DRIVERS OF INCREASED SUMMER ANTARCTIC SEA ICE VARIABILITY

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INTRODUCTION

In comparison to the first two decades of the satellite era beginning in 1979, more recently there has been an apparent increase in Antarctic sea ice variability.

Here we consider the evidence that there has been a change in the Antarctic sea ice variance, and its drivers over the last 15 years.

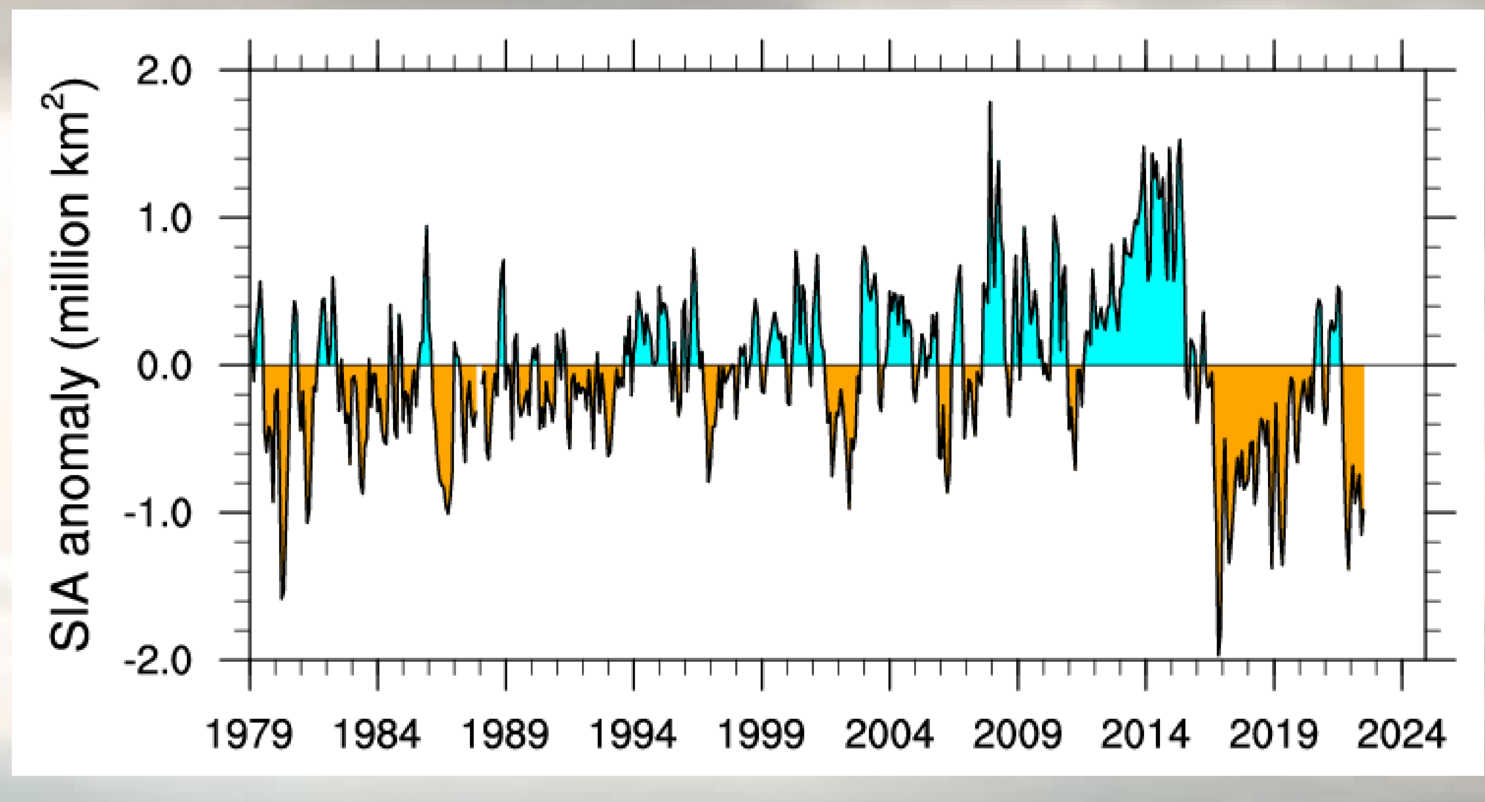

Figure 1 – Antarctic sea ice area (SIA) observed monthly anomalies. Hobbs et al. under review

IS IT THE ATMOSPHERE?

