Ensemble forecasting and data assimilation at SAWS

Robert Maisha[1], Stephanie Landman[1] ,Mary-Jane Bopape[1] and Douglas Boyd[2]

[1] SAWS, Pretoria, South Africa; [2] UKMO, Exeter, United Kingdom

robert.maisha@weathersa.co.za

Abstract

The South African Weather Service (SAWS) applies the Unified Model (UM) to provide daily numerical weather forecasts to both South African and Southern African Development Community (SADC) respectively. The UM is run inhouse to produce deterministic and convective-scale ensemble forecasts. Also, a multi-model ensemble prediction system is applied over the SADC domain. The probabilistic predictions of a tornado event in the KwaZulu-Natal Province were captured in both temporal and spatial scale. However, a need to improve the diurnal cycle of convection has led SAWS to implement data assimilation with assistance from the UK Met Office through the Newton Fund partnership. The plan is to incorporate observations from satellites, surface and upper-air observations, including radar reflectivity data into the local DA system.

1 Introduction

The SAWS has been mandated by the South African government to produce daily weather forecasts to safeguard the nation from weather disasters. This includes extreme weather resulting from heavy rainfall, thunderstorms, floods, tropical cyclones and heatwaves. Therefore, SAWS run a numerical weather prediction (NWP) model operationally to support the weather forecasters when they produce daily forecast guidance.

In order to improve numerical forecasts, SAWS is in the process of implementing data assimilation (DA) to their numerical forecasts. In DA, the latest observations are combined with previous forecasts to create an analysis [1]–[4]. The aim of convective-scale DA is to improve forecast quality relative to Global and downscaler forecasts, over a lead time of 6-18 hours.

The DA process is applied in many global meteorological centres, whereby either three-dimensional (3DVAR) or four-dimensional (4DVAR) system is applied. These global centers include the United Kingdom's Met Office (UKMO)[5], Meteo-France [6], [7] and others. The paper is outlined as follows. In section 2, data and methodology are described, and in Section 3, the results are presented.

2 Data and methodology

2.1 The Unified Model

The SAWS applies the UM, developed by the UKMO for daily NWP purpose. The UM is a fully non-hydrostatic model. Currently, the UM version 11.4 is applied and is configured to run operationally as a regional model. Firstly, the UM is run for the SADC region at a horizontal resolution of 4.4 km, stretching north-south from 0^0 to 38^0S and from west-east (5^0E to 54^0E). The second configuration is the South African domain with a resolution of 1.5 km and stretches north-south from 20^0S to 36^0S and from west-east (15^0E to 34^0E) (Figure 1).

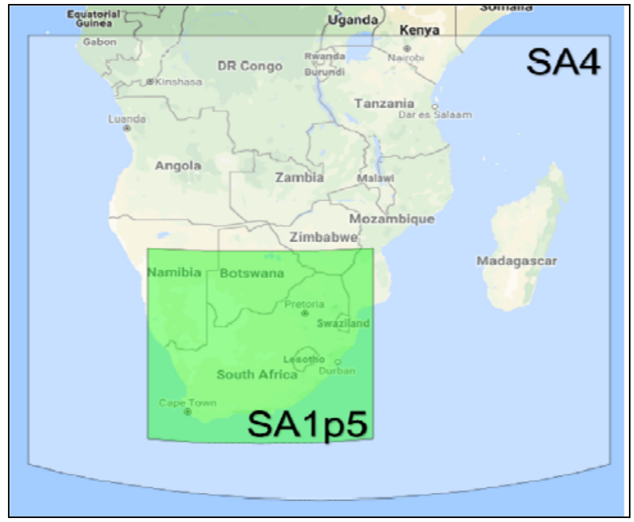

Figure 1: The UM model domains for the SA4 km and SA1.5 respectively

2.2 Data and methodology

For the two UM deterministic downscalers, initial and boundary conditions are obtained from the 10 km Global Atmosphere (GA) model, four times daily (00Z, 06Z, 12Z and 18Z) from the UKMO data server. The GA forecasts support several regional models within the UM partnership.

The SAWS UM convection permitting ensemble prediction system (CSEPS) has a horizontal resolution of 4.5 km, covering the South African domain and consist of 18 members. The system runs with initial and boundary conditions from the UKMO global ensemble prediction system (MOGREPS-G)[8].

A multi-model ensemble (MMENS) prediction system was developed with a domain covering the SADC region (similar to the 4.4 km UM downscale). The system combines forecasts from different global and regional model configurations such as (i) SAWS-SADC configuration (4.4 km), (ii) German Weather Service's (DWD) ICON (13 km), (iii) NCEP Global Forecast System (GFS, 25 km) and (iv) UKMO Global Atmosphere (GA, 10km). All four ensemble members are rescaled to a corresponding horizontal resolution of 6 km. To achieve an ensemble size of 12 members, a pseudo-ensemble method[9] is performed on each model to obtain six additional members. The MMENS produces forecasts with a lead time of 48 hours once a day at 00Z.

2.3 Implementation of DA

SAWS is in the process of implementing the Convective-Scale Data Assimilation Common Test Framework (CSDA-CTF), originally developed as part of the SINGV project (a collaboration between the Met Office and Meteorological Service Singapore), which provides UM partners with a portable way to run and validate regional DA configurations. A 4.5km resolution 3-hourly cycling 3D-Var configuration of CSDA-CTF has been setup, for research purpose on a CRAY (XC30) machine, to assimilate observations from the Met Office and this will in future be extended to assimilate data from SAWS observation network.

