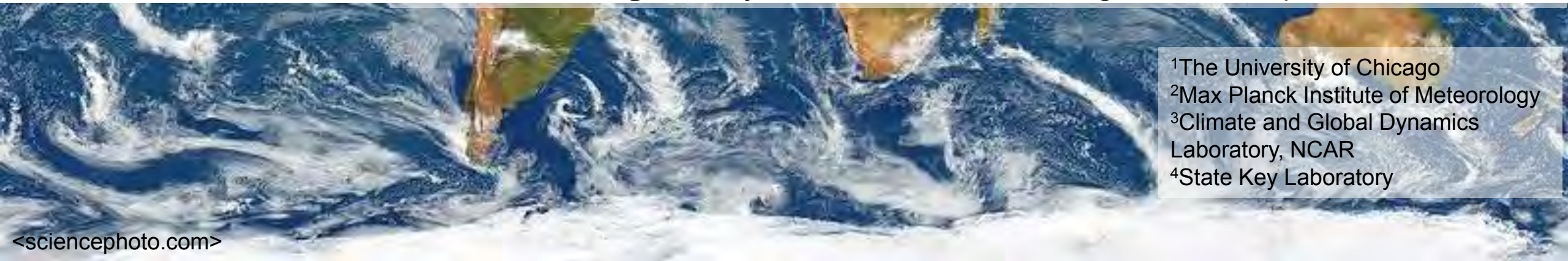


Revisiting the reanalysis-model discrepancy in Southern Hemisphere winter storm track trends

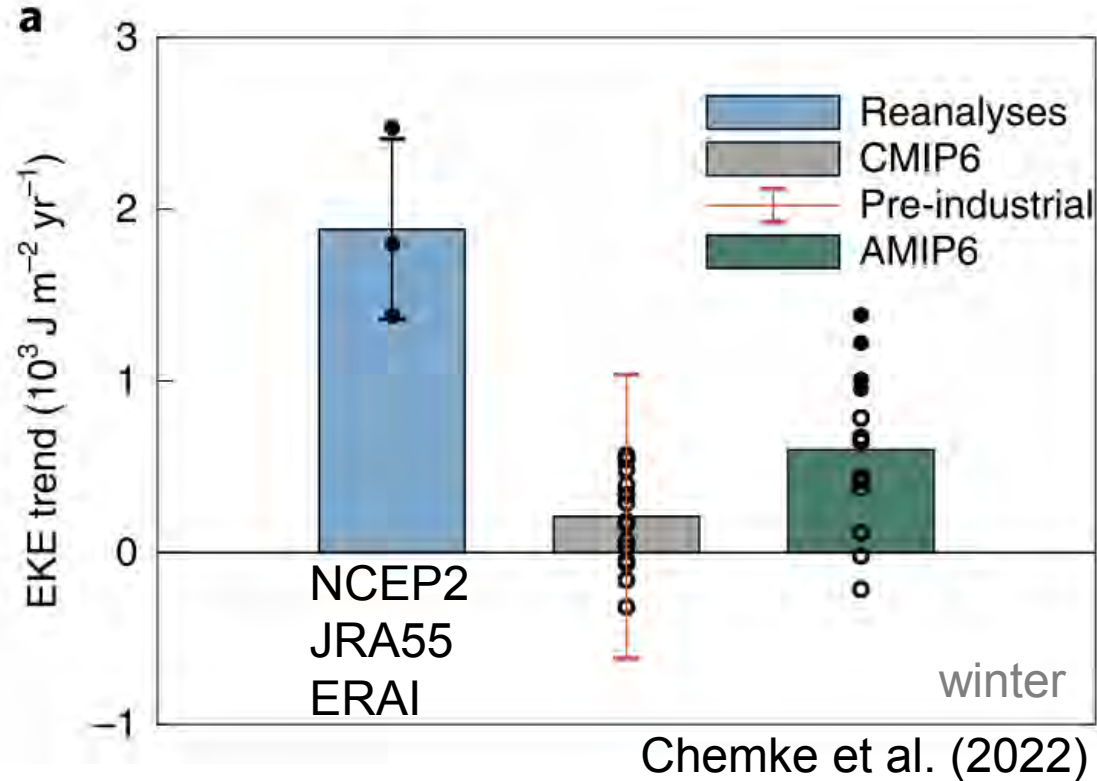
Joonsuk M. Kang¹, Tiffany A. Shaw^{1,2}, Sarah M. Kang², Isla R. Simpson³, and Yue Yu⁴

¹The University of Chicago
²Max Planck Institute of Meteorology
³Climate and Global Dynamics Laboratory, NCAR
⁴State Key Laboratory



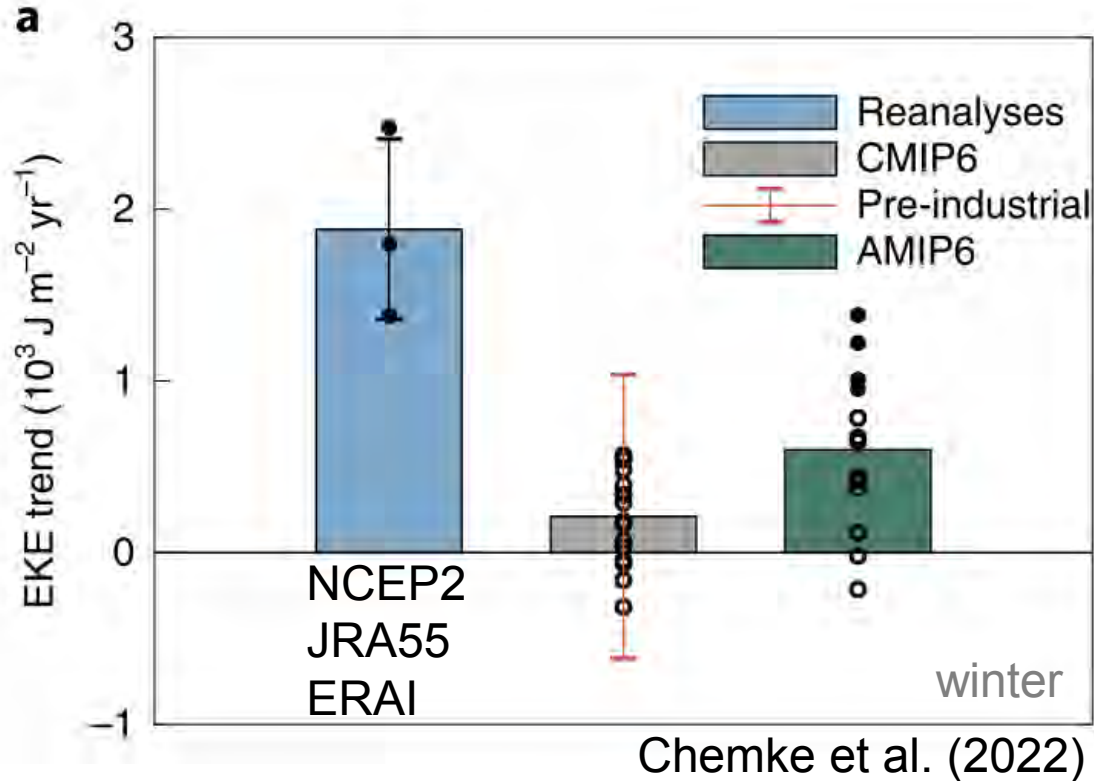
SH winter storm track is strengthening, and reanalysis trend seems to fall outside the model distribution

Vertically integrated EKE trends (1979–2018)

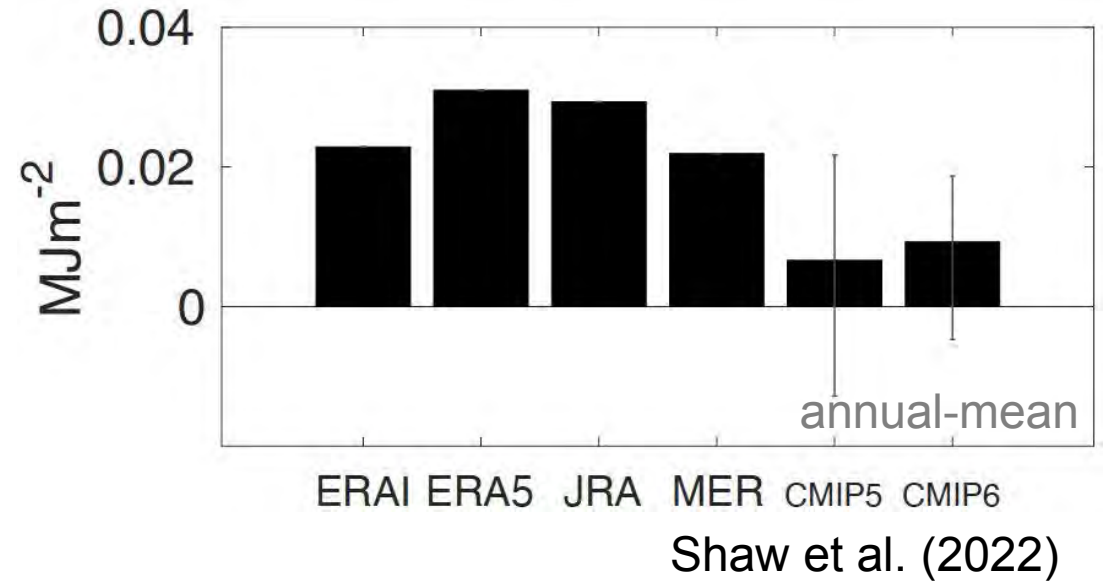


SH winter storm track is strengthening, and reanalysis trend seems to fall outside the model distribution

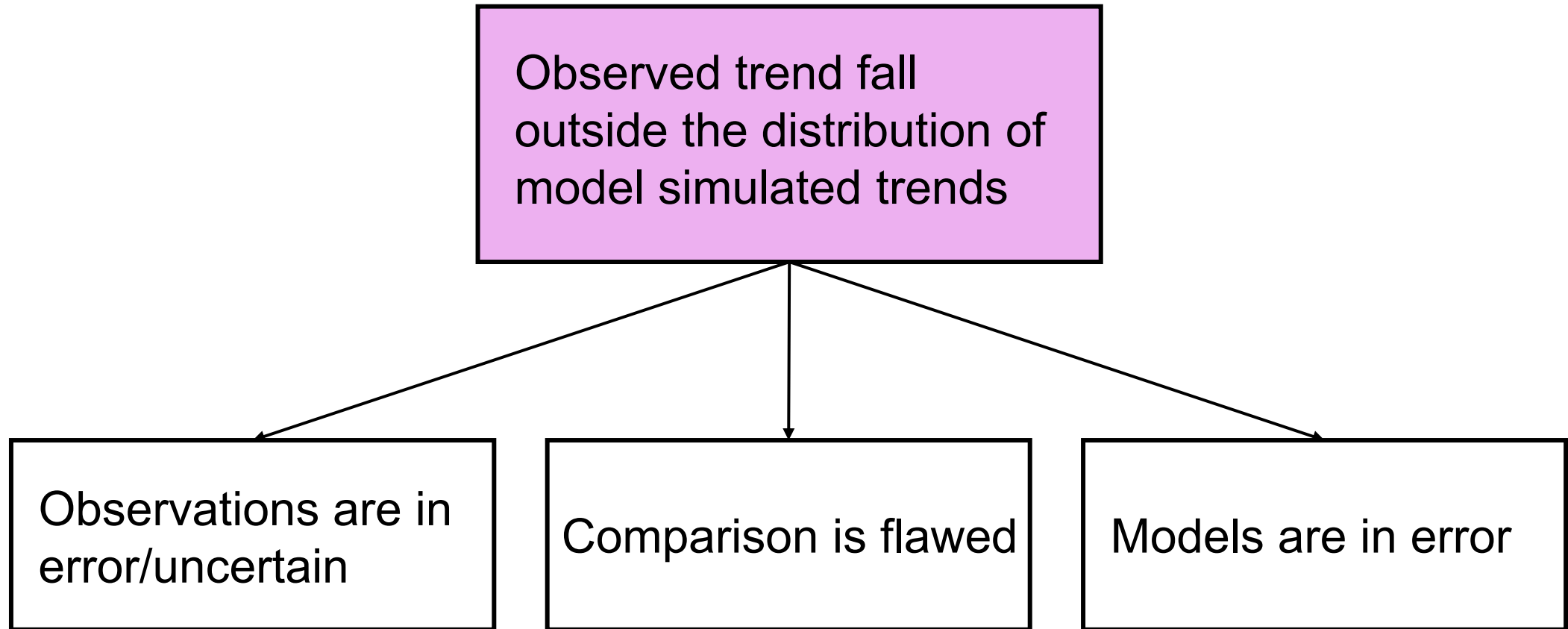
Vertically integrated EKE trends (1979–2018)



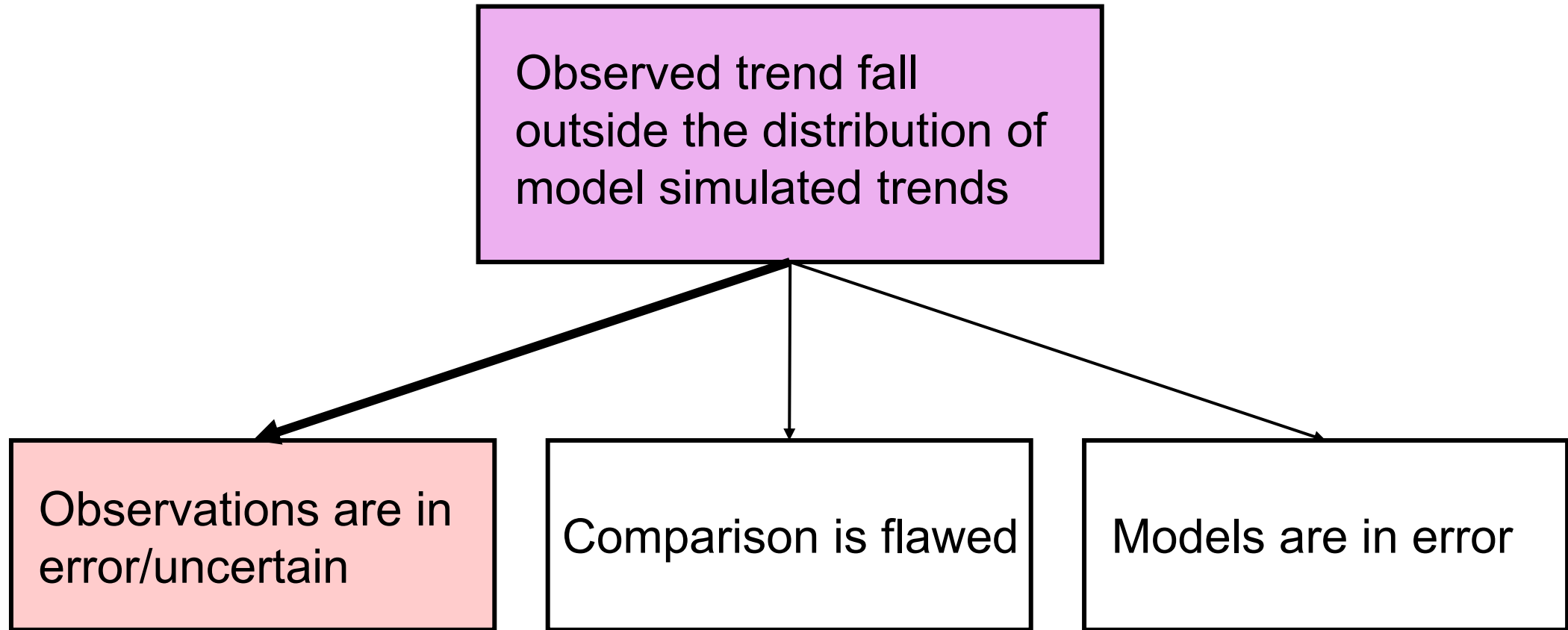
Vertically integrated EKE trends (1980–2020)



