Using Multiple Large Ensembles to Elucidate the Discrepancy Between the 1979–2019 Modeled and Observed Antarctic Sea Ice Trends

the role of internal variability vs. external forcing

Rei Chemke and Lorenzo Polvani

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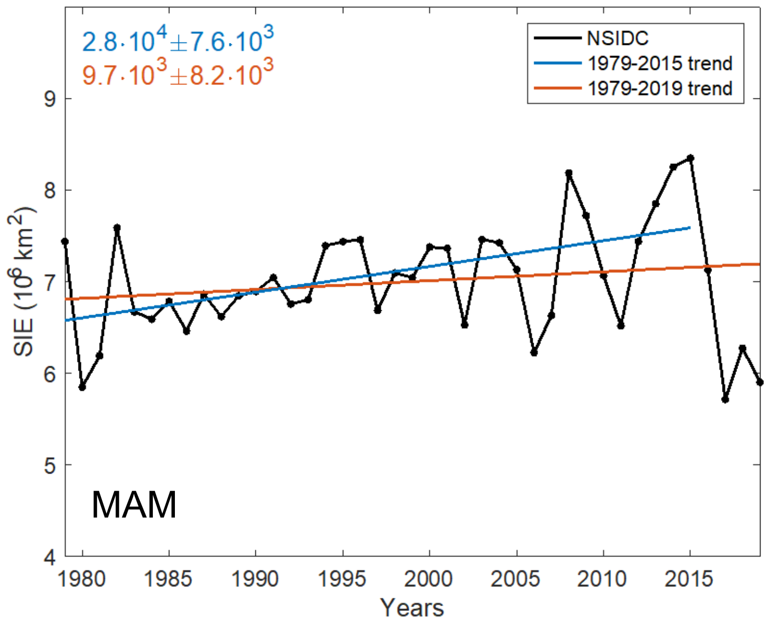
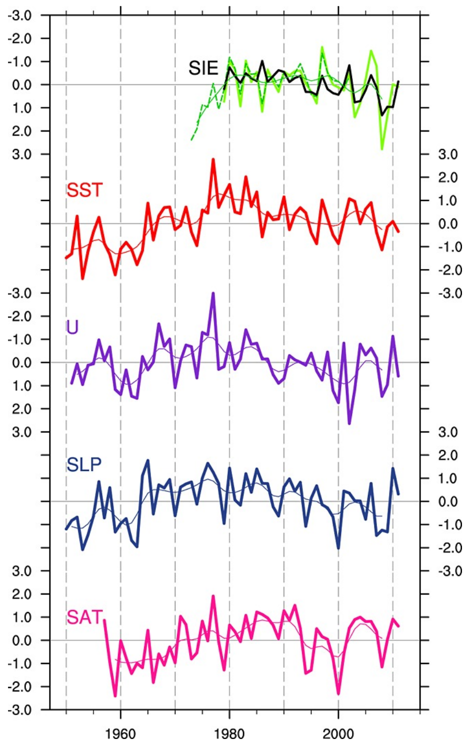
Discrepancy in sea-ice extent trends between climate models and observations

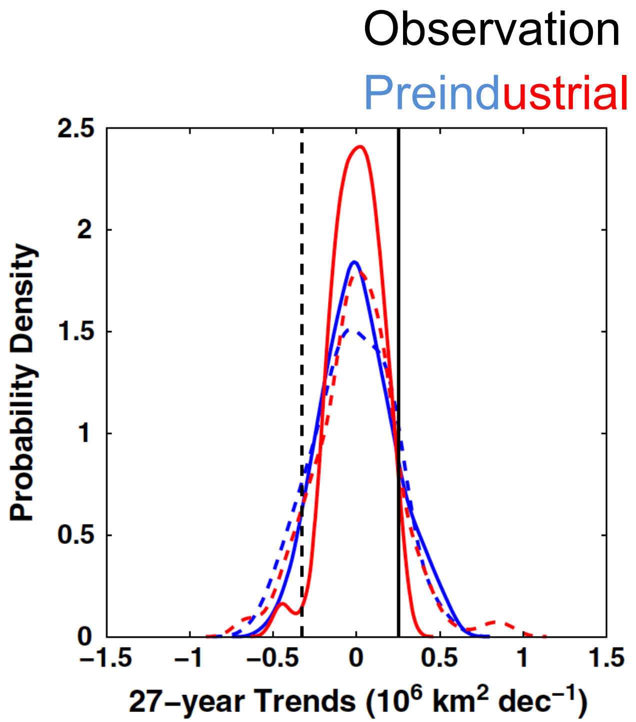


Chemke and Polvani 2020, GRL

The recent sea-ice trend is likely part of the internal variability of the climate system

