Anonymous Referee #1

This work investigates tendencies in the ice cloud frequency, effective radius (rei), optical depth (tau) and cloud top temperature in retrievals from the Atmospheric infrared sounder. The authors also analyze tendencies in the information content of the retrieval ruling out possible artifacts. Significant trends are found in the effective size, increasing over most of the globe, and also in other variables. The authors also show that rei is correlated with the column water vapor, and surface winds and temperature, particularly for opaque clouds suggesting an strong role of convection on the observed trends. Clouds are very sensitive to changes in the atmospheric state and trends in cloud properties may signal important systematic changes in Earth's climate. Hence this work is highly relevant to the atmospheric community and within the scope of ACP. The methods are sound and valid and the results interesting. I have some comments on the organization of the work and in some places where more explanation and further analysis is required. After those are addressed this paper would be suitable for publication.

We thank the reviewer for the positive comments about the paper. Our responses to the reviewer comments are included below.

Comments: The paper reads a little bit like two separate works, with the second one starting in Section 5. Are the authors trying to use their analysis of convective processes to explain the observed tendencies? How do Figures 7-10 relate to the previous ones? I'd encourage the authors to work on making a consistent point throughout the paper.

We agree that the paper would benefit from additional clarification regarding how the different sections are connected to each other. To address this concern, we have made the following edits to the manuscript:

We have added the following statement as the last line of the last paragraph in the Introduction: '*The collocation of pixel-scale data among AIRS, AMSR, and DARDAR is a first step towards illuminating the potential processes that may be responsible for secular changes in ice cloud properties*.'

To link earlier sections with AMSR-AIRS joint histograms, we have added the following sentence to the end of the paragraph in Section 3.3: '*Convective and non-convective cloud types are shown separately in order to highlight the much larger responses of rei to thermodynamic and dynamical variability in tropical convection*.'

To link earlier sections with AIRS-DARDAR results, we have added the following sentence to the end of the paragraph in Section 3.4: '*As mentioned in Section 3.3, the coarse classification of convective intensity helps highlight differences in cloud top rei for non-convective, weakly, and strongly convective scenes*.'

In the first paragraph of Section 5, we have replaced the last line with the following text to emphasize that dynamic and thermodynamic variability lead to changes in rei and hence offer possible reasons for trends in rei: '*Collectively, the*

***aforementioned modeling and observational investigations suggest that rei varies significantly at the tops of convective ice clouds and motivates the synergistic use of AMSR and AIRS at the pixel scale to capture convective-scale processes*.'**

We have modified the second to last line in the first paragraph of Section 6 to tie together AIRS-DARDAR to convective processes and observations of trends: '*Systematic changes in the global circulation and changes in convective clustering and cloud overlap may lead to a higher frequency of overlapping cirrus on top of convection, and a reduced frequency of thin cirrus with climate change evidenced by trends in the Multi-angle Imaging SpectroRadiometer (MISR) derived cloud texture (Zhao et al., 2016)*.'

We have added the following statement as the second to last line in the second to last paragraph of Summary and Conclusions: '*The pixel-level collocations of AIRS, AMSR, and DARDAR are a first attempt at identifying atmospheric processes that could be responsible for secular trends in ice cloud properties*.'

How do the results compare to other instruments? They authors use MODIS and DARDAR in the analysis of the second part of the paper, but they seem to abstain of comparing the decadal trends from those products against their results. Are the tendencies from AIRS similar, at least qualitatively, to those of MODIS and DARDAR?

We appreciate the reviewer suggestion to include other data sets to assess trends. We ultimately decided not to focus on data sets from other instruments for multiple reasons. First, an assessment of the retrieval algorithms and stability of e.g. the MODIS radiances/reflectances, CloudSat reflectivity, and CALIOP/IIR backscatter/radiances would require significant research to assess suitability for trend analysis, and the expertise of the lead author is limited to AIRS instrumentation. This is well beyond the scope of the current investigation, but it is reasonable to expect that in the future this may be possible in collaboration with multiple instrument/algorithm teams. Second, with regard to MODIS cloud retrieval data, the lead author has been in contact with the MODIS team (personal communication) and they are currently performing a similar analysis for MODIS Aqua to infer cloud property trends, including ice clouds. With recent advancements in MODIS calibration, they are now pushing harder on quantifying trends. We defer to the expertise on the MODIS team to determine suitability for trend analysis. Third, the CloudSat temporal record begins in July 2006, the spatial sampling is restricted to near nadir view in the AIRS swath, and the sensitivity to thin cirrus is limited. (Similar limitations are noted for CALIPSO, but may be more relevant to AIRS comparisons because of excellent sensitivity to thin cirrus.) Thus, the DARDAR product (which combines CloudSat, CALIPSO, and MODIS) ultimately contains these spatial and temporal sampling limitations, and possible radiometric drift uncertainties.

