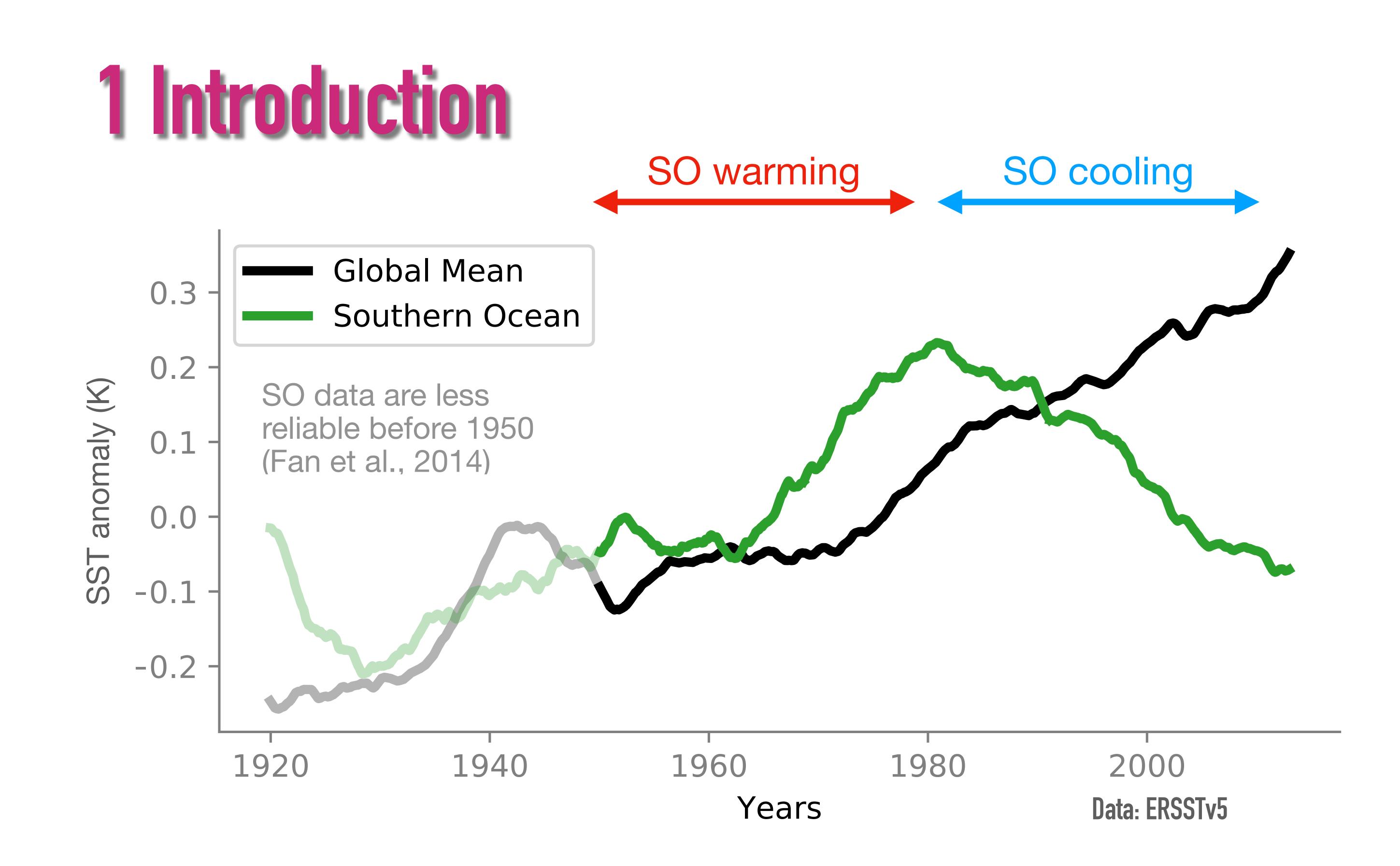
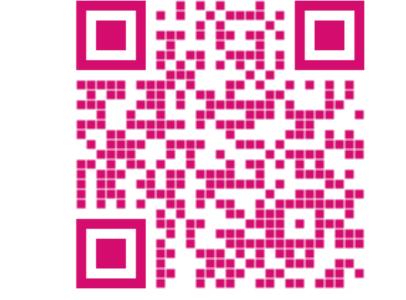
# The remote impact of Southern Ocean surface warming and cooling

