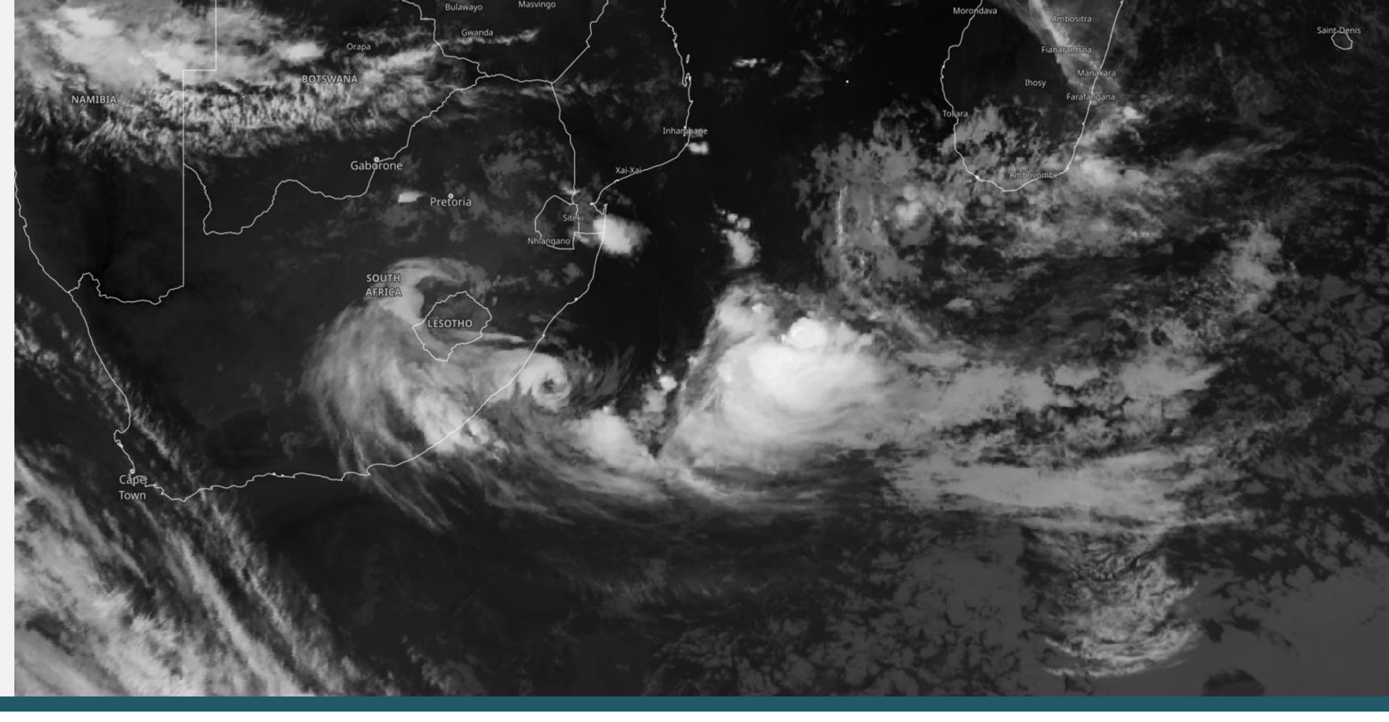
An African-based Climate Change Event-Attribution System using a Regional Climate Model



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Introduction

Motivation

The attribution of severe weather events to climate change is becoming an increasingly important research field, which directly underpins the UNFCCC's 'International Mechanism for Loss and Damage'. RCMs can add value to such investigations through their ability to resolve the dynamics of extreme weather events in detail. Here we present a new African-based event-attribution system, using the RCM CCAM, which can be applied at convection-resolving resolutions over an area of interest. We apply this system to the 'Durban floods', which killed more than 540 people in South Africa in April 2022.

