South Asian monsoon connections to ENSO in different present and future climate base states

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Meehl, G.A., C. Shields, J.M. Arblaster, H. Annamalai, R. Neale, J.-C. Golaz, J. Fasullo, L. Van Roekel, A. Capotondi, and A. Hu, 2023: Climate base state influences on South Asian monsoon processes derived from analyses of E3SMv2 and CESM2, *Geophys. Res. Lett.*, **50**, e2023GL104313, https://doi.org/10.1029/2023GL104313.

Meehl et al., 2024: Processes that contribute to future South Asian monsoon differences in E3SMv2 and CESM2, *Geophys. Res. Lett.,* in revision.

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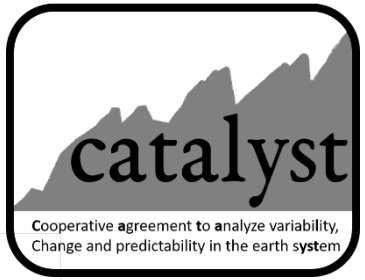
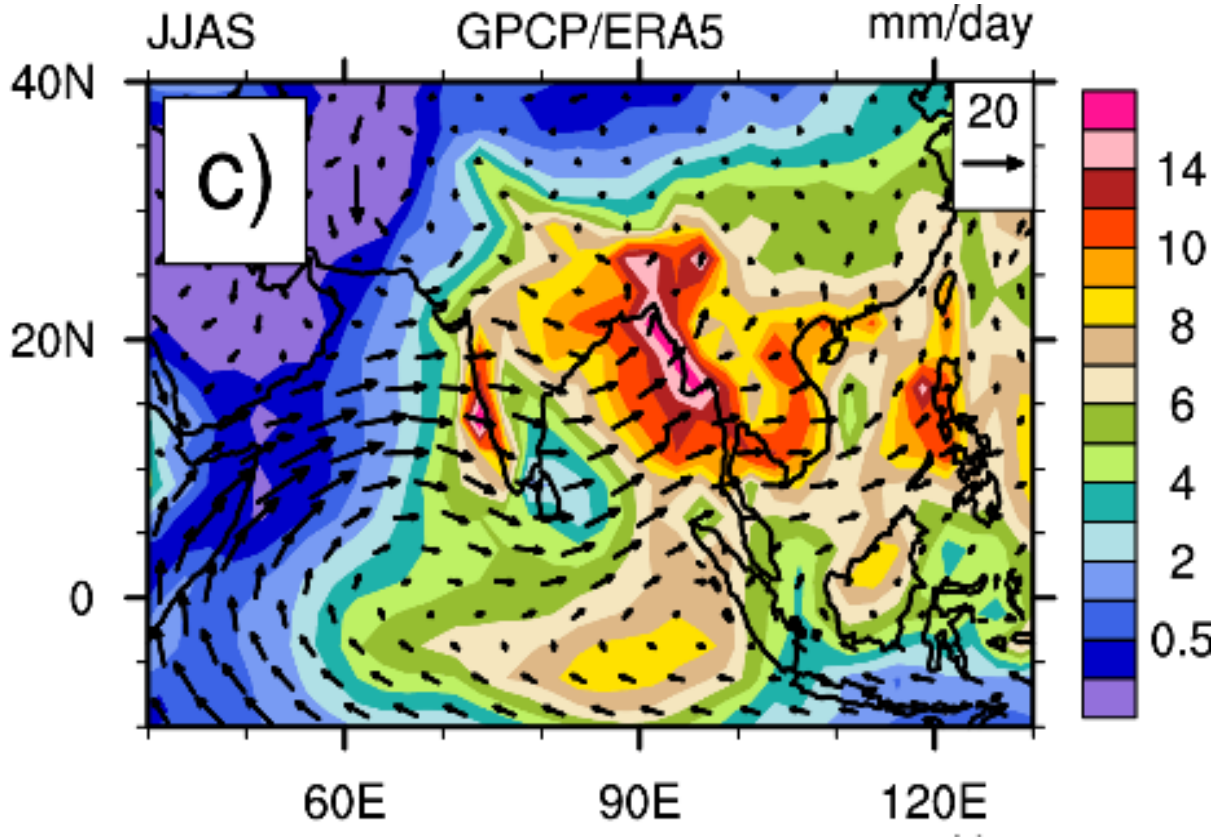


The South Asian monsoon is of vital socioeconomic importance to the ~2 billion people living across that region

Accurate prediction of South Asian monsoon rainfall on all timescales requires an understanding of processes and mechanisms that can provide skill



How does the climate base state (tropical SSTs and ENSO amplitude) affect the Walker Circulation and consequent monsoon-ENSO connections in present-day and future climates?

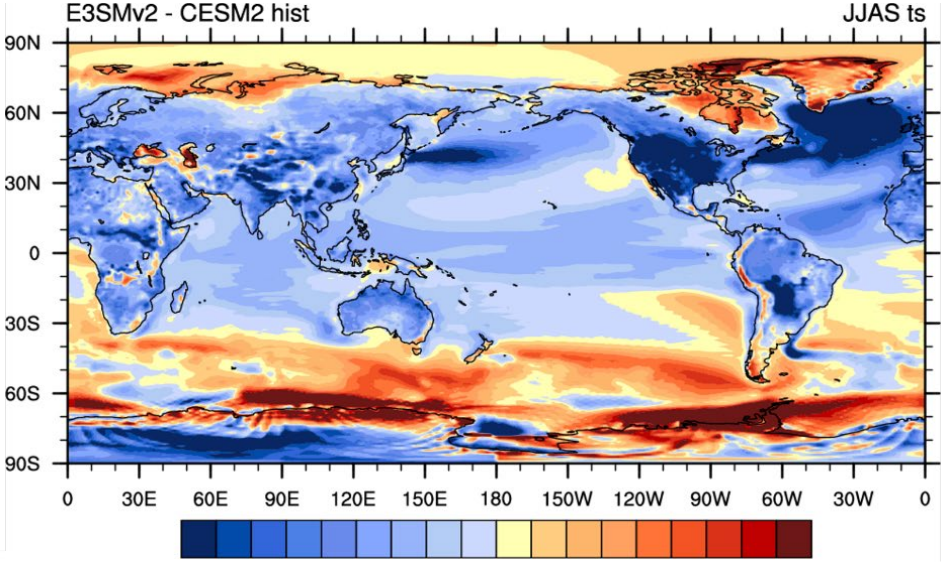
Perform analyses of two 1° class Earth system models (CESM2 and E3SM2) with contrasting climate base states

Historical climate simulations: 1850-2014, both models have 20 ensemble members each

Future climate simulations: CESM2 and E3SM2 are ensemble means (20 ensemble members for CESM2, 20 ensemble members for E3SM2) run for future climate with the SSP370 emission scenario from 2015 to 2100.

