

Use of Physics in Weather and Climate Sciences

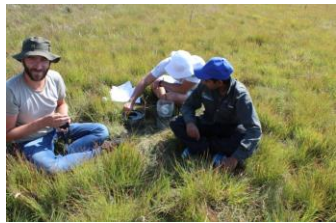
3rd Biennial African Conference on Fundamental and Applied Physics
(ACP 2023)

Protea Hotel, George, South Africa,
27 September 2023

Mary-Jane Bopape



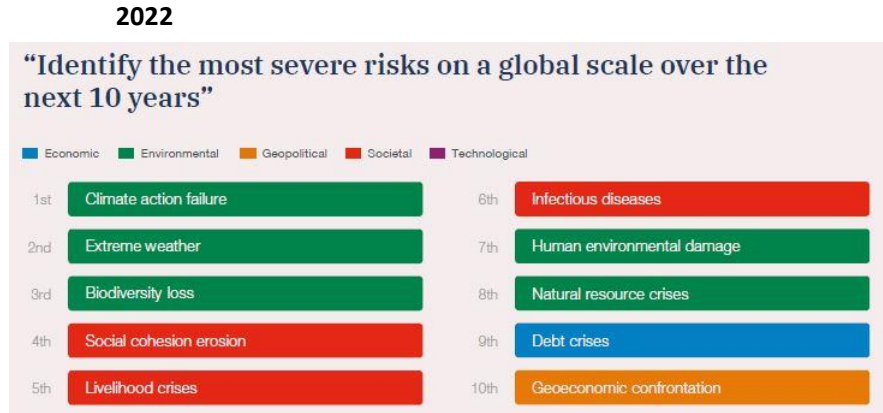
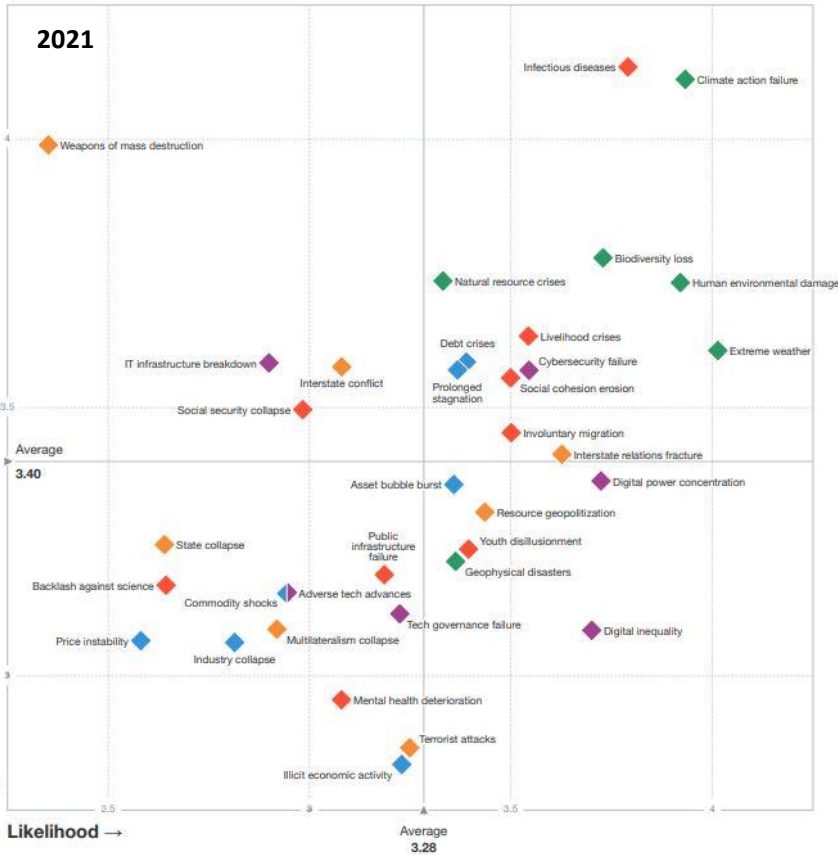
South African Environmental Observation Network (SAEON)



- Established in 2002 within the National Research Foundation (NRF) - Department of Science and Innovation (DSI)
- One of five national facilities
 - **Biodiversity & environmental sciences:** South African Institute for Aquatic Biodiversity (SAIAB) and SAEON
 - **Nuclear science:** iThemba Labs – Laboratory for Accelerator Based Sciences
 - **Astronomy:** South African Astronomical Observatory (SAAO) and South African Radio Astronomy Observatory (SARAO)
- Vision “*World-class environmental research platforms for a sustainable society*”



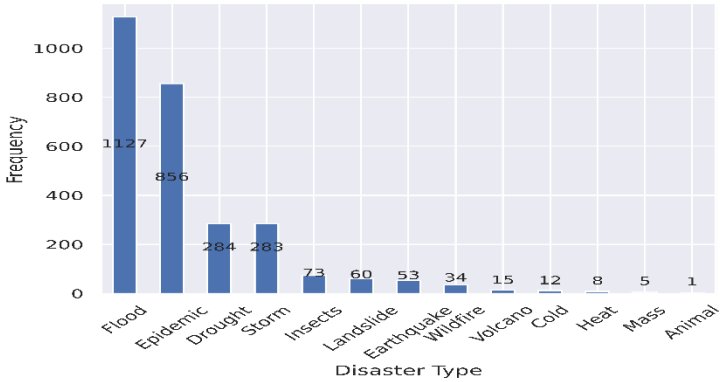
Global Risk Report



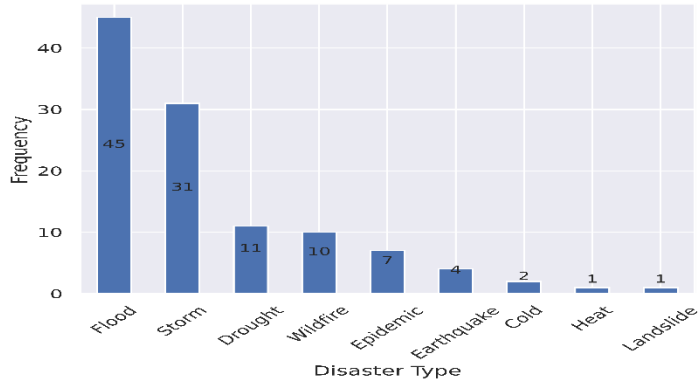
Source: World Economic Forum

Centre for Research on the Epidemiology of Disasters (CRED) launched the Emergency Events Database (EM-DAT)

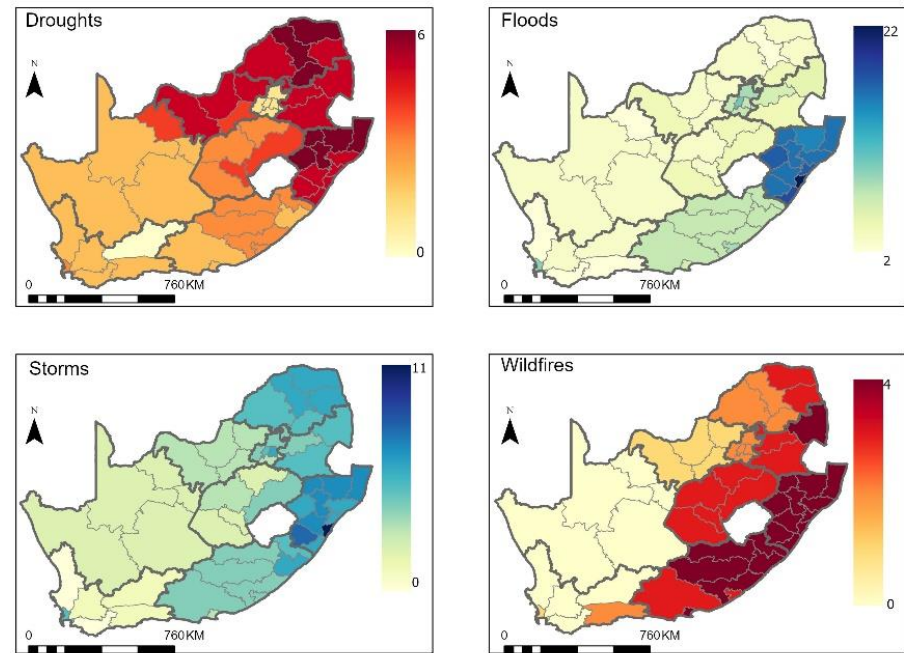
(a) Natural Disasters in Africa from 1979 to 2022



