Article Title: Assessment of Longshore Sediment Transport Using LITPACK

Assessment of Longshore Sediment Transport Using LITPACK

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ABSTRACT

The coastal zone has become one of the most important activity zones in the world as it is thickly populated and has several industries and other establishments. Development activities in the coastal zone must be systematic within the framework of well-defined Coastal Zone Management Plans. Thorough understanding of coastal processes which are controlled by coastal hydrodynamics and the resulting sediment transport is essential for development of coastal zone management plans. The study of these processes can help in developing appropriate strategies for coastline management and conservation. This study has been conducted at Thiruvananthapuram coastal stretch (78km) for wave analysis and estimation of longshore sediment transport. Dedicated wave model has been developed using MIKE 21 SW model and the simulated wave climate has been used in LITPACK model for estimation of sediment transport which is calibrated and validated with the real data. Study has conducted from 2013 to 2022 during south-west monsoon season. Study shows that the Thiruvananthapuram district seashore experiences significant longshore sediment transport, with sediment moving predominantly towards the south during monsoon season with gross sediment transportation of 1.34x10⁶m³

Keywords: Littoral Drift, Wave climate, MIKE 21 SW, LITPACK

1 Introduction

The coast is probably the most diverse and dynamic environment found anywhere on earth. Many geologic, physical, biologic, and human factors are responsible for shaping the coast and keeping it in constant flux.

Major natural factors responsible for coastal processes are waves, tides, currents. The first and foremost factor which is responsible for wave formation is wind. Wind blowing over water transfers its energy to the water surface causing it to form wind waves. Coastal structures such as jetties, groins, seawalls, bulkheads, harbour breakwaters and revetments are probably the most dramatic cause of man-induced coastal erosion. Longshore transport refers to the cumulative movement of beach and nearshore sand parallel to the shore by the combined action of tides, wind, and waves. Longshore sediment transport on beaches is caused by wave-induced current in the surf zone and the turbulence induced by wave breaking.
This study contains development of MIKE21-SW wave model to assess wave climate and to estimate littoral drift at the study area using LITPACK software along South coast of India in Kerala state.

2 Study Area

The Thiruvananthapuram district seacoast extending from Edava to Poovar is in the southernmost part of India, on the western side of the Indian peninsula is selected as study area as in Figure 1. The district is bordered by the Arabian Sea on the west, and is surrounded by the districts of Kollam, Pathanamthitta, and Kanyakumari. Thiruvananthapuram is the capital city of the state of Kerala and is known for its beautiful beaches, lush green forests, and rich cultural heritage. The Thiruvananthapuram district seacoast is characterized by a variety of coastal features, including beaches, cliffs, and rocky headlands. The coastline is approximately 78 km long, and is subject to a range of environmental conditions, including strong monsoon winds, high waves, and intense rainfall. These environmental factors play an important role in shaping the coastline, and in driving sediment transport processes.

![Figure 1: Trivandrum Coast](image)

3 Proposed Work Explanation

This study aims to develop an integrated numerical modelling approach for simulating wind wave dynamics and sediment transport in coastal environments. For simulation of the wave climate the Spectral Wave model (MIKE 21 SW) of MIKE 21 model suites was used. The MIKE 21 SW is a new generation spectral wind-wave model based on unstructured meshes. The model simulates the growth, decay and transformation of wind generated waves and swells both in offshore and coastal areas. For the present study the
fully spectral formulation based on the wave action conservation equation was adopted. The major inputs used for the numerical model are the bathymetry and the wind data collected. Outputs from the model are the wave parameters like significant wave height, mean wave period, mean wave direction. The governing equation used in wave model is conservation equation for wave action formulated in either Cartesian of spherical coordinates. These outputs are calibrated and validated to increase the accuracy and provided as inputs for the LITPACK model.

LITPACK is a numerical model in MIKE software package for simulating non-cohesive sediment transport driven by waves and currents, littoral drift, coastline evolution and profile development along quasi-uniform beaches. The LITDRIFT module combines STP with coastal hydrodynamic model to give a deterministic description of the littoral drift. The sediment transport program (STP) is the core of LITPACK modelling system. It is integrated in all LITPACK modules and forms the basis for all sediment calculations in LITPACK. It provides a detailed deterministic description of the cross-shore distribution of the longshore sediment transport. The longshore and cross-shore momentum balance equation is solved to give the cross-shore distribution of longshore current and setup. The governing equations are solved using finite difference approach. The grain size distribution of sediment and bed roughness at selected locations are also given as additional inputs model. LITDRIFT calculates the net/gross littoral transport over a specific design period. Calculated sediment transport is then calibrated and validated with known values. The integration of these models will enable a comprehensive understanding of wave-sediment interactions and their impact on coastal processes.

### 3.1 Data Collection

Wave modelling requires accurate bathymetry data because the ocean floor's shape and variations significantly influence the behaviour of ocean waves. One of the most widely used datasets for bathymetry information is the General Bathymetric Chart of the Oceans (GEBCO). GEBCO provides bathymetric data in various resolutions. Here we are using Grid resolution. Wind data is a critical input parameter for wave modelling as it directly affects the generation, propagation, and behaviour of ocean waves. The European Centre for Medium-Range Weather Forecasts (ECMWF) provides valuable wind data that is essential for wave modelling. Wind speed and direction vary with altitude. For longshore wave modelling wind data at 10m from mean sea level for past 10 years (2013 to 2022) is taken for this study.

