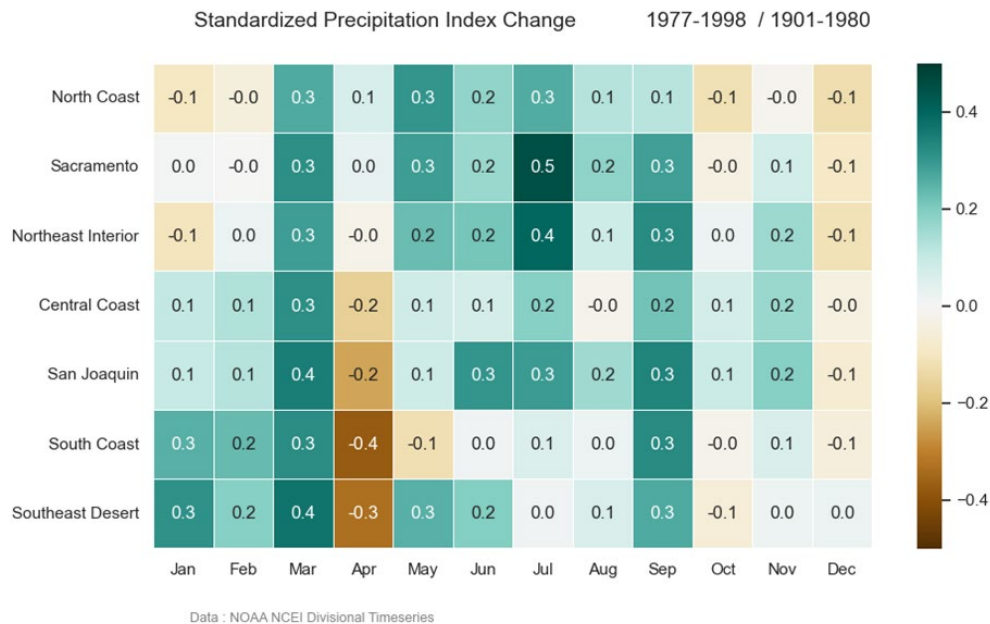


From: Deirdre Des Jardins <ddj@cah2oresearch.com>
Sent: Friday, June 21, 2024 2:30 PM
To: Delta Council ISB DeltaCouncilISB@deltacouncil.ca.gov

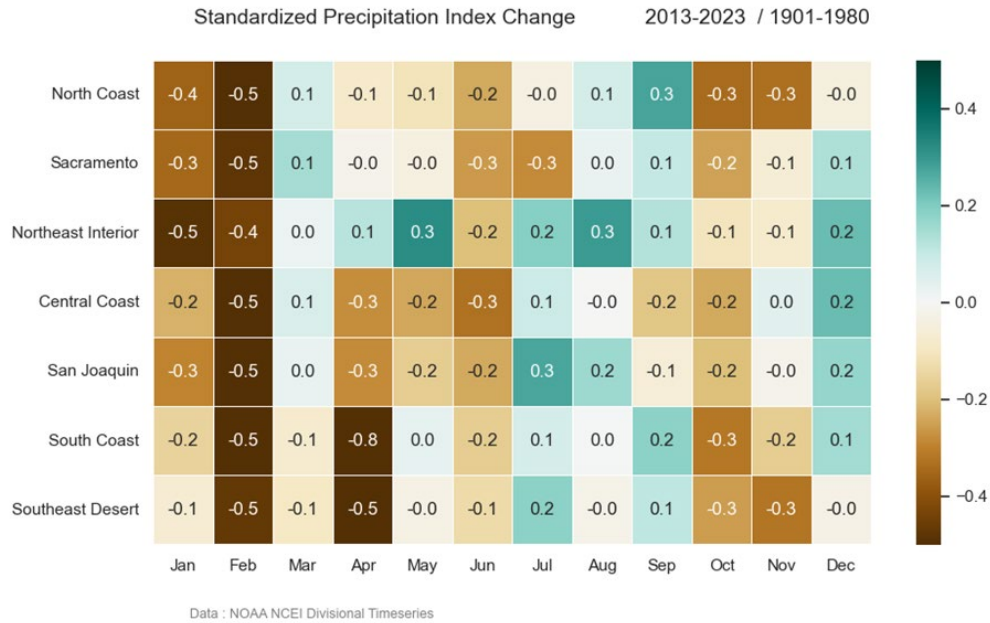
Subject: Could we see the western NA hydroclimate shift towards a wetter pattern?

