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Long term statıstıcs by usıng Log-normal dıstrıbutıon in case of Lapta region, North Cyprus

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Abstract

In this study, the long term statistics is investigated to forecast the significant wave height *(Hs)* and wave period *(Ts)* for planned overpass bridge in Lapta coastal region in North Cyprus. The monthly recorded wind data retrieved from two different stations namely Alsancak and Esentepe. The long-term wave climate of the region are studied utilizing the wave heights, wave periods and wave directions, estimated from the wind data and fetch lengths by CERC (1984) method. The log-normal probability distribution is used to represent the durations of exceedances for the significant wave heights. The extreme wave heights are calculated for 5-10-25-100 years return period and the results are presented in tables. The outputs of this paper are useful to understand the distribution of extreme waves in Lapta region.

Keywords: Long-term statistics, Lapta Region - North Cyprus, hydrodynamics, wind climate, wave climate

Introduction

In engineering applications, a significant fact for the design of offshore and coastal structures is the appearance of extreme wave conditions which can cause a damage to structures. It is very important phase to obtain information on wave characteristics during the lifetime of structures. For an accurate prediction of wave parameters such as significant wave height and peak wave period, the statistical properties of wind and waves should be examined with statistical contingency methods. Two approaches are applied as climate statistics including long-term statistics and extreme statistical analysis. These approaches different from each other in terms of databases and results.

In many applications, it is necessary to use long-term wind and wave data to obtain the parameters required to determine the wave forces acting on structures. Long-term statistics is the statistical information of wind and wave characteristics accumulated over a sufficiently long period of time. In accumulating data for long-term statistics provides methods to estimate how rough conditions are likely to happen at a given location over a time span of, say 20,50,100 years. Unfortunately, data of long term measurements are not useable in many areas and it is necessary to use wave prediction models. For defining a significant wave height where actual wave measurements are not available consists of gathering pertinent long term wind data, making wave hindcasts from the wind data, and subsequently performing statistical analysis on the hindcast wave data to estimate significant waves.

During the past decades, researchers work on the development of empirical and numerical models for wave prediction. The investigation of the long-term modeling of high crest to trough wave heights was firstly proposed by Jasper [1956]. As for the long-term statistics, Isaacson and Mackenzie [1981], Guedes Soares [1989] and Goda [1999] presented some complete reviews. Arena and Pavone [2006] investigated effects relevant to the design of offshore structures by the Equivalent Triangular Storm (ETS) method in conjunction with the Forristall [2000]. Soares et al. [2004] applied the joint asymptotic distribution of the r largest-order statistics to model the occurrences of high sea states and to extrapolate their extreme values. A new method for the geographical transposition of extreme wave height is obtained by Gencarelli et al. [2006] to determine the value of the extreme significant wave height with a long term return period at a sea area where only a few years of wave records are available. Vanem [2011] summarized the methods from different fields but potentially relevant to the sea wave long-term analysis. More recently, Arena et al. [2014] examined the long-term statistics of nonlinear wave crests in finite water depths. Non-stationary time variability of the significant wave height was modelled by equivalent power storm method.

In this study to determine significant wave height and wave period overpass bridge in Lapta coastal region is likely to encounter during its lifetime, the long term statistics is treated by extreme wave statistics.

Lapta, which is approximately 12 km far from west of Kyrenia, located along the narrow coastline between Beşparmak Mountains and Mediterranean in North Cyprus and shown in Fig.1.

Figure 1: Location of the project area.

According to the available batimetric maps the maximum depth of the coastal zone is 4m. The route of coastal walkway which is going to be built in Lapta Region, provides an impression as the coast that shaped by headland. The region between two consecutive headlands take the form of a bay due to the erosion resistance of coastal landform. Headlands are usually formed of more resistant rock types. Reflection involves a change in direction of waves as they slows down when waves enter the sheltered bay in Lapta Region. Consequently, waves lose their energy and influences. In addition, broken waves are effective in construction locations. Hydrodynamic forces to be used in static and dynamic analysis of the structure should be calculated taking into account these criteria. Therefore, the accurate estimation of the design wave parameters acting on piles of overpass bridge gains importance.

In this study, coastline of Lapta Region located at the North Cyprus is chosen as the study.

