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A novel database of Antarctic meteorological extremes over key ice shelves during 1995-2023

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Abstract

The climate of Antarctica is showing increasing signs of being impacted by the warming trend in global temperatures, which has potential to result in accelerated break up of key ice shelves, which would contribute to global sea level rise. Here, we present a novel database of Antarctic extreme weather events over a selection of key ice shelves (Larsen, George VI, Wilkins, Abbot, Thwaites, Totten, Amery, Lazarev), using simulations from four regional climate models (RCMs: RACMO2, HCLIM, MetUM and MAR), driven by the ERA5 reanalysis, examining surface air temperature, precipitation, wind and surface pressure. In addition, we examine trends in the frequency of extreme events above or below specified thresholds (5th, 10th, 50th, 90th and 95th percentiles) and spatial atmospheric circulation and temperature anomaly patterns over Antarctica that are commonly associated with extreme events over key ice shelves. The RCM simulations have been compared with station observations close to the ice shelves, and we developed regressions to estimate simulated values during periods when only one or two of the RCMs were available.

Keywords: Antarctica, climate change, extreme weather events, regional climate models

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1. Introduction

There has been a growing amount of research into Antarctic extreme weather events in recent years, particularly given the potential for them to contribute to the break-up of key ice shelves. For example, high temperature events generate surface melting (Orr et al. 2023), which result in surface meltwater ponds over many ice shelves in austral summer. This can result in hydrofracturing (vertical fracturing) if the meltwater penetrates downward and enlarges existing fractures in the ice shelf (Scambos et al. 2000), which can potentially result in the break-up and collapse of the ice shelf (Lai et al. 2020). Strong winds can fuel ocean swells and waves and removal of nearby sea ice, which make the ice shelves susceptible to calving, and are also commonly associated with a warming föhn effect in the lee of high ground (Massom et al. 2018). On the other hand, extreme precipitation events, which predominantly fall as snow, tend to add to the surface mass balance over Antarctica and can offset ice mass losses caused by melting, and to reduce surface meltwater ponding (van Wessem et al. 2023).

The ice sheet mass balance over Antarctica has turned negative since the 1990s, with increased ocean-driven melting of ice shelves (Otosaka et al. 2022). Warm ocean currents also exacerbate increased melting and ice sheet collapse (Hanna et al. 2024). While the break-up of ice shelves does not directly cause sea level rise, the Antarctic ice shelves help to reduce the rate of flow of the Antarctic ice sheet into the ocean (buttressing) and to have the effect of shielding the ice sheets and glaciers from warm ocean currents, which limits Antarctica's contributions to global sea level rise (Wang et al. 2025), and so their disintegration contributes indirectly to sea level rise.

Atmospheric circulation patterns that commonly contribute to extreme weather events include variations in the Southern Annular Mode (SAM), the climatological Amundsen Sea Low and occurrence of atmospheric river events (Kolbe et al. 2026). The SAM is the leading mode of atmospheric circulation variability in the extratropical Southern Hemisphere (Rogers and van Loon, 1982, Thompson and Wallace, 2000) . A positive SAM sees a poleward shifted jet stream and intensification of the westerlies, which is linked with warming in the Antarctic Peninsula but cooling in central Antarctica (King et al. 2023). The Amundsen Sea Low is a dominant low pressure centre in the Amundsen Sea, where a weaker Amundsen Sea Low can lead to warm water intrusions into the ice shelves, contributing to melt (Hall et al. 2025).

Atmospheric rivers are narrow bands of abundant moisture and precipitation, associated with the poleward transport of air masses by hundreds of kilometres. These deliver persistent precipitation near windward coasts and strong föhn effects on the leeward side of high ground, such as over the eastern Antarctic Peninsula and the Larsen C Ice Shelf (Clem et al. 2022), and can result in exceptional warmth and precipitation in affected areas (Siegert et al. 2023). For example, the unusually extensive calving of the Brunt Ice Shelf in February 2021, which resulted in the A74 iceberg breaking off, was associated with a very deep depression which transported warm moist air into the region (Francis et al., 2022).

One particularly extreme example was the event in March 2022, which resulted in temperature anomalies (relative to the long-term average) well in excess of 30°C over some regions (Wille et al. 2024a). Anomalous easterly winds, associated with a stationary cyclone to the west of the atmospheric river, probably triggered the collapse of the Conger Ice Shelf, as well as exacerbating anomalously low sea ice extent in the region (Wille et al. 2024b).

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In February 2022, there was also an exceptional warming event over the Antarctic Peninsula (Gorodetskaya et al. 2023). While such events produced rain and exceptional ice melt near the coasts, precipitation fell predominantly as snow across Antarctica as a whole, and so the Antarctic ice sheets ended up with a record high surface mass balance and a positive net mass balance for the first time in records back to 1993 (Clem et al. 2023).

Teleconnections that commonly contribute to Antarctic extreme weather events include the El Nino Southern Oscillation (ENSO), and there are also interdecadal variations associated with the Interdecadal Pacific Oscillation (IPO) and the Atlantic Multidecadal Oscillation (AMO) (Pezza et al. 2012, Li et al. 2021). For example, deep convection in the tropical Pacific tends to result in atmospheric circulation anomalies that transport warm, moist air into the Antarctic, often via atmospheric rivers, Strong concurrent El Nino events, which are associated with anomalously high sea surface temperatures in the Pacific Ocean, can strengthen these moist warm air masses and increase the likelihood of extreme summer melting, as has been studied for example in West Antarctica (Nicholas et al. 2017).

Since 2009, major calving events have occurred over the ice shelves not just in the Antarctic Peninsula, but also at the Thwaites and Pine Island ice shelves in West Antarctica, and Nansen, Mertz, Brunt, Amery and Conger ice shelves in East Antarctica (Siegert et al. 2023). Interactions between the atmosphere and oceans, especially during extreme atmospheric conditions, as well as the condition of the ice shelves, likely all contribute to iceberg calving and the disintegration of ice shelves. This was the case with the calving of the Amery ice shelf on 25 September 2019, which was triggered by a combination of a long-term increase in rifts in the ice shelf and two explosive cyclones which brought atmospheric rivers and strong winds (Francis et al. 2022), as well as with the disintegration of part of the Conger ice shelf which was related to the March 2022 atmospheric river event.

The Antarctic Peninsula warmed considerably during the second half of the 20th century, with a temporary cooling during the 2000s and early 2010s, likely associated with a shift in the SAM to a negative state, which is consistent with natural variability (Turner et al. 2016), and then a resumption of the warming since the mid-2010s. Overall, over the Antarctic Peninsula there has been a linear positive trend in temperature of around +0.26 °C per decade over the period 1978-2020 (Carrasco et al. 2021). This has been associated with increased melt ponding over many of the Antarctic Peninsula ice shelves. Larsen A collapsed in January 1995 and Larsen B collapsed in 2002 (Siegert et al. 2023), and there have been several notable disintegration events affecting parts of the Wilkins Ice Shelf, most notably between 28 February and mid-July 2008 (Scambos et al. 2009). In the summer of 2019/20, an exceptional melt event affected the northern George VI ice shelf in the Antarctic Peninsula (Banwell et al. 2021), and to a lesser extent there was also widespread meltwater ponding on the north-western Larsen C, the eastern Wilkins, and the north-western Bach ice shelves. During this spell, a maximum of 18.3 °C was recorded at Esperanza station, which as of March 2026 remains the highest temperature on record on the Antarctic continent, enhanced by a local föhn effect (González-Herrero et al. 2022). Iceberg A68 broke off from Larsen C in 2017, which was one of the largest icebergs on record and raised concerns about potential decreased stability of what remained of Larsen C. While this happened through a natural calving process, it is possible that it may have been exacerbated by the warming climate (Rignot et al. 2021).

Despite a continued rise in global temperatures since 1979, the Antarctic sea ice extent showed a small but

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significant upward trend between 1979 and 2014, reaching a record maximum value on 20 September 2014 (Wang et al. 2019). However, Antarctic sea ice extent then declined dramatically between 2014 and 2016, which may have been linked with some exceptionally deep depressions and changes in wind patterns around Antarctica (Wang et al. 2019), leading to a strongly negative SAM (Chan et al. 2025). One stark example of this sort of feedback affected the Weddell Sea in the austral summer of 2016/17 (Turner et al. 2020), starting with record strength westerly winds in September 2016, pushing multi-year sea ice out of the region, and exceptional storms combined with a record negative phase of the Southern Annual Mode (SAM) in September, which also subsequently resulted in above-average ocean temperatures in the region.

The Antarctic sea ice extent remained close to record lows after 2016 and dropped further in 2022 and 2023, setting new record lows. This appears to have substantially modified air-sea interactions in the Southern Ocean and increased wintertime ocean heat loss to the atmosphere, and increased atmospheric storm frequency. There is evidence for this triggering a poleward shift in the jet stream (Zhu and Song, 2022). This may be associated with changes in deep ocean currents, and reduced sea ice may increase circumpolar deep water advection onto the Antarctic ice shelves (Josey et al. 2024).

There remain gaps in the understanding of the characteristics of the relationships between temperature, precipitation and wind variability and extremes over Antarctic ice shelves and impacts on melt potential due to sparse and unevenly distributed coverage of meteorological observations, and limitations in the resolution of model parametrisations that cannot capture or resolve small scale processes adequately, such as föhn winds and barrier winds (Orr et al. 2023).

In this study we produce and discuss a novel database of Antarctic meteorological extremes between 1995 and 2023 over a selection of key ice shelves (Larsen, George VI, Wilkins, Abbot, Thwaites, Totten, Amery and Lazarev), examining surface air temperature, precipitation, surface pressure and surface wind speeds, in identifying extreme events (for example, occurrences of exceptionally high temperatures or precipitation totals) over these ice shelves over the 30-year period.