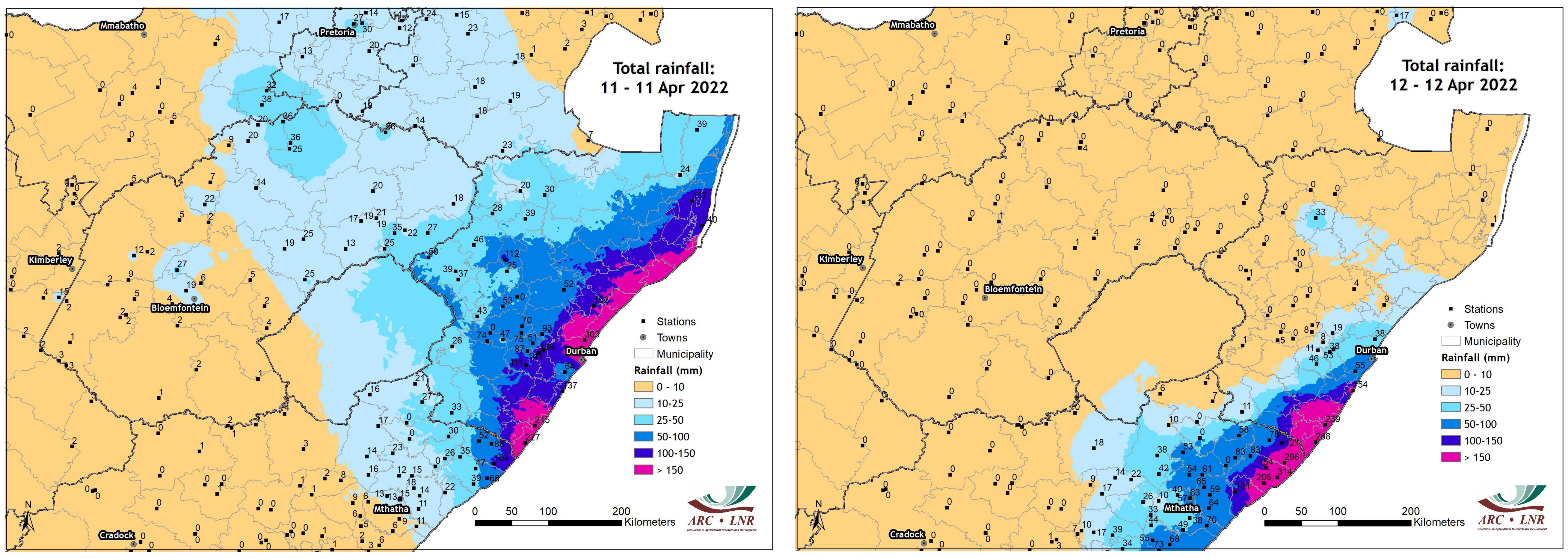

Fig. 1: Observed rainfall totals (mm) over Durban for 11 Apr 2022 (left) and 12 Apr 2022 (right) as recorded by the Agricultural Research Council.

