Summary:
The authors introduce a novel measure of the state of spring sea ice melt - Melt Advance (MA). Four scenarios of melt advance in the Laptev (LS) and East Siberian (ESS) seas are identified. For each scenario, a composite map and atmospheric parameters and sea ice concentration are derived. Based on the composite analysis authors conclude that "each scenario is driven by a distinct circulation of the low atmosphere in May". The identification of four scenarios of melt advance in the Laptev (LS) and East Siberian (ESS) seas is a valuable contribution. However, I find that the current results and their interpretation do not robustly support the conclusion drawn in the paper.

General comments:

R: Thanks for all the insightful comments and suggestions from this referee. Our reply follows each specific comment, which probably also answers for those general comments.

The overall standard of result interpretation seems to be less than satisfactory.

1. The authors' interpretation of the influence of atmospheric circulation on Melt Advance (MA) appears speculative. While various atmospheric parameters are examined, the discussion lacks depth regarding atmospheric circulation. Descriptions such as "northeasterlies seem to bring slightly moist air masses" and "westerlies may contribute to positive anomalies in TWS and SAT" are somewhat vague.

2. The attribution of the slow Melt Advance in the 1980s to a cyclonic anomaly in the lower troposphere seems to me nonsensical. The association of a significant negative anomaly in surface air temperature with northerly winds appears contradictory to the well-established concept of Arctic warming and amplification. This inconsistency raises questions about the reliability of the study and concerns about the quality of interpreting the results.

3. Region-specific sea-ice processes are not adequately addressed in the interpretation of the results.

In general, the observed SIC anomalies in the Laptev Sea are related to the polynya activity. The northward sea ice drift results in the opening of polynya at the fast ice edge. Westerly winds would not typically result in reduced sea ice concentration in the region, as stated in the paper. The negative Sea Ice Concentration (SIC) anomaly in the Laptev Sea is resulted from polynya opening in response to northward wind and sea ice drift (e.g., Krumpen et al. 2011). In contrast, one would expect westerlies to close the polynya, leading to an increase in SIC. Please, also see Specific comment 6.

In describing another Melt Advance (MA) scenario, the authors mention that due to wind action, sea ice consolidates against the coast, resulting in a positive sea ice anomaly. Unlike the authors describe, sea ice does not consolidate at the coast in May. The consolidated fast ice cover is formed by April (Selyuzhenok et al. (2014)). The subsequent SIC anomalies are related to the polynya activity in the region. Please, see Specific comment 4.

Specific comments:

1. As the paper aims “to demonstrate the springtime processes related to different MO scenarios’’ presence of polynya might be considered:

From Fig. 2 and Fig. 4 it seems to me that polynya plays a curtail role in the MA scenarios. Of course, the presence of polynya is accounted for in SIC, but there is also another effect e.g., precondition state of sea ice before MO. Sea ice type and as a result surface albedo in the region depends on the polynya activity. It seems that if polynya is active in May, the MA develops under LS-faster or faster scenario.

R: Agree. We may account for the polynya by SIC, but polynya presence and activity are vital in this region. We would incorporate this into the text.

2. Lines 23-30 (and elsewhere): As the authors showed, the slow scenario of MA was present only during the 1980s. Fig. 2, 3 show negative SEB, positive SIC anomaly, and negative SAT anomaly everywhere in the region. In my opinion, the slow scenario is purely related to the different states of sea ice and atmosphere in 1980s. The authors should make it clear that the slow scenario is not related to the “interannual flexibility of spring circulation in the low troposphere” (also addressed in General comment 2).

R: We appreciate this perspective, which is a helpful complement for the conclusion.

Note that all the three sample years are from the 1980s. So, the larger sea ice cover and cooler atmosphere mainly reflect the Arctic state in the 1980s, which is a decadal phenomenon rather than interannual characteristics.

3. Lines 117-119: Please, explain what is meant by “date-dependent metric”. It is not clear why MA potentially has an advantage over regional MO in predicting summer sea ice extent. Please, explain what is the advantage of MA over other September sea ice prediction methods based on MO (e.g. Petty et al. 2017). Fig.6 shows that MA performs slightly better than May SIC predicting in September SIC in the ESS. Is there any explanation for that?

R: We revise this part as the demonstration of “date-dependent metric” may be confusing. The metric of Melt Advance is in essence similar to the average MO date, except that by the end of May we can retrieve the Melt Advance if real-time satellite MO data is available. This may help timely seasonal prediction in a given year. As Fig. 6 shows, the Melt Advance seems statistically to have similar predictive skill as the May SIC. We do not argue that MA has significant advantage over May SIC.

