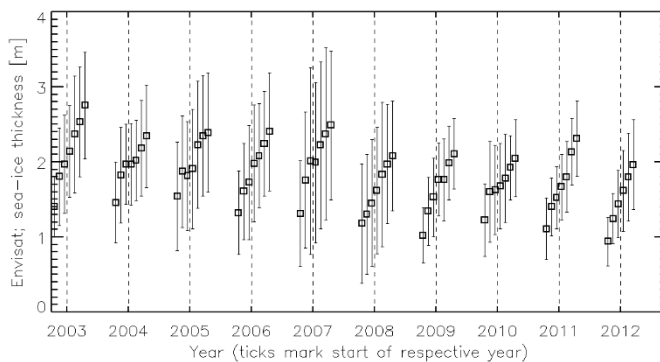

Figure 4: As figure 3 but showing the mean Envisat sea-ice thickness for the ring between 81.0°N and 81.5°N.

For the Arctic, the final sea-ice volume is then computed as $V = V_{valid} + V_{interp} + V_{polehole}$. Here V_{valid}, V_{interp}, and $V_{polehole}$ are the volume computed from all grid cells up to the altimeter observation gap at the pole, the volume resulting from the grid cells of valid SIC values but missing SIT values, and the volume of the altimeter observation gap area, respectively.

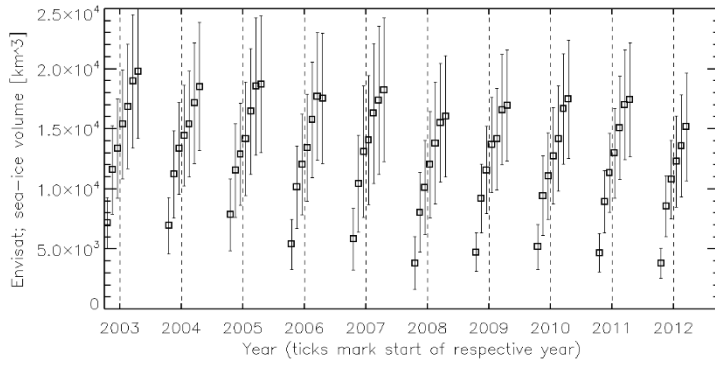For the Antarctic it is $V = V_{valid} + V_{interp}$.

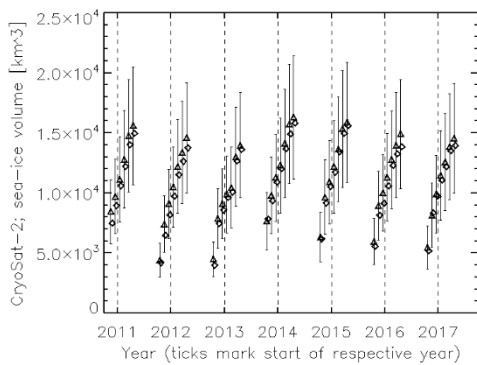Figure 5: Sea-ice volume time series for the Arctic, sector "Arctic Ocean" based on Envisat SIT.

Figure 6: Sea-ice volume time series for the Arctic, sector "Arctic Ocean" based on Cryosat-2 SIT (triangles) but extended to match Envisat (diamonds).

