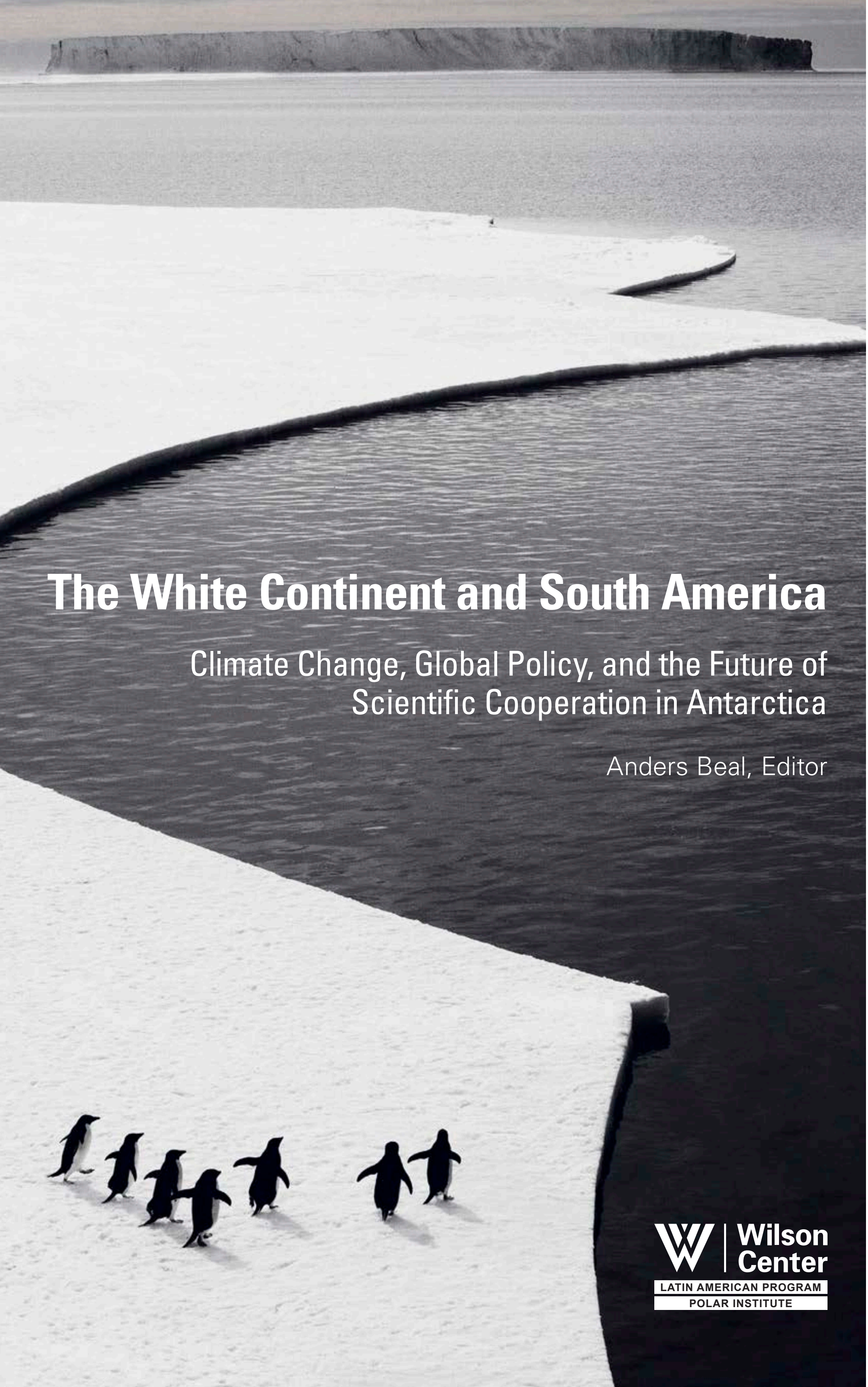

The White Continent and South America

Climate Change, Global Policy, and the Future of Scientific Cooperation in Antarctica

Anders Beal, Editor

Wilson Center
LATIN AMERICAN PROGRAM
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Anders Beal

October 2020

Washington

Melting ice on and around Eagle Island in Antarctica, Feb. 4, 2020. Photo by: NASA Earth Observatory.

Introduction

Anders Beal

South America and Antarctica share commonalities and connections spanning geologic time. Scientists examine how this southern polar region underwent previous change thousands, if not millions, of years ago. Complex modeling—alongside satellite imagery, analysis of ice cores, and other methods of obtaining crucial data—have replaced the historic voyages of iconic explorers. However, a similar quest for knowledge and information now drives modern science today, delivering answers about the past, in order to strengthen our understanding of the future.

This report hopes to shed light on this rich natural history, dovetailing earlier conversations with colleagues on the importance of scientific cooperation in Latin America and regional efforts to address climate change. Latin American scientists have much to offer in understanding their own "backyard." The region is host to a wide range of universities and institutes that possess cutting-edge knowledge and research. Given its diverse biomes necessary to sustain Earth's climate as a hospitable one, enhancing regional and international cooperation has become increasingly more critical to foster.[1]

Originally, the desire was to convene a discussion on South America's role in the Antarctic as a side meeting at the UN Conference on Climate Change (COP 25). However, an explosion of social protests in Chile, and the decision to hold the summit in Spain, postponed such plans.[2] Nevertheless, the presence of Wilson Center staff in Madrid last December resulted in valuable conversations with a diverse group of people. Chilean diplomats; friendly observers from Canada; senior officials at the European Space Agency; as well as youth and indigenous delegates—all uttered a common refrain: *We are running out of time*. Indeed, a UN special report from the Intergovernmental Panel on Climate Change made clear that roughly a decade remains to take action and keep global warming to a maximum of 1.5° Celsius.[3]

From the twelfth floor of a hotel room along the Gran Vía, a main artery of Madrid, one could hear 500,000 people marching in the streets.[4] Amid the chants, sounds of drums, and blaring horns, Spanish news outlets began broadcasting a young Swedish girl giving a speech for Madrileños and the world to hear. Greta Thunberg's school strike for climate (Skolstrejk för klimatet) first drew attention outside parliament in Stockholm. What followed was a global movement incorporating thousands of teenagers and youth activists from diverse backgrounds. Speaking to those in the crowded streets, Thunberg highlighted her sense of hope and optimism that ambitious action could occur if young people continued to demand it.

For three decades, there has been a strong sense of urgency for multilateral action. While the process has been full of good intentions, the global politics of climate change continue to be messy; often resulting in a sense of pessimism and defeat.[5] For many young activists, COP 25 was yet another symbolic gesture of leaders dragging their feet in addressing the greatest existential threat of their generation and generations to come. Although the United States rescinded its leadership role on climate diplomacy and began

a formal withdrawal process from the Paris Agreement, Chile stepped in alongside its partners in the European Union, to continue the hard work of negotiating a global response and implementing policies back home. And though ambitious action remains a priority, much will be left to negotiators at the next global summit.

> **For many young activists, COP 25 was yet another symbolic gesture of leaders dragging their feet in addressing the greatest existential threat of their generation and generations to come.**

As this publication becomes ready for its initial launch, a global pandemic continues unabated, the US presidential election is imminent, and the postponement of COP 26 in Glasgow has added yet another layer of uncertainty. Meanwhile, calls for significant action grow louder by the day, with private-sector actors slowly joining the ranks of environmental activists, proposing a new framework for stakeholder capitalism.[6] Governments around the world receive pressure from constituencies to go further in their commitments as media coverage of natural disasters and extreme weather events more regularly cite climate change.[7] There is also a growing discussion concerning the incorporation of climate risks into core elements of the global economy, to better mitigate and adapt to a warming planet.[8]

Youth delegates demanding action on climate change at COP 25 Source: United Nations, Flickr.

With humanity's continued incursion into wild habitats, new zoonotic pathogens emerge and harbor the potential for yet another disruptive pandemic. Climate change will likely increase the odds of this happening.[9] The American philanthropist Bill Gates recently framed the issue of climate change as potentially worse than the current pandemic, highlighting that "if we learn the lessons of COVID-19, we can approach climate change more informed about the consequences of inaction."[10] But will the international community take the lessons of COVID-19 seriously?

> **As the COVID-19 pandemic upends the global economy and continues to result in loss of life, it will become even more urgent to address climate change in the immediate future.**

As of this writing, more than 600,000 deaths have resulted from the pandemic in the Western Hemisphere alone.[11] A 2014 estimate by the World Health Organization projected that between 2030 and 2050, about 250,000 deaths would occur each year due to climate change, mainly from malnutrition, malaria, diarrhea, and heat stress.[12] Another, more recent study concluded that even after accounting for adaptation, an additional 1.5 million people will die each year from climate change by the end of this century.[13] Such projections may get worse as better modeling and data improve calculations for climate mortality rates. If the potential loss of life were not tragic enough, the economic fallout will also be overwhelmingly devastating.

The Economist Intelligence Unit provided analysis last year that the global economy could shrink 3 percent by 2050, representing a loss of $7.9 trillion—all due to increased natural disasters threatening food supply, infrastructure, and global health. The unit also found that while Africa will likely face the brunt of the costs associated with climate change, Latin America follows closely behind, with a projected 3.8 percent loss in real GDP by 2050.[14] This one-two combo of a devastating pandemic alongside rising temperatures and major natural disasters will represent a monumental challenge for the region and the developing world in particular.

Another UN flagship report in September highlighted the dramatic level of action needed by world leaders to curb the worst effects of climate change. According to the report, *United in Science*, the past five years are likely to be the warmest on record and global emissions are already on track to surpass pre-pandemic levels. As UN secretary general António Guterres stressed in the report, "We need science, solidarity and solutions to tackle both the COVID-19 pandemic and the climate crisis." Unfortunately, scientists project the world has a 20 percent chance of exceeding the limit of 1.5° Celsius by the end of 2024.[15] Such a scenario of not keeping the rise in global temperature below this important threshold could prove catastrophic and represent a point of no return for our planet.

As the COVID-19 pandemic upends the global economy and continues to result in loss of life, it will become even more urgent to address climate change in the immediate future. The idea of "building back better" has included influential voices and multilateral institutions in response to the economic fallout from the pandemic.[16] However, beyond proposing ways of restarting the global economy in a more sustainable manner, the multilateral process will require an even greater incorporation of scientific research and new data.

Despite significant progress since the Rio Summit in 1992, there is still an existing narrative that the current multilateral framework is not effective enough; that the necessary political will to address climate change renders it an issue for major powers alone to solve. However, strong international cooperation and a legacy of effective multilateralism can be found in the example of the Antarctic Treaty System.[17] Here, small and large nations alike have contributed to a broader understanding of the science of climate change, with significant collaboration between countries in South America and the rest of the world.

At the start of the treaty more than sixty years ago, military and most commercial activities on the continent were banned, making this gargantuan area of our planet one of common interest, through the peaceful pursuit of scientific discovery and knowledge. Of the original twelve signatories to the Antarctic Treaty, Argentina and Chile have played a prominent role in strengthening cooperation both bilaterally and internationally since the very beginning.[18] Overall, Latin American nations have considerable influence in the treaty system and its forums. Not only is the headquarters of the Antarctic Treaty Secretariat located in Buenos Aires, but ten of the fifty-four countries that are party to the treaty are located in Latin America. Argentina, Brazil, Chile, Ecuador, Peru, and Uruguay all hold consultative status; meanwhile, Colombia, Cuba, Guatemala, and Venezuela hold nonconsultative status.

In many ways, Antarctica and its surrounding ocean represent an age-old commons dilemma. However, the tragedy of the commons here could lead to the tragedy of humanity. The Antarctic, both symbolically and quite literally, serves as a litmus test for our warming planet. The existing vulnerabilities to climate change for many countries in the hemisphere could influence the desire of Latin American nations to preserve this peaceful status quo—helping to foster greater scientific cooperation in the Antarctic and thus benefit domestic research institutions.

The outsized influence of the Antarctic continent in regulating Earth's climate will become incredibly important to understand as it undergoes change in the near future. Equally important is the surrounding Southern Ocean, which houses high levels of biodiversity and is undergoing dramatic change as well. Since the 1970s, there has been a decline of more than 80 percent of global krill populations. A study in 2016 projected that by the end of this century, Antarctic krill could lose most of their current habitat due to climate change, resulting in significant effects on the marine food web.[19]

Greater support and international funding for scientific cooperation may be needed to not only ensure that the Antarctic remains an isolated and unexploited continent but also, just as important, to inform evidence-based policymaking. So much is still unknown. In 2018, a well-cited study in *Nature* highlighted that ice melt in Antarctica was occurring three times faster than a decade ago. A total of 40 percent of the ice melt that had occurred since 1992 was attributed to the previous five years alone.[20] Another more recent study, suggested that up to 60 percent of Antarctica's ice shelves could be at risk of fracturing.[21] Any major collapse of Antarctic ice shelves in the future could result in a dramatic rise in sea level.These warming trends and their influence on the continent are only expected to continue if not get worse over time. As a novel coronavirus in Wuhan began to spread and make headlines earlier this year, Argentina's Esperanza Base reported the hottest temperature ever recorded in Antarctica: 18.4° Celsius (64.9 °F). Just several days later, this record was broken by reports from Brazilian scientists: 20.75° Celsius (69.3 °F).[22]

> **Since the 1970s, there has been a decline of more than 80 percent of global krill populations. A study in 2016 projected that by the end of this century, Antarctic krill could lose most of their current habitat due to climate change, resulting in significant effects on the marine food web.**

How might these climate and geophysical trends affect broader issues of concern for global policy? Will nations be able to adequately work together to implement adaptation measures and long-term planning? How will the scientific community better communicate, inform, and influence policymaking and decisionmaking in the future? These are important questions to consider as Antarctica's influence on sea level rise, biodiversity, and the health of our oceans and atmosphere becomes increasingly more salient toward the end of this century, if not sooner.

Beyond the practical example that this region of the world can represent for humanity's efforts to rein in unfettered growth and development, the Antarctic also represents the intrinsic value of unspoiled wilderness, a place for biodiversity to flourish, and one part of our globe that can heal the externalities of current and past industrialization. As much as an example of strength and nature's resolve, it also reflects the fragility of our planet and the widespread influence and impact of human activities.[23] This dualism can be best understood from the perspective of those who have visited the continent and whose work revolves around encouraging others to value and understand its place in the future.

The diverse perspectives laid out in this report are intended to inform the public about a part of the world that a large majority may never have the privilege to visit. It is also intended to influence debates within the policy community, highlighting the success of a multilateral framework that can inspire future negotiation and action on a wide variety of issues connected to climate change and the role of scientific cooperation in Antarctica and beyond.

The report begins with Paul Andrew Mayewski, director of the University of Maine's Climate Change Institute. An internationally acclaimed scientist, Mayewski has led major expeditions to some of the most remote areas of the world. He and his colleagues often focus on analyzing ice cores, which offer a glimpse into the Earth's climate thousands of years ago. He provides a scientific overview for understanding the polar regions and how anthropogenic climate change is affecting what has taken millennia to develop in an often profound and abrupt manner.

Next, the report examines the world's oceans for their awe-inspiring vast size and the diverse forms of life found within them. A former chief scientist for the National Oceanic and Atmospheric Administration and a renowned marine biologist, "Her Deepness" Sylvia Earle writes alongside a leading Chilean environmentalist and COP 26 Oceans Champion Maximiliano Bello. Together, they dive into the reasons for greater protection of the high seas and how large-scale conservation in the Southern Ocean can be another success story for multilateralism and the diplomatic legacy of the Antarctic.

In the next chapter, Chilean foreign minister Andrés Allamand defines his country's political position on the White Continent, highlighting that beyond national interests and territorial claims, Chile is leading efforts to not only protect the continent but also have its southern regions become a hub for scientific research and international cooperation.

Next comes a truly inspiring chapter that highlights the eyewitness accounts of the world's most prominent nature photographers. Cristina Mittermeier, John Weller, and Paul Nicklen take us on a descriptive journey of how a paradise of ice in the Southern Hemisphere faces daunting challenges, especially for those that call it home. These firsthand accounts of the harsh beauty of Antarctica demand a greater appreciation of nature from all of us.

Marcelo González and Marcelo Leppe take us into a paleontological time machine, examining how Antarctica came into being millions of years ago. As lead researchers at the Chile Antarctic Institute (INACH), they help us take a step back to discover the multitude of connections between South America and Antarctica. In doing so, they shed light on how climate change and other human effects are creating new connections, often with disastrous results.

Peter Carey—who is based in New Zealand as a Global Fellow for the Wilson Center's Polar Institute—has described the Antarctic as "the most beautiful place on the planet," with a growing number of people seemingly in agreement. In this chapter, he discusses the role of Antarctic tourism.

We learn of the opportunities that tourism may have for placing value on conservation and generating environmental awareness, but also the management challenges from a growing number of visitors each year.

Jefferson Cardia Simões, a leading polar researcher in Brazil and vice president of the Scientific Committee on Antarctic Research, delves into the intricate connections between South America and the Southern Ocean. He provides a scientific overview of how climate effects in this polar region specifically, can affect the South Atlantic and even some agricultural crops in southern Brazil. He alludes to the potential of future effects of sea level rise and extreme weather events, arguing that a key task for science diplomacy will be to improve and further international cooperation on these issues.

From the gateway city of Ushuaia in southern Argentina, Cristian Lorenzo, an expert in international relations at Universidad Nacional de Tierra del Fuego and researcher within Argentina's National Scientific and Technical Research Council (CONICET), discusses cooperation among countries in South America. He argues that the geopolitics of cooperation among Latin American countries is related to several underlying factors and is largely dependent on the desire to strengthen and improve the Antarctic Treaty System. He provides context for the role of cooperation among countries such as Argentina and Chile, including their capacity to enhance bilateral relations on Antarctic issues and thus help strengthen academic and scientific networks across the global research community.

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Schoolchildren in Italy participate in a "Fridays for the Future" climate strike. Photo by Fabio Michele Capelli / Shutterstock.

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From the Arctic to Antarctica:

Understanding Climate Change in the Polar Regions

Paul Andrew Mayewski

The polar regions are vast, and, certainly in the case of Antarctica, greatly unexplored by scientists given the tremendous size of the continent.[1] There is a growing consensus in the scientific community that climate change is rapidly overpowering what many had thought were timeless landscapes—built up over thousands of years from ice and naturally occurring processes.

The contrast in geography between Antarctica and the Arctic foretells the complexity in their response to past, modern, and future climate change. The Arctic is an ocean fringed by land. The Antarctic, conversely, is an ice sheet surrounded by ocean. Arctic sea-ice is partially anchored by land, while Antarctic sea-ice extends seaward with at best minor anchoring on small islands. The change in the extent of sea-ice is one of the greatest seasonal events that occur on our planet.

Changes in the size and seasonal timing of the extent of Antarctic and Arctic sea-ice, as well as the resulting changes in the degree of open ocean, greatly influence the distribution of heat across the Earth. This process in turn can trigger changes in the shape and strength of atmospheric circulation patterns that distribute heat, moisture, and pollutants throughout both hemispheres. With relatively thin sea-ice of 1 to 3 meters in thickness being common in the polar regions, the

Photo by John Weller / SeaLegacy. Used with permission.

difference between sea-ice cover and open ocean requires only small changes in temperature to therefore have broader, far-reaching effects around the globe.

Arctic and Antarctic ice cores provide robust reconstructions of the past climate, and as such they represent an unsurpassed climate change perspective. Ice core records from the Antarctic demonstrate how levels of modern-day greenhouse gases such as carbon dioxide and methane (CO_2 and CH_4) are unique to the past 800,000 years.[2] Ice core records in Greenland provided the first demonstration that climate need not change slowly over hundreds of years; instead, it can change abruptly, in less than one to five years, in the form of dramatic changes in temperature, precipitation, atmospheric circulation, and sea-ice extent.[3]

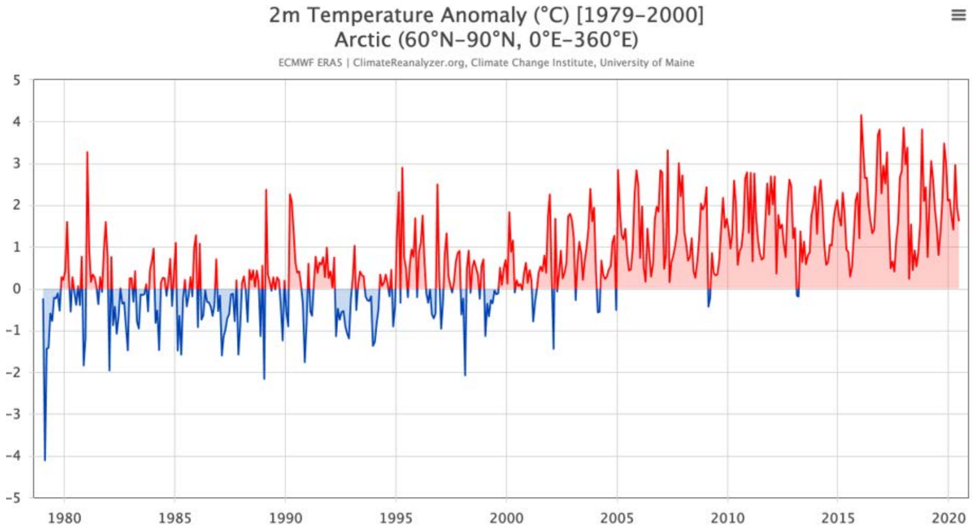
Abrupt shifts in atmospheric circulation have also been affected by marked changes in the shape and intensity of the Arctic polar vortex, the edge of which is the jet stream.[4] The shape of the jet stream in both polar regions determines how much and how far latitudinally warm and cold air can mix. The greater the mixing, the greater the instability in climate—meaning an increase in storm frequency and strength, as well as increased occurrence and magnitude of droughts and floods.

