EGU2020-10538
https://doi.org/10.5194/egusphere-egu2020-10538
EGU General Assembly 2020

Exploration of WRF simulations of extreme rainfall in Egypt

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This research evaluates the performance of the Weather Research and Forecasting model (WRF-ARW, version 4.0) in simulating a regional extreme rainfall event over the Alexandria region of Egypt. Different domain configurations, spin-up times and physical schemes are explored to work out appropriate settings for using WRF in the region. Alexandria is an important economic region of the West Nile Delta that faces a growing climate crisis (e.g. rising temperature, rising sea level, increasing flooding) in recent decades, whilst inadequate coverage of in-situ rainfall observations (radars and rain gauges) makes the development of a hydrological early warning system very difficult. Although some researchers have conducted many WRF studies in countries with rich hydrological data, such as the United States and the United Kingdom, there are not many studies in exploring the ability of WRF to reproduce extreme weather events in countries with insufficient data like Egypt. Therefore, we carry out WRF sensitivity studies of an extreme rainfall event (occurred on 04 November 2015) in the Alexandria region to find out the optimal model configurations for Egypt and other similar areas.

In this study, WRF was tested in five scenarios with different types of configurations. The model sensitivity was evaluated for: (1) domain size, (2) number of vertical levels, (3) horizontal resolution (nesting ratio), (4) spin-up times, (5) physical parameterisation schemes (MP, PBL, CU). During the entire screening process, the best configuration identified in each scenario will be adopted as the corresponding configuration in the following scenarios. All simulations used the newly developed ERA5 reanalysis dataset as the forcing data. Model simulations were verified at high temporal and spatial resolutions against the Global Precipitation Measurement data (GPM data). Seven objective verification metrics (POD, FBI, CSI, FAR, RMSE, MBE and SD) were used to calculate the performance of WRF simulations to identify the likely optimal model configurations.

The sensitivity study shows that the rainfall distribution and magnitude are most sensitive to the spin-up time and physical schemes (especially the cumulus convection scheme). It is observed that the improvement of WRF's reproducibility of rainfall intensity may be accompanied by a decrease in the reproducibility of rainfall distribution. The most recommended configurations include three-level nesting (D01 80x80; D02 112x112; D03 88X88), 58 vertical levels, 1:3:3 (31.5, 10.5 and 3.5km) grid ratio, 48h spin-up time, WSM6 microphysics scheme, MYJ planetary boundary layer scheme, and Grell-Freitas cumulus convection scheme. Its hitting rate is 0.818, the false alarm rate is 0.088 and the rainfall mean bias error is -1.639. The knowledge gained in this study provides a useful foundation for developing a flood early warning system by linking WRF with WRF-Hydro.