WIND AND SWELL WAVE CLIMATE FOR TURKISH COAST OF THE AEGEAN AND MEDITERRANEAN SEA

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ABSTRACT

WIND AND SWELL WAVE CLIMATE FOR THE AEGEAN AND THE MEDITERRANEAN SEA

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The swell waves which are an important component of wind generated waves have significant effects on small craft and fisheries. The swell wave climate has an important role in the design and operation of fishing harbors and harbors for small craft. Despite this fact the swell wave climate is not well known for the Turkish coasts. The purpose of the present study was to identify the swell wave climate along the Aegean and Mediterranean Sea coastline of Türkiye. For this purpose wind and swell wave data for a 72 months period is obtained from ECMWF for the analysis. And the data are analyzed for twenty one locations selected along the Turkish coast. For every location the wind and swell wave roses, significant swell wave height versus Mean period of primary swell relations, extreme probability distribution and log-linear cumulative probability distribution are presented. Also some extreme swell events in the Aegean and Mediterranean Sea occurred in the data period are presented for a better understanding of generation and propagation of swell waves.

The results showed that the swell wave activity and severity is higher in the Aegean and Mediterranean Sea coastline of Türkiye. The investigation of extreme swell events provided that the swell waves occur and diminish in a relatively short duration and the data available from ECMWF which is provided for 12 hour intervals is not sensitive to time enough for the investigation of swell wave occurrence and propagation. The significant swell wave height versus Mean period of primary swell relations and analysis on period of swell waves showed that the swell wave periods could reach up to 12 seconds in the Western and Southern shores of Türkiye.

Keywords: Wind Climate, Swell Climate, Aegean and Mediterranean Sea, Swell Propagation

ÖZ

EGE DENİZİ VE AKDENİZ'DE RÜZGAR VE SOLUĞAN DALGA İKLİMİ

DEREBAY, Saygın Kemal

Yüksek Lisans, İnşaat Mühendisliği Bölümü

Tez Yöneticisi: Yrd. Doç. Dr. Ahmet Cevdet Yalçıner

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Rüzgar kaynaklı dalgaların önemli bir kesimini oluşturan soluğan dalgalar, balıkçı barınakları ve küçük deniz araçları üzerinde önemli etkilere sahiptir. Soluğan dalga iklimi balıkçı barınakları ve küçük limanların tasarımında önemli yere sahiptir. Bununla beraber Türkiye kıyılarında soluğan dalga iklimi iyi bilinmemektedir. Bu çalışmanın amacı Türkiyenin Ege Denizi ve Akdeniz kıyılarındaki soluğan dalga ikliminin açığa çıkarılmasıdır. Bu amaçla ECMWF (Avrupa Orta Vadeli Tahminler Merkezi) tarafından 72 ay süreli veri sağlanmıştır. Elde edilen veri Türkiye'nin Ege Denizi ve Akdeniz kıyıları boyunca seçilen yirmibir bölgede incelenmiştir. Her bölge için rüzgar ve soluğan dalga gülleri, belirgin dalga yüksekliğine karşılık ortalama ana soluğan dalga periyodu ilişkisi, en yüksek değerler istatistiği analizi ve log-lineer toplam dağılımları sunulmuştur.

Sonuçlar göstermektedir ki, Akdeniz kıyılarında soluğan dalga aktivitesi ve şiddeti daha yüksektir. Uç soluğan dalga olayları incelendiğinde soluğan dalgaların kısa sürede oluşup kayboldukları görülmüştür. Bu nedenle ECMWF tarafından sağlanan 12 saat aralıklı veri soluğan dalgaların oluşumunu ve dağılımını incelemek için yeterli olamamaktadır. Belirgin dalga yüksekliğine

karşılık ortalama ana soluğan dalga periyodu ilişkisi grafikleri ve soluğan dalga periyodu analizleri sonucunda Türkiyenin batı ve güney kıyılarında soluğan dalga periyodunun 11 saniyeye ulaştığı görülmüştür.

Anahtar Kelimeler: Rüzgar İklimi, Soluğan Dalga İklimi, Ege Denizi ve Akdeniz, Soluğan Dalga Yayılımı

To My Parents

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ABBREVIATIONS AND ACRONYMS

WIND	10 meter wind speed (m/s)
MDPS	Mean direction of primary swell (degrees)
MPPS	Mean period of primary swell (s)
SHPS	Significant height of primary swell (m)
C_0	Wave celerity
L	Wave length
L_0	Wave length at deep water
T	Wave period

CHAPTER 1

INTRODUCTION

1.1. PURPOSE AND SCOPE

The aim of this study is to put forth the wind and especially swell wave climate along the coastline of Aegean and Mediterranean Sea by using satellite and wave model data. The field of study is Aegean and Mediterranean Sea which has an important economical value gaining its importance from mainly tourism industry and transportation. Studies on wave climate of Aegean and Mediterranean Sea along Turkish coasts are very limited and are focused on wind wave and swell wave climate collectively and the swell wave climate have not been scrutinized separately.

The term swell waves refer to wind generated waves that have moved out of their generation zone. Swell waves can travel long distances and show distinct characteristics such as regular heights, periods and directions with rounded crests and troughs. Swell waves are important for small craft harbors and fisheries since they cause harbor tranquility dangerous for small craft. Also swell waves have an important role on cross-shore sediment transport. Period is an important characteristic of swell waves. Since swell waves have larger periods, their penetration through floating structures into the harbor may become severe in terms of wave agitation inside the harbor or resonance phenomenon.

The scope of this study is limited to investigation of wind and swell wave climate along the coastline of Aegean and Mediterranean Sea. The area in scope is analyzed in 21 locations from 39.5˚N 26.0˚E, Edremit to 36.0˚N 35.5˚E, Samandağ. Statistical analyses are carried out for these locations and results are presented by wind and swell wave roses, significant wave height versus Mean period of primary swell relations, extreme probability distribution and log-linear cumulative probability distribution. The results are provided separately for locations and entirely for the region in scope. Also three extreme events are investigated in detail for a visualization of swell wave generation and propagation in Aegean and Mediterranean Sea.

1.2. GEOGRAPHIC LOCATION

The region of study is Aegean and Mediterranean Sea shores of Türkiye. For the purpose of the study, data is obtained from ECMWF [ECMWF, 2006] for the whole Aegean and Mediterranean Sea Basin for 72 months period. Twentyone locations are identified along the Aegean and Mediterranean Sea which are 1.125 arc degree far from each other along the longitude. And the obtained data is analyzed in detail for the selected locations. The twentyone locations are identified as Edremit, Dikili, Seferihisar, Kuşadası, Bodrum, Datça, Dalaman, Fethiye, Kaş, Finke, Kemer, Side, Alanya, Anamur, Silifke, Kazanlı, Karataş, Samandağ, Güzelyurt, Girne and Karpas. There exist over 100 ports and nearly 200 coastal plants in Aegean and Mediterranean Sea, totally [DLH, 2007].

1.3. PREVIOUS STUDIES

Previous works on wave climate of Turkish Aegean and Mediterranean Sea shores is limited mainly because of limitations on obtaining data. The "Turkish Coast Wind and Deep Water Wave Atlas, 1999" (Özhan and Abdalla, [1999] and "15 Region Report" Ergin and Özhan [1985] are the two main works on wave climate research both of which include Aegean and Mediterranean Sea coastline of Türkiye. Where wind speeds and significant wave heights; yearly and seasonal wind and wave roses, monthly means and extreme values, extreme value statistics and also significant wave height vs. mean wave period relations in 30 km intervals along all coast of Türkiye (Özhan and Abdalla, 1999). However neither of the studies mentioned in this section considered swell waves separately.

1.4. METHOD OF STUDY

The method of this study is carried in the following steps; the data gathering, re-arrangement and refining of data, analysis of data in scope and presentation of findings. Data used in this study is obtained from the ECMWF Data Server. [ECMWF, 2006] The data is obtained for the whole Aegean and Mediterranean Sea basin. The data period is between 01.01.2001 to 31.12.2006, totally 72 months in length. Data for the 21 locations are extracted from the whole data group and re-arranged for analysis. The 21 locations are analyzed separately and for every location results are presented graphically. The wind and swell wave roses, significant wave height versus Mean period of primary swell relations, extreme probability distribution and log-linear cumulative probability distribution are provided for the locations. In the discussion chapter of this study more detailed analyses, such as the frequencies of swell wave heights and mean periods and inspection of some selected extreme events are given.

The arrangement of the subsequent sections of this study is as follows. Chapter 2 presents a summary of theoretical considerations on swell waves and previous works related to this study. Detailed methodology of analysis and details on obtained data are presented in Chapter 3, followed by results of analysis for the thirteen locations in Chapter 4. Summaries and discussions of the results and some detailed analysis are given in Chapter 5. Finally conclusion of the study is given in Chapter 6.

CHAPTER 2

LITERATURE REVIEW

In this chapter general information on swell wave characteristics and previous works on swell wave climate researches are given. In section 2.1. information about swell waves, their propagation and importance is given in general. In section 2.2 previous works on swell wave climate researches are given.

2.1. GENERAL INFORMATION ON SWELL WAVES

The term swell wave refers to wind generated waves that have moved out of their generation zone [CEM, 2006]. During storms strong winds generate irregular patterns of waves, varying in height, length and direction, which radiate from the generating area. The longest waves move most rapidly, and are most durable, so that as waves move across the ocean they become sorted into swell of more regular (gradually diminishing) height and (gradually increasing) length, which eventually arrives to break on a distant shore [Bird E., Coastal Geomorphology, 2004].

Swell waves propagate in the form of wave trains, where the wave train means the group of waves that have the same wave period and direction. The rate of propagation of waves or the wave celerity is;

$$C_o = L/T \tag{1}$$

where L and T are wave length and wave period respectively.

The energy of wave train travels with group velocity which is defined as half of the wave celerity for waves traveling in deep water. In deep water wave length is defined as;

$$L_0 = \frac{g.T^2}{2.\pi} \tag{2}$$

where g is the gravitational acceleration.

Substituting equation (2) in (1), follows that the speed of waves on deep water is only affected by wave period.

$$C_o = \frac{g}{2.\pi}.T \tag{3}$$

The consequence of the above equation is that swell waves with different periods propagates with different velocities. Swell waves with higher periods moves ahead of the lower period swell waves. In a sufficiently long basin the swell wave trains are dispersed according to their periods and this process provides swell waves their regular period characteristic. [CEM, 2006]

The regularity of swell waves causes them to be critical for the harbor resonance phenomenon. The performance of ports and harbors which experience downtime due to excessive vessel motion induced by long period swells is a critical consideration. Small crafts are dangerously affected by swell waves when the rolling period of craft coincides and resonates with the swell wave period.

The swell waves also have an important role on cross-shore sediment transport. The relatively low wave steepness of swells causes them to transport sediment from offshore to onshore [CSMW, 2007]. Swells tend to mobilize offshore sediment bar and redeposit onshore and the littoral drift and littoral current decrease as the offshore bar is removed [CSMW, 2007]

2.2. LITERATURE SURVEY

In this section previous works related to wind and wave climate analysis is summarized. In this scope works on swell wave propagation and climate analysis in the world seas and wind and wave climate works in Aegean and Mediterranean Sea are listed. The current information on wind and wave climate in Aegean and Mediterranean Sea along Turkish coast is very limited. Also swell waves have not been studied on these works.

The study "Özhan, E. and Abdalla, S.: "Turkish Coast Wind and Deep Water Wave Atlas" 1999" is an atlas of wind and wave climate prepared for Turkey and comprise wind and wave climate of Aegean and Mediterranean Sea along Turkish coast. Principle elements for wind and wave climate are given in 30 kilometer intervals for Black Sea, Aegean Sea, and Mediterranean Sea and in 10 kilometer intervals for Marmara Sea. The following elements of climate were given for every location for surface wind speeds and significant wave heights; yearly and seasonal wind and wave roses, monthly means and extreme values, extreme value statistics and also significant wave height vs. mean wave period relations. In this work [Özhan, 1999] meteorological and wave models were prepared and used in addition to existing models. The meteorological and wave models uses wind fields as input, and wind fields were obtained form ECMWF (European Centre for Medium Range Weather Forecast) and Synoptic Maps. The atlas used continuous data with 3 hours sampling duration for an 8 years span were used for the long-term statistics. For extreme value statistics, 20 years' (1976-1995) yearly maximums of wind speed and significant wave height were used for Aegean and Mediterranean Sea.

The problem of forecasting sea and swell is one of current interest. The state of the sea and the length and height of the swell in the open sea under stormy conditions are well-known from various authorities. The wind waves are defined as waves which are growing in height under the influence of wind, and swell waves consist of wind-generated waves which have advanced into regions having local winds whose direction is different from that of the wave motion [H. Arakawa and K. Suda, Analysis of winds, wind waves, and swell over the sea to the east of Japan during the typhoon of September 26, 1935, 1953].

Fabrice Ardhuin and Alastair D. Jenkins is investigated the effect of wind and of contributing to the evolution of swell is proposed, combining direct interactions of swell with the wind and upper ocean turbulence, and interaction with shorter wind waves. They found that the observations of swell decay in the Pacific (Snodgrass et al., 1963) are quantitatively consistent with the effects of wind stress modulation and direct to wave momentum transfer.

The influence swell on the sea surface roughness and the growth of wind waves is researched by Qin Chen, Paul A. Hwang and James M. Kaihatu in 2004. The study utilizes an extended Boussinesq wave model incorporating the wind forcing to examine the effects of swell on the spatial variation of the sea surface roughness and the growth of wind waves.

Chen et al. published a paper in November 2002, "A global view of swell and wind sea climate in the ocean by satellite altimeter and scatterometer". In this paper, a feasibility study is presented using collated wind speed and significant wave height measurements from simultaneous satellite scatterometer and altimeter sources to observe the spatial and seasonal pattern of dominant swell and wind wave zones in the world's oceans.

The following Figure 2.2.1 has been extracted from The Technical Standards and Commentaries for Port and Harbour Facilities in Japan (Japanese Standard, 2000) and is used for swell hindcasting by Bretschneider method. According to the figure, the swell waves with 10, 8 and 6 seconds periods can decay in 573 km's, 430 km's and 344 km's respectively.

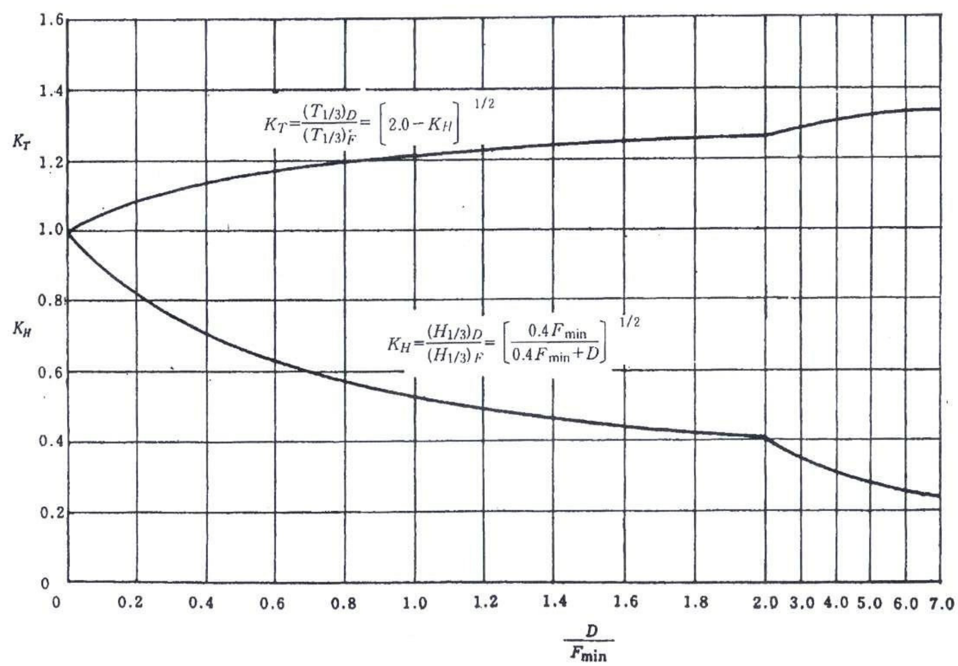

Figure 2.2.1 Swell Hindcasting Diagram

Also the study "The effect of islands on surface waves" by Arthur R. S. is an extensive study on the wave propagation including swell waves. With this study, Arthur R. S. concluded that the penetration of wave energy into the region to the lee of the island is determined by the following factors: (1) effect of underwater topography off the island's shores in refracting wave energy into the lee, (2) the effect of currents near the island in refracting energy, (3) the diffraction effect resulting when a barrier interrupts wave fronts, and (4) the effect of variability in direction of wave travel in limiting the extent of the shadow. The quantitative results indicate that the important effects in the penetration of wave energy into the lee are generally the result of refraction by underwater topography and variability in direction.

CHAPTER 3

DATA SOURCE AND ANALYSES OF DATA

In this chapter information about the data that is used in the analyses are given and analyses steps are explained. In section 3.1. the details of data source and download procedure are explained. In section 3.2. information on obtained data and the rearrangement of the data are discussed. Finally in section 3.3. the analysis procedures and presentation steps are given.

3.1. DATA SOURCE AND OBTAINING DATA

3.1.1. The Data Source

The data source for this study is the European Centre for Medium-Range Weather Forecasts (ECMWF in short). ECMWF, the Centre is an independent international organization established in 1975 and is currently supported by 28 States. [ECMWF, 2006] The organization has co-operation agreements with several other international organizations. Türkiye, being a member of this organization, does assist ECMWF and has access to ECMWF data by the Turkish State Meteorological Service. The ECMWF runs atmosphere global forecasts, ocean wave forecasts and seasonal forecast, stores the data obtained from observations, analyses, forecasts and research experiments, provides an ensemble prediction system and carries a range of research programs which are available to its member states and co-operatives. The ECMWF Operational data, used in this study have been obtained from the ECMWF Data Server by special permission from General Directorate of Turkish State Meteorological Service and ECMWF.

The data archiving services of ECMWF is used to download the data. In the archive service, there are three sets of data available, which are Operational Archive, ERA-15 and ERA-40. ERA-15 and ERA-40 are archives of re-analysis of global and short range forecasts of relevant weather parameters for 15 and 40 years duration respectively. The operational archive of ECMWF is used in this study, which in turn is divided into six classes of data sets. The data sets; atmospheric and wave models are used to gather data. Atmospheric model is the richest data set from the space resolution and time duration point of view. The atmospheric model supports thirteen separate data sets. From these data sets, surface analysis data set is used and wind data are obtained from this set. In a similar manner the wave model is divided into four data sets, namely sets of Global and Mediterranean wave analysis and forecasts. For the purpose of this study the Mediterranean wave analysis set is selected. The parameters to be ordered are selected from parameter list of the data sets. Two parameters from surface analysis data set and four parameters from Mediterranean wave analysis data set are selected and these parameters are given as a list in Section 3.2.1.

3.1.2. Obtaining Data

In this section obtaining data is explained in brief. Ordering of data from ECMWF can be made in different ways. Ordering data online is an easy way for selective parameters. Mainly Meteorological Archival and Retrieval System (MARS) is used for downloading bulk data with its own script language. However for small amount of data, data can be ordered directly from data services. In this study data is directly ordered from the Mediterranean Wave model of Operational archive. In this way the interactive web environment directs user through the ordering process. After the selection of the data set, pages for selection of the data time range, available daily times, parameters and finally the area and grid spacing selection pages are opened. The request is evaluated and prepared by ECMWF for download. Afterwards the requested data is downloaded in GRIB file format. A single file for every month, totally 72 files in the data period, is downloaded for wind and wave data.

3.2. INFORMATION ON DATA AND DATA RE-ARRANGEMENT

3.2.1. Information on Obtained Data

The data to be used in the analysis are ordered from two data sets. Wind data are ordered from surface analysis data set and wave data are ordered from Mediterranean wave analysis data set. The parameters ordered form the wind data set of the atmospheric model is listed in the following;

10U - 10 meter height U wind component (m/s)

10V - 10 meter height V wind component (m/s)

The parameters ordered from the Mediterranean wave data set of Analysis wave model is listed in the following;

WIND – 10 meter height wind speed (m/s)

MDPS - Mean Direction of Primary Swell (degrees)

MPPS - Mean Period of Primary Swell (s)

SHPS - Significant Height of Primary Swell (m)

These parameters can also be attained from the parameter catalogue of ECMWF.

The 10 meter wind components which are downloaded from wind data set refer to wind speeds 10 meter above surface given in meters/seconds units. They are abbreviated as 10U and 10V. The abbreviation U specifies that the component is along the latitude and similarly V specifies that the component is along the longitude. The positive direction for the U component is towards east and for the V component it is towards north. The resolution of the wind components are selected as 1.125°x1.125°.

In the wave data set 4 parameters are ordered with a resolution of 1.125°x1.125°. The WIND abbreviated parameter gives only speed at 10 meters above water surface in meters/seconds units. Because this parameter does not contain direction of wind, this parameter is only used to cross-check wind speeds obtained from wind data.

The other three parameters MDPS, MPPS and SHPS are complementary parameters in defining swell waves. MDPS is an abbreviation for Mean Direction of Primary Swell, given in degrees measured clockwise starting from north. MDPS indicates the direction of incoming swells. MPPS is an abbreviation for Mean Period of Primary Swell, given in seconds. Finally Significant Height of Primary Swell is abbreviated as SHPS and is given in meters units. Due to recent changes in ECMWF data service, these parameters are being served as regard to total swell replacing primary swell applicable by November 2006.

For the purpose of this study, the study area covers whole Aegean and Mediterranean Sea region. The wind and swell wave data is obtained for a 72 months period starting from 01.01.2001 to 31.12.2006 with 12 hour data record interval covering whole Aegean and Mediterranean Sea basin. Totally 4380 data records for every data location inside the matrix are acquired with every data record providing four data elements which are the wind components 10 meter above sea level, the mean direction of primary swell, the mean period of primary swell and the significant height of primary swell. However for some locations, 3514-Datça, 4214-Kemer, 5214-Karataş and 4611-Güzelyurt, wave data is limited.

Table 3.2.1.1: Index, name and coordinates of the 21 locations

Index	Location Name	E Coordinate (Degrees)	N Coordinate (Degrees)
3320	Edremit	26.00	39.50
3419	Dikili	26.50	39.00
3217	Seferihisar	26.50	38.00
3516	Kusadası	27.00	37.50
3615	Bodrum	27.50	37.00
3514	Datça	27.50	36.50
3814	Dalaman	28.50	36.50
3913	Fethiye	29.00	36.50
4013	Kaş	29.50	36.00
4113	Finike	30.00	36.00
4214	Kemer	30.50	36.50
4314	Side	31.00	36.50
4414	Alanya	31.50	36.50
4314	Side	31.00	36.50
4613	Anamur	32.50	36.00
4813	Silifke	33.50	36.00
5114	Kazanlı	35.00	36.50
5214	Karataş	35.50	36.50
5213	Samandağ	35.50	36.00
4611	Güzelyurt	32.00	35.00
4712	Girne	33.00	35.50
4912	Karpas	34.00	35.50

21 locations along the Turkish coast are selected for analysis and given in Table 3.2.1.1. In this study the locations index, name and coordinates are used in conjunction. The locations on Aegean and Mediterranean Sea are also given in Figure 3.2.1.1.

Figure 3.2.1.1 The Layout of the 21 locations

3.2.2. The GRIB File Format

The source data are obtained in GRIB format as explained in Section 3.1.2. The GRIB is an abbreviation for "Gridded Binary". The GRIB file format is a bit-oriented data exchange and storage format. In GRIB form the data is efficiently packed and compacted and this way storage and transmission of data is made efficiently. However GRIB files cannot be opened and/or viewed in conventional software before extraction. Special software is needed to unpack the GRIB files. Few programs exist for this purpose and unfortunately it is hard to find satisfactory documentation for any of them. In this study free software named WGRIB is used. But also the ECMWF serves another free software product, named GRIBEX for handling GRIB files which is available for UNIX systems. [ECMWF, 2006] WGRIB runs in DOS environment and is well established and usage is quite simple and straightforward once commands are understood. The program is available from National Oceanic & Atmospheric Administration (NOAA) of U.S. Department of Commerce. [NOAA, 2006] The decoding process is carried out by using WGRIB program and the decoded GRIB files are saved as text files. Every GRIB file contained data for a month period, and so text files for every month was produced for wind and wave data totaling in 65 separate text files. The usage of WGRIB and links to detailed help files are given in the appendix. Although the extracted text files can be viewed in conventional software at this level, they are still not meaningful. The data in text files had to be re-arranged for processing the data as described in the following section.

3.2.3. Re-arrangement of Data

In this section the re-arrangement of text files obtained from the decoding of GRIB files is described. The text files are composed of one column data and header information included in GRIB files does not exist. Inside the text files, in the first row total row and column counts are given, i.e. the matrix dimensions. In the following rows all data, covering whole region is listed, where the region is the total of locations. The data is listed starting from the upper right corner of the matrix and flowing in left-to-right and top-to-bottom order. For every location there is a data group listed. That is, for wind data the wind parameters 10U and 10V is listed in an alternating order. And for wave data the parameters WIND, MDPS, MPPS and SHPS are listed in an alternating order. In the file, the parameter group is given for a date and time value for all locations following the flow direction, and then the date and time value is incremented and the data flow continues in this way. The text files are re-arranged by Visual FORTRAN 6.0 program written for especially re-arrangement of these files.

Briefly the FORTRAN program takes the text files as input and extracts the parameters, and stores the monthly values of the parameter in a matrix form covering whole area. Also the programs are made to extract data for a single location in a tabular format as a data file (*.dat), indicating date and time of measurement and parameters in the following columns. The latter extracted data can neatly be viewed in a spreadsheet and forms a basis for all analysis. These files are named as location-data type.dat e.g. 3320-WIND.dat or 3419-WAVE.dat. These files are later modified and necessary calculations made directly on them as needed.

3.3. DATA ANALYSIS AND PRESENTATION

In this section the analysis procedure and presentation steps are given. Before starting any analysis the data files that have been divided according to locations and obtained for every month of every year, are combined. And thus one single data file for every location is produced. Totally 21 files for wind data and 21 files for wave data are obtained. Some additional columns that are needed for analysis are calculated in the spreadsheet and added to these data files. For wind data, the wind vector that is given as U and V components are converted to polar coordinates. Thus wind speed and angle from North direction measured clockwise is computed along with the geographical bearing. For wave data only geographical bearing of mean direction of primary swell is computed. Also for both wind and wave data the year, month, day and hour values of every measurement is extracted and placed on different columns merely for analysis purposes.

3.3.1. Wind and Wave Roses

Roses are angular histograms plotted on polar coordinate system. Roses give the frequency distribution of geographical bearing of incoming winds and swell waves. The frequency is given in percent of all directions plus the calm duration and the percent scale is given on the polar coordinate system. The roses at the same time have a magnitude scale and show the percentage of each magnitude interval. The magnitude intervals legend is given on a color scale. For every bearing the percentages of magnitude intervals are added on former interval and thus the percent of any bearing is the total of percentages of each interval. So the calculation of percent of an interval e.g. 7.5 to 10 m/s for wind speed should be made for any direction by subtracting the percent reading of interval minimum from interval maximum.

Roses are plotted by using a rose plotting program, namely WRPLOT View. WRPLOT is an acronym for Wind Rose Plot and the software name will be referred as WRPLOT thereafter in this study. The WRPLOT software is freely available from Lakes Environmental Software and works in Windows environment. Although the software is prepared for generation of wind roses it is used for generation of swell wave roses as well.

The wind classes, that are the colored magnitude scale or intervals, are prepared as; 3-5, 5-7.5, 7.5-10, 10-12.5, 12.5-15, 15-17.5 and 17.5 and higher in meters/second. This way wind speed spectrum is divided into 7. The wind speeds lower than 3 m/s is treated as calm and the calm percentage is indicated at the lower right corner of the roses separately. If the calm duration or 0-3 m/s interval was to be indicated in the rose, the total of all petals would have made 100%. However in the given roses the total percentage of all petals made up to 100% minus the percentage of calm duration or interval.

The swell wave roses are handled in a similar way to wind roses. The wave classes or intervals are selected as; 0.5-1, 1-2, 2-3, 3-4, 4-5, 5-6 and 6 and higher in meters. The wave spectrum is divided into 8 intervals. Swell wave heights lower than 0.5 meters is treated as calm and the calm percentage is indicated at the lower right corner of roses separately. The total percentage of petals of the rose makes 100% minus the calm percentage similar to the wind roses.

The generation procedure for wind and wave roses is similar. The data files that have been prepared are directly used as input to WRPLOT at this step. These files were divided according to location and included the 72 month data covering all data period. For a single location the data file is first imported to WRPLOT using the import feature of WRPLOT directly from Microsoft Excel. Since the month information is involved inside the files, the seasonal partitioning of the data can be handled through WRPLOT. As soon as the data file is imported and wind or wave classes are defined the rose is plotted.

On the roses only the cardinal directions are given. The calm data frequency is indicated at the lower right corner of each rose as "calms" in percent. The corresponding season of the roses are indicated. The color scale and wind and wave classes are kept constant through all locations. For the sake of presentation the seasonal and full year roses are assembled in a single page for every location as given in Chapter 5. In between the roses the geographical location and corresponding data is indicated.

3.3.2. H_s vs. T_m Relation Graphs

The graphs of significant swell wave height versus mean period of swell waves, as will be shortly expressed as H_s vs. T_m relations thereafter, are the plot of every data point according to its significant height and mean period. The horizontal axis of the graph is significant swell wave height (H_s) in meters and the vertical axis is mean period of swell waves (T_m) in seconds. In the H_s vs. T_m relations, differently from the roses, all data points are plotted. These graphs effectively represent the relation between H_s vs. T_m and the maxima. The H_s vs. T_m relations are given for different bearings and one relation covering all directions. A simplification to the H_s vs. T_m relations is made by omitting unnecessary bearings. In this way the H_s vs. T_m relations are composed of totally 10 graphs, nine related to directions one for All Directions'.

The H_s vs. T_m relations are given in a single page in a clockwise order according to bearings. And the directions are indicated below the graphs. The axis maximum and minimum values are kept constant through the locations. The H_s maximum is 3.5 meters for Aegean Sea and 4.5 meters for Mediterranean Sea and T_m maximum is 12 seconds and the minima are zero.

3.3.3. Extreme Probability Distribution Graph

The Extreme Probability distribution is a tool for estimating probable swell wave heights for a given return period. In this section the method that has been followed in this study for generation of extreme probability distribution graphs is explained.

In the extreme data analysis, many theoretical distributions are employed for fitting to samples. In this study, for extreme swell wave analysis Gumbel distribution is used to fit obtained data:

$$F(x) = \exp\left[-\exp\left(-\frac{x-B}{A}\right)\right] \qquad : \qquad -\infty < x < \infty$$

In above formula, $F(x)$ is denoted as cumulative distribution function, and x stands for the extreme variate (i.e., swell wave height). The parameter A is called the scale parameter because it governs the linear scale of x. The parameter B is called the location parameter because it fixes the location of the axis of x.

The data that is used for generation of extreme probability distributions consist of the yearly maximums of swell wave heights. The yearly maximums of swell wave heights for the locations are given in Table 3.3.3.1. The yearly extremes are obtained from the data files that have been generated for 21 locations. In the spreadsheet environment for every location the data is sort according to swell wave heights and maximum swell wave heights for every year is noted. The extreme value probability distributions are plotted by using Microsoft Excel software. There are some years in which records are not available for some locations, since related data show land values.

Table 3.3.3.1: Yearly maximums of significant swell wave heights in meters for locations (The sign “-“indicates missing data)

Location / Year		2001	2002	2003	2004	2005	2006
3320	Edremit	1.731	1.383	2.136	1.384	1.712	1.358
3419	Dikili	1.770	1.396	1.670	1.537	1.400	0.910
3217	Seferihisar	2.393	2.192	2.265	1.805	1.947	2.170
3516	Kuşadası	1.498	1.195	1.556	1.438	1.201	1.019
3615	Bodrum	1.814	1.926	2.259	1.610	1.100	1.009
3514	Datça	2.824	3.144	2.735	3.134	-	1.663
3814	Dalaman	2.603	3.289	2.601	2.408	1.458	1.792
3913	Fethiye	2.160	2.021	2.469	2.473	2.241	2.166
4013	Kaş	2.426	2.167	2.404	2.979	2.330	2.328
4113	Finike	2.426	2.167	2.404	2.979	2.330	2.398
4214	Kemer	2.288	2.164	2.514	3.212	-	-
4314	Side	2.655	2.344	2.434	3.753	1.647	1.988
4414	Alanya	2.923	2.600	2.732	3.973	1.871	2.665
4613	Anamur	2.684	2.659	3.427	3.191	2.244	3.059
4813	Silifke	1.960	2.392	3.040	1.998	1.755	2.169
5114	Kazanlı	1.657	2.044	1.858	2.532	1.423	2.143
5214	Karataş	2.083	1.852	2.281	2.794	1.738	2.043
5213	Samandağ	2.180	1.998	3.005	2.822	1.725	2.457
4611	Güzelyurt	1.286	1.108	2.034	2.566	3.225	2.565
4712	Girne	2.189	2.279	3.043	2.748	2.226	2.085
4912	Karpas	2.042	2.051	3.029	3.508	1.446	1.602

The maximum values for axis are selected the same for every location. The vertical axis in the graphs represents the significant swell wave height in meters and the range is selected as zero to six. The below horizontal axis show the non-exceedance probability and the upper horizontal axis show the return period in years.

3.3.4. Log-Linear Cumulative Probability Distribution

The log-linear cumulative probability distribution gives a relation between the occurrence probability and a given significant swell wave height. The graph is generally used for estimating the duration of exceedance of a certain swell wave height. In this section the method that has been followed in this study for generation of Log-Linear cumulative probability distributions is explained.

In this study, for long term swell wave analysis Lognormal distribution is used to fit obtained data:

$$f(x) = \frac{1}{\sqrt{2\pi}Ax} \exp\left[-\frac{(\ln x - B)^2}{2A^2} \right] \qquad : \qquad 0 < x < \infty$$

In above formula, $f(x)$ is denoted as probability density function, and x stands for the extreme variate (i.e., swell wave height). The parameter A is called the scale parameter because it governs the linear scale of x. The parameter B is called the location parameter because it fixes the location of the axis of x.

The frequency distribution of incoming swell waves is used as input for generation of log-linear cumulative probability distributions. The frequency distribution shows the counts of swell wave occurrences divided according to swell wave heights as used in swell wave roses and from each direction. These frequency distributions are obtained from WRPLOT along with the swell wave roses. Using the report function of WRPLOT frequency distributions are generated and exported to spreadsheet environment. The frequency distributions are modified to obtain the cumulative frequency distributions. In the cumulative frequency distribution, every smaller swell wave height interval includes the occurrences observed at higher intervals. In this way the smallest interval shows the total number of observations excluding calms. Afterwards the significant directions are extracted from the whole frequency distribution table. Also an “all directions” case is composed by adding counts for all directions. Then the all directions case and other significant directions are tabulated as cumulative frequency distribution table. Finally the frequencies are converted to percentages by dividing table cells by total number of occurrences excluding calms. The final cumulative percent frequency distributions are plotted on a logarithmic-linear graph and a logarithmic trend is added to these data.

The horizontal axis in the graphs show probability and the maximum and minimum values are fixed to 1 and 0.0001 for every location. The vertical axis is the significant height of swell waves in meters. The range of vertical axis is arranged so that the graphs are better viewed.

CHAPTER 4

RESULTS

In this chapter results of the analysis for each location are given. As described in detail in the 3rd Chapter, there are 21 locations along the Aegean and the Mediterranean Sea encompassing Turkish coasts. For each location firstly a brief description of location is given and following this description analysis results are discussed based on provided graphics.

The results of each location are given in a sub-chapter and follow an ascending order of location index. Geographical coordinates of the location is indicated both in discussion and graphics parts. Also the location is approximately shown by a star on the Aegean and the Mediterranean Sea map given with the graphs. Inside the sub-chapters, the graphics provided from analysis results are given in the following order; Wind Roses, Swell Wave Roses, Significant Swell Wave Height (H_s) vs. Mean Swell Wave Period (T_m) Relations, Extreme value probability statistics and Log-Linear cumulative probability distribution graph. Detailed descriptions of generation of these graphs are explained in section 3.3. Data Analysis and Presentation.

The wind and swell wave roses carry important information such as dominant directions, calm durations, and range of observed magnitudes with occurrence probability and seasonal changes of these parameters. The relations of significant height and mean period of swell waves show all available data for all considerable directions along with the maximum values. The distributions of extreme probability and log-linear cumulative probability are useful for analysis purposes.

The wind and swell wave roses show the yearly and seasonal distribution of occurrence probability and magnitude of incoming winds or swell waves respectively. Roses are divided into 16 geographical directions. The directions are indicated on roses as N (North), NNW (North-Northwest), NW (North-West) etc. Every direction counts for a total of 22.5° (degrees) segment. The percentile distribution is scaled on the roses. The magnitude of the parameter can be seen from the color scale on the figure. The scale starts from a non-zero value. Magnitudes below that minimum value are regarded as "calm" values. The percentage of calm duration is indicated at right-bottom of each rose. The roses are given for full year and for all seasons separately.

Wind roses are related to wind speed which is given as wind speed 10 meters above the sea, i.e. U10 in meters/second. For wind roses magnitude scale is from 3 m/s to 17.5 m/s. Minimum wind speed is 3 m/s, below that level the wind state is regarded as calm. In the discussions of each results section comparisons with Özhan and Abdalla, 1999 are given. Since this study and the study Özhan and Abdalla, 1999 are based on different data sources the differences may be expected. In the case of using these results in any future engineering applications, the user must perform his/her own analysis procedure with the new available wind data and perform further comparisons between the results given in these studies and also his/her and other available result.

Swell waves are related to significant height of swell wave in meters. For swell waves magnitude scale is from 0.5 m to 6 m. Minimum swell wave height is 0.5 m, below that level swell wave state is regarded as calm.

Roses are followed by Significant Wave Height (H_s) vs. Mean Wave Period (T_m) Relation Graphs. In this graph the horizontal axis is significant height of swell waves (H_s) in meters and the vertical axis is mean period of swell waves (T_m) in seconds. For all graphs regarding Aegean Sea the maximum value on the horizontal axis is 3.5 m and 4.5 m for Mediterranean Sea. The maximum value in the vertical axis is 12 seconds. In these graphs every dot relates to a swell wave data, plotted according to its H_s (m) and T_m (s) respective to swell wave incoming direction. Only northern half of all directions are plotted as they have significance for our purpose. As all data points' southern part is faced to land, and no significant waves are generated from these directions. Nine directions, from West to East and All Directions' graphs are given in (H_s) vs. (T_m) Graphs. These graphs can be used to relate swell wave height to swell wave period. Also these graphs show the general distribution of swell waves according to their directions.

Extreme value probability statistics graph follows the H_s vs. T_m graph. Yearly maximum values for significant wave height of swell waves are plotted on extreme value graph, as the distribution of yearly maximums is assumed to be fitting Gumbel distribution. In this graph below horizontal axis is percent non-exceedance probability, above horizontal axis is return period in years and vertical axis is significant swell wave height in meters. Best line is fit to these data values and the best line is elongated. Using this graph expected significant wave height can be obtained for reasonable return periods.

Log-linear cumulative probability distribution follows the extreme value probability graph. In this graph horizontal axis is occurrence probability and the vertical axis is significant swell wave height in meters. As the name of the graph implies the horizontal axis is in logarithmic scale. The log-linear cumulative distribution graph is useful for estimating the duration of exceedance of a certain swell wave height. The orientation of the data points in the graph should be close to a line ideally. However because of limited data the linear distribution cannot be observed.

Results relate to data covering all year of analysis duration, i.e. 72 months, as described in the 3rd Chapter. However some locations have less data. These are explained in the discussion section of the respective location. Also extreme value probability graph is not given for these locations because of lack of data. Details on extreme value probability graphs are also given in the 3rd Chapter.

4.1. LOCATION 3320 - EDREMİT

The 3320 abbreviated point is located approximately 5 km West of Baba Burnu (80 km West of Edremit), 20 km North of Midilli Island and 30 km South of Bozcaada. In this context Edremit (3320) is the most northward point among all data points. The coordinates of point 3320 is; 39.50˚ N, 26.00˚ E.

The Wind Roses, Swell Wave Roses, Significant Wave Height (Hs) vs. Mean Wave Period (Tm) Relations, Extreme value probability statistics and Log-linear cumulative probability distribution are given in this section for this location.

Wind roses are given in Figure 4.1.1 and show that location 3320 is subject to mainly N to NNE winds. Strong winds are effective in N and NNE directions in all seasons and slides to N direction in summer at this location. Also relatively strong winds are seen from reverse direction, namely SW&SSW in all seasons except summer.

Wind Roses are compared with the wind roses at the nearest location (39.50 N˚, 25.90˚ E) in Ozhan and Abdalla, (1999) where the dominant wind is from N to NNE direction for this location. The yearly wind roses are in correlation with both studies. But there are some differences in the respective roses belonging to summer season. In Ozhan and Abdalla, 1999, the north-northeastern winds have higher occurrence compared to this study.

Swell wave roses are given in Figure 4.1.2. Nearly 7% of the time swell waves are coming from SW and SSW directions totally in a full year. SW and SSW swell waves' percentile increases in winter up to 6%. N swell waves' percentile reaches up to 5% in winter also. The maximum swell wave height is between 1.5 and 2.0 meters.

The relations between Significant Wave Height (Hs) vs. Mean Wave Period (Tm) are given in Figure 4.1.3. In this graph SW and SSW swell wave domination can be seen via Figure 4.3.2. Also N and NNW swell waves are observed commonly. Several data points, exceeding 8 second periods and few data points exceeding 1.5 m of swell wave heights are observed for southern directions with a maximum wave height of 2.136 m. The average steepness of swell waves at this location (From Figure 4.1.3) is 0.010.

The graph of extreme value probability statistics is given in Figure 4.1.4. Data values show high correlation. Significant swell wave height is estimated as 3.0 meters for 100 year return period.

Log-linear cumulative probability distribution is given in Figure 4.1.5. Four dominating directions; NNE, SSW, SW and NNW are plotted along with all directions. It is seen from this graph that significant height of swell waves exceeds 2.2 meters in about 10 hours duration every year.

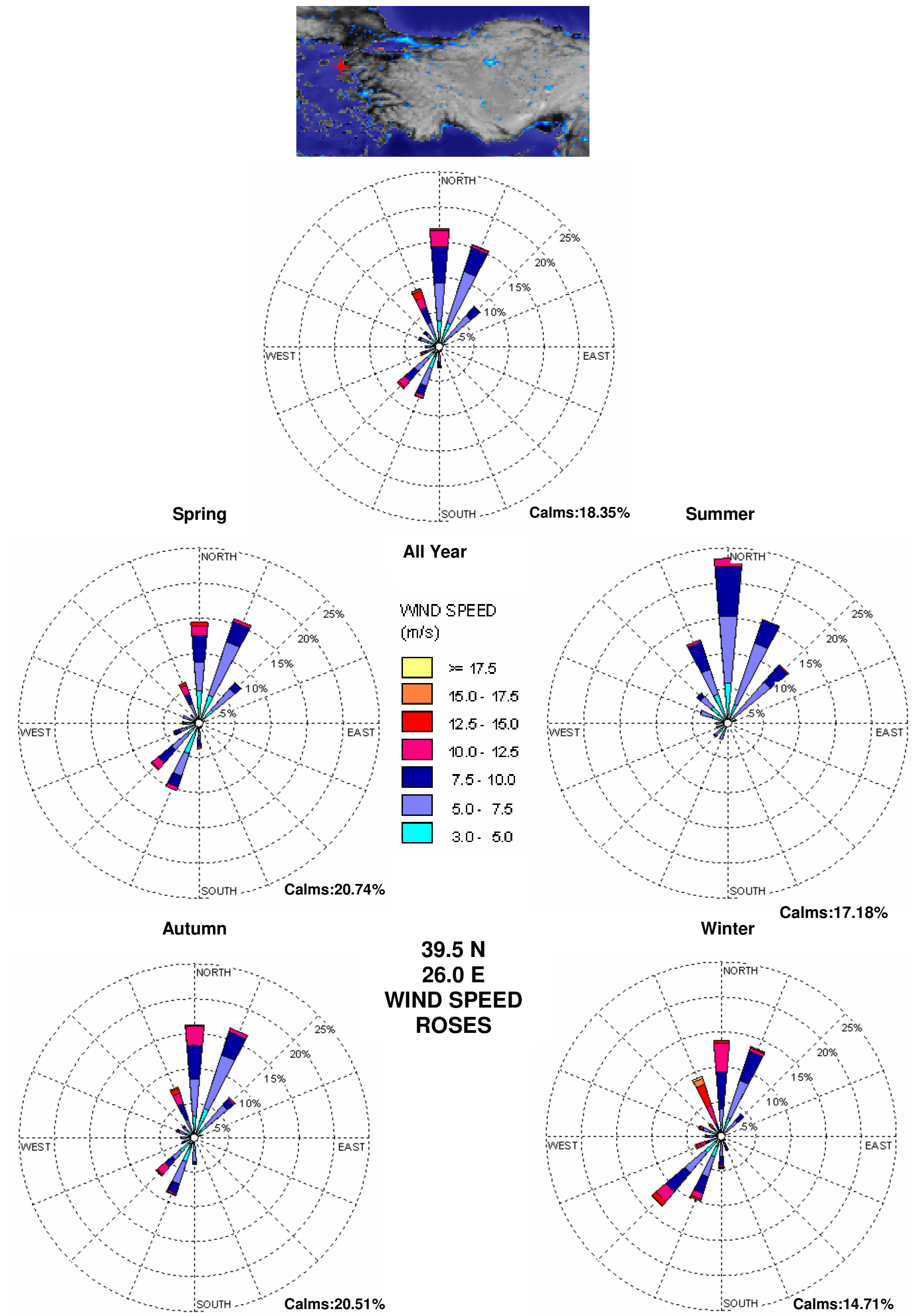

Figure 4.1.1 Wind climate at 39.5 N, 26.0 E

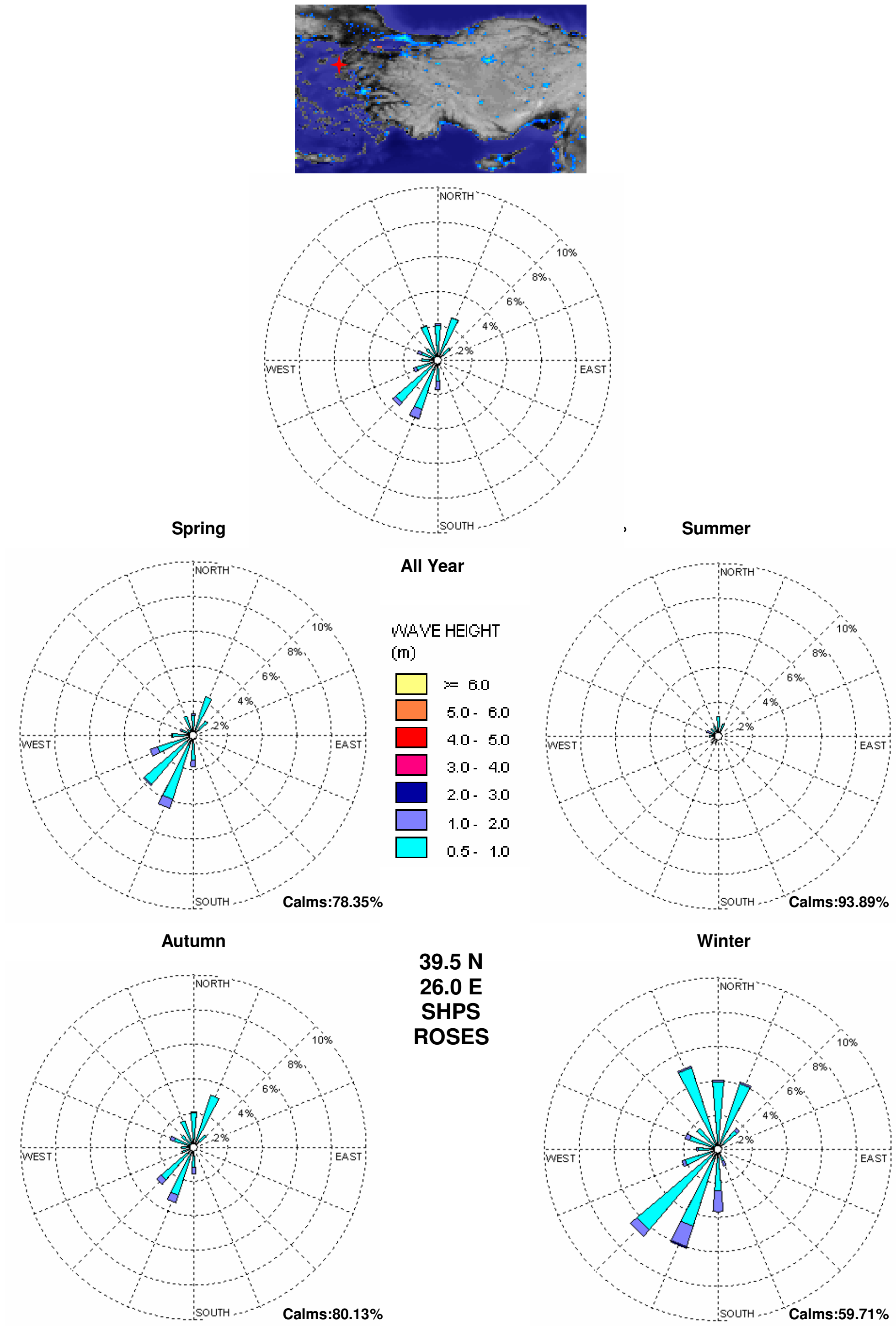

Figure 4.1.2 SHPS climate at 39.5 N, 26.0 E

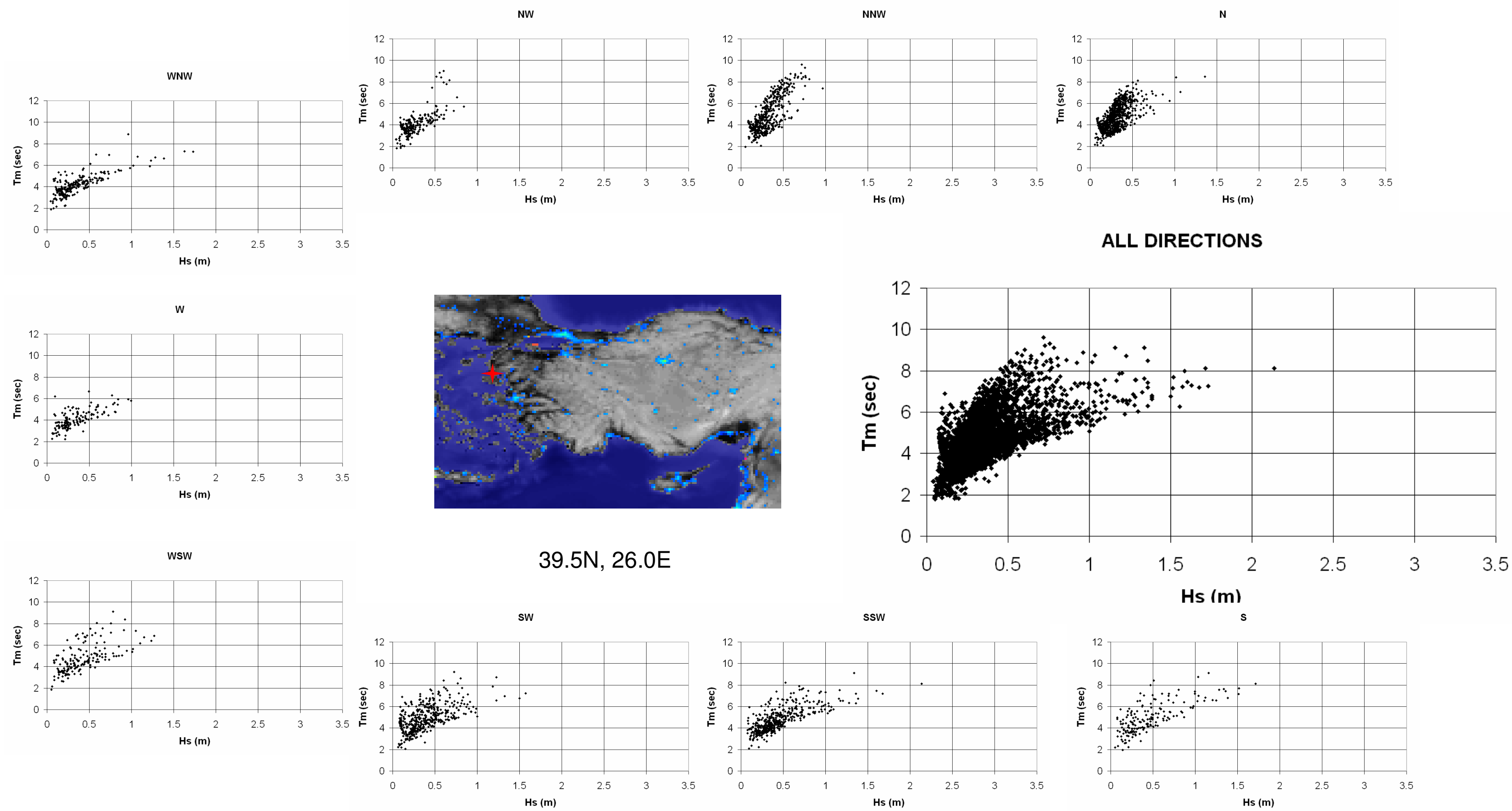

Figure 4.1.3 Relationship between MPPS & SHPS at Edremit

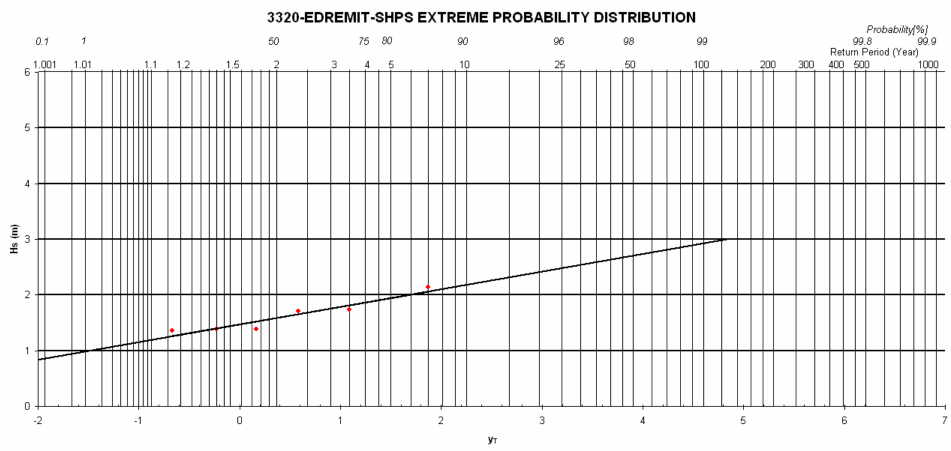

Figure 4.1.4 Extreme Probability Distribution at Location 39.5 N, 26.0

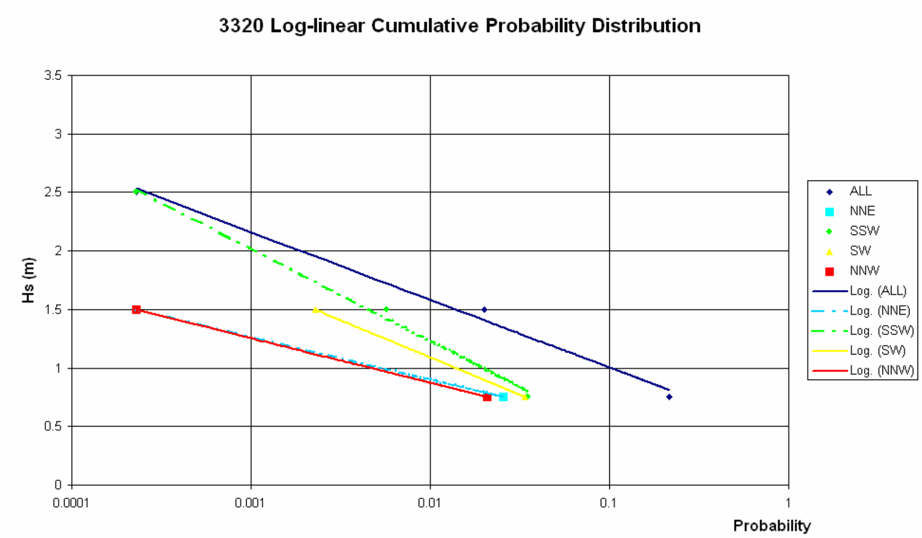

Figure 4.1.5 Log-Linear Cumulative Probability Distribution at 39.5 N, 26.0 E

4.2. LOCATION 3419 - DİKİLİ

The 3419 abbreviated point is located approximately 15 km West of Dikili and at the most eastern part of Midilli Island. The coordinates of point 3419 is; 39.00˚ N, 26.50˚ E.

