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Estimation of Significant Wave Height Using Satellite Data

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Abstract: Among the different ocean physical parameters applied in the hydrographic studies, sufficient work has not been noticed in the existing research. So it is planned to evaluate the wave height from the satellite sensors (OceanSAT 1, 2 data) without the influence of tide. The model was developed with the comparison of the actual data of maximum height of water level which we have collected for 24 h in beach. The same correlated with the derived data from the earlier satellite imagery. To get the result of the significant wave height, beach profile was alone taking into account the height of the ocean swell, the wave height was deduced from the tide chart. For defining the relationship between the wave height and the tides a large amount of good quality of data for a significant period is required. Radar scatterometers are also able to provide sea surface wind speed and the direction of accuracy. Aim of this study is to give the relationship between the height, tides and speed of the wind, such relationship can be useful in preparing a wave table, which will be of immense value for mariners. Therefore, the relationship between significant wave height and the radar backscattering cross section has been evaluated with back propagation neural network algorithm.

Keywords: Back propagation, neurons, neural network, OceanSAT, radar scatterometers, Significant Wave Height [SWH]

INTRODUCTION

It is very sensitive-though electronics in the field of prediction of Ocean Parameters, proper utilization of the same is not well found. The advancement of electronics and Information Technology with Satellite Images, have revealed the prediction science more appropriately and accurately, particularly in the case of cyclone and to a certain extent, Tsunami. Off late, the advancement of Science and Technology in the ocean science has enabled the scientists to assess many of the Ocean Parameters from the Satellite Images. The application of altimeter has been coupled with images to assess the elevation. There are few sporadic attempts. To assess the Wave Heights however, no systematic and authentic method of assessment has so far recorded. The laurel has triggered me to choose the Ocean Parameters like ocean wave tides, Significant Wave Height, Salinity and Temperature. To take effort to propose the application of Images in assessing the Significant Wave Heights and their estimation. In the mean time I have compared actual values with Internet projections, I have attempted to assess the significant Wave Height by using the associated influencing parameters like salinity, Temperature, etc., after applying suitable error corrections on the actual data through modeling. The study area for our assessment is the Nagapatinam coast of Bay of Bengal, which is also one of the big seashores and also highly vulnerable to Tsunami and frequent cyclone attacks, as it is a low lying coast it established an unpredictable climatic changes. It has shown the highest impact during the recent Tsunami and storm surge.

Wave parameters are required for coastal and offshore structures design, sediment transport estimation and other coastal engineering works. In the literature, several approaches have been proposed for wave height prediction such as empirical based, soft computing based and numerical based approaches. Different formulations have been developed for wave prediction such as SMB (Bretschneider, 1970). With developments of wave theories, high-speed processors and numerical methods, sophisticated third generation models such as WAM and SWAN, Booij *et al*. (1999) have been developed for wave prediction.

Recently, soft computing techniques such as Artificial Neural Networks (ANNs), Fuzzy Inference System (FIS), Adaptive-Network-based Fuzzy Inference System (ANFIS), Genetic Programming (GP), decision trees and support vector machines have been used to develop wave prediction models (Deo and Naidu, 1999; Agrawal and Deo, 2004; These studies have shown that the wind speed is the most important parameter in wave prediction. Furthermore, using sensitivity analysis, they showed that wind speed is the most important parameter for wave hindcasting.

Muraleedharan *et al*. (2007) have applied Calibration coefficients incorporated in the modified Weibull distribution which is more effective for maximum wave

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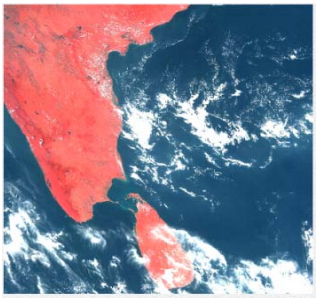


Fig. 1: Oceansat image

height simulation. The parametric relations are derived to estimate various wave height statistics including extreme wave heights and the characteristic function of the Weibull distribution is derived. The statistical tools suggested and developed is used for predicting the required wave height and the statistics are validated against the wave data (both deep and shallow) of eastern Arabian Sea comprising rough monsoon conditions also, giving reasonable accuracy.

