Modeling needs and opportunities for attribution science

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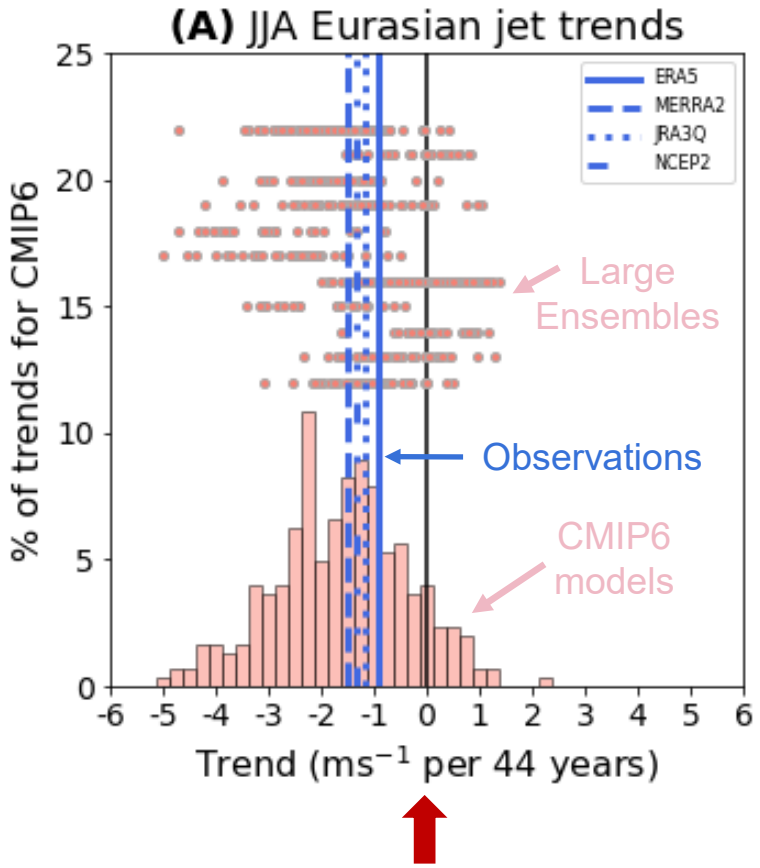
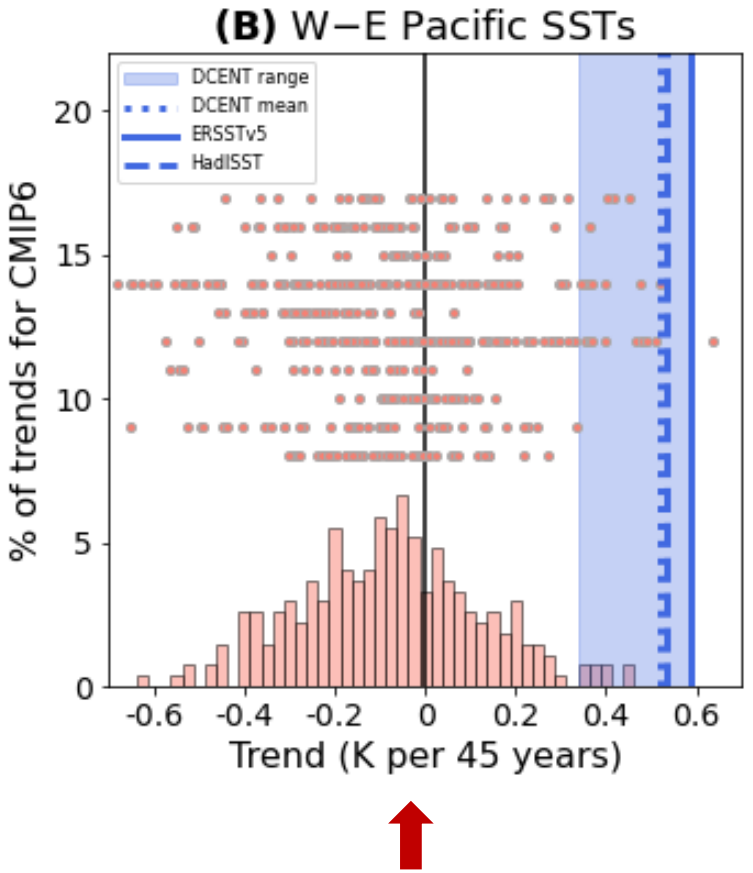
A wide variety of situations for using models in attribution science

Trends in the summertime Eurasian jet stream (Dong et al. 2022)



