

A COMPARATIVE STUDY ON THE WAVE CLIMATE OF  
SOUTHERN AEGEAN COASTLINE OF TURKEY

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SOUTHERN AEGEAN COASTLINE OF TURKEY

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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## **ABSTRACT**

### **A COMPARATIVE STUDY ON THE WAVE CLIMATE OF SOUTHERN AEGEAN COASTLINE OF TURKEY**

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In this thesis, the wind and wave climate of southern Aegean Sea coastline of Turkey are studied. Six coastal areas to the South of İzmir Bay are selected for the analysis, namely as Kuşadası, Yalıkavak, Turgutreis, Marmaris, Fethiye and Datça coastal areas. In the wind climate analysis, the over land measurements of General Directorate of Meteorology (GDM) are compared with the over sea wind estimates of European Centre for Medium-Range Weather Forecasts (ECMWF) operational archive. Additionally, the monthly maximum values of wind speeds are compared with the short-term over sea measurements of GDM. It is concluded that ECMWF over sea wind estimates present the wind conditions better than the over land and over sea wind measurements of GDM. In the wave climate analysis two methods are utilized. First, CEM empirical method is used to estimate the wave heights for the wave climate analysis. ECMWF wind predictions are selected in the CEM method. Secondly, the wave results of WAM numerical model are used for the wave climate analysis directly. In the wave climate the long term and extreme value statistics are studied.

The significant wave height results of two methods from the long-term wave statistics are compared by studying nearshore and offshore locations for each coastal area. It is concluded that, for the nearshore part, WAM model gives lower wave heights than the CEM method. For the offshore part, WAM Model gives higher wave heights than the CEM Method, if the fetch lengths are relatively short. For the enclosed basins, it is seen that WAM model under estimates the wave heights, and therefore it is concluded that CEM Method gives more reliable results.

Keywords: Wind climate, Wave climate, HYDROTAM-3D, ECMWF, WAM model

## ÖZET

### TÜRKİYE’NİN GÜNEY EGE KIYILARI İÇİN KARŞILAŞTIRMALI DALGA İKLİMİ ÇALIŞMASI

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Bu tez çalışmasında, Türkiye’nin Güney Ege kıyılarından seçilen altı denizel alan için rüzgar ve dalga iklimi çalışılmıştır. Çalışılan denizel alanlar sırasıyla Kuşadası, Yalıkavak, Turgutreis, Marmaris, Fethiye and Datça’dır. Rüzgar iklimi çözümlemesinde, Devlet Meteoroloji Genel Müdürlüğü (DMGM) kara üstü rüzgar hızı ölçümleri Avrupa Orta Vadeli Hava Tahmin Merkezi’nin (ECMWF) deniz üstü rüzgar hızı tahminleri ile karşılaştırılmıştır. Ayrıca DMGM’nin kısa dönem deniz üstü rüzgar ölçümlerinden elde edilen aylık en yüksek değerler ECMWF’in tahminlerinden elde edilen aylık en yüksek değerler ile karşılaştırılmıştır. Karşılaştırma sonucunda ECMWF deniz üstü rüzgar tahminlerinin Meteoroloji İstasyonları kara ve deniz üstü rüzgar ölçümlerine göre, çalışılan denizel alanları daha iyi temsil ettiği görülmüştür. Dalga iklimi çalışmalarında iki yöntem kullanılmıştır. Birinci yöntemde CEM ampirik yöntemi dalga yüksekliği değerlerini elde etmek için kullanılmıştır. ECMWF deniz üstü rüzgar tahminleri CEM yöntemine girdi oluşturmuştur. CEM yöntemi sonuçları ile uzun dönem ve en yüksek dalga istatistiği çalışılmıştır. İkinci yöntemde WAM sayısal modelinin deniz üstü dalga yüksekliği tahminleri uzun dönem ve en yüksek

dalga istatistiđi alıřmalarında dođrudan kullanılmıřtır. İki yntemin uzun dnem dalga istatistiđi sonuları kıyıya yakın ve kıyıya uzak iki denizel nokta seilerek karřılařtırılmıřtır. Karřılařtırma sonucunda, fe mesafelerin kısa olduđu durumlarda, kıyıya uzak alanlarda WAM Modelinin CEM Yntemine gre belirgin olarak yksek deđerler verdiđi, kıyıya yakın alanlarda ise WAM Modeli dalga yksekliti sonularının dřk kaldıđı sonucuna varılmıřtır. zellikle kapalı denizel alanlar iin WAM modeli dalga yksekliti sonularının belirgin olarak daha dřk olması nedeniyle, CEM Metodu tahminlerinin daha gvenilir olduđu grlmřtr.

Anahtar Kelimeler: Rzgar iklimi, Dalga iklimi, HYDROTAM-3D, ECMWF, WAM model

*Al hamedallah always*

*To my great parents who  
support me in my life*

*To my wonderful sister*

*The reason of my strong*

*To my lovely wife who is my  
happiness*

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## LIST OF SYMBOLS/ABBREVIATIONS

<b>ECMWF</b>	the European Centre for Medium-Range Weather Forecasts
<b>CEM</b>	coastal engineering manual
<b>WAM</b>	wave model prediction of ECMWF
<b>GDM</b>	General Directorate of Meteorology
<b>SMB</b>	Sverdrup Munk Bretschneider
<b>JONSWAP</b>	JOint North Sea WAve Project
<b>SPM</b>	Shore protection manual

# CHAPTER 1

## INTRODUCTION

Coastal Engineering is an old profession as people have been living near the coast since the start of civilization. Coastal engineers design and built structures to protect and to control the coastal area of concern. Breakwaters, groins, jetties and quay walls are some typical coastal structures. Common applications of coastal engineering include shoreline stability, the longshore and off shore sediment transport. Coastal engineering applications are in nature, and coastal areas and coastal structures, one way or the other, are subjected to wave action. Most of the design in coastal engineering depend on wave loads. Understanding and predicting the design wave is a complex phenomenon. Waves are irregular and variable in nature. Consequently, waves must be studied in detail for a coastal engineering design.

Waves can be classified in different ways: according to its period, the generating force or restoring force. Wind is one of the generating forces of waves. Therefore, wind data is important especially in studying the wave from wind. Turkish Coasts are dominated by wind waves. In this thesis, numerical wave results of wind-generated waves are compared with empirical wave results.

There are four main sources for the wind and wave data: buoy measurements; voluntary observing ship (VOS) data, satellite measurements and meteorological and wave models operational at various meteo-oceanographic centers. The limitations of each data source are different. Bouy measurements have high cost and generally are for a short period of time. Generally they are located close to the shore and do not represent the off shore conditions. Therefore, they do not represent the seasonal variations of the wind and wave data. However, buoys provide information to calibrate the predicted wave data for specific locations ([1]-[3]).

Voluntary observing ship (VOS) data give wave observations in a global scale. The data has limitations though. It is not homogenous, generally limited to ship routes and does not reflect extreme weather conditions resulting in under estimated wave conditions. These data are used to consolidate wave statistics globally ([4]).

Satellite radar altimeters present the wave height at the satellite route and the wind speed at 10 m. heightl. Calibration of satellite data is through local measurements and results of global models. As the signal of satellite is affected from land echo, it's data close to the shore has low quality.

In the study of coastal engineering applications, numerical modeling is an effective tool especially when simulating the physical, chemical and biological features of coastal environments. Numerical models are cost-effective when global scaleis considered. Their limitation depends on their underlying physical model ([5]). Global climatology models produce long-term forecasts and analysis worldwide. One important model is the global, third generation meteorological model (Wave Model-WAM) of European Centre for Medium-Range Weather Forecasts (ECMWF), which has high resolution especially for the Mediterranean basin ([2], [6]). WAM has two versions: one for global scale and the other for the Mediterranean. The WAM model is a continous model, which makes it ideal for an atlas. However, when close to the shore WAM model under estimates the wave heights ([7]).

Turkey is a coastal country with a coastline of 8372 km. It is surrounded by Black Sea, Sea of Marmara, Aegean Sea and Eastern Mediterranean Sea. Wind generated waves are the dominating waves along the Turkish coasts. In the coastal applications design process, the most important difficulty is the lack of long term wave measurements. Consequently, wind data is needed to estimate the wave heights. Turkish General Directorate of Meteorology has hourly over land wind measurements for the last 50 years. In the last decade, the Directorate has also started over sea wind measuring stations.

In the wind climate studies, there are two modelling approaches in the modelling of wind waves: empirical models and numerical models ([8]). SMB (Sverdrup Munk Bretschneider), JONSWAP (JOint North Sea WAve Project ), SPM (Shore protection manual) and CEM methods (coastal engineering manual) can be listed as the most commonly used empirical models in the World ([8][9]).

In this thesis, the wave climate of southern Aegean Sea coastal area of Turkey is analyzed. In the analysis, the results of empirical and numerical models are compared using the HYDROTAM 3D model. HYDROTAM- 3D model is presented briefly in Chapter 3. For the comparison, six coastal points are selected along the southern part of Aegean Sea: Kuşadası, İzmir coastal area, Yalıkavak, Muğla coastal area, Turgutreis, Muğla coastal area, Marmaris, Muğla coastal area, Fethiye, Muğla coastal area and Deveboynu, Datça, Muğla coastal area. (Figure 1-1).

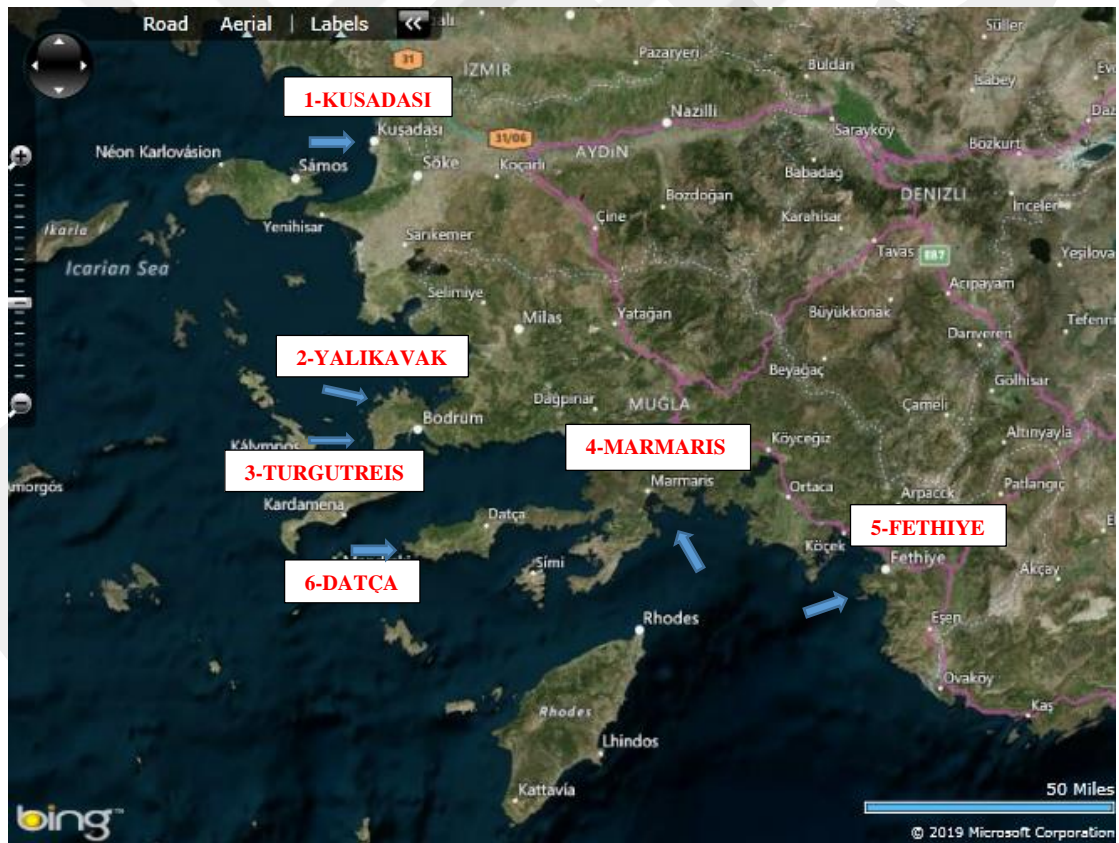


Figure (1-1) Map showing the location of Kusadası , Yalikavak , Turgutries , Marmaris , Fethiye ,Datca

The wind and wave climate of the coastal areas shown in Figure 1-1 are presented in Chapter 4. In the wind climate analysis, overland and over sea measurements of General Directorate of Meteorology (GDM) and over sea wind estimates of ECMWF are used and compared. For the over sea wind estimates of ECMWF, long-term wind statistics is presented. In the wave climate analysis, two approaches are employed: empirical method and numerical model. CEM (Coastal Engineering Manual) Method is used for the wave estimation. The wave estimates of WAM numerical method are selected as the numerical model results. The two resultant data sets are used in the long-term and extreme wave statistics. In the comparison of wave results, two points are taken for each coastal area: Near shore and off shore points of the coastal area of study. For each point long-term wave estimates of empirical CEM method are WAM model are compared. For different values of the parameters of CEM method, which are wind speed tolerance, wind direction tolerance, maximum speed and maximum fetch distance long-term wave heights are presented and discussed. The conclusions and recommendations for future studies are given in Chapter 5.

## **CHAPTER 2**

### **BACKGROUND THEORY AND METHODOLOGY**

#### **2.1 Background theory**

Coastal structures design involves the study of wind and wave climate of the area in concern. Waves are classified according to their period, the generating force or restoring force. Wind generated waves are of importance to Turkey, as Turkish coasts are dominated by wind waves. Therefore, wind data is an important source for wave estimations where there is a lack of long-term wave measurements. Wave generation from wind involves the transfer of turbulence from winds, which blow at 10 m altitude over the sea surface with a speed greater than 5 m/s. ([10]).

In the definition of wave formation, it has been found that spectral methods are successful ([10]). Potential and kinetic energy of the wave is shown by wave spectra analysis, which depends on wave frequency ([11]). It has been shown that linear growth of the wave controls the early stages of wave growth. This knowledge was later integrated by Pierson and Moskowitz through wave measurements, also known as Pierson-Moskowitz Spectrum. The development of the first generation (1G) wave models was initiated by Pierson-Moskowitz Spectrum ([10]). Hasselmann et al. [12] have shown that wave prediction models should also include wave to wave interactions, in a research which collected an extensive wave data in “Joint North Sea Wave Project- JONSWAP” Project. This work resulted in the second generation (2G) wave models. They later developed the third generation (3G) models, [13], by introducing a different solution methodology than the 2G wave models. The WAM (Wave Model), which is one of the most widely used models in wave prediction, is a third generation model and it is developed by WAMDI (Wave Model Development and Implementation) group. WAM Model is being used operationally in ECMWF (European Centre for Medium-Ranged Weather Forecasts) ([6], ([7]).

As stated above, wind and wave climate is essential for a coastal engineering design. Consequently, research on wind prediction and wave estimation is a fundamental

research area of coastal engineering. Today, in the World two important research centers have a significant effect on wind and wave research: The European center for medium-range weather Forecasts (ECMWF) and the National center for Environmental prediction (NCEP). The analysis and forecasts of these centers are being widely used ([14]).

The European Centre for Medium-Range Weather Forecasts (ECMWF), found in 1975, is an independent intergovernmental organisation, a research institute and an operational service which supplies weather predictions to its 34 member states. ECMWF studies numerical climate models worldwide on a medium, extended and long range. WAM model is run operationally in ECMWF. ERA-Interim, is the reanalysis of ECMWF data which involves wind and wave characteristics ([16]). NCEP (National center for Environmental Prediction), founded in 1958, is the National Meteorological Center in the US. NCEP produces both US weather forecasts and global climate analysis.

In Turkey, the coastline along Aegean Sea is characterized by semi- enclosed coastal areas. In order to study the wave climate of this region, reliable wind is needed. Of the wind data is forecasted, wave is forecasted. If the wave data is historical wind data, then it is wave hindcasting. If wave calculations depend on present wave data, it is called wave analysis ([15]).

Several studies have been made on the wind and wave climate of Mediterranean Sea. Zacharioudaki et al (2015) used a ERA 40 reanalysis to study the extremes of wave climate of Aegean Sea and Ionian Sea. They concluded that, the mean wave height range is high at the exit of the Aegean Sea.

Malliouri et al [16] showed that wave propagating from deep waters to shallow waters have a significant wave statistics change in the Aegean Sea by calibrating their model with field measurements. Afentoulis et al [18] estimated wave, hydrodynamic and morphodynamic characteristics of a coastal area. Their results were used to assess the coastal processes.

Gedik et al [19] analyzed wind and wave climate in Bozcaada coastal area by using the hourly wind data of the Meteorological wind station number 17111. They studied

the hourly wind distributions percentage, frequency distributions and obtained the wave parameter of this area by the SMB method. Saraçoğlu et al (2017) they studied wave climate of the Black Sea coastline of Turkey by comparing the results of Mike 21 spectral wave model with Wind and Deep water wave Atlas for Turkish coastline.

## 2.2 Methodology

In the wind and wave analysis, HYDROTAM-3D model is used. HYDROTAM-3D is a 3-D numerical model, applied to many coastal areas of Turkey. HYDROTAM 3D is given in detail in Chapter 3 ([21]-[25]). The “Wind Climate Module” and the “Wave Climate Module” of HYDROTAM-3D are utilized in this study. For the wind climate, long term and extreme value, directional wind statistics are calculated, and yearly and seasonal wind roses are presented. In the “Wave Climate Module” the significant wave height and period, long term and extreme wave statistics, yearly and seasonal wave roses are analyzed and presented. The database of HYDROTAM 3D includes hourly wind data of Turkish Meteorological Stations (1970-present), ECMWF analysis wind data (2000-2016) and ECMWF wave predictions by WAM Model (2000-2016) ([26]).

In the wave climate analyses, CEM empirical method is used. CEM method depends on dimensionless wave parameters, which govern the wave generation. These wave parameters are fetch length, wind duration and overwater wind speed. In CEM method the fetch is a region where wind direction variation do not exceed  $15^{\circ}$  and wind speed variations do not exceed 2.5 m/s from the mean as given in Equations 2-1 and 2-2 ([10]). The limitation on the fetch is a coastline upwind from the coastal area of study. Wind duration at the  $i^{\text{th}}$  hourly data should satisfy the conditions given in Equations (2-1) and (2-2).

$$|U_i - \bar{U}| < 2.5 \text{ m/s} \quad (2-1)$$

$$|D_i - \bar{D}| < 15^{\circ} \quad (2-2)$$

Where  $U_i$  is the wind speed at the  $i^{\text{th}}$  hourly data point (m/s);  $\bar{U}$  is average of preceding consecutive hourly wind speed (m/s);  $D_i$  is the wind direction at  $i^{\text{th}}$  hourly data point (degree) and  $\bar{D}$  is the average of preceding consecutive hourly wind direction (degree). The third parameter, overwater wind speed should be adjusted to 10 m. above sea surface. The observed wind speed at any level is adjusted by using the Equation (2-3).

$$U_{10} = U_z \left[ \frac{10}{z} \right]^{\frac{1}{7}} \quad (2-3)$$

Where  $U_{10}$  is the wind speed at 10 m. over sea surface (m/s),  $U_z$  is the wind speed at height  $z$  m. over sea surface (m/s) as stated, the CEM method depends on dimensionless wave parameters and predicts the significant wave height and the peak spectral period for fetch limited, fully developed and duration-limited conditions. The equation used to determine whether waves are, fetch limited or not is given in Equation (2-4) (CEM, 2006):

$$t_{x,u} = 77.23 \frac{X^{0.67}}{u^{0.34} g^{0.33}} \quad (2-4)$$

Where  $t_{x,u}$  is the time required for waves to cross an  $X$  length fetch under wind velocity  $u$  and  $g$  is the gravitational acceleration. Under these conditions energy-based significant wave height,  $H_{m0}$  and peak frequency,  $T_p$  can be calculated as:

$$\frac{gH_{m0}}{u_*^2} = 4.13 \times 10^{-2} \left( \frac{gX}{u_*^2} \right)^{\frac{1}{2}} \quad (2-5)$$

$$u_* = U_{10} C_D^{\frac{1}{2}} \quad (2-6)$$

$$\frac{gT_p}{u_*} = 4.13 \times 10^{-2} \left( \frac{gX}{u_*^2} \right)^{\frac{1}{3}} \quad (2-7)$$

Where  $u_*$  is the friction velocity and  $C_D$  is the drag coefficient. For the duration-limited case, duration is converted to equivalent fetch (Equation 8). Using Equations 5 and 7. Equations 9 and 10 give the values of  $H_{m0}$  and  $T_p$  for the fully developed condition (CEM, 2006).

$$\frac{gX}{u_*^2} = 5.23 \times 10^{-3} \left( \frac{gt}{u_*} \right)^{\frac{3}{2}} \quad (2-8)$$

$$\frac{gH_{m0}}{u_*^2} = 2.115 \times 10^2 \quad (2-9)$$

$$\frac{gT_p}{u_*} = 2.398 \times 10^2 \quad (2-10)$$

The results of the CEM empirical method are analysed for long-term wave statistics. The probability distribution that shows the relation between the significant wave heights generated in a sea state and their probabilities of occurrence is the log-linear distribution. The equation of the log-linear probability distribution is given below (Kamphuis, 2010):

$$Q(H_{1/3}) = e^{2.3 \left( \frac{H_{1/3}^{-B}}{A} \right)} \quad (2-11)$$

In Equation 11,  $Q(H_{1/3})$  is the probability that the significant wave height generated in a storm is greater than or equal to  $H_{1/3}$ , and  $A$  and  $B$  are distribution parameters. Equation 11 can also be written as:

$$H_{\frac{1}{3}} = A \log Q \left( H_{\frac{1}{3}} \right) + B \quad (2-12)$$

The wind data used in the analysis is the hourly wind data of Meteorological Stations of Turkey from the year of their establishment to present, and the 6-hour wind data of ECMWF Operational archive produced with a  $0.1^{\circ}$  horizontal resolution. The wave data used in the analysis is the 6-hour wave height and periods obtained from WAM numerical with a  $0.1^{\circ}$  horizontal resolution. In HYDROTAM 3D, when the coastal area is to be studied, locations of the closet databases are shown on a GIS based map. The wind climate is studied through the wind climate sub-module. In the wave, climate sub-module the wave climate is studied both by CEM empirical method and the wave results of WAM numerical model.

## **CHAPTER 3**

### **HYDROTAM 3D**

Wind, waves and flows are fundamental parameters that shape the coasts. Understanding the coastal process is crucial issue to plan and deal with the coasts. Plan and the board of coasts are extremely confused thusly they require incorporated methodology. With the models, physical, chemical and biological behaviours can be mimicked rapidly and financially. Numerical models center around hydrodynamic, wind and wave climate, wave, sediment, water quality modeling, which depict the coastal processes. They can be utilized as prediction and early cautioning devices. At first, the wind and wave climate of a coastal area ought to be resolved to comprehend study field. Hydrodynamic modelling is principle part of for the most part coastal assignments. Other than it is significant in itself, it give contributions for residue transport, water quality or natural framework models. Ecological effects, coastal and oceanographic disseminations, hydrodynamics of coastal areas like inlets, lagoons, the distribution of saline or salt waters can be recreated with hydrodynamic modelling apparatuses. Number of effectiveness in coastal engineering depends on wave modelling. Wave conditions in a coastal region ought to be known for the plan, development and establishments of beach front structures, sustainable power source gadgets at the sea. Wave propagation, transformations, dissipations and transmissions are simulated with wave models. HYDROTAM 3D utilizes cloud computing, it provides a wide scope of clients with cloud access to adaptable, virtualized equipment as well as programming infra-structure over the web. . It has wind and wave climate, wave propagation, hydrodynamic, transport and turbulence, water quality model components. The details of cloud computing system and theories of the submodels are explained below.

#### **3.1 Cloud Computing**

Generally, cloud computing is a conveyed registering worldview that centers around furnishing a wide scope of clients with cloud access to versatile, virtualized equipment as well as programming infra-structure over the web. Numerous definitions have been

offered for this term ([26]). Cloud computing is characterized as an extensive scale conveyed registering worldview that is driven by economies of scale, in which a pool of preoccupied, virtualized, powerfully versatile, oversight processing power, stockpiling, stages, and administrations are conveyed on interest to outside clients over the web ([27]). Cloud computing is another age of figuring that utilizes far off servers to give administrations and capacity got to over the Internet, frequently on an utilization based model. Common cloud computing suppliers convey applications online that are gotten to from a Web program while client information is put away on remote servers. In cloud computing, those servers are generally possessed and kept up by an outsider supplier on a united premise in a remote server farm. Cloud computing executions can be portrayed in two different ways: by the capacities they give and by who can get to their assets. In view of capacities, there are fundamentally three sorts of cloud computing executions, in particular Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS) ([27]).

### **3.2 Infrastructure as a Service (IaaS):**

This is for the most part computational framework accessible over the web, for example, figure cycles and capacity, which can be used similarly as inside possessed assets. IaaS suppliers en-drive insignificant confinements on their clients to permit them greatest control and design of the assets. These assets ordinarily give an assortment of interfaces to encourage connection, and there are generally extra administrations given, for example, question administrations for capacity assets.

### **3.3 Platform as a Service (PaaS) :**

PaaS alludes to application improvement stages (hardware and software components) that empower clients to use the assets of built up associations to make and host uses of a bigger scale than an individual or a little association would have the capacity to deal with. Administrations incorporate, yet are not constrained to, programming establishment and arrangement, asset scaling, and stage support and overhauling. So as to empower these administrations, the supplier places limitations on the client by determining different parts of the stage, for example, the programming dialects upheld, information stockpiling components, and asset observing capacities. In this model, client associations use assets from the cloud and convey their applications in the cloud

too. From the client's point of view, these suppliers offer critical usefulness out-of-the-container.

### 3.4 Software as a Service (SaaS) :

SaaS centers around furnishing clients with business-explicit abilities (hardware and software applications). As a rule, SaaS is a model of programming sending in which a supplier licenses an application to client associations for use as an administration on interest. HYDROTAM 3D is a model of IaaS. IaaS is the base layer of the cloud stack. It fills in as an establishment for the other two layers, for their execution (Fig.3-1). HYDROTAM 3D is additionally a genuine case of the Modeling as a Service (MaaS) activity. Like SaaS, MaaS would permit the sending and on-request execution of displaying and model-driven administrations over the Internet. Cloud computing structure of the model HYDROTAM 3D is introduced in Figure 3-2.

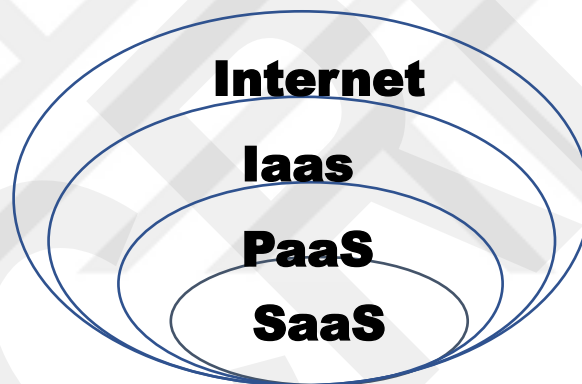


Fig. (3-1): Types of cloud computing executions

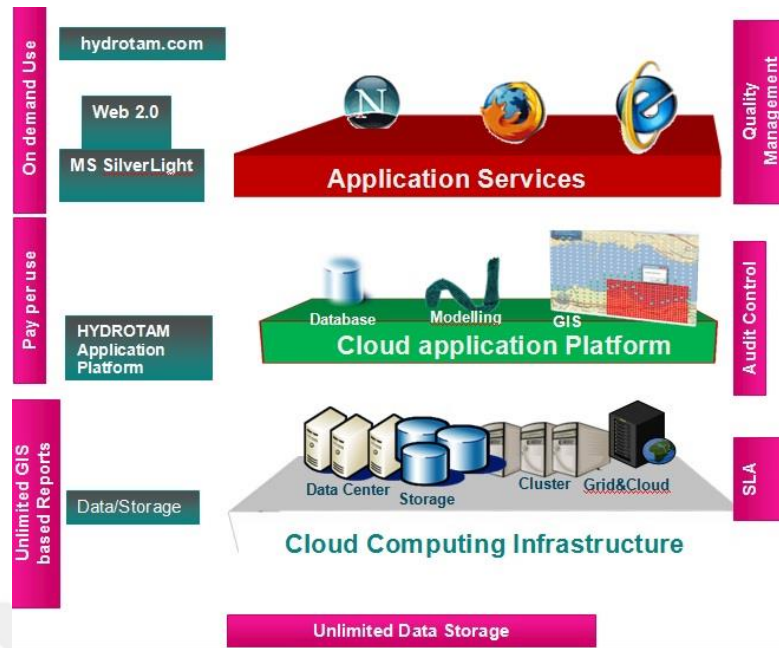


Fig. (3-2): HYDROTAM 3D cloud computing Structure

### 3.5 HYDROTAM 3D Modules

Enclosed or semi-enclosed coastal regions have constrained water interchange. In this way, to comprehend water circulation and transport forms is a fragile issue. Since field estimations are typically exorbitant and once in a while incomprehensible because of physical ineptitudes, use of numerical models turns out to be increasingly more critical in the reproductions of coastal water forms. Utilization of three-dimensional models is unavoidable in all situations where the impact of density distribution, or the vertical speed variations can't be dismissed and in the simulation of wind induced circulation. HYDROTAM 3D predictions have been verified by studies since 1990 ([29]-[41]).

HYDROTAM 3D is a Geographic Information System (GIS) integrated, three-dimensional baroclinic numerical model that has been developed to simulate the hydrodynamic and transport forms in coastal waters. The framework of the program depends on cloud computing innovation. GIS stage encourages the tedious assignment of arrangement of information and yield. In its interface all elements of the MS Silverlight structure are accessible to the client in a menu driven graphical (UI). In the hydrodynamic model part of the numerical model, the solution of the 3D Navier–Stokes equations are made with approximations of Boussinesq. Sediment transport and pollution transport models are included in the Transport Model Sub-Module of the program. The Turbulence Sub-Module includes three dimensional k-ε model. In Wave

Propagation Sub-Module mild slope equations are solved. Model involves electronic atlas of wind climate, wave climate and current climate of Turkish coastline. HYDROTAM 3D is:

- A three dimensional numerical model.
- It uses cloud computing technology, so an internet connection is needed to run the program.
- It uses a multi procesor environment, so it is fast.
- Input and output is GIS based.
- It includes bathymetries for most of the coastal areas of Turkey.
- The database includes almost 50 years (1970-present) of hourly wind data of Turkish Meteorological Stations, and wind predictions and wave estimations of ECMWF (European Centre for Medium Range Weather Forecast) from 2000-present.
- Finite volume and finite difference method is used calculations.
- It is a baroclinic model. Density, water temperature and salinity can be defined to the model.

The sub-modules of HYDROTAM 3D are shown in Figure 3-3. Among these “Wind Climate Sun-Module” and “Wave Climate Sub-Module” are utilized in the analysis part of this study. Wind and wave sub-modules are detailed in Section 3-5-1 and Section 3-5-2 respectively.

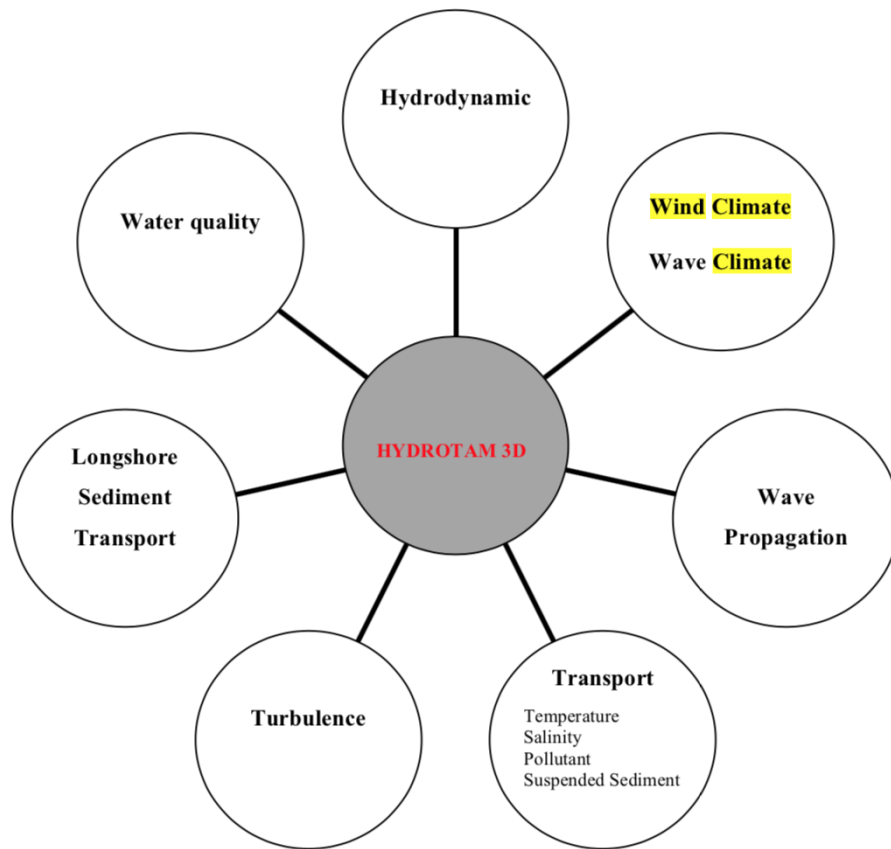


Figure (3-3) Sub-Modules of HYDROTAM 3D

### 3.5.1 Wind Climate Sub-Module

Wind climate studies are essential for a coastal project when detailed knowledge on the wind characteristics of the region is required. In the database of HYDROTAM 3D, there are two databases for the wind. The first one is the hourly wind speed and direction measurements of Turkish Meteorological Stations from 1970-present. The second source is the numerical wind predictions of ECMWF (European Centre for Medium Range Weather Forecast) for every  $0.1^{\circ}$  horizontal grid spacing and 6 hour time intervals covering all of Turkish coastal waters from 2000-present. These stations are shown on a GIS based map. In the wind climate analysis, wind characteristics of the area of concern is studied. Investigation of storm periods are carried out and yearly, seasonal and monthly wind roses are produced. From maximum wind speeds and related directions, dominant wind direction for the area is identified.

In the yearly wind climate, number of occurrences of winds blowing with different speeds and from different directions are presented. The main wind directions are:

North (N), NNE (NorthNorthEast), NE (NorthEast), ENE (EastNorthEast), E (East), ESE (EastSouthEast), SE (SouthEast), SSE (SouthSouthEast), S (South), SSW (SouthSouthWest), SW (SouthWest), WSW (WestSouthWest), W (West), WNW (WestNorthWest), NW (NorthWest), NNW (NorthNorthWest). Seasonal wind roses are presented in a similar approach. In the seasonal analysis, winter December, January and February; spring covers March, April, and May; summer covers June, July and August; and autumn covers September, October and December. The monthly extreme wind speeds, the maximum, the minimum and the average wind speeds of the highest wind speeds observed in that month for each of the years are given.

In the wind statistics, “long term” and “extreme value” statistics are applied. Long term statistics use all wind data and presented by log-normal probability distributions for each of the wind directions. In the extreme value wind statistics, the highest wind speeds in each year are used. This data is analyzed Gumbel Probability distribution and presented graphically on the Gumbel papers. The best line is fitted to the wind speeds on the Gumbel paper and the return periods of all wind speeds are given.

### **3.5.2 Wave Climate Sub-Modules**

As stated above, study of wind and wave characteristics is necessary for most of the coastal engineering applications in coastal waters. Long-term wind and wave data is required for most of the applications. However, in most of the cases, long-term wave measurements are not available, so wave prediction models are used for wave hindcasting. Two approaches exist in wave prediction modeling: empirical and numerical models. Numerical models, solve the energy balance equation, and thus, need a significant number of bathymetric, meteorological and oceanographic data. Among the numerical models existing in practice, WAM numerical model ([6]), which is a third generation wave model, is a popular and well-tested model. It computes spectra of random short-crested wind-generated waves. In the data base of HYDROTAM 3D, predicted significant deep water heights and periods at every  $0.1^{\circ}$  horizontal grid spacing and 6 hour time intervals covering all of Turkish coastal waters for 2000-present exist.

In some cases, bathymetric, meteorological and oceanographic data may not be available, and numerical modeling may be difficult and expensive. Additionally, numerical models sometimes have a problem in getting accurate results for specific coastal areas, such as the Aegean Sea and the Sea of Marmara coasts of Turkey. These coastlines may introduce the limitations in computational mesh size, so they may not be represented well in the modeling process. Empirical models arise at that point. Empirical models base on relationships between dimensionless parameters. Some important empirical models can be listed as SMB, JONSWAP, SPM, and CEM ([10]-[14]). HYDROTAM 3D utilizes CEM Method in the wave climate analysis. In HYDROTAM 3D, the wave parameters, significant wave height ( $H_s$ ) and corresponding wave period ( $T_s$ ), are estimated by CEM empirical method. In the analysis, wind speed measurements are converted to wind speeds at 10 m height and the fetch lengths are determined for the point of concern. Effective fetch lengths are calculated by the cosine average method (Equation 3.1). The average of fetch distances in the  $\pm 22.5^\circ$  interval with  $7.5^\circ$  increments are computed:

$$X_{ef} = \frac{\sum X_i \cos^2 \theta_i}{\sum \cos \theta_i} \quad (3.1)$$

where  $X$  is the fetch length and  $X_{ef}$  is the effective fetch length.

In the long-term wave climate of HYDROTAM 3D, the wave heights, wave periods and wave directions are either estimated from the hourly wind data and fetch lengths by CEM method or from the wave data predicted by WAM. Once the wave data is obtained, yearly and seasonal wave roses, the monthly mean and the monthly peak wave heights significant wave heights are computed. The relation between the significant wave heights and the wave periods is given as a graph so that the range of wave periods associated with a given wave height can be studied.

In the long term wave statistics all of the wave data are used. The log-normal probability distribution is used in the long term wave statistics that is widely used to represent the durations of exceedences for the significant wave heights from each direction. The graphs of significant wave heights,  $H_s$  and their exceeding probabilities,  $P(>H_s)$  for every propagation direction are prepared. Then wave rose of the region is

prepared that shows the long-term distribution of wave height and direction. Log-normal probability distribution equation is given in Equation 3-2 as follows:

$$Q\left(H_{\frac{1}{3}}\right) = e^{-\frac{2.3\left(\frac{H_1-B}{\frac{1}{3}}\right)}{A}} \quad (3-2)$$

where  $Q(H_{1/3})$  is the exceedence probability of predicted wave height to  $H_{1/3}$ ,  $H_{1/3}$  is the significant wave height, A and B are distribution parameters.

Log-normal probability distribution can be also be written as given in Equation 3-3.

$$H_{\frac{1}{3}} = A * \log\left(\frac{Q}{H_{\frac{1}{3}}}\right) + B \quad (3-3)$$

The log-normal probability graphs are given for each direction, and the exceedence probabilities are given as hours per year. From the wave data of long term, yearly and seasonal wave roses are drawn involving each 16 main geographical direction. The calm sea state limit is set to 0.5 m by default but it can be lowered or altered. Extreme value statistics is applied to the predicted significant wave heights by fitting the highest significant wave heights of each year to the Gumbel probability distribution. On the upper horizontal axis, the return periods of all wave heights are given.

## CHAPTER 4

### ANALYSIS, RESULTS AND DISCUSSION OF RESULTS

In this section the wind and wave climate of for selected coastal areas of Southern Aegean Sea are presented. Wind and wave climate of Kuşadası, Yalıkavak, Turgutreis, Marmaris, Fethiye and Datça coastal areas are analyzed and discussed in the sub-sections below.

#### 4.1 Wind climate

##### 4.1.1 Kuşadası Coastal Area

Kuşadası coastal area is a resort town on Turkey's Aegean coast, and the center of the seaside district of the same name within Aydın Province. It is located in the South West (SW) of Turkey at the Aegean seaboard. Kuşadası Meteorological Station is the closest over-land station, and it's hourly wind data is compared with the 6-hour over-sea wind estimates of ECMWF (38.0N, 26.7E) coordinate. The comparison of the two data sets are given in Figure (4-1-2).



Figure (4-1-1) Location of Kuşadası coastal area and the wind data sources (HYDROTAM 3D)

In Figure (4-1-2), the six-hour overland wind measurements of Kuşadası metrological station is compared with wind predictions of ECMWF (38N, 26.7E) coordinate for the years 2000-2016. It is seen from the Figure (4-1-2) that the 6 hr wind predictions of ECMWF (38N, 26.7E) coordinate is almost equal 2.2 times of Kuşadası metrological station wind data. In the literature, the oversea wind is approximated as 1.5-2.0 times of overland wind data ([10]). For Kuşadası coastal area, this value is 2.2. The reason for low wind speeds for Kuşadası meteorological station may be the orographic effects and urbanization.

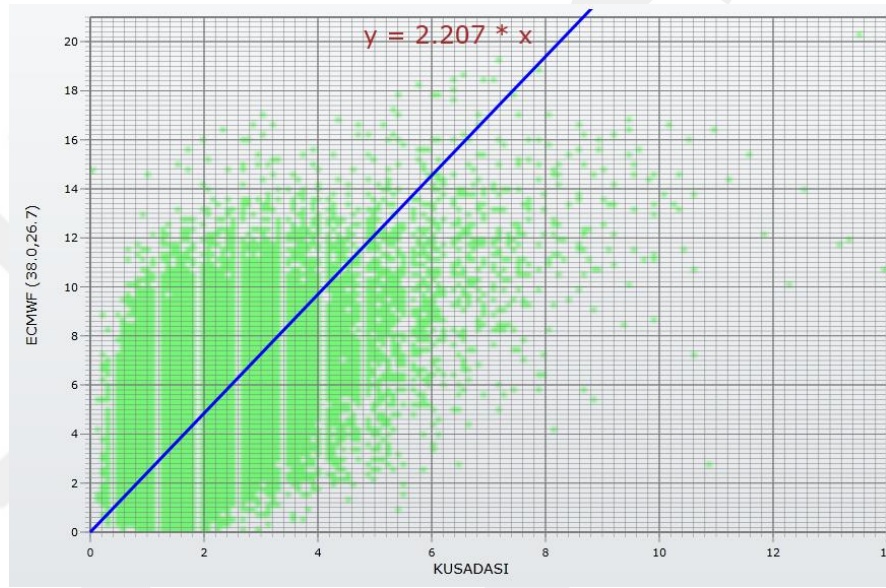


Figure (4-1-2) Comparison of wind data (Kuşadası metrological station vs ECMWF (38N,26.7E) (m/s) (HYDROTAM 3D)

In Figure 4-1-3(a) the wind rose of Kuşadası meteorological station shows that the dominant seaward wind directions are from NNW(NorthNorthWest)-W(West) in counter-clockwise direction. From figure 4-1-3(b) the wind estimates of ECMWF (38.0N, 26.7E) give the dominant seaward directions as NNW-WNW(WestNorthWest) in counter-clockwise direction.

The wind climate analysis is carried out by using the wind estimates of ECMWF (38.0N, 26.7E) coordinate by applying HYDROTAM-3D software ([26]). In wind climate long term statistics is carried out by log-linear probability distribution. From Table 4-1-1 it is seen that (NNW) direction gives the highest wind speed values for probabilities of 1hr/yr, 5hr/yr, and 10hr/yr. The yearly maximum wind speed is 20.31

m/s from SSE (SouthSouthEast) direction. The maximum of seaward wind speeds is 19.05 m/s from North (N) direction (Figure 4-1-4). The highest of the maximum values of wind speeds is 21 m/s and it is effective in January (Figure 4-1-5).

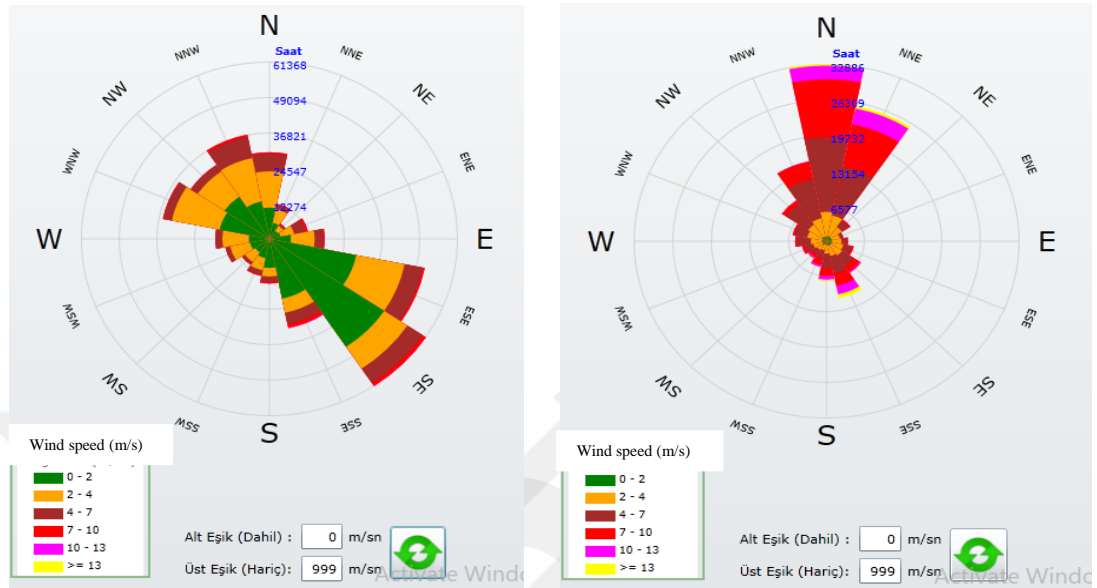


Figure (4-1-3) a) Kuşadası metrological station b) ECMWF (38.0N, 26.7E); (HYDROTAM 3D)

Table (4-1-1) Directional log-linear probability distribution of wind speeds ECMWF (38N, 26.7E) (HYDROTAM 3D)

Direction	Equation		1	5	10
	VS	R <sup>2</sup>	hour/year	hours/year	hour/year
			vs (±m/s) (%90)	vs (±m/s) (%90)	vs (±m/s) (%90)
W (West)	-3.361 - 1.628*LN(P(Vs))	0.9536	11.4±0.715	8.8±0.517	7.7±0.466
WNW (WestNorthWes)	-4.319 - 1.812*LN(P(Vs))	0.9671	12.1±0.529	9.2±0.415	8±0.402
NW (NorthWest)	-1.735 - 1.469*LN(P(Vs))	0.9339	11.6±0.878	9.2±0.652	8.2±0.583
NNW (NorthNorthWest)	0.074 - 1.314*LN(P(Vs))	0.8289	12±1.272	9.9±1.272	9±1.113

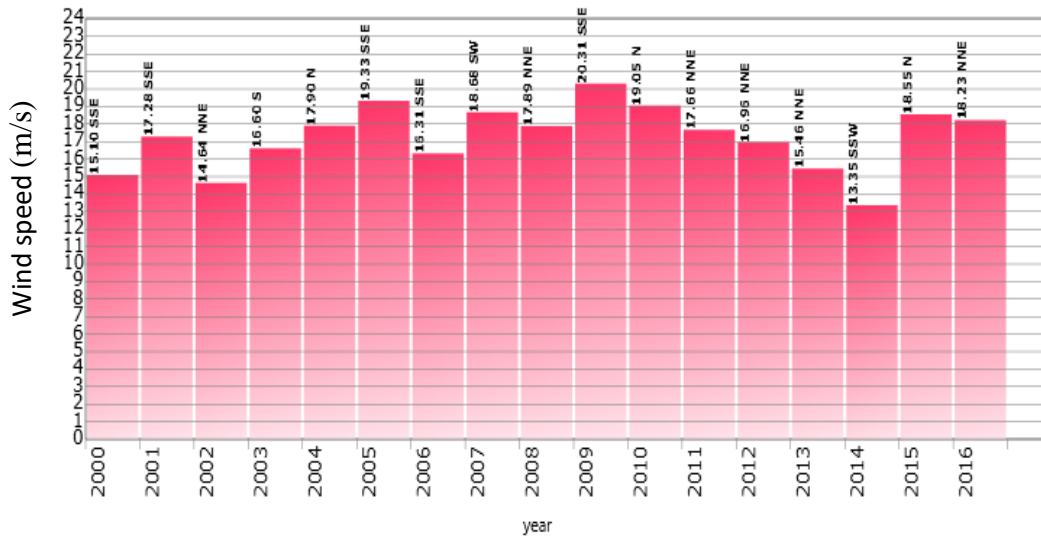


Figure (4-1-4) yearly maximum wind speed & directions (ECMWF (38N, 26.7E))

Some of the stations of The General Directorate of Meteorology of Turkey have oversea wind measurements at particular points along the coast line of Turkey. Kuşadası Buoy No.3 is the meteorological station which makes oversea measurements. In Figure 4-1-6, the maximum, average and minimum of highest wind speeds from oversea measurements for Kuşadası using the data for the years 2013-2018 are given. The comparison of Figure 4-1-5 and 4-1-6 show that the oversea measurements are almost 2.5 times of wind estimates of ECMWF. However the oversea measurements is short-term, and does not have a full record. The values may be the instantaneous extremes.

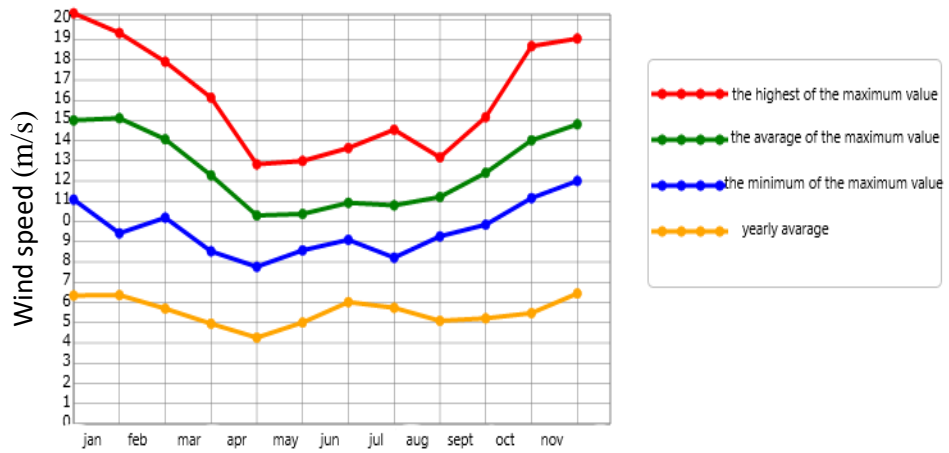


Figure (4-1-5) The maximum, average and minimum of highest wind speeds monthly average & maximum of extreme value (ECMWF (38N, 26.7E)) (HYDROTAM 3D)

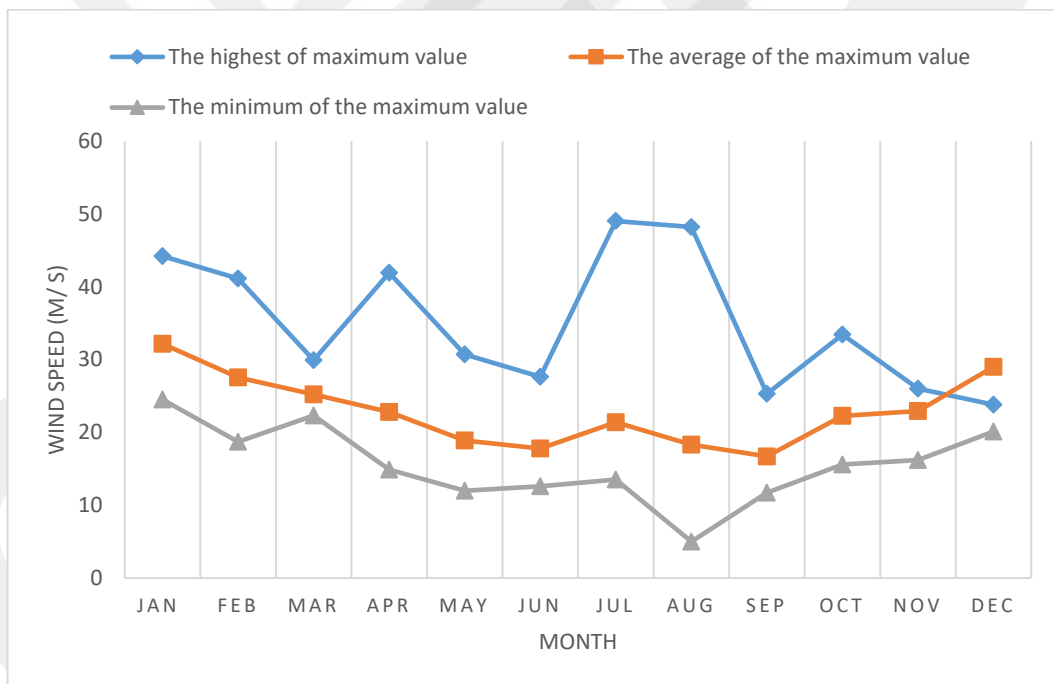


Figure (4-1-6) The maximum, average and minimum of highest wind speeds from oversea measurements for Kuşadası (Kuşadası Buoy No.3 Over-sea measurements)

#### 4.1.2 Yalıkavak Coastal Area

Yalıkavak is a town near Bodrum in Muğla province, on the Aegean coast of Turkey. It is 18 kilometers (11 miles) from Bodrum, on the northern side of the Bodrum peninsula. Yalıkavak is surrounded by hills providing views of the town and surrounding Aegean coastline in the south west of Turkey, at the Aegean seaboard. Bodrum Meteorological Station is the closest over-land station, and it's hourly wind data is compared with the 6-hour over-sea wind estimates of ECMWF (37.0N, 27.3E) coordinate. The comparison of the two data sets are given in Figure 4-1-8. In Figure (4-1-8), the six-hour overland wind measurements of Bodrum meteorological station is compared with wind predictions of ECMWF (37.2N, 27.3E) coordinate for the years 2000-2016. It is seen from the Figure (4-1-8) that the 6 hr wind predictions of ECMWF (37.2N, 27.3E) coordinate is almost equal 1.85 times of Bodrum metrological station wind data.