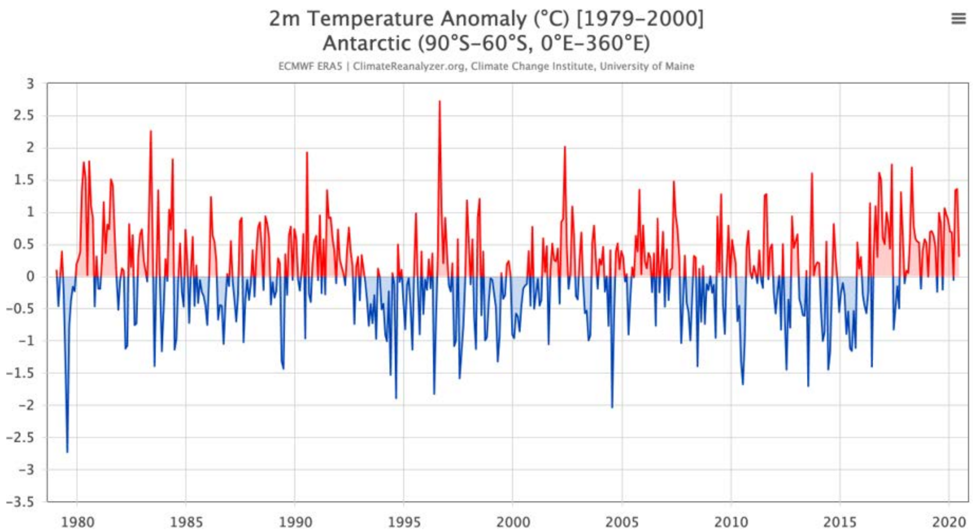
Although the polar regions, notably Antarctica, are distant from major population centers, ice and snow cores from both regions reveal the fingerprint of anthropogenic activity. Toxic substances—such as radioactivity, sulfur, and lead—have increased dramatically in recent decades throughout the Arctic.[5] Antarctic ice cores contain evidence of the long-range effects of the Chernobyl nuclear accident, including evidence of lead, uranium, and barium emissions.[6]

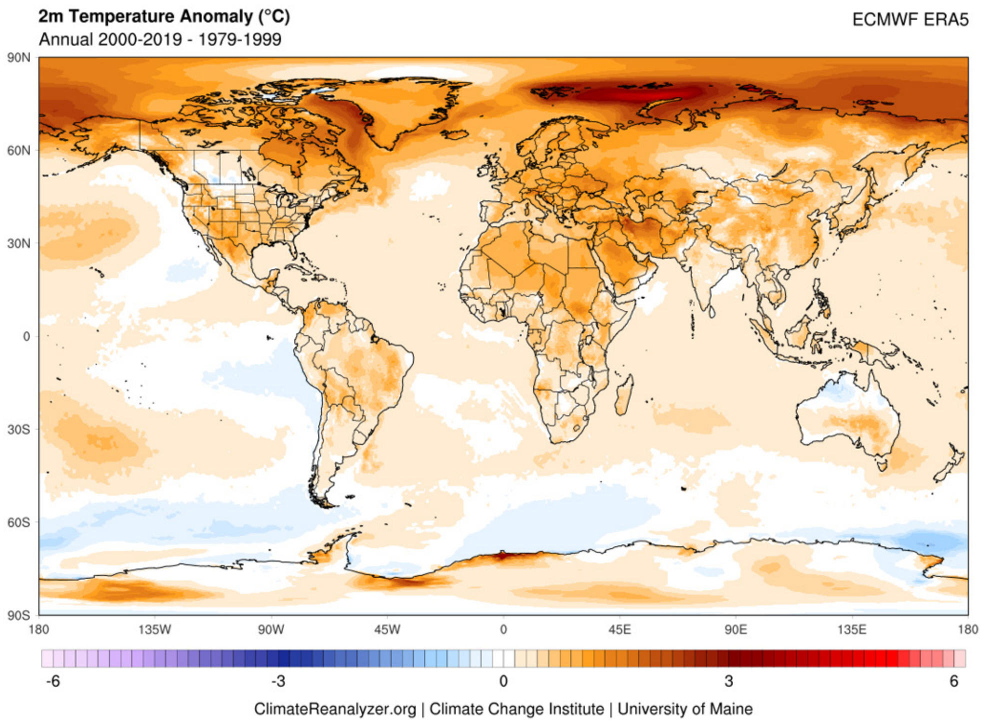
These ice core records however, also demonstrate the success of clean air legislation and other significant international treaties that aim to lower emissions and lessen the extent of atmospheric pollution. In order to

FIGURE 1

2 m Temperature Anomaly (°C) [1979–2020]. Top left: Arctic (60°N–90°N, 0°E–360°E). Bottom left. Antarctic (60°S–90°S, 0°E–360°E). Right: 2m Temperature anomaly annual 2000–2020, minus 1979–99.







better understand the polar regions and their influence on the Earth's climate, we focus here on three basic elements of recent climate change: surface temperature, atmospheric circulation, and sea-ice extent. Taken together, these variables reveal the interplay between the polar regions and global climate change.

Source:
All data from European Center for Medium-Range Weather Forecasting ERA5. Plotted using Climate Reanalyzer.

Surface Temperature

Recent changes in near-surface (2 m) temperature are not distributed evenly over the polar regions, much less over the planet. Comparison of Antarctic versus Arctic temperature anomalies (figure 1), relative to the period 1979–2000, reveal significant differences. In the Arctic, surface temperatures begin to rise by the mid-1990s, and as of 2000

FIGURE 2

10 m surface winds, positive values indicate intensified transportation, west to east, for the period 2000–2020 minus 1979–99 using data from European Center for Medium-Range Weather Forecasting ERA5 and plotted using Climate Reanalyzer.

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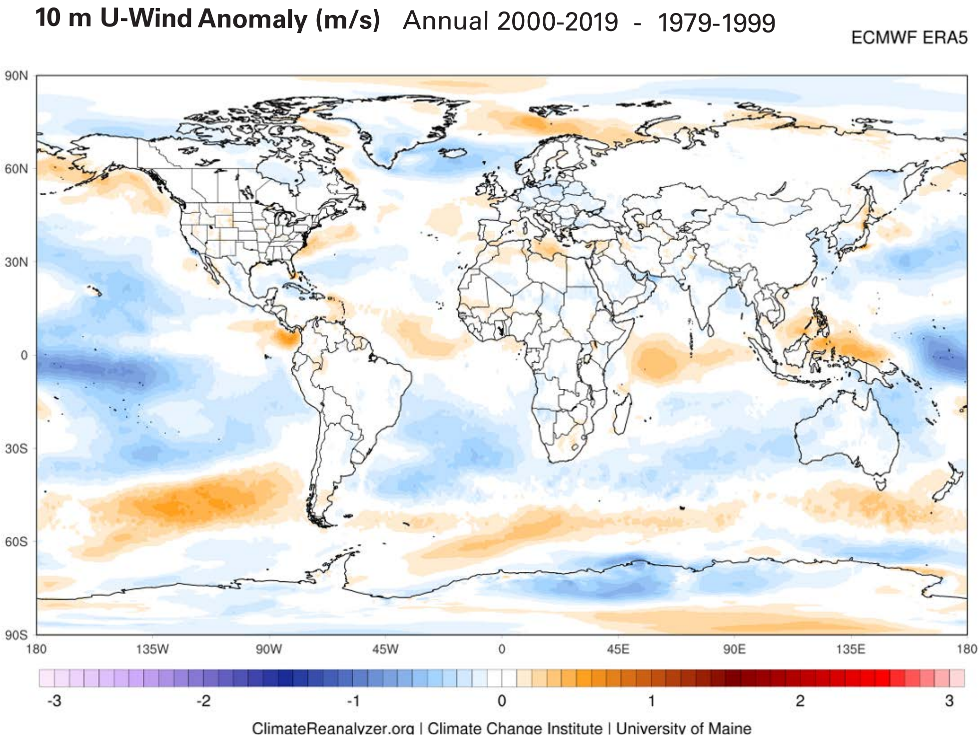
the rise is relatively steady, with annual scale variability. For the Antarctic, temperatures were variable from 1979 to 2020.

Examination of the difference in 2 m temperature globally for the period 2000–20 highlights the larger increases over the Arctic relative to the rest of the planet (figure 1). In the eastern Arctic, for example, the increase in temperature from 2007 to 2012 of up to 5 degrees Celsius is equivalent to a doubling in the length of summer in this region. It is as fast and as much as the transition from the vestiges of the last ice age to the onset of modern climate about 11,500 years ago, making it the first onset of "abrupt climate change" in the modern era.[7] Recognizing the potential for abrupt change in future climate predictions is essential if we are to develop plausible scenarios for the future climate. With continued Arctic warming and the potential release of methane gas trapped below frozen ground, the likelihood of yet another abrupt climate event is growing.

Near-surface (2 m) temperatures over the Antarctic for the period 2000–20 minus 1979–99 reveal the largest warming over the Antarctic Peninsula and Antarctic coastal zones, but there are also portions of the Southern Ocean where cooling is apparent (figure 1). An Antarctic ice sheet mass balance inventory for the period 1979–2017 reveals increasing mass loss due to ice shelf melting and consequent destabilization of glaciers draining into these ice shelves associated with proximity to warm, subsurface deep water currents and warm air that is migrating southward as westerly winds surrounding Antarctica migrate southward.[8]



Atmospheric Circulation

Source:
All data from European Center for Medium-Range Weather Forecasting ERA5. Plotted using Climate Reanalyzer.

The atmosphere transports heat, moisture, and pollutants and affects the strength and position of surface ocean currents. We focus here on changes in zonal wind patterns, notably the westerlies—the west-to-east air flow separating the polar regions from the middle latitudes. Northern Hemisphere westerlies are diverted in their flow by the continents surrounding the Arctic Ocean; the Southern Hemisphere westerlies flow around the Antarctic, with their only continental constriction being the passage between South America and the Antarctic Peninsula. Recent changes in zonal winds (2000–20 minus 1979–99) are presented in figure 2.

Brief camp stop during an Antarctic oversnow traverse. Photo by Paul Andrew Mayewski

Over the Northern Hemisphere, westerly winds have in general weakened, in particular over the Western Hemisphere. Greenhouse-gas-induced Arctic warming has resulted in a temperature decrease from the Arctic to the mid-latitudes, as a result weakening the barrier between cold Arctic air and warm air to the south.[9] This in turn leads to tongues of cold air moving farther south, with warm air moving farther north than usual.

“Relative to past modeling efforts, CMIP6 offers distinct improvements in sea-ice volume and extent, with some improvements still needed with respect to the representation of winter temperatures. CMIP6 predictions suggest that the Arctic will likely be free of sea-ice by 2050 under most greenhouse gas emission scenarios.”

Over the Southern Hemisphere, westerly winds have in general intensified and have been displaced southward, in response to a steepening of the temperature gradient between the poles and mid-latitudes resulting from greenhouse gas warming and upper atmosphere ozone depletion.[10] Lower surface temperatures (1992–2016, figure 1) throughout portions of the Southern Ocean demonstrate the increased upwelling of colder water in response to the increase in strength of the Southern Hemisphere westerlies (figure 2). In addition, as the westerlies intensify and are forced through the Drake Passage, cold Southern Ocean surface currents are forced farther north on both

the west and east sides of southern South America.[11] As greenhouse gas warming continues and healing of the Antarctic ozone hole continues, the shape and intensity of the Southern Hemisphere westerlies and their impact on the climate of the Southern Hemisphere remain an open question for scientists, requiring further research.

Sea Ice Concentration

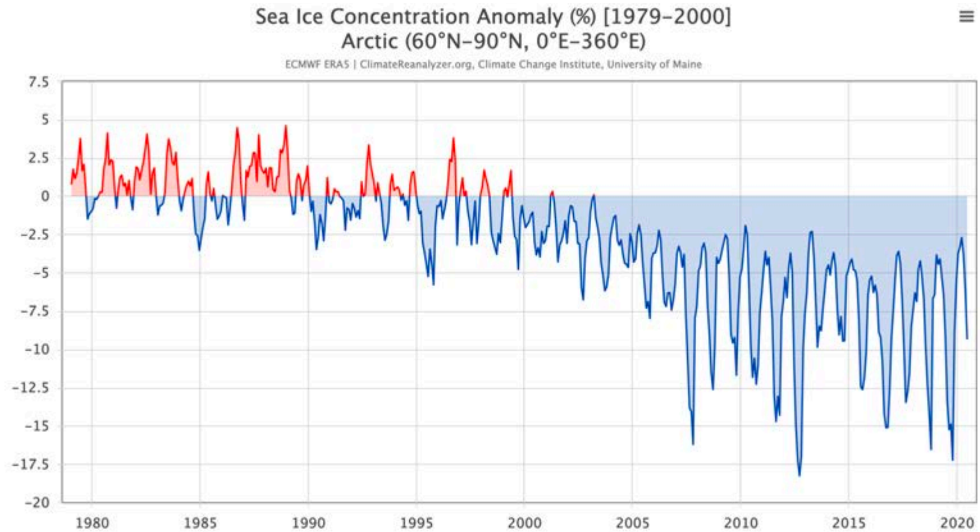
Arctic versus Antarctic sea-ice concentration over the period 1979–2020 differs markedly (figure 3). For the Arctic, it has been decreasing steadily since the mid-1990s with a marked decrease as of 2007 because of warming. Around the Antarctic, sea-ice concentration has a more complicated history, increasing from the early 1990s until 2017, when it decreases and increases in annual scale variability in response to ocean surface temperature and the strength and pattern of atmospheric circulation.

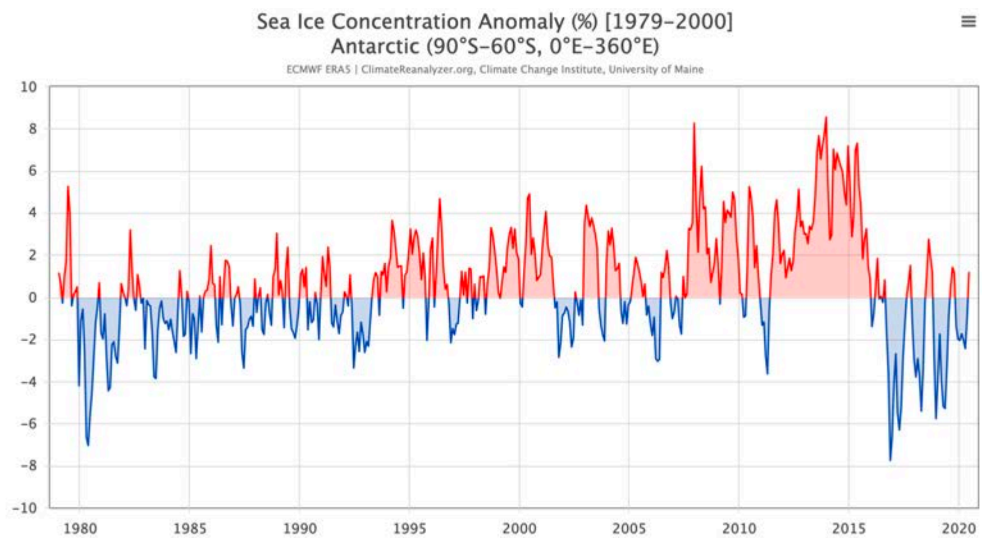
Future Scenarios for Arctic and Antarctic Climates

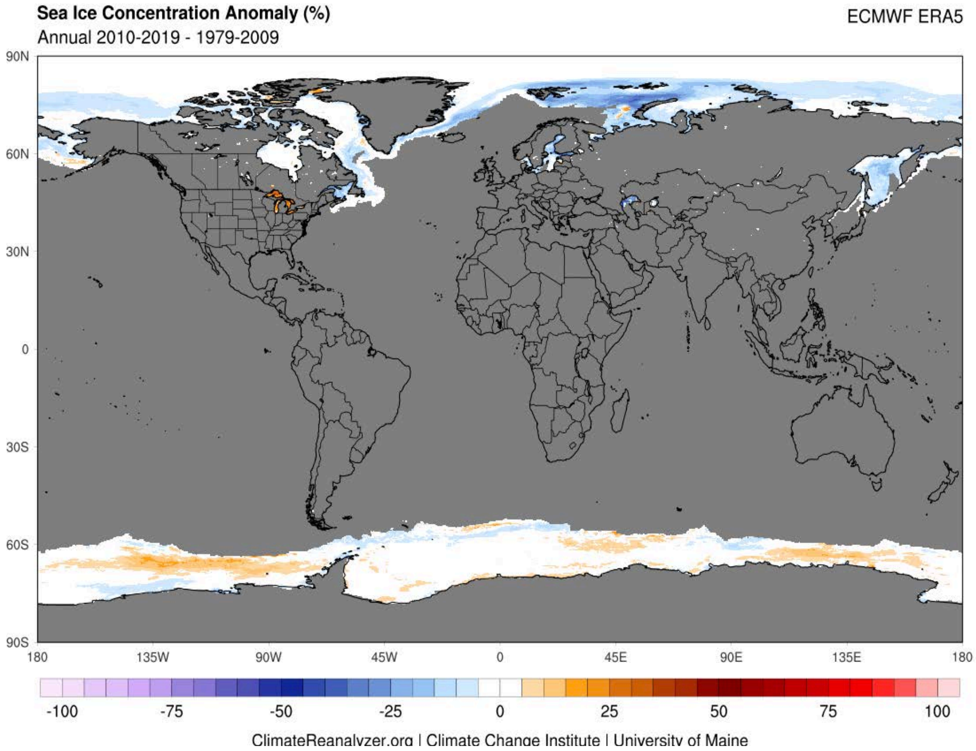
The Antarctic ice sheet encompasses 14 million square kilometers (some 5,600 km x 4,400 km), with a maximum ice thickness of 4,800 meters. Melted completely, it would increase the sea level by about 60 meters. The eastern part rests on continental substrate, while the western side facing South America lies on islands that are depressed below sea level.

FIGURE 3

Annual sea ice concentration [1979-2020]. Top left. Arctic (60°N-90°N, 0°E-360°E). Bottom left. Antarctic (60°S-90°S, 0°E-360°E). Right. Sea ice concentration anomaly annual 2000-2019 minus 1979-1999. All data from ECMWF ERA5. Plotted using Climate ReanalyzerTM.







Source:
All data from European Center for Medium-Range Weather Forecasting ERA5. Plotted using Climate Reanalyzer.

This makes at least the western side of the Antarctic ice sheet less stable in a warming world. As air and sea surface temperatures continue to rise, portions of the West Antarctic ice sheet are more likely to disintegrate, leading to sea level rise. In contrast, the Greenland ice sheet is 1.7 million square kilometers (2,400 km x 1,100 km), with a maximum thickness of 3,000 meters. All of it rests on a continental substrate. If melted completely, it would increase the sea level by about 7 meters.

As first identified by John H. Mercer, portions of Antarctica (notably West Antarctica) melted during the last naturally warm period, about 120,000 years ago, and along with the melting of ice in Greenland and high mountain glacier ice, resulted in a sea level rise of some 6 meters.

In 1978, Mercer warned that such a rise in sea level would potentially be the price paid for the use of fossil fuels. Predicting future Arctic and

Early formation of sea ice along the coast of Northern Victoria Land, Antarctica
Photo by: Paul Andrew Mayewski. Used with permission.

Traverse team exploring the Transantarctic Mountains and identifying early stages of glacier recession. Photo by: Paul Andrew Mayewski. Used with permission.

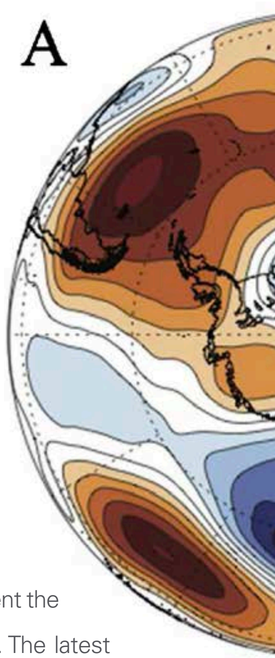
Center: Snowpit used to identify the first evidence of Chernobyl in the Southern Hemisphere 100 miles from South Pole. Photo by: Paul Andrew Mayewski. Used with permission.

> **Recognizing the potential for abrupt change in future climate predictions is essential if we are to develop plausible scenarios for the future climate. With continued Arctic warming and the potential release of methane gas trapped below frozen ground, the likelihood of yet another abrupt climate event is growing.**

Snow cave serves as a laboratory for examining Greenland ice cores.
Photo by: Paul Andrew Mayewski. Used with permission.

FIGURE 4

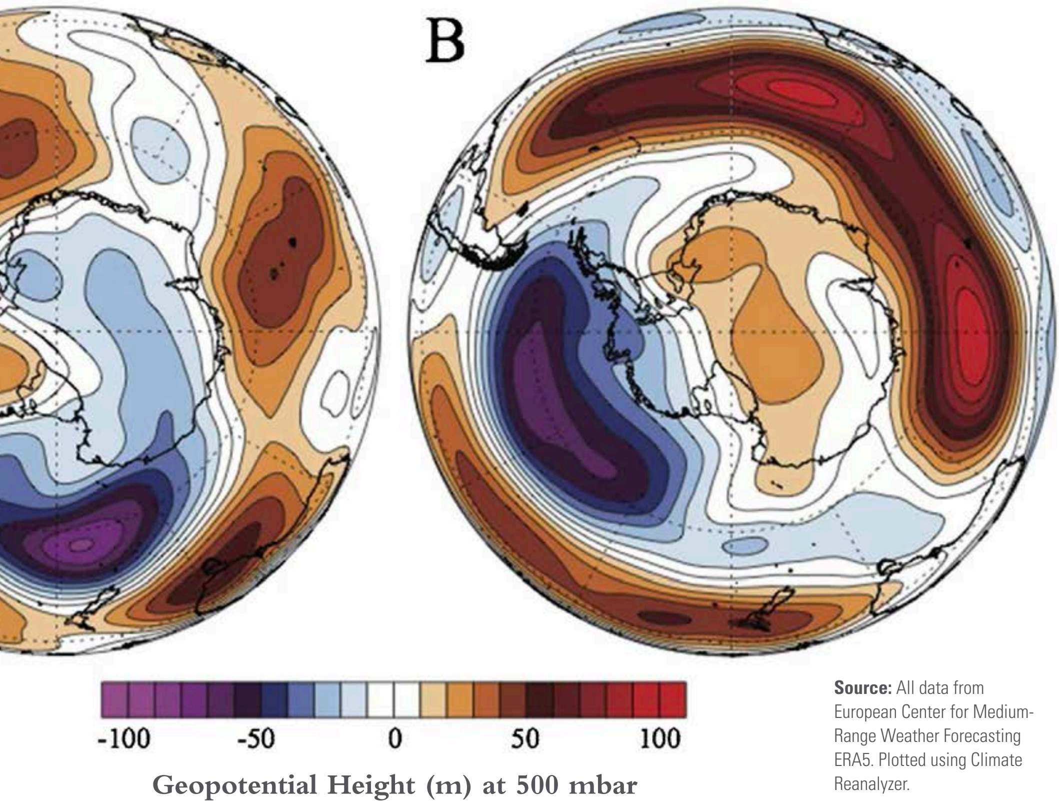
DJF (December, January, February) 1979 (A) and DJF 2011 (B) 500-mbar geopotential height anomalies developed from European Center for Medium range Weather Forecasting ERA-Interim re-analysis plotted using Climate ReanalyzerTM to demonstrate examples of meridional-like and zonal-like, respectively, atmospheric circulation patterns. Taken from Mayewski et al. (2015, figure 2). using Climate ReanalyzerTM.



