Weather and Climate Science for Service Partnership (WCSSP) South Africa

2024

Science Highlights Report

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This Annual Highlights Report reflects the work of many people, directly and indirectly, across the project team. We gratefully acknowledge the ongoing support of project manager Hannah Manton, project management supports Esme Gourlay, Ferhan Dack and Leighane Cregan, Stakeholder Engagement leads Catriona McCabe and Oliver Seagrove, Impacts and Benefit lead Nick Hopkins-Bond, and WCSSP programme manager David Riddell.

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Executive Summary

The Weather and Climate Science for Service Partnership (WCSSP) South Africa aims to build and strengthen collaborations amongst the UK and South African weather and climate science and services community. This initiative is supported by the International Science Partnership Fund (ISPF) from the UK's Department for Science, Innovation and Technology (DSIT), and focuses on advancing innovative science and service development to promote resilience, economic development, reduce risks, and safeguard lives and livelihoods in a changing climate. The project is a partnership between the Met Office and research partners in the UK with the South African Weather Service (SAWS), Agricultural Research Council (ARC), Council for Scientific and Industrial Research (CSIR), University of Witwatersrand (Wits), and Alliance for Collaboration on Climate & Earth Systems Science (ACCESS), as well as the wider weather and climate research community in South Africa.

In this 2024 science highlights report, summaries of progress made across the four work packages are provided, along with details of key engagements with partners. Effective engagement between UK and South African partners is key to the project's success. Regular Executive Committee meetings and engagement visits, facilitate productive discussions about project collaborations, science objectives, and future priorities. The annual science meeting, held from 25-26 June 2024 at the University of Witwatersrand, brought partners and scientists together to share knowledge, discuss evolving priorities, and build relationships to forge new collaborations.

A new Science Review Panel (SRP) was established in 2024 to review the quality of science conducted in the project and ensure it delivers on its aims and objectives in an equitable, inclusive and societally relevant way. The SRP includes esteemed panel members from a range of South African institutions with expertise across meteorology and climate science and is chaired by Professor Debra Roberts.

This report highlights several findings from key research conducted in 2024. A study analysing output from CP4-Africa model simulations, relevant to urban planning in Johannesburg, reveals an overestimation of the urban heat island (UHI) effect, leading to excessive rainfall predictions, but found that the model correctly captures the mechanism of UHI-induced mesoscale circulation. New work to develop rip current forecasts for beach locations across South Africa has progressed, with refined hazard thresholds and a recommended tiered communication approach for stakeholders. High-resolution wave climate projections using machine learning shows a positive bias in significant wave height predictions around the coastline, with ongoing analysis to address uncertainties. Lastly, a framework for forecasting medium-range heat-related mortality risks is introduced, integrating weather pattern analysis and impact-based forecasting to enhance preparedness to high-impact weather.

Overall, the WCSSP South Africa project continues to support collaborative efforts of UK and South African partners to advance science and services relevant to different sectors, leveraging new scientific innovations, and responding to evolving priorities.

1. Introduction

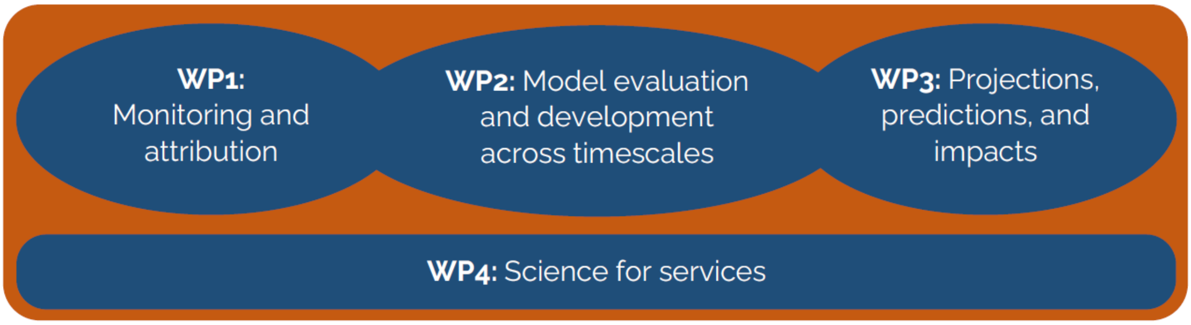
1.1 Overview and background to WCSSP South Africa

The Weather and Climate Science for Service Partnership (WCSSP) South Africa project aims to build and strengthen partnerships amongst the UK and South African weather and climate science and services communities. It does so through promoting collaborative and innovative science and service development, to support resilience, economic development, reduce risks and safeguard lives and livelihoods in a changing climate.

The project is a partnership between the Met Office and UK research organisations with the South African Weather Service (SAWS), Agricultural Research Council (ARC), Council for Scientific and Industrial Research (CSIR), University of Witwatersrand (Wits), and Alliance for Collaboration on Climate & Earth Systems Science (ACCESS) in South Africa.

Research addresses frontier scientific challenges to enhance understanding and improve simulations of the weather and climate in South Africa and the wider region, as well as pursuing opportunities to leverage new scientific innovations and progress in the development of impact-based weather and climate services. The project is advancing science and services relevant to different sectors but with particular emphasis on four priority sectors: agriculture, energy, health, and marine/coastal. These sectors have been jointly identified as areas where the partnership is well positioned to develop new science, information and knowledge to advance understanding of risks facing these sectors. In addition, the scope of science covers multiple weather and climate hazards, including compound and cascading hazards, with emphasis on heat, drought, inland and coastal flooding.

WCSSP South Africa is composed of four interlinking work packages (WPs). Work packages 1 to 3 are focused on advancing different areas of weather and climate science, modelling, and impacts. Work package 4 focuses on developing sector-relevant weather and climate services and supporting broader service capabilities in South Africa. The work package activities are designed to meet the overarching objectives of the project, with some activities conducted in collaboration across work packages.



1.2 Partner Engagement

Engagement between partners in the UK and South Africa is key to the success and sustainability of the WCSSP South Africa project. Regular Executive Committee meetings are held to share partner updates, discuss upcoming opportunities and events, and raise awareness of challenges to address. In addition to regular online engagement, in-person interactions help build and sustain relationships to enable effective and trusted collaborations.

A successful engagement visit by Joseph Daron (Senior Supplier), Hannah Manton (Project Manager) and Catriona McCabe (WCSSP Stakeholder Lead) was held from 15-17 April. The visit to Pretoria and Johannesburg provided an opportunity for the team to visit partner institutions and meet with most South African core partners (ARC, CSIR, SAWS and Wits), as well as the British High Commission and South African Department for Science and Innovation (DSI). The meetings facilitated productive discussions about project collaborations, high-level science objectives, and future priorities, as well as opportunities to build personal relationships amongst the project team.

Photos: Visits to partner institutions. High-level engagement visit, April 2024.

1.3 Annual Meeting

Like other WCSSP projects, WCSSP South Africa holds an annual science meeting each year, with the aim of bringing partners together to share knowledge and present scientific progress, discuss evolving priorities and opportunities, and build relationships to forge strengthened collaborations. The 2024 annual meeting was hosted by the Global Change Institute at the University of Witwatersrand from 25-26 June and held at Wits Club, with online attendees to facilitate wider engagement from UK and South African scientists. The meeting celebrated 10 years since the project first began, initially as a partnership between the Met Office and SAWS before later expanding in 2019 to the wider partnership.