### Xiyue (Sally) Zhang<sup>#</sup> and Clara Deser<sup>%</sup>



**Despite global warming**, the Southern Ocean (SO) surface temperatures since 1950 display a warming phase followed by a cooling phase. Previously, Zhang et al. (2021) found a significant response to observed SO cooling in the tropical South Atlantic, where increased clouds and strengthened trade winds cool the sea surface, partially offsetting the radiatively forced warming trend. Here we expand on Zhang et al. (2021) and boost the signal in the tropical Pacific by including the earlier SO warming phase to our experiment.

## 2 Method



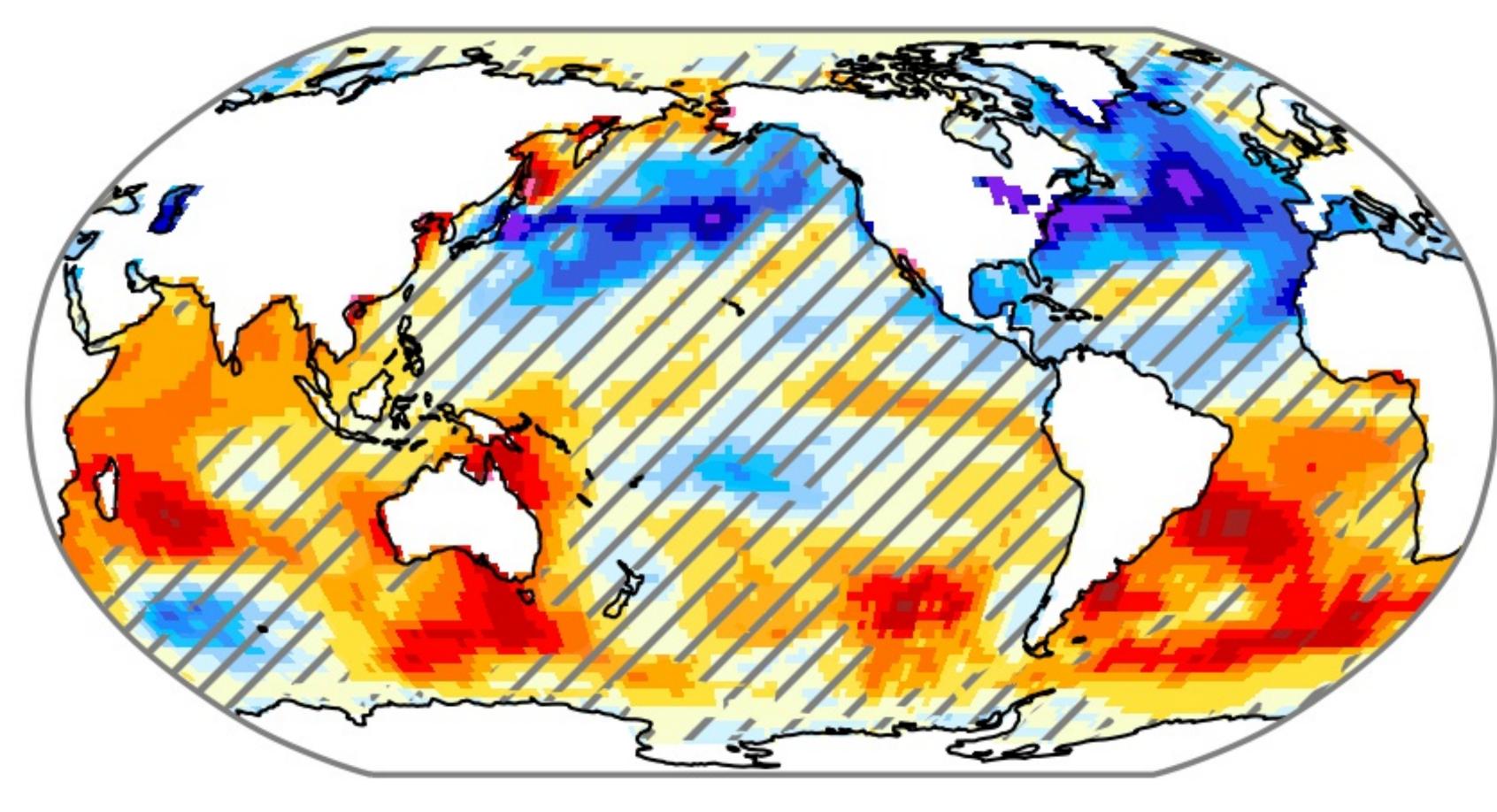
Scan for Zhang et al. (2021) GRL

#### Southern Ocean pacemaker (SOPACE)

We apply the CESM1 large-ensemble (LENS) framework and nudge SST anomalies to observed anomalies (ERSSTv3b) over the Southern Ocean (south of 40S) during 1945–2016. Outside of the Southern Ocean, the model is fully coupled. SOPACE consists of 20 ensemble members and is subject to historical and RCP8.5 radiative forcing.