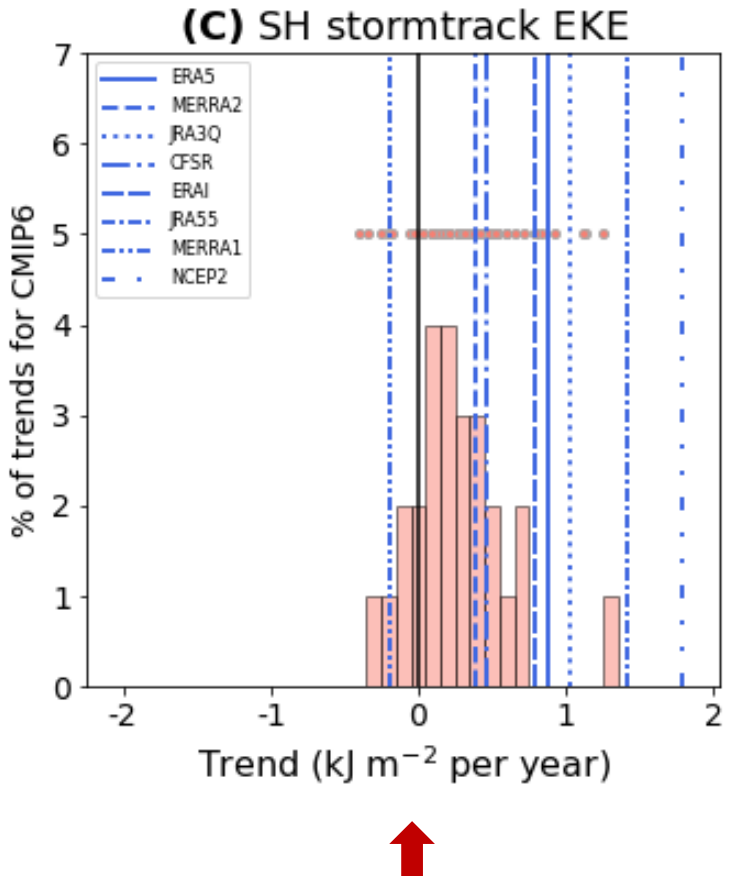
Modelled forced trends agree well with observed trends

Trends in the West-East difference in tropical Pacific SSTs (Seager et al. 2019, Wills et al. 2022)



Observed trends lie outside of the model distribution

Southern Hemisphere winter storm track activity (Kang et al. 2024)



