The Cryosphere Discuss., 7, C405–C411, 2013
www.the-cryosphere-discuss.net/7/C405/2013/

The Cryosphere Discussions

Interactive comment on "A combined approach of remote sensing and airborne electromagnetics to determine the volume of polynya sea ice in the Laptev Sea" *by* L. Rabenstein et al.

L. Rabenstein et al.

rabenstein@aug.ig.erdw.ethz.ch

Received and published: 29 April 2013

In the following we answer to all comments, referring to content. Corrections of single words and typos are all considered in the revised manuscript and are not mentioned here again:

Response to General Comment 1: The mentioned 16-days old sea-ice area was formed on March 28. The massive area reduction by about 62% took place from March 29 to March 30. Taking this area loss and the HEM mean thickness for this area of 2.4 and 1.9 m on April 16, the thickness of the area on March 28 must have been 0.7 or 1.2 m (assumed that volume is constant except a thermodynamic thickness correction by app. 0.5 m (see Figure 9)), which is not realistic. It is in fact physically impossible. Therefore it becomes obvious that these two very short overflown segments are not representative for the entire 16 years old area but represents a localized deformation zone. The 16 days old area is anyway exceptional, since it has an irregular shape and it cannot be assumed, that the entire area acts as one rheological unit to such fast and drastic convergence. This example shows once more the limitations of the volume estimations the presented method has. However, this is accounted for in the large error bounds of our volume estimation, which are based on observed spatial variability of mean thickness within areas of same age. Thickness segments shorter than a certain threshold length should anyway not be taken as representative for entire areas of same origin time. A suggestion for the length of representative HEM transects can be taken from Rabenstein et. al, 2011, who found on 10 km long transects mean thicknesses, which were representative for sea ice which originated during similar periods.

However, the observed thicknesses can also be a result of unknown dynamic growth processes, which built ice thicknesses larger than pure area reduction calculations would allow, as the resulting fields of deformed ice are not solid ice blocks. Here we have to admit that it is not well understood how the HEM instrument react to very porous ice ridges.

We changed the passage in the manuscript as follows: “According to the SAR images, this 16-day old ice began forming on March 28 and convergence with surrounding floes on March 30 caused a reduction of the freshly produced sea-ice area by 60%. Consequently, sections 16c and 16f mostly comprise heavily deformed ice (e.g., piled rubble of thin ice blocks) and only small areas of level sea ice. However, such large mean thicknesses cannot be explained with the observed area reduction alone, and are therefore not representative. It is more likely that the thickness profile transected singular extreme features within this very irregularly shaped area (see Figure 5).“

Response to General Comment 2: From a modeler’s point of view, the agreement between model and measurement derived ice thickness is quite good. One has to keep in mind that the fast ice edge in the model is prescribed from monthly mean MODIS data and the model resolution of 1/12 degree ($\sim$9 km) is still coarse compared to a few kilometer wide polyna. Here the position of the polynya is simply as correct as a monthly mean of MODIS observation can be. One has also to keep in mind, that the the derived thickness in fig 8a is the result of a coarse interpolation of single measurement to satellite derived areas of equal age. This figure is highly dependent on the number of observations per area of same age.

We added the following sentence to the manuscript: "In addition to the consistent total sea-ice volumes, the general distribution of ice thicknesses in Fig. 8a and 8b are similar, with most of the thickest ice in the middle and northern regions and some of the thinnest ice near the southern and eastern margins of the maps. Despite this general agreement between both methods, in detail the thickness distributions differ owing to three facts; (1) the fast ice edge in the NAOSIM model is based on monthly means, (2) the model resolution is with 1/12 degree ($\sim$9 km) still coarse, (3) the SAR-HEM approach has an averaging effect due to the limited coverage of the thickness measurements. Knowing that the total sea-ice volume of the Naosim model output is in good agreement with our SAR-HEM sea-ice volume ...."

Specific comments: P446 lines 26-29: Is it reasonable / feasible to assume a uniform spatial gradient of surface water conductivity? A: No, probably it is not. We anyway did not intend to introduce a gradient here, but simply the range of conductivities measured during the field campaign. However, that the water was less saline close to the river mouth was at least not unexpected. We changed the sentence to: From in-situ measurements, a surface-water electrical conductivity range of 2.28 S/m close to the Lena river mouth to 2.5 S/m 140 km north of the river was observed (Krumpen et al., 2011). We took this range as the worst case scenario for changes of sea-water electrical conductivity during one flight without recalibration, although we have no detailed information of the conductivity distribution between our in-situ measurement spots."

