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Overshoot of 1.5°C and implications for Antarctica and the Southern Ocean

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Information paper submitted by ASOC

Summary

This paper presents the concept of climate "overshoot"—the temporary exceedance of the lower Paris Agreement 1.5°C temperature limit followed by a permanent return to lower temperatures—and highlights implications for the Antarctic Ice Sheet and Southern Ocean system. It draws attention to the reality that under current Nationally Determined Contributions (NDCs) and resulting greenhouse gas emissions, limiting warming to 1.5°C without overshoot will become increasingly difficult. This paper outlines how overshoot magnitude, duration, and its subsequent stabilization temperature all influence the risk of crossing irreversible thresholds in the Antarctic Ice Sheet. This has severe implications for committed global sea-level rise, adaptation, and loss and damage in coastal communities and ecosystems, as well as impacts of CO_2 emissions in driving Southern Ocean acidification alongside temperature rise. This paper invites the ATCM and CEP to consider the implications of overshoot pathways for long-term Antarctic and global environmental outcomes.

Introduction

The Paris Agreement aims to limit global warming to well below 2°C and pursue efforts to limit it to 1.5°C above pre-industrial levels.[1] However, current Nationally Determined Contributions (NDCs, or climate pledges from each Party to the Paris Agreement) and resulting global emissions trajectories suggest that a temporary exceedance ("overshoot") of the 1.5°C limit has become increasingly likely, potentially within the next five years.[2,3]

Overshoot scenarios have three key dimensions: the *magnitude* of temperature exceedance, the *duration* of time spent above that threshold, and the long-term *stabilization* ("landing") climate following the achievement of net zero greenhouse gas emissions and subsequent carbon removal.[4] These dimensions are important for Antarctica and the Southern Ocean, where response to greenhouse gas forcing can include sudden thresholds potentially causing long-term irreversible consequences.[5,6]

Climate overshoot as an emerging policy-relevant scenario

Recent assessments indicate that global temperatures may approach or exceed 1.5°C/430ppm CO_2 concentrations in the atmosphere within the next few years under currently projected emissions trajectories.[2,3] Ambitious mitigation combined with carbon dioxide removal could return temperatures and atmospheric CO_2 below these levels by 2100, but still include a limited period of overshoot.[7]

This raises important questions regarding the extent to which temporary overshoot differs from stabilization at or below a given temperature level.[8,9] For systems characterized by thresholds and long response times, such as the Antarctic Ice Sheet and the Southern Ocean, transient warming may still

[1] UNFCCC. Paris Agreement: Article 2. United Nations (2015).
[2] Forster et al. (2025), https://doi.org/10.5194/essd-17-2641-2025.
[3] Bevacqua et al. (2025), https://doi.org/10.1038/s41558-025-02246-9.
[4] Reisinger et al. (2025), https://doi.org/10.1146/annurev-environ-111523-102029.
[5] Armstrong McKay et al. (2022), https://doi.org/10.1126/science.abn7950.
[6] Global Tipping Points Report (2023), https://report-2023.global-tipping-points.org.
[7] IPCC AR6 WG3 (2022), https://www.ipcc.ch/report/ar6/wg3/.
[8] Schleussner et al. (2024), https://doi.org/10.1038/s41586-024-08020-9.
[9] Ritchie et al. (2021), https://doi.org/10.1038/s41586-021-03263-2.

lead to long-lasting or irreversible ice loss and environmental impacts.[10,11,12] Accordingly, evaluating climate outcomes requires consideration not only of long-term temperature targets, but also of the pathways taken to reach them.

Implications for the Antarctic Ice Sheet

The Antarctic Ice Sheet exhibits strong regional differences in its sensitivity to warming, with different sectors responding to distinct atmospheric and oceanic forcing thresholds.[13] Some basins, particularly in the West Antarctic Ice Sheet (WAIS), may approach thresholds for irreversible loss at present-day warming of 1–2°C, while major marine-based sectors of the East Antarctic Ice Sheet (EAIS) may have slightly higher thresholds of 2–3°C. Current NDCs would lead to about 2.6°C, thereby causing long-term multi-meter sea-level rise over coming centuries.[14]

In an overshoot context, these characteristics have several implications:

- **Temporary threshold crossing during overshoot:** Even a temporary overshoot may be sufficient to initiate irreversible ice sheet retreat in vulnerable regions due to the presence of self-sustaining feedbacks and internal instabilities within the ice.
- **Dependence on peak warming and overshoot duration:** The maximum temperature reached during overshoot as well as the time spent above the threshold determine the probability of triggering ice sheet instabilities, particularly where thresholds are clustered near 1–2°C.
- **Irreversibility:** Once initiated, ice sheet retreat will likely continue even if global temperatures are subsequently reduced; due to internal feedbacks, strong inertia, and geometric changes in the ice sheet system.