The agenda featured panel sessions, talks across the four work packages, breakout group exercises, and discussions on priority areas – e.g., AI and Machine Learning applications, use of the CP4-Africa convective-scale climate simulations, and pathways for science to enhance resilience. The meeting also provided opportunities for individual work packages to come together and discuss ongoing work and future plans for key activities. On the final afternoon, a plenary session covered cross-cutting topics and emerging areas, including a discussion on extreme event attribution and how the WCSSP South Africa project could support innovation in this area, facilitating Global North-South collaboration.

Photo: Attendees at WCSSP South Africa Annual Science Meeting: University of Witwatersrand, 25-26 June 2024.

1.4 Science Review Panel

A new Science Review Panel (SRP) was established in 2024, with the primary aim of reviewing the quality of science conducted in the project, while also providing a mechanism to offer independent review on how the project can best deliver to its aims and objectives, promoting scientific innovation through effective partnership and collaborations.

The project welcomed Professor Debra Roberts (University of Twente, and IPCC AR6 WG2 co-chair) to chair the SRP. She brings with her a wealth of experience both as a practitioner working in local government in South Africa and as a scientist with a breadth of expertise across physical and social sciences related to climate and the environment. Prof Roberts is joined by an esteemed panel: Professor Thando Ndarana (University of Pretoria), Dr Mary-Jane Bopape (South African Environmental Observation Network – SAEON), and Dr Piotr Wolski (University of Cape Town). Together they span a range of expertise across meteorology and climate science, including experience in modelling, climate dynamics, impacts assessment, attribution and climate policy. The SRP will be engaging with WCSSP South Africa partners to help identify priority areas for science and service development, and support in developing an equitable and inclusive UK-South Africa partnership.

2. Work package progress and collaborations

2.1 Work Package 1: Monitoring and attribution

WP Leads: Philip Brohan (Met Office), Charlotte McBride (SAWS) and Stefan Grab (Wits)

WP1 is advancing work on new methods for climate data rescue and monitoring dataset construction.

Archives at SAWS and elsewhere contain paper records with millions of historical weather observations which would be of great value to analyses of South African climate. But digitisation of historical data by hand is unacceptably slow and expensive, so a project led by the University of Southampton is producing new software tools to try and automate the process.

In 2024, three new tools were released:

- A Table structure recognition (TSR) model
- A Text recognition (Optical Character Recognition) model
- A Tabular data reconstruction model

In addition, a test dataset of document images was constructed, including records contributed directly from the SAWS Archive. The software tools have shown good potential for use for automated data rescue, though they still struggle with the more challenging document layouts.

Also, a machine learning model architecture, based on the Deep Convolutional Variational Autoencoder, was produced. This provides a new tool for dataset construction.

2.2 Work Package 2: Model evaluation and development across timescales

WP Leads: Jeff Knight and Douglas Boyd (Met Office), Jessica Steinkopf (Wits) and Stephanie Landman (SAWS)

WP2 continues to build new modelling capability and evaluate regional processes that influence South African weather and climate across timescales (in conjunction with WP3).

A new suite of Convection Permitting climate simulations for Africa (CP4A) have been produced using a state-of-the-art Met Office Hadley Centre regional model. Initial evaluation shows a more realistic simulation of African climate than in either coarser resolution global climate models, or in previous high-resolution regional model versions. Data from this activity comprises ensembles of present-day and projected future time-slice simulations, allowing application to regional climate change studies. It is anticipated that following a further period of evaluation by Met Office teams, these simulations will become a valuable resource for WP3 and WP4 as well as partners in WCSSP South Africa and researchers across Africa.

A first high-resolution regional simulation has been successfully performed using the Momentum model with a new dynamical core. The new approach reformulates the fundamental calculation of atmospheric motion in Met Office models going forward, including those for regional climate simulations of southern Africa. As a result, achieving a first working run in this framework (albeit of only a few days' duration) is a strategic milestone for WCSSP South Africa. In parallel, work has been ongoing to develop the new "CSET" toolkit to facilitate evaluation of convective scale processes in high-resolution models. This work also has potential to deliver capability across the partnership looking 2-3 years ahead.

Analysis of the variability of the seasonal-timescale connection between South African climate and the El Niño-Southern Oscillation (ENSO) has highlighted Rossby waves propagating eastward in the southern hemisphere towards southern Africa. The phenomenon is found to be well represented in a range of climate modelling systems. The results will help understand the origins of seasonal-scale extremes such as droughts.

Study of how weather features are simulated and contribute to changing climate is also yielding valuable results. Feature tracking methods have been evaluated on satellite observations of Mesoscale Convective Systems (MCSs), which account for a substantial fraction of southern African rainfall. Successful tracking of observed features has allowed application to model outputs such as those from CP4A. This allows questions such as how the properties of MSCs might change to be addressed.

On weather timescales, work continues with SAWS to implement and evaluate NWP infrastructure. Tests of most recent versions of high-resolution nested regional model configurations and the IMPROVER Met Office post-processing system are ongoing.

2.3 Work Package 3: Projections, predictions, and impacts

WP Leads: Andrew Hartley (Met Office), Mohau Mateyisi (CSIR) and Sarah Roffe (ARC)

WP3 is building understanding and utilising the capability of existing and new modelling to provide user-relevant predictions across weather and climate timescales.

Over the course of the last year, work has been trying to better align science in WP3 to services that are important to South African partners. In some cases, this has involved understanding the relevant people in South African organisations who may be able to utilise work that is currently ongoing, whereas in other cases, this has involved re-aligning the work in the UK to have a greater relevance to the South African context. Building personal relationships and having regular meetings has helped to achieve this, which has included hosting a 2-week visit from Mohau Mateyisi (CSIR) and Sarah Roffe (ARC) to the UK in February 2025. These visits created a shared understanding of priorities for WP3.The work highlighted here reflects those shared priorities and has a clear route to impact in South Africa.

Based on the weather patterns identified in Ireland et al (2024), work has been undertaken to analyse heat-related mortality risk in different demographic groups and regions across South Africa (see section 7). This has been developed based on mortality data from Statistics South Africa and uses an exposure-lag-response model to consider changes in relative risk of mortality linked to weather patterns. This approach is then applied to an ensemble of medium-range weather forecasts in order to understand the lagged effects of heat waves on mortality. Work is ongoing to explore applications both in SAWS impact-based weather forecasting, and potentially also in ARC warnings for heat stress in agricultural workers. There are also plans to explore the potential for using this weather pattern-based approach to characterise other impacts, such as fire or drought.

Additionally, work has been ongoing to characterise multi-sector impacts, in particular to support collaboration between the Met Office, ARC, CSIR and Wits on the compound impacts of drought on water supply, agricultural production and fire weather. On their recent visit to the UK, Mohau Mateyisi and Sarah Roffe successfully installed and ran a suite of impacts indices from the Met Office impacts toolbox. Results from their work using ERA5 data whilst in the UK has helped to characterise better historical events for a number of impacts indices, such as fire weather, human heat stress, cattle heat stress, drought and vegetation distributions. The fire weather index was also run for a seasonal forecast ensemble to understand potential future applications at this time scale. Work this year in the UK has developed additional capability to calculate the Standardised Precipitation Evapotranspiration Index (SPEI) on a daily time step. This has been identified by South African partners to be important for estimation of water availability.

