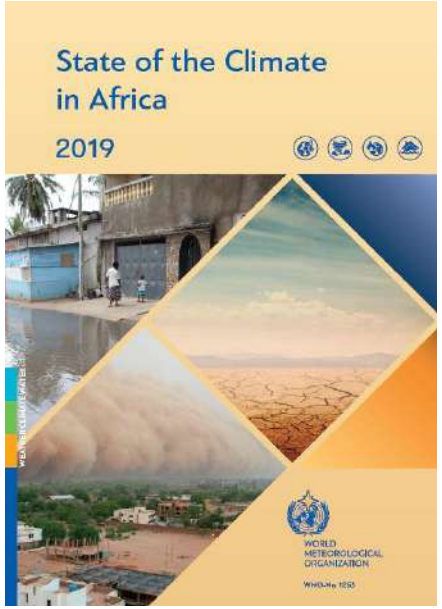
Improving weather and climate early warnings in Southern Africa

Mary-Jane Bopape, South African Weather Service, Senior Manager: Research

Impact of Weather and climate extremes

- Extreme weather impacts – property damage, loss of life, health issues

- Impacts policy space; Science, Technology & Innovation Strategy for Africa (STISA)



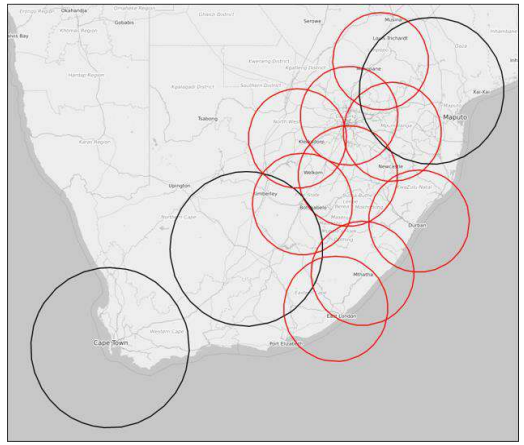
- Build resilience through effective multi-hazard early warning systems (MHEWS) & appropriate prevention and risk management strategies
- National Development Plan
- National Climate Change Strategy

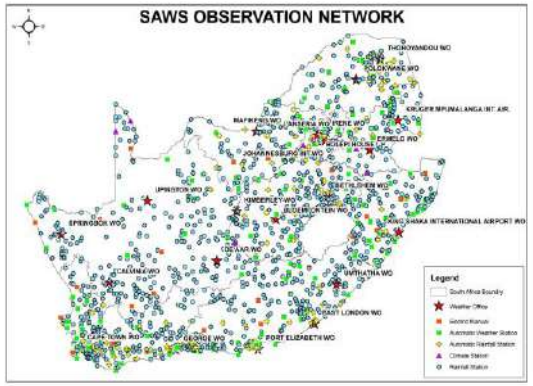
- Based on Emergency Events database (1995-2015), Centre for research on the Epidemiology of Disasters CRED reports majority of deaths occur in lower-middle-income countries (89%) although only 26% of storms are reported there

The African Academy of Sciences · United Nations Economic Commission for Africa · WISER · UKaid · CR4D

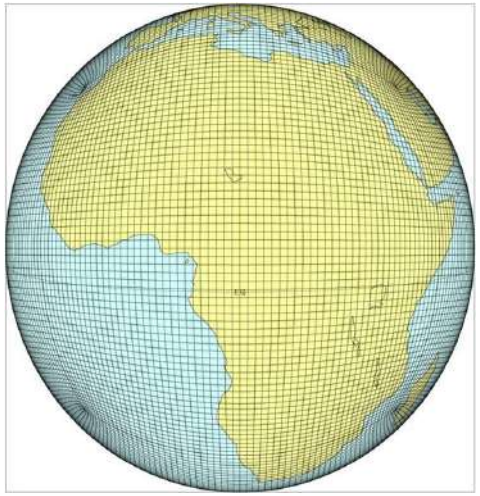
Weather and Climate Early Warnings – value chain

Observations





Models



$$\frac{Du}{Dt} - fv + \frac{\partial \varphi}{\partial x} - \sigma \frac{\partial \varphi}{\partial \sigma}\frac{\partial \ln p_s}{\partial x} = 0$$

$$\frac{Dv}{Dt} + fu + \frac{\partial \varphi}{\partial y} - \sigma \frac{\partial \varphi}{\partial \sigma}\frac{\partial \ln p_s}{\partial y} = 0$$

$$\frac{R}{g}\frac{D}{Dt}\left(\frac{\omega T}{p}\right) + g + \frac{p}{p_s}\frac{g}{RT}\frac{\partial \varphi}{\partial \sigma} = 0$$

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial \dot{\sigma}}{\partial \sigma} + \frac{D \ln p_s}{Dt} = 0$$

$$\frac{DT}{Dt} - \kappa \frac{\omega T}{p} = 0$$

Challenges

- No models running
- Models running at lower resolution than forcing global models
- Black boxes – don't understand how models work
- Waiting for others to tell us settings to use
- Implementations without testing
- Lack of confidence in what is issued

POSTPROCESSING

Forecasters

DISSEMINATION

Applications – weather and climate sensitive sectors

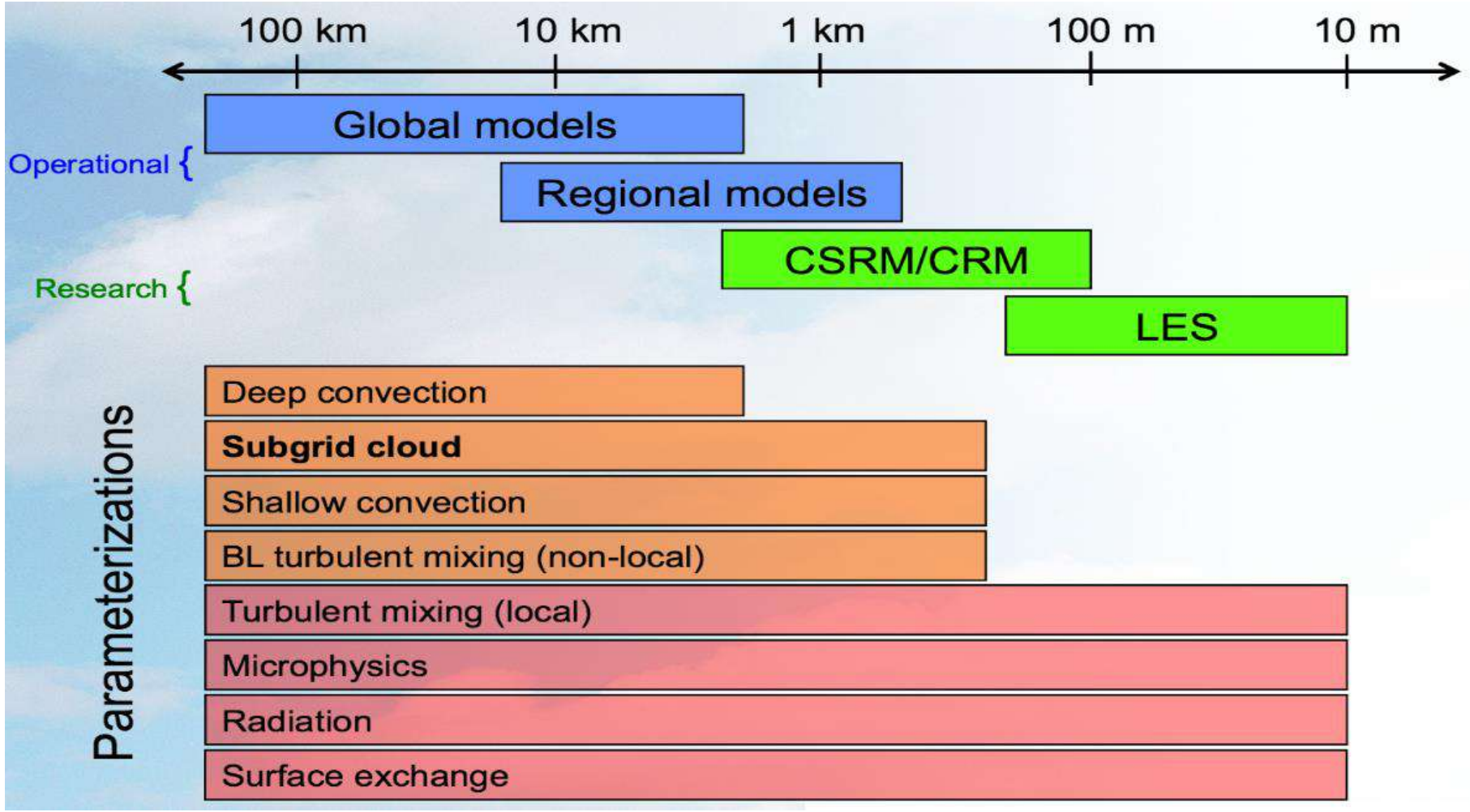
Agriculture
Health
Energy
Water

The African Academy of Sciences
United Nations Economic Commission for Africa
WISER
UKaid
CR4D

Aim

- The aim of this project is to improve weather and climate early warning systems within Southern Africa.
- Specific objectives – modelling + process understanding
  - Study atmospheric processes using different sources of data
  - Evaluate and verify current Numerical Weather Prediction models using a number of observation sources .
  - Test different model configurations to determine the most efficient choices .
  - Improve simulations through modification of the model physics (i.e. boundary layer and microphysics).
- Countries: Botswana, Mozambique, Namibia, South Africa, Tanzania, Zambia – Met Services and HPC hosts

Spatial Scales in Atmospheric Modelling



Workshops

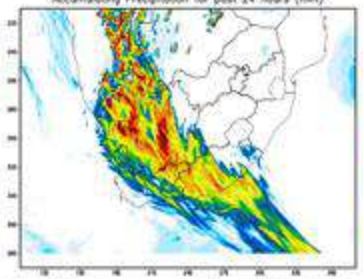
- 26-28 August 2019
  - Weather scientists & HPC specialists
  - Implementation of WRF
  - Ann Fridlind & colleagues (cloud microphysics, satellite data, WRF sensitivity, radar software)
- 1 December 2019
  - Presentation on results obtained for heavy rainfall events
  - Bob Plant (University of Reading)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

South Africa 1: Model Intercomparison

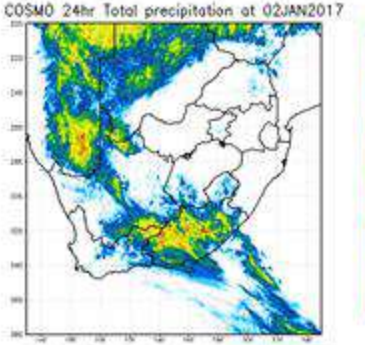
- SADC NWP models
  - Consortium for Small-scale Modelling (COSMO)
  - Weather Research and Forecasting model (WRF) – open source
  - Unified Model (UM partnership)
- 9 high impact weather events
- Grid length: 4.4km across Southern Africa: 30 hours simulations
- UM – nested within UM Global Atmosphere (10km)
- WRF – nested within GFS (0.25 deg)
- COSMO – nested within ICON (13 km)

Date	Weather events
02/01/2017	A severe storm was observed in Umtata. Deep surface trough over the central interior coupled with an upper-air trough and a coastal low over the Eastern Cape area, including Umtata.
07/01/2017	Heavy rainfall was reported in Nqutu. Deep surface trough with a ridging high over the eastern half of the country.
16/02/2017	Heavy rain as a result of tropical cyclone Dineo over Mbombela.
20/02/2017	Heavy rainfall over Phokeng due to tropical temperate trough, Rustenburg.
06/06/2017	A cold front associated with gale-force winds, storm and lightning were reported over parts of the Western Cape.
27/06/2017	A cold front coupled with an upper air trough was observed over the country.
15/07/2017	A cold front that resulted in wide spread showers, snow and rain was observed over the Western Cape, the Northern Cape and Eastern Cape. Parts of the Northern Cape were very hot. A coastal low was observed ahead of the cold front, producing light precipitation.
21/08/2017	A cold front associated with an upper-air trough was situated over the south-eastern parts of the country.
10/10/2017	Floods were observed over parts of Kwa-Zulu Natal when severe thunderstorms, accompanied by heavy rains, strong winds and lightning hit the area on 10 October 2017. A cut-off-low with a high ridging over the southern parts of the country.
30/12/2017	A tornado in Soweto. A surface trough extended over the western and central interior, with a high east of the country.

