

Using the CESM2 Large Ensemble to Evaluate CSEOF Separation of Internal and Forced Components of Sea Level Change

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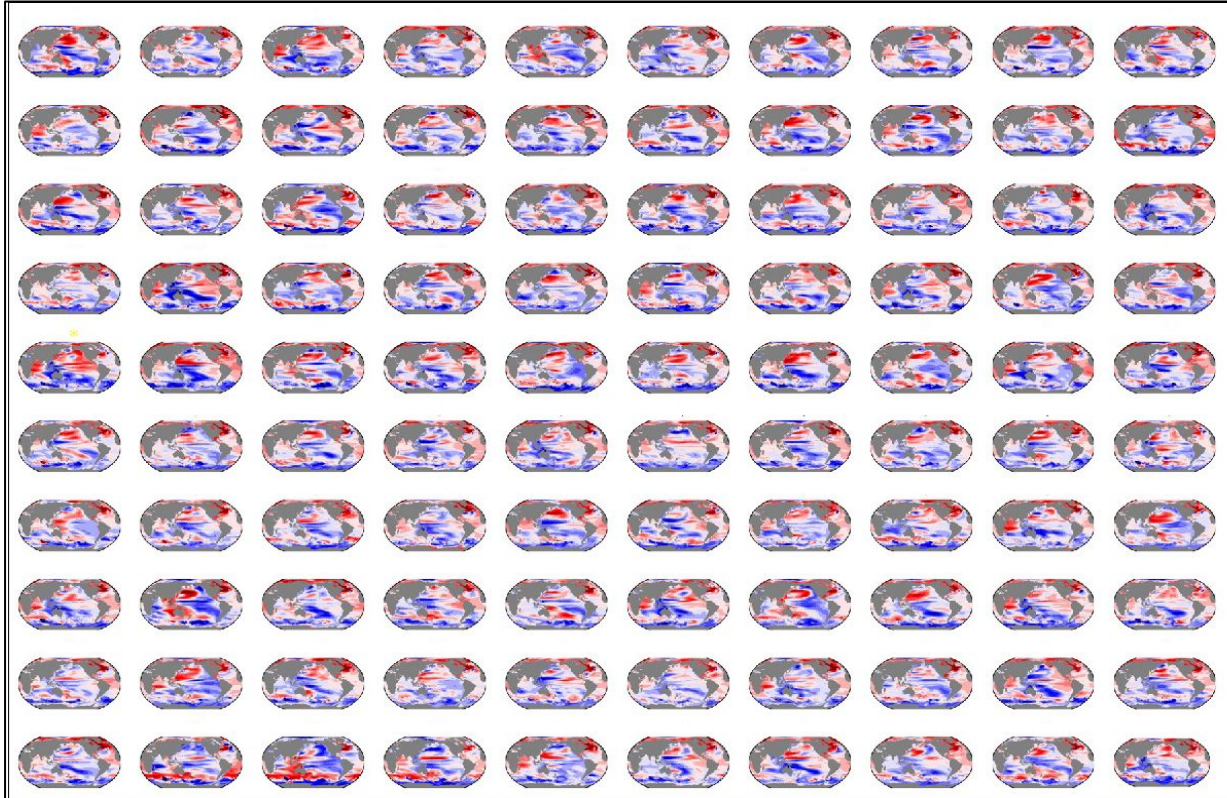
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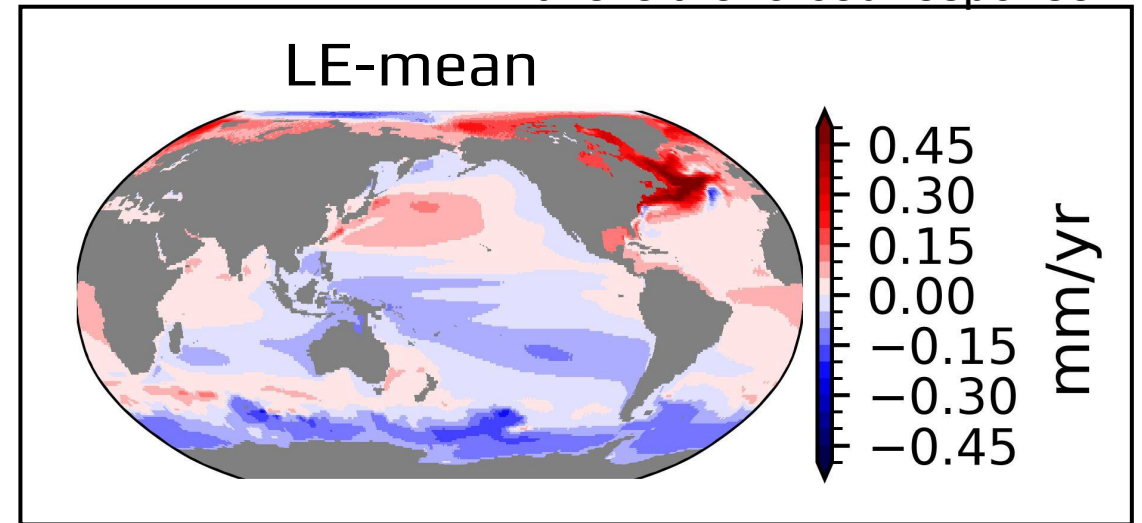
Motivation & main points

