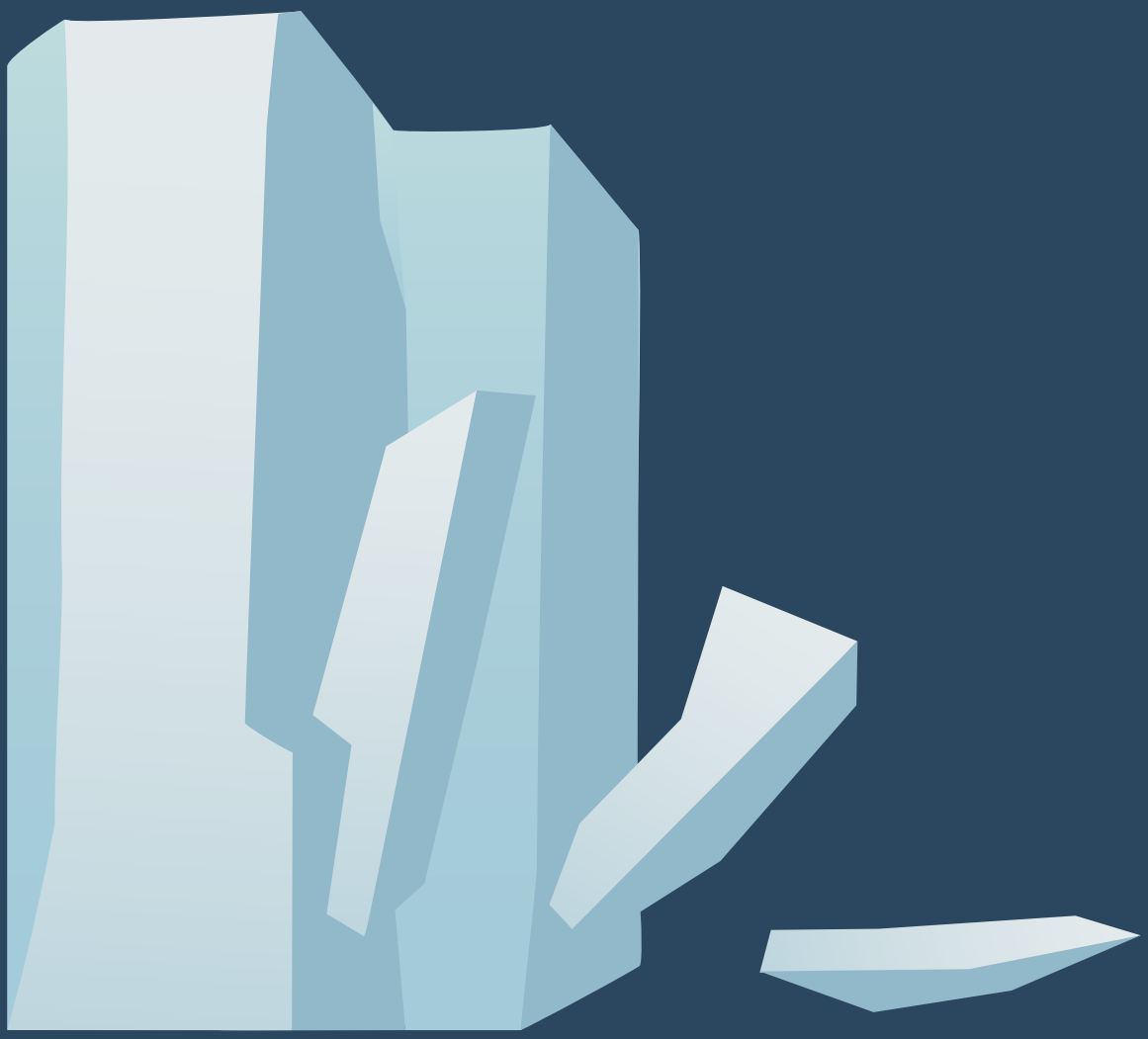
Antarctic Climate Change and the Environment