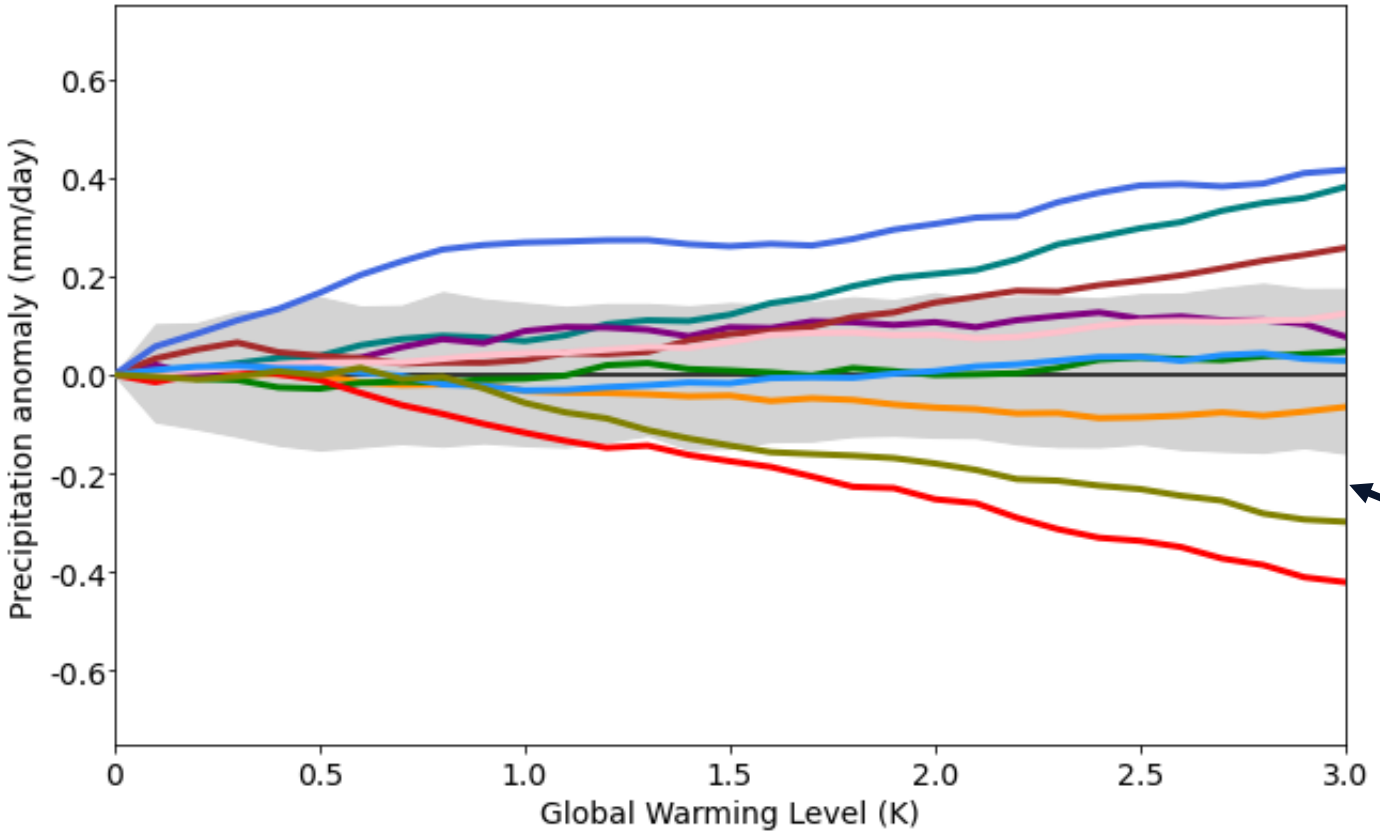
Observed trends are really uncertain

Simpson, Shaw, et al, Science Advances, In Press

Model response uncertainty in precipitation projections

Using 10 large ensembles from CMIP5 and CMIP6 that have at least 20 members

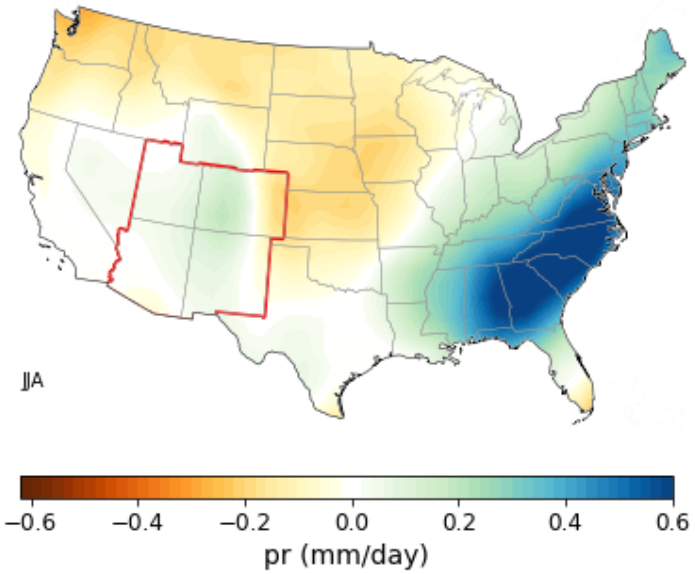
Precipitation anomalies at different global warming levels relative to 1970-1989 using 20 year running means



Range of differences between 20 year means that can arise due to internal variability (95% confidence interval)

Ensemble mean forced response in different models

Ensemble Mean (JJA) precipitation anomalies at 2K global warming



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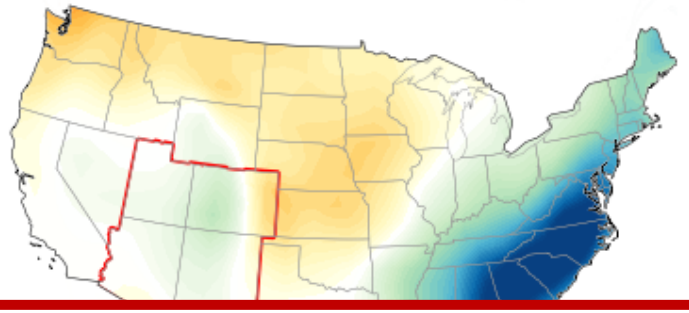

