Supporting Information for "The Radiative and Cloud Responses to Sea Salt Aerosol Engineering in GFDL Models"

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Introduction

Text S1: Full chain of processes

The full chain of processes of marine cloud brightening is shown in Figures S1 and S2. An increase in the emission rates of sea salt aerosol leads to an increase in its loading in the first (lowest) model layer and consequently, the sea salt aerosol column burden increases. As a result, the net shortwave flux decreases which leads to cooler surface temperatures and lower precipitation.

While both the reference and geoengineering simulations warm overall due to increased greenhouse gases following the SSP2-4.5, G4sea-salt is consistently ∼0.5 K cooler while the SSA emissions are enhanced 2020–2070. The 2035-2065 average local differences between G4sea-salt and SSP2-4.5 are shown in Figure S2. Cooling is pronounced in the tropics, an expected direct response to the negative ERF locally. Outside the tropics, cooling in G4 relative to SSP is also pronounced in near the poles.

Text S2: The radiative breakdown

The radiative code is called to calculate several components of the net radiative imbalance atop the atmosphere, N:

- N_{all} is the total imbalance in the presence of clouds and aerosols;
- N_{clr} is the total imbalance in the presence of aerosols, but in the absence of clouds;
- N_{ad} is the total imbalance in the presence of clouds, but in the absence of aerosols;
- $N_{\text{clr,ad}}$ is the total imbalance in the absence of both clouds and aerosols.

We keep the subscripts as are customarily outputted in climate models. The above components are plotted in Figures S3 and S4, where "clr,ad," "ad," "all," and "clr" refer to "Neither clouds nor aerosols," "No aerosols," "All," and "No clouds", respectively. The radiative components appearing in the main text can then be calculated, following Ghan whose Technical Note is cited in the main text, as:

- $N_{\text{All}-\text{Clear}} = N_{\text{all}} - N_{\text{ad}}$;
- $N_{\text{Cloud}} = N_{\text{ad}} - N_{\text{clr,ad}}$;
- $N_{\text{Surface}} = N_{\text{clr,ad}}$;
- $N_{\text{Direct}} = N_{\text{all}} - N_{\text{ad}}$;

- $N_{\text{All}} = N_{\text{all}}$;
- $N_{\text{Clear}} = N_{\text{clr}}$.

The "Surface" term refers to the "surface albedo" effects, that result from changes in the surface albedo due to the deposition of absorbing aerosols, changes in snow cover, and by other forcing mechanisms. Please refer to the original cited work in the main text for more information.

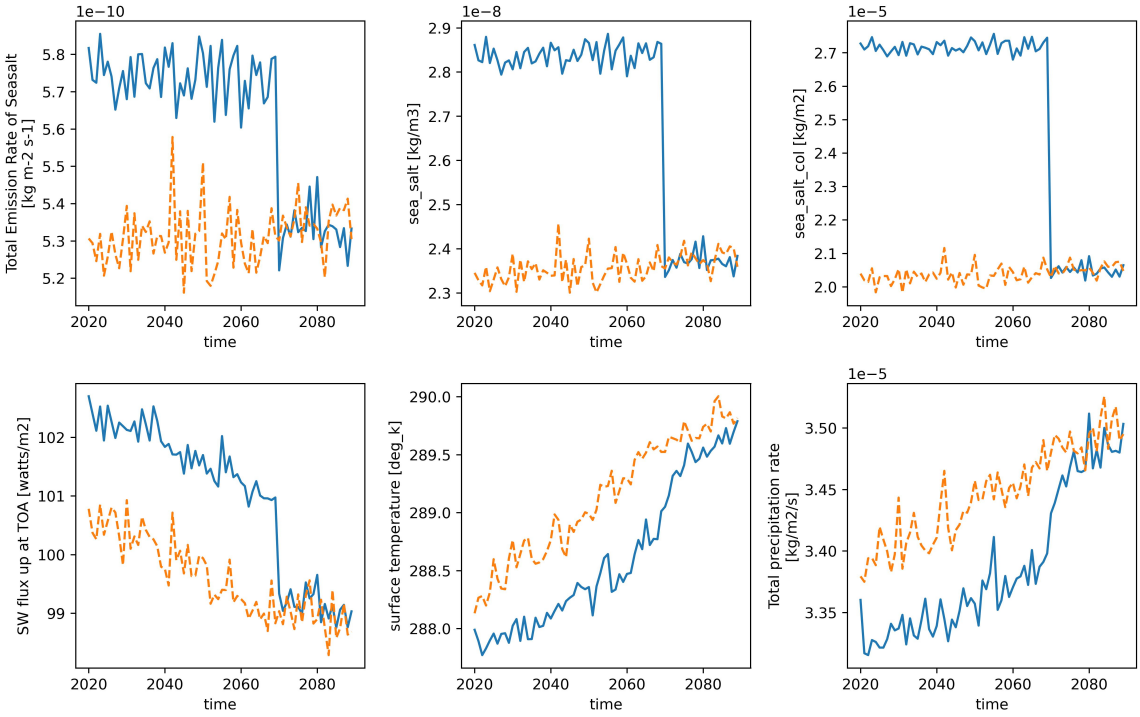

Figure S1. Annual global-mean values for the full chain of processes of marine cloud brightening in CM4, with blue solid lines representing G4sea-salt simulations and dashed orange lines representing reference SSP2-4.5 simulations. The variable "sea_salt_col" refers to the sea salt aerosol column burden, that is the concentration integrated over the atmospheric column of all layers.

