

Can multidecadal variability of the Southern Ocean explain observed Antarctic sea ice expansion?

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1. Introduction and Data

Antarctic sea ice expanded from the beginning of the satellite record to ~2014. Here we consider the hypothesis that internal variability alone can explain the expansion by comparing observations to two climate model ensembles of different horizontal resolutions.

- Community Earth System Model v1.3 (MESACLIP)
 - High-res (HR): 1/10° ocean/sea ice, 1/4° atmos/land
 - Low-res (LR): 1° all components
 - Historical + RCP8.5 forcing
 - 10-member HR and 22-member LR ensembles
- Observations
 - NSIDC Climate Data Record SIC v6
 - OSI SAF (Interim) Climate Data Record SIC
 - HadISST1 SIC

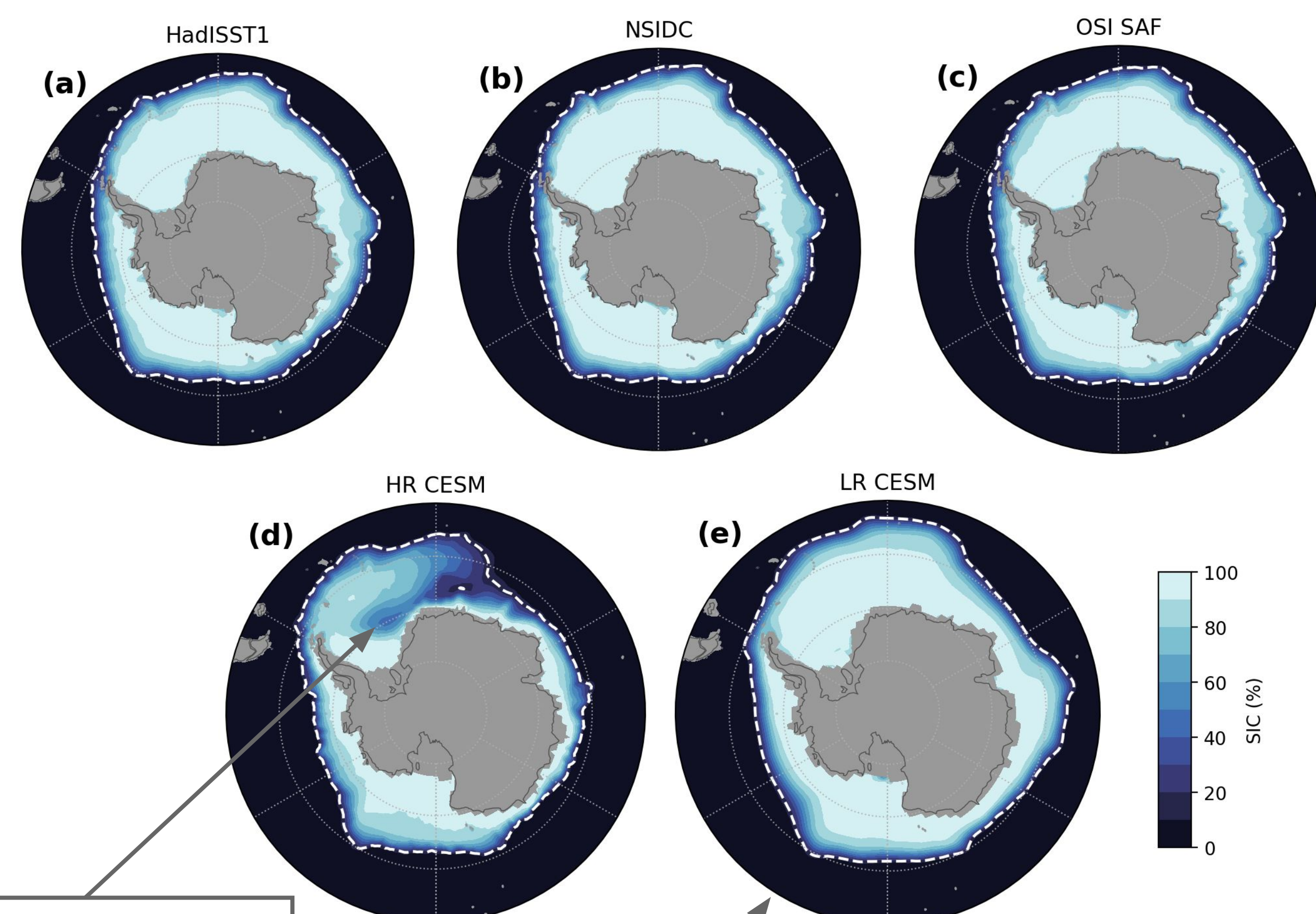


Figure 1. September sea ice concentration (SIC) averaged over 1979–2024 across (a–c) observations and (d, e) two versions of the CESM1.3.

2. Variability and Trends

If the kind of variability exhibited by the HR and LR CESM1.3 were correct, how often would we expect to see a multidecadal increase in Antarctic sea ice area similar to that observed due to internal variability alone?

