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Interactive comment

Interactive comment on "Use of spectral cloud emissivity to infer ice cloud boundaries: Methodology and assessment using CALIPSO cloud products" *by* Hye-Sil Kim et al.

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General comments: This paper described a method to estimate the height of ice clouds from satellite measurements of three infrared channels. The paper is well written and includes useful information for researchers in the field of satellite remote sensing. However, it was difficult to understand how the vertical inhomogeneity of ice clouds was considered in this method. The reviewer concluded that additional explanation is necessary in the manuscript before AMT publication. Specific comments are addressed below.

We greatly appreciate your detailed comments, which we used to revise and improve our paper as shown below.

(1) Page 5 line 138-140 and Fig.1: What does e_cËĘi (i=1âN ÌĄ ÌĄrn) in Fig.1b mean? Why e_c and T_c represent inhomogeneous layer? In the reviewer's understanding, e_c (and T_c) describes a range of possible cloud emissivity (and temperature) that can simulate the measured channel radiances assuming a homogeneous cloud layer.

Response: Modified as suggested. [Lines 188 –190] "The ec and ∆ec in Fig. 2(b) describes a range of possible spectral cloud emissivity values that can simulate the measured channel radiances. Thus, this study aims to produce Tc given the ec and ∆ec, and to examine how closely the retrieved Tc are to the actual vertical cloud structure."

[the caption of Figure 2, 20 pp] Figure 2: The conceptual model for (a) a plane parallel homogeneous cloud layer with no scattering, characterized by cloud emissivity (ec) and cloud emissivity differences between two infrared channels (∆ec) at the cloud temperature (Tc) and (b) a number of plane parallel homogeneous cloud layers (the stripes box) with a possible range of ec and ∆ec such as ec = [e_cˆ1,e_cˆ2, âŃŕ,e_cˆn] and ∆ec = [ãĂŰ∆eãĂŮ_cˆ1,ãĂŰ∆eãĂŮ_cˆ2, âŃŕ,∆e_cˆn] corresponding to a possible range of cloud temperature, Tc = [T_cˆ1,T_cˆ2, âŃŕ,T_cˆn], where Iclr and B are the clear-sky radiance and the Planck's function, respectively. Arrows represent upwelling radiances.

(2) Page7 line 197-200: I suppose that the LUT for the empirical relationship between cloud emissivity and BT/BTD is a key of the proposed method. Does the author assume the dataset MYD021KM and MYD06 provide the relationship for vertically inhomogeneous cloud layer? I think that the author should express the basic idea of your approach for inhomogeneous cloud layer in the manuscript.

Response: The LUTs for the relationship between cloud emissivity and BT/BTD were constructed using MYD021KM and MYD06 products. Even MYD06 products are retrieved under the assumption of the single-layer cloud, they are useful to express uncertainties in cloud emissivity due to diverse cloud microphysical properties that are likely to exist in the vertical cloud structure. Thus, we explicitly stated that vertical inhomogeneity was not considered in the generated LUTs and also explained how those LUTs can work to infer uncertainties in cloud emissivity in the vertical cloud structure in the revised manuscript as below.

[Lines 261–267] “Note that the cloud emissivity data from C6 MYD06 are retrieved under the assumption of the single-layered cloud. Here the possible ranges of ec and Δec are determined as the min/max(ec) and (Δec) among cloud emissivity values allocated by the bins of three parameters. To exclude extreme values, the min/max(ec) and (Δec) are defined as the 2nd /98th percentiles of the ec and Δec distributions when there are at least 5,000 pixels available for a given bin. When there are between 500 and 5000 pixels, the 5th /95th percentiles are chosen as the min/max(ec) and (Δec). In the rare case when there are between only 200 and 500 pixels, the 10th /90th percentiles are used. Any case with fewer than 200 ice cloud pixels is not included in the LUTs.”

(3) Page 8 line 233-237 and Fig.5: The reviewer cloud not understand what does the author intend to show in Fig.5a and 5b. What does the region of large differences of I_(clr|11)-I_(clr|12) in Fig.5b suggest?

Response: Our intent for Figs. 5a and 5b (Fig. 1a and Fig. 1b in the revised manuscript) is (hopefully) more clear in the text and replicated as follows.

[lines 126–137] “The MODIS pixels identified as being clear-sky are used to generate a gridded clear-sky map, which is another ancillary product required for our method. To simplify the generation of this map, the MODIS data with 1km resolution are converted to 5 km resolution. Monthly composites of clear-sky radiances (Iclr) at $0.1^\circ \times 0.1^\circ$ resolution are generated by choosing the maximum value among radiances for three months of August (2013–2015) in each $0.1^\circ \times 0.1^\circ$ grid box. To confirm the availability of the generated Iclr, we present the spatial distribution of Iclr at 11

μm (Iclr|11, Fig. 1(a)), from 8 to 11 W m-2 μm-1 sr-1. The largest Iclr|11 values are shown over the northwestern region of the domain, whereas the smallest Iclr|11 values are shown over the southeastern region of the domain. The pattern of Iclr|11 is similar to the spatial distribution of the monthly average of sea surface temperature in 2015 (https://bobtisdale.wordpress.com/2015/09/08/august-2015-sea-surface-temperature-sst-anomaly-update/). Also, we show the spatial distribution of spatial distribution of differences of Iclr|11 from Iclr|12 in Fig. 1(a), examining the reliability of the generated Iclr|12. Note that the differences of Iclr|11 and Iclr|12 are positive over the domain, because water vapor absorption is stronger at 12 μm than at 11 μm. Large differences are shown in the western region, near the Philippines (green-colored contours in Fig. 1)."

(4) Page 22 Fig.6b and Page 8 Fig.8b: What is the enhancement of EEL at latitude 15.6âŮę of Fig. 6b? Similar enhancement is also appeared at latitude 25.7âŮę in Fig. 8b. Response: Added the explanation about the enhancement of EEL shown in Fig. 6b and Fig. 8b, as detailed below.

[Line 311–312] The enhancement of EEL at approximately 15.6°N in Fig. 6(b) is caused by an extraordinary value of Qe provided in the CALIOP V4. [Line 340–341] The enhancement of EEL at around 25.7°N in Fig. 8(b) is also caused by an extraordinary value of Qe provided in the CALIOP V4 product.

Please also note the supplement to this comment:
https://www.atmos-meas-tech-discuss.net/amt-2019-148/amt-2019-148-AC3-supplement.pdf

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