Answer to RC1

We thank the anonymous reviewer for their constructive feedback. Please find our answers below. The original review in italic, our answers in black font below and changes to the manuscript in bold.

1) First of all, the authors find that the atmosphere mostly drives sea ice conditions in spring, that there's no strong link in summer between sea ice and the atmosphere (nor extending to the adjacent land), but that there's a stronger southward transport of both energy and moisture in low sea ice autumns, when the sea ice starts to freeze again. This is not a new finding. This has been shown before at the pan-Arctic level in several publications by James Screen and co-authors (see e.g. Screen et al., 2012b, 2012a;Screen and Simmonds, 2010) but also others (For example Bintanja and Selten, 2014; Pithan and Mauritsen, 2014; Serreze et al., 2009; Serreze and Barry, 2011). It's surprising that none of these studies have been cited in this paper (although the authors cite another, less relevant, paper by Pithan et al. from the same year. Wrong citation perhaps?). At least some of these should be added next to the papers by Lawrence et. al and Parmentier et al. that are already cited. Btw, the latter found strong correlations only in spring and autumn, but they argued that these correlations were contemporary in spring and only causal in the autumn, which corresponds to the findings by this study (but this is not mentioned here). The work by Graversen et al. is also a nice addition, since it shows a different view on the role of sea ice in arctic amplification (that north-ward atmospheric transport of heat may be more important). An alternate view on arctic amplification is given in the cited paper by Ogi et al but that's a very limited study of just nine weather stations, which is far from enough to grasp the drivers of arctic amplification beyond some local effects. While I appreciate the introduction of causal-effect networks to study ocean-atmosphere interactions, the general conclusions about the role of sea ice in ocean-atmosphere feedbacks are not new and the studied region is rather small, which makes it hard if not impossible to generalize to the whole of the Arctic.

R1) These papers are valuable additions to our introduction. We included the mentioned papers in the first paragraph of the introduction, which we adapted as below. Additionally, we added selected papers as references at appropriate locations throughout the manuscript:

> **To better understand both the mechanisms behind as well as the strength of the interaction between sea ice and land we explore links between sea ice and the atmosphere over land and identify local and large-scale drivers of sea-ice cover in the Laptev Sea. Sea ice interacts with the atmosphere on different scales. However, while links from sea ice to large-scale atmospheric processes have been shown (e.g. Samarasinghe et al., 2019; Screen et al., 2018; Luo et al., 2017; Simmonds, 2015), the strongest coupling to the atmosphere is local (Screen and Simmonds, 2010; Screen et al., 2013). Sea ice influences near-surface temperatures by changing the local energy budget and regulating the moisture and energy which enter the lower atmosphere (Screen and Simmonds, 2010; Screen et al., 2013). This effect is more predominant in fall than in spring (Serreze et al., 2009; Serreze and Barry, 2011; Screen et al., 2012). Additionally, downward radiation plays a role in changing the surface fluxes and thereby the surface temperature. Downward radiation has been associated with the moisture fluxes from mid-latitudes into the Arctic, which show a positive trend in recent decades (Lee et al., 2017; Serreze and Barry, 2011). Little attention has been focused on the physical mechanisms through which variability in sea ice influences the atmosphere over land. Nevertheless, from prior research we know that sea ice can exert such an influence on land (Lawrence et al., 2008; Ogi et al., 2016). Changes in the atmosphere over land, which are attributed to declining sea ice, lead to various responses in the permafrost landscapes,**

> **ranging from increased methane emissions (Parmentier et al., 2015, 2013) to vegetation productivity (Bhatt et al., 2008; Macias-Fauria et al., 2017) and vegetation composition (Post et al., 2013). Thus, a better understanding of the connection between sea ice and land is valuable, especially since sea ice and the permafrost covering adjacent landmasses are both highly vulnerable to climate change. In this paper, we aim for a better understanding of the physical mechanisms behind the connection of sea ice to the atmosphere over land.**

Additionally, we added some of the papers also in the discussion to embed our findings better in the literature, like a reference to Parmentier et al. (2015) at the discussion of the fall fluxes.
It is true that our study focus is on a very small region and we make our argument clearer for the choice of the Laptev Sea. Also, in our conclusions we only hypothesize what this could mean for the Arctic as a whole. Please also refer to our answer R9).

