

The Continuing Decline in Southwestern U.S. Precipitation in a High-Resolution Climate Model



Jeremy M. Klavans¹, Amy C. Clement¹, Mark A. Cane², Pedro N. DiNezio³,
Timothy M. Shanahan⁴

¹Rosenstiel School of Marine, Earth, and Atmospheric Science, ²Lamont Doherty Earth Observatory, ³University of Colorado Boulder, ⁴University of Texas at Austin

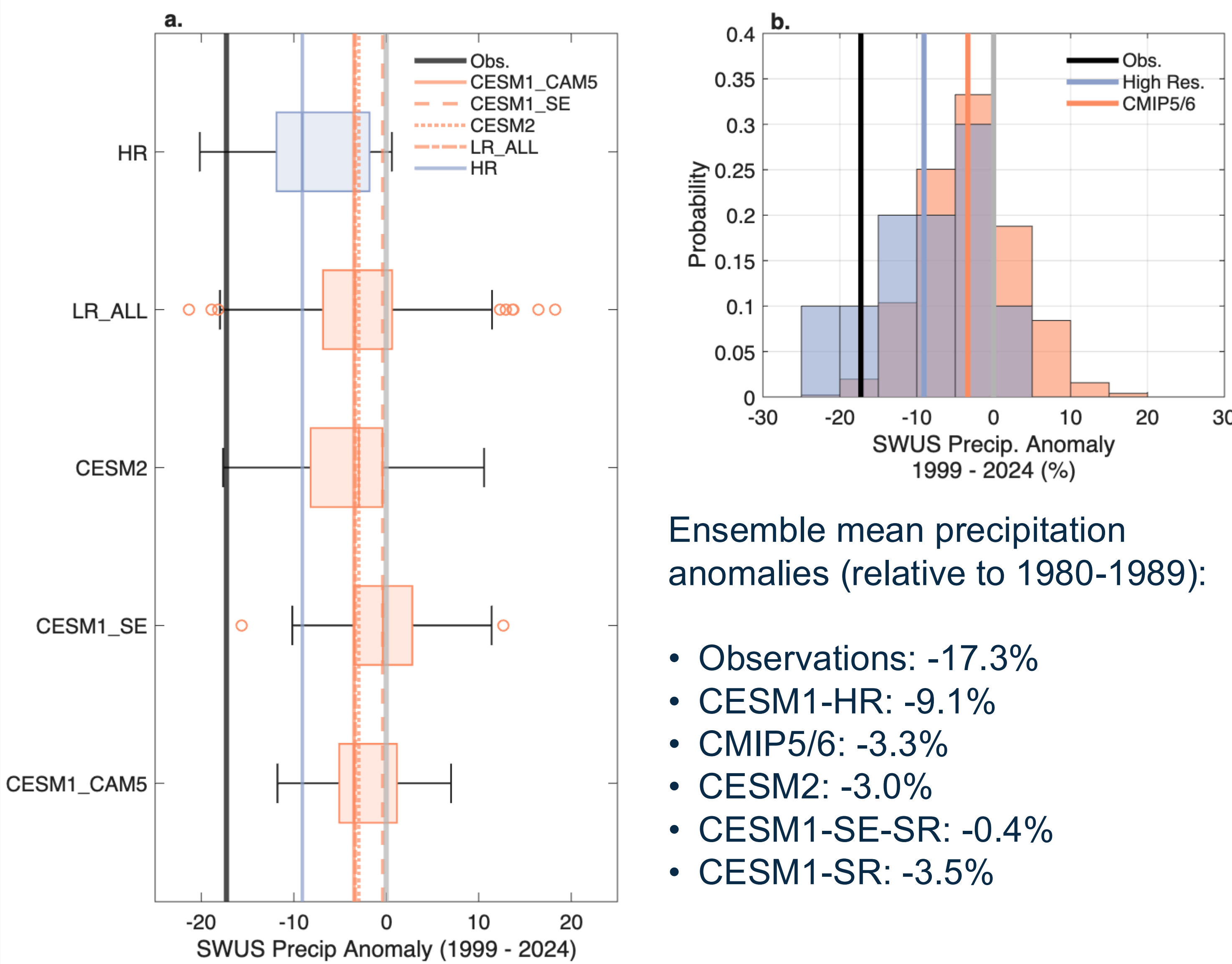
Introduction

- The southwestern U.S. has been suffering from persistent drought conditions for decades, which current generation models do not consistently simulate.
- Drought is associated with North Pacific climate trends, which are largely assumed to be internally generated.

