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Atmospheric Measurement Techniques
Discussions

Interactive comment on “Simulating the effects of mid- to upper-tropospheric clouds on microwave emissions in EC-Earth using COSP” *by* M. S. Johnston et al.

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My comments on this paper will focus on why in the tropics the simulations of cloudy brightness temperatures produce warm biases of up to ∼30 K in the ITCZ. The paper briefly speculates that this warm bias could be due to “incorrect ice particle scattering assumptions used in the COSP microwave forward model.” They also state on page 11758 lines 7-9 “The precise amount of scattering will depend not only on total ice water path but also on the ice particle shape and size distributions.” In my view, the paper does not explore this sentence in sufficient detail. The assumed PSD and shape are important contributions. The reason why the scattering could be wrong is

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not only due to PSD assumptions, and shape, but also the assumed density-size relationship predicted by the adopted model, which being related to shape, is probably the more important consideration at microwave frequencies. If the density-size relationship is in error, then of course the single-scattering properties will also be in error, and these errors can be very significant (see 3rd paragraph below). The importance of the density-size relationship is not discussed and whether or not their choice of relationship is consistent with the most recent observations of cirrus microphysics.

The paper by Geer and Baordo, 2014 is cited, and in that paper, they favour the Liu (2008) sector snowflake model, the single-scattering properties of which were calculated using the DDA code made available by Draine and Flatau (2000). As an aside, in the paper under discussion the DDA code made available by Yurkin et al., (2007) is cited rather than Draine and Flatau (2000). Are the authors absolutely sure that the DDA code of Yurkin was used rather than the former code? This is important as the two codes could produce very different results even for the same crystal model. If the authors have used the Yurkin code, then they should compare the single-scattering solutions obtained from that code to those presented by Liu (2008). Liu (2008) tested his circular cylinder DDA solutions against T-matrix solutions. However, it is unknown as to whether the single-scattering solutions obtained for the snowflake are correct, as it cannot be assumed that the convergence criteria found for circular cylinders will be the same as that for snowflakes using the DDA method. To test the numerical accuracy of the employed electromagnetic method then, in general, the reciprocity theorem should be applied (Schmidt K,Yurkin M A, Kahnert M . A case study on the reciprocity in light scattering computations. Opt Express 2012;20(21):23253–74) as well as comparisons against other electromagnetic methods. To this end, another publicly available electromagnetic code is the boundary element method (BEM), called BEM++, which could, in principle, be applied to snowflakes such as the model of Liu (2008), and the paper describing BEM++ and its application to atmospheric ice can be found at the following link http://www.sciencedirect.com/science/article/pii/S0022407315002769.

Now back to the density-size relationship. The sector snowflake model of Liu (2008) predicts a density-size relationship of the form ∼Dm-1.566 , where Dm is the maximum dimension of the ice crystal. However, this form of the density-size relationship is not supported by aggregation models and observations, which show that the ice mass of aggregating particles follows ∼Dmˆ2 and so, the density should follow ∼Dmˆ-1.0 (see the following papers, Westbrook CD, Ball RC, Field PR, Heymsfield AJ. 2004. Universality in snowflake aggregation. Geophys. Res. Lett. 31: L15104, DOI:10.1029/2004GL020363, Brown PRA, Francis PN. 1995. Improved measurement of the ice water content in cirrus using a total-water probe. J. Atmos. Oceanic Technol. 12: 410 – 414, Heymsfield AJ, Schmitt C, Bansemer A. 2010. Improved representation of ice-particle masses based on observations in natural clouds. J. Atmos. Sci. 67 : 3303 – 3318, Cotton, R. J., Field, P. R., Ulanowski, Z., Kaye, P. H., Hirst, E., Greenaway, R. S., Crawford, I., Crosier, J. and Dorsey, J. (2013), The effective density of small ice particles obtained from in situ aircraft observations of mid-latitude cirrus. Q.J.R. Meteorol. Soc., 139: 1923–1934. doi: 10.1002/qj.2058).

In the tropics, ice crystals aggregating to maximum dimensions of order 1000s of microns would be expected, and at these sizes the Liu (2008) snowflake model under predicts the density (relative to Cotton et al. 2013 and others) by several factors and consequently, the bulk extinction coefficient of these ice aggregates will also be under estimated. Due to the particles becoming very thin or in the case of hexagons, for example, becoming elongated or tending to large aspect ratios (to conserve observed mass-D relationships), hence their volume extinction coefficients will become small relative to equal Dm hexagons of aspect ratio unity. These elongated or thin ice particles become essentially weakly interacting large particles or “WILPS” for short! As a consequence, WILPS will transmit more upwelling microwave radiation and hence warmer upwelling brightness temperatures will result. Therefore, a further reason for the warm brightness temperature bias in the ITCZ could be due to their model particles becoming WILPS at sizes typically encountered in the tropics. Ice crystal models that follow observed mass-D and density-size relationships are required, if the simulations discussed by the authors are to be further improved in the tropics. This also requires PSDs which are representative of the tropics and are sufficiently broad to include the occurrence of very large ice crystals.

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