Impacts of marine instability across the East Antarctic Ice Sheet on Southern Ocean dynamics

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1. Introduction

- Recent observations and modelling studies have demonstrated the potential for rapid and substantial retreat of large sectors of the East Antarctic Ice Sheet (EAIS).
- However, the effects of increasing Antarctic meltwater on the ocean circulation have not been fully explored, even though such changes may already be occurring.
- Here we use a climate model to examine the effects of increasing meltwater from the Wilkes Basin, one of the major marine-based sectors of the EAIS, on Southern Ocean dynamics.

2. Methods

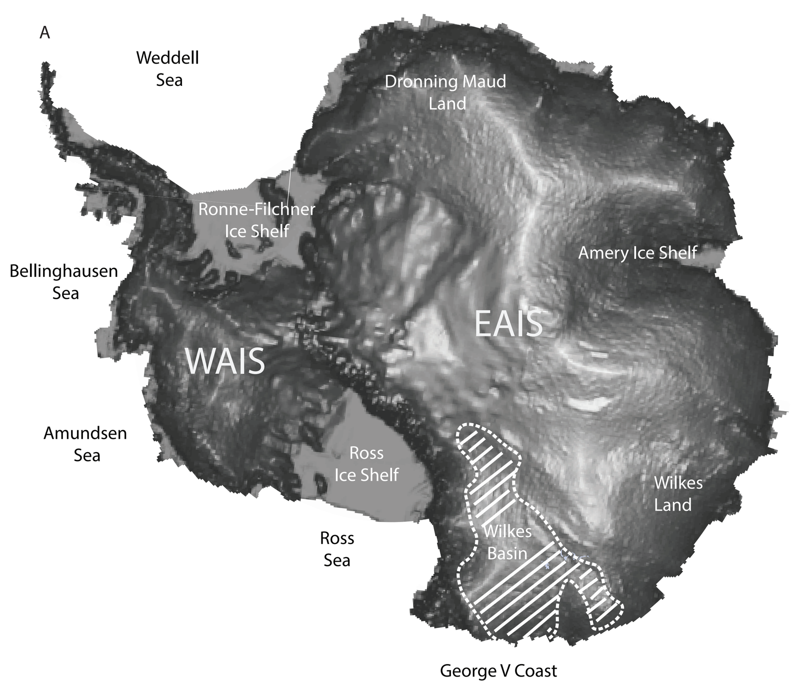

Figure 1. Location of the Wilkes Basin.

- We use the CSIRO Mk3L climate system model, driven by two idealised scenarios.
- Experiment WILKES simulates a hypothetical collapse of the Wilkes Basin, applying a freshwater flux of 0.048 Sv for 900 years.
- Experiment 4CO2 simulates a four-fold increase in the atmospheric CO_2 concentration over a period of 140 years.
- An ensemble modelling approach is employed, in which each experiment is run three times using different initial conditions.

3. Ocean circulation

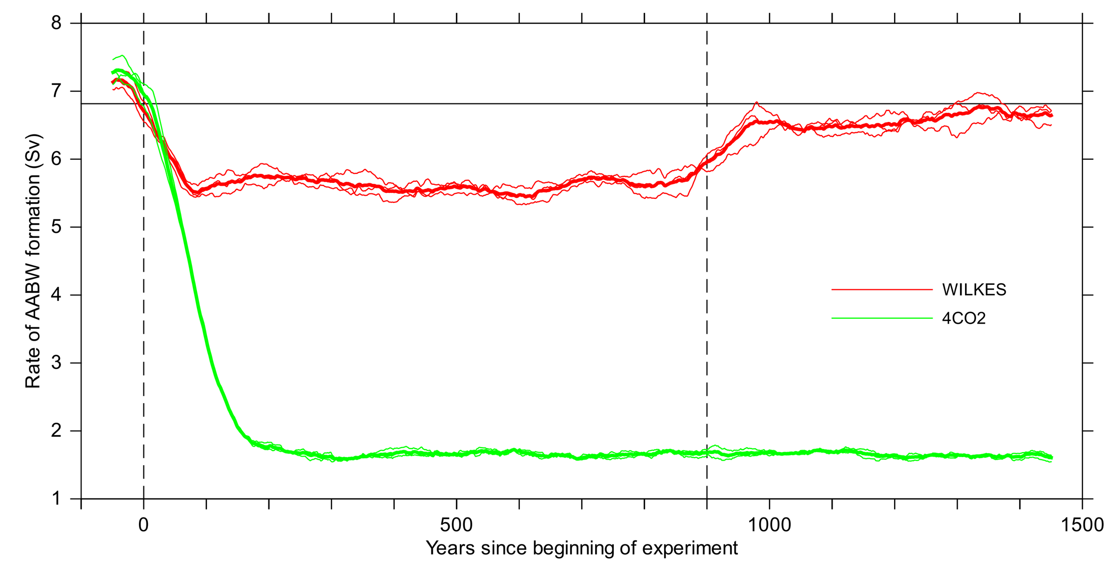

Figure 2. Rate of AABW formation in WILKES (red) and 4CO2 (green).