(b) Natural Disasters in South Africa from 1979 to 2022



THE NUMBER OF SOUTH AFRICAN WEATHER DISASTERS BY TYPE FROM 1980 TO 2022



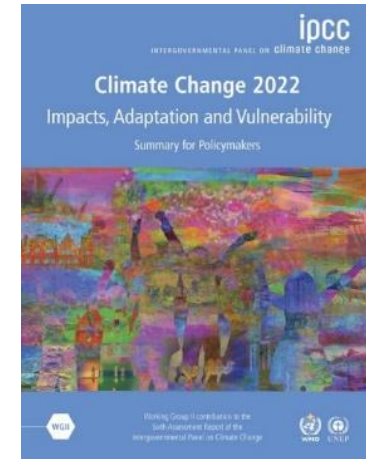
South African Risk And Vulnerability Atlas (SARVA)
[\(https://sarva.saeon.ac.za/atlas/\)](https://sarva.saeon.ac.za/atlas/)

IPCC: The Physical Science basis

Region	Heat and Cold				Wet and Dry							
	Mean air temperature	Extreme heat	Cold spell	Frost	Mean precipitation	River flood	Heavy precipitation and pluvial flood	Landslide	Aridity	Hydrological drought	Agricultural and ecological drought	Fire weather
North Africa ^a	●	●	●	●	●							
Sahara (SAH)	●	●	●	●								
Western Africa (WAF)	●	●	●		1				1	1	1	
Central Africa (CAF)	●	●	●									
North Eastern Africa (NEAF)	●	●	●		2				1	1	1	
South Eastern Africa (SEAF)	●	●	●						1	1	1	
West Southern Africa (WSAF)	●	●	●	●								
East Southern Africa (ESAF)	●	●	●	●								
Madagascar (MDG)	●	●	●									

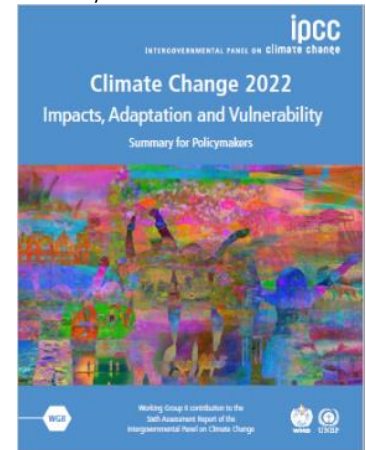
High confidence of decrease
Medium confidence of decrease
Low confidence in direction of change
Medium confidence of increase
High confidence of increase
Not broadly relevant

August 2021



IPCC: Impacts, Adaptation and Vulnerability

February 2022



Human systems	Impacts on water scarcity and food production				Impacts on health and wellbeing				Impacts on cities, settlements and infrastructure			
	Water scarcity	Agriculture/crop production	Animal and livestock health and productivity	Fisheries yields and aquaculture production	Infectious diseases	Heat, malnutrition and other	Mental health	Displacement	Inland flooding and associated damages	Flood/storm induced damages in coastal areas	Damages to infrastructure	Damages to key economic sectors
Global	±	-	○	-	-	-	-	-	-	-	-	-
Africa	-	-	-	-	-	-	-	-	-	-	-	-
Asia	±	±	-	-	-	-	-	-	-	-	-	-
Australasia	±	-	±	-	-	-	-	not assessed	-	-	-	-
Central and South America	±	-	±	-	-	-	-	not assessed	-	-	-	-
Europe	±	±	-	±	-	-	-	-	-	-	-	-
North America	±	±	-	±	-	-	-	-	-	-	-	-
Small Islands	-	-	-	-	-	-	-	-	-	-	-	-
Arctic	±	±	-	-	-	-	-	-	-	-	-	±
Cities by the sea	○	○	○	-	○	-	-	not assessed	○	-	-	-
Mediterranean region	-	-	-	-	-	-	-	not assessed	±	-	○	-
Mountain regions	±	±	-	○	-	-	-	-	-	na	-	-

Confidence in attribution to climate change

- High or very high
- Medium
- Low
- Evidence limited, insufficient
- na Not applicable

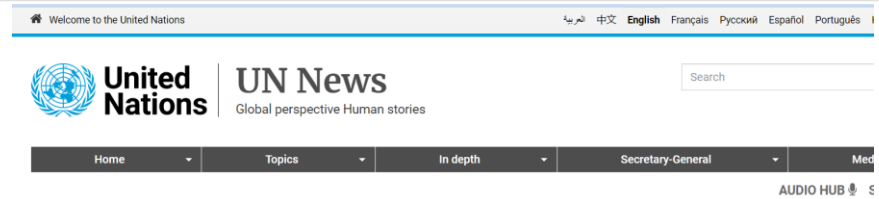
Impacts to human systems in panel (b)

- Increasing adverse impacts
- ± Increasing adverse and positive impacts

Early Warning System

23 March 2022 | Climate and Environment

The UN set an ambitious five year deadline on Wednesday for countries to ensure that citizens worldwide are protected by early warning systems against extreme weather and climate change, the UN chief announced, marking [World Meteorological Day](#).



COP27: \$3.1 billion plan to achieve early warning systems for all by 2027

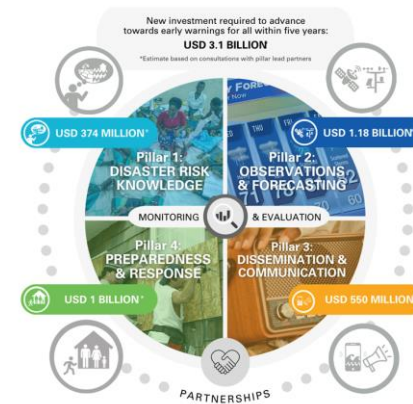


Figure 1: Budget overview for the four Pillars of the Early Warnings for All Initiative

2022 report

- 110 million directly affected
- 5000 fatalities
- Over US\$8.5 billion in damages
- Droughts – lead in deaths & people affected
- Floods lead in economic damages



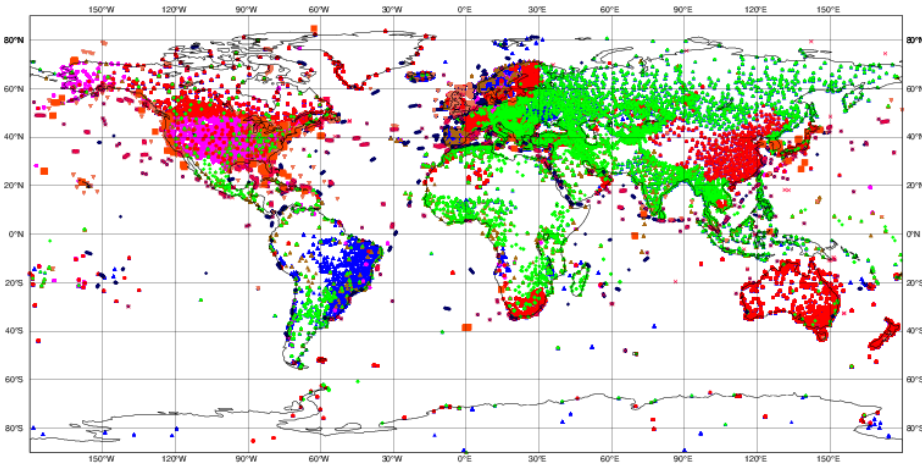
Investing in early warnings and early actions is a priority for saving lives, promoting economic development, valuing development gains and livelihoods, protecting the environment, and reducing the cost of disaster responses.

