South African Weather Service – Weather and Climate Services

Objective Climate Forecasts for Agriculture and Food Security Sector in Eastern and Southern Africa Training Workshop

Victoria Falls, Zimbabwe

30 August – 5 September 2021

Mary-Jane Bopape

South African Weather Service

The South African Weather Service

Objectives of the South African Weather Service (extract)

- to ensure the ongoing collection of meteorological and ambient air quality data over South Africa and surrounding southern oceans for the use by current and future generations;
- to be the long-term custodian of a reliable national climatological and ambient air quality record

Functions of the South African Weather Service (extract)

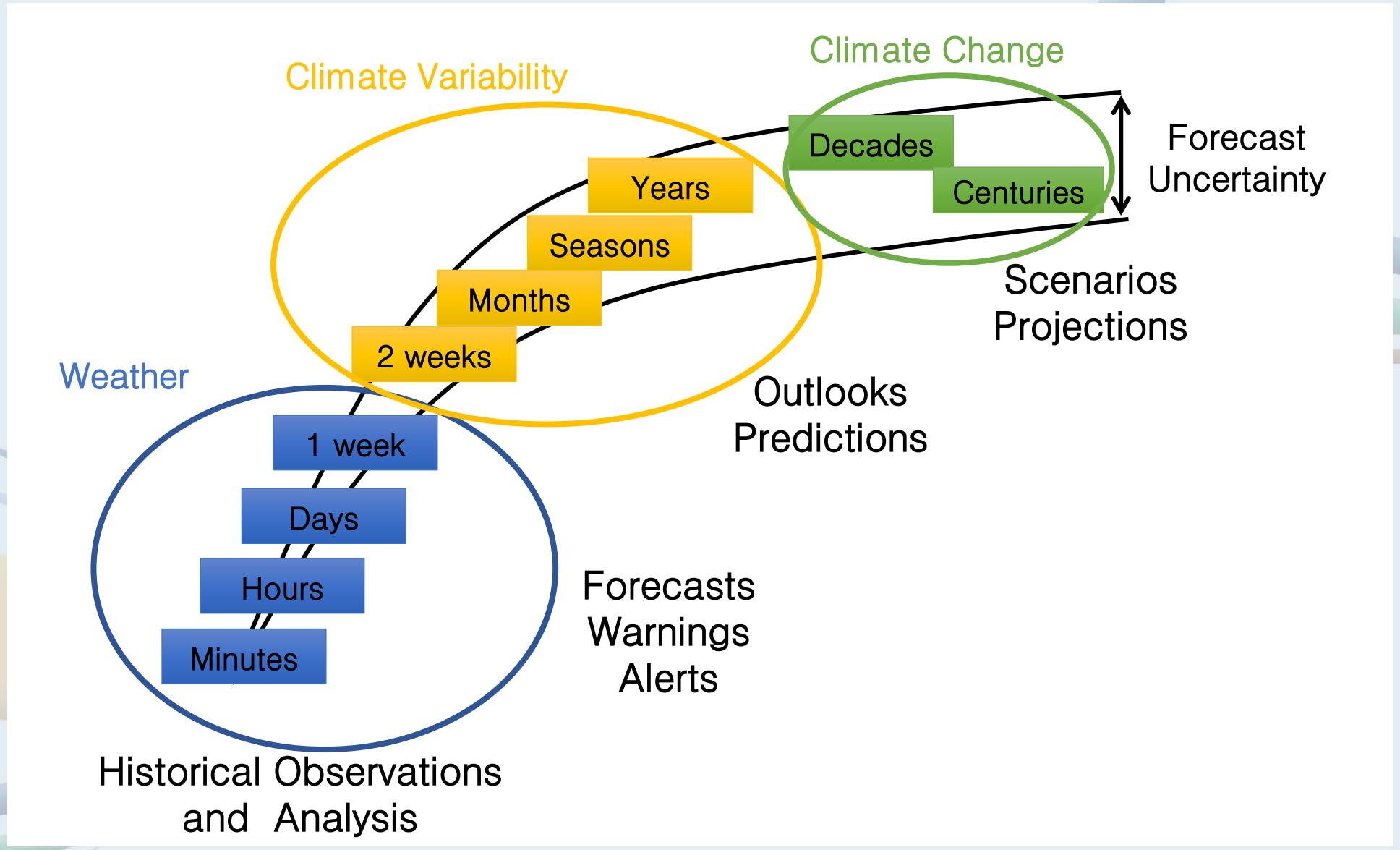
- only the Weather service may issue severe weather-related warnings over South Africa in order to ensure that there is a single authoritative voice in this regard

WMO designation

- Regional Specialised Meteorological Centre, Global Producing Centre for Long Range Forecasts, Regional Training Centre

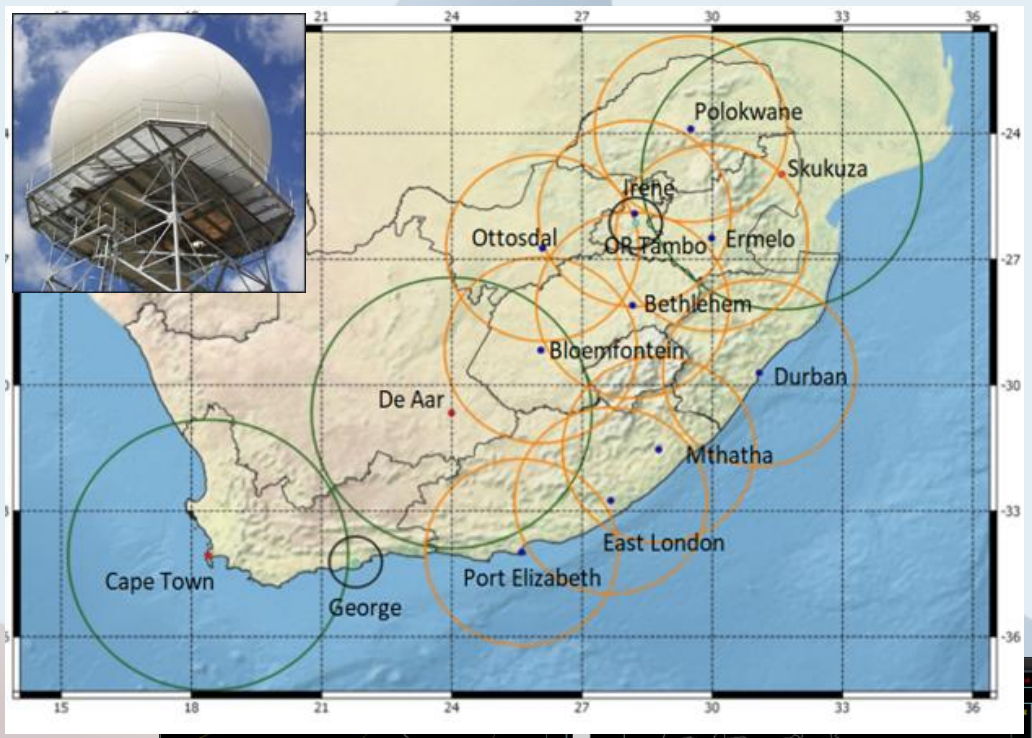
South African Weather Service

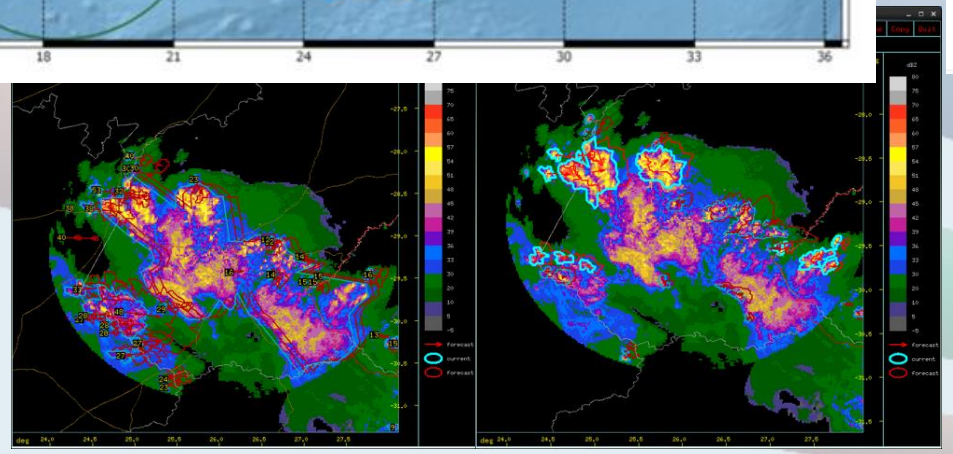
Seamless Forecasting Services



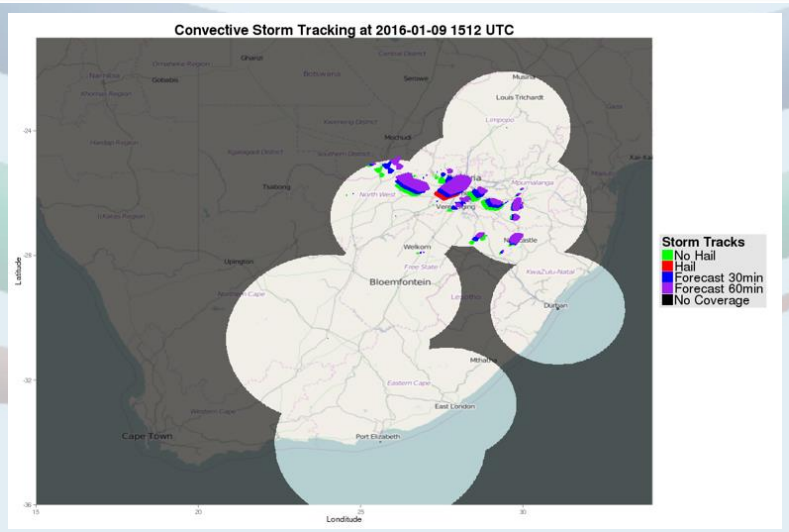
South African Weather Service

Radar Products



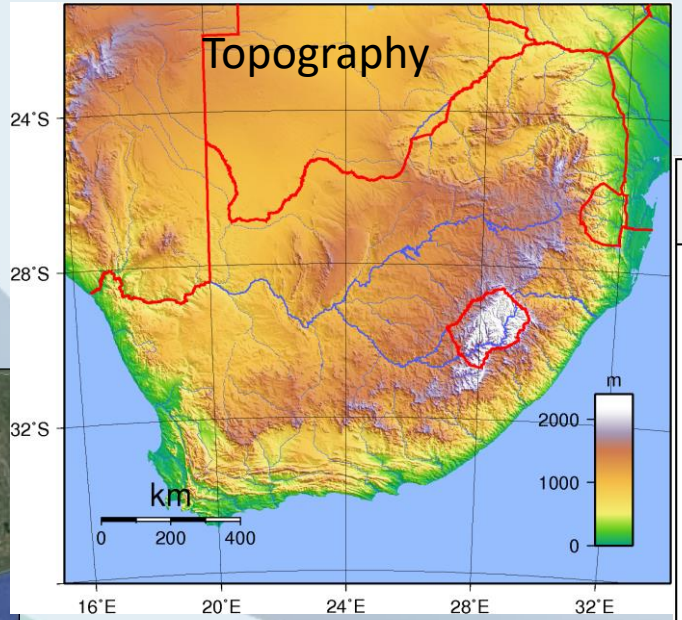


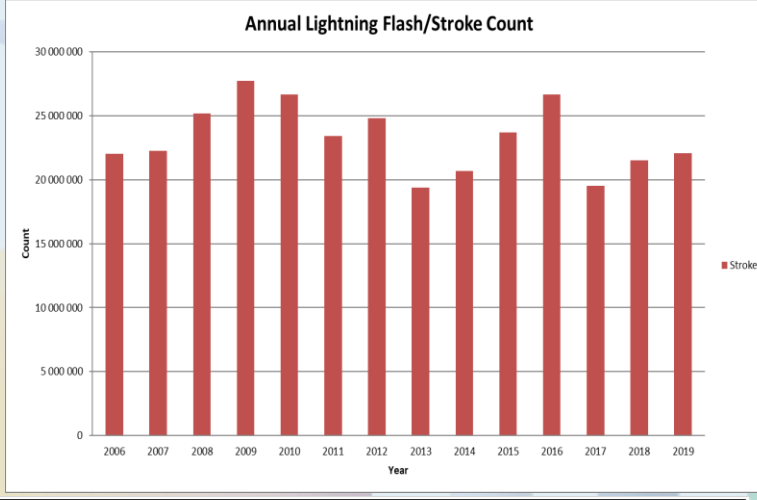
- 10 S-band, 3 C-band and 2 X-band radars
- Quantitative Precipitation Estimates
- Storm tracks
- Hail tracking

