Supporting Information for "Sea-surface temperature patterns, radiative cooling, and hydrological sensitivity"

Andrew I. L. Williams[1] and Nadir Jeevanjee[2]

[1]Program in Atmospheric and Oceanic Sciences, Princeton University

[2]Geophysical Fluid Dynamics Lab, Princeton, NJ

Contents of this file

1. Text S1
2. Figures S1 to S6

1. Text S1 - list of models used

The 8 CMIP5 models we use in the main text are: MRI-CGCM3, MPI-ESM-MR, IPSL-CM5A-LR, bcc-csm1-1, CNRM-CM5, MPI-ESM-LR, CanAM4, HadGEM2-A.

The 7 CMIP6 models we use in the main text are: HadGEM3-GC31-LL, IPSL-CM6A-LR, MRI-ESM2-0, CNRM-CM6-1, CanESM5, CESM2, MIROC6.

2. Text S2 - a note on OLS regression

In the main text, we discuss the relationship between the total $\Delta\eta_{\mathrm{LW,clear}}$ and its tropical $\Delta\eta^{\mathrm{trop}}_{\mathrm{LW,clear}}$ and extratropical $\Delta\eta^{\mathrm{extratrop}}_{\mathrm{LW,clear}}$ contributions. Here we provide a short mathematical note to support our statements in the main text. We also drop the Δs and the $()_{\mathrm{LW,clear}}$ subscripts in this section, for brevity.

Because the tropics ($\pm 30°$) cover half of the surface area of the Earth, we can write

$$\eta = \frac{1}{2}\left(\eta^{\mathrm{trop}} + \eta^{\mathrm{extratrop}}\right). \tag{1}$$

Assuming that our regressions yield noiseless estimates of these terms for the 15 CMIP5/6 models, the OLS slope between η and η^{trop} can be written as:

$$\frac{d\eta}{d\eta^{\mathrm{trop}}} = \frac{\mathrm{cov}(\eta, \eta^{\mathrm{trop}})}{\mathrm{var}(\eta^{\mathrm{trop}})} \tag{2}$$

where cov is the covariance and var is the variance. Substituting in Eq. (1) and expanding yields

$$\frac{d\eta}{d\eta^{\mathrm{trop}}} = \frac{\frac{1}{2}\mathrm{var}(\eta^{\mathrm{trop}}) + \frac{1}{2}\mathrm{cov}(\eta^{\mathrm{extratrop}}, \eta^{\mathrm{trop}})}{\mathrm{var}(\eta^{\mathrm{trop}})} = \frac{1}{2}\left(1 + \frac{\mathrm{cov}(\eta^{\mathrm{extratrop}}, \eta^{\mathrm{trop}})}{\mathrm{var}(\eta^{\mathrm{trop}})}\right). \tag{3}$$

Equation (3) makes it clear that the regression slope between global and tropical η will only be $= 1/2$ if the tropical and extratropical components are uncorrelated (i.e., $\mathrm{cov}(\eta^{\mathrm{extratrop}}, \eta^{\mathrm{trop}}) = 0$). However, across the CMIP5/6 simulations there is a slight anti-correlation between the tropical and extratropical components of $\Delta\eta_{\mathrm{LW,clear}}$ (Fig. S2), which makes the slope less than 1/2.

Furthermore, in OLS regressions the slope ($\hat{\beta}$) and intercept ($\hat{\alpha}$) are related by ($\hat{\alpha} = \overline{y} - \hat{\beta}\,\overline{x}$). Hence, the fact that the regression slope is 'biased low' by the covariance between tropical and extratropical components also explains why the intercept is 'biased high' compared to our simple estimate of $\frac{1}{2}\overline{\eta^{\mathrm{extratrop}}}$.

