Are observed SST trends in the tropical Pacific externally forced?

Insights from single forcing large ensembles

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Main results

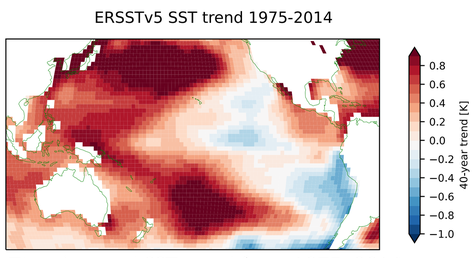
- Cooling trends over the eastern tropical Pacific in the recent decades contain a forced response to anthropogenic aerosols in model simulations
- Internal variability is large enough to mask this forced trend entirely in a single realisation
- The three models with single-forcing large ensembles (CESM1, CESM2, CanESM5) qualitatively agree

Next steps

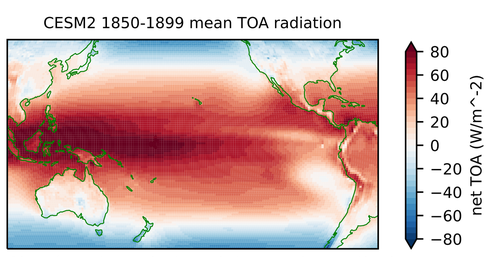
- Investigate state-dependence of response using all-but-one experiments (xAER)
- Quantify implications for the warming in the next decades
- Translate the effect of forced patterns into $\lambda_{(t)}$
- Extend model evaluation to include observations for clouds and radiation fields
- Further explore the estimated forced response in observations (*Wills et al. 2020, J.Clim.*)

Background & approach

- Identifying the origin of the recent observed cooling in the eastern tropical Pacific has important implications for feedbacks and climate sensitivity.
- We use CMIP6 single forcing and CMIP5&CMIP6 full forcing large ensemble simulations with CESM2 to robustly quantify the externally forced signal and internal variability.

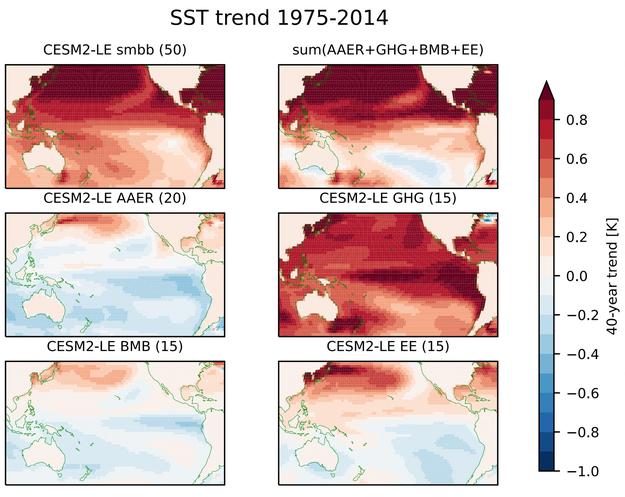


The observed SST trend from 1975–2014



Simulated pre-industrial net TOA radiation

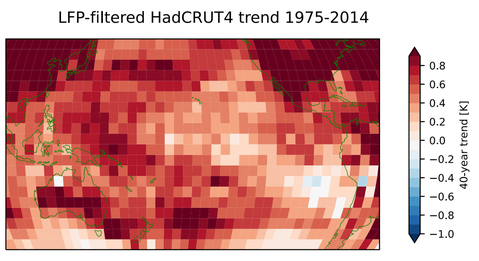
Simulated forced SST trends 1975–2014



Forced response (ensemble mean) trends in the all-forcing (CESM2-LE smbb) and single-forcing simulations. The top right panel shows the sum of all individual forcings.

- The forced response to aerosols in CESM2 causes a 0.5K cooling trend in the eastern tropical Pacific that is partly compensated by the greenhouse-gas forced warming trend.
- Other forcings (Everything Else: volcanic, solar, land-use, strat. O_3) and biomass burning (BMB) contribute to the cooling.
- Potential state-dependence of forcing (sum of individual ≠ full forcing)

