RC2: Interactive comment on "Circumpolar polynya regions and ice production in the Arctic: Results from MODIS thermal infrared imagery for 2002/2003 to 2014/2015 with a regional focus on the Laptev Sea" by Andreas Preußer et al.

Received from Prof. Göran Björk (referee) on August 23, 2016

General comments

This work gives a comprehensive description of Arctic polynyas based on high resolution surface temperature (MODIS) data. This data set has the advantage of a higher spatial resolution compared with satellite products used in earlier investigations. It gives a 22 % higher total polynya ice production than recent results which shows that the development of satellite products, algorithms and analyses is still an important issue in order to follow the past and future development of the Arctic Ocean ice cover. It reveals significant positive trends of the polynya ice production in the eastern arctic which can be further utilized for analyses of the effect on dense water mass formation on the shelves which likely have influence on shelf circulation, shelf basin interaction and water chemistry. The paper is generally of a high quality in language and analyses and is therefore well suited for publication.

We would like to thank the Prof. Göran Björk (referee #2) for his valuable comments and remarks. We carefully went over the mentioned parts of the manuscript. Specific comments will be addressed in the following.

Specific comments

I'm not perfectly happy with the sentence starting on line 6 page 3 ("A regular monitoring...''). It appears to be somewhat a repetition of the sentence on page 5 line 8 ("Hence an accurate...'').

Thank you for this remark, but in our sense the sentence on page 6 refers to the general monitoring of thin-ice areas using remote sensing data, while the section on page 5 refers to the determination of sea-ice production.

Page 9 Table1 text. I miss some more explanation of what the "interannual average coverage" means. Coverage of what? It is hard to understand as it stands now.

The referee is right regarding the somewhat misleading / confusing formulation of the caption here. We changed it accordingly to read:

"Areal extents (i.e. total ocean area) of all applied polynya masks in km². Further, the interannual average amount of MODIS swaths that could be used for calculating daily composites in a given region is indicated, together with the interannual average daily MODIS coverage (decimal cover fraction ranging from 0 to 1 with their respective standard deviations) before (COV2) and after (COV4) application of the Spatial Feature Reconstruction (SFR) for each polynya region from 2002/2003 to 2014/2015 (November to March). (…)"

Page 9 Line 2 and before. It is hard to follow the logic why fixed values for ice and Lf are used. The arguments regarding frazil ice crystals are not clear to me.

The presented thin-ice algorithm does not explicitly discriminate between different ice types. It follows the assumption that a linear temperature profile can be used to calculate the heat conduction through the ice. Hence, we added this information to the manuscript. Regarding the choice of constant values

for the ice density and latent heat of fusion (L_f), we followed earlier studies (e.g. Willmes et al. (2011), Tamura and Ohshima (2011), Iwamoto et al. (2014)) to ensure comparability of achieved results. These studies followed an even earlier characterization of sea-ice formation mechanisms by Martin (1981).

Page 12 Line 2. It is interesting to see persistent leads well off the shelf in the Beaufort Sea. These must be related to the large scale ice circulation in the area and it is remarkable that they are so persistent that the show up as well defined bands in this type of data (most notable in Feb-Mar). I wonder if this structure has been described before or if it is a new finding. It is worth some more comment anyhow.

Thank you for this interesting remark. Indeed, these broad lead-structures in the Beaufort Sea (related to the clockwise rotation of the Beaufort Gyre) have been previously described e.g. by Willmes and Heinemann (2015, Remote Sens., doi:10.3390/rs8010004), who also used MODIS TIR data, and also by Röhrs et al. (2012, TC, doi:10.5194/tc-6-343-2012), who used coarser resolution AMSR-E passive microwave data for their analysis.

What is interesting in the present study though, is the relatively high persistence of these leads (so that they are not discarded from our daily thin-ice distributions) together with apparently distinct favorable locations of appearance so that they appear in the these interannual frequencies of TIT ≤ 0.2m. Therefore, we added the following statement *"(…) leads are mainly located in the area of the Beaufort Sea and north of Greenland (shear zones) **which can be attributed to their relatively high spatial and temporal persistence. (…)**"*.

Page 12 Line 3. I can't see the leads along the Transpolar drift in figure 4. The central area around the North Pole appears to be without leads in the figure.

The referee is correct with this remark, as we were aiming to highlight enhanced TIT frequencies in the Atlantic sector of the Transpolar Drift (~Fram Strait region; see above for FEB). However, as frequencies are quite low and mainly located outside our indicated regions of interest (i.e. polynya margins; Fig.1), we decided to remove this sentence to avoid confusion.

Page 15 Line 8. Suggestion: "is especially large" instead of "increases".

Fixed, thank you for this suggestion.

