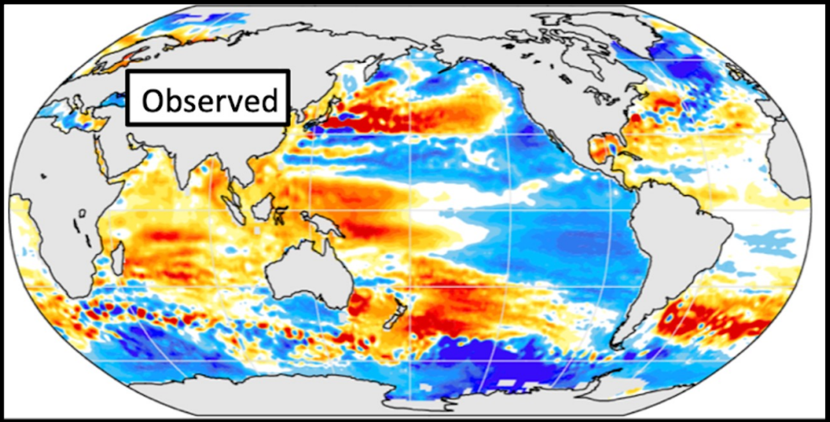
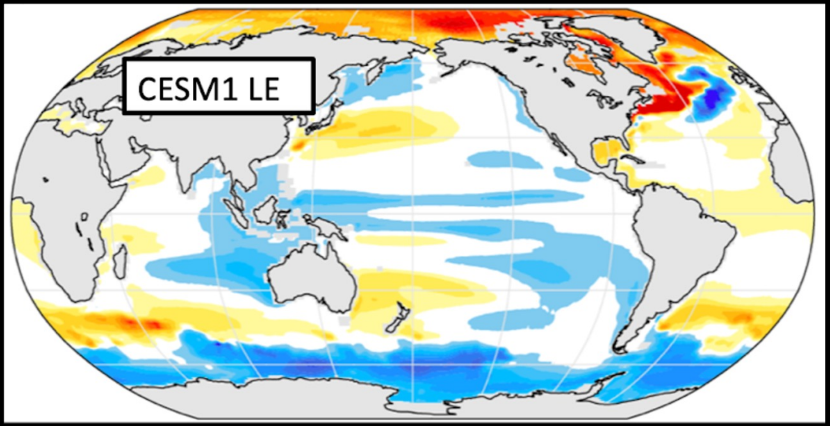
Understanding Differences Between Regional Sea Level Trends from Altimetry and Climate Model Large Ensembles





