Supplementary Material for
Dynamic climate emulator for solar geoengineering

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The list of climate models that participated in the Geoengineering Modeling Intercomparison Project (GeoMIP) and are used here is given in Table S1. Impulse response functions for individual models are shown in Figure S1. Several additional emulator results are given in Figures S2 and S3, comparing the simulated and emulated temperature and precipitation differences between land and ocean. Figure S4 illustrates for one model the emulator capturing of the first few principal components of the spatial temperature response. Figure **??** illustrates the ability of the dynamic emulator to capture modeled changes in Net Primary Productivity (NPP); changes in global-mean NPP are relatively linear in these climate models, and relatively unaffected by a solar reduction.

Climate Model	Solar Reduction for G1 (%)
CanESM2	4.0
CESM-CAM5.1-FV	4.7
GISS-E2-R	4.5
HadCM3	4.1
HadGEM2-ES	3.9
IPSL-CM5A-LR	3.5
MIROC-ESM	5.0
MPI-ESM-LR	4.7
CSIRO-Mk3L-1.2	3.2

Table S1: Climate models used here, with the solar reduction $g_{4\times}$ used in each model to compensate for $4\times CO_2$

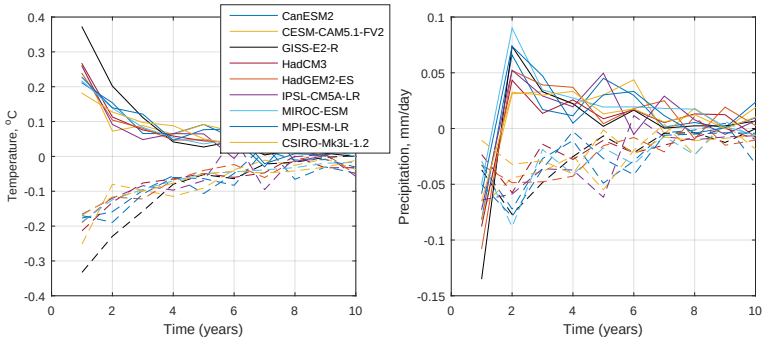

Figure S1: As in Figure 2 but for individual climate models. Responses are normalized by the 70-year temperature response to $4\times CO_2$ in order to highlight the differences in dynamics; e.g., whether more or less of the long-term response happens in the first few years, and the relative strength of the fast and slow precipitation responses.

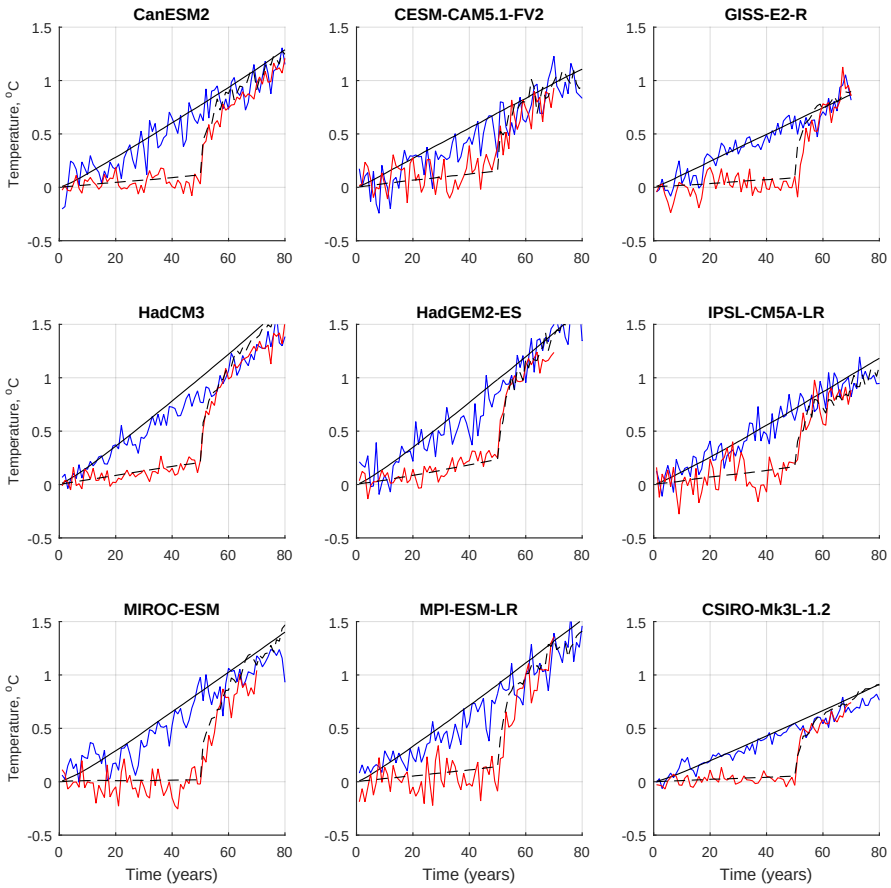

Figure S2: As in Figure 3 but for difference between average temperature over land and average temperature over oceans, for 1% per year increase in CO_2 and GeoMIP experiment G2 for each of the climate models considered here.