We examine recurring atmospheric circulation characteristics associated with these events, and assess whether these extreme events have become more common and more extreme over the period, to provide a basis for improving the understanding of the key triggers for calving and disintegration of the ice shelves and addressing the gaps in the current understanding of these triggers. This study also aims to identify extreme events that have not been widely covered in the current literature, as well as comparing with well-known extreme events that have been widely discussed such as the March 2022 heatwave/atmospheric river event. Without an extremes database, extreme events can get overlooked if they have minimal impacts at the time, but they could, for example, contribute to impacts on ice shelves later on by undermining their stability.

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2. Data

To generate the database of Antarctic extreme weather events, we primarily used evaluation simulations over Antarctica from the four regional climate models (RCMs) that were used in the PolarRES dataset (Gilbert et al. 2025): RACMO2, HCLIM, MetUM and MAR. PolarRES was a multi-model ensemble run over the period 2000-2019 for Antarctica and the Southern Ocean, to help investigate the ocean-atmosphere-ice interactions in the Antarctic region in understanding how the Antarctic climate system may evolve with global and regional climate change. Each model used the same domain, resolution, forcing and time period, thus providing a mini-ensemble of RCMs covering Antarctica and the surrounding area. In some cases, we were able to obtain updated versions of the models and runs for a longer span of years. The details of these models are given in Table 1.

RACMO version 2.4 has been shown to perform well for variables including the surface mass balance, temperature and wind speed (van Dalum et al. 2025). HCLIM has been shown to represent precipitation better than the older HIRHAM5 model especially over steep mountains (Belušić et al. 2020), but has a known warm bias over the ice shelves, though in the PolarRES simulations, none of the four models performed any better or worse than the others overall (Gilbert et al. 2025).

All four models were forced by the ERA5 reanalysis (Hersbach et al. 2020). We did not use ERA5 directly in this study as ERA5 is at considerably lower horizontal resolution (~30 km) which means that localised topographic effects are more likely to be missed by the ERA5 reanalysis, and small-scale circulations such as cloud processes may also be better resolved.

Regional climate model	Version (if named)	Time period	Horizontal resolution
RACMO2	2.4pl	1995-2023	12 km
HCLIM		1995-2020	11 km
MetUM		2000-2020	11 km
MAR	3.13	2000-2020	12 km

Table 1. Characteristics of the RCMs used in the study.

To help validate the regional climate models against observations, we used automatic weather station data, obtained from BAS, using the READER dataset (Turner et al. 2004). Monthly data were obtained from https://www.bas.ac.uk/project/reader/#data and daily and sub-daily data were obtained via https://legacy.bas.ac.uk/met/READER/ANTARCTIC_METEOROLOGICAL_DATA/. The stations used, which were chosen due to their continuous long running records and their position on or adjacent to three of the key ice shelves, are shown in Figure 1. For this study we did not use the AntAWS dataset (Wang et al. 2022) as the highest resolution of AntAWS data that we had was 3-hourly, while the READER data are available at up to hourly resolution. Data from one of the three sites used, Fossil Bluff are only available from 2008 at finer than daily temporal resolution from AntAWS, while regular daily or sub-daily READER data for Fossil Bluff start in 2005. As precipitation data are not as reliable at Antarctic stations (for example issues due to blowing snow) it was not possible to validate the model simulations of precipitation over Antarctica, but validation of

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surface air temperature, pressure and winds proved possible by comparing station observations against RCM simulations for the corresponding model(nearest neighbour) grid cell.

To validate the RCMs, we compared station observations at Fossil Bluff (on the edge of the George VI ice shelf in the Antarctic Peninsula), Larsen Ice Shelf (also Antarctic Peninsula) and Amery G3 (Amery Ice Shelf, East Antarctica) against the model simulations of conditions at the grid box corresponding to those weather station sites, to provide some indication of the models' accuracy. George VI was selected as the first case study for this because of its position within the Antarctic Peninsula, its close proximity to a long-standing station at Fossil Bluff (which has continuous records from 2006, and partial records since 1961), and as a recent record breaking melt event occurred over the ice shelf during the summer of 2019/20 (Banwell et al. 2021). Larsen Ice Shelf has continuous records from 1985 to 2016, providing an overlap of up to 21 years with the RCMs, and Amery G3 has continuous records from 1999 to 2011.

For wider context, for example when examining extreme temperature and precipitation patterns over Antarctica associated with extreme months that were identified by the RCMs, we used plots derived from the ERA5 reanalysis (Hersbach et al. 2020).

3. Methods

High resolution vector polygons of the Antarctic coastline were obtained via Gerrish et al. (2020). From these, we extracted the polygons that corresponded to a selection of key Antarctic ice shelves, which were used as masks for analysis of the areal mean model simulated values of temperature, precipitation, surface pressure and winds. Figure 1 gives an example of the high resolution polygon for the George VI ice shelf.

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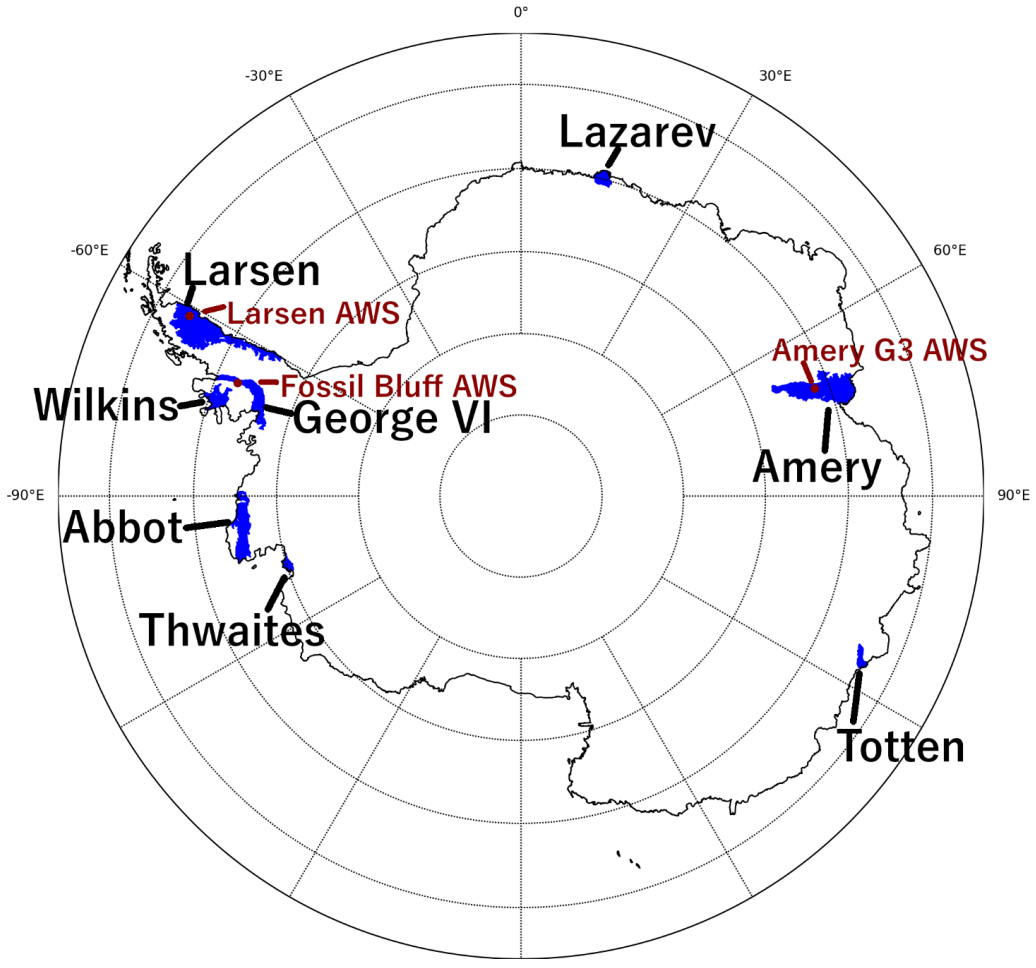

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196 Figure 1 The high resolution vector polygons corresponding to the ice shelves considered in the study, plotted
197 on a map of Antarctica. The three automatic weather stations used in the study are also shown.

198

199 Using the vector polygons from Gerrish et al. (2020), we extracted the grid cells that corresponded to a selection
200 of key Antarctic ice shelves (Table 1), and calculated the daily mean temperature, precipitation, surface pressure
201 and surface wind speeds averaged over the ice shelves, from hourly acquired data, for each of the four RCMs. In
202 each case the default rotated pole coordinates were converted to actual latitude and longitude points, temperatures
203 were converted to degrees Celsius, precipitation to mm day^{-1}, surface pressure to hPa and surface wind speeds to
204 m/s, also combining the u and v wind vectors to obtain the overall wind speeds. Hourly values were averaged or
205 summed to daily before calculating climatology and extremes.

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We developed a database of extreme weather events for Antarctic ice shelves, defining extremes as either one day exceeding the 2nd, 5th, 95th or 98th percentiles, or three consecutive days exceeding the 10th or 90th percentiles, for each day of the year. The one day exceeding the higher percentiles was chosen because the standard index which uses three consecutive days above the 90th percentile or below the 10th percentile may miss extreme events which were of shorter duration, but still potentially impactful over ice shelves. This was applied to each of the four variables (surface temperature, precipitation, surface pressure and surface wind speed).