To test whether atmosphere and climate modes (e.g. Indian Ocean Dipole IOD) alone can explain the change, we fit a regression model to predict summer (DJF) sea ice anomalies, using large-scale modes (SAM, ASL, ZW3, SOI, IOD). The model works well up to 2006 (**black dots**) but can't predict more recent positive and negative sea ice anomalies (red dots).

Major atmospheric modes are not enough to explain the increased variance!

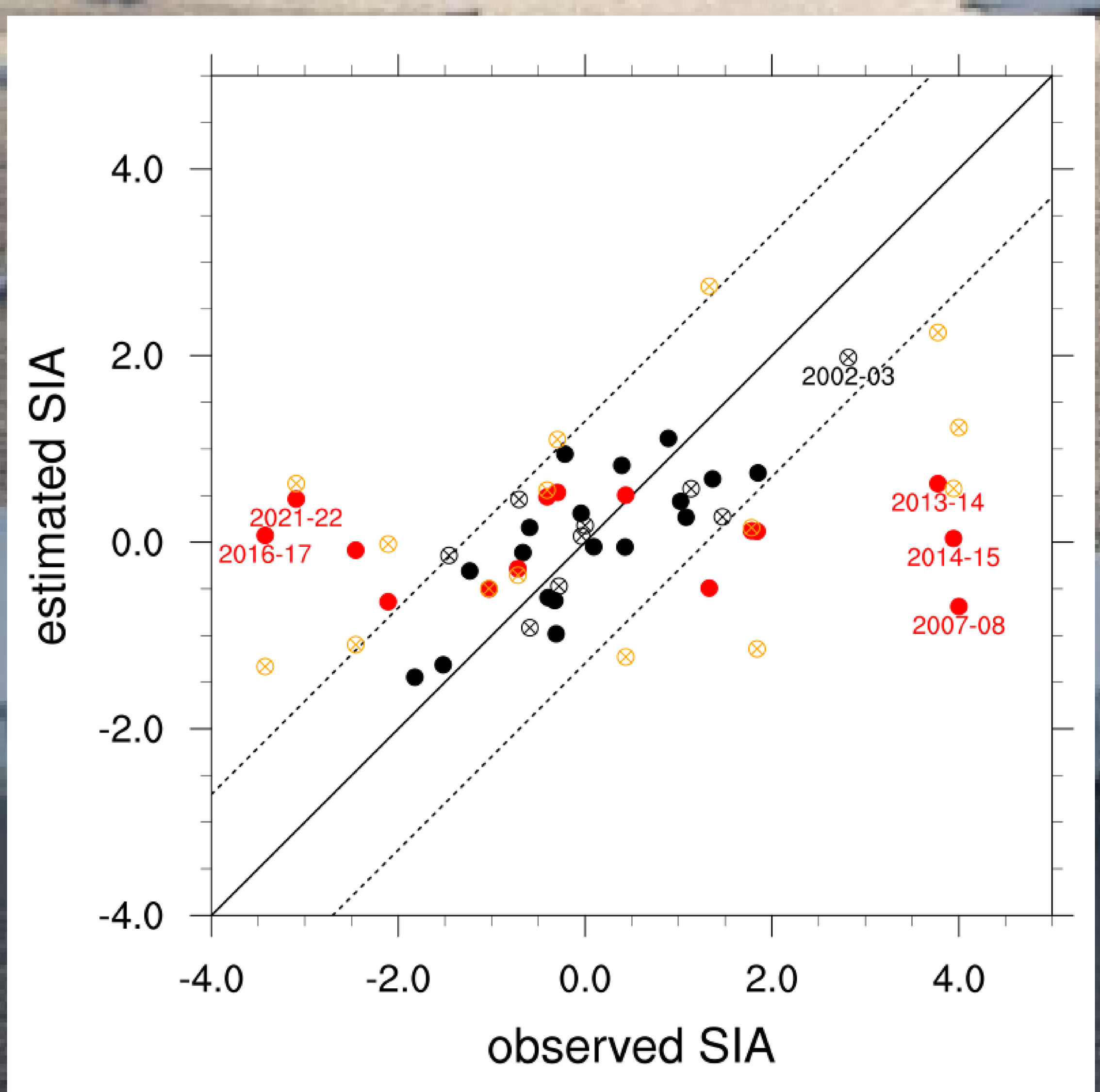

Figure 2 - Observed summer Sea Ice Area (SIA) (x-axis;), and SIA predicted by linear model (y-axis), plotted as standardised anomalies (i.e., a value of 2 denotes a 2 standard deviation anomaly). Black dots are calibration period (1979-1997); black crosses are validation period (1998-2006); red dots are for test period (2007-2021; orange crosses are estimates after training the data on the 2007-2021 test period, to maximize fit with that period. Hobbs et al. under review.

IS IT THE OCEAN?

Hello ACCESS-OM2 (ocean-sea ice model)! The black lines below show sea ice from the ACCESS-OM2-025 interannual forcing in (IAF), which models the observed changes very well. To test the impact of ocean warming, we run this model using the 2008-present day atmosphere, but with 1978 initial conditions, when Circumpolar Deep Water was about 0.2°C cooler. This increases sea ice thickness (and to a small extent area) but doesn't change the response to atmospheric forcing.