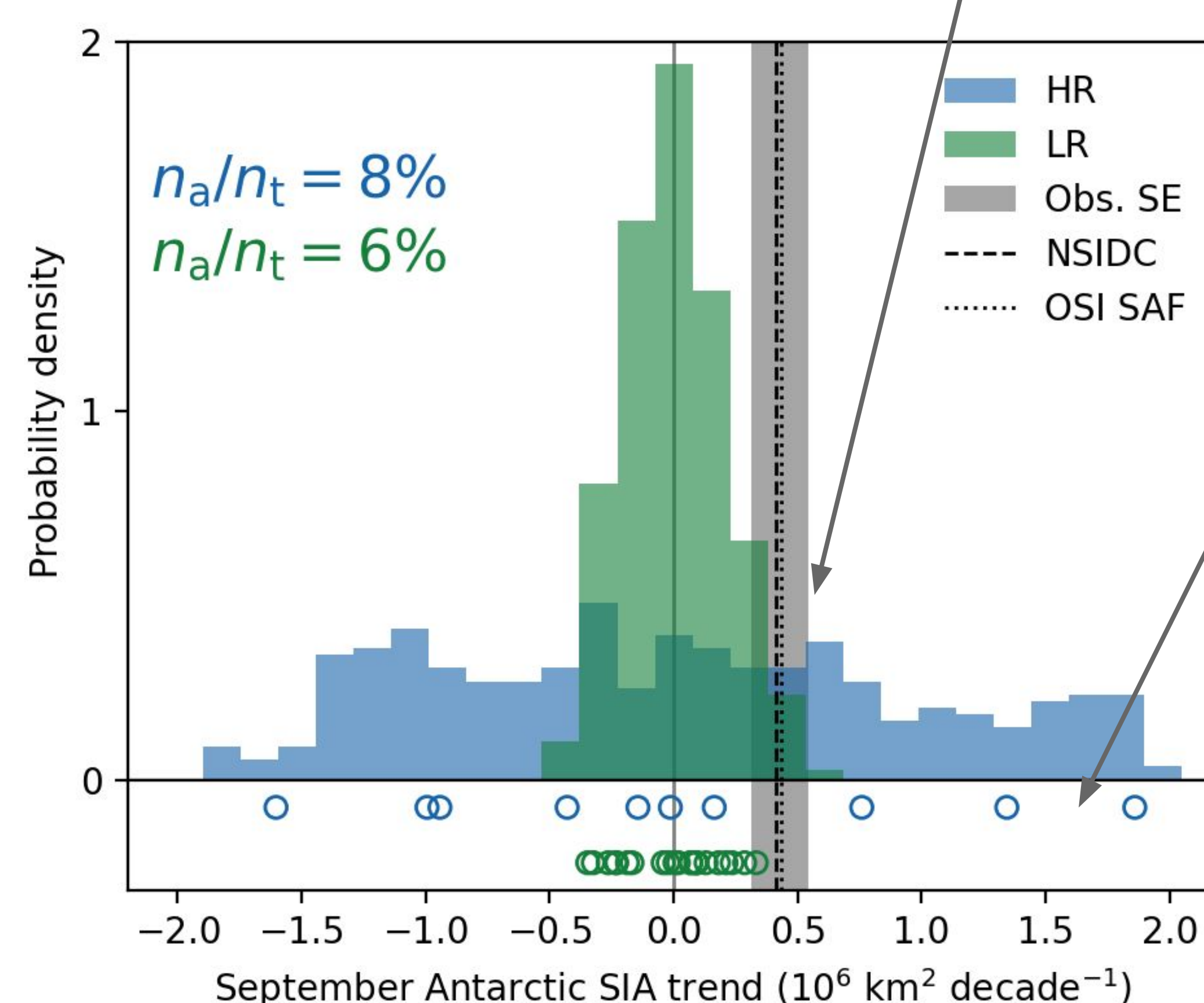


Figure 2. Time series of September Antarctic sea ice area (SIA) in HR and LR CESM1.3 (1920–2100; historical and RCP8.5 forcing) and observations (1979–2024). The CESM1.3 ensemble means are plotted in the solid lines, while the ensemble ranges are plotted in the blue and green envelopes.

Observed trend would be expected under HR's variability, but rare under LR's variability

Only using 1986–2014 from the models would undersample the trends

We compare the observed trend for 1986–2014 to all consecutive and overlapping 29-year trends in both ensembles. The forced components of the trends are estimated from the ensemble mean and subtracted out.

Figure 3. Histograms of all overlapping 29-year September Antarctic sea ice area (SIA) trends in HR and LR CESM1.3 within 1950–2014 (HR) or 1930–2014 (LR) associated with internal variability. The 1986–2014 observed trends are plotted as the dashed and dotted black lines. Below the histograms, the blue (HR) and green (LR) open circles show the modeled 1986–2014 trends associated with internal variability.

3. Spatial Patterns

HR might be able to regularly simulate sea ice expansion, but are the spatial patterns realistic?

We compare the spatial patterns of the modeled and observed trends two ways:

- (1) Taking the average of all samples within the observed trend uncertainty (see Fig. 3)
- (2) Out of those, finding the best-fit trend as the sample with the highest correlation with observations over longitude

Observed pattern: decreases in Bellingshausen and western Weddell Seas, increases elsewhere

