Response to Reviewer 2

Thank you very much for your time and effort dedicated to our manuscript! With the help of your advices, we have prepared an improved version of the manuscript. Our responses to your comments are marked in red below.

The authors present a study on specific humidity inversions over the pan-Arctic region during the year 2000-2009. Using radiosondes and similar methodology to a study in the Antarctic, the authors are able to present a climatology of Arctic humidity inversion characteristics, comparing with other studies in the Arctic region as well as with the results from the Antarctic. The main results indicate the frequent presence of multiple humidity inversions across the Arctic, with a substantial seasonal cycle in many inversion properties. These results broadly agree with other Arctic studies, but the actual numbers of humidity inversion properties differ. These differences are related primarily to differences in methodology.

I find the study to be very well written, the results are presented openly (for the most part, see detailed comment #5 below) and the Arctic atmospheric research community would greatly benefit from this brief climatological study of thermodynamic properties. My suggestion is to publish this paper in ACP after the following concerns have been sufficiently addressed.

Major concerns:

The methodology of humidity inversions (from here on referred to as q-inversions) identification from radiosondes becomes a philosophical question. In this study, as in Nygård et al. (2013), there is no restriction on the depth/strength of a negative q-lapse rate between inversion layers; statistics presented in Nygård et al. (2013) showed little impact of such a restriction on the statistics and so it was motivated that this restriction was unnecessary. Have similar tests been done for this study.

We made similar sensitivity tests as in Nygård et al. (2013). These showed that if a layer up to 200 m thick with a negative q-lapse rate is allowed between the inversion layers, the statistics were affected as follows: (a) the number of inversions in a profile was on average 0.3 (14%) smaller, (b) the inversion was on average 0.002 g/kg (0.1%) weaker, and (c) the inversion layer was on average 20 m (6%) thinner than in the case that all inversion layers are analysed separately. Accordingly the results were not sensitive to this methodological aspect. These findings are now reported in Section 3.1.

Secondly, in a thermodynamic and radiative sense, the question emerges: Which q-inversions are most important? Are a number of thin and relatively weak q-inversions important for the radiative impact of the atmosphere? Are these weak q-inversions generated by cloud formation (Qv becomes Ql)? Yes, it is true they can potentially indicate vertical variation in meridional flux distributions, but are the main advective q-inversions containing the majority of the column integrated water vapor more important?

We have added discussion on this issue in Section 4.

These questions further arise when reading pages 22582-83 regarding the differences between the strongest inversions and the median statistics of all inversions. I am not sure of the answer to these questions, but I hope the authors can elaborate more on the importance of observing multiple q-inversions over the Arctic.

The question is very relevant, as in this part of the manuscript we present detailed analyses on the sensitivity of inversion statistics to the calculation method. We do it to because detailed knowledge on the sensitivity is a prerequisite for meaningful comparison of studies based on different methodology. Our data are not sufficient to quantitatively study how small q-inversions affect physical processes, but, as noted above, we have added some discussion on their potential effects in Section 4.

The above concerns could be better quantified if the study included, as one of the 1st figures, example profiles of temperature and humidity, showing cases where both temperature and q-inversions coexist, are separated vertically, and cases where multiple q-inversions are present. I am particularly interested in cases where there is a deep, strong q-inversion present, with variable advection vertically such that additional, thin q-inversions are present within the large-scale q-inversion. These structures seem to occur quite frequently, for example, see the specific humidity profiles in Fig. 7 of Shupe et al. (2013, ACP). Examining these profiles begs the question: should individual, small increases/decreases in q within a deeper q-inversion be considered separate inversion structures? After all, the q-values within these thinner, more frequent inversions are still larger than the main q-inversion base level.

We have added such an illustration of example profiles as a new Figure 2.

Additionally, the majority of these radiosonde stations are central land stations, with extremely different climatology than the interior central Arctic for which results from Devasthale et al. (2011) were focused. This is likely also causing the Russian stations, most "interior" stations in this study, to have systematic differences compared to the other stations with a closer footprint to the Arctic Ocean. Yet there is little to no description of the potential biases that may be a result of the station location.

This was an important point. Although we discuss the geographical differences in inversion occurrence and properties in several places in the manuscript, this was not done in the fourth paragraph of Section 4 (Discussion). We have now added the discussion on the effects of the geographic differences between our data set and that of Devasthale et al. (2011).

Detailed comments

(1) Table 1 shows a wide range of radiosonde sensors, yet there is not text considering the potential uncertainties/errors in humidity observations relative to each sounding system.