Many factors can contribute to observation-model trend discrepancy



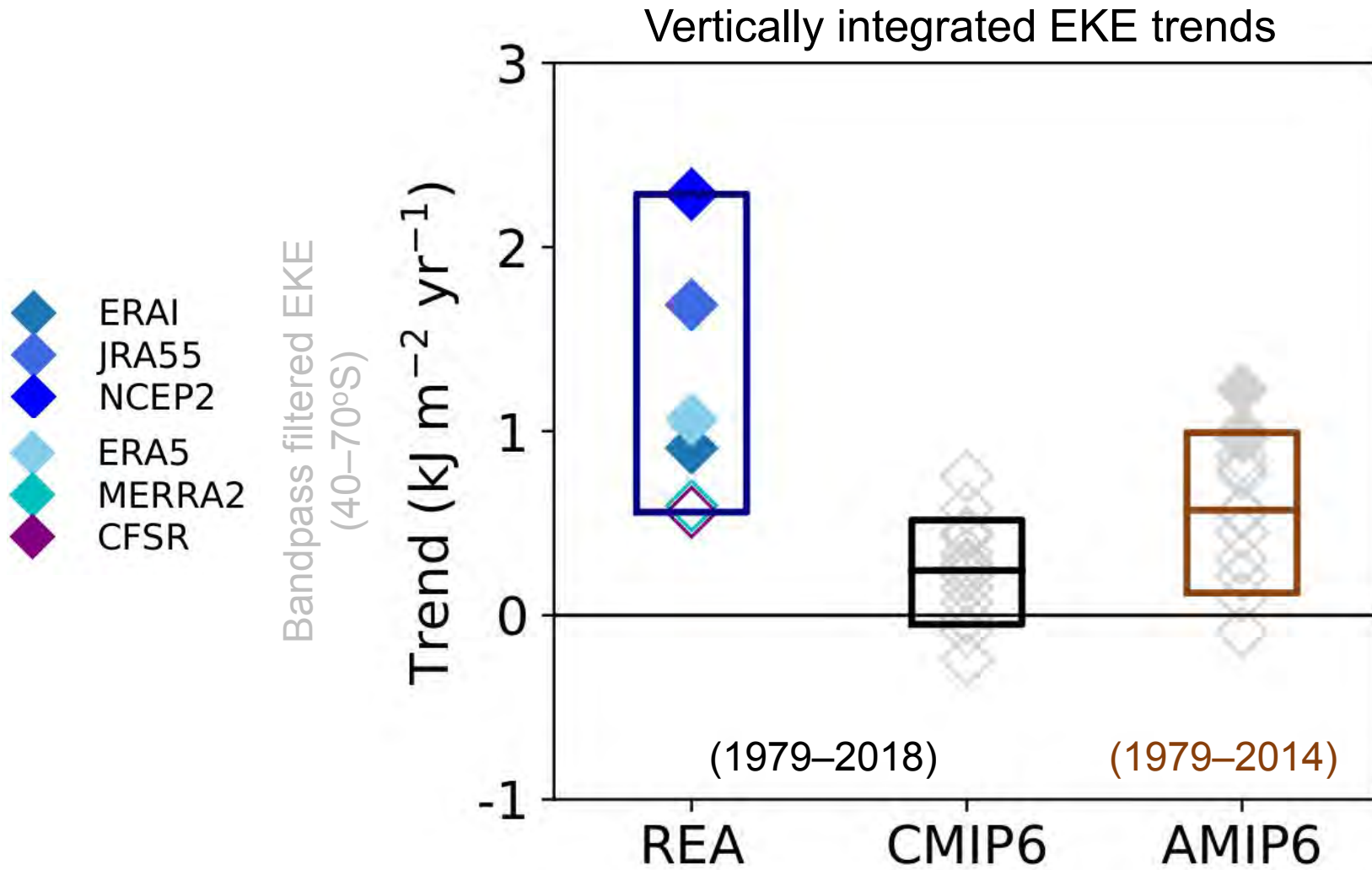
Reanalyses SH storm track trends can have large uncertainty



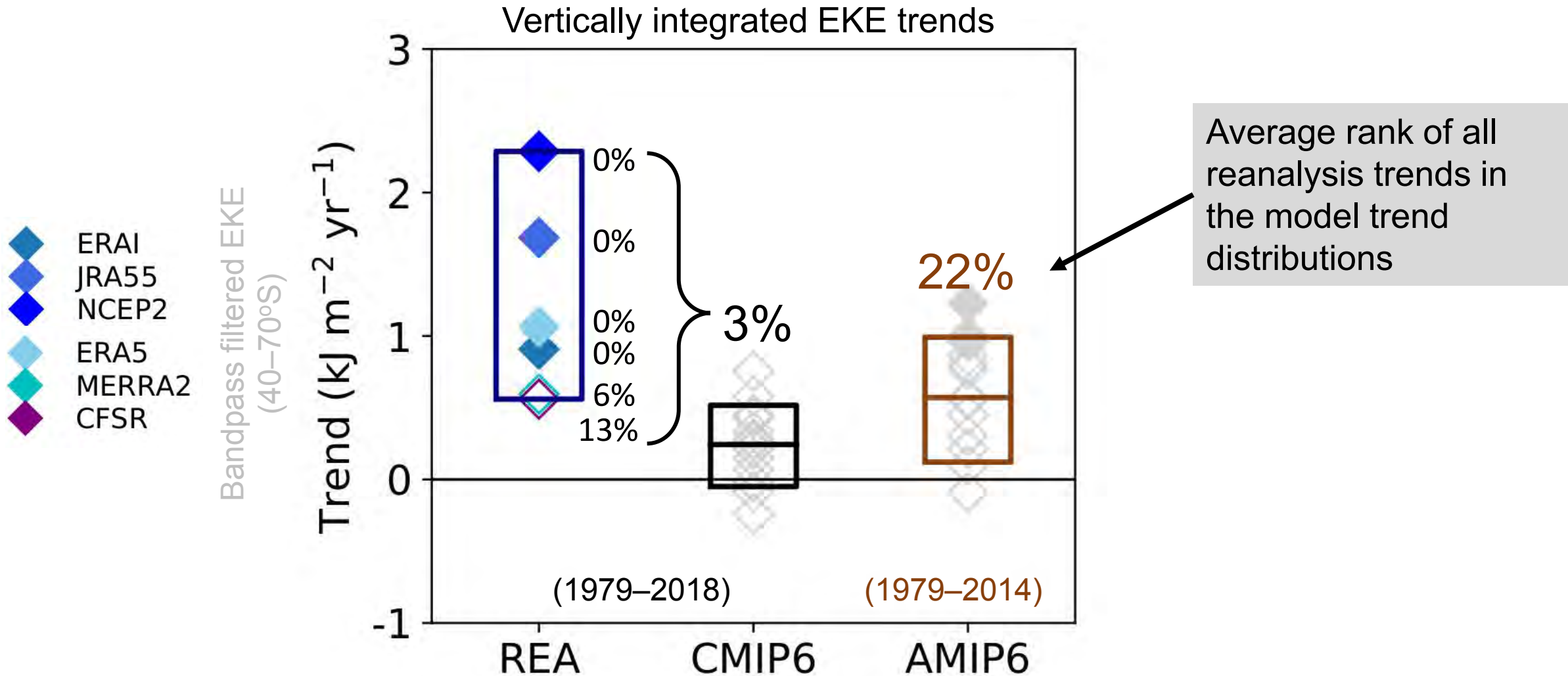
Guo et al. (2009)

Martineau et al. (2024)

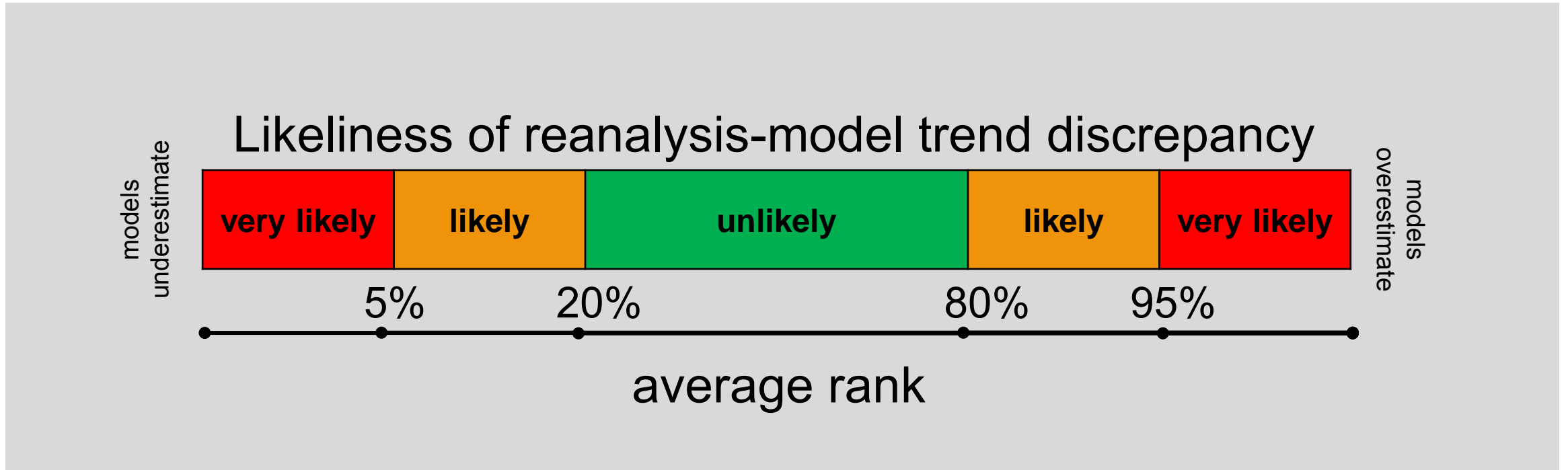
Uncertainty in reanalysis is large



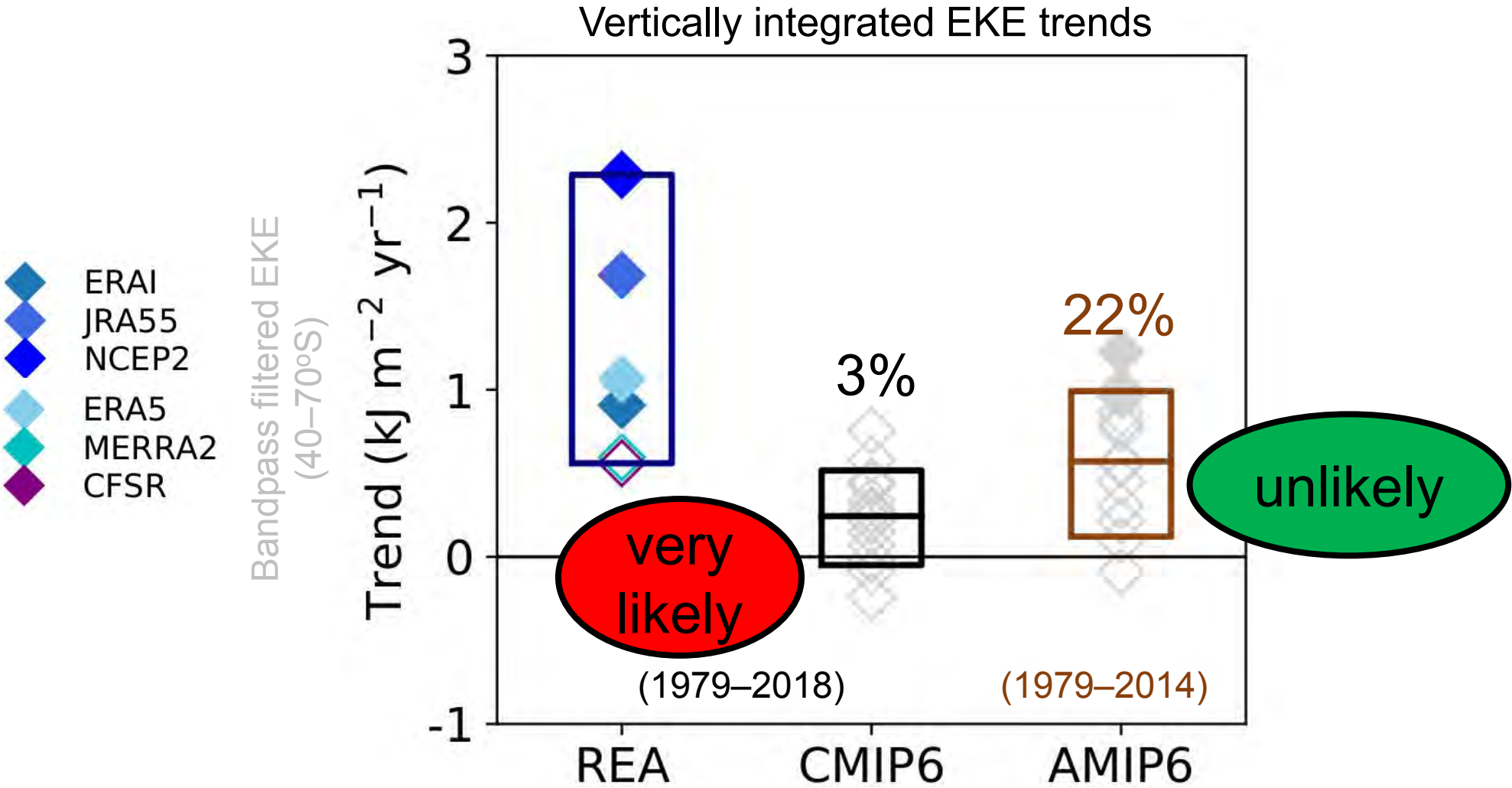
Reanalysis-model trend discrepancy is evaluated using average reanalysis rank



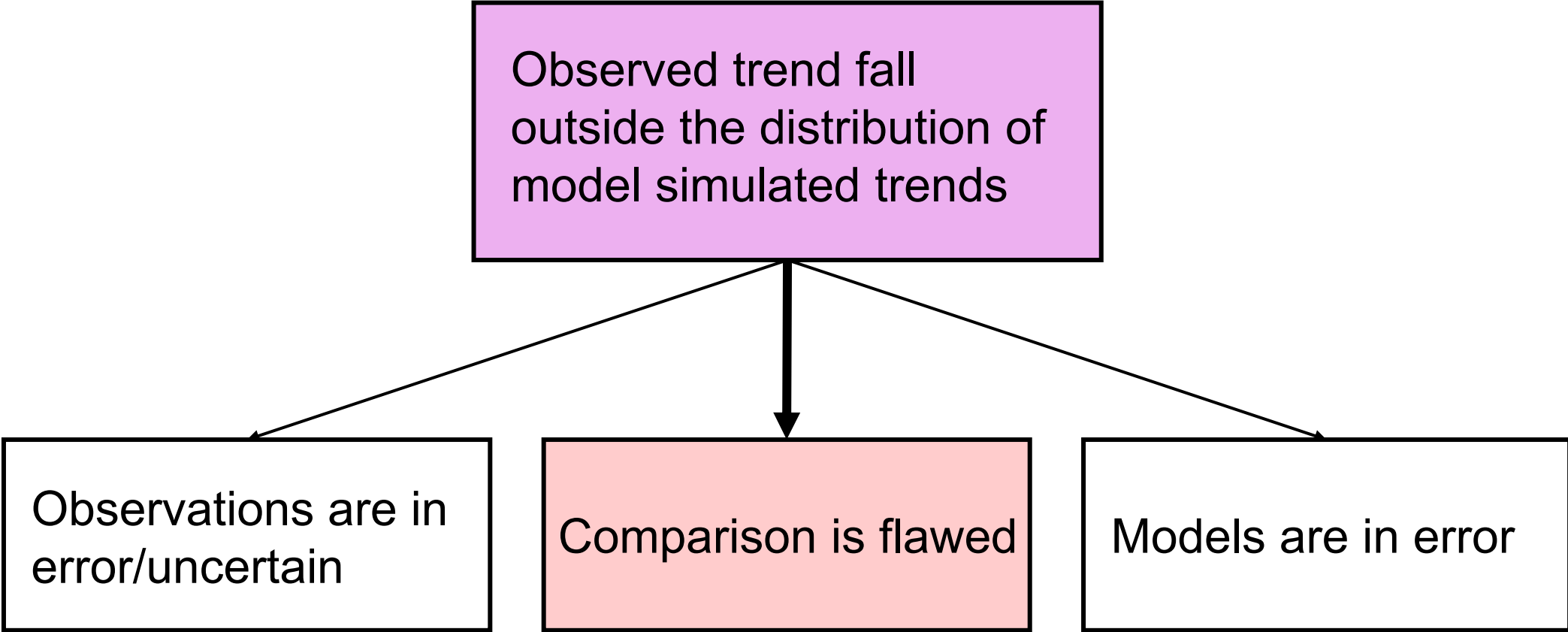
Reanalysis-model trend discrepancy is evaluated using average reanalysis rank



