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EVALUATING COASTAL RESPONSE TO ESTUARINE HARBOUR CONSTRUCTION IN KERALA: DYNAMIC SIMULATIONS AND FUTURE PROJECTIONS

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Abstract:
Different dynamic elements, such as bathymetry, wave characteristics, currents, and coastal direction, are responsible for the periodic changes that occur along the coastline, which means that the land and sea border are also vulnerable to these changes. Along the shore, erosion and accretion are two processes that are caused by variations in the coastline. For the purpose of this research, the numerical approach is used to investigate the coastal alterations that have occurred around three estuary harbours along the coast of Kerala in India. The findings of this research are used to evaluate the effects that harbour projects have on the coastline. To forecast the changes that will occur to the coastline at these three estuarine harbour locations along the coast of Kerala, the Mike 21 SW and LITPACK modules are used. By analysing the oscillations of the coastline surrounding three estuary harbours, it is clear that the building of harbours has a substantial influence on the coast that is near to them.
Keywords: Accretion, Breakwater, Erosion, Harbour, LITPACK, and Shoreline make up some of the

1. Introduction

It is generally agreed that the ideal definition of shoreline is the physical barrier that separates land and water (Dolanet al., 1980). In point of fact, the location of shorelines is constantly shifting throughout the course of time as a result of the fluid nature of water levels shifting. Consequently, shorelines may be analysed in a temporal framework, and the time period that is taken into consideration is determined by the requirements of the data. At a certain instant in time, the water-land border is the coastline that is immediately next to the water at that moment in time. According to a number of writers (Morton, 1991; List and Farris, 1999; Smith and Zarillo, 1990), the assumption that the immediate coastline experiences "average" or "normal" circumstances is the most likely to be incorrect in the majority of shoreline surveys.

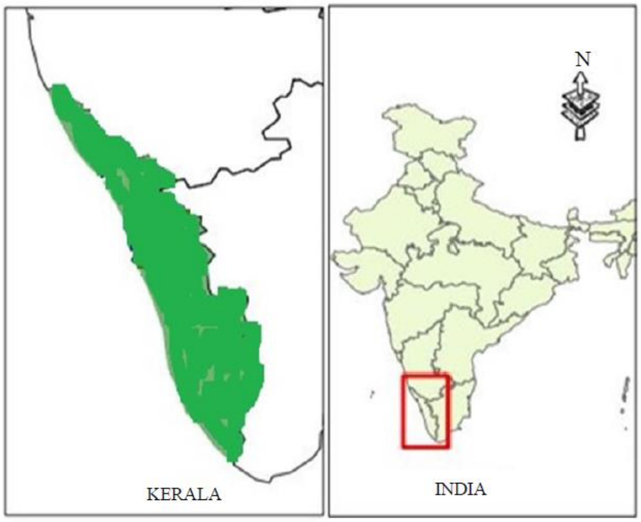
It is also possible to observe a coastline over a somewhat longer period of time, such as a tidal cycle, taking into consideration the characteristics of the beach and the wave environment that is prevalent. It is possible for the position of the coastline to change by multiples of hundred metres or even more when engineering time is measured on a longer scale, such as one hundred years (Komar, 1998). According to Balaji et al. (2014), dynamic processes such as accretion and erosion take occur along the beaches. This is because the coasts are exposed to a wave environment that varies over time, which makes them the most dynamic. According to

Constanza et al. (1997), coastal ecosystems are very difficult since they include a large number of resources, both living and non-living sources equally. The coastal areas are very dynamic in nature, and the changes that occur along the shore may result in the loss of land and life, as well as the danger to ports and harbours, and the loss of other resources that are located on land. According to Rasuly et al. (2010), it is crucial to examine the location of the coastline in order to ensure that the coastal region is monitored and protected. This is because the growth of any country is very dependent on the coastal area. There are a number of major elements that impact the oscillations of the coastline, including the flow of sediment, variations in sea level, and contributions from humans. There are a number of elements that impact the location of the coastline, including storm surges, estuary conditions, the sorts of landforms that are located along the coast, and hydrodynamic characteristics that are located along the beach (Narayana and Priju, 2006; Scott, 2005; Kumar and Jayappa, 2009). Either coastal erosion or accretion is intimately tied to the phenomenon known as shoreline oscillation. According to Burgess et al. (2001), the most important requirements are the potential alterations in the shoreline as well as the accurate evaluations of the risks associated with various time periods.In terms of the supply of sediments, the coastline may be exposed to three distinct conditions, which include a surplus condition, a balanced situation, or a deficit position in sediment budgeting. A surplus or deficit sediment budget is created as a result of the huge shift in the supply of sediments, which causes shoreline oscillations (Mukhopadhaya et al. 2012). This occurs when the time period is either shorter or much longer. In most cases, the rise in sea level that occurs as a result of storms, an increase in global warming, and other factors will result in flooding along the coast, as well as erosion and accretion processes occurring along the coastline (Dattatri et al. 1997).