1. Internal variability can obscure the forced response
2. CSEOFs have been used to reduce the internal variability in, e.g., the satellite altimeter data, but it's not clear
 - a) **how much internal variability remains in the CSEOF-corrected data?**
 - b) **how well are internal variability and the forced response separated by the CSEOF modes?**
3. With the CESM2 large ensemble, ***we know the forced response*** and can therefore assess the efficacy of CSEOFs at removing internal variability

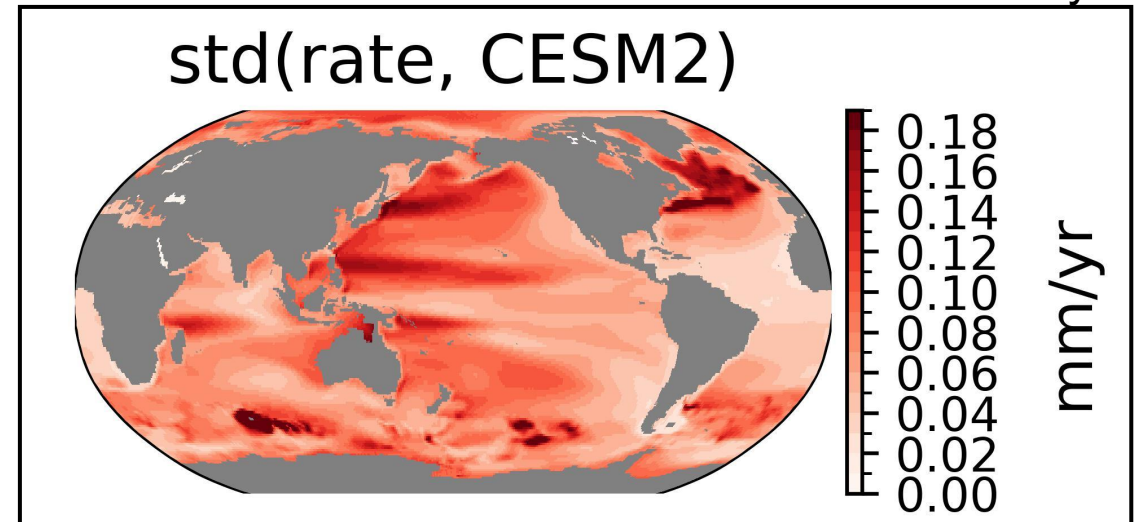
Rate of Sea Level Change in the CESM2 Large Ensemble



*this is the forced response!



*this is internal variability!