<https://public.wmo.int/en/media/press-release/early-warnings-all-action-plan-unveiled-cop27>

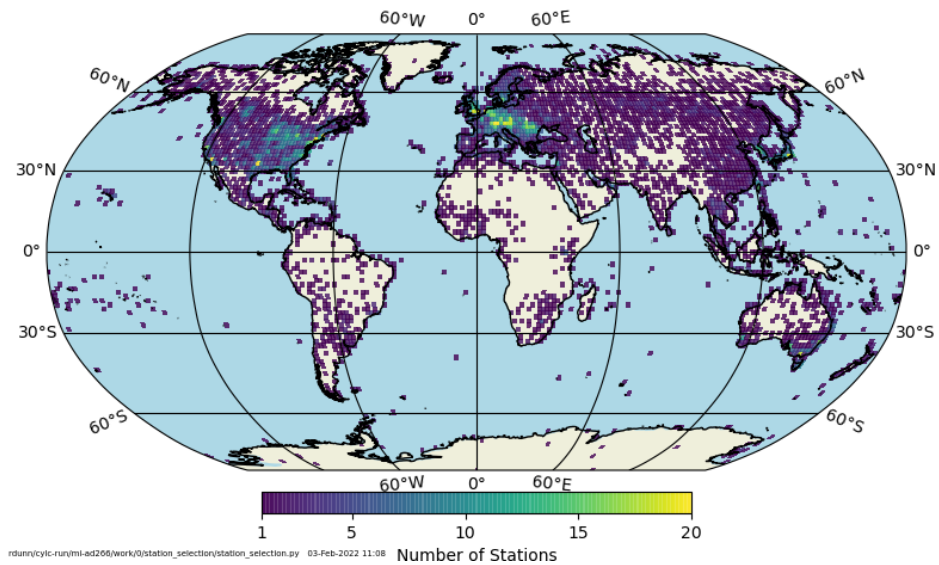
Observations

ECMWF data coverage (all observations) - SYNOP-SHIP-METAR
 2023092603 to 2023092609
 Total number of obs = 267047

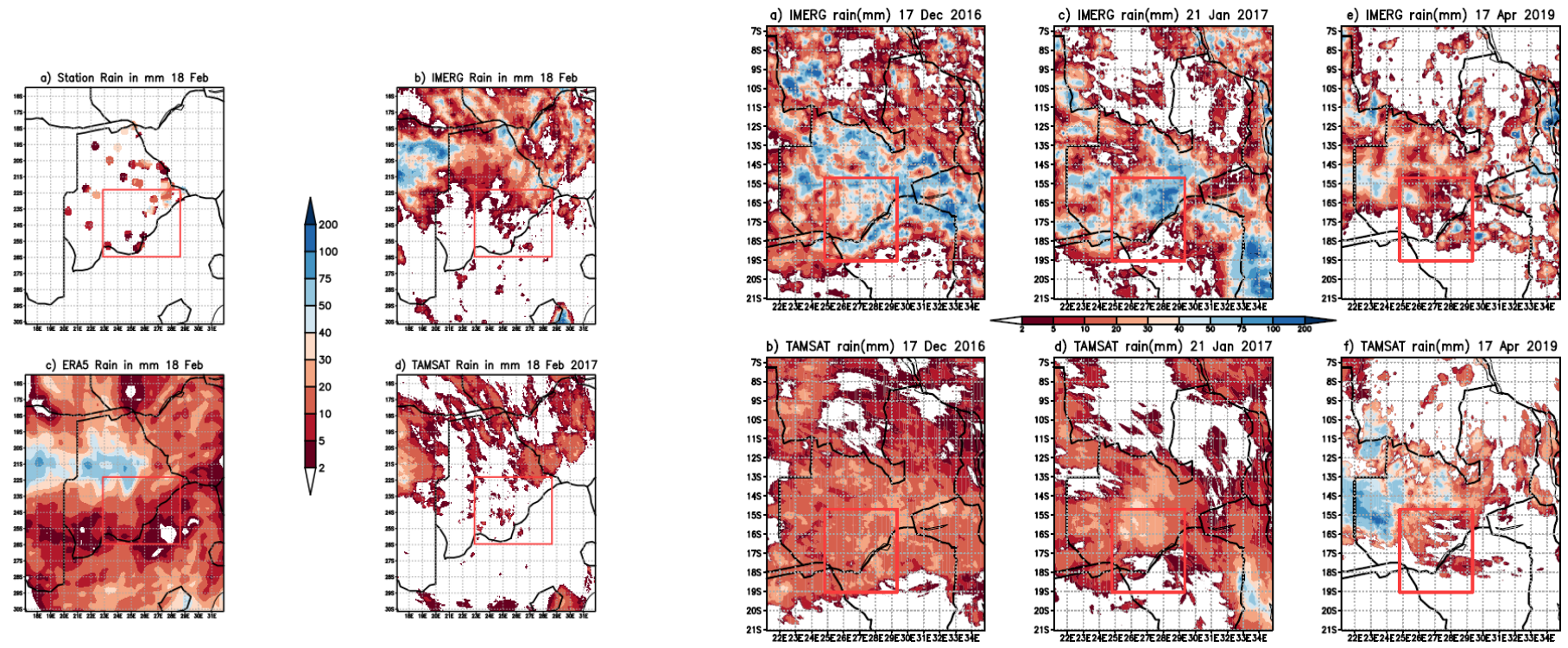
- Automatic Land SYNOP (15338)
- ◆ Manual Land SYNOP (9788)
- ▲ METAR (19079)
- ▼ Automatic SHIP (3399)
- × SHIP (1294)
- Abbreviated SHIP (320)
- Automatic METAR (38090)
- ◆ BUFR SHIP SYNOP (4173)
- ▲ BUFR LAND SYNOP (17586)



Stations reporting at least 6hly



Remote sensing and Reanalysis – Twenty four hour rainfall



Botswana 18 February 2017

Zambia 17
December 2016

Zambia 21
January 2017

Zambia 17 April
2019

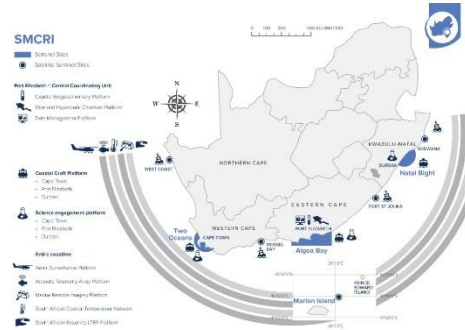


Implementation of the SADC Cyber-Infrastructure Framework

SAEON, EFTEON, SMCRI and SAPRI areas of operation



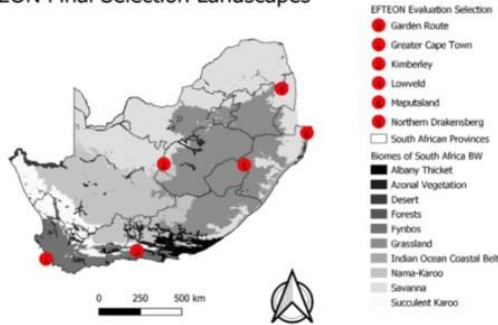
Shallow Marine and Coastal Research Infrastructure



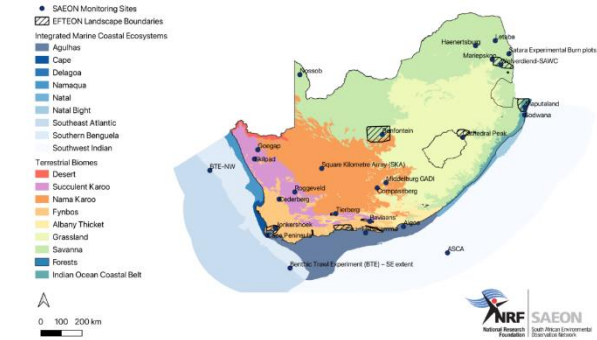
- South African Environmental Observation Network (SAEON) - South Africa investing in longterm observation networks
- SAEON hosts three South African Research Infrastructure Roadmap (SARIR) sites namely SMCRI, SAPRI and EFTEON
- Sites distributed carefully to cover surrounding oceans and different biomes
- Data helps with development of multi-hazard early warning systems

The Expanded Freshwater and Terrestrial Environmental Observation Network

EFTEON Final Selection Landscapes



South African Polar Research Infrastructure (SAPRI)



SAEON Data Catalogue:

<https://catalogue.saeon.ac.za/>

South African Risk and Vulnerability Atlas

SARVA is an initiative of the Department of Science and Innovation and forms a 10-year Global Change Grand Challenge. It is currently in its third phase of implementation with this phase focusing on improved access to ecological, economic, human, and settlement data and the development of decision-support tools that assist with evaluating and managing of the risks associated with global change.

[Visit SARVA 3.0](#)



The Marine Information Management System (MIMS)

The Marine Information Management System (MIMS) is an open repository that archives and publishes collections and subsets of marine related datasets for the Department of Forestry, Fisheries and the Environment: Oceans and Coastal Research (DFFE:OCR), South Africa.

