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# Cyclone Gabrielle, more to come?

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February 2023 will go into the record books as a month during which Aotearoa New Zealand experienced one of its worst weather disasters in modern history, by way of ex-tropical cyclone Gabrielle.

From 12-14 February, Cyclone Gabrielle passed the northern and eastern regions of the North Island, exposing much of the island to extreme rainfall and river flooding not seen in many years, catastrophic wind damage, and substantial storm surge.

The Gisborne Te Tairāwhiti and Hawke's Bay Te Matau-a-Māui regions were particularly affected. Rainfall rates exceeded 20 mm/hour for more than six hours across multiple high-elevation rain gauges in these regions. This culminated in widespread destruction of critical infrastructure and agricultural and land, dozens of impassable roads, severe coastal erosion, the country's third-ever national state of emergency declaration, and loss-of-life. Significant damage also occurred in Northland, Auckland, the Coromandel Peninsula, and east-coastal Manawatū-Whanganui.

## A significant event

Among other storms, Cyclone Gabrielle will be remembered alongside Cyclone Bola (1988), Gisele (1968), and the 'Cyclone of 1936' for its historically significant impact. The available meteorological data supports this comparison. February 14, the day on which Gabrielle was closest to New Zealand, was the North Island's second lowest 'pressure day'[1] on record using all available climate station data since 1960. At 4:00 am on 14 February, NIWA's climate station at Whitianga reported a minimum mean sea level pressure of 968 hPa (Figure 1), which, since at least 1960, was surpassed only by pressure observations during the 26 July 2008 storm in the North Island. This low air pressure reading helps contextualise the strength of the cyclone, which reintensified as it approached the northern North Island. As with Gabrielle, reintensification can happen when former tropical cyclones interact with the mid-latitude jet stream and/or other atmospheric disturbances, leading to a widening of the zone of impact.

In comparison, Bola had a minimum central pressure around 980 hPa[2], Gisele 964 hPa[3], and 'Cyclone of 1936' 970 hPa[4] based on available records. While Bola wasn't as intense as Gabrielle from a pressure perspective, it came with an impact that was drawn out over several days whereby the storm's southward progression was blocked by a ridge of high pressure. The worst of Gabrielle's rain, wind, and surge was confined to a 24-hour window for most regions. Figure 2 shows the air pressure patterns that were associated with Gabrielle, Bola, and Gisele in the Southwest Pacific. Based on this analysis, guided by ECMWF ERA5, Gabrielle was one of the most intense storms to pass near New Zealand's coastlines since at least 1950[5].

## Climate drivers

Gabrielle occurred amidst a unique set of climate drivers – specifically, a 'triple dip' (third consecutive) La Niña, which, although its strength was waning, continued to have a meaningful influence on New Zealand's weather patterns. Notably, seasonal sea surface temperature (SST) anomalies in the Coral Sea, where Gabrielle formed, were 0.5°C to 1.5°C above average. Sub-surface waters were unusually warm by a similar magnitude. This abnormally warm water sat along the periphery of La Niña's 'West Pacific Warm Pool' and was fuel for Gabrielle's development. In the atmosphere, a pulse of the Madden-Julian Oscillation, or area of cloud and thunderstorm activity that circumnavigates the globe every 30-60 days, was active over the warm waters of the west-central Pacific during the first half of February. This contributed to more favourable environmental conditions for tropical cyclone development in the Southwest Pacific.

Monthly mean sea level pressure, as shown in Figure 3, was below normal across the country, producing frequent cyclonic air flows from the easterly quarter. This was consistent with the widespread heavy rainfall and excess cloud cover that was experienced in the North Island and northern South Island.

A marine heatwave persisted near the South Island during February (Figure 4). Monthly SSTs were record breaking (since at least 1982) in the west of the South Island, with a regional anomaly of +2.9°C. SSTs around the North Island were above average, ranging from +0.4°C in the east to +1.2°C in the west.