A DECADAL SYNOPSIS AND RECOMMENDATIONS FOR ACTION



STEVEN L CHOWN
RACHEL I LEIHY
TIM R NAISH
CASSANDRA M BROOKS
PETER CONVEY
BENJAMIN J HENLEY
ANDREW N MACKINTOSH
LAURA M PHILLIPS
MAHLON C KENNICUTT II
SUSIE M GRANT

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Compiled by:

Steven L Chown, Rachel I Leihy, Tim R Naish, Cassandra M Brooks, Peter Convey, Benjamin J Henley, Andrew N Mackintosh, Laura M Phillips, Mahlon C Kennicutt II, Susie M Grant

The report has been compiled from the findings presented in the reports of the *Intergovernmental Panel on Climate Change* predominantly, and of the *Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*.

The IPCC reports are cited extensively in this document and provide the foundation for the majority of this report's findings. The IPCC and IPBES reports should be consulted and are available at:

Intergovernmental Panel on Climate Change
https://www.ipcc.ch/about/

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
https://www.ipbes.net/

For citation: Chown, S.L., Leihy, R.I., Naish, T.R., Brooks, C.M., Convey, P., Henley, B.J., Mackintosh, A.N., Phillips, L.M., Kennicutt, M.C. II & Grant, S.M. (Eds.) (2022) *Antarctic Climate Change and the Environment: A Decadal Synopsis and Recommendations for Action*. Scientific Committee on Antarctic Research, Cambridge, United Kingdom. www.scar.org

Affiliations

SL Chown AN Mackintosh LM Phillips	Securing Antarctica's Environmental Future, Monash University, Melbourne, Australia
RI Leihy	Arthur Rylah Institute for Environmental Research, Department of Environment, Land, Water and Planning, Melbourne, Australia
TR Naish	Antarctic Science Platform, Antarctica New Zealand, Christchurch; Victoria University of Wellington, Wellington, New Zealand
CM Brooks	Department of Environmental Studies, University of Colorado Boulder, Colorado, United States of America
P Convey* SM Grant	British Antarctic Survey, Natural Environment Research Council, Cambridge, United Kingdom; *and Department of Zoology, University of Johannesburg, Auckland Park, South Africa
BJ Henley	Securing Antarctica's Environmental Future, School of Earth and Environmental Sciences, University of Wollongong, Wollongong, Australia
MC Kennicutt II	Scientific Committee on Antarctic Research, Scott Polar Research Institute, Cambridge, United Kingdom

Review Acknowledgments

This edited compilation was reviewed in its original form and revised accordingly. The review comments and responses are available from SCAR (www.scar.org) on request. The reviewers are thanked for their contributions. **Reviewers:** Julie M Arblaster (Monash University, Melbourne, Australia); Antje Boetius (Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Germany); Thomas J Bracegirdle (British Antarctic Survey, United Kingdom); David H Bromwich (The Ohio State University, United States of America); S Craig Cary (University of Waikato, New Zealand); Rachel D Cavanagh (British Antarctic Survey, United Kingdom); Eileen E Hofmann (Old Dominion University, United States of America); Emilia Kyung Jin (Korea Polar Research Institute, Republic of Korea); Heather J Lynch (Stony Brook University, United States of America); Kenichi Matsuoka (Norwegian Polar Institute, Norway); Sophie Nowicki (University at Buffalo, United States of America); Frank Pattyn (Université libre de Bruxelles, Belgium); Antonio Quesada (Universidad Autónoma de Madrid/Spanish Polar Committee, Spain); Eric J Rignot (University of California, Irvine, United States of America); Stephen R Rintoul (CSIRO Oceans and Atmosphere, Australia); Ted A Scambos (University of Colorado Boulder, United States of America); Aleks Terauds (Australian Antarctic Division, Australia); Roderik S W van de Wal (Utrecht University, Netherlands).

