Antarctic Polynyas and their role in Deep Water Formation

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Coastal and open-ocean polynyas play crucial roles in the formation of deep water by creating cold, dense AABW due to sea-ice production and open-ocean deep convection, respectively. The evolution of polynyas under climate change is uncertain.

Polynyas: Formation and Processes

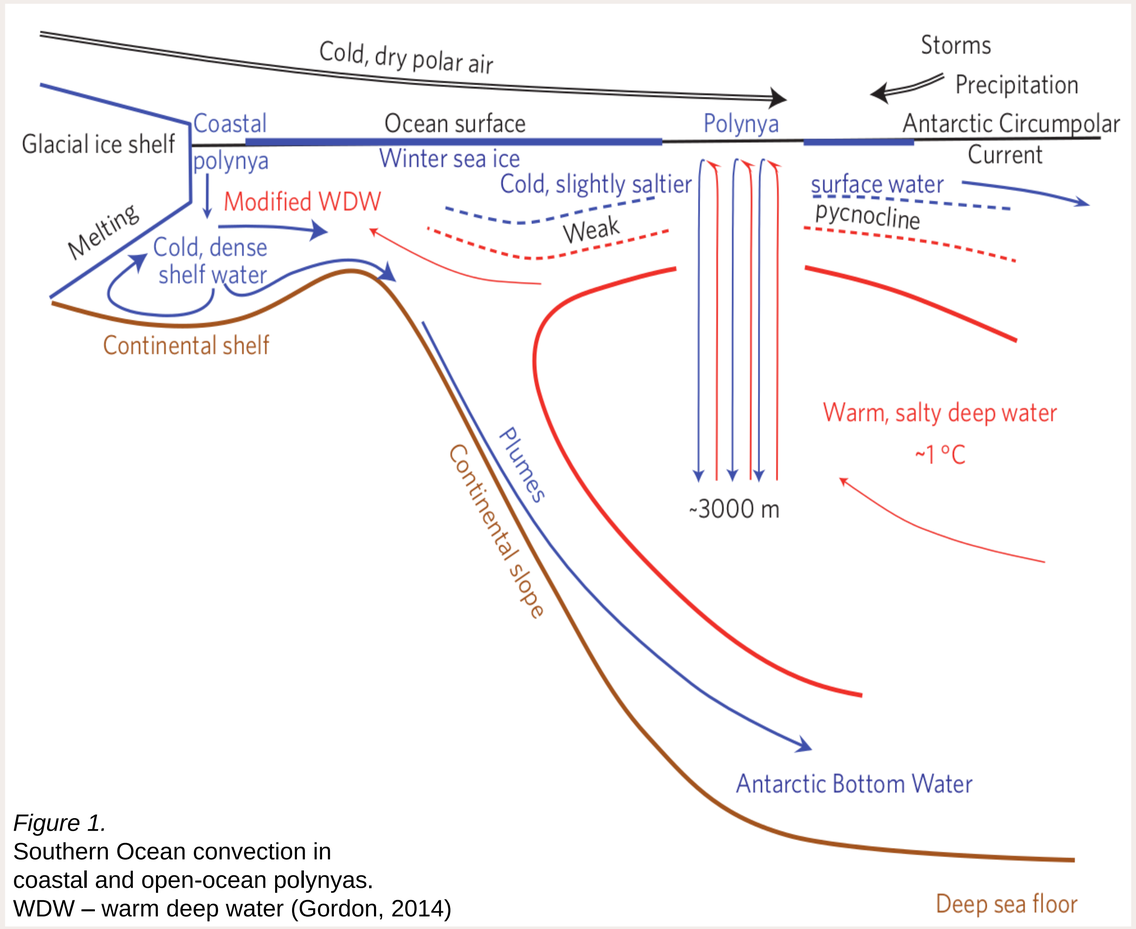

Figure 1.
Southern Ocean convection in coastal and open-ocean polynyas.
WDW – warm deep water (Gordon, 2014)

Coastal polynyas

Formation:

- Katabatic winds advect the adjacent pack ice away from the coast

Deep water formation:

- The rapid and continuous formation of sea ice produces cold, dense shelf water (due to brine release)
- Once this dense water has gained sufficient negative buoyancy, it can mix down the continental slope with ambient water to produce Antarctic Bottom Water (AABW)