Both a multi-model mean and ensemble approach were used. For the multi-model mean approach, for the common period 2001-2019, for which data from all four RCMs were available, daily values of temperature, precipitation, surface pressure and surface wind speed were generated based on the ensemble mean of the four RCMs. Percentiles for each day of the year were calculated based on this period 2001-2019, again based on the mean of the four models. In addition, in cases where not all of the models were available, we developed linear regressions of the form $y = ax + b$, where y is the estimated mean value based on the four models, and x is the value for the combination of models that is available, for each day of the year. This was done to estimate the differences between the estimated mean value using only one, two or three of the RCMs, and the estimated mean value based on the mean of the four RCMs. For periods (1995-2000 and 2020-2023) when some RCMs were not available, we applied the regressions to the mean of the models that were available for those periods, to provide an estimate of daily values that corresponds roughly to the result that may have been obtained from the mean of all four models, to retain consistency with the daily percentiles that were calculated over 2001-2019.

For the ensemble based analysis, percentiles for each day of the year were generated individually for each model for the common period 2001 to 2019, and each model's simulated daily value was compared against the percentiles of that model's own distribution, so that extreme events could be assessed on a model by model basis. They also provide counts of the number of models that exceeded particular thresholds for a given day, for we can generally have greater confidence in an extreme event if it was picked out by multiple RCMs, and especially if all four RCMs were available and pinpointed a particular extreme event. We calculated daily mean climatologies and percentiles for each ice shelf over all of the years from 2001-2019. To estimate the mean climatology while removing excess noise from the data, we applied a 3-point harmonic filter, following Bracegirdle et al. (2024), to the mean climatology, including the percentiles and the mean. For all ice shelves, an extreme event is defined relative to the smoothed percentiles (for example. 90th, 95th). We initially attempted analysis based on a 5-day moving average of the percentiles, but determined that, given the relatively short time span of observations, the 5-day moving average was not sufficient to remove the noise in the daily data associated with natural short-term variability. For example, this issue arises when daily percentiles are heavily influenced by one or two extreme events in a given year, which serves to obscure the thresholds corresponding to extreme events when performing an analysis of extremes above or below certain percentile thresholds, due to undersampling of the climatology (Risien and Chelton 2008, Narapusetty et al. 2009). It is also important to avoid over-smoothing and filtering out periodic variability that may be down to regional climate characteristics, so we determined that the 3-point harmonic filter was an optimal compromise.

We also derived monthly, seasonal and annual time series of temperature, precipitation, surface pressure and

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surface wind based on the four RCMs, including the individual RCM outputs and the mean of the four models. In addition, we produced time series of counts of extreme events by year and by season. Each of these series were compared with seasonal and annual time series of the El Nino Southern Oscillation (ENSO), Southern Annular Mode (SAM) and sea ice extent in the seas adjacent to the ice shelves (all derived from monthly data) to provide some context regarding the relationships between these modes of variability and mean and extreme weather over the ice shelves. The sea ice extent data were obtained from the National Snow and Ice Data Center (NSIDC), while SAM time series were obtained from the British Antarctic Survey, based on the methods of Marshall et al. (2003). ENSO data, based on the Multivariate ENSO Index Version 2, were obtained from the National Oceanic and Atmospheric Administration (NOAA): see Zhang et al. (2019).

When validating the RCMs by comparing with station observations, we extracted the models' estimated height above sea level for the corresponding grid point and applied a correction of 8°C per kilometre (as used for example by Hanna et al. 2011 in assessing Greenland Ice Sheet mass balance) to correct for the discrepancies, as due to model resolution and the variable topography around the edge of the ice shelves, the models commonly overestimate the height above mean sea level.

To validate the RCM simulations, for the initial analysis, we compared station observations from automatic weather stations with over 10 years of data within the 1995-2023 period that are located on or adjacent to key ice shelves. We determined the estimated elevation of the grid point from the surface elevation fields from the RCMs for basis of comparison as, particularly in regions of variable topography, the RCMs are prone to smoothing out topography and overestimating elevations. The true elevation of Fossil Bluff is 66m above mean sea level, but RACMO, HCLIM, MetUM and MAR had the corresponding grid point at 227m, 271m, 109m and 150m respectively. For the Larsen Ice Shelf site, there was less bias, with RACMO, HCLIM, MetUM and MAR simulating heights of 37m, 35m, 0m and 33m, compared with the actual site elevation of 43m. For the Amery G3 site, again MetUM had the simulated height at 0m but the other three models had the height simulated within 5m of the observed height of the site (84m).

In addition, we also examined the relationships between mean temperature, precipitation, pressure and wind, and counts of extreme events, with the sea ice extent over the seas adjacent to the ice shelves, together with the SAM and ENSO indices. For the sea ice analysis, rather than taking the overall Antarctic sea ice extent, which would mask regional variations in the sea ice extent, we created annual and seasonal series of Antarctic sea ice extent for the Amundsen-Bellingshausen, Indian, Pacific, Ross and Weddell Seas from the National Snow and Ice Data Center (NSIDC), based on Meier et al. (2023), so that seasonal and annual data for each ice shelf could be compared with the overall sea ice extent for the nearest adjacent sea.

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4. Results

4.1 RCM comparisons with station observations

Variable	RACMO	HCLIM	MetUM	MAR
Fossil Bluff				
Correlations				
Temperature (°C)	0.89	0.94	0.94	0.89
Pressure (hPa)	0.99	0.99	0.99	0.90
Wind (m/s)	0.71	0.70	0.80	0.27
RMSE				
Temperature (°C)	3.86	3.23	7.38	4.96
Pressure (hPa)	33.1	29.2	13.4	18.6
Wind (m/s)	2.00	2.17	1.93	3.03
Larsen Ice Shelf				
Correlations				
Temperature (°C)	0.94	0.95	0.96	0.91
Pressure (hPa)	0.90	0.89	0.99	0.82
Wind (m/s)	0.61	0.65	0.75	0.50
RMSE				
Temperature (°C)	3.70	3.51	3.01	4.44
Pressure (hPa)	5.20	6.61	1.55	6.44
Wind (m/s)	2.42	1.92	1.80	2.37
Amery G3				
Correlations				
Temperature (°C)	0.96	0.95	0.97	0.96
Pressure (hPa)	0.98	0.97	0.99	0.89
Wind (m/s)	0.84	0.79	0.88	0.72
RMSE				
Temperature (°C)	3.20	6.36	2.37	2.93
Pressure (hPa)	8.84	11.2	1.72	11.1
Wind (m/s)	4.32	6.05	5.08	4.63

Table 2. Correlations between the model simulations of daily values and Antarctic automatic weather station observations used for comparison with RCMs at the three sites, over 2005-2023 (Fossil Bluff), 1995-2016 (Larsen Ice Shelf) and 1999-2011 (Amery G3). The root mean square error of the correlations (RMSE) is also shown. Due to the large sample size (daily data), all correlations were significant at the 99% level ($p < 0.01$).

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Correlations with temperature observations at each of the sites were reliably high ($p < 0.01$ in all cases), but higher in the case of HCLIM and MetUM than for/of MAR. For surface pressure, correlations with observations were higher, but lower for MAR than for the other models. For surface wind speed, correlations with observed values were lower, but again substantially lower in the case of MAR than the other models, particularly in the case of Fossil Bluff. The lower correlations with wind speed observations can be explained by the relatively limited model resolution failing to capture variations in topography that create localised differences in wind speeds depending on the wind direction and the specific pressure pattern. The root mean square error (RMSE) varied between models depending on the ice shelf, but the larger RMSE for HCLIM compared with the other models in the case of Amery G3 may be linked with the summer warm bias shown in Figure 2 (see also Fig. 9 in Gilbert et al., 2025).

A further comparison (see Figure 2) to test the model simulations of extreme weather events, was to plot daily station temperature, and the 95th percentile of the station temperature (x axis), and model simulations of daily temperature minus daily station temperature. For temperature (Figure 2), the results comparing Amery G3 with observations particularly show HCLIM having a strong warm bias, but mainly on occasions when temperatures at Amery G3 were between 0 and 10°C below the 95th percentile, and not when temperatures exceeded the 95th percentile. Further analysis which broke the results down by season (Figure 3) suggest that the HCLIM warm bias comes mainly from summer (DJF). The plots for the other three models in Figure 2 suggest a small tendency to underestimate extreme high temperatures, except in the case of Fossil Bluff, where MetUM has a large underestimate especially for low temperatures, and MAR a large overestimate.

The HCLIM warm bias proved to be less strong when comparing the model simulations with the observations over Fossil Bluff at the edge of the George VI ice shelf, and over the Larsen Ice Shelf, but there was still a warm bias in summer, with values mostly in the range of 2 to 10 °C, rather than approaching 20 °C as in the case of Amery. This implies that HCLIM should be used with caution when assessing the magnitude and likely impacts of warm summer events over Antarctica.