3 Results

In this report, we present the results for the case studies from the deterministic downscaler forecasts, SAWS multi-model ensemble forecasts as well as CSEPS forecasts. We present a case study of a tornado event over the Kwazulu-Natal Province of South Africa (Figure 2). Tornado occurrences are common over the north-eastern parts of South Africa, with an average of 7 events per year. During November 2019, three tornado events (12, 22 and 23 November) occurred over KwaZulu-Natal. The late afternoon tornado event over the town of Hanover on 12 November 2019 is presented here. Two fatalities were reported, including several injuries and damages to houses, trees and vehicles. The 18Z CSEPS forecast of maximum reflectivity, as well as observed maximum reflectivity, is presented in Figure 2. The CSEPS captured the spatial and temporal observed location of the storm. The probabilistic forecast over Kwazulu-Natal also captured the areas of reflectivity higher than 30 dBz and the temporal distribution of wind speed (Figure 3).

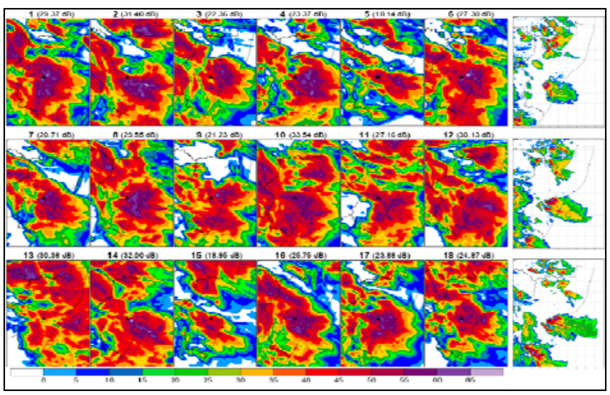

Figure 2: Postage stamps of the 18 members from the 18Z 11 November 2019 forecast for the maximum reflectivity between 15–18 for 12 November 2019. Maps to the right are the maximum reflectivity observed for 15, 16 and 17Z. The black triangle is the location of the observed tornado at Hanover.

4 Discussion and conclusions

From the results presented, ensembles have captured the probability of an extreme event occurrence. The CSEPS captured both the spatial and temporal scale of the extreme event. Future work will look at providing operational forecasts products, ingesting local observations to DA, operationalizing DA and producing DA forecasts at high resolution of about 1 km.

Acknowledgements (Optional)

The authors would like to thank the UKMO UM Partnership for funding the NCMRWF trip and the NCMRWF for the invitation.

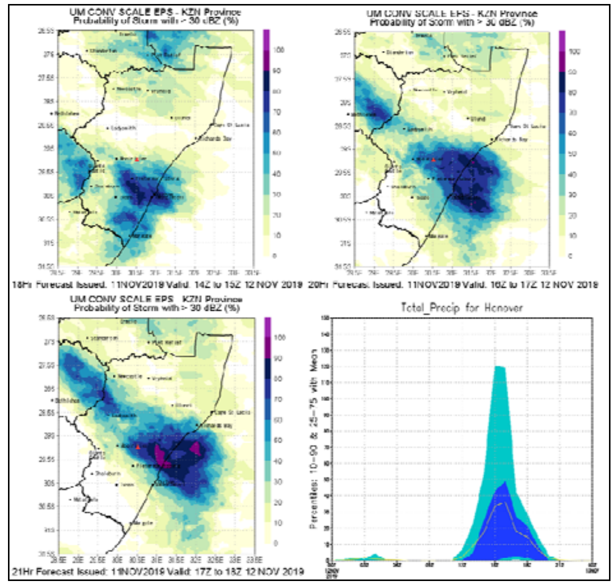

Figure 3: The three hourly probabilistic forecasts for reflectivity exceeding 30 dBZ. The last image indicates the spread of the total rainfall for Hanover.

References

[1] D. M. Barker, W. Huang, Y.-R. Guo, A. J. Bourgeois, and Q. N. Xiao, "A Three-Dimensional Variational Data Assimilation System for MM5: Implementation and Initial Results," *Mon. Weather Rev.*, vol. 132, no. 4, pp. 897–914, 2004.

[2] D. Barker *et al.*, "The weather research and forecasting model's community variational/ensemble data assimilation system: WRFDA," *Bull. Am. Meteorol. Soc.*, vol. 93, no. 6, pp. 831–843, 2012.

[3] A. M. Clayton, A. C. Lorenc, and D. M. Barker, "Operational implementation of a hybrid ensemble/4D-Var global data assimilation system at the Met Office," *Q. J. R. Meteorol. Soc.*, vol. 139, no. 675, pp. 1445–1461, 2013.

[4] F. Rabier, "Overview of global data assimilation developments in numerical weather-prediction centres," *Q. J. R. Meteorol. Soc.*, vol. 131, no. 613, pp. 3215–3233, 2006.

[5] A. C. Lorenc and M. Jardak, "A comparison of hybrid variational data assimilation methods for global NWP," *Q. J. R. Meteorol. Soc.*, vol. 144, no. 717, pp. 2748–2760, 2018.

[6] Y. Seity *et al.*, "The AROME-France convective-scale operational model," *Mon. Weather Rev.*, vol. 139, no. 3, pp. 976–991, 2011.

[7] L. Auger, O. Dupont, S. Hagelin, and P. Brovelli, "AROME – NWC : a new nowcasting tool based on an operational mesoscale forecasting system," no. July, pp. 1603–1611, 2015.

[8] S. Hagelin, J. Son, R. Swinbank, A. McCabe, N. Roberts, and W. Tennant, "The Met Office convective-scale ensemble, MOGREPS-UK," *Q. J. R. Meteorol. Soc.*, vol. 143, no. 708, pp. 2846–2861, 2017.

[9] S. E. Theis, A. Hense, and U. Damrath, "Probabilistic precipitation forecasts from a deterministic model: A pragmatic approach," *Meteorol. Appl.*, vol. 12, no. 3, pp. 257–268, 2005.