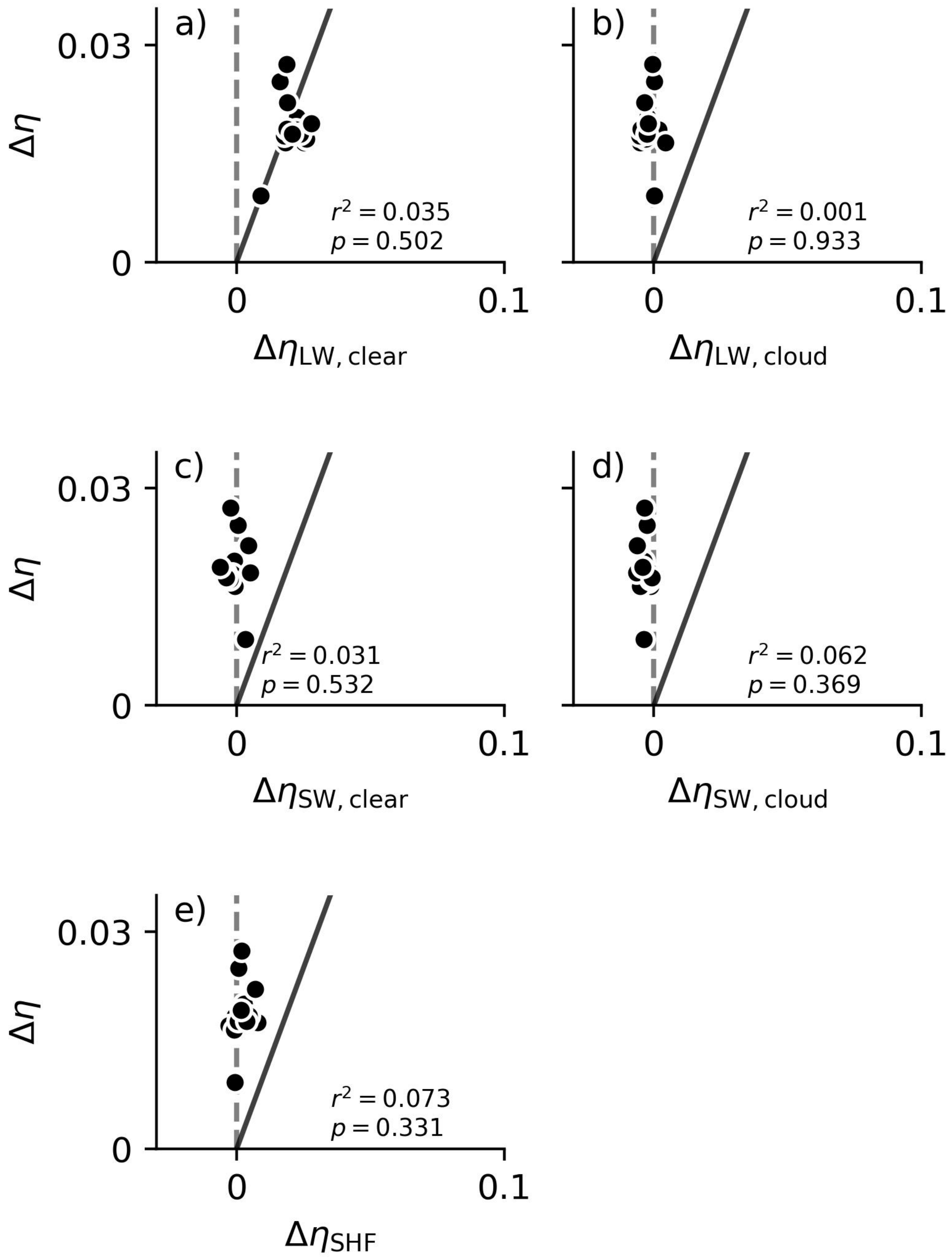

Figure S1. ***Inter-model spread in $\Delta\eta$ is not captured by longwave, clear-sky cooling, but the mean value is.*** Scatter plots of $\Delta\eta$ against its contributions from different components of the atmospheric energy budget.