2. Area of the Study

Kerala's coastline extends over 590 km, making it one of the longest in the country. On this coast, which is a low-lying strip of land that is squeezed between a succession of lagoons and backwaters on the southern side, the Arabian Sea may be found on the western side of the coast. Along these networks of water basins, there are a variety of various locations from which one may reach the Arabian Sea. The bulk of Kerala's commercial operations, as well as the state's most important industries and agricultural endeavours, are situated along this shore. Nearly continual erosion and accretion are taking place throughout this shoreline. These processes are causing the coastline to change. It has been estimated that the pace of erosion in Kerala is much greater than the rate of accretion, which leads to the loss of land that is of significant value from the state. As a result of the studies, it has been claimed that around 320 km of this coastline are having significant erosion problems. Within the state of Kerala, there are forty-one rivers that flow in a direction that is westerly. The Western Ghats are said to be the source of the bulk of these rivers, according to conventional wisdom. From a westerly direction, they make their way to the lagoons and backwaters that are situated along the coast of Kerala, where they ultimately find their destination. There are 34 lagoons or backwaters that are located on the shoreline and flow into the Arabian Sea. These inlets are known as inlets. The findings of Kunhimammu et al. (1997) indicate that just 21 of the 34 inlets will remain open during the whole year. Only a portion of the remaining inlets will be open throughout the year. This means that they will be open during the monsoon season, but they will be closed for the rest of the year. The movement of the littoral zone is primarily responsible for this phenomenon. Additionally, there are twenty-five separate harbour structures located around the coast of Kerala. There are breakwaters established in each and every harbour that has been constructed. As a result of the construction of these harbours along the coast of Kerala, a substantial number of repercussions are generated. Along the coast of Kerala, there are a total of three different classifications of fishery harbours that have been constructed. It is possible to construct three distinct types of harbours, which are as follows: harbours that are constructed at river mouths or estuaries, harbours that are constructed in bays that already exist along the coast, and harbours that are made on the open coast. It has been suggested by Kunhimammu et al. (2007) that each of these sorts of harbours may be referred to by a different term. Basin harbours, bay harbours, and sea harbours are their respective names. In Kerala, there are 21 inlets that are entirely exposed to the sea, and it has been observed that a substantial percentage of these inlets are susceptible to instability. There is a lack of maintenance of safe navigating paths for boats at these coastal inlets (Kunhimammu et al., 2006, 2009, 2012). This occurs as a result of the unstable nature of the natural circumstances that are now existent. According to Moni et al. (1973), these inlets canals may be classified as either managed (improved) or uncontrolled, depending on whether or not artificial river training structures are present. This classification is based on the presence of certain features. The sediments that are given by rivers that discharge from inlets or the sediments that are transferred along the coast by littoral movement are the two types of sediments that have an effect on the coastal inlets. It is common for the man-made structures that are situated on the shores of the inlets to have an impact on the stability of the coasts that are placed on either side of the inlets.