Antarctic climate change has significant importance with respect to ecosystems, resources, and overall habitability in the polar regions and globally. Accurate predictions are based on the availability of reliable observational data. Data coverage is shorter and sparser over the polar regions, notably the Antarctic and Southern Ocean.

Coupled Models (atmosphere, ocean, sea-ice) represent the current state-of-the-art in climate model predictions. The latest version of these, the Coupled Model Intercomparison Project Phase 6 (CMIP6) is compared with ERA5 climate reanalysis based on observational data for the period 1979–2004. Relative to past modeling efforts, CMIP6 offers distinct improvements in sea-ice volume and extent, with some improvements still needed with respect to the representation of

Flying over the receding western edge of the Greenland ice sheet. Photo by Paul Andrew Mayewski. Used with permission.



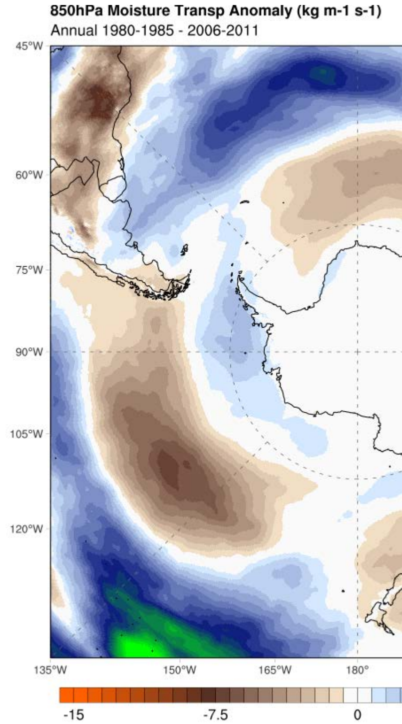
Source: All data from European Center for Medium-Range Weather Forecasting ERA5. Plotted using Climate Reanalyzer.

winter temperatures.[12] CMIP6 predictions suggest that the Arctic will likely be free of sea-ice by 2050 under most greenhouse gas emission scenarios.[13]

CMIP6 simulations, using four greenhouse-gas-forcing scenarios from the Inter-Governmental Panel on Climate Change for the Antarctic climate, suggest increases in surface air temperature of 1.3 to 4.8 degrees Celsius and precipitation increases of 8 to 31 percent by 2100.[14] Bracegirdle and others (2020) emphasize the potential for significant regional differences, notably in coastal Antarctica, where ice shelf stability is particularly sensitive to ocean and atmosphere warming, even under low greenhouse gas emission scenarios. They also focus on the role of Antarctic stratospheric ozone recovery and

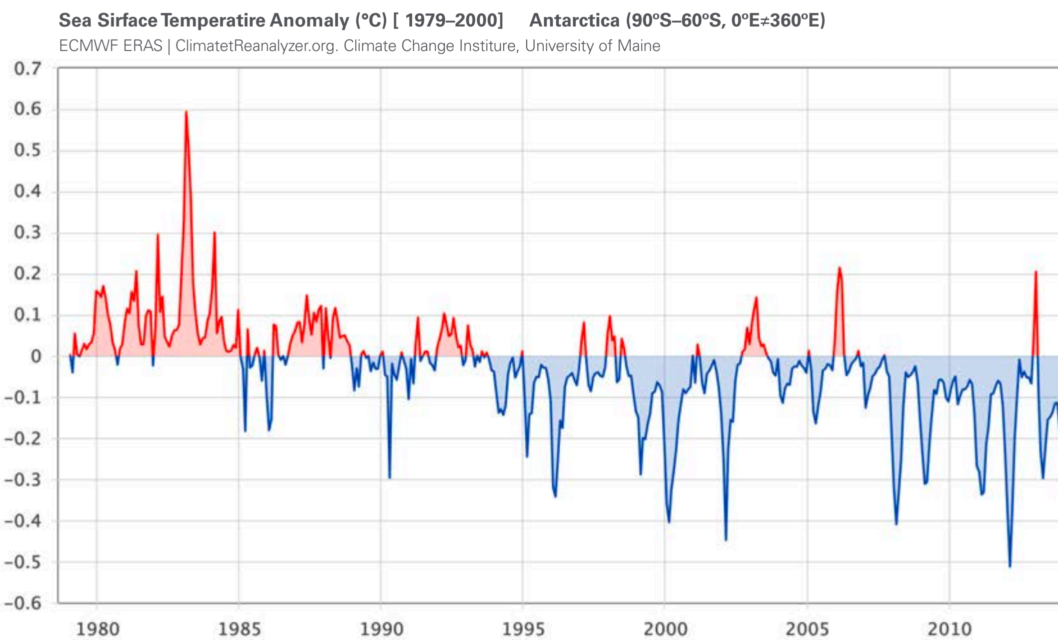
FIGURE 5

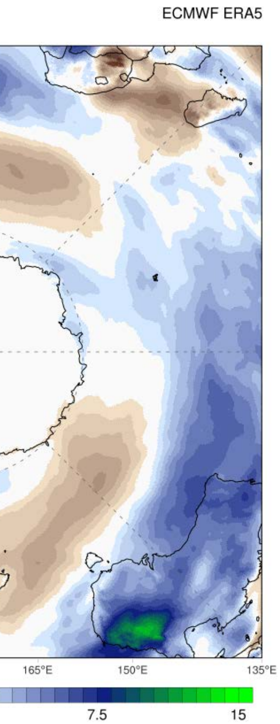
Annual Southern Ocean sea surface temperature time series (left side). Moisture transport difference under warmer (2016-2019) compared to colder (2012-2015) sea surface temperatures. . All data from ECMWF ERA5. Plotted using Climate Reanalyzer™

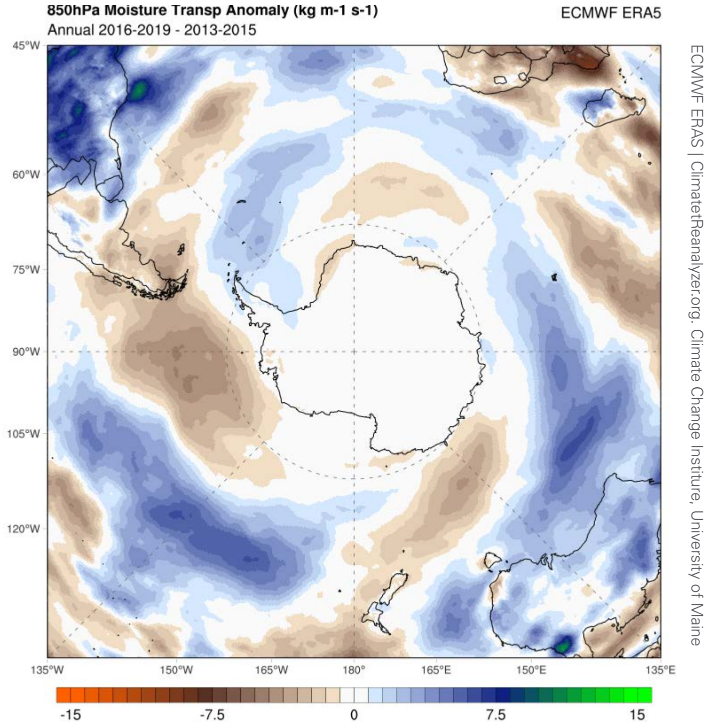


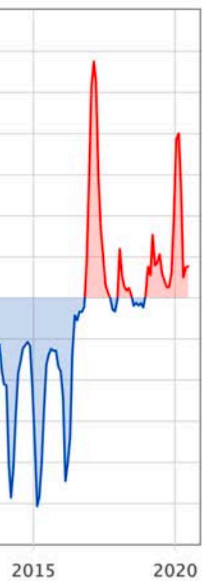
effects on the strength and poleward migration of the westerlies.

Past climate reconstructions developed using Arctic and Antarctic ice core records demonstrate that changes in atmospheric circulation patterns can be abrupt and accompanied by increases and decreases in meridional (north-south) winds. Inland migration of warm marine air and consequent changes in moisture transportation over Antarctica and the Southern Ocean could result in greater instability in climate for this region, as is already the case in the Northern Hemisphere.[15]









The two examples of atmospheric circulation patterns in figure 4 show the result of increased (1979 example) or decreased (2011 example) mixing of air; and therefore, changes in the magnitude and location of heat, precipitation, and pollutants between the Southern Hemisphere mid-latitudes and the Antarctic. Increased mixing, in response to a wavier pattern in the westerlies with more meridional (north-south) flow, results in warm air moving farther south into the Antarctic and decreased mixing buffers invasion of warm, marine air. Modern analogs for warmer versus colder periods of Southern Ocean sea surface temperature provide a view of how moisture transportation could change in the future with warming (figure 5). Based on this

Source: All data from European Center for Medium-Range Weather Forecasting ERA5. Plotted using Climate Reanalyzer.

modern analog, under warmer sea surface conditions, transportation of moisture to southern South America and parts of southern Africa and New Zealand could decrease by 25 to 30 percent, as evidenced by the 2019 drought in South Africa.

Ice core reconstructions of past climate, coupled with climate reanalysis using observational data, provide past and modern analog approaches for developing plausible scenarios for future changes in winds, atmospheric circulation, temperature, precipitation, and sea-ice cover.[16] Integrating these analog approaches with the latest climate models offers the best opportunity for reducing uncertainty in climate prediction and developing a range of plausible scenarios that can guide adaptation and mitigation planning, to include large-scale conservation initiatives.

Notes

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Gordon Hamilton monitoring ice discharge along the east coast of Greenland. Photo by Climate Change Institute Archives. Used with permission.


Image by Petra Christen / Shutterstock

The Anthropocene and Marine Conservation Efforts in the Southern Ocean

2

Sylvia Earle and Maximiliano Bello

Every year, thousands of tourists travel to the bottom of the Earth to see Antarctica's ancient icy landscape and experience wildlife safaris in a frozen world. Many embark on these adventures to escape to an untouched realm. Unfortunately, this is far from reality.

Since the 1800s, the frozen Antarctic continent has felt the effects of humans' touch. Many of the first visitors ventured to the great south with visions of claiming new territory and to exploit the animals that lived there. Sealers, whalers, and others aiming to make a profit from the continent's living marine treasures hunted and killed for centuries, bringing many species to the brink of collapse.

Antarctic wildlife were particularly easy targets because humans were not a known predator in their evolutionary timeline. As populations of many species dropped to unprofitable levels, hunters pushed past traditional hunting grounds pursuing the animals in the surrounding Antarctic Islands.[1] At the same time, scientific exploration in the region began to increase.

In 1882, the first International Polar Year saw coordinated scientific exploration of the polar regions between twelve countries. Fifty years later, during the second International Polar Year, even more countries participated in a global effort to improve weather forecasting and air and sea transportation. During the International Geophysical Year, from 1957 to 1958, scientific discoveries yielded a new awareness of the significant role the polar regions have on climate, weather, and other planetary processes.

These scientific breakthroughs and collaborations between countries helped plant the seeds for what Antarctica was to become, a place of peace and continued scientific exploration. On December 1, 1959, one year after the International Geophysical Year, the Antarctic Treaty was signed in Washington, establishing that "Antarctica shall be used for peaceful purposes only," and that there should be "freedom of scientific investigation in Antarctica and cooperation toward that end." The treaty entered into force in 1961, and has since been acceded to by over fifty countries.[2] The timing of the treaty was particularly significant because it took place at the height of the Cold War, demonstrating international collaboration even in the midst of global competition.

While it was a great step forward in enhancing global cooperation and scientific discovery, at its inception, the Antarctic Treaty did not address the overexploitation and degradation that had been eroding the Antarctic ecosystem since the time of humanity's first arrival. It was not until 1964 that the treaty incorporated environmental protection measures. At the third Antarctic Treaty Consultative Meeting, parties to the treaty initiated the "Agreed Measures for the Conservation of Antarctic Fauna and Flora."[3] These measures helped to conserve species by prohibiting the taking of species without a permit and designating specially protected species.

Over a decade later, in 1978, the Convention for the Conservation of Antarctic Seals was formed to offer protections and kill limits to populations of seals severely depleted by hunting. During the same year, the UN Conference on the Human Environment voted for a ten-year moratorium on whaling. Conservation actions continued to ramp up in the 1980s and 1990s, with two significant developments focused on more comprehensively governing the marine life in Antarctica. The first was the negotiation and adoption of the Commission for the Conservation of Marine Living Antarctic Resources (CCAMLR) in 1980.

CCAMLR advanced existing protections on the Antarctic continent by going beyond mere individual species conservation measures, seeking instead to manage the ecosystem as a whole. Second, in 1991, a critical addition to the Antarctic Treaty was agreed upon that elaborated a number of environmental principles to which CCAMLR parties needed to adhere. This addition, which is known as the Protocol on Environmental Protection, came into force in 1998. Among other provisions, the protocol prohibits mineral and gas development, forbids pollution and dumping, and established regulations for environmental impact assessments. Most importantly, the protocol established that the protection of the Antarctic environment should be considered paramount when planning and executing any activities, thereby expanding the original remit of the Antarctic Treaty to incorporate a more conservation-focused lens.[4]

> **On December 1, 1959, one year after the International Geophysical Year, the Antarctic Treaty was signed in Washington, establishing that "Antarctica shall be used for peaceful purposes only," and that there should be "freedom of scientific investigation in Antarctica and cooperation toward that end."**

Despite these important advances in policies governing Antarctic marine life, exploitation of Antarctica's living resources did not cease. A new chapter of exploitation began in the 1960s, when the Soviet Union began fishing for krill. Krill are a keystone species in the Southern Ocean ecosystem, feeding on phytoplankton and supporting a wide variety of life, including fish, penguins, seals, seabirds, and whales. Krill are absolutely critical for the functioning of the ecosystem because they are a primary (sometimes the only) food source for many animals, thereby transmitting the energy from phytoplankton to biodiversity higher up the food chain. Unfortunately, the exploitation of these crucial species only grew as more

A small crustacean species, Antarcturus signiensis, sits atop a glass sponge.

Photo by: Paul Nicklen / SeaLegacy. Used with permission.

countries followed suit, including Chile, China, Japan, South Korea, Norway, Poland, the Russian Federation, and Ukraine—all establishing krill fishing operations in the Southern Ocean.[5]

Since the 1970s, krill biomass has declined up to 80 percent; in addition to fishing pressure, these declines are attributed to climate change and the related loss of sea-ice.[6] Biomass declines have also been documented, with the heavily fished Antarctic toothfish (Chilean Sea Bass), a species of fish endemic to Antarctica and prized as a delicacy around the world. In addition to losses in biomass of krill and Patagonian toothfish, scientists have documented significant declines in nonexploited species, including Adélie penguins and Chinstrap penguins, who are heavily dependent on krill for their diets.

> **“Antarctica’s Southern Ocean supplies the lifeblood of the planet, providing upwelling, cycling nutrient-rich cold water from its depths, and thereby feeding the global ocean. Circulation from the Southern Ocean has a profound impact on the Earth’s heat balance, carbon cycle, and ocean biology. However, these essential services are under threat as the Southern Ocean experiences dramatic losses in sea-ice and ocean warming due to climate change.”**

Adélie penguins show decreases at almost all locations on the Antarctic Peninsula, and significant declines have been documented for chinstrap penguins regionally.[7] These declines have prompted CCAMLR to take measures to better monitor and regulate fisheries. However, recognizing krill’s essential role in the ecosystem and their vulnerability to climate change, many conservationists question whether this is enough. With combined improvements in technology and experience, humans’ capacity to exploit living resources has reached new levels.

As the Earth continues to experience the age of humans, the Anthropocene, the compounding threats of climate change, exploitation of natural resources, degradation of the environment, ocean

acidification, and pollution are threatening the healthy functioning of our world's systems. Antarctica's Southern Ocean supplies the lifeblood of the planet, providing upwelling, cycling nutrient-rich cold water from its depths, and thereby feeding the global ocean. Circulation from the Southern Ocean has a profound impact on the Earth's heat balance, carbon cycle, and ocean biology. However, these essential services are under threat as the Southern Ocean experiences dramatic losses in sea-ice and ocean warming due to climate change.[8]

After centuries of exploitation and the rise of the climate crisis, challenges in ocean conservation may seem insurmountable. Yet humanity has risen to the occasion before, and there is hope for action again. In 2016, in an incredible act of international diplomacy, the CCAMLR parties agreed by consensus to establish the world's largest marine protected area (MPA) in Antarctica's Ross Sea.[9] The Ross Sea covers 2.02 million square kilometers, of which 1.62 million square kilometers are fully protected.[10] The area supports a wide range of biodiversity, including significant populations of Adélie and Emperor penguins, as well as Antarctic petrels, in addition to killer whales, seals, whales, and seabirds. The Ross Sea is also home to Antarctic toothfish, krill, and rare and unique sponges that can live for up to five hundred years.[11]

The Ross Sea MPA has been heralded as a global success story, demonstrating the international community's capacity for political cooperation, wildlife conservation, and prioritization of scientific research and exploration. However, though the Ross Sea MPA was a huge step in the right direction for conserving our global ocean, much of the Southern Ocean still remains unprotected. More must be done to secure the recovery and achieve the health of a system that has been stressed by climate change and centuries of exploitation. Increasingly, MPAs are being identified as a key tool in the global effort to address climate change.

The 2019 United Nations Climate Summit (UN Framework Convention on Climate Change's 25th Conference of the Parties—COP 25) was the first COP to identify itself as a "Blue COP," prioritizing ocean actions to address climate threats. In fact, the government of Chile, the COP 25 Presidency, encouraged countries to embrace ocean actions, including MPAs, in their nationally determined contributions under the Paris

Photo by Paul Nicklen / SeaLegacy. Used with permission.

Agreement. As the United Kingdom takes the helm for UNFCCC COP 26, to take place in 2021, the focus on marine protection and MPAs looks to continue. MPAs are proven and effective tools for managing fisheries, conserving species and habitats, maintaining ecosystem function and resilience,[12] and enhancing biomass and species diversity.[13] Additionally, they protect vulnerable areas like spawning grounds and help reverse the effects of overfishing and destructive fishing practices.[14]

Since the successful establishment of the Ross Sea MPA, the CCAMLR parties have proposed additional MPAs to expand protections in the Southern Ocean. Currently, three MPA proposals are under consideration to protect the East Antarctic, Weddell Sea, and Antarctic Peninsula areas of the Southern Ocean. Although these MPAs do not provide full protection for all species in the areas, the level of protection for the Southern Ocean would be substantially enhanced. If established, these MPAs would protect nearly 1 percent of the global ocean, or 4 million square kilometers.

“Currently, three MPA proposals are under consideration to protect the East Antarctic, Weddell Sea, and Antarctic Peninsula areas of the Southern Ocean. Although these MPAs do not provide full protection for all species in the areas, the level of protection for the Southern Ocean would be substantially enhanced. If established, these MPAs would protect nearly 1 percent of the global ocean, or 4 million square kilometers.”

A group of high-level influencers and ocean leaders have joined together to form Antarctica 2020, a global campaign advancing protections for the Southern Ocean.[15] With hopes to build on the success of the Ross Sea MPA and CCAMLR's conservation track record, this group is calling for the adoption of all three MPAs at CCAMLR's annual meeting this year. Mission Blue is proud to play an active role in this group and in advocating for additional protections for the Southern Ocean.

Although the proposed areas are an essential step forward, full protection of the Southern Ocean is required if the stated goals are to be attained for climate benefits. To seriously address climate change and biodiversity issues, there should be no extraction of wildlife from the ocean surrounding Antarctica. The rationale is that this part of our planet must be regarded as a global commons, where no nation should engage in the commercial taking of wild animals, from plankton to whales, as well as no "scientific research taking" unless approved by CCAMLR.

"This delicate system of balance is off kilter after centuries of exploitation and the compounding effects of climate change. We have an opportunity to take immediate action now to preserve the Southern Ocean's essential life services."

Without a long-term plan to fully protect the Southern Ocean, current proposals are like a band-aid on the serious issue of overexploitation. There are also other concerns, such as noise, pollution, fossil fuels required to take ships to and from Antarctica, subsidies, and human rights issues. There is also the matter of ballast water and hull-hitchhikers that can be introduced and intrude on ecosystems largely isolated from ship traffic until recent years. Already there is growing concern about invasive species such as decapods, notably the Arctic "king crab," making a place for itself at the expense of Antarctic natives.

There is no way that any exploitation of Antarctica's wildlife should be condoned. Protecting some, but not all, implies that the commercial extraction of wildlife (krill, fish, seals, and all else) in Antarctica can be done without harm to the system. There is no evidence to support the concept of "sustainable fishing." We should do everything possible to take the pressure off the natural system that is already showing serious decline owing to changing temperature and chemistry.

Photo by Paul Nicklen / SeaLegacy. Used with permission.

Antarctica's scenic beauty and iconic wildlife continue to inspire visitors and admirers to protect this remarkable place. At the same time, we must remember the critical role the Southern Ocean plays in regulating the planet's biological systems. This delicate system of balance is off kilter after centuries of exploitation and the compounding effects of climate change. We have an opportunity to take immediate action now to preserve the Southern Ocean's essential life services. Securing three MPAs this year is an essential step in the right direction, and the minimum we should be striving for to protect the marine life around our frozen continent.

Notes

1 International Law for Antarctica, p. 637, https://books.google.com/books?id=cIFAZPBKKu-wC&hl=es&source=gbs_navlinks_s.

2 https://www.ats.aq/e/antarctictreaty.html.

3 https://www.antarctica.gov.au/law-and-treaty/history/.

4 https://www.asoc.org/advocacy/antarctic-governance/overview-of-antarctic-governance.

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13 S.E. Lester, B. S. Halpern, L. Grorud-Coveret, J. Lubchenco, B. I. Ruttenberg, S. D. Gaines, et al., "Biological Effects Within No-Take Marine Reserves: A Global Synthesis," *Marine Ecology Progress Series* 384 (2009): 33–49.

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Leopard seal, Antarctica, February 2019. Photo by: SZakharov/ Shutterstock.

