ASSESSMENT OF WIND ENERGY POTENTIAL MAPPING FOR PENINSULAR MALAYSIA

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ABSTRACT

Wind energy generation is growing rapidly worldwide and will continue to do so for the foreseeable future. In this study, the most accepted 2-parameter Weibull distribution model has been applied for assessment of wind energy potentiality. The wind directions have been also identified using the WRPLOT View software. The Geographical Information System (GIS), ArcGIS 9.3 software, has been applied to present the predicted monthly and yearly mean wind speed in the form of contour maps. The wind speed data of 15 stations has been collected from the Malaysian Meteorological Department over the period of 2008-2009.

Based on the experimental data, it is found that the numerical values of both Weibull parameters (k and c) for Peninsular Malaysia vary over a wide range. It is found that the daytime, from 8 am to 6 pm, is windy for all the years, while the night time is relatively calm. Most of the monthly mean wind speed values are between 1.5 m/s to 4.5 m/s, but some are over 4.5 m/s and few are under 1.5 m/s. The mean wind speeds for all the years are lower than 4.5 m/s and the range of the yearly mean wind speed values is from 0.90 to 4.06 m/s. It is found that the yearly mean wind speed at Mersing is 4.06 m/s in 2008 and 4.01 m/s in 2009, which is capable of producing commercial wind energy by using current technology.

The monthly highest value of wind power density was found to be 227.1 W/m^2 at Mersing in January, 2009 and the lowest value of wind power density was 1.3 W/m^2 in November 2008 at Batu Embun. The average value of the monthly wind power density was estimated 26.76 W/m^2. The range of the values of monthly wind energy density was found to be between 11.23 to 1962 kWh/m^2/year whereas the average wind energy density was found to be 231.20 kWh/m^2/year.

Mersing is the most 'windy' place with the largest scale parameter c, and its most frequent wind speed is 3.5 m/s. The maximum percentage of error between Weibull and observed wind speed frequencies occur at 3 m/s or more than 3 m/s is around 20%. From cumulative distribution function, it is found that Mersing will have the highest operating possibility of 67% (around 5789 hours per year). For all the sites, the prevailing winds from the most probable wind directions on the percentage ranging from 15 to 41% and the wind speeds less than 3 m/s are ranging from 11.2-89.2%.

The geographical parameters (latitude, longitude, and altitude), and months of the year were used as input data, while the monthly and yearly mean wind speeds were found as the output. It is seen that the southern part of Peninsular Malaysia is windier than that of the other parts in Peninsular Malaysia. The predicted wind speed values are given in the form of monthly and yearly maps, which can be easily used for assessment of wind energy potential for different locations within Peninsular Malaysia.

ABSTRAK

Penjanaan tenaga angin kiri berkembang pesat di seluruh dunia dan akan terus bekkembang di masa akan datang. Dalam kajian ini, model pengedaran 2-parameter Weibull telah dilaksanakan untuk penilaian potensi tenaga angin. Arah angin telah juga dikenalpasti menggunakan perisian WRPLOT view. Perisian sistem Maklumat Geografi (SIG), ArcGIS 9.3, telah diaplikasikan untuk menunjukkan ramalan parata kelajuan angin bulanan dan tahunan dalam bentuk peta kontur. Data kelajuan angin dari 15 stesen telah dikumpulkan daripada Jabatan Meteorologi Malaysia (MMD) selama tempoh 2008-2009.

Berdasarkan data eksperimen, didapati bahawa nilai berangka kedua parameter Weibull (k dan c) untuk Semenanjung Malaysia adalah berbeza-beza dalam julat yang besar. Hal ini ditemui bahawa pada siang hari, 08:00-6:00, keadaan berangin untuk semua pusingan tahun, sedangkan pada malam hari keadaan secaravelatif tenang. Sebahagian besar nilai parata kelajuan angin bulanan adalah antara 1.5 m/s hingga 4.5 m/s, namun ada juga yang lebih dari 4.5 m/s dan beberapa berada di bawah 1.5 m/s. Purata kelajuan angin untuk semua tahun lebih rendah daripada 4.5 m/s dan julat nilai purata kelajuan angin tahunan adalah 0.90-4.06 m/s. Didapati bahawa purata kelajuan angin tahunan di Mersing adalah 4.06 m/s pada tahun 2008 dan 4.01 m/s pada tahun 2009, yang mampu menghasilkan tenaga angin komersial dengan menggunakan teknologi masa kini.

Nilai tertinggi bulanan ketumpatan tenaga angin adalah 227.1 W/m^2 di Mersing pada bulan Januari tahun 2009 dan nilai terendah ketumpatan tenaga angin adalah 1.3 W/m^2 pada bulan November tahun 2008 di Batu Embun. Nilai purata ketumpatan tenaga angin bulanan dianggarkan 26.76 W/m^2. Julat nilai ketumpatan tenaga angin bulanan ditemui antara 11.23-1962 kWh/m^2/tahun dan ketumpatan purata tenaga angin adalah 231.20 kWh/m^2/tahun.

Mersing merupakan tempat yang paling 'berangin' dengan skala terbesar parameter c, dan kelajuan angin paling sering adalah 3.5 m/s. Peratusan maksimum ralat antara frekuensi Weibull dan frekuensi kelajuan angin yang diamati terjadi pada 3.0 m/s atau lebih dari 3.0 m/s adalah sekitar 20%. Dari fungsi edaran kumulatif, kita mendapati bahawa Mersing akan mempunyai kemungkinan operasi tertinggi 67% (sekitar 5789 jam setahun). Untuk semua kawasan kajian, angin yang berlaku dari arah angin yang paling mungkin dengan peratusan antara 15 hingga 41% dan kelajuan angin kurang dari 3.0 m/s adalah berkisar 11.2-89.2%.

Parameter geografi (lintang, bujur, dan ketinggian), dan bulan dalam setahun yang digunakan sebagai data input, sedangkan purata kelajuan angin bulanan dan tahunan rata-rata digunakan sebagai output dari rangkaian. Didapati bahawa bahagian selatan Semenanjung Malaysia adalah lebih berangin dibandingkan dengan bahagian lain. Nilai purata kelajuan angin difunjukkan dalam bentuk peta bulanan dan tahunan, yang dapat digunakan dengan mudah untuk penilaian potensi tenaga angin untuk pelbagai lokasi di Semenanjung Malaysia.

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NOMENCLATURE

kWh	Kilo Watt Hour
TWh	Tera Watt Hour
GDP	Gross Domestic Product
PPP	Purchasing Power Parity
GW	Giga Watt
Mtoe	Million Tons of Oil Equivalent
GHG	Green House Gas
RE	Renewable Energy
R&D	Research and Development
GIS	Geographical Information System
PhD	Doctor of Philosophy
WECS	Wind Energy Conversion System
MECM	Ministry of Energy, Communication and Multimedia
MMD	Malaysian Meteorological Department
SN	Skew Normal
RMSE	Room Mean Square Error
NREL	The National Renewable Energy Laboratory
VAWT	Vertical Axis Wind Turbine
HAWT	Horizontal Axis Wind Turbine
SREP	Small & Renewable Energy Program
a.s.l	Above Sea Level
PNNL	The Pacific Northwest National Library
A	Area (m^2)
f(v)	Weibull probability density function of observing wind speed
F(v)	Weibull cumulative distribution function

k	the dimensionless shape parameter showing how peaked the wind distribution is
c	the dimensionless scale parameter showing how windy the wind location under consideration is.
V	Velocity of the wind at height, z [m/s]
V_0	Velocity of the wind at height, z_0 [m/s]
α	Wind speed power law co-efficient
h	Height (m)
N	Number of observations
n	Number of constants
P/A	Wind power density (W/m^2)
E/A	Energy density (kWh/m^2/year)
ρ	Density of air (Kg/m^3)
σ	Standard deviation
Γ( )	Gamma function of ( )

CHAPTER 1: INTRODUCTION

1.1 Background

Our civilization thrives largely based upon the availability of inexpensive energy sources and the expectation that these sources will not be exhausted. However, it is known that the primary energy sources, the fossil fuels, will be exhausted, since they are used at a much higher rate than they are formed in the earth's crust. Over the last decade, it became apparent that the world's resources of fossil fuels are beginning to come to an end. Estimates of energy resources vary but oil and gas reserves are thought to come to an end in roughly 40 and 60 years respectively and coal reserves could only be able to last another 200 years (Rahman & Lee, 2006). According to International Energy Outlook 2009, World energy consumption will increase from 1.38×10^{23} kWh in 2006 to 1.62×10^{23} kWh in 2015 and 2.0×10^{23} kWh in 2030-a total increase of 44.2% over the projection period 2006-2030 (Güler, 2009; IEA, 2009; Kaygusuz, 2010).

Another key reason to reduce our reliance on fossil fuels is the growing evidence of the global warming phenomena. Since the industrial revolution, by burning these fossil fuels, there is a dramatic increase in the release of carbon dioxide into the atmosphere. The carbon dioxide gathers in the atmosphere and soaks up the long-wave, infrared radiation reemitted from the earth that would normally be released into space. By keeping this radiation in the earth's atmosphere, it has caused a rise in the earth's temperature. This global warming effect will have far-reaching consequences if it is not minimized as soon as possible. The natural balance of earth is very delicate and a rise in temperature even by 1˚C or 2˚C can melt the ice caps causing wide spread flooding across the world. Consequentially the United Nations Framework Convention on Climate Change conference (UNFCCC) was to establish a legally binding international agreement, whereby all the participating nations commit themselves to tackle the issue of global warming and greenhouse gas emissions, and they targeted an average reduction of 5.2% from 1990 levels by the year 2012. Large-scale and global environmental hazards to human health include climate change, stratospheric ozone depletion, loss of biodiversity, changes in hydrological systems and the supplies of freshwater, land degradation and stress on food-producing systems. Indoor air pollution from burning solid fuels causes a lot of death in Asia, and it is about 65% of the world total. The reasons behind the human health hazardous are shown in Figure 1.1.

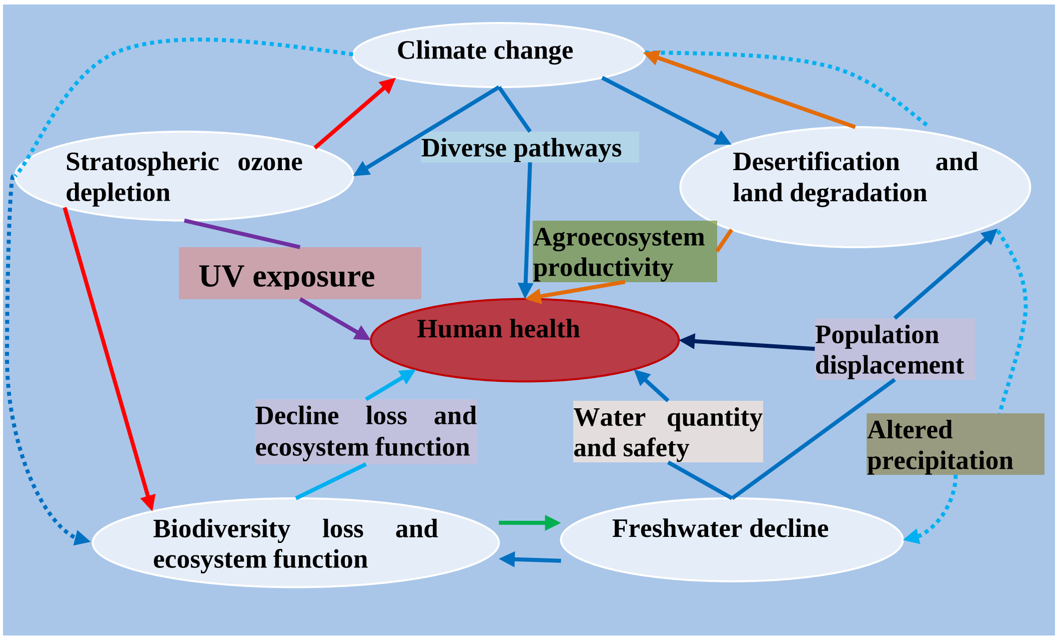

Figure 1.1 Global environmental changes and its effect on human health. (WHO, 2009)

Renewable energies are regarded as a key factor in mitigating global climate change in the future. Among various renewable energy sources, wind energy, in particular, has achieved maturity in the energy market, and has experienced the greatest growth worldwide over the past few years (Yue et al., 2001). According to the assessment of the Intergovernmental Panel on Climate Change concerning wind energy potential, intermittent wind power on a large grid can contribute an estimated 15-20% of annual electricity production without special arrangements for storage, backup, or load management. Renewable energy sources are easily accessible to humankind around the world. It is not only available in a wide range but is also abundant in nature. Increased use of wind energy and other renewable energy sources will spur economic growth, create a job opportunity, enhance national security, protect consumers from price spikes or supply shortages associated with global fuel markets and dramatically reduce the pollutant that is warming the planet which causes greenhouse effect (IPCC, 2010; Varun et al., 2009).