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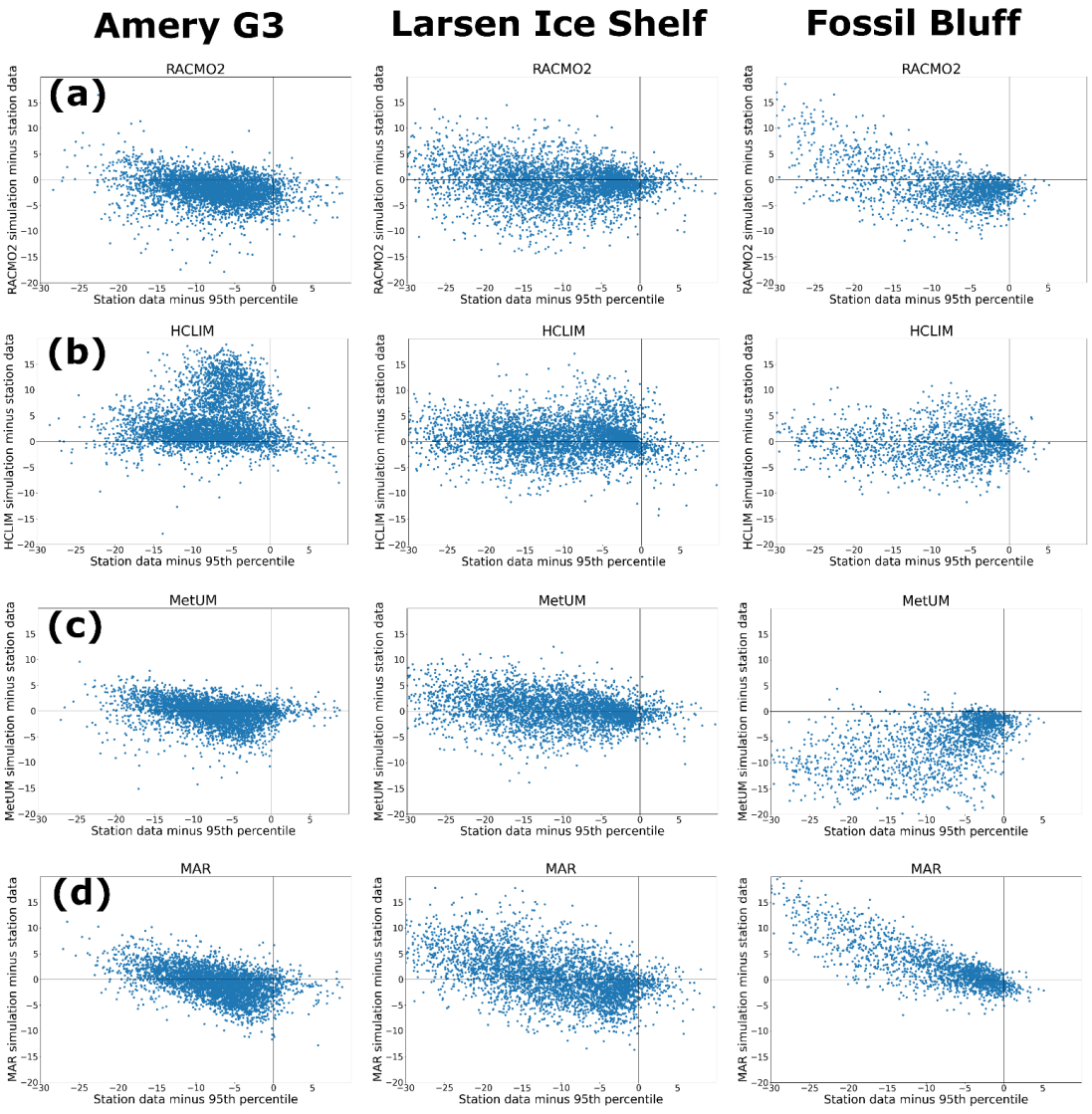

Figure 2. Comparisons between the station temperature minus the 95th percentile of the station temperature (x axis), and model simulations of daily temperature minus daily station temperature (y axis), for (a) RACMO2, (b) HCLIM, (c) MetUM and (d) MAR, for all data. Amery G3 data were available over 1999-2011, Larsen Ice Shelf over 1985-2016, and Fossil Bluff over 2005-2023. Points to the right of the vertical line indicate daily temperatures that exceeded the 95th percentile of the model data. Temperatures are in °C.

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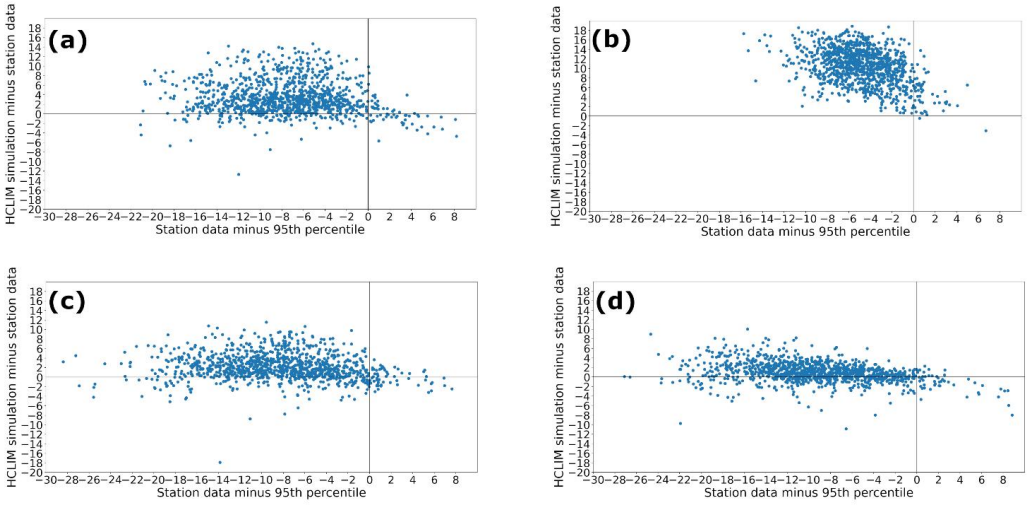

Figure 3. Comparisons between daily station temperature and the 95th percentile of the station temperature (x axis), and HCLIM simulations of daily temperature minus daily station temperature (y axis), for Amery G3, for (a) spring, (b) summer, (c) autumn and (d) winter. The warm bias is most evident in summer and reduces to near zero in winter. Temperatures are in °C.

The results for surface pressure (not shown) show greater consistency between the models for Fossil Bluff, but with some evidence of HCLIM and MetUM overestimating the extremes of pressure. For wind speed (not shown), the graph for MAR suggests that MAR underestimates extreme high wind speeds at Fossil Bluff. For the Larsen and Amery sites, the results consistently pointed to the models being consistent with observations or slightly underestimating the extremes.

4.2 The extremes database

4.2.1 Consistent model differences across the different ice shelves

When considering the percentile distribution of the individual RCMs, one feature that stands out is that HCLIM consistently simulates higher temperatures than the other three models during the summer months, especially January, and the difference is largest for the cold extremes. For example, averaged over the Abbott ice shelf over the month of January (Tables 3 and 4), the 2nd percentile averages -10.1°C according to RACMO2, -10.0°C according to MetUM, -8.3°C according to MAR, but the HCLIM value is -3.0°C. HCLIM also simulates higher high extreme temperatures, but to a lesser extent, with HCLIM tending to produce 90th, 95th and 98th percentiles that are 1 to 2°C higher than the other models, as opposed to as much as 7°C higher for the 2nd percentile. The difference is present for all ice shelves, but is stronger over some ice shelves than over others. For example, over

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the Antarctic Peninsula ice shelves at Larsen and George VI, HCLIM simulates warm extremes that are around 3°C higher than the other models, and over Amery the 98th percentile of HCLIM is over 8°C higher than for the other models. This does not appear to bias the statistical distribution of extreme events, as events that appear as extremes on the other three models also predominantly appear in the HCLIM extremes. However, it implies that HCLIM has some temperature biases that may affect simulations of surface melt over some of the ice shelves, due to simulating longer periods with above freezing temperatures and potentially rain instead of snow. Similar HCLIM temperature biases were also found over various regions of Antarctica in the PolarRES model analysis of Gilbert et al. (2025). Other consistent issues include a tendency for MetUM and RACMO2 to simulate a larger range of temperatures (for example, higher 95th percentile, lower 5th percentile) than the other models, with MAR simulating the lowest range, which is consistent with the results of the extremes analysis in section 4.1.

Model	Larsen	George VI	Wilkins	Abbot	Thwaites	Totten	Amery	Lazarev
RACMO2	-6.6	-7.6	-6.1	-10.1	-10.7	-10.7	-10.8	-10.0
HCLIM	-2.7	-1.6	-3.0	-3.1	-3.7	-3.5	0.5	-2.9
MetUM	-7.5	-8.8	-8.0	-10.1	-10.4	-8.6	-3.9	-10.2
MAR	-7.6	-6.5	-7.5	-8.4	-8.7	-11.0	-12.4	-12.2

Table 3. Model simulated mean daily 2nd percentile temperatures in degrees Celsius for the month of January, over each of the ice shelves.

Model	Larsen	George VI	Wilkins	Abbot	Thwaites	Totten	Amery	Lazarev
RACMO2	1.0	1.3	1.8	0.5	-0.4	-0.2	-1.0	-0.8
HCLIM	4.5	2.7	2.0	1.4	1.5	0.4	8.7	2.4
MetUM	0.4	1.3	1.3	0.5	0.4	-0.1	0.4	-0.4
MAR	1.6	1.7	1.3	-0.5	-0.8	-0.0	-2.0	-1.6

Table 4. As Table 3 but showing the mean daily 98th percentile temperatures for January

A sample plot of the four models' simulations of temperature over the Larsen ice shelf during the calendar year 2006, which includes the percentile distributions, is shown in Figure 4. All four models pick out an extreme winter warm spike at the end of June 2006, and simulate temperatures exceeding the 95th percentile in several spells during January and February 2006. The HCLIMsummer warm bias is also evident over Larsen, with 95th and 98th percentiles coming out close to 5°C while the other three models produce 95th and 98th percentiles close to 0°C.