There are a substantial number of fishery harbours along the coast of Kerala, and the most of them are located outside of estuaries. The presence of a pair of breakwaters is essential for the operation of any estuary fisheries harbour. The need of this cannot be avoided. Together with the development of fishery harbours or small ports, the construction of breakwaters is scheduled to be carried out at twelve distinct inlets along the coast of Kerala. These breakwaters will be constructed in combination with the construction of small ports. A list of coastal inlets is provided below for your convenience. These inlets are as follows: Muthalapozhy, Neendakara, Kayamkulam, Chethi, Munambam, Chettuva, Ponnani, Beypore, Azhikkal, Cheruvathur, Ksaragod, and Manjeswaram. As part of the ongoing inquiry, three estuarine harbors—specifically, those situated at Azhikkal, Beypore, and Munambam—are being taken into account. Figure 1 illustrates the particular locations of these harbours that are located around the coast of Kerala. At Azhikkal, a pair of parallel breakwaters with lengths of 1070 metres (north) and 1150 metres (south) were constructed, which resulted in the establishment of a fishery harbour as well as a small port. from the two centres of the breakwaters, there is a distance of 370 metres that separates them from each other. The construction of the building began in January 1995 and continued until March 2009, when it was finally completed. The breakwaters on the debris pile are exactly what they are. It was constructed close to the mouth of the Valapatnam river, as stated by Kunhimammu et al. (2009), and its coordinates are 11 degrees 94 minutes north latitude and 75 degrees 31 minutes east longitude. Between the years 1982 and 1988, the building of two breakwaters that are parallel to one another was carried out at Beypore. Breakwaters were 860 metres in length in the north and 820 metres in the south, and the distance between their centres was 280 metres. The lengths of the breakwaters were measured in metres.



Following that, during the 2008-2009 season, the southern breakwater was extended by a distance of three hundred metres. It is now the case that the breakwater in the north measures 860 metres in length, whilst the breakwater in the south is 1120 metres in length. It is situated in a latitude of 11o10' North and a longitude of 75o 48' East, as stated by Kunhimammu et al. (2009). It is situated close to the mouth of the Chaliyar river. At Munambam inlet, in order to build a fisheries port, two breakwaters measuring 625 metres in length (north) and 360 metres in length (south) were constructed. There was a space of two hundred metres between each of the breakwaters, measured from centre to centre. September 1992 was the month that construction began, and January 1997 was the month that the project was completed. The mouth of the Periyar river is the place where it was created, and its position is at a latitude of 10 degrees 10 minutes north and a longitude of 76 degrees 10 minutes east (Kunhimammu et al, 2009).

Figure 1: Locations of Estuarine Harbours Along the Kerala Coast

3. Methodology

For the purpose of analysing the coastal oscillations that take place following the construction of harbours and breakwaters, the MIKE 21 Spectral Wave (SW) and LITPACK modules are used.

Through the use of the MIKE21 Spectral Wave (SW) module, waves that start in the deep ocean are transformed into waves that are located in the near shore zone. By using this model, it is feasible to do a simulation of waves that are formed by wind, including the growth and decrease of these waves. The SW module of MIKE 21, which is a spectral wind-wave module, makes use of unstructured meshes in its operational configuration. This module takes into consideration a variety of important phenomena, such as the creation of waves that are affected by the wind, dissipations that occur as a result of white capping, the interaction between non-linear waves, bottom friction, and wave breaking. The wave diffraction that occurs on large coastal projects like breakwaters, groynes, and other structures of a similar kind is also taken into account by the model. Furthermore, the model considers the wave shoaling and refraction that happens in the area of the beach, as well as the interaction that occurs between waves and currents (DHI, 2011, 2017).

Once the outcomes of the SW transformation have been received, the LITPACK module is used in order to produce forecasts on the alterations that will occur to the coastline. During the simulation of the LITPACK module, the response of the coast to gradients in the capacity of along-shore sediment flow is taken into consideration. This reaction is taken into account in connection to the natural conditions and the structures that are already existent along the coast. By using the method of finding a solution to a continuity equation for the sediments in the littoral region, LITPACK is able to calculate the development of the coastline. Furthermore, the influence of coastal buildings, the origin of silt, and the sinks for it have all been taken into consideration. The relative alignment of the coastline, bathymetry, the profile of the cross-shore, active transport depth, contour angles, wave data, tidal currents, water level, and structure size are some of the factors that are considered to be the most important input data for the purpose of running the model and receiving the result from it (DHI, 2022).