3

The Chilean Position on Antarctica:

A Continent for the Future of Humanity

Andrés Allamand

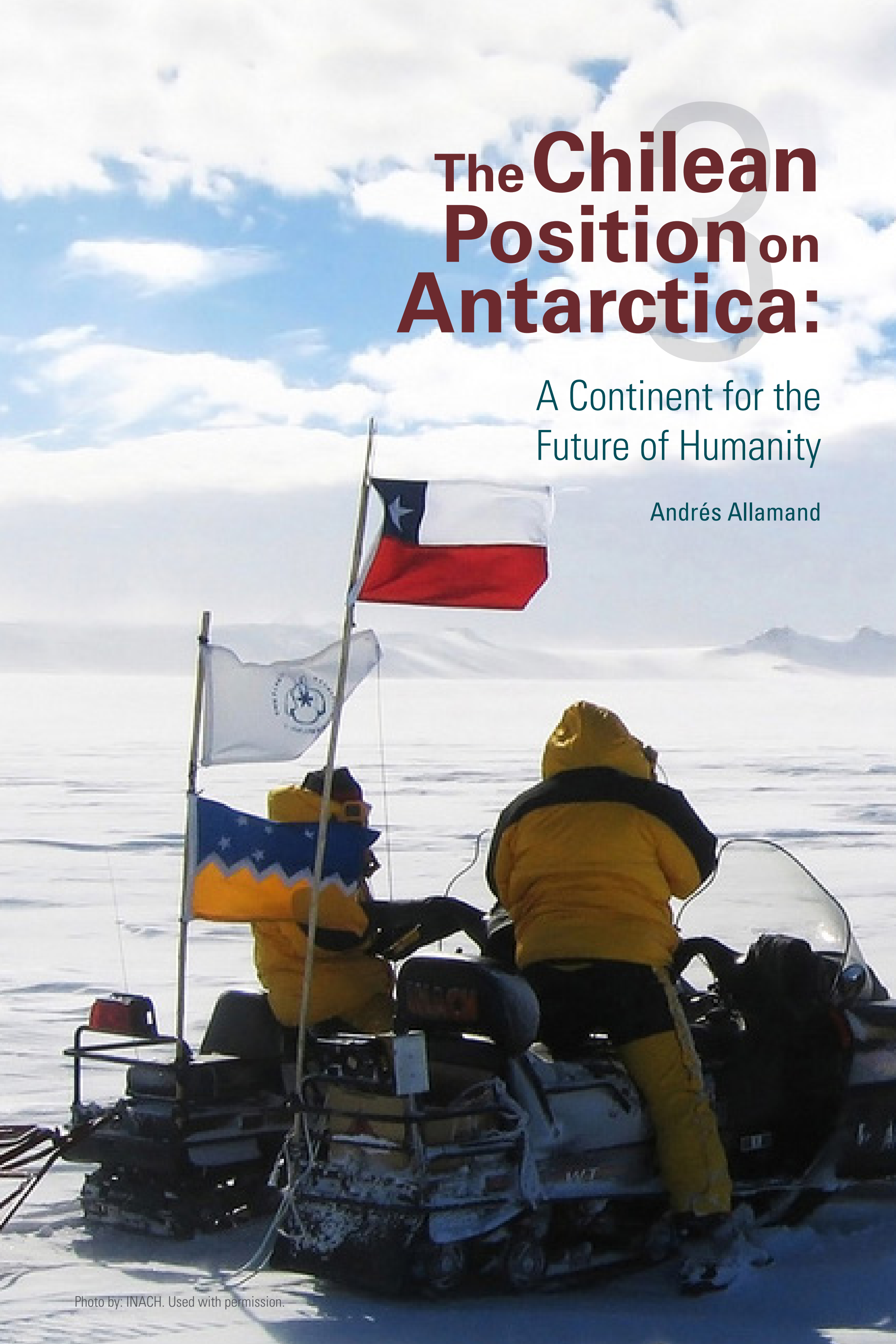


Photo by: INACH. Used with permission.

Chile is an Antarctic nation. Even before it was founded as an independent country, a geographic, economic, and climate relationship between Chile and the White Continent has always existed. This has given rise to a comprehensive national policy and overall concern for leading environmental protection in Antarctica.

The sovereign position of Chile over its Antarctic Territory, and the country's permanent presence there, have gone hand and hand with the Antarctic Treaty System. Chile was one of the twelve original signatories of the treaty in Washington in 1959. It helped establish guiding principles for the Antarctic: peace, science, and cooperation. Since then, Chile's Antarctic policy has sought to safeguard its national interest within the framework of this multilateral agreement and its various forums, ensuring the protection and care of the continent.

Antarctica is a space that is of vital importance for the world, but especially for Chile. Everything that happens on the continent has an immediate influence on the activities of our nation. The Antarctic helps regulate Chile's climate. A large part of Chilean national life, culture, and economy depends on this southern polar region, due not only to its influence on climate but also the effects of cold marine currents that allow for the proliferation of life on Chile's coasts and throughout the Americas.

The Global Climate Regulator

Antarctica's surface, which is 99.6 percent ice, also represents 77 percent of all available fresh water in the world. This water in its solid state, known as the cryosphere, has a tremendous influence on sea level rise. The gradual melting of the Antarctic ice sheet is estimated to exacerbate global sea level rise by about 0.2 millimeter each year. Another critical phenomenon is Antarctica's role in deflecting the Sun's radiation, ensuring that our planet and its oceans avoid absorbing what would quickly accelerate ice melt in the polar regions.

Photo by Armada de Chile. Used with permission.

It is clear that one of the most relevant challenges for humanity is to reverse the effects of climate change, especially those occurring in Antarctica. These will be devastating, if the efforts of the scientific community cannot influence the political and economic decisionmaking community, in order to favor a model of development that is more sustainable. Therefore, one of our primary tasks must be to better understand this White Continent and strengthen global efforts to protect its fragile ecosystems. By protecting Antarctica, we protect ourselves alongside future generations.

Antarctica's Importance for Chile

Today, there is no doubt that Antarctica plays a significant role in the balance of life on our planet. For Chile, understanding and protecting the continent is essential for the development of the country. Alongside the Pacific Ocean, the Antarctic represents a strategic space for the nation's present and future. Chile not only has historical and legal antecedents that connect its territory with that of Antarctica, but there is also a permanent connection to unique ecosystems. Chile needs Antarctica to visualize its future, and Antarctica needs Chile for its understanding and continued care.

It is in this regard that Chile has made important contributions through its scientific activities in this "natural laboratory." The Chilean Antarctic Institute (INACH) was created in 1962 and has had its headquarters in

Punta Arenas since 2003. INACH has become a leader at the international level in the study of climatology, helping to understand the phenomena of climate change associated with the past, present, and future of the Antarctic environment.

The Chilean Antarctic Scientific Program (PROCIEN) began its fifty-seventh expedition between December 2020 and March 2021, focusing on high-quality research under six areas of investigation, including a focus on climate change in the Antarctic. The possibilities for Chile to develop scientific research that is focused on Antarctica, including the country's ability to receive and host international scientists from around the world, are indeed unique.

> **"It is clear that one of the most relevant challenges for humanity is to reverse the effects of climate change, especially those occurring in Antarctica. These will be devastating, if the efforts of the scientific community cannot influence the political and economic decisionmaking community, in order to favor a model of development that is more sustainable."**

The Magellan and Antarctic Region of Chile

Chile is the closest country to Antarctica—at only 500 miles from Cape Horn, near the extreme end of South America, down to the islands of the Antarctic Peninsula. Punta Arenas, the capital of the Magellan and Antarctic Region of Chile, sits roughly 600 miles away from this entrance to the continent.

The city, located next to the Strait of Magellan, celebrates its founding by European explorers five hundred years ago this year. Today it represents one of the principal ports and gateways for visiting the Antarctic. Over twenty national scientific programs are based here, including those for the United States, led by the National Science

Foundation. The logistics organized here in Punta Arenas often rely on local institutions and businesses.

The Antarctic activity carried out in Punta Arenas—as well as in Puerto Williams, the southernmost city in the world, located in the Chilean province of Cape Horn—represents important economic activities for the region and its people. Both of the icebreaking vessels for the National Science Foundation, known as the *Laurence M. Gold* and *Nathaniel B. Palmer*, are permanent fixtures in the bay area landscape of Punta Arenas, alongside the scientific ships and ice-breaking vessels of several other countries.

Antarctic tourism, alongside logistical activities, is also attracting increased interest. With a high level of tourism controlled annually, primarily to the Antarctic Peninsula, the regulation and sustainability of tourist activity are one of the major challenges for Chile in the development of its Antarctic policy. Understanding the local economic benefits and development opportunities that tourism can provide for the Magellan and Antarctic Region is also one way to raise awareness of Antarctica's importance.

However, there must be a delicate balance in preserving this fragile southern environment, which is why Chile has developed a national Antarctic tourism policy. It seeks to promote sustainable and

Photo by: INACH. Used with permission.

noninvasive activities that guarantee the protection of the country's territories, subject to specific controls and regulations at the national level.

It is for these reasons that Chile seeks to strengthen its capacities to offer high-quality and sustainable services to those who travel to Antarctica from Chile, both for science and for those who seek an experience that marks their lives forever. In the future, the International Antarctic Center of Punta Arenas (Centro Antártico Internacional) will transform the Magellan and Antarctic Region of Chile, becoming a global reference point for knowledge, dissemination of Antarctic issues, and ecological tourism, and it will contain platforms for research, logistics, and an eventual museum.

> **It is in this regard that Chile has made important contributions through its scientific activities in this "natural laboratory." The Chilean Antarctic Institute (INACH) was created in 1962 and has had its headquarters in Punta Arenas since 2003. INACH has become a leader at the international level in the study of climatology, helping to understand the phenomena of climate change associated with the past, present, and future of the Antarctic environment.**

Commitment to Protection

An important challenge for Chile's Antarctic policy is environmental protection, including of marine wildlife around Antarctica and the Southern Ocean. Chile not only complies with the regulations emanating from the Environmental Protocol and the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR) but also encourages actions that effectively protect spaces, which represent important refuges for biodiversity.

One clear example of this is the joint proposal between Argentina and Chile in 2018 to establish a marine protected area in Domain 1 of the convention. This is expected to protect more than 650,000 square kilometers of marine habitat. We hope that this high-impact proposal for the

Photo by: Felipe Waghorn. Used with permission.

planet will be approved in 2021. Another example of Chile's commitment is the constant supervision by our national agencies in southern ports and the waters south of the 60th Parallel, where Chile works to deter illegal, unreported, and unregulated fishing, with a special emphasis on the protection of krill, the cornerstone of the entire Antarctic ecosystem.

Strengthening Local Regulations

The sovereign responsibility of Chile, and its vocation for protecting the Antarctic continent, mean that it actively participates in all Antarctic activity—including logistics, science, and environmental protection—to fulfilling international responsibilities for search-and-rescue operations and for the care of human life at sea. It is for these reasons that on August 4, 2020, after almost ten years of analysis and collaboration among several government agencies and institutions, the National Congress passed the Antarctic Law of Chile. The law links Chile's historic connection to the continent with its Antarctic regulations, while modernizing and ultimately perfecting, these regulations.

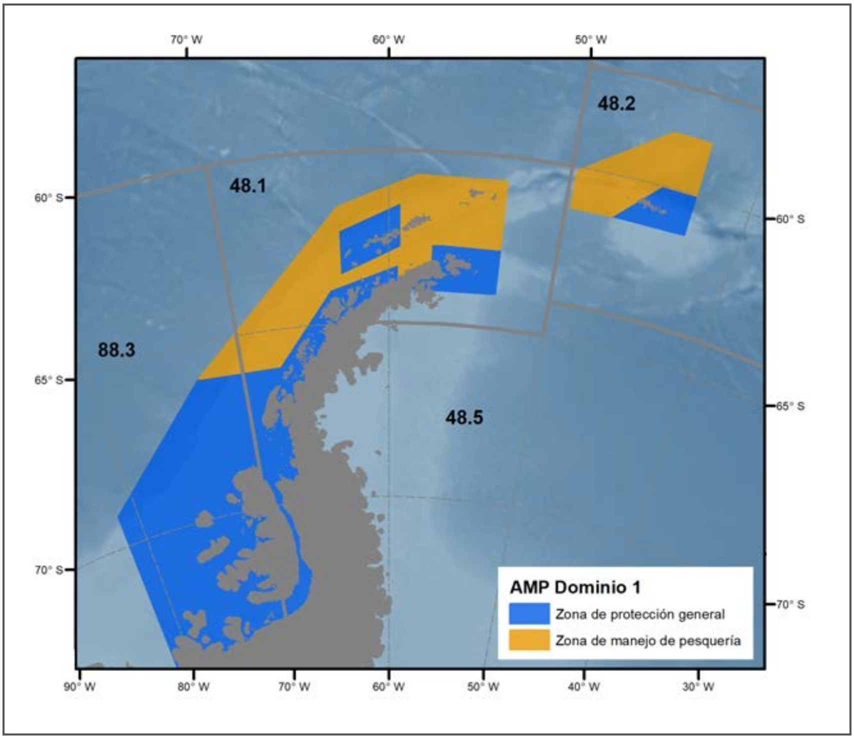
The main purpose of this law is to reaffirm the rights of Chile in Antarctica. The law reinforces and updates national institutional frameworks, clearly establishing the obligations that correspond to each of the national actors, including the operational role of the Chilean Armed Forces.

The new law also establishes procedures and conditions for carrying out activities in Antarctica, a system of provisions designed to protect the fragile and exceptional Antarctic environment, including the ability to sanction crimes and misdemeanors that go against established norms. This law is consistent with the Antarctic Treaty System and is unique among other countries that represent a gateway to the continent. A next step for national regulations in the Antarctic includes approval by the legislature of Annex VI of the Environmental Protocol, which will deepen the responsibility of states in protecting Antarctica's ecosystems.

The Pandemic and Antarctica

As the COVID-19 pandemic advances, one of the major challenges and commitments for Chile remains to keep Antarctica free of the virus, not only to protect the men and women who remain at research stations but also to protect Antarctic fauna, which are at obvious risk due to the effects of the virus being not yet known. Thus, following these guidelines, Chile has been the first gateway country to establish a new protocol for entering Antarctica, which has been highlighted by administrators of Antarctic programs in their last meeting.

Today, the challenge is to standardize this protocol to other activities, such as tourism and fishing. The Chilean government is working with different national actors and coordinating actions with Argentina, a country with which Chile has common challenges on the continent.



Proposed MPA by Argentina and Chile along the Antarctic Peninsula.Image by INACH. Used with permission.

Challenges for Chile and the World

There is no doubt about Chile's commitment to Antarctica and its duty to protect it, thus ensuring both our present moment and the destiny of future generations. However, there are a number of challenges facing all countries that understand the relevance of the continent for the future of humanity. The first of these relates to reinforcing the Antarctic Treaty System, a multilateral agreement that after sixty years has demonstrated its success in maintaining peace and dedicating Antarctica to science and cooperation.

> **"There is no doubt about Chile's commitment to Antarctica and its duty to protect it, thus ensuring both our present moment and the destiny of future generations. However, there are a number of challenges facing all countries that understand the relevance of the continent for the future of humanity."**

It is through the treaty and its forums that global challenges related to Antarctica must be faced, such as its protection from climate change. It is also through the treaty, where member countries must seek a deeper consensus on the issues that are still pending, such as bioprospecting, the responsibility of states for environmental damage, and greater regulation of Antarctic tourism.

For its part, the CCAMLR has several challenges concerning the advancement of a network of marine protected areas, thus returning to its original values within the convention, that is, the effective conservation of marine resources. Unfortunately, certain countries have sought to block various initiatives in pursuit of their commercial fishing interests.

For Chile in particular, future challenges involve participating with a proactive leadership in order to strengthen the Antarctic Treaty System, increasing the development of national science programs, and making the country's capacities available to researchers and scientists around the world. Chile must also integrate new technologies that will come by connecting the Magellan and Antarctic Region with a project for southern fiber-optic connections, including eventual connections to the Antarctic Peninsula.

Chile is renewing its commitment to Antarctica, looking to the future with an even stronger conviction of its dependence on its polar territory. Chile's National Antarctic Policy is a nonpartisan, state policy that rests on solid pillars. However, the challenges of the present are such that only a global view can support a future with Antarctica and for Antarctica. Without it, Chile will not be able to continue building the world it desires.

Photo by Felipe Waghorn. Used with permission.

4 A Paradise in the Ice

Cristina Mittermeier, John Weller, and Paul Nicklen

Paradise Bay Antarctica. Image by Wim Hoek/ Shutterstock.

Two thousand years before heroic explorers pioneered impossible routes across the treacherous Southern Ocean in their wooden ships to first spot the land of ice, the ancient Greeks predicted that there must be a great southern continent. Without it, they said, the Earth would topple over.[1]

The Southern Ocean is equal parts unfathomable power and delicate magic. Days from land in either direction, north or south, each 10-meter swell sends a ship cork-screwing down into the next oncoming wave, shooting a curtain of salt-white spray 20 meters into the air. On the extremes of the worst rolls, you can walk on the walls as the ship navigates the endless silver-black mountains of water.

"Time itself seems to bend to the hypnotic force of the unrelenting sea until, days further south, the ocean calms to nearly glass and a thin white line stretches across the entire southern horizon, splitting the sea and sky."

An albatross suddenly wheels into view like a mirage, nonchalantly skims a wingtip across a mighty wave, then disappears again behind another crest. A flock of petrels appears just as suddenly, banking and dipping in unison like a school of fish. Time itself seems to bend to the hypnotic force of the unrelenting sea until, days further south, the ocean calms to nearly glass and a thin white line stretches across the entire southern horizon, splitting the sea and sky. As the ship cuts through that line and into the sea ice, the endless towering waves fade like a memory of a dream, and a jigsaw puzzle of ice stretches out to the edge of your imagination.

Antarctica effectively has one day and one night each year. At the South Pole, the sun rises in September and sets in March. As temperatures plummet during the 6-month-long Antarctic night, the surface of the ocean around Antarctica freezes into a 2-meter-thick slab of sea-ice, doubling the size of the continent before it slowly breaks up the next Antarctic summer and floats north to melt. This is the world's grandest annual cycle.

Photo by Paul Nicklen / SeaLegacy. Used with permission.

In many places, the jigsaw puzzle of ice is more than 800 kilometers across. The only other features of this frozen desert are the icebergs, sculpted mountains that dwarf the ship and saw at the sky like jagged teeth. There are no words to describe their scale, their silent power.

But this is all just a backdrop. Because though it boasts one of the most extreme environments of the world, Antarctica's ocean teems with life.

Deep upwellings of nutrients and the six straight months of daylight fuel the largest phytoplankton bloom in the world's oceans.[2] This, in turn, supports enormous numbers of Antarctic krill, small shrimp-like crustaceans, with more biomass than any other population of animals on the planet.[3] And on the backs of these small creatures, the icy waters explode with life. Minke and humpback whales pioneer deep into the sea-ice, popping up in the most improbable small breathing holes, gorging themselves on krill and small fish. The whales will bring critical nutrients back from this feast to more northern waters when they return in the fall, enriching the waters along their migration.[4] Platoons of Adélie, Gentoo, and Chinstrap penguins zoom past the edges of the ice, herding the swarms of krill into tight groups to attack. They explode out of the sea and onto the ice like corks, leaving parts of their stories written in the snow. Crab-eater seals, misnamed as they eat krill almost exclusively, rest uneasily on their chosen puzzle pieces, watching for pods of killer whales, which often hunt together, charging one of the floating ice platforms to create enough of a wave to rock the seals off into the water for an easy meal.

Every one of the inhabitants of Antarctica has its own fantastical story. Emperor penguins, for instance, breed in the dead of Antarctic winter, the males each holding a single egg on their feet as they huddle together in high winds and temperatures of –50 degrees C. But their diving physiology is even more profound. These are the deepest diving birds in the world, reaching depths of 600 meters and dive times of 25 minutes. Just before a dive, an Emperor pumps its heart rate up to 250 beats a minute, saturating its body with oxygen. As it hits the water, it immediately drops its heart rate back down to 60; and over the course of a long dive, its heart will slow to just 6 beats a minute. When it resurfaces, it immediately accelerates its heart back to 250 beat a minute. In doing this, the birds replicate the stresses of a human heart attack with each dive.[5]

And this is just the view from above water.

The water temperature is below freezing, liquid only because of its salt, and here the Antarctic is even more humbling. In each encounter with Antarctic creatures, you are witnessing a masterpiece of evolution—fish that make their own antifreeze,[6] seaspiders the size of dinner plates, sponges that live a thousand years and grow as large as oil drums—each supremely adapted to the unimaginable rigors of living in a sea of ice.

Under the ice, Weddell seals will often confront a diver, inspecting our alien presence at close range. They are the southernmost breeding mammals in the world, and the only air-breathing animals besides Emperor Penguins to brave the Antarctic winter. But to do this, they must, at times, dive 800 meters deep,[7] enduring the pressure of a car crusher, stay submerged for an hour and a half, eat their way through the ice to keep their dive holes open through the winter, and speak in voices as loud as a blast of dynamite.[8]

Leopard seals, too, will approach divers:

After the first encounter, my fear was overwhelmed by my respect for its grace and power. The seal was 12 feet long and probably 1,300 pounds, but it could glide, accelerate, and turn effortlessly. And what followed was unlike any other experience in my life. The seal approached me again and again, presenting me with penguin after penguin. I believe she was trying to help me, to teach me how to hunt. As a photographer, it was the most profound imagery of my life. But as a person, it had an even deeper effect, because I recognized that this phenomenal creature, which was trying to help me find a meal, was in imminent peril because of us. Because of people. —*Paul Nicklen*

Photo by Andy Mann / SeaLegacy. Used with permission.

Photo by Andy Mann / SeaLegacy. Used with permission.

An Existential Threat

This is the heart of the matter. Antarctica, and all the creatures that inhabit its icy waters, are hurtling toward a cliff. In just a few decades, climate change has been transforming the very fundamentals of the environment,[9] and the northernmost point of Antarctica, the Antarctic Peninsula, provides a window into the likely long-term future of the Antarctic. Dozens of ice shelves—massive floating glaciers, thousands of feet thick—line the Antarctic Peninsula, filling in bays along the steep rocky coast. Under normal conditions, these ice shelves regularly calve large icebergs and then expand again to recover that area, retreating and advancing, as Antarctica's immense mass of ice slowly flows off the continent, one chunk at a time. This process has been stable for the last 10,000 years.[10] But now, more than 90 percent of the glaciers along the peninsula are in rapid retreat:[11]

> **The sound was so thunderous that I felt it in my chest before the actual "snap." My immediate thought was that something serious had broken on the ship, or someone was in danger. You cannot hear a sound like that without assuming its**

repercussions are life threatening. It was confusing to my senses, honestly. But my rising panic was replaced with unexplainable awe as I realized the source of the sound and the calving ice shelf let loose and rocketed into the Antarctic ocean in front of me. The power was overwhelming, and in that moment was the realization that an amalgamation of so many seemingly tiny ripples had caused such a monumental effect. I have been burdened ever since knowing that this event itself was only a tiny ripple of climate change. I was witnessing a crack in the foundation of our environment, and its ultimate impact on humanity will be tremendous. —*Andy Mann*

A dozen ice shelves have collapsed completely, breaking up and floating out to sea to melt. And this is just the proverbial tip of the iceberg. Antarctica as a whole is melting at an accelerating rate, changing the entire physical nature of the continent and driving sea level rise.[12] Maps of Antarctica have to be redrawn every year, and if these trends continue, most coastal cities will be underwater in a few centuries.[13]

Photo by Cristina Mittermeier / SeaLegacy. Used with permission.