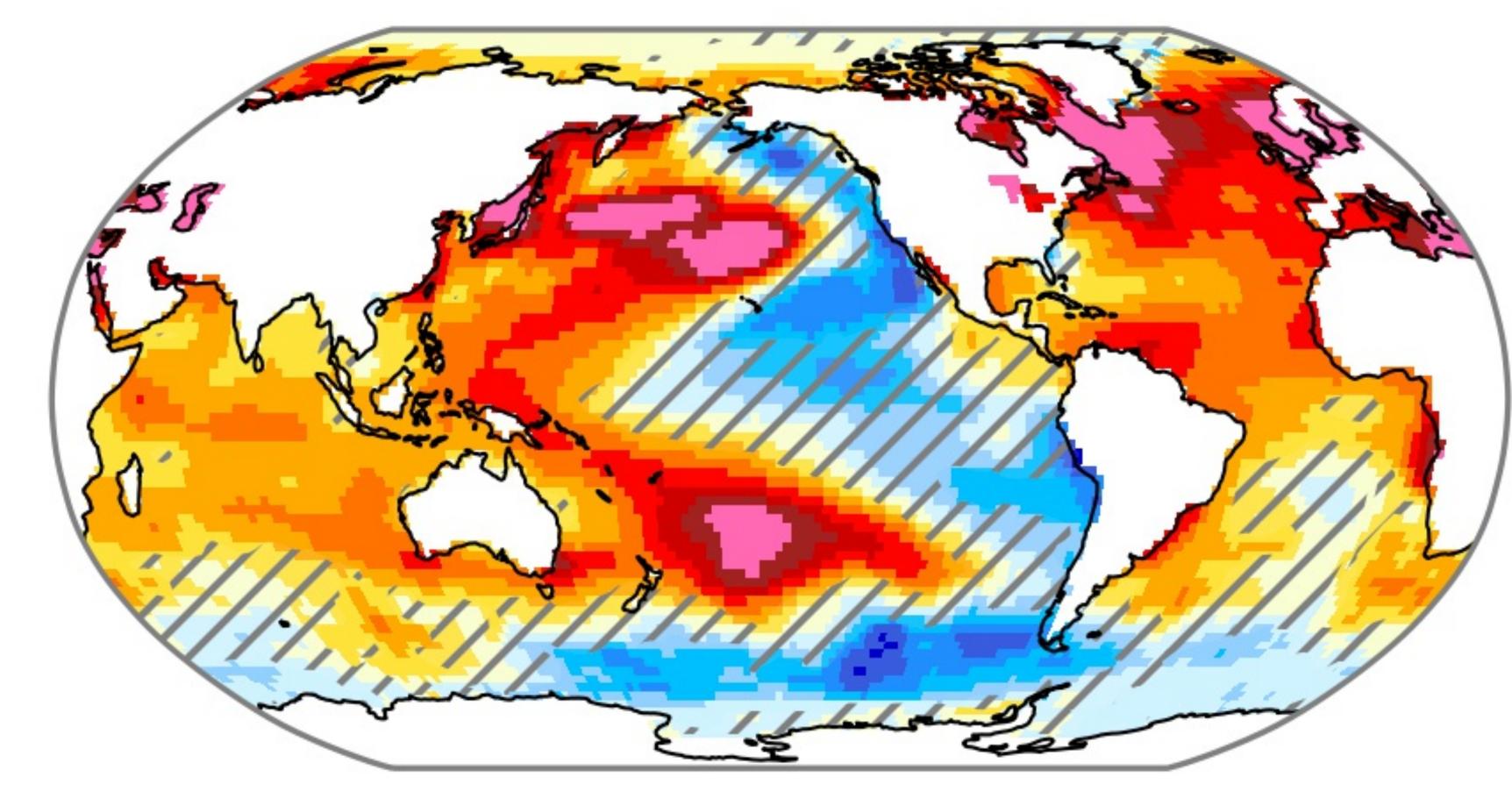
#### Observed (ERSSTv3b) SST trends -

Regions with significant trends at 95% confidence interval are NOT hatched. Significance is not available on the rightmost panel.