Figure (4-1-7) Location of Yalıkavak of coastal area and the wind data sources (HYDROTAM 3D)

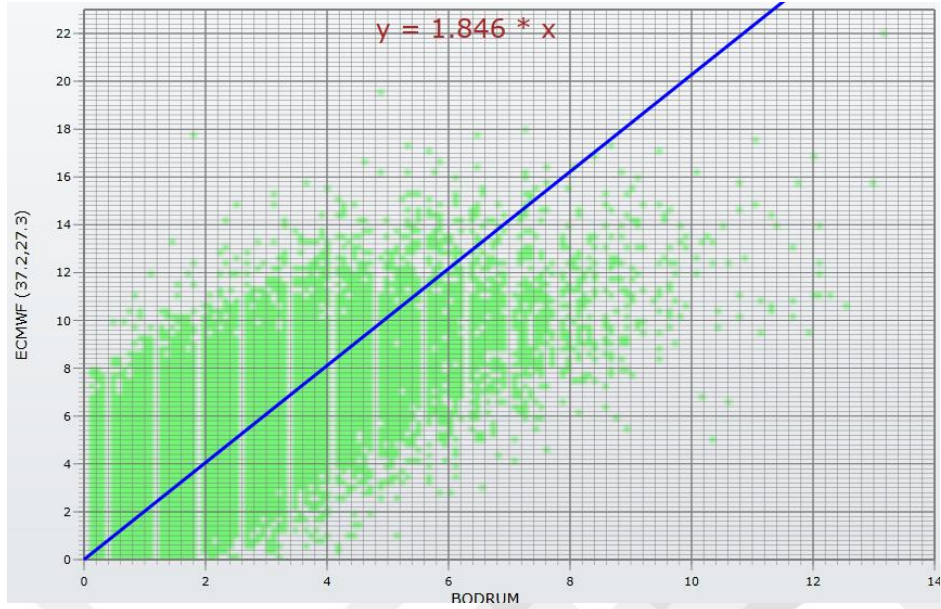


Figure (4-1-8) Comparison of wind data Yalıkavak metrological station vs ECMWF (37N, 27.3E) (m/s) (HYDROTAM 3D)

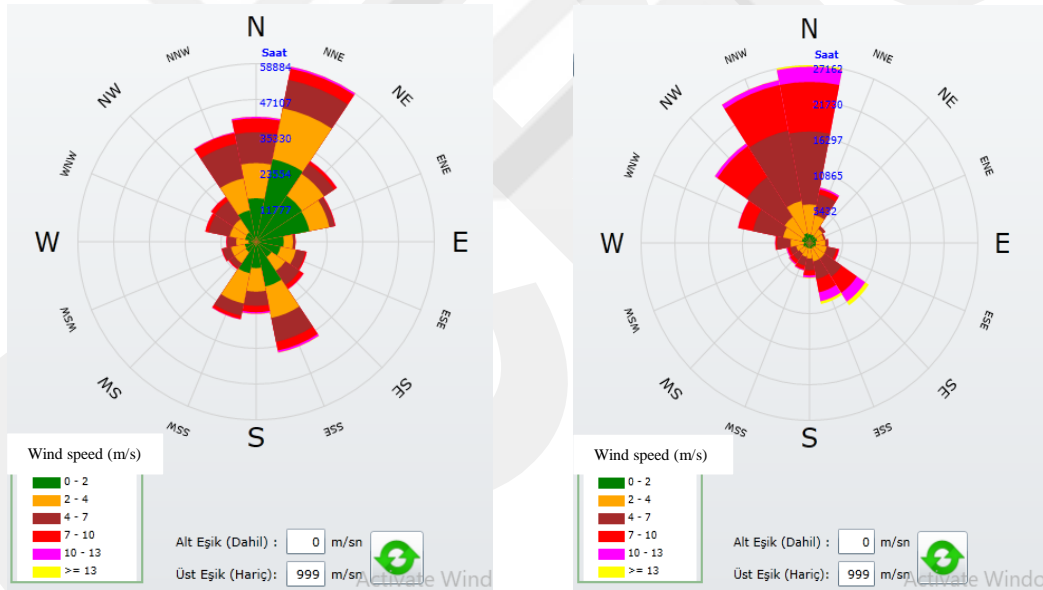


Figure (4-1-9) a) Bodrum meteorological station b) ECMWF (37N, 27.3E); (HYDROTAM 3D)

In Figure 4-1-9(a) the wind rose of Bodrum meteorological station shows that the dominant seaward wind directions are from NNE (NorthNorthEast)-WNW in counter-clockwise direction. From figure 4-1-9(b) the wind estimates of ECMWF (37N, 27.3E) give the dominant seaward directions as N-WNW in counter-clockwise direction.

The wind climate analysis is carried out by using the wind estimates of ECMWF (37N, 27.3E) coordinate by applying HYDROTAM-3D software ([26]). In wind climate long term statistics is carried out by log-linear probability distribution. From Table 4-1-2 it is seen that N direction gives the highest wind speed values for probabilities of 1hr/yr, 5hr/yr, and 10hr/yr. The yearly maximum wind speed is 22.01 m/s from SSE direction. The maximum of seaward wind speeds is 17.89 m/s from NNW direction (Figure 4-1-10). The highest of the maximum values of wind speeds is 22 m/s and it is effective in January (Figure 4-1-11).

Table (4-1-2) Directional log-linear probability distribution of wind speeds ECMWF (37.2N,27.3E). (HYDROTAM 3D)

Direction	Equation		1 hour/year	5 hours/year	10 hour/year
	VS	R <sup>2</sup>	vs (±m/s) %90 confidence	vs (±m/s) %90 confidence	vs (±m/s) %90 confidence
N	0.151 -1.972*LN(P(Vs))	0.8916	18.0±1.746	14.9±1.308	13.5±1.135
NNW	0.533 -1.567*LN(P(Vs))	0.9223	14.8±1.013	12.2±0.789	11.1±0.715
NW	0.481 -1.410*LN(P(Vs))	0.807	13.3±1.935	11±1.456	10±1.274
WNW	-0.804 -1.440*LN(P(Vs))	0.8964	12.3±0.97	10±0.774	9±0.729

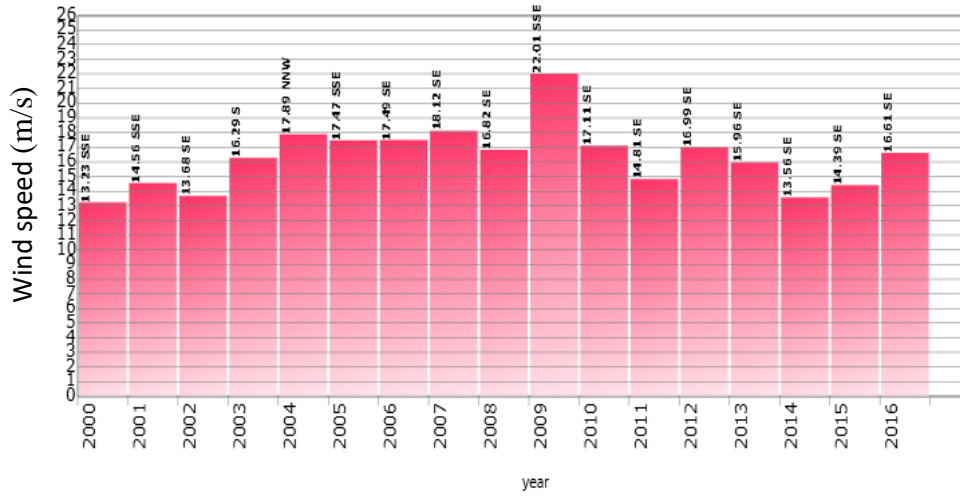


Figure (4-1-10) Yearly maximum wind speed and directions of ECMWF (37.2N, 27.3E) coordinate (HYDROTAM 3D)

Yalıkavak Gemitaşı Lighthouse is the meteorological station which makes oversea measurements. In Figure 4-1-12, the maximum, average and minimum of highest wind speeds from oversea measurements for Yalıkavak using the data for the years 2013-2018 are given. The comparison of Figure 4-1-11 and 4-1-12 show that the oversea measurements are almost 2.5 times of wind estimates of ECMWF. The same discussion for Kuşadası coastal area can be made here, as the oversea measurements is short-term, and the values may be the instantaneous extremes.

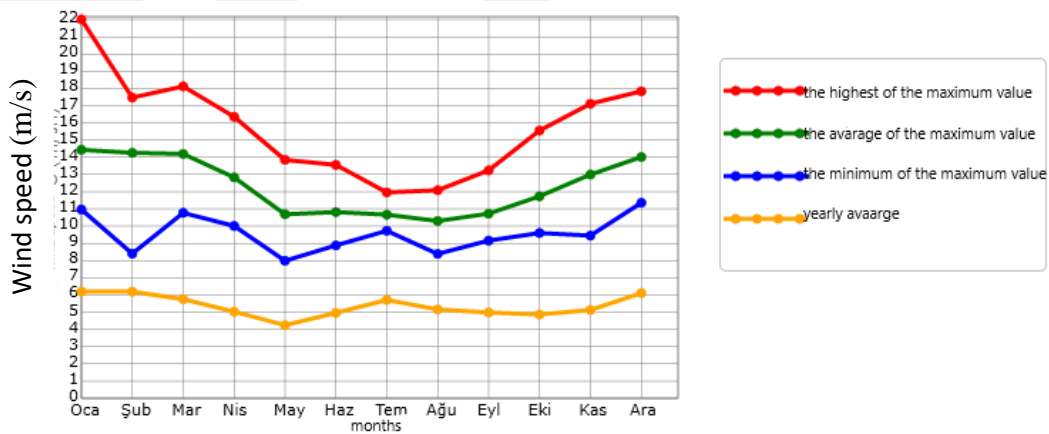


Figure (4-1-11) The maximum, average and minimum of highest wind speeds monthly average & maximum of extreme value (ECMWF 37.2N, 27.3E) (HYDROTAM 3D)

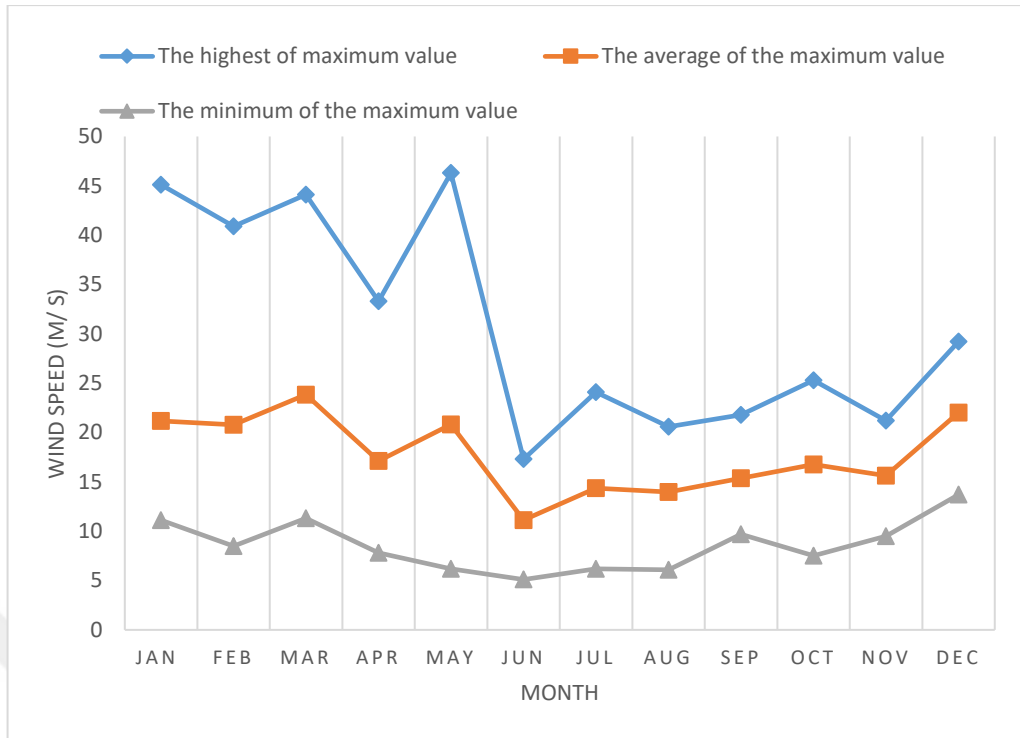


Figure (4-1-12) The maximum, average and minimum of highest wind speeds from overseas measurements for Yalıkavak (Yalıkavak Gemitaşı Lighthouse)

### 4.1.3 Turgutreis Coastal Area

Turgutreis is a town near Bodrum in Muğla province (Figure 4-1-13), on the Aegean coast of Turkey and on the western side of the Bodrum peninsula. Turgutreis is surrounded by hills providing views of the town and surrounding Aegean coastline in the south west of Turkey, at the Aegean seaboard. Bodrum Meteorological Station is the closest over-land station, and its hourly wind data is compared with the 6-hour over-sea wind estimates of ECMWF (37.0N, 27.2E) coordinate. The comparison of the two data sets are given in Figure 4-1-14. In Figure (4-1-14), the six-hour overland wind measurements of Bodrum meteorological station is compared with wind predictions of ECMWF (37.2N, 27.2E) coordinate for the years 2000-2016. It is seen from the Figure (4-1-14) that the 6 hr wind predictions of ECMWF (37.2N, 27.3E) coordinate is almost equal 2 times of Bodrum metrological station wind data.



Figure (4-1-13) Location of Turgutreis coastal area and the wind data sources (HYDROTAM 3D)

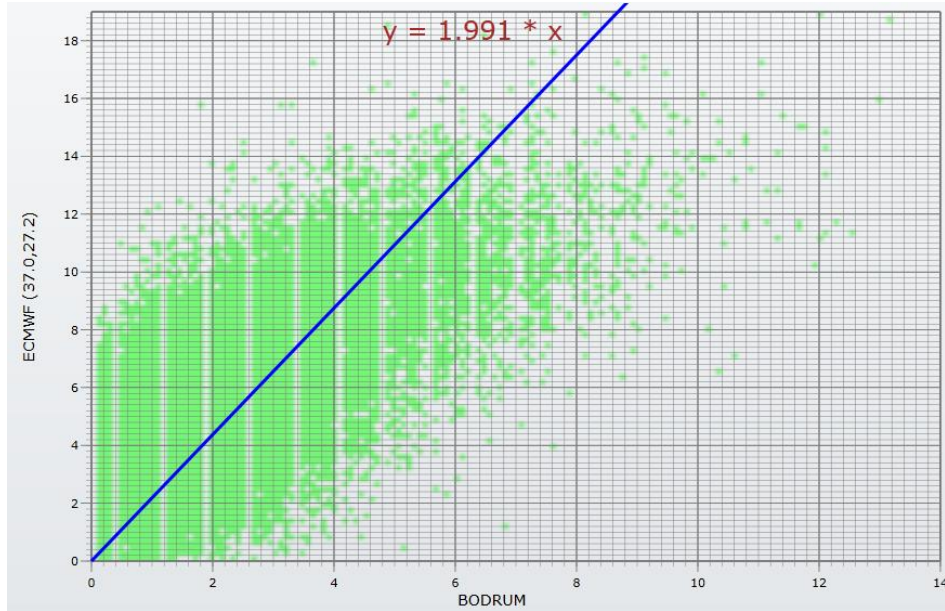


Figure (4-1-14) Comparison of wind data Turgutreis meteorological station vs ECMWF (37N, 27.2E) (m/s) (HYDROTAM 3D)

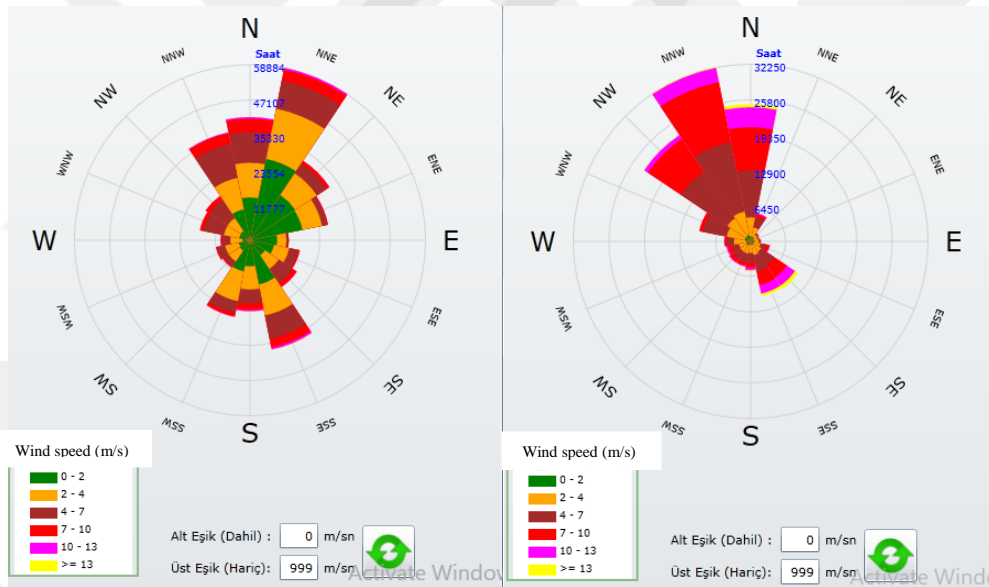


Figure (4-1-15) a) Bodrum meteorological station b) ECMWF (37N, 27.2E); (HYDROTAM 3D)

In Figure 4-1-15(a) the wind rose of Bodrum meteorological station shows that the dominant seaward wind directions are from WSW to S (south in counter-clockwise direction). From figure 4-1-15(b) the wind estimates of ECMWF (37N, 27.2E) give the dominant seaward directions as WNW to SSW (SouthSouthWest) in counter-clockwise direction.

Table (4-1-3) Directional log – linear probability distribution of wind speeds  
ECMWF (37N,27.2E) (HYDROTAM 3D)

Direction	Equation		1 hour/year	5 hours/year	10 hour/year
	VS	R <sup>2</sup>	vs (±m/s) %90 confidence	vs (±m/s) %90 confidence	vs (±m/s) %90 confidence
WNW	-0.804 -1.440*LN(P(Vs))	0.8964	12.3±0.97	10±0.774	9±0.729
W	-4.733 -1.933*LN(P(Vs))	0.9732	12.8±0.638	9.7±0.436	8.4±0.375
WSW	-6.221 -2.236*LN(P(Vs))	0.9527	14.1±0.836	10.5±0.566	8.9±0.495
SW	-5.563 -2.243*LN(P(Vs))	0.9448	14.8±0.852	11.2±0.603	9.6±0.546
SSW	-5.637 -2.197*LN(P(Vs))	0.9578	14.3±0.807	10.8±0.551	9.2±0.478

The wind climate analysis is carried out by using the wind estimates of ECMWF (37N, 27.2E) coordinate by applying HYDROTAM-3D software ([26]). In wind climate long term statistics is carried out by log-linear probability distribution. From Table 4-1-3 it is seen that SW direction gives the highest wind speed values for probabilities of 1hr/yr, 5hr/yr, and 10hr/yr. The maximum wind speed is 18.97 m/s from SSE direction. The yearly seaward maximum wind speed is 15.10 m/s from SSW direction. The highest of the maximum values of wind speeds is 20 m/s and it is effective in February (Figure 4-1-17).

Hüseyin Burnu Lighthouse is the meteorological station which makes oversea measurements. In Figure 4-1-17, the maximum, average and minimum of highest wind speeds from oversea measurements for Yalıkavak using the data for the years 2013-2018 are given. The comparison of Figure 4-1-16 and 4-1-17 show that the oversea measurements are almost 1.5 times of wind estimates of ECMWF, which is less than the ratios given for Kuşadası and Yalıkavak coastal area.

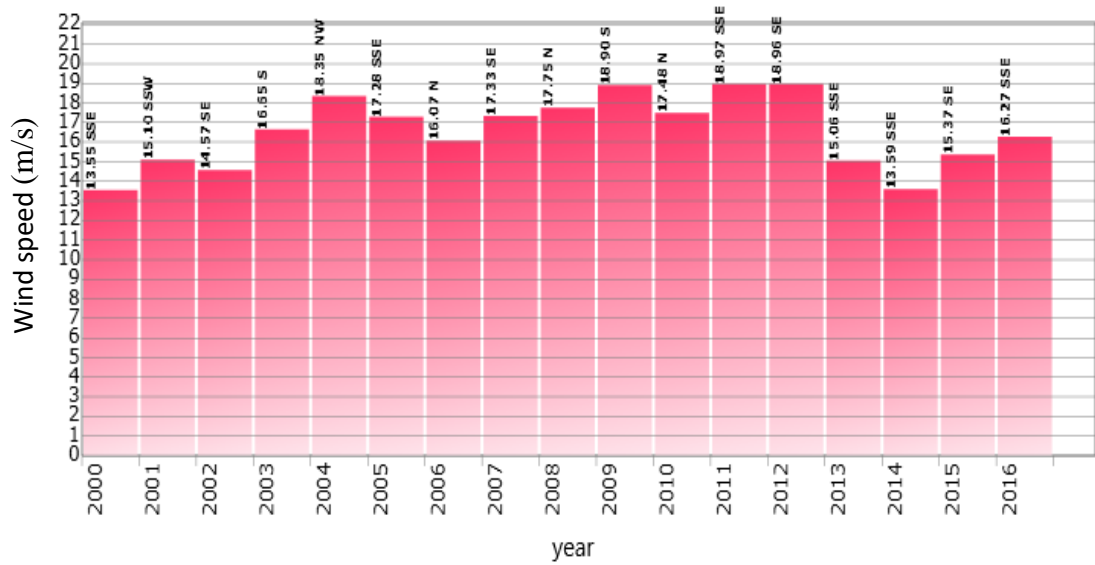


Figure (4-1-16) Yearly maximum wind speed & directions for ECMWF (37N, 27.2E)  
(HYDROTAM 3D)

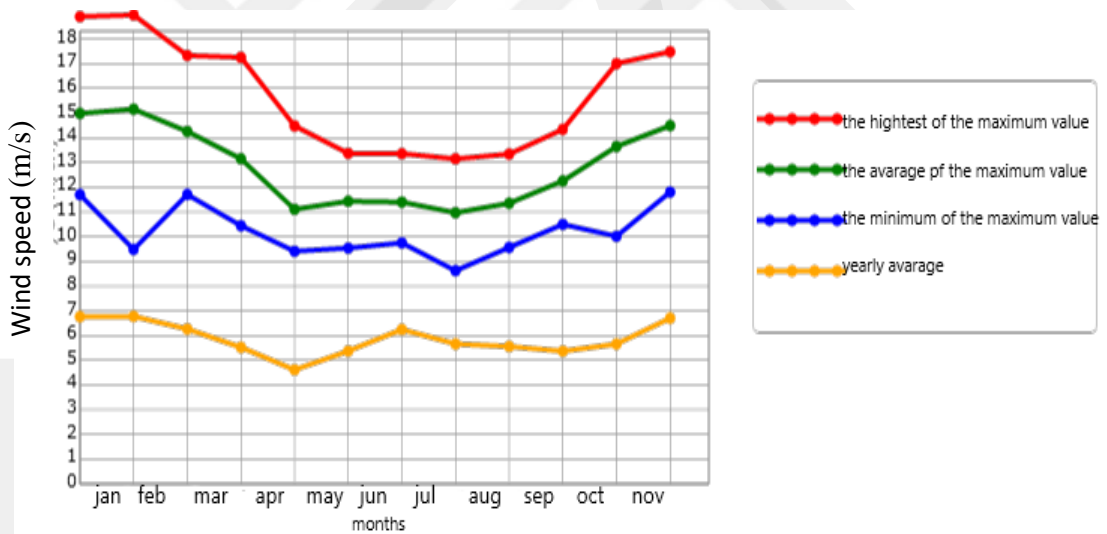


Figure (4-1-17) The maximum, average and minimum of highest wind speeds  
monthly average & maximum of extreme value (ECMWF 37N, 27.2E)  
(HYDROTAM 3D)

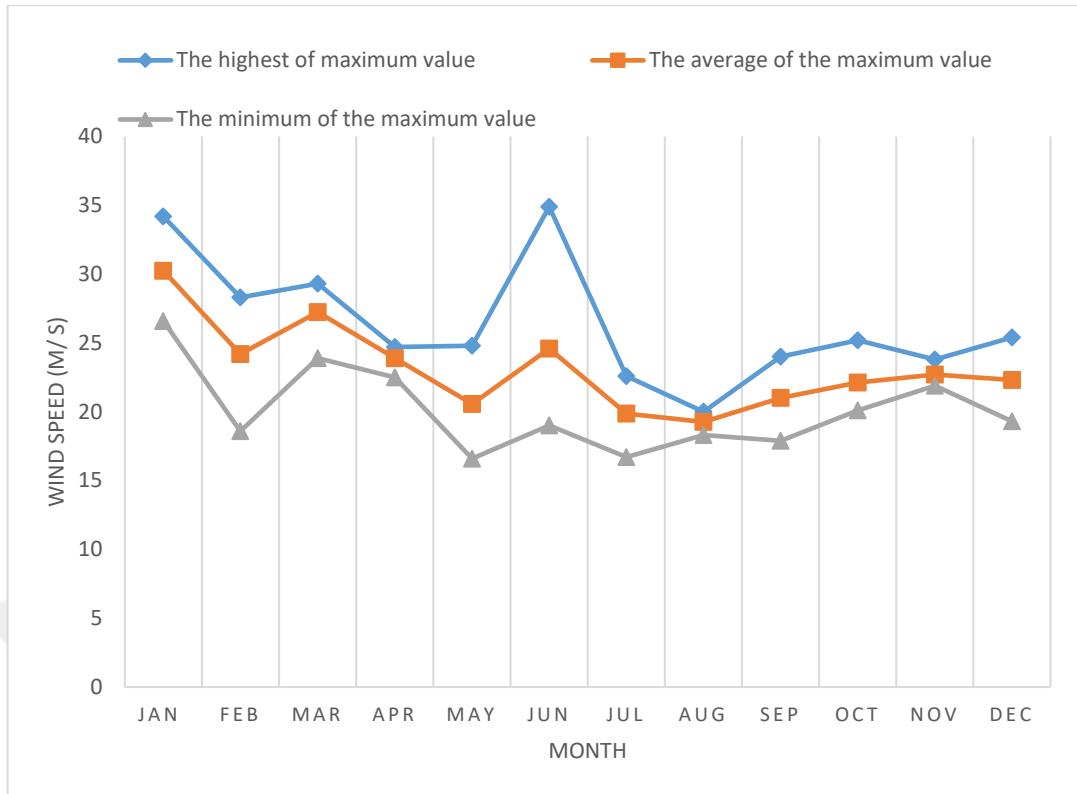


Figure (4-1-18) The maximum, average and minimum of highest wind speeds from oversea measurements for Yalıkavak

#### 4.1.4 Marmaris Coastal Area

Marmaris, located in the south of Mugla province and in south west of Turkey, at the Aegean seaboard. It is a part city and tourist resort on the Mediterranean coast, with its beautiful pine forests (Figure 4-1-19). Marmaris Meteorological Station is the closest over-land station, and its hourly wind data is compared with the 6-hour over-sea wind estimates of ECMWF (36.7N, 28.4E) coordinate. The comparison of the two data sets are given in Figure 4-1-20. In Figure (4-1-20), the six-hour overland wind measurements of Marmaris meteorological station is compared with wind predictions of ECMWF (36.7N, 28.4E) coordinate for the years 2000-2016. It is seen from the Figure (4-1-20) that the 6 hr wind predictions of ECMWF (36.7N, 28.4E) coordinate is almost equal 1.9 times of Marmaris metrological station wind data.



Figure (4-1-19) Location of Marmaris of coastal area and the wind data sources (HYDROTAM 3D)

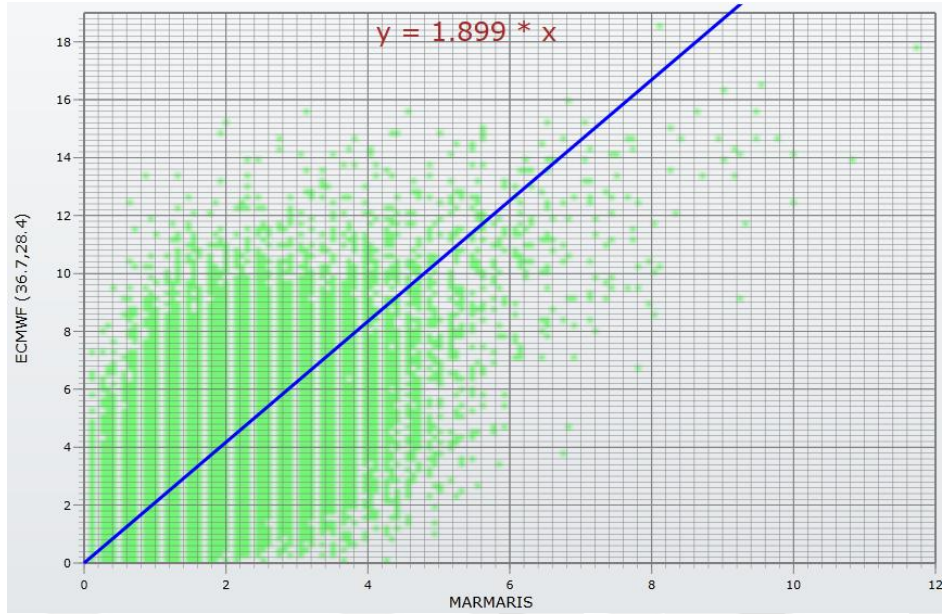


Figure (4-1-20) Comparison of wind data Marmaris metrological station vs ECMWF (36.7N, 28.4E) (m/s) (HYDROTAM 3D)

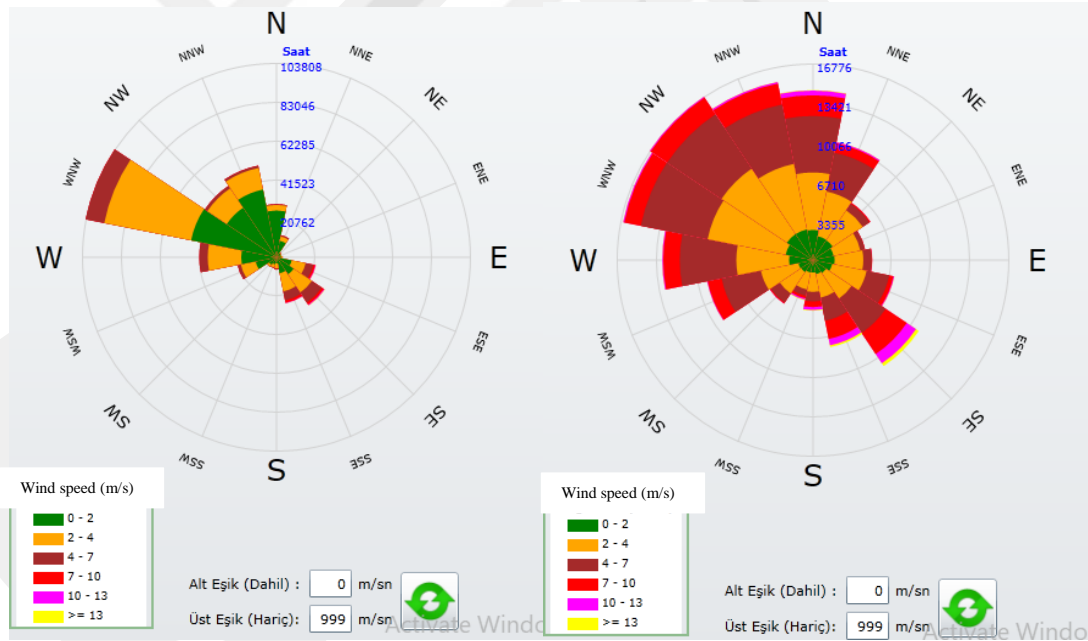


Figure (4-1-21) a) Marmaris metrological station b) ECMWF (36.7N, 28.4E) (HYDROTAM 3D)

In the figure (4-1-21-a) the wind rose of Marmaris metrological station shows that the dominant seaward wind direction is from SSE to ESE(EastSouthEast) in counter-clockwise direction. In the figure (4-1-21-b) the wind rose of ECMWF (36.7N,28.4E) coordinate shows that the dominant seaward wind direction is from S to ESE in counter

clockwise direction. The wind climate analysis is carried out by using the wind estimates of ECMWF (36.7N, 28.4E) coordinate by applying HYDROTAM-3D software ([26]). In wind climate long term statistics, from Table 4-1-4, it is seen that SE direction gives the highest wind speed values for probabilities of 1hr/yr, 5hr/yr, and 10hr/yr. The yearly maximum wind speed is 18.67 m/s from SSE direction which is from seaward. (Figure 4-1-22). The highest of the maximum values of wind speeds is 20 m/s and it is effective in April (Figure 4-1-23).

Table (4-1-4) Directional log – linear probability distribution of wind speeds ECMWF (36.7N,28.4E) (HYDROTAM 3D)

Direction	Equation		1 hour/year	5 hours/year	10 hour/year
	VS	R <sup>2</sup>	vs (±m/s) %/90 confidence	vs (±m/s) %/90 confidence	vs (±m/s) %/90 confidence
<b>S</b>	-7.855 -2.677*LN(P(Vs))	0.964	16.4±0.912	12.1±0.59	10.3±0.964
<b>SSE</b>	-3.860 -2.306*LN(P(Vs))	0.9318	17.1±1.102	13.4±0.783	11.8±0.9318
<b>SE</b>	-2.444 -2.219*LN(P(Vs))	0.8894	17.7±1.604	14.1±1.148	12.6±0.8894
<b>ESE</b>	-4.218 -1.861*LN(P(Vs))	0.9845	12.7±0.493	9.7±0.312	8.4±0.9845

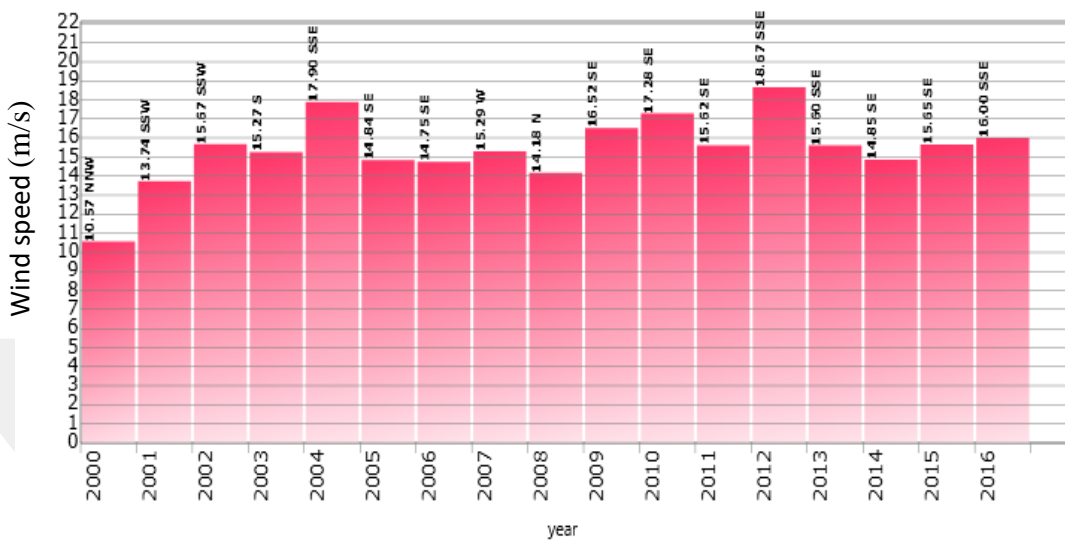


Figure (4-1-22) Yearly maximum wind speed & directions (ECMWF (36.7N, 28.4E)) (HYDROTAM 3D)

İnceburun Lighthouse is the meteorological station which makes oversea measurements, and in Figure 4-1-24, the maximum, average and minimum of highest

wind speeds from overseas measurements for İnceburun Lighthouse using the data for the years 2013-2018 are given. The comparison of Figure 4-1-23 and 4-1-24 show that the overseas measurements are almost 2.5 times of wind estimates of ECMWF.

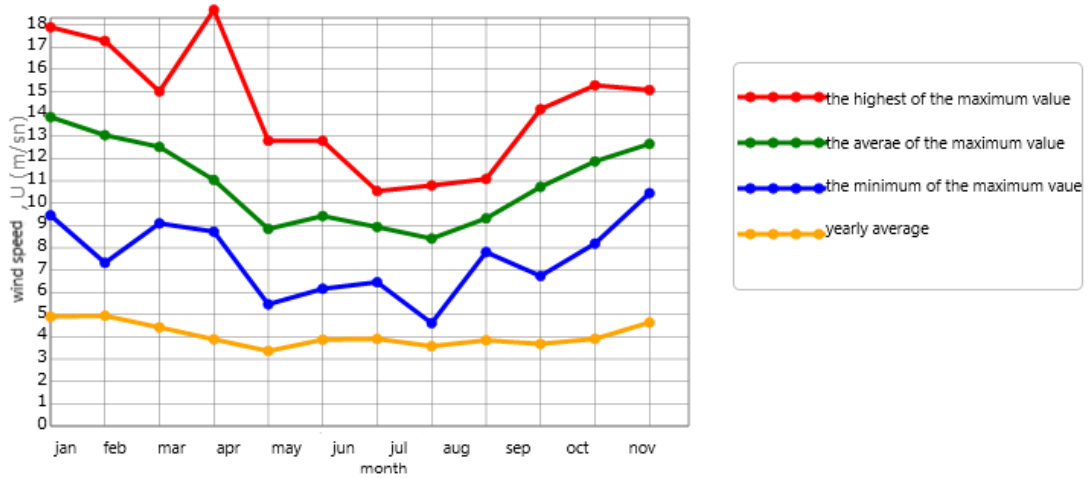


Figure (4-1-23) The maximum, average and minimum of highest wind speeds monthly average & maximum of extreme value (ECMWF 36.7N, 28.4E) (HYDROTAM 3D)

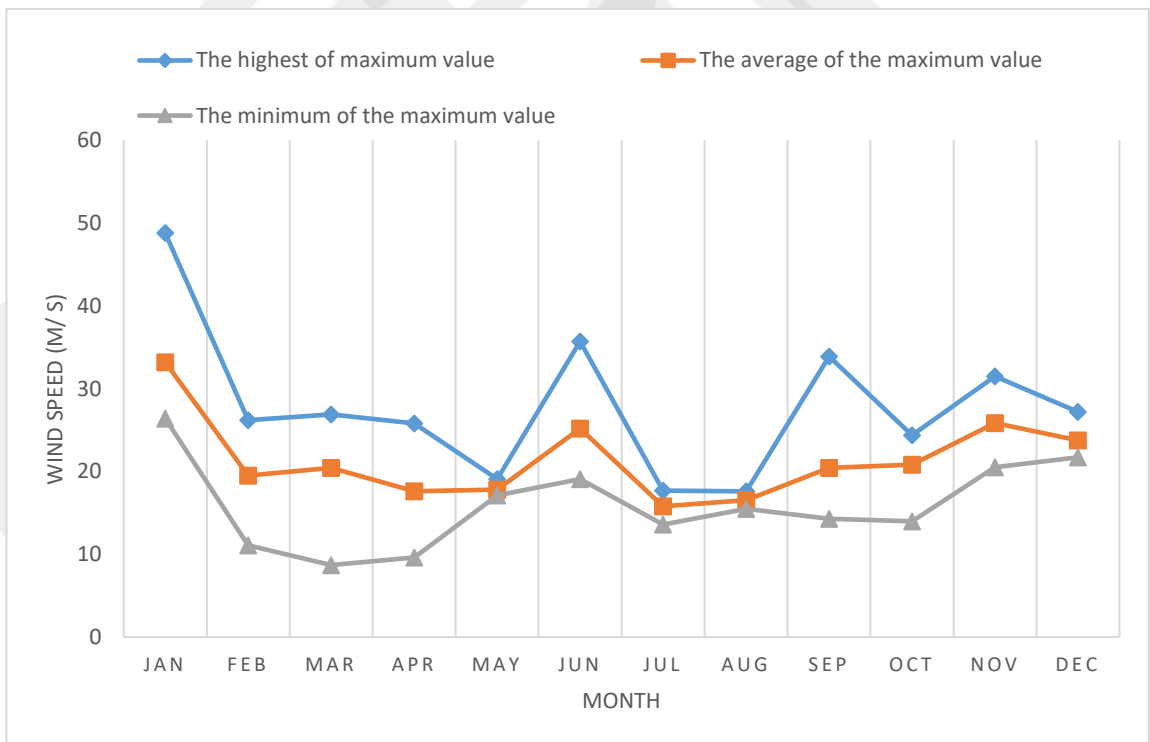


Figure (4-1-24) The maximum, average and minimum of highest wind speeds from overseas measurements for Marmaris (Inceburun Lighthouse)

#### 4.1.5 Fethiye Coastal Area

Fethiye Coastal Area is located at southwest of Turkish coastline and it is a district in Muğla Province. It is a natural harbour scattered with small islands. Fethiye is a Specially Protected Area (SPA) and an important yacht tourism center of Turkey (Figure 4-1-25). Fethiye Meteorological Station is the closest over-land station, and it's hourly wind data is compared with the 6-hour over-sea wind estimates of ECMWF (36.6N, 28.9E) coordinate. The comparison of the two data sets are given in Figure 4-1-26.

In Figure (4-1-26), the six-hour overland wind measurements of Fethiye meteorological station is compared with wind predictions of ECMWF (36.6N, 28.9E) coordinate for the years 2000-2016. It is seen from the Figure (4-1-26) that the 6 hr wind predictions of ECMWF (36.6N, 28.9E) coordinate is almost equal 2 times of Bodrum metrological station wind data.

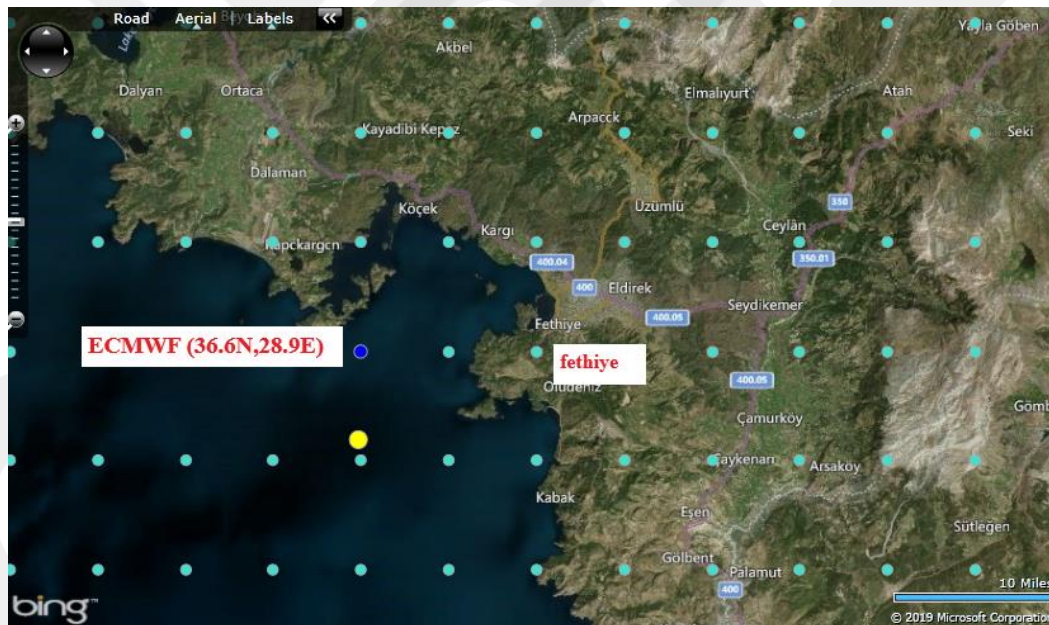


Figure (4-1-25) Location of Fethiye of coastal area and the wind data sources (HYDROTAM 3D)

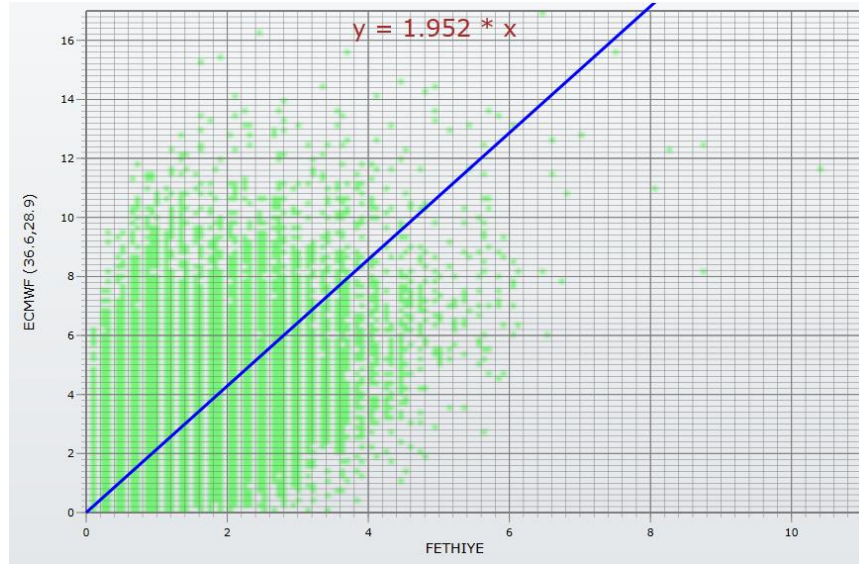


Figure (4-1-26) Comparison of wind data Fethiye metrological station vs ECMWF (36.6N, 28.9E) (m/s) (HYDROTAM 3D)

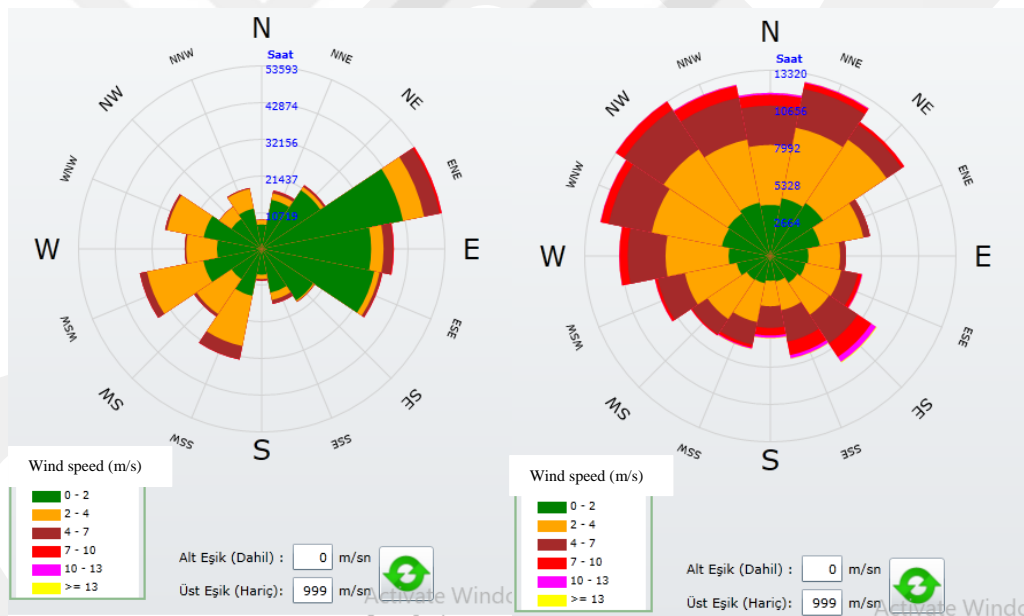


Figure (4-1-27) a) Fethiye meteorological station b) ECMWF (36.6N, 28.9E) (HYDROTAM 3D)

In the figure (4-1-27-a) the wind rose of Fethiye meteorological station shows that the dominant seaward wind direction is from WSW to SSW (SouthSouthWest) in counter-clockwise direction. In the figure (4-1-27-b) the wind rose of ECMWF (36.7N,28.4E) coordinate shows that the dominant seaward wind direction is from W to SE in counter clockwise direction. The wind climate analysis is carried out by using the wind estimates of ECMWF (36.6N, 28.9E) coordinate by applying HYDROTAM-3D

software ([26]). In wind climate long term statistics, from Table 4-1-5, it is seen that SE direction gives the highest wind speed values for probabilities of 1hr/yr, 5hr/yr, and 10hr/yr. The yearly maximum wind speed is 16.96 m/s from SSE direction which is from seaward (Figure 4-1-28). The highest of the maximum values of wind speeds is 18 m/s and it is effective in January (Figure 4-1-29).

Table (4-1-5) Directional log – linear probability distribution of wind speeds  
ECMWF (36.6N,28.9E) (HYDROTAM 3D)

Direction	Equation		1 hour/year	5 hours/year	10 hour/year
	VS	R <sup>2</sup>	vs (±m/s) %90 confidence	vs (±m/s) %90 confidence	vs (±m/s) %90 confidence
SE	-4.363 -2.299*LN(P(Vs))	0.9340	16.5±1.356	12.8±0.934	11.2±0.775
SSE	-4.161 -2.119*LN(P(Vs))	0.9568	15.1±0.822	11.7±0.58	10.2±0.507
S	-5.914 -2.312*LN(P(Vs))	0.9765	15.1±0.646	11.4±0.436	9.8±0.371
SSW	-5.931 -2.181*LN(P(Vs))	0.9911	13.9±0.35	10.4±0.241	8.8±0.213
SW	-3.161 -1.407*LN(P(Vs))	0.9758	9.6±0.536	7.3±0.376	6.4±0.328
WSW	-3.070 -1.531*LN(P(Vs))	0.9659	10.8±0.758	8.4±0.526	7.3±0.444
W	-2.405 -1.551*LN(P(Vs))	0.9671	11.7±0.572	9.2±0.432	8.1±0.398

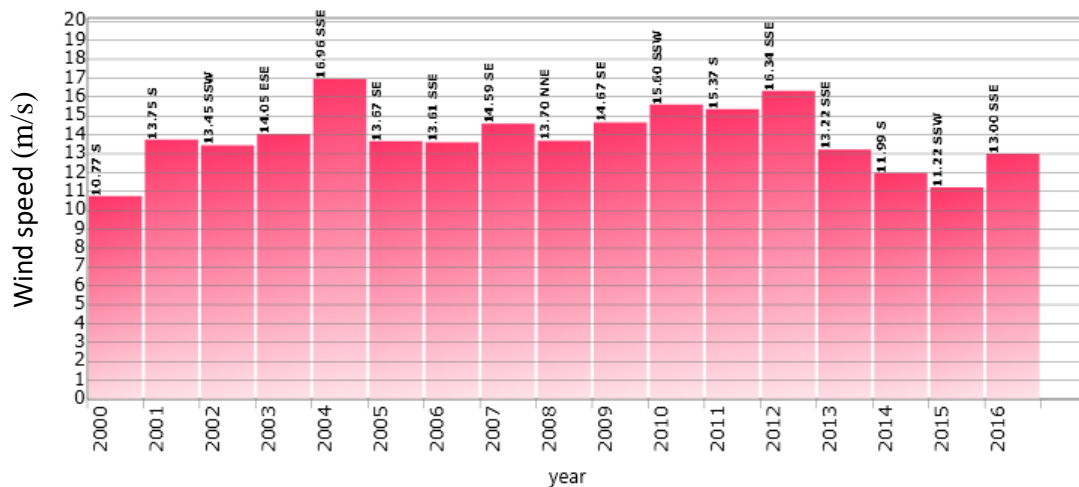


Figure (4-1-28) Yearly maximum wind speed & directions (ECMWF (36.6N, 28.9E)  
(HYDROTAM 3D)

Kızılada Lighthouse is the meteorological station which makes oversea measurements, and in Figure 4-1-30, the maximum, average and minimum of highest wind speeds from oversea measurements for İnceburun Lighthouse using the data for the years 2013-2018 are given. The comparison of Figure 4-1-29 and 4-1-30 show that the oversea measurements are almost half of wind estimates of ECMWF for the first eight months and almost double for October and November.

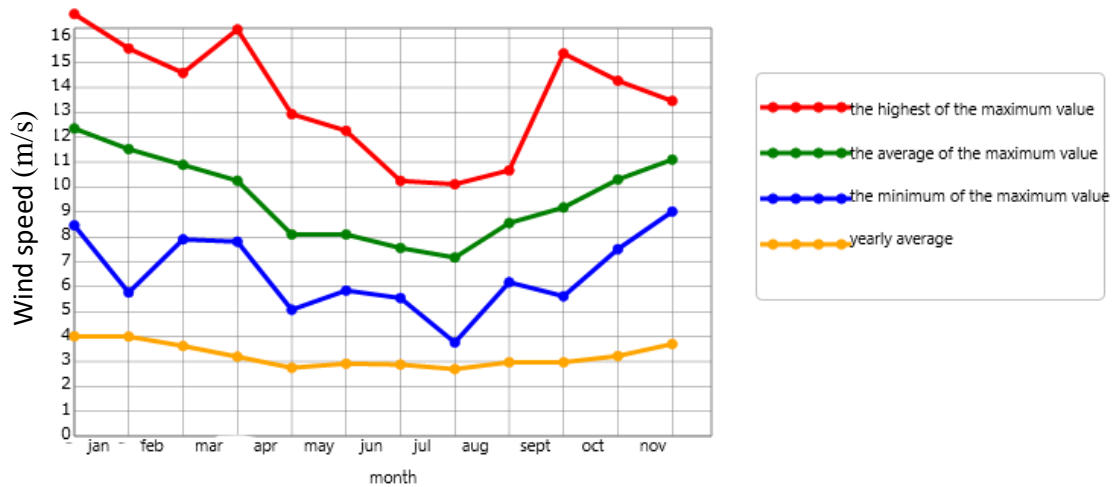


Figure (4-1-29) The maximum, average and minimum of highest wind speeds monthly average & maximum of extreme value (ECMWF 36.6N, 28.9E) (HYDROTAM 3D)

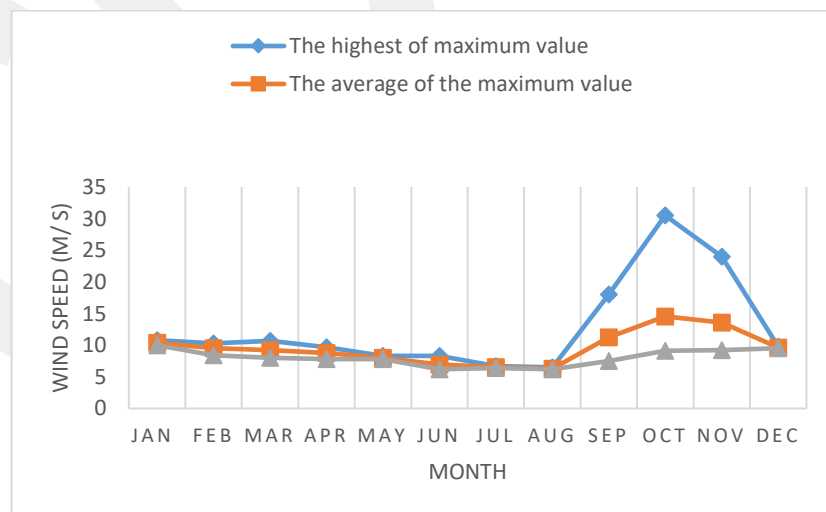


Figure (4-1-30) The maximum, average and minimum of highest wind speeds from oversea measurements for Fethiye coastal area (Kızılada Lighthouse)

#### 4.1.6 Datça Coastal Area

Datça Coastal Area is located in the province of Mugla (Figure (4-1-31)) at the southwest of and southwest of Turkey, the Aegean seaboard. Datça Meteorological Station is the closest over-land station, and it's hourly wind data is compared with the 6-hour over-sea wind estimates of ECMWF (36.7N, 27.3E) coordinate. The comparison of the two data sets are given in Figure 4-1-32. In Figure (4-1-32), the six-hour overland wind measurements of Datça meteorological station is compared with wind predictions of ECMWF (36.7N, 27.3E) coordinate for the years 2000-2016. It is seen from the Figure (4-1-32) that the 6 hr wind predictions of ECMWF (36.7N, 27.3E) coordinate is almost equal 1.4 times of Datça meteorological station wind data.



