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NUMERICAL INVESTIGATION OF WAVE ENERGY OF SAINT MARTIN REGION OF BANGLADESH

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ABSTRACT

St. Martin island (20° 37′ 57.04″ north latitude and 92° 19′ 11.80″ east longitude) is a small island in the northeastern part of the Bay of Bengal, about 9 km south of the tip of the Cox's Bazar-Teknaaf peninsula, and forming the southernmost part of Bangladesh. It is also known as 'Coconut Island' and it is also the only coral island of the country. Because of the geographic position of the island, the electricity cannot be supplied from the mainland through the electricity grid. The only means of electricity is the diesel generator and solar power. The electricity demand is partially fulfilled by standalone diesel generators. On the other hand, ocean waves are a power-dense, predictable source of clean and sustainable energy that has not yet been exploited to any significant extent in the Bay of Bengal of Bangladesh. The main objective of this research work is to estimate wave energy available per meter front in coastal waters by setting up a simulation model (Flow and Wave model). Relevant data has been collected from European Centre for Medium Range Weather Forecasts (ECMWF) website, General Bathymetric Chart of Ocean (GEBCO) and Bangladesh Navy Hydrographic and Oceanographic Centre (BNHOC). Based on this research findings, resource mapping of wave energy can be carried out for more suitable renewable energy harvesting.

Keywords: *Renewable energy, ocean waves, electricity, Saint Martin.*

1.0 INTRODUCTION

Bangladesh Government has produced policies in respect of renewable electrical energy production. The government has established Sustainable and Renewable Energy Development Authority (SREDA) to promote renewable energy and energy efficiency in 2014 [3].

Renewable energy sources contains less than 2% share of total power. The 7th 5 year plan of the Govt. of Bangladesh is to generate 5-10% power from renewable energy sources [3].

It is researched that the wave energy contains 15-20 times energy than wind or solar energy per square meter [4]. The availability of wave energy is almost 90% [2]. In contrast, the availability of wind and solar energy is only 20-30% [2]. Any sites in the world with an average power level of over 15 kw/m have the potential to generate power at competitive prices [4].

Ocean wave energy is the energy that has been transferred from the wind to the ocean. As the wind blows over the ocean, air-sea interaction transfer some of the wind energy to the water, forming wave, which store this energy as potential and kinetic energy. The size and period of the resulting waves depends on the amount of transferred energy, which is a function of wind speed, the length of time the wind blows and the length of ocean over which the wind blows.

The island communities in Saint Martin are lagging in development. For electricity, they currently depend on diesel generators. The high cost of diesel, difficulties of transporting diesel during the monsoon seasons, low and variable solar flux, high maintenance cost of solar cells and batteries are perennial issues with the current energy system.

For this particular region, no research has been done yet to estimate wave energy. So, this research provides an overview of the available wave energy per meter wave front. A numerical model has been developed using Delft3D software which results have been used to determine the wave power. Delft3D is an integrated modeling suite, which simulates two-dimensional (in either the horizontal or a vertical plane) and three-dimensional flow, sediment transport and morphology, waves, water quality and ecology and is capable of handling the interactions between these processes. In addition, the output of the model has been calibrated with the satellite data. So, it is possible to assess monthly variation of wave power accurately and thus fulfilling the power requirement of the island communities and attracting more tourists to visit this only coral island in future.

2.0 METHODOLOGY

2.1 Data Collection

Bathymetry data of our computational grid has been collected from General Bathymetric Chart of Ocean (GEBCO). Water level data at the downstream boundary of the flow grid has been extracted from Tidal Model Database (TMD) for the period April to September of the year 2016 at 1 hour interval and discharge data of Meghna River at the upstream boundary has been purchased from Bangladesh Water Development Board (BWDB) at 1 day interval. Necessary datas for wave model have been collected from ECMWF ERA-INTERIM. This data includes time and space varying wind velocity, wind direction, wave parameters like significant wave height, peak wave period, wave direction and directional spreading of the wave at the boundary of the computational grid. The interval of the data collection period was 1 day and spatial resolution of the grid was 1°x1°.

2.2 Model Development

A computational grid surrounding the study region has been generated by using Delft-3D RGFGRID. Depth file of this computational grid has been created by Delft-3D QUICKIN. Necessary datas have been given as input to the Delft3D Flow Module and the observation point has been located in the flow grid. In the wave model, necessary boundary datas have been given.

