Response to Reviewer #1

General comment:

Review of the manuscript titled "Optimizing cloud optical parameterizations in RTTOV for data assimilation of satellite visible reflectance data: an assessment using observed and synthetic images" by Yongbo Zhou, Tianrui Cao, and Lijian Zhu.

This paper evaluates parameterizations of visible reflectance simulated from CMA-MESO and ERA5 using RTTOV with observations from instruments onboard the satellites FY-4B and Himawari-9.

Results show that the observed reflectance is higher than modelled reflectance, on average, and that the choice of an optimal configuration yields the lowest bias while only slightly increasing unbiased error (standard deviation of O-B). In clear-sky pixels, the atmospheric contribution to visible reflectance is near zero. Thus, the choice of parameterization had no effect. The bias is induced by the land surface representation in the NWP model. In cloudy sky, bias is more relevant than in clear sky cases, because the bias is responsible for a larger fraction of error, as shown in Figures 10, 11, and 12. In clear sky, bias was mostly lower than unbiased error, except of experiment CM-FY-DM in April (Figure 3).

The authors already nicely addressed my comments to an earlier version of the manuscript in review for another journal. For example, the authors extended the analysis by the standard deviation of O-B. The manuscript is now an extensive evaluation and in a very good condition. I recommend publication after minor comments are addressed.

Our response:

We would like to extend our sincere gratitude for your time and effort in reviewing our manuscript again. We carefully considered all your comments and suggestions and made revisions to the manuscript accordingly. We believe your review of this manuscript has greatly enhanced the clarity and rigor of our manuscript. A point-by-point response addressing each of your concerns is attached below.

Minor comment 1:

The increased B for C213 would amplify the O-B differences, leading to the increased standard deviations". The standard deviation (SD) is not influenced by the bias (average O-B). Thus, a change in average B does not change the SD. The explanation for an increased SD must be larger O-B differences, due to B being too high and too low (increase in |O-B|).

Our response:

Thank you for pointing this out. This part was re-written in the revised manuscript. (Line: 290-297)

The optical characteristics of the “Baran 2014 + B02” ice cloud parameterization may partially explain the observed phenomenon where the C213 parameterization successfully corrects the systematic underestimation of B while introducing greater standard deviation (or local variability) (Figure 3(a)-(d) in the revised manuscript). Within the same cloud water path (CWP) range, C213 produces the largest variation amplitude in B when transitioning from cloud-free to cloudy scenarios (Figure 5(b) in the revised manuscript). The impact of cloud optical parameterizations should be mainly determined by the upper ice clouds. The lower-layer liquid water clouds should be less pronounced in synthetizing visible images due to the radiative effects of the upper-layer ice clouds. Therefore, when transitioning from cloud-free to cloudy conditions, the “Baran 2014 + B02” scheme exhibits the most significant reflectance variation range (the yellow line Figure 5(b)). This enhanced variability in B could potentially broaden the distribution of O-B discrepancies, thereby increasing the standard deviation of O-B.

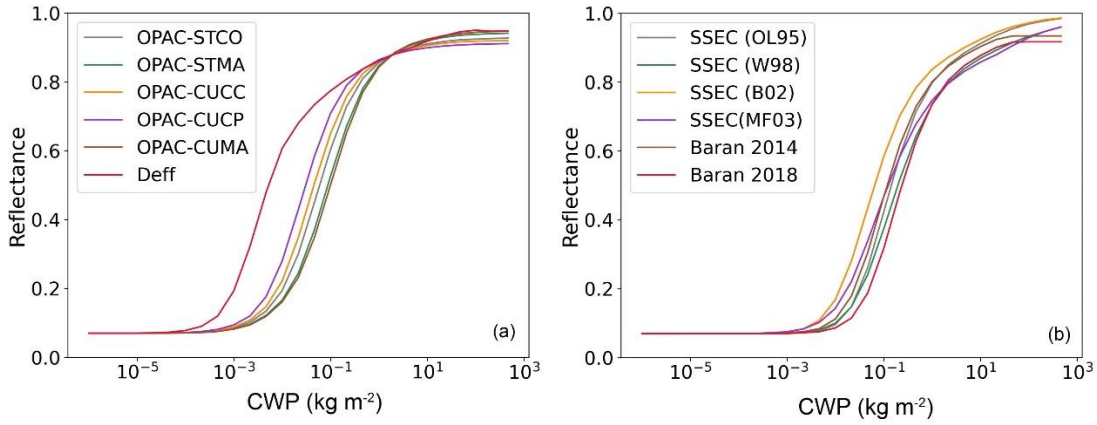

Figure 5. Dependence of FY-4B/AGRI band 2 reflectance on cloud water path (CWP) for different (a) liquid water cloud optical parameterizations and (b) ice cloud optical parameterizations. For this simulation, the solar zenith angle, viewing zenith angle, and relative azimuth angle are set to 25 °, 40 °, and 135 °, respectively.