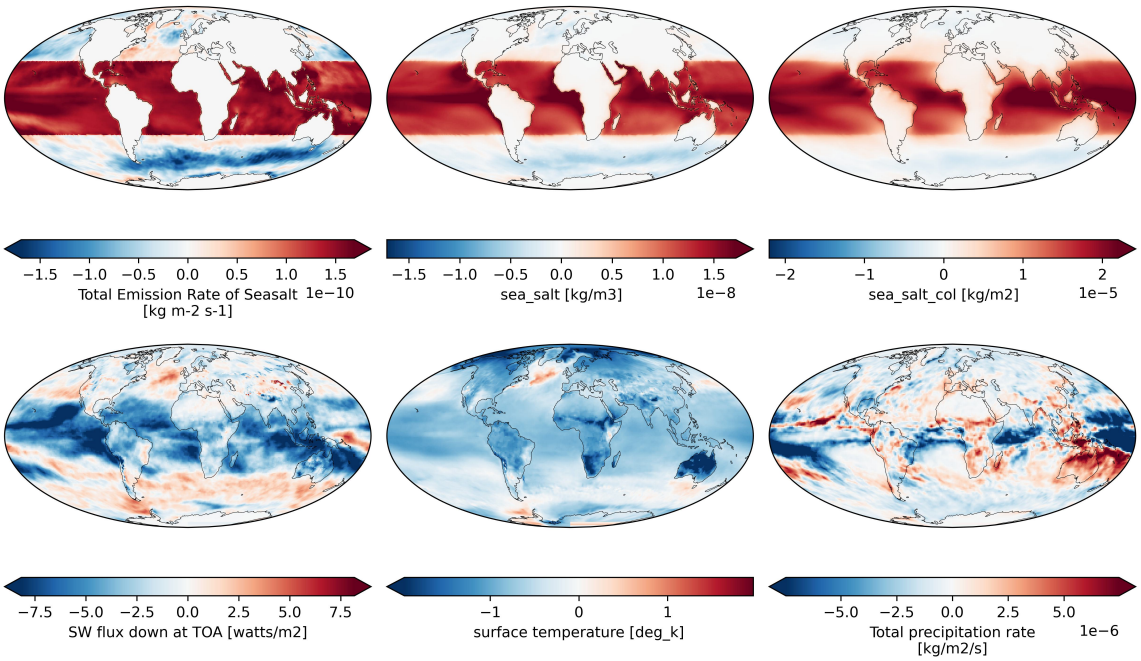

Figure S2. As in Figure S1, but spatial temporal means (2035–2065) for the values for the full chain of processes of marine cloud brightening in CM4.

