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Interactive comment on “Microphysical and optical properties of Arctic mixed-phase clouds – the 9 April 2007 case study” by J.-F. Gayet et al.

Anonymous Referee #2

Received and published: 16 June 2009

This paper discusses in-situ and remote-sensed observations of a region of mixed-phase stratocumulus clouds observed to the east of Greenland during the ASTAR campaign. Analysis of micro- and macrophysical properties is completed, along with an assesment of the ability of the ECMWF operational analysis to correctly replicate these clouds.

Major Comments:

1) Grammar/writing: Overall, I found this paper difficult to read. Generally, sentence structure and grammar employed could use significant improvement. Some examples of this include:

- Page 11339, line 20: “. . . 250 km heading strait towards. . .” “strait” is the wrong word

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here. Instead, “straight” should be used.

- Page 11341, line 4: “The CALIOP measurements reveal. . .” “The” is not necessary in this sentence. . .removal of excess “the”s will greatly improve the flow of the manuscript.

- Page 11344, line 11: “. . .of the presence of relatively large concentration of ice. . .” “a” is needed between “of” and “relatively”, OR “concentrations” should be plural

As an additional example, I have altered the abstract with recommended changes, and encourage the authors to seek out similar changes throughout the manuscript.

“Airborne measurements of Arctic boundary-layer stratocumulus were carried out near Spitsbergen on 9 April 2007 during the Arctic Study of Tropospheric Aerosol, Clouds and Radiation (ASTAR) campaign. A unique set of co-located observations is used to describe cloud properties, including detailed in situ cloud microphysical and radiation measurements along with airborne and co-located spaceborne remote sensing data (CALIPSO lidar and CloudSAT radar). CALIPSO profiles indicate a cloud top temperature between -24 C and -21 C. In situ measurements confirm that the cloud-top lidar attenuated backscatter signal along the aircraft trajectory is linked to the presence of liquid water, a common feature observed in Arctic mixed-phase stratocumulus clouds. A low concentration of large ice crystals is also observed up to cloud top, resulting in significant CloudSAT radar echoes. Since the ratio of extinction of liquid water droplets to ice crystals is high, broadband radiative effects near cloud top are mostly dominated by water droplets. CloudSAT observations and in situ measurements reveal high reflectivity factors (up to 15 dBZ) and precipitation rates (1 mm h-1). This feature results from efficient ice production processes. About 25% of the theoretically available liquid water is converted into ice water with large precipitating ice crystals. Using an estimate of mean cloud cover, a considerable value of 106 m3 h-1 of fresh water could be settled over the Greenland sea pool. European Centre for Medium-Range Weather Forecast (ECMWF) operational analyses reproduces boundary layer height variation along the flight track. However, small-scale features in the observed cloud field cannot

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be resolved by the ECMWF analysis. Furthermore, ECMWF's diagnostic partitioning of condensed water into ice and liquid reveals serious shortcomings for Arctic mixed-phased clouds. Too much ice is modeled."

I realize that much of this may be likely lost in translation, but I feel that the readability of the manuscript can be significantly improved with some editing effort.

2) I agree with one of the other reviewers that a comparison of the measurements taken here with those from previous studies would help to place them into context. I am a bit worried that conclusions are being drawn from one single case, particularly one that seems to fall significantly outside of observations taken over longer timescales at SHEBA (Shupe et al., 2006), MPACE (Shupe et al., 2008), and during SEARCH (de Boer et al., 2009). Also, in addition to McFarquhar (2007) there are several other papers discussing in-situ measurements of mixed-phase stratiform clouds (e.g. Rangno and Hobbs, 2001; Pinto, 1998).

3) Regarding the estimation of freshwater accumulation over the Greenland sea pool, I'm a bit skeptical about this estimation. There is no discussion of error estimates for the numbers provided, yet some of the assumptions made along the way are relatively large. For one, the authors demonstrate no evidence that I can see that the precipitation is actually reaching the surface. The aircraft does not fly at low enough altitudes to detect near-surface precipitation, and CloudSAT has surface clutter issues in the lowest 500 m. Perhaps this evidence is available from the aircraft lidar, but it is not presented in the manuscript. Additionally, error estimates based on the instrument limitations used to gather the IWC would be useful.

Minor Comments:

1) In the abstract, I suggest clarifying the section on temperature estimates to illustrate that CALIPSO is only being used to find the cloud locations (and not the temperature itself)

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2) I would also clarify what is meant by “a cloud-top layer dominated by liquid-water”. Yes, the radiative effects may be dominated by liquid (along with the lidar signal), but from Figure 10, the IWC and LWC appear to be comparable.

3) p. 11335, line 15: Ice crystals are not always non-spherical. In the case of frozen droplets, they can be very close to spherical. These types of crystals have been detected in mixed-phase stratiform clouds (Rangno and Hobbs, 2001).

4) p. 11337, line 6: “artefact” should be “artifact”

5) p. 11337, line 16: again, not all ice is totally non-spherical

6) general comment/question: Any issues with icing when flying the probes through a supercooled liquid cloud?

7) p. 11339, line 20: “strait” should be “straight”

8) p. 11339, line 27: should read: “In the following section microphysical. . .”

9) general: How is the aircraft trajectory corrected? Just in flight, based on wind speeds?

10) p. 11342, line 19: Suggest removing “with the same representation as Fig 3a”.

11) p. 11343, line 10: What about the smaller crystals? Did they have the same characteristics? These are the crystals that have recently been nucleated, and are potentially of greater interest to the modeling community than those that have grown via deposition/riming.

12) p. 11343, line 13: 800 L-1 seems like a HUGE number to me. Previous studies have shown values closer to 10 (or maybe 100) per liter. Some further error analysis, or at least an explanation as to why this was so big would be useful.

13) p. 11343, line 24: What about spherical crystals? Any detected? Did they fall under the “graupel” category?

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- 14) p. 11344, line 17: Insert the mean value for Deff in the text to be consistent.
- 15) p. 11345, lines 16-29: Explain this relationship further. Is it possible that there is simply more ice in the juicier clouds, resulting to higher depolarization values?
- 16) p. 11346, line 6: “production” is a misleading word. Typically, it implies ice nucleation, but here it is more likely ice growth that increases IWC.
- 17) p. 11346, line 22: “hypothesizing” should be “hypothesized”
- 18) p. 11346-11347: Regarding the precipitation rate. . .again, how much is actually reaching the ground? Any error analysis on this number?
- 19) p. 11347, lines 6-9: This paragraph should be reworded to provide further meaning.
- 20) p. 11349, line 1: Again, is the ice reaching the surface?
- 21) p. 11349, line 22: Again, I would use an alternative word over “production”
- caption for figure 7: Please indicate which line represents the CloudSAT measurements, and which come from the CPI either on the figure, in the caption, or both.

Interactive comment on Atmos. Chem. Phys. Discuss., 9, 11333, 2009.

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