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Comment on acp-2021-926

Gerald Mace (Referee)

Referee comment on "Exploring relations between cloud morphology, cloud phase, and cloud radiative properties in Southern Ocean's stratocumulus clouds" by Jessica Danker et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2021-926-RC1, 2021

The manuscript by Danker et al. examines phase partitioning in Southern Ocean low-level clouds and draws very interesting and potentially important conclusions regarding the relationships between phase and albedo and how phase responds to large-scale dynamics and cloud morphology. These findings are derived through an innovative analysis of the so-called DARDAR cloud classification product combined with MODIS-derived albedo. I find the paper to be very interesting, generally well written and well organized. I recommend publication after minor revisions addressing the following concerns.

Major Comment:

The authors base their analysis on a classification product that was designed to assist implementation of algorithms being developed for the EarthCare satellite. It was adapted to the CloudSat and CALIPSO data sets augmented by thermodynamic information from ECMWF. The authors of this paper have more or less adopted this classification scheme as the primary source of information for their analysis without, in my opinion, sufficient critical assessment of it for their specific purpose. The DARDAR algorithm was developed to be applied globally and was not specifically tuned to the clean maritime environment of the SO where INP concentrations are very low. Therefore, I think the authors should explain in their methods section 1) what actual information, beyond simple model-based temperature threshold relationships, exists at 60m resolution in the vertical profile of an optically thick cloud that is sampled by CloudSat to distinguish phase and 2) how such an algorithm can distinguish or not supercooled liquid drizzle from ice-phase precipitation? Based on Ceccaldi et al. (2013) Figure 1, the DARDAR algorithm uses radar reflectivity and thus the presence of precipitation-sized hydrometeors) along with how that reflectivity is distributed relative to wet-bulb temperature to prescribe phase in optically thick clouds. Thus my third question: 3) To what extent has the DARDAR algorithm been validated in a clean maritime environment where there may not be sufficient INP to nucleate ice phase hydrometeors and where supercooled drizzle may be common in clouds that do not have sufficient updraft strength to initiate secondary ice processes?

Specific Questions Related to this Comment:

Line 109: This logic to derive a column phase type seems reasonable. However, the authors must explain what in the DARDAR algorithm distinguishes the liquid types from the mixed types? What, in the actual data, is providing the information? If it is the wet-bulb temperature threshold combined with radar reflectivity, then it is important to explain whether this threshold can identify the presence of liquid supercooled drizzle in optically thick closed cell stratocumulus.

Line 115: Supercooled drizzle has been observed in Southern Ocean stratocumulus clouds to temperatures of -25C. It seems as though the wet bulb threshold might have difficulty identifying the presence of supercooled drizzle. Mace and Protat (2018 DOI: 10.1175/JAMC-D-17-0194.1) document supercooled drizzle occurrence with a cloud temperature near -10C. See also Silber, I., Fridlind, A. M., Verlinde, J., Ackerman, A. S., Chen, Y.-S., Bromwich, D. H., et al. (2019). Persistent supercooled drizzle at temperatures below −25 observed at McMurdo Station, Antarctica. Journal of Geophysical Research: Atmospheres, 124, 10878–10895. https://doi.org/10.1029/2019JD030882

Line 151: Again, what "signals"? Where is the information coming from? From Mace et al. (2021) CALIPSO is mostly unable to identify the presence of ice when it occurs in optically thick clouds.

Line 160: The value of 0.5% is 20 times lower than 10% that is reported by Mulmenstadt. Mace et al. (2021) analyzed cloudsat and calipso data between 2007 and 2010 and find that ~25% of the SO MBL clouds are precipitating. I am aware that Marchand and his student (paper in review) find a substantially larger precipitating fraction from data collected at Macquarie Island. The magnitude of this discrepancy between what is found in this paper and what has been reported in the past is large and those differences have implications for our understanding of Southern Ocean climate.

Line 165: Might it also be that optically thin clouds are much more likely to be categorized as liquid because they are optically thin and that optically thick layers are more likely to be classified as mixed because it is impossible to distinguish the phase of the precipitation that is in them?

Line 419: Might it be that my third question above has been addressed by the authors' comparison to the in situ data analysis of D'Alessandro et al. (2021) where the aircraft data show a lower occurrence of MPC than what is suggested in the DARDAR product? I wonder if the authors should reconsider the possibility that the lower occurrence of MPC in the aircraft data may actually be indicative of the inability of the radar reflectivity-wet bulb relationship to distinguish the difference between supercooled liquid precipitation and ice-phase precipitation?

Minor Comments:

Line 87: The asymmetry parameter g is a function of the droplet size distribution (effective radius and width of the distribution). How might g vary in realistic southern ocean clouds?

Line 101: Since CloudSat's reported resolution is 240 m, it seems that there may not be much difference in what is known about phase or anything else between 720 and 780 m in an optically thick cloud. Also, the conservative rule of thumb is that clutter begins at 1 km. However, this could be checked by examining the CloudSat cloud mask product to see if the Marchand et al., algorithm is identifying clutter or not at a particular height since the height where clutter begins varies by 1-2 (240 m) range bins around an orbit.

Line 104: I'm not sure I understand "orginal" in this context. The actual vertical resolution of CloudSat is 480 m and it is oversampled twice to provide return in 240 m range bins. The 60 m resolution of DARDAR is purely a construct and represents an extrapolation of the CloudSat data. That vertical resolution is a function of the CALIPSO lidar data. Information at 60 m resolution below the point where the lidar attenuates is likely not a function of the actual data but may be due entirely to the model-derived therodynamics and the DARDAR decision tree.

Line 121: Problems with the MODIS CTT are a potentially important piece of information for the community. Can the authors elaborate, provide an example, or provide a reference if this problem has been previously reported?

Line 156: What does "internally mixed" mean in this context? If it means that the DARDAR algorithm is identifying the presence of ice and liquid, then, again, I ask where the information is coming from and can it distinguish supercooled liquid precipitation from ice-phase precipitation?

line 445: Please define in-cloud albedo. Apologies if I missed this definition earlier.

With Compliments,

Jay Mace