WIND AND SWELL WAVE CLIMATE FOR THE SOUTHERN PART OF BLACK SEA

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ABSTRACT

WIND AND SWELL WAVE CLIMATE FOR THE SOUTHERN PART OF BLACK 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 Black Sea coastline of Türkiye. For this purpose wind and swell wave data for a 65 months period is obtained from ECMWF for the analysis. And the data are analyzed for thirteen 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 Black 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 western Black 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 11 seconds in the Northern shores of Türkiye.

Keywords: Wind Climate, Swell Climate, Black Sea, Swell Propagation

ÖZ

KARADENİZ’İN GÜNEY KESİMİNDE RÜZGAR VE SOLUĞAN DALGA İKLİMİ

BERKÜN, Uğur

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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 barınkları ve küçük limanların tasarımında önemli yere sahiptir. Bununla beraber Türkiye kıyılarında soluğan dalga iklimi iyi bilinmemektedir. Bu çalışmanın amacı Türkiyenin Karadeniz kıyılarındaki soluğan dalga ikliminin açığa çıkarılmasıdır. Bu amaçla ECMWF (Avrupa Orta Vadeli Tahminler Merkezi) tarafından 65 ay süreli veri sağlanmıştır. Elde edilen veri Türkiye’nin Karadeniz kıyıları boyunca seçilen onüç bölgede incelenmiştir. Her bölge için rüzgar ve soluğan dalga gülleri, belirgin dalga yüksekliğine karşılık ortlama ana soluğan dalga peryodu ilişkisi, en yüksek değerler istatistiği analizi ve log-lineer toplam dağılımları sunulmuştur. Ayrıca soluğan dalgaların oluşumunun ve dağılımının anlaşılabilmesi için veri peryodu boyunca Karadenizde oluşan bazı uç soluğan dalga olayları incelenmiştir.

Sonuçlar göstermektedir ki, Batı Karadeniz 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 peryodu ilişkisi grafikleri ve soluğan dalga peryodu analizleri sonucunda Türkiyenin kuzey kıyılarında soluğan dalga peryodunun 11 saniyeye ulaştığı görülmüştür.

Anahtar Kelimeler: Rüzgar İklimi, Soluğan Dalga İklimi, Karadeniz, Soluğan Dalga Yayılımı

To My Family

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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 Southern coastline of Black Sea by using satellite and wave model data. The field of study is Black Sea which has an important economical value gaining its importance from mainly fishing industry and transportation. The Black Sea is in an enclosed basin and is highly utilized by the surrounding six countries. At the same time Black Sea is known by its rigorous waters compared to other seas surrounding Turkish coasts. However studies on wave climate of Black 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 put up 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.

The scope of this study is limited to investigation of wind and swell wave climate along the southern coastline of Black Sea. The area in scope is analyzed in 13 locations aligned along the 42.056° N latitude. 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 Black Sea.

1.2. GEOGRAPHIC LOCATION

The region of study is Black Sea shores of Türkiye. For the purpose of the study, data is obtained from ECMWF [ECMWF, 2006] for the whole Black Sea Basin for 65 months period. Thirteen locations are identified along the southern part of Black Sea located at 42.056° N latitude 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 thirteen locations are identified as Akhtopol, North of İstanbul, North of Kefken (Kocaeli), Zonguldak, Amasra, İnebolu, Sinop, Bafra, Samsun, Bulancak, North of Trabzon, West of Poti and Poti. There exist 107 fishing ports, harbour launches and refuge harbors along the Black Sea shores of Türkiye [KKGM, 2006] and currently about 15 fishing ports are under project [DLH, 2006].

1.3. PREVIOUS STUDIES

Previous works on wave climate of Turkish Black 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 Ergin and Özhan [1985] are the two main works on wave climate research both of which include Black 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 north 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 Black Sea basin which rests in 25.875 E to 42.75 E and 39.813 N to 48.785 N geographical coordinates. The data period is between 01.10.2000 to 28.02.2006, totally 65 months in length. Data for the 13 locations are extracted from the whole data group and re-arranged for analysis. The 13 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]. Wind seas and swells together account for more than half of the energy carried by all waves on the ocean surface, surpassing the contribution of tides, tsunamis, coastal surges, etc. [Alves, 2004][Kinsman, 1965]. But it is necessary to differentiate swell waves from other surface waves since swell waves have some unique characteristics. In calm areas far from winds, some characteristics of swell waves can be observed with bare eye. Such as their uniform shapes, smooth and well-defined crests and relatively long periods.

Swell waves attain these characteristics while they propagate over long distances. Swell is known to propagate across entire ocean basins along great circle paths with very little attenuation [Kantha, 2004] [Barber and Ursell, 1948; Munk and Snodgrass, 1957; Munk et al., 1963]. The wave-dissipation process, or wave decay, is brought about by (1) internal friction within the waves, (2) resistance met as waves overtake the wind, (3) restraint caused by crosswinds, (4) action of ocean currents in the path of waves, and (5) effects of seaweed, ice, shoals, islands, or continents in the path of waves. [Aerographer's Mate 1&C, 2006] However it is the dispersion process that makes swell waves organized according to wave periods.

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;

$C_o = L/T$ .... (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;

$$L_0 = \frac{g.T^2}{2.\pi} \quad \text{... (2)}$$

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.

$$C_o = \frac{g}{2.\pi}.T \quad \text{... (3)}$$

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 Black Sea are listed. The current information on wind and wave climate in Black 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 Black Sea along Turkish coast. Principle elements for wind and wave climate are given in 30 kilometer intervals for Black Sea, Aegean Sea, and Mediterranean 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 Black Sea.

Alves, J.H.G.M. (2004) worked on propagation of swell waves on global scale. In his work the oceans are divided into thirteen regions, which are identified as hurricane generating regions. The generation and propagation of wave systems were simulated with the wind-wave model WAVEWATCH III. And the input data which are the wind and air-sea temperature difference were obtained from hindcast archives of NCEP's wave prediction system. Preliminary climatologic analyses of swells generated at each region are presented. It is seen that swells propagated entire ocean basins and contributed significantly to the global wave climate.

D. Scott et al. carried out a detailed study of swell wave conditions in the Southern Pacific ocean with emphasis on the Chile Coastline. The WAVAD wave model was used for the hindcasting carried out in the study. The input data which is the wind fields is derived form the NCEP/NCAR Reanalysis Project data set. It is seen from the study that the wave climate is complex and very high percent of the time swell waves are effective from multiple directions for Chile coasts. The seasonal variations of the multi-directional wave conditions are also examined and seen that in winter months complexity is less due to stagnating northern storms.

One of the informative sections is given in The Technical Standards and Commentaries for Port and Harbour Facilities in Japan, page 46.

(Japanese Standard, 1999) The following figure 2.2.1 has been extracted from The Technical Standards and Commentaries for Port and Harbour Facilities in Japan (Japanese Standard, 1999) 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 344 km's, 430 km's and 573 km's respectively.

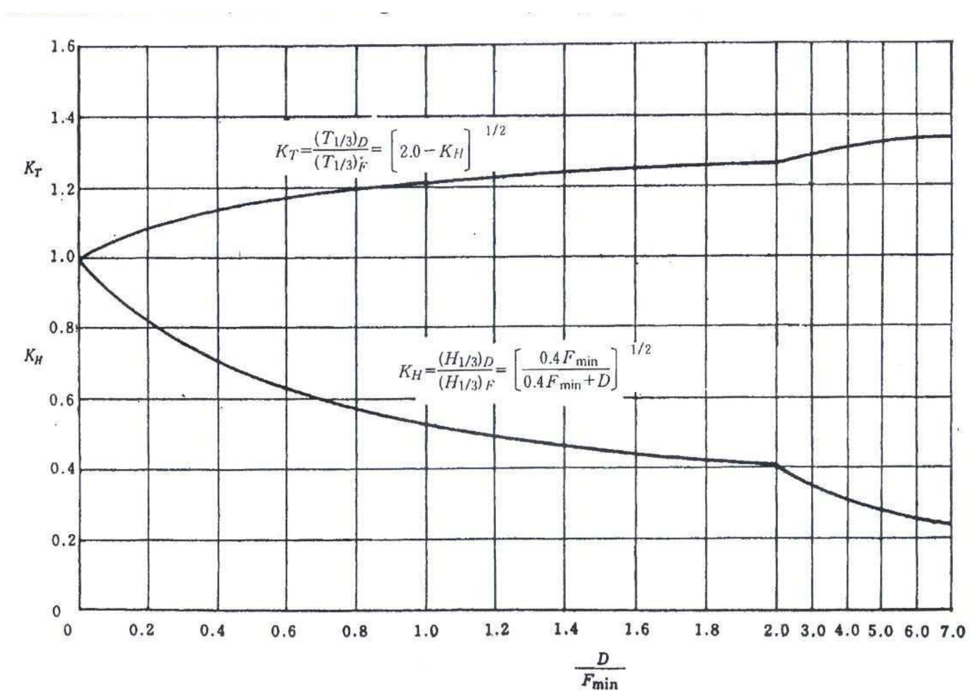

Figure 2.2.1 Swell Hindcasting Diagram

Also the study "Filyos Limanı dalga ölçümleri ve bu ölçümlerin çeşitli dalga tahminleri ile karşılaştırılması" "Filyos Harbor wave measurements and comparison of these measurements by various wave forecasts" by Arıkan Ş. E., Bilyay E., Ünal A. and Özbahçeci B. is an extensive study on the wave measurements belonging to Filyos Harbor. Wave measurements have been taken for a two years duration and the measurements have been analyzed and compared with three different wind data and two different wave data. (Arıkan Ş.E., Bilyay E., Ünal A. and Özbahçeci B., 2004) The results of this study (Arıkan Ş.E., Bilyay E., Ünal A. and Özbahçeci B., 2004) have been compared with this study and it is seen that the results are in correlation with the respective location.

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 65 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 U wind component (m/s)
- 10V - 10 meter 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 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. Although the above listed parameters are available in multiple parameter tables with different catalogue numbers, they can be found in the parameter tables 128 and 140 for wind and wave data respectively.

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 is selected as 25.875 E to 42.75 E and 39.813 N to 48.785 N which is enough to cover whole Black Sea region. The spatial resolution is selected as 1.125°x1.125° for all parameters which are stated above. This way a 16x9 matrix is formed over the Black Sea region where every cell indicates a location. And the naming of locations was made due to this matrix, e.g. 04-03 refers to 4^{th} column, 3^{rd} row of this matrix counted from left to right and bottom to top. The wind and wave data is obtained for a 65 months period starting from

01.10.2000 to 28.02.2006 with 12 hour data record interval covering whole Black Sea basin. Totally 3954 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, two of which are locations 0803-İnebolu and 0903-Sinop, wave data is limited to 24 months. This is because that these locations were interpreted as land before 03.2004. Thus analysis made on the locations 0803-İnebolu and 0903-Sinop relies on data acquired between 08.03.2004 to 28.02.2006.

Table 3.2.1.1: Index, name and coordinates of the 13 locations

Index	**Location Name**	**E Coordinate (Degrees)**	**N Coordinate (Degrees)**
0303	Akhtopol	28.125	42.056
0403	North of İstanbul	29.250	42.056
0503	North of Kefken, Kocaeli	30.375	42.056
0603	Zonguldak	31.500	42.056
0703	Amasra	32.625	42.056
0803	İnebolu	33.750	42.056
0903	Sinop	34.875	42.056
1003	Bafra	36.000	42.056
1103	Samsun	37.125	42.056
1203	Bulancak	38.250	42.056
1303	North of Trabzon	39.375	42.056
1403	West of Poti	40.500	42.056
1503	Poti	41.625	42.056

13 locations being in the 3rd row of the data matrix and 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 Black Sea are also given in Figure 3.2.1.1.

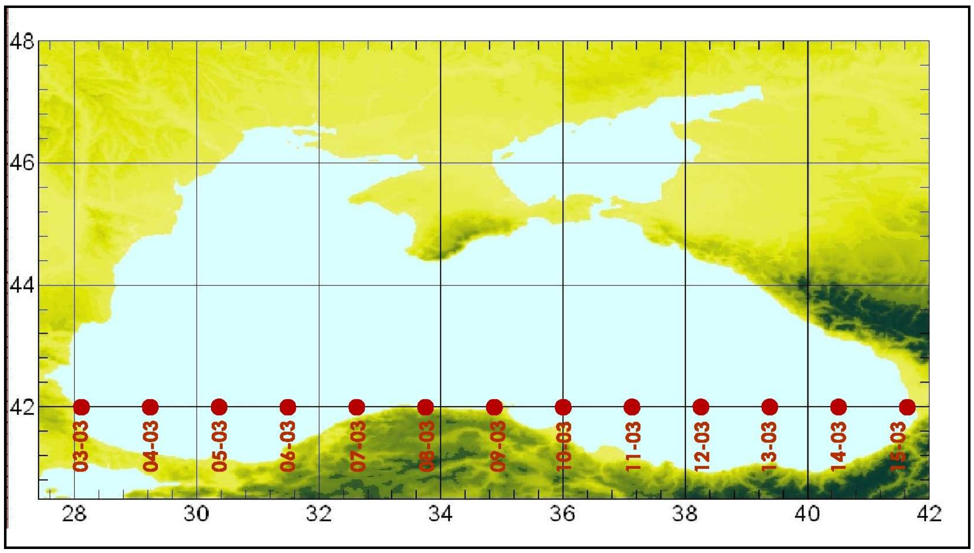

Figure 3.2.1.1 The Layout of the 13 locations

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 can not 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 a 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 FORTRAN programs written for especially re-arrangement of these files.

Briefly the FORTRAN programs 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. 03-03-WIND.dat or 14-03-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 13 files for wind data and 13 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 65 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. The percent scale of the roses is fixed to 20 percent excluding some exceptional locations. The exceptional locations are mentioned in the 5th chapter. 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. This simplification is possible since every location in this context is bounded by land from South and no significant swell waves can be generated from these directions. Only northern half of the bearings are plotted as they have significance for our purpose. In this way the H_s vs. T_m relations are composed of totally 10 graphs, nine related to directions from West to East and one for All Directions'.

The H_s vs. T_m relations are given in a single page in a clockwise order according to bearings. The All directions' relation is given in center. 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 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.

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 13 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. In the locations İnebolu (08-03) and Sinop (09-03), the extreme probability distributions are not generated because these locations have only 24 months of data available. The extreme value probability distributions are plotted by using Minitab 14 statistical software. In Minitab 14, the probability plot function is used for data input and graph plot.

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

Location / Year		**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
0303	Akhtopol	1.161	1.64	1.813	1.532	2.869	2.47	3.274
0403	North of İstanbul	1.419	2.008	2.596	2.199	2.682	2.219	2.512
0503	North of Kefken	1.526	2.189	2.541	2.586	3.336	2.227	2.524
0603	Zonguldak	1.698	1.97	2.152	2.645	3.262	2.302	2.754
0703	Amasra	1.72	2.78	2.201	2.431	3.289	2.247	2.915
0803	İnebolu	-	-	-	-	2.03	2.38	2.628
0903	Sinop	-	-	-	-	1.651	2.137	2.482
1003	Bafra	1.648	1.776	2.564	2.326	1.973	2.207	2.298
1103	Samsun	1.526	1.95	2.425	2.474	2.24	2.07	2.071
1203	Bulancak	1.571	2.022	2.419	2.117	2.476	2.533	2.213
1303	North of Trabzon	1.558	1.98	2.341	2.129	2.431	2.076	2.677
1403	West of Poti	1.62	1.85	1.983	1.988	2.129	2.008	2.885
1503	Poti	1.368	1.903	1.892	2.14	1.852	1.8	2.631

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 ten. 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.

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 13 locations along Black Sea encompassing Turkish coasts. The locations are approximately 90 km apart. 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 Black 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 the maximum value on the horizontal axis is 3.5 m and 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 can not be observed.

Results relate to data covering all year' of analysis duration, i.e. 65 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 03-03 - AKHTOPOL

The 03-03 abbreviated point is located approximately 16 km East-South East of Akhtopol (Ahtenbolu) and approximately 11 km NE of Turkish-Bulgarian Border. In this context Akhtopol location (03-03) is the most westward point among all data points and the point is quite close to land. The coordinates of point 03-03 is; 42.056 N, 28.125 E.

The Wind Roses, Swell Wave Roses, Significant Wave Height (H_s) vs. Mean Wave Period (T_m) 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 03-03 is subject to mainly N to NE winds. Strong winds effective in N direction in winter and slides to NE direction in summer. Also relatively strong winds are seen from reverse direction, namely SW & SSW, in winter.

Wind Roses are compared with the wind roses at the nearest location (42.0 N, 28.1 E) in Ozhan and Abdalla, (1999) where the dominant wind is from N to NE 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 winter season. In Ozhan and Abdalla, 1999, the north-eastern winds have higher occurrence comparing to this study generally.

Swell wave roses are given in Figure 4.1.2 and show a clear indication of direction of incoming swell waves. Definitely west and southern part of the grid is unsuitable for generation of waves. Nearly 15 % of the time swell waves are coming form ENE and 12 % of time coming from NE direction in a full year. NE swell waves' percentile increases in winter. The maximum swell wave height is between 2 and 3 meters.

The relations between Significant Wave Height (H_s) vs. Mean Wave Period (T_m) are given in Figure 4.1.3. In this graph NE and ENE swell wave domination can be seen aiding Figure 4.1.2. A rather more scattered distribution is observed in ENE direction. Several data points, exceeding 10 second periods and few data points exceeding 2.5 m of swell wave heights are observed for ENE direction with a maximum wave height of 3.274 m. Swell waves having 11 seconds periods can be observed for E, ENE and NE directions. The average steepness of swell waves at this location (From Figure 4.1.3) is 0.014.

The graph of extreme value probability statistics is given in Figure 4.1.4. Data values show a good correlation. Significant wave height is estimated as 4.5 meters for 100 year return period.

Log-linear cumulative probability distribution is given in Figure 4.1.5. Two dominating directions, namely ENE and NE 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.

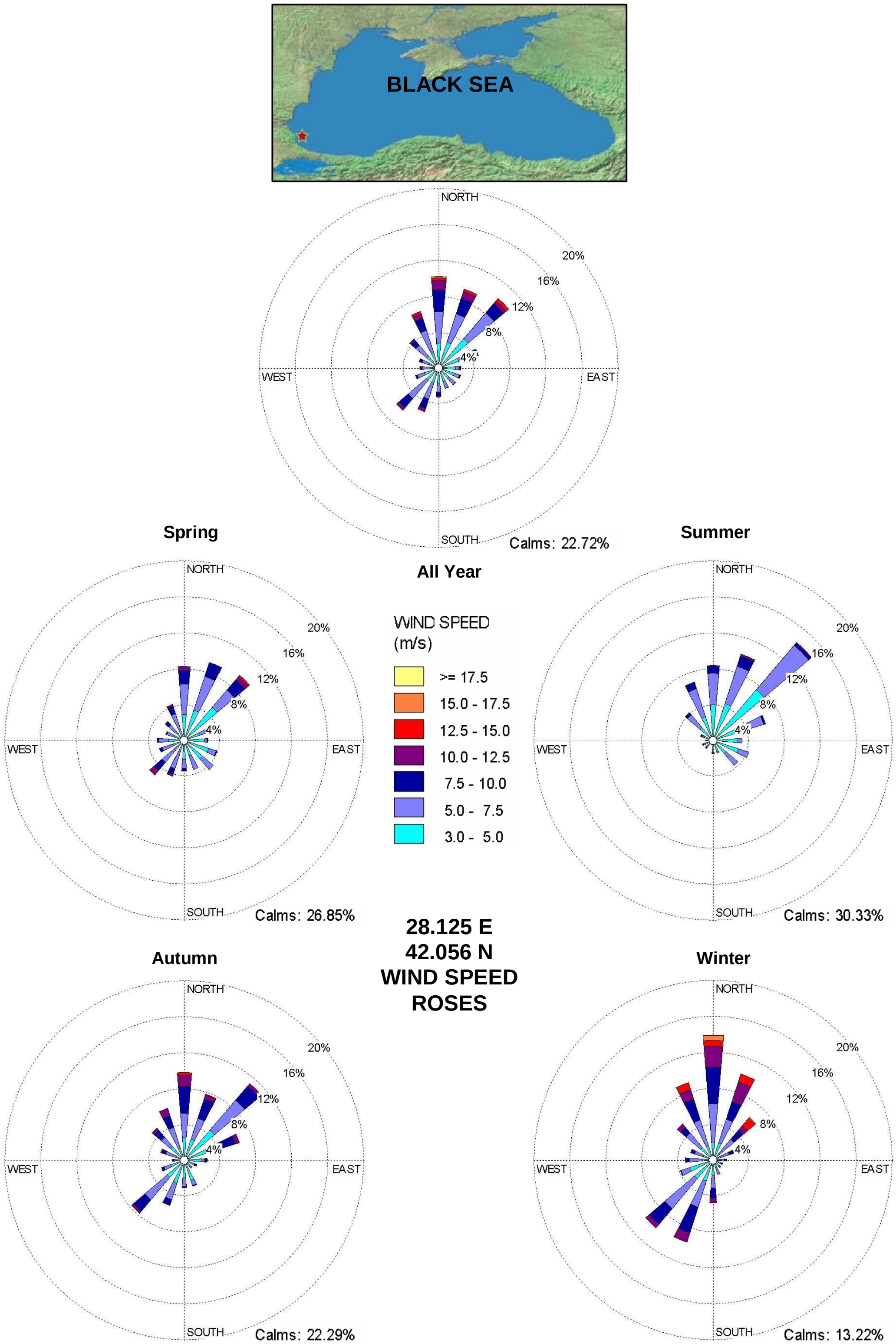

Figure 4.1.1 Wind climate at 42.056 N, 28.125 E

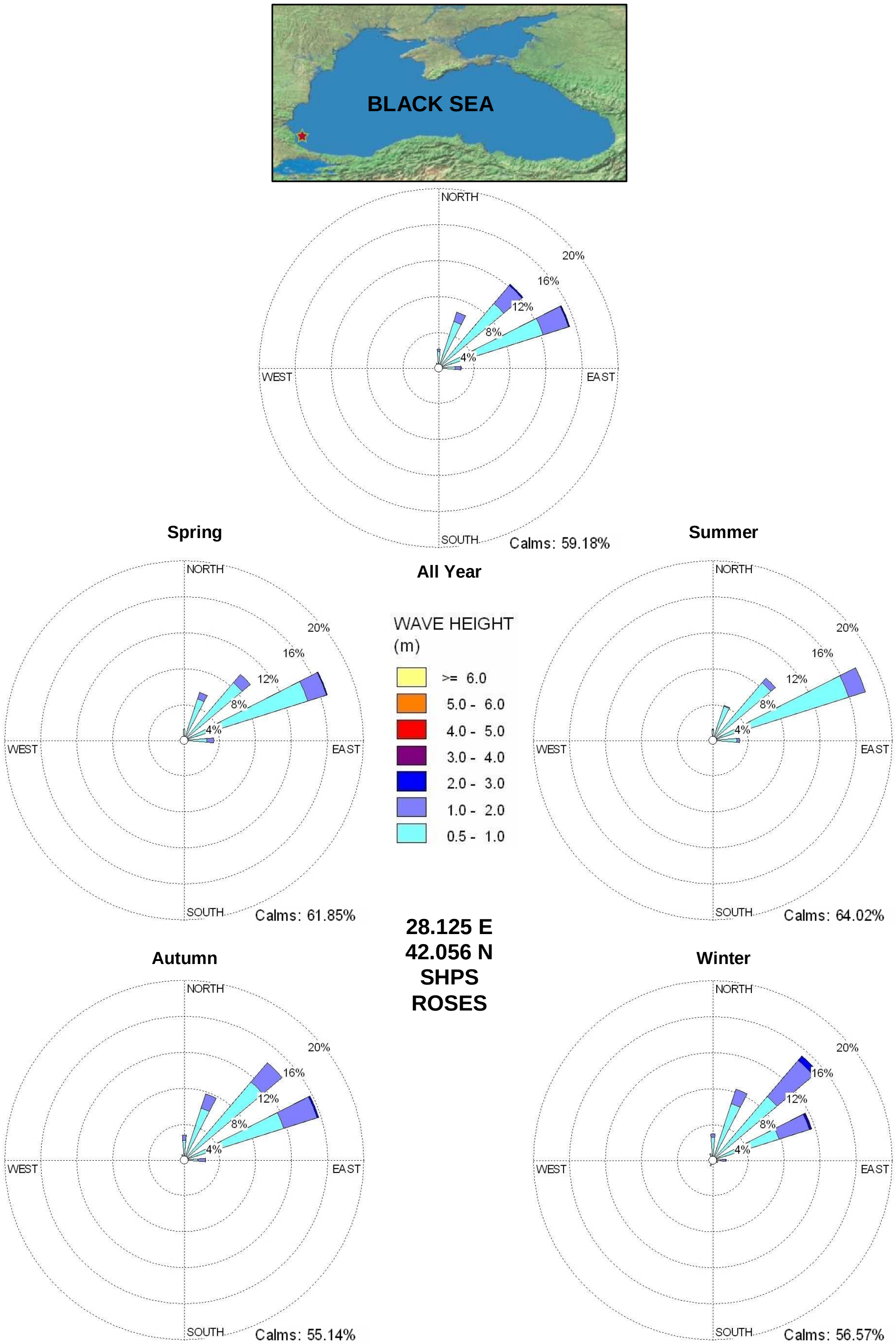

Figure 4.1.2 SHPS climate at 42.056 N, 28.125 E

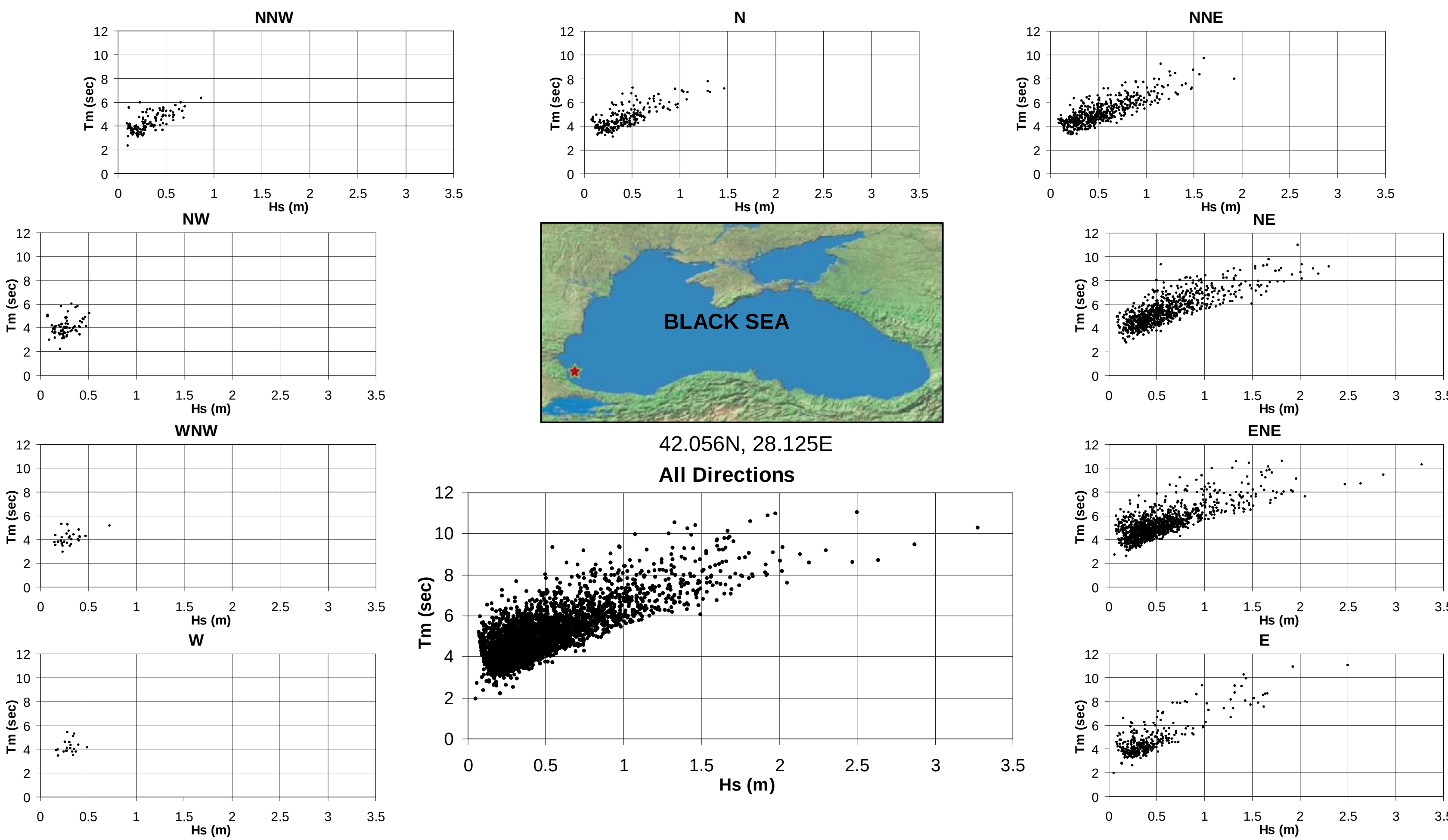

Figure 4.1.3 Relationship between MPPS & SHPS at location 03-03

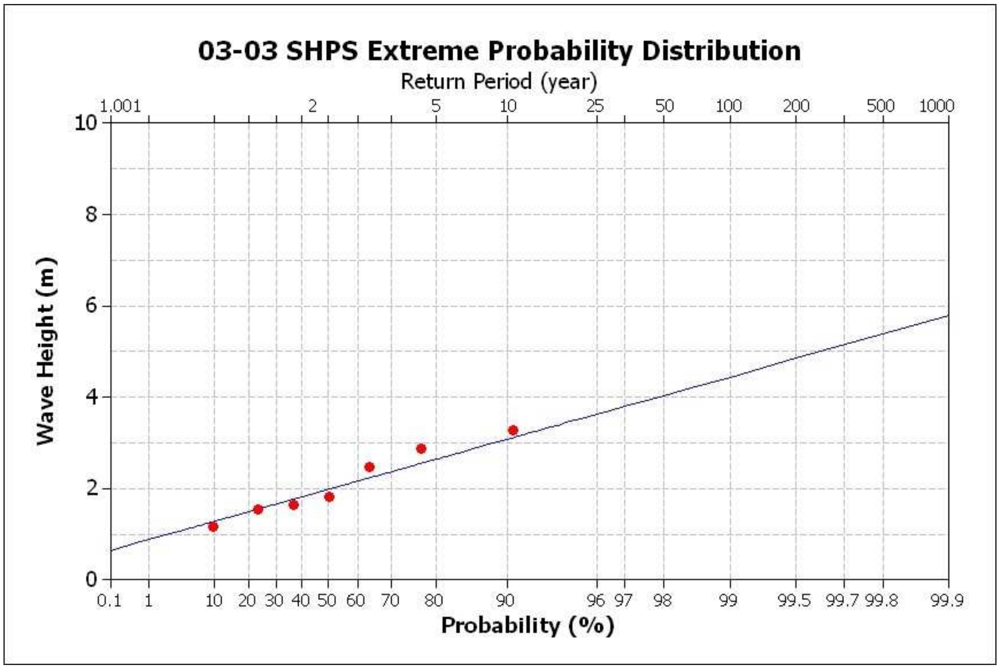

Figure 4.1.4 Extreme probability distribution at location 42.056 N, 28.125 E

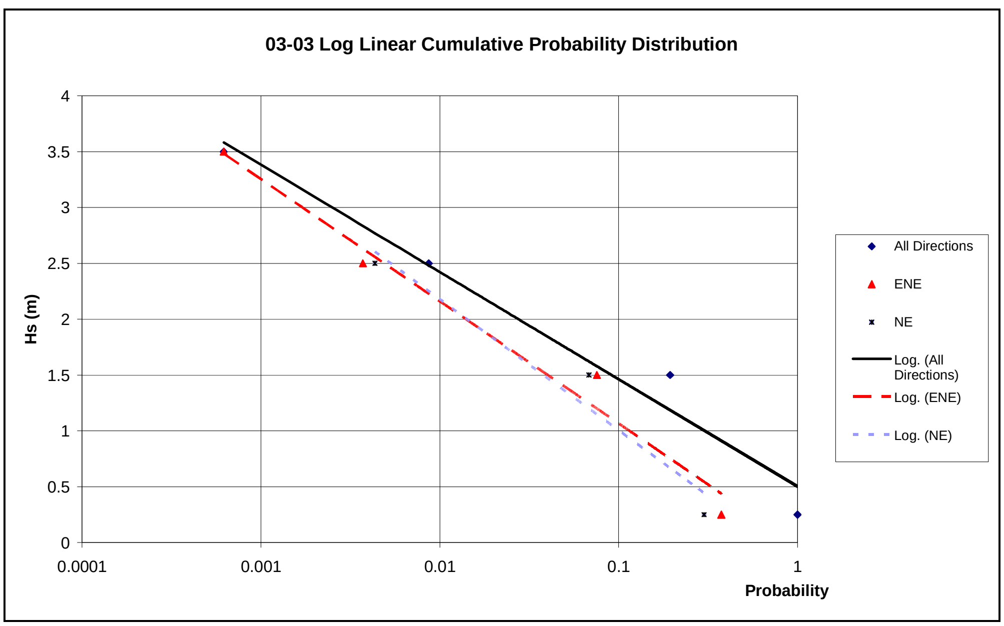

Figure 4.1.5 Log-Linear cumulative probability distribution at 42.056 N, 28.125 E

4.2. LOCATION 04-03 – NORTH OF İSTANBUL

The 04-03 abbreviated point is located approximately 95 km north of Black Sea entrance of Bosporus. Although the location is quite far from land it would represent the swell wave climate along the northern shores of İstanbul. The coordinates of point 04-03 is; 42.056 N, 29.25 E.

The Wind Roses, Swell Wave Roses, Significant Wave Height (H_s) vs. Mean Wave Period (T_m) 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 NE winds dominate in a full year and in the seasons except winter. Neighboring directions NNE and ENE directions have a secondary dominance. However in winter incoming wind occurrence probabilities is not concentrated to any direction. Probabilities of occurrences from N, NNE, NE, ENE and SW directions are nearly the same, though very strong winds prevails form northern directions. And winds speeds exceeding 17.5 m/s is observed from North direction.

Wind Roses are compared with the wind roses at the nearest location (41.25 N, 29.30 E) in Ozhan and Abdalla, (1999) where the dominant wind is from NE direction for this location. The yearly wind roses are in a very good correlation with both studies. But there are some differences in the respective roses belonging to seasons.

Swell wave roses are given in Figure 4.2.2. Swell waves can be said to be effective only from East to North directions for every season. ENE direction is dominant generally, though dominance slides to NE and NNE directions in winter. In spring and summer occurrence probabilities decreases in counterclockwise direction form ENE to North. Maximum swell wave heights are between 2 and 3 meters for any season.

The relations between Significant Wave Height (H_s) vs. Mean Wave Period (T_m) are given in Figure 4.2.3. In this graph a few swell wave heights around 2.5 meters is observed for NNE, NE and ENE directions. However no data point reaches 3 meters of swell wave height. Also wave periods passing 10 seconds is observed for swell wave heights larger than 1 meter. The average steepness of swell waves at this location (From Figure 4.2.3) is 0.013.

The graph of extreme value probability statistics is given in Figure 4.2.4. Data values show a good correlation except two values. Significant wave height is estimated as 4 meters for 100 year return period.

Log-linear cumulative probability distribution is given in Figure 4.2.5. The four significant directions, N, NNW, NW and WNW are plotted along with all directions. It is seen from this graph that significant height of swell waves exceeds 3.8 meters in about 10 hours duration every year.

