The pattern effect impact on observationally-constrained warming projections

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Motivation

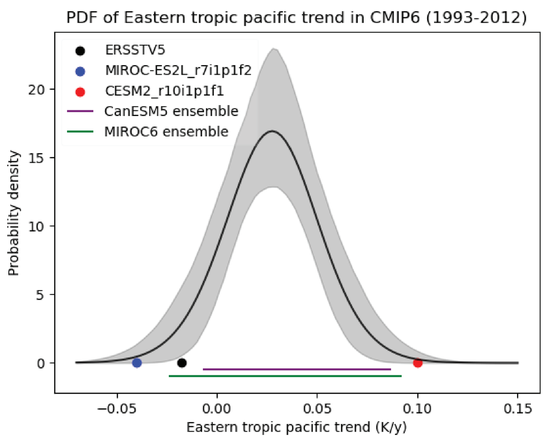
There is a strong impact of the pattern effect in the eastern tropical pacific (ETP) on the global mean surface air temperature (GSAT) trend (Andrews et al. 2018; Dong et al. 2020; Gregory et al. 2020; Zhou et al. 2016, 2021; Forster et al. 2021)

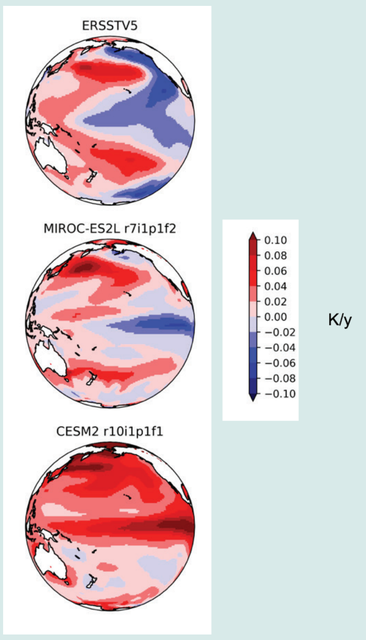
The observed and simulated pattern effect can be understood as internal variability which means recent observed trends in Eastern tropical Pacific SST are not expected to continue in the future (Forster et al. 2021; Watanabe et al. 2021)

Can we narrow the uncertainty in projected warming by constraining based on the observed GSAT trend with the pattern effect removed?

A broad range of simulated trend of SST patterns over tropical pacific

- Models show a broad range of SST trend over the ETP ocean
- Most models' realizations cannot reproduce the observed pattern
- The SST pattern over the tropical pacific ocean as the so-called pattern effect can exert a strong impact on GSAT change (Forster et al. 2021; Dong et al. 2020; Zhou et al. 2021)

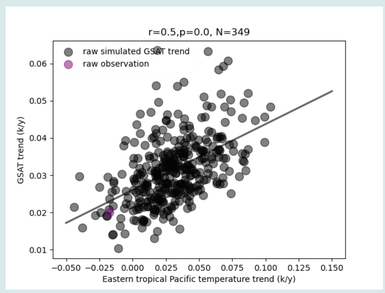




SST trend 1993-2012

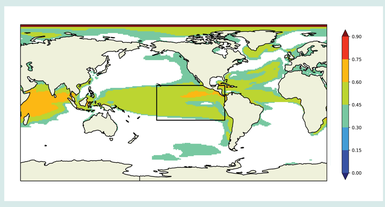
The impact of pattern effect on GSAT in CMIP6 archive

Relationship between GSAT trend and ETP trend across all realizations



Similar to CMIP5 realizations (Fyfe et al., 2014), CMIP6 archive also shows a tight correlation between GSAT trend and ETP trend

Correlation between GSAT trend and local trend across all realizations



The correlation is likely strengthened by model differences in forced response

Data

Model in use:
28 CMIP6 models

Projected variable: GSAT changes
Calculated as changes of 2081-2100 (SSP5-8.5) relative to 1995-2014

Constraint:
GSAT trend in 1993-2012 with/without pattern effect

Observation:
HadCRUT5 and ERSST V5

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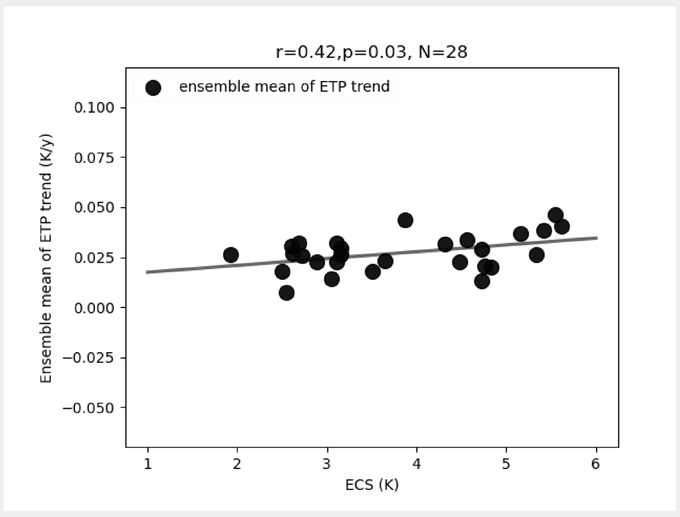
Step1: Remove the model difference in forced response from the ETP trend by regressing out ECS variations