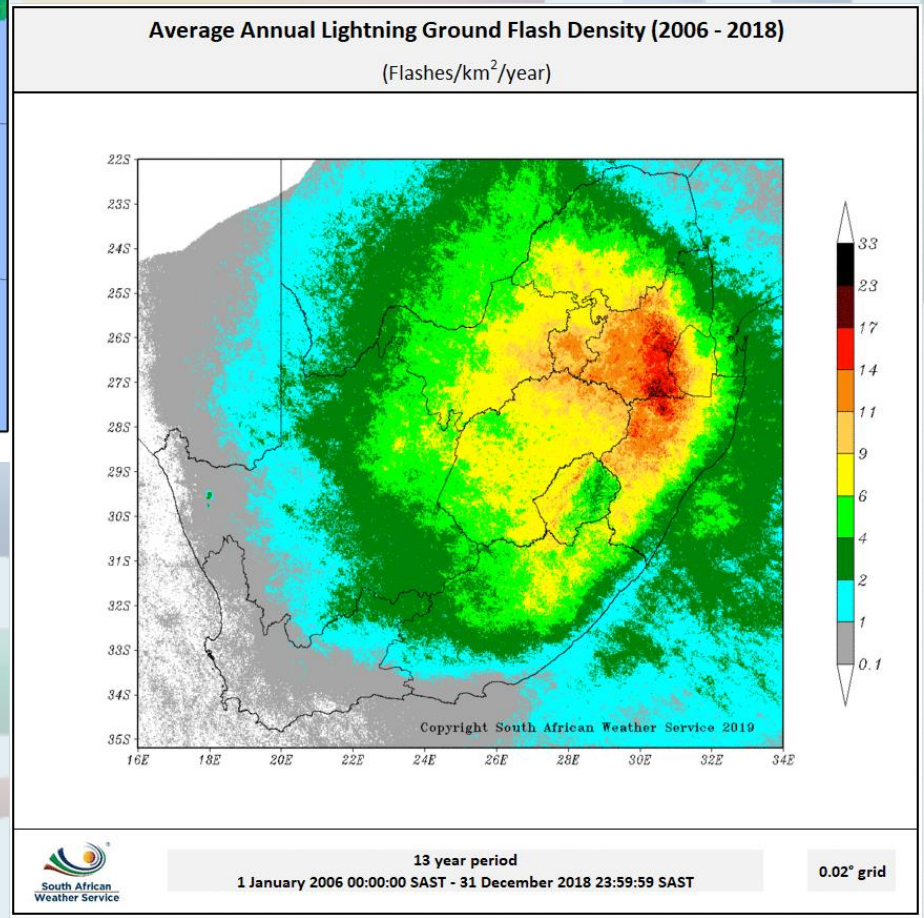


South African Weather Service

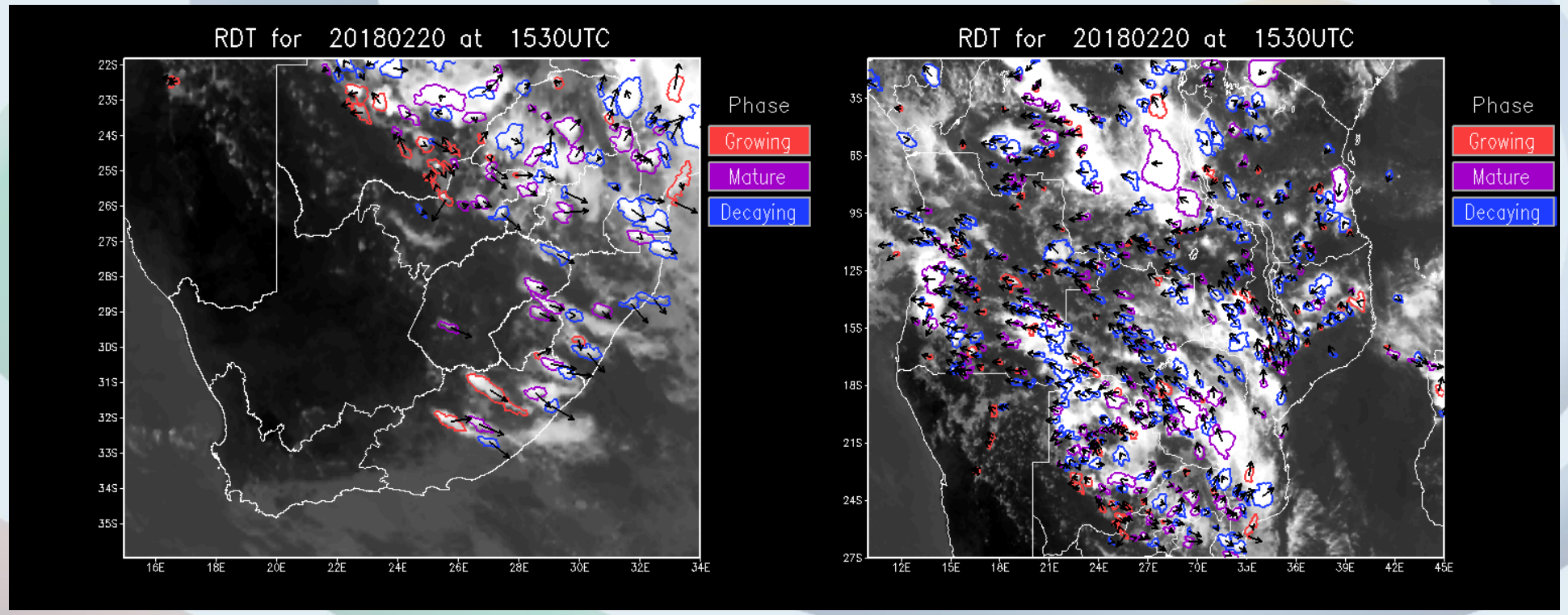
Lightning Detection Network







Satellite Product



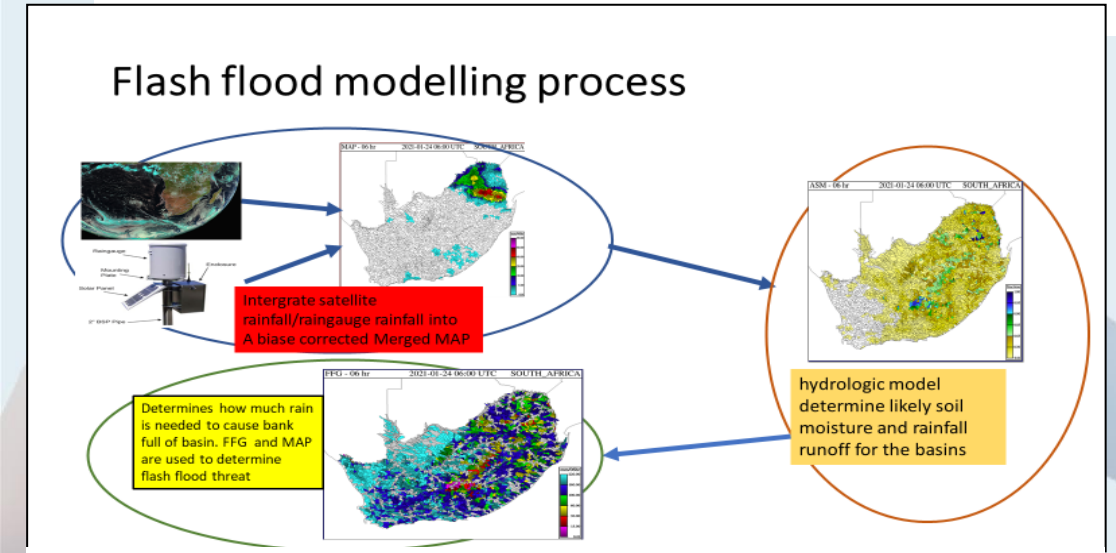
- Nowcasting Satellite Application Facility: Meteosat Second Generation
- Rapidly Developing Thunderstorms
- Southern Africa: Regional Specialized Meteorological Centre
- Share through RSMC Pretoria site: http://rsmc.weathersa.co.za/login.php

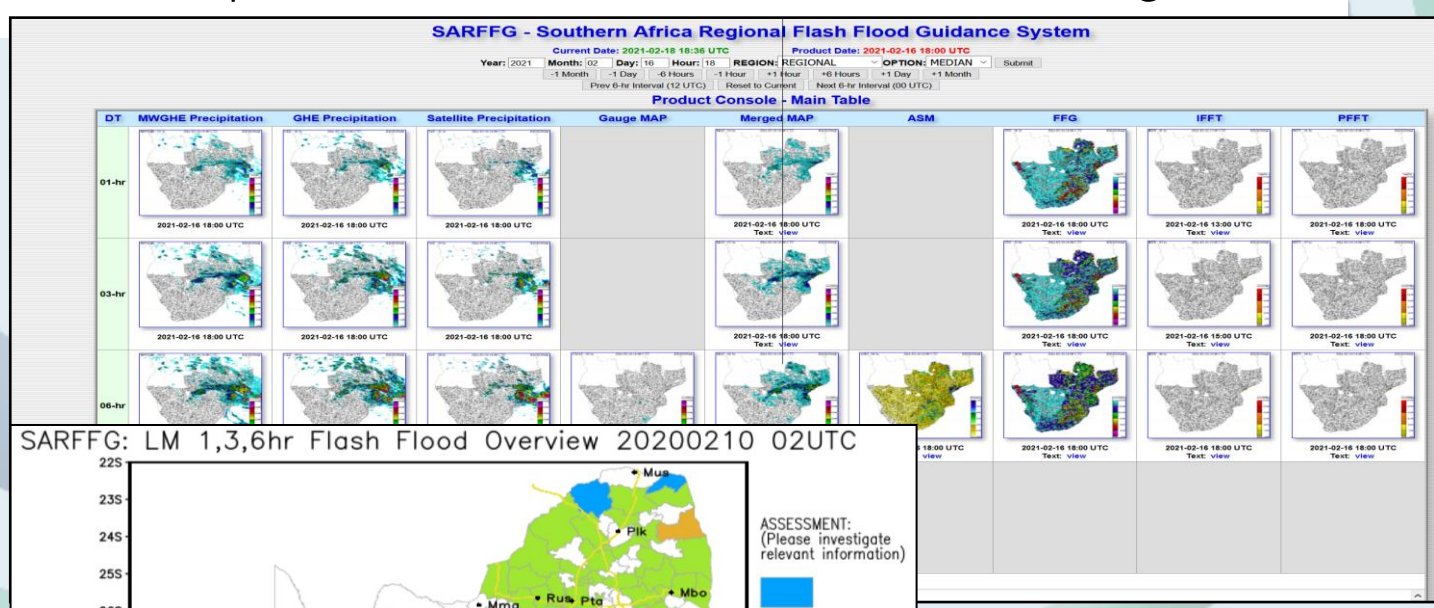
South African Weather Service

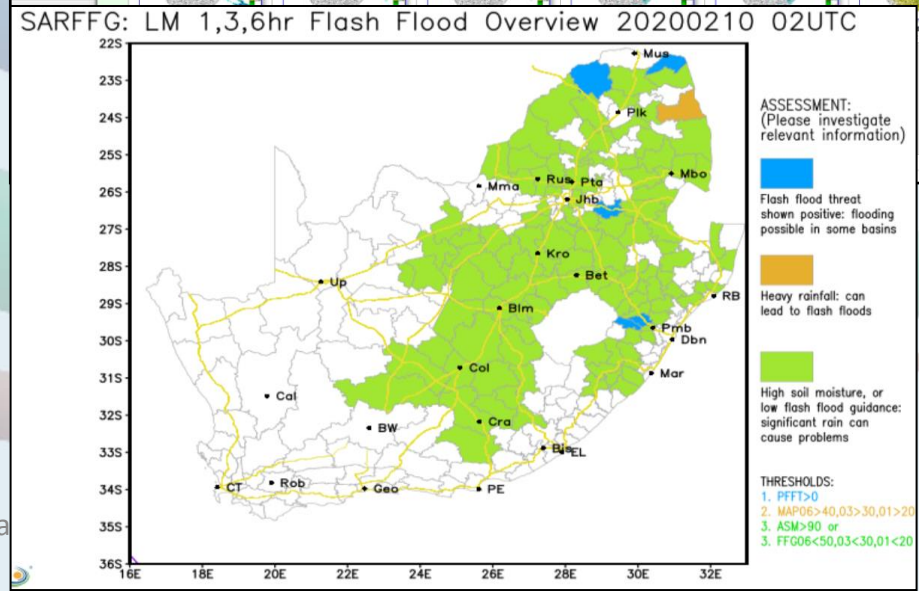
Flash Flood Guidance

Southern Africa Regional Flash Flood Guidance

- SARFFG – Hydro-meteorological modelling system that is used to assist and capacitate Operational forecasters in identifying areas that pose a threat or risk for flash flooding.





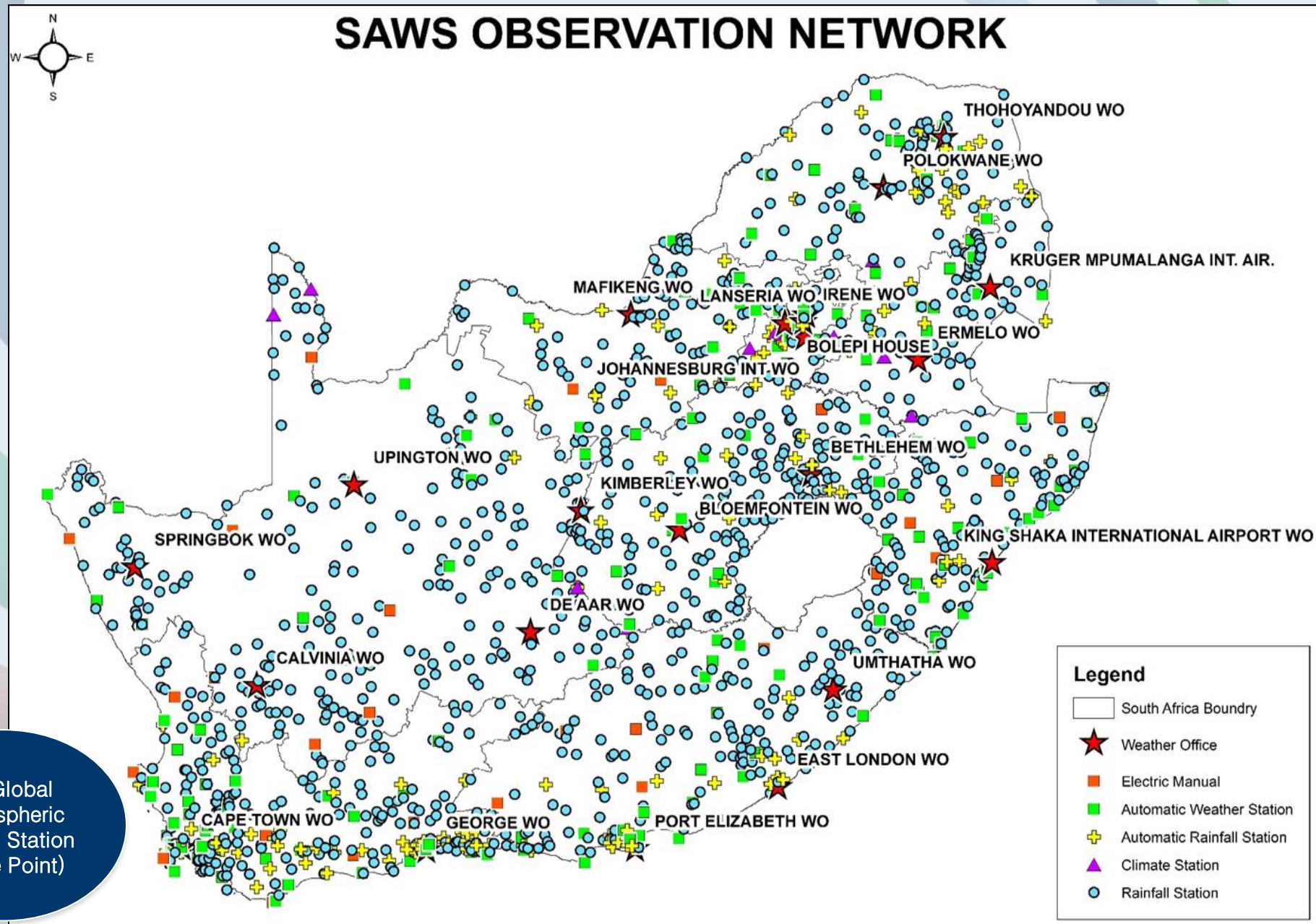


- SARFFG domain covers 9 countries in the SADC region
- The gauges, FFG and soil moisture updates values 6 hourly.
- Alert users when a certain threshold is reached on the amount of rainfall required for a basin to flood