Dear Delta ISB members.

This is the briefing I have been sending to climatologists. It's a bit technical -- but the key takeaway is that we could see a decadal-scale El Nino-like, warm Pacific Decadal Oscillation pattern in the Pacific Ocean. This could be a much wetter pattern, perhaps closer to the pluvial during the warm PDO from 1977-98.

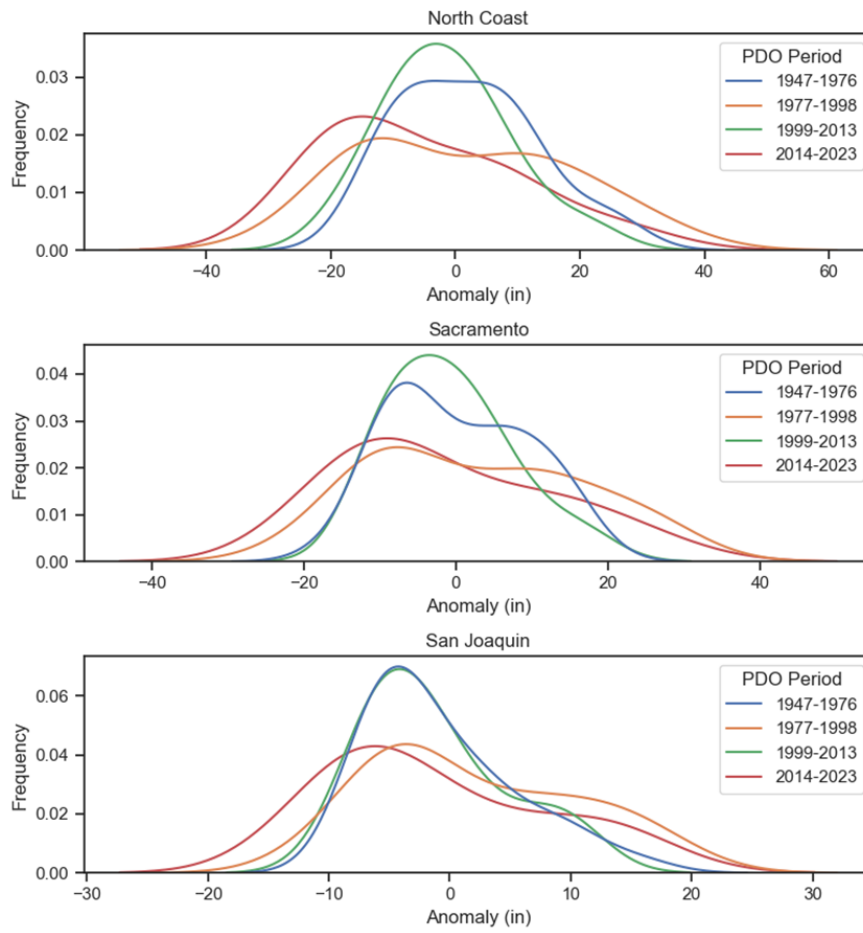


In contrast, this is the pattern we've seen since 2013. It has been a *very* droughty decade.



