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# The relative importance of forced and unforced SST patterns in driving the time variations of low cloud feedback

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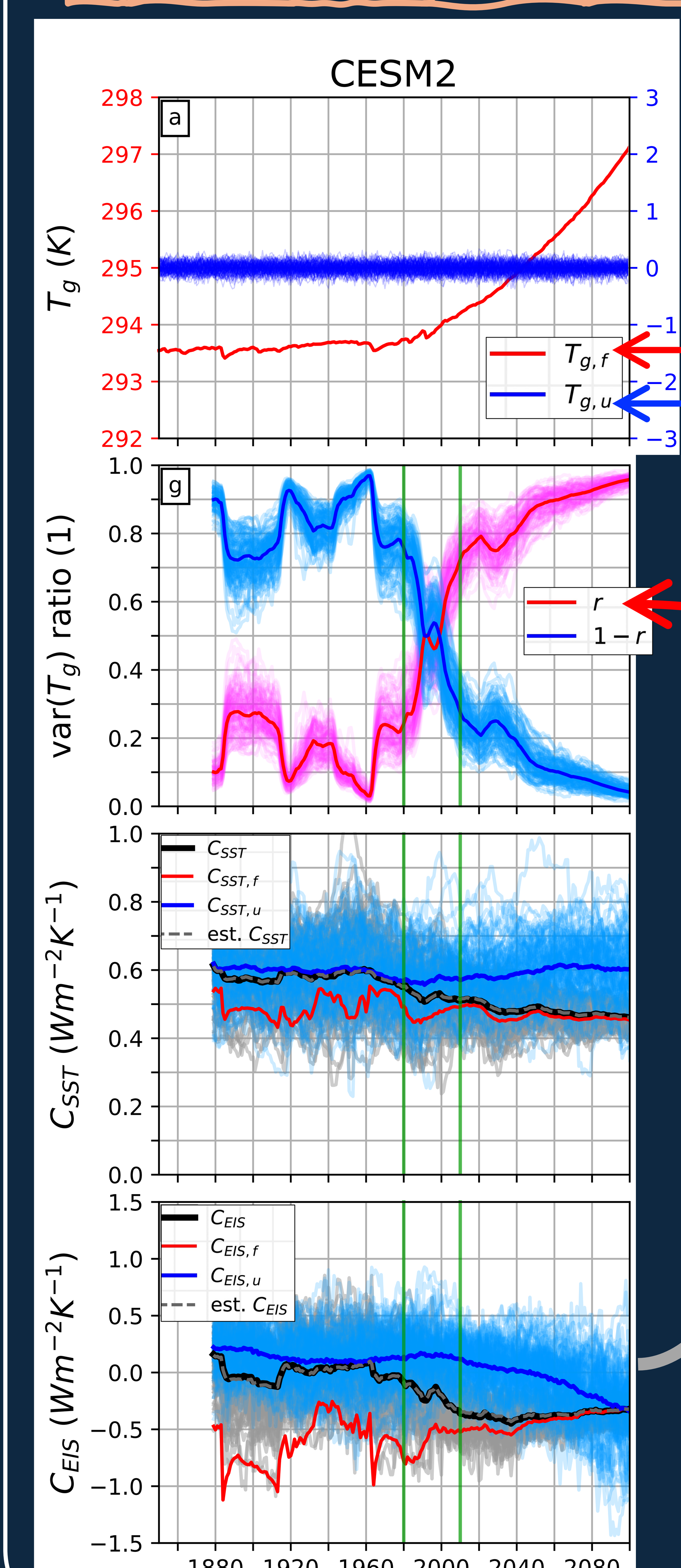
## Take-home message #1

- *Low-cloud feedback has contributions from both forced and unforced feedback components, and that its time variation arises in large part through changes in the relative importance of the two over time, rather than through variations in forced or unforced feedbacks themselves.*




Forced ($\cdot_f$) and unforced ($\cdot_u$) contribution on OLS regressions

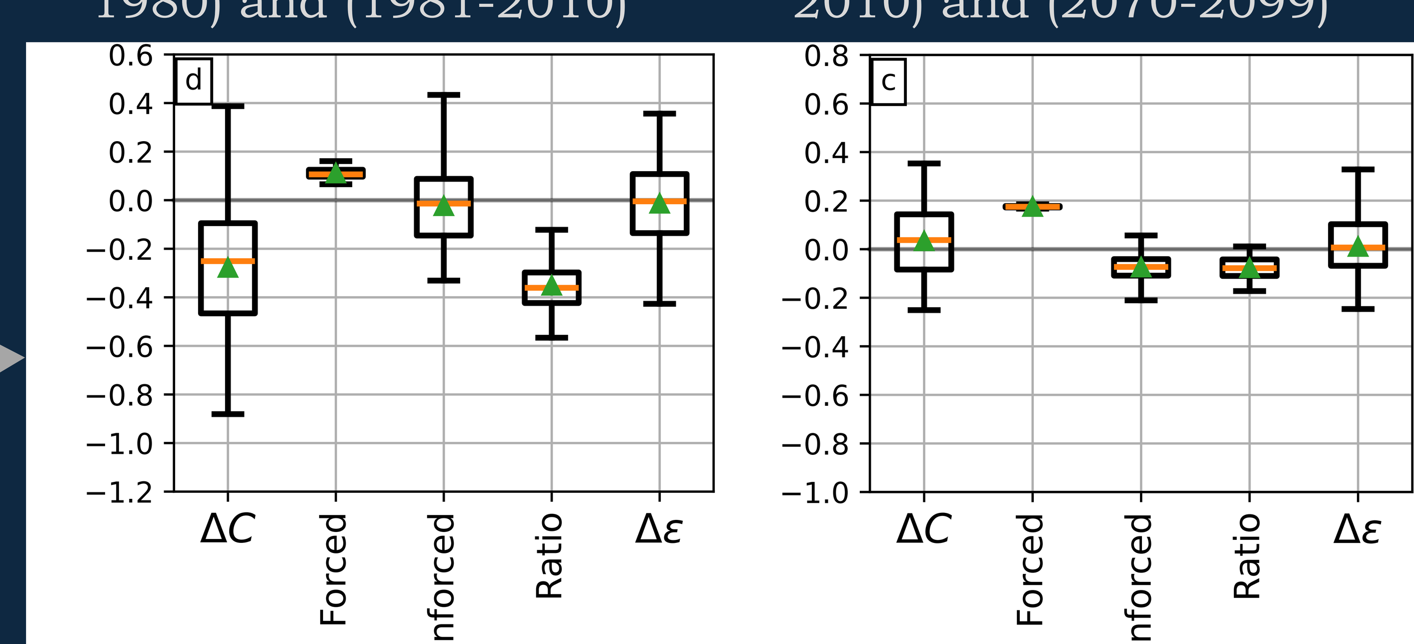
$$X = X_f + X_u,$$
$$T_g = T_{g,f} + T_{g,u}.$$