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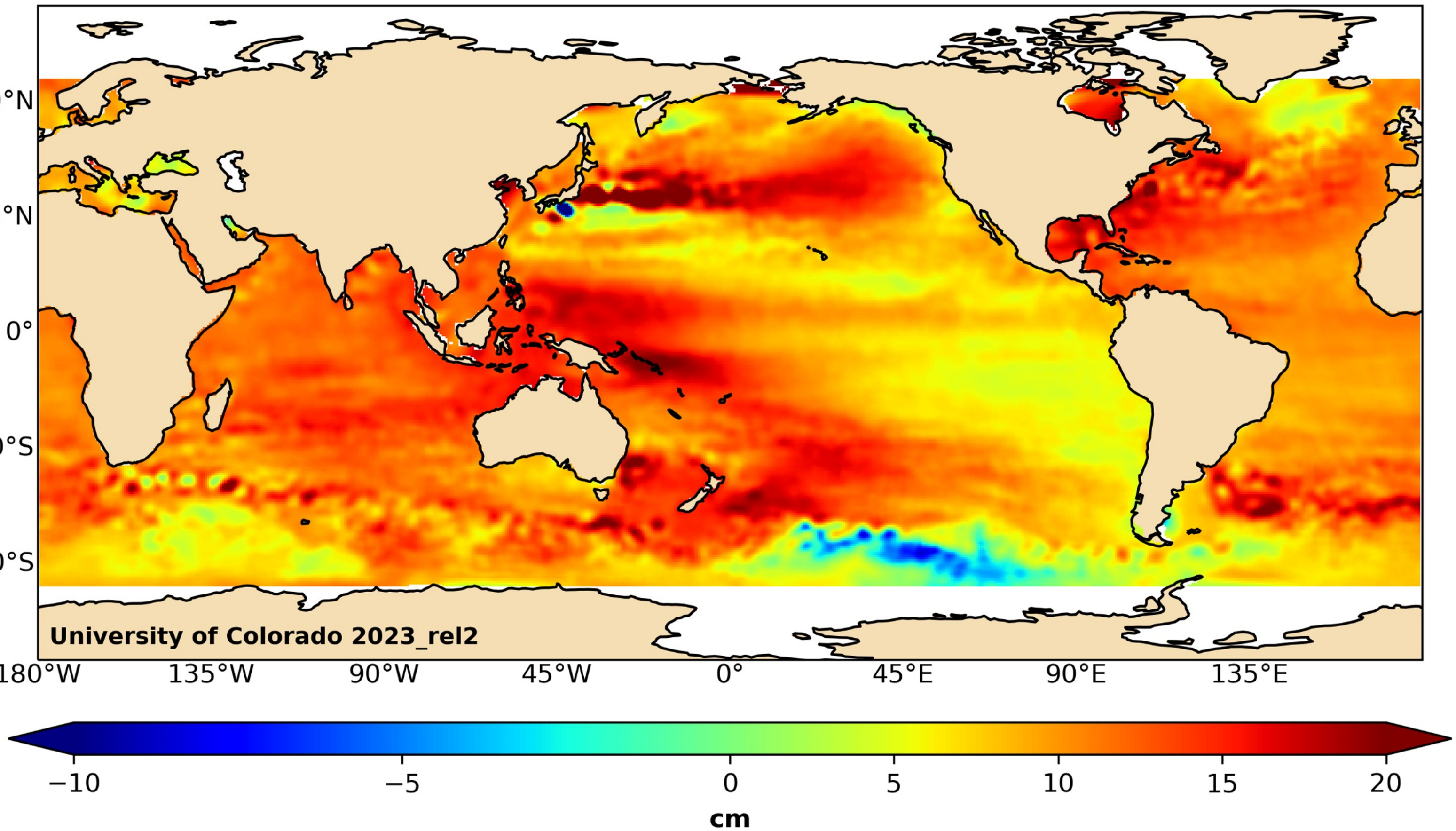
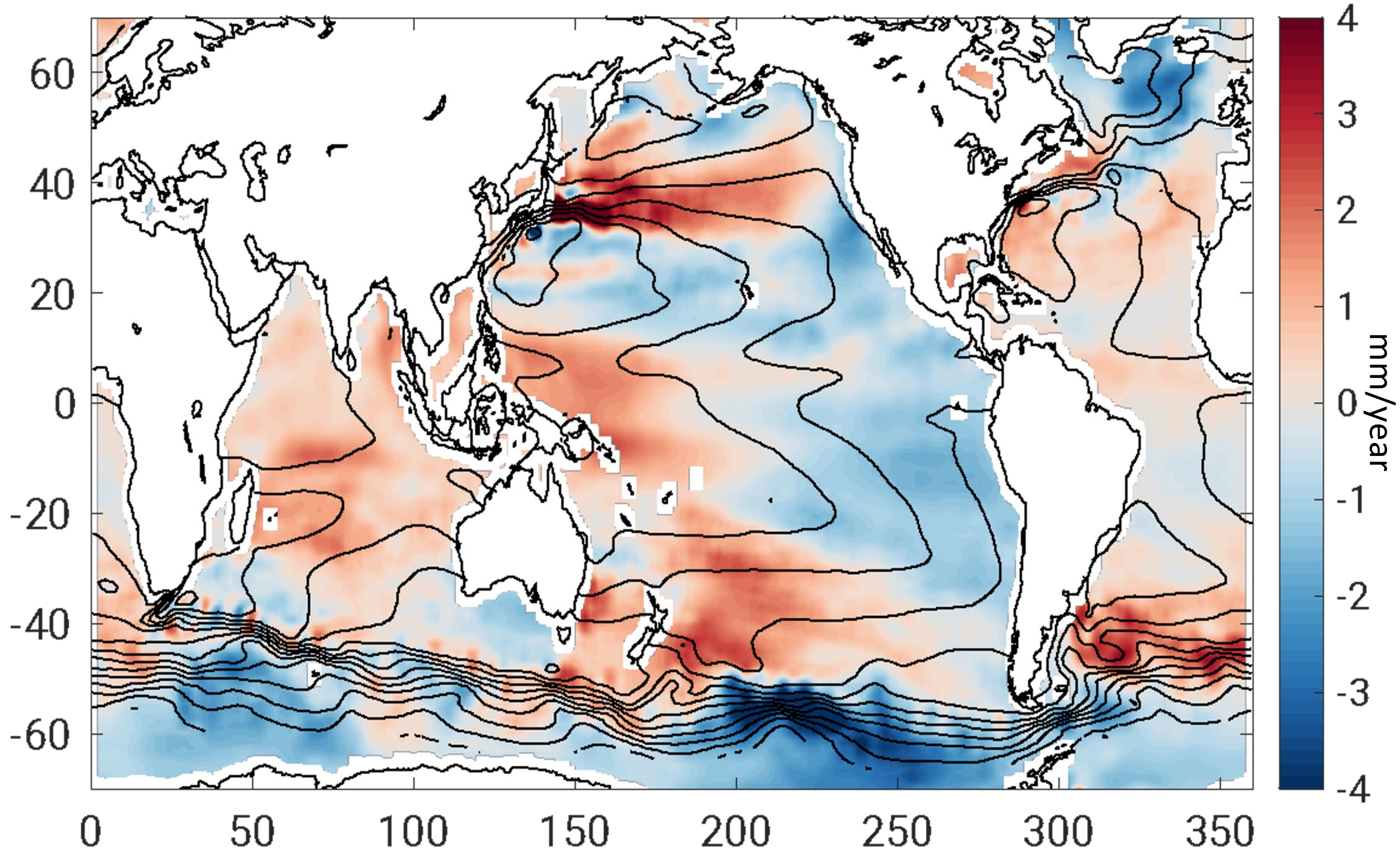
Total Sea Level Change (1993 – 2023)



