Antarctic Climate Change Report Card 2014
An Antarctic Climate Change Report Card

Information paper submitted by ASOC

Summary

Research on climate change has implications for Antarctica, and it is vital that Antarctic Treaty Parties understand the latest findings to manage the continent effectively. This paper summarises some recent results to assist ATCM/CEP delegates in becoming familiar with the latest scientific findings. Climate change is a global problem, but Antarctic Treaty Consultative Parties can play an important leadership role in taking action to mitigate the impacts of climate change in Antarctica and around the world.

Introduction

This paper summarizes and highlights some climate-related changes and research findings in Antarctica over the past year. The large volume of high-quality scientific research in Antarctica produces a steady flow of information on climate change. Keeping track of all of this information is a challenge even for scientists. In this paper, ASOC is providing an update to its first report card, which was presented to the ATCM last year.

Since last year's ATCM, the Intergovernmental Panel on Climate Change (IPCC) has published a new assessment report on the state of climate science, so some of our attention is focused on findings from that major report.

Environmental Changes

Temperature

Antarctica has been warming since the late 1950s. However, there are factors that give IPCC assessors “low confidence” in these findings, including the widely dispersed instruments, multi-annual variability, multi-decadal variability, and other uncertainties. Warming in Antarctica is almost certainly anthropogenic, though confidence over this fact is lower than in the rest of the world. The IPCC states that, “over every continental region except Antarctica, anthropogenic forcings have likely made a substantial contribution to surface temperature increases since the mid-20th century”. For Antarctica, large observational uncertainties result in low confidence that anthropogenic forcings have contributed to the observed warming averaged over available stations. Again, it appears that some of the uncertainty over Antarctic temperatures is due to the availability of instrumentation around the continent.

It is important to note that western Antarctica includes some of the most rapidly warming areas in the world, including the Antarctic Peninsula and Central West Antarctica. There has been a linear increase between 1958 and 2010 at Byrd Station of 2.18 +/- 1.25 °C.

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1 Lead authors: Claire Christian, Dr. Jessica O’Reilly and Pam Pearson, with comments from James Barnes, Ricardo Roura and Bob Zuur.
3 Ibid, Figure SPM.6.
In sum: Some parts of West Antarctica, including the Antarctic Peninsula and Central West Antarctica, are among the most rapidly warming areas on the planet. More consistent meteorological observations continentally would help increase certainty about what is happening continent-wide.

Changes from last year: similar temperatures, increasing warming area.

Ice sheets and glaciers
When reporting on the status of Antarctic ice sheets, we rely primarily on two sources of information. First, we look at observations made by scientists in the field or through analysis of remote sensing data to understand the behaviour of the ice sheet in real time. Second, we look at models to understand projections for future behaviour of the ice sheet. While the observational data is fairly straightforward, modelling, while improving, continues to inadequately depict ice sheet dynamics.

Observationally, Antarctica is losing ice mass overall, and this loss is accelerating. According to the IPCC Fifth Assessment Report (AR5), “the average rate of ice loss from the Antarctic ice sheet has likely increased from 30 [−37 to 97] Gt yr−1 over the period 1992–2001 to 147 [72 to 221] Gt yr−1 over the period 2002 to 2011. There is very high confidence that these losses are mainly from the northern Antarctic Peninsula and the Amundsen Sea sector of West Antarctica.” Major ice loss is occurring in the areas that are mostly quickly warming, though there is only low confidence in the attribution for this recent ice loss.

Modelling ice sheets, particularly the marine West Antarctic Ice Sheet (WAIS) has been a scientific challenge. 2007’s IPCC Fourth Assessment Report chose to not speculate at all on possible rapid disintegration of ice sheets since modelling capability was inadequate to the task of modelling “non-linear” events like glacier collapse. However, modellers are able to reasonably project more linear glacial activity such as snow accumulation, surface melting, and glacial melting. The AR5 contains more updated modelling results. In the models, Antarctica is expected to experience increased snowfall (with medium confidence), which causes negative sea level rise as water is removed from the oceans. However, projected changes in outflow from both the East and West Antarctic Ice Sheets are expected to contribute 0.03-0.20m by 2081-2100 (also with medium confidence). To summarize, linear Antarctic ice sheet processes are expected to make a modest increase to global sea level over this century.

