Responses to reviewer #3 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 #3
Received and published: 19 March 2018

This manuscript investigates the forecast skill of the sea ice thickness distribution in the East Siberian Sea in early summer for a lead time from a few days to 10 days. The description and validation of the TOPAZ4 reanalysis utilized for this analysis are clear. They demonstrate the characteristic time evolution of the prediction skill and suggest the reasons for such as the abrupt reduction of the skill after 4 days. Their explanations by using simple models are reasonable and useful for the community of the Arctic sea ice monitoring and prediction. Therefore, I recommend this manuscript to be accepted for publication in the Cryosphere.

Please check the minor comments as described below.
L53: "CMIP" firstly appears here.
*** According to the reviewer's comment, we have corrected the corresponding part as follows;**
", based on the Coupled Model Intercomparison Project Phase 5 (CMIP5)…" (Lines 55)
"…using the CMIP3 and CMIP5 global climate model simulations…" (Lines 561-562)

L212: The bias quantities described in this paragraph seem to depend on the definition of the ESS with negative biases in the north and positive biases in the south (Fig. 1c).

This should be mentioned here and the conclusion section. I believe it does not degrade the analysis of this study and help to avoid too much damaging the pedigree PIOMAS data.

***As the reviewer pointed out, the definition of the ESS is crucial for our conclusion. To take care of this point, we have added the following sentence as follows;**
"From the difference map of the climatological SIT between TOPAZ4 reanalysis data and PIOMAS output, the TOPAZ4 SIT is thicker near the coastal region with ~50 cm (Fig. 1c), although the SIT in the offshore region is underestimated. These positive and negative biases are compensated each other and thus the mean bias of the TOPAZ4 SIT is 21 cm in July, which is smaller than those in winter (Table 3)." (Lines 242-247)

For the positive bias of the SIT in TOPAZ4 along the coastal region of the ESS, there is possibility that the SIT estimates (PIOMAS and CS2SMOS) used for the comparison are themselves underestimated. Schweiger et al. [2011] pointed out that the SIT of PIOMAS is underestimated by -17cm in the basin area of the Arctic Ocean including the Beaufort Sea where the heavy deformed sea ice formation occurs. Also, it was reported that the CS2SMOS data tend to show the underestimation in the region such where multi-year ice and first-year ice are formed, due to the spatio-temporal resolution of CryoSat-2 and SMOS and the merging algorithm [Ricker et al. 2017]. Since in the ESS, sea ice motion is strongly converged during winter [Kimura et al. 2013], there is possibility that the sea ice in the ESS is also heavily deformed to form the sea ice thicker than 1 m along the coastal region. In fact, our analysis based on the AIS data suggests that the SIT in excess of 100 cm is found in the coastal region of the ESS. Thus, for the precise evaluation of the SIT distribution in the ESS, the further improvement of ice-type as well as the accumulation of in-situ SIT measurement is needed. These discussions have been added in section 6 in the revised version (Lines 4853-496).

L230: I consider that the 2nd "errors" can be eliminated.

*** Through the revision, this sentence was removed in the revised version (Line 297).**

L252: The abrupt reduction in October in Fig. 5 is not clear to me. Please chick this.

*** As the reviewer pointed out, the abrupt reduction of prediction skill in October is obscure in Fig. 5. We checked the prediction skill in October and found that it**

shows discontinuous change from the lead time of 3 to 4 days, but the reduction rate and the enhancement of the STD is smaller than those in May and July (Fig. A1). On the other hand, the prediction skill in September, in which the seasonal reduction rate of SIT is small, shows the abrupt reduction in Fig. 6. Thus, we removed the statement in the prediction skill in October in the revised version, and added some additional statements as follows;

"Such an abrupt reduction of the prediction skill and the enhanced standard deviation are also found in May and September, although the absolute values of the reduction rates are smaller than that in July. Since the influence of sea ice melt is small in these months (Fig. 5c), the abrupt reduction of early summer SIT prediction skill might be attributable to dynamical advection of sea ice." (Lines 328-332)