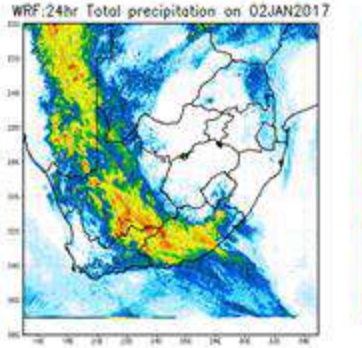
02 January 2017



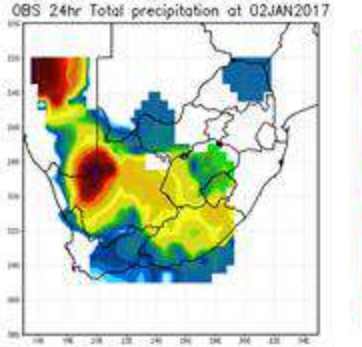
COSMO 24hr Total precipitation at 02JAN2017



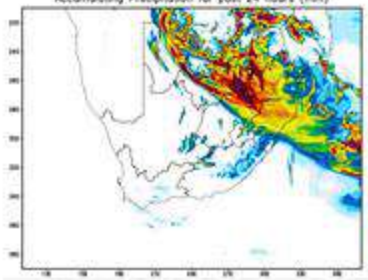
WRF:24hr Total precipitation on 02JAN2017



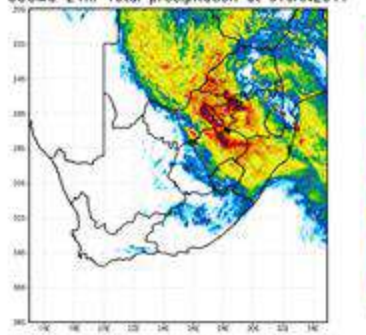
OBS 24hr Total precipitation at 02JAN2017



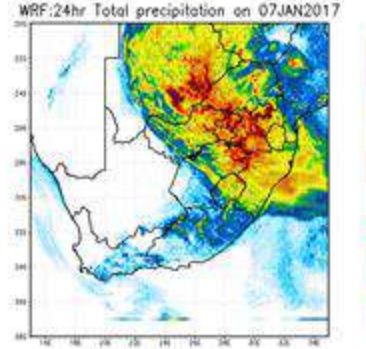
07 January 2017



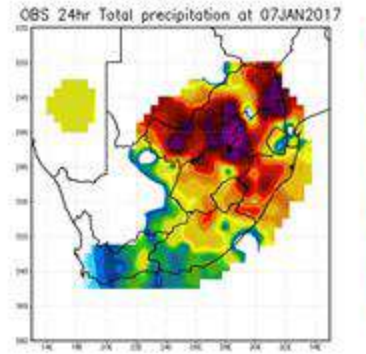
COSMO 24hr Total precipitation at 07JAN2017



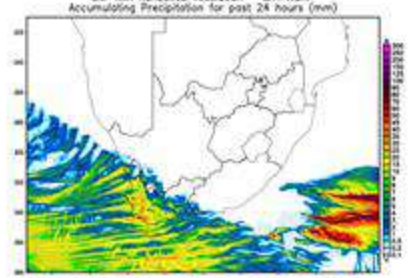
WRF:24hr Total precipitation on 07JAN2017



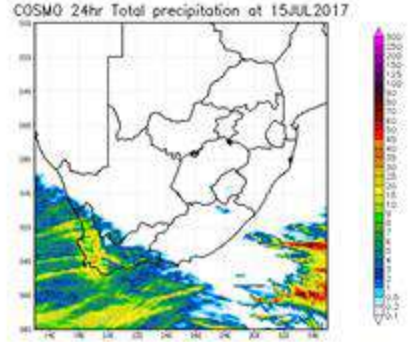
OBS 24hr Total precipitation at 07JAN2017



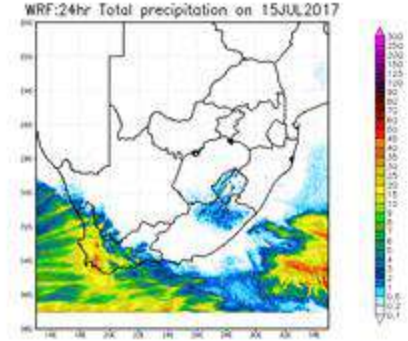
15 July 2017



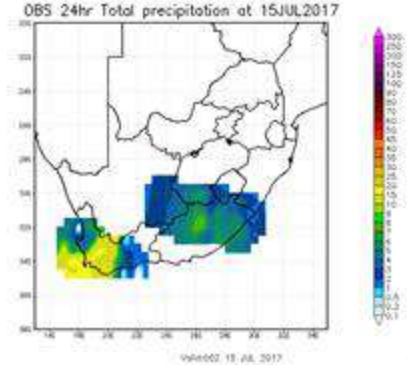
COSMO 24hr Total precipitation at 15JUL2017



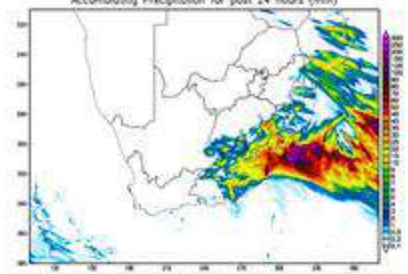
WRF:24hr Total precipitation on 15JUL2017



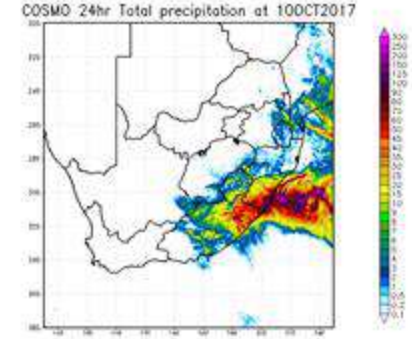
OBS 24hr Total precipitation at 15JUL2017



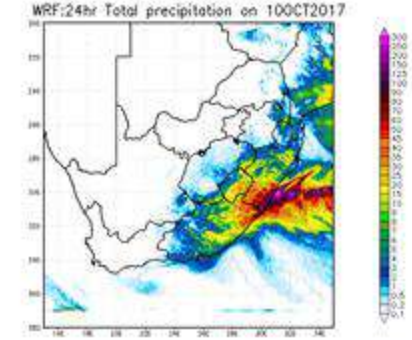
10 October 2017



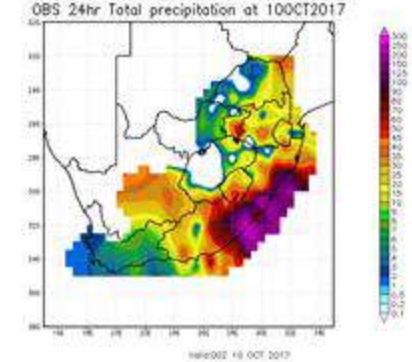
COSMO 24hr Total precipitation at 10OCT2017



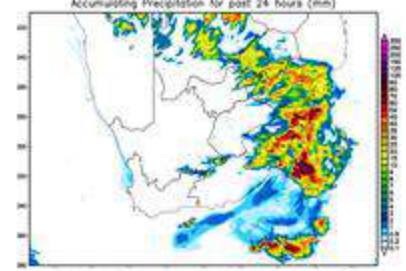
WRF:24hr Total precipitation on 10OCT2017



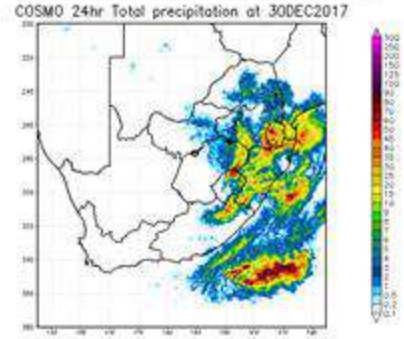
OBS 24hr Total precipitation at 10OCT2017



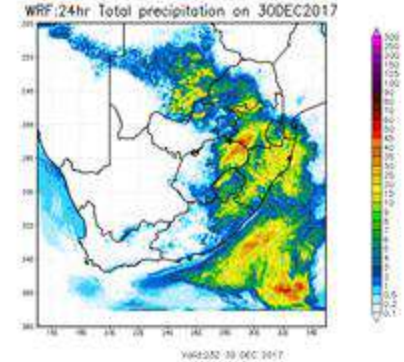
30 December 2017



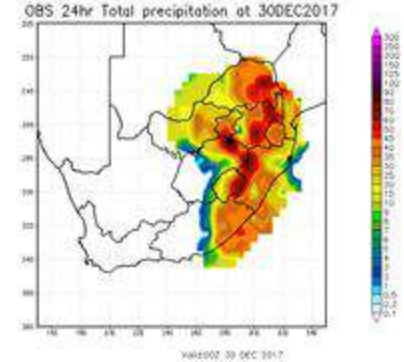
COSMO 24hr Total precipitation at 30DEC2017



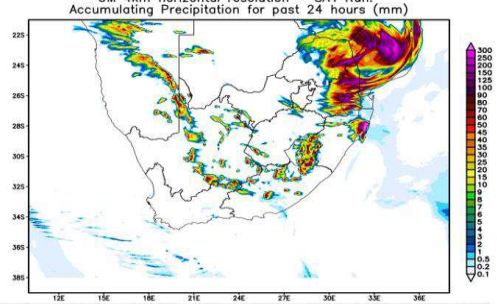
WRF:24hr Total precipitation on 30DEC2017



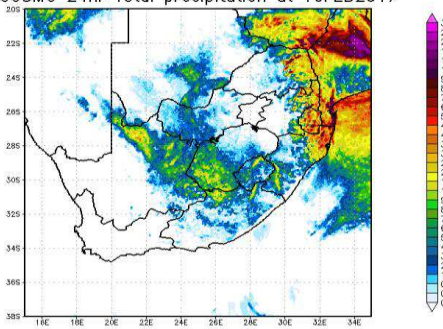
OBS 24hr Total precipitation at 30DEC2017



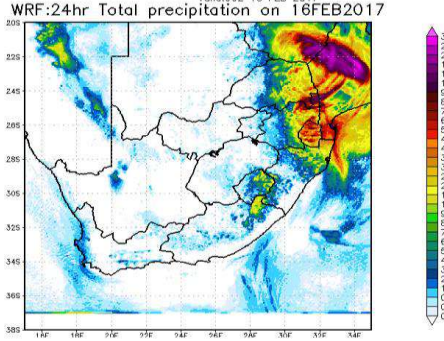
16 February 2017

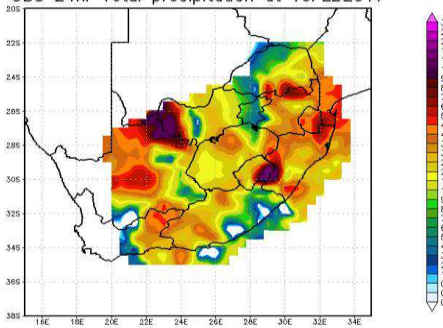


Total precipitation of 00Z to 24Z, 16 FEB – Initiated 00Z 16 FEB 2017



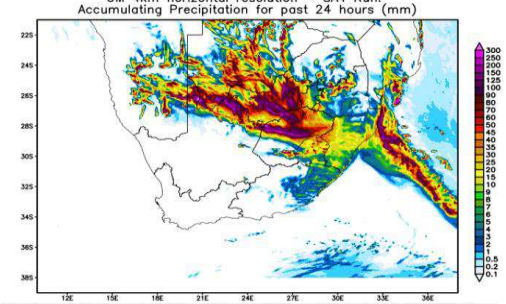
Analysis: Valid:00Z 16 FEB 2017



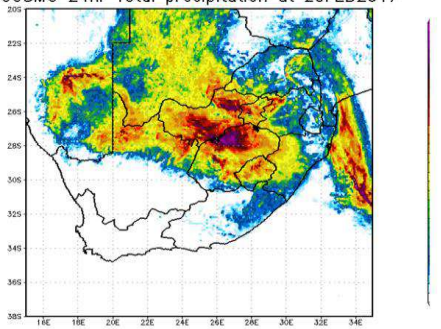


Analysis: Valid:00Z 16 FEB 2017

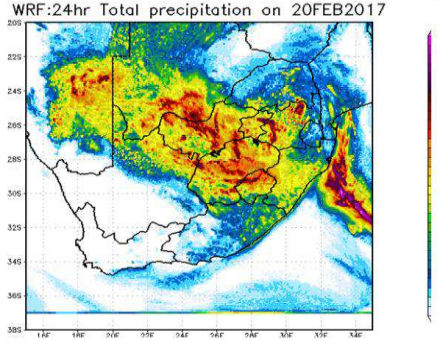
20 February 2017

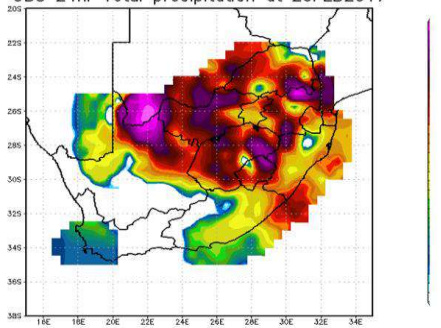


Total precipitation of 00Z to 24Z, 20 FEB – Initiated 00Z 20 FEB 2(



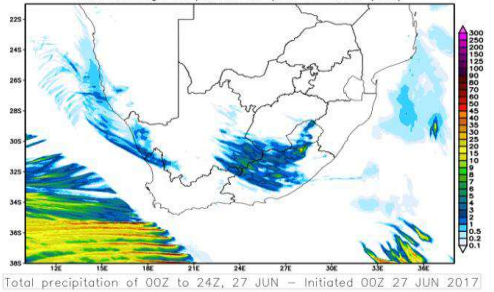
Analysis:



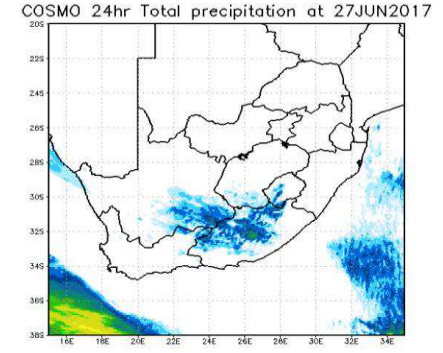


Analysis: Valid:00Z 20 FEB 2017

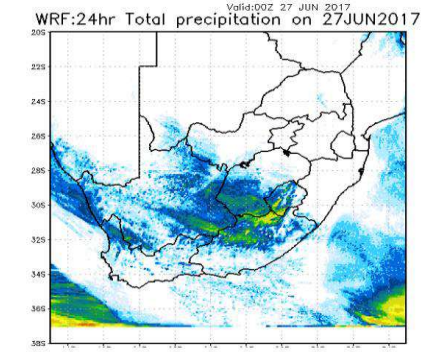
27 June 2017

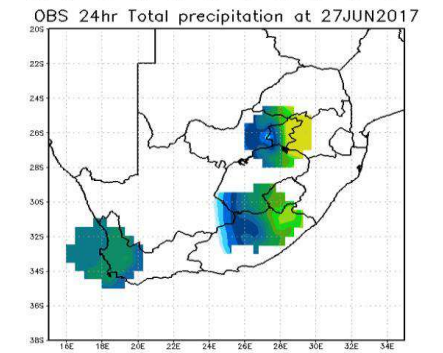


Total precipitation of 00Z to 24Z, 27 JUN – Initiated 00Z 27 JUN 2017



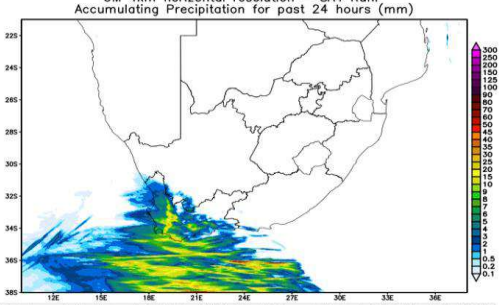
Analysis: Valid:00Z 27 JUN 2017



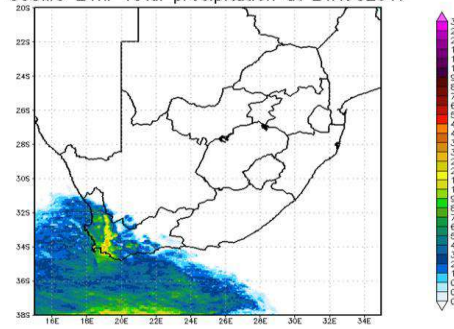


Analysis: Valid:00Z 27 JUN 2017

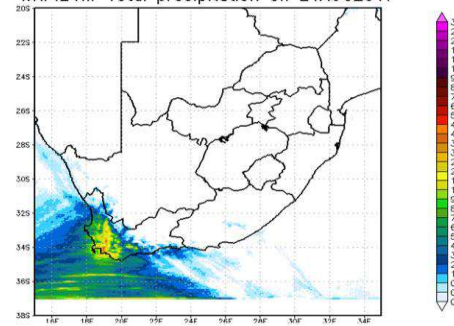
21 August 2017

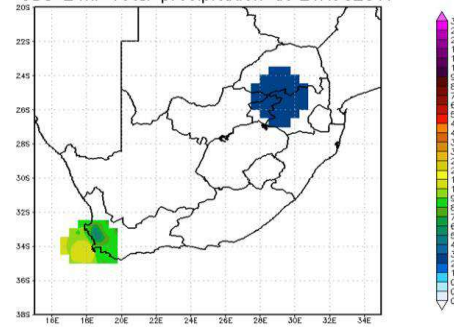


Total precipitation of 00Z to 24Z, 21 AUG – Initiated 00Z 21 AUG 2017



Analysis: Valid:00Z 21 AUG 2017





Analysis: Valid:00Z 21 AUG 2017

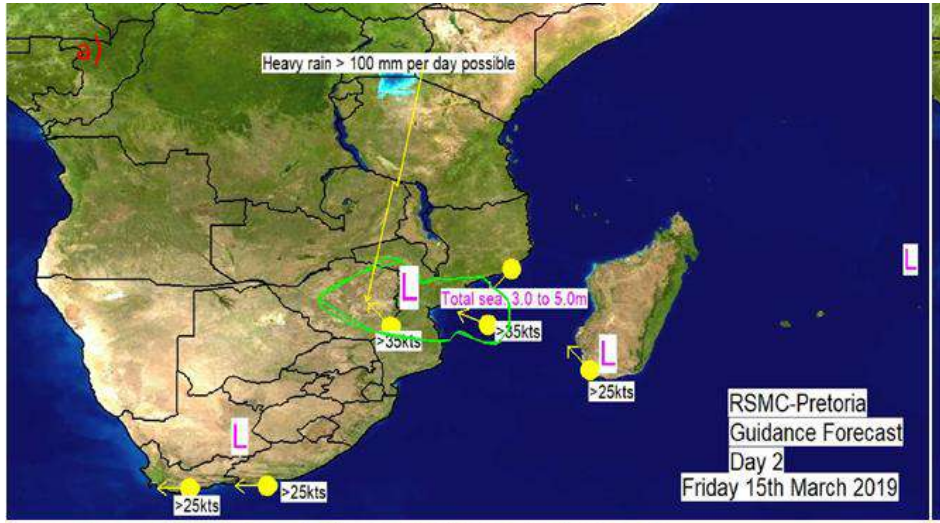
Model Intercomparison: Conclusions

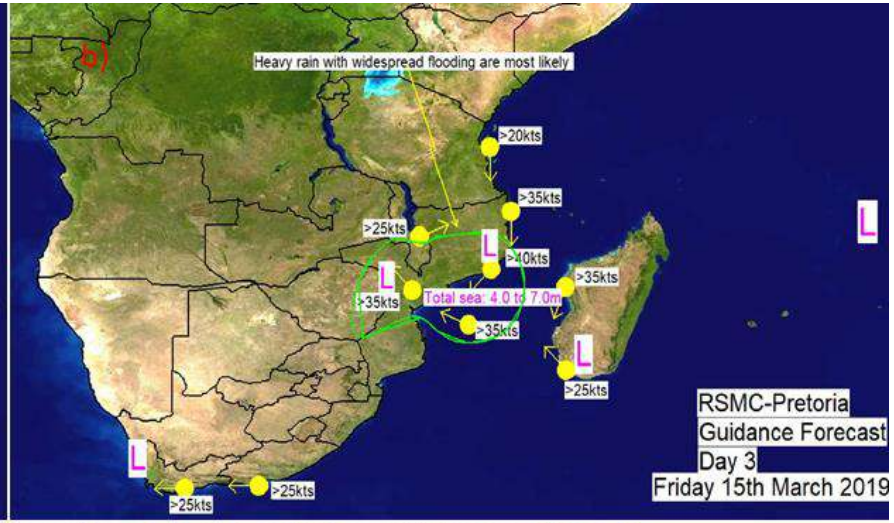
- All models captured all major events
- Wind, temperature and rainfall - generally similar
- No indication of models forced with higher resolution global model data performing better
- 10m winds underestimated across all models
- COSMO underestimated area associated with lower temperatures
- Models cooler in Limpopo province
- Mulovhedzi PM, Rambuwani GT, Bopape MM, Maisha R, Monama N, 2021: Model inter-comparison for short range forecasts over the Southern African domain. South African Journal of Science. In press (only three cases)

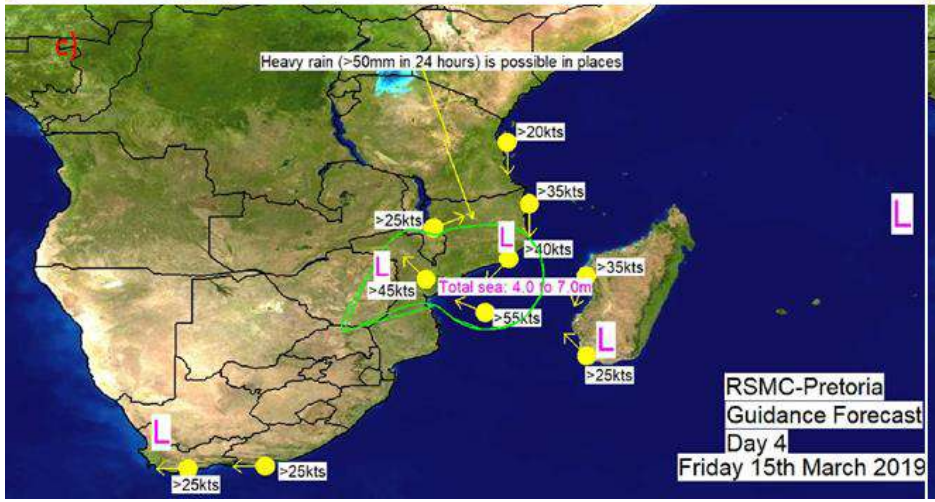
South Africa 2: South African Weather Service early warning systems

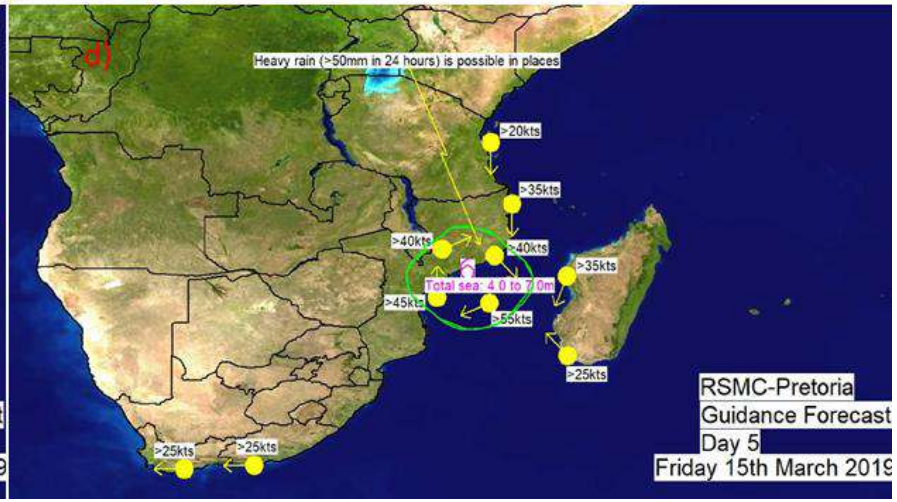
- Regional Specialised Meteorological Centre: Idai tropical cyclone (death toll: over 1000)
- National Mandate: Kwa Zulu Natal floods (death toll: over 70)
- Questions considered:
  - Model performance: Unified Model (4.4 km and 1.5km) and ECMWF IFS (16 km)
  - Availability of nowcasting to very short range system (SARFFG, SAFFG, satellite and radar tracking products)
  - Information issued from the forecasting office

