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Antarctic Climate Change and the Environment – 2017 Update

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Summary

This paper presents an update on the Antarctic Climate Change and the Environment Report (2009 initial publication and 2013 update), providing an overview of recent science. The update is not meant to be read as a synthesis report, but as a perspective on recent scientific advances.

Introduction

Here we provide an update on recent significant advances in our understanding of climate change across the Antarctic continent and the Southern Ocean, and the impacts on the terrestrial and marine biota. This document builds on the material included in the Antarctic Climate Change and the Environment (ACCE) report, which was published by SCAR in 2009 [*Turner et al.,* 2009], with an update of the key points appearing in 2013 [*Turner et al.,* 2014]. At the request of the ATCM, SCAR agreed to provide regular updates on the original report (e.g. ATCM Resolution 4 (2010)). That activity is coordinated by the SCAR ACCE Expert Group (see http://www.scar.org/ssg/physical-sciences/acce), which has provided annual updates to the ATCM. The scope of the group is to keep abreast of recent advances in climate science, with a particular focus on Antarctic climate change and the biological implications of such changes. A recent development has been that the original ACCE report and the updated key points have been made available online as a wiki at http://acce.scar.org/wiki/Antarctic_Climate_Change_and_the_Environment. This online version is being progressively updated by a number of editors with input from many active scientists.

Changes in the Antarctic physical environment

1. In contrast to the Arctic, since the late 1970s the extent of sea ice around Antarctica has been increasing slightly, with record maximum late winter extents observed in 2012, 2013 and 2014. However, on 1 March 2017 Antarctic late summer sea ice extent dropped to just over 2 million square kilometres, which is the smallest amount yet observed since 1979 (Figure 1). The amount of sea ice was particularly low around the coast of West Antarctica. This is an example of the large variability of the Antarctic climate system on annual and decadal timescales. At present, it is difficult to reliably quantify any contribution that increasing greenhouse gas concentrations may have made to the record minimum and whether this represents a more general switch from increasing to decreasing sea ice extent. For more details on the record minimum see www.nsidc.org.
2. The Antarctic Circumpolar Current rings the Antarctic and is the largest wind-driven ocean current on Earth and the only ocean current to travel all the way around the planet. Now researchers have found that the current transports 30% more water than previously thought. The revised estimate is an important update for scientists studying how the world's oceans will respond to a warming climate [*Donohue et al.,* 2016].
3. Since the 1950s the Antarctic Peninsula has experienced a well-publicised warming, which was larger than at any other location in the Southern Hemisphere. However, it is now clear that the warming trend stopped in the late 1990s and that since that time temperatures have been decreasing, especially during the austral summer. The cooling has occurred because of a greater frequency of cold, easterly winds arriving at the Peninsula from the ice-covered Weddell Sea, arising from the development of a

climatological centre of low pressure between the Peninsula and South America, and once again highlighting the large variability of the Antarctic climate [*Turner et al.,* 2016]. Nevertheless, Peninsula temperatures are still higher than in the 1950s and glacier retreat is still ongoing.

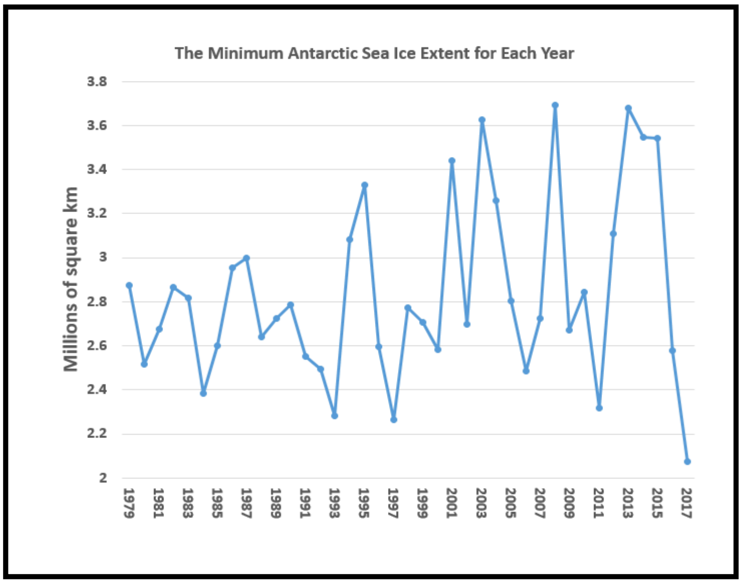

Figure 1. The annual sea ice minimum since 1979.