2.3 Data Analysis

2.3.1 Flow model calibration:

Flow model has been calibrated by comparing water level data obtained from the model at point (Longitude – 92.317^0Latitude – 20.6^0) with water level data extracted from Tidal Model Database (TMD) for the month July. The calibration curve is as follows –

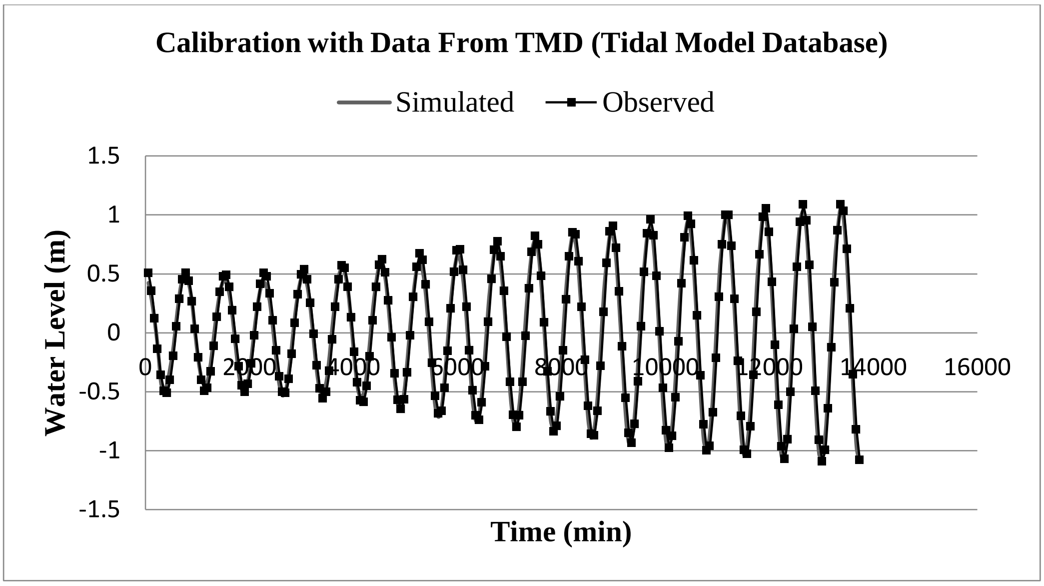

Figure 1: Calibration with Data from TMD (Tidal Model Database)

2.3.2 Wave Model Calibration

The wave model has been calibrated by comparing significant wave heights obtained from the model at the same observation point (Longitude – 92.317^0, Latitude – 20.6^0) for the months April to July, with significant wave heights estimated by ECMWF ERA-INTERIM. The comparison curve is as follows –

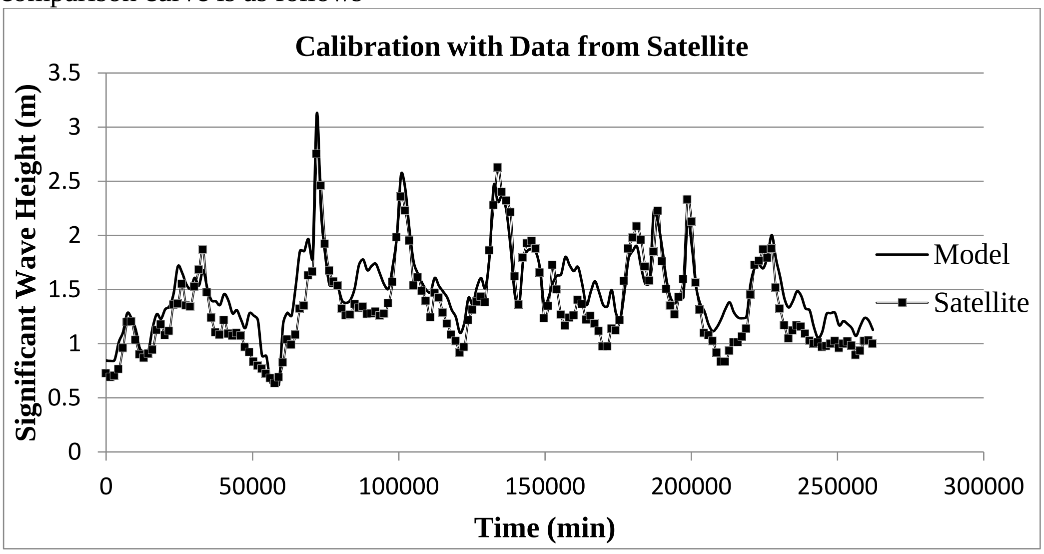

Figure 2: Calibration with Data from Satellite

The wave model has been coupled with the flow model. The trend of variation of significant wave height is nearly same as data extracted from ECMWF website but magnitude varies slightly due to the fact that measured water level data was unavailable during the generation of flow grid. So, another model data (Tidal Model Database) have been used as the open boundary of the flow grid. The affect of temperature, salinity, density change of water with variation of water depth has not been considered. Also, uniform value of bottom roughness has been considered, but bottom roughness in the computational grid actually varies from the land to the deep sea.