South African Weather Service

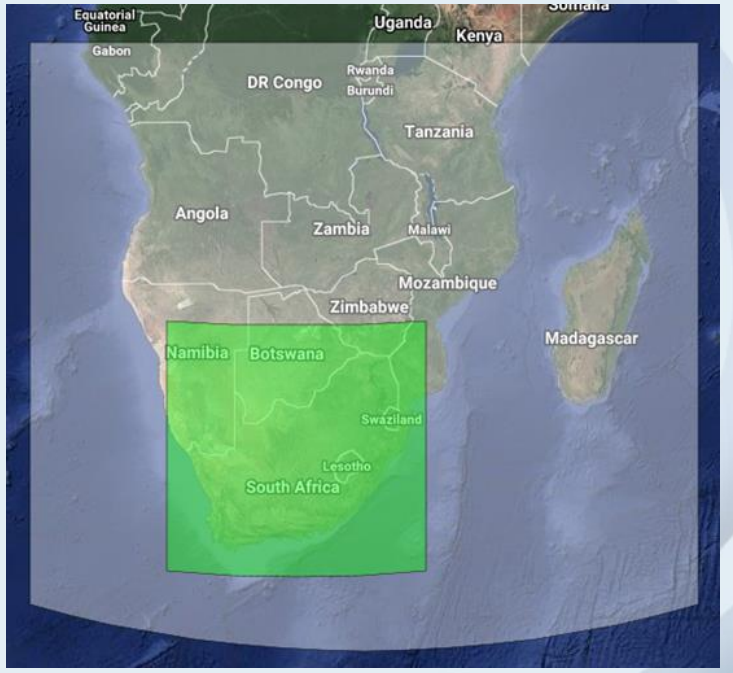
National *in situ* Observation Network

- 1 National Forecasting Centre in Pretoria
- 2 Dobson Ozone Spectrophotometer Stations (Irene & Springbok)
- 1277 Rainfall Stations (Observers – Manual)
- 13 Air Quality Measuring and Monitoring Stations (SAAQIS)
- 214 Automatic Weather Stations
- 11 Upper–Air Sounding Stations (Inc. Marion & Gough)
- 141 Automatic Rainfall Stations
- 25 Climate Stations
- 13 Solar Radiation Measuring Stations
- 40 Weather buoys (annually)
- 1 x Global Atmospheric Watch Station (Cape Point)



Numerical Weather Prediction

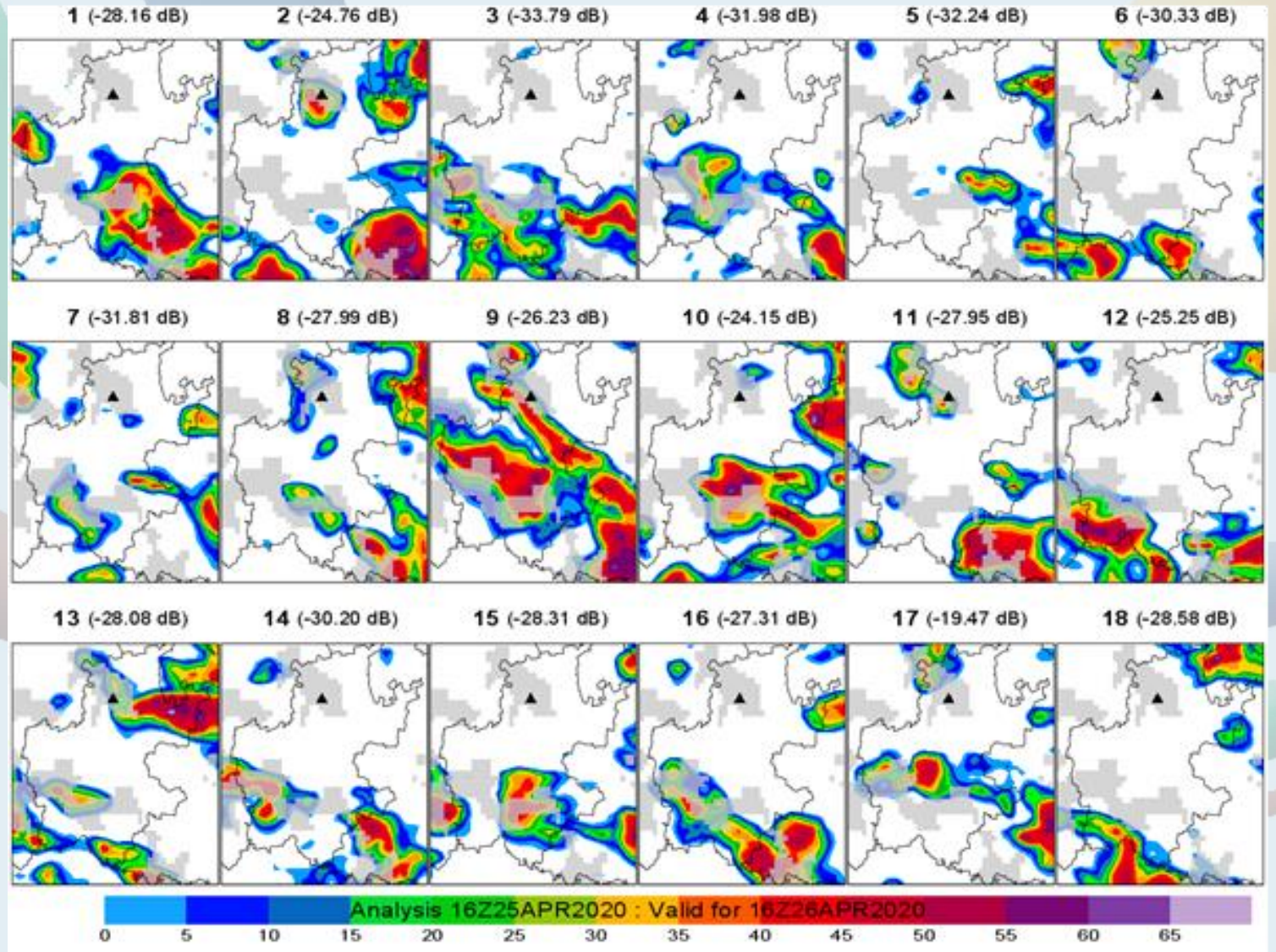
- SAWS HPC System – for large operational jobs
  - CRAY XC-30 system with 168 nodes
  - 1.7 PB Lustre system
- Fail-over: CHPC system
- Operational atmospheric forecast model: Unified Model (Met Office)
- 4.4 km – initialised 4 times a day
  - 00Z and 12Z for 72 hours
  - 06Z for 48 hours
  - 18Z for 60 hours
- 1.5 km – initialised 4 times a day
  - 00Z, 16Z, 12Z, 18Z for 48 hours
- NCEP GEFS 14 days



South African Weather Service

Numerical Weather Prediction

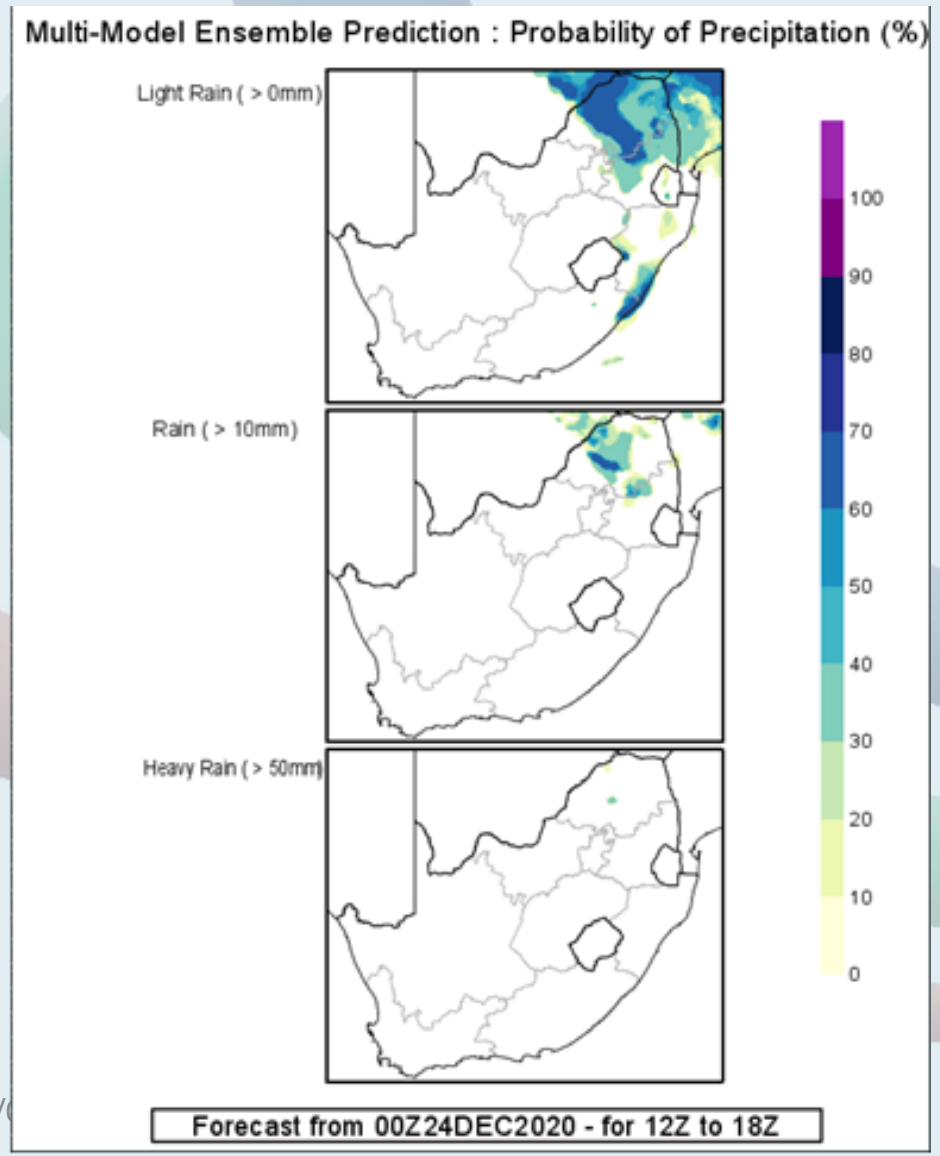
- The Convective Scale Ensemble over South Africa with 4.5km grid spacing with lead-time of 60 hours. It updates at 12Z and 18Z



South African Weather Service

Numerical Weather Prediction

- Multi-Model Ensemble system

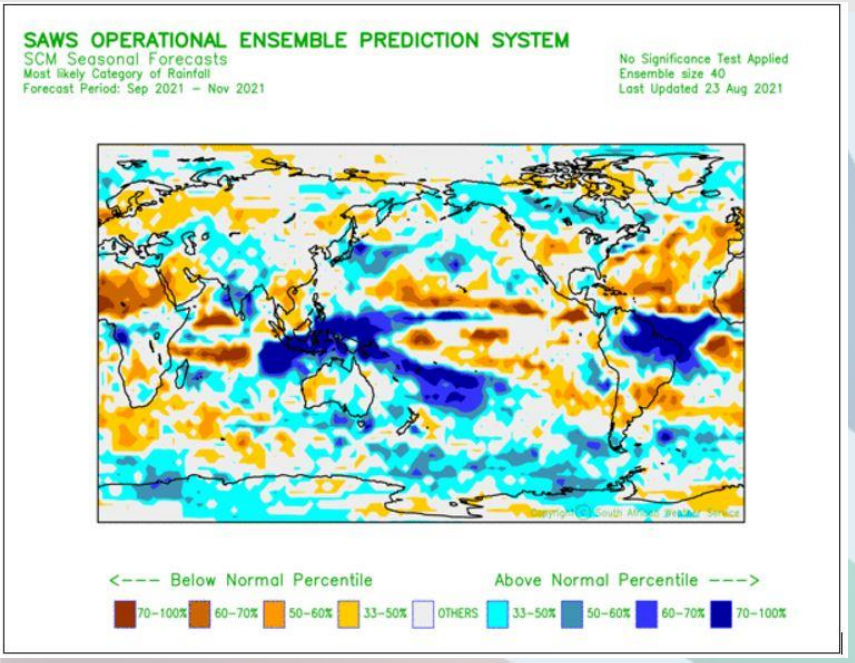


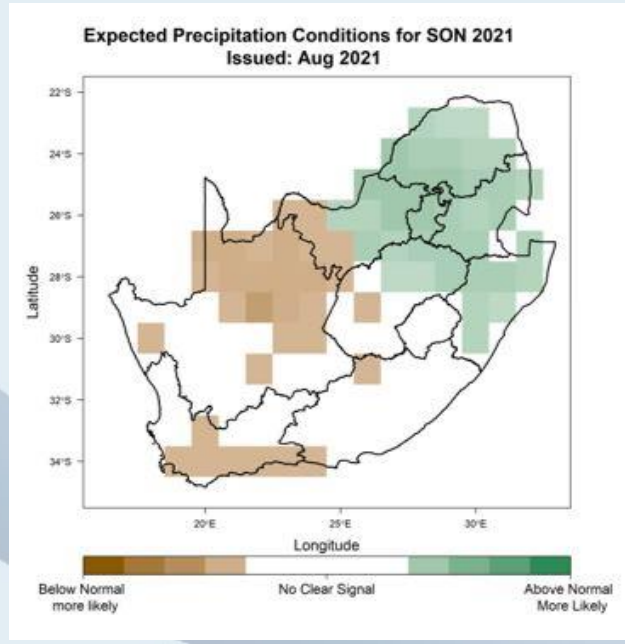
- Ensemble members are rescaled to a corresponding horizontal resolution of 6 km
- MMENS produces forecasts with a lead time of 48 hours once a day at 00Z
- ICON, GA, GFS, SA4