Figure (4-1-31) Location of Datça of coastal area and the wind data sources (HYDROTAM 3D)



The wind climate analysis is carried out by using the wind estimates of ECMWF (36.7N, 27.3E) coordinate by applying HYDROTAM-3D software ([26]). In wind climate long term statistics is carried out by log-linear probability distribution. From Table 4-1-6 it is seen that SSE direction gives the highest wind speed values for probabilities of 1hr/yr, 5hr/yr, and 10hr/yr. The yearly maximum wind speed is 20 m/s from SE direction (Figure 4-1-34). The highest of the maximum values of wind speeds is 21 m/s and it is effective in February (Figure 4-1-35).

Deveboynu Lighthouse is the meteorological station which makes oversea measurements, and in Figure 4-1-36, the maximum, average and minimum of highest wind speeds from oversea measurements for Deveboynu Lighthouse using the data for the years 2013-2018 are given. The comparison of Figure 4-1-35 and 4-1-36 show that the oversea measurements are almost double of wind estimates of ECMWF.

Table (4-1-6) Directional log – linear probability distribution of wind speeds  
ECMWF (36.7N,27.3E) (HYDROTAM 3D)

Direction	Equation		1 hour/year	5 hours/year	10 hour/year
	VS	R <sup>2</sup>	vs (±m/s) %90 confidence	vs (±m/s) %90 confidence	vs (±m/s) %90 confidence
<b>E</b>	-8.140 -2.182*LN(P(Vs))	0.9809	11.7±0.512	8.2±0.324	6.6±0.284
<b>SE</b>	-2.197 -2.338*LN(P(Vs))	0.8788	19±1.662	15.3±1.199	13.6±1.034
<b>SSE</b>	-2.349 -2.216*LN(P(Vs))	0.8803	17.8±1.581	14.2±1.138	12.7±0.982
<b>S</b>	-5.321 -2.512*LN(P(Vs))	0.8998	17.5±1.492	13.4±1.016	11.7±0.855
<b>SSW</b>	-5.988 -2.402*LN(P(Vs))	0.9264	15.8±1.089	11.9±0.746	10.3±0.652
<b>SW</b>	-6.230 -2.385*LN(P(Vs))	0.9604	15.4±0.813	11.6±0.551	9.9±0.476
<b>WSW</b>	-4.392 -2.200*LN(P(Vs))	0.8928	15.6±1.497	12±1.026	10.5±0.864
<b>W</b>	-4.349 -2.123*LN(P(Vs))	0.9521	14.9±0.854	11.5±0.602	10±0.528

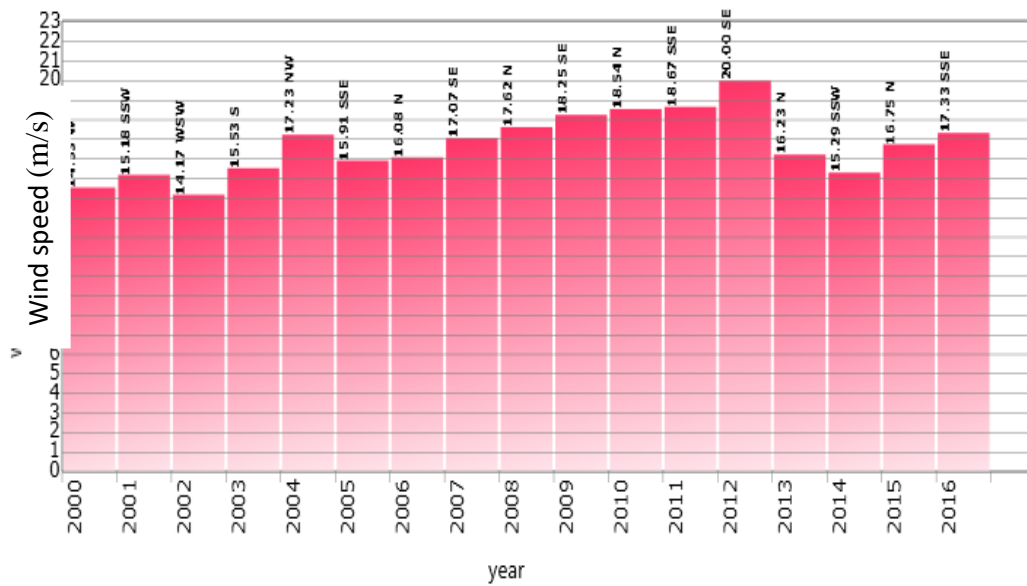


Figure (4-1-34) Yearly maximum wind speed & directions (ECMWF (36.7N, 27.3E))

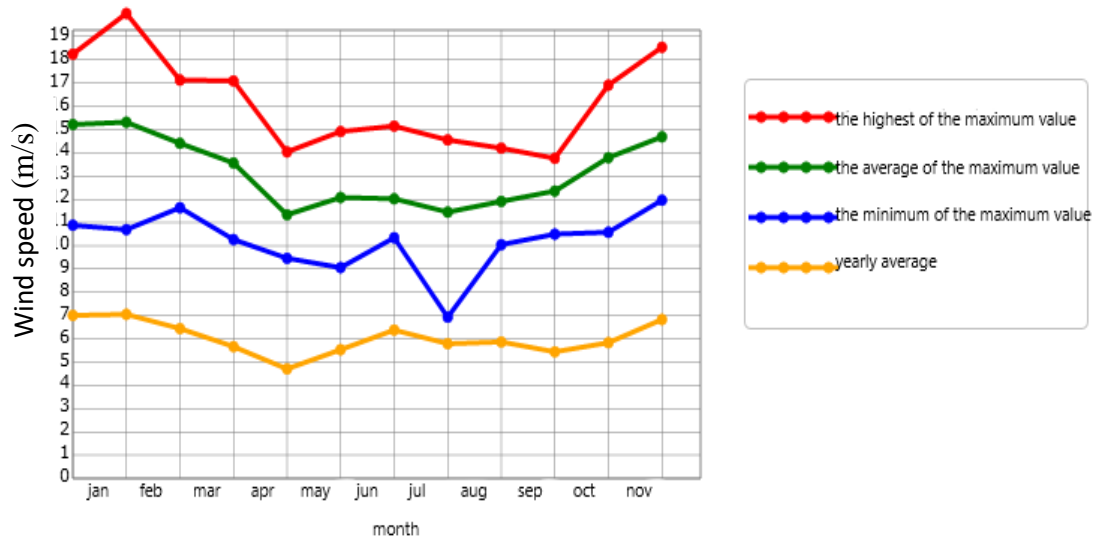


Figure (4-1-35) The maximum, average and minimum of highest wind speeds monthly average & maximum of extreme value (ECMWF 36.7N, 27.3E) (HYDROTAM 3D)

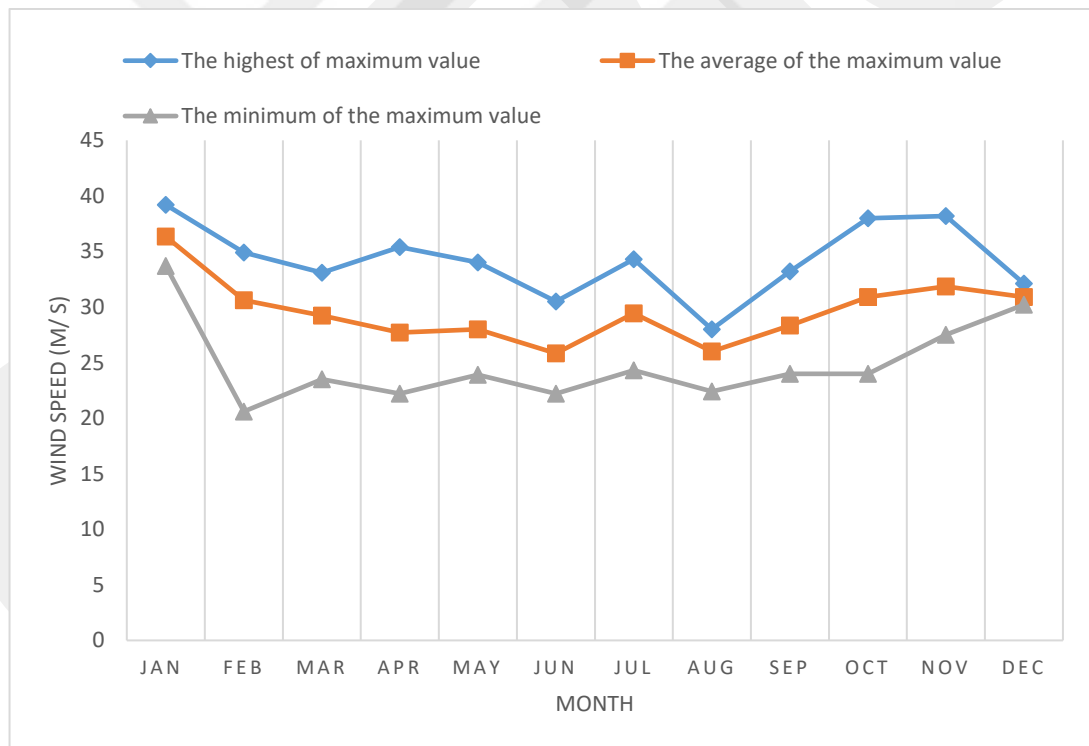


Figure (4-1-36) The maximum, average and minimum of highest wind speeds from oversea measurements for for Datça (Deveboynu Lighthouse)

## 4.2 Wave climate

### 4.2.1 Kuşadası Coastal Area

In this section the wave climate of the Kuşadası coastal area is given. In wave climate studies two approaches are used. In the first approach the wind estimates of ECMWF is used as input to CEM method, and in the second approach numerical wave estimates of ECMWF are used for wave statistics. In Figure 4-2-1 and Table 4-2-1 the fetch and Fetch distances for Kuşadası are given. The longest Fetch is the W direction followed by WNW and WSW.

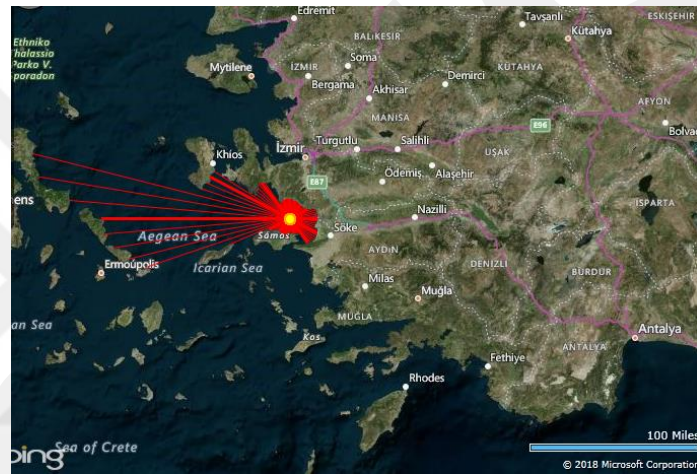


Figure (4-2-1) The fetch for Kuşadası coastal area (HYDROTAM 3D)

Table (4-2-1) The directions and the fetch distances for Kuşadası coastal area (HYDROTAM 3D)

Direction	Distance (km)
SW	15
WSW	62
W	195.5
WNW	94.7
NW	34.6
NNW	18.1

#### 4.2.1.1 Wave Climate by CEM method:

In this section the results of long-term wave statistics and extreme value statistics with wind data from ECMWF (38N, 26.7E) coordinate applied through CEM method are given. The exceedance probabilities of significant wave heights and probability distributions from long term wave statistics are given in Table 4-2-2. As it's seen from Table 4-2-2 the highest waves are in W direction in accordance with fetch direction. In Figures 4-2-2 and 4-2-3, wave period, T(s)-Significant wave height, H<sub>s</sub> (m) scatter plot and mean wave period, T<sub>m</sub>(s)-Significant wave height, H<sub>s</sub> (m) relation plot are given respectively.

Table (4-2-2) exceedance probabilities of Significant wave heights and probability distributions (long term) (HYDROTAM 3D)

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	H <sub>s</sub>	R <sup>2</sup>	H <sub>s</sub> (±m)	T <sub>m</sub> (sn)	H <sub>s</sub> (±m)	T <sub>m</sub> (sn)	H <sub>s</sub> (±m)	T <sub>m</sub> (sn)
			%90 confidence		%90 confidence		%90 confidence	
SW	-2.086 - 0.606*LN(P(H <sub>s</sub> ))	0.972	3.41±0.149	3.9	2.4±0.090	3.4	2.0±0.069	3.2
WSW	-1.611 - 0.482*LN(P(H <sub>s</sub> ))	0.969	2.8±0.127	4.7	2.0±0.076	4.1	1.7±0.058	3.8
W	-1.363 - 0.444*LN(P(H <sub>s</sub> ))	0.962	2.7±0.142	5.6	2±0.090	4.8	1.6±0.073	4.4
WNW	-0.997 - 0.367*LN(P(H <sub>s</sub> ))	0.974	2.3±0.094	4.6	1.7±0.061	4.1	1.5±0.050	3.8
NW	-0.688 - 0.360*LN(P(H <sub>s</sub> ))	0.974	2.6±0.118	4.4	2±0.081	3.9	1.7±0.067	3.7
NNW	-0.158 - 0.359*LN(P(H <sub>s</sub> ))	0.874	3.1±0.363	3.4	2.5±0.267	3.2	2.3±0.226	3.1

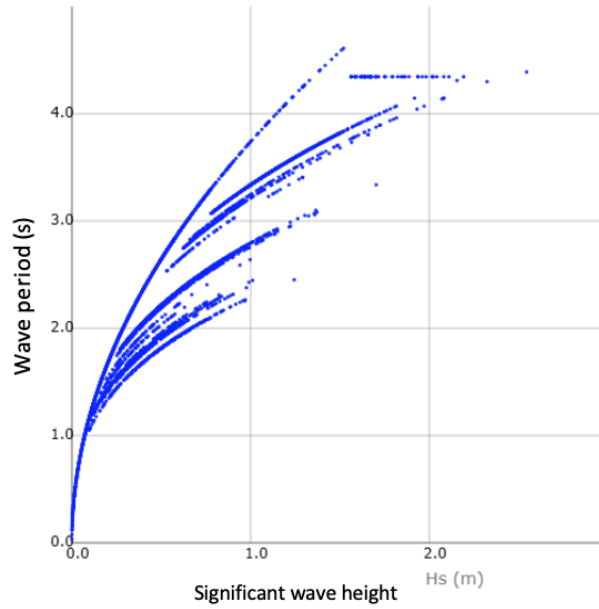


Figure (4-2-2) Wave period,  $T(s)$ -Significant wave height,  $H_s$  (m) scatter plot (HYDROTAM 3D)

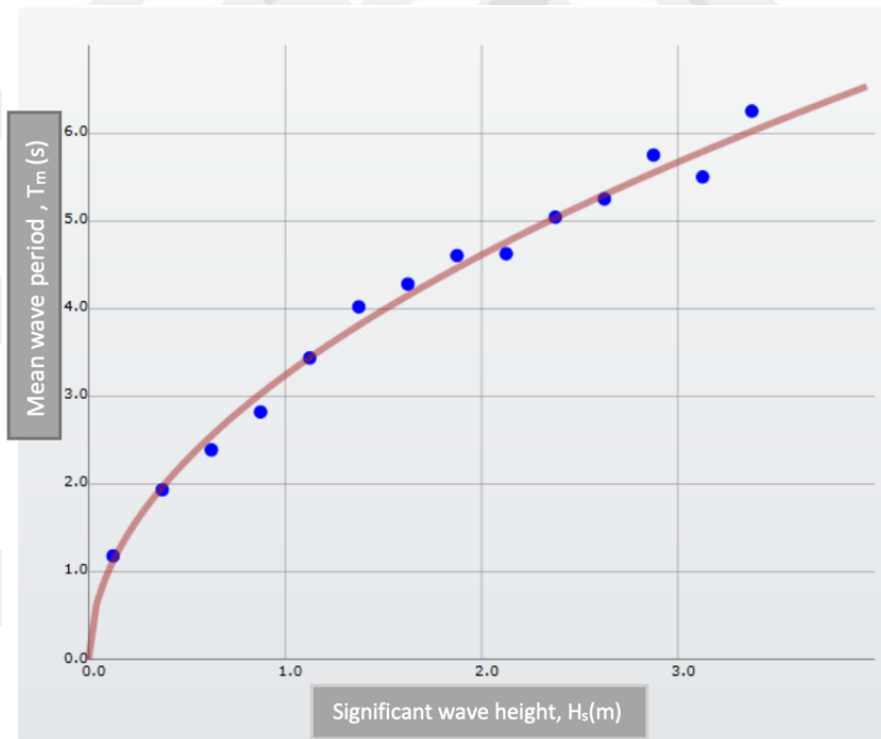


Figure (4-2-3) Mean wave period,  $T_m$ (s)-Significant wave height,  $H_s$ (m) relation plot (HYDROTAM-3D)

In Figure 4-2-4 yearly wave rose for Kuşadası coastal area is given. It is seen that S to SW direction have the highest waves which is between 2 m to 3 m. Almost 35.2% waves are smaller than 50 cm.

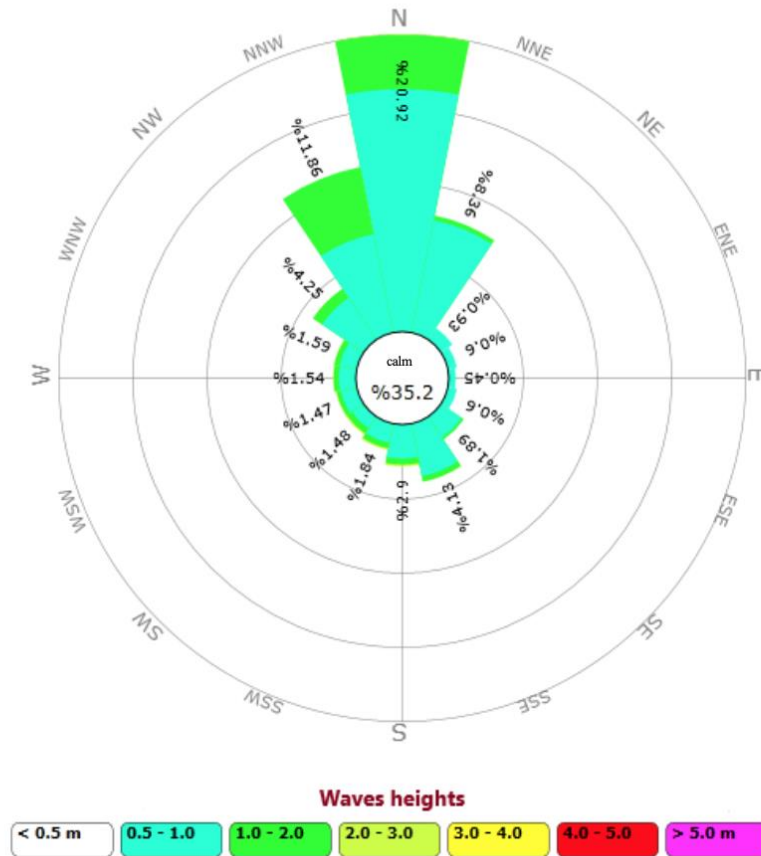


Figure (4-2-4) Yearly wave rose (HYDROTAM 3D)

In Figure 4-2-4 and Table 4-2-3, the results of extreme value statistics for Kuşadası coastal area are given. The wave height,  $H_s$  value corresponding to 100 year return period is calculated as 4.25 m.

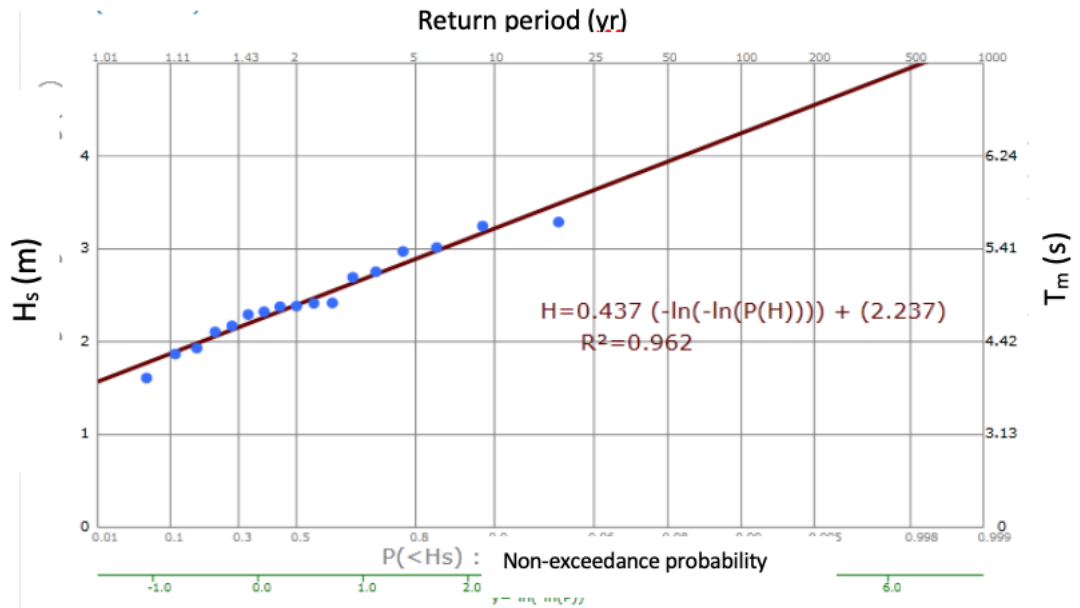


Figure (4-2-5) Extreme value statistics (Gumble distribution) with CEM Method (HYDROTAM 3D)

Table (4-2-3) The significant wave height,  $H_s$  values for extreme value statistics (HYDROTAM 3D)

Return period (yr)	$H_s$ (m)	%90 confidence(m)	$T_s$ (s)
5	2.892	0.056	5.310
10	3.220	0.079	5.601
25	3.634	0.113	5.949
50	3.941	0.139	6.194
100	4.246	0.165	6.429

#### 4.2.1.1 Wave Climate by WAM Numerical Model Results

In this section the results of long-term wave statistics and extreme value statistics with wave results of ECMWF (38N, 26.7E) coordinate are given. The exceedance probabilities of significant wave heights and probability distributions from long term wave statistics are given in Table 4-2-2. As it's seen from Table 4-2-2 the highest waves are in W direction. In Figures 4-2-6 and 4-2-7, wave period, T(s)-Significant wave height, H<sub>s</sub> (m) scatter plot and mean wave period, T<sub>m</sub>(s)-Significant wave height, H<sub>s</sub> (m) relation plot are given respectively.

Table (4-2-4) Exceedance probability of significant wave heights and probability distributions (HYDROTAM 3D)

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	H <sub>s</sub>	R <sup>2</sup>	H <sub>s</sub> (±m) %90 confidence	T <sub>m</sub> (sn)	H <sub>s</sub> (±m) %90 confidence	T <sub>m</sub> (sn)	H <sub>s</sub> (±m) %90 confidence	T <sub>m</sub> (sn)
SW	-1.039 0.453*LN(P(H <sub>s</sub> ))	0.992	3.1±0.054	6.4	2.3±0.036	6	2.0±0.030	5.8
WSW	-1.382- 0.479*LN(P(H <sub>s</sub> ))	0.993	3±0.045	6.6	2.2±0.029	6	1.9±0.025	5.7
W	-1.048- 0.331*LN(P(H <sub>s</sub> ))	0.877	2±0.203	5.7	1.4±0.136	5.2	1.2±0.121	4.9
WNW	-0.904- 0.324*LN(P(H <sub>s</sub> ))	0.962	2±0.084	5.9	1.5±0.058	5.4	1.3±0.054	5.2
NW	-0.365- 0.224*LN(P(H <sub>s</sub> ))	0.859	1.7±0.2	4.4	1.3±0.145	3.9	1.2±0.129	3.7
NNW	-0.166- 0.228*LN(P(H <sub>s</sub> ))	0.966	1.9±0.074	5.2	1.5±0.054	5	1.4±0.048	4.8

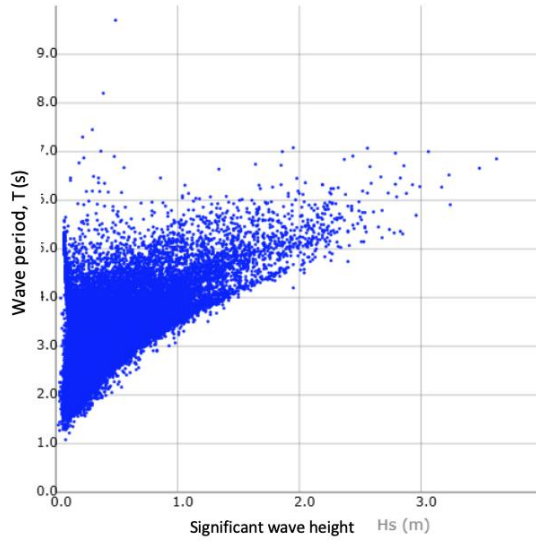


Figure (4-2-6) Wave period, T(s)-Significant wave height,  $H_s$  (m) scatter plot (HYDROTAM 3D)

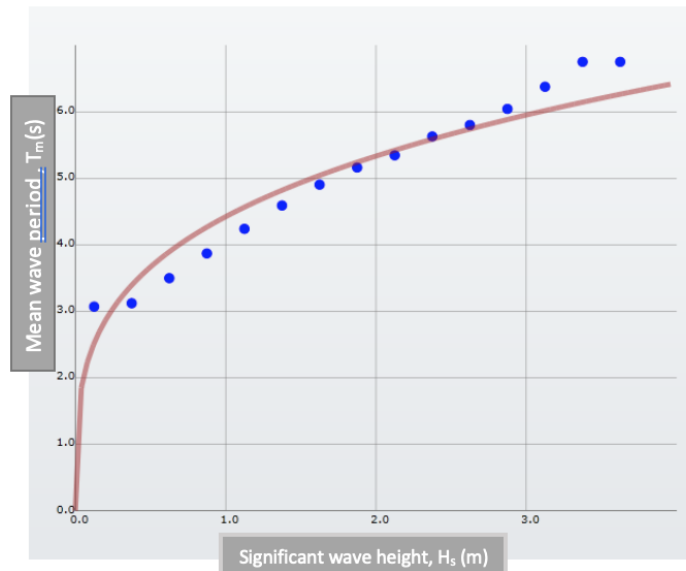


Figure (4-2-7) Mean wave period,  $T_m$ (s)-Significant wave height,  $H_s$ (m) relation plot (HYDROTAM-3D)

In Figure 4-2-8 yearly wave rose for Kuşadası coastal area is given. It is seen that S to SW direction have the highest waves which is between 2 m to 3 m. Almost 61.3 % waves are smaller than 50 cm.

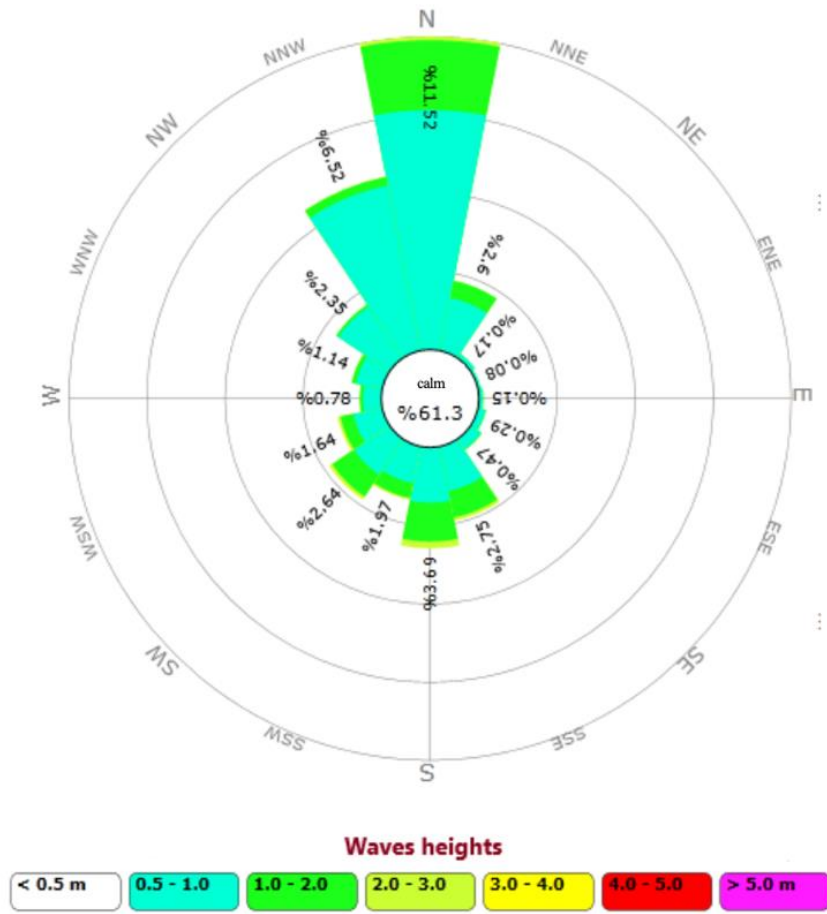


Figure (4-2-8) Yearly wave rose (HYDROTAM 3D)

In Figure 4-2-9 and Table 4-2-3, the results of extreme value statistics for Kuşadası coastal area are given. The wave height,  $H_s$  value corresponding to 100 year return period is calculated as 4.56 m.

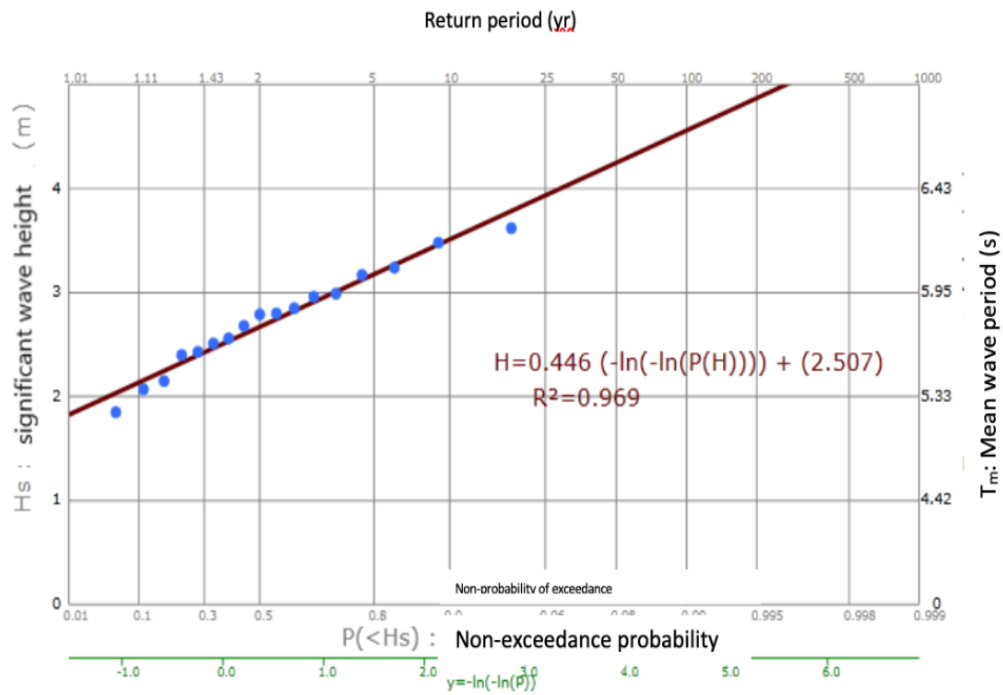


Figure (4-2-9) Extreme value statistics (Gumble distribution) with WAM numerical wave estimation results (HYDROTAM-3D)

Table (4-2-5) The significant wave height,  $H_s$  values for extreme value statistics (HYDROTAM 3D)

Return period (yr)	$H_s$ (m)	%90 confidence(m)	$T_s$ (s)
5.0	3.176	0.052	6.043
10.0	3.511	0.073	6.209
25.0	3.934	0.104	26.403
50.0	4.248	0.128	6.537
100.0	4.560	0.152	6.663

#### 4.2.2 Yalıkavak Coastal Area

In this section the wave climate of Yalıkavak coastal area is given. In wave climate studies two approaches are used. In the first approach the wind estimates of ECMWF is used as input to CEM method, and in the second approach numerical wave estimates of ECMWF are used for wave statistics. In Figure 4-2-10 and Table 4-2-6 the fetch and Fetch distances for Kuşadası are given. The longest Fetch is the NW direction followed by WSW and WNW.

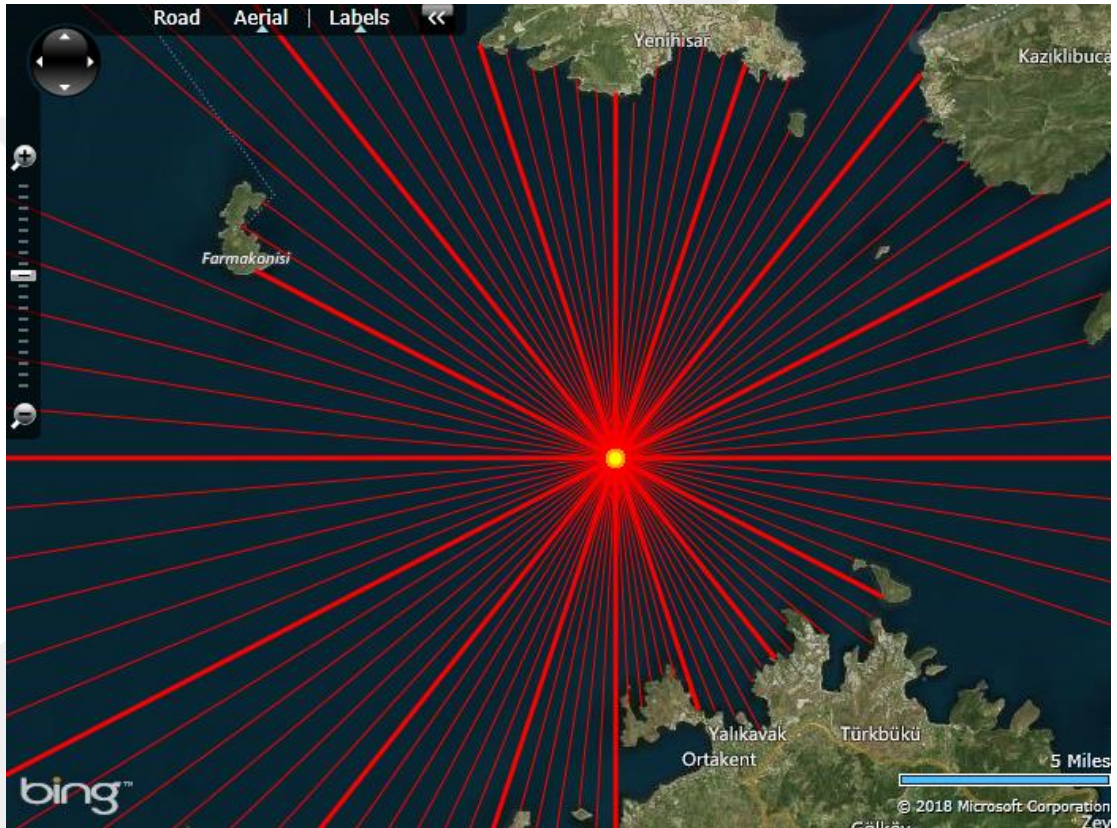


Figure (4-2-10) The fetch for Yalıkavak coastal area (HYDROTAM 3D)

Table (4-2-6) The directions and the fetch distances for Yalıkavak coastal area  
(HYDROTAM 3D)

Direction	Distance (km)
N	14.6
NNW	33.3
NW	96.5
WNW	77.2
W	65.6
WSW	81.8

#### 4.2.2.1 Wave Climate by CEM method:

In this section the results of long-term wave statistics and extreme value statistics with wind data from ECMWF (37.2N, 27.3E) coordinate applied through CEM method are given. The exceedance probabilities of significant wave heights and probability distributions from long term wave statistics are given in Table 4-2-7. As it's seen from Table 4-2-7 the waves are in the same order in accordance with fetch directions. In Figures 4-2-11 and 4-2-12, wave period, T(s)-Significant wave height, H<sub>s</sub> (m) scatter plot and mean wave period, T<sub>m</sub>(s)-Significant wave height, H<sub>s</sub> (m) relation plot are given respectively.

Table (4-2-7) Exceedance probabilities of Significant wave heights and probability distributions (HYDROTAM 3D)

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
			H <sub>s</sub> (±m) %90 confi	T <sub>m</sub> (s)	H <sub>s</sub> (± m) %90 confi	T <sub>m</sub> (s)	H <sub>s</sub> (± m) %90 confi	T <sub>m</sub> (s)
	H <sub>s</sub>	R <sup>2</sup>						
WSW	-1.019 - 0.365*LN(P(H <sub>s</sub> ))	0.976	2.3±0.08	4.5	1.7±0.05	3.9	1.5±0.042	3.7
W	-0.858 - 0.335*LN(P(H <sub>s</sub> ))	0.976	2.2±0.074	4.3	1.6±0.049	3.8	1.4±0.043	3.6
WNW	-0.301 - 0.262*LN(P(H <sub>s</sub> ))	0.946	2.1±0.115	4.3	1.7±0.08	3.9	1.5±0.067	3.7
NW	0.287 0.192*LN(P(H <sub>s</sub> ))	0.848	2±0.195	4.4	1.7±0.148	4.1	1.6±0.13	4
NNW	0.353 - 0.227*LN(P(H <sub>s</sub> ))	0.759	2.4±0.367	3.8	2±0.279	3.6	1.9±0.243	3.5
N	-0.001 - 0.279*LN(P(H <sub>s</sub> ))	0.937	2.5±0.183	3.1	2.1±0.134	2.9	1.9±0.114	2.8

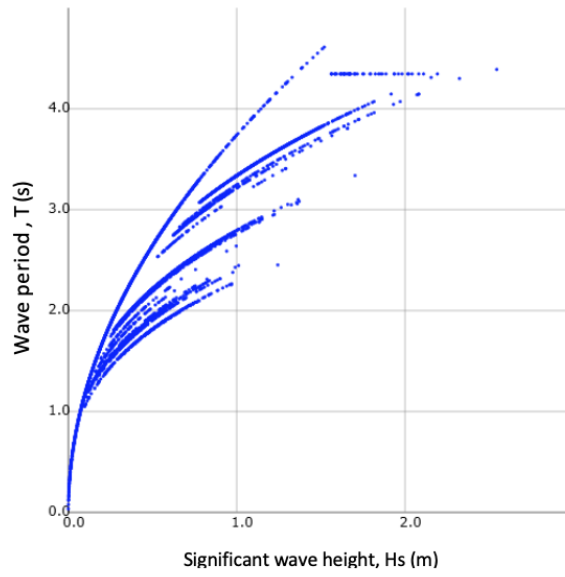


Figure (4-2-11) The relation between significant wave height,  $H_s$  and wave period,  $T$  (HYDROTAM 3D)

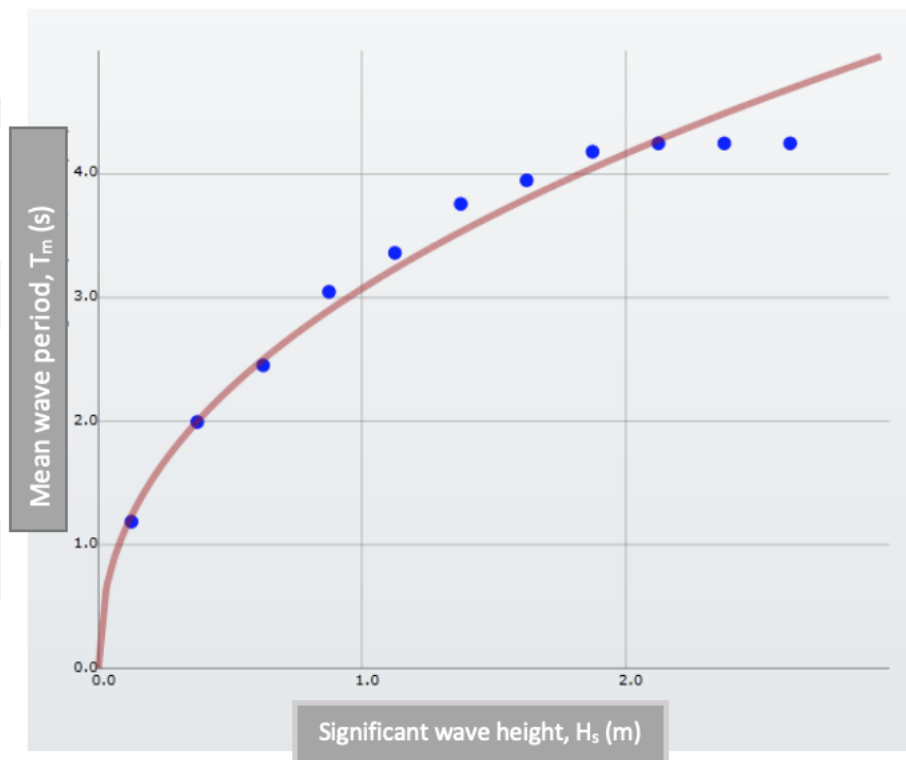


Figure (4-2-12) The relation between significant wave height,  $H_s$  and mean wave period,  $T_m$  (HYDROTAM 3D)

In Figure 4-2-13 yearly wave rose for Yalıkavak coastal area is given. It is seen that NNW to WNW direction have the highest waves which is between 1m to 2 m. Almost 35 % waves are smaller than 50 cm.

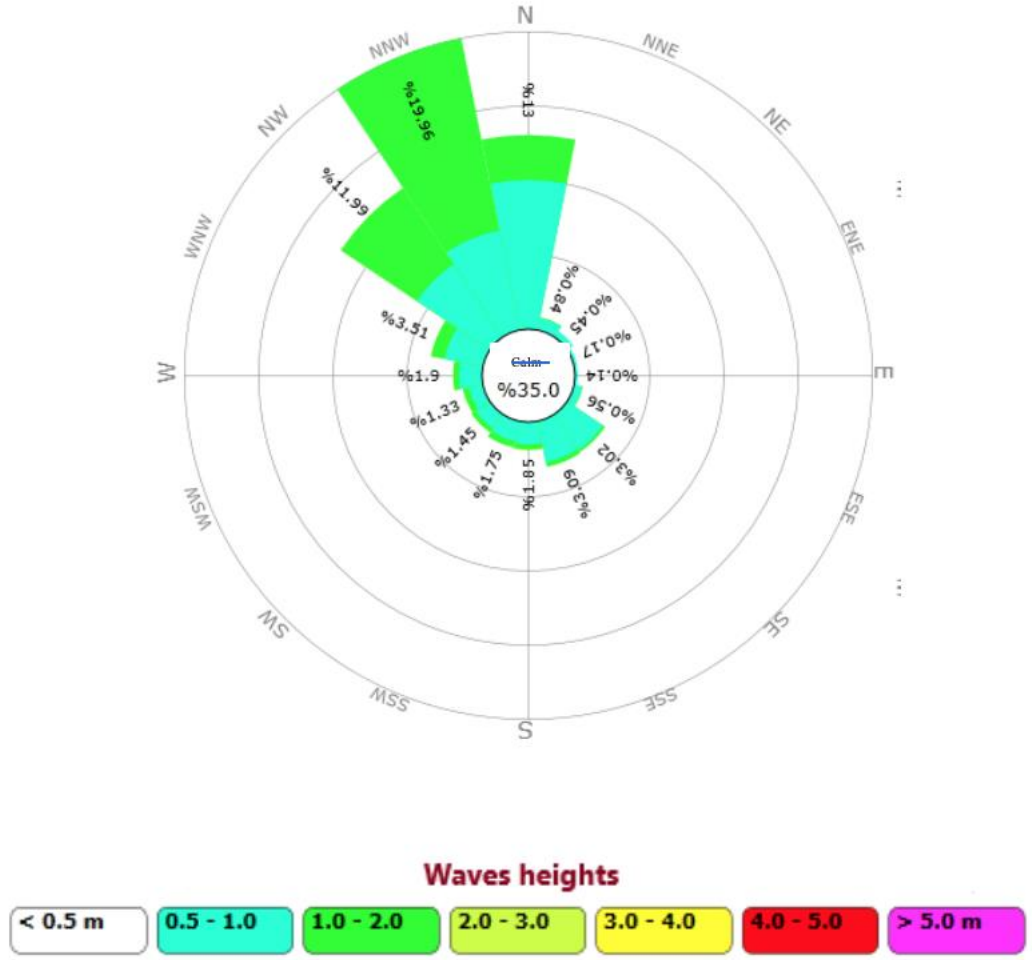


Figure (4-2-13) Yearly wave rose (HYDROTAM 3D)

In Figure 4-2-14 and Table 4-2-8, the results of extreme value statistics for Yalıkavak coastal area are given. The wave height,  $H_s$  value corresponding to 100 year return period is calculated as 2.84 m.

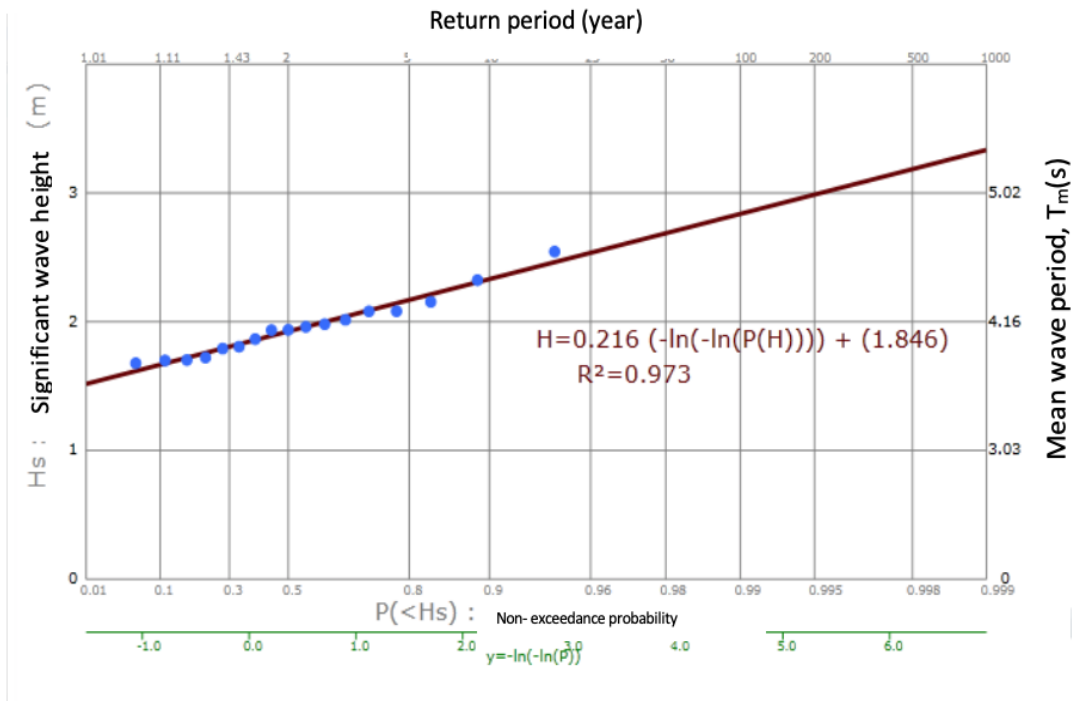


Figure (4-2-14) Extreme value statistics (Gumble distribution) from CEM method (HYDROTAM 3D)

Table (4-2-8) The significant wave height,  $H_s$  values for extreme value statistics (HYDROTAM 3D)

Return period (yr)	$H_s$ (m)	%90 confidence(m)	$T_s$ (s)
5.0	2.169	0.023	4.321
10.0	2.331	0.033	4.467
25.0	2.535	0.047	4.643
50.0	2.687	0.057	4.769
100.0	2.838	0.068	4.890

#### 4.2.2.2 Wave Climate by WAM Numerical Model Results

In this section the results of long-term wave statistics and extreme value statistics with wave results of WAM numerical model from ECMWF (37.2N, 27.3E) coordinate are given. The exceedance probabilities of significant wave heights and probability distributions from long term wave statistics are given in Table 4-2-9. As it's seen from Table 4-2-9 the waves are in the same order. In Figures 4-2-15 and 4-2-16, wave period, T(s)-Significant wave height, H<sub>s</sub> (m) scatter plot and mean wave period, T<sub>m</sub>(s)-Significant wave height, H<sub>s</sub> (m) relation plot are given respect  $C_{calm}$

Table (4-2-9) Exceedance probability of significant wave heights and probability distributions (HYDROTAM 3D)

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	H <sub>s</sub>	R <sup>2</sup>	H <sub>s</sub> (±m) %90 confidenc e	T <sub>m</sub> (sn)	H <sub>s</sub> (±m) %90 confidenc e	T <sub>m</sub> (sn)	H <sub>s</sub> (±m) %90 confidenc e	T <sub>m</sub> (sn)
WSW	-0.651- 0.327*LN(P(H <sub>s</sub> ))	0.994	2±0.038	5.4	1.8±0.026	5.2	1.6±0.022	5
W	-1.244- 0.369*LN(P(H <sub>s</sub> ))	0.977	2.1±0.072	5.3	1.5±0.047	5	1.3±0.044	4.8
WNW	-0.340- 0.242*LN(P(H <sub>s</sub> ))	0.955	1.9±0.094	4.8	1.5±0.069	4.6	1.3±0.062	4.5
NW	-0.151- 0.181*LN(P(H <sub>s</sub> ))	0.962	1.8±0.08	4.9	1.5±0.06	4.7	1.4±0.053	4.6
NNW	-0.135- 0.296*LN(P(H <sub>s</sub> ))	0.991	2.5±0.044	5.1	2.1±0.032	4.9	1.9±0.028	4.8
N	-0.616- 0.304*LN(P(H <sub>s</sub> ))	0.99	2.1±0.042	5	1.7±0.029	4.7	1.4±0.025	4.6

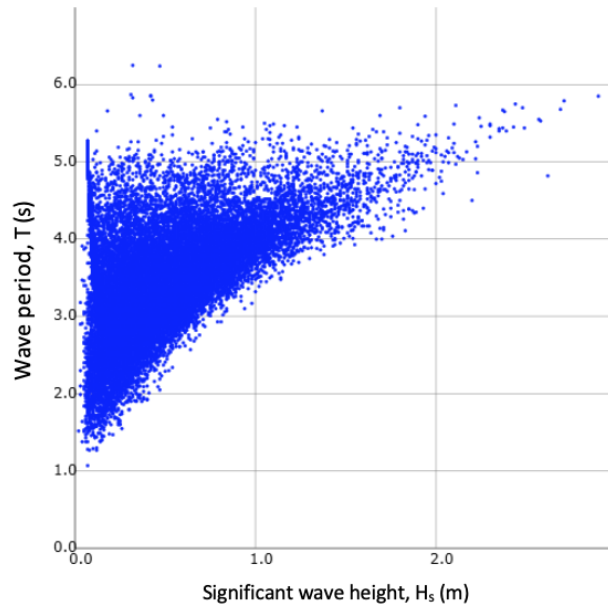


Figure (4-2-15) The relation between significant wave height,  $H_s$  and wave period,  $T$  (HYDROTAM 3D)

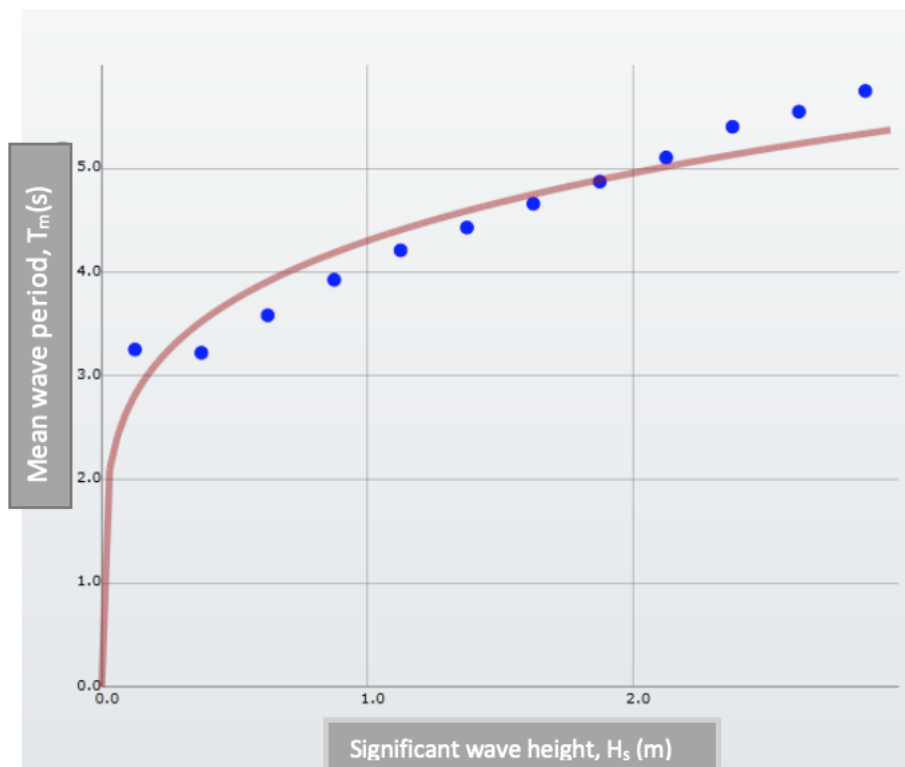


Figure (4-2-16) show the relation between significant wave height,  $H_s$  and medium wave period,  $T_m$  (HYDROTAM 3D)

In Figure 4-2-17 yearly wave rose for Yalıkavak coastal area is given. It is seen that NNW to WNW direction have the highest waves which is between 1m to 2 m. Almost 60.1 % waves are smaller than 50 cm.

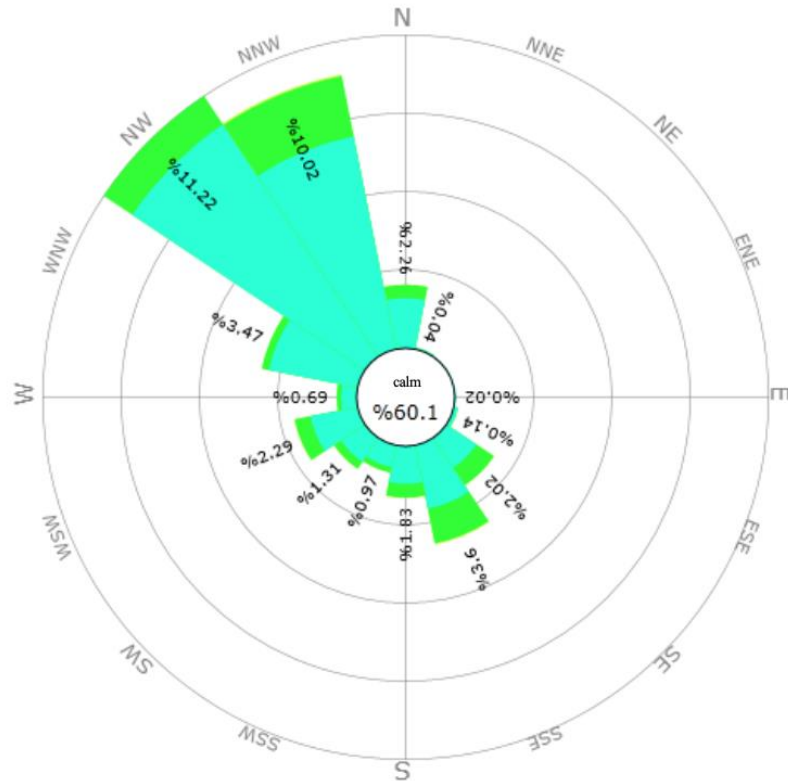


Figure (4-2-17) Yearly wave rose (HYDROTAM 3D)

In Figure 4-2-18 and Table 4-2-10, the results of extreme value statistics for Yalıkavak coastal area are given. The wave height,  $H_s$  value corresponding to 100 year return period is calculated as 3.81 m.

