We would like to thank both referees for their helpful and constructive remarks. Please find point-by-point reply to your comments below. Please note that the figure numbers are changed in the revised manuscript, but to avoid confusion, all references to figures below are to the ACPD version.

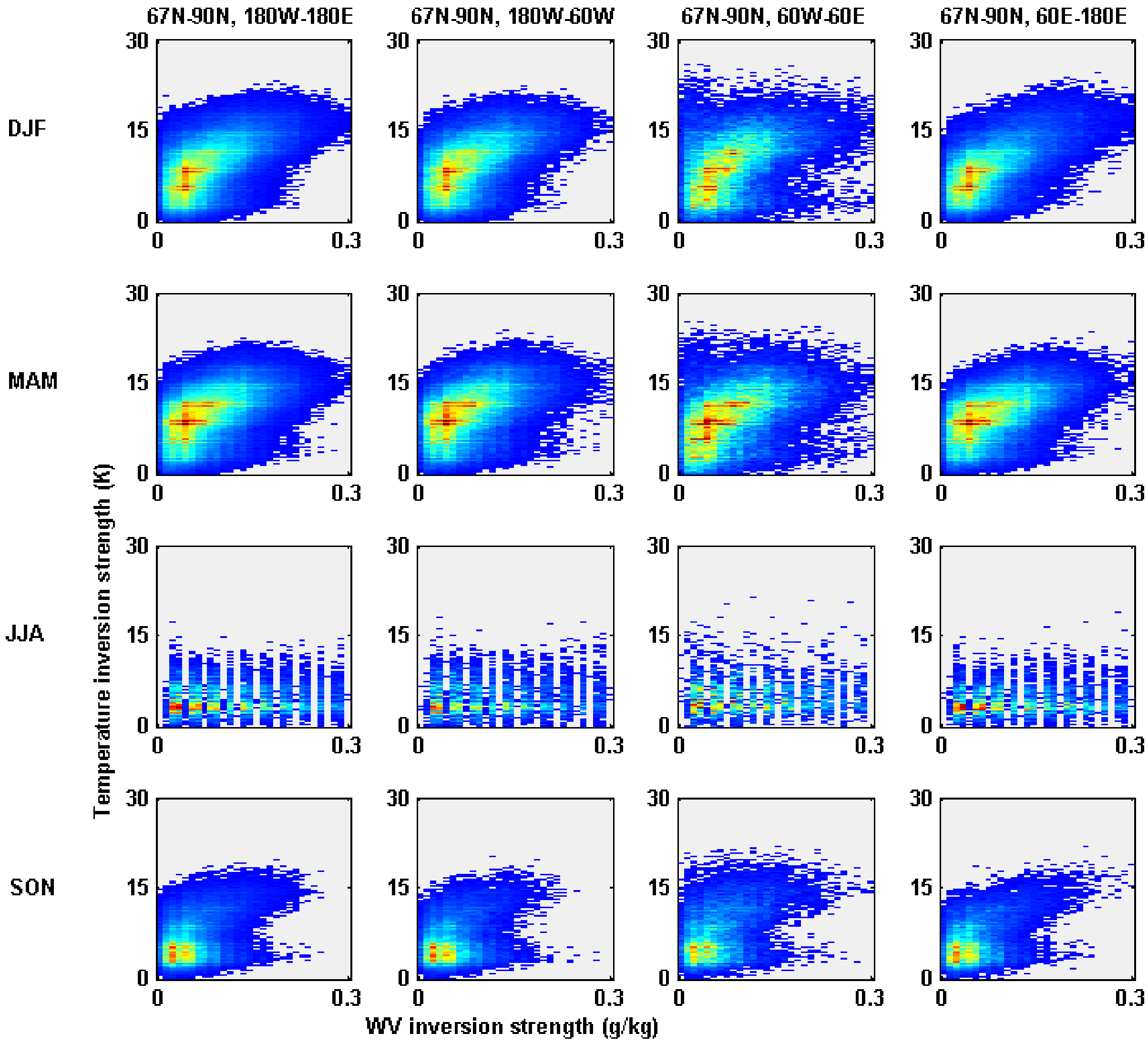
Response to Anonymous Referee #1

This paper uses AIRS retrievals of water vapour profiles over the Arctic from 2002 to 2010 to characterize water vapour inversions under clear sky conditions. The results are validated with radiosondes from Barrow and SHEBA. It provides a spatial distribution by season of water vapour inversion properties, such as frequency, strength and height, giving a useful climatology. The results should prove useful for modelers wishing to validate their models in the Arctic. It is a sound and well written paper but the authors should address the following questions and comments.

