Responses to reviewer #1 comments
(Italic: comment from reviewer; * and bold: our reply)

Thank you very much for your careful reviewing of our manuscript. We found reviewer's comments most helpful and have revised the manuscript accordingly. Note that the line numbers are those of "the manuscript with changes noted (tc-2018-25R_noted.pdf)", not of "the original revised manuscript (tc-2018-25R.pdf)". Please refer to "the manuscript with changes noted".

Interactive comment on "Medium-range predictability of early summer sea ice thickness distribution in the East Siberian Sea: Importance of dynamical and thermodynamic melting processes" by Takuya Nakanowatari et al.

Anonymous Referee #1
Received and published: 11 March 2018

General Comments
The paper addresses a relevant and current topic, seasonal sea ice prediction as it pertains to increased maritime operations in northern waters in the summer season. The authors highlight the utility of the TOPAZ4 forecast system for estimating sea ice thickness distributions in the East Siberian Sea, an area that has seen increased vessel activity during summer in recent years. Sea ice thickness outputs are compared to satellite (Cryosat-2 and SMOS) and in situ (ice mass balance buoy) observations, with a negative bias of 20cm from winter to summer shown to be smaller than other model outputs. Skillfull predictions of sea ice thickness are limited to lead times of up to 3 days due to the influence of dynamical processes, which is somewhat expected based on similar studies and here attributed to the influence of Arctic cyclones on sea ice drift. Interestingly, the authors study the effect of thermodynamic melting processes on sea ice thickness prediction skill at longer time scales, demonstrating dependency of prediction skill on those processes. A case study of two ships is used to show how vessel speeds were related to TOPAZ4 sea ice thickness estimates in July, when ice thickness up to 150cm caused vessel blocking. The paper is well written, the data and methods generally well described, and the results presented and discussed in a logical manner with clear figures and tables. Descriptions of data and methods are clear enough to allow repeatability. Some further editing is needed (e.g. reference to Fig. 14 on Line 370; "There" instead of "Their" on Line 394) but otherwise there isn't any need to

make any major adjustments to the text like removing or combing sections.

*** We have revised the above editing errors (Line 455, 458, and 504).**

Specific Comments

The title of the paper is perhaps too broad given that the focus is on the performance of the TOPAZ4 system on predictions in the East Siberian Sea, rather than an overall assessment of dynamic and thermodynamic processes on medium-range predictions.

*** As the reviewer pointed out, the original title may give a general aspect of the physical mechanism of SIT prediction in ESS. Since our study highly depends on the TOPAZ4 system, we have modified the title as follows;**

"Medium-range predictability of early summer sea ice thickness distribution in the East Siberian Sea based on the TOPAZ4 ice-ocean data assimilation system" (Lines 5-6)

The authors use the merged Cryosat-2/SMOS satellite-based sea ice thickness product to evaluate TOPAZ4 sea ice thickness estimates. Some qualitative statements about the uncertainty of this product are made, but more information on potential bias is needed since these data are used to assess TOPAZ4 (and PIOMAS) outputs (see Figure 2).

*** Thank you very much for your notification that we have overlooked the reliability of CS2SMOS data. Indeed, it was reported that this dataset has non-negligible negative bias and errors by comparing it with the independent sea ice thickness data derived from Airborne EM sensor in the corresponding paper (Ricker et al. 2017). Therefore, we had to evaluate and discuss the reliability of the CS2SMOS in the ESS.**

Since the CS2SMOS highly depends to the reliability of the merging SIT data, which are CryoSat-2 and SMOS SIT products [Ricker et al. 2017], there is possibility that the CS2SMOS SIT is underestimated in the ESS. To check this possibility, we briefly examined the ice type data which were used for the determination of merged SIT products. In the first ice periods from 2011 to 2013, the uncertainty of CS2SMOS SIT is out of range for that of PIOMAS, but the CS2SMOS SIT is comparable to that for PIOMAS in 2014 when the sea ice is classified as multi-year ice (Fig. 3). This result implies that the CS2SMOS SIT is underestimated in the ESS. These descriptions have been added in the revised version as follows;

"In the freezing season, the TOPAZ4 SIT in the ESS tends to be thinner than the PIOMAS SIT, and seems comparable to the CS2SMOS SIT. The monthly mean

bias of TOPAZ4 SIT relative to CS2SMOS SIT is -23 cm and 1 cm in March and April, respectively (Table 3). On the other hand, we should pay attention to the possibility that the CS2SMOS SIT may be underestimated in this region, because the CS2SMOS highly depends on the reliability of merging two SIT data, which are CryoSat-2 and SMOS SIT products [Ricker et al. 2017]. To check the possibility that the CS2SMOS SIT has a negative bias in this area, we briefly examined the ice type data which were used for the determination of merged SIT products. In the period from 2011 to 2013, the uncertainty of CS2SMOS SIT is out of range for that of PIOMAS, but the CS2SMOS SIT is comparable to that for PIOMAS in 2014 when the sea ice is classified as multi-year ice (Fig. 3). This result implies that the CS2SMOS SIT is underestimated in the ESS due to the large fraction of SMOS SIT products even in the sea ice thicker than 1 m." (Lines 269-280)

In addition to this revision, the bias and uncertainty of SIT in TOPAZ4 highly depends on the data source of SIT to be used for the comparison as well as the region within the ESS. Thus, we realize that the specific value of the bias of TOPAZ4 should not be included in the abstract. Thus, we also have modified the corresponding sentence in the abstract and summary as follows;

"Comparison of the operational model SIT data to reliable SIT estimates (hindcast, satellite, and in situ data) showed that the TOPAZ4 reanalysis reproduces qualitatively the tongue-like distribution of SIT in ESS in early summer and the seasonal variations." (Lines 24-27)