Idai tropical cyclone

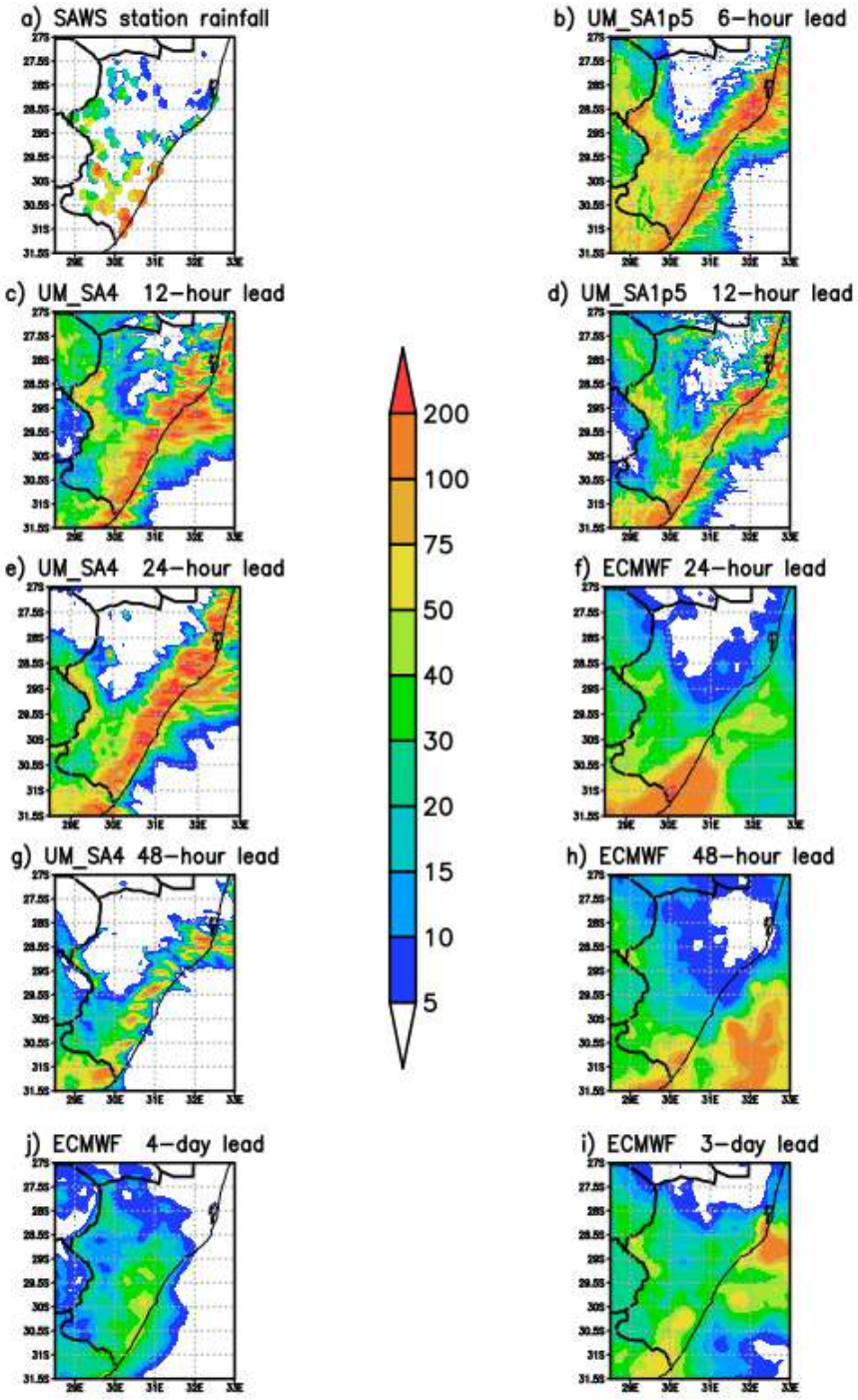








- Indication of landfall with 5 day leadtime
- Amount and area of impact revised slightly with reduced lead time
- UM in agreement with other models
- Southern African Flash Flood Guidance System available to provide information on basins likely to flood in the very short range timescale



KZN floods

- ECMWF – longest lead time: amount of rainfall increased as lead time reduced
- UM- Little change with changing lead time
- 1.5km model not better than 4.4km model
- UM extended heavy rainfall across most of coast of the province
- Forecasters issued warnings of heavy rainfall over southern parts of province
- SAFFG, radar and satellite all available for this event
- Work needed to reach those that need to respond

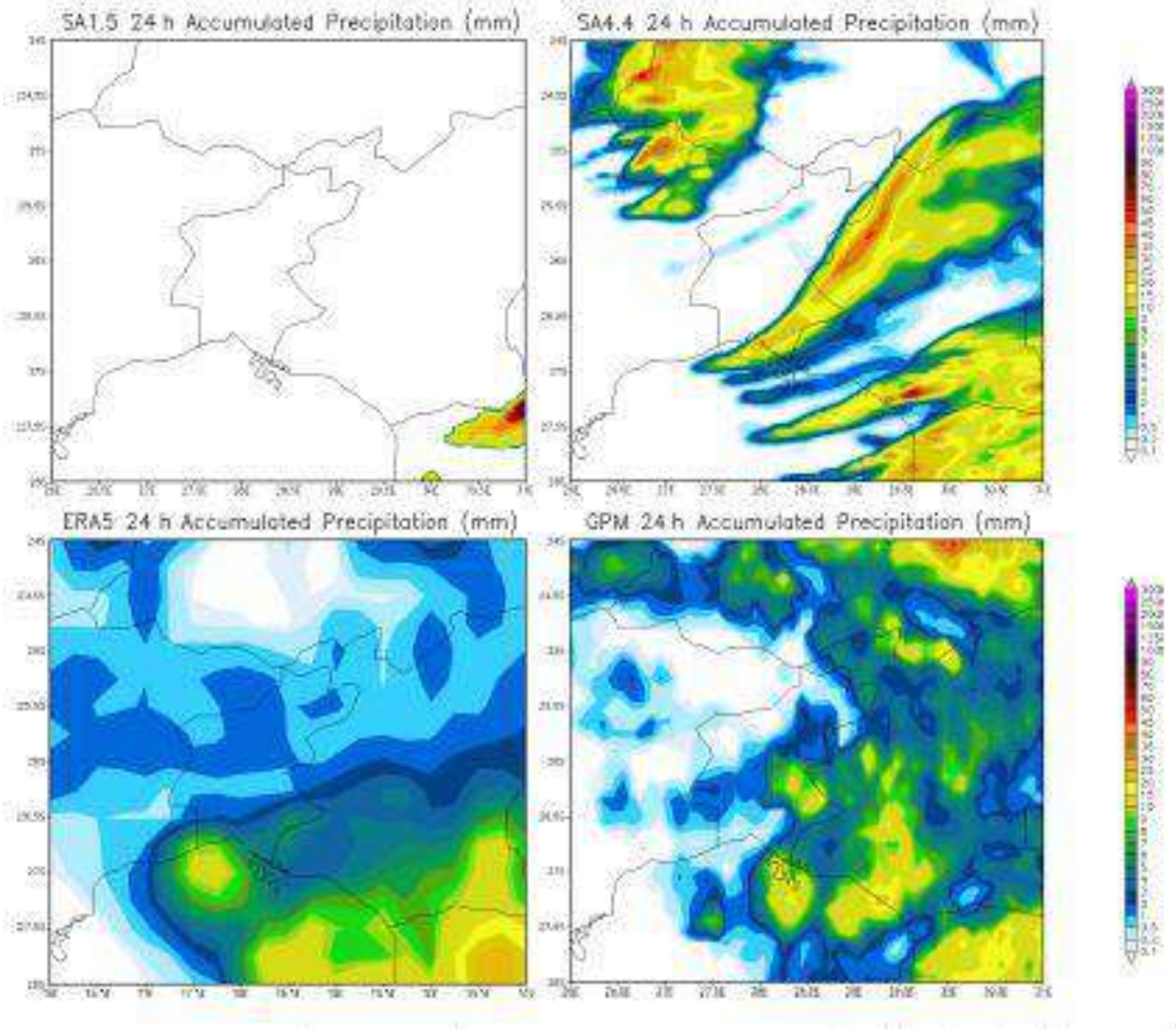
Check for updates

AUTHORS:
Mary-Jane M. Bopape[1]
Ezekiel Bebego[1]
Thando Ndarana[2]
Bathobile Maseko[1]
Masindi Netshilema[1]
Morne Gijben[2]
Stephanie Landman[1]
Elelwani Phadull[1]
Gift Rambuwani[1]
Louis van Hemert[1]

Evaluating South African Weather Service information on Idai tropical cyclone and KwaZulu-Natal flood events

Severe weather events associated with strong winds and flooding can cause fatalities, injuries and damage to property. Detailed and accurate weather forecasts that are issued and communicated timeously, and actioned upon, can reduce the impact of these events. The responsibility to provide such forecasts

South Africa 3: Tornado over Vaal Marina



- Supercell thunderstorm produced a tornado over north eastern part of South Africa (1000 people displaced)
- Model: UM SA4 and SA1p5
- Thunderstorm formed as part multicell cluster over a dry line
- SA1p5 missed it, while SA4 captured the event better but it was underestimated

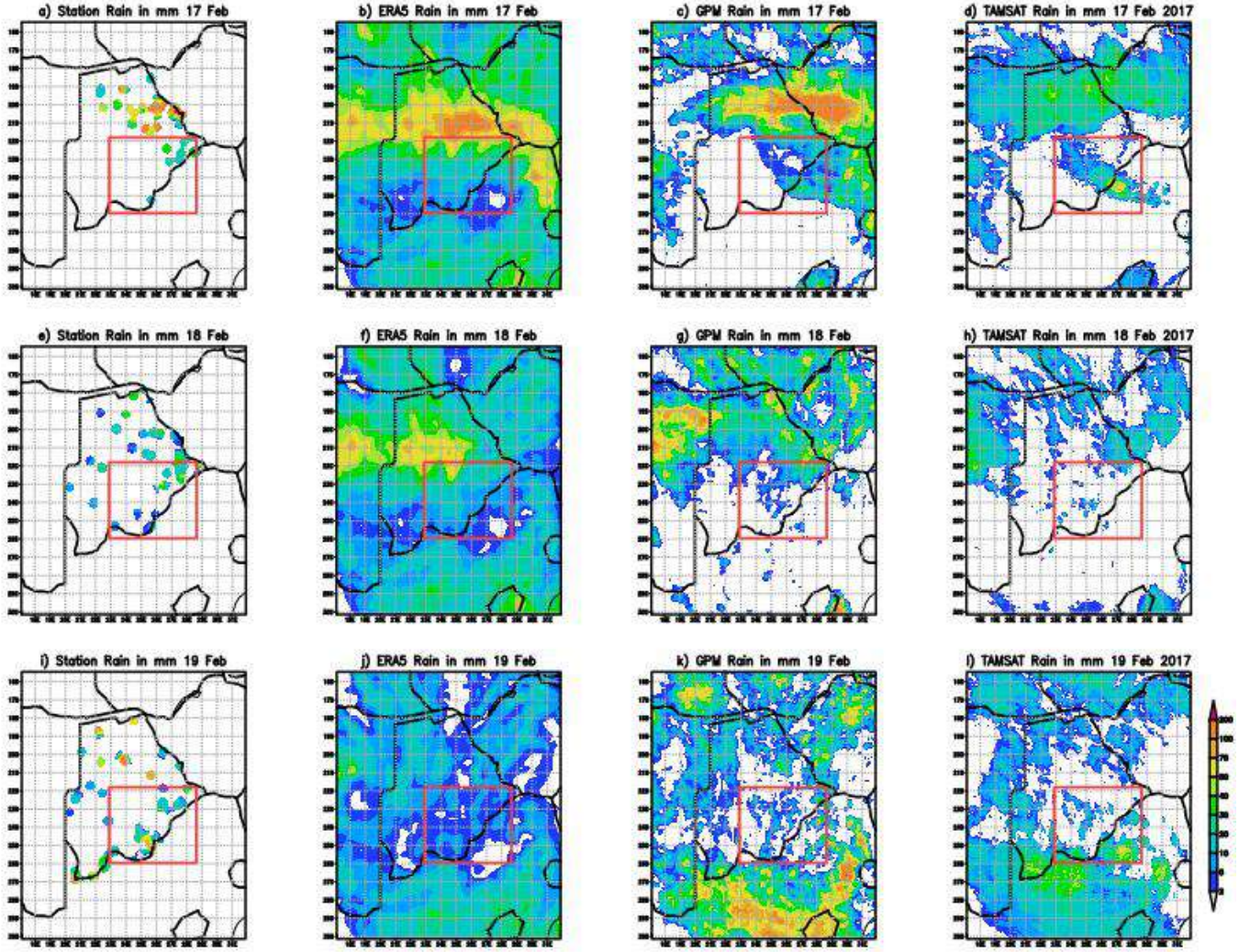
Weather Clim. Dynam., 2, 373–393, 2021
https://doi.org/10.5194/wcd-2-373-2021

