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Interactive comment on "Marine cloud brightening – as effective without clouds" *by* Lars Ahlm et al.

Anonymous Referee #1

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Review of Marine cloud brightening – as effective without clouds, by Ahlm, Jones, Stjern, Muri, Kravitz, Egill Kristjansson

This manuscript describes a multi-model study to evaluate the efficacy of marine cloud brightening geoengineering using enhanced emissions of sea-salt particles (nominally in the accumulation mode, although the GISS model's accumulation mode has a major contribution from supermicron diameter particles). Emissions are enhanced only in the tropical belt from 30S to 30N. The simulations were conducted as part of the GeoMIP project. As with other GeoMIP comparisons, the radiative forcing from the enhanced aerosol emissions is specified, and then each model tunes its emission rate to produce a -2 W/m2 global mean effective radiative forcing (ERF). The aerosols produce both direct and indirect radiative effects, and the direct effects are found to be as large, or larger, than the indirect effects.

In my view, the direct effects produce a large fraction of the ERF for the following reasons:

1. The assumed diameter of the emitted particles is larger than that recommended in specific studies. Connolly et al. (2014), which appeared in a Phil Trans special issue on geoengineering, used detailed parcel modeling to show that median dry particle diameters from 35-100 nm are optimal for brightening marine low clouds. The diameters used in this study are 200 nm (HadGEM), 260 nm (NorESM), and 880 nm (GISS), which require at least an order of magnitude more mass to be sprayed to produce the same brightening effect (see Fig. 1b in Connolly et al. 2014). This would require enormous amounts of energy (the energy required for the production of aerosol particles scales approximately with the overall mass of salt sprayer) compared to the case with smaller particles. Small particles are most effective for brightening clouds, whereas somewhat larger particles (0.2-1 micron) are optimal for the direct effect. Given this information, one could probably have predicted that the direct forcing would be dominant before the model experiments were conducted.

2. Seeding takes place over the entire tropical ocean. Low cloud cover is limited over much of the warm tropics, so this favors direct forcing to achieve -2 W/m2 ERF. Furthermore, there is cirrus above much of the low cloud in the warm Tropics. This is not how marine cloud brightening would work in practice.

3. Cloud LWP decreases over much of the region, thus countering some of the Twomey effect.

The results presented here are quite interesting, especially the LWP responses in 3 above. However, given the choice of particle sizes used, together with a seeding strategy that would not be used in practice, leads me to question the utility of this paper. The cloud LWP reductions are interesting, but it is not clear that this pattern of response would be the same if a more appropriate seeding strategy had been used. Thus the paper is not a good strawman for how marine cloud brightening would be deployed in practice.

No provision for separating direct from indirect effects was built into the experimental design, which is troubling, and should be addressed. APRP is one way to achieve this without re-running simulations.

Although the authors may argue that further experiments cannot be performed, I am going to recommend that the authors try their study again using particle sizes that have been shown in the literature to be appropriate for brightening clouds. I cannot recommend publication in its current form. There are a number of minor comments that I could make, but the major issues need to be addressed first.

References:

Connolly, P. J., G. B. McFiggans, R. Wood, and A. Tsiamis. “Factors Determining the Most Efficient Spray Distribution for Marine Cloud Brightening.” Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences 372, no. 2031 (November 17, 2014): 20140056–20140056. doi:10.1098/rsta.2014.0056.

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