Antarctic Climate Change Report Card
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Submitted by ASOC

Summary

<table>
<thead>
<tr>
<th>Overview of research focus</th>
<th>In Sum</th>
<th>Changes from Last Year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Temperature</strong></td>
<td>Observations and models</td>
<td>Antarctica is warming, particularly on the Antarctic Peninsula</td>
</tr>
<tr>
<td><strong>Ice Sheets and Glaciers</strong></td>
<td>Paleoclimatic studies, observations, models</td>
<td>A major improvement in ice sheet modelling suggests a potential 1m SLR by 2100</td>
</tr>
<tr>
<td><strong>Sea Ice</strong></td>
<td>Observations and models</td>
<td>Antarctic sea ice is increasing</td>
</tr>
<tr>
<td><strong>Ocean Acidification</strong></td>
<td>Observations and models</td>
<td>Onset of widespread ocean acidification will be abrupt</td>
</tr>
<tr>
<td><strong>Blue Carbon</strong></td>
<td>Observations</td>
<td>Impact of benthic species as a carbon sink is significant but relatively understudied</td>
</tr>
<tr>
<td><strong>Impacts on Antarctic Species</strong></td>
<td>Observations</td>
<td>Changing sea ice conditions could have direct impacts on benthic species as well as seabirds</td>
</tr>
</tbody>
</table>

Introduction

For the fourth year, ASOC presents its Climate Change Report Card, a summary of notable scientific breakthroughs and climate events related to anthropogenic climate change in the Antarctic. We track scientific publications and science reporting to bring up-to-date findings to the ATCM and provide policy advice connecting Antarctic climate science to Antarctic environmental management decisions.

Temperature

The Antarctic continent overall has been warming since the late 1950s, though some areas, especially in the Antarctic Peninsula, are warming rapidly, others, such as the interior are warming at a much lower rate or cooling.2

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1 Lead authors Jessica O’Reilly and Claire Christian.
Antarctic warming is considered through two primary sources: global atmospheric warming and in relation to the warming of the Southern Ocean. For the planet as a whole, temperatures are warming and this warming is "extremely likely" to be caused by anthropogenic activities. In an update of the Goddard Institute for Space Studies (GISS) global temperature analysis, the data suggest that 2015 was the warmest year recorded, showing a global surface temperature 0.87°C warmer than 1951-1980, the base period for this analysis. Part of this increase may be attributed to the strong El Niño last year.

Antarctic warming is likely to be anthropogenic, though expert assessors express low confidence in this, due to the more scattered temperature measurement instruments over Antarctica compared to the rest of the planet. Further research on detection, attribution, and the long term persistence of Antarctic surface temperatures continues to examine the significance and uncertainties surrounding Antarctic temperature records.

In models, a warming Southern Ocean can explain up to 2°C of continental warming through heat exchange between the ocean and atmosphere. Pedro et al.‘s findings suggest a 50-year lag between ocean warming and continental temperature response. These open ocean deep convection events are rare in the contemporary Southern Ocean, so this study proposes further paleoclimatic research, which indicates that such convection processes may have been more common in the past.

In sum: On a planetary scale, 2015 was the warmest year since instrumental measurements began. The Earth is warming due to anthropogenic forcings: the same is happening in the Antarctic, with less confidence. Research continues around the significance of Antarctic warming data due to patchy instrumentation. The role of the Southern Ocean is considered as influencing continental warming.

Changes from last year: consistent.

Ice Sheets And Glaciers

Research on the Antarctic Ice Sheets is dynamic, with regular new findings and discoveries. The West Antarctic Ice Sheet (WAIS), as a marine-grounded ice sheet, is inherently unstable. The East Antarctic Ice Sheet (EAIS) is grounded on the continent and is generally considered stable. The Antarctic Ice Sheets, combined, are losing mass, this loss is accelerating, and the resulting increase in global sea level is significant to much of society.

DeConto and Pollard published findings based on their improved model. Modeling ice sheets, especially instabilities caused by a marine grounding line, has been challenging, though innovations are continuous. A major success of DeConto and Pollard’s model is that it is able to adequately reproduce paleoclimatic ice behavior of the ice sheets from the Last Interglacial (130,000-115,000 years ago) and the Pliocene epoch (approximately 3 million years ago). Inability to reproduce past glacial events was a major limitation in verifying older ice sheet models, so this model marks a significant step forward in modeling ice sheets, and therefore, projecting future sea level change.

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5 Hansen et al., 2016.