- In experiment 4CO2, there is a rapid and persistent collapse in the rate of Antarctic Bottom Water (AABW) formation.
- There is also a reduction of ∼20% in the rate of AABW formation in WILKES. It remains in a weakened state throughout the hosing phase, recovering rapidly as soon as the hosing ceases.
- Melting of the EAIS might therefore be expected to amplify anthropogenic impacts on the rate of deep water formation.

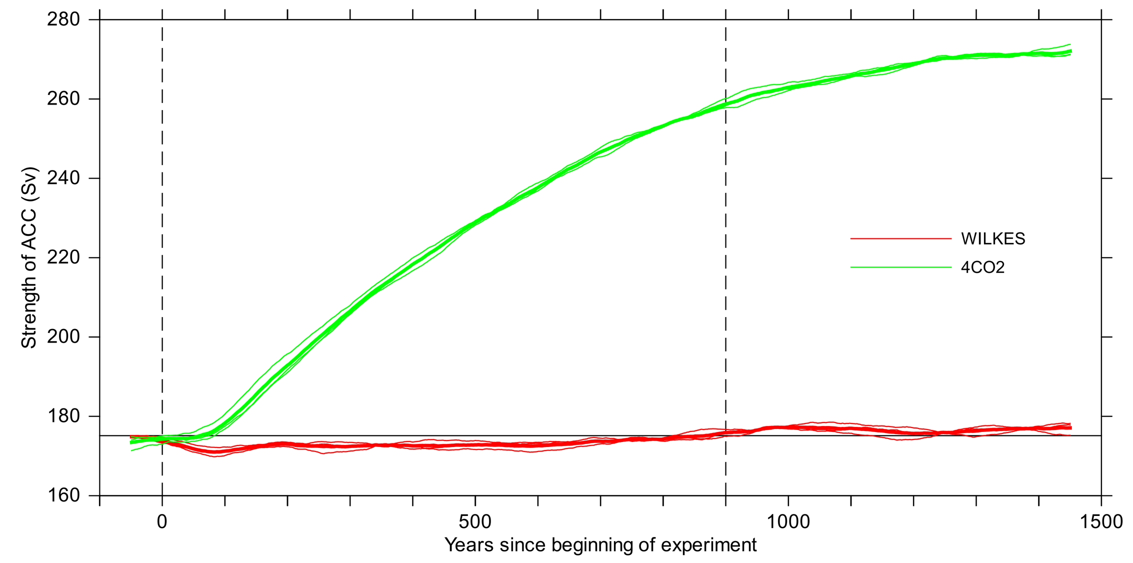

Figure 3. Strength of ACC in WILKES (red) and 4CO2 (green).

- In experiment 4CO2, there is a strong and persistent increase in the strength of the Antarctic Circumpolar Current (ACC).
- There is a small reduction in the strength of the ACC in WILKES, although this does not persist until the end of the hosing phase.
- This suggests that ice sheet melting acts as a weak negative feedback in the case of the ACC.