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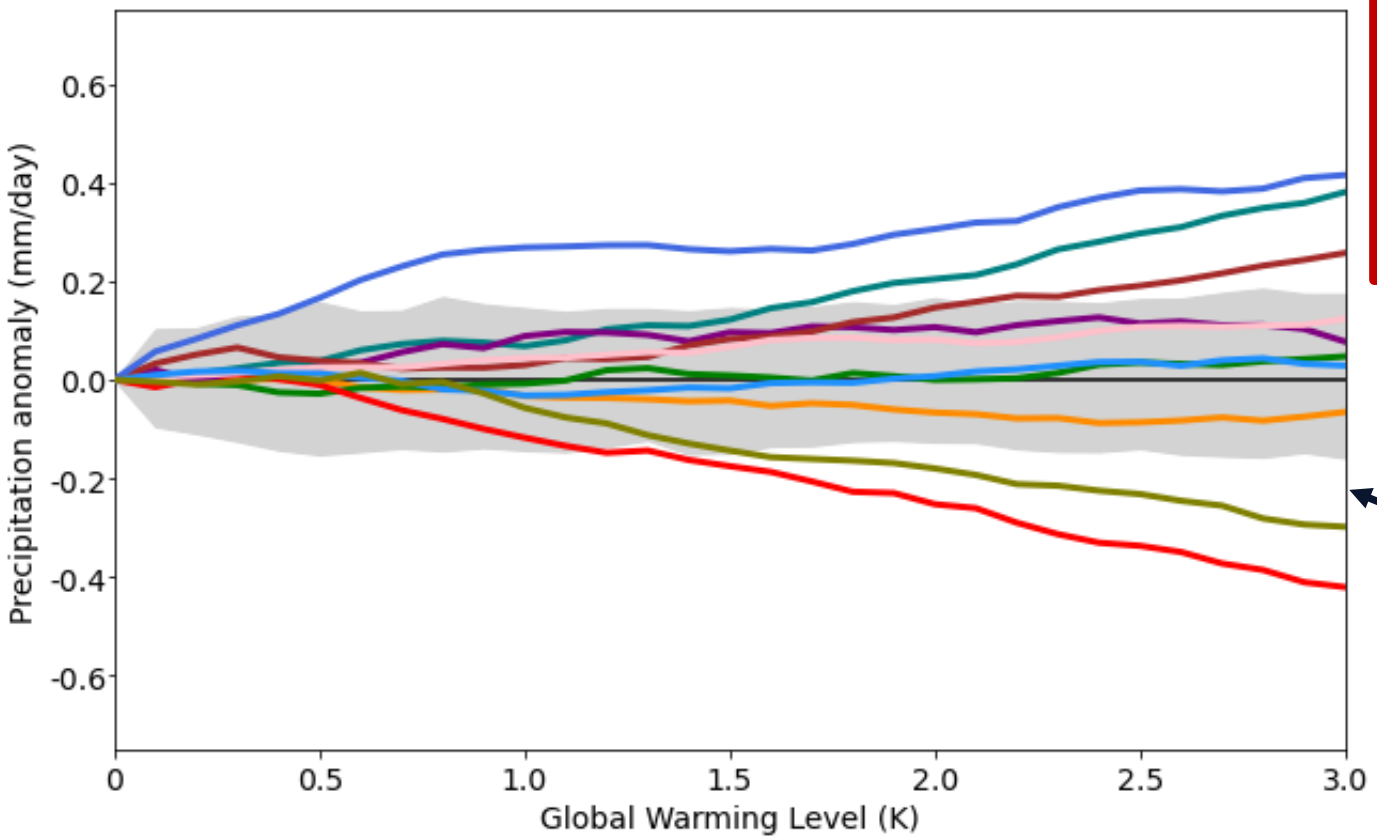


Need/Opportunity # 1

Understand inter-model spread in forced signals and narrow down this uncertainty

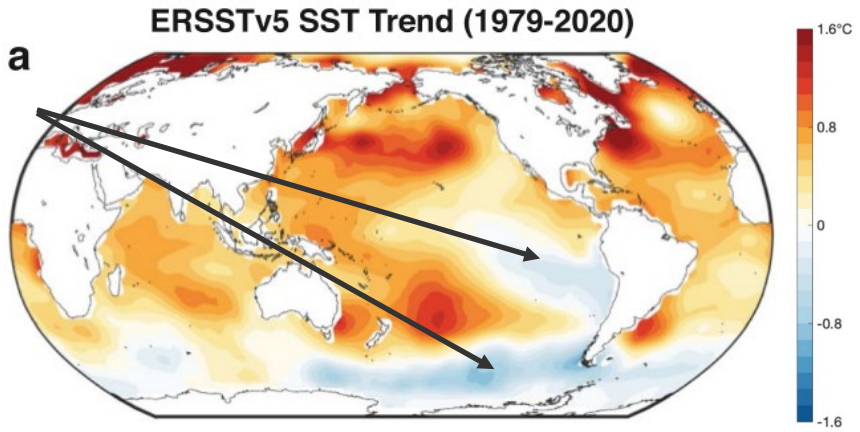
Range of differences between 20 year means that can arise due to internal variability (95% confidence interval)