In the shorter term, the sea ice around the peninsula has already changed dramatically. Not only is it much less extensive, but the sea-ice is now only present for a few months of the summer.[14] Each species' interaction with the sea-ice is unique and complex, and these changes have torn apart the complex web of interconnections.[15] Populations of Adélie and Emperor penguins, which depend on sea-ice, are on the decline. Adelies have declined by 65 percent along the peninsula in the last twenty-five years. Chinstrap and Gentoo penguins, more northern species that avoid sea-ice, are starting to replace them.[16] Weddell seals are also on the decline,[17] as are silverfish,[18] one of the most important prey species in the coastal Antarctic aside from krill. The entire ecosystem is contracting with the ice,[19] squeezed even further south into regions of the Antarctic that have not yet warmed as much as the peninsula. There is not much further south that they can go.

> **Just before a dive, an Emperor pumps its heart rate up to 250 beats a minute, saturating its body with oxygen. As it hits the water, it immediately drops its heart rate back down to 60; and over the course of a long dive, its heart will slow to just 6 beats a minute. When it resurfaces, it immediately accelerates its heart back to 250 beat a minute. In doing this, the birds replicate the stresses of a human heart attack with each dive.**

Also, the effects of climate change are not confined to melting ice. Every year, the Southern Ocean absorbs a third of all atmospheric CO_2,[20] buffering the entire globe—including humanity—from the full force of greenhouse gases. But the more CO_2 the ocean absorbs, the more acidic it becomes. Already, populations of small calcifying organisms like pteropods are declining, because they are unable to form shells in the newly acidic water.[21] And, along with melting ice and acidic oceans, come even more surprising effects, like rain:

> **When we landed, we could see that there was something terribly wrong in the colony. The penguin chicks were soaked,**

Photo by Paul Nicklen / SeaLegacy. Used with permission

their downy feathers matted to their bodies and streaked with mud. They were shivering, and so did we as we realized the gravity of what we were witnessing. At the wrong time of year, before the chicks have grown their adult feathers, rain or even snow can wipe out entire generations of these birds. It was like photographing a death march. —*Cristina Mittermeier*

Compounding these overwhelming challenges, Antarctic animals must contend with external pressure on their fast-changing ecosystems from another top predator—humans. Our exploitation of the Southern Ocean started in the 1790s, when sealers started hunting fur seals for their thick pelts. In just thirty years, many populations were on the brink of collapse, and the industry turned to elephant seals and penguins for their oil. Industrial whaling began in the Southern Ocean in the early 1900s. Whale oil quite literally lubricated the Industrial Revolution, and by the time industrial whaling was banned globally in the 1980s, populations of great whales were less than 10 percent of their original numbers. Most species have never recovered.[22] Finfish fisheries started in the 1960s, crashing after only a few years. Next came fisheries for Patagonia toothfish, which were sold as "Chilean Seabass" and known as "white gold" for their high market prices, which started in the 1990s. These fisheries were also quickly overexploited, forcing fishing vessels even further south in search of Antarctic toothfish, an even more vulnerable species, which is the target of the ongoing and highly contentious Ross Sea toothfish fishery, the most remote fishery on Earth. Krill fishing actually started in the 1960s, but the difficulty in processing the massive catches before they degraded made most of this catch unfit for human consumption, so it was instead used as fishmeal for aquaculture.

In 1982, fearing the overexploitation of krill, nations signed a treaty to form CCAMLR, the Commission for the Conservation of Antarctic Marine Living Resources, to manage the fishery. CCAMLR did just that, instituting catch limits and rough spatial management. But CCAMLR's mandate went much further. The language of the treaty is beautiful, rational, and forward thinking. And, despite the need for a 100 percent consensus from more than two dozen nations to adopt any policy, CCAMLR has proven that it can take action on furthering important conservation initiatives.

In 2002, CCAMLR committed to create a network of marine protected areas (MPAs) to guard the core of the Southern Ocean. On October 28, 2016, CCAMLR adopted the world's largest MPA, and the first large-scale international MPA in the Ross Sea of Antarctica. It was a triumph of international cooperation:

> **I wish you could have been there with us, on the floor of CCAMLR, when it happened. When the gavel finally dropped, and the MPA was adopted, this room of stoic international diplomats erupted. People were laughing and cheering and crying. Nations were literally hugging other nations. So, I want you to understand that this was not just a massive win for Antarctica, not just a massive win for our global oceans, though it was both. This was also a peace treaty. I had been working on the**

Ross Sea for twelve years, and what happened in the stone fortress of CCAMLR gives me hope that if enough of us speak up and commit ourselves to making a better world for our children, then that is what we can achieve. —*John Weller*

A Vision for the Future

Now we have the chance to act again. Currently, there are three large-scale MPAs on the floor of CCAMLR—in the Antarctic Peninsula region, Weddell Sea, and East Antarctic. If they are all adopted, it would be one of the largest acts of conservation in the history of humanity.

> **There is one thing we know for sure: we are just beginning to understand the importance of Antarctica and the Southern Ocean for our global ocean. If there is anything that we must learn from terrifying current events, it is that we are tightly tied to each other and to our environment.**

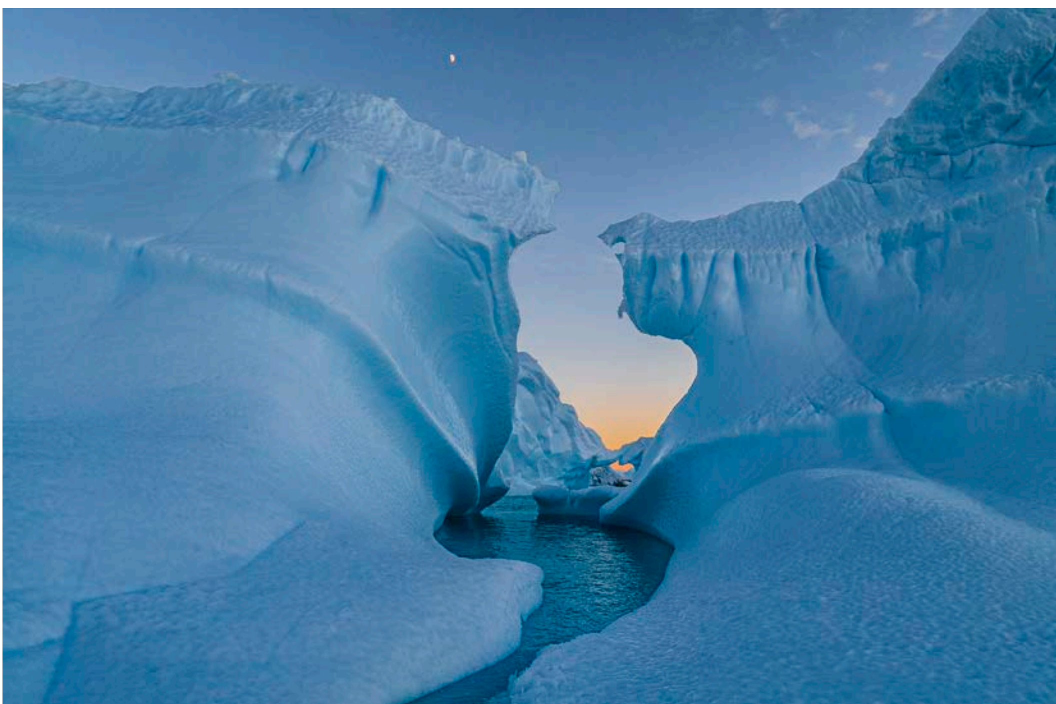
Recent reports from the IPCC (Intergovernmental Panel on Climate Change) and the IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services) underscore that we are reaching the point of no return with respect to climate change, and at the same time facing a fourth great extinction. If we are to change our course, we must introduce sweeping changes within the next decade. We must protect ourselves by protecting our environment. And when it comes to the oceans, nothing works better than an MPA.[23] An MPA with the highest level of protection, a no-take MPA, can expect a dramatic and rapid rebound from previous effects. Several recent studies hammer this point home. Assessing independent data from 124 no-take MPAs, one set of researchers recorded average increases of 446 percent in biomass, 166 percent in the density of organisms, 28 percent in the size of individual organisms, and 21 percent in species diversity.[24] MPAs have also been shown to buffer the effects of climate change.[25]

If our history in the Antarctic has taught us anything, it is that we continuously overestimate how much we can exploit and underestimate how quickly resources are depleted. Even the krill industry, which is well managed in comparison to other global fisheries, has potentially devastating effects. Krill populations, too, are contracting around Antarctica, dependent on the ice at critical moments in their lifecycle. Thus, the industry has become more and more concentrated.[26] Recent studies suggest that even the relatively low catch limits result in local depletions of krill in areas that are critical for Antarctica's embattled denizens.[27] The Ross Sea toothfish fishery also has the potential to do great harm, despite the MPA.[28] We must do better.

The ancient Greeks were strangely correct: the Southern Ocean regulates our climate, recycles sunken nutrients from the deep oceans, and supports one of the most productive ecosystems on Earth. For now. The loss of these functions would indeed be like the Earth toppling over.

There is one thing we know for sure: we are just beginning to understand the importance of Antarctica and the Southern Ocean for our global

Photo by Cristina Mittermeier / SeaLegacy. Used with permission.



ocean. If there is anything that we must learn from terrifying current events, it is that we are tightly tied to each other and to our environment. We must work together if we are to survive the coming catastrophes of a changing climate and fast-disappearing resources. In the long run, the only way to protect Antarctica is to reduce emissions and keep it frozen. But we must also provide all the protections we can to help these ecosystems deal with the coming changes. While we squabble over a few thousand tons of toothfish and krill, the extraordinary creatures of the Southern Ocean are fighting for their very existence.

As we stand by, ocean health continues to decline precipitously. We need to take a stand. We need to open the door to a new age of enlightenment, a new global ocean culture. Antarctica holds a key. The proposed network of MPAs would be a quarantine for some of the most vulnerable members of our planet. It would be a start in aligning our nations, our cultures, and our efforts for our common good. It would be a step toward ensuring a safe and abundant world for our children. It would be a chance to accomplish one of the largest acts of conservation in the history of humanity. Most importantly, it is our global responsibility to protect this important refuge now, in the immediate future.

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Killer whales in Antarctica. Image by vladsilver/ Shutterstock.

5 Exploring the Connections Between Antarctica and South America

Marcelo González and
Marcelo Leppe

Photo by Marcelo González.Used with permission.

The celebrated British naturalist Joseph Dalton Hooker visited Antarctica 180 years ago. On his long journey south, he joined Sir James Clark Ross, a British Royal Navy officer, aboard the ships *Erebus* and *Terror*.[1] The expedition visited parts of South America and Oceania, where Hooker developed the idea that the floristic similarities he had seen between Patagonia and New Zealand could be due to the existence of "emerging bridges" connecting the continents of Oceania and South America through Antarctica. It was a provocative idea, but was very poorly received by the scientific community. At the time, it was inconceivable that such a major role was being played by the inhospitable and depopulated continent of Antarctica.

Indeed, about 70 to 80 million years ago, avian and nonavian dinosaurs, and a great variety of mammals, moved among forests and marshes of plants with flowers, as well as conifers and ferns in what is today a vastness of ice. Marine reptiles and invertebrates such as ammonites and belemnoids, among other living organisms that are now extinct, populated the sea. The environment during the end of the "Age of Dinosaurs" in Antarctica defined a biotic imprint connecting Patagonia, Queensland, and New Zealand in Oceania. Together, they had more than fifty families of plants in common, as well as a significant number of marsupial vertebrates and marine invertebrates. This geologic heritage is reflected in a range of common landscapes, in regions that are currently disjointed, representing commonalities confirmed today by using the modern tools of molecular biology, and that have finally given the justice due to Hooker's early visionary work.

Roughly 30 million years ago, Antarctica began its final separation from the continent of Oceania, first with the opening of the Tasmanian Passage, and then with the opening of the Drake Passage. These geologic events influenced a megatrend toward global cooling. The glaciation process would have occurred slowly, taking several million years. Fossil findings obtained 500 kilometers from the South Pole, only 14 million years old; show that there was still vegetation in this region—very similar to that of Herschel Island in Chile's Cape Horn National Park.

However, the most obvious evidence of the biogeographical link between these landmasses, which are currently separated, is evidenced by the spectacular fossil record of the genus *Nothofagus*, which currently has thirty-five tree living species between Oceania and southern South America. This lineage of plants found its origin in Antarctica 80 million years ago, from where it would have embarked on an epic diaspora toward the landmasses that today constitute its distribution. These ancient forests of oaks, raulíes, coihues, ñirres, and lengas are today a dominant part of the Chilean forests from the Valparaíso region to Cape Horn. Their presence in Patagonia has been documented for 70 million years. It may be hard to imagine that Antarctica was once green with bushy forests, similar to those in southern Chile or New Zealand, but it is well documented by the extensive paleontological record that has been recovered from the South Shetland Islands and the Trans-Antarctic Mountains.

> **"Indeed, about 70 to 80 million years ago, avian and nonavian dinosaurs, and a great variety of mammals, moved among forests and marshes of plants with flowers, as well as conifers and ferns in what is today a vastness of ice. Marine reptiles and invertebrates such as ammonites and belemnoids, among other living organisms that are now extinct, populated the sea. The environment during the end of the "Age of Dinosaurs" in Antarctica defined a biotic imprint connecting Patagonia, Queensland, and New Zealand in Oceania."**

Most recently, significant evidence based on macro DNA and microorganisms, through new techniques and approaches of geological study (geochronology, provenance, and paleomagnetism), has also established another influential factor in South America's connection to Antarctica. Along

Photo by Felipe Waghorn.Used with permission.

the Trinity Peninsula, rocks have been found that were temporarily formed, holding a geochemical footprint that is identical to rocks found in the Madre de Dios Accretionary Complex, located in Chile's southern Patagonia—providing further evidence that South America and the Antarctic Peninsula were once connected by the western edge of South America.

Fauna and Flora, Always Connected

If we think that these connections finished with the *Nothofagus* diaspora and its subsequent disappearance in Antarctica, we are wrong. Various biogeographic studies about the dispersal of marine and terrestrial organisms carried out by Chilean researchers in collaboration with several scientists from abroad, associated with the Chilean Antarctic Science Program (PROCIEN in Spanish), have shown that after the separation and cooling of Antarctica, these connections have all but continued.

In this regard, it has been useful to study one of the two native flowering plants found in the Antarctic region: the Antarctic pearlwort (*Colobanthus quitensis*). A recent study of this species' populations found a wide distribution in South America, indicating that its arrival on the Antarctic continent was more recent than previously thought. In the late Pleistocene, migrating bird populations probably played a key role in the distribution of this plant on the Antarctic Peninsula.[2]

Another case study is represented by the history of penguins. Penguins would have first originated about 22 million years ago. They currently represent at least eighteen species, distributed from polar to tropical environments in the Southern Hemisphere. The history of their diversification and adaptation to these extreme environments remains controversial. However, this enigma concerning the origin of penguins has been solved by a group of researchers at Pontificia Universidad Católica de Chile.

A team led by Juliana Vianna examined twenty-two new genomes from eighteen penguin species to reconstruct the order, timing, and location of their diversification. They were able to track changes in thermal niches through time, and to test for associated adaptation across the genome. Their results indicate that the penguin crown group originated during the Miocene in New Zealand and Australia, not in Antarctica, as many had previously thought.[3]

Furthermore, several studies researching the role of marine organisms are also supporting these important links. Some populations of red algae survived the last glacial maximum about 20,000 years ago in intertidal or shallow subtidal refuges; however, they showed an incredibly low genetic diversity.[4] Questions associated with the differences between the populations of Patagonia and their biogeographic characteristics concerning the populations present in the Antarctic Peninsula and the role that the Antarctic Circumpolar Current (ACC) played in this separation remain open for scientists to answer.

For example, it has been found that the separation between the Antarctic and South American populations of a cold adapted red algae (*Iridaea cordata*) occurred at the end of the Miocene, between 5 and 9 million years ago.[5] Regarding the Antarctic marine invertebrates that have greater mobility than algae, they can adjust their distribution by changing geographical area or depth distribution patterns, or they can remain in a specific refuge.

Research on sea urchins, limpets, snails, clams, and worms has helped to show that the separation between South America and Antarctica was a lot later than previously thought. The results obtained support a genetic continuity between Antarctica and South America, probably along the Scotia Arc, up to the middle Miocene (15 million years ago) and a late intensification of the ACC at the Mio-Pliocene boundary. The separation between the lineages of these Southern Ocean provinces occurred during the Mio-Pliocene, long after the physical separation of these continents.[6]

A limpet species of the genus *Nacella* has been the research focus of a group of Chilean scientists who have contributed to a better understanding

of the patterns and processes underlying the origin and diversification of the benthic marine fauna in this region of global importance.[7] Major periods of climate and oceanographic change strongly affected the *Nacella* biogeography and demonstrate both the long and short-term influence of the ACC across the Southern Ocean. Now it is possible to recognize a new lineage of these limpets in Patagonia.

The Antarctic Circumpolar Current: A Permeable or Impermeable Barrier?

The Antarctic Circumpolar Current is a cold water marine current that flows west to east around Antarctica. It is one of the strongest and most extensive currents on the planet, capable of influencing vast areas. This current is a barrier that has kept most species of plants and animals from going in and going out of the Antarctic region.

It is no longer the influence of ice from glaciations that modifies the connections between South America and Antarctica. The impact of climate change and the presence of a growing human footprint in Antarctica is influencing nonnative species, which arrive due to movements associated with human activities (i.e., industrial fishing, tourism, logistics, and science).

Although these connections between diverse populations of organisms are regulated by the force of the ACC, there is recent evidence that this barrier

Photo by Felipe Waghorn.Used with permission.

appears to be weakening and therefore is becoming more permeable to nonnative species. The recent discovery of fragments of southern bull kelp (*Durvillaea antárctica*) in Antarctic waters provides further evidence that the long-distance transfer of organisms from subantarctic areas is feasible.[8] There has been growing concern about the arrival of these nonnative algae, as has been reported from Deception Island and Livingston Island.[9]

> **"It is no longer the influence of ice from glaciations that modifies the connections between South America and Antarctica. The impact of climate change and the presence of a growing human footprint in Antarctica is influencing nonnative species, which arrive due to movements associated with human activities (i.e., industrial fishing, tourism, logistics, and science)."**

In October 2018, researchers from nine countries met at a workshop in Cambridge to undertake a horizon-scanning exercise to identify the species that present the highest risk to biodiversity and ecosystems on the Antarctic Peninsula over the next ten years. Using this approach, they were able to propose a list of invasive, nonnative terrestrial and marine species that could threaten biodiversity and ecosystems in the region of the peninsula.[10]

The first invasive species on this list were the mussel species (*Mytillus chilensis* and *Mytillus edulis*), followed by some insects and decapod crustaceans (*Halicarcinus planatus* and *Carcinus maenas*). Surprisingly, during the summer of 2019, Chilean researchers associated with PROCIEN and the IDEAL Research Center for High-Latitude Ecosystems found in the waters of Fildes Bay (King George Island) a cohort of *Mytilus cf. platensis* settled successfully in a shallow subtidal habitat. This study demonstrated the ability of this nonantarctic species to complete its early life stages in this extreme environment and confirmed previous predictions.[11]

Teleconnections: Chile–Antarctica

During the mid-1980s, the discovery of a hole in the ozone layer above Antarctica greatly influenced a growing interest in the polar regions. This example showed how humans could seriously affect nature on a global scale like never before. It also showed that Antarctica was not isolated and could serve as a sensor for the health of our planet. The phenomenon of climate change continues to influence the Antarctic Peninsula, making it one of many critical areas to help track global warming. Climate change has brought the White Continent into the center of global discussions on conservation priorities as well as multinational and multidisciplinary scientific efforts to understand the problem.

“A new, younger generation of Chilean scientists from different disciplines and with a strong component of international collaboration is trying to understand how Chile and Antarctica are connected through physical, biological, environmental, and historical dimensions.”

Because Chile is one of the closest countries to Antarctica, the interdependence between the country and continent has become a focal point for Chilean researchers. It is obvious that this narrow relationship between Antarctica and climate change likely determines many aspects of the daily life of Chileans. But how? A new, younger generation of Chilean scientists from different disciplines and with a strong component of international collaboration is trying to understand how Chile and Antarctica are connected through physical, biological, environmental, and historical dimensions.

Current and projected atmospheric changes occurring in the West Antarctic Peninsula (WAP) will have significant effects on Antarctic ecosystems. Therefore, an accurate evaluation of the health status of these ecosystems is essential for their correct management, as well as the generation of appropriate policies for their sustainable use and conservation.

