Typhoon wave modelling application for planning the harbor in Danang city, Viet Nam

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Abstract. Analysis of wave propagation in shallow water is considered as one of the important keys in assessing the shoreline evolution, as well as an important basis for assessing the impact of waves on coastal structures. With the purpose of simulating the wave propagation process in the area of Danang Bay, as a basis for assessing the impact of waves and wind on the shoreline evolution as well as giving appropriate construction measures, the study has analysed wave propagation in an area of about 60.3×10³ km². Using the MIKE 21/3 module of the Danish Hydraulics Institute, and simulating under the most extreme wave conditions, under the impact of hurricanes level 10, level 13 and level 16 (conditions and storm trajectories based on Nari storm in 2013) as well as the influence of the flow of the Cu De and Han rivers, the study initially showed changes in velocity fields over time, changes in water level and waves in Danang Bay. These results are expected to become the basis for consultation with local authorities in coastal management and disaster prevention, especially in the context of increasingly complex climate change and sea level rise.

1. Introduction
Da Nang coast has a key role towards the city's economy with many marine economic activities such as fishing, aquaculture, seaports and water transport, tourism, etc. Besides the benefits, the sea is also the source of unpredictable disasters. Many storms annually hit the city, causing heavy losses for the people and materials, especially coastal infrastructure such as houses, dykes and wharves. In order to mitigate these disadvantages, understanding the hydrodynamic regime in this area is very necessary.

Numerical modeling in coastal estuarine research is seen as a helpful tool to assess hydrodynamic regime [1]. Therefore, a model could effectively represent the reality when input data are accurate. This condition is quite difficult towards the coastal modelling due to characteristic of liquid environment. Multi-ratio simulation is considered as the current popular approach to solve this problem [2]. Accordingly, an overall model is used to describe the phenomenon for larger area. Detailed model with finer mesh size will be used to analyze the evolution of coastal phenomena.

Lien Chieu Port located in Da Nang Bay area is one of the important traffic hubs serving the socio-economic development of the central region of Vietnam. Hydrodynamic analysis is requisite for Lien Chieu Port design, as well as to mitigate the negative impact of this construction to Danang Coastal area. With this aim, the Danang’s coast area model is setup in this study with the boundary conditions data taken from the larger scale model – the East Sea model. With the purpose of simulating the wave
propagation process in the area of Danang Bay, as a basis for assessing the impact of waves and wind on the shoreline evolution as well as giving appropriate construction measures, the study has analyzed wave propagation in an area of about $60.3 \times 10^3$ km$^2$. Using the MIKE 21/3 module of the Danish Hydraulics Institute, and simulating under the most unfavorable wave conditions, under the impact of hurricanes level 10, level 13 and level 16 (conditions and storm trajectories based on Nari storm in 2013) as well as the influence of the flow of the Cu De and Han rivers, the study initially showed changes in velocity fields over time, changes in water level and waves in Danang Bay. The study results are considered as important consultation for local authorities in coastal management and disaster prevention in general as well in Danang harbor planning, in particular to respond the negative impact of climate change and sea level rise.

2. Methodology and materials

2.1. Methodology
This study aims to make the completed, accurate & reflected study with hydrodynamic aspects compared with reality based on using MIKE 21/3 powered by DHI (Danish Hydraulics Institute), Denmark. The model is constructed based on multi-ratio method, beginning with case study in East sea model to specific study area. Figure 1 illustrates the general approach of this study for Da Nang bays in term of different scales as well as levels are established. The Model 1 which covers all East sea area extending to Taiwan, Philippines and Mallaca is used to representing the tidal processes as well as waves and seawater surges from the offshore areas to coastline areas, with 5 main boundaries from Taiwan, Luzon, Mindoro, Babalac and Malacca. Results extracted from study were used for constructing boundaries for the specific 2D model of Da nang bay (Model 2) (Figure 1).

Figure 1. Case study area.
To evaluate the efficiency of different levels of hurricane to Danang bay, authors decided to separate this case study into 3 hurricane scenarios with level 10, 13 and 16 corresponding with tidal levels respectively (Table 1). The trajectories of hurricane along with its data corresponding with scenarios are established base on the hurricane Nari 2013 and collected from Japanese meteorological agency [3].

Table 1. Hurricane levels, tidal level with respective scenarios of Danang bay.

| Study area | Scenario | Hurricane level | Type |
|------------|----------|-----------------|------|
| Danang bay | KB1      | 10              | Tide |
|            | KB2      | 13              | Tide |
|            | KB3      | 16              | Tide |

2.2. Data and materials

The flow data of Cu De, Han rivers to Danang bay inherited and extracted from study results of authors [4]. The topography using in Model 1 is taken from SRTM15_PLUS V1.0 from Scripps Institution of Oceanography, University of California, USA. This is a dataset of 15″×15″ resolution (about 450m) [5]. Tidal water level data in Son Tra, Ly Son station in 2016 were gathered and adjusted relied to the national elevation system for Model 2 [6].

The wave data is come from the AVISO organization (France), and WAVEWATC-III model of NCEP/NOAA organization (USA) [7], [8]. The wind forcing data and atmospheric pressure data in this study are extracted from the global climate model CFSR (Climate Forecast System analysis) of the National Center for Environmental Prediction – National Oceanic and Atmospheric Administration Commissioned Corps (NCEP/NOAA) [9].