Research Questions

1. To what degree can CSEOFs increase the correlation of the rate map with the forced response?

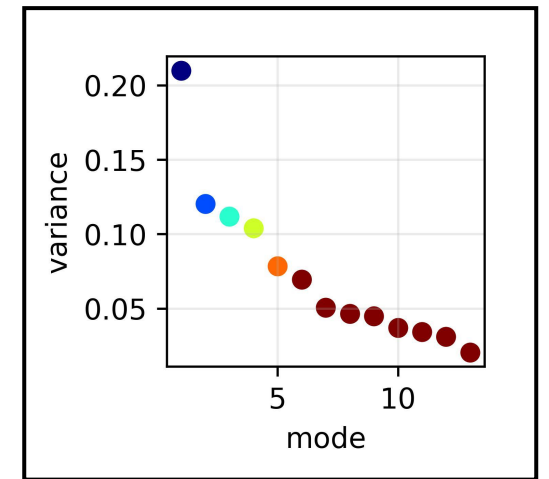
Answer: 0.00-0.15

2. To what degree can CSEOFs reduce the standard deviation of the rate map across members?

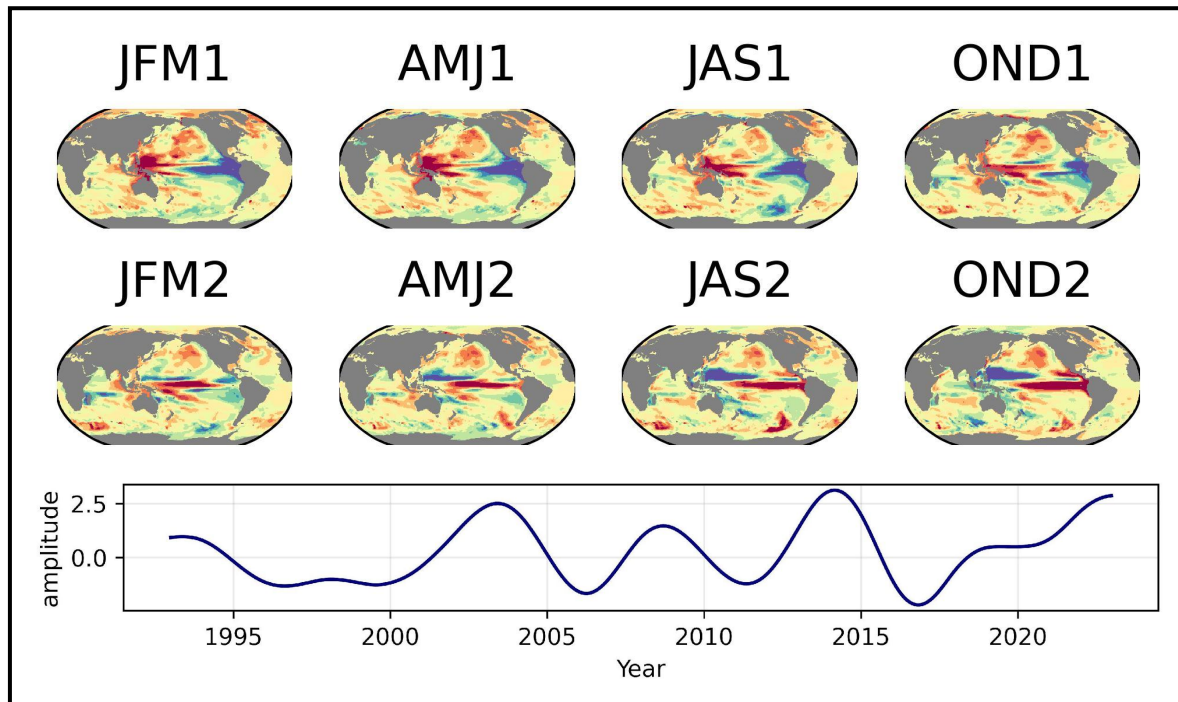
Answer: 0%-50%

CSEOF Modes

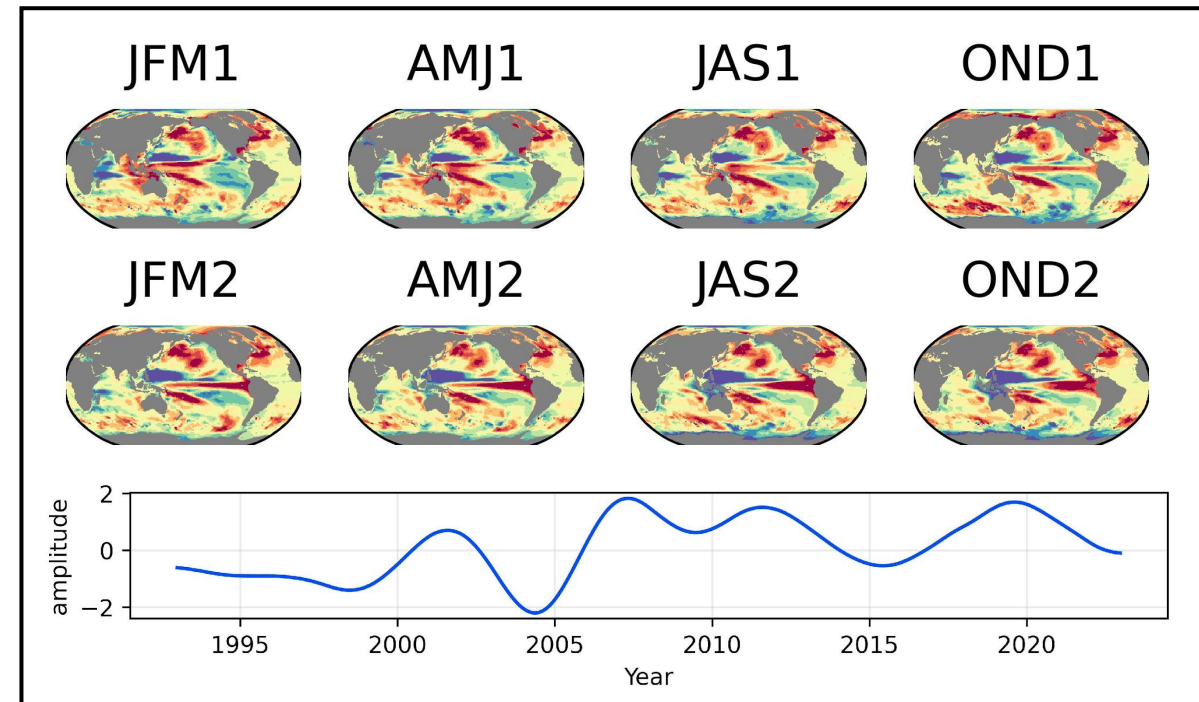
- CSEOFs are **cyclo-stationary** EOFs
- The spatial component of CSEOF modes can vary periodically on a **nested period**
- We choose **nested period equal to 2 years**