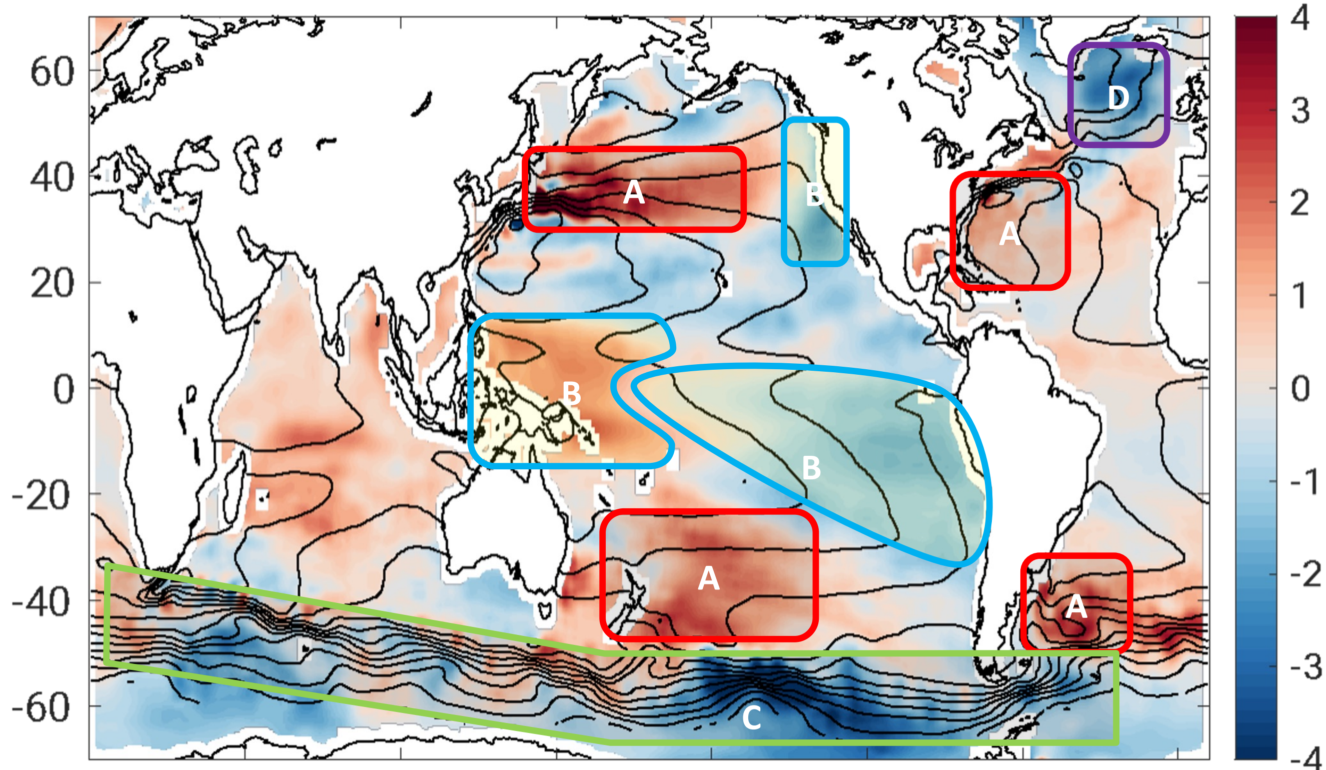
SSH Trends versus Ocean Dynamic Topography



Changes in Oceanic & Atmospheric Circulations Drive SLR Patterns Through Coupled Dynamics

A. Sverdrup transport convergence driving changes in subtropical gyres/WBCs, driven by changes in Hadley cells, jet stream, gradients in DT.