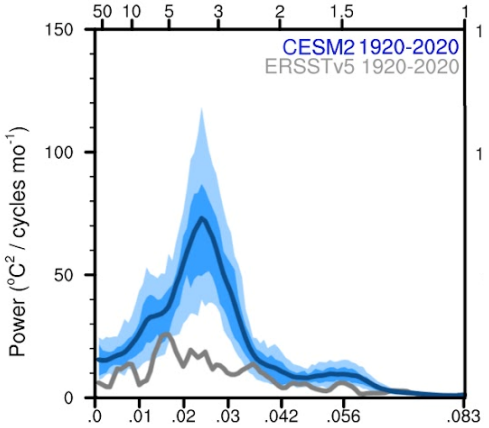
Present-day JJAS base state climate differences between E3SMv2 and CESM2 (1995-2014)

Tropical Pacific and Indian SSTs about 1°C cooler in E3SMv2 compared to CESM2

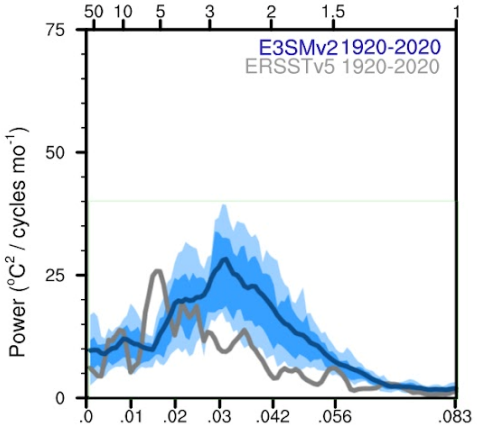


Mean base state differences for E3SMv2 minus CESM2, JJAS, for 1995-2014

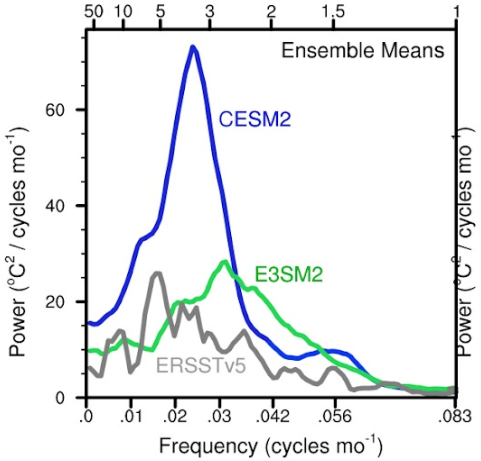
CESM2 compared to obs



E3SM2 compared to obs
(note different y axis scale)



CESM2, E3SM2 and obs



CESM2 ENSO amplitude is about twice that in E3SM2

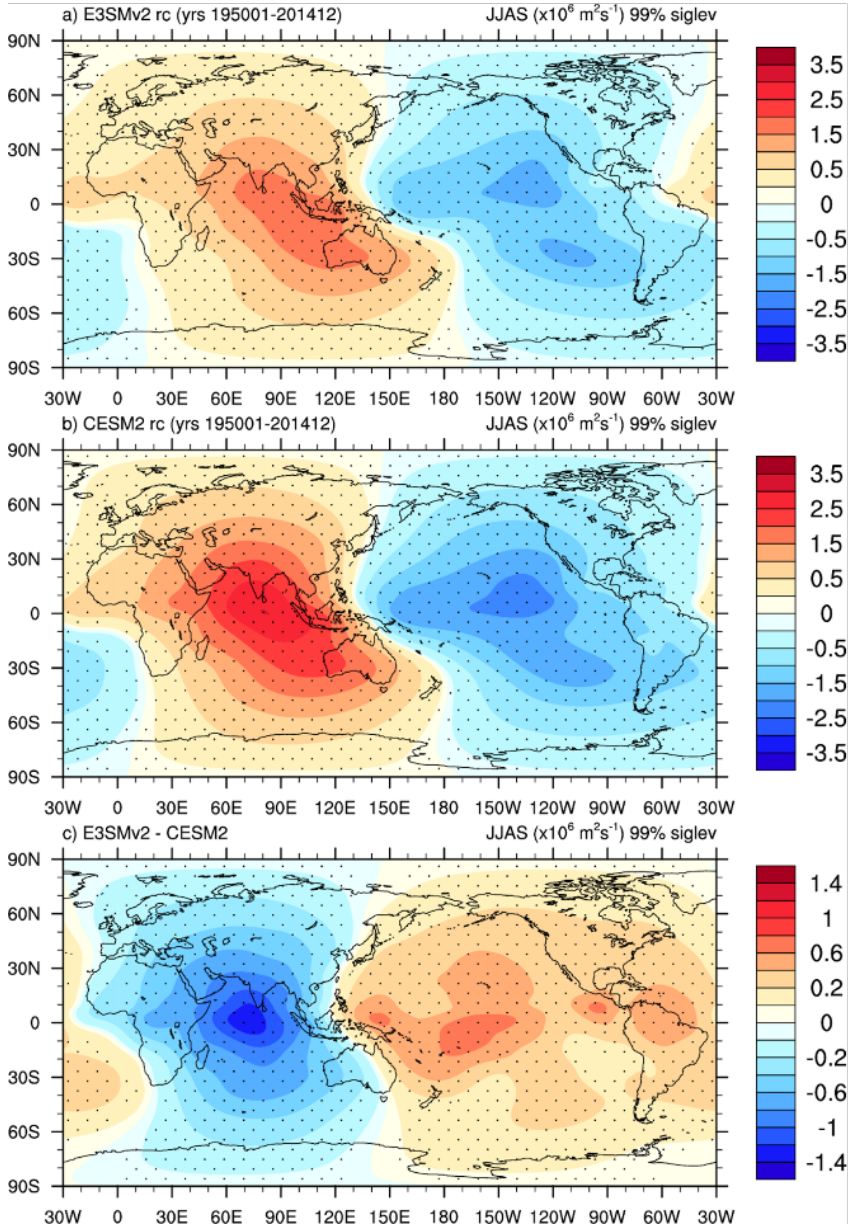
Nino34 regressions with 200 hPa CHI (velocity potential) JJAS

Nino 3.4 onto 200mb chi units . *x10e6 m2/s / degC*

E3SM2

CESM2

E3SM2 minus CESM2



Larger amplitude regression pattern for CESM2 indicating stronger monsoon-ENSO connection in CESM2

Larger ENSO amplitude and warmer base state SSTs both contribute to the stronger monsoon-ENSO connection in CESM2 compared to E3SM2

But which is more important?