So no, the ocean doesn't explain changes in sea ice variance…

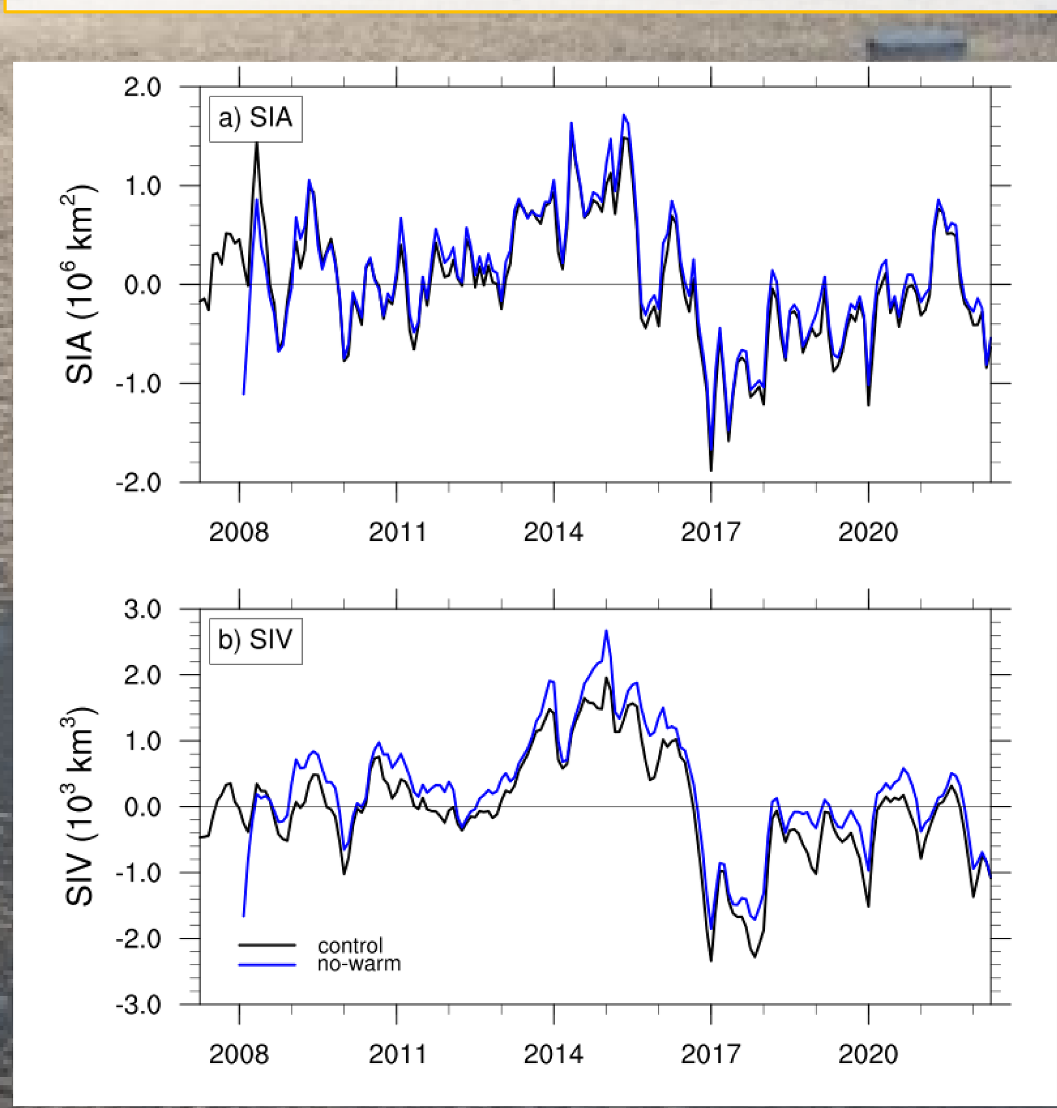

Figure 3 – 2008-2022 ACCESS-OM2-025 sea ice area and volume, from IAF (black line), and from 1978 initial conditions (blue line). Hobbs et al. under review.

OR IS IT THE SEA ICE ITSELF?

Antarctic sea ice trends show intense losses in the Amundsen-Bellingshausen Seas (ABS region; Figure 4b) and a reduced summer variance (see Table) -> there just isn't much ice there in summer now.

This means the Antarctic Dipole (where Weddell and ABS sea ice anomalies compensate each other) has broken down (Figure 4c) and the Weddell Sea region dominates total sea ice anomalies (Figure 4b) and so the total sea ice area variance has increased.

Recent changes in sea ice variability are due to the significantly reduced summer sea ice area in the Amundsen-Bellingshausen Seas. This has increased the contribution of the Weddell Sea (a region that strongly affected by weather) to the total circumpolar sea ice variance.

The Weddell sector is less affected by large scale atmospheric modes such as the Southern Annular Mode (SAM) (Figure 4a), which explains why those modes have less skill in predicting summer sea ice anomalies (Figure 2).

Sector	Zonal range (°E)	σ (10⁶ km²) 1979-2006	σ (10⁶ km²) 2007-2021	F-test
King Haakon VII (KHS)	0-60	0.11	0.14	0.664
East Antarctic (EA)	60-150	0.05	0.08	0.997*
Ross Sea (RS)	150-190	0.15	0.15	0.301
Amundsen-Bellingshausen Seas (ABS)	190-297	0.22	0.13	0.986*
Weddell Sea (WS)	297-300	0.26	0.37	0.936
Total		0.38	0.69	0.999*

Summer (i.e., DJF) Sea ice area standard deviation by individual sector, for late 20th century and early 21st century. Final column shows results of F-test on variances of the two different periods (asterisks = 95% statistically significant). Hobbs et al. under review