Finally, ongoing research is now working towards understanding convection-permitting model sensitivity to representation of convective processes, to better inform expert judgement on the reliability of regional climate projections. The work, described in more detail in section 4 and in collaboration with WP2, has initially focused on tracking and characterising meso-scale convective systems in these high resolution regional simulations (see section 2.2). Future work will consider the value of these simulations for climate impacts studies.

2.4 Work Package 4: Science for services

WP Leads: Nefeli Makrygianni and Anna Steynor (Met Office), Andries Kruger (SAWS), Johan Malherbe (ARC) and Neville Sweijd (ACCESS)

Work package 4 continues to support science for services through support to the South African partners working in climate services and pulling through NWP to renewable energy and marine forecasting services.

This year saw the culmination of the climate services gaps analysis work led by HR Wallingford. This work resulted in a collaborative published paper (Lumbroso et al. 2024). As a final activity under this work, the identified gaps were used in an exercise at the annual meeting in South Africa to understand what gaps are currently being filled. The exercise at the meeting highlighted potential remaining gaps in the heat-health and socio-economic benefit space – both potential areas for collaboration under WCSSP SA in future years.

An additional area of potential is the appropriate dissemination and action on early warnings. With South African partners, a 2025 defrayment call has been developed focused on informing context-specific needs for impact-based early warning systems. In an aligned activity, a South Africa and UK consortium expression of interest has been submitted to the Lloyd's Register

Foundation World Risk Poll call for proposals to enhance dissemination and use of early warnings in the “missing middle” second-lowest income quintile in South Africa.

In sea-level rise work, there have been discussions and collaborations initiated between the WCSSP SA programme and both South African National Parks (with a focus on climate assessment for marine national parks) and ESKOM (with a focus on sea level rise assessments for nuclear facility planning). The objective of the work is to develop sea-level rise storylines to information coastal adaptation planning and decision-making.

In the energy sector, the Met Office have worked with SAWS to develop a machine learning (ML) model for forecasting solar power using the site-specific forecasting capability at SAWS (built in previous years of the WCSSP-SA partnership). The ML model was delivered to SAWS and a training course was given by the Met Office to SAWS on using machine learning with forecasting data. In addition, the Met Office assisted SAWS in delivering a report on future options for wind energy forecasting at SAWS. Finally, a paper was published on ‘An Analysis of the Effects of Clouds in High-Resolution Forecasting of Surface Shortwave Radiation in South Africa’ in the Journal of Applied Meteorology and Climate, building on many years of collaboration between SAWS and the Met Office.

In the marine sector, ML techniques were used to improve wave forecasts and to develop a marine climate emulator for future wave forecasts. This work was previously presented at the Africa Conference on Data Science & AI in October 2023 in Pretoria, and was followed by a visit from Met Office scientists to the SAWS Marine group in Cape Town to install the ML bias correction wave forecast model on the SAWS system. The work continues in 2024/25 with a new approach to improving short-range forecasts, utilizing a more advanced ML tool. While initially developed for the UK, this tool will be tested in South Africa in the next FY. Meanwhile, the climate emulator is now validated against low-resolution model outputs as a reference (Section 6). Additionally, a visit to South Africa is planned in April 2025 to attend the International Conference on Southern Hemisphere Meteorology and Oceanography and provide training to SAWS on this second component of the tool.

In addition to the above, the work on rip current forecasts, which began in 2019, has now entered its second phase. The pilot tool developed earlier is being expanded for broader application and enhanced functionality – see Section 5 for more detail.

2.5 Supporting collaborations

WCSSP South Africa supporting a range of opportunities that foster collaboration amongst partners and institutions in the UK, South Africa and elsewhere, recognising that the collaborative science is vital to address contemporary science challenges. The annual meeting and April 2024 engagement visit (see section 1) provided opportunities to consider the strategic direction of the project, while other more focused engagement opportunities support scientist-to-scientist collaborations and interaction with societal stakeholders.

Understanding, simulating and responding to extreme weather and climate is a theme that cuts across activities in WCSSP South Africa. Members of the WCSSP South Africa team across partner institutes attended the international conference on “Integrated Responses to the Intensification of Extreme Climate and Weather Events in Developing Economies” hosted by the University of Stellenbosch from 22-24 May 2024, and supported by WCSSP partners. Jenny Weeks and Matt Palmer from the Met Office attended the extremes conference, and while in South Africa progressed collaborations as part of work in WP4 on the “distillation of sea-level rise information for different decision-making contexts”. They engaged with SAWS, the University of Cape Town, and the City of Cape Town municipality, as well as meeting with Eskom to discuss sea level rise impacts on nuclear energy facilities in the Western Cape.

Also focusing on marine risks, the University of Plymouth are engaging closely with the SAWS marine team in the development of rip current forecasts (see extended highlights, section 5). Aligned to this work, WCSSP South Africa supported SAWS and Met Office staff to attend the OceanPredict 2024 conference in Paris in November 2024 focused on the development of operational oceanography for social benefit. This provided an opportunity to showcase WCSSP work, including to UN agencies, and support engagement with the global ocean scientist community.

Other collaborations are documented elsewhere in this report, including in the extended highlights that follow. In future years, collaboration will remain a key objective, supported through project activities, high-level planning meetings, and additional support for scientist exchange visits.

3. Publications

Journal papers published in 2024 supported by WCSSP South Africa

Brönnimann, S., Brugnara, Y., & Wilkinson, C. (2024). Early 20th century Southern Hemisphere cooling. Climate of the Past, 20(3), 757-767. https://doi.org/10.5194/cp-20-757-2024

Ireland, L. G., Robbins, J., Neal, R., Barciela, R., & Gilbert, R. (2024). Generating weather pattern definitions over South Africa suitable for future use in impact-orientated medium-range forecasting. *International Journal of Climatology*, 44(5), 1513-1529. https://doi.org/10.1002/joc.8396

Keat, W. J., Short, C. J., & Kendon, E. J. (2024). Are convection-permitting climate projections reliable for urban planning over Africa? A case study of Johannesburg. Atmospheric Science Letters, e1264. https://doi.org/10.1002/asl.1264

Lumbroso, D., Vincent, K., Murambadoro, M., Steynor, A., Tsarouchi, G., & Nezi, M. (2024). Current uses and potential future needs for climate services in South Africa. *Climate Services*, 36, 100516. https://doi.org/10.1016/j.cliser.2024.100516

Mendes, J., Zwane, N., Mabasa, B., Tazvinga, H., Walter, K., Morcrette, C. J., & Botai, J. (2024). An analysis of the effects of clouds in high-resolution forecasting of surface shortwave radiation in South Africa. Journal of Applied Meteorology and Climatology, 63(2), 227-244. https://doi.org/10.1175/JAMC-D-23-0058.1

Warner, J. L., Munday, C., & Engelstaedter, S. (2024). Resolving the Turkana Jet—Impact of model resolution in simulating channel flow and inversions. Journal of Geophysical Research: Atmospheres, 129(14), e2023JD040299. https://doi.org/10.1029/2023JD040299

Other publications produced in 2024 supported by WCSSP South Africa

Brohan, P., A DIY Machine Learning Climate Model. http://brohan.org/DCVAE_Climate/

4. Are convection-permitting climate projections reliable for urban planning over Africa? A case study of Johannesburg

Authors: William Keat, Chris Short and Elizabeth Kendon (Met Office)

Summary

A paper assessing the reliability of the CP4-Africa (CP4) model at representing the Johannesburg urban heat island (UHI) effect and its interactions with local rainfall was published in Atmospheric Science Letters. Compared with the limited observations available, we found that the UHI of Johannesburg was too strong in CP4, leading to too much rainfall over the city primarily from additional convective triggering via a UHI-induced mesoscale circulation. However, we find that this UHI-induced overestimation of rainfall is likely of secondary importance in terms of future rainfall percentage change. Consequently, we recommend that urban planners consider applying relative changes in CP4 as an uplift to observations, where available, or treat absolute future rainfall as an upper estimate if used directly.

