

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

# 2025

## Science Highlights Report

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## Executive Summary

The Weather and Climate Science for Service Partnership (WCSSP) South Africa project is strengthening collaborations amongst the UK and South African weather and climate science and services community to advance innovative science, modelling and service development. The project is delivered in partnership by the Met Office, 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 and Earth Systems Science (ACCESS), together with research organisations across the UK and South Africa.

A key development in 2025 has been a revised project Science Plan, guiding activities across the project over the next three years. The updated plan recognises evolving institutional priorities, technological advancements, and emerging scientific frontiers. It has also informed a revised Work Package structure, now comprising three main delivery work packages, and has expanded the range of focal sectors to include the water sector given the intersections with other priority sectors: agriculture, energy, health and marine.

This year the project supported several scientist exchange and engagement visits, strengthening relationships amongst partners and supporting collaborative research across work packages. New collaborations are forming in land surface modelling and attribution science as well as innovative work in service development, from managing coastal risks to deepening understanding of vulnerable communities to enhance Early Warning Systems.

Since the project began in 2014, SAWS have remained a key partner and this relationship continues within the Momentum Partnership aligned to WCSSP. Collaboration between the Met Office and SAWS is evaluating the use of the LFRic next generation modelling system in South Africa and the IMPROVER system to enhance probabilistic forecast products. Wider scientific collaborations include advancing kilometre scale-modelling and the use of the recently completed CP4-Africa ensemble climate simulations which are now being evaluated across partners. In addition, a new study on seasonal forecasting timescales is enhancing understanding of El Niño teleconnections to South Africa, highlighting mechanisms to explain different responses of the southern Africa climate in El Niño years.

In June 2025, three new research projects were launched under WCSSP South Africa following a funding call that was co-designed by partners: 1) the Attribution of extreme Weather for southern African ImpacTs (AWAIT) project led by the University of Oxford; 2) the Water Availability duRing Drought (WARD) project led by the UK Centre for Ecology and Hydrology (CEH); and 3) the South African impact-based Forecasting and Early warnings (SAFE) project led by HR Wallingford. A new aligned project led by SAWS began at the end of 2025, funded by the Lloyd's Register Foundation with in-kind support from WCSSP South Africa: Strengthening Access to Forecasts for Early Response in South Africa (SAFER SA).

Together these new projects and ongoing work are supporting a broadening of activities under WCSSP South Africa, enriching the project and strengthening research collaborations.

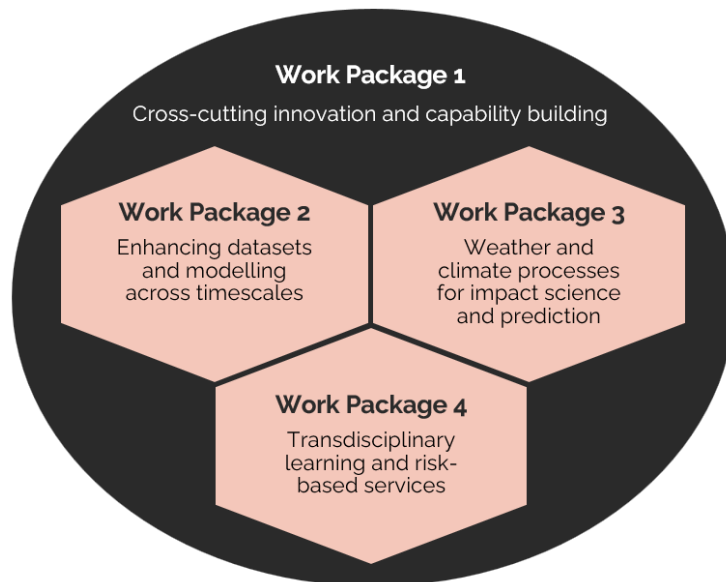
# 1. Introduction: Overview of WCSSP South Africa

**Mission: Advance innovative science, modelling, and development of weather and climate services to support actions and policy that reduce risk, enhance equity, safeguard lives and livelihoods, and build resilience in a changing climate.**

Achieved through harnessing technological developments, supporting collaborations spanning physical and social sciences, alignment with regional, national and institutional priorities, and strengthening broader partnerships amongst the UK and South African weather and climate science and services communities.

The WCSSP South Africa project was initiated in 2014 and has evolved over the past 11 years to continue supporting emerging scientific as well as national and institutional priorities. The project is a strategic partnership between South African and UK weather and climate research organisations, led by the Met Office in the UK and in partnership 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 and societally relevant challenges to enhance understanding, improve forecasts and advance modelling of the weather and climate in South Africa and the wider region. Opportunities are pursued to leverage new scientific innovations and progress the development of impact-based weather and climate services.



WCSSP South Africa is composed of four interlinking work packages (WPs) depicted above. Work Package 1 provides a space for cross-cutting innovation and capacity building. Work Packages 2 to 4 comprise the main research activities spanning physical, social and applied interdisciplinary science and modelling across weather and climate timescales. Work Packages are co-led by scientists at the Met Office and South African partner organisations.

## 2. Partner Engagement

### 2.1 Scientist and institutional engagement

Engagement between scientists and forecasters across partner organisations in the UK and South Africa is critical to the success and sustainability of the WCSSP South Africa project. In 2025 the project supported several visits and engagements, strengthening personal relationships and trust, supporting skills development and knowledge sharing, and providing opportunities to collaborate on a range of research activities.

In February 2025, the Met Office hosted a 2-week visit from scientists Sarah Roffe (ARC) and Mohau Mateyisi (CSIR) to work on WP3 research. During the visit, they collaborated with UK scientists and successfully installed and ran a suite of impacts indices from the Met Office Climate Impacts Toolbox. Using ERA5 reanalysis data, their work has helped to better characterise historical events for a number of impacts indices (e.g., fire weather, heat stress). Later in the year, prior to the annual science meeting in October 2025 (see section 2.2), CSIR hosted a hybrid workshop to discuss opportunities for collaborative work in WP3 as well as facilitate technical support for South African scientists to use the Joint Analysis System for Integrated Modelling (JASMIN), describe further in section 4.3.

A high-level planning meeting took place in March 2025, bringing together focal points across WCSSP South Africa partner organisations as well as government stakeholders and representation from the Science Review Panel (SRP). The meeting had three main objectives:

1. Evaluate progress against objectives for each work package and project overall, as expressed in the Science Plan developed in 2023.
2. Agree on high-level science aims and objectives for a new joint Science Plan looking forward over the next three years.
3. Articulate an updated work package structure to more efficiently and effectively facilitate collaborative research across partners to achieve project aims.



**Photo:** WCSSP South Africa High-Level Planning Meeting. African Hills Lodge, Magaliesburg, 10-11 March 2025. Left to right: Joe Daron (Met Office), Anna Steynor (Met Office), Francois Engelbrecht (Wits), Ezekiel Sebege (SAWS), Johan Malherbe (ARC), Nico Kroese (SAWS), Alex Crook (FCDO), Keith Williams (Met Office), Neville Sweijd (ACCESS), Hannah Manton (Met Office), Loice Alusala (FCDO), Mohau Mateyisi (CSIR).

The planning meeting facilitated detailed discussions and time to hear from all partners on perspectives regarding the partnership and priorities for the future. An updated Science Plan (see section 3) was produced based on the outcomes of the meeting, reflecting joint priorities of partners as well as supporting and aligning efforts of the broader UK and South African weather and climate community to advance key areas of science and service development.

The South African Society for Atmospheric Science (SASAS) held its annual conference in Cape Town in November 2025, hosted by the Climate System Analysis Group (CSAG). Many scientists from across South Africa, including WCSSP partner organisations, attended to share research and strengthen professional networks. Jennifer Weeks from the Met Office attended to present work on storyline approaches for communicating sea level change and a new framework to explore high-end sea level rise scenarios tailored to risk-averse stakeholders. Jennifer then led a collaborative workshop between the Met Office and South Africa National Parks (SANParks) using scenario-based decision gaming to support national park planning for sea level rise in the Wilderness estuary along South Africa's Garden Route – see extended highlight, section 6.2.

Scientists working on the project also engaged in other forums. One notable example was the 14<sup>th</sup> International Conference on Southern Hemisphere Meteorology and Oceanography (ICSHMO) held in Cape Town, where South African partners and scientists from the Met Office presented and discussed work with colleagues, primarily based in the southern hemisphere.

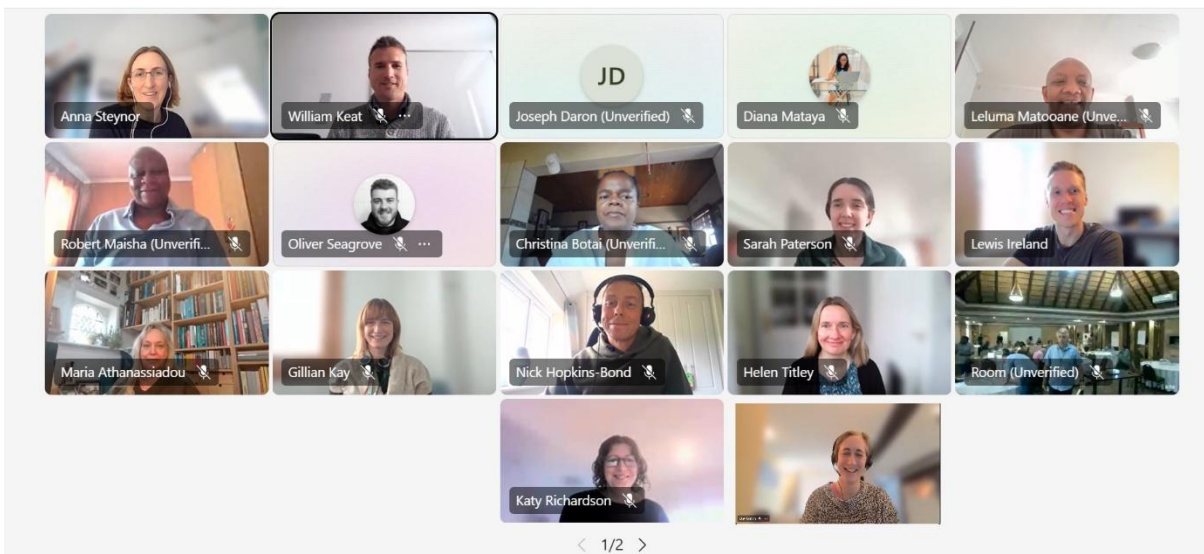
## 2.2 2025 Annual Science Meeting

Each year WCSSP South Africa holds an annual science meeting bringing partners together to share knowledge, present progress on specific pieces of work, discuss evolving priorities and opportunities, and build relationships to forge strengthened collaborations. The 2025 annual meeting was held in South Africa at Kloofzicht Lodge, Muldersdrift from 14-15 October 2025. Held over two days, the agenda featured welcome remarks from government stakeholders and WCSSP partners, science presentations across the main work packages, and interactive activities on priority topics.

Work Package focused sessions featured talks from UK and South African scientists on the latest scientific progress and plans across activities. Talks included initial work and plans for three new research projects launched under WCSSP South Africa in June 2025. Sarah Sparrow (University of Oxford) introduced the Attribution of extreme Weather for southern African ImpactTs (AWAIT) project, which aims to enhance understanding of methods for extreme event attribution methods and strengthen skills of South African scientists to conduct attribution studies. Helen Baron (UK Centre for Ecology and Hydrology - CEH) spoke about the Water Availability duRing Drought (WARD) project, working to improve the representation of hydrological systems in the JULES land-surface model to better understand impacts of climate variability and change on water scarcity. And Emma Brown and Darren Lumbroso presented initial findings and outlined plans for the South African impact-based Forecasting and Early warnings (SAFE) project, working with South African partners to enhance

understanding of community contexts to support effective severe weather warning systems.

Dedicated Work Package sessions were run for scientists to discuss ongoing work, plan activities and consider emerging opportunities. In addition, Amy Waterson (Met Office) facilitated an interactive session on attribution science utilisation, building on work exploring opportunities and barriers to the uptake of attribution science under WCSSP South Africa and the Met Office Hadley Centre Climate Programme “bridging science” project.