$$\frac{dX}{dT_g} = \frac{cov(X,T_g)}{var(T_g)} = \frac{cov(X_f+X_u, T_{g,f}+T_{g,u})}{var(T_{g,f}+T_{g,u})}$$
$$= \frac{cov(X_f,T_{g,f})+cov(X_f,T_{g,u})+cov(X_u,T_{g,f})+cov(X_u,T_{g,u})}{var(T_{g,f})+2cov(T_{g,f},T_{g,u})+var(T_{g,u})}$$

$$\frac{dX}{dT_g} = \frac{dX_f}{dT_{g,f}} r + \frac{dX_u}{dT_{g,u}}(1-r) + \sigma,$$
$$r = \frac{var(T_{g,f})}{var(T_{g,f}) + var(T_{g,u})}.$$

### *Low-cloud feedback change (EIS component)*

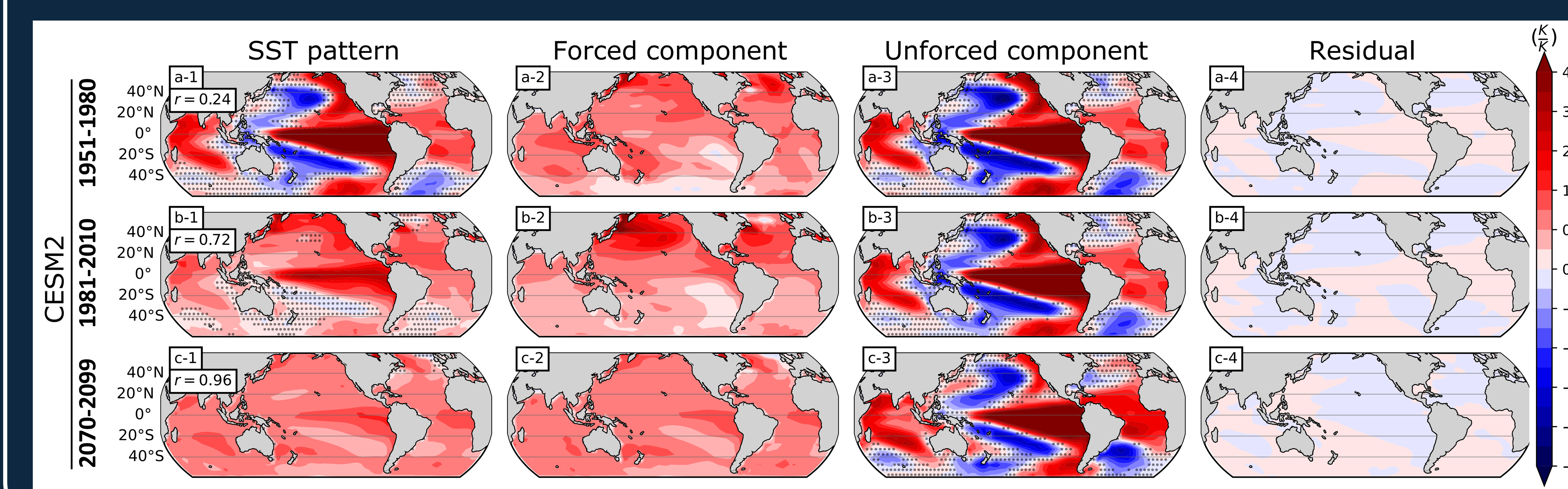
- Difference between (1951-1980) and (1981-2010)
- Difference between (1981-2010) and (2070-2099)




$$\Delta C = \underbrace{\sum \delta C_f \bar{r}}_{\text{Forced}} + \underbrace{\sum \delta C_u (1-\bar{r})}_{\text{Unforced}} + \underbrace{\sum \delta r (\overline{C_f} - \overline{C_u})}_{\text{Ratio}} + \Delta\epsilon$$

## Take-home message #2

- *SST patterns are dominated by unforced variations for 30-year windows ending before the 1980s, which are representative of an ENSO-like pattern (weaker low-level stability in the tropics and less-stabilizing low-cloud feedback).*
- *Since the 1980s, forced signals have strengthened, outweighing unforced variations for the 30-year windows ending after the 2010s. Forced SSTs exhibit relatively uniform warming, enhanced in the WP, leading to a more-stabilizing low-cloud feedback.*




## Take-home message #3

- *Using single-forcing LEs, we find that if only greenhouse gases evolve with time, the transition to the domination of forced signals occurs 10-20 years earlier compared to the LEs with full forcings, which can be understood through the compensating effect between aerosols and greenhouse gases.*