[Visit MIMS](#)



National Climate Change Response Database

The platform was developed by SAEON for the Department of Forestry, Fisheries and the Environment (DFFE) to facilitate the monitoring and tracking of national, provincial and local responses to climate change.

[Visit NCCRD](#)



BioEnergy Atlas

The BioEnergy Atlas for South Africa is a repository of information, tools, and data supporting the bioenergy industry in South Africa.

[Visit SARVA 3.0](#)



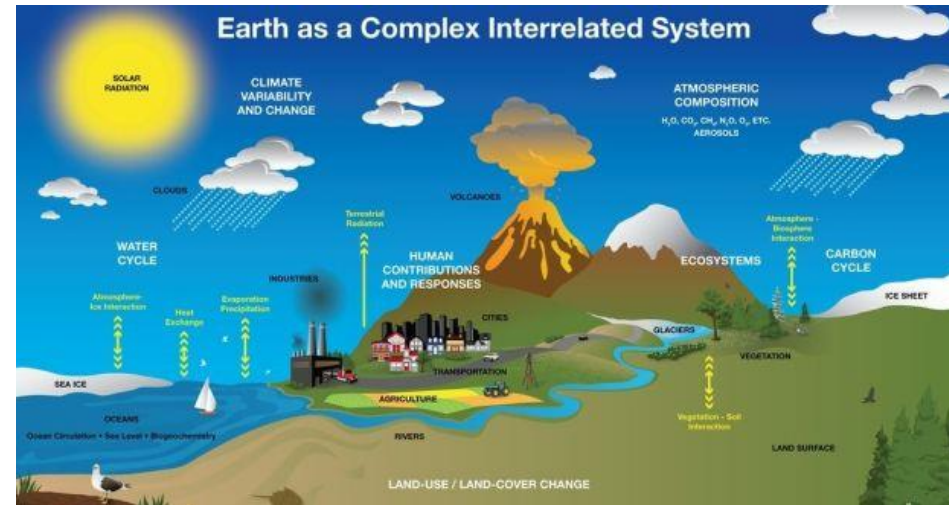
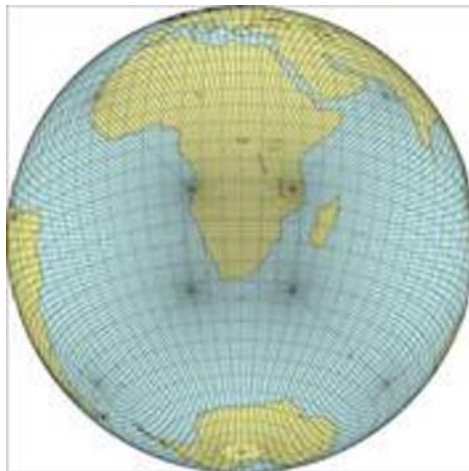
The screenshot shows the SAEON Data Portal interface. At the top, there is a search bar with the text 'sdg' and a magnifying glass icon. Below the search bar, it indicates '476 RESULTS'. On the left side, there is a sidebar with various filters: EXTENT FILTER, KEYWORDS, PUBLICATION YEAR, PUBLISHER, CREATORS, DATA FORMAT, DATA PROVIDER, and COLLECTION. The main content area displays two search results. The first result is titled 'SDG 1.2.1 PERCENTAGE OF POPULATION LIVING BELOW THE NATIONAL POVERTY LINE (PPL -R400 PER MONTH), BY SEX AND AGE FROM THE 2011 CENSUS' by HAYDEN WILSON. The second result is titled 'PROPORTION OF POPULATION WITH ACCESS TO ELECTRICITY' by THATO THUBELA, HAYDEN WILSON. Both results include a brief description of the data and a 'SHAPFILE (ARCHIVE)' link.

Weather and Climate Numerical Modelling

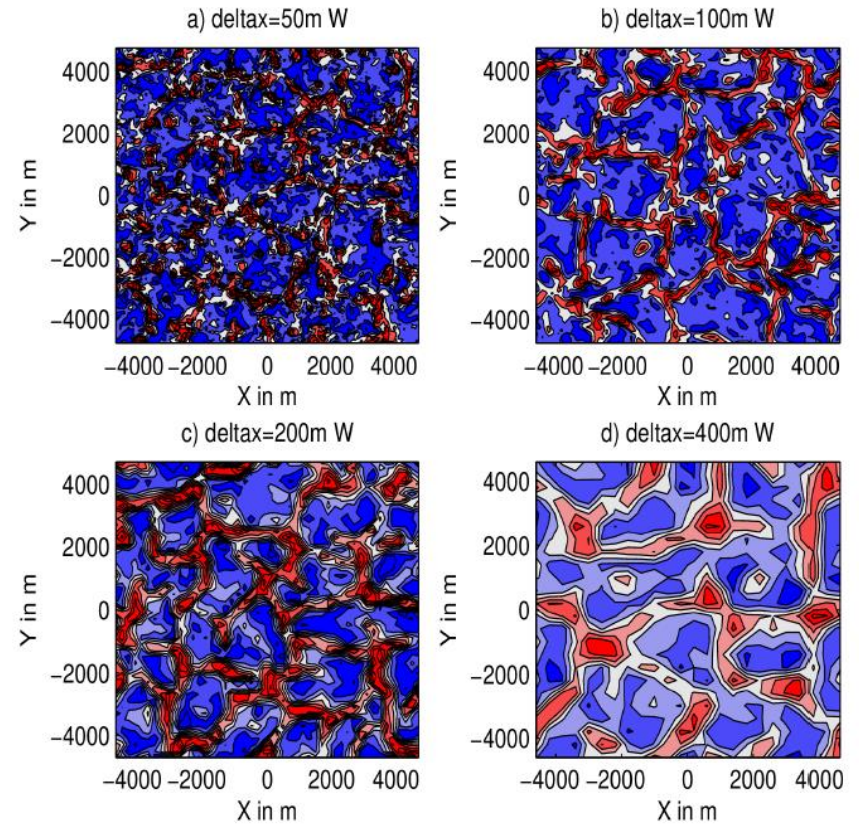
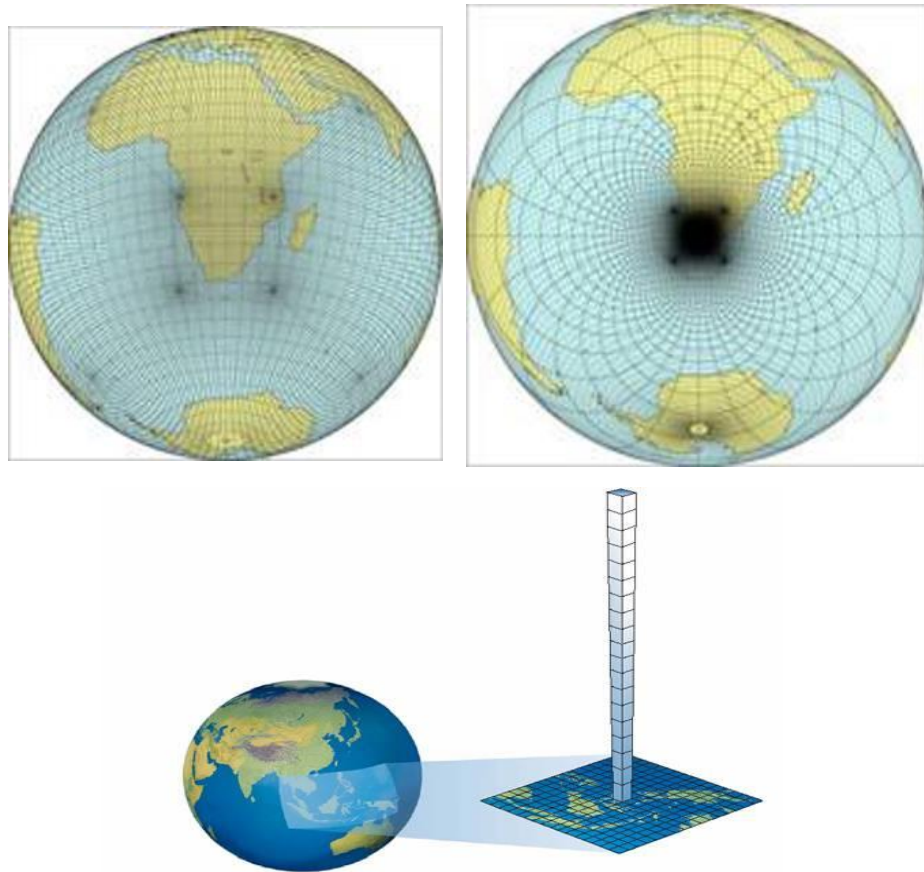
$$\frac{DV}{Dt} = -\frac{1}{\rho}\nabla p - fk \times V - gk + F$$