Extended Highlights

The urban heat island effect

Urban areas influence their local climate by altering the surface energy balance, with the most well-known phenomenon being the UHI effect, whereby urban areas are warmer than surrounding rural areas. This arises due to a combination of factors, including additional absorption of heat by urban surfaces, effects of urban geometry (i.e. street canyons) on radiation, reduced evapotranspiration due to a lack of vegetation, and anthropogenic heat sources (Arnfield, 2003). In recent years, there has been increasing interest in the impact of urban areas on rainfall, with studies showing strong enhancements both over (16%) and downwind (18%) of cities with respect to storm direction (Liu and Niyogi, 2019). The finding of strong urban rainfall modification over cities has important implications as they are particularly vulnerable to surface water flooding.

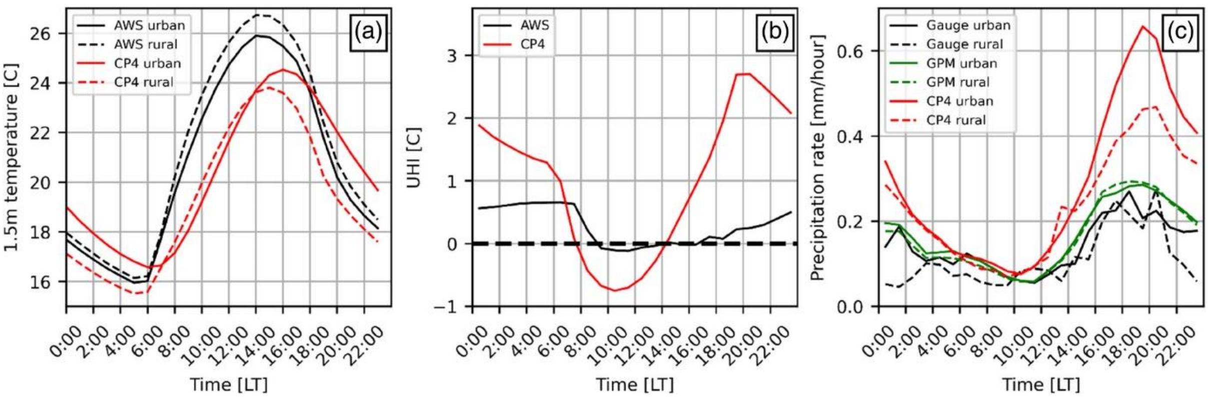


Figure 1: Summer (DJF) mean diurnal cycles of urban (solid lines) and rural (dashed lines) estimates of temperature (a), UHI (b) and rainfall (c). CP4 is shown in red, observations from AWS for temperature and rain gauges in black (urban station is Johannesburg Botanical Gardens and rural is Ventersdorp), and nearest-neighbour GPM-IMERG rainfall estimates in green. AWS, gauge, and GPM-IMERG data is shown for 2000-2015 period. Due to differences in elevation above mean sea level between the two sites, an elevation correction of +0.85°C has been applied to the UHI.

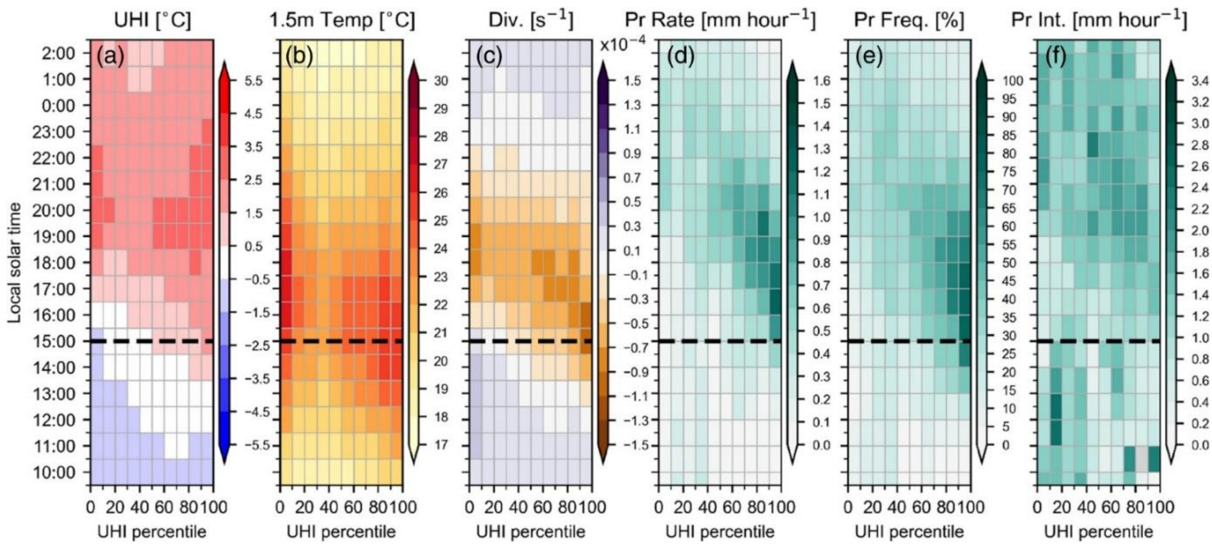


Figure 2: Urban diurnal cycles of hourly UHI (a), 1.5 m temperature (b), 10 m-divergence (c), rainfall rate (d), frequency (e) (>0.1 mm h^{-1}) and intensity (f) (during hours when rainfall rate >0.1 mm h^{-1}) on days when the UHI falls in each UHI percentile bin at 15:00 LT (dashed black line) for CP4 (at native resolution).

UHI-rainfall enhancement mechanism

In the present day, we found that CP4 produces too much rainfall over Johannesburg, which is strongly related to an overestimated UHI effect (Figure 1), which we believe to be primarily due to the overly simplistic “concrete slab” one-tile urban scheme used in the model. To investigate potential UHI-rainfall interactions, we examined characteristics of rainfall on days when the UHI falls within different percentile bins during mid-afternoon (Figure 2). 15:00LT is chosen as this is typically before the onset of convection and so samples the UHI in the “pre-convective” environment. By definition, the UHI (Figure 2a) monotonically increases with UHI percentile at 15:00LT. The diurnal cycle of temperature and rainfall can clearly be seen (Figure 2b,d), with more rainfall occurring across all UHI percentiles in the hours after 15:00LT than before (Figure 2d). However, there is a strong increase in rainfall rates with increasing UHI, with the largest rainfall rates occurring in the hours following the largest UHI (>p90). There is a disproportionate contribution to rainfall accumulations after 15:00LT from higher UHI bins: between 15:00 and 21:00LT, 49% of total rainfall comes from days when UHI > p70. This additional rainfall is primarily driven by a disproportionate frequency of rainfall, which is strongly associated with 10 m-convergence (Figure 2c).

