Review of

‚Technical note: An automated cirrus classification‘

by Gryspeerdt et al.

General:

In the manuscript, a classification system for cirrus clouds that is based on re-analysis and satellite data is presented. Cirrus clouds are separated in four main types, differing by meteorological/dynamical situation and thus microphysical and radiative properties. The topic of the study is very interesting and timely and I recommend the paper for publishing in ACP.

However, before final publication, I think that the manuscript should be revised taking into account the following points.

1) To my opinion, the study has more potential and relevance than currently elaborated. Though it is claimed to be a ‚technical note‘, the link or physical mechanisms, respectively, between cirrus classes (meteorology), updraft, microphysical property (IWC or OD) and radiative property (CRE) needs to be shown and discussed in more detail to make the study scientifically sound.

The exciting is that with the applied method it seems that these links can be identified !

- In Fig. 4 the link between cirrus class and updraft is seen (the standard deviation of the respective updraft distribution could serve as measure for class specific updraft);
- also, the mean CREs of the cirrus classes shown in Fig. 5 must be caused by a respective microphysical property (IWC, OD).

2) The aim of the paper is to identify cirrus clouds by their formation mechanisms:
orographic, frontal, convective, in-situ

2 a) The name ‚in-situ‘ does not match to the other names, which describe the meteorological situation – it should be renamed to ‚synoptic‘.

2 b) The defined classes refers to meteorological (dynamical) situations, not to formation mechanisms (as stated in the abstract and elsewhere). Formation mechanisms are

– homogeneous or heterogeneous ice nucleation for in-situ origin cirrus (here called ice origin cirrus, see comment 3 below) and

– heterogeneous or (sometimes) homogeneous drop freezing for liquid origin cirrus.

So it should better be stated that cirrus clouds should be identified by the meteorological (dynamical) situation, which is what has been done in the paper.

2 c) I also recommend to link the meteorological to the dynamical situation:

synoptic (in-situ), frontal, orographic and convective cirrus are cirrus in increasing updraft regimes from low to high.

To identify cirrus by their formation mechanism, I would recommend to define for example three updraft regimes (weak, middle, high) and assign the them to the meteorological types:

synoptic (in-situ) - weak updraft,
frontal - middle updraft,
orographic/convective - high updraft.

Then, the cirrus formation mechanisms can be identified (to a certain degree) by the updrafts:
weak updraft: mostly heterogeneous freezing – low IWC/OD – low CRE ?
Middle/high updrafts: increasing homogeneous ice formation – higher IWC/OD – higher CRE ?

This is true for ‚liquid origin‘ as well as for ‚ice origin‘ cirrus.

As far as I can see, these links apparant in the paper and I would recommend to point that out in the paper.

3) ‚in-situ‘ : beside the previous comment on the term ‚in-situ‘ (2 a), I also like to mention that ‚in-situ origin cirrus‘ is recently introduced (by Kraemer et al. (2016), ACP, Luebke et al. (2016) and Wernli et al (2016), GRL) for those cirrus that you name ‚ice origin cirrus‘. Though ‚ice origin‘ might be the better companion of ‚liquid origin‘, for consistency reasons I would recommend to keep the terms as they are now introduced.

4) Cirrus formation mechanisms of in-situ origin and liquid origin cirrus and their link to cirrus properties and meteorological situations are also discussed in Kraemer et al. (2016), ACP, and Luebke et al. (2016), ACP.
Also, cirrus clouds classification, formation and so on is summarized in the recent review article of Heymsfield et al. (2017), Meteorological Monographs
(see http://journals.ametsoc.org/doi/pdf/10.1175/AMSMONOGRAPHS-D-16-0010.1).

These studies should be considered in your work.

In more detail, Luebke et al. (2016) compared aircraft measurements in mid-latitude frontal liquid origin and in in-situ origin cirrus (+). They show the microphysical properties of the cirrus types and their distribution with temperature – which is quite similar to what is found in this study. This should be discussed, it is a good confirmation of the approach used here.
(+) Liquid and in-situ cirrus are classified by means of trajectory analysis, similar as in Wernli et al. (2016).

5) The CRE is shown for the various cirrus types in Fig. 5 c). The highest total CRE is for F and C, followed by O1 and O2, and around zero CRE is for the other types. This seems to be related to the optical thickness or IWC, respectively of the cirrus types, which in turn depend on the updraft. A plot showing this would greatly improve the paper.

Also, it would be good to know if the cooling effect from F and C is because thick liquid origin cirrus constitute a large part of these cirrus types ?

In general, it would be good to see the difference in microphysical and radiative properties between liquid origin and ice origin in more detail.

