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Interactive comment on "Technical note: An automated cirrus classification" *by* Edward Gryspeerdt et al.

Anonymous Referee #2

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General Comments:

This is a very innovative approach for classifying the various types of cirrus clouds in a way that provides qualitative knowledge about cloud updrafts and whether the cirrus ice crystals formed near -38 °C from supercooled liquid cloud droplets advected into the T < -38 °C zone, classified as "liquid origin cirrus", or from another ice nucleation process (e.g. immersion freezing, vapor deposition or homogeneous freezing), classified as "ice origin cirrus". As such it represents a potentially significant contribution to scientific progress within the scope of ACP.

However, a key parameter not mentioned in the methodology for determining cirrus cloud regimes is temperature T. To begin with, the authors need to define what they mean by "cirrus cloud". Most investigators define cirrus as a pure ice cloud (i.e. no

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liquid water is present), and the best way to insure this is to require T < -38 °C. Such a restriction was not applied in this study, making the proposed classification scheme ambiguous, especially in regards to cloud radiative properties. Unless I have not understood this classification scheme properly, this appears to be the main drawback.

It is evident from Fig. 3 that the classification scheme is applied for T < -20 °C, and supercooled liquid water may exist between -20 and -38 °C. Over this T range, the clouds should not be regarded as cirrus clouds. The differences between the cirrus categories in Fig. 3 become much more subtle if cirrus are defined as being colder than -40 °C, but the cloud categories can be distinct for -40 °C < T < -20 °C. Perhaps this classification scheme could be improved if each class were divided into two T regimes; T < -40 °C and -40 °C < T < -20 °C.

Figure 4 introduces even more mixed phase ambiguity by applying the classification scheme to cloud temperatures between 0 °C and -90 °C.

Although I am familiar with the concepts of liquid origin and ice origin cirrus clouds, I felt that these complex concepts were not clearly explained in this paper, especially in regards to what kind of knowledge they impart to this classification scheme. More explanation should be given.

The paper is well organized and well written, with a sufficient number of quality figures to illustrate the main points. Many other important concerns are listed below. Given these concerns, I recommend major revisions.

Major Comments:

1. Page 2, line 18: In this section on "Existing Classifications", the authors might also want to mention the work of Tselioudis et al. (2013, J. Climate), who used cluster analysis to define 11 atmospheric weather states (WSs) based on optical depth and pressure level. While only one WS is primarily cirrus, other WSs contain cirrus contributions.

2. Page 3, line 15: This is the 1st mention of the ICON model that is used extensively in this work. The full name of the model and/or a reference should be given here (along with acronym).

3. Page 3, line 31: In some mountainous regions, 850 hPa may be below the surface. What is done when this occurs?

4. Section 2 (Methods): Since MODIS was used to develop this classification scheme, it would be helpful to show in this paper a mean visible cloud optical depth (OD) associated with each cirrus cloud category, as well as the corresponding standard deviations. This would be helpful for understanding the net CRE of each category that is discussed later.

5. Section 2 (Methods): A temperature criteria of T < -38 °C is not used to select cirrus in any of these cirrus categories, raising the possibility that some clouds classified as cirrus may actually be mixed phase clouds. Figures 3 and 4 suggest that this classification scheme was applied for T < -20 °C and T < 0 °C, respectively. If either is correct, then mixed phase conditions are built into this classification scheme, and this should be made clear. Moreover, the word "cirrus" in the paper's title should be replaced by "ice cloud", and all references to "cirrus" in the paper should be replaced by "ice cloud".

6. Page 9, lines 2-8: Since this classification scheme is for cirrus clouds, this implies only ice exists. But when classifying clouds between -20 and -40 C, what assurance is there that these clouds are "ice only" based on Wernli et al. (2016)? And even if the Wernli et al. analysis shows that the classified "cirrus" in Fig. 3 between -20 and -40 C are ice only, the phase partitioning in cloud resolving models is not an exact science, is highly variable between models, and depends strongly on the parameterization scheme used. Thus it is difficult to understand just what exactly is being shown in Fig. 3 at warmer temperatures (e.g. are the clouds ice only or mixed phase?). Please address these concerns, clarifying all these issues. If the authors insist on using their classification scheme at these warmer temperatures, they need to

be clear just what kind of cloud they are classifying (e.g. all-ice or mixed phase).

7. Figure 5c and associated discussion: Two questions come to mind here: (1) How much do mixed phase conditions contribute to these CRE values? Even if liquid water comprises only 10% of the total water content, it can still have a large impact on cloud radiative properties (e.g. Mitchell and d'Entremont, 2012, AMT; Shupe and Intrieri, 2004, J. Climate). Thus, a small liquid water fraction is likely to have a strong impact on the net CREs given in Fig. 5c, increasing the SW over the LW contribution.

8. And regarding the 2nd question (wrt Fig. 5c), CRE is evaluated from CERES SYN1deg daily data at 1:30 pm LST. At this time, SW CRE is near maximum, whereas LW CRE is much less variable over a 24 hr. daily cycle. This sampling time will negatively bias the net CRE, making it non-representative of the daily-mean net CRE associated with cirrus clouds having low-to-moderate ODs.

9. Fig. 5b and c: It is commendable that the authors have partly explained why all the in situ cirrus categories have more SW CRE than LW CRE (due to low clouds). These cirrus are typically having lower optical depth and thus lower SW & LW CRE (Fig. 5c), with TOA LW CRE > SW CRE (e.g. Fu, 2008, Fig. 4; Hong and Liu, 2015, J. Climate). But after removing the low clouds in Fig. 5c, in situ cirrus still have a net CRE $\sim$ zero, whereas other studies infer positive values. For example, for cirrus OD < 3.6 and cloud top pressure <440 mb, the net CRE reported by Chen et al. (2000, J. Clim.) was positive, as was also true for Hartman et al. (1992, J. Clim.) for cirrus OD < 9.4. Based on the ECHAM6 GCM, the global average net CRE of cirrus clouds is +5.7 W/m2 (Gasparini & Lohmann, 2016, JGR). The proposed technical note appears to be at variance with the literature in regards to the overall sign of the net cirrus forcing, and this discrepancy should be addressed. Note that the calculations in Fu are for the equator during an equinox when the sun is highest in the sky, which maximizes the SW CRE.

10. Page 14, line 16: "As seen in previous studies, the net cloud radiative forcing (CRE)

is negative". Yes, but this paper is about cirrus clouds, and their net CRE is positive. Please cite these "previous studies" that pertain to cirrus clouds. One study by Chen et al. (2000, J. Clim.) was cited in the Introduction and could be cited again here. As noted above, Chen et al. (2000) and Hartman et al. (1992) found that for cirrus OD < 3.6 or 9.4, respectively, their net CRE is positive.

Minor Comments:

1. Page 2, line 2: Remove "and" from this sentence.

2. Page 2, line 12: Comma not needed

3. Page 2, line 18: "Existing Classifications" should be given a sub-header value of 3.1.

4. Page 3, line 27: determines => determining?

5. Figure 4: Please label all the panels as a, b and c. Also, what do the 3 horizontal lines indicate in the middle-regions of Fig. 4b and 4c?

6. Page 12, line 15: Fig. 5a does not show RFO; please clarify. Also, "frontal convective regimes" => "frontal and convective regimes"? Based on Fig. 5b, frontal & convective regimes appear to account for slightly > 12%.

7. Page 13, line 8: "once" => "until"?

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