According to estimation done by the international Energy Agency (IEA), a 44.2% increase in global energy consumption is foreseen by 2030, with 70% of the growth in demand coming from developing countries. Malaysia is one of the most developing countries, with GDP of US$15,400 per capita (PPP basis), and steady GDP growth rate of 4.6 in 2009 (IMF, 2010; Saidur & Lai, 2011). The economy of Malaysia grew by 5% in 2005 and overall energy demand is expected to increase at an average rate of 6% per annum. In parallel with the rapid economic development of Malaysia, final energy consumption grew at the rate of 5.6% from 2000 to 2005 to reach 38.9 Mtoe in 2005. The final energy consumption is expected to be 98.7 Mtoe in 2030, nearly three times the 2002 level (Balo, 2011; Oh & Chua, 2010b; Saidur et al., 2009a). The industrial sector will have the highest growth rate of 4.3 percent. Industrial sector accounted for some 48% of total energy use in 2007, which represents the highest percentage. It is estimated that the natural-gas reserve is expected to last for around 70 years, while oil is expected to be depleted in 16 years at the current rate of usage (Poh & Kong, 2002; Saidur et al., 2009b).

Malaysia is in the midst of an era of vigorous industrial growth brought about by strong domestic demand together with its significant science and technology development. The government’s vision of turning Malaysia into a humane industrialized country by the year 2020 will have a great impact on the usage of energy in the country. In the next three decades, Malaysia plans to develop itself in such a manner that it will not only be a consumer of technology but also contribute to the fulfillment of the scientific and technological needs of the future. Malaysia has also committed itself under Articles 4 and 12 of the United Nations Framework Convention on Climate Change (UNFCCC) to prepare a national greenhouse gas (GHG) inventory. Accordingly, it has planned to review and update the assessment of vulnerability to climate change, and assess adaptation needs and prepare its initial National Communications to the Conference of Parties (COP). Malaysia is also a signatory to the Kyoto Protocol.

The crucial challenge facing the power sector in Malaysia is the issue of sustainability that is to ensure the security and reliability of energy supply and the diversification of the various energy resources. In Malaysia, green technology application is seen as one of the sensible solutions, which are being adopted by many countries around the world to address the issues of energy and environment simultaneously (Leo, 1996). The Government of Malaysia declared the Eighth Malaysian Plan in 2001 where RE was regarded as the fifth fuel in the new five-fuel strategy in the energy mix and set a target of 5% (600 MW) RE contribution in the electricity mix by the year 2005. However, the development pace of RE in Malaysia is rather slow and still at its nascent stage, with its current contribution at around 1% only of the total energy mix, even though the fifth fuel policy had been announced a decade ago. The notion is further pursued in the 9th Malaysia Plan (2006-2010) which has also set a target of 5% RE in the country's energy mix (Oh et al., 2010; Rahman & Lee, 2006; Zamzam et al., 2003). In Malaysia, little effort has been made on the use of wind energy. The potential for wind energy generation in Malaysia depends on the availability of the wind resource. The availability of the wind resource varies with location.

Among the sources of RE, the wind energy is the fastest growing energy technology in terms of percentage of yearly growth of installed capacity per technology source (Akdag & Güler, 2010). The worldwide wind energy installed capacity from 1996-2010 has been shown in Figure 1.2. As Harborne and Hendry (2009) noticed wind has advanced more quickly to commercialization than other technologies such as solar power, fuel cells and wave power with relatively little R&D expenditure. By the end of 1999, around 70% of the world-wide wind energy capacity was installed in Europe, a further 19% in North America and 9% in Asia and the Pacific (Ackermann & Söder, 2002).

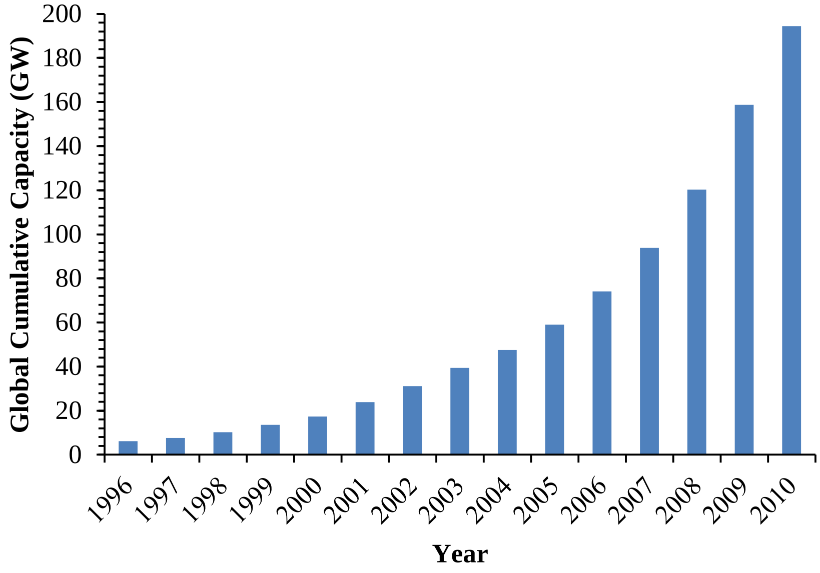

Figure 1. 2 Worldwide wind energy installed capacity (Data: GWEC). (GWEC, 2011b)

To build-up wind farm, it is necessary to carry out a general assessment of the wind energy potential nationwide. This can then be followed with detailed assessment in the promising locations. These assessments must be completed before making any final decision to install wind energy plant. The wind resource is a crucial step in planning a wind energy project and detailed knowledge of the wind at a site is needed to estimate the performance of a wind energy project.

By keeping in mind the critical situation of energy worldwide and considering the present and future energy scenario of Malaysia, this dissertation will focus on the assessment of wind energy potentiality and wind energy mapping in Peninsular Malaysia. For assessing the wind energy potentiality, in the case of HAWT, it is very much necessary to set-up the wind turbine in the direction of most available wind speed, so wind direction has been also determined. For determining the wind direction of the available wind, a reliable software ‘wind rose’ has been applied in this study. This dissertation is also focused on the contour mapping of Peninsular Malaysia. For representing the contour mapping of Peninsular Malaysia, a reliable method, Geographical Information System (GIS), has been implemented.

1.2 Wind energy basics

Wind is simply air in motion. It is caused by the uneven heating of the Earth’s surface by the sun. During the daytime, air on the land surface gets heated up faster than air on the water surface. The hot air expands and rises to the atmosphere and the cold air over the water surface tries to move to that place due to low pressure on the land as a result wind is produced. At nighttime, the process is reversed, the air on the land surface gets cooled faster than the air on the water surface, and the same principle is applied for the atmospheric winds. Sun is the ultimate source of energy for all renewable and almost all conventional energy sources. On an average earth receives $1.74 x 10^{17}$ watts of power from which about 1 to 2 percent is converted into wind energy, which accounts to 50 to 100 times more than the energy converted into biomass by all plants on earth (Garlapati, 2006; Li, 2011; Nasir, 1993).

The terms “wind energy” or “wind power” describes the process by which the wind is used to generate mechanical power or electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. In a conventional wind energy conversion system (WECS), the wind turbine traps the wind by means of rotor blades connected to the rotor hub. The gathered mechanical energy from the wind is transferred to a low-speed shaft and transmits the power to a high-speed shaft through a gearbox. The high speed shaft is connected to an electric motor which converts the mechanical energy of the wind to electrical energy. Induction generator does this process of converting mechanical energy into electrical energy and the output power produced is sent to the grid via transmission lines (Miller et al., 1997; Siegfried, 1998).

1.3 Objectives of the study

The vision for Malaysia stipulates the overall target of becoming an industrialized country by 2020. Similarly, the Ministry of Energy, Communication and Multimedia (MECM) has elaborated the vision for the energy sector for 2020. According to MECM vision, every member of Malaysian society should have access to high quality, secure electrical power and other convenient forms of energy supplied in a sustainable, efficient and cost-effective manner. However, Malaysia's energy sources primarily comprise oil, natural gas, hydropower and coal and recently renewable energy sources such as solar power and biomass are being exploited. In Malaysia, wind energy conversion is a serious consideration. The potential for wind energy generation in Malaysia depends on the availability of the wind resource. The availability of the wind resource varies with location. It is necessary to first carry out a general assessment of the wind energy potential nationwide. This can then be followed with detailed assessment in promising locations. These assessments must be completed before further action can be decided on. The wind resource is a crucial step in planning a wind energy project and detailed knowledge of the wind at a site is needed to estimate the performance of a wind energy project, keeping these in mind the objectives of this dissertation are as follows:

- To evaluate the availability of wind energy resources in Peninsular Malaysia based on the hourly surface wind speed and direction data.
- To develop the contour map to identify the potential wind regions in Peninsular Malaysia.

1.4 Scope of the study

This dissertation deals with the assessment of wind energy potentiality at various locations in Peninsular Malaysia. At first, it is needed to collect the data of wind speed from the Malaysian Meteorological Department. As many years wind speed data can be collected, it will be better for reliable wind energy assessment and contour mapping. The main scopes of this study are given below:

- As the wind turbines are generally installed at the height of 50 m, 100 m or 150 m and the wind resource of Malaysia is not so good, the 10 m height wind speed data has to be converted to 100 m wind speed data by using power law.

- Calculating the diurnal, monthly and yearly mean wind speed from the surface mean hourly wind speed. By plotting graphically the diurnal and monthly wind speed, the characteristics of wind speed have to be analyzed.

- The Weibull distribution function and cumulative distribution function are to be plotted and from these two distribution functions wind characteristics and suitable sites for the wind energy project has to be selected. From cumulative function, it is also being determined how many hours a wind project can be functional.

- The monthly and annually wind power and wind energy density for all the sites in Peninsular Malaysia are to be calculated from the meteorological wind speed data and distribution function.

- As the wind speed direction is very important for the wind project, the maximum wind flowing directions can be established by wind rose software.

- At last, by using the GIS method the contour map of Peninsular Malaysia will be presented.

1.5 Limitations of the study

Whenever the research proposal for this study was submitted, the surface wind speed and direction data was free of charge but from the year 2010 and onward Malaysian Meteorological Department (MMD) has introduced a new policy that everyone has to purchase wind speed data. However, to understand the weather behavior well, an adequate source of measuring weather data is very much essential. The relationship between the climatic data and energy performance of wind machines rely heavily on both the quality and quantity of the meteorological observations. Though, it is believed that wind speed data of shorter periods, less than 30 years, may inherit variations from the long term average but most of the developing countries do not possess accurate long term data (Lun & Lam, 2000; Weisser, 2003b). As a result, for this study initially it has been decided to study 10-year data of 32 stations in Peninsular Malaysia as in this study considered only Peninsular Malaysia. MMD fixes the rate of RM 1,440 for one year data of one station data. If it has been taken 10-year data of 32 stations then it is needed about RM 460,800, which is quite impossible for any project to provide. At last, it has been decided altogether to take two-year data of 15 stations for which cost around RM 46,080. This amount had been paid from the UMRG project (Project No. RG056-09AET) and IPPP project (PS091/2009C).

1.6 Outline of the dissertation

This dissertation comprises five chapters. The contents of each chapter are described briefly here:

CHAPTER 1: This is the introduction chapter, gives the brief overview on world energy related problems, Greenhouse gases and energy demand trend. Malaysian energy status and why Malaysia needs the RE has been briefly discussed. Backgrounds of the study, objectives and scope of study have been discussed in this chapter.

CHAPTER 2: This is the literature review chapter and in this chapter the present works which have been done in this field have been highlighted. The literature review of this study has been divided into two parts namely assessment of wind energy potentiality and wind energy contour mapping for Peninsular Malaysia.

CHAPTER 3: Methodology chapter where the method of assessing the wind energy potentiality has been described thoroughly. 2-parameter Weibull distribution model has been taken for the wind energy assessment in this dissertation. For showing the wind direction the WRPLOT software, version 5.9 has been used. Geographical Information System (GIS), ArcGIS 9.3, has been used to present the predicted monthly and yearly mean wind speed in the form of contour maps.

CHAPTER 4: This is the result and discussion chapter. In this chapter, the result of the wind energy assessment has been discussed thoroughly. The diurnal, monthly and yearly wind speed variations, wind power and energy density, Weibull and Cumulative distribution, Wind directions, etc. have been discussed. The contour maps of wind energy in Peninsular Malaysia have been discussed in this chapter.

CHAPTER 5: Conclusions and suggestions chapter. In this chapter the main outcome of the dissertation has been given very precisely. The main outcomes of the assessment of wind energy potentiality and wind energy mapping have been given appositely. The valuable suggestions have been given for the future work.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

In recent years, wind energy (wind turbine power generation) applications have grown rapidly to meet environmental protection requirements and electricity demands. Global capacity of wind power installations grew by 35.8 giga watts (GW) in 2010, a 22.5% increase on the 158.7 GW installed at the end of 2009. Currently, wind energy contributes less than 1% to total world electricity supply. However, wind energy grows at an exponential rate, from 20% to 40% per year and BTM consult ApS estimates that by 2012 wind energy will contribute 2% of world energy supply (GWEC, 2011a; Paul, 2007). Numerous researches related to wind energy assessment and mapping have been carried out with respect to its application, potential, performance, optimization, integration with other kinds of power generation systems, etc.