Weather and Climate Dynamics
Open Access
EGU

A dynamic and thermodynamic analysis of the 11 December 2017 tornadic supercell in the Highveld of South Africa

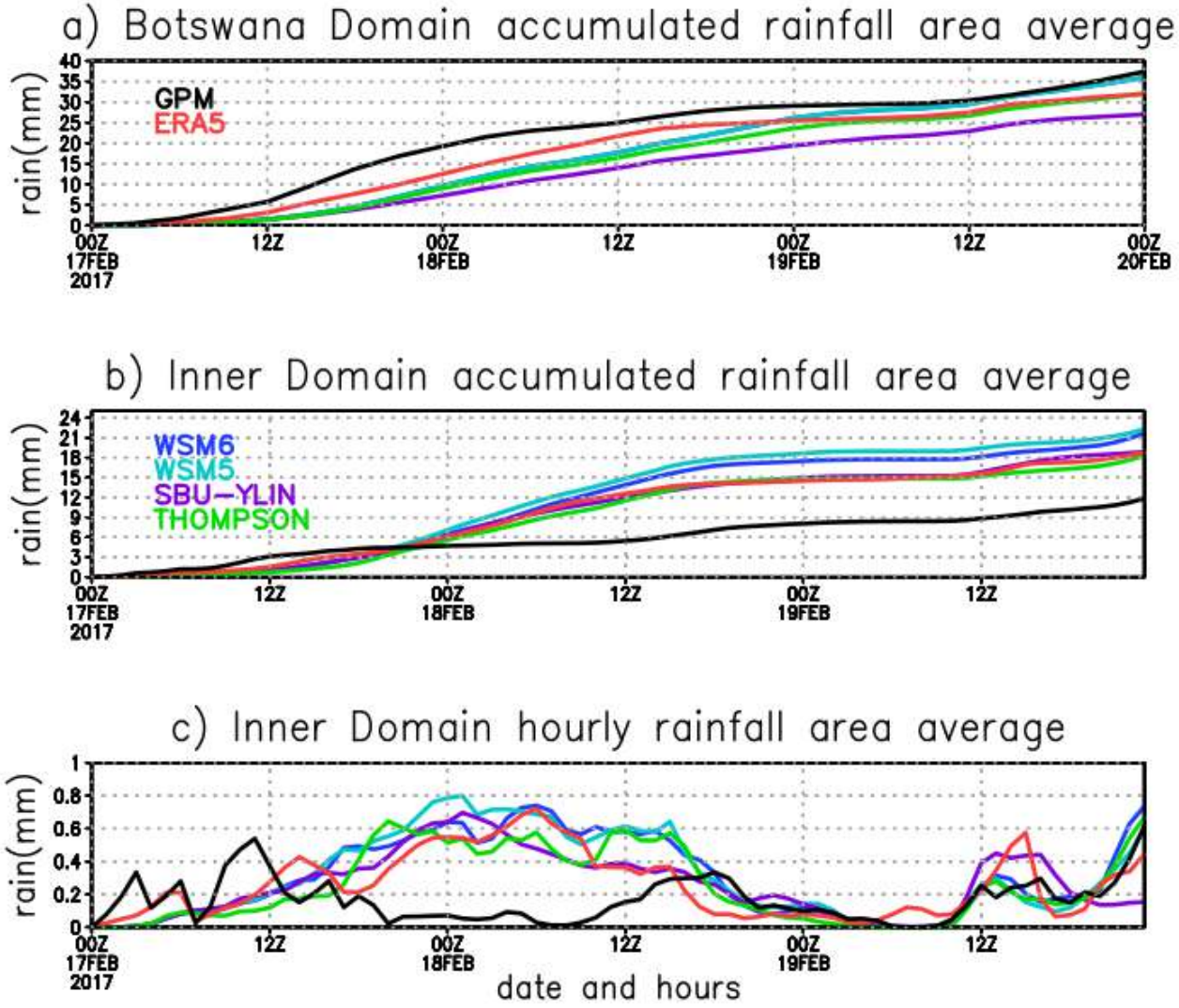
Lesetja E. Lekoloane[1,2], Mary-Jane M. Bopape[1], Tshifhiwa Gift Rambuwani[1], Thando Ndarana[3], Stephanie Landman[1], Puseletso Mofokeng[1,4], Morne Gijben[1], and Ngwako Mohale[1]

Botswana: Microphysics schemes- Extropical cyclone Dineo

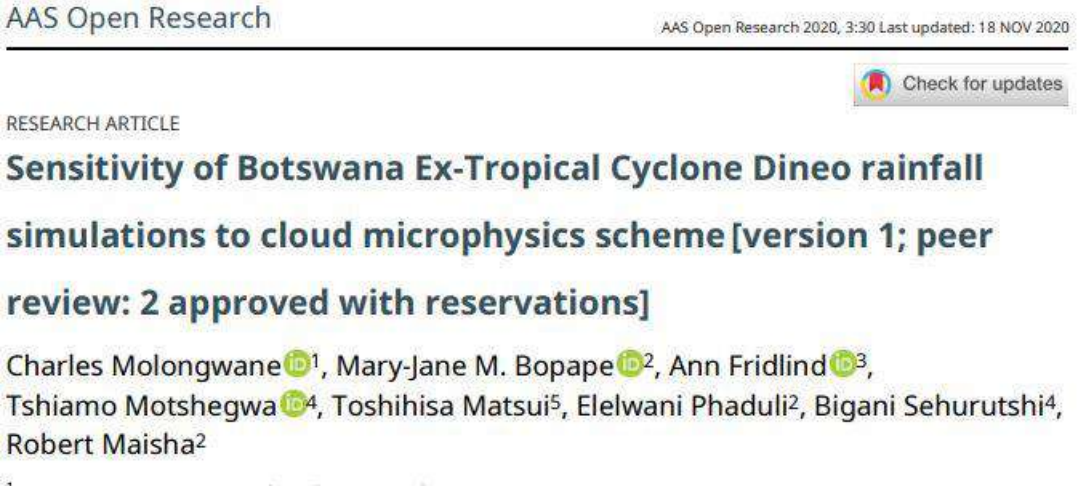


- Model: WRF
- Model setup: GFS – 9km – 3km (convection off) – 72 hour simulation
- Microphysics schemes:
  - Weather Research and Forecasting Single Moment 6-class scheme (WSM6);
  - Weather Research and Forecasting Single Moment 5-class scheme (WSM5)
  - Stony Brook University scheme (SBU-YLIN)
  - Thompson scheme

Botswana: Results



- Model simulations more similar to one another than observations to observations
- WSM6 and WSM5 – generally similar – indicates little effect of graupel for this event
- All simulations produced a vortex not seen in observations (not even ERA5)
  - Hypothesis: effect of multi-nesting