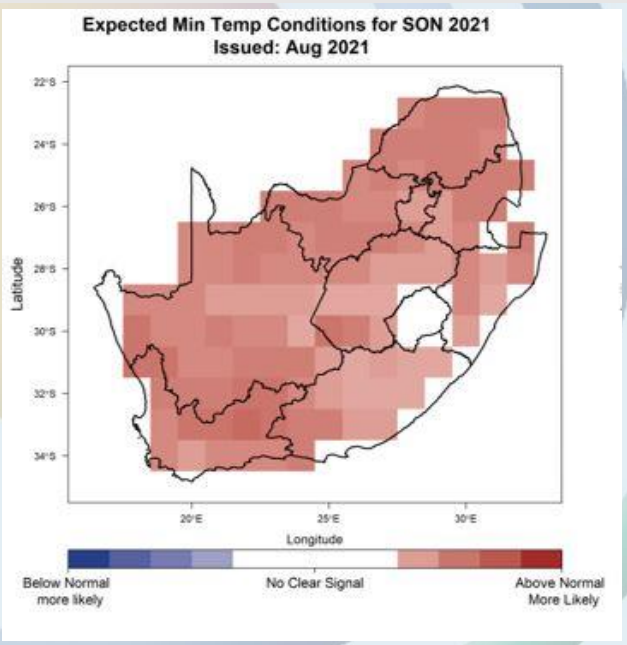
South African Weather Service

Sub-Seasonal and Seasonal Forecasting

Seasonal Forecast Products



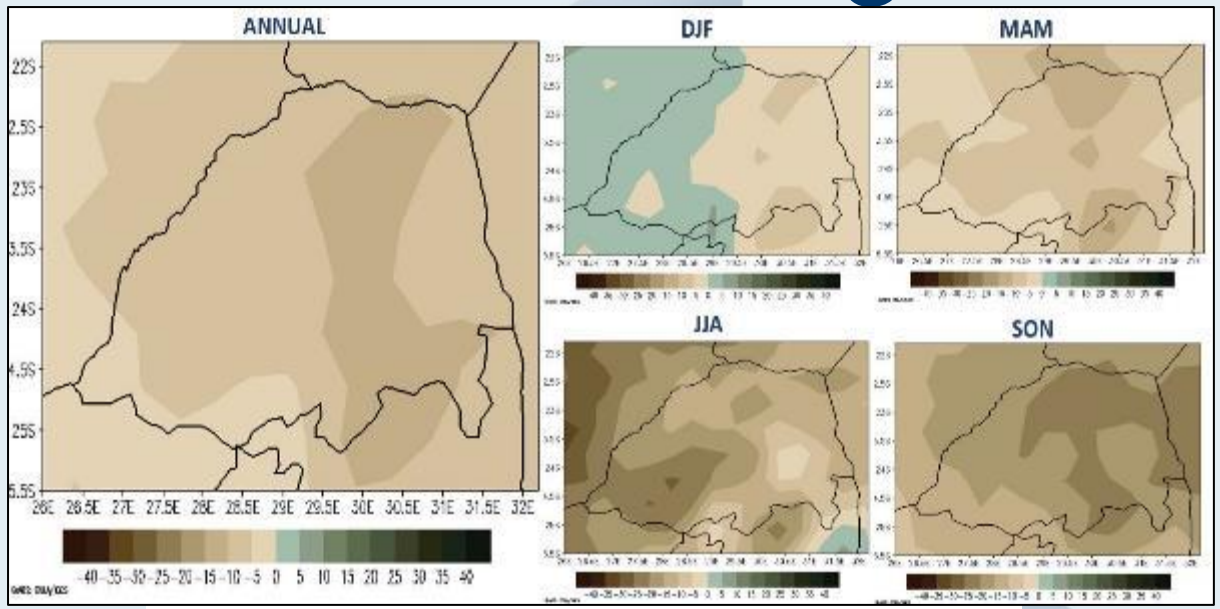




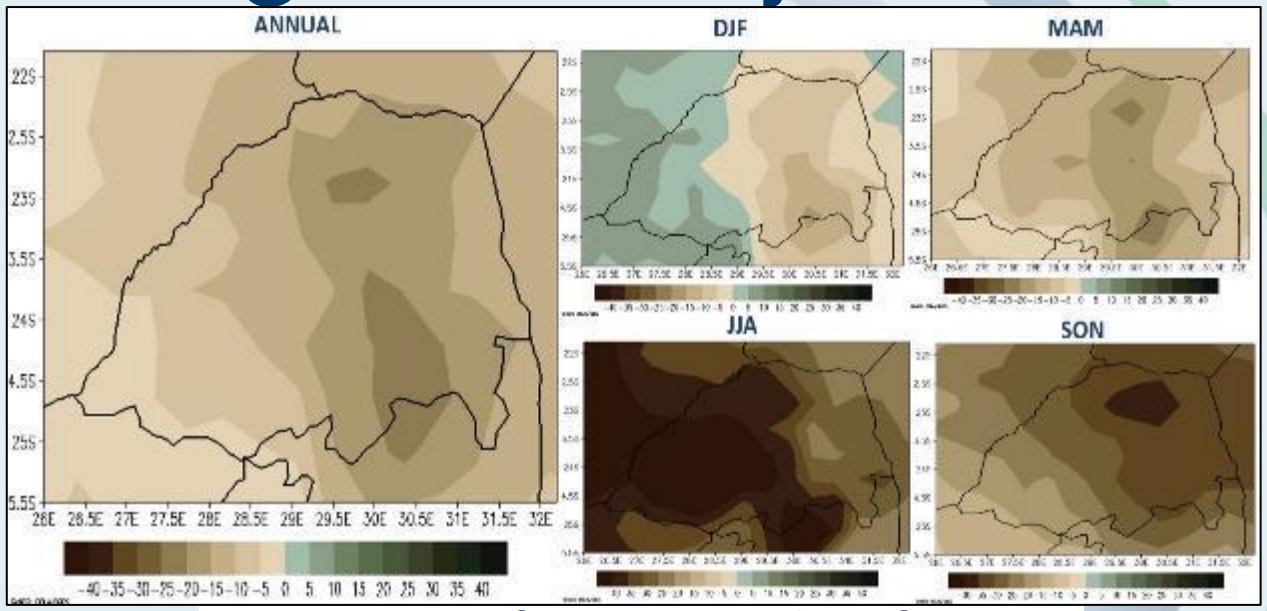
- 2 models from North American Multi-Model Ensemble (CCSM4 and GFDL)
- Working to include Met Office and ECMWF via Corpenicus Climate Change service