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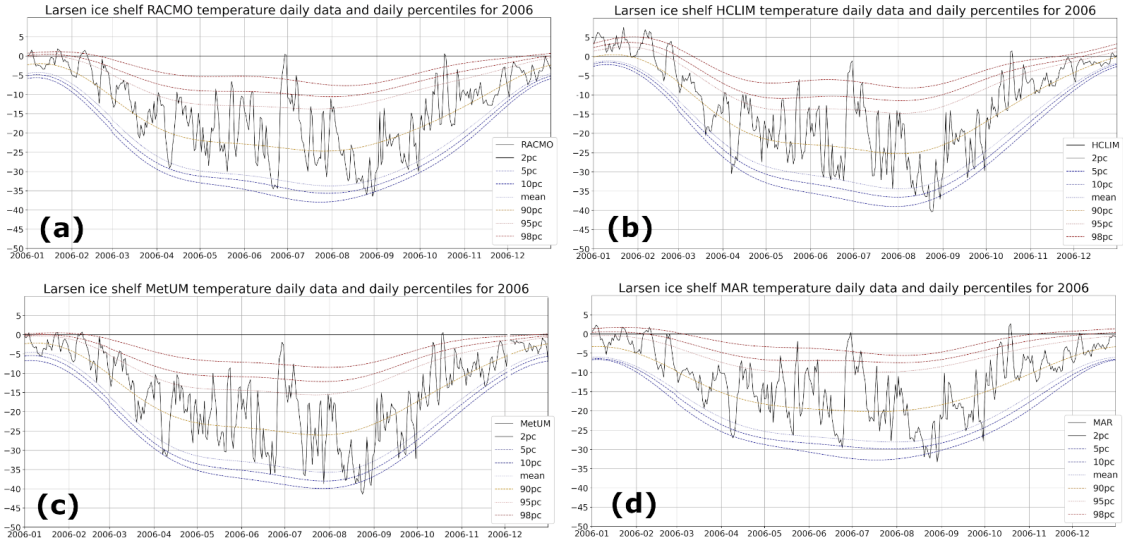

Figure 4. Model simulations of daily surface temperature (°C) over the Larsen ice shelf for 2006, using (a) RACMO2, (b) HCLIM, (c) MetUM and (d) MAR, and daily percentiles for the common period 2001-2019.

Considering the other three variables (not shown), considering the whole 1995-2023 period in the study, there are no strong systemic differences in extreme values between the models for precipitation, but MAR consistently simulates lower wind speeds than the other models, with RACMO2 simulating the highest wind speeds. For surface pressure, MetUM consistently simulates higher pressure than the other models, typically by around 5 hPa, but as with the HCLIM winter warm bias, this appears to be a largely systemic difference that does not affect the detection of extreme events.

4.2.2 Trends in annual and seasonal mean values and in counts of extreme events

Examining trends in annual and seasonal mean values and extremes over the Antarctic ice shelves is currently problematic due to the relatively short time span of the extremes database (1995-2023, 29 years). With a few exceptions, trends in both mean and extreme temperature and precipitation have been weak over the ice shelves over the period. Exceptions include a positive trend in high temperature extremes in spring over Amery, an overall annual (but not seasonal) increase in extreme high precipitation events over Larsen, an increase in extreme summer precipitation events over Thwaites, and a decrease in extreme summer high temperatures over Wilkins. Figure 5 shows the annual and seasonal counts of daily extreme temperatures above the 95th percentile, while Figure 6 is as Figure 5 but for precipitation extremes, both using the model mean. The annual counts of extreme events show signs of an increase in extreme events after 2015, when the overall Antarctic sea ice extent dropped from setting record highs to increasingly setting record lows, but due to regionally large interannual variability 2016-2023 is too short a time period to be able to draw clear conclusions from, and not long enough to produce strong overall upward trends in extremes over the period considered. Instead, of more interest are periods of

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multi-year persistence and variability. Most of the ice shelves saw at least one year with an unusually high number of extreme high temperature events during the period 1995-1998, comparable to those of more recent years such as 2016, 2019 and/or 2020, which contributed to the recent extreme years generally failing to result in an overall increasing trend in temperature extremes during the period. The lack of a significant warming trend in the study over the Antarctic Peninsula ice shelves is likely due to the choice of period, which sees relatively warm temperatures early and late and a cooler period around the early 2010s (Turner et al. 2016), and also the high inter-annual temperature variability that characterises the region.

Over the Antarctic Peninsula ice shelves of George VI, Larsen, and nearby Wilkins, 1998 and 2016 were extreme warm years, both in terms of mean temperature and extreme high temperature events, but most of the extreme warm events of those years happened in the winter half-year, leading to relatively limited impacts on the ice shelves. Larsen also had a high number of extreme precipitation events in 2017.

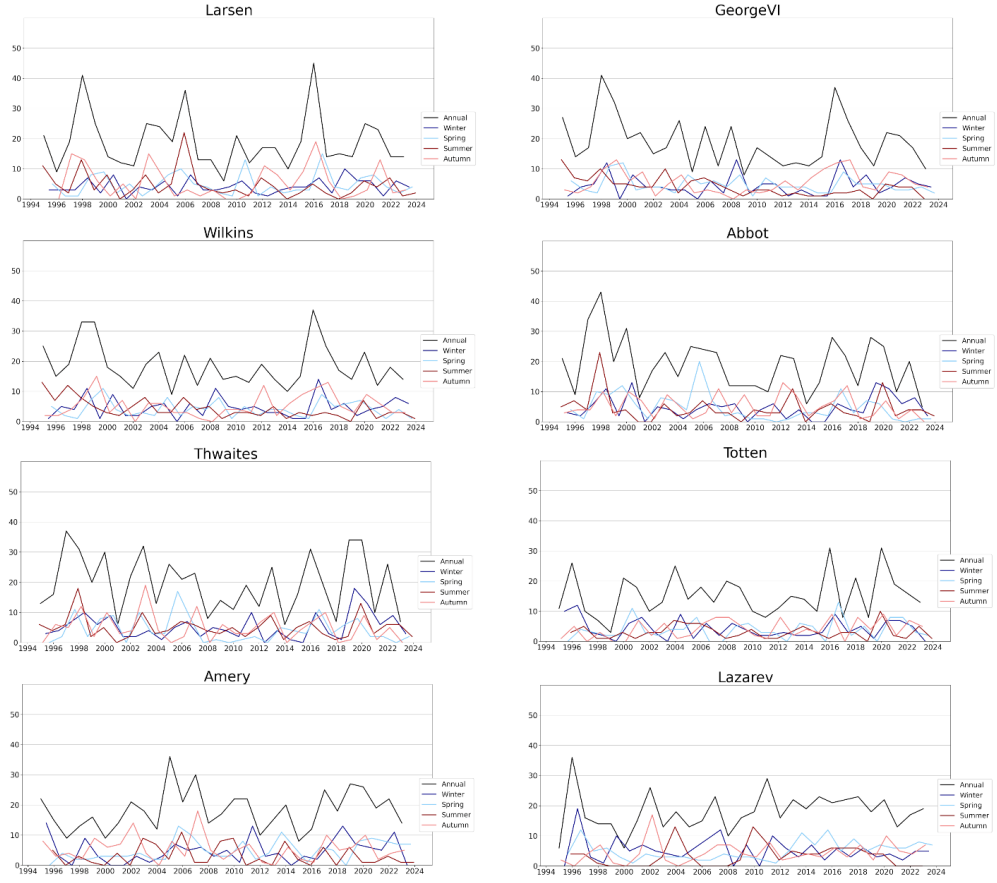

Figure 5. Seasonal and annual counts of daily temperature (°C) events (number of days) above the 95th percentile over the eight ice shelves.

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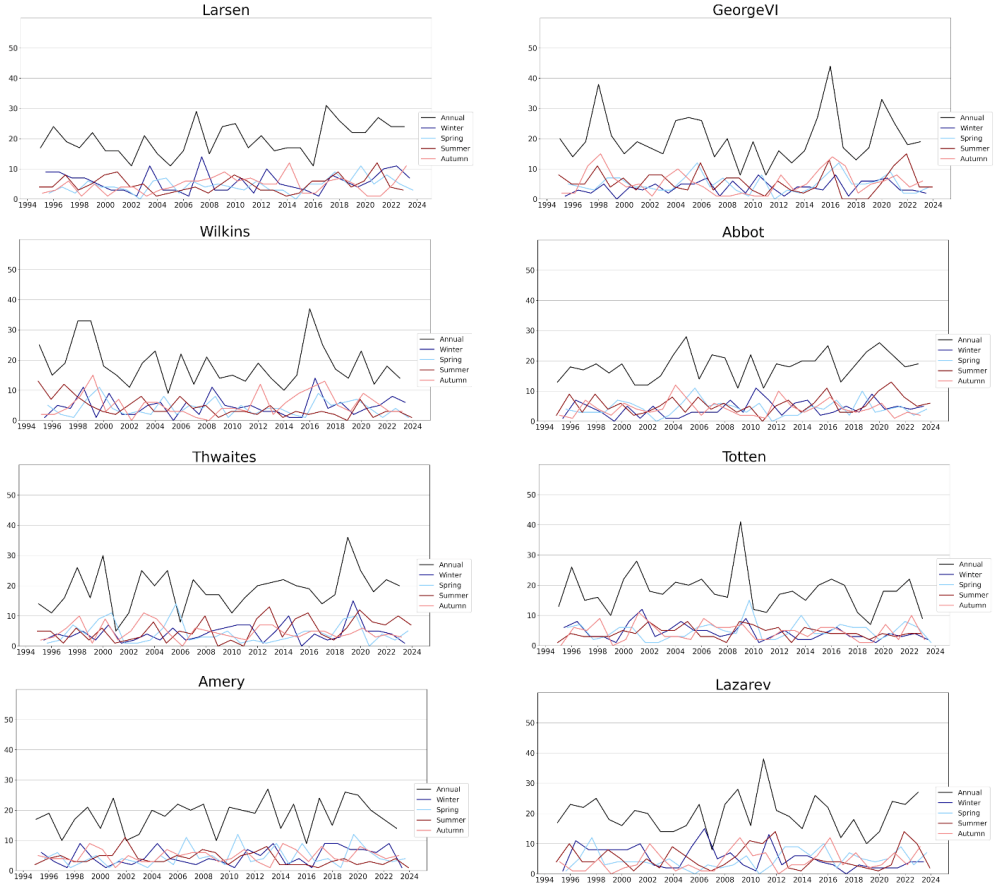

Figure 6. Seasonal and annual counts of daily precipitation (mm) events (number of days) above the 95th percentile over the eight ice shelves.