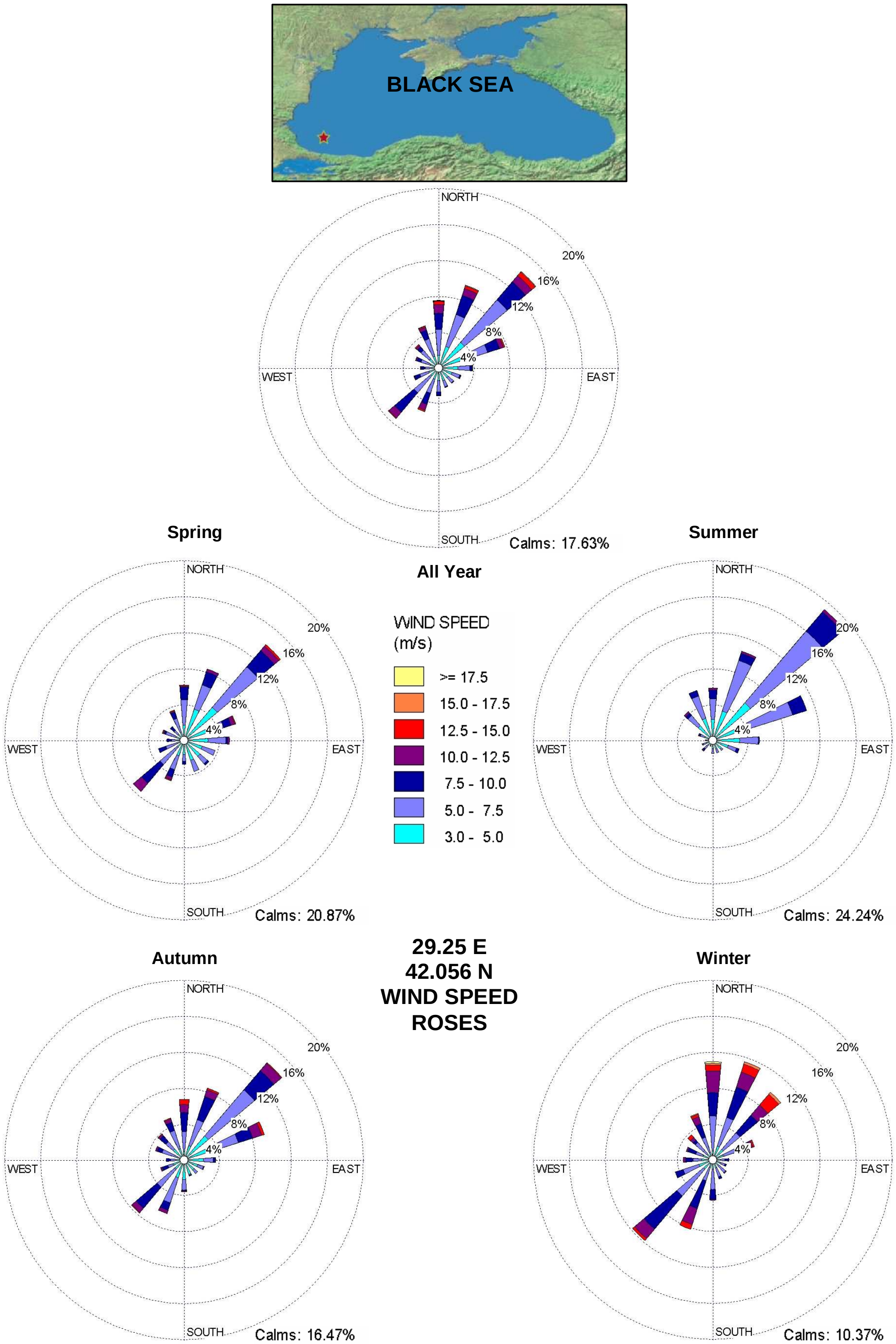

Figure 4.2.1 Wind climate at 42.056 N, 29.25 E

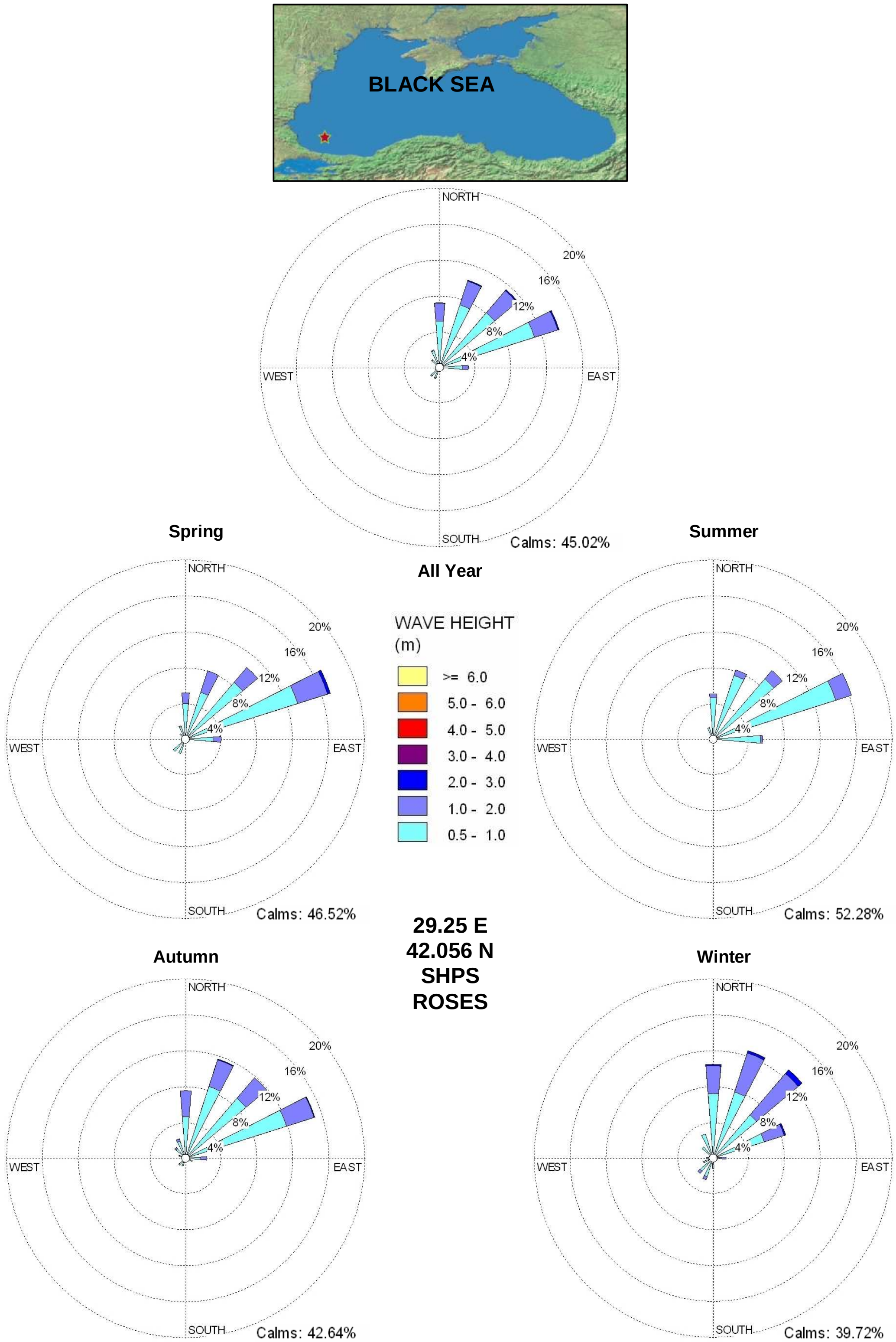

Figure 4.2.1 SHPS climate at 42.056 N, 29.25 E

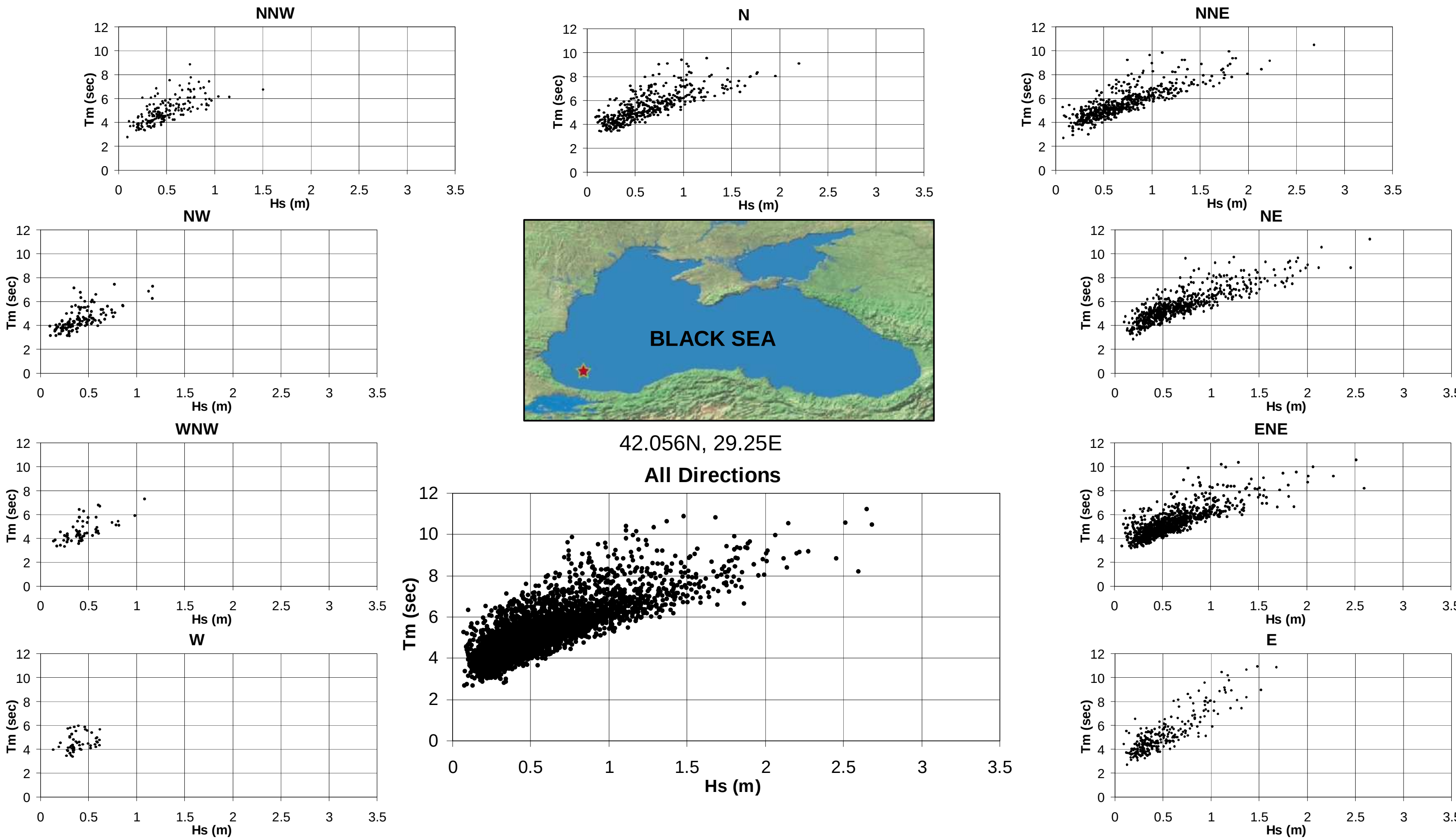

Figure 4.2.3 Relationship between MPPS & SHPS at location 04-03

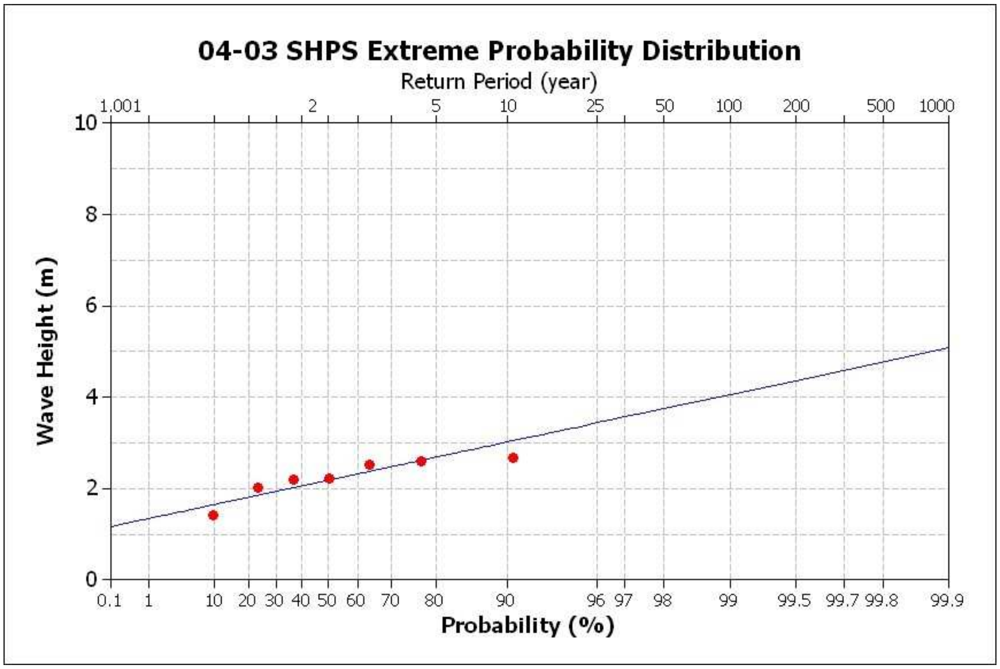

Figure 4.2.4 Extreme probability distribution at location 42.056 N, 29.25 E

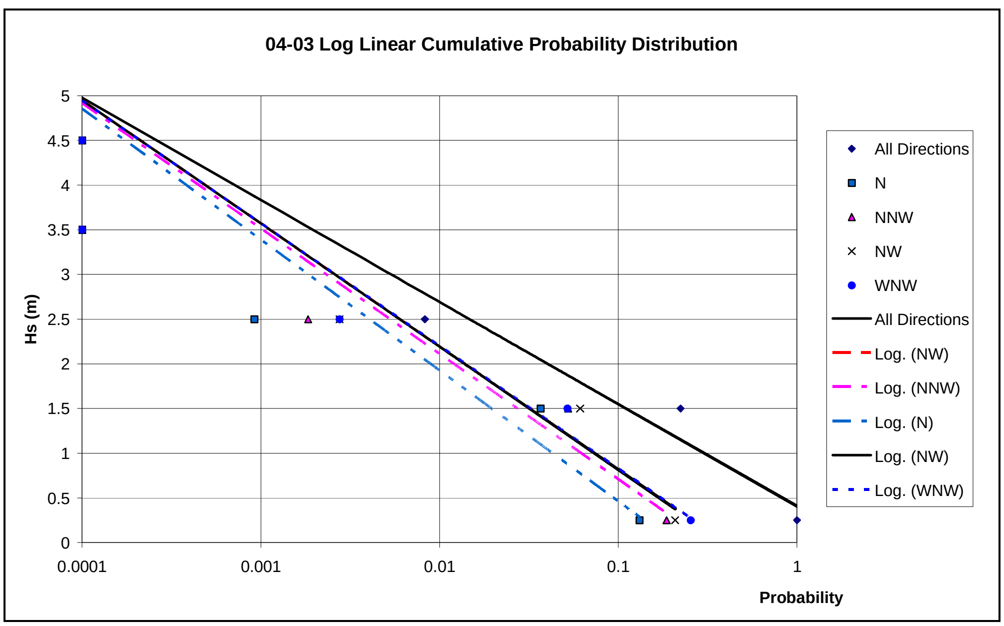

Figure 4.2.5 Log-Linear cumulative probability distribution at 42.056 N, 29.25 E

4.3. LOCATION 05-03 – NORTH OF KEFKEN, KOCAELİ

The 05-03 abbreviated point is located approximately 100 km North of Kefken, Kocaeli. The coordinates of point 05-03 is; 42.056 N, 30.375 E.

The Wind Roses, Swell Wave Roses, Significant Wave Height (H_s) vs. Mean Wave Period (T_m) 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 NE and ENE directions dominate mainly except winter. Especially in summer total of 36 percent of winds comes from NE and ENE directions. In winter SW direction slightly dominates and wind speeds higher than 15 m/s can be observed from NE and NNE directions.

Wind Roses are compared with the wind roses at the nearest location (41.25 N, 30.50 E) in Ozhan and Abdalla, (1999) where the dominant wind is from NE direction for this location. The yearly and seasonal wind roses are in correlation with both studies. In Ozhan and Abdalla, 1999, the south-western winds have less occurrence comparing to this study.

Swell wave roses are given in Figure 4.3.2. Dominating direction slightly changes over a year, however for a full year a single dominating direction does not exist. Rather N, NNE, NE and ENE directions have quite close occurrence probabilities around 10 percent. Occurrence probabilities of eastward swell waves are limited to 4 percent and can be observed in spring and summer and very slightly in autumn. Swell wave occurrence from NNW direction can clearly be observed in autumn and winter having around 7 percent occurrence. Swell wave heights between 2-3 meters are clearly observed for winter.

The relations between Significant Wave Height (H_s) vs. Mean Wave Period (T_m) are given in Figure 4.3.3. In this graph high swell wave heights can be observed coming from N and NNE directions. Maximum wave height coming from N is 3.336 meters with period of approximately 10.1 seconds. High values of swell wave height and period are condensed between 2-2.5 meters and 8-10 seconds. The average steepness of swell waves at this location (From Figure 4.3.3) is 0.013.

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 4.5 meters for 100 year return period.

Log-linear cumulative probability distribution is given in Figure 4.3.5. Directions N, NNE, NE, ENE and NNW are plotted along with all directions. It is seen from this graph that significant height of swell waves exceeds 3.8 meters in about 10 hours duration every year.

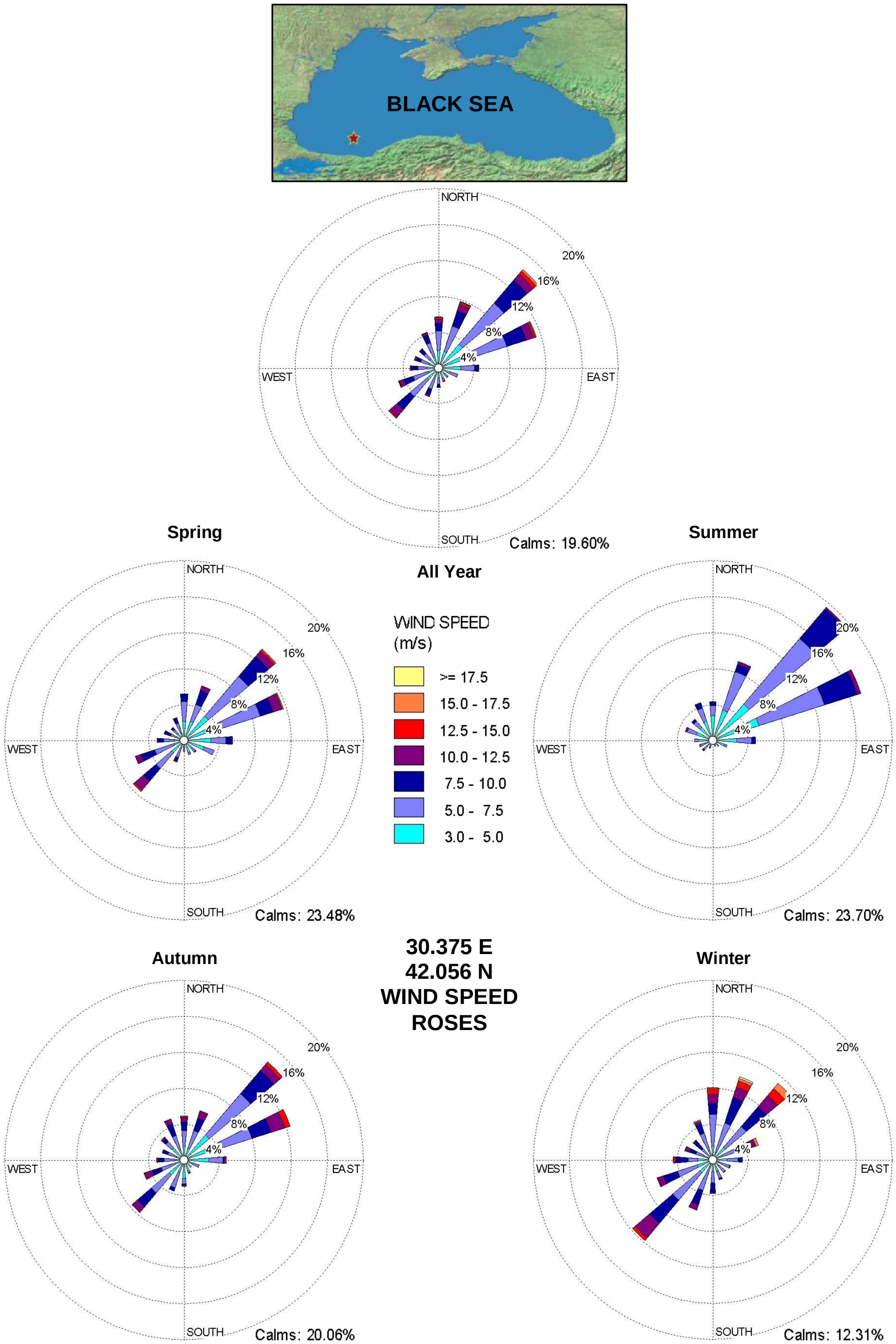

Figure 4.3.1 Wind climate at 42.056 N, 30.375 E

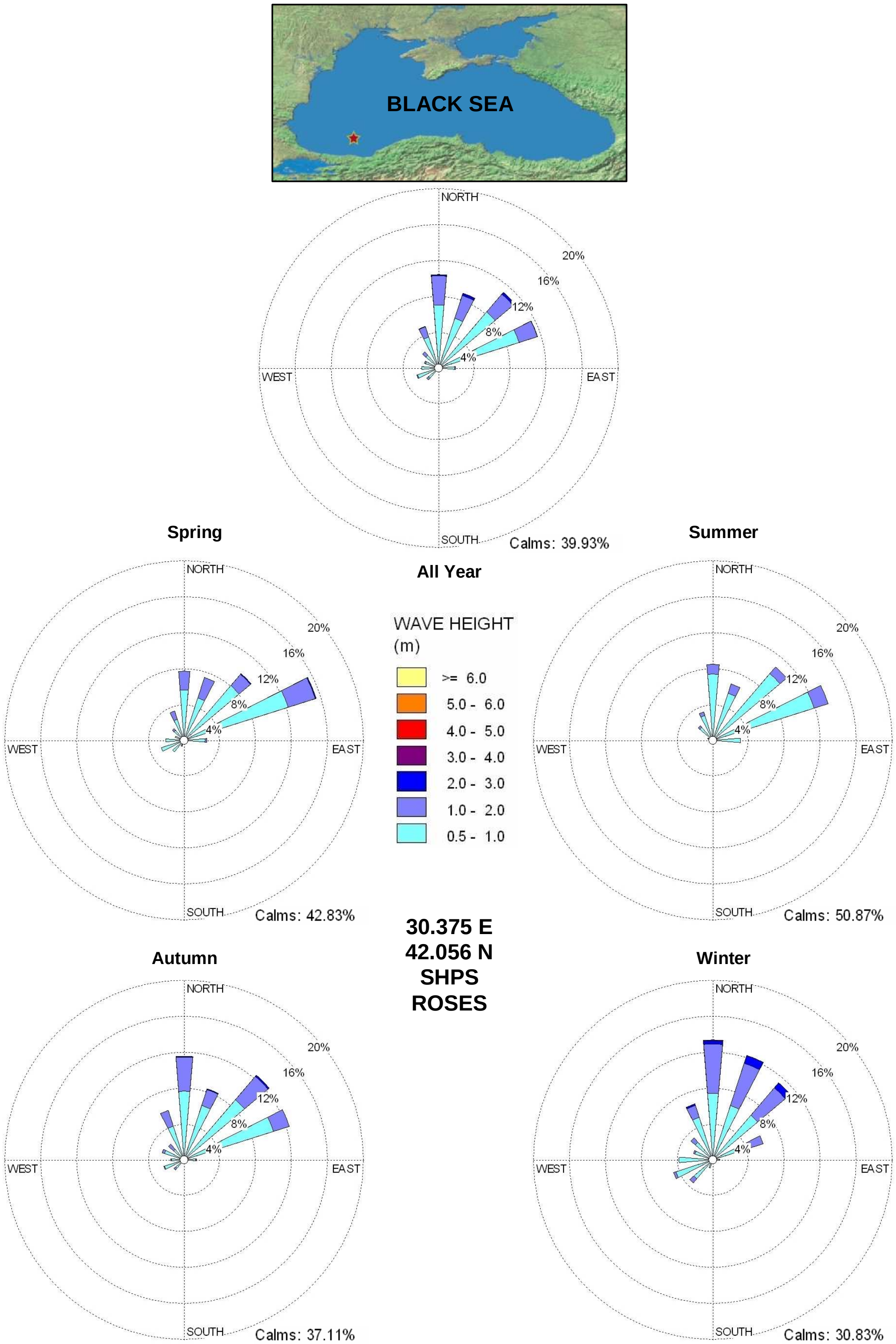

Figure 4.3.2 SHPS climate at 42.056 N, 30.375 E

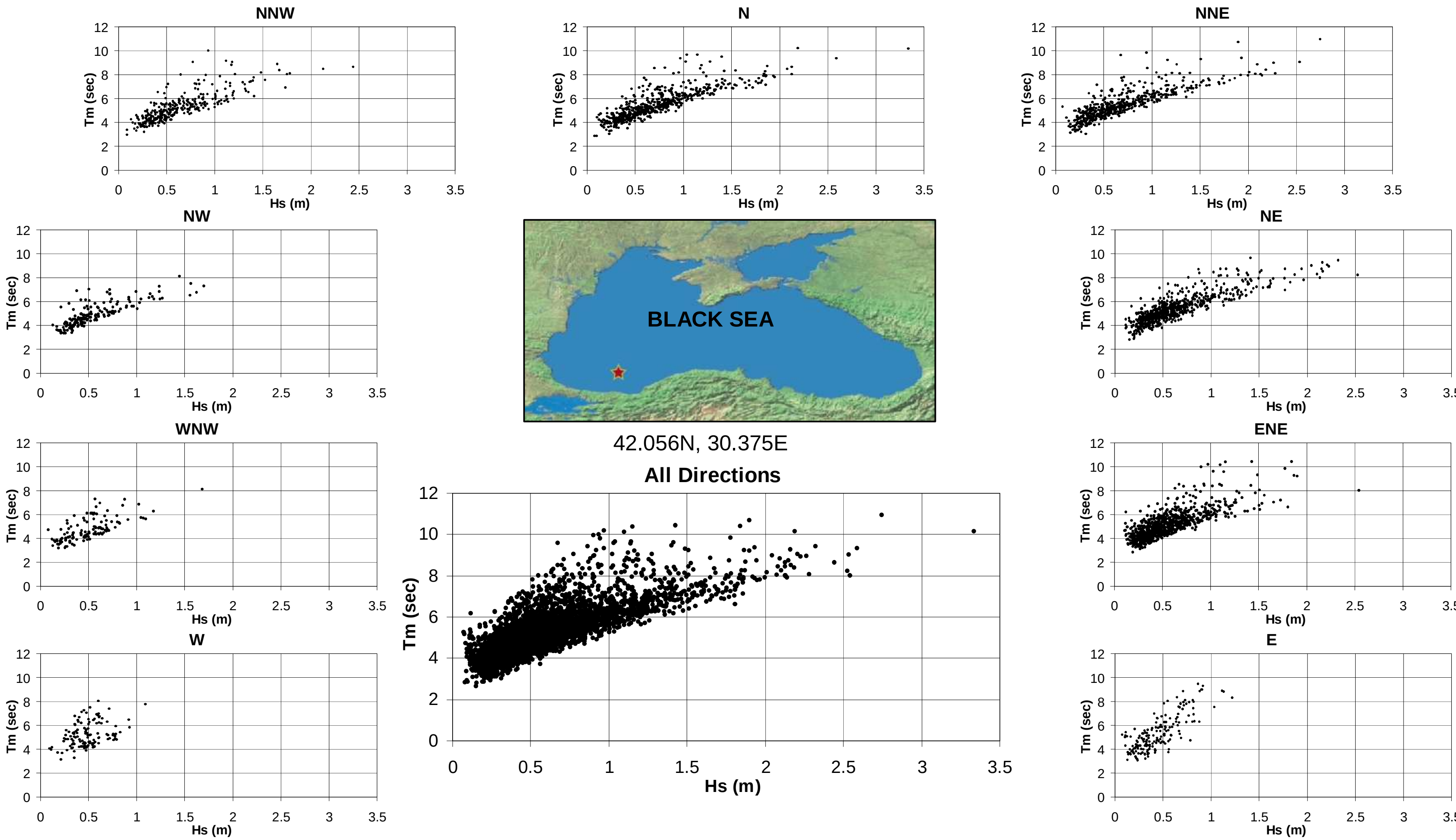

Figure 4.3.3 Relationship between MPPS & SHPS at location 05-03

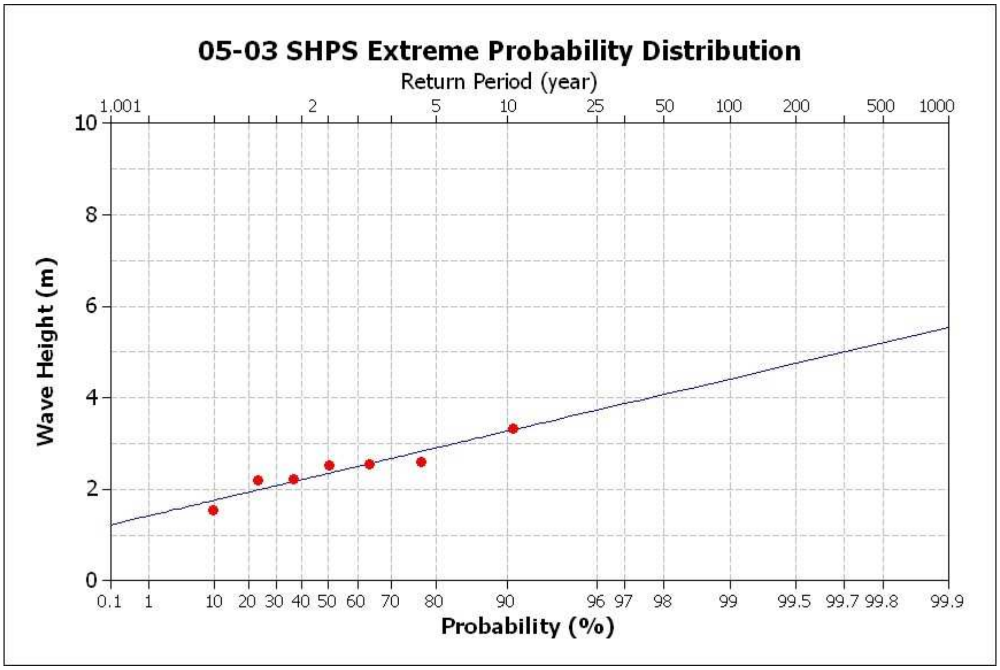

Figure 4.3.4 Extreme probability distribution at location 42.056 N, 30.375 E

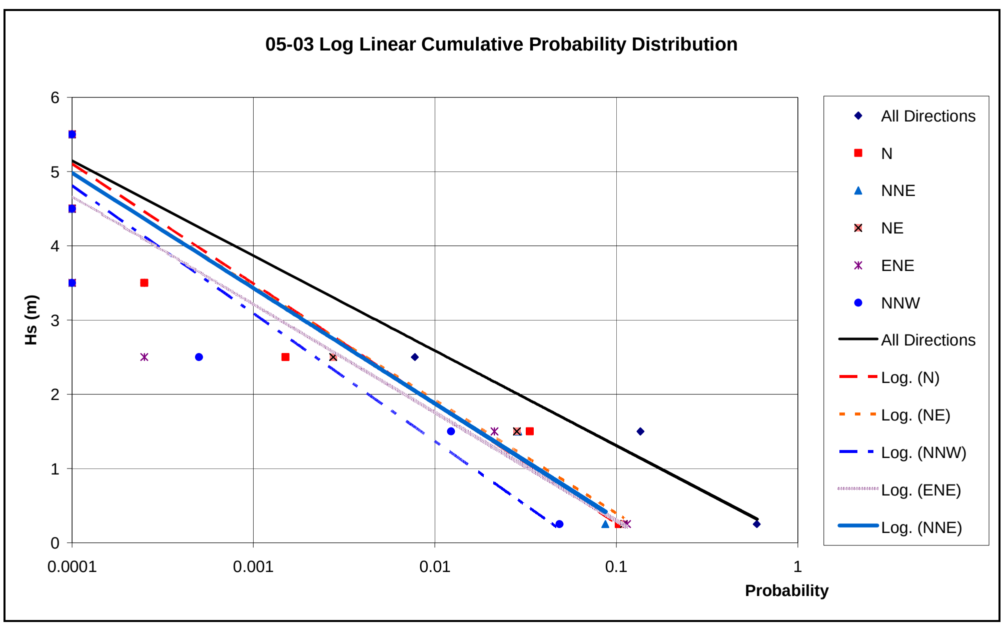

Figure 4.3.5 Log-Linear cumulative probability distribution at 42.056 N, 30.275 E

4.4. LOCATION 06-03 – ZONGULDAK

The 06-03 abbreviated point is located approximately 75 km North-north West of Zonguldak. The coordinates of point 03-03 is; 42.056 N, 31.5 E.

The Wind Roses, Swell Wave Roses, Significant Wave Height (H_s) vs. Mean Wave Period (T_m) 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 06-03 is subject to mainly ENE and NE winds. Excluding winter, occurrence probabilities of winds form ENE and NE directions are much higher compared to other directions. As in summer occurrence probability of ENE winds is 22 percent and occurrence probability of NE winds is 20 percent. In winter occurrence probability of NE and SW winds are quite close. However wind speeds higher than 15 m/s are observed from NE and ENE directions.

Wind Roses are compared with the wind roses at the nearest location (41.5 N, 31.4 E) in Ozhan and Abdalla, (1999) where the dominant wind is from NE 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 spring and summer seasons. In Ozhan and Abdalla, 1999, the north-eastern winds have higher occurrence comparing to this study in summer.

Swell wave roses are given in Figure 4.4.2. Occurrence of swell waves from ENE to WSW is observed. However in summer swell waves are not observed from WNW, W and WSW directions. For other seasons swell wave occurrences form W and WSW directions are quite noticeable. At all times swell wave occurrences from WNW direction is small. Swell wave roses for summer and autumn are quite similar from the dominant direction point of view. For winter dominant direction is north and for spring it is ENE. From all year swell wave rose it can be concluded that northward swells are effective for this location. NE swell wave's percentile increases in winter and swell wave heights passes beyond 2 meters.

The relations between Significant Wave Height (H_s) vs. Mean Wave Period (T_m) are given in Figure 4.4.3. Significant swell wave heights higher than 2.5 meters are observed form NNE and NNW directions with NNW maxima being 3.262 meters. Also periods around 11 seconds can be observed. Significant swell wave heights larger than 2 meters and mean periods higher than 8 seconds are observed for ENE, NE, NNE, N and NNW directions. Higher and lower limits of the steepness of swell waves at this location (From Figure 4.4.3) are 0.02 and 0.005 respectively.

The graph of extreme value probability statistics is given in Figure 4.4.4. Data values show a very good correlation. Significant wave height is estimated as 4.2 meters for 100 year return period.

Log-linear cumulative probability distribution is given in Figure 4.4.5. Directions N, NNE, NE, ENE and NNW are plotted along with all directions. It is seen from this graph that significant height of swell waves exceeds 4.0 meters in about 10 hours duration every year.