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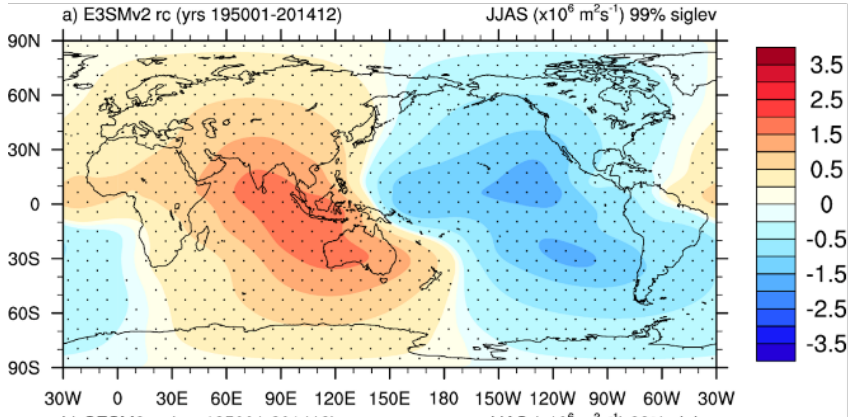
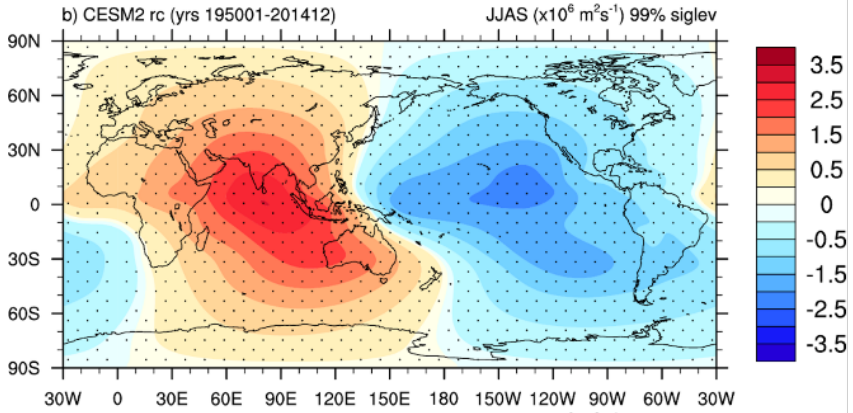
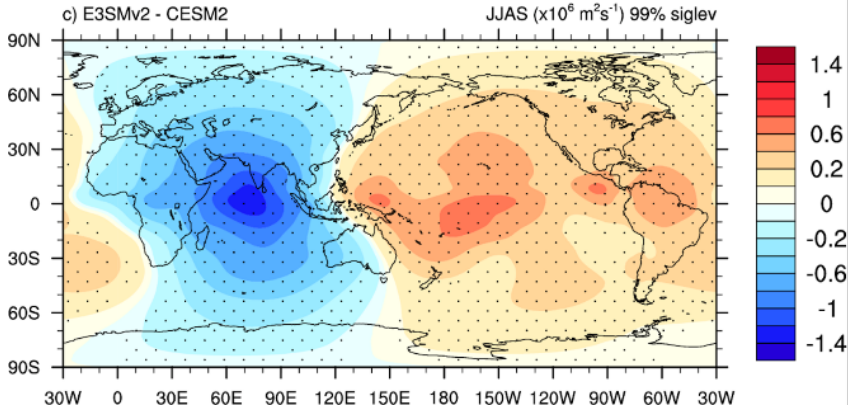
E3SM2



CESM2



E3SM2 minus CESM2



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But which is more important?

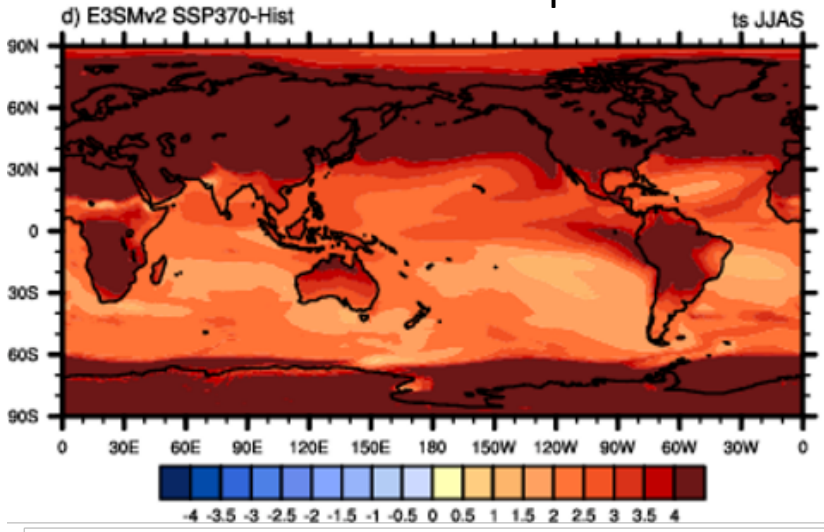
Results from pacemaker experiments show that about half due to ENSO amplitude, half due to base state tropical SSTs

Can we apply to future climate what we've learned about the processes involved with monsoon-ENSO connections related to different climate base states?