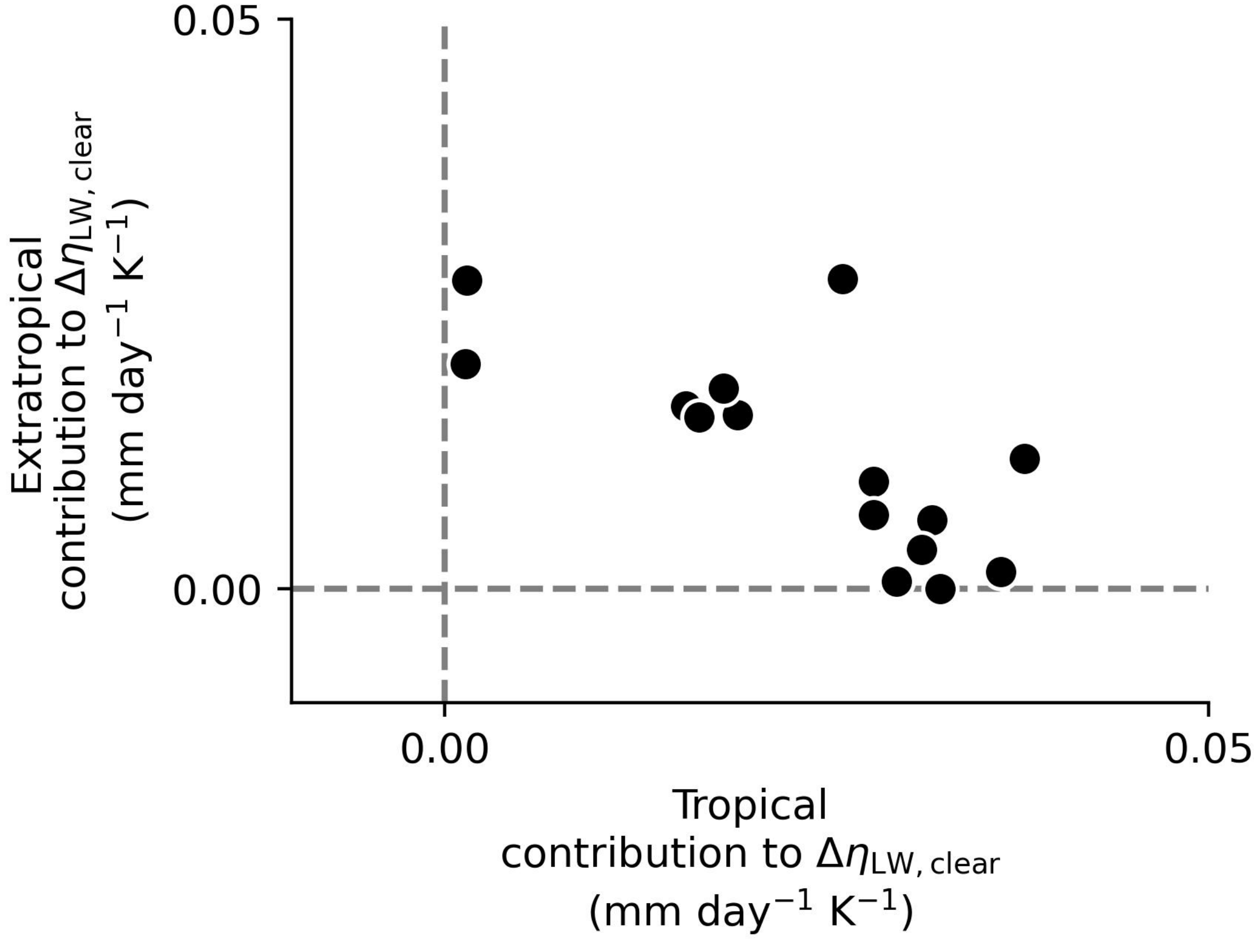

Figure S2. ***Tropical and extratropical contributions to*** $\Delta\eta_{\mathrm{LW,clear}}$ ***are anti-correlated.***