The forced response in observed SST

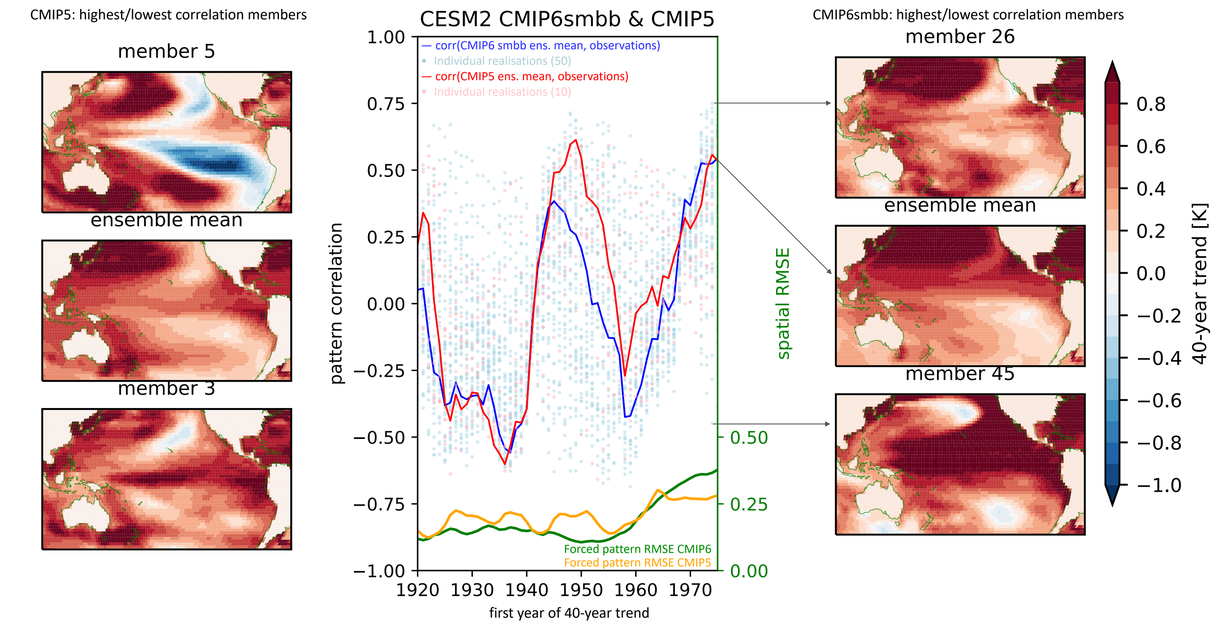


Estimated forced trend in observations

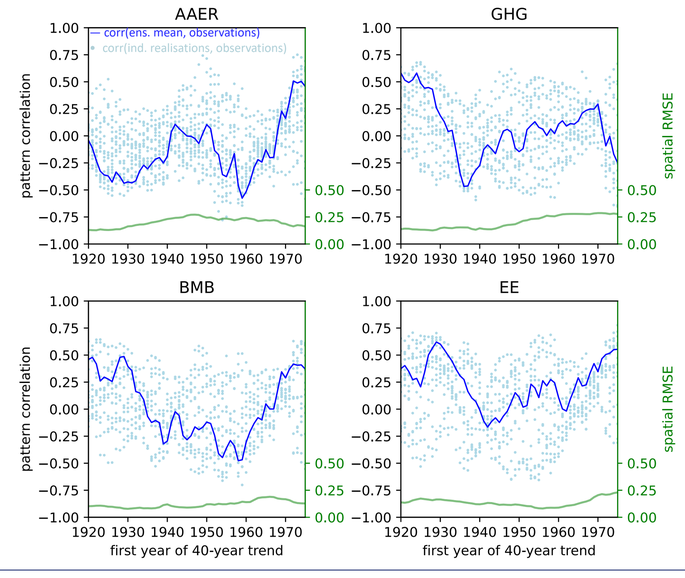
Isolating the forced response in observations is challenging. Here we show the estimated forced trend pattern in HadCRUT4 observations using the method by *Wills et al. (J.Clim. 2020).*
The lowpass-cutoff is 10-years, the number of EOFs is 25, and the estimated forced response is constructed from the first 2 LFPs.

Internal variability and forced response in 40-year SST trends

We analyze pattern correlations between observed and simulated SST trends using running 40-year windows for both CESM2/CMIP5 (10 members) and CESM2/CMIP6 (50 members) all-forcing ensembles.



- The pattern correlation is increasing with the emergence of a forced pattern in the 1960s.
- The spread among individual members is large and can mask the forced response, resulting in pattern correlations between individual members and observations in the range <0 to 0.75 for the 1975–2014 trends.

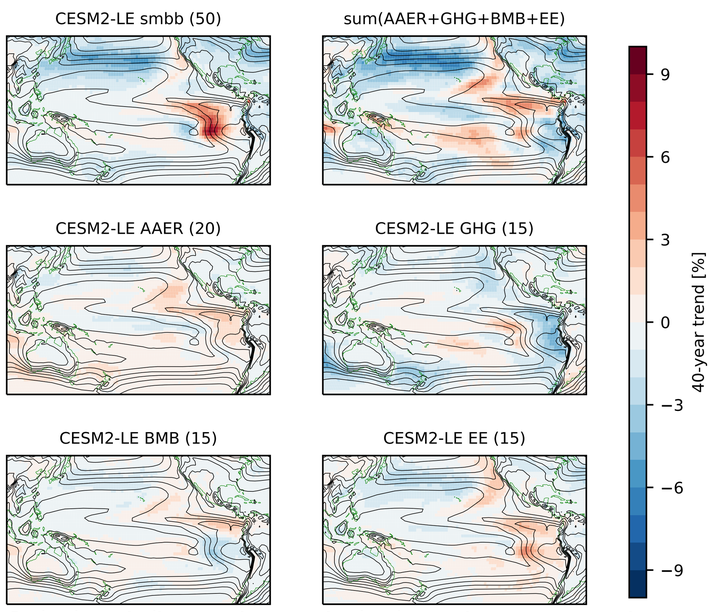


On the left, we show pattern correlations for each of the 4 CESM2 single-forcing large ensembles.