P449, lines 15-18. I feel the meaning of this sentence needs to be clarified. Do the authors mean that if ice dynamics are excluded from consideration, then such differences have to be accounted for by variations in ocean heat flux, snow depth, etc? We changed the sentence to: However, when linking level ice thicknesses to thermodynamic growth (i.e. no rafting), reasons for such differences have to be caused by different heat flows from the ocean, a changing snowfall pattern and/or different air temperatures associated with open leads in the ice cover.

P 451, lines 11-13: This sentence could be reworded to better explain the two different ways of calculating area. The first case is referring to the total area encompassed by the polygon, whereas the second case is the integration of ice concentration over this area. This is analogous to the difference between ice extent and ice area. A: We agree, therefore we just mention sea ice area now. “The sea-ice area highlighted in Fig. 8b is 49 800km2, assuming a complete sea-ice coverage for each grid cell.”

Figure 1,3 and 5: It would help readers unfamiliar with the study area if the region shown in Figure 5 was the same as that shown in Figure 3 and the extent of this region was illustrated on Figure 1. I also recommend adding coastlines to Figures 3 and 5. Figures 1,3 and 5 are now updated. See attachment. Added the following sentence to the caption of Figure 1: ... The blue and red frames indicate the outline of the areas shown in Figure 3 and 5. Figure 5: ... Yellow lines separate zones of same age.

Interactive comment on The Cryosphere Discuss., 7, 441, 2013.

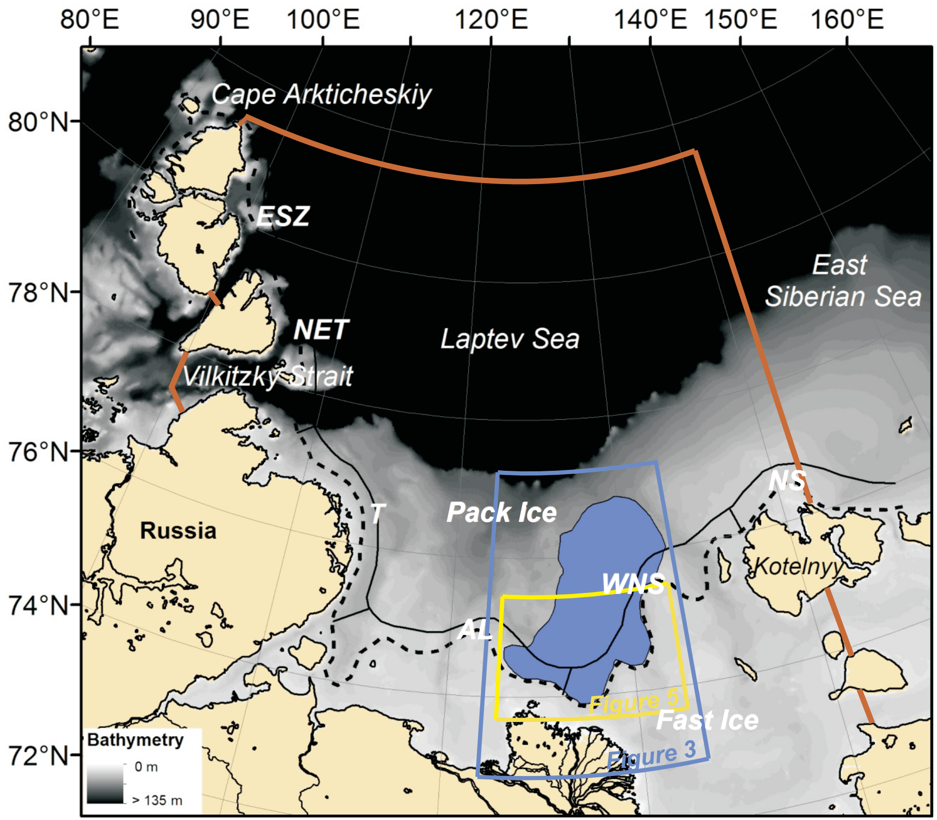

Fig. 1. Map of the Laptev Sea showing three distinct sea-ice components: fast ice, pack ice, and polynyas. Black solid and dashed lines delineate the mean lateral extent of fast ice and beginning of pack ice,