Flow Chart methodology is given below:

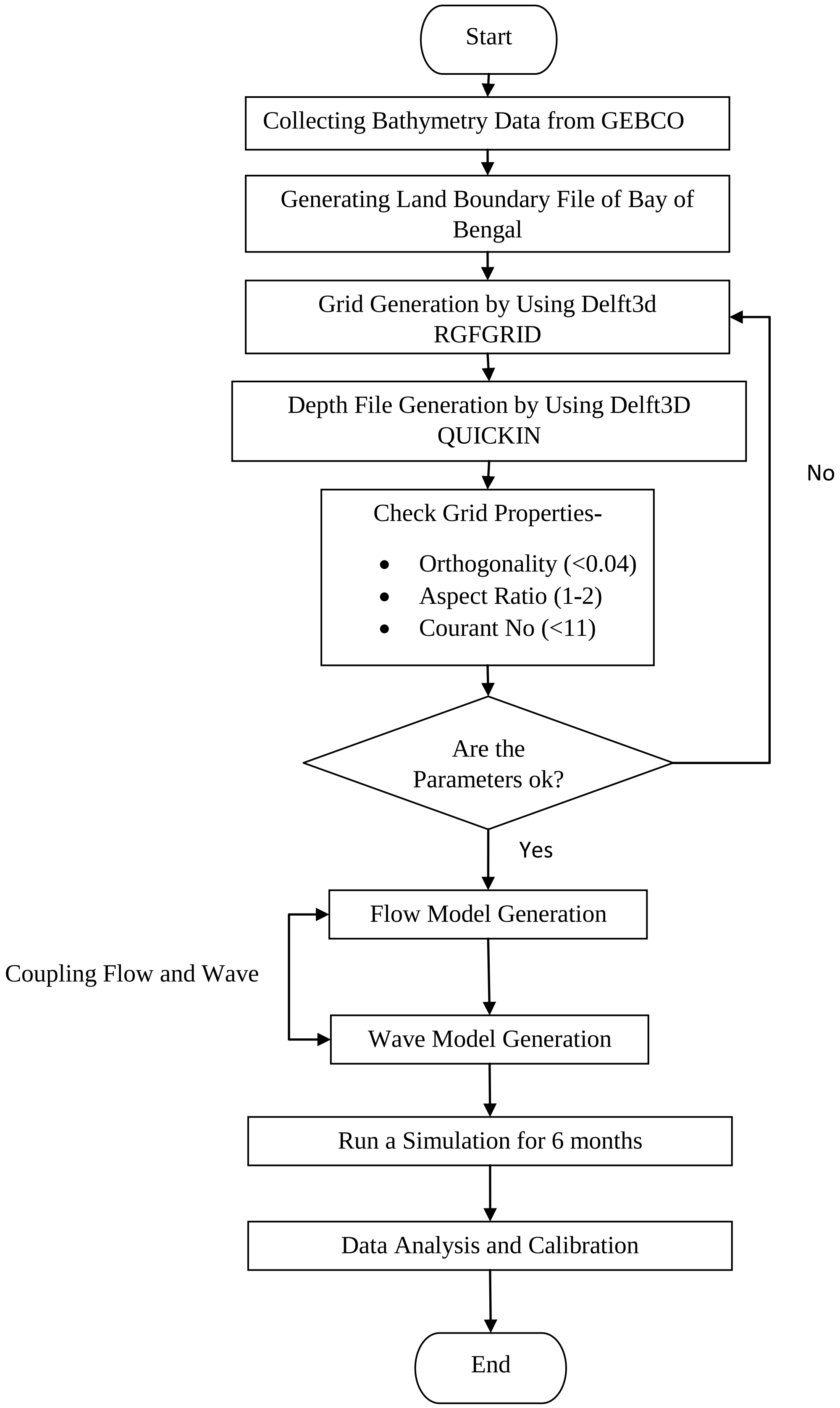

Figure 3: A Flowchart of Methodology

3.0 Results and discussion

Using Delft3D, a simulation has been run for 6 months (April-September, Year 2016) and the results of the simulation are as follows –

From the month April to June, the significant wave height fluctuated abruptly within 0.84m to 3.13m. The highest wave height occurs at May which is 3.13m. From the month July to September, the significant wave height fluctuated abruptly within 1.05m to 2.5m. The highest wave height occurs at July which is 2.5m. Maximum average power obtained at month July is 6.734 kw/m.