- Preindustrial runs (which includes only the internal variability) capture well the observed trend
- Multidecadal variability over the Southern Ocean in recent decades



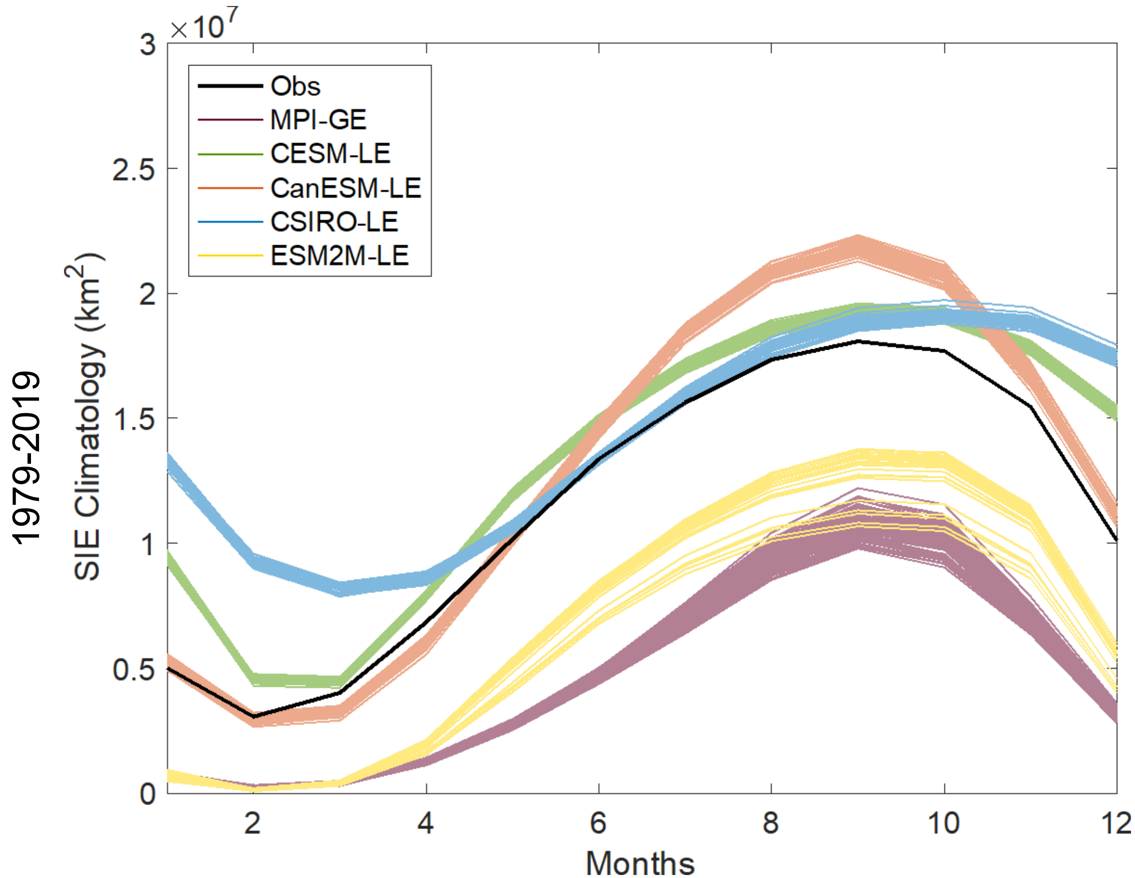


Fan et al., 2014

Polvani and Smith, 2013

Sea-ice extent climatology in multiple LE

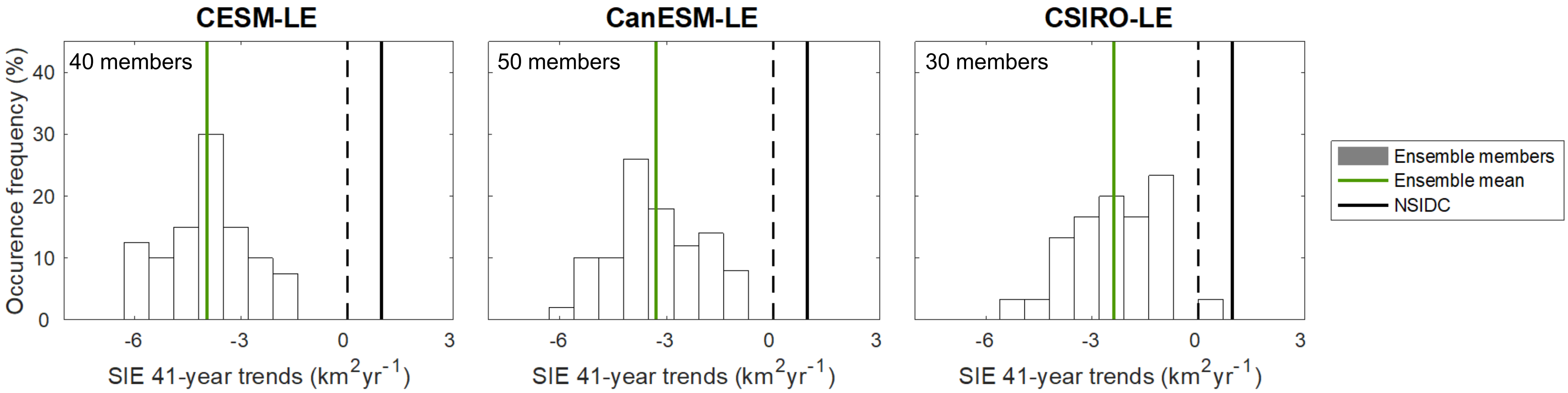
- Ensemble of simulations under the same forcing and using the same model
- Each simulation is initialized with different initial conditions