$$\frac{D\rho}{Dt} = -\rho\nabla \cdot V$$

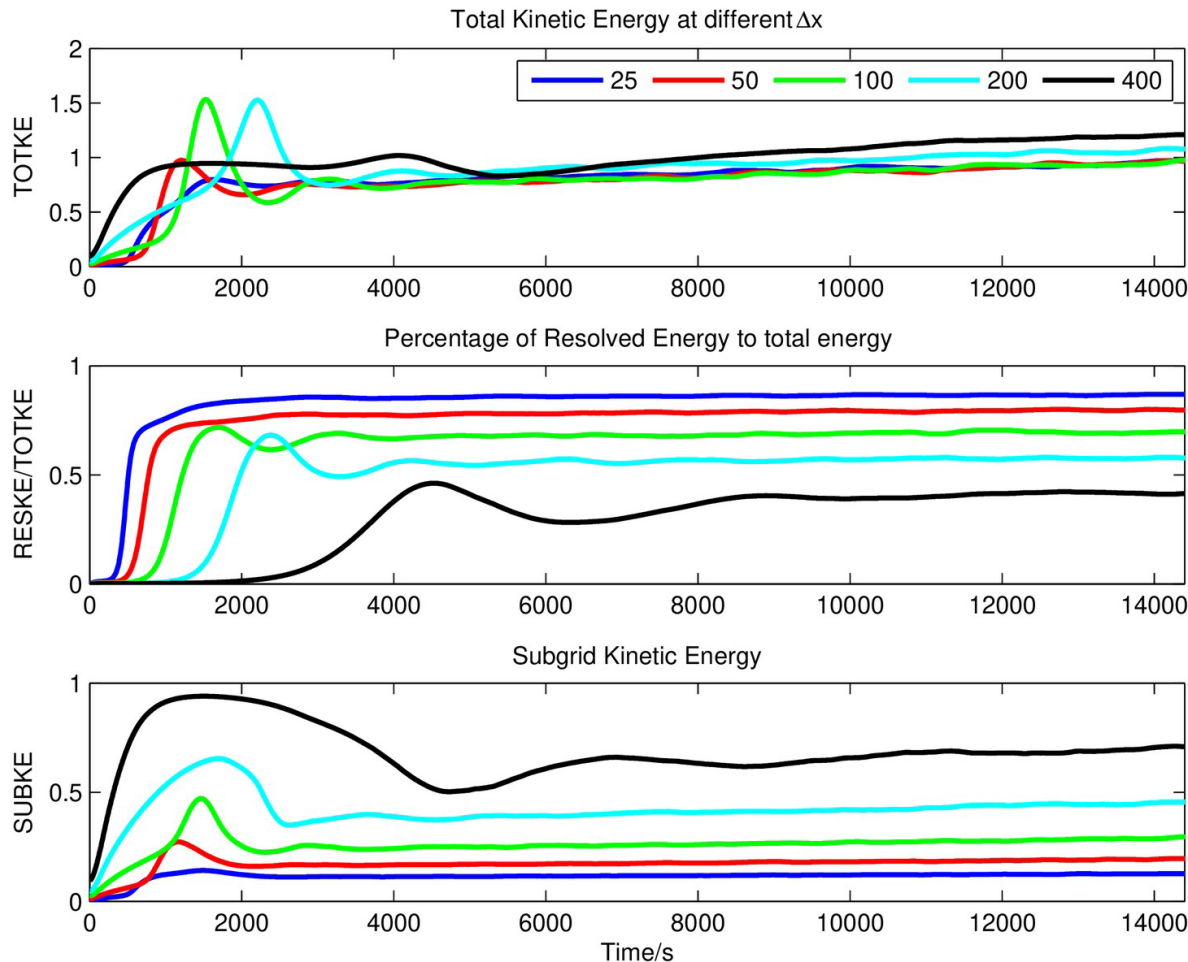
$$c_p \frac{DT}{Dt} - \alpha \frac{Dp}{Dt} = 0$$