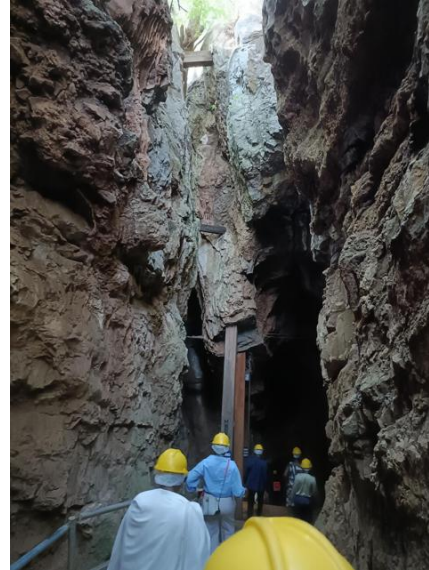


**Photos:** (top) In-person and (bottom) online attendees at WCSSP South Africa Annual Science Meeting: Kloofzicht Lodge, Muldersdrift, 14-25 October 2025.

A highlight of the annual meeting was a field visit to the nearby Sterkfontein caves managed by the University of Witwatersrand and part of the Cradle of Humankind UNESCO World Heritage Site. The caves are known internationally for significant contributions to the field of palaeoanthropology. The visit provided an opportunity for those attending the annual meeting to learn more about this hugely important cave network, with many important findings helping to understand the evolution of humans. The site for the meeting and visit to the caves served as a timely reminder that humans have had to adapt to changing environmental conditions

over many thousands of years, with the current era and impacts of climate change presenting a hugely significant challenge for humankind.

At the end of the annual meeting, the British High Commission hosted an evening reception at the High Commission Residence in Pretoria. UK Deputy High Commissioner Lisa Weedon spoke at the event, highlighting the importance that the UK government places on scientific partnerships and evidenced-based policy, highlighting the value of WCSSP South Africa.



**Photos:** Field visit to Sterkfontein caves in the Cradle of Humankind, managed by University of Witwatersrand.

### 3. Updated Science Plan

The March 2025 high-level planning meeting (section 2.1) provided an opportunity to evaluate the overall status and progress of science activities across the project and consider new science ambitions for the coming years. A key outcome of the meeting was an updated mission statement (section 1) and refined objectives for a new joint Science Plan looking forward over the next three years. The meeting also discussed and proposed an updated work package structure to support collaborative research across partners.

The Science Plan provides a high-level overview and list of objectives to guide the scientific research, service development, and capability strengthening across the WCSSP South Africa project. From 2014 to 2019, the project focused on activities supporting the partnership between the South African Weather Service (SAWS) and the Met Office. Following an expansion of the project, and inclusion of additional partners, a revised Science Plan was agreed during a high-level partner meeting in November 2019. It has subsequently been updated in June 2021 and March 2023 following further engagements between partners. The current plan represents an evolution, prioritising ongoing areas of collaboration that align to the long-term project aims and integrating new areas of scientific innovation and service development, while recognising the need for an equitable science partnership.

Six project aims are articulated in the updated Science Plan:

1. Address frontier scientific and service development across weather to climate timescales.
2. Enhance system understanding and improve simulations of the weather, climate variability and climate change in South Africa and the wider region.
3. Strengthen South African and UK weather and climate science and services capabilities.
4. Leverage new scientific innovations, technology, and knowledge from physical and social sciences in research and applications.
5. Foster equitable collaborations amongst institutions and researchers across South Africa and the UK, striving to achieve benefits to all parties.
6. Promote an ethos of capacity sharing, recognising the common goals of achieving a society more resilient to hazardous weather and a changing climate.

The Science Plan further elaborates a set of objectives that cut across overarching scientific priorities, ensuring sustainability and impact of the work and, critically, how people engage to deliver joint science activities across partners. The updated plan highlights that the project aims to advance science and services relevant to different sectors but with particular emphasis on five priority sectors: agriculture, energy, health, marine (coastal), and water. 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. The scope of science covers multiple weather and climate hazards, including compound and cascading hazards, with emphasis on heat, drought, flooding, wind, and coastal hazards (sea level, waves, rip currents).

A key decision taken at the planning meeting in March was to move the existing activities in Work Package 1, previously titled “Observations and Attribution”, into Work Package 2 and consolidate as a work package focused on the generation, processing and analysis of observations and model datasets across weather and climate timescales. The rationale to move from four to three work packages was to create efficiencies in work package activities and management but also recognise that work on attribution was highly aligned with existing activities in Work Package 2. The important work on observations, including the DR-Africa project advancing AI methods for data digitization, has not been de-prioritized and is still a key activity within WCSSP South Africa.

During the meeting, there was wider consideration of the previous Work Packages 3 and 4. For these work packages, the consensus was to maintain them as separate work packages with clear points of distinction, particularly in the context of Work Package 4 which incorporates social science and transdisciplinary science activities.

To avoid unnecessary changes to administrative processes, Work Package 1 was maintained but with a new focus on cross-cutting innovation and capability building, providing a “landing space” for new innovative work. For example, Work Package 1 can be a home for new work exploiting and supporting advances in the application of AI and Machine Learning, where not integrated into existing activities. As such, the work package aims to explore new areas of research and development, with potential to propose and support activities that are high technical risk, high reward, and potentially transformative, as well as facilitating cross-cutting capability strengthening that responds to partner priorities but does not neatly fall into the other three work packages.

The Science Plan explicitly states how the science activities in WCSSP South Africa align to the Met Office and South African partner strategic priorities. As a joint Science Plan, the work does not aim to serve an individual organisation’s interest but rather align to shared priorities and foster collaborations that benefit UK and South African science through long-term partnership.

## 4. Work package progress and collaborations

### 4.1 Work Package 1: Cross-cutting innovation and capability building

**WP Lead:** Joseph Daron (Met Office)

Work Package 1 (WP1) is a “landing space” for new research and ideas that can support other activities in the project and more widely. In particular, recognising that the world is experiencing a major technological transformation with the emergence of new Artificial Intelligence (AI) and Machine Learning (ML) capabilities, WP1 will support new work that doesn’t align neatly with other WPs but that represents a need amongst partners to leverage and explore AI capabilities. In doing so, it will coordinate with other work at the Met Office and partner organisations supporting advances in this area. In addition, WP1 can also support further activities and innovations that are not AI related but that go beyond the focal topics of WP2, WP3 and WP4.

Under the International Science Partnership Fund (ISPF) that supports the WCSSP programme, the AI for Climate project is advancing the development of a new AI-based Earth System Model as well as work to advance downscaling capabilities for regional climate modelling. To align with these activities, and wider initiatives on AI in weather and climate science and applications, WP1 has supported initial exploration of a new “AI for WCSSP” initiative, aiming to fast-track innovative ideas that may develop into research projects. At the time of writing this report, this work is in progress.

As a new work package, this is an evolving space to be reviewed in future years. Conversations are ongoing on how to best leverage this work package and create new activities that support innovation and capability building, recognising resource limitations and diverse priorities.

### 4.2 Work Package 2: Enhancing datasets and modelling across timescales

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

Work Package 2 (WP2) continues to build new capability in the exploitation of observations and development and evaluation of regional modelling for South African weather and climate across timescales.

In 2025, work continued on the production of automated methods to digitise data from paper-based observation archives – see extended highlights, section 6.1. These have used advanced techniques in optical character recognition and machine learning, and results produced this year show accuracy rates that can reach levels similar to those of human transcription. Samples from the archives of SAWS (among others) have been used in the training and testing of these methods.

A suite of convection permitting climate simulations for Africa (CP4A), using the Met Office

Hadley Centre regional model, have been finalised. These outputs represent a new high-water mark in the simulation of projected southern African climate change, offering better resolution of local weather processes while assessing the uncertainty from using different global models to drive the regional model. An initial set of key data have been uploaded on the Joint Analysis System for Integrated Modelling (JASMIN) platform for ease of access by a wide range of partners. Currently, the data have been released in an evaluation phase ahead of an open release planned for next year. WCSSP South Africa partners are actively engaged in this initial assessment of the output, and a paper describing the properties of the simulations is due for submission to a peer-reviewed journal imminently. Further evaluation has been conducted using the ESMValTool program on the CP4A data to compute the LaunchPAD (Priority on African Diagnostics) outputs.

Following previous years' development and evaluation of feature tracking methods to analyse the representation of Mesoscale Convective Systems (MCSs), this year has seen the tracking calculation applied systematically across the CP4A ensemble. The resulting database of simulated MCSs is being analysed for comparison with observations and to diagnose climate change trends. This has important implications for the analysis of extreme rainfall over South Africa and will constitute an important part of the evaluation of CP4A.

The development of future regional capability beyond the current CP4A-generation modelling has been an important strand of work in recent years. This has previously involved the development of a regional model configuration based on an entirely new dynamical core. This year has seen a slight shift of emphasis towards development of tools that unlock the diagnosis of processes in these very high-resolution models - the Community Seamless Evaluation Toolkit (CSET). Work has ranged widely, including development of the capability to interface with rainfall radar data for verification, new diagnostics for assessment of structural similarity, and improvements in speed. When completed, these tools will facilitate partners' use of high-resolution regional climate modelling, overcoming part of the considerable challenge of working with these large datasets.

On weather timescales, work continues with SAWS to evaluate Momentum Numerical Weather Prediction (NWP) configurations. From April to December 2025, SAWS conducted ongoing development and testing of the IMPROVER system. This system combines outputs from the 4.4km SADC domain model and the 1.5km South Africa domain model. The goal of this work was to make guidelines for storm-related activities in southern Africa more consistent and useful. SAWS used the Unified Model (UM) forecasts and its own satellite-based Convective Rainfall Rate (CRR) product to test the IMPROVER blending methods. The main purpose of this approach was to assist with short-term forecasting. The initial assessments were subjective, by comparing the blended guidance with satellite images. While the underlying models had different spatial scales and domain size, the comparisons indicated that the blended method was able to effectively capture major storm features. Met Office supported with objective verification through the World Meteorological Organisation (WMO) AvRDP2 project. Objective verification indicated that the system was good at aspects like general calibration, but it also showed that it was unable to differentiate between conditions with and without storm activity. This study showed that combining different sources of

forecasts can lead to improved probabilistic guidance. The study also found important areas for future research, such as improving the identification of different storm events and conducting additional study and evaluation of IMPROVER's different blending methods for other case types, such as extreme temperature events.

As contributions to a RAL3-LFRic evaluation project, eleven high-priority South African case study simulations using UM13.1 and LFRic Ifric\_apps\_vn1.2 were conducted at the Met Office. Both models used the RAL3.3 science configuration, with some stability adjustments applied to the LFRic runs. All simulations employed the Regional Nesting Suite and were assessed using CSET. An initial subjective evaluation focused on the 96-hour forecast for tropical cyclone Eloise's landfall and the associated heavy rainfall from the low-pressure system. Over this 4-day period, the average surface temperature showed that LFRic\_708.1 generally predicted lower temperatures over central South Africa and the Namibia coast, with higher temperatures elsewhere. This temperature variation corresponds with areas where LFRic\_708.1 indicates increased cloud cover, evidenced by a higher cloud area fraction parameter. Notably, the differences in lightning flash distribution and count over the landfall region merit further study. Additional RAL3.3 cases related to the IMPROVER activities will also be evaluated to provide a broader understanding of the events across various forecast components.

SAWS continues to operate a 4.5km UM Data Assimilation configuration that can resolve large convective storms, with the aim of improving the forecast accuracy of thunderstorm timing and location over the whole of South Africa. The system runs 3-hourly 3D-Var cycles and work has included updates to RAL3 science components and ongoing development of capabilities to incorporate local observation types.