The long-term wind statistics is determined for the area as a part of a project aiming to identify the significant wind parameters. To investigate the long-term wave climate, the wave characteristics of Lapta region are estimated by CERC (1984) method utilizing the monthly extreme wind data of Alsancak and Esentepe Stations. Significant wave height, *Hs* can be described as the mean of the highest one-third of waves and significant wave period *Ts*, are calculated for 5-10-25-100 years return period by the log-normal probability distribution. This paper presents wave statistics information which plays a significant role in predicting responses of coastal structures planned in Lapta region in North Cyprus.

Wınd clımate

Wind climate which have a direct effect on the climate of wave, is the fundamental factor for all coastal and marine activities and structures. Nowadays wave forecasts are based on wind measurements or models in Cyprus as the world. There is no measured wave data which can be used in studies of wave climate in Lapta Region in North Cyprus. Therefore, the monthly maximum wind speed data which retrieved from Alsancak and Esentepe Stations are used to perform long term statistical analysis. A study is undertaken using 51 and 24 monthly wind speed records from Alsancak and Esentepe Stations respectively. (Fig. 1a-1b). Maximum wind speeds which are selected through from all measured monthly data, performed statistical analysis.

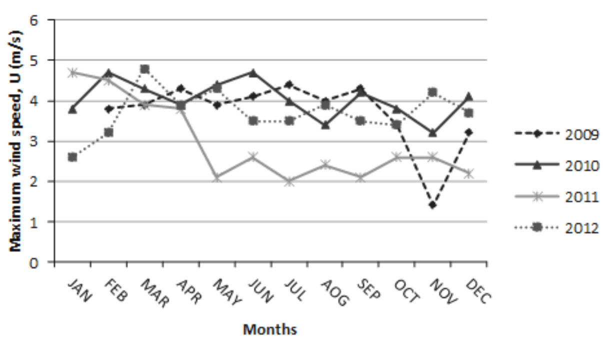

Figure 1a: Monthly maximum value of wind speeds from Alsancak station.

Alsancak station provides wind data from 2009 through 2012, Esentepe station provides wind data from 2011 through 2012. Alsancak Station measurements which contain greater number of records are taken into account to investigate the direction of dominant wind. 51 monthly data relating to maximum wind speed of Lapta region are grouped by considering effective 9 directions. The directional distribution of wind blowing time is determined and presented in Fig. 2. The direction which has the biggest percent value is evaluated as the dominant wind direction.

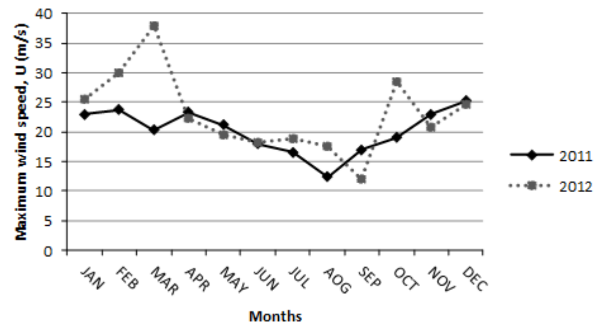

Figure 1b: Monthly maximum value of wind speeds from Esentepe station.

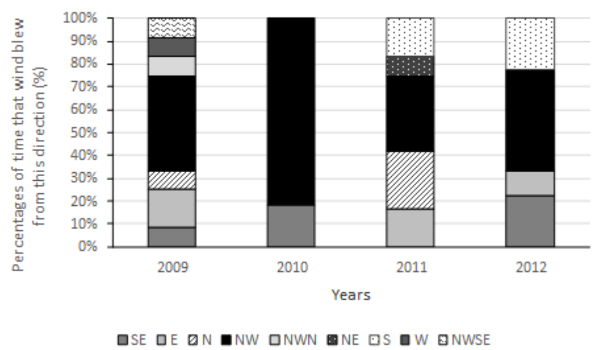

Figure 2: Directional distribution of wind blowing time.

Due to the location of the project area, the dominant direction for the wind wave growth is determined as North-west (NW). It is seen that for the average annual value of the wind speeds that blow this direction, is 2,4 m/s. For the wind speeds greater than 10 m/s, occurrences of north westerly winds increase.The recorded maximum wind speed is 32,6 m/s blowing from North (N). Effects of North-westerly winds show an increase in the summer season.

