Responses to reviewer #2 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 #2
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General comments:
This paper evaluates (1) sea ice thickness (SIT) from the 4th version of the Towards an Operational Prediction system for the North Atlantic European coastal Zones (TOPAZ4) ocean data assimilation system and (2) medium range forecast of SIT distribution in the Eastern Siberian Sea (ESS) from the TOPAZ ocean data assimilation system forced by the ECMWF atmospheric medium-range forecast data. The evaluation of TOPAZ4 SIT uses observational data from satellite retrievals, in situ observations and model generated output from the Pan-Arctic Ice Ocean Modeling and Assimilation System (PIOMAS). The forecast evaluation analyzes impacts of dynamic and thermodynamic processes. Descriptions of the methods and analysis are clear. The results are interesting. I recommend the paper be accepted for publication after a minor revision.

Specific comments
1. The SIT from the TOPAZ4 assimilation contains large errors which are comparable to that in PIOMAS. I would suggest that the both TOPAZ4 SIT and PIOMAS SIT be used for the evaluation of the forecast to reduce the observational uncertainties. I also suggest PIOMAS be included in Figure 1.
***According to the reviewer's comment, we examined the forecast skill of TOPAZ4 assuming that the PIOMAS SIT is the true value. However, the prediction skill is**

quite low in a whole season (Fig. A1). This is probably due to the spatial distribution of SIT in TOPAZ4 analysis is different from that in PIOMAS on daily mean field. Although the overall pattern of the SIT distribution in TOPAZ4 is similar with that in PIOMAS in and around the ESS in the climatological field (Fig. 1), the location of ice edge and small-scale undulation near the shelf region of ESS highly depends to the original model resolution. Since our study focus on the small-scale disturbance of SIT in the ESS, we believe that the evaluation of the prediction skill based on TOPAZ4 analysis and its forecast is appropriate for our purpose.

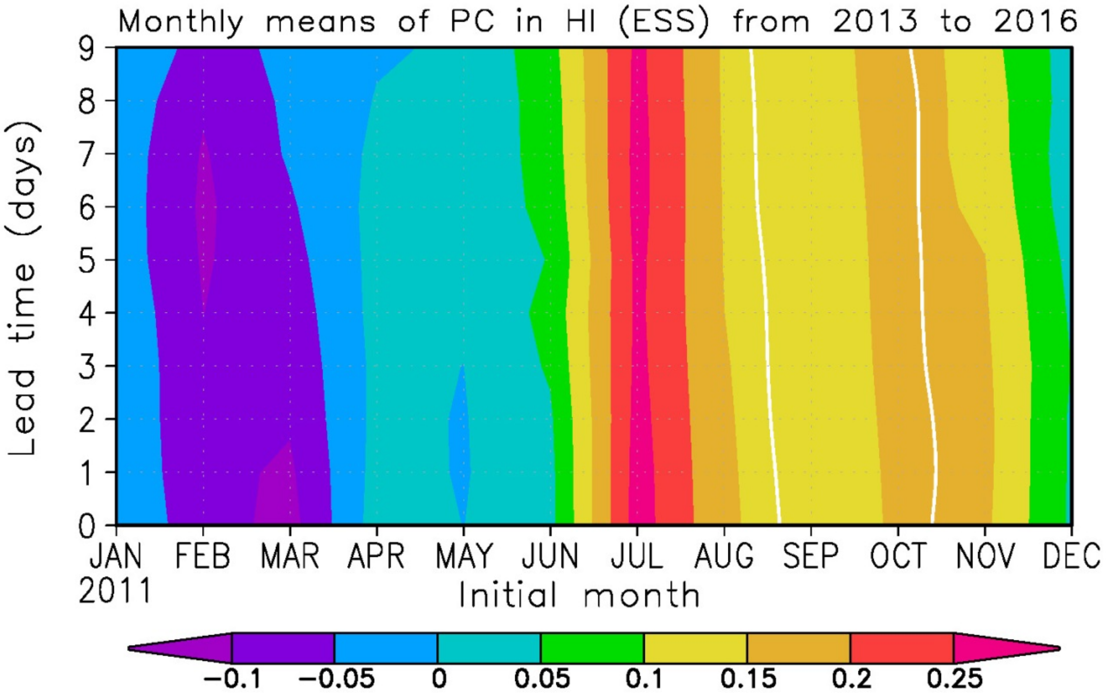

Figure A1. The prediction skill (PCC) of SIT forecast in the ESS (70°–80°N, 150°–180°E) in each month obtained from TOPAZ4 operational forecast model with PIOMAS hindcast SIT data, averaged from 2013–2016. The standard deviations of the PCCs are shown with white contours.

