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Seamless forecast prediction system framework - Earth system model approach

Evaluation/validation from weather to monthly time scales and tailored services development for the health sector

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Outline

- Provide a sense of key focus of climate modelling work done at the CSIR across different time scales.
- Exemplify the status of components of the seamless climate modelling-based trail service/prototype development.
- Highlight the current thinking around development for sectors-specific tailored products (e.g., energy + health sector relevant examples).
- Share areas where research and development collaborations/partnerships could impact climate change resilience building sector-specific

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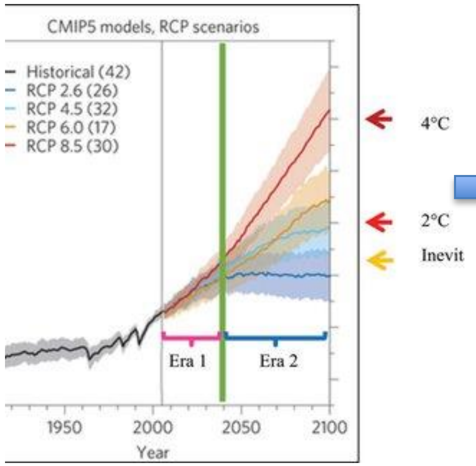
Climate model science base for the project

1 Standardized Emission projections/SST/Sea ICE

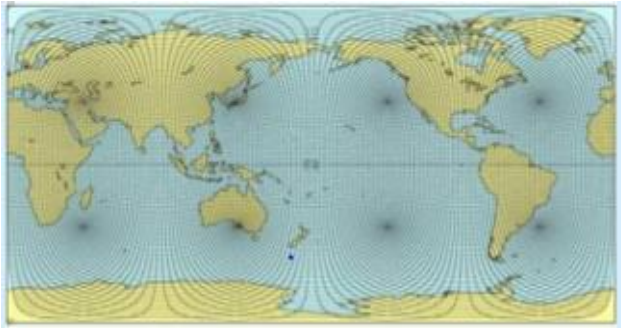
2 Global Climate Model (GCM)

3 Downscaling

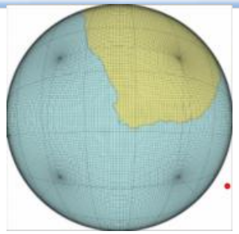
4 Secondary impact model



CSIRO CCAM-CABLE



Global simulation, quasi-uniform C192 resolution (~50km)



dynamical downscaling

Statistical downscaling

Impact modelling

Hydrology

Climate – epidemiology

Agric. and food security

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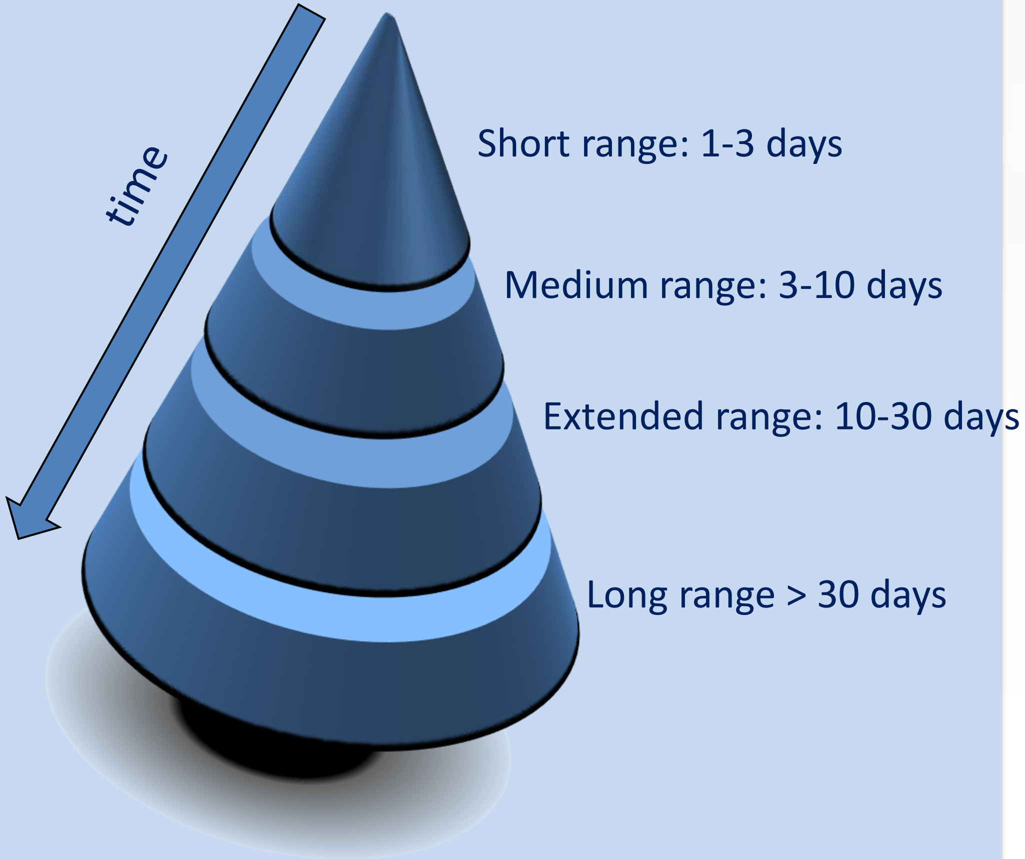
Linking earth system-based climate modelling and services across timescales



Simulation experiments by time scales and their data dependencies

Timescale	Forcing data	Collaborating Intuitions/ Projects
Short to Medium range	• Atmospheric Initial states reanalysis • Lower layer atmospheric data temperature layer • Satellite-derived observations	• NCEP – Department of Energy (DOE) • Geophysical Fluid Dynamics Laboratory(GFDL) data assimilation system data (upper layer)
Seasonal Forecasts	• Atmospheric initial states, • Sea Surface temperatures (SSTs) from • Sea Ice • Emissions and	• Same as short to medium-range prediction CCAM system • University of Pretoria & North American Multi-Model Ensemble(NMME) • Syntax F2 (Jumstec) • CMIP5/6
Decadal predictions	• Planning phase	??
Climate Modelling	• Sea Ice and SST • Emissions & aerosols	CMIP5/6 models

Collaborations/MoUs/cooperation agreements across partner institutions are critical

Research and development focus

Seamless forecasting platform component	R&D offerings
Climate modelling	• Scientific evidence of climate change - at impact modelling relevant spatial and temporal resolutions (**cover all economic sectors)**
Seasonal forecasting	• Application of earth system model for seasonal forecasting (AMIP-type experiments) • Explore the models' representation of the drivers of variability (**Collaboration with UP – Prof. Willem Landman group & Prof. Thando Ndarana**). • Explore avenues for improving model skill • Develop early warning systems (**Present climate services focus is Water, Energy, Food security, and Health**)
Numerical Weather Predictions & Nowcasting	• Understand the relationship between CoLs and Thunderstorm development (**Collaboration with UP – Prof. Thando Ndarana's Group**)
Climate Service development	• Full-Value-Chain Optimisated Climate User-centric Climate services development in Africa (FOCUS-Africa**): WMO coordinated European Commission-funded project**, • CSIR & ESKOM energy sector adaptation project, • CSIR precision agriculture project.

Approach to the development of trail – climate services

Follow the principles of responsible research:

- Co-defining,
- Co-development,
- Co-production,
- Co-delivery

of climate services

Bringing Climate Services to resilience building

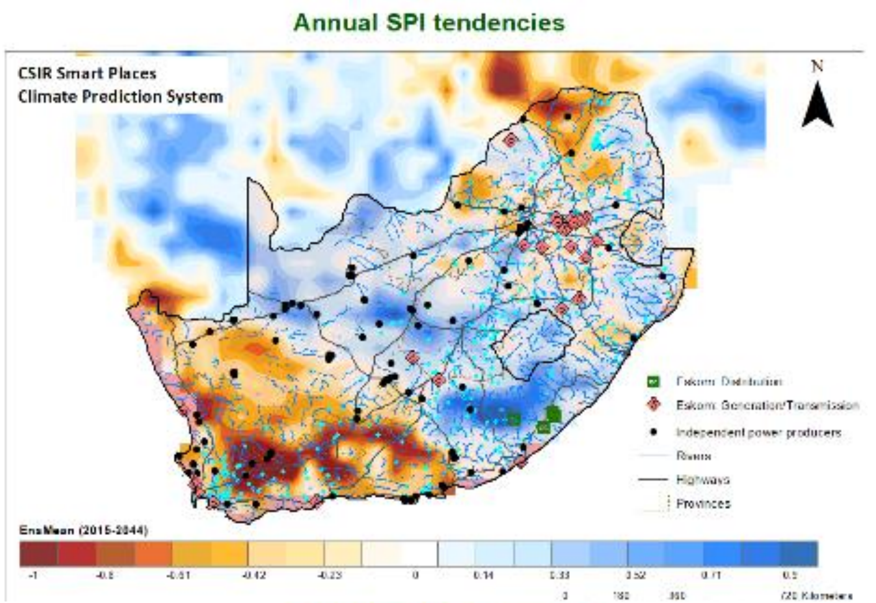
Screening process overview: Map risk to weather and conditions (energy sector case)