- The forced responses to AAER, EE, and BMB show increasing similarity with observed trends in the recent past.
- The forced response to GHG is negatively correlated with observations in the recent past.
- The spatial RMSE of the AAER and BMB patterns is decreasing in the last decades, while the GHG and EE RMSE is increasing.

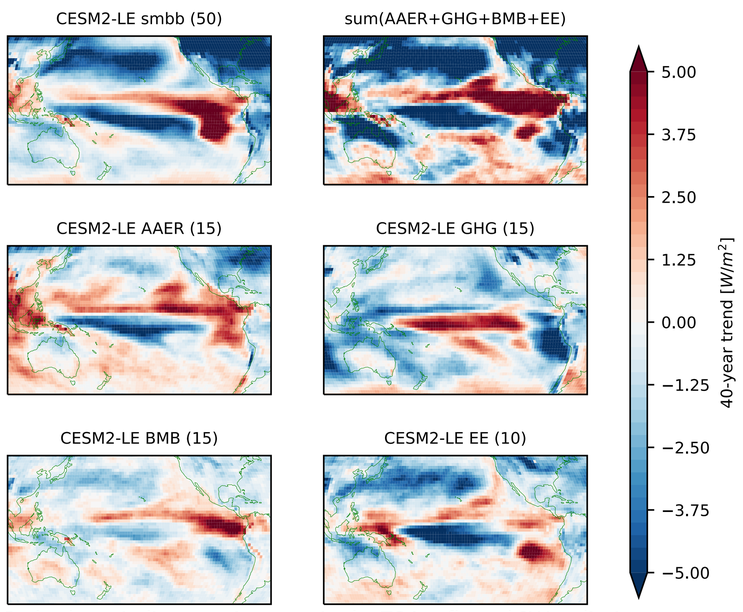
Forced trends in low clouds and radiation 1975–2014

- Increase in low cloud cover in the stratocumulus region is due to Aerosol and EE forcing, but compensated by a decrease in low cloud cover due to GHG and BMB.
- Individual forcings do not add up to the full forcing, indicating a state dependence.



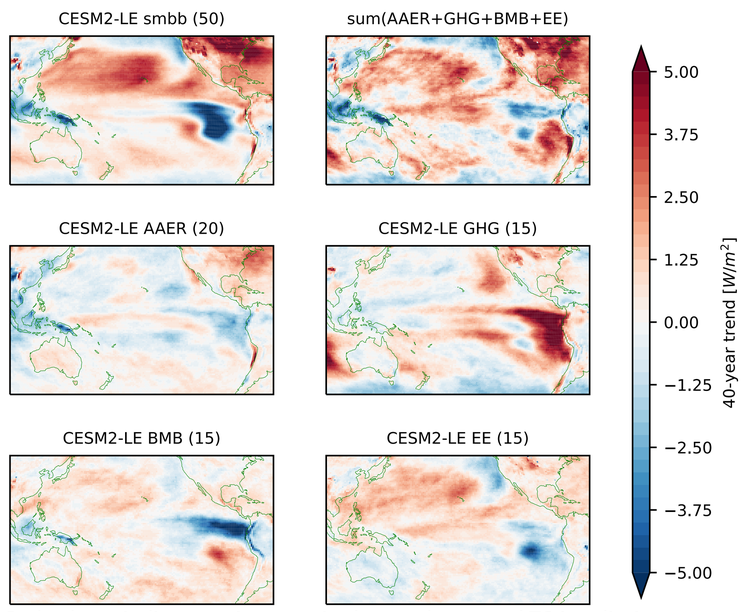
Red colours indicate an increase in cloud cover in percentage points.

- Forced increase in reflected shortwave radiation in eastern tropical Pacific is largely due to aerosol forcing and contributions from EE-forcing.



Red colours indicate an increase in the TOA reflected SW radiation.

- The net TOA radiation trend broadly follows the reflected SW trend in the eastern tropical Pacific.
- The sum of individual forcings in the near-coastal region in the southeast shows a trend opposite to the trend in the full-forcing simulation.



Red colours indicate an increase in the net downward TOA radiation.

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