It would be useful to have some discussion about the relationship between temperature and water vapour inversions. To first order one might expect a close correspondence, particularly in the winter when strong surface based temperature inversions are present. Differences between the temperature and water vapour inversion structures would be a measure of the vertical variation in the relative humidity which may have useful dynamical implications. Since the AIRS retrievals also includes the vertical variation of temperature why did the authors not try to do this comparison? It strikes me that a great value can be added to this paper with relatively little additional work. I would argue that differences in the temperature and water vapour inversions are a more physically powerful constraint for model to validate against instead of the solely water vapour inversion statistics presented here.

The referee raises a good point here. In order to establish powerful physical constraint to evaluate model statistics, studying the co-variability of temperature and WV inversions is important. We believe that the investigations of co-variability of temperature and WV inversion **strength** over the Arctic, as shown in the figure below, should provide a robust metric. If a regional and/or global climate model captures the statistically accurate relationship between WV and temperature inversion strengths and its seasonal behaviour, then the large-scale coupling between circulation, moisture transport, local meteorology and radiation is also essentially represented well in such a model. To study this co-variability, we divided the Arctic (67N-90N, 180W-180E) into three large regions (180W-60W, 60W-60E, and 60E-180E), which exhibit different inversions frequencies and strengths. We analysed the joint histograms of WV and temperature inversions for different seasons using 8 yr data where AIRS profiles contained both temperature and WV inversion structures. A non-linear relationship between inversion strengths is clearly seen in all seasons except during the JJA months. The relationship is most prominent during boreal winter, when the lack of moisture source at surface together with (relatively) increased water-vapour holding capacity in strong temperature inversions through transient component of heat and moisture flux into the Arctic supports such vertical structure. However, during the summer months, the relatively well-mixed boundary layer does not permit this relationship. Among all three regions in the Arctic, the region between 60W-60E shows a distinctive secondary tail in the joint histograms reflecting the influence of a major gateway for the total moisture flux into the Arctic from the mid-latitudes and North Atlantic Ocean. The MAM and SON months seem to have transitional characteristics between winter and summer modes.

We have added the following figure and above discussion in the revised manuscript.



Page 15804. Lines 14-18. There are some confusing statements here. Higher water vapour aloft does not imply a downward transport. Subsidence or turbulence may achieve this but it is not necessary. Also connecting higher water vapour aloft to "very" high relative humidity in the lowest troposphere is not a generally valid remark. This section needs to be removed or rewritten.

Following Curry (1983), we assume that a positive gradient of water vapor would indicate a potential down-gradient transport towards the surface, where water vapor is colloidially unstable with the sea ice boundary. We have clarified the text to reflect the reviewer's concern. The statement of "contributes to keep the lowest troposphere at very high relative humidity" has now been clarified and supplemented with the citation to Persson et al. (2002) and Tjernström et al. (2004), who show the lower troposphere is often supersatured wrt ice.

Page 15808, Line 18. What is meant by "accurate" estimates of WV MRs? Please quote the accepted error limits for AIRS retrievals of water vapour.

The accuracy of AIRS WV profiles is 15% / 2 km.

Page 15806, Line 9. Please state numerically what the “coarse” resolution is.

Here, we are referring to the coarser vertical resolution of AIRS compared to radiosonde. The standard AIRS moisture profiles are available at 1000, 925, 850, 700, 600, 500 hPa and so on, while the radiosonde resolution is finer. This sentence is rephrased.

Page 15809, Line 23. What grounds or references do you have to back up the claim of homogeneity of water vapour over the Arctic Ocean?