The literature review of this dissertation will give an overview of the present status of the related field and show the future work of the relevant field. This chapter presents a literature review on the assessment of wind energy potentiality and contour mapping of Peninsular Malaysia. For assessing the wind energy potentiality, the most versatile method '2-parameters Weibull distribution function' has been used and for mapping GIS method adopted in this study. A good collection of PhD and Master thesis, journal articles, reports, conference papers, internet sources and books have been used for this study. It should be mentioned that about 80-90% of the journal papers are collected from most pertinent and prestigious peer reviewed international referred journals such as Energy, Energy Policy, Applied Energy, Renewable and Sustainable Energy Reviews, Renewable Energy, Journal of Wind Engineering and Industrial

Aerodynamics, Environmental Research and International Journal of Energy Research. Some international high quality masters and PhD theses in the relevant field by Garlapati (2006); Khan (2004); Nasir (1993); Lackner (2008); Liddle (2008) may be considered as a strong support for this work. Moreover, a substantial amount of relevant information has been collected through personal communication with the key researchers around the world in this research area.

2.2 General history of wind technology

The history of wind power shows a general evolution from the use of simple, light devices driven by aerodynamic drag forces; to heavy, material-intensive drag devices; to the increased use of light, material-efficient aerodynamic lift devices in the modern era. But it shouldn't be imagined that aerodynamic lift (the force that makes airplanes fly) is a modern concept that was unknown to the ancients. The earliest known use of wind power, of course, is the sail boat, and this technology had an important impact on the later development of sail-type windmills. Wind indeed was almost the only source of power (Musgrove, 1987) for ships until this day in some locations; clearly show their debt to the sailing ship, with cloth sails attached to radial wooden spars. This allows the power output to be limited in strong winds by wrapping part of each sail around its spar. The Chinese reportedly invented the windmill. West of China in Persia windmills were used around 200 BC. By 1000 A.D. the Vikings had explored and conquered the North Atlantic because of the power of the wind. Windmills were introduced to the western-world in the 1100's AD. The earliest references that appear in the literature are 1105's AD in Arless France, 1180 A.D. in Normandy and 1191 A.D. in England. By 13th century windmills were used extensively throughout most of Europe. Around the 14th century, the Dutch used passive wind power to pump water from flooded fields with a device called a windmill. Much of Holland is below sea-level and is often flooded. The windmill was the transition invention that led to modern wind power turbines and other devices.

The windmills refer to the operation of grinding or milling grain. This application was so common that most wind turbines were called wind mills, even when they actually pumped water or performed some other function. By the late 19th century, the multi-vane windmill was invented in the United States to pump groundwater; this assisted in the settlement of the West and Midwest by providing water for humans, livestock, and railroads.

In the 1930s a Frenchman named G. J. M. Darrieus invented a wind power design in the shape of an eggbeater. By 1940 there were around 6 million windmills of the type introduced in the United States almost a century earlier in 1854. In 1941 near Rutland, Vermont a giant 1.5 MW machine powered the Central Vermont Public Service electric grid. Just as solar power technology accelerated during the oil embargo of 1973 - 1974, wind power made large strides. Westinghouse Electric Company received Department of Energy (DOE) / NASA contracts for building large scale wind turbines. The greatest capacity wind turbine was built in Oahu, Hawaii, with a 3.2 MW power rating.

A 25% tax credit for investors of wind turbines was made through the Public Utilities Regulatory Policies Act (PURPA) of 1978. Between 1981 and 1984 6,870 turbines were installed in California. At the end of 1983, there were around 4600 wind turbines operating out of California. These turbines together produced 300000 KW of electricity. The change in prices of wind power electricity dropped from 14 cents per kWh in 1985 to 5 cents per kWh in 1994 making wind power a much greater competitor in the electricity market (Andersen, 2011; Telosnet, 2011; Wikipedia, 2011).

2.3 Review on assessment of wind energy potentiality

Wind energy site assessment evaluates the potential for a given site to produce energy from wind turbine. Typically, wind energy development is initiated by a private company, government body, or utility that is interested in producing wind energy in a particular region. The process generally begins with a “preliminary area identification’, which entails identifying a relatively large area where wind energy development is viable. This type of rudimentary assessment has been going on all over the world to assist the final assessment to the Governmental agencies. Keyhani et al. (2010) assessed the wind energy potentiality as a power generation source in the capital of Iran. For doing this, they used the wind speed data over an eleven-year period from 1995-2005. The wind speed data was collected from the Meteorological department of Iran. The authors showed that the diurnal, monthly and annual wind speed variation over the projected period. From these data, by the 2-parameter Weibull distribution, the authors evaluated the wind energy potentiality at Tehran. Wind direction has been also shown by the Wind Rose Polar diagram. According to the authors' estimation, the monthly mean wind speed values are between 4.00 m/s and 5.00 m/s, but some are over 5.00 m/s, while only a few are over 5.50 m/s and under 3.50 m/s. The yearly mean wind speed values range from 3.86 m/s to 4.5m/s. The authors found that the monthly maximum wind power density at Tehran was 106.49 W/m^2, whereas the yearly maximum wind power density was 115.5 W/m^2 in 2003.

Fyrippis et al. (2010) evaluated the wind energy potentiality in Naxos Island, Greece. For evaluating the wind energy potentiality, Weibull distribution and Rayleigh distribution have been used. To evaluate the performance of these distribution methods, the root mean square error (RMSE) parameter, the chi-square (χ^2) test and the modeling efficiency test have been implied. From these test, it was found that the Weibull distribution represented the actual data better than the Rayleigh distribution. It was found that the highest and lowest value of the mean wind power density was 730 W/m^2 and 180 W/m^2 respectively, while the mean annual wind power density was estimated to be 420 W/m^2. It is concluded that the region falls in the wind class of 7, and it is suitable for large scale wind energy production.

Angreh et al. (2010) made the assessment of renewable energy potential at Aqaba in Jordan. To assess the renewable energy potentiality, they implemented the skew-normal statistical method. They analyzed the daily mean wind speed of 10 years and five years of solar insolation level data. The goodness of fit of SN models has been examined graphically and statistical tests through chi-square (χ^2) and Kolmogorob-Smirnov tests. After analyzing the authors strongly recommended that the fitted SN distribution as an appropriate model for daily mean wind speeds data, since the fitted SN-distribution passes both graphical and goodness fit tests. The maximum wind power density was found to be 304.32 W/m^2 and 326.75 W/m^2 by Skew-Normal test and from Meteorological data respectively.

Zaharim et al. (2009) analyzed the wind speed in the east coast of Malaysia by using Weibull, Lognormal and Gamma distribution functions. Two-year data have been collected from the University of Malaya and University of Terengganu stations. It is found that the highest and lowest wind speeds are found to be 6.54 m/s and 2.04 m/s, whereas the mean wind speed was about 3.7 m/s. From the distribution functions, it is found that the all distribution functions represent a narrow peak for the whole distributions in the range of 2.0 m/s to 3.0 m/s.

Khadem and Hussain (2006) studied the feasibility of wind resources in Kutubdia Island, Bangladesh. For assessing the feasibility, they collected the wind speed data from Bangladesh Meteorological Department (BMD) and Bangladesh Centre for Advance Studies (BCAS). From the wind speed data of BMD stations, they found the yearly mean wind speed was 1.80 m/s at 13 m height over the 10 years period, whereas from BCAS data, they found the yearly mean wind speed was 4.40 m/s at 25 m height.

Their main objective of this study was to assess the wind resources over the island and to predict good locations for wind energy generation. To do this, they implied the Wind Atlas Analysis and Application Program (WAsP) for vertical and horizontal extrapolation, which uses time series of wind data along with information on surface characteristics of the location. By applying WAsP, they developed the frequency of wind speed, monthly and yearly Weibull parameters, wind directions by wind rose and the wind atlas at 50 m height. It was found that the maximum mean wind speed value was 5.79 m/s, whereas the maximum power density was 250 W/m^2.

Tarawneh and Sahin (2003) have estimated the mean wind speed in some parts of Jordan using standard regional dependence function (SRDF) by using the wind speed records of 1977-1998 at the Jordanian Meteorological Department. The SRDF gives flexibility in obtaining dependent weighting factors, leading to more realistic point estimations. Celik (2003) has estimated monthly wind energy production using Weibull representative wind data in the time series format for a total of 96 months from five different locations in the world. The Weibull parameters (shape factor and scale factor) were determined based on wind distribution statistics, calculated from measured data with the help of gamma function. The main objective of this study was to estimate the wind energy output for small-scale systems. Using the Weibull representative and measured data in the time-series format, the monthly energy outputs were calculated for a wind turbine of 50 W nominal power. The author concluded from this study that the Weibull-representative data are very successful in representing the time-series data.

Chang et al. (2003) have assessed the wind characteristics and wind turbine characteristics in Taiwan by analyzing the 39 years wind speed data source (1961–1999) at 25 meteorological stations. To investigate wind characteristics and wind turbine characteristics, a 2-stage evaluation procedure has been carried out. To get the basic information regarding wind resources, the yearly wind speed distribution and wind power density have been evaluated. The wind turbine characteristics: the availability factor, the capacity factor and wind turbine efficiency for different high-wind locations were calculated and integrated to map out the wind energy resources. It was found that the availability factor varies from 0.794 to 0.929, the wind turbine efficiency was located between 0.246 to 0.29, and the capacity factor was between 0.45 to 0.64.

Sopian et al. (1995) analyzed the 10 years wind speed data of 10 stations for Malaysia. The annual frequency distribution of wind speeds for the ten stations has been shown. The wind distribution has been classified into four categories: (i) the month of April (ii) the month of May-September (iii) the month of October and (iv) the months of November-March. It is found that Mersing and Kuala Ternggganu has the greatest wind power potential in Malaysia.

2.4 Review on contour mapping for wind energy

Generally, the wind energy mapping system is designed to display regional (greater than 50,000 km^2) distributions of the wind resource. The maps are intended to denote areas where wind energy projects might be feasible. The national Renewable Energy Laboratory (NREL) has developed an automated technique for wind resource mapping to aid in the acceleration of wind energy deployment. The commercially available geographic information system software packages have been used in mapping system by NREL. Regional wind resource maps using this new system have been produced for areas of the United States, Mexico, Chile, Indonesia, and China. Countrywide wind resource assessments are under way for Philippines, the Dominican Republic, and Mongolia. Some of the counties in the world like Argentina and Russia are scheduled to begin in the near future (Schwartz, 1999). As fossil fuel has been depleted gradually, most of the countries in the world are now interested in renewable energy expansion. However, most of the countries still did not take any effective steps to develop contour mapping but separately contour map development has been going on in the various places all over the world. Some of them are given in this section.

Beccali et al. (2010) have estimated the wind speed over the complex terrain using the generalized mapping regressor. For this study, the hourly mean wind speed data from 29 different stations of Sicilian territory have been collected. The curvilinear Component Analysis (CCA) has been used to find the underlying manifold of data (the average manifold) and to map it onto a p-dimensional output Y. The very important factor, surface roughness that can influence the wind profile has been considered. To assess the performances of the implemented models, the predicted values of the wind speed at 10 m a.g.l has been compared with those obtained by the NNRK approach. Finally, a map has been obtained of the estimated average wind speed at 50 m a.g.l.

Fadare (2010) has produced the wind energy mapping for energy application in Nigeria using the artificial neural networks. For doing this, the author used the Geographical Information System (GIS) Software ArcView® 3.2. The author has analyzed 20 years (1983-2003) wind speed data from 28 meteorological stations. From the coastal region in the south to savannah region in the north, the monthly mean wind speed has been varied greatly. The monthly mean wind speeds are found to be 7.0-13.1 m/s and 0.9-13.1 m/s for the southern region and northern region respectively. The highest monthly wind energy has been found to be 6027.7 W. The author has concluded that the ANN based model has the acceptable accuracy with Mean Absolute Percentage Error (MAPE) of 8.9% and correlation coefficient (r-value) of 0.9380 was found for prediction of wind speed profile in Nigeria.

Ramachandra and Shruthi (2005) have employed the geographical information system (GIS) to map the wind energy resources at Karnataka state and analyzed their variability considering spatial and seasonal aspects. They developed a spatial database with the wind speed data and used to evaluate of the theoretical potential through continuous monitoring and mapping of the wind resources. The wind speed data have been collected from the India Meteorological Department (IMD) in Karnataka of 29 stations. The author did not consider the yearly mean wind speed less than 5 m/s as suitable for generating energy, and they found Chikkodi, Horti, Kahanderayanahalli and Kamkarhatti as the promising sites for harnessing wind energy. These sites have been recommended for construction of wind farms (Ramachandra & Shruthi, 2007)

Khan et al. (2004) have generated a wind energy map of Bangladesh, which incorporates several microscale features, such as terrain roughness, elevation, etc. with a mesoscale model. A mesoscale map has been obtained from several global climatological databases was adjusted for the 30-m elevation, and terrain condition, which would suit the land profile of Bangladesh. The available surface measurement data were investigated, corrected, correlated and compared with this model. From this map, the authors have been found that the coastal belt of Bangladesh has an annual average wind speed above 5 m/s, whereas the wind speed in the northeastern districts is around 4.5 m/s.

CHAPTER 3: METHODOLOGY

3.1 Introduction

The methodology section comprises mainly two parts: assessment of wind energy potentiality and contour mapping of wind energy for Peninsular Malaysia. In this chapter, the methods of assessment of wind energy and contour mapping have been discussed individually.

3.2 Assessment of wind energy potentiality

The assessment of the wind energy resource is a crucial step in planning a wind energy project and detailed knowledge of the wind at a site is needed to estimate the performance of a wind energy project. In this dissertation, Weibull distribution model has been taken for the assessment for wind energy potentiality. Along with the Weibull distribution model, general climate of Malaysia, wind data collection, site's description, wind data adjustment, etc. have been clearly described in this section.