As a result, overshoot pathways may commit the Antarctic Ice Sheet to long-term ice loss and associated sea-level rise, even if Paris Agreement temperature targets are ultimately re-attained.[15]
While temperature rise and fall determined by greenhouse gas concentrations will change over decadal timescales, the ice sheet response and adjustment will take place over centuries to millennia. This means that short-lived periods of higher temperatures can have long-lasting consequences.[15] In particular:

- **Overshoot magnitude** influences the likelihood of triggering critical thresholds.
- **Overshoot duration** affects the extent to which instabilities develop and spread.
- **Stabilization climate** determines the long-term amount and rate of ice loss, but may not reverse initiated ice sheet retreat and resulting sea-level rise.

Consequently, sea-level rise from Antarctica is best understood as a committed response: once triggered, it is likely to continue independently of subsequent reductions in temperature.[15] Even "temporary" overshoot can result in persistent and irreversible sea-level rise on human timescales.[16]

Implications for the Southern Ocean

Temperature-driven impacts of overshoot in the Southern Ocean include freshening from ice sheet loss, warming of marine waters, and disturbances of vital ocean current systems such as the Antarctic

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[10] Mengel et al. (2018), https://doi.org/10.1038/s41467-018-02985-8.
[11] Schellnhuber et al. (2016), https://doi.org/10.1038/nclimate3013.
[12] Wunderling et al. (2023), https://doi.org/10.1038/s41558-022-01545-9.
[13] Noble et al. (2020), https://doi.org/10.1029/2019RG000663.
[14] Winkelmann et al. (2026), https://doi.org/10.1038/s41558-025-02554-0.
[15] Clark et al. (2016), https://doi.org/10.1038/nclimate2923.
[16] Strauss et al. (2021), https://doi.org/10.1088/1748-9326/ac2e6b.

Circumpolar Current (ACC)[17] and Antarctic Bottom Water (AABW) formation, which drive the global ocean circulation system.

In addition, high CO_2 emissions have direct consequences for the Southern Ocean ecosystem, as it plays a key role in absorbing anthropogenic CO_2,[18] but this uptake leads to acidification that has become particularly pronounced in the waters around Antarctica.[19] Further elevated CO_2 concentrations during overshoot will increase the extent, intensity and impacts of acidification. Southern Ocean acidification impacts vital marine ecosystems, particularly organisms at the base of the food web.[20] Crucially, unlike temperature, ocean chemistry responds primarily to cumulative emissions, which remains unaffected by potential subsequent atmospheric carbon drawdown and cooling. As a result, even if CO_2 levels are reduced following overshoot, acidification effects will persist on scales of thousands, to tens of thousands of years, with limited potential for reversal.[21]

Concluding remarks

Climate overshoot introduces an additional dimension to the assessment of Antarctic, and thereby global, climate risks. In the Antarctic system, overshoot risks come with a dual nature: while *temperature* overshoot affects ice sheet stability, sea-level rise, ocean currents and marine warming, *carbon dioxide* overshoot affects ocean chemistry and ecosystems. Available evidence suggests that:

- Temporary exceedance of critical temperature thresholds within the Antarctic ice sheet–ocean system may trigger irreversible changes in the Antarctic Ice Sheet and Southern Ocean, with long-term and potentially irreversible impacts on marine ecosystems and global sea-level rise.
- In addition to the eventual stabilization temperature, peak warming levels and duration of overshoot are critical in determining long-term outcomes.
- Southern Ocean acidification is governed by cumulative CO_2 emissions, with long-lasting ecological consequences.

This paper invites the ATCM and CEP to note the relevance of overshoot scenarios for understanding future Antarctic change and its global implications. This information may be of value in discussions related to climate change impacts, long-term environmental trajectories, and communication of Antarctic science in broader international contexts.

[17] Sohail et a. (2025), https://doi.org/10.1088/1748-9326/adb31c.
[18] Caldeira & Duffy (2000), https://doi.org/10.1126/science.287.5453.620.
[19] Findlay et al. (2025), https://doi.org/10.1111/gcb.70238.
[20] Figuerola et al. (2021), https://doi.org/10.3389/fmars.2021.584445.
[21] Hönisch et al. (2012), https://doi.org/10.1126/science.1208277.