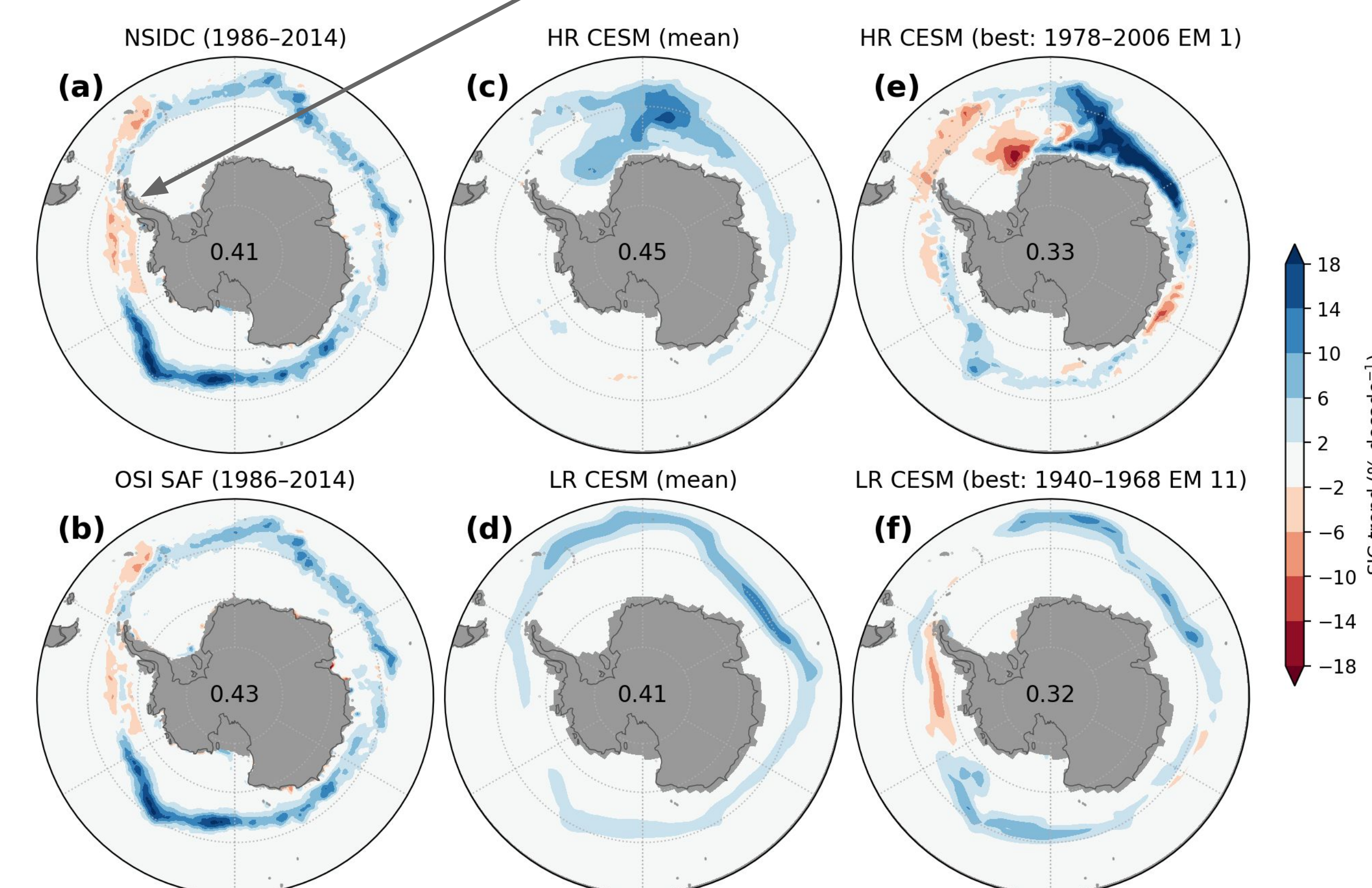
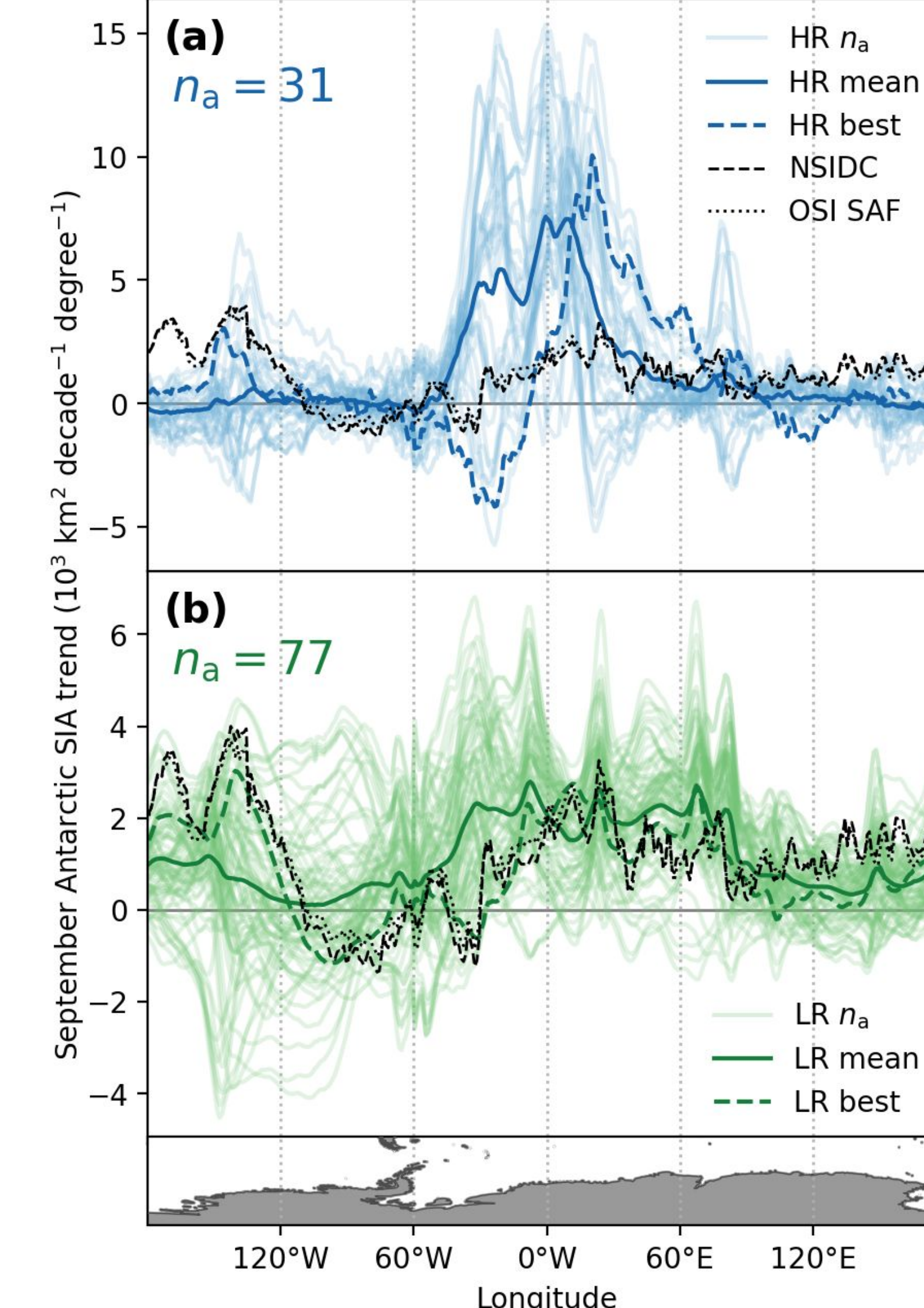


Figure 4. September sea ice area (SIA) trends as a function of longitude for (a) HR and (b) LR that are within the observed SIA trend standard error shown in Fig. 3. The darker blue/green solid lines indicate the average of the samples, while the darker blue/green dashed lines indicate the sample with the highest ('best') correlation with observations over longitude.



In the mean and best trend maps, LR more closely resembles observations. We may speculate that LR is getting the trend correct for the correct reason, but the sea ice expansion is still quite rare, even assuming zero forced response in observations (Fig. 3).

Figure 5. September sea ice concentration (SIC) trends. (a, b) Observed SIC trends over 1986–2014. (c) HR and (d) LR SIC trends averaged over all samples that agree with the observed sea ice area (SIA) trend. (e) HR and (f) LR SIC trends that best match the observed SIA trends over longitude. The number in the center of each map is the corresponding hemisphere-wide SIA trend in units 10^6 km^2 decade^-1.

4. Summary

- HR CESM1.3 simulates observation-like periods of Antarctic sea ice area expansion more often than LR CESM1.3, but the spatial patterns of the trends in LR look more realistic
- From the LR results, we cannot rule out the hypothesis that internal variability is enough to explain the observed expansion
- When assessing agreement between modeled and observed sea ice trends, spatial patterns must be considered

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