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Numerical Modeling of Tropical Cyclone Generated Waves; Case studies of Irma, Maria and Dorian

Gozde Guney Dogan[1], Pamela Probst[2], Bora Yalciner[1], Alessandro Annunziato[2], Narcisse Zahibo[3], and Ahmet Cevdet Yalciner[1]

[1]METU, Ocean Engineering Res. Center, Dept. of Civil Engineering,, Ankara, Turkey (yalciner@metu.edu.tr)

[2]European Commission Joint Research Center, Ispra, Italy

[3]Université des Antilles et de la Guyane, Guadeloupe

Tropical cyclones can be considered one type of extreme event, with their destructive winds, torrential rainfall and storm surge. Every year these natural phenomena affect millions of people around the world, leaving a trail of destruction in several countries, especially along the coastal areas. Only in 2017, two devastating major hurricanes (Irma and Maria) moved across the Caribbean and south-eastern USA, causing extensive damage and deaths. Irma formed in the far eastern Atlantic Ocean on 30 August 2017 and moved towards the Caribbean islands during the following week, significantly strengthening, becoming a Category 5 Hurricane. It caused wide-ranging impacts such as significant storm surge (up to 3m according to US National Oceanic and Atmospheric Administration, NOAA report) to several islands in the Caribbean and Florida. On the second half of September, 2017, another strong Category 5 Hurricane named Maria formed over the Atlantic and moved west towards the Caribbean Sea. Maria also caused several impacts and severe damage in Caribbean Islands, Puerto Rico and the U.S. Virgin Islands due to high speed winds, rainfall, flooding and storm surge with a maximum runup of 3.7 m (US NOAA) on the southern tip of Dominica Island. The most recent devastating event for the Atlantic is Hurricane Dorian. It formed on August 24, 2019 over the Atlantic Ocean and it moved towards the Caribbean islands, as getting stronger as moving, becoming a Category 5 before reaching the Bahamas, where it left a trail of destruction after its passage. The major effect of Dorian was on north-western Bahamas with very strong winds, heavy rainfall and a large storm surge.

In this context, a rapid and reliable modeling of storm surge generated by such kind of events is essential for many purposes such as early accurate assessment of the situation, forecasting, estimation of potential impact in coastal areas, and operational issues like emergency management.

A numerical model, NAMI DANCE GPU T-SS (Tsunami-Storm Surge) is developed building up on tsunami numerical model NAMI DANCE GPU version to solve nonlinear shallow water equations, using the pressure and wind fields as inputs to compute spatial and temporal distribution of water level throughout the study domain and respective inundation related to tropical cyclones, based on the equations used in the HyFlux2 Code developed by the Joint Research Centre of the European Commission. The code provides a rapid calculation since it is structured for Graphical

Processing Unit (GPU) using CUDA API.

NAMI DANCE GPU T-SS has been applied to many cases as regular shaped basins under circular static and dynamic pressure fields separately and also different wind fields for validation together with combinations of pressure and wind fields. This study has been conducted to investigate the potential of numerical modeling of tropical cyclone generated storm surge based on recent events Irma, Maria and Dorian. The results are presented and discussed based on comparison with the measurements and observations. The study shows promise for developing a cyclone modeling capability based on available measurement and observational data.