Prior to the arrival of Cyclone Gabrielle, much of the North Island had experienced several

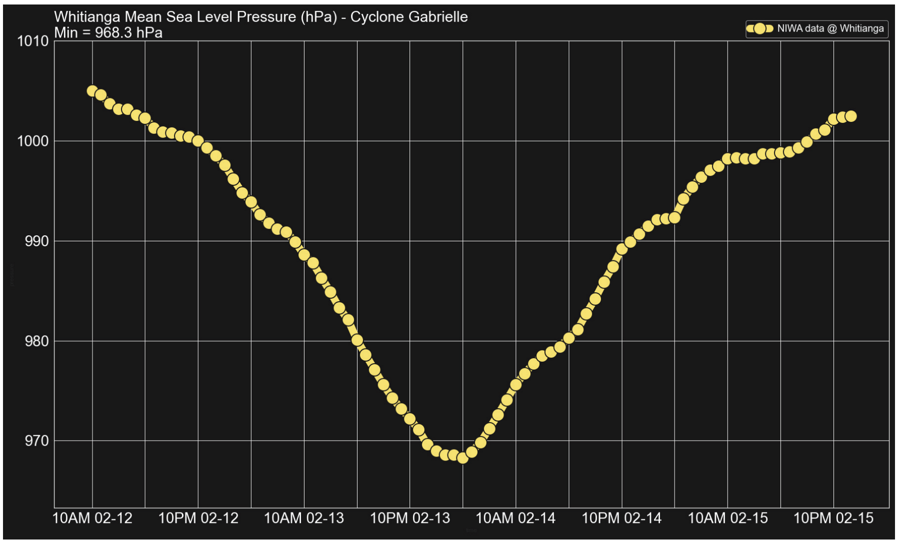


*Figure 1: Mean sea level pressure readings at Whitianga from 12-15 February; the centre of Gabrielle made its closest approach in the early morning hours of 14 February, seeing the pressure dip to 968 hPa.*

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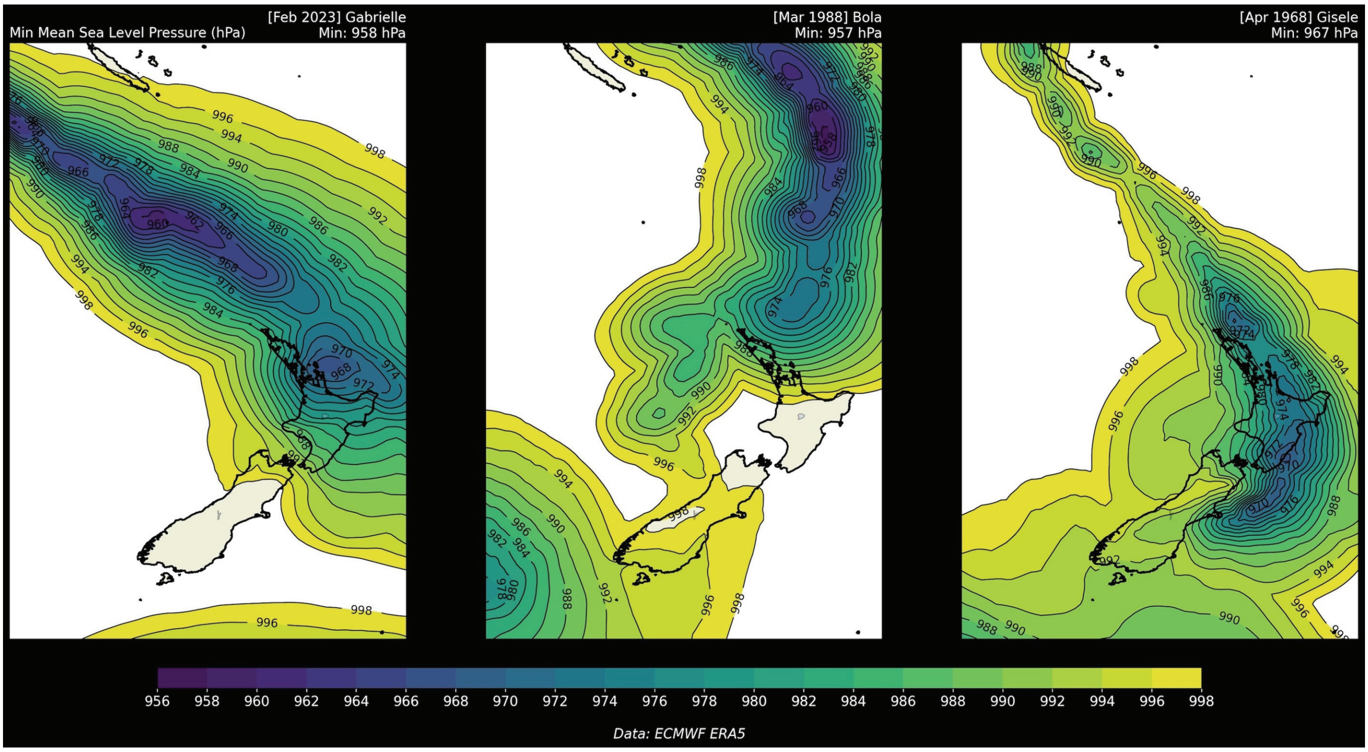