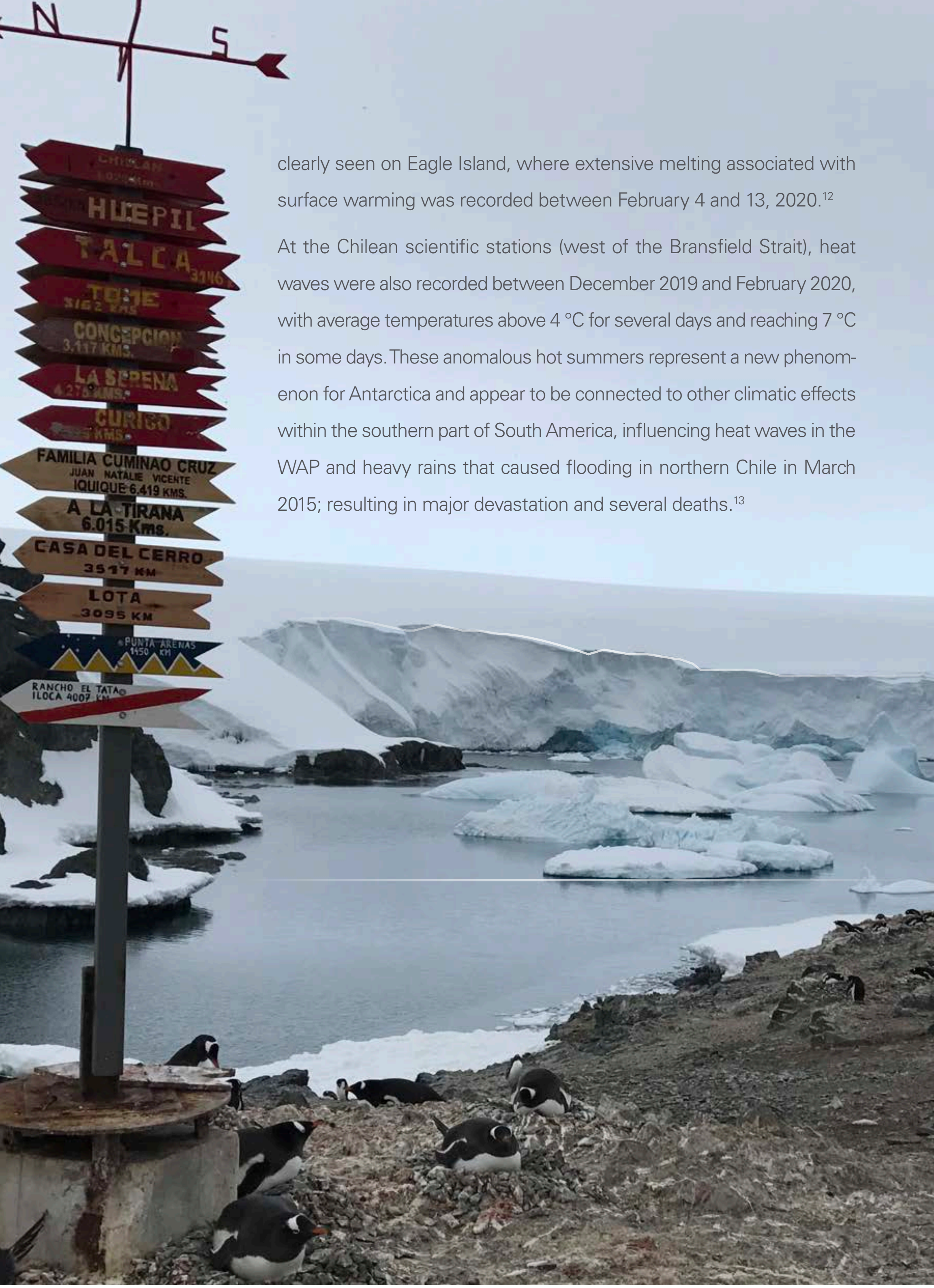
The last austral summer (early 2020) is remembered as the warmest in history. The records of the Australian Antarctic Scientific Station Casey showed that the first heat wave recorded in the area lasted three days—the minimum temperatures exceeding zero, while the daily maximums going higher than 7.5 °C. Then, on January 24, a maximum of 9.2 °C was recorded, almost 7 °C above the average temperature of the last thirty years.

During the same month, most of the heat was concentrated in the northern WAP and the South Shetland Islands. On February 6, a new maximum temperature of 18.4 °C was recorded at the Argentine base Esperanza, almost 1°C above the previous record (17.5 °C) recorded on March 24, 2015. Three days later, it was recorded at 20.75 °C near Marambio station, Seymour Island, east of the peninsula. The effects of this heat wave were

Image Source: Felipe Waghorn. Used with permission.

clearly seen on Eagle Island, where extensive melting associated with surface warming was recorded between February 4 and 13, 2020.[12]

At the Chilean scientific stations (west of the Bransfield Strait), heat waves were also recorded between December 2019 and February 2020, with average temperatures above 4 °C for several days and reaching 7 °C in some days. These anomalous hot summers represent a new phenomenon for Antarctica and appear to be connected to other climatic effects within the southern part of South America, influencing heat waves in the WAP and heavy rains that caused flooding in northern Chile in March 2015; resulting in major devastation and several deaths.[13]



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We can currently witness the effect of reduced rainfall in central Chile, a product of the reduction of the ozone layer in the austral summer (December–February), which leads to a stratospheric cooling that favors the positive phase of the South Annular Mode. In other words, Antarctica can influence droughts and can have a great impact on the Chilean national economy.

The ozone hole that has appeared over Antarctica every year since the late 1970s (between August and December) causes changes in atmospheric circulation, which in turn generate anomalies in the pattern of winds, cloudiness, and precipitation. In South America, these anomalies have particularly affected the southern Pacific coast (30–45° S), where persistent drops in precipitation (about 8 percent per decade) have been observed in recent decades during the austral summer.[14]

Thankfully, the ozone layer has recovered due to international agreements such as the Montreal Protocol, which made it possible to reduce the emissions of chlorofluorocarbons on the planet. However, now we are facing a new problem, which perhaps is more complex, which includes plastic pollution.

Antarctica does not escape this environmental scourge, and the presence of microplastics in the Southern Ocean and the ingestion of these by penguin populations have been already reported.[15] This will be a complex challenge for the Antarctic Treaty System and the Environmental Protection Committee, not only to be able to regulate human activities and lessen the impact on the continent but also to help governments reach a consensus regarding the production of single-use plastics at the planetary level.

In order to improve our understanding of these teleconnections, it is necessary to implement a national scientific strategy in the near future that incorporates a coupled land-ocean-atmosphere monitoring network, helping to detect in real time extreme weather events such as the heat waves reported this past summer on the Antarctic Peninsula.

In this regard, the Antarctic Peninsula and the extensive South American continental territory of Chile provide a unique opportunity to analyze diverse geographic gradients in order to study climate change, its latitudinal response, and its effects, including the phenomena of polar amplification. The challenges associated with climate change will certainly continue to have an impact on Chile and Antarctica in the years to come.

This represents an important moment for the country to consolidate its national Antarctic program, aiming to advance Chile's state-of-the-art research, improve its collaborative and multidisciplinary outreach alongside greater gender equity in science, and thus understand local problems within the global scope of climate change.

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1 The authors wish to thank Reiner Canales and Cesar Cárdenas for their revisions and critical comments on this chapter.

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Environmental activists march in downtown Manhattan as part of the UN Climate Action Summit, September 2019. Photo by Noah Labinaz / Shutterstock.

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6 A Growing Tourism Industry in the Antarctic:

Challenges and Opportunities

Peter W. Carey

Near the bottom of South America lies Ushuaia, one of the southernmost cities in the world.[1] This busy Argentine city calls itself the "End of the World," but to tens of thousands of tourists each year, Ushuaia is instead the starting point for a vacation destination that is even farther away: Antarctica. This geographical proximity to Antarctica makes Ushuaia—and nearby Punta Arenas in Chile—natural gateways to the continent. On ships, yachts, and airplanes, almost all tours begin here—before making the journey south to the icy white continent.

Antarctica was the last continent to be explored, and it remains the only continent without any permanent inhabitants. Everyone who goes to Antarctica is just visiting, whether they come for science, fishing, national agendas, or simply to have a look around and gaze in awe at its harsh beauty. Tourists began coming in 1956, less than fifty years after Roald Amundsen led the first expedition to the South Pole, and before many parts of the icy interior had ever been seen.

From Unusual to Mainstream: The Growth of Tourism

The first tours to Antarctica were sightseeing flights that departed from Chile in 1956, which were followed two years later by the first dedicated

Antarctic tourist cruise, from Ushuaia, in 1958.[2] In an era when a cruise normally meant fancy dining, laying in the sun, and stopping at a variety of beach resorts, Antarctic voyages were very much a niche market that appealed to only a tiny number of vacationers; in the 1950s, only 538 tourists cruised to Antarctica.[3] But from those modest beginnings, Antarctic tourism snowballed in popularity, with visitor numbers quadrupling in the 1960s, while in the 1970s over 14,600 passengers made the trip.[4]

During the summer of 1990–91, the number of tourists exceeded the number of national program personnel for the first time,[5] and the gap between these two groups of Antarctic visitors has only continued to grow in the last three decades. In the 2019–20 season (November 2019–March 2020), a record 74,401 tourists visited Antarctica,[6] compared with about 8,400 national program personnel.[7] Today, Antarctic tourism has diversified to include a broad range of travel options, and a range of activities. Small numbers of tourists (less than 1 percent) depart from Cape Town, Hobart (Australia), and New Zealand, but South America is by far the busiest Antarctic tourism gateway, catering to the many travel options that are currently available, including:

- Cruises with visits ashore (from ships and yachts)
- Cruises with no visits ashore (sightseeing from the deck of the ship)

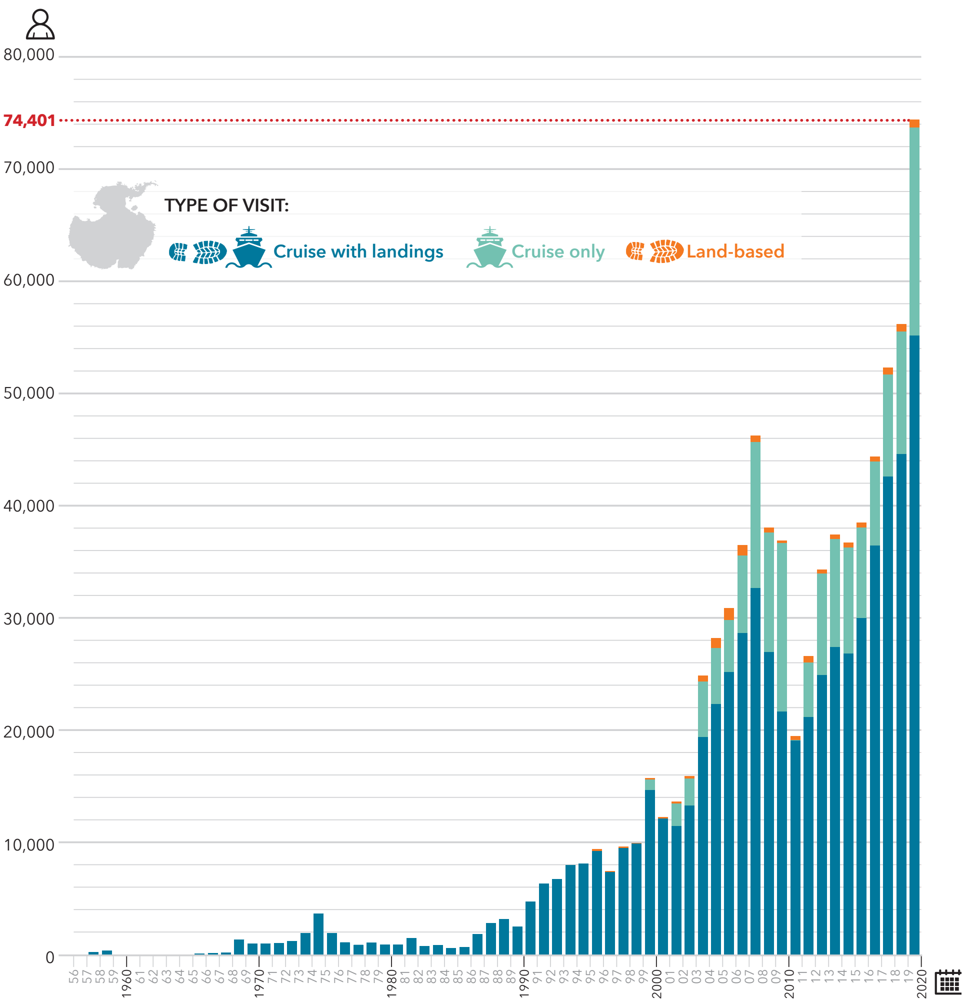
- Fly-cruise with visits ashore (passengers fly from South America to Antarctica and join their ship/yacht there, thus reducing the travel time)
- Flightseeing with no landing (overflight only)
- Fly-in and out to Antarctica for a short ground visit
- Fly-in and out to the interior of the continent for an extended stay (a week or more), often with adventure activities

Cruises with visits ashore are the most popular way to see Antarctica, with 55,164 (74 percent of all tourists) choosing this option in 2019–20. The ships used are small by cruise ship standards, carrying a maximum of 500 passengers, although many vessels hold less than half that number. Most voyages begin and end in Ushuaia. Punta Arenas is occasionally used as a departure port, but its more northerly location adds an extra day of travel each way, making it hard for this Chilean city to compete with Ushuaia's geographic advantage. A very small number of voyages go from Puerto Williams (Chile) on the Beagle Channel, which is about two hours closer to Antarctica than Ushuaia. However, this small settlement has a limited tourism infrastructure, and its airport is too small to accommodate planes of the size needed to move big groups of passengers.

Photo by Peter Carey. Used with permission.

Figure 1:

Antarctic Tourism: Annual Visitors, 1956–2020



Source: Infographic, copyright 2020 by Peter Carey; data from International Association of Antarctica Tour Operators, "Visitor Statistics," 2020 Enzenbacher, Debra J. Enzenbacher, "Tourists in Antarctica: Numbers and Trends." Polar Record 28, no. 164 (1992): 17–22; and Rosamunde J. Reich, "The Development of Antarctic Tourism," Polar Record 20, no. 126 (1980): 203–14.

Also included in this category of tourists are those traveling on small yachts. About a dozen of these small commercial vessels brought fare-paying tourists to Antarctica in the 2019–20 season, with a total of 165 passengers.[8] Yacht travel appeals to the part of the tourism market that wants a customized experience with more adventure and small group size. Most of these vessels carry no more than twelve passengers and are often chartered by a single family or group of friends.

At the other end of the size and adventure scales are Antarctic voyages on larger cruise ships that do not make shore landings. On these cruise-only voyages, adventure is replaced with comfort and on-board amenities like multiple restaurants and live entertainment in the evenings. These are features found on larger vessels, sometimes carrying up to 2,000 passengers. Antarctic Treaty regulations prohibit shore landings from ships carrying more than 500 passengers. Cruise-only voyages spend two to four days sailing along the scenic coast of the Antarctic Peninsula, sightseeing from the decks of the ship. The use of larger ships means that cruise-only voyages are generally much less expensive than trips on the smaller ships that make landings, and as such they appeal to a very different market. Cruise-only trips have seen a recent spike in popularity, jumping from 10,889 passengers in 2018–19 to 18,506 in 2019–20, a 70 percent increase in just one year.[9] Cruise-only tourists now account for 25 percent of all tourist visitors. These cruises usually start or finish in Buenos Aires or Valparaiso (Chile) and, unlike most Antarctic voyages on smaller ships, will also stop at several traditional cruise ports in southern South America.

For many would-be cruise tourists, the potentially rough waters between South America and Antarctica are a fearsome obstacle to be avoided. An increasingly popular option for these tourists is the "fly-cruise," where visitors fly from Punta Arenas to King George Island (Antarctica) and board their vessel there, thus skipping at least one sea crossing of the Drake Passage. Also operating from Punta Arenas are fly-land trips to King George Island, with options to stay for a few hours or overnight.[10] Thus, it is possible to leave Punta Arenas in the morning, have lunch in Antarctica, and be back in Chile in time for dinner that same day. The convenience of this is extraordinary, and the idea that Antarctica could be visited on a day-trip would probably sound like science fiction to early Antarctic explorers, whose voyages lasted months, if not years.

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Cruise tourists who land on the continent are now offered a wide variety of activities to entertain and engage them; early visitors only had wildlife viewing and sightseeing to fill their days. Today's tourist visitor has the chance to climb mountains, compete in marathons, kayak, ski, snowshoe, scuba dive, paddleboard, ride in a submarine or helicopter, or camp overnight on shore. This diversification of activities is offered by tour operators as a means to differentiate their product from their competitors', although it gives the impression that the beauty of Antarctica is no longer enough of a drawing card on its own.

Perhaps the most adventurous of today's Antarctic tourists are those who fly to the continent's interior for climbing, ski trekking, and visits to remote attractions like Emperor Penguin colonies or the South Pole itself. The remoteness of Antarctica's interior makes any trip here extremely expensive, but 731 visitors took the opportunity in the 2019–20 season.[11] This made up only 0.98 percent of all Antarctic tourists last season. Commercial access to the interior is available through tour operators in Punta Arenas and Cape Town. Truly independent travel is all but unknown in Antarctica, which does not currently have resort hotels or the kind of tourism facilities regularly found at other destinations.

Although South America is the main departure point for Antarctic tours, only four of forty-three current tour operators are based here, with Chile hosting three companies and Argentina one. Most tour operators are based in the Northern Hemisphere, with the United States (fifteen), the United Kingdom (six), and Canada and Germany (three each) together having more than half of all operators. However, these foreign tour operators support the local economies by employing a range of local professional services in Punta Arenas and Ushuaia, including tour and maritime agencies, port services, airport logistics, and provisioning.

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Travel to Antarctica is expensive, and it is not surprising that most tourists come from countries with strong economies. In the 2019–20 season, 81 percent of all Antarctic tourists came from just seven countries (in decreasing order): the United States, China, Australia, Germany, the United Kingdom, Canada, and France. And the health of the economy has been shown to have an impact on the popularity of Antarctic tourism; in a 2016 study, the number of visitors from the United States, Germany, Australia, and the United Kingdom was found to fluctuate in correlation with each country's gross domestic product.[12]

Also tied to improving economic conditions is the rise of visitors from China.[13] In the last decade, the number of Chinese tourists to Antarctica

Photo by Peter Carey. Used with permission.

has grown faster than for any other nationality, from 1,158 visitors in 2010–11 to 8,132 in 2019–20.[14] This is an increase of 602 percent, at a time when the overall visitor numbers increased by 68 percent. China is now the second most common country of origin, making up 11 percent of the total (the United States accounts for 36 percent).

Negative Effects of Tourism

Wherever people travel, they make an impact on the environment they visit, and this is especially noticeable in a natural and unpopulated place like Antarctica. Areas near scientific stations were quick to show negative effects once those bases were established,[15] and some of these effects can be long lasting (e.g., soil contamination due to fuel spills[16]). Tourist visitors can also have effects, and concern about this was voiced even in the 1970s, when there were still fewer tourists than personnel from national programs in Antarctica. [17] That said, tour companies take great care to minimize their environmental effects, and indeed doing so is a condition of their permit to operate. Like all activities planned for Antarctica, tourism is regulated by the Protocol on Environmental Protection to the Antarctic Treaty.

Anyone wishing to undertake an activity south of 60 °S must apply for a permit from their nation's Antarctic authorities. Part of the application is an environmental evaluation demonstrating that the planned activity can be conducted safely and with an impact on the environment that is "less than minor or transitory." Most tour operators minimize environmental disturbance by educating their clients during the voyage and by adhering to strict rules that keep visitors closely supervised and under control. Nevertheless, with the increase in visitors has come an increase in concern about the potential problems they may cause.[18] This concern has led to several studies of the impact of tourist landings on penguin colonies and their results so far show either minimal disturbance,[19] or no disturbance.[20] Unfortunately, studies of cumulative effects are rare, as are detailed studies of the effects of tourism on some of the less conspicuous creatures, like terrestrial invertebrates.

But no matter how small or well behaved a group is, their very presence can make an impact on some of the intrinsic values of a site.[21] The Antarctic Treaty's Environmental Protocol calls for the protection of scientific, aesthetic, and wilderness values, although this same document fails to specifically define what those are.[22] In an effort to better understand these values, sites in the region favored by tourists (at the northern end of the Antarctic Peninsula) are currently being investigated by the Scientific Committee on Antarctic Research, in conjunction with the International Association of Antarctica Tour Operators (IAATO). This is part of a systematic conservation planning exercise that seeks to understand values and identify those sites that are best suited for different activities, including science and tourism.[23]

Positive Effects of Tourism

Not all effects are negative, and tourism has made positive contributions to Antarctic culture. Unlike most of the world, where the positive impact is usually measured in economic gains for the people living in a tourist region, Antarctica's lack of a resident population means that one must look deeper to find positive effects.[24] The most commonly touted example is the creation of "ambassadors" for Antarctica, which is based on the idea that people who have an educational, first-hand experience of a place will engage with it deeply, and advocate for its protection.[25] The IAATO is deeply invested in the idea that their members are creating ambassadors, and it has been the centerpiece of an established media campaign.[26] However, the goal of creating ambassadors may be aspirational, given that there are as yet no data to confirm that taking an Antarctic tour results in greater advocacy for the continent's welfare.[27] Nevertheless, more recently, Baker has conducted "before and after" surveys of passengers on two Antarctic voyages, and has reported that respondents had a statistically significant increase in "awareness and concern for Antarctic conservation," after they had experienced Antarctica.[28] Whether this awareness and concern result in a change of behavior once back home has not yet been demonstrated.

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Tourism has also had a positive impact on Antarctic culture by providing a means for women to visit the continent.[29] The history of Antarctic exploration and scientific research is male-dominated, and sexism was rife in many national research programs until the latter part of the twentieth century.[30] In the 1960s, when tourists were just starting to visit Antarctica's Ross Sea, the "no women" attitude was so deeply entrenched among national station leaders that they even resisted (but eventually acquiesced to) having women tourists visit the base for a few hours as part of a shore visit from a cruise ship.[31] Gradually, women have become increasingly better represented in these government programs, but they still make up less than 50 percent of the populations of most Antarctic stations.[32] In contrast, tourist flights and cruises have no such prejudice, and with most tourist trips having a 1:1 sex ratio, it is through these nongovernmental ventures that most women reach Antarctica.

Tourism has also improved Antarctica by virtue of simply being there; the presence of tourists has meant that national programs are no longer operating out of sight and beyond criticism. The presence of large groups of visitors—many of whom support these governmental programs as taxpayers—has brought witnesses, and therefore accountability, to those who operate at the bottom of the world. This includes reporting illegal vessels or unregulated activities. In addition, the frequency with which tour ships and planes move to and from Antarctica has also provided logistical help for science programs, moving their personnel and also providing medical evacuation services.

Challenges in Managing Antarctic Tourism

Many aspects of the Antarctic tourism industry are market driven, and it has grown with very little strategic planning or restraint. Because the Antarctic region is not the sovereign territory of a single country but is instead governed by international agreement through the Antarctic Treaty System, enacting laws to regulate tourism is challenging.