3.2.1 General climate of Malaysia

Malaysia, in the southeast part of Asia, has a geographic coordinate, and it lies on latitude 2° 30'N and longitude 112° 30'E. The country is recognized by two lands mass, which separated by South China Sea. One is in Peninsula Malaysia region, and another two states (Sabah and Sarawak) are in Borneo Island and total up the sum 329,847 square kilometers (127,355 sq. mi.) with 27 million populations live in Malaysia.

The characteristic feature of the climate of Peninsular Malaysia is equatorial and is characterized by fairly high but uniform temperatures (ranging from 23° to 31° C /73° to

88° F throughout the year), high humidity, and copious rainfall (averaging about 250 cm/100 in annually). Being located near the equator, the weather in Malaysia is generally considered ‘hot’ and ’sunny’. It is extremely rare to have a full day with clear sky even during periods of severe drought. On the other hand, it is also rare to have a stretch of a few days with completely no sunshine except during the northeast monsoon seasons.

Though wind speed over the country is generally variable, there are, however, some uniform periodic changes in the wind flow patterns. Based on these changes, four seasons can be distinguished, namely, the southwest monsoon, northeast monsoon and two shorter periods of inter-monsoon seasons. The southwest monsoon season is usually established in the latter half of May or early June and ends in September. The prevailing wind flow is generally southwesterly and light, below 7.725 m/s.

The northeast monsoon season usually commences in early November and ends in March. During this season, steady easterly or northeasterly winds of 5.15 to 10.30 m/s prevail. The east coast states of Peninsular Malaysia where the wind may reach 15.45 m/s or more during periods of strong surges of cold air from the north (cold surges). During the two intermonsoon seasons, the winds are generally light and variable. During these seasons, the equatorial trough lies over Malaysia (Exell & Fook, 1986; Sopian et al., 1995).

It is worth mentioning that during the months from April to November, when typhoons frequently develop over the west Pacific and move Westwards across the Philippines, Southwesterly winds over the Northwest coast of Sabah and Sarawak region may strengthen to reach 10.30 m/s or more. An average of 6 to 7 tropical cyclones traverses over the Philippines and South China Sea per year. More precisely, it occurred 7 times in 1996, 5 times in 1997, 4 times in 1998, 2 times in 1999, 7 times in 2000, 3 times in

2001, 5 times in 2002, 8 times in 2003, 12 times in 2004 and 4 times in 2005 (Pacheco et al., 2007). For protecting any unexpected incident of wind turbine, a control strategy which provides the Asian and Pacific area against the strong typhoon relates to the pitch and yaw system can be used. With the regulation of the pitch angle and the yaw angle, the load of blade, nacelle and tower structure could be reduced (Yen-Chieh et al., 2010). The Typhoon II, a unique vertical axis wind turbine (VAWT), can also be applied in this region. It provides improved performance with both a substantially higher degree of efficiency and a wider range of exploitable wind speeds than those of the now prevailing horizontal axis wind turbines (HAWT) (CTV, 2010).

3.2.2 Wind data collection and site description

The wind speed data for this study has been collected from the Malaysian Meteorological Department (MMD) at Petaling Jaya, Selangor during the period of 2008-2009. MMD collected wind speed data from different stations throughout Peninsular Malaysia. A 10 m height mast, made of steel in the solid tubular form was used to install the anemometer and wind vane for selected stations. A rotating cup type anemometer and a wind vane were both installed at the top of the mast for measuring the surface wind speed and wind direction respectively. The temperature and the relative humidity were also measured using a thermometer and a hygrometer respectively. The reason for performing wind speed measurement at 10 m height was that according to Katsoulis (1993), for climatological and practical reasons it has been agreed that this should be the standard meteorological reference level in order to achieve representative recording of the wind potential of the area. Furthermore, the wind speed at higher heights could be calculated using the power law. Wind speed was taken every 10 seconds and averaged over 5 minutes and stored in a data-logger. The 5-minutes averaged data were further averaged over an hour. At the end of each hour, the hourly mean wind speed was calculated and stored sequentially in a permanent memory (Azami et al., 2009; Hrayshat, 2005; Keyhani et al., 2010).

Regions near the Equator may not be a good place for wind power generation, but analysis of wind data at windy sites in Malaysia is important for prospective wind power applications and for the estimation of available power density within a time period. Though the SREP has targeted to generate 5% (600 MW) of the country's electricity consumption from RE by 2005, only 0.3% were achieved. Obviously, the progress in bringing RE generation into the mainstream has been slow due to several reasons and limitations (Oh & Chua, 2010a). On the other hand, it is estimated that the natural gas reserve is expected to last for around 70 years, while oil is expected to be depleted in 16 years at the current rate of usage. To continue the economic development in the current pace, there is no other way to meet the energy demand but RE. In this study, 15 stations from the peninsular Malaysia, for initial wind energy assessment and contour mapping, have been selected based on the availability of the wind speed data and for evenly distribution all over the Peninsular Malaysia. The details of these stations are given in Table 3.1.

Malaysia is situated right in the heart of South East Asia and is divided into two geographical sections: Peninsular Malaysia and the East Malaysian provinces of Sabah and Sarawak in North Borneo. The two parts are separated 650 km (403 miles) apart by the South China Sea. Peninsular Malaysia's neighbors are Thailand and Singapore. Sabah and Sarawak border Kalimantan (the Indonesian part of Borneo) and Sarawak surrounds the tiny enclave of Brunei. The Andaman Sea is on the West Coast of the peninsula. The East Coast of the peninsula, Sabah and Sarawak all adjoin the South China Sea.

Table 3.1 The location and elevation of the selected stations

Station name	Station ID	Latitude ˚N	Longitude ˚E	Height a.s.l. (m)
Batu Embun	48642	3˚58′ N	102˚21′ E	59.5
Bayan Lepas	48601	5˚18′ N	100˚16′ E	2.8
Butterworth	48602	5˚28′ N	100˚23′ E	2.8
Cameron Highlands	48632	4˚28′ N	101˚22′ E	1545
Chuping	48604	6˚29′ N	100˚16′ E	21.7
Ipoh	48625	4˚34′ N	101˚06′ E	40.1
KLIA Sepang	48650	2˚44′ N	101˚42′ E	16.3
Kota Bharu	48615	6˚10′ N	102˚17′ E	4.6
Kuala Krai	48616	5˚32′ N	102˚12′ E	68.3
Kuala Terengganu	48618	5˚23′ N	103˚06′ E	5.2
Kuantan	48657	3˚47′ N	103˚13′ E	15.3
Malacca	48665	2˚16′ N	102˚15′ E	8.5
Mersing	48674	2˚27′ N	103˚50′ E	43.6
Senai	48679	1˚38′ N	103˚40′ E	37.8
Sitiawan	48620	4˚13′ N	100˚42′ E	7

The topography of Peninsular Malaysia is characterized by the central mountain ranges running from north to south. A mountainous spine, known as the Main Range or Banjaran Titiwangsa, runs from the Thai border southwards to Negeri Sembilan, effectively separating the eastern and western parts of the peninsula. The highest peak, Gunung Tahan, is 2,187 m a.s.l. In Sabah and Sarawak, a similar topography of high mountain ranges occurs in the interior, with all ranges below 1,800 m except Mt Kinabalu, which at 4,101 m a.s.l., is the highest peak in S.E. Asia. Four-fifths of Peninsular Malaysia is covered by rainforest and swamp. The northern regions are divided by a series of mountain ranges that rise abruptly from the wide, flat coastal plains. The main watershed follows a mountain range about 80 km (50 mi) inland, roughly parallel to the west coast. The rivers flowing to the east, south, and west of this range are swift and have cut some deep gorges, but on reaching the coastal plains, they become sluggish. The western coastal plain contains most of the country's population and the main seaports, George Town (on the offshore Pulau Pinang) and Kelang (formerly Port Swettenham). The eastern coastal plain is mostly jungle and lightly settled. It is subject to heavy storms from the South China Sea and lacks natural harbors.

As a result of the configuration of the country and of the heavy rainfall, many rivers originate in the mountains and fall to the sea on both sides of the peninsular. A number of large rivers such as Sungai Rajang, Sungai Baram in Sarawak and Sungai Kinabatangan in Sabah, originate from these mountainous areas. Rice cultivation is practiced throughout the peninsula, but the main and traditional centers are the states of Perlis, Kedah, Selangor, Kelantan, and mainland Pulau Pinang. Most of the larger rubber and oil palm estates are located on the peninsula.

3.2.3 Wind data adjustment

The variation in velocity with altitude, called wind shear, is most pronounced near the surface and the wind blows faster at higher altitudes because of the drag of the surface (sea or land) and the viscosity of the air. Typically, in the daytime the variation follows the 1/7th power law, which predicts that wind speed rises proportionally to the seventh root of altitude. In the night time, or better when the atmosphere becomes stable, wind speed close to the ground usually subsides, whereas at turbine hub altitude, it does not decrease that much or may even increase.

As the wind speed changes with height and the anemometer at different meteorological stations are set at different levels, it is necessary, prior to any analysis, to adjust the recorded wind speed data to the same height. The wind power law has been recognized as a useful tool and is often used in wind power assessments where the wind speeds at the height of a turbine (>~ 50 meters) must be estimated from near surface wind observations (~10 meters), or where wind speed data at various heights must be adjusted to a standard height prior to use.

The wind profile power law relationship is:

$$v = v_0 \left(\frac{z}{z_0} \right)^{\alpha} \tag{3.1}$$

The exponent (α) is an empirically derived coefficient that varies dependent upon the stability of the atmosphere. For neutral stability conditions, α is approximately 1/7, or 0.143 is commonly assumed to be constant in wind resource assessments, because the differences between the two levels are not usually so great as to introduce substantial errors into the estimates (usually < 50 m). However, when a constant exponent is used, it does not account for the roughness of the surface, the displacement of calm winds from the surface due to the presence of obstacles (i.e., zero-plane displacement), or the stability of the atmosphere.

The value of the coefficient varies from less than 0.10 for very flat land, water or ice to more than 0.25 for heavily forested landscapes and the typical value of 0.14 for low roughness surfaces (Ramachandra et al., 2005; Zhou, 2008). The value 0.143 for the co-efficient of α has been chosen for this experiment.

3.2.4 Data description

In this study, the hourly mean surface wind speed and direction data has been collected from the Malaysian Meteorological Department. The MMD has collected these wind speed data at the 10 m height from the ground. As the wind speed in Malaysia is not so much potential and for the better distribution results, the 10 m height data have been converted to 100 m height wind speed data. After that the hourly surface wind speed data has been averaged in monthly basis wind speed data. Some of them are given here in Tables 3.2 to 3.4 and rests of them are given in the Appendix A.

Table 3.2 Monthly basis hourly surface wind speed data at Batu Embun in 2008

Hour \ Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hourly Mean
1	0.42	0.21	0.16	0.58	0.56	0.38	0.48	0.46	0.43	0.37	0.4	0.26	0.39
2	0.42	0.21	0.23	0.52	0.45	0.43	0.44	0.47	0.34	0.4	0.44	0.4	0.4
3	0.42	0.18	0.39	0.43	0.31	0.34	0.39	0.43	0.36	0.46	0.29	0.41	0.37
4	0.22	0.19	0.2	0.57	0.32	0.32	0.26	0.32	0.29	0.4	0.33	0.42	0.32
5	0.38	0.21	0.28	0.42	0.31	0.4	0.27	0.27	0.22	0.44	0.44	0.37	0.34
6	0.29	0.18	0.23	0.39	0.35	0.4	0.29	0.17	0.36	0.39	0.43	0.36	0.32
7	0.31	0.22	0.26	0.45	0.26	0.42	0.25	0.26	0.22	0.4	0.4	0.46	0.33
8	0.27	0.28	0.39	0.6	0.37	0.44	0.31	0.47	0.37	0.56	0.5	0.53	0.42
9	0.95	0.99	0.85	1.25	0.85	0.81	0.78	1.1	0.9	1.12	0.95	1.03	0.96
10	1.41	1.48	1.25	1.71	1.39	1.38	1.25	1.58	1.29	1.43	1.32	1.74	1.43
11	1.74	1.84	1.63	1.79	1.72	1.67	1.58	1.76	1.64	1.75	1.54	1.84	1.71
12	1.83	2.05	1.44	1.9	1.73	1.83	1.93	2.14	1.95	1.71	1.69	1.88	1.84
13	1.73	2	1.78	1.61	1.68	1.79	1.91	1.99	1.94	1.71	1.75	1.92	1.82
14	1.73	1.93	1.53	1.65	1.86	1.81	2	2.08	2.03	1.59	1.47	1.67	1.78
15	1.69	1.93	1.52	1.76	1.84	1.94	2.13	1.78	1.86	1.51	1.39	1.69	1.75
16	1.56	1.58	1.7	1.52	1.66	1.64	1.95	1.72	1.74	1.38	1.33	1.34	1.59
17	1.44	1.47	1.39	1.37	1.37	1.69	1.72	1.68	1.76	1.21	1.26	1.17	1.46
18	1.2	1.14	1.02	1.36	1.26	1.35	1.25	1.38	1.32	0.99	1.01	1.23	1.21
19	0.78	0.77	1.02	0.86	0.61	0.89	0.91	0.82	0.83	0.8	0.61	0.68	0.8
20	0.42	0.56	0.71	0.76	0.48	0.57	0.74	0.7	0.61	0.93	0.63	0.63	0.64
21	0.5	0.59	0.61	0.61	0.71	0.51	0.47	0.51	0.72	0.91	0.57	0.43	0.6
22	0.45	0.47	0.52	0.74	0.72	0.47	0.57	0.57	0.5	0.58	0.45	0.19	0.52
23	0.49	0.19	0.39	0.68	0.7	0.47	0.39	0.51	0.42	0.5	0.42	0.23	0.45
24	0.37	0.26	0.27	0.64	0.56	0.5	0.48	0.58	0.38	0.43	0.38	0.24	0.43
Monthly Mean	0.88	0.87	0.82	1.01	0.92	0.94	0.95	0.99	0.94	0.92	0.83	0.88	