4. Further indications of improvement in stratospheric ozone levels above Antarctica in spring and summer are emerging, although meteorological factors continue to significantly influence the year-to-year depth and size of the ozone hole [*Solomon et al.,* 2016]. The 2016 Antarctic ozone hole was a little smaller than that observed during 2014 and 2015 and was present from early August to mid-November; an earlier finish than in either of the last two years. It's difficult to predict exactly when there will cease to be a springtime ozone hole, but estimates suggest this will be sometime during the second half of this century.
5. Coupled atmosphere-ocean-sea ice models are the main tool we have to predict how the climate of the Antarctic will evolve over the coming decades. Sea ice is one of the most difficult aspects of the environment to incorporate correctly in these models, as it is thin and susceptible to changes in both atmospheric and oceanic conditions. Recently it has been shown that predictions of temperature and precipitation are strongly associated with how these models represent sea ice in their runs over the period since the late 1970s indicating that it is essential to improve the representation of sea ice in climate models [*Bracegirdle et al.,* 2015].
6. Ocean temperatures around the Antarctic continent have increased more rapidly and to greater depth than the global average in recent decades [*Roemmich et al.,* 2015]. Between 500 and 2,000 m warming averaged 0.002 °C/year with a broad intermediate-depth maximum between 700 and 1,400 m. Most of the heat gain (67 to 98%) occurred in the Southern Hemisphere extratropical ocean.
7. West Antarctic glaciers continue to retreat. Konrad et al. [2017] used data from five separate satellite missions spanning 1992-2015 to show that the region's glaciers thinned extensively during this period. Thinning was not uniform, but spread upstream along the centre of the Pine Island and Thwaites glaciers twice as fast (13-15 km/yr) as it did elsewhere in the region. The thinning has spread up the Thwaites and Pine Island ice streams into the interior of West Antarctica, likely contributing to an accelerating Antarctic contribution to global sea level rise [*Forsberg et al.*, 2017]. The current thinning episode began in about 1980 in the Pope-Smith-Kohler basin, about 1990 in the Pine Island glacier, and about 2004 on the Thwaites Glacier.

8. A paper by Smith et al. [2017], analysed sediment cores from the seabed beneath the Pine Island ice shelf and suggested that ice shelf retreat began there about 1945, triggered by a period of strong warming of West Antarctica that was associated with El Niño activity in the tropical Pacific. Atmosphere-ocean-ice interactions within the whole Amundsen Sea Embayment have recently been reviewed by Turner et al [2017] who noted that the linkages were not well represented in the current generation of climate models.
9. The water chemistry of the Southern Ocean appears to be changing at a faster rate than previously estimated, particularly in the deep ocean layers. In the cold Southern Ocean, CO_2 is being absorbed at a higher rate than in subtropical waters [*Hauri et al.,* 2016].
10. As a contribution to the SCAR Antarctic Climate 2100 (AntClim21) programme a paper has recently been published that suggests a framework for the development of analogues for understanding past, present and future climates for the Antarctic and Southern Hemisphere [*Mayewski et al.,* 2017], facilitating improved predictions of climate change across the regions. Several future climate scenarios, derived using multiple climate reanalysis data sets, were presented considering the impacts of warming, ozone depletion and changes in the zonal and meridional winds.

Changes in the Antarctic biological environment

1. Climate change is thought to have influenced Southern right whale breeding success in southern Brazil by causing variation in food (krill) availability for the species. Under these circumstances it seems likely that an increase in the frequency of years with reduced krill abundance around South Georgia, may reduce the current rate of recovery of southern right whales from historical overexploitation [*Seyboth et al.,* 2016].
2. A boreal sea-star (*Asterias amurensis*) (Figure 2) that has been transferred to the Southern Hemisphere, most likely in ballast water, has established extensive invasive populations in southern Australia. It is a potentially high-risk invader of the sub-Antarctic and Antarctic, where it could alter community structure and ecosystem functioning because it is a benthic keystone predator [*Byrne et al.,* 2016].

Figure 2. The sea-star *Asterias amurensis.*

3. Fast ice expansion, and the associated increase in the distance Adélie penguins have to forage to find food, have been linked to declines in size and breeding success (*Wilson et al.,* 2016). Another recent

study showed that declining Adélie penguin populations experienced more years with warm sea surface temperature in their foraging areas compared to Adélie populations that are increasing. Based on this relationship, it has been projected that one-third of current Adélie penguin colonies, representing ~20% of their current population, may be in decline by 2060 as Antarctic seas continue to warm. However, climate model projections suggest refugia may exist in continental Antarctica beyond 2099, buffering distribution-wide declines. Climate change impacts on penguins in the Antarctic will likely be highly site-specific based on regional climate trends, but a southward contraction in the range of Adélie penguins is expected over the next century [*Cimino et al.,* 2016].

4. Several recent studies show that response to climate change is highly species specific. This has important implications not only for projecting ecosystem response to climate change, but also for addressing conservation issues. A consequence of these findings is that the tolerance limits to environmental changes of all important key species must be quantified before assessments (up-scaling) of large scale biodiversity shifts and whole ecosystem changes can be made. Recent studies that highlight species responses to climate change include demersal (bottom feeding) fish [*Sandersfeld et al.,* 2017], various marine invertebrates [*Clark et al.,* 2017], amphipods [*Schram et al.,* 2016], sea birds [*Grecian et al.,* 2016]), top predators [*Younger et al.,* 2016], lichens [*Bokhorst et al.,* 2016] and mosses [*Ashcroft et al.,* 2016]
5. A major recent synthesis has assessed the overall levels of protection of Antarctic biodiversity in comparison with other regions of the planet [*Chown et al.*, 2017] concluding that much scope exists for improving the situation. From a protected area perspective, including in response to climate change, readily applicable approaches exist to give effect to such improvements [*Coetzee et al.*, 2017; *Hughes & Grant*, 2017].
6. The population of wandering albatrosses (*Diomedea exulans*) at South Georgia is decreasing because of bycatch in longline fisheries. Breeding females are at higher risk than males from all the main pelagic longline fleets in the south-west Atlantic. The results have important implications for the management of longline fisheries and the conservation of this highly threatened albatross population [*Jiménez et al.,* 2016].

The SCAR ACCE Expert Group consists of John Turner (Chair), Colin Summerhayes, Tom Bracegirdle, Daniella Liggett, Jenny Baeseman, Paul Mayewski, Pete Convey, Guido di Prisco, Julian Gutt, Dominic Hodgson, Tony Worby, Zhaomin Wang and Alexander Klepikov.

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