This comment was mainly based on the visual inspection of hundreds of images of WV distribution in different seasons. It is also a question of the scale. We are referring to the large-scale influences, wherein this claim would hold true, but once we start investigating WV distribution at the process level using radiosonde data with very high vertical resolution, one obviously needs to consider small-scale variations in the WV distribution.

Page 15810, Line 18. I assume you mean “negatively” skewed. Please add this.

This sentence is rephrased.

Figures 1 and 3. Explain the source of the ring artifact in the inversion strength around the North Pole during the non-summer months. If there are sampling issues then this area should be greyed out.

It is indeed a sampling issue, as shown in Fig. 1. The area is now shaded grey.

Figure 3. I assume the noise in the summer months is related to the cloud frequency and poorer statistics. Please explain this.

Yes. Since we analyzed only clear-sky profiles with cloud fraction 0.0, the number of available samples in summer months, when cloud fraction is high, is reduced. This was shown in Fig. 1 and partly explained in the text. However, it is more elaborated in the revised manuscript.

Figures 6 and 7 are missing a colour scale. Please add one

Colorbars have been added to Figures 6 and 7 according to the reviewer's suggestion.

Figure 8 is too small and the lines are not visible. Please replace with a larger version. I am not convinced that Figures 8a and b has much significance. How do you avoid allowing noise to be counted as an inversion? I think this might be a useful metric of the degree of vertical structure in water vapour but you need to establish a good criterion of when an inversion is deemed real versus an artifact due to measurement noise and uncertainty.

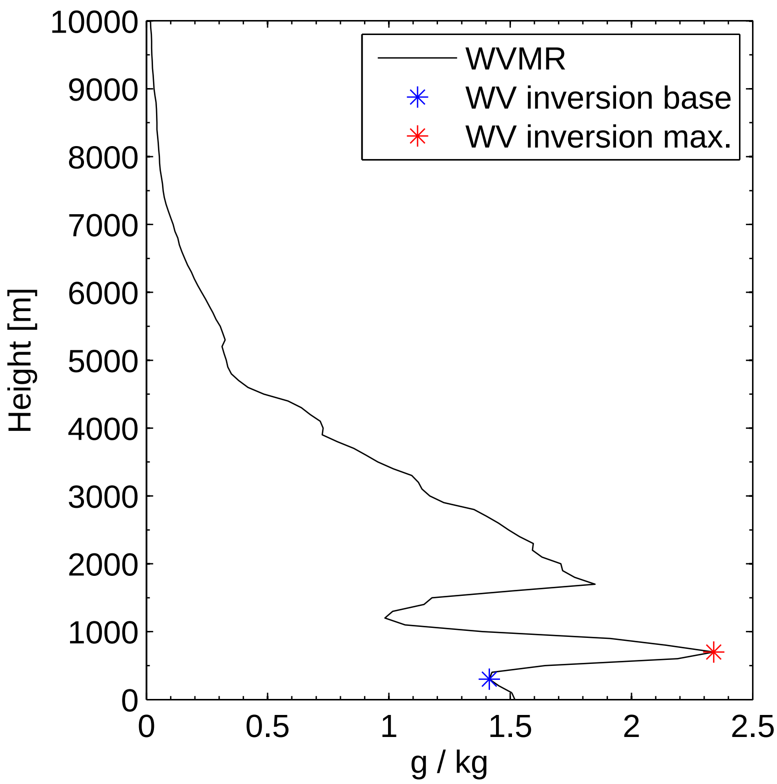
The lines have been enhanced for clarity following the suggestion. We disagree with the 2nd comment by the reviewer. Figures 8 a-b clearly show that multiple water vapor inversions are the norm and very few profiles indicate the absence of water vapor inversions. These results are not described, to the authors' knowledge, in any other observational study, and therefore are an important in describing the climatological thermodynamic state of the Arctic atmosphere. Noise is removed from the profiles by interpolating the radiosonde observations to 100 m vertical resolution and requiring at least 3 consecutive vertical levels to have a positive gradient in WVMR in order to be considered a water vapor inversion. This was described in Section 2.2, lines 10-17.