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Over Thwaites, 2019 stands out as an extreme year, having had the highest number of days with extreme high precipitation, the highest annual mean temperature, and it also had among the highest counts of extreme warm temperature events, but not as high as 1997. Most of the extremes of 2019 were clustered in winter and early spring, but the summer of 2019/20 contained numerous extreme high temperature events. Over Abbot, 2016, 2019 and 2020 all had a high number of extreme high temperature events. Breaking it down by season, 2019/20 was a recent extreme summer over Thwaites and Abbot, but again not more extreme than several earlier years in the late 1990s and early 2000s.

Over Totten, 2016, 2018 and 2020 stand out as having a high number of extreme temperature events, but not as extreme years for precipitation, while recent years do not stand out as having high counts of extreme events over Amery and Lazarev.

Comparing the SAM, ENSO and Antarctic sea ice with mean temperature, precipitation, pressure and wind, the results suggest that the SAM is positively linked with both annual mean temperatures and extremes around the Antarctic Peninsula (Table 5), but significantly negatively correlated with annual mean temperature (but in most cases not temperature extremes) over the Totten, Amery and Lazarev ice shelves, bordering the Pacific and Indian Oceans, as was also found by Orr et al. (2023). In spite of the El Nino years of 1998 and 2016 having been exceptionally warm around the Antarctic Peninsula, mean annual temperatures over George VI and Wilkins have significant negative correlations with ENSO. .Correlations of annual mean temperature and annual counts of extremes were mostly negatively correlated with sea ice extent, but in most cases not significantly so ($p > 0.05$), and when considering individual seasons (not shown), the relationships were weaker than when examining annual data. Both annual mean precipitation and extreme precipitation events over the 95th percentile were strongly negatively correlated with sea ice extent over Larsen ($p = 0.011$ in both cases), but not the other ice shelves.

Over Thwaites, ENSO and sea ice extent proved to be negatively related to extreme high winds over the 95th percentile (Table 8), and there was also a strong negative correlation between sea ice extent and wind extremes over the Totten ice shelf, but otherwise correlations between these indices and extreme winds tended to be weak. The SAM was negatively linked with high surface pressure extremes over the Antarctic Peninsula ice shelves during the period (Table 7). Tables 5 and 6 provide a summary of the correlations between temperature and precipitation and the three potential drivers of extreme weather events.

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Variable	Larsen	George VI	Wilkins	Abbot	Thwaites	Totten	Amery	Lazarev
Mean annual temperature								
ENSO	0.10	**-0.38**	**-0.38**	-0.14	0.13	0.10	0.14	0.22
SAM	0.32	**0.37**	**0.44**	0.07	0.08	**-0.53**	**-0.50**	**-0.53**
Sea ice extent	-0.20	-0.25	-0.34	**-0.63**	-0.15	-0.21	0.21	**-0.46**
Annual count of daily temperature events above the 95th percentile								
ENSO	0.26	-0.13	0.11	**0.39**	**0.38**	-0.03	-0.17	-0.03
SAM	**0.41**	**0.48**	0.33	-0.07	0.09	-0.11	-0.27	-0.35
Sea ice extent	0.01	-0.30	-0.21	-0.34	**-0.37**	0.17	-0.08	-0.34

Table 5. Correlations between mean annual temperature and annual counts of daily temperature over the 95th percentile and three potential drivers of extreme events, with bold indicating significance at p <= 0.05, and underline indicating significance at p <= 0.01.Correlations are based on calculating annual mean values of ENSO, SAM and sea ice extent against annual counts of extreme events in the database.

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Variable	Larsen	George VI	Wilkins	Abbot	Thwaites	Totten	Amery	Lazarev
Mean annual precipitation								
ENSO	**-0.46**	0.24	0.16	0.00	0.12	-0.16	-0.08	0.02
SAM	0.13	**0.41**	**0.48**	0.32	0.04	-0.01	-0.03	0.18
Sea ice extent	**-0.47**	-0.19	-0.18	-0.32	-0.18	-0.31	**0.37**	-0.29
Annual count of daily precipitation events above the 95th percentile								
ENSO	-0.16	0.26	0.11	0.02	0.14	-0.16	-0.22	-0.11
SAM	0.00	0.26	**0.51**	0.25	0.16	0.06	0.06	0.15
Sea ice extent	**-0.47**	-0.20	-0.29	-0.08	0.02	-0.22	0.04	-0.16

Table 6. As Table 5, but examining mean and extreme precipitation.

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Variable	Larsen	George VI	Wilkins	Abbot	Thwaites	Totten	Amery	Lazarev
Mean annual pressure								
ENSO	0.15	0.28	0.33	**0.37**	0.34	-0.21	0.05	0.01
SAM	**-0.73**	**-0.72**	**-0.70**	**-0.76**	**-0.76**	**-0.37**	**-0.85**	**-0.82**
Sea ice extent	0.24	-0.16	-0.17	-0.06	-0.02	0.02	-0.21	0.07
Annual count of daily pressure events above the 95th percentile								
ENSO	0.21	0.30	0.30	0.04	0.16	-0.30	0.04	-0.35
SAM	**-0.60**	**-0.50**	**-0.52**	**-0.59**	**-0.59**	**-0.60**	**-0.63**	**-0.59**
Sea ice extent	0.09	-0.01	-0.07	-0.15	-0.12	-0.16	0.08	-0.03

Table 7. As Table 5, but examining mean and extreme pressure.

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Variable	Larsen	George VI	Wilkins	Abbot	Thwaites	Totten	Amery	Lazarev
Mean annual wind speed								
ENSO	-0.13	-0.33	-0.29	-0.31	-0.34	-0.20	-0.17	-0.23
SAM	**0.38**	**0.44**	**0.52**	**0.41**	**0.39**	0.35	0.32	0.33
Sea ice extent	**-0.45**	-0.01	-0.06	-0.04	-0.01	-0.14	-0.34	**-0.46**
Annual count of daily wind speed events above the 95th percentile								
ENSO	0.33	-0.17	-0.11	-0.24	**-0.38**	-0.01	0.03	-0.07
SAM	-0.14	0.09	0.34	0.19	0.24	-0.05	0.03	0.27
Sea ice extent	0.20	-0.26	-0.08	-0.34	**-0.36**	**-0.53**	0.06	-0.01

Table 8. As Table 5, but examining mean and extreme wind speeds.

4.3 Case studies

4.3.1 Extreme events in the late 1990s and 2000s

The Larsen A ice shelf disintegrated between January and March 1995, losing half of its floating area in the last week of January (Royston and Gudmundsson, 2016). This analysis starts only in January 1995, but January 1995 was an anomalously warm month over the Antarctic Peninsula (Figure 7), with two separate warm events where temperatures over the ice shelf were simulated to be well above freezing and well above the 98th percentile on two separate occasions during the month – the 9th/10th January and between the 24th and 26th January (Figure 8). There were also exceptionally strong winds, well above the 98th percentile, on the 25th January, indicating that a substantial storm affected the region. In contrast, most of the rest of Antarctica had temperatures below the 1981-2010 average.

Larsen B disintegrated during February and March 2002 (Scambos et al. 2004). Unlike the Larsen A disintegration, this extremes database suggests that any contribution from surface weather conditions to the disintegration of Larsen B was probably cumulative rather than caused by individual extreme events (Fahnestock et al. 2002). Temperatures were persistently above the 1981-2020 long-term average over the Larsen ice shelf, and the Antarctic Peninsula generally, between mid-September 2001 and early March 2002, but not exceptionally so. An extreme wind and precipitation event is picked out for 10/11 March 2002, but this was after the period of peak decline over Larsen B.

February 2006 stands out as an extreme month over West Antarctica, a month which saw exceptional melting over the nearby Peter 1st Island in the Bellingshausen Sea (Thomas et al. 2024). The warmth affected a large area. The extremes database picks out extreme warm events in February 2006 affecting the Larsen, George VI, Wilkins, Abbot and Thwaites ice shelves, with two marked ones early and late in the month, also accompanied

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by unusually high precipitation. Mean sea level pressure anomaly charts from February 2006 (Figure 7) show a strong high pressure anomaly over the Peninsula, shifted south from its position in January 1995. However, this extreme month appears not to have been associated with substantial impacts on the ice shelves of mainland Antarctica., as we are unable to find any relevant reports in the literature. The extremes database also picks out an exceptional winter storm in late June 2006, with exceptionally high temperatures accompanied by high precipitation and strong winds, especially affecting the Peninsula. June 2006 also had a similar mean sea level pressure anomaly pattern to January 1995, with anomalously high pressure off the coast of the Peninsula. However, with temperatures modelled to be just below freezing over Larsen, George VI and Wilkins, it may not have been warm enough to cause substantial melting.