South African Weather Service

Climate Change Modelling and Projections

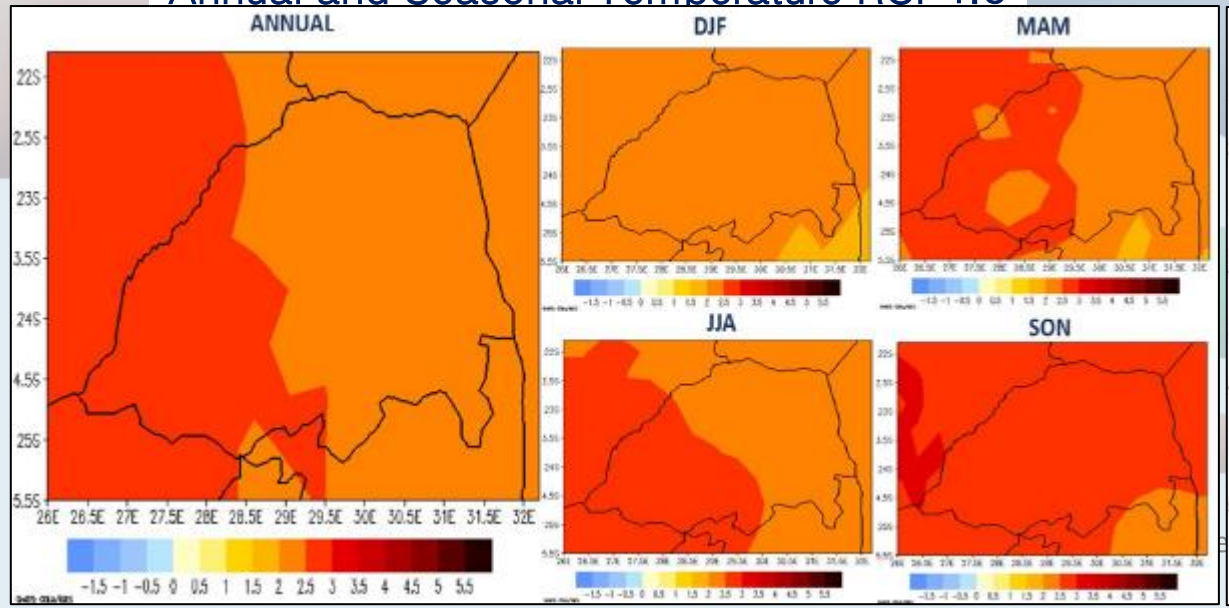


Annual and Seasonal Rainfall RCP4.5

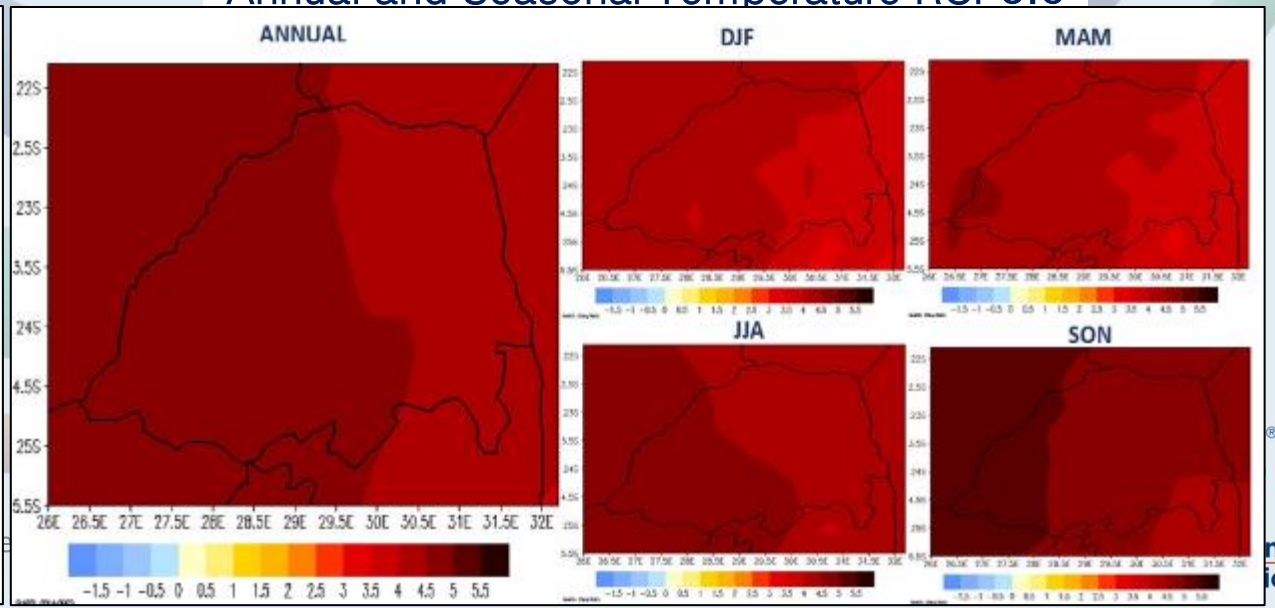


Annual and Seasonal Rainfall RCP8.5

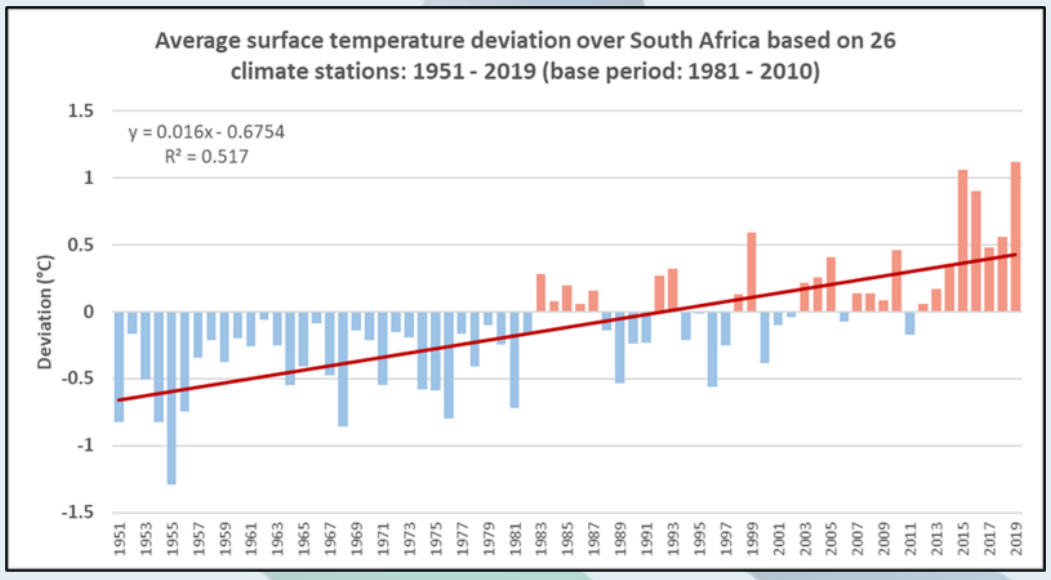
Annual and Seasonal Temperature RCP4.5



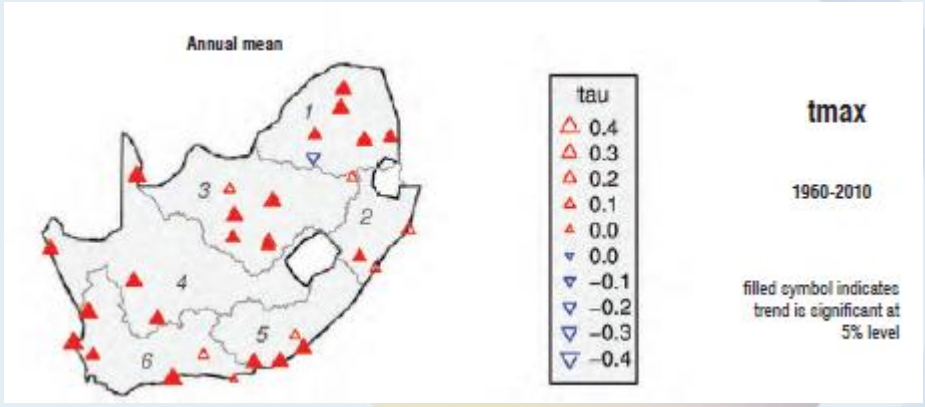
Annual and Seasonal Temperature RCP8.5



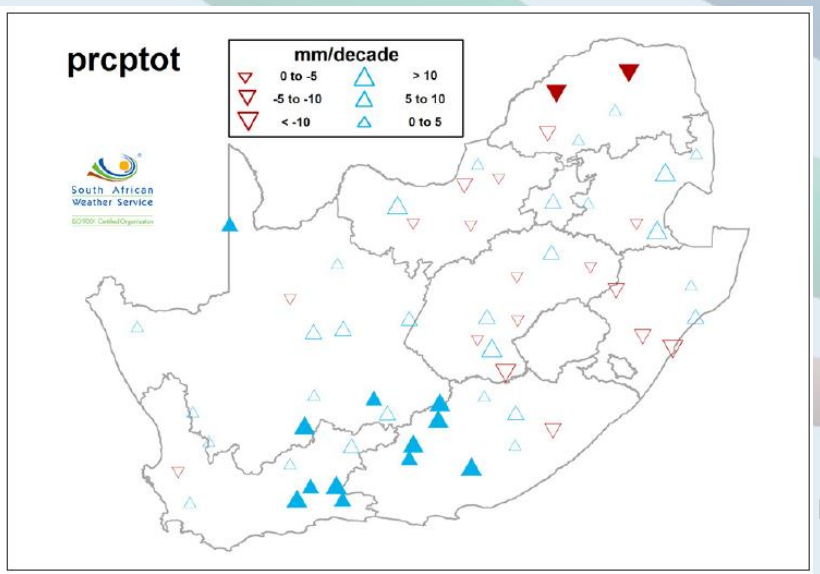
Climate change – temperature changes

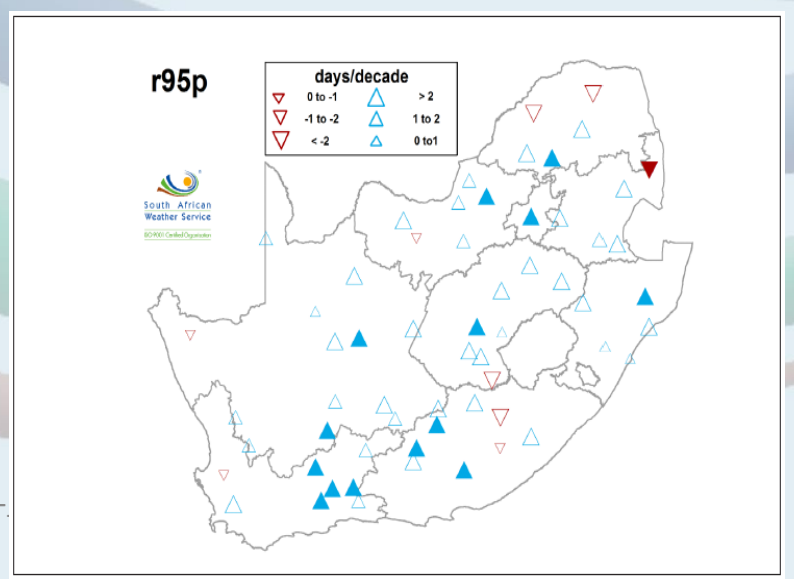


Source: Kruger & Nxumalo 2017 Water SA – 1921-2015



Source: MacKellar et al 2014 SAJS- 1960-2010





South African Weather Service

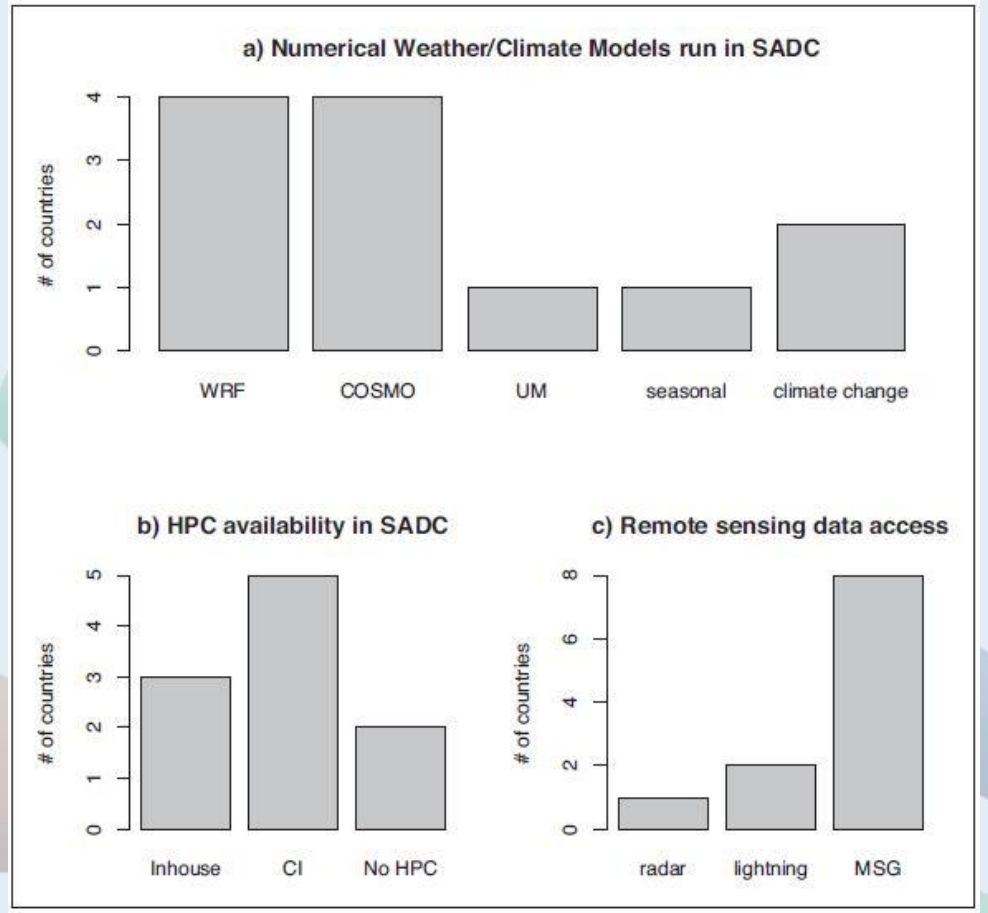
Climate Research for Development Fellowship (18 months)

science & innovation
Department:
Science and Innovation
REPUBLIC OF SOUTH AFRICA

- Title: “Improving Weather and Climate early warning systems over Southern Africa”
- Pilot project to include: Botswana, Mozambique, Namibia, South Africa, Tanzania, Zambia
- Collaborators: NASA, UK Met Office, University of Reading

South African Weather Service

Situational analysis



- WRF and COSMO used in a number of countries
- Seasonal forecasting – only one country running coupled ocean-atmosphere model
- All countries used statistical downscaling- benefits of Southern African Climate Outlook Forum (SARCOF) process
- Some meteorological Services not aware of other HPC systems in their country

Challenges

- No models running – limited computational resources
- Models running at lower resolution than forcing global models
- Black boxes – don't understand how models work
- Implementations without testing (no updates)
- Human Capital Development

DATA SCIENCE JOURNAL

Bopape, M-JM, et al. 2019. A Regional Project in Support of the SADC Cyber-Infrastructure Framework Implementation: Weather and Climate. *Data Science Journal*, 18: 34, pp.1–10. DOI: https://doi.org/10.5334/dsj-2019-034

PRACTICE PAPER

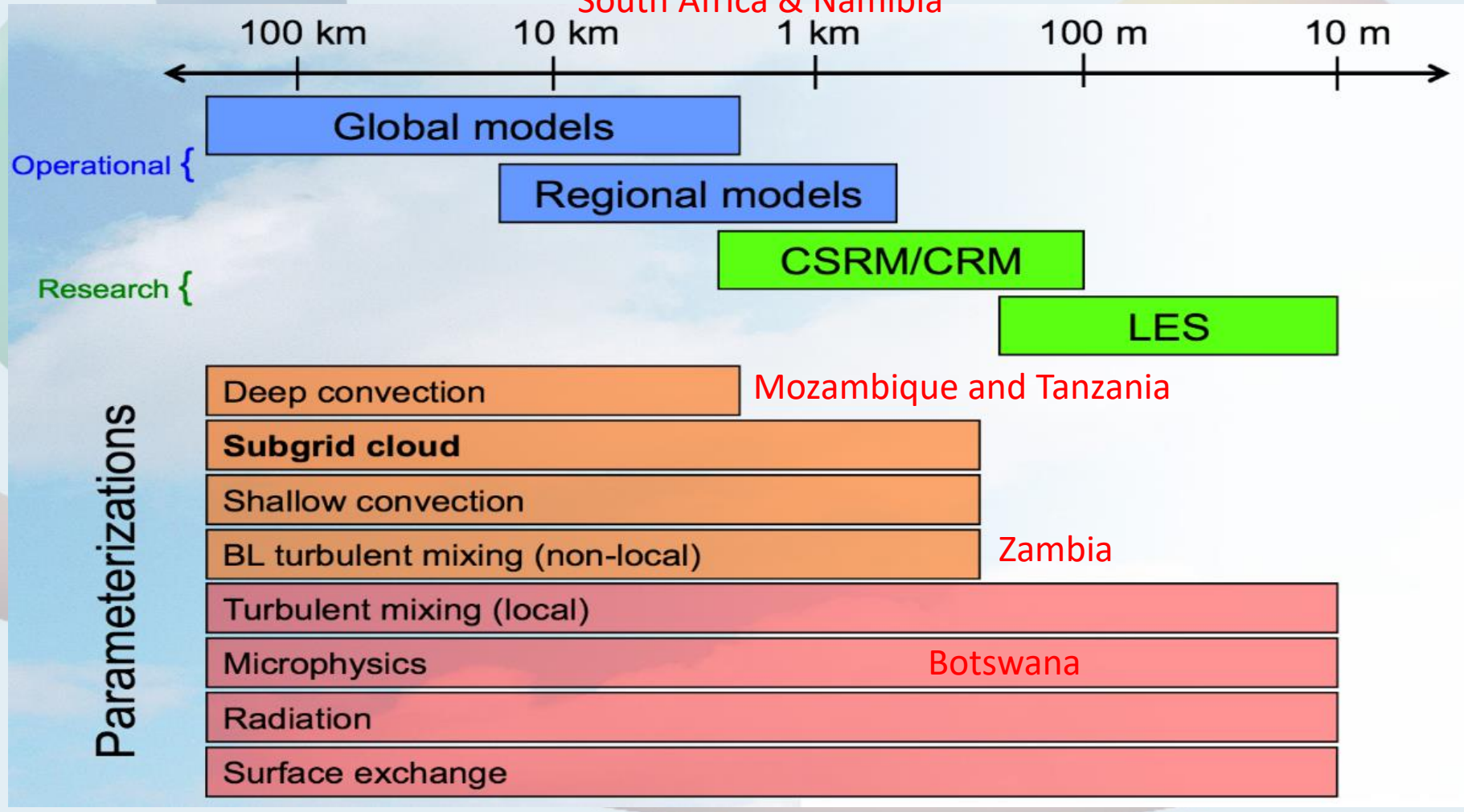
A Regional Project in Support of the SADC Cyber-Infrastructure Framework Implementation: Weather and Climate

Mary-Jane Morongwa Bopape[1], Happy Marumo Sithole[2], Tshiamo Motshegwa[3], Edward Rakate[4], Francois Engelbrecht[5], Emma Archer[6], Anneline Morgan[7], Lwando Ndimeni[8] and Joel Botai[1]

Workshops

- 26-28 August 2019
  - Weather scientists & HPC specialists
  - Implementation of WRF
  - Ann Fridlind & colleagues (cloud microphysics, satellite data, WRF sensitivity, radar software)
- 1 December 2019
  - Presentation on results obtained for heavy rainfall events
  - Bob Plant (University of Reading)
  - Brazil (ML) & Russia (LES, Land surface modelling)
- 3 December 2019: Applications workshop
  - Agromet, hydromet, energy, health, socio-economic benefits