Figures 5 and 6 display the resulting sea-ice volume time series for the Arctic, sector "Arctic Ocean" for Envisat and Cryosat-2, respectively. In Figure 6 diamonds display the sea-ice volume computed from Cryosat-2 sea-ice thickness data as if the observation gap of Envisat would apply. Instead of using the mean SIC and mean SIT computed north of 87.0°N (Figure 3 and 4, triangles) the mean SIC and mean SIT computed from Cryosat-2 data for the ring 81.0°N to 81.5°N (Figure 3 and 4, diamonds) is used.
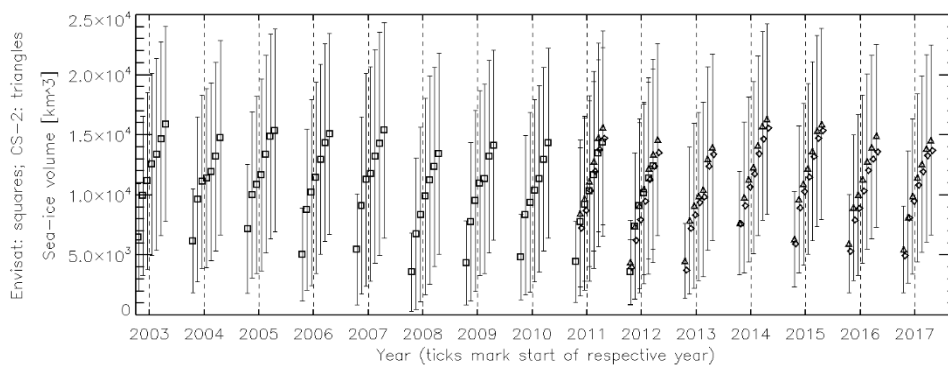

Figure 7: The sea-ice volume time series displayed in Figure 5 and 6 in one plot. Note that this is also an example of the sea-ice volume uncertainty that would result when taking the SIT uncertainty of the CDR.

Now, to provide one consistent time series of the sea-ice volume we merged the Envisat-based and the Cryosat-2 based sea-ice volume time series by applying a bias correction factor for the period June 2002 (Antarctic) / October 2002 (Arctic) through October 2010 to the Envisat sea-ice volume. This correction factor is simply the arithmetic mean of the sea-ice volume differences of the months of the overlap period of Envisat and Cryosat-2. Note that for the Arctic, an arithmetic mean could not be computed for October and April; similarly, for the Antarctic, an arithmetic mean could not be computed for months June to October and April, May. Applying this bias correction factor results in the sea-ice volume time series shown in Figure 8.
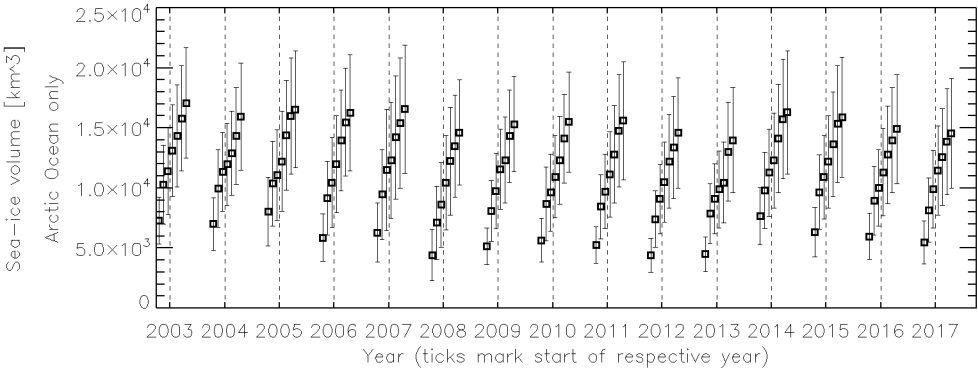

Figure 8: Arctic sea-ice volume time series for sector "Arctic Ocean" based on bias-corrected Envisat data until including 10/2010 and on Cryosat-2 data from 11/2010 onward.
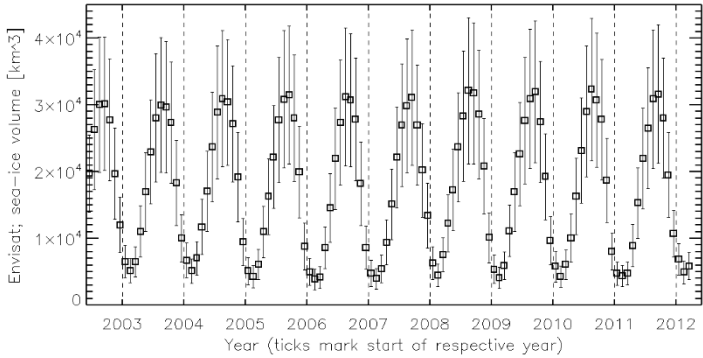