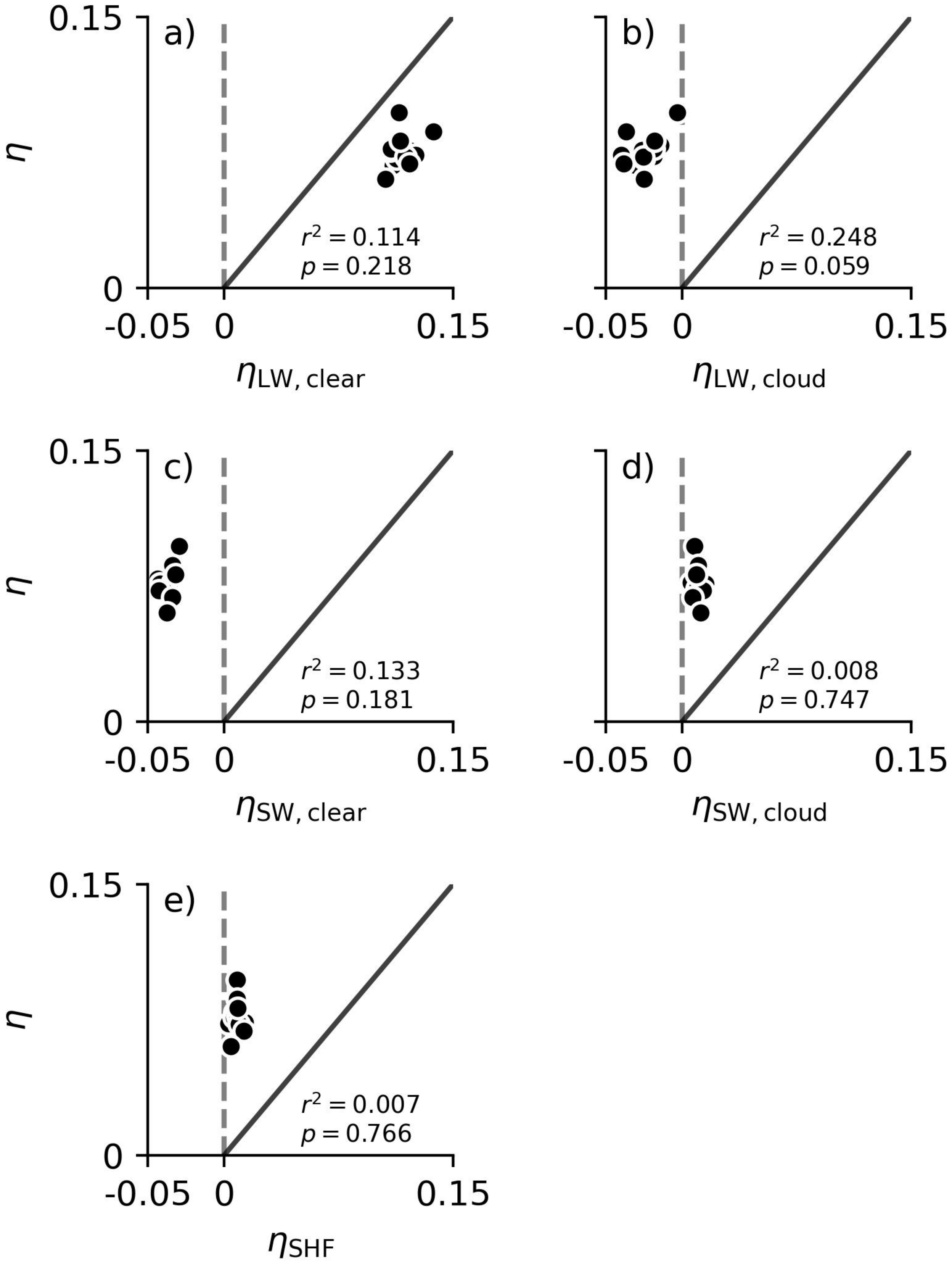

Figure S3. ***Inter-model spread in η_{abrupt} is not captured by any of the individual energy budget contributions.*** Scatter plots of η_{abrupt} against its contributions from different components of the atmospheric energy budget.