3. Model setup

3.1. Model setup

The Model 1 - East Sea model is constructed for an area up to 3.45×10⁶ km². The topography is expressed via the irregular mess with 64680 elements (Figure 1). Boundary condition is set up at 5 locations (Taiwan, Luzon, Mindoro, Babalac and Malacca) with the parameters of sea water level and lateral boundary for the wave spectrum module.

Model 2 - detail model is used to represent for area of 60.3×10³ km². The model 2 is set up with the mess 13065 elements and the average size of mesh is 4.62 km². Four boundaries of this model are extracted from model 1. The bed resistant is assigned based on research results of Manh and measured data, the detail is show cased in Figure 2 [10].

Figure 2. Model set up, (a) Topography map, (b) Bed resistant (Manning’s coefficient).
3.2. Calibration and validation

The East sea model is calibrated and validated by comparing the sea water level with observed data in Phu Quy, Con Dao and global tide FES2014 model. Tidal simulated results are compared with observed data extracted from meteorology stations Bach Ho and with the observed wave data from satellites of AVISO organization (France) as well as wave simulation results by WAVEWATCH-III model of NCEP/NOAA, USA.

3.2.1. East sea model. **Sea water level with calibration & validation:** Main parameter of calibration and validation is the Manning’s coefficient. Simulated results and observed data collected from meteorology Phu Quy and Con Dao are showed in Figure 3 & 4 respectively.

![Figure 3](image1)

**Figure 3.** Water level comparison between MIKE21/3 and observed data collected at Phu Quy station.

![Figure 4](image2)

**Figure 4.** Water level comparison between MIKE 21/3 and observed data collected at Con Dao station.

**Tidal level with calibration & validation:** To evaluate the simulation results extracted from MIKE 21/3 for East sea model, simulated results has been compared with observed data at Bach Ho station (Figure 5).

![Figure 5](image3)

**Figure 5.** Wave height comparison between MIKE 21/3 and observed data at Bach Ho station 1996.
3.2.2. Model 2D. Calibrated and validated model with observed water level at Son Tra, Ly Son station during 25/05-25/06/2016 illustrated respectively (Figure 6, 7 & 8). The comparisons result in the high similarities between observed and simulated data, in which, correspondent coefficient – NASH are 0.95, 0.78 and 0.94, 0.78 at Son Tra, Ly Son respectively.

![Locations of calibration, validation and extraction.](image1)

Figure 6. Locations of calibration, validation and extraction.

![Sea water level comparison between model 2 and observed data at Son Tra station.](image2)

Figure 7. Sea water level comparison between model 2 and observed data at Son Tra station.

![Sea water level comparison between model 2 and observed data at Ly Son station.](image3)

Figure 8. Sea water level comparison between model 2 and observed data at Ly Son station.
The results are calibrated and validated versus the data WAVEWATCH-III at 03 selected points of Da nang bay from 25/05 to 25/06/2016 (Figure 6). Results illustrated the similarity with tendency and amplitude as Figure 9.

![Figure 9](image)

Figure 9. Comparison of significant wave height results of model 2 versus wave data of WAVEWATCH-III at the point S2.

4. Application for Hurricane modelling

From the model set up with boundary data and wind, this study concentrated on 3 hurricane scenarios with level 10, 13 and 16 corresponding with tidal levels. The hurricane trajectory and its parameter established based on the hurricane Nari 2013 and collect from Japanese meteorological agency [3]. The wind speed as level 10 is showed at Figure 10.

![Figure 10](image)

Figure 10. Wind distribution level 10 before reaching to Da nang bay.

The corresponding results with case study area – Da nang bay are showed as Figures respectively. When storms lands to Danang, their energies make the huge variation in velocity and water level. The simulation results show that the velocity will increase from 0.44 m/s to 0.96 m/s with the storm level 10, 1.04 m/s with the storm level 13, 1.12 m/s with the storm level 16 (Figure 11 & 12). Similarly, the tidal wave height also raises up to 3.75 m with the storm level 10, 6.5 m with the storm level 13, 9.0 m with the storm level 16 (Figure 13, 14 & 15). The value are kind alike with the events which landed to Danang in the past, such as Xangsane hurricane [11]. These changes definitively bring out negative impact to Danang coastal line zone as well as construction in this area.
Figure 11. Field of water level before the hurricane reaches to Da nang bay level 10(a), 13(b), 16(c).

Figure 12. Field of water level when the hurricane reaches to Da nang bay level 10(a), 13(b), 16(c).

Figure 13. The development of tidal wave height at point P1 corresponded with hurricane level 10, 13 and 16.

Figure 14. The development of tidal wave height at point P2 corresponded with hurricane level 10, 13 and 16.

Figure 15. The development of tidal wave height at point P3 corresponded with hurricane level 10, 13 and 16.
5. Conclusion
This study has setup, calibrate and validate the East sea model (using MIKE 21/3 SW) via using observed data collected from the meteorology station Bach Ho, monitoring data from satellite of AVISO organization (France). The hydrodynamic model has been verified with suitable data (using MIKE 21/3 with 02 modules HD & SW) and observed data collected in various sources.

Also, this study has simulated scenarios with different hurricane wind level (10, 13, 16) corresponded with hypothesis trajectories causing threats to coastline of Da nang bay. Results of wave height, water level $H_{max}$ (m) before and when hurricane reaches to, water surge $\Delta h$ (m) at respectively selected points, results illustrate the development of characteristics from hurricane level 10 to 13. The maximum wave height extracted at the point P3 (on the right coast of Da nang bay) that effected significantly by the distribution of wind direction, the wave height grows up from 2.37m to 6.0m with the hurricane level 10 and 16 respectively.

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