Mode 1



Mode 2

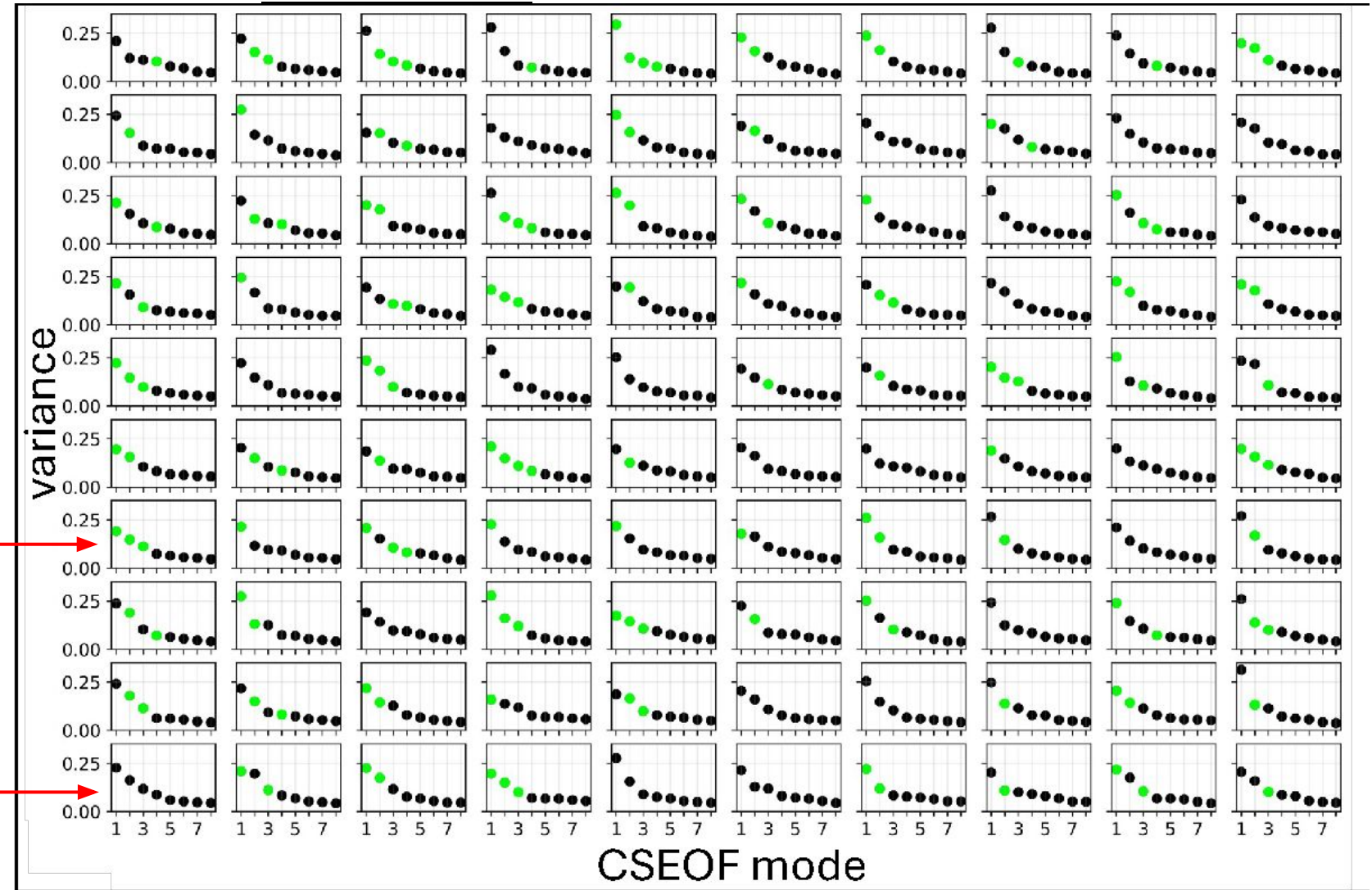


CSEOF Decomposition of Monthly Sea Level Data from the CESM2 Large Ensemble

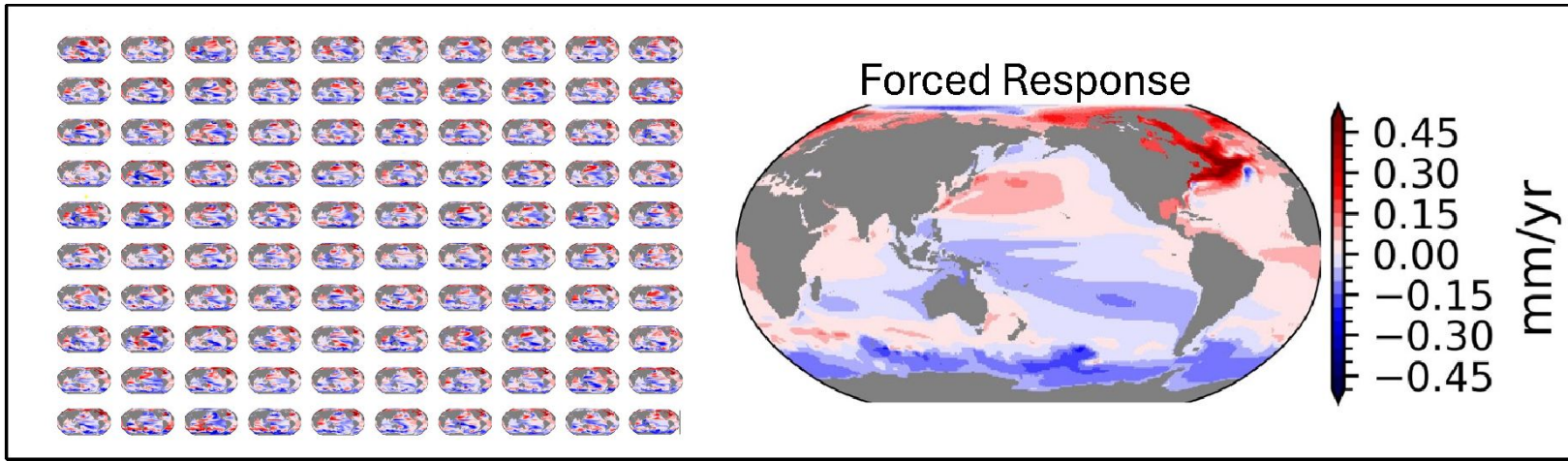
Modes that represent internal variability are marked in green