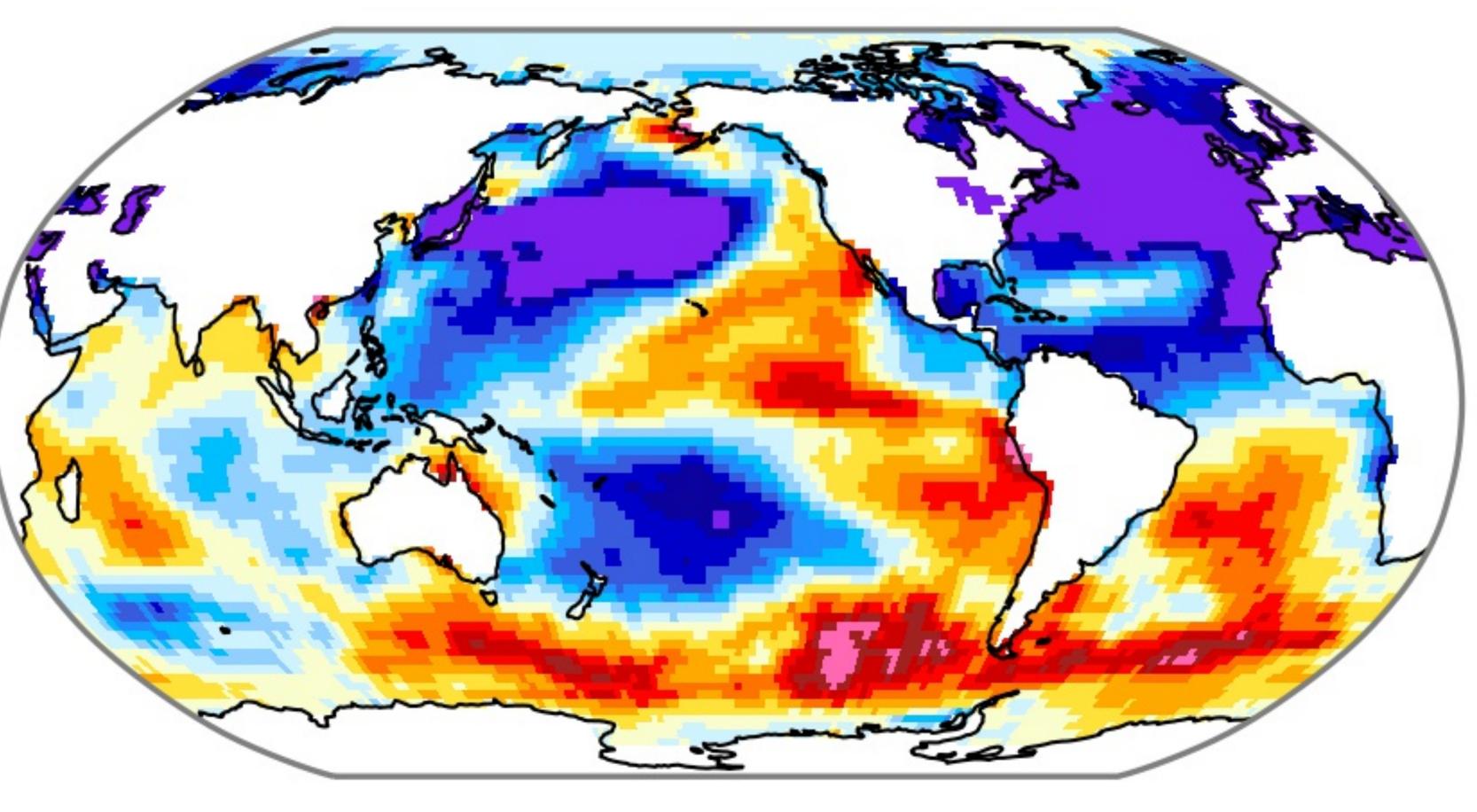
sallyz@jhu.edu

SO warming (1949-1978)



SO cooling (1979-2013)





SO warming – cooling



**To isolate the effect of Southern Ocean warming/cooling,** we subtract LENSensemble mean (EM) from SOPACE-EM (i.e., SOPACE-internal-EM). The tropical signal is boosted by calculating the difference between the two periods. Southern Ocean warming induces a significant