The wind speed measurements are turned into wind speeds at 10 m height and the fetch lengths are determined by cosine average method. Wind fetch is defined as the unobstructed distance generally coincides with the longest axis in the general wind direction. Fetch is an important characteristic in the generated of wind and longer fetch can result in larger waves. The longest shoreline-to-shoreline distance regardless of whether or not the line is broken by a shoreline feature for Lapta region is shown in Fig.3.

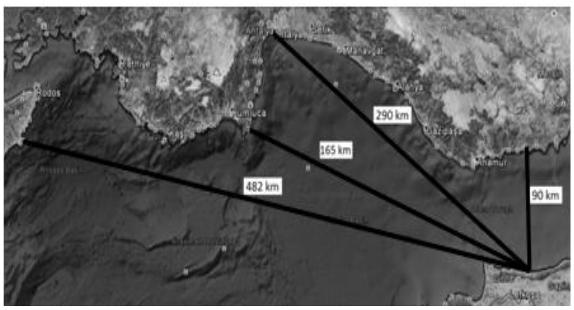

Figure 3: Fetch length of particular point which is located of overpass bridge in Lapta region.

An effective fetch is determined and applied to wave forecasting equations to predict significant wave height and period. The effective fetch is defined as follows:

$$F = \frac{\sum \cos \alpha_i^2 F_i}{\sum \cos \alpha_i} \qquad (1)$$

where F is effective fetch, F_i is length of the straight-line fetch and α_i is angle from mean wind direction. For a certain direction, straight-line fetches are measured at increments of 7,5 deg over a ±22,50 deg arc.

Wave clımate

One of the first considerations when solving a coastal engineering problem is the estimation of a significant wave height. Significant wave height, *Hs*, is the fundamental parameter which demonstrates the effectiveness of the hydrodynamic forces acting on the coastal structures. Also the power of waves is one of the most important forces that change the shape of the coast.

There are two approaches in the modeling of wind waves; numerical models and empirical models. However, numerical models themselves require care and expertise in their implementation. Besides, using the numerical models or conducting field surveys to estimate the wave height, period and direction may be too costly, time-consuming and complex. Therefore, in many coastal engineering projects, engineers tend to use simplified empirical wave prediction methods. In this case, wind parameters are used in a series of empirical equations and nomograms to derive the wave parameters such as significant wave height *Hs* and mean wave period *Tm*. The wave period that induces response of ocean structures to wave excitation, is equally important as wave heights in wave climatology. The accuracy of analysis of “wind field” is crucially important for accurate estimation of “wave fields”. In this study predicting the extreme value of significant wave height from the long-term accumulation of data is also discussed for dominant wind direction North-west (NW).

There are various probability distributions used for the long-term wave climate studies. Since measured wave data are not available in the coastal wave climate in Lapta region, an empirical model is preferred in the design process. Thus, the long-term wave climate of the area is studied utilizing the wave heights, wave periods and wave directions, estimated from the mountly wind data by CERC (1984) method. First, data sets retrieved from Alsancak and Esentepe stations are divided into 8, 6 groups respectively, considering the lower and upper limit values in the preferred method. The extreme speed *Uf* is calculated by averaging the minimum and maximum values of grouped data and *t* which is the duration of passing a-mile length is determined. The average wind speed blowing for an hour U_{3600} is determined by using Fig.4.

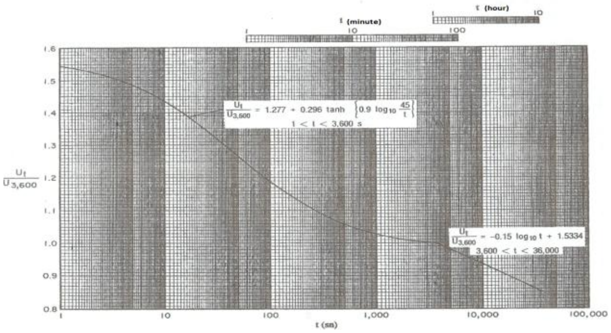

Figure 4: Ratio of wind speed of any duration, U_f , to the one hour wind speed, U_{3600}.