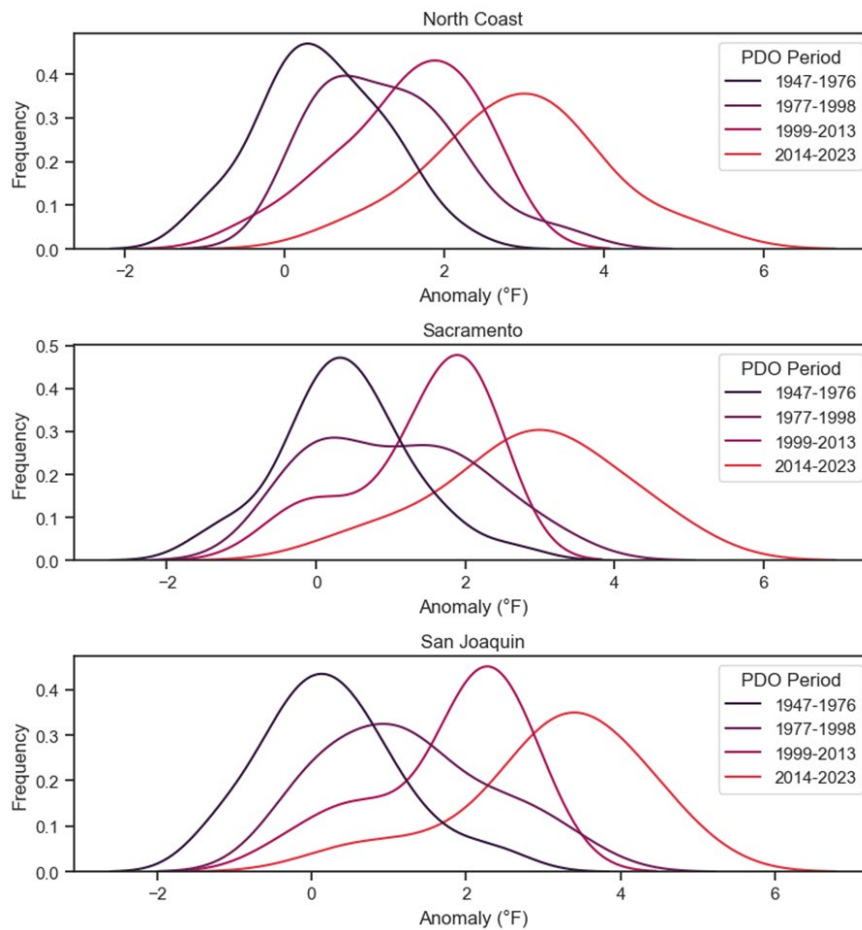
This shows changing distributions of precipitation by Pacific Decadal Oscillation period.

WY Mean Precipitation Anomalies by PDO Period



There has also been a significant shift in the temperature distribution.

WY Mean Temperature Anomalies by PDO Period



Here's the briefing I've been sending on new high resolution climate modeling showing forcing towards an El Nino-like, warm PDO pattern.

The Equilibrium Climate Sensitivity and Cloud Feedback virtual symposiums feature presentations by leading researchers on climate dynamics. The April 30 symposium was a panel discussion, "[Can we rule out internal variability as the main driver of recent tropical SST trends?](#)" Robert Jngln Wills presented a synthesis of recent research showing that the pattern of recent tropical SST trends is partly forced.

Partially

The Recent Tropical SST Trend Pattern is Forced

Contributions from:
 Yue Dong, Cristian Proistosescu, Kyle Armour, David Battisti, Pedro DiNezio, Maria Rugenstein, Shreya Dhame, Dirk Olonscheck, Richard Seager, Masahiro Watanabe, and the ForceSMIP project

Robert Inglin Wills
 ECS & Cloud Feedback Symposium
 April 30, 2024

ETH zürich

Wills also presented the results of new high-resolution CESM1 modeling which showed a dramatic reversal in forcing this decade towards an El-Nino like, warm Pacific Decadal Oscillation pattern in the eastern Pacific.

These are a few key slides from Wills' presentation -- shared with permission. Wills showed two competing mechanisms of tropical Pacific climate change -- a transient response with La-Nina like warming, and an equilibrium response with El-Nino like warming.