Hierarchy of Historical Ensembles

- High-resolution CESM1 ensemble: 10 members (MESACLIP)
- Standard-resolution CESM1 ensemble: 40 members
- Standard-resolution, multi-model ensemble: 13 different CMIP5/6 models, 682 members
- Observations: HadISST and ERA5 Reanalysis

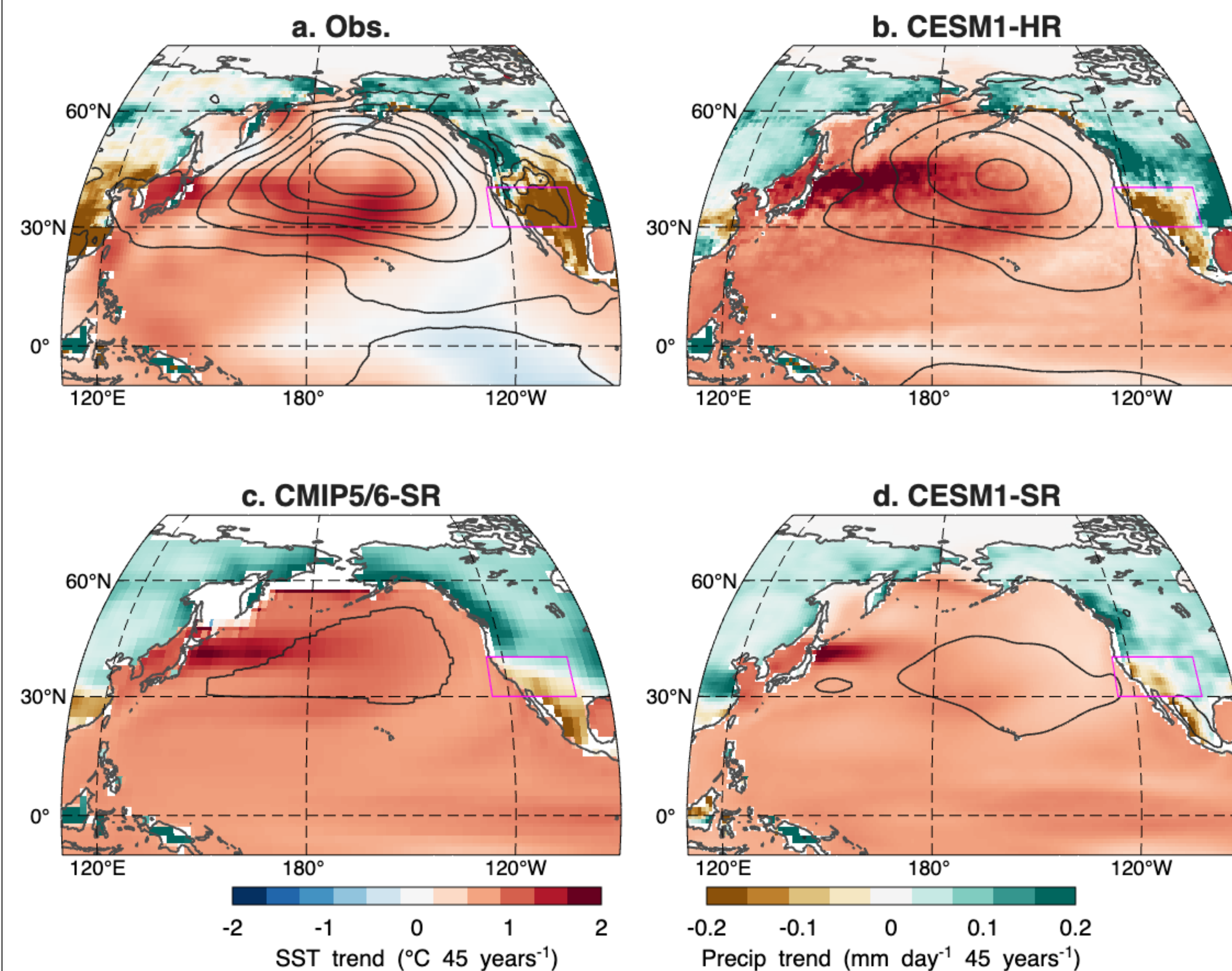
Increasing resolution improves the simulation of SW U.S. precipitation trends



Ensemble mean precipitation anomalies (relative to 1980-1989):