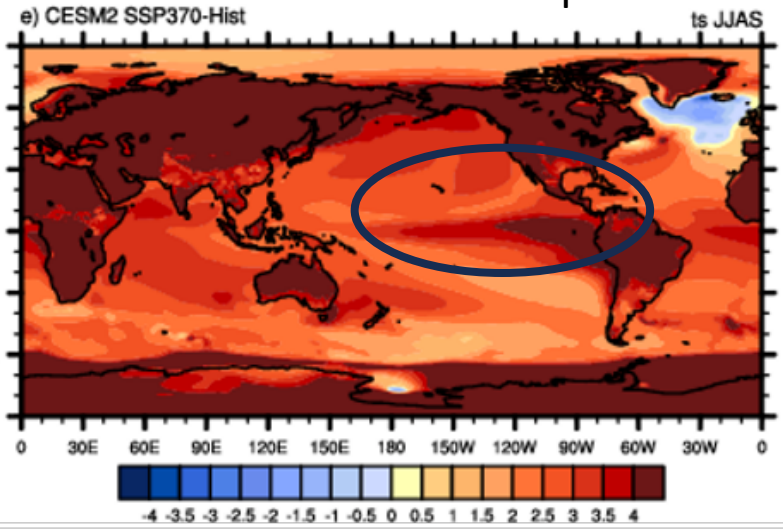
Future changes in surface temperature

CESM2 has more of an El Niño-like response

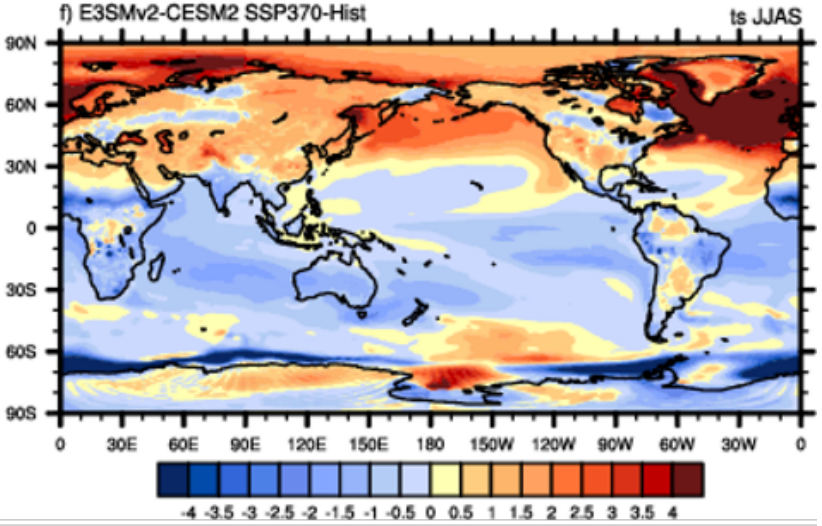
E3SMv2 future minus present



CESM2 future minus present



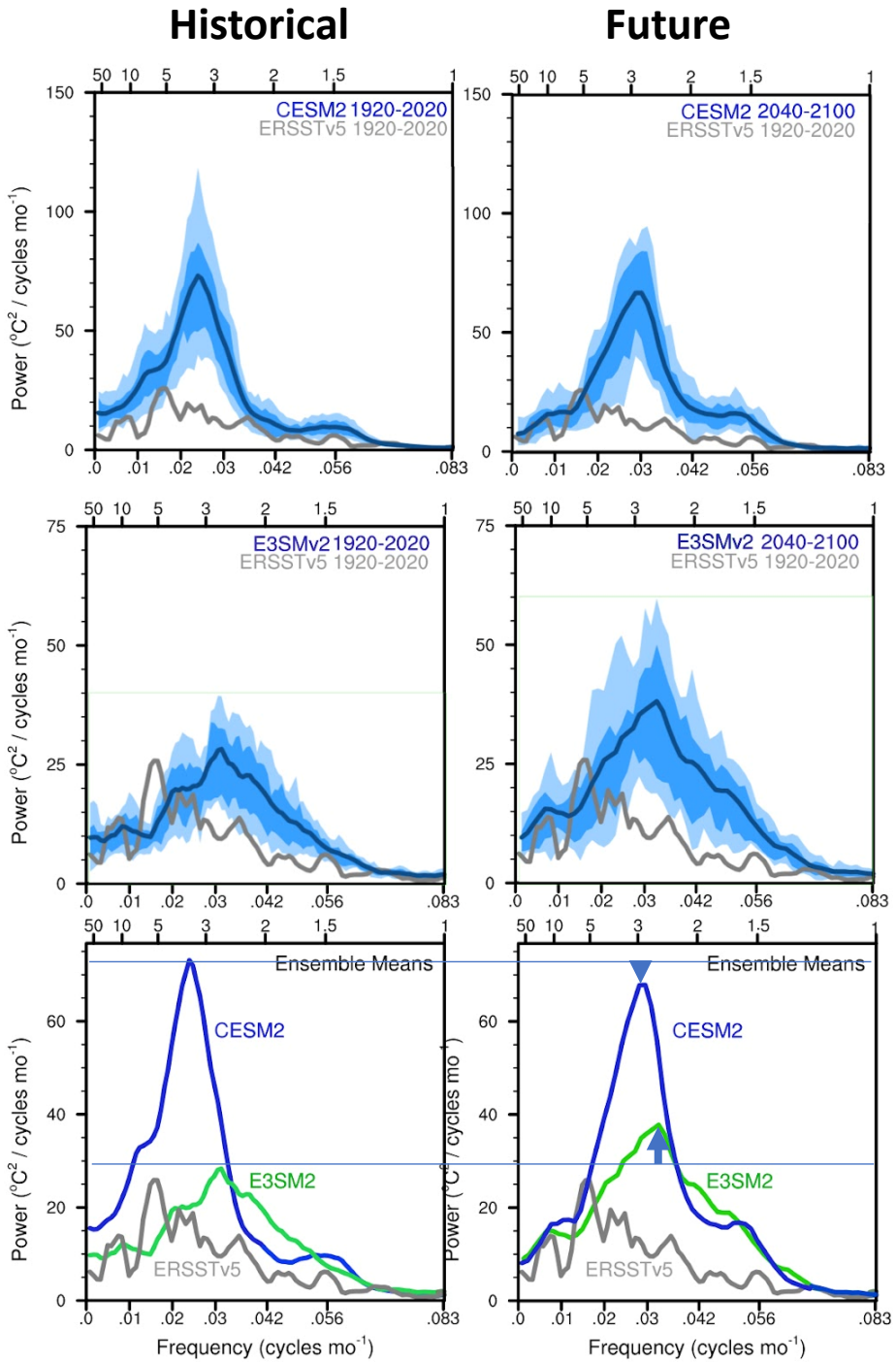
E3SMv2 minus CESM2



CESM2

E3SM2
(note different y axis scale)

