Sensitivity of WRF microphysics schemes: case study of simulating a severe rainfall over Egypt

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Abstract. In this work, sensitivity of ten microphysics schemes of Weather Research and Forecasting model were compared to determine which is more accurate. A case study of heavy rains over the Red Sea coast of Egypt on 26th October 2016 that caused damaging floods is the subject of this study. Three coastal areas were chosen, the city of Ras Ghareb, Wadi Elgemal National park, and Elba National park. The output precipitation from the model was compared to the satellite data obtained from Tropical Rainfall Measuring Mission (TRMM). Our analysis showed that the model has the capability to simulate the rainy events spatially and produce the cloud pattern. The results showed also that the model generally tends to overestimate the precipitation for all the ten schemes compared to TRMM data.

Keywords. Precipitation, WRF, Microphysics, TRMM

1. Introduction
Extreme weather events have negative impacts on communications and transportations, consequently resulting in catastrophic effects on distinct aspects of people’s lives and economy, Figure 1. Egypt, despite being mostly desert land, is susceptible to multiple severe rainfalls over its coastlines every year with effects extending sometimes over the entire country. Which urged for the need for prediction system to help authorities take preventive measures. Different numerical weather models alongside observations from both ground stations and satellite data are the base of such systems. Weather Research Forecast (WRF) model shows the capability to simulate such events and can be considered a corner stone of a prediction system [1]. WRF was also used before to simulate similar rainy event over Sinai Peninsula, Egypt on 18th January 2010 [2]. Microphysics schemes in numerical models play key role in simulating formation of cloud droplets, precipitation and land surface temperature (LST). It’s also considered a key parameter in many hydrological, meteorological and environmental studies as it merges the interactions between the surface - atmosphere and energy fluxes between the atmosphere and the surface [3]. In this paper the effect of alternating microphysics schemes on simulating the rainfall that extended for two days was investigated and validated against satellite observations obtained from Tropical Rainfall Measuring Mission (TRMM) over three coastal regions.
2. Data preparation

Weather Research Forecasting (WRF) framework is an efficient framework for atmospheric simulation systems on different scales and one of the most used tools in both research and operational applications. The WRF Software Framework (WSF) works as an incubator for the dynamics solvers, physics packages that deals directly with the solvers, programs for initialization, chemistry and WRF Data Assimilation module (WRFDA). WSF contains two dynamics solvers (Both are Eulerian mass dynamical cores with terrain-following vertical coordinates), The first is the Advanced Research WRF (ARW) solver, and the second is the NMM (Non-hydrostatic Mesoscale Model), a solver developed at NCEP/EMC. Those two dynamic solvers are the main Components of WRF used in this study.

2.1. Model Setup

WRF version 3.8 is used in this study to simulate meteorology over model domain with terrain shown in Figure 2. The model domain is defined as Lambert Projection extends from 24 E to 36 E (120 grid points) in the east-west direction and from about 21.5 N to 32.5 N (120 grid points) in the north-south direction at horizontal grid 10×10 Km². The vertical grid consists of 41 level from surface up to 10 hpa. The static geographical fields, such as terrain height, soil properties, vegetation fraction, land use and albedo, etc., are interpolated and prepared to the model domain by using geogrid program in the WRF preprocessing system (WPS).

The initial and lateral boundary conditions for the meteorological fields are obtained from the National Center for Environmental Predictions (NCEP). Final Analysis (FNL) fields available every 6 hours at a spatial resolution of 1°×1°. They were interpolated to the model domain by using ungrib and metgrid programs in the WRF preprocessing system (WPS).