In the new IPCC assessment report, assessors remain cautious about prospects for the collapse of the West Antarctic Ice Sheet, including the likelihood of it occurring this century as well as the amount of sea level rise such an event would trigger. While the AR4 assessors declined to provide any numerical value, the AR5 assessors wrote that, “based on current understanding, only the collapse of marine-based sectors of the Antarctic ice sheet, if initiated, could cause global mean sea level to rise substantially above the likely range during the 21st century. However, there is medium confidence that this additional contribution would not exceed several tenths of a meter of sea level rise during the 21st century.” So while projecting a disintegration of WAIS remains difficult, the IPCC noted that such an event could lead to additional sea level rise this century.

In sum: Observations show the Antarctic ice sheets contributing modestly to sea level rise now, and this contribution is increasing over time. Making future projections, especially on ice sheet collapse, remains scientifically challenging. Such a collapse could however raise sea level up to several decimeters additional to the approximately 0.5-1 meter already projected by AR5 for the end of this century.

Changes from last year: Similar. Uncertainty over collapse remains a major research and policy concern.

Sea ice

the most rapidly warming regions on Earth.” Nature Geoscience 7, no. 1 (2014): 76-76.

6 IPCC 2013 page 9.
7 IPCC 2013 SPM page 19.
8 IPCC 2013 SPM page 25.
9 IPCC 2013 SPM 25.
Last year, ASOC reported that sea ice in Antarctica had been markedly increasing in some areas and decreasing in others, with a slight net increase in Antarctic sea ice in area. The IPCC AR5 reports that mean Antarctic Sea ice extent “increased at a rate in the range of 1.2 to 1.8% per decade (range of 0.13 to 0.20 million km per decade) between 1979 and 2012. There is high confidence that there are strong regional differences in this annual rate, with extent increasing in some regions and decreasing in others”\(^{10}\).

This anomaly has been difficult to assess, with the IPCC noting that, “there is low confidence in the scientific understanding of the small observed increase in Antarctic sea ice extent due to the incomplete and competing scientific explanations for the causes of change and low confidence in estimates of natural internal variability in that region”\(^{11}\). That is, there appears to be much more to learn about historical and contemporary sea ice behaviour, particularly in understanding why sea ice has been increasing along with increasing continental temperatures and increasing outflow from the ice sheet.

The changes to sea ice are highly regional and explanations are diverse. As presented in last year’s report card: the area with the most significant increase in sea ice extent is the Ross Sea area, with positive accrual in the Weddell Sea and Indian Ocean areas as well. Negative accrual is occurring in the Bellinghausen/Amundsen Sea regions, though sea ice extent is positive continent-wide. The patterning of Antarctic sea ice extent suggests changes in atmospheric circulation in the region\(^ {12}\).

Bintanja et al. (2013) suggest that there is a causal relationship between increased ice sheet outflow and increased sea ice: they conclude, through models, that the cool, fresh glacial water in the summer freezes in winter and leads to increased winter sea ice extent\(^ {13}\).

Modeling through the year 2100 shows a small decrease in Antarctic sea ice extent, which contrasts with current observations\(^ {14}\). Overall, the IPCC projects that “in the Antarctic, a decrease in sea ice extent and volume is projected with low confidence for the end of the 21st century as global mean surface temperature rises”\(^ {15}\).

However, Turner et al. (2013) suggest that the models are not projecting correctly, since some models also fail to match observations on increased sea ice extent over the past decades\(^ {16}\).

**In sum:** There are clear differences in sea ice behaviour between East and West Antarctica. Nonetheless, current scientific views say that sea ice extent will decrease in the coming decades.

**Changes from last year:** Observational data is the same, modelling data contradicts observational data.

### Ocean acidification

The impact of ocean acidification on krill (*Euphausia superba*) is a key area of research. The importance of krill to many Southern Ocean food webs means that even small changes as the result of acidification could have significant impacts on higher trophic levels. Kawaguchi et al. used the results of studies of krill embryonic development under higher levels of CO\(_2\) to develop models predicting krill hatching success under future levels of CO\(_2\). Researchers used the Representative Concentration Pathway\(^ {17}\) (RCP) 8.5 and 6.0 scenarios. The 8.5 scenario predicts that atmospheric CO\(_2\) concentrations will reach nearly 2000 ppm around the year 2200. The 6.0 scenario predicts that atmospheric CO\(_2\) concentrations will stabilize at around 500 ppm shortly after 2100. Results of modeling demonstrate that krill hatching success under the RCP 8.5

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\(^{10}\) IPCC 2013 SPM 9.