General Acknowledgments

SCAR acknowledges the contributions of all of those involved in the documents that form the basis of this synoptic report, in particular the thousands of contributors to and administrators of the IPCC and IPBES processes and the researchers whose work was cited either in those reports or here. SCAR acknowledges the review contributions of the Standing Committee on the Antarctic Treaty System. Editorial review assistance from Emma E Ramsay and Eleanor M Hay. Chapter 4 Title Page Image by Felicity S McCormack. Artwork and infographics by Laura M Phillips. Final printed report design by OÙ Design oudesign.com.au

Summary

Scientific evidence is abundantly clear and convincing that due to the current trajectory of human-derived emissions of CO_2 and other greenhouse gases, the atmosphere and ocean will continue to warm, the ocean will continue to acidify, atmospheric and ocean circulation patterns will be altered, the cryosphere will continue to lose ice in all forms, and sea level will rise.

While uncertainties remain about various aspects of the Earth System, what is known is beyond dispute. The trends, based on observations and confirmed by modelling, will accelerate if high rates of CO_2 and other greenhouse gas emissions continue.

The IPCC AR6 WGII Summary for Policymakers (SPM D.5.3) unambiguously emphasises this conclusion: *The cumulative scientific evidence is unequivocal: Climate change is a threat to human well-being and planetary health. Any further delay in concerted anticipatory global action on adaptation and mitigation will miss a brief and rapidly closing window of opportunity to secure a liveable and sustainable future for all*.

Human influence on the climate is clear, with observed changes in the climate and in greenhouse gas concentrations unequivocally attributable to human activities.

Human-induced climate change has caused extensive negative impacts, including losses to people and to nature, some of which are irreversible, such as the extinction of species.

Climate change is increasingly exacerbating the impact of other human-caused effects on nature and human well-being, and the impacts are expected to grow with increasing climate change magnitude.

Observations, modelling and global assessments describe significant changes in Antarctic physical and living systems, both marine and terrestrial.

Changes in Antarctic and Southern Ocean environments are linked to and influence climate impact drivers globally.

The most significant potential influence of Antarctica's changes will be on global mean sea level change and its influence on society and nature in all coastal regions of the globe.

Further global impacts influenced by Antarctic change include extreme climate and weather events, droughts, wildfires and floods, and ocean acidification. These impacts cause ecosystem disruption and loss of biodiversity beyond the Antarctic region.

Under current projections, and without nations meeting the Nationally Determined Contributions of the Paris Climate Agreement, the rate of global change will outpace societal, political, and economic responses that will facilitate adaptation and strengthen resilience to the impacts of climate change.

The agreements of the Antarctic Treaty System will not escape these influences. Rapidly changing Antarctic and Southern Ocean environments require similarly rapid environmental governance responses, including potential changes to agreements that have previously taken many years to reach. Impacts of climate change are also likely to challenge geopolitical relations in regions outside the Antarctic, in turn influencing relations within the Antarctic Treaty System.

Past global arrangements and isolated responses have been ineffective in addressing cross-boundary challenges that require an Earth System approach. Research conducted in the Antarctic and Southern Ocean regions, and strong policies developed from its results, are critical for the development of an integrated Earth System approach and the discernment of a path to a sustainable future for the planet.

Cooperative and coordinated international responses are required to address critical research needs in Antarctica and the Southern Ocean. In turn, receptive Antarctic governance is needed to use the knowledge generated by the research to create effective policy and decisions. Enhanced investment in science will provide policymakers and planners with more comprehensive and coherent sets of information over time to help put in place timely, scalable adaptation and mitigation strategies. Investment in new science and technology that provides updated information on the likelihood of major drivers of climate risk will more than repay itself.

Science communication and education in partnership with other cultural and societal actors is essential to enable further appreciation of the value of Antarctica and the Southern Ocean for current and future human well-being, for biodiversity, and for the interdependence of humans and nature.

To limit further change, immediate and deep emissions reductions are required across all sectors.

Effective action is now more urgent than it has ever been.

