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Response of emperor penguins to changing ice conditions at the Astrid, Mertz, and Sanae colonies using satellite remote sensing (1984-2024)

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Emperor penguins are an iconic Antarctic species threatened by climate change. The birds are highly reliant on stable fast ice for successful breeding, and some studies project possible quasi-extinction for over 90% of colonies by 2100 due to future sea ice loss. Recent record-low Antarctic sea ice conditions highlight the threat to the species. In order to better model the future response of emperor penguins to climate change, and increasing extreme ice events in sea ice and at the margins of the ice sheet, it is essential to better understand how colonies have responded to past conditions. In this study we identify the location of the Sanae, Astrid, and Mertz colonies in all available Landsat 4-9, ASTER, and Sentinel-2 imagery, spanning the years 1984-2024. We manually record the location of the colonies through and between years, while also recording major calving events, early fast ice break-out, and distance to the fast ice edge. Colonies typically return to approximately the same sheltered sites annually throughout the 35-40 year period, but we observe variations due to major calving events. Following major calving events at Mertz and Sanae that disrupt breeding sites, colonies relocate to different sites where they may be more vulnerable to earlier fast ice break-out, or need to travel longer distances for foraging. In subsequent years the colonies eventually return to sites close to their original location. Additionally, we observe early fast ice break-out events that are likely to impact breeding success at Mertz and Sanae colonies, including as early as September at Mertz in 2016. Such events are related both to regional sea ice conditions and variations in colony location. Notably, we observe all three colonies to move onto the neighbouring ice shelf in some years (and at Mertz, onto icebergs too), including when stable fast ice is available. Observation of these behaviours contributes to broader understanding of emperor penguins' adaptability and will aid future efforts to model the response of the species to ice loss.