On the other hand, we have added the climatological SIT of PIOMAS in July in the revised version (Fig. 1) to evaluate the overall distribution of SIT in TOPAZ4 analysis. The PIOMAS show relatively thick ice (>1.0 m) extends from the North Pole to the ESS (Fig. 1a). These features are qualitatively simulated in the TOPAZ4 reanalysis data (Fig. 1b). The PCC of the climatological SIT between TOPAZ4 and PIOMAS in the Arctic marginal seas is larger than 0.9 from March

to July (Table 2). Notes that the region for the Arctic marginal seas is partly shrunk in the revised version, because we don't focus on the Kara Sea (Fig. 1a). The PCCs of the climatological SIT between TOPAZ4 and CS2SMOS from March to April are comparable to those for PIOMAS (Table 2), and thus these results support the reliability of the spatial distribution of SIT in and around the ESS. These results have been added in the revised version (Lines 225-241).

In addition, the monthly mean biases of TOPAZ4 SIT data relative to PIOMAS in Jun to July are smaller than those in March to May (Table 3), although the TOPAZ4 SIT in the ESS tends to be thinner than the PIOMAS SIT in freezing season. Also, the TOPAZ4 SIT is within the standard deviation of PIOMAS SIT anomaly in each grid relative to the area-averaged value in early summer (June-July) (Fig. 3). Thus, at least the overall spatial distribution of SIT in the ESS is qualitatively simulated in the TOPAZ4 and the inherent negative bias is suppressed in early summer, which is partly related to the compensation by the positive bias near the shelf region of the ESS. These results and discussions have been added in the revised version (Lines 242-268).

Along with this revision, Figure for the comparison of climatological SIT distribution between CS2SMOS and TOPAZ4 in April has been moved to Fig. 2.

2. A large portion of the PCC skill in Figure 5 is from the persistence. A comparison with persistence skill is needed to see to what extent the sill in Figure 5 has benefited from the persistence of the initial anomalies.

*** According to the reviewer's comment, we have added the prediction skill obtained from the persistency in Fig. 6b and the difference in the prediction skill between the operational forecast model and persistency (Fig. 6c). As expected, a large portion of the prediction skill originates from the persistency at the lead times of 0-3 days (the explained variance is about 95%). On the other hand, the fraction of the prediction skill related to the operational model increases at longer lead times in a whole season except for May and October. In July, the contribution of the operational model on the prediction skill reaches ~15% at 7 day lead time. These results and implication have been added in the revised version as follows;**

"We found that the overall prediction skill is relatively low in warm season (June-September) with a larger spread compared with the cold season (October–May). This result is roughly consistent with the larger variance of the SIT anomaly in the warm season in the ESS (Fig. 5c). A large portion of the prediction skill at the lead times of 0–3 days can be explained by the persistency

effect based on the initial SIT (Fig. 6b). The contribution of the operational model on the forecast skill is less than 5% at shorter timescale (<3 days) (Fig. 6c), but the contribution of the operational model gradually increases at longer lead times except in May and October. In July, the contribution of the operational model on the prediction skill reaches ~15% at 7 day lead time. These results indicate that the operational model substantially improves the medium-range prediction skill of the SIT distribution in summer." (Line 314-324)

3. Lines 134-138. Move the portion "In this . . .process [Startk et al. 2008]" into the first paragraph of section 2.

***According to the reviewer's comment, we have moved these sentences into the first paragraph of section 2 (Lines 130-134).**

4. Line 145. How is the 10-member ensemble produced?

*** To produce the ensemble members in the TOPAZ4 forecast system, the atmospheric forcing (e.g. wind speed), which is the ECMWF global atmospheric forecast data, as well as several parameter of sea ice model (such as e: the ratio of yield curve for rheology) are perturbed by adding stochastic forcing term due to inherent model errors [Evensen, 2003]. In this perturbation, the model error (q_k) is calculated based on the assumption that the perturbations of the forcing fields are related to red noise as follows;**

$$\vec{q}_k = \alpha \vec{q}_{k-1} + \sqrt{1-\alpha^2}\,\vec{w}_{k-1}. \tag{1.1}$$

Where, α is lag 1 auto-correlation and w_k is a sequence of white noise with the mean 0 and variance 1. This stochastic forcing term is added to the atmospheric forecast value and several parameters of sea ice model. In the revised version, we have added the essence of these descriptions as follows;