Environmental Change Summary

ATMOSPHERE

Surface warming has been variable

Forecast to

INCREASE

by

0.5°C – 3.6°C

very low emissions – high emissions

by 2100

HEAT WAVES

forecast to increase

PRECIPITATION

variable

Forecast to

INCREASE

by

5% – 25%

very low emissions – high emissions

by 2100

WIND SPEEDS

have increased

and will continue to do so

SOUTHERN ANNULAR MODE

forecasts

vary by season – continue positive trend

low emissions – high emissions

OCEAN

The Southern Ocean is crucial for absorbing

anthropogenic HEAT & anthropogenic CO_2

Slow surface & pronounced deep ocean

WARMING

Southern Ocean sea surface temperatures are forecast to

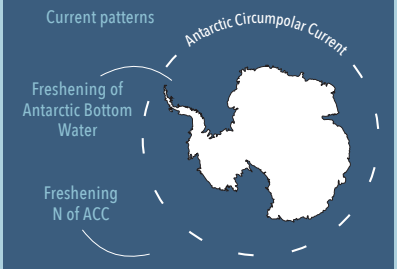
INCREASE

by

0.5°C – 1.75°C

low emissions – high emissions

by 2100



Current declines in

pH O_2

Forecasts for ongoing

FRESHENING ACIDIFICATION

DEOXYGENATION

CRYOSPHERE

SEA ICE

extent is currently

variable

future forecasts are

uncertain

ICE SHELVES

have experienced

thinning, retreat & disintegration

Ice shelves are forecast to continue melting, and they could face

rapid decline

ANTARCTIC ICE SHEET

mass loss has accelerated

WAIS loss EAIS loss

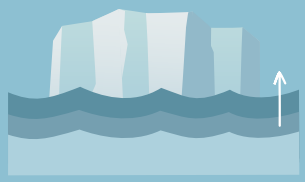
WAIS may be lost by 2300

FROZEN GROUND

temperatures have increased

Ongoing thawing is forecast

SEA LEVEL



Ice sheet contributions to global mean sea level rise have **increased** but the contribution so far has been small

Current expectations for 2100 Antarctic contributions are UNCERTAIN

Projections

0.03 - 0.34 m

or

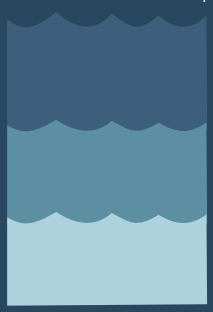
0.02 - 0.56 m

or

≈ 0.7 m

including non-linear processes

non-linear processes could lead to an increase of up to



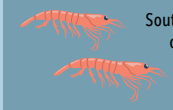
13 m

by 2300

MARINE LIFE

Seabirds and mammals have experienced population declines and increases, range shifts, and changing life histories

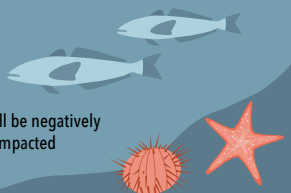
Population changes for birds and seal populations will continue



Southward movement of krill has occurred and is forecast to continue

Acidification has had mixed and negative impacts

Ongoing impacts will be **negative**



Fish will be negatively impacted

Changes to benthic systems are largely unknown

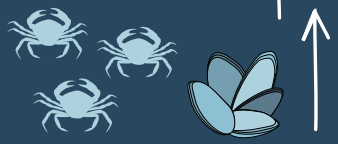
Changes in distributions are forecast

EMPEROR PENGUIN EXTINCTION RISK

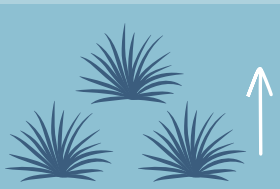
under business-as-usual climate scenarios

INVASIONS

Few currently but forecast to INCREASE



TERRESTRIAL LIFE



Flowering plant populations increase on the Antarctic Peninsula

GROWTH RATES have increased too

SPECIES REPLACEMENT

has occurred

in East Antarctica & the Dry Valleys

Future changes in ranges and populations are uncertain with little long-term data

INVASIONS

Few currently but forecast to INCREASE in number & distribution

Recommendations

POLICY RECOMMENDATIONS

Policy recommendations are made throughout this report. Here, these recommendations are made in order of significance. They include advice for the policymakers of the Antarctic Treaty System (ATS) and advice for National Antarctic Programs (NAPs). The recommendations from this report will be conveyed specifically to the XLIV Antarctic Treaty Consultative Meeting and, as appropriate, to the 41st Meeting of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR).