The World Meteorological Organization (WMO) organizes an intercomparison campaign for radiosonde systems every 4-5 years. The latest intercomparisons were arranged in Mauritius in 2005 (Nash et al. 2006) and in China in 2010 (Nash et al. 2011). From these intercomparisons, it is clear that humidity sensors in general have suffered, and in some extent, still suffer from uncertainties in cold temperatures and cloudy and rainy conditions. However, the instruments have extensively improved compared the earlier decades. This is a reason why we wanted to focus climatologically on relatively short period of time, and not to include data from the 1980's and 1990's in the analysis.

Of the radiosonde systems included in this study, only Vaisala RS92 was represented in the WMO intercomparisons. That is why we cannot show a clear comparison between the systems. As the errors vary with the sensor type, we did not attempt any humidity corrections to the radiosounding data. However, we excluded the coldest and driest profiles as described in Section 2.2. We have now added notes on the uncertainties/errors of sounding systems in Section 2.2 where we also refer to Table 1. The different results obtained from nearby stations using the Vaisala and Russian systems are discussed in Sections 3.1 and 3.2.

J. Nash, R. Smout, T. Oakley, B. Pathack, S. Kurnosenko (2006): The WMO Intercomparison of Radiosonde Systems - Final Report Vacoas, Mauritius, 2-25 February 2005. Instruments and Observing Methods Report No. 83. WMO/TD-No. 1303.

J. Nash, T. Oakley, H. Vömel, L. Wei (2011): The WMO Intercomparison of High Quality Radiosonde Systems Yangjiang, China, 12 July – 3 August 2010. Instruments and Observing Methods Report No. 107. WMO/TD-No. 1580.

(2) Have the humidity profiles been averaged vertically using, for example, a 3-point vertical averaging window? It seems the requirement of a 10 m thick inversion layer, with subsequent inversion separated by negative humidity lapse rates, should be very easily passed with rather noisy radiosonde profile data. As mentioned above, see the specific humidity profiles in Fig. 7 of Shupe et al. (2013, ACP).

We have not done any vertical averaging. The IGRA archive includes data from (a) the mandatory pressure levels and (b) levels at which a sounding variable deviates from the linearity. On average, Greenlandic and Nordic sounding stations had 15 vertical levels below 500 hPa in the IGRA archive, Russian stations 10 levels, and North American stations 18 levels. As these include five mandatory pressure levels (1000, 925, 950, 700, and 500 hPa) it means that the number of levels where a sounding variable deviates from the linearity was only 10, 5, and 13 for the above-mentioned regions, respectively. These numbers are probably dominated by levels where the wind profile changes. Hence, it is evident that some kind of vertical averaging is been done in the national meteorological services, which provide data for IGRA. If the data sent to IGRA were not averaged, but comparable to that shown in Figure 7 of Shupe et al. (2013), there would be much more levels below 500 hPa. Details of the vertical averaging are unfortunately not documented by IGRA. Hence, the small-scale features that the original high-resolution sounding data sets include (nicely illustrated in Figure 7 of Shupe et al., 2013) do not significantly affect our statistics; they are mostly eliminated by vertical averaging.

(3) Pg. 22584, Line 13-14: What does "markedly different" mean here? It would help if the authors added another panel to Fig. 5 showing the clear-sky inversion number RFD.

We have redrawn the previous Figure 5 (now Figure 6) so that the statistics are now presented separately for overcast and clear-skies, which clarifies the issue. New text referring to the new Figure 6 is written in Section 3.1

(4) Pg. 22584, Final paragraph: It is difficult to follow the results discussion when so many of the stated results are "not shown". Either remove those not shown from the discussion or include the necessary figures.

We have included the necessary information in the text.

(5) Pg. 22586, Line 10 as well as Lines 10-25 on Pg. 22587: This is an interesting result, and one that seems to contradict recent studies that show inversions of temperature and humidity coincide near cloud top and potentially are the source for cloud moisture (e.g. Sedlar and Tjernström 2009; Solomon et al. 2011; Sedlar et al. 2012). These aforementioned studies are focussed over the remote, sea-ice covered Arctic Ocean. The analysis in this study comes from profiles that are more representative of the high latitude pan-Arctic land mass. Could you comment on the potential differences and how thermodynamic advection over sea ice may lead to more coordinated temperature and humidity inversions over the Arctic Ocean?

We have added discussion in the second paragraph of Section 4. We think that the differences between land and sea areas are potentially related to a stronger role of surface forcing over land areas. Differences between the surface fluxes of sensible and latent heat weaken the link between temperature and humidity inversions.

(6) Pg. 22588, Lines 8- : It is important to note that the radiosonding analysis in Devasthale et al. (2011) differed from the AIRS results in terms of frequency of inversion presence and inversion strength, and agreed much more closely with the radiosonding analysis performed in this study.

We have added a sentence on this important point.