Supporting Information for "Interpreting Differences in Radiative Feedbacks from Aerosols Versus Greenhouse Gases"

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Table S1. Experiment names and details for the CMIP6 experiments used in this paper. The "piClim" prefix denotes fixed-SST experiments, while the rest are coupled atmosphere-ocean experiments. piClim-control is an AGCM experiment with SSTs and sea ice climatologies taken from piControl. The fourth column includes three prescribed-SST experiments: piClim-histall, piClim-histGHG and piClim-histaer.

	piClim-control	**hist-GHG & hist-aer**	**historical**	**piClim-histxxx**
CanESM5	r1i1p2f1	r[1-10]i1p2f1	r[1-10]i1p2f1	r1i1p2f1
GISS-E2-1-G	r1i1p1f1	r[1-5]i1p1f1	r[1-10]i1p1f1	r1i1p1f1
HadGEM3-GC31-LL	r1i1p1f3	r[1-4]i1p1f3	r[1-5]i1p1f3	r[1-3]i1p1f3
IPSL-CM6A-LR	r1i1p1f1	r[1-10]i1p1f1	r[1-10]i1p1f1	r1i1p1f1
MIROC6	r1i1p1f1	r[1-3]i1p1f1	r[1-10]i1p1f1	r[1-3]i1p1f1
NorESM2-LM	r1i1p1f1	r[1-3]i1p1f1	r[1-3]i1p1f1	r1i1p1f1

Table S2. All-sky radiative feedback parameter (α), CRE (α_{CRE}), and clear-sky radiative feedback parameters (α_{CS}) for each model and the multi-model mean, to 2 d.p. Also shown is the estimated error from variance in the historical variants ($\sigma_{\text{historical}}$).

	hist-aer	**hist-GHG**	**historical**	$\sigma_{\text{historical}}$
CanESM5	0.75	0.80	0.87	0.02
GISS-E2-1-G	1.45	1.69	1.71	0.02
HadGEM3-GC31-LL	1.09	0.98	1.00	0.08
IPSL-CM6A-LR	0.96	1.31	1.22	0.02
MIROC6	1.86	1.78	1.68	0.04
NorESM2-LM	0.95	2.24	1.90	0.04
MMM	1.14	1.37	1.46	0.02