Significant wave height *Hs* and significant wave period *Ts* are determined using the nomogram of significant wave characteristics. (Fig.5)

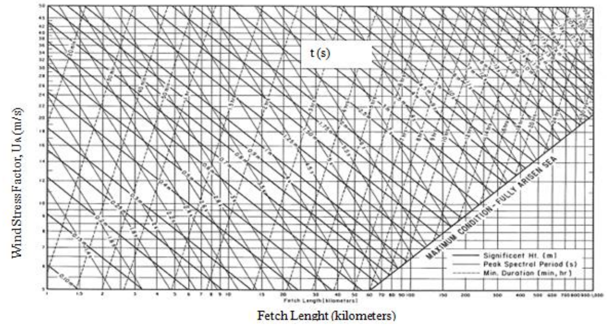

Figure 5: Nomogram of significant wave prediction curves as function of windspeed, fetch lenght and wind duration (metric units).

The significant wave height and period are also calculated separately by using data received from Alsancak and Esentepe stations, as given by Tables1-2.

The relation between the significant wave heights and the wave periods are presented in the tables not on the wave rose with the aim to examine quantitative results.

Table 1: Significant wave height and period based on the data of Alsancak station.

No	Wind Speed Groups (m/s)		Uf	t	U_f/U_{3600}	U_{3600}	U_A	Hs	Ts
	lower	upper	(m/s)	(hour)		(m/s)	(m/s)	(m)	(s)
1	10,0	13,0	11,5	11	1,20	9,6	11,5	2,8	8,5
2	13,0	16,0	14,5	9	1,20	12,1	15,2	4,0	10,5
3	16,0	19,0	17,5	7	1,20	14,6	19,2	5,0	11,0
4	19,0	22,0	20,5	6	1,25	17,1	23,3	7,0	12,5
5	22,0	25,0	23,5	5	1,25	19,6	27,6	9,0	14,0
6	25,0	28,0	26,5	5	1,27	22,1	31,9	10,0	14,5
7	28,0	31,0	29,5	4	1,27	24,6	36,5	11,5	15,5
8	31,0	34,0	32,5	3	1,27	27,1	41,1	13,0	16,5

Table 2: Significant wave height and period based on the data of Esentepe station.

No	Wind Speed Groups (m/s)		Uf	t	U_f/U_{3600}	U_{3600}	U_A	Hs	Ts
	lower	upper	(m/s)	(hour)		(m/s)	(m/s)	(m)	(s)
1	10,0	14,0	12,0	11	1,20	10,0	12,1	3,0	8,6
2	14,0	18,0	16,0	7	1,22	13,1	16,8	4,5	9,9
3	18,0	22,0	20,0	6	1,25	16,0	21,5	6,0	10,9
4	22,0	26,0	24,0	5	1,26	19,0	26,6	8,0	12,4
5	26,0	30,0	28,0	4	1,27	22,0	31,8	9,0	13,3
6	30,0	42,0	34,0	3	1,28	26,7	40,4	13,0	14,9

$$Y = z = \phi^{-1}(P) = \frac{\ln H - \overline{\ln H}}{\sigma_{\ln H}} = \frac{1}{\sigma_{\ln H}} \ln H - \frac{\overline{\ln H}}{\sigma_{\ln H}} \quad (2)$$

$$Y = \phi^{-1}(P); \qquad X = \ln H; \qquad A = \frac{1}{\sigma_{\ln H}}; \qquad B = -\frac{\overline{\ln H}}{\sigma_{\ln H}} \quad (3)$$

Records are limited in terms of the duration of collecting data and based on discrete measurements which do not allow to identify periods of wind in a certain direction. For this reason, Weibull and Gumbel probability distributions can not be used for long-term statistical evaluation. In this study log-normal probability distribution is used to represent the durations of exceedences for the significant wave heights. The log-normal probability distribution which is given by Equation (2) is probably the most commonly used distribution in reliability applications.

X is distributed log normally with parameters $\overline{H}$,mean wave height and σ_H , standard deviation of wave heights . Where *Y* is the log-transformed variable, *z*, is standard normal variable, A and B are the parameters of the distribution.

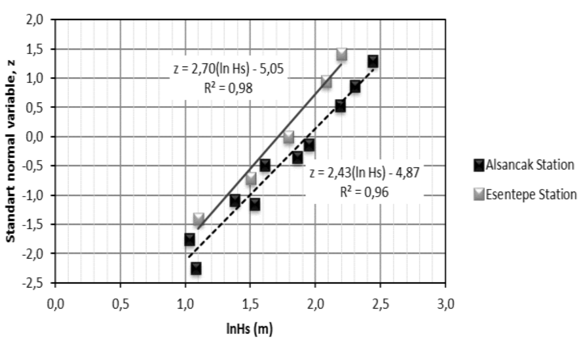

Figure 6: Log-normal distribution of the significant wave heights.