*Figure 2: Minimum mean sea level pressure 'swathes' associated with Gabrielle (left), Bola (centre), and Gisele (right), showing the approximate track and strength of each of the cyclones; data: ECMWF ERA5 (atmospheric reanalysis).*

high rainfall events, including the Auckland-Tāmaki Makaurau Anniversary floods which also affected Northland-Te Tai Tokerau. Earlier in January, Cyclone Hale also resulted in significant rainfall across many regions of North Island. It was the wettest January on record for nearly all locations in the North Island that were subsequently impacted by Gabrielle (Figure 5), with such precursor conditions exacerbating the speed that rivers rose and the number of landslides that occurred in the aftermath of Gabrielle.

## The impact of climate change

With all the record breaking weather, a key question that keeps arising is whether the impacts from Gabrielle were exacerbated by climate change.

Attribution is a fast-growing field of climate science that aims to identify the 'fingerprint' of climate change on extreme-weather events. An attribution study[6], undertaken via the World Weather Attribution (WWA) initiative, was completed by a cross-disciple team to investigate the impact of climate change on rainfall from Gabrielle over New Zealand.

The attribution study used climate models that inform future projections of climate change to compare the world as it is today to a world without human-caused climate change. The intent of this study was to distinguish the climate change signal in rainfall from the cyclone over New Zealand.

The attribution study analysed 24 rainfall stations operated by NIWA and MetService throughout the Gisborne and Hawke's Bay regions, noting that only six recorded rainfall during the cyclone with the remaining stations losing power. Figure 6 shows the 24 weather stations. The black crosses indicate stations that recorded rainfall data during the cyclone, while blue crosses indicate stations that did not. A further three rainfall records curated by the councils are shown by numbers 1-3. The shading indicates the two-day accumulated rainfall from Cyclone Gabrielle over 13-14 February from the Multi-Source Weighted-Ensemble Precipitation (MSWEP) v2.8 dataset, where darker shading indicates heavier rainfall. MSWEP combines gauge, satellite, and reanalysis-based data for reliable precipitation estimates, globally.

The study found that the extreme rainfall seen during Cyclone Gabrielle is rare. Rainfall of that level has return periods ranging from once every 70 to 320 years

