Responses to referee 1 comments

We thank anonymous referees for their constructive comments and helpful suggestions.

We have revised our manuscripts based on their comments. We wrote responses to each referees' comments below.

Referee's comments are indicated in Italics and underscored, and then our answer follows immediately.

This study investigates the relationship between Arctic sea ice retreat and local cloud cover using the MIROC5 GCM. The subject matter is timely, and the results are generally consistent with recent research suggesting a positive feedback between expanding open water in the Arctic and cloud coverage that enhances downwelling radiation to the surface. As such, this new study is relevant and appropriate for ACP. In this revised version, the authors have improved the manuscript considerably and have addressed my major concerns, the biggest of which is distinguishing cause-and-effect between the monthly changes in cloud cover and sea ice coverage. I still have some suggested changes to help clarify and clean up the article, as described below.

Major comments:

1. I appreciate the addition of Figure 4c, which addresses the causality question. However, it's hard for me to follow the lead-lags in this figure that are described in the text. It would help to label on the figure which variable is leading which for positive and negative values on the x axis. Also, providing a clear example in the text would also help readers. For instance, I think—but I'm still not sure–that the green diamond for a Lead/Lag of -1 represents where September cloud leads October ice and that the red diamond for a Lead/Lag of -1 represents where September sea ice leads October cloud.

We deeply thank you for giving a useful comment. As you commented, we modified Figure 4c. Labels of month were added below labels of lead/lag number in the x axis of Figure 4c, and also legend in Fig. 4c was modified. Further, we provided an example in the text to help reader as you suggested. However, we are very sorry that, in the original manuscript, explanation by green line in Fig. 4c was exchanged with that by red line. This was revised.

(Section 3.2.1 Autocorrelation and lead/lag correlation analysis in the revised manuscript.)
"Lead/lag correlations in the Arctic subregion demonstrated that cloud cover in October was negatively correlated with the lead/lagged SIC (red diamond in Fig. 4c). For instance, the red diamond for a lead/lag of -1 (+1) represents where SIC in September (November) leads (lags) cloud

cover in October. This negative correlation of cloud cover in October with SIC in September suggested that small SIC continuing from September led to increased cloud cover in October."

"However, SIC in October was also negatively correlated with lead/lagged cloud cover (green diamond in Fig. 4c). The green diamond for a lead/lag of -1 (+1) represents where cloud cover in September (November) leads (lags) SIC in October. The correlation of SIC in October and cloud cover in September (green diamond) was weaker than that of cloud cover in October and SIC in September (red diamond), as shown at an abscissa -1 of the lead/lag month in Fig. 4c."

2. The sensitivity tests added in this version are helpful in making the authors' case. One minor point, however, is that I don't understand the meaning of the chosen names (A2K, TA2K, etc.). A brief explanation in the introduction would help.

To help reader to understand meaning of experiment names, names of experiments, A2K, TA2K, IA2K, and SIA2K, were changed to OF2000, SSTOF2000, SIOF2000, and ALL2000, respectively. The each experiment name indicates changes of the condition from CTL. The letters of SI, SST, and OF before 2000 in the name indicate that sea ice, SST and other (atmospheric) forcings in 1980 or 1980s were changed to those in 2000 or 2000s. Then, Table 1 was modified according to these changes. Also, the explanation for the names was added in the Table 1 caption.

(Revised Table 1)

"Table 1. Sea surface temperature (SST), sea ice, and other forcing conditions in the sensitivity experiments with MIROC5-AGCM. Other forcings include land use, greenhouse gas concentrations, aerosol emissions, and total solar irradiance. Data in the 1980s indicate an average over the period 1976-1985, and the data in the 2000s combine data for the 1980s and changes for the following 20 years, which were estimated using the linear trend from 1976 to 2005 in the historical simulations. The each experiment name except CTL indicates changes of the condition from CTL. The letters of SI, SST, OF and ALL before 2000 in the name indicate that sea ice, SST, other (atmospheric) forcings and all the three conditions in 1980 or 1980s were changed to in 2000 or 2000s, respectively.

