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Atmospheric Chemistry and Physics
Discussions

Interactive comment on "Ice Particle Production in Mid-level Stratiform Mixed-phase Clouds Observed with Collocated A-Train Measurements" *by* Damao Zhang et al.

Anonymous Referee #2

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In their paper, Zhang et al. analyse collocated CloudSat and CALIPSO lidar measurements between 2006 and 2010 to study ice number concentration in stratiform mixed-phase clouds. They divide the global data set into six latitude bands (northern and southern tropical, mid- and high-latitudes) for their analysis. In general the paper is well written and the results are of interest to the community. However, the method needs further explanation and the analysis/interpretation should take into account differences in the macro- and microphysical properties of Arctic and mid-latitude clouds. The paper needs major revision before it can be published in ACP. Page and line number below refer to the document uploaded by the authors.

Comments:

In the introduction the authors should discuss the specific characteristic of Arctic mixed-phase clouds (e.g. observation, life time and limited CCN). For example the observed CCN concentrations in Arctic mixed phase clouds are usually of the order of 10 cm^{-3} (rarely as high as 100 cm^{-3}) and sometimes less than 1 cm^{-3} (Birch et al. 2012). This is in contrast to lower latitudes where typical concentrations range from approximately 100 cm^{-3} to several 1000 cm^{-3} in the marine environment (Raes et al., 2000). Such low CCN number concentrations affect cloud droplet size spectra, and hence, radiative properties of these clouds will differ from those at mid- latitudes. Mauritsen et al. (2011) argue that cloud formation is frequently limited by CCN availability in the central Arctic. They use the term "tenuous cloud regime" to describe situations in between an abundance of aerosol needed to form clouds and a hypothetical situation where aerosols are absent and cloud formation does only occur at very high super-saturation (âĹij400% relative humidity). Further, Arctic mixed-phase clouds are governed by a combination of local and large-scale processes (Morrison et al., 2012). At the small scale, the Wegener–Bergeron– Findeisen (WBF) process is one of the main mechanisms responsible for ice crystal growth at the expense of super-cooled water droplets (Bergeron, 1935; Findeisen, 1938; Wegener, 1911). Such a mechanism leads to a rapid glaciation of mixed-phase clouds. On the other hand, dynamical processes, such as turbulence or entrainment may facilitate the formation of new super-cooled water droplets. For example, resupply of water vapour from the surface or from entrainment of moisture from above the clouds may contribute to the continuous formation of liquid droplets. The coupling of various processes is, thus, necessary to maintain the unstable equilibrium between liquid droplets and ice crystals within Arctic mixed-phase clouds (Mioche et al 2015). This may explain the long lifetime of Arctic mixed-phase clouds, which can last up to several days or weeks. (Shupe, 2011; Verlinde et al., 2007; Morrison et al., 2012). Previous studies of Korolev et al. (2003), Korolev and Isaac, (2003) and Korolev (2007) also point out that the lifetime of Arctic mixed-phase depends on local thermodynamical conditions or is linked to cloud dynamics. Local and long-range dynamic processes (aerosol, heat and moisture transport) also have a significant impact on Arctic mixed-phase cloud formation and properties (Cesana et al. 2012, Morrison et al. 2012).

Page 5, line 129-133. Why do you use max Ze and not mean Ze as Zhang et al. (2014)? Your results in Figure 3b (90-60 N) are similar to Figure 10 in Zhang et al. (2014) but shifted to larger values. What is the effect of using max or mean on the relationship between Ze and ice number concentration? Is Ze normally distributed to allow for a retrieval of a relationship to aerosol concentrations and the subsequent statistical analysis?

Page 6, line 156 to 160: Does the selected LWP range (20 to 70 gm-2) have an effect on the statistics for high-latitude clouds? Arctic mixed-phase clouds usually peak at lower LWP (Tjernström et al., 2012).

Page 6 six latitudes bands: Can you please repeat your analysis for an Arctic latitude band (> 70°). Figure 1 shows the highest occurrence of mixed-phase clouds over the ocean in the Arctic and Antarctic (> 70° and <-70°) while Figure 7 shows aerosol occurrence beyond 70° that is lower than at latitudes below 70° in spring. Your results might be biased by your choice of latitude band, i.e. the results for the latitude bands 60-90° might be dominated by the signals from between 60 and 70°. In other words: I don't think that there is so much dust in the Arctic that it could have such a strong effect in the clouds (see comments regarding the Introduction).

Page7, line 221-222, supercooled cloud fraction, [] lowest during springtime: Is the occurrence frequency of mixed-phase clouds according to Figure 5 not the highest in spring at high-latitudes?

Page 7, line 187, delete greater

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