Table 3.3 Monthly basis hourly surface wind speed data at Batu Embun in 2009

Hour \ Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hourly Mean
1	0.13	0.21	0.56	0.33	0.33	0.46	0.22	0.37	0.48	0.5	0.51	0.29	0.37
2	0.35	0.13	0.36	0.43	0.28	0.38	0.35	0.27	0.28	0.45	0.42	0.39	0.34
3	0.27	0.17	0.42	0.37	0.27	0.36	0.26	0.18	0.38	0.38	0.4	0.39	0.32
4	0.32	0.13	0.28	0.24	0.17	0.26	0.26	0.25	0.18	0.46	0.45	0.48	0.29
5	0.3	0.28	0.38	0.34	0.29	0.26	0.22	0.22	0.39	0.47	0.48	0.43	0.34
6	0.3	0.22	0.4	0.31	0.22	0.26	0.13	0.07	0.24	0.44	0.49	0.48	0.30

Month / Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hourly Mean
7	0.26	0.03	0.29	0.28	0.48	0.45	0.23	0.14	0.29	0.39	0.38	0.49	0.31
8	0.24	0.11	0.47	0.46	0.59	0.5	0.41	0.34	0.41	0.51	0.59	0.66	0.44
9	0.85	0.67	0.91	1.08	1.05	1.00	0.82	0.85	0.98	0.96	1.09	1.00	0.94
10	1.44	1.31	1.41	1.64	1.35	1.39	1.17	1.38	1.47	1.56	1.41	1.33	1.41
11	1.82	1.70	1.69	1.66	1.57	1.55	1.59	1.57	1.81	1.77	1.75	1.71	1.68
12	1.79	1.86	1.77	1.84	1.71	1.86	1.72	1.65	1.84	1.87	1.77	1.78	1.79
13	1.94	1.83	1.89	1.68	1.59	1.8	2.05	1.8	2.02	1.79	1.72	1.82	1.83
14	1.85	1.8	1.86	1.57	1.55	1.75	2.04	1.87	1.79	1.57	1.74	1.79	1.77
15	1.71	1.79	1.62	1.58	1.64	1.65	1.83	1.69	1.74	1.63	1.55	1.62	1.67
16	1.68	1.59	1.88	1.83	1.47	1.62	1.73	1.76	1.64	1.36	1.54	1.64	1.65
17	1.44	1.22	1.96	1.55	1.48	1.5	1.47	1.5	1.61	1.26	1.63	1.39	1.50
18	1.17	1.29	1.36	1.24	1.32	1.04	1.08	1.25	1.3	1.22	0.85	0.98	1.18
19	0.67	0.74	1.07	0.68	0.83	0.48	0.61	0.81	1.07	1.09	0.64	0.67	0.79
20	0.51	0.56	0.75	0.84	0.76	0.63	0.61	0.82	0.76	0.71	0.51	0.46	0.66
21	0.46	0.71	0.82	0.83	0.71	0.69	0.43	0.95	0.67	0.73	0.53	0.38	0.66
22	0.46	0.71	0.74	0.48	0.67	0.59	0.39	0.61	0.54	0.58	0.6	0.35	0.56
23	0.25	0.61	0.52	0.36	0.61	0.46	0.43	0.37	0.37	0.77	0.41	0.3	0.45
24	0.32	0.49	0.4	0.38	0.43	0.72	0.36	0.41	0.26	0.69	0.37	0.38	0.43
Monthly Mean	0.86	0.84	0.99	0.92	0.89	0.9	0.85	0.88	0.94	0.97	0.91	0.88	

Table 3.4 Monthly basis hourly surface wind speed data at Butterworth in 2008

Month / Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hourly Mean
1	1.74	2.4	1.33	2.3	1.39	1.48	1.06	1.53	1.05	1.97	1.77	1.78	1.65
2	1.69	2.63	1.49	1.73	1.21	1.5	1.2	1.44	1.94	1.9	1.67	1.98	1.7
3	1.91	2.3	1.38	1.8	1.69	1.27	1.46	1.67	1.72	1.98	1.61	1.88	1.72
4	1.72	2.07	1.47	1.77	1.58	1.12	1.56	1.92	2.11	2.22	1.53	1.61	1.72
5	1.5	2.08	1.24	1.61	1.74	1.19	1.43	1.86	2.06	2.13	1.64	1.57	1.67
6	1.42	2.12	1.35	1.76	2.16	1.47	1.21	1.95	1.75	1.9	1.58	1.74	1.7
7	1.31	1.93	1.54	1.49	1.51	1.26	1	1.72	1.71	1.62	1.4	1.83	1.53
8	1.3	1.63	1.3	1.61	1.74	1.86	1.32	1.89	2.15	2.37	1.91	2.14	1.77
9	2.02	2.36	2.49	2.35	2.35	2.22	2.17	2.35	2.49	2.62	2.46	3.13	2.42
10	3.03	3.47	2.77	2.51	2.41	2.12	2.16	2.71	2.64	2.43	2.7	3.19	2.68
11	2.97	3.47	2.43	2.53	2.57	2.52	3.5	3.19	2.9	2.3	2.78	3.14	2.86
12	3.1	3.6	2.65	2.98	3.34	3.54	4.59	4.13	3.4	3.08	3.11	4.03	3.46

Month / Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hourly Mean
13	3.99	3.94	3.74	3.92	3.89	4.17	4.65	4.85	3.75	3.91	3.76	4.54	4.09
14	4.55	4.76	4.55	4.72	4.69	4.65	4.89	5.05	4.57	4.46	4.45	5.27	4.72
15	5.25	5.15	5.23	4.88	4.99	4.43	5.21	5.34	4.85	4.78	4.64	5.44	5.02
16	5.66	5.37	4.8	4.63	4.76	4.29	4.8	5.3	4.03	4.69	4.66	5.46	4.87
17	4.95	5.36	4.44	4.65	4.74	4.12	5.05	5	4.2	4.55	4.32	5.05	4.7
18	4.53	4.22	3.74	4.1	4.17	3.41	4.52	4.56	3.98	4.3	4.14	4.37	4.17
19	3.52	4.16	3.05	3.52	3.44	2.91	3.75	3.79	3.29	3.25	3.42	4.07	3.51
20	3.29	3.51	3.01	2.83	2.76	2.81	2.86	3.31	2.97	2.78	3.22	4.28	3.14
21	3.74	3.17	2.52	2.8	2.5	2.47	2.39	2.69	2.57	2.63	2.65	3.37	2.79
22	2.59	2.71	2.34	2.77	2.34	1.52	2.15	2.05	2.1	2.37	2.67	3.12	2.39
23	2.16	3.04	1.62	2.48	1.77	1.41	2.08	1.85	1.62	2.43	2.52	3.14	2.18
24	2.22	2.21	1.46	2.01	1.6	1.5	1.74	1.78	1.71	1.97	2.38	2.83	1.95
Monthly Mean	2.92	3.24	2.58	2.82	2.72	2.47	2.78	3	2.73	2.86	2.79	3.29	

3.2.5 Analysis procedure

3.2.5(a) Wind speed distribution parameters

In order to assess the wind energy potentiality of a particular area and hence the economical viability of a particular area, it is very much necessary to know the wind speed distribution over a period of time. The wind speed distribution predominantly determines the performance of wind power systems. From the literature, it is observed that different wind speed distribution models (such as the Weibull, the Rayleigh and the Lognormal) are used to fit the wind speed distributions over a period of time. Among them, the 2-parameter Weibull function is accepted as the best all over the world. It is because the Weibull distribution function has its merits in wind resource assessment due to great flexibility and simplicity, but particularly it has been found to fit a wide collection of recorded wind speed data. This statistical tool also indicates how often winds of different speeds will be seen at a location with a certain average (mean) wind speed and knowing this one can easily choose a wind turbine with the optimal cut-in speed (the wind speed at which the turbine starts to generate usable power), and cut-out speed (the speed at which the turbine hits the limit of its alternator and can no longer put out increased power output with further increases in wind speed) (Celik, 2003; Weisser, 2003a; Zhou, 2008). Weibull distribution model has been chosen for the assessment of wind energy potentiality in this paper. However, it has limitations as well. The main limitation of the Weibull distribution function is that it is unable to represent the probabilities of observing zero or very low wind speeds. However, for the purpose of estimating wind energy potentiality for the commercial use of wind turbines, it is worthless as the energies available at low speeds are very negligible (Persaud et al., 1999; Weisser, 2003a).

3.2.5(b) Weibull distribution function

The wind speed data obtained, with various observation methods, has usually wide ranges and could not be taken as sufficient for obtaining a clear view of the available wind potential. Therefore, it is necessary to have only a few key parameters that can explain the behavior of the wide range of wind speed data. In order to minimize the required time and expenses for processing long-term, usually hourly, wind speed data, it is preferred to describe the wind speed variations using statistical functions. The 2-parameter Weibull function can be used for this purpose as one can adjust the parameters to suit a period of time, usually one month or one year and can use widely both in wind speed and wind energy analysis (Gökçek et al., 2007; Kenisarin et al., 2006). In Weibull distribution, the variation in wind velocity is characterized by two parameter functions, the probability density function and the cumulative distribution function.

The wind speed probability distribution function indicates the fraction of time for which a wind speed possibly prevails at the area under investigation. The wind speed probability density function can be calculated by the following equation (Ahmed, 2010; Fyrippis et al., 2010):

$$f(v) = (\frac{k}{c})(\frac{v}{c})^{k-1} \exp\left[-\left(\frac{v}{c}\right)^k\right] \tag{3.2}$$

Another important aspect should be considered during the statistical analysis is the prediction of the time for which an installed turbine could be potentially functional in this area. In order to achieve this, the determination of the cumulative distribution function is required. Since the cumulative distribution function of the velocity v indicates the fraction of time the wind speed is equal or lower than the speed v, by taking the difference of its values it is possible to estimate the functional time of the wind turbine. Therefore, the cumulative distribution is the integral of the probability density function and can be expressed as (Akpinar & Akpinar, 2005):

$$F(v) = 1 - e^{-(v/c)^k} \tag{3.3}$$

For the analysis of a wind regime using the Weibull distribution, the Weibull parameters k and c must be calculated. Under the Weibull distribution, the major factor determining the uniformity of wind is the shape factor k. Uniformity of wind at the site increased with k. For example, with k=1.5, the wind velocity is between 0 and 20 m/s for 95 percent of the time. Whereas, when k=4, the velocity is more evenly distributed within a smaller range of 0 to 13 m/s for 95 percent of the time. In the first case, the most frequent wind speed is 5 m/s, which is expected for 7.6 percent of the total time. The most frequent wind speed of 9 m/s would prevail for 15.5 percent of the time in the second case. Some of the methods used for determining k and c are:

1. Weibull probability plotting method
2. Moment method
3. Energy pattern factor method

4. Standard deviation method
5. Maximum likelihood method

Though all the above mentioned methods are widely used, in this study Standard deviation method has been used. In this method, by calculating the mean wind speed $\bar{v}$, and the variance σ of the known wind speed data, the following approximation can be used to calculate the Weibull parameters c and k:

$$\bar{v} = \frac{1}{n}\left[\sum_{i=1}^{n} v_i\right] \tag{3.4}$$

$$\sigma = \left[\frac{1}{n-1}\sum_{i=1}^{n}(v_i - \bar{v})^2\right]^{1/2} \tag{3.5}$$

$$k = \left(\frac{\sigma}{\bar{v}}\right)^{-1.086} (1 \le k \le 10) \tag{3.6}$$

$$c = \frac{\bar{v}}{\Gamma(1+1/k)} \tag{3.7}$$

Where, Γ is the gamma function and using the Stirling approximation the gamma function of (x) can be given as follows:

$$\Gamma(x) = \int_0^{\infty} e^{-u} u^{x-1} du \tag{3.8}$$

Higher values of c indicate that the wind speed for that particular month is higher than that of the other months. In addition, the values of k indicate wind stability (Sopian et al., 1995)

3.2.5(c) Most probable wind speed

The most probable wind speed denotes the most frequent wind speed for a given wind probability distribution. From the scale parameter and shape parameter of Weibull distribution function, the most probable wind speed can be easily obtained from the following equation (Keyhani et al., 2010).

$$V_{mp} = c\left(1-\frac{1}{k}\right)^{\frac{1}{k}} \tag{3.9}$$

3.2.5(d) Maximum energy carrying by the wind speed

The maximum wind energy carrying by the wind speed can be calculated from the scale parameter and shape parameter of Weibull distribution function. The wind speed carrying maximum wind energy can be expressed as follows (Jamil et al., 1995):

$$V_{\max.E} = c\left(1+\frac{2}{k}\right)^{\frac{1}{k}} \tag{3.10}$$

3.2.5(e) Wind power density

The power of the wind that flows at a speed (v) through a blade sweep area (A) can be expressed by the following equations (Pimenta et al., 2008):

$$P(v) = \frac{1}{2}\rho v^{3} \tag{3.11}$$

Besides, calculation of wind power density based on the wind speed provided by field measurements can be developed by Weibull distribution analysis using the following equation (Keyhani et al., 2010):

$$\frac{P}{A} = \int_{0}^{\infty} \frac{1}{2}\rho v^{3} f(v)dv = \frac{1}{2}\rho c^{3}\Gamma\left(\frac{k+3}{k}\right) \tag{3.12}$$

Where, ρ is the standard air density, found to 1.225 kg/m^3 at sea level with mean temperature of 15˚C and 1 atmospheric pressure which, depends on altitude, air pressure and temperature. For wind power estimation, it is assumed that the air density is not correlated with wind speed. By this assumption, the error may occur on a constant pressure surface is less than 5%. It is also seen from the above equation that wind power density increases with the cube of the wind speed (Alboyaci & Dursun, 2008).