"Comparisons between the operational model, observed, and TOPAZ4 reanalysis SIT data showed that the TOPAZ4 reanalysis qualitatively reproduces the tongue-like distribution of SIT in the ESS in early summer, and its seasonal variation (maximum in April–May and minimum in October–November) including the rates of advance and melting of sea ice in the ESS). Although in this region, the inherent negative bias of SIT in TOPAZ4 is relatively large in March to May, the bias is reduced in early summer (June-July) within ~±20 cm due to the excess of SIT along the coastal region in the ESS. The TOPAZ4 SIT data also shows a good correspondence with IMB buoy data in and around the ESS with the mean bias of ~9 cm and the root mean square error of ~30 cm. Thus, the TOPAZ4 SIT data could be considered reliable estimates for the ESS even in the absence of satellite observations in summer." (Lines 470-484)

The authors need to be cautious about attributing model skill from a comparison between simulated sea ice thickness and limited measurements from ice mass balance buoys in a single melting season (2014). The agreement is certainly good, but the statement made on Lines 226-230 is not well supported given the lack of supporting data. If more comparisons are possible, they would certainly add value to the paper.

*** As the reviewer pointed out, only one buoy data is not enough to support the reliability of SIT in TOPAZ4. We re-checked all of the IMB data in and around the ESS and found that additional 3 buoy data are available near the ESS (Please refer Fig. 1a and Table 1 for the location and periods). Although the location of these buoy data does not necessarily cover the ESS on which we focused in this study, these data seem to be appropriate for our purpose, because the range of the climatological SIT in these region is similar to that in the ESS (Fig. 1a). The direct comparison between the TOPAZ4 and IMB shows that the mean bias and root mean square error of TOPAZ4 is 8.3 cm and 30 cm, respectively. In particular, the TOPAZ4 SIT data shows a good correspondence with IMB buoy data in 2014, which is near the ESS in July (Fig. 1a and Table 1). These results support that the reliability of TOPAZ4 SIT data in the ESS in early summer. There results and Fig. A1 have been added in the revised version (Lines 282-293 and Fig. 4).**

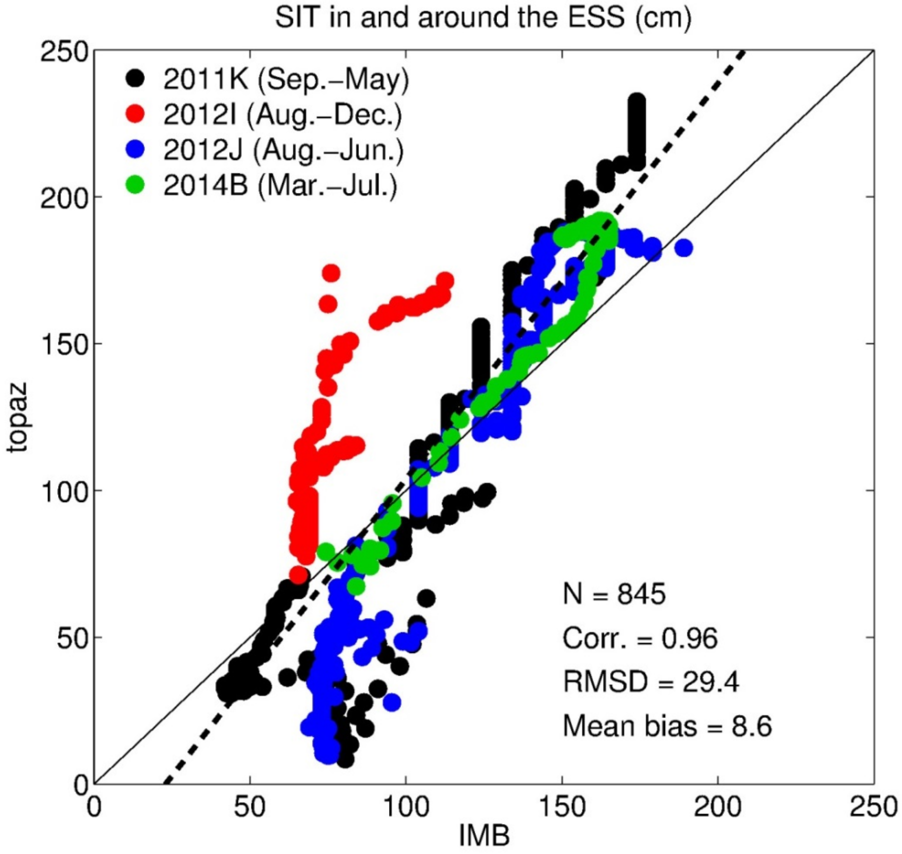

Figure A1. The comparisons of the daily mean SITs derived from IMB buoy data with the corresponding SIT in TOPAZ4 reanalysis data from 2011 to 2014 in and around the ESS. The SIT data are re-sampled per 7 days. The reference unit line and the regression lines onto IMB buoy data are shown by solid and dashed lines, respectively.

According to this revision, we have removed Fig. 3 in the original version and the related sentence.

In addition to the revision based on the reviewer's comments, we also have revised the following items listed below;

1) We have refined several sentences for clarification (e.g., Lines 146, 149, 186, 213).
2) We removed the citation [Nakanowatari et al. 2017], which is it is a proceeding of Monbetu-2017 Symposium (Line 100) and the reference which is not cited in this paper [Nakanowatari et al. 2014] (Lines 667-669).
3) We have updated the following reference information.

Yamagami A., Matsueda M., & Tanaka H. L. 2018. Predictability of the 2012 great Arctic cyclone on medium-range timescales, 15, 13-23, doi: 10.1016/j.polar.2018.01.002. (Lines 747-748)