Results

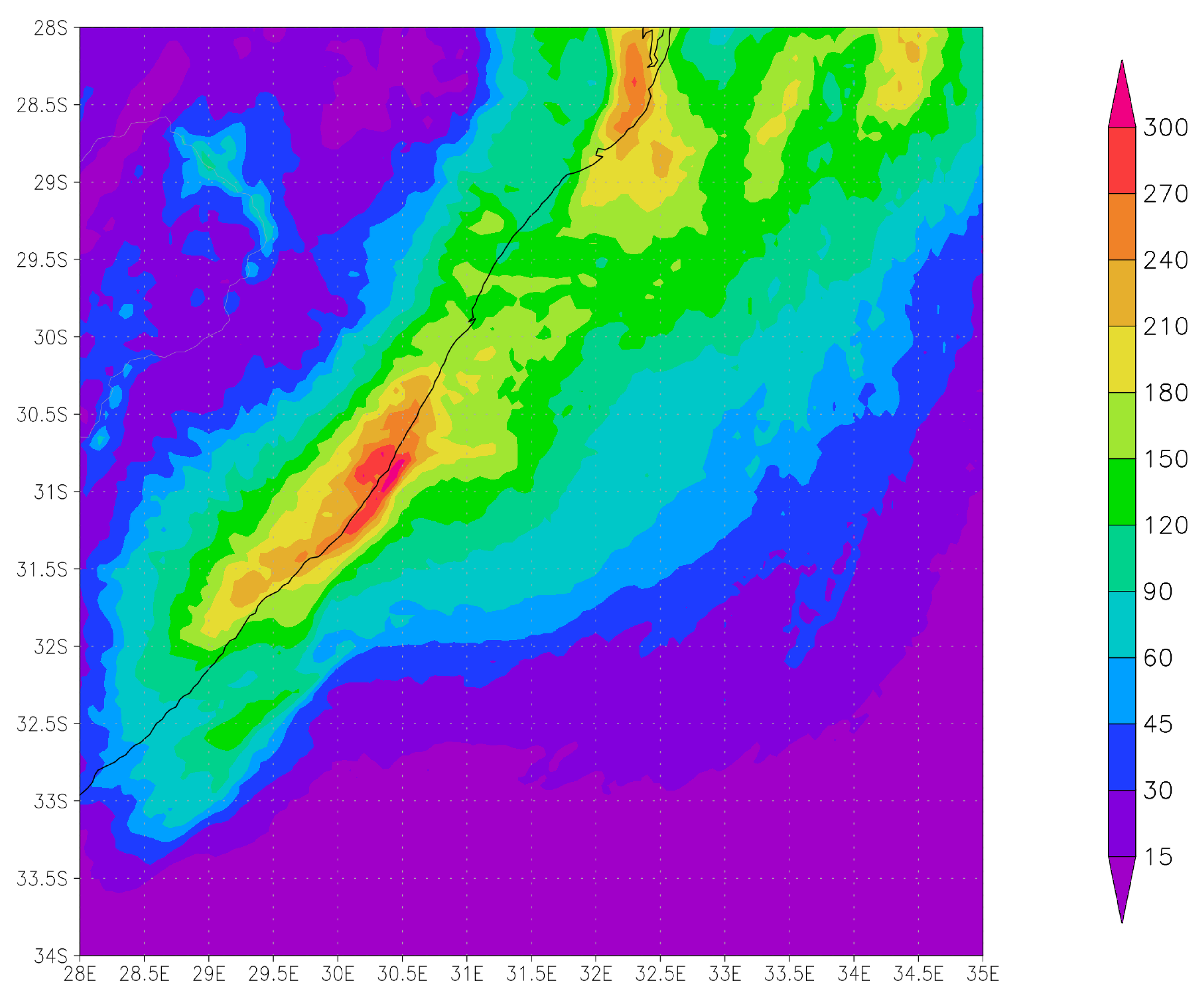

Fig. 2: Median of the CCAM 64-member ensemble simulation of 48-hour rainfall totals (mm) over KwaZulu-Natal in South Africa.