Competing mechanisms of tropical Pacific climate change

**El-Niño-like warming,
weaker Walker circulation**

Relevant mechanisms: In a warmer/moister climate, increased energetic demands to sustain zonal evaporative contrast and convective mass flux (*this is the equilibrium response in GCMs*)

**La-Niña-like warming,
stronger Walker circulation**

Relevant mechanisms: Delayed warming of upwelling sub-surface water; northward ITCZ shift due to aerosol or other non-GHG external forcing (*these mechanisms apply to transient climate change*)

The transient response was found in a forcing experiment with the CESM1 model by Yen Ting Hwang et al. with Clara Deser. The experiment suddenly switched on a forcing by constant sulfate aerosol emissions representative of 1980s levels for the first 30 years, followed by an abrupt return to 1850 levels for an additional 30 years. The modeling showed a fast response to an El Niño-like pattern when the aerosol forcing was abruptly increased, and a slow component with a La Niña-like pattern. See [Contribution of anthropogenic aerosols to persistent La Niña-like conditions in the early 21st century \(pnas.org\)](https://www.pnas.org).

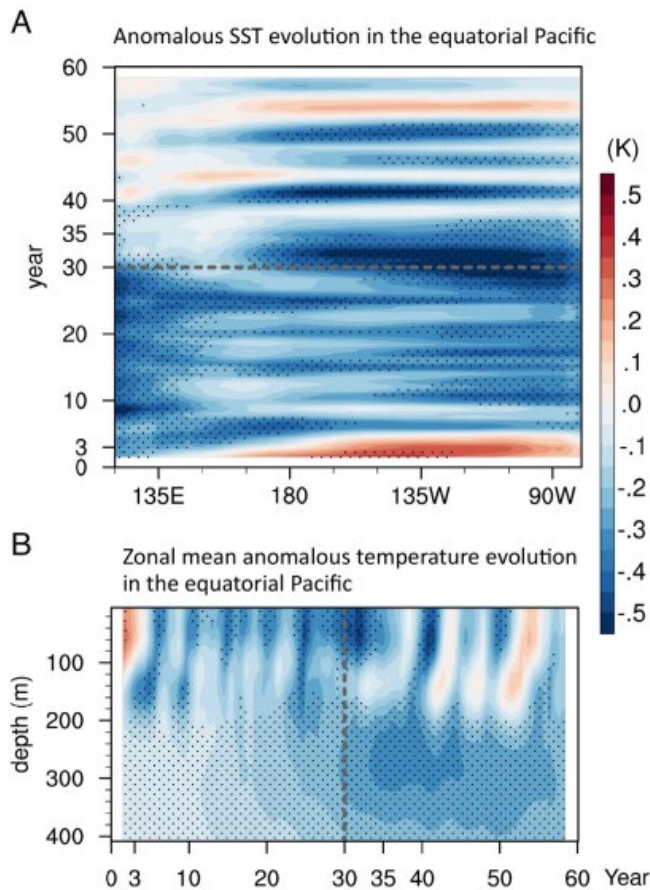


Fig. 1. Temporal evolutions of anomalous oceanic temperature in the idealized aerosol experiments relative to the climatology in the control simulation. (A) The 3-y running mean of meridionally averaged SST anomalies in the equatorial Pacific (5°S-5°N). (B) The 3-y running mean of the equatorial Pacific temperature response which is zonally and meridionally averaged (5°S-5°N; Pacific basin). Dotted region indicates statistically significant values of temperature anomalies at the 95% confidence level based on two-sided t test.