Ensemble mean forced response in different models

Opportunity #2: Potential gains from moving toward moderately higher resolution

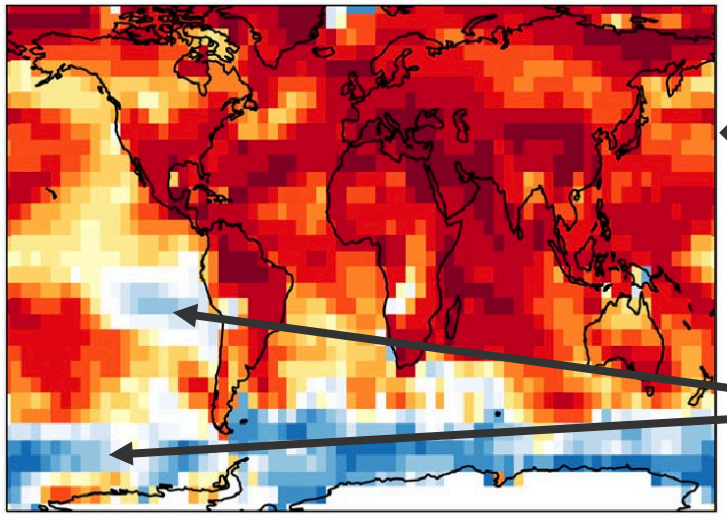
CMIP models seems to fail to capture the cooling trend in the Southern Ocean and in the Eastern low latitude Pacific that has been observed

Observed SST trends



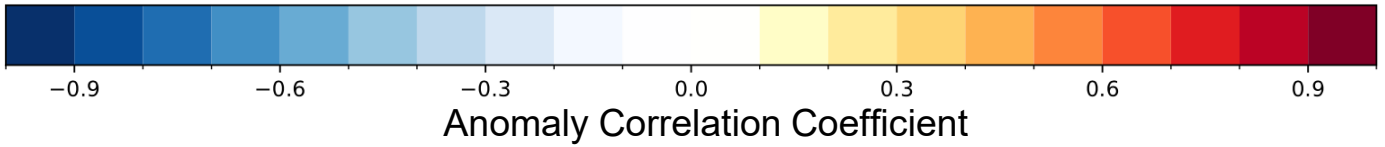
Wills et al (2022)

Low Res (1°atm, 1°ocn)



Lead year 1-5 prediction skill in CESM1 initialized predictions

Initialized hindcasts at standard resolution also don't have multi-year skill in these regions.



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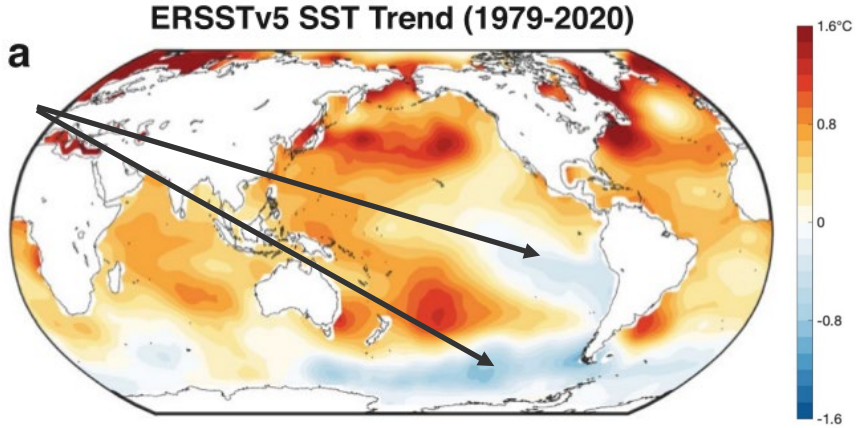
Opportunity #2: Potential gains from moving toward moderately higher resolution

CMIP models seems to fail to capture the cooling trend in the Southern Ocean and in the Eastern low latitude Pacific that has been observed

Higher resolution simulations have much improved skill in these regions.