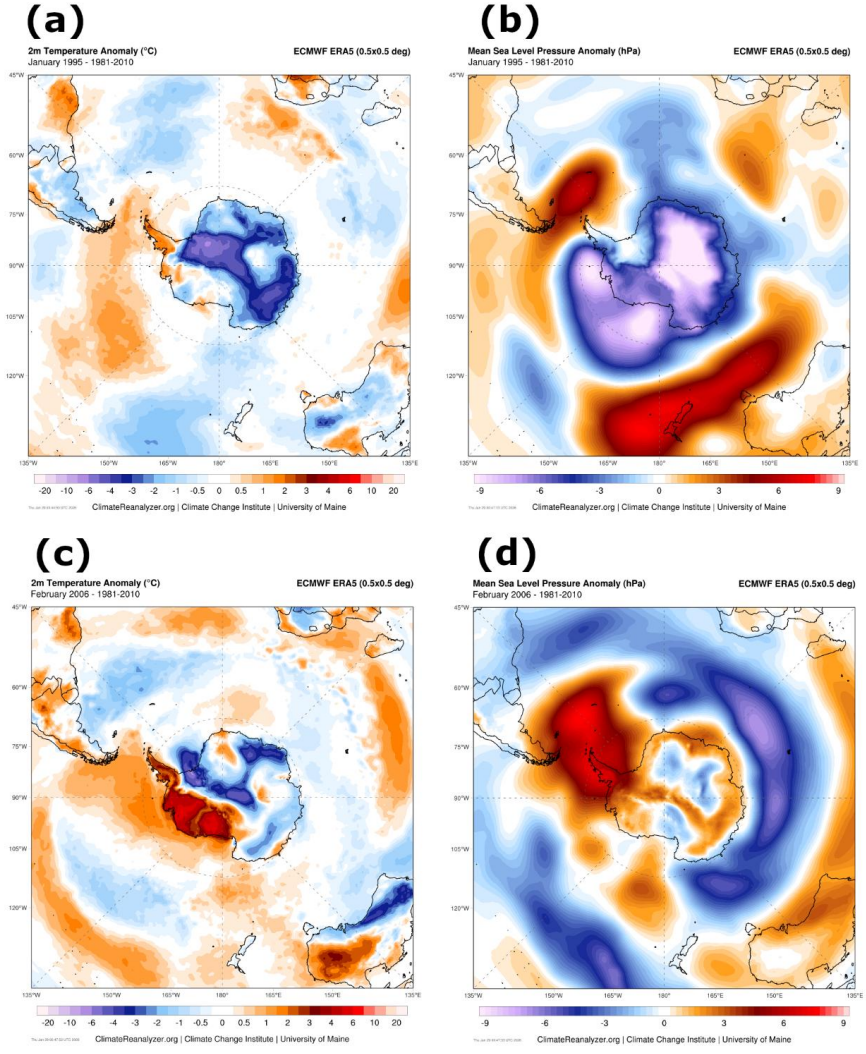

Figure 7. (a) and (b) show the mean 2m temperature anomaly in °C and mean sea level pressure (hPa) anomaly respectively, relative to 1981-2010, for January 1995. (c) and (d) are as (a) and (b), but for February 2006. All charts are courtesy of Climate Reanalyzer.

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The succession of calving events at the Wilkins ice shelf between February and July 2008 does not appear to have been associated with a particularly extreme year. However, the summer of 2007/08 was generally warmer than average except for a cool first half of January, and there were two temperature spikes in quick succession exceeding the 95th percentile on 11 and 15 February 2008, which could have helped precondition the ice shelf for some melting later in the season.

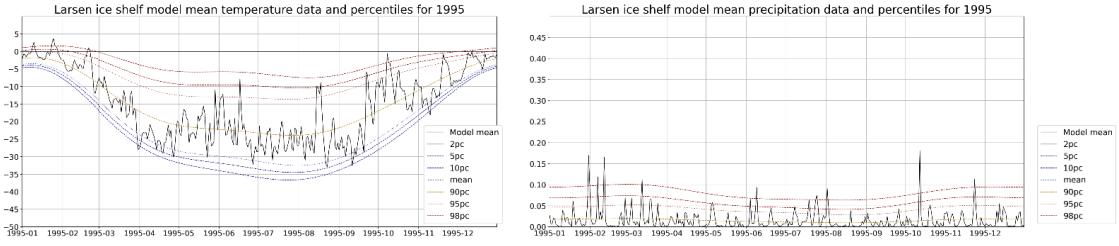

Figure 8. Model simulations of daily surface temperature and daily surface wind speed over the Larsen ice shelf, compared with daily percentiles over 2001-2019, for 1995, based on the mean of the available models (RACMO2 and HCLIM for 1995).

4.3.1 Extreme events since 2016

Although the unusual conditions over the Weddell Sea in the 2016/17 season are not associated with any notable extremes in this Antarctic extremes database, Figure 9a shows that March 2017 showed strong positive monthly temperature anomalies of up to 8°C over West Antarctica and the Peninsula. Again, it was characterised by anomalously high pressure over the coastal Peninsula (Figure 9b), perhaps leading to westerly winds and a föhn effect in some regions. Temperatures were persistently high, and sometimes in excess of the 98th percentile, over Larsen, George VI, Wilkins, Abbot and Thwaites, and averaged over Wilkins the temperature is simulated to be just above freezing on several days during the month. This may have been linked with an exceptionally low Antarctic sea ice extent at the beginning of March 2017, which was particularly low around West Antarctica (Figure 9c, Turner and Comiso, 2017).

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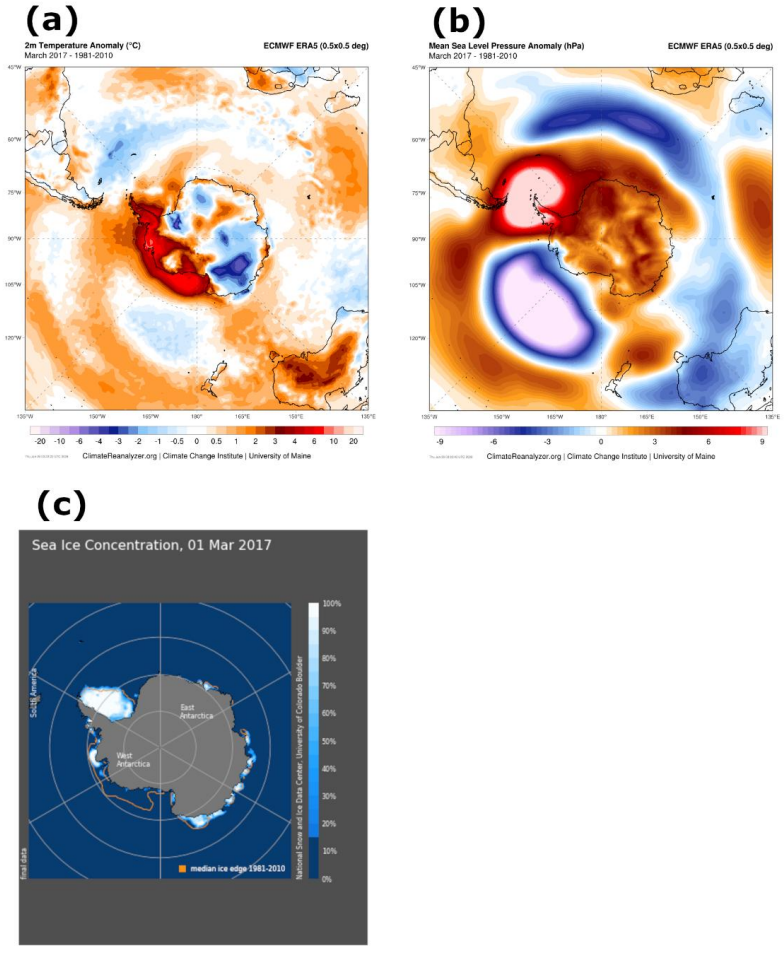

Figure 9. (a) The mean temperature anomaly in °C over Antarctica relative to 1981-2010 for March 2017, courtesy of Climate Reanalyzer. (b) The mean sea level pressure anomaly in hPa over Antarctica relative to 1981-2010 for March 2017, also courtesy of Climate Reanalyzer. (c) Sea ice extent and anomaly on 1 March 2017, courtesy of the National Snow and Ice Data Center.

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532 The calving event on the Amery ice shelf on 25 September 2019 is not picked out by the extremes database as
533 being associated with extreme temperatures, precipitation or wind, although temperatures were persistently above
534 the 1981-2010 average over Amery during the second half of September 2019, exceeding the 95th percentile on
535 20 September.

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The summer of 2019/20, which had an exceptional melt over the northern George VI ice shelf (Banwell et al. 2020, Xu et al. 2021), stands out as an extreme summer over the Antarctic Peninsula (Figure 10). Over George VI, the mean temperature over the ice shelf is simulated to repeatedly reach close to or just above freezing between late November 2019 and mid-March 2020. An extreme event is picked out over Larsen between 6 and 10 February 2020, with temperatures exceeding the 98th percentile on the 6th, 8th, 9th and 10th, accompanied by precipitation totals exceeding the 95th percentile (not shown). Over Abbot and Thwaites, the 2019/20 season also sticks out as an extreme one except for January 2020, which had close to average temperatures.

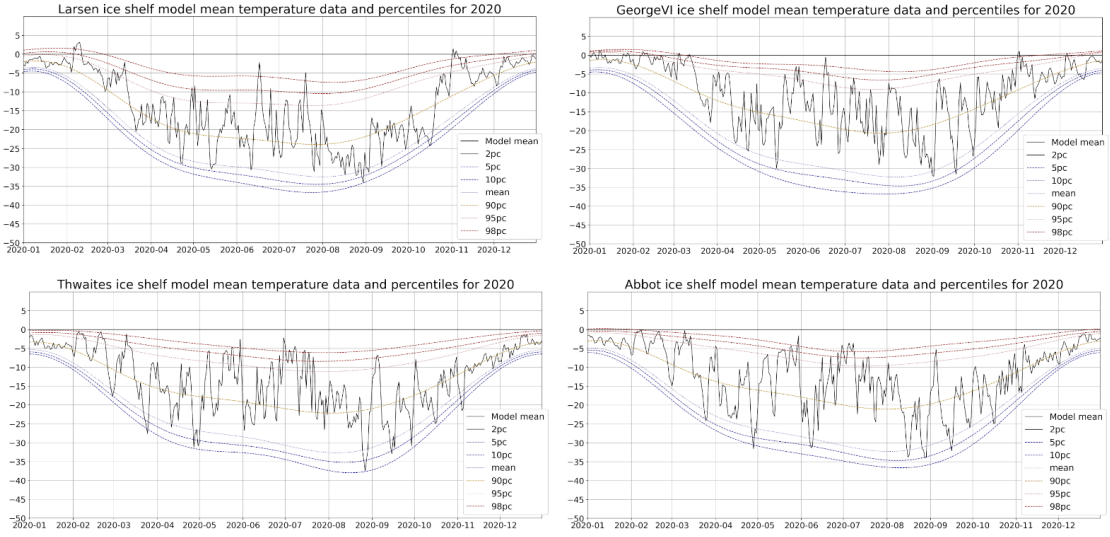

Figure 10. Based on the mean of the available models, simulated daily temperature in °C over the Larsen, George IV, Thwaites and Abbot ice shelves for 2020, and daily percentiles for 2001-2019.