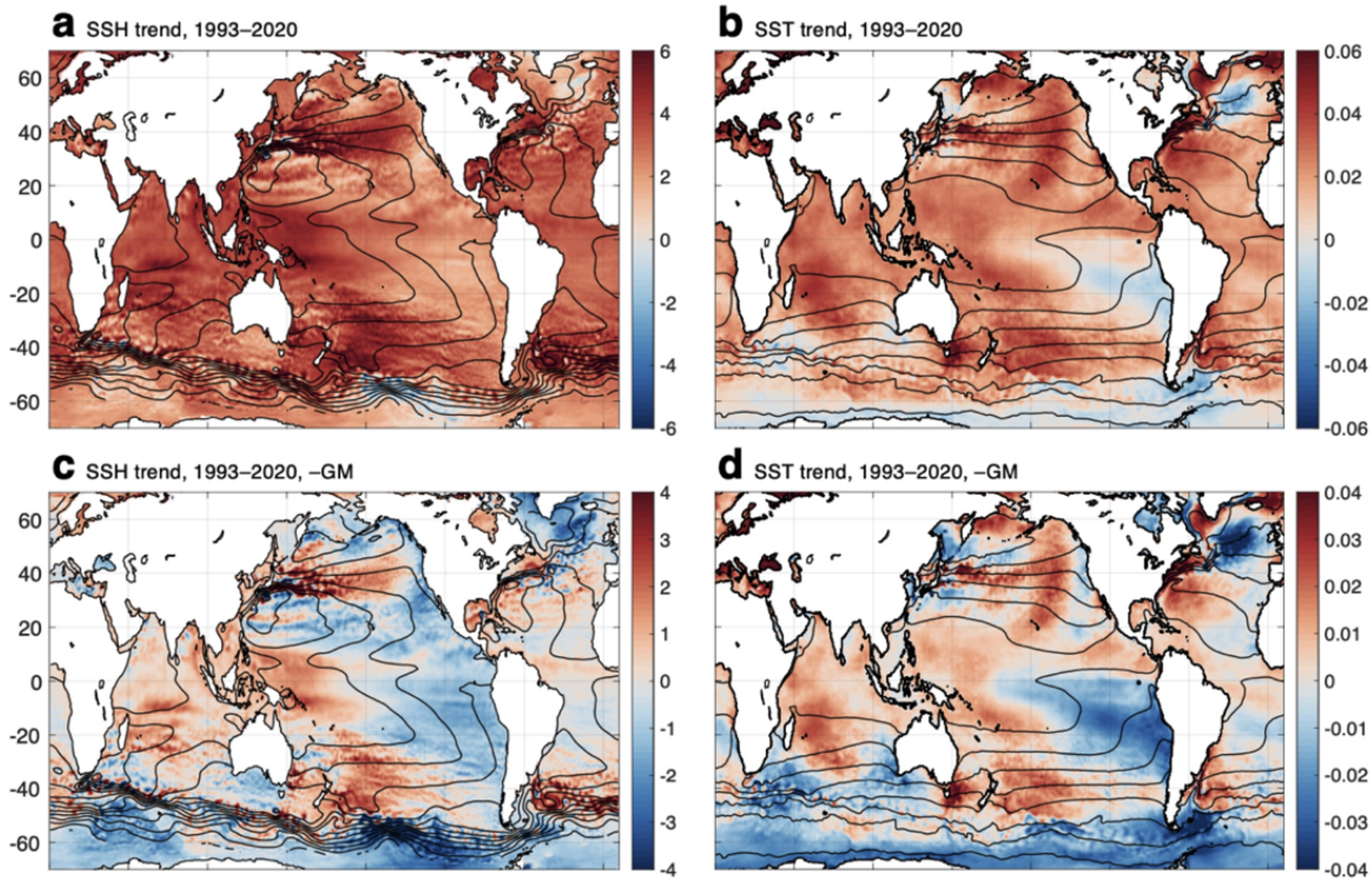
B. Stronger trade winds leads to Ekman dynamics driving changes in upwelling and thermocline depth tilt.