Exp. Name	Sea Ice (SI)	SST	Other Forcing (OF)
CTL	1980s	1980s	1980
OF2000	1980s	1980s	**2000**
SSTOF2000	1980s	**2000s**	**2000**
SIOF2000	**2000s**	1980s	**2000**
ALL2000	**2000s**	**2000s**	**2000**

"

3. I think the description of Figure 6 could be condensed, as it takes up nearly three pages. The central explanation of the entire figure seems to be that cloud cover changes are a function of relative humidity changes, which in turn depend on the competing influences of the warming versus moistening at each level. These relationships differ in understandable ways between the delta ai+ and delta ai- points because of differences in the magnitude of surface heating between these two surface types.

According to this comment and reviewer 2's comment similar to this comment, we modified section 3.3. Descriptions on the lapse rate and the decreasing rate of specific humidity with altitude in the latter half of section 3.3 have removed from the text, because the description was not for a main issue in the section 3.3.

4. Figure 8: I appreciate the authors taking my suggestion to heart by analyzing the role of atmospheric stability as a potential explanation for the increased October cloudiness simulated over the interior Arctic, but I'm not sure that the trend in this variable is the most relevant to address this question. If atmospheric stability is playing such a role, I would suspect that the relevant difference is not temporal but spatial: the presumably higher atmospheric stability over perennial sea ice points in either time period, compared with the declining stability over the recently melted-off areas along the periphery. It's possible that the injection of so much moisture into the Arctic during October in recent years could be trapped more effectively within lower tropospheric layers above the colder perennial ice pack and thus promote more cloudiness in the later time period.

We appreciate this comment and your suggestion. As we mentioned in Discussion section, more

ensemble members of the historical simulations would be needed to clarify a cause of the increased October cloudiness simulated over the interior Arctic. Thus, because this topic is not a main target in this study, we would like to treat this in the future. However, your potential explanation for the increasing cloud cover over the interior Arctic was included as a potential mechanism in Discussion section..

(Section 4 Discussion in the revised manuscript)

"The figure shows that the static stability in the lower troposphere decreased over most part of the Arctic Ocean, although large decreases in static stability did not always correspond with large increases in cloud cover in regions without large reductions in sea ice. This result was common in each ensemble member. Therefore, an appropriate and systematic cause of the large increases in cloud cover over the region without substantial reduction in sea ice remains unclear. It may be possible that the injection of much moisture into the Arctic during October in recent years could be trapped more effectively within lower tropospheric layers above the colder perennial ice pack and thus promote more cloudiness in the latter period. To clarify this finding, more ensemble members may be required in the experiment.
"

Minor comments:
1. Abstract: The sentence from lines 17-19 is confusing, because it reads as if the oceanic heat is directly responsible for the reductions in overlying sea ice, but I think the authors mean that the enhanced oceanic heat fluxes to the atmosphere have a time-lagged effect on subsequent ice coverage.

The sentence was revised as follows,
(Abstract in the revised manuscript)
"The delayed response leads to extensive sea ice reductions because the heat and moisture fluxes from the underlying open ocean into the atmosphere are enhanced."

2. Page 2, lines 16-18: Do the authors really mean that the ice-albedo feedback is larger in fall (than summer) or rather that the impact of this feedback is larger in the fall?

We are afraid that we found to have misunderstood the result of Yoshimori et al.(2014). Thus, the sentence was revised as follows,
(Section 1. Introduction in the revised manuscript)
" However, as Yoshimori et al. (2014) mentioned with the climate model results that Arctic surface warming in autumn-winter is attributed to seasonal reduction of ocean heat storage and increased

cloud greenhouse effect, other processes such as ocean heat uptake process, atmospheric stability, and low-level cloud response may require further attention to better understand the Arctic warming mechanism."

3. Page 5, line 17: Changing ". . .the surface DLR and those due to increased air temperature. . . " to ". . .the surface DLR versus those due to increased air temperature. . . " would make the sentence clearer.