Figure 1. Damages in Ras Ghareb city in 26th October 2016

Figure 2. WRF Terrain map of Egypt showing the locations of the three selected domains for validation
2.2. **Physical Parameterizations**
The physical schemes used to configure the model are summarized in Table 1.

| Scheme          | Option number | Model                                      |
|-----------------|---------------|--------------------------------------------|
| Microphysics    |               | Kessler [4]                                |
|                 |               | Lin (Purdue) [5]                           |
|                 |               | WRF single moment 3 (WSM3) [6]             |
|                 |               | WRF single moment 5 (WSM5)                 |
|                 |               | Eta (Ferrier)                              |
|                 |               | WRF single Scheme 6b (WSM6) [7]           |
|                 |               | Goddard [8]                                |
|                 |               | Thompson [9]                               |
|                 |               | Milbrandt-Yau Double Moment [10]           |
|                 |               | Morrison Double Moment [11]                |
| L               | 4             | RRTMG [12]                                 |
| S               | 4             | RRTMG                                      |
| Land surface    | 2             | Unified Noah Land surface [13]             |
| PBL model       | 1             | Yonsei University                          |
| Surface Layer   | 1             | MM5 similarity [14]                        |
| Cumulus         | 5             | Grell 3D Ensemble Scheme [15]              |

3. **Comparison and observations**

3.1. **Using maps**
The spatial distribution for precipitation from ten different microphysics and TRMM data are shown in Figure 3. Generally, all the schemes successfully simulated the event with spatial distribution varying in the intensity of precipitation from one scheme to the other. TRMM always underestimated the precipitation with maximum reading of 35 mm over the Red sea, while the maximum precipitation from all the schemes reached up to 85 mm over different spatial domains depending on which scheme was used.
Figure 3. Spatial distribution for precipitation from TRMM satellite data and the ten microphysics over Egypt at midnight of the 26th October 2016.

3.2. Averaging over three domains

Three domains over Ras Ghareb, Wadi Elgemal National park and Elba National park were selected to evaluate model performance with boundaries shown in Table 2.

| Domain                        | Upper boundary | Lower boundary | Left boundary | Right boundary |
|-------------------------------|----------------|---------------|---------------|----------------|
| Ras Ghareb                   | 29             | 27.5          | 32            | 34             |
| Wadi Elgemal National park   | 24.83          | 24.1          | 33.9          | 36.46          |
| Elba National park           | 23.9           | 21.97         | 33.9          | 37.6           |

The resulting average precipitation over the three domains using the same ten microphysics schemes were plotted against the TRMM average data for the exact same domains at the same time figure 4. All the schemes resulted in a high precipitation over both Elba National park and Wadi Elgemal National park while TRMM data underestimated the reading over both areas. Average Precipitation over Wadi Elgemal from TRMM was 12.716 mm. The Lin scheme was the closest to TRMM over wadi Elgemal by overestimating the precipitation by 14.2 mm while the farthest scheme was Eta scheme by 24.1 mm. The precipitation over Elba National park was 4.65. The closest scheme was Thompson which estimate the precipitation by 12.9. ETA scheme was the farthest one which evaluates it by 15.39 mm. While the average precipitation over Ras Ghareb from TRMM was 7.19 mm. The closest scheme to TRMM was Morrison double moment, overestimating precipitation by 8.5 mm while the farthest scheme was Kessler by almost 14.6 mm.
3.3. Cloud pattern simulation
The model also successfully simulated the cloud pattern as shown in Figure 5 using Thompson scheme. This pattern is a function of the model height layer which is divided into three domains. Low cloud starts from the surface up to 0.66 eta level, mid cloud from 0.66 to 0.33 eta level and high cloud from 0.33 to 0 eta level. Clouds exist at all the height layers over Sinai, while there are generally clouds at low level over the coast of the red sea and on various levels at different spatial areas.

4. Conclusions and future work
In this work the impact of several microphysics schemes on precipitation simulation was investigated. Performance of the WRF model was compared to TRMM satellite data in terms of precipitation. Three areas within the domains were selected to validate the model. WRF successfully simulated the spatial pattern of the precipitation, when compared to data obtained from TRMM, it was found that the model always overestimated the precipitation values. Alternating between different microphysics schemes has direct impact on the spatial pattern of precipitation and on the distribution of the precipitation’s density. The difference in the output among the ten microphysics schemes was very small, hence no specific scheme was alone very close to TRMM data over the three domains. Future works should include testing sensitivity of the model to changes in the preferences of the cloud scheme, also the performance of the model using data assimilation techniques should be investigated.

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