4. The Information Employed The data from the C-Map have been utilised for the goal of acquiring bathymetric data in locations that have deep water. The Hydrographic Survey Wing of the Kerala Government is the one that is in charge of collecting bathymetry data for all of the coastal districts. This data, which ranges from three metres to twenty metres, is used for the research that is now being conducted. Furthermore, the Hydrographic Survey Wing is accountable for the compilation of bathymetric charts on a consistent basis for each and every one of the existing fishing harbours in the state of Kerala. Taking soundings and conducting surveys at the different harbour sites is an extra action that is taken by the Kerala Government's Department of Harbour Engineering. The model makes use of the information that is collected from two stations that are located off the coast of Thiruvananthapuram and Kasaragod districts. These stations are responsible for collecting data on the deep sea waves. In terms of distance from the shore, these stations are situated 160 km distant.

This data collection covers a period of 10 years, starting in 2007 and ending in 2017. The time span covered ranges from 2007 to 2017. According to the decision that was made, this specific study will make use of flexible mesh. With a depth of fifty metres to the shore, this mesh has a size of five kilometres, a mesh size of ten kilometres for sea depths ranging from one thousand metres to fifty metres, and a mesh size of twenty kilometres for water that is deeper. It was found that the mesh size resolution that was specified earlier was suitable for a number of water depth ranges, and it obtained good results during the process of model calibration and its subsequent validations. This was the conclusion that was reached. As can be seen in Figure 2, the mesh is represented by a schematic.