A significant amount of the total variance is internal variability

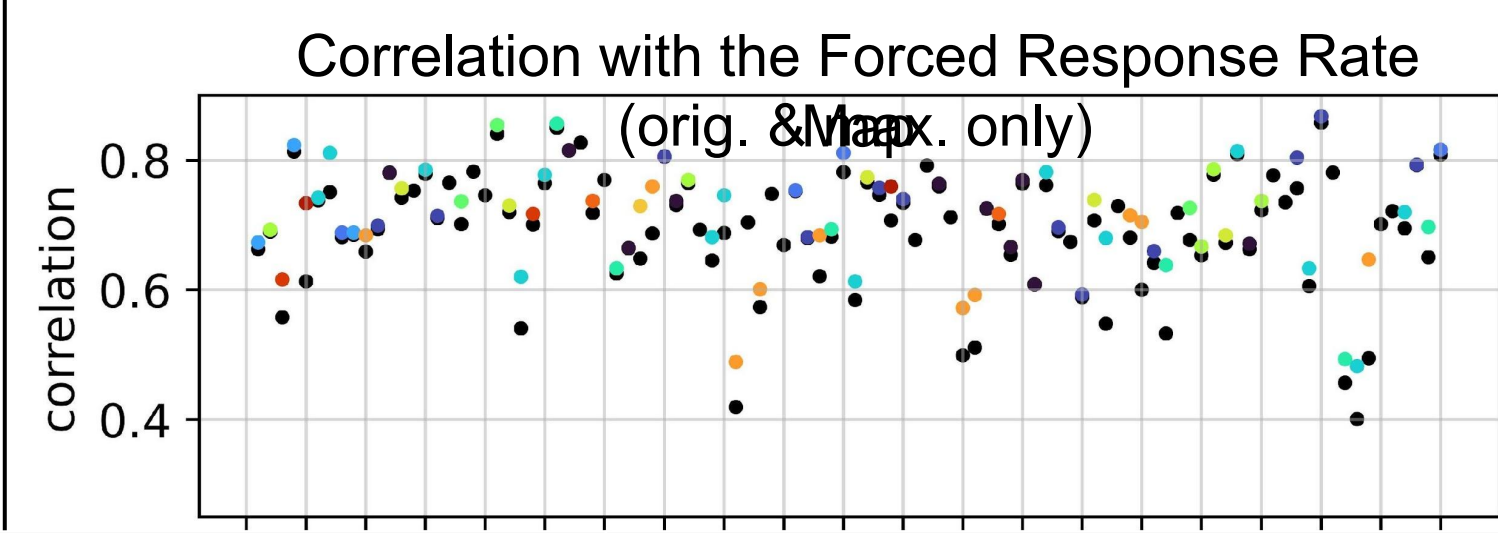
None of the variance is identified as internal variability



Which modes represent internal variability?