The Antarctic Treaty and its associated annexes set measures for the management of human activities south of 60 °S. Worldwide, the treaty has fifty-four signatory countries. Of South American nations, it has been signed by Argentina, Brazil, Chile, Colombia, Ecuador, Peru, Uruguay, and Venezuela, representing 95 percent of the population in South America. While the treaty does a masterful job of handling geopolitical challenges like competing territorial claims, it is less effective at regulating commercial activities. Tourism has been a persistently thorny issue that has been raised at the meetings of the Antarctic Treaty consultative parties as far back as

1966,[33] and annually since 1991.[34] Despite that attention, the treaty parties have only enacted a few tourism-specific regulations. Instead, they have viewed tourism through the lens of generic "human activities" and have relied on two outside bodies to help control how tourism is practiced in Antarctica. For cruise operators, the International Maritime Organization sets worldwide standards for how ships operate, and it also has specific requirements regarding safety and environmental management for vessels sailing in the polar regions.[35] Also involved with the operational standards of tourism is IAATO, which sets guidelines and procedures for its members. These guidelines and the organization's by-laws have an enormous influence on how tours are conducted, and IAATO works closely with the treaty parties as an expert body. Membership in IAATO is not compulsory, but its member companies benefit from sharing operational protocols, and from being represented by its lobbying efforts. Currently, all tour companies operating in Antarctica are members. Unlike those of the International Maritime Organization, IAATO's guidelines are not legally binding. And yet adherence to them is central to the current plan for industry self-management. While it is the Treaty Parties that govern Antarctic tourism, they rely heavily on a cohesive and compliant tourism industry.

Panoramic view of kayaking in the Iceberg Graveyard in Antarctica. Source: NicoElNino/Shutterstock

The Future of Antarctic Tourism

The drastic warming of the Antarctic Peninsula will likely not have a negative impact on the tour industry. Indeed, at least in the short term, anecdotal evidence suggests the warmer temperatures make it easier for ships to access areas that were previously inaccessible due to sea-ice. However, this increased access brings with it an increased risk of environmental damage, such as the introduction of nonnative species to areas formerly protected by their inaccessibility. Tour operators are already paying attention to the risk of invasive species, with strict cleaning protocols in place between landing sites.

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Tours to Antarctica are projected to continue their dramatic rise in popularity, at least after the end of the coronavirus pandemic. The pandemic, which was caused by a novel coronavirus in early 2020 just as the 2019-20 Antarctic season finished, will severely limit tourism numbers in the 2020–21 season. Before the pandemic, tourist numbers were expected to increase to yet a new record high, as a further twenty-nine new ships are under construction and due to be launched by 2023. These will join an Antarctic tour fleet that already numbers over forty ships, and will double the capacity compared with 2018.[36] But as an economic recession sets in around the world, leisure travel will decline everywhere as border closures, port access, and insolvency take their toll. Antarctica's remoteness will not protect it from these industry challenges.

Critical to the resumption of Antarctic tourism will be the actions taken by the governments of Chile and Argentina to manage COVID-19. Antarctic tourists will need to feel safe coming in and out of Ushuaia and Punta Arenas, and the local population will need to feel safe allowing them in. Protocols and operational procedures must be established by municipal, provincial, or federal governments so that tourism can safely resume without endangering the health of local people. Chile and Argentina's international borders need to be open (a central government issue), but so do the ports (a local government issue). In addition, there will be no tourism if airlines are not operating with enough capacity to bring visitors into the region.

A big challenge to the industry will likely come when growth resumes after the economy recovers. More visitors will mean a higher potential impact on the environment and on the continent's important intrinsic wilderness and aesthetic values. And these in turn will see tourism conflicting more with the Environmental Protocol and its regulatory mandate, especially around preserving wilderness values. A recent study has shown that Antarctica's wilderness area is shrinking, particularly in areas of high biodiversity.[37] These are also the areas most favored by tourists. In this respect, the slowing/pausing of tourism caused by COVID-19 is an opportunity to reduce visitor pressure and plot a new course for the future of tourism management. But the Antarctic Treaty parties will need to find creative ways to more closely manage tourism within the diplomatic confines that are at the core of how Antarctica is governed.

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7

A Brazilian Perspective on Antarctica and the Southern Ocean

Jefferson Cardia Simões

Over the past three decades, there has been more and more rapid environmental change in Antarctica. However, this change has primarily occurred in warmer areas, such as on the Antarctic Peninsula (AP). Rapid change has also occurred on subantarctic islands, as well as in the surrounding Southern Ocean. The scientific evidence of this rapid physical change to the continent includes a general retreat of glaciers, discharging ice from the AP plateau and tidewater glaciers from offshore islands.[1] There has also been the ongoing collapse of ice shelves,[2] during one of the greatest atmospheric periods of warming on Earth in the last six decades.[3]

Although no trend was observed at the beginning of the twenty-first century,[4] there has been a reduction of the sea-ice extent to the west of the AP and also to the east in the Weddell Sea region from 2016 onward.[5] The Southern Ocean surface waters also show clear signs of warming,[6] and increased acidity from the excess absorption of atmospheric carbon dioxide,[7] as well as reduced salinity.[8] More importantly, in the last fifty years a decrease in the thermal gradient between the tropics and the poles has been observed—that is, there has been a change in the energy gradient responsible for the imbalance that forces global atmospheric and oceanic circulation.[9]

If such evidence of rapid changes in the environmental system were not enough, the animal and plant life of the AP is already responding to increased warming. Krill migrate further south,[10] and crabeater seals follow.[11] Gentoo Penguins (*Pygoscelis papua*) expand their area of occurrence in the AP, while the Adélie (*Pygoscelis adeliae*) and Chinstrap (*Pygoscelis antarcticus*) penguins migrate further south as well.[12] Moss field areas have expanded,[13] and nonnative grass species have been detected on the South Shetland Islands.[14]

Despite these rapid changes in the region closest to South America (Tierra del Fuego is about 1,000 kilometers from the northern tip of the AP), few studies have been conducted on how the South American climate system in the Southern Atlantic Ocean sector will respond to changes in Antarctica and the Southern Ocean. This chapter examines the relevance of Antarctica to the climate of South America from the Brazilian point of view (i.e., for the western coast of the South Atlantic), and it points out several issues that deserve further investigation, including the potential for international cooperative efforts to support such research.

The Role of Antarctica in South America's Climate

Within the global environmental system, the polar regions are just as important as the tropics. The Antarctic region, due to the presence of 90 percent of the planet's ice mass volume, is the Earth's main energy sink, and plays an essential role in global atmospheric and oceanic circulation. In addition, the Southern Ocean is the scene of the phenomenon with the greatest areal seasonal variation in the world, the sea-ice cover extent, which on average ranges from 2 million square kilometers in late February to 20 million square kilometers in September, strongly altering the Southern Hemisphere's energy balance.

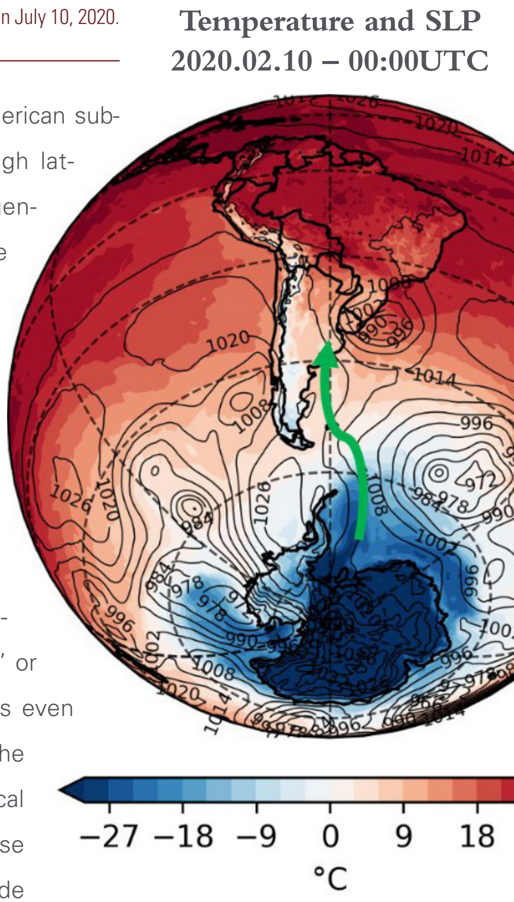
> **"Despite these rapid changes in the region closest to South America, few studies have been conducted on how the South American climate system in the Southern Atlantic Ocean sector will respond to changes in Antarctica and the Southern Ocean."**

The expansion of Antarctic sea-ice increases the hemisphere's meridional temperature gradient and forces the oceanic and atmospheric frontal zones to move toward the equator and vice versa. Mechanisms originating in the tropics also affect the Antarctic climate; for example, the surface temperature of the tropical Atlantic Ocean played a role in the warming observed in the AP and Western Antarctica,[15] and the phenomenon El Niño–Southern Oscillation can have significant effects on high southern latitudes.[16]

Photo by: Jefferson Cardias Simões. Used with permission.

FIGURE 1

Pressure and temperature fields in the Southern Hemisphere on July 10, 2020.



Note: On this day, an explosive extratropical cyclone was formed over Rio Grande do Sul State, in the southernmost region of Brazil. In this event, an intense cold front with rapid advance can be observed, facilitating the penetration (marked in green) of maritime polar air through Argentina, Uruguay, Southern Brazil, Paraguay, and southern Bolivia. Also, observe the advection of the cold Antarctic air mass leaving the Weddell Sea, crossing the Southern Ocean, and moving toward the South of Brazil—the strong tropic-pole contrast resulted in an explosive cyclone.

In relation to the South American subtropics and tropics, the high latitudes are linked by the genesis and dynamics of the cold air masses generated in the Southern Ocean, which, at a synoptic scale, advance toward the subtropics of South America,[17] producing low temperature events and frosts in the Brazilian southern states (these "*friagens*," or cold fronts, can sometimes even reach southern Amazonia). The synoptic-scale meteorological systems responsible for these events and dynamics include extratropical cyclones and anticyclones, which are the main atmospheric systems found in the Southern Ocean.[18]

In general, these cold air masses come from the Bellingshausen Sea (which is west of the AP) as cyclones originating in the Amundsen Sea Low (ASL). The ASL is an area of low climatic pressure located in the Southern Pacific sector of the Southern Ocean (including the seas of Amundsen, Bellingshausen, and Ross). Then, these air masses follow two main frontal systems tracking over the South American continent—one in the interior, extending from northern Argentina to the western Amazon region; and another along the east coast of Brazil.

For most regions, there is one per week in winter and early spring (June–October) and a minimum of one in January and February. These cold front events have a direct impact on agriculture and regulate the southernmost latitude for some crops, for example, coffee in Brazil. More recently, studies have identified a new area of origin for these cold air masses,[19] the Weddell Sea—where these fronts travel through the Atlantic Ocean and reach the South of Brazil, generating extreme events, including a marked decrease in monthly mean temperature and snowfall in the extreme south of the country (figure 7.1).

Case studies and climatological research demonstrate that these extratropical cyclones are formed at the limit between two adjacent air masses, marked by a strongly baroclinic zone with marked temperature gradients in La Plata River region and southernmost Brazil. In the Southern Hemisphere, the greatest tropospheric meridional temperature change occurs in the Antarctic Polar Front, also known as the Antarctic Front or Antarctic Convergence, which separates tropical and polar air masses. According to Aquino, marked negative anomalies in the mean temperature in Southern Brazil (SB) are due to this cold air.[20]

> **In relation to the South American subtropics and tropics, the high latitudes are linked by the genesis and dynamics of the cold air masses generated in the Southern Ocean, which, at a synoptic scale, advance toward the subtropics of South America, producing low temperature events and frosts in the Brazilian southern states (these "friagens," or cold fronts, can sometimes even reach southern Amazonia).**

Some research investigations reveal complex teleconnections (relationships between large-scale atmospheric patterns) between the Antarctic climate variability modes and extra polar processes. The ASL is associated with processes that occur in the tropical Pacific; for example, its absolute depth

Photo by: Jefferson Cardias Simões. Used with permission.

is significantly less during La Niña phases.[21] The Southern Annular Mode (SAM), also known as the Antarctic Oscillation, describes the north-south movement of the west wind belt surrounding Antarctica, which dominates the Southern Hemisphere's middle to high latitudes. It is defined based on the difference in zonal pressure between 40° S and 65° S latitudes,[22] that is, the SAM index measures a "seesaw" of the atmospheric mass between the middle and high latitudes of the hemisphere. Positive values of the SAM correspond to westerlies stronger than the mean in the middle to high latitudes (50° S–70° S), and this belt contracts toward Antarctica and the westerlies become weaker in the middle latitudes (30° S–50° S).

> **"These cold front events have a direct impact on agriculture and regulate the southernmost latitude for some crops, for example, coffee in Brazil. More recently, studies have identified a new area of origin for these cold air masses, the Weddell Sea—where these fronts travel through the Atlantic Ocean and reach the South of Brazil, generating extreme events, including a marked decrease in monthly mean temperature and snowfall in the extreme south of the country"**

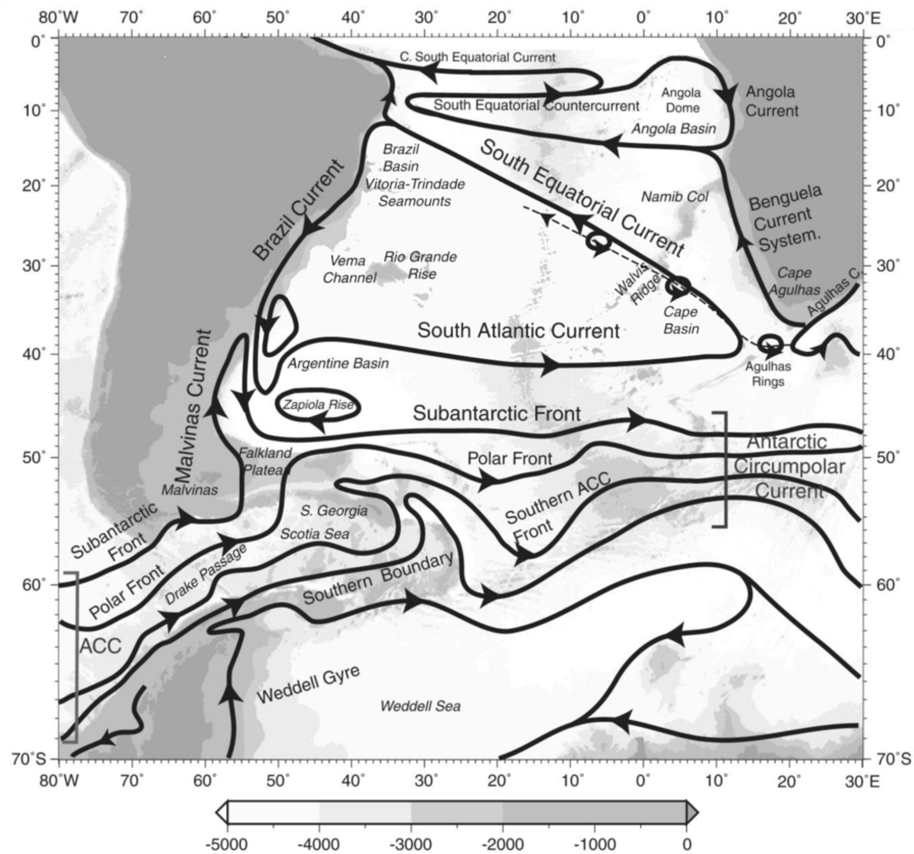
In the negative phase of SAM, the trajectory of cyclones across the Southern Hemisphere moves to the north, when compared with the positive phase, and in the South

Atlantic sector there is intense frontogenetic activity and positive precipitation anomalies on the southeast coast of South America,[23] and vice versa in a SAM positive phase. In other words, the SAM behavior has a great impact on the seasonal and monthly mean temperatures in southern Brazil and on the AP. Negative (positive) anomalies of the mean monthly temperature in southern Brazil and positive (negative) in the AP are associated with positive (negative) phases of the SAM.[24] The positive and negative seasonal extremes and the average monthly temperatures in southern Brazil result, in part, from variations in atmospheric circulation thousands of kilometers away in the AP region.

Therefore, these observations show that atmospheric anomalies in the Southern Hemisphere can be controlled by atmospheric processes in the Antarctic region and connect with the subtropical/tropical regions, especially with the southern region of Brazil. Global warming has intensified the occurrence of climatic anomalies on the planet, especially in the polar regions,[25] alerting the international scientific community to the importance of understanding climate relations and the teleconnections between these regions and the tropical and subtropical regions of South America. Recent research shows that the future retraction of Antarctic sea-ice will have a profound influence on the tropics, including an equator-ward intensification of the Intertropical Convergence Zone.[26]

Figure 2

Oceanic circulation in the Atlantic sector of the Southern Ocean and in the South Atlantic. Note the position of confluence of the Brazil and Malvinas currents off the Argentine and Uruguayan coasts.



Source: Modified from Lynne D. Talley, George L Pickard, William J. Emery, and James H. Swift, ***Descriptive Physical Oceanography*** (New York: Academic Press, 2011).

Evidently, the climate system has these connections in both directions—that is, tropical processes also affect the climate of the polar regions. On this point, research shows that changes in the sea surface temperature in the tropical Atlantic Ocean are linked to the rapid winter warming observed on the western coast of the AP.[27] In addition, anomalies in the tropical sea surface temperature, which are related to the El Niño–Southern Oscillation phenomenon, affect the high latitudes' annular modes by modulating the mean zonal winds in the tropics and subtropics.

The Southern Ocean also has a strong influence on the South American east coast, as it projects northward by a branch of the Antarctic Circumpolar Current, the Malvinas/Falklands Current (figure 7.2). Off the Uruguayan and Argentine coasts, the warm Brazil current collides with this Antarctic Circumpolar Current branch, which transports relatively cold and low salinity subantarctic water toward the equator. The collision of these water bodies, together with the River de La Plata freshwater discharge, generates one of the most energetic regions of the oceans, the confluence Brazil-Malvinas (or Brazil-Falklands)—BMC—generating many eddy fields. The region of this confluence oscillates latitudinally, but it is usually between 35° and 45° S and 50° and 79° W. In this confluence, there is a very large thermal gradient (about 5 °C), sinking the relatively cold waters along its limit. It is an important process for generating a body of water that spreads over the entire Atlantic Ocean in its subsurface.[28] Cold-core vortexes, originating in the Malvinas Current, transport nutrients and phytoplankton to the warm portion of the confluence.

Possible Effects of Climate Change in Antarctica on South America

As the temperature gradient between the poles and the tropics decreases, there will be less energy for extratropical storms to absorb, a change that can weaken or make them less frequent. Thus, it is not surprising to find that the frequency of extratropical cyclones has decreased in the coastal zone of Antarctica (60–70 °S) (except in the ASL region). Conversely, their intensity has increased, and the number of extreme extratropical cyclones reaching the South Atlantic tends to increase with the warming of the ocean surface.[29]

Some extreme events in southern Brazil show a clear sign of association with processes in the Southern Ocean. For example, recent research has shown the instability that formed in the La Plata Basin in late October 2016 and evolved into an explosive cyclone (producing waves, tides, and extreme winds in the extreme South of Brazil) as it moved eastward.[30] This explosive cyclogenesis had a clear synoptic relationship with a negative SAM and zonal wave three pattern in the Antarctic atmosphere during the spring of 2016, a condition that was responsible for a record retraction in the extent of sea-ice in the Southern Ocean and a series of storms in the middle latitudes in the same period. The study of these extreme precipitation events in southern Brazil indicates that there is an interaction of air masses transported from the Amazon, by the South American low-level jet, with cold front penetrations, intensifying the cyclogenesis process, presenting a synoptic pattern that corresponds to an anomalous temperature dipole between southern Brazil and the AP, intensifying extreme temperatures and precipitation events in the La Plata Basin and southern Brazil.[31]

"Studies based on numerical models have pointed out that a positive SAM trend, observed in the last few decades, is expected to continue in the next century as the atmosphere and oceans warm, affecting the precipitation pattern in the South American subtropics. However, this trend will depend on the behavior of the ozone hole, and on its retraction, as occurred in the spring of 2016, which resulted in a reduction in the sea-ice extent, and may result in a greater frequency of extreme events."

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The Brazil current is more intense and is moving southward, and intense heating is already observed along the South Brazil Bight and in the Rio de la Plata area. One of the consequences of this warming, along with the migration to the south of the Malvinas/Brazil confluence, is the shift southward of commercially important pelagic species and a long-term shift from cold water species to warm water species in industrial fisheries of Uruguay.[34] It is therefore essential to assess and maintain monitoring of these changes that affect coastal fisheries because they will have a major economic impact on countries along the eastern coast of South America. In addition, research has also concluded that the reduction in the abundance of krill in the Southern Ocean, due to global warming, will likely affect the southern right whales that migrate to southern Brazil, hindering their recovery rate from past overexplotation.[35]

> **Because the sea level rise is not regionally uniform, it is essential to create scenarios about effects on the east coast of South America. Here, 26 percent of Brazil's population, 212.5 million people, live. In addition, large portions of the populations of Argentina (45 million people) and Uruguay (3.5 million people) also live along the coast. Sea level rise will likely affect these large urban centers, which are more sensitive to extreme sea level events due to storm surges.**

Finally, the glaciers' and Antarctic ice sheet's contribution to raising the average sea level is increasing (currently contributing about 0.43 mm yr^{-1}), and may reach up to 14 centimeters per decade by the end of the twenty-first century, in the worst case scenario.[36] The different scenarios point to an overall sea level increase between 0.29 centimeter and 1.10 meters by 2100,[37] where Greenland's contribution and thermal expansion of seawater are the most important.[38] Because the sea level rise is not regionally uniform, it is essential to create scenarios about effects on the east coast of South America. Here, 26 percent of Brazil's population, 212.5 million people, live. In addition, large portions of the populations of Argentina (45 million people) and Uruguay (3.5 million people) also live along the coast. Sea level rise will likely affect these large urban centers, which are more sensitive to extreme sea level events due to storm surges.

Brazilian Science and Antarctic Climate Change Research

Since 2013, the Brazilian Antarctic Program has reorganized its research planning in consideration of the relevance of Antarctica for the South American environment, investigating several of the processes described above. Today, the Brazilian research program has among its goals to (1) investigate connections between the coupled atmosphere-cryosphere-Antarctic ocean system and the meteorological and climatic processes in South America (with an emphasis on Brazil) and the South Atlantic, in particular the tropical and subtropical response to Antarctic sea-ice loss; (2) investigate the anthropic impact over the atmospheric chemistry of the Southern Hemisphere's high latitudes; (3) investigate the relationship between the Antarctic sea-ice cover variability with climatic process over South America and its variablity since the end of the last ice age (about 11,900 years ago); (4) establish a network of atmosphere and weather monitoring stations from 85 °S to the north of the Antarctic Peninsula, linked to the South American network; and (5) model and develop scenarios for cryospheric responses to climate change over the next 100 years and the consequences for the Brazilian environment, particularly on cold front dynamics and implications for sea level rise.[39]

It remains a central question as to how these changes will modify the interaction of air masses coming from the Amazon, which bring humidity to the South of Brazil, with cold air masses coming from the Antarctic region. Such interaction occurs mainly in the 35–20 °S latitudinal range, one of the most productive farming areas in Brazil, including the production of crops for domestic consumption and exporting. A scenario of fewer cold days and frosts will negatively affect the production of some crops (e.g., wheat) in southern Brazil. However, it will benefit other crops, such as coffee.[40]

Finally, considering the extensive geographic area to be covered to deepen our knowledge of the impact of Antarctic changes to South America, the teleconnections between polar atmospheric processes and the tropics (including the issue of rapid environmental changes in the Arctic[41]), greater international cooperation and partnership among a diverse group of governments and research institutes will be needed.