We changed the sentence as you commented.
(Section 1. Introduction in the revised manuscript)
" Furthermore, to provide information on the role of Arctic clouds in the mechanism of Arctic warming, this study evaluates the relative importance of changes in cloud radiative forcing on the surface DLR versus those due to increased air temperature and water vapor."

4. Page 6, line 22: Similarly, replacing "considered" with "applied" sounds better.

We changed the sentence as you commented.
(Section 2. Model and Experiments in the revised manuscript)
"In the simulation, changes in the solar constant are applied according to Lean et al. (2005).)"

5. Page 7, line 18: Define "AA" in its first usage.
We added 'Arctic Amplification' before AA in the sentence.

(Section 2, Model and Exepriment in the revised manuscript)
"This result clearly reveals the Arctic Amplification (AA), indicating that the MIROC5 is able to simulate the AA in historical simulations."

6. Page 9, lines 4 and 5: Change "substantially" to "substantial" and remove "also".

We changed the word "substantially" to "substantial" according to this comment. However, the sentence including the word "also" was removed according the second reviewer's comment.
(Section 3. Result in the revised manuscript)
"The simulated Arctic cloud cover for fall, winter, and spring increased between two periods, 1976-1985 and 1996-2005, are shown in Figure 2d, although the change was not substantial."

7. Figure 5: I understand why higher evaporation could lead to more clouds, but why would higher

sensible heat fluxes? Is the figure and accompanying text implying that increases of both fluxes are contributing to more Arctic clouds?

Much sensible heating makes lower atmosphere more unstable, and then enhance convection. The convection can help to produce and increase cloud cover. From these points, by using Figure 3, we would like to mention that both sensible heating and latent heating contribute to increase in cloud cover. We modified the sentence to help reader.

(Section 3.3. Cloud cover changes resulting from reduced sea ice)
"The increased LE and SH fluxes could play roles in the increased cloud cover in October through enhanced unstable atmospheric condition and increased water vaper."

8. Figure 6: Why does cloud fraction increase above the 0.95 level overlying delta ai+ points, even though the change in relative humidity at these levels for these points is negative? There is no such mismatch between cloud fraction and RH for the delta ai- points.

Comparing with cloud cover change in ΔSI- case , cloud cover change in ΔSI+ is close to zero. Also, change in relative humidity in ΔSI+ is negative and small. However, there are grids in which cloud cover increases substantially, even though the sea ice cover was not reduced substantially, in ensemble members. In this study, we have not revealed a plausible cause of the increase in cloud cover without substantial reduction of sea ice, despite of analyses on lower atmospheric stability and water vapor transportation in the lower atmosphere. As we discussed in discussion section, more ensemble members of the historical simulations would be needed for the analysis. Further, another analysis for this point which is beyond the purpose in this study is need. Therefore, we would like to treat this point in the future. This discussion has already been included in discussion of the original manuscript.

9. Figure 6: What do the horizontal bars on the delta ai+ curves represent, and why are there no such error bars on the delta ai- curves? This information should appear in the figure caption.

The horizontal bars represents standard deviation between ensemble members in ΔSI+. In addition, standard deviation in ΔSI- has been represented by grey shade in the figure of the original manuscript. However, the grey shade may be not clear. Thus, we made the grey shade more clear and modified its legends. The information of error bars and grey shade in Fig. 6 has been included in the figure captions.