CESM2, E3SM2 and obs



future ENSO in E3SM2 is larger than present,
but about the same in CESM2

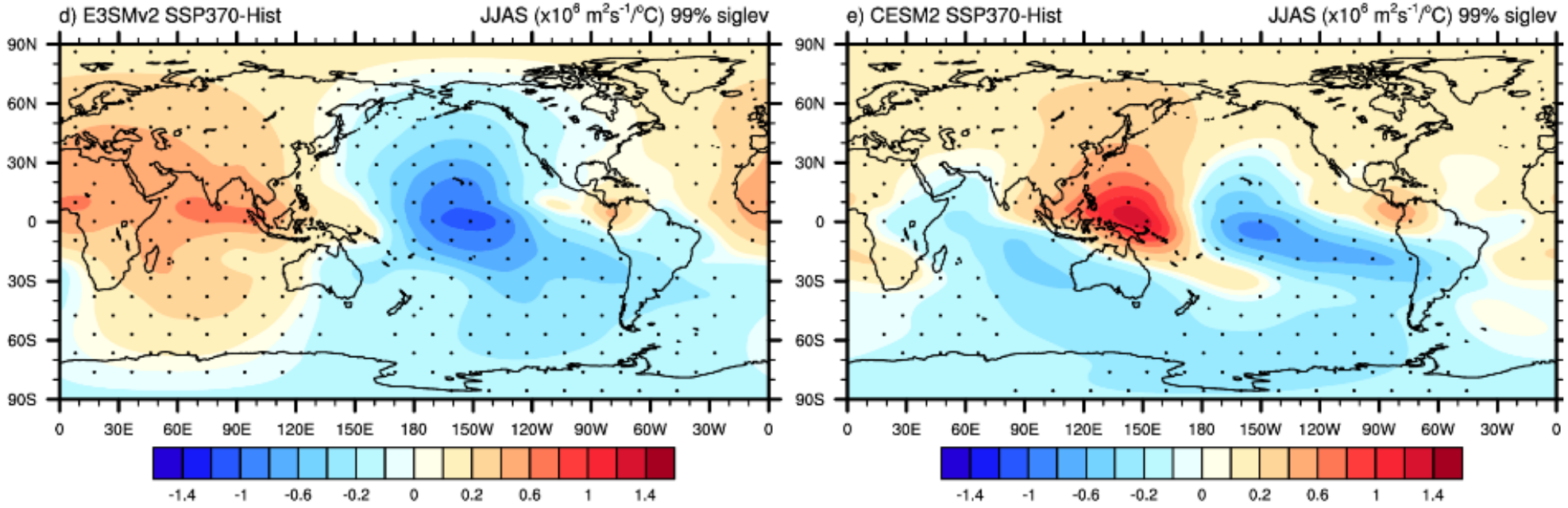
Future strengthening of the monsoon-ENSO connection in E3SM2 compared to CESM2:

1. **The larger future El Niño-like SST response in CESM2 shifts the anomalous Walker Circulation eastward and weakens the monsoon-ENSO connection in CESM2 compared to E3SM2**
2. **Larger amplitude increase in future ENSO in E3SM2 strengthens the monsoon-ENSO connection compared to CESM2**

Differences of regressions of Niño3.4 SSTs onto 200 hPa velocity potential, JJAS:

E3SM2 future minus present

CESM2 future minus present



Summary

Present-day climate: key processes that weaken the monsoon-ENSO connection in E3SM2 compared to CESM2:

1. cooler tropical Indian and Pacific SSTs in E3SM2
2. reduced ENSO amplitude in E3SM2

Pacemaker experiments show both contribute about equally to weaken present-day monsoon-ENSO teleconnections in E3SM2 compared to CESM2

Future climate: key processes that weaken the monsoon-ENSO connection in CESM2 compared to E3SM2:

1) relatively larger increase of future amplitude ENSO in E3SM2
2) larger El Niño-like response CESM2 and the consequent eastward shift of the Walker Circulation in CESM2

Future changes in surface temperature, precipitation and low-level winds:

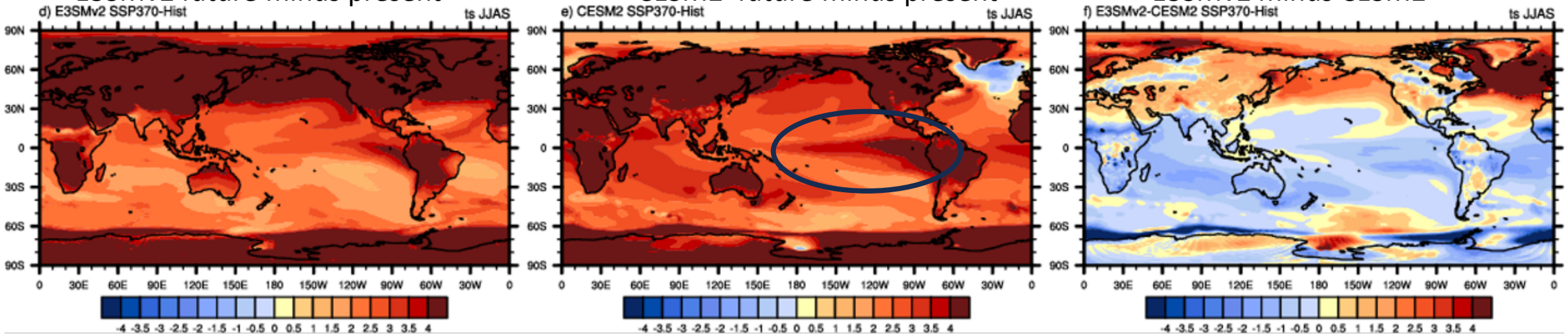
--E3SM2 warms less, but has a greater future increase in South Asian monsoon precipitation

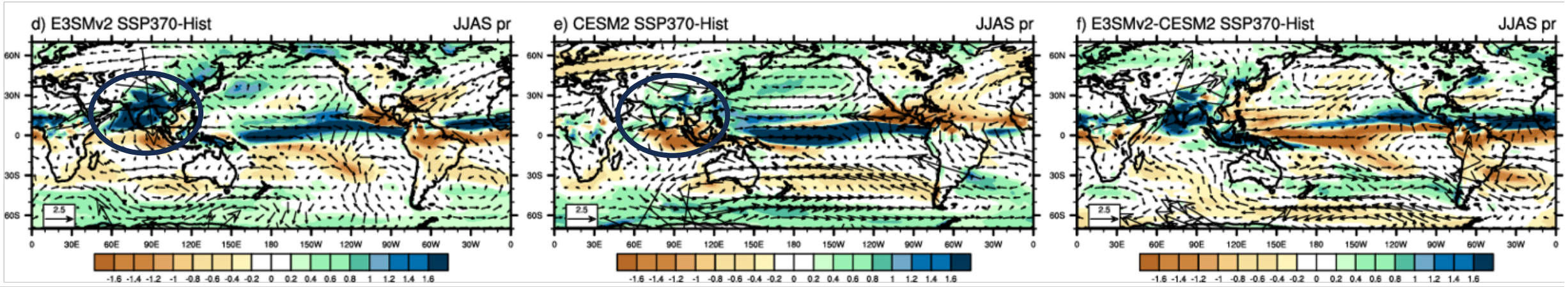
--CESM2 has more of an El Niño-like response, and greater increases of tropical Pacific precipitation