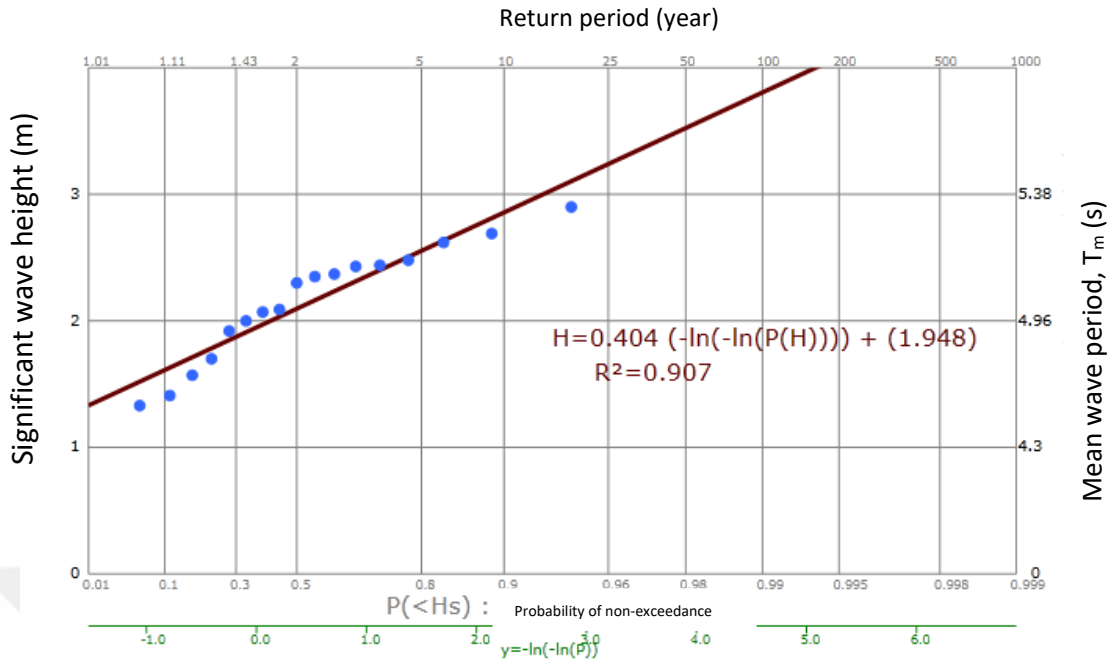


Figure (4-2-18) Extreme value statistics for Yalıkavak coastal area with WAM model numerical results (HYDROTAM 3D)

Table (4-2-10) show the significant wave height respect with significant wave period for 100 year for gumble chart (HYDROTAM 3D)

Return period (yr)	$H_s$ (m)	%90 confidence(m)	$T_s$ (s)
5.0	2.554	0.083	5.210
10.0	2.857	0.118	5.331
25.0	3.239	0.168	5.469
50.0	3.523	0.207	5.564
100.0	3.805	0.246	5.652

### 4.2.3 Turgutreis Coastal Area

In this section the wave climate of the (Turgutreis) is given in wave climate studies two approaches are used. In the first approach the wind estimates of ECMWF is used as input to CEM method , and in the second approach numerical wave estimates of ECMWF are used for wave statistics. In Figure 4-2-19 and Table 4-2-11 the fetch and Fetch distances for Kuşadası are given. The longest Fetch is the NNW direction followed by NW and WNW.

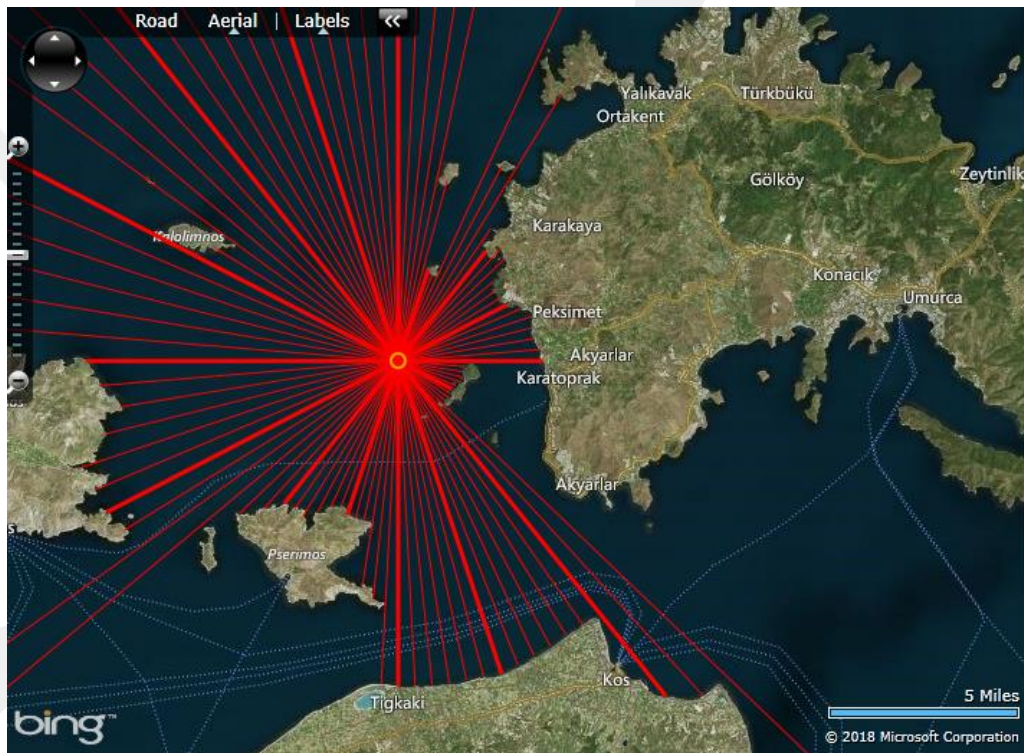


Figure (4-2-19) The fetch for Turgutreis coastal area (HYDROTAM 3D)

Table (4-2-11) The directions and the fetch distances for Turgutreis coastal area (HYDROTAM 3D)

Direction	Distance (km)
WSW	247.5
W	270
WNW	292.5
NW	315
NNW	337.5

#### 4.2.3.1. Wave Climate by CEM method:

In this section the results of long-term wave statistics and extreme value statistics with wind data from ECMWF (37.0N, 27.2E) coordinate applied through CEM method are given. The exceedance probabilities of significant wave heights and probability distributions from long term wave statistics are given in Table 4-2-12. As it's seen from Table 4-2-12 the highest waves are in NNW direction in accordance with fetch direction. In Figures 4-2-20 and 4-2-21, wave period, T(s)-Significant wave height, H<sub>s</sub> (m) scatter plot and mean wave period, T<sub>m</sub>(s)-Significant wave height, H<sub>s</sub> (m) relation plot are given respectively.

Table (4-2-12) exceedance probabilities of Signifiant wave heights and probability distributions (HYDROTAM 3D)

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	H <sub>s</sub>	R <sup>2</sup>	H <sub>s</sub> (±m) %90 confidence	T <sub>m</sub> (sn)	H <sub>s</sub> (±m) %90 confidence	T <sub>m</sub> (sn)	H <sub>s</sub> (±m) %90 confidence	T <sub>m</sub> (sn)
WSW	-0.349 - 0.232*LN(P(H <sub>s</sub> ))	0.883	1.8±0.194	3.5	1.4±0.129	3.1	1.2±0.104	3
W	-0.549 - 0.276*LN(P(H <sub>s</sub> ))	0.958	2±0.122	3.2	1.5±0.081	2.9	1.3±0.065	2.8
WNW	-0.270 - 0.223*LN(P(H <sub>s</sub> ))	0.936	1.8±0.14	3.4	1.4±0.095	3.1	1.2±0.078	3
NW	0.237 - 0.223*LN(P(H <sub>s</sub> ))	0.901	2.3±0.172	4.4	1.9±0.131	4.1	1.7±0.115	4
NNW	0.492 - 0.203*LN(P(H <sub>s</sub> ))	0.796	2.3±0.258	4.3	2±0.199	4.1	1.9±0.176	4

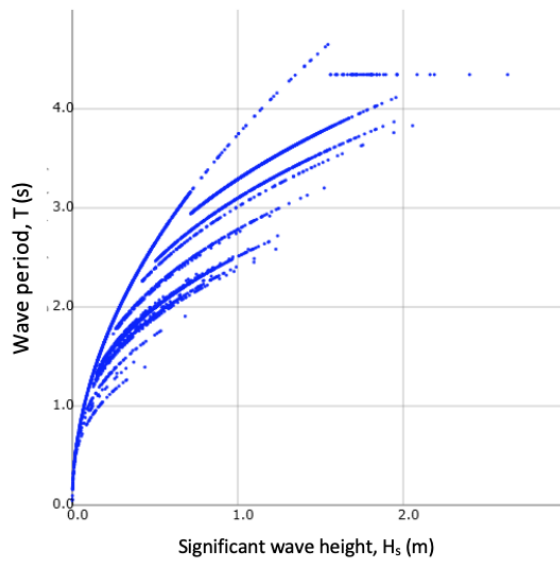


Figure (4-2-20) Wave period,  $T$ (s)-Significant wave height,  $H_s$  (m) scatter plot (HYDROTAM 3D)

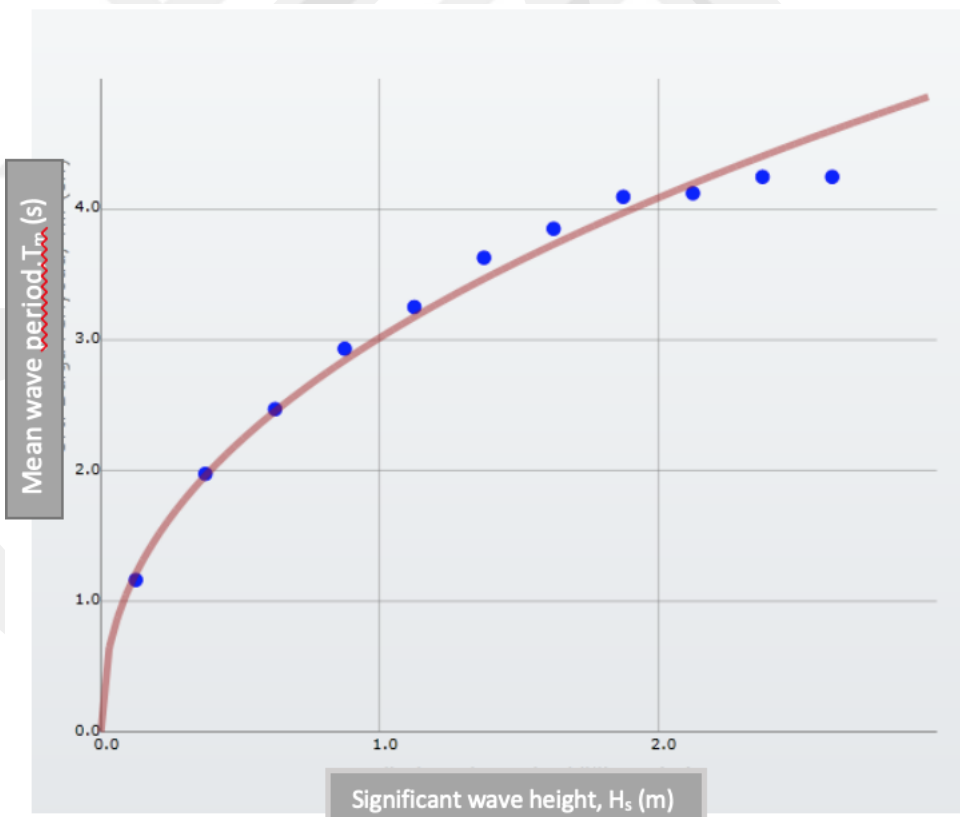


Figure (4-2-21) Mean wave period,  $T_m$ (s)-Significant wave height,  $H_s$ (m) relation plot (HYDROTAM-3D)

In Figure 4-2-22 yearly wave rose for Turgutreis coastal area is given. It is seen that NNW to WNW direction have the highest waves which is between 1 m to 2 m. Almost 27.9% waves are smaller than 50 cm.

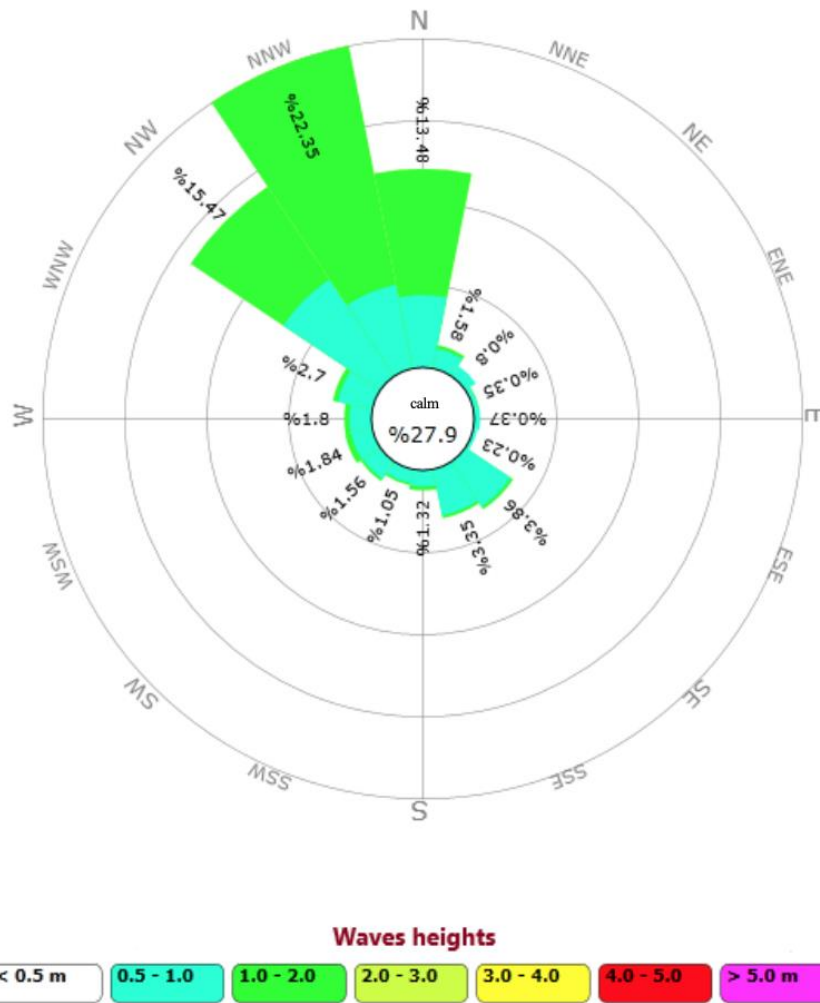


Figure (4-2-22) Yearly wave rose (HYDROTAM 3D)

In Figure 4-2-23 and Table 4-2-33, the results of extreme value statistics for Turgutreis coastal area are given. The wave height,  $H_s$  value corresponding to 100 year return period is calculated as 2.74 m.

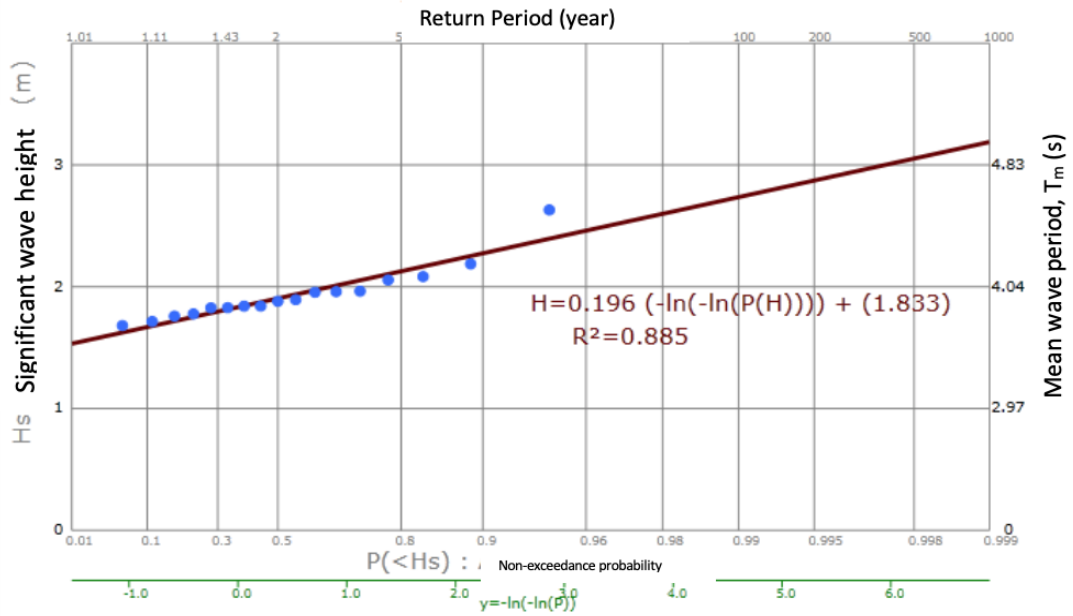


Figure (4-2-23) Extreme value statistics (Gumble distribution) with CEM Method (HYDROTAM 3D)

Table (4-2-13) The significant wave height,  $H_s$  values for extreme value statistics (HYDROTAM 3D)

Hr/ yr	Hs(m)	%90confidence(m)	Ts(s)
5.0	2.128	0.046	4.148
10.0	2.275	0.065	4.273
25.0	2.461	0.092	4.425
50.0	2.599	0.114	4.534
100.0	2.736	0.135	4.630

#### 4.2.3.2 Wave Climate by WAM Numerical Model Results

In this section the results of long-term wave statistics and extreme value statistics with wave results of ECMWF (37.0N, 27.2E) coordinate are given. The exceedance probabilities of significant wave heights and probability distributions from long term wave statistics are given in Table 4-2-14. As it's seen from Table 4-2-14 the highest waves are in NNW direction. In Figures 4-2-24 and 4-2-25, wave period, T(s)-Significant

wave height,  $H_s$  (m) scatter plot and mean wave period,  $T_m$ (s)-Significant wave height,  $H_s$  (m) relation plot are given respectively.

Table (4-2-14) Exceedance probability of significant wave heights and probability distributions (HYDROTAM 3D)

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	$H_s$	$R^2$	$H_s (\pm m)$ %90 confidence	$T_m (sn)$	$H_s (\pm m)$ %90 confidence	$T_m (sn)$	$H_s (\pm m)$ %90 confidence	$T_m (sn)$
<b>WSW</b>	-0.528 - 0.302*LN(P( $H_s$ ))	0.993	2.2±0.044	5.1	1.7±0.029	4.9	1.5±0.024	4.8
<b>W</b>	-1.131 - 0.334*LN(P( $H_s$ ))	0.951	1.9±0.097	5.2	1.4±0.064	4.9	1.1±0.06	4.7
<b>WNW</b>	-0.617 - 0.254*LN(P( $H_s$ ))	0.978	1.7±0.064	4.7	1.3±0.044	4.5	1.1±0.04	4.4
<b>NW</b>	0.145 - 0.190*LN(P( $H_s$ ))	0.966	1.9±0.076	4.7	1.6±0.057	4.6	1.4±0.05	4.5
<b>NNW</b>	0.077 - 0.274*LN(P( $H_s$ ))	0.977	2.6±0.076	5.1	2.1±0.057	5	1.9±0.049	4.9

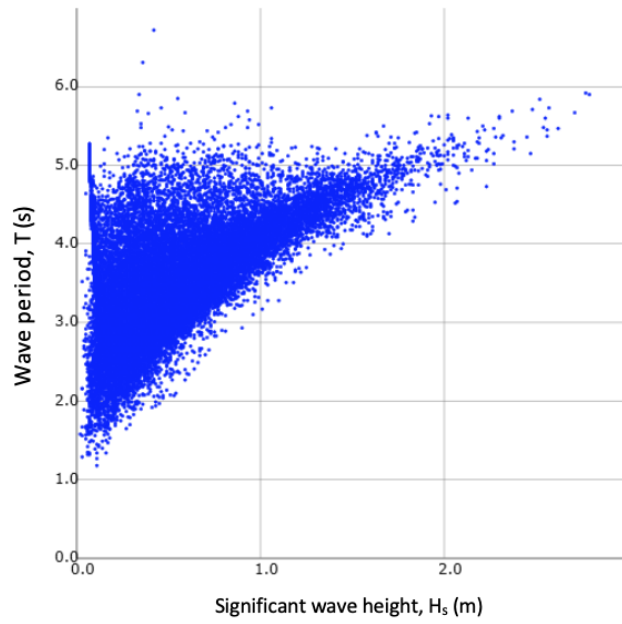


Figure (4-2-24) Wave period, T(s)-Significant wave height,  $H_s$  (m) scatter plot (HYDROTAM 3D)

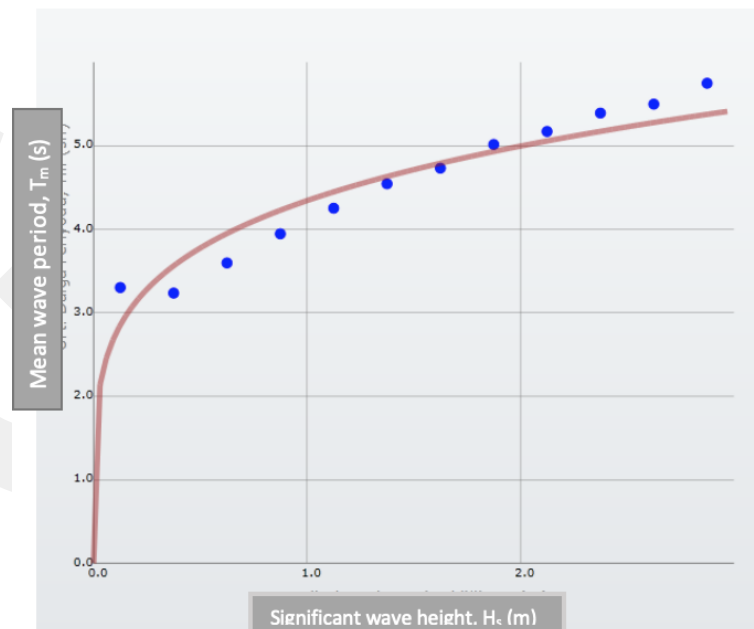


Figure (4-2-25) Mean wave period,  $T_m$ (s)-Significant wave height,  $H_s$ (m) relation plot (HYDROTAM-3D)

In Figure 4-2-26 yearly wave rose for Turgutreis coastal area is given. It is seen that NNW to WNW direction have the highest waves which is between 1 m to 2 m. Almost 56.1 % waves are smaller than 50 cm.

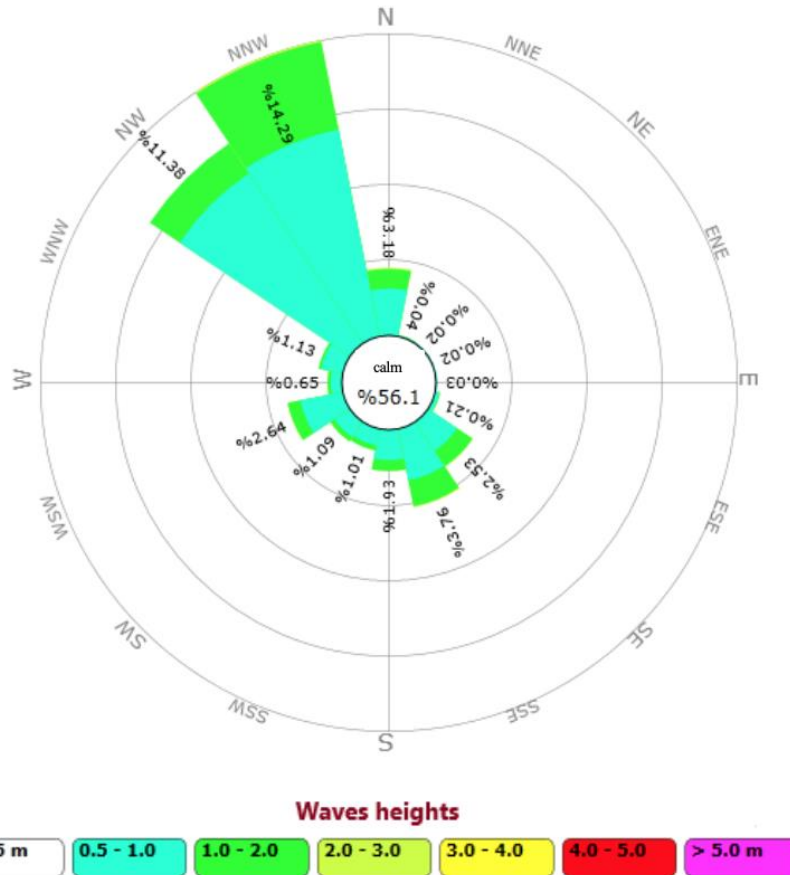


Figure (4-2-26) Yearly wave rose (HYDROTAM 3D)

In Figure 4-2-27 and Table 4-2-15, the results of extreme value statistics for Turgutreis coastal area are given. The wave height,  $H_s$  value corresponding to 100 year return period is calculated as 3.78 m.

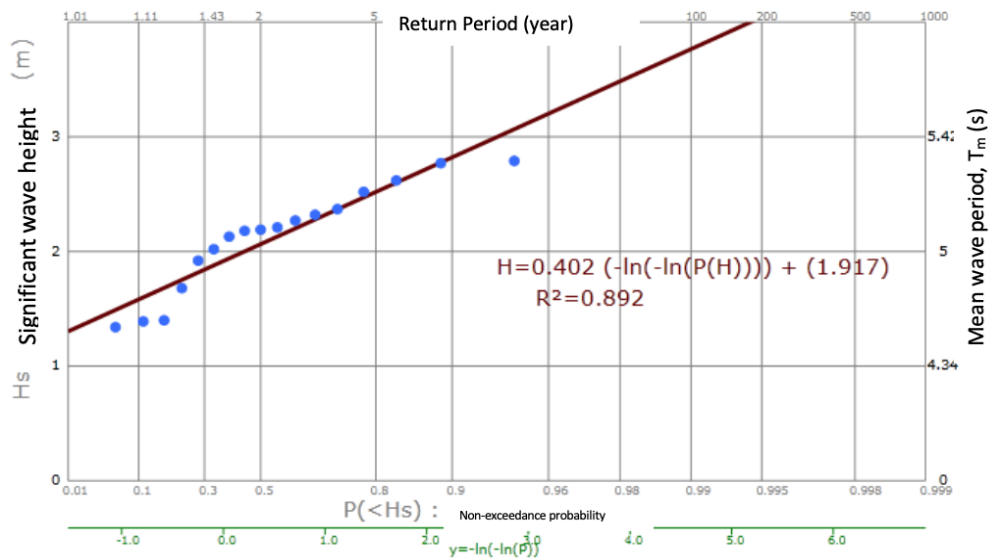


Figure (4-2-27) Extreme value statistics (Gumble distribution) with WAM numerical wave estimation results (HYDROTAM-3D)

Table (4-2-15) The significant wave height,  $H_s$  values for extreme value statistics (HYDROTAM 3D)

Return period (yr)	$H_s$ (m)	%90 confidence(m)	$T_s$ (s)
5.0	2.519	0.090	5.236
10.0	2.821	0.128	5.356
25.0	3.202	0.182	5.495
50.0	3.485	0.224	5.590
100.0	3.765	0.266	5.678

#### 4.2.4 Marmaris Coastal Area

In this section the wave climate of the Marmaris coastal area is given. In wave climate studies two approaches are used. In the first approach the wind estimates of ECMWF is used as input to CEM method, and in the second approach numerical wave estimates of ECMWF are used for wave statistics. In Figure 4-2-28 and Table 4-2-16 the fetch and Fetch distances for Marmaris are given. The longest Fetch is the SE direction followed by SSE and S.

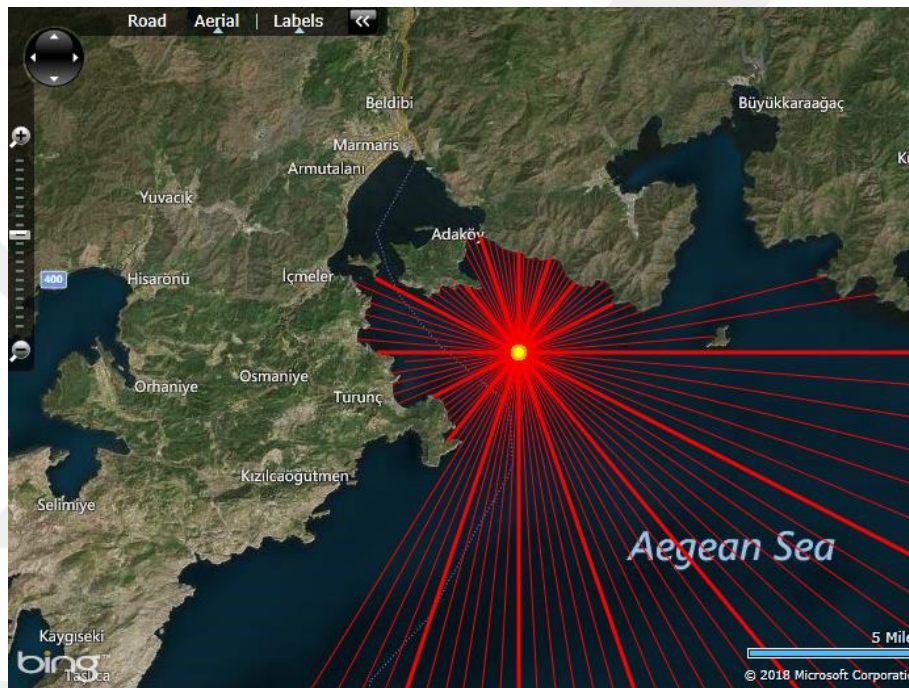


Figure (4-2-28) The fetch for Marmaris coastal area (HYDROTAM 3D)

Table (4-2-16) The directions and the fetch distances for Marmaris coastal area (HYDROTAM 3D)

direction	Distance(km)
E	17.9
ESE	253.9
SE	760.5
SSE	636.1
S	632.4
SSW	202.5

#### 4.2.4.1 Wave Climate by CEM method:

In this section the results of long-term wave statistics and extreme value statistics with wind data from ECMWF (36.7N, 28.4E) coordinate applied through CEM method are given. The exceedance probabilities of significant wave heights and probability distributions from long term wave statistics are given in Table 4-2-17. As it's seen from Table 4-2-17 the highest waves are in SE- SSE directions in accordance with fetch direction. In Figures 4-2-29 and 4-2-30, wave period, T(s)-Significant wave height, H<sub>s</sub> (m) scatter plot and mean wave period, T<sub>m</sub>(s)-Significant wave height, H<sub>s</sub> (m) relation plot are given respectively.

Table (4-2-17) Exceedance probabilities of significant wave heights and probability distributions (HYDROTAM 3D)

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	H <sub>s</sub>	R <sup>2</sup>	H <sub>s</sub> (±m) %90 confidence	T <sub>m</sub> (sn)	H <sub>s</sub> (±m) %90 confidence	T <sub>m</sub> (sn)	H <sub>s</sub> (±m) %90 confidence	T <sub>m</sub> (sn)
			e	e	e	e		
<b>E</b>	-1.620 - 0.426*LN(P(H <sub>s</sub> ))	0.863	2.2±0.304	3.4	1.6±0.189	3	1.3±0.158	2.7
<b>ESE</b>	-1.880 - 0.574*LN(P(H <sub>s</sub> ))	0.962	3.3±0.147	6.3	2.4±0.091	5.4	2±0.073	4.9
<b>SE</b>	-2.968 - 1.333*LN(P(H <sub>s</sub> ))	0.978	8±0.224	11.4	7±0.153	10	6.1±0.14	9.3
<b>SSE</b>	-4.279 - 1.442*LN(P(H <sub>s</sub> ))	0.975	8±0.241	11.2	6.5±0.157	9.5	5.5±0.123	8.7
<b>S</b>	-6.792 - 1.546*LN(P(H <sub>s</sub> ))	0.983	7.2±0.213	10.1	4.8±0.12	8.1	3.7±0.086	7.1
<b>SSW</b>	-6.531 - 1.434*LN(P(H <sub>s</sub> ))	0.951	6.5±0.319	7.6	4.2±0.172	6.2	3.2±0.123	5.5

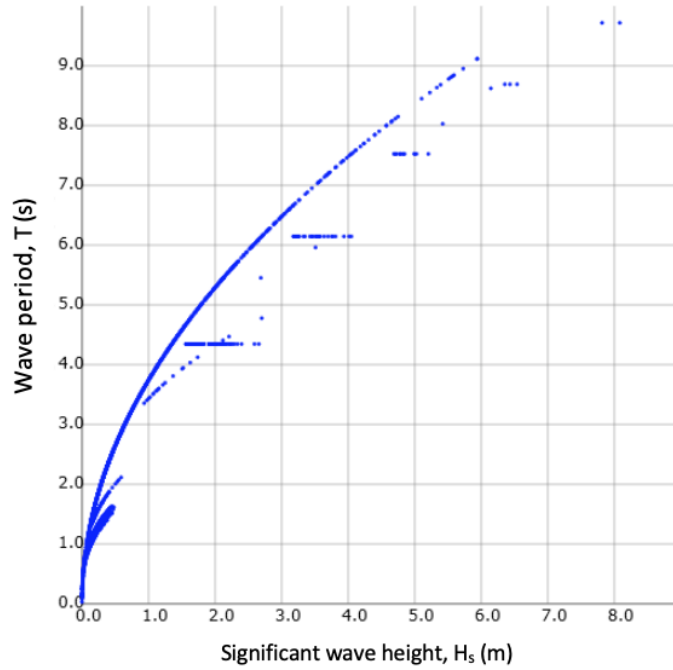


Figure (4-2-29) Wave period,  $T$ (s)-Significant wave height,  $H_s$  (m) scatter plot (HYDROTAM 3D)

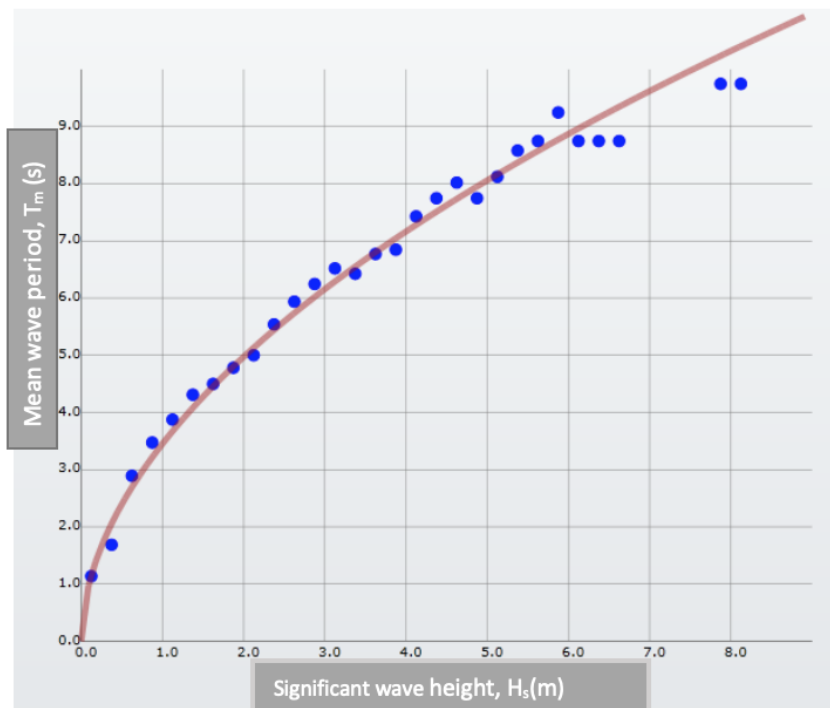


Figure 4-2-30 Mean wave period,  $T_m$ (s)-Significant wave height,  $H_s$ (m) relation plot (HYDROTAM-3D)

In Figure 4-2-31 yearly wave rose for Marmaris coastal area is given. It is seen that SSE-Se directions have the highest waves which is between 4 m to 5 m. Almost 74.6 % waves are smaller than 50 cm. It is seen from the wave rose that, Marmaris coastal area gets higher waves, but most of the year has a calm sea.

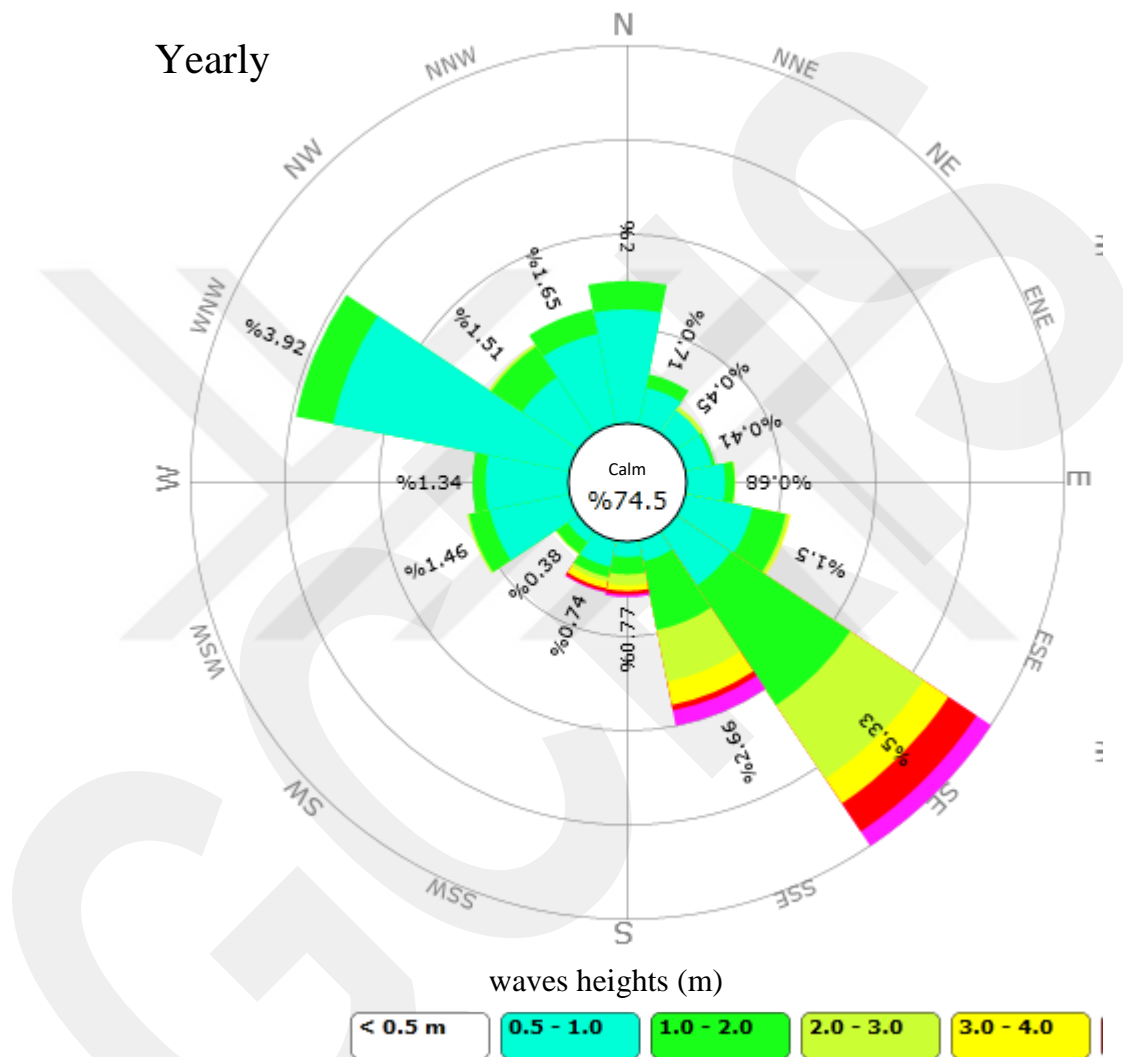


Figure (4-2-31) Yearly wave rose (HYDROTAM 3D)

In Figure 4-2-32 and Table 4-2-18, the results of extreme value statistics for Marmaris coastal area are given. The wave height,  $H_s$  value corresponding to 100 year return period is calculated as 10.42 m.

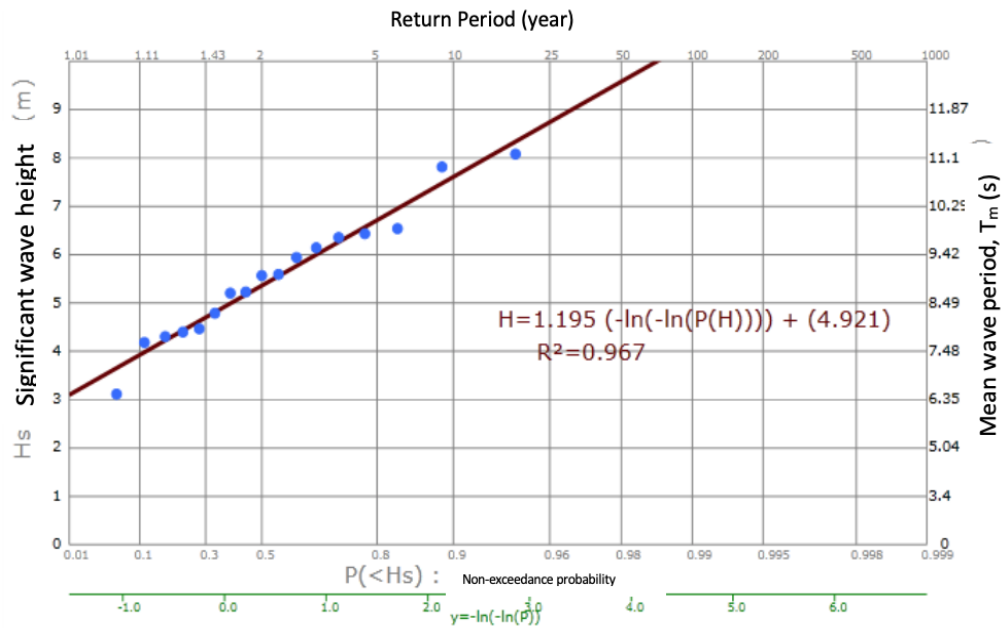


Figure (4-2-32) Extreme value statistics (Gumble distribution) with CEM Method (HYDROTAM 3D)

Table (4-2-18) The significant wave height,  $H_s$  values for extreme value statistics (HYDROTAM 3D)

Return period (yr)	$H_s$ (m)	%90 confidence(m)	$T_s$ (s)
5.0	6.713	0.143	10.043
10.0	7.609	0.202	10.786
25.0	8.742	0.287	11.673
50.0	9.582	0.353	12.299
100.0	10.416	0.420	12.897

#### 4.2.4.2 Wave Climate by WAM Numerical Model Results

In this section the results of long-term wave statistics and extreme value statistics with wave results of ECMWF (36.7N, 28.4 E) coordinate are given. The exceedance probabilities of significant wave heights and probability distributions from long term wave statistics are given in Table 4-2-19. As it's seen from Table 4-2-19 the highest waves are in SSE. In Figures 4-2-33 and 4-2-34, wave period, T(s)-Significant wave height, H<sub>s</sub> (m) scatter plot and mean wave period, T<sub>m</sub>(s)-Significant wave height, H<sub>s</sub> (m) relation plot are given respectively.

Table (4-2-19) Exceedance probability of significant wave heights and probability distributions (HYDROTAM 3D)

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	H <sub>s</sub>	R <sup>2</sup>	H <sub>s</sub> (±m) %90 confidence	T <sub>m</sub> (sn)	H <sub>s</sub> (±m) %90 confidence	T <sub>m</sub> (sn)	H <sub>s</sub> (±m) %90 confidence	T <sub>m</sub> (sn)
<b>E</b>	-0.582 - 0.140*LN(P(H <sub>s</sub> ))	0.943	0.7±0.075	4.9	0.5±0.062	4.2	0.4±0.072	3.9
<b>ESE</b>	-0.599 - 0.170*LN(P(H <sub>s</sub> ))	0.988	0.9±0.038	5.1	0.7±0.023	4.6	0.6±0.022	4.3
<b>SE</b>	-1.547 - 0.593*LN(P(H <sub>s</sub> ))	0.995	3.8±0.048	7.3	2.9±0.031	6.7	2.5±0.0236	6.4
<b>SSE</b>	-0.741 - 0.538*LN(P(H <sub>s</sub> ))	0.992	4.1±0.06	7.2	3.3±0.042	6.7	2.9±0.036	6.5
<b>S</b>	-1.262 - 0.497*LN(P(H <sub>s</sub> ))	0.992	3.3±0.055	7.3	2.5±0.036	6.7	2.1±0.031	6.3
<b>SSW</b>	-0.987 - 0.362*LN(P(H <sub>s</sub> ))	0.994	2.3±0.035	6.6	1.7±0.023	6.1	1.5±0.02	5.8

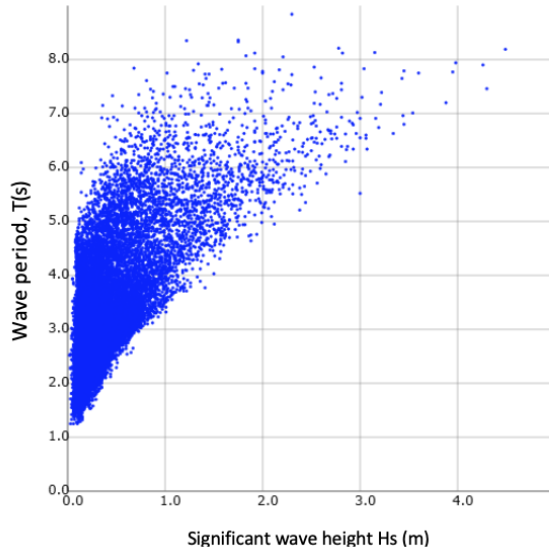


Figure (4-2-33) Wave period,  $T$ (s)-Significant wave height,  $H_s$  (m) scatter plot (HYDROTAM 3D)

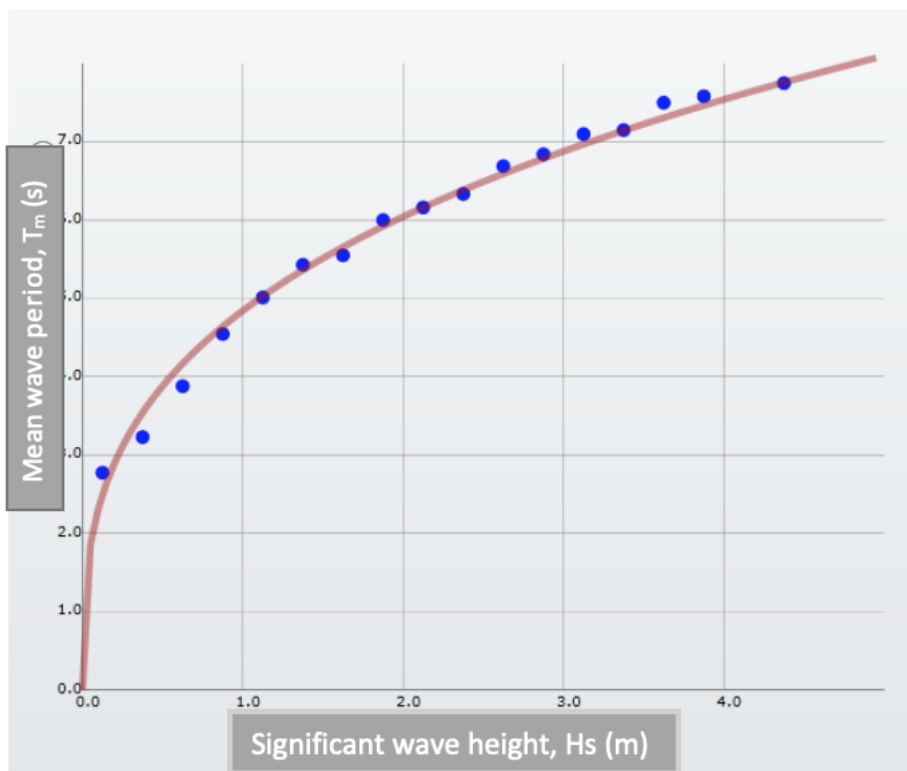


Figure (4-2-34) Mean wave period,  $T_m$ (s)-Significant wave height,  $H_s$ (m) relation plot (HYDROTAM-3D)



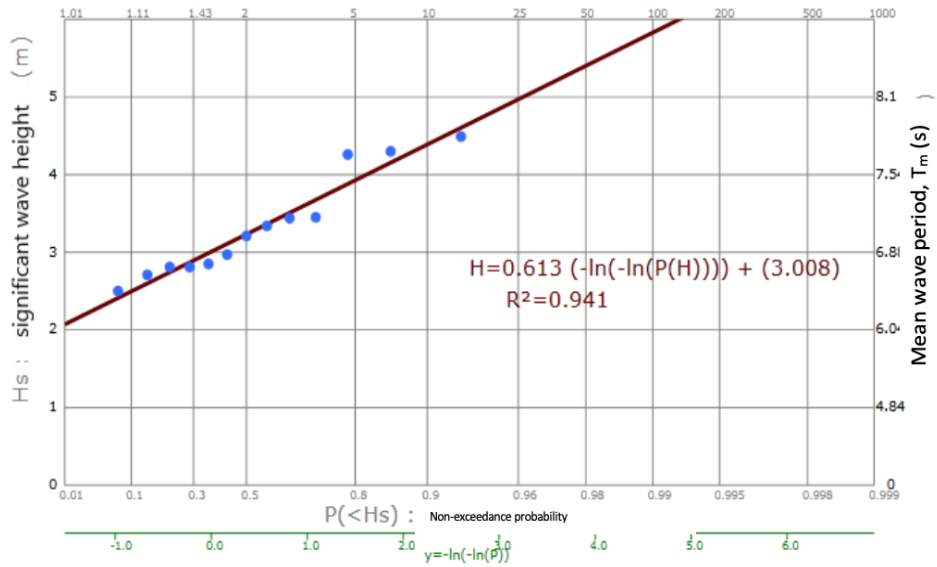


Figure (4-2-36) Extreme value statistics (Gumble distribution) with WAM numerical wave estimation results (HYDROTAM-3D)

Table (4-2-20) The significant wave height,  $H_s$  values for extreme value statistics (HYDROTAM 3D)

Return period (yr)	$H_s$ (m)	%90 confidence(m)	$T_s$ (s)
5.0	3.928	0.117	7.497
10.0	4.388	0.166	7.767
25.0	4.969	0.238	8.082
50.0	5.401	0.293	8.300
100.0	5.829	0.349	8.504

#### 4.2.5 Fethiye Coastal Area

In this section the wave climate of the Fethiye coastal area is given. In wave climate studies two approaches are used. In the first approach the wind estimates of ECMWF is used as input to CEM method, and in the second approach numerical wave estimates of ECMWF are used for wave statistics. In Figure 4-2-37 and Table 4-2-21 the fetch and Fetch distances for Fethiye coastal area are given. The longest Fetch is the W direction followed by WNW and WSW.

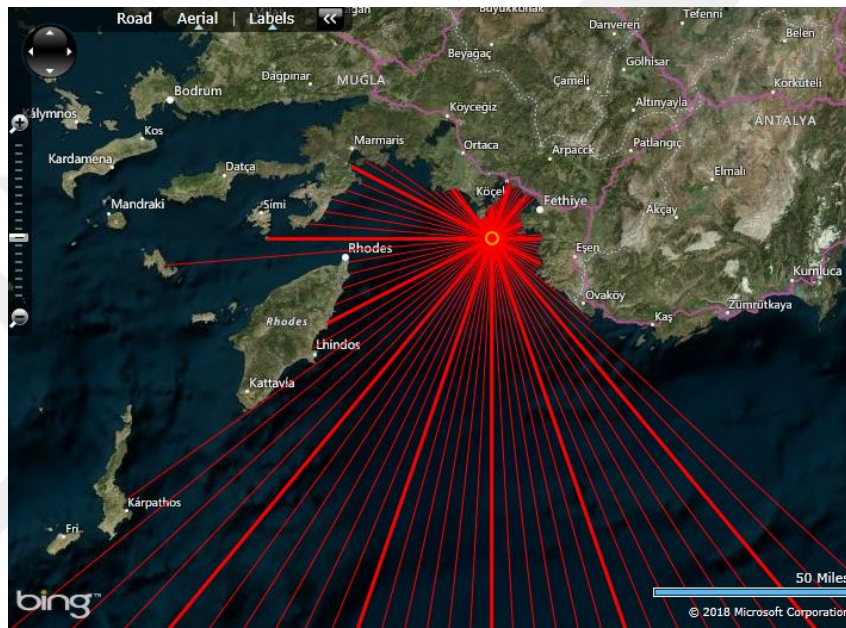


Figure (4-2-37) The fetch for Fethiye coastal area (HYDROTAM 3D)

Table (4-2-21) The directions and the fetch distances for Fethiye coastal area (HYDROTAM 3D)

Direction	Distance (km)
S	606.5
SSW	599.2
SW	653.6
WSW	172.4
W	79.7

#### 4.2.5.1 Wave Climate by CEM method:

In this section the results of long-term wave statistics and extreme value statistics with wind data from ECMWF (36.6N, 28.9E) coordinate applied through CEM method are given. The exceedance probabilities of significant wave heights and probability distributions from long term wave statistics are given in Table 4-2-22. As it's seen from Table 4-2-22 the highest waves are in S direction in accordance with fetch direction. In Figures 4-2-38 and 4-2-39, wave period, T(s)-Significant wave height, Hs (m) scatter plot and mean wave period, Tm(s)-Significant wave height, Hs (m) relation plot are given respectively.