2) *Second, the paper starts of by presenting itself as a study where links are investigated between the ocean, the atmosphere and subsequently the land (i.e. permafrost thaw and carbon fluxes). However, despite using a regionally coupled model, they do not appear to have included a land surface model to actually model the response of the land surface (apart from runoff). So, in the end, the response of permafrost and carbon fluxes to changes in the atmospheric forcing due to sea ice decline remains unclear. The authors mention that this study is a first step, but the introduction suggests that this topic will be investigated in more detail – which isn't the case – and the topic doesn't come back until the conclusions as a possible outcome, but it has not been analyzed. So why lead with this topic in the first sentence of both the abstract and the main text if the paper does not deal with this topic at all? Also here, the literature already holds many examples of possible connections which should be acknowledged if this topic is to be studied at a later stage (see e.g. Bhatt et al., 2010; Macias-Fauria et al., 2017; Parmentier et al., 2013; Post et al., 2013).*

R2) We shifted the focus of the abstract by changing the first sentences as follows:

> **We investigate how sea ice interacts with the atmosphere over adjacent landmasses in the Laptev Sea Region as a step towards a better understanding of the connection between sea ice and permafrost.**

All papers mentioned are now also included in the first paragraph of the introduction. See also R1).

3) *Apart from excluding a land surface model, the model setup also raises a few questions. First of all, why only focus on the Laptev Sea and the adjacent land? The regional model appears to have been run for most of the northern hemisphere and repeating the same analysis for other regions should be trivial. It would also show whether the found connections hold up in other regions where sea ice export is strong (e.g. along the coast of Greenland).*

R3) We want to look at physical mechanisms in depth, so we decided that it is more appropriate to focus on one region, rather than comparing several. We chose the Laptev Sea region, because it shows large interannual variability and borders on Eastern Siberia, which is covered by carbon-rich permafrost landscapes. The only other region with comparable interannual variability in the model is the Barents Sea, which is much more influenced by the North Atlantic than the Laptev Sea. Thus, for extracting the influence of sea ice on land, we deemed the Laptev Sea more fitting. Line 54:

The Laptev Sea is one of the key contributors to net sea-ice production in the Arctic (Bauer et al., 2013; Bareiss and Görgen, 2005) and shows large year-to-year variability (Haas and Eicken, 2001) as can be seen in Fig. 2. Its surrounding landmasses are characterized by near-pristine permafrost landscapes.

4) Also, why did the authors choose to run the model for the era before sea ice melt truly began (1950-1989)? This may lead to an underestimation of the role of sea ice in arctic climate feedbacks. If this is to be investigated, why not do this analysis for the period where sea ice started to decline and perhaps compare to the era of relatively stable ice conditions? The authors also repeat the same time period 4 times, but sea ice conditions are quite different between the four model runs. Why is this? It is not explained in the paper.

R4) Our aim is to first understand the underlying processes, before we investigate possibly interacting changes in the processes. Even if we might underestimate the effects of strong changes, we look at stable conditions instead to be able to extract the possibly weak signal from ice better. A possible next step would be to look at climate change.

The model has internal variability: The atmospheric model nearly covers the whole northern hemisphere and, consequently, can evolve freely without strong constrains by the external forcing. This is precisely the reason why we can run the model with the same forcing repeatedly, thereby prolonging the time series, without having the same values multiple times.

5) *Overall, I think that the study is interesting, but the authors appear to present it as more novel than it is, and they should contextualize it better in the existing literature. A lot of work has been done on this topic, and a rather limited regional analysis over a historical time period with stable sea ice cannot be used in this way to draw strong conclusions on how sea ice decline has affected the whole arctic system, including the adjacent land, in recent decades.*

R5) With the adjustments made in the manuscripts it should be clear, that we focus on the climate before warming and that we focus on one specific region.