4. Impacts of marine instability on the Southern Ocean

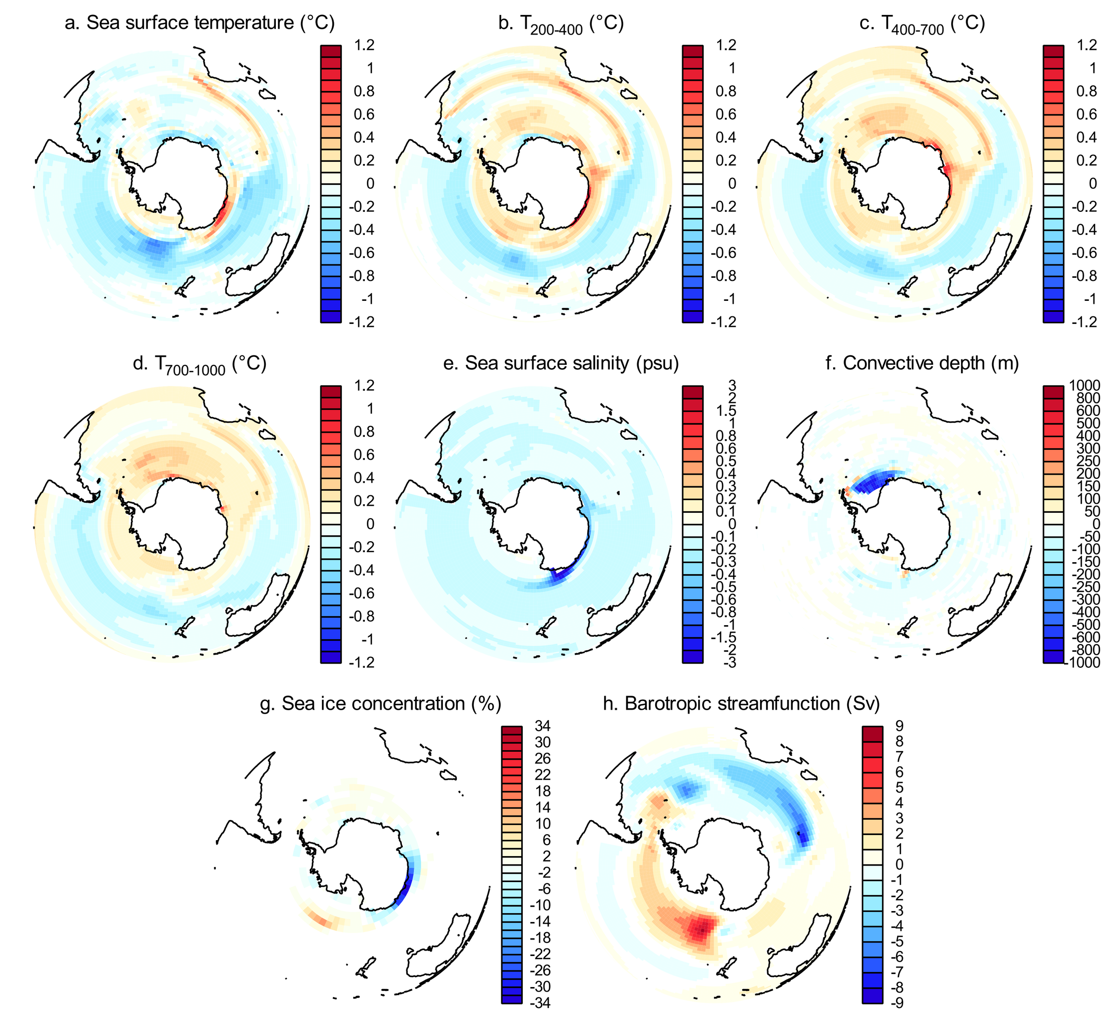

Figure 4. Mean anomalies for the final 100 years of the hosing phase (i.e. years 801–900) in experiment WILKES: (a) sea surface temperature, (b) mean temperature at a depth of 200–400 m, (c) mean temperature at a depth of 400–700 m, (d) mean temperature at a depth of 700–1000 m, (e) sea surface salinity, (f) convective depth, (g) sea ice concentration, and (h) barotropic streamfunction.

- In response to a collapse of the Wilkes Basin, sea surface temperatures (SSTs) increase by ∼1°C off the coast of Wilkes Land (Fig. 4a).
- A warming signal is also found throughout the water column, propagating westwards around the coast of Antarctica with depth (Fig. 4b–d).
- These changes are driven by the surface freshening in the hosing region, which is carried westward by the coastal currents (Fig. 4e).
- The freshening propagates as far as the Weddell Sea, increasing stratification of the water column and reducing convective depth (Fig. 4f).
- The reduction in vertical mixing reduces the exchange of cold surface waters with the underlying water column, leading to warming at depth.
- This warming signal has the potential to enhance melting along grounding lines across the EAIS, destabilising large sectors of the ice sheet.