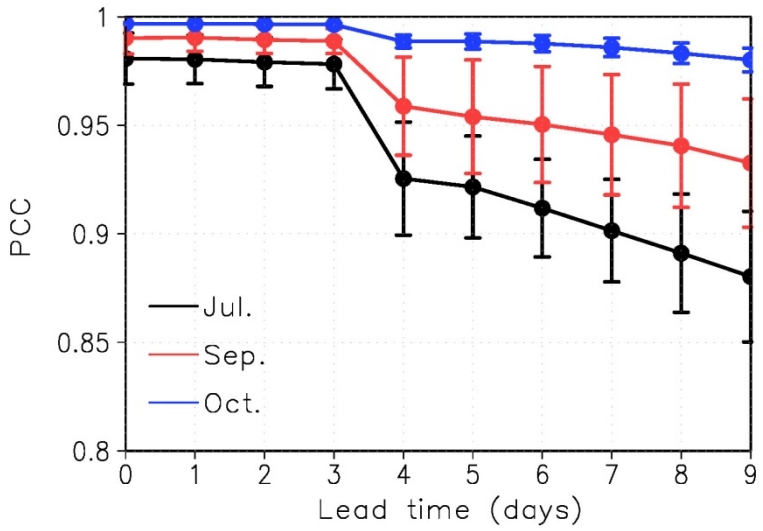

Figure A1. PCCs between forecast and analysis SIT in TOPAZ4 in July (black), September (red), and October (blue) averaged on 2014-2016. Error bar indicates the standard deviation of the PCCs.

In addition to this revision, we have merged Figures 6 and 7 in old version into Figure 7 in the revised version.

L261: Please weaken the statement "the SIT distribution has a zonally homogeneous pattern".

***According to the reviewer's comment, we have rephrased the corresponding sentence as follows;**

"Since the SIT distribution has a tongue-like distribution (Fig. 5a),…" (Line 342)

L272: "directed southward" should also be weakened if it is not exactly southward.

***According to the reviewer's comment, the direction of predicted sea ice velocity is not exactly southward. To avoid the misleading, we have rephrased this sentence as follows;**

"The resultant onshore anomaly of sea ice velocity leads to positive and negative anomalies..." (Line 355)

L277: "a deficiency at predicting Arctic cyclone". Please check this "at". (I am not a native English speaker and sorry if this is correct.)

*** As the reviewer pointed out, this preposition is not appropriate in this case. We have rephrased this as follows;**

"… is related to a deficiency in the prediction of Arctic cyclone formation." (Line 360)

L312 and L313: I think the units "cm s-1" should be "m s-1". Please check them.

*** We apologize for the incorrect unit. We have corrected the unit by m s^{-1} (Lines 396z-397)**

L320: Since the authors describe on the reduction of the prediction skill in the 4th day, some words should be added to "remains at high level after the lead time of 4 days" on how high it is in order to avoid confusing.

*** As the reviewer pointed out, this description is misleading, because this sentence is somewhat inconsistent with the abrupt reduction of prediction skill at 4^{th} day. Thus, we have appropriately revised the corresponding sentence as follows;**

"It is interesting that the prediction skill of SIT in early summer remains ~0.9 at the lead times longer than 4 days (Fig. 7a), despite the poorer prediction skill… (Fig. 7b)." (Lines 404-406)

In addition to this revision, we have removed the related sentence in section 6 (Lines 525-527).

L358: "controlled by the weak skill of atmospheric prediction" is not clear to me.

***As the reviewer pointed out, the prediction skill in winter is not necessarily controlled only by the atmospheric prediction skill but also ocean current change. Since the uncertainty of this discussion seems to be large, we have removed them in**

the revised version (Lines 439-445).

L366: "Figure 13" -> "Figure 12"

*** We apologize for the wrong Figure number. We have appropriately corrected the figure number in the revised version (Line 451).**

L370: "Fig. 14a" -> "Fig. 13"

*** We apologize for the wrong Figure number. We have appropriately corrected the figure number in the revised version (Line 455).**

L371: Please provide the significance of the difference between these two correlation coefficients if possible. Even if it is not significant, please do not consider to delete this interesting section. The sample number will be increased in the future to determine its significance as described in the final section. However, more careful discussion seems to be required for the conclusion in this section, since 1) the SIT and SIC time series can be resemble and 2) reproduction of SIC in the TOPAZ4 reanalysis is not validated in this study.