(The revised Figure 8)
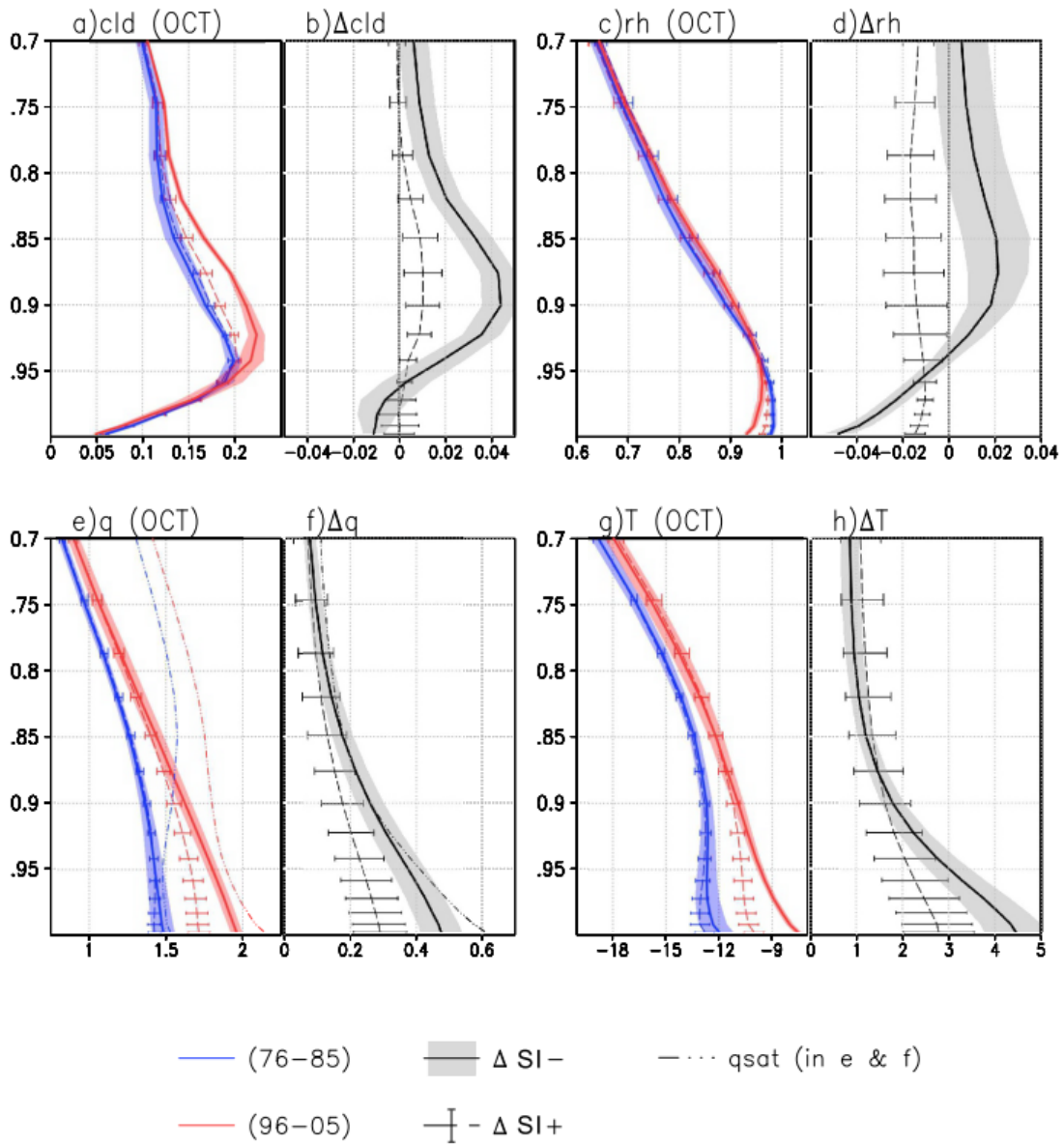
Figure 8. Vertical profiles of the average a) cloud fraction, c) relative humidity, e) specific humidity, and g) air temperature in October in the MIROC5 simulations for the periods 1976-1985 (blue) and 1996-2005 (red). The solid (broken) line represents the ΔSI- (ΔSI+) case. See the text for the definitions of the ΔSI- and ΔSI+ cases. Vertical profiles of the differences between average b) cloud fraction, d) relative humidity, f) specific humidity, and h) air temperature in October in the MIROC5 simulations for the periods 1976-1985 and 1991-2005. The solid (broken) line represents the ΔSI- (ΔSI+) case. The dot-dot-dash lines in e) and f) indicate the saturated specific humidity. The units of air temperature and specific humidity are K and g kg^{-1}, respectively. Shading and error bars indicate the standard deviations for the ensemble members in the ΔSI- and ΔSI+ cases,

respectively.