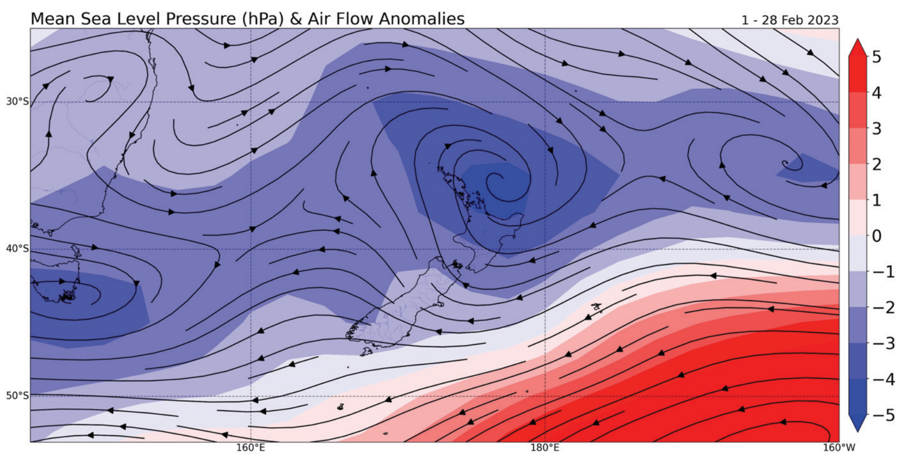
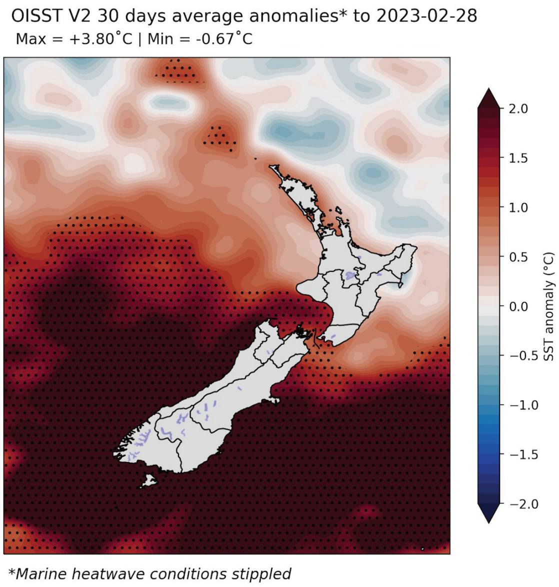



*Figure 3: Mean sea level pressure anomalies (shaded) and air flow anomalies during February (Data: NCEP).*

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|---|---|
| North NI | +0.49˚C |
| West NI | +1.15˚C |
| East NI | +0.36˚C |
| North SI | +1.65˚C |
| West SI | +2.88˚C |
| East SI | +2.20˚C |

*NZ 30-day coastal SST anomalies (to 28 February 2023)*

*Figure 4: 30-day SST anomalies and marine heatwave conditions (stippled), calculated with respect to the 1991-2020 climatological period.*

across the different measurement stations, and averaged over the whole study area, the return period was between 10 and 35 years.

The study could not quantify the specific role of human-induced climate change for Gabrielle due to the confined study area (relative to climate model resolution) and the reliability of the available models in simulating rainfall over the affected region. However, the study did find based on the relationship between historical weather station data (1979-2023) and global mean temperature to extrapolate back to colder climates, the 2-day maximum rainfall over the Gisborne and Hawke's Bay regions is now about 30% more intense than it might have been compared to pre-industrial times when the climate was 1.2°C cooler. Furthermore, 'very heavy rain', comparable to the extreme rainfall event seen during Cyclone Gabrielle, is now four times more common in the region.

## Future projections

A warmer atmosphere can hold more moisture, about 7%-8% more for every 1°C increase in temperature, so there is potential for heavier extreme rainfall with global increases in temperatures under climate change. IPCC (2013; 2021) concluded that the frequency of heavy precipitation events is 'very likely' to increase over most mid-latitude land areas, including New Zealand. Given the mountainous nature of New Zealand, spatial patterns of changes in rainfall extremes are expected to depend on changes in atmospheric circulation and storm tracks.

Past research including the IPCC (2021) AR6 assessment shows that climate change will most likely lead to slightly reduced numbers of tropical cyclones in the Southern Hemisphere, while increasing the intensity of the cyclones that do form.

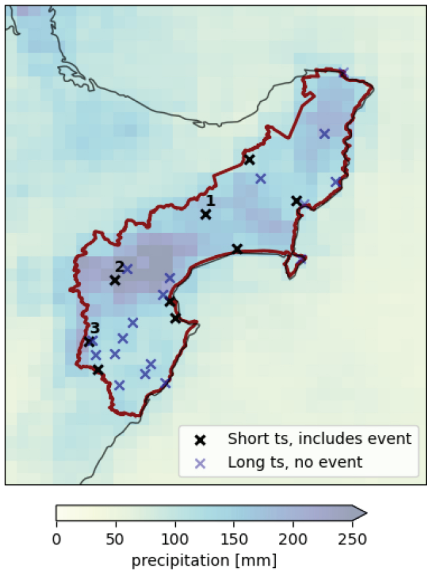


*Figure 6: 2-day accumulated precipitation [mm] from Cyclone Gabrielle in the MSWEP data with station locations overplotted (Source: WWA, 2023).*

For the Gisborne and Hawke's Bay regions the NIWA climate projections are consistent with global trends with extreme, rare rainfall events projected to become more severe in the future[7]. Short duration rainfall events are likely to have the largest relative increases compared with longer duration rainfall events. Rainfall depths for 1-in-50-year and 1-in-100-year events are projected to increase across the greenhouse gas concentration scenarios and future time periods.