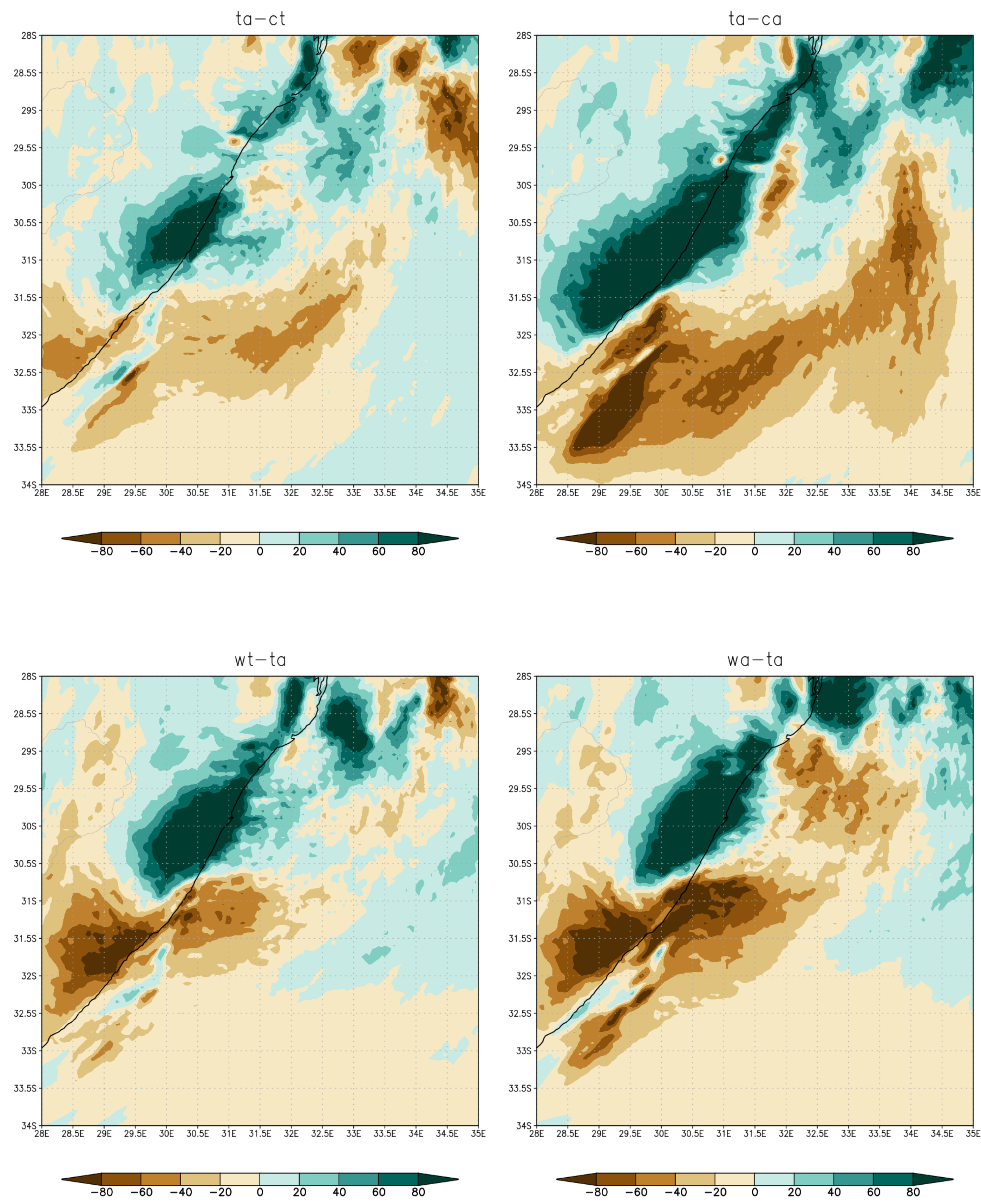

Fig. 3: Projected differences in 48-hour rainfall totals (mm) between the median of the 64-member CCAM simulations used to simulate the April 2022 Durban floods, and the ensemble medians for a 'cooler world' constructed with detrended temperatures (top left) and a 'cooler world' constructed from detrended temperatures and humidity (top right). Projected (median) rainfall differences (mm) for a warmer world and a warmer-and-moisture world, compared to the April 2022 event, are shown in the bottom-left and bottom-right panels.