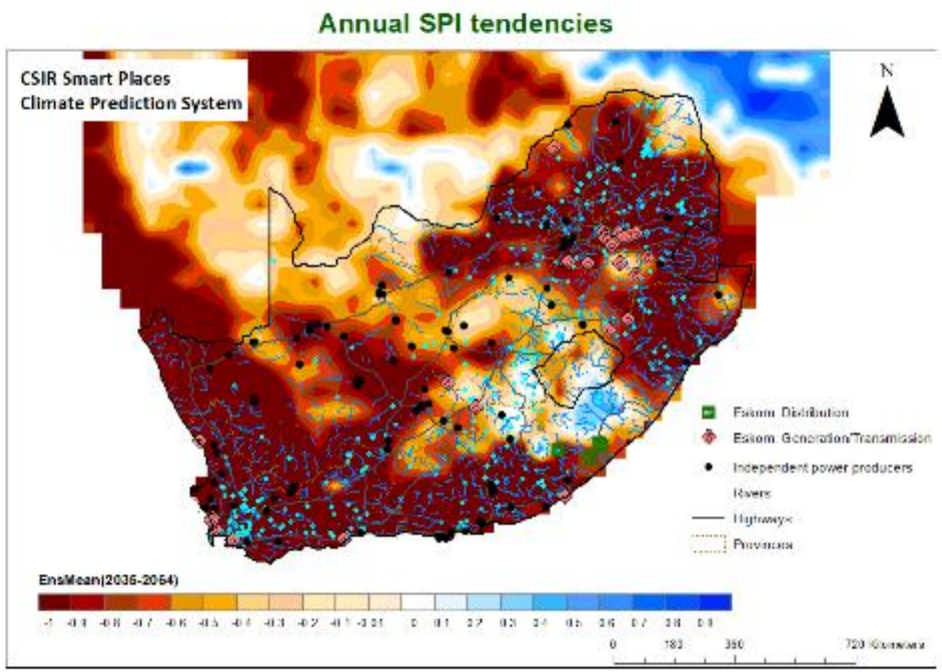
Drought tendencies Anomalies

Projected change in the drought (flood) tendencies (i.e., number of cases exceeding natural variability per decade) over South Africa for the period:

- 2035 - 2064 &
- 2018 -2044

relative to the 1986-2005 baseline period, under a low mitigation scenario (**RCP8.5**).





System Risk = Aggregated unavailable supply
\+
Exceptional demand
\+
employee health and safety.

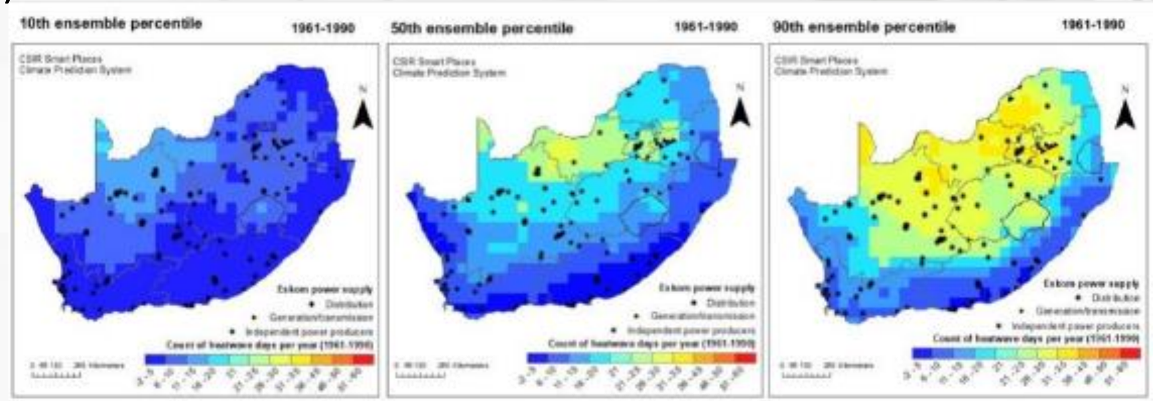
Users determine demands associated with extremes

We apply scenario reduction techniques will be applied:

- to ensure that the diversity of tail risk events is examined to establish the likelihood of occurrence.

Screening process overview Hazard, impact representation (energy sector case)

a)



b)

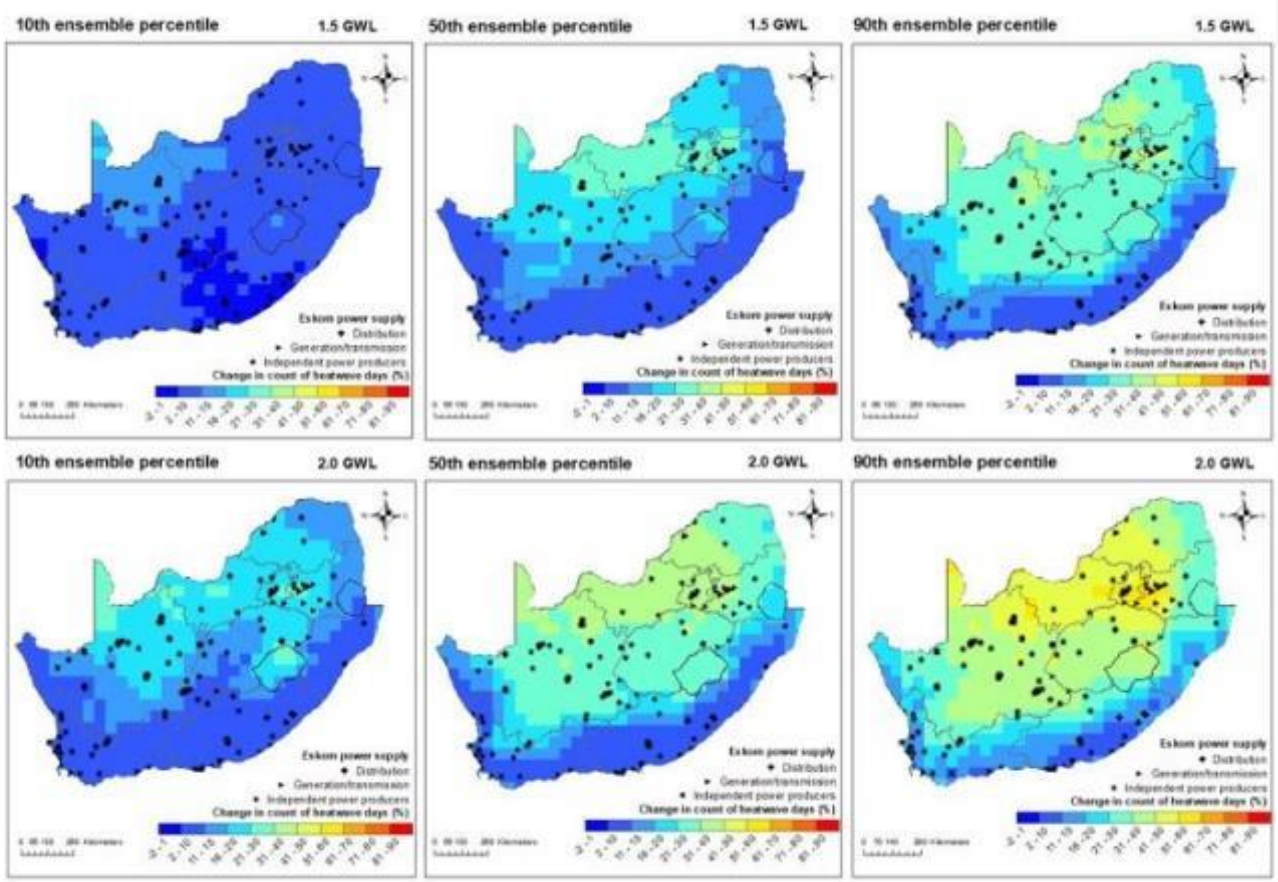


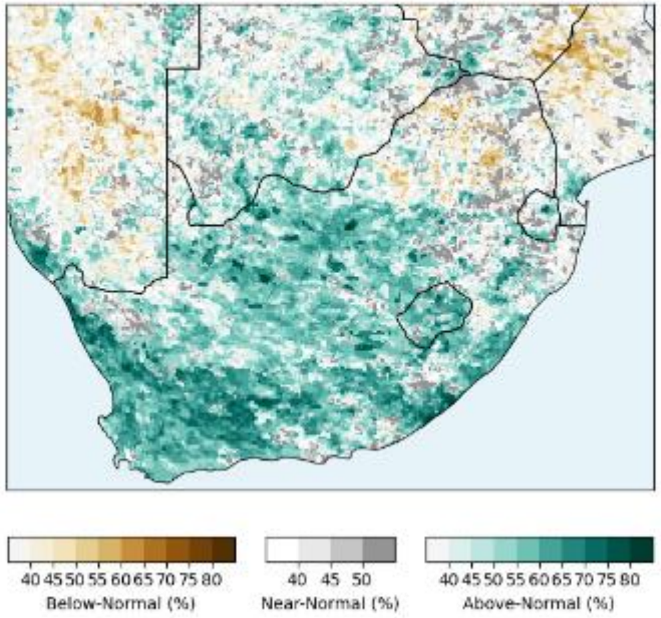
Figure: (a) Total number of heatwave days, over South Africa under the 1.5° C and 2.0° C Global Warming Levels relative to the 1961–1990 baseline (shown in (b)). The 10th percentile, median (50th percentile), and 90th percentiles are shown for the ensemble of 10 downscaled **CMIP6 ISMIP3b** model projections under 1.5° and 2.0 C GWL calculated from the SSP5-8.5 scenario.

