




Editorial

Extremes in Antarctica – the ever more pressing headline?

Peter Convey^{1,2,3,4}  and Katharine Hendry^{1,5}

¹British Antarctic Survey, Cambridge, UK; ²University of Johannesburg, Johannesburg, South Africa; ³Millennium Institute - Biodiversity of Antarctic and Sub-Antarctic Ecosystems, Santiago, Chile; ⁴University of Birmingham, Birmingham, UK and ⁵Queens' College, University of Cambridge, Cambridge, UK

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Antarctica is a continent of extremes, as we often say, so what exactly constitutes an extreme event in Antarctica? Antarctica and the surrounding Southern Ocean are central to global atmospheric and oceanic processes and climate. In turn, teleconnections with lower latitudes, including to the tropical regions, feed back into Antarctica. The concept of 'extreme events' in Antarctica was discussed in the Scientific Committee on Antarctic Research (SCAR) Horizon Scan activities a decade ago (Kennicutt *et al.* 2015), but this concept has received increasing prominence in recent literature across a wide range of disciplines and contexts (Siebert *et al.* 2023).

There is no one simple definition of an 'extreme event', making discussion of their nature and impacts challenging. The links between 'extreme weather', 'extreme climate' and 'abrupt change' are critical, given that it is increasingly clear that extreme events can trigger abrupt changes and regime shifts in a system preconditioned by longer-term warming. Whether or not these shifts signify 'tipping points' - rapid, large-scale systematic shifts that are irreversible (or very difficult to reverse) - is a matter of debate. This is, again, largely due to the lack of a clear and quantitative definition of what exactly a 'tipping point' constitutes. Furthermore, we often lack the data we need to statistically identify extreme events, because our observational records are not long enough and are often patchy, while palaeoclimate archives (despite being highly valuable for extending observations back in time) are not sufficiently well resolved in space or time.

These challenges aside, extreme events are increasingly being recognized in all components of the Antarctic climate system (Abram *et al.* 2025). Atmospheric rivers have brought enormous volumes of exceptionally warm and moist air deep into the continent itself, leading to winter temperatures 30°C and more higher than climatological averages, exceptional melt and precipitation events and impacts on ecosystems. Successive years with record low summer (and winter) sea-ice formation directly impact the Southern Ocean albedo and marine ecosystems and primary production, posing apparently dire threats to the continued existence of, for example, the iconic emperor penguin, the poster child of the need for the protection of Antarctica. Ice-shelf collapses, resulting from both atmospheric and oceanic warming, 'release the brakes' on their adjoining glaciers, accelerating rates of ice loss into the

surrounding ocean and compounding the already serious threats of global sea-level rise. The recent considerable reduction in cold Antarctic Bottom Water formation has implications for deep ocean currents globally as well as for oxygen transfer to depth. As has also been seen in the Arctic, short-term high-temperature events over land accelerate surface ice and snow melt, threatening their contained microbial communities, with impacts ranging from curtailing primary production to drastically reducing surface albedo - a strong positive feedback further accelerating ice loss. Until recently, Antarctica's mostly small and cryptic terrestrial diversity has been thought to be relatively robust to the scale of warming currently predicted, at least on century timescales, but even this is now being questioned for both microbes and invertebrates in both polar regions, as short-term warm extremes appear to be approaching their functional limits (Bahrndorff *et al.* 2025). At completely the opposite physical scale, the melting and plausible collapse of the West Antarctic Ice Sheet is now locked in, regardless of the emission scenario, even if we do not have a good handle on when it will occur and whether its effects are reversible (Naughten *et al.* 2023).

While the very broad climatic and environmental changes underlying these diverse impacts are undoubtedly anthropogenic in origin, these are far from the only 'extreme events' humans have imposed on the high southern latitudes, and others are certainly plausible into the future. For instance, the Southern Ocean itself is still a long way from recovering from the drastic impacts of the uncontrolled anthropogenic marine exploitation industries from the late eighteenth to mid-twentieth centuries (i.e. sealing, whaling, fishing), with continued concerns existing regarding the potential for the overexploitation of fish and krill species to the present day. Similarly, there is contemporary recognition and concern regarding the risks posed by the human-assisted introduction of non-native invasive species, itself an example of a risk that is likely to act in synergy with climate change, which in effect represents another extreme event being imposed on these ecosystems that is likely to lead to step changes in ecosystem functions and services.

In a very recent horizon scanning study, Carter *et al.* (2025) concluded that one of the most important threats to the future of Antarctic ecosystems is the possibility of failure of the Antarctic Treaty System itself and the regulatory mechanisms it puts in place. While the study identified multiple key future conservation challenges, those related directly or indirectly to climate change were in the minority, outweighed by those driven by the

Corresponding author: Peter Convey; Email: pcon@bas.ac.uk

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ineffectiveness of the Antarctic governance regime, global disruptions, resource exploitation and economic interests and human footprint and activity expansion. Imminent challenges to regulation extend as far as future mineral exploitation, as there are very well-qualified commentators who already publicly press the view that the first stages of this process are already underway with no effective response (e.g. Walters 2024, 2025).

The severe and all-too-obvious contemporary geopolitical divides impacting multiple elements of the global community at present increasingly underlie the concerns being expressed by those knowledgeable about different aspects of Antarctica, and it would be no exaggeration to say that they themselves are might be harbingers of the collapse of the current world order. Direct anthropogenic impacts such as the exploitation of marine living resources and the continent's mineral resources, never mind the recent highlighting of the extreme risks to the Antarctic region posed by 'geoengineering solutions' (Siegert *et al.* 2025), are no longer hypothetical questions and, if and when they come to pass, will represent 'extreme events' that could have far greater impacts on the continent and its associated ecosystems than those driven by anthropogenic climate change itself.

It is now abundantly clear that 'what happens in Antarctica does not stay in Antarctica', so we should be seriously concerned about how extreme events increasingly affecting Antarctica are connected with and impact the rest of the world and the global population. While it has long been common practice to consider Antarctica as an isolated and protected 'jewel' and the Antarctic Treaty as an 'exemplar' of a successful international treaty - and it is very tempting to do so - clearly these views can be strongly challenged, highlighting the urgency with which all Treaty Parties need to stand together to face and address the very real challenges facing the region and the globe.

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