Log-Normal Probability Distribution of significant wave heights based on data from Alsancak is presented with the distribution of data from Esentepe station in Fig. 6.

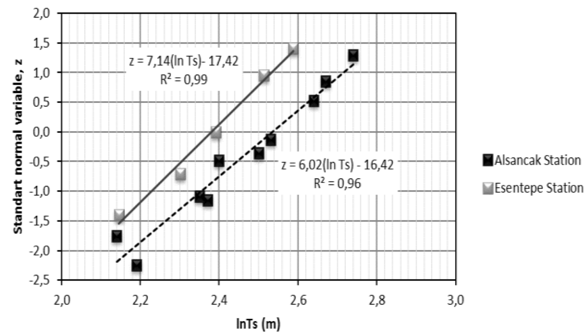

Figure 7: Log-normal distribution of the significant wave periods.

Log-Normal Probability Distribution of significant wave periods based on data from Alsancak station is presented with the distribution of data from Esentepe station in Fig. 7. The values related the significant wave heights and periods are compatible with log-normal distributions as shown in Fig. 6-7.In this case the extreme wave heights are calculated for 5-10-25-100 years return period and the results are presented in Table 3.

Conclusıon

This study presents wind and wave information which plays a significant role in predicting responses of the overpass bridge which will be built in Lapta coastal region in North Cyprus. First step of designing high cost coastal structures is to forecast the significant wave height *(Hs)*. The wind data and fetch lengths are utilized in CERC (1984) method for estimating design values of wave heights, wave periods for the long-term (lifetime) approach.

Table 3: Significant wave height and period according to recurrence duration.

	Alsancak Station		Esentepe Station	
T_R (year)	Hs (m)	Ts (s)	Hs (m)	Ts (s)
5	2,94	8,90	2,82	8,37
10	4,63	10,68	4,24	9,76
25	4,70	10,77	4,30	9,81
100	8,50	13,68	7,33	12,01

The reports of the wind speed and direction obtained from Alsancak and Esentepe stations between the years 2009 and 2012 are used to generate extreme event models for wave. According to these data, the dominant direction for the wind wave growth is determined as North-west (NW) for the project area. The effective fetch lenght is defined as 400 m. The wave data is generated from wind data using an empirical method, namely CERC (1984). The log-normal probability distribution is used for the long-term wave climate studies. As seen Fig. 6-7 high correlation values are obtained for wave parameters. It is thus concluded that the proposed models can efficiently be used to estimate missing wave data. It is observed in Table 3 that the significant wave heights for 5-10-25-100 years return period for NW, the dominant wave direction with a fetch length of 400 km, have been estimated as 2.94 m, 4.63 m, 4.70 m and 8.50 m, respectively. According to the results of the long-term statistical analysis, the significant period is determined as 8.90, 10.68, 10.77 and 13.68 s. for 5-10-25-100 years return period. The significant wave height and period are determined using the values obtained by analysis of data from Alsancak station. Because the duration of recording time is longer than Esentepe station so the results are larger and more reliable. The results of this paper will provide a perception about the distribution of extreme waves in Lapta region. And the outputs are useful to obtain foresight on the coastal hydrodynamics, wave and current system in the project area.

References

Arena, F., Malara G & Romolo, A.,(2006) “On long-term statistics of high waves via the equivalent power storm model”, Prob. Engrg. Mech., 0266-8920, (2014).Arena, F., Pavone, A., “Return period of nonlinear high wave crests”, J. of Geophysıcal Res., 111, C08004

Balas, L., Genç, A., N., Inan, A., (2013) “Wave Prediction for Port Design”, Dokuz Eylul University, Journal on Faculty of Maritime, 5(2)(in Turkish)

Battijes, J., A., (1977) “Probabilistic aspects of ocean waves”, Report 77-2, Laboratory of Fluid Mech., Communications on Hydraulics Dept. of Civil Eng., Delft Univ. of Tech.

