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Atmospheric Chemistry and Physics Discussions

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

Anonymous Referee #2

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The authors compare simulations from three coupled atmosphere-ocean ESM models (NorESM1-M; GISS-E2-R; HadGEM2-ES) as part of the Geoengineering Model Intercomparison Project to study how radiative forcing partitions between total and clear-sky effects when sea salt is injected into the atmosphere at rates sufficient to maintain a top-of-the-atmosphere (TOA) radiative forcing of -2 W/m2 relative to the RCP4.5 scenario. The simulations are carried out for the years 2020-2090, and the forced injections are maintained for the first 50 years. Important differences among the models are that the GISS model injects particles with a mean radius of 0.44 um compared with smaller particles injected by the Nor and Had models (0.13 and 0.10, respectively), and GISS simulates reduced amounts of low clouds over the injection region (30oN to 30oS). Based on the clear to total sky results, the bottom line is that these simulations suggest clear-sky forcing is comparable to the total forcing. In particular, the GISS model indicates a slightly larger clear-sky effect, the Had model showing a

slightly lower clear-sky effect and the Nor model a roughly equal effect. The authors conclude that "These findings suggest a more important role of the aerosol direct effect in sea spray climate engineering than previously thought."

The paper is well organized and well written. The result is important, but a little more insight is needed. The current results suggest another question: to what degree is optimization of particle injections necessary? Despite the factor of four difference in the mean size representation of the particle size distribution of the GISS model compared with the other two models, differences in the clear-sky forcing among the models appear to be relatively small (e.g. Fig. 2b). Considering the injection sizes, should greater differences be expected if the forcing is direct? Neither question can be considered because relatively simple explanations of fundamental particle representations used in each model are missing: 1) sub-saturated hygroscopic growth; 2) cloud activation; 3) deposition processes; 4) vertical distributions of the injected particles; 5) number size distributions of the simulated injections. The complexities and subtleties of the many aerosol processes, including effects on cloud, may offset to some degree. For example, as you know, if you try to optimize for the indirect effect by injecting particles smaller than 100 nm you expect to reduce the direct component. However, it may be difficult to either avoid spraying some larger particles or the presence of natural sea salt particles, either of which will tend to reduce the indirect effect by competition for water vapour. There is some discussion at the top of page 8, but it focusses on activation only. Some additional discussion of these processes with a focus on why the clear-sky forcing is not so different despite the substantial difference in particle representations between GISS and the other models, as well as a figure comparing injected number size distributions, would offer some insight.

Minor comments:

1) Page 2, line 31 – Should this be "an uncertainty" rather than "the uncertainty"?

2) Page 4, line 32 – Perhaps use "low-cloud amounts".

3) Page 5, lines 24-25 - How frequent are clear-sky conditions in each model?

4) Page 7, lines 11-12 and Figure 4 - Is it truly increasing or just altering the mechanism, since the ERF-TOF is held constant?

5) Page 7, line 31 - It would be more instructive to include changes in number concentrations of sea-salt particles.

6) Page 8, lines 11-14 - What are the ranges of background CDNC in each model? Why does CDNC over northern Greenland reduce so much in NorESM, and over the high Arctic in HadGEM2?

7) Page 9, lines 8-10 - Of course the relative impact of LWP is well known. What would be helpful is to know how Figures 9c and 9d compare with observations, if there are sufficient data to do that.

8) A note - Sea salt particles of 0.88 um diameter (GISS) or larger will be very hard to activate (by definition) in clouds. To reach their activation point they need to take up a very large amount of water, and that may not happen.

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