For the seasonal prediction of summer sea ice, this metric of Melt Advance is in essence similar to the average MO date, but may have advantages if we can get real-time satellite MO for the region. Then, at the end of May or other specific date, we can get the MA pattern which supports timely seasonal prediction in a current year.

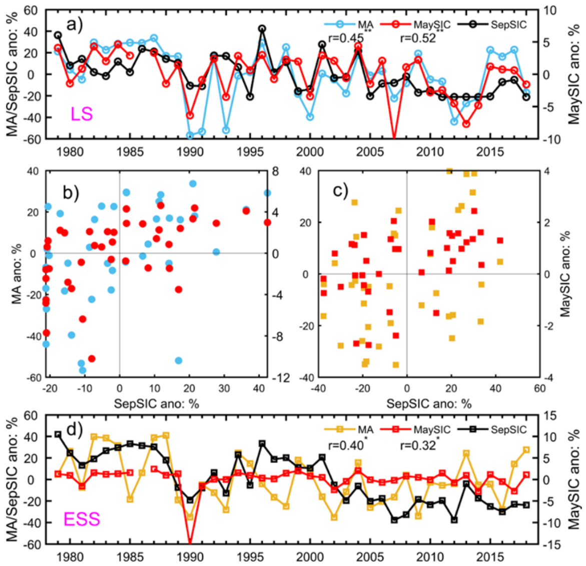

Fig. 6. Sea-ice surface Melt Advance, SIC in May and September sea ice cover in the Laptev Sea (subplot a and b) and East Siberian Sea (subplot c and d), 1979-2018. September sea ice cover is denoted by the areal percentage of sea ice cover relative to the whole sea. To facilitate viewing, Melt Advance is timed by -1. Correlation coefficients with double asterisks denote 99% confidence, while those with a single asterisk denote 90% confidence.

4. Lines 207-210: The description is not accurate: "In the ESS-faster-scenario (see second row in Fig. 3 and blue bars in Fig. 4), prevailing northeasterlies in the lower troposphere push and consolidate the sea ice against the land, especially for the LS, which increases surface albedo and decreases solar radiation absorption." The shelf areas of the Laptev and East Siberian Seas are covered with extensive fast ice (up to 200 km wide). The fast ice cover can be seen as a near-zero SIC anomaly along the coast in Fig.3. In May sea ice does not consolidate against the land. The SIC anomaly in Fig.3 is related to polynya occurrence.(e.g. Willmes et al. 2011). (also addressed in General comments)

R: Agree. The original description seems to indicate that more fast ice is formed in this case which probably is not true. We would like to incorporate this useful information about fast ice in the Discussion section.

prevailing northeasterlies in the lower troposphere tend to increase SIC and reduce polynya area, especially for the LS, which increases surface albedo and decreases solar radiation absorption.

5. Lines 211-212: The TWV does not seem to be close to climatological. It has positive anomalies in the ESS and negative anomalies in the LS. This aligns with the later drawn conclusion that a moist atmosphere facilitates Melt Advance. Moreover, in lines 218-219 the authors explicitly say that TWV is increased in the ESS.

R: Yes, some paradox. We agree that it has positive TWV anomalies in the ESS and negative anomalies in the LS, which supports the ESS-faster-scenario.

6. Lines 220-223: It seems to be not logical that westerlies result in the reduced sea ice concentration over the Laptev Sea and increased concentration over the East Siberian Sea. Here again, the negative SIC anomaly in the LS reshapes polynya at the fast ice edge. The SIC in the region, which opens due to northward sea ice drift (e.g. Krumpen et. al. 2011)

R: The westerlies may have offshore wind component in the LS, which opens up polynya and reduces SIC, echoing the study of Krumpen et al. (2011). We add some explanation here.

Such circulation has offshore wind component in the LS, which probably leads to more polynya opening and reduced SIC (Krumpen et al., 2011).

7. Lines 225-228: "The westerlies may also contribute to positive anomalies of TWV and SAT in the LS, which promotes faster MA." Do westerlies always bring moisture and warm air to the region? Please provide the background for this statement.

R: The statement is somewhat speculative. We think that westerlies may bring air masses from the North Atlantic part, which should be moist and warm.

8. Lines 317-319: "Composite analyses reveal that the dominant driver is circulation in the lower troposphere, which regulates sea ice dynamics as well as air mass advection." I do not agree with this conclusion. It seems to me that the authors described the results in the way that all four scenarios of MA are attributed to a mean wind direction. Their interpretation of the results contains logical errors and a disconnection from real processes. Please, see Specific comments 4-6.