warming in the tropical eastern Pacific and South Atlantic. Note that the tropical Pacific response is not statistically significant in either period.

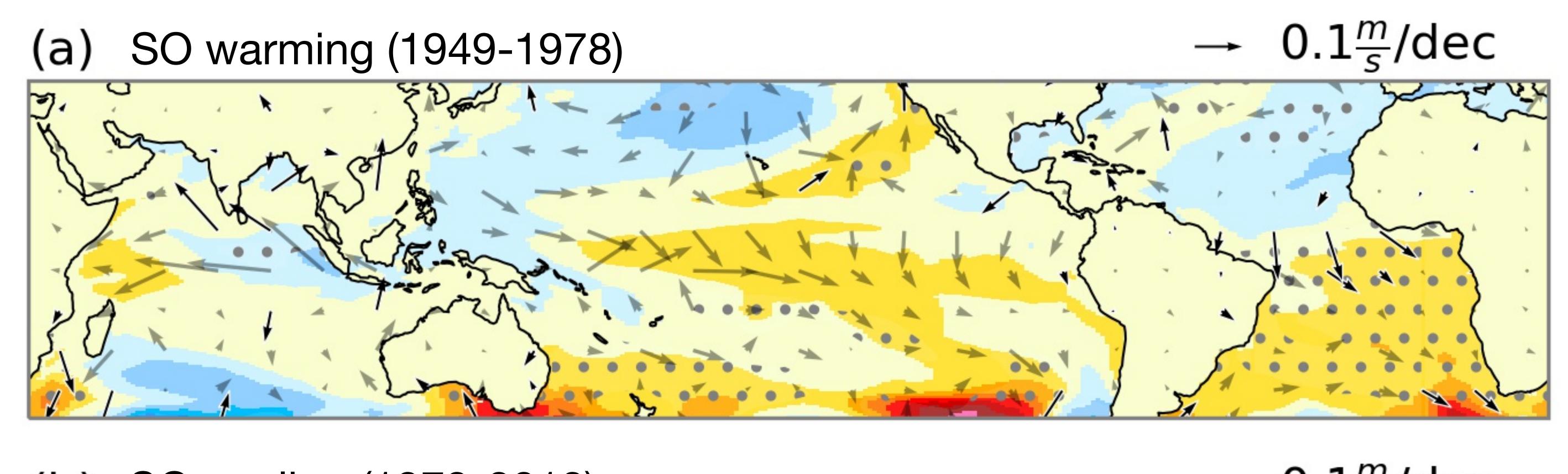
What do they represent?	Radiatively- forced response	SO-induced response	Other natural variability
Observations	X	X	X
LENS-EM	X		
LENS member	Χ		X
SOPACE-EM	X	X	
SOPACE member	X	X	X
SOPACE-internal-EM		X	