Resolution and dynamical downscaling

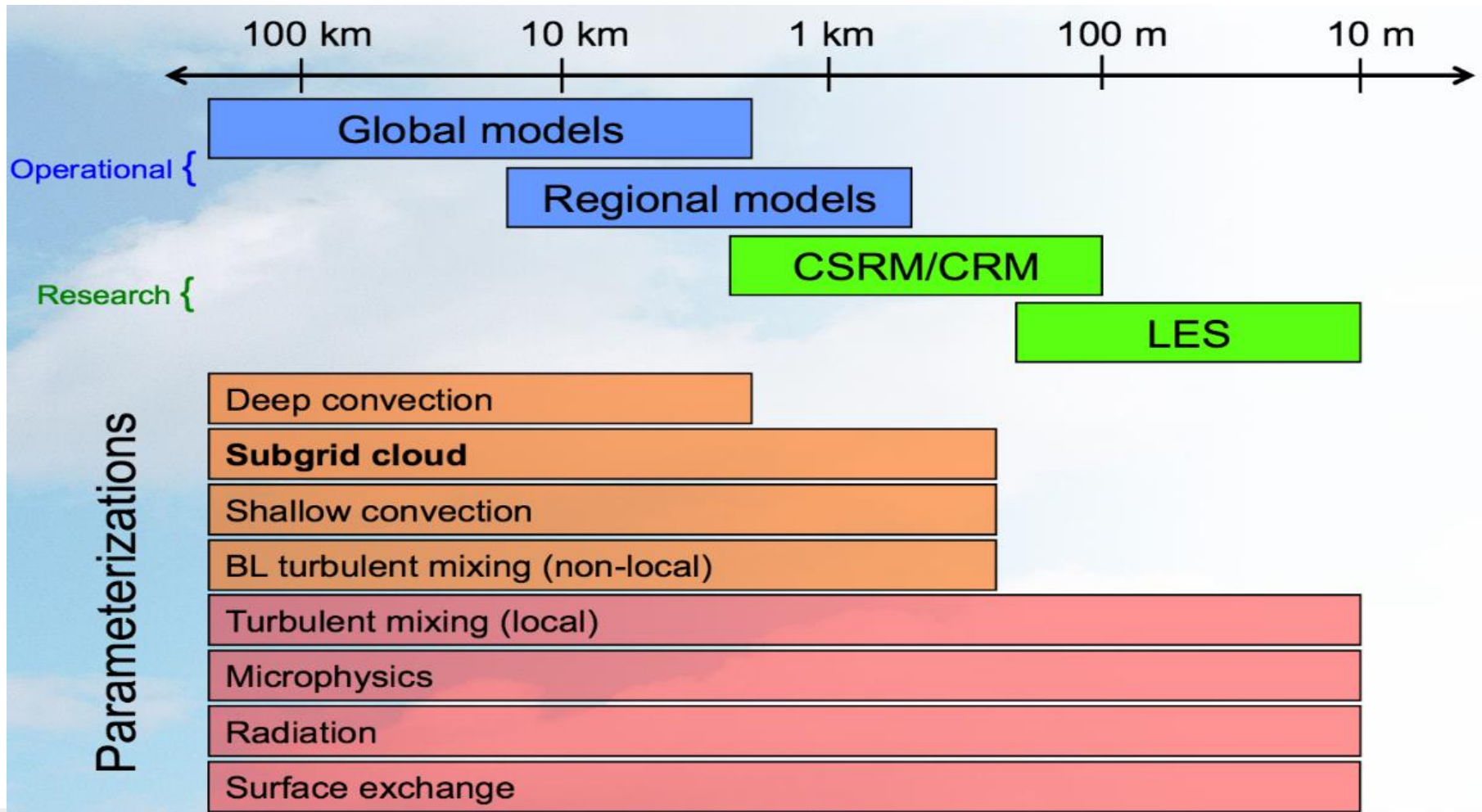


Turbulent Kinetic Energy



- Dry atmosphere
- Scale-awareness
- Energy spike during the spin up period

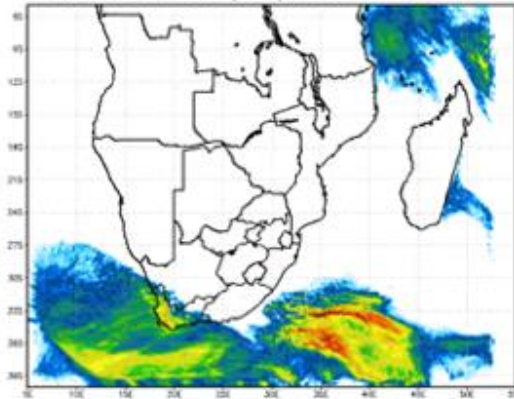
Spatial Scales in Atmospheric Modelling



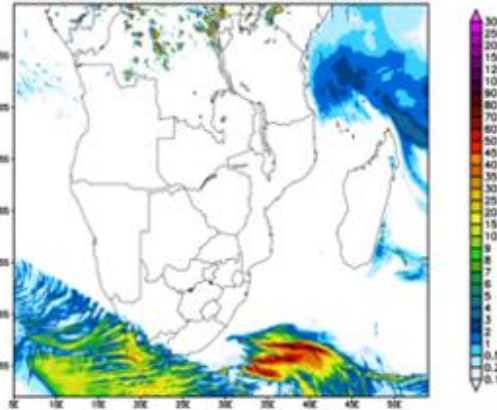
Courtesy of Dr Bouyssel

South African Context: Models running

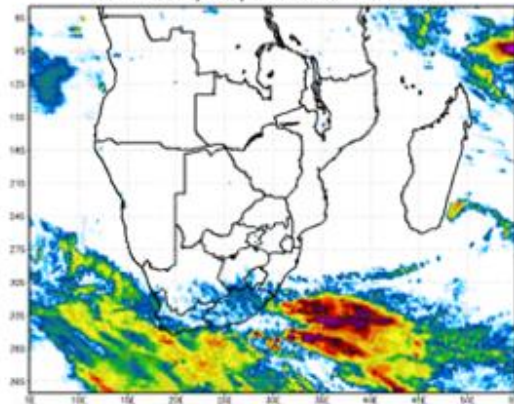
COSMO 24hr Total precipitation on 15JUL2017



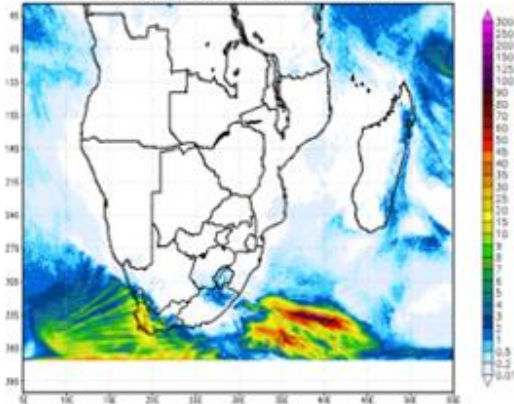
UM 4km horizontal resolution – SA4 Run:
Accumulating Precipitation for past 24 hours (mm)



GPM Total precipitation on 15JUL2017



WRF Total precipitation on 15JUL2017



Analysis

Value:00Z 15 JUL 2017

- Many models in used for research and operations
- Global & downscaled
- Available computations resources:
 - Operational convective scale modelling
 - Operational seasonal forecasting
 - Climate change projections
 - Paleo climate studies
 - Sensitivity studies



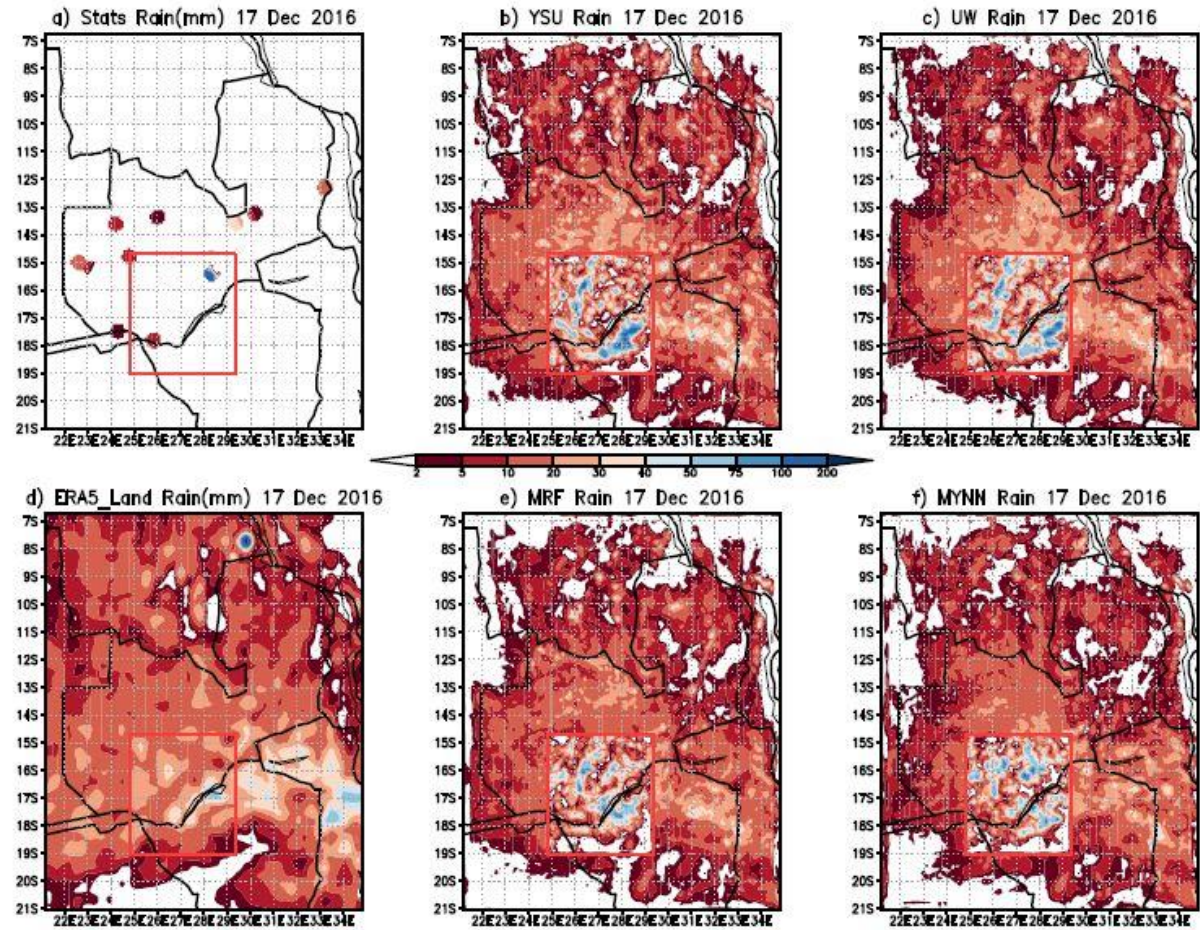
science & innovation

Department:
Science and Innovation
REPUBLIC OF SOUTH AFRICA

Advancing knowledge. Transforming lives. Inspiring a nation.



Model Sensitivity Studies: WRF



- Cloud Microphysics: mostly similar, presence of graupel no difference, SBU-YLIN- least rainfall
- Planetary boundary layer schemes – non-local and TKE-based- no major differences
- Convection scheme – use resulted in biggest difference



Implementation of the SADC Cyber-Infrastructure Framework

Model Development

On the development of a new nonhydrostatic atmospheric model in South Africa

F.A. Engelbrecht^{a,†}, J.L. McGregor^b and C.J. deW. Rautenbach^a



Recreating Earth through code

12 November 2019 - Schalk Mouton

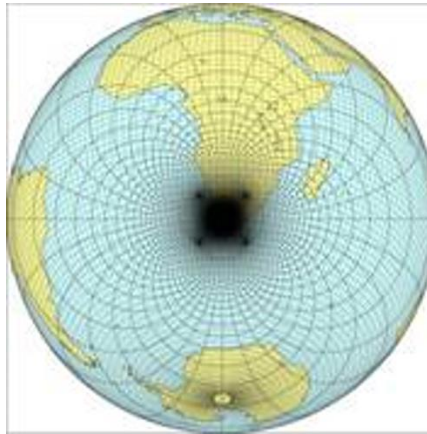
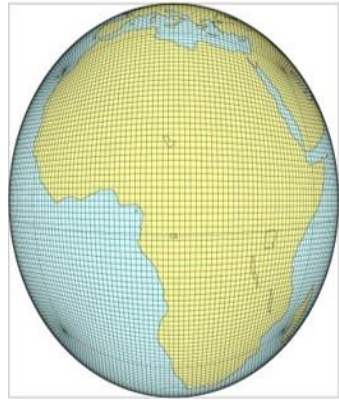
The first Earth System Model developed and based in Africa are creating one of the most reliable and most detailed modulations of climate change.