E3SMv2 future minus present

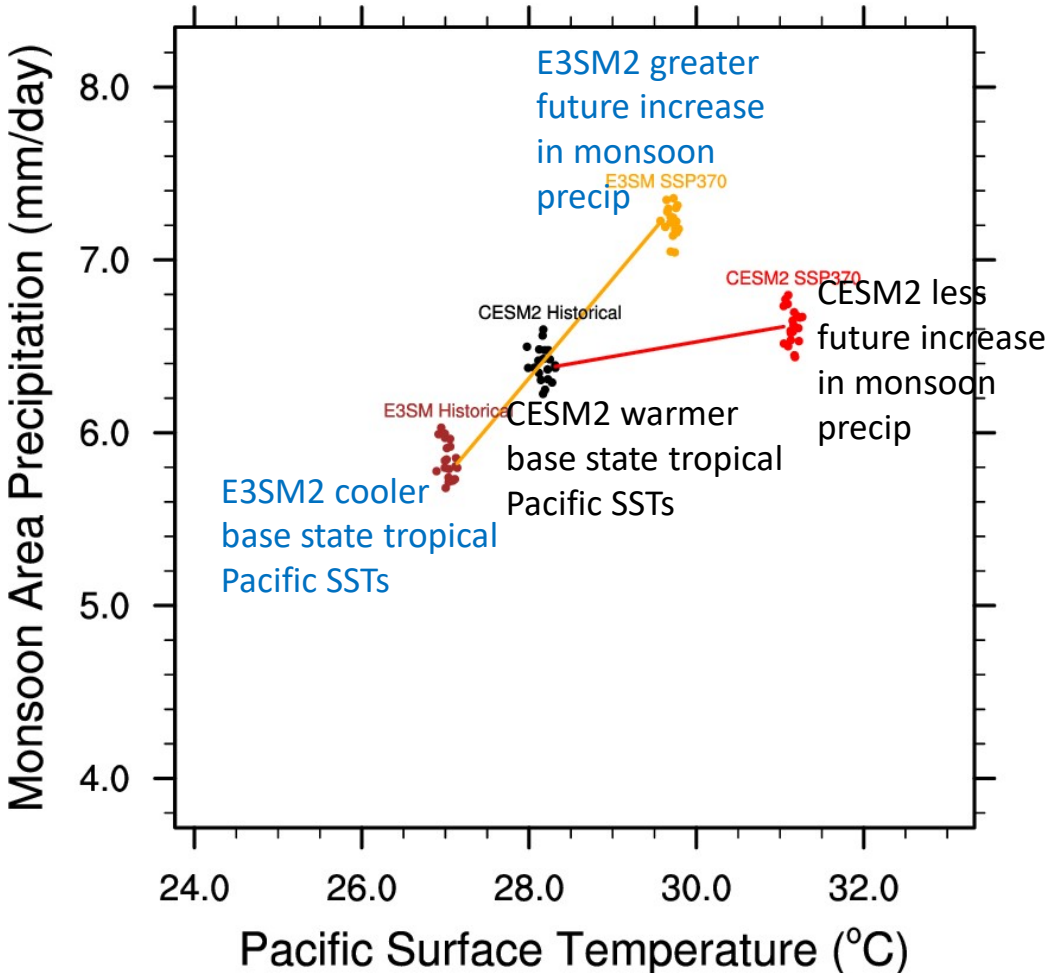
CESM2 future minus present

E3SMv2 minus CESM2





Effect of present-day base state tropical Pacific SSTs on increases in future South Asian monsoon precipitation