The Wind Roses, Swell Wave Roses, Significant Wave Height (Hs) vs. Mean Wave Period (Tm) Relations, Extreme value probability statistics and Log-linear cumulative probability distribution are given in this section for this location.

Wind roses are given in Figure 4.2.1 and show that location 3419 is subject to mainly NNE winds. Strong winds are effective in NNE directions in winter and autumn. Also relatively strong winds are seen from reverse direction, namely S in winter and autumn.

Wind Roses are compared with the wind roses at the nearest location (39.00˚ N, 26.20˚ E) in Ozhan and Abdalla, (1999) where the dominant wind is from N to NNE direction for this location. The yearly wind roses are in correlation with both studies. But there are some differences in the respective roses belonging all seasons except winter. In Ozhan and Abdalla, 1999, the northern winds have higher occurrence compared to this study generally.

Swell wave roses are given in Figure 4.2.2 and show a wide range of direction of incoming swell waves. Nearly 3% of the time swell waves are coming from N and beyond 2% of the time coming from SW and SSW directions in a full year. Additionally, NNW directed swell waves' percentile reaches up to 2%. Swell waves' percentile increases in winter. The maximum swell wave height is between 1.5 and 2.0 meters.

The relations between Significant Wave Height (Hs) vs. Mean Wave Period (Tm) are given in Figure 4.2.3. In this graph N and SSW swell wave domination can be seen via Figure 4.2.2. A rather more scattered distribution is observed in SW direction. Several data points, exceeding 8 second periods and few data points exceeding 1.0 m of swell wave heights are observed for SW direction with a maximum wave height of 1.770 m. The average steepness of swell waves at this location (From Figure 4.2.3) is 0.010.

The graph of extreme value probability statistics is given in Figure 4.2.4. Data values show high correlation. Significant swell wave height is estimated as 3.6 meters for 100 year return period.

Log-linear cumulative probability distribution is given in Figure 4.2.5. Four dominating directions; namely SSW, SW, NNW and N are plotted along with all directions. It is seen from this graph that significant height of swell waves exceeds 2.0 meters in about 10 hours duration every year.

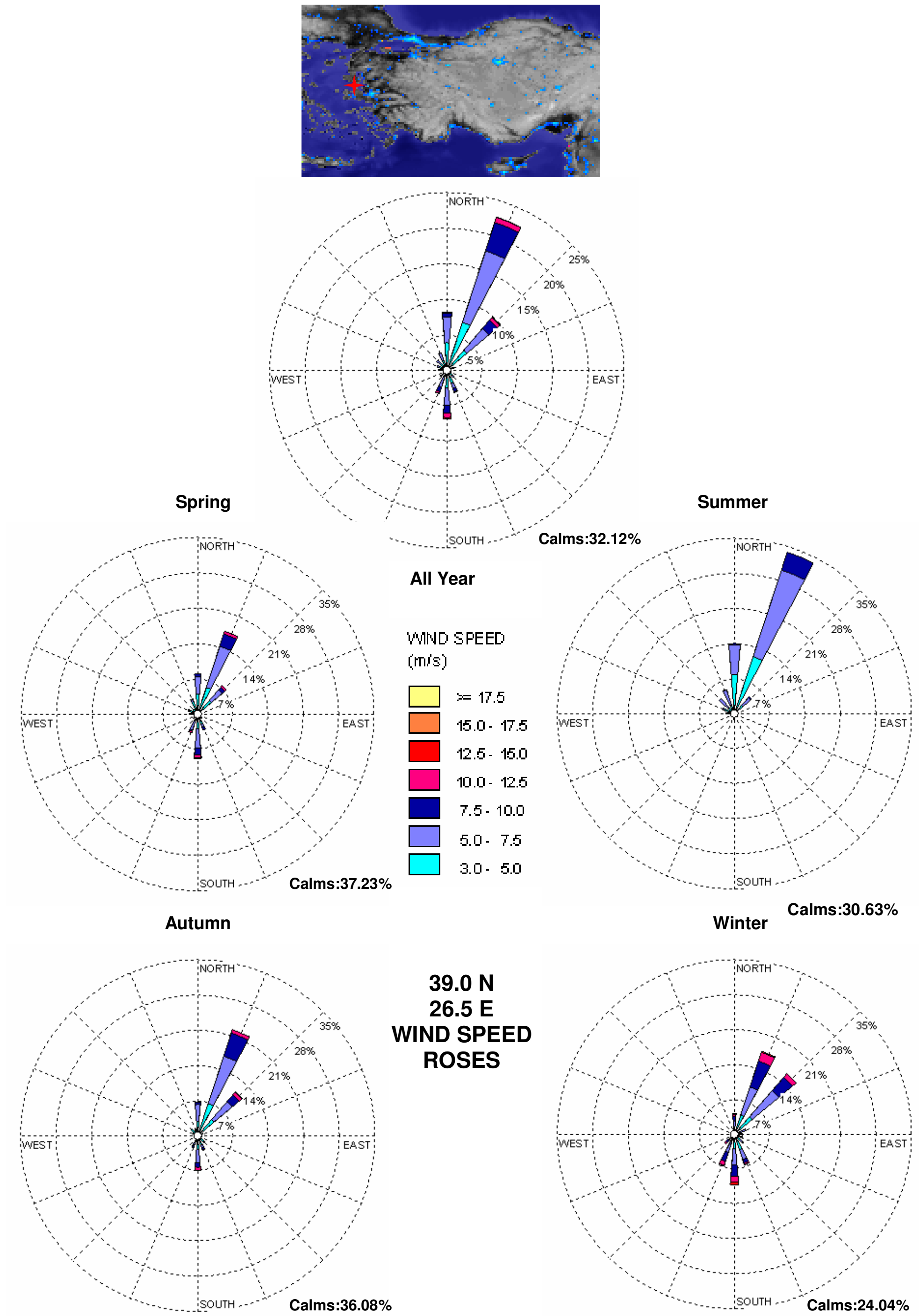

Figure 4.2.1 Wind climate at 39.0 N, 26.5 E

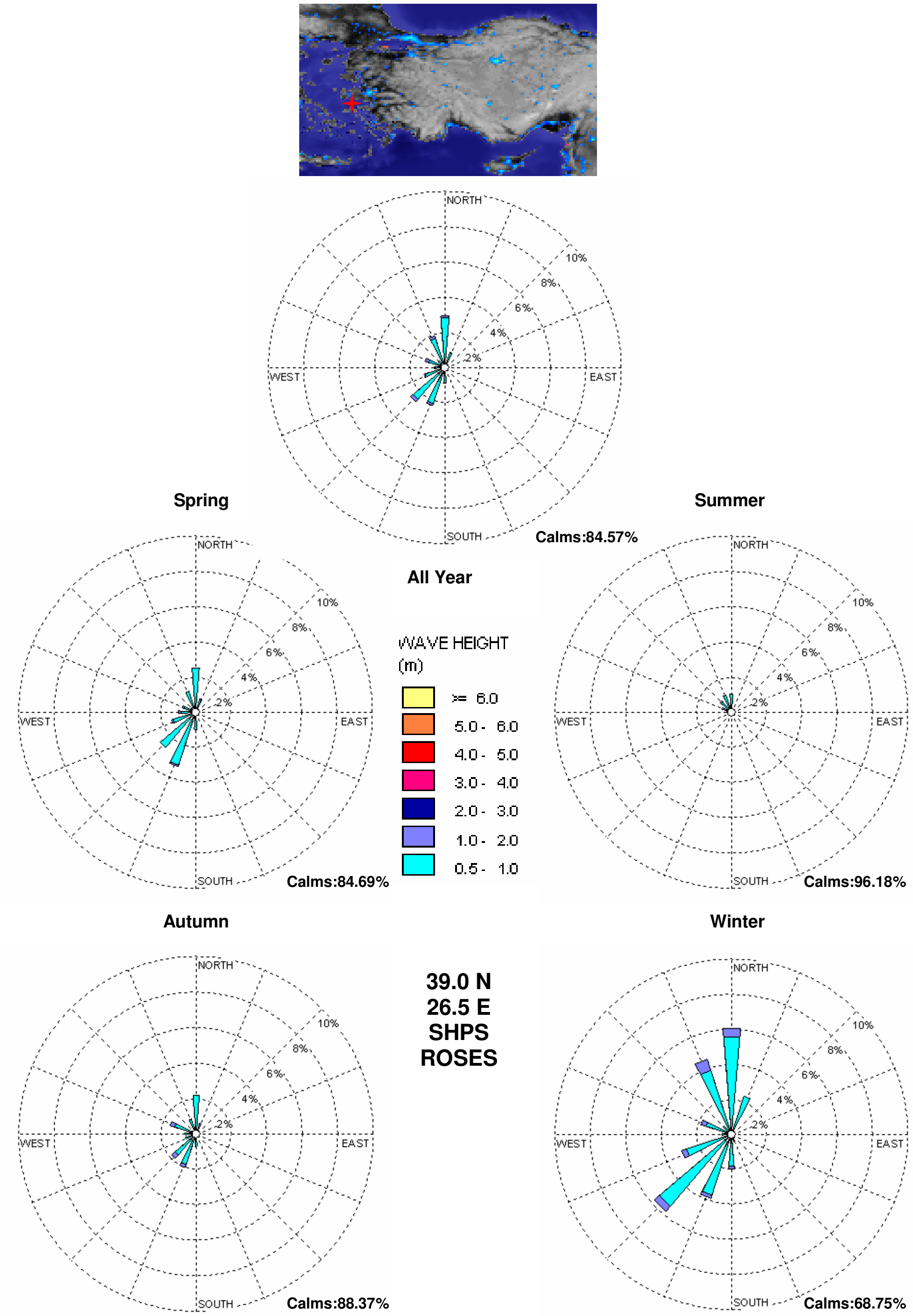

Figure 4.2.2 SHPS climate at 39.0 N, 26.5 E

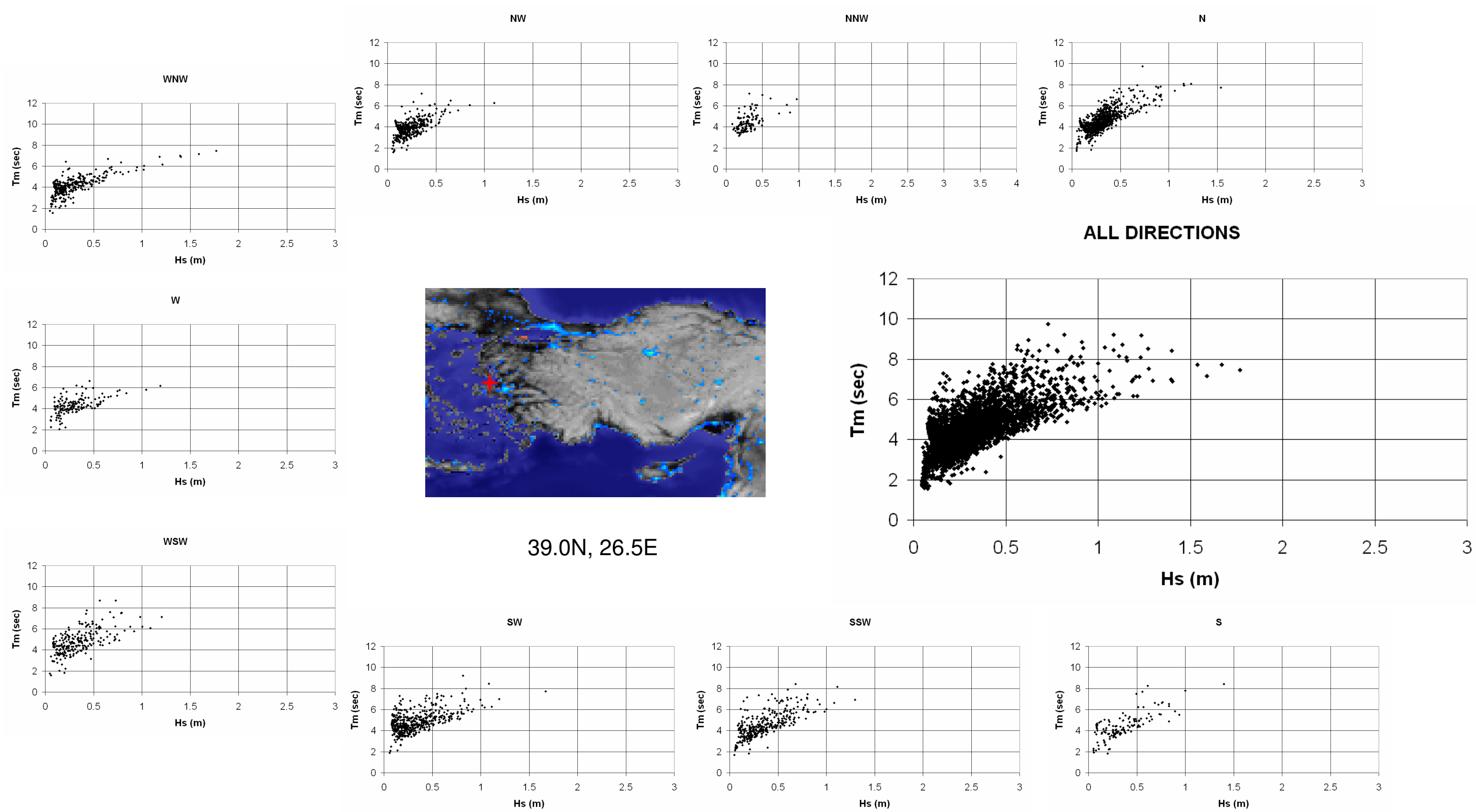

Figure 4.2.3 Relationship between MPPS & SHPS at Dikili

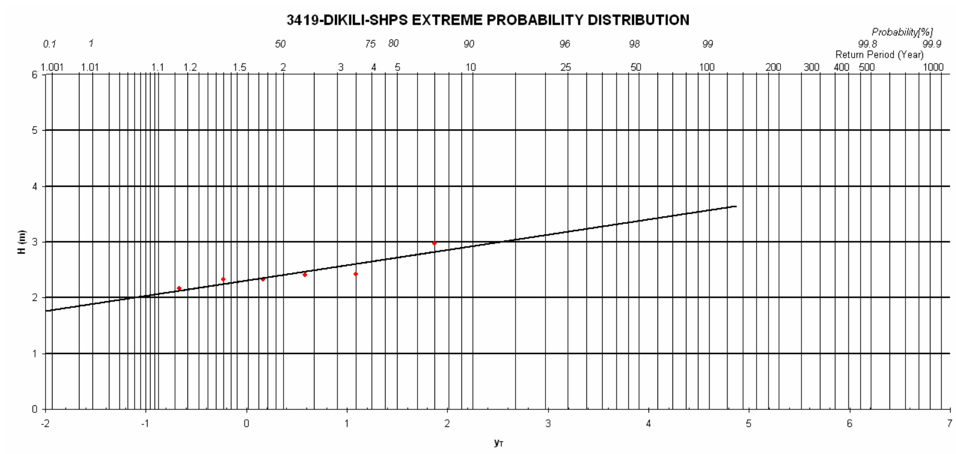

Figure 4.2.4 Extreme Probability Distribution at Location 39.0 N, 26.5

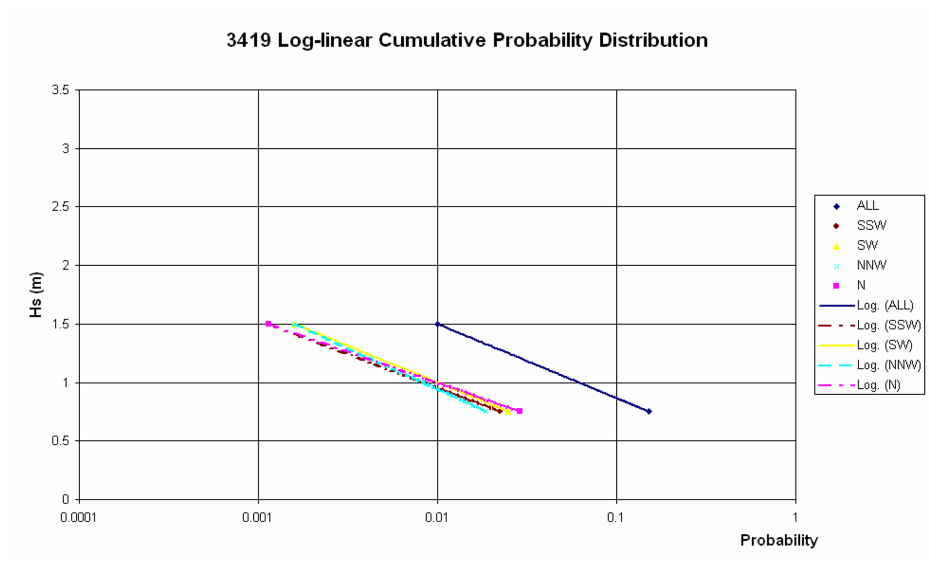

Figure 4.2.5 Log-Linear Cumulative Probability Distribution at 39.0 N, 26.5 E

4.3. LOCATION 3217 - SEFERİHİSAR

The 3217 abbreviated point is located approximately 35 km South West of Seferihisar. The coordinates of point 3217 is; 38.00˚ N, 26.50˚ E.

The Wind Roses, Swell Wave Roses, Significant Wave Height (Hs) vs. Mean Wave Period (Tm) Relations, Extreme value probability statistics and Log-linear cumulative probability distribution are given in this section for this location.

Wind roses are given in Figure 4.3.1 and show that location 3217 is subject to mainly NNW to NNE winds. Strong winds are effective in N direction generally in every season at this location. Especially, northern winds' percentile reaches up to 50% of the time. NNE winds are rather seen in winter mostly and also relatively strong winds are existent from southern directions, in winter.

Wind Roses are compared with the wind roses at the nearest location (38.00˚ N, 26.50˚ E) in Ozhan and Abdalla, (1999) where the dominant wind is from NNW to NNE direction for this location. The yearly wind roses are in correlation with both studies, except some differences in the respective roses belonging to calm durations. In Ozhan and Abdalla, 1999, the calm durations have higher occurrence compared to this study. The winds' percentile of occurrence is higher for all directions in this study.

Swell wave roses are given in Figure 4.3.2 and show a clear indication of direction of incoming swell waves. Nearly 8% of the time swell waves are coming from N and 6% of the time coming from NNE direction in a full year. N swell waves' percentile increases in autumn and winter. The maximum swell wave height is between 2.0 and 2.5 meters.

The relations between Significant Wave Height (Hs) vs. Mean Wave Period (Tm) are given in Figure 4.3.3. In this graph N and SW swell wave domination can be seen via Figure 4.3.2. A rather more scattered distribution is observed in N direction. Few data points, exceeding 10 second periods and several data points exceeding 2.0 m of swell wave heights are observed for N direction with a maximum wave height of 2.393 m. Few swell waves around 10 second periods can be seen for NW and NNW directions. The average steepness of swell waves at this location (From Figure 4.3.3) is 0.010.

The graph of extreme value probability statistics is given in Figure 4.3.4. Data values show a good correlation. Significant wave height is estimated as 3.0 meters for 100 year return period.

Log-linear cumulative probability distribution is given in Figure 4.3.5. Three dominating directions, namely NNE, SW and N are plotted along with all directions. It is seen from this graph that significant height of swell waves exceeds 2.5 meters in about 10 hours duration every year.

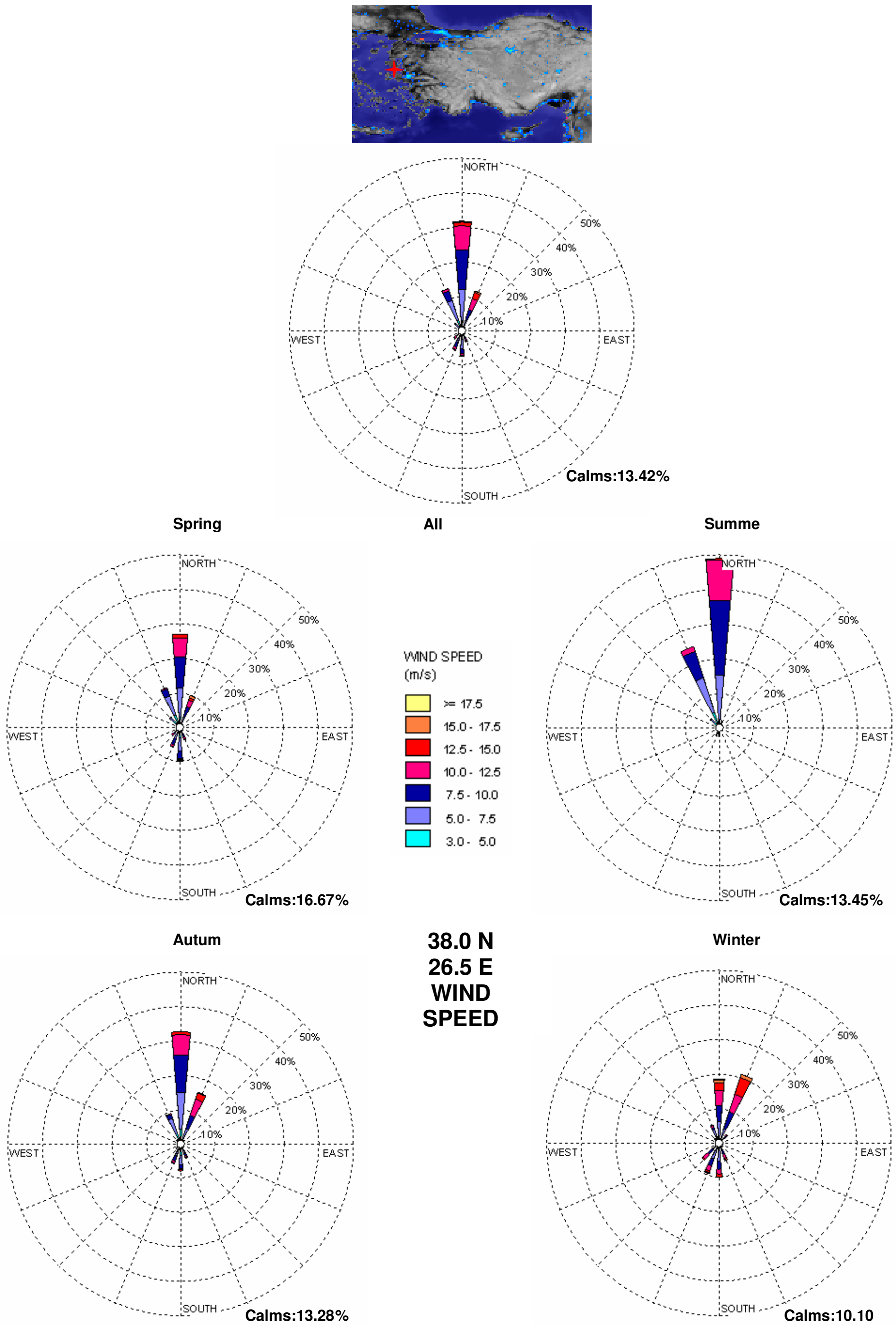

Figure 4.3.1 Wind climate at 38.0 N, 26.5 E

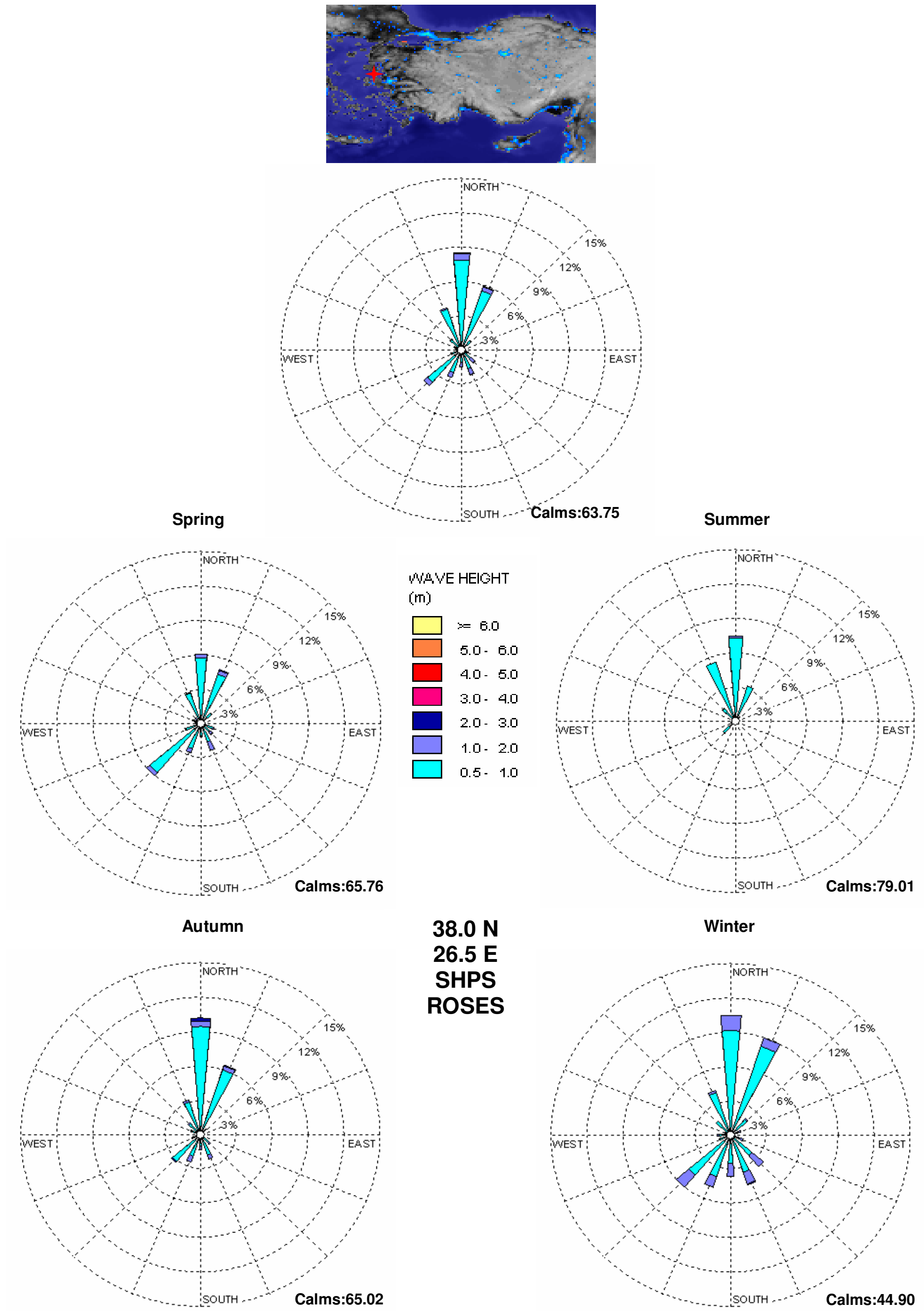

Figure 4.3.2 SHPS climate at 38.0 N, 26.5 E

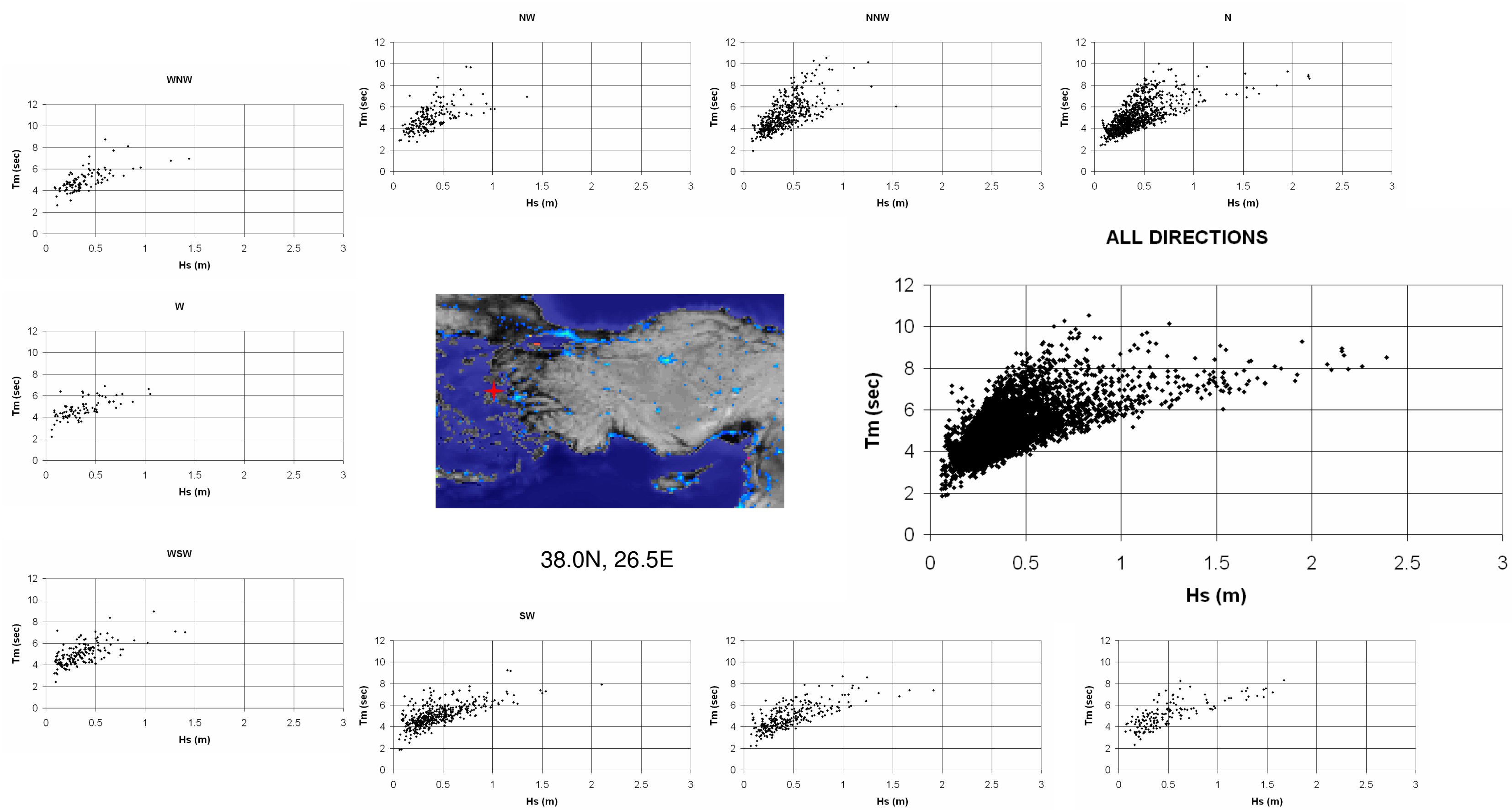

Figure 4.3.3 Relationship between MPPS & SHPS at Seferihisar

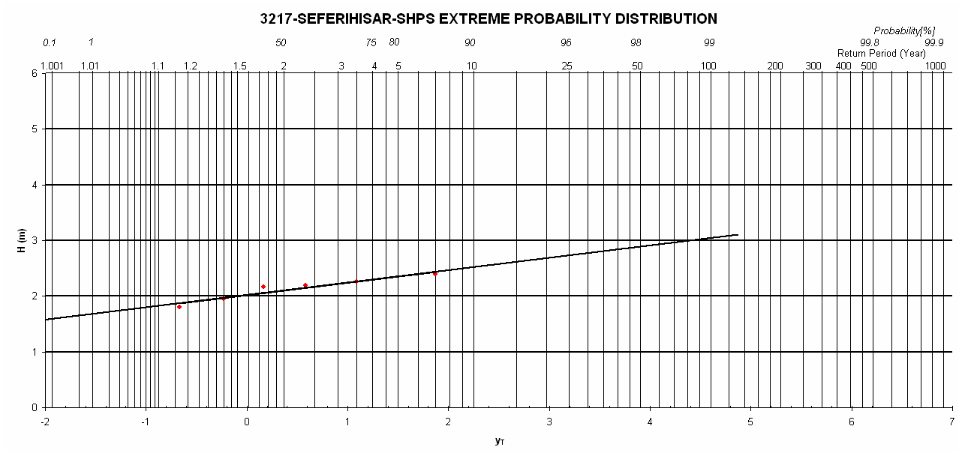

Figure 4.3.4 Extreme Probability Distribution at Location 38.0 N, 26.5

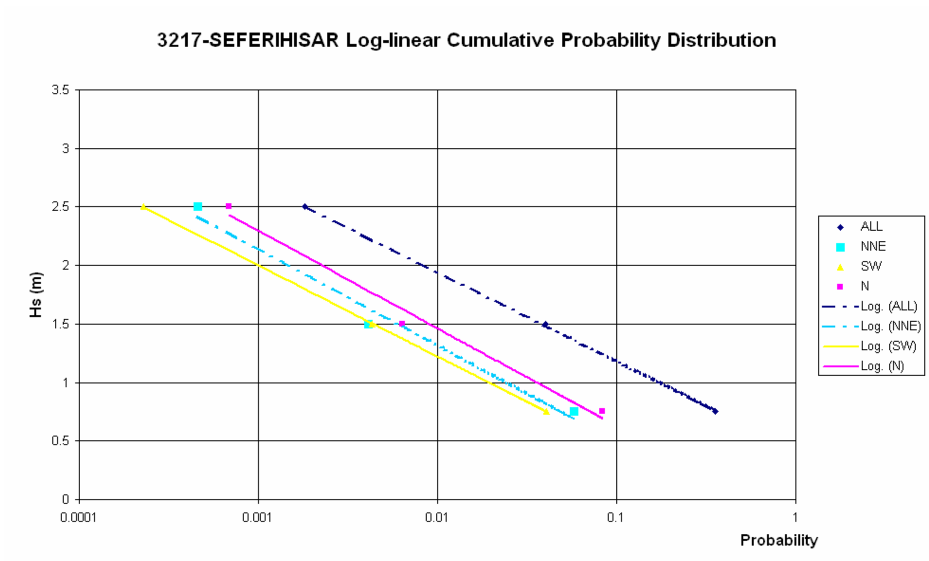

Figure 4.3.5 Log-Linear Cumulative Probability Distribution at 38.0 N, 26.5 E

4.4. LOCATION 3516 - KUŞADASI

The 3516 abbreviated point is located approximately 15 km West of Akköy and 20 km North West of Didim. The coordinates of point 3516 is; 37.50˚ N, 27.00˚ E.

The Wind Roses, Swell Wave Roses, Significant Wave Height (Hs) vs. Mean Wave Period (Tm) Relations, Extreme value probability statistics and Log-linear cumulative probability distribution are given in this section for this location.

Wind roses are given in Figure 4.4.1 and show that location 3516 is subject to mainly N to NNW winds. Strong winds are effective in N direction in all seasons and slides to NNW in summer. Also relatively strong winds are seen from reverse direction, namely S&SSE in winter.

Wind Roses are compared with the wind roses at the nearest location (37.75˚ N, 27.10˚ E) in Ozhan and Abdalla, (1999) where the dominant wind is from N to NNW direction for this location. The yearly wind roses are in correlation with both studies. But there are some differences in the respective roses belonging to calm durations. In Ozhan and Abdalla, 1999, the calm durations in every season are higher than this study.

Swell wave roses are given in Figure 4.4.2. This location is generally calm with respect to swell waves. Nearly 6% of the time swell waves are coming from WSW and 6% of the time coming from NW and SW directions together in a full year. WSW swell waves' percentile increases in winter. The maximum swell wave height is between 1.0 and 1.5 meters.

The relations between Significant Wave Height (Hs) vs. Mean Wave Period (Tm) are given in Figure 4.4.3. In this graph WSW and NW swell wave domination can be seen via Figure 4.4.2. Several data points, reaching to 10 second periods and few data points exceeding 1.0 m of swell wave heights are observed for WSW direction with a maximum wave height of

1.556 m. The average steepness of swell waves at this location (From Figure 4.4.3) is 0.010.

The graph of extreme value probability statistics is given in Figure 4.4.4. Data values show high correlation. Significant swell wave height is estimated as 2.2 meters for 100 year return period.

Log-linear cumulative probability distribution is given in Figure 4.4.5. Three dominating directions; namely WSW, SW and NW are plotted along with all directions. It is seen from this graph that significant height of swell waves exceeds 2.0 meters in about 10 hours duration every year.

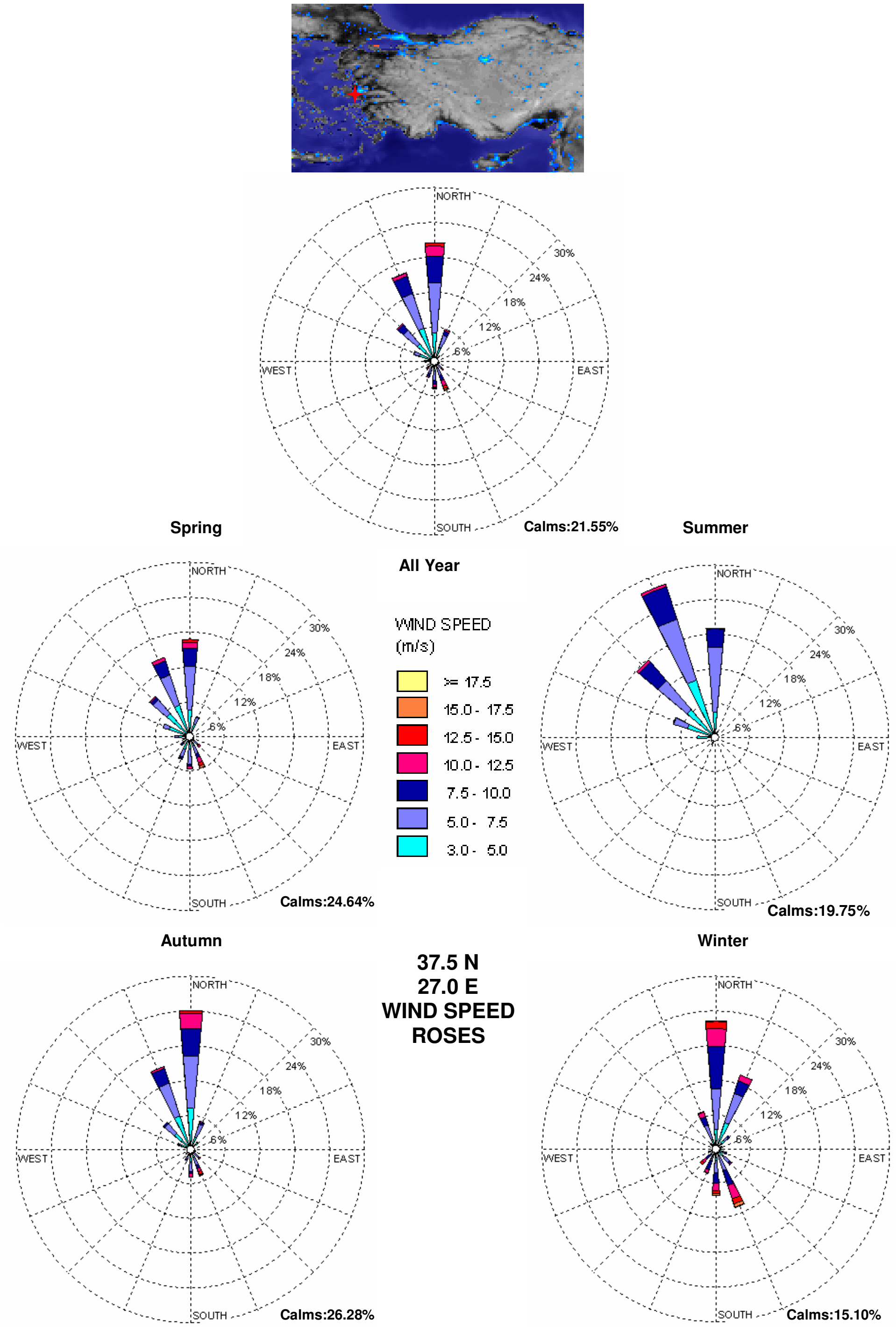

Figure 4.4.1 Wind climate at 37.5 N, 27.0 E

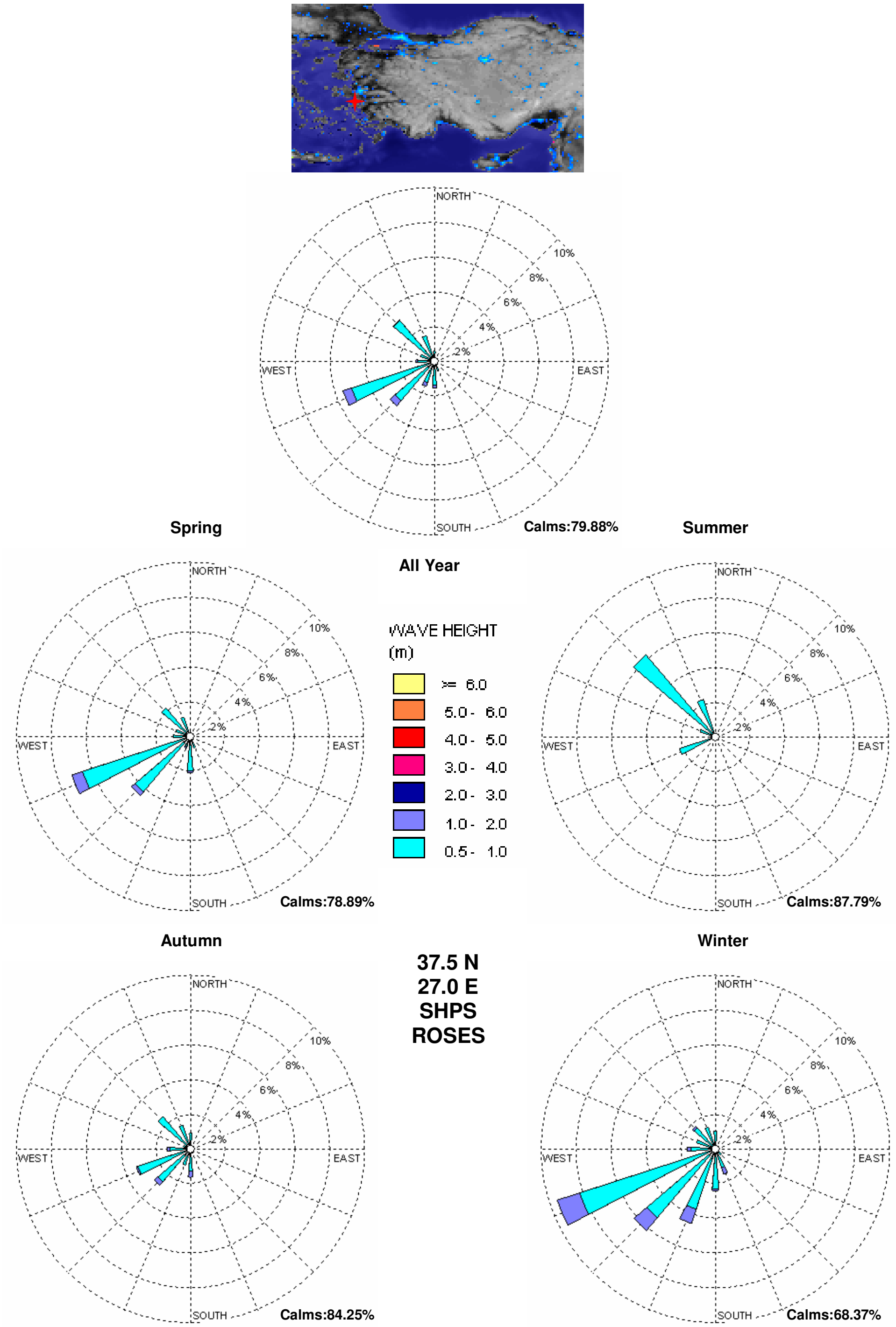

Figure 4.4.2 SHPS climate at 37.5 N, 27.0 E

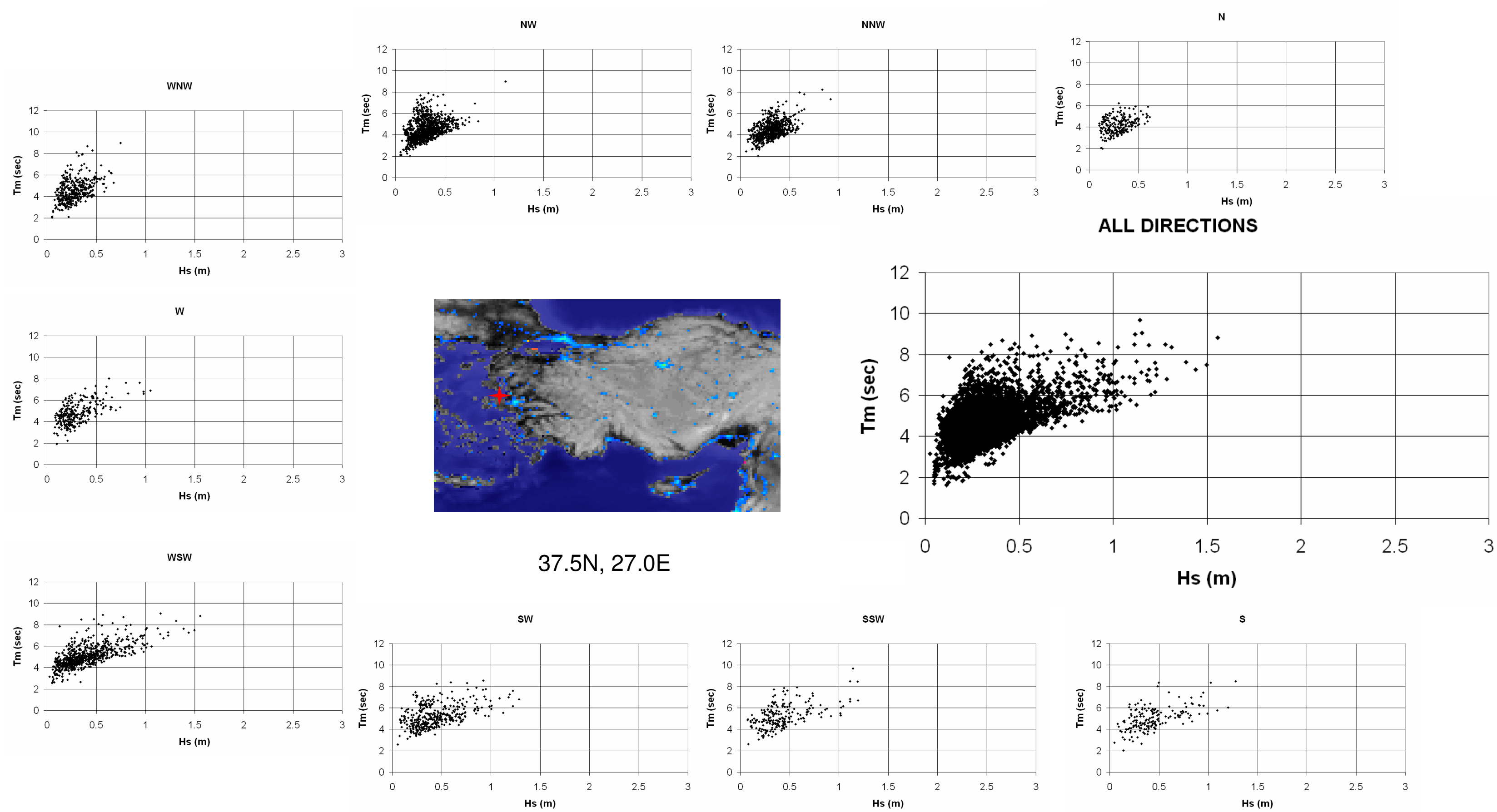

Figure 4.4.3 Relationship between MPPS & SHPS at Kusadasi

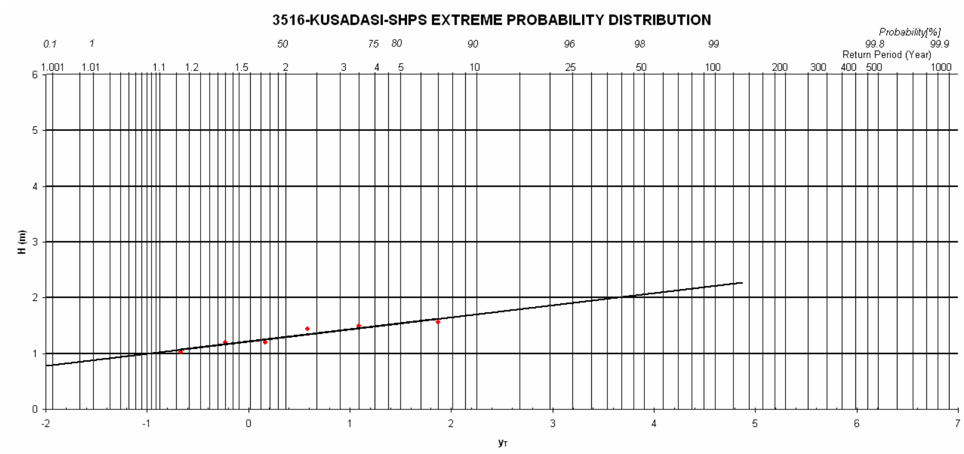

Figure 4.4.4 Extreme Probability Distribution at Location 37.5 N, 27.0

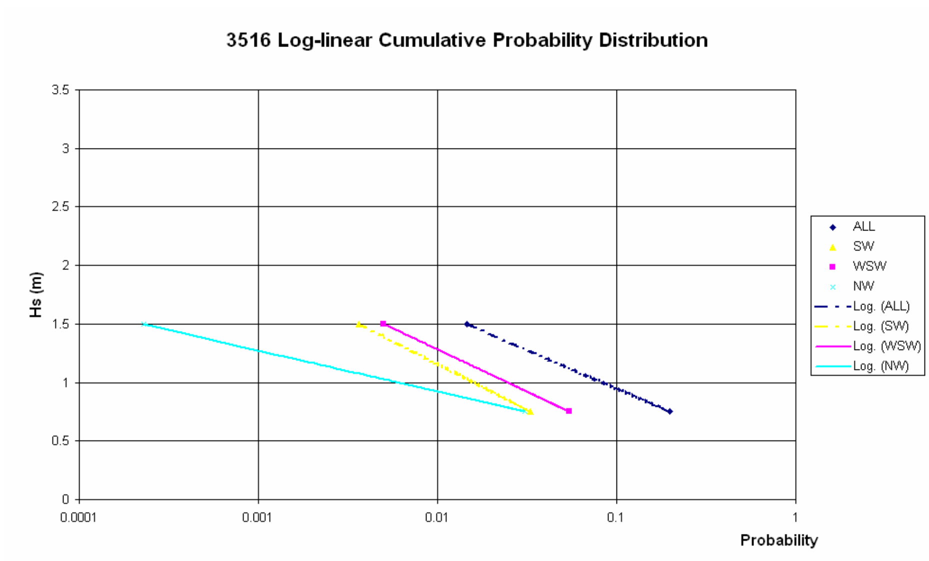

Figure 4.4.5 Log-Linear Cumulative Probability Distribution at 37.5 N, 27.0 E

4.5. LOCATION 3615 - BODRUM

The 3615 abbreviated point is located at the North of Kara Island and 2 km South of Bodrum. The coordinates of point 3615 is; 37.00˚ N, 27.50˚ E.

The Wind Roses, Swell Wave Roses, Significant Wave Height (Hs) vs. Mean Wave Period (Tm) Relations, Extreme value probability statistics and Log-linear cumulative probability distribution are given in this section for this location.

Wind roses are given in Figure 4.5.1 and show that location 3615 is subject to mainly NW to NNW winds. Strong winds are effective in NNW and N directions and slides to NW in summer. Also relatively strong winds are seen from reverse direction, namely SSW&SW in winter.

Wind Roses are compared with the wind roses at the nearest location (37.00˚ N, 27.40˚ E) in Ozhan and Abdalla, (1999) where the dominant wind is from NW to N direction for this location. The yearly wind roses are in correlation with both studies. But there are some differences in the respective roses belonging to wind directions and calm durations. The dominant wind directions differ in every season, except spring. Also, in Ozhan and Abdalla, 1999, the calm durations have less occurrence in every season, except winter.