Table (4-2-22) Exceedance probabilities of Significant wave heights and probability distributions (HYDROTAM 3D)

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	Hs	R <sup>2</sup>	Hs (±m) %90 confidence	Tm(sn)	Hs(±m) %90 confidence	Tm(sn)	Hs(±m) %90 confidence	Tm(sn)
<b>S</b>	-5.532- 1.373*LN(P(Hs))	0.979	6.5±0.201	10	4.7±0.117	8.1	3.8±0.086	7.2
<b>SSW</b>	-3.439- 0.866*LN(P(Hs))	0.947	4.4±0.241	7.8	3±0.139	6.4	2.4±0.104	5.7
<b>SW</b>	-2.594- 0.632*LN(P(Hs))	0.797	3.1±0.388	6.7	2.1±0.23	5.4	1.7±0.191	4.8
<b>WSW</b>	-1.823- 0.506*LN(P(Hs))	0.775	2.8±0.406	5.6	2±0.251	4.8	1.6±0.203	4.3
<b>W</b>	-2.208- 0.629*LN(P(Hs))	0.853	3.5±0.356	5.4	2.5±0.225	4.6	2.1±0.185	4.2

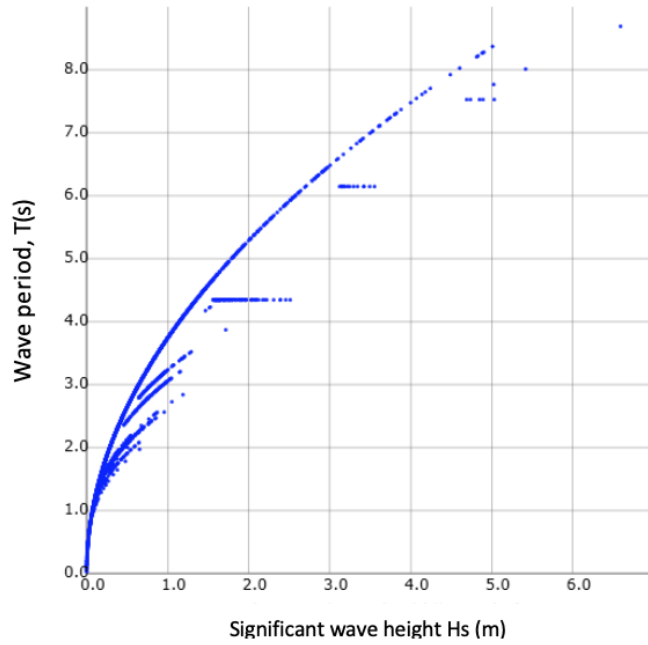


Figure (4-2-38) Wave period,  $T$ (s)-Significant wave height,  $H_s$  (m) scatter plot (HYDROTAM 3D)

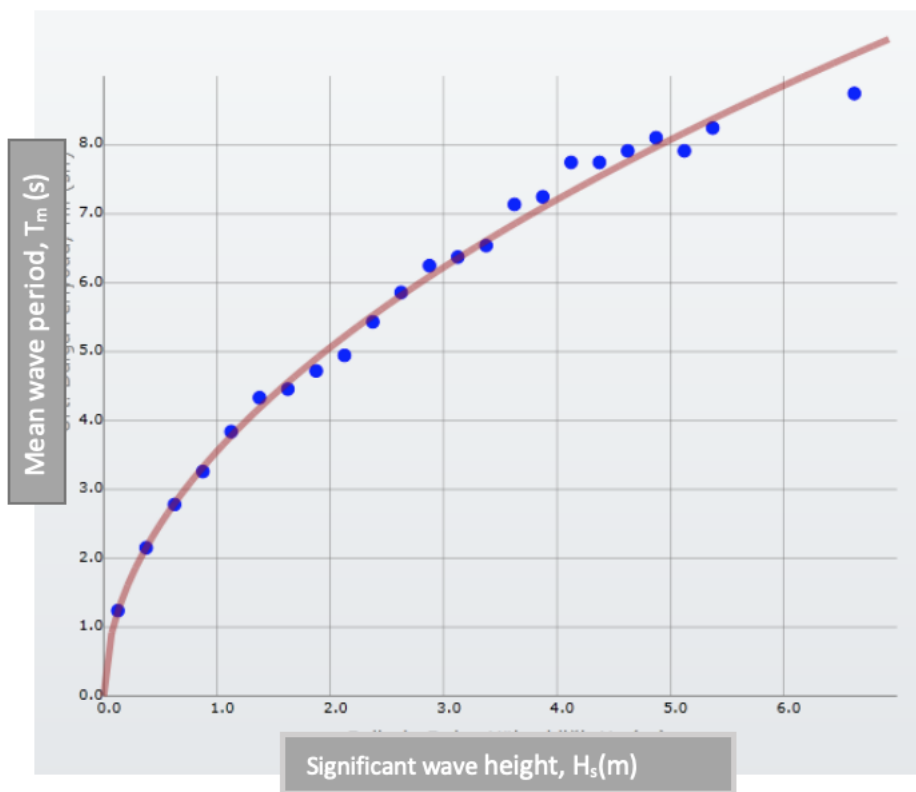


Figure (4-2-39) Mean wave period,  $T_m$ (s)-Significant wave height,  $H_s$ (m) relation plot (HYDROTAM-3D)

In Figure 4-2-40 yearly wave rose for Marmaris coastal area is given. It is seen that S to SE direction have the highest waves which is between 4 m to 5 m. Almost 67.9% waves are smaller than 50 cm.

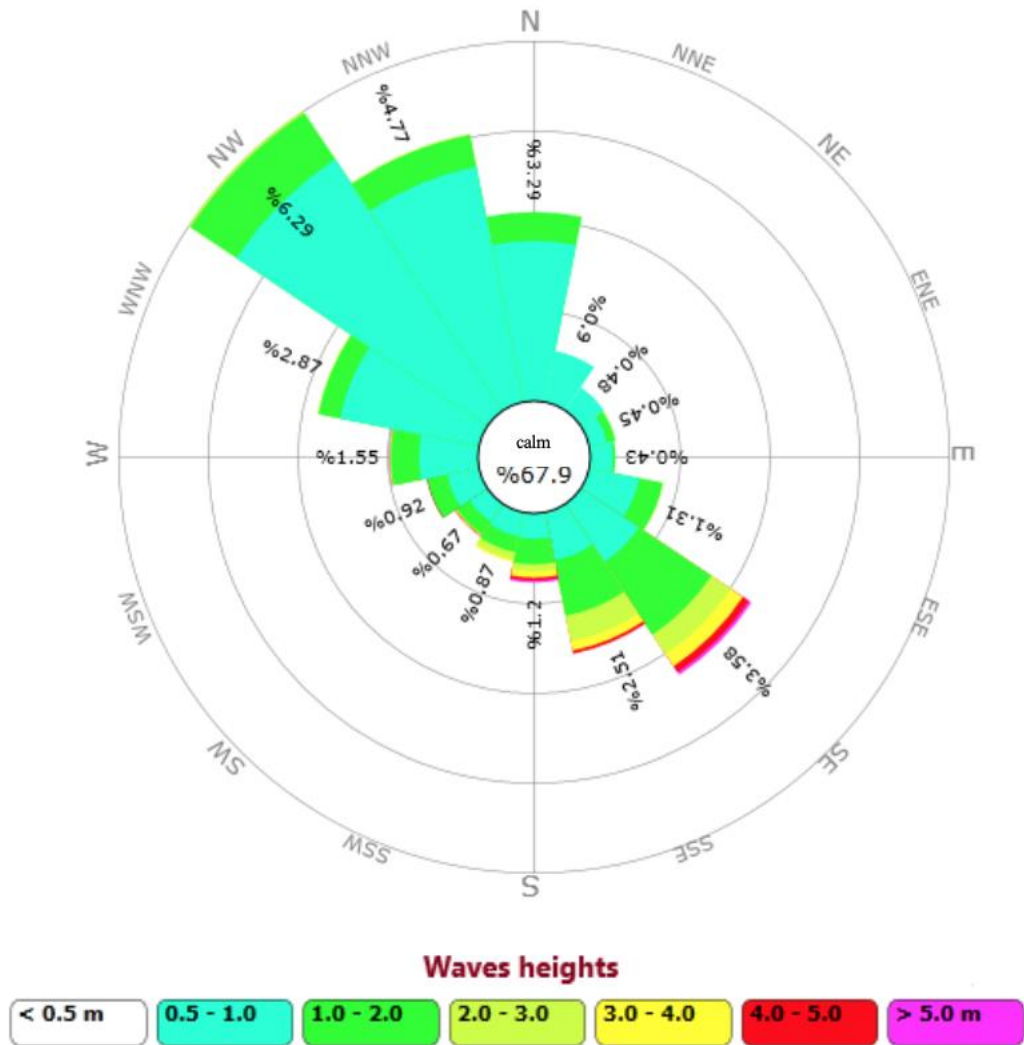


Figure (4-2-40) Yearly wave rose (HYDROTAM 3D)

In Figure 4-2-41 and Table 4-2-23, the results of extreme value statistics for Fethiye coastal area are given. The wave height,  $H_s$  value corresponding to 100 year return period is calculated as 7.9 m.

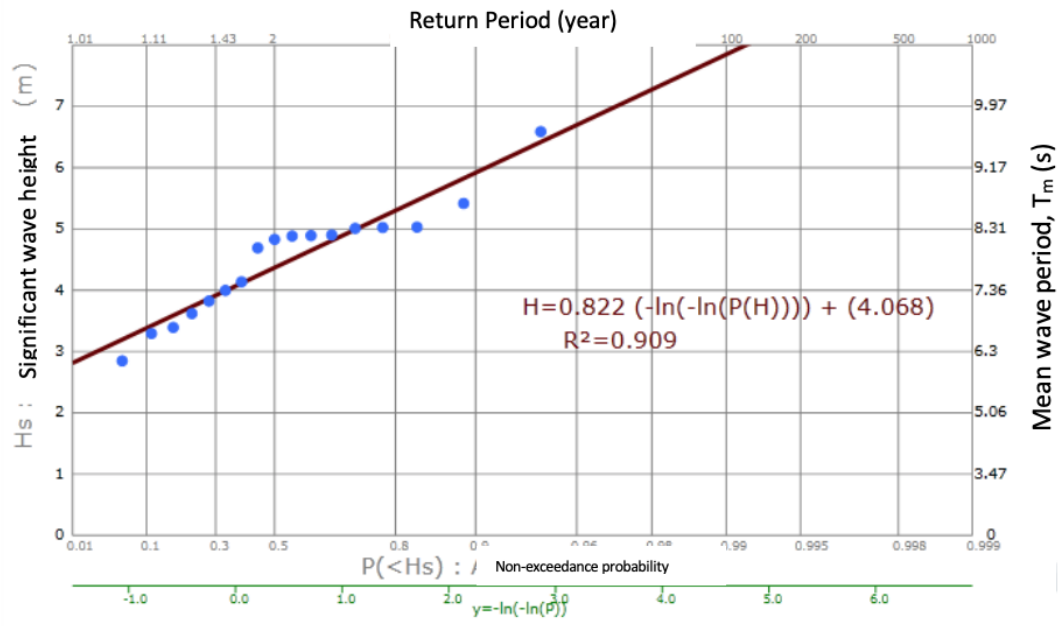


Figure (4-2-41) Extreme value statistics (Gumble distribution) with CEM Method (HYDROTAM 3D)

Table (4-2-23) The significant wave height,  $H_s$  values for extreme value statistics (HYDROTAM 3D)

Return period (yr)	$H_s$ (m)	%90 confidence(m)	$T_s$ (s)
5.0	5.301	0.168	8.573
10.0	5.917	0.237	9.100
25.0	6.697	0.338	9.731
50.0	7.275	0.416	10.177
100.0	7.849	0.495	10.604

#### 4.2.5.2 Wave Climate by WAM Numerical Model Results

In this section the results of long-term wave statistics and extreme value statistics with wave results of ECMWF (36.6N, 28.9E) coordinate are given. The exceedance probabilities of significant wave heights and probability distributions from long term wave statistics are given in Table 4-2-24. As it's seen from Table 4-2-24 the highest waves are in SSW-SSE direction. In Figures 4-2-42 and 4-2-43, wave period, T(s)-Significant wave height, H<sub>s</sub> (m) scatter plot and mean wave period, T<sub>m</sub>(s)-Significant wave height, H<sub>s</sub> (m) relation plot are given respectively.

Table (4-2-24) Exceedance probability of significant wave heights and probability distributions (HYDROTAM 3D)

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	H <sub>s</sub>	R <sup>2</sup>	H <sub>s</sub> (±m) %90 confide	T <sub>m</sub> (sn)	H <sub>s</sub> (±m) ) %90 confide	T <sub>m</sub> (sn)	H <sub>s</sub> (±m) ) %90 confide	T <sub>m</sub> (sn)
SE	-1.078- 0.386*LN(P(H <sub>s</sub> ))	0.969	2.4±0.089	6.5	1.8±0.056	6.1	1.5±0.048	5.8
SSE	-0.794 - 0.435*LN(P(H <sub>s</sub> ))	0.993	3.2±0.047	6.8	2.5±0.032	6.4	2.2±0.028	6.2
S	-0.967- 0.443*LN(P(H <sub>s</sub> ))	0.993	3.1±0.045	7.1	2.3±0.031	6.6	2±0.027	6.4
SSW	-1.257- 0.564*LN(P(H <sub>s</sub> ))	0.995	3.9±0.044	7.9	3±0.029	7.3	2.6±0.025	7
SW	-0.760 - 0.380*LN(P(H <sub>s</sub> ))	0.995	2.7±0.038	7.6	2.1±0.025	7	1.8±0.021	6.7
WSW	-0.647 - 0.316*LN(P(H <sub>s</sub> ))	0.9	2.2±0.168	7.2	1.7±0.123	6.6	1.5±0.112	6.3
W	-0.140 - 0.207*LN(P(H <sub>s</sub> ))	0.992	1.7±0.04	6.5	1.4±0.029	6.1	1.3±0.025	5.9

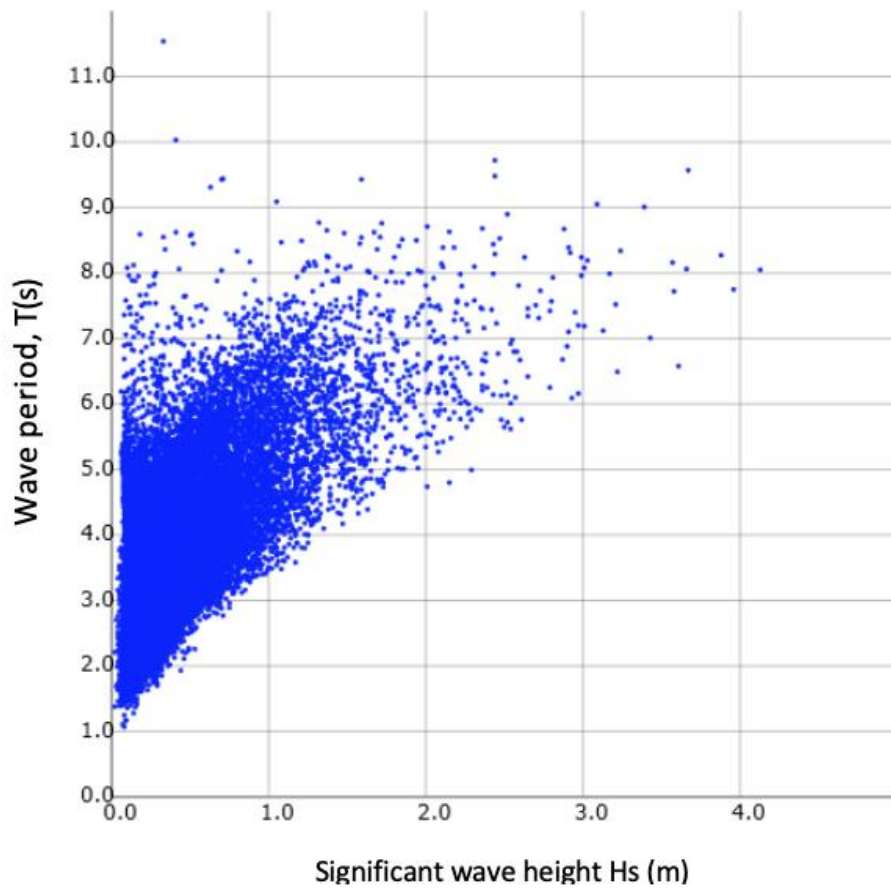


Figure (4-2-42) Wave period,  $T$ (s)-Significant wave height,  $H_s$  (m) scatter plot  
(HYDROTAM 3D)

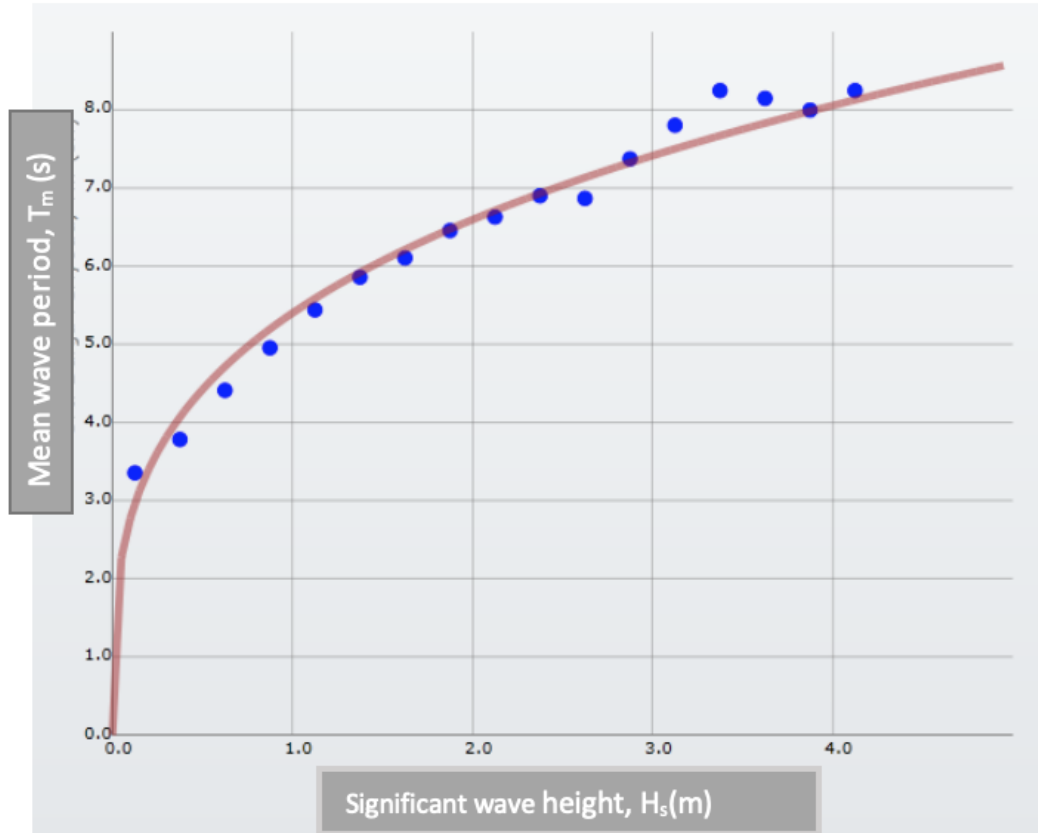


Figure (4-2-43) Mean wave period,  $T_m$ (s)-Significant wave height,  $H_s$ (m) relation plot (HYDROTAM-3D)

In Figure 4-2-44 yearly wave rose for Fethiye coastal area is given. It is seen that SSE to W direction have the highest waves which is between 3 m to 4 m. Almost 72.3 % waves are smaller than 50 cm.

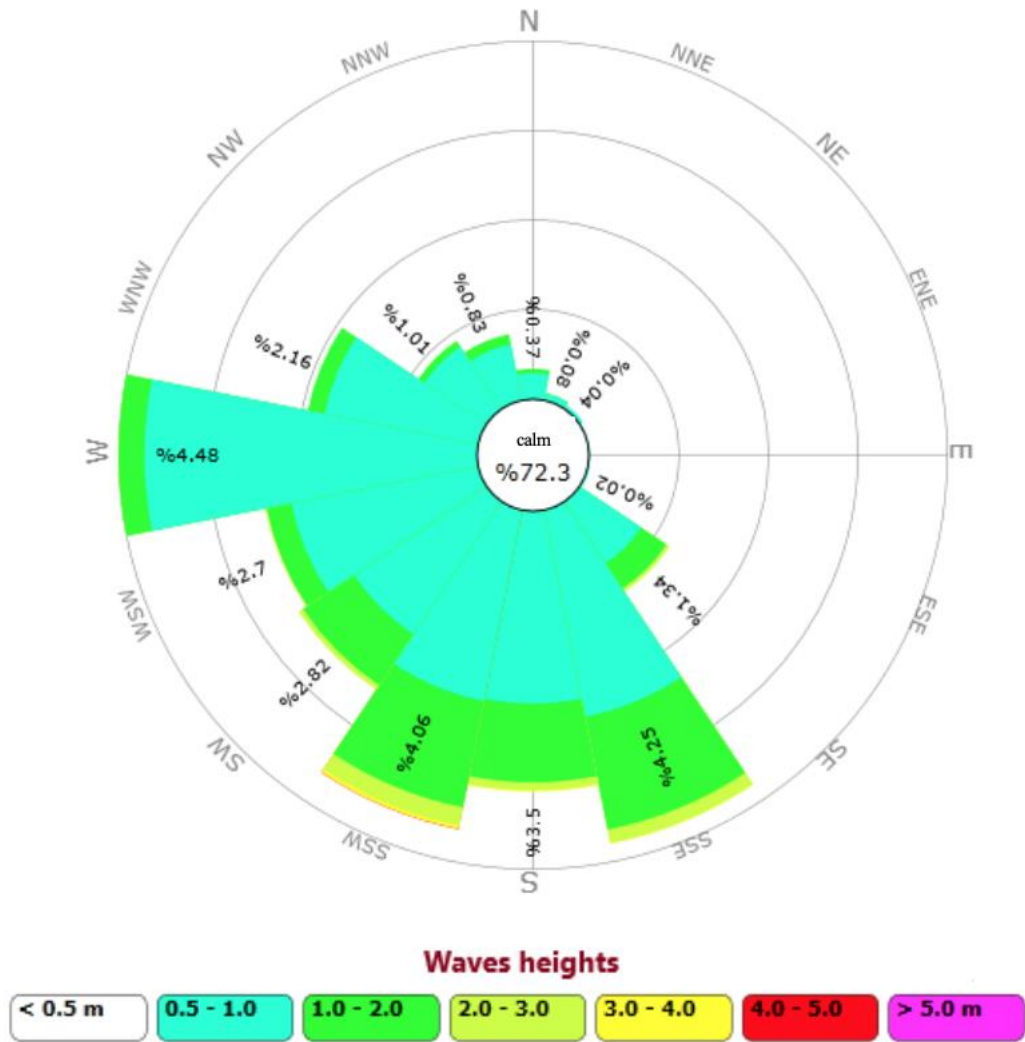


Figure (4-2-44) Yearly wave rose (HYDROTAM 3D)

In Figure 4-2-45 and Table 4-2-25, the results of extreme value statistics for Fethiye coastal area are given. The wave height,  $H_s$  value corresponding to 100 year return period is calculated as 5 m.

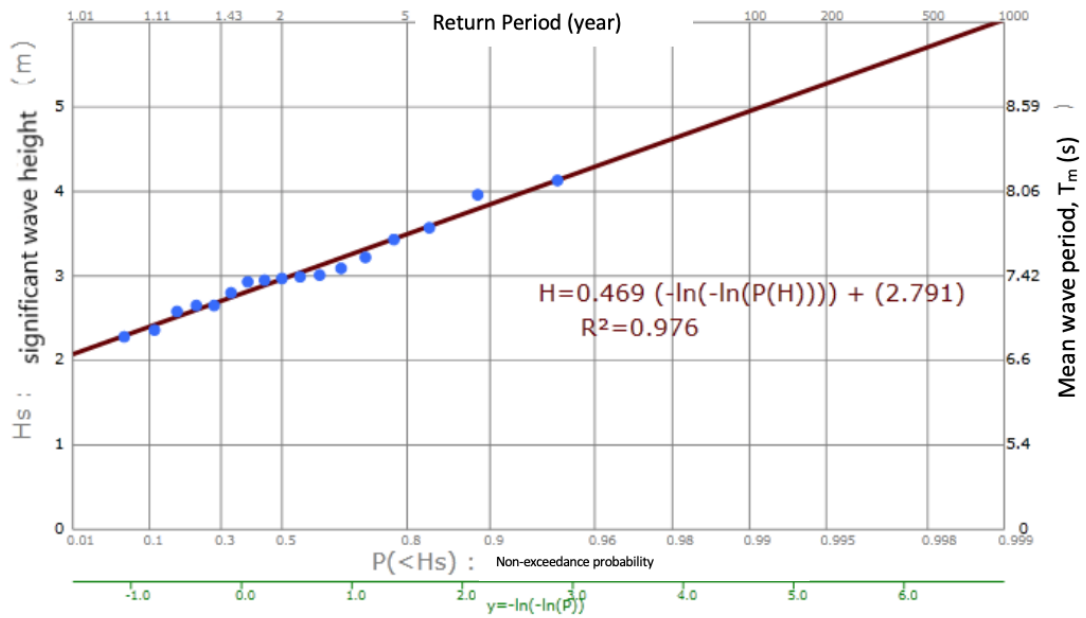


Figure (4-2-45) Extreme value statistics (Gumble distribution) with WAM numerical wave estimation results (HYDROTAM-3D)

Table (4-2-25) The significant wave height,  $H_s$  values for extreme value statistics (HYDROTAM 3D)

Return period (yr)	$H_s$ (m)	%90 confidence(m)	$T_s$ (s)
5.0	3.494	0.047	7.750
10.0	3.846	0.067	7.968
25.0	4.291	0.095	8.223
50.0	4.621	0.117	8.401
100.0	4.949	0.140	8.569

#### 4.2.6 Datça Coastal Area

In this section the wave climate of the Datça coastal area is given. In wave climate studies two approaches are used. In the first approach the wind estimates of ECMWF is used as input to CEM method, and in the second approach numerical wave estimates of ECMWF are used for wave statistics. In Figure 4-2-46 and Table 4-2-26 the fetch and Fetch distances for Datça are given. The longest Fetch is the W direction followed by SW and WSW.

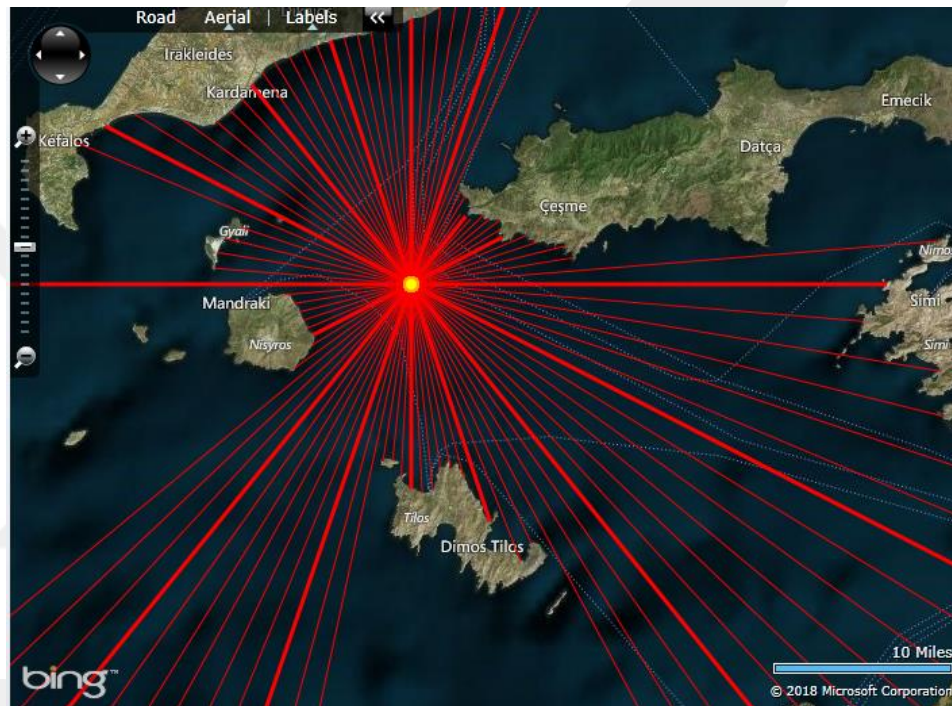


Figure (4-2-46) The fetch for Datça coastal area (HYDROTAM 3D)

Table (4-2-26) The directions and the fetch distances for Datça coastal area (HYDROTAM 3D)

direction	Distance (km)
E	43.3
ESE	66.7
SE	54.2
SSE	22.9
S	16.51
SSW	369.5
SW	251.6
WSW	46.9
W	35.9

#### 4.2.6.1 Wave Climate by CEM method:

In this section the results of long-term wave statistics and extreme value statistics with wind data from ECMWF (36.7N, 27.3E) coordinate applied through CEM method are given. The exceedance probabilities of significant wave heights and probability distributions from long term wave statistics are given in Table 4-2-7. As it's seen from Table 4-2-2 the highest waves are in WSW and SW directions in accordance with fetch direction. In Figures 4-2-47 and 4-2-48, wave period, T(s)-Significant wave height, H<sub>s</sub> (m) scatter plot and mean wave period, T<sub>m</sub>(s)-Significant wave height, H<sub>s</sub> (m) relation plot are given respectively.

Table (4-2-27) Exceedance probabilities of significant wave heights and probability distributions (HYDROTAM 3D)

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	H <sub>s</sub>	R <sup>2</sup>	H <sub>s</sub> (±m) %90 confidence	T <sub>m</sub> (sn)	H <sub>s</sub> (±m) %90 confidence	T <sub>m</sub> (sn)	H <sub>s</sub> (±m) %90 confidence	T <sub>m</sub> (sn)
<b>E</b>	-0.920 - 0.290*LN(P(H <sub>s</sub> ))	0.921	1.7±0.149	3.6	1.2±0.091	3.2	1±0.075	3
<b>ESE</b>	-0.995 - 0.392*LN(P(H <sub>s</sub> ))	0.875	2.6±0.204	4.6	1.9±0.128	4.1	1.7±0.103	3.8
<b>SE</b>	-0.791 - 0.470*LN(P(H <sub>s</sub> ))	0.799	3.5±0.413	4.9	2.7±0.285	4.5	2.4±0.235	4.2
<b>SSE</b>	-2.134 - 0.791*LN(P(H <sub>s</sub> ))	0.947	4.8±0.274	4.5	3.8±0.183	4.1	3.2±0.148	3.9
<b>S</b>	-3.568 - 1.039*LN(P(H <sub>s</sub> ))	0.963	5.1±0.24	4.8	4.2±0.148	4.2	3.5±0.114	3.9
<b>SSW</b>	-3.734 - 1.092*LN(P(H <sub>s</sub> ))	0.936	5.1±0.296	8.7	4.4±0.179	7.4	3.7±0.135	6.7
<b>SW</b>	-2.851 - 0.895*LN(P(H <sub>s</sub> ))	0.992	5.2±0.096	7.9	3.8±0.6	6.7	3.2±0.046	6.2
<b>WSW</b>	-2.846 - 0.919*LN(P(H <sub>s</sub> ))	0.983	5.2±0.143	5.6	4±0.09	5	3.4±0.07	4.7
<b>W</b>	-1.834 - 0.639*LN(P(H <sub>s</sub> ))	0.937	4±0.289	4.7	2.9±0.187	4.2	2.5±0.147	3.9

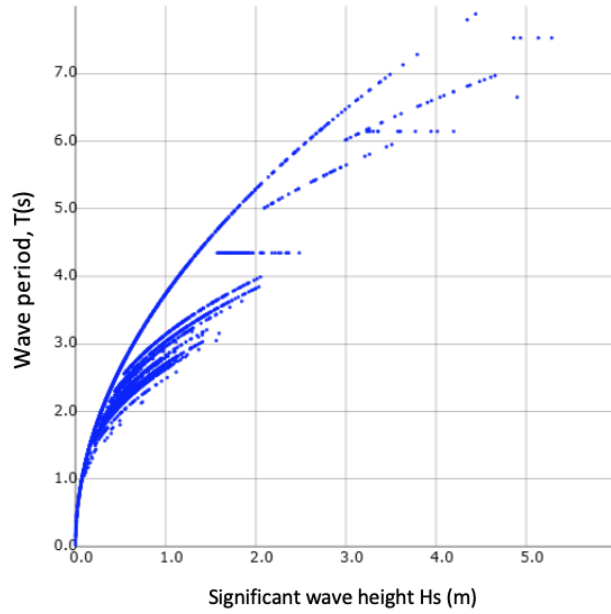


Figure (4-2-47) Wave period,  $T$ (s)-Significant wave height,  $H_s$  (m) scatter plot (HYDROTAM 3D)

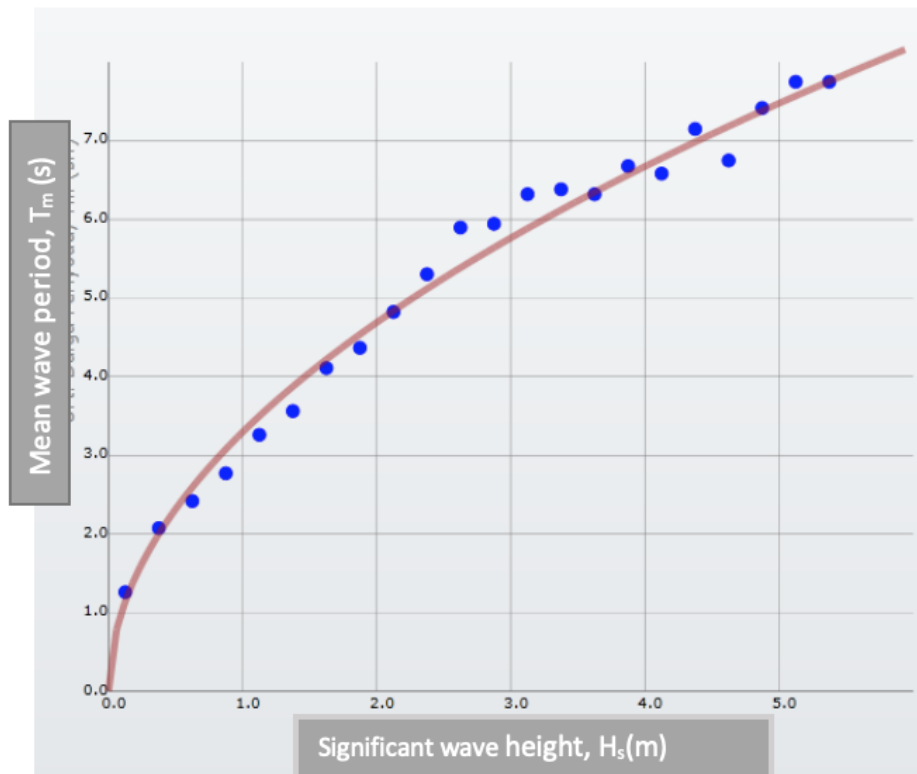


Figure (4-2-48) Mean wave period,  $T_m$ (s)-Significant wave height,  $H_s$ (m) relation plot (HYDROTAM-3D)

In Figure 4-2-49 yearly wave rose for Datça coastal area is given. It is seen that SSE to WSW direction have the highest waves which is between 4 m to 5 m. Almost 26.7 % waves are smaller than 50 cm.

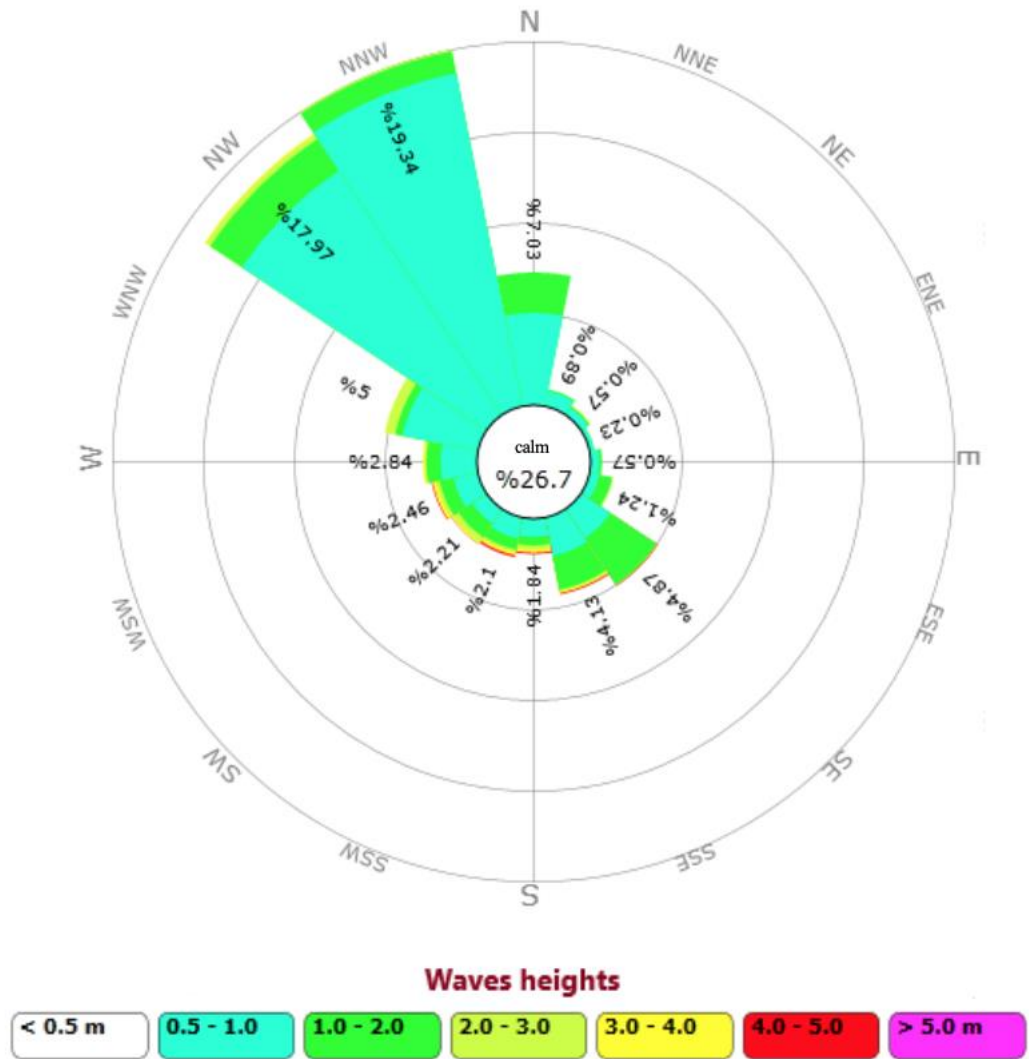


Figure (4-2-49) Yearly wave rose (HYDROTAM 3D)

In Figure 4-2-50 and Table 4-2-28, the results of extreme value statistics for Datça coastal area are given. The wave height,  $H_s$  value corresponding to 100 year return period is calculated as 6.7 m.

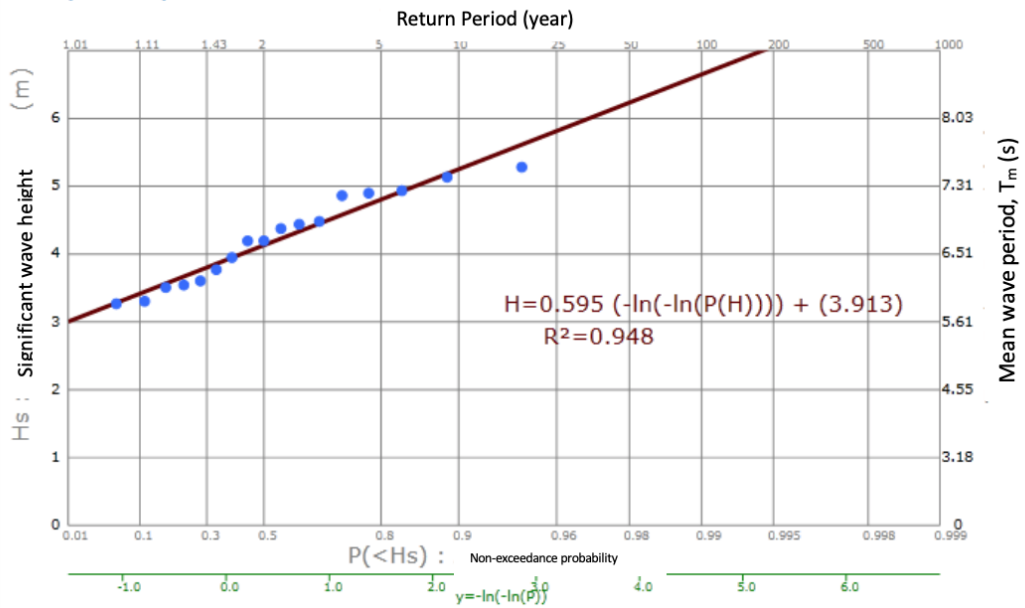


Figure (4-2-50) Extreme value statistics (Gumbel distribution) with CEM Method (HYDROTAM 3D)

Table (4-2-28) The significant wave height,  $H_s$  values for extreme value statistics (HYDROTAM 3D)

Return period (yr)	$H_s$ (m)	%90 confidence(m)	$T_s$ (s)
5.0	4.805	0.090	7.162
10.0	5.251	0.127	7.499
25.0	5.815	0.181	7.905
50.0	6.233	0.223	8.195
100.0	6.648	0.265	8.473

#### 4.2.6.2 Wave Climate by WAM Numerical Model Results

In this section the results of long-term wave statistics and extreme value statistics with wave results of ECMWF (36.7N, 27.3E) coordinate are given. The exceedance probabilities of significant wave heights and probability distributions from long term wave statistics are given in Table 4-2-29. As it's seen from Table 4-2-29, the highest waves are in S-SS directions. In Figures 4-2-51 and 4-2-52, wave period, T(s)-Significant wave height, H<sub>s</sub> (m) scatter plot and mean wave period, T<sub>m</sub>(s)-Significant wave height, H<sub>s</sub> (m) relation plot are given respectively.

Table (4-2-29) Exceedance probability of significant wave heights and probability distributions (HYDROTAM 3D)

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	H <sub>s</sub>	R <sup>2</sup>	H <sub>s</sub> (±m) %90 confidence	T <sub>m</sub> (sn)	H <sub>s</sub> (±m) %90 confidence	T <sub>m</sub> (sn)	H <sub>s</sub> (±m) %90 confidence	T <sub>m</sub> (sn)
<b>E</b>	-2.246- 0.389*LN(P(H <sub>s</sub> ))	0.913	1.3±0.124	4.6	0.7±0.1	4.2	0.4±0.127	3.9
<b>ESE</b>	-1.635- 0.408*LN(P(H <sub>s</sub> ))	0.993	2.1±0.043	5.1	1.4±0.025	4.7	1.1±0.022	4.5
<b>SE</b>	-1.292 - 0.530*LN(P(H <sub>s</sub> ))	0.978	3.5±0.096	6.1	2.7±0.063	5.7	2.3±0.052	5.5
<b>SSE</b>	-0.632 - 0.436*LN(P(H <sub>s</sub> ))	0.948	3.3±0.143	5.9	2.6±0.098	5.6	2.3±0.082	5.5
<b>S</b>	-1.079 - 0.486*LN(P(H <sub>s</sub> ))	0.994	3.3±0.047	5.8	2.5±0.031	5.5	2.2±0.026	5.4
<b>SSW</b>	-1.230 - 0.464*LN(P(H <sub>s</sub> ))	0.976	3±0.085	5.9	2.2±0.055	5.6	1.9±0.045	5.5
<b>SW</b>	-1.095 - 0.398*LN(P(H <sub>s</sub> ))	0.995	2.5±0.038	5.9	1.9±0.025	5.6	1.6±0.021	5.4
<b>WSW</b>	-0.646 - 0.396*LN(P(H <sub>s</sub> ))	0.994	3±0.043	6	2.3±0.03	5.7	2±0.025	5.6
<b>W</b>	H <sub>s</sub> =-1.150 - 0.411*LN(P(H <sub>s</sub> ))	0.987	2.6±0.058	6.1	1.9±0.038	5.8	1.6±0.033	5.6

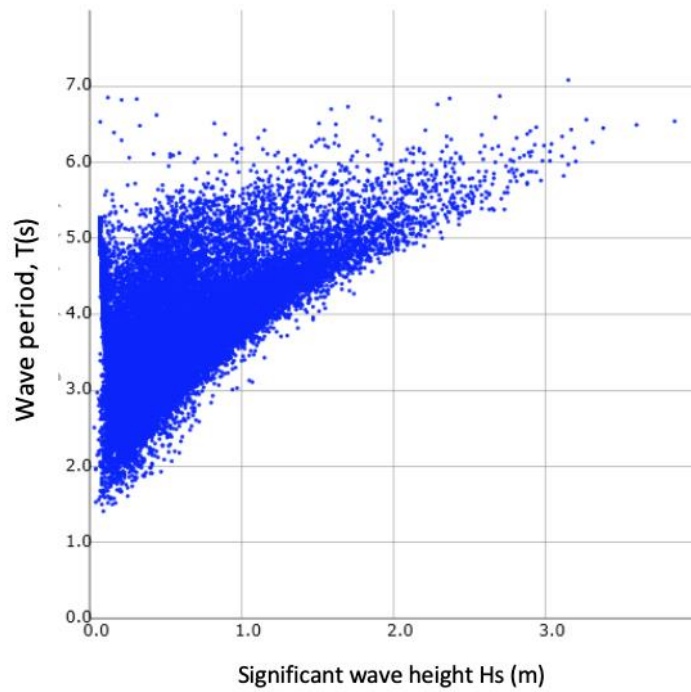


Figure (4-2-51) Wave period,  $T$ (s)-Significant wave height,  $H_s$  (m) scatter plot (HYDROTAM 3D)

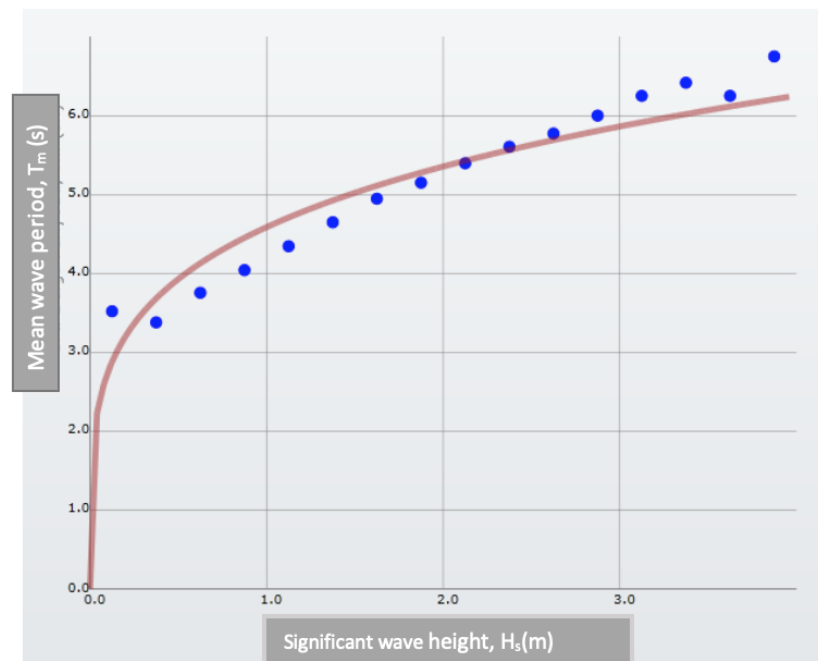


Figure (4-2-52) Mean wave period,  $T_m$ (s)-Significant wave height,  $H_s$ (m) relation plot (HYDROTAM-3D)



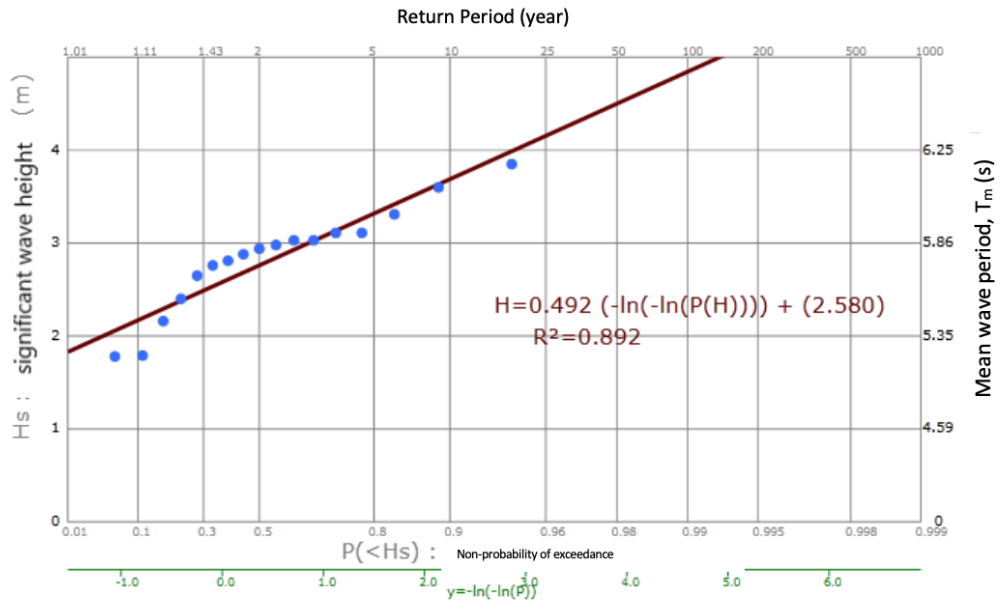


Figure (4-2-54) Extreme value statistics (Gumble distribution) with WAM numerical wave estimation results (HYDROTAM-3D)

Table (4-2-30) The significant wave height,  $H_s$  values for extreme value statistics (HYDROTAM 3D)

Return period (yr)	$H_s$ (m)	%90 confidence(m)	$T_s$ (s)
5.0	3.318	0.111	5.995
10.0	3.687	0.157	6.138
25.0	4.154	0.223	6.304
50.0	4.500	0.275	6.418
100.0	4.844	0.327	6.524

### **4.3 Comparison of WAM numerical and CEM method**

In this section, the significant wave height values from the long term statistics with a probability of 1 hr exceedance are used for the comparison of WAM numerical model and CEM empirical model. For the coastal areas presented in this chapter, two points are studied. One point offshore and one point near the shore are selected. For each point, the closest ECMWF coordinate wind predictions and wave estimates are used in the analysis. In the comparison, the aim was to form an envelope where the limitations were either Cem empirical wave results or WAM numerical model wave results, depending on the coastal area studied. As the wave estimates of WAM can not be altered, the aim was to change the packaging parameters of CEM method, given in Equations 2-1 and 2-2 and to see the effect of packaging parameters. The different packaging parameters (wind speed tolerance, wind direction tolerance, maximum speed and maximum fetch distance) for different cases are given in the Appendix. The case which gives the closest value and the case (Default) which gives the highest values and already presented in the sections above, are presented. In default case the fetch distance is maximized and wind speed is taken as the average of the mean wind speed and maximum wind speed. This approach was based on the knowledge that, long fetch distances give high wave height values. Additionally, wind speed values which are between the mean and maximum value is used. The purpose was not to over-maximize the wave height values from Cem method, as in CEM method it is assumed that the wind speed is constant along the fetch distance.

#### **4.3.1 Kuşadası Coastal Area**

In this section, the deep-water significant wave height values, ( $H_s$ ) of Kuşadası coastal area are compared and discussed and (1hr) wave height values of ECMWF numerical WAM model are compared with the wave estimates of CEM empirical method. Two points are selected for the comparison. One point is a nearshore point and the other point is offshore point as given in figure (4-3-1).



Figure (4-3-1) show the nearshore and offshore (HYDROTAM 3D)

#### 4.3.1.1 Kuşadası - Nearshore (37.9N, 27.1E)

The comparison of WAM model and CEM method wave estimates are given in Figure (4-3-1-1). It is seen that CEM method wave estimates are 1.5 times higher than WAM model wave estimates if the maximum fetch and maximum wind speed are used in CEM method. If average fetch and average wind speed are used ( shown as CEM minimum in figure) the WAM model and CEM empirical model wave estimates are almost in the same order on the average CEM method assuming a constant wind speed over the fetch . This assumption becomes unreasonable for long fetches, as it is not very likely to have a constant speed in the full duration. This result in overestimated wave heights. And the other hand WAM model tend to give lower wave heights when close to the shore .The reason is the resolution of WAM model is not sufficient to give accurate values for the wave height when close to shore.

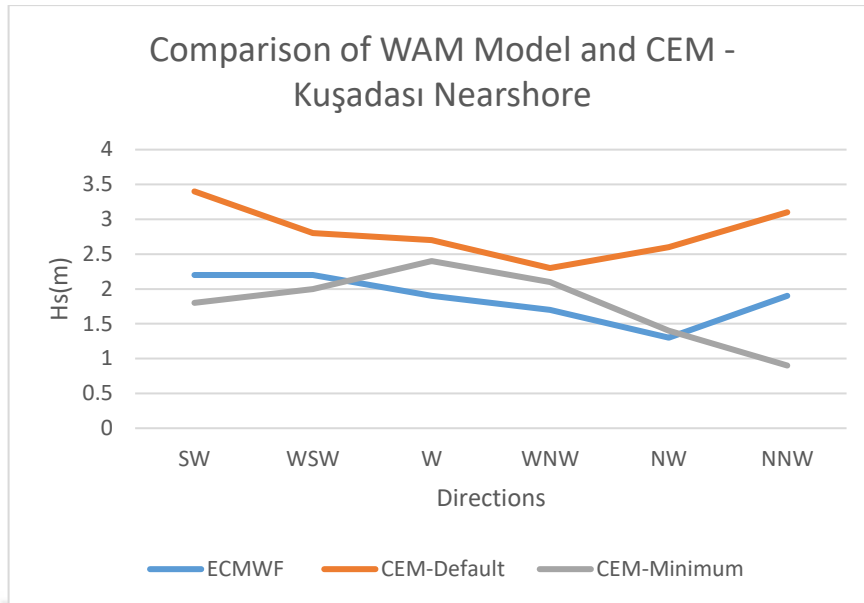


Figure (4-3-1-1) Comparison of WAM model and CEM Kuşadası Nearshore

#### 4.3.1.2 Kuşadası - Offshore (37.9N, 26.7E)

The comparison of WAM model and CEM method wave estimates are given in figure (4-3-1-2) it is seen that CEM method wave estimates are equal (0.7 WAM model) wave estimates if the maximum fetch and maximum wind speed are used in CEM method. if average fetch and average wind speed are used ( shown as CEM minimum in figure) the CEM method are equal (0.4 WAM model ), assuming a constant wind speed over the fetch

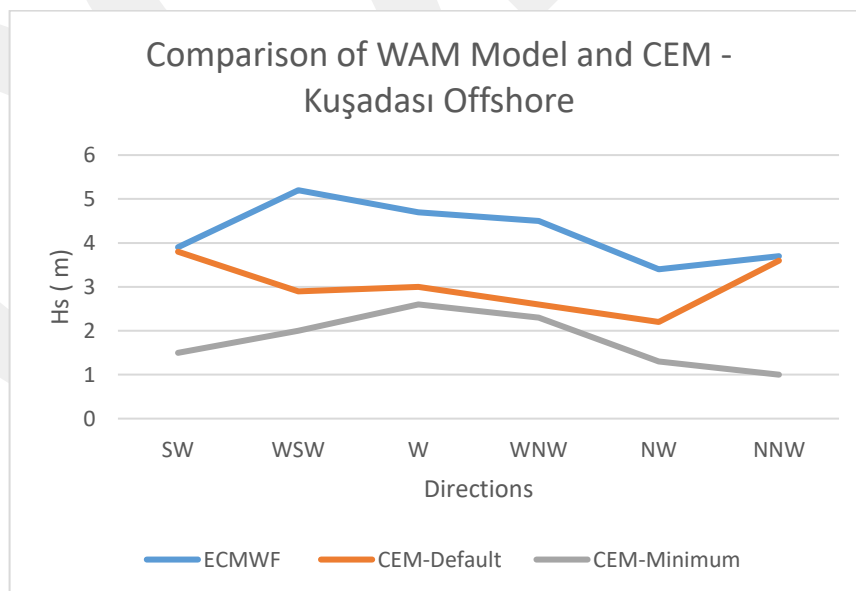


Figure (4-3-1-2) Comparison of WAM model and CEM Kuşadası-Offshore

### 4.3.2 Yalikavak Coastal Area :

In this section, the deep-water significant wave height values, ( $H_s$ ) of Yalikavak coastal area are compared and discussed and (1hr) wave height values of ECMWF numerical WAM model are compared with the wave estimates of CEM empirical method. Two points are selected for the comparison. One point is a nearshore point and the other point is offshore point as given in figure (4-3-2).