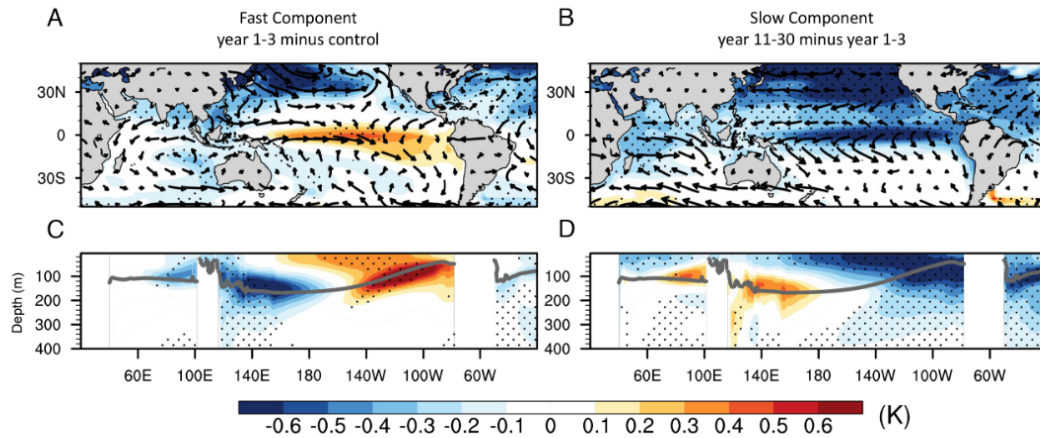


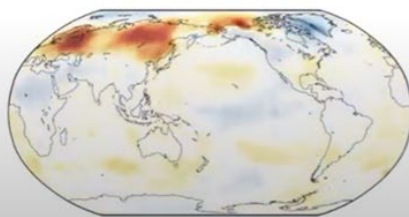
Fig. 3. The fast and slow responses in the idealized aerosol experiments. (A and B) Spatial patterns of SST (shaded) and surface wind stress (vector) anomalies. (C and D) Vertical structure of potential temperature anomalies along the equator (5°S–5°N mean) as a function of depth (m). Dotted region indicates statistically significant values of temperature anomalies at the 95% confidence level based on two-sided *t* test.

The Forced Component Statistical Method Intercomparison Project, conceptualized by Robert Ingle Wills and Clara Deser, is trying to estimate the forced response using statistical and Machine Learning methods. From the April 30 presentation by Robert Ingle Wills.

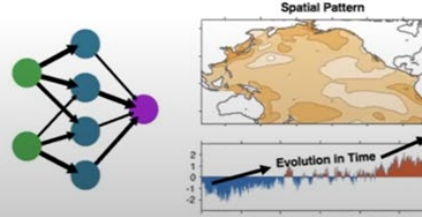
What is the forced response in observations?

- Rather than testing whether it is possible that the observed trends can be explained by models, we should be trying to figure out what the true forced response is.
- This is the goal of the Forced Component Statistical Method Intercomparison Project (ForceSMIP)

The ForceSMIP challenge: (1) Develop statistical and ML methods that, given a single realization of the climate system (and training data from climate models), can estimate the spatiotemporally evolving forced response, (2) Test with large ensembles, (3) Apply to observations



HadCRUT4 3-month running mean surface temperature anomalies



Example forced response estimate from Wills et al. 2018

What is the forced response in observations?

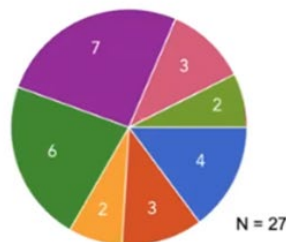
Forced Component Statistical Method Intercomparison Project (ForceSMIP)

ForceSMIP Organizers: Robert Jnglin Wills¹, Clara Deser², Karen McKinnon³, Adam Phillips², Stephen Po-Chedley⁴, Sebastian Sippel⁵