Swell wave roses are given in Figure 4.5.2 and show a clear indication of direction of incoming swell waves. Nearly 10% of the time swell waves are coming from NW and 7% of the time coming from WSW direction in a full year. NW swell waves' percentile increases in summer and reaches up to 18% of the time. The maximum swell wave height is between 1.5 and 2.0 meters.

The relations between Significant Wave Height (Hs) vs. Mean Wave Period (Tm) are given in Figure 4.5.3. In this graph WSW and NW swell wave domination can be seen via Figure 4.5.2. A rather more scattered distribution is observed in WSW direction. Several data points, exceeding

9 second periods and 1.0 m of swell wave heights are observed for WSW direction with a maximum wave height of 2.259 m. The average steepness of swell waves at this location (From Figure 4.5.3) is 0.011.

The graph of extreme value probability statistics is given in Figure 4.5.4. Significant swell wave height is estimated as 3.7 meters for 100 year return period.

Log-linear cumulative probability distribution is given in Figure 4.5.5. Four dominating directions; namely WSW, SW, NNW and NW are plotted along with all directions. It is seen from this graph that significant height of swell waves exceeds 2.2 meters in about 10 hours duration every year.

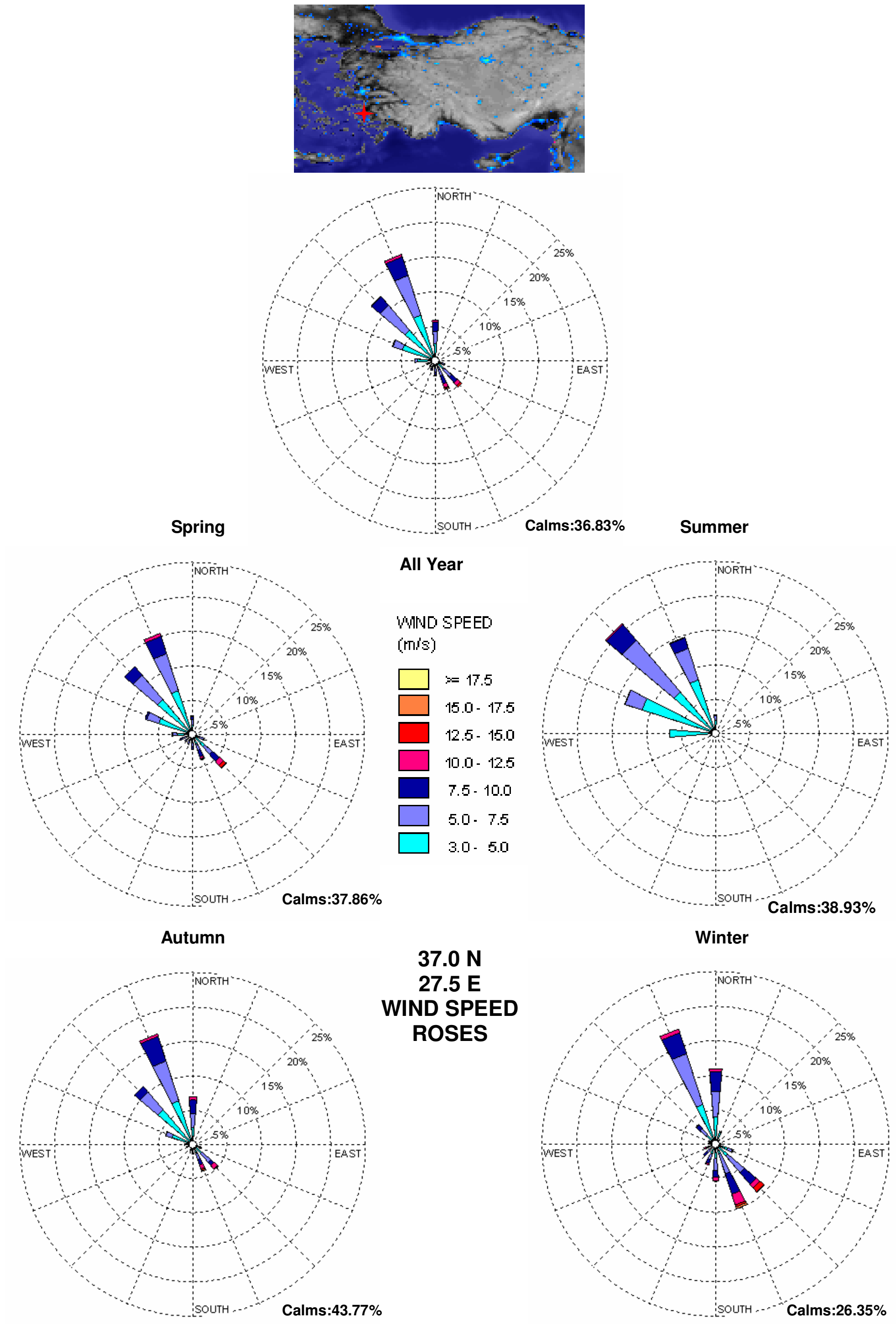

Figure 4.5.1 Wind climate at 37.0 N, 27.5 E

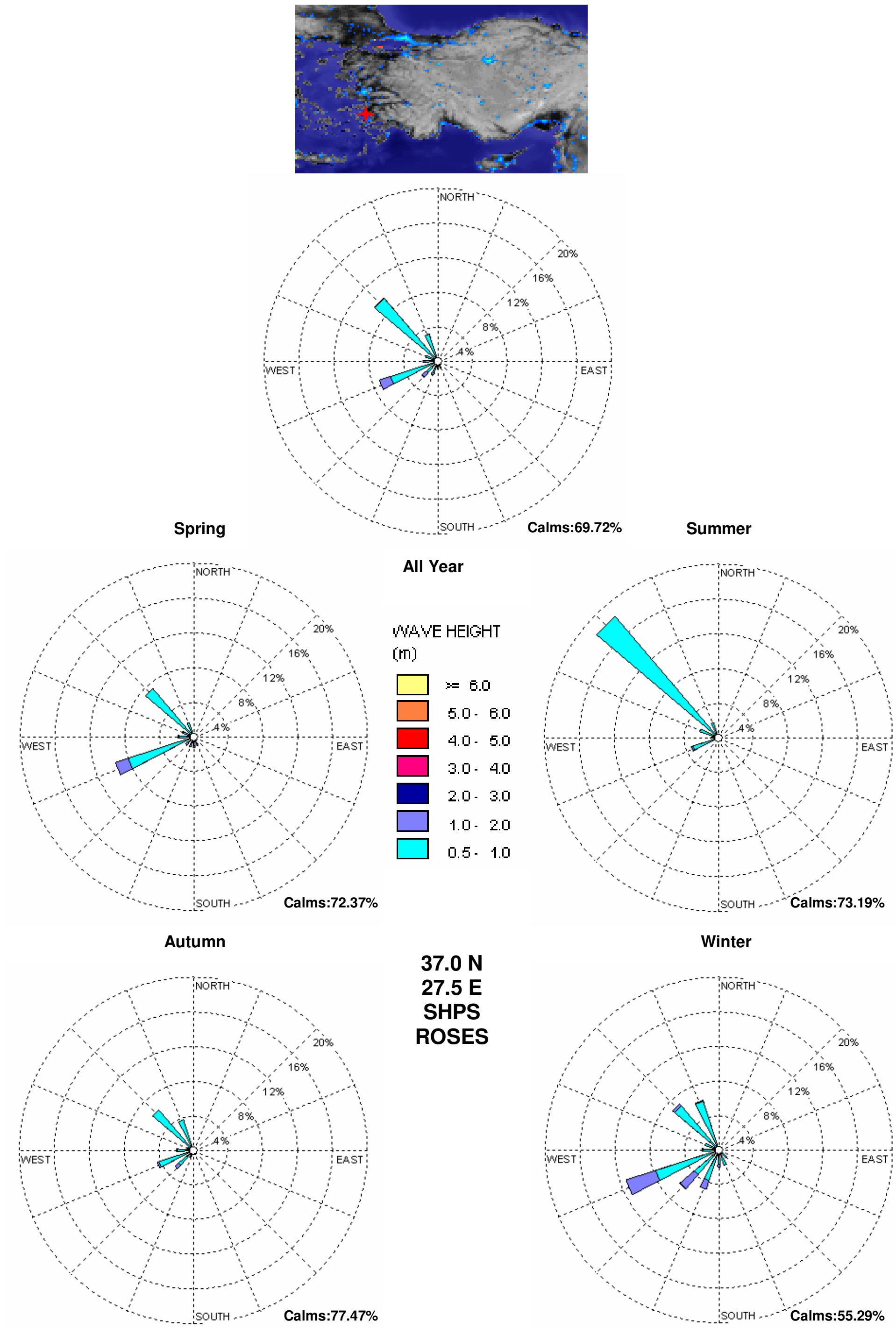

Figure 4.5.2 SHPS climate at 37.0 N, 27.5 E

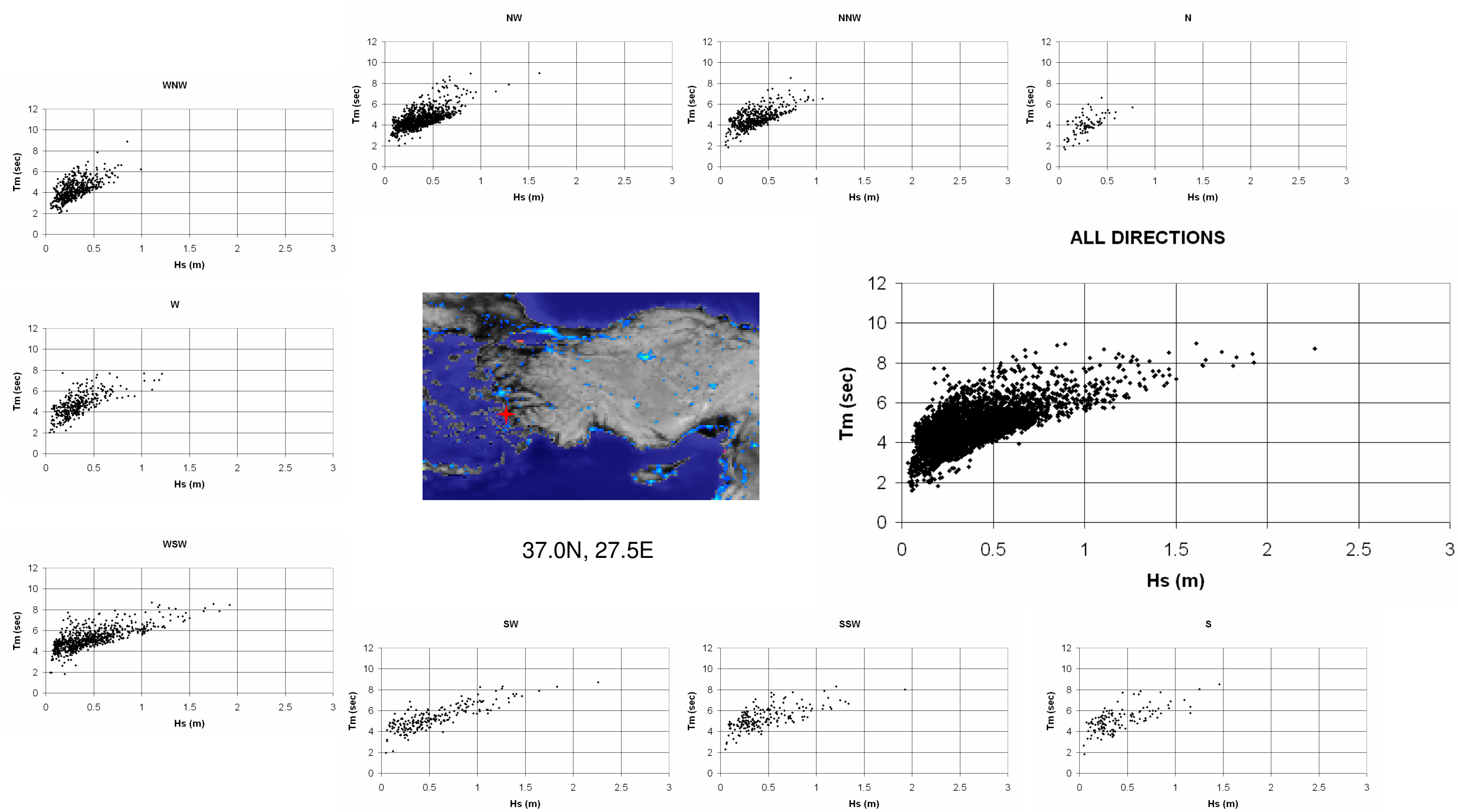

Figure 4.5.3 Relationship between MPPS & SHPS at Bodrum

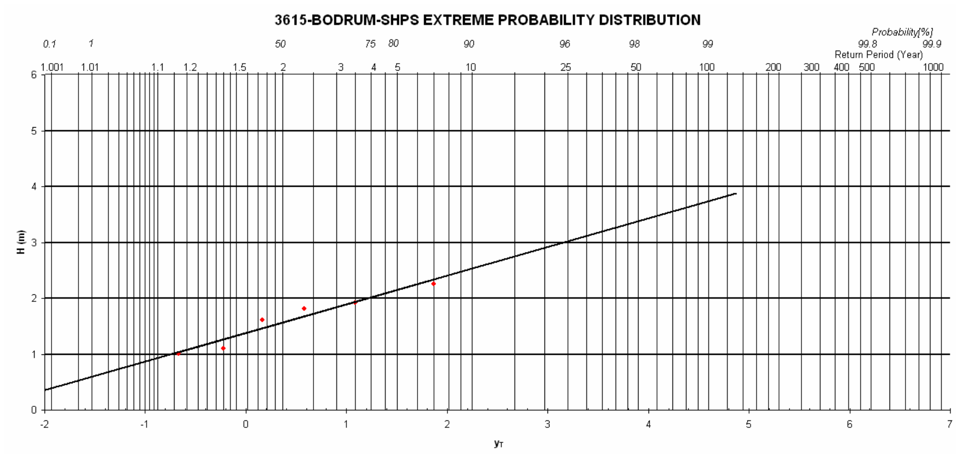

Figure 4.5.4 Extreme Probability Distribution at Location 37.0 N, 27.5

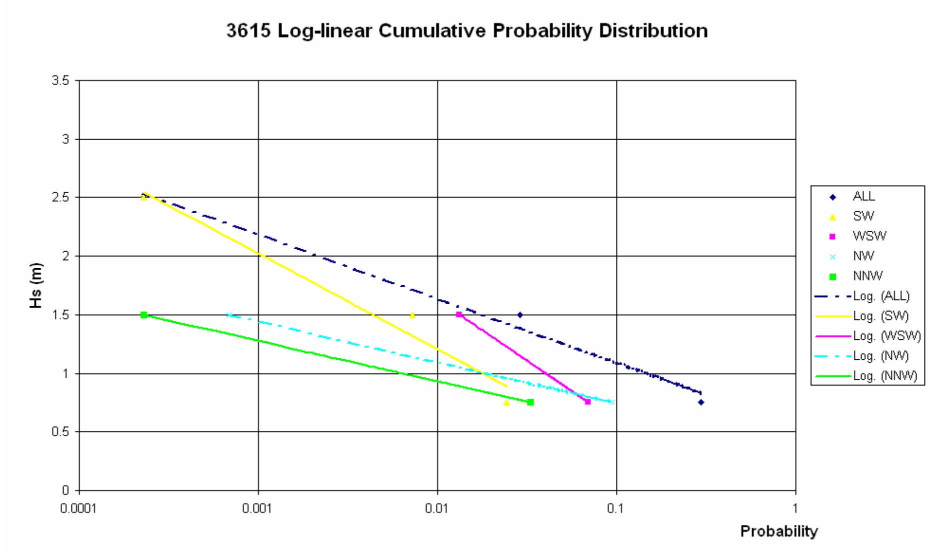

Figure 4.5.5 Log-Linear Cumulative Probability Distribution at 37.0 N, 27.5 E

4.6. LOCATION 3514 - DATÇA

The 3514 abbreviated point is located approximately 15 km South of Reşadiye Yarımadası and 20 km West of Simi Island. The coordinates of point 3514 is; 36.50˚ N, 27.50˚ E.

The Wind Roses, Swell Wave Roses, Significant Wave Height (Hs) vs. Mean Wave Period (Tm) Relations, Extreme value probability statistics and Log-linear cumulative probability distribution are given in this section for this location.

Wind roses are given in Figure 4.6.1 and show that location 3514 is subject to different wind directions such as; NW, WNW, NNW and SE. Strong winds are effective in SE direction in winter and in WNW direction in summer. Also relatively strong winds are seen from N direction in every season except in summer.

Wind Roses are compared with the wind roses at the nearest location (36.75˚ N, 27.40˚ E) in Ozhan and Abdalla, (1999) where the dominant wind is from NW to N direction for this location. The yearly wind roses are not compatible with both studies generally. Against this study, in Ozhan and Abdalla, 1999, the dominant wind directions are in a range between N and NW. Whereas, strong winds are observed in SW and SSW directions in this study. There are also sharp differences in the respective roses belonging to calm durations. In Ozhan and Abdalla, 1999, calm durations change approximately between 20% and 30%. On the other hand, calm durations are around 70% of the time in this study.

Swell wave roses are given in Figure 4.6.2 and show a clear indication of direction of incoming swell waves. Nearly 14% of the time swell waves are coming from W and 9% of the time coming from WSW direction in a full year. W swell waves' percentile increases in summer. The maximum swell wave height is between 2.5 and 3.0 meters.

The relations between Significant Wave Height (Hs) vs. Mean Wave Period (Tm) are given in Figure 4.6.3. In this graph W, WSW and WNW swell wave domination can be seen via Figure 4.6.2. Several data points, exceeding 8 second periods and 2.0 m of swell wave heights are observed for W, WSW and SW directions with a maximum wave height of 3.144 m. The average steepness of swell waves at this location (From Figure 4.6.3) is 0.011.

The graph of extreme value probability statistics is given in Figure 4.6.4. Significant swell wave height is estimated as 5.0 meters for 100 year return period.

Log-linear cumulative probability distribution is given in Figure 4.6.5. Four dominating directions; namely WSW, SW, W and WNW are plotted along with all directions. It is seen from this graph that significant height of swell waves exceeds 2.7 meters in about 10 hours duration every year.

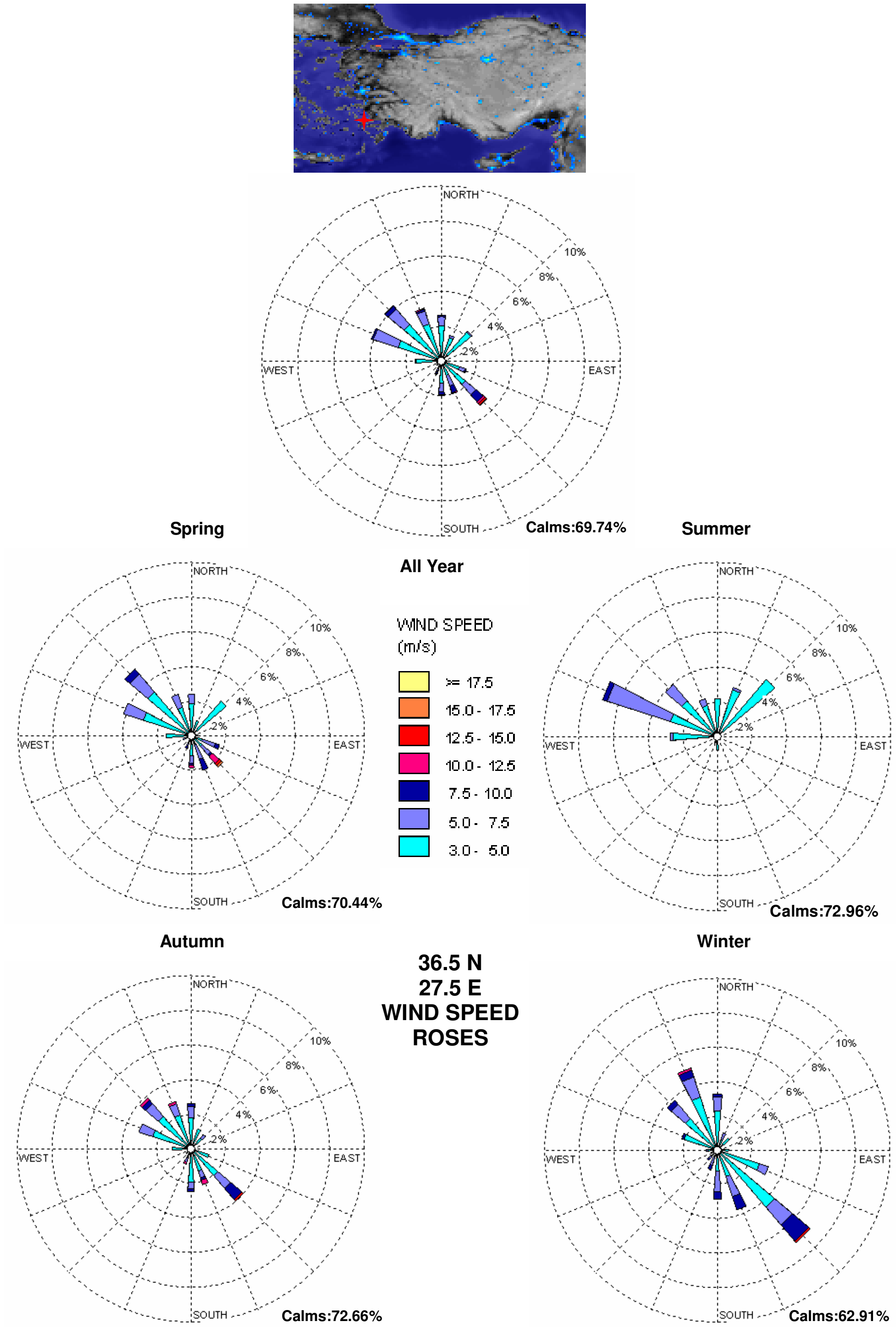

Figure 4.6.1 Wind climate at 36.5 N, 27.5 E

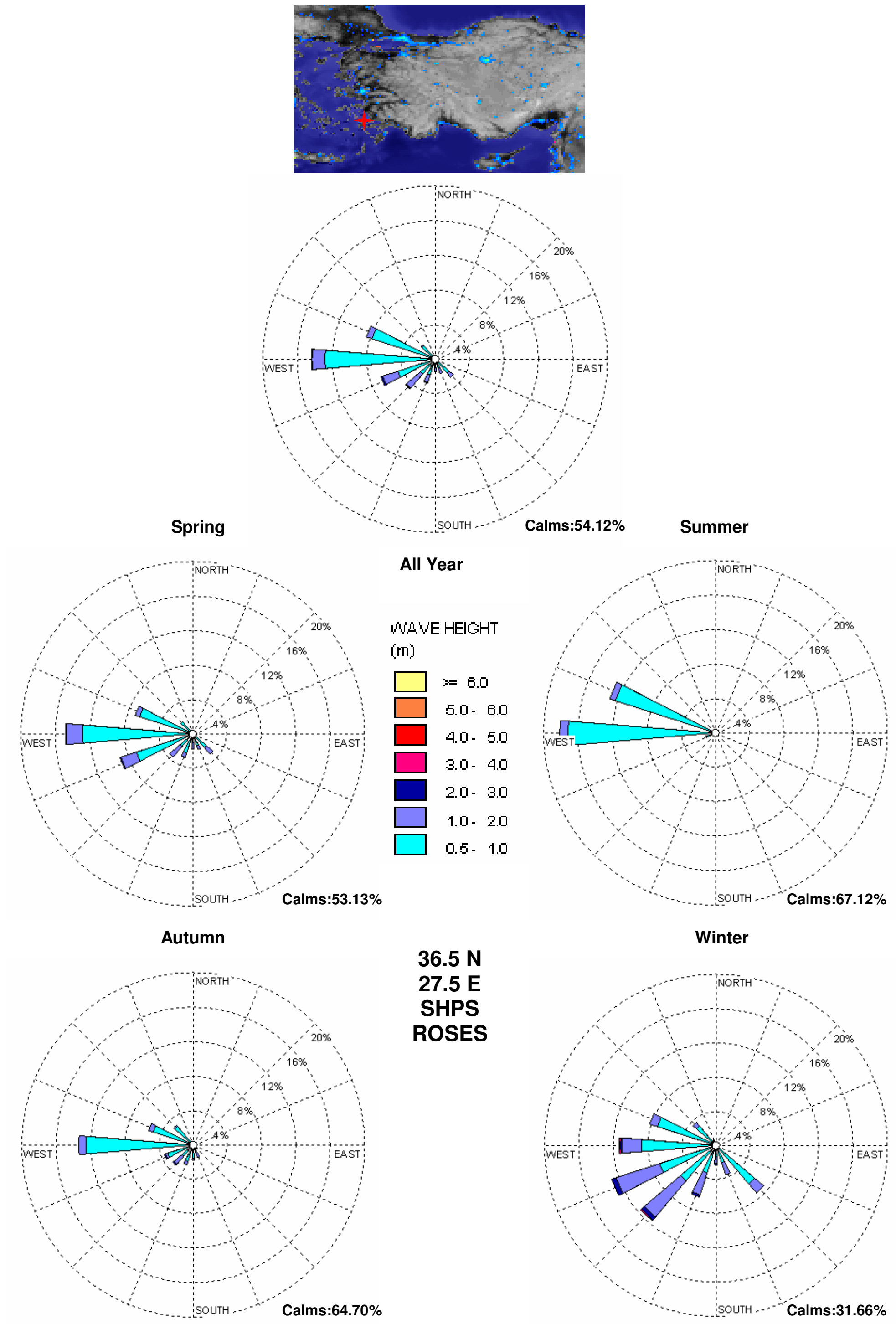

Figure 4.6.2 SHPS climate at 36.5 N, 27.5 E

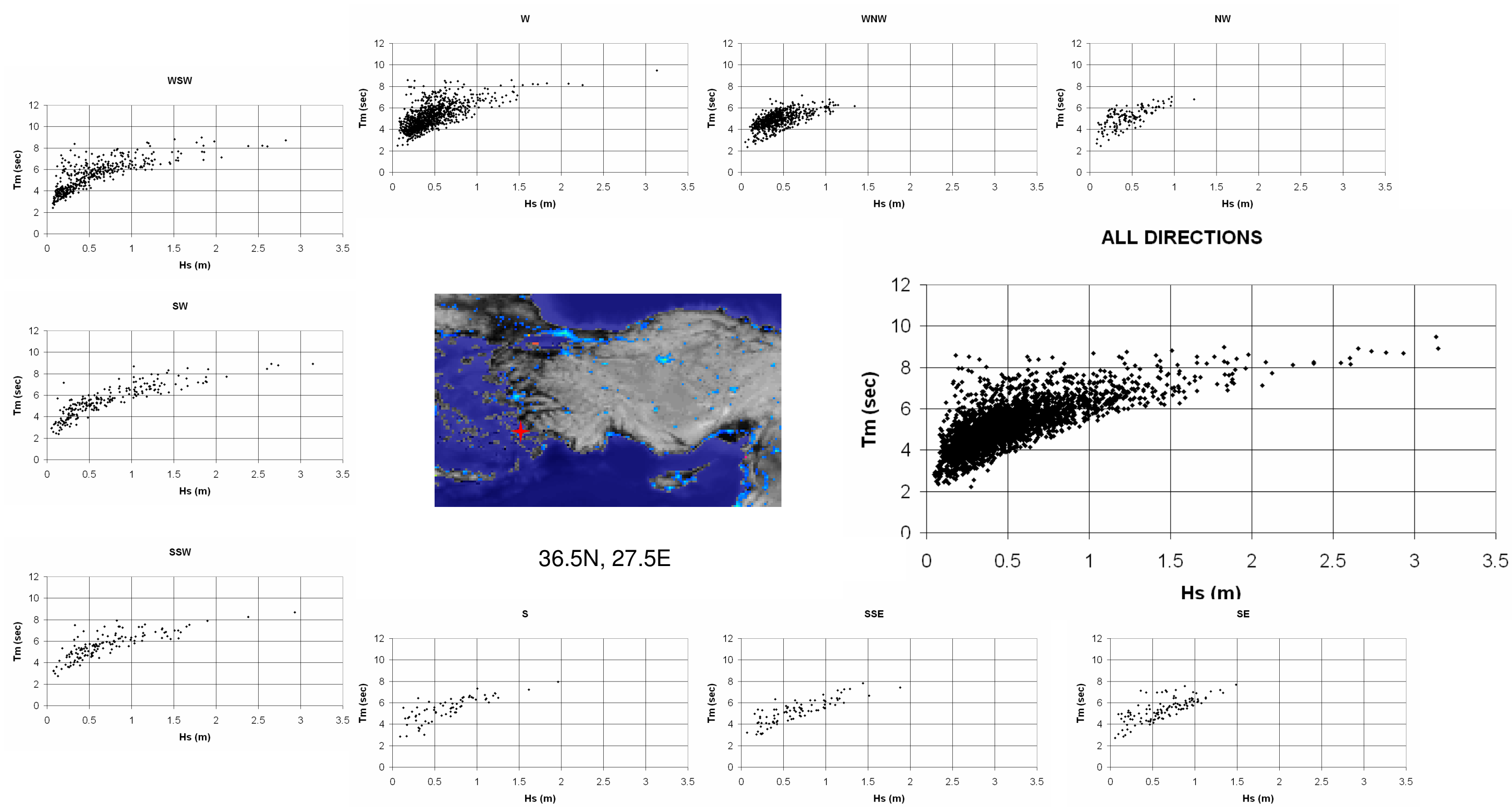

Figure 4.6.3 Relationship between MPPS & SHPS at Datça

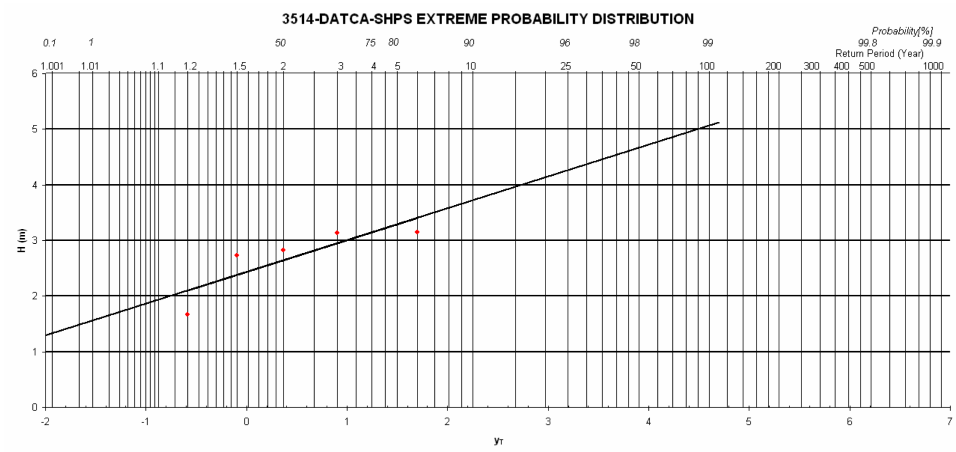

Figure 4.6.4 Extreme Probability Distribution at Location 36.5 N, 27.5

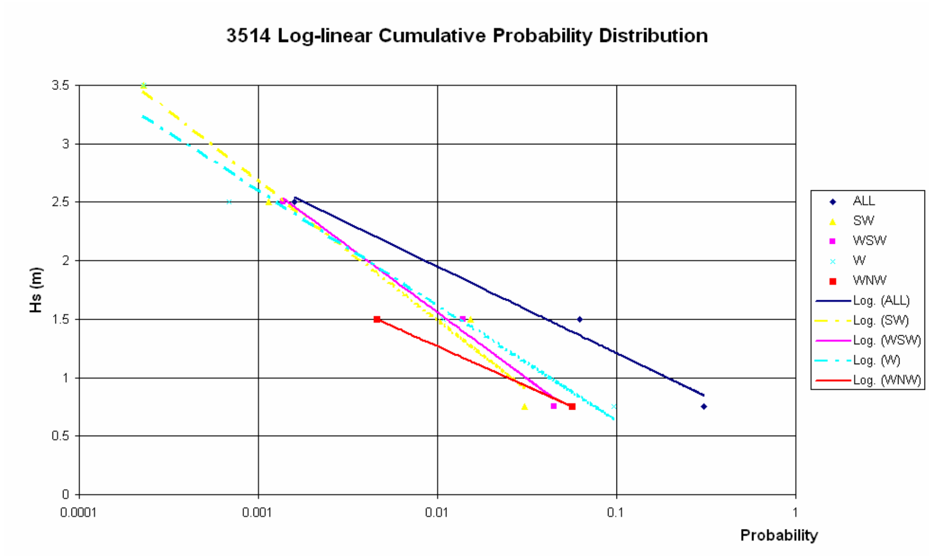

Figure 4.6.5 Log-Linear Cumulative Probability Distribution at 36.5 N, 27.5 E

4.7. LOCATION 3814 - DALAMAN

The 3814 abbreviated point is located approximately 35 km South West of Dalaman. The coordinates of point 3814 is; 36.50˚ N, 28.50˚ E.

The Wind Roses, Swell Wave Roses, Significant Wave Height (Hs) vs. Mean Wave Period (Tm) Relations, Extreme value probability statistics and Log-linear cumulative probability distribution are given in this section for this location.

Wind roses are given in Figure 4.7.1 and show that location 3814 is subject to mainly W to NNW winds. Strong winds are effective on the alignment of NW to SE directions in winter and slides to W-SW range in summer. Also relatively strong winds are seen from N direction in winter.

Wind Roses are compared with the wind roses at the nearest location (36.75˚ N, 28.60˚ E) in Ozhan and Abdalla, (1999) where the dominant wind is from NW to N direction for this location. The yearly wind roses are in correlation with both studies. However, there are slight differences between them. In this study, western winds are commonly seen in summer and southeastern winds have higher percentage in winter, which are not same in Ozhan and Abdalla, 1999.

Swell wave roses are given in Figure 4.7.2. Nearly 9% of the time swell waves are coming form W and 7% of the time coming from WNW direction in a full year. WNW swell waves' percentile increases in summer and SE swell waves' percentile increases in winter obviously. The maximum swell wave height is between 2.0 and 3.0 meters.

The relations between Significant Wave Height (Hs) vs. Mean Wave Period (Tm) are given in Figure 4.7.3. In this graph W and WNW swell wave domination can be seen via Figure 4.7.2. A rather more scattered distribution is observed in W direction. Several data points, around 10 second periods and 2.0 m of swell wave heights are observed for both W and WSW directions. The maximum swell wave height is 3.289 m. The average steepness of swell waves at this location (From Figure 4.7.3) is 0.011.

The graph of extreme value probability statistics is given in Figure 4.7.4. Significant swell wave height is estimated as 5.2 meters for 100 year return period.

Log-linear cumulative probability distribution is given in Figure 4.7.5. Four dominating directions; namely SW, WSW, W and WNW are plotted along with all directions. It is seen from this graph that significant height of swell waves exceeds 2.7 meters in about 10 hours duration every year.

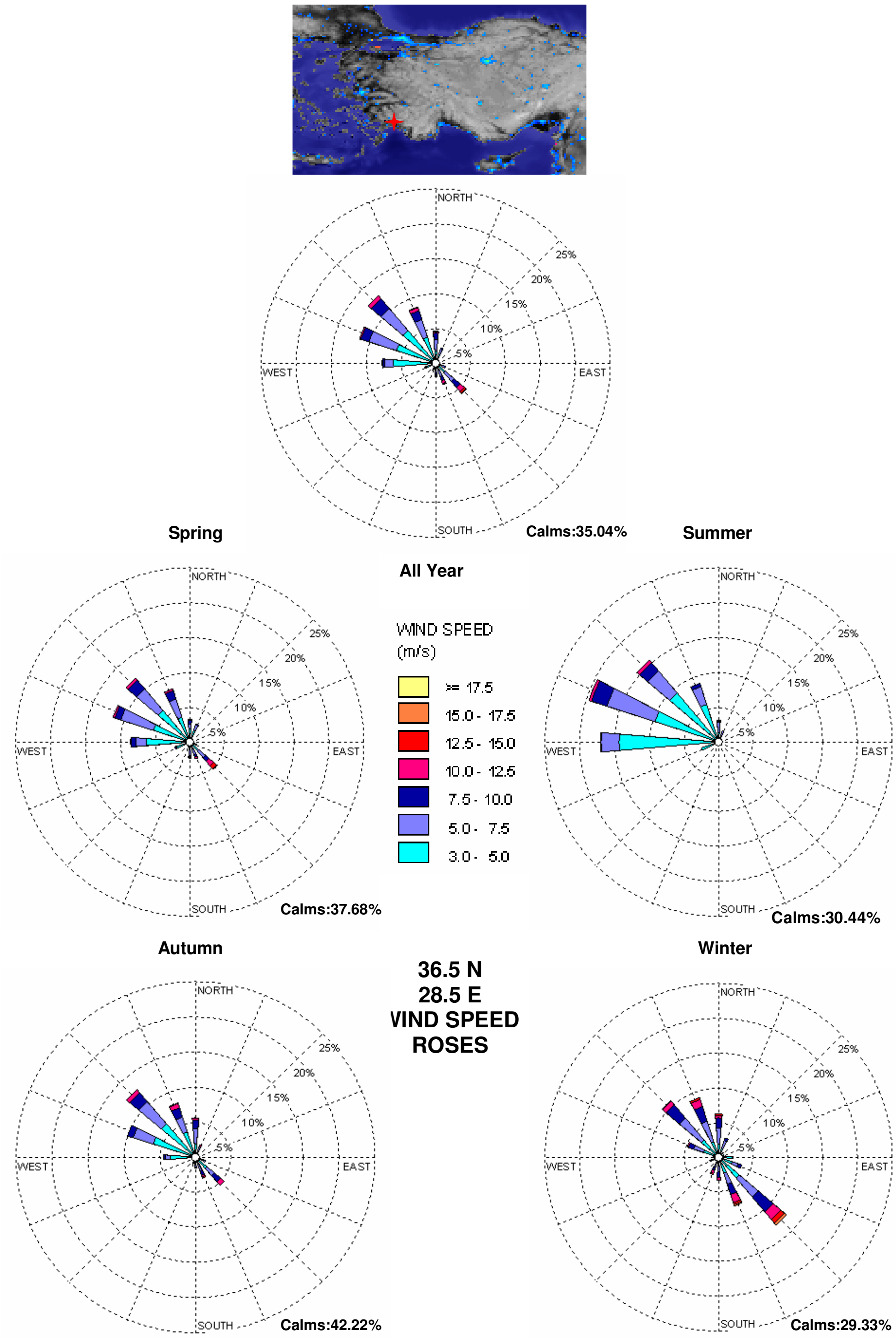

Figure 4.7.1 Wind climate at 36.5 N, 28.5 E

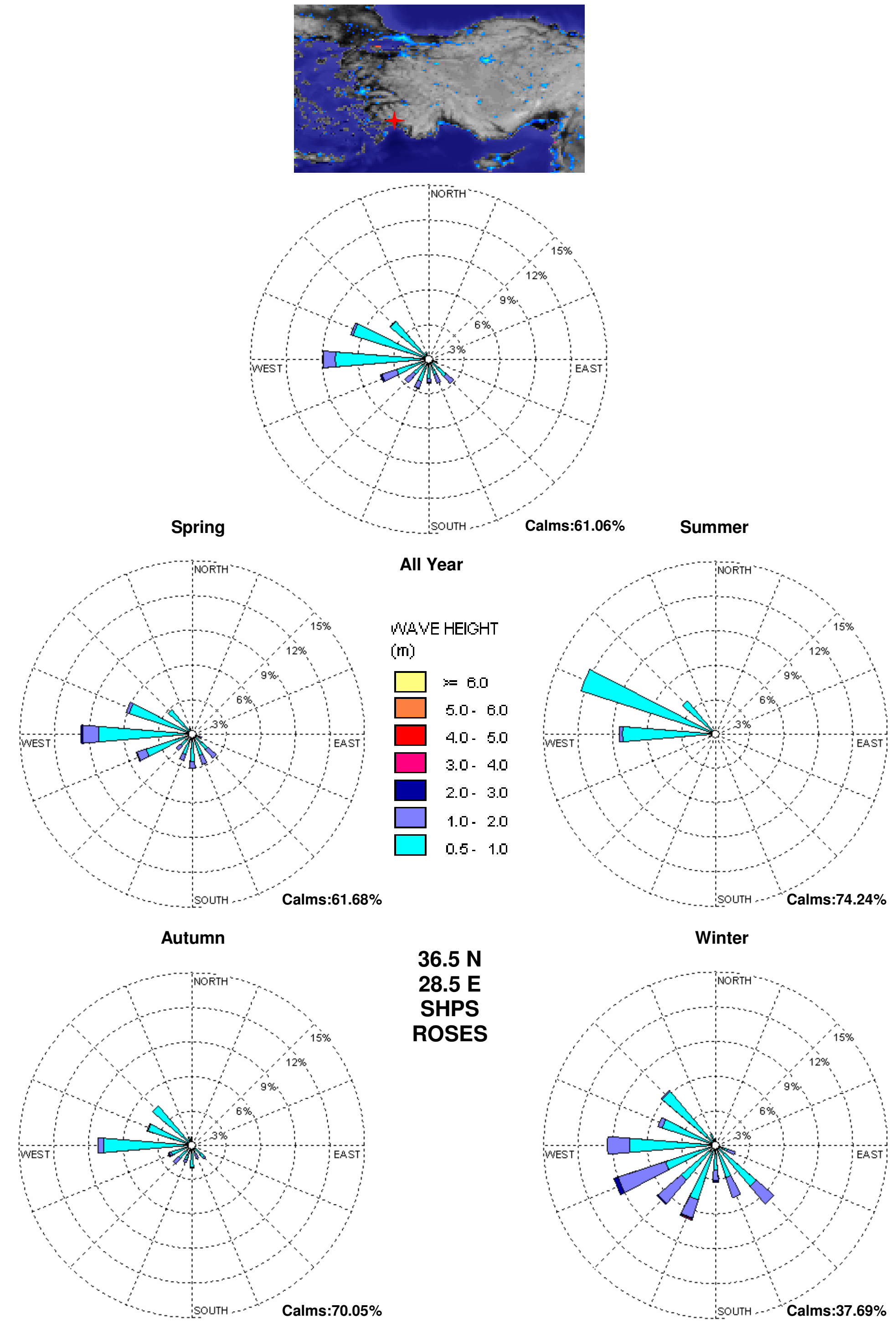

Figure 4.7.2 SHPS climate at 36.5 N, 28.5 E

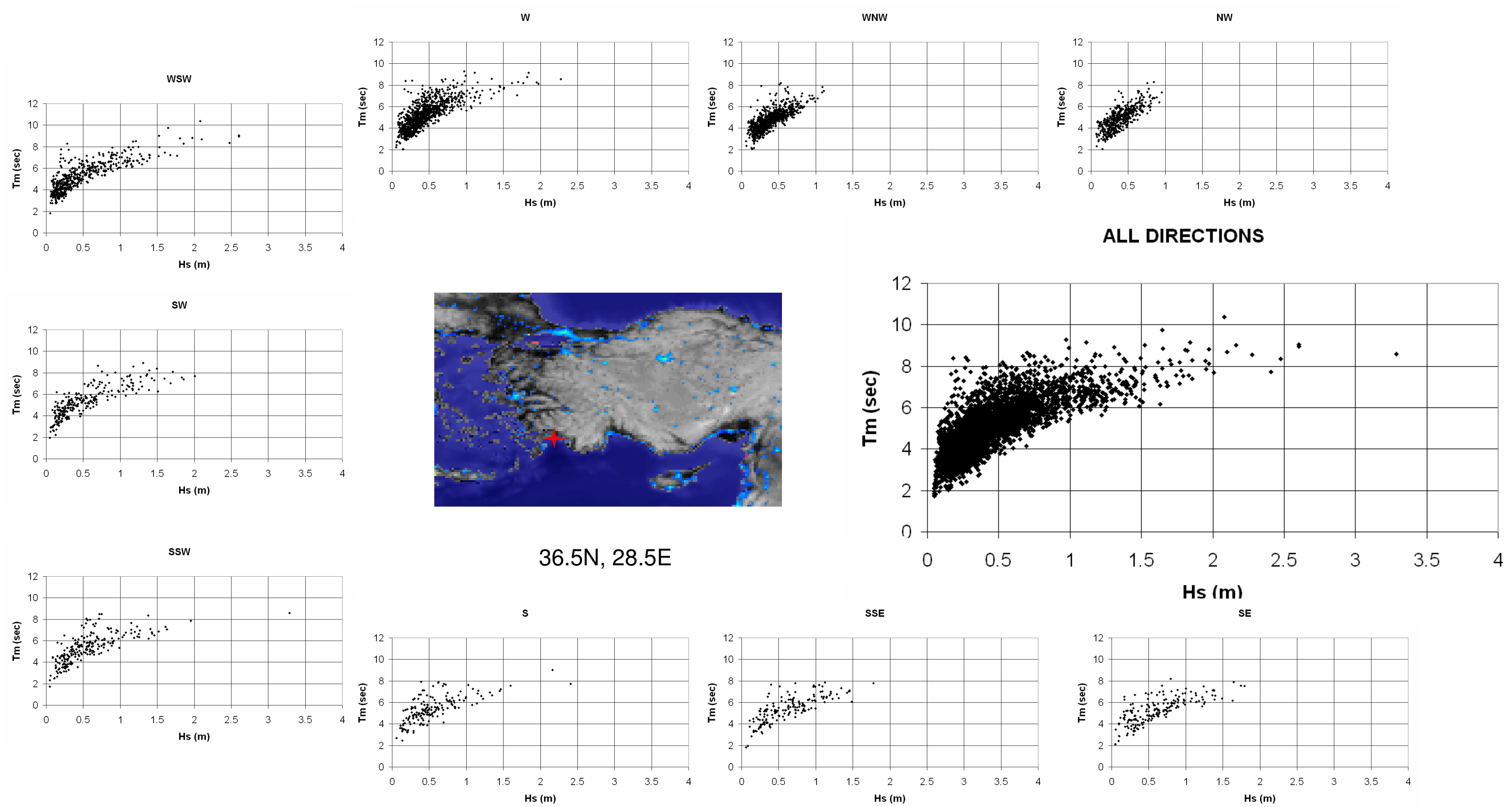

Figure 4.7.3 Relationship between MPPS & SHPS at Dalaman

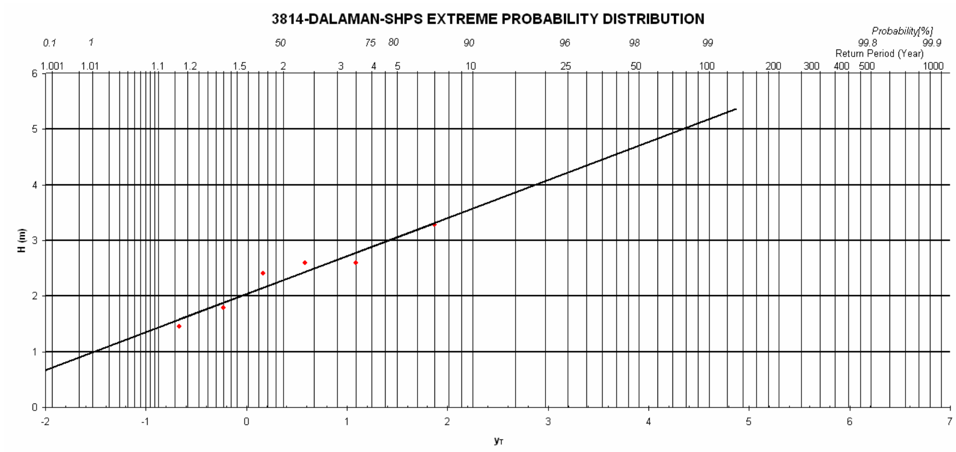

Figure 4.7.4 Extreme Probability Distribution at Location 36.5 N, 28.5

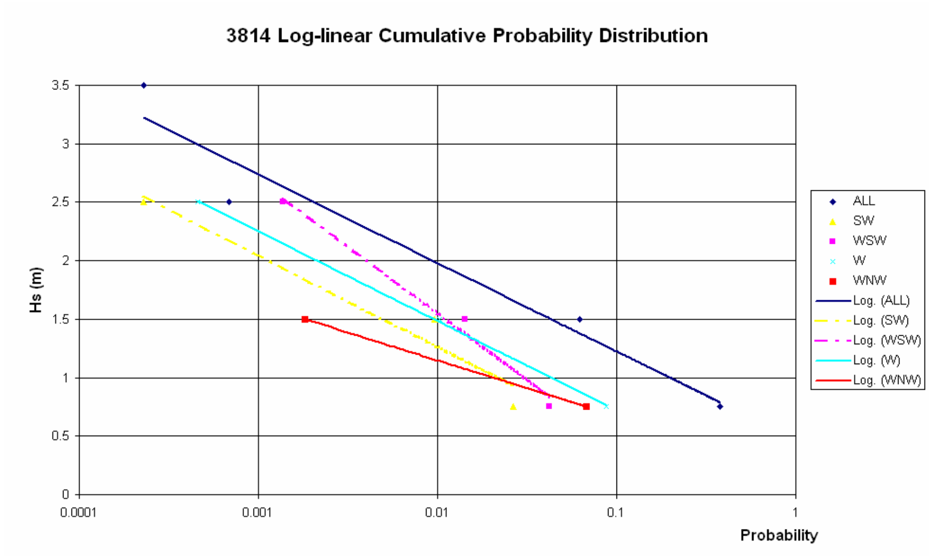

Figure 4.7.5 Log-Linear Cumulative Probability Distribution at 36.5 N, 28.5 E

4.8. LOCATION 3913 - FETHİYE

The 3913 abbreviated point is located approximately 10 km South of Fethiye. The coordinates of point 3913 is; 36.50˚ N, 29.00˚ E.

The Wind Roses, Swell Wave Roses, Significant Wave Height (Hs) vs. Mean Wave Period (Tm) Relations, Extreme value probability statistics and Log-linear cumulative probability distribution are given in this section for this location.

Wind roses are given in Figure 4.8.1 and show that location 3913 is subject to mainly WNW to NW winds. WNW directed winds dictate reaching nearly 40% percentile and also strong winds occur in ESE direction in winter.

Wind Roses are compared with the wind roses at the nearest location (36.50˚ N, 28.90˚ E) in Ozhan and Abdalla, (1999) where the dominant wind is from NW to NNW direction for this location. The yearly wind roses are in correlation with both studies. However, there are slight differences in winter season. In Ozhan and Abdalla, (1999), the northern winds occur more than that of this study. Besides, in this study; East Southeast directed winds are seen with 15% percentile in winter.

Swell wave roses are given in Figure 4.8.2 and show a wide range of directions of incoming swell waves. Nearly 5% of the time swell waves are coming from each WNW, W, WSW and SW directions. WNW swell waves' percentile increases in summer and SW swell waves' percentile increases in winter. The maximum swell wave height is between 1.5 and 2.5 meters.

The relations between Significant Wave Height (Hs) vs. Mean Wave Period (Tm) are given in Figure 4.8.3. In this graph a range of directions from WNW to SW swell wave domination can be seen via Figure 4.8.2. Several data points, around 10 second periods and exceeding 2.0 m of swell wave heights are observed for SW direction. The maximum swell wave height is 2.473 m for S direction. The average steepness of swell waves at this location (From Figure 4.8.3) is 0.012.

The graph of extreme value probability statistics is given in Figure 4.8.4. Data values show high correlation. Significant swell wave height is estimated as 3.0 meters for 100 year return period.

Log-linear cumulative probability distribution is given in Figure 4.8.5. Wide range of dominating directions; namely SW, WSW, W, WNW, SSW and ESE are plotted along with all directions. It is seen from this graph that significant height of swell waves exceeds 2.5 meters in about 10 hours duration every year.

It is noted the results of Fethiye region are not fully compatible with nearby study regions Dalaman and Kaş. It is recommended that further analysis is needed for practice applications for Fethiye results.