3.2.5(f) Wind energy density

Energy is defined as the ability to do work or the amount of work actually performed. By knowing the wind power density as shown in Equation (3.12), wind energy density can be estimated by the following equation for the desired time, T (Keyhani et al., 2010):

$$\frac{E}{A} = \frac{1}{2}\rho c^3 \Gamma\left(\frac{k+3}{k}\right)T \qquad (3.13)$$

Equation (3.13) can be used to calculate the available wind energy for any specific period when the wind speed frequency distributions are different.

3.2.5(g) Wind rose plot

WRPLOT Software: WRPLOT View is a fully operational wind rose program for the meteorological data. It provides visual wind rose plots, frequency analysis, and plots for several meteorological data formats. A wind rose depicts the frequency of occurrence of winds in each of the specified wind directional sectors, and wind speed classes for a given location and time period.

The wind rose is the time-honored method of graphically presenting the wind conditions, direction and speed, over a period of time at a specific location. To create a wind rose, average wind direction and wind speed values are logged at a site, at short intervals, over a period of time, e.g. one week, one month, or longer. The collected wind data is then sorted by wind direction so that the percentage of time that the wind was blowing from each direction can be determined. Typically, the wind direction data is sorted into twelve equal arc segments, 30° each segment, in preparation for plotting a circular graph in which the radius of each of the twelve segments represents the percentage of time that the wind blew from each of the twelve 30° direction segments. Wind speed data can be superimposed on each direction segment to indicate, for example, the average wind speed when the wind was blowing from that segment's direction and the maximum wind speed during the logging period. The information provided by the wind rose can be applied to many and varied situations. Wind power "farms" do extensive wind rose type studies prior to erecting their wind turbines. Thus, the wind rose is a simple information display technique that has a multitude of uses.

3.3 Contour Mapping of wind energy

To make a reliable contour map of wind energy, especially for specific location with a difficult topography and insufficient meteorological information like Malaysia, we have to follow three very important steps: data collection, interpolation and extrapolation of the data using a suitable interpolation method to visualize the result and statistical analysis. The first one, data collection, has been discussed in section 3.2.2 and the rest two steps are discussed hereafter.

3.3.1 Interpolation and extrapolation of data

As the wind speed data has been collected from the 15 meteorological stations of Peninsular Malaysia, to make a good contour map with high resolution, an interpolation or extrapolation is needed to make a contour map. The interpolation and extrapolation are a process in mathematics used to find the value of a function outside its tabulated values. Interpolation is the process of obtaining a value from a graph or table that is located between major points given, or between data points plotted. A ratio process is usually used to obtain the value. Extrapolation is the process of obtaining a value from a chart or graph that extends beyond the given data. The "trend" of the data is extended past the last point given and an estimate made of the value.

To make a good interpolation and/or extrapolation for specific data, it is very important to note which interpolation and/or extrapolation method is suitable and, which leading program has to be used. In this study, the Geographic Information system (GIS) has been chosen for contour mapping of wind energy for Peninsular Malaysia. A Geographic Information System (GIS) integrates hardware, software, and data to capture, store, analyze, manage, and display various forms of geographically referenced information. Today's GIS involves collaboration of various technologies and discipline like geography, cartography, surveying, remote sensing, satellite imagery, photogrammetry, spatial statistics, mathematics, geometry, topology, computer science, information science, library science, web-technology, etc. Among the GISs ArcGIS 9.3 has been used for this study. ArcGIS 9.3 is the special type of software that is very useful for data interpolation and/or extrapolation. The built-in toolbox, such as IDW, Kriging, Spline, PointInterp, Natural Neighbor and trend method, for different interpolation and extrapolation techniques, can be used for the surface representation. Each toolbox is useful for a specific situation where it is depended on reference data (elevation, temperature distribution, human density…etc.) and type of the surface produced (Childs, 2011). In the present work, the spline toolbox has been used as an interpolation and extrapolation method. In this method, a mathematical function is used to estimate different values. It minimizes the overall surface curvature, and this will give a smooth surface that will pass exactly through the input points.

3.3.2 Data Analysis

For this study, 15 meteorological stations all over the Peninsular Malaysia have been chosen based on evenly distribution. From these 15 stations, total 30 years (each station two years) hourly mean surface wind speed data have been collected. From these hourly mean wind speed data, the daily mean speed data have been calculated, which are shown in Tables 3.2 to 3.31. The wind speed data which are collected by MMD from 10 m height from ground has been converted to 100 m height from the ground. These converted hourly wind speed data have been averaged to daily, monthly and yearly mean wind speed data and after that used to make the contour map of Peninsular Malaysia.

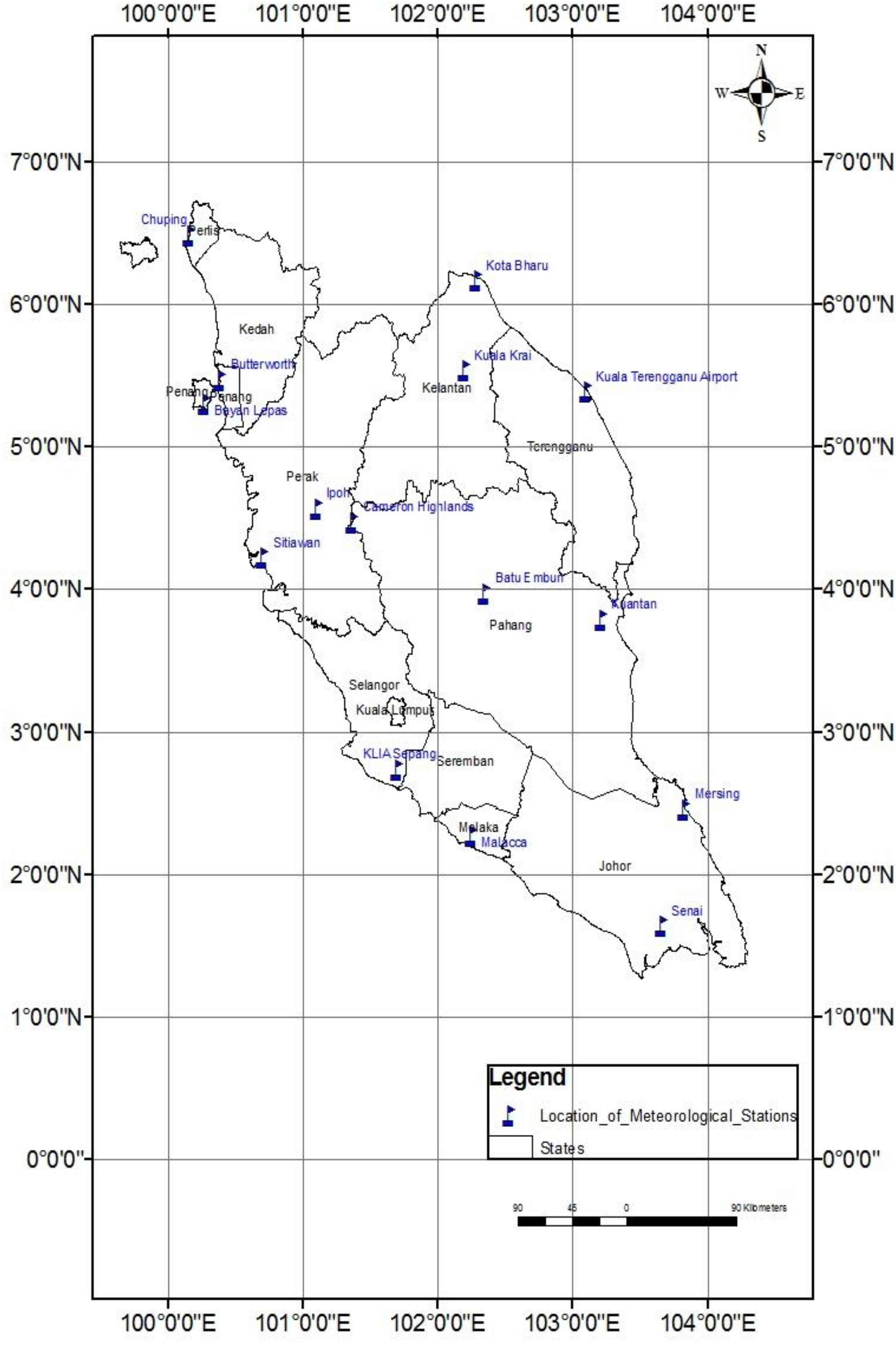

Figure 3.1 Location of the selected Meteorological Stations in Peninsular Malaysia

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 Introduction

The results and discussions section gives the details result of the assessment of the wind energy potential and contour mapping in the peninsular Malaysia. The assessment section has been divided into small subdivisions like variations of the diurnal wind speed, monthly wind speed, standard deviations, shape factor and scale factor, Weibull distribution function, cumulative distribution function and wind rose plot. On these sub-divisions, point-by-point discussion has been given. At the end results and discussions on the contour mapping has been given.

4.2 Assessment of wind energy potentiality

To understand the weather behavior well, an adequate source of measuring weather data is very much essential. The relationship between the climatic data and energy performance of wind machines rely heavily on both the quality and quantity of the meteorological observations. Though it is believed that wind data of shorter periods, less than 30 years, may inherit variations from the long term average but most of the developing countries do not possess accurate long term data. As a result, information of shorter recording periods has to be used to suffice for resource assessment (Kainkwa, 2000; Lun & Lam, 2000; Weisser, 2003a).

The determination of the wind potential of the selected sites was made by analyzing the wind characteristics in details, such as the mean wind speed, the prevailing direction, their duration and availability, as well as, the resulting power density. The 10 m height wind speed data has been converted to 100 m height wind speed data by using Equation

(3.1) and then the converted data have been used for assessing the potentiality of wind energy in Peninsular Malaysia.

4.2.1 Diurnal wind speed variations

The expansion of electricity capacities or application of Wind Energy Conversion technologies (WECTs) in small isolated power systems requires not only the monthly or seasonal probability distribution of wind velocities but also needs to assess at least hourly probabilities of wind speeds. Considering distributions that are solely based on daily mean wind speed neglect the significant variations of wind velocity throughout any given day. In particular, as load duration curves of electricity demand vary significantly throughout the day. The diurnal mean wind speed variations of the 15 selected stations are illustrated in Figures 4.1 to 4.15 for a period of two years for each station and evaluated by Equation (3.4).

It is found that the values of the hourly mean wind speed ranges are between 0.32 m/s to 5.67 m/s. The bell shaped trend of wind speed variations can be found at Batu Embun, Bayan Lepas, Butterworth, Chuping, Kuantan, Malacca and Senai, though, their size, shape and peak of the bell shape are a little bit different. It is found that the daytime, from 8 am to 6 pm, is windy for all the years round, while the nighttime is relatively calm. The hourly mean wind speed is gradually increasing from 6 am until 3 pm, and then it is decreasing for these places for all the years until 11 pm. The remaining time from 11 pm to 8 am, the wind speed variations remain almost constant, which indicates that the nighttime of these eras is stable in comparing to the daytime. From this trend, it can be concluded that the energy demands and characteristics of the wind speed are coincident as the energy demand in the daytime is greater than at nighttime.

However, the trend of wind speed variations is slightly different for the other study places. At Cameron Highland, wind speed start increasing from 9 am until 12 pm then it is decreasing up to 6 pm. It is found that from 6 pm to 9 am, the wind speed variations remain almost constant. The main reason behind this slightly different wind profile is its topographical distinction to the other sites. As it is mentioned at section 3.2.2, Cameron Highland is situated at 1545 m above the sea level. It is generally spoken that wind speeds tend to be higher in the highlands, but topographical features can aggravate winds and cause strong gusts in lowland areas (Mortensen & Petersen, 1997; Wikepedia, 2011). At KLIA Sepang, Kota Bharu, Kuala Terengganu and Sitiawan, the wind speed is gradually increasing from 6 am to 3 pm then decreasing. Except Ipoh, where highest average wind speed is shown at 9 am and 3 pm, at all the stations the highest average wind speeds are observed at 3 pm for the study period.