Page 19 Line 13. Sentence starting with "A pronounced seasonal..." is unclear. I can see that the seasonal variation is largest in the late half of the period, but the last part is confusing.

We slightly changed the sentence in order to make it less confusing, so that it now reads:

"***A pronounced seasonal variation is visible for the winter seasons 2004/2005, 2005/2006 and from 2010/2011 onwards, while the other years show less polynya activity (more lengthy periods with a closed polynya; white color in Fig. 10) and overall smaller polynya extents in February and March.***"

Page 19 Line 18. I think the reader needs some more help to identify the fast ice edge in figure 11 and also in earlier figures. It is not clear to me since there are several bands of high ice production from the coast and outward in most of the fields.

The referee is right that characteristics of the fast-ice edge might be difficult to assess for readers who are unfamiliar with the topic. This is especially true when showing plots that integrate over the period from Nov.-Mar., and therefore inhibit different stages of fast-ice development. However, a complete mapping / marking of these areas is a quite challenging task and definitively not feasible for this present study. In order to address your remark, we decided to keep most of the figures as they are (except for Fig.9 where we inserted the approximate average position of the fast-ice edge at the end of March; see below) and put more effort on describing the characteristics.

P21 Line 9. IAE need to be defined better. Is it the export just outside the Laptev Sea or what?

To quote Krumpen et al. (2013), the ice area flux is calculated as the integral of the product between the U and V component of the ice drift velocity and ice concentration at the northern boundary (NB) and eastern boundary (EB) of the Laptev Sea. In their study, a positive flux (given in km²) is referred to an export out of the Laptev Sea into the Transpolar Drift and East Siberian Sea, while a negative flux denotes to an import into the Laptev Sea. Please refer to the mentioned study for more details on the data sets, calculation procedure and outcomes.

The geographical locations of these two boundaries (NB/EB) on which meridional and zonal ice area flux estimates were based in Krumpen et al. (2013) are now additionally illustrated in Fig.9 (see below, cyan solid lines in the inset) and **some further explanation on the IAE values are now given in the manuscript.**
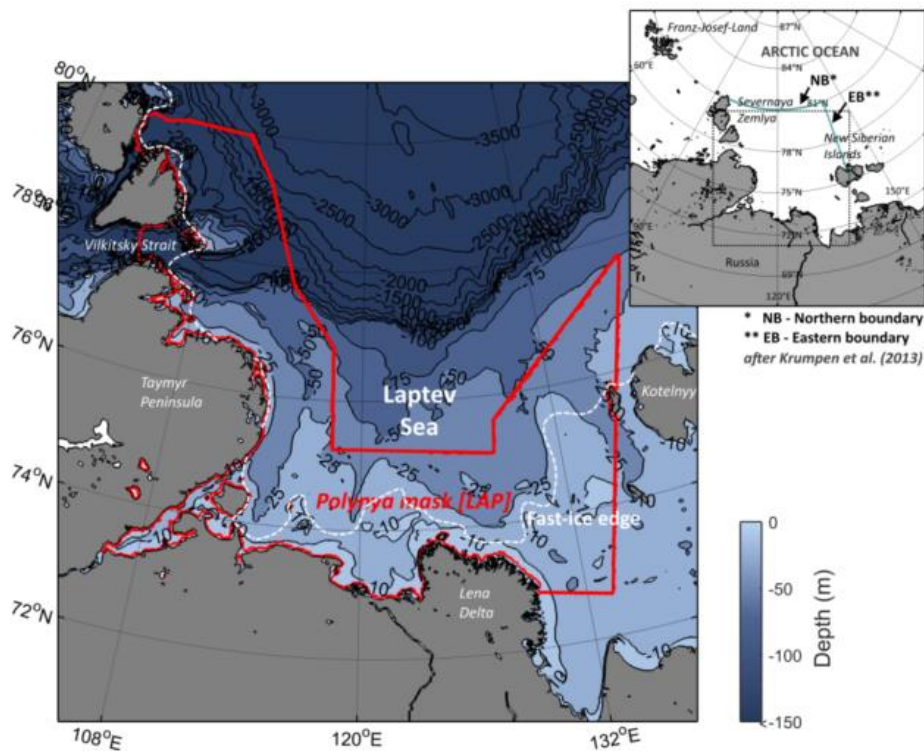

Figure 1 The geographical location of the Laptev Sea in the eastern Arctic. The applied polynya mask is marked in red, enclosing the locations of typical polynya formation along the coast and fast-ice edge (dashed white line; position derived from long-term thin-ice frequencies in March (Fig. 4)). Flux gates from the study by Krumpen et al. (2013) at the northern (NB) and eastern (EB) boundary of the Laptev Sea are shown in the inset map (grey solid lines). Bathymetric data by Jakobsson et al. (2012) (IBCAO v3.0).

Technical corrections

None