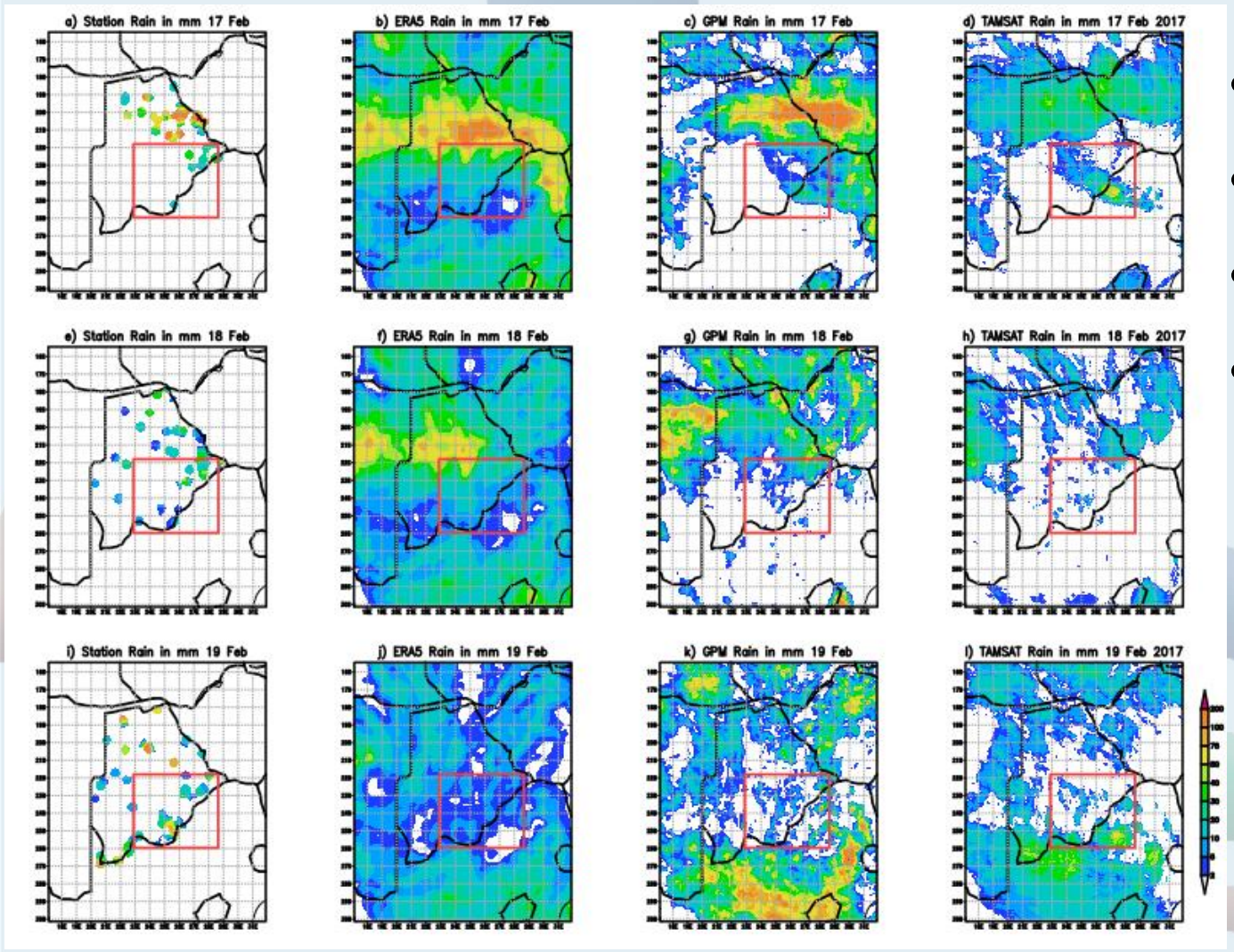
Spatial Scales in Atmospheric Modelling



Courtesy of Dr Bouyssel

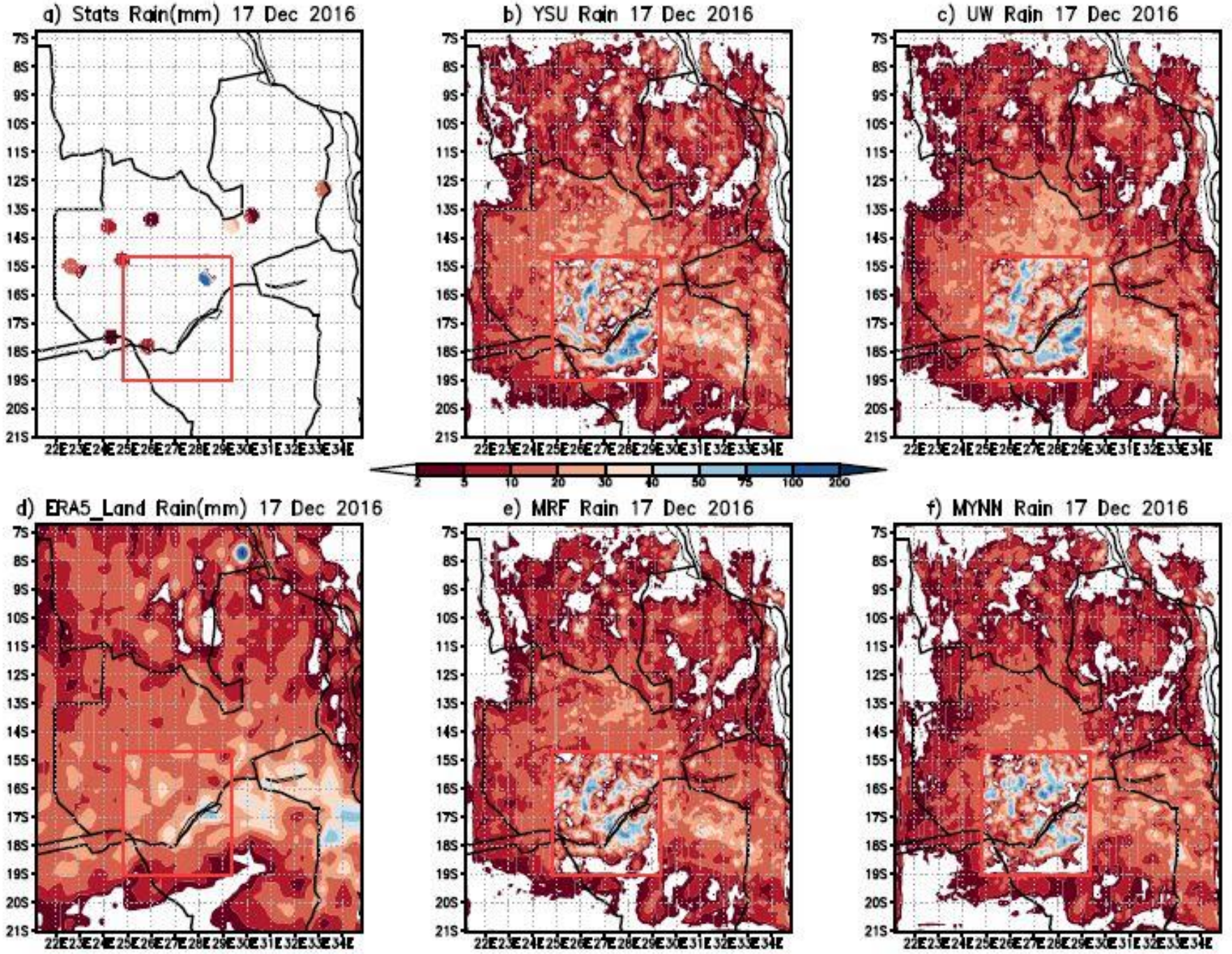
South African Weather Service

Observations



- Station data
- IMERG
- TAMSAT
- ERA5
- Challenge
  - Observations are different
  - More ground observations
  - Difficult knowing what models should target
  - Knowing what to change in model less straight forward than in idealized studies

South African Weather Service



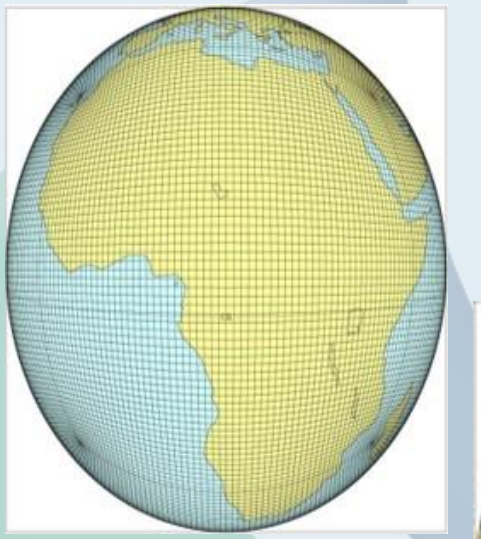
Model/ Physics Comparison

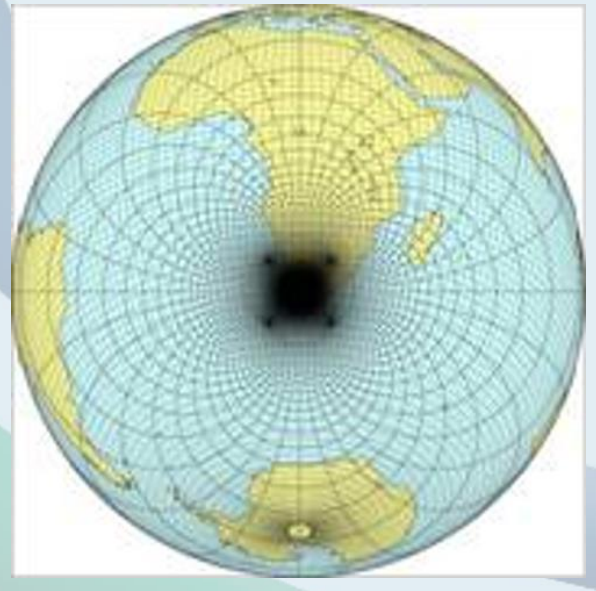
- High impact weather events captured
- Microphysics and planetary boundary layer schemes – smaller differences
- Convection scheme - Biggest difference – scale awareness

South African Weather Service

- **SA**- Mulovhedzi PM, Rambuwani GT, Bopape MM, Maisha R, Monama N, 2020: Model inter-comparison for short range forecasts over the Southern African domain. South African Journal of Science. In press.
- **Mozambique**- Mary-Jane Morongwa Bopape, Hipolito Cardoso, Robert Plant, Elelwani Phaduli, Hector Chikoore, Thando Ndarana, Lino Khalau, Edward Rakate, 2021: Sensitivity of tropical cyclone Idai simulations to cumulus. Atmosphere, 12(8), 932; https://doi.org/10.3390/atmos12080932
- **SA**- Lekoloane, L. E., Bopape, M.M., Rambuwani, G., Landman, S., Mofokeng, P., Gijben, M., and Mohale, N.: A dynamic and thermodynamic analysis of the 11 December 2017 tornadic supercell in the Highveld of South Africa, Weather Clim. Dynam. ., 2, 373–393, https://doi.org/10.5194/wcd-2-373-2021, 2021.
- **SA**- Bopape MM, Sebego E, Ndarana T, Maseko B, Netshilema M, Gijben M, Landman S, Phaduli E, Rambuwani G, Van Hemert L, Mkhwanazi M, 2021: South African Weather Service Idai tropical cyclone and KwaZulu-Natal flood early warnings. South African Journal of Science. 117, NO 3/4 (2021). https://doi.org/10.17159/sajs.2021/7911
- **Zambia**- Mary-Jane Bopape, David Waitolo, Robert Plant, Edson Nkonde, Henry Simfukwe, Nosiku Sikanyika, Stein Mkandawire, Edward Rakate, Robert Maisha, 2021: Sensitivity of simulations of a Zambian heavy rainfall event to the atmospheric boundary layer schemes. Climate 2021, 9(2), 38; https://doi.org/10.3390/cli9020038 .
- **Namibia**- Somses S, Bopape M, Ndarana T, Fridlind A, Matsui T, Phaduli E, Limbo A, Maikhudumu S, Maisha R, Rakate E, 2020: Convection parametrization and multi-nesting dependence of a heavy rainfall event over Namibia with Weather Research and Forecasting (WRF) model. Climate, 8(10), 112; https://doi.org/10.3390/cli8100112.
- **Botswana** - Molongwane C, Bopape MJM, Fridlind A et al. Sensitivity of Botswana Ex-Tropical Cyclone Dineo rainfall simulations to cloud microphysics scheme [version 1; peer review: 2 approved with reservations]. AAS Open Res 2020, 3:30 (https://doi.org/10.12688/aasopenres.13062.1)

Model Development- Conformal Cubic Atmospheric Model





- Build from another model: Norway and Brazil examples
- Used in SA for over 2 decades
- Cube based system
- Global model (quasi-uniform resolution)
- Regional model
- Similar equation set to Nonhydrostatic Sigma Coordinate Model

Engelbrecht FA, WA Landman, CJ Engelbrecht, S Landman, MM Bopape,

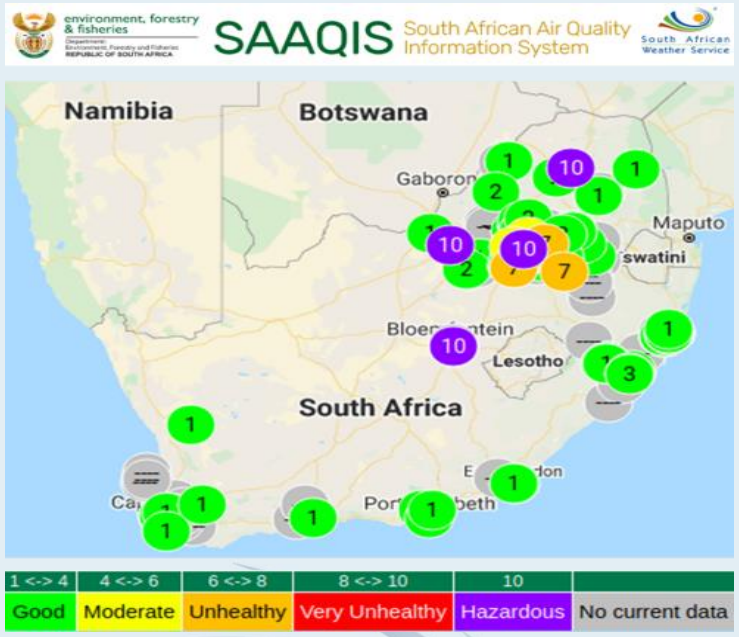
B Roux, JL McGregor and M Thatcher, 2011: Multiscale Climate

Modelling over Southern Africa using a variable-resolution global model.

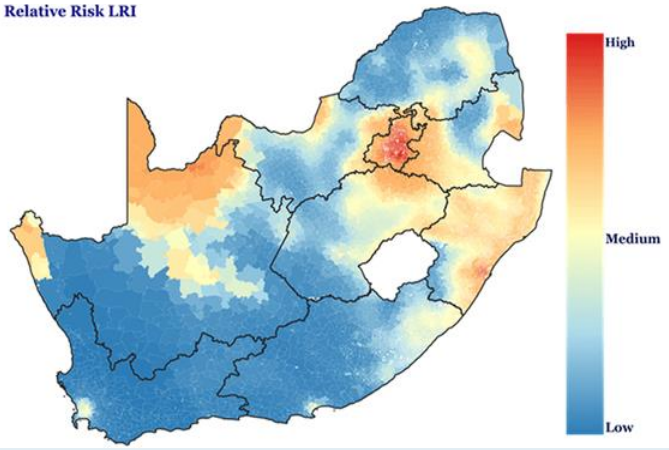
Water SA, 37, 647-658.

South African Weather Service

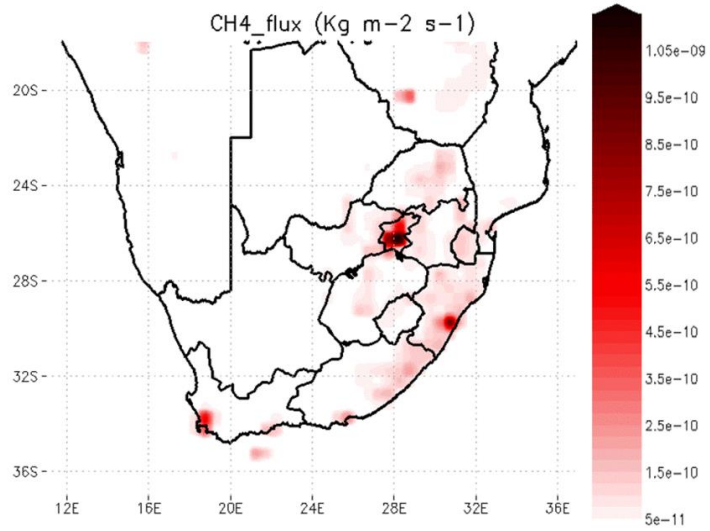
Air Quality: Products and Services



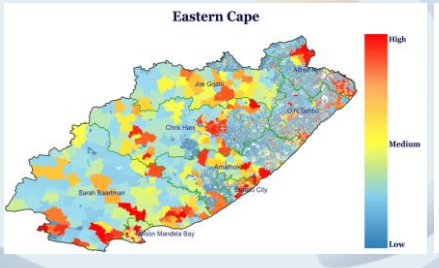
Ambient air pollutant contributions to the national burden of disease

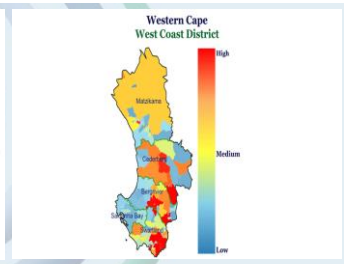


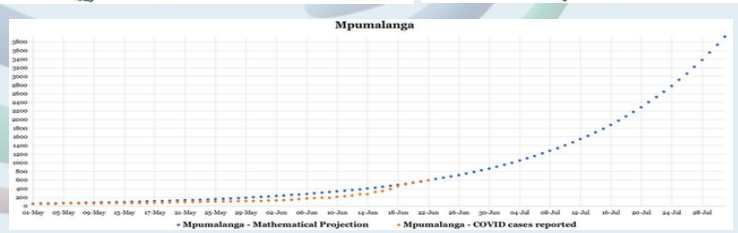
Optimized emission climatology of anthropogenic activities and natural events

