Performance of the WRF Model in simulating the Tropical Temperate Troughs over southern Africa

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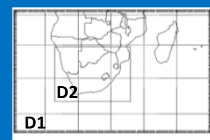
INTRODUCTION

The dominant weather systems contributing to the spatial and temporal distribution of the rainfall over Southern Africa during the austral summer season (December to February, DJF) are the Tropical Temperate Troughs (TTT).

The TTTs form due to the interactions among the tropical convective systems and the extratropical transient eddies and extend from northwest to southeast; from the southern African landmass to the southwest Indian Ocean (SWIO).

In this study we evaluated the WRF model in simulating the TTT events observed over southern Africa during January 1998 and January 2011.

Model Domain



Domain	D1	D2
Horizontal resolution	27 km	9 km
Grid point (E-W)	215	247
Grid point (N-S)	150	199
Topography resolution	30 s	30 s

MODEL, DATA AND METHODOLOGY

Weather Research and Forecasting (WRF) model (Skamarock, et al. 2008) is used to simulate two extreme rainfall events observed over southern Africa during (i) 1-6 January 1998 and (ii) 20-23 January 2011.

To test the sensitivity of the results to the cumulus parameterization scheme used in the model, we made the model runs with four different cumulus schemes viz Kain-Fritsch scheme (KF; Kain, 2004), Betts-Miller-Janjic scheme (BMJ; Janjic, 1994; Betts and Miller, 1986), and two Grell schemes (Grell and Devenyi, 2002) namely Grell-Devenyi ensemble (GDE) and Grell-3D ensemble (G3DE).

The initial 3-dimensional atmospheric fields and time varying boundary conditions were taken from the NCEP Reanalysis II available at 2.5 degree resolution and at 6 hours interval.

RESULTS AND DISCUSSION

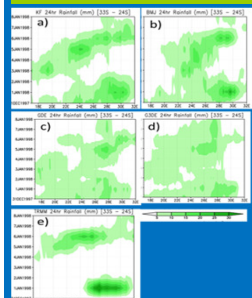


Fig. 1: Time-Longitude section of daily Rainfall (mm) averaged over the latitude zone 33^0S – 24^0S.

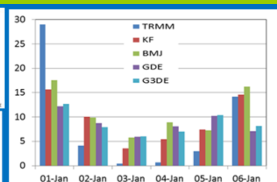


Fig. 2: Model simulated and TRMM obtained Rainfall (mm) averaged for the region 24^0E – 30^0E and 32^0S – 25^0S.

Event I: 1-6 Jan 1998

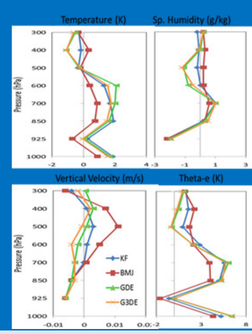


Fig. 3: Vertical profiles of the differences of Model-NCEP averaged over the domain 24^0E – 30^0E and 32^0S – 25^0S for 1 January 1998.

The KF simulated rainfall (Fig 1a) captures the heavy rainfall events of 1st and 6th Jan though the intensity of the rainfall is less compared to the observed. The model with the BMJ scheme (Fig 1b) could also capture the events though with less intensity and could not capture the break in the rainfall. The Grell schemes had (Fig 1c, 1d) difficulty in simulating the heavy rainfall during both the events.

Area averaged (24^0E - 30^0E and 32^0S – 25^0S) rainfall (Fig. 2) shows that the KF scheme simulated rainfall are comparable to observations throughout the period. However, the KF scheme along with all the other schemes had difficulty in simulating observed intensity of the heavy rainfall event of 1st Jan 1998.

The vertical profiles of the error (Fig.3) of 1 Jan 1998 shows that all the schemes simulated a warmer middle atmosphere with BMJ being closer to the observations. The specific humidity simulated by KF and BMJ schemes are comparable to observations. The GR simulated equivalent potential temperature profile error becomes more negative with height in the middle levels, indicating a more unstable atmosphere compared to observations. The reason for the less rainfall in GR may be due to the infrequent triggering of the scheme.

Fig.4 shows four days accumulated rainfall (mm/day) for the heavy rainfall event of 20-23 January 2011. All the schemes simulated the heavy rainfall zones over Southern Africa though weaker in magnitude. Area averaged rainfall (Fig.5) shows that the rainfall simulated by KF scheme is closer to observations compared to other schemes. The KF and BMJ simulated vertical profiles of the temperature, specific humidity and equivalent potential temperature are closer to the observations. BMJ scheme produces less convective rainfall and more non-convective rainfall compared to other three schemes. Fig. 6 shows that KF and BMJ scheme produce high integrated moist static energy (MSE) compared to the GDE and G3DE scheme but lesser than the magnitude of reanalysis value. The rainfall produced by KF scheme coincides with the region of maximum MSE and close to the reanalysis. The higher value of MSE generated by KF and BMJ scheme can be attributed to the comparatively high amount of specific humidity simulated by the model.

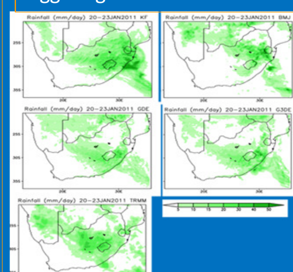


Fig. 4: Four days accumulated rainfall (mm/day) for the heavy rainfall event during 20-23 January 2011.

Event II: 20-23 Jan 2011

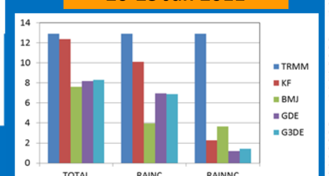


Fig. 5: Four days accumulated total, convective and non-convective rainfall (mm/day) for the heavy rainfall event during 20-23 January 2011.

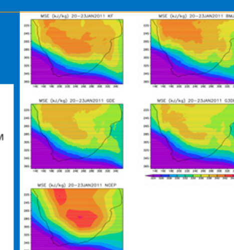


Fig. 6: Integrated moist static energy (kJ/kg) averaged for the period 20-23 January 2011.

CONCLUSION

In this study we tried to validate the WRF model for the simulation of TTTs and to test the sensitivity of the model results to four different cumulus parameterization schemes.

We chose two case studies for the study that produced heavy rainfall over Southern Africa.

The results show that all the schemes are able to simulate the large scale features of the heavy rainfall events. However, large differences were seen in the temporal and spatial rainfall distribution.

It is seen that the KF scheme simulated the regional rainfall most-accurately among all the cumulus schemes.

The difference in the simulated regional rainfall was due to the differences in the simulation of the vertical profiles of specific humidity, temperature and equivalent potential temperature.

REFERENCES

Skamarock, W. C., J. B. Klemp, J. Dudhia, D. O. Gill, D. M.Barker, M. G. Duda, X-Y. Huang, W. Wang, and J. G. Powers, 2008: A description of the Advanced Research WRF version 3. NCAR Tech.Note, NCAR/TN-475STR, 113 pp.

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