Finally, a novel analysis that more clearly shows the mechanism of the influence of the El Niño-Southern Oscillation (ENSO) on South African climate at seasonal timescales has been completed – see extended highlights, section 6.4. A paper is currently under consideration for publication in the journal Environmental Research Letters. This work, involving scientists from the Met Office, SAWS and the University of Pretoria, also shows how this connection can fail in certain ENSO events. Following interest from the South African community, new work looking at the seasonal prediction of the Western Cape winter rainfall region has now been initiated.

### **4.3 Work Package 3: Weather and climate processes for impact science and prediction**

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

#### ***WP3 focused workshop***

The Work Package 3 (WP3) team hosted a two-day workshop on 9<sup>th</sup> and 10<sup>th</sup> October 2025, ahead of the WCSSP South Africa Annual Meeting. This was run both in-person, at CSIR in

South Africa, and online, bringing together everyone working on WP3. Andy Hartley and Anna Bradley (Met Office) attended the workshop in person as part of their trip for the Annual Meeting. The aim of this workshop was to identify new ideas for collaborative analysis through discussing existing work and potential opportunities, with separate discussion sessions for several key sectors. There was also a session focusing on technical support for JASMIN, through which analysis and data will be shared through the new WP3 workspace. Both the sectoral discussions and the JASMIN support are continuing into 2026.

### ***Sectoral discussions***

Five different sectoral themes were chosen, aligned to the WCSSP South Africa project Science Plan (see section 3), and a separate discussion session was held for each. These sectors were: agriculture and food security; health; urban and energy; water security; and coastal and marine. Each session was led by one scientist from the Met Office and one scientist from South African partner organisations, with two other people assigned to be notetakers. Each session followed the same format: the session leads gave an initial summary of work currently being done in this space, followed by an open discussion around ideas for future work.

Each discussion aimed to identify relevant climate indices and data processing requirements for any ideas presented. Structured notetaking tables, where this information could be filled in, were produced in advance of the workshop and distributed to the notetakers. Filling in these tables was sometimes challenging, as the open discussion format encouraged broader conversations that didn't always align with the table structure. Nevertheless, these discussions provided valuable insights and revealed several potential opportunities for each sector.

The outcomes of these sessions is being used to prioritise data processing tasks as part of Deliverable 3.1.4 (developing an atlas of climate indices datasets). Next steps will involve collating the initial information from the tables from the focus days into a collaborative document, which will then be used to identify ideas and opportunities for future work. This will form Deliverable 3.2.3 (scoping/initiation of impacts and risk-based analysis using atlas outputs).

### ***JASMIN account support***

On the final afternoon of the workshop, a technical support session was held to help South Africa partners gain access to JASMIN and the WCSSP South Africa WP3 workspace, where data and analysis will be shared. Guidance was given on how to set up JASMIN accounts, including setting up ssh keys and applying for access to group workspaces. Two follow-up sessions (led by Anna Bradley and Christophe Sarran) were arranged to provide further support. These sessions were held on 9 December 2025 and 30 January 2026.

### ***Visit to ARC***

At the end of October, following the WCSSP South Africa Annual Workshop, Anna Bradley (Met Office) spent a week working alongside Dr. Sarah Roffe at the Agricultural Research Council (ARC). During this time, Anna focused on developing a research proposal, which will use a compound methodology to investigate the impact of weather and climate on livestock

numbers and assess how projected climate change may influence these interactions in the future. This work will sit within the Agrometeorology Division at ARC, though the organization’s scope is far broader. The visit provide a fascinating learn opportunity, to hear about the diverse range of departments and on-the-ground research conducted at the ARC.

During the visit, Anna had the opportunity to present some previous work on compound drought–heatwave events to Dr. Roffe and ARC colleagues, and attend presentations from ARC researchers. The discussions that followed were highly valuable, with excellent questions and constructive feedback that will help shape future collaborative work under WCSSP South Africa.

#### 4.4 **Work Package 4:** Transdisciplinary learning and risk-based services

**WP Leads:** Kate Salmon and Anna Steynor (Met Office), Johan Malherbe (ARC) and Neville Sweijd (ACCESS)

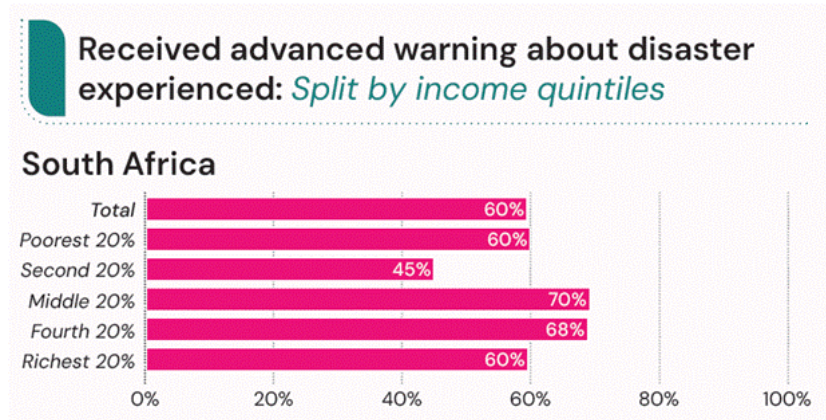
Work Package 4 (WP4) has continued to support dialogue and science engagements required to address planning needs, helping stakeholders identify barriers, trade-offs and long-term adaptation considerations. This work has included integration of sea level projection insights into coastal decision-making processes, contribution of wave projections from an emulator model, an understanding of the value of attribution science, and working alongside SAWS to increase access to early warning of hazardous weather.

##### ***SAFER SA: Strengthening Access to Forecasts for Early Response in South Africa (Lloyd’s Register Foundation Project)***

A significant highlight of 2025 was the successful joint application for funding to the Lloyd’s Register Foundation to support a 2-year project in enhancing access to early warnings in South Africa. The project team is made up of a consortium between SAWS, the Met Office and the University of Bristol. SAFER SA aims to identify communities in the second lowest income quintile (the “missing 20%” – figure 1) at three SAWS sites to understand barriers and improve dissemination mechanisms of hazardous weather early warnings. The lessons learned will be used to scale up improved early warnings across southern Africa.

While the project is still in its early stages, a preliminary statistical analysis of the World Risk Poll data has been compiled, identifying potential driving factors behind access to early warnings amongst different socio-economic groupings. In 2026, the project will initiate community engagement and co-production processes to understand the decision-contexts of communities at three SAWS control room sites.

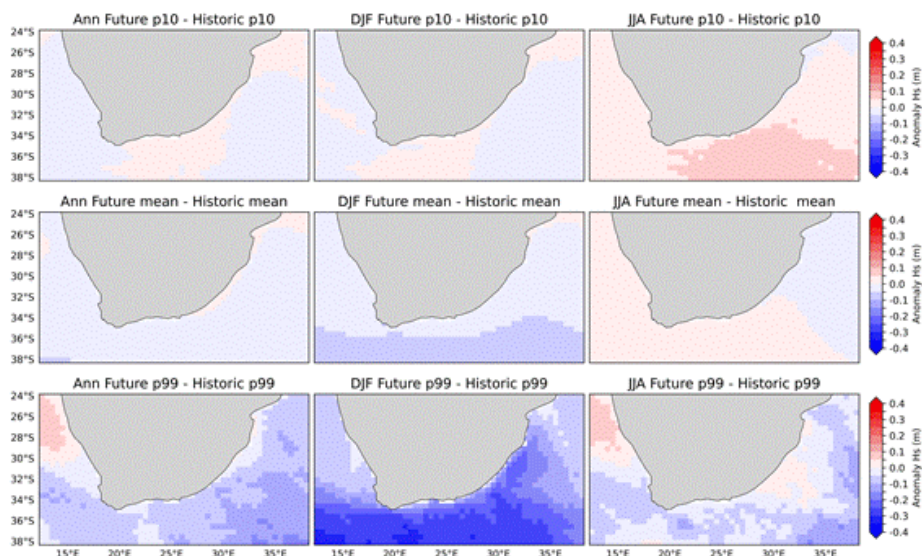
The SAFER SA project is strongly aligned to the HR Wallingford-led SAFE project, also initiated this year- see section 2.2.



**Figure 1:** The percentage of people that received an advance warning in South Africa, by income groups. (Lloyd's Register Foundation, 2024)

### Wave Climate Projection and Marine Hazard Services

The machine learning wave climate projection framework, assessing future Significant Wave Height projections over South Africa, has continued in 2025, with applications expanding to future scenarios, RCP4.5 and RCP8.5; projections under RCP8.5 are shown in Figure 2.



**Figure 2:** Wave climate ( $H_s$ ) anomaly against historic period under RCP8.5 for 2085-2095, demonstrating the annual mean change (top left) and higher extreme change (99th percentile) (bottom left), Austral summer mean change (top middle) and extreme change (bottom middle), Austral winter mean change (top right) and extreme change (bottom right) for ensemble mean.

The wave climate dataset has now been verified against the Coordinated Ocean Wave CLimate Project (COWCLIP2.0) dataset over all available ensembles. SAWS successfully ran the emulator locally after resolving data and environment issues through in person training and support. A paper is currently being developed in collaboration with SAWS on these initial findings. The work was also presented at several conferences and meetings this year including the 14th International Conference on Southern Hemisphere Meteorology and Oceanography (ICSHMO), Exeter Climate Conference, the 4th International Workshop on Waves, Storm

Surges, and Coastal Hazards, the WCSSP South Africa annual science meeting (section 2.2) and the Nansen-Tutu Centre 15-Year Anniversary Symposium. A proposal is being developed to incorporate Mean Sea Level rise into the projections in future work. Future work may also involve improving the emulator using a higher resolution wave hindcast dataset and expanding the dataset to other wave parameters (e.g. wave period).

Aligned to this work is a Plymouth university-led project on rip current forecasting which has been guiding efforts to operationalise the system on the SAWS website – see extended highlights section 6.3. Technical challenges — notably model spin up times — were actively addressed through collaborations with Deltares. Workshops are planned to ensure outputs meet user needs, especially for safety and emergency response partners.

### ***Attribution Services Landscape & Utilisation Research***

A programme of work was initiated this year to investigate how attribution science can be better integrated into decision-making in South Africa. Two main products emerged: 1) Draft paper on attribution utilisation, and 2) Report on the Southern Africa attribution services landscape and opportunities. Both pieces form a foundational body of work that will inform future work in this work package.

A paper is being co-authored between the Met Office and scientists from South Africa and elsewhere, including contributions from researchers at the University of Cape Town. This piece is undergoing internal review by the extended co-author group, with submission anticipated for early 2026. The paper provides a body of evidence for using attribution science, with a particular focus on the potential applications and limitations in communication and awareness raising, disaster risk management, climate adaptation, Loss and Damage, and climate litigation. The intended audience for this is (1) attribution science researchers and providers (with the latter moving beyond opportunistic application of the science and beginning to set protocols), and (2) stakeholders who are already familiar with attribution science. The paper seeks to identify evidence gaps that need to be tackled so that the attribution research and provider communities, together with informed stakeholders in relevant use-case communities (e.g. adaptation managers, city planners) can collectively consider the range of attribution methods available and target these methods appropriately for different uses.

A report was compiled outlining findings from breakout group discussions on attribution utilisation during the 2025 WCSSP South Africa annual science meeting, expert consultations and discussions with South African attribution specialists and a literature review. The report maps current applications and interest areas, user needs in this space and potential avenues for developing attribution services across sectors and to support decision-making contexts in Southern Africa. See extended highlight section 6.5 for further details.

### ***High-End Sea Level Rise Scenario Planning with SANParks***

This year saw the codesign and delivery of a major decision gaming workshop focused on coastal flood and sea level rise risks. The workshop brought together 26 staff from SANParks,



## 5. Publications

### 5.1 Journal articles supported by WCSSP South Africa

#### **Published in 2025**

Singh, L. G., & Middleton, S. E. (2025). Tabular context-aware optical character recognition and tabular data reconstruction for historical records: LG Singh, SE Middleton. *International Journal on Document Analysis and Recognition (IJ DAR)*, 1-20.