ForceSMIP Contributors: Constantin Bône⁶, Céline Bonfils⁴, Gustau Camps-Valls⁷, Stephen Cropper³, Charlotte Connolly⁸, Shiheng Duan⁴, Homer Durand⁷, Alexander Feigin⁹, Martin Fernandez⁸, Guillaume Gastineau⁶, Andrey Gavrilov⁹, Emily Gordon⁸, Moritz Günther¹⁰, Maren Höver¹, Sergey Kravtsov¹¹, Yan-Ning Kuo¹², Justin Lien¹³, Gavin Madakumbra³, Nathan Mankovich⁷, Matt Newman¹⁴, Jamin Rader⁸, Jia-Rui Shi¹⁵, Sangik Shin¹⁴, Gherardo Varando⁷, Tristan Williams⁷

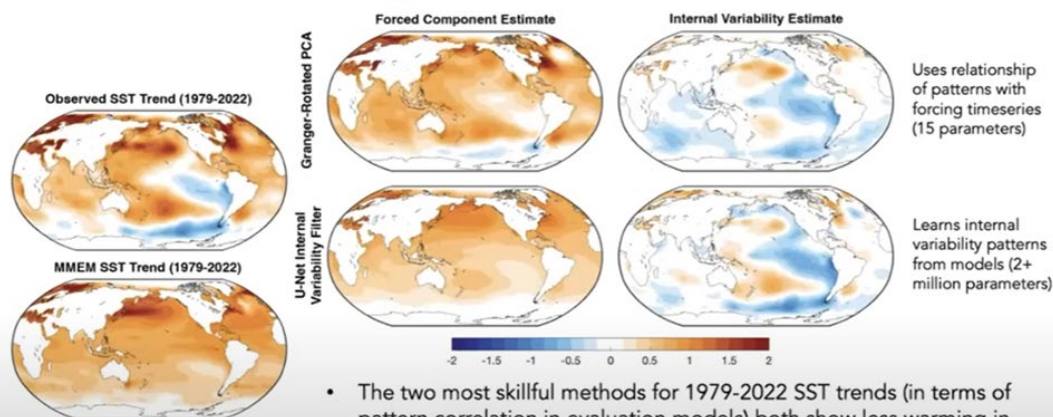
¹ETH Zürich, ²NCAR, ³UCLA, ⁴LLNL, ⁵University of Leipzig, ⁶LOCEAN, ⁷University of Valencia, ⁸Colorado State University, ⁹Institute of Applied Physics, RAS, ¹⁰MPI-Meteorology, ¹¹University of Wisconsin Milwaukee, ¹²Cornell, ¹³Tohoku University, ¹⁴NOAA PSL, ¹⁵WHOI

27 methods of widely varying complexities



- Neural network
- Other machine learning method
- Linear timescale separation method (e.g., LFCA)
- Linear fingerprinting method
- Linear dynamical mode method (e.g., LIM)
- Linear regression (e.g., on GMST or forcing timeseries)
- Combination of methods

What is the forced response in observations?



- The two most skillful methods for 1979-2022 SST trends (in terms of pattern correlation in evaluation models) both show less warming in East Pacific than West Pacific despite very different methods and complexities
- Caveat: methods that estimate that the observed forced response looks like models are only moderately less skillful

ForceSMIP project
Methods: Bône et al. (preprint),
Varando et al. (preprint)

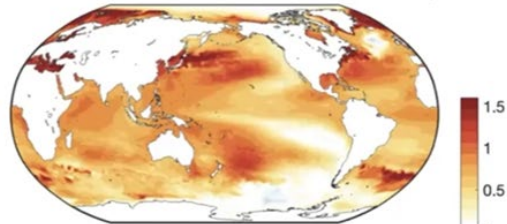
More about ForceSMIP is here: [Advanced Techniques Help Decipher Past Climate Change | Earth & Environmental Systems Modeling \(energy.gov\)](#). It was jump-started in late 2023.

Wills concluded with a slide showing results from a high res version of CESM1, indicating a dramatic reversal from the forced response in recent decades.