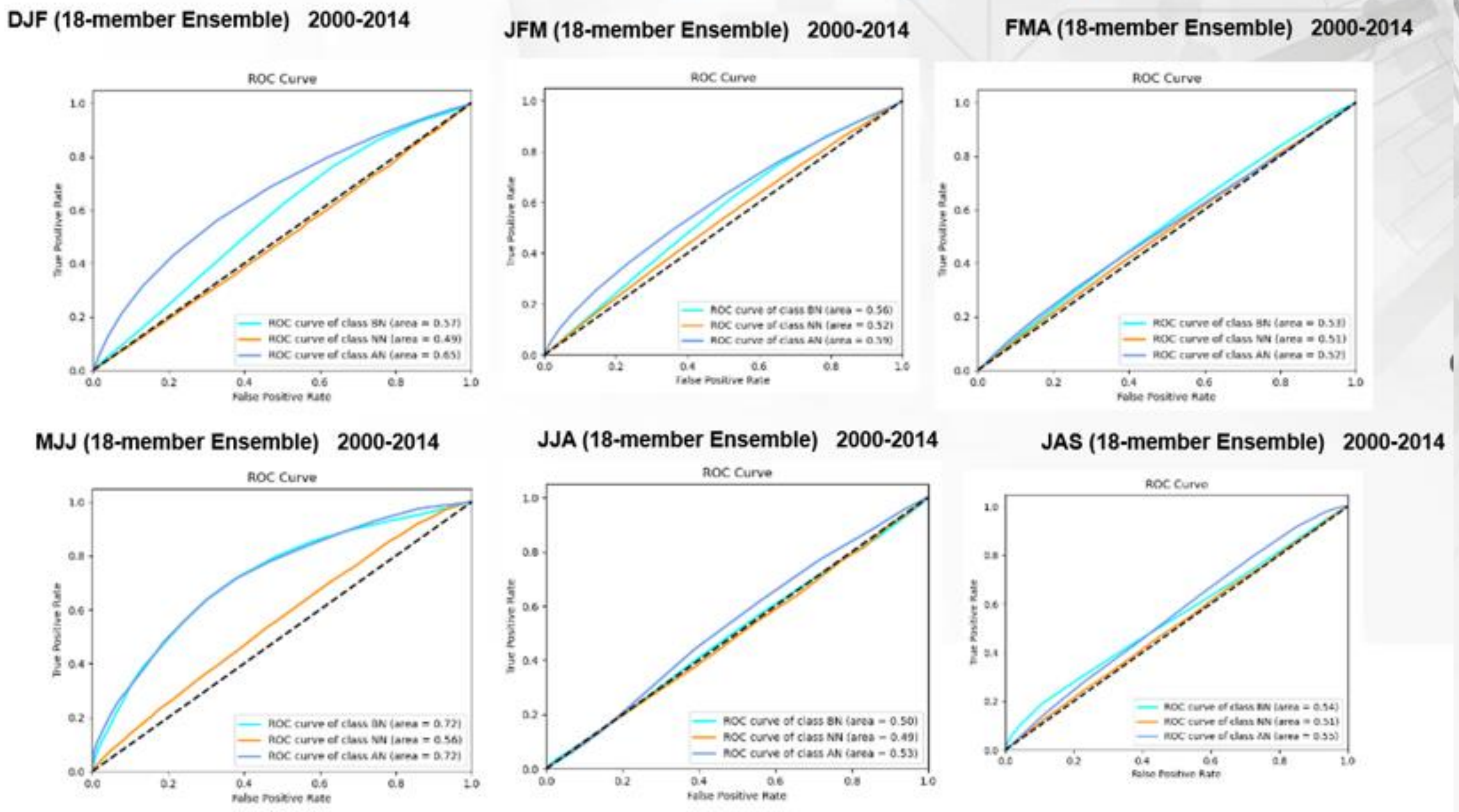
- Follow similar steps on the risk-screening tool
    - Physical hazards and their compounding climatic factors
    - Identify credible events
    - Map systems under the hazard footprint as impacted these also depend on characteristics defining exposure, vulnerability (sensitivity vs adaptive capacity), and hence risk.

Bringing seasonal Forecasts trial-service for operational planning
CCAM-Earth system model

Model Performance Evaluation (Hindcast): Precipitation

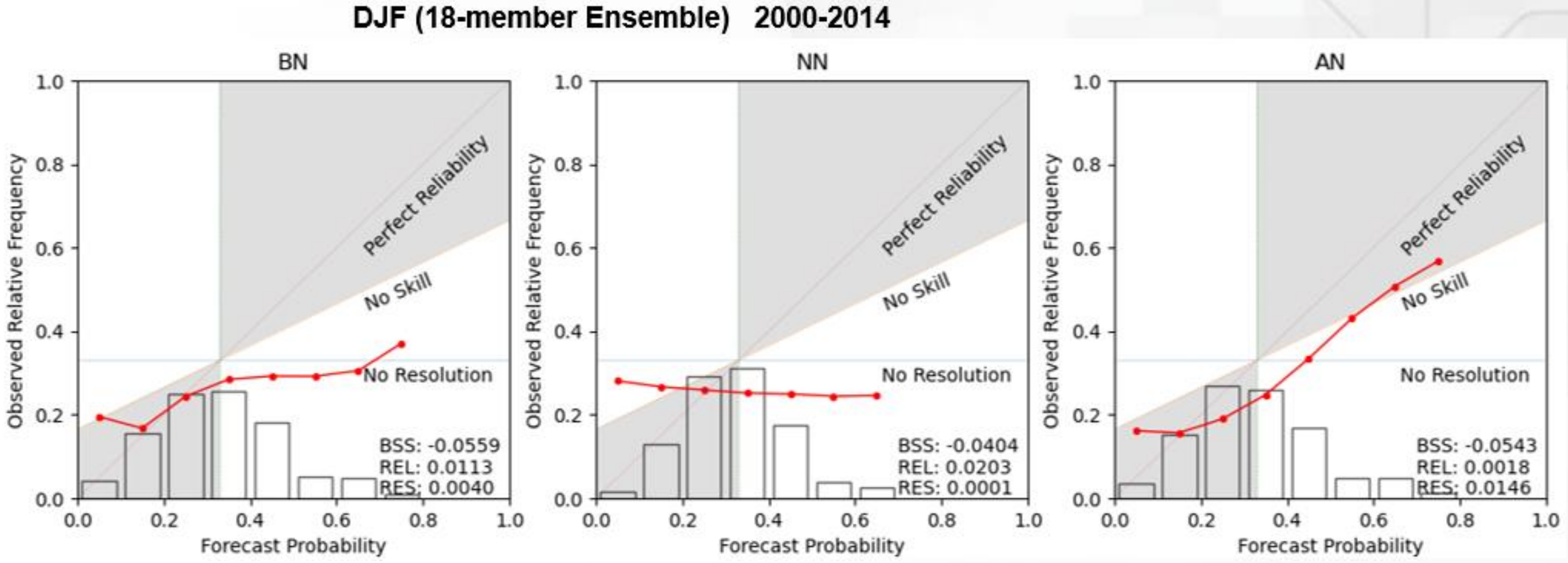
Precipitation forecast (e.g., DJF 2019 lead-1)