NIWA is currently downscaling AR6 projections for New Zealand as part of the National Adaptation Plan and updated projections, and these are expected to be available early- to mid-2024.

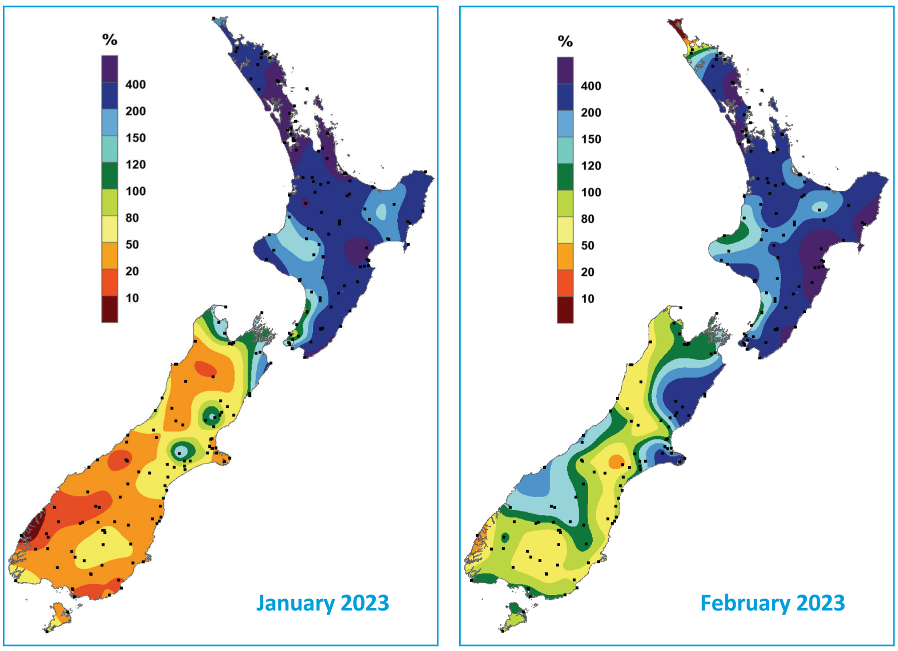


*Figure 5: Monthly rainfall expressed as a percentage of the 1991-2020 normal.*

## Notes

1 The lowest air pressure observed on any given day.

2 From NIWA's *New Zealand Historic Weather Events Catalogue*.

3 Revell, MJ, and Gorman, RM (2003). The 'Wahine storm': Evaluation of a numerical forecast of a severe wind and wave event for the New Zealand coast. *New Zealand Journal of Marine and Freshwater Research*, 37:2, 251-266. https://doi.org/10.1080/00288330.2003.9517163

4 Stephens, SA, Reeve, G, and Bell, RG (2009). *Modelling of the 2 February 1936 Storm tide in Wellington Harbour*. NIWA Client Report HAM-2009-014.

5 Reanalysis combines model data with observations from across the world into a globally complete and consistent dataset using the laws of physics.

6 Harrington, LJ et al (2023). *The role of climate change in extreme rainfall associated with Cyclone Gabrielle over Aotearoa New Zealand's East Coast*. World Weather Attribution Initiative Scientific Report. https://doi.org/10.25561/102624

7 NIWA (2020). *Climate change projections and impacts for Tairāwhiti and Hawke's Bay* (https://www.gdc.govt.nz/__data/assets/pdf_file/0023/19733/2020-Climate-Change-Projections-and-Impacts-for-Tairawhiti-and-Hawkes-Bay-Niwa-Report.pdf).