AAS Open Research

AAS Open Research 2020, 3:30 Last updated: 18 NOV 2020

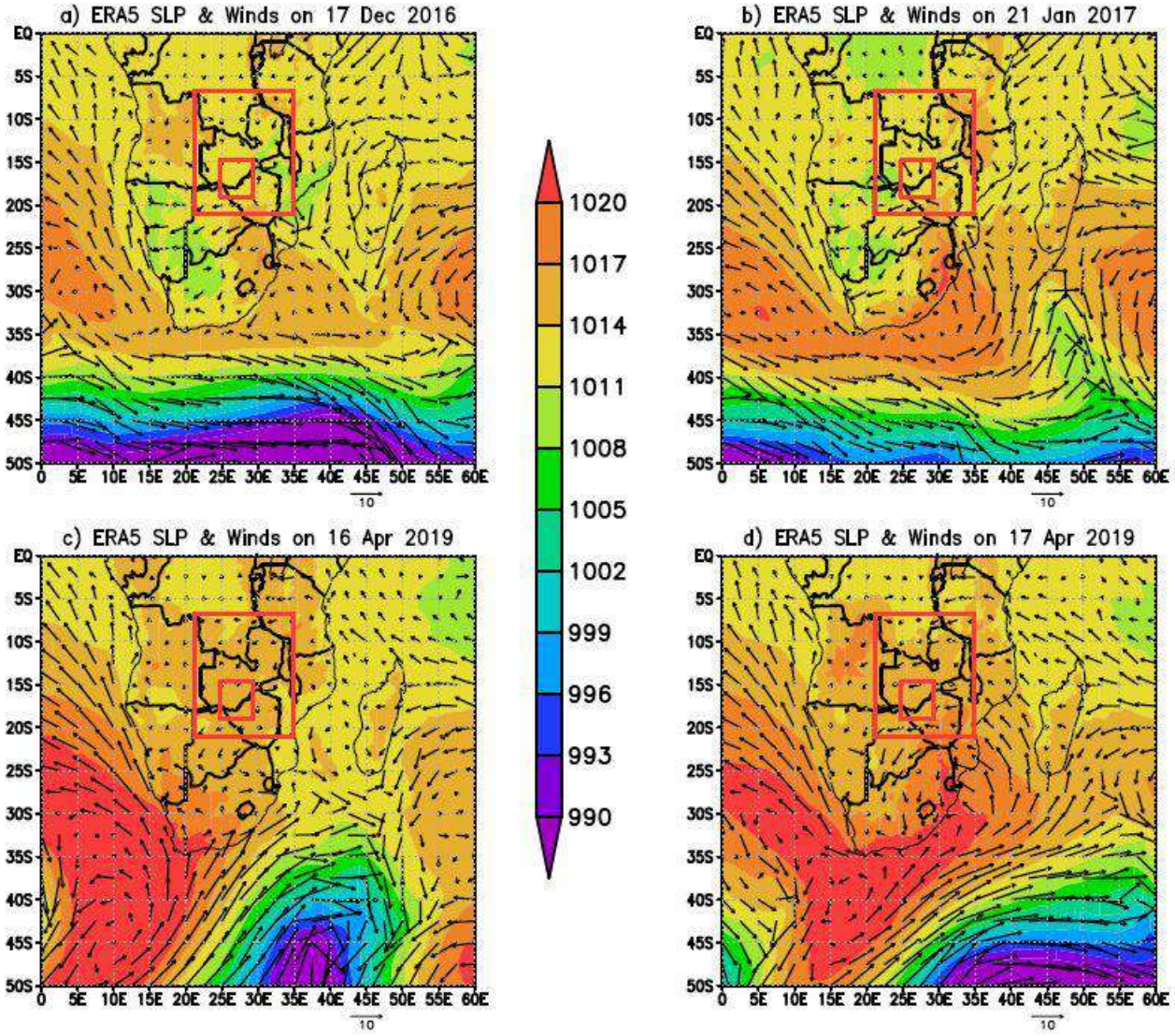
Check for updates

RESEARCH ARTICLE

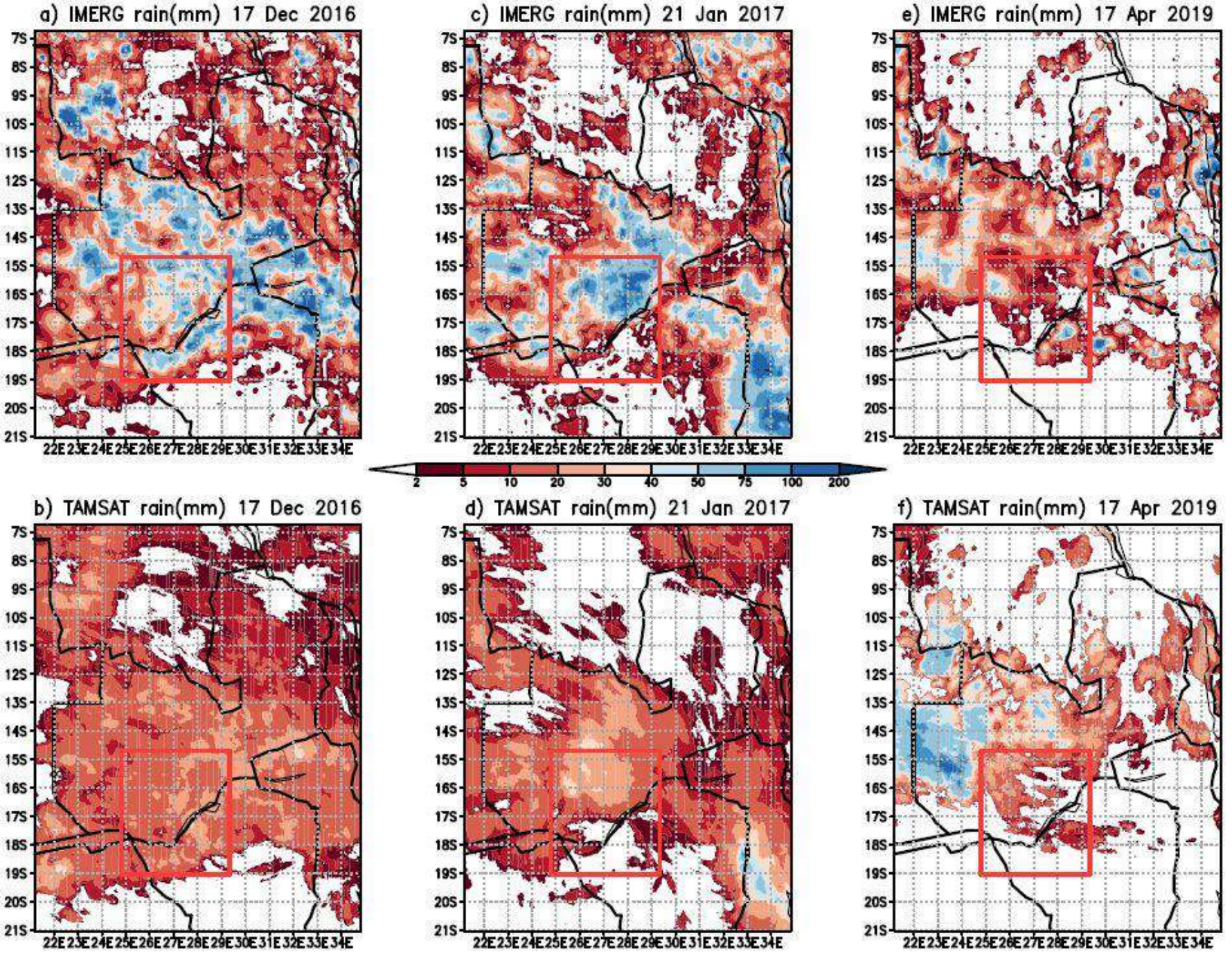
Sensitivity of Botswana Ex-Tropical Cyclone Dineo rainfall simulations to cloud microphysics scheme [version 1; peer review: 2 approved with reservations]

Charles Molongwane[1], Mary-Jane M. Bopape[2], Ann Fridlind[3], Tshiamo Motshegwa[4], Toshihisa Matsui[5], Elelwani Phaduli[2], Bigani Sehurutshi[4], Robert Maisha[2]

Zambia: PBL schemes- three heavy rainfall events



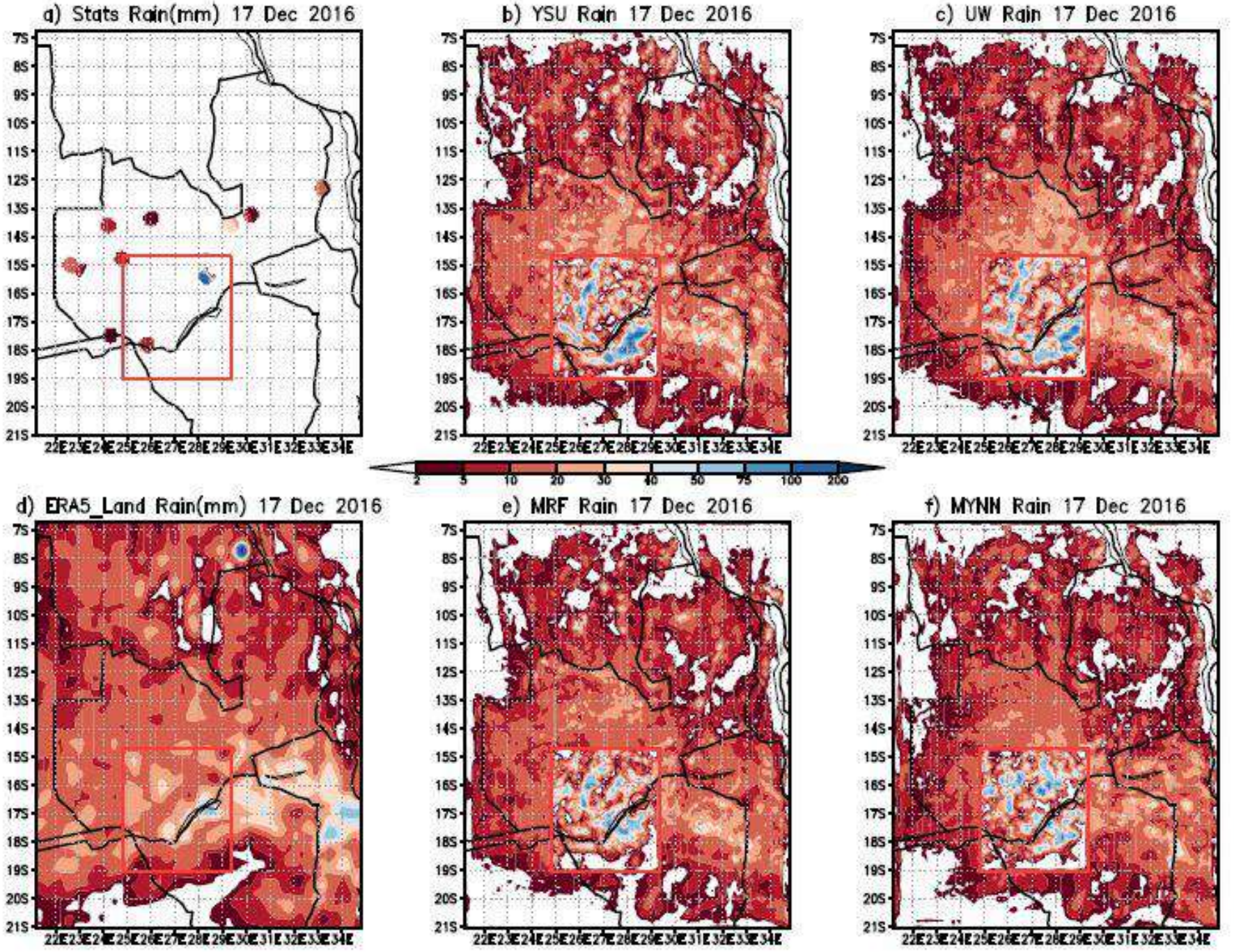
- Model: WRF
- Model setup: GFS – 9km – 3km (convection off) – 72 hour simulation
- PBLs schemes:
  - The Mellor–Yamada–Nakanishi–Niino (MYNN) PBL scheme: this scheme is the improved Mellor–Yamada scheme based on TKE.
  - The Community Atmosphere Model (CAM) University of Washington (UW) Moist Turbulence scheme: this scheme is TKE based and also considers shallow convection.
  - The Medium Range Forecast (MRF) Model PBL scheme: this scheme includes a non-local term.
  - The Yonsei University (YSU) PBL scheme: this scheme includes a diagnostic non-local term, and considers shallow convection, along with a top-down turbulence contribution associated with cloud-top radiative cooling.



Observations

- Difficult to know what the model is supposed to produce
- Good spread of ground observations needed to inform modelling studies
- "Observations" performance differs

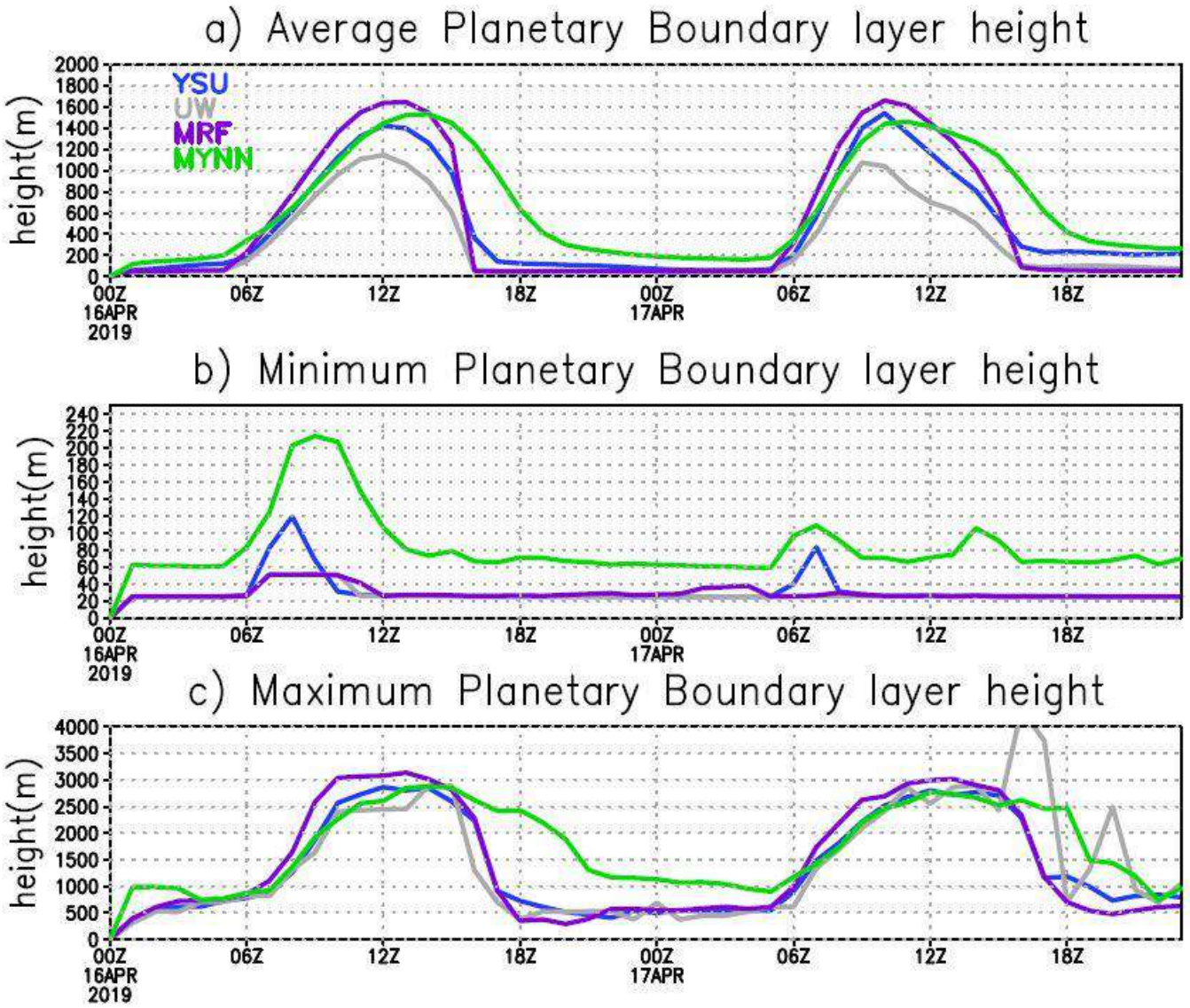
nited Nations
conomic Commission for Africa



Comparison

- Biggest difference: due to switching off the convection scheme.
- Area of heavy rainfall generally similar
- Performance statistics: not very helpful