C. ACC changes: Strong DT gradient + Ekman dynamics

D. Possible AMOC slowing, less heat being delivered, freshwater from Greenland?

SSH versus SST Trends Over the Altimeter Era

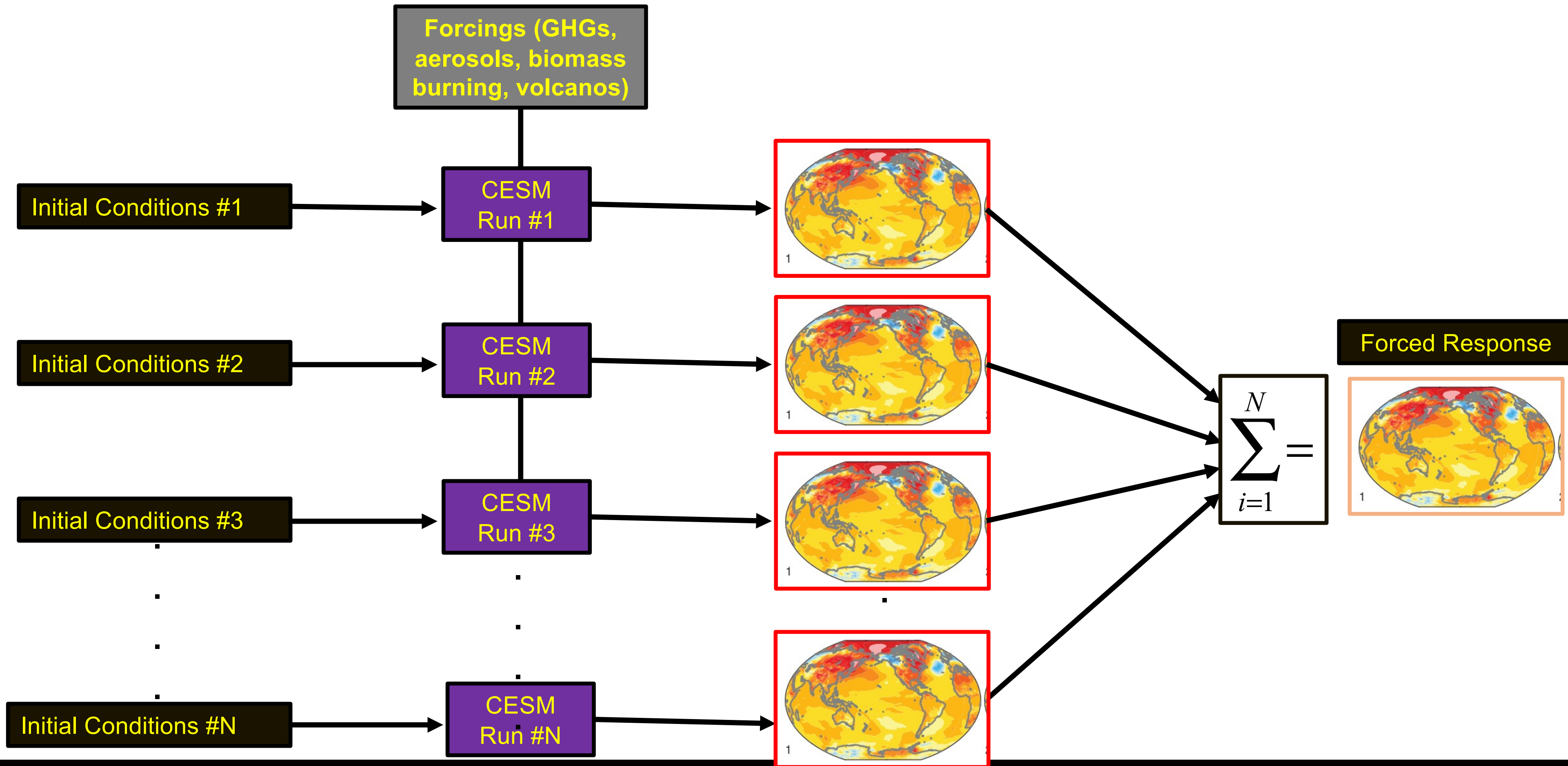


Global
Mean
Removed

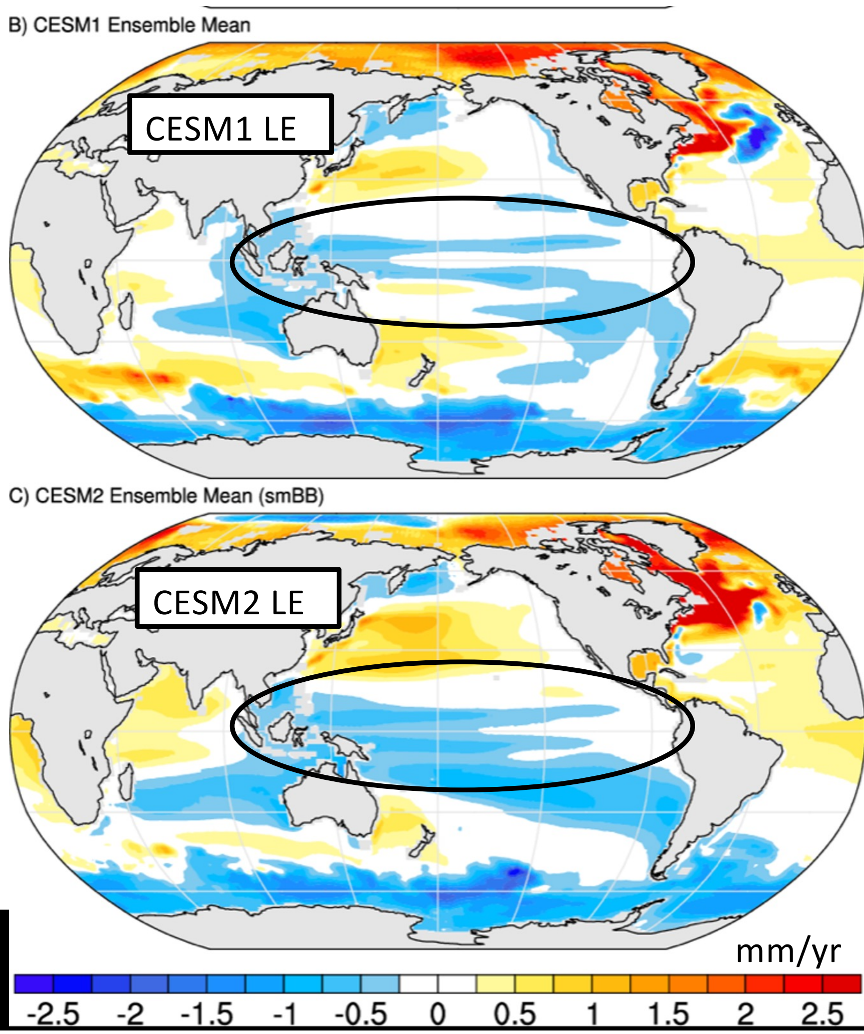
Using Climate Model Large Ensembles to Identify the Forced Response

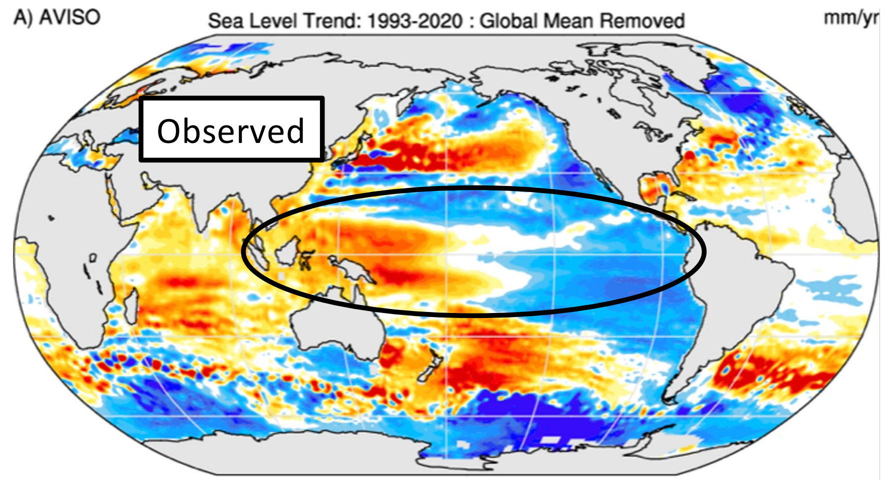
- Used to isolate the effects of Greenhouse gases and aerosols ("The Forced Response (FR)").
- Multi-Model Large Ensembles – averages of many different climate models (e.g., CMIP5, CMIP6).
- Single-Model Large Ensembles – a single model, run many times, with different initial conditions but with the same forcings (e.g. CESM 40-member LE).
- Multi-Model LEs will contains structural differences between the models which may lead to errors in estimating the FR and its emergence.
- Ice sheets are not currently included in these models, so we are only using the models to interpret sterodynamic effects.