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Conducting field research within the aggressive environment of Antarctica has an extremely high cost. In order to address these topics fully, it will be essential to further international scientific cooperation, reinforcing both regional and global efforts as a task for science diplomacy. Such diplomatic actions and an interest in understanding the science of climate change are important not only for the implementation of mitigation efforts, such as large-scale conservation, but also to begin addressing tremendous governance challenges, with difficult social, political, and economic choices to be made in the near future.

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8

Understanding Latin American Cooperation on Antarctic Issues

Cristian Lorenzo

A Starting Point: The Status Quo and Its Challenges

This concluding chapter examines Latin American cooperation on Antarctic issues.[1] At first glance, we should consider the Antarctic status quo and its challenges as the context of such cooperation. A major observation one can make is the prevailing peace below the 60th Parallel of the Southern Hemisphere, contrasted with wars in other regions of

the world, which have resulted in destruction and difficult humanitarian realities. This peaceful situation in which Antarctica finds itself is possible due to a regulatory and diplomatic framework that has guided the relationship between nations and the continent. Above all else, there has been the political will to maintain this status quo in the Antarctic. In particular, Article IV of the Antarctic Treaty has been key to addressing territorial claims in such a way that the continent represents a major example of global cooperation today.[2] This status quo, however, coexists with several challenges.

> **If we consider that Antarctica is part of a global system and that at a scientific level there is strong evidence of environmental change, there are critical questions worth asking, such as what countries are most responsible for climate change? What commitments do these countries hold under the UN Framework Convention on Climate Change?**

Climate change represents one of the major challenges for Antarctic cooperation. During the last summer season in Antarctica, there was a record increase in temperature. According to the National Meteorological Service of Argentina, on February 6, 2020, the Esperanza Base registered temperatures of 18.4 °C, breaking the previous record of 17.5 °C on March 24, 2015.[3] The changes to Antarctic ecosystems caused by a warming planet can result in a much broader discussion that goes beyond the Antarctic Treaty System. If we consider that Antarctica is part of a global system and that at a scientific level there is strong evidence of environmental change,[4] there are critical questions worth asking, such as what countries are most responsible for climate change? What commitments do these countries hold under the UN Framework Convention on Climate Change?[5] Greater international cooperation on climate change is vital not only to limit the effects of global warming but also to better understand such changes, including in the Antarctic region.

> **“These examples of bilateral cooperation reveal that the broader efforts between countries often aim for a framework that addresses national interests alongside the strengthening of the Antarctic Treaty System.”**

Simultaneously, we must also take into account the effects of the COVID-19 pandemic. Beyond having an impact on the lives of millions of people, including infections and deaths from the virus,[6] the pandemic has also led to several important outcomes for Antarctica. These include, for example, delayed operations and logistics of scientific expeditions,[7] effects on decisionmaking[8] and planning processes, and severe effects on Antarctic tourism. On this final point, it is important to consider the growing presence of tourism in Antarctica[9] and the unknown outcomes associated with the future development of this sector.[10] These are a few of the challenges facing the continent, as outlined in this publication, and may influence how countries view Antarctica and cooperation more broadly in the future.

Defining Latin American Cooperation

Latin American cooperation on Antarctic issues concerns a diverse range of topics within the Antarctic Treaty System. We can examine cooperation between countries that belong to the Latin American region, as well as the cooperation between any of them and countries outside the region, which belong to the Antarctic Treaty System.

Regarding this first instance of cooperation among Latin American countries, it is often based on strategic decisions and debates about how to strengthen cooperation within the Antarctic Treaty System more broadly. Such decisions and debates are expressed within formal meetings whereby Latin American countries coordinate their positions and propose agenda items of common interest with relation to the Antarctic Treaty System.

An example of this includes ad hoc meetings involving high-level authorities from Argentina and Chile starting in 2012, as well as more regionally focused annual meetings organized by the Administrative Network of Latin American Programs in Antarctica since 1990, known by its acronym in Spanish, RAPAL. It is worth mentioning that despite the declaration of the COVID-19 pandemic by the World Health Organization earlier this year, cooperative efforts between Latin American countries were not fully interrupted but simply moved online for virtual meetings and discussions.

Latin American cooperation on Antarctic issues also requires an understanding of the context of bilateral relations. Let us take the case of Argentina and Chile, two original signatories of the Antarctic Treaty, which account for a long history of peaceful coexistence, with moments of agreement and disagreement. Since the Treaty of Peace and Friendship in 1984, Argentina and Chile have developed cooperative efforts in multiple areas concerning foreign policy. This initial bilateral treaty framework helped reinforce a historically strategic relationship with Antarctica.

In 2016, during the Eighth Binational Meeting of Ministers, a cooperative agreement was signed involving the Antarctic Institutes of Chile and Argentina, INACH and IAA, respectively.[11] Another example involves the relationship between Chile and Brazil. In a visit to Chile in 2013, Brazilian president Dilma Roussef met with her counterpart, Chilean president Sebastián Piñera, to sign three agreements including one related to Antarctic cooperation.[12] These examples of bilateral cooperation reveal that the broader efforts between countries often aim for a framework that addresses national interests alongside the strengthening of the Antarctic Treaty System.

Furthermore, Latin American countries also collaborate extensively with other countries that are signatories to the Antarctic Treaty. Here, there is a multitude of examples to consider. On the Argentine Carlini Base, the Dallmann Laboratory has been operating since 1994, which allows for scientific collaboration between Argentine and German researchers. The recent Uruguayan expedition of 2019, developed research projects aboard the *BIO-Hespérides*, a polar research vessel from Spain. Yet another example involves collaboration between the Chilean Antarctic Institute and the Korean Polar Research Institute (KOPRI) in Punta Arenas. In 2012, a cooperative agreement was signed between both countries' national

Antarctic programs. Three years later, the two countries had signaled interest in collaboration by developing formal mechanisms; and in 2016, the Center for Antarctic Cooperation Chile-Korea was inaugurated.[13] Chile also maintains strong bilateral relations with other countries that form part of the Antarctic Treaty System, including the United States, Norway, and the United Kingdom.[14]

Another form of cooperation includes international forums and meetings on Antarctica, where scientific knowledge is oriented toward influencing diplomatic decisions. Latin American countries actively participate in debates and multilateral decisions with the goal of reaching a consensus using the best science available. As an example, we can consider the cooperation between Argentina and Chile to establish a marine protected area around the Antarctic Peninsula through the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR).[15] This proposal is currently being considered, where a consensus will depend on multiple interests (geopolitical, scientific, environmental, and fisheries). The recent context for this proposal can relate to previous marine protected areas, including one in 2009 near the South Orkney Islands and the most recent one in the Ross Sea in

Biennial Conference of SCAR SC-HASS, "Antarctic Connections at the End of the World: Understanding the Past and Shaping the Future" (2019). Photo by: Matías Martinioni, Fundación para la Conservación del Patrimonio Antártico. Used with permission.

2016. Other protected areas are also being debated concerning the Weddell Sea and East Antarctic.

Underlying Factors of Cooperative Efforts

In order to better understand Latin American cooperation on Antarctic issues, it is necessary to refer to several underlying factors and established precedents. Such factors include the leading role of Argentina and Chile as original signatories of the Antarctic Treaty and the increased involvement of other Latin American countries since the 1970s; the active participation of Latin American countries in international Antarctic forums; the establishment of the Antarctic Treaty Secretariat in Buenos Aires; the presence of Latin American researchers and scientists on the continent; and the close geographic proximity of Ushuaia (Argentina) and Punta Arenas (Chile) to the Antarctic Peninsula.

In 1959, twelve countries signed the Antarctic Treaty in Washington. A central theme during treaty negotiations was how to address territorial claims. At the time, there were seven claims, with three overlapping—involving Argentina, Chile, and the United Kingdom. Since the initiation of the treaty process and acceptance of Article IV, the Antarctic Treaty has in effect "frozen" these territorial claims, putting greater emphasis at the forefront on peace and scientific cooperation. Among these developments, Argentina and Chile were, as noted, original signatories to the treaty, obtaining consultative status in 1961. Since then, both countries have actively participated in the Antarctic Treaty System.[16]

In addition to the role of Argentina and Chile, an increased involvement of other Latin American countries began during the 1970s, with several joining the Antarctic Treaty System. Currently, the countries that hold consultative status in South America include Argentina, Brazil, Chile, Ecuador, Peru, and Uruguay. These countries have a voice in the Antarctic Treaty consultative meetings, along with a vote. Nonconsultative members include

Colombia, Cuba, Guatemala, and Venezuela. These countries have a voice but no vote. The Antarctic Treaty System represents the primary framework and legal system, which defines actions in the Antarctic and regulates relations among countries on the continent and its surrounding waters.

In terms of participation in international forums and meetings on Antarctic issues, the six consultative parties of South America are members of COMNAP, the Council of Managers of National Antarctic Programs, as well as SCAR, the Scientific Committee on Antarctic Research. In terms of participation in CCAMLR, all the consultative parties of South America are also part of this convention, except for Ecuador. The participation in Antarctic forums and international meetings are important in two ways—first, to participate in emerging debates. The second, of course, involves voting on issues of interest, especially for those countries that hold consultative status.[17]

> **National research institutions and universities based in Ushuaia and Punta Arenas have the potential to strengthen bilateral and Latin American cooperation further, as well as cooperative efforts outside the region. These scientific organizations can play a leading role in the development of interdisciplinary research by strengthening academic and scientific networks across the Antarctic research community.**

Another important underlying factor for cooperation is the designation of Buenos Aires as headquarters of the Antarctic Treaty System, which reinforced a leading role for Argentina and the overall positioning of Latin American countries within the Antarctic Treaty. After several years of negotiations in consultative meetings, the decision was approved after broad support from Latin American delegations—despite opposition from the United Kingdom. The headquarters was inaugurated in September 2004, representing an innovative approach for the entire treaty system institutionally, going from a decentralized secretariat to one that was now permanently established in South America.[18]

Concerning research stations in Antarctica, Argentina and Chile can be highlighted as having an active presence on the continent due to the scale of their operations during both summer and winter seasons. This is not only in relation to other Latin American countries, but also at an international level, when comparing research operations on Antarctica.[19] The Argentine and Chilean presence shows that scientific research represents an important component of the activities carried out by Latin American countries and it serves as a significant contribution to the Antarctic Treaty System.

Finally, the last underlying factor concerns the geography and proximity of Antarctica and South America, representing another critical element that helps define the connections between both continents. Ushuaia and Punta Arenas, given their close proximity to the Antarctic Peninsula, provide Argentina and Chile with a natural projection and international position for maintaining their interests in the Antarctic. There are other cities that also represent a gateway to the Antarctic, including Cape Town; Hobart, Australia; and Christchurch. However, the Argentine and Chilean gateways have a fundamental comparative advantage in terms of distance and logistics.

Another aspect related to such proximity worth taking into account involves the role of science in understanding environmental connections between South America and Antarctica. National research institutions and universities based in Ushuaia and Punta Arenas have the potential to strengthen bilateral and Latin American cooperation further, as well as cooperative efforts outside the region. These scientific organizations can play a leading role in the development of interdisciplinary research by strengthening academic and scientific networks across the Antarctic research community. For example, during previous years, two major scientific events were organized by these two gateway cities: In 2017, the IX Latin

American Congress of Antarctic Science was held in Punta Arenas, and in 2019, the Biennial Conference of SCAR SC-HASS was held in Ushuaia.

A Latin American Perspective: Why Geopolitics Matter

Cooperation among Latin American countries in the Antarctic occurs within a geopolitical space. Many times, when examining Antarctic cooperation, there is little need to discuss the dimension of geopolitical interests. However, if this aspect is ignored, it becomes difficult to better understand the dynamics of international relations, because the geopolitics of cooperation is implicit in the design and development of bilateral or multilateral efforts.

The position of countries within the global structure of power is varied, as are the ways in which countries see and plan for the short, medium, and long term. Therefore, the place from which we view and understand these issues matter. This is why for Latin American countries, it is important to understand Antarctic debates in the Northern Hemisphere by examining the roles of diverse actors with the aims of identifying potential dilemmas. This will allow countries in Latin America to better understand potential areas for greater cooperation within the Antarctic Treaty System.

To conclude, Latin American cooperation in Antarctica is undergoing global challenges associated with climate change and the impact of the COVID-19 pandemic. It is under this panorama of challenges and related underlying factors that such cooperation can represent a fundamental tool for strengthening the Antarctic Treaty System. In the future, Latin American countries must continue to think strategically on how to merge the challenges for Antarctic cooperation alongside their respective interests in the continent.

Notes

1 Use of "Latin American countries" refers to those countries that form part of the framework known as the Administrative Network of Latin American Programs in Antarctica (RAPAL in Spanish).

2 Article IV of the Antarctic Treat states: "Nothing contained in the present treaty shall be interpreted as: (a) a renunciation by any Contracting Party of previously asserted rights of or claims to territorial sovereignty in Antarctica; (b) a renunciation or diminution by any Contracting Party of any basis of claim to territorial sovereignty in Antarctica which it may have whether as a result of its activities or those of its nationals in Antarctica, or otherwise; (c) prejudicing the position of any Contracting Party as regards its recognition or non-recognition of any other States right of or claim or basis of claim to territorial sovereignty in Antarctica. 2. No acts or activities taking place while the present treaty is in force shall constitute a basis for asserting, supporting or denying a claim to territorial sovereignty in Antarctica or create any rights of sovereignty in Antarctica. No new claim, or enlargement of an existing claim, to territorial sovereignty in Antarctica shall be asserted while the present treaty is in force."

3 Servicio Meteorológico Nacional de Argentina, "Récords antárticos y cambio climático," February 14, 2020, https://www.smn.gob.ar/noticias/r%C3%A9cords-ant%C3%A1rticos-y-cambio-clim%C3%A1tico.

4 Steven L. Chown and Cassandra M. Brooks, "The State and Future of Antarctic Environments in a Global Context," *Annual Review of Environment and Resources*, 2019, https://doi.org/10.1146/annurev-environ-101718-033236.

5 In relation to climate change, there exist important debates about the political characterization surrounding climate change. Without providing an exhaustive list of all of these perspectives, a recent article provided a few central points concerning global inequality and greenhouse gas emissions in the atmosphere. For more information, see Jason Hickel, "Quantifying National Responsibility for Climate Breakdown: An Equality-Based Attribution Approach for Carbon Dioxide Emissions in Excess of Planetary Boundary," *Lancet Planetary Health* 4, no. 9 (2020), https://doi.org/10.1016/S2542-5196(20)30196-0.

6 World Health Organization, "Weekly Operational Update on COVID-19," September 9, 2020, https://www.who.int/docs/default-source/coronaviruse/weekly-updates/wou-9-september-2020-cleared.pdf?sfvrsn=d39784f7_2.

7. Programa Antartico Brasileiro, "PROANTAR adequa ações para a nova OPERANTAR durante período de pandemia da COVID-19," July 22, 2020, https://proantar.com.br/news/proantar-adequa-acoes-para-a-nova-operantar-durante-periodo-de-pandemia-da-covid-19-1595459278.

8 Secretariat at the Antarctic Treaty, "Cancellation of ATCM XLIII–CEP XXIII," March 13, 2020, https://ats.aq/devph/en/news/176.

9 International Association of Antarctica Tour Operators, "IAATO and the Response to COVID-19," July 21, 2020, https://iaato.org/iaatos-response-to-covid-19/.

10 Peter Carey. "Is It Time for a Paradigm Shift in How Antarctic Tourism Is Controlled?" Woodrow Wilson International Center for Scholars, July 2020, https://www.wilsoncenter.org/publication/polar-perspectives-no-1-it-time-paradigm-shift-how-antarctic-tourism-controlled.

11 Instituto Antártico Chileno, "Sellan acuerdo de cooperación antártica entre Chile y Argentina," December 21, 2016, https://www.inach.cl/inach/?p=20729.

12. Instituto Antártico Chileno, "Chile y Brasil firman acuerdo de cooperación antártica," January 27, 2013, https://www.inach.cl/inach/?p=8118.

13 Instituto Antártico Chileno, "Inauguran Centro de Cooperación Antártica Chile–Corea," February 29, 2016, https://www.inach.cl/inach/?p=18811.

14 Ministerio de Relaciones Exteriores del Gobierno de Chile, "Memoria Anual: Ministerio de Relaciones Exteriores de Chile 2017," https://minrel.gob.cl/biblioarchivo/site/artic/20131015/asocfile/20131015154606/Memoria2017.pdf.

15 Ministerio de Relaciones Exteriores, Comercio Internacional y Culto de la República Argentina, "Península Antártica: Argentina y Chile presentan propuesta binacional para un Área Marina Protegida," November 6, 2018, https://cancilleria.gob.ar/es/actualidad/noticias/peninsula-antartica-argentina-y-chile-presentan-propuesta-binacional-para-un.

16 By the Antarctic Treaty System, we can assume all norms and institutions that arose from the Antarctic Treaty. Components of this system include the Antarctic Treaty and all the international instruments associated with the treaty, such as the Convention on the Conservation of Antarctic Seals in 1972; the Convention on the Conservation of Antarctic Marine Living Resources in 1980; and the Protocol to the Antarctic Treaty on Environmental Protection, including the annexes of 1991. For more information, see https://www.cancilleria.gob.ar/es/iniciativas/dna/divulgacion/tratado-antartico.

17 Adrian Hawkins and Cristian Lorenzo, "Latin America and Antarctica: New Approaches to Humanities and Social Science Scholarship," *Polar Journal* 9, no. 2 (2019), https://doi.org/10.1080/2154896X.2019.1685176.

18 Miryam Colacrai, "La meta de la Secretaría del Tratado Antártico como 'Política de Estado' de la Argentina (1992–2001)," *Relaciones Internacionales* 26 (2004).

19 Council of Managers of National Antarctic Programs, "Antarctic Station Catalogue," 2017, https://www.comnap.aq/wp-content/uploads/2019/11/COMNAP_Antarctic_Station_Catalogue.pdf.

Contributors

The Honorable Andrés Allamand is the foreign minister of Chile. Before his current role, he served in the Chilean Senate from 2014 to 2020 for the National Renovation Party, of which he is a founding member and former president from 1990 to 1996. He has also served as minister of defense during the first term of President Sebastián Piñera from 2011 to 2012. Beyond his role in government, he was a consultant for the Inter-American Development Bank and the first dean of the School of Government at the Universidad Adolfo Ibáñez. He received his law degree from the Universidad de Chile, with highest honors.

Anders Beal is an associate in the Wilson Center's Latin American Program. He has worked with several nonprofit organizations and as an independent consultant. From 2013 to 2014, he was assistant to the executive secretary of the Chilean American Chamber of Commerce, where he supported bilateral cooperation on energy issues through the US-Chile Energy Business Council. Before his work with the chamber, he was a graduate intern at the US Embassy in Santiago. He received a BA in Spanish and economics and an MA in global policy from the University of Maine.

Maximiliano Bello is an international ocean policy expert who has worked in the environmental arena for over two decades to advance marine conservation priorities. He has worked for various nongovernmental organizations in Chile and the United States, including the Pew Charitable Trusts, Oceana, World Wildlife Fund, Island Conservation, and the Blue Whale Center, among others. He has operated within a wide array of international forums, including UN conventions and bodies. Additionally, he has worked directly with governments in Latin America and around the world to establish marine protected areas. His work at Mission Blue and Island

Conservation involves engaging at national and international levels to further marine conservation efforts.

Peter Carey is a zoologist who has worked in Antarctica and the Southern Ocean since 1983. In addition to doing research with the national Antarctic programs of New Zealand and Australia, he has worked in polar tourism for several decades as a program developer, expedition leader, and educator. He is the coauthor of the *Antarctica Cruising Guide* (with Craig Franklin; Awa Press). In addition to his work in tourism, he is also director of the SubAntarctic Foundation for Ecosystems Research, a nonprofit organization that works to enhance native biodiversity.

Sylvia Earle is president and chair of Mission Blue and the Sylvia Earle Alliance. She is also a National Geographic Society Explorer in Residence. Known for international marine conservation work and broad expertise on the world's oceans, she has been called "Her Deepness" by the *New Yorker* and the *New York Times*, Living Legend by the Library of Congress, and first Hero for the Planet by *Time Magazine*. She is an oceanographer, explorer, author, and lecturer with experience as a field research scientist, government official, and director for several corporate and nonprofit organizations. In 1990, she became the first female chief scientist at the National Oceanic and Atmospheric Administration, and throughout her career, she has published over a hundred scientific papers.

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Marcelo Leppe is director of the Chilean Antarctic Institute (INACH). Before this, he was a researcher for the institute for fifteen years, having led the scientific department from 2010 to 2016. His research interests include multidisciplinary work on the evolution of Antarctic and Patagonian flora. He has a diverse international network, having conducted research abroad in Germany and Asia, and presented at more than fifty scientific symposiums and congresses. Since 2015, he is president of the National Committee for Antarctic Research (CNIA) and represents Chile before the Scientific Committee on Antarctic Research. He received his PhD in biological sciences and paleobotany from the University of Concepción in Chile.

Cristian Lorenzo is a researcher at the Austral Center for Scientific Research in Ushuaia, Argentina, part of the National Scientific and Technical Research Council (CONICET). He also lectures at the Universidad Nacional de Tierra del Fuego and is a member of the Standing Committee on the Humanities and Social Sciences (SC-HASS) in the Scientific Committee on Antarctic Research (SCAR). He recently edited the book *Latin America in Times of Global Environmental Change*, published by Springer, and coedited the special volume by *The Polar Journal* on Latin America and Antarctica in December 2019. He was also chair of the Biennial Conference of SCAR SC-HASS, "Antarctic Connections at the End of the World: Understanding the Past and Shaping the Future" (2019). He received his master's degree from FLACSO in Buenos Aires and his PhD in international relations from the Universidad de Salvador in Argentina.

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Paul Nicklen grew up in the Canadian Arctic, making him uniquely qualified to create a brand of documentary photography that informs and creates an emotional connection with wild subjects in extreme conditions. His work delivers audiences to an underwater realm witnessed by few. And his work has garnered more than thirty of the highest awards given to any photographer in his field, including the BBC Wildlife Photographer of the

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