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Atmospheric Measurement Techniques Discussions

Interactive comment on "Using Two-Stream Theory to Capture Fluctuations of Satellite-Perceived TOA SW Radiances Reflected from Clouds over Ocean" *by* Florian Tornow et al.

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We thank the Referee very much for taking the time to review our manuscript. Please find point-by-point responses to the Referee's feedback below.

Abstract, line 4: 'Like previous approaches' - sounds confusing was trained -> was statistically trained

We will adopt the proposed changes in the final version.

Define 'cloud phase' line 78

We plan to amend "cloud particle phase (involving MODIS band 3.7um)" to "cloud

condensate phase (i.e. liquid, ice, or a mixture of both; involving MODIS band 3.7um)".

More general remarks: authors consider very simple radiative transfer models (two-stream, Eddington etc). Why not to use more accurate models, e.g. MOMO developed by the co-authors?

We would like to emphasize that two-stream theory was not used to simulate radiances. Of course, for radiative transfer simulations we would rely on more accurate methods, as the Reviewer suggested.

In this study, we used the functional form of two-stream equations to linearly relate MODIS-retrieved cloud properties with CERES-measured top-of-atmosphere shortwave radiances.

As seen in Fig. 1a, MODIS cloud optical thickness (or more precisely the parameter x, defined in Sec. 3.1) plotted against CERES radiance shows a sigmoidal shape. Because two-stream functions (Eq. 10-12) reproduce this sigmoidal shape, we could link MODIS properties in a linear manner to CERES radiances. Statistical optimization (Sec. 3.2.2) further improved our efforts to explain CERES-measured radiances. The use of higher-order schemes (e.g. four-stream functions) was not tested as two-stream theory produced a satisfactory outcome.

To better emphasize the role of two-stream theory in our manuscript, we plan to make following changes:

- l. 8: instead of "serving as a function of..." put "serving to statistically incorporate..."
- l. 11: instead of "two-stream albedo" put "two-stream functional form"
- l. 58: instead of "to explain cloud albedo based on" put "to statistically ingest"
- l. 154: instead of "two-stream cloud albedo that uses cloud optical thickness and

cloud micro-physical properties" put "two-stream equations as a function to ingest MODIS-retrieved cloud optical thickness and cloud-top effective radius"

Several cloud types are considered in the paper. Different cloud types have different expansion coefficients of the phase function. The differences are significant for high order expansion terms. Simplistic radiative transfer models hardly can capture them. I doubt that just asymmetry parameter is sufficient to describe different types of cloud models. In this regard, the choice of the two-stream model needs to be justified. Perhaps, authors could elaborate.

We agree with the Reviewer that the asymmetry parameter (e.g. derived from Mie-theory, and a function of effective radius) is too simple to accurately capture radiance fluctuations for all cloud types and for all viewing-illumination geometries. Because of this limitation, we decided to also statistically optimize the asymmetry parameter (and its change with effective radius). We performed this optimization (Sec. 3.2.2) for each angular bin (i.e. each discrete bin of viewing-illumination geometry) and for each cloud phase (i.e. liquid and ice). For an exemplary angular bin, Fig. 2b presents Mie-calculated asymmetry parameters versus statistically optimized ones.

We hope to have circumvented the limitations of a steady asymmetry parameter by using optimized asymmetry parameters. This allows us to have viewing-illumination-geometry-dependent radiance changes for different effective radii (e.g. effects like the cloud bow and cloud glory). Fig. 5e shows that our approach plausibly produced such radiance changes with effective radius.

To better highlight the use of statistically optimized asymmetry parameters, we plan to make following changes:

- l. 9: after "…footprint." add "Effective radius-dependent asymmetry parameters were obtained empirically and separately for each viewing-illumination geometry."

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