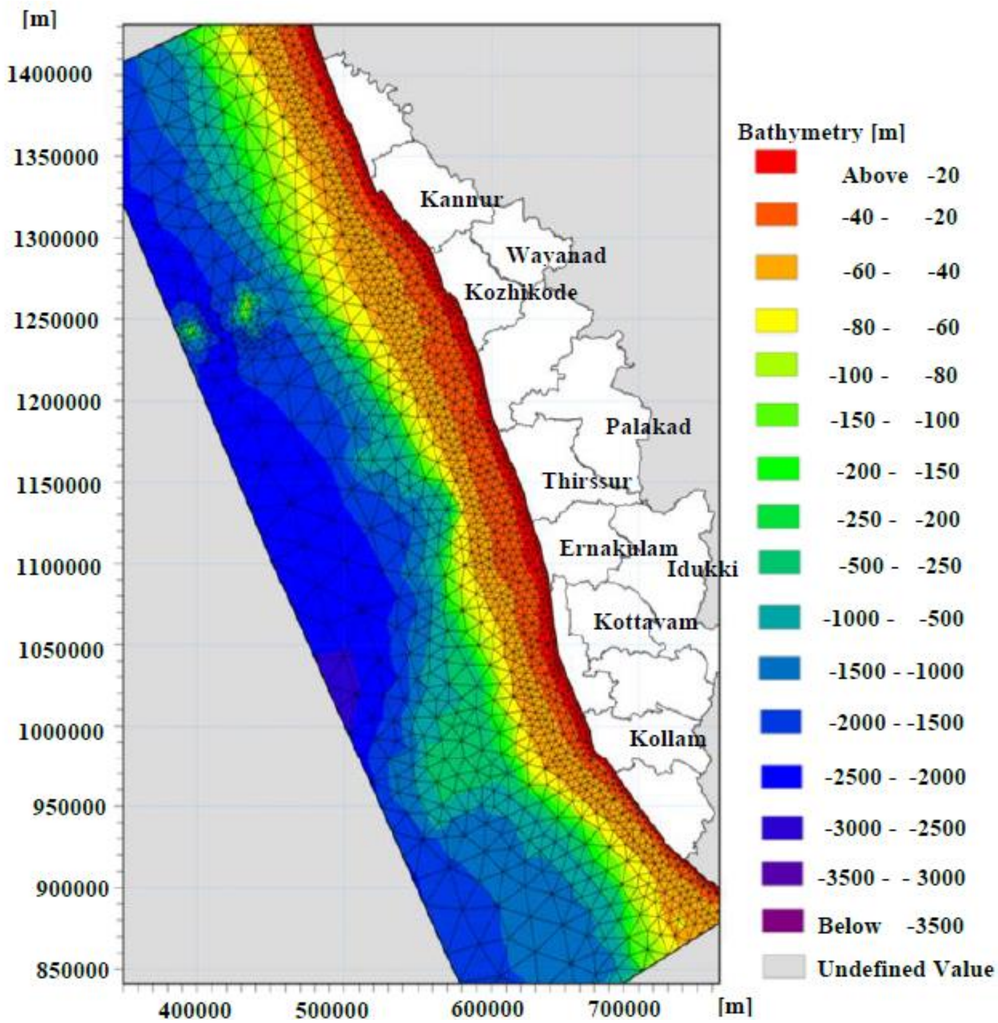


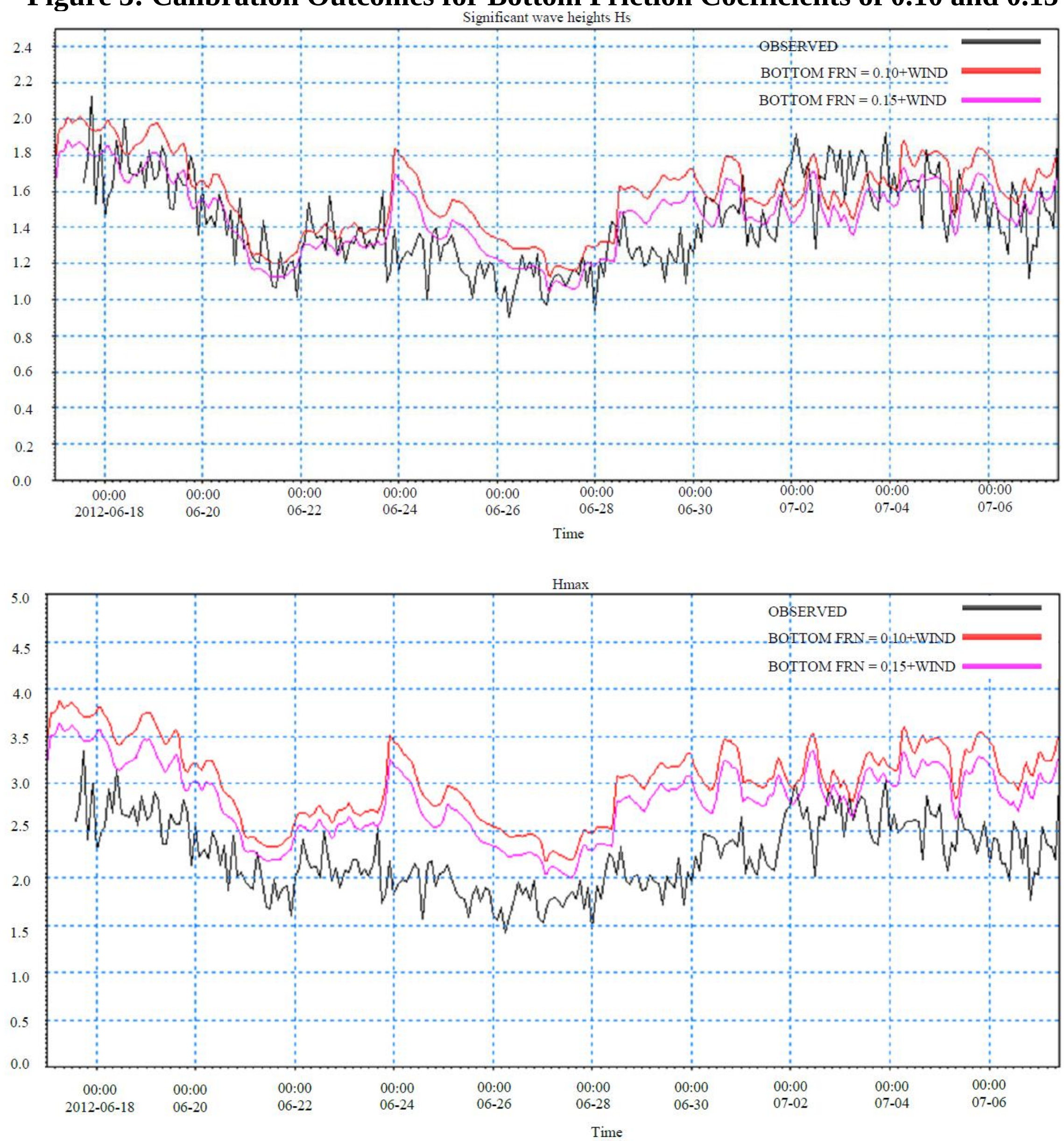
Figure 2: Bathymetry and Computational Mesh Used in the Coastal Model Study