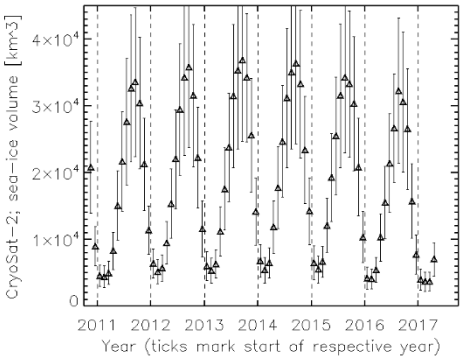Figure 9: Antarctic sea-ice volume time series based on Envisat.

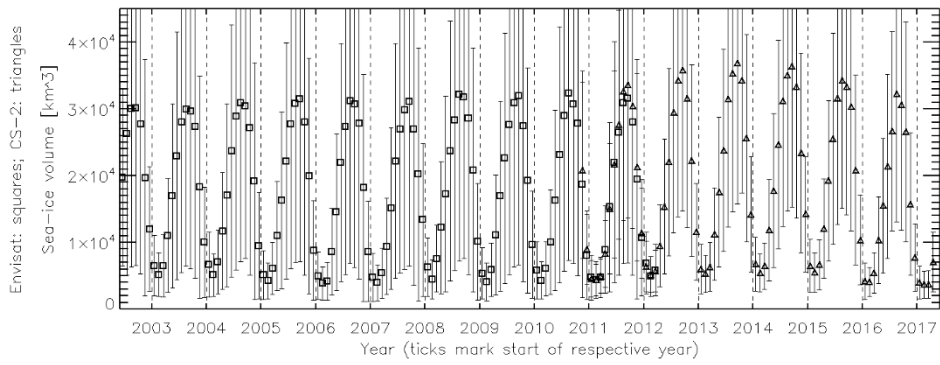Figure 10: Antarctic sea-ice volume time series based on Cryosat-2.

Figure 11: Antarctic sea-ice volume time series from Envisat and Cryosat-2 using original sea-ice thickness uncertainties (compare Fig. 7). Note the uncertainties appear to be smaller for the Cryosat-2 period – which is in line with the CDR, where SIT uncertainties for Cryosat-2 are smaller than for Envisat.
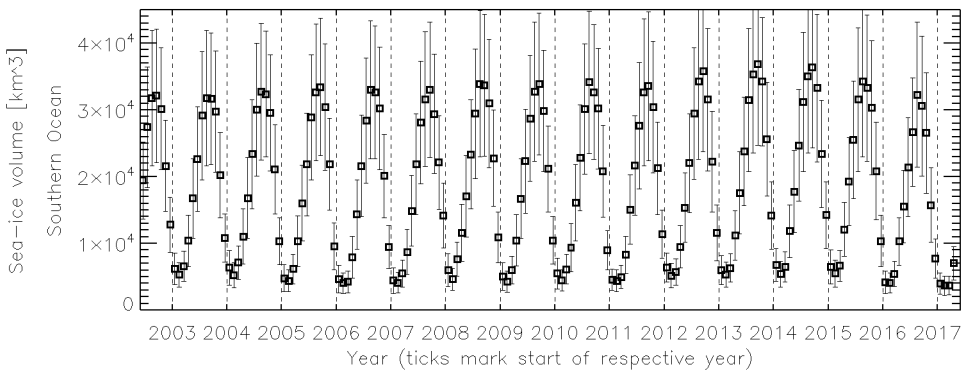

Figure 12: Antarctic sea-ice volume time series based on bias-corrected Envisat data until including 10/2010 and on Cryosat-2 data from 11/2010 onward.