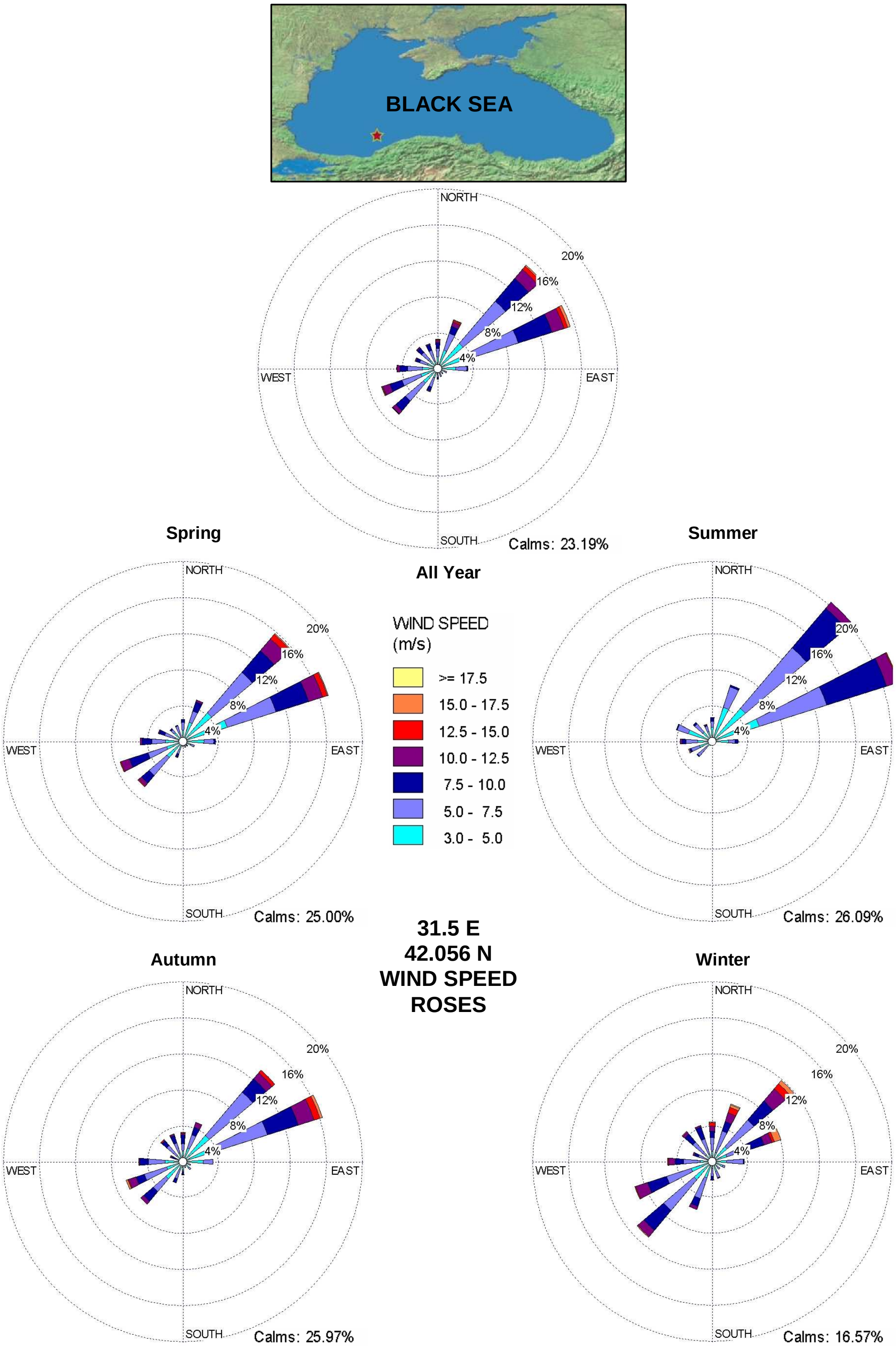

Figure 4.4.1 Wind climate at 42.056 N, 31.5 E

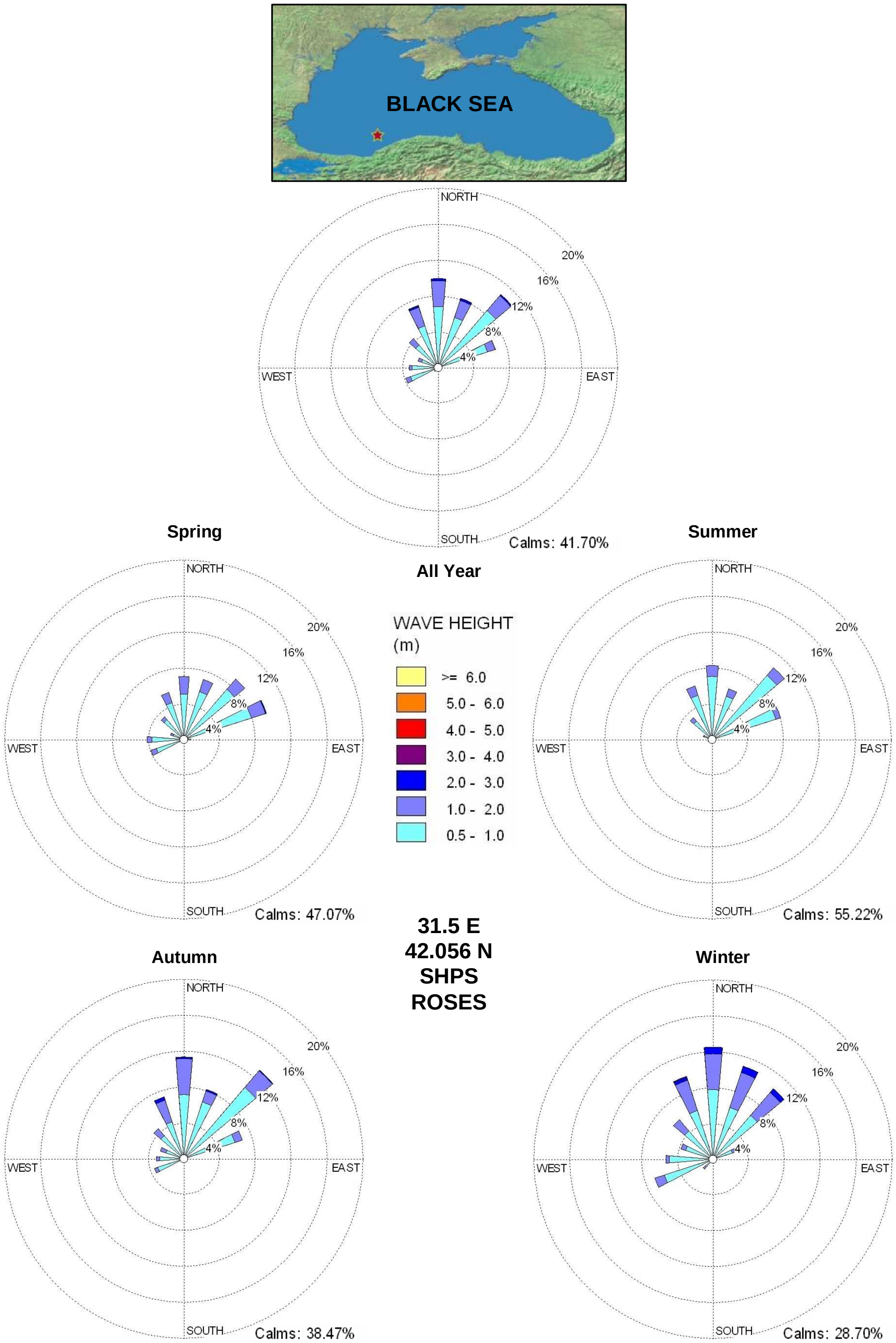

Figure 4.4.2 SHPS climate at 42.056 N, 31.5 E

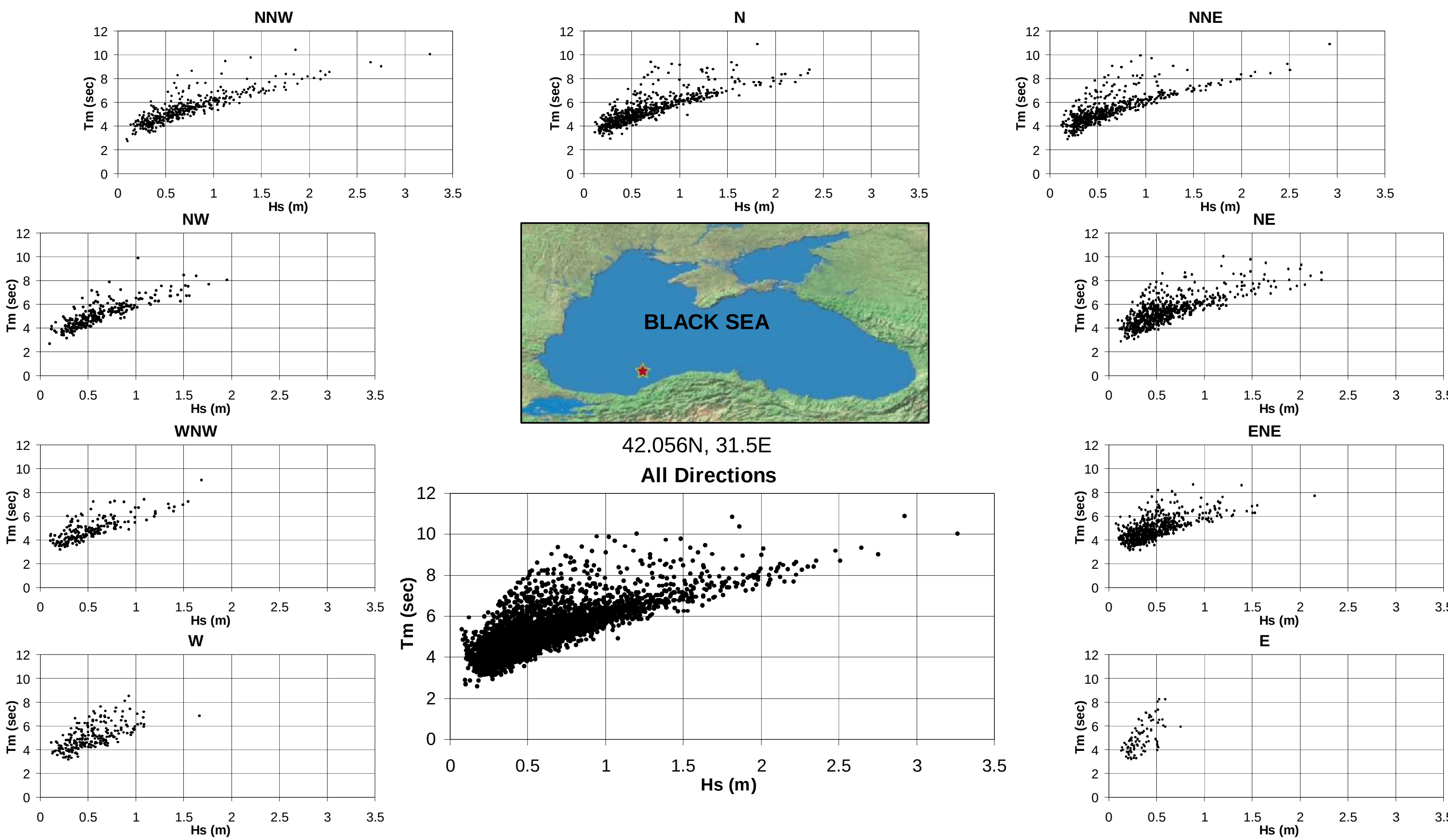

Figure 4.4.3 Relationship between MPPS & SHPS at location 06-03

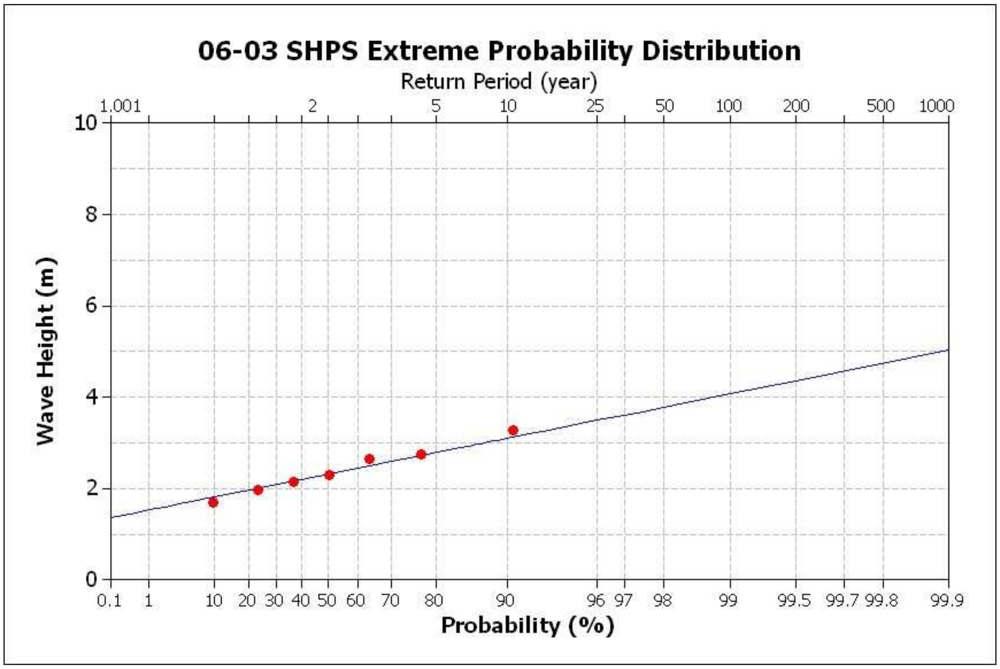

Figure 4.4.4 Extreme probability distribution at location 42.056 N, 31.5 E

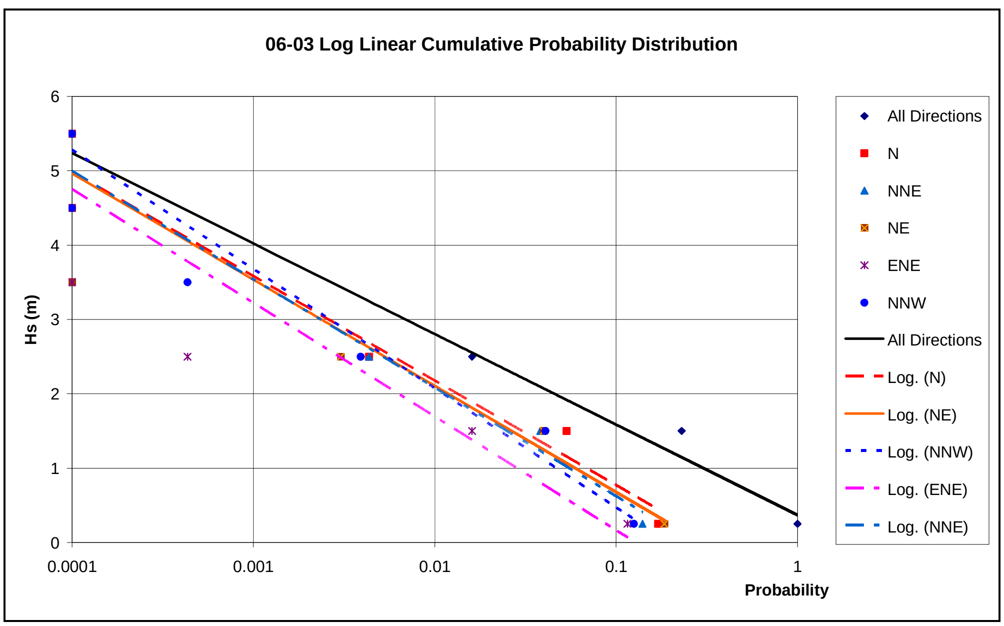

Figure 4.4.5 Log-Linear cumulative probability distribution at 42.056 N, 31.5 E

4.5. LOCATION 07-03 – AMASRA

The 07-03 abbreviated point is located approximately 40 km NNE of Amasra and approximately 25 km NNW of Kurucaşile, Kastamonu. The coordinates of point 07-03 is; 42.056 N, 32.625 E.

The Wind Roses, Swell Wave Roses, Significant Wave Height (H_s) vs. Mean Wave Period (T_m) 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 07-03 is subject to winds in ENE-WSW orientation Eastward winds being higher in magnitude. In summer occurrences of winds from ENE is around 18 percent. In winter wind occurrences from SW direction dominates and is around 15 percent, however still winds form ENE direction are stronger.

Wind Roses are compared with the wind roses at the nearest location (42.0 N, 32.6 E) in Ozhan and Abdalla, (1999) where the dominant wind is from ENE 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 seasons. In Ozhan and Abdalla, 1999, the north-eastern winds have less occurrence comparing to this study in all seasons.

Swell wave roses are given in Figure 4.5.2. Dominant direction is NNW for all seasons with a slight prevail. Also swell wave's form W reaches 8 percent in spring and winter. Swells from N, NNE and NE can be said to be secondary in effect each having around 8 percent occurrence probability for all year. Maximum significant swell wave heights are observed in winter and are between 2 and 3 meters.

The relations between Significant Wave Height (H_s) vs. Mean Wave Period (T_m) are given in Figure 4.5.3. Maximum significant swell wave heights are observed from N direction, maximum data point being 3.289 meters. NNW, N and NNE directions have considerable amount of points having Hs value higher than 2 meters. Periods very close to 10 seconds are observed however no Tm value having period's higher than 10 seconds is observed. The average steepness of swell waves at this location (From Figure 4.5.3) is 0.02.

The graph of extreme value probability statistics graph is given in Figure 4.5.4. Data values show a good correlation. Significant wave height is estimated as 4.4 meters for 100 year return period.

Log-linear cumulative probability distribution is given in Figure 4.5.5. Directions N, NNE, NNW, and NW are plotted along with all directions. It is seen from this graph that significant height of swell waves exceeds 4.0 meters in about 10 hours duration every year.

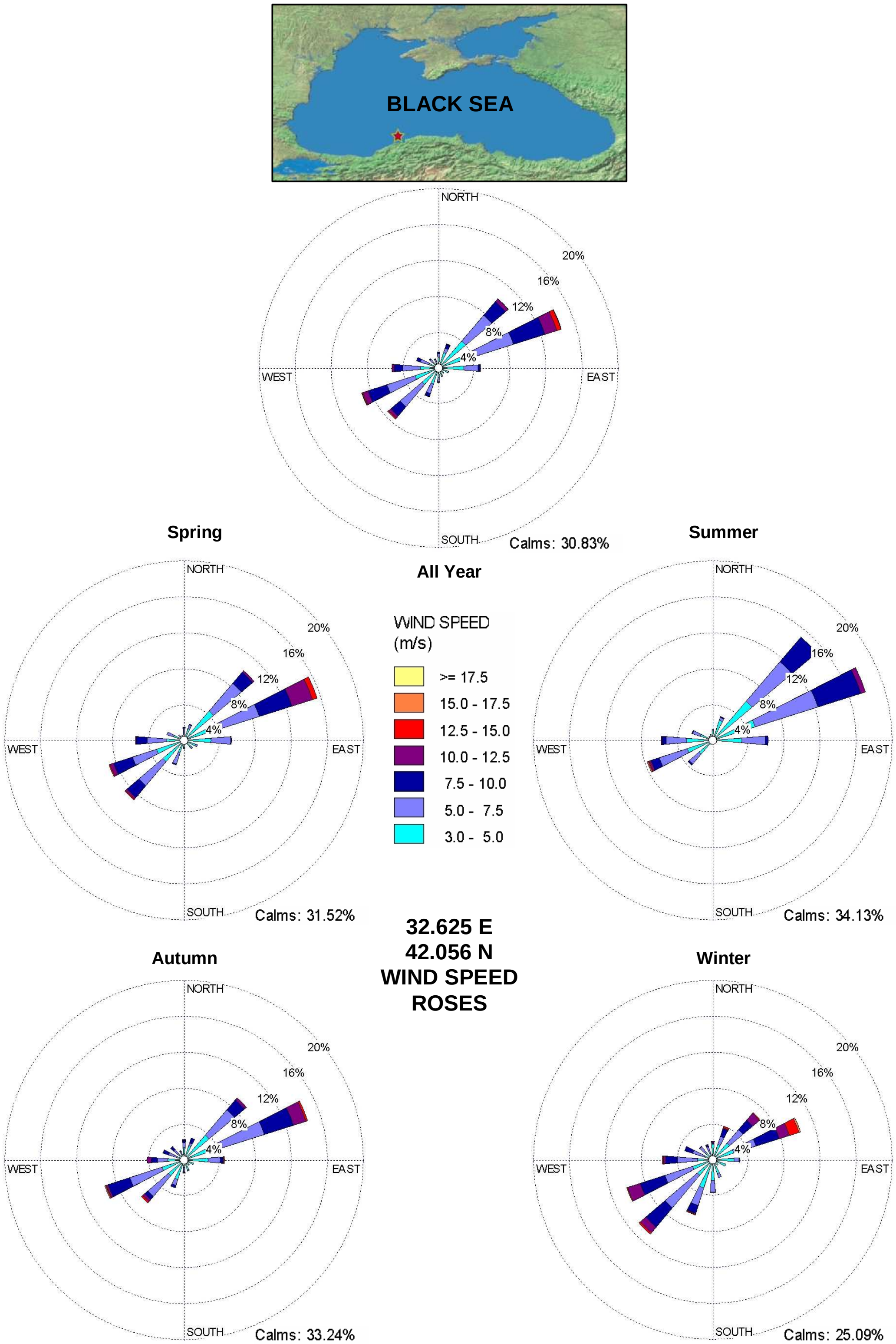

Figure 4.5.1 Wind climate at 42.056 N, 33.625 E

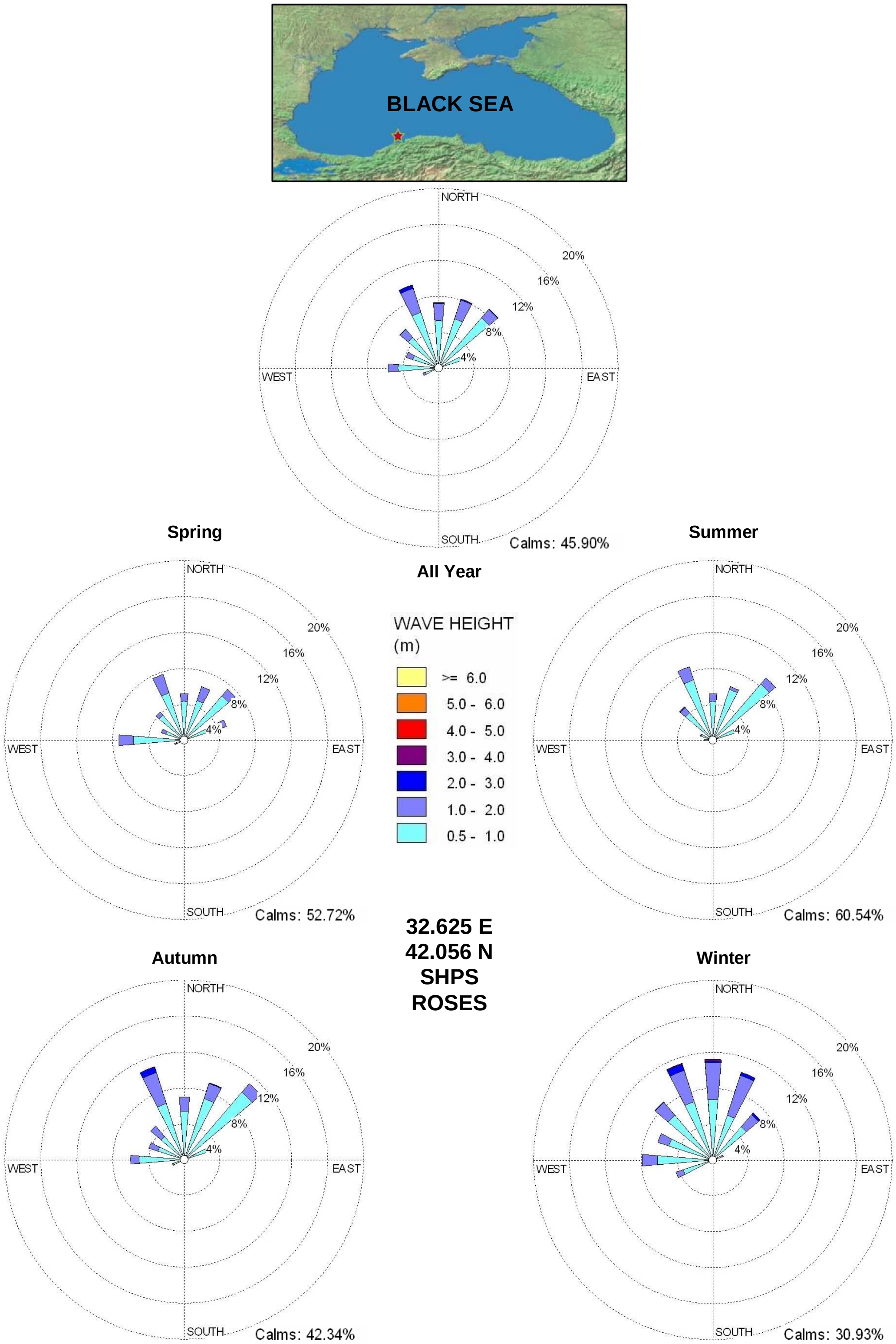

Figure 4.5.2 SHPS climate at 42.056 N, 32.625 E

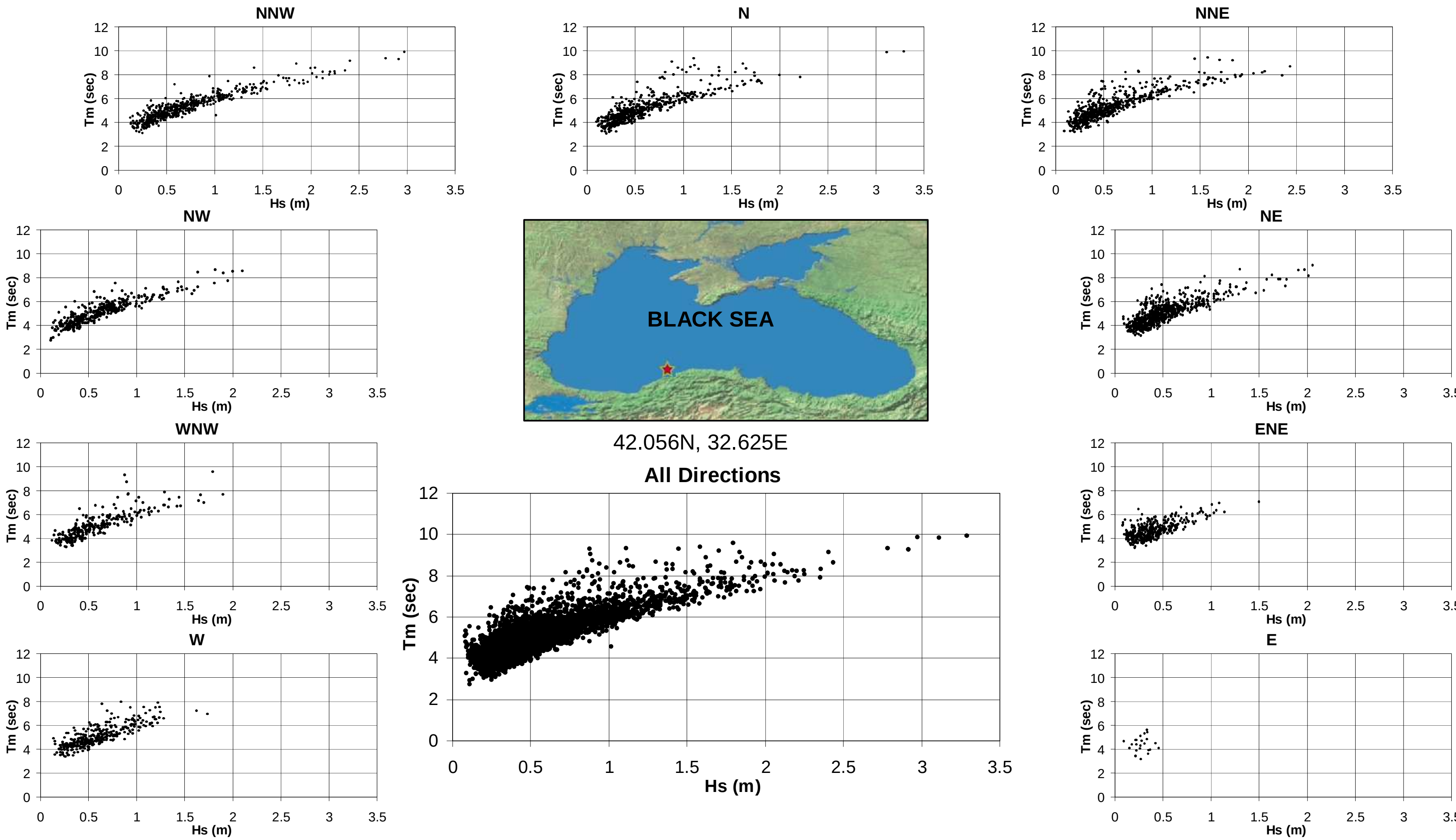

Figure 4.5.3 Relationship between MPPS & SHPS at location 07-03

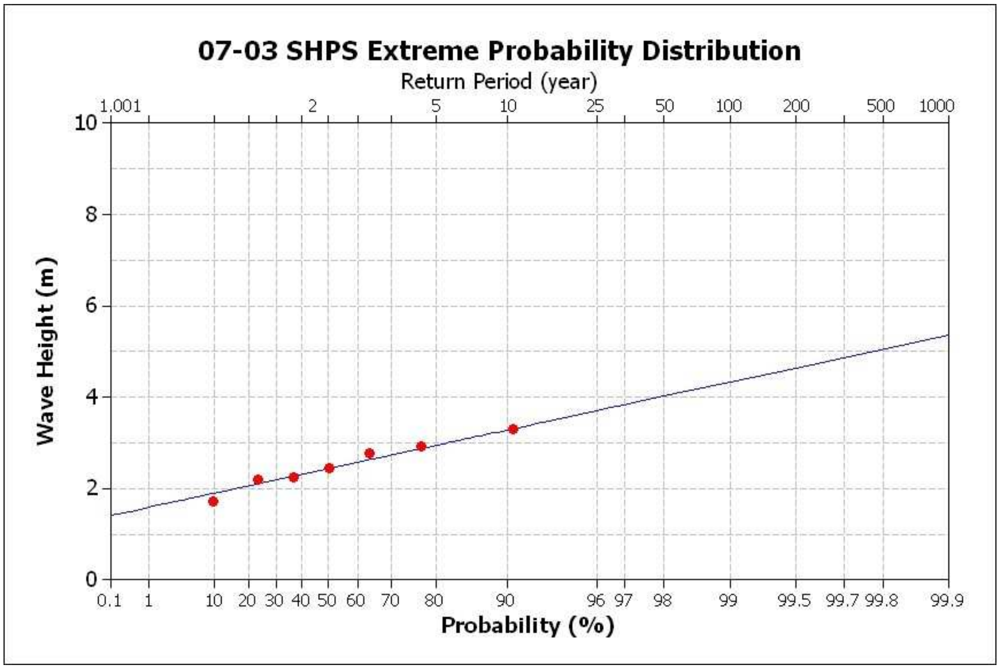

Figure 4.5.4 Extreme probability distribution at location 42.056 N, 32.625 E

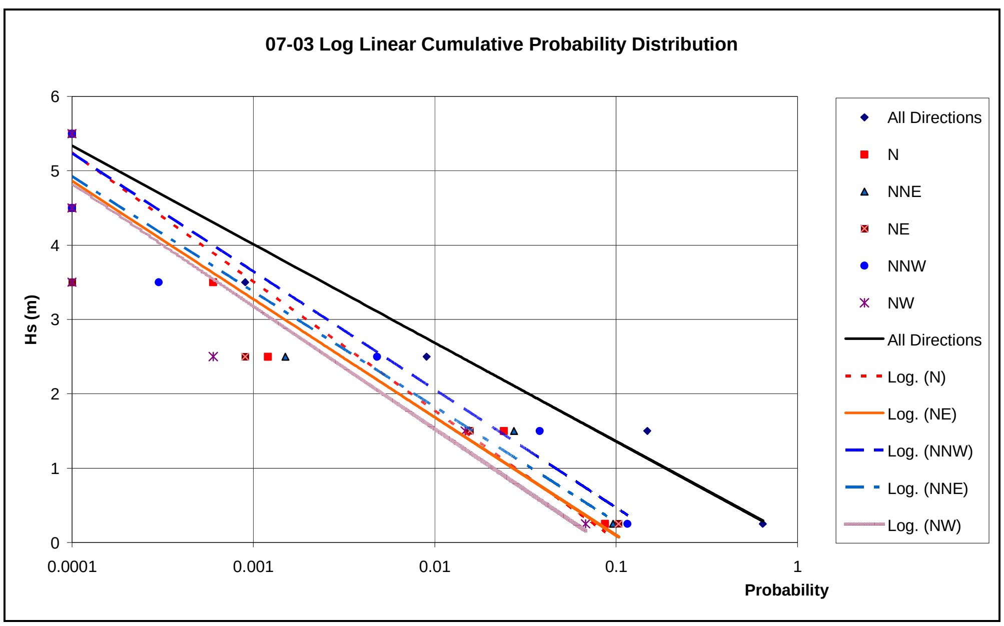

Figure 4.5.5 Log-Linear cumulative probability distribution at 42.056 N, 32.625 E

4.6. LOCATION 08-03 – İNEBOLU

The 08-03 abbreviated point is located approximately 9 km North of İnebolu. The point is quite close to shore and the shore is oriented in E-W direction. The coordinates of point 08-03 is; 42.056 N, 33.75 E.

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

In this location available data is limited to 3 years, as details are given in the 3rd Chapter. From this point of view the analysis for this location can not be as accurate as other locations having full data. Slight inaccuracies should be expected for roses, as wind and swell wave roses gives a general and relative measure. Larger ambiguities should be faced about H_s and T_m maxima in H_s vs. T_m graph. Similarly Extreme value probability statistics graph is not given at all as the graph would not be meaningful enough with 3 data points.

Wind roses are given in Figure 4.6.1. Very clearly the dominant wind has an E-W orientation. For winter dominant direction is W with 12 percent of occurrence probability. For other seasons occurrence probability from East direction prevails. However contrary to the locations stated in previous chapters, in this location stronger winds are observed from westward direction compared to east direction. Secondary directions can be said to be the neighboring directions to East and West.

Wind Roses are compared with the wind roses at the nearest location (42.0 N, 33.8 E) in Ozhan and Abdalla, (1999) where the dominant winds is in E-W orientation 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 western winds have higher occurrence comparing to this study in summer.

Swell wave roses are given in Figure 4.6.2. All observed directions belong to upper half of the rose as the location is very close to shore. Effective swell waves are observed form NNE direction for spring, autumn and winter. In winter occurrence probability of swell waves form NNE direction is as high as 18 percent and significant swell wave heights higher than 2 meters can be seen. For a full year 50 percent of time swell wave climate is regarded as calm.

The relations between Significant Wave Height (H_s) vs. Mean Wave Period (T_m) are given in Figure 4.6.3. In this graph it is observed that scatter is narrower compared to previous locations. H_s maximum is seen as 2.628 meters coming form NNE direction and T_m maximum is seen as 9.611 seconds coming form NNW direction. Only two data points with significant swell wave height higher than 2.5 meters is observed. Compared to previous locations 08-03 location has comparatively smaller Hs and Tm values and narrower scatter. The reason of this can be due to lack of data. The average steepness of swell waves at this location (From Figure 4.6.3) is 0.019.

The graph of extreme value probability statistics is not given because of lack of data as only three years' of data is available for this location.

Log-linear cumulative probability distribution is given in Figure 4.6.4. Four significant directions NNE, NE, NNW and NW are plotted along with all directions. It is seen from this graph that significant height of swell waves exceeds 3.9 meters in about 10 hours duration every year.

