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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Retrieval of the vertical profile of the cloud effective radius from the Chinese FY-4 next-generation geostationary satellite" *by* Yilun Chen et al.

Anonymous Referee #2

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General remarks

This is a review of the manuscript "Retrieval of the vertical profile of the cloud effective radius from the Chinese FY-4 next-generation geostationary satellite" submitted by Yilun Chen et al. to Atmospheric Chemistry and Physics Discussions.

In this manuscript, the authors present methods to study the vertical evolution of the cloud effective radius of convective cloud ensembles using data from the Chinese FY-4 next-generation geostationary satellite. The authors present a method to identify contiguous clusters of convective clouds. In a second step, a bi-spectral algorithm is

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presented and used to retrieve cloud effective radius r_{eff} and optical thickness τ. The application of both methods is demonstrated for a heavy convective rain event where the temperature - r_{eff} relationship is discussed.

I enjoyed reading this manuscript since it is mostly well written and clearly structured. The presented appraoch is the consistent further development of the ideas of Rosenfeld et al. (2008) and as such an important contribution to advance the scientific understanding of precipitation forming processes. While this work definitely deserves to be published, the description of the used methods is, however, insufficient to reproduce their results. Moreover, the presented manuscript would better fit into the scope of "Atmospheric Measurement Methods", since this manuscript is mainly about a "Retrieval of the vertical profile of the cloud effective radius". However, this decision should be made by the editor as retrieval papers can also be found in ACP. Below, I compiled a list of comments which should be considered in a revised version of this manuscript.

Major comments

1. **Description of methods**

   A paper in AMT/ACP should enable the reader to understand and to replicate the presented results and should not limit itself to report on its scientific advancements. The two methods central to this manuscript, however, are not adequately described to guarantee the reproducibility of the presented results. While the description of a bi-spectral retrieval algorithm should be well established and straightforward, the method to find independent cloud clusters seems new and worth to be described in more detail. In the following, I will try to give more specific advices what is still missing in section "2.2. Methods" and how to organize it in subsections:

   - First, I strongly suggest to explain the forward simulations with libRadtran in

more detail. The authors should clearly state all cloud parameters and theirs boundaries which have been varied during the forward simulations. To understand the discrepancies between retrieved r_{eff} from FY-4 and MODIS, the reader needs to know the range and steps of optical thickness, effective radius, illumination and viewing angles. The current manuscript does not explain how the model clouds were set up, if an standard aerosol environment was considered and if a variable ground albedo was taken into account? The given citation for the used optical properties parameterization for ice clouds (Baum et al., 2014) also does not explain if the *baum v36* (Heymsfield et al., 2013; Yang et al., 1993; Baum et al., 2014) parameterization with the *general habit mixture*, the *rough-aggregates* or the *solid-columns* option has been used? Moreover, the authors state that they used the optical properties parameterization for liquid clouds of Hu et al. (1993), but should be aware that the developers of libRadtran state that:
Note that this parameterization has been developed to calculate irradiances, hence it is less suitable for radiances. This is due to the use of the Henyey-Greenstein phase function as an approximation of the real Mie phase function.

- Second, the authors do not describe how they handle the phase discrimination between water and ice clouds at all. The example discussed in section 4 clearly contains water as well as ice clouds. Inferring from the retrieved r_{eff}, the retrieval seems to handle water and ice clouds quite well. There is, however, no explanation if a threshold technique is used to separate ice from water clouds and how the mixed-phase region is handled. This is especially important since the discussion in section 4 is focused on the region of cloud glaciation.
- At last, section 2.2 “Methods” also introduces the technique to identify cloud clusters which is a central aspect of this study. While this technique should get its own subsection, it also deserves a more visual and complete de-

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scription: The authors miss to provide important details, like the size of the Gaussian filter and the used value of the distance threshold. Furthermore, the authors write that "**the** local temperature minimum" (P5, L135) is determined, but to the reader it is not clear if this is done pixel-wise or for the complete scene. Do you identify all local temperature minima in the scene or only for a search radius around each pixel?

Moreover, the authors write on P5, L139ff:

*"3) Combining the processed 10.8 micron brightness temperature and the local minimum using **the maximum temperature gradient method**, a sequential search is carried out to determine the convective core to which each pixel belongs, thereby dividing the cloud clusters."*

Here, it is not clear how *the maximum temperature gradient method* (which is never explained!) can be combined with a brightness temperature to determine the convective core for each pixel in a *sequential search* (which is also not explained). Here, a descriptive figure could significantly improve the comprehensibility of this paragraph. In my opinion, the revision of this section should be of major concern since it seems to be the main novelty of this work.

2. Discussion of results

As also pointed out by RC1, the discussion about the microphysical evolution of the cloud cluster on page 8 is not very convincing. In my opinion, the authors focus on details in Figure 8 and on processes (collision-coalescence, precipitation formation), which their spaceborne technique probably never can resolve in detail. As long as the handling or the influence of mixed-phase cloud regions is not explained, their discussion oversells their approach while it misses to highlight its strength: to observe the timescales between initiation, invigoration and the ma-

ture phase of a convective cluster. Examples of unclear or unproven sentences are:

Page 8, L239f: *"Re changed almost linearly with temperature between 285 and 230 K and did not exhibit the characteristics of the earlier zones"*

What do you mean here by "earlier zones"?