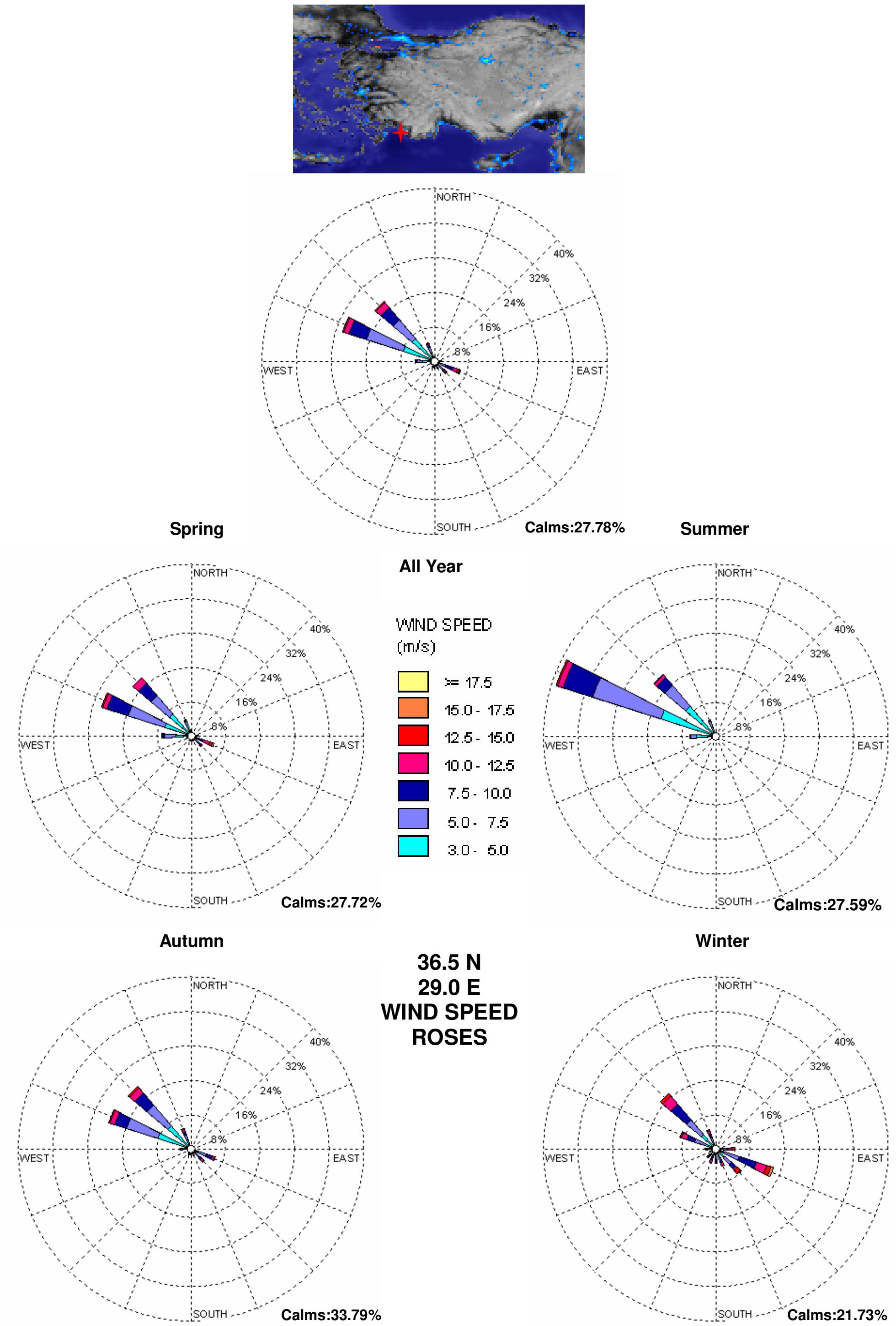

Figure 4.8.1 Wind climate at 36.5 N, 29.0 E

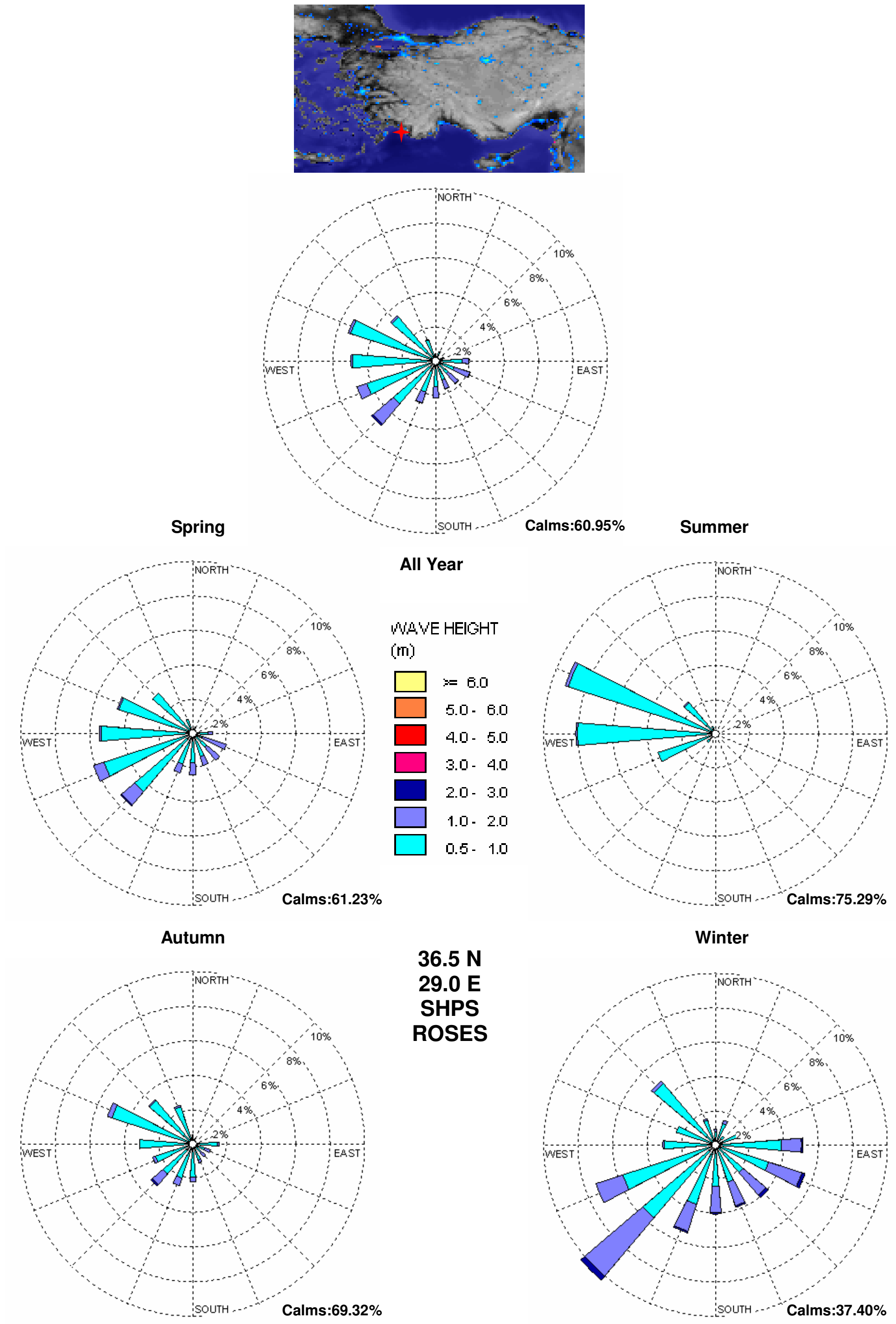

Figure 4.8.2 SHPS climate at 36.5 N, 29.0 E

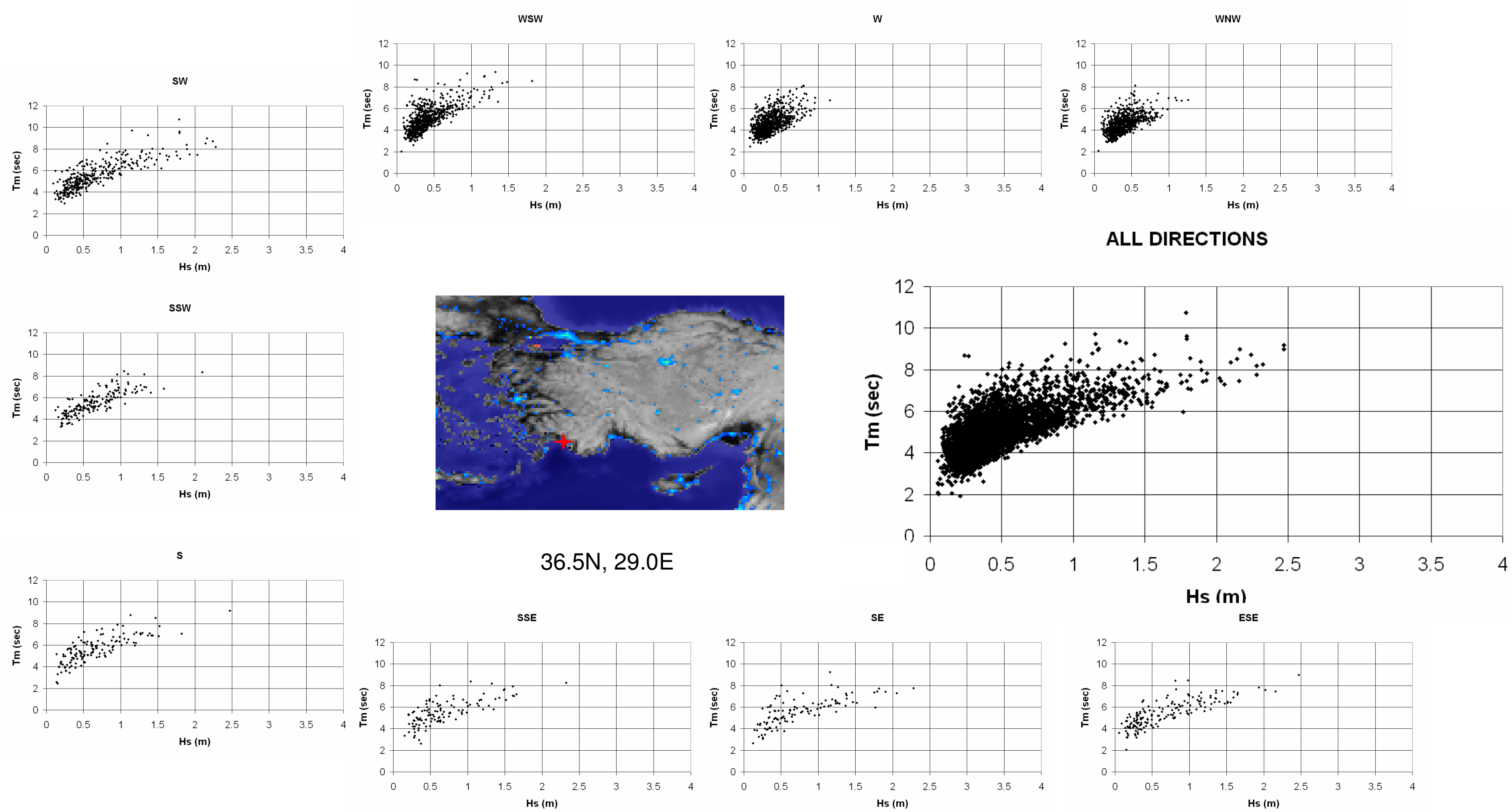

Figure 4.8.3 Relationship between MPPS & SHPS at Fethiye

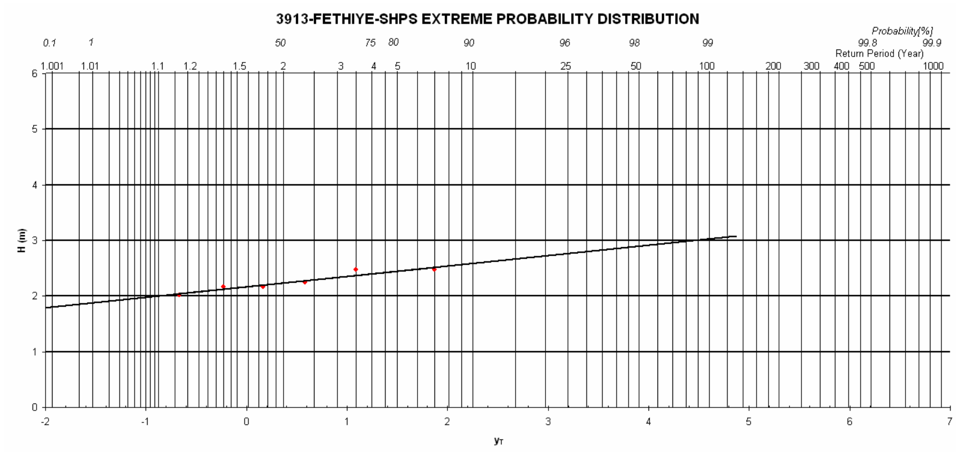

Figure 4.8.4 Extreme Probability Distribution at Location 36.5 N, 29.0

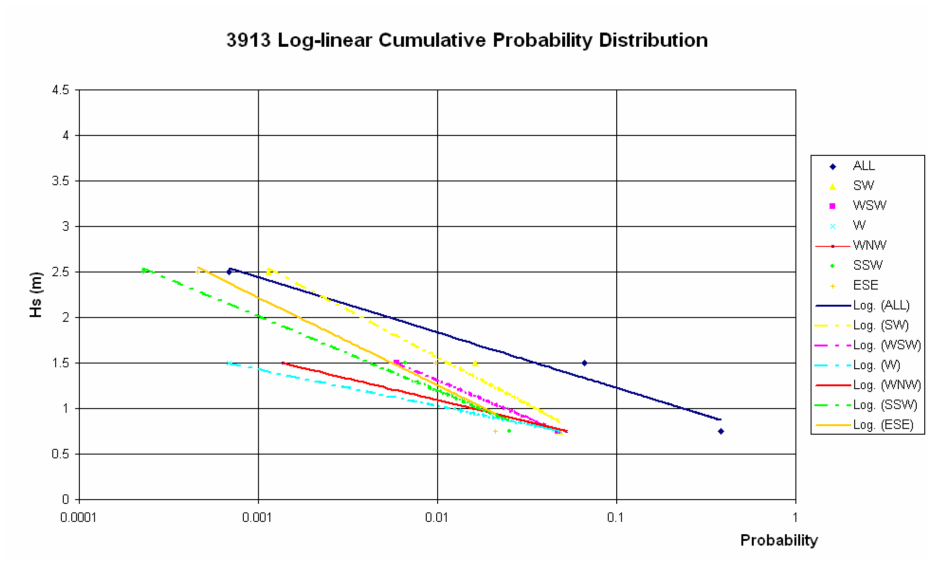

Figure 4.8.5 Log-Linear Cumulative Probability Distribution at 36.5 N, 29.0 E

4.9. LOCATION 4013 - KAŞ

The 4013 abbreviated point is located approximately 22 km of South Southwest of Kaş and 11 km South of Castellorizo (Megisti) [Turkish: Meis] Island. The coordinates of point 4013 is; 36.00˚ N, 29.50˚ E.

The Wind Roses, Swell Wave Roses, Significant Wave Height (Hs) vs. Mean Wave Period (Tm) Relations, Extreme value probability statistics and Log-linear cumulative probability distribution are given in this section for this location.

Wind roses are given in Figure 4.9.1 and show that location 4013 is subject to mainly W to WNW winds. Strong winds are effective in E direction in winter and slides to WNW direction in summer.

Wind Roses are compared with the wind roses at the nearest location (36.00˚ N, 29.50˚ E) in Ozhan and Abdalla, (1999) where the dominant wind is from WNW to NNW direction for this location. Both studies have differences in dominant wind direction generally. In Ozhan and Abdalla, (1999), the NW winds take part as the dominant wind direction mostly, whereas in this study the dominant wind is from W to WNW direction. Also, calm durations in summer occur more according to this study.

Swell wave roses are given in Figure 4.9.2 and show that generally western directed swell waves are effective for this location. In winter, swell waves are observed for a wide range of directions, from WNW to ESE. Nearly 9% of the time swell waves are coming from each W and 7% of the time coming from WNW direction in a full year. SW swell waves are the commonly observed swell waves in winter, with 12% percentile. In summer, W swell waves' percentile rises to 15%. The maximum swell wave height is between 2.0 and 2.5 meters.

The relations between Significant Wave Height (Hs) vs. Mean Wave Period (Tm) are given in Figure 4.9.3. In this graph a range of directions from WNW, W, WSW and SW swell wave domination can be seen via Figure

4.9.2. Several data points, exceeding 10 second periods and exceeding 2.0 m of swell wave heights are observed for SW direction. The maximum swell wave height is 2.979 m. The average steepness of swell waves at this location (From Figure 4.9.3) is 0.013.

The graph of extreme value probability statistics is given in Figure 4.9.4. Data values show high correlation. Significant swell wave height is estimated as 3.5 meters for 100 year return period.

Log-linear cumulative probability distribution is given in Figure 4.9.5. Four dominating directions; namely SW, WSW, W and WNW are plotted along with all directions. It is seen from this graph that significant height of swell waves exceeds 3.0 meters in about 10 hours duration every year.

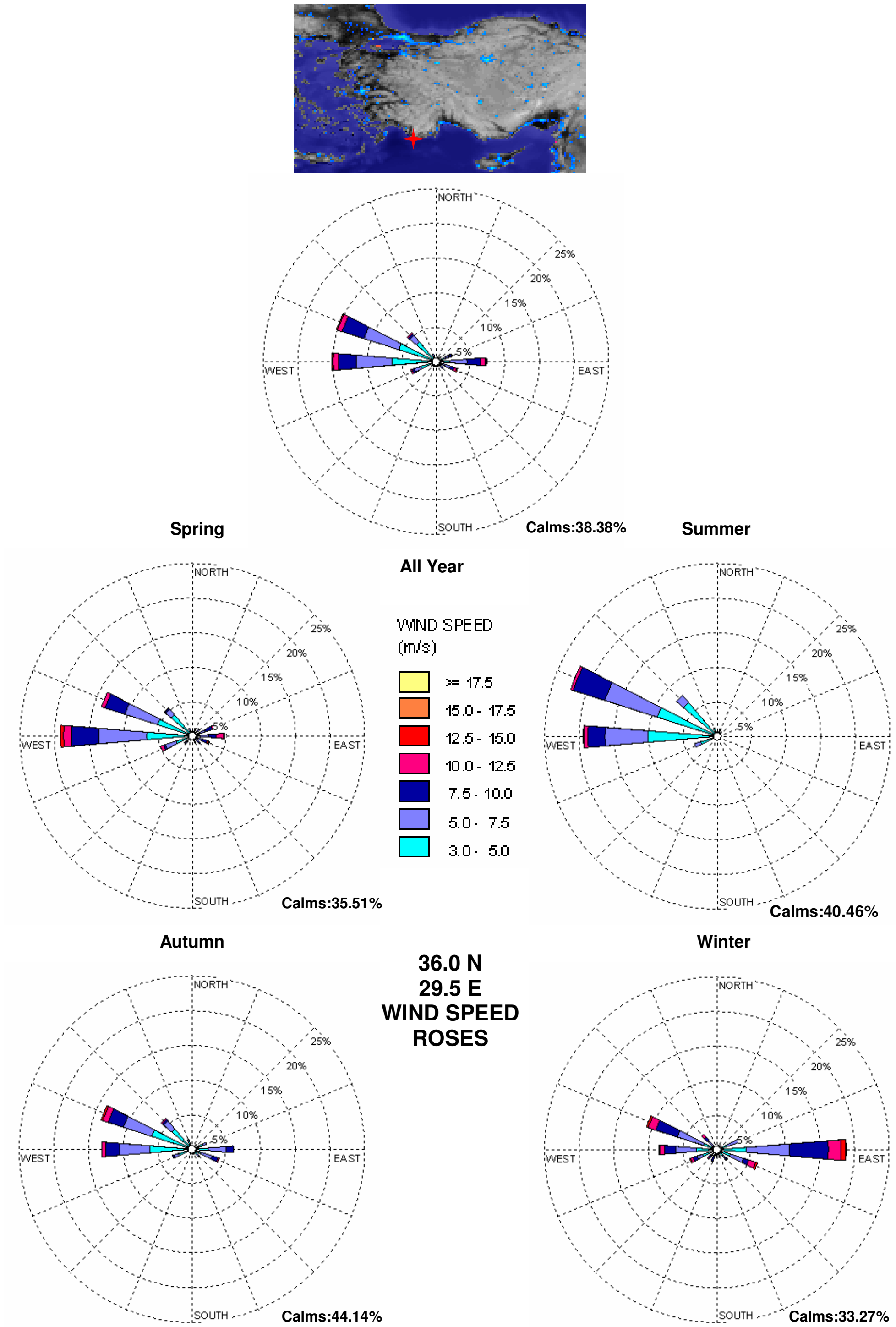

Figure 4.9.1 Wind climate at 36.0 N, 29.5 E

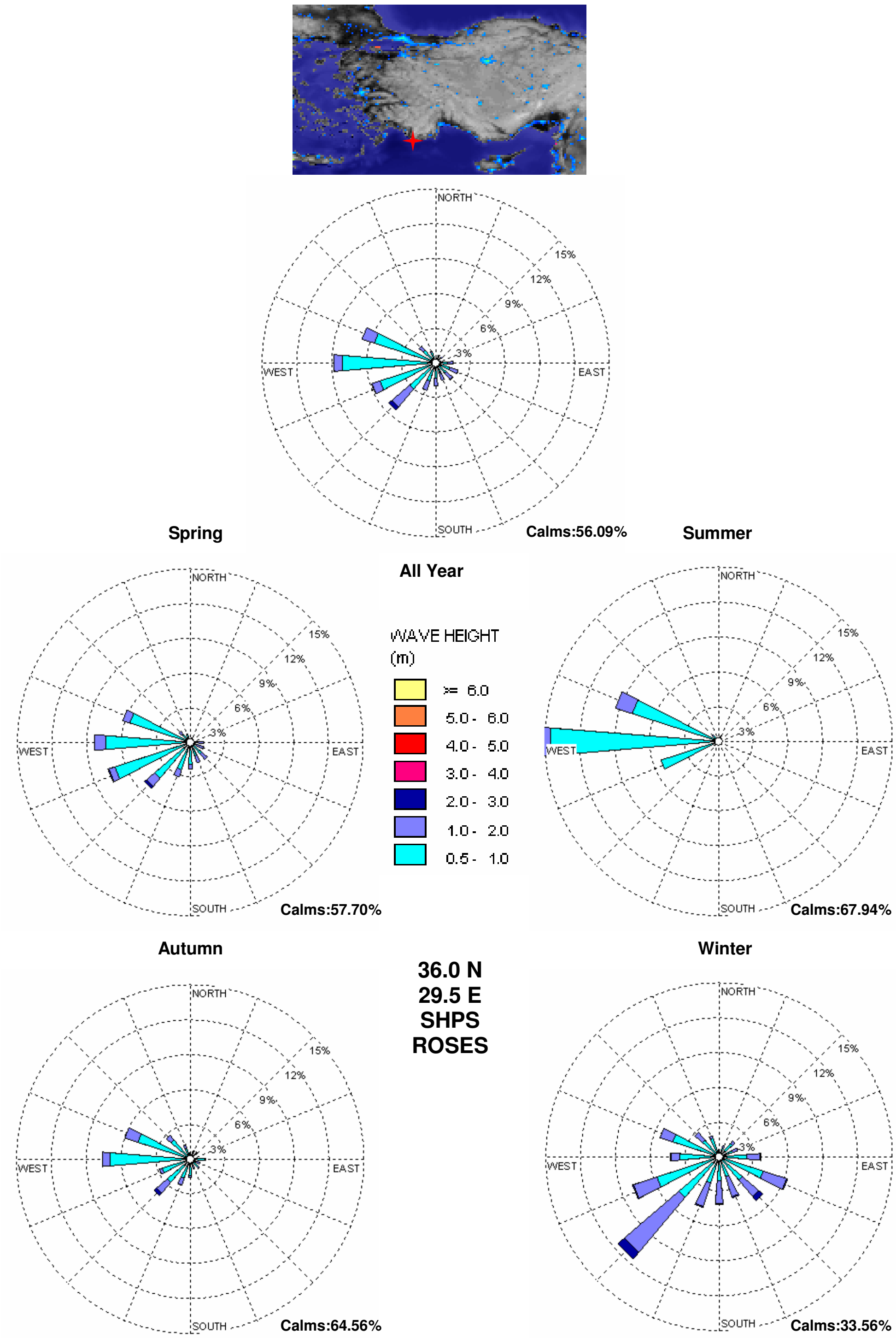

Figure 4.9.2 SHPS climate at 36.0 N, 29.5 E

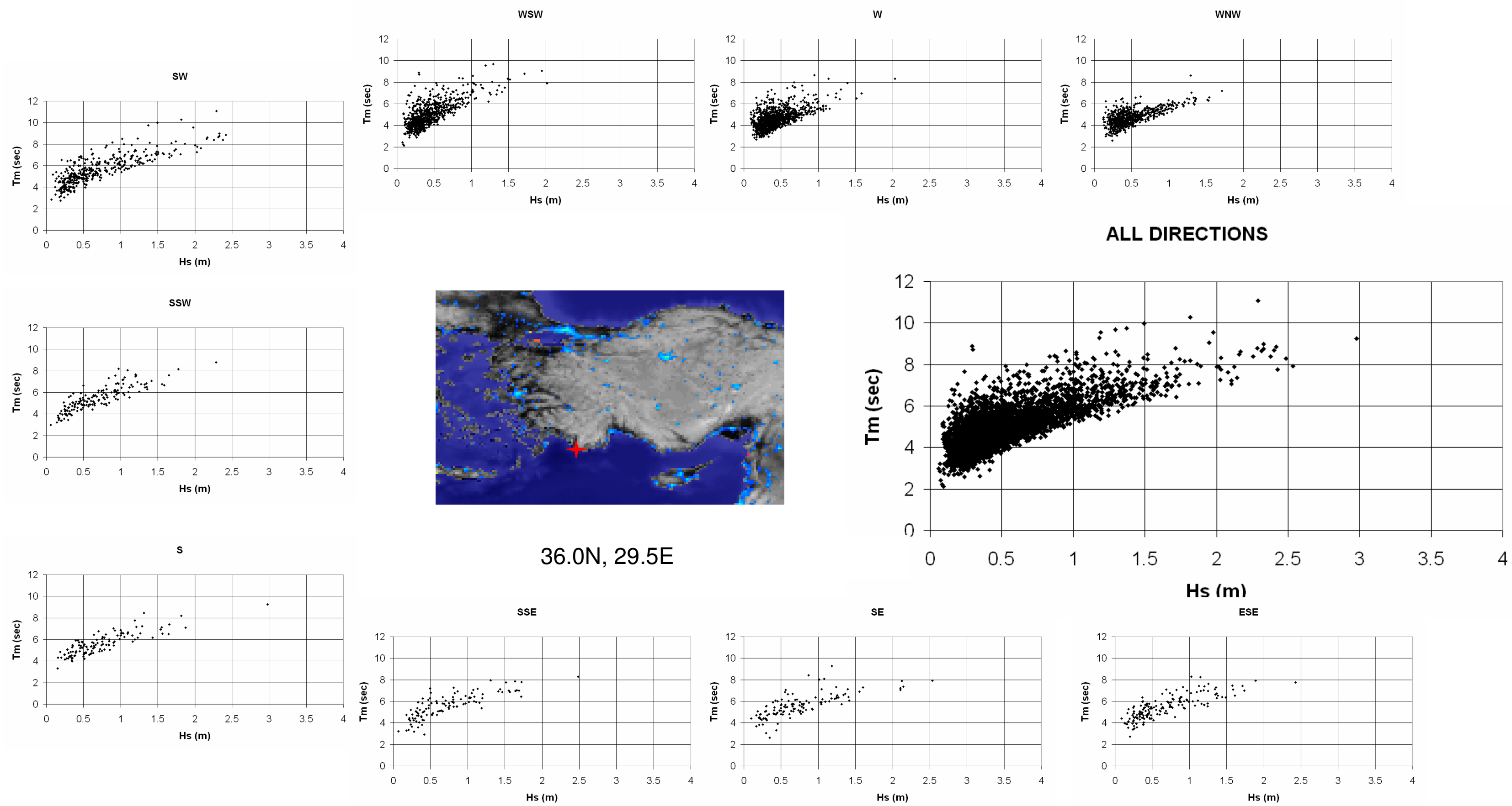

Figure 4.9.3 Relationship between MPPS & SHPS at Kaş

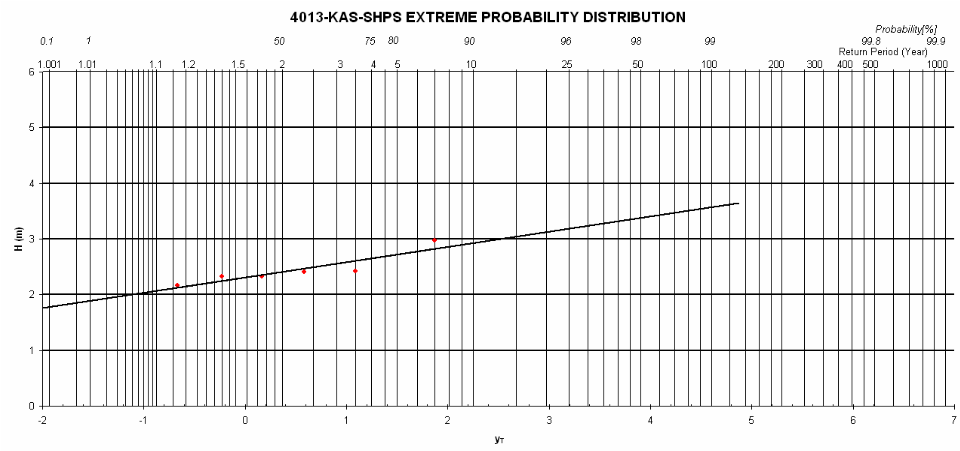

Figure 4.9.4 Extreme Probability Distribution at Location 36.0 N, 29.5

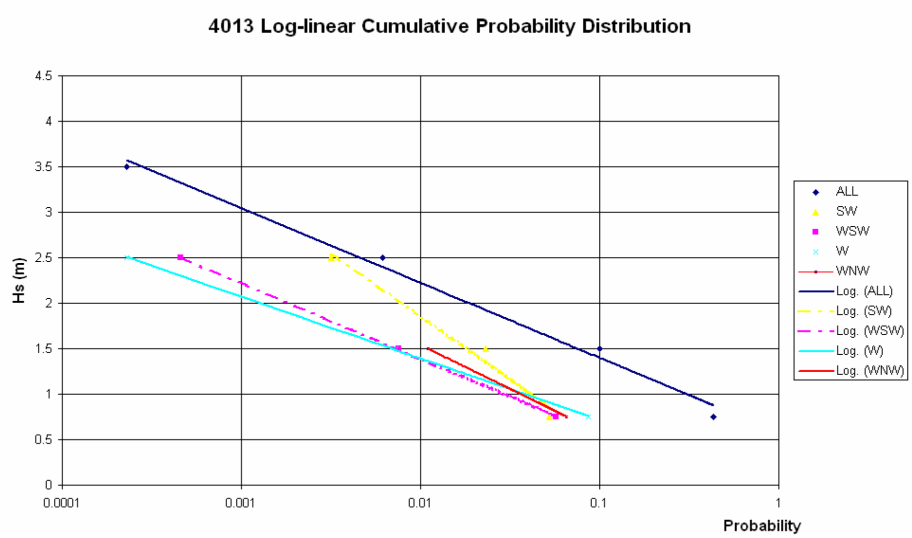

Figure 4.9.5 Log-Linear Cumulative Probability Distribution at 36.0 N, 29.5 E

4.10. LOCATION 4113 - FİNİKE

The 4113 abbreviated point is located approximately 23 km of South Southwest of Finike and 21 km South of Tasdibi. The coordinates of point 4113 is; 36.00˚ N, 30.00˚ E.

The Wind Roses, Swell Wave Roses, Significant Wave Height (Hs) vs. Mean Wave Period (Tm) Relations, Extreme value probability statistics and Log-linear cumulative probability distribution are given in this section for this location.

Wind roses are given in Figure 4.10.1 and show that location 4113 is subject to mainly W to WNW winds. Strong winds are effective in E direction in winter and slides to WNW direction in summer. Also relatively strong winds are seen from WSW and ESE directions, especially in winter.

Wind Roses are compared with the wind roses at the nearest location (36.00˚ N, 30.10˚ E) in Ozhan and Abdalla, (1999) where the dominant wind is from WNW to NW direction for this location. Two studies are compatible with the wind roses to some extent; however there are slight differences between them. In Ozhan and Abdalla, (1999), the northwestern winds have higher occurrence compared to this study. Besides, in Ozhan and Abdalla, (1999), eastern winds are not commonly seen winter, whereas eastern winds have nearly 18% percentile in winter, in this study.

Swell wave roses are given in Figure 4.10.2 and show that there is western swell wave domination for this location, generally. In winter, swell waves are observed in a wide range of directions, from WNW to ESE. Nearly 10% of the time swell waves are coming from each W and each 6% of the time coming from WNW, WSW and SW directions in a full year. SW swell waves are commonly observed in winter, with 12% percentile. In summer, W swell waves' percentile rises to 16%. The maximum swell wave height is between 2.0 and 2.5 meters.

The relations between Significant Wave Height (Hs) vs. Mean Wave Period (Tm) are given in Figure 4.10.3. In this graph a range of directions from W, WSW and SW swell wave domination can be seen. Several data points, around 10 second periods and 2.0 m of swell wave heights are observed for WSW and SW directions. The maximum swell wave height is 2.979 m. The average steepness of swell waves at this location (From Figure 4.10.3) is 0.013.

The graph of extreme value probability statistics is given in Figure 4.10.4. Data values show high correlation. Significant swell wave height is estimated as 3.5 meters for 100 year return period.

Log-linear cumulative probability distribution is given in Figure 4.10.5. Four dominating directions; namely SW, WSW, W and WNW are plotted along with all directions. It is seen from this graph that significant height of swell waves exceeds 3.0 meters in about 10 hours duration every year.

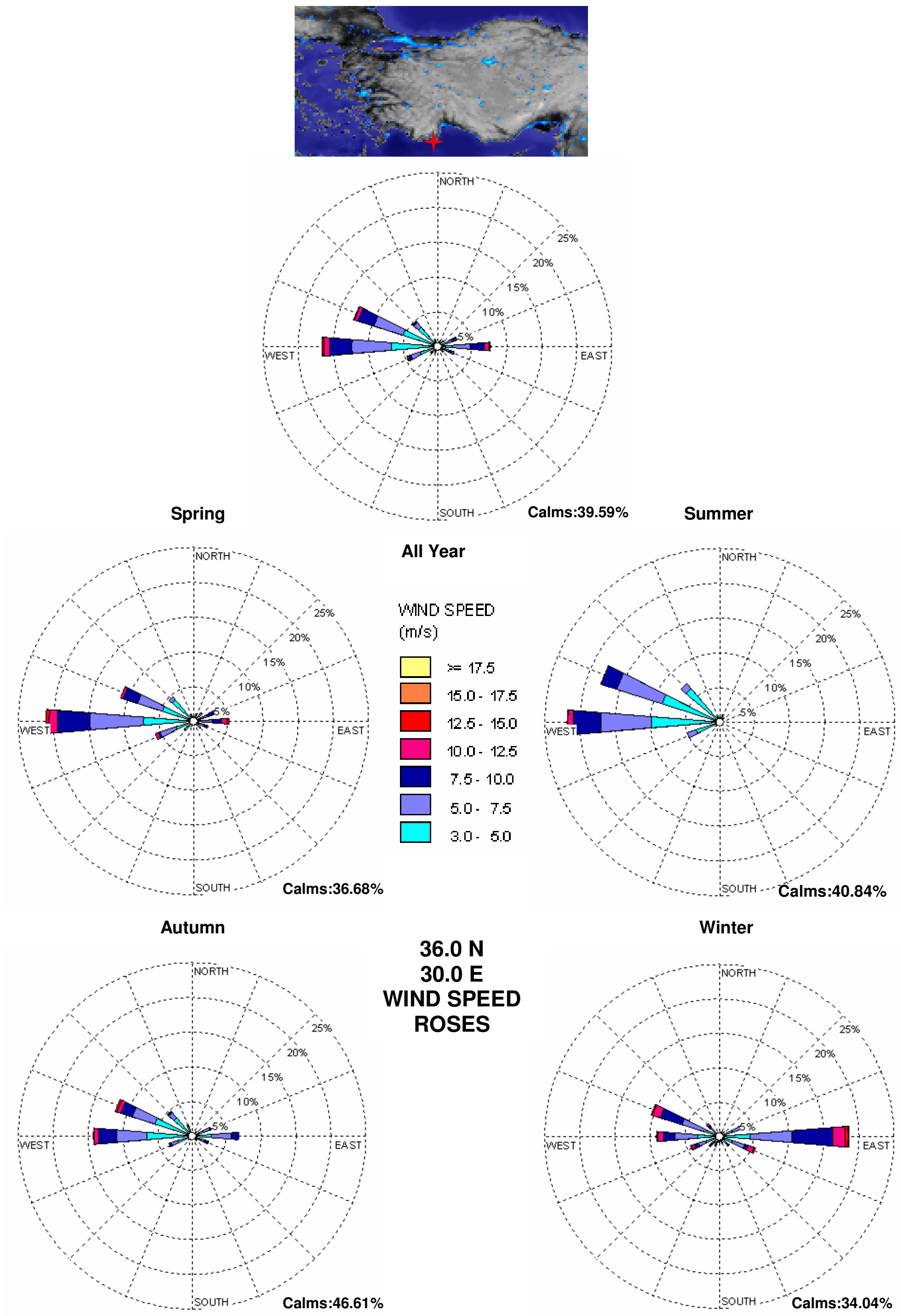

Figure 4.10.1 Wind climate at 36.0 N, 30.0 E

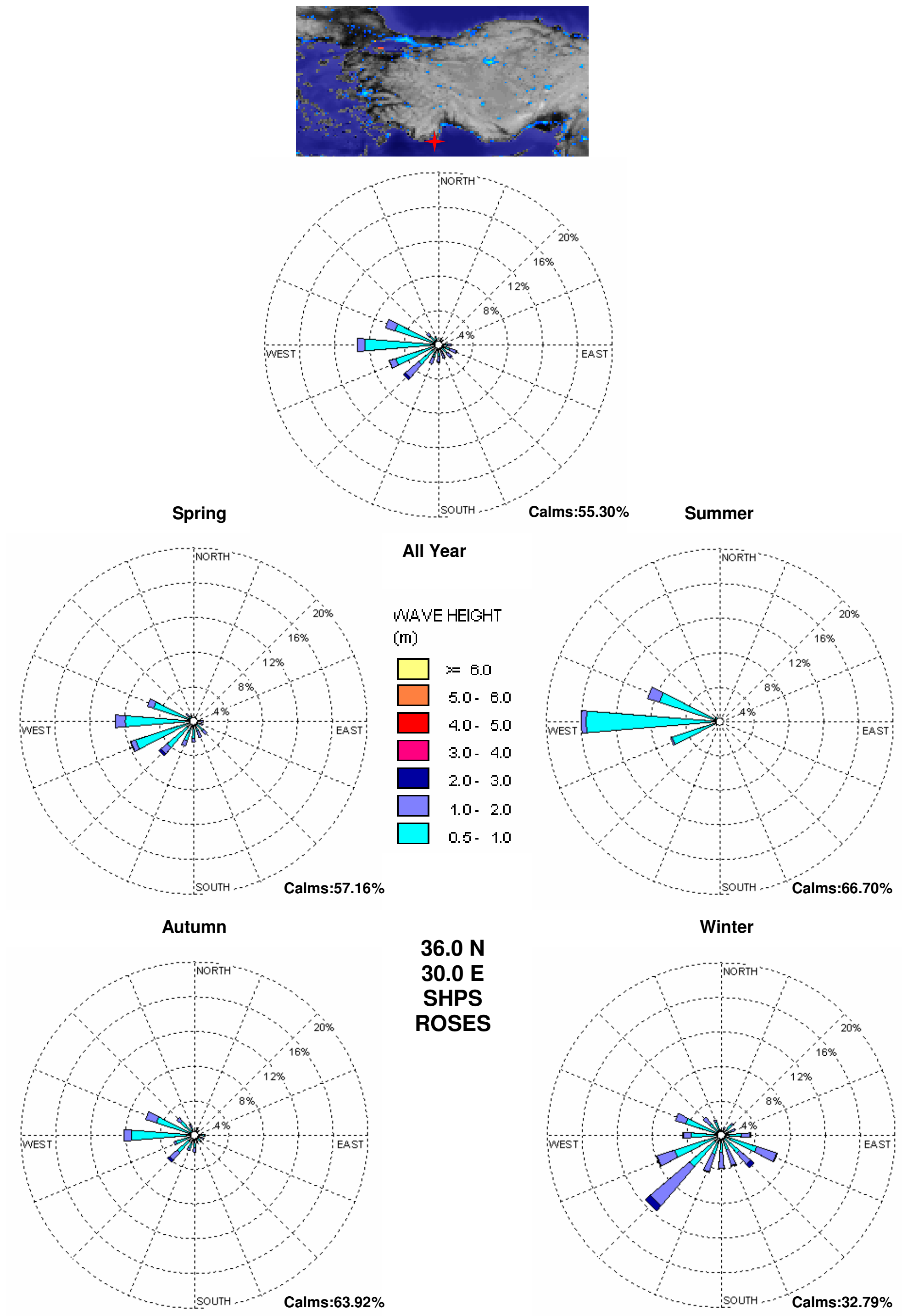

Figure 4.10.2 SHPS climate at 36.0 N, 30.0 E

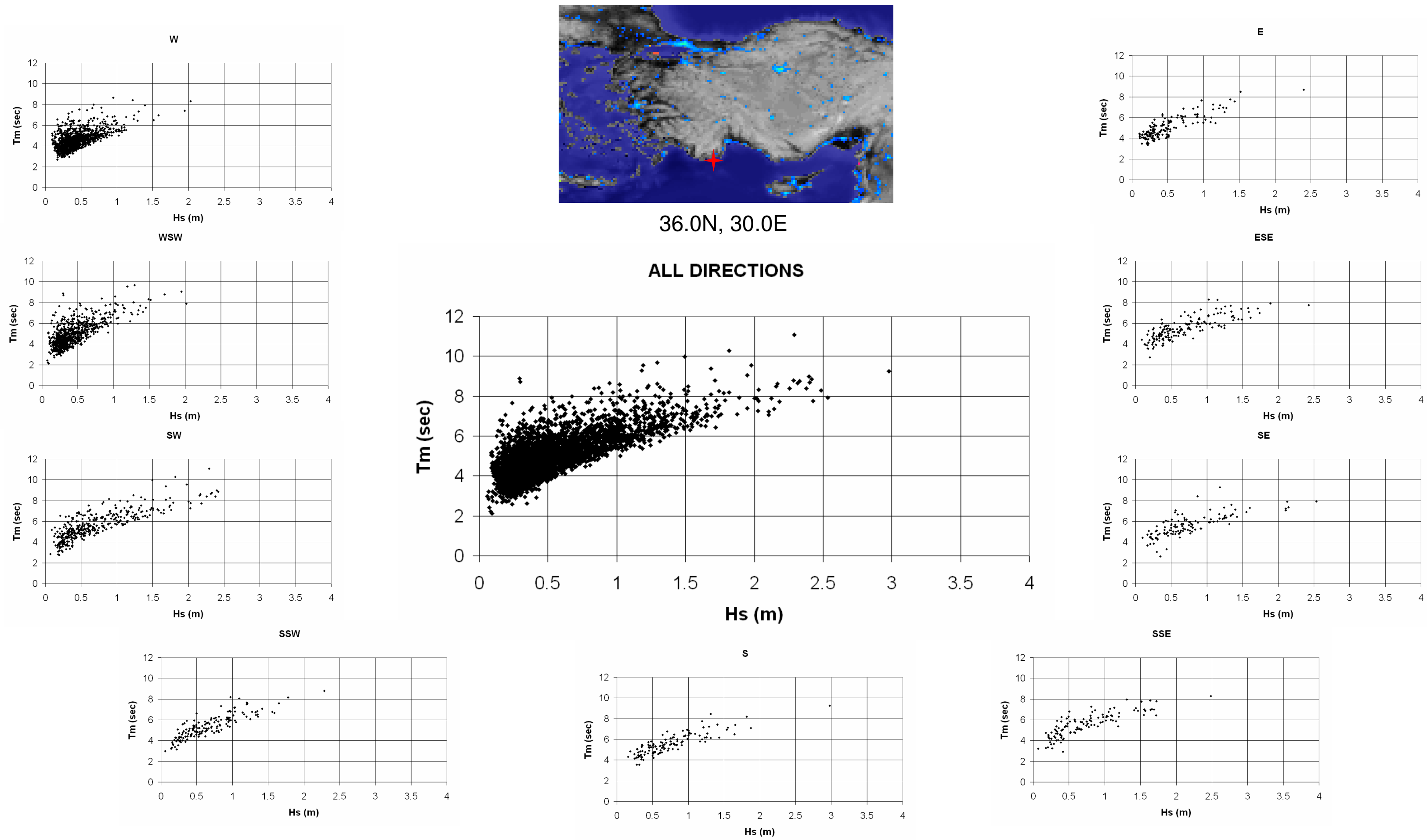

Figure 4.10.3 Relationship between MPPS & SHPS at Finike

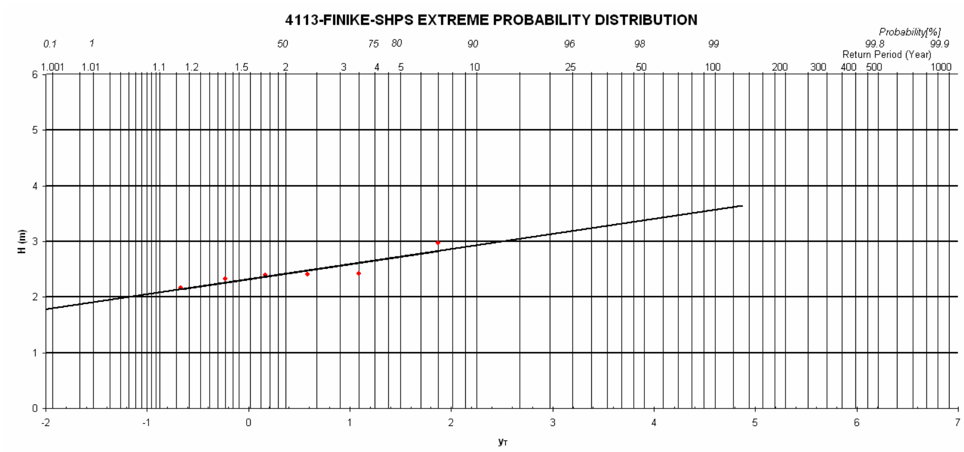

Figure 4.10.4 Extreme Probability Distribution at Location 36.0 N, 30.0 E

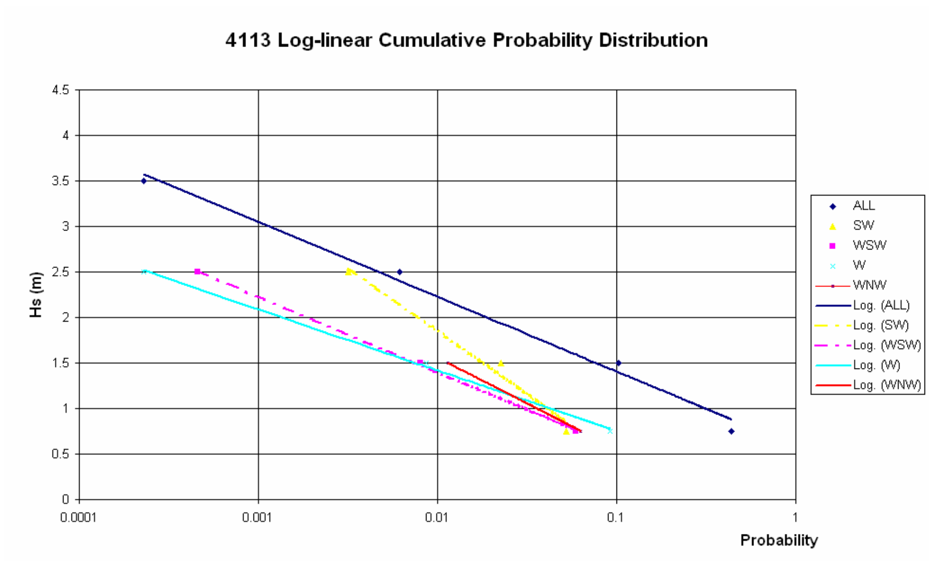

Figure 4.10.5 Log-Linear Cumulative Probability Distribution at 36.0 N, 30.0 E

4.11. LOCATION 4214 - KEMER

The 4214 abbreviated point is located approximately 20 km of South of Kemer and 5 km East of Çıralı. The coordinates of point 4214 is; 36.50˚ N, 30.50˚ E.

The Wind Roses, Swell Wave Roses, Significant Wave Height (Hs) vs. Mean Wave Period (Tm) Relations, Extreme value probability statistics and Log-linear cumulative probability distribution are given in this section for this location.

Wind roses are given in Figure 4.11.1 and show that location 4214 is subject to mainly N winds. This location is quite calm in every season. Also relatively moderate winds occur in SSW direction, in winter.

Wind Roses are compared with the wind roses at the nearest location (36.50˚ N, 30.70˚ E) in Ozhan and Abdalla, (1999) where the dominant wind is from WNW to NW direction for this location. Two studies show differences in the respective roses belonging all seasons. In Ozhan and Abdalla, (1999), the northwestern winds have higher occurrence compared to this study. Also, in Ozhan and Abdalla, (1999), calm durations are less than those of in this study.

Swell wave roses are given in Figure 4.11.2. Nearly 80% of the time is calm in a full year. Dominant swell wave direction is SW, with 7% percentile of all time. SSW and SE swell waves' percentile increase in winter. The maximum swell wave height is between 2.0 and 2.5 meters.

The relations between Significant Wave Height (Hs) vs. Mean Wave Period (Tm) are given in Figure 4.11.3. In this graph SW and SSW swell wave domination can be seen via Figure 4.11.2. A rather more scattered distribution is observed in SW direction. Several data points, exceeding 8 second periods and very few data points exceeding 2.5 m of swell wave heights are observed for SW directions. The maximum swell wave height is

3.212 m. The average steepness of swell waves at this location (From Figure 4.11.3) is 0.009.

The graph of extreme value probability statistics is given in Figure 4.11.4. Data values show high correlation. Significant swell wave height is estimated as 4.7 meters for 100 year return period.

Log-linear cumulative probability distribution is given in Figure 4.11.5. Four dominating directions; namely SW, SE, SSW and S are plotted along with all directions. It is seen from this graph that significant height of swell waves exceeds 2.7 meters in about 10 hours duration every year.