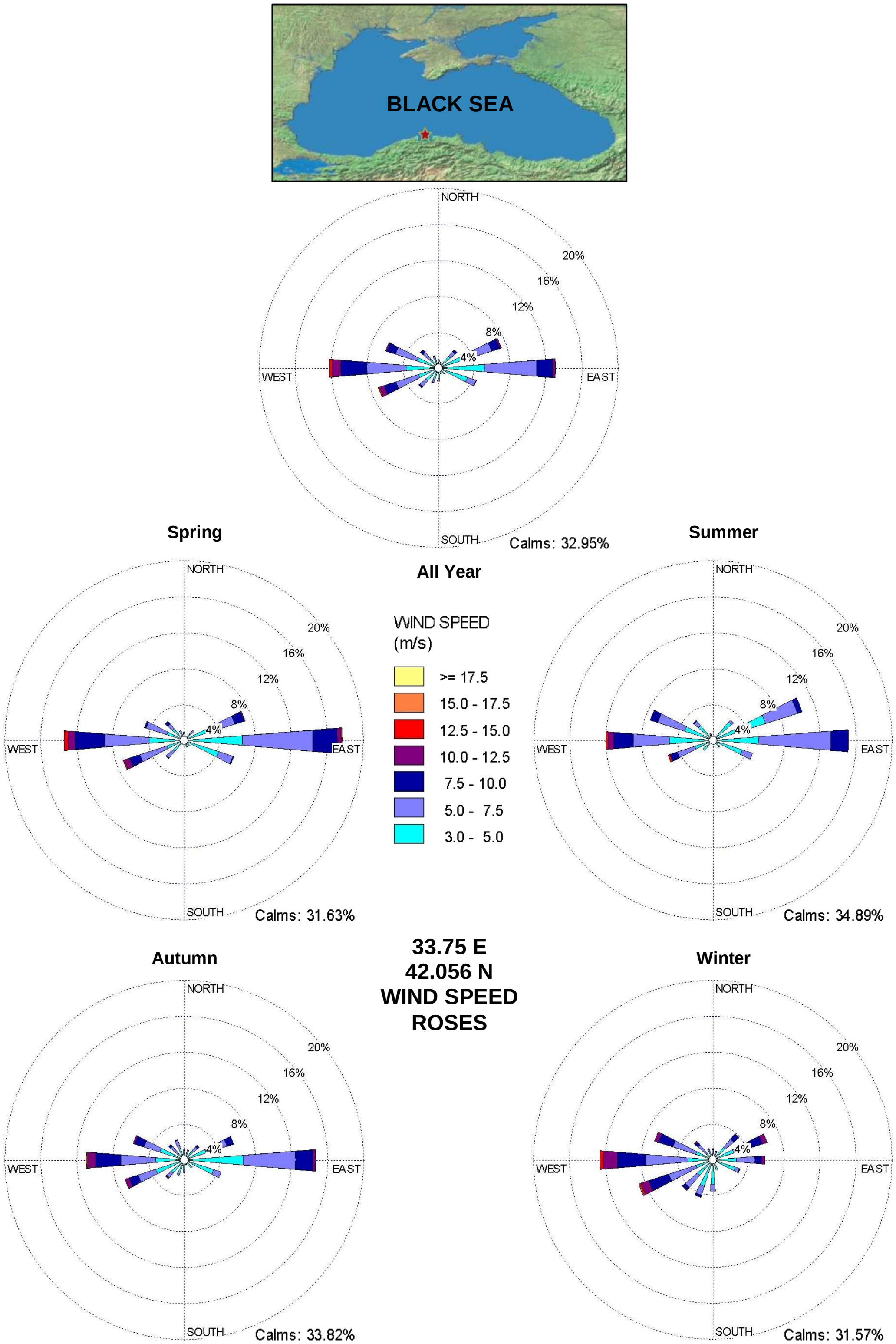

Figure 4.6.1 Wind climate at 42.056 N, 33.75 E

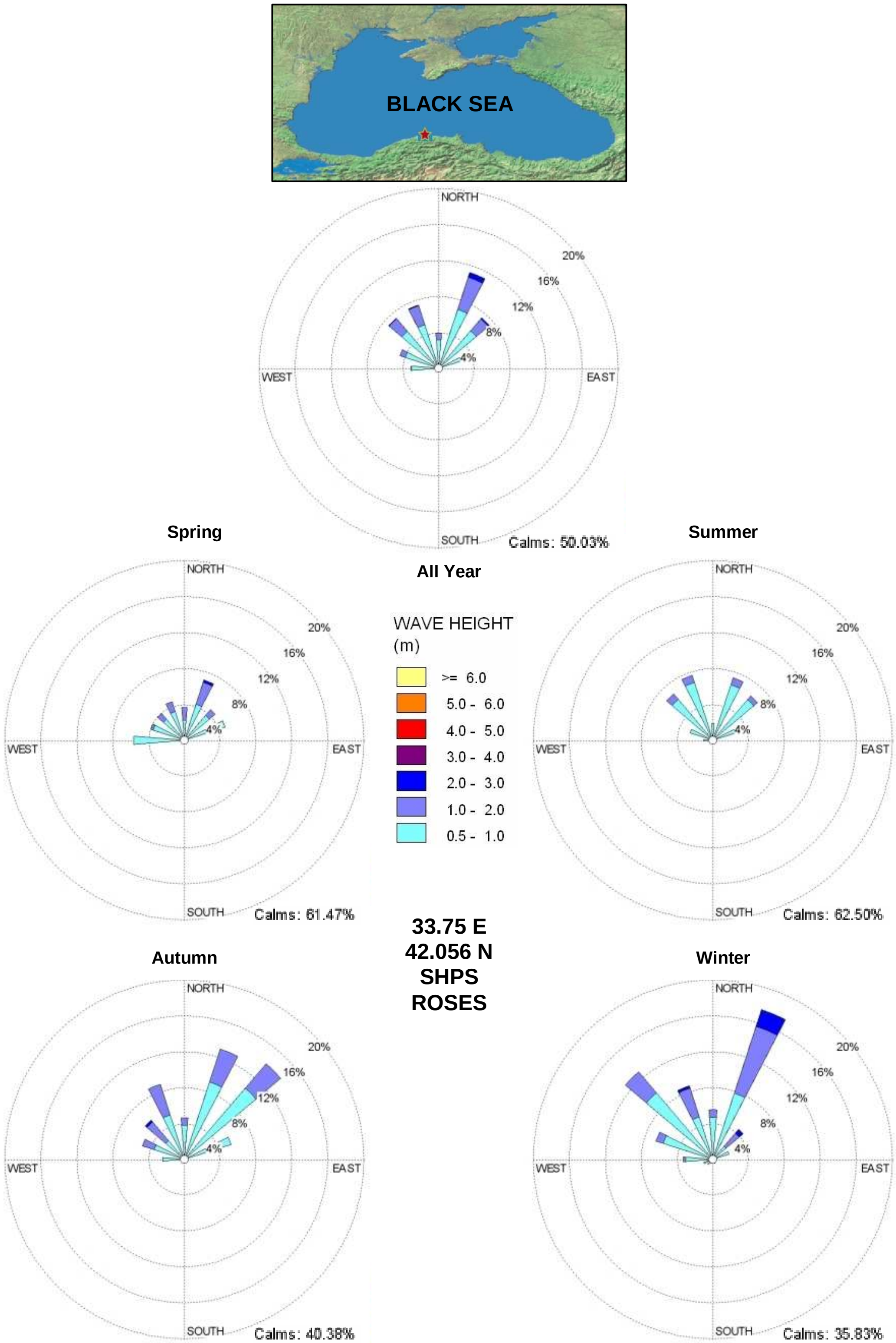

Figure 4.6.2 SHPS climate at 42.056 N, 33.75 E

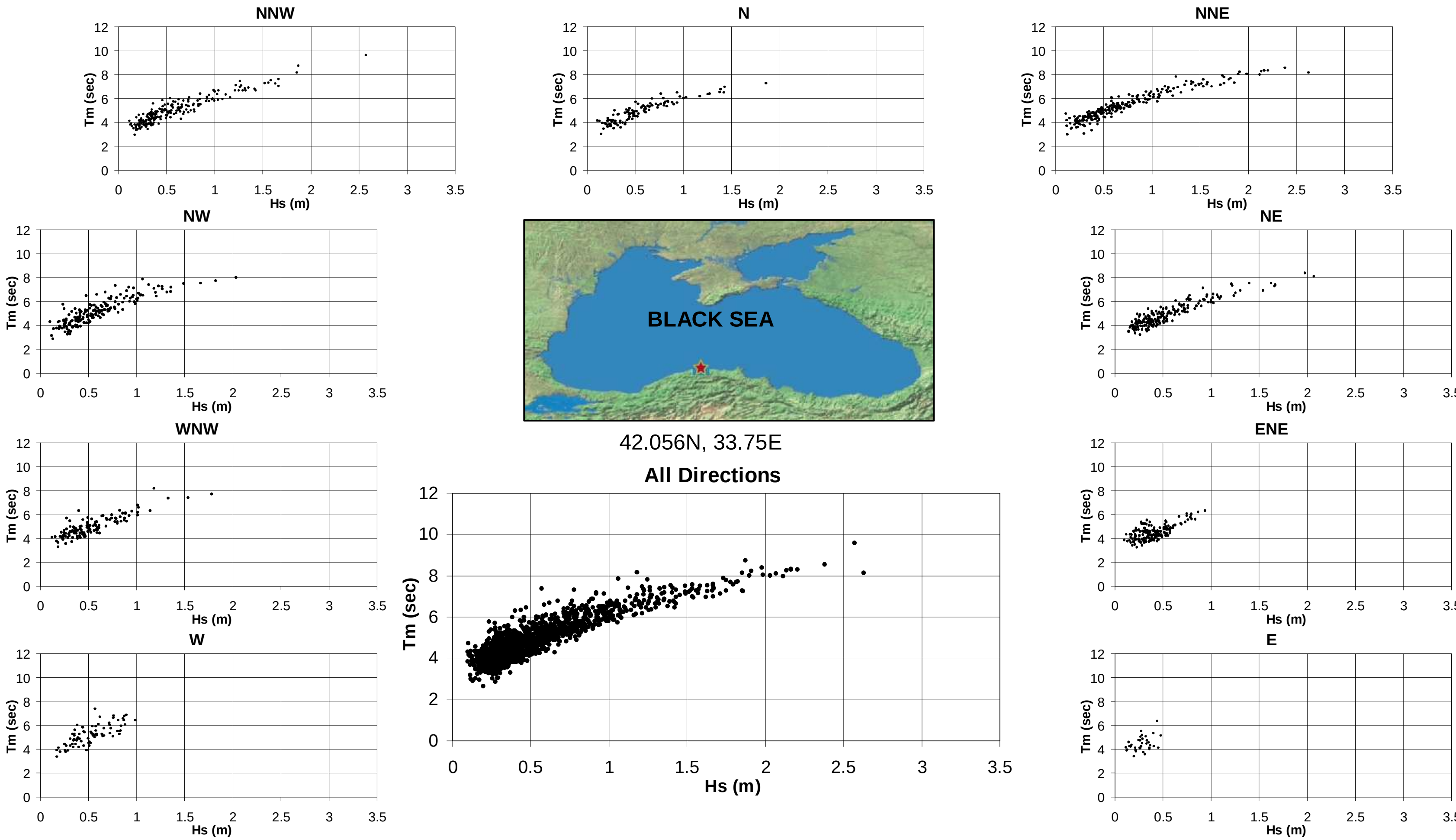

Figure 4.6.3 Relationship between MPPS & SHPS at location 08-03

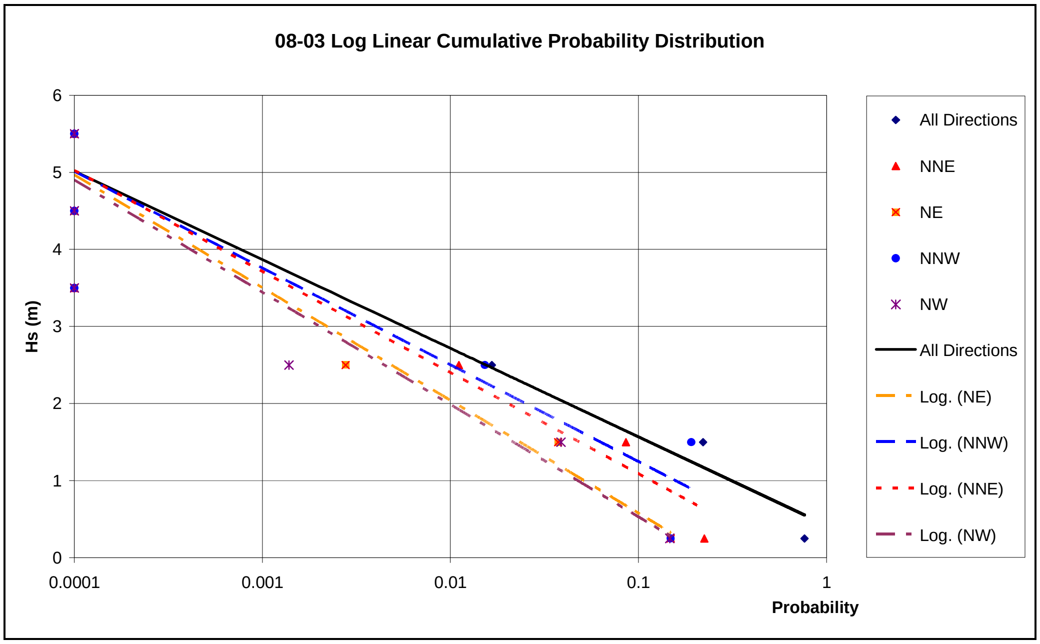

Figure 4.6.4 Log-Linear cumulative probability distribution at 42.056 N, 33.75 E

4.7. LOCATION 09-03 – SİNOP

The 09-03 abbreviated point is located approximately 25 km West-North west of Sinop and approximately 7 km South-West of Sinop Cape. But location is on the other side of the Sinop peninsula and is as close to shore as 4 km. As the 09-03 is located at south of Sinop cape, the location is under the shelter of peninsula from eastward effects. The coordinates of point 03-03 is; 42.056 N, 34.875 E.

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

In this location available data is limited to 3 years, as details are given in the 3rd Chapter. From this point of view the analysis for this location can not be as accurate as other locations having full data. Slight inaccuracies should be expected for roses, as wind and swell wave roses gives a general and relative measure. Larger ambiguities should be faced about H_s and T_m maxima in H_s vs. T_m graph. Similarly Extreme value probability statistics graph is not given at all as the graph would not be meaningful enough with 3 data points.

Wind roses are given in Figure 4.7.1. The dominant wind direction is WSW for every season. Secondary direction can be accepted as West for all year. Excluding winter, winds from East and ESE nearly 10 percent of the time. Calm percentage is around 30 percent for all year.

Wind Roses are compared with the wind roses at the nearest location (42.0 N, 35.0 E) in Ozhan and Abdalla, (1999) where the dominant wind is from WNW 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 spring season. In Ozhan and Abdalla, 1999, the western winds have less occurrence comparing to this study in spring.

Swell wave roses are given in Figure 4.7.2. The main direction of incoming swell waves is NNE for every season and secondly NW. In winter and autumn occurrence probability of swell waves form NNE direction is as high as 19 percent. In autumn no other direction passes beyond 8 percent. However in winter NW direction reaches up to 14 percent. But it should be noted that there is a 10 percent calm duration difference between autumn and winter. The significant swell wave heights passes beyond 2 meters in winter. The full year calm percentage is 51 percent. However it should also be noted that, the 09-03 location is under the shelter of Sinop peninsula from any wave effect from NE and lower directions.

The relations between Significant Wave Height (H_s) vs. Mean Wave Period (T_m) are given in Figure 4.7.3. In this graph especially for NNE direction it is observed that scatter is very narrow. Highest significant swell wave height is observed from NNE direction as 2.482 meters. And a singular maximum T_m value is observed from NNW direction as 10.331 seconds. Compared to previous locations 09-03 location has comparatively smaller Hs and Tm values and narrower scatter. The reason of this can be due to lack of data. The average steepness of swell waves at this location (From Figure 4.7.3) is 0.019.

The graph of extreme value probability statistics is not given because of lack of data as only three years' of data is available for this location.

Log-linear cumulative probability distribution is given in Figure 4.7.4. The tow dominant directions NNE and NW 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.

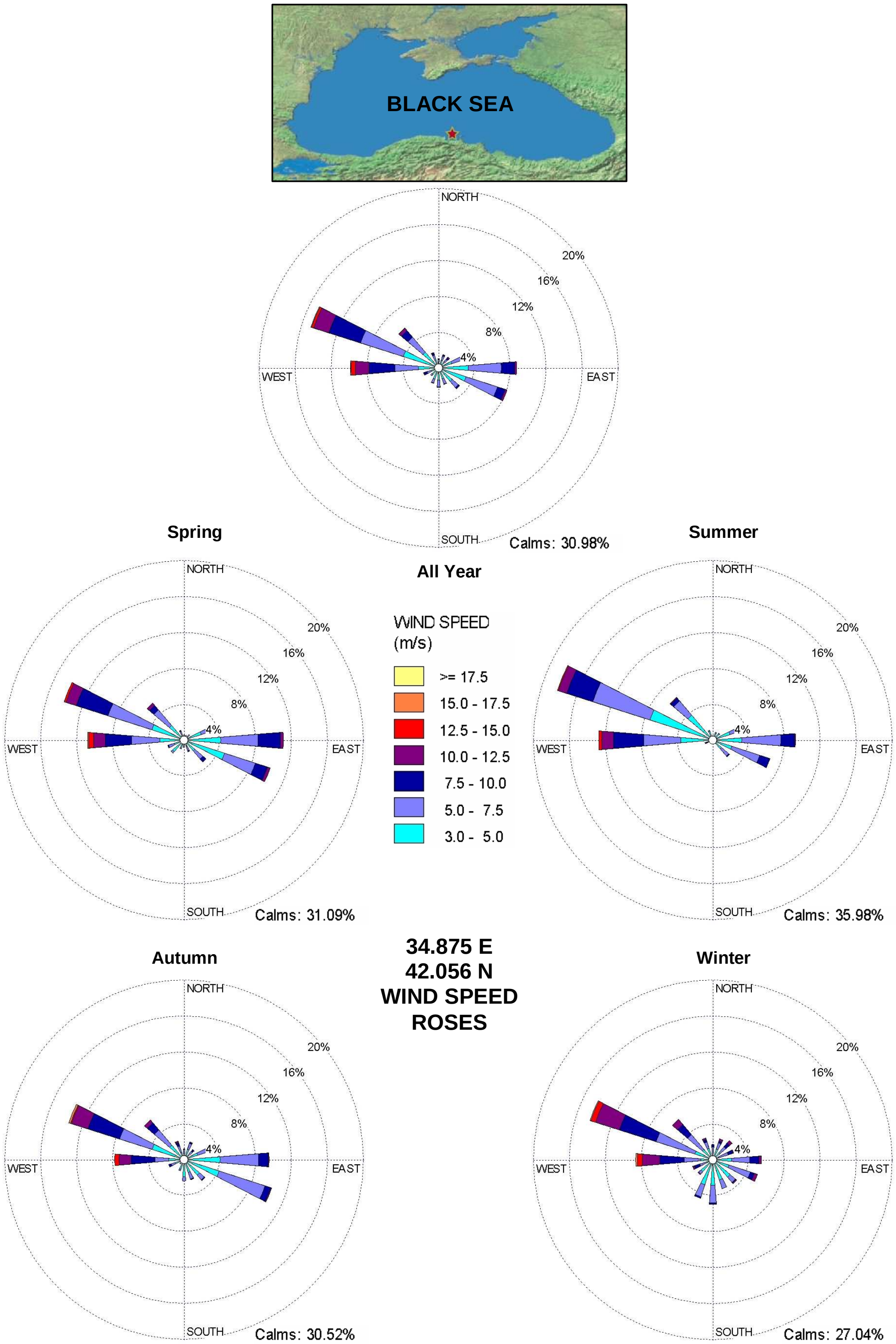

Figure 4.7.1 Wind climate at 42.056 N, 34.875 E

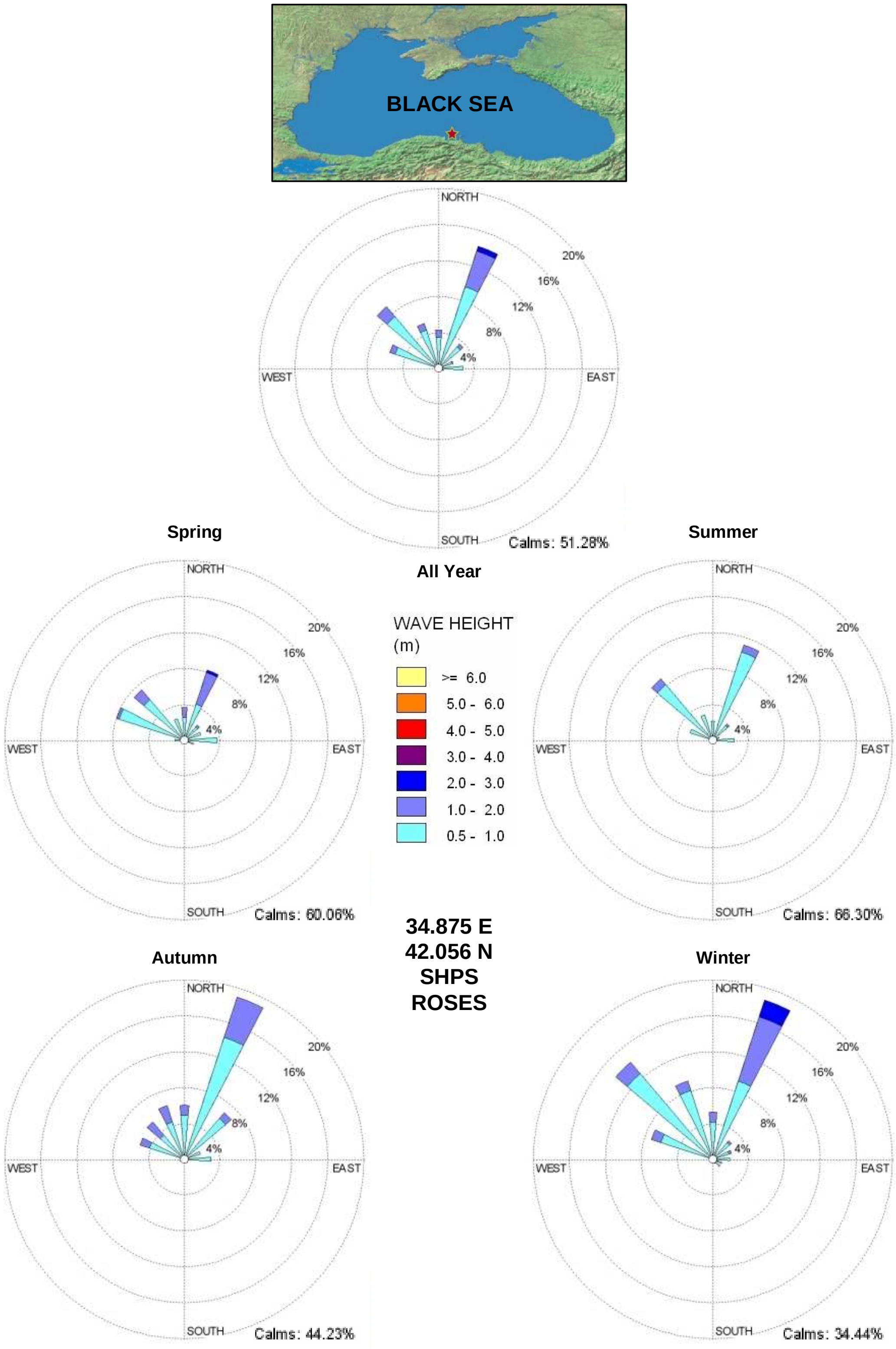

Figure 4.7.2 SHPS climate at 42.056 N, 34.875 E

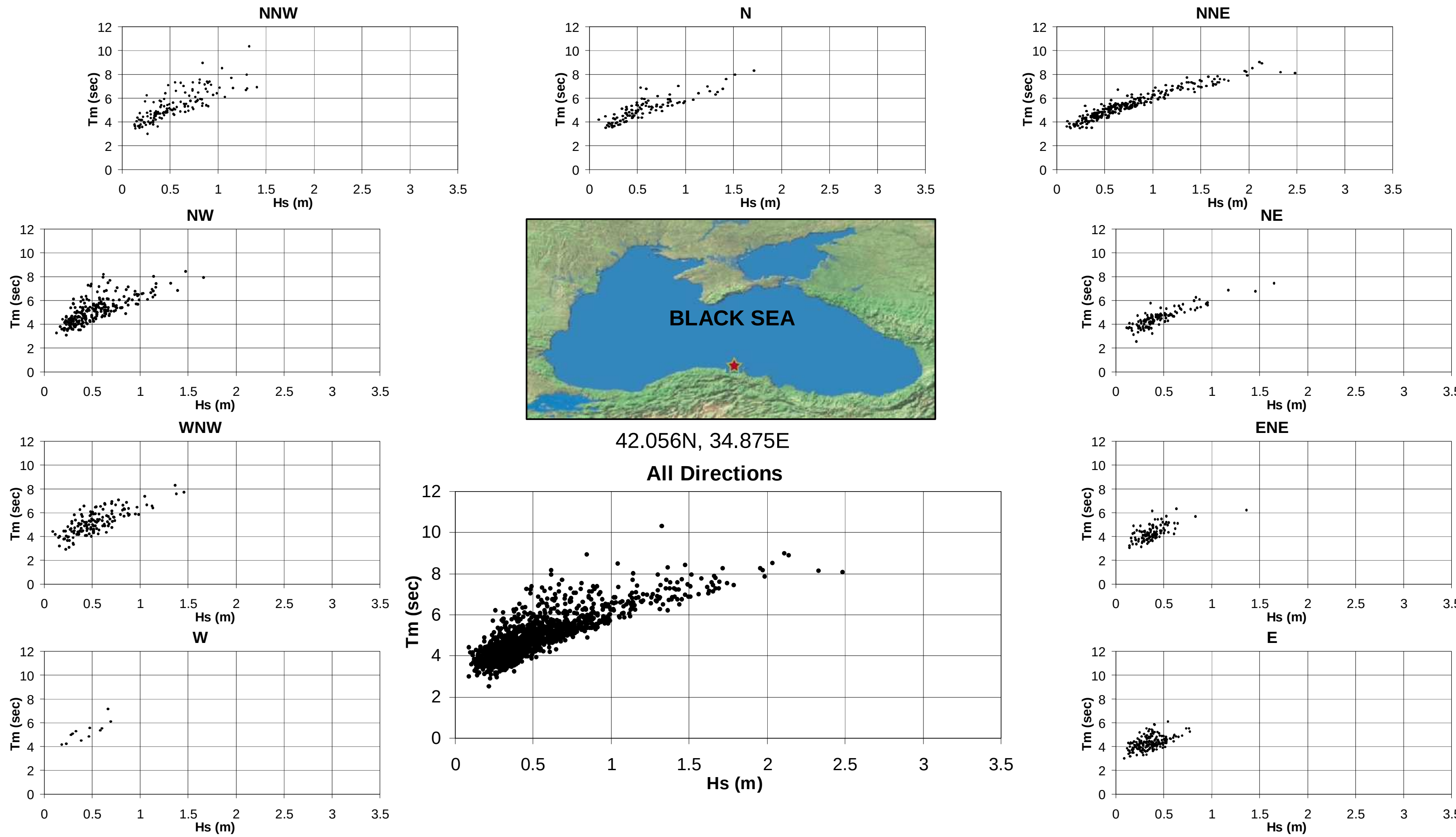

Figure 4.7.3 Relationship between MPPS & SHPS at location 09-03

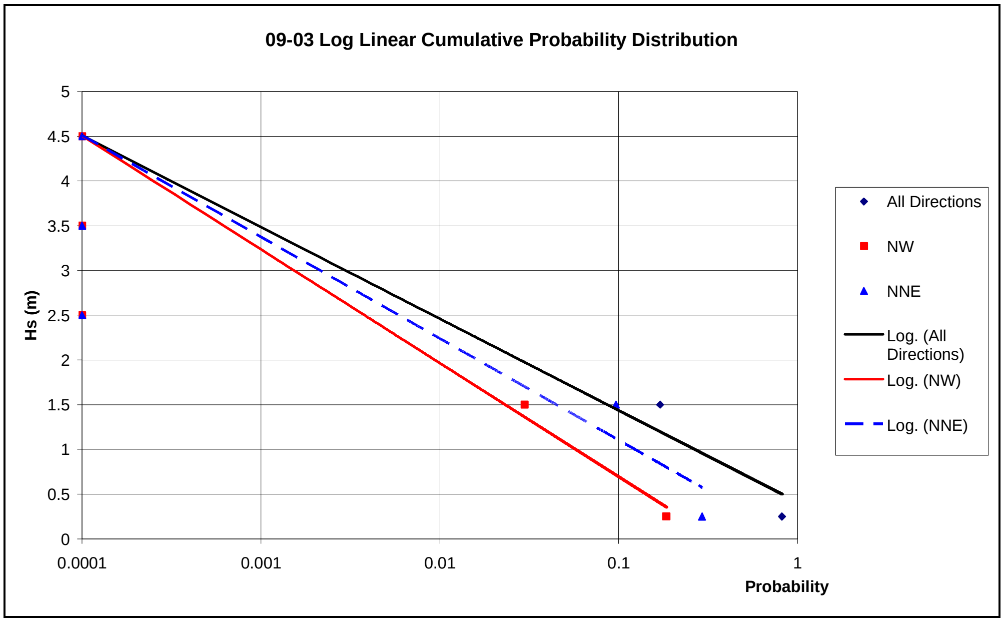

Figure 4.7.4 Log-Linear cumulative probability distribution at 42.056 N, 34.875 E

4.8. LOCATION 10-03 – BAFRA

The 10-03 abbreviated point is located approximately 40 km North of Bafra, Samsun shores i.e. Kızılırmak delta and 70 km East of Sinop. In this context Bafra location (10-03) is in the eastern part of Black Sea. The coordinates of point 10-03 is; 42.056 N, 36 E.

The Wind Roses, Swell Wave Roses, Significant Wave Height (H_s) vs. Mean Wave Period (T_m) 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. The dominant direction is WNW for every season, with 20 percent of occurrence in summer. And secondary direction can be said to be NW. Also relatively strong winds are seen from reverse direction, namely ESE. Calm duration is about 25 percent for a full year.

Wind Roses are compared with the wind roses at the nearest location (41.75 N, 35.9 E) in Ozhan and Abdalla, (1999) where the dominant wind is from WNW 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 winter season. In Ozhan and Abdalla, 1999, the south-western winds have less occurrence comparing to this study in winter.

Swell wave roses are given in Figure 4.8.2. Swell waves are effective in a range from WNW to NNE, dominant direction being NNE. Calm duration is around 50 percent for a full year. It should be noted that swell waves from NNW direction is limited. Swell wave heights larger than 2 meters are significant in winter.

The relations between Significant Wave Height (H_s) vs. Mean Wave Period (T_m) are given in Figure 4.8.3. Significant swell wave heights higher than 2 meters are observed generally only from NNE direction. The scatter is quite narrow for NNE direction and all Mean periods are smaller than 10 seconds. The maxima are observed as 2.564 meters of wave height from NNE and 10.994 seconds of period from NNW. Higher and lower limits of the steepness of swell waves at this location (From Figure 4.8.3) are 0.022 and 0.005 respectively.

The graph of extreme value probability statistics is given in Figure 4.8.4. Data values show a good correlation. Significant wave height is estimated as 3.3 meters for 100 year return period.

Log-linear cumulative probability distribution is given in Figure 4.8.5. Directions NNE, NNW, NW and WNW are plotted along with all directions. It is seen from this graph that significant height of swell waves exceeds 3.8 meters in about 10 hours duration every year.