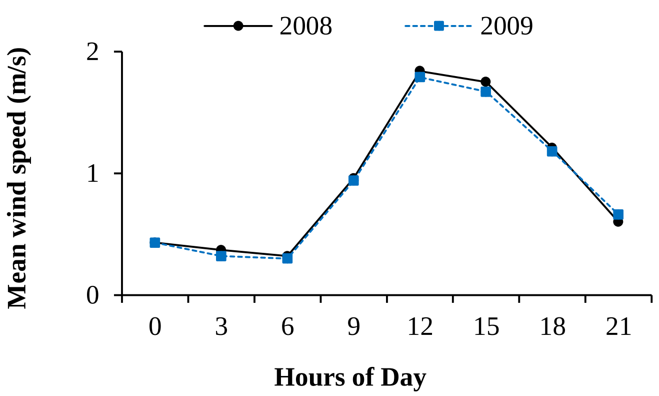

Figure 4.1 Diurnal variation of wind speed at Batu Embun.

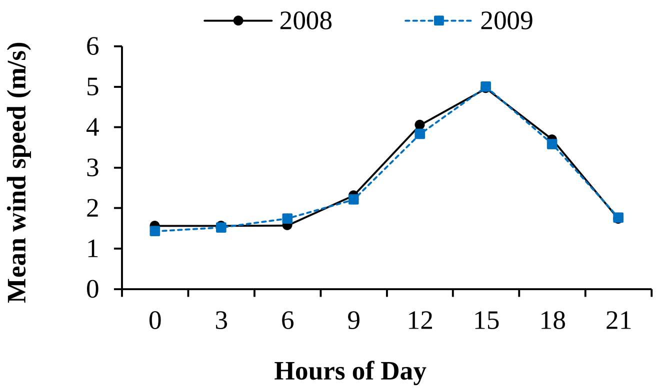

Figure 4.2 Diurnal variation of wind speed at Bayan Lepas.

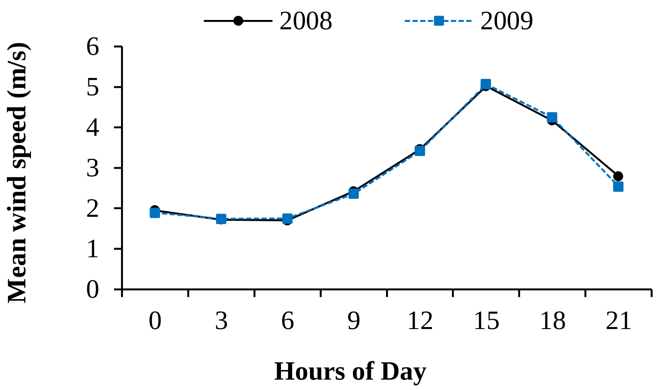

Figure 4.3 Diurnal variation of wind speed at Butterworth

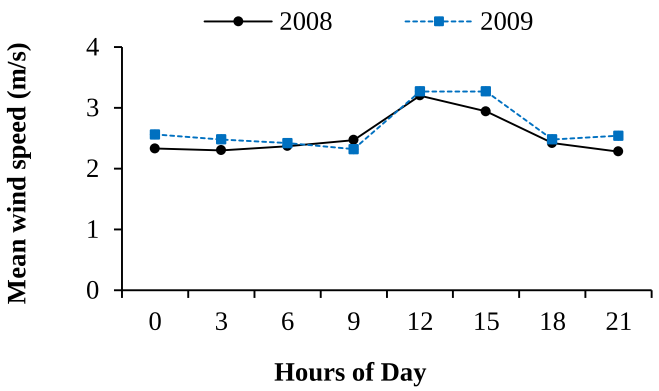

Figure 4.4 Diurnal variation of wind speed at Cameron Highland

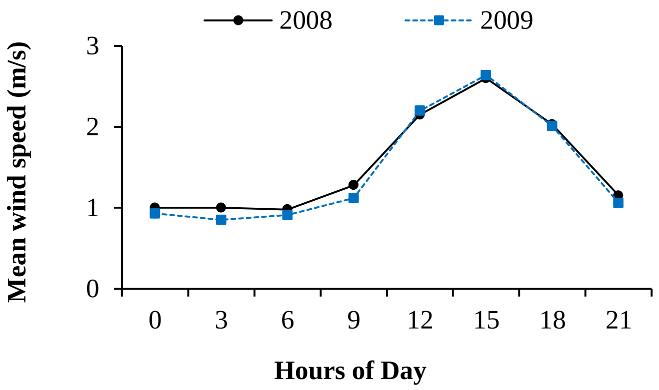

Figure 4.5 Diurnal variation of wind speed at Chuping

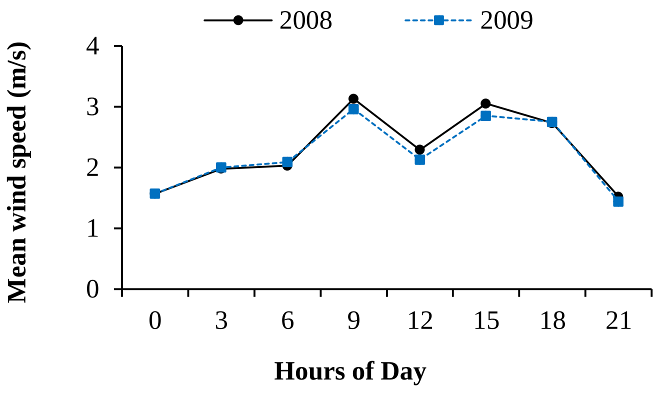

Figure 4.6 Diurnal variation of wind speed at Ipoh

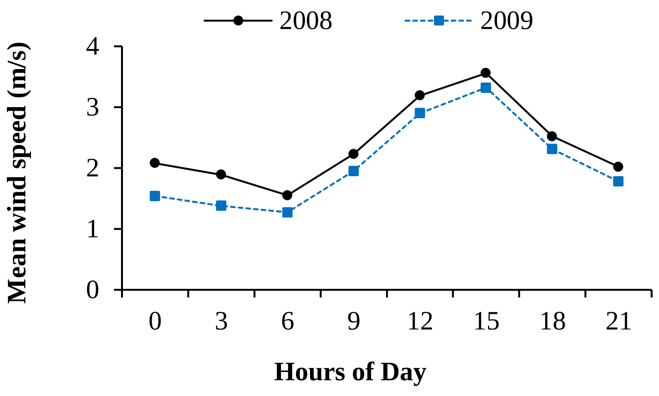

Figure 4.7 Diurnal variation of wind speed at KLIA Sepang

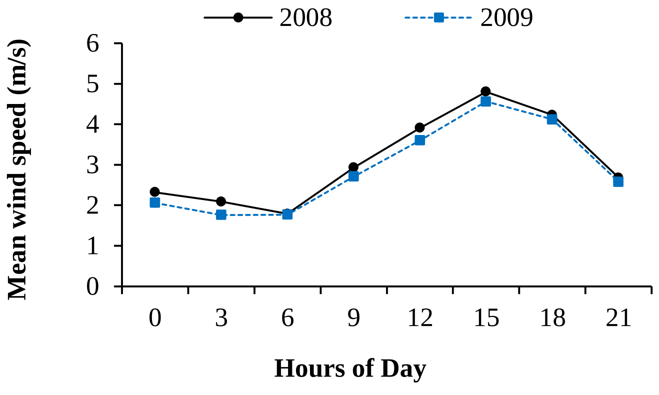

Figure 4.8 Diurnal variation of wind speed at Kota Bharu

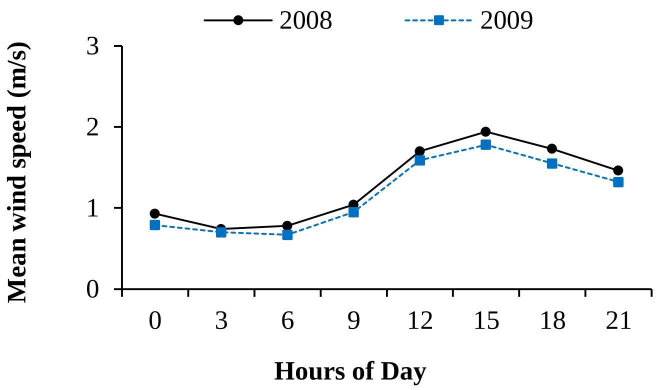

Figure 4.9 Diurnal variation of wind speed at Kuala Krai

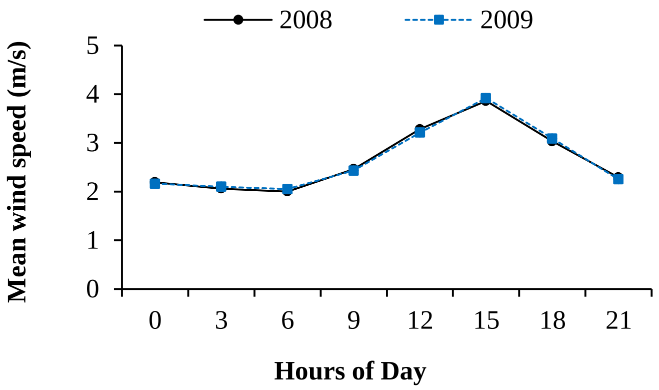

Figure 4.10 Diurnal variation of wind speed at Kuala Terengganu

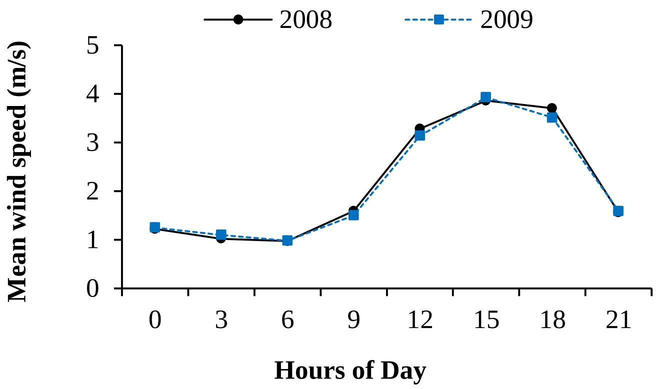

Figure 4.11 Diurnal variation of wind speed at Kuantan

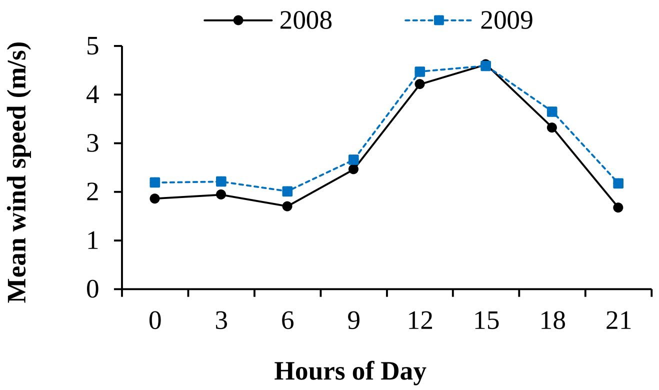

Figure 4.12 Diurnal variation of wind speed at Malacca

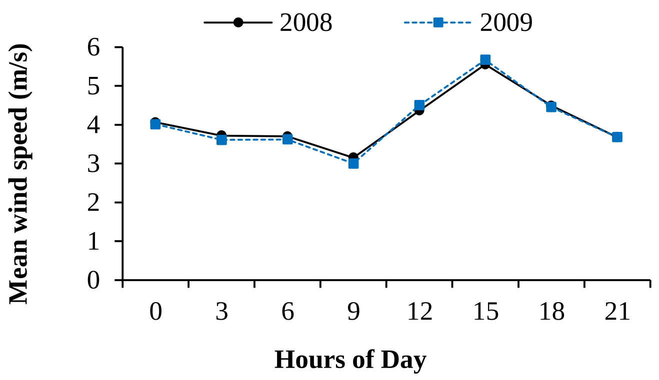

Figure 4.13 Diurnal variation of wind speed at Mersing

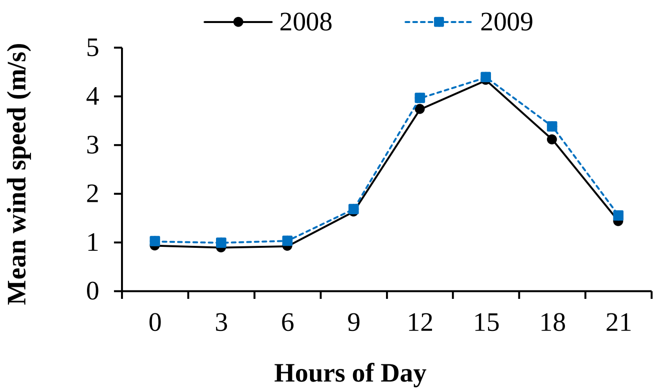

Figure 4.14 Diurnal variation of wind speed at Senai

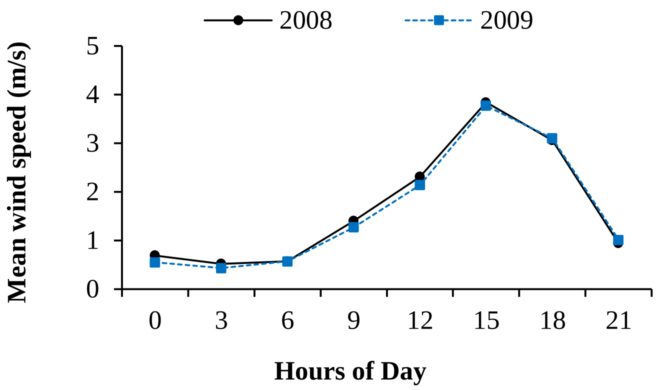

Figure 4.15 Diurnal variation of wind speed at Sitiawan

4.2.2 Monthly and yearly mean wind speed variations

The monthly mean wind speed variation has been determined by the Equation (3.4) as shown in Figures 4.16 to 4.30. The trends of the monthly mean wind speed for the study sites can be divided into two groups. First the wind speed variations for Bayan Lepas, Cameron Highland, Chuping, Kota Bharu, Kuala Terengganu, Kuantan, Malacca, Mersing and Senai for all years are quite similar. For all the study years and stations, it is found that the month of December to March is windier than that of the remaining months in a year. This is because, may be due to the northeast monsoon season on December to March, steady easterly or northeasterly strong winds prevail and the strong surges of cold air from the north (cold surges) occur in these areas. Second, the wind speed variations of Batu Embun, Butterworth, Ipoh, KLIA Sepang, Kuala Krai, and Sitiawan are also quite similar. In these areas, whole years, there is no any significant change in the wind speed variations.