AUTHORS:
Mary-Jane M. Bopape^{1,2}
Francois Engelbrecht^{2,4}
Babatunde Abiodun⁵
Asmerom Beraki^{6,8}
Thando Ndarana⁶
Lucky Ntsangwane¹
Happy Sithole⁷
Mithetho Sovara^{7,8}
Jongikhaya Will⁹

Programme for the development of weather and climate numerical modelling systems in South Africa

Weather and climate numerical models have been in use in South Africa for many decades, both in operational and research mode.¹ All the models currently in use for operational purposes in the country were developed in developed countries. South African scientists started participating in the development or improvement of weather and climate numerical models in 2002, after being inactive in the area for over a decade.² The regeneration of model development activities started at the University of Pretoria through a Water Research Commission funded project in



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.

Simulation of South Africa streamflow over natural and urban landscapes using the INM RAS-MSU land surface model

Candidate : Mr. T Mohomi
Supervisor : Dr MM Bopape (NRF-SAEON)
Co-Supervisor : Prof H Chikoore
 Dr VM Stepanenko (MSU, Russia)
 Prof I Dhau

Objectives:

1. To evaluate the performance of the INM RAS-MSU LSM when simulating river flows in South Africa.
2. To study the sensitivity of the INM RAS-MSU LSM to spatial resolution.
3. To investigate the potential impacts of climate change on future river flows in South Africa (1979-2100).
4. To develop an urban scheme within the INM RAS-MSU LSM and simulate urban landscapes effects on surface hydrological processes in Gauteng.

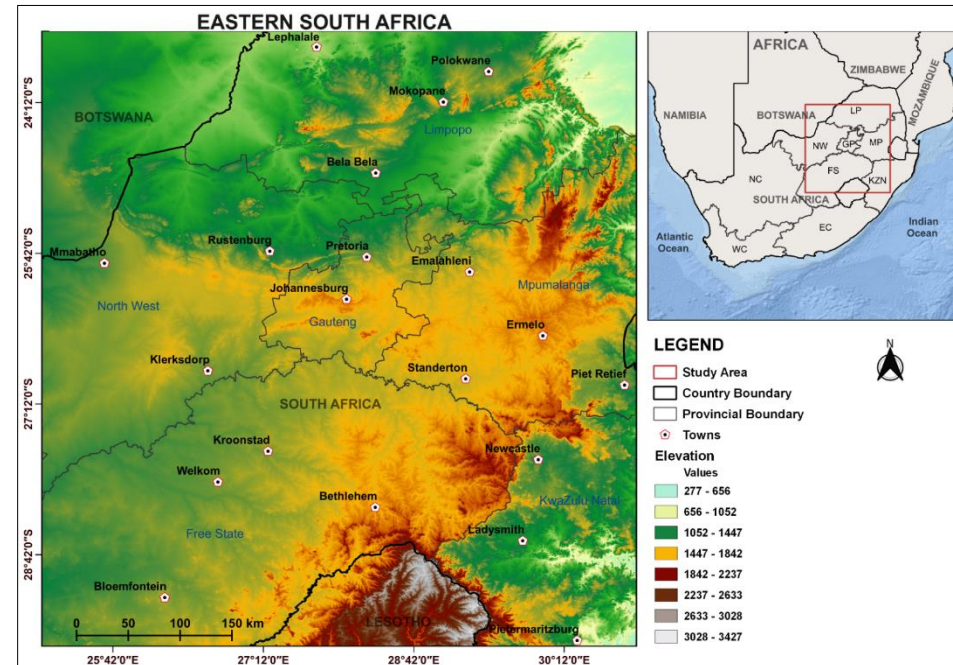
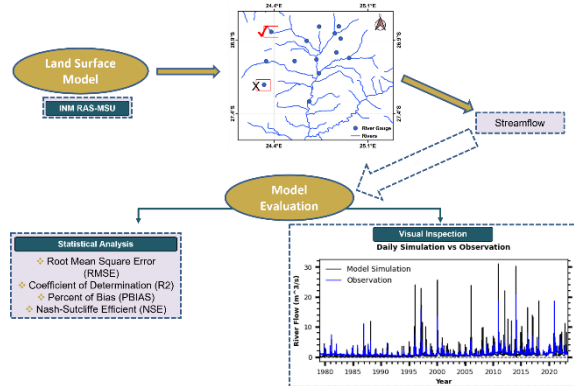
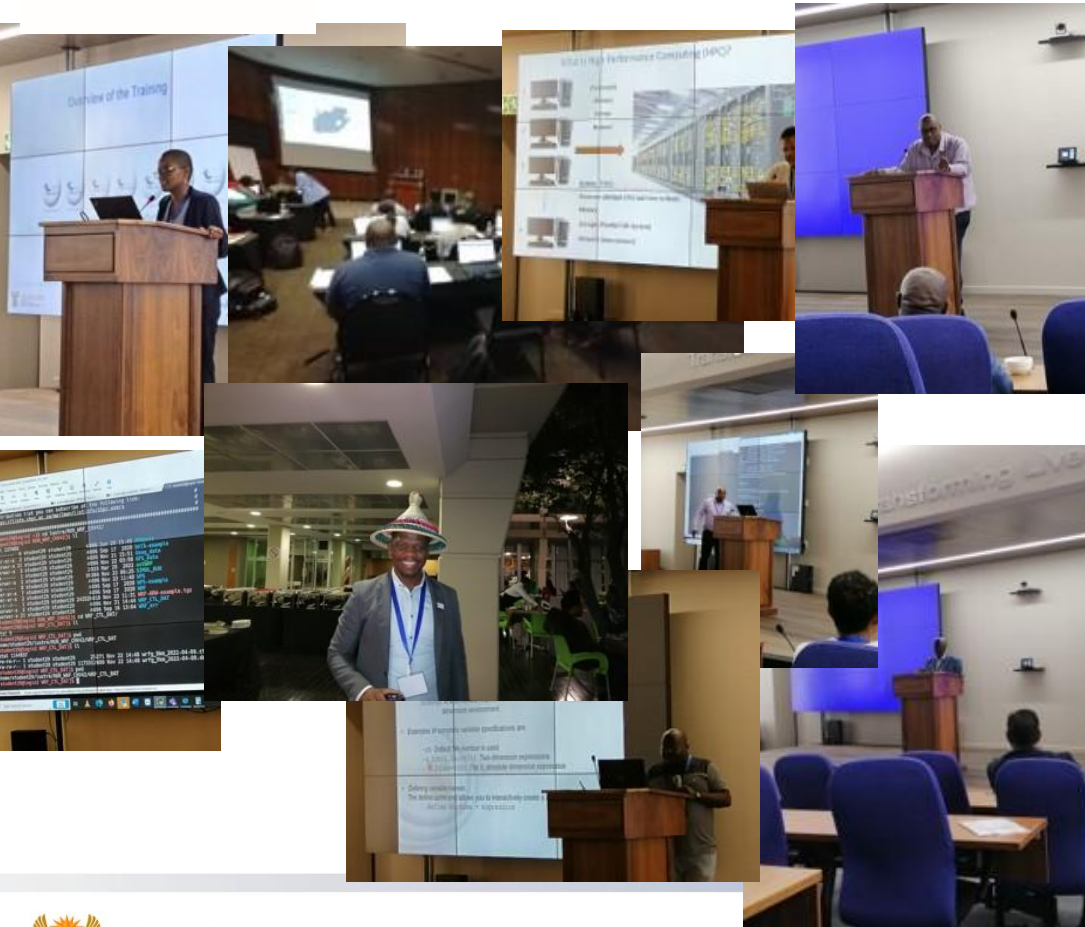