R: We agree that this conclusion is oversimplified. We should mention that the slow-scenario mainly reflect the Arctic state in the 1980s when sea ice cover is more and atmosphere is cooler. In addition, polynya activity and initial sea ice condition are also not neglectable.

9. I would interpret Fig 3 as follows: ESS-faster scenario is associated with positive TWV anomaly and negative SAT anomaly over the ESS and negative TWV and positive SIC over the LS. LS-faster and fast scenarios seem to occur when polynya is observed in the Laptev Sea. Motrin et al. (2016) showed that moist and warm air trigger melt onset. The observed TWV anomaly repeats their finding (see Fig.2 in Mortin et al. (2016). I would be interested to see how much polynya contributes to MA in the region.

R: Agree. We would like to incorporate this insight into the conclusion.

Technical comments:

Lines 67-68: ''heaviest ice block", please re-formulate

R: We use "most persistent sea ice coverage" instead.

Lines 69-70: Do you mean MA scenarios?

R: Yes.

Lines 91-94: Please define SEB here. Is only data from May used? Please specify this in the Data and Methods section for all variables.

R: Yes, only data from May is used. We also define SEB here.

Note that the four components of the surface energy balance (SEB) include NLR, NSR, SLHF, and SSHF.

Lines 104-111: This is general information that can be moved to the introduction.

R: Corrected.

Lines 112: "Interannually, MO is expected to change within one month (Fig. 1b)". The sentence is not clear to me. Please, consider reformulation.

R: Corrected.

The range for the interannual change of MO in a given place is expected to be around one month (Fig. 1b).

Lines 116-117: The sentence seems to be not completed. " …as well as the spatial pattern" probably "of the melt advance" should be added.

R: Added.

Line 169: Please, define SEB in the Data and Method section.

R: Agree.

Lines 215-216: Please, refer to Figure S4 in terms of SEB. Here authors state that the solar radiation absorption in the LS is higher than in the ESS. How can you support this conclusion?

R: Yes, we need to refer to Fig. S4 in terms of SEB. Here, we mean that negative anomaly of solar radiation absorption in the LS is greater than in the ESS.

Lines 261-263: starting with "In addition.." Please, provide references.

R: Added.

Mortin et al. (2016) argued that on a synoptic scale, increased water vapor in the atmosphere favors stronger DLR, which promotes sea-ice surface melting.

Lines 283-285: Please, elaborate. There is no information in this sentence. How are the modes of MO in the work in press related to the MA?

R: Corrected.

Liang and Zhou (2023) identified three modes of Melt Onset in the LS and ESS by EOF decomposition. The positive L-mode and E-mode correspond to LS-faster-scenario and ESS-faster-scenario, while the positive and negative LE-mode relate to fast-scenario and slow-scenario, respectively.

Lines 286-299: This part presents a new analysis and resulting figure. Please, move it to the Results section.

R: Corrected.

Figures:

Fig.1. Caption “Four categories of sample years are marked”. Are there only 16 years out of 40 years long time-series that fall into one of four categories? Or these are only selected “sample” years?

R: We mean that only 16 years out of the long time-series fall into one of four categories. We reformulate this sentence accordingly.

References:

Krumpen, T., et al. (2011), Sea ice production and water mass modification in the eastern Laptev Sea, J. Geophys. Res., 116, C05014, doi:10.1029/2010JC006545.

Mortin, J., G. Svensson, R. G. Graversen, M.-L. Kapsch, J. C. Stroeve, and L. N. Boisvert (2016), Melt onset over Arctic sea ice controlled by atmospheric moisture transport, *Geophys. Res. Lett.*, 43, 6636–6642, doi:10.1002/2016GL069330.

Petty, A.A., Schröder, D., Stroeve, J.C., Markus, T., Miller, J., Kurtz, N.T., Feltham, D.L. and Flocco, D. (2017), Skillful spring forecasts of September Arctic sea ice extent using passive microwave sea ice observations. Earth's Future, 5: 254-263. https://doi.org/10.1002/2016EF000495

Selyuzhenok, V., T. Krumpen, A. Mahoney, M. Janout, and R. Gerdes (2015), Seasonal and interannual variability of fast ice extent in the southeastern Laptev Sea between 1999 and 2013, *J. Geophys. Res. Oceans*, 120, 7791–7806, doi:10.1002/2015JC011135.

Willmes S., Adams S., Schröder D., & Heinemann G. (2011). Spatio-temporal variability of polynya dynamics and ice production in the Laptev Sea between the winters of 1979/80 and 2007/08. *Polar Research*. https://doi.org/10.3402/polar.v30i0.5971