As noted in the introduction, there was an exceptional atmospheric river event in March 2022 over East Antarctica. A caveat when analysing this event is that of the four models used in this analysis, only RACMO2 was available for March 2022. Nonetheless, RACMO2 picked out four consecutive days of temperatures exceeding the 98th percentile over the Totten ice shelf from 16-19 March 2022 (Figure 11), combined with unusually strong winds and unusually high precipitation amounts, exceeding three times the 98th percentile. Temperatures are, however, simulated to be just above -5°C, which is consistent with the observation of Clem et al. (2023) that rain and extensive melting along the coast was outweighed by snow accumulations inland, leading to a net increase in the ice mass balance. However, the event produced temperatures that are rarely exceeded in heatwaves even in high summer, and were a similar atmospheric river event to happen in high summer instead of March, the impacts may be very different. In addition, the event contributed to the collapse of the nearby Conger ice shelf (Wille et al. 2024a). Temperature extremes exceeding the 98th percentile by over 1°C are picked out afterwards over the Amery ice shelf on 22/23 March 2022, perhaps associated with the atmospheric river moving from west to east around East Antarctica but reducing in intensity as it headed between Totten and Amery. As this atmospheric river primarily affected East Antarctica, it does not show up as an extreme weather event over the other ice shelves.

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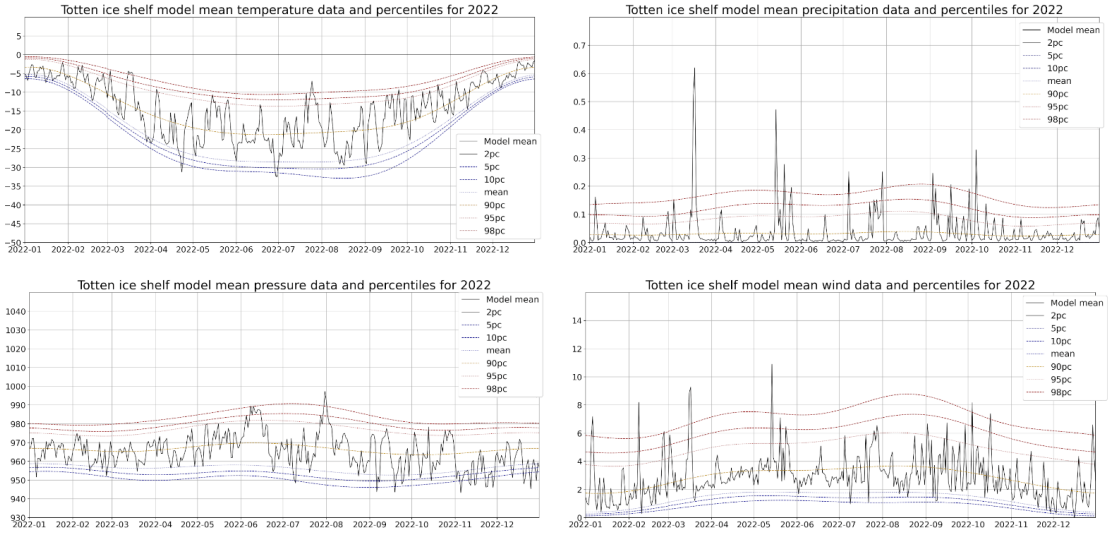

Figure 11. RACMO2 simulated daily surface temperature (°C), precipitation (mm), surface pressure (hPa) and wind speed (m/s) data for 2022, and daily percentiles from 2001 to 2019, for the Totten Ice Shelf.

5. Discussion

We have developed a database of Antarctic meteorological extremes that identifies a succession of warm summers in the mid to late 1990s, especially over the Antarctic Peninsula and West Antarctica, followed by a lull in the late 2000s and early 2010s, and then an increase again after around 2015. This is reflected both in the mean temperature time series and in the distributions of extreme temperature events, with most of the ice shelves considered having at least one extreme year for high temperature events between 1995 and 1998, and having at least one more in 2016, 2019 and/or 2020. Although several of the ice shelves had exceptional warm years in 1998 and 2016, which corresponded to strong El Nino events, there does not appear to be a strong overall link between high temperatures and ENSO in most cases.

While many of the known extreme ice shelf melt or breakup events over the ice shelves correspond to extreme values of temperature, precipitation, wind or pressure, some do not, such as the disintegration of Larsen B in early 2002 (van den Broeke, 2005), and the calving event over the Amery ice shelf on 25 September 2019 (Francis et al., 2022). It is possible that the extreme conditions in the Weddell Sea documented by Turner et al. (2017) may not have strongly affected the Amery ice shelf directly and that impacts from the ocean may have been a more important cause than the surface weather over Amery. However, for example, the disintegration of Larsen A in January 1995, the extreme melt over George VI in summer 2019/20, and the atmospheric river of March 2022, do correspond to extreme weather events in the database. The mean sea level pressure anomaly for January 1995 (Figure 7) shows below-average pressure over much of Antarctica but a high pressure anomaly off the coast

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of the Peninsula which implies that westerly winds blew more strongly and/or frequently than usual over the Peninsula. These conditions are also potentially conducive to a föhn effect over the Larsen ice shelf, and föhn winds over Larsen can be linked with extreme melt episodes (Turton et al. 2020). The database also shows up the succession of warm summers that preceded and probably contributed to the disintegration of Larsen B (for example van den Broeke, 2005).

There were other months with repeated extreme meteorological events that did not have widely documented impacts on the Antarctic ice shelves, such as February 2006, which was associated with intense melting on Peter 1st Island, and March 2017. Presumably in these cases, temperatures were not generally high enough for long enough to have a substantial impact on the affected ice shelves. However, events such as these are worth monitoring because in a warmer future climate, these events may bring rain instead of snow to parts of the affected ice shelves, leading to them being associated with substantial melting and calving events in the future (Wille et al. 2024b, Chan et al. 2023).

Over the period considered (1995-2023), the results suggested that low sea ice extent over neighbouring seas tended not to be significantly linked with an increased number of extreme temperature or precipitation events, which also implies that caution is needed over linking recent extreme events to reduced sea ice cover. However, the links could become statistically significant if a longer period is used. There is also potential for this to change in a future warmer climate, should Antarctic sea ice become persistently low, combined with the general warming trend in the global climate (Wille et al. 2024a).

There was little evidence for an increase in extreme weather events over the period, but signs that, especially for the Peninsula and West Antarctica, we may have seen a decline in extreme events as well as mean temperatures between around 1995 and 2010, followed by another increase since around 2015, which may be linked with variations in the Interdecadal Pacific Oscillation and allied variability in the Amundsen sea low (Meehl et al. 2016). As with the exceptionally low surrounding sea ice extent of recent years, it is currently too early to determine whether this increase since 2015 is associated mainly with short term variability or whether it is the beginning of a long-term climatic shift.

6. Conclusions

Using daily, monthly, seasonal and annual temperature, precipitation, wind and pressure from existing simulations with four RCMs, we have created a novel database of Antarctic extreme weather events over eight key Antarctic ice shelves. These extreme events often, but not always, align with notable melting and calving events over the ice shelves. There is no clear evidence of an increase in extreme weather events over the period 1995-2023, but in many cases there is evidence of a decline in extreme events between around 1995 and 2010, followed by an increase since then, albeit not to higher levels than these ice shelves saw in the mid to late 1990s.

It would be useful to extend the analysis back into the 1980s to determine whether the well-documented upward trend in mean temperatures in the Antarctic Peninsula is matched by a long-term increase in extreme weather

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events. As only one model was available for the 1980s and early 1990s (RACMO2), we chose not to look at RACMO2 before 1995 for this paper, but the full set of RACMO2 data will be the subject of future work. The extremes database produced here is expected to be of use for validating model simulations of extremes against observations, which may provide useful insights for future development of model simulations over Antarctica and the surrounding region. The database also provides information which can be used to assist case-study analysis, such as of conditions leading up to and during ice-shelf breakup events or exceptional heatwaves or melt events. The extremes database can also be used to help assess the weather system drivers of extreme events, looking at temperature, precipitation, surface wind speeds and surface pressure. For example, atmospheric river catalogues, storm track and blocking databases and empirical orthogonal function analysis can be used to make comparisons with extreme events that are picked out in the database.

Author contributions

Ian Simpson wrote the manuscript draft and produced and analysed the extremes database. Edward Hanna, Ruam Williams, Linh Luu, Andrew Orr, Julie Jones and Xavier Fettweis reviewed and edited the manuscript. Julie Jones, Edward Hanna, Sihan Li and Andrew Orr raised funding for the project. Jose Abraham Torres Alavez, Ole Bøssing Christensen, Xavier Fettweis, Ella Gilbert, Sid Gumber, Christoph Kittel, Damien Maure, Ruth Mottram, Tony Phillips, Willem Jan van de Berg and Kristiina Verro provided the regional climate model simulations.

Competing interests

At least one of the co-authors is a member of the editorial board of *The Cryosphere*. There are no other competing interests to declare.

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Data availability statement

It is anticipated that the database of Antarctic meteorological extremes will be made available at the Centre for Environmental Data Analysis (CEDA) following the end of the research grant for the analysis in 2028. Prior to this time, the database will be available upon request from the primary corresponding author.

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