Figure (4-3-2) show the nearshore and offshore (HYDROTAM 3D)

#### 4.3.2.1 YALIKAVAK - Nearshore (37.2N, 27.3E)

The comparison of WAM model and CEM method wave estimates are given in figure (4-3-2-1) it is seen that CEM method wave estimates are 1.2 times higher than WAM model wave estimates if the maximum fetch and maximum wind speed are used in CEM method. if average fetch and average wind speed are used ( shown as CEM minimum in figure) the CEM method wave estimates is equal 0.85 WAM model wave estimates , assuming a constant wind speed over the fetch . This assumption becomes unreasonable for long fetches, as it is not very likely to have a constant speed in the full duration. This result in overestimated wave heights. And the other hand WAM model tend to give lower wave heights when close to the shore .the reason is the

resolution of WAM model is not sufficient to give inaccurate values for the wave height when close to shore.

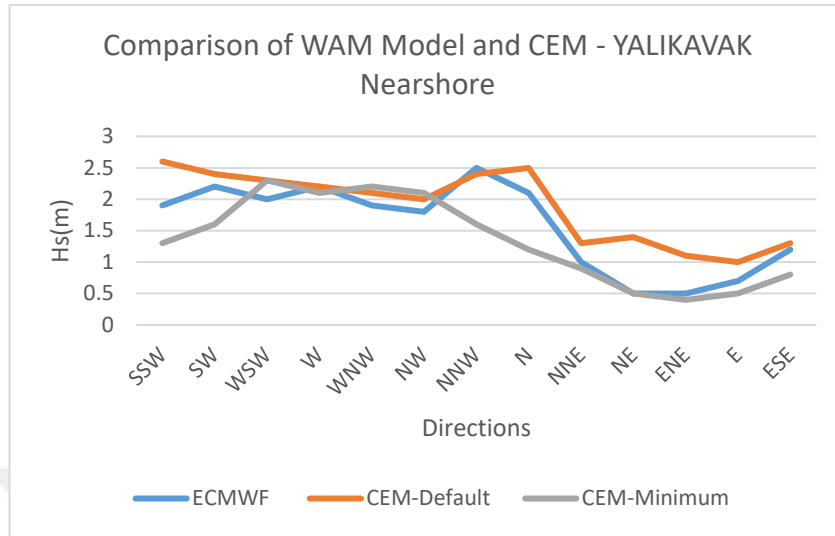


Figure (4-3-2-1) Comparison of WAM model and CEM Yalıkavak-Nearshore

#### 4.3.2.2 YALIKAVAK- Offshore (37.4N, 27E)

The comparison of WAM model and CEM method wave estimates are given in and figure (4-3-2-2) it is seen that CEM method wave estimates are equal WAM model wave estimates if the maximum fetch and maximum wind speed are used in CEM method. If average fetch and average wind speed are used (shown as CEM minimum in figure) the CEM method are equal (0.75 WAM model), assuming a constant wind speed over the fetch.

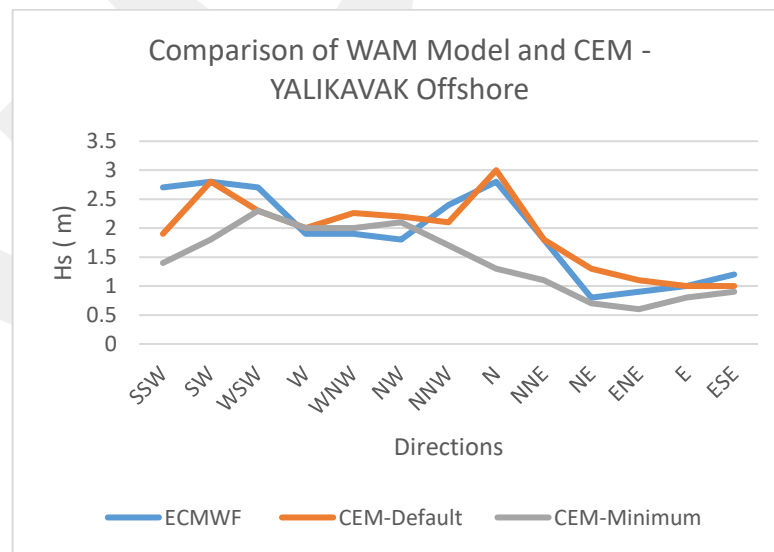


Figure (4-3-2-2) Comparison of WAM model and CEM Yalıkavak Off-shore.

### 4.3.3 Turgutreis Coastal Area:

In this section, the deep-water significant wave height values, ( $H_s$ ) of Turgutreis coastal area are compared and discussed and (1hr) wave height values of ECMWF numerical WAM model are compared with the wave estimates of CEM empirical method. Two points are selected for the comparison. One point is a nearshore point and the other point is offshore point as given in figure (4-3-3).



Figure (4-3-3) show the nearshore and offshore (HYDROTAM 3D)

#### 4.3.3.1 TURGUTREIS Nearshore (37N, 27.2E)

The comparison of WAM model and CEM method wave estimates are given in figure (4-3-3-1) it is seen that CEM method wave estimates are equal WAM model wave estimates if the maximum fetch and maximum wind speed are used in CEM method. if average fetch and average wind speed are used ( shown as CEM minimum in figure) CEM method is equal 0.7 WAM model wave estimates , assuming a constant wind speed over the fetch .

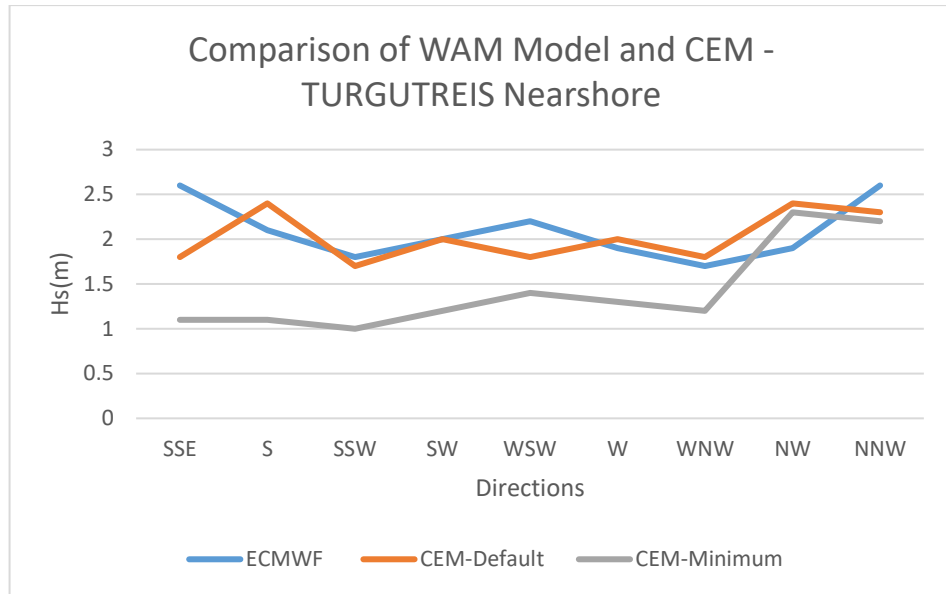


Figure (4-3-3-1) Comparison of WAM model and CEM Turgutreis-Nearshore

#### 4.3.3.2 TURGUTREIS - Offshore (36.8N, 26.9E)

The comparison of WAM model and CEM method wave estimates are given in figure (4-3-1-2) it is seen that CEM method wave estimates are equal (0.62 WAM model) wave estimates if the maximum fetch and maximum wind speed are used in CEM method. if average fetch and average wind speed are used ( shown as CEM minimum in figure) the CEM method are equal (0.43 WAM model ), assuming a constant wind speed over the fetch .

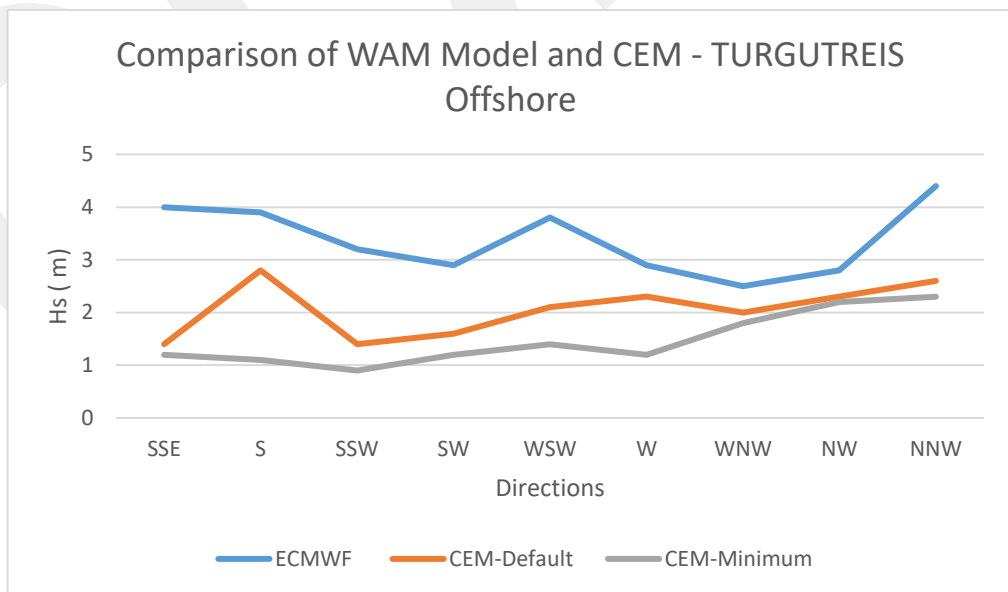


Figure (4-3-3-2) Comparison of WAM model and CEM Turgutreis-Offshore

#### 4.3.4 Marmaris Coastal Area:

In this section, the deep-water significant wave height values, ( $H_s$ ) of Marmaris coastal area are compared and discussed and (1hr) wave height values of ECMWF numerical WAM model are compared with the wave estimates of CEM empirical method. Two points are selected for the comparison. One point is a nearshore point and the other point is offshore point as given in figure (4-3-4).

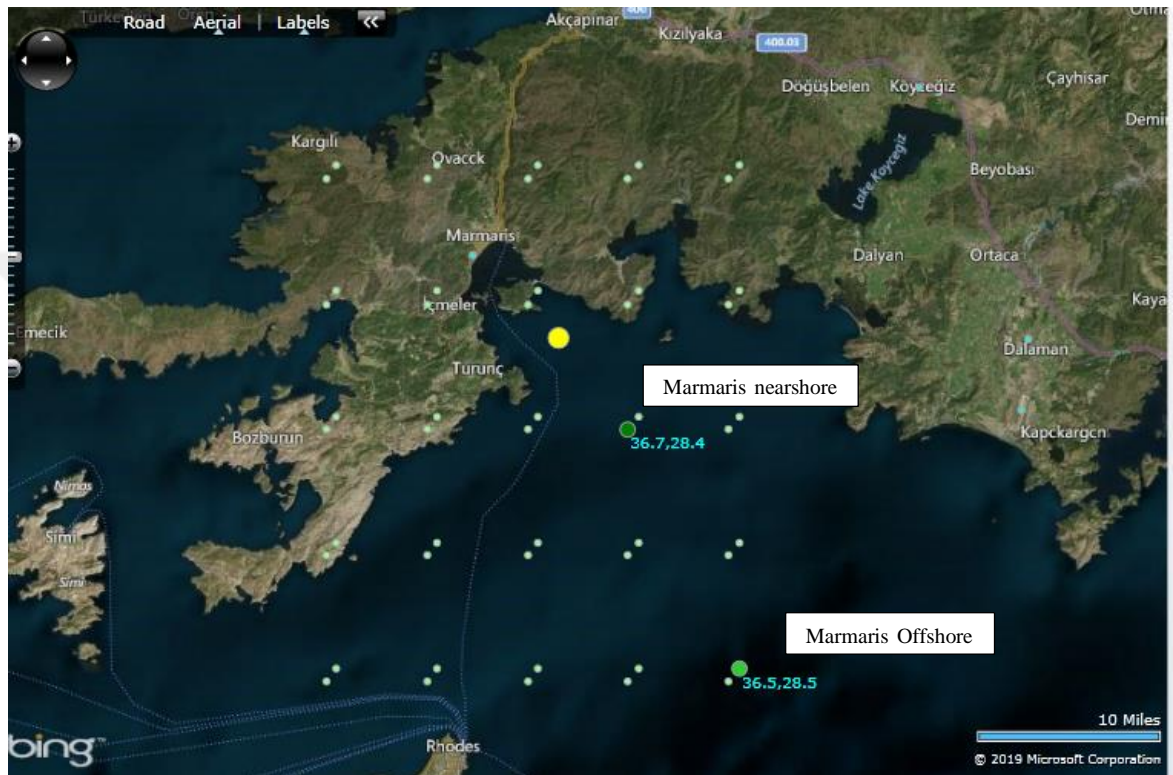


Figure (4-3-4) show the nearshore and offshore (HYDROTAM 3D)

##### 4.3.4.1 MARMARIS - Nearshore (36.7N, 28.4E)

The comparison of WAM model and CEM method wave estimates are given in figure (4-3-4-1) it is seen that CEM method wave estimates are equal 2.3 times of WAM model wave estimates if the maximum fetch and maximum wind speed are used in CEM method. if average fetch and average wind speed are used ( shown as CEM minimum in figure) CEM method is equal 1.78 times of WAM model wave estimates , assuming a constant wind speed over the fetch .

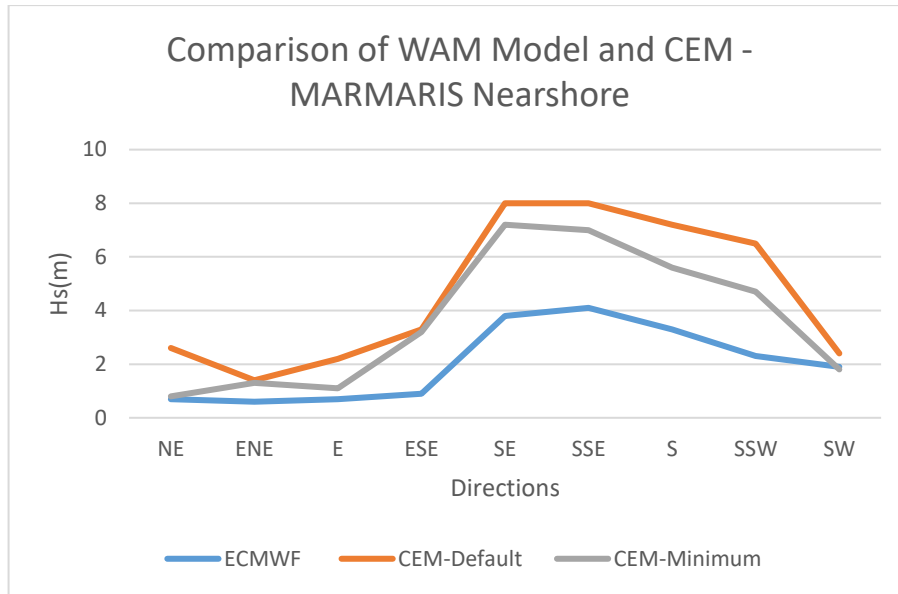


Figure (4-3-4-1) Comparison of WAM model and CEM Marmaris-Nearshore

#### 4.3.4.2 MARMARIS - Offshore (36.5N, 28.5E)

The comparison of WAM model and CEM method wave estimates are given in figure (4-3-4-2) it is seen that CEM method wave estimates are equal 2 times WAM model wave estimates if the maximum fetch and maximum wind speed are used in CEM method. If average fetch and average wind speed are used (shown as CEM minimum in figure) the CEM method are equal 1.49 times WAM model, assuming a constant wind speed over the fetch.

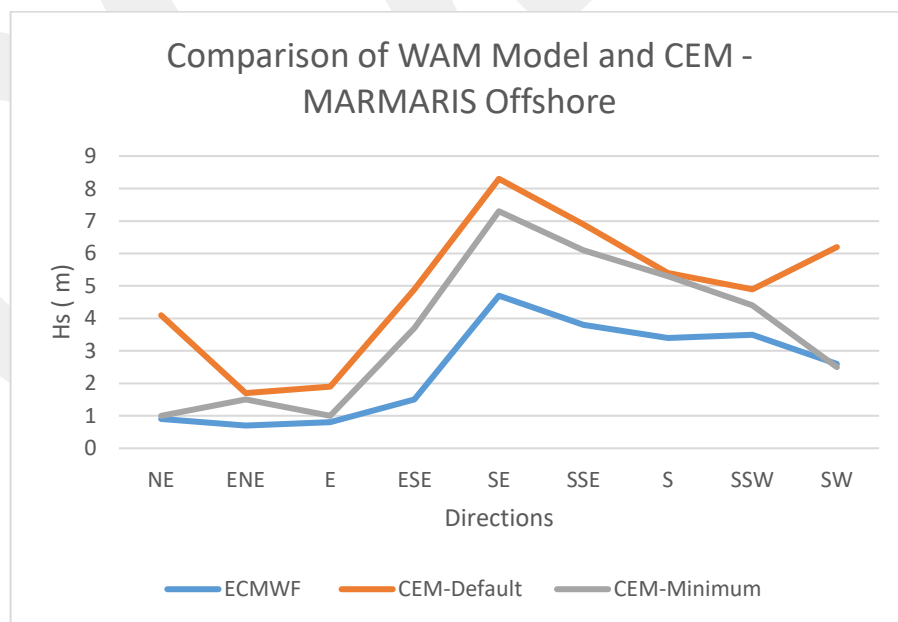


Figure (4-3-4-2) Comparison of WAM model and CEM Marmaris-Offshore

### 4.3.5 Fethiye Coastal Area:

In this section, the deep-water significant wave height values, ( $H_s$ ) of Fethiye coastal area are compared and discussed and (1hr) wave height values of ECMWF numerical WAM model are compared with the wave estimates of CEM empirical method. Two points are selected for the comparison. One point is a nearshore point and the other point is offshore point as given in figure (4-3-5).



Figure (4-3-5) show the nearshore and offshore (HYDROTAM 3D)

#### 4.3.5.1 FETHYIE - Nearshore (36.6N, 28.9E)

The comparison of WAM model and CEM method wave estimates are given in figure (4-3-5-1) it is seen that CEM method wave estimates are equal 1,6 times of WAM model wave estimates if the maximum fetch and maximum wind speed are used in CEM method. if average fetch and average wind speed are used ( shown as CEM minimum in figure) CEM method is equal 1.35 times of WAM model wave estimates , assuming a constant wind speed over the fetch .

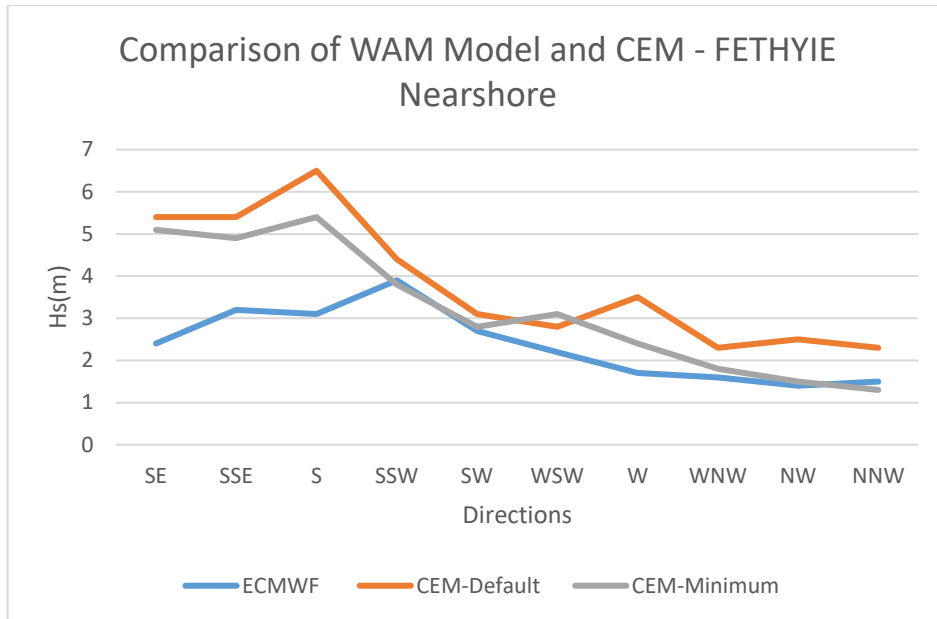


Figure (4-3-5-1) Comparison of WAM model and CEM fethyie Nearshore

#### 4.3.5.2 FETHIYE - Offshore (36.4N, 28.8E)

The comparison of WAM model and CEM method wave estimates are given in figure (4-3-5-2) it is seen that CEM method wave estimates are equal 1,78 times WAM model wave estimates if the maximum fetch and maximum wind speed are used in CEM method. If average fetch and average wind speed are used (shown as CEM minimum in figure) the CEM method are equal 1.4 times WAM model, assuming a constant wind speed over the fetch.

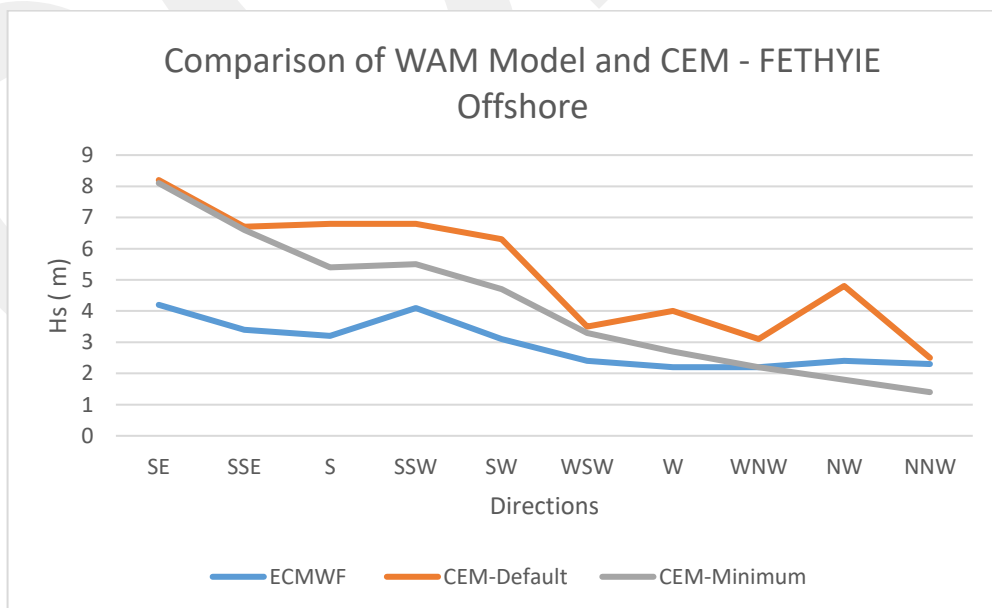


Figure (4-3-5-2) Comparison of WAM model and CEM Fethyie Offshore

#### 4.3.6 Datca Coastal Area:

In this section, the deep-water significant wave height values, ( $H_s$ ) of Datca coastal area are compared and discussed and (1hr) wave height values of ECMWF numerical WAM model are compared with the wave estimates of CEM empirical method. Two points are selected for the comparison. One point is a nearshore point and the other point is offshore point as given in figure (4-3-6).

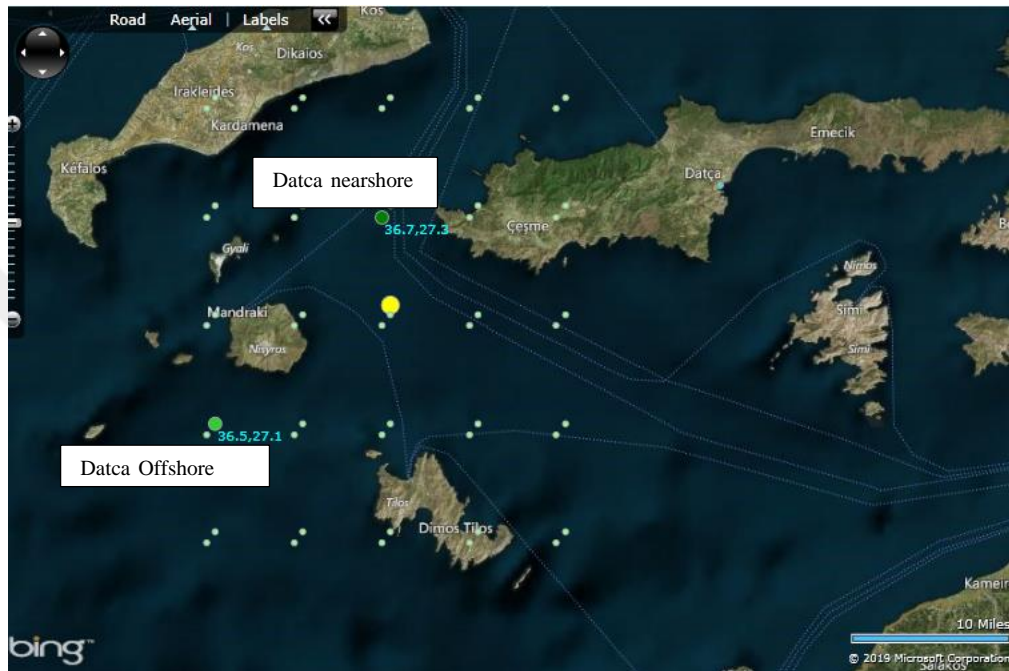


Figure (4-3-6) show the nearshore and offshore (HYDROTAM 3D)

##### 4.3.6.1 DATCA - Nearshore (36.7N, 27.3E)

The comparison of WAM model and CEM method wave estimates are given in table (4-3-6-1) and figure (4-3-6-1) it is seen that CEM method wave estimates are equal 1.42 times of WAM model wave estimates if the maximum fetch and maximum wind speed are used in CEM method. if average fetch and average wind speed are used ( shown as CEM minimum in figure) the WAM model and CEM empirical model wave estimates are almost in the same order on the average CEM method assuming a constant wind speed over the fetch, assuming a constant wind speed over the fetch .

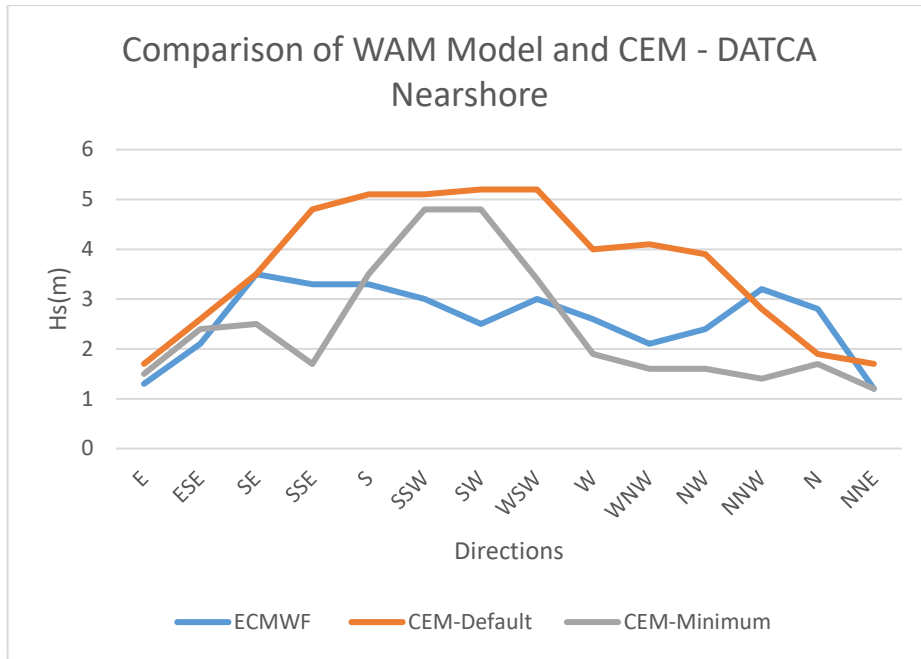


Figure (4-3-6-1) Comparison of WAM model and CEM Datcta Nearshore

#### 4.3.6.2 DATCA-Offshore (36.5N, 27.1E)

The comparison of WAM model and CEM method wave estimates are given in table (4-3-6-2) and figure (4-3-6-2) it is seen that CEM method wave estimates are equal 1.16 times WAM model wave estimates if the maximum fetch and maximum wind speed are used in CEM method. If average fetch and average wind speed are used (shown as CEM minimum in figure) the CEM method are equal (0.79) WAM model, assuming a constant wind speed over the fetch.

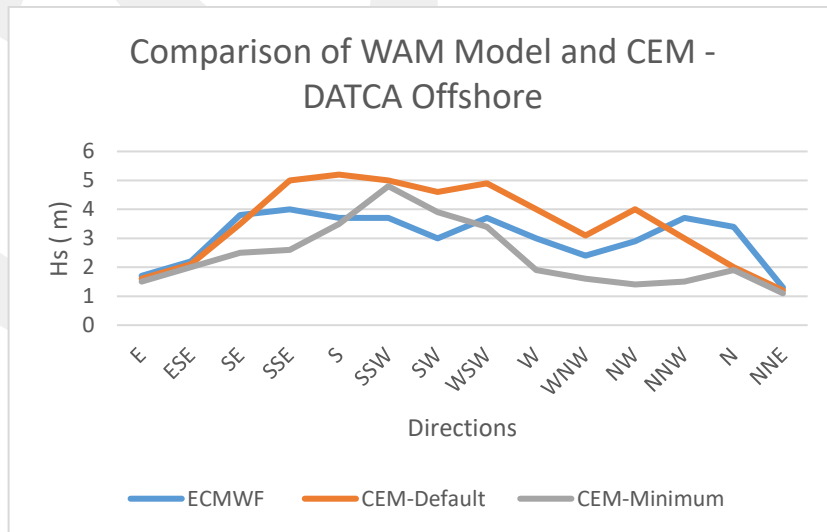


Figure (4-3-6-2) Comparison of WAM model and CEM Datça Offshore

In the literature, it has been shown that WAM numerical model underestimate the wave heights especially enclosed seas where the dominant condition is wind sea. Additionally, The other reason is the resolution of WAM numerical model close to coastal areas or enclosed basins is problematic([14]). Janssen et al., [45]), have shown that WAM gives lower wave heights in regional and seasonal wave climate by verifying the WAM numerical wave estimations with measured wave data. Hsu et al., ([46]) have emphasized the sensitivity grid resolution of WAM numerical model as a significant effect on the results. Bidlot et al., ([47]) have concluded that, analysis wind data results in lower wave heights in WAM model. Lavrenov et al., ([7]) showed that, for the Aegean SEa, WAM numerical models tends to give lower wave heights by comparing their results by altimeter data.

## CHAPTER 5

### CONCLUSIONS AND RECOMMENDATION

In this thesis, the wind and wave climate of southern Aegean Sea coastline of Turkey are studied. Six coastal areas to the South of İzmir Bay are selected for the analysis, namely as Kuşadası, Yalıkavak, Turgutreis, Marmaris, Fethiye and Datça coastal areas. The following conclusions are reached from the wind and wave climate analysis studies:

- 1) From the comparison of wind data, it is seen that the over sea wind estimates of ECMWF are always greater than the overland wind measurements of GDM for all of the coastal areas studied. It is concluded that the correction factors for over land wind measurements of Yalıkavak, Turgutreis, Marmaris, Fethiye and Datça coastal areas are between the range (1.5-2.0). However, for Kuşadası coastal area, that factor has increased up to 2.2.
- 2) It is concluded that if the over land wind measurements are to be used, they have to be corrected with a factor. This factor can be obtained by comparing the field measurements and/or wind predictions with the overland wind data. Especially for the CEM empirical method, the selection of input wind data is very important as it directly affects the results. In this study, for the southern part of Aegean Sea coastline of Turkey, the wind estimates of ECMWF are found to be more suitable for the analysis.
- 3) The comparison of the maximum, average and minimum of highest wind speeds from short term over sea measurements of GDM with the with estimates of ECMWF have shown that the GDM data is two times of the ECMWF data. However, the GDM data is short term and is discontinuous. So it is concluded that, ECMWF over sea wind estimates are more reliable for the wave analysis.
- 4) When CEM method is applied, it seen seen that Marmaris and Datça coastal areas have the highest value of long-term and extreme value wave heights with

- 5) respect to Kuşadası, Yalıkavak, Turgutreis and Fethiye as they have longer fetch distances with respect to other coastal areas. So for these areas, when CEM method is applied, a careful handling of packaging parameters are required.
- 6) In the comparison of wave height results from CEM method and WAM method, it is seen that, for the nearshore point, CEM method gives higher wave height values than WAM method except for Turgutreis coastal area, where the wave height values resulting from both methods are the same. For Kuşadası coastal area the average ratio of CEM wave height results to WAM wave height results is 1.5; for Yalıkavak coastal area, it is 1.2; for Marmaris coastal area, it is 2.3; for Fethiye coastal area, it is 1.6 and for Datça coastal area, it is 1.4.
- 7) The comparison of wave height results from CEM method and WAM method for the offshore point showed a different pattern. The wave results of WAM method for Kuşadası coastal area are 1.4 times higher than CEM Method. The wave results of WAM method for Yalıkavak coastal area are the same with CEM Method. The wave results of WAM method for Turgutreis coastal area are 1.6 times higher than CEM Method. The comparison for Marmaris, Fethiye and Datça coastal area showed that CEM method wave results are greater than WAM method for the offshore points. The ratio values are 2, 1.8 and 1.16 for Marmaris, Fethiye and Datça respectively. It is noted that the fetch distances are relatively longer in these areas with respect to Kuşadası, Yalıkavak and Turgutreis coastal areas, so the CEM Method resulted in higher wave heights.
- 8) It is concluded that, for the nearshore part, WAM model gives lower wave heights than the CEM method. For the offshore part, WAM Model gives higher wave heights than the CEM Method, if the fetch lengths are relatively short.
- 9) For the enclosed basins, it is seen that WAM model under estimates the wave heights, and therefore it is concluded that CEM Method gives more reliable results.
- 10) It is recommended that for enclosed areas, as the fetch distances are reasonable, CEM method should be considered in wave climate analysis. However, It is also recommended that both solution approaches should be analyzed and compared before making a analysis.

11) It is seen that, sometimes an more simple approach like CEM Method can give better results than a more complicated approach like WAM numerical model. So it is concluded that, in studying the wave climate, experience and a detailed knowledge of the coastal area in concern is an important factor to make a sound comparison of different wave estimate approaches.

For future studies, ECMWF WAM model can be compared with other global climate models like NCEP Climate Forecast System Reanalysis for the Northern part of Aegean Sea. Additional coastal points are suggested to be studied to give a more clear picture of the efficiency of the numerical and empirical methods in the Aegean Sea. It is also suggested that, with the increase of marine automatic meteorology observation stations, numerical and empirical wave estimates could be compared with field data to obtain more accurate results.

## APPENDIX A

### CEM PARAMETERS

#### KUSADASI

- When speed tolerance = 2 m /s
- CASE 1
- Coordinate (38 N, 26.7 E)

Table (A-1) CEM parameters

Speed factor	1
Speed tolerance	2
Direction tolerance	10 <sup>0</sup>
Maximum speed factor	0
Maximum fetch factor	0

Table (A-2) long-term statistics waves heights

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	H <sub>s</sub>	R <sup>2</sup>	H <sub>s</sub> (±m) %90 confidence	T <sub>m</sub> (sn)	H <sub>s</sub> (±m) %90 confidence	T <sub>m</sub> (sn)	H <sub>s</sub> (±m) %90 confidence	T <sub>m</sub> (sn)
SW	H <sub>s</sub> =-0.871 - 0.291*LN(P(H <sub>s</sub> ))	0.989	1.8±0.053	3.1	1.3±0.032	2.7	1.1±0.026	2.6
WSW	H <sub>s</sub> =-0.909 - 0.315*LN(P(H <sub>s</sub> ))	0.965	2±0.079	4	1.4±0.05	3.6	1.2±0.045	3.3
W	H <sub>s</sub> =-1.331 - 0.408*LN(P(H <sub>s</sub> ))	0.982	2.4±0.085	5.3	1.7±0.052	4.5	1.4±0.041	4.2
WNW	H <sub>s</sub> =-1.176 - 0.365*LN(P(H <sub>s</sub> ))	0.994	2.1±0.041	4.4	1.5±0.025	3.9	1.3±0.021	3.6
NW	H <sub>s</sub> =-0.285 - 0.189*LN(P(H <sub>s</sub> ))	0.947	1.4±0.109	3.4	1.1±0.074	3.1	1±0.063	2.9
NNW	H <sub>s</sub> =0.181 - 0.079*LN(P(H <sub>s</sub> ))	0.826	0.9±0.172	2.3	0.8±0.129	2.2	0.7±0.113	2.2

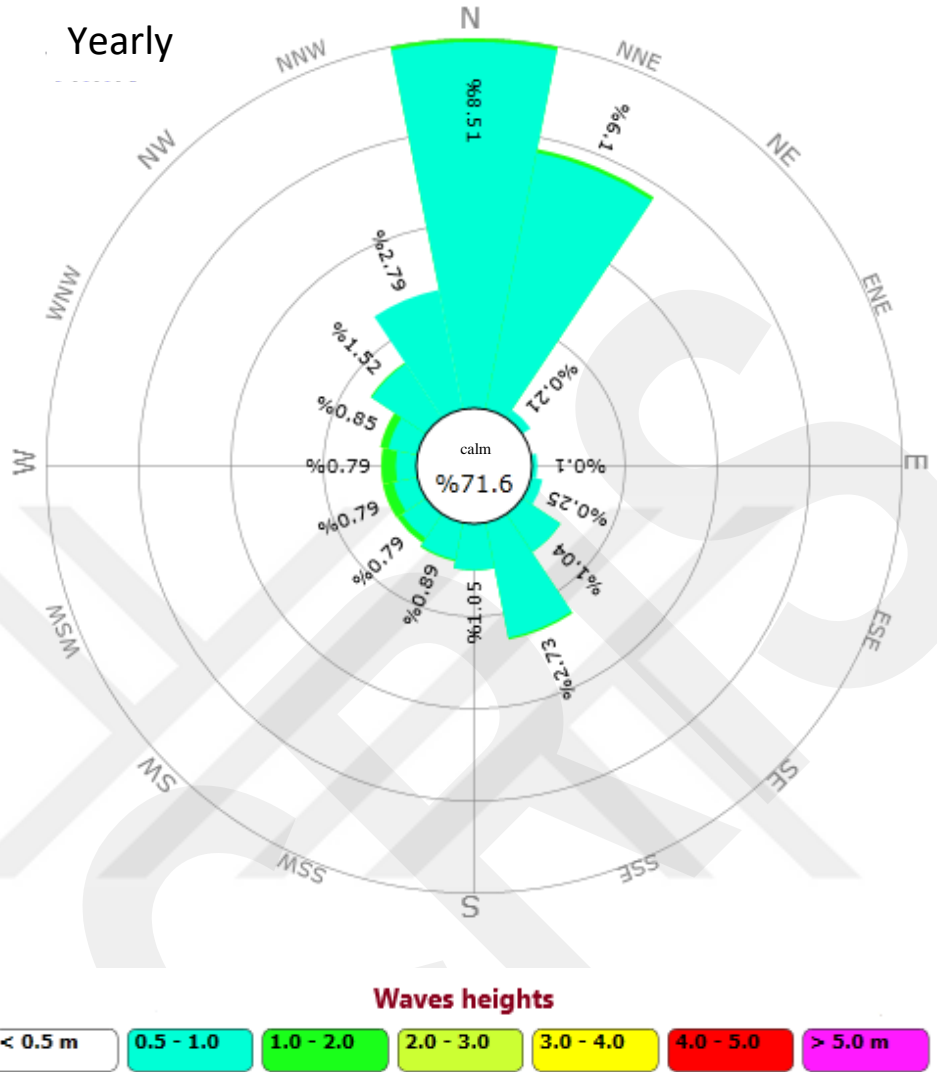


Figure (A-1) wave rose for kuşadası

**CASE 2**

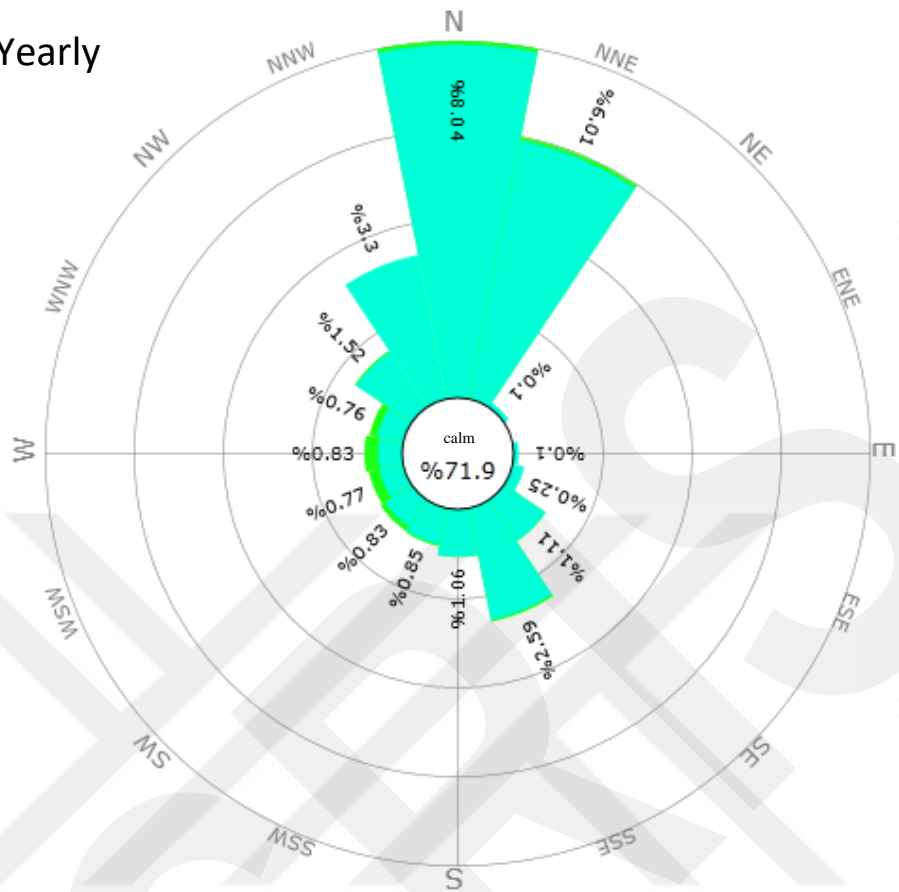
Table (A-3) CEM parameters

Speed factor	1
Speed tolerance	2
Direction tolerance	15 <sup>0</sup>
Maximum speed factor	0
Maximum fetch factor	0

Table (A-4) long-term statistics waves heights

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	Hs	R <sup>2</sup>	Hs (±m) %90 confidence	Tm (sn)	Hs (±m) %90 confidence	Tm (sn)	Hs (±m) %90 confidence	Tm (sn)
SW	Hs=-0.830 - 0.281*LN(P(Hs))	0.985	1.7±0.06	3	1.3±0.037	2.7	1.1±0.03	2.5
WSW	Hs=-0.931 - 0.317*LN(P(Hs))	0.967	1.9±0.076	4	1.4±0.049	3.5	1.2±0.043	3.3
W	Hs=-1.329 - 0.406*LN(P(Hs))	0.99	2.4±0.063	5.3	1.7±0.038	4.5	1.4±0.03	4.1
WNW	Hs=-1.246 - 0.372*LN(P(Hs))	0.992	2.1±0.048	4.4	1.5±0.029	3.9	1.3±0.024	3.6
NW	Hs=-0.286 - 0.188*LN(P(Hs))	0.946	1.4±0.109	3.4	1.1±0.075	3.1	1±0.063	2.9
NNW	Hs=0.193 - 0.077*LN(P(Hs))	0.819	0.9±0.172	2.3	0.8±0.129	2.2	0.7±0.113	2.2

Yearly



**Waves heights**

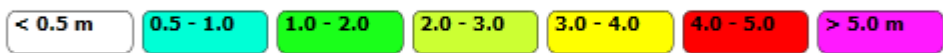


Figure (A-2) wave rose for kuşadası

**CASE 3**

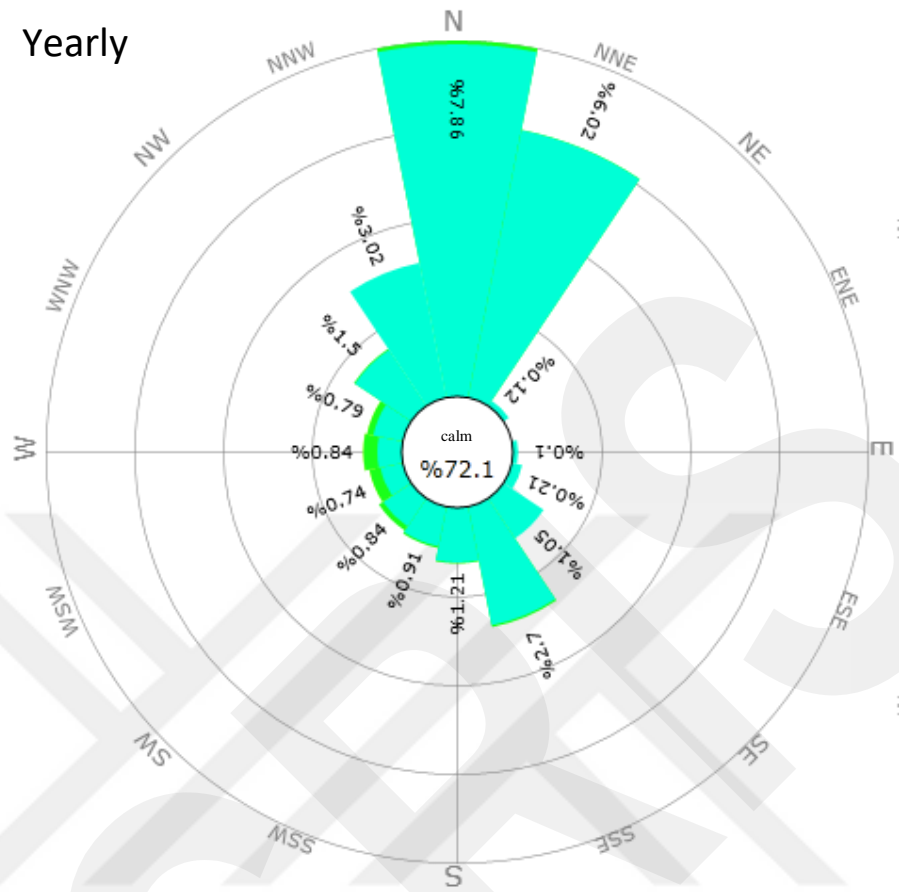
Table (A-5) CEM parameters

Speed factor	1
Speed tolerance	2
Direction tolerance	20 <sup>0</sup>
Maximum speed factor	0
Maximum fetch factor	0

Table (A-6) long-term statistics waves heights

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	Hs	R <sup>2</sup>	Hs(±m) %90 confidence	Tm(sn)	Hs(±m) %90 confidence	Tm(sn)	Hs(±m) %90 confidence	Tm(sn)
SW	Hs=-0.830 - 0.280*LN(P(Hs))	0.984	1.7±0.061	3	1.3±0.037	2.7	1.1±0.031	2.5
WSW	Hs=-1.004 - 0.330*LN(P(Hs))	0.967	2±0.079	4.1	1.5±0.049	3.6	1.2±0.043	3.3
W	Hs=-1.337 - 0.407*LN(P(Hs))	0.99	2.4±0.064	5.3	1.7±0.039	4.5	1.4±0.031	4.1
WNW	Hs=-1.235 - 0.370*LN(P(Hs))	0.991	2.1±0.055	4.4	1.5±0.034	3.8	1.3±0.028	3.6
NW	Hs=-0.269 - 0.183*LN(P(Hs))	0.937	1.4±0.115	3.4	1.1±0.079	3.1	1±0.067	2.9
NNW	Hs=0.194 - 0.074*LN(P(Hs))	0.818	0.9±0.166	2.3	0.8±0.125	2.2	0.7±0.11	2.2

Yearly



Waves heights

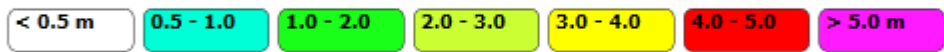


Figure (A-3) wave rose for kuşadası

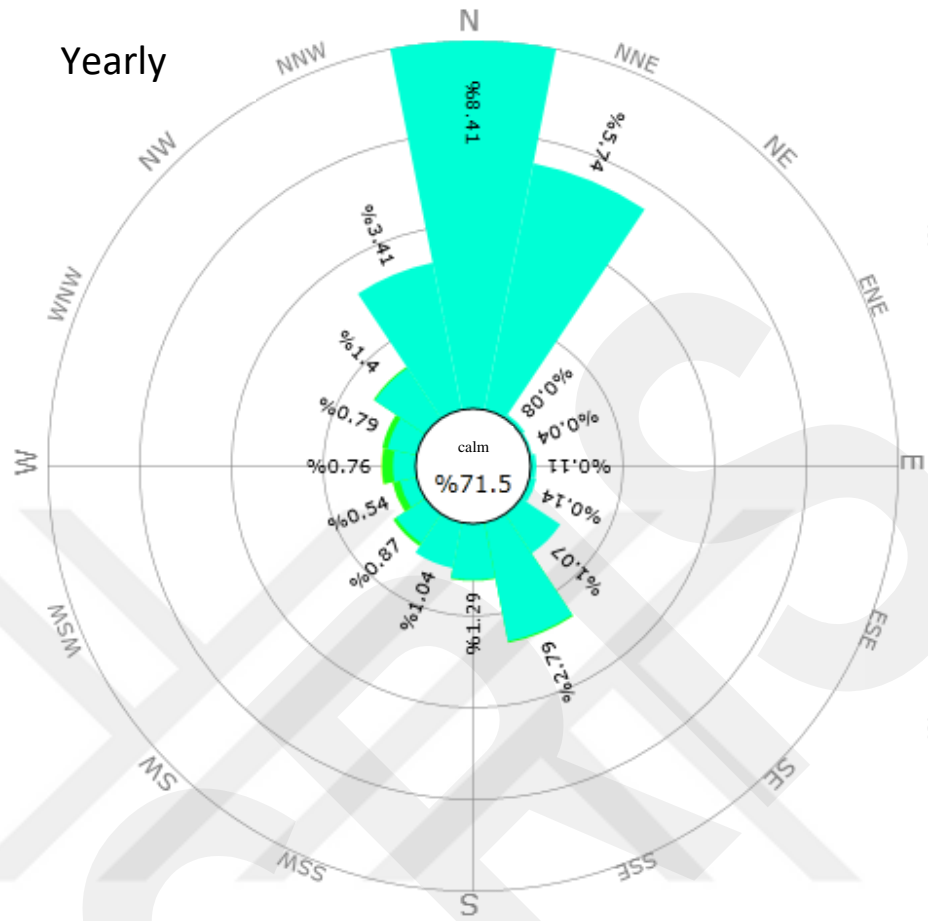
**CASE 4**

Table (A-7) CEM parameters

Speed factor	1
Speed tolerance	2
Direction tolerance	25 <sup>0</sup>
Maximum speed factor	0
Maximum fetch factor	0

Table (A-8) long-term statistics waves heights

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	Hs	R <sup>2</sup>	Hs(±m) %90 confidence	Tm(sn)	Hs(±m) %90 confidence	Tm(sn)	Hs(±m) %90 confidence	Tm(sn)
SW	Hs=-0.700 - 0.257*LN(P(Hs))	0.984	1.6±0.059	3	1.2±0.038	2.7	1±0.038	2.5
WSW	Hs=-1.060 - 0.323*LN(P(Hs))	0.978	1.9±0.065	4	1.3±0.04	3.5	1.1±0.035	3.2
W	Hs=-1.405 - 0.408*LN(P(Hs))	0.996	2.3±0.033	5.2	1.6±0.02	4.4	1.4±0.016	4.1
WNW	Hs=-1.125 - 0.342*LN(P(Hs))	0.982	2±0.079	4.3	1.4±0.047	3.7	1.2±0.036	3.5
NW	Hs=-0.459 - 0.225*LN(P(Hs))	0.906	1.6±0.174	3.6	1.2±0.12	3.2	1.1±0.104	3
NNW	Hs=0.154 - 0.090*LN(P(Hs))	0.751	1±0.316	2.4	0.8±0.234	2.3	0.8±0.201	2.2



**Waves heights**

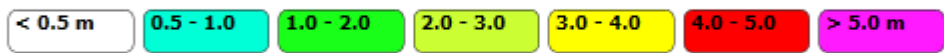


Figure (A-4) wave rose for kuşadası

- when speed tolerance = 2.5 m /s
- Coordinate (38 N , 26.7 E)
- CASE 1

Table (A-9) CEM parameters

Speed factor	1
Speed tolerance	2.5
Direction tolerance	10 <sup>0</sup>
Maximum speed factor	0
Maximum fetch factor	0

Table (A-10) long-term statistics waves heights

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	Hs	R <sup>2</sup>	Hs(±m) %90 confidence	Tm(sn)	Hs(±m) %90 confidence	Tm(sn)	Hs(±m) %90 confidence	Tm(sn)
SW	Hs=-1.017 - 0.324*LN(P(Hs))	0.987	1.9±0.065	3.2	1.4±0.039	2.8	1.2±0.3	2.6
WSW	Hs=-0.892 - 0.298*LN(P(Hs))	0.97	1.8±0.072	3.9	1.3±0.047	3.4	1.1±0.043	3.2
W	Hs=-1.319 - 0.388*LN(P(Hs))	0.987	2.2±0.065	5.1	1.6±0.039	4.4	1.3±0.032	4
WNW	Hs=-1.182 - 0.343*LN(P(Hs))	0.976	1.9±0.071	4.2	1.4±0.046	3.7	1.1±0.043	3.4
NW	Hs=-0.313 - 0.193*LN(P(Hs))	0.952	1.4±0.117	3.4	1.1±0.080	3.1	1±0.068	2.9
NNW	Hs=0.132 - 0.101*LN(P(Hs))	0.846	1±0.212	2.5	0.9±0.156	2.3	0.8±0.134	2.3