- CESM2_dszn
- rmv mode 1
- rmv mode 2
- rmv mode 3
- rmv mode 4
- rmv mode 12
- rmv mode 13
- rmv mode 14
- rmv mode 23
- rmv mode 24
- rmv mode 34
- rmv mode 123
- rmv mode 134
- rmv mode 234



mean correlation prior to removing CSEOFs

mean correlation after removing CSEOFs

max increase in correlation

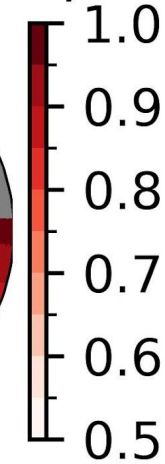
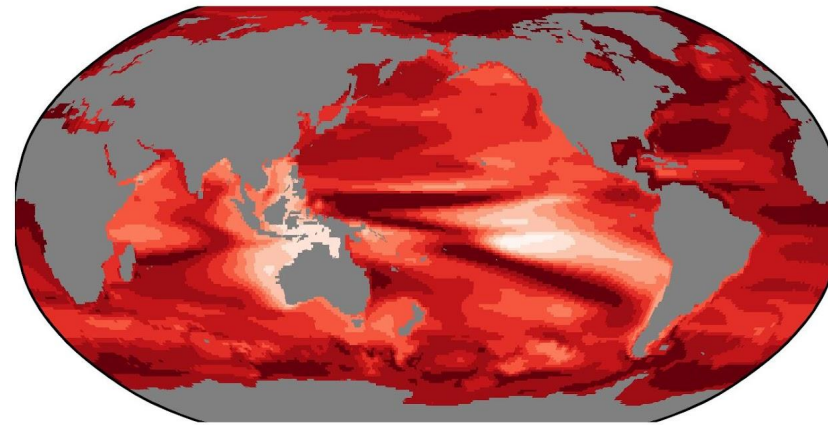
0.69

0.72

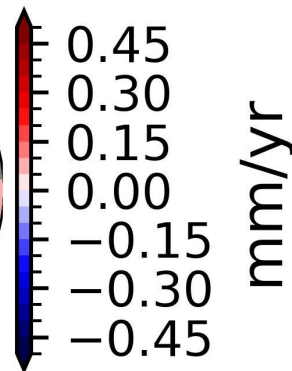
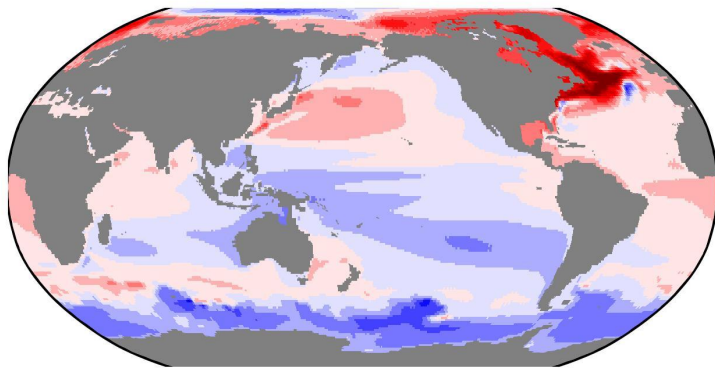
0.15