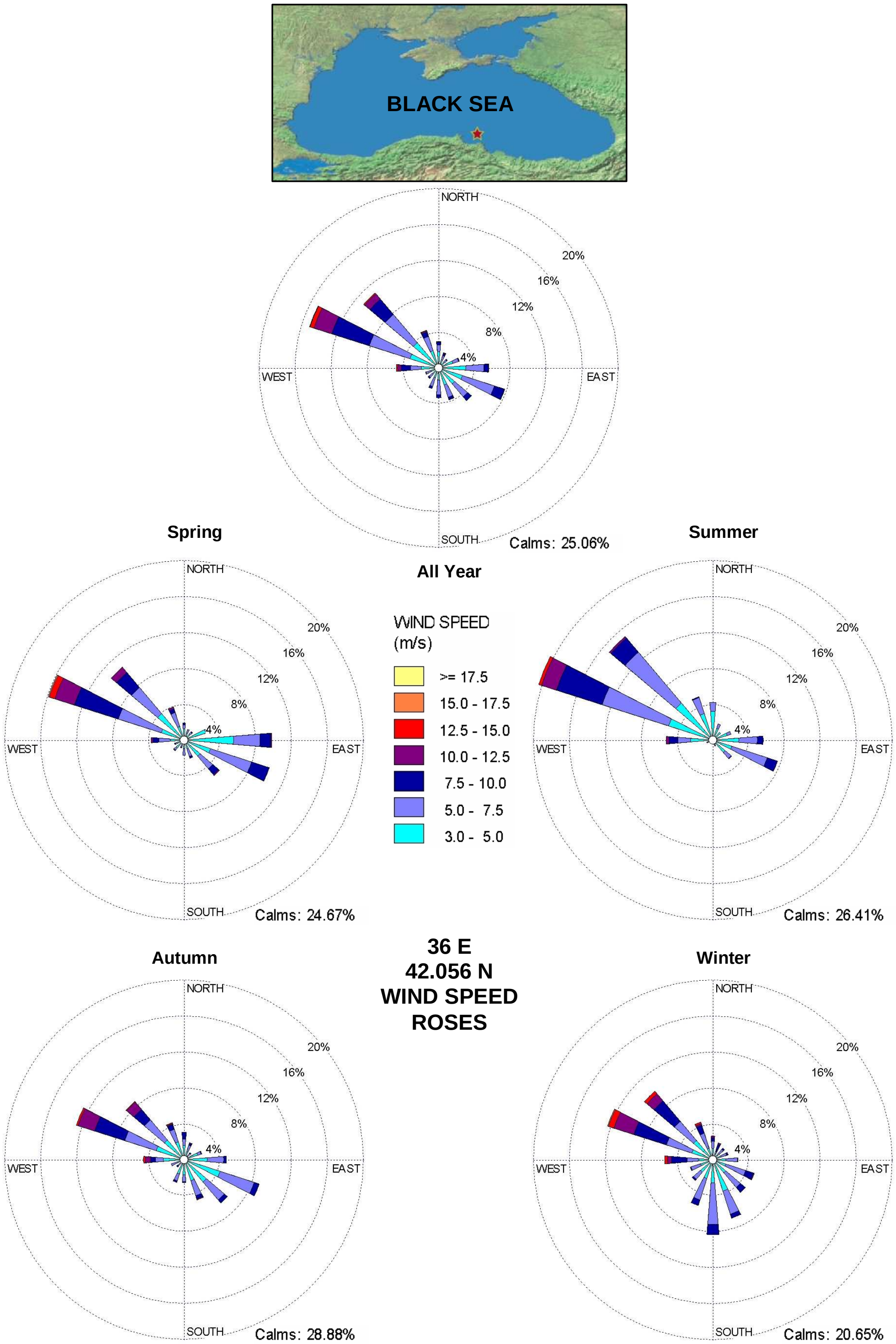

Figure 4.8.1 Wind climate at 42.056 N, 36 E

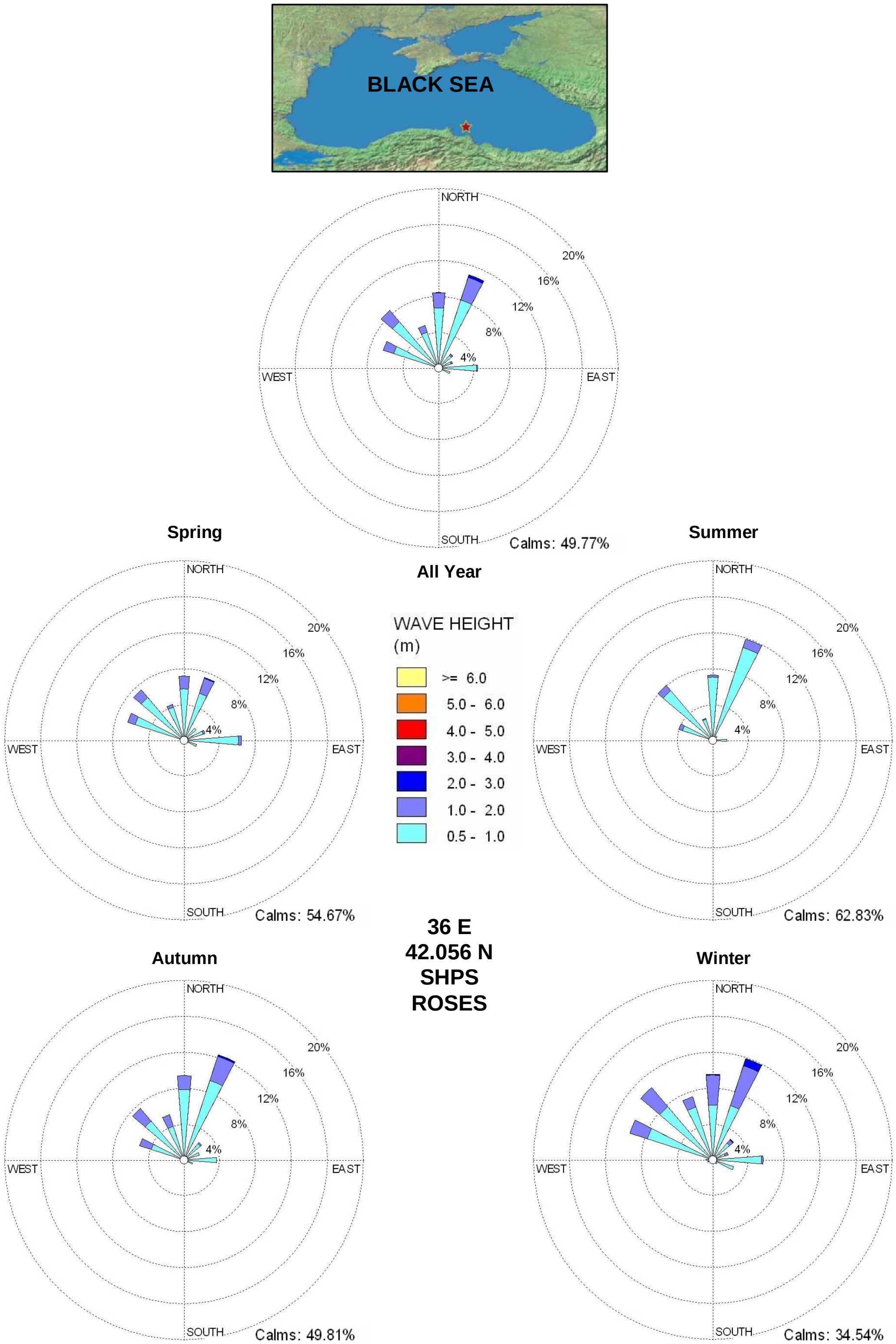

Figure 4.8.2 SHPS climate at 42.056 N, 36 E

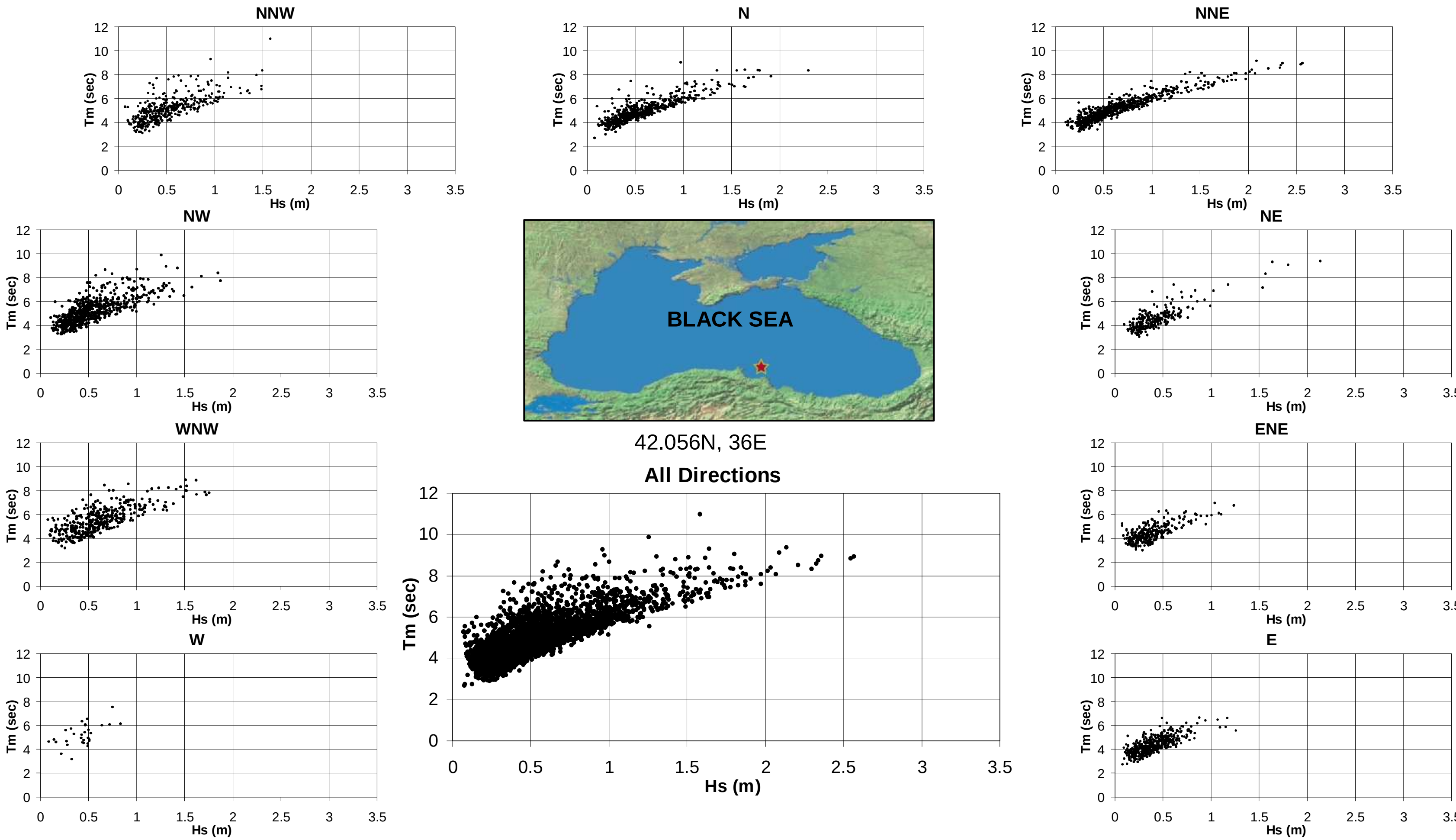

Figure 4.8.3 Relationship between MPPS & SHPS at location 10-03

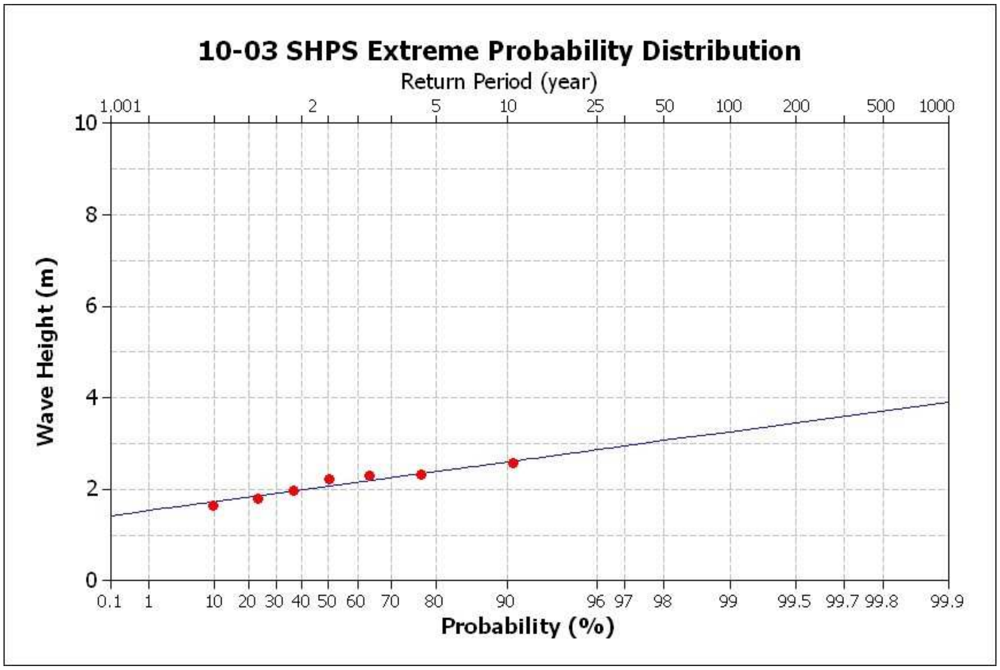

Figure 4.8.4 Extreme probability distribution at location 42.056 N, 36 E

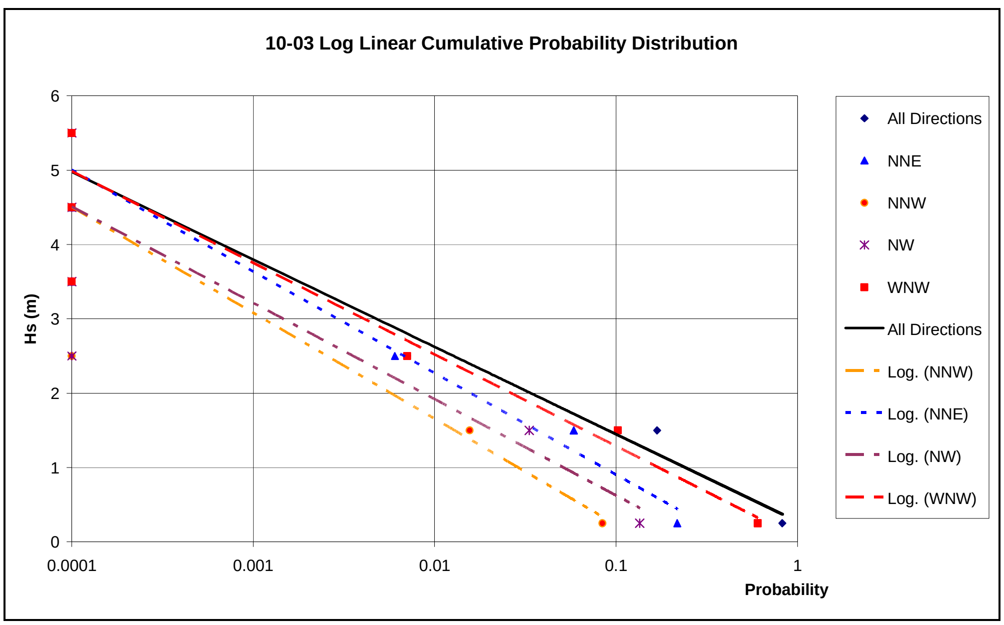

Figure 4.8.5 Log-Linear cumulative probability distribution at 42.056 N, 36 E

4.9. LOCATION 11-03 – SAMSUN

The 11-03 abbreviated point is located approximately 108 km North-East of Samsun. The coordinates of point 11-03 is; 42.056 N, 37.125 E.

The Wind Roses, Swell Wave Roses, Significant Wave Height (H_s) vs. Mean Wave Period (T_m) 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. Main direction of incoming winds are WNW and NW and WNW prevails NW except winter. Calm duration is about 27 percent for a full year. In winter considerable amount of occurrences are from South and SSE both being around 7 percent.

Wind Roses are compared with the wind roses at the nearest location (41.5 N, 37.1 E) in Ozhan and Abdalla, (1999) where the dominant wind is from WNW direction for this location. The yearly wind roses are in correlation with both studies except the ESE direction which is larger in this study. Also there are some differences in the respective roses belonging to seasons. In Ozhan and Abdalla, 1999, the western winds have less occurrence comparing to this study in spring.

Swell wave roses are given in Figure 4.9.2. In spring and winter dominating direction is WNW and in summer and autumn dominating direction is N. NW and NNW directions are also in considerable amounts however occurrence probability of swell waves from NNW direction is very limited compared to NW. For a full year occurrence probability of swells from WNW direction is approximately 13 percent and from N direction is approximately 10 percent. And again for the full year calm duration is 47 percent.

The relations between Significant Wave Height (H_s) vs. Mean Wave Period (T_m) are given in Figure 4.9.3. In this location there is no significant wave height value larger than 2.5 meters. Maximum significant wave height is 2.474 meters and is observed from N direction. Only one data point passes 10 seconds period, this Tm maximum is 11.098 seconds observed from NW direction. The average steepness of swell waves at this location (From Figure 4.9.3) is 0.015.

The graph of extreme value probability statistics is given in Figure 4.9.4. Data values show a good correlation. Significant 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 significant directions NNE, NNW, NW and WNW are plotted along with all directions. It is seen from this graph that significant height of swell waves exceeds 3.8 meters in about 10 hours duration every year.

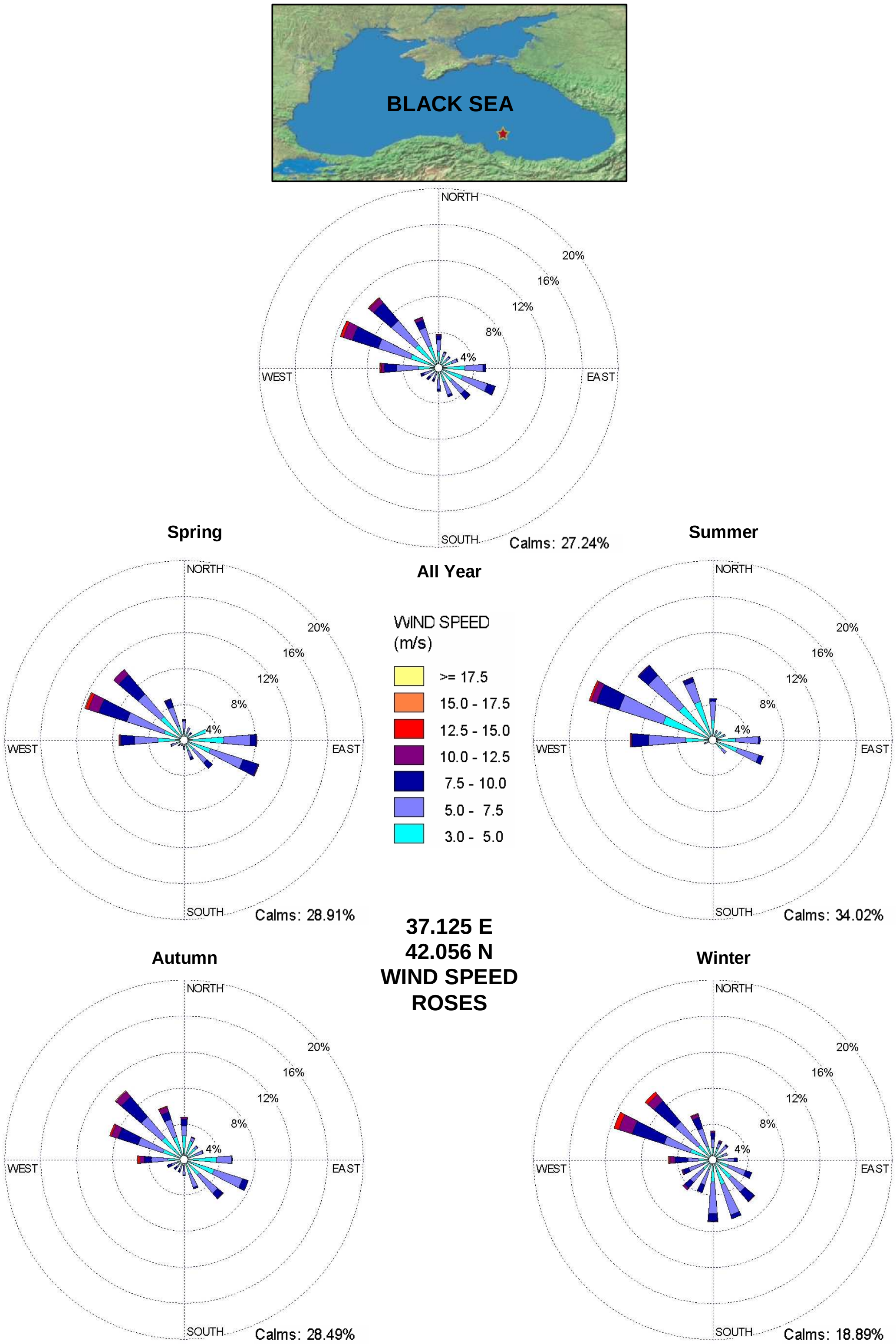

Figure 4.9.1 Wind climate at 42.056 N, 37.125 E

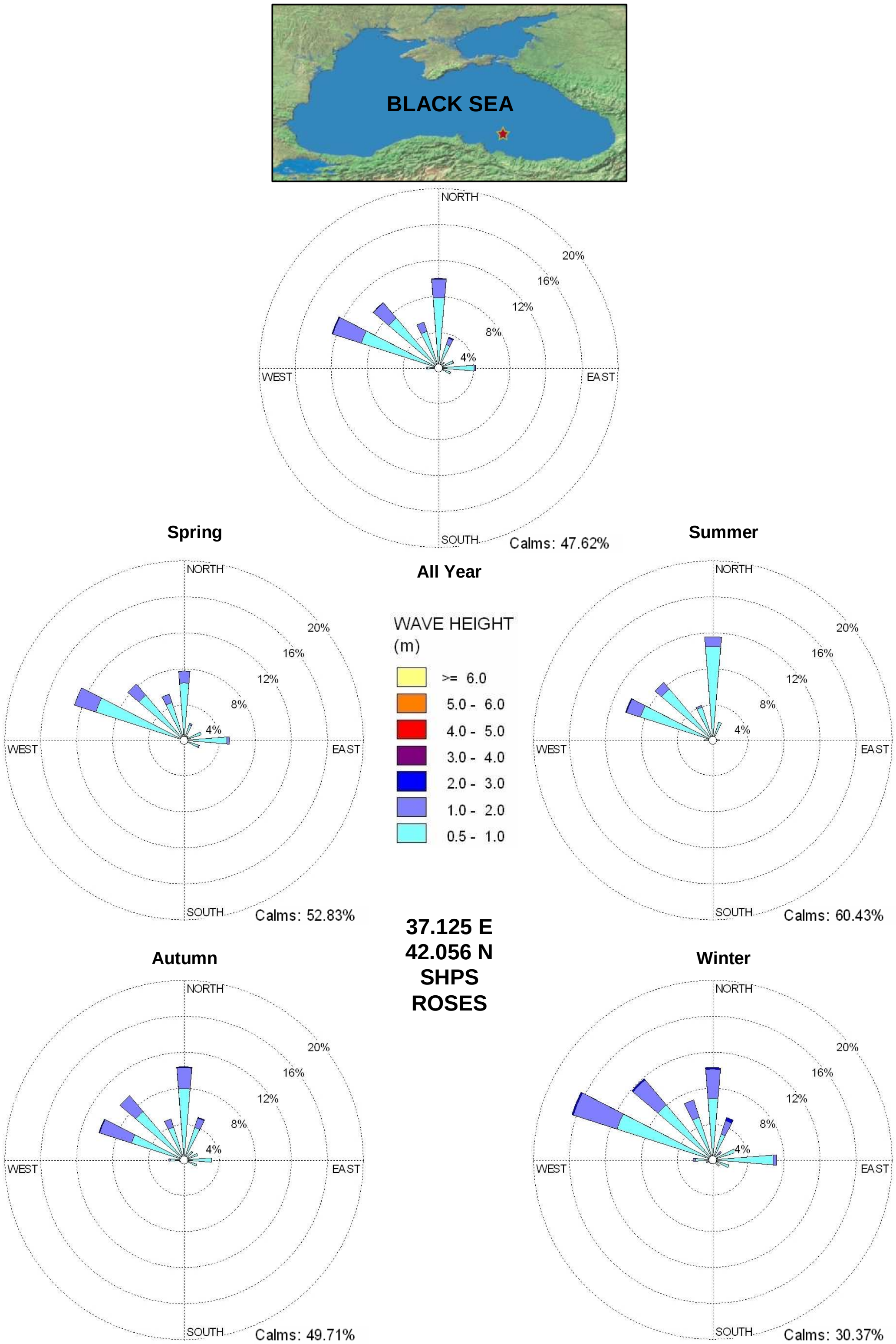

Figure 4.9.2 SHPS climate at 42.056 N, 37.125 E

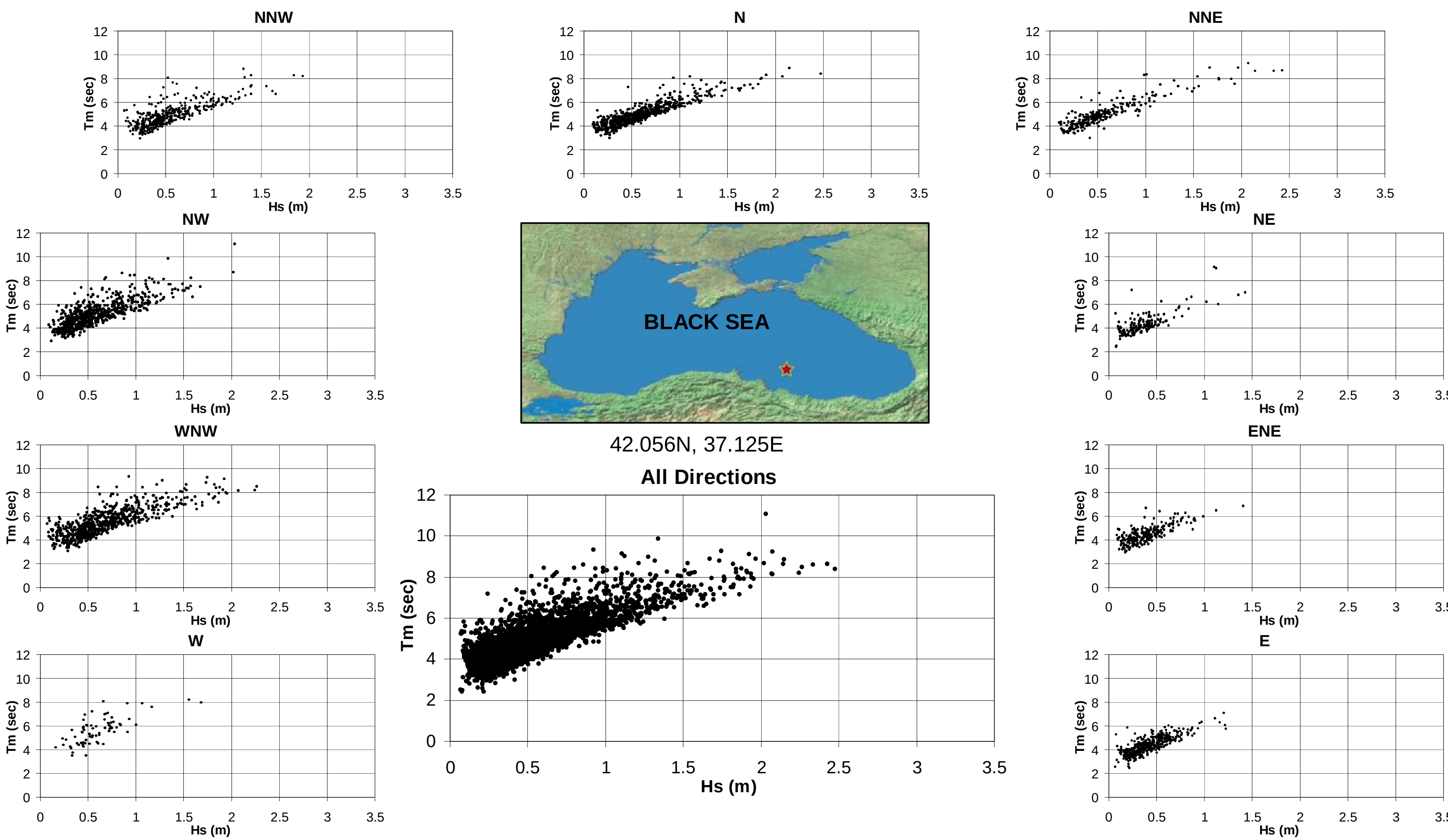

Figure 4.9.3 Relationship between MPPS & SHPS at location 11-03

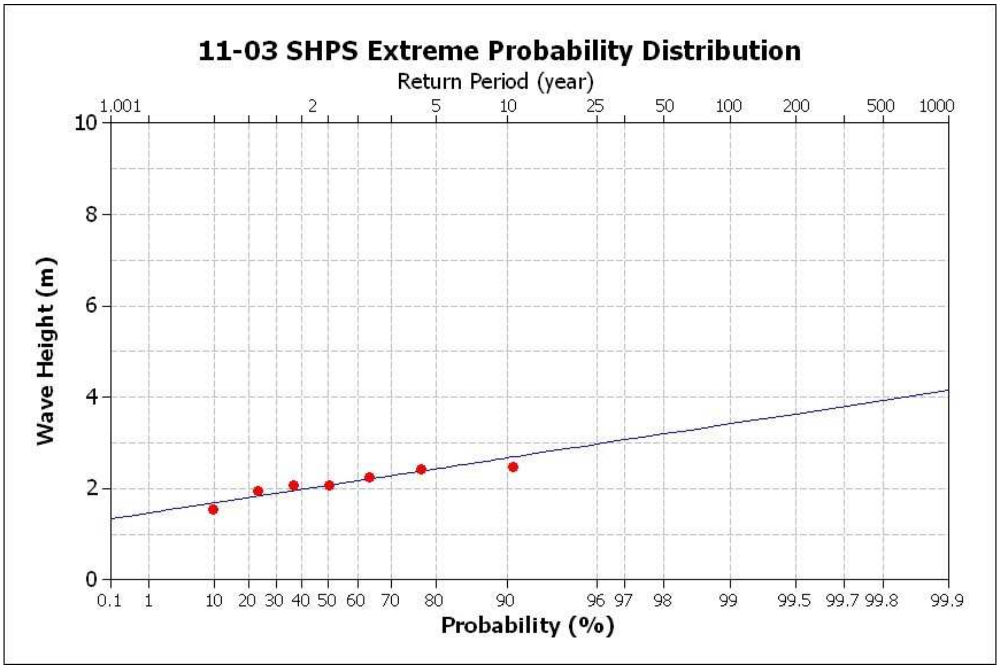

Figure 4.9.4 Extreme probability distribution at location 42.056 N, 37.125 E

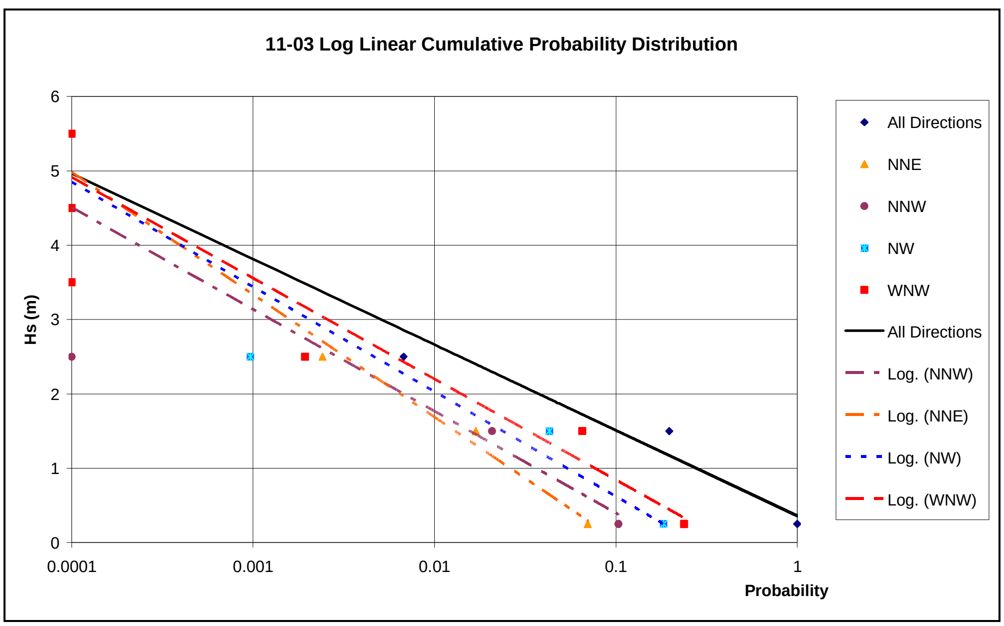

Figure 4.9.5 Log-Linear cumulative probability distribution at 42.056 N, 37.125 E

4.10. LOCATION 12-03 – NORTH OF BULANCAK

The 12-03 abbreviated point is located approximately 125 km North of Bulancak, Giresun. The location is in the eastern part of Black Sea and quite far from shore. The coordinates of point 12-03 is; 42.056 N, 38.25 E.

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

Wind climate roses are given in Figure 4.10.1. The roses show that about 30 percent of the time in a full year wind climate is considered as calm. In autumn and winter winds are effective along NW-SE direction, in spring winds are effective along W-E direction. In summer winds are only effective from W to NW and the calm percentage increases to about 45 percent. In winter the calm percent is as low as 22 percent.

Wind Roses are compared with the wind roses at the nearest location (41.25 N, 38.3 E) in Ozhan and Abdalla, (1999) where the dominant wind is from WNW direction for this location. The yearly wind roses are in correlation with both studies except the south-western winds. There are some differences in the respective roses belonging to seasons. In Ozhan and Abdalla, 1999, the western winds have much less occurrence comparing to this study generally.

Swell wave climate roses are given in Figure 4.10.2 and show a clear indication of direction of incoming swell waves. Dominant direction is WNW at all times, having approximately 18 percent of occurrence probability. Secondary dominant directions, NW and NNW are limited to 10 percent of occurrence. Also swell waves coming from E is noticeable for all seasons except summer. Significant swell wave heights higher than 2 meters can be seen for all seasons.

The relations between Significant Wave Height (H_s) vs. Mean Wave Period (T_m) are given in Figure 4.10.3. Hs maximum is seen as 2.533 meters coming form N direction and Tm maximum is seen as 10.606 seconds coming form NW direction. But waves with Hs higher than 2 meters and Tm greater than 8 seconds are also observed coming from WNW direction. Higher and lower limits of the steepness of swell waves at this location (From Figure 4.10.3) are 0.019 and 0.01 respectively.

The graph of extreme value probability statistics is given in Figure 4.10.4. Data values show a good correlation. Significant wave height is estimated as 3.6 meters for 100 year return period.

Log-linear cumulative probability distribution is given in Figure 4.10.5. Directions NNW, NW, WNW and N are plotted along with all directions. It is seen from this graph that significant height of swell waves exceeds 3.6 meters in about 10 hours duration every year.

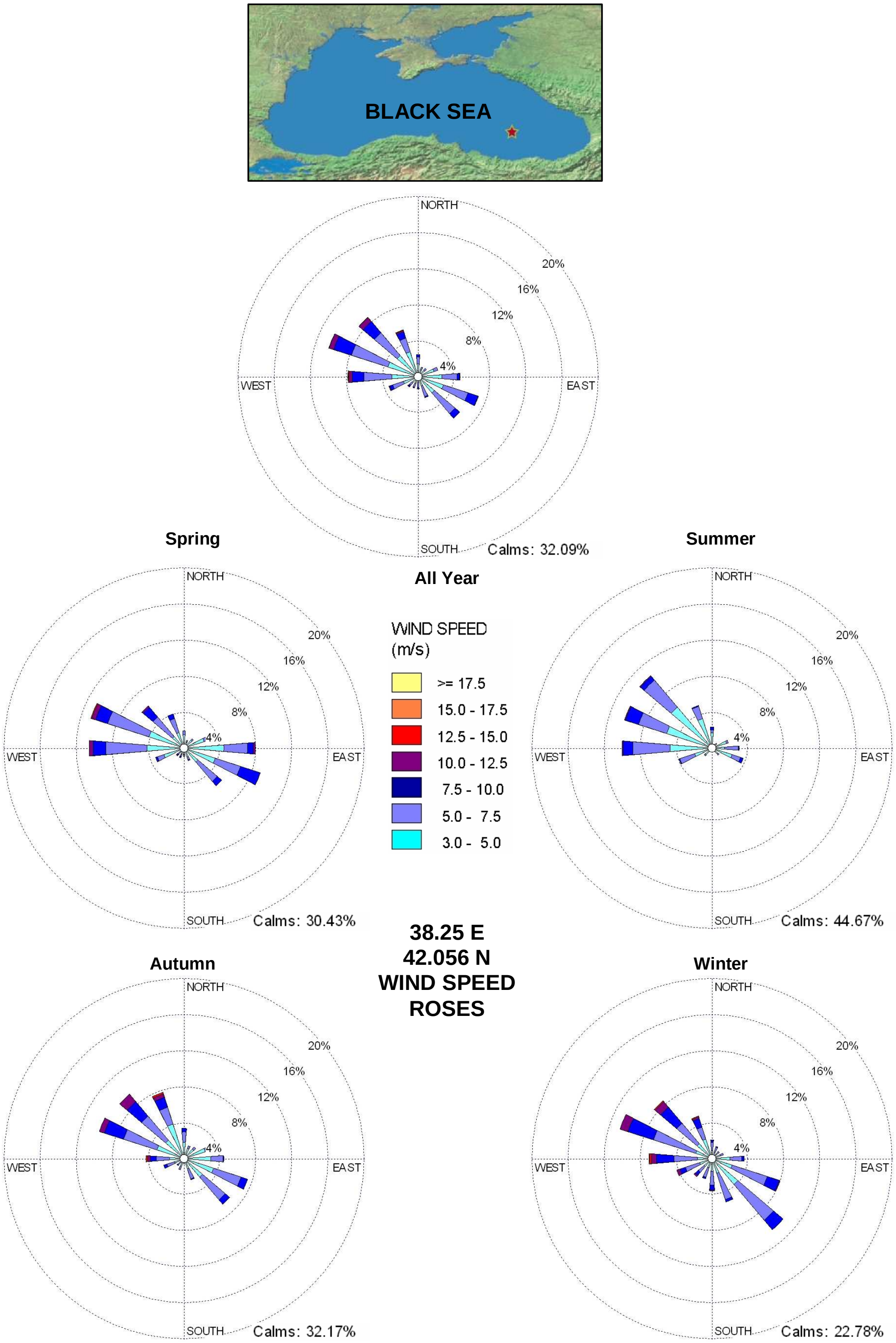

Figure 4.10.1 Wind climate at 42.056 N, 38.25 E

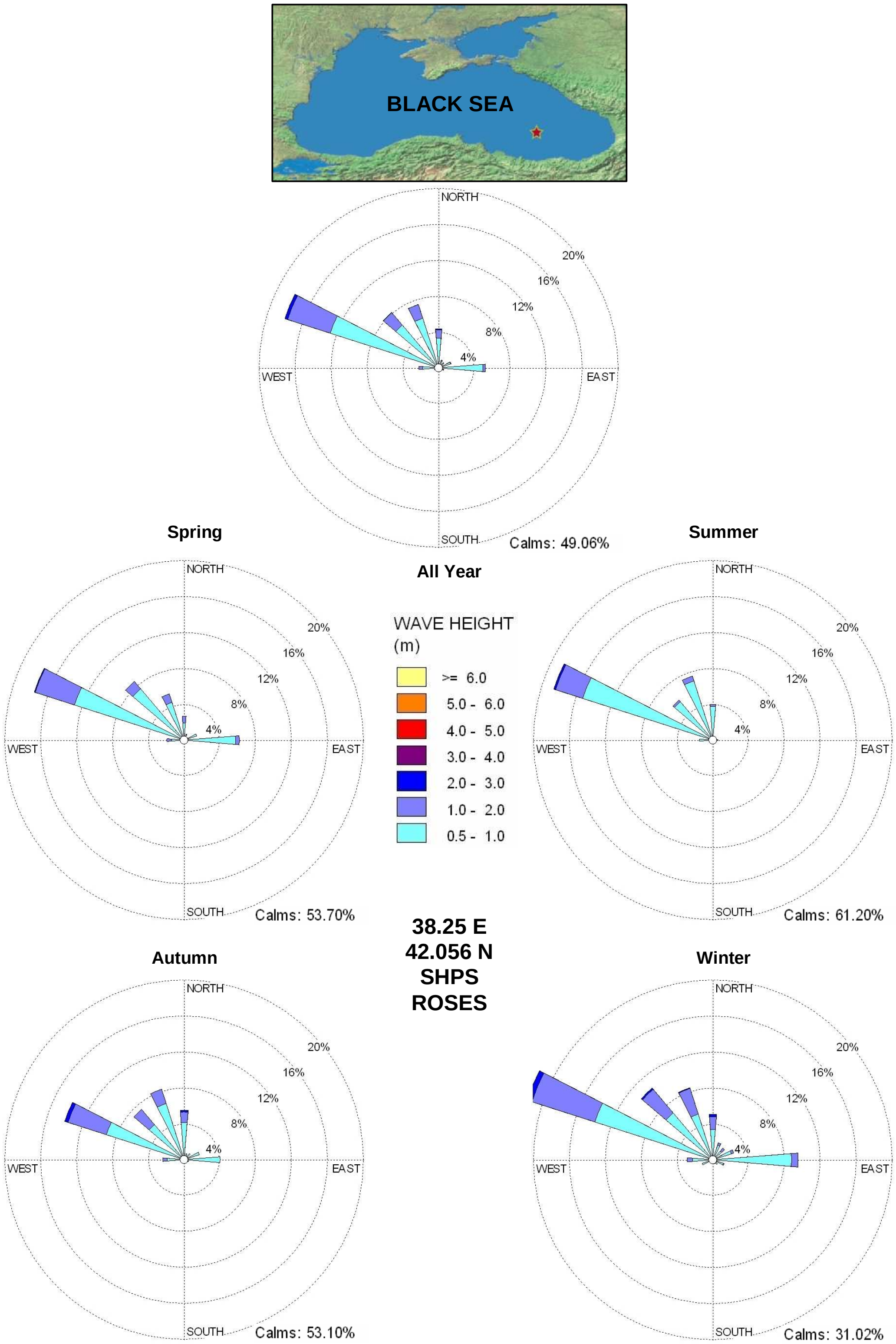

Figure 4.10.2 SHPS climate at 42.056 N, 38.25 E

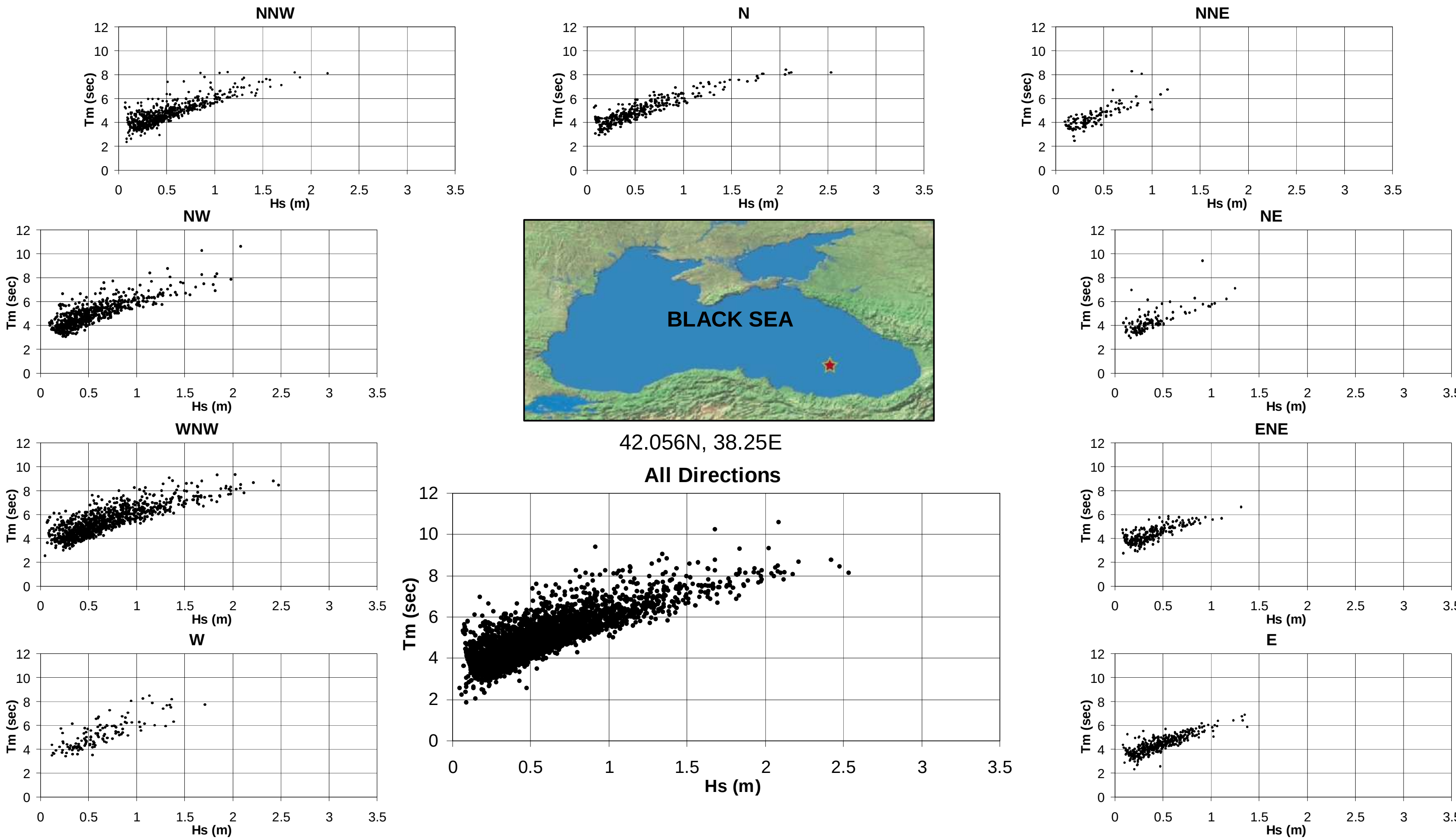

Figure 4.10.3 Relationship between MPPS & SHPS at location 12-03

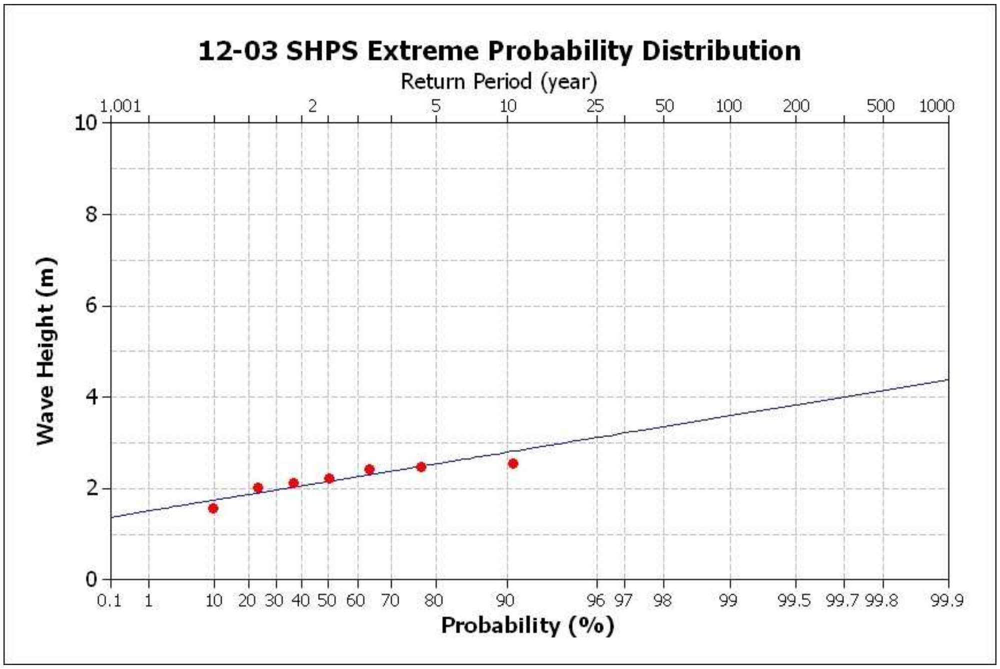

Figure 4.10.4 Extreme probability distribution at location 42.056 N, 38.25 E

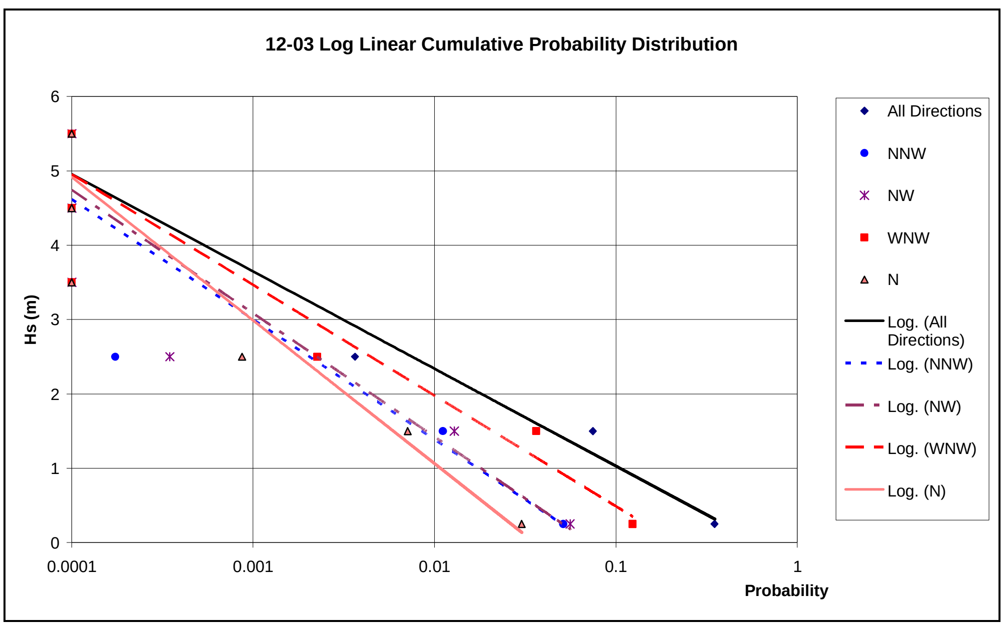

Figure 4.10.5 Log-Linear cumulative probability distribution at 42.056 N, 38.25 E