6) *A diagram of which time periods and variables are compared to each other would be useful. From the text it can be difficult to follow which is being discussed. Perhaps label them?*

R6) We added a table providing an overview over the variables used in each set-up as well as, in the figure description, a summary of the analysis done. The table is appended to this document. This allows for a better overview. We added additional pointers throughout the paper as to which run was used for a certain conclusion.

7) Page 5, line 94: which drivers of variables? Please specify.

R7) To make it clearer, we changed the sentence as follows:

We look at the connection between land and sea ice especially during June - September when vegetation is photosynthesizing, and sea-ice cover is low and variable. This variability accentuates the differences between high and low sea-ice-cover years which is important for the composite analysis.

8) Page 10, line 195-196: why wasn't the causal effect network reanalyzed with long-wave radiation added? Seems important.

R8) Upward longwave radiation and temperature are highly correlated as the atmosphere is heated from below. To account for an influx of warm air (or cold air) we include the latitudinal and longitudinal temperature and moisture transport. Upward longwave radiation is also more directly connected to sea-ice cover than temperature. To reduce redundancies, we did not include upward longwave radiation in the analysis.

9) Page 14, line 317-321: this conclusion is a rather big statement for an analysis of a limited area during an era of stable sea ice. It's not supported by this study nor the existing literature. Perhaps the link to land has been weak for the Laptev region during 1950-1989 but that doesn't mean it hasn't been strong in the past two decades in the same region or other parts of the Arctic!

R9) With the changes below, the restrictions of the study are clearer.

A general warming and an enhanced hydrological cycle are key features of global climate change (Stocker et al., 2013; Huntington et al., 2006). In our model study we find that lower than usual sea ice in the Laptev Sea causes warming and an increase in air moisture over land, which might add to the above-mentioned trends. Nevertheless, we found the link from sea ice to land to be weak under stable conditions, and, if this relation holds under different conditions, we expect climate change over land to be driven primarily by large-scale circulation.

variable	reduction method	spring & fall mm	spring & fall dm	summer mm	summer dm
fractional cloud cover	mean	✓	✓	✓	✓
fractional sea-ice cover	mean	✓	✓	✓	✓
gross mass export of sea-ice	transect sum*	✓	✓		
gross mass import of sea-ice	transect sum*	✓	✓		
meridional heat transport‡	mean	✓	✓	✓†	✓†
zonal heat transport‡	mean	✓	✓		
height of ABL	mean	✓	✓	✓	✓
latent heat flux at surface	weighted sum	✓	✓	✓	✓
meridional moisture transport‡	mean	✓	✓	✓†	✓†
zonal moisture transport‡	mean	✓	✓		
NAO index	pressure diff.	✓		✓	
precipitation	sum	✓	✓	✓	✓
absolute downward LW radiation at surface	weighted sum	✓	✓	✓	✓
absolute downward SW radiation at surface	weighted sum	✓	✓	✓	✓
sea-level pressure	mean	✓	✓	✓	✓
sea-surface salinity	mean	✓	✓		
sensible heat flux at surface	weighted sum	✓	✓	✓	✓
Siberian high index	regional SLP	✓		✓	
snow height	mean	✓	✓		
2m temperature	mean	✓	✓	✓	✓
fresh-water flux from land to ocean	sum	✓	✓	✓	✓
spec. humidity‡	mean	✓	✓	✓	✓
10m meridional wind speed	mean	✓	✓	✓	✓
10m zonal wind speed	mean	✓	✓	✓	✓
	$\sum$	24	22	18	16

Table A1. Time series included in Causal-Effect Networks of monthly means (mm) and daily means (dm) to determine dominant drivers of sea-ice in spring and fall in the Laptev Sea as well as the influence of sea ice on the atmosphere over land during the summer. While atmospheric variables were integrated over both land and ocean for spring and fall, only the atmosphere over land was used in the summer Causal-Effect Networks.

* - sea-ice ex- and import are computed by summing the gross positive and negative values of transects at the outer borders of the areas indicated by the masks in Fig. 3.

† - to estimate the influence on land not the mean meridional transport was calculated but the flow through a transect at the southern border of the masked area.

‡ - vertically integrated over all atmospheric model layers.

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