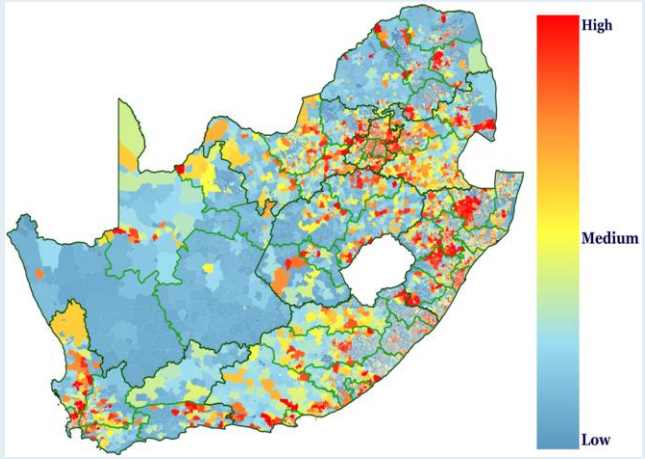


COVID-19 Vulnerability Risk Indictor Tool

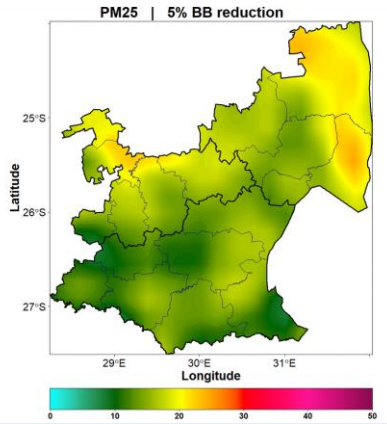


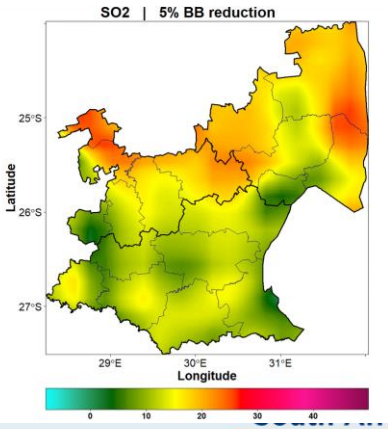






Scenario based air pollution management tool





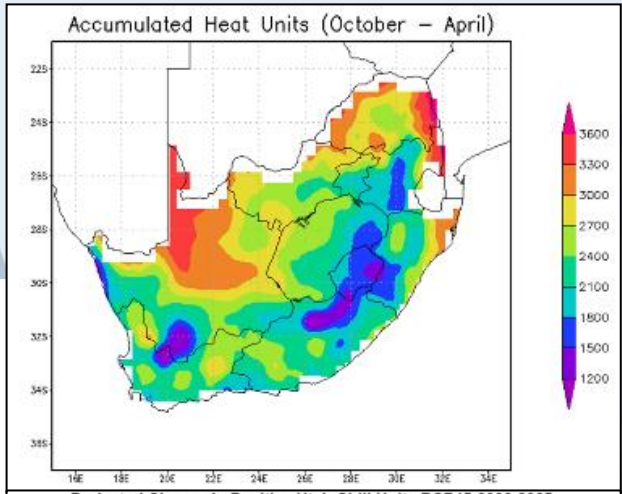
South African Weather Service

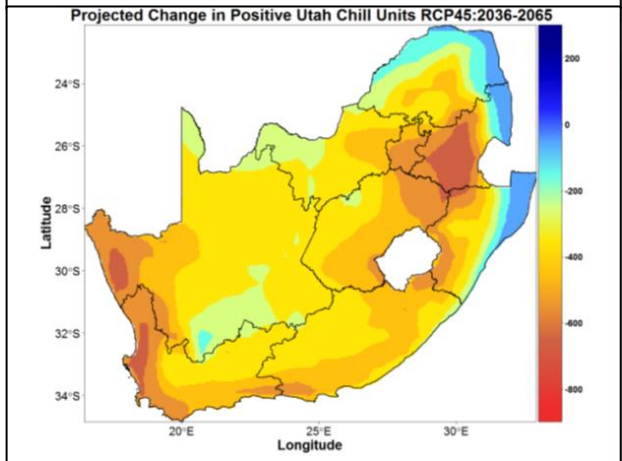
Applications: Agrometeorology

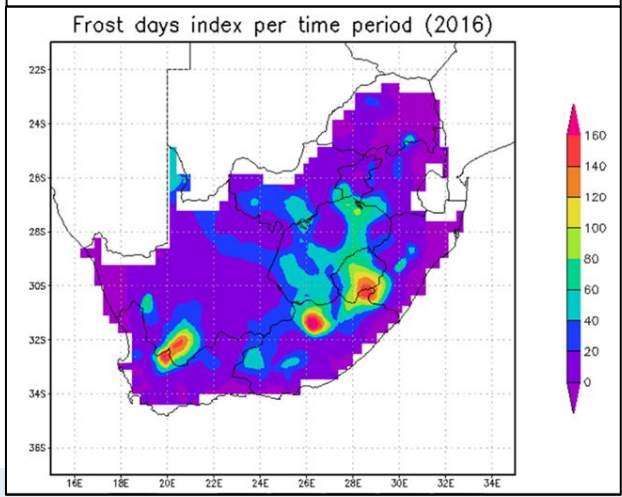
To support agricultural production and activities by providing meteorological services to the agricultural sector

Product Focus Areas

- Operational Agrometeorology
  - Development and implementation of agrometeorological products and services.
  - Provide guidance to enhance agrometeorology research for operational applications in the agricultural sector.
- Agrometeorological modelling systems
  - Application of crop simulation models for forecasting and yield prediction.
  - Application of agrometeorological models for decision making.
- Micrometeorology
  - Investigations of energy and water balances between the soil, plants and atmosphere interactions.
  - Development and application of science and new technology to provide high quality observation data and products.
- Remote Sensing and GIS applications in Agrometeorology
  - Vegetation cover and water stress monitoring.
  - Water use of different vegetation types
- Climate variability and climate change impacts on agriculture
  - Impacts of climate variability and change on agriculture
  - Investigate impacts of weather and climate extremes on agriculture







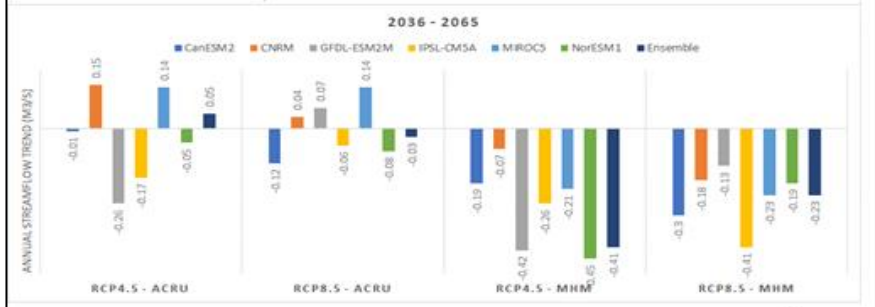
Applications: Hydrometeorology

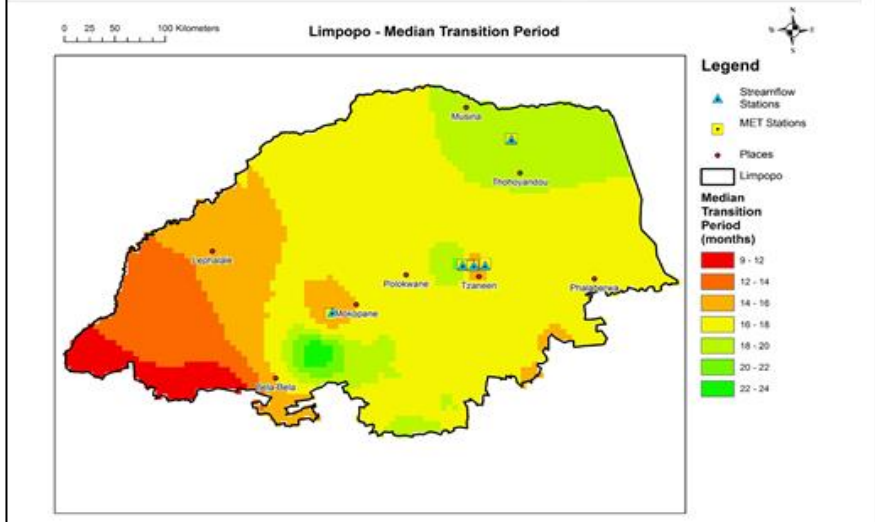
To contribute to a safe and sustainable society, water management, environmental protection, and building of infrastructure

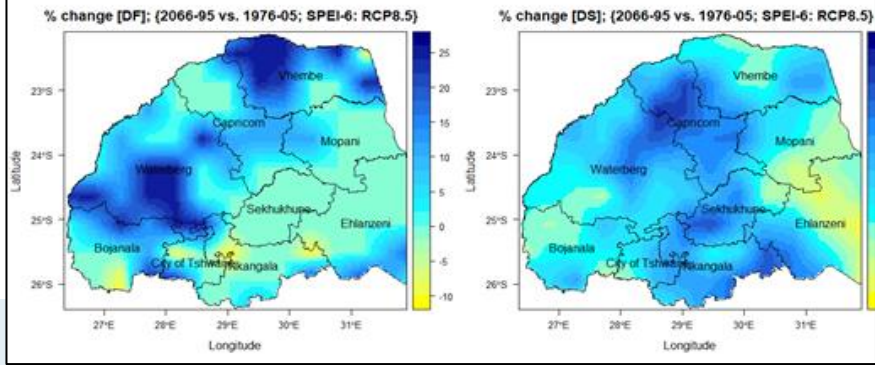
Product Focus Areas

- Operational Hydrometeorology
  - Monitoring and forecasting of hydro-meteorological hazards
  - Risk assessments
  - Return period
- Hydrometeorological modelling systems
  - Scenario-based forecasting
  - Streamflow forecasting
  - Drought monitoring and prediction: (characteristics, categories & evolution) near-real time monitoring provide early warnings.
- Analysis of extreme hydro-meteorological events
  - Risk assessment studies
  - Weather/climate sensitivity analysis
  - Impact of weather and climate on the water resources

Hydraulic modelling, machine learning and artificial intelligence applications for flow routing and flood forecasting







Applications: Health

Focus on environmental exposures and vector-borne diseases related to human health and the uncertainty inherent in weather, climate and health systems

Environmental Exposures

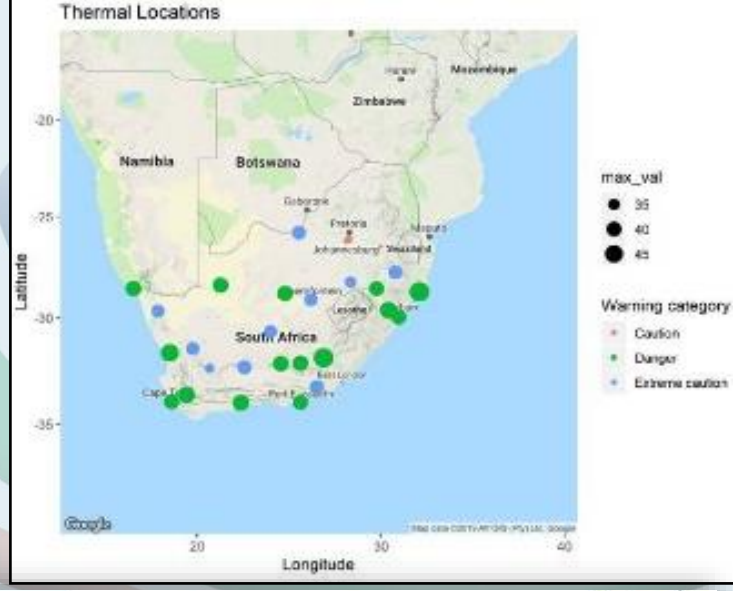
- Characterize climatic conditions and variability of temperature, Ultraviolet radiation (UV), humidity and heat-health across South Africa, with particular interest in high-risk areas.

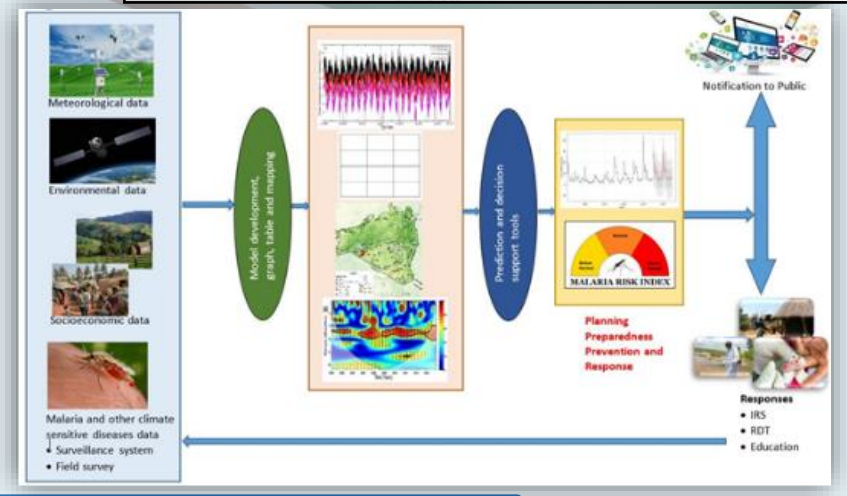
Vector-Borne Diseases

- Quantify the association of malaria, pneumonia and diarrhoea incidences and weather/environmental factors

Biometeorological Monitoring

- Measure Air temperature (°C), relative humidity (%), wind speed (ms-1) and direction at 2 m above ground, rain (mm), solar radiation (Wm-2), erythemal irradiance (Wm-2), Nitrogen dioxide (NO2), Sulphur dioxide (SO2), Carbon monoxide (CO) and Ozone (O3), and Particulate Matter (PM2.5 and PM10).





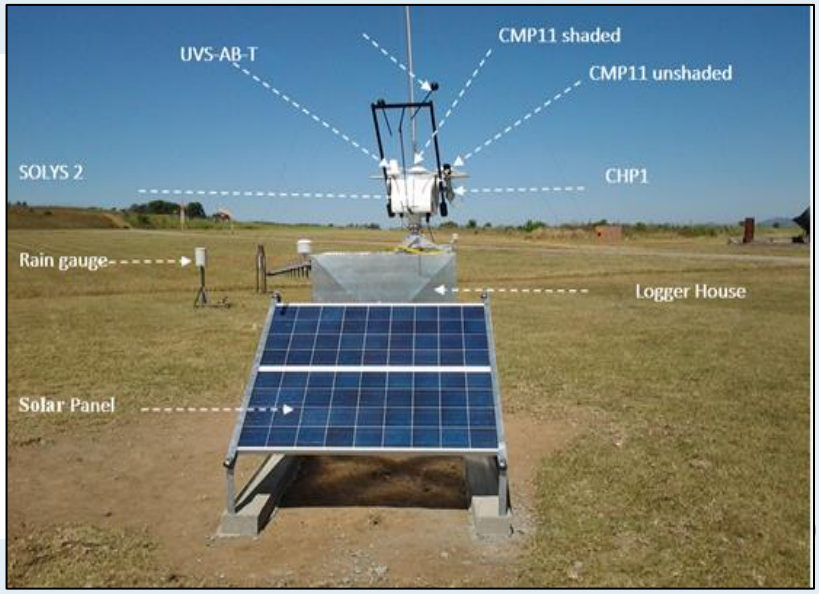
South African Weather Service

Applications: Energy

Solar Radiation Data

Measurements	
Solar Radiation Parameter	Instrument
Direct Normal Irradiance (DNI)	Kipp & Zonen Pyrheliometer (CHP1)
Global Horizontal Irradiance (GHI)	Kipp & Zonen pyranometer (CMP21)
Diffuse Horizontal Irradiance (DIF)	Shaded Kipp & Zonen pyranometer (CMP21)
Longwave Downward radiation (LWD)	Kipp & Zonen Pyrgeometer (CGR4)
UVA & B	Kipp & Zonen UV-S AB-T

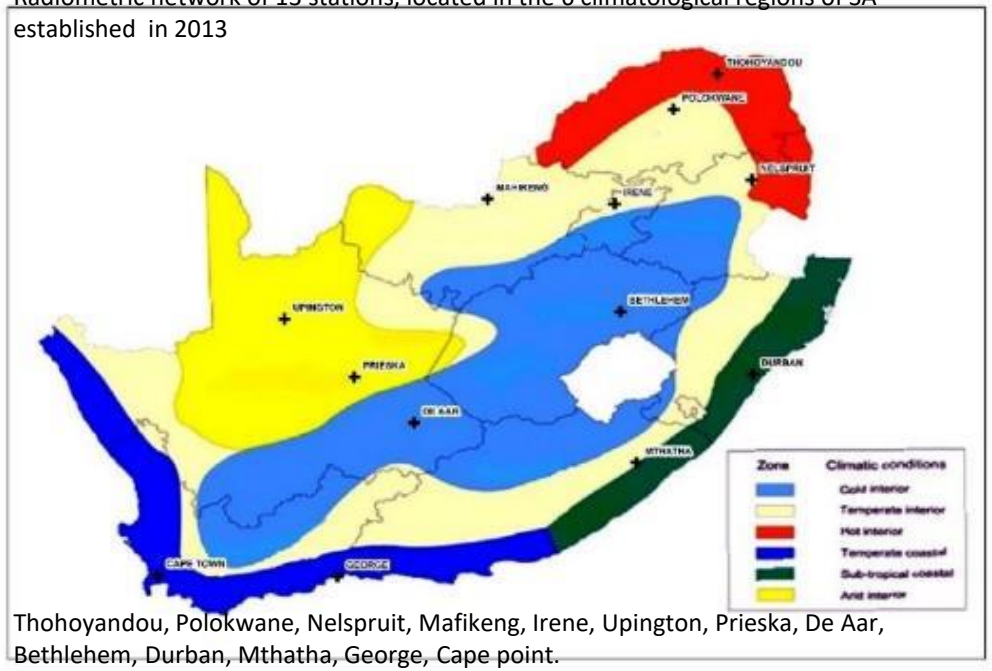
Data is quality controlled using Baseline Surface Radiation Network (BSRN) Quality Control Protocols



Direct Normal Irradiance (DNI) Monitoring Index (DNIMI) Product

1. Resource assessment to determine the suitability of different regions where SAWS radiometric stations are located for the installation of CSP Technology.
2. Estimate the number of low (<3000 W/m^2) DNI days per season to determine the regions that are not suitable for the installation of CSP Technology.