Zambia: PBL height



- UW (TKE)– lowest PBL height
- MYNN (TKE) – delayed transition from CBL to SBL
- MRF (NL) – high PBL not supported by higher temo compared to other schemes
- YSU - recommended

climate

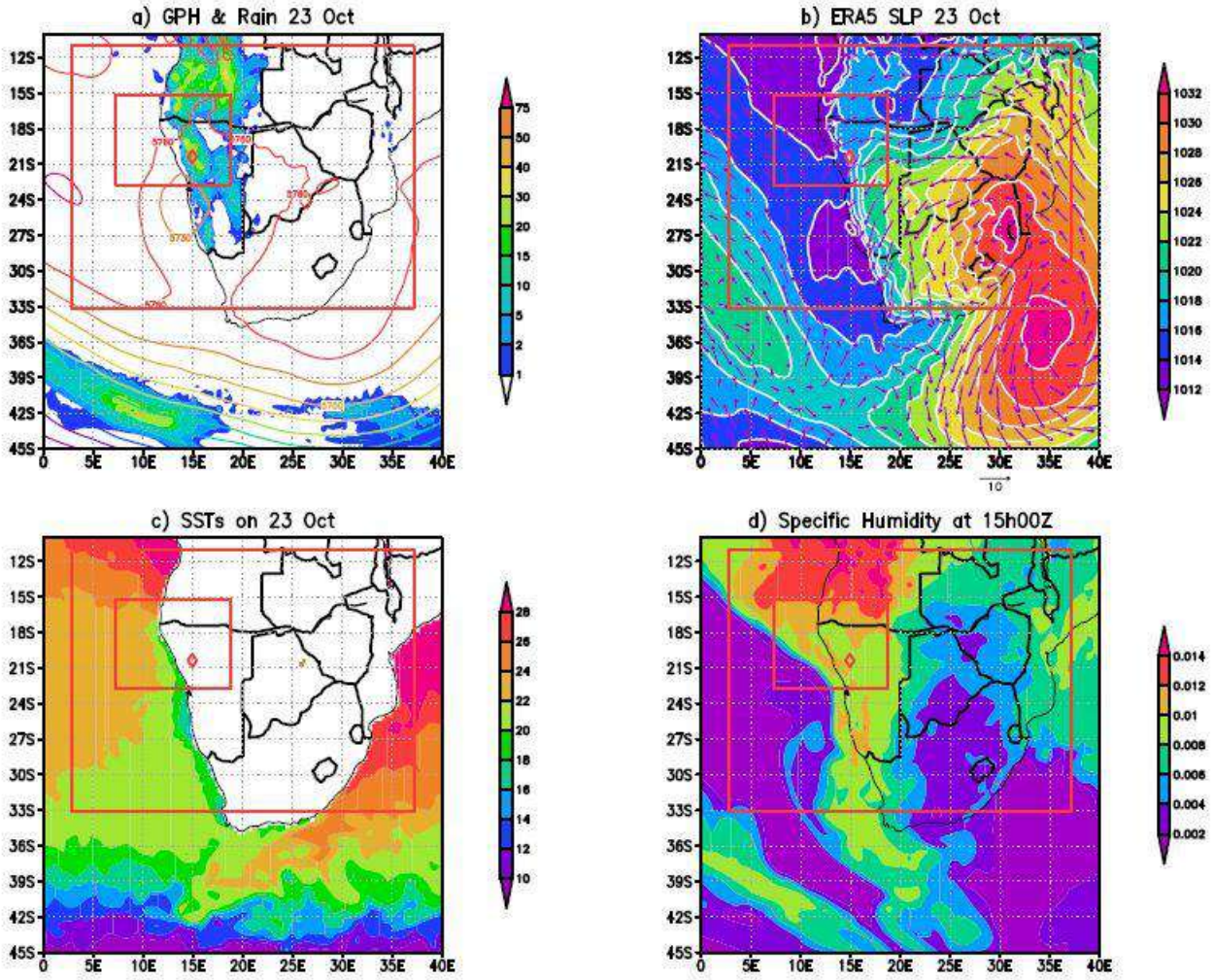
MDPI

Article

Sensitivity of Simulations of Zambian Heavy Rainfall Events to the Atmospheric Boundary Layer Schemes

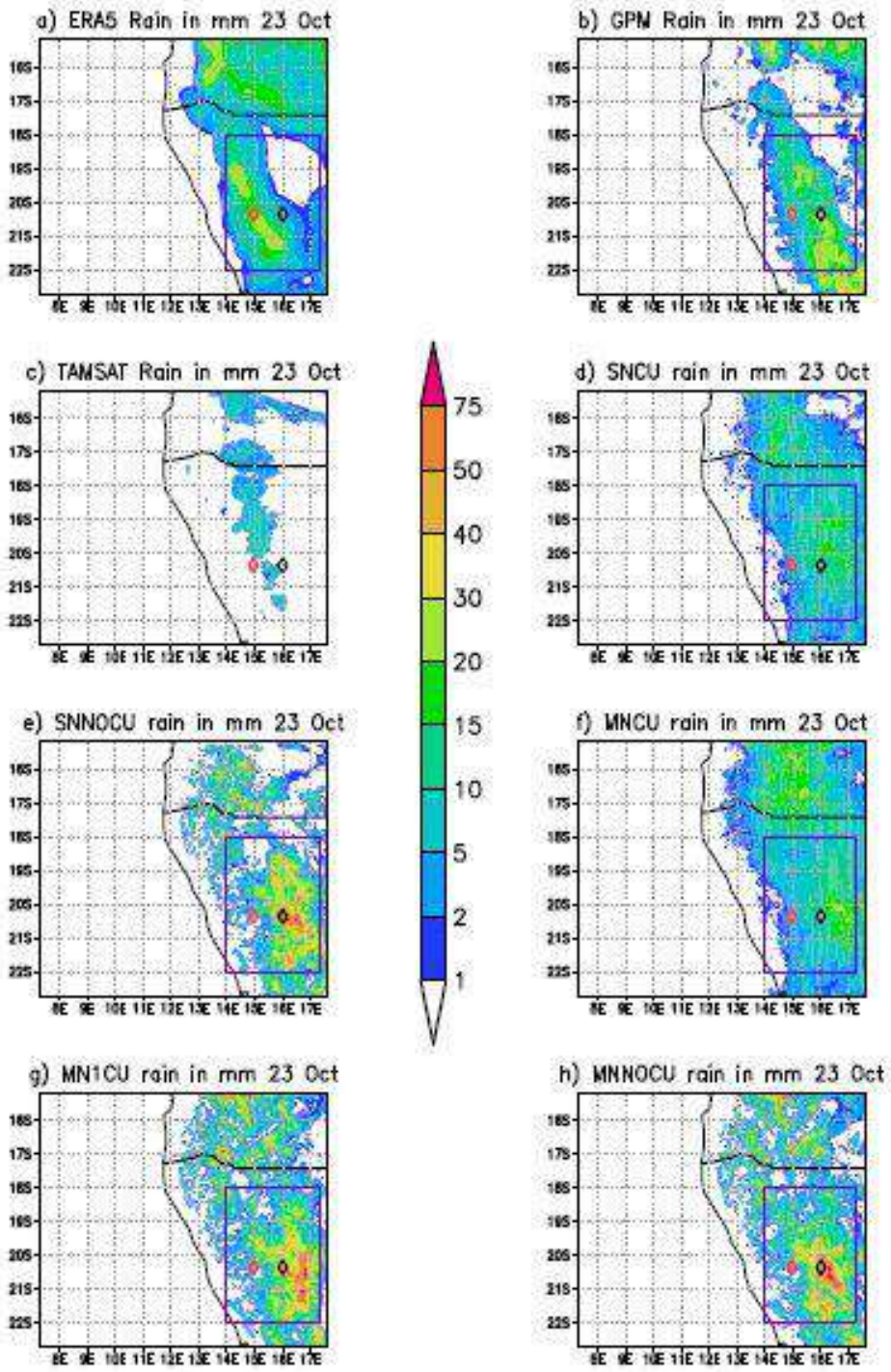
Mary-Jane M. Bopape [1], David Waitolo [2,*], Robert S. Plant [3], Elelwani Phaduli [1], Edson Nkonde [2], Henry Simfukwe [4], Stein Mkandawire [4], Edward Rakate [5] and Robert Maisha [1]

Namibia: Multi-nesting and convection scheme



- Short lived heavy rainfall in the Kunene area
- No consensus on when convection scheme needs to be switched off (Weisman - 4 km, WRF- 3km, Roberts-1km)
- 1:3-5 : Nesting

Parent Domain	Child Domain	Short Name
9 km (Yes)	3 km (Yes)	MNCU
9 km (Yes)	3 km (No)	MN1CU
9 km (No)	3 km (No)	MNNOCU
3 km (Yes)	N/A	SNCU
3 km (No)	N/A	SNNOCU



Namibia: Results

- Different “observations”
- Small differences between multi-nest and single nest
- No benefit of high resolution when convection scheme left on, even with 3km grid length
- Apply setting correctly