6 IPCC 2014.


9 Pedro et al. 2016.

10 IPCC 2014.

DeConto and Pollard state that, “Antarctica has the potential to contribute more than a metre of sea-level rise by 2100 and more than 15 metres by 2500, if emissions continue unabated.”\textsuperscript{12} They also note that, “atmospheric warming will soon become the dominant driver of ice loss, but prolonged ocean warming will delay its recovery by thousands of years.”\textsuperscript{13} While these results suggest that Antarctic ice loss is not inevitable, it is important to note that ice loss is fundamentally irreversible on a human timescale.

A collapse of WAIS, according to models by Steig et al., could influence surface climate for the rest of the continent. These simulations suggest that areas of the EAIS adjacent to WAIS would warm, while the coastal portions of Marie Byrd Land would warm.\textsuperscript{14}

In paleoclimate research on the ancient Antarctic Ice Sheet, Galeotti et al. found that the stable Antarctic Ice Sheet formed about 32.8 million years ago, when atmospheric carbon dioxide concentration levels fell below 600 ppm.\textsuperscript{15} This suggests a threshold for the contemporary continental Antarctic Ice Sheet, with marine portions of the Antarctic Ice Sheet vulnerable at lower carbon dioxide levels.\textsuperscript{16}

**In sum:** An improved model suggests an unstable Antarctic Ice Sheet that could significantly contribute to global sea levels by the end of this century and beyond, with recovery taking thousands of years due to a lag in ocean warming.

*Changes from last year: new research that underscores need for prompt abatement of carbon emissions.*

**Sea Ice**

Sea ice in Antarctica is increasing and has been doing so for several decades. Indeed there are increasing sea ice accumulations annually as well as during all Antarctic seasons.\textsuperscript{17} Given what we know about Antarctic surface temperature increase and changes in the ice sheets, there are several lines of inquiry to follow in the case of Antarctic sea ice.

First, models suggest a decrease in Antarctic sea ice extent (SIE), which does not conform to observed changes.\textsuperscript{18} This most plausible explanation to this is that the physics in the models is incorrect: Simmonds suggests that polar sea ice physics in models is based upon Arctic sea ice behavior, which the models adequately capture.\textsuperscript{19}

Second, and related to physics in models, is the relationship between changes in atmospheric circulation, wind patterns, and atmospheric chemistry and the patterning and accumulation of sea ice.\textsuperscript{20, 21} Simmonds notes that, in contrast to the Arctic, “the high southern latitudes SLPs [sea level pressures] have exhibited strong and significant changes in the 35 years considered here [1979-2013].”\textsuperscript{22}

\textsuperscript{12} DeConto and Pollard 2016, page 591.
\textsuperscript{13} Ibid.
\textsuperscript{16} Ibid.
\textsuperscript{18} Simmonds 2015.
\textsuperscript{19} Ibid.
\textsuperscript{22} Simmonds 2015, brackets added.
Third, investigators are studying the relationship between freshening of the sea near the continent as the ice sheets melt, which could lead to positive accumulation of sea ice.\textsuperscript{23}

Finally, some experts suggest that the increase in Antarctic SIE is due simply to internal variability. Gagne et al. used data from the Nimbus Data Rescue Project at the National Snow and Ice Data Center (NSIDC) to extend analysis of sea ice extent beyond the continuous satellite observations that began in 1979. Their data stretches to 1960 to test their hypothesis: “if the observed increase in SIE were largely driven by greenhouse gas increase or stratospheric ozone depletion, then a positive trend before 1979 would also be expected, whereas if it were largely driven by internal variability, then a negative trend prior to 1979 would be more likely.”\textsuperscript{24} Their results showed a negative trend between before 1979, suggesting that while there is inconsistency of SIE in the recent short term, a longer time period of analysis provides more consistency with the CMIP5 ensemble mean.\textsuperscript{25}

\textbf{In sum:} Sea ice in Antarctica is increasing. Research continues to investigate improving models and factors contributing to this, including atmospheric circulation, the contribution of fresh water from melting ice, and internal variability.

\textit{Changes from last year: similar, research continues.}

\section*{Ocean Acidification}

Ocean acidification is expected to impact large swaths of the Southern Ocean within the next few decades. The overall impact of this phenomenon on ecosystems remains unknown. Despite growing worldwide concerns about what OA means for ocean life, however, the amount of biological research on OA effects remains low according to a recent analysis, with only 12 papers out of 539 focusing on the Southern Ocean.\textsuperscript{26} The polar regions are expected to experience widespread acidification sooner than other parts of the world.\textsuperscript{27} Furthermore, as much as 98\% of the pelagic region is predicted to be undersaturated in aragonite until 2100 if emissions continue at their current rate.\textsuperscript{28} Researchers have recently predicted that occurrences of undersaturation will be “abrupt”, starting in 2030, and will last for six months by 2050.\textsuperscript{29} With this in mind, the relative lack of information on SO acidification is troubling. Although their data have not yet been published, researchers studying shell-forming pteropods in the Southern Ocean reported that they have collected numerous specimens with evidence of shell dissolution.\textsuperscript{30} This suggests that OA may already be having impacts on organisms that could impact the entire food web.