Radiometric network of 13 stations, located in the 6 climatological regions of SA established in 2013



Thohoyandou, Polokwane, Nelspruit, Mafikeng, Irene, Upington, Prieska, De Aar, Bethlehem, Durban, Mthatha, George, Cape point.

3. Summary implications to various economic sector decision makers

Water and Energy

The anticipated above-normal rainfall in the Northern Cape, Western Cape parts of the Eastern Cape, Free State and the North West provinces provides an opportunity for recovery of water reservoirs, during both early- and mid-summer seasons. Water reservoirs are likely to significantly recover during the late-summer season, across the country. Such recoveries might not be relieving communities in Limpopo, KwaZulu-Natal and the Eastern Cape provinces, given that most dams in these provinces are on average below 60% full storage capacity, based on the information from the Department of Water and Sanitation, and also due to the fact that some of the provinces were projected to experience below normal rainfall during the early- and mid-summer seasons. In addition, the expected above-normal rainfall conditions pose the risk of flash flooding and urban localized flooding, particularly in areas prone to flooding like in Gauteng, particularly in the late summer season. Hence there is a need for citizens to watch out for short-term forecasts and warnings as the summer season progresses.

Energy: The normal to above normal temperatures in parts of provinces like Limpopo and Mpumalanga, while the mostly uncertain and below normal temperatures in the rest of the provinces will slightly increase the demand for heating and cooling.

Health

The predicted above-normal maximum temperatures in Limpopo and Mpumalanga provinces might lead to prolonged and intense exposure to high solar ultraviolet radiation (UV) and hot temperatures that have the potential to cause UV and heat-related illnesses. The relevant decision-makers are therefore encouraged to advise the public to take appropriate sun protection measures to reduce overexposure by staying in the shade, using sunscreen and wearing protective clothing, particularly during the mid-day period. Skin and eye allergies are likely to increase because of greater pollen released into the air and increased ambient heat during this time. Also, most foodborne pathogens are likely to grow rapidly during high temperatures. The public is, therefore encouraged to practice good food hygiene. Additionally, the above-normal rainfall forecast for the most part of the country with exception to Limpopo, Mpumalanga and Kwa-Zulu Natal provinces might increase waterborne diseases such as diarrhoea.

Agriculture

The seasonal rainfall forecasts show that there is higher likelihood of above-normal rainfall over the provinces of Free State, North-West, Eastern Cape, Northern Cape and Western Cape, which is likely to be favourable for the agricultural sector. Decision makers may advise farmers to practice soil and water conservation, and establish good drainage systems. However, the mid and late-summer rainfall forecast for Limpopo, Gauteng, KwaZulu-Natal, and Mpumalanga provinces indicate higher likelihood of below-normal rainfall (please note the uncertainty highlighted in the overview section). As a result, the relevant decision makers are encouraged to advise farmers to adopt soil and water conservation practices and water harvesting and storage. Farmers are also encouraged to approach the season with caution, especially in areas that have been experiencing dry conditions constantly.

- Summary for different sectors now included in seasonal outlook

South African Weather Service

Impact Based Forecasting

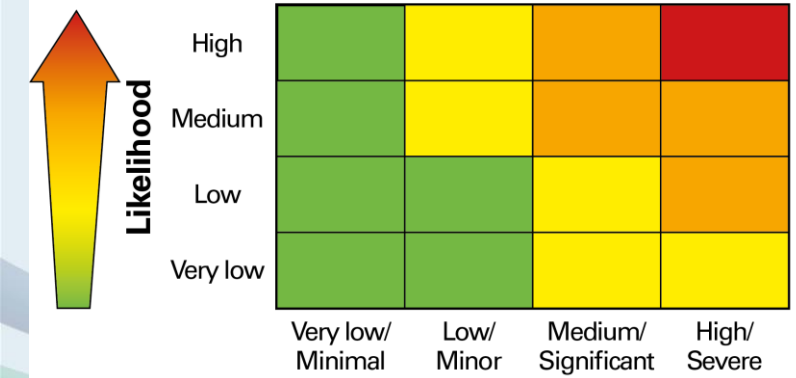
Moving from:

What the weather will ***be***:
(Meteorological thresholds)
- 50mm in 24 hours
- 35 knot winds

To:

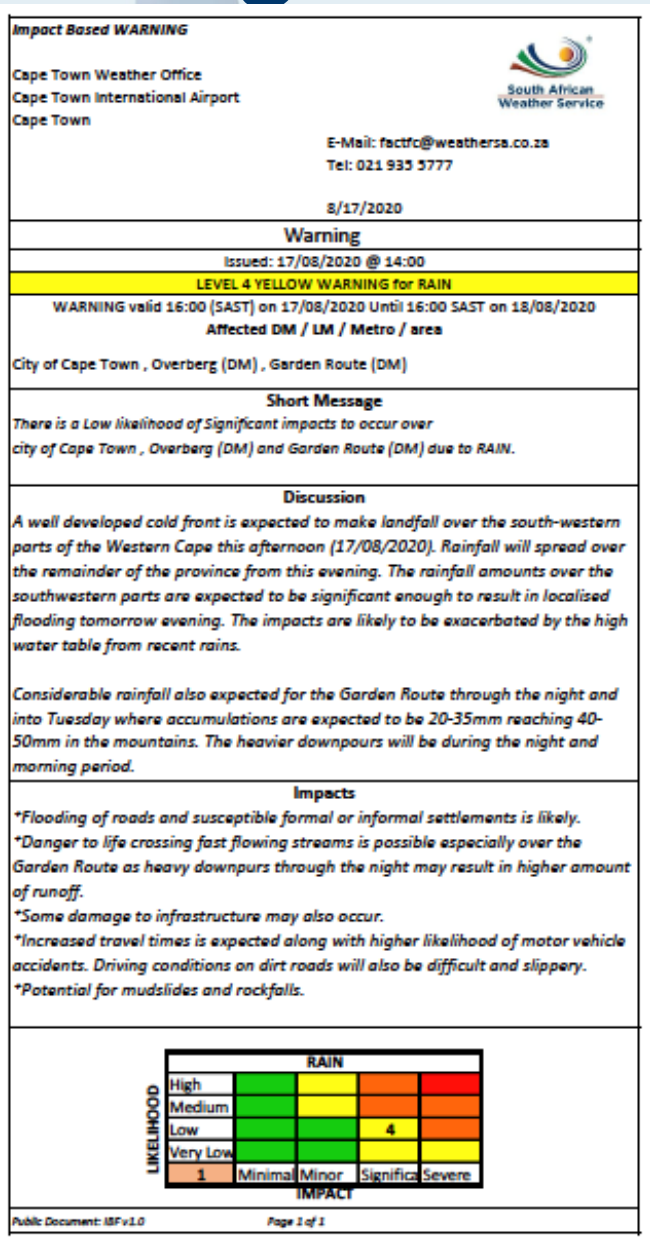
What the weather will ***do***:
(Impact Warnings)
- Roads flooded
- Communities cut off

Warning Risk Level (green, yellow, amber, red)



Parameters include:

Wind
Rain
Snow
Waves
Storm surge
Severe Thunderstorms
Fog



Impact Based WARNING

Cape Town Weather Office
Cape Town International Airport
Cape Town

South African Weather Service

E-Mail: factfc@weathersa.co.za
Tel: 021 935 5777

8/17/2020

Warning

Issued: 17/08/2020 @ 14:00

LEVEL 4 YELLOW WARNING for RAIN

WARNING valid 16:00 (SAST) on 17/08/2020 Until 16:00 SAST on 18/08/2020

Affected DM / LM / Metro / area

City of Cape Town , Overberg (DM) , Garden Route (DM)

Short Message

There is a Low likelihood of Significant impacts to occur over city of Cape Town , Overberg (DM) and Garden Route (DM) due to RAIN.

Discussion

A well developed cold front is expected to make landfall over the south-western parts of the Western Cape this afternoon (17/08/2020). Rainfall will spread over the remainder of the province from this evening. The rainfall amounts over the southwestern parts are expected to be significant enough to result in localised flooding tomorrow evening. The impacts are likely to be exacerbated by the high water table from recent rains.

Considerable rainfall also expected for the Garden Route through the night and into Tuesday where accumulations are expected to be 20-35mm reaching 40-50mm in the mountains. The heavier downpours will be during the night and morning period.

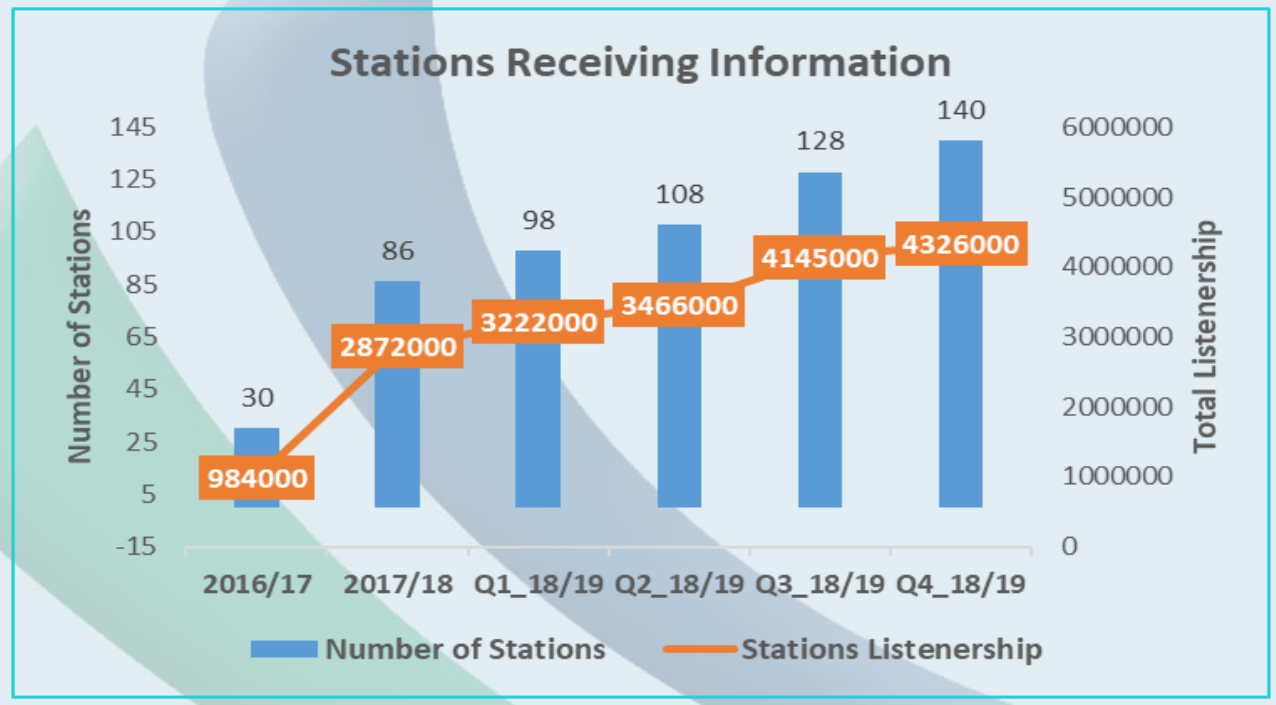
Impacts

**Flooding of roads and susceptible formal or informal settlements is likely.*
**Danger to life crossing fast flowing streams is possible especially over the Garden Route as heavy downpurs through the night may result in higher amount of runoff.*
**Some damage to infrastructure may also occur.*
**Increased travel times is expected along with higher likelihood of motor vehicle accidents. Driving conditions on dirt roads will also be difficult and slippery.*
**Potential for mudslides and rockfalls.*

Public Document: IBFv1.0 *Page 1 of 1*

South African Weather Service

Community radio



- At least *140 community stations receiving information daily from SAWS
- Stations have a total listenership of 4.3million
- SAWS has potential to reach 4.3m people daily via community radio stations
- More than 30m people reached via SABC Radio

South African Weather Service

Programming training

- Weather and Climate programming and modelling training workshop (February 2021)
- Cohosted with CHPC, Universities of Witwatersrand, North West, Pretoria, Zululand
- Topics
  - Linux basic commands: The session should assist those new to Linux learn how to navigate in a Linux operating system using a terminal.
  - Git and GitHub: The session will introduce using Git for version-control and GitHub as a means to share code, how it is used, and why it is useful to use.
  - Slack channel: The Slack channel will be introduced as a means to share communicate and share information in our community.
  - Python: The session will introduce attendees to using python to analyse weather and climate data.
  - Fortran: the session will introduce the basics of Fortran programming, and linking modules, subroutines and libraries.
  - Atmospheric modelling
  - Conformal Cubic Atmospheric Model (CCAM)
- Advertised week before- 7 countries
- Over 100 people registered, minimum 70 people per session

South African Weather Service

Concluding Remarks

- Weather, climate, air quality, and applications area (agro, hydro, health, energy, socio-economic benefits.
- Marine and Aviation
- Model development research
- Email: mary-jane.bopape@weathersa.co.za

- Thank you

South African Weather Service