Rank metric suggests very likely discrepancy for CMIP6, but unlikely for AMIP6

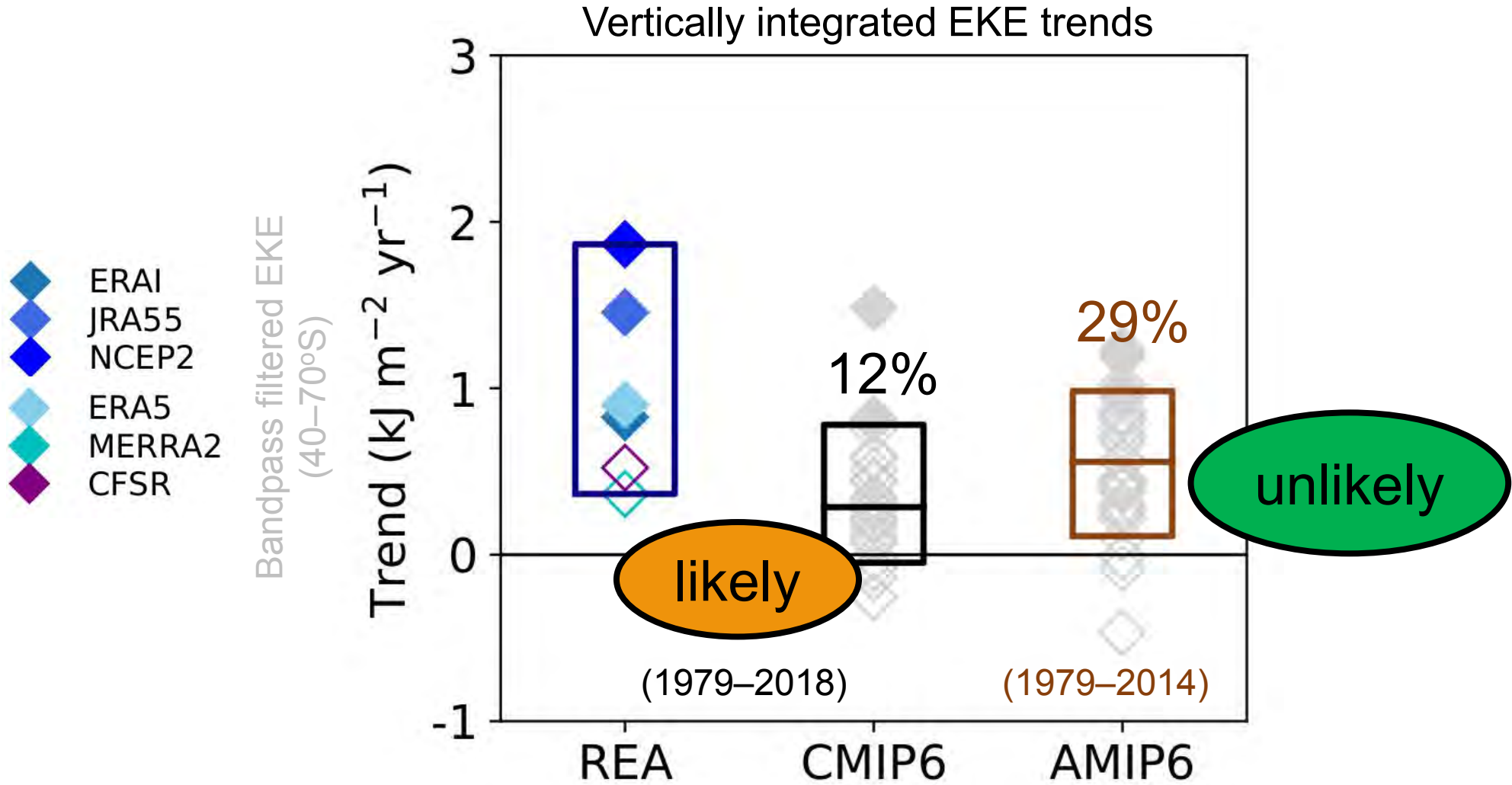


Reanalyses and models have different frequency, spatial grids, and ensemble members

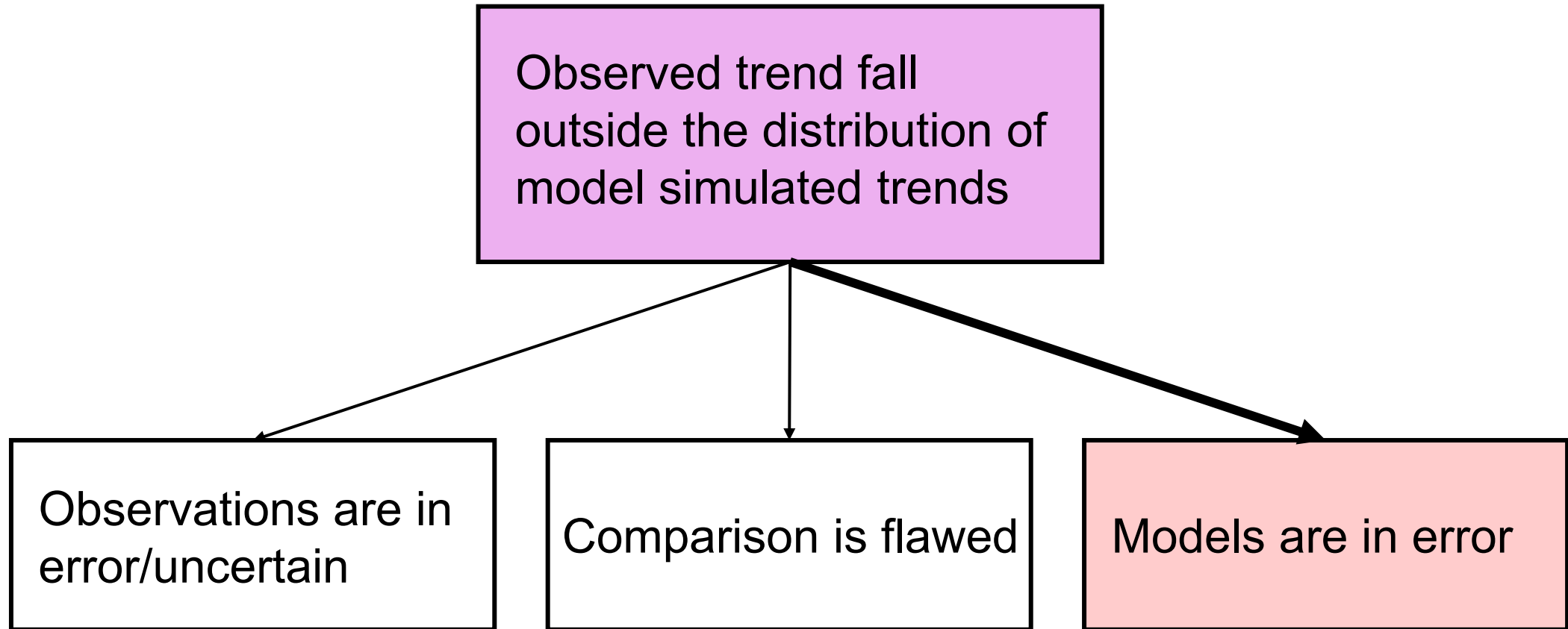


Schmidt (2013)
Shaw et al. (2024)

Like-for-like comparison suggests reanalysis-AMIP6 storm track trend discrepancy is unlikely



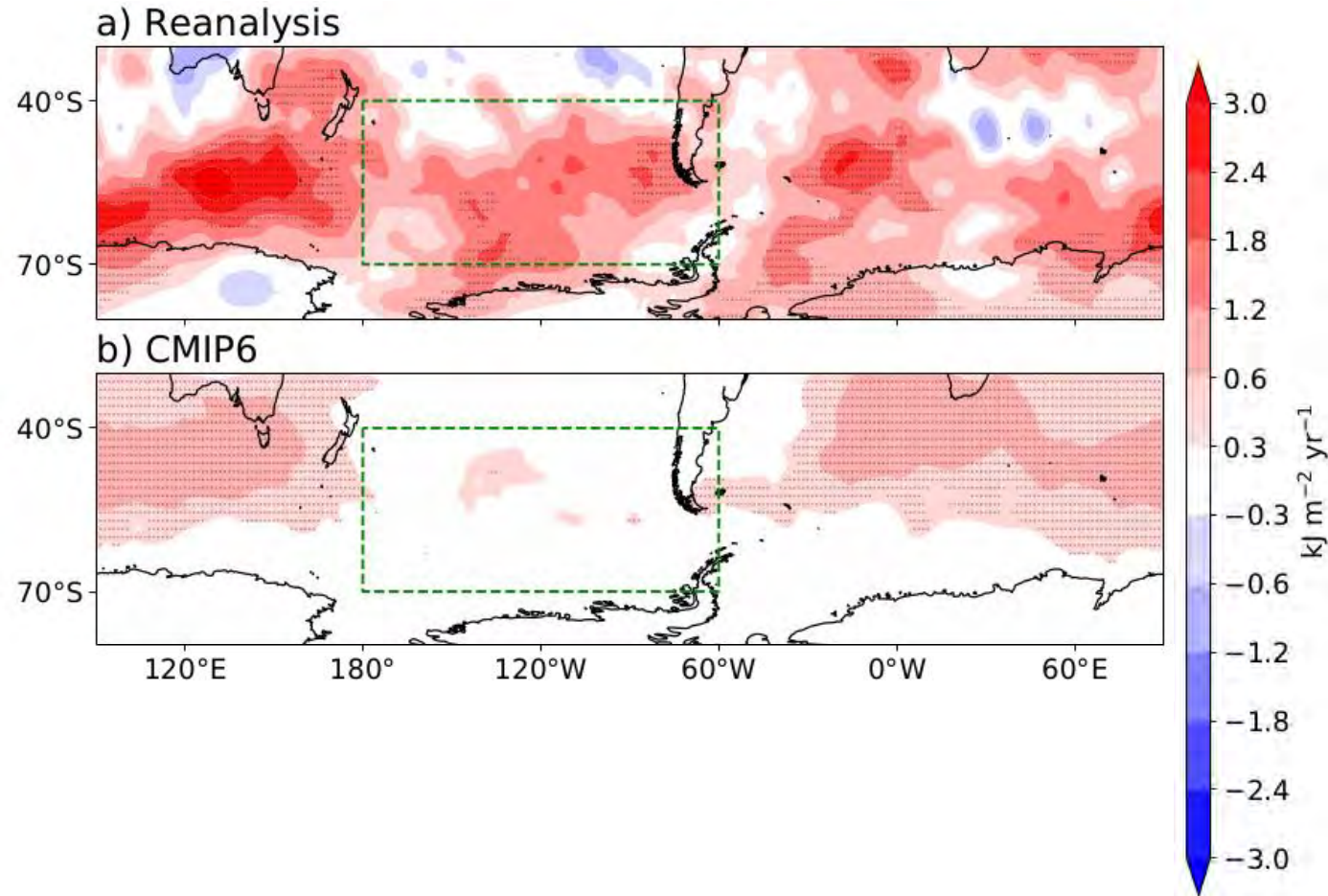
Reanalysis-CMIP6 trend discrepancy is still likely after and like-for-like comparison



Schmidt (2013)
Shaw et al. (2024)

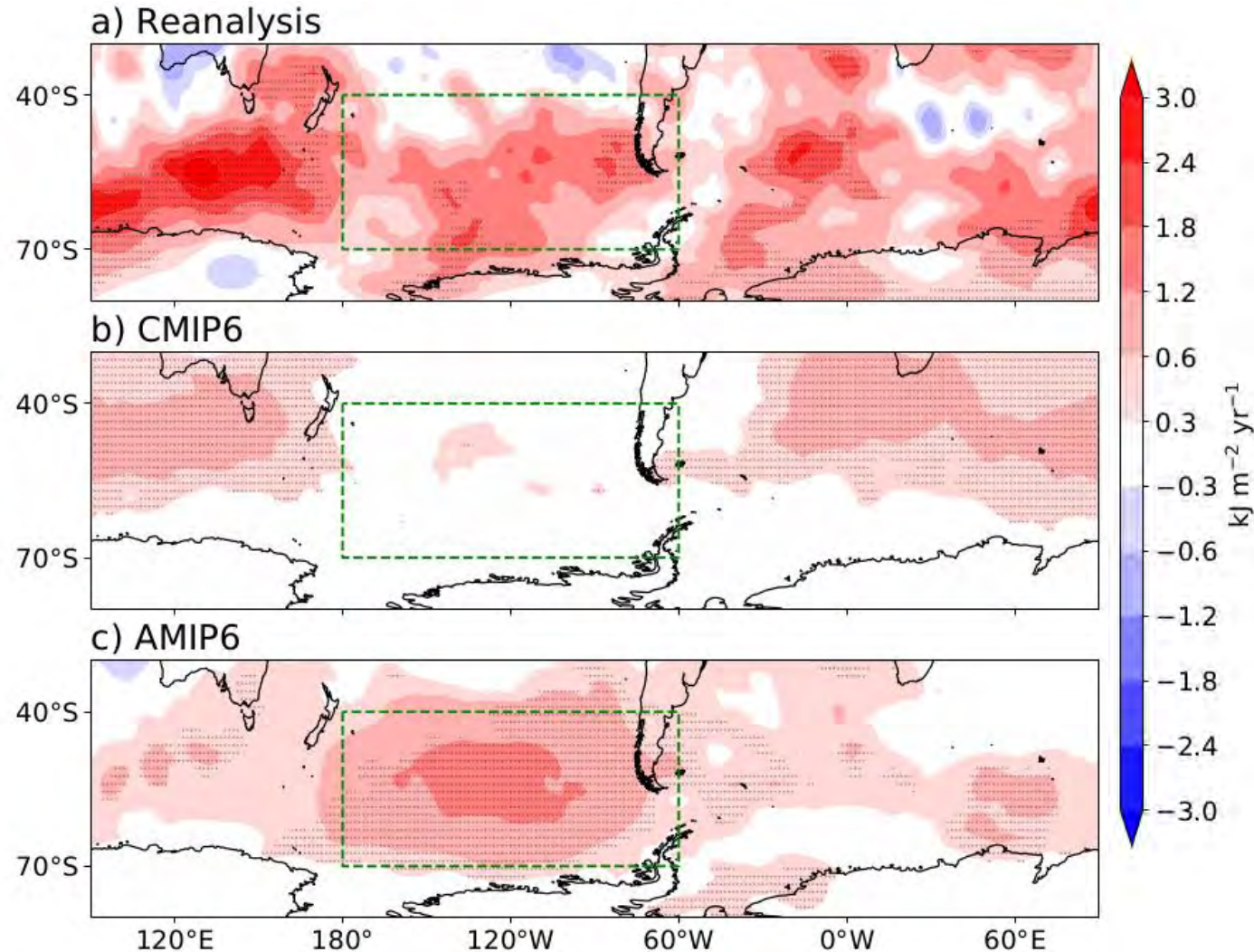
CMIP6 models do not capture the trend in the South Pacific

Vertically integrated EKE trend



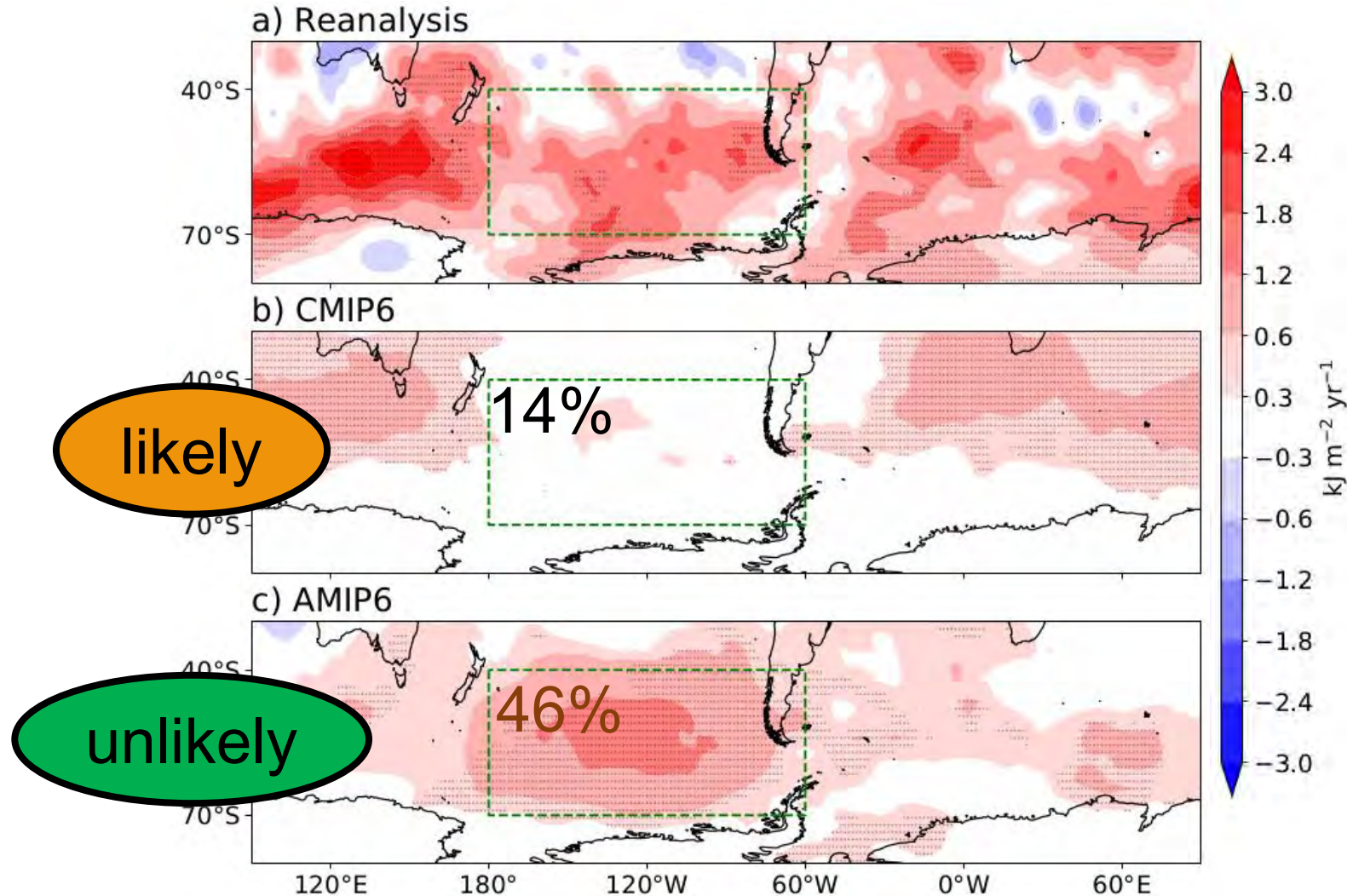
CMIP6 and AMIP6 difference suggests SST trend discrepancies influence SH storm track trends