- The spread across the simulations is only due to internal variability
- The mean of the ensemble averages out the variability –> forced response



Sea-ice extent trends (1979-2019) in LE

- The ensemble members do not capture the observed trend

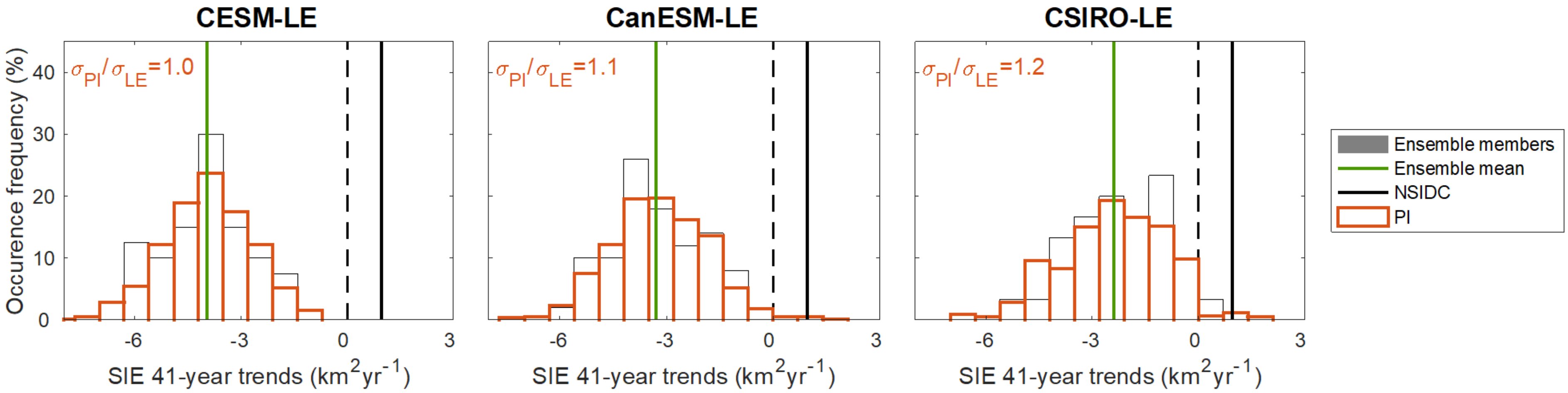
1979-2019



Is the ensemble size sufficiently large to capture the SIE variability?

- Sea-ice extent trends distribution from the preindustrial run is similar to the LE distribution
- The ensemble size is sufficient to capture the variability