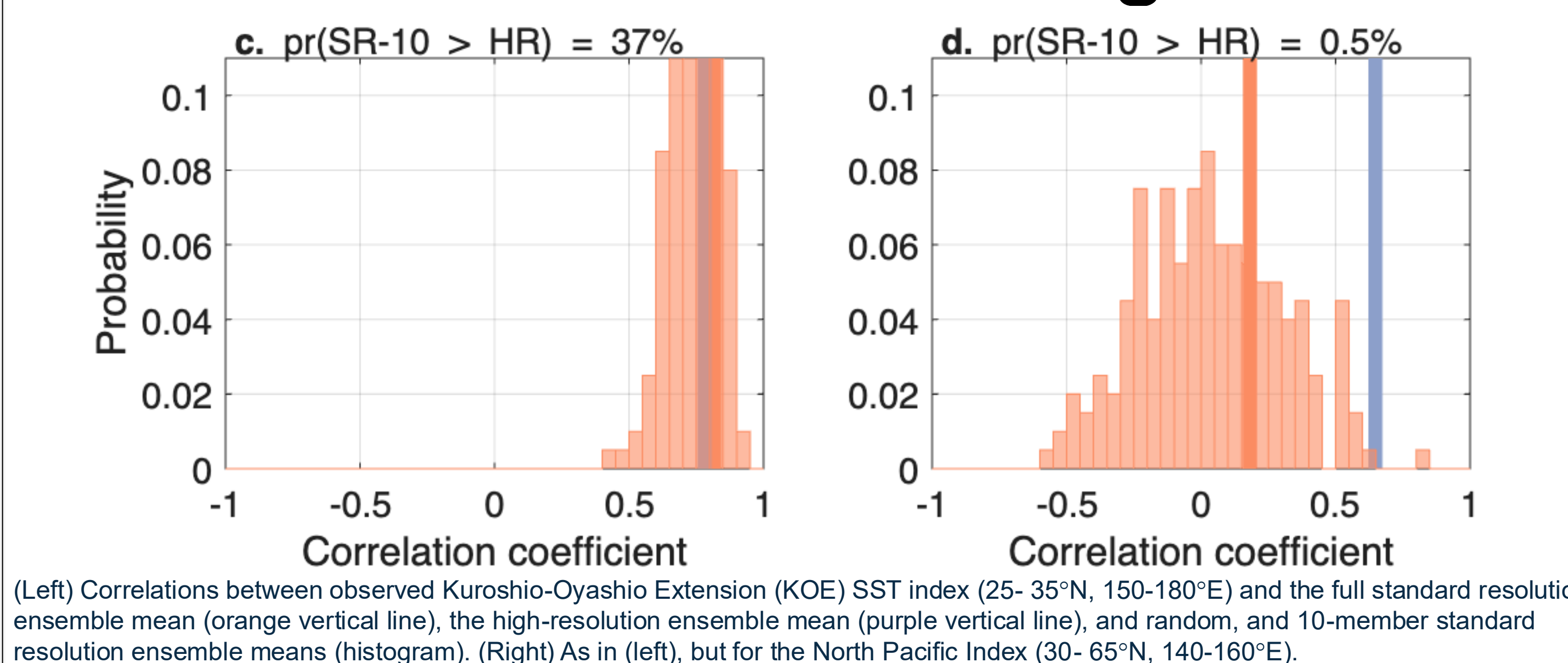
- Observations: -17.3%
- CESM1-HR: -9.1%
- CMIP5/6: -3.3%
- CESM2: -3.0%
- CESM1-SE-SR: -0.4%
- CESM1-SR: -3.5%

Improvement in SW U.S. precipitation associated with refined North Pacific climate trends