PR 1 The Antarctic Treaty Parties (ATPs) and observers to the Treaty should communicate to governments and to civil society the urgency of, at the very least, meeting the Nationally Determined Contributions (i.e., country greenhouse gas emissions reduction targets) of the Paris Climate Agreement to ensure that Antarctic and Southern Ocean environments are maintained in a state close to that known for the past 200 years, and in so doing help ensure achievement of the Sustainable Development Goals. The ATPs and observers are also encouraged to convey to governments, to parties to other international environmental agreements, and to civil society the outcomes of climate change-related research, and the benefits of informed immediate management actions in the Antarctic region. The need for additional extensive research to resolve uncertainties about cryosphere change, its rate, and its implications is urgent. Equally pressing is the need for effective communication to international efforts to address climate change beyond Antarctica.

PR 2 The Antarctic Ice Sheet (AIS) is changing rapidly, with the anthropogenic signal starting to become apparent. The AIS is projected to contribute substantially to global mean sea level rise, but the risks of significantly larger rates and magnitudes of sea level rise from rapid ice sheet mass loss in the coming decades to centuries are not well known, particularly from vulnerable marine basins in West Antarctica and parts of East Antarctica. Reducing this uncertainty is a globally urgent research priority that will require further support from NAPs. Novel observations along sensitive marine-based sectors, and from paleoclimate archives, are urgently needed over the time scale of a decade to improve understanding of the physical processes driving the retreat, document the current evolution in detail, and comprehensively, and critically improve the skills of numerical projections.

PR 3 The consequences of sea level rise and melting ice (sea, land and shelves) around Antarctica's coastline will present significant risks to society. The need for, and outcomes from, research on sea level in the Antarctic should be communicated by the ATPs and observers: to international agreements, governments at all levels, the economic sector, and to civil society, as these entities will largely have to plan for, manage, and endure the impacts of sea level rise and its associated costs.

PR 4 The Southern Ocean is undergoing changes and these changes will continue under higher emissions scenarios. Major impacts on the cryosphere, marine ecosystems and their constituent species, and consequently on the ecosystem services they deliver, including on systems and services outside the Antarctic region, are expected. Significant changes are anticipated in areas that may be especially vulnerable to ice sheet instability and collapse once thresholds are reached. Changes to the Southern Ocean and its ecosystems will present growing management difficulties, logistics challenges and research requirements that will require special attention within the ATS. Research on these questions, including through expanded long-term monitoring, is imperative.

PR 5 Changes to the Southern Annular Mode, a major climate driver, have implications for climate means, and climate extremes which may be accompanied by extreme events, such as major fires and droughts, especially on Southern Hemisphere land masses. Research to support further understanding of these influences, and their interactions with greenhouse gas-related climate change, should be supported by NAPs. The outcomes of this work and its significance for disaster preparedness and environmental management must be communicated by the ATPs and observers to governments and to civil society.

PR 6 The ATPs have declared an obligation to implement the mitigation and adaptation actions that will reduce climate change-related and other human impacts on Antarctic marine and terrestrial environments, their ecosystems and biodiversity, and the ecosystem services they deliver. Continued support for the research required to deliver evidence-informed options for action, including through coordinated, international and transdisciplinary research efforts across Antarctica and the Southern Ocean by all ATPs; the development of an appropriately-resourced scientific workforce for the future; and well-supported long-term monitoring programs of the physical and living environment, are essential to meet this obligation. Our human future depends on the success of these actions.

PR 7 National Antarctic Programs and International Association of Antarctica Tour Operators members are encouraged to strengthen biosecurity protocols for all pathways (ships, aircraft, and people), especially to the Antarctic Peninsula. Procedures to remove weeds and to trap other pests in ports of departure to the Antarctic need to be strengthened in anticipation of growing ease of establishment of non-native species owing to climate change. Surveillance and decision-making processes for determining actions for newly arrived species, especially in the vicinity of stations and sites with high visitor numbers, should be adopted. Collaborations with SCAR and other researchers are needed to establish an image- and DNA-based diagnostic service for newly detected species, building on the Barcode of Life Data System approach.