Reduced standard deviation indicates reduced internal variability

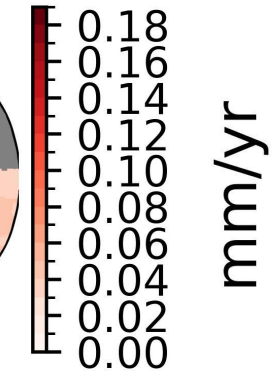
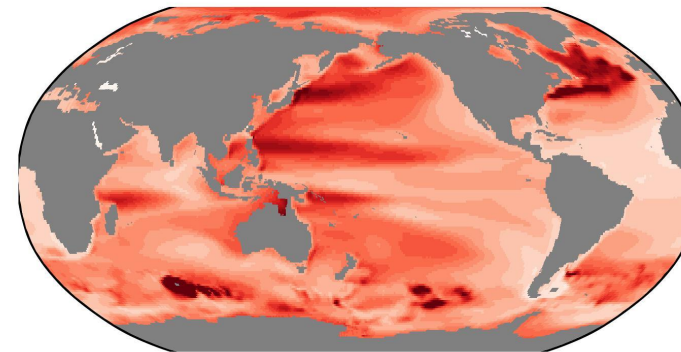
$\text{std}(\text{rate, CESM2-CSEOFs})/\text{std}(\text{rate, CESM2})$



Forced Response



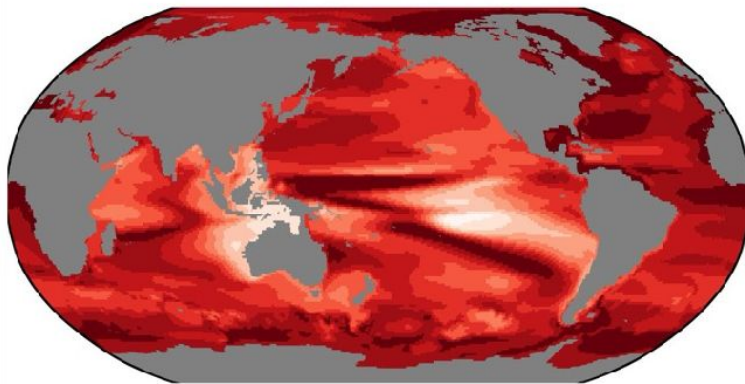
$\text{std}(\text{rate, CESM2})$



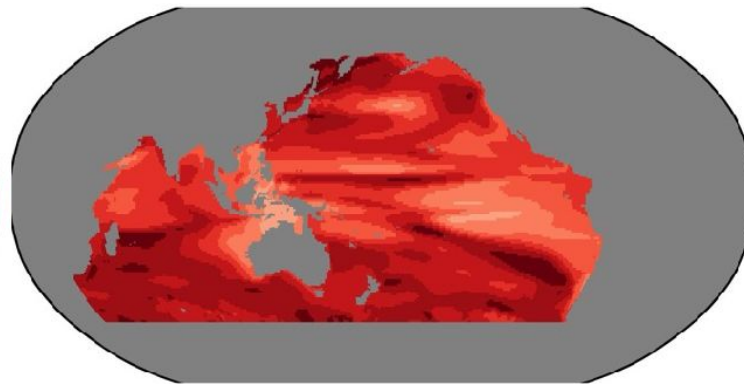
Consider Regions Independently

Region	mean correlation prior to removing CSEOFs	mean correlation after removing CSEOFs	max increase in correlation
Global	0.69	0.72	0.15
Indo-Pacific	0.50	0.55	0.25
Atlantic	0.85	0.86	0.21

$\text{std}(\text{rate, CESM2-CSEOFs})/\text{std}(\text{rate, CESM2})$



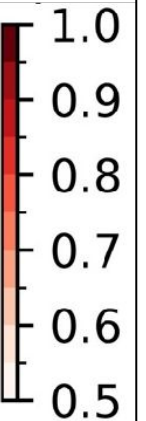
Global



Indo-Pacific



Atlantic



Conclusions & Future Work

1. How well are internal variability and the forced response separated by the CSEOF modes?
 - *i.e., to what degree can CSEOFs increase the correlation of the rate map with the forced response?*

Answer: 0-0.15

 - Instead of removing CSEOF modes based on optimizing the rate map, try based on mode similarity to the member-specific PDO and/or ENSO indices
2. How much internal variability is removed in the CSEOF-corrected data?
 - *i.e., to what degree can CSEOFs reduce the standard deviation of the rate map across members?*

Answer: 0-50%