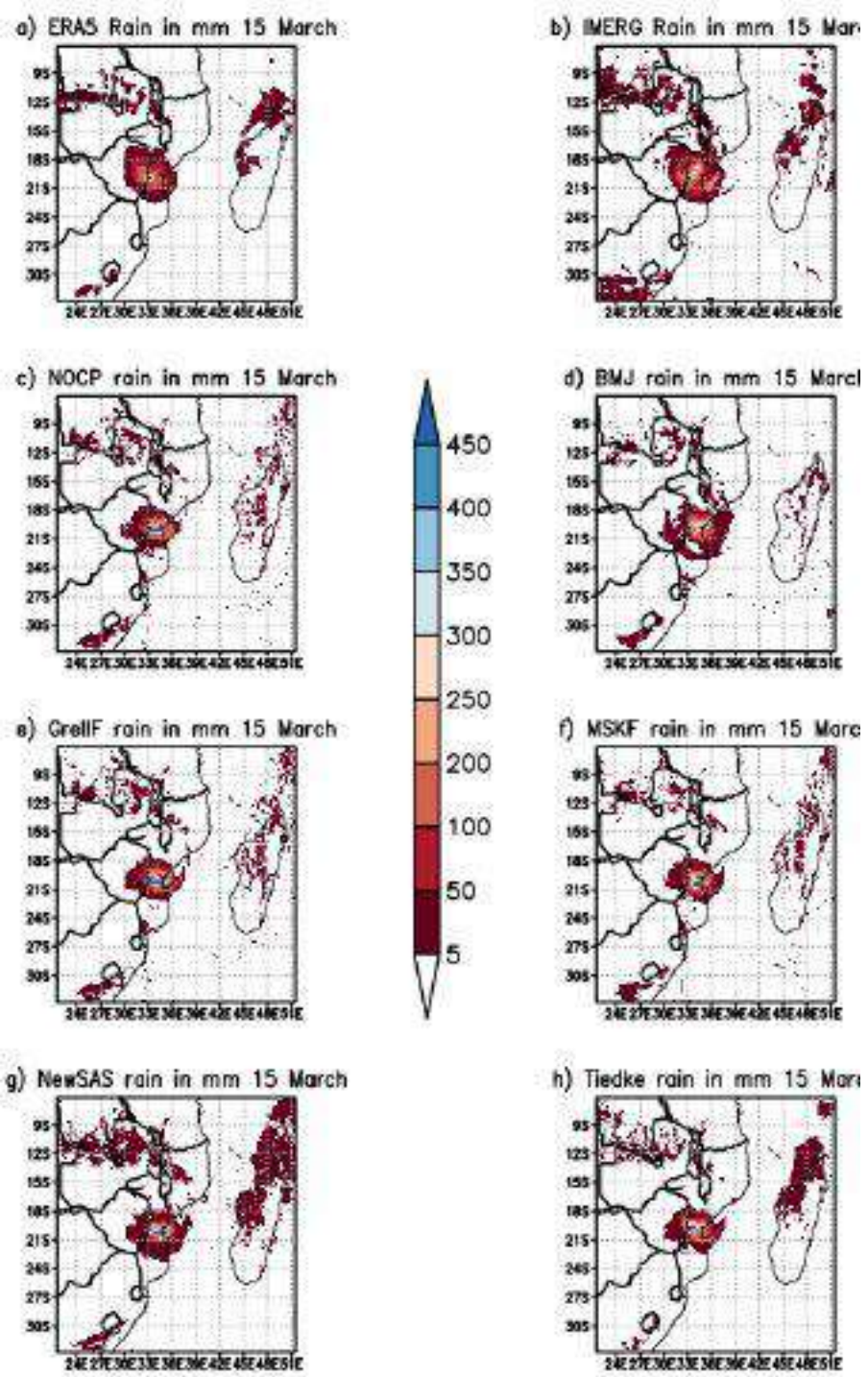
climate

MDPI

Article

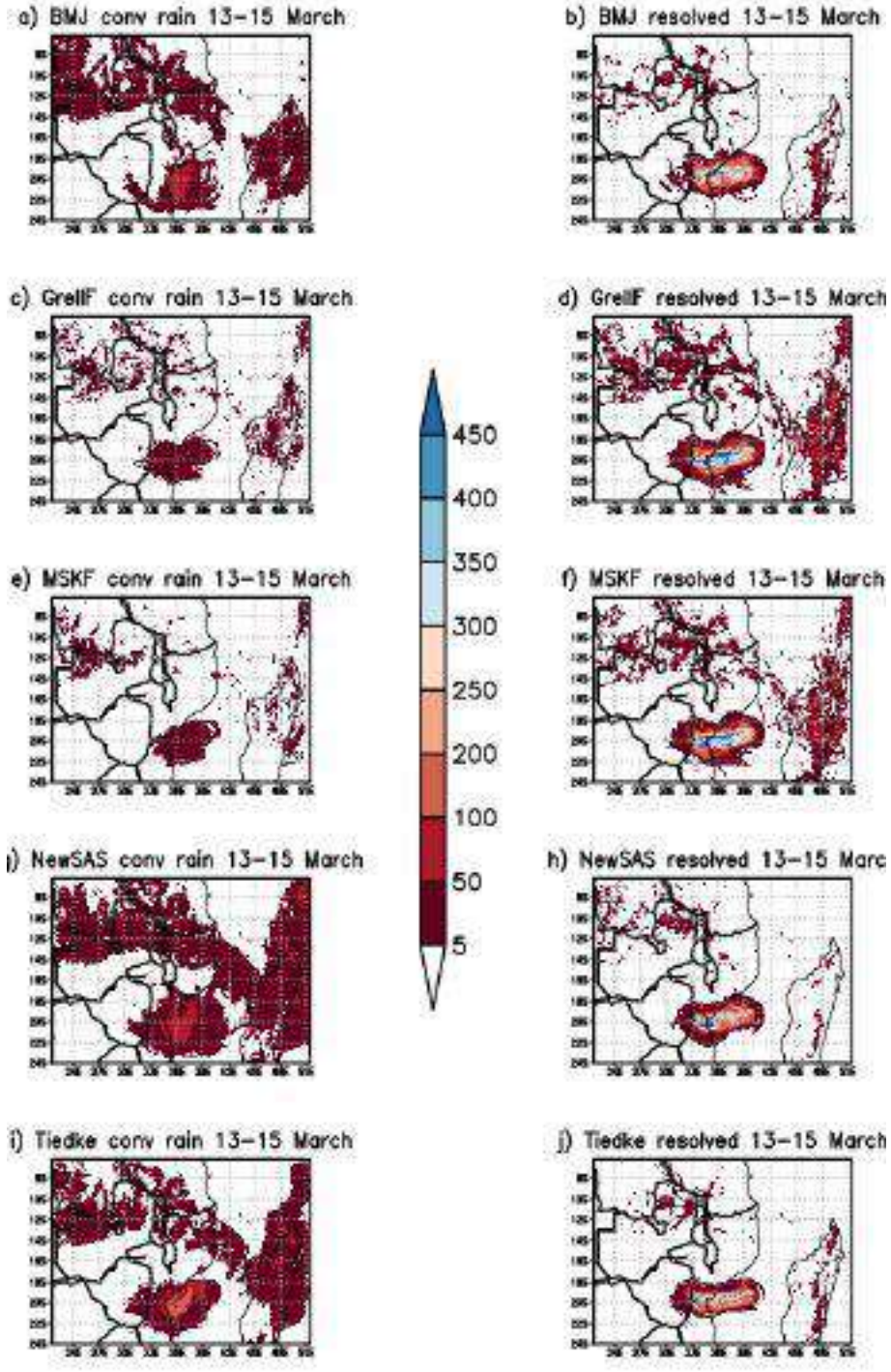
Convection Parametrization and Multi-Nesting Dependence of a Heavy Rainfall Event over Namibia with Weather Research and Forecasting (WRF) Model

Sieglinde Somses [1,*], Mary-Jane M. Bopape [2], Thando Ndarana [3], Ann Fridlind [4], Toshihisa Matsui [5,6], Elelwani Phaduli [2], Anton Limbo [7], Shaka Maikhudumu [7], Robert Maisha [2] and Edward Rakate [8]



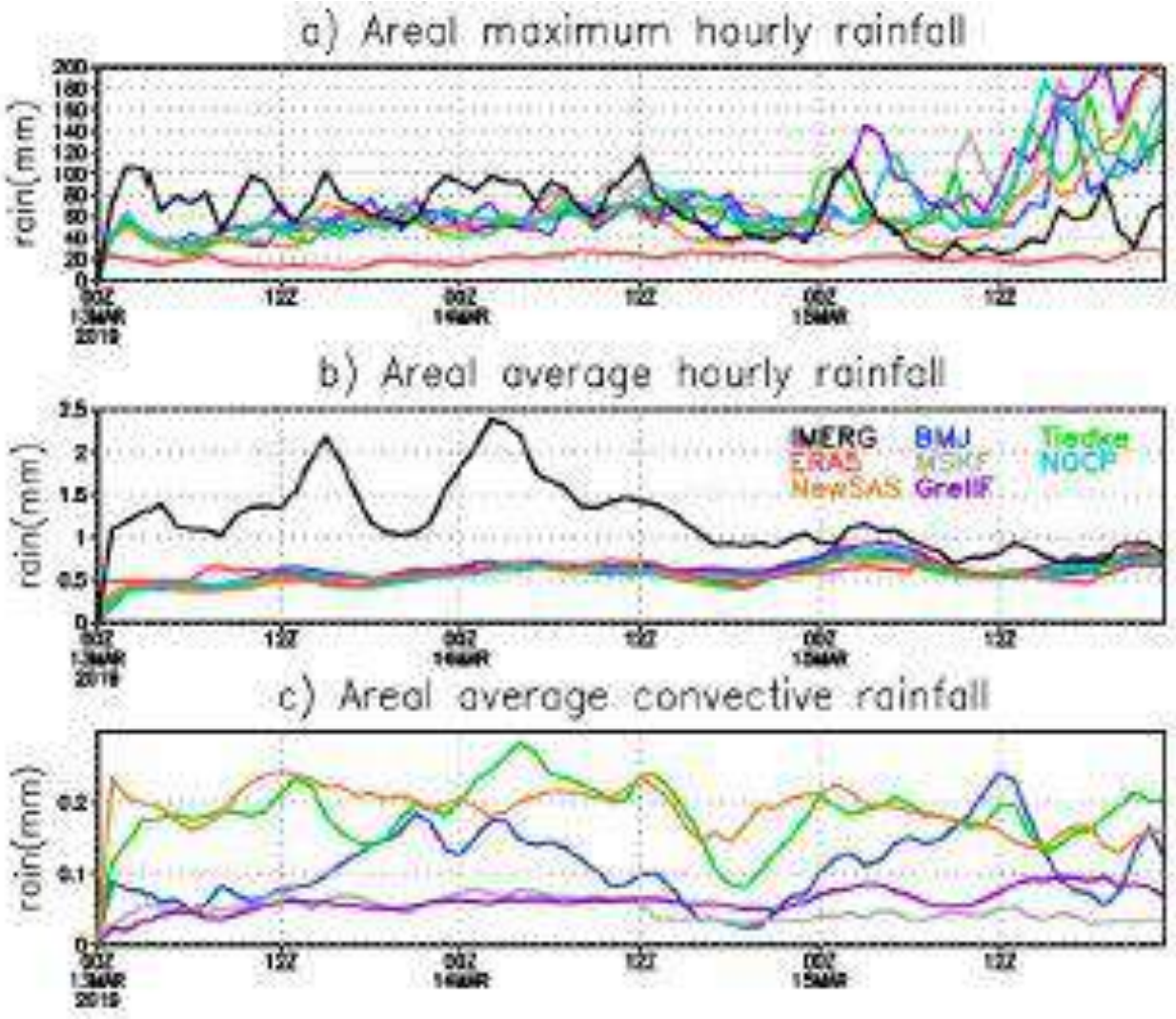
Mozambique: Idai tropical cyclone

- Tropical cyclone Idai
- 72 hour simulations
- WRF: 6km grid length
- New Simplified Arakawa Schubert (NewSAS) scheme
- The New Tiedtke scheme
- Multi-Scale Kain-Fritsch (MSKF) scheme
- Grell-Freitas scheme
- Betts-Miller-Janjic (BMJ) scheme
- No Convection scheme on

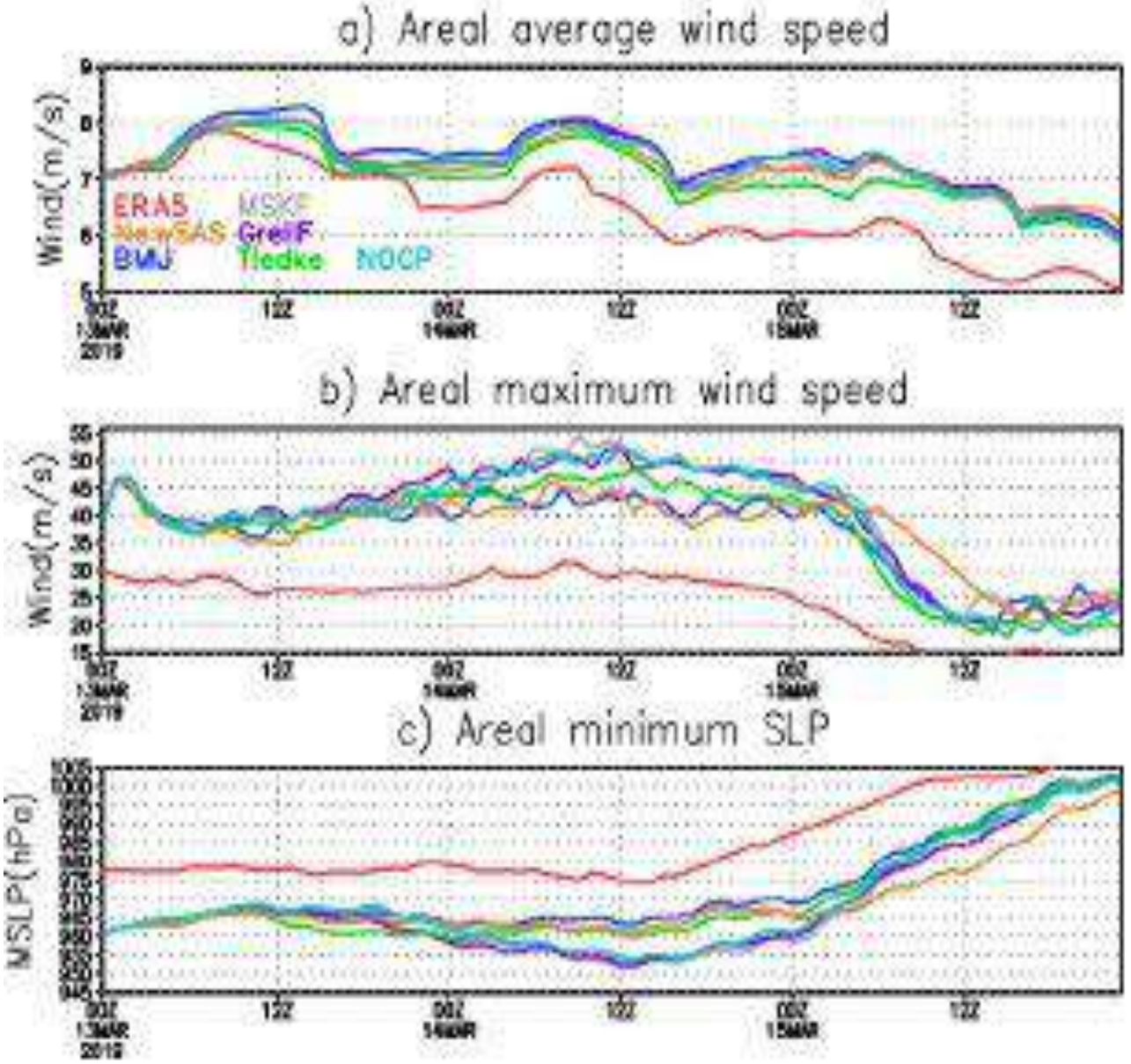


Mozambique: Idai tropical cyclone

- Scale aware schemes simulate least amount of rainfall



Mozambique: Idai tropical cyclone



- Domain wide statistics: don't single out one scheme as best performing
- Maximum wind speeds and minimum SLP underestimated in conventional schemes
- Scale aware schemes perform better in this regard
- Paper being considered in Atmosphere (revisions due)

Conclusions

- Other work:
  - Tanzania (convection schemes) – paper rejected with encouragement to resubmit. Lead author working on revisions to resubmit
  - South Africa (resolution + convection scheme) – paper rejected – all configurations missed the small scale event – study could be resurrected when there is DA scheme + sub-kilometre models
- CR4D – made collaboration within SADC between HPC specialists + weather scientists possible.
- Made it possible engagements with Ann Fridlind (cloud microphysics) and Bob Plant (cumulus schemes + PBL schemes)
- Improved modelling skills in the region- with clear research questions
- Increased research output on numerical modelling – some first time authors (6)