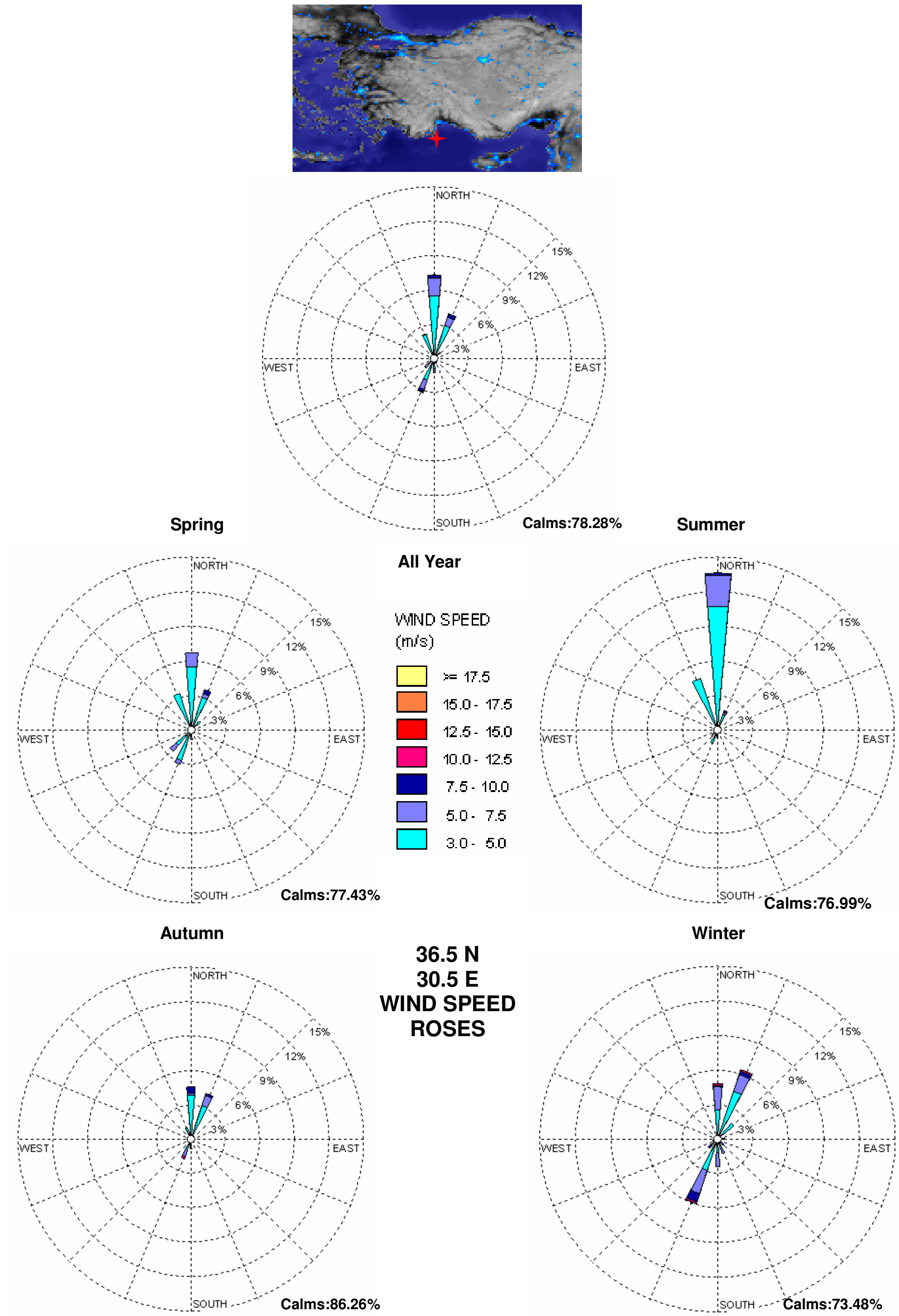

Figure 4.2.1 Wind climate at 36.5 N, 30.5 E

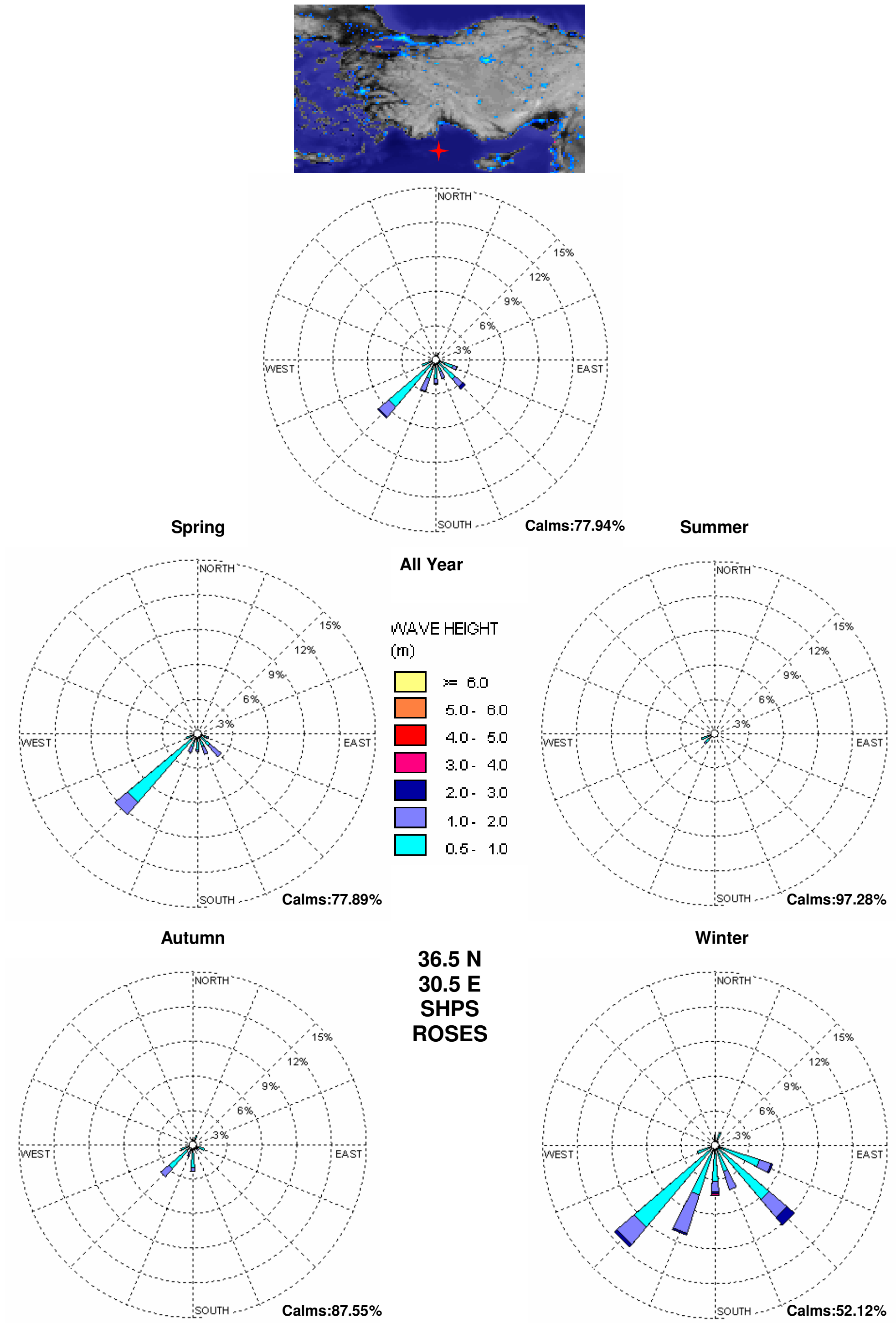

Figure 4.2.1 SHPS climate at 36.5 N, 30.5 E

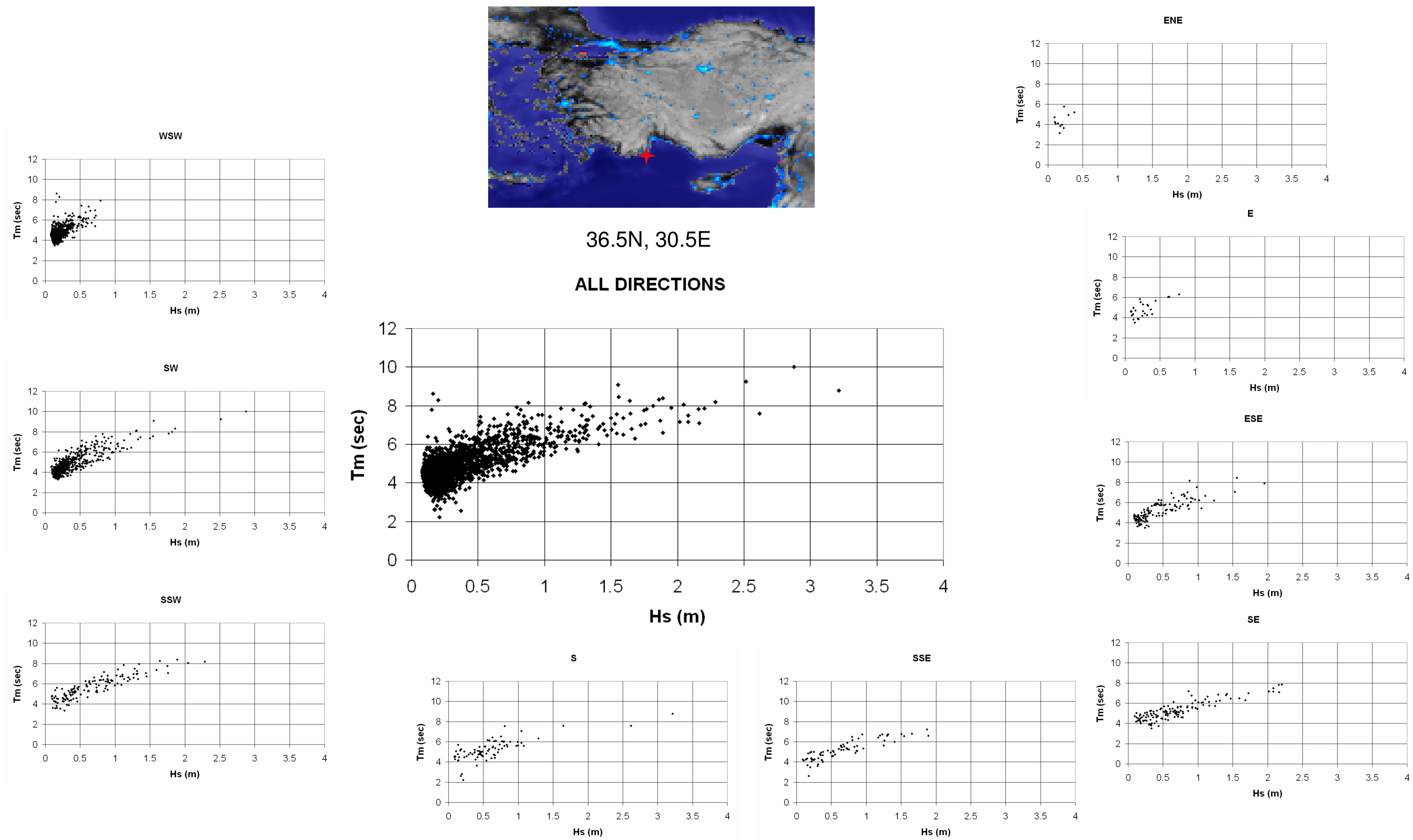

Figure 4.1.3 Relationship between MPPS & SHPS at Kemer

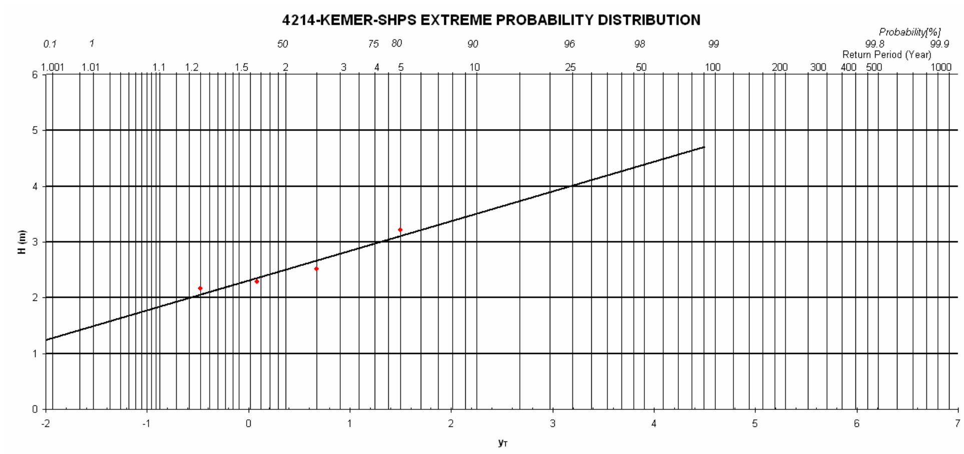

Figure 4.11.4 Extreme Probability Distribution at Location 36.5 N, 30.5

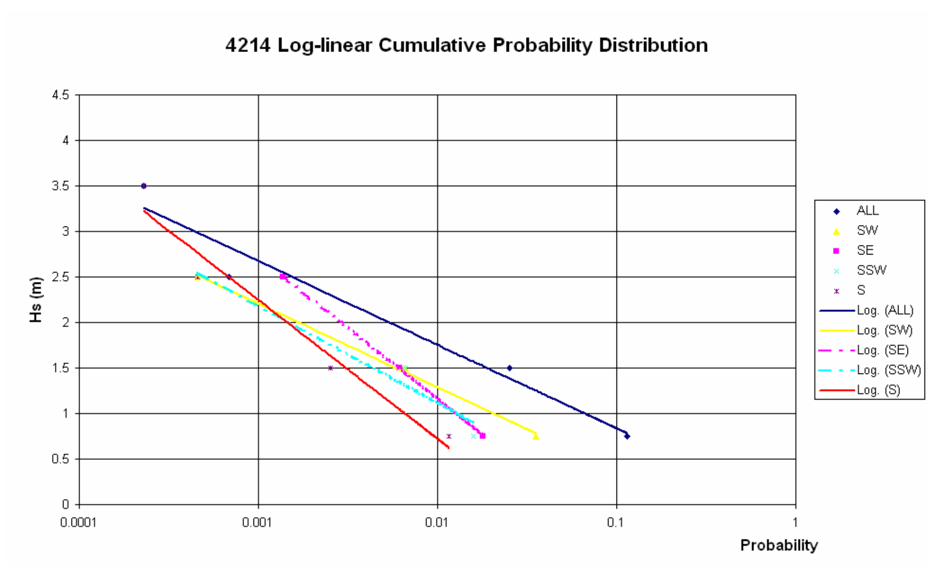

Figure 4.11.5 Log-Linear Cumulative Probability Distribution at 36.5 N, 30.5 E

4.12. LOCATION 4314 - SİDE

The 4314 abbreviated point is located approximately 40 km of South West of Side. The coordinates of point 4314 is; 36.50˚ N, 31.00˚ E.

The Wind Roses, Swell Wave Roses, Significant Wave Height (Hs) vs. Mean Wave Period (Tm) Relations, Extreme value probability statistics and Log-linear cumulative probability distribution are given in this section for this location.

Wind roses are given in Figure 4.12.1 and show that location 4314 is subject to mainly NNW to N winds. Strong winds are effective in N direction both in winter and autumn. Also relatively strong winds are seen from SE direction, in winter. Wind roses show that there are moderate winds occurring from SW and SSW directions, in spring and summer.

Wind Roses are compared with the wind roses at the nearest location (36.75˚ N, 31.00˚ E) in Ozhan and Abdalla, (1999) where the slightly dominant wind is from NW direction for this location. The yearly wind roses are slightly different in both studies. In Ozhan and Abdalla, (1999), calm durations have more occurrences than this study, and there is not extremely dominant wind direction as in this study.

Swell wave roses are given in Figure 4.12.2 and show a clear indication of direction of incoming swell waves. Nearly 9% of the time swell waves are coming from SW direction in a full year. SW swell waves' percentile increases in winter. Also northern winds increase their percentile in winter. The maximum swell wave height is between 2.0 and 3.0 meters.

The relations between Significant Wave Height (Hs) vs. Mean Wave Period (Tm) are given in Figure 4.12.3. In this graph WSW and SW swell wave domination can be seen via Figure 4.12.2. A rather more scattered distribution is observed in SW direction. Several data points, exceeding 9 second periods and 2.0 m of swell wave heights are observed for SW directions with a maximum swell wave height is 3.753 m. The average steepness of swell waves at this location (From Figure 4.12.3) is 0.011.

The graph of extreme value probability statistics is given in Figure 4.12.4. Data values show high correlation. Significant swell wave height is estimated as 5.5 meters for 100 year return period.

Log-linear cumulative probability distribution is given in Figure 4.12.5. Three dominating directions; namely SW, SE and SSW are plotted along with all directions. It is seen from this graph that significant height of swell waves exceeds 2.75 meters in about 10 hours duration every year.

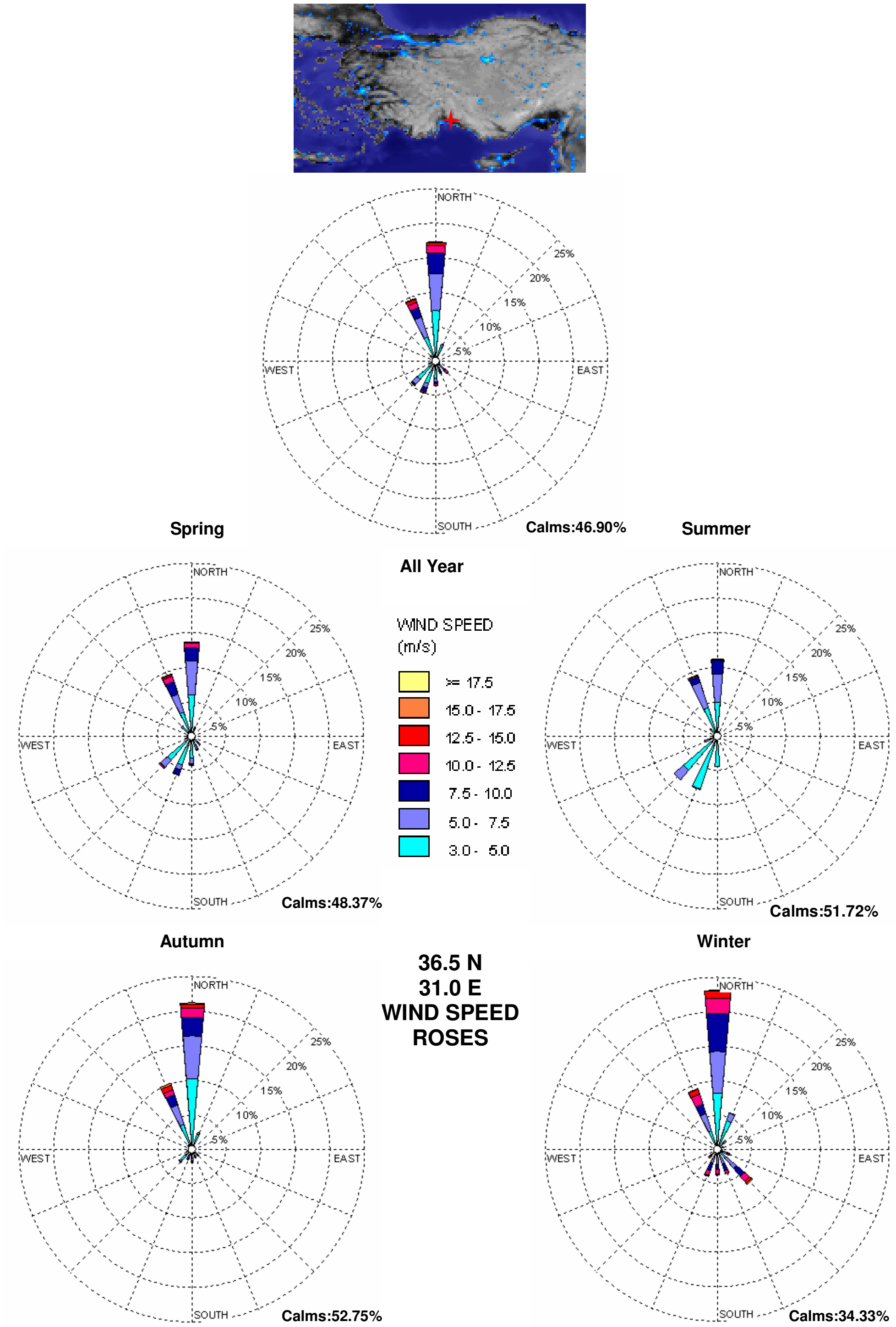

Figure 4.12.1 Wind climate at 36.5 N, 31.0 E

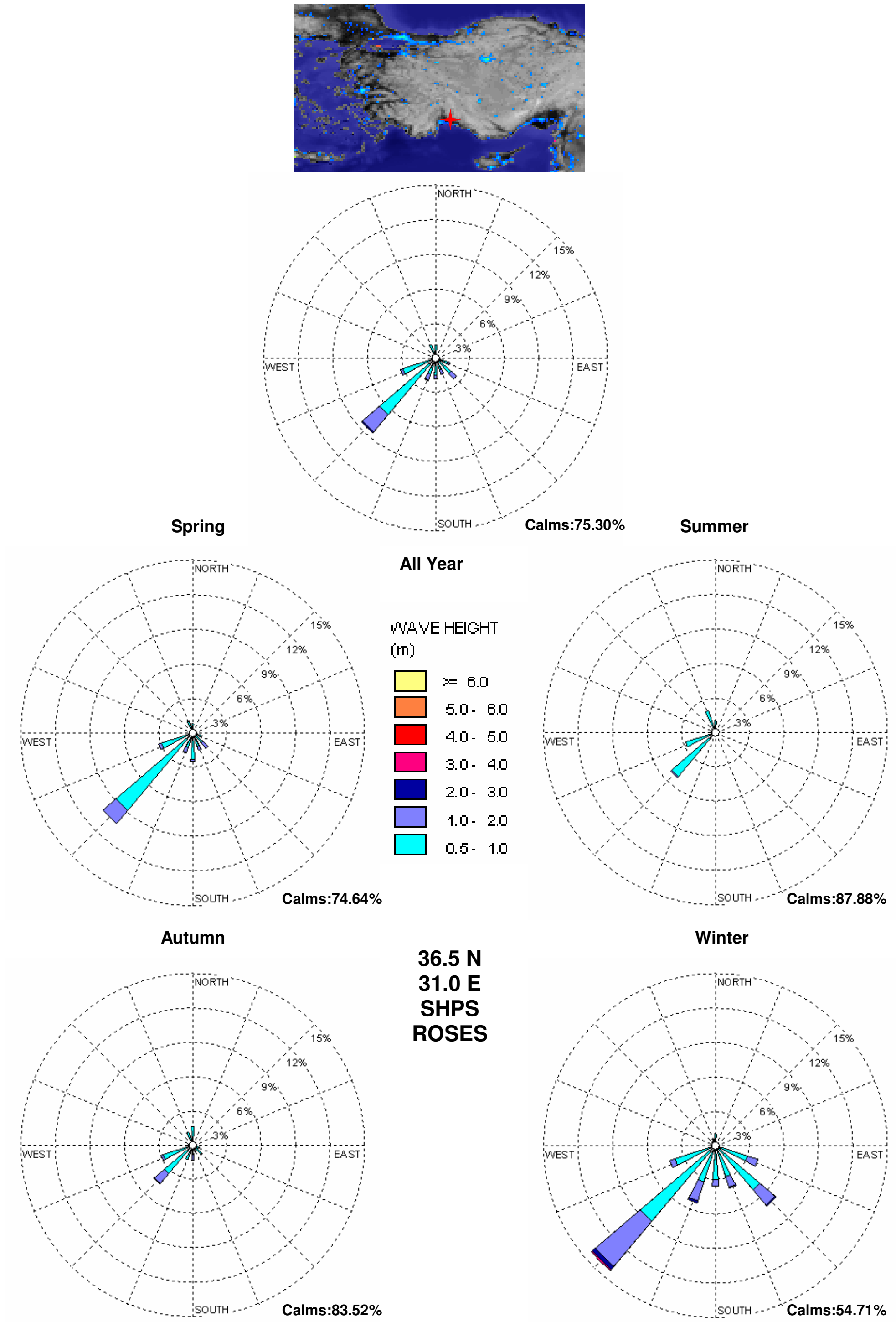

Figure 4.12.2 SHPS climate at 36.5 N, 31.0 E

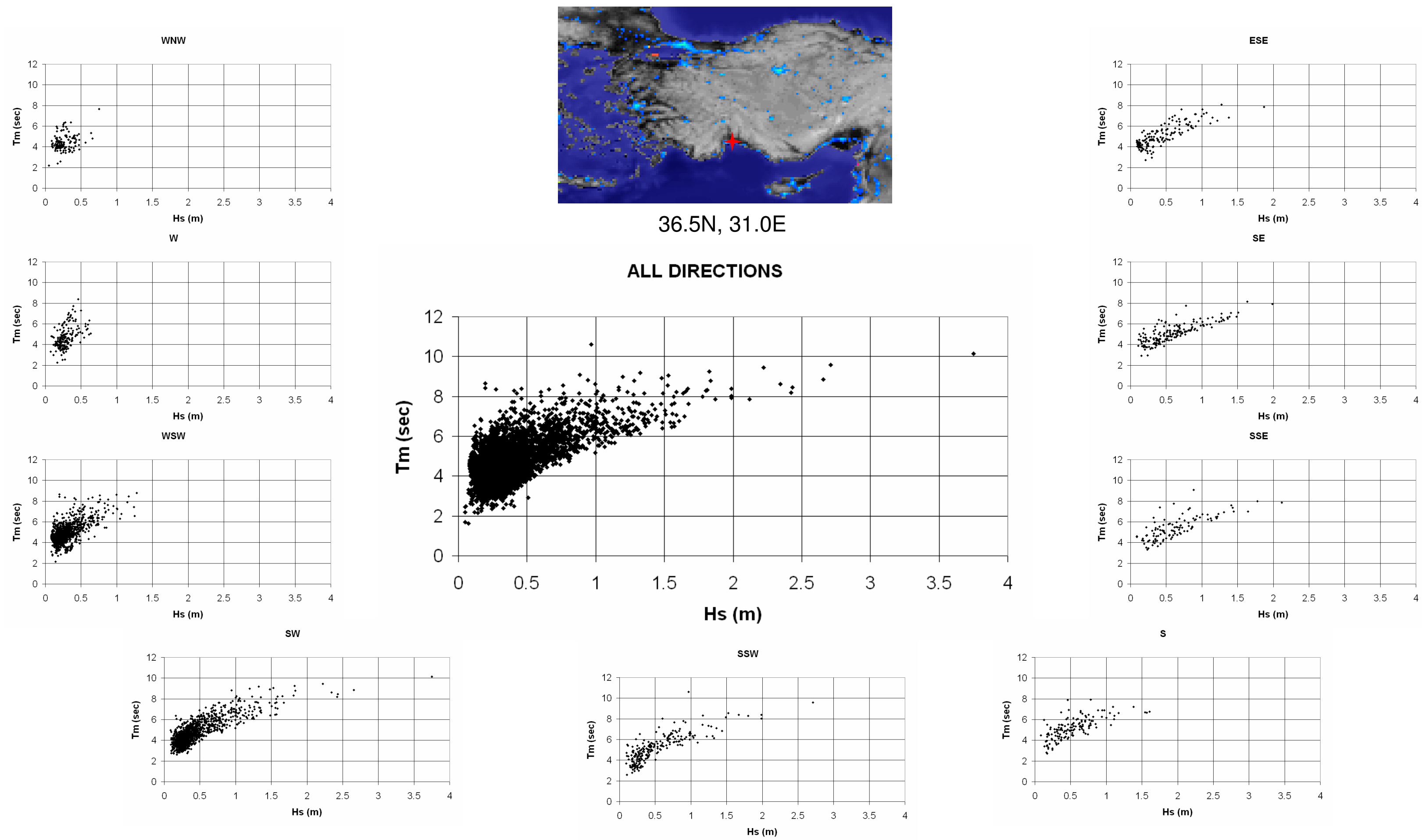

Figure 4.12.3 Relationship between MPPS & SHPS at Side

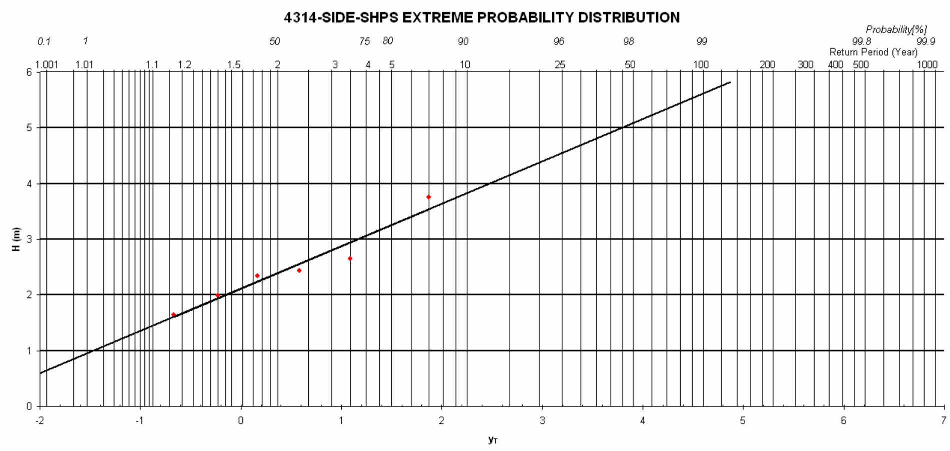

Figure 4.12.4 Extreme Probability Distribution at Location 36.5 N, 31.0

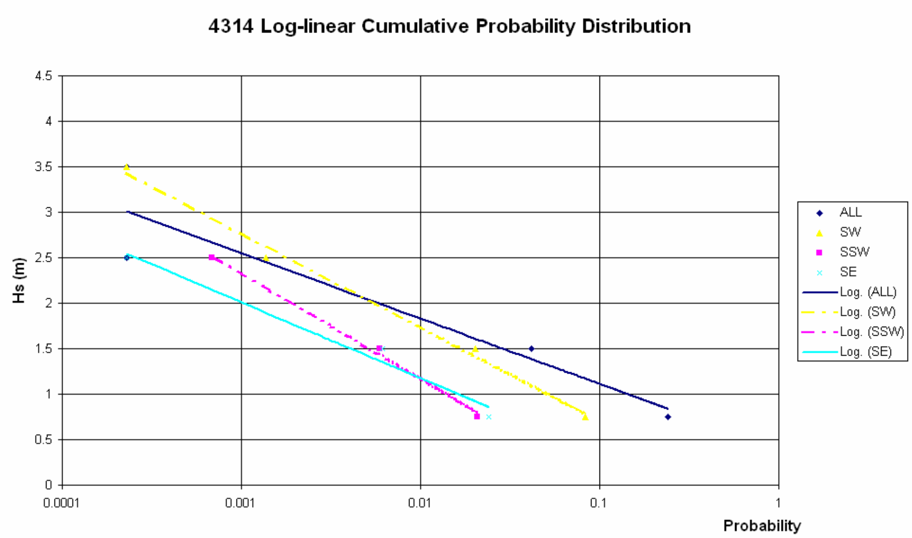

Figure 4.12.5 Log-Linear Cumulative Probability Distribution at 36.5 N, 31.0 E

4.13. LOCATION 4414 - ALANYA

The 4414 abbreviated point is located approximately 45 km of West of Alanya and 25 km of South of Manavgat. The coordinates of point 4414 is; 36.50˚ N, 31.50˚ E.

The Wind Roses, Swell Wave Roses, Significant Wave Height (Hs) vs. Mean Wave Period (Tm) Relations, Extreme value probability statistics and Log-linear cumulative probability distribution are given in this section for this location.

Wind roses are given in Figure 4.13.1 and show that location 4414 is subject to moderate winds generally from a wide range of directions. Calm durations are quite long. Strong winds are effective in SE direction in winter and slides to SSW direction in summer. Also relatively strong winds are seen from NNW-SSE alignment in winter.

Wind Roses are compared with the wind roses at the nearest location (36.50˚ N, 31.60˚ E) in Ozhan and Abdalla, (1999) where the slightly dominant wind is from NW direction for this location. The yearly wind roses are not in correlation with both studies. In Ozhan and Abdalla, (1999), the northwestern winds have higher occurrences, whereas northwestern and also southeastern winds have higher occurrence in this study. However, in both studies, it is seen that long calm durations occur in every season.

Swell wave roses are given in Figure 4.13.2 and show a clear indication of direction of incoming swell waves. Nearly 9% of the time for each, swell waves are coming from WSW and SW directions in a full year. SW swell waves' percentile increases in winter and WSW swell waves' percentile increases in summer. The maximum swell wave height is between 2.5 and 3.0 meters.

The relations between Significant Wave Height (Hs) vs. Mean Wave Period (Tm) are given in Figure 4.13.3. In this graph WSW and SW swell wave domination can be seen. A rather more scattered distribution is observed in SW direction. Several data points, around 10 second periods and exceeding 2.5 m of swell wave heights are observed for SW directions with a maximum swell wave height is 3.973 m. The average steepness of swell waves at this location (From Figure 4.13.3) is 0.011.

The graph of extreme value probability statistics is given in Figure 4.13.4. Significant swell wave height is estimated as 5.6 meters for 100 year return period.

Log-linear cumulative probability distribution is given in Figure 4.13.5. Four dominating directions; namely SW, WSW, SSW and SE are plotted along with all directions. It is seen from this graph that significant height of swell waves exceeds 3.4 meters in about 10 hours duration every year.

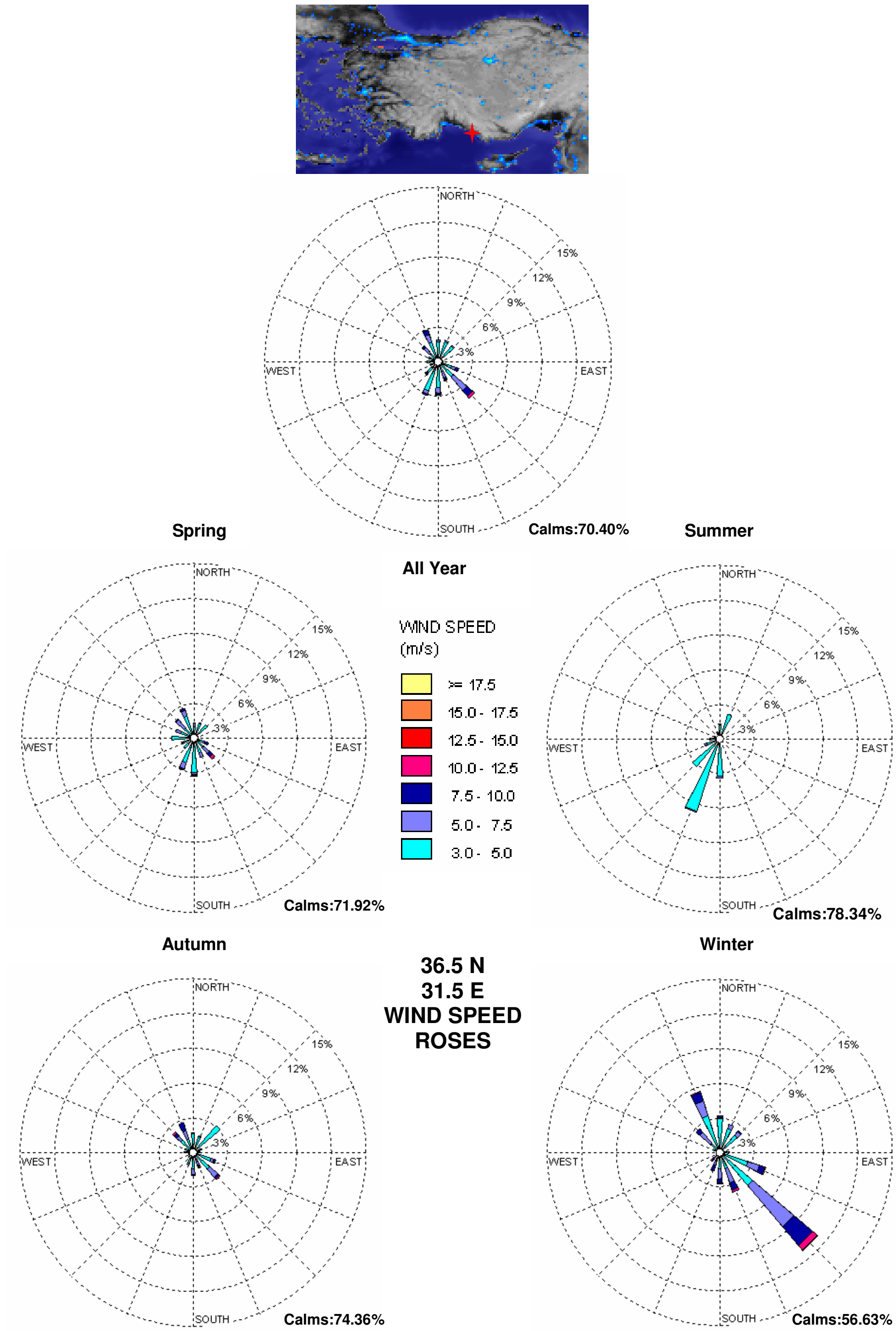

Figure 4.13.1 Wind climate at 36.5 N, 31.5 E

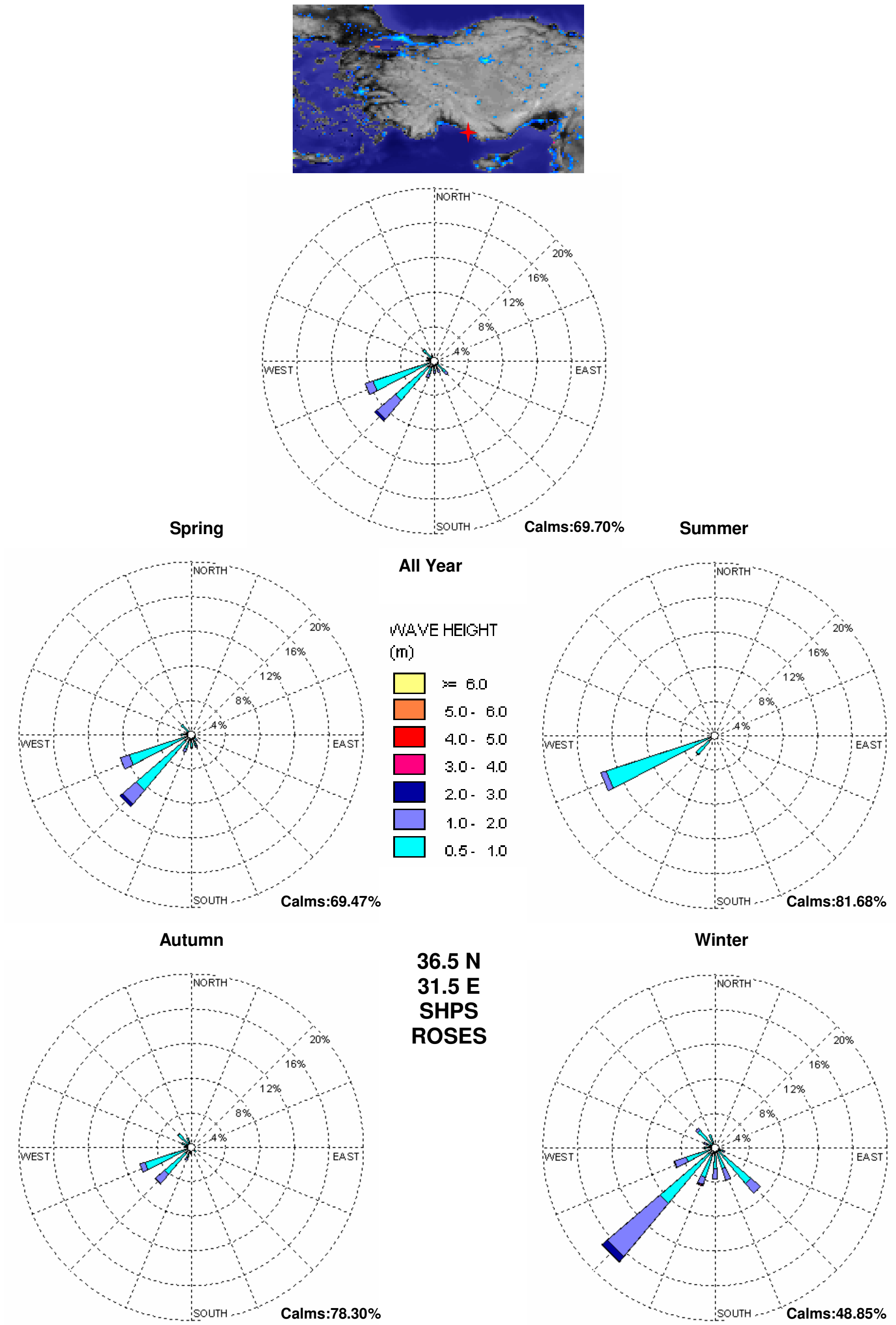

Figure 4.13.2 SHPS climate at 36.5 N, 31.5 E

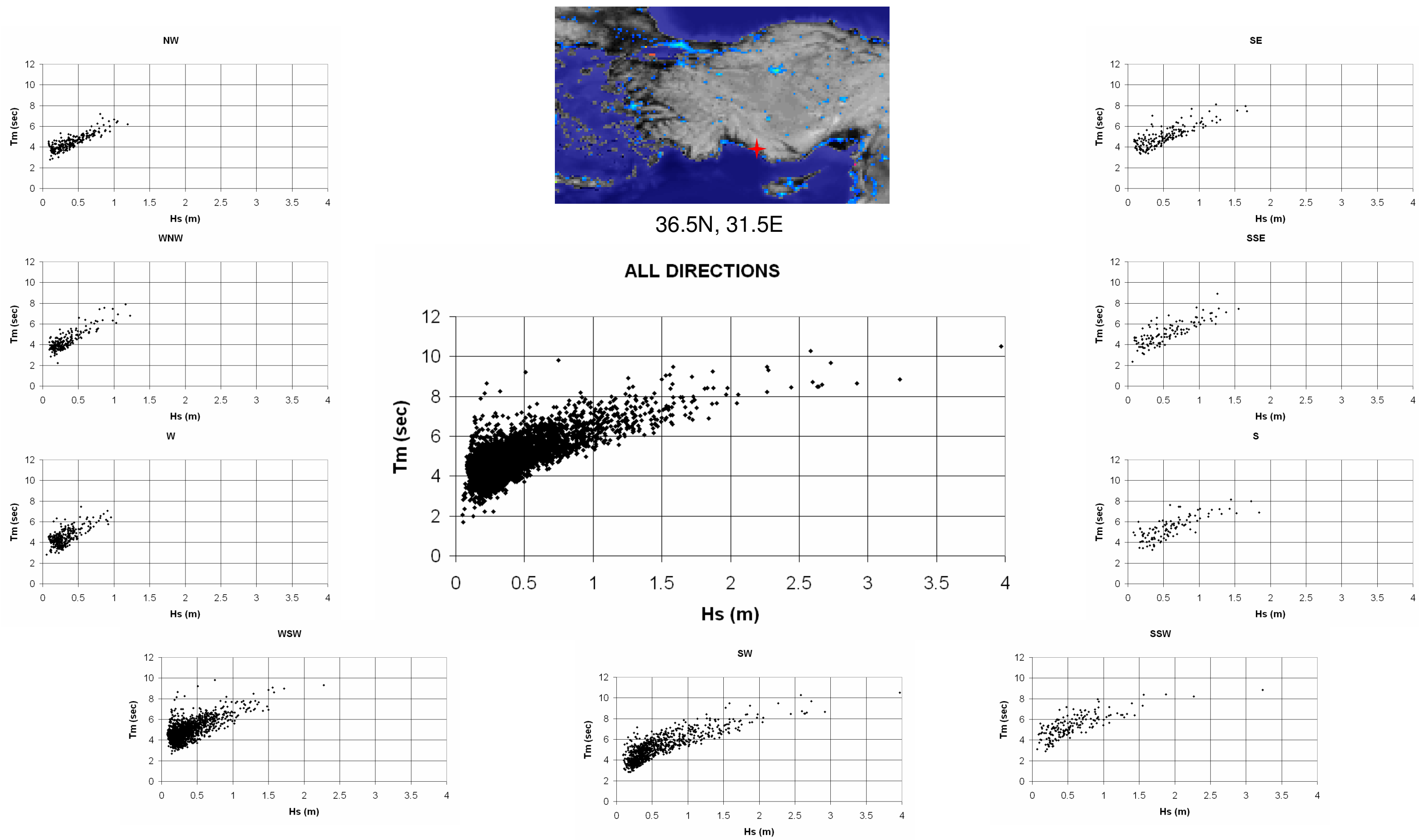

Figure 4.13.3 Relationship between MPPS & SHPS at Alanya

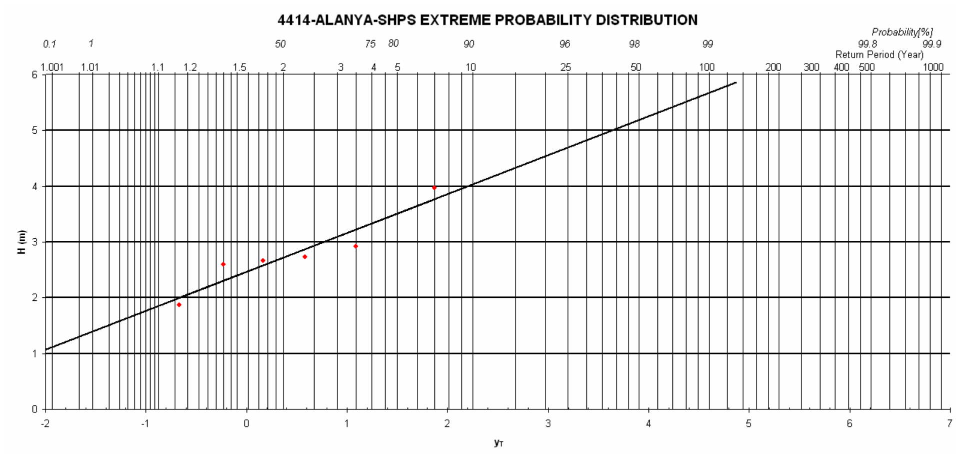

Figure 4.13.4 Extreme Probability Distribution at Location 36.5 N, 31.5

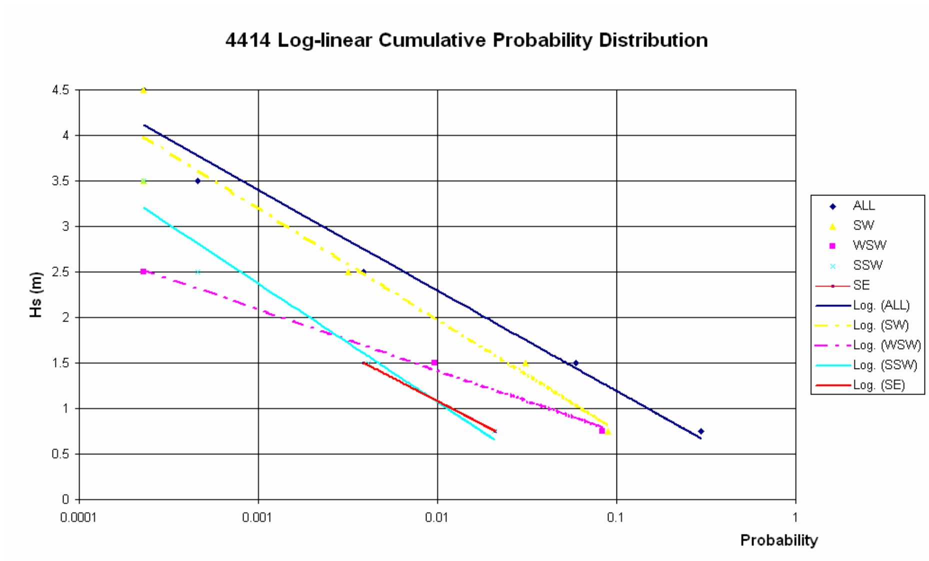

Figure 4.13.5 Log-Linear Cumulative Probability Distribution at 36.5 N, 31.5 E

4.14. LOCATION 4613 - ANAMUR

The 4613 abbreviated point is located approximately 22 km of West of Anamur, the most southern location of Türkiye. The coordinates of point 4613 is; 36.00˚ N, 32.50˚ E.

The Wind Roses, Swell Wave Roses, Significant Wave Height (Hs) vs. Mean Wave Period (Tm) Relations, Extreme value probability statistics and Log-linear cumulative probability distribution are given in this section for this location.

Wind roses are given in Figure 4.14.1 and show that location 4613 is subject to mainly W to WSW winds. Strong winds are effective in E direction. In every season, W and WSW directed winds are seen from Figure 4.14.1, reaching up to 16% percentile in summer. In winter, the most commonly observed winds are from E direction exceeding 16% percentile.

Wind Roses are compared with the wind roses at the nearest location (36.00˚ N, 32.50˚ E) in Ozhan and Abdalla, (1999) where the dominant wind is from W to WSW direction for this location. The yearly wind roses are compatible with both studies. However, there is a slight difference in calm durations. In Ozhan and Abdalla, (1999), the calm durations are a bit higher compared to this study. Also, E direction is not the dominant wind direction in winter in Ozhan and Abdalla, (1999), as it is in this study.

Swell wave roses are given in Figure 4.14.2 and show a clear indication of direction of incoming swell waves. Nearly 25% of the time for each, swell waves are coming from WSW directions in a full year. The second dominant swell wave direction is W with an approximate 7% percentile. E swell waves' percentile increases in winter. The maximum swell wave height is between 2.0 and 3.0 meters.

The relations between Significant Wave Height (Hs) vs. Mean Wave Period (Tm) are given in Figure 4.14.3. In this graph W and WSW swell wave domination can be seen. For WSW direction, there are few data points exceeding 10 second periods and 2.5 m of swell wave heights. The maximum swell wave height is 3.427 m. The average steepness of swell waves at this location (From Figure 4.14.3) is 0.012.

The graph of extreme value probability statistics is given in Figure 4.14.4. Data values are in high correlation. Significant swell wave height is estimated as 4.7 meters for 100 year return period.

Log-linear cumulative probability distribution is given in Figure 4.14.5. Four dominating directions; namely SW, WSW, W and E are plotted along with all directions. It is seen from this graph that significant height of swell waves exceeds 3.4 meters in about 10 hours duration every year.

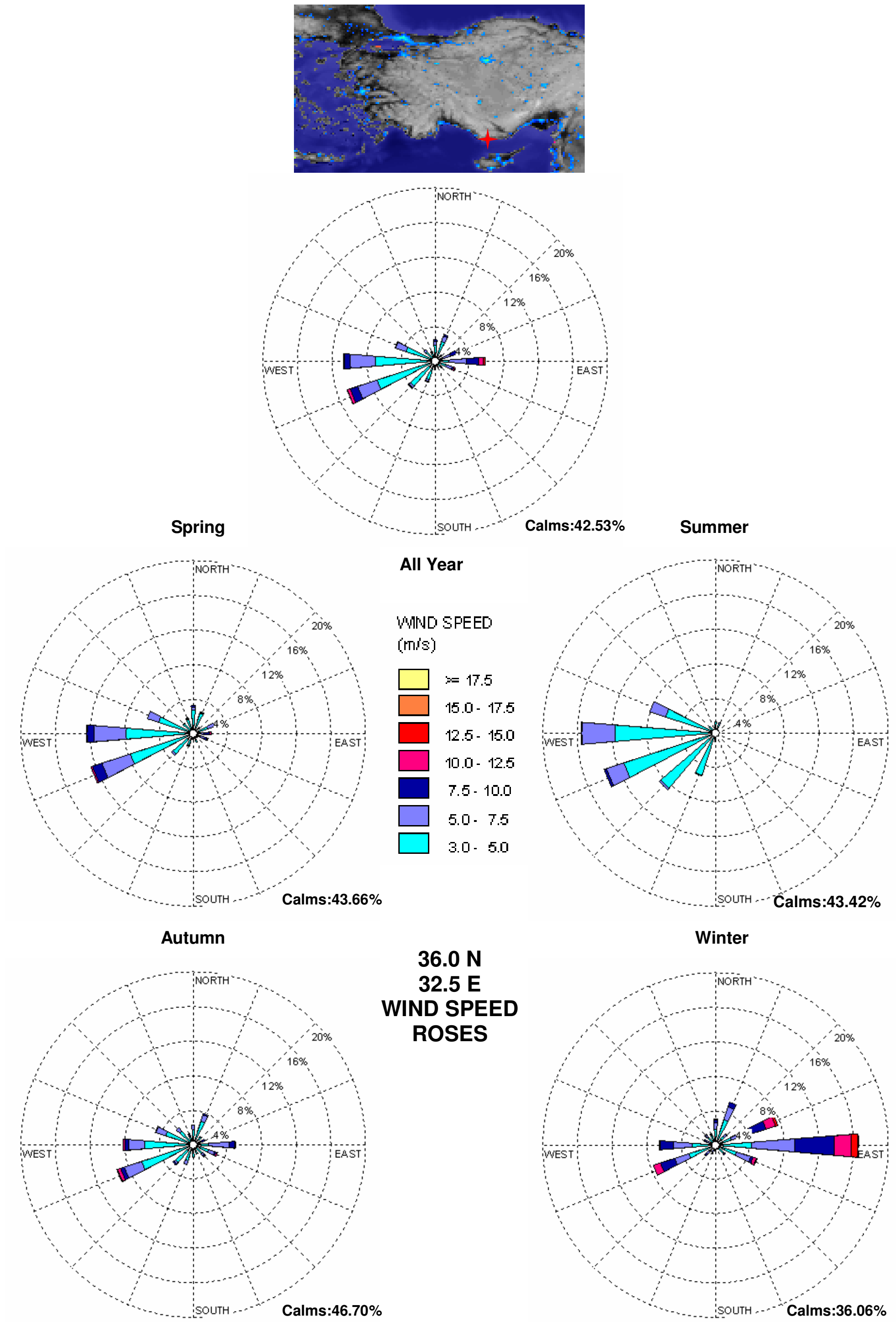

Figure 4.14.1 Wind climate at 36.0 N, 32.5 E

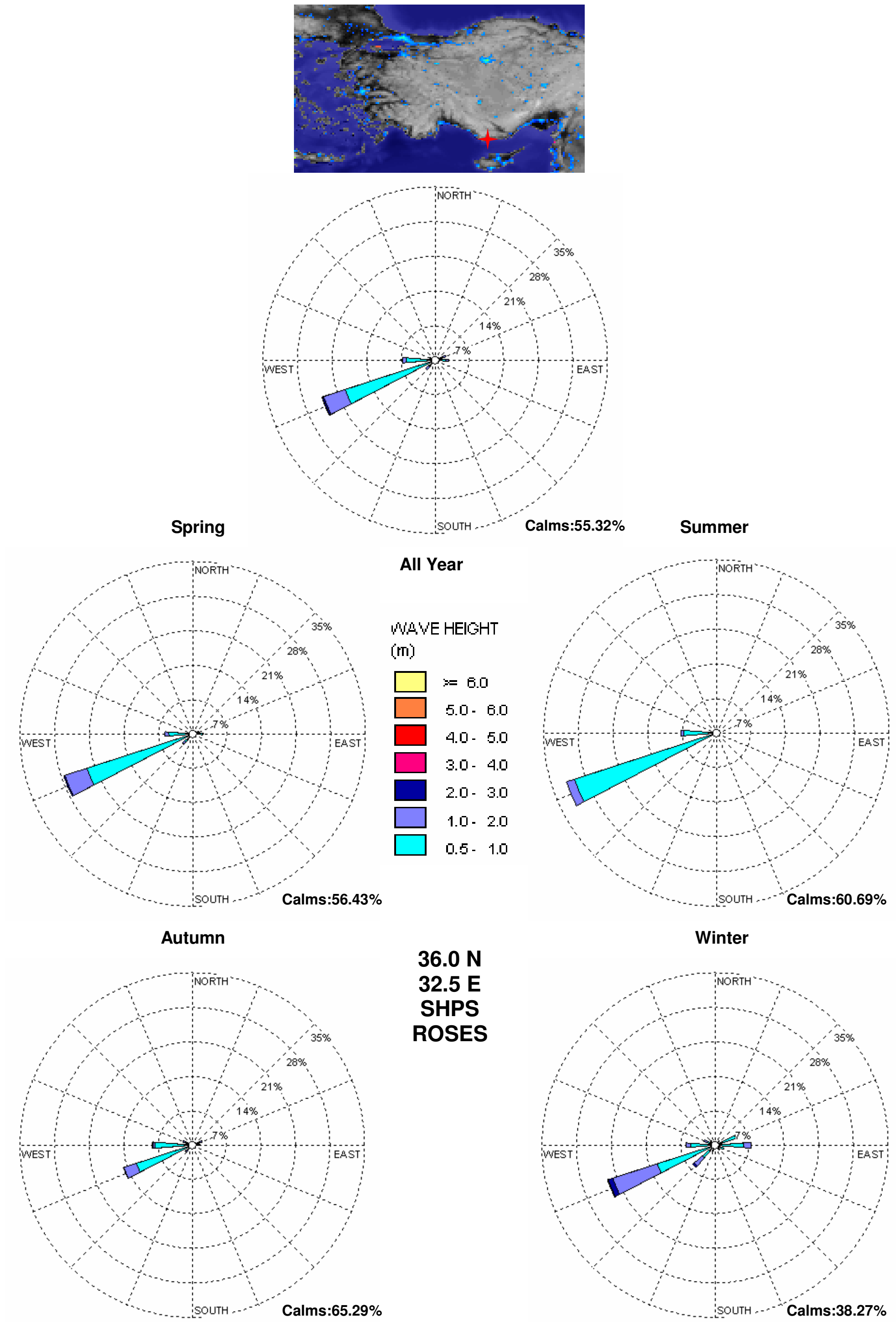

Figure 4.14.2 SHPS climate at 36.0 N, 32.5 E

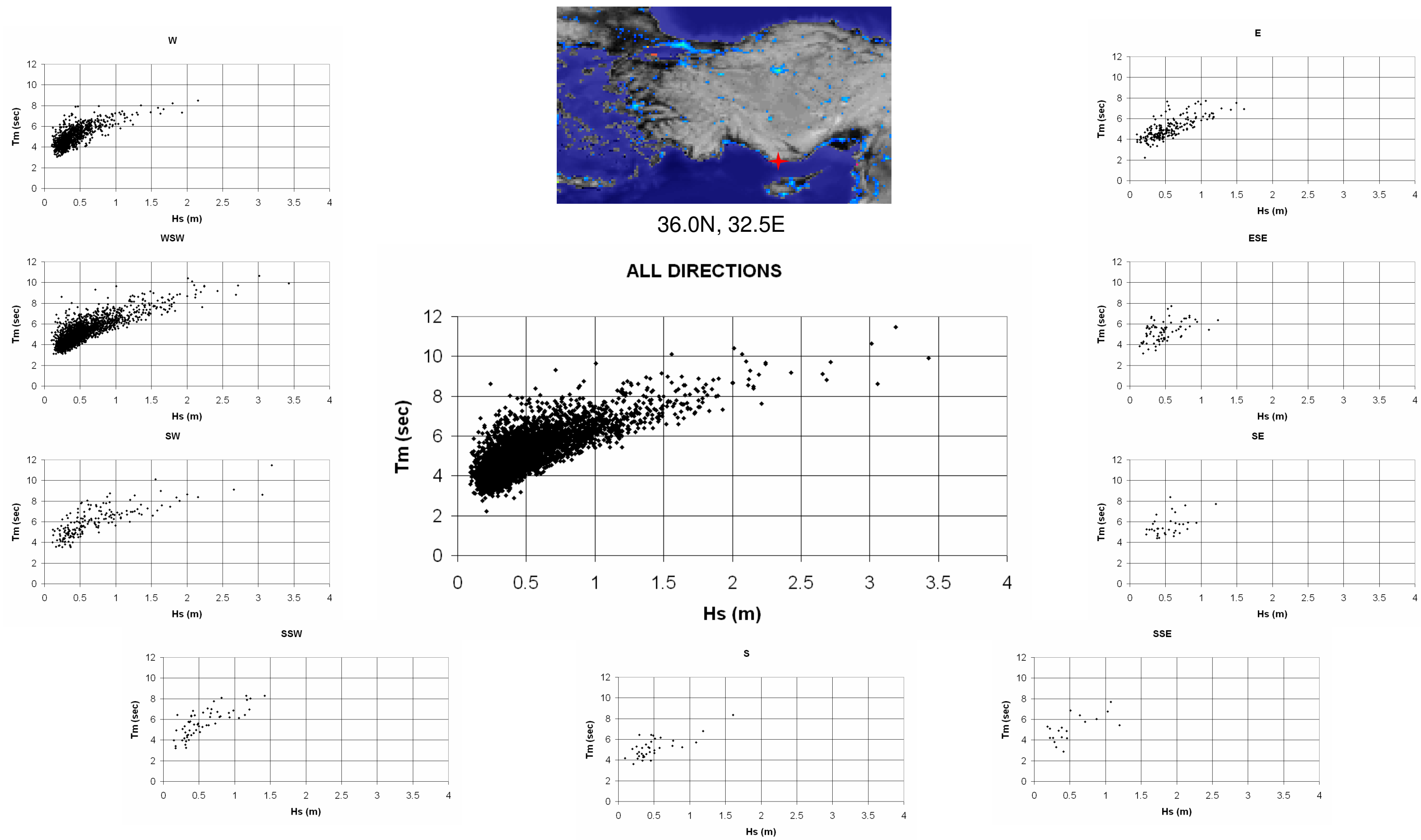

Figure 4.14.3 Relationship between MPPS & SHPS at Anamur

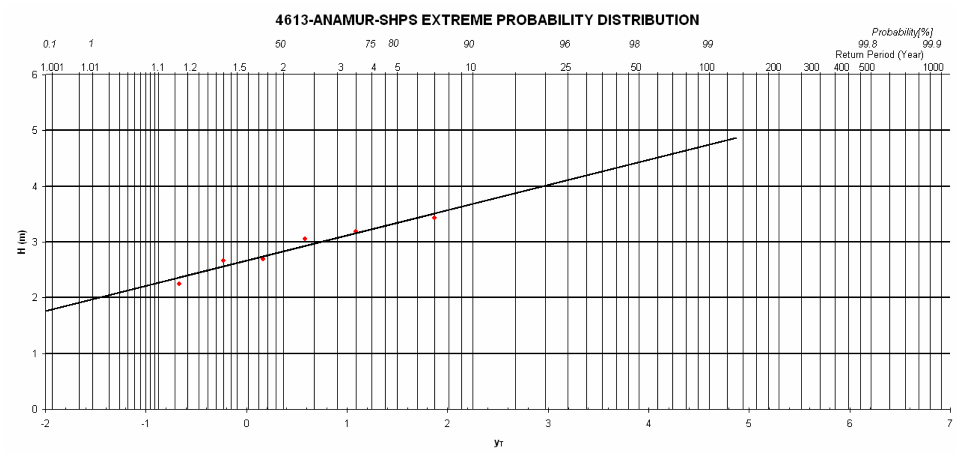

Figure 4.14.4 Extreme Probability Distribution at Location 36.0 N, 32.5

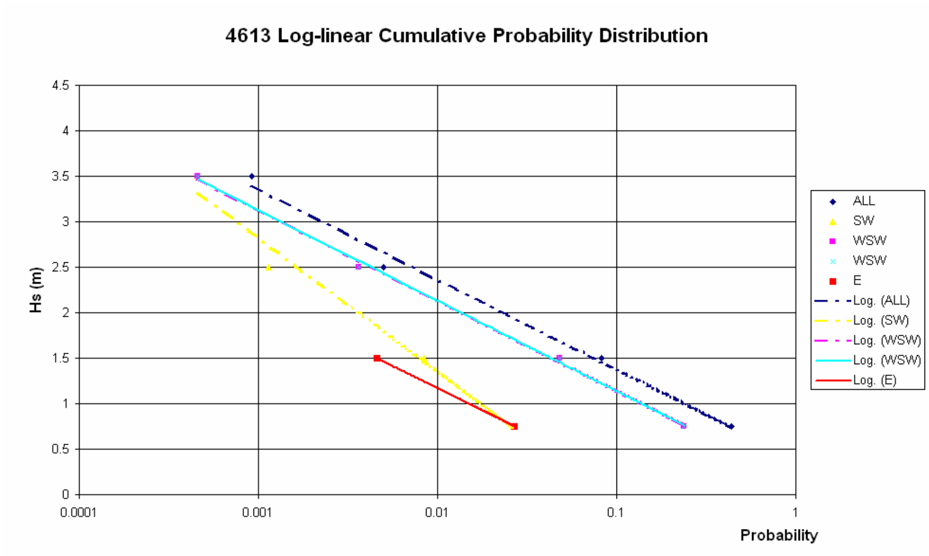

Figure 4.14.5 Log-Linear Cumulative Probability Distribution at 36.0 N, 32.5 E

4.15. LOCATION 4813 - SİLİFKE

The 4813 abbreviated point is located approximately 45 km of South West of Silifke. The coordinates of point 4813 is; 36.00˚ N, 33.50˚ E.