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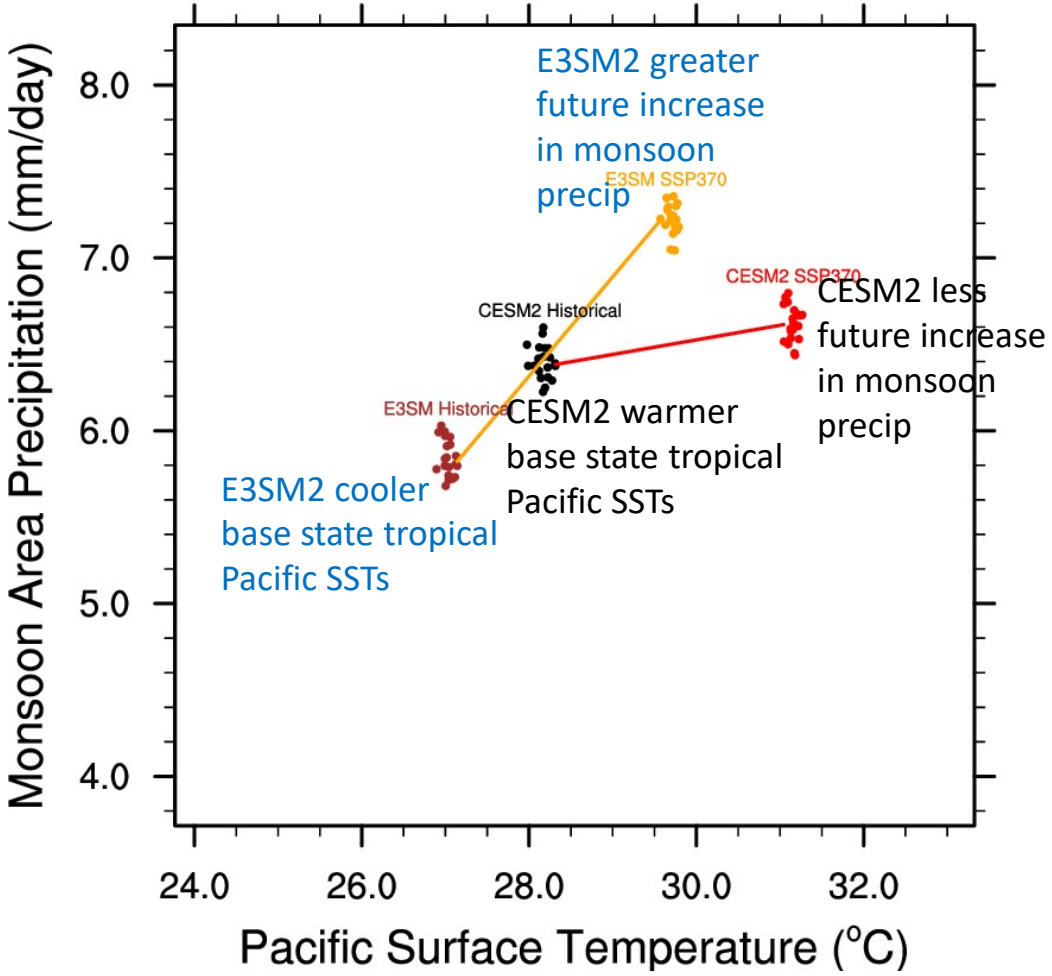
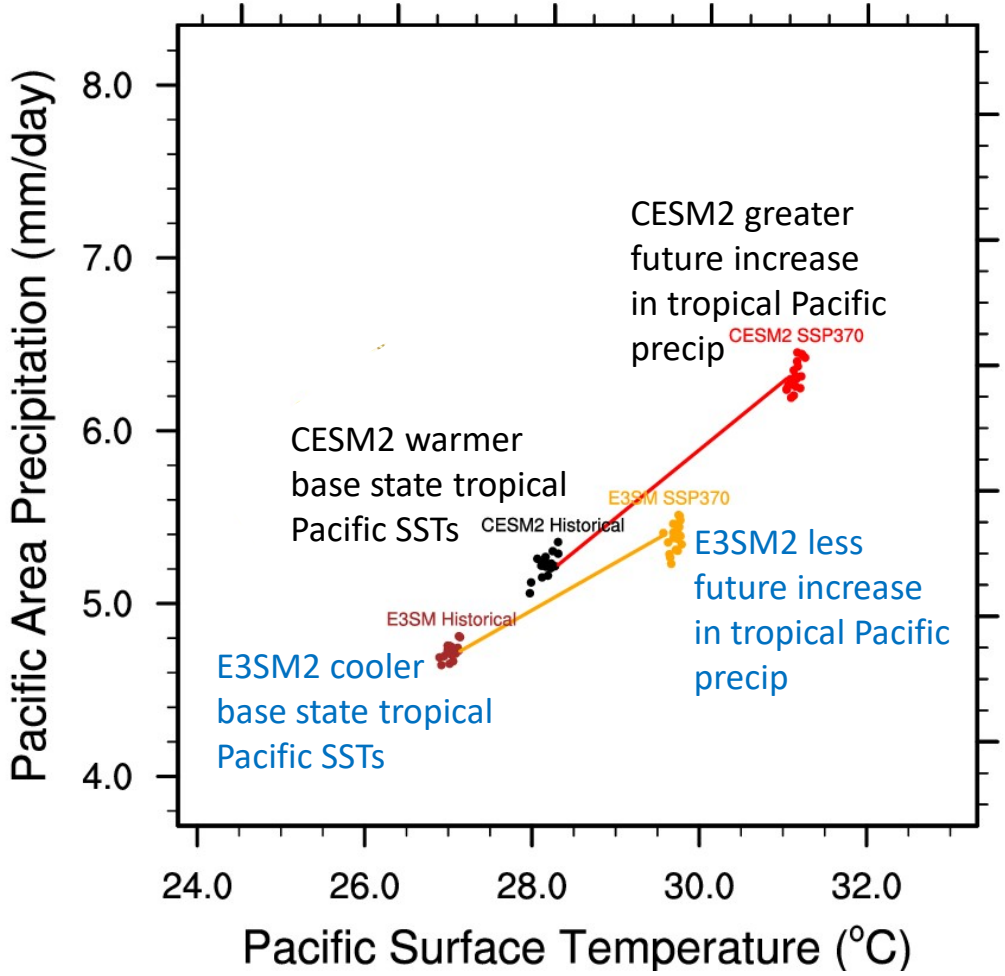
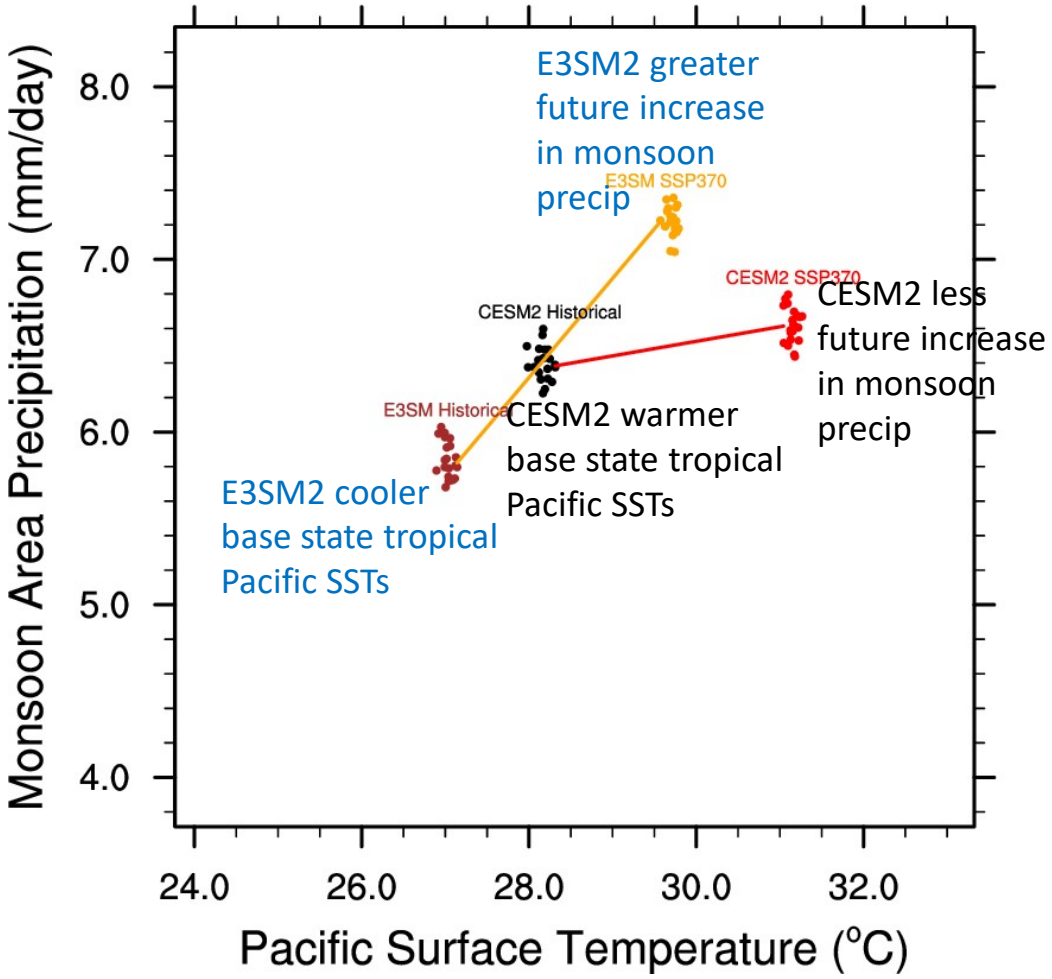