Vertically integrated EKE trend

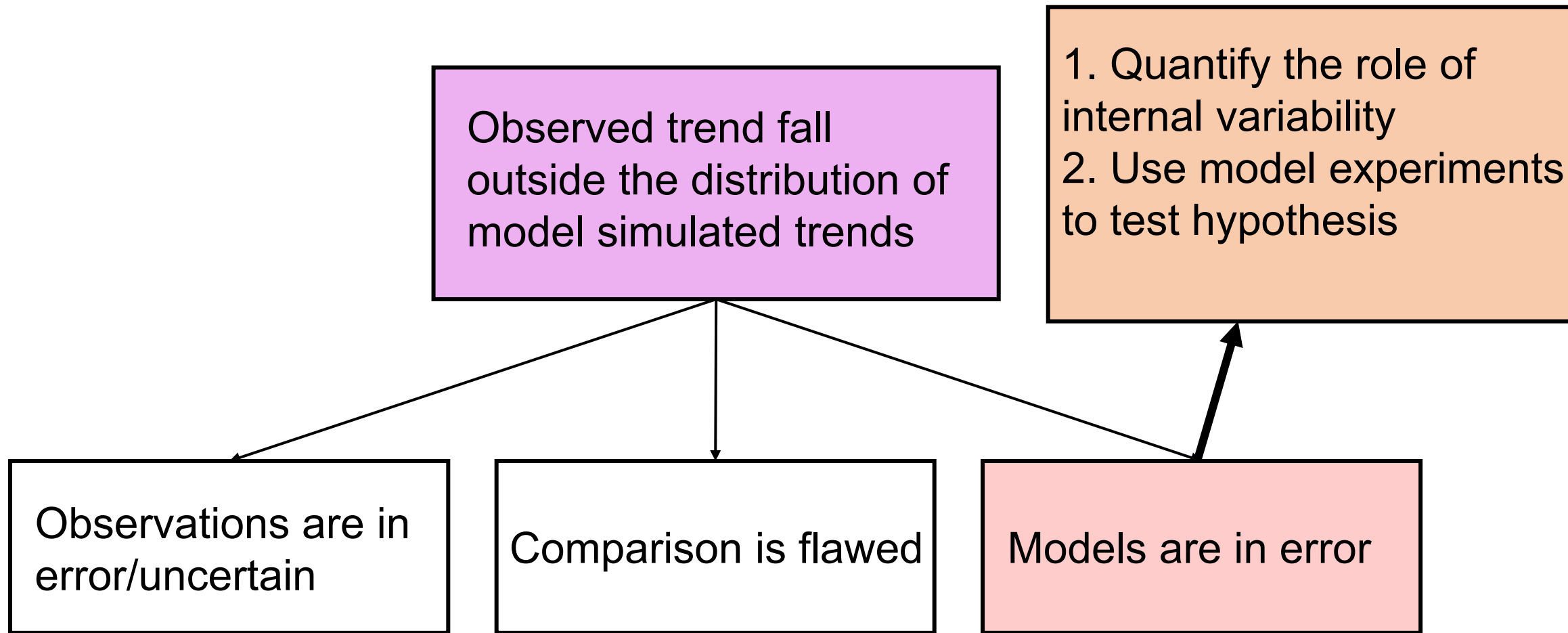


CMIP6 and AMIP6 difference suggests SST trend discrepancies influence SH storm track trends

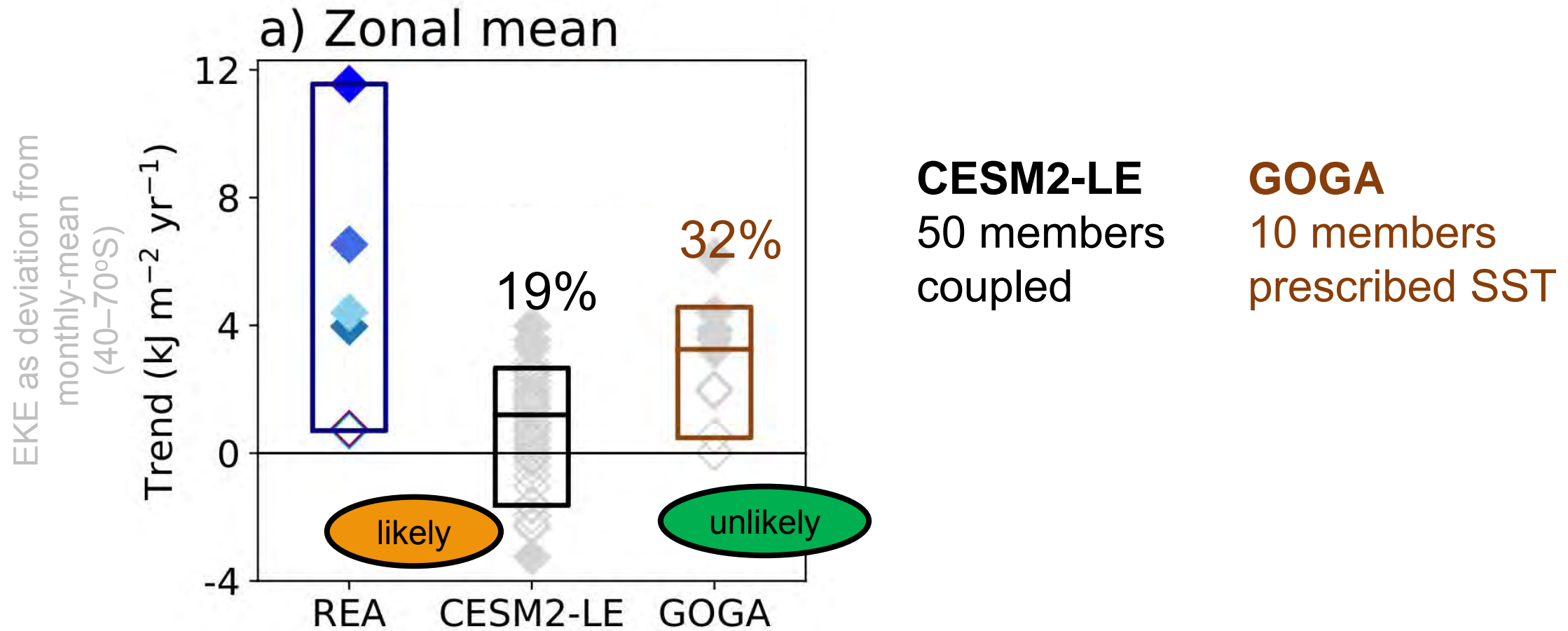
Vertically integrated EKE trend



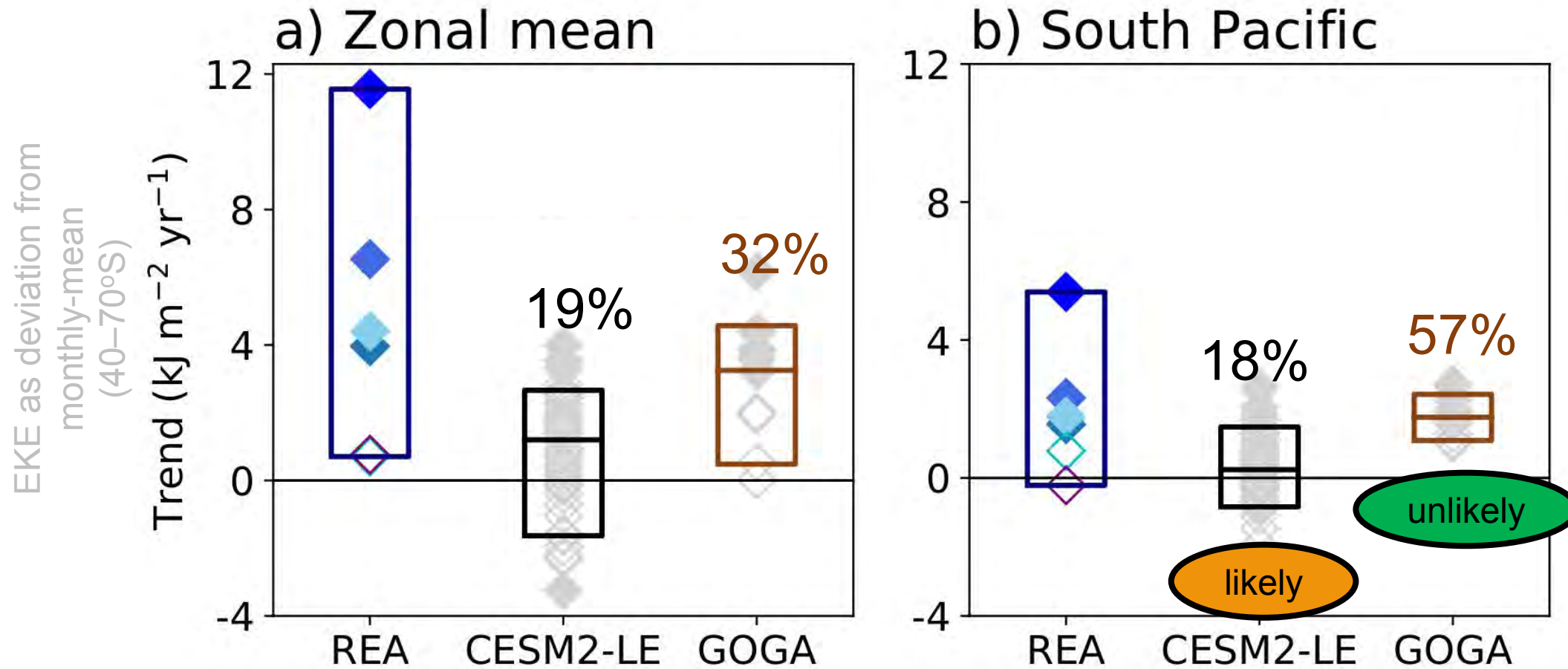
We use CESM2 large ensemble and pacemaker simulations to test the hypothesis



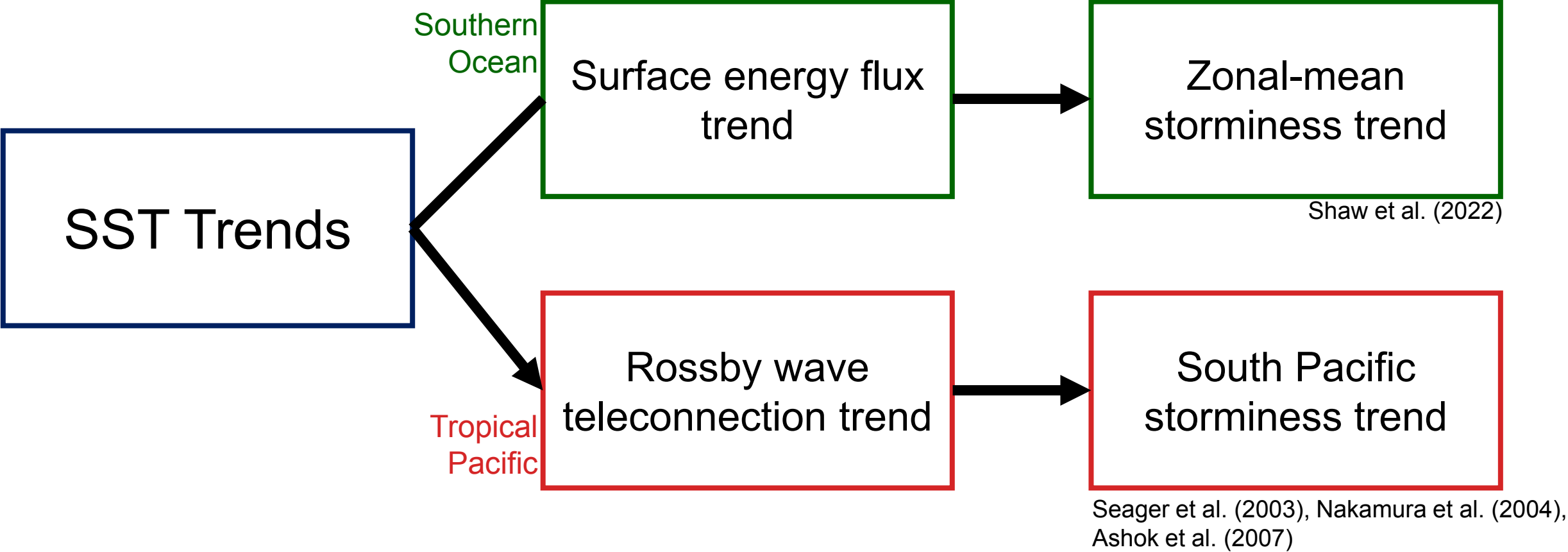
Internal variability is not likely responsible for the coupled model trend discrepancy



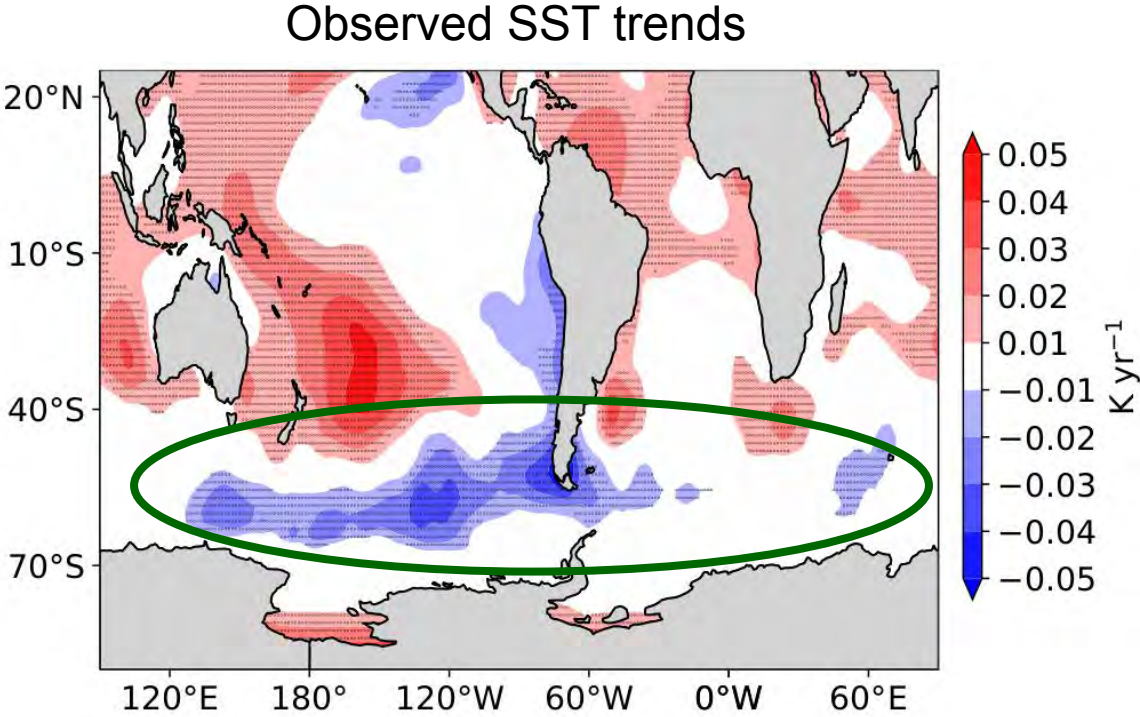
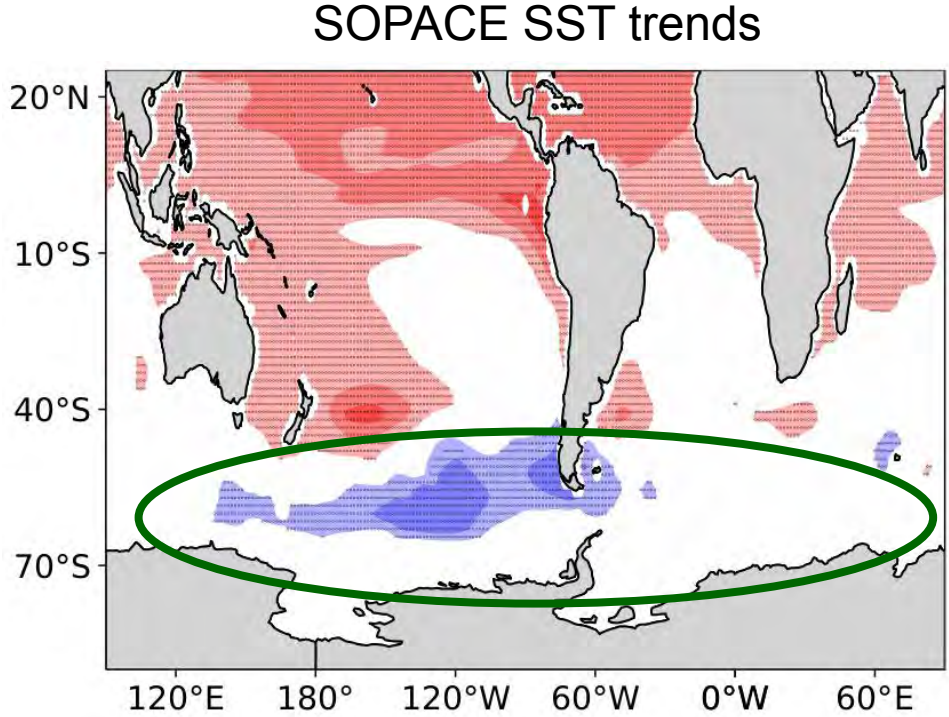
Internal variability is not likely responsible for the coupled model trend discrepancy