Page 8, L241f: *"Under the influence of such strong ascending motion, the boundary between the zones is broken and there is not enough time for the growth of precipitation."*

This statement is incomprehensible to me since I can not observe clear boundaries in Figure 8.

Page 8, L255f: *"In addition, because of the deposition of aerosols after precipitation, sufficient water vapor allowed Re to exceed* $20\,\mu m$ *at higher temperatures."*

Can you deduce this observation from your retrieval results alone? I doubt that you can observe the deposition of aerosols from a geostationary satellite. As the cluster during this phase is mainly governed by a thinning anvil, multilayer cloud effects have to be taken into account for the discussion of the observed r_{eff} profile.

Minor comments

- **Title:** I suggest a slight change to the title of the manuscript, since the original title "Retrieval of the vertical profile ... " gives the impression of a retrieval which can be applied to a single cloud like multi-wavelength retrievals (e.g. Chang et al. (2003)). In my opinion, the title "Retrieval of the vertical evolution of the cloud effective radius from the Chinese FY-4 next-generation geostationary satellite"

better captures the approach to retrieve the vertical profile of r_{eff} by observing the evolution of r_{eff} using a cloud ensemble approach.

- **References:** Please check all references for chronological order
- **P1, L31:** Freud and Rosenfeld (2003) showed that the rate of droplet coalescence is proportional to the mean volume radius r_v^5 and not the mean effective radius r_{eff}^5.
- **P2, L38f:** Reword you sentence "More aerosols result in more cloud condensation nuclei (CCN), leading to a higher height of the $14\,\mu m$ threshold for Re and a smaller coalescence efficiency" into "More aerosols result in more cloud condensation nuclei (CCN) and smaller r_{eff} with coalescence occurring at an higher altitude during ascent"
- **P2, L49f:** Besides the multi-wavelength approach you should also mention the cloud side perspective approach to directly retrieve the vertical profile of r_{eff} (e.g. Ewald et al. (2019)).
- **P3, L74f:** *"To the best of our knowledge, no instrument has yet provided an official Re vertical profile product."*

  This statement is not true. You should at least mention multi-instrument products like DARDAR, 2C-ICE or Cloudnet which provide effective radius profiles on an operational basis:

  Delanoe, J., and R. J. Hogan, 2010: Combined CloudSat-CALIPSO-MODIS retrievals of the properties of ice clouds. J. Geophys. Res., 115, D00H29.

  Deng M, Gerald G. Mace, Zhien Wang, and R. Paul Lawson, 2013: Evaluation of Several A-Train Ice Cloud Retrieval Products with In Situ Measurements Collected during the SPARTICUS Campaign. J. Appl. Meteor. Climatol., 52, 1014–1030.

Moreover, it is not clear what you mean with “official”. Maybe you mean “operational” in this context?

- **P4, L95** “We selected Chinese regional data”. Please be more precise what data and from which source (model, measurements?).
- **P4, L98** Please refer to different sub-panels (a, b, c) in Figure 2. Moreover I do not understand what you mean with “closely related to the retrieval”.
- **P4, L100** *“The spectral retrieval algorithm of cloud properties is based on the characteristics of the cloud itself and the bi-spectral reflectance algorithm is the most representative.”*

  This sentence is incomprehensible. What do you mean by that?
- **P5, L130** Please elaborate what you mean by “The original data are pre-processed”.
- **P5, L154ff** You only mention MODIS in your manuscript and never mention the satellite and the actual retrieval product you used in your comparison. You obviously used data from MODIS on Terra. Moreover, there are multiple scientific datasets (SDS) for cloud effective radius retrieved with different techniques and filters. Did you use the SDS *Cloud_Effective_Radius_16* with the same channel combination?
- **P6, L174** Weather radars (here with a coarser resolution than the satellite!) should not be used to explain resolution effects between different satellites working in the visible wavelength region. Drizzle or a few rain drops in a pixel can give you a radar signal which seems to be clear in the visible wavelength region.
- **P9, L274** “The glaciation temperature increased significantly during the period of dissipation” Have you shown this observation in the results? And with which method?

Wording

- **P1, L2** "from the first of the Chinese" ... "from the first Chinese"
- **P1, L28** "determining the effects of radiation and the water cycle on the Earth's climate system" ... "determining their impact on the water cycle and their radiative effects on Earth's climate system"
- **P2, L55** "obtain" ... "correlate"
- **P3, L93** "the shortwave distribution of AGRI" ... "the shortwave spectral characteristics of AGRI bands"
- **P4, L97** Please rephrase "... and the three angles important for retrieval"
- **P9, L259** "We used bi-spectral reflectance observations from the FY-4 AGRI to calculate a lookup table to retrieve Re and τ." This sentence does not make sense.

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