Minor comment 2:

Figure 4: The caption seems to have an error, as the x-axis label is "reflectance" not "O-B departure".

Our response:

Thank you for pointing this out. We made a mistake here. It should be the “reflectance” rather than the “O-B” departure. (Line: 270)

Minor comment 3:

Equation 6 seems to be incorrect, not all terms are in the exponent, compared to Equation 2 of McFarquar et al. (2003).

Our response:

This is an interesting question. Actually this problem made me confused at the beginning of this work. The Equation in McFarquhar et al. (2003) is given by following equation,

$$r_e = 10^a + blog(z) + clog(z)^2$$

where $z = \mathrm{IWC}/IWC_0$(IWC_0=1.0 g m^{-3}). a, b, and c are 1.78449, 0.281301, and 0.0177166 respectively. McFarquhar et al. (2003) also provided a figure to show the best fit (the solid line) of Deff as a function of IWC.

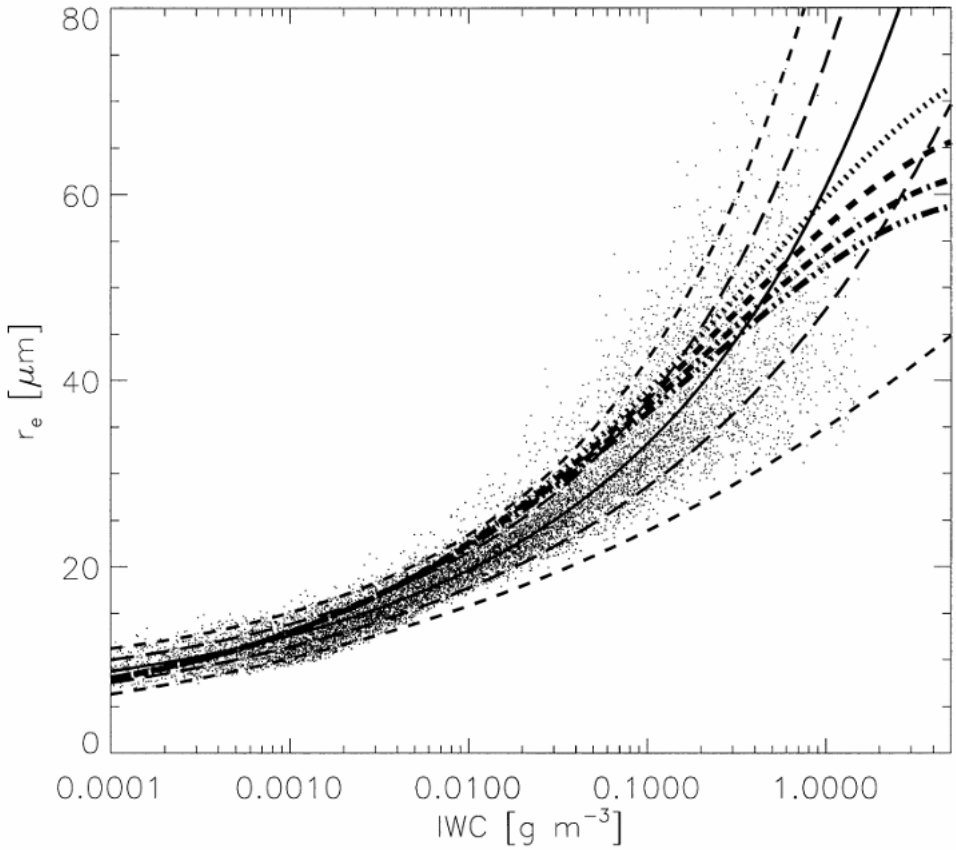

FIG. 2. Here r_e, defined from CEPEX in situ data as described in text, is presented as a function of IWC, also derived from in situ data. Each dot represents 10 s (or 2 km) averaged-size distribution. Solid line represents best fit to data, thin long dashes and thin short dashes represent plus and minus one and two std devs from mean relation (see text for details). Thick lines represent relationships determined by McFarquhar (2001): vertical bars, −65°; dashes, −55°; dashes and vertical bars, −45°; dashes and 3 vertical bars, −35°C.