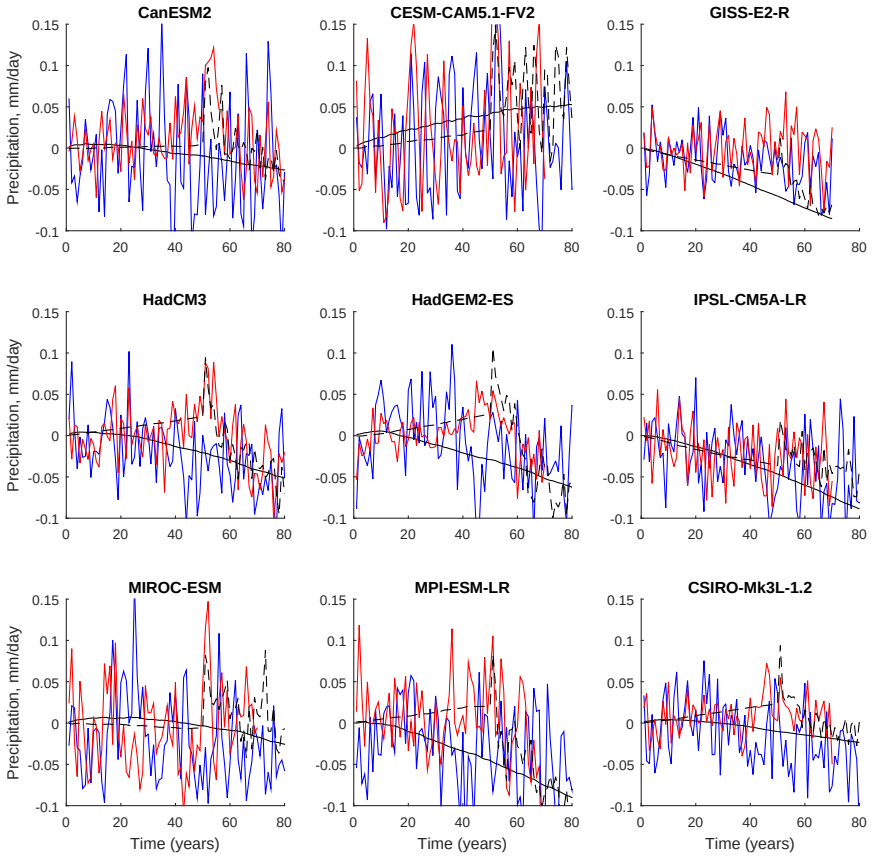

Figure S3: As in Figure 3 but for difference between average precipitation over land and average precipitation over oceans, for 1% per year increase in CO_2 and GeoMIP experiment G2 for each of the climate models considered here.

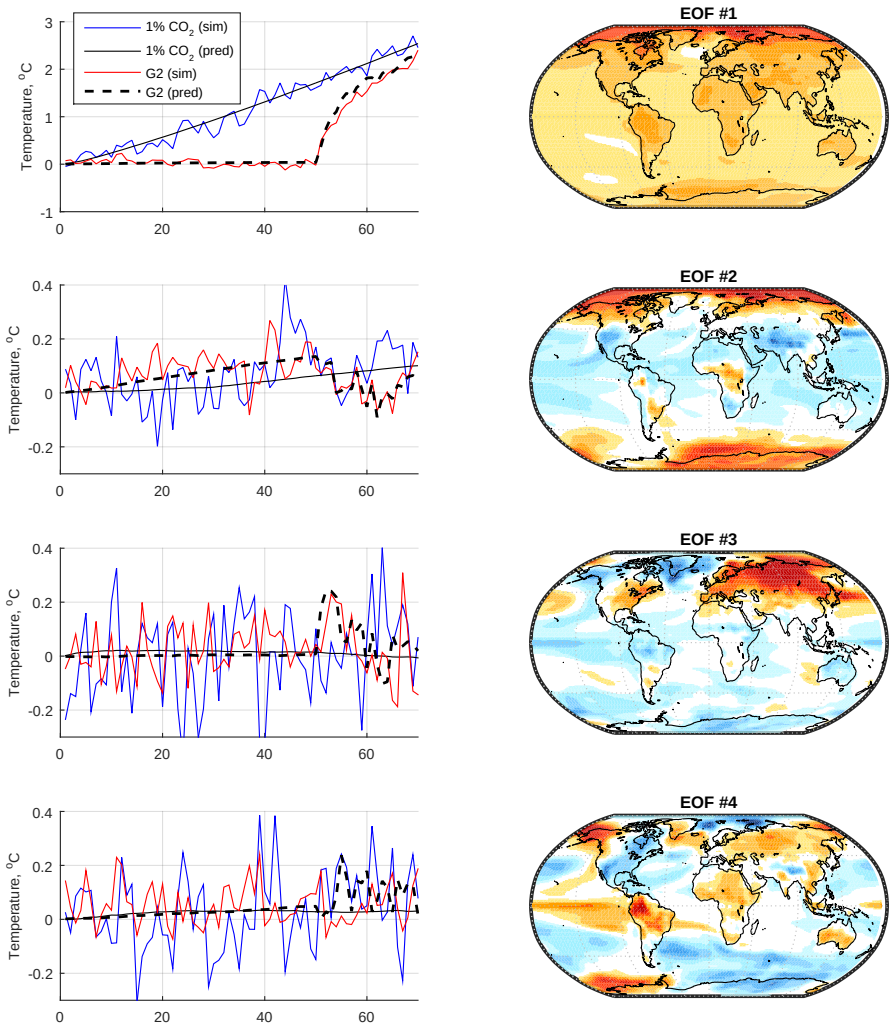

Figure S4: First few temperature EOFs for CanESM (right column), and the simulated and emulated time-history of the projection onto these EOFs for both 1% per year CO_2 increase and G2 simulation for CanESM; other models give broadly similar results. The first EOF here gives the pattern of warming from CO_2, while the second captures most of the difference in the response between CO_2 and solar forcing. In this model, higher EOFs are primarily describing natural variability rather than forced response.