Despite the paragraph above, the lead author has calculated trends in MODIS CER and COT using the Collection 6, Level 3, monthly gridded data. The anomaly time

series is calculated using the same approach and software routine for AIRS data. The results for the same 14-year period are shown below in two panels. The level of agreement in the spatial patterns of COT, even for fairly small-scale features that could be interpreted as noise, is quite remarkable between AIRS and MODIS. Note that the trend magnitude in the color scale for MODIS is an order of magnitude larger than AIRS, however. With regard to CER, MODIS shows more expansive negative regions than AIRS and the patterns are rather dissimilar in various regions. There may be geophysical, algorithmic, cloud type sensitivity, sampling, and additional reasons for this but a robust explanation is well beyond the scope of this article. The lead author (Kahn) has agreed to work with the MODIS team in the near-term to reconcile these differences once the MODIS team has published the results of their trend study.

Page 11 Line 3. Please define the effective cloud fraction.

We have added the following text to the next line in the same paragraph: '*The ECF is a cloud product that represents the convolution of cloud fraction and cloud emissivity. Nasiri et al. (2011) showed that ECF from AIRS and effective emissivity from MODIS is in excellent agreement for both single and multi-layered cloud configurations.'*

Section 5.1. The terms opaque and transparent seem ambiguous here. The authors draw a direct correlation between the covered area and the optical thickness of the clouds. But transparent cirrus (which most of the time refer to low optical depths) can be extended or simply cover a small fraction of the grid cell. Please clarify.

We agree with the reviewer. After further thought about the naming convention, we have decided to change 'Transparent' to 'Non-Opaque', which implies either full coverage of a pixel by a transparent cloud, or partial coverage of a pixel by optically thick clouds, or somewhere in between. We have made the text changes in the manuscript, figure captions, and the figures themselves.

We also note that suggestions by reviewer #2 led us to define a third category of cloud configuration called 'Multi-Layer'. We have added a new Table 3 that defines these categories and have edited the first paragraph of Section 5.1 to clarify these definitions. Please refer to the response to reviewer #2 for a detailed explanation of our related changes to the revised manuscript.

Section 5.2 and also in Section 5.3. Please add a paragraph explaining what you expect to see in the histograms (e.g., Figure 8) and how to interpret them. They are not obvious at all.

We have added the following text to the first paragraph in Section 3.3: '*The histograms each contain one of several AMSR variables on the x-axis and the AIRS upper layer T_{cld} on the y-axis*.'

We have added substantial revisions to Section 5.1 to 5.3 that address both reviewer concerns about interpretation and reviewer #2's concerns about lower-layer clouds. Please refer to the response to reviewer #2 for additional detail.

Page 11 Line 28. Here and in other places. It is not clear what the "reduction" is referring to. What is the control in this case? Please clarify.

In this instance, we have changed '*reduction*' to '*weaker vertical dependence*'. In Section 2.1, we have changed a few instances from '*reduction*' to '*lower magnitude*' or '*minima*'. In Section 4.2, we have changed '*reduction*' to '*decrease*'. In Section 5.2, we have changed '*reduction*' to '*change'*. In Section 7, we have changed '*reduction'* to '*weaker dependence'*. All of these changes are included in the track change version.

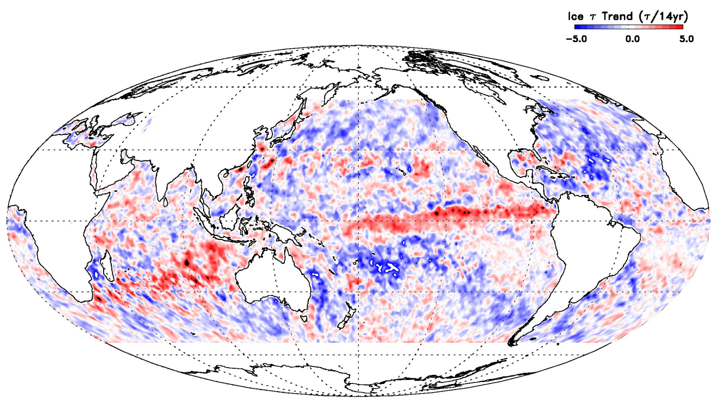

Figure 1. MODIS ice COT trends for the same 14-year period shown in the manuscript Fig. 3 for AIRS.

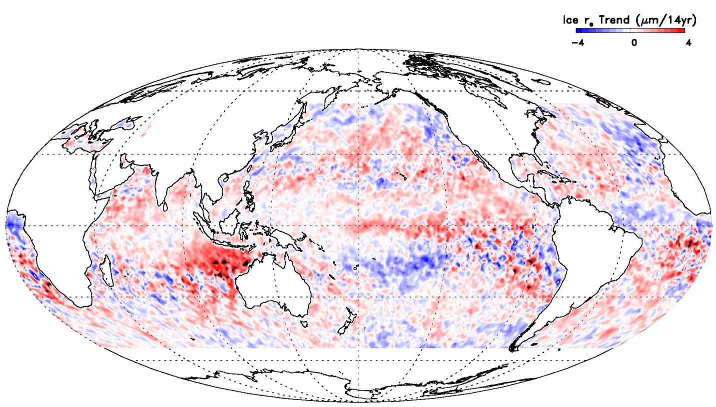

Figure 2. MODIS ice CER trends for the same 14-year period shown in the manuscript Fig. 3 for AIRS.