<https://doi.org/10.1007/s10032-025-00543-9>

Talib, J., Taylor, C. M., Klein, C., Warner, J., Munday, C., Folwell, S., & Charlton-Perez, C. (2025). Modelling the influence of soil moisture on the Turkana jet. *Quarterly Journal of the Royal Meteorological Society*, e4972. <https://doi.org/10.1002/qj.4972>

Warner, J. L., Franklin, C. N., Roux, B., Cooper, S., Rennie, S., & Kumar, V. (2025). Diagnosing lateral boundary spin-up in regional models using an age-of-air diagnostic. *Quarterly Journal of the Royal Meteorological Society*, e4971. <https://doi.org/10.1002/qj.4971>

#### **In review**

Kaye, G., Dunstone, N. J., Englebrecht, C. J., Landman, W. A., & Scaife, A. (in review at *Environmental Research Letters*) Extratropical wavetrain from ENSO drives summer seasonal prediction skill for South Africa.

Nishino, T., & Smyth, A. S. M. (in review at *Flow: Applications in Fluid Mechanics*) Power loss mechanisms and optimal induction factors for realistic large wind farms.

### 5.2 Articles from aligned projects supported by WCSSP South Africa

#### **SALIENT project: funded by UKRI through the Future Leadership Fellowship, grant number MR/W013223/1**

Craig, A., James, R.A., Archer, E., Daron, J., Jack, C.D., Jones, R.G., Kennedy-Asser, A.T., Lee, J., McClure, A., Shaw, C. & Steynor, A. (2025). How is climate science used to inform national-level adaptation planning in southern Africa? *Climate Policy*, 1-16. <https://doi.org/10.1080/14693062.2025.2488988>

Craig, A., Taylor, A., Steynor, A., Shaw, C., McClure, A., & James, R. A. (2025). Communicating uncertain climate futures: Lessons from the literature. *Wiley Interdisciplinary Reviews: Climate Change*, 16(6), e70027. <https://doi.org/10.1002/wcc.70027>

Kennedy-Asser, A. T., James, R., Daron, J., Craig, A., Jack, C. D., Wolski, P., & Jones, R. (2025) Do climate models agree on seasonal rainfall patterns and future changes over southern Africa? *Climatic Change*, 179(22). <https://doi.org/10.1007/s10584-025-04073-5>

#### **REPRESA project: funded by IDRC and FCDO through the Climate Adaptation and Resilience (CLARE) programme**

Kendon et al. (submitted) Opportunities for increasing resilience to changing severe weather: "Early Action and Enhanced Adaptive Capacity for All", *Submitted to BAMS*

## 6. Extended Highlights

### 6.1 AI for Data Rescue: Tabular Data Reconstruction of Historical Records

**Authors:** Stuart E. Middleton<sup>1</sup>

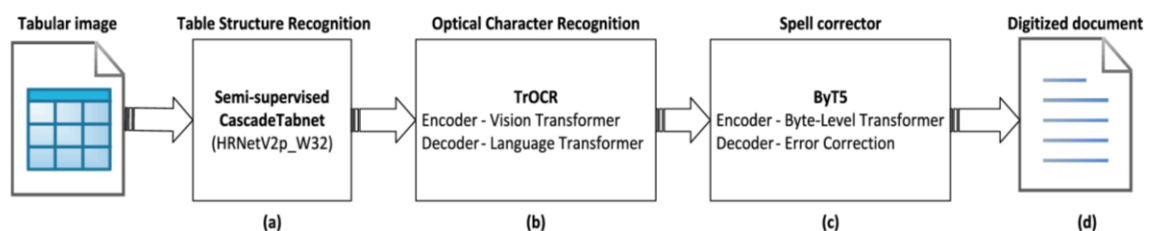
<sup>1</sup>University of Southampton, UK

#### Summary

Digitizing historical tabular records is essential for preserving valuable data in many domains, including weather and climate science. However, data rescue from scanned documents presents challenges due to complex data table layouts, mixed text types and degraded quality of scanned documents. This article outlines work from two papers [1] [2] published in the International Journal on Document Analysis and Recognition (IJ DAR) describing a novel semi-supervised context-aware framework for Tabular Structure Recognition (TSR) of historical meteorological measurement data in scanned document pages. We first describe two human annotated data rescue datasets designed to train and evaluate machine learning models. The first is the GloSAT Historical Measurement Table Dataset, containing 500 scanned historical logbook images, and the second is the UoS\_Data\_Rescue dataset, containing 1,113 scanned historical logbook images. We then describe our novel semi-supervised and context-aware text extraction models and our data rescue results. All code and data are available from Github [3] [4] and Zenodo [4] [5].

#### Extended Highlights

We implement an approach that integrates transfer learning for model fine-tuning and develops a robust tabular data reconstruction pipeline consisting of three components: (i) Table Structure Recognition (TSR), (ii) a customized tabular context-aware Optical Character Recognition (OCR) model based on TrOCR, and (iii) a reconstruction module. This pipeline is shown in figure 1. We also explore how semi-supervised learning can boost performance further, iteratively re-training the model using annotation labels generated by running earlier versions of the model. The semi-supervised training workflow is shown in figure 2. Full technical details can be seen in our published work [1] [2].



**Figure 1:** Tabular data reconstruction pipeline, source [1]

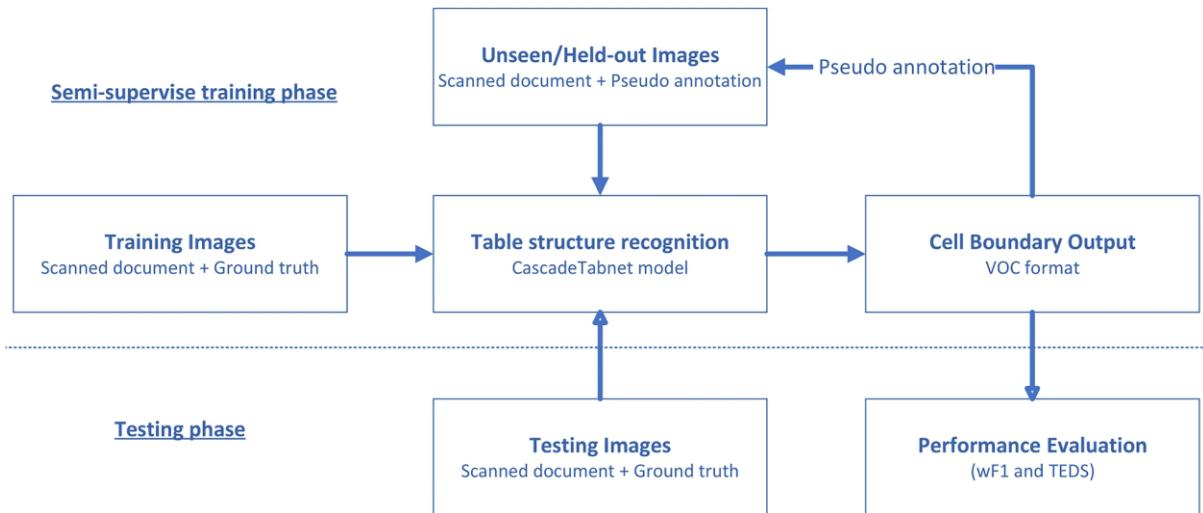


Figure 2: Tabular data reconstruction pipeline, source [2]

## Datasets

*GloSAT Historical Measurement Table Dataset* contains 500 scanned historical measurement table documents from ship logs and land measurement stations. Annotations provided in this dataset are designed to allow fine-grained table detection and table structure recognition models to be trained and tested. Annotations are region boundaries for tables, cells, headings, headers and captions.

Table 1: GloSAT Historical Measurement Table Dataset [3]

Source ID; Region; Timeframe	Images / Tables / Headers	Page Style; Table Style
20cr_DWR_MO; India; 1970s	24 / 31 / 31	Printed; Borderless
20cr_DWR_NOAA; India; 1930s	24 / 24 / 24	Printed; Semi-bordered
20cr_Kubota; Philippines; 1900s	24 / 28 / 28	Printed; Semi-bordered
20cr_Natal_Witness; Africa; 1870s	26 / 26 / 26	Printed; Semi-bordered
Ben Nevis; UK; 1890s	97 / 137 / 82	Printed; Semi-bordered
DWR; UK and world; 1900s	93 / 139 / 139	Mixed; Semi-bordered
WesTech Rodgers; Arctic; 1880s	82 / 164 / 82	Mixed; Semi-bordered
WR_10_years; UK; 1830s to 1930s	97 / 129 / 129	Mixed; Bordered
WR_Devon_Extern; UK; 1890s to 1940s	33 / 33 / 33	Mixed; Bordered
<b>Total</b>	<b>500 / 710 / 573</b>	

*UoS\_Data\_Rescue* contains 1,113 scanned historical climate logbook images. This dataset is specifically designed to support OCR and table structure recognition tasks by capturing diverse text types (typed, mixed, handwritten) and intricate table layouts. Table 2 provides a detailed overview of the distribution of unlabelled and annotated logbook images classified by year, region, and source. The source documents originate from institutions such as the UK Met Office, US NOAA, US naval ship logs, and Meteo-France and cover many geographic regions explicitly including Africa.

To ensure high-quality annotations, we use a crowdsourced approach via the Appen platform. Six annotators proficient in English and familiar with Latin alphabetical characters were employed to annotate the dataset in 18 batches, each containing approximately 1,500 images with no more than 40 cells per image. After each batch, quality evaluations were conducted to ensure accuracy; incorrectly annotated batches were re-run following evaluation.