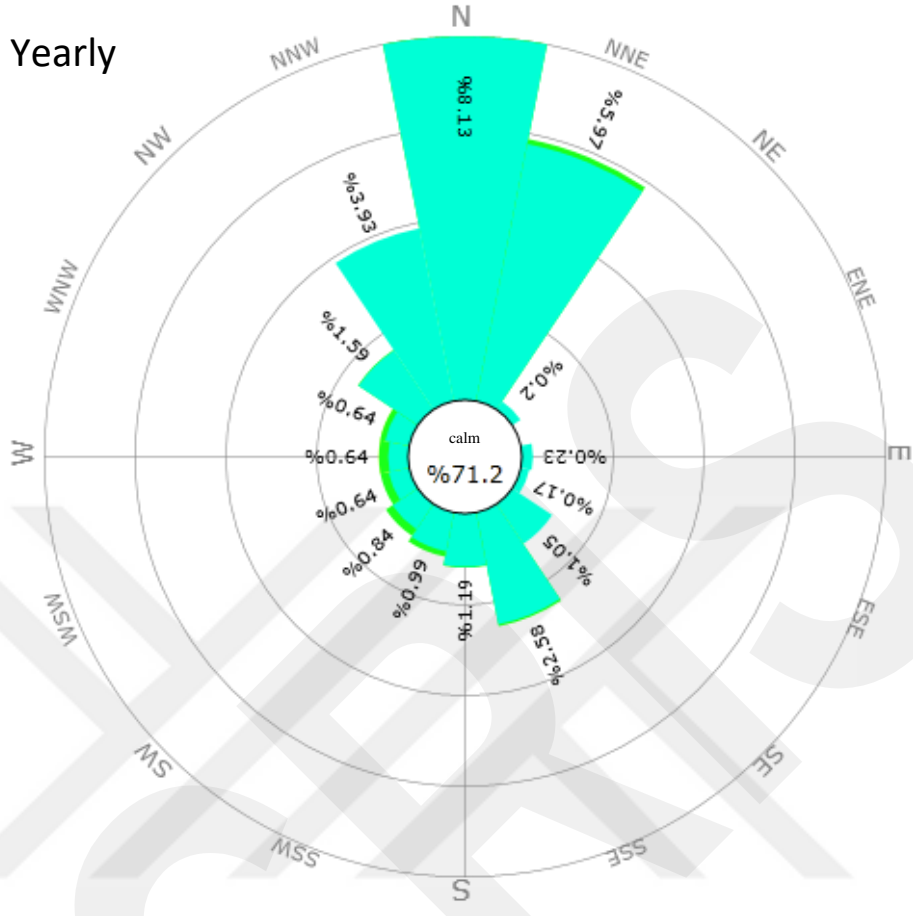
**CASE 2**

Table (A-11) CEM parameters

Speed factor	1
Speed tolerance	2.5
Direction tolerance	15 <sup>0</sup>
Maximum speed factor	0
Maximum fetch factor	0

Table (A-12) long-term statistics waves heights

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	Hs	R <sup>2</sup>	Hs (±m) %90 confidence	Tm(sn)	Hs(±m) %90 confidence	Tm(sn)	Hs(±m) %90 confidence	Tm(sn)
SW	$H_s = -0.948 - 0.311 * LN(P(H_s))$	0.983	1.9±0.072	3.1	1.4±0.043	2.8	1.2±0.34	2.6
WSW	$H_s = -0.896 - 0.297 * LN(P(H_s))$	0.973	1.8±0.068	3.9	1.3±0.044	3.4	1.1±0.04	3.2
W	$H_s = -1.323 - 0.386 * LN(P(H_s))$	0.989	2.2±0.059	5.1	1.6±0.036	4.4	1.3±0.029	4
WNW	$H_s = -1.150 - 0.340 * LN(P(H_s))$	0.979	1.9±0.069	4.2	1.4±0.045	3.7	1.2±0.042	3.4
NW	$H_s = -0.315 - 0.191 * LN(P(H_s))$	0.944	1.4±0.125	3.4	1.1±0.086	3.1	1±0.073	2.9
NNW	$H_s = 0.135 - 0.100 * LN(P(H_s))$	0.844	1±0.212	2.5	0.9±0.156	2.3	0.8±0.134	2.3



**Waves heights**

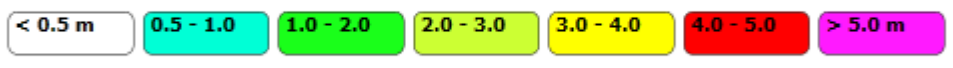


Figure (A-6) wave rose for kuşadası

**CASE 3**

Table (A-13) CEM parameters

Speed factor	1
Speed tolerance	2.5
Direction tolerance	20 <sup>0</sup>
Maximum speed factor	0
Maximum fetch factor	0

Table (A-14) long-term statistics waves heights

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	Hs	R <sup>2</sup>	Hs(±m) %90 confidence	Tm(sn)	Hs(±m) %90 confidence	Tm(sn)	Hs(±m) %90 confidence	Tm(sn)
SW	$H_s = -0.906 - 0.304 * LN(P(H_s))$	0.98	1.9±0.077	3.1	1.4±0.047	2.8	1.2±0.37	2.6
WSW	$H_s = -0.810 - 0.279 * LN(P(H_s))$	0.956	1.7±0.087	3.8	1.3±0.056	3.4	1.1±0.051	3.2
W	$H_s = -1.300 - 0.382 * LN(P(H_s))$	0.988	2.2±0.06	5.1	1.6±0.036	4.3	1.3±0.03	3.9
WNW	$H_s = -1.185 - 0.341 * LN(P(H_s))$	0.97	1.9±0.079	4.2	1.4±0.051	3.7	1.1±0.048	3.4
NW	$H_s = -0.297 - 0.186 * LN(P(H_s))$	0.927	1.4±0.139	3.4	1.1±0.095	3	1±0.081	2.9
NNW	$H_s = 0.130 - 0.100 * LN(P(H_s))$	0.851	1±0.206	2.5	0.9±0.151	2.3	0.8±0.129	2.3

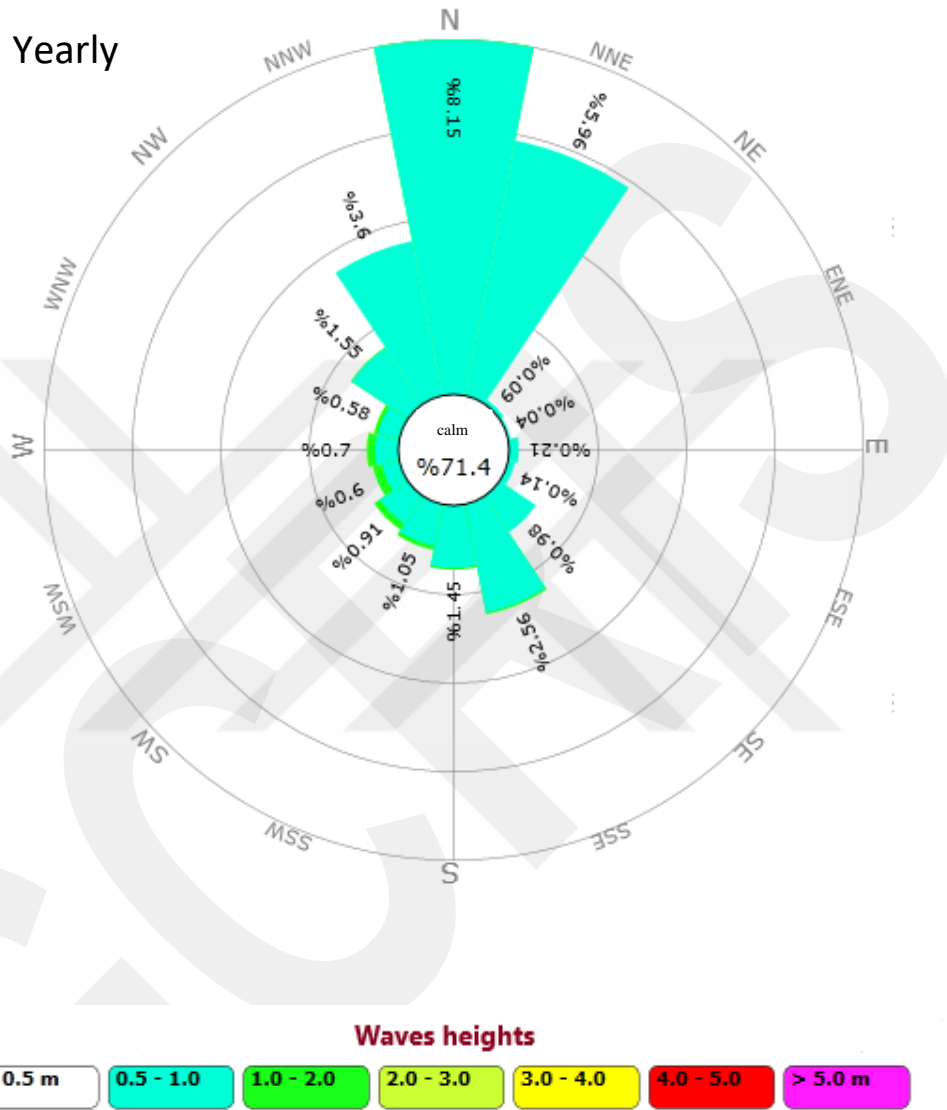


Figure (A-7) wave rose for kuşadası

**CASE 4**

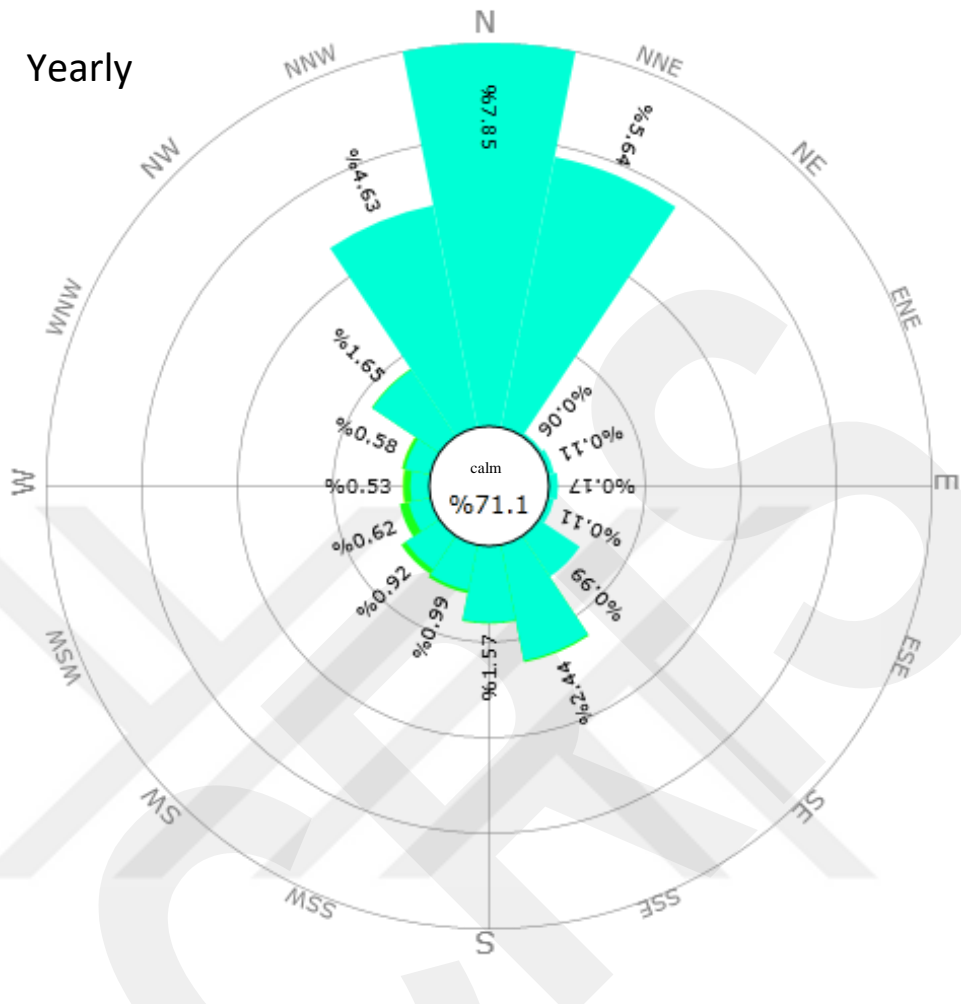
Table (A-15) CEM parameters

Speed factor	1
Speed tolerance	2.5
Direction tolerance	25 <sup>0</sup>
Maximum speed factor	0
Maximum fetch factor	0

Table (A-16) long-term statistics waves heights

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	Hs	R <sup>2</sup>	Hs (±m) %90 confidence	Tm(sn)	Hs(±m) %90 confidence	Tm(sn)	Hs(±m) %90 confidence	Tm(sn)
SW	-0.585 - 0.235*LN(P(Hs))	0.974	1.6±0.071	2.9	1.2±0.046	2.6	1±0.39	2.5
WSW	-1.382 - 0.383*LN(P(Hs))	0.992	2.1±0.05	4.2	1.5±0.029	3.6	1.2±0.023	3.3
W	-1.450 - 0.396*LN(P(Hs))	0.979	2.1±0.075	5	1.5±0.045	4.3	1.2±0.038	3.9
WNW	-1.232 - 0.348*LN(P(Hs))	0.942	1.9±0.137	4.2	1.4±0.086	3.7	1.1±0.075	3.4
NW	0.422 - 0.218*LN(P(Hs))	0.87	1.6±0.224	3.5	1.2±0.158	3.2	1.1±0.138	3
NNW	-0.162 - 0.094*LN(P(Hs))	0.826	1±0.216	2.4	0.9±0.16	2.3	0.8±0.138	2.3

Yearly



Waves heights

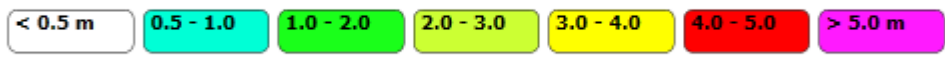


Figure (A-8) wave rose for kuşadası

- when speed tolerance = 3 m /s
- Coordinate (38 N , 26.7 E)
- CASE 1

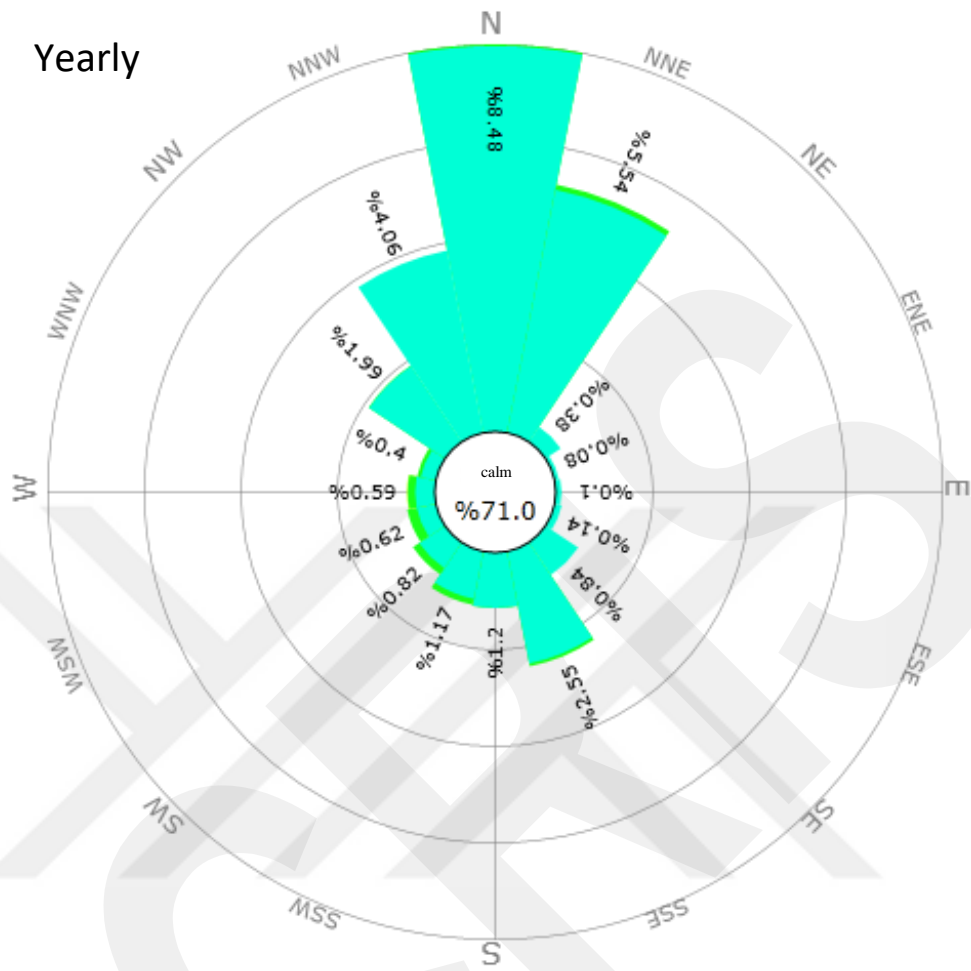
Table (A-17) CEM parameters

Speed factor	1
Speed tolerance	3
Direction tolerance	10 <sup>0</sup>
Maximum speed factor	0
Maximum fetch factor	0

Table (A-18) long-term statistics waves heights

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	Hs	R <sup>2</sup>	Hs (±m) %90 confidence	Tm(sn)	Hs(±m) %90 confidence	Tm(sn)	Hs(±m) %90 confidence	Tm(sn)
SW	Hs=-0.948 - 0.308*LN(P(Hs))	0.982	1.9±0.072	3.1	1.4±0.043	2.8	1.1±0.034	2.6
WSW	Hs=-0.924 - 0.300*LN(P(Hs))	0.972	1.8±0.079	3.9	1.3±0.05	3.4	1.1±0.042	3.2
W	Hs=-1.509 - 0.405*LN(P(Hs))	0.974	2.2±0.084	5.1	1.5±0.051	4.3	1.2±0.044	3.9
WNW	Hs=-0.781 - 0.265*LN(P(Hs))	0.952	1.6±0.102	3.9	1.2±0.069	3.5	1±0.063	3.3
NW	Hs=-0.170 - 0.160*LN(P(Hs))	0.924	1.3±0.124	3.3	1±0.089	3	0.9±0.079	2.8
NNW	Hs=0.127 - 0.103*LN(P(Hs))	0.896	1.1±0.144	2.5	0.9±0.105	2.3	0.8±0.091	2.3

Yearly



**Waves heights**

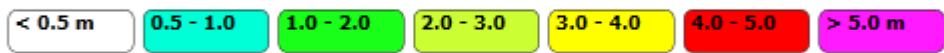


Figure (A-9) wave rose for kuşadası

**CASE 2**

Table (A-19) CEM parameters

Speed factor	1
Speed tolerance	3
Direction tolerance	15 <sup>0</sup>
Maximum speed factor	0
Maximum fetch factor	0

Table (A-20) long-term statistics waves heights

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	Hs	R <sup>2</sup>	Hs(±m)	Tm(sn)	Hs(±m)	Tm(sn)	Hs(±m)	Tm(sn)
			%90 confidenc e		%90 confidenc e		%90 confidenc e	
SW	Hs=-0.913 - 0.303*LN(P(Hs))	0.978	1.8±0.079	3.1	1.3±0.048	2.8	1.1±0.038	2.6
WSW	Hs=-0.815 - 0.275*LN(P(Hs))	0.957	1.7±0.097	3.8	1.2±0.059	3.3	1±0.05	3.1
W	Hs=-1.468 - 0.397*LN(P(Hs))	0.965	2.1±0.102	5	1.5±0.062	4.2	1.2±0.054	3.9
WNW	Hs=-0.761 - 0.265*LN(P(Hs))	0.956	1.6±0.091	4	1.2±0.061	3.5	1±0.056	3.3
NW	Hs=-0.167 - 0.158*LN(P(Hs))	0.905	1.3±0.137	3.2	1±0.098	2.9	0.9±0.087	2.8
NNW	Hs=0.130 - 0.103*LN(P(Hs))	0.9	1.1±0.141	2.5	0.9±0.103	2.3	0.8±0.089	2.3



**CASE 3**

Table (A-21) CEM parameters

Speed factor	1
Speed tolerance	3
Direction tolerance	20 <sup>0</sup>
Maximum speed factor	0
Maximum fetch factor	0

Table (A-22) long-term statistics waves heights

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	Hs	R <sup>2</sup>	Hs(±m) %90 confidence	Tm(sn)	Hs(±m) %90 confidence	Tm(sn)	Hs(±m) %90 confidence	Tm(sn)
<b>SW</b>	Hs=-0.639 - 0.245*LN(P(Hs))	0.98	1.6±0.064	2.9	1.2±0.041	2.6	1±0.035	2.5
<b>WSW</b>	Hs=-1.136 - 0.338*LN(P(Hs))	0.975	1.9±0.088	4	1.4±0.054	3.5	1.2±0.045	3.2
<b>W</b>	Hs=-1.501 - 0.403*LN(P(Hs))	0.97	2.2±0.09	5.1	1.5±0.055	4.3	1.2±0.048	3.9
<b>WNW</b>	Hs=-0.817 - 0.270*LN(P(Hs))	0.941	1.6±0.112	4	1.2±0.077	3.5	1±0.071	3.3
<b>NW</b>	Hs=-0.169 - 0.158*LN(P(Hs))	0.907	1.3±0.135	3.2	1±0.097	2.9	0.9±0.086	2.8
<b>NNW</b>	Hs=0.142 - 0.101*LN(P(Hs))	0.901	1.1±0.139	2.5	0.9±0.102	2.3	0.8±0.088	2.3

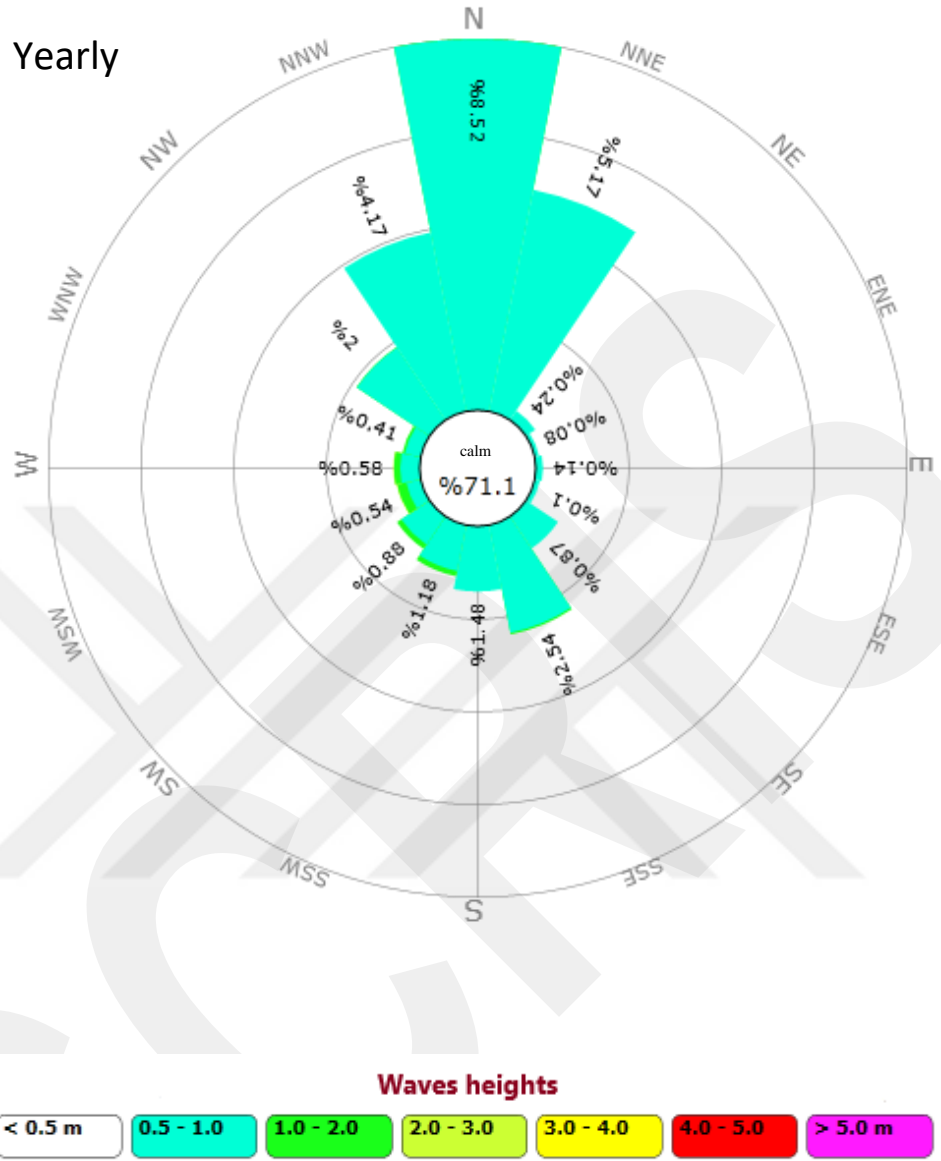


Figure (A-11) wave rose for kuşadası

**CASE 4**

Table (A-23) CEM parameters

Speed factor	1
Speed tolerance	3
Direction tolerance	25 <sup>0</sup>
Maximum speed factor	0
Maximum fetch factor	0

Table (A-24) long-term statistics waves heights

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	Hs	R <sup>2</sup>	Hs (±m) %90 confidence	Tm (sn)	Hs (±m) %90 confidence	Tm (sn)	Hs (±m) %90 confidence	Tm (sn)
SW	$H_s = -0.630 - 0.238 * LN(P(H_s))$	0.965	1.5±0.089	2.9	1.1±0.057	2.6	1±0.049	2.5
WSW	$H_s = -1.330 - 0.369 * LN(P(H_s))$	0.97	2±0.112	4.1	1.4±0.065	3.5	1.2±0.051	3.3
W	$H_s = -1.556 - 0.407 * LN(P(H_s))$	0.936	2.1±0.148	5	1.5±0.091	4.2	1.2±0.08	3.8
WNW	$H_s = -1.053 - 0.320 * LN(P(H_s))$	0.915	1.9±0.184	4.2	1.3±0.119	3.7	1.1±0.103	3.4
NW	$H_s = -0.192 - 0.161 * LN(P(H_s))$	0.893	1.3±0.168	3.2	1±0.119	2.9	0.9±0.103	2.8
NNW	$H_s = 0.200 - 0.084 * LN(P(H_s))$	0.809	1±0.205	2.4	0.8±0.154	2.3	0.8±0.134	2.2

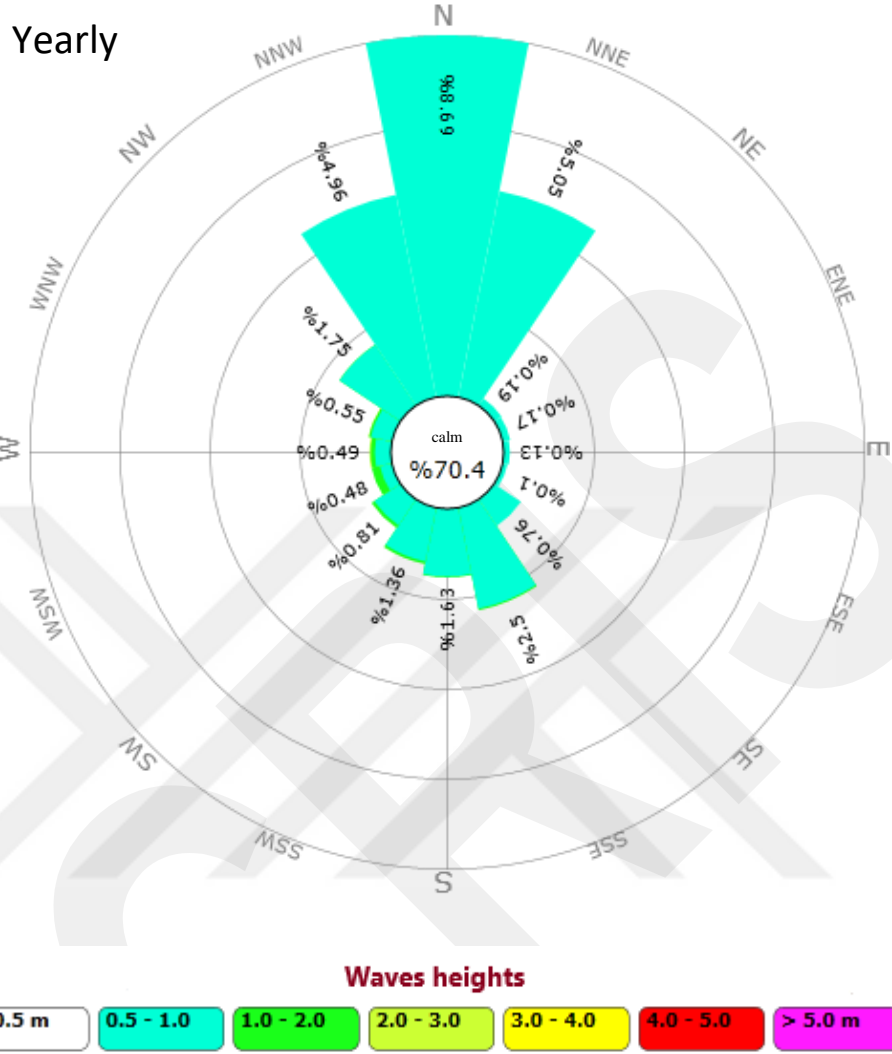


Figure (A-12) wave rose for kuşadası

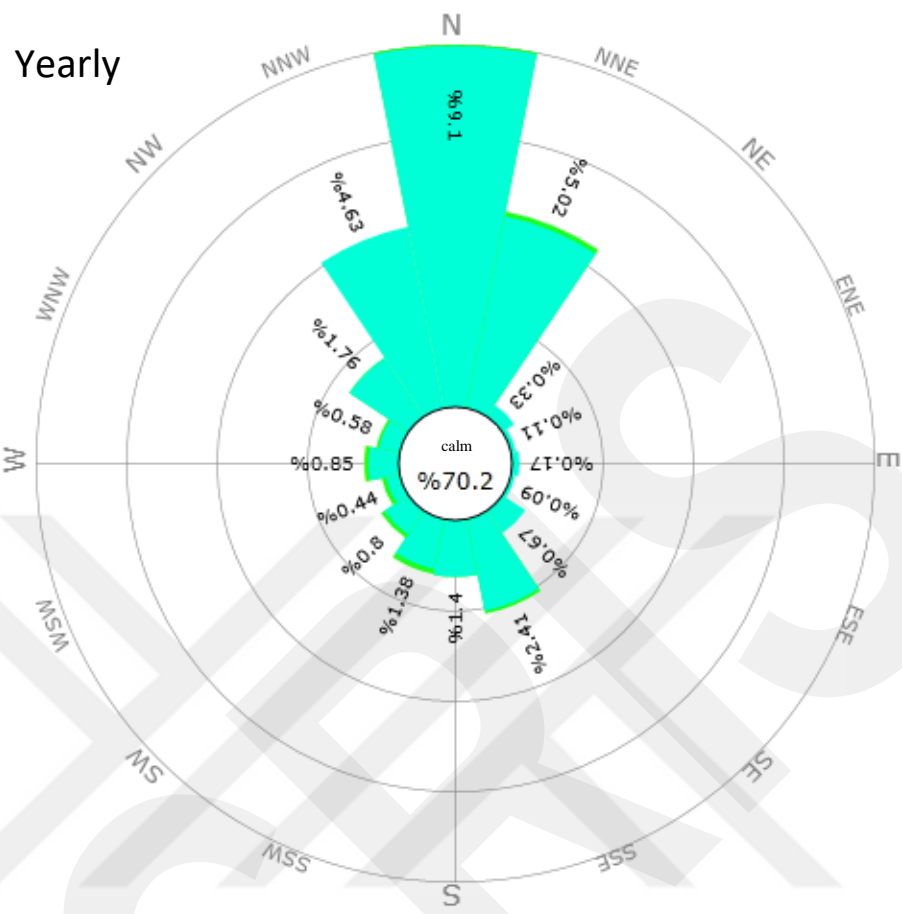
- When speed tolerance = 3.5 m /s
- Coordinate (38 N, 26.7 E)
- CASE 1

Table (A-25) CEM parameters

Speed factor	1
Speed tolerance	3.5
Direction tolerance	10 <sup>0</sup>
Maximum speed factor	0
Maximum fetch factor	0

Table (A-26) long-term statistics waves heights

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	Hs	R <sup>2</sup>	Hs(±m) %90 confidence	Tm(sn)	Hs(±m) %90 confidence	Tm(sn)	Hs(±m) %90 confidence	Tm(sn)
SW	Hs=-0.960 - 0.305*LN(P(Hs))	0.964	1.8±0.107	3.1	1.3±0.064	2.7	1.1±0.051	2.6
WSW	Hs=-0.799 - 0.272*LN(P(Hs))	0.974	1.7±0.076	3.9	1.2±0.051	3.4	1±0.046	3.1
W	Hs=-1.165 - 0.351*LN(P(Hs))	0.902	2±0.169	4.9	1.5±0.109	4.2	1.2±0.098	3.8
WNW	Hs=-0.701 - 0.249*LN(P(Hs))	0.864	1.6±0.2	3.9	1.2±0.127	3.4	1±0.108	3.2
NW	Hs=-0.135 - 0.146*LN(P(Hs))	0.86	1.2±0.153	3.2	1±0.113	2.9	0.9±0.102	2.7
NNW	Hs=0.157 - 0.099*LN(P(Hs))	0.874	1.1±0.157	2.5	0.9±0.116	2.3	0.8±0.1	2.3



**Waves heights**

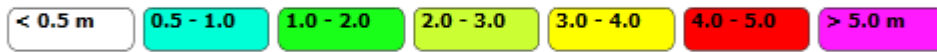


Figure (A-13) wave rose for kuşadası

**CASE 2**

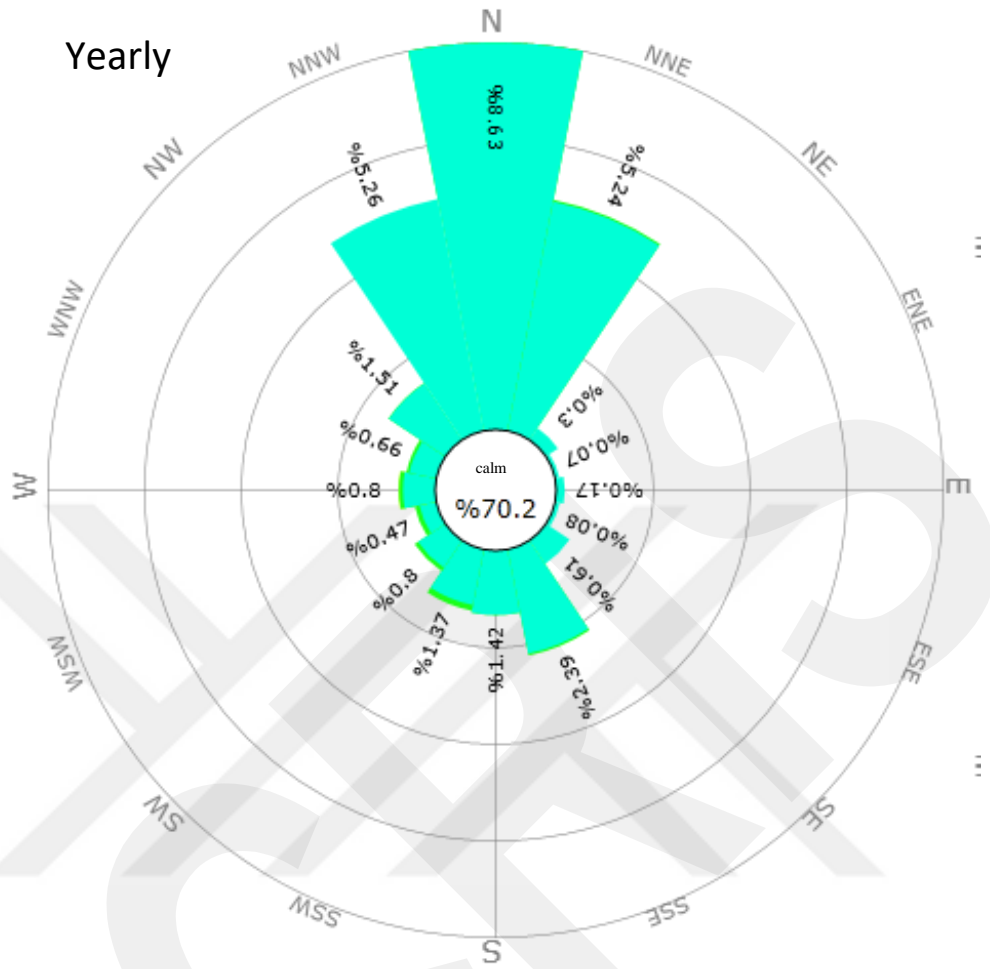
Table (A-27) CEM parameters

Speed factor	1
Speed tolerance	3.5
Direction tolerance	15 <sup>0</sup>
Maximum speed factor	0
Maximum fetch factor	0

Table (A-28) long-term statistics waves heights

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	Hs	R <sup>2</sup>	Hs (±m) %90 confidence	Tm(sn)	Hs(±m) %90 confidence	Tm(sn)	Hs(±m) %90 confidence	Tm(sn)
SW	Hs=-0.973 - 0.306*LN(P(Hs))	0.962	1.8±0.11	3.1	1.3±0.066	2.7	1.1±0.052	2.6
WSW	Hs=-0.669 - 0.247*LN(P(Hs))	0.946	1.6±0.124	3.7	1.2±0.081	3.3	1±0.07	3.1
W	Hs=-1.200 - 0.354*LN(P(Hs))	0.896	2±0.173	4.9	1.4±0.112	4.2	1.2±0.1	3.8
WNW	Hs=-0.699 - 0.257*LN(P(Hs))	0.936	1.6±0.143	4	1.2±0.092	3.5	1±0.077	3.3
NW	Hs=-0.170 - 0.150*LN(P(Hs))	0.865	1.2±0.15	3.2	1±0.11	2.9	0.8±0.1	2.7
NNW	Hs=0.167 - 0.097*LN(P(Hs))	0.875	1±0.155	2.5	0.9±0.115	2.3	0.8±0.1	2.3

Yearly



Waves heights

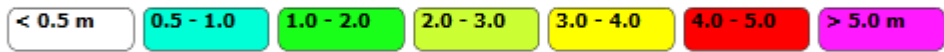


Figure (A-14) wave rose for kuşadası

**CASE 3**

Table (A-29) CEM parameters

Speed factor	1
Speed tolerance	3.5
Direction tolerance	20 <sup>0</sup>
Maximum speed factor	0
Maximum fetch factor	0

Table (A-30) long-term statistics waves heights

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	H <sub>s</sub>	R <sup>2</sup>	H <sub>s</sub> (±m) %90 confidence	T <sub>m</sub> (sn)	H <sub>s</sub> (±m) %90 confidence	T <sub>m</sub> (sn)	H <sub>s</sub> (±m) %90 confidence	T <sub>m</sub> (sn)
SW	H <sub>s</sub> =-0.621 - 0.241*LN(P(H <sub>s</sub> ))	0.965	1.6±0.092	2.9	1.2±0.059	2.6	1±0.05	2.5
WSW	H <sub>s</sub> =-1.073 - 0.328*LN(P(H <sub>s</sub> ))	0.963	1.9±0.114	4	1.4±0.07	3.5	1.1±0.058	3.2
W	H <sub>s</sub> =-1.235 - 0.359*LN(P(H <sub>s</sub> ))	0.886	2±0.171	4.9	1.4±0.11	4.2	1.2±0.1	3.8
WNW	H <sub>s</sub> =-0.728 - 0.257*LN(P(H <sub>s</sub> ))	0.915	1.6±0.182	3.9	1.2±0.117	3.5	1±0.097	3.3
NW	H <sub>s</sub> =-0.171 - 0.151*LN(P(H <sub>s</sub> ))	0.873	1.2±0.147	3.2	1±0.107	2.9	0.9±0.097	2.7
NNW	H <sub>s</sub> =0.180 - 0.096*LN(P(H <sub>s</sub> ))	0.87	1±0.158	2.5	0.9±0.118	2.3	0.8±0.102	2.3

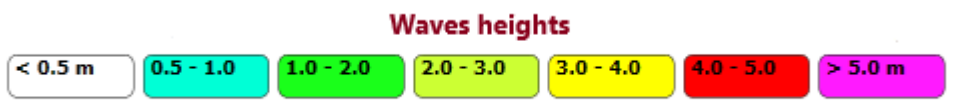
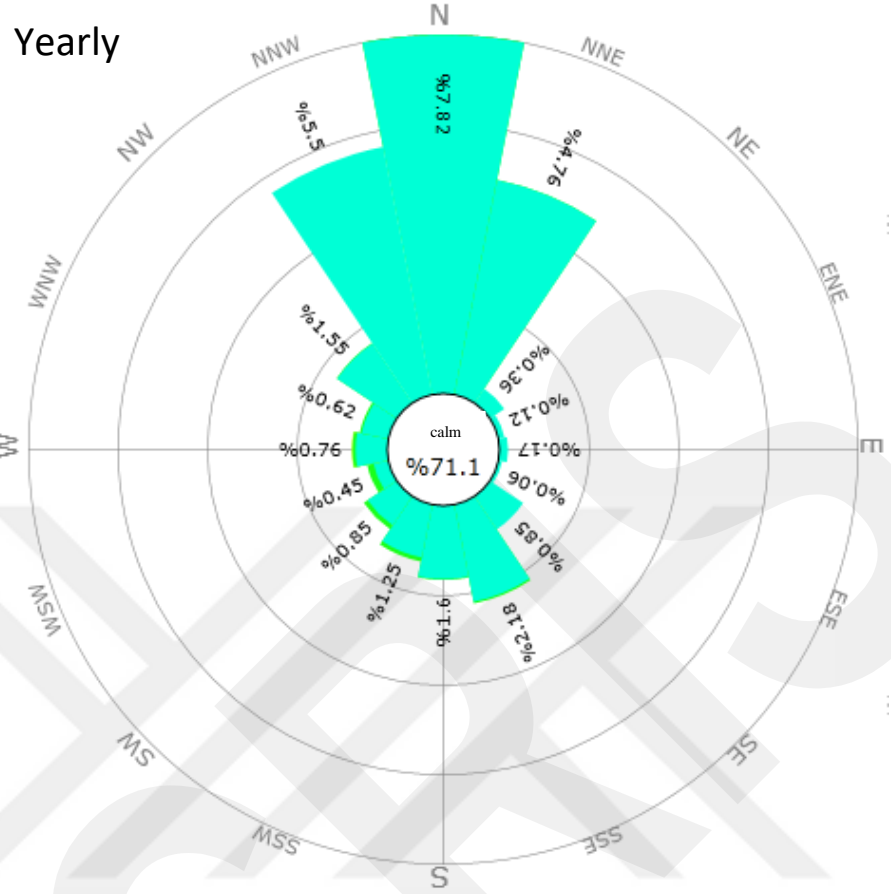


Figure (A-15) wave rose for kuşadası

**CASE 4**

Table (A-31) CEM parameters

Speed factor	1
Speed tolerance	3.5
Direction tolerance	25 <sup>0</sup>
Maximum speed factor	0
Maximum fetch factor	0

Table (A-32) long-term statistics waves heights

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	Hs	R <sup>2</sup>	Hs (±m) %90 confidence	Tm(sn)	Hs(±m) %90 confidence	Tm(sn)	Hs(±m) %90 confidence	Tm(sn)
SW	$H_s = -0.774 - 0.262 * LN(P(H_s))$	0.955	1.6±0.12	2.9	1.2±0.077	2.6	1±0.065	2.5
WSW	$H_s = -1.199 - 0.345 * LN(P(H_s))$	0.952	1.9±0.135	4	1.4±0.08	3.5	1.1±0.065	3.2
W	$H_s = -1.122 - 0.331 * LN(P(H_s))$	0.862	1.9±0.197	4.7	1.4±0.13	4	1.1±0.12	3.7
WNW	$H_s = -0.634 - 0.242 * LN(P(H_s))$	0.891	1.6±0.201	3.9	1.2±0.131	3.5	1±0.11	3.3
NW	$H_s = -0.114 - 0.140 * LN(P(H_s))$	0.820	1.2±0.193	3.1	0.9±0.141	2.8	0.8±0.125	2.7
NNW	$H_s = 0.171 - 0.097 * LN(P(H_s))$	0.878	1±0.153	2.5	0.9±0.114	2.3	0.8±0.099	2.3

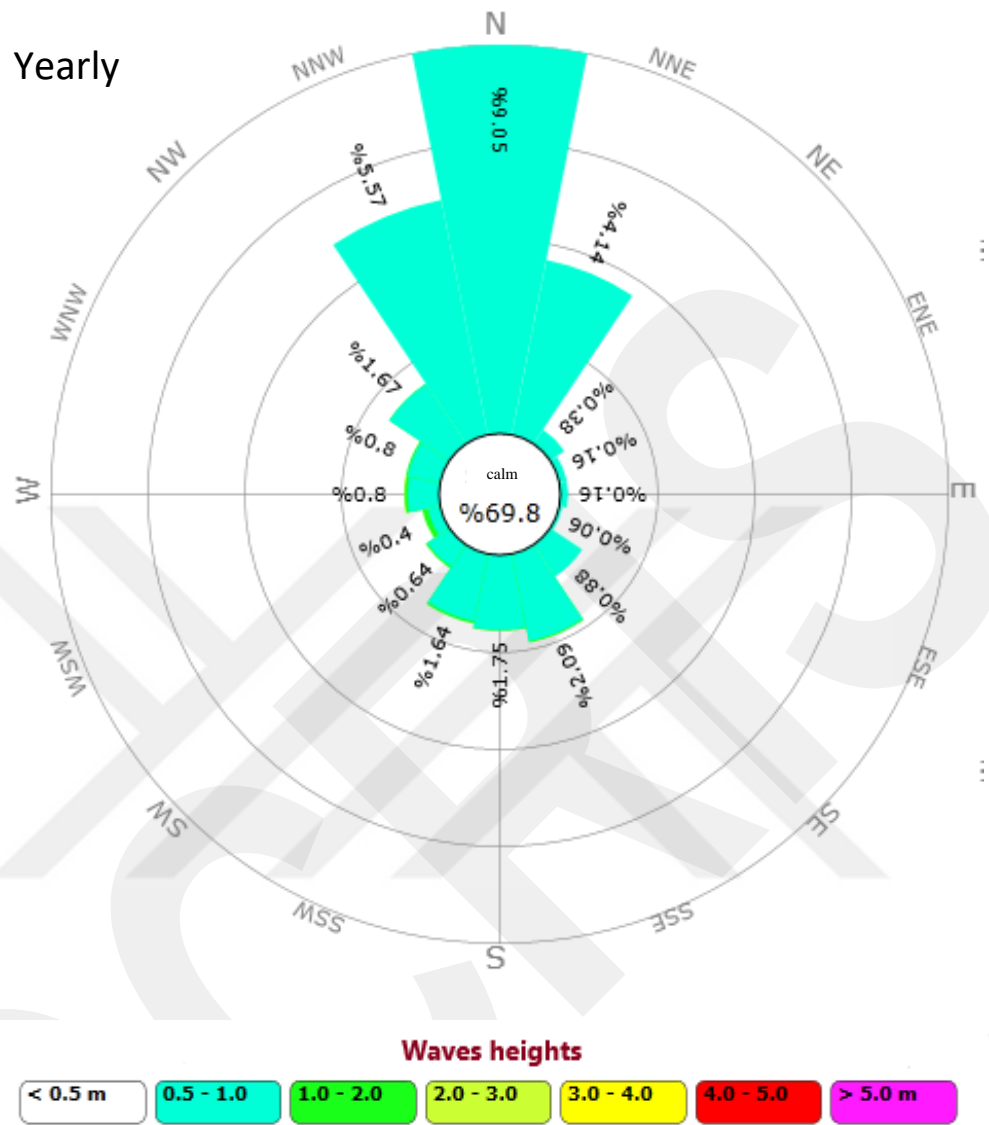


Figure (A-16) wave rose for kuşadası

# YALIKAVAK

Coordinate (37.2 N, 27.3 E)

## CASE 1

Table (A-33) CEM parameters

Speed factor	1
Speed tolerance	2
Direction tolerance	10 <sup>0</sup>
Maximum speed factor	0
Maximum fetch factor	0

Table (A-34) long-term statistics waves heights

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	Hs	R <sup>2</sup>	Hs(±m) %90 confidenc e	Tm(sn)	Hs(±m) %90 confidenc e	Tm(sn)	Hs(±m) %90 confidenc e	Tm(sn)
<b>SSW</b>	Hs=-0.402 - 0.190*LN(P(Hs))	0.984	1.3± <b>0.047</b>	3.1	1± <b>0.032</b>	2.8	0.9± <b>0.028</b>	2.7
<b>SW</b>	Hs=-0.726 - 0.260*LN(P(Hs))	0.985	1.6± <b>0.054</b>	3.4	1.2± <b>0.033</b>	3	1± <b>0.028</b>	2.8
<b>WSW</b>	Hs=-1.284 - 0.395*LN(P(Hs))	0.99	2.3± <b>0.052</b>	4.5	1.7± <b>0.032</b>	3.9	1.4± <b>0.026</b>	3.6
<b>W</b>	Hs=-1.146 - 0.359*LN(P(Hs))	0.995	2.1± <b>0.033</b>	4.3	1.5± <b>0.021</b>	3.7	1.3± <b>0.018</b>	3.4
<b>WNW</b>	Hs=-0.499 - 0.292*LN(P(Hs))	0.941	2.2± <b>0.129</b>	4.3	1.7± <b>0.085</b>	3.9	1.5± <b>0.07</b>	3.7
<b>NW</b>	Hs=0.026 - 0.223*LN(P(Hs))	0.945	2.1± <b>0.107</b>	4.4	1.7± <b>0.079</b>	4.1	1.5± <b>0.069</b>	3.9
<b>NNW</b>	Hs=0.232 - 0.153*LN(P(Hs))	0.916	1.6± <b>0.129</b>	3.3	1.4± <b>0.097</b>	3.1	1.3± <b>0.086</b>	3
<b>N</b>	Hs=0.136 - 0.120*LN(P(Hs))	0.91	1.2± <b>0.144</b>	2.5	1± <b>0.106</b>	2.3	0.9± <b>0.091</b>	2.3
<b>NNE</b>	Hs=-0.122 - 0.109*LN(P(Hs))	0.951	0.9± <b>0.103</b>	2.3	0.7± <b>0.07</b>	2.1	0.6± <b>0.059</b>	2.1
<b>NE</b>	Hs=-0.074 - 0.065*LN(P(Hs))	0.965	0.5± <b>0.28</b>	2	0.4± <b>0.185</b>	1.8	0.4± <b>0.158</b>	1.7
<b>ENE</b>	Hs=-0.061 - 0.056*LN(P(Hs))	0.968	0.4± <b>0.205</b>	1.9	0.4± <b>0.148</b>	1.7	0.3± <b>0.141</b>	1.6
<b>E</b>	Hs=-0.111 - 0.068*LN(P(Hs))	0.979	<b>0.5±0.059</b>	2	0.4± <b>0.045</b>	1.8	0.3± <b>0.045</b>	1.7
<b>ESE</b>	Hs=-0.265 - 0.116*LN(P(Hs))	0.989	0.8± <b>0.031</b>	2.2	0.6± <b>0.022</b>	2	0.5± <b>0.021</b>	1.9

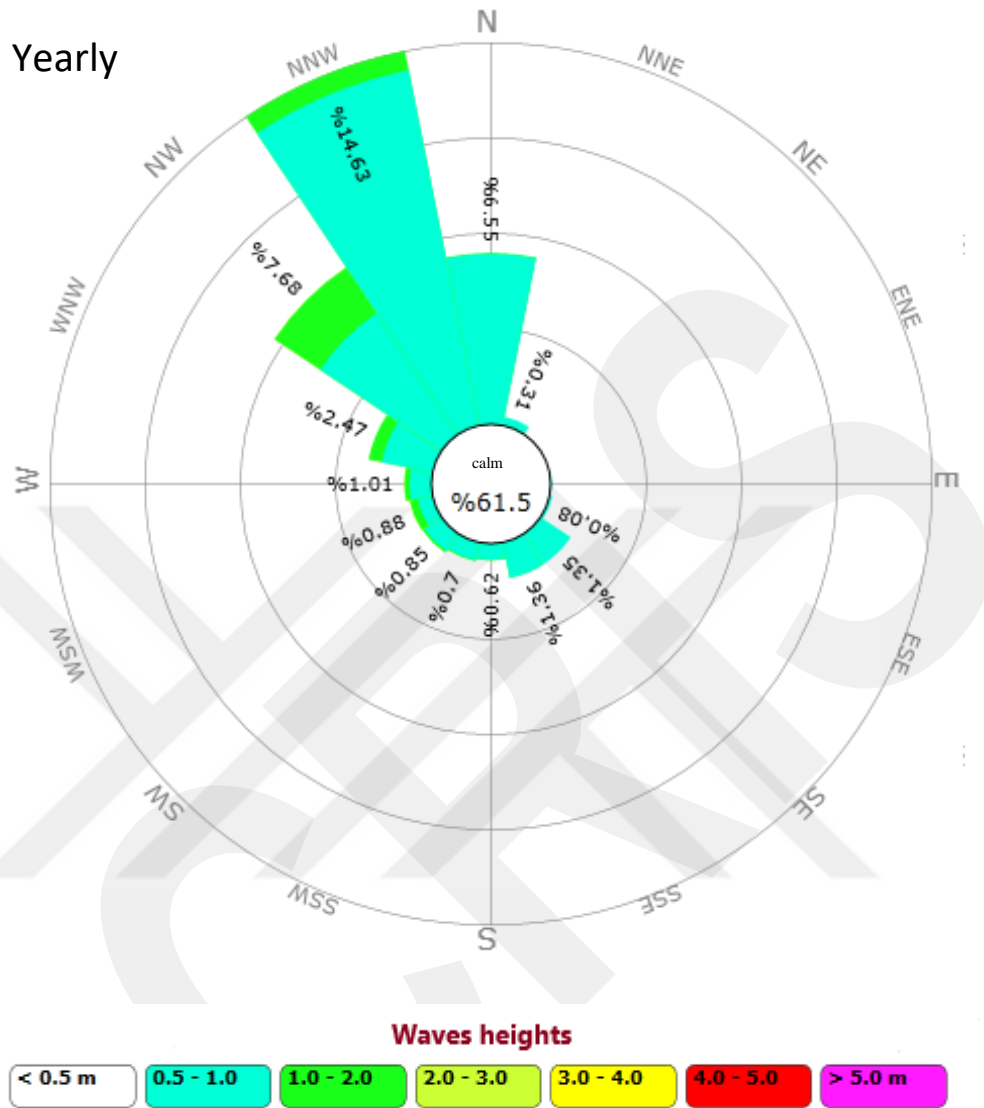


Figure (A-17) wave rose for yalikhavak

CASE 2

Table (A-35) CEM parameters

Speed factor	1
Speed tolerance	3.5
Direction tolerance	25 <sup>0</sup>
Maximum speed factor	0
Maximum fetch factor	0