The CCAM 64-member perturbed physics ensemble (median shown in Figure 2) realistically portrays the observed distribution of rainfall along the KwaZulu-Natal coast for the 48-hour period of 11 and 12 April 2022, when the Durban floods occurred. The rainfall event was caused by an Atlantic-Ocean cut-off low, which propagated across the South Africa interior to spawn a low-pressure system off the KwaZulu-Natal coast (see insert of satellite picture). This low developed and exhibited subtropical low attributes, possibly in response to regional warming in the southwest Indian Ocean and enhanced moisture and latent heat fluxes into the system. The rainfall event was about 20% more intense compared to the system simulated to occur in a world cooled down to 1979 temperatures (Figure 3). Moreover, if the trend is reversed and the system is simulated to have occurred in a warmer world, precipitation is about 20% higher compared to that of the 2022 event (Figure 3).

Conclusions

The Global Change Institute (GCI) of the University of the Witwatersrand in South Africa has developed a new weather event attribution system using the RCM CCAM of the CSIRO in Australia. The modelling system employs a perturbed-physics ensemble to explore the role of circulation dynamics in the occurrence of a severe weather event, and subsequently exerts the weather system into "cooler" and "warmer" worlds that are constructed via the detrending of reanalysis data. Moreover, the system is applied at convection-resolving resolutions over an area of interest, implying the potential to add value to 'traditional' attribution systems that rely on ensembles of GCM simulations.

By applying the new attribution system to the mesoscale weather event that caused the Durban floods in April 2022, we demonstrate that regional warming of the southwest Indian Ocean and resulting increases in water vapour atmosphere intensified this event. The rainfall event was about 20% more intense compared to the system simulated to occur in a world cooled down to 1979 temperatures. Moreover, if the trend is reversed and the system is simulated to have occurred in a warmer world, precipitation is about 20% higher compared to that of the 2022 event. Early Warning Systems and climate change adaptation along the KwaZulu-Natal coast need to take into account the likely more frequent occurrence of 'subtropical lows' causing heavy rainfall and flooding along the coast.

Methodology

The modelling system employs a perturbed-physics ensemble to explore the role of circulation dynamics in the occurrence of a severe weather event. We subsequently used reanalysis data for the last four decades to detrend the initial state of the above mentioned simulations. The perturbed physics ensemble is then reconstructed, this time for the weather system in question inserted into a 'cooler world'. The trend is then reversed to also insert the weather system into a 'warmer world'. A statistical comparison between ensembles is undertaken to quantify the role of climate change in the severity of the event.

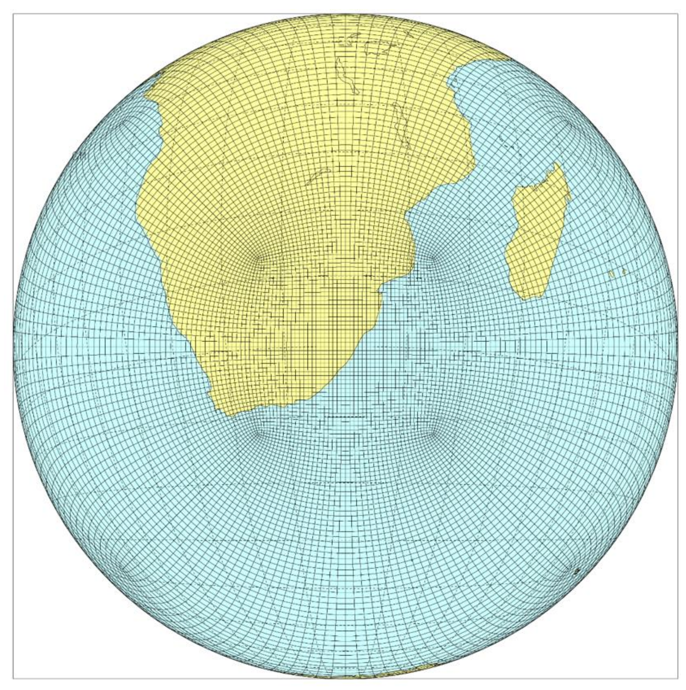

Fig. 4: Durban C384 grid having 3.8 km resolution, 30.0. -30.0, 0.152381. View = 1.4, every 8th point shown.

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