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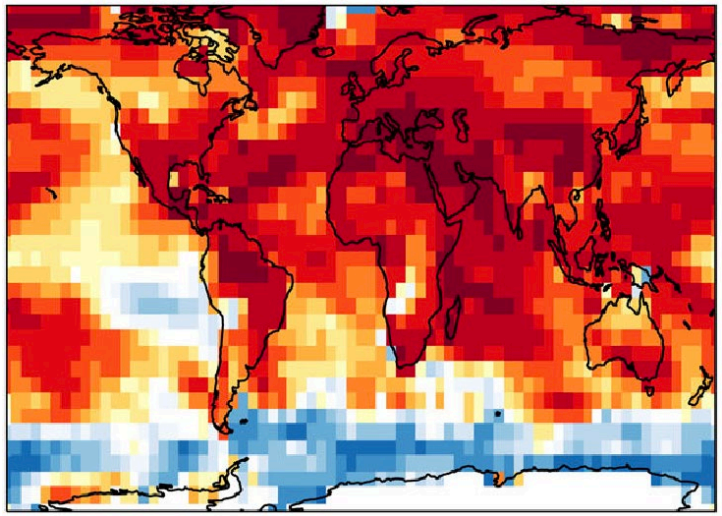
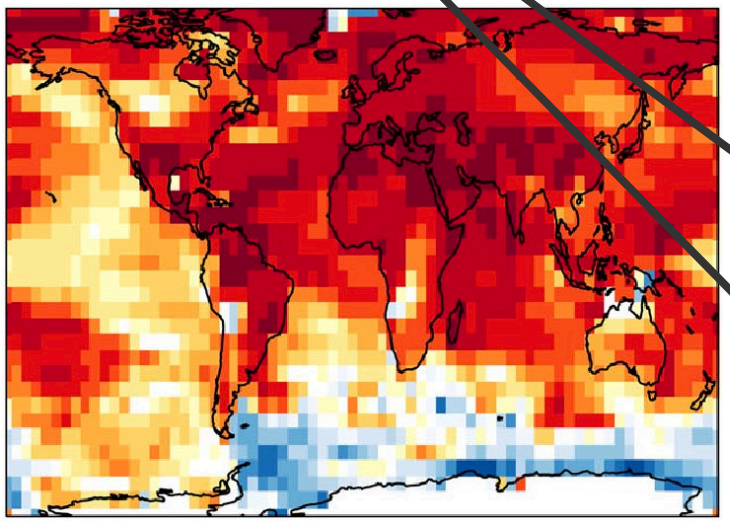
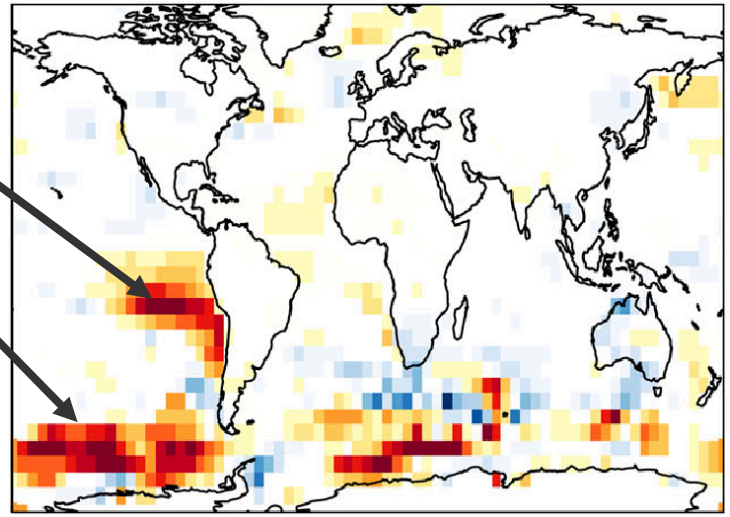
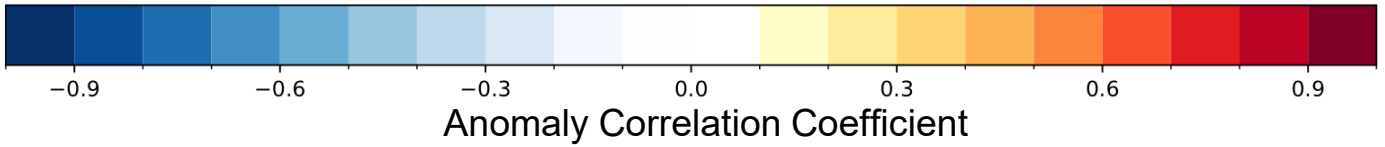