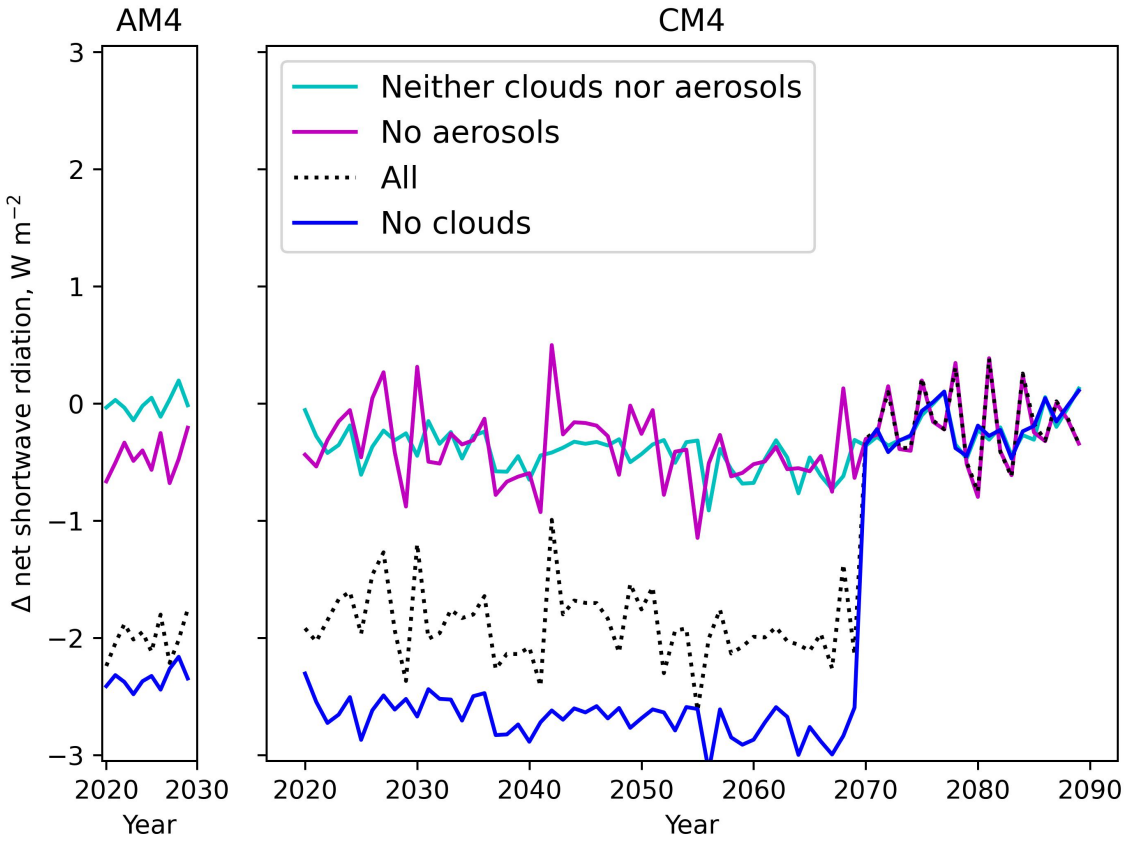

Figure S3. As in Figure 1 in the main text, but for the raw components of the radiation.

See text for description.

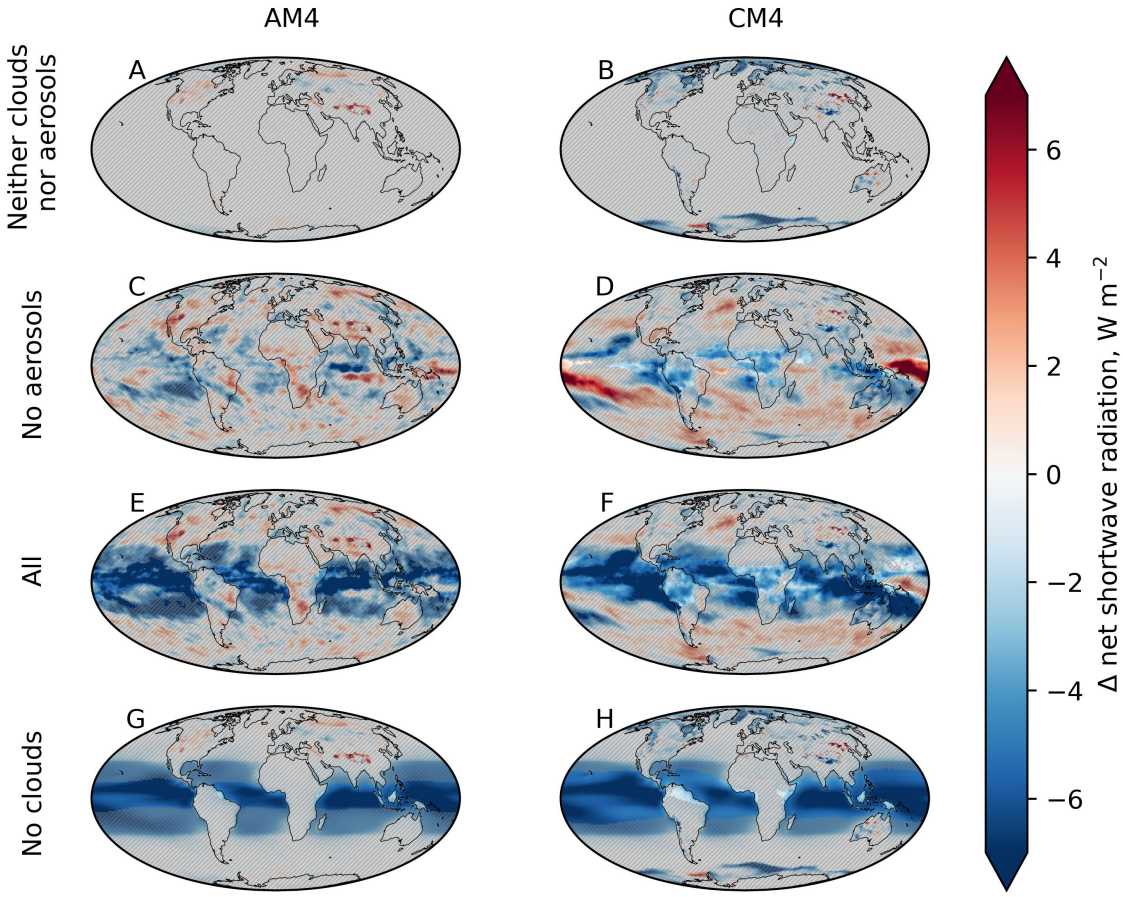

Figure S4. As in Figure 2 in the main text, but for the raw components of the radiation.

See text for description.