4.11. LOCATION 13-03 – NORTH OF TRABZON

The 13-03 abbreviated point is located approximately 125 km North-North-North west of Trabzon. The location is quite far from shore. The coordinates of point 13-03 is; 42.056 N, 39.375 E.

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

Wind climate roses are given in Figure 4.11.1. A single dominant direction can not be stated for this location. For full year the occurrence probabilities of winds from W, WNW and ESE are approximately equal and about 10 percent. However in seasons the dominant directions are easily noticeable. Calm percentage is around 35 percent for a full year.

Wind Roses are compared with the wind roses at the nearest location (41.25 N, 39.5 E) in Ozhan and Abdalla, (1999) where the dominant wind is from WNW direction for this location. The yearly wind roses are in correlation with both studies except the south-western winds. There are some differences in the respective roses belonging to seasons. In Ozhan and Abdalla, 1999, the south-western winds have much less occurrence comparing to this study generally.

Swell wave climate roses are given in Figure 4.11.2 and show a clear indication of direction of incoming swell waves. The dominant swell wave direction is WNW with a high occurrence probability as high as 25 percent in winter. For this reason scale is exaggerated to 25 percent. For the full year occurrence probability is about 19 percent and calm duration is about 55 percent. The secondary direction is NW with an occurrence rate of about 8 percent.

The relations between Significant Wave Height (H_s) vs. Mean Wave Period (T_m) are given in Figure 4.11.3. In this graph there exists one data point having Hs greater than 2.5 meters. The maximum belongs to WNW with Hs being 2.677 meters and Tm 9.931 seconds. Also there are several data points passing 2 meters of significant swell wave height and all are generated from WNW direction. The average steepness of swell waves at this location (From Figure 4.11.3) is 0.017.

The graph of extreme value probability statistics is given in Figure 4.11.4. Data values show a good correlation. Significant wave height is estimated as 3.6 meters for 100 year return period.

Log-linear cumulative probability distribution is given in Figure 4.11.5. The three dominating directions, namely NW, WNW and W are plotted along with all directions. It is seen from this graph that significant height of swell waves exceeds 3.8 meters in about 10 hours duration every year.

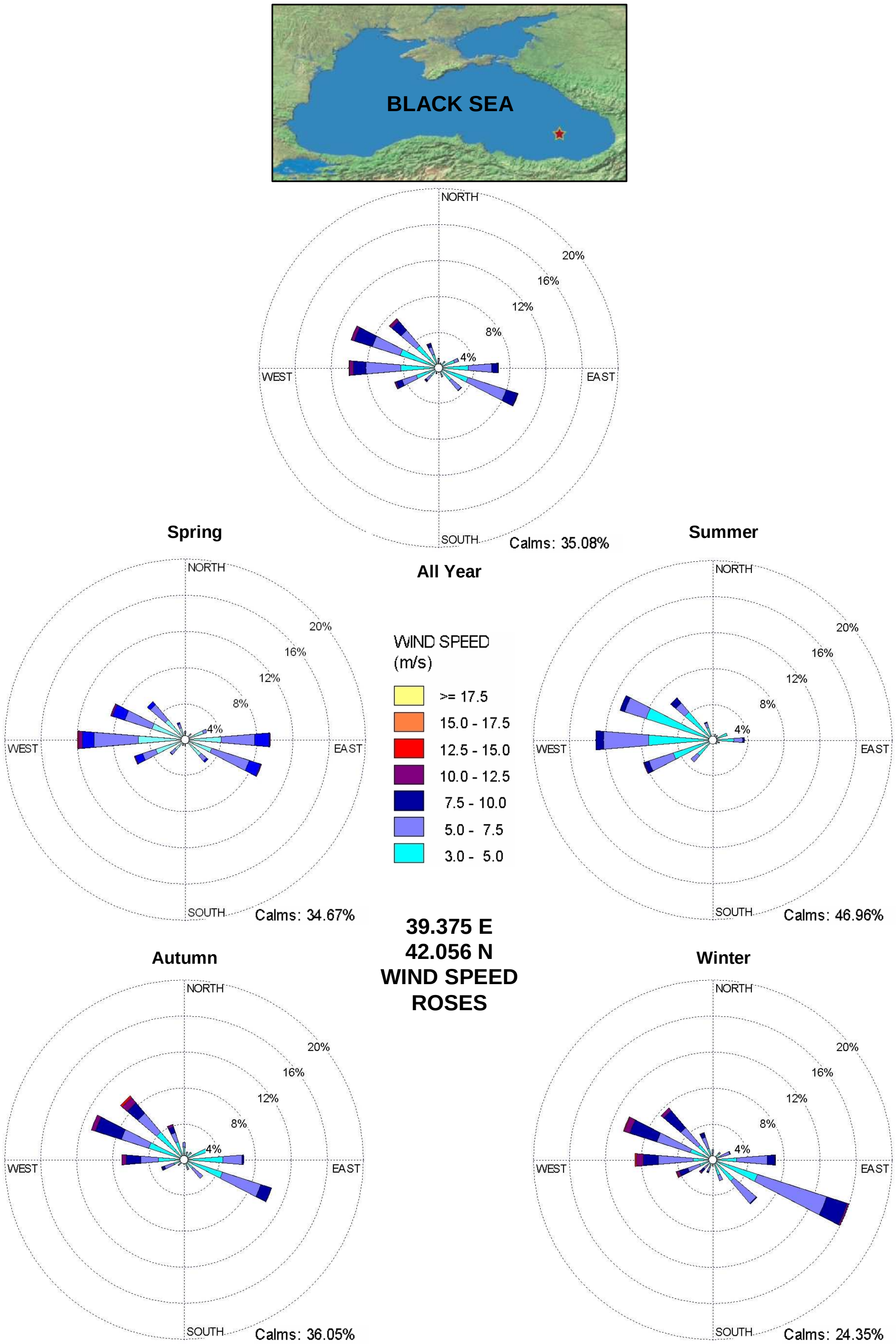

Figure 4.11.1 Wind climate at 42.056 N, 39.375 E

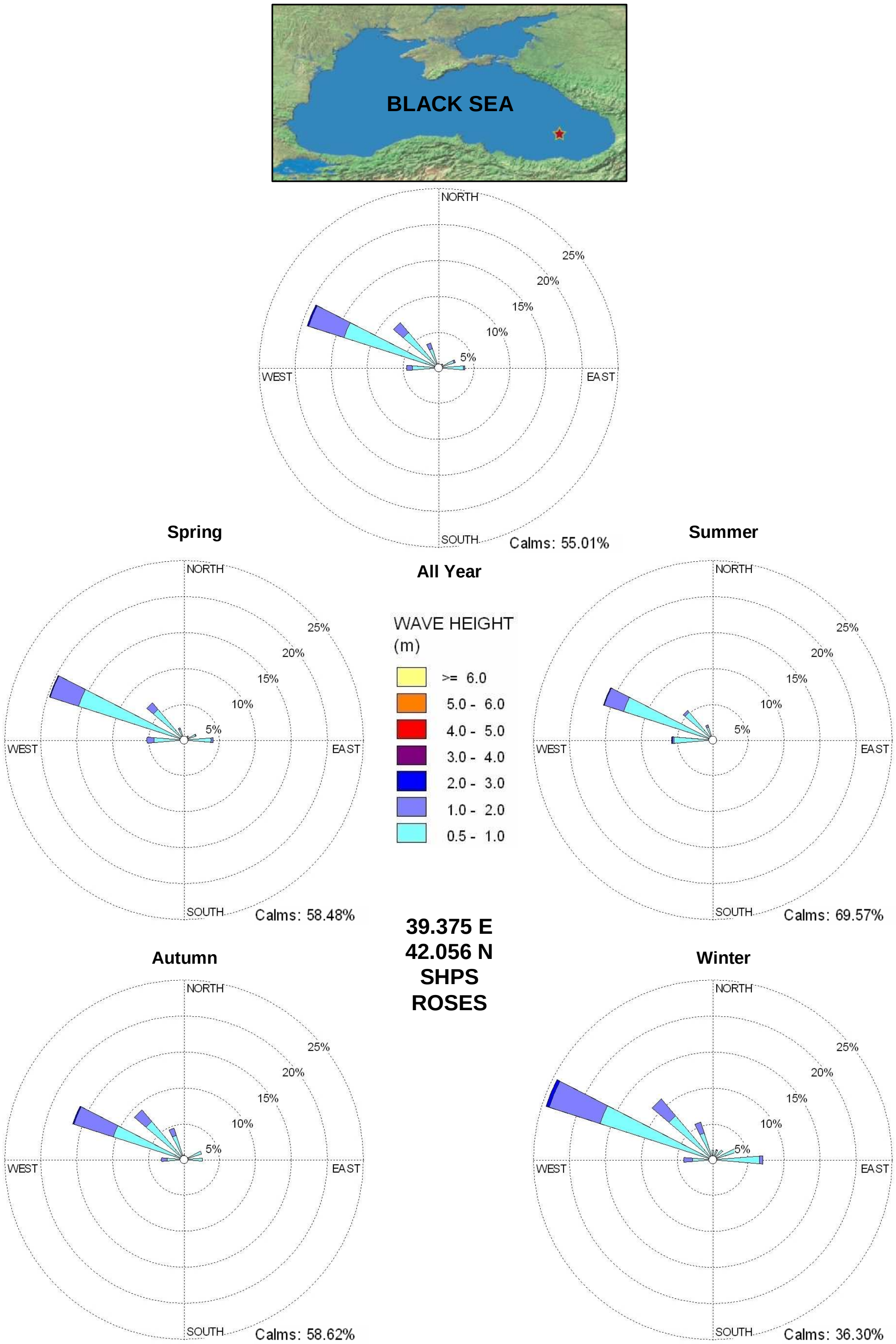

Figure 4.11.2 SHPS climate at 42.056 N, 39.375 E

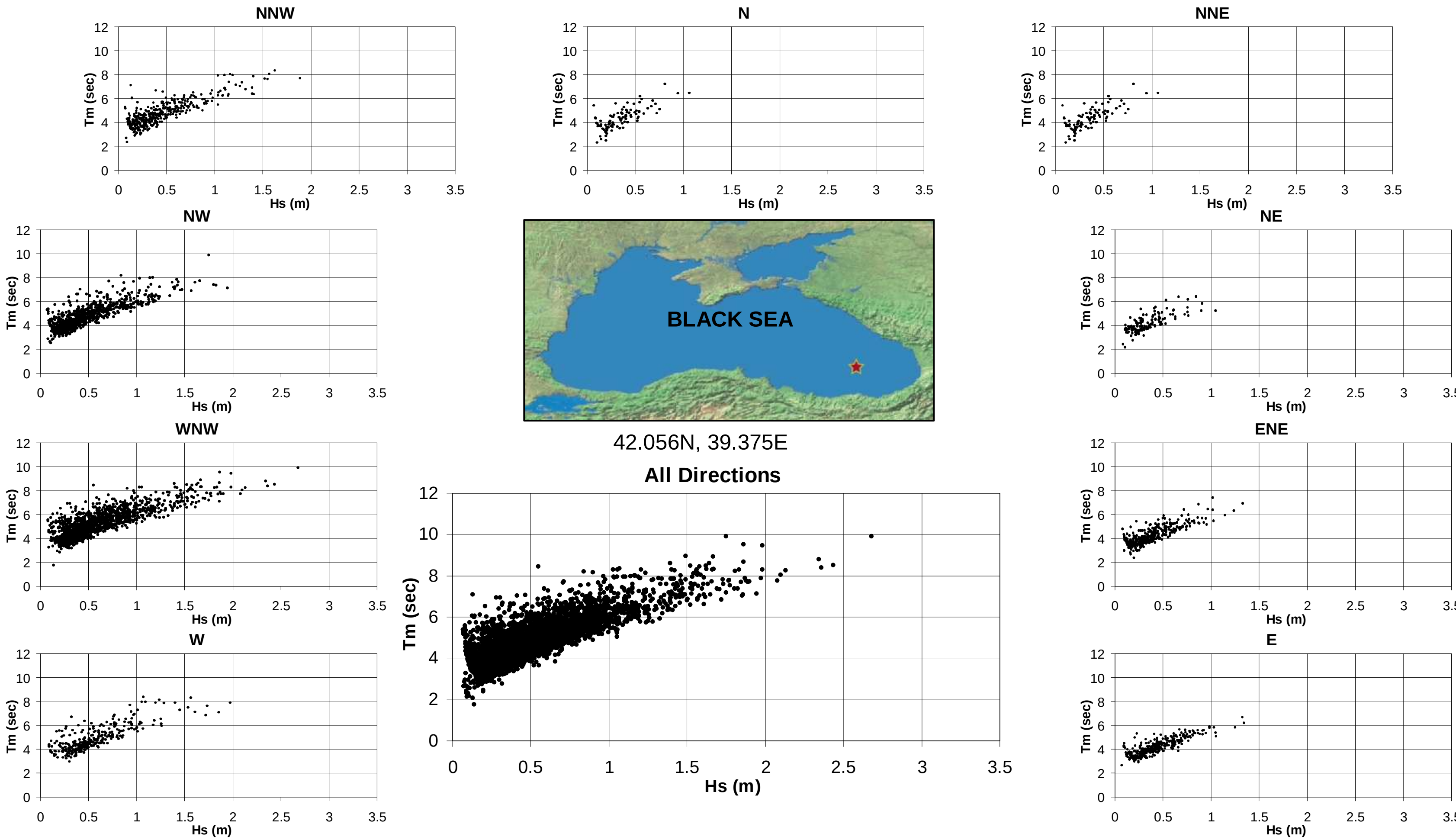

Figure 4.11.3 Relationship between MPPS & SHPS at location 13-03

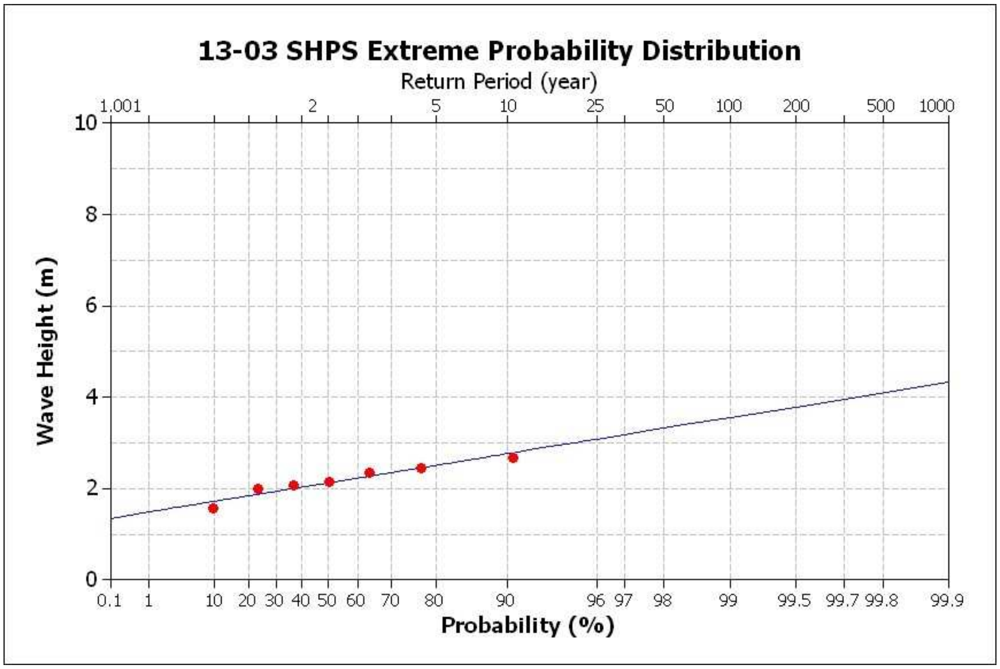

Figure 4.11.4 Extreme probability distribution at location 42.056 N, 39.375 E

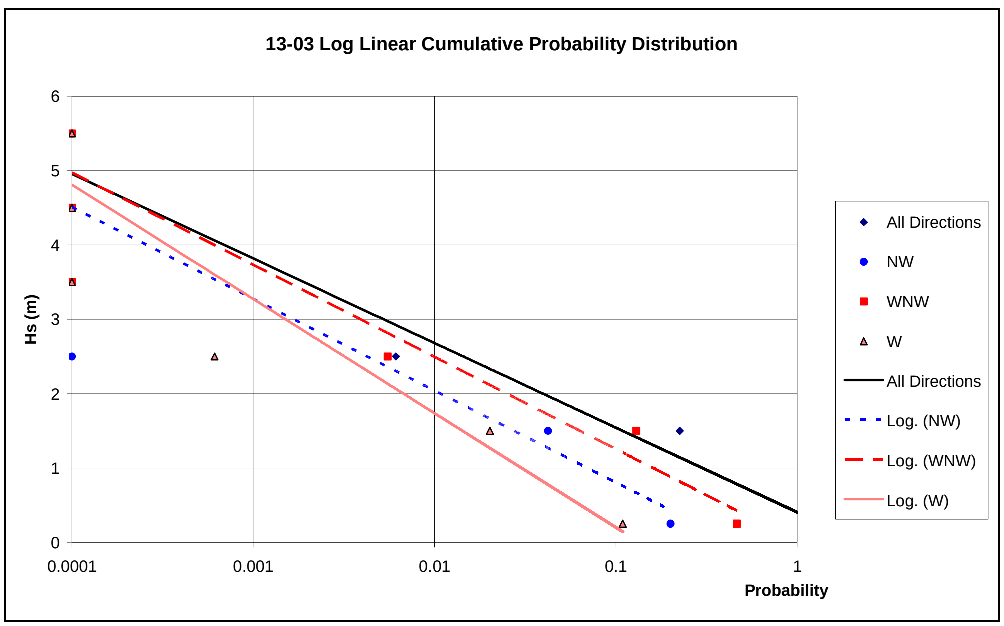

Figure 4.11.5 Log-Linear cumulative probability distribution at 42.056 N, 39.375 E

4.12. LOCATION 14-03 – WEST OF POTİ

The 14-03 abbreviated point is located approximately 97 km West of Poti, Georgia and approximately 106 km NW of Turkish-Georgian Border. The 14-03 point is approximately at equal distances to shore from North and South, each approximately around 115 km. The coordinates of point 14-03 is; 42.056 N, 40.5 E.

The Wind Roses, Swell Wave Roses, Significant Wave Height (H_s) vs. Mean Wave Period (T_m) 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 5.13.1. The dominant direction is E with a yearly occurrence rate of 15 percent. The occurrence rate of winds from E is maximum in winter with 25 percent and negligible in summer with about 2 percent. However in the opposing side winds from a range is effective for all seasons. Winds coming from WNW and W direction are about 9 and 8 percent respectively for a full year. The calm duration is about 37 percent in a year.

Wind Roses are compared with the wind roses at the nearest location (41.25 N, 40.4 E) in Ozhan and Abdalla, (1999) where the dominant wind is from E direction for this location in this study and from WNW direction in Özhan and Abdalla, (1999). The yearly wind roses are in weak correlation with both studies. There are some differences in the respective roses belonging to seasons. In Ozhan and Abdalla, 1999, the western winds have much less occurrence comparing to this study in spring.

Swell wave climate roses are given in Figure 4.12.2. Clearly the dominant direction is WNW. The occurrence rate of swell waves from WNW changes from 13 percent in summer to 25 percent in winter with a yearly average of approximately 20 percent. Neighboring directions of WNW are also observed. Calm duration is about 63 percent for a full year.

The relations between Significant Wave Height (H_s) vs. Mean Wave Period (T_m) are given in Figure 4.12.3. In this graph there exists one data point having Hs greater than 2.5 meters. The maximum belongs to WNW with Hs being 2.885 meters. The Tm maximum also belongs to WNW with 9.931 seconds. Also there are several data points passing 2 meters of significant swell wave height and all are generated from WNW direction. Higher and lower limits of the steepness of swell waves at this location (From Figure 4.12.3) are 0.02 and 0.012 respectively.

The graph of extreme value probability statistics is given in Figure 4.12.4. Data values show a fair correlation. Significant wave height is estimated as 3.1 meters for 100 year return period.

Log-linear cumulative probability distribution is given in Figure 4.12.5. The three dominating directions NW, WNW and W are plotted along with all directions. It is seen from this graph that significant height of swell waves exceeds 3.7 meters in about 10 hours duration every year.

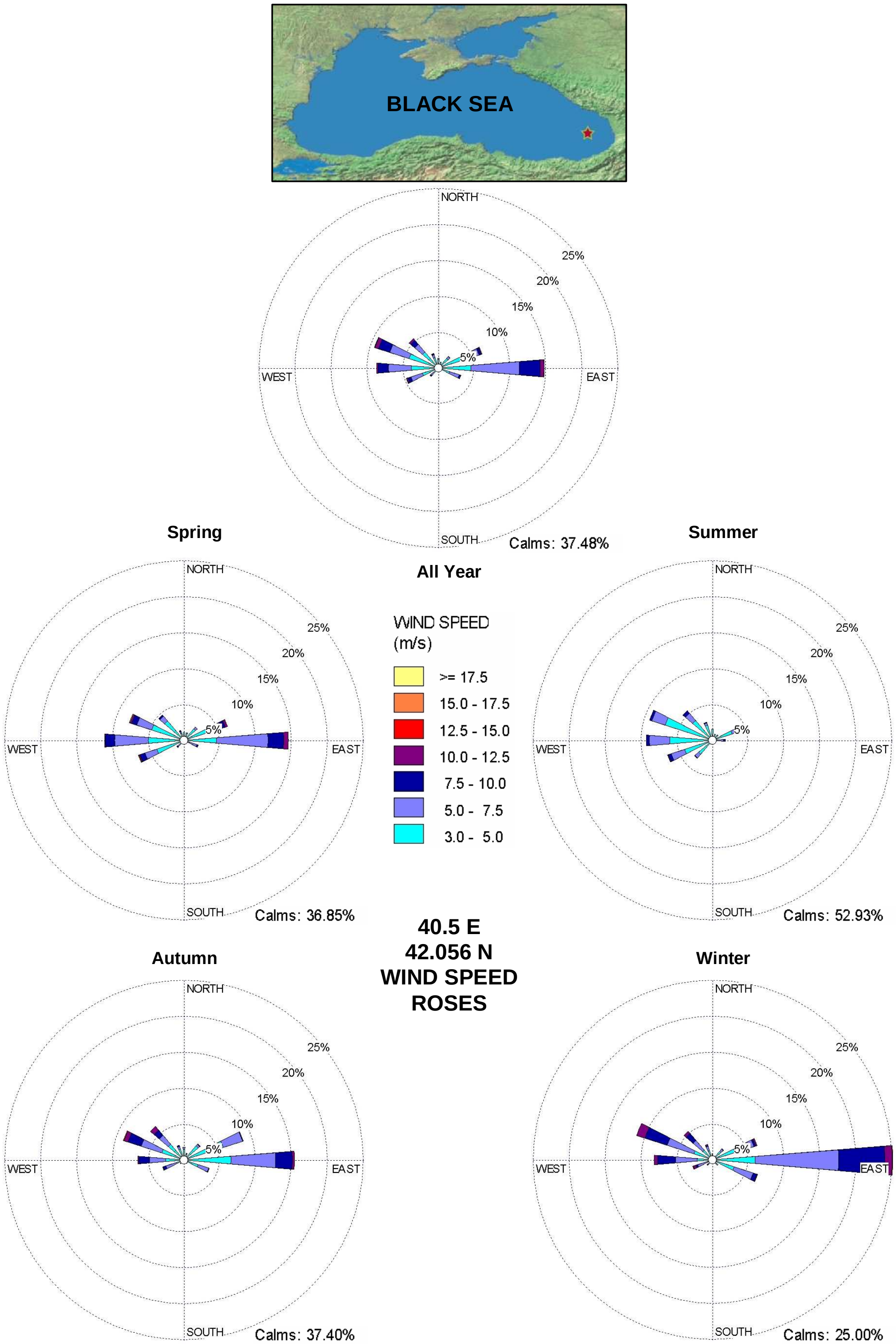

Figure 4.12.1 Wind climate at 42.056 N, 40.5 E

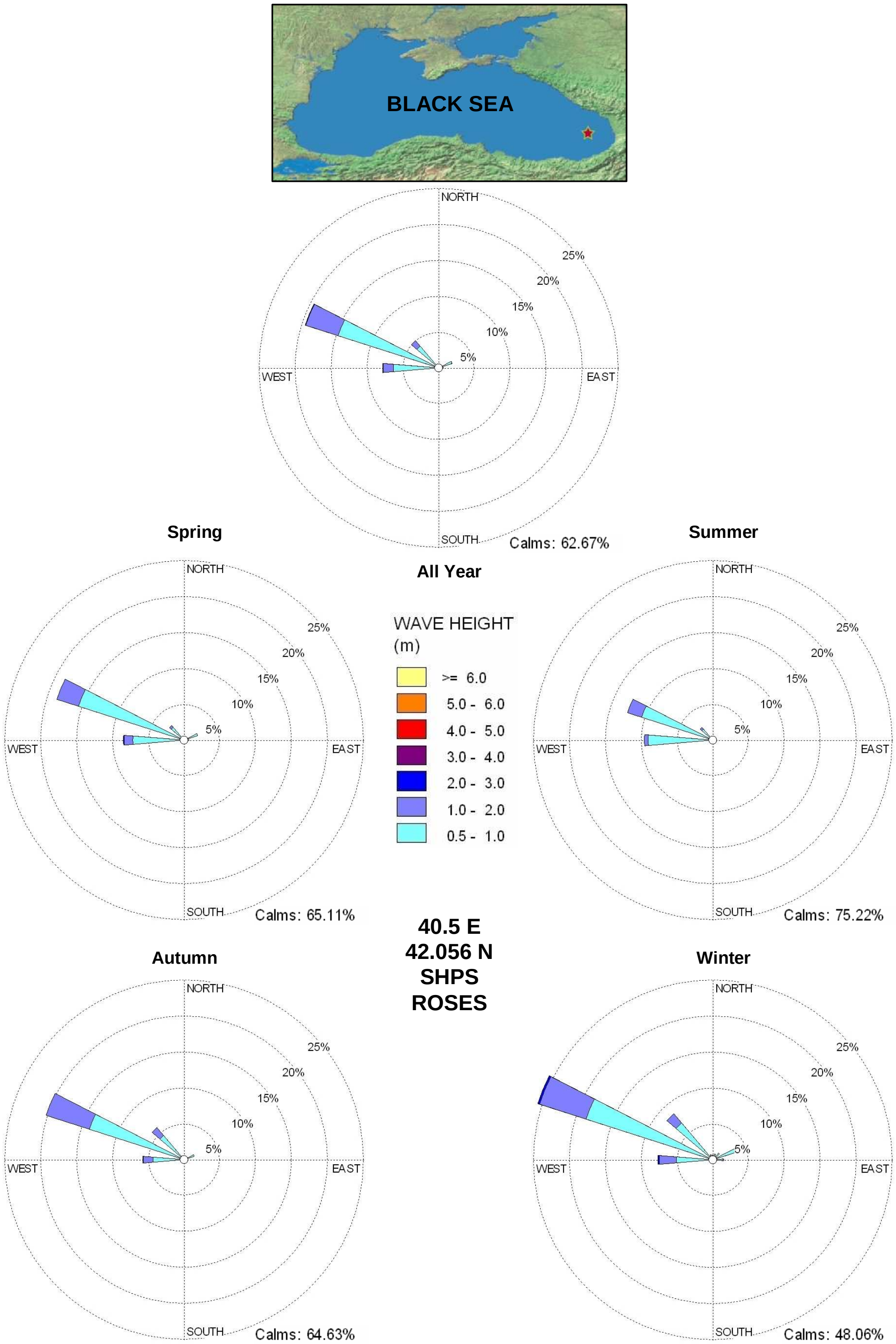

Figure 4.12.2 SHPS climate at 42.056 N, 40.5 E

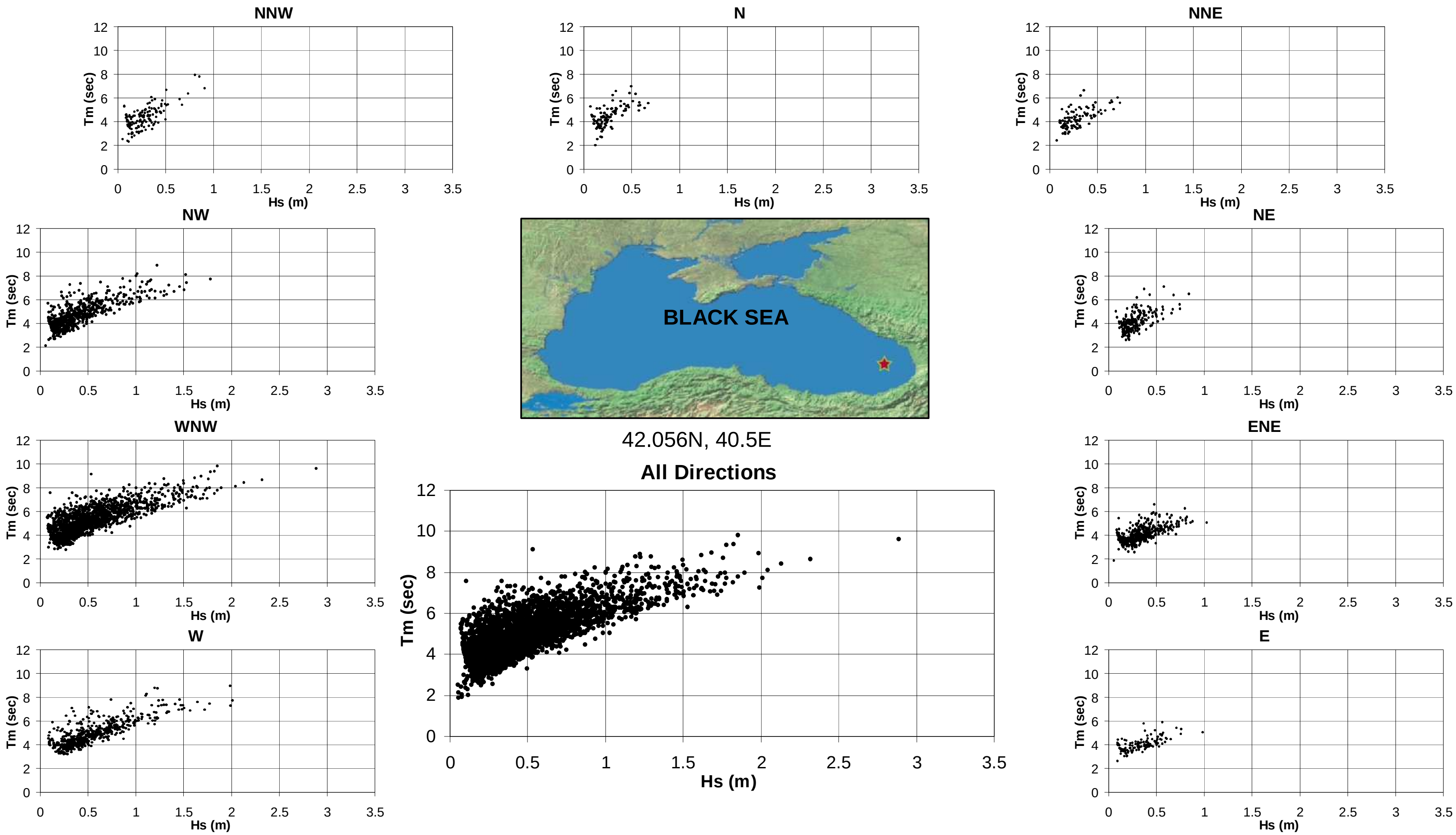

Figure 4.12.3 Relationship between MPPS & SHPS at location 14-03

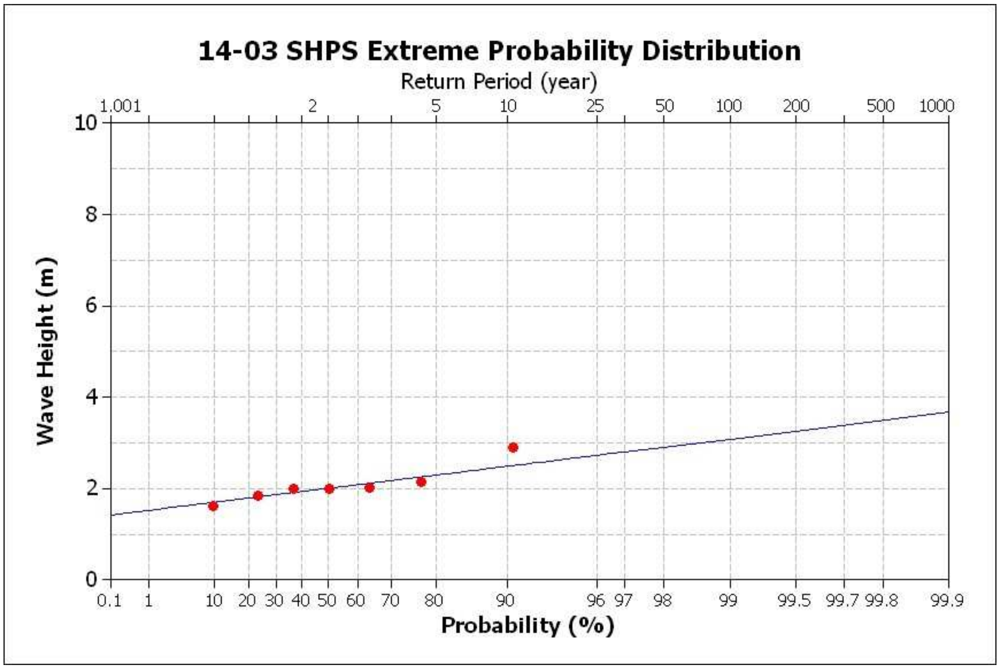

Figure 4.12.4 Extreme probability distribution at location 42.056 N, 40.5 E

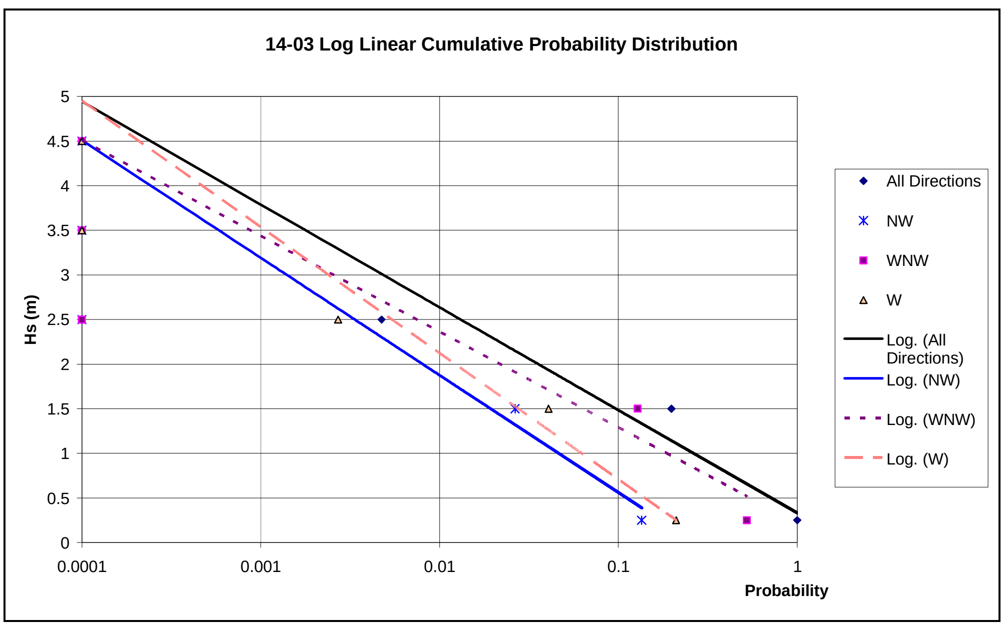

Figure 4.12.5 Log-Linear cumulative probability distribution at 42.056 N, 40.5 E

4.13. LOCATION 15-03 – POTİ

The 15-03 abbreviated point is located approximately 10 km South-South East of Poti and is only about 7 km from shore. In this context Poti location (15-03) is the most eastward point among all data points and the point is quite close to land. The coordinates of point 15-03 is; 42.056 N, 41.625 E.