Figure 3a-d shows that on days when UHI > p90, the enhanced convergence and additional rainfall is local to Johannesburg and Pretoria. This points to the existence of a UHI-induced mesoscale circulation, with more buoyant air associated with relatively warmer urban areas rising and drawing in surrounding air to replace it. This then enhances rainfall, primarily through additional triggering (Figure 2e). The fact that convergence occurs hours before additional urban rainfall after 15:00LT supports the interpretation of this as a causal mechanism rather than being associated with the rainfall itself.

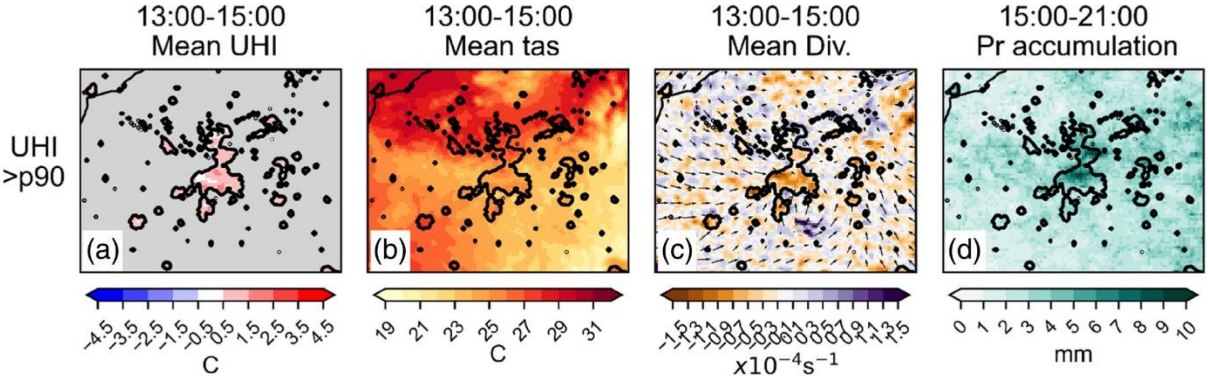


Figure 3: Maps of UHI (a), 1.5 m temperature (b) and 10 m-divergence (c) in the two hours prior to, and accumulated rainfall (d) in the six hours after 15:00LT on days when the urban heat island is below the 10th percentile at 15:00LT for CP4. Divergence plots also include mean wind field, with arrow length proportional to wind speed). Black contour indicates boundary of 0.1 urban fraction.

Recommendations for urban planners

Compared with the limited observations available, CP4 produces too much rainfall over Johannesburg, which appears to be strongly related to an overestimated UHI effect and associated UHI-mesoscale circulation**Error! Reference source not found.**. However, the e nhanced triggering of rainfall by this circulation is consistent with other studies (e.g. Li et al., 2020), suggesting that while the UHI is overestimated, CP4 is correctly capturing this mechanism.

In future, we find that there is little change in the urban enhancement of rainfall (not shown here), which suggests that deficiencies in the urban representation are likely of secondary importance in terms of future percentage change (i.e. to first order, biases cancel in present and future). We expect future changes in rainfall (not specifically urban rainfall) to more reliable in convection-permitting models compared with regional or global models, due to their higher resolution and explicit convection. Given this, we recommend that urban planners consider applying relative changes from CP4 as an uplift to observations, where these are available. The secondary importance of urban effects is true for both mean and extreme daily rainfall accumulations, suggesting this approach would be appropriate in both cases. Alternatively, if future rainfall values are used directly, they should be considered an upper estimate.

References

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5. Advancing Rip Current forecasts for beach locations across South Africa

Authors: Tim Poate and Joseff Saunders (CMAR, University of Plymouth)

Summary

A previous pilot operational rip hazard forecast for Cape Town has been formally established and integrated by SAWS into their Marine Forecast Services. Alongside this, continued incident analysis using beach rescue records from Durban, Port Elizabeth/Gqebertha and Cape Town with hindcast wave data has been used to further develop and refine rip hazard thresholds to improve forecast performance. Operational forecasts for Durban and Port Elizabeth/Gqebertha are currently being tested using the revised thresholds. Stakeholder engagement is helping to improve and refine the forecast format and determine the communication strategy for the service.

Extended Highlights

The team have been performing calibration and validation on rip hazard thresholds generated by CMAR during the first phase of the WCSSSP project in 2019. By incorporating additional incident data from Cape Town and two sites in South Africa between 2020 and 2024 we have reviewed the current rip hazard thresholds (Figure 1). Furthermore, the results from fieldwork performed in Cape Town by CMAR in 2022 has been used to help incorporate a tidal component to the hazard threshold, building on experience from local lifeguards.

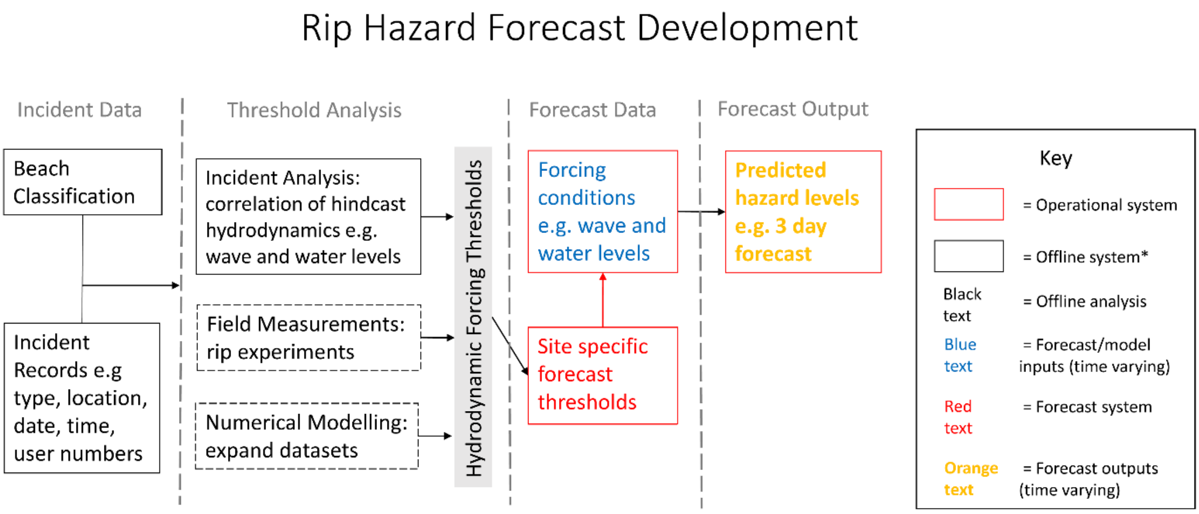

Figure 1: Schematic flow chart indicating the process for developing an operational rip forecast such as that in development for Cape Town, Gqeberha/Port Elizabeth, and Durban.