**Table 2:** UoS\_Data\_Rescue Dataset [5]

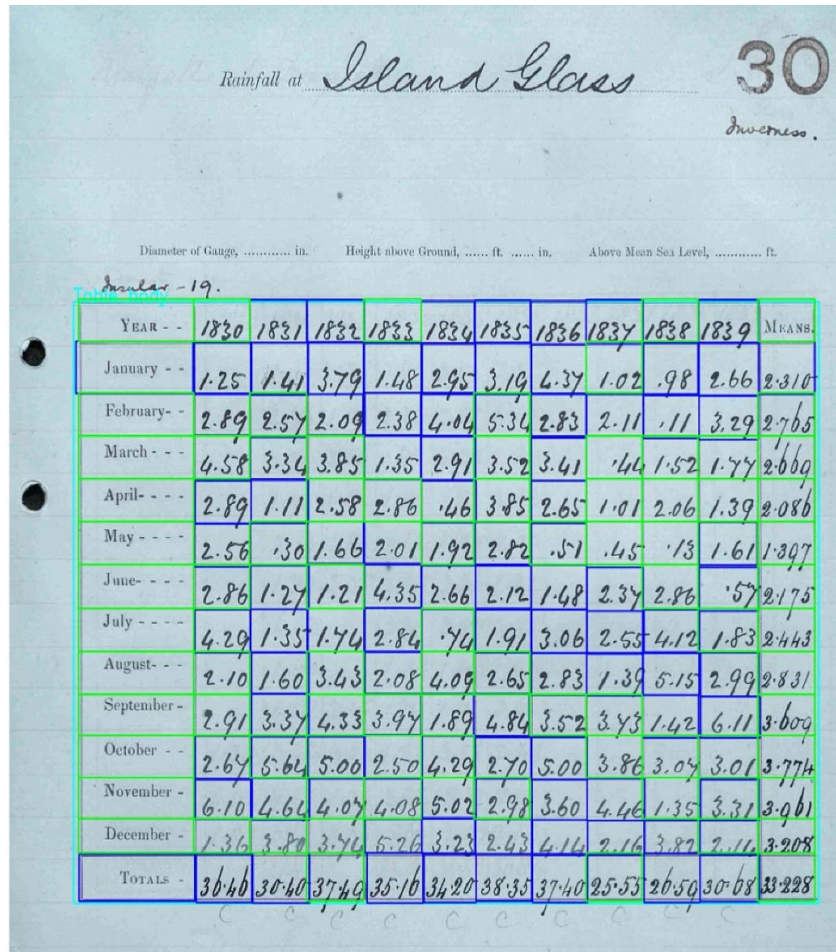
Location	Year	# Labelled images	Average cells/image	Average cells/image (hard-to-annotate)	# Unlabelled images
<a href="https://digital.nmla.metoffice.gov.uk/">Sources: https://digital.nmla.metoffice.gov.uk/</a>					
UK	1830-1930	97	208.959	3.804	–
Natal, Africa	1870	26	99.429	0.048	46
Artics	1880	82	477.122	30.22	–
Devon, UK	1890-1940	33	229.545	1.758	–
Ben Nevis, UK	1890	97	1511.247	11.557	–
UK and World	1900	93	622.793	31.141	1330
Philippines	1900	24	740.292	5.458	6077
India (NOAA)	1930	24	2197.429	7.476	380
India (MO)	1970	24	1971.667	17.208	276
<a href="https://digital.nmla.metoffice.gov.uk/">Sources: https://digital.nmla.metoffice.gov.uk/</a>					
Zanzibar	1881-1882	8	133.5	9.25	12
Blantyre	1882	–	–	–	6
Egypt	1885-1886	6	699.5	17.667	9
Morocco	1891	–	–	–	2
<a href="https://libguides.library.noaa.gov/weather-climate/foreign-climate">Sources: https://libguides.library.noaa.gov/weather-climate/foreign-climate</a>					
Mauritius	1862-1972	34	227.559	0.235	13887
Algeria	1877-1968	113	90.947	7.292	22356
Madagascar	1889-1968	40	148.775	2.925	10035
Egypt	1900-1966	51	148.137	6.412	44199
Tunisia	1907-1932	29	119.207	4.034	2531
Uganda	1909-1937	5	188	0	456
Mozambique	1909-1968	44	289.364	2.909	19547
South Africa	1920-1982	74	109.946	0.757	36502
Libya	1922-1931	3	221	12	501
Kenya	1936-1937	–	–	–	31
Angola	1937-1952	–	–	–	1840
Namibia	1941-1948	–	–	–	52
Djibouti	1950-1974	–	–	–	1695
Cameroon	1950-1975	–	–	–	1830
Morocco	1954-1978	58	223.914	9.724	10575
Guinea-Bissau	1957-1972	–	–	–	3331
<a href="https://catalog.archives.gov">Sources: https://catalog.archives.gov</a>					
Bear	1940	12	792.583	1.917	21
Tennessee	1946	36	880.611	1.472	17
<a href="http://archives-climat.fr">Sources: http://archives-climat.fr</a>					
Ambanja Août-décembre	1904	5	559.2	95.8	–
Diego-Suarez	1949	47	640.447	30.255	1
Tromelin	1956	48	651.396	33.021	–
Total	–	1113	–	–	177545

## Results

We show in our results (table 3; figure 3) that open source machine learning models for table data reconstruction are now able to provide a promising pipeline which is worth serious consideration for large scale data rescue. Exact Match (EM) scores, which represent the percentage of cells extracted perfectly, for some regions are as high as 91%. Also, many of the errors made are relatively easy to pickup via post-processing heuristics being single character errors – the F1 (Char) scores, which represent the percentage of characters correctly extracted from cells, confirm this.

**Table 3:** Performance across different regions in the UoS\_Data\_Rescue dataset

Regions	Table structure recognition			Tabular data reconstruction					
	P	R	F1	Rouge-L	WER	CER	EM	F1 (Char)	F1 (Token)
Tromelin	0.903	0.903	0.897	0.928	0.088	0.081	0.912	0.949	0.912
Diego-Suarez	0.836	0.866	0.84	0.902	0.115	0.109	0.885	0.936	0.885
UK	0.666	0.998	0.782	0.939	0.131	0.121	0.869	0.942	0.869
Ambanja Août-décembre	0.588	0.944	0.719	0.922	0.131	0.068	0.869	0.945	0.869
South Africa	0.64	0.954	0.764	0.909	0.133	0.178	0.867	0.895	0.867
Natal, Africa	0.757	0.697	0.72	0.951	0.135	0.117	0.865	0.931	0.865
Tunisia	0.853	0.935	0.89	0.906	0.153	0.215	0.847	0.904	0.847
Zanzibar	0.912	0.946	0.928	0.905	0.156	0.162	0.844	0.884	0.844
Algeria	0.787	0.904	0.832	0.913	0.175	0.135	0.825	0.905	0.825
Tennessee	0.414	0.914	0.53	0.822	0.188	0.218	0.812	0.86	0.812
Libya	0.782	0.881	0.819	0.898	0.199	0.205	0.801	0.858	0.801
Bear	0.352	0.875	0.488	0.834	0.201	0.177	0.799	0.869	0.799
Devon, UK	0.907	0.986	0.943	0.839	0.202	0.182	0.798	0.861	0.798
Arctic	0.737	0.969	0.834	0.663	0.313	0.327	0.687	0.727	0.687
Egypt	0.42	0.896	0.552	0.791	0.339	0.26	0.661	0.8	0.661
India	0.781	0.915	0.841	0.663	0.345	0.297	0.655	0.789	0.655
Uganda	0.838	0.893	0.864	0.856	0.362	0.46	0.638	0.693	0.638
Morocco	0.508	0.722	0.589	0.706	0.377	0.481	0.623	0.71	0.623
Egypt	0.779	0.822	0.783	0.854	0.423	0.381	0.577	0.744	0.577
Madagascar	0.819	0.923	0.864	0.778	0.426	0.598	0.574	0.627	0.574
Mozambique	0.729	0.765	0.73	0.745	0.469	0.77	0.531	0.603	0.531
India	0.884	0.876	0.879	0.566	0.473	0.576	0.527	0.665	0.527
UK and World	0.821	0.863	0.834	0.547	0.489	0.812	0.511	0.633	0.511
Mauritius	0.846	0.831	0.834	0.786	0.506	0.725	0.494	0.583	0.494
Ben Nevis, UK	0.981	0.845	0.907	0.627	0.52	0.51	0.48	0.668	0.48
Philippines	0.869	0.858	0.842	0.406	0.711	0.652	0.289	0.482	0.289



(a)

YEAR - - -	1830	1831	1832	1833	1834	1835	1836	1837	1838	1839	MEANS.
January - -	1.25	1.41	3.79	1.48	2.95	3.19	4.37	1.02	.98	2.66	2.310
February - -	2.89	2.57	2.09	2.38	4.04	5.34	2.83	2.11	.11	3.29	2.765
March - - - -	4.58	3.34	3.85	1.35	2.91	3.52	3.41	.44	1.52	1.77	2.669
April - - - - -	2.89	1.11	2.58	2.86	.46	3.85	2.65	1.01	2.06	1.39	2.086
May - - - - -	2.56	.30	1.66	2.01	1.92	2.82	.51	.45	.13	1.61	1.397
June - - - - -	2.86	1.27	1.21	4.35	2.66	2.12	1.48	2.37	2.86	.51	2.175
July - - - - -	4.29	1.35	1.74	2.84	.74	1.91	3.06	2.55	4.12	1.83	2.443
August - - -	2.10	1.60	3.43	2.08	4.09	2.65	2.83	1.39	5.15	2.99	2.831
September -	2.91	3.37	4.33	3.97	1.89	4.84	3.52	3.73	1.42	6.11	3.609
October -	2.67	5.62	5.00	2.50	4.29	2.70	5.00	3.86	3.05	3.01	3.774
November -	6.10	4.64	4.07	4.08	5.02	2.98	3.60	4.46	1.35	3.31	3.061
December -	1.36	3.80	3.76	5.26	3.23	2.43	4.14	2.16	3.82	2.16	3.208
TOTALS -	36.46	30.40	37.49	35.16	34.20	38.35	37.40	25.55	26.59	30.68	33.228

(b)

**Figure 3:** Example of tabular data reconstruction process using a Ben Nevis, UK logbook image.

We also show in our results (figure 4) that using scanned document pages without any annotations during training can boost training performance further using a semi-supervised training regime. This involves model iterations being run on unannotated images of scanned document to generate a new set of weakly labelled training instances, which are then added to the original human annotated training dataset.

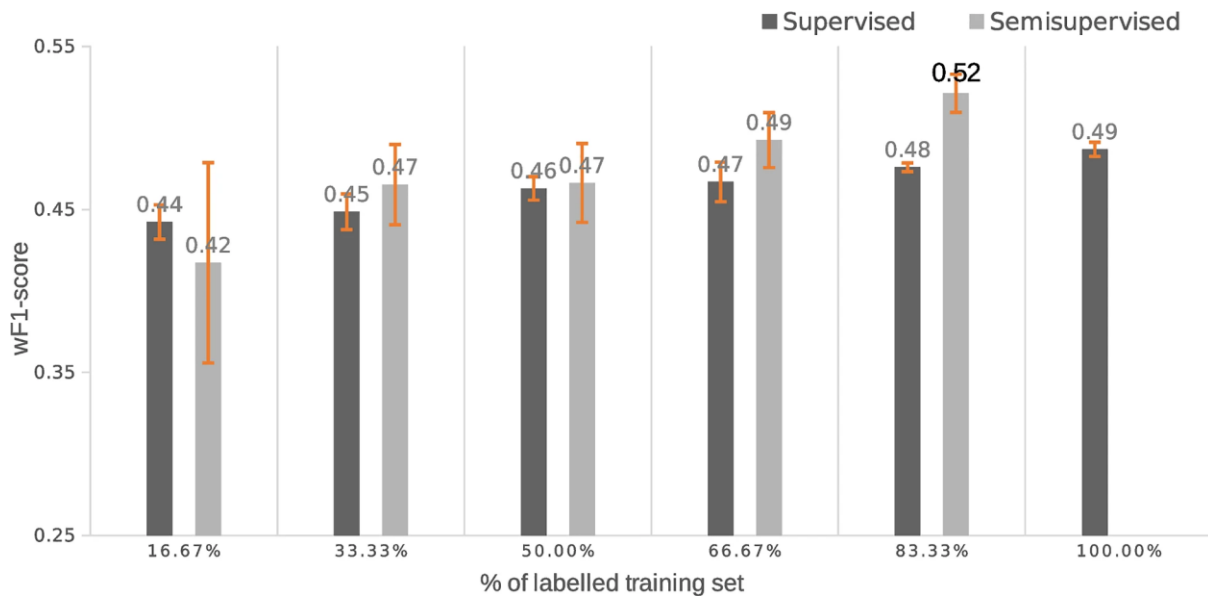


Figure 4: Tabular data reconstruction pipeline, source [1]

This work has been performed under the DR-Africa project [6]. We are currently exploring the latest generation of commercial LLMs, such as Gemini 3, and early results from this exploration are that we can expect to see a significant reduction in error rates on top of the reports published in this article. Our goal is to provide by the end of DR-Africa a pipeline that can perform data rescue at scale (i.e. processing 10,000's of scanned document pages), with accuracies approaching that seen through citizen-science based human annotation and little or no need for pre-annotation of scanned page images.

### Acknowledgements

This work is jointly funded through WCSSP South Africa and the Natural Environment Research Council (grant NE/S015604/1). The authors acknowledge the IRIDIS High-Performance Computing Facility at the University of Southampton.

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## 6.2 A decision-gaming workshop to support planning for sea level rise in South African national parks

**Authors:** Jennifer H. Weeks<sup>1,2</sup>, Clement Arendse<sup>3</sup>, Nicola Bredenkamp<sup>3</sup>, Ailish Craig<sup>2</sup>, Cloverley Lawrence<sup>3</sup>, Susan Parnell<sup>2,4</sup>, Matthew D. Palmer<sup>1,2</sup> & Emma Wright<sup>3</sup>

<sup>1</sup>Met Office, UK; <sup>2</sup>University of Bristol, UK; <sup>3</sup>SANParks, South Africa; <sup>4</sup>University of Cape Town, South Africa

### Summary

A collaborative workshop between the Met Office and South Africa National Parks (SANParks) used scenario-based decision gaming to support national park planning for sea level rise in the Wilderness estuary along South Africa's Garden Route. Participants explored high-end and intermediate sea level storylines in a time-step based decision exercise to test responses under uncertainty and across timescales. The decision-gaming process was effective in exposing legal, financial, and institutional constraints on adaptation. The findings demonstrate that tools such as storylines can be useful when adapted to the specific decision context.