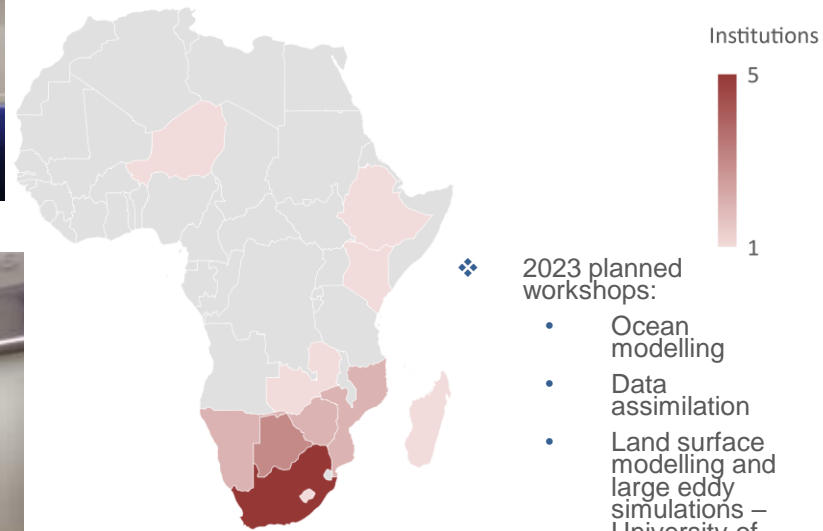
Figure 1: Topography over Eastern interior of South Africa

Training Workshops

- Modelling and Postprocessing training workshop : e.g. 21 to 25 November 2022



Countries & institutions



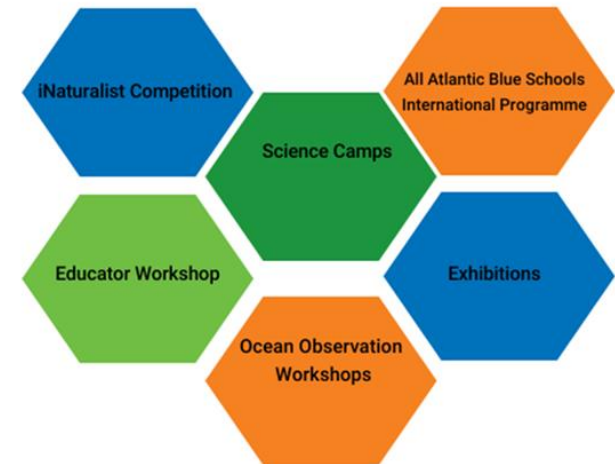
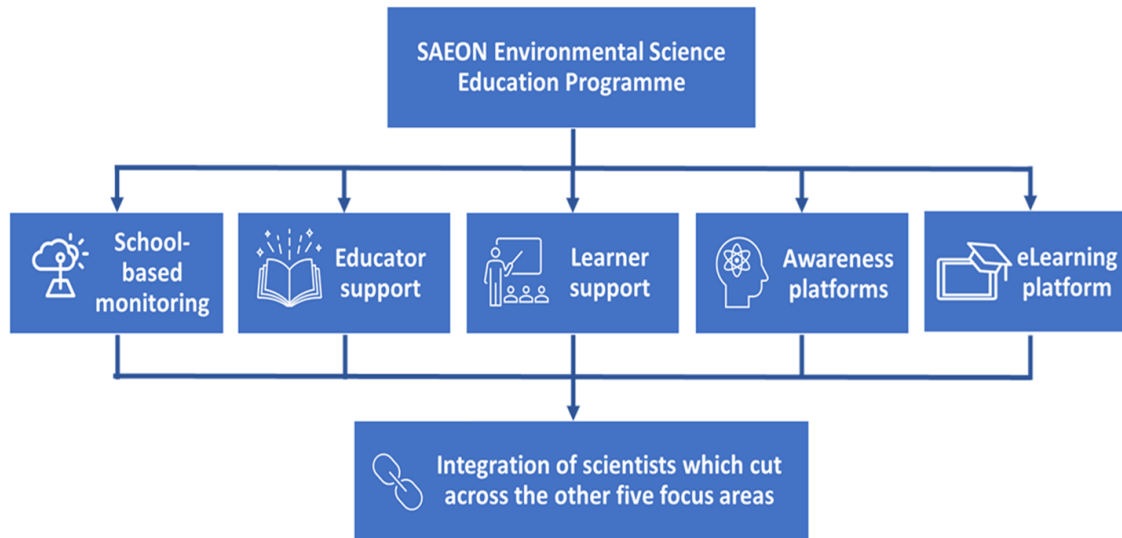
© GeoNames, Microsoft, OpenStreetMap, TomTom



Advancing knowledge. Transforming lives. Inspiring a nation.



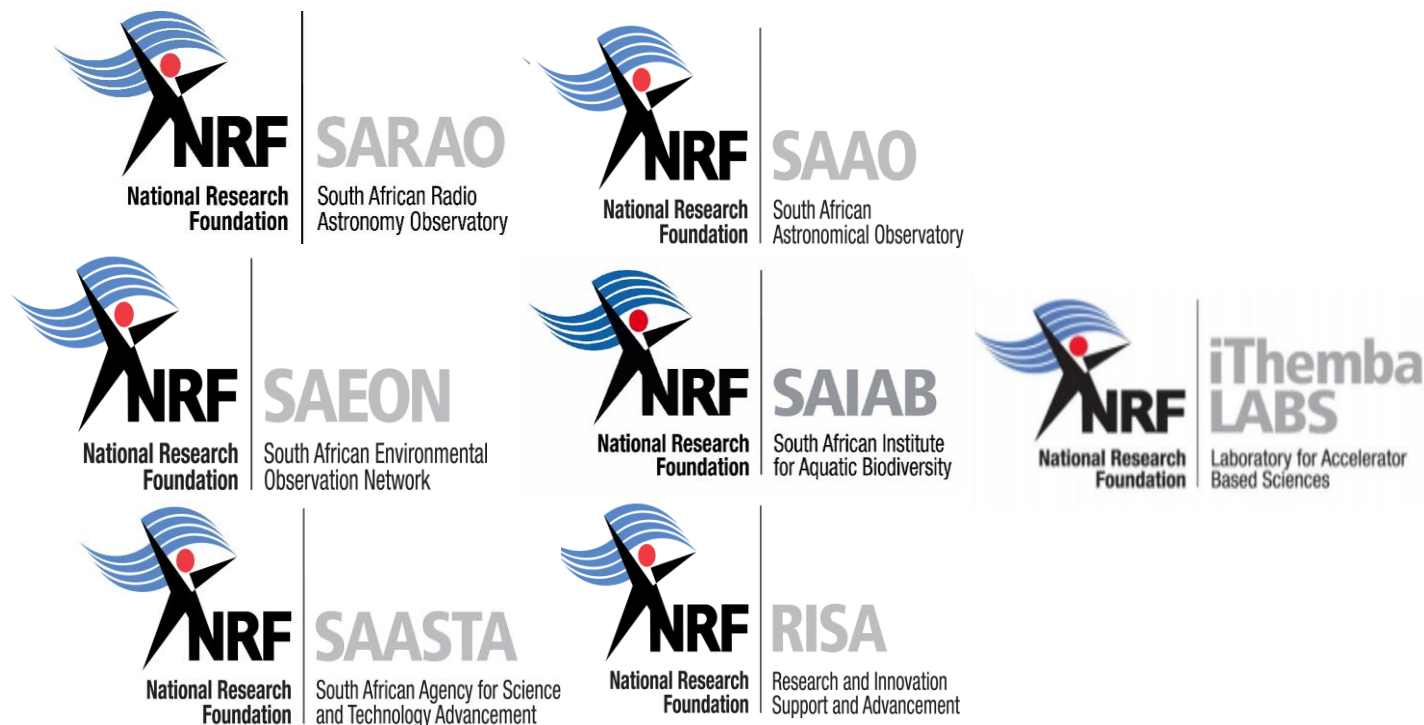
SAEON Science Engagement



Concluding Remarks

- Multi-disciplinary research is essential for understanding environmental/ earth systems change and variability (natural and human-induced)
- Observations – technicians, engineers & scientists – process studies
- Models – process understanding, numerical techniques, software development for different architectures, machine learning for parametrizations
- NRF funding opportunities for Hons, Masters and PhD
- Graduate Student Network (GSN) – for postgraduate students – annual meetings
- Happy to collaborate

Enkosi, Thank you,
Re a leboga, Siyabonga, Dankie



Contact Details: Dr Mary-Jane Bopape
mm.bopape@saeon.nrf.ac.za