

Response to Anonymous Referee #1

(Referee comments are in black; our responses are in blue.)

Thanks very much for the compliments and for the constructive comments. We've chosen to address the comments point-by-point below

L39-40 "Through these processes, clouds shape the temperature and sea ice variability and trends in the central Arctic representing a potentially significant climate feedback." This sentence is worded in a confusing manner. Should the second "and" be deleted?

This sentence is now written as "Through these processes, clouds shape long-term trends in both temperature and sea ice variability in the central Arctic, representing a potentially significant climate feedback."

L103 The description of the cloud sampling method would be easier to follow if it is mention that the 2mm wire is used for the calculation of cloud water. This explanation is given in the following paragraph but I don't see the harm in telling the reader this fact on the spot.

done

L121/L130 Specifically, will ASRv3 have more sophisticated cloud microphysics scheme?

Yes. The earlier ASR used the Goddard microphysics scheme of Tao et al. (2003). Many of the details of the microphysics are given by Tao and Simpson (1989). The next version of the ASR will use a more advanced microphysics scheme with a demonstrated ability to model polar clouds, perhaps the two-moment P3 scheme of Morrison and Milbrandt (2015).

L130 "...with issues such as explored here." Could add the word "those" in front of explored.

done

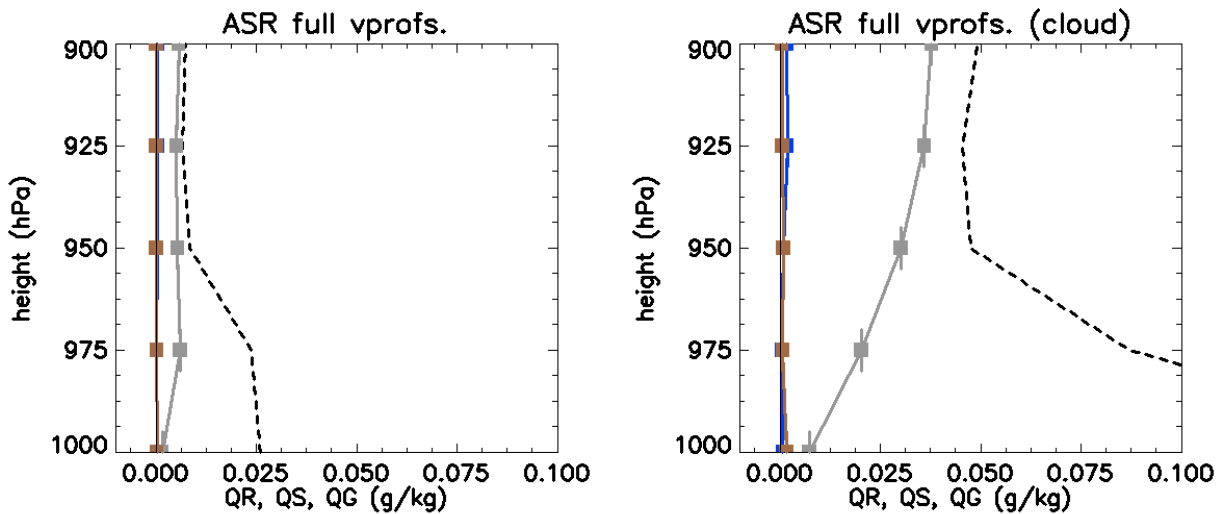
L185/L405 Do you know why mixed-phase cloud processes are not occurring in ASR? In explaining the lack of ice, could ice be forming but quickly falling out? That is, I'm unclear about the evidence supporting the notion that mixed-phase cloud processes are not occurring in ASR versus mixed-phase processes just being poorly implemented. Though I admit that this distinction is not terribly important. Also, it's not clear if the use of the term precipitation in the manuscript includes ice and liquid, or only liquid?

This is a complex topic to address, and one that is not necessarily entirely in the scope of the paper. There are a few things to consider:

1. Even if ASR simulated realistic amounts of cloud ice, there was not much cloud ice observed by ARISE, so there would be few opportunities for simulated mixed-phase processes to occur.
2. The purpose of the dashed lines in Figs. 4e and 4f are to show that simulated cloud ice is not simply converting into snow. Yes, by "precipitation" we mean both liquid and ice forms – in fact, snow is the main precipitation species, with rain and graupel being almost nonexistent.
3. If the concern is that cloud ice is converted to snow and then quickly falls out, perhaps because of an overaggressive fall speed parameter, we might expect to see that the precipitation vertical profile is shifted lower in the atmosphere with respect to the cloud water, with the rapidly-falling snow accumulating as it descends through the cloud layer. But this is not observed in the data.

Below are mean vertical profiles of snow (QS, gray), rain (QR, blue), graupel (QG, brown), and QC (dashed black) for the full ASR dataset (left) and the full cloud-only set (right). We set the vertical

coordinate .to pressure to better display the reanalysis data. QS clearly increases with height, the opposite of QC. This does not resemble the profile we might expect from an unrealistic conversion rate from QC to QS, and QS fall speed.



4. ASR has a warm bias over ARISE, particularly in cloudy conditions (about 3°C, see Fig. 3f). While this warm bias does not entirely eliminate all possible conditions for significant cloud ice formation, it makes ice formation less likely.
5. In certain conditions when both ARISE and ASR observe/produce cloud ice, it is possible that ARISE has greater QI because of secondary ice production processes, namely ice crystal splintering, that ASR does not simulate. This was observed in other field campaigns near Antarctica, and in conditions with $T > -10^{\circ}\text{C}$, and can boost QI by 1-3 orders of magnitude greater than predicted without this process (Grosvenor et al., 2012; O'Shea et al., 2017). Perhaps this occurred on occasion during ARISE, where T was often greater than -10°C . But the main problem with this argument is that ice splintering is a *secondary* process, so even if it was perfectly accounted for in ASR, it would have no effect when ASR fails to produce *any* QI, which is very common. So it isn't clear how significant this issue is. It could be an interesting topic for future research.

Grosvenor, D.P., Choullarton, T.W., Lachlan-Cope, T., Gallagher, M., Crosier, J., Bower, K.N., Ladkin, R.S., & Dorsey, J.R. (2012), In-situ aircraft observations of ice concentrations within clouds over the Antarctic Peninsula and Larsen Ice Shelf, *Atmos. Chem. Phys.*, 12, 11,275-11,294, doi:10.5194/acp-12-11275-2012.

O'Shea, S.J., Choullarton, T.W., Flynn, M., Bower, K.N., Gallagher, M., Crosier, J., Williams, P., Crawford, I., Fleming, Z.L., Listowski, C., Kirchgassner, A., Ladkin, R.S., & Lachlan-Cope, T. (2017), In situ measurements of cloud microphysics and aerosol over coastal Antarctica during the MAC campaign, *Atmos. Chem. Phys.*, 17, 13,049-13,070, doi:10.5194/acp-17-13049-2017.

L238 Should it be “sizes”, and not “sized”? This sentence could be worded in a less confusing manner.

done

L322 The sentence starting “Implied...” is awkwardly associated with the previous sentence.

The sentence now starts with “This implies...”

L436-437 The first sentence of this paragraph is incomplete.

We inserted an “is” to give the sentence a verb.

L555, Fig 1: The left panel needs units or label.

done