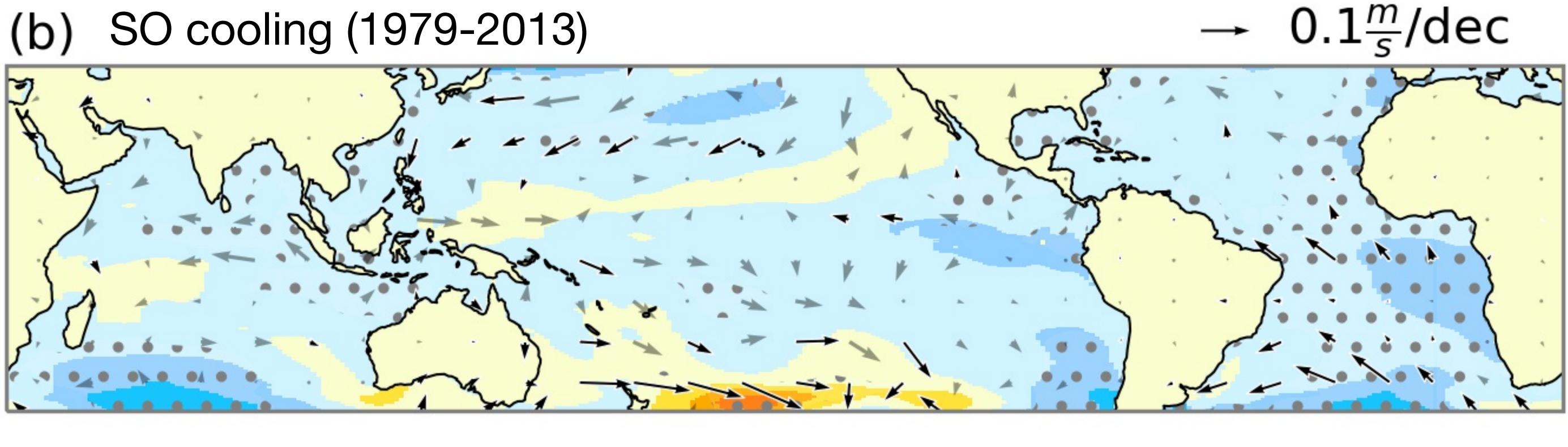
**SOPACE-internal-EM SLP trends** -

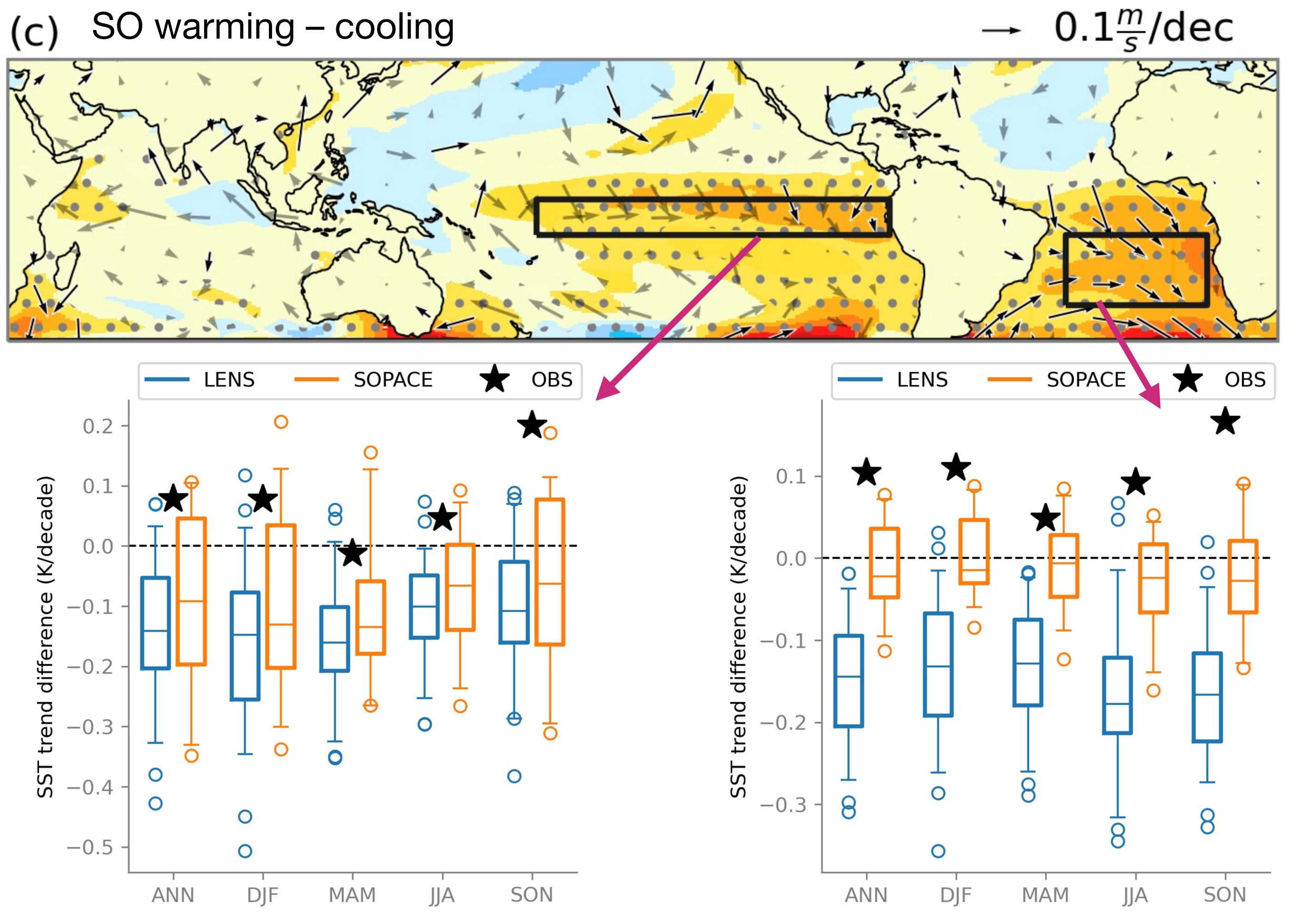
Regions with significant SLP trends at 95% confidence interval are stippled. SO warming – cooling

