SIMULATION EXPERIMENT OF TROPICAL CYCLONE MOCHA (2023) AND ASSOCIATED STORM SURGE USING DIFFERENT PHYSICS OPTIONS OF WRF

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INTRODUCTION

In May 2023, Cyclone Mocha marked its place in history as the second strongest tropical cyclone (TC) to make landfall in the Indian Ocean. The core of our research delves into the intricacies of Mocha's modeling, highlighting the importance of accurate wind speed and sea level pressure data for enhancing the fidelity of storm surge models. This study concentrated on the impact of physics options in the Weather Research and Forecasting Model (WRF; Skamarock et al. 2008) on TC and storm surge simulation accuracy. Physics options are crucial for parameterizing sub-grid scale effects, which significantly influence TC characteristics and behavior. Given the inherent uncertainty these options introduce in TC forecasting, they are indispensable in accurately predicting storm surges. This research aimed to identify how varying physics options in the WRF model affect the prediction accuracy of Mocha and storm surge.

METHOD

In this study, we used WRF to calculate the TCs. It is an open-source numerical weather model and has widely been used in TC simulation studies (e.g., Shirai et al. 2022). For the storm surge simulation, we used STOC-ML (Tomita and Kakinuma, 2005), a quasi-3D model using the hydrostatic pressure approximation and is based on the nonlinear shallow water equations. Although there are large number of combinations of physics options in WRF, we used eight combinations selected by Shirai et al. 2022 based on a review of various previous studies. The horizontal resolution of the grid used for the TC simulation was 4.5 km. For comparison, results downscaled by 1/3 were also used in the storm surge calculations. The initial conditions required for WRF-run were obtained from NCEP FNL data (ds083.2).

RESULT AND SUMARRY

Figure 1 (Left) shows the simulated tracks. Track errors ranged from 75 to 135 km in eight cases. In all cases, the landfall points were shifted to the northwest, landfalls delayed from 3 to 12 hours. Figure 1 (Right) shows the time series of the minimum central pressure (MCP) and the maximum wind speed (MWS). Comparing the maximum and minimum values, there is a difference of 30 hPa and 15.4 m/s at the peak. For MCP, the peak at 918 hPa was reproduced in some cases, but MWS did not reach 71 m/s in any case. Figure 2 is simulated and satellite-observed surface wind speeds at approximately the same time (5 minutes difference). The root mean square errors (RMSEs) ranged from 10.4 to 20.9 hPa and 13.8 to 16.6 m/s, respectively. To summarize, this study found an average error of about 155 km in the simulated storm tracks near landfall. Regarding intensity, while the MCP generally fell within the spread of the physics-ensemble, the MWS was consistently underestimated. Additionally, the radius of maximum wind speed was larger than observed. Improving wind field forecasts and track reproducibility through data assimilation and other methods is essential for enhancing the accuracy of storm surge predictions.

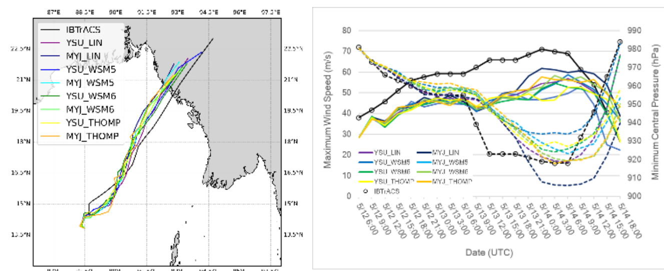

Figure 1 - Simulated tracks (Left) and intensity (Right) by 8 different combination of physics options. Observation data were obtained from IBTrACS. Legend indicates (planetary boundary layer_microphysics)

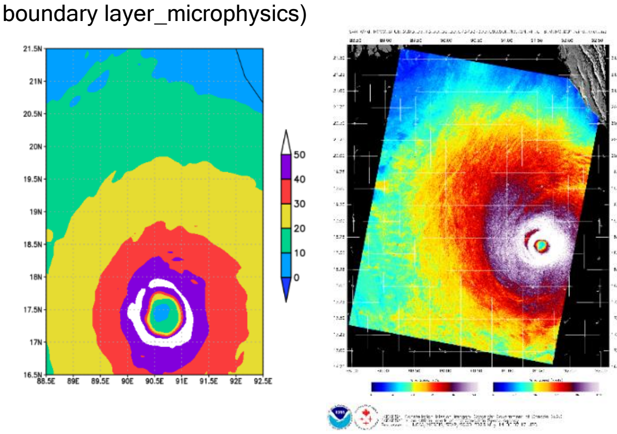

Figure 2 - Simulated Wind Speed at 10m (m/s) (Left) and Observed Surface Wind Speed (Right). Observed data obtained from The NOAA STAR Water Surface Conditions.

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