Most of the monthly mean wind speed values are between 1.5 m/s to 4.5 m/s, but some are over 4.5 m/s and few are under 1.5 m/s. While January 2009 at Mersing shown the highest mean wind speed value with 6.62 m/s, May 2009 at Chuping shown the minimum wind speed value with 0.81 m/s. The yearly mean wind speeds can be obtained by averaging all the available monthly mean wind speed in a year for all the sites. The average wind speed values for each year for all the sites are listed in Table 4.3. From the result, it can be shown that mean wind speeds for all the years are lower than 4.5 m/s and the range of the yearly mean wind speed values from 0.90 to 4.06 m/s. Whether constructing a wind turbine is economically viable depends most strongly on the quality of the wind resource. Generally annual wind speeds of at least 4.0-4.5 m/s are needed for a small wind turbine to produce enough electricity to be cost effective (Clarke, 2011). In the study period, it is found that the yearly mean wind speed at Mersing is 4.06 m/s in 2008 and 4.01 m/s in 2009, which is capable of producing commercial wind energy by using the current technology. At the current technology, some horizontal axis wind turbine (i.e. Evance R9000) can generate electricity at the wind speed 3 m/s, and some vertical axis wind turbine can produce the electricity at the wind speed 2.3 m/s (GLT, 2010). If we consider the vertical axis wind turbine for producing electricity then it is found that the sites Bayan Lepas, Butterworth, Cameron Highlands, Kota Bharu, Kuala Terengganu and Malacca are also suitable for small-scale electricity generation. Small-scale (5 to 15 kilowatts) wind turbines can be used in domestic, community and small wind energy projects, and these can be either stand–alone or grid-connected systems. Stand-alone systems are used to generate electricity for charging batteries to run small electrical applications, often in remote locations where it is expensive or not physically possible to connect to a mains power supply. Recently, the Government of Malaysia is making lot of colonies outside the main town for the future generation. So this type of small-scale wind can be used to supply electricity to the remote colonies.

But according to the Pacific Northwest National Laboratory (PNNL) classification system, most wind turbines start generating electricity at wind speeds of around 3-4 m/s (eight mph); generate maximum ‘rated’ power at around 15 m/s (30 mph); and shut down to prevent storm damage at 25 m/s or above (50 mph or above). Most of the stations fall outside of the category if based on the yearly mean wind speed. This means that under the current wind turbine technology, the Peninsular Malaysia may not be suitable for year round large-scale electricity generation due to the cost factor. However, for small scale applications, and in the long run with the development of wind turbine technology, the utilization of wind energy, especially at Mersing is still promising.

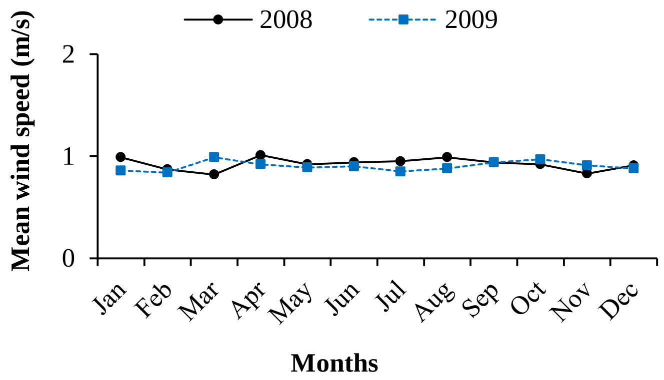

Figure 4.16 Monthly mean wind speed at Batu Embun

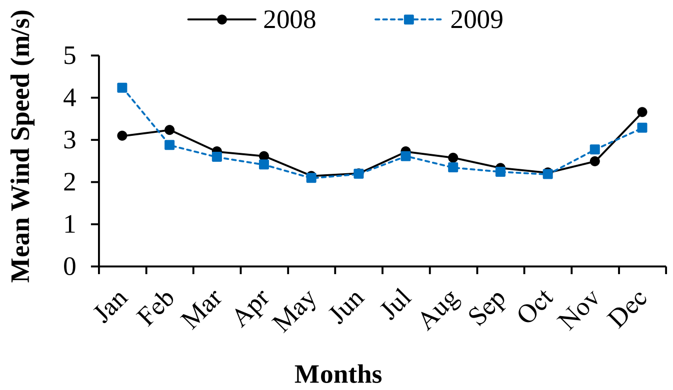

Figure 4.17 Monthly mean wind speed at Bayan Lepas

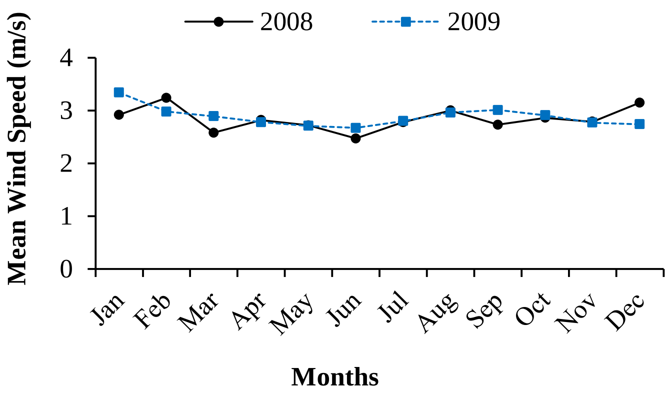

Figure 4.18 Monthly mean wind speed at Butterworth

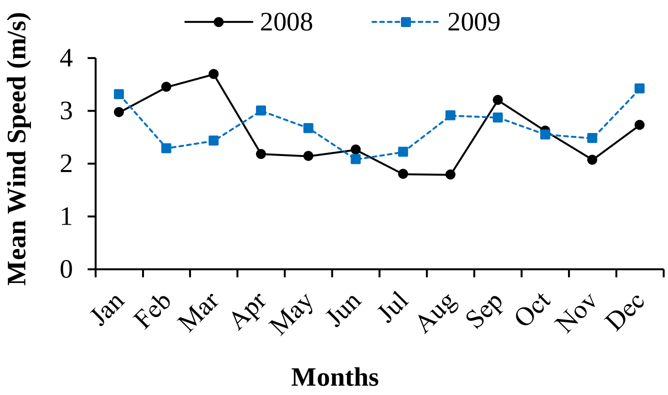

Figure 4.19 Monthly mean wind speed at Cameron Highland

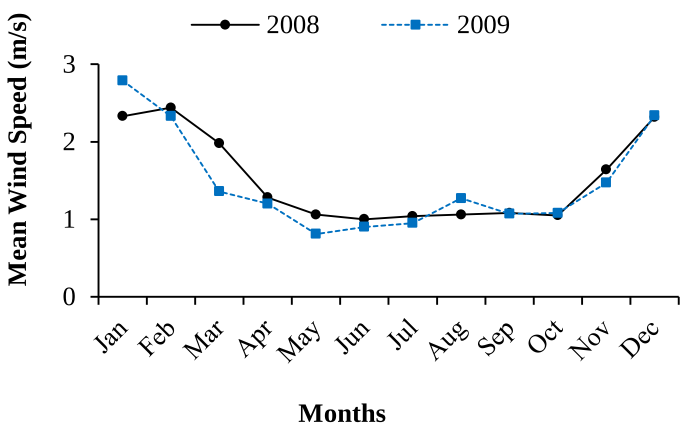

Figure 4.20 Monthly mean wind speed at Chuping

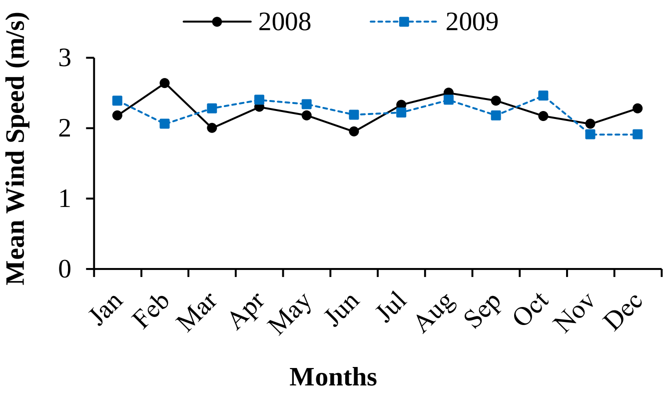

Figure 4.21 Monthly mean wind speed at Ipoh

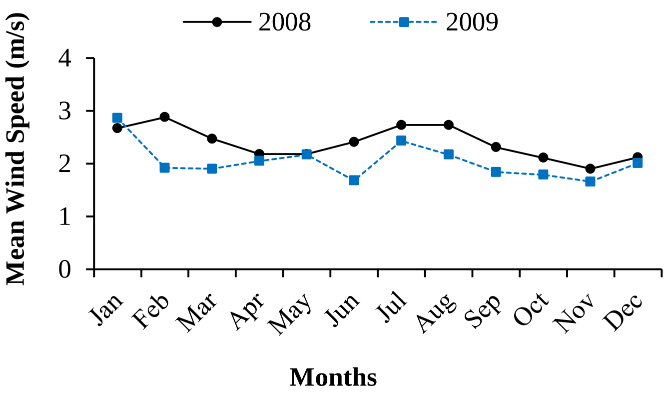

Figure 4.22 Monthly mean wind speed at KLIA Sepang

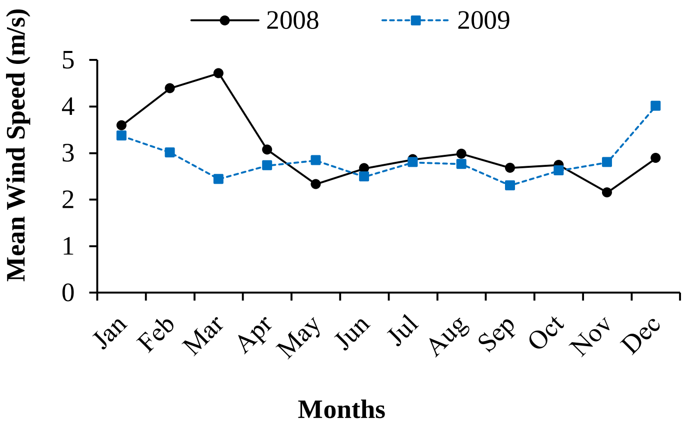

Figure 4.23 Monthly mean wind speed at Kota Bharu

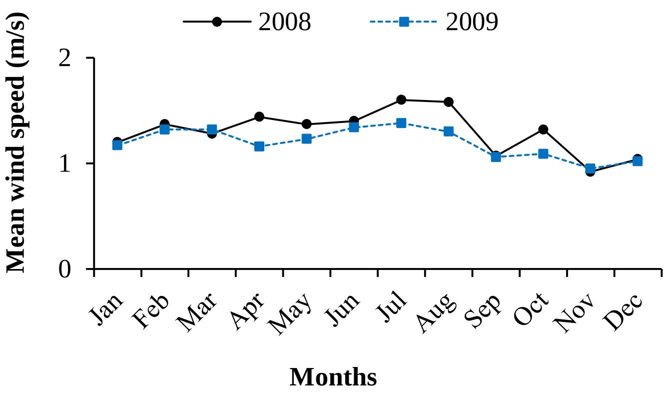

Figure 4.24 Monthly mean wind speed at Kuala Krai

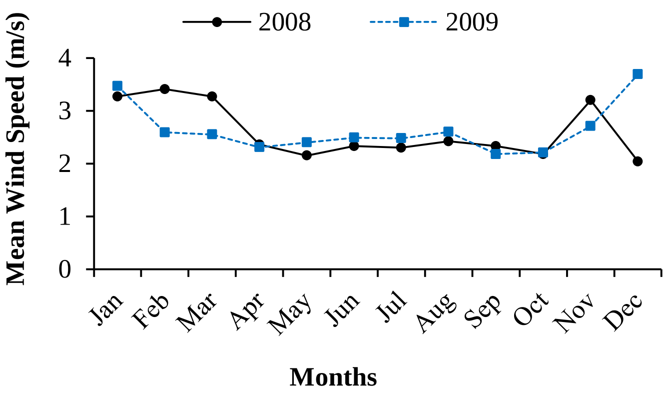

Figure 4.25 Monthly mean wind speed at Kuala Terengganu