Climate Model Large Ensembles



Modeled and Observed Sea Level Trends (1993-2020)





- Global mean trend removed
- Modeled trends are generally smaller than observed trends
- Gradient across the tropical Pacific is missing in the models
- We are decomposing this using single-forcing model experiments.

Altimeter - Model Differences: Some Questions

- Why do the models show lower magnitude sea level trends than the observations?
- Why do the model trends not show the gradient across the tropical Pacific that is seen in the observations? (forced response or internal variability?, model structural bias? (Walker Cell)).
- Evidence is pointing towards the gradient being a forced response and that there is structural bias in the models, but the jury is still out.

Forced Response from Large Ensembles and Their Emergence

This slide shows the pattern of the forced response, the role of GHG and aerosols, and evidence that these patterns have emerged in altimetry (distribution of pattern correlations with the ensemble mean distinct from the PI control)

(*Fasullo and Nerem* 2018; *Fasullo et al*. 2020)

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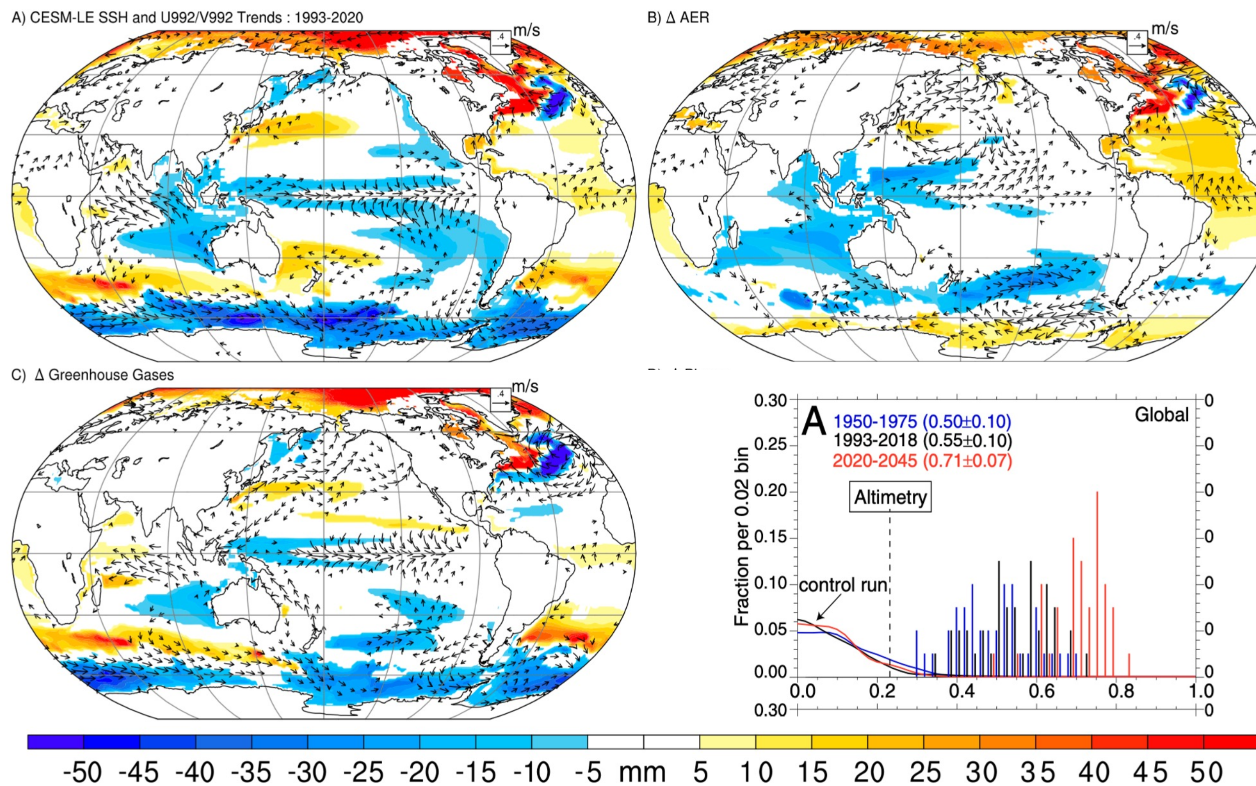
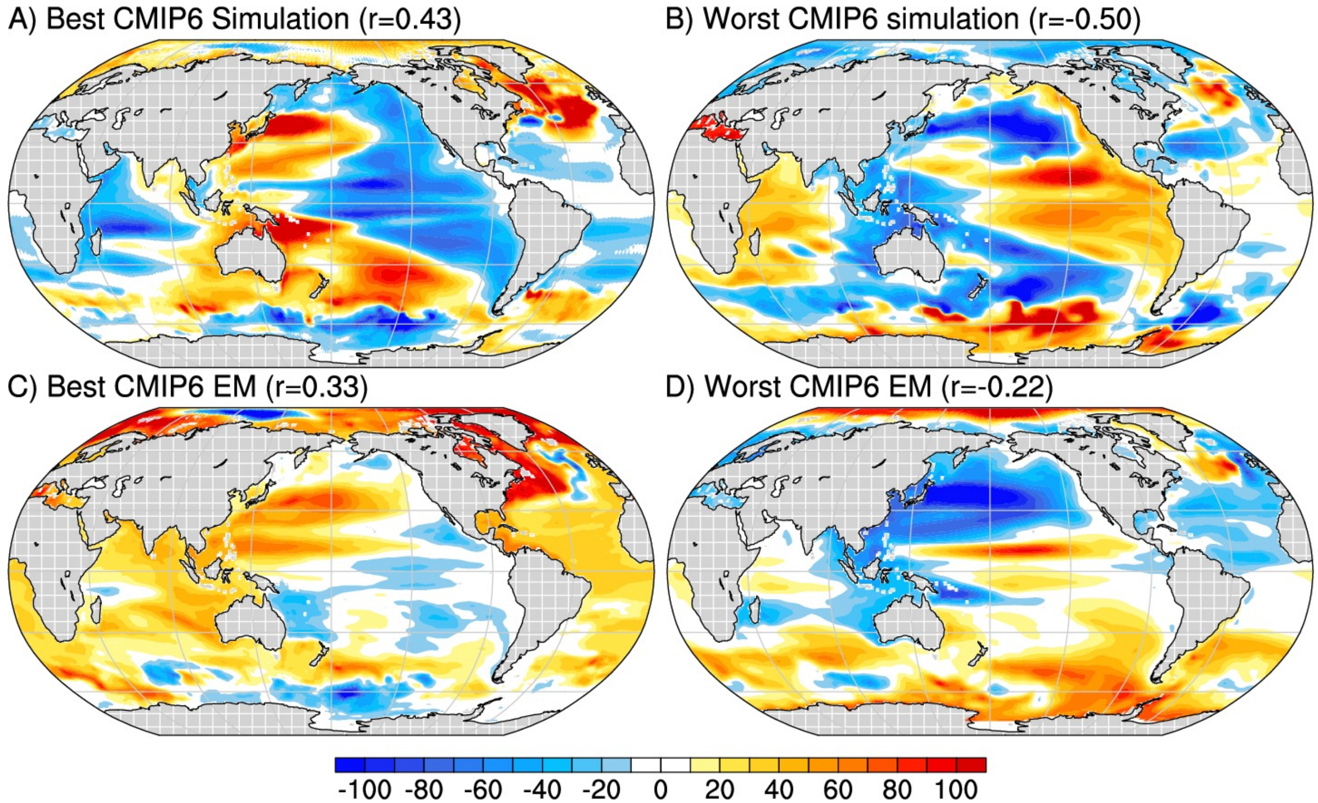