The objective aim of our study is to evaluate the wave height directly from the satellite sensors from Oceansat 1 and 2 (Fig. 1) for that we need to the following:

- To assess or evaluate the wave heights directly from the satellite imagery.
- To propose a method of assessing the wave height after making the necessary error corrections for their interference
- To identify the type of need to refine the heights so as to attain the perfection as close as possible

Estimating the Wave Height can be surely useful the areas of:

- Advice to Fisheries Department
- Naval Wing
- Weather forecasting community
- Coastal Zone Management Planning body
- Tourism Department
- Wave energy ports for facing data buoys
- Boat Channel guide, etc

Scope: Our study enables one to assess the wave height, supposed to be a difficult parameter, as accurate as possible from the images without going for laborious field procedures. It increases the accuracy and automation of prediction of waves, Preparation of atlas because of the easy digitization of wave properties in advance Altimeter values can be calibrated. It saves time, energy and human error. It saves not only the time of collection but also the huge expenditure warranted.

Pilot study: Researchers could observe such applications of Information technology as a continuous observation. Monitoring of the various ocean parameters at the case of salinity, temperature, number of waves, movement of the fish soil, turbidity, etc., However, there is only sporadic attempt in assessing the wave heights which is treated to be one of the important parameters to project the roughness of the sea and the smoothness of the sea bed.

Need for significant wave heights: Accurate prediction of significant wave height enables an ocean Engineer to understand the nature of force acting upon the structure. Brings out a refinement in evaluating the different coastal engineering projects. Especially in the construction design, analysis and determination of the viable economical means.

METHODOLOGY

- The source of Information is scanning the wave data for the last 10 years for the study area.
- Actual measurement of Wave height for the 24 h in the beach of the study area (Nov 12-13, 2011).
- Assess the nature of Satellite Image value to the actual height measured on a particular day of satellite pass.
- Comparative Estimation of the Significant wave height from the satellite imagery in relation to the actual measurements.
- Prediction of the Significant Wave Height to another unknown site and evaluate the error to actual measurement subsequently.
- To work out the various error corrections so as to approach the perfection in assessing the Heights of the Waves.

Ocean parameters: Among the various oceanographic parameters like tide, salinity, temperature, turbidity, etc., Waves and their heights are found to be the parameters which have not been worked out satisfactorily to apply in the research, still no systematic approach in estimating the Significant Wave Height. [SWH-Hs]

Ocean waves: It's a moving palette of ocean energy. Waves are vertical expressions of energy. Waves begin

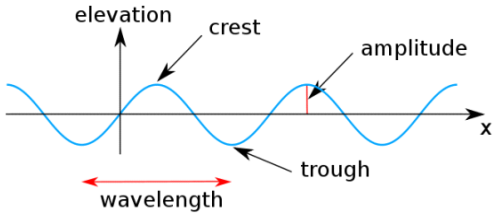


Fig. 2: Ocean characteristics

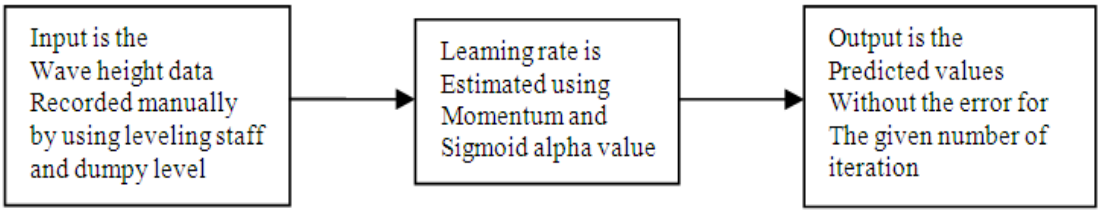


Fig. 3: Model of SWH

far out at sea, where they're whipped up by the wind In shallow water, wave length decreases (Fig. 2).

The bottom of the wave drags on the sea floor and the crest of the wave rises, moving along until it breaks.

If speed decreases, wavelength decreases and the height of the wave increases If the tide direction is against the wind this will also increase Wave Height and decreases the wavelength.