High Res (0.25°atm, 0.1°ocn)



High Res – Low Res

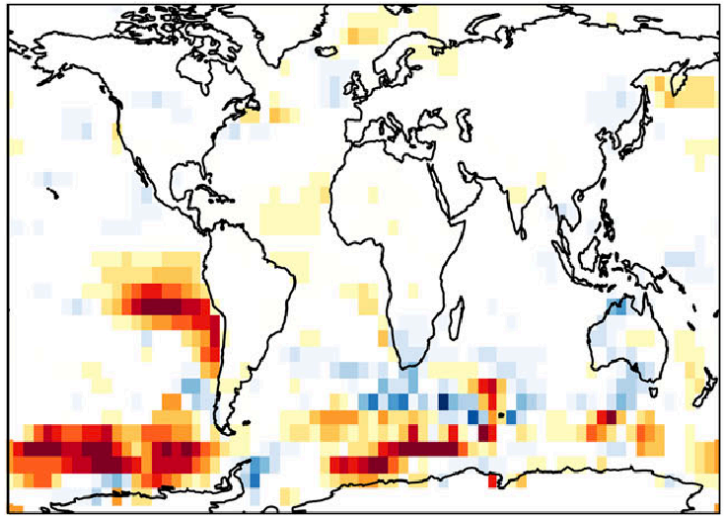




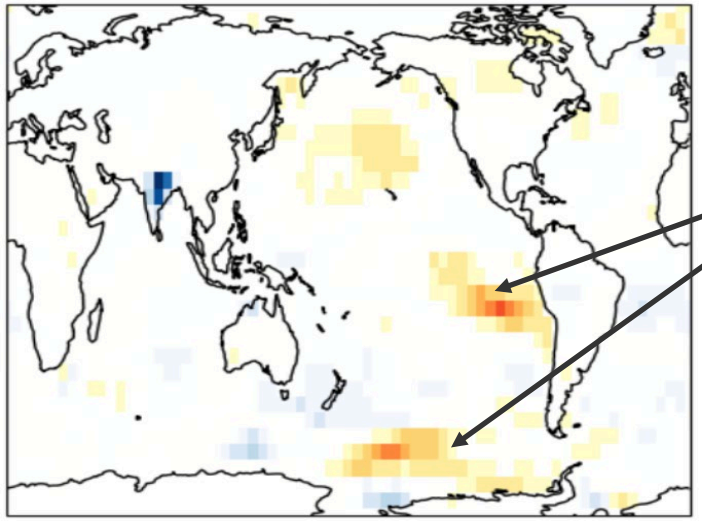
Yeager et al. (2023)

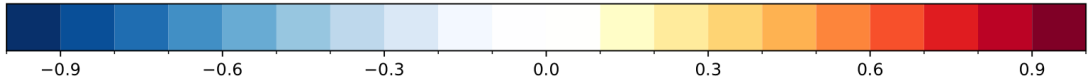
Opportunity #3: Improving our models in other ways

CESM1 high resolution – low resolution



CESM2 – CESM1 (both low resolution)





Physics changes at low resolution also have the potential improve hindcast skill in these problematic regions. (Figure Steve Yeager)

See also Kang et al. (2023)