The Wind Roses, Swell Wave Roses, Significant Wave Height (Hs) vs. Mean Wave Period (Tm) Relations, Extreme value probability statistics and Log-linear cumulative probability distribution are given in this section for this location.

Wind roses are given in Figure 4.15.1 and show that location 4813 is subject to mainly WSW winds. Strong winds are effective in reverse direction, ENE in winter. In summer, WSW winds' percentile increases up to 35%. Also, there are strong winds from N direction, in winter and moderate winds from W direction in remaining seasons.

Wind Roses are compared with the wind roses at the nearest location (36.00˚ N, 33.40˚ E) in Ozhan and Abdalla, (1999) where calm durations have the largest ratio of the time. The dominant wind direction is relatively W and WSW. The yearly wind roses are in correlation despite calm durations are seen quite different. In Ozhan and Abdalla, (1999), the calm durations have 65% percentile in a year, whereas in this study this value is half of it.

Swell wave roses are given in Figure 4.15.2. In this figure WSW swell wave domination can easily be seen. Nearly 21% of the time swell waves are coming from WSW directions in a full year with nearly 61% calm durations. In winter, E directed swell waves are also seen. In summer, WSW swell waves' percentile increases up to nearly 30% of the time. The maximum swell wave height is between 1.5 and 2.0 meters.

The relations between Significant Wave Height (Hs) vs. Mean Wave Period (Tm) are given in Figure 4.15.3. The graph displays that there are W and WSW swell wave dominations for location 4813. A rather more scattered distribution is observed for WSW direction. Few data points exceeding 10 second periods are observed for WSW direction. For the same direction, there are several data points observed which have around 10 second periods and exceeding 1.5 m of swell wave height. The maximum swell wave height is 3.040 m. The average steepness of swell waves at this location (From Figure 4.15.3) is 0.011.

The graph of extreme value probability statistics is given in Figure 4.15.4. Data values are in high correlation. Significant swell wave height is estimated as 4.2 meters for 100 year return period.

Log-linear cumulative probability distribution is given in Figure 4.15.5. Four dominating directions; namely SW, WSW, W and E are plotted along with all directions. It is seen from this graph that significant height of swell waves exceeds 2.8 meters in about 10 hours duration every year.

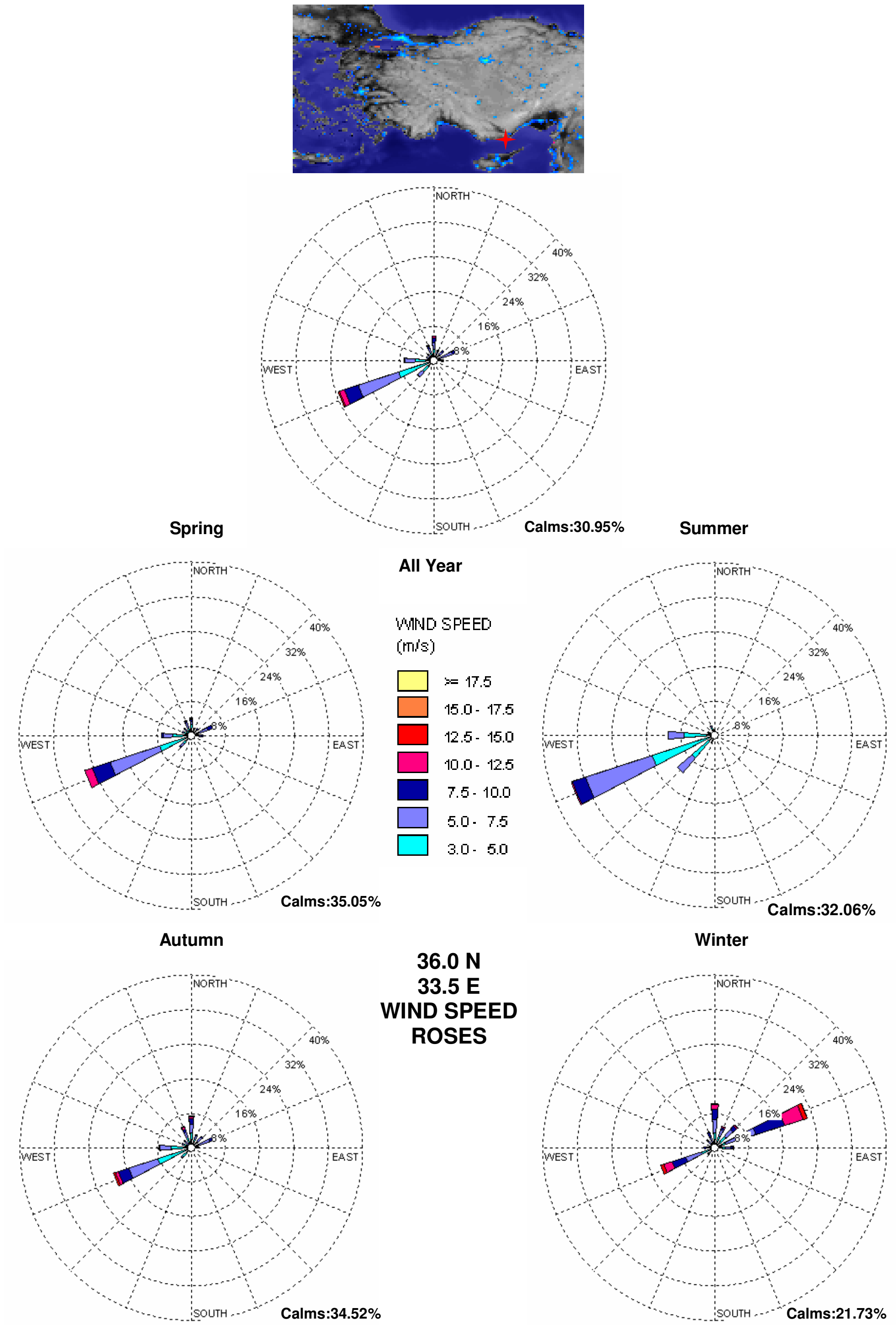

Figure 4.15.1 Wind climate at 36.0 N, 33.5 E

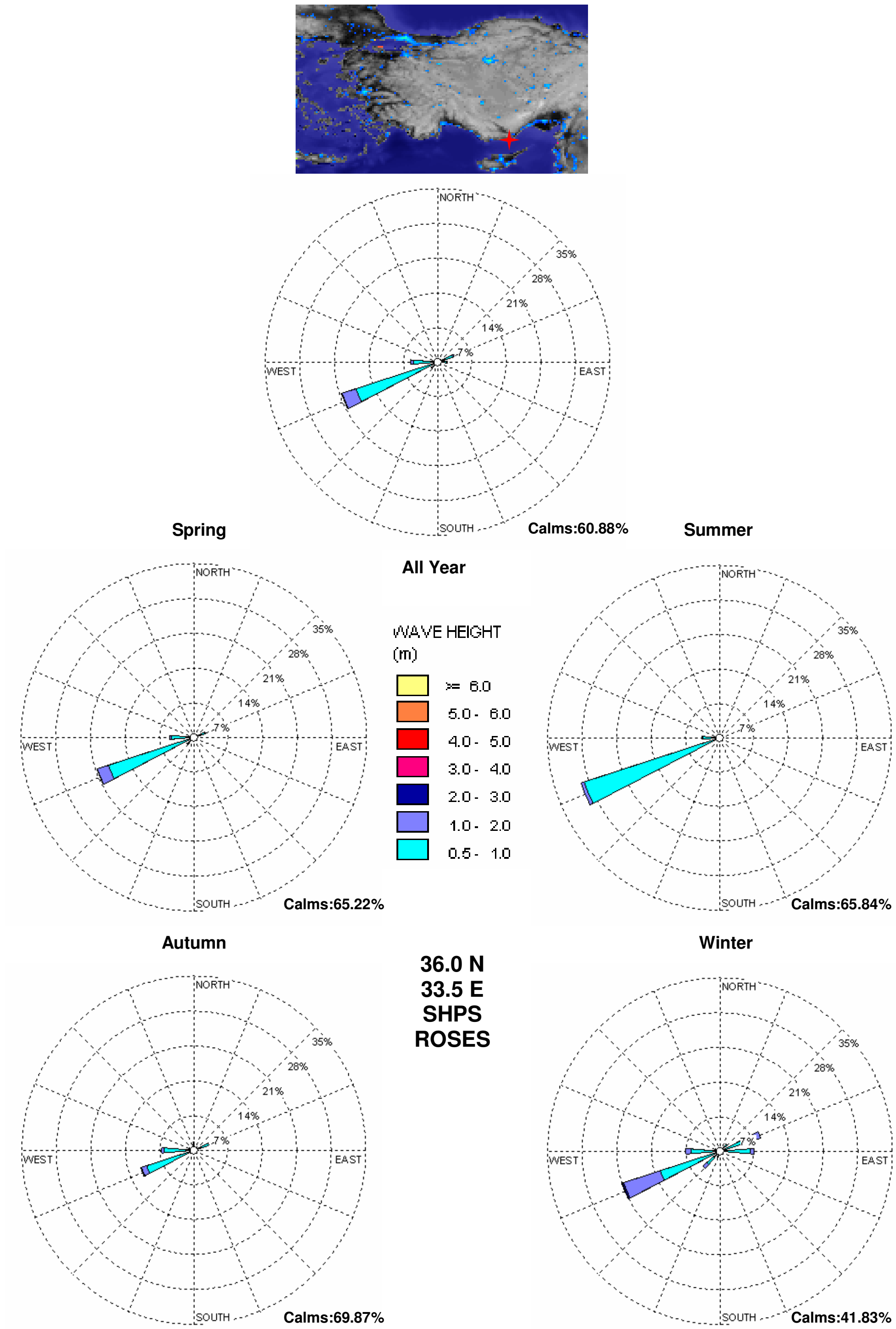

Figure 4.15.2 SHPS climate at 36.0 N, 33.5 E

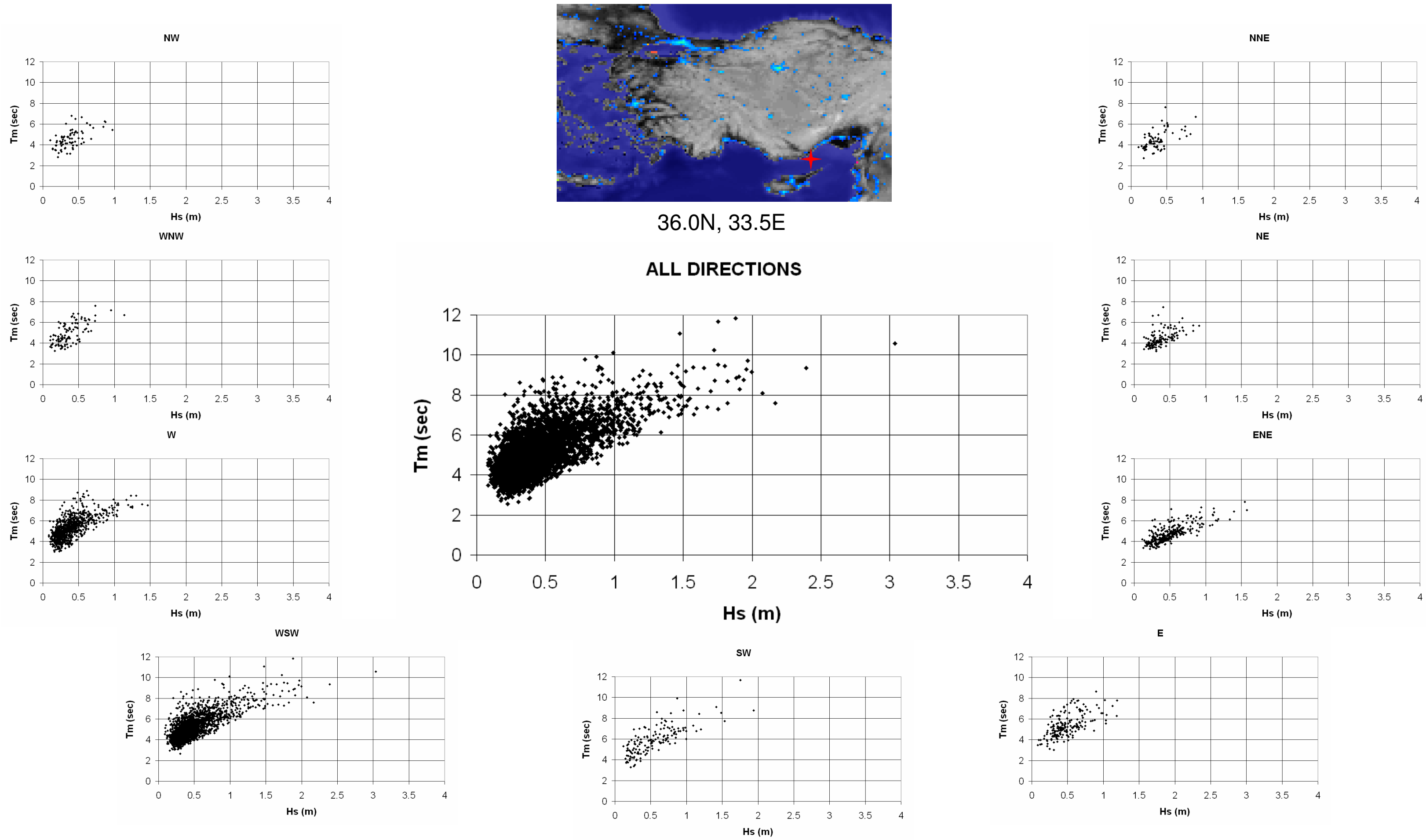

Figure 4.15.3 Relationship between MPPS & SHPS at Silifke

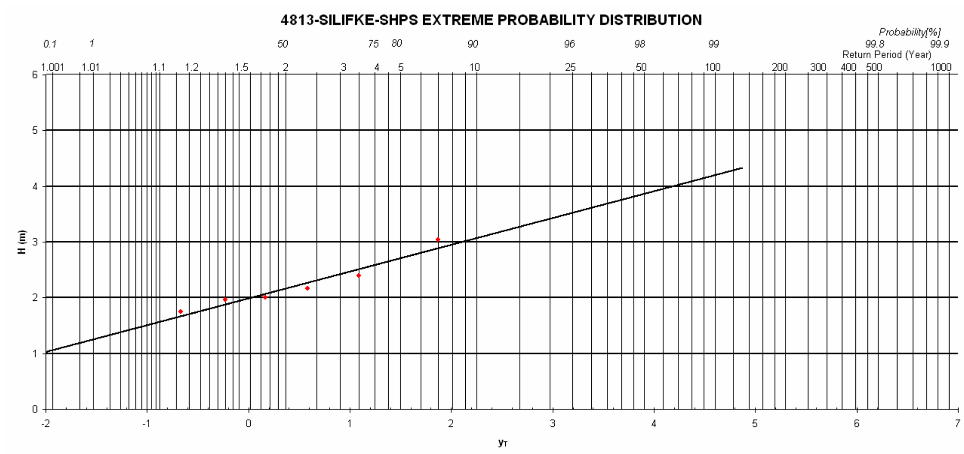

Figure 4.15.4 Extreme Probability Distribution at Location 36.0 N, 33.5

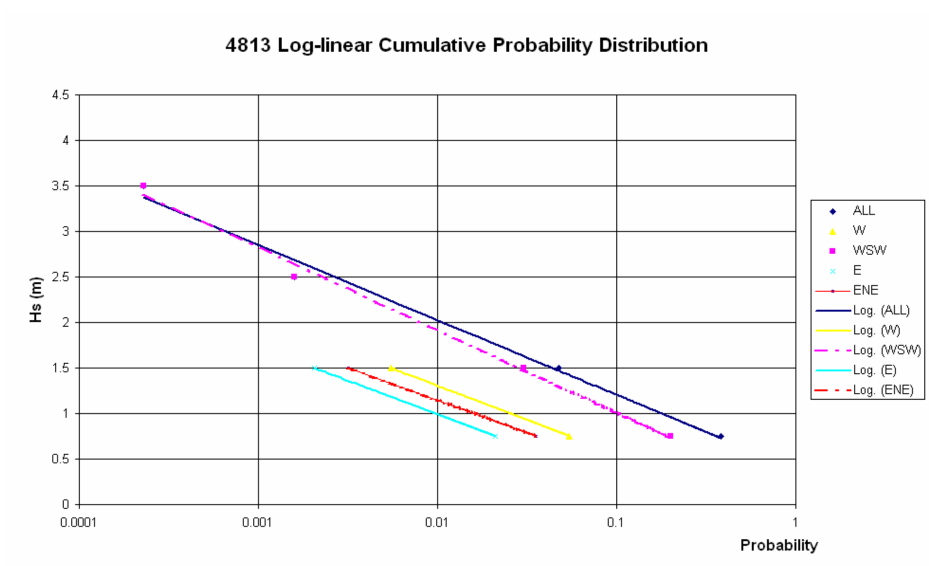

Figure 4.15.5 Log-Linear Cumulative Probability Distribution at 36.0 N, 33.5 E

4.16. LOCATION 5114 - KAZANLI

The 5114 abbreviated point is located approximately 30 km of South-South West of Kazanlı. The coordinates of point 5114 is; 36.50˚ N, 35.00˚ E.

The Wind Roses, Swell Wave Roses, Significant Wave Height (Hs) vs. Mean Wave Period (Tm) Relations, Extreme value probability statistics and Log-linear cumulative probability distribution are given in this section for this location.

Wind roses are given in Figure 4.16.1 and show that location 5114 is subject to mainly NE winds. Also SSW is the second dominant wind direction. Strong winds are effective in NE direction in winter and slides to SSW direction in summer.

Wind Roses are compared with the wind roses at the nearest location (36.50˚ N, 34.90˚ E) in Ozhan and Abdalla, (1999). Against to this study, there is not a definite dominant wind direction in Ozhan and Abdalla, (1999). In Ozhan and Abdalla, (1999), the calm durations have nearly 94% percentile of the full year.

Swell wave roses are given in Figure 4.16.2 and show a clear indication of direction of incoming swell waves. Although nearly 80% of the whole year the sea state is calm in terms of swell waves, SW and SSW swell domination can easily be seen. Nearly 11% of the time in winter, SW directed swell waves are coming to this location. The maximum swell wave height is between 1.5 and 2.0 meters.

The relations between Significant Wave Height (Hs) vs. Mean Wave Period (Tm) are given in Figure 4.16.3. In this graph, SW and SSW swell wave domination is observed. A rather more scattered distribution via Figure 4.16.2. Several data points exceeding 8 second periods and few data points exceeding 1.5 m of swell wave heights are observed for SW direction. The maximum swell wave height is 2.532 m. The average steepness of swell waves at this location (From Figure 4.16.3) is 0.011.

The graph of extreme value probability statistics is given in Figure 4.16.4. Data values show quite good correlation. Significant swell wave height is estimated as 3.7 meters for 100 year return period.

Log-linear cumulative probability distribution is given in Figure 4.16.5. Three dominating directions; namely SW, S and SSW are plotted along with all directions. It is seen from this graph that significant height of swell waves exceeds 2.4 meters in about 10 hours duration every year.

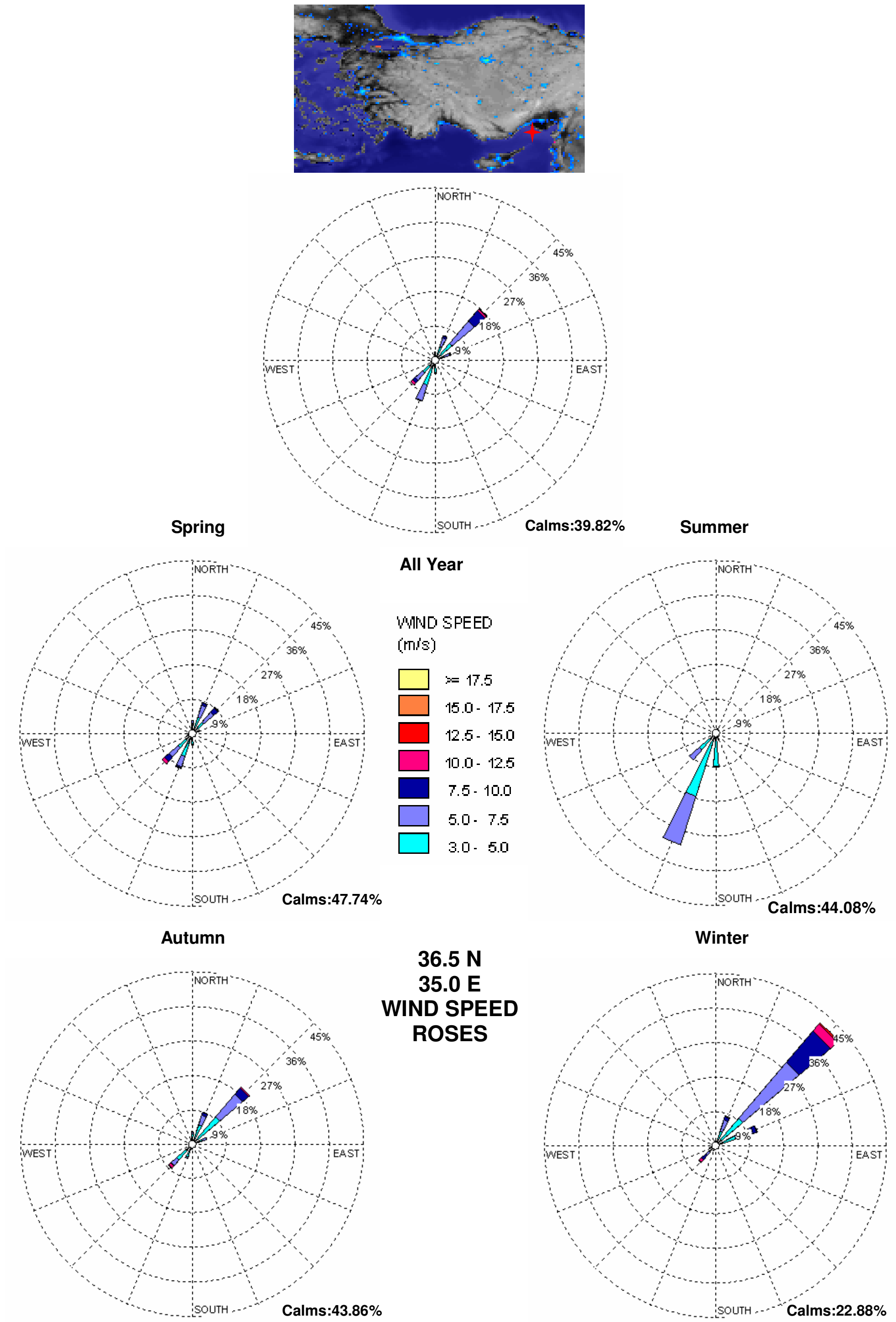

Figure 4.16.1 Wind climate at 36.5 N, 35.0 E

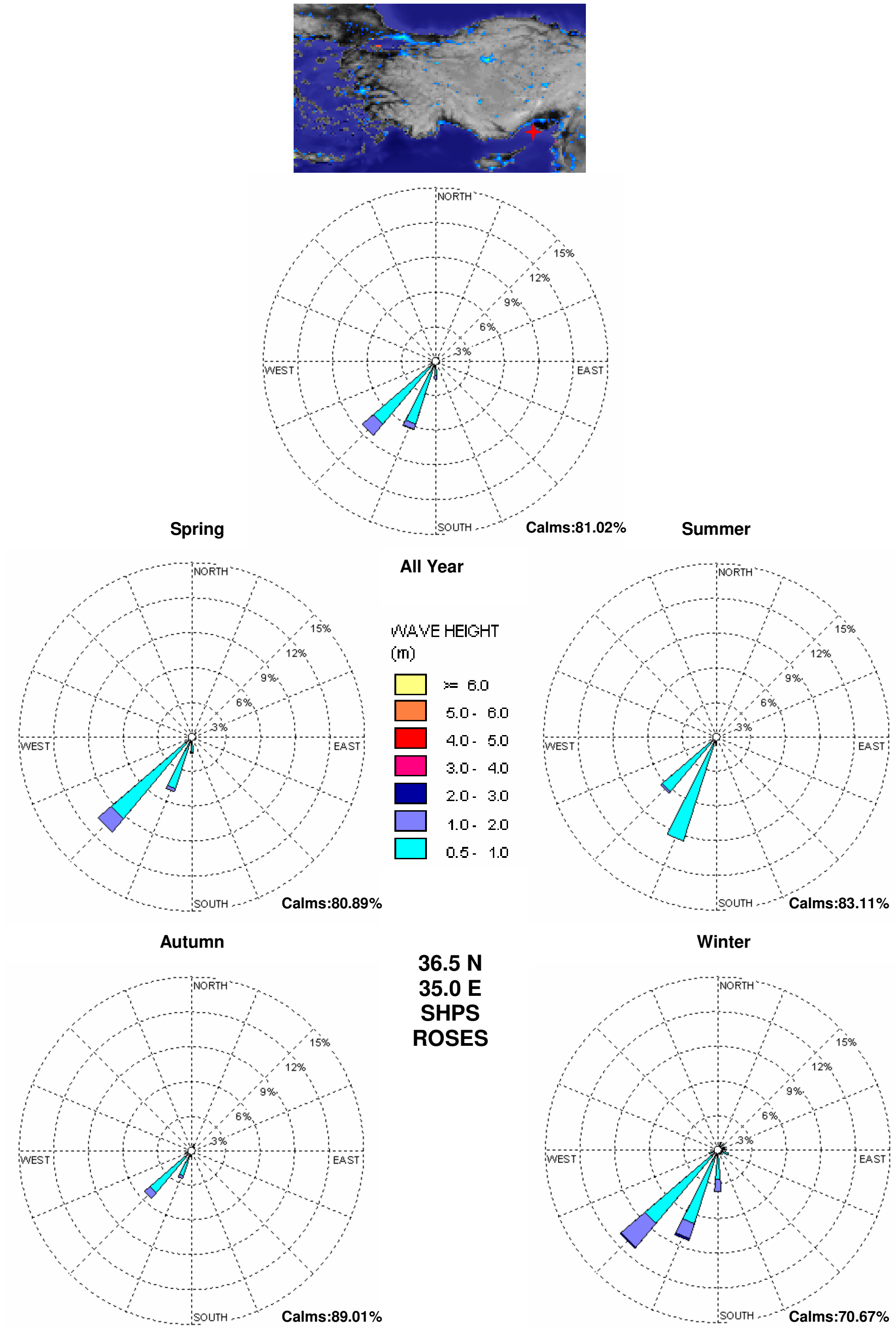

Figure 4.16.2 SHPS climate at 36.5 N, 35.0 E

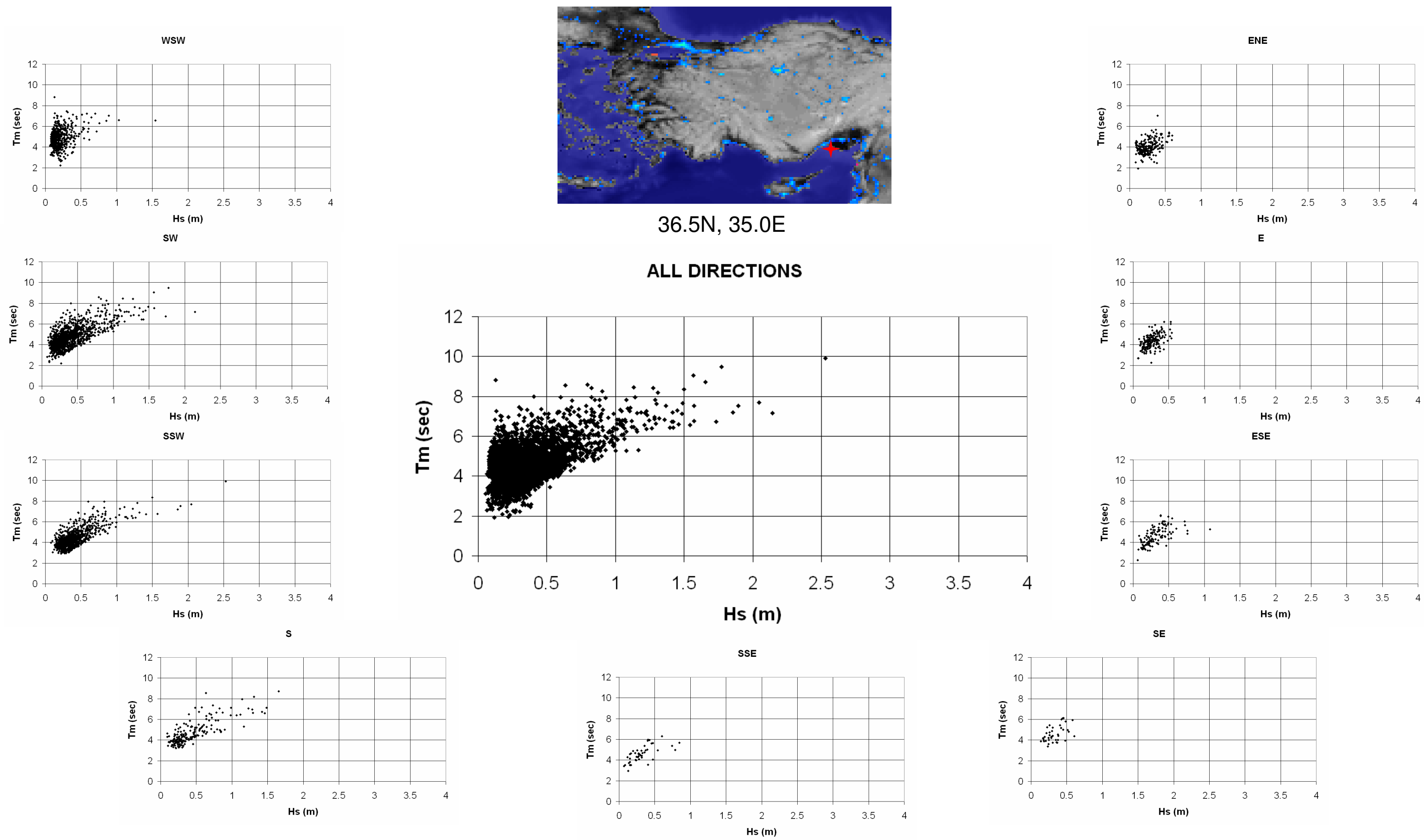

Figure 4.16.3 Relationship between MPPS & SHPS at Kazanli

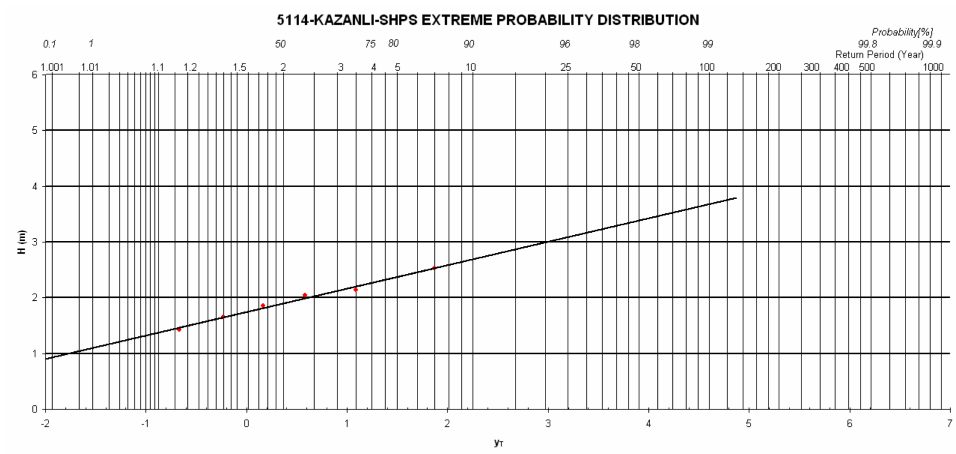

Figure 4.16.4 Extreme Probability Distribution at Location 36.5 N, 35.0

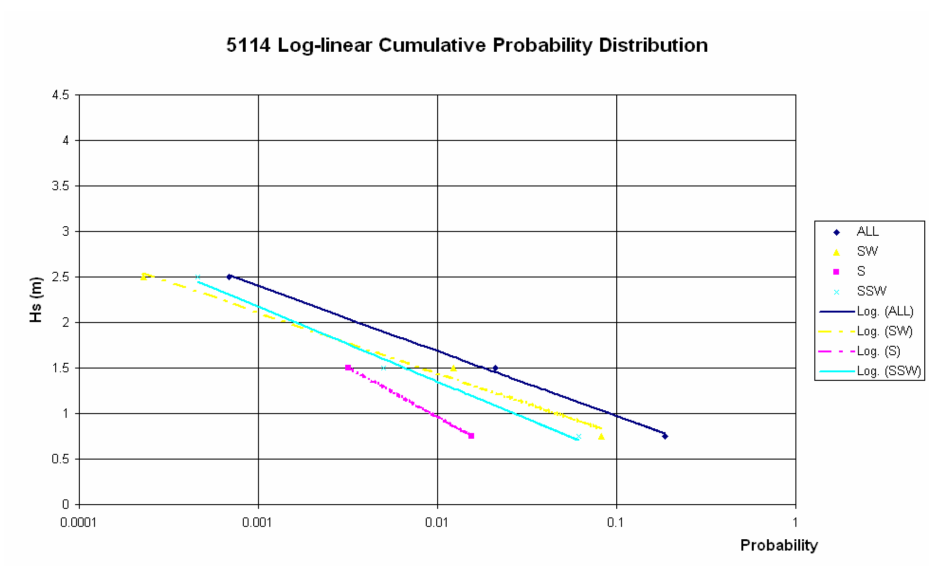

Figure 4.16.5 Log-Linear Cumulative Probability Distribution at 36.5 N, 35.0 E

4.17. LOCATION 5214 - KARATAŞ

The 5214 abbreviated point is located approximately 10 km of South East of Karataş. The coordinates of point 5214 is; 36.50˚ N, 35.50˚ E.

The Wind Roses, Swell Wave Roses, Significant Wave Height (Hs) vs. Mean Wave Period (Tm) Relations, Extreme value probability statistics and Log-linear cumulative probability distribution are given in this section for this location.

Wind roses are given in Figure 4.17.1 and show that location 5214 is subject to wide range of wind directions, NNE to ENE and SW to SSW. Strong winds are effective in ENE direction in winter and slides to SSW direction in summer. Relatively strong winds are observed in SW direction in spring and autumn.

Wind Roses are compared with the wind roses at the nearest location (36.50˚ N, 35.50˚ E) in Ozhan and Abdalla, (1999). Against to this study, in Ozhan and Abdalla, (1999), there is not a definite dominant wind direction. In Ozhan and Abdalla, (1999), the calm durations have nearly 98% percentile of the full year.

Swell wave roses are given in Figure 4.17.2 and show a clear indication of direction of incoming swell waves. Nearly 10% of the time swell waves are coming from SW direction in a full year. SW swell waves' percentile increases in winter up to 16%. The maximum swell wave height is between 2.0 and 2.5 meters.

The relations between Significant Wave Height (Hs) vs. Mean Wave Period (Tm) are given in Figure 4.17.3. In this graph, WSW, SW and SSW swell wave domination can be seen. Several data points exceeding 1.5 m of swell wave heights and few data points around 10 second periods are observed for SW direction. The maximum swell wave height is 2.794 m. The average steepness of swell waves at this location (From Figure 4.17.3) is 0.010.

The graph of extreme value probability statistics is given in Figure 4.17.4. Data values are in high correlation. Significant swell wave height is estimated as 3.8 meters for 100 year return period.

Log-linear cumulative probability distribution is given in Figure 4.17.5. Four dominating directions; namely SW, WSW, SSW and S are plotted along with all directions. It is seen from this graph that significant height of swell waves reaches to 2.5 meters in about 10 hours duration every year.

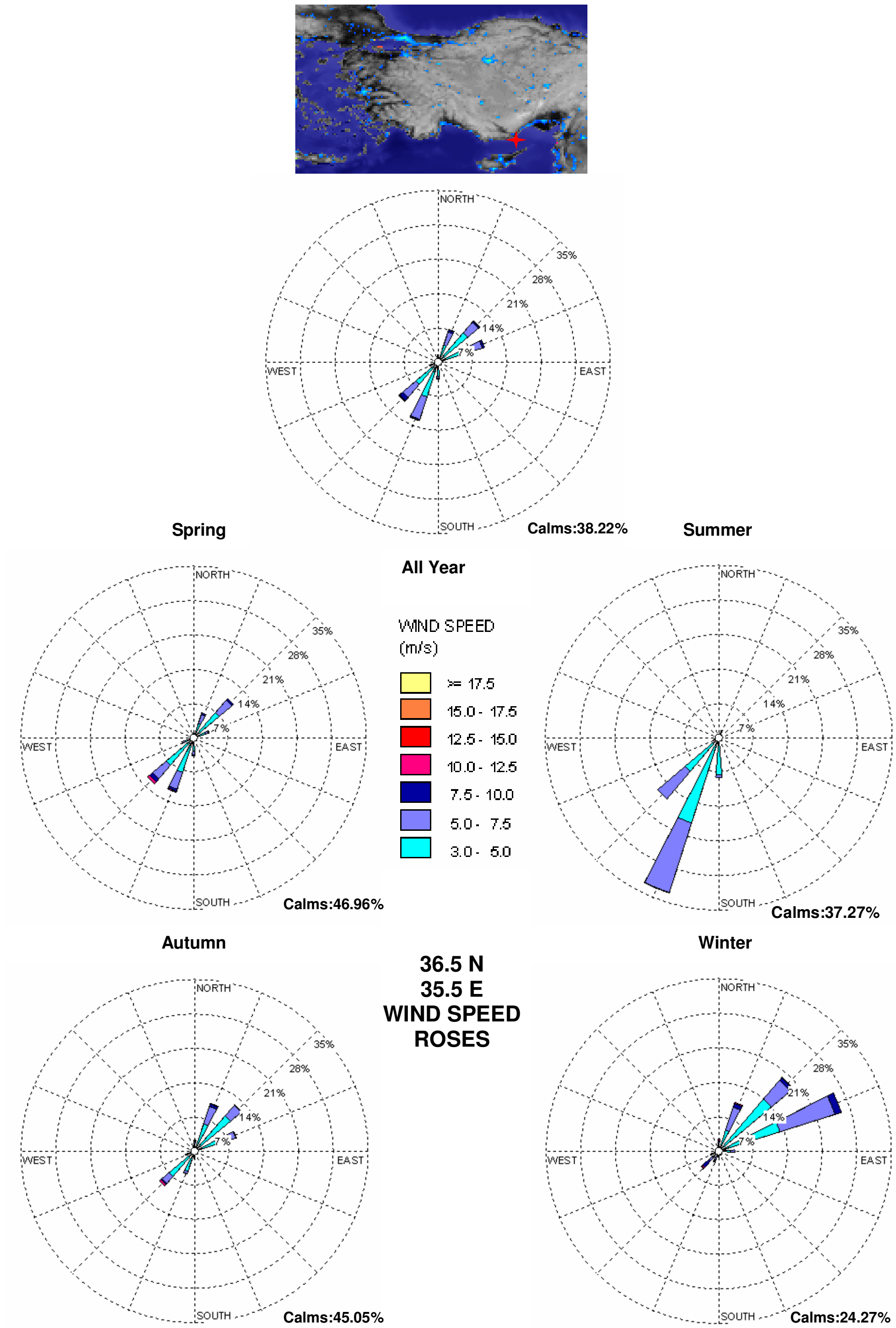

Figure 4.17.1 Wind climate at 36.5 N, 35.5 E

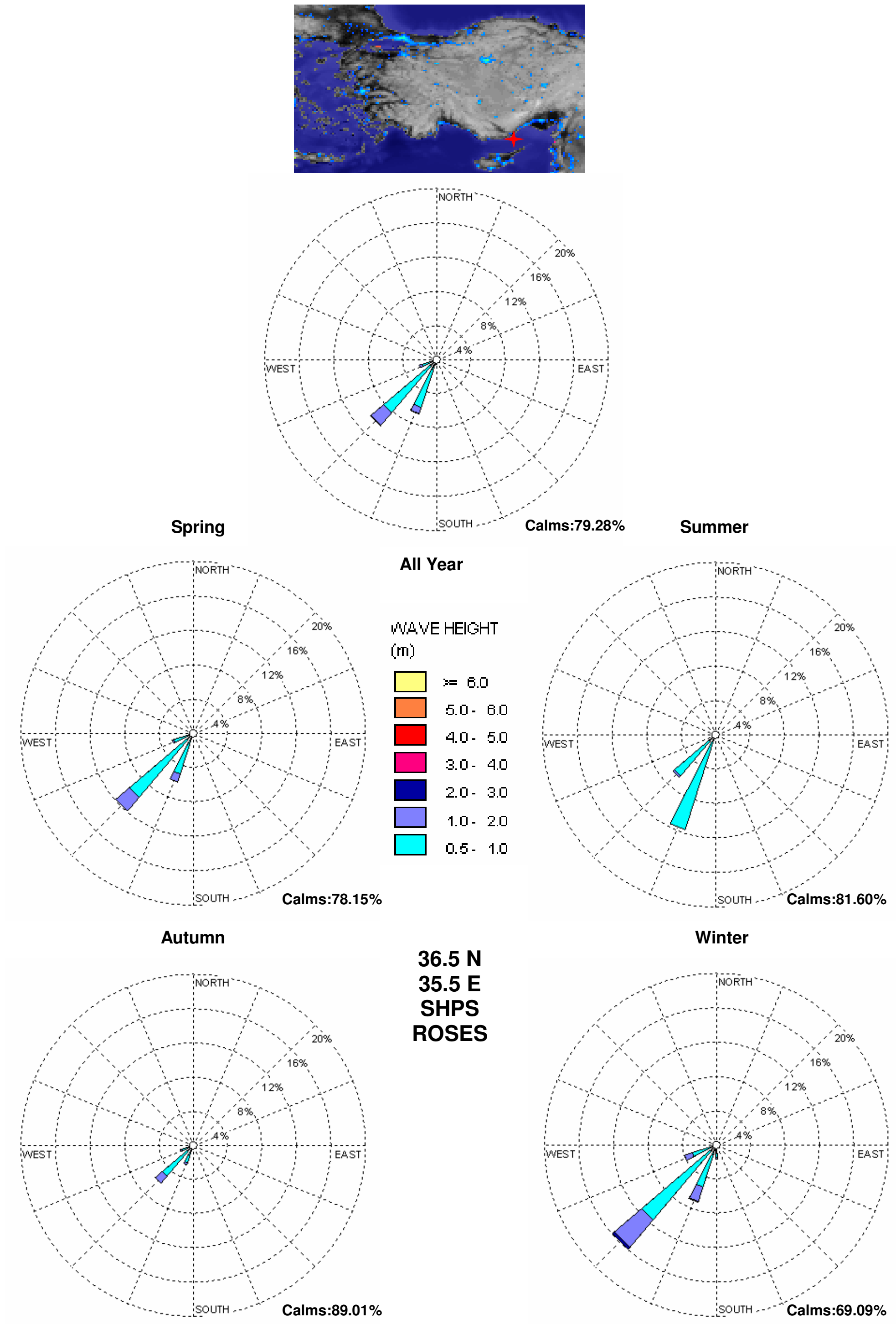

Figure 4.17.2 SHPS climate at 36.5 N, 35.5 E

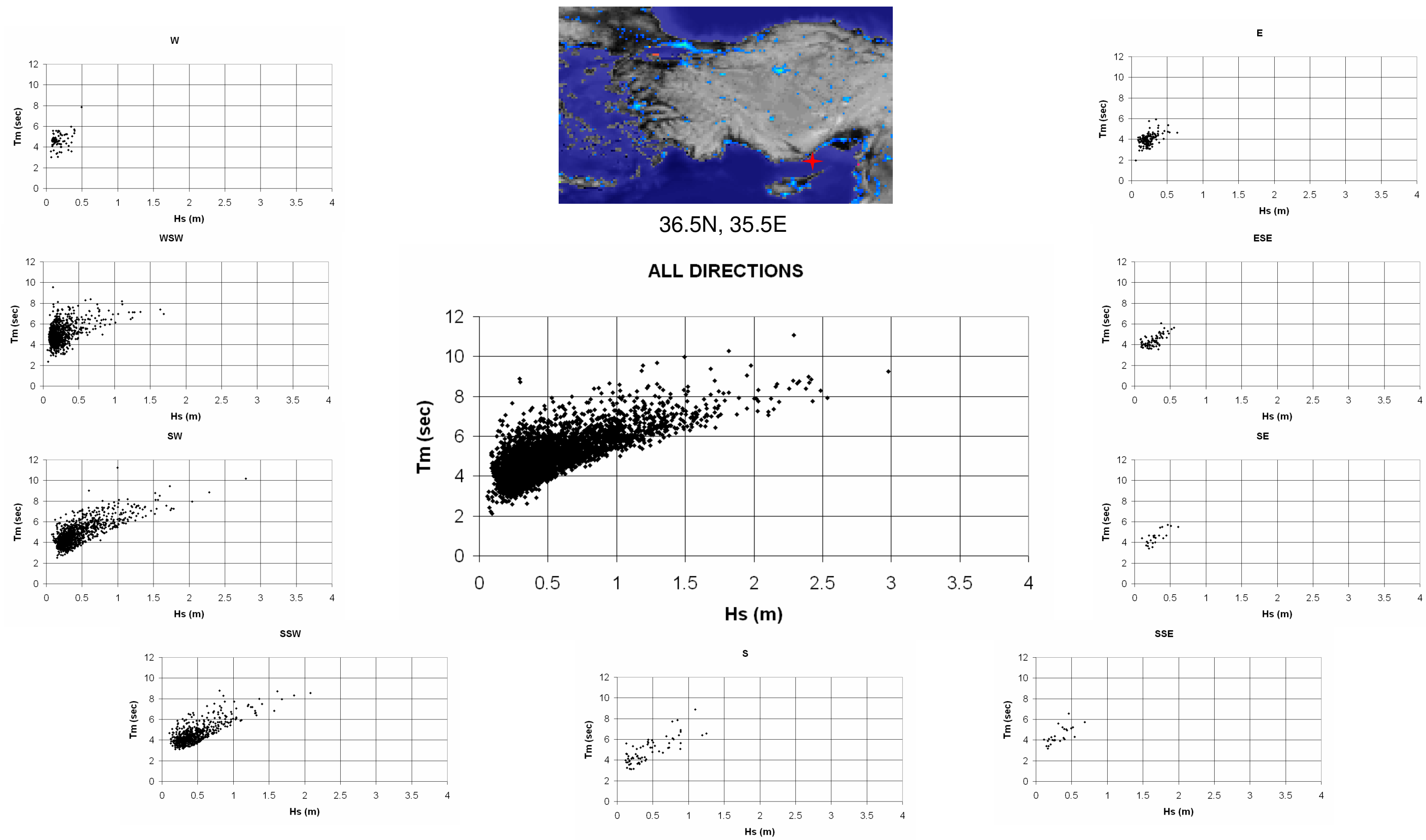

Figure 4.17.3 Relationship between MPPS & SHPS at Karatas

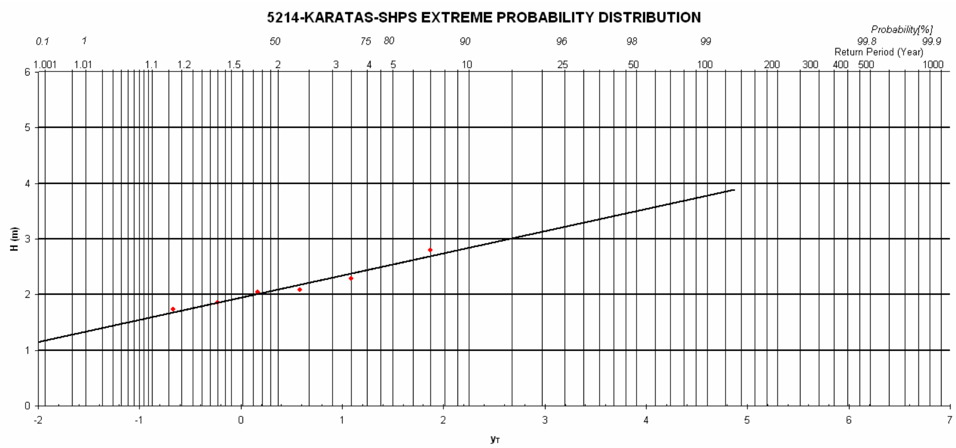

Figure 4.17.4 Extreme Probability Distribution at Location 36.5 N, 35.5

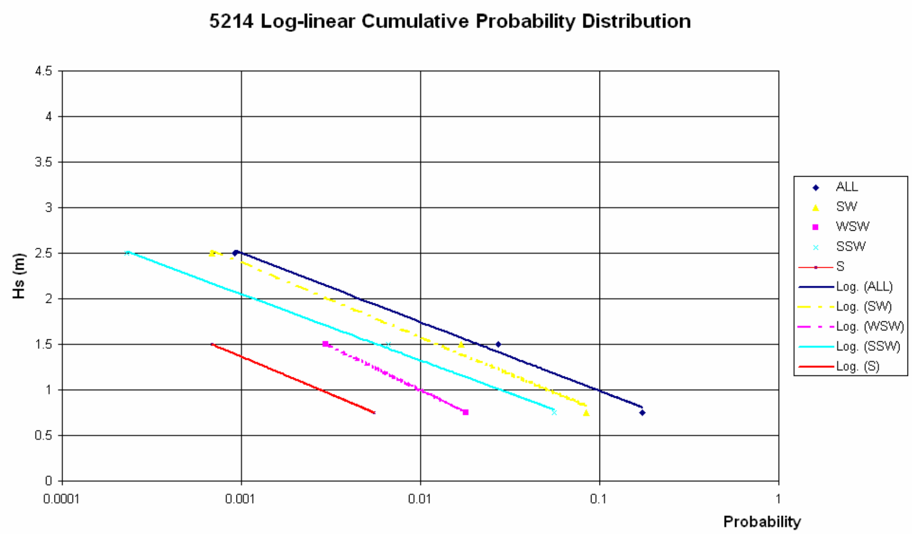

Figure 4.17.5 Log-Linear Cumulative Probability Distribution at 36.5 N, 35.5 E

4.18. LOCATION 5213 - SAMANDAĞ

The 5213 abbreviated point is located approximately 37 km of West-South West of Samandağ. The coordinates of point 5213 is; 36.00˚ N, 35.50˚ E.