5. Results and Discussion

5.1. Model Calibration

The Directional Wave Recorder (DWR) was used by the port Engineering Department of the Kerala Government in order to carry out an observation of a wave that was seen in shallow water in the year 2012 at South Paravur, which is located in the Kollam district. This action was taken in connection with the field investigations that were carried out with the intention of building a new micro fishing port at that specific location. The data on the field waves was collected at a depth of eight metres, and the findings of the wave transformation were calibrated and further confirmed by making use of the data that was gathered. In the beginning, the model simulation did not include any wind data into its calculations. In spite of this, the model was simulated once again by including the wind data after the calibration experiment that was conducted using field data was successfully completed. At this time, it has been found that the conclusions obtained from simulation are incredibly well matched with the data gathered from the field (Figure 3). This was observed at this point.It has been found that the outcomes of model calibration are the most appropriate for the circumstance, and this was identified via the utilisation of wind data and a bottom friction metric of 0.15. The configuration of this model was taken into consideration with the intention of carrying out more research on shoreline oscillations in a variety of locations. The study takes use of the data collected in the field on waves that was available and accessible during the whole year of 2017. After the model has been calibrated, it is validated once again by making use of the field wave data that was collected at Paravur between the 9th and 29th of July in the year 2012. Regarding the Paravur location, the data that was anticipated and the data that was seen are in a state of exceptionally high agreement with one another. Both Figure 4 and Figure 5 provide the results in their respective formats. As soon as the model has been calibrated using the field wave data that was acquired in Kozhikode in 2017, a second round of validation is carried out on the model. It was discovered that the data that was expected to be seen and the data that was actually seen for the Kozhikode location were pretty similar to one another. Figures 6 and 7 exhibit the results, respectively, when they are presented.

