What Causes **Extreme Sea Ice Loss**? Investigating **Sea Ice Anomalies** Through CMIP6 Models

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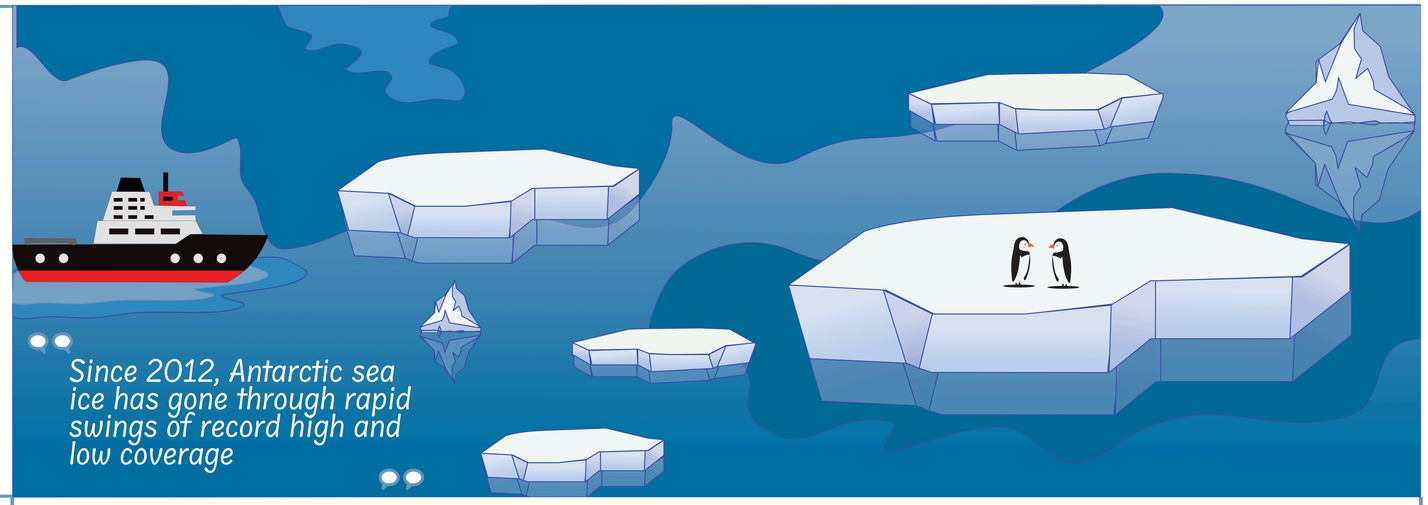


Background

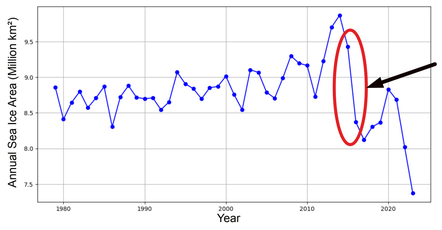


Figure 1 - Annual sea ice area in Antarctica from 1979 to 2023. The red eclipse highlights the extreme sea ice loss event on the time-series.

- Between **2015 and 2016** annual mean, Antarctic sea ice experienced an abrupt decline of **1.056** million km² in area, the **largest loss event** in recorded history (1).
- The **drivers and mechanisms** of this rapid retreat are not well understood. Is this an isolated episode of **internal climate variability**, or is it the start of a **long term melting trend?**

Methodology

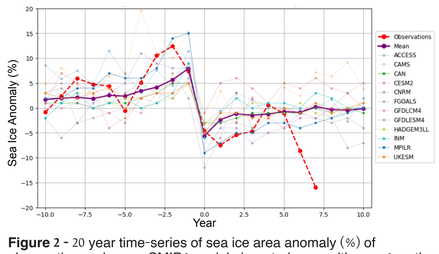


Figure 2 - 20 year time-series of sea ice area anomaly (%) of observation and mean CMIP6 model pi-control runs, with year 0 as the extreme sea ice loss event year

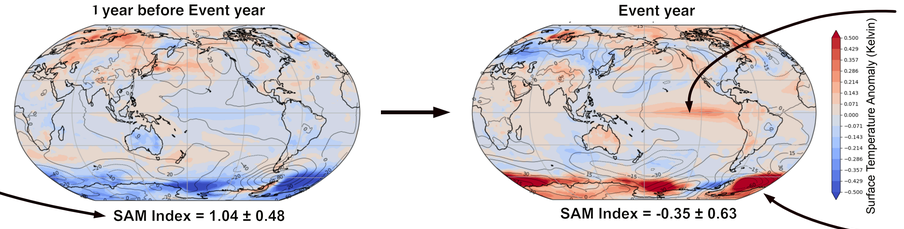
- We use CMIP6 **pre-industrial control** runs to explore extreme sea ice loss events in an **internal climate variability** setting.
- **87** sea ice loss events passing observation threshold in **12** models occurred over **12000** model run years, resulting in a probability rate of **0.07%**.
- **Teleconnections**, subsurface **ocean** heat content, and **atmospheric** variability to the years preceding the events summarised with a **weighted average.**