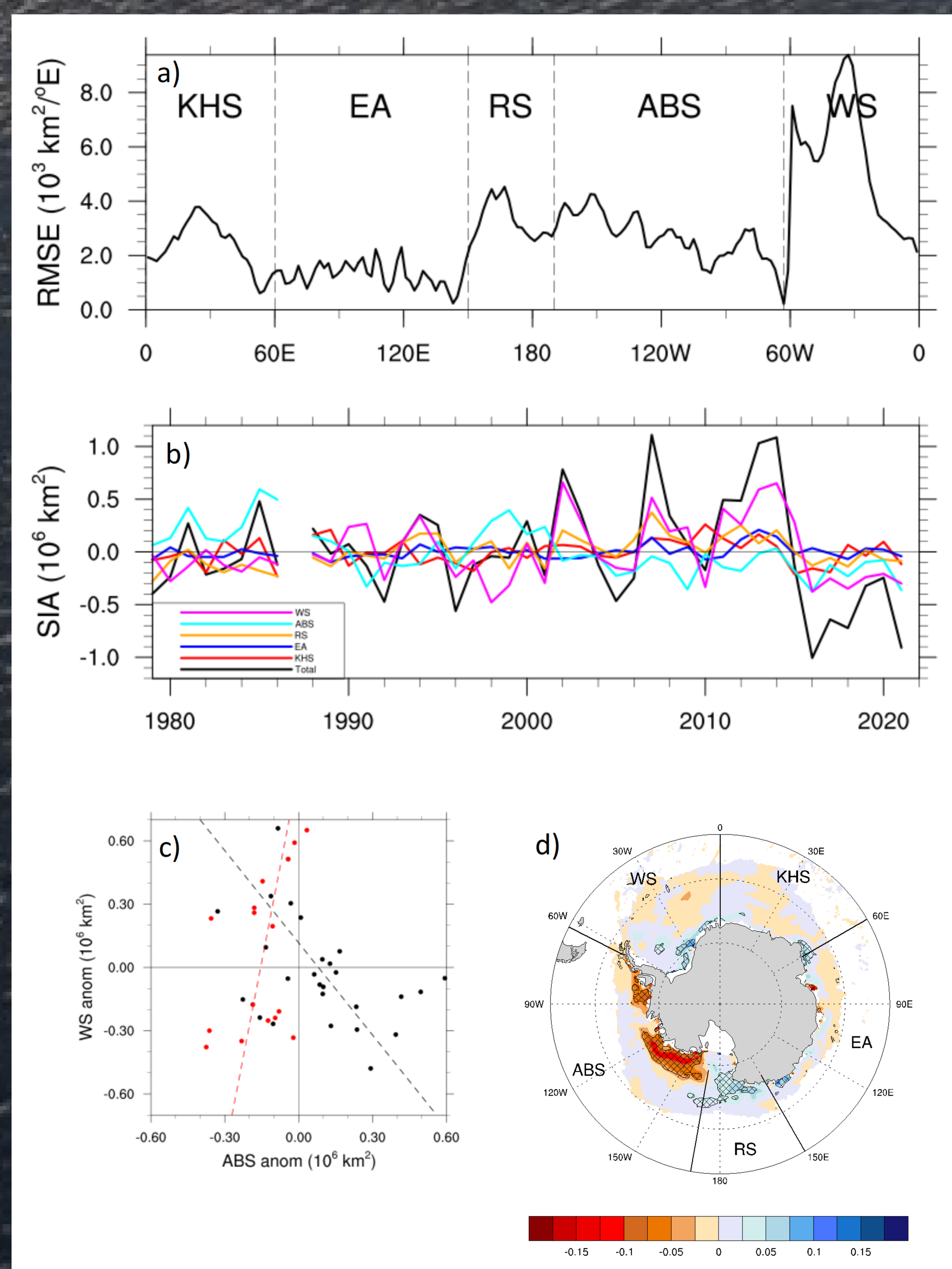

Figure 4 - a) Root-mean-square error (RMSE) of training empirical model at specific longitudes.

b) Summer (DJF) SIA anomalies by sector.

c) Summer SIA anomalies (10^6 km²) in ABS (x-axis) and Weddell Sea (y-axis). Black indicates 1979-2000, red indicates 2001-2021; dashed lines are best-fit lines for each period estimated using Total Least Squares regression.

d) 1979-2021 observed summer (DJF) SIC trends.

Hobbs et al. under review.