PR 8 The ATPs and members of the Committee for Environmental Protection (CEP) are encouraged to increase the priority given to documenting terrestrial and marine biodiversity (including in lakes and streams) at the population, species, and community levels. In some cases, to enable observation of these systems before they disappear. Such an enhanced focus, further informed by long-term monitoring of change, is essential to ensure the efficacy of environmental protection and to document the benefits of environmental management.

PR 9 The loss of sea ice, fast ice and ice shelves together with the expansion of ice-free areas on the Antarctic continent and changes to temperatures and precipitation, including extreme weather events, will present new challenges for the management of areas of high human activity in the Antarctic (including where infrastructure and other NAP assets are deployed). Biodiversity will change and conditions will become more suitable for the establishment of non-native species, especially along the Antarctic Peninsula. These challenges should be urgently addressed by the ATPs and by members of the CEP.

RESEARCH RECOMMENDATIONS

Specific research recommendations from this report are included within each of the major chapters. The sources of the recommendations, where details may also be found, are the SCAR Horizon Scan [Kennicutt *et al.* 2019] and SCAR Scientific Research and other programs [SCAR 2022], though several modifications have been made to these recommendations in light of new research findings.

Here we make recommendations for the most significant and urgent research needed. Given the climate change focus of this report, the recommendations focus on changes in the region that have significant implications for the Earth System and for society, and on the expected impacts of climate change on the region's biodiversity.

RR 1 Further support the research required to reduce uncertainty about the future of the region and its impact on the Earth System and to identify commensurate management responses. Integrated, international and targeted long-term monitoring programs and observatories are among the most important for reducing uncertainty and for understanding the likely impacts of mitigation and adaptation responses.

RR 2 Urgently reduce uncertainty about the current and future behaviour of the Antarctic Ice Sheet. The current observation network, especially for the hydrology and conditions at the base of the ice sheet, and the temperature and bathymetry of ice shelf cavities, coastal regions and the continental shelf, is inadequate to

fully anticipate change and to understand the risks of ice shelf collapse, loss of buttressing and rapid ice sheet mass loss in the coming decades. An international effort is urgently required to address this. A major exploration is required of key (unexplored) ice shelves and upstream glaciers using direct access techniques, ocean and airborne robotics, icebreaking ships, aircraft and space-borne remote sensing and other means to understand the ablation regime of the Antarctic ice sheet along the periphery; how it is has changed in the past, is currently changing and will change in the future; and how this will drive rapid ice mass loss and sea level rise from Antarctica.

RR 3 Understand how changes in atmospheric circulation drive changes in ocean currents around Antarctica and the advection of ocean heat onto the continental shelf, into the ice shelf cavities and in contact with the glaciers, and the influence of meltwater feedbacks.

RR 4 Determine what the contribution will be of the Antarctic Ice Sheet to future sea level rise and reduce uncertainties in projections of the rate and magnitude of that contribution, and effectively communicate the impacts and risks to stakeholders and users.

RR 5 Account for and develop a detailed process-based understanding of the contemporary annual-to-decadal time-scale trends in the Antarctic climate system. Knowledge of how climate change and variability in the high southern latitudes are connected to lower latitudes, including the tropical oceans and monsoon systems, and will respond to ongoing changes to the ozone hole and to other anthropogenic forcing, is critical for improved climate projections and anticipation of extreme climate events.

RR 6 Determine why the properties and volume of Antarctic Bottom Water are changing, and what the consequences are for global ocean circulation and climate.

RR 7 Establish which species, ecosystems and food webs are most vulnerable in the Southern Ocean, how they are likely to change, and which organisms are most likely to go extinct and over what period, as a consequence of climate change and local interactions such as with non-native species.

RR 8 Determine how increases in marine living resource harvesting in the context of climate change impacts will affect harvested, associated and dependent species and Southern Ocean biogeochemical cycles, in contrast with other groups.

RR 9 Establish which terrestrial ecosystems and food webs are most vulnerable, how they are likely to change, and which organisms are most likely to decline and/or to go extinct and over what time period, as a consequence of climate change and local interactions such as with non-native species.