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Atmospheric Chemistry and Physics Discussions

Interactive comment on "A microphysics guide to cirrus clouds – Part 1: Cirrus types" *by* M. Krämer et al.

Anonymous Referee #1

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General Comments:

This paper is an excellent blend of theory and observations, and demonstrates how a Lagrangian ice particle tracking model (MAID) with detailed microphysics and aerosol-cloud interactions can be used to reveal potential dynamical and microphysical mechanisms when compared against observations. This is a potentially large contribution to our understanding of cirrus clouds. The paper is well organized and written with figures of high quality.

My main concern is that the Cirrus Guide may be over-generalized. For example, in Muhlbauer et al. 2014 (Impact of large-scale dynamics on the microphysical properties of midlatitude cirrus, JGR), they describe 4 principal cirrus categories and their physical and microphysical characteristics (e.g. altitude, temperature, updraft speed, relative

humidity with respect to ice or RHi, ice water content or IWC, ice particle number concentration or Ni, and ice particle size distribution or PSD parameters), based on SPARTICUS data. The cirrus clouds were grouped into categories based on their large-scale dynamic characteristics (inferred from ECMWF ERA-Interim reanalysis and ground based radar), with most cirrus falling into the following 4 categories: (1) upper-level ridges, (2) subtropical jets, (3) anvil cirrus and (4) frontal cirrus. This makes their results amenable to comparison with the Cirrus Guide proposed.

Ridge-crest cirrus (category 1) had relatively low IWC and relatively high Ni, and were fairly thin. This seems to contradict the proposed Cirrus Guide, which associates relatively high Ni with relatively high IWC for in situ cirrus. Table 2 of Muhlbauer et al. shows the days associated with each category, and the following NASA website: http://www-angler.larc.nasa.gov/cgi-bin/site/showdoc?docid=4&cmd=flight-track&exp=ARM-SPARTICUS-2009&ds=cp , gives satellite retrievals of SPARTICUS cloud physical properties, showing that the ridge-crest cirrus tend to be relatively thin with lower ice water path (IWP). One might expect such cirrus to belong to the slow updraft category of the Cirrus Guide, which would tend to predict low Ni and low IWC. Ridge-crest cirrus often have Ni > 500 per liter, which is difficult to achieve through heterogeneous ice nucleation (Barahona & Nenes, 2009b, ACP). But in the Cirrus Guide, homogeneous ice nucleation producing high Ni is associated with fast updraft in situ cirrus.

Muhlbauer et al. also found that PDFs of cloud updraft did not differ between the above 4 cirrus categories, indicating that cloud updraft was a poor predictor for explaining the microphysical variability in cirrus. The Cirrus Guide invokes cloud updraft as a key parameter for explaining different types of cirrus. On the other hand, the anvil cirrus category and description in Muhlbauer et al. appears consistent with the description of anvil cirrus in the Cirrus Guide, which places anvil cirrus in the liquid origin cirrus category.

Since there appear to be differences in the conclusions reached in the proposed Cirrus

Guide and in Muhlbauer et al., this reviewer recommends an extensive discussion contrasting the two studies. There may be other differences not mentioned here.

Another factor affecting cirrus cloud characteristics is their stage of evolution. The authors may want to consult papers by Minghui Diao et al. (e.g. Evolution of ice crystal regions on the microscale based on in situ observations, GRL, 2013; Hemispheric comparison of cirrus cloud evolution using in situ measurements in HIAPER Pole-to-Pole Observations, GRL, 2014; Distributions of ice supersaturation and ice crystals from airborne observations in relation to upper tropospheric dynamical boundaries, JGR, 2015). The question comes whether the observations are reflecting a certain stage of cloud evolution or whether they are seeing a distinct type of cirrus. This topic could be relevant to the Cirrus Guide.

Major Comments:

1. Section 2, page 31541: The paper would be enhanced if it included the SPARTICUS (2010) and recent ATTREX (near Guam) field campaign data. Both campaigns used modern probes (2D-S, FSSP, Hawkeye) and algorithms that minimize shattering where IWC can be calculated as a PSD integrated quantity (a practice used in this paper). SPARTICUS continuously sampled continental synoptic and anvil cirrus over a 6-month period, producing excellent statistics on cirrus cloud microphysical properties. It appears that most cirrus were sampled over land in this study (Fig. 1), making the ATTREX sampling over the western Pacific of greater interest. Enough field campaigns are already included in this study to lend sufficient credibility to the results, but it is possible something new would be revealed by including these two field campaigns.

2. Section 2.1, lines 13-20: It would be interesting to compare IWC calculated in this way to IWC calculated using the new approach described in Erfani and Mitchell (2015, ACPD), especially for D < 200 microns.

3. Section 4.1 and Fig. 5: Do the minimums (e.g. regarding Rice, etc.) indicate model initialization points? Please make it clear how this and other figures were produced

using the MAID model.

4. Section 4.2.2, first 6 lines: Here it becomes evident that cirrus lifetime actually refers to the lifetime of a cloud parcel. This distinction should be made early in the paper to avoid confusion.

5. Section 4.2.3; TTL cirrus: Ni predicted here are < 1 per liter, whereas in Spichtinger and Krämer (2013, ACP) Ni for TTL cirrus averages $\sim$ 30 per liter. This should be addressed.

6. Page 31557, lines 24-26: This sentence could be somewhat confusing if a reader thinks that anvil cirrus are considered here (which are very common). Perhaps it should be stated here that anvil cirrus will be addressed later as belonging to another category.

7. Page 31565, last sentence of paper: Anvil cirrus are liquid origin cirrus and are hypothesized here to have a net radiative cooling effect. I suggest that the authors look at Fig. 4 in Fu et al. (2002, ACP; "Tropical cirrus and water vapor: an effective Earth infrared iris feedback?"), showing net cloud radiative forcing as a function of cloud top height and optical depth. Fig. 4. of Fu et al. indicates that many tropical anvils, given their height, could have a warming effect if their optical depth is less than $\sim$ 8 or 10 (which is quite common I think).

Minor Comments:

1. Page 31539, line 26: Diameter and radius are not measured and they refer to a sphere; ice crystals are generally non-spherical. Consider another size descriptor, such as length or maximum dimension.

2. Page 31546, line 4: lesser => less? lesser overall => reduced overall?

3. Page 31555, line 7: warmer => all?

Interactive comment on Atmos. Chem. Phys. Discuss., 15, 31537, 2015.