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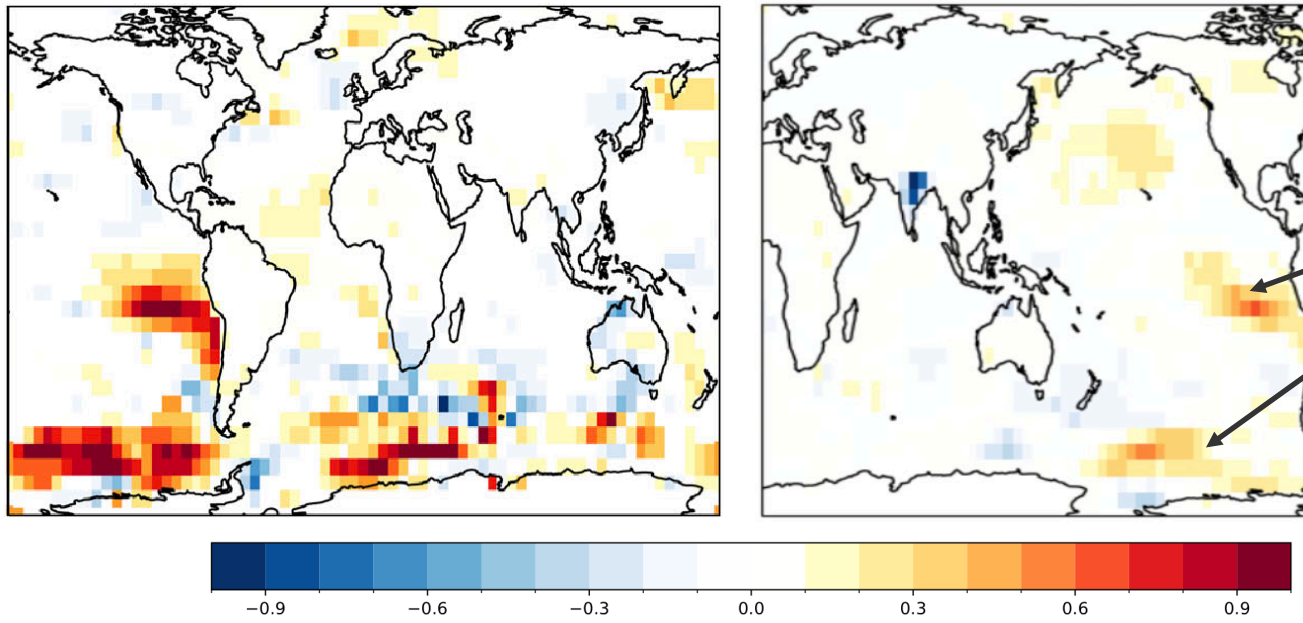

Physics changes at low resolution also have the potential improve hindcast skill in these problematic regions. (Figure Steve Yeager)

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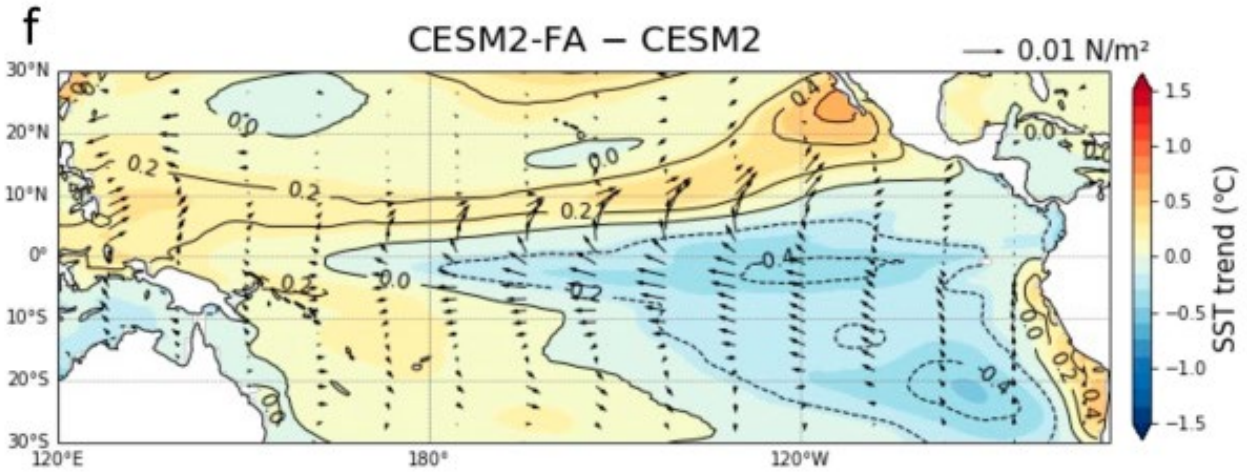
A flux adjusted version of CESM2, which has mean state biases in SST removed, shows more cooling in the Eastern Tropical Pacific

Zhuo et al (2025)



Summary of Needs and Opportunities

(1) Improved understanding of inter-model differences in forced signals → narrowing down of our model uncertainty

(2) Move towards higher resolution. I would argue this should be done incrementally in a way that we can still be able to run sufficiently long simultions/large ensembles and understand resolution impacts.

(3) Alleviate climate model biases, improve model physics.

Not discussed directly in the slides

(1) Approaches for assessing model representation of extreme events that are really rare e.g., the Pacific Northwest Heatwave. Ensemble boosting approaches (Fischer et al. 2023), quantifying expectations based on the characteristics of the distribution and increasing sample sizes through use of the spatial dimension too (McKinnon and Simpson, 2022)

(2) Emulators for representing probability distributions, particularly at higher resolution.