SST trend discrepancy can be connected to storminess trend through different mechanisms



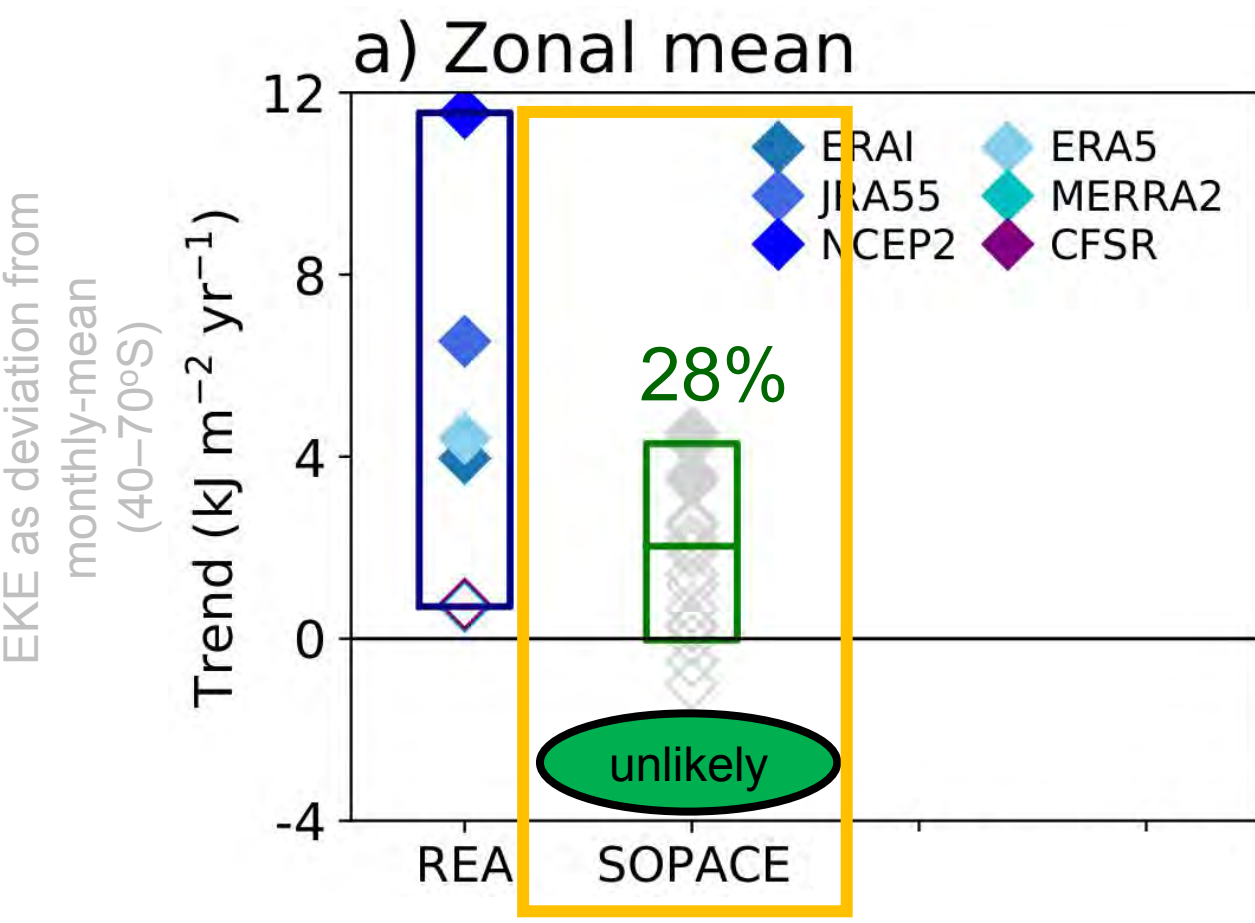
Southern Ocean pacemakers remove the SST trend discrepancy, and can be used to test the hypothesis



Southern Ocean pacemaker: Kang et al. (2023)

See also Wills et al. (2022), Seager et al. (2022), Lee et al. (2022)

By pacemaking Southern Ocean, reanalysis-coupled model discrepancy is unlikely in the zonal mean



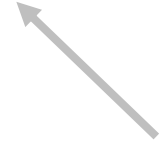
Improving surface energy flux trends enhances storminess trends when Southern Ocean is pacemaker

Poleward atmospheric energy transport



$$\nabla \cdot F_{SFC} = S$$

Surface energy flux



Representation of ocean circulation and heat storage



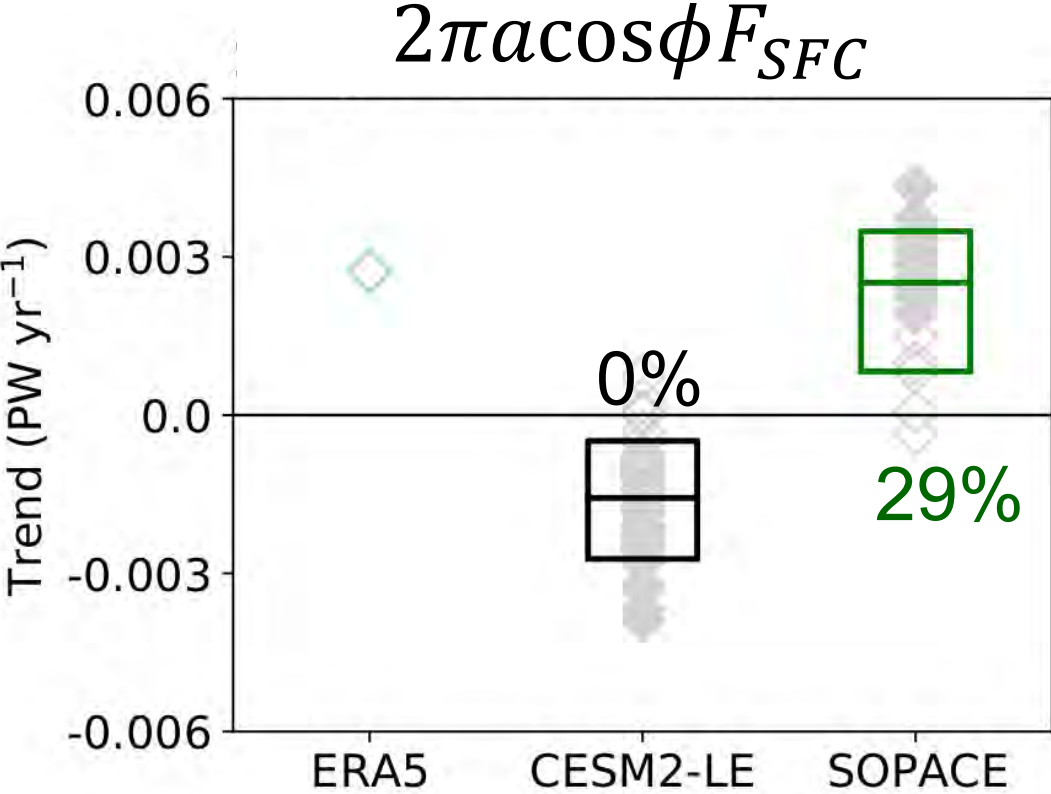
Improving surface energy flux trends enhances storminess trends when Southern Ocean is pacemaked

Poleward atmospheric energy transport

$$\nabla \cdot F_{SFC} = S$$

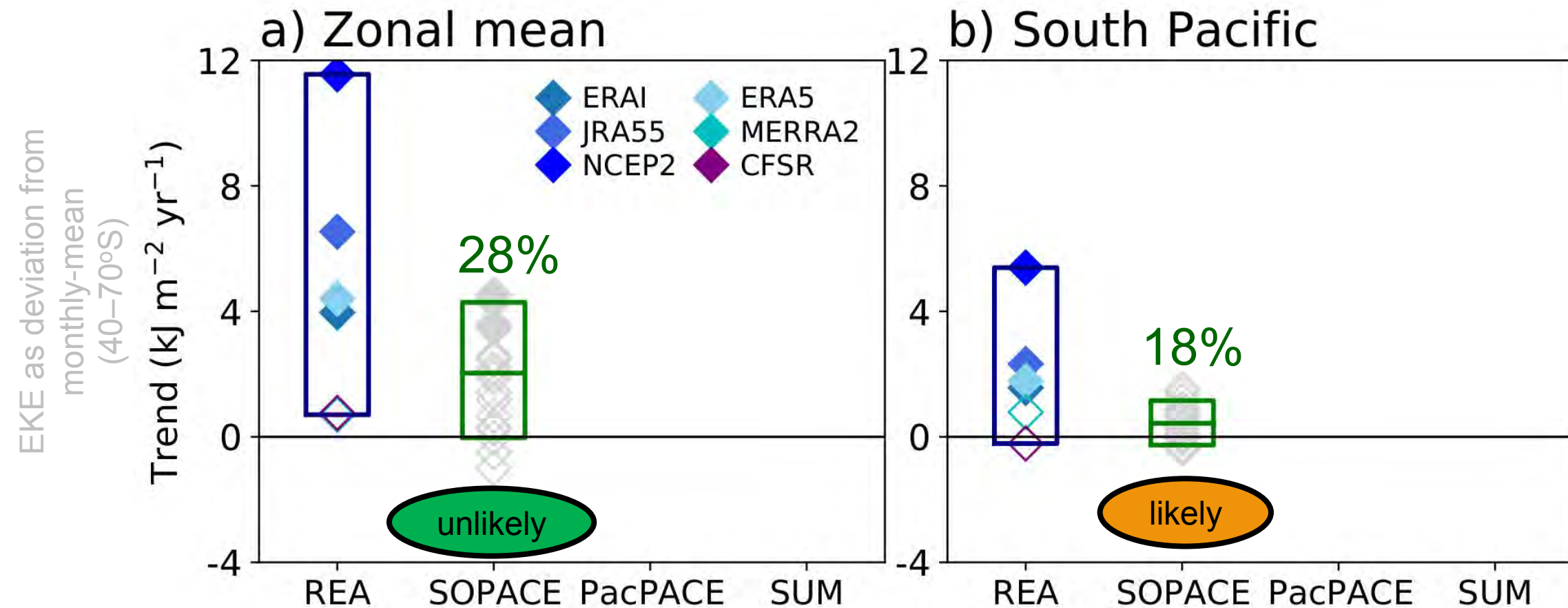
Surface energy flux

Representation of ocean circulation and heat storage

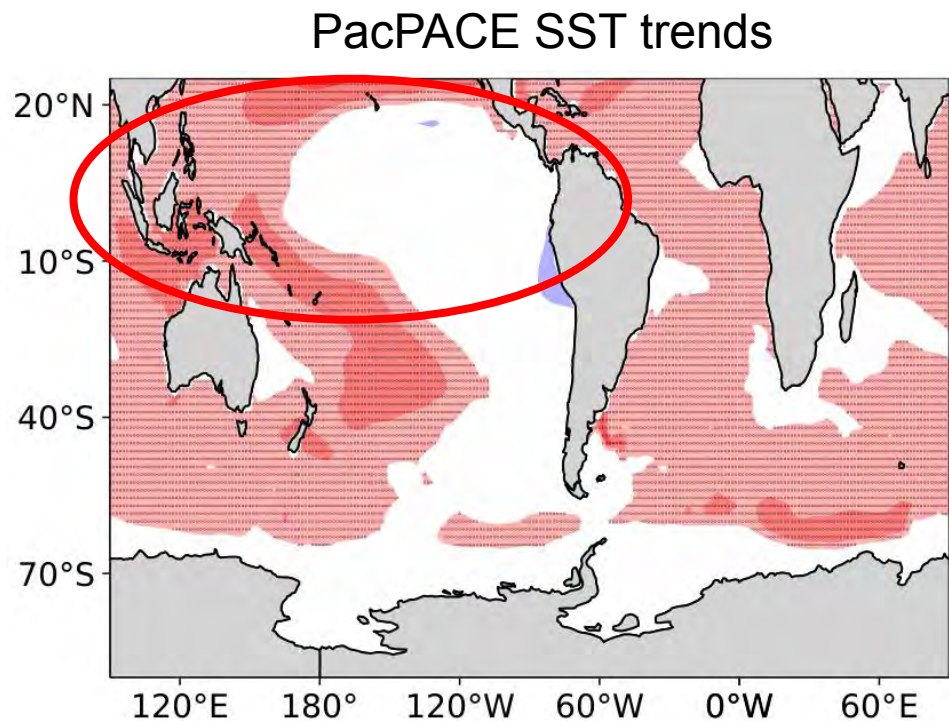


See also Shaw et al. (2022)

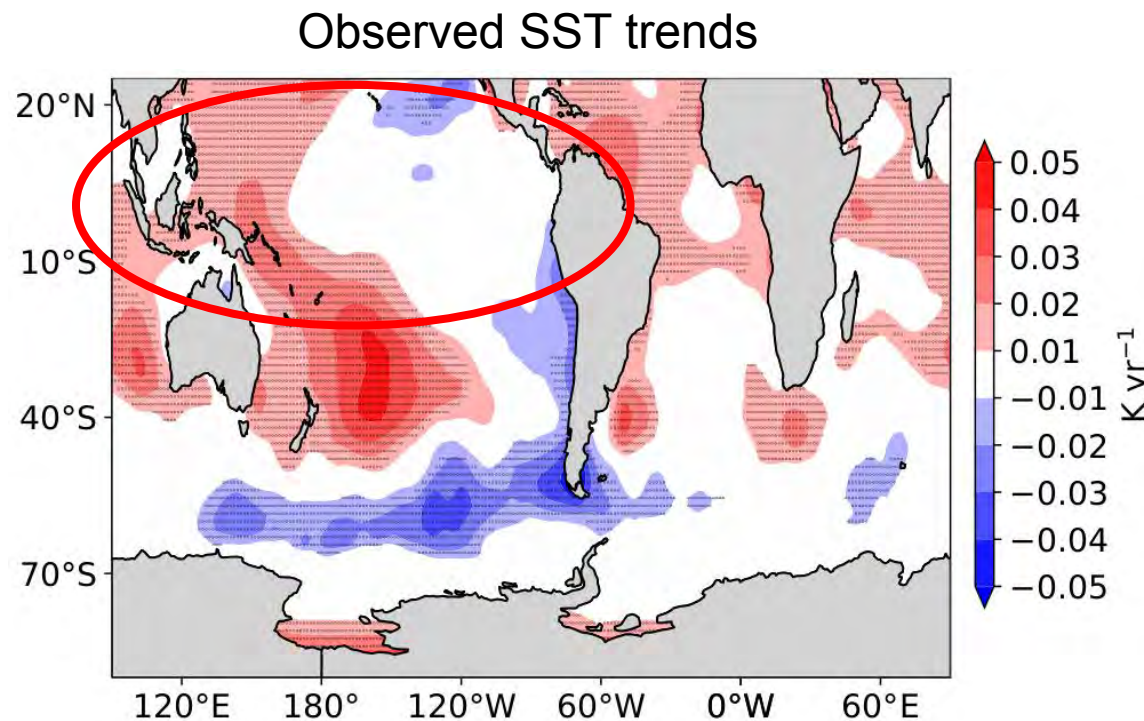
Even after pacemaking Southern Ocean, discrepancy is still likely over South Pacific