6) Methods: The ‚Criteria for regime assignment' (please specify regime in Table 1, I guess the cirrus classes are meant) are not very clear. I strongly recommend to add two columns, one containing the range of updrafts for each class and one with their range of microphysical properties, IWC or optical depth.

7) Abstract: Include not only the method but also the most important results! In the current form, the paper will not get much attention when potential readers look at the abstract – which I think is a pity.

8) Conclusions: The properties of the cirrus classes are described, but I miss explanations of physical mechanisms leading to the properties. Two examples:

– ‚*The in-situ (*synoptic*) regimes in this classification are primarily composed of in-situ/ice-origin cirrus clouds, even to temperatures as warm as -20◦ C, while the frontal and convective regimes contain a much higher proportion of liquid-origin cirrus to much colder temperatures.*'

This is related to the updrafts, yes ? The larger the updrafts, the higher the liquid origin cirrus can rise = colder temperatures.

– ‚*The frontal and convective regimes have the strongest LW, SW and net negative CRE. ‚...*'

This could again be related to the updrafts, yes ? High updrafts → thick cirrus, many liquid origin→ strong CRE, yes ?

This comment relates to comment 1) and 2) .

Specific:

S1: Page 1, line 15: Please delete ‚*While*'

S2: Page 1, line 20-21: ‚*... aerosol influence on ice clouds would likely modify ice nucleation processes, changing the ICNC, perhaps by orders of magnitude ...* '

‚orders of magnitude‘ is definitively too high, please scale back this statement. Also, aren‘t more recent publications available studying the effect of IN on cirrus properties ?

Another point to think about is that the most prominent parameter influencing the radiative cirrus properties is the ice water content (IWC). Changing the ICNC by influencing the IN number does not necessarily means that the IWC is changed, since the available water vapor distributes on the present ICNC. The result are different sizes of the ICNC (but not IWC) and thus differing sedimenation behavior, which influences the further development of the cloud.

S3: Page 1-2, lines 23-1: ‚*... ice crystals are formed either by heterogeneous nucleation from ice nucleating particles (INP) or freezing of liquid droplets by either INP or existing ice crystals.*‘

Do you mean either immersion freezing or contact freezing ? Please specify.

S4: Page 2, line 2: ‚*.. freezing of and remaining liquid droplets.*‘ Please remove ‚and‘.

S5: Page 2, line 5: ‚.. (e.g. Kärcher, 2017), ..‘ Since this is the introductary part of the manuscript, I would recommend to cite some more basic studies on the influence of freezing mechanisms on cirrus microphysical properties, e.g. the work of P. Spichtinger, E. Jensen, M. Kraemer, A. Heymsfield.
Include references.-→ Heymsfield 2017, review article.

S6: Page 2, line 6-7: Heterogenous freezing in cirrus is in most cases determined by the INP number. This should be mentioned here.

S7: Page 2, line 8: ‚*Convective clouds* can *contain liquid water to temperatures as low as -37 ◦ C ...*‘

S8: This happens only in very strong updrafts, please explain.

S9: Page 2, line 10: ‚*... importance of the origin of the ice in a cloud (liquid or ice) has recently been* introduced and *demonstrated by Krämer et al. (2016).*‘

S10: Page 2, lines 14-16: ‚*However, information on the in-cloud updraught and the ice origin has a strong dependence on the microphysics and convection schemes used in a model and so may not be suitable for use as an observations-based constraint on cloud ice microphysics parametrisations in general circulation models (GCMs).*‘

To me this sentence is not very clear – can you reformulate what you mean ?

S11: Page 2: ‚***Existing classifications***‘ I highly recommend to cite here the recent overview article of Heymsfield et al. (2017) (see http://journals.ametsoc.org/doi/pdf/10.1175/AMSMONOGRAPHS-D-16-0010.1).

S12: Page 2, last paragraph: This paragraph reads clumsy ….

S13: Page 3, lines 23-24: ‚…, *irrespective of whether a cloud is observed such that a simpler comparison with models (which may produce sub-visible cirrus) can be made.*‘ ????

S14: Page 4, lines 1-3: What is the meaning of the ‚windspeed-height variation product‘ that defines O1 and O2?

S15: Page 9, lines 6-8: ‚*In all the regimes, almost all clouds colder than -60◦ C are formed directly as ice and many of those warmer than -40◦C are originally formed as liquid (Fig. 3, "Total" column). However, there is considerable variation between the regimes between these temperatures.*‘

This nice result should appear in the conclusions and maybe also in the abstract.

S16 : Page 14, lines 6-7: ‚*The in-situ regimes in this classification are primarily composed of in-situ/ice-origin cirrus clouds, ...*‘

I guess you mean liquid here.

S17 : Page 14, line 16: ‚*As seen in previous studies, the net cloud radiative forcing (CRE) is negative, ...*‘

Which previous studies ?