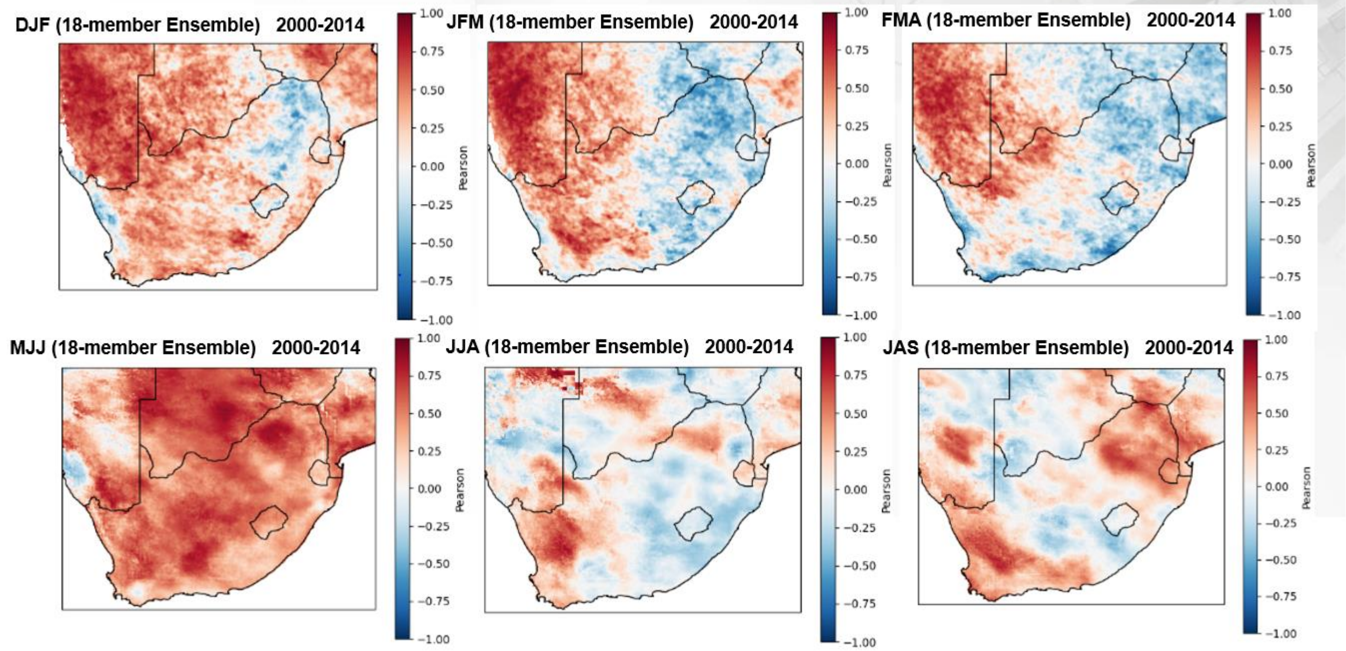
- Model simulation approach inspired by approaches used by the Institute for Climate and Society (**IRI**) - Columbia University - SAWS collaboration (**Dr Asmerom Beraki & Prof. Landman**) were directly involved.
- Hindcast for 2000 -2014
- Probabilistic forecasts initialized in **Nov** (2020,2021,2023) and **May** for (2020,2021,2022)
- Skill declines significantly with increasing lead times
- No predictive skill for normal category

Precipitation forecast reliability and correlation (e.g., DJF lead-1)

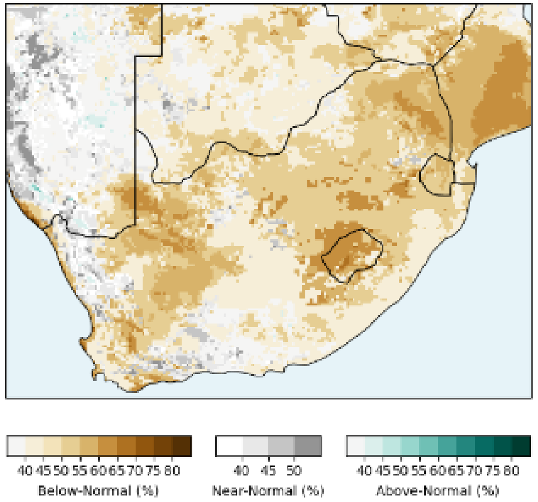


- The reliability diagram suggests that the model is over-confident for the Below-Normal precipitation category.
- Almost no skill for the normal precipitation

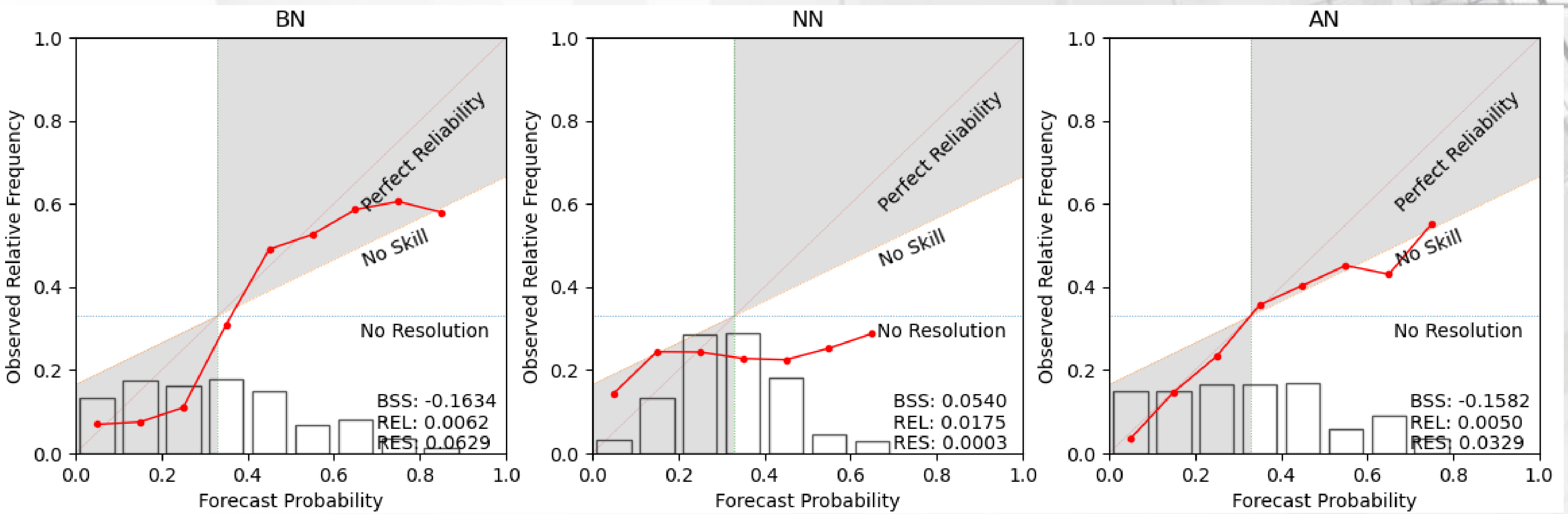
- Over the escapement precipitation has a major contribution from mesoscale convective processes (not representative at 8km resolution).
- Observation density is not representative



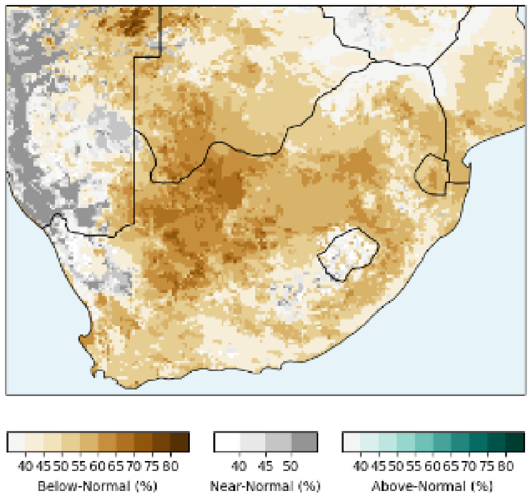
Tasmax forecast
(e.g., DJF 2020/21 lead-1)