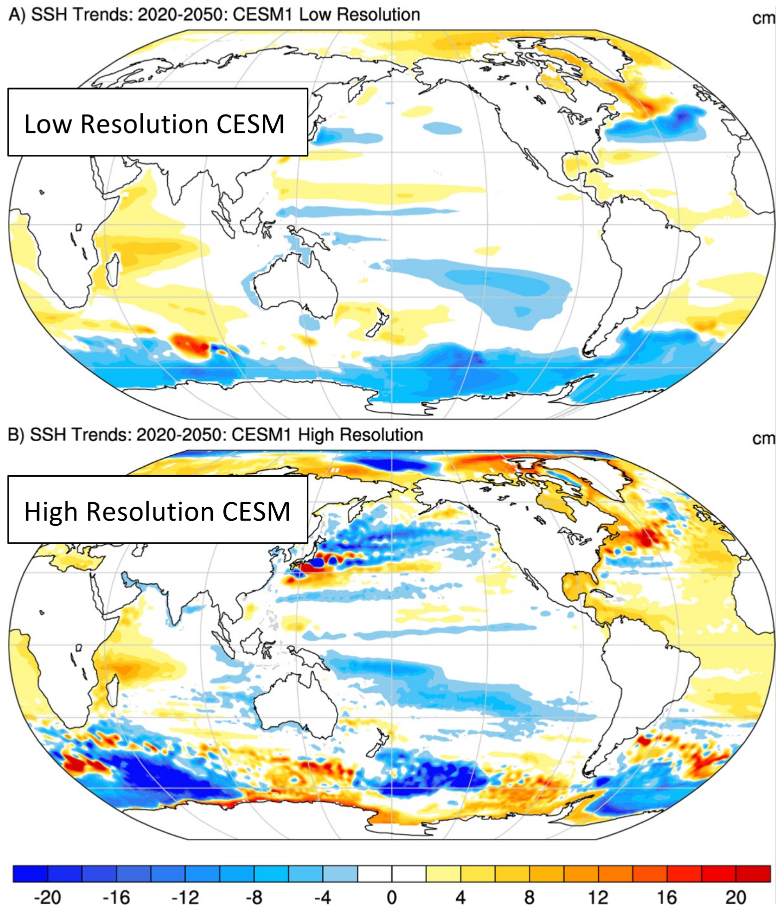
FIG. 5. As in Fig. 3, but for 1993–2020.