"To produce 10 ensemble members in the TOPAZ4 forecast system, the ECMWF global atmospheric forecast data as well as several parameters of sea ice model are perturbed by adding stochastic forcing term [Evensen, 2003]." (Lines 155-158)

5. Line 146. Spell out ECMWF.

*** According to the reviewer's comment, I have spelled out ECMWF in the first appearance of this manuscript as follows;**

"…, forced at the surface by the European Centre for Medium-Range Weather Forecasts (ECMWF) operational atmospheric forecasts,…"(Line 96)

6. Line 149. Please make clear how the 259 cases come out.

*** We apologize for the inappropriate number of forecast data of 259, which was not for 4 years (2013 to 2016), but for 5 years (2012 to 2016). On the other hand, we found that the prediction skills are strongly fluctuated before 2013 at initial step, after we have rechecked the PCC in each case (Fig. A1). According to coauthor's comment, such case is related to the free run without the initialization based on observational data (For example, 17th July 2014). Since these forecast data substantially reduce the initial prediction skill and increases its spread, we used the forecast data from 2014 to 2016 (Line 152) and removed the forecast data in July 2014 in the revised version. Consequently, the total of 150 cases was assembled during 4 years (2014-2016). I have modified the corresponding sentence in the revised version as follows;**

"In this study, we excluded the forecast data in July 2014, because of a real-time forecast production incident (the forecast were in free-running mode then) [H. Engedahl, personal communication]. Since the forecast data were only provided weekly before 2016, the total of 150 cases was assembled during the study period." (Lines 159-162)

Based on this new forecast dataset, we recalculated the prediction skill of SIT, sea ice velocity, and wind speed by removing these spurious forecast data. Thus, Figures 6, 7, and 10 were changed in the revised version. Overall features of PCCs were not essentially changed, but the absolute values somewhat have been increased.

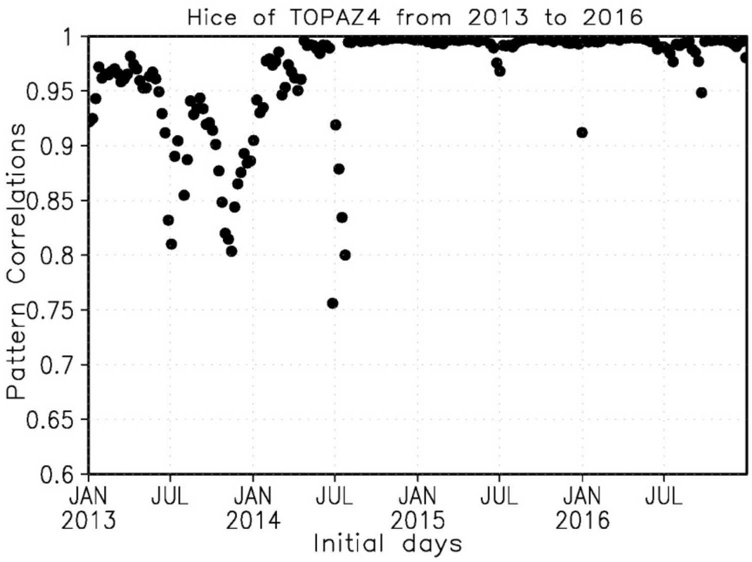

Figure A1. Daily means of the PCCs between forecast and analysis SIT at first step during 2013-2016.

7. Line 172. Spell out PIOMAS.

*** According to the reviewer's comment, I have spelled out PIOMAS in this sentence as follows;**

"…, we used the Pan-Arctic Ice Ocean Modeling and Assimilation System (PIOMAS) outputs,…" (Line 170-172)

8. Line 272. Change "completely" to "largely". The correlation shows that they are still related to some extent.

*** As the reviewer pointed out, our sentence is not accurate. According to the reviewer's suggestion, we have rephrased the corresponding sentence as follows;**

"…, the predicted and analyzed sea ice velocities are largely unrelated." (Line 355)

9. Line 371. Fig.14a does not exist.

*** I apologize for the typograph error. We have modified the figure number correctly as follows;**

"…during the entire passage (Fig. 13a),…" (Line 455)

10. "Figure" and "Fig." are used interchangeably.

*** In this manuscript, in the case of the first word in sentences, we adopt the word "Figure". On the other hand, the word "Fig." is used in the case for the last word**

in sentences. The use of “ Figure” and “Fig.” appropriately depends on the rule of the manuscript format in this journal.

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)