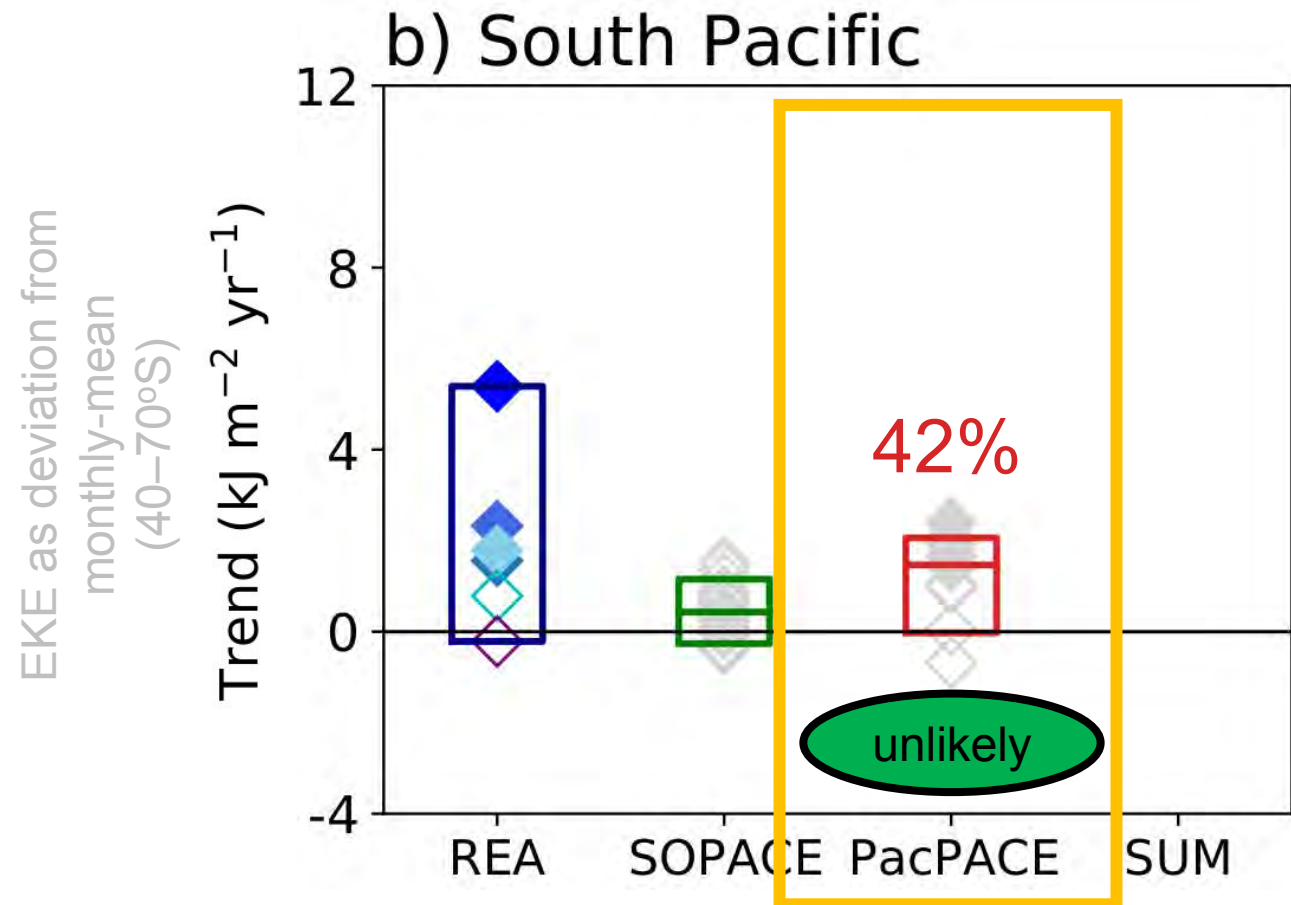
Pacific pacemakers remove tropical SST trend discrepancy in the tropical Pacific and can be used to test the hypothesis



Tropical Pacific Pacemakers: CVCWG

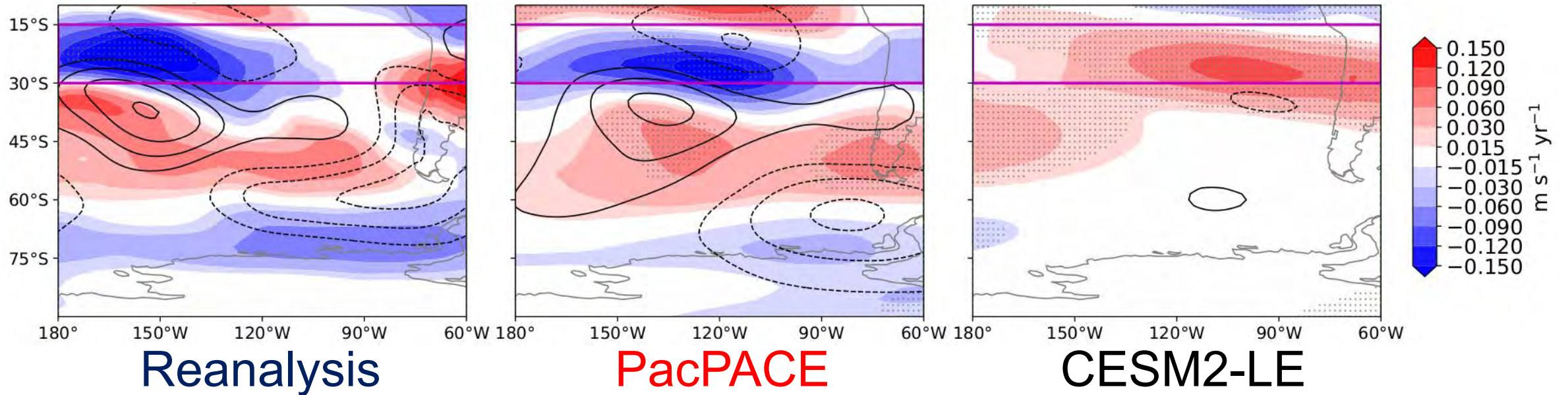


By pacemaking tropical Pacific, reanalysis-coupled model discrepancy is unlikely in the South Pacific



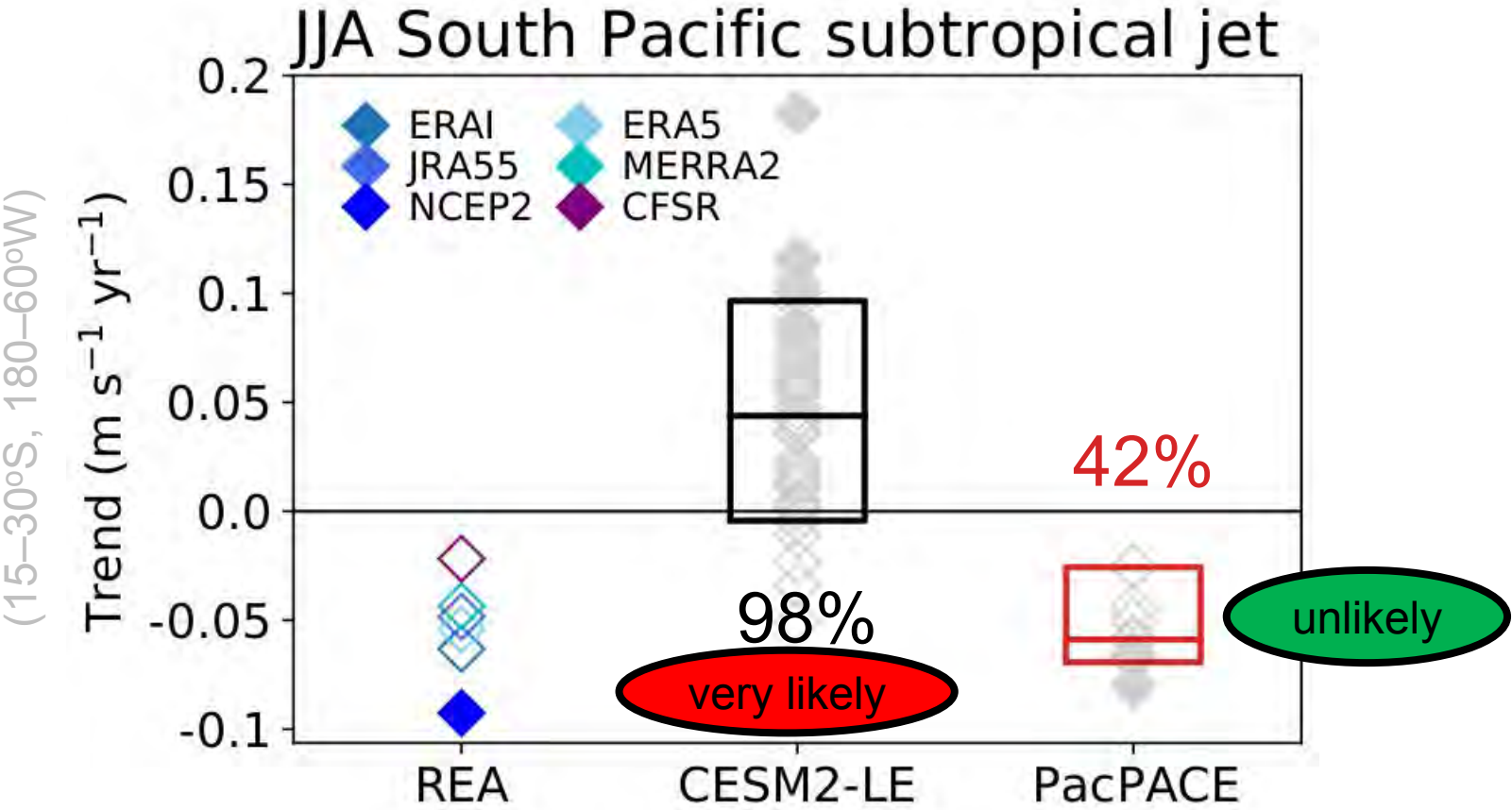
Capturing La Nina-like teleconnection trends enhances the storminess trends when tropical Pacific is pacemaked

South Pacific 200-hPa zonal wind and eddy geopotential trends

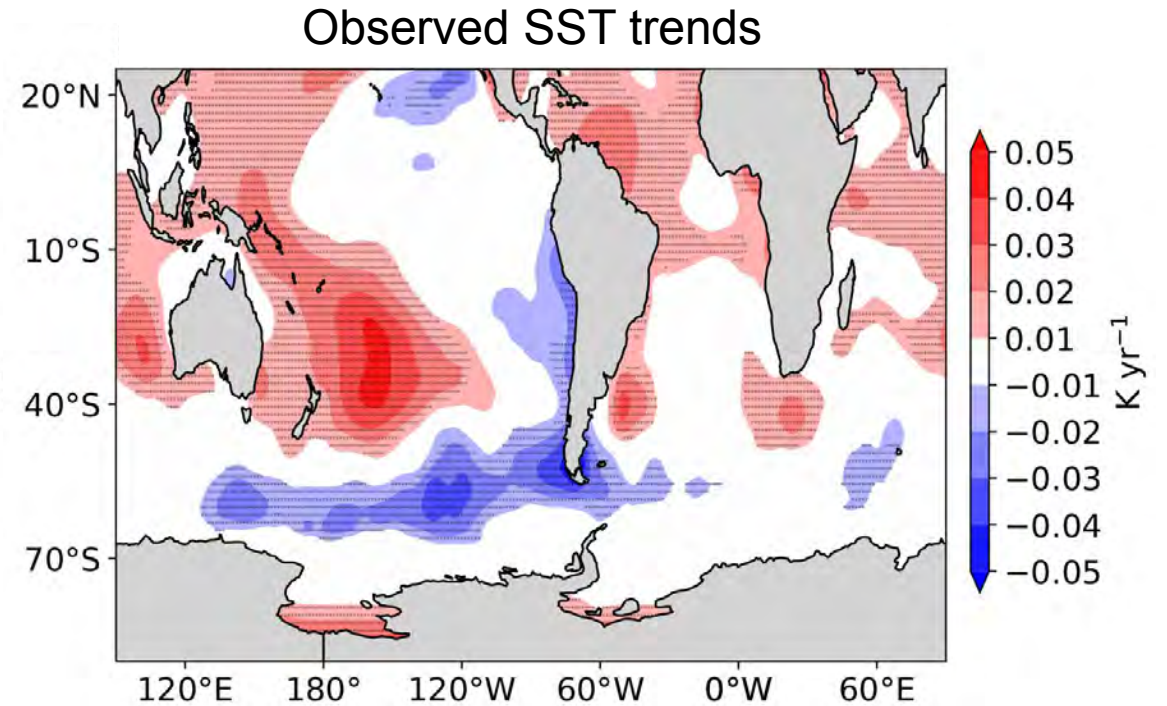
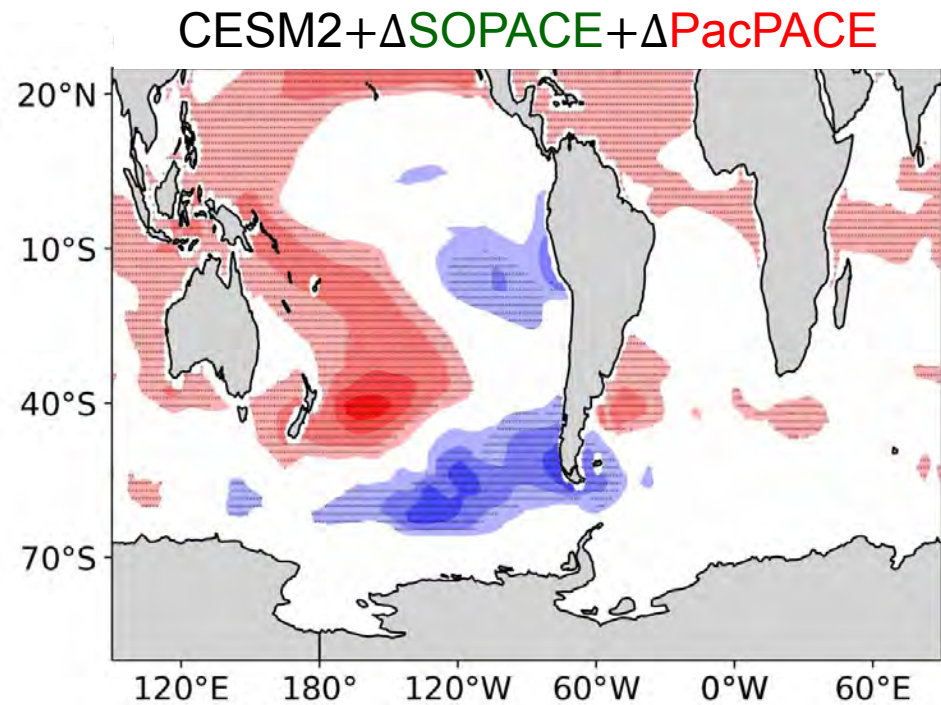


See also Seager et al. (2003), Nakamura et al. (2004), Ashok et al. (2007)