5. Comparison with response to enhanced CO_2

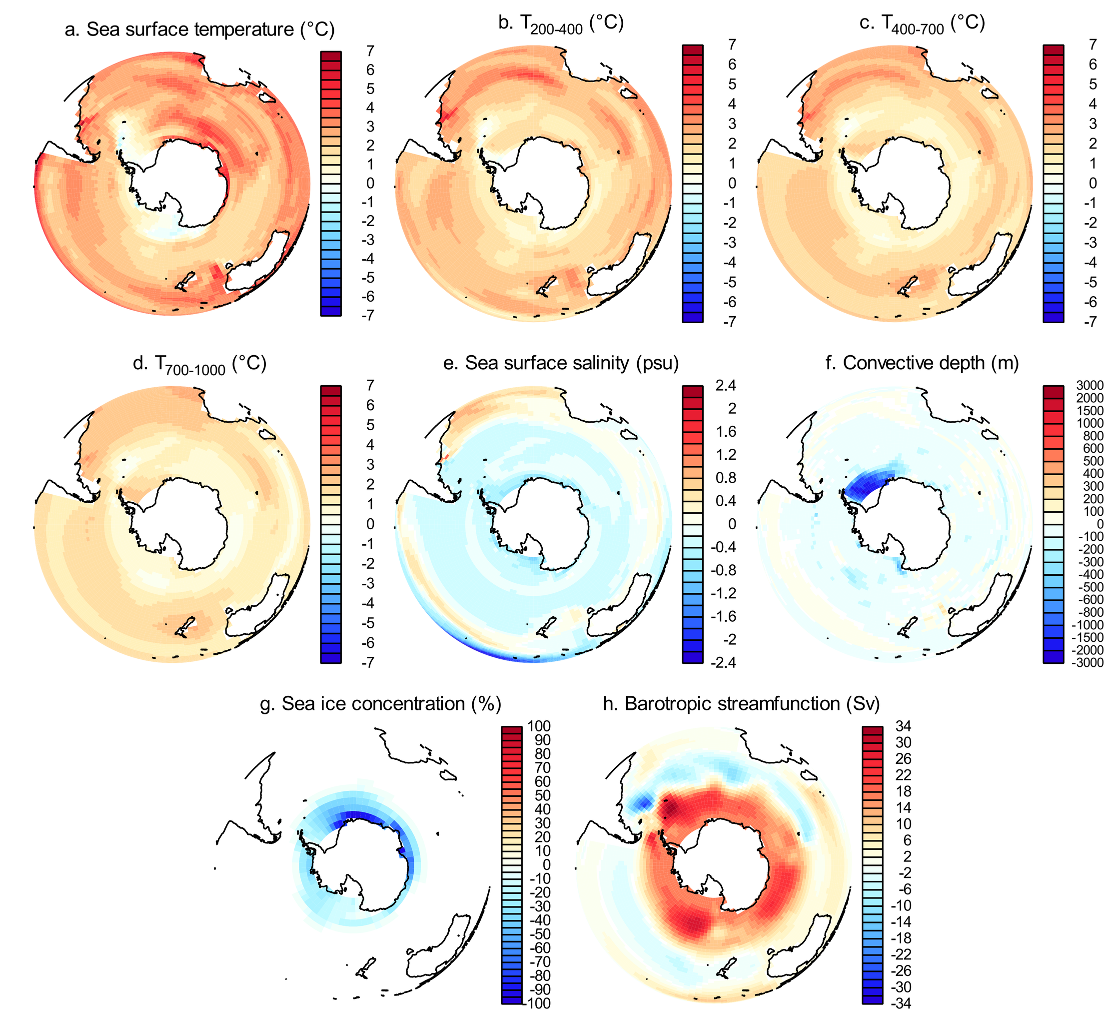

Figure 5. As Fig. 4, but for the first 100 years after the atmospheric CO_2 concentration has stabilised (i.e. years 141–240) in experiment 4CO2.

- In response to a four-fold increase in the atmospheric CO_2 concentration, SSTs increase by up to 5.4°C along the coast of Antarctica (Fig. 5a).
- However, the magnitude of the warming decreases with depth, with maximum warming of just 2.3°C at a depth of 700–1000 m (Fig. 5b–d).
- In specific locations, for example at the mouth of the Amery Ice Shelf, the warming at depth is as strong in WILKES as it is in 4CO2.
- Ice shelf melting can therefore act as a strong positive feedback, amplifying the warming adjacent to the grounding lines of the EAIS.
- In experiment 4CO2, the persistent collapse in the rate of AABW formation is due to the large reduction in sea ice cover (Fig. 5g).

6. Conclusions

- We identify the existence of a possible "domino effect", whereby melting of one sector of the EAIS causes warming that propagates around Antarctica.
- This represents a positive feedback mechanism, which has the potential to amplify anthropogenically-induced melting around the continent.

Reference

Phipps, S. J., C. J. Fogwill and C. S. M. Turney (2016), Impacts of marine instability across the East Antarctic Ice Sheet on Southern Ocean dynamics, *The Cryosphere*, 10, 2317–2328, doi:10.5194/tc-10-2317-2016.