A new Rip Current Hazard threshold table has been devised that incorporates the new incident data analysis and results from the Cape Town field work. There is no change in the wave characterises for each hazard level, however, a tidal component is included that is focused on increased rip current flow rates around low water (Figure 2). The revised thresholds have been applied to the previous 2017-2020 incident data to examine the assigned hazard levels during the time of those incidents. The revised thresholds significantly improved the "hit rate," reducing false-positive Level 1 incidents from five to two and reclassifying several Level 2 incidents to the higher-hazard Level 3 category. Similarly, when applied to the more recent incident data in Gqeberha/Port Elizabeth, despite having only seven incidents with available metocean data from 2020, the incorporation of the tidal element resulted in three incidents shifting from a forecast Level 2 to Level 3.

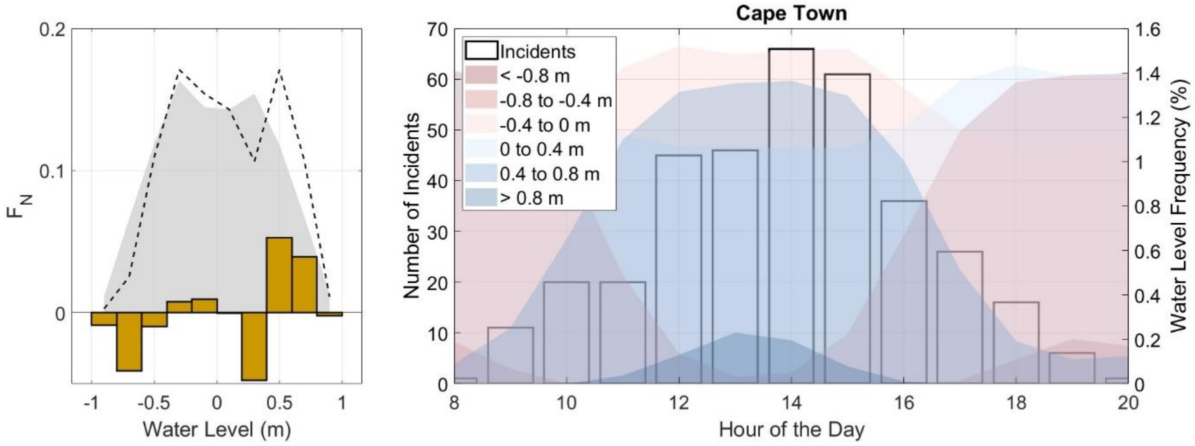

Figure 2: Left column: Normalised frequency distributions (F_N) of rip current incidents at Cape Town, shown with associated water levels. Yellow bars represent the deviation from background forcing distributions (grey shaded area), with dashed lines indicating incident conditions. Positive yellow bars highlight above-average incident occurrences. Right column: Hourly distribution of recorded incidents overlaid with water level frequency, spanning Mean High-Water Spring to Mean Low Water Spring in 40 cm increments for Cape Data covers incidents and tidal data from 2017–2024 for Cape Town.

Alongside the incident analysis the University of Cape Town have been working with stakeholders to help develop the dissemination strategy for future rip forecasts. Based on these discussions, a tiered communication approach is recommended, catering to the two main audiences of trained professionals and the broader community. Several key considerations were identified including communication frequency and mediums, symbology (Figure 3) and language in messaging and adaptation by stakeholder organisations. The foundation of an effective dissemination strategy is built on essential elements, including the use of consistent terminology and symbology across all platforms. Furthermore, stakeholders highlighted the importance of education, collaboration, and leveraging pre-existing networks to improve the effectiveness of the forecasting service.

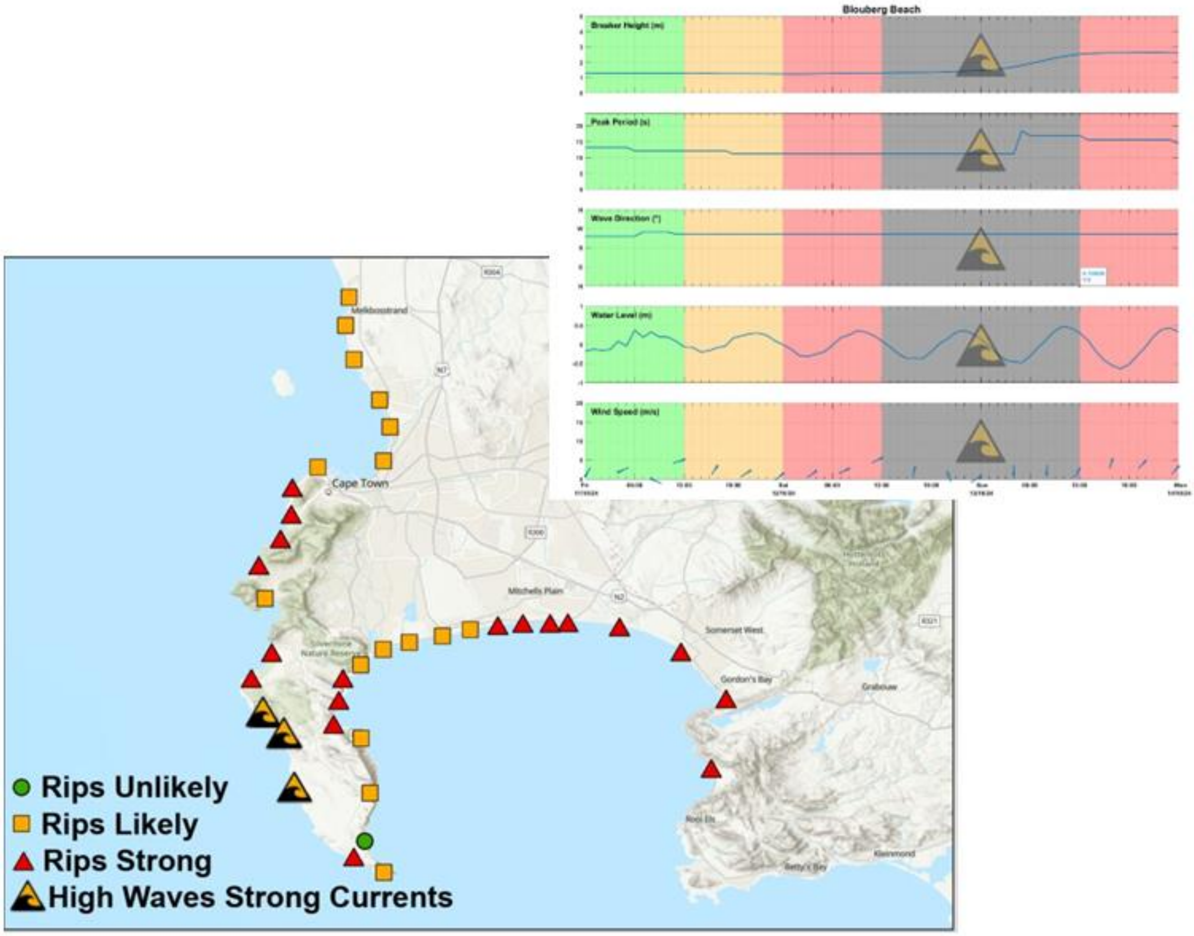

Figure 3: Example rip hazard forecasts for Cape Town with updated symbology to reflect stakeholder feedback.