The Wind Roses, Swell Wave Roses, Significant Wave Height (Hs) vs. Mean Wave Period (Tm) Relations, Extreme value probability statistics and Log-linear cumulative probability distribution are given in this section for this location.

Wind roses are given in Figure 4.18.1 and show that location 5213 is subject to mainly SSW winds. Strong winds are effective in ENE direction in winter and slides to SSW direction in summer. Also relatively strong winds are observed in NNE and WSW directions.

Wind Roses are compared with the wind roses at the nearest location (36.00˚ N, 35.80˚ E) in Ozhan and Abdalla, (1999). Against to this study, in Ozhan and Abdalla, (1999), there is not a definite dominant wind direction. In Ozhan and Abdalla, (1999), the calm durations have nearly 86% percentile of the full year. Excluding durations, wind directions show some similarities with both studies.

Swell wave roses are given in Figure 4.18.2 and show a clear indication of direction of incoming swell waves. Nearly 18% of the time swell waves are coming from WSW direction in a full year. WSW swell waves' percentile increases in summer up to nearly 23% of the time. The maximum swell wave height is between 2.0 and 2.5 meters.

The relations between Significant Wave Height (Hs) vs. Mean Wave Period (Tm) are given in Figure 4.18.3. In this graph, W, WSW and SW swell wave domination can be seen via Figure 4.18.2. Several data points around 10 second periods and few data points exceeding 1.5 m of swell wave heights are observed for WSW direction. The maximum swell wave height is 3.005 m. The average steepness of swell waves at this location (From Figure 4.18.3) is 0.011.

The graph of extreme value probability statistics is given in Figure 4.18.4. Data values show a very good correlation. Significant swell wave height is estimated as 4.5 meters for 100 year return period.

Log-linear cumulative probability distribution is given in Figure 4.18.5. Four dominating directions; namely SW, WSW, SSW and W are plotted along with all directions. It is seen from this graph that significant height of swell waves exceeds 2.7 meters in about 10 hours duration every year.

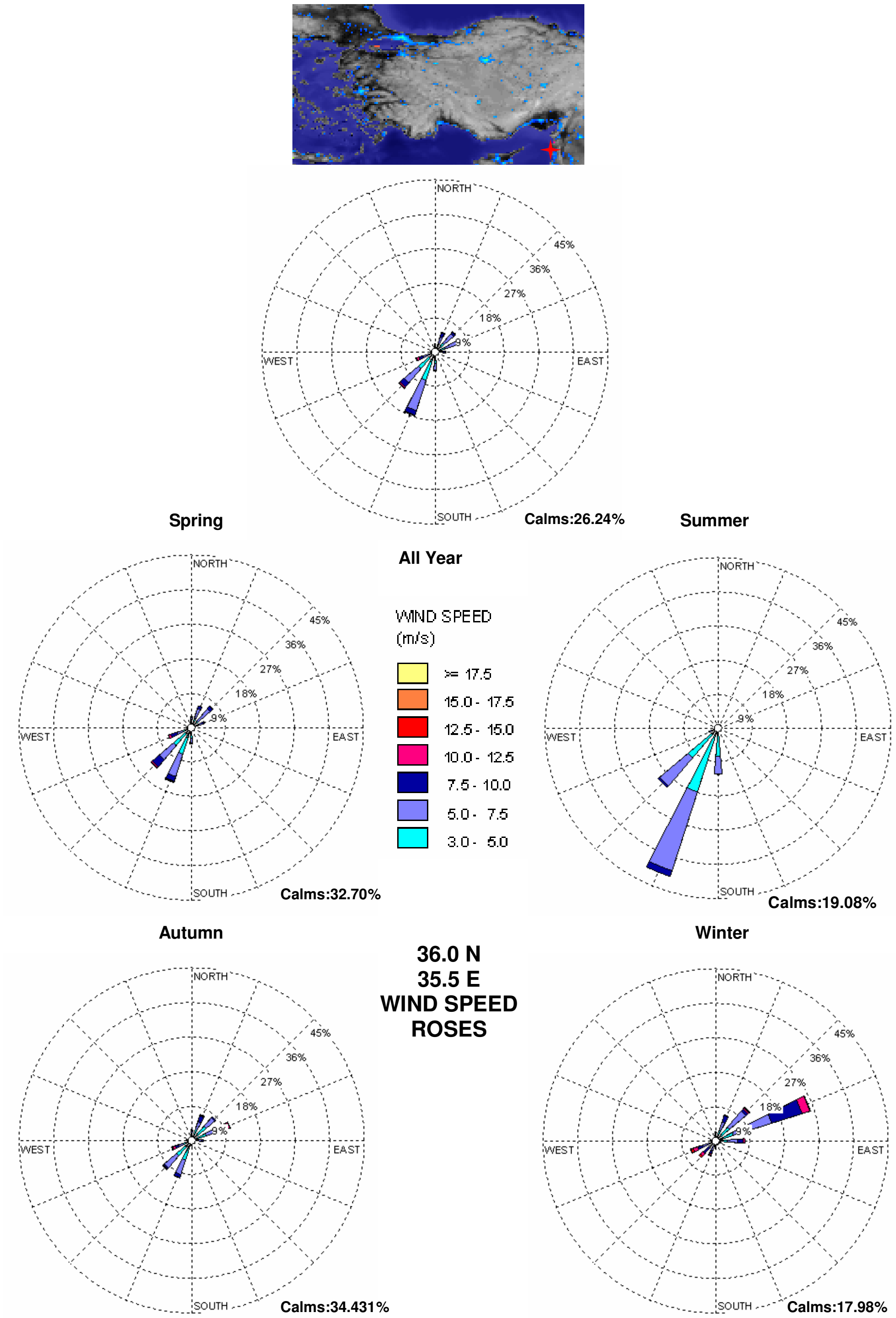

Figure 4.18.1 Wind climate at 36.0 N, 35.5 E

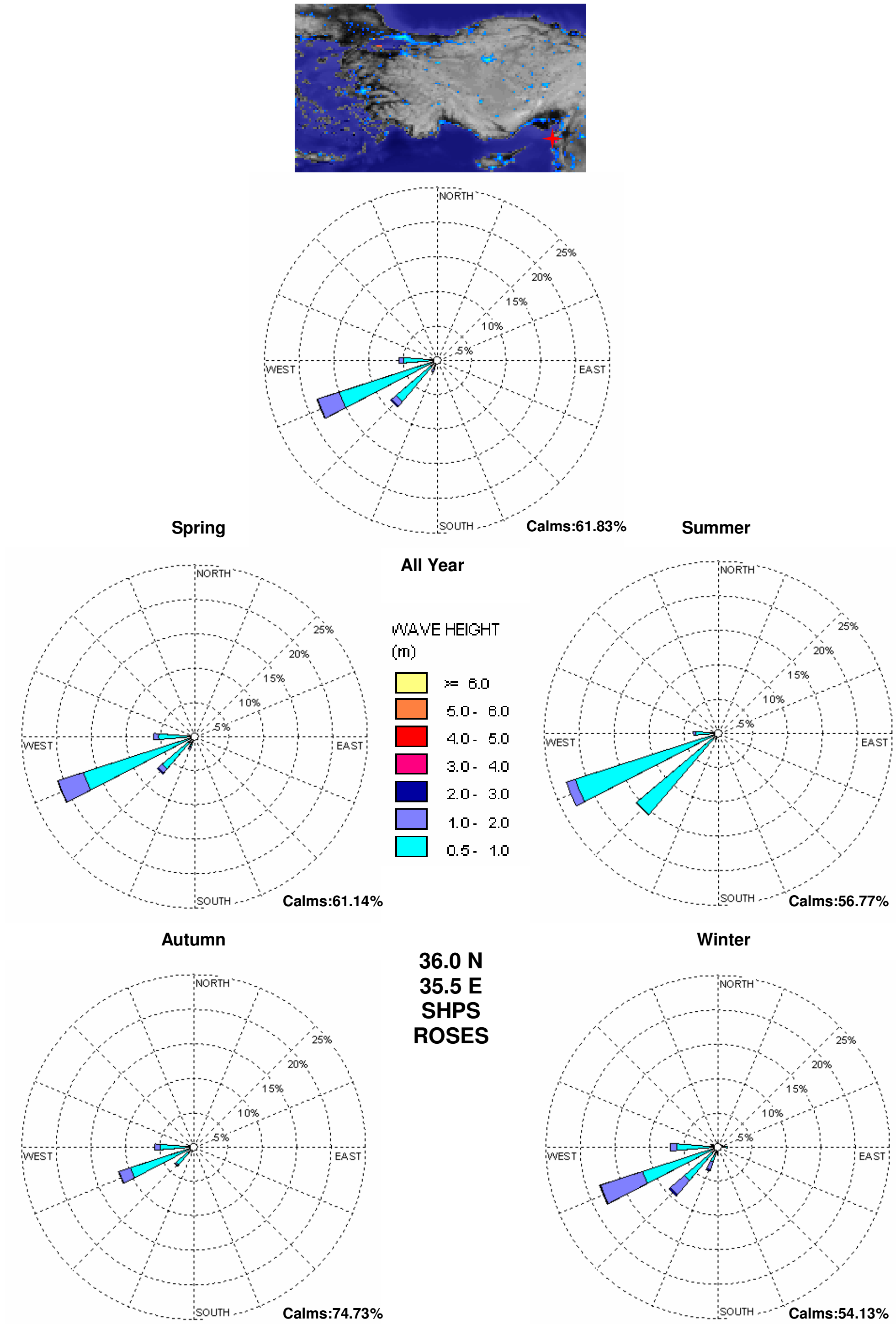

Figure 4.18.2 SHPS climate at 36.0 N, 35.5 E

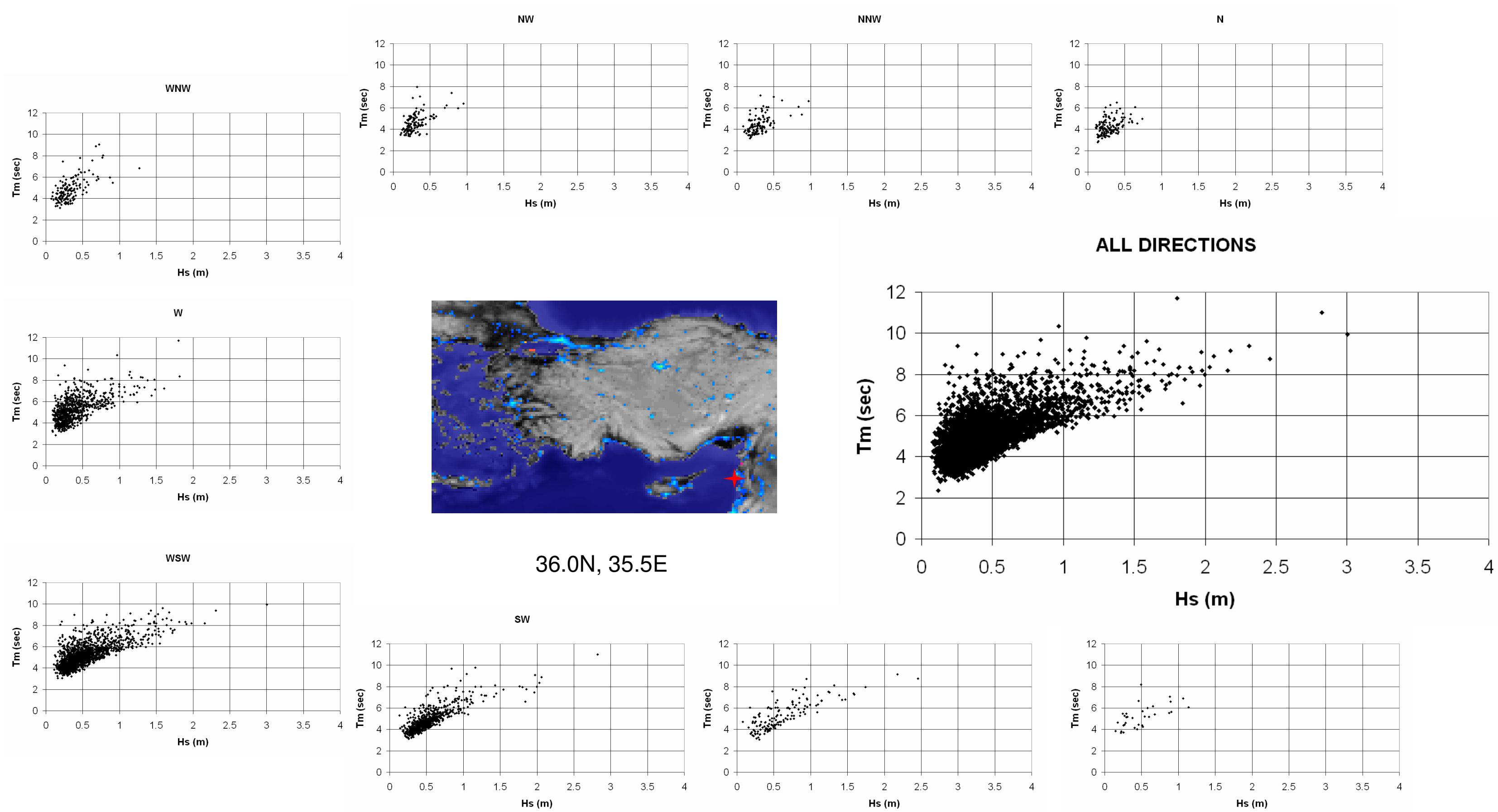

Figure 4.18.3 Relationship between MPPS & SHPS at Samandag

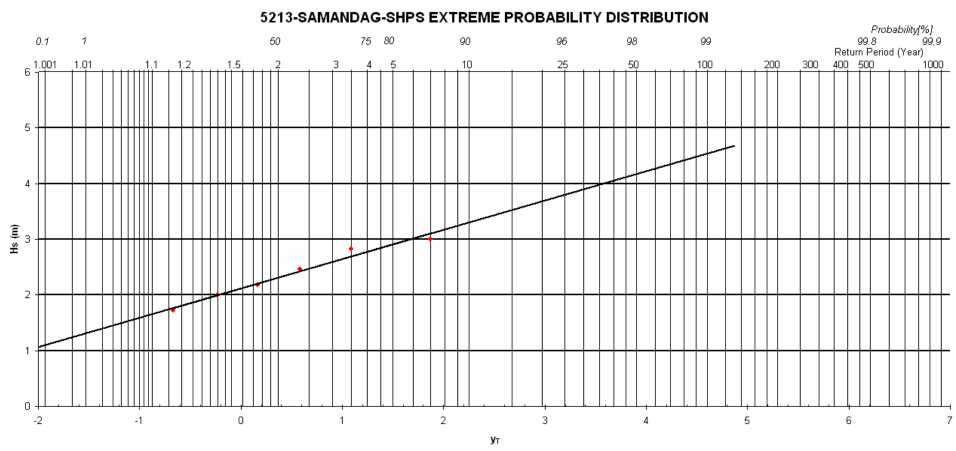

Figure 4.18.4 Extreme Probability Distribution at Location 36.0 N, 35.5

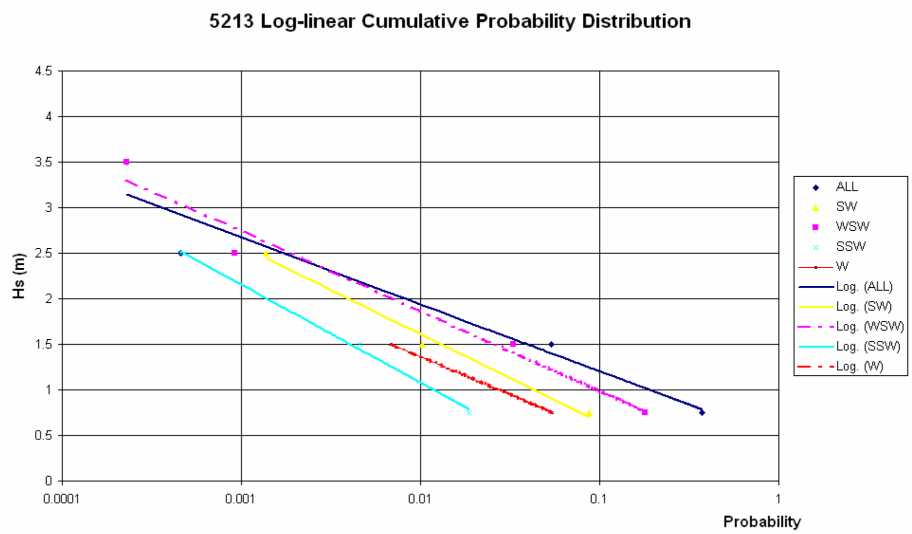

Figure 4.18.5 Log-Linear Cumulative Probability Distribution at 36.0 N, 35.5 E

4.19. LOCATION 4611 - GÜZELYURT

The 4611 abbreviated point is located approximately 45 km of West of Güzelyurt. The coordinates of point 4611 is; 36.00˚ N, 32.00˚ E.

The Wind Roses, Swell Wave Roses, Significant Wave Height (Hs) vs. Mean Wave Period (Tm) Relations, Extreme value probability statistics and Log-linear cumulative probability distribution are given in this section for this location.

Wind roses are given in Figure 4.19.1 and show that location 4611 is subject to wide range of wind directions. Considering the full year, W direction is the dominant wind direction. Strong winds are effective in W and ENE directions in winter and slides to W and WSW directions in summer. Also relatively strong winds are observed from NW to S directions in winter.

Wind roses cannot be compared with the wind roses in Ozhan and Abdalla, (1999), since there is no point representing this location.

Swell wave roses are given in Figure 4.19.2 and show a clear indication of direction of incoming swell waves. Nearly 16% of the time swell waves are coming from W direction in a full year with nearly 70% calm durations. W swell waves' percentile increases in summer up to 27% of the time. The maximum swell wave height is between 2.0 and 2.5 meters.

The relations between Significant Wave Height (Hs) vs. Mean Wave Period (Tm) are given in Figure 4.19.3. In this graph, W and WSW swell wave domination can be seen. Several data points around 10 second periods and few data points exceeding 1.5 m of swell wave heights are observed for W direction. The maximum swell wave height is 3.225 m. The average steepness of swell waves at this location (From Figure 4.19.3) is 0.008.

The graph of extreme value probability statistics is given in Figure 4.19.4. Significant swell wave height is estimated as 5.6 meters for 100 year return period.

Log-linear cumulative probability distribution is given in Figure 4.19.5. Four dominating directions; namely WNW, WSW, W and NW are plotted along with all directions. It is seen from this graph that significant height of swell waves reaches to 3.2 meters in about 10 hours duration every year.

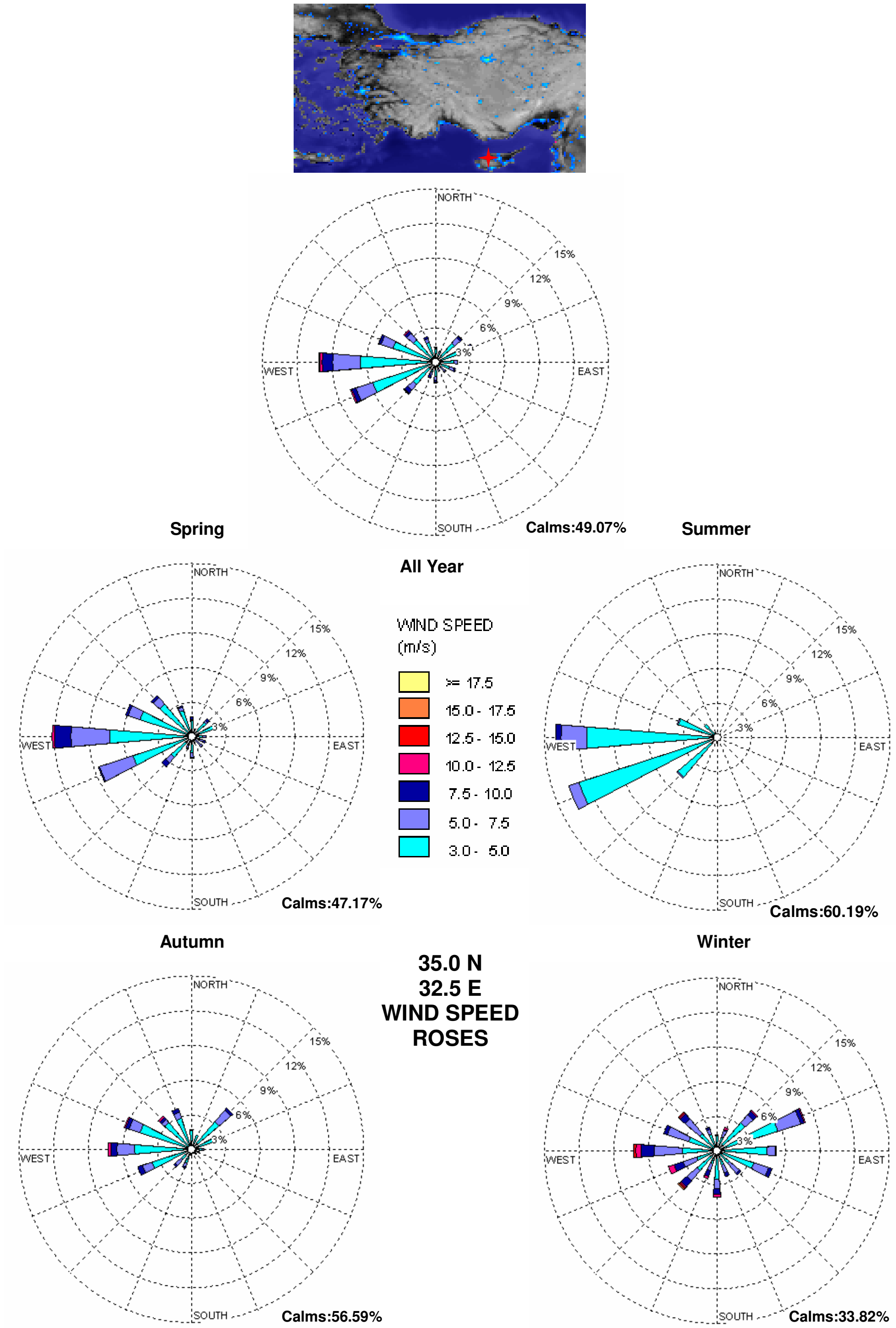

Figure 4.19.1 Wind climate at 35.0 N, 32.5 E

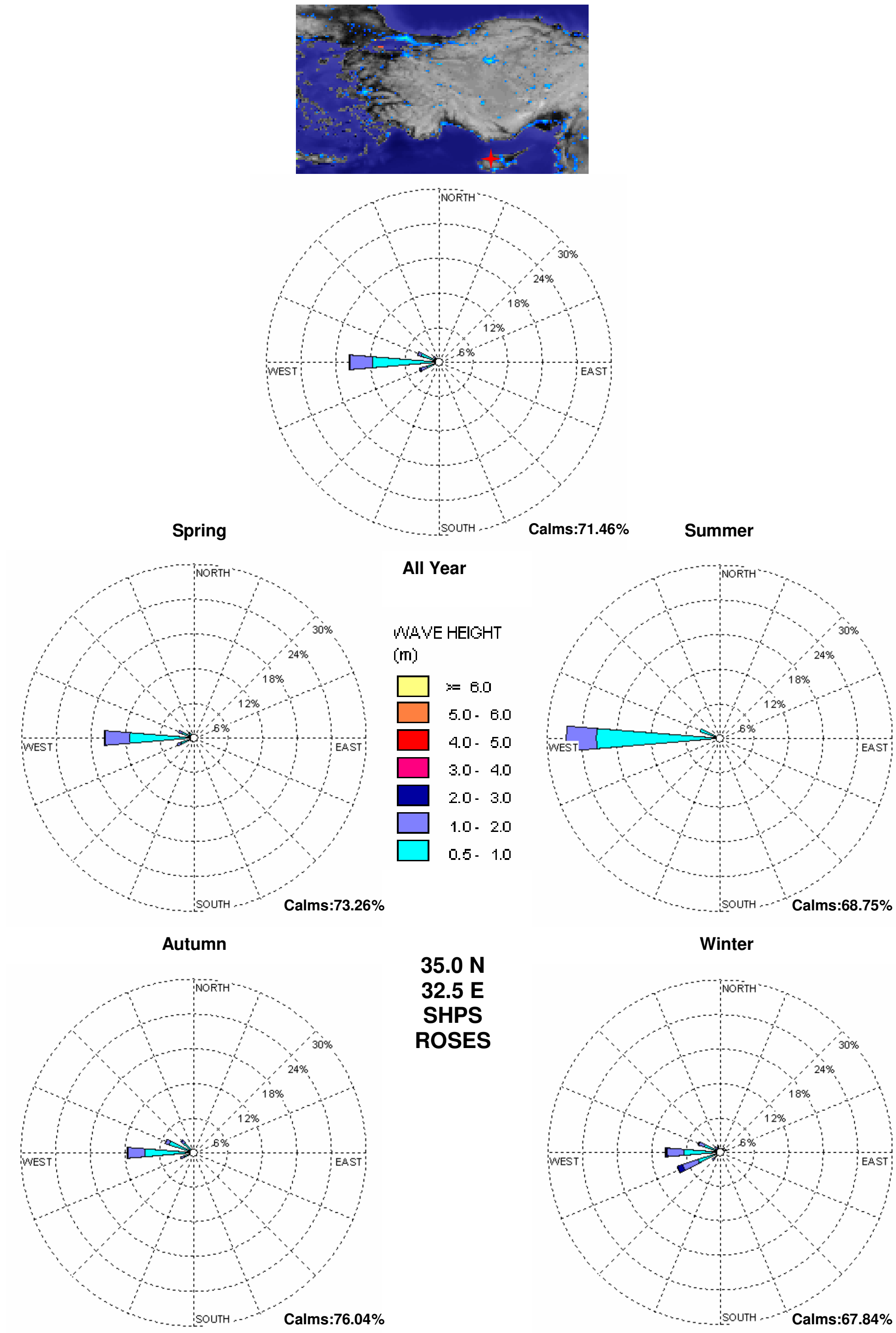

Figure 4.19.2 SHPS climate at 35.0 N, 32.5 E

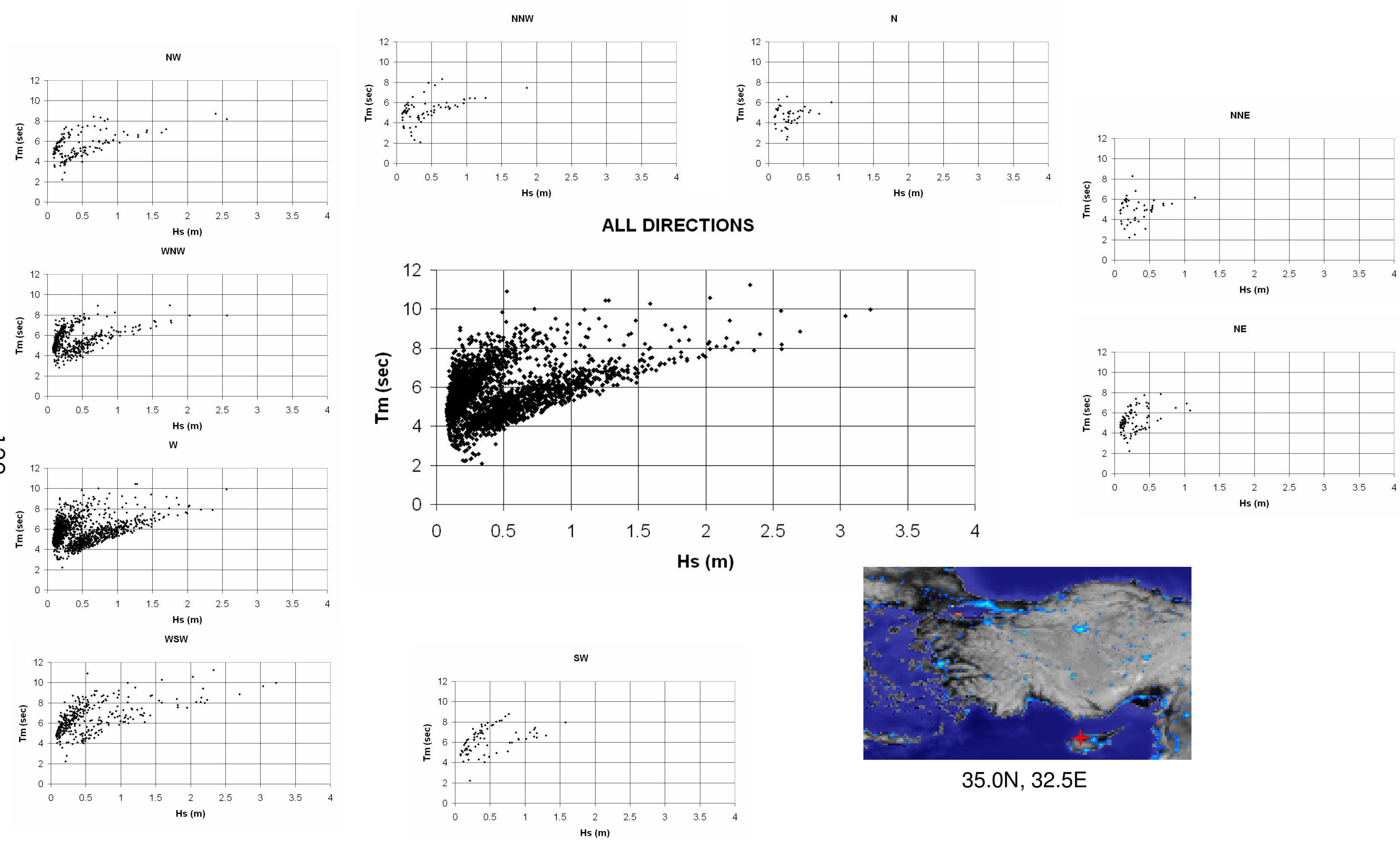

Figure 4.19.3 Relationship between MPPS & SHPS at Guzelyurt

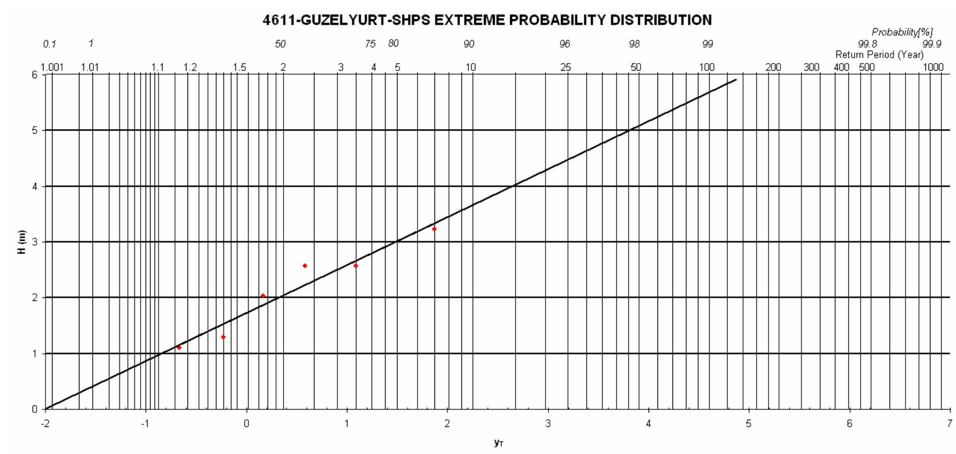

Figure 4.19.4 Extreme Probability Distribution at Location 35.0 N, 32.5

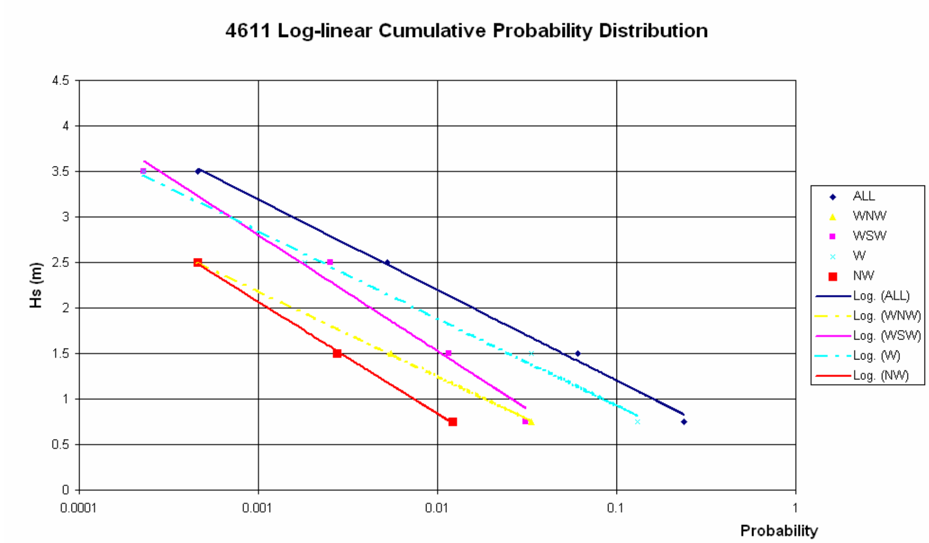

Figure 4.19.5 Log-Linear Cumulative Probability Distribution at 35.0 N, 32.5 E

4.20. LOCATION 4712 - GİRNE

The 4712 abbreviated point is located approximately 28 km of West-North West of Girne. The coordinates of point 4712 is; 35.50˚ N, 33.00˚ E.

The Wind Roses, Swell Wave Roses, Significant Wave Height (Hs) vs. Mean Wave Period (Tm) Relations, Extreme value probability statistics and Log-linear cumulative probability distribution are given in this section for this location.

Wind roses are given in Figure 4.20.1 and show that location 4712 is subject to mainly W directed winds. Strong winds are effective in ENE direction in winter and slides to W direction in summer. Also relatively strong winds are observed from WSW direction, especially in summer.

Wind roses cannot be compared with the wind roses in Ozhan and Abdalla, (1999), since there is no point representing this location.

Swell wave roses are given in Figure 4.20.2 and show a clear indication of direction of incoming swell waves. Nearly 30% of the time swell waves are coming from W direction in a full year, of which calm durations' percentile is approximately 50%. W swell waves' percentile increases up to 40% in summer. The maximum swell wave height is between 1.5 and 2.0 meters.

The relations between Significant Wave Height (Hs) vs. Mean Wave Period (Tm) are given in Figure 4.20.3. In this graph, W swell wave domination can be seen via Figure 4.20.2. Few data points exceeding 10 second periods and 2.0 m of swell wave heights are observed for W direction. Also there are few data points exceeding 10 second periods and 2.0 m of swell wave heights for WSW direction. The maximum swell wave height is 3.043 m. The average steepness of swell waves at this location (From Figure 4.20.3) is 0.011.

The graph of extreme value probability statistics is given in Figure 4.20.4. Data values show a goof correlation. Significant swell wave height is estimated as 4.1 meters for 100 year return period.

Log-linear cumulative probability distribution is given in Figure 4.20.5. Four dominating directions; namely W, WSW, WNW and NE are plotted along with all directions. It is seen from this graph that significant height of swell waves reaches to 2.8 meters in about 10 hours duration every year.

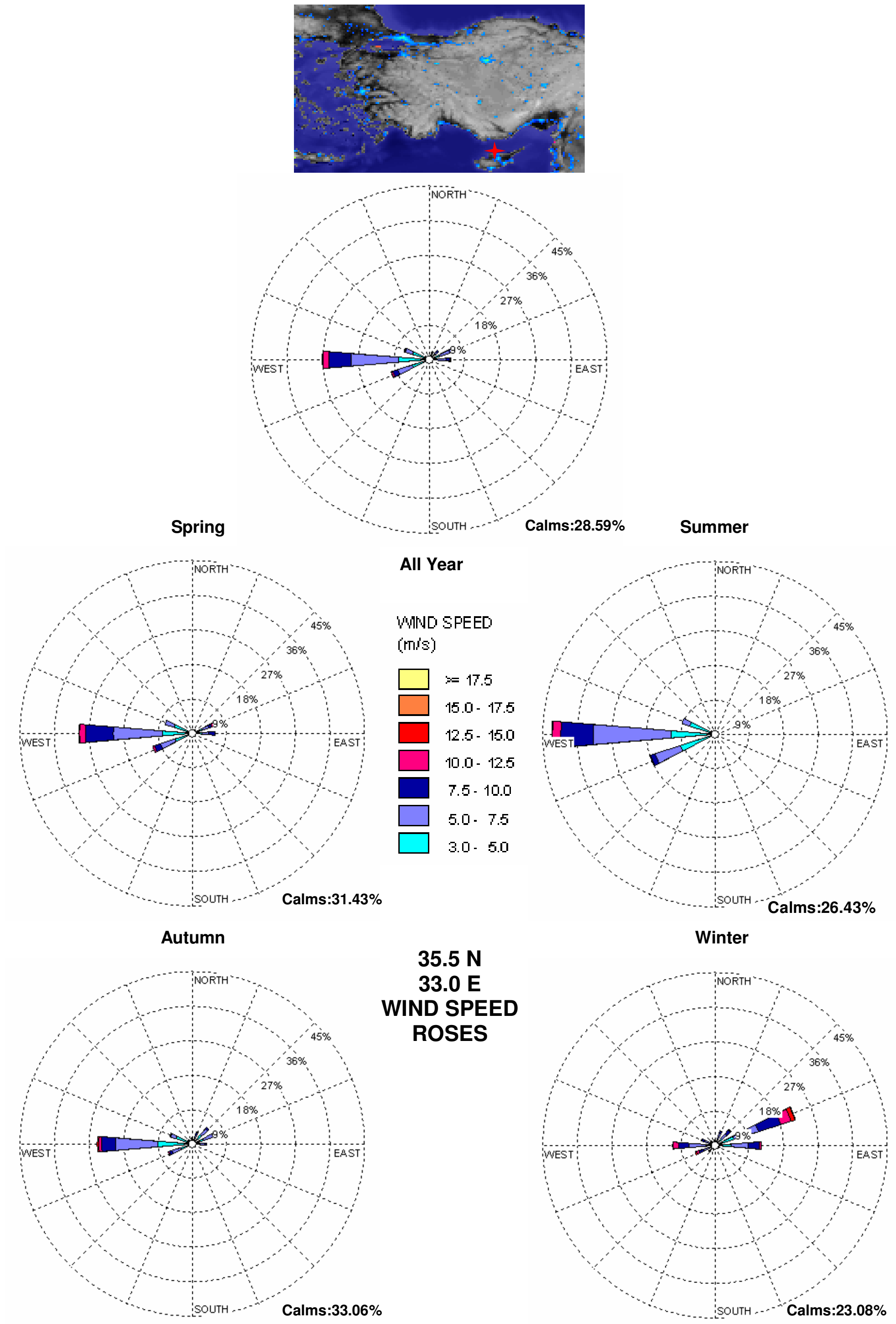

Figure 4.20.1 Wind climate at 35.5 N, 33.0 E

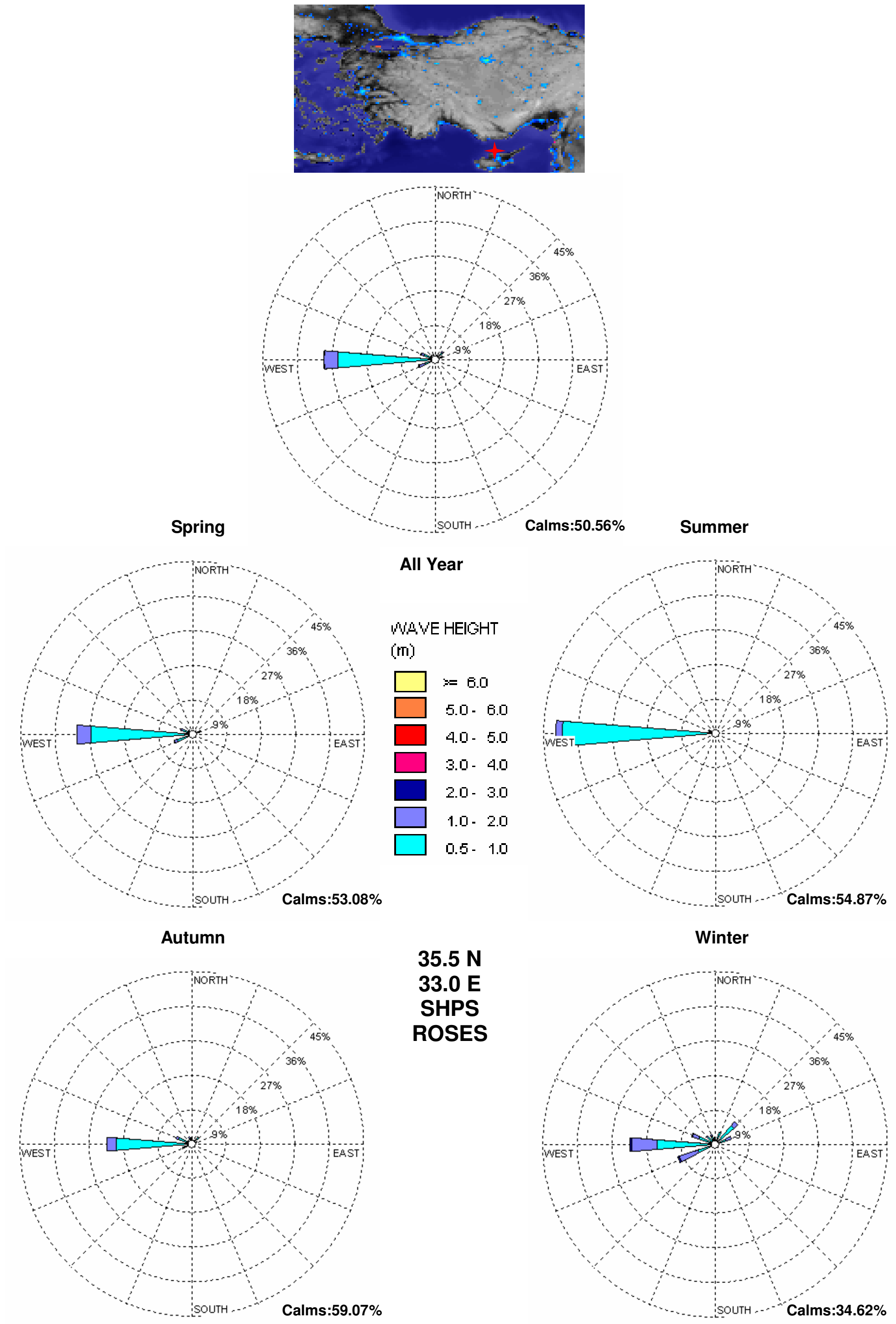

Figure 4.20.2 SHPS climate at 35.5 N, 33.0 E

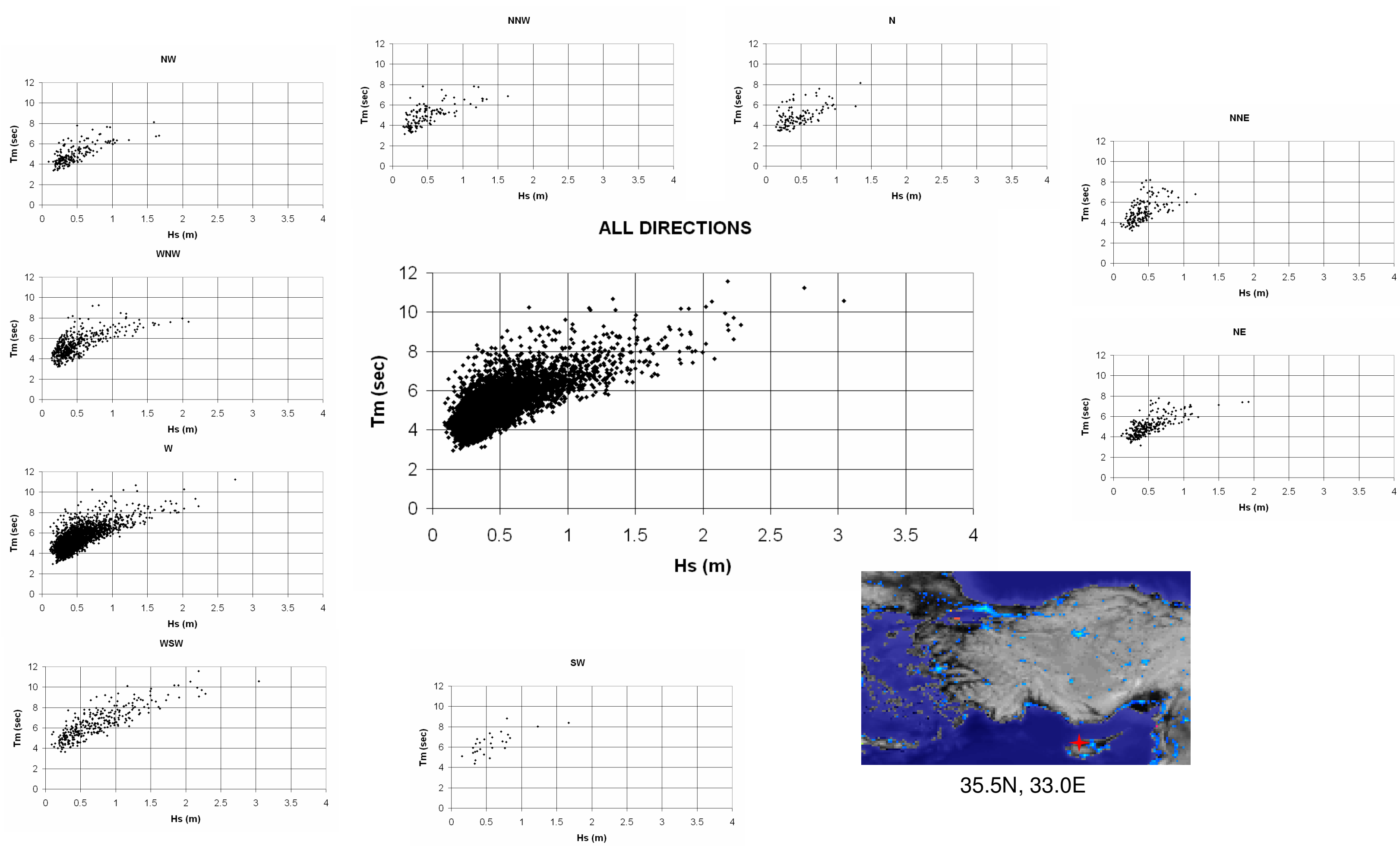

Figure 4.20.3 Relationship between MPPS & SHPS at Girne

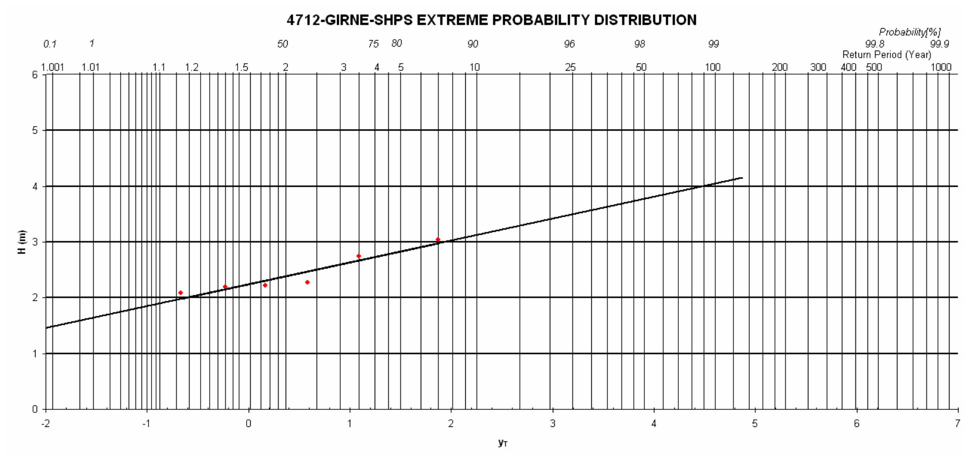

Figure 4.20.4 Extreme Probability Distribution at Location 35.5 N, 33.0

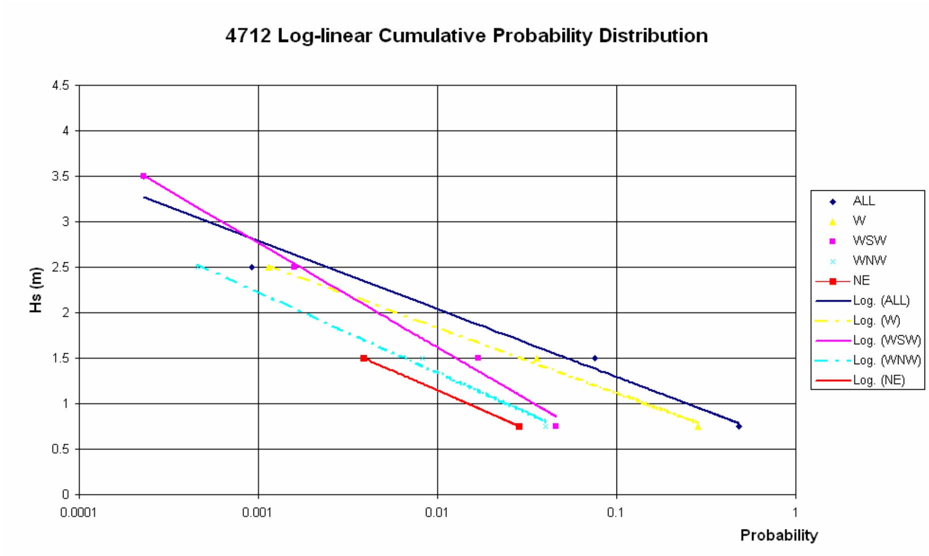

Figure 4.20.5 Log-Linear Cumulative Probability Distribution at 35.5 N, 33.0 E

4.21. LOCATION 4912 - KARPAS

The 4912 abbreviated point is located approximately 15 km of West-South West of Yenierenköy. The coordinates of point 4912 is; 35.50˚ N, 34.00˚ E.

The Wind Roses, Swell Wave Roses, Significant Wave Height (Hs) vs. Mean Wave Period (Tm) Relations, Extreme value probability statistics and Log-linear cumulative probability distribution are given in this section for this location.

Wind roses are given in Figure 4.21.1 and show that location 4912 is subject to mainly W to WSW winds. Strong winds are effective in NE to ENE direction in winter and slides to W to WSW direction in summer.

Wind roses cannot be compared with the wind roses in Ozhan and Abdalla, (1999), since there is no point representing this location.

Swell wave roses are given in Figure 4.21.2 and show a clear indication of direction of incoming swell waves. Nearly 20% of the time swell waves are coming from W direction in a full year. Also NE swell waves' percentile increases up to 12% in winter. The maximum swell wave height is between 2.0 and 2.5 meters.

The relations between Significant Wave Height (Hs) vs. Mean Wave Period (Tm) are given in Figure 4.21.3. In this graph, W and WSW swell wave domination can be seen. Several data points around 10 second periods and exceeding 1.5 m of swell wave heights are observed for W and WSW directions. The maximum swell wave height is 3.508 m. The average steepness of swell waves at this location (From Figure 4.21.3) is 0.012.

The graph of extreme value probability statistics is given in Figure 4.21.4. Significant swell wave height is estimated as 5.8 meters for 100 year return period.

Log-linear cumulative probability distribution is given in Figure 4.21.5. Four dominating directions; namely SW, WSW, W and NE are plotted along with all directions. It is seen from this graph that significant height of swell waves reaches to 3.1 meters in about 10 hours duration every year.