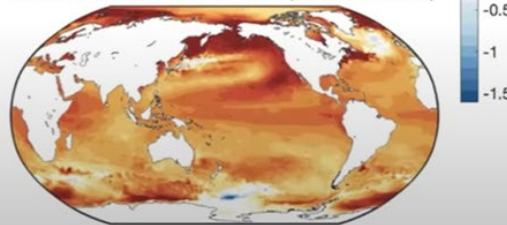
The forced response in a high-resolution model with reduced double-ITCZ bias

- Looking to the future (under high emissions), CESM1-HR shows an SST warming pattern associated with much more positive feedbacks, suggesting a very large pattern effect in this model
- We are investigating possible mechanisms for this reversal in the forced response (e.g., transient thermostat response, large response to aerosols or other non-GHG forcing)

CESM1-HR 1980-2022 SST Trend (4-member mean)

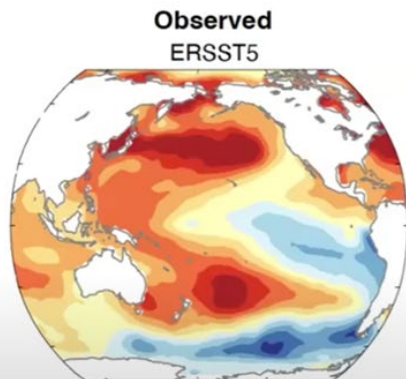


CESM1-HR 2023-2050 SST Trend (4-member mean)

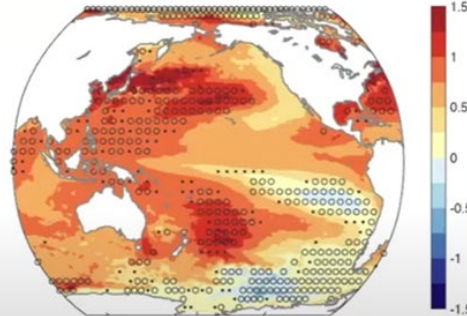


The high res model with reduced double-ITCZ bias does a much better job of capturing the recent pattern of warming in the Pacific better than the CESM1 low resolution model.

The forced response in a high-resolution model with reduced double-ITCZ bias



CESM1-HR
(0.25-degree atmosphere, 0.1-degree ocean)
4-member mean

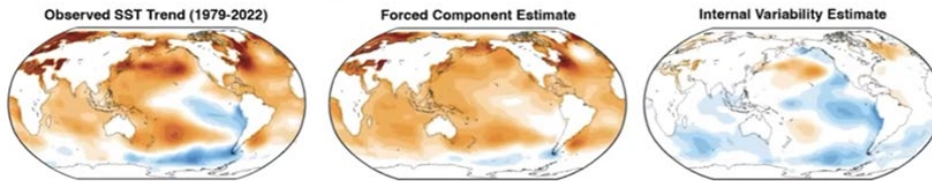


Open circles: Outside the distribution of subsamples from CESM1-LR
Dots: Outside 95% CI of subsamples from CESM1-LR

DiNezio et al. (in prep.)

These were Wills' conclusions about the recent pattern of sea surface temperatures in the Pacific.

Conclusions: Is recent tropical SST trend pattern forced or unforced?



- **Both.** Some of this pattern is certainly internal variability, but given systematic climatological biases, we should expect the multi-model-mean forced response to be biased. The challenge is figuring out exactly what the trend bias looks like
- Statistical estimates of the forced response from observations (from the ForceSMIP project) are highly uncertain but suggest that western intensified warming is part of the forced response over 1979-2022
- CESM1-HR shows an SST trend pattern similar to observations and illustrates a link between the double-ITCZ bias and the SST-trend-pattern bias, suggesting that fixing this long-standing bias may be essential for improving simulations of the pattern effect

Robert Jnglin Wills, ETH Zürich

Contact: r.jnglinwills@usys.ethz.ch

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Deirdre Des Jardins

California Water Research

"The future enters into us, in order to transform itself in us, long before it happens" --
Rainer Maria Rilke

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