➔ Dominant contributor to AABW production

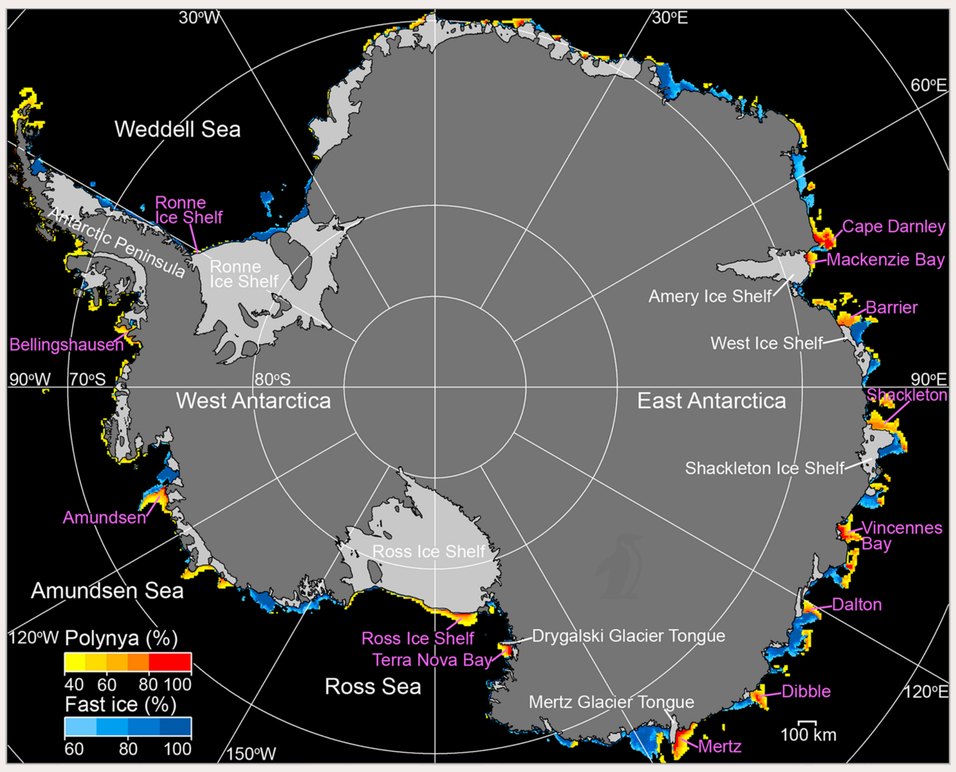

Figure 2. Map of coastal polynyas and landfast sea ice In the Southern Ocean. Frequency of occurrence during the freezing period (Mar-Oct) for the period of 2003-2011 is shown by *colour shadings*. Land mass is *grey*, and ice shelves & glacier tongues are *light grey*. (Ohshima et al. 2016)

Open-ocean polynyas

Most prominent example: Weddell Sea polynyas

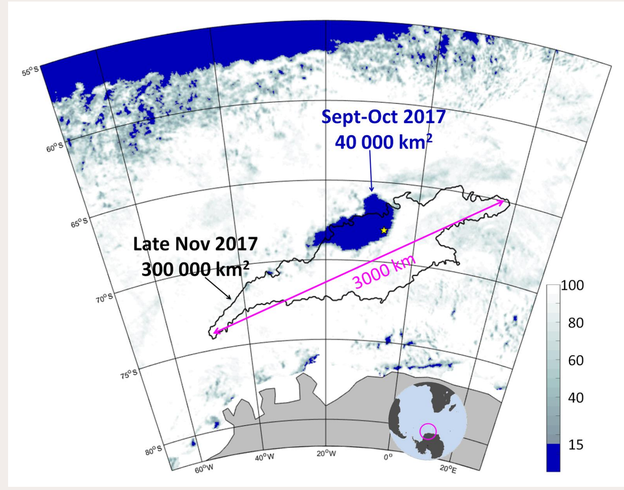

Figure 3. Extent of the 2017 Weddell Polynya (sea ice concentation, in %, from AMSR2; Swart et al. 2017)

Formation:

- Created by concurrent upper-ocean preconditioning (weakened stratification) and meteorological perturbations (storms)
- Maintained by a rapid ventilation of deep-ocean heat through convective mixing

Role of eddies and topography:

- The interaction between circulation and topography can activate cyclonic eddies at Maud Rise that increase upwelling and transmit divergent Ekman stress to the sea ice cover.

Deep water formation:

- This open-ocean deep convection may have presented a dominant mode of deep water formation in past climates.

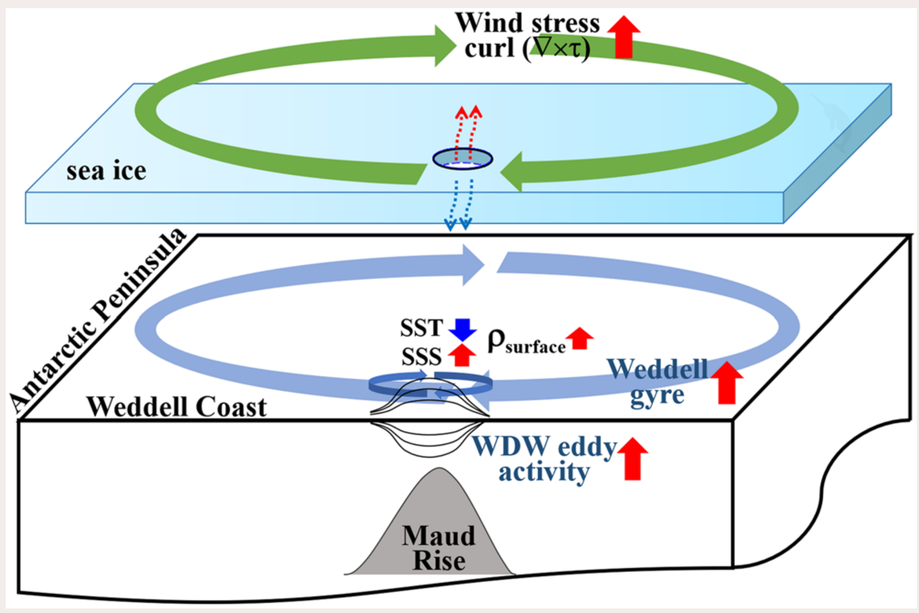

Figure 4. Schematic illustrating how an open-ocean polynya is triggered in the Weddell Sea by both hydrological and dynamical processes (Cheon & Gordon, 2019).

Polynyas and Climate Change

Two competing effects:

- Freshening of the surface waters would increase the stratification, which may inhibit convection and thereby the occurrence of open-ocean polynyas.
- Intensifying Southern Hemisphere westerly winds could increase the upwelling of warm, salty deep water and by that intensify the creation of polynyas.

➔ Both effects are predicted by the CMIP5 models.
➔ The dominating effect remains uncertain.

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