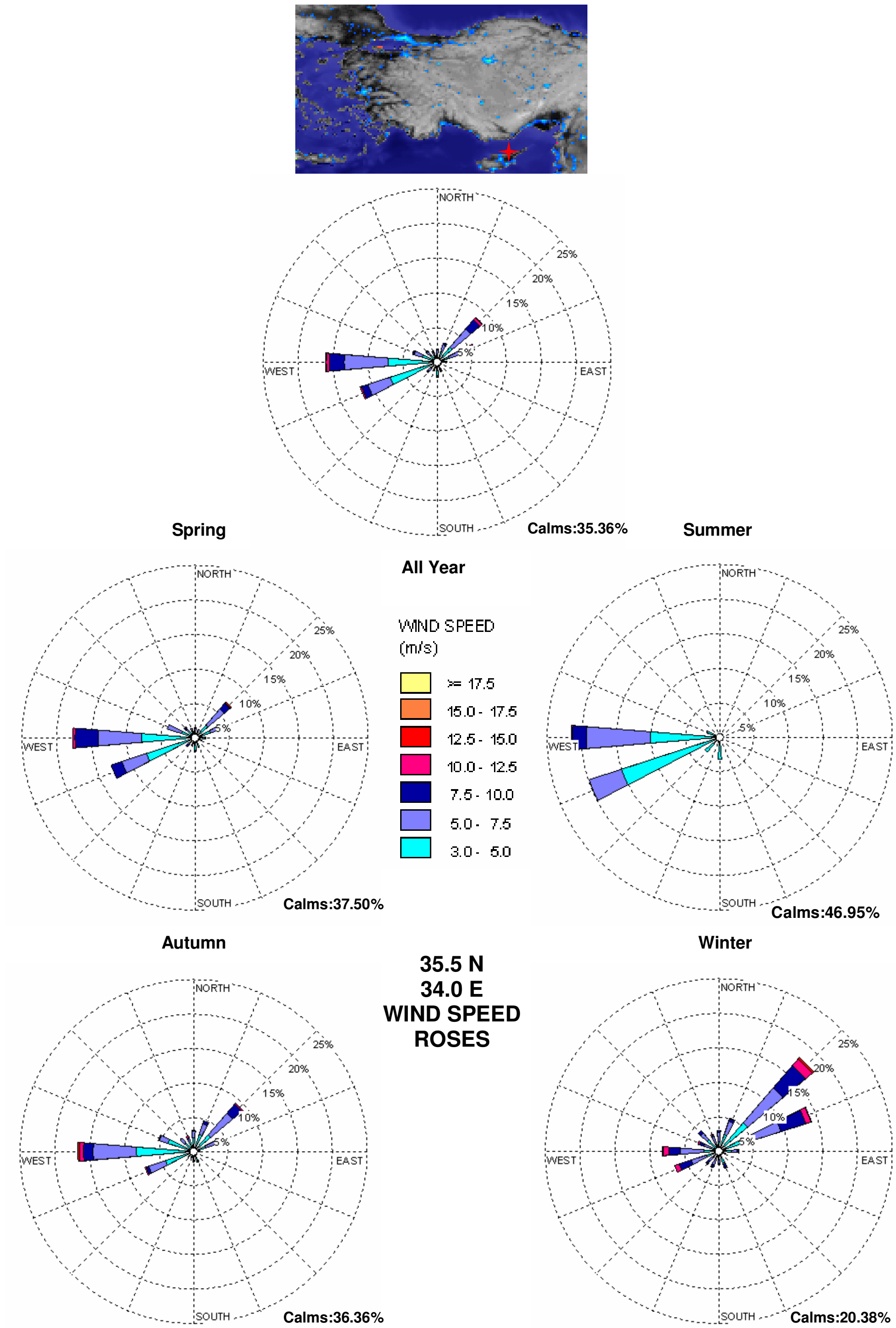

Figure 4.21.1 Wind climate at 35.5 N, 34.0 E

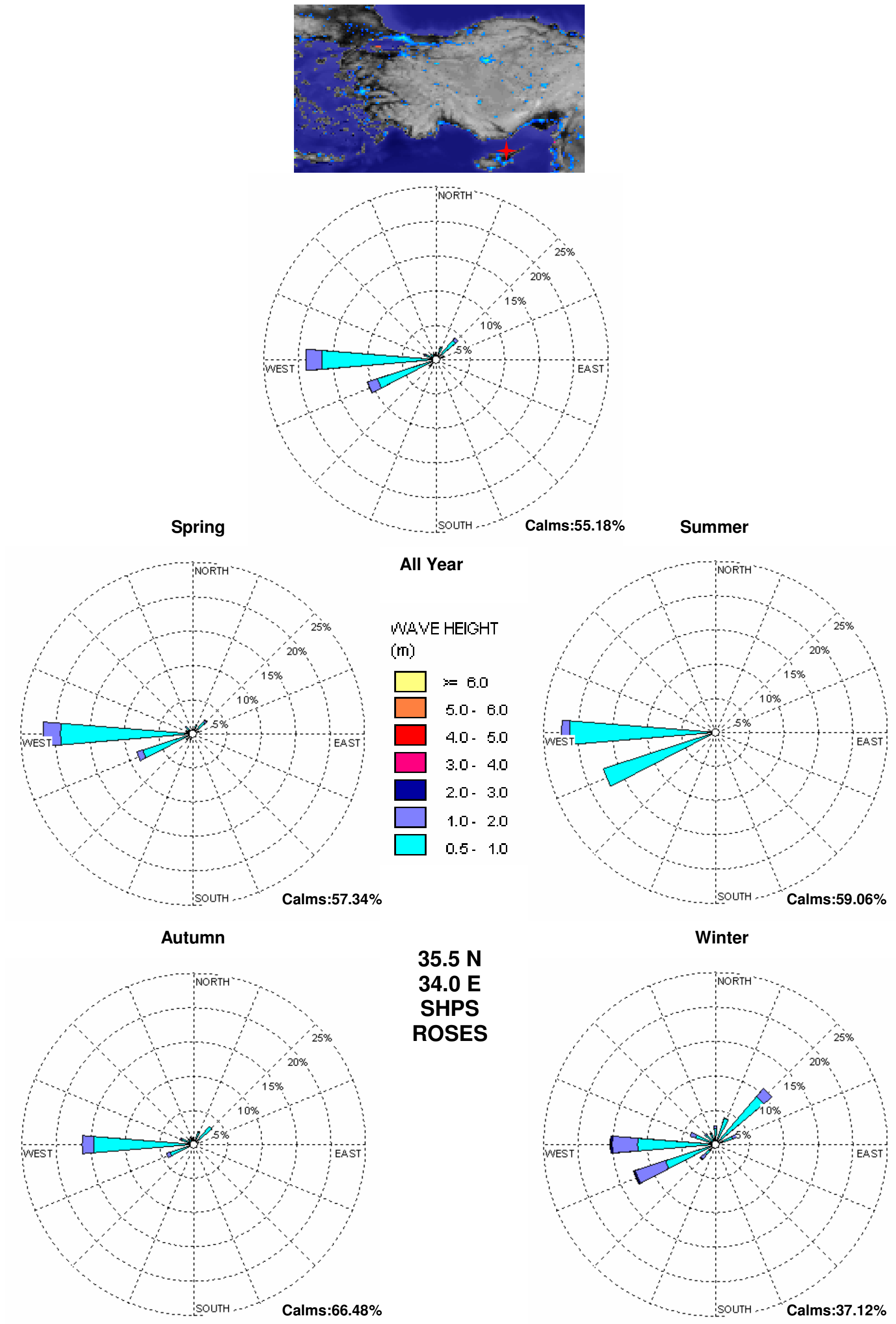

Figure 4.21.2 SHPS climate at 35.5 N, 34.0 E

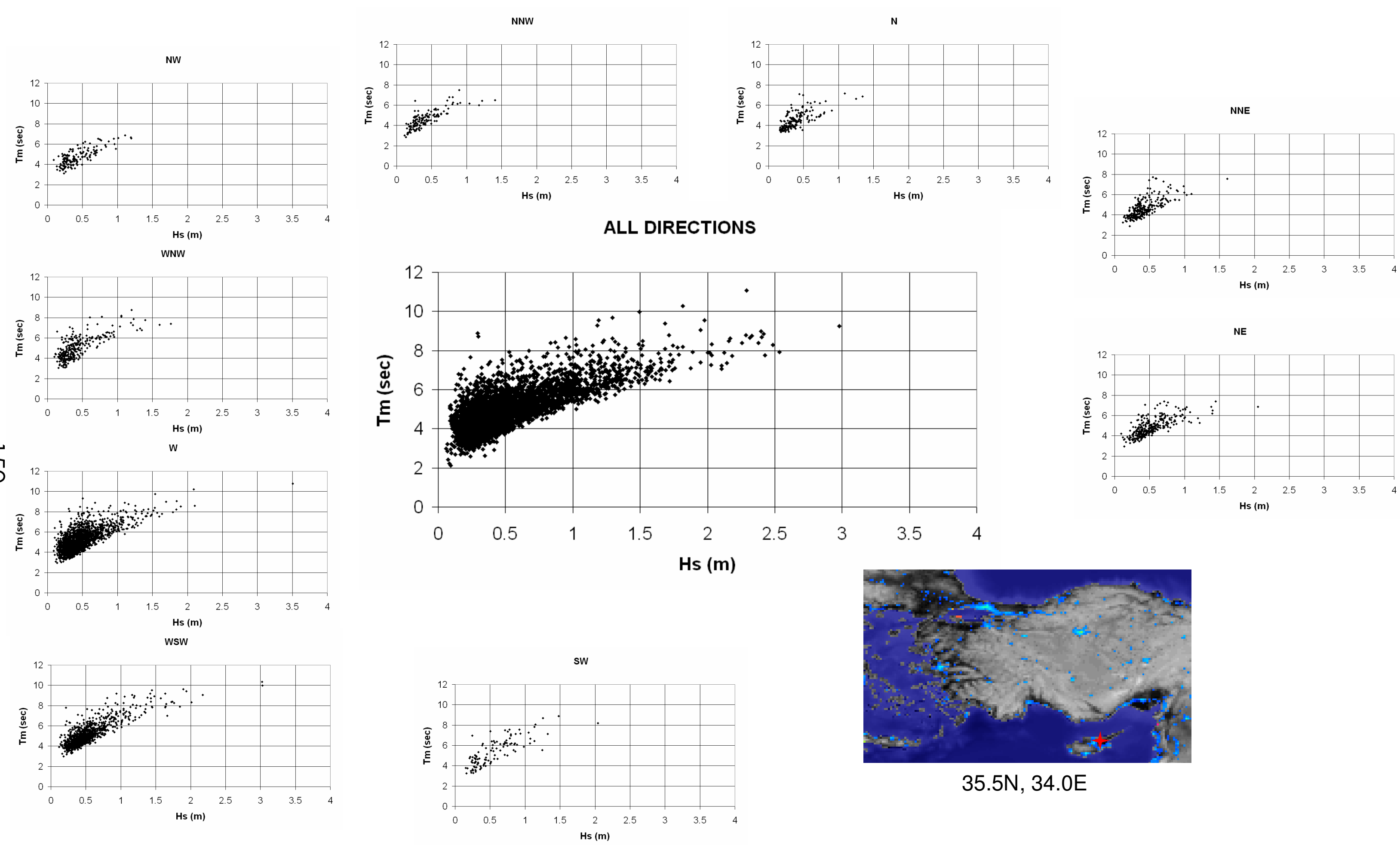

Figure 4.21.3 Relationship between MPPS & SHPS at Karpas

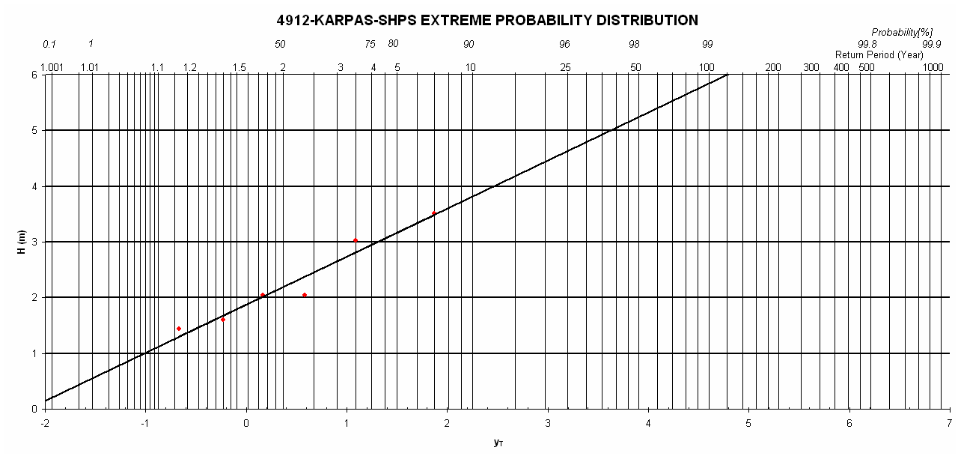

Figure 4.21.4 Extreme Probability Distribution at Location 35.5 N, 34.0

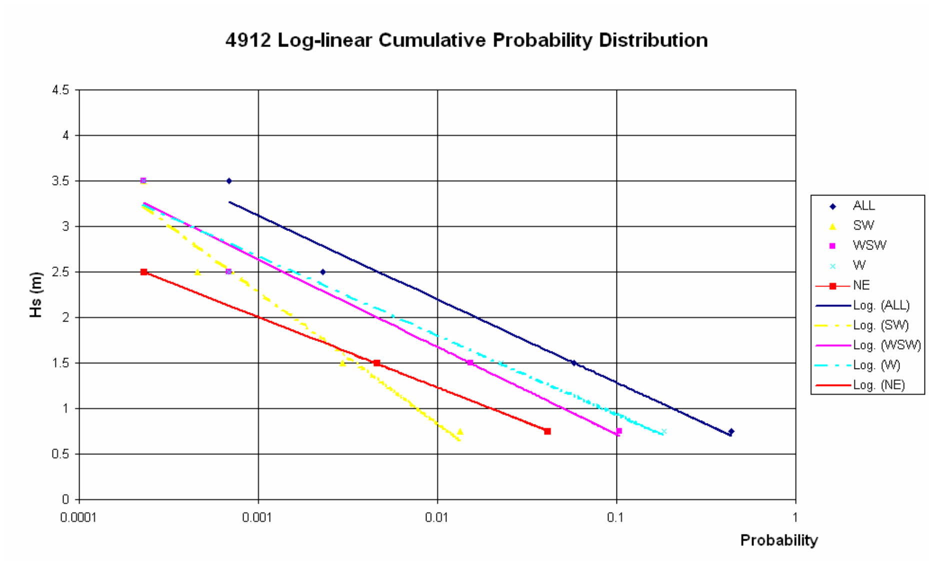

Figure 4.21.5 Log-Linear Cumulative Probability Distribution at 35.5 N, 34.0 E

CHAPTER 5

DISCUSSION OF RESULTS

The results of analysis were given in Chapter 4 for every location. In this chapter a general discussion considering all locations as a whole and inspections of some extreme events are given. Analyses were made for the 21 locations. The details of locations were given in Chapter 3. The overall interpretation of locations reveals important information about swell wave climate along Aegean and Mediterranean Sea coast of Türkiye.

Discussions on the results are given in the following section. General notes are stated here before the discussion. The data are obtained for 72 months duration in 12 hour intervals and the results are based on only this duration of data. As will be shown later in this chapter, 12 hour interval is rough for swell wave observations in Aegean and Mediterranean Sea. Thus the actual maximums may be larger than the maximum values given in this study. However wind and wave climate would be affected very slightly with the large data record intervals. Another note is that, the results are not given for on shore but rather given for locations up to 45 km away from shore. Although the results would be representative for the offshore region, it should be kept in mind that the swell wave heights could be higher at shallower regions near the shore.

5.1. GENERAL DISCUSSION OF RESULTS

The overall studies of swell waves along the Aegean and Mediterranean Sea coast of Türkiye present a clear view of swell wave climate. The outcome of the study confirms the swell wave generation theory. It is seen from the swell wave roses that the spectrum of directions gets wider in the Mediterranean locations since the Mediterranean locations are open to more directions. The dominant and significant directions of swell wave roses for all locations as given in Figure 5.1.1.

Regarding the swell generating regions and the yearly swell wave roses the locations can be grouped into 3 as western, southern and Cyprus locations. The western group consists of locations Edremit (3320), Dikili (3419), Seferihisar (3217), Kuşadası (3516) and Bodrum (3615). The southern group consists of more locations namely Datça (3514), Dalaman (3814), Fethiye (3913), Kaş (4013), Finike (4113), Kemer (4214), Side (4314), Alanya (4414), Anamur (4613), Silifke (4813), Kazanlı (5114), Karataş (5214) and Samandağ (5213). Finally the Cyprus group consists of 3 locations which are Güzelyurt (4611), Girne (4712) and Karpas (4912).

For the western group all locations except the 3516 (Kuşadası) and Bodrum (3615), show a typical distribution. In this group, dictating swell wave directions are northern and south-western directions. For locations 3516 (Kuşadası) and Bodrum (3615), northern swell domination diminishes. For these two locations, swell waves are effective from western directions. The all locations in the western group have seldom swell waves of height greater than 1.5 m. But the swell waves observed around the Seferihisar region have larger wave heights as can be seen from the swell rose of Seferihisar (3217).

Figure 5.1.1.: The SHPS roses given collectively. The bars indicate the percent of observance

The south-western group of Mediterranean Sea consisting of Datça, Dalman, Fethiye, Kaş and Finike is differentiated from the other group locations by the swell waves' directions. These locations are effected by swell waves from West to West-Southwest directions. Swells coming to Datça, Dalman, Fethiye, Kaş and Finike have obviously high occurrences. The high dominancy of south-western swells can be seen in the locations Kemer (4214), Side (4314), Alanya (4414), Anamur (4613), Silifke (4813), Kazanlı (5114), Karataş (5214) and Samandağ (5213). The rate of western swells is higher in the central locations. Also it should be noted that the calm percentages constantly increases for locations Kemer (4214), Side (4314) and Alanya (4414). Also the Alanya (4414) and Anamur (4613) locations are differentiated from other locations by the fact that the swell occurrences are higher since the two locations are objected to wider open directions.

The Cyprus group consists of Güzelyurt, Girne and Karpas. The dominating swell generating region is West for this group. The swell occurrences are high for Güzelyurt (4611) and Girne (4712). In Güzelyurt, it is seen from the Hs-Tm graph that two definite bands are observed. One of the bands corresponds to the short range distance (Aegean Sea) and the other corresponds to the long range distance (Mediterranean Sea). The calm percentages for all locations given in Figure 5.1.2 below, provides a general view for the swell wave activity of locations.

It is seen that the calm percentages changes in between 43 to 85 percent for a full year. It is seen that locations Dikili, Kusadası, Kemer, Side, Kazanlı and Karataş have the lowest calm percentages. The mean calm percentage of swell waves for Aegean group is about 75 percent, for Mediterranean group is about 64 percent and for Cyprus group is about 59 percent.

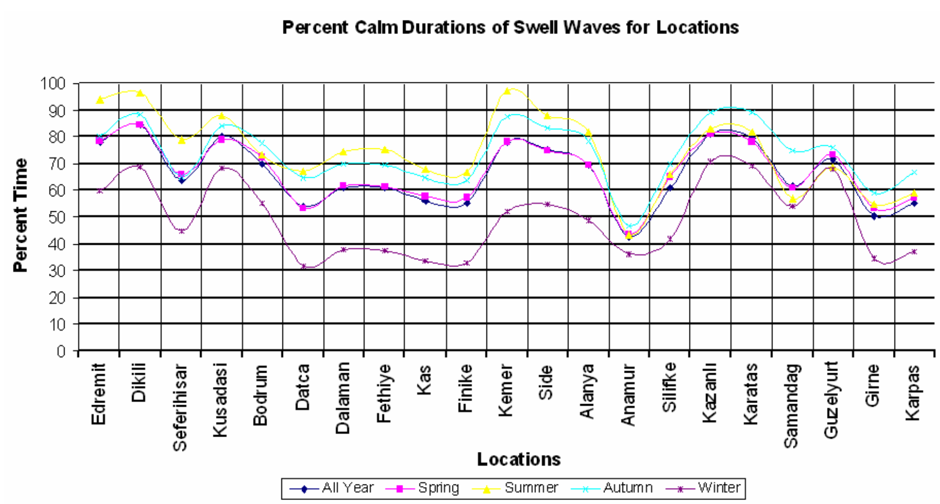

Figure 5.1.2: Yearly and seasonal calm durations for locations in percent

In seasonal basis remarkable changes can be observed. The calm percentages significantly increase in summer from Edremit till Anamur and decrease in winter whereas increase in autumn from Anamur till Samandağ including Cyprus group. Also in winter, swell waves are effective in more directions and are higher compared to other seasons. In contrast the summer roses generally are less dispersed, have less number of directions in action. And thus percentages for dominant directions are high.

An important outcome of this study is the verification that the Mediterranean Sea coastline of Türkiye is susceptible to higher swell waves compared to Aegean Sea coasts. This can be observed from extreme probability and Log-Linear cumulative probability distributions. Also the maximum observed swell wave heights belong to Mediterranean group. The maximum expected significant wave heights, as given in chapter 4 by extreme probability distributions, for a return period of 100 years for all locations are summarized in Table 5.1.1. The expected significant swell wave height for 100 years return period is maximum around 5.5 meters in the locations Karpas, Alanya and Side. It is immediately seen from Table 5.1.1 that the Mediterranean locations are susceptible to higher swell waves.

Table 5.1.1.: Expected significant swell wave heights in meters for 100 years return period for locations. (Retrieved from 01.2001 - 12.2006 data)

Location		**Expected H_s (m)**
3320	Edremit	2.9
3419	Dikili	3.6
3217	Seferihisar	3.0
3516	Kuşadası	2.2
3615	Bodrum	3.7
3514	Datça	5.0
3814	Dalaman	5.2
3913	Fethiye	3.0
4013	Kaş	3.5
4113	Finike	3.5
4214	Kemer	4.7
4314	Side	5.5
4414	Alanya	5.6
4613	Anamur	4.7
4813	Silifke	4.2
5114	Kazanlı	3.7
5214	Karataş	3.8
5213	Samandağ	4.5
4611	Güzelyurt	5.6
4712	Girne	4.1
4912	Karpas	5.8

In Table 5.1.2 the occurrence counts of swell waves higher than 1.5 meters are given for all locations for the whole data period. Table 5.1.2 provides an overview to swell waves higher than 1.5 meters. The higher swell wave heights at Mediterranean locations compared to Aegean locations can also be observed from this table. The locations from Datça (3514) to Anamur (4613) have considerably higher occurrences of extreme swell wave heights.

Table 5.1.2: The counts of selected swell heights according to locations for the whole data period (01.2001-12.2006) (Total number of occurrences is 2325 for Kemer (4214), 2951 for Datça (3514), 3658 for Güzelyurt (4611) and Karataş (5214) and 4284 for other locations) (intervals are in meters)

Location		**1.5<Hs<2.0**	**2.0<Hs<2.5**	**2.5<Hs<3.0**	**3.0<Hs<3.5**	**3.5<Hs**
3320	Edremit	10	1	0	0	0
3419	Dikili	4	0	0	0	0
3217	Seferihisar	32	8	0	0	0
3516	Kuşadası	1	0	0	0	0
3615	Bodrum	10	1	0	0	0
3514	Datça	40	6	7	2	0
3814	Dalaman	37	7	2	1	0
3913	Fethiye	40	13	0	0	0
4013	Kaş	54	23	2	0	0
4113	Finike	56	23	2	0	0
4214	Kemer	22	8	3	1	0
4314	Side	29	5	2	0	1
4414	Alanya	43	6	7	1	1
4613	Anamur	51	15	3	4	0
4813	Silifke	29	3	0	1	0
5114	Kazanlı	9	2	1	0	0
5214	Karataş	17	3	1	0	0
5213	Samandağ	36	6	1	1	0
4611	Güzelyurt	35	14	4	2	0
4712	Girne	45	11	1	1	0
4912	Karpas	27	7	0	2	1

In Table 5.1.3 the counts of mean periods that fall into specified intervals are given. It is seen from this table that high mean periods of swell waves are observed more frequently on Mediterranean locations. In Aegean locations mean periods higher than 10 seconds are seldom observed only for Seferihisar (3217). From Anamur (4613) to Samandağ (5213) including Cyprus locations, it can be said that the observances of higher swell wave periods are more compared to Aegean locations. The swell wave periods higher than 10 seconds are mostly observed in Girne (4712), Güzelyurt (4611), Anamur (4613) and Silifke (4813) locations.

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Table 5.1.3: The counts of mean period of swell waves according to locations for the whole data period (10.2000-02.2006) (Total number of occurrences is 2325 for Kemer (4214), 2951 for Datça (3514), 3658 for Güzelyurt (4611) and Karataş (5214) and 4284 for other locations) (intervals are in seconds)

Location		**$4<T_m<5$**	**$5<T_m<6$**	**$6<T_m<7$**	**$7<T_m<8$**	**$8<T_m<9$**	**$9<T_m<10$**	**$10<T_m$**
3320	Edremit	1514	786	362	136	41	7	0
3419	Dikili	1740	655	227	84	23	4	0
3217	Seferihisar	1438	1192	621	268	37	21	4
3516	Kuşadası	1758	1005	330	88	25	2	0
3615	Bodrum	1902	992	322	92	26	0	0
3514	Datça	964	928	446	155	41	1	0
3814	Dalaman	1345	1148	557	234	49	7	1
3913	Fethiye	1656	1130	486	167	40	9	1
4013	Kaş	1746	1153	437	145	42	8	2
4113	Finike	1737	1159	437	144	39	8	2
4214	Kemer	1167	498	189	52	12	2	1
4314	Side	1666	911	377	109	41	6	2
4414	Alanya	1764	1051	400	119	29	9	2
4613	Anamur	1681	1217	574	192	56	12	5
4813	Silifke	1568	1230	565	225	63	19	6
5114	Kazanlı	1749	707	231	67	10	3	0
5214	Karataş	1446	688	263	92	18	3	2
5213	Samandağ	1665	1151	441	164	60	15	3
4611	Güzelyurt	1085	1305	709	262	97	22	7
4712	Girne	1423	1396	742	261	83	23	12
4912	Karpas	1694	1171	538	175	63	12	3

5.2. INSPECTION OF SELECTED EXTREME EVENTS

In this section three extreme events that generated during the data period, which is between January 2001 and December 2006, are inspected in detail for a deeper understanding of swell wave generation and propagation in the Aegean and Mediterranean Sea coastline of Türkiye. For this purpose data for all locations are listed according swell wave heights. Then swell waves higher than 2.5 meters are extracted and then listed according to date. The extreme events that occurred in the data period are listed according to date and given in Table 5.2.1.

Table 5.2.1.: Extreme swell events (H_s > 2.5 m) along Aegean and Mediterranean coast of Türkiye. Extreme values are in bold. (MPPS is in seconds and SHPS is in meters)

Location		Year	Month	Day	Hour	MDPSB	MPPS	SHPS
3514	Datça	2001	11	25	9	WSW	8.711	2.824
3514	Datça	2001	11	24	21	SW	8.448	2.602
3814	Dalaman	2001	11	25	09	WSW	8.942	2.603
4314	Side	2001	11	25	09	SW	8.842	2.655
4414	Alanya	2001	11	25	09	SW	8.642	2.923
4613	Anamur	2001	11	25	09	WSW	8.815	2.684
3514	Datça	2002	01	04	21	SW	8.904	3.144
3514	Datça	2002	03	25	09	WSW	8.139	2.608
3814	Dalaman	2002	01	04	21	SSW	8.592	3.289
4414	Alanya	2002	01	05	09	SW	8.725	2.600
4613	Anamur	2002	01	05	09	SW	9.122	2.659

Table 5.2.1: (Continued) Extreme swell events (H_s > 2.5 m) along Aegean and Mediterranean coast of Türkiye. Extreme values are in bold. (MPPS is in seconds and SHPS is in meters)

3514	Datça	2003	02	06	09	SW	8.786	**2.735**
3514	Datça	2003	02	06	21	SW	8.903	**2.653**
3514	Datça	2003	02	02	21	WSW	8.215	2.549
3814	Dalaman	2003	02	06	21	WSW	9.035	2.601
4214	Kemer	2003	12	17	21	SW	9.256	2.514
4414	Alanya	2003	12	18	09	SW	9.679	2.732
4414	Alanya	2003	02	08	09	SW	8.473	2.643
4414	Alanya	2003	12	17	21	SW	10.281	2.585
4613	Anamur	2003	12	18	09	WSW	9.906	3.427
4813	Silifke	2003	12	18	09	WSW	10.591	3.040
5213	Samandağ	2003	12	18	09	WSW	9.955	3.005
4712	Girne	2003	12	18	09	WSW	10.56	3.043
4912	Karpas	2003	12	18	09	WSW	9.988	3.029
3514	Datça	2004	01	23	09	W	9.491	3.134
3514	Datça	2004	01	22	21	SSW	8.676	2.931
4013	Kaş	2004	01	22	21	S	9.252	2.979
4013	Kaş	2004	12	19	21	SE	7.92	2.537
4113	Finike	2004	01	22	21	S	9.252	2.979
4113	Finike	2004	12	19	21	SE	7.92	2.537
4214	Kemer	2004	01	22	21	S	8.777	**3.212**
4214	Kemer	2004	01	23	09	SW	10.023	**2.879**
4214	Kemer	2004	01	25	21	S	7.583	2.617
4314	Side	2004	01	23	09	SW	10.141	**3.753**
4314	Side	2004	01	22	21	SSW	9.595	**2.710**
4414	Alanya	2004	01	23	09	SW	10.517	**3.973**
4414	Alanya	2004	01	22	21	SSW	8.857	**3.235**
4414	Alanya	2004	01	26	09	SW	8.488	2.633
4613	Anamur	2004	01	23	09	SW	11.459	3.191
4613	Anamur	2004	01	23	21	WSW	10.626	3.014

Table 5.2.1: (Continued) Extreme swell events (H_s > 2.5 m) along Aegean and Mediterranean coast of Türkiye. Extreme values are in bold. (MPPS is in seconds and SHPS is in meters)

5114	Kazanlı	2004	01	23	09	SSW	9.904	2.532
5214	Karataş	2004	01	23	09	SW	10.174	2.794
5213	Samandağ	2004	01	23	09	SW	11.017	2.822
4611	Güzelyurt	2004	11	26	21	NW	8.194	2.566
4611	Güzelyurt	2004	11	26	09	W	9.926	2.558
4712	Girne	2004	01	23	21	W	11.23	2.748
4912	Karpas	2004	01	23	21	W	10.78	3.508
4912	Karpas	2004	01	23	09	WSW	10.329	3.025
4611	Güzelyurt	2005	02	04	09	WSW	9.988	3.225
4611	Güzelyurt	2005	02	04	21	WSW	9.653	3.037
4611	Güzelyurt	2005	02	03	21	WSW	8.84	2.700
4414	Alanya	2006	03	08	21	SW	8.596	2.665
4613	Anamur	2006	03	08	21	SW	8.622	3.059
4613	Anamur	2006	03	09	09	WSW	9.708	2.714
4611	Güzelyurt	2006	01	20	21	WNW	7.944	2.565

In Table 5.2.1 three swell events are shown for the dates 06/February/2003, 17/December/2003 and 23/January/2004. Table 5.2.1 shows extreme swell observations for Mediterranean regions exceeding 2.5 swell wave height and highest periods. From Table 5.2.1, it is obviously shown that there is no observation point exceeding 2.5 swell wave height for Aegean regions. In Figures 5.2.1, 5.2.2 and 5.2.3, it is clearly seen that southwestern swell waves generated from eastern Mediterranean countries reach Mediterranean coasts of Türkiye in one day duration.

The evolutions of the three events are presented in Figures 5.2.1, 5.2.2 and 5.2.3 below. The state of wind field and swell wave field are given together in the figures for 48 hours time segment.

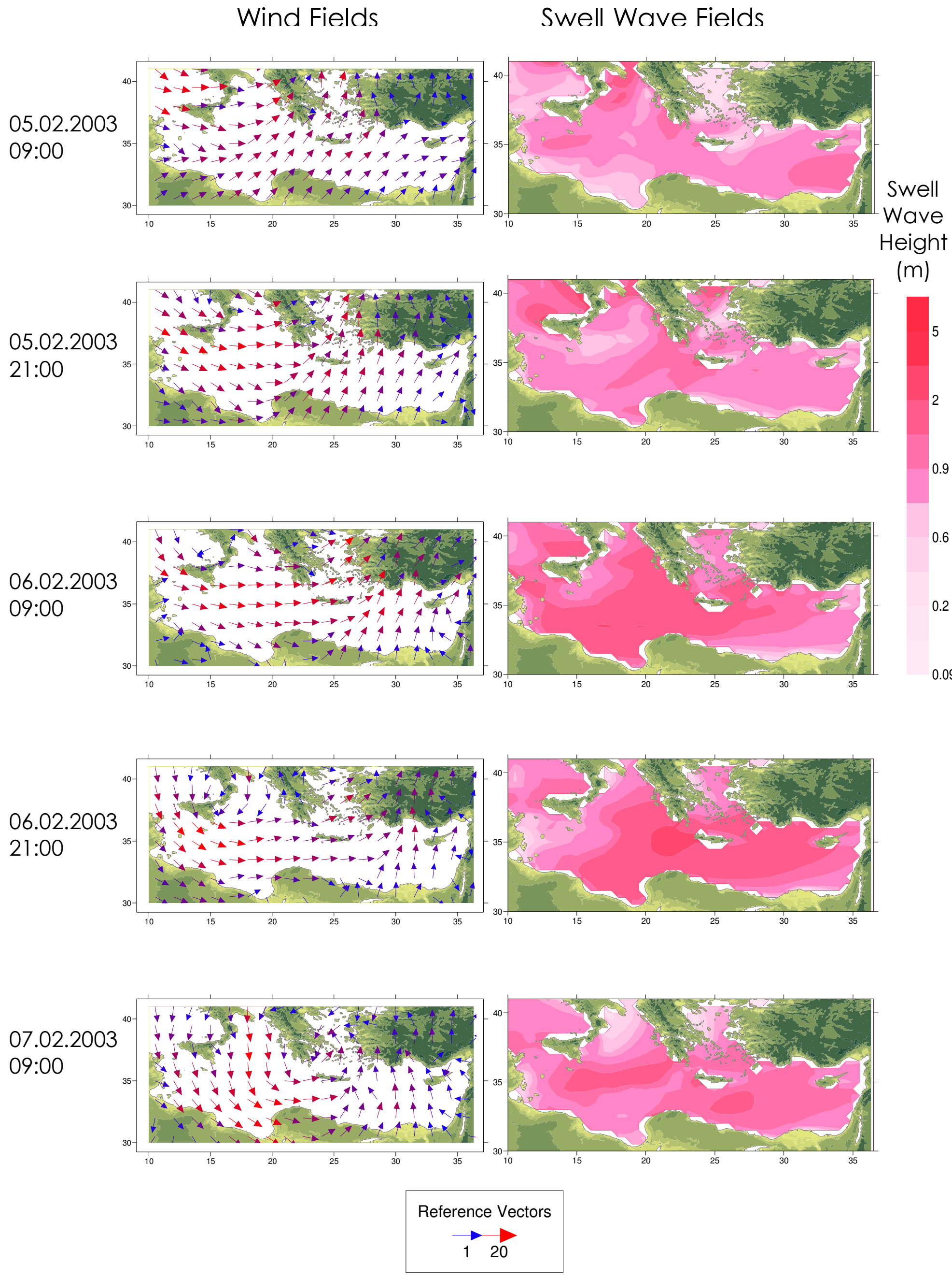

Figure 5.2.1: The evolution of wind and swell wave fields between 05.02.2003-07.02.2003.

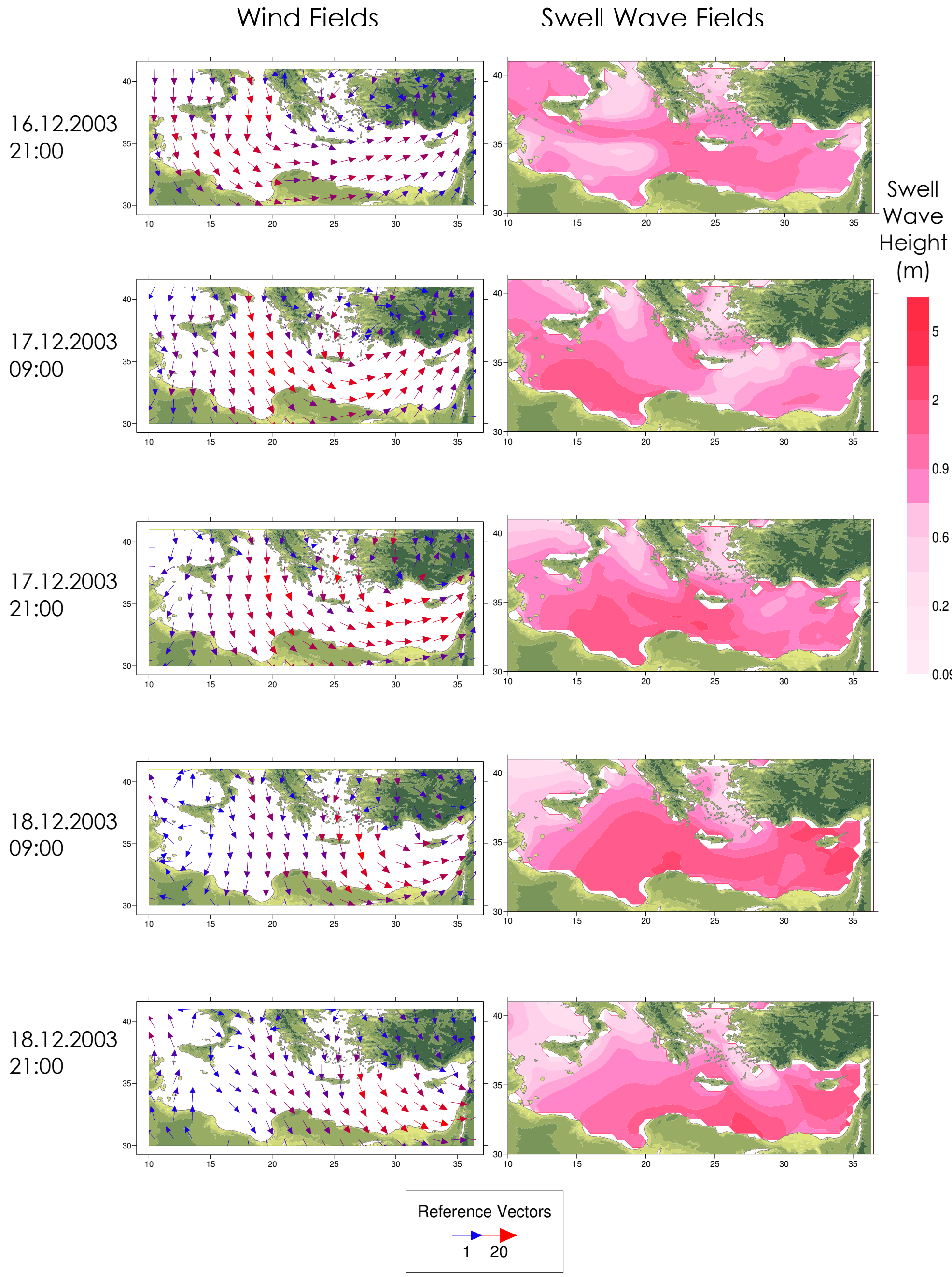

Figure 5.2.2: The evolution of wind and swell wave fields between 16.12.2003-18.12.2003.

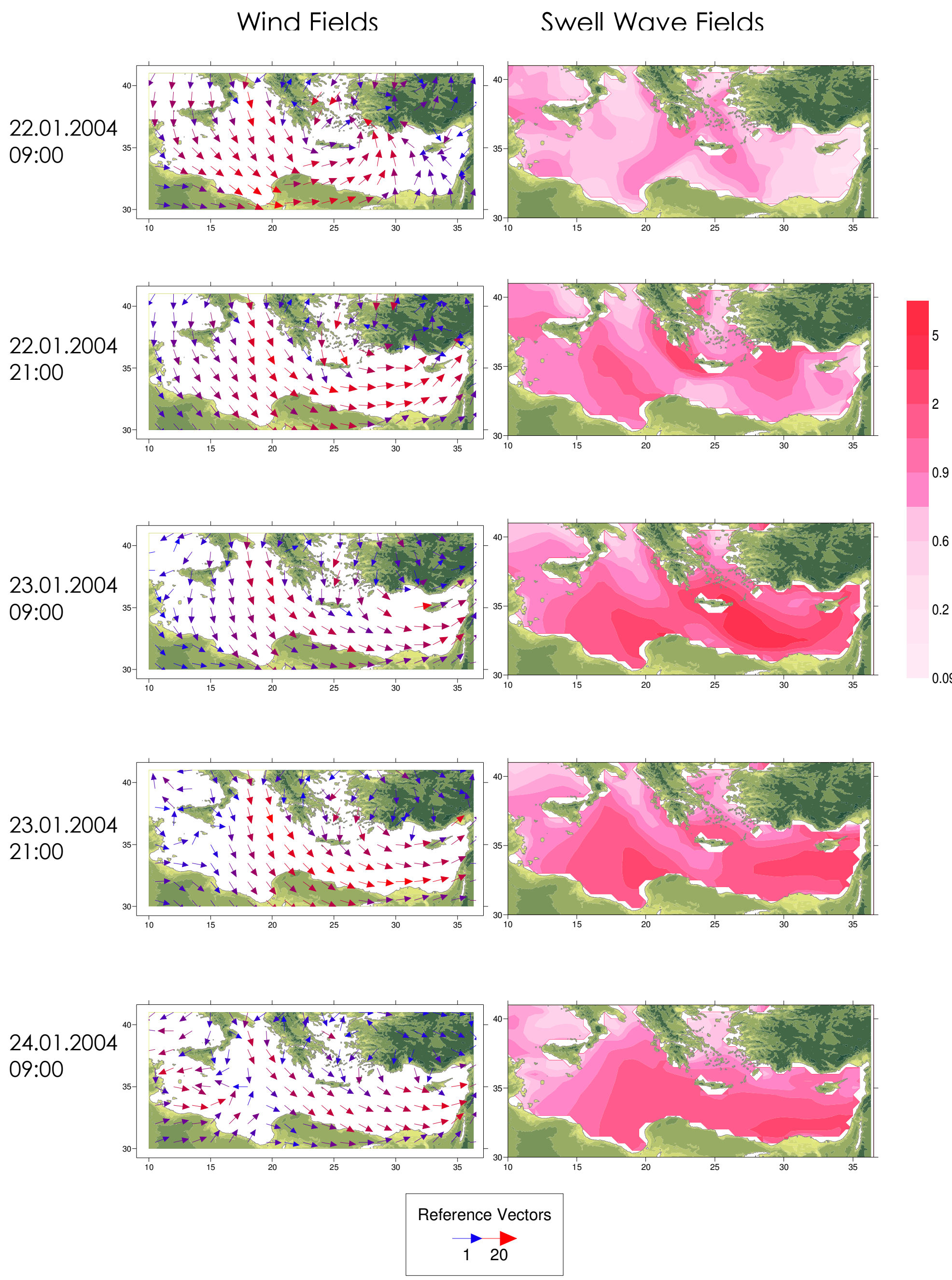

Figure 5.2.3: The evolution of wind and swell wave fields between 22.01.2004-24.01.2004.

By the inspection of extreme events the following can be deduced. It is seen that the swell waves generates and ceases in a relatively short time. Step by step investigation shows that the swell waves reaches to coastline at the next time step of their generation which conforms to the wave propagation theory. The swell waves having periods between 7 and 10 seconds move with the group velocities of 20 to 28 km/hr. In 12 hours swell waves travels about 240 to 336 km's (Berkün, 2007). Because the distance between Mediterranean locations and the swell wave generating Southwestern regions are about 500 km's, the swell waves generated in these regions are observed in the central locations at the next time step of data records. And in the second time step swell waves end up in the far most locations. This indicates that the 12 hour data record interval is rough for tracking swell wave propagation.

CHAPTER 6

CONCLUSIONS AND SUGGESTIONS

In this study wind and swell wave climate along the Aegean and the Mediterranean Sea coast of Türkiye is attempted to be enlightened by analysis of certain wind and wave data. The data used in this study is obtained from the ECMWF Data Server. [ECMWF, 2006] The data is obtained for the whole Aegean and Mediterranean Sea basin. The data period is between 01.01.2001 to 31.12.2006, totally 72 months in length. Analyses were made for 21 locations along the Aegean and Mediterranean Sea coastline of Türkiye.

In this study the 21 locations are analyzed separately and for every location results are presented graphically. The wind and swell wave roses, significant wave height versus Mean period of primary swell relations, extreme probability distribution and log-linear cumulative probability distributions are provided for the locations and are presented in the 4th chapter. The 4th chapter thus presents the swell wave climate for the south coast of Aegean and Mediterranean Sea. In the 5th chapter, more detailed analyses, such as the frequencies of swell wave heights and mean periods and inspection of some selected extreme events are given along with the discussions of findings.

The results of swell wave climatology analyses expose the directions and magnitudes of swell waves that the selected locations are subject to. The results are provided in seasonal basis for comparison of seasonal differences. The calm durations, which indicate very limited swell or wind activity, are also given for the locations. It is seen from these analyses that high swell wave heights are observed mainly in winter and very limitedly in autumn and spring. Also the calm durations decrease significantly in winter for all locations. In winter, swell waves are effective in more directions and are higher compared to other seasons.

The long term analyses of swell wave occurrences indicated that the locations of the Mediterranean Sea is susceptible to higher period and heights of swell waves compared to Aegean Sea locations. Tables 5.1.1 and 5.2.3, which give expected significant swell wave heights and swell wave periods distributions for locations, present the more rigorous swell wave activity in the Mediterranean Sea. However the results presented in this study are given for off shore locations. Thus the swell wave heights could be higher at shallower regions near the shore.

In this study a sound and straightforward method for inspection of wind and wave climate is introduced and the method is used to discover wind and swell wave climate along the Aegean and Mediterranean Sea. It is hoped that this study would be a starting point for further similar studies. The analysis method can be adopted to other basins and made more detailed by reduced spatial resolution. Also the method can be broaden by addition of other climate parameters such as wind waves and other atmospheric parameters. For the Aegean and Mediterranean Sea basin this study can be carried to one step further by inspection of whole Aegean and Mediterranean Sea coastline with a reduced spatial resolution. However for detailed wave propagation analyses finer data record intervals are required which is not available for the time being [ECMWF, 2006].

The results of this study are compared with those of the study of Berkün, U., 2007, "Wind and Swell Wave Climate for the Southern Part of Black Sea. In terms of yearly maximums of significant swell wave heights, both studies are in high correlation. The average yearly maximum significant swell wave heights have similar magnitudes. On the other hand, the expected significant swell wave heights for 100 years return period are found higher in this study. The counts of mean period of swell waves are also compared for both studies. In this study, for the Mediterranean Sea, the counts of mean period of swell waves greater than 9 seconds are much compared to those for locations observed in the study of Berkün, U., 2007. Whereas, in Berkün's study, the western Black Sea locations swell waves having greater than 9 seconds period have higher occurrence than the locations along the Aegean Sea.

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APPENDIX A

USAGE OF WGRIB

The steps followed for handling for *.grib files by WGRIB program is given in the following. Further help on WGRIB can be found at;

http://dss.ucar.edu/datasets/common/ecmwf/ERA40/software/wgribexamples.html

http://tmap.pmel.noaa.gov/~tmap/ecmwf/wgrib.html

WGRIB is a tool for handling *.grib files and works in DOS environment. In Microsoft Windows hit win+R and type "cmd" to open command prompt. Using DOS commands locate the directory of WGRIB executable. The following commands are given assuming that the input file, "wgrib.exe" and "cygwin1.dll" are in the same directory. (The wgrib program is standalone and can be carried and run in any directory, in the following commands wgrib is located in c:/wgrib/ and the input file name is 2001_06.grib)

c:/wgrib>wgrib

Starts wgrib and/or shows the help screen

C:/wgrib>wgrib 2001_06.grib -s

Displays short inventory of the input file (replace -s with -v for verbose)

C:/wgrib>wgrib 2001_06.grib -V -d N

Displays the details of a single (N'th) data record (if –d is not stated all data records are displayed in this way)

C:/wgrib>wgrib 2001_06.grib -d N –text

The N'th data record is extracted to a "dump" file in ascii format.

C:/wgrib>wgrib 2001_06.grib -d all -text -o -2001_06.txt

The input file is transformed into 2001_06.txt file in ascii format. This command is sufficient for generally all cases. A single data record can be opened by replacing "all" with data record number "N".

APPENDIX B

DATA RE-ARRANGEMENT PROGRAM SOURCE CODE

The following source code is written for Fortran, and is general for wind and wave data. Source code has to be changed slightly for changes in hour and parameter number.

```
c   HAVUZ DATA URETME PROGRAMI
        PARAMETER (IF=16, JF=9)
      DIMENSION wind(IF,JF)
      DIMENSION shps(if,jf)
      DIMENSION shww(IF,JF), zoku(if,jf),zyaz(if,jf)
        REAL mdps(IF,JF), mpps(IF,JF), mdww(if,jf), mpww(if,jf)
      character*40 namein,nameout

        WRITE(NAMEin,'(A11)') 2001_06.txt'

        OPEN (1,FILE=namein)

      igun=0

        DELX=1.125
        DELY=1.125
      xl=25.875
        xr=42.75
        yb=39.813
      yt=48.785


 5000 igun=igun+1

       isaat=09
      write(*,7000)namein,igun,isaat
 7000 format(a15,2i5)

      read(1,1000,end=6000)idummy
 1000 format(i3)
```

```
call oku(if,jf,zoku,zyaz,1)

call ayarla      (nameout,namein,igun,isaat,'WIND')

OPEN(77,FILE=NAMEout,STATUS='UNKNOWN')

CALL OUT66(IF,JF,Zyaz,77,xl,xr,yb,yt)
close (77)

read(1,1000,end=6000)idummy
call oku(if,jf,zoku,zyaz,1)

call ayarla      (nameout,namein,igun,isaat,'MDPS')

OPEN(77,FILE=NAMEout,STATUS='UNKNOWN')
CALL OUT66(IF,JF,Zyaz,77,xl,xr,yb,yt)
close (77)
read(1,1000,end=6000)idummy
call oku(if,jf,zoku,zyaz,1)

call ayarla      (nameout,namein,igun,isaat,'MDWW')

OPEN(77,FILE=NAMEout,STATUS='UNKNOWN')
CALL OUT66(IF,JF,Zyaz,77,xl,xr,yb,yt)
close (77)
read(1,1000,end=6000)idummy
call oku(if,jf,zoku,zyaz,1)

call ayarla      (nameout,namein,igun,isaat,'MPPS')

OPEN(77,FILE=NAMEout,STATUS='UNKNOWN')
CALL OUT66(IF,JF,Zyaz,77,xl,xr,yb,yt)
close (77)
read(1,1000,end=6000)idummy
call oku(if,jf,zoku,zyaz,1)

call ayarla      (nameout,namein,igun,isaat,'MPWW')


OPEN(77,FILE=NAMEout,STATUS='UNKNOWN')
CALL OUT66(IF,JF,Zyaz,77,xl,xr,yb,yt)
close (77)

read(1,1000,end=6000)idummy
call oku(if,jf,zoku,zyaz,1)

call ayarla      (nameout,namein,igun,isaat,'SHPS')
```

```
      OPEN(77,FILE=NAMEout,STATUS='UNKNOWN')
      CALL OUT66(IF,JF,Zyaz,77,xl,xr,yb,yt)
      close (77)

      read(1,1000,end=6000)idummy
      call oku(if,jf,zoku,zyaz,1)

      call ayarla      (nameout,namein,igun,isaat,'SHWW')


      OPEN(77,FILE=NAMEout,STATUS='UNKNOWN')
      CALL OUT66(IF,JF,Zyaz,77,xl,xr,yb,yt)
      close (77)

C     HOUR CHANGE

      isaat=21

      write(*,7000)namein,igun,isaat

      read(1,1000,end=6000)idummy
      call oku(if,jf,zoku,zyaz,1)

      call ayarla      (nameout,namein,igun,isaat,'WIND')


      OPEN(77,FILE=NAMEout,STATUS='UNKNOWN')

      CALL OUT66(IF,JF,zyaz,77,xl,xr,yb,yt)
      close (77)

      read(1,1000,end=6000)idummy
      call oku(if,jf,zoku,zyaz,1)
      call ayarla      (nameout,namein,igun,isaat,'MDPS')

      OPEN(77,FILE=NAMEout,STATUS='UNKNOWN')
      CALL OUT66(IF,JF,Zyaz,77,xl,xr,yb,yt)
      close (77)

      read(1,1000,end=6000)idummy
      call oku(if,jf,zoku,zyaz,1)

      call ayarla      (nameout,namein,igun,isaat,'MDWW')

      OPEN(77,FILE=NAMEout,STATUS='UNKNOWN')
      CALL OUT66(IF,JF,Zyaz,77,xl,xr,yb,yt)
      close (77)

      read(1,1000,end=6000)idummy
```

```
      call oku(if,jf,zoku,zyaz,1)

      call ayarla      (nameout,namein,igun,isaat,'MPPS')

      OPEN(77,FILE=NAMEout,STATUS='UNKNOWN')
      CALL OUT66(IF,JF,Zyaz,77,xl,xr,yb,yt)
      close (77)

      read(1,1000,end=6000)idummy
      call oku(if,jf,zoku,zyaz,1)

      call ayarla      (nameout,namein,igun,isaat,'MPWW')

      OPEN(77,FILE=NAMEout,STATUS='UNKNOWN')
      CALL OUT66(IF,JF,Zyaz,77,xl,xr,yb,yt)
      close (77)

      read(1,1000,end=6000)idummy
      call oku(if,jf,zoku,zyaz,1)

      call ayarla      (nameout,namein,igun,isaat,'SHPS')

      OPEN(77,FILE=NAMEout,STATUS='UNKNOWN')
      CALL OUT66(IF,JF,Zyaz,77,xl,xr,yb,yt)
      close (77)

      read(1,1000,end=6000)idummy
      call oku(if,jf,zoku,zyaz,1)
      call ayarla      (nameout,namein,igun,isaat,'SHWW')


      OPEN(77,FILE=NAMEout,STATUS='UNKNOWN')
      CALL OUT66(IF,JF,Zyaz,77,xl,xr,yb,yt)
      close (77)

      go to 5000
 6000 continue

        stop
        END


      subroutine OUT66(IF,JF,Zyaz,nfile,xl,xr,yb,yt)
      dimension zyaz(if,jf)

      zmin=100000.
        zmax=-100000.
        do 1003 i=1,if
        do 1003  j=1,jf
```

```
c       if(zyaz(i,j).eq.47.00)write(*,*)i,j,zyaz(i,j)
c      if(zyaz(i,j).ge.17.00)write(*,*)i,j,zyaz(i,j)
c       if(zyaz(i,j).eq.47.00)pause 1000
c       if(zyaz(i,j).eq.17.00)pause 1000

        if(zyaz(i,j).ge.999)go to 1003
      if(zyaz(i,j).le.zmin)zmin=zyaz(i,j)
        if(zyaz(i,j).ge.zmax)zmax=zyaz(i,j)
 1003 continue

        write(nfile,1001)if,jf,xl,xr,yb,yt,zmin,zmax
 1001 format('DSAA',/,2i6,/,2f10.3,/,2f10.3,/,2f10.3)
      do 1000 j=1,jf
        WRITE(nfile,2) (Zyaz(I,J),i=1,if)
      write(nfile,*)
 1000 continue
   2   FORMAT (10F10.4)
      return
      end


      subroutine ayarla(nameout,namein,igun,isaat,ne)
       character*4 ne
      character*40 namein,nameout

      if(igun.le.9.and.isaat.gt.9)
     *WRITE(NAMEout,'(A7,A2,i1,a1,i2,A1,a4,a4)')
     *namein,'-0',igun,'-',isaat,'-',ne,'.grd'

      if(igun.gt.9.and.isaat.le.9)
     *WRITE(NAMEout,'(A7,A1,i2,a2,i1,a1,a4,a4)')
     *namein,'-',igun,'-0',isaat,'-',ne,'.grd'

      if(igun.le.9.and.isaat.le.9)
     *WRITE(NAMEout,'(A7,A2,i1,a2,i1,A1,a4,a4)')
     *namein,'-0',igun,'-0',isaat,'-',ne,'.grd'

       if(igun.gt.9.and.isaat.gt.9)
     *WRITE(NAMEout,'(A7,A1,i2,a1,i2,A1,a4,a4)')
     *namein,'-',igun,'-',isaat,'-',ne,'.grd'
       return
        end

      subroutine oku(if,jf,zoku,zyaz,noku)
      dimension zoku(if,jf),zyaz(if,jf)
        do 1200 j=jf,1,-1
        do 1200 i=1,if
      read(noku,*)zoku(i,j)
```

```
        if(zoku(i,j).gt.999)zoku(i,j)=999.
c       zyaz(i,jf+1-j)=zoku(i,j)
      zyaz(i,j)=zoku(i,j)
 1200 continue
      return
        end
```