\textbf{In sum:} Research is clear that widespread ocean acidification will affect broad swaths of the Southern Ocean in the next two decades. Preliminary results suggest ocean acidification is already having an effect on the Southern Ocean, but there is not enough research occurring to understand the full ecosystem impacts of these changes.

\textit{Changes from last year: Similar, with preliminary findings indicating OA is already having a demonstrable impact on some species.}


\textsuperscript{24} Gagné et al. 2015, page 91.

\textsuperscript{25} Ibid, page 94.


Impacts on Antarctic species

Changing ice conditions in the Antarctic have regional and local implications as well as global ones, with many species sensitive to even small shifts in environmental conditions. Increased sea ice cover in the Antarctic is often identified by climate change skeptics as a positive sign that global warming, but this ignores the massive implications that such shifts could have for the ecosystem. For example, a dramatic increase in sea ice cover in the Dumont D’Urville Sea region of East Antarctica during January and February 2014 has been linked to equally dramatic breeding failures for several local bird species, with Adélie (Pygoscelis adeliae) and Wilson’s storm petrel (Oceanites oceanicus) producing no viable offspring that season. The researchers note that predicted decreases in sea ice towards the end of the century will also have a negative impact on many Antarctic species.

Sea ice extent is not the only consideration, however. Fast ice in the West Antarctic Peninsula has been disappearing earlier over the past 30 years, and this may put coastal benthic ecosystems at risk, since the absence of ice will change environmental conditions, increasing light, water turbulence, and iceberg scouring events. The invertebrates that make up these relatively rare but diverse ecosystems will be at significant risk.

The decline in Adélie penguins and increase in gentoos in the West Antarctic Peninsula have been linked to climate change, although it is not certain which specific factors are the most influential. New research comparing the foraging behavior of gentoo and Adélie penguins indicates that these species are not in competition for prey that in turn are declining due to climate change, since they do not forage in the same places (other research shows that prey populations are not decreasing in size). However, other factors related to climate change are still the most likely cause for these population trends in the WAP.

In sum: It is clear that changes to sea ice have variable, but sometimes dramatic, impacts on Antarctic species. Adélie penguin declines are almost certainly linked to climate change impacts, but it remains unclear which factors are responsible.

Changes from last year: Greater understanding of the impact of extreme climate events and sea ice variations, ruling out competition for prey as a reason for Adélie penguin declines.

Blue Carbon

Although declines in sea ice will likely disrupt Antarctic ecosystems in shallow waters, research has shown that this may result in increased carbon uptake by benthic organisms living at greater depths. Indeed, researchers have identified the South Orkney Islands Marine Protected Area (MPA) as a ‘carbon immobilization hotspot’ due to the fact that bryozoan species there sequestered more carbon than those at other sites due to the abundance of phytoplankton. If sea ice continues to break up at earlier dates in the Antarctic summer, it is possible that the resulting phytoplankton blooms could increase carbon accumulation.

32 Ibid.
34 Ibid.
36 Ibid.
38 Barnes et al. 2016.
in other areas as well. This phenomenon will not be sufficient to impact global climate change in any significant way, but it is important to understand how these processes function.

In sum: Scientists are still learning about the impact of marine species on the carbon cycle. Warming trends in the Antarctic may result in increased carbon sequestration in some benthic species due to increased growth resulting from increased food supplies.

Changes from last year: Deepening our knowledge of the carbon system in Southern Ocean ecosystems.

Conclusions and Recommendations

The predictions about how climate change will affect Antarctica have grown increasingly serious. The recent meeting of the United Nations Framework Convention on Climate Change (UNFCCC) indicated that policymakers may finally have appreciated the need for action to prevent further increases in warming by limiting carbon emissions. Nevertheless, we can expect that the significant changes already seen in parts of the Antarctic will continue into the near future. Antarctic science, already so crucial to our understanding of global climate change, will only grow in importance over the next several decades. ASOC therefore strongly recommends:

- That all ATCPs make clear commitments to funding research into the impacts of climate change and ocean acidification, and the possible ramifications for Antarctica and the rest of the world.
- That all ATCPs work closely with officials responsible for implementation of UNFCCC pledges to reinforce scientific findings about the serious impact on sea level rise that melting Antarctic ice sheets are predicted to have.

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39 Barnes 2015.