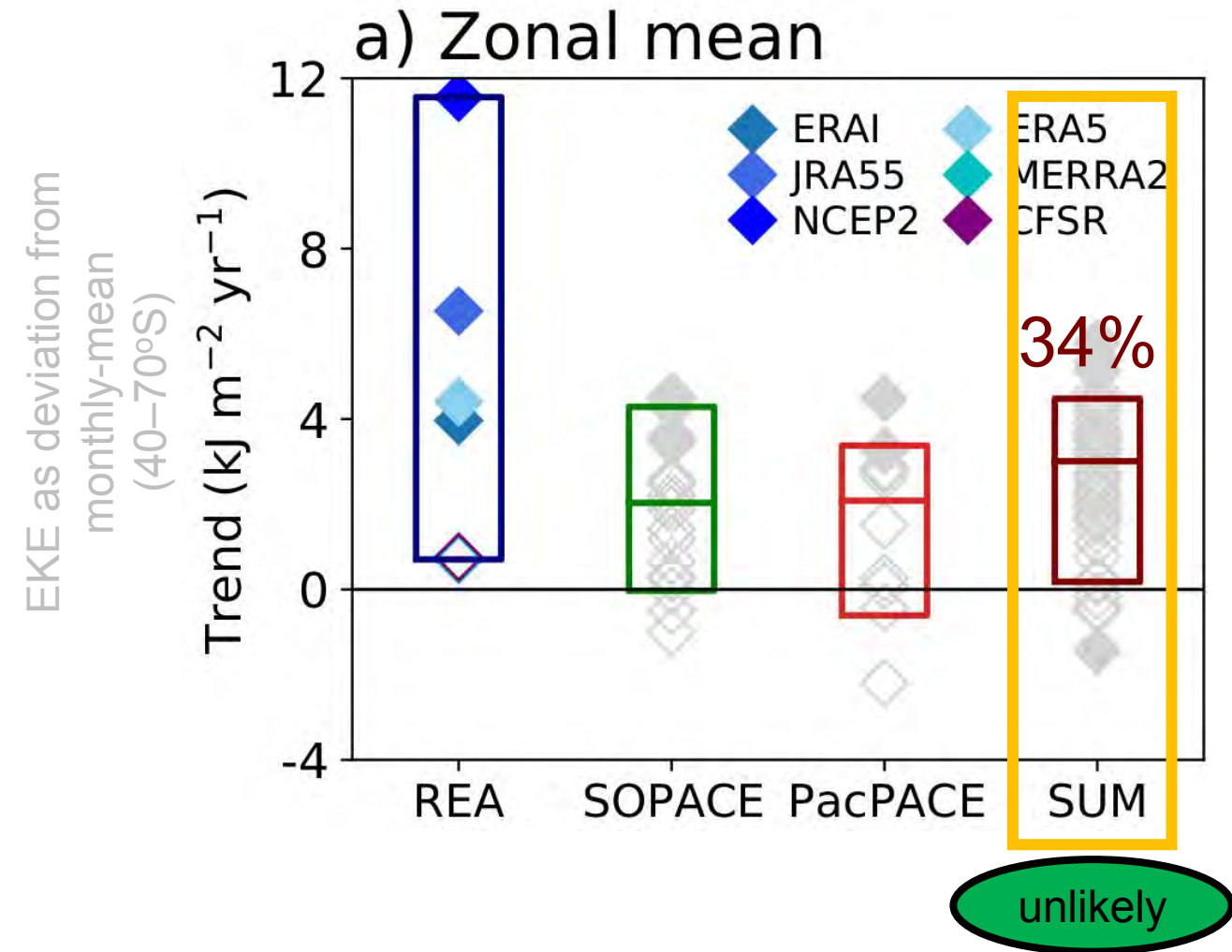
Capturing La Nina-like teleconnection trends enhances the storminess trends when tropical Pacific is pacemaked



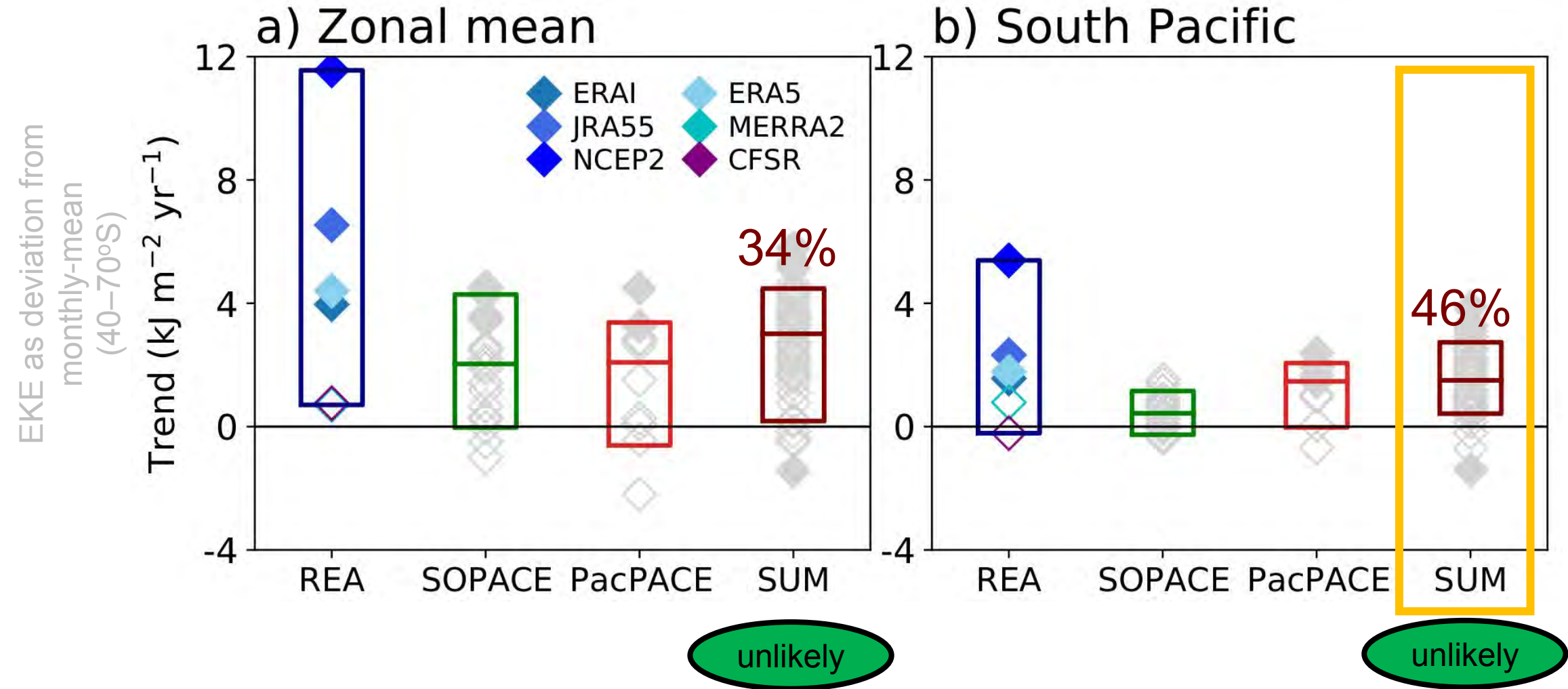
Together, pacemakers rectify the SST trend discrepancy in the coupled simulations



When coupled models capture SST trends, storminess trend discrepancy is unlikely



When coupled models capture SST trends, storminess trend discrepancy is unlikely



Take-Away messages

- After accounting for observational uncertainty, model ensemble size, and like-for-like comparison, the storminess trend discrepancy between reanalyses and prescribed SST models are unlikely.
- Pacemaker experiments confirms that SST trend discrepancies in the Southern Ocean and tropical Pacific are connected to storm track trend discrepancy in the coupled models.

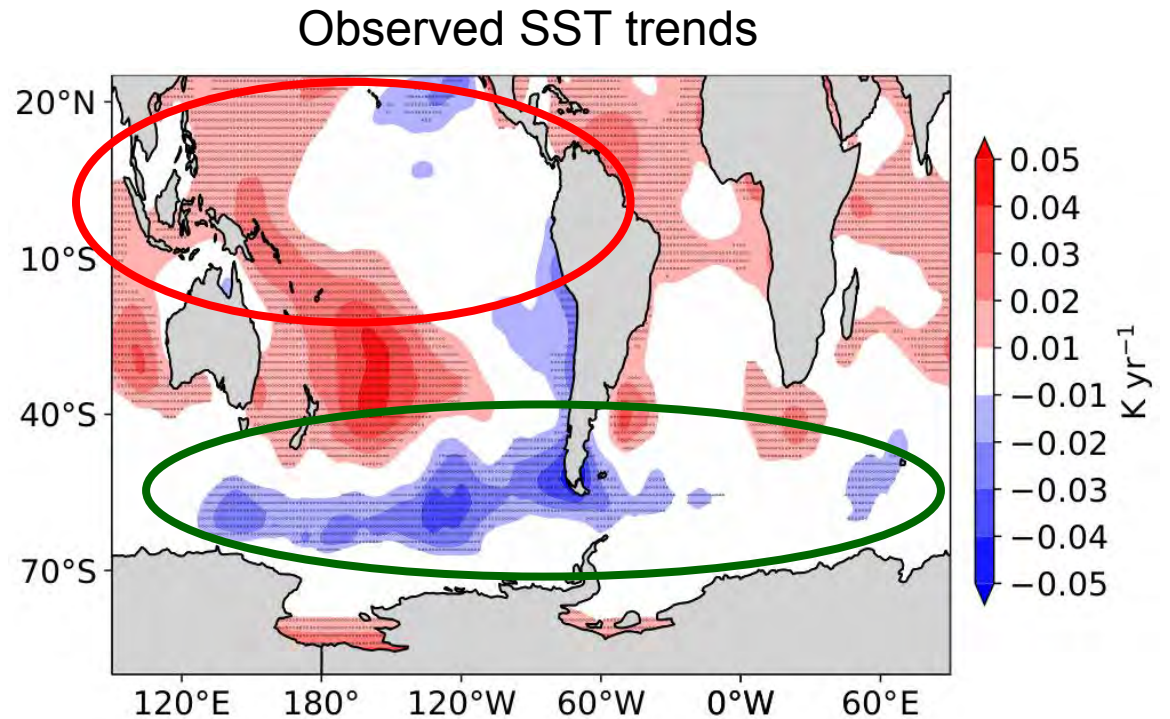
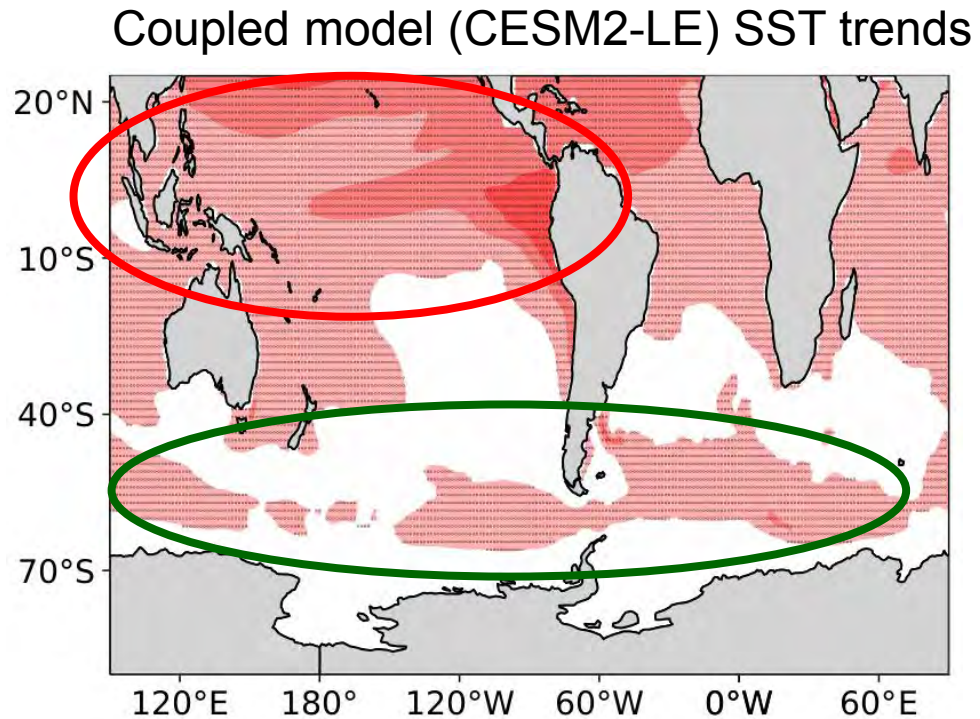
Reanalyses and models have different frequency, spatial grids, and ensemble members

Reanalyses	CMIP6 Models
6 hourly instantaneous	Daily-mean
~37 pressure levels	8 pressure levels
~0.5°×0.5° horizontal grid	>1.5°×1.5° horizontal grid
1 realization	Multiple models and realizations

Reanalyses and models have different frequency, spatial grids, and ensemble members

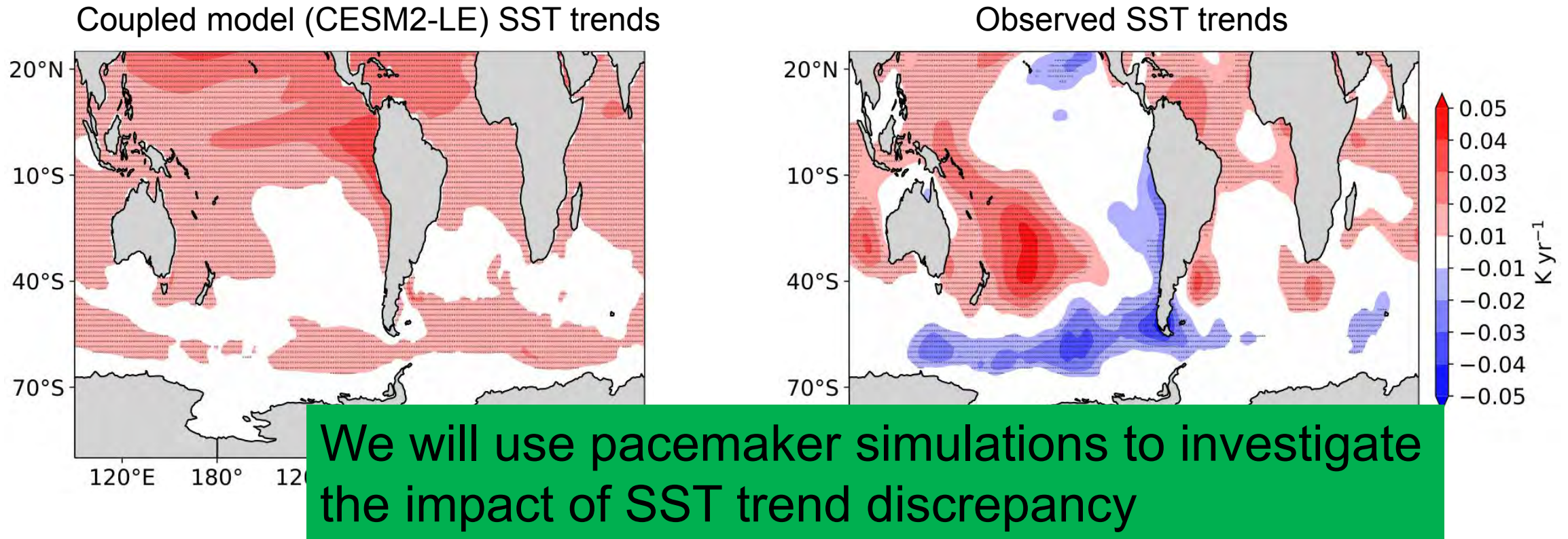
Reanalyses	CMIP6 Models
Daily-mean	Daily-mean
8 pressure levels	8 pressure levels
1.5°×1.5° horizontal grid	1.5°×1.5° horizontal grid
1 realization	26 CMIP6, 32 AMIP6 models and realizations

Coupled model SST trends are discrepant across Tropical Pacific and Southern Ocean



