Changing ocean properties, circulation and sea ice in the polar regions: causes and consequences


Climate change in the Arctic and Antarctic is exerting a profound influence both within the polar regions themselves, and over all of our planet. Physical changes influence ecosystems, societies, cultures and economies. The IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC) assesses past, ongoing and future changes in the polar regions, the impacts of those changes, and possible options for mitigation and adaptation under different climate change scenarios.

Observed changes in the Arctic and Southern Ocean assessed in SROCC include:-

Arctic sea ice extent continues to decline in all months of the year; the strongest reductions in September are unprecedented in at least 1000 years (Figure 1). Since 1979, the areal proportion of thick ice at least 5 years old has declined by approximately 90%. Approximately half the observed sea ice loss is attributable to increased atmospheric greenhouse gas concentrations. Changes in Arctic sea ice can influence mid-latitude weather on timescales of weeks to months.

The polar oceans have continued to warm in recent years, with the Southern Ocean especially important in global ocean heat increase. Over large sectors of the seasonally ice-free Arctic, summer upper-ocean temperatures increased at ~0.9°C per decade during 1982-2017. During 1979-2017, the Southern Ocean accounted for 35-43% of the global ocean heat gain in the upper 2000 m; in recent years (2005–2017), it was responsible for an increased proportion (45-62%)

The Arctic and Southern Oceans continue to remove CO₂ from the atmosphere and to acidify. The amount of CO₂ drawn into the Southern Ocean has varied decadally since the 1980s. Rates of calcification, by which marine organisms form hard skeletons and shells, declined in the Southern Ocean between 1998 and 2014. In the Arctic, the ocean corrosive to organisms that form shells and skeletons using aragonite expanded between the 1990s and 2010, with instances of extreme aragonite undersaturation.

Sea level rise has accelerated due to the increased ice loss from the Greenland and Antarctic ice sheets. Mass loss from Antarctica over the period 2007–2016 tripled relative to 1997–2006. For Greenland, mass loss doubled over the same period. Oceanic change is strongly implicated as a driver, for Antarctic change especially.

Southern Ocean circulation is responding to climatic changes in forcing in complex ways, with global-scale implications via changing water mass production and export to lower latitudes (Figure 2).

Projected changes in the Arctic and Southern Ocean assessed in SROCC include:-

Arctic warming will result in continued loss of sea ice and snow, and reductions in the mass of glaciers. For stabilised global warming of 1.5°C, an ~1% chance of a given September being sea ice free in 2100 is projected; for stabilised warming at 2°C increase, this rises to 10–35%. Projected mass reductions for polar glaciers between 2015 and 2100 range from 16% to 33% depending on the level to which greenhouse gas concentrations are limited.

The polar oceans will be increasingly affected by CO₂ uptake, causing conditions corrosive for carbonate shell-producing organisms (Figure 3). This will have associated impacts on marine organisms and ecosystems. It is very likely that both the Southern Ocean and the Arctic will experience year-round conditions of surface water undersaturation for mineral forms of carbonate by 2100 if anthropogenic CO₂ emissions are not strongly reduced.

The polar ice sheets will make increasing contributions to global sea level rise by 2100, with the amount dependent on future climate change. Antarctica is projected to contribute ~0.04 m for a low greenhouse gas scenario, up to ~0.12 m for a high greenhouse gas scenario. Greenland’s contribution in 2100 is projected to be ~0.07 m to ~0.15 m, dependent on scenario. Whilst Greenland is currently contributing more to sea level rise than Antarctica, the latter could become a larger contributor by the end of the century as a consequence of potential rapid retreat.

Figure 1. Observed trends in sea ice concentration and sea surface temperature for the Arctic and Southern Ocean (maps), plus historical and future trajectories under different greenhouse gas concentration scenarios (time series)

Figure 2. Observed changes in Southern Ocean circulation, as assessed in SROCC.

Figure 3. Regions of the surface ocean characterized by year-round aragonite undersaturation in 2100 for a low greenhouse gas scenario (left) and a high greenhouse gas scenario (right).

Take home messages:-

1) The polar oceans are changing rapidly and losing ice. The consequences of this polar transition extend to the whole planet, and are affecting ecosystems and people in multiple ways.
2) The polar oceans will be profoundly different in future compared with today, and the degree and nature of that difference will depend strongly on the rate and magnitude of global climatic change. This will challenge adaptation responses regionally and globally.
3) Response options exist that can ameliorate the impacts of polar change, build resilience and allow time for effective mitigation measures, including major reductions in emissions of greenhouse gases.
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