Forced Response from CMIP6 Ensembles



As we have broadened our scope to more large ensembles, we find substantial model contrasts, both in patterns and emergence. Uncertainties in forcing as well (e.g. Pinatubo, etc.)

Early Results from High Resolution Simulations

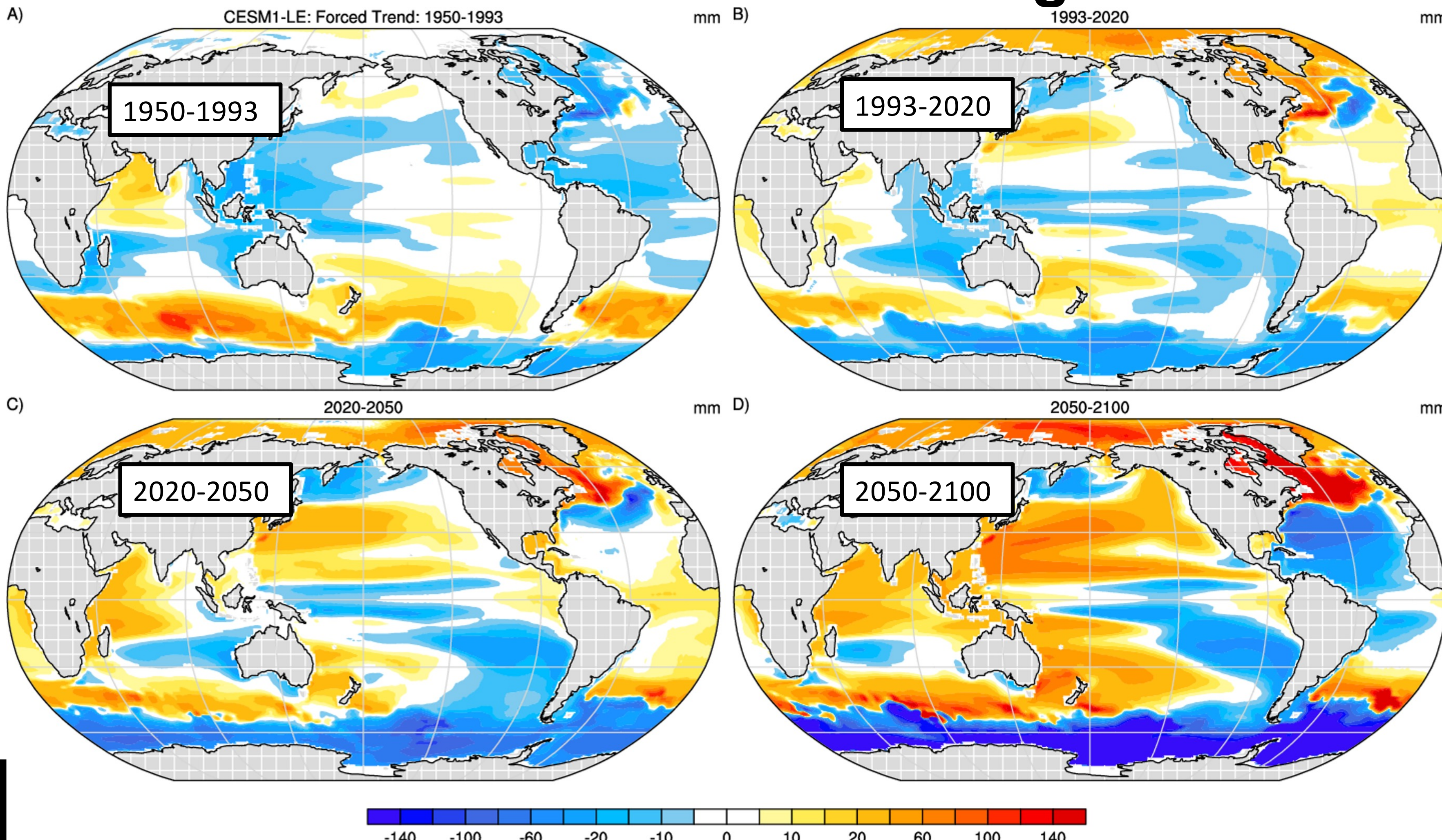


~1 degree

~0.1 degree

Initial examination of high-resolution simulations suggests they produce substantially more spatial variance than their low-resolution versions.

Forced Trends in the CESM1 Large Ensemble



Conclusions

- While there is agreement between some of features in the observations and the models, there are important differences.
- The forced response varies considerably across models and forcing uncertainty is as large an uncertainty as model structural uncertainty in diagnosing some effects (e.g. Pinatubo – Fasullo, biomass emissions).
- Averaging those patterns across models leads to an offsetting of random model structural error and a significant underestimate of the likely magnitude of the forced pattern in nature.
- The gradient across the Pacific seen in the 30-year sea level trends observations remains to be identified as a forced response or internal variability - arguments exist for both.
- High resolution models seem to better recover the magnitudes seen in the altimetry than low resolution models. Patterns of response are also improved. This is a recent result that needs to be further investigated in ensembles (under production).