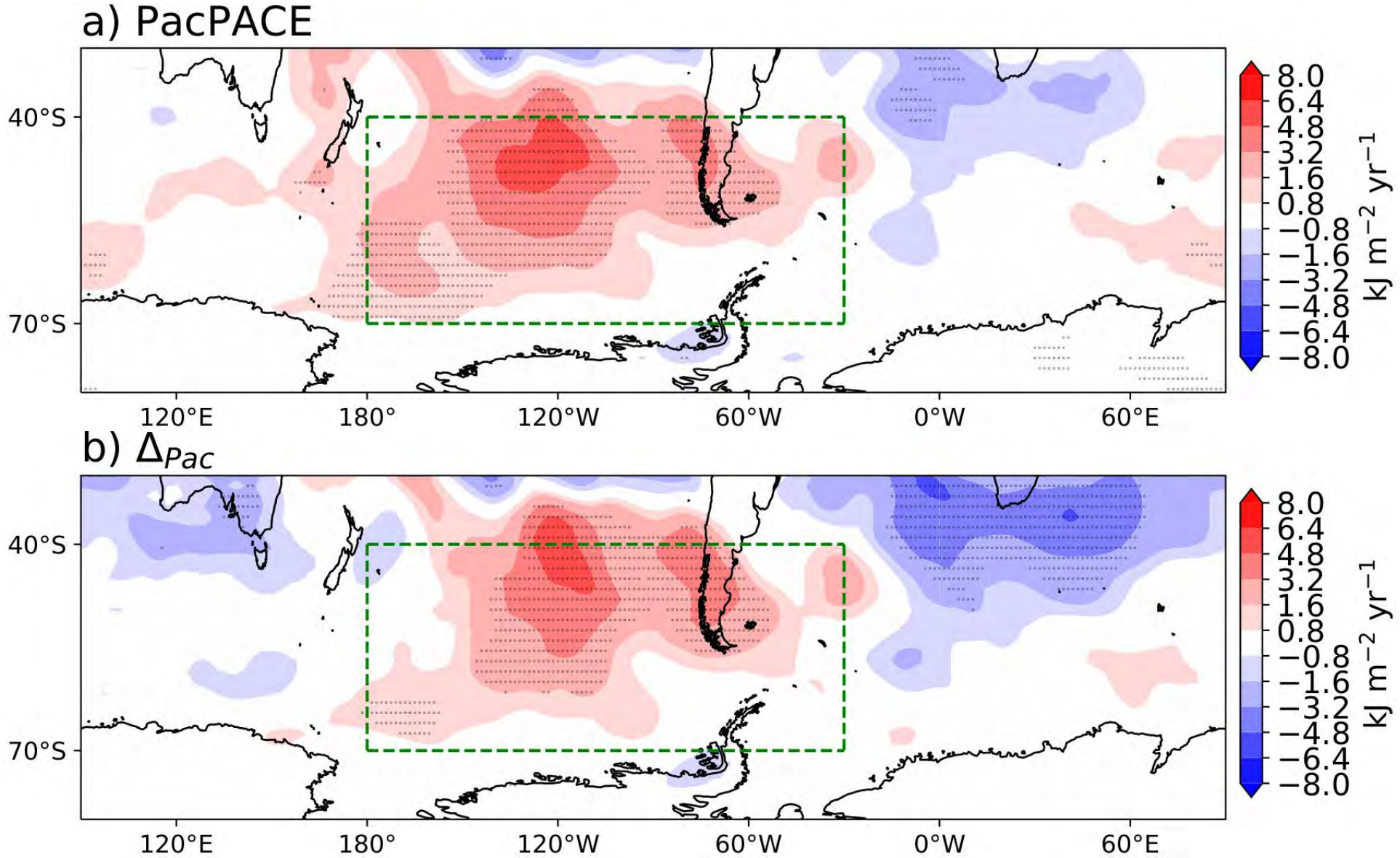
See also Wills et al. (2022), Seager et al. (2022), Lee et al. (2022)

Coupled model SST trends are discrepant across Tropical Pacific and Southern Ocean

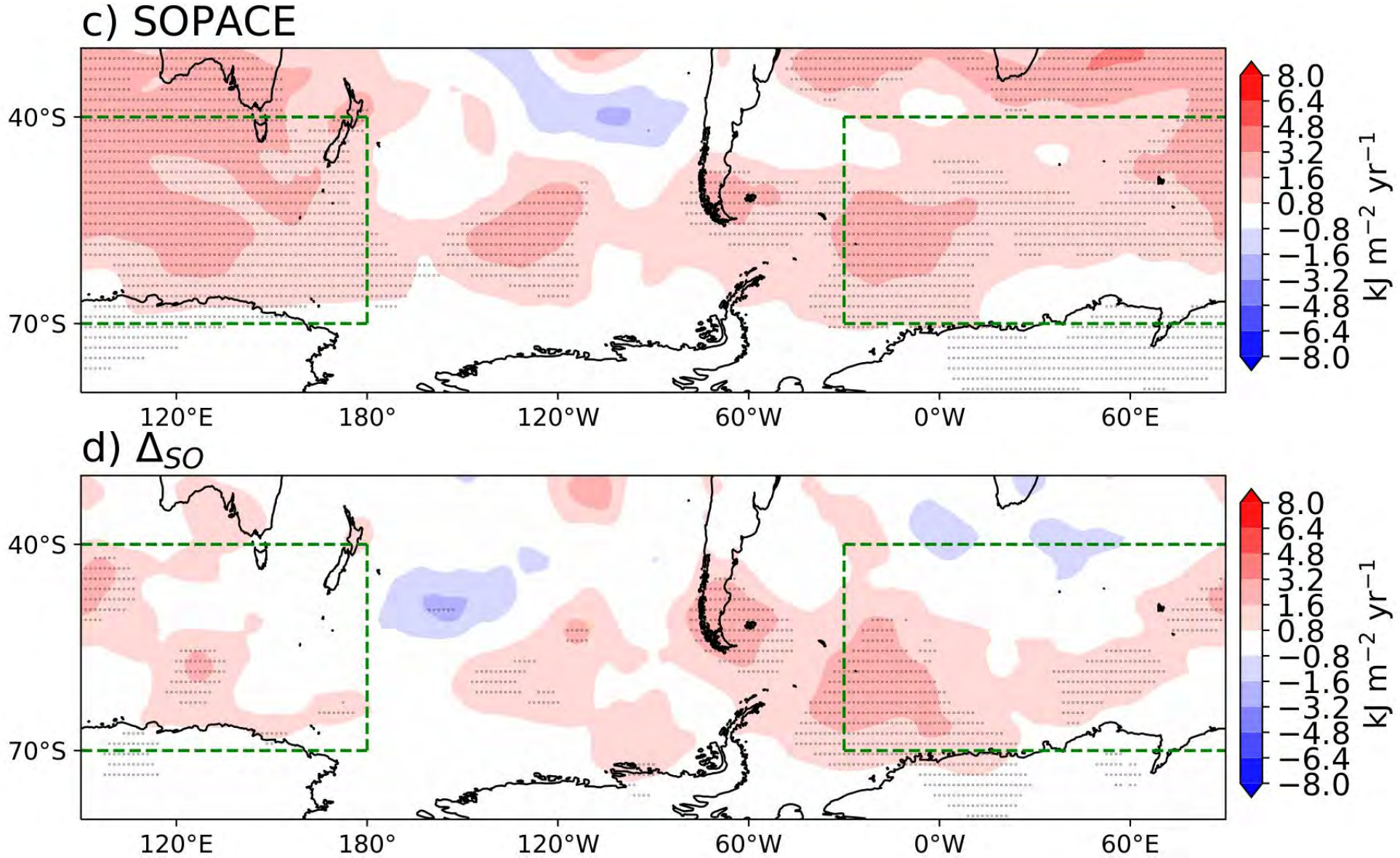


See also Wills et al. (2022), Seager et al. (2022), Lee et al. (2022)

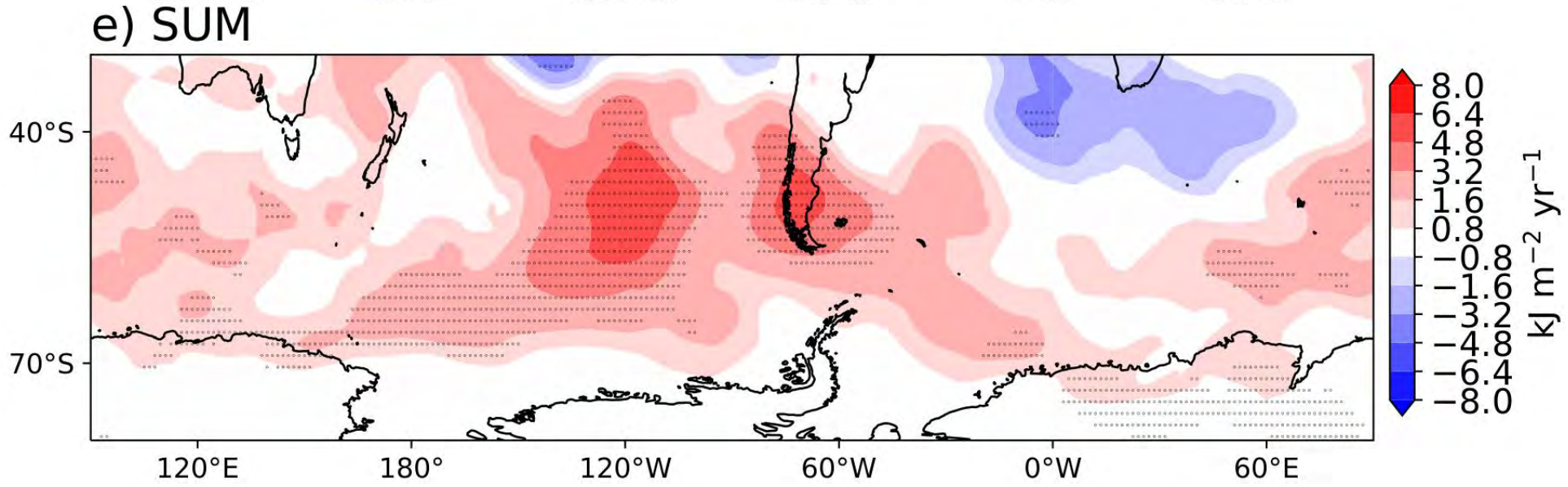
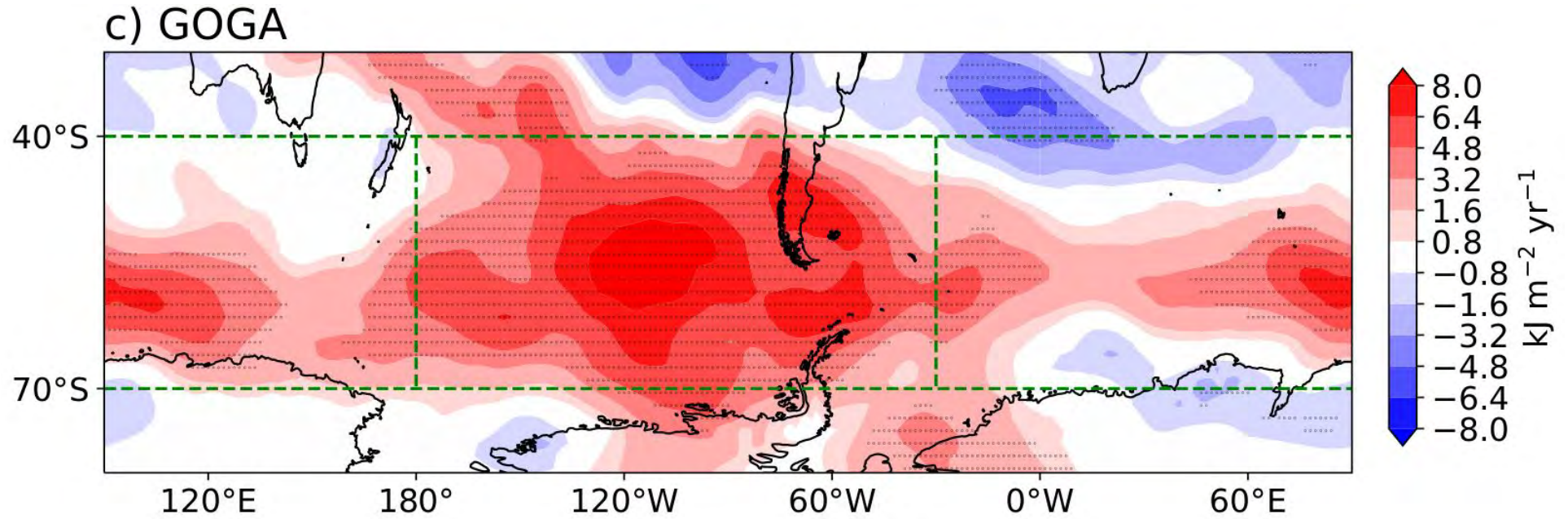
Pacific Pacemaker EKE trends



Pacific Pacemaker EKE trends

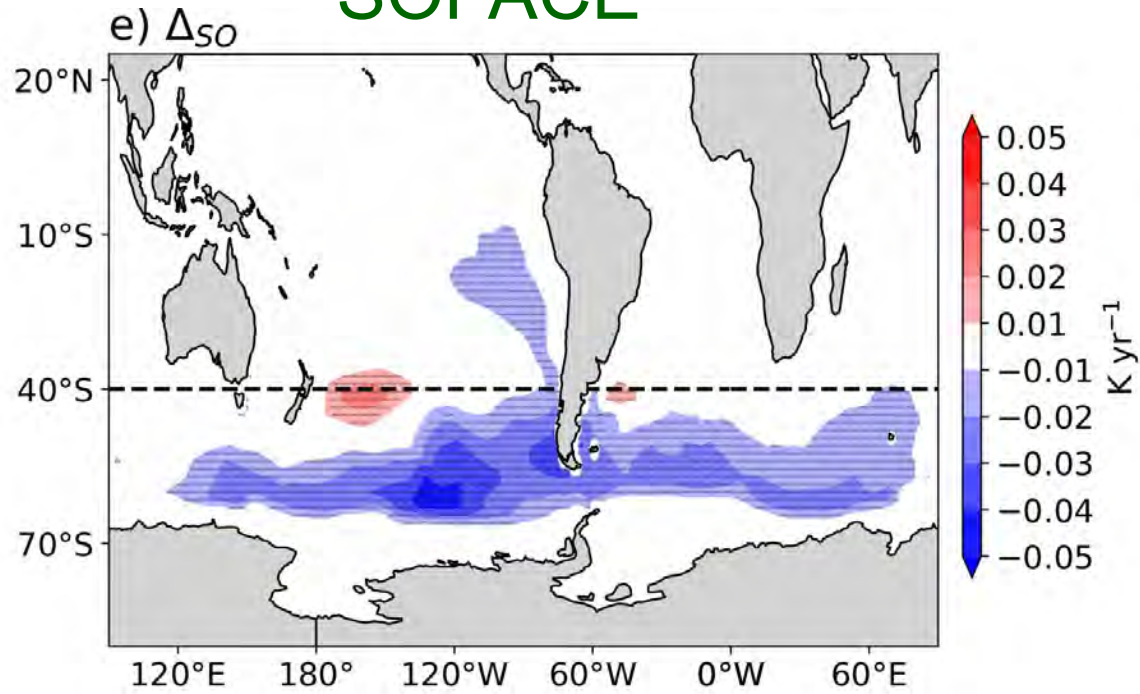


GOGA and SUM EKE trends

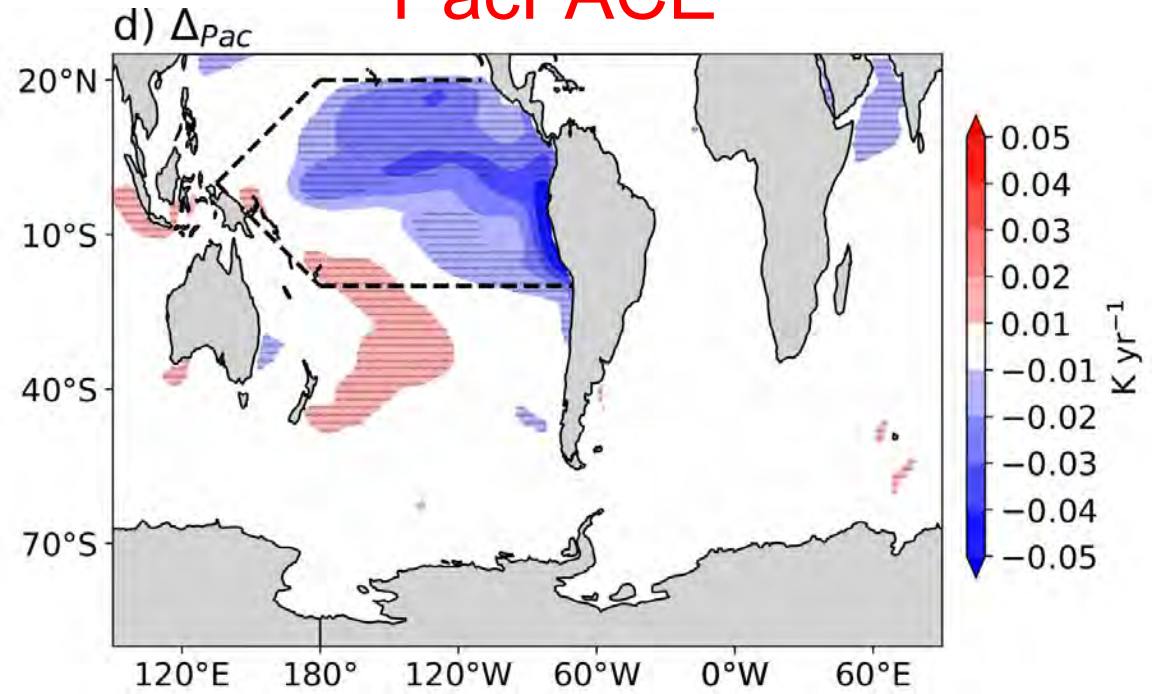


SST nudging area

SOPACE



PacPACE



By pacemaking tropical Pacific, reanalysis-coupled model discrepancy is unlikely in the South Pacific

Capturing La Nina-like teleconnection trends in reanalysis enhances the South Pacific storminess