### Extended Highlights

A workshop was held in a collaboration between the Met Office and SANParks to help support future national park planning for sea level rise in the Wilderness estuary. The Wilderness estuary, located along the Garden Route, faces many legal, ecological and climatic hazard challenges. The workshop aimed: 1) to explore decision-making under uncertainty using hazard- and scenario-based exercises, 2) to clarify roles, responsibilities, and responses to different climate futures and management pathways, and 3) to understand the consequences and trade-offs of different decisions across timescales. In particular, the workshop aimed to shed light on whether strategies for delivering sea level information can be used, and how best they could be adapted, across different decision contexts. 26 participants attended, split into two groups (Group A and Group B) who each focussed on a different sea level scenario. Participants included marine and climate scientists, municipal government workers, ecological planners, and conservation planners.

Before the workshop, information packs were created to summarise the available sea level information for the nearest tide gauge locations to Wilderness (Mossel Bay, Knysna and Gqeberha). This included WCSSP South Africa sea level science: local sea level projections to 2100 following Allison et al., (2022), sea level allowances following Howard et al., (2023), sea level projections that extend to 2300 and "storylines" that present single future timeseries of sea level change constrained to different literature estimates.

The decision-gaming workshop broadly followed the methodology outlined in Weeks et al., (2025). Two sea level storylines were generated for Wilderness: the first following a high-end sea level scenario (i.e. including ice sheet instability processes) and the second following an intermediate emissions scenario (i.e. current international emissions pledges). Following consultations with SANParks in the workshop planning phase, the storylines were combined with information on storm surge return levels, and presented as spatial maps, as this was considered a more recognisable framing to the community. During workshop "play",

participants were presented with the available information on sea level rise for Wilderness and walked through the storylines in a time-step based progression. For example, at the year 2025, they were asked to make decisions for the next 10 years, and after these 10 years, they were asked to reflect on their decision making. The timestep approach helped to reveal insights into which factors beyond the changing hazard profile played an important role in decision making.



**Photos:** (left) Group A discussing the vulnerability, exposure and climatic hazards faced by the Wilderness estuary. (right) Understanding key assets at risk in national park planning.



**Figure 1:** Key feedback collected after the workshop.

Feedback collected after the workshop (figure 1) indicated that participants found the information packs, the “deep dive” into science presented at the beginning of the workshop, and the hazard maps all to be useful in aiding their understanding. However, the decision-gaming process itself was found to be the most useful resource to help prime long-term thinking and reveal limitations to decision-making, including legal, financial and institutional factors. Moreover, the workshop revealed that tools and methods developed elsewhere, such as sea level storylines, can be useful when adapted to the specific decision context. The results have been written up as a journal manuscript, to be submitted by March 2026.

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Allison, L. C., Palmer, M. D., & Haigh, I. D. (2022). Projections of 21st century sea level rise for the coast of South Africa. *Environmental Research Communications*, 4(2), 025001. <https://doi.org/10.1088/2515-7620/ac4a90>

Howard, T., L. C. Allison, & M. Palmer (2023), Sea level rise allowances for South Africa. Met Office report: WCSSP South Africa

Weeks, J. H., Allison, L., Beverton, A., Lowe, J., Orr, H. G., Roberts, H., & Palmer, M. (2025). A new framework to explore high-end sea level rise for the UK: Updating H++. *Earth's Future*, 13(11), e2025EF006086. <https://doi.org/10.1029/2025EF006086>

## 6.3 Advancing Rip Current Forecasts for Beach Locations across South Africa – Highlights

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<sup>1</sup>CMAR, University of Plymouth, UK; <sup>2</sup>SAWS, South Africa; <sup>3</sup>University of Cape Town, South Africa

### Summary

Rip currents remain one of the leading causes of drowning along the South African coastline. Building on earlier phases of the WCSSP South Africa rip current project, recent activities have focused on strengthening the scientific basis of the rip current forecast through targeted fieldwork, while simultaneously advancing community science to improve how forecasts are communicated, interpreted, and used in practice. Together, these strands support the ongoing expansion of a three-day, beach specific rip current hazard forecast delivered through SAWS, with the overarching aim of reducing risk and supporting lifesaving operations.

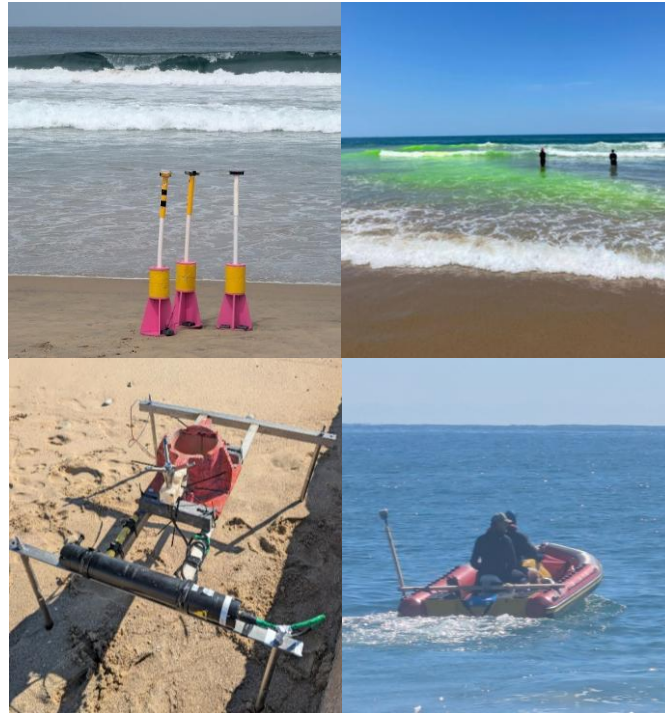
### Extended Highlights

#### *Linking field observations to operational forecasts*

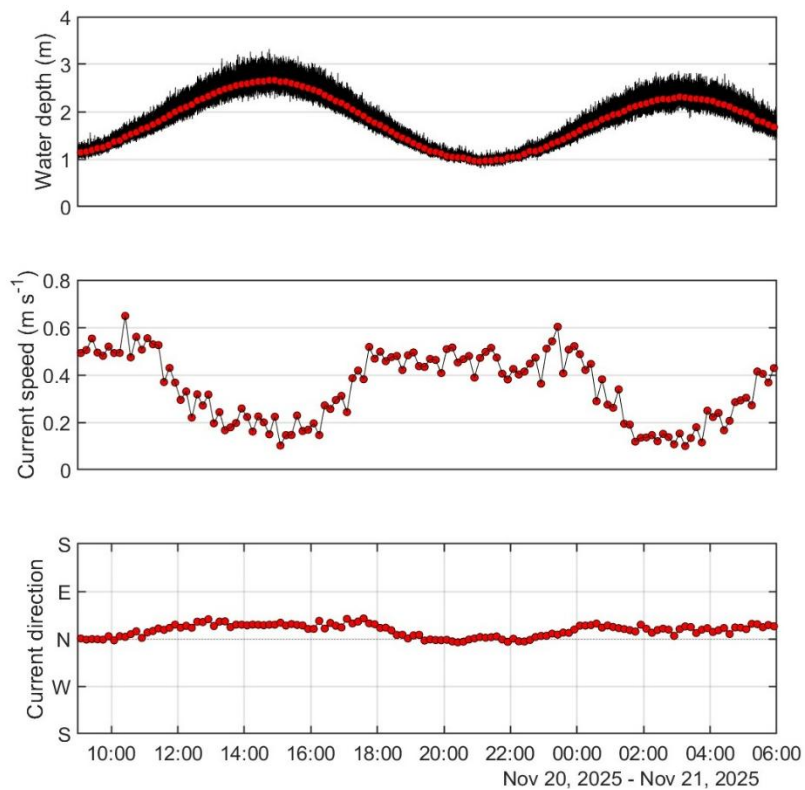
Field experiments undertaken at key sites in eThekweni (Durban) and Nelson Mandela Bay (Gqeberha) over two weeks in November 2025 have provided the first detailed, in situ validation of the rip current forecasting approach outside the Western Cape. Intensive multi-day deployments combined GPS drifter experiments, dye releases, hydrodynamic measurements, and high-resolution beach and nearshore surveys to directly observe rip current behaviour under a range of wave, wind, and tidal conditions (Figure 1). Invaluable fieldwork support was given by Lifesaving South Africa (LSA) at both sites, and SAEON in Gqeberha.

The fieldwork demonstrated how rip current strength and pathways vary systematically with tidal stage, wave and wind conditions, and local beach morphology. At both Durban and Gqeberha sites, rip flows were typically strongest at lower tidal stages (Figure 2), with exits through rip channels into deeper water (Figure 3) occurring most frequently during low to mid tide under moderate wave conditions. High resolution digital elevation models revealed the controlling role of sandbar and channel morphology, providing essential context for interpreting drifter trajectories and understanding why some conditions lead to offshore transport while others result in alongshore or onshore motion.

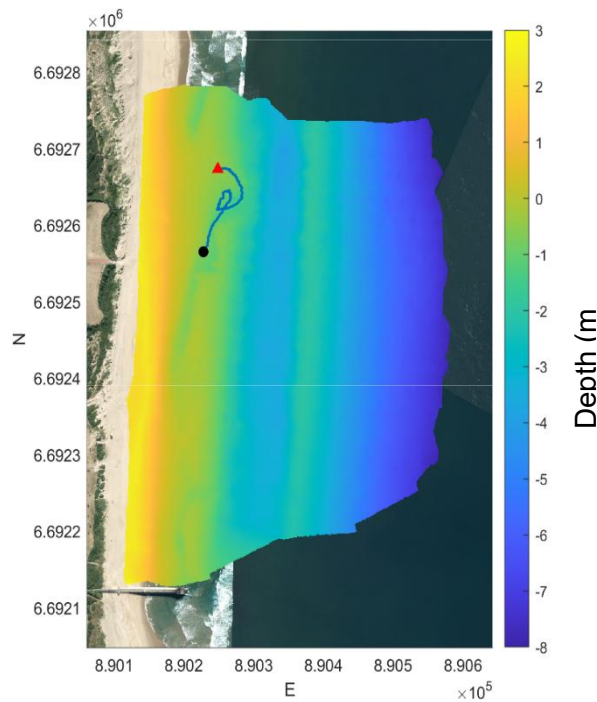
These observations provide confidence that the empirical thresholds derived from lifeguard rescue and assist records are physically consistent with measured rip current dynamics. The field datasets are now being used to refine region-specific hazard thresholds and to guide future modelling and validation efforts, strengthening the scientific credibility of the operational forecast.



**Figure 1:** Field methods used to observe and quantify rip current dynamics. *Top left:* Rip-current drifters designed to simulate a human floating in the surf zone. *Top right:* Dye release experiment used to visualise rip-current flow in Durban. *Bottom left:* Instrument rig deployed within a rip channel, housing an acoustic doppler velocimeter and a pressure transducer. *Bottom right:* Single-beam echosounder survey conducted from a SAEON surf craft in Gqeberha.



**Figure 2:** Output from an acoustic doppler velocimeter deployed below the low-tide limit within a rip-current channel at Durban. *Top panel:* Water-level observations show two consecutive high-tide peaks. *Middle panel:* Rip-current velocities decrease within the channel during high tide. *Bottom panel:* Rip-current flow direction remains largely consistent, predominantly alongshore (northward), with minor eastward deviations during high tide.



**Figure 3:** One-metre resolution Digital Elevation Model (DEM) of Battery Beach, Durban, combining topographic data from an ATV-mounted GPS survey with bathymetric data from single-beam surf-craft surveys. A rip-current drifter trajectory (blue line) is overlaid, with the deployment point marked by a black circle and the recovery point by a red triangle. The drifter follows the rip-current channel, moving predominantly northward and in an offshore direction.

