Response to Referee #3 (F. Pithan)

I have a few comments and suggestions regarding the description of atmospheric processes and climate feedbacks in the review paper.

1. Role of different feedback processes in causing Arctic amplification

The authors mention a number of studies that have looked at the role of single feedback mechanisms in causing Arctic amplification, but largely overlook the literature that attempts to quantify and compare the contribution of different mechanisms. The latter includes both arguments in favor of a dominant role of surface albedo feedback (eg Crook et al, 2011 Taylor et al. 2013) and studies concluding that atmospheric longwave feedbacks are dominant (Winton 2006, Pithan and Mauritsen 2014).

Thanks for the helpful hints. We acknowledge that both the description of the individual processes and the interaction between the different processes, although briefly discussed in the original version, benefit from an extension. We have substantially modified section 2.1 (arctic amplification) by describing the processes in more detail and by discussing their relative importance including possible reasons for opposing findings. As this is a broad review article and the processes responsible for the Arctic amplification are among many others to be described, we cannot discuss the processes at the same level of detail as in specialized articles.

The latter studies might also call into question the claim that "The Arctic sea ice is the central and essential component of the Arctic climate system" - in my view, that claim could be made more specific or better explained.

That statement on the role of the sea ice in the Arctic needs to be compact in the abstract of the Article. Taking into account the reviewers comments, we modify it to "The sea ice is the central component and sensitive indicator of the Arctic climate system.", which is a weaker message and indicates a less active role of the sea ice.

2. The lapse-rate feedback

The explanation of the lapse-rate feedback and its contrast between low latitudes and the Arctic (mostly p. 10935) could be improved: The lapse-rate feedback is negative in the tropics (which dominate the global mean) not just because of mixing, but because moist convection keeps the tropical atmosphere close to a moist adiabat. As the climate warms, the moist adiabat becomes steeper, leading to stronger warming in the upper troposphere than at the surface. I also believe that a clear definition of the lapse-rate feedback as the change in TOA radiation caused by warming that deviates from the vertically uniform reference response (the Planck feedback) is missing in the manuscript.

In the new version we are describing the Planck feedback and we are refining the definition of the lapse rate feedback.

3.The planck feedback

The contribution of the Planck feedback to Arctic amplification , i.e. the weaker increase in blackbody radiation per unit warming at colder temperatures is not mentioned in the review. That contribution is smaller than that of the lapse-rate feedback, but still important enough to be mentioned (cf fig. 2a: http://www.nature.com/ngeo/journal/v7/n3/full/ngeo2071.html)

The Planck feedback is now mentioned as the vertically uniform contribution to the temperature feedback.

4. changes in atmospheric moisture

At several instances in the text, the authors discuss changes in atmospheric moisture as a result of changes in evaporation. However, changes in moisture largely follow temperature changes at constant RH, both in the Arctic and globally (nicely explained by Isaac Held: http://www.gfdl.noaa.gov/blog/isaac-held/2011/06/29/13-the-strength-of-the-hydrological-cycle/). If the Authors refer to changes in RH, this should be made more explicit in the text.

The current manuscript discusses changes in atmospheric water vapour content and cloudiness over the Arctic (section 4.3) which could be due to increased evaporation or due to changes large scale advection. Different studies (see section 4.3) give increasing trends in vertically integrated water vapour content and seasonal and regionally varying decreasing or increasing trends in evaporation. Results are based both on observations (using specific humidity) and reanalysis. Several studies also find changes in clouds. Thus, the RH must have increased. Effects of increased cloudiness and specific humidity are now mentioned e.g. in the first paragraph of section 4.2 and in the 5th paragraph of section 4.3.

Specific comments:

5. p 10932, ll 11ff: Manabe and Wetherald also mentioned the role of the vertical structure of warming, i.e. the lapse-rate feedback

Thanks, this is included in the new version

6. p 10936, l 15: water vapour feedback is indeed stronger in the Tropics than the Arctic and does not lead to AA, “even” and “likely” could be omitted here (see figure from comment 3)

This is done in the new version

7. p 10936, ll 21 ff: The referenced papers do not show that cloud feedbacks alone can cause Arctic amplification, since they disable the surface albedo feedback but not the lapse-rate feedback, planck feedback or changes in atmospheric heat transport.

We have modified the paragraph for the new version of the manuscript:

“The cloud feedback contribution is potentially capable of explaining an Arctic amplification on its own without the support of a sea ice albedo feedback. This is indicated in model studies with sea ice-albedo-feedback disabled by a fixed albedo (Langen and Alexeev, 2007; Graversen and Wang, 2009). Among the remaining mechanisms, the combined cloud feedback and the water vapour feedback (which not in itself generates an amplification) play the leading roles. Similar to the lapse rate feedback, the effect is supported by a generally stable stratification without convective mixing in the Arctic atmospheric boundary layer, hindering vertical mixing of humidity and thus keeping up increased humidity at lower levels. A more complete summary of the mechanisms involved in the Arctic amplification is given by Serreze and Barry (2011) and Pithan and Mauritsen (2014).”