Table (A-36) long-term statistics waves heights

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	Hs	R <sup>2</sup>	Hs (±m)	Tm(sn)	Hs(±m)	Tm(sn)	Hs(±m)	Tm(sn)
			%90 confidence		%90 confidence		%90 confidence	
<b>SSW</b>	Hs=-0.402 - 0.190*LN(P(Hs))	0.958	1.4± <b>0.101</b>	3.2	1.1± <b>0.066</b>	2.9	0.9± <b>0.053</b>	2.7
<b>SW</b>	Hs=-0.726 - 0.260*LN(P(Hs))	0.996	1.6± <b>0.034</b>	3.4	1.2± <b>0.021</b>	2.9	1± <b>0.017</b>	2.7
<b>WSW</b>	Hs=-1.284 - 0.395*LN(P(Hs))	0.965	1.9± <b>0.095</b>	4.1	1.4± <b>0.058</b>	3.6	1.2± <b>0.048</b>	3.3
<b>W</b>	Hs=-1.146 - 0.359*LN(P(Hs))	0.875	2± <b>0.164</b>	4.1	1.4± <b>0.102</b>	3.6	1.2± <b>0.092</b>	3.3
<b>WNW</b>	Hs=-0.499 - 0.292*LN(P(Hs))	0.969	1.4± <b>0.082</b>	3.7	1.1± <b>0.056</b>	3.3	1± <b>0.047</b>	3.2
<b>NW</b>	Hs=0.026 - 0.223*LN(P(Hs))	0.962	1.7± <b>0.088</b>	4	1.4± <b>0.065</b>	3.7	1.2± <b>0.056</b>	3.6
<b>NNW</b>	Hs=0.232 - 0.153*LN(P(Hs))	0.757	1.4± <b>0.331</b>	3.1	1.2± <b>0.25</b>	2.9	1.1± <b>0.217</b>	2.9
<b>N</b>	Hs=0.136 - 0.120*LN(P(Hs))	0.919	1.2± <b>0.133</b>	2.5	1± <b>0.097</b>	2.3	0.9± <b>0.083</b>	2.3
<b>NNE</b>	Hs=-0.122 - 0.109*LN(P(Hs))	0.92	1± <b>0.226</b>	2.4	0.8± <b>0.151</b>	2.2	0.7± <b>0.12</b>	2.1
<b>NE</b>	Hs=-0.074 - 0.065*LN(P(Hs))	0.945	0.8± <b>0.242</b>	2.4	0.6± <b>0.151</b>	2.1	0.6± <b>0.116</b>	2
<b>ENE</b>	Hs=-0.061 - 0.056*LN(P(Hs))	0.924	0.8± <b>0.936</b>	2.6	0.6± <b>0.602</b>	2.3	0.5± <b>0.465</b>	2.1
<b>E</b>	Hs=-0.111 - 0.068*LN(P(Hs))	0.989	1.1± <b>0.518</b>	2.6	0.8± <b>0.326</b>	2.3	0.7± <b>0.245</b>	2.2
<b>ESE</b>	Hs=-0.265 - 0.116*LN(P(Hs))	0.835	0.7± <b>0.193</b>	2.1	0.6± <b>0.124</b>	2	0.5± <b>0.104</b>	1.9

Yearly

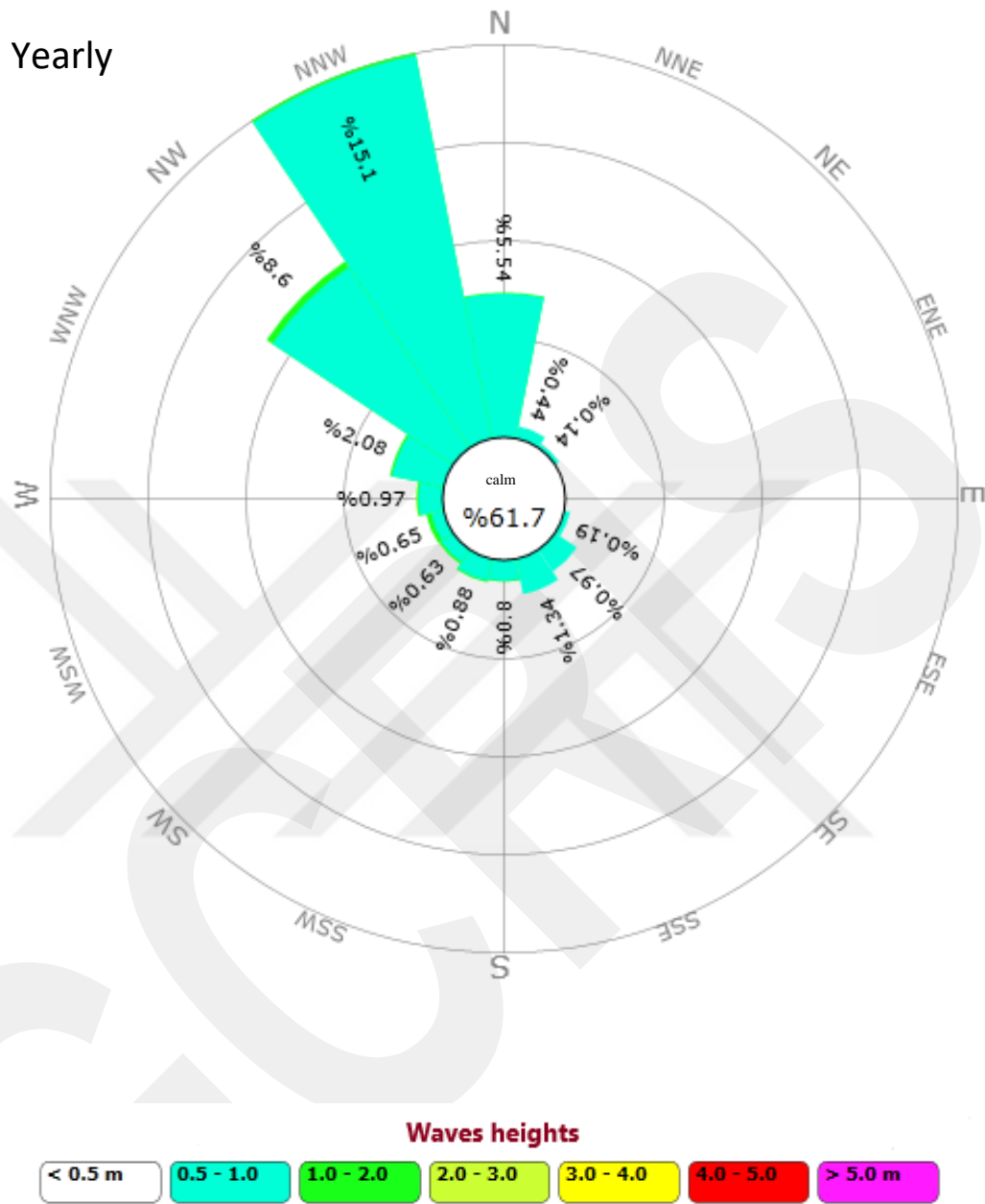


Figure (A-18) wave rose for yalikhavak

# TURGUTREIS

Coordinate (37 N, 27.2 E)

## CASE 1

Table (A-37) CEM parameters

Speed factor	1
Speed tolerance	2
Direction tolerance	10 <sup>0</sup>
Maximum speed factor	0
Maximum fetch factor	0

Table (A-38) long-term statistics waves heights

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	Hs	R <sup>2</sup>	Hs(±m) %90 confidence	Tm(sn)	Hs(±m) %90 confidence	Tm(sn)	Hs(±m) %90 confidence	Tm(sn)
<b>SSE</b>	0.021 - 0.124*LN(P(Hs))	0.888	1.1± <b>0.126</b>	2.4	0.9± <b>0.091</b>	2.3	0.9± <b>0.08</b>	2.2
<b>S</b>	-0.173 - 0.135*LN(P(Hs))	0.941	1.1± <b>0.089</b>	2.4	0.8± <b>0.06</b>	2.2	0.7± <b>0.052</b>	2.1
<b>SSW</b>	-0.323 - 0.148*LN(P(Hs))	0.991	1± <b>0.057</b>	2	0.8± <b>0.036</b>	1.9	0.7± <b>0.028</b>	1.8
<b>SW</b>	-0.304 - 0.162*LN(P(Hs))	0.959	1.2± <b>0.077</b>	2.7	0.9± <b>0.05</b>	2.5	0.8± <b>0.043</b>	2.4
<b>WSW</b>	-0.407 - 0.198*LN(P(Hs))	0.972	1.4± <b>0.067</b>	3.2	1.1± <b>0.045</b>	2.8	0.9± <b>0.039</b>	2.7
<b>W</b>	-0.463 - 0.196*LN(P(Hs))	0.983	1.3± <b>0.061</b>	2.8	1± <b>0.04</b>	2.5	0.9± <b>0.034</b>	2.4
<b>WNW</b>	-0.196 - 0.158*LN(P(Hs))	0.945	1.2± <b>0.114</b>	3	1± <b>0.076</b>	2.7	0.9± <b>0.062</b>	2.6
<b>NW</b>	-0.016 - 0.250*LN(P(Hs))	0.975	2.3± <b>0.075</b>	4.4	1.9± <b>0.055</b>	4.1	1.7± <b>0.049</b>	3.9
<b>NNW</b>	0.286 - 0.210*LN(P(Hs))	0.939	2.2± <b>0.113</b>	4.2	1.9± <b>0.086</b>	4	1.7± <b>0.077</b>	3.8

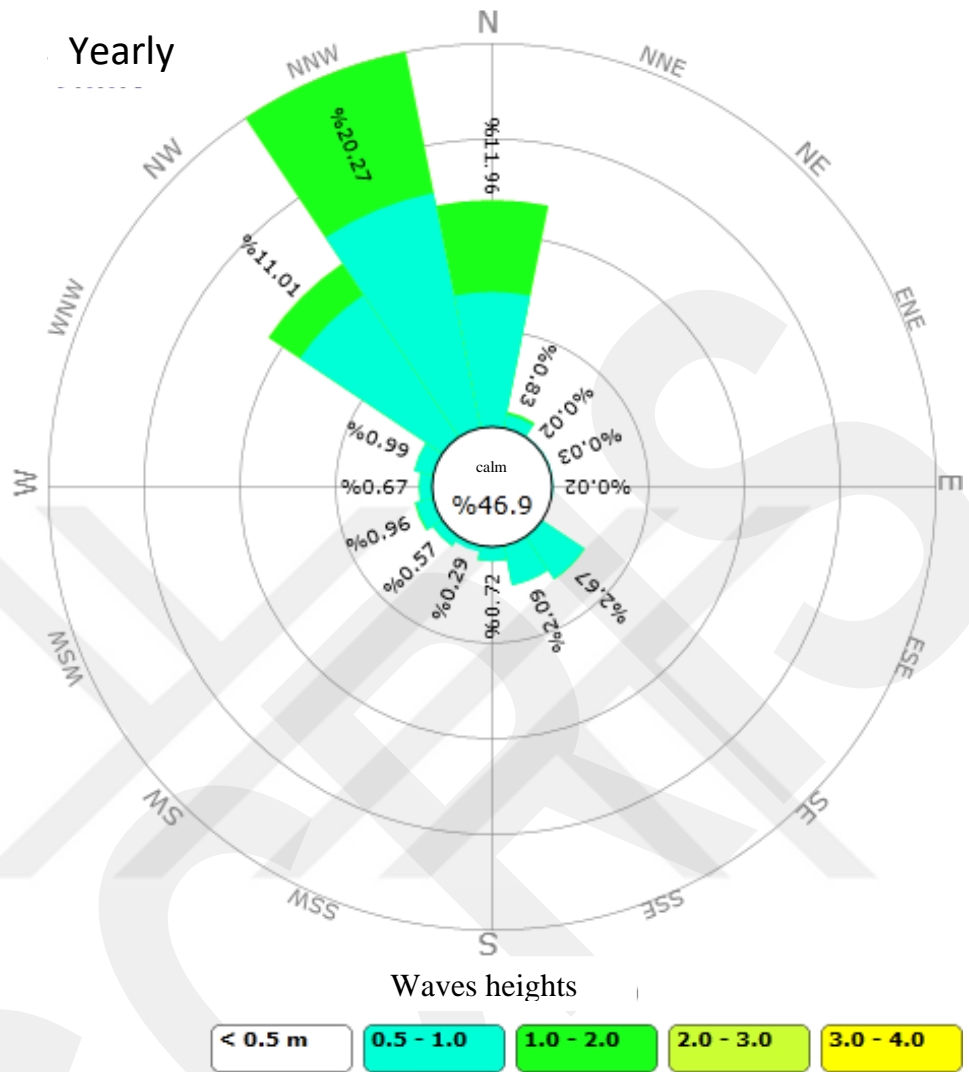


Figure (A-19) wave rose for turgutreis

**CASE 2**

Table (A-39) CEM parameters

Speed factor	1
Speed tolerance	3.5
Direction tolerance	25 <sup>0</sup>
Maximum speed factor	0
Maximum fetch factor	0

Table (A-40) long-term statistics waves heights

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	Hs	R <sup>2</sup>	Hs (±m) %90 confidence	Tm(sn)	Hs(±m) %90 confidence	Tm(sn)	Hs(±m) %90 confidence	Tm(sn)
<b>SSE</b>	Hs=-0.136 - 0.155*LN(P(Hs))	0.87	1.3± <b>0.221</b>	2.5	1± <b>0.151</b>	2.3	0.9± <b>0.123</b>	2.3
<b>S</b>	Hs=-0.122 - 0.129*LN(P(Hs))	0.867	1.1± <b>0.16</b>	2.4	0.8± <b>0.108</b>	2.2	0.8± <b>0.091</b>	2.2
<b>SSW</b>	Hs=-0.442 - 0.197*LN(P(Hs))	0.937	1.3± <b>0.197</b>	2.2	1± <b>0.126</b>	2	0.9± <b>0.098</b>	1.9
<b>SW</b>	Hs=-0.200 - 0.125*LN(P(Hs))	0.953	0.9± <b>0.091</b>	2.5	0.7± <b>0.059</b>	2.3	0.6± <b>0.049</b>	2.2
<b>WSW</b>	Hs=-0.436 - 0.204*LN(P(Hs))	0.986	1.4± <b>0.055</b>	3.2	1.1± <b>0.036</b>	2.9	0.9± <b>0.03</b>	2.7
<b>W</b>	Hs=-0.058 - 0.121*LN(P(Hs))	0.906	1± <b>0.129</b>	2.6	0.8± <b>0.09</b>	2.4	0.8± <b>0.077</b>	2.3
<b>WNW</b>	Hs=-0.121 - 0.166*LN(P(Hs))	0.957	1.4± <b>0.105</b>	3.1	1.1± <b>0.074</b>	2.9	1± <b>0.062</b>	2.8
<b>NW</b>	Hs=0.148 - 0.169*LN(P(Hs))	0.949	1.7± <b>0.091</b>	3.9	1.4± <b>0.069</b>	3.7	1.3± <b>0.062</b>	3.5
<b>NNW</b>	Hs=0.241 - 0.194*LN(P(Hs))	0.868/	2± <b>0.201</b>	4.1	1.7± <b>0.155</b>	3.8	1.6± <b>0.137</b>	3.7

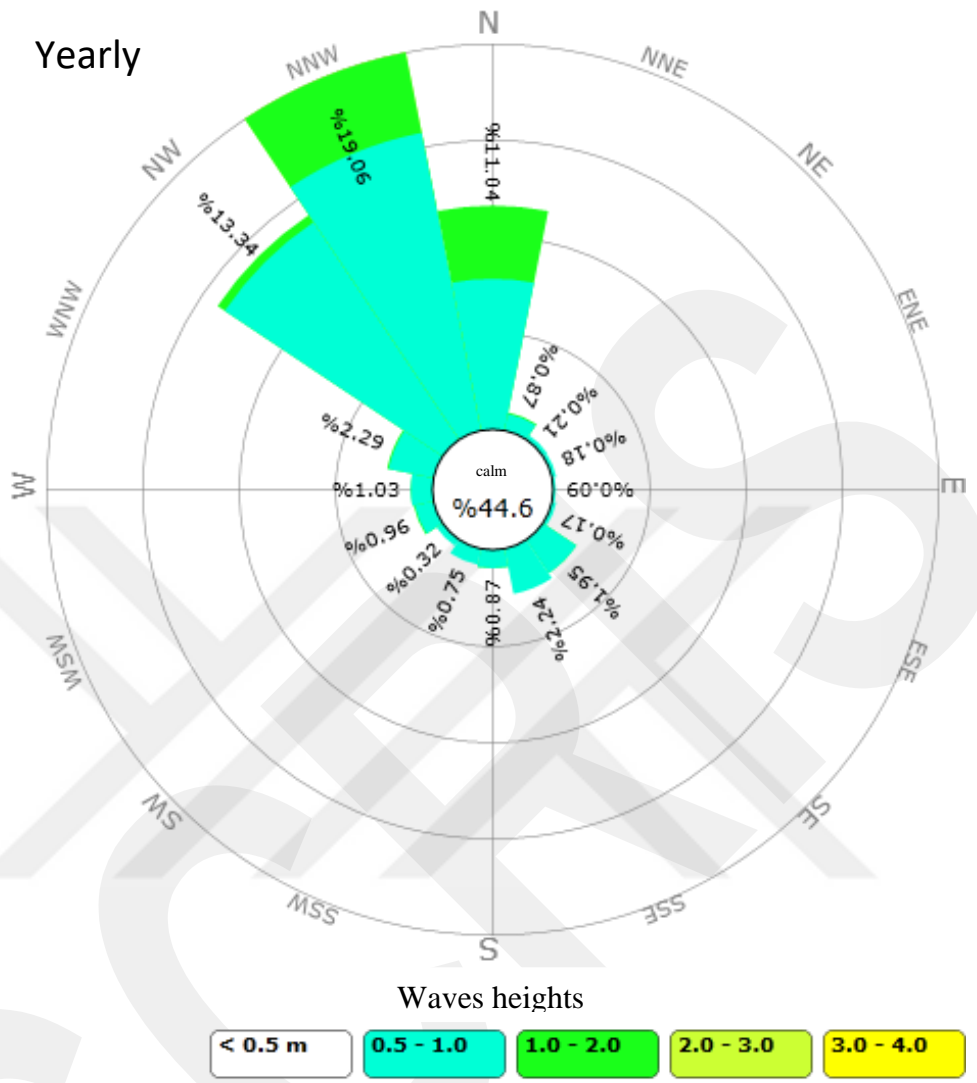


Figure (A-20) wave rose for turgutreis

# MARMARIS

Coordinate (36.7N, 28.4E)

## CASE 1

Table (A-41) CEM parameters

Speed factor	1
Speed tolerance	2
Direction tolerance	10 <sup>0</sup>
Maximum speed factor	0
Maximum fetch factor	0

Table (A-42) long-term statistics waves heights

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	Hs	R <sup>2</sup>	Hs (±m) %/90 confidence e	Tm(sn)	Hs (±m) %/90 confidence e	Tm(sn)	Hs (±m) %/90 confidence e	Tm(sn)
NE	-0.261 - 0.114*LN(P(Hs))	0.953	0.8±0.115	1.7	0.6±0.07	1.5	0.5±0.056	1.4
ENE	-0.952 - 0.254*LN(P(Hs))	0.759	1.4±0.291	2.1	0.9±0.17	1.8	0.8±0.147	1.7
E	-0.541 - 0.185*LN(P(Hs))	0.986	1.1±0.049	2.6	0.8±0.029	2.4	0.7±0.024	2.2
ESE	-2.170 - 0.586*LN(P(Hs))	0.823	3.2±0.345	6.1	2.2±0.211	5.2	1.8±0.174	4.7
SE	-3.150 - 1.211*LN(P(Hs))	0.995	7.2±0.098	10.6	5.9±0.065	9.1	5.1±0.052	8.4
SSE	-3.498 - 1.157*LN(P(Hs))	0.986	7±0.147	9.9	5.1±0.094	8.4	4.3±0.073	7.7
S	-4.393 - 1.100*LN(P(Hs))	0.966	5.6±0.222	8.8	3.8±0.129	7.2	3.1±0.095	6.4
SSW	-4.445 - 1.007*LN(P(Hs))	0.910	4.7±0.32	6.6	3.1±0.168	5.4	2.4±0.117	4.8
SW	-1.509 - 0.360*LN(P(Hs))	0.917	1.8±0.168	2.1	1.2±0.096	1.9	0.9±0.085	1.7

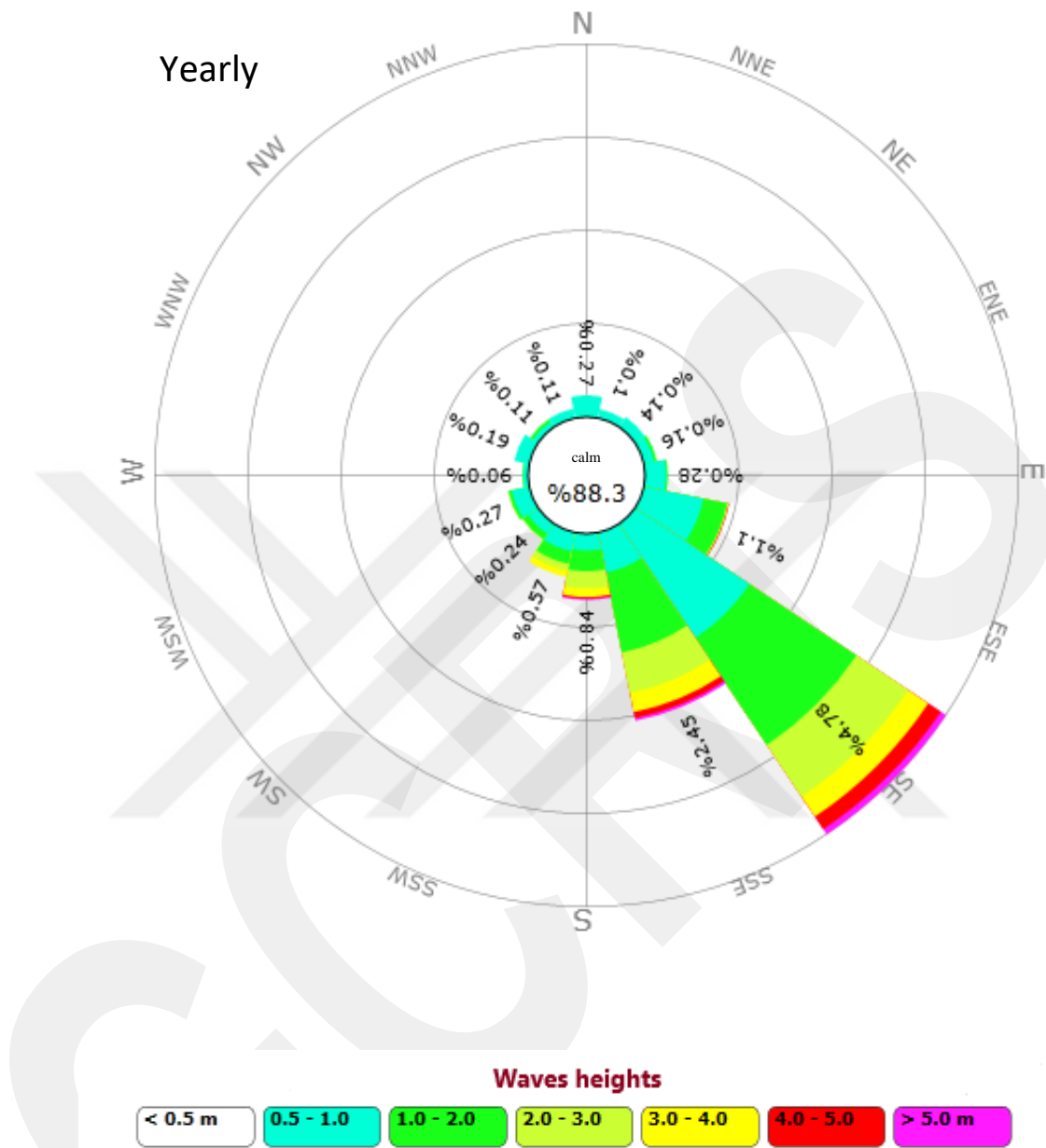


Figure (A-21) wave rose for marmaris

**CASE 2**

Table (A-43) CEM parameters

Speed factor	1
Speed tolerance	3.5
Direction tolerance	25 <sup>0</sup>
Maximum speed factor	0
Maximum fetch factor	0

Table (A-44) long-term statistics waves heights

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	Hs	R <sup>2</sup>	Hs (±m)	Tm (sn)	Hs (±m)	Tm (sn)	Hs (±m)	Tm (sn)
			%90 confidence		%90 confidence		%90 confidence	
NE	-1.125 - 0.334*LN(P(Hs))	0.960	1.9±0.186	2.6	1.4±0.111	2.2	1.1±0.081	2.1
ENE	-0.249 - 0.126*LN(P(Hs))	0.925	0.8±0.313	1.8	0.7±0.202	1.6	0.6±0.157	1.5
E	-2.239 - 0.535*LN(P(Hs))	0.903	2.6±0.582	3.6	1.8±0.374	3.1	1.4±0.308	2.8
ESE	-3.501 - 0.802*LN(P(Hs))	0.896	3.8±0.374	6.7	2.5±0.216	5.5	1.9±0.176	4.8
SE	-2.079 - 0.913*LN(P(Hs))	0.930	4.8±0.309	9.4	4.7±0.207	8.1	4.1±0.166	7.6
SSE	-5.028 - 1.469*LN(P(Hs))	0.980	6.7±0.231	10.9	5.9±0.144	9.1	4.9±0.11	8.3
S	-2.852 - 0.831*LN(P(Hs))	0.870	4.7±0.407	8	3.4±0.237	6.7	2.8±0.177	6.1
SSW	-5.166 - 1.164*LN(P(Hs))	0.944	5.4±0.324	7	3.5±0.174	5.8	2.7±0.117	5.1
SW	-3.407 - 0.738*LN(P(Hs))	0.907	3.3±0.35	2.7	2.1±0.186	2.3	1.6±0.136	2.1

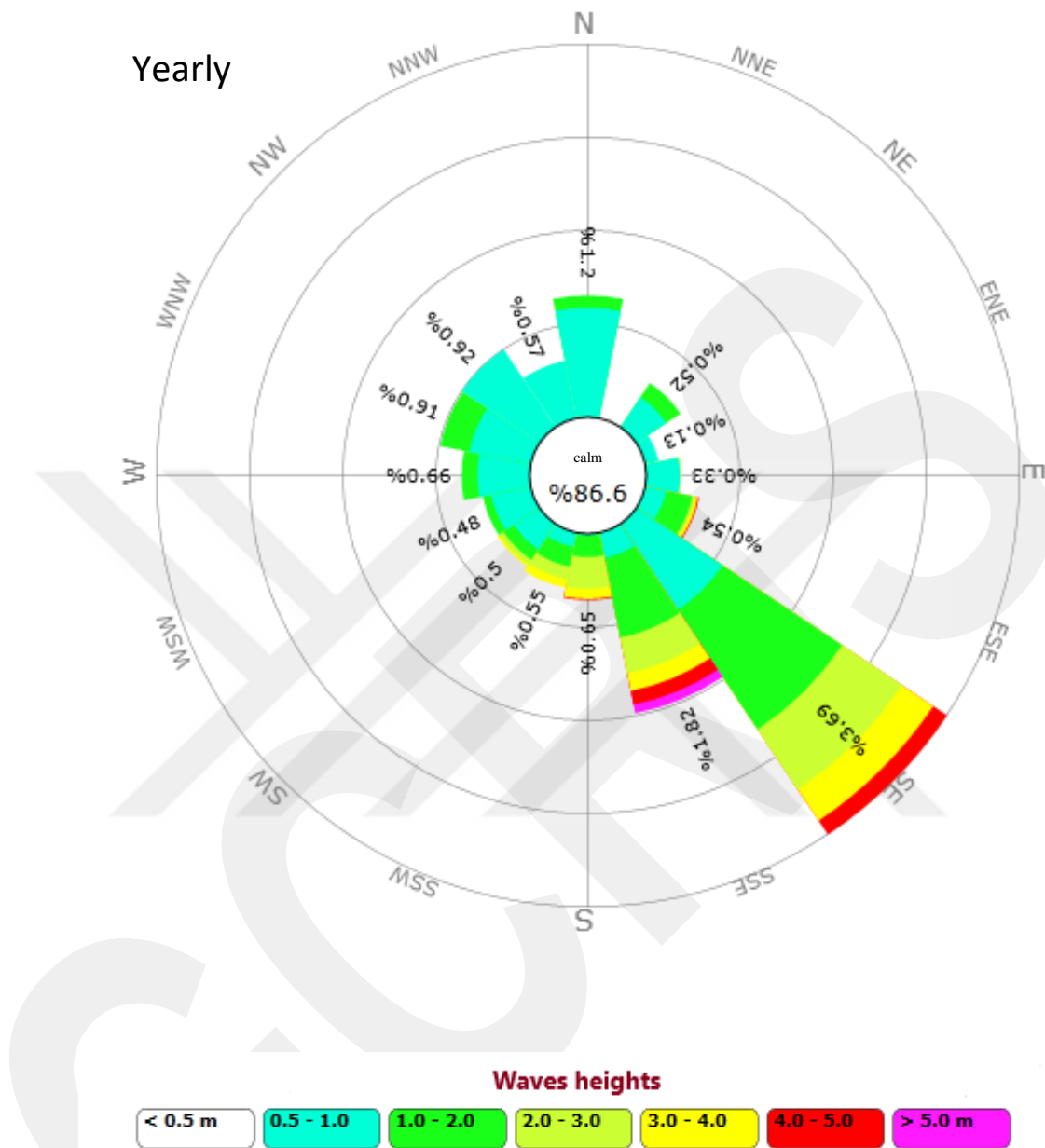


Figure (A-22) wave rose for marmaris

# FETHIYE

Coordinate (36.6N, 28.9E)

## CASE1

Table (A-45) CEM parameters

Speed factor	1
Speed tolerance	2
Direction tolerance	10 <sup>0</sup>
Maximum speed factor	0
Maximum fetch factor	0

Table (A-46) long-term statistics waves heights

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	Hs	R <sup>2</sup>	Hs(±m) %90 confidenc e	Tm(sn)	Hs(±m) %90 confidenc e	Tm(sn)	Hs(±m) %90 confidenc e	Tm(sn)
SE	Hs=-2.631 - 0.899*LN(P(Hs))	0.989	5.1± <b>0.112</b>	8.8	4.1± <b>0.072</b>	7.5	3.5± <b>0.056</b>	6.9
SSE	Hs=-2.336 - 0.800*LN(P(Hs))	0.983	4.9± <b>0.123</b>	8.4	3.6± <b>0.078</b>	7.1	3.1± <b>0.061</b>	6.5
S	Hs=-4.133 - 1.048*LN(P(Hs))	0.944	5.4± <b>0.276</b>	8.7	3.7± <b>0.161</b>	7.1	3± <b>0.12</b>	6.3
SSW	Hs=-3.190 - 0.770*LN(P(Hs))	0.966	3.8± <b>0.162</b>	7.2	2.6± <b>0.091</b>	5.9	2± <b>0.070</b>	5.2
SW	Hs=-2.795 - 0.620*LN(P(Hs))	0.903	2.8± <b>0.228</b>	6.4	1.8± <b>0.123</b>	5	1.4± <b>0.102</b>	4.4
WSW	Hs=-2.310 - 0.593*LN(P(Hs))	0.878	3.1± <b>0.309</b>	5.9	2.1± <b>0.181</b>	5	1.7± <b>0.14</b>	4.5
W	Hs=-1.054 - 0.381*LN(P(Hs))	0.930	2.4± <b>0.158</b>	4.6	1.8± <b>0.1</b>	4	1.5± <b>0.081</b>	3.7
WNW	Hs=-0.601 - 0.269*LN(P(Hs))	0.958	1.8± <b>0.095</b>	4	1.4± <b>0.063</b>	3.6	1.2± <b>0.054</b>	3.3
NW	Hs=-0.231 - 0.190*LN(P(Hs))	0.991	1.5± <b>0.046</b>	2.9	1.2± <b>0.032</b>	2.6	1.1± <b>0.026</b>	2.5
NNW	Hs=-0.217 - 0.169*LN(P(Hs))	0.940	1.3± <b>0.115</b>	2.4	1± <b>0.077</b>	2.2	0.9± <b>0.064</b>	2.1

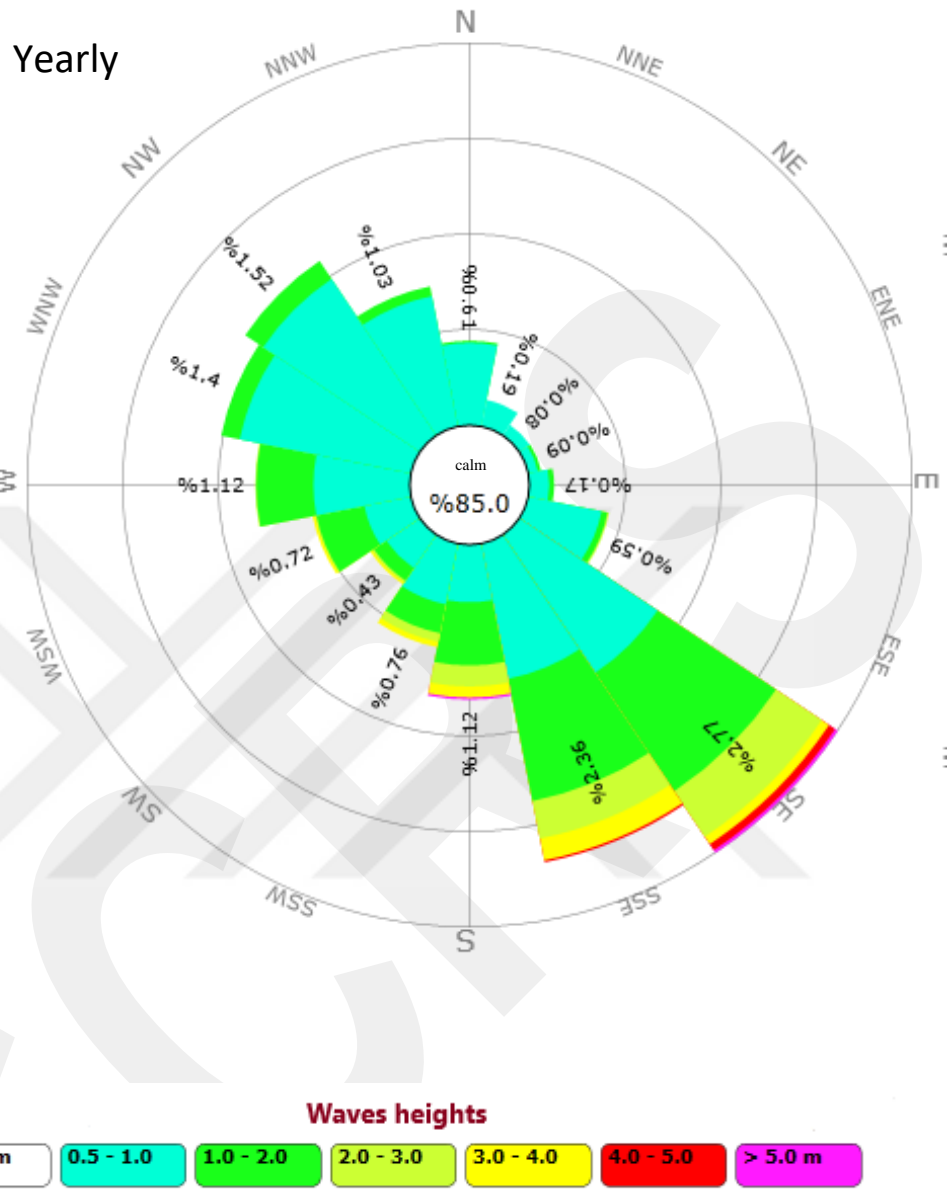


Figure (A-23) wave rose for fethiye

**CASE 2**

Table (A-47) CEM parameters

Speed factor	1
Speed tolerance	3.5
Direction tolerance	25 <sup>0</sup>
Maximum speed factor	0
Maximum fetch factor	0

Table (A-48) long-term statistics waves heights

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	Hs	R <sup>2</sup>	Hs(±m) %90 confidence	Tm(sn)	Hs(±m) %90 confidence	Tm(sn)	Hs(±m) %90 confidence	Tm(sn)
<b>SE</b>	Hs=-2.393 - 0.798*LN(P(Hs))	0.943	<b>4.8±0.249</b>	8.2	<b>3.6±0.157</b>	7	<b>3±0.122</b>	6.4
<b>SSE</b>	Hs=-2.772 - 0.880*LN(P(Hs))	0.928	<b>4.2±0.307</b>	8.6	<b>3.8±0.192</b>	7.3	<b>3.2±0.148</b>	7.3
<b>S</b>	Hs=-3.540 - 0.892*LN(P(Hs))	0.902	<b>4.6±0.322</b>	8	<b>3.1±0.183</b>	6.5	<b>2.5±0.136</b>	5.8
<b>SSW</b>	Hs=-4.452 - 1.020*LN(P(Hs))	0.952	<b>4.8±0.295</b>	8.2	<b>3.2±0.161</b>	6.6	<b>2.5±0.113</b>	5.7
<b>SW</b>	Hs=-4.112 - 0.820*LN(P(Hs))	0.773	<b>3.3±0.521</b>	7	<b>2±0.288</b>	5.3	<b>1.4±0.268</b>	4.4
<b>WSW</b>	Hs=-0.938 - 0.272*LN(P(Hs))	0.909	<b>1.5±0.113</b>	4.2	<b>1.1±0.071</b>	3.6	<b>0.9±0.069</b>	3.3
<b>W</b>	Hs=-1.507 - 0.423*LN(P(Hs))	0.845	<b>2.3±0.261</b>	4.6	<b>1.7±0.16</b>	3.9	<b>1.4±0.134</b>	3.5
<b>WNW</b>	Hs=-0.362 - 0.194*LN(P(Hs))	0.974	<b>1.4±0.072</b>	3.5	<b>1.1±0.049</b>	3.2	<b>1±0.042</b>	3
<b>NW</b>	Hs=-0.362 - 0.227*LN(P(Hs))	0.936	<b>1.7±0.159</b>	3	<b>1.3±0.107</b>	2.7	<b>1.2±0.086</b>	2.6
<b>NNW</b>	Hs=-0.290 - 0.197*LN(P(Hs))	0.966	<b>1.5±0.094</b>	2.5	<b>1.2±0.064</b>	2.3	<b>1±0.054</b>	2.2

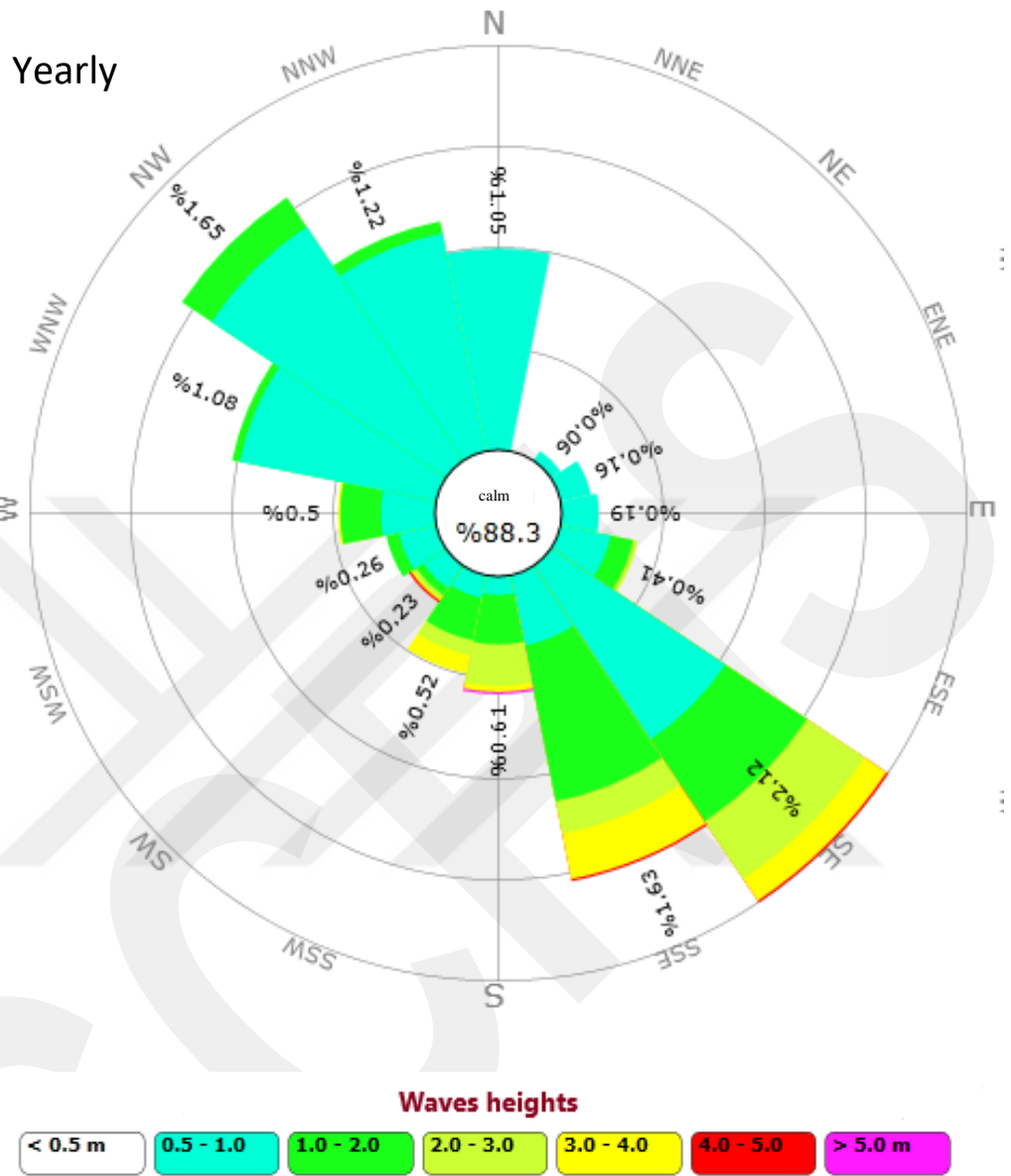


Figure (A-24) wave rose for fethiye

**DATCA:**

**CASE 1**

**Coordinate (36.7N, 27.3E)**

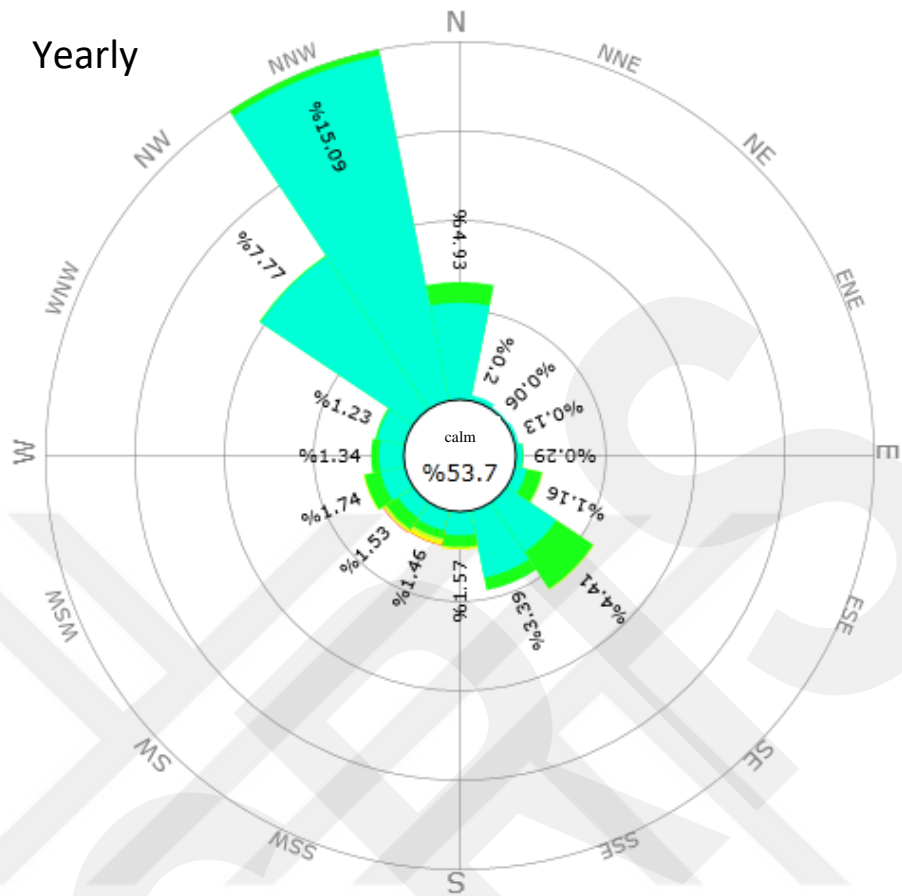
Table (A-49) CEM parameters

Speed factor	1
Speed tolerance	2
Direction tolerance	10 <sup>0</sup>
Maximum speed factor	0
Maximum fetch factor	0

Table (A-50) long-term statistics waves heights

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
	Hs	R <sup>2</sup>	Hs(±m) %90 confidenc e	Tm(sn)	Hs(±m) %90 confidenc e	Tm(sn)	Hs(±m) %90 confidenc e	Tm(sn)
<b>E</b>	Hs=-1.252 - 0.304*LN(P(Hs))	0.969	1.5± <b>0.081</b>	3.4	1± <b>0.05</b>	2.9	0.8± <b>0.048</b>	2.6
<b>ESE</b>	Hs=-0.975 - 0.371*LN(P(Hs))	0.946	2.4± <b>0.111</b>	4.5	1.8± <b>0.071</b>	4	1.5± <b>0.061</b>	3.7
<b>SE</b>	Hs=-0.306 - 0.310*LN(P(Hs))	0.915	2.5± <b>0.169</b>	4.3	2± <b>0.117</b>	3.9	1.8± <b>0.097</b>	3.8
<b>SSE</b>	Hs=-0.144 - 0.205*LN(P(Hs))	0.895	1.7± <b>0.161</b>	3.1	1.4± <b>0.112</b>	2.9	1.2± <b>0.093</b>	2.8
<b>S</b>	Hs=-2.002 - 0.610*LN(P(Hs))	0.967	3.5± <b>0.144</b>	4	2.6± <b>0.088</b>	3.5	2.1± <b>0.07</b>	3.3
<b>SSW</b>	Hs=-3.376 - 0.935*LN(P(Hs))	0.963	4.8± <b>0.207</b>	8	3.6± <b>0.124</b>	6.7	3± <b>0.094</b>	6.1
<b>SW</b>	Hs=-3.099 - 0.865*LN(P(Hs))	0.973	4.8± <b>0.169</b>	7.5	3.4± <b>0.103</b>	6.3	2.8± <b>0.081</b>	5.7
<b>WSW</b>	Hs=-1.785 - 0.567*LN(P(Hs))	0.954	3.4± <b>0.17</b>	4.7	2.5± <b>0.109</b>	4.1	2.1± <b>0.089</b>	3.8
<b>W</b>	Hs=-0.586 - 0.275*LN(P(Hs))	0.958	1.9± <b>0.109</b>	3.6	1.5± <b>0.07</b>	3.2	1.3± <b>0.056</b>	3.1
<b>WNW</b>	Hs=-0.506 - 0.233*LN(P(Hs))	0.928	1.6± <b>0.14</b>	3	1.2± <b>0.092</b>	2.8	1.1± <b>0.077</b>	2.7
<b>NW</b>	Hs=0.002 - 0.174*LN(P(Hs))	0.882	1.6± <b>0.195</b>	2.9	1.3± <b>0.145</b>	2.8	1.2± <b>0.127</b>	2.7
<b>NNW</b>	Hs=0.273 - 0.121*LN(P(Hs))	0.888	1.4± <b>0.137</b>	2.8	1.2± <b>0.105</b>	2.7	1.1± <b>0.092</b>	2.6
<b>N</b>	Hs=-0.010 - 0.192*LN(P(Hs))	0.881	1.7± <b>0.191</b>	3.2	1.4± <b>0.137</b>	3	1.3± <b>0.115</b>	2.9
<b>NNE</b>	Hs=-0.741 - 0.215*LN(P(Hs))	0.987	1.2± <b>0.061</b>	3	0.9± <b>0.034</b>	2.6	0.7± <b>0.025</b>	2.4

Yearly



**Waves heights**

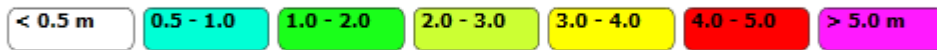


Figure (A-25) wave rose for datca

## CASE 2

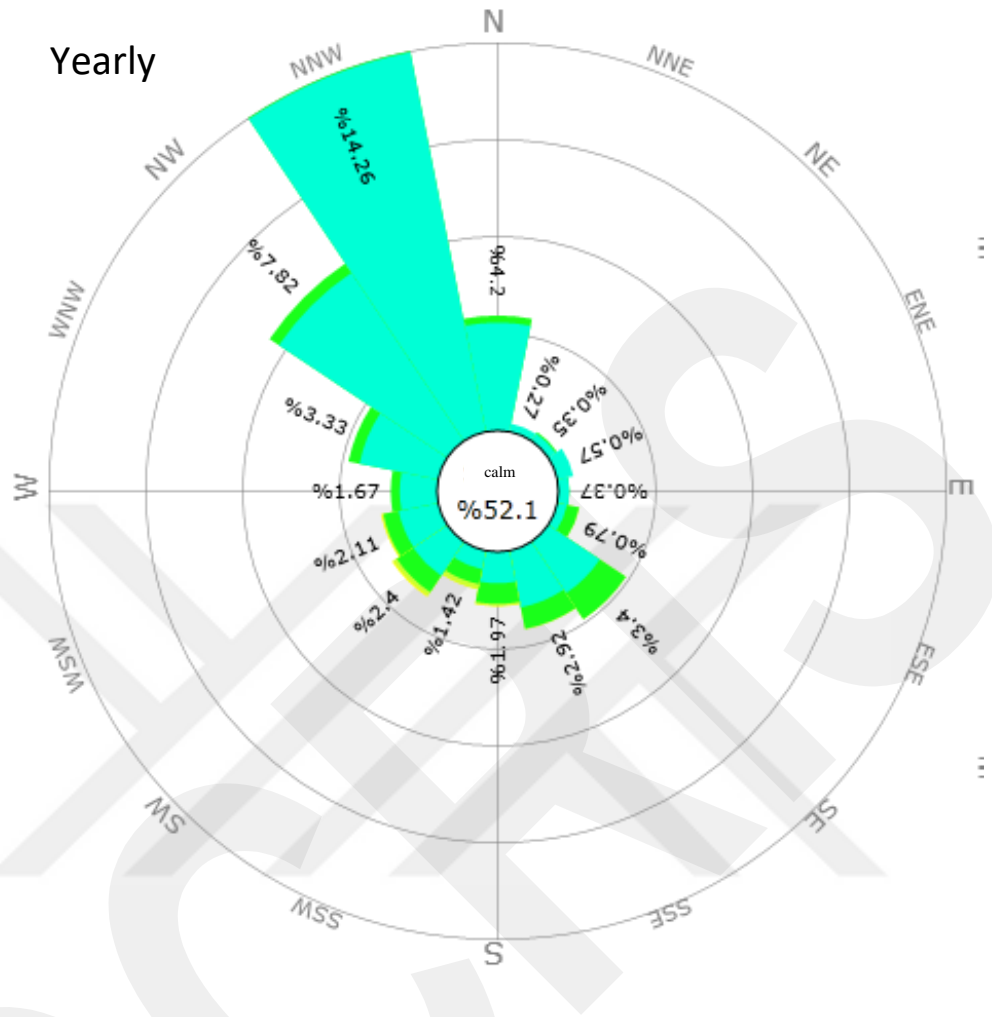
Table (A-51) CEM parameters

Speed factor	1
Speed tolerance	3.5
Direction tolerance	25 <sup>0</sup>
Maximum speed factor	0
Maximum fetch factor	0

Table (A-52) long-term statistics waves heights

Direction	Equation		1 hour/year		5 hours/year		10 hour/year	
			Hs (±m) %90 confidenc e	Tm(sn)	Hs(±m) %90 confidenc e	Tm(sn)	Hs(±m) %90 confidenc e	Tm(sn)
	Hs	R <sup>2</sup>						
E	Hs=-0.735 - 0.217*LN(P(Hs))	0.928	1.2± <b>0.152</b>	3.2	0.9± <b>0.101</b>	2.8	0.7± <b>0.092</b>	2.5
ESE	Hs=-1.088 - 0.358*LN(P(Hs))	0.958	2.2± <b>0.114</b>	4.3	1.6± <b>0.075</b>	3.8	1.3± <b>0.066</b>	3.5
SE	Hs=-0.296 - 0.274*LN(P(Hs))	0.9	2.2± <b>0.176</b>	4.1	1.8± <b>0.121</b>	3.7	1.6± <b>0.101</b>	3.6
SSE	Hs=-0.800 - 0.372*LN(P(Hs))	0.966	2.6± <b>0.143</b>	3.6	2± <b>0.095</b>	3.3	1.7± <b>0.077</b>	3.1
S	Hs=-1.360 - 0.490*LN(P(Hs))	0.975	3.1± <b>0.128</b>	3.8	2.3± <b>0.082</b>	3.4	2± <b>0.066</b>	3.2
SSW	Hs=-2.174 - 0.675*LN(P(Hs))	0.958	4± <b>0.177</b>	7	2.9± <b>0.109</b>	6	2.4± <b>0.085</b>	5.5
SW	Hs=-1.754 - 0.615*LN(P(Hs))	0.99	3.8± <b>0.08</b>	6.7	2.8± <b>0.051</b>	5.8	2.4± <b>0.042</b>	5.4
WSW	Hs=-1.806 - 0.573*LN(P(Hs))	0.943	3.4± <b>0.231</b>	4.7	2.5± <b>0.149</b>	4.1	2.1± <b>0.121</b>	3.9
W	Hs=-0.343 - 0.231*LN(P(Hs))	0.937	1.8± <b>0.137</b>	3.4	<b>1.4±0.093</b>	3.1	1.2± <b>0.077</b>	3
WNW	Hs=0.009 - 0.157*LN(P(Hs))	0.85	1.3± <b>0.195</b>	2.9	1.1± <b>0.138</b>	2.7	1± <b>0.116</b>	2.7
NW	Hs=0.037 - 0.177*LN(P(Hs))	0.962	1.6± <b>0.127</b>	2.9	1.4± <b>0.094</b>	2.8	1.2± <b>0.081</b>	2.7
NNW	Hs=0.242 - 0.119*LN(P(Hs))	0.791	1.3± <b>0.266</b>	2.8	1.1± <b>0.202</b>	2.7	1± <b>0.175</b>	2.6
N	Hs=-0.005 - 0.171*LN(P(Hs))	0.847	1.5± <b>0.223</b>	3.1	1.3± <b>0.159</b>	2.9	1.2± <b>0.133</b>	2.8
NNE	Hs=-0.443 - 0.165*LN(P(Hs))	0.891	1.1± <b>0.225</b>	2.9	0.8± <b>0.134</b>	2.5	0.7± <b>0.1</b>	2.4

Yearly



**Waves heights**

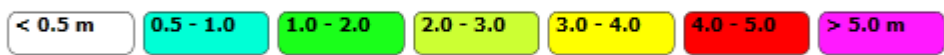


Figure (A-26) wave rose for datca

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