Significant wave heights: Accurate prediction of significant wave height can assist the planning coastal and offshore structures and Analysis of statistical parameters so as to evaluate the status of coastal projects and, especially in the design, determination of the economical and social life related to ocean engineering.

Determining the significant: Wave Height In physical oceanography, the Significant Wave Height (Hs or SWH) is defined traditionally as the mean wave height (trough to crest) of the Highest third of the waves (H1/3)) (Fig. 3):

$$H_{1/3} = \frac{1}{\frac{1}{3}N}\sum_{m=1}^{\frac{1}{3}N} H_m$$

Calculating ocean tide: Generally, the statistical distribution of the individual wave heights is well approximated by a Rayleigh Distribution. For example, given that:

Hs = 10 m, or 33 feet, statistically:
1 in 10 will be larger than 10.7 m (36 ft)
1 in 100 will be larger than 15.1 m (51 ft)
1 in 1000 will be larger than 18.6 m (62 ft)

Tide analysis satellite-based observations: Satellites have been used to observe the ocean since the 1970s, for climatology, reanalysis and validation purposes, from past missions or from satellites. *In-situ observations* Oceanographers have used in-situ platforms to observe the ocean for ages. Today, in-situ observations are very important as a complement to satellite-based observations.

Fig. 4: Study area- nagapattinam

When assimilated into numerical models, *in-situ* observations calibrate the model and serve as a reference point

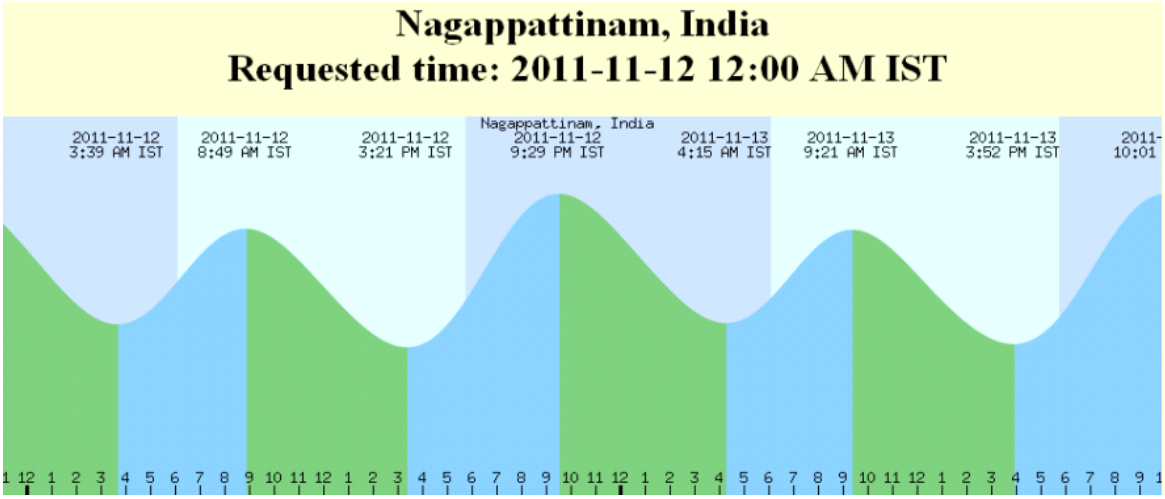
Satellite image processing: Today, many in-situ observation systems use satellites to relay data from remote areas such as the ocean or the poles to scientists for their research or operational needs. The research has to be concentrated on the satellite images from 1981 to 2011. Satellite images are applied to infer the nature of physico chemical parameters. Such efforts lead the scientific community to propound fast predictions.

Satellite imagery types: Spatial, Spectral, Temporal and Radiometric Images. The resolution of satellite images varies depending on the instrument used and the altitude of the orbit. Satellite imagery can be combined with vector or raster data in a GIS. Provided that the imagery has been spatially rectified so that it will properly align with other data sets.