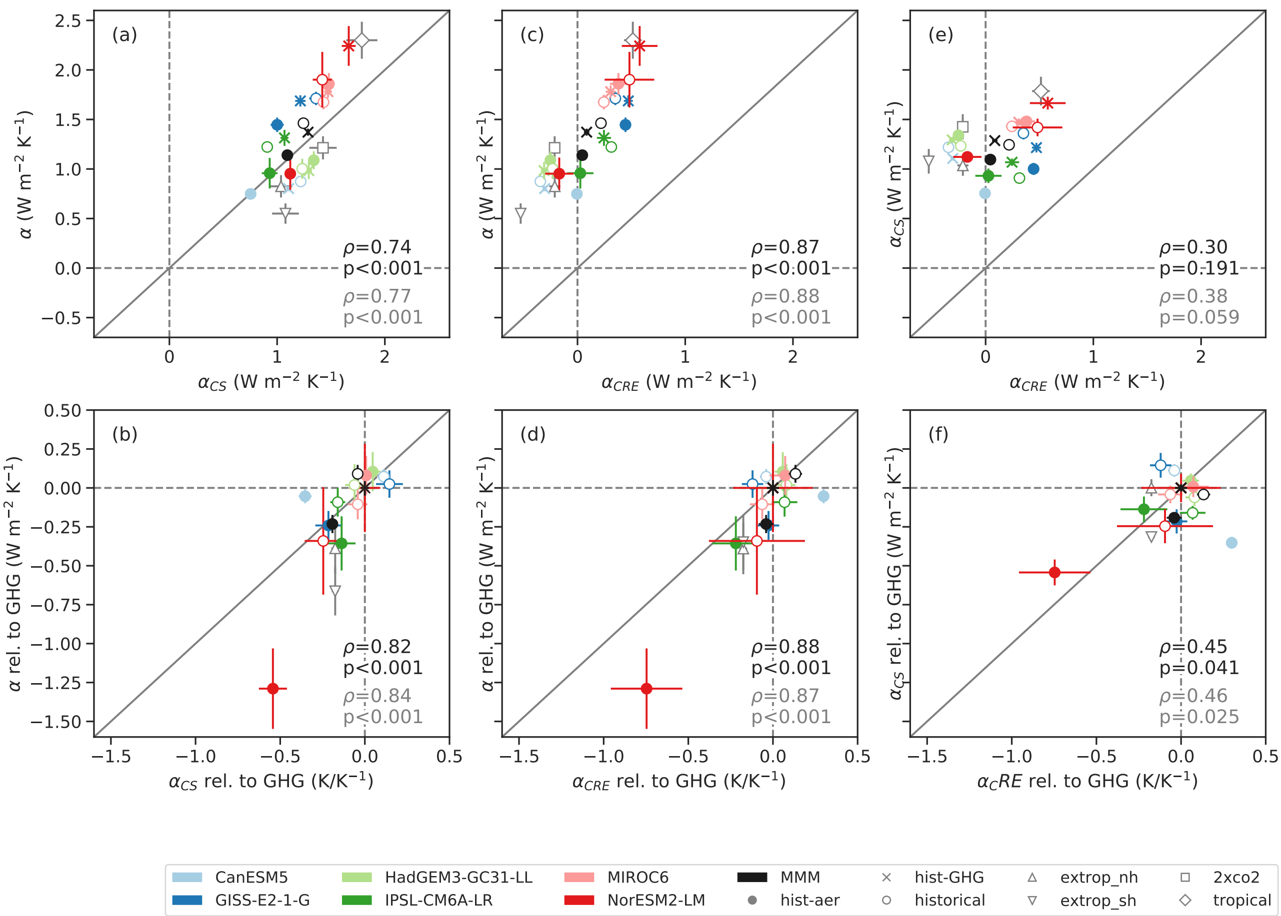

Figure S1. A similar plot as Fig. 2 in the main text, comparing the all-sky radiative feedback parameter (α) to CRE (α_{CRE}) and clear-sky radiative feedback parameters (α_{CS}) for each model and the multi-model mean. Values are shown as absolutes (*top* row) and as the difference from hist-GHG values (*bottom* row). All panels contain a 1:1 line (*solid grey*)

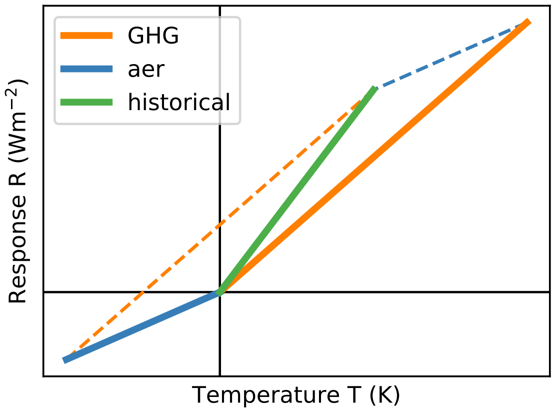

Figure S2. A geometric explanation of why the historical all-forcing feedbacks do not lie between the historical aerosol and historical GHG feedbacks. If the all historical is roughly a linear combination of the historical aerosol (*blue*) and historical GHG (*orange*) results, and the historical aerosol induces a negative temperature change with negative forcing unlike the positive forcing and temperature change from GHGs, then the all historical feedbacks parameter (the gradient of the *green* line) will be more positive than the hist-GHG feedback parameter.

Appendix A Why $\frac{\Delta X_{hist}}{\Delta \overline{T}_{hist}} - \frac{\Delta X_{GHG}}{\Delta \overline{T}_{GHG}}$ anti-correlates well with $\frac{\Delta X_{aer}}{\Delta \overline{T}_{aer}} - \frac{\Delta X_{GHG}}{\Delta \overline{T}_{GHG}}$

We expect that the results from the historical case can be approximated as a sum of hist-GHG and hist-aer cases:

$$\Delta X_{hist} \approx \Delta X_{GHG} + \Delta X_{aer} \tag{A1}$$

$$\Delta \overline{T}_{hist} \approx \Delta \overline{T}_{GHG} + \Delta \overline{T}_{aer} \tag{A2}$$

Given that the global average surface air temperature changes $\Delta \overline{T}$ are, by definition, constants in latitude and longitude, we can relate $\Delta \overline{T}_{GHG}$ and $\Delta \overline{T}_{aer}$ by some function of time a:

$$\Delta \overline{T}_{aer} = a \cdot \Delta \overline{T}_{GHG} \tag{A3}$$

This allows us to rewrite the expression, for the difference between feedbacks in the historical case and the GHG case, in the following way:

$$\begin{aligned}
\frac{\Delta X_{hist}}{\Delta \overline{T}_{hist}} - \frac{\Delta X_{GHG}}{\Delta \overline{T}_{GHG}} &= \frac{\Delta X_{GHG} + \Delta X_{aer}}{\Delta \overline{T}_{GHG} + \Delta \overline{T}_{aer}} - \frac{\Delta X_{GHG}}{\Delta \overline{T}_{GHG}} \\
&= \frac{\Delta X_{GHG}}{\Delta \overline{T}_{GHG} + \Delta \overline{T}_{aer}} + \frac{\Delta X_{aer}}{\Delta \overline{T}_{GHG} + \Delta \overline{T}_{aer}} - \frac{\Delta X_{GHG}}{\Delta \overline{T}_{GHG}} \\
&= \frac{\Delta X_{GHG}}{(a+1) \cdot \Delta \overline{T}_{GHG}} + \frac{\Delta X_{aer}}{(\frac{1}{a}+1) \cdot \Delta \overline{T}_{aer}} - \frac{\Delta X_{GHG}}{\Delta \overline{T}_{GHG}} \\
&= \frac{\Delta X_{GHG}}{(a+1) \cdot \Delta \overline{T}_{GHG}} + \frac{a \cdot \Delta X_{aer}}{(a+1) \cdot \Delta \overline{T}_{aer}} - \frac{\Delta X_{GHG}}{\Delta \overline{T}_{GHG}} \\
&= \frac{a \cdot \Delta X_{aer}}{(a+1)\Delta \overline{T}_{aer}} - \frac{a \cdot \Delta X_{GHG}}{(a+1) \cdot \Delta \overline{T}_{GHG}} \\
&= \frac{a}{(a+1)} \left(\frac{\Delta X_{aer}}{\Delta \overline{T}_{aer}} - \frac{\Delta X_{GHG}}{\Delta \overline{T}_{GHG}} \right)
\end{aligned}$$

We expect that $a < 0$ for all points in time, since we expect aerosol to reduce surface air temperatures where GHGs increase surface air temperatures. We also generally expect that $|a| < 1$ since the historical case gives rising temperatures i.e. the aerosol forcing does not outweigh the GHG forcing. As such, we expect that $\frac{a}{a+1} < 0$ to provide the observed anti-correlation.