From the output of the numerical model, maximum value of wavelength during the period April to September has been found 57.668m. At the observed location (Longitude – 92.317^{0}Latitude – 20.6^0) water depth is 2.98m.So the ratio of water depth and wave height is almost 0.0517 (intermediate wave). So, at this location, by applying dispersion relationship, the value of wave period has been calculated 6.083 sec. And from the model output for 57.668m wavelength, the value of wave period has been obtained 6.413 sec. So, it concludes that the model output slightly differs from the theoretical results and it is happened because of using TMD and non availability of measured data of water level and using satellite data at the wave boundary.

3.1 Wave Front Power:

Wave front power is calculated using the following formula, $P_{wf} = \frac{\rho_w T g^2 H_m^2}{64\pi}$

Table 1: Monthly average value of Significant Wave Height, Peak Wave Period, power per meter wave front:

Year – 2017			
Month	Significant Wave Height (Average) (m)	Peak Wave Period (Average) (sec)	Power per Meter Wave Front (Average) (KW/m)
April	1.3184	4.2653	3.3740
May	1.4434	4.7857	4.5376
June	1.6347	5.2451	6.3787
July	1.7000	5.1200	6.7340
August	1.5420	5.1020	5.5209
September	1.4000	5.0800	4.5313

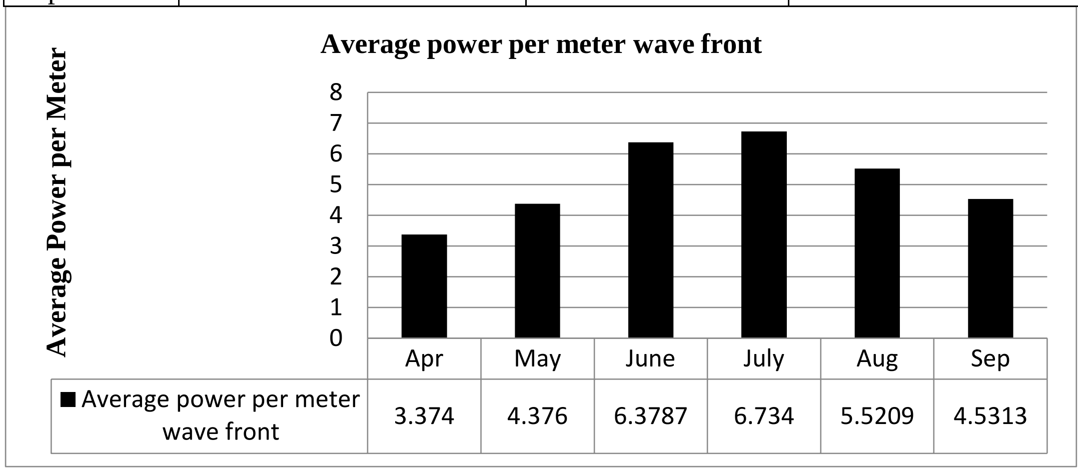

Figure 4: Average power per meter wave front

4.0 Conclusion

Based on the discussion, the present model developed for the computation of the wave energy of Saint Martin Island provides data that follows similar trend of data extracted from TMD and ECMWF ERA-INTERIM. Furthermore, this model can be used for estimating wave energy per meter wave front of other locations of coastal regions of Bangladesh like Kutubdia, Sandwip, Patenga, Cox's Bazar etc and thus it is possible to locate suitable sites with concentrated wave energy (Hotspots). By analyzing variation of wave power for several years the future power can be forecasted and thus help to design suitable wave energy extraction device and thus meet the goal of Bangladesh Govt. to generate 10% power from renewable sources by the year 2020.

NOMENCLATURE

g	:Acceleration due to gravity
P_{wf}	:Power per Meter Wave Front
ρ_w	:Seawater Density
H_m	:Significant Wave Height
T	:Time Period

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