Study area:

Nagapatinam coastal area: Nagapatinam which is located in the eastern coast of south India is a big sea shore area and a dangerous one too because it is a low lying coast enabling the quick changes during cyclone and Tsunami. The process of calculating the oceanic parameters will be helpful to predict such dangerous disasters. We are going to use the feed forward neural network model for that process.

Nagapatinam (Fig. 4) is a coastal city in Indian state of Tamil Nadu, it was carved out by bifurcating the composite Thanjavur district on October 18, 1991. Nearby towns include Tiruvarur, Karaikal and Mayiladuthurai



(a)

Nagappattinam, India
10.7667° N, 79.8500° E

2011-11-12	3:39 AM IST	0.26 meters	Low Tide
2011-11-12	6:04 AM IST	Sunrise	
2011-11-12	8:49 AM IST	0.67 meters	High Tide
2011-11-12	3:21 PM IST	0.16 meters	Low Tide
2011-11-12	5:44 PM IST	Sunset	
2011-11-12	9:29 PM IST	0.81 meters	High Tide
2011-11-13	4:15 AM IST	0.27 meters	Low Tide
2011-11-13	6:05 AM IST	Sunrise	
2011-11-13	9:21 AM IST	0.66 meters	High Tide
2011-11-13	3:52 PM IST	0.18 meters	Low Tide
2011-11-13	5:44 PM IST	Sunset	
2011-11-13	10:01 PM IST	0.81 meters	High Tide

(b)

Fig. 5: Wave height recorded on study area

System flow of the model:

- Image segmentation combined with neural network techniques for processing data can be used for the analysis
- Segmentation and edge detection techniques can be used for detection of clouds, waves, forest cover and other analysis factors
- Neural Network techniques can be applied for processing the climatic condition prediction systems
- The ANN has to be trained with the known data and then can be used for processing the unknown data

EXPERIMENTS AND RESULTS

The algorithm of deriving ocean wave parameters: The retrieved H1/3 and H1/3/ (gT2) from scatterometer data are compared with the H1/3 and H1/3/ (gT2) values from in situ data.

Future tides are calculated by multiplying the tidal potential by the admittance function:

- The technique requires only a few months of data.
- The tidal potential is easily calculated, and knowledge of the tidal frequencies is not needed.