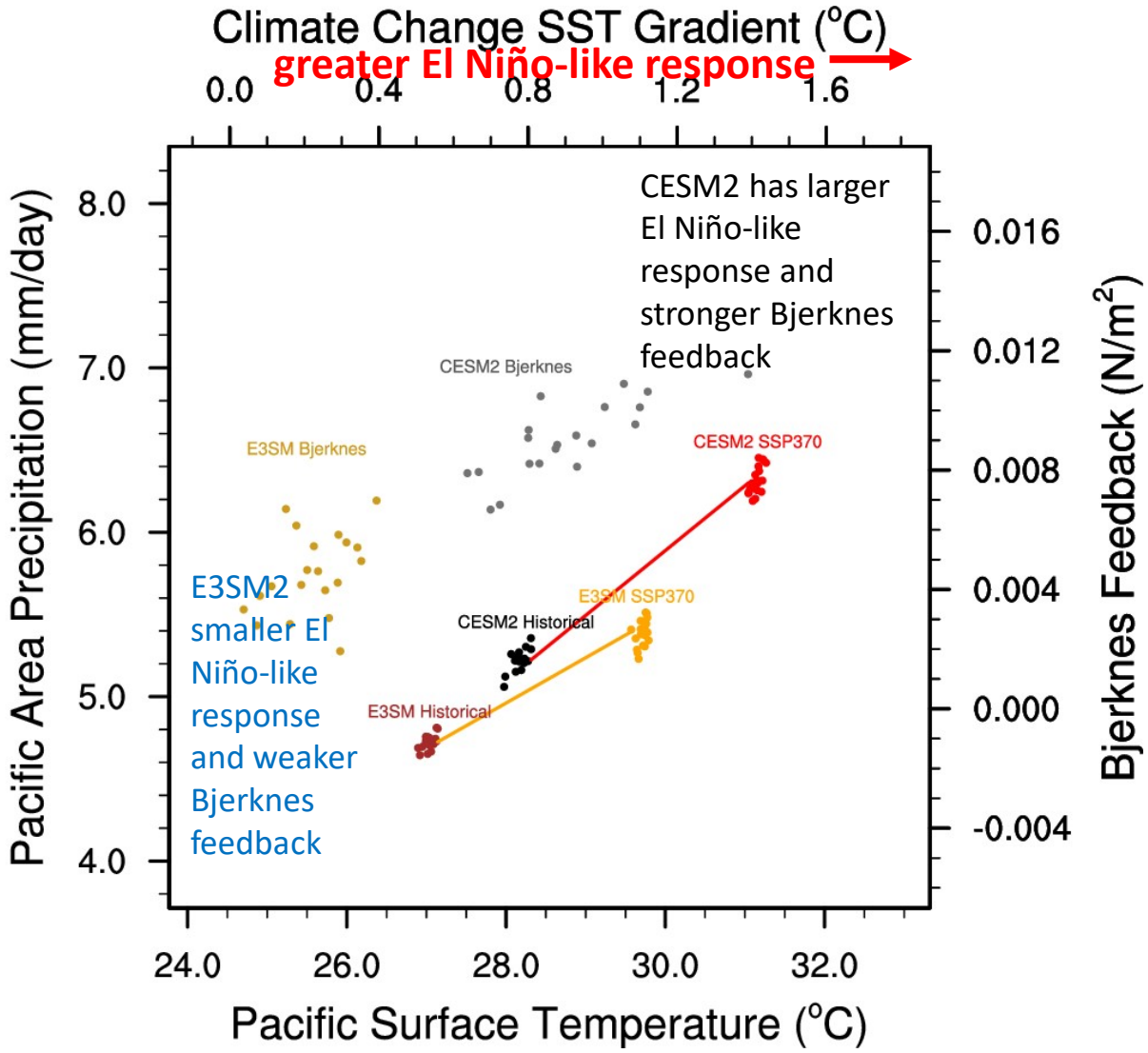
Effect of present-day base state tropical Pacific SSTs on increases in future tropical Pacific precipitation



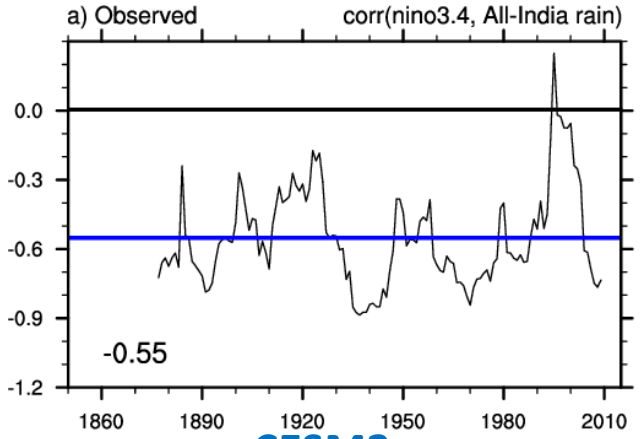
Effect of present-day base state tropical Pacific SSTs on increases in future South Asian monsoon precipitation



Effect of present-day base state tropical Pacific SSTs on increases in future El Niño-like response and Bjerknes feedback



Observed

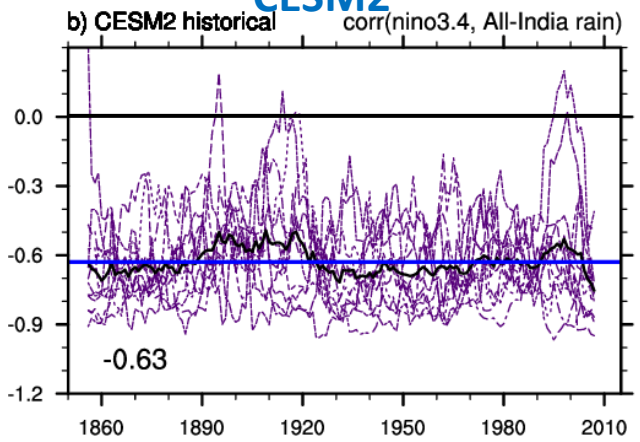


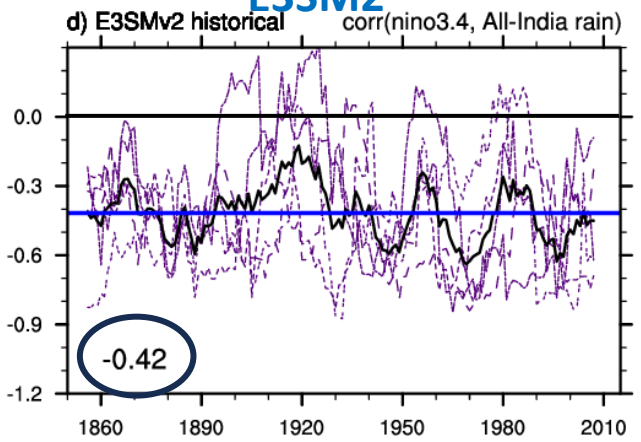
Negative correlations between Niño3.4 and Indian monsoon rainfall (13 year sliding window): larger in E3SM2 in future (stronger monsoon-ENSO connection), and about the same in CESM2

CESM2

E3SM2

Historical





Future