1979-2019

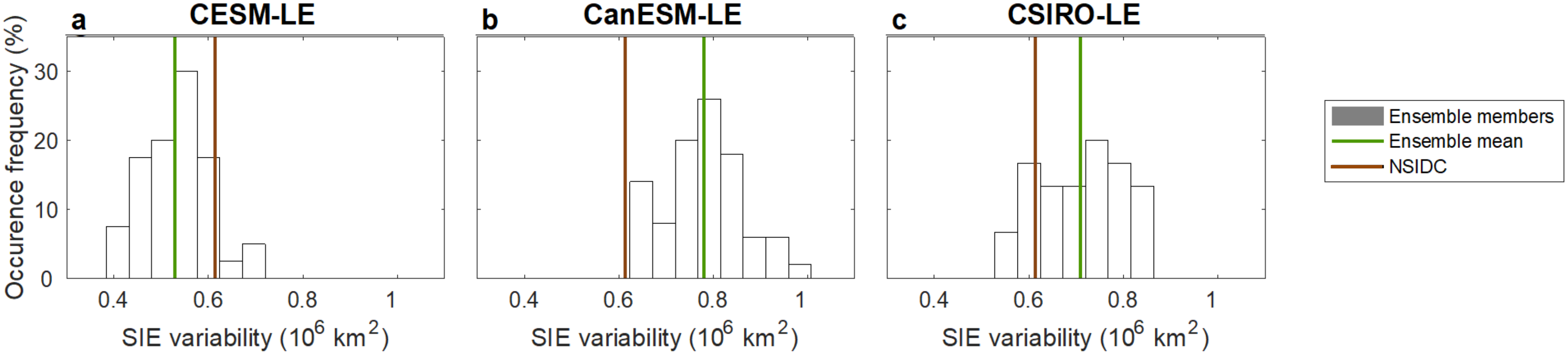


Do the ensembles adequately simulate the internal variability of Antarctic SIE?

- Compare the modeled and observed SIE interannual variability:
  - standard deviation of the detrended SIE time series

- Two of the three large ensembles are able to capture the SIE interannual variability

The ensembles' inability to capture the observed SIE trend is likely due to biases in the models' forced response



The ocean's role in the forced sea-ice trend?

- Hierarchy of ocean-locking experiments run over the 20th and 21st century:

1. Full physics ocean (active thermodynamic and dynamic coupling)
2. Fixed ocean heat flux convergence (active thermodynamic coupling)
3. Fixed ocean temperature (inactive thermodynamic and dynamic coupling)

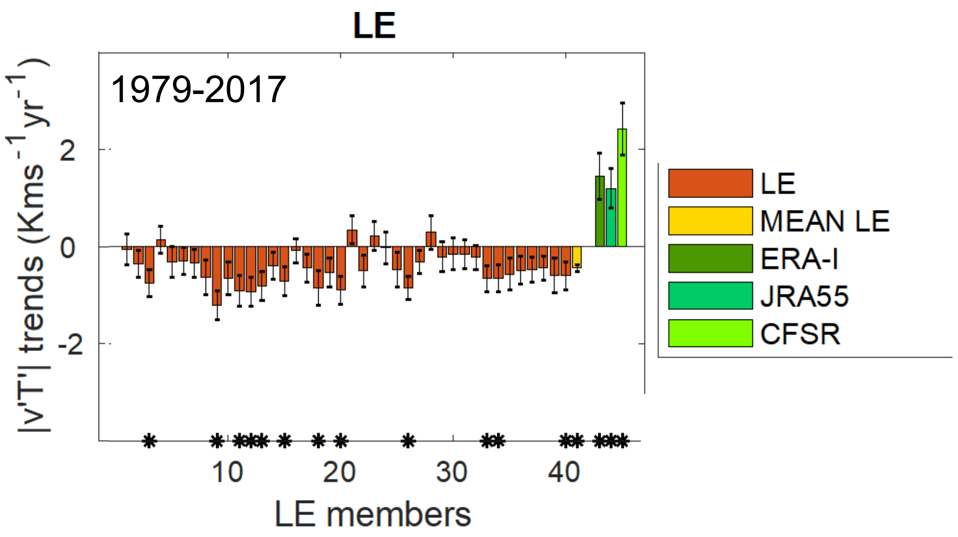
1-2: OHFC; 1-3: oceanic feedbacks; 2-3: surface heat fluxes

- Ocean feedbacks, via thermodynamic coupling, are responsible for most of the sea-ice loss in CESM
- Ocean heat flux convergence reduces the simulated sea-ice loss by 26%
- Climate models fail to capture the recent trends in surface heat fluxes over the Southern Ocean (ocean-atmosphere thermodynamic coupling)

Further motivation to investigate the above discrepancy: model biases in Southern Ocean temperature can affect the midlatitude climate

$$\overline{v'T'} \propto -\overline{T_y}$$

Models fail to capture the strengthening of eddy heat fluxes in the SH



Chemke and Polvani 2020, npj Climate and Atmospheric Sciecnes

Summary

Using multiple large ensembles to elucidate the discrepancy between modeled and observed Antarctic sea-ice trends

- Internal variability is not likely to explain the discrepancy in SIE trends between climate models and observations
- Such discrepancy stems from biases in the models' forced response
  - Likely due to ocean thermodynamic coupling
  - Models fail to capture recent trends in surface heat fluxes

- Since models fail to capture the cooling of Southern Ocean surface, they are unable to capture the strengthening of eddy heat fluxes

- Model biases in polar regions can affect the midlatitude climate