The inter-model correlation between climate sensitivity and ensemble mean of ETP trend shows ETP warming is also associated with models' difference in climate sensitivity

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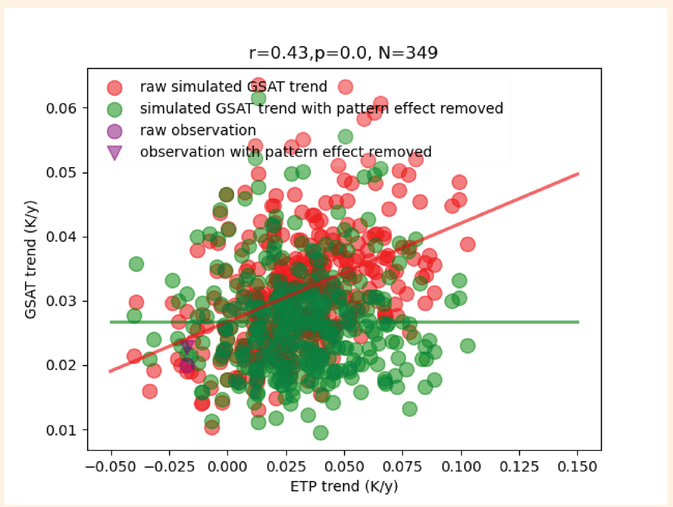
Step2: Regress out the pattern effect (using ETP trend with forced response removed) in simulated and observed GSAT trend



After removing the model difference in forced response, the variability of the GSAT trend is still tightly connected with the variability due to the pattern effect (red dots)

The green dots show the GSAT trend has been regressed out the pattern effect

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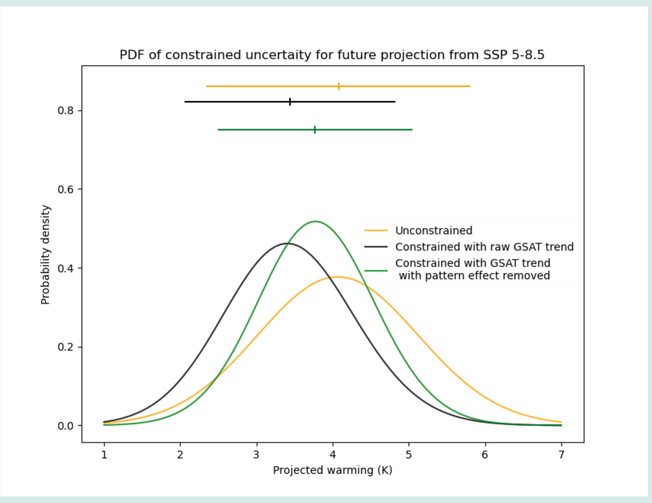
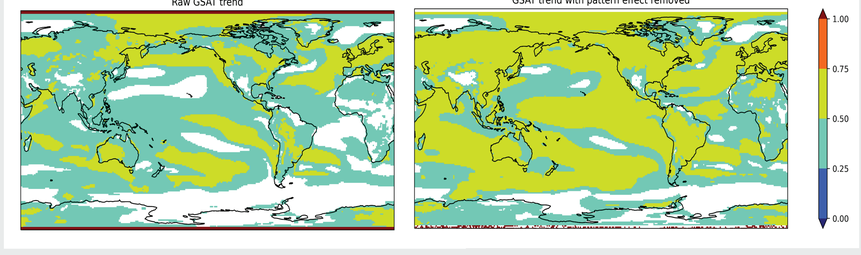
Step3: Observationally constrained model projected warming using observed GSAT trend with pattern effect removed



The GSAT trend metric with the pattern effect removed results in a larger mean and higher 5-95% range than the raw GSAT trend metric

Metric performance: Raw GSAT trend VS GSAT trend with pattern effect removed

Correlation between GSAT trend and local projected warming across models



The GSAT trend metric with the pattern effect removed produces more robust emergent relations, suggesting the pattern effect is likely internal variability

Cross validation test: each model serving pseudo observation in turn, using the rest of models to predict the pseudo observation

	Correlation coefficient *	RMSE*	Width of the uncertainty range*
Constrained with raw GSAT trend	0.45	0.81 K	2.84 K
Constrained with GSAT trend with pattern effect removed	0.55	0.76 K	2.67 K
Unconstrained	-1	0.96 k	2.91 K

Correlation coefficient *: the correlation coefficient is calculated as pseudo-observations and projected best estimate.

RMSE*: RMSE is calculated as the root mean square error for the projected best estimate to pseudo-observations.

Width of the uncertainty range*: this quantity is calculated as the width of the projected 5-95 uncertainty

The imperfect model test shows the constrained projections can be improved by the GSAT trend metric with pattern effect removed

Summary & Conclusions

Projections constrained using observed GSAT warming can be improved by removing the pattern effect first

Stronger constrained projected warming is obtained when we remove the pattern effect in both observations and model realizations [it is more consistent with other global-scale constraints (Liang et al. 2022)]

Key Reference

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Questions, Comments?

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