**Community science to inform safer use of forecasts**

In parallel with the physical science, a large beach user survey was undertaken across four coastal regions (Cape Town, Mossel Bay, Gqeberha, and eThekweni) to establish baseline awareness of rip currents, swimming ability, and beach safety practices. The survey revealed low general awareness of rip currents, limited ability to identify rips from beach level, and a high proportion of beachgoers who report being weak or non-swimmers. At the same time, strong trust in lifeguards and demarcated bathing areas was evident, with the presence of lifeguards being a major influence on beach choice.

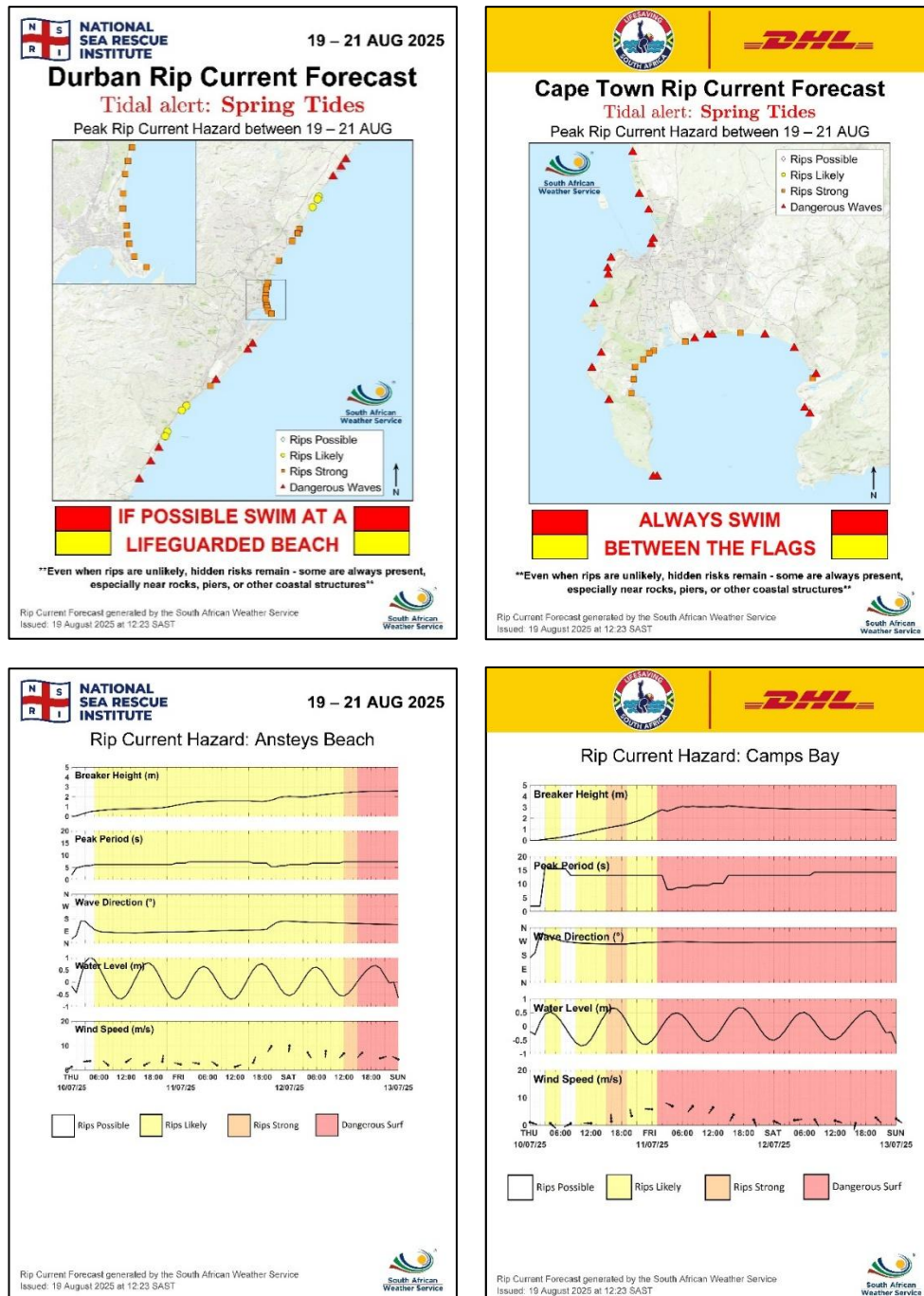
These findings highlight the importance of coupling rip current forecasts with clear, targeted communication and education strategies. They emphasise that rip current forecasts must support decision making by lifeguards and beach managers, while public facing messaging should prioritise simple, actionable advice—such as where it is safest to swim and when to avoid the water—rather than technical descriptions of rip dynamics.

**From science to service**

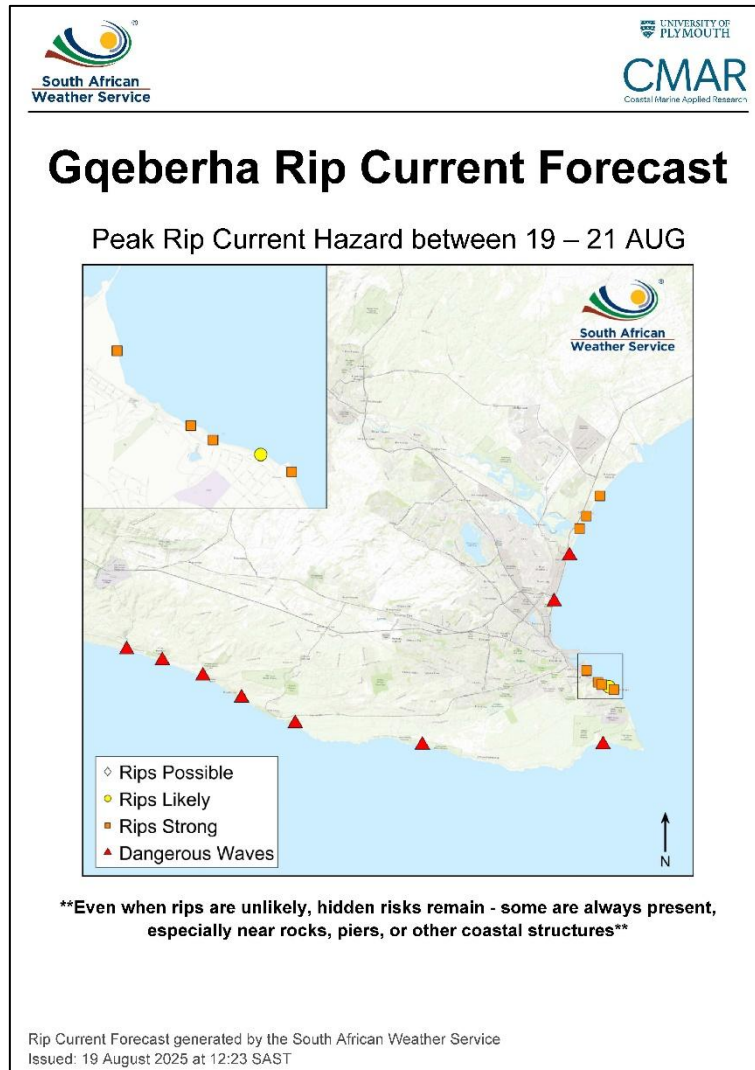
Together, the fieldwork and community science activities represent a significant step towards a more robust, impact focused rip current warning service for South Africa. The integration of physical measurements, historical rescue data, and social science insights is helping to ensure that rip current forecasts are not only scientifically sound, but also relevant, trusted, and usable by those responsible for beach safety.

The work supports the ongoing rollout of a tiered, beach specific rip current hazard outlook

within the SAWS marine forecast, providing daily guidance to municipalities, Lifesaving South Africa, and the National Sea Rescue Institute. A two-tiered dissemination strategy: Tier 1 (professional audience; Figure 4;) for daily multi-day forecasts, and Tier 2 (public audience; Figure 5), via the SAWS website. By grounding the forecast in both observed coastal processes and an improved understanding of beach user behaviour, this phase of the project strengthens the pathway from research to operational service, with clear potential to reduce drowning risk along South Africa’s coast.



**Figure 4:** Example ‘Tier 1’ rip forecast outputs generated by SAWS and distributed to the professional users e.g. LSA and NSRI, with associated ‘branding’. Top panels show the peak rip hazard during the forecast period at each beach for Durban (*left panel*) and Cape Town (*right panel*). Bottom panels show the detailed timeseries plot of the met-ocean forcing conditions overlaid on to the assigned rip hazard for each beach.



**Figure 5:** Example 'Tier 2' rip forecast output generated by SAWS and distributed online via the SAWS website for the public audience. This example shows the peak hazard at Gqeberha beaches during the forecast period.

## 6.4 Extratropical wavetrain from ENSO drives summer seasonal prediction skill for South Africa

**Authors:** Gillian Kay<sup>1</sup>, Nick Dunstone<sup>1</sup>, Christien Engelbrecht<sup>2</sup>, Willem Landman<sup>3</sup>, Adam Scaife<sup>1</sup>

<sup>1</sup>Met Office, UK; <sup>2</sup>SAWS, South Africa; <sup>3</sup>University of Pretoria, South Africa

### Summary

The El Niño-Southern Oscillation (ENSO) underpins summer seasonal predictability in South Africa, enabling warnings to be made about extreme conditions such as drought. But sometimes the response to ENSO over South Africa does not unfold as expected, meaning that forecasts fail and indicating that there is more to learn about the teleconnection. Researchers from the Met Office, SAWS and the University of Pretoria have been working together to improve understanding of how the ENSO signal is transmitted to South Africa and have found an atmospheric wave pattern that plays a critical role in the teleconnection. Improving the understanding and modelling of key dynamical processes could increase the value of seasonal forecasting for South Africa.