However, in the RTTOV codes (${RTTOV}/src/main/rttov_profaux.F90), Deff was calculated by the following methods,

```
            ELSE IF (prof(iprof)%idg == 3) THEN
              ! Scheme by Boudala et al., 2002, Int. J. Climatol., 22, 1267-1284.
              ztempc             = prof(iprof)%t(lev) - rtt
              aux%ice_dg(lay, iprof) = 53.005_jprb * ((prof_int(iprof)%cloud(6, lay)) ** 0.06_jprb) * EXP(0.013_
jprb * ztempc)
            ELSE IF (prof(iprof)%idg == 4) THEN
              ! Scheme by McFarquhar et al. (2003)
              amcfarq                = 1.78449_jprb
              bmcfarq                = 0.281301_jprb
              cmcfarq                = 0.0177166_jprb
              zmcfarq                = prof_int(iprof)%cloud(6, lay)
              aux%fac1_ice_dg(lay, iprof) =      &
                & 10.0_jprb ** (amcfarq + (bmcfarq * LOG10(zmcfarq)) + (cmcfarq * LOG10(zmcfarq) * LOG10(zmcfarq
)))
```

If we translate the codes in to a formula form, it is the Equation (6) in our manuscript. Therefore, there much be some errors in either Equation (6) or the Equation (2) in McFarquhar

et al. (2003). This problem can be easily solved by comparing the Deff-IWC function with the Fig. 2 in McFarquhar et al. (2003). We did such a simulation and the result is shown by Fig. R1. Therefore, we believe there should be a typo error of the Equation (2) in McFarquhar et al. (2003).

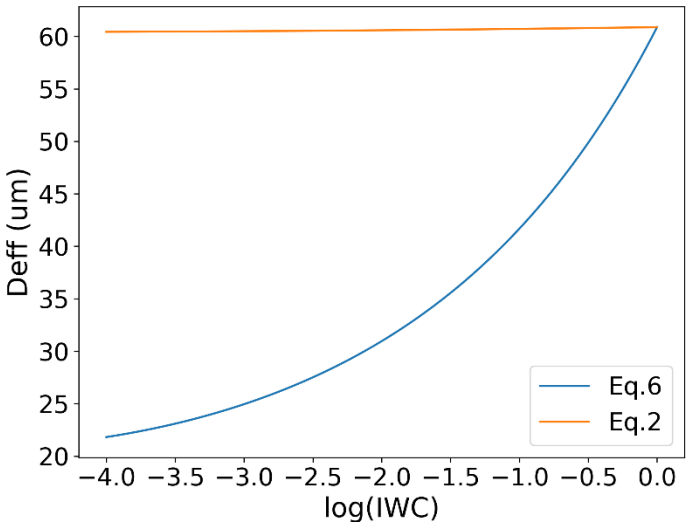

Figure R1. The Deff-IWC function derived from the Equation (6) in our manuscript and the Equation (2) in McFarquhar et al. (2003)

Minor comment 4:

L237, L275: Language: Instead of "was expected", you probably mean "was found"? Or was there an expectation before seeing the results?

Our response:

This is a misunderstanding due to our poor English skill. The word “expected” was replaced by “revealed” or “found”. (Line: 256; 288)

Minor comment 5:

L243: You state "opposite circumstance" but the same sign (O-B>0) as in the line above. Probably you mean O-B < 0?

Our response:

Thank you for pointing this out. You are correct. Since we re-wrote this part. The sentences you mentioned were deleted in the revised manuscript. (Line: 290-297)

Minor comment 6:

L248: "at the low- or high-reflectance ends": Maybe you can quantify this, e.g. "at low reflectance (<0.1)" or similar.

Our response:

Corrected. (Line: 264)

Minor comment 7:

L271: "The results in Figure 4 suggested that the Baran 2018 ice scheme should be used with caution ...". I am confused, because Figure 4 shows results for ice_scheme=1 (SSEC) and not for "Baran" parametrization. Maybe you meant Figure 5?

Our response:

Yes you are correct. The information is given by Figures 3 and 5. The error was corrected in the revised manuscript. (Line: 284)

Minor comment 8:

Figure 7 caption (c) missing.

Our response:

Corrected. (Line: 315-317)

Minor comment 9:

L367: Language, "B was consistently underestimated compared with O", I think this should be "B consistently underestimated O".

Our response:

Corrected. (Line: 390)

Minor comment 10:

L393: "The smallest O-B bias". Good, but can you quantify it? For example "the optimal configuration reduced the bias by 0.04 on average, while standard deviation increased by less than 0.005.

Our response:

Corrected. (Line: 479-480)