Figure 3: Calibration Outcomes for Bottom Friction Coefficients of 0.10 and 0.15



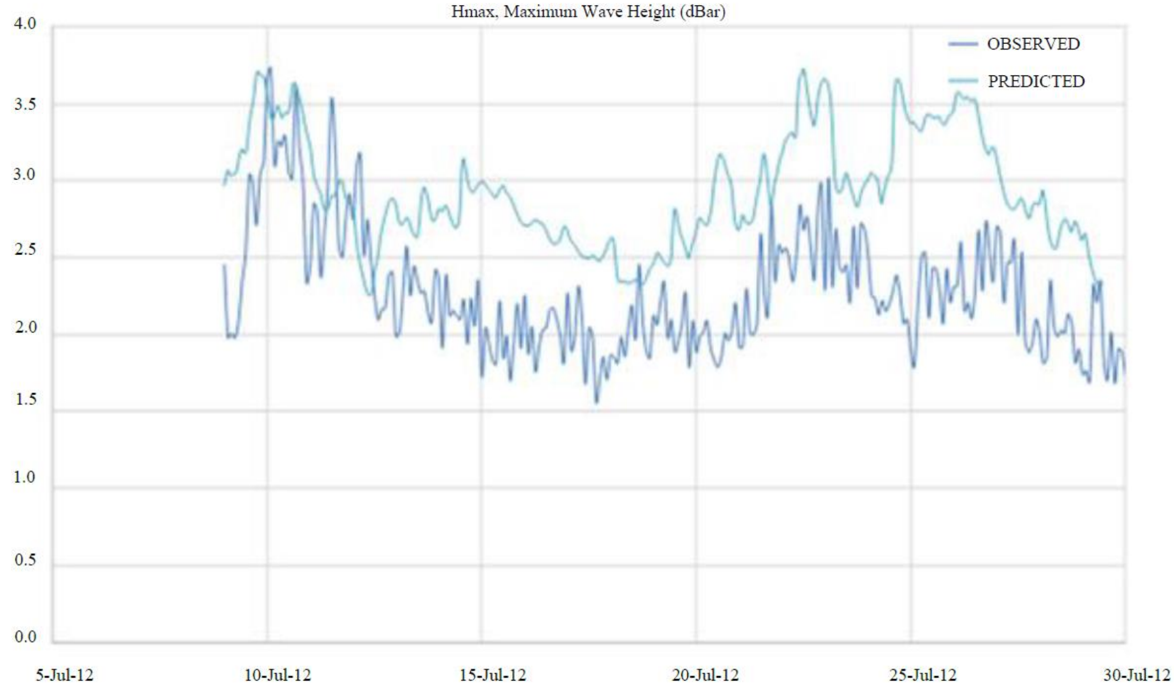


Fig. 4 Results of validation for Paravur site – Hmax

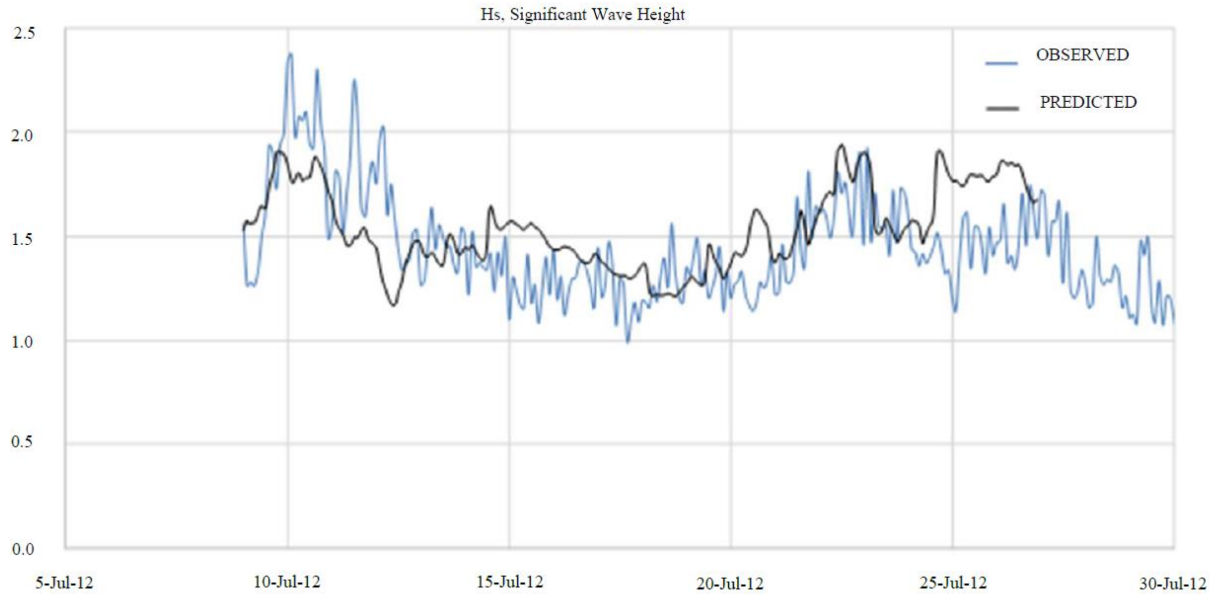


Fig. 5 Results of validation for Paravur site - Hs

The data that were predicted indicate that there is a considerable amount of accretion taking place to the north of the breakwater that is located in the northern region. On the other hand, there is a propensity for erosion to occur on the southern side of the breakwater that is located to the south. It has been found that the construction of the breakwater in the Munambam estuary has had a substantial impact on the shoreline. This was established after extensive research. The data that were projected make it abundantly evident that there is a considerable amount of deposition and a net advancement of the coastline on the north side of the north breakwater, but on the south side of the south breakwater, there is a net loss of land. This is the case because the north breakwater is located on the mainland. The accretion and erosion tendencies that are showing on the north and south sides of breakwaters, respectively, are the result of the reduction in the amount of littoral drift that is occurring in the direction of the south. The view of Munambam harbour from above is shown in figure 20 at this point in time.

Conclusion

The LITPACK Module Mike 21 software was used in order to carry out an examination of the costal changes that took place in the area of three estuary harbours that were created along the coast of Kerala in India. These harbours were developed along the coast of Kerala. The major conclusions drawn are: • At Azhikkal harbour, on either sides of the estuary considerable accretion is observed; • At Beypore harbour there is tremendous deposition on the south side up to the rocky promontory and also marginal accretion on the northern side; • At Munambam harbour, tremendous accretion on the north side is noticed and net erosion on southern side; and • The analyses on coastline oscillations around three estuarine harbours show significant impact of harbour construction on adjacent coast.

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