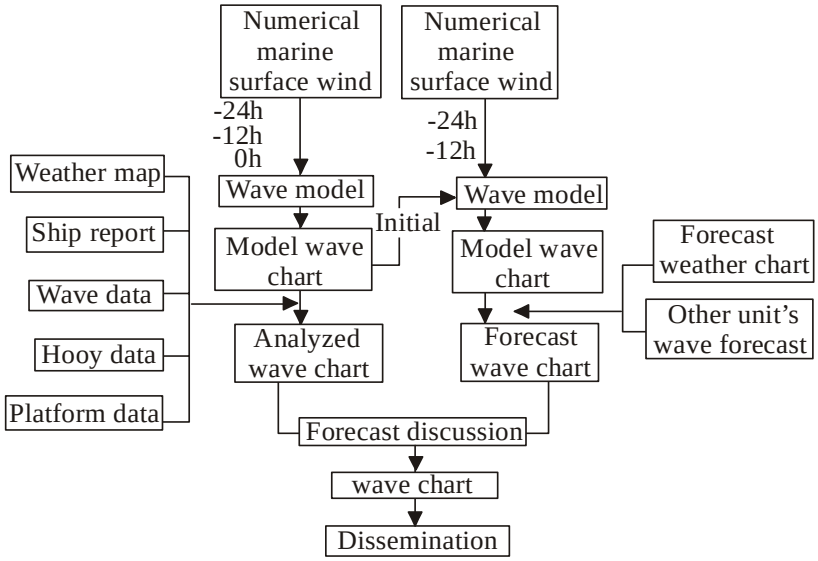


Fig. 6: Schematic representation

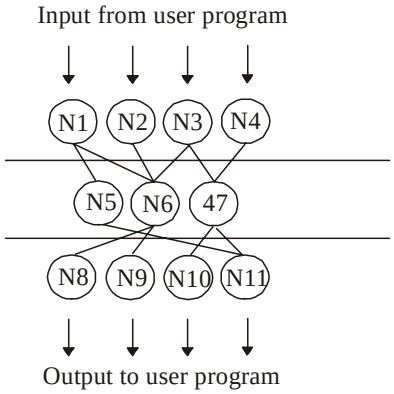
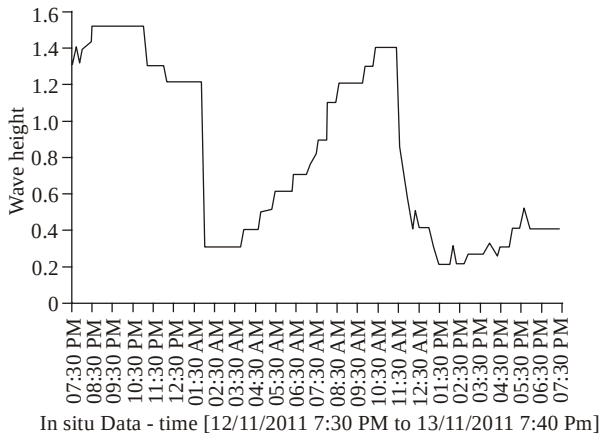


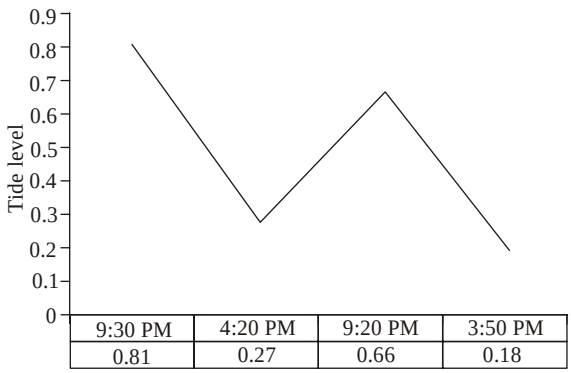
Fig. 7: Neural network layers

- The admittance is Z(f) = G(f)/H(f). G(f) and H(f) are the Fourier transforms of the potential and the tide gage data and f is frequency.
- The admittance is inverse transformed to obtain the admittance as a function of time.
- The technique works only when the waves propagate as linear waves. Error calculation is an important part of the supervised training algorithm. In this model we will examine an error calculation method that can be employed by supervised training. For supervised training there are two components to the error that must be considered. First, we must calculate the error for each of the training sets as they are processed. Secondly we must take the average across each sample for the training set. There are many rule-of-thumb methods for determining the correct number of neurons to use in the hidden layers. Some of them are summarized as follows. (Fig. 5, 6, 7, 8 and 9):
- The number of hidden neurons should be in the range between the size of the input layer and the size of the output layer.
- The number of hidden neurons should be 2/3 of the input layer size, plus the size of the output layer.
- The number of hidden neurons should be less than twice the input layer size.
- The "backward selection method", begins by using a large number of hidden neurons. If the network contains any hidden neurons which contains only zero weighted connections, they can be removed.



In situ Data - time [12/11/2011 7:30 PM to 13/11/2011 7:40 Pm]

(a)



Satilitte Data - time [12/11/2011 9:30 PM to 13/11/2011 30:50 Pm]

(b)

Nagapattinam			Vishagapattinam			Chennai	
9:30 PM	0.81		9:30	1.63		9:20	1.27
4:20 AM	0.27		3:40	0.44		3:40	0.41
9:20 AM	0.66		9:20	1.35		9:20	1.05
3:50 PM	0.18		3:30	0.29		3:20	0.28