Page 15812, Line 28. WWMR should be WVMR.

Changed.

Page 15814, Lines 15-17. I am not quite sure what you did here. How do you define the inversion base? Is the base usually the ground? Is the base often above a lower inversion? Wouldn't it be best to always use the ground as the base?

The inversion base is defined as the 1st vertical level, followed by at least 2 subsequent levels, where WVMR is observed to increase with height. An example of the inversion base for an example profile from SHEBA is shown in the figure below is now added in the revised manuscript. The inversion base was above the surface for > 63% of the SHEBA profiles and > 73% of the Barrow profiles.



Page 15816, Line 6-7. Although summer inversions are the strongest they are also the least frequent. You mention the frequency in the first conclusion but perhaps these statements should be combined in some way.

The first two conclusions are written about the inversion frequency, while the third conclusion about the inversion strength. Therefore, these two pieces of information were separated. However, we have added small sentence in the third conclusion to highlight the fact that although summer inversions are the strongest they are also the least frequent.

Page 15816, Lines 20-25. To properly appreciate the role of partial precipitable water from inversions to the total precipitable water it would be useful to know what the vertical extent of the inversion is. In other words that is the average difference between z1 and z2 in Equation 1. This statistic might be more useful than the rather confusing Figure 9.

The median inversion base and top heights (pressures) have been appended on pg. 15814, line 17 as suggested by the reviewer:
SHEBA:
base = 200 m (982 mb)
top = 1000 m (888 mb)
BARROW:
base = 600 m (941 mb)
top = 1300 m (859 mb)

Response to Anonymous Referee #2

The paper "Characteristics of water-vapour inversions observed over the Arctic by Atmospheric Infrared Sounder (AIRS) and radiosondes“ by Devasthale et al. deals with water-vapour inversions. It is already a good paper, but the authors should consider the following comments and remarks.

1. At first I totally agree with the first referee comment about suggestion to analyze also the temperature inversions.

Following the suggestion by both referees, co-variability between temperature inversions and water vapour inversions is investigated and the relevant discussion is added in the revised manuscript. Please refer to our response to the first referee for further details.

2. The water-vapour inversion should be clearly defined in the beginning. From Figure 3 it seems that there is inversion even if the increase in the MR is very small. What is the accuracy of AIRS and radiosonde MR? If the increase is smaller than the accuracy, you shouldn’t say that there is humidity inversion.

Once the retrieved profile satisfies the quality control criteria, which we believe would screen out inaccurate retrievals and/or outliers including clear-sky criterion, we assume the lowest available retrieval level as the reference and compare retrievals vertically above this level for inversion (i.e. positive difference). If inversion is not detected, the WV retrieval at the second lowest level is assumed as the reference and the procedure is thus repeated recursively up to 400 hPa level. The accuracy of AIRS WV profiles is 15% / 2 km and sufficient for studying such large-scale feature (i.e. WV inversion) that is ubiquitous over the Arctic. Furthermore, as the independent statistics based on radiosonde data compares well with AIRS, this gives us confidence in the AIRS retrievals.

3. Figures 6 and 7: add colour bars

Colour bars are added.

4. Page 15803 line 24: waver –> water

Corrected.

5. Page 15804 line 11: attitude –> latitude

Corrected.

Next comment is for following papers I hope you will prepare.
6. You suggest this work for models validation, but have you considered to do identical analysis for the AIRS period using some reanalysis model? If you do it for both clear-sky conditions and all days, you will see if the AIRS clear-sky limitation limits its statistics usability in all days conditions.

Thank you very much for the suggestion. We plan to investigate similar statistics from CMIP5 runs of EC-EARTH and ERA-Interim reanalysis data. We, if fact, carried out analysis for the all-sky conditions using radiosonde data (not shown in the manuscript), and found that the large-scale clear-sky statistics do not vary significantly from the all-sky statistics at least for the stations studied (SHEBA and Barrow). However, for individual cases, how WV inversions are influenced by clouds and vice-versa is not yet fully investigated.