### 3.2 Development of wave model

MIKE21-SW model was used for the computation of suitable wave transformation from deep to shallow coastal waters. The work consists of defining and limiting the wave problem, collecting data, setting up the model, calibrating and verifying the model, running the production simulation, and presenting the result.
The Mesh Generator provides a work environment for creating detailed digital mesh for use in the MIKE Zero models. Figure 2 shows refined mesh generated for study area. Grid series module of MIKE ZERO is used for Grid series generation. Spectrum wave module of MIKE21 is used to generate wave climate. Mesh file and wind data are provided as input. The outputs of the model are significant wave height, mean wave period and mean wave direction.

Figure 2: Refined mesh generated for Study area

3.3 Development of sediment model

Littoral drift model is selected to process the LITDRIFT model for the estimation of longshore sediment transport along the Trivandrum coast. LITDRIFT simulates the littoral drift or shore parallel sediment transport, and it is a part of the software package LITPACK developed by DHI Water & Environment. Total sediment transport is dominated by transport contributions from areas where wave breaking occurs. This gives the distribution of sediment transport across the profile, which is integrated to obtain the total longshore sediment transport rate. Annual drift is evaluated by the contribution of transport from each of the incident wave occurring over the year. This model type calculates the longshore transport for one or several cross-shore profiles. It is assumed that each cross-shore profile represents uniform conditions along a straight coast. The longshore sediment transport is simulated by integrating the calculated sediment transport for the grid points in the profile. Total of eight profiles are selected to obtain the longshore sediment transport in the shoreline stretching from Edava beach to Poovar beach, as shown in Figure 3.
Calibration and validation of model

Calibration is used to tune model to reproduce the measured conditions. Wave model calibration is done using known measurements collected from INCOIS without changing any tuning parameter. Above model simulations are undertaken to calibrate the MIKE 21 SW model by trial-and-error technique. Wave data collected from buoy measurements taken for Trivandrum coast for the year 2020 from 01/06/2020 to 31/07/2020 is used for model calibration. To validate the hydrodynamic model performance, some statistical parameters such as mean, bias, RMSE, scatter index and correlation coefficient have been determined with updated model results. All the validation indices point to the fact that the performance of the model is quite satisfactory.

Sediment model calibration is done using sedimentation data from the report “Shoreline Change Analysis of Vizhinjam Coast Using Satellite Images” done in the year 2018 by Coastal and Environmental Engineering Division, Chennai. Spreading factor and bed roughness are selected as calibrating parameters. To validate the sediment model performance, some statistical parameters such as scatter index and correlation coefficient have been determined with updated model results.

4. Results and Discussion

Observations from the beach profile analysis done using LITPACK for the entire 78 km stretch is presented as bar diagram on yearly basis for the year 2013 to 2022 in Figure 3.
From the Figure 4, in 2018 only accretion happened during monsoon months. The beach exhibits more erosion during 2022 and accretion is high during 2018. The impact of severe cyclonic storm Ockhi that occurred during the end of November and the beginning of December 2017 has large impact on the beach. This may be the reason for higher accretion during 2018.

Figure 5 shows the total cumulative monthly changes during the calendar year based on the available data. This enables to understand the beach variations that happen in a year.
Figure 5: Profile variations during (a)2013 (b)2014 (c)2015 (d)2016 (e)2017 (f)2018 (g)2019 (h)2020 (i)2021 (j) 2022
From the Figure 5, it can be inferred that during the year 2013 the coast was found to have an alternative erosion and accretion trend almost at all profiles. 2016, 2017, 2019, 2020, and 2022 had more net erosion rate and beach formation was found to be very low throughout the year, which is an expected behaviour of south-west monsoon months. From various literatures it can be understood that sediment transportation is high during the years after 2017 comparing to 2013 to 2016 which supports findings of this study. Higher erosion after the year 2017 can be due to climate change. During the year 2018 significant amount of accretion was observed as most of the coastal stretch shows net accretion as in Figure 5(f).

Erosion/Accretion/Stable condition of beach for 2013 to 2022 are marked in Thiruvananthapuram coastal map for each profile as shown in Figure 6. Red represents erosion, green represents accretion and blue stable condition of beach.

![Figure 6: Erosion/Accretion/Stable condition of beach for 2013 to 2022](image)

From the Figure 6, it can be observed that beach erosion was more during the monsoon season. Beach erosion is high at Edava beach and Poonthura beach and beach accretion is more at Vizhinjam beach. On considering Vizhinjam beach, it is observed from the Figure 6 that more accretion occurs at northern side and erosion at southern side of Vizhinjam beach. It may be due to the construction of Vizhinjam port. Beach erosion is more at northern part and beach accretion is more at Southern part of Trivandrum coast, which suggest sedimentation transport is southerly during south-west monsoon season.

During the monsoon season, the coastline is more vulnerable to storms, heavy rainfall, and strong winds, which cause significant erosion and sediment transport along the shoreline.
5 Conclusions

A dedicated wave model and sedimentation model are setup, calibrated and validated for the Thiruvananthapuram coast study area. Large amount of accretion happened on the year 2018, which may be the after effect of Ockhi cyclone happened during 2017 December. Edava, Poonthura and St. Andrews beach have been identified as zones of high erosion, whereas Vizhinjam and Perumathura regions are identified as zones of high accretion. Beach erosion is more at northern part and beach accretion is more at Southern part of Trivandrum coast. During the year 2018 significant amount of accretion was observed as most of the coastal stretch shows net accretion. The littoral drift study indicated that at the study area, the southward littoral sand transport is more dominant during monsoon season with gross sediment transportation of $1.34 \times 10^6 \text{ m}^3$.

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