6. Developing high-resolution wave climate projections

Authors: Kimberley Eastaugh (Met Office)

Summary

A high-resolution wave climate projections dataset produced using machine learning, is currently in development to simulate historic and future wave conditions for South Africa (SA). This can act as a low computational cost and higher resolution alternative to projections that are based on standard wave forecasting models forced with atmospheric outputs from General Circulation Models (GCMs). To verify the high-resolution dataset emulator performance, current emulator outputs are compared to existing lower resolution climate projections output from the Coordinated Ocean Wave Climate Project (COWCLIP) (Morim et al., 2020).

This work has been presented at several internal meetings and will be presented at the International Conference on Southern Hemisphere Meteorology and Oceanography (ICSHMO) in April 2025.

Extended Highlights

The wave climate emulator was trained using an Artificial Neural Network (ANN) (Abraham, 2005) model based on historic ERA5 reanalysis atmospheric and wave data, and projections forced using CMIP atmospherics, initially using one GCM from the CMIP5 ensemble (HadGEM2-ES). The emulator output has been compared geospatially to the equivalent existing lower resolution climate projection from COWCLIP GCM outputs.

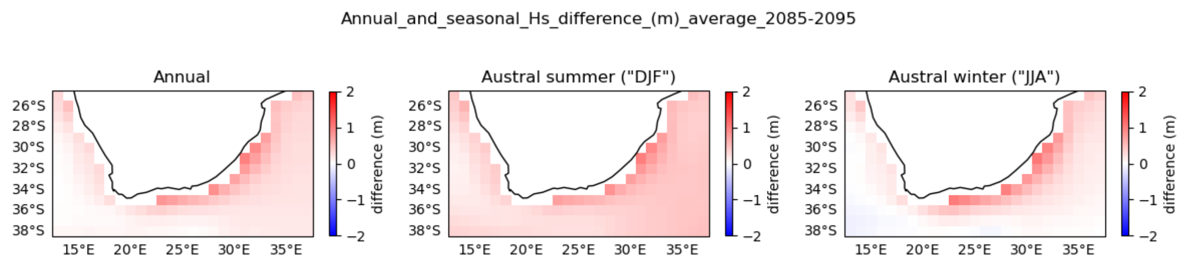

Figure 1: Difference (Hs in m) between emulator and COWCLIP data (average) (Annual, Austral Summer, Austral Winter)

Initial results indicate that for average end of century projections under a high emissions scenario (Figure 1) the emulator illustrates a positive bias compared to the COWCLIP outputs, with slightly greater Significant Wave Height (Hs) (illustrated as difference in meters) predictions around the coastline, particularly around the south-east coast of SA. Further offshore, the difference is less pronounced, and the emulator matches well. Seasonally, austral summer leans towards a positive bias in the emulator, whereas this is more variable over austral winter, with a positive bias towards the coast and a slightly negative bias offshore towards the south-west. Lower extremes illustrate greater Hs compared to the COWCLIP outputs (not shown).

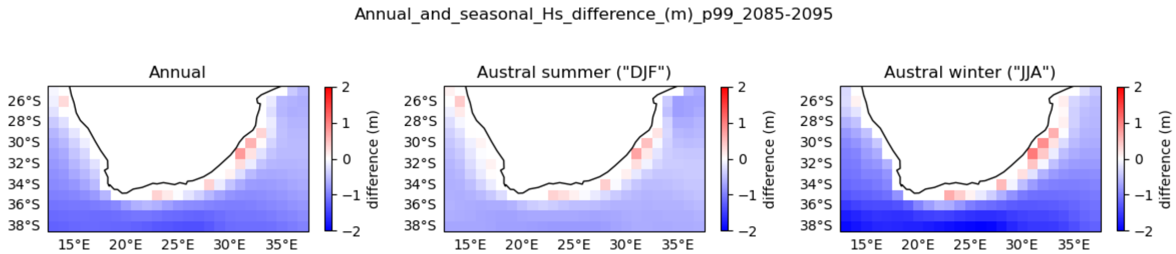

Figure 2: Difference (Hs in m) between emulator and COWCLIP data (99th percentile) (Annual, Austral Summer, Austral Winter)

However, towards the higher extremes (Figure 2) a negative bias can be seen offshore, particularly annually and in austral winter, which could potentially indicate underestimation of Hs in the higher extreme projections. Although a slight positive bias is still maintained around the coastline.

Historical simulations (not shown) have also been analysed, and on average indicate good agreement with only small positive and negative biases annually. Seasonal differences are slightly greater showing positive biases in austral winter and negative biases in austral summer.

Further analysis is currently being conducted over other CMIP ensemble members to address and understand the bias indication and uncertainty in the emulator projections overall.

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7. Forecasting medium-range heat-related mortality risk using weather patterns

Authors: Lewis Ireland, Robert Neal, Joanne Robbins, Rebecca Gilbert, Rosa Barciela (Met Office) and Theo Economou (University of Exeter)

Summary

We introduce a framework for forecasting medium-range heat-related mortality risks in South Africa by integrating weather pattern analysis and impact-based forecasting (IBF). By defining circulation types through k-means clustering on ERA5 reanalysis data, a set of 30 distinct weather patterns is derived to encapsulate meteorological variability. These patterns are linked to health impacts through an exposure-lag-response model, enabling forecasts of relative mortality risks due to heat events. This approach aims to enhance preparedness and targeted interventions during high-impact weather events.

Extended Highlights

This research aims to use a pre-defined representative set of weather patterns over South Africa to support IBF through the development of a medium-range forecasting application. The motivation behind the weather pattern approach is to improve forecast lead time for high-impact events, extending the window for pre-preparedness activities, and to provide a direct description of the circulation driving these events. Accurate temperature and precipitation forecasts are challenging beyond several days, but this method allows for informed assumptions based on specific weather patterns and their climatologies.

Weather patterns, derived from the analysis of daily-mean mean sea-level pressure (MSLP) fields over South Africa, serve as the foundation of the forecasting framework (Ireland et al., 2024). The k-means clustering technique, applied to ERA5 reanalysis data (1979–2020), was used to produce 30 unique weather patterns (Figure 1). These patterns were evaluated for their ability to reproduce variability in daily-maximum 2-m temperature (T_{max}), ensuring their relevance for forecasting heat-related impacts.

A prototype weather pattern IBF tool for South Africa is currently under development. It provides daily 00/12 UTC ECMWF medium-range weather pattern probability forecasts, determined by the number of ensemble members objectively assigned to each pattern. Understanding weather pattern characteristics, including their climatologies and impacts, enables interpretation of forecast output and prediction of likely consequences. A heatwave forecasting application has been developed, which converts weather pattern forecasts into probabilities of exceeding temperature thresholds relative to normal conditions. This is achieved by calculating empirical probabilities of threshold exceedance for the SAWS heatwave criterion using ERA5 reanalysis data (1979–2020).