Burcharth, H. F., & Liu, Z., (1996) “Design wave height related to structure lifetime”, In Proceedings of the 25th Int. Coastal Engrg Conf., ICCE '96, Orlando, Florida, pp. 2560-2572

Castillo, E. & Sarabia J. M.,(1994) “Extreme value analysis of wave heights”, J. of the Nat. Inst. Of Stnd. and Tech., 99(4)

Chakrabarti, S., K., (2001) “Hydrodynamics of Offshore Structures”, WİTpress, 464 pages, Boston

Chen, Y., Xie, D., Zhang, C., Qian, X.,(2013) “Estimation of long-term wave statistics in the East China Sea”, J. of Coastal Res., 65, pp. 177-182

Coastal Engineering Research Center, (1984) “Shore Protection Manual Vol 1-2”, Government Printing Office, Washington, DC

Gencarelli, R., Tomasicchio, G., R., Veltri, P.,(2006) "Long term trends in NSW coastal wave climate and derivation of extreme design storms", 30th Int.Conf. on Coastal Engrg, San Diego, California

Goda, Y.,(1988)“Chapter 67-On the methodology of selecting design wave height”, Coastal Engıneerıng Proceedings, pp. 889-913, Japan

Goda, Y.,(1999) “Random seas and design in maritime structures”, World Scientific.

Guedes S., C.,(1989) “Bayesian prediction of design wave height”, Reliability and Opt. of Structural Sys.’ 88. Springer-Verlag, pp. 311-323

Fedele, F., Arena, F.,(2010) “Long-Term Statistics and Extreme Waves of Sea Storms”, J. of Phys. Oceanography 40

Forristall, G., Z.,(2000) “Wave crest distributions: observations and second-order theory,” J. Physl Oceanography, vol. 30(8), pp. 1931–1943

Haring, R., E., Osborne, A., R., & Spencer, L., P.,(1976) “Chapter 10- Extreme wave parameters based on continental shelf storm wave records”, pp. 151-170

Isaacson M. & Mackenzie, N.G.,(1981) “Long-term distributions of ocean waves: a review”,

J. Waterway, Port, Coastal Ocean Div., 107, 93-109.

Jasper, N.,.H.,(1956) “Statistical distribution patterns of ocean waves and of wave-induced ship stresses and motions, with engineering applications”, Prepr. Soc. Nay. Architects Mar. Engrg., :No. 6 (New York Meeting)

Krogstad, H., E. And Arntsen, Ø., A.,(2001) “Linear wave theory part b random waves and wave statistics”, Norwegian Unıversıty of Scıence and Technology, Norway, (2000).

Liu, P., C.,(1986) “Chapter 39-Estimating long-term wave statisticsfrom long-term wind statistics”, Coastal Engıneerıng Proceedings, pp. 512-521, Japan

Ochi, M., K.,(1978). Chapter 2-On long-term statistics for ocean and coastal waves. Coastal Engineering Proceedings, pp. 59-75.

Parnaste, Z., I., Suursaar, Ü., Kullas, T., Lapimaas, S. and Soomere, T.,(2009) “Seasonal and long-term variations of conditions in the northern Baltic Sea”, J. of Coast. Res., 0749-0258, 277-281

Shand, T., D., et al.,(2011) "Long term trends in nsw coastal wave climate and derivation of extreme design storms." NSW Coastal Conf.

Smith, J., M.,(1991) “Wind-wave generation on restricted fetches”, Department of the Army, Waterways Experiment Station, Final Report Washington, DC 20314-1000

Soares, C., G., Scottob, M., G.,(2004) “Application of the r largest-order statistics for long-term predictions of significant wave height”, Coastal Engrg., Vol 51 (5-6), pp. 387-394

Soomere, T., Zaitseva-Paernaste, I., & Raeaemet, A.,(2011) “Variations in wave conditions in Estonian coastal waters from weekly to decadal scales”, Boreal Environment res., 16, 175-190.

Toffoli, A., Miguel, O. & Jaak M.,(2006) "Wave statistics in unimodal and bimodal seas from

a second-order model." European J. of Mech.-B/Fluids, 25.5, 649-661.

Tür, R., & Balas, C., E.,(2010)“Significant Wave Height Prediction by Using Neural Fuzzy Approach: in case of Filyos coast , J. Fac. Engrg. Arch. Gazi Univ., 25(3), pp. 505-510(in Turkish).

Vanem, E.,(2011) “Long-term time-dependent stochastic modelling of extreme waves”, Stoch. Environ. Res. Risk Assess., vol. 25, pp. 185–209.