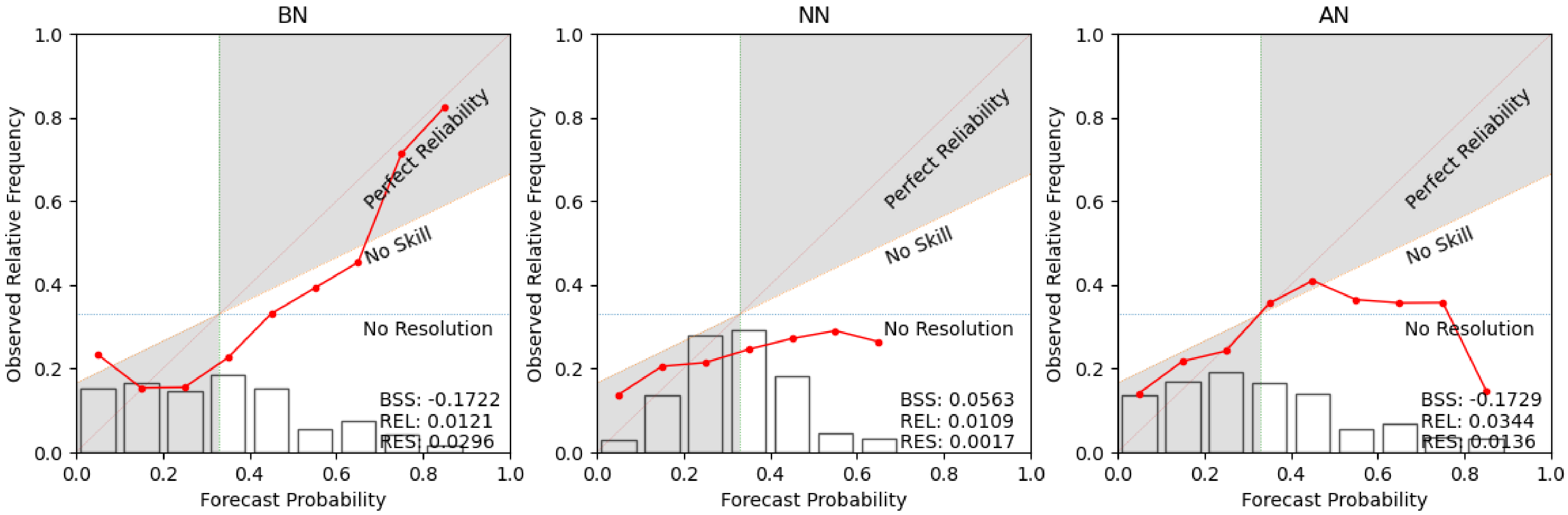
Tasmax forecast reliability e.g., DJF lead-1 2000 - 2014)



Tasmin forecast
(e.g., DJF 2020/21 lead-1)

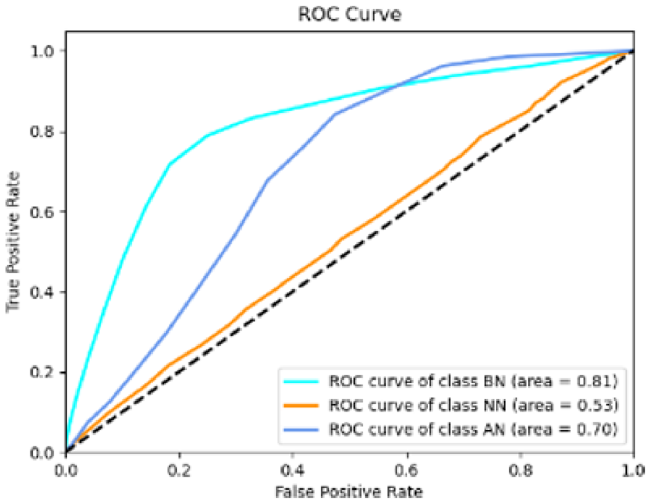


Tasmin forecast reliability e.g., DJF lead-1 2000 - 2014)

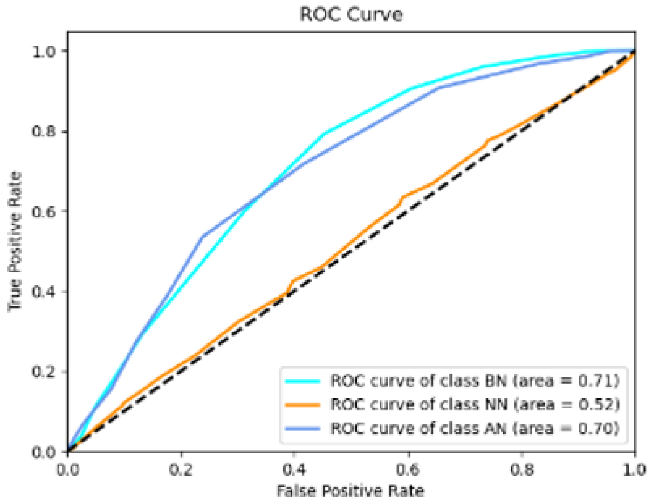


Tasmax ROC score (Lead-1)

DJF (18-member Ensemble) 2000-2014

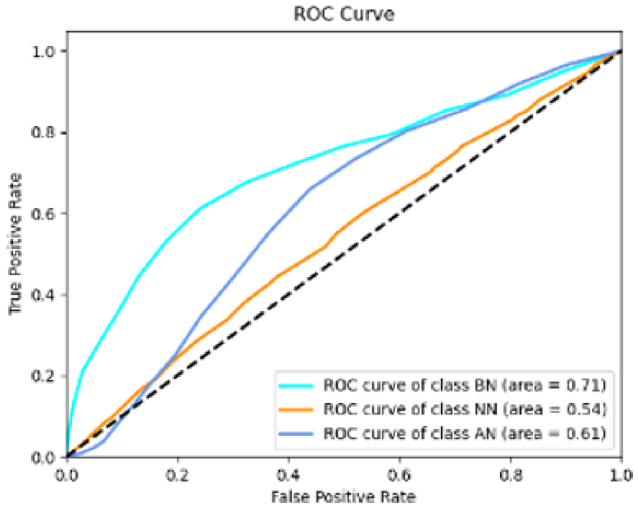


MJJ (18-member Ensemble) 2000-2014

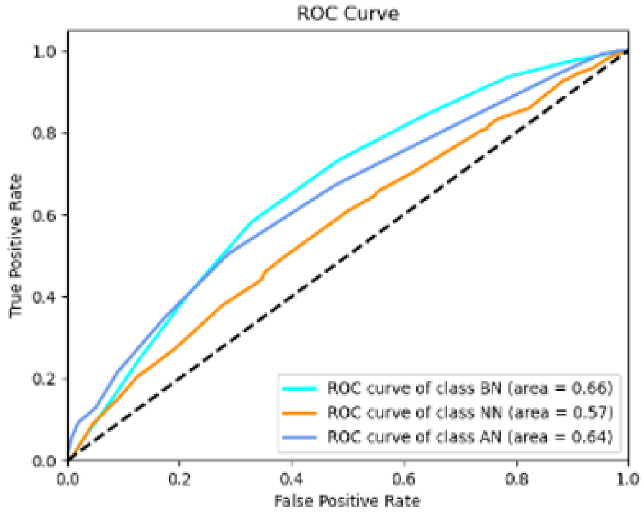


Tasmin ROC score (Lead-1)