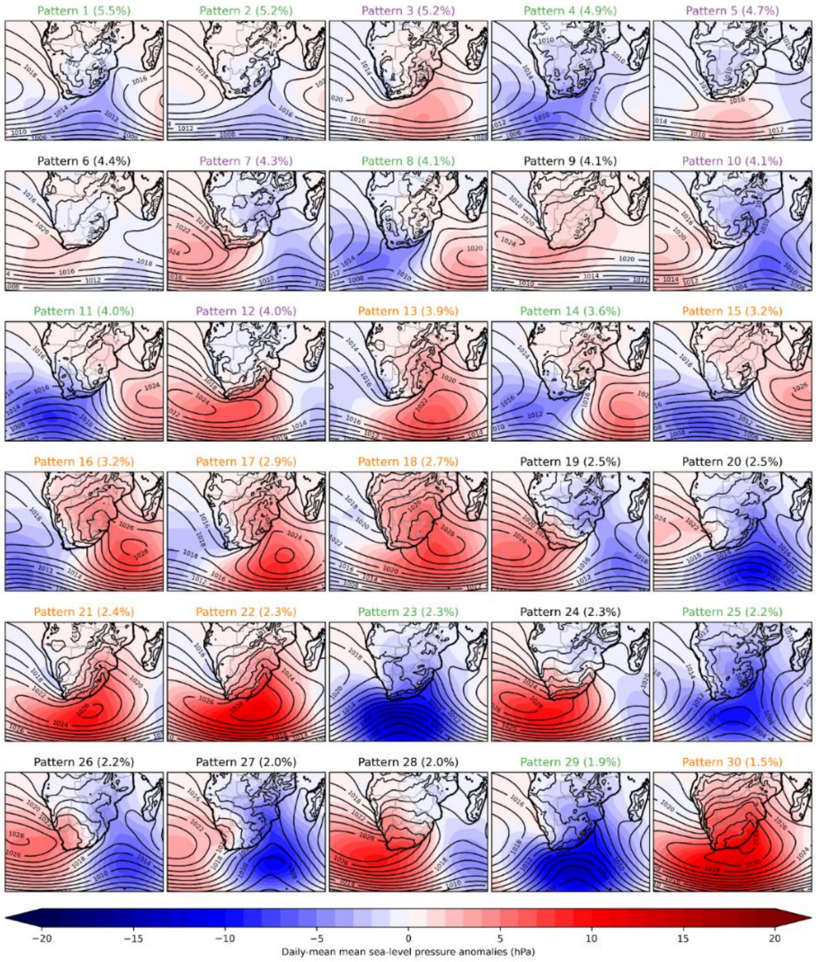

Figure 1: Weather patterns capturing daily-maximum 2-m temperature variability (1979–2020), with contours showing annual mean MSLP and anomalies. Percentages indicate annual occurrence.

Mortality risk forecasts have been generated by coupling weather pattern probabilities with exposure-lag-response functions, developed using distributed lag non-linear models (DLNMs) (Gasparrinia et al., 2010). Mortality data (1997–2018) (Statistics South Africa, 2024) and historical daily-mean 2-m temperature records (ERA5; 1979–2020) form the basis for these models, capturing the delayed and cumulative impacts of heat on cardiovascular and respiratory mortality. Provincial-level analyses highlight demographic variations in risk (Figure 2), as well as sex-based differences in vulnerability (Figure 3).

Two forecasting perspectives are employed: a forward-looking perspective to assess potential future risks, supporting proactive interventions, and a backward-looking perspective to explore cumulative or delayed impacts of past exposures. This dual approach enables both immediate and strategic responses to heat events.

Future developments will enhance the IBF tool's utility by integrating risk matrices directly into forecasts and extending demographic-specific mortality forecasts. These advancements aim to refine public health interventions and align forecasting capabilities with the needs of vulnerable populations. The outcomes underscore the potential of combining meteorological and health data for impact-oriented forecasting, offering a replicable framework for other regions experiencing climate-related health challenges.

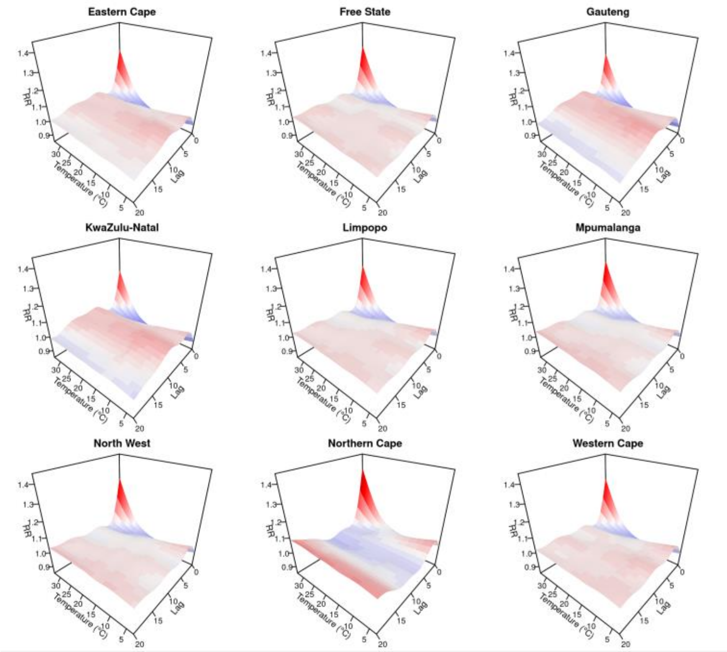

Figure 2: Provincial exposure-lag-response curves illustrating heat-based mortality risk.

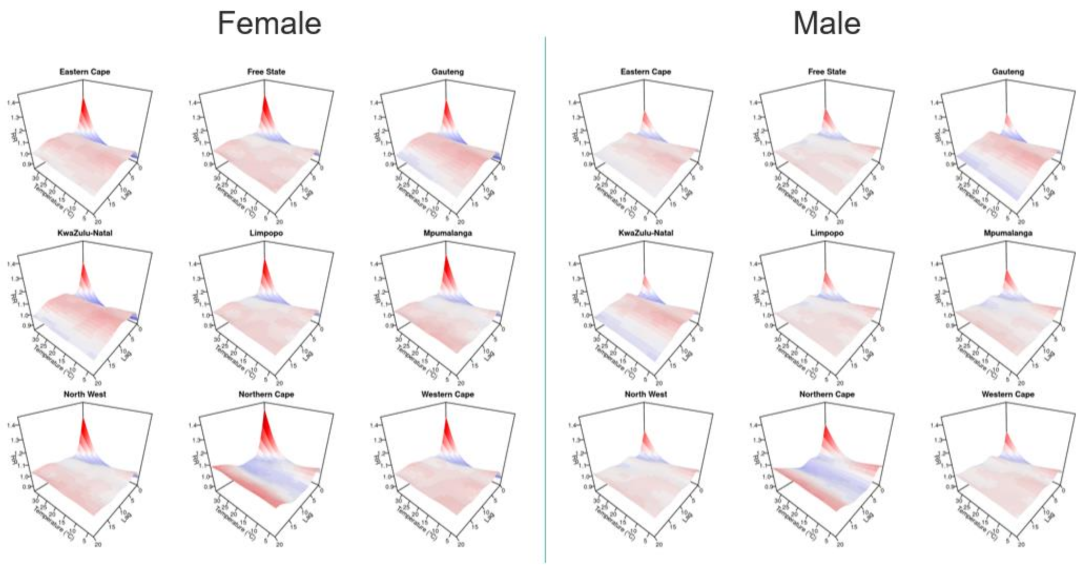

Figure 3: Provincial exposure-lag-response curves for females (left) and males (right) illustrating heat-based mortality risk.

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