\(^{11}\) IPCC 2013 SPM page 19.


\(^{14}\) IPCC 2013 SPM 16.

\(^{15}\) IPCC 2013 SPM page 25.


\(^{17}\) Representative Concentration Pathways are four greenhouse gas concentration (not emissions) trajectories adopted by the IPCC for its fifth Assessment Report.
scenario will be at 20% or less of current levels in much of the Southern Ocean by 2300, which would represent a population collapse\(^\text{18}\). Under the RCP 6.0 scenario, hatching success will be at 75% or less of current levels by 2300, with large areas under 65%, including in area 48, which is where most commercial krill fishing occurs\(^\text{19}\). Under both scenarios, hatching success declines by the largest amounts in the Haakon VII and Weddell Seas\(^\text{20}\). Moreover, past the larval stage, increased acidification will likely have further negative effects on developing krill, so the modeling results may underestimate the impact of increased CO\(_2\)\(^\text{21}\).

**In sum:** It is already predicted that the Southern Ocean will be one of the first regions to experience ocean acidification. However, the impacts on Southern Ocean species will vary. The results of Kawaguchi et al. indicate that the impacts on krill will be severe and widespread. If emissions continue to rise, it is likely that the krill population of the entire Southern Ocean would collapse.

*Changes from last year:* More detailed predictions on how ocean acidification will affect krill have been developed.

**Impact of black carbon and other short-lived climate pollutants**

A recent report published by the World Bank and the International Cryosphere Climate Initiative (ICCI) has analysed the impact of black carbon and other short-lived climate pollutants (SLCPs) on Antarctica\(^\text{22}\). The report, titled *On Thin Ice*\(^\text{23}\), showed some degree of black carbon impact (radiative forcing) on Antarctica — equaling about two-thirds of the forcing on the Arctic. Employing three global climate models (NASA-GISS, HadGem3 and ECHAM), the study examined total radiative forcing impacts of taking seven existing and feasible anti-pollution measures that target black carbon (including co-emissions of cooling aerosols), as well as seven methane-reducing measures. The models predict that these measures can result in significant decreases to radiative forcing in Antarctica. In particular, the implementation of methane-reducing measures could help avoid 0.3°C of warming on the Antarctic Peninsula by 2050.

Because little atmospheric mixing occurs between the hemispheres on the few day timescale of black carbon’s atmospheric lifetime, the black carbon affecting Antarctica likely arises primarily from southern hemisphere sources, particularly from cookstoves and biomass cooking. These sources of black carbon are known to have negative local impacts on humans and ecosystems as well. Thus, all of these methane and black carbon measures would result in health and crop benefits in South America and sub-Saharan Africa as well as potential climate benefits in Antarctica. For example, cookstove mitigation benefits alone would result in over 200,000 lives saved annually in sub-Saharan Africa and South America\(^\text{24}\).

Work characterizing the impact of SLCP measures on sea level rise, due to lower rates of warming including on Antarctica, is in the early stages but a recent study by Hu et al.\(^\text{25}\) found that SLCP measures could cause a leveling of the rate of sea level rise by 2050; and a downward trend in rate beginning in 2060 were the SLCP measures combined with CO\(_2\) reductions aimed at a stabilization level at 450ppm. This could avoid about 10cm of sea level rise by 2100 with action on SLCPs alone, which represents about 42% of projected sea level rise if emissions continue at their current rate.

**In sum:** Measures to reduce black carbon and short-lived climate pollutants would have significant local and global benefits as well as potentially reduce the impacts of climate change in Antarctica, but only when combined with CO\(_2\) reductions.


\(^{19}\) Ibid.

\(^{20}\) Ibid.

\(^{21}\) Ibid.

\(^{22}\) For more information, see IP 72 by ASOC, *Near-term Antarctica Impacts of Black Carbon and Short-lived Climate Pollutant Mitigation* submitted to ATCM XXXVII.


\(^{24}\) Ibid.