*** As the reviewer pointed out, the difference between the correlations based on SIT and SIC is not so large (0.03, which accounts for only 5% of variance). In fact, the SIT is significantly correlated with SIC (r=0.86). We also admit that the number of sample is not enough to discuss the difference of the correlation relationship between SIT and SIC.**

Our analysis based on the daily-mean AIS data might not be appropriate, which was noticed by my co-author during this revision process, because the vessel speed is fast to experience the multiple grids of TOPAZ4 SIT data during one day. To check the above possibility, we examined the statistical relationship between raw AIS data, whose time interval is about 2-3 hours, and daily mean SIT in TOPAZ4. The corresponding scatter plots of SIT and SIC to the corresponding vessel speed are shown in Figure A2, respectively. The correlation between the vessel speed and SIT is -0.56 (n=160), which is significant at 99% confidence level (Fig. A2a). On the other hand, the correlation between the vessel speed and SIC is -0.41 (n=160), which is insignificant at 99 confidence level. The scatter plots for SIC (Fig. A2b) indicates that the SIC value is somewhat insensitive to the vessel speed higher than 10 knot. Although the problem of sample size number still remains even in this analysis, these results support that the vessel speed was influenced by sea ice stress due to SIT and indirectly supports the reliability of the daily mean SIT of the

TOPAZ4 reanalysis data in the ESS in early summer. Thus, we have replaced Figure 12 in old version by Figure A2 and modified the corresponding sentence as follows;

“A joint statistical analysis of the daily mean SIT in the TOPAZ4 reanalysis and the vessel speed along the route indicates that vessel speed is significantly anticorrelated with SIT (–0.56) during the entire passage (Fig. 13a), significant at the 99 % confidence level based on a Monte Carlo technique [Kaplan and Glass, 1995]. We also examined the corresponding SIC data in TOPAZ4 reanalysis data, but the correlation between the vessel speed and SIC is -0.41 (Fig. 13b), which is insignificant at 99% confidence level. The scatter plots for SIC indicates that the SIC value is somewhat insensitive to the vessel speed higher than 10 knot. Although the problem of sample size number still remains in this analysis, these results support that the vessel speed was influenced by sea ice stress due to SIT and indirectly supports the reliability of the daily mean SIT of the TOPAZ4 reanalysis data in the ESS in early summer.” (Line 453–462)

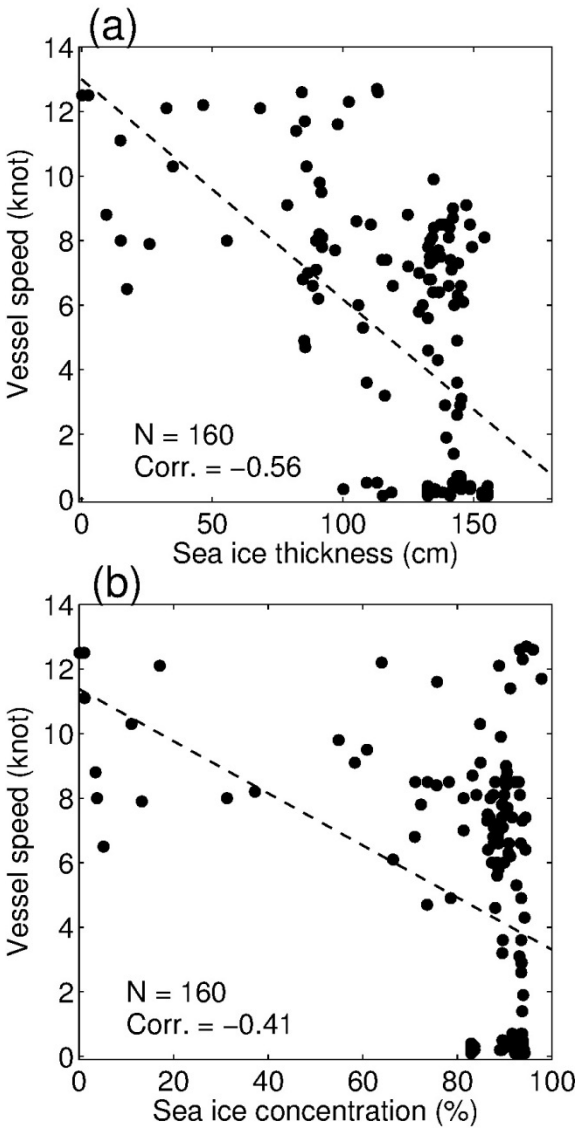

Figure A2. Scatter plots of hourly vessel speeds (knots) and (a) daily mean SIT (cm) and (b) SIC (%) in TOPAZ4 reanalysis from 4–30 July 2014. In each panel, the regression line of vessel speed onto each variable is shown by broken line.

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)