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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Meteorological and cloud conditions during the Arctic Ocean 2018 expedition" *by* Jutta Vüllers et al.

Anonymous Referee #1

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Full review of Vüllers et al., ACPD 2020

Summary of the manuscript acp-2020-219

The study titled "Meteorological and cloud conditions during the Arctic Ocean 2018 expedition" by J. Vüllers et al. gives an overview of the Arctic Ocean 2018 expedition with the Swedish icebreaker Oden into the Central Arctic in Aug-Sep 2018. It describes the atmospheric conditions encountered with an emphasis on the synoptic-scale events, a statistical analysis of the thermodynamic profiles of the atmosphere, the atmospheric boundary layer (ABL) characteristics, the cloud conditions and puts the AO2018 observations into context to previous expeditions into the Arctic Ocean. It was found that due to high cyclonic activity, the ABL was often well-mixed and a higher-than normal amount of multi-layer or mid-level clouds occurred while single-layer low-level stratocu-

mulus was observed less frequently than during previous expeditions. For several aspects of the statistical analysis like inversion strength/thickness/height as well as near-surface meteorological conditions, the observation period was divided into melt- and freeze up period as well as into synoptic-event dependent 8 periods. I would suggest the manuscript to be published after major revisions. The authors should address the following points: Major comments

l.242-247: Please connect this paragraph better to the previous results (and Fig6): under which synoptic and cloud conditions did which of the bimodal main capping inversion base heights occur? Under which synoptic and cloud conditions did which coupling state prevail?

- l.253: Explain why fog was misclassified as "Aerosol, Aerosol & Insects" by the Cloudnet algorithms. In Fig.31 d) these incidences were already filtered? Please add the fog depths in Fig.31 d). Griesche et al., 2019 (https://doi.org/10.5194/amt-2019-434) described a Raman-lidar based approach to introduce fog into the Cloudnet classification category based on Arctic cloud observations. – If possible, please apply this method to the HALO Photonics Doppler lidar/ceilometer observations and compare this method to your fog detection. As you mention, liquid occurrence would increase in Fig.10 if you included your fog detection results. In case you can use the lidar observations to detect fog, please include this fog category as liquid cloud in Fig 10 etc. to improve your cloud classification statistics. The lidar-based fog detection would also allow for fog characterization in P2 in Fig.17.

l.280f: A fixed threshold of Cloudnet mixed-phase layer depth of 700m seems a bit arbitrary for determination of single vs multiple cloud layers. The used reference Sotiropolou et al., 2014 is missing in the reference list. Based on your radar and radiosonde observations, you can determine if the clouds are thick mixed-phase clouds or actually multi-layer mixed-phase clouds as illustrated by Vassel et al., 2019 (https://doi.org/10.5194/acp-19-5111-2019). – Please apply this method to substantiate your AO2018 cloud statistics overview. This will then of course also affect the

single-vs-multi-layer cloud statistics in Fig.14+15 and the discussion on p.12ff.

Section 5.3: In multi-layer cloud conditions, please explain why you compare the statistics of first and second layer cloud base and depth (Fig.16). . .if you do not do a more detailed/precise characterization of multi-layer clouds as suggested above, these differences don't seem to have a solid basis.

Precipitation conditions were only mentioned briefly in the manuscript even though cloud radar and micro rain radar measurements were made. Please describe Fig.4f more in detail and include a discussion of Fo of precipitation during the different periods, accumulated precip amount, snow vs rain vs supercooled drizzle.

Minor comments

- p.1 abstract: mention that the Arctic Ocean 2018 was a ship-based expedition with the Swedish icebreaker Oden - l.28f and following: citations to one specific fact should always be in chronological order - l.29: past five years is not true anymore since we are now in 2020, please rephrase - l.45: mid-latitudes are only well-characterized in the Northern Hemisphere, please adjust. - l.52: radiative effect of mixed-phase clouds is surface dependent: over ice warming, over open ocean not. Please be more specific. - l.66f: The comparability of AO2018 to the mentioned four previous campaigns would benefit from a map and a table: A map showing the focus areas of the other campaigns and the corresponding sea ice cover (in comparison to Fig1.) and a table stating the time periods of the other campaigns - did they all happen during Aug-Sep or earlier in the summer? - l.86: add websites of the two projects as footnote - l.89: "atmospheric" remote sensing instruments - l. 90f: Why was only the lidar horizontally stabilized? - l.96: Just to clarify, 6 hourly radiosonde data instead of GDAS or ECMWF re-analysis was used in the Cloudnet processing of the data? - p.4: Please include a photo of the Oden and label the positions of the mentioned long-list of instruments. - l.102 and 106: How did the two ceilometers compare? - l.127: Doesn't the LI-COR LI-7500 measures fluxes of water vapor and CO2? - l.128: at which altitude above the snow surface

were the solar- and IR radiometers installed? Please add. - l.161: Define how the "net surface energy" was determined, it should be the sum of the net radiation + latent + turbulent heat fluxes + ground (soil) heat flux. – Did you measure ground heat flux? Or do you refer to "net surface radiation" instead of energy? (Also Fig5f) Please be precise in your use of "net surface radiation budget" vs "net surface energy budget" throughout the manuscript - l.188: "near-surface air" instead of "surface" - l.200: "wind speeds" - l.253: You have not mentioned the duty cycle of the radar measurements previously. In the measurement description please add the cycle of cloud radar RHI scans (1x/hour? 2x/hour?...?) as well as the RHI scan angles. - l.274: According to Fig10 b) and c), mixed-phase clouds had a higher occurrence frequency than ice clouds below 3.5km for both, the melt and freeze-up period. Also, mention that the Cloudnet target classification likely underestimates the FoO of mixed-phase clouds during multi-layer situations since it only classifies liquid in the presence of a lidar signal which in turn gets fully attenuated at an optical thickness of three though. - l.287: I suppose the listed liquid cloud statistics again do NOT include the fog classification? – If so, please update after including the fog occurrence as liquid cloud. -l.290: It sounds like as if you used the Cloudnet target classification mask for cloud base altitude determination. Why don't you use the multiple lidar observations (HALO, 2x ceilometer) to determine cloud base? What are the lowest observation range gates of the lidars? - l.291: Again, emphasize that ice clouds refer to "ice clouds and ice precipitation" leading to such deep cloud depths. - l.325: Here you state that P7 was characterized by mostly cloud-free conditions. Fig.14 however shows that during P7 cloud-free conditions occurred only for about 5% of the time while for P3 and P8 cloud-free conditions occurred more frequently, namely about 15%, and 10% of the time. – Please adjust. - l.404: Here you mention that cloud radar data was only available during the first 3 days of P8. – Please bundle data gaps earlier on in one paragraph when describing the measurements.

Comments on Figures:

Fig. 4: Please indicate the phase of the precipitation reaching the ground (snow/rain

or ice/mixed-phase/liquid) in panel e). Did you experience supercooled drizzle?

Fig.5: I am surprised that the PDF of SW/LW/Net surface radiation balance do not differ much for the ship- vs. ice period. – Can you explain why?

Fig.6: What do the grey stripes in d) represent? – Ok, seems like the answer is on p.10: No radar observations (and thus Cloudnet target classifications) were possible during the ice-breaking period between Aug 4-12. This should be mentioned much earlier. Also in Fig. 14 it should be explicitly stated in the caption that P2 had to be excluded.

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