DJF (18-member Ensemble) 2000-2014



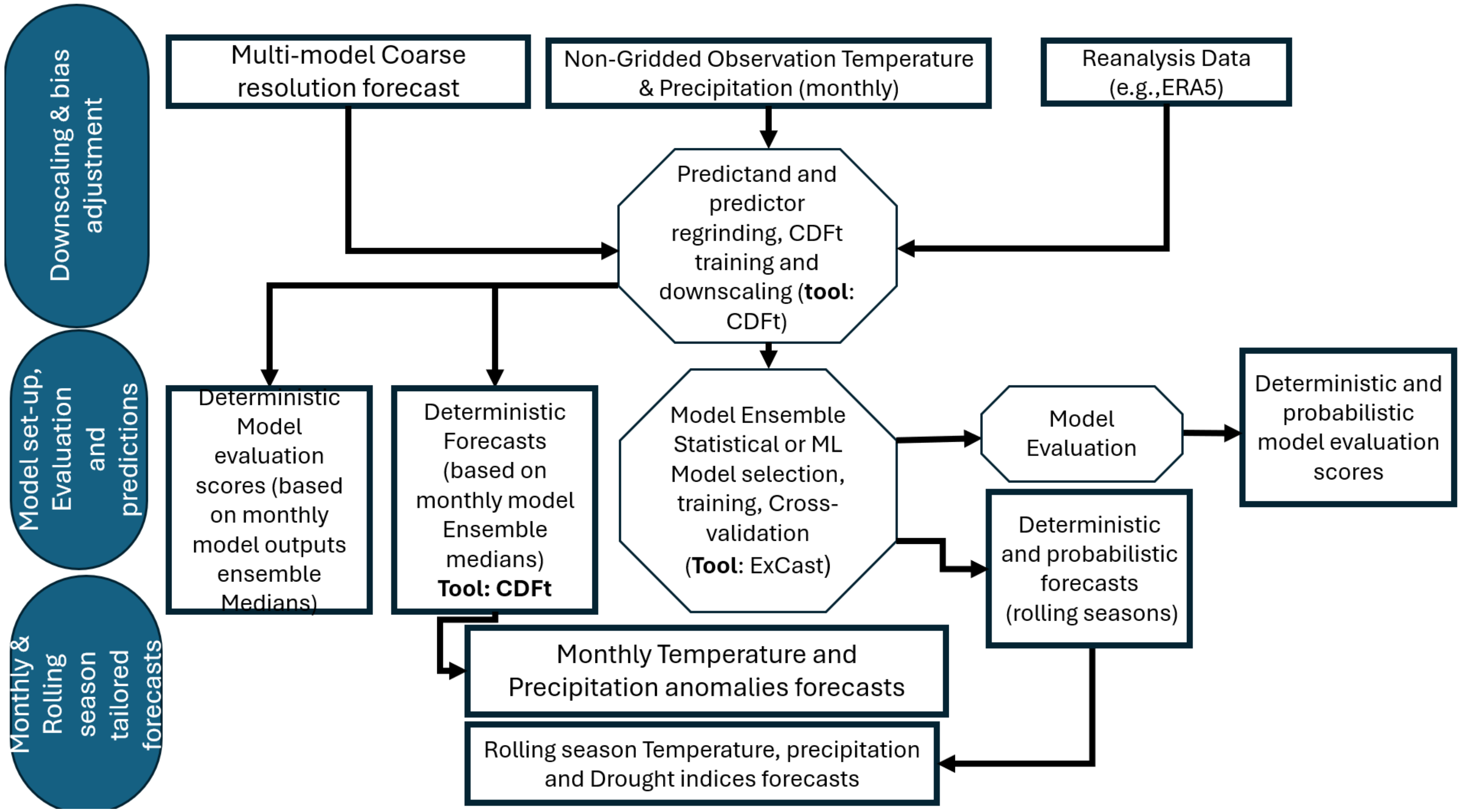
MJJ (18-member Ensemble) 2000-2014



Tasmin ROC score

- ROC Score may decline should some of the boundary forcing and initial conditions be not available.
- ROC is above 0.6 for both Tasmax and Tasmin Above-normal and Below-Normal forecast categories.

GPC Seasonal forecasts post processing workflow

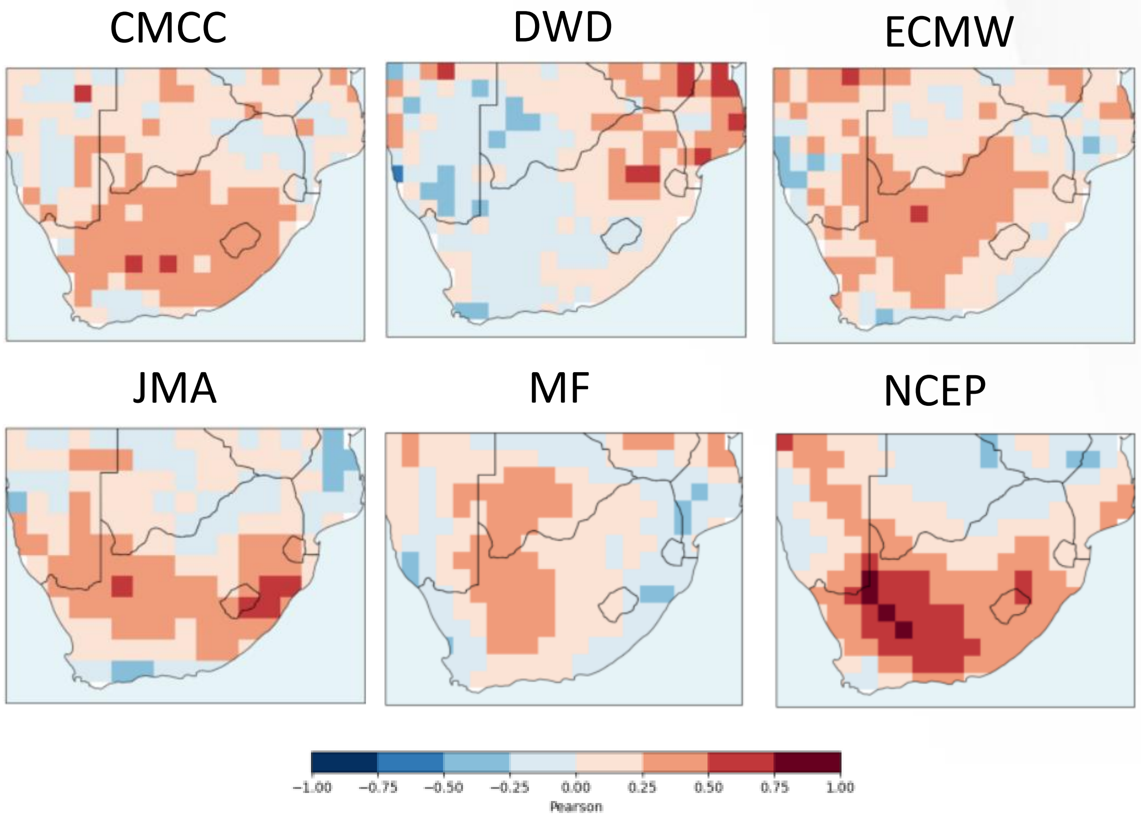


The multi-model seasonal forecast downscaling, cross validation, model training, evaluation and forecasting workflow. **The workflow shows steps for the monthly deterministic forecasts as well probabilistic forecast**

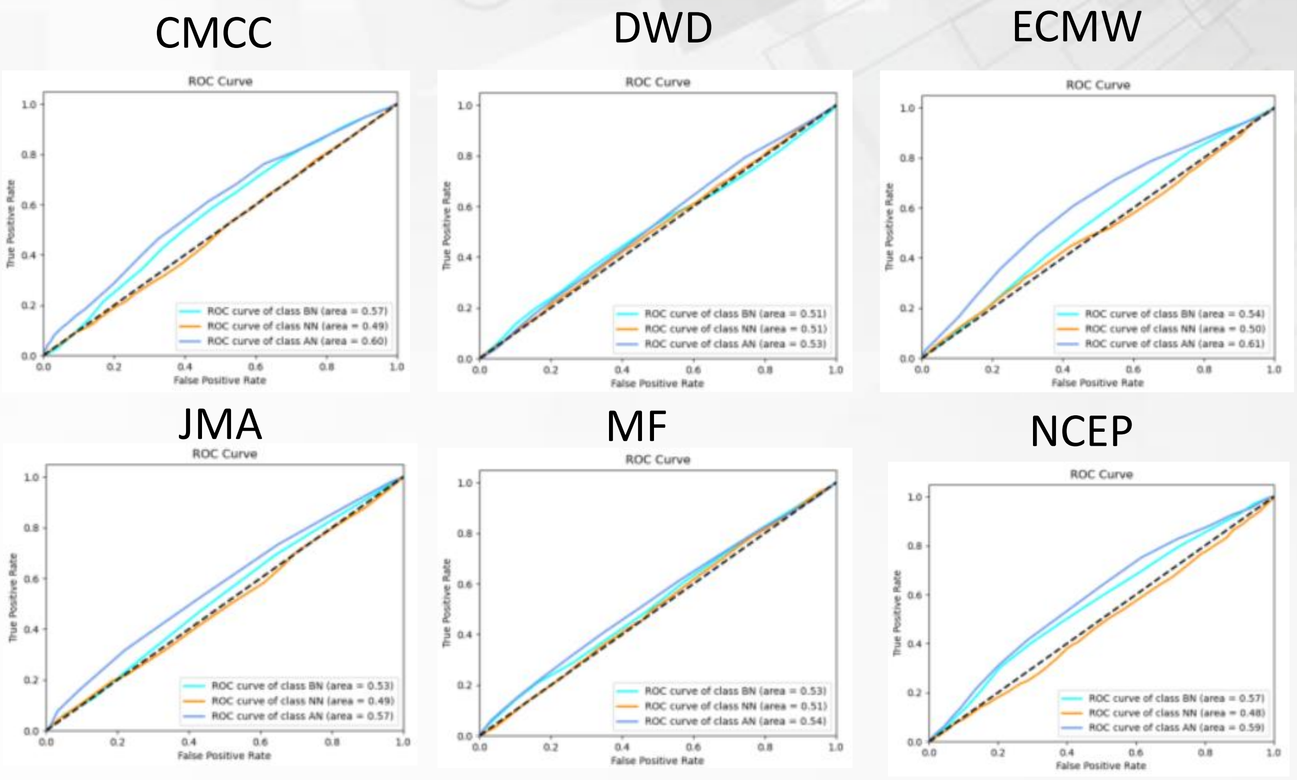
Precipitation seasonal forecast evaluation (raw data)

Initialized in May

Approach using XCast (**A python climate forecasting toolkit**): Kyle and Nachiketa (2022)