The Wind Roses, Swell Wave Roses, Significant Wave Height (H_s) vs. Mean Wave Period (T_m) 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. The wind roses are similar to wind roses of location 14-03. The dominant direction is E and the secondary directions are W and WSW. The dominant direction is E in autumn and winter. In spring and summer dominant direction is WSW. For a full year occurrence rate of winds from W and WSW are around 8 percent. The calm duration is lowest in winter with 34.17 percent and highest in summer with 52.93 percent. For a full year calm duration is about 43 percent.

Wind Roses are compared with the wind roses at the nearest location (42.0 N, 41.6 E) in Ozhan and Abdalla, (1999) where the dominant wind is from E 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 spring season. In Ozhan and Abdalla, 1999, the western winds have less occurrence comparing to this study in spring.

Swell wave roses are given in Figure 4.13.2. Only two directions are effective for all seasons. In autumn and winter swells from WNW dominates and occurrence rates are 20 and 25 percent respectively. In spring occurrence rates of swells form WNW and W are approximately equal and around 8 percent. In summer swells form W dominates and is about 12 percent. Calm duration is about 71 percent for a full year.

The relations between Significant Wave Height (H_s) vs. Mean Wave Period (T_m) are given in Figure 4.13.3. In this graph there exists only three data points with Hs greater than 2 meters and all belongs to WNW. The maxima are 2.631 meters for HS and 10.127 seconds for Tm. Higher and lower limits of the steepness of swell waves at this location (From Figure 4.13.3) are 0.02 and 0.003 respectively.

The graph of extreme value probability statistics is given in Figure 4.13.4. One data point is deduced for obtaining a better fit. This way the correlation of data is better. Significant wave height is estimated as 2.8 meters for 100 year return period.

Log-linear cumulative probability distribution is given in Figure 4.13.5. The two dominating directions, WNW and W are plotted along with all directions. It is seen from this graph that significant height of swell waves exceeds 3.7 meters in about 10 hours duration every year.

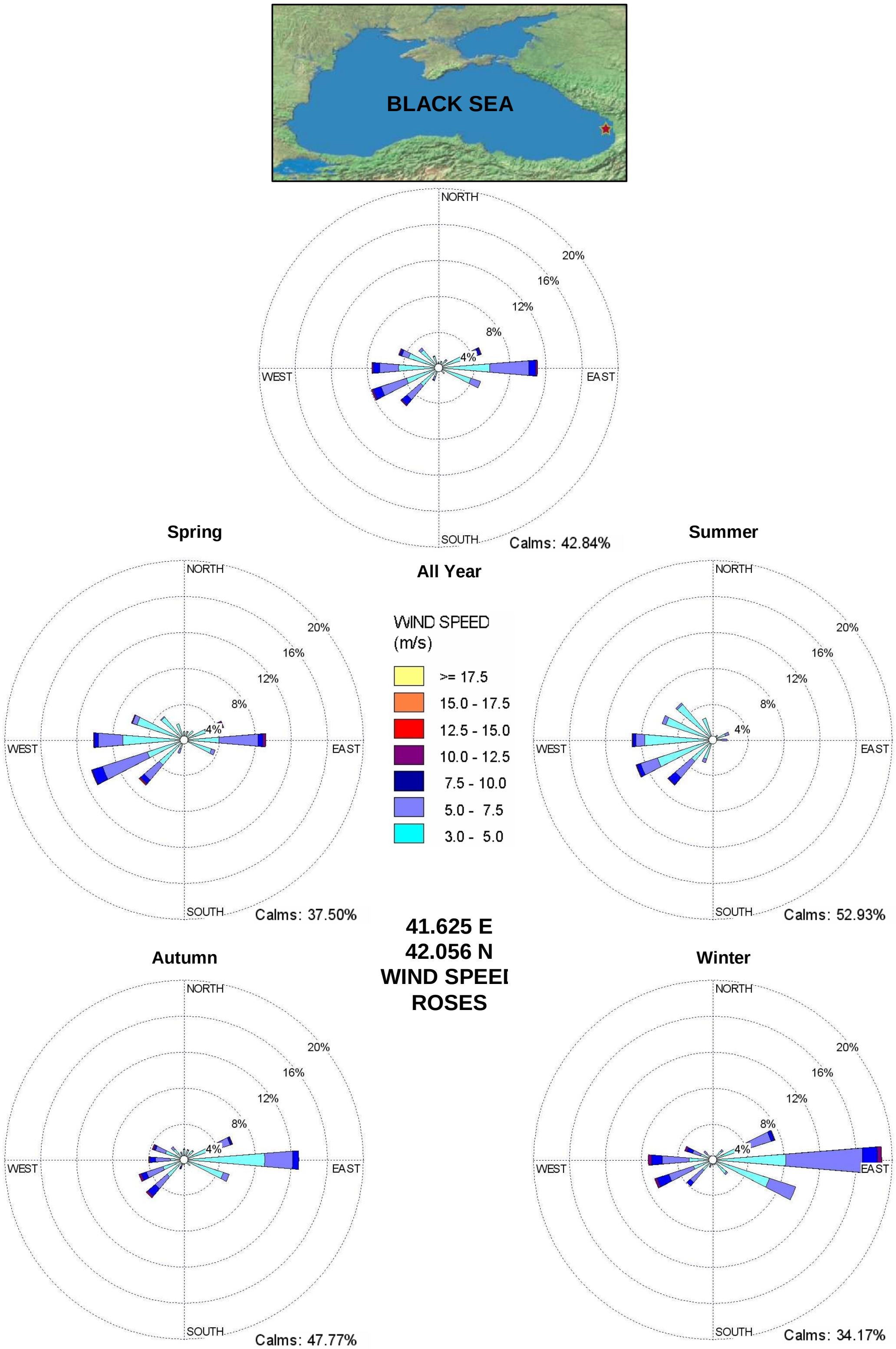

Figure 4.13.1 Wind climate at 42.056 N, 41.625 E

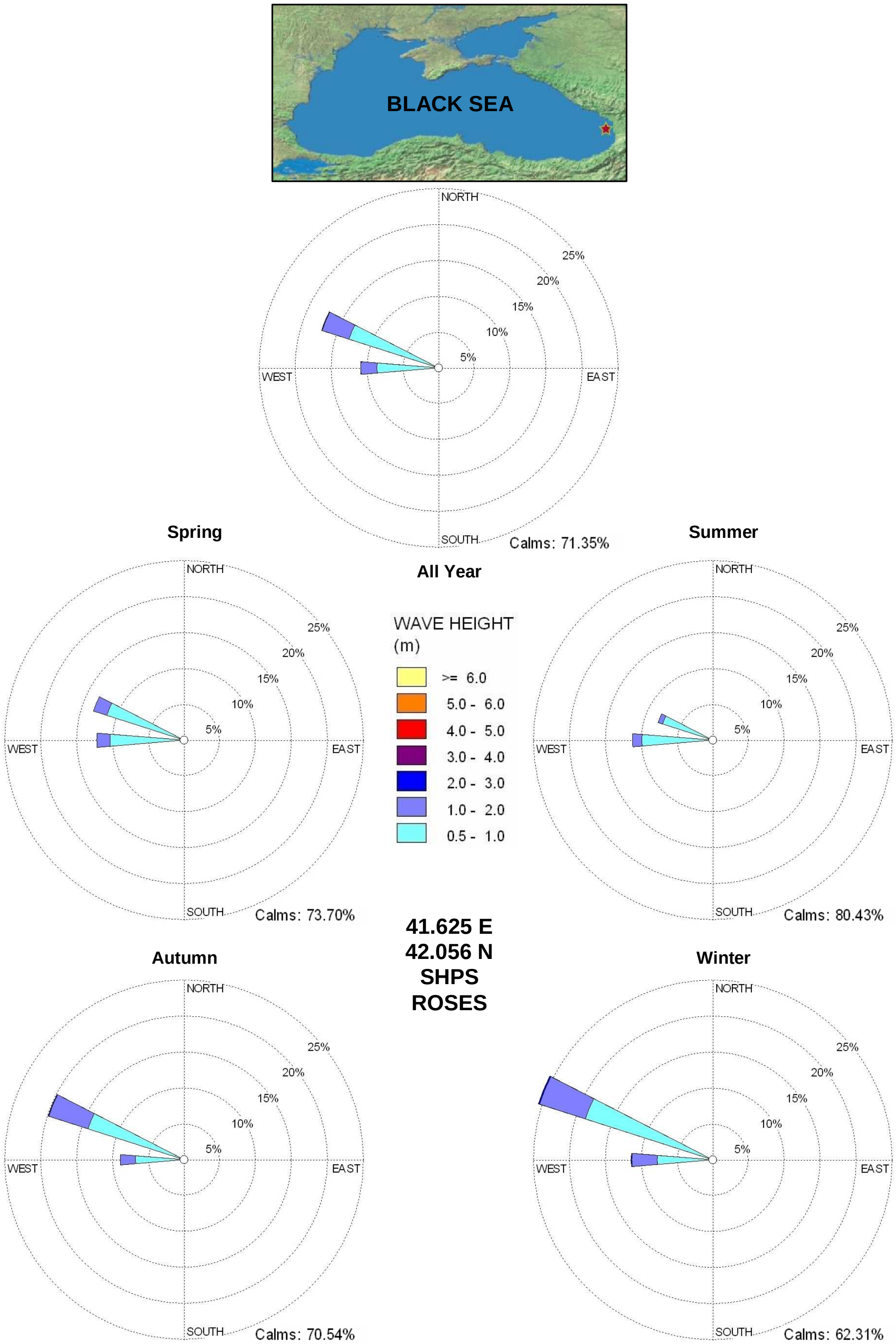

Figure 4.13.2 SHPS climate at 42.056 N, 41.625 E

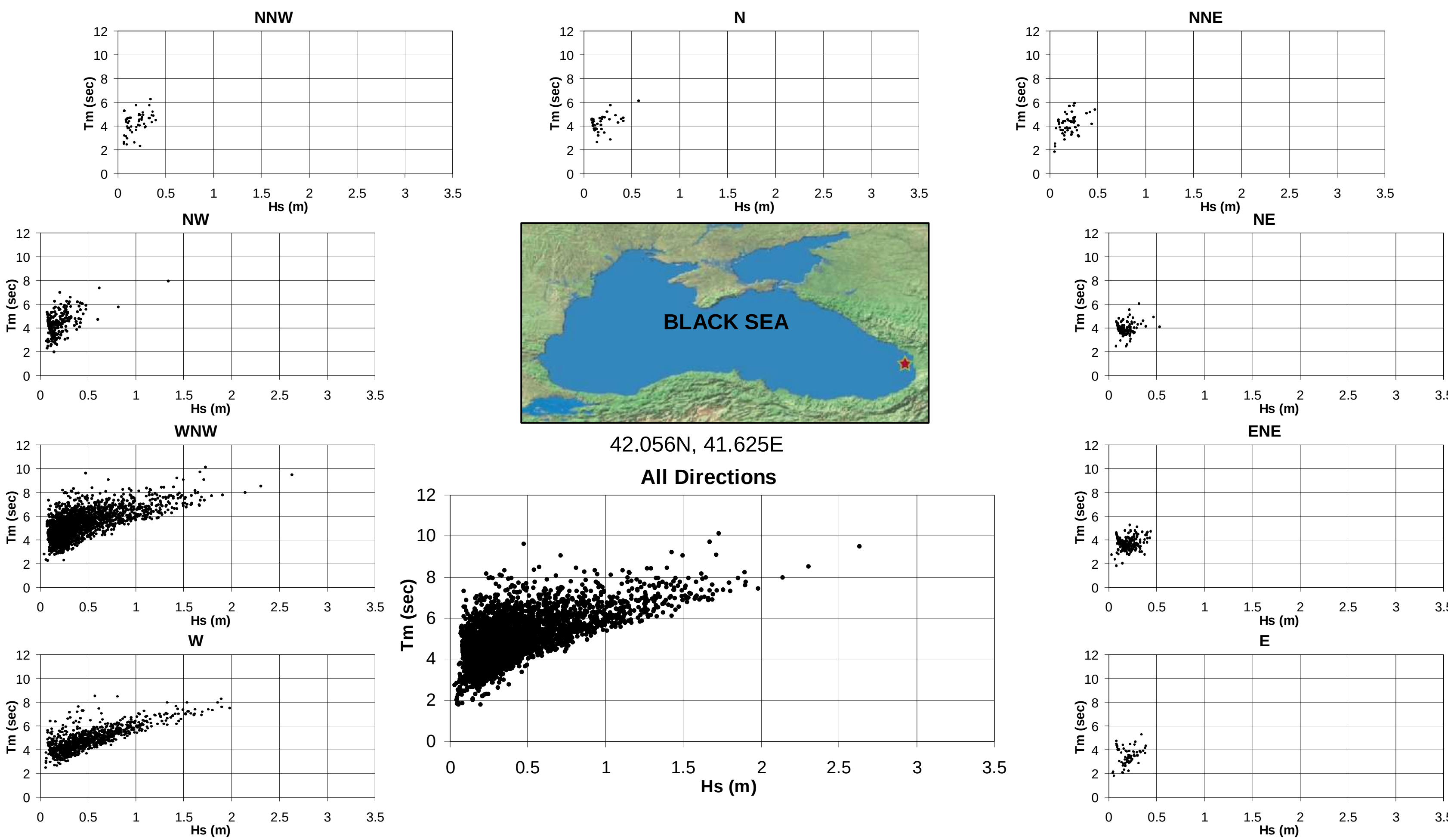

Figure 4.13.3 Relationship between MPPS & SHPS at location 15-03

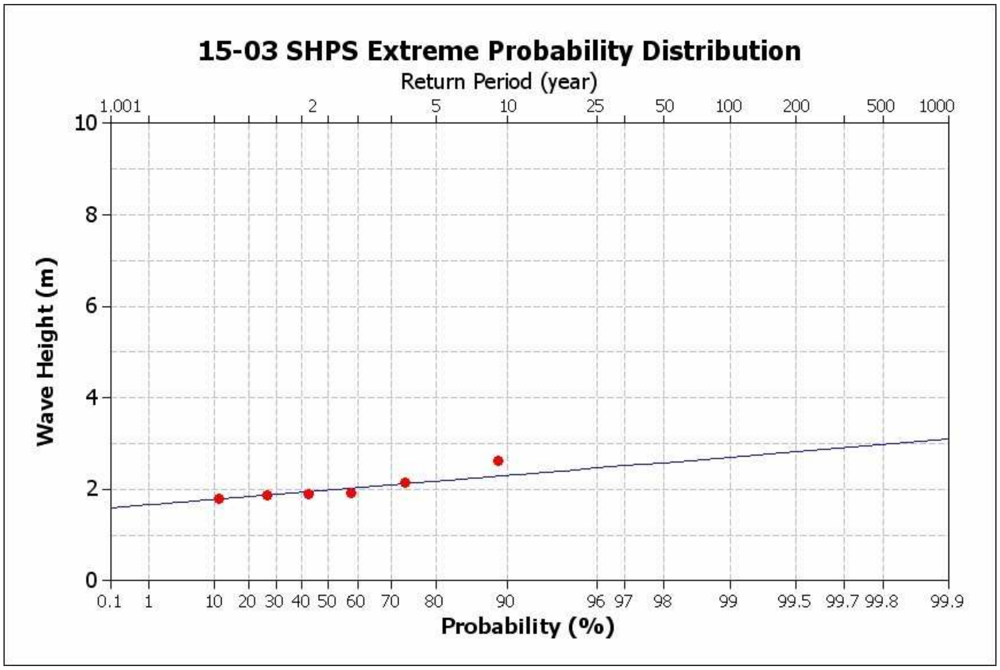

Figure 4.13.4 Extreme probability distribution at location 42.056 N, 41.625 E

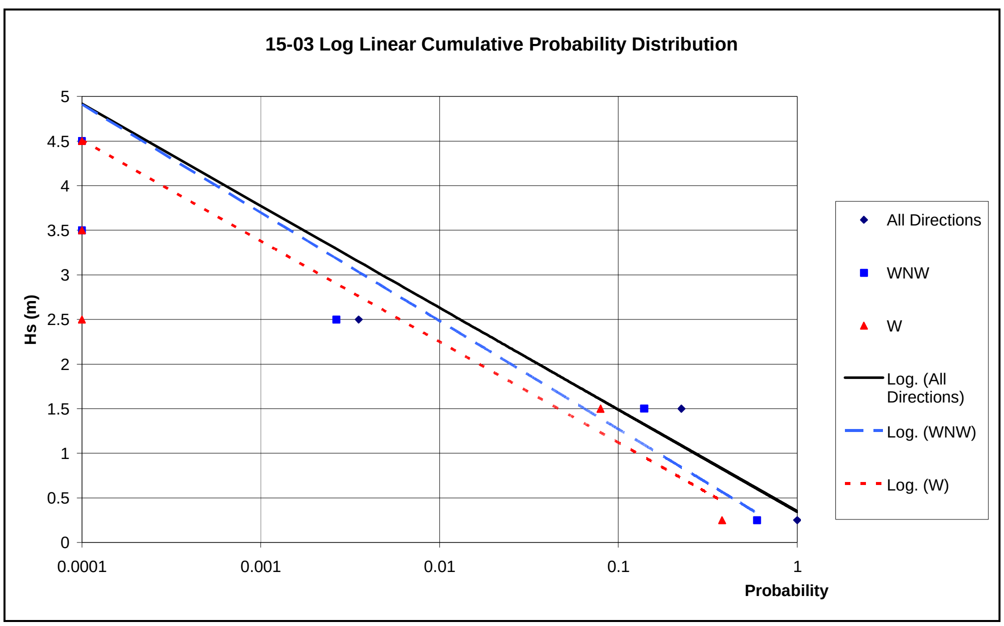

Figure 4.13.5 Log-Linear cumulative probability distribution at 42.056 N, 41.625 E

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 13 locations lying in 42.056° N latitude. There is a 1.125 arc degree difference between the locations along the longitude, the westward location being at 28.125 E and eastward location being at 41.625 E. The details of locations were given in Chapter 3. In this way the locations are located the Black Sea coast of Turkey. Although 6 of the locations are about 100 km far from shore, the overall interpretation of locations reveals important information about swell wave climate along Black 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 65 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 Black Sea. Thus the real life (instantaneous) 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 100 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 Black Sea coast of Türkiye present a clear view of swell wave climate. The outcome of the study confirms the swell wave generation theory. In the eastward and westward edges of Black Sea the range of incoming swell wave directions are narrower compared to central locations. Actually it is seen from the swell wave roses that the spectrum of directions gets wider in the central locations since the central locations are open to more directions. However effective swell wave incoming directions are limited to utmost 4 for a full year, i.e. 90 degrees. Generally two swell generating regions for Türkiye coasts can be identified by tracing the dominant and significant directions of swell wave roses for all locations as given in Figure 5.1.1. The swell wave generating regions can be noted as the North-Western part of Black Sea and the North-Eastern part of Black Sea.

Regarding these two swell generating regions and the yearly swell wave roses the locations can be grouped into 3 as western, central and eastern locations. The western group consists of locations Akhtopol (03-03), North of İstanbul (04-03), North of Kefken, Kocaeli (05-03), Zonguldak (06-03) and Amasra (07-03). The central group consists of four locations namely İnebolu (08-03), Sinop (09-03), Bafra (10-03) and Samsun (11-03). Finally the eastern group consists of 4 locations which are Bulancak (12-03), North of Trabzon (13-03), West of Poti (14-03) and Poti (15-03).

For the western group all locations except the west most location, 03-03 Akhtopol, show a typical distribution. The 03-03 Akhtopol location show a different swell wave rose since it is bounded by land from almost three sides. The swell wave rose for location 03-03 Akhtopol show that the there are three effective swell directions for this location and they point to the North-western part of Black Sea. The other four locations in the western groups have swell wave roses having a range of incoming effective swell wave directions. These four locations are heavily effected by swell waves coming from both North-western and North-Eastern parts of Black Sea. But the north-western swell generating region generates swell waves having larger wave heights as can be seen from the swell rose of Amasra (07-03)

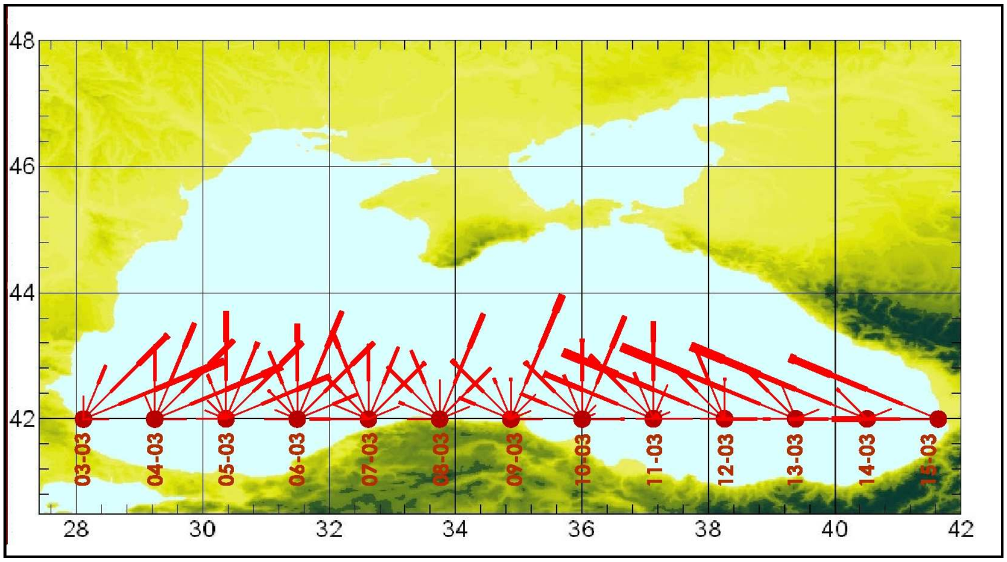

Figure 5.1.1.: The SHPS roses given collectively. The bars indicate the percent of observance.

The central group consisting of İnebolu, Sinop, Bafra and Samsun is differentiated from the other groups by the bifurcated swell roses. The two locations are effected by swell waves from both swell generating regions as in the case for western group. However swells coming from both regions can be spotted easily since they are divided by a sharp decrease in the occurrence rate of swell waves from North or North-Northwest. Also the central group is differentiated from western group by the fact that the dominant swell generating region is North-eastern part of Black Sea except for the location Samsun (11-03). The high dominancy of north-eastern swells can be seen in the locations İnebolu (08-03) and Sinop (09-03). The rate of western swells increases in the eastern locations.

The eastern group consists of Bulancak, North of Trabzon, West of Poti and Poti. The bifurcation of swell wave directions that is seen in central locations is lost for the eastern group. The locations in eastern group are effected by a single clear dominant direction which is WNW. Only the secondary directions change orientation by rotating from NW to W in counterclockwise direction as the locations moves towards east. In the locations, West of Poti and Poti, the swell rose spectrums are very narrow. Also it should be noted that the calm percentages constantly increases when moving west to east for this eastern group. 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 40 to 71 percent for a full year. In the group wise it is seen that the western group has the lowest calm percentages. The mean calm percentage of central group is about 50 percent and the calm percent varies significantly for the eastern group.

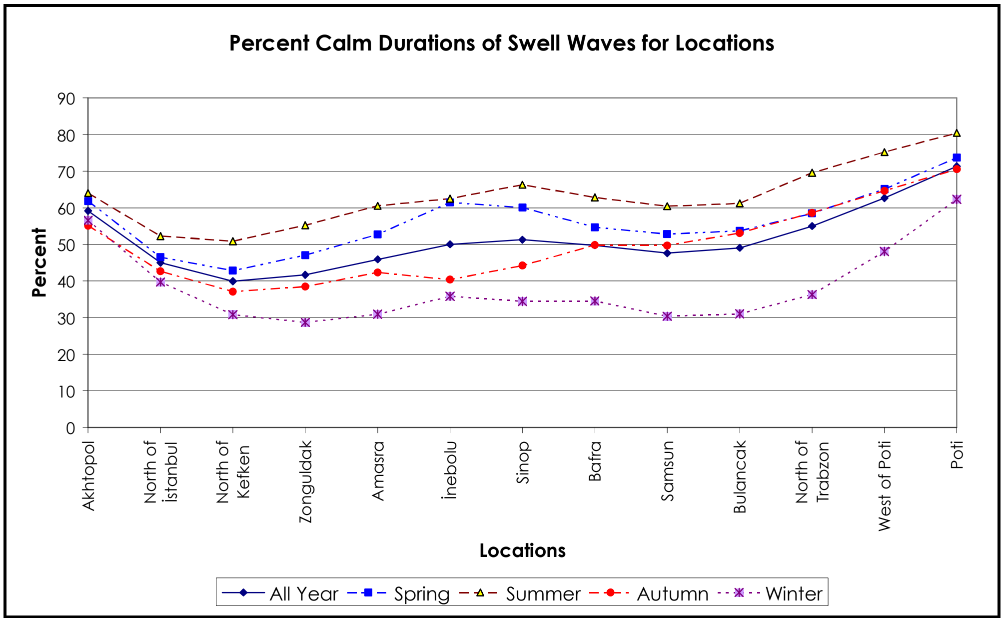

Figure 5.1.2: Yearly and seasonal calm durations for locations in percent

In seasonal basis remarkable changes can be observed. The calm percentages significantly increase in summer and decrease in winter. 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 western Black Sea coastline of Türkiye is susceptible to higher swell waves compared to eastern Black sea coasts. This can be observed from extreme probability and Log-Linear cumulative probability distributions. Also the maximum observed swell wave heights belong to western 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 with 4.5 meters in the locations Akhtopol and North of Kefken, Kocaeli. It is immediately seen from Table 5.2 that the western 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 11.2000 - 02.2006 data)

Location		**Expected H_s (m)**
0303	Akhtopol	4.5
0403	North of İstanbul	4.0
0503	North of Kefken, Kocaeli	4.5
0603	Zonguldak	4.2
0703	Amasra	4.4
0803	İnebolu	-
0903	Sinop	-
1003	Bafra	3.3
1103	Samsun	3.5
1203	Bulancak	3.6
1303	North of Trabzon	3.6
1403	West of Poti	3.1
1503	Poti	2.8

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 5.2.2 provides an overview to swell waves higher than 1.5 meters. The higher swell wave heights on western locations compared to eastern locations can also be observed from this table. The three locations namely are North of Kefken (0503), Zonguldak (0603) and Amasra (0703) that are mainly in the effect of Northern swells 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 (10.2000-02.2006) (Total number of occurrences is 1446 for 0803 and 0903 and 3954 for other locations) (intervals are in meters)

Location		$1.5<H_s<1.8$	$1.8<H_s<2.0$	$2.0<H_s<2.2$	$2.2<H_s$
0303	Akhtopol	43	12	6	6
0403	North of İstanbul	51	20	8	7
0503	North of Kefken	59	27	17	12
0603	Zonguldak	67	23	15	14
0703	Amasra	62	22	12	13
0803	İnebolu	26	10	6	4
0903	Sinop	19	3	3	2
1003	Bafra	47	11	5	7
1103	Samsun	41	20	7	5
1203	Bulancak	45	20	11	4
1303	North of Trabzon	46	17	3	4
1403	West of Poti	35	7	3	2
1503	Poti	34	6	1	2

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 western locations. In eastern locations mean periods higher than 9 seconds are seldom observed. Although the data is deficient for locations İnebolu and Sinop, it can be said that the observances of higher swell wave periods are close to that of the eastern locations. The swell wave periods higher than 8 seconds are mostly observed in Akhtopol (0303), North of İstanbul (0403) and North of Kefken (0503) locations.

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 1446 for 0803 and 0903 and 3954 for other locations) (intervals are in seconds)

Location		**$4<T_m<5$**	**$5<T_m<6$**	**$6<T_m<7$**	**$7<T_m<8$**	**$8<T_m<9$**	**$9<T_m$**
0303	Akhtopol	1550	994	372	160	66	38
0403	North of İstanbul	1395	1154	522	212	99	47
0503	North of Kefken	1428	1166	546	213	89	40
0603	Zonguldak	1514	1165	543	189	77	26
0703	Amasra	1606	1172	464	151	48	15
0803	İnebolu	613	378	152	59	15	1
0903	Sinop	601	380	141	60	14	1
1003	Bafra	1633	1075	357	142	47	7
1103	Samsun	1599	1014	377	139	53	8
1203	Bulancak	1578	939	382	131	46	6
1303	North of Trabzon	1457	916	391	126	39	4
1403	West of Poti	1390	904	433	149	34	5
1503	Poti	1322	972	490	160	21	8

5.2. INSPECTION OF SELECTED EXTREME EVENTS

In this section three extreme events that generated during the data period, which is between 11.2000 and 02.2006, are inspected in detail for a deeper understanding of swell wave generation and propagation in the Black Sea. For this purpose data for all locations are listed according swell wave heights. Then swell waves higher than 2.2 meters are extracted and then listed according to date. Studying this list the extreme events are spotted. 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 > 2.2 m) along Northern 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
07-03	Amasra	2001	11	17	15	NNW	9.345	2.78
07-03	Amasra	2002	2	26	3	NNW	8.228	2.201
12-03	Bulancak	2002	2	26	15	WNW	8.792	2.419
13-03	North of Trabzon	2002	2	26	15	WNW	8.818	2.341
11-03	Samsun	2002	2	26	15	WNW	8.499	2.261
04-03	North of İstanbul	2002	3	12	3	ENE	8.199	2.596
05-03	North of Kefken	2002	3	12	3	ENE	8.014	2.541
05-03	North of Kefken	2002	12	7	15	NNE	8.959	2.261
10-03	Bafra	2002	12	8	15	NNE	8.76	2.336
10-03	Bafra	2002	12	9	3	NNE	8.835	2.547
11-03	Samsun	2002	12	9	3	NNE	8.663	2.425
10-03	Bafra	2002	12	9	15	NNE	8.947	2.564

Table 5.2.1: (Continued) Extreme swell events (H_s > 2.2 m) along Northern coast of Türkiye. Extreme values are in bold. (MPPS is in seconds and SHPS is in meters)

11-03	Samsun	2002	12	9	15	NNE	8.623	2.334
10-03	Bafra	2002	12	10	3	NNE	8.955	2.357
05-03	North of Kefken	2003	2	3	3	NNE	9.036	2.534
06-03	Zonguldak	2003	2	3	3	N	8.723	2.356
06-03	Zonguldak	2003	2	8	3	N	7.696	2.21
06-03	Zonguldak	2003	2	8	15	NNW	9.333	2.645
05-03	North of Kefken	2003	2	8	15	N	9.359	2.586
07-03	Amasra	2003	2	8	15	NNW	9.152	2.405
06-03	Zonguldak	2003	2	25	15	NNE	9.21	2.477
07-03	Amasra	2003	2	25	15	NNE	8.666	2.431
10-03	Bafra	2003	2	25	15	NNE	8.574	2.326
05-03	North of Kefken	2003	2	25	15	NE	9.436	2.322
11-03	Samsun	2003	10	29	15	N	8.399	2.474
06-03	Zonguldak	2003	11	11	15	NNE	8.709	2.506
07-03	Amasra	2003	12	18	3	N	7.77	2.214
06-03	Zonguldak	2003	12	18	15	N	8.27	2.261
07-03	Amasra	2003	12	18	15	NNW	8.1	2.251
07-03	Amasra	2004	1	23	3	N	9.938	**3.289**
06-03	Zonguldak	2004	1	23	3	NNE	10.885	**2.922**
05-03	North of Kefken	2004	1	23	3	NNE	10.952	2.744
04-03	North of İstanbul	2004	1	23	3	NE	11.227	2.65
05-03	North of Kefken	2004	1	23	15	N	10.17	**3.336**
06-03	Zonguldak	2004	1	23	15	NNW	10.042	**3.262**
07-03	Amasra	2004	1	23	15	NNW	9.884	**2.973**
04-03	North of İstanbul	2004	1	23	15	NNE	10.474	2.682
12-03	Bulancak	2004	2	11	3	WNW	8.448	2.476
13-03	North of Trabzon	2004	2	11	3	WNW	8.541	2.431
11-03	Samsun	2004	2	11	3	WNW	8.205	2.24

Table 5.2.1: (Continued) Extreme swell events (H_s > 2.2 m) along Northern coast of Türkiye. Extreme values are in bold. (MPPS is in seconds and SHPS is in meters)

07-03	Amasra	2004	2	13	15	N	9.864	**3.11**
07-03	Amasra	2004	2	14	3	NNW	8.336	2.356
06-03	Zonguldak	2004	2	14	3	N	8.443	2.338
03-03	Akhtopol	2004	10	13	21	ENE	9.462	**2.869**
03-03	Akhtopol	2004	10	14	9	ENE	8.717	2.636
04-03	North of İstanbul	2004	10	14	9	ENE	9.197	2.276
04-03	North of İstanbul	2005	2	4	21	NNE	9.144	2.219
08-03	İnebolu	2005	2	5	9	NNE	8.312	2.205
05-03	North of Kefken	2005	2	5	21	NE	8.925	2.227
06-03	Zonguldak	2005	2	5	21	NE	8.664	2.225
06-03	Zonguldak	2005	2	6	9	NNE	8.431	2.302
05-03	North of Kefken	2005	2	6	9	NE	9.068	2.206
08-03	İnebolu	2005	2	7	21	NNE	8.572	2.38
12-03	Bulancak	2005	2	8	9	N	8.159	2.533
03-03	Akhtopol	2005	3	2	21	ENE	8.631	2.47
10-03	Bafra	2005	10	5	9	NNE	8.514	2.207
07-03	Amasra	2005	11	21	9	NNW	8.261	2.247
06-03	Zonguldak	2005	11	21	9	NNW	8.548	2.211
07-03	Amasra	2006	1	20	9	NNW	9.27	**2.915**
06-03	Zonguldak	2006	1	20	9	NNW	9.02	2.754
08-03	İnebolu	2006	1	20	9	NNW	9.611	2.57
05-03	North of Kefken	2006	1	20	9	NNW	8.64	2.442
14-03	West of Poti	2006	1	20	21	WNW	9.631	**2.885**
13-03	North of Trabzon	2006	1	20	21	WNW	9.931	2.677
15-03	Poti	2006	1	20	21	WNW	9.494	2.631
13-03	North of Trabzon	2006	1	21	9	WNW	8.399	2.36
14-03	West of Poti	2006	1	21	9	WNW	8.657	2.316
15-03	Poti	2006	1	21	9	WNW	8.538	2.305

Table 5.2.1: (Continued) Extreme swell events (H_s > 2.2 m) along Northern coast of Türkiye. Extreme values are in bold. (MPPS is in seconds and SHPS is in meters)

12-03	Bulancak	2006	1	21	9	WNW	8.672	2.213
03-03	Akhtopol	2006	1	25	9	E	11.046	2.499
03-03	Akhtopol	2006	1	25	21	ENE	10.292	**3.274**
04-03	North of İstanbul	2006	1	25	21	ENE	10.575	2.512
05-03	North of Kefken	2006	1	26	9	NE	8.229	2.524
04-03	North of İstanbul	2006	1	26	9	NE	8.852	2.452
03-03	Akhtopol	2006	1	26	9	NE	9.191	2.301
06-03	Zonguldak	2006	1	26	9	NE	8.049	2.224
05-03	North of Kefken	2006	1	26	21	NNE	8.099	2.281
07-03	Amasra	2006	2	6	9	NNE	7.925	2.352
08-03	İnebolu	2006	2	6	21	NNE	8.148	2.628
09-03	Sinop	2006	2	6	21	NNE	8.093	2.482
09-03	Sinop	2006	2	7	9	NNE	8.155	2.331
10-03	Bafra	2006	2	7	9	N	8.341	2.298

Using Table 5.2.1 three extreme events to be inspected are selected as 23/January/2004, 25/January/2006 and 13/October/2004. The 23.01.04 event that effected western locations survived for one day duration but generated the largest swell wave height in the data period. In 25.01.06 two different events are generated one after another, the first generating the 8th largest and the second one generating the 3rd largest swell wave heights. But the two events are inspected together to clarify their relations. The 13.10.04 event is the 4th extreme event that happened in the data period. The event was restricted to two locations and swell wave heights higher than 2.2 meters endured for a single day.

