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Comment on acp-2022-395

Anonymous Referee #3

Referee comment on "Investigating the radiative effect of Arctic cirrus measured in situ during the winter 2015–2016" by Andreas Marsing et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2022-395-RC3, 2022

This paper uses the measurements of a hygrometer (WARAN) to infer the water contents of cirrus clouds and then based on the inferred cloud water content to quantify the radiative effects of the cirrus in the arctic region. As the authors correctly state, cirrus clouds are frequent in the arctic and potentially play an important role in influencing the radiative balance in the region. However, it is difficult to ascertain their radiative effect because the effect depends not only on the cloud properties, which are difficult to measure, but sensitively on various environment variables such as solar zenith angle and surface albedo which can affect both the magnitude and sign of the radiative effect. I am convinced the topic and objective of this work are both important and think works like this one that base on data to assess the radiative effect of cirrus clouds in the arctic are much needed and should be encouraged. I also find the paper generally well written, providing a clear documentation of the research steps and results.

Although the research is well motivated, I found several critical issues with this work. These include the quantification of the ice water content and the configuration of the environmental profiles for the radiative assessment. These deficiencies limit the usefulness of this work and should be addressed before the paper is considered for publication.

- IWC

Given that IWC is not directly measured but inferred in the total water measurements. The accuracy of the data are especially in need of validation. I found it unsatisfactory to only present a PDF summary (fig 1) of the WARAN vs FISH comparison, without explaining the different behaviour documented here compared to the literature (overestimation of WARAN) or analyzing the biases pattern, e.g., under moist vs. dry conditions, at different times of the day (solar angles), association with underlying surface types (albedo), and collocated dynamical fields.

Moreover, it seems the authors completely ignored the possibility of ice supersaturation in inferring the ice content from the total water measurement. Given how common the UTLS air is found to be in a supersaturated state and how the ice and supersaturated air are intrinsically related in influencing the radiation fields (e.g., Tan et al. 2016, https://doi.org/10.1002/2016GL071144), this is not acceptable. It is understood that independent data not available from the campaign, but at minimum this issue should be recognized and discussed, preferably using the statistics of the supersaturation or its relation to environment conditions obtained from other campaigns. In this regard, it appears especially hand-wavy, and possibly wrong, to inflate the IWC by 5 times in the radiative assessment.

- Radiative assessment

The authors correctly recognize that the radiative assessment is sensitive to the environment conditions coexisting with the cirrus, such as the solar angle and surface albedo. However, it doesn't appear logic to me that they extensively use idealized (nominal) values of these parameters rather than best estimates of them from appropriate datasets. Generally speaking, we don’t need another set of sensitivity experiments to illustrate how complex the cirrus radiative effects are but are in great need of measurement data to nail down what exact effects are in the nature. The authors need to either provide convincing arguments as to how the sensitivity computations done here are new or useful (how it can be related to nature), or change their strategy and properly pair their cirrus data with the values of those parameters appropriate to the time and location in their assessment.

Also, these aspects of the assessment probably can be better documented or explained:

The configuration of the RT model, e.g., how many streams are used in the RT solver, how the scattering angles are discretized, … these aspects all affect the results. The sensitivity of cirrus effect to the solar zenith angle is not well explained in the current paper; unclear how the scattering angle effect (forward scattering) and light path effect respectively affect the result and which dominates.

Possibility of sub-cirrus cloud layers, which are often found in nature and are expected to strongly affect the assessment of the radiative impacts of cirrus.

Optical depth of the aerosol (haze) layer prescribed – how much does it affect the lower boundary reflectance, and how are the cirrus effect depends on this factor.