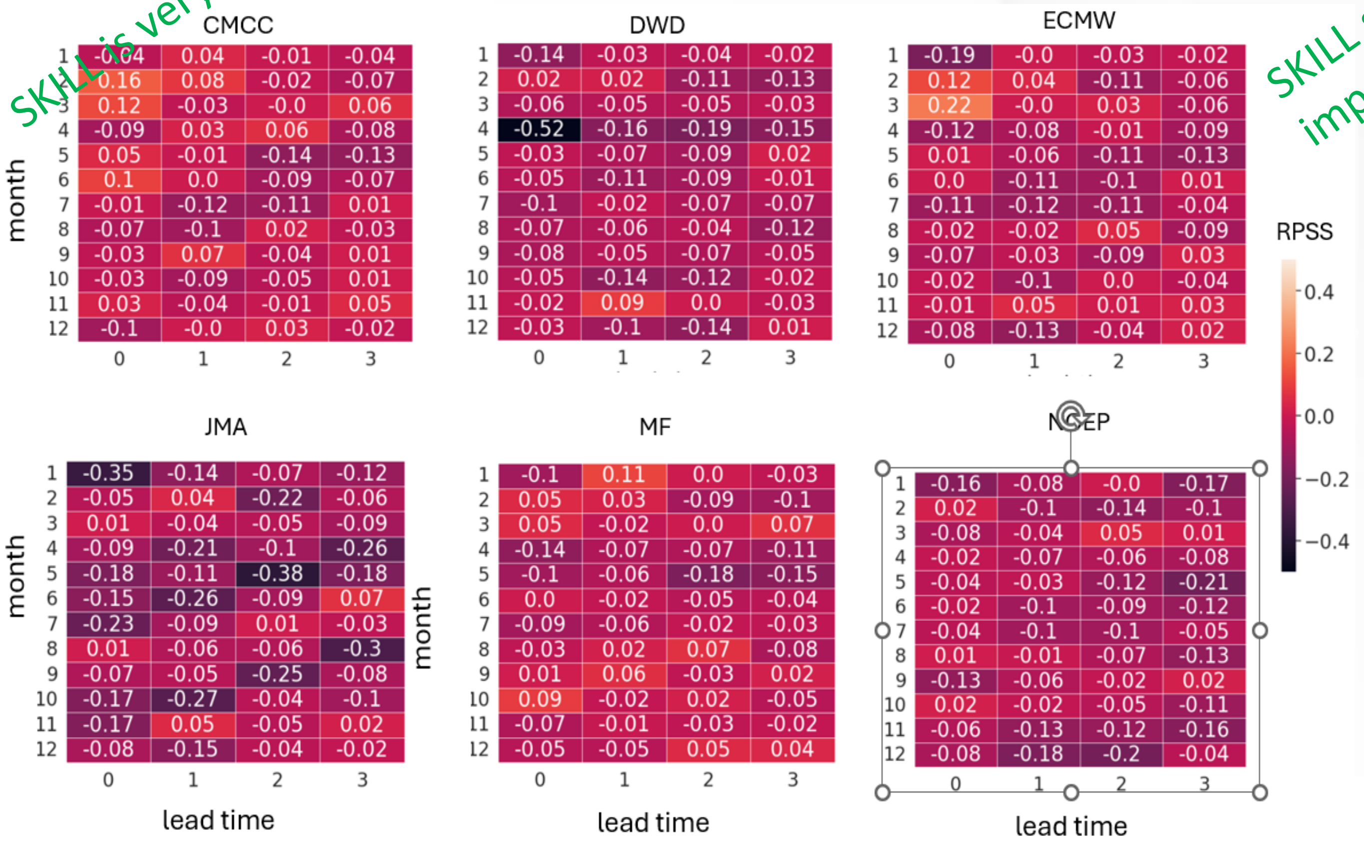
Pearson Correlation Coefficient for REG-based cross validated deterministic hindcast data (1993 -2015).



Receiver Operating Curve (ROC) for REG-based cross validated probabilistic hindcast data (1993 -2015).

Mauritius Case Study: Downscaled probabilistic forecast evaluation: testing different approaches

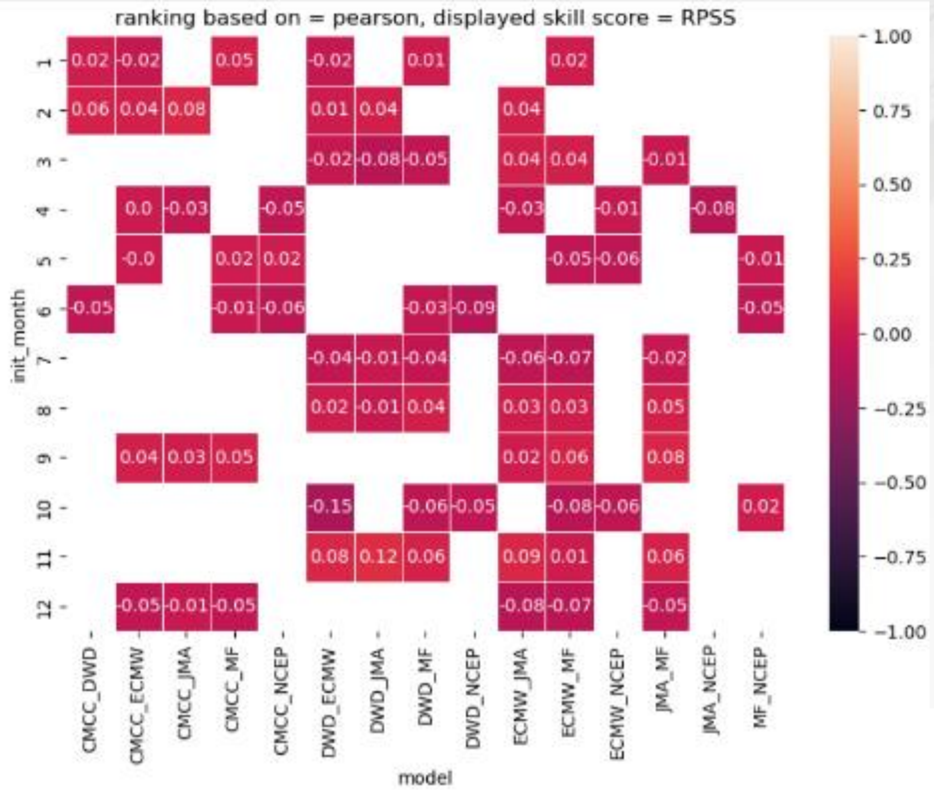
SKILL is very low



Spatially Rank probability Skill Score (RPSS) for the REG model cross-validated ensemble hindcast data (1993 -2015).

SKILL shows improvement

Probabilistic forecast skill improved by combining signal from best performing models.

