Referee comment on “Supercooled liquid water clouds observed over Dome C, Antarctica: temperature sensitivity and surface radiation impact” by Ricaud et al.

The study investigates the relation between temperature and liquid water path in the presence of supercooled liquid water clouds, and analyzed the cloud radiative effect in terms of net surface radiation.

In general, the authors have attempted to thoroughly revise their manuscript according to the reviewers' comments. The relationship between temperature and LWP is well described. However, I have still some concerns regarding the methodology used to estimate the cloud radiative effect. Overall, I cannot recommend publication without a major revision.

Major Comments

1. In the revised version, the authors included ERA5 and CERES data to evaluate the surface radiation in cloudless conditions. I don't think this significantly supports the study for several reasons. First, a potential effect of surface roughness (sastrugi) on surface albedo could be directly estimated from the pyranometer measurements. Second, it is not clear to me, for what reason ERA5 and CERES data were introduced here. It is known, that these data sets are not very reliable in representing the surface albedo, as also shown by the authors. Both data sets were fudged to the measurements by using the measured surface albedo for scaling the upward irradiance. What is to be done with the fitted results? How does it help to estimate the radiative effect of clouds based on the ERA5/CERES data, since they are still based on the near-time measured albedo? How do they prove the stability of conditions?
2. A more feasible approach was already suggested by the previous reviewers. I strongly encourage the authors to use radiative transfer modeling to estimate the cloudless reference surface radiation. Since the surface albedo are available directly from the measurements in cloudless conditions, even the diurnal pattern can be considered. Note, that snow/white ice albedo is also dependent on the solar zenith angle (e.g., Gardner and Sharp, 2010 - https://doi.org/10.1029/2009JF001444). Atmospheric profiles of temperature and humidity should be taken from radio soundings, as they provide a reliable description of the atmospheric state on the considered cloudy day. The use of longwave radiation measurements on cloudless days is not advisable because they are not representative of cloudy days. Temperature and humidity profiles have a strong effect on the longwave radiation.
3. The figures are well described but the interpretation should be extended, e.g. what causes the effects of the single radiation components.

Minor/Specific Comments

The page and line numbers refer to the pdf file: acp-2022-433-ATC1.pdf

1. The authors should be more precise in using specific terms. (i) “Radiative flux” is often wrongly used in literature. It describes a flux in units of Watt, but pyranometers and pyrgeometers measure flux densities in units of Watt per square meter. Either use the term "flux density" or, what is often used in the literature, "irradiance". (ii) Further use “surface albedo” instead of albedo. Albedo can also refer to the albedo of a cloud. (iii) Consider using the term “cloudless” or “cloud-free” instead of “clear-sky”. The term “clear-sky” indicates an atmosphere that is also free of aerosols. (iV) “surface radiation anomaly‟ – anomaly sounds weird. Actually it is a ‟cloud radiative forcing”, as used in literature.
2. P3L62-64: You should also mention the role of CCNs and INPs here.
3. P5L99: “surface radiation” – I would prefer to use the term “surface irradiance” and symbols in Eq. (1) something like that: F_net = (F_down-F_up)_LW + (F_down-F_up)_SW.

4. P8L187: What is a “regular” temperature profile?
5. P10L231-233: Give a reason for the variability. In SW it is clearly an effect of SZA.
6. P10L239-241: What is the contribution of temperature and humidity on the differences in LW? That could be analyzed by radiative modeling.
7. P11L244-245: Spikes can be attributed to cloud edge effects, when direct fraction of the solar incident radiation and an additional diffuse contribution scattered from cloud edges falls on the radiation sensor.
8. P11L257: “The study is focuses on …” – already mentioned before. Skip it. Also details of binning were described before.
9. P14L322: Don’t mention binning details.
10. P15L342-345: “Considering the SR vs. LWP relationship…” - I don't quite understand the connection with Table 3. If there is a mode that is centered around 0 W m^-2, then it probably refers to a low LWP.
11. Sec. 5.2 on the Reference Surface Radiation and sastrugi effect: Here it is not clear to me, what the benefit of using ERA5 and CERES data is for this study. Remove this section and use radiative modeling to create your cloudless references.
12. P22L513: “a lower layer being made of liquid water and an upper layer being made of solid water” – I am sure this generally true for mixed-phase clouds. To my knowledge liquid cloud particles are mainly near cloud top (https://www.pnas.org/doi/full/10.1073/pnas.1418197111).
13. P22L519-522: The positive part in the SW is probably due to cloud edge effects rather than the presence of liquid and ice particles in the cloud.
14. P22L530: “during the local "night" at 00:00-06:00 LT” – should by polar day.
15. Sec. 5.6 on the potential radiative impact of SLWCs over Antarctica: The estimation of an Antarctica-wide radiative impact of SLWCc is based on the maximum net difference. How is the effect of SZA on F_net(SW) accounted for here, how the effect of seasonal dependent atmospheric profiles that determines the LW contribution? The 50 W m-2 is probably not a representing number for a larger area and time frame.