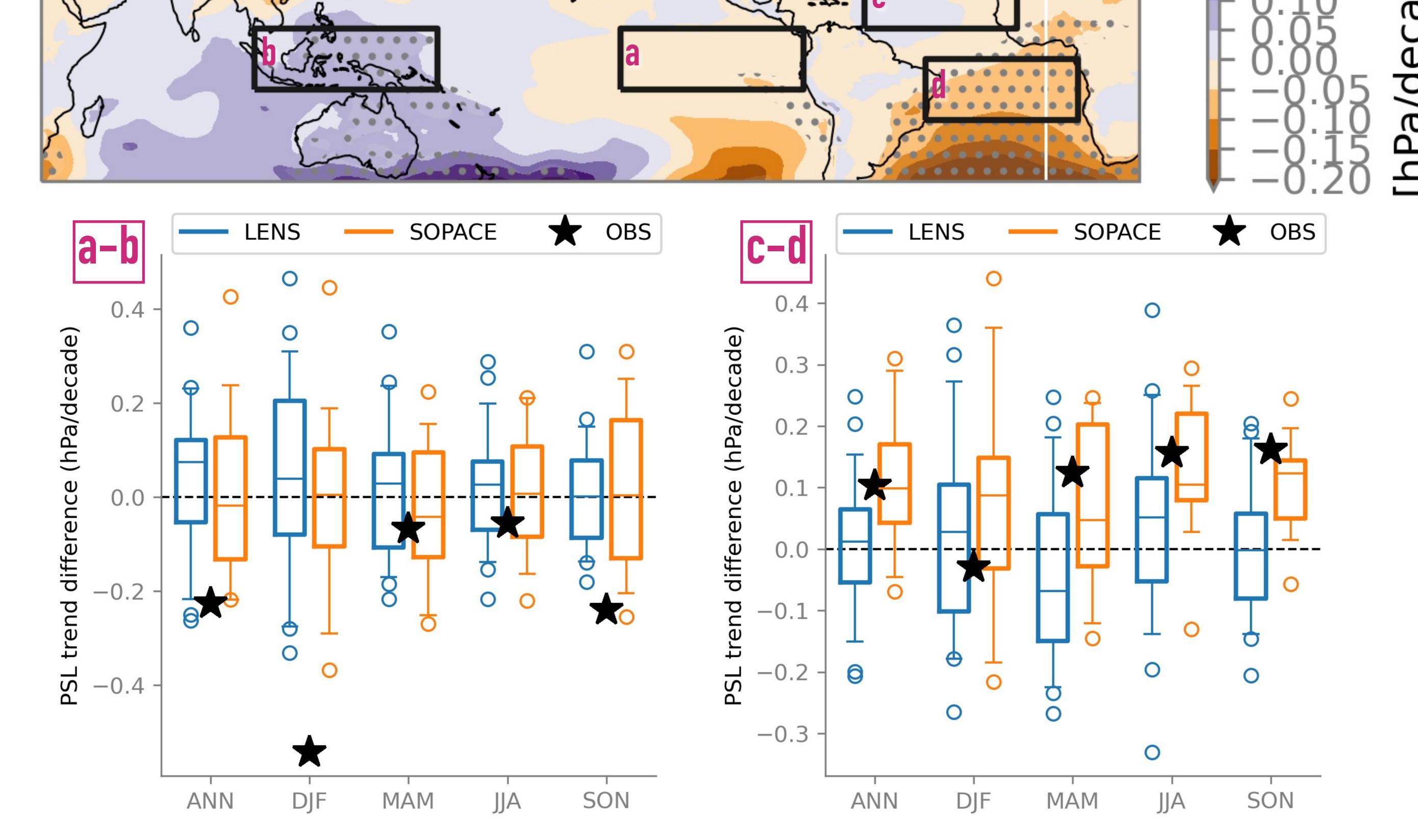


Regions with significant SST trends at 95% confidence interval are stippled. Regions with significant either U or V trends at 95% confidence interval have black arrows.

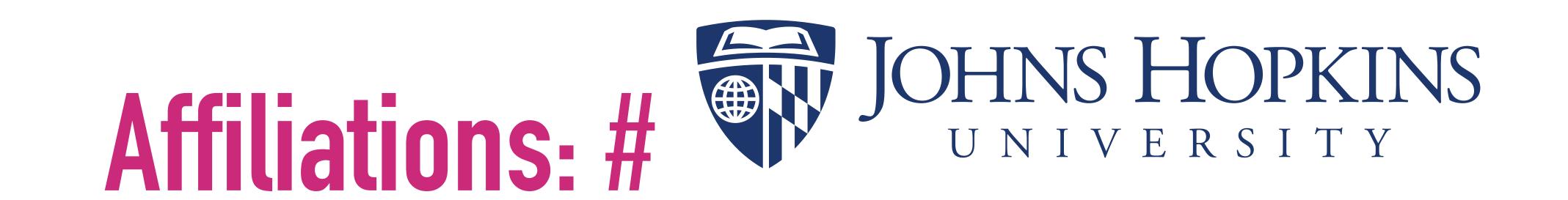








**Observed SO SST trends have a negligible impact on the tropical Pacific surface zonal pressure gradient**, but a significant impact on the tropical Atlantic meridional surface pressure gradient. Observed SLP is represented by ERA-20C and ERA-I.



Are the observed SST trends captured by LENS or SOPACE? In the tropical eastern Pacific, LENS captures observations except for SON. SOPACE members are shifted toward observations in all seasons. In the tropical South Atlantic, LENS is unable to capture observations. SOPACE trends are significantly higher and closer to observations in all seasons.

**% NCAR NATIONAL CENTER FOR ATMOSPHERIC RESEARCH**