Time [12/11/2011 7:30 PM to 13/11/2011 7:40 PM]	Wave Height from ground	High Tide	Low Tide	Actual Wave Height
7:30 PM	1.3			
7:40 PM	1.4			
7:50 PM	1.3			
8:00 PM	1.4			
8:10 PM	1.4			
8:20 PM	1.42			
8:30 PM	1.5			
8:40 PM	1.5			
8:50 PM	1.5			
9:00 PM	1.5			
9:10 PM	1.5			
9:20 PM	1.5			
9:30 PM	1.5	0.81		0.69
9:40 PM	1.51			
9:50 PM	1.51			
10:00 PM	1.5			
10:10 PM	1.5			
10:20 PM	1.5			
10:30 PM	1.5			
10:40 PM	1.5			
10:50 PM	1.5			
11:00 PM	1.5			
11:10 PM	1.3			
11:20 PM	1.3			
11:30 PM	1.3			
11:40 PM	1.3			
11:50 PM	1.3			
12:00 AM	1.3			
12:10 AM	1.2			
12:20 AM	1.2			
12:30 AM	1.2			
12:40 AM	1.2			
12:50 AM	1.2			
1:00 AM	1.2			
1:10 AM	1.2			
1:20 AM	1.2			
1:30 AM	1.2			
1:40 AM	1.2			
1:50 AM	1.2			
2:00 AM	0.3			
2:10 AM	0.3			
2:20 AM	0.3			
2:30 AM	0.3			
2:40 AM	0.3			
2:50 AM	0.3			
3:00 AM	0.3			
3:10 AM	0.3			
3:20 AM	0.3			
3:30 AM	0.3			
3:40 AM	0.3			
3:50 AM	0.3			
4:00 AM	0.4			
4:10 AM	0.4			
4:20 AM	0.4		0.27	0.13

Fig. 8: Actual data taken compared with the satellite\derived data

CONCLUSION

Evaluation of Significant Wave Height still more methods can be adapted to rough weather and fair weather to evolve suitable error correction accordingly. Multi dimensional geospatial technology becomes increasing in demand in the 21st century. Major research areas in multi-dimensional geospatial technology in a timely fashion, will stimulate future research in this direction. In the direction of inferring the ocean parameters and their role in prediction of weather climate. Ocean surface observations are obtained for diverse and useful information through satellite remote sensing.

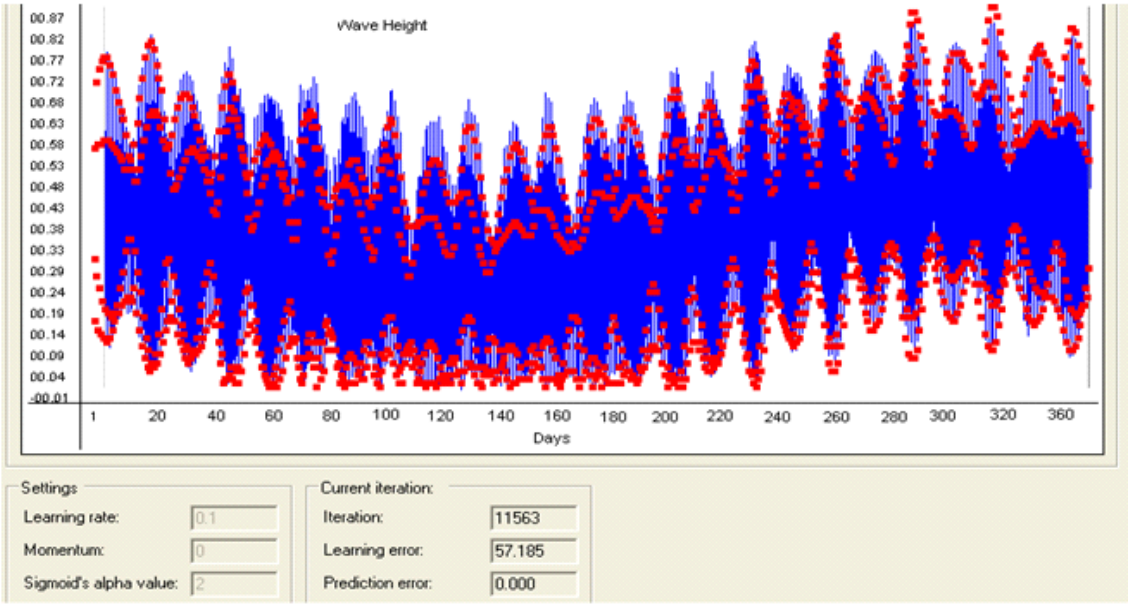


Fig. 9: Supervised learning method

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