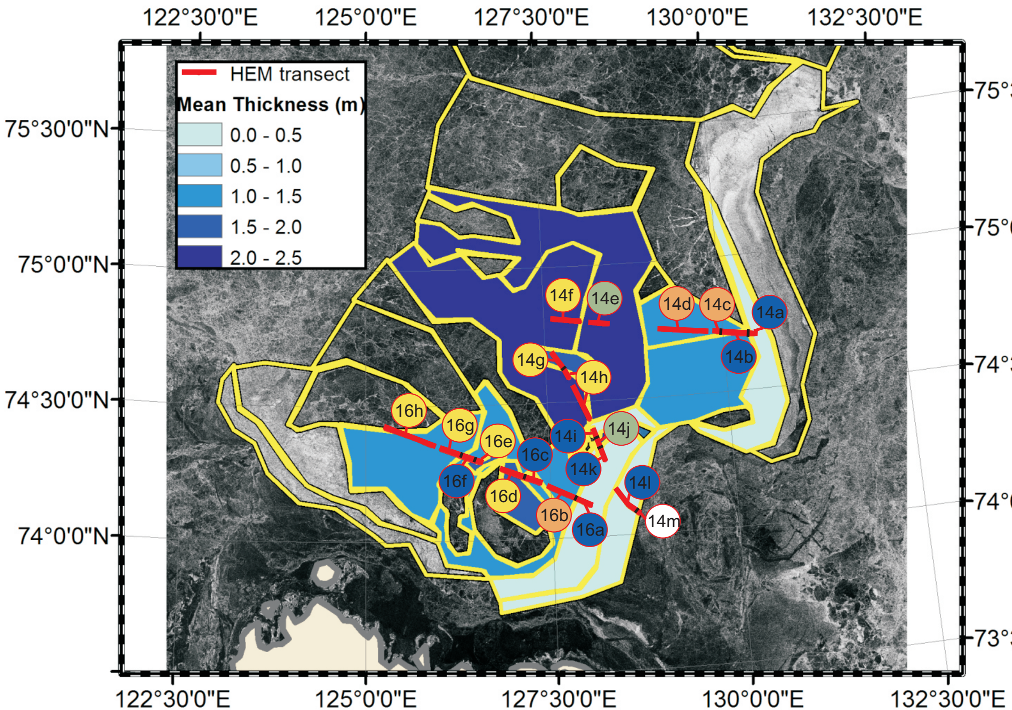

Fig. 2. Map with all HEM sea-ice thickness profiles. Northern and southern profiles flown on April 14 and 16 are coded 14a-m and 16a-h, respectively. Circle colors refer to the polynya events in which the res

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

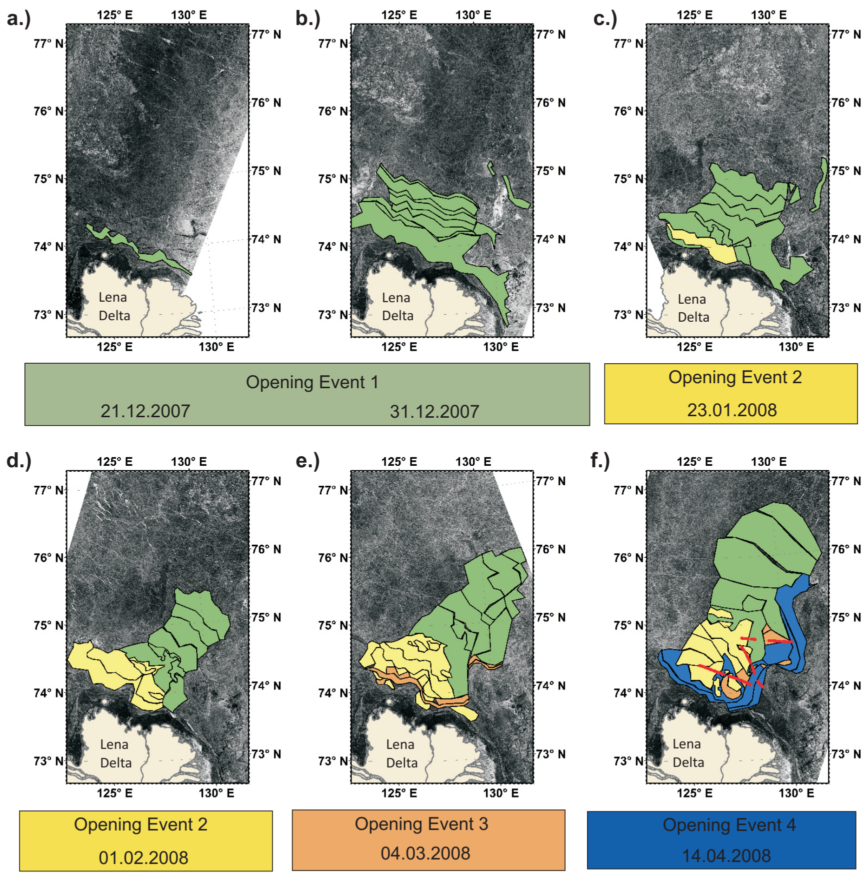

Fig. 3. Snapshots of sea-ice tracking on SAR satellite images. Areas contain sea ice formed after polynya opening events along the fast ice edge between 21 December 2007 and 14 April 2008: Green - Event 1 (De