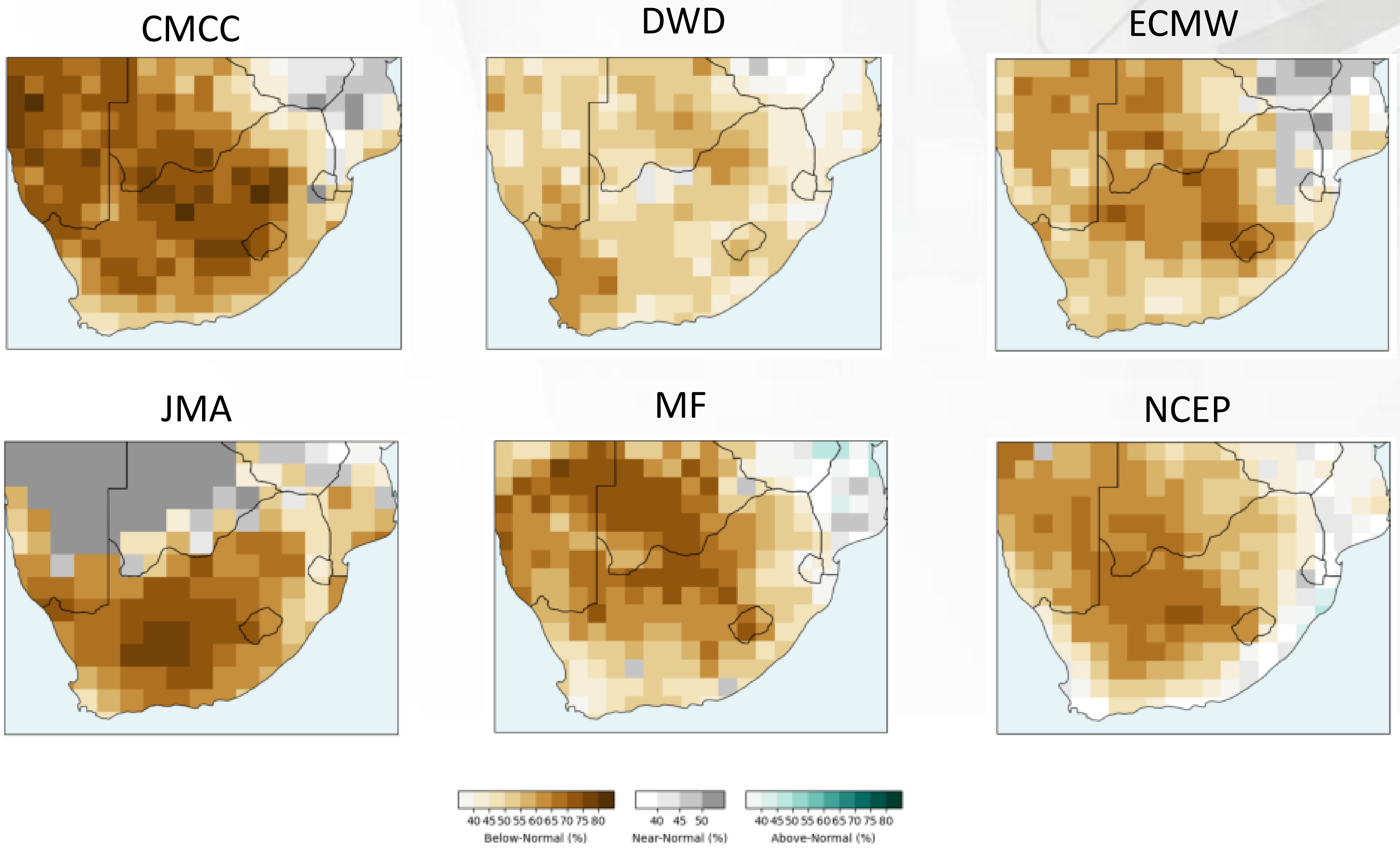


Muti-model Spatially averaged Rank Probability Skill Score (RPSS) for the REG model cross-validated ensemble hindcast data (1993 -2015): lead-1

Precipitation probabilistic seasonal forecast

Initialized in May 2024

Approach using XCast (**A python climate forecasting toolkit**): Kyle and Nachiketa (2022)



Probabilistic seasonal forecast for JJA , with a May 2024 initialization

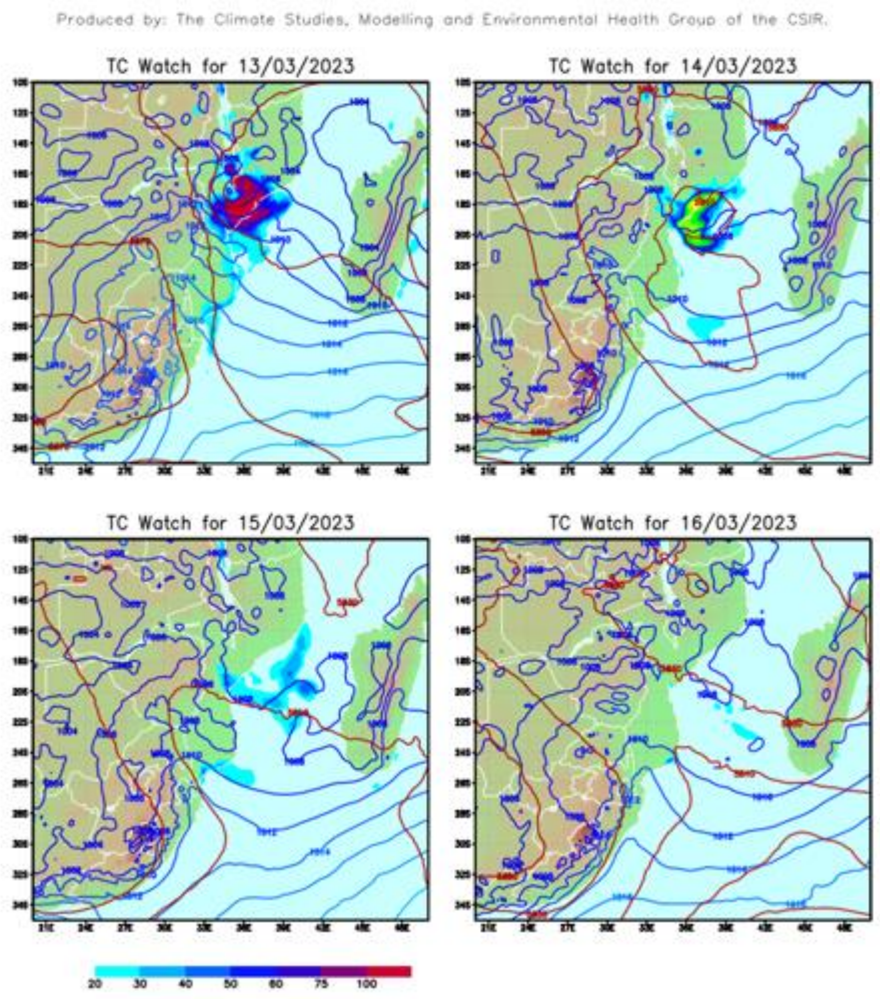
Challenges and opportunities

- System is a good candidate for improving an understanding of the ability of earth system models to **respond or representatively of divers** of variability in the Southern hemisphere.
- Seasonal trailered services could be expanded to include probabilistic for cast with **August initialization (relevant for SACOF)** in addition to November and May ones.
- Maintenance of the system needs investment **in capacity**.
- Data storage and computing infrastructure bottlenecks.
- At seasonal time scales unavailability of forcing data introduces hindcast–forecast experiment inconsistencies at risk of decline in model skill.

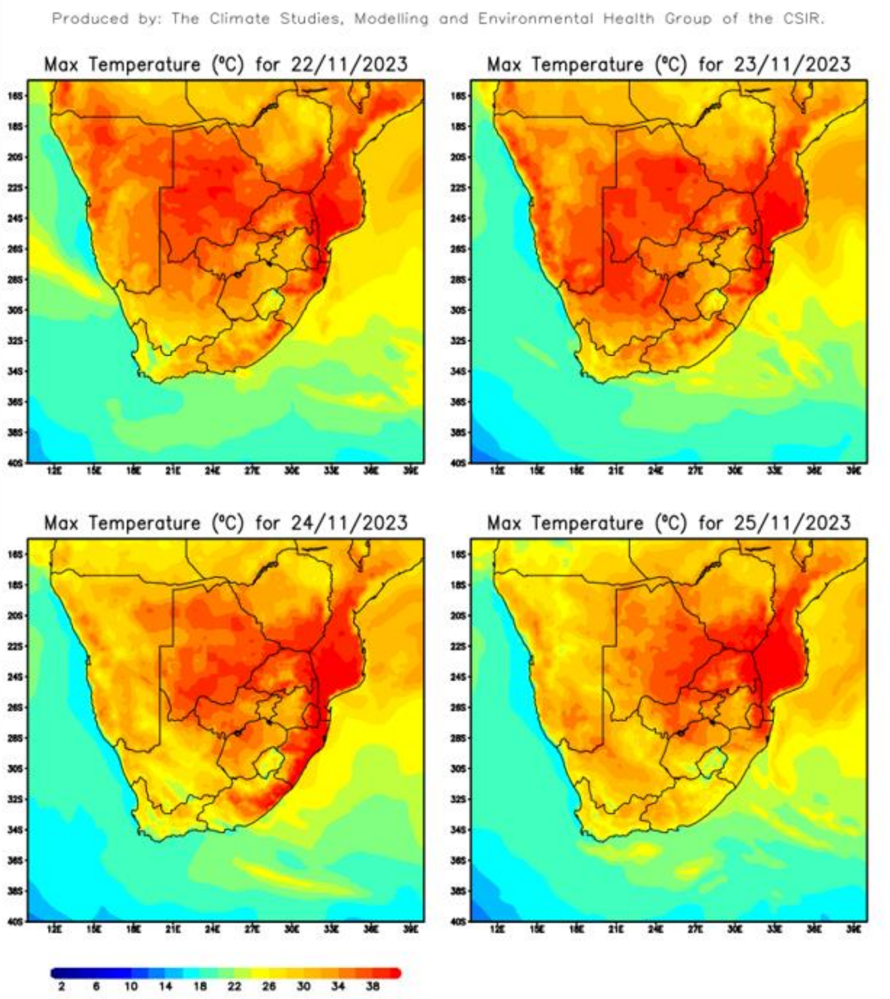
Bringing weather forecasts to climate extremes resilience building

Research and development on proliferation and uptake of weather forecasts

E.g., CCAM forecast: Tropical cyclone Freddy



E.g., the recent heatwave (25/11/2023)



- Stimulate conversations around the use and uptake of tailored weather forecasts.
- Verify the forecast of extremes and their usefulness in inducing desired behavior and operational decisions.
- Research on circulation patterns (leading to extremes).
- Integration of climate information to different delivery methods beyond well-established ones.
- Promote research around impact-based forecast and its tailoring.

Way forward

- We would like to bring more model forecast outputs at varying resolutions to better understand uncertainty in the predictions.
- Produce 4 km climate models to resolve convective processes (**to explore convective systems**).
- Explore processes that drive climate variability and their teleconnection.
- Engage with more research partner institutions to develop tailored services.
- Continue the seamless climate predictions including seasonal forecast evaluation.

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- Eskom Project

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