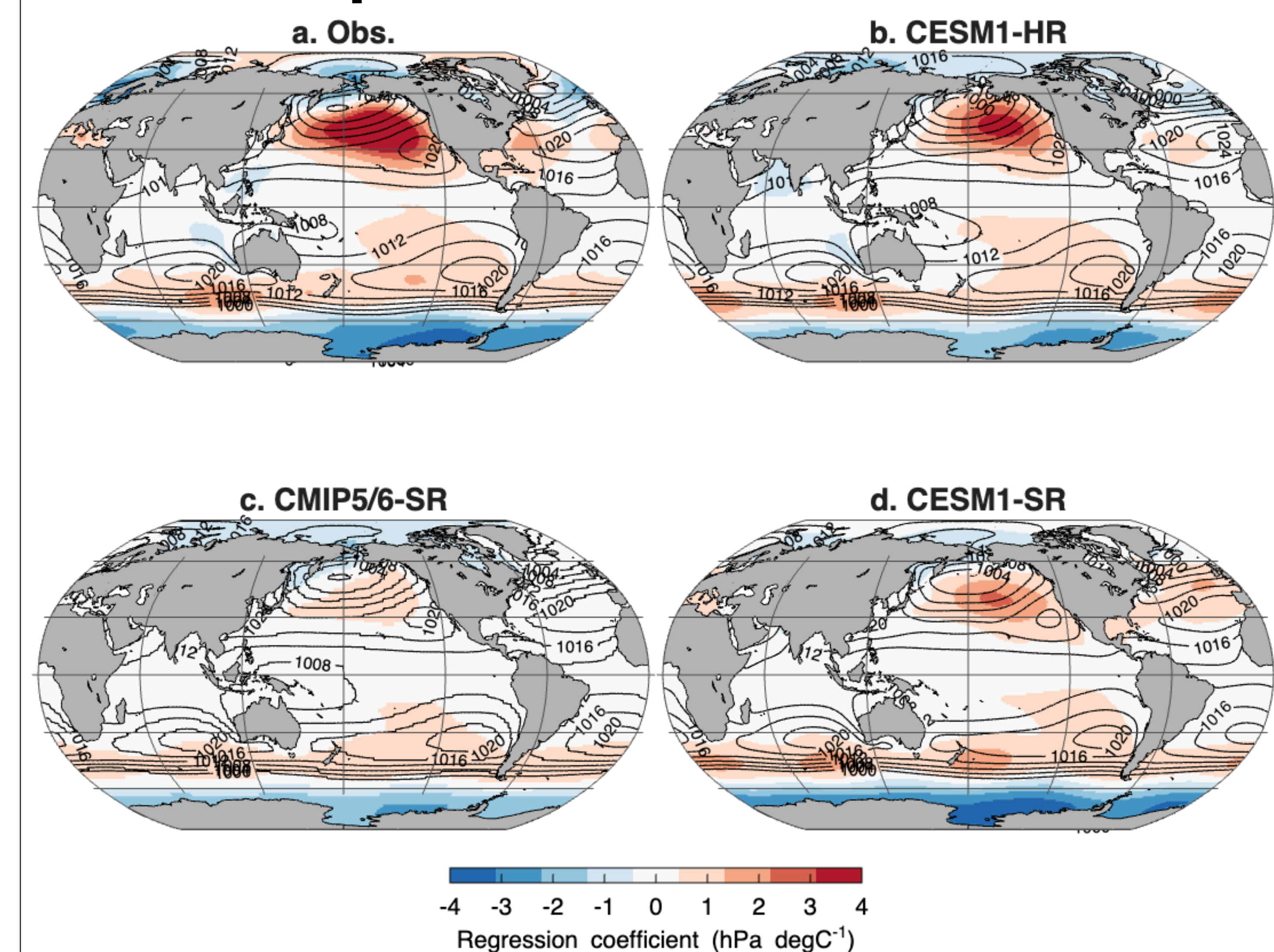


(a) Observed trends from 1980-2024 in SST (red to blue colors, HadISST), precipitation (green to brown colors, ERA5 Reanalysis), and sea-level pressure (contours every 0.5 hPa; ERA5 Reanalysis). (b, c, and d) As in (a) but for the ensemble mean trends from (b) the CESM1 high resolution ensemble, (c) the multimodel ensemble of CMIP5 and CMIP6 models, and (d) the CESM2 large ensemble run at standard resolution. The purple box denotes the area for which we calculate southwest U.S. precipitation, over land.

Increasing resolution reveals a significant forced component in Aleutian Low strength



Increasing resolution amplifies atmosphere-ocean interactions



(a – d) The regression of DJF average sea-level pressure on the DJF average KOE SST index in (a) observations, (b) the CESM1-HR ensemble mean, (c) the multi-model standard resolution ensemble mean, (d) and the standard resolution CESM1 ensemble mean.

Summary

- CESM1-HR simulates negative SW U.S. precipitation trend at a much larger and more realistic magnitude, confirming the role of external forcing in recent drought conditions
- More accurate precipitation trends are a result of improved North Pacific climate trends
- Improvements in North Pacific regional climate are driven by amplified atmosphere-ocean interactions, which enhance the forced signal and therefore the signal-to-noise ratio
- More faithful reproductions of observed regional climate suggests that high resolution climate models may offer more trustworthy projections of future climate impacts