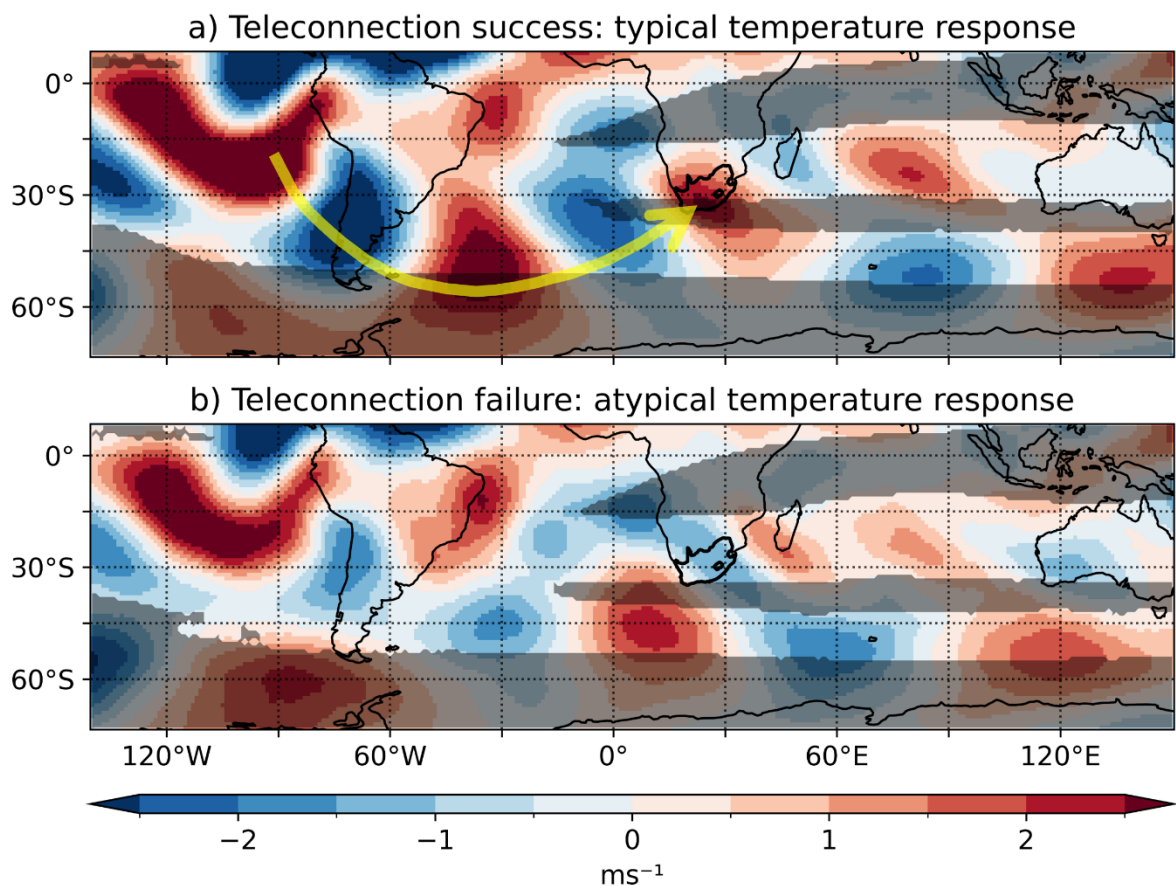
### Extended Highlights

Researchers from the Met Office, SAWS and University of Pretoria have been working together with the aim of understanding and improving seasonal forecasts of summer climate over South Africa. The El Niño-Southern Oscillation (ENSO) has long been recognised to have a major influence over the region's summer climate and underpins its seasonal predictability, which is key for warning about extreme conditions such as drought. For example, severe drought conditions over southern Africa during the 2015/16 El Niño led to significant negative impacts on agriculture and food security. But the mechanisms of the teleconnection are not fully established and sometimes the forecasts fail, like during the El Niños of 1997/98 and 2009/10 when the anticipated warm and dry conditions did not materialise. Improved understanding of the mechanisms of the teleconnection could in turn help in the understanding of the seasonal forecasts and provide better indications of whether ENSO will create its expected impacts.

The predictability and dynamics of South African summer climate were examined in near-term (seasonal, interannual and decadal) prediction systems from the Met Office and the European Centre for Medium-range Weather Forecasts (ECMWF), with a focus on the ENSO-South Africa teleconnection. During ENSO events, a pattern of alternating atmospheric cyclonic and anticyclonic anomalies was found to connect the tropical Pacific and southern Africa. This type of pattern, known as a wavetrain, is characteristic of Rossby wave propagation. The wavetrain was found to propagate eastwards and southwards out of the tropical Pacific and across southern South America before refracting in the South Atlantic back towards the tropics and across southern Africa (Figure 1a). This finding brings a new dimension to the teleconnection and to seasonal forecasts for South Africa where, generally, there has been less focus on large-scale dynamical influence from the west. There is only a limited number of ENSO events in the observational record, but the model ensembles provide many more samples to

investigate, including cases where the climate response over South Africa is as expected – and when it is not. When the simulated ENSO teleconnection with the South Africa fails, leading to failure of the summer forecast, the wavetrain is distorted, which appears as a change in phase and/or position (Figure 1b). This suggests that an atmospheric dynamical connection from ENSO to South Africa is critical in determining the predictability of summer climate in South Africa.

The role of the extratropical stationary wavetrains in the ENSO-South Africa summer teleconnection is still a relatively new area of study, particularly when applied to near-term climate prediction systems. Better understanding and modelling of these key dynamical processes could increase the value of seasonal forecasting for South Africa. The results also suggest ways in which the impact of climate change on the critical ENSO teleconnection with South Africa could be investigated.



**Figure 1:** Simulated atmospheric circulation (250hPa meridional wind) anomalies when the ENSO teleconnection with South Africa a) succeeds, with the Rossby wavetrain highlighted by the yellow arrow, and b) fails. The grey shaded areas are regions where wavetrains may be prevented from propagating by the structure of the background winds.

## 6.5 Understanding the landscape and opportunities for Attribution Services in South Africa

**Authors:** Amy Waterson (Met Office)

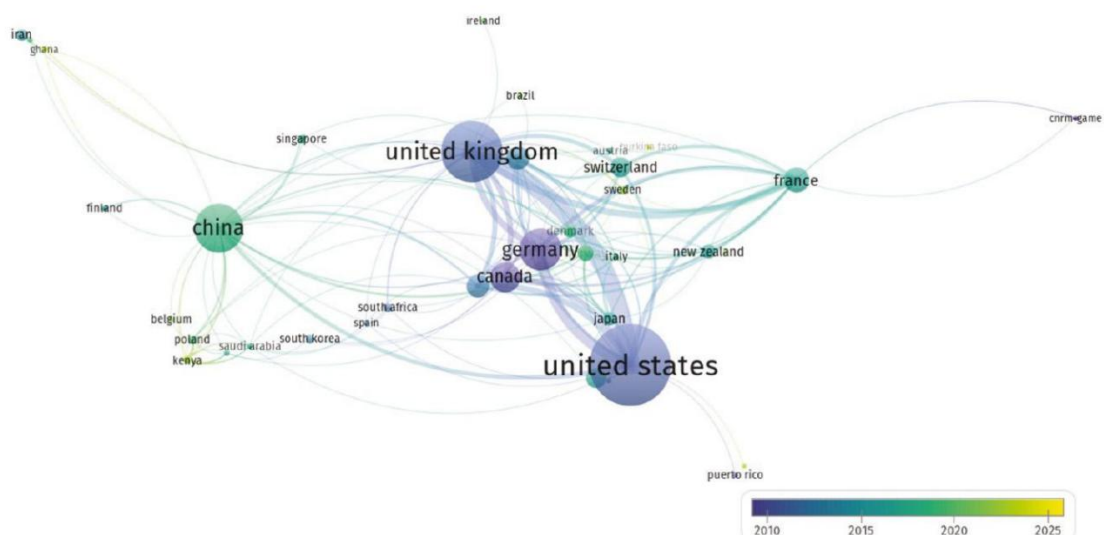
### Summary

A programme of work was initiated this year to understand the landscape and opportunities for attribution services in South Africa. Various attribution assessments have been produced for impactful extreme weather and climate events in southern Africa over recent years, including for heavy rainfall and flooding, and drought. This exploratory work sought expertise from the South African attribution science and wider climate science community. Perspectives on the potential opportunities for attribution science to help inform a range of applications and decision-making contexts were gathered, alongside barriers and evidence gaps to applying this area of science.

### Extended Highlights

Human-caused warming has led to more frequent and intense extreme weather events, resulting in adverse impacts and related losses and damages for people and nature across most inhabited regions (IPCC, 2021). The most vulnerable people and systems are being disproportionately affected. The field of attribution science has advanced rapidly since the early 2000s (Allen, 2003), with a number of different methods now available that can assess the influence of different climate and non-climate drivers on extreme weather events. This has enabled the scientific community to answer questions such as ‘Did climate change make this event more likely, or more intense? If so, by how much?’

### Geographical coverage of attribution studies



**Figure 1:** Co-occurrence network showing climate extreme attribution studies produced by country, between 2010-2025. Node size corresponds to number of papers published by authors from the countries shown, and the width of lines between show number of collaborations between countries (Figure credit: Nangombe et al., 2025).

Geographical coverage of attribution assessments is uneven, with many more studies conducted for extreme events in higher income countries. The geographically uneven potential

for and application of attribution capability globally presents ethical challenges for using attribution science in an equitable way (Otto et al., 2020). Comparatively few attribution studies have focussed on weather extremes in Africa (Figure 1) (Nangombe et al., 2025), despite the continent having experienced a high frequency of weather extremes, leading to severe impacts, losses and damages (IPCC, 2022).

Attribution assessments have been produced for the southern Africa region in recent years have focussed primarily on heavy rainfall and flooding (Clark et al., 2025), including the KwaZulu-Natal 2022 flooding (Pinto et al., 2022; Engelbrecht et al., 2025) and drought (Otto et al., 2018; Holden et al., 2022; Kimutai et al., 2024). There are several current attribution science projects and programmes running in Southern Africa, including the AWAIT project (Attribution of Extreme Weather for Southern African Impacts, as a part of WP2), and AFRIVERSE, which is focussed on climate-health impacts attribution in Africa<sup>1</sup>.



**Photo:** Breakout group discussions during the attribution utilisation session at the WCSSP South Africa Annual Science Meeting, October 2025.

### ***Use of attribution science***

While some studies have explored the potential use and limitations of applying attribution science in different decision-making contexts, a standardised framework which provides guidance on the use of specific methodological approaches within different decision-making contexts (and the limitations that are key to consider) does not yet exist. There is also currently limited reporting (Machin et al., 2025) of how the results from attribution assessments are understood by different audiences, how this affects their engagement with climate change more broadly (Perkins-Kirkpatrick et al., 2024) and any behavioural responses.

One-to-one conversations with southern African attribution experts and breakout group discussions on attribution utilisation during the 2025 WCSSP South Africa Annual Science workshop collectively explored (a) the potential applications of attribution science within different communication and decision-making contexts, and (b) the barriers, challenges and evidence gaps to using attribution science.

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<sup>1</sup> <https://acdi.uct.ac.za/afriiverse>

## Potential applications

Potential applications for attribution science that were explored in the discussions include:

- *Key hazards:* Drought, heavy rainfall and flooding, and wildfire weather attribution were hazards all highlighted as priorities for attribution assessment in the region.
- *Climate change awareness raising and education:* the value of attribution analyses for providing an entry point to conversations about climate change, connected to direct experiences of an extreme event, was highlighted.
- *Impact attribution:* The area of impact attribution was noted for its potential to communicate in terms of impact terminology or values that are highly relevant to decision-makers.
- *Disaster Risk Reduction:* The ability of attribution assessments to assess the changing risk of extremes was noted as relevant to disaster risk planning.
- *Adaptation:* The ability of attribution studies to link the direct experience of a recent weather extreme and its impacts and estimate how this may look in the future under different climate scenarios/warming levels was noted as a particularly powerful way to connect with stakeholders.
- *Loss and Damage:* Participants highlighted the interest in attribution assessments for informing Loss and Damage funding decisions. The development and adoption of international guidelines was noted as key for shaping the direction of any application of attribution science in this decision context.
- *Legal Challenge:* discussions noted the growing interest in climate litigation and incorporation of attribution science within some recent cases. A recent report<sup>2</sup> from the Centre for Environmental Rights in South Africa details a route for legal challenge in response to the 2022 KwaZulu-Natal flooding, which incorporate attribution analyses.

Several barriers, challenges and evidence gaps were highlighted. These include:

- *Attribution science literacy:* Participants noted challenges in understanding attribution assessments and a need for work to improve attribution literacy in contexts where the science could be readily used (for example, around the communication of extreme weather forecasts).
- *Relevance for decisions:* Identifying relevance of attribution at decision-making levels was noted as an evidence gap, with a need to bring in voices from all potential users to understand evidence needs in relation to attribution science, and to help guide future science development.
- *Information channels that inspire trust:* The context-specific nature of credible climate information providers was noted as key to engaging with decision-makers.
- *Non-climatic factors:* The consideration of climate and non-climate drivers of disasters in attribution assessments noted as important, particularly in the context where a focus on the role of climate change only in the aftermath of an extreme event may lead to inaction from those responsible for other contributing factors.

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<sup>2</sup> <https://cer.org.za/wp-content/uploads/2024/03/Polluter-Pays.pdf>

- *Data and modelling availability and accessibility:* Availability climate observation data for some types of extremes or in some regions was noted as a barrier to conducting attribution assessments, alongside the availability of suitable models.
- *Computing and skills resource:* The data-intensive nature of attribution assessments was noted as barrier. An attribution science skills gaps was noted, with this being crucial for the region to draw on particularly in response to demand for rapid assessments.

### Next Steps

WCSSP partners are now exploring possible next steps of this exploratory work in WP4. Future work will include prioritisation of application areas to engage further with existing or potential users of attribution science, as well as engagement with SAWS and partners to consider potential for operational attribution services for high-impact events.

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