Summary

- Extreme sea ice loss events are possible in the abscence of anthropogenic emissions, but occurances are considered rare
- Teleconnections relating to **ENSO** and **SAM** are the main factors affecting sea ice build - up and loss, consistant with observational records of 2015/2016
- Lack of evidence of a build-up of subsurface ocean heat due to internal variability
- Most models show a **sustained recovery** of sea ice. Observational records in 2023 reached a new sea ice minimum. The role of anthropogenic emissions may play a role in this. We see little evidence of internal variability for the second 2023 sea ice loss event.

1 Loss of Sea Ice Linked with ENSO and SAM Index

Surface temperature and Sea level pressure linked to a transition to a negative ENSO and SAM Index during extreme sea ice events, as observed in 2015/16 (3)



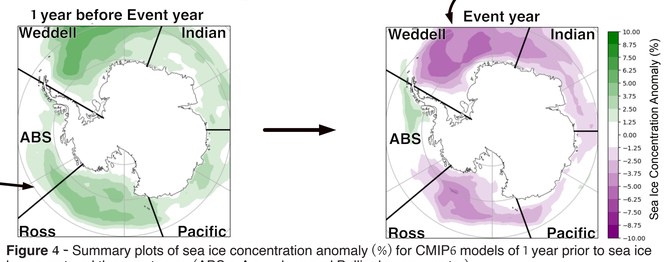
El - Nino warming event in central equatorial Pacific Ocean evident in most models

Warming is localised in the Weddell and Ross Sea Regions

Figure 3 - Summary plots of surface temperature and sea level pressure for CMIP6 models of 1 year prior to sea ice loss event and the event year. Contour lines represent anomolous sea level pressure with zonal mean removed. SAM Index calculated following the methodology of Gong & Wong (2)

2 Sea Ice Loss is Limited to Localised Regions

A continous build up of sea ice observed across Antarctica, with the highest in the Weddell and Ross Sea.



Around 3/4 of the events show a large negative sea ice loss event in the Weddell Sea, consistent with observational records in 2015/2016.

On the other hand, 1/5 of the events show a substantial growth of sea ice in the ABS despite loss in other areas.

Figure 4 - Summary plots of sea ice concentration anomaly (%) for CMIP6 models of 1 year prior to sea ice loss event and the event year. (ABS = Amundsen and Bellinghausen sector)

3 No evidence of Subsurface Ocean Heating Found Due to Internal Variability

Observed (4) warming trend in the subsurface layer of the Southern ocean but this contrasts with the general cooling pattern shown in the models

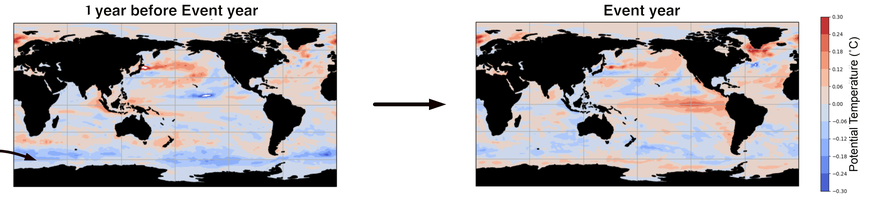
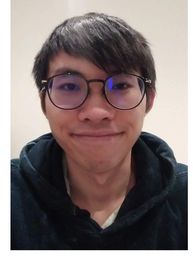


Figure 5 - Summary plots of subsurface ocean potential temperature (°C) between 0 - 100 m water depth for CMIP6 models of 1 year prior to sea ice loss event and the event year.



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(1) Turner, J., Phillips, T., Marshall, G.J., Hosking, J.S., Pope, J.O., Bracegirdle, T.J. and Deb, P., 2017. Unprecedented springtime retreat of Antarctic sea ice in 2016. Geophysical Research Letters, 44(13), pp.6868-6875.
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(4) Purich, A. and Doddridge, E.W., 2023. Record low Antarctic sea ice coverage indicates a new sea ice state. Communications Earth & Environment, 4(1), p.314.

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