Changes from last year: Modeling shows benefits for Antarctica through the implementation of black carbon and SLCP mitigation measures.

**Ecosystem changes**

**Invasive species**

Invasive species remain a key area of concern for the Antarctic Treaty System as warming areas become more susceptible to invasion. A precautionary and proactive approach is advisable even though no major invasions have occurred yet in Antarctica, although outside the Antarctic Treaty area - Macquarie Island and South Georgia have experienced some significant invasions.

Recent research demonstrates that some species with a high potential to become invasive could persist at low levels in the Antarctic environment until conditions are more suitable for their expansion. The grass *Poa pratensis* (commonly known as Kentucky bluegrass) has survived for decades at Cierva Point on the Antarctic Peninsula. The grass, accidentally introduced in the mid-1950s, has expanded significantly since the early 1990s. Although the current temperatures at Cierva Point are probably too low to permit germination of new seeds, the plant is clearly still able to persist and even expand\(^{26}\). Researchers observed that the *P. pratensis* colony appeared to have expanded into areas formerly occupied by native mosses\(^{27}\). Therefore, prevention of the introduction of non-native species, and eradication of species that may have established themselves on the continent are key. Plants like *P. pratensis* can clearly persist despite a lack of ideal environmental conditions. If not eradicated as the researchers recommend, this grass would likely survive until temperatures on the rapidly warming Peninsula are suitable for reproduction, at which point its range could quickly expand.

**In sum:** For some potential and actual plant invasives, prevention and eradication are critically important so that these species are not able to expand their range as temperatures increase.

Changes from last year: Similar. Invasive species remain a threat.

**Impacts on Antarctic species**

Another study designed to model the impacts of climate change on krill provides further evidence that krill in the Weddell Sea region will be dramatically affected by warming conditions. Researchers found that even under a scenario in which chlorophyll concentrations increased by 50%, the ability of krill to feed and grow normally could decrease in areas close to the Antarctic Circumpolar Current due to warming\(^{28}\). However, the current trend for chlorophyll concentrations shows a decrease, and modeling shows that these decreasing conditions coupled with increases in global CO\(_2\) emissions will result in a large area that includes the Peninsula and Weddell Sea regions being unable to support krill growth at current levels\(^{29}\). This situation would have significant impacts on predators, and on the krill fishery, which takes a large proportion of its catch from this area. In combination with the analysis of krill populations under increased ocean acidification, the future for krill and many krill predators in the Weddell Sea seems grim.

Although often identified as being at risk from warming temperatures, Adélie penguins in some regions may benefit from climate change. Glacial retreat in the Ross Sea appears to have played a key role in the expansion of an Adélie penguin colony on Beaufort Island\(^{30}\). Warmer temperatures in the Antarctic Peninsula are associated with more negative outcomes for Adélies because they have been resulted in more


\(^{27}\) Ibid.


\(^{29}\) Ibid.

snow and less sea ice, but those phenomena have not yet occurred in the vicinity of this colony. Climate change impacts can thus be of one kind in one area and of a different kind in the other.

**In sum: Evidence of climate change impacts on Antarctic species continues to accumulate. However, these impacts vary across Antarctic regions, and do not affect all species equally.**

*Changes from last year: Similar, climate change is further predicted to have varying impacts on species but many impacts will be negative.*

**Conclusions and Recommendations**

1) Anthropogenic climate change is happening in Antarctica and causing impacts on the Antarctic (and global) environment, especially in West Antarctica. A strong international policy response to mitigate climate effects is critical. ATCPs must continue to work for a global reduction in CO₂ emissions. Additionally, actions taken to reduce the amount of black carbon and short-lived climate pollutants in the Southern Hemisphere could be carried out relatively quickly as a complementary measure to CO₂ reductions, yet still have a significant potential positive impact on slowing Antarctic warming, while bringing unquestioned development benefits to the Southern Hemisphere.

2) Scientific research in Antarctica is critical to understanding global climate change. Some Antarctic research, such as that on ice sheets and sea ice, form some of the key uncertainties around climate change. Scientific research should be supported broadly (with appropriate management plans for the fragile environments in Antarctica) as well as increased support for remote monitoring and communicated in peer reviewed publications as well as to decision makers in relevant international fora outside the Antarctic Treaty System and the public.