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 for a data record.

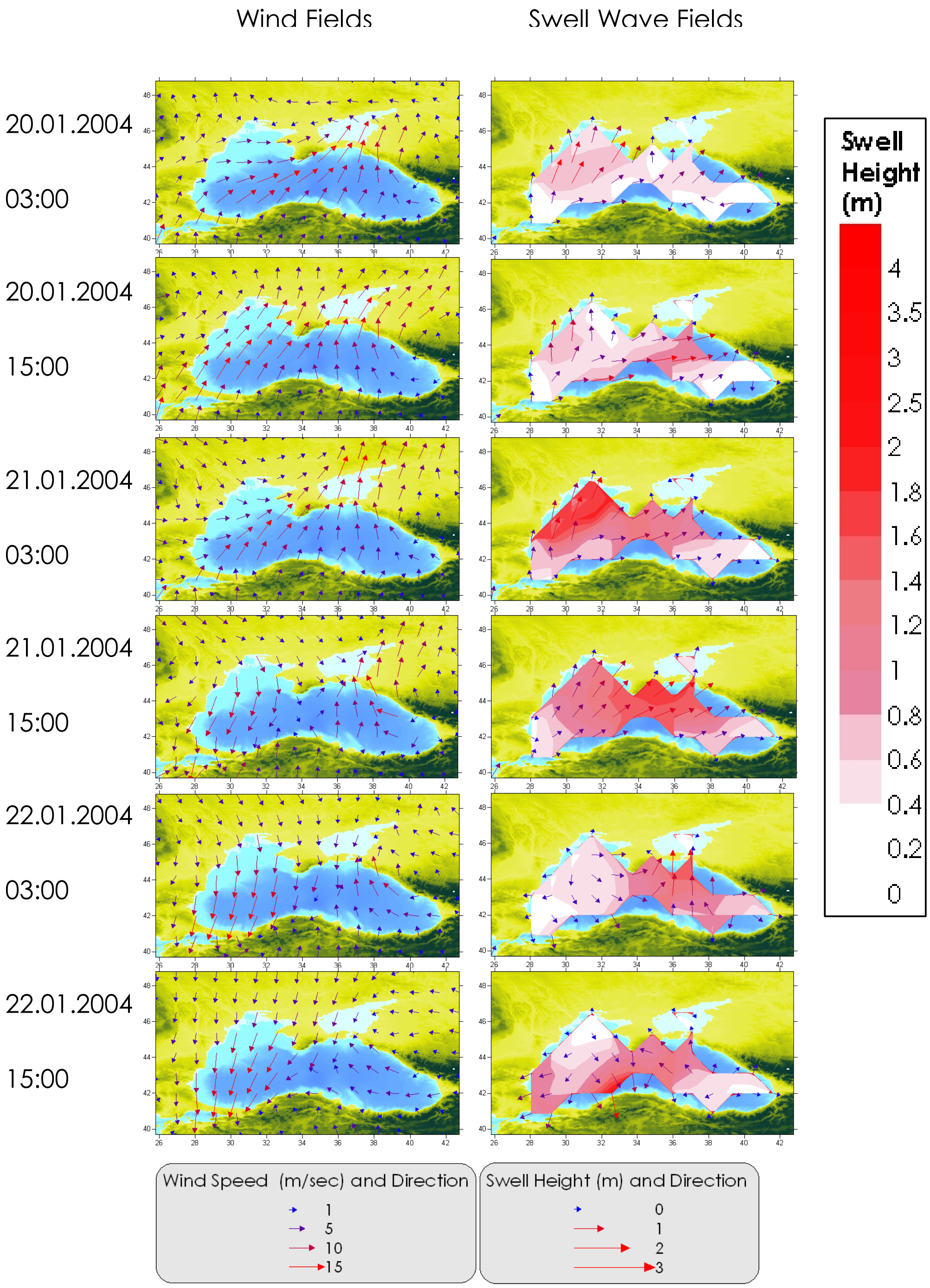

Figure 5.2.1: The evolution of wind and swell wave fields between 22.01.2004-25.01.2004.

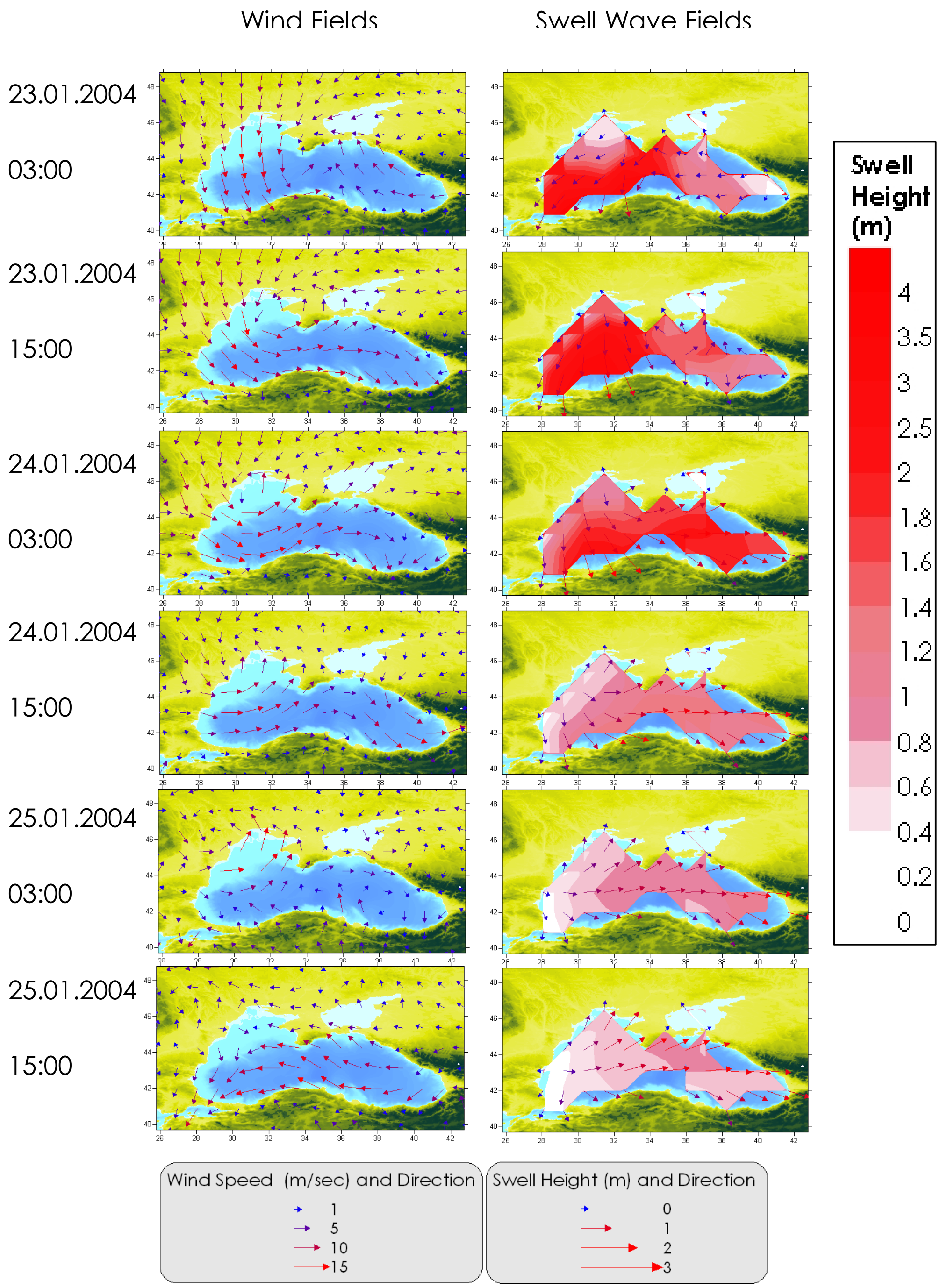

Figure 5.2.1: (Continued) The evolution of wind and swell wave fields between 22.01.2004-25.01.2004.

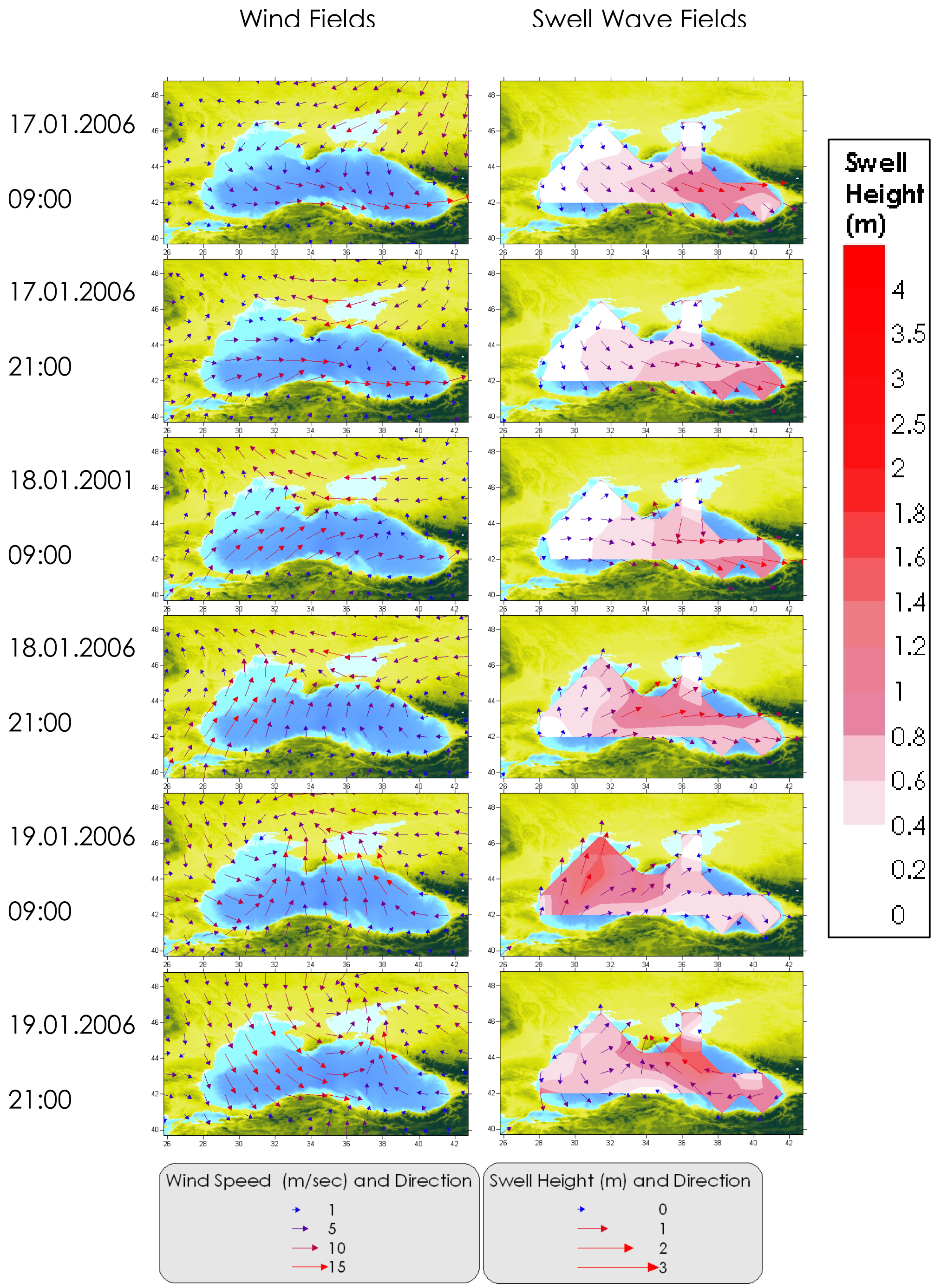

Figure 5.2.2: The evolution of wind and swell wave fields between 17.01.2006 - 28.01.2006.

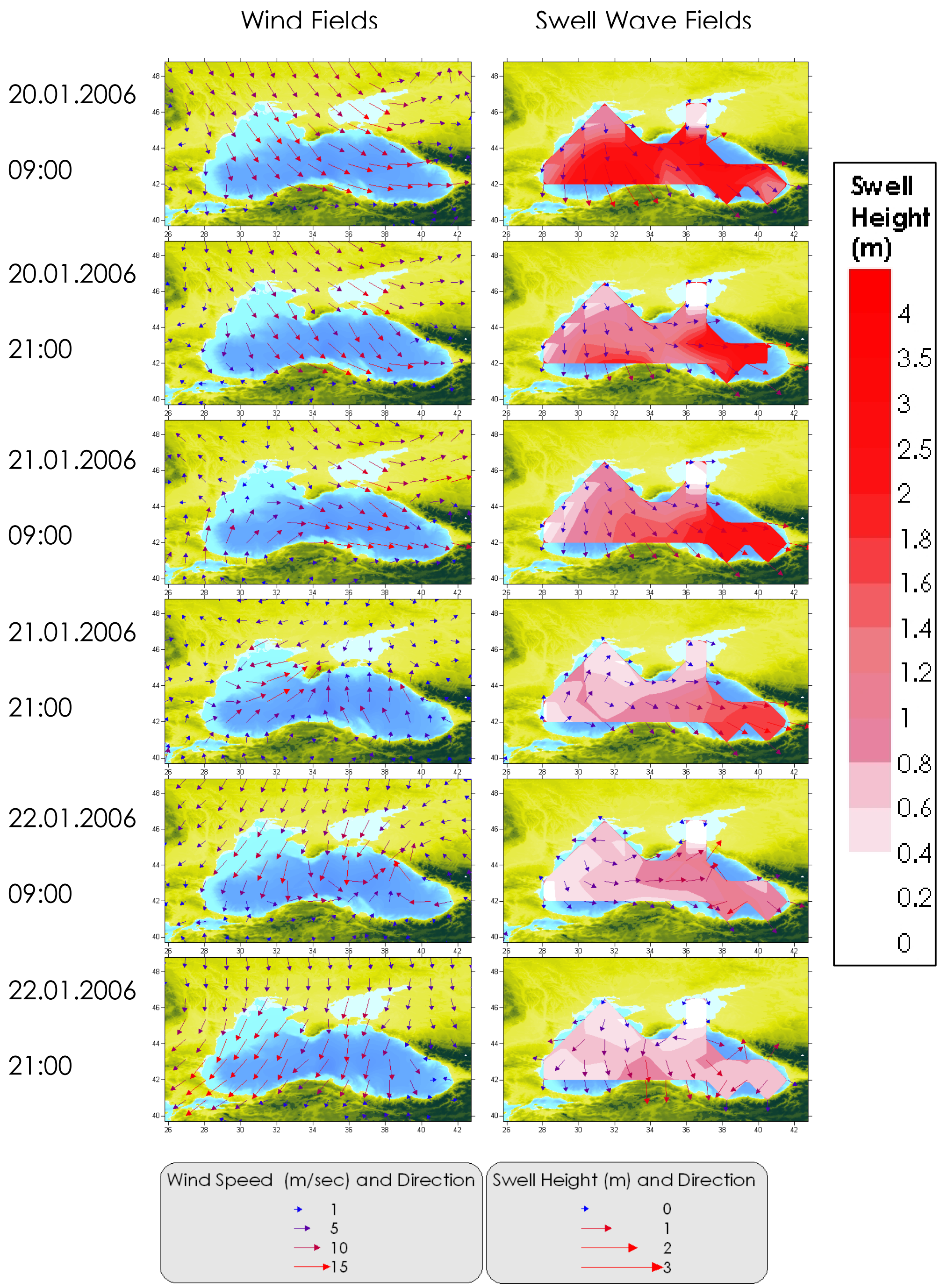

Figure 5.2.2: (Continued) The evolution of wind and swell wave fields between 17.01.2006 - 28.01.2006.

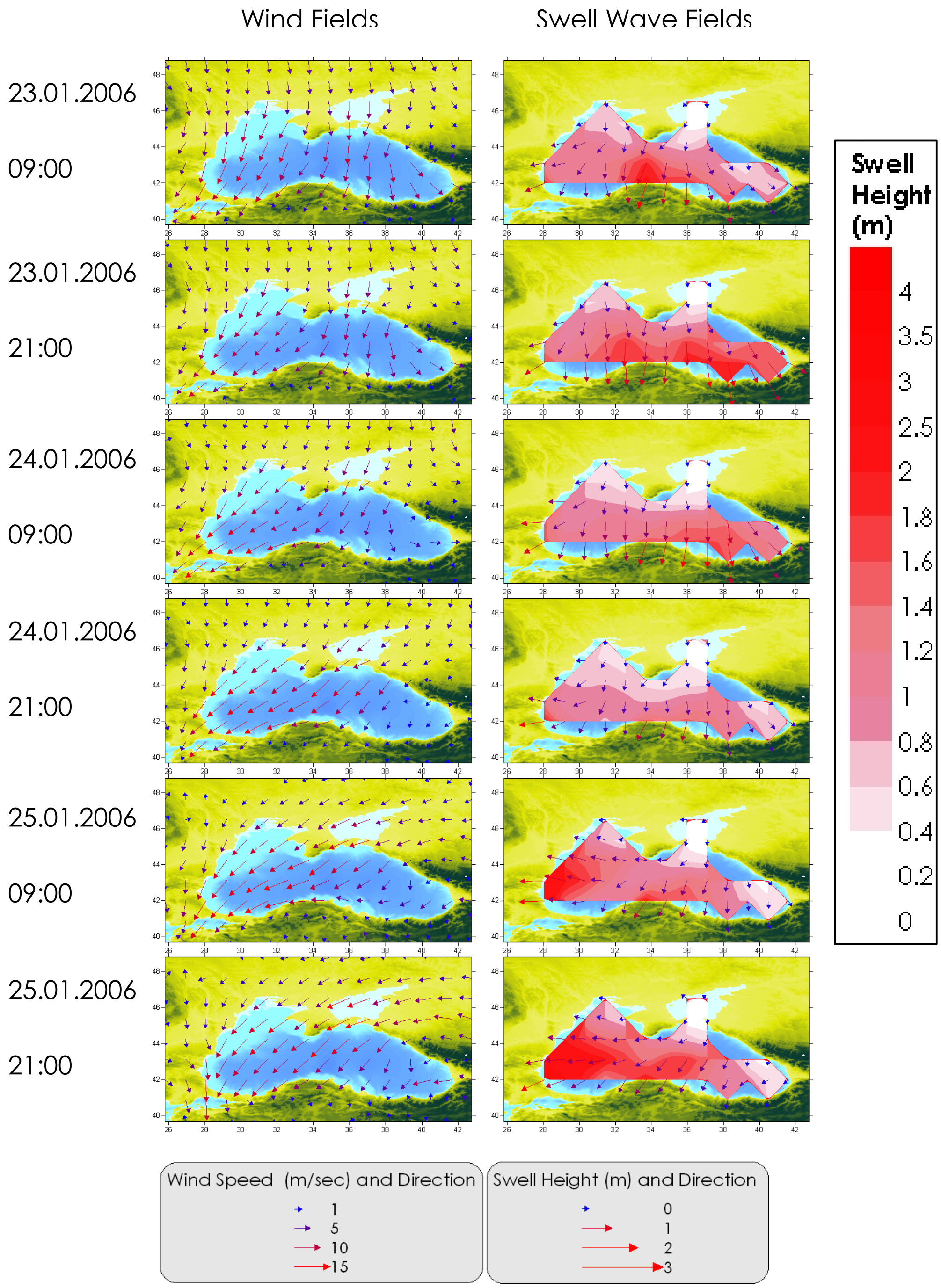

Figure 5.2.2: (Continued) The evolution of wind and swell wave fields between 17.01.2006 - 28.01.2006

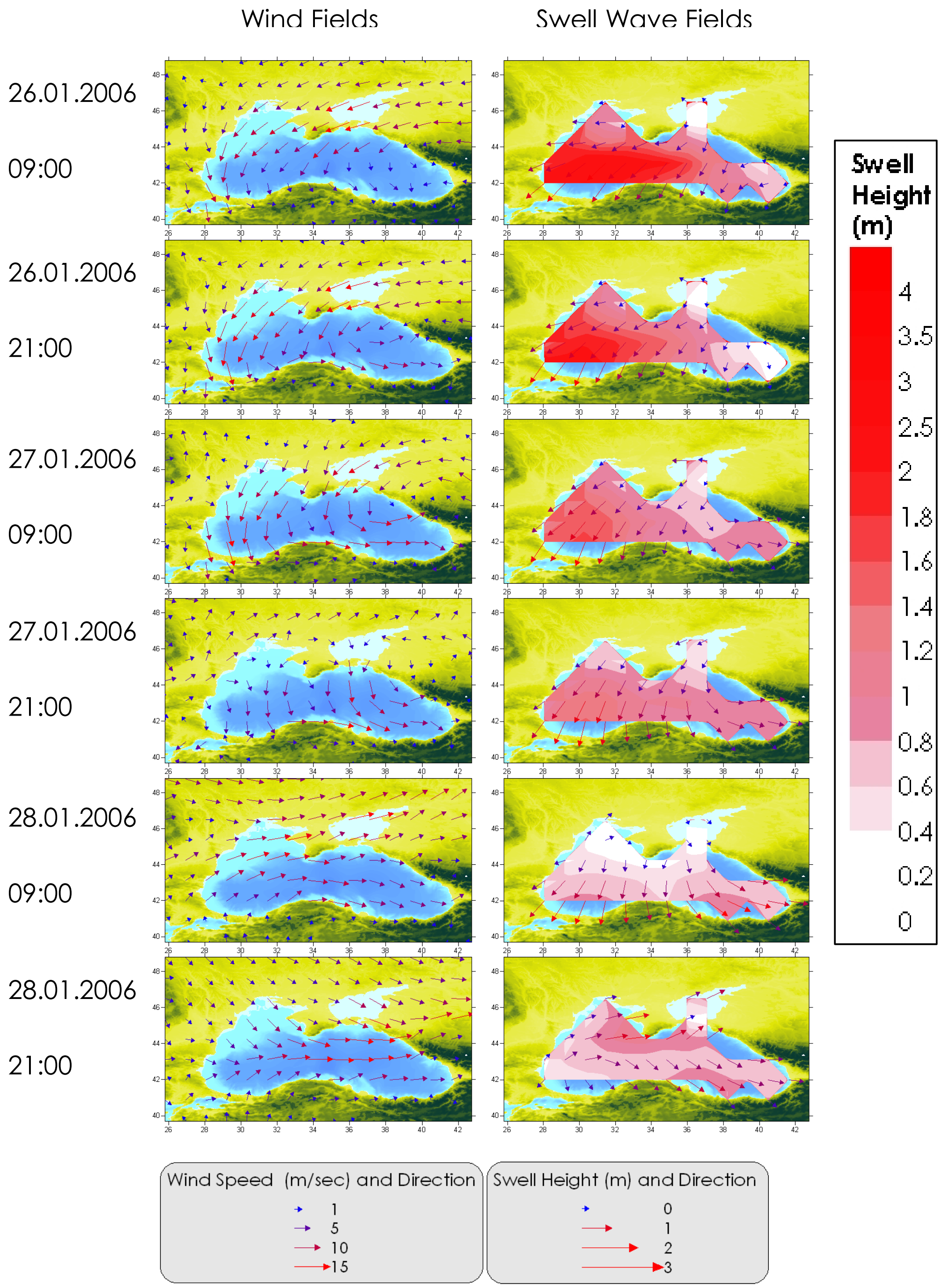

Figure 5.2.2: (Continued) The evolution of wind and swell wave fields between 17.01.2006 - 28.01.2006.

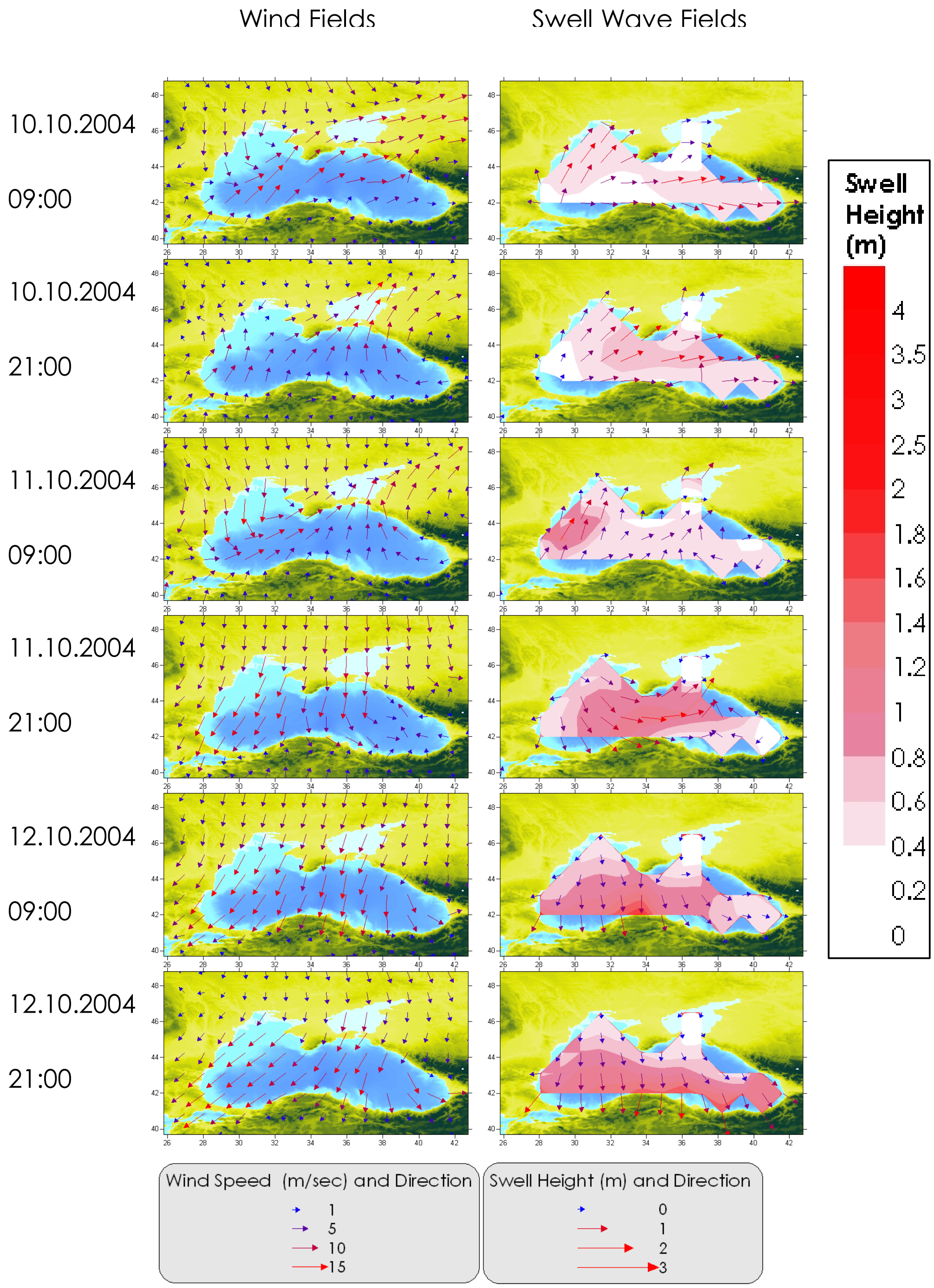

Figure 5.2.3: The evolution of wind and swell wave fields between 10.10.2004 - 15.10.2004.

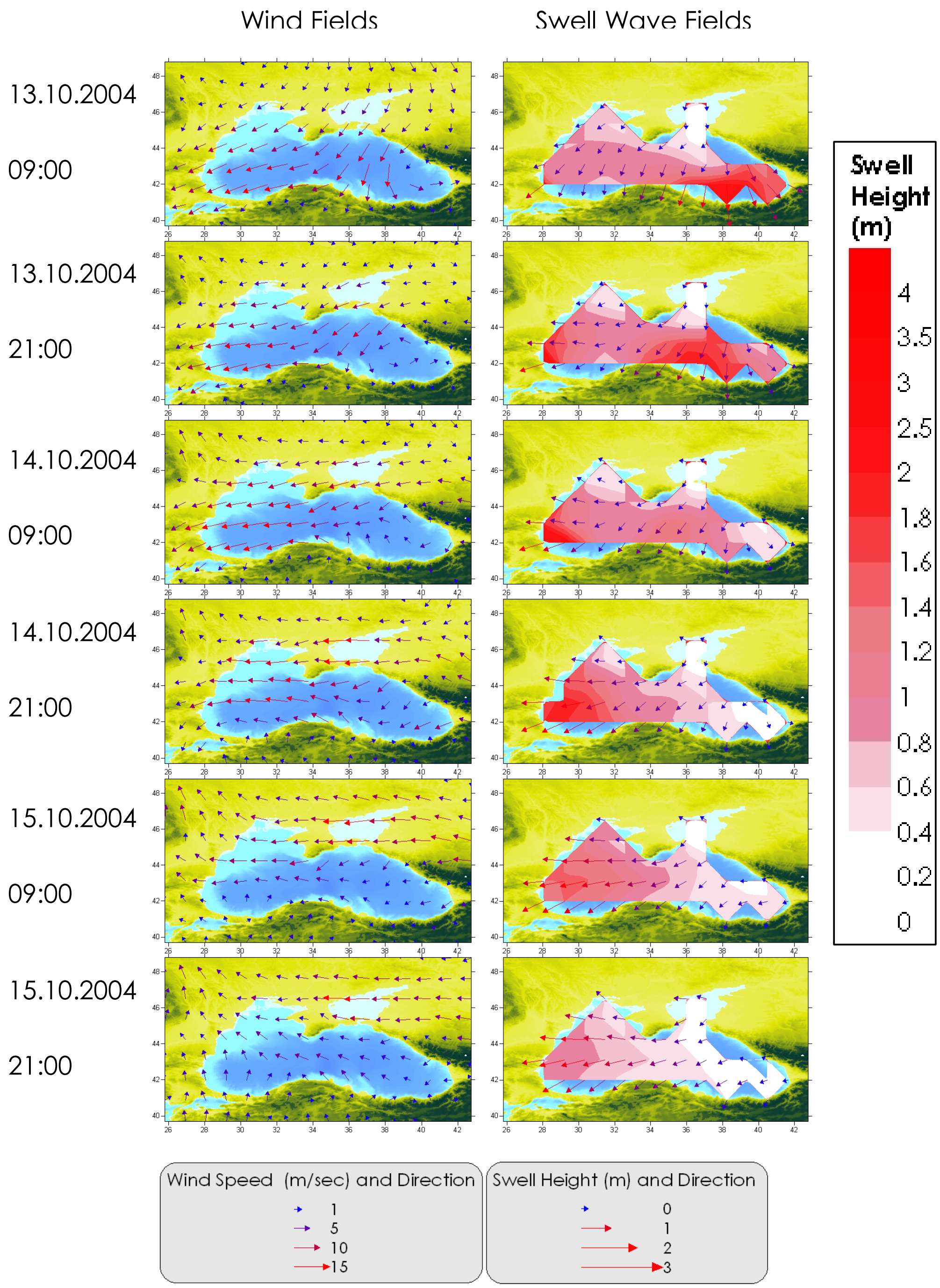

Figure 5.2.3: (Continued) The evolution of wind and swell wave fields between 10.10.2004 - 15.10.2004.

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. Because the distance between central locations and the swell wave generating North-west and North-East regions are about 400 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 in the Black Sea basin. Also the swell wave train diminishes in the third time step if it has not been fed by winds in the previous time steps. The wave dispersion is not significant in the duration of swell wave observation time and the elongated durations of extreme events are mainly related to enduring swell generating winds in Black Sea. The swell wave observation duration is also effected by the wind field by the fact that the wind field is generally effective for the whole Black Sea basin.

In the case of the three extreme events, the swell generating wind field becomes effective in the whole Black Sea basin at least for one time step. This brings an extra complexity as the swell waves and wind waves get mixed. However in the figures only the swell waves are displayed and swells are related to winds in the previous time step.

CHAPTER 6

CONCLUSIONS AND SUGGESTIONS

In this study wind and swell wave climate along the Black Sea coast of Türkiye is tried 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 Black Sea basin which rests in 25.875 E to 42.75 E and 39.813 N to 48.785 N geographical coordinates. The data period is between 01.10.2000 to 28.02.2006, totally 65 months in length. Analyses were made for 13 locations along the Black Sea coastline of Türkiye lying in 42.056° N latitude which are a 1.125 arc degree far from each other along the longitude.

In this study the 13 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 Black 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 exposes 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 western part of the Black Sea is susceptible to higher period and heights of swell waves compared to eastern 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 south-western part of Black 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.

The inspection of extreme swell events revealed that the swell waves propagates entire Black Sea basin in a single day. The extreme events are generated by wind fields which are covering about half of the Black Sea basin. It is seen that the swell waves generated at one part of Black Sea propagates to opposing part in the second time step of data records. Thus the data record interval which is 12 hours in this study is insufficient for swell wave propagation surveying for Black Sea. This relatively large data record interval may also have caused deficiency in obtaining the instantaneous maxima of swell wave heights and periods.

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 Southern coast of Black 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 Black Sea basin this study can be carried to one step further by inspection of whole Black 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].

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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 2003_04.grib)

c:/wgrib>wgrib

Starts wgrib and/or shows the help screen

C:/wgrib>wgrib 2003_04.grib -s

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

C:/wgrib>wgrib 2003_04.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 2003_04.grib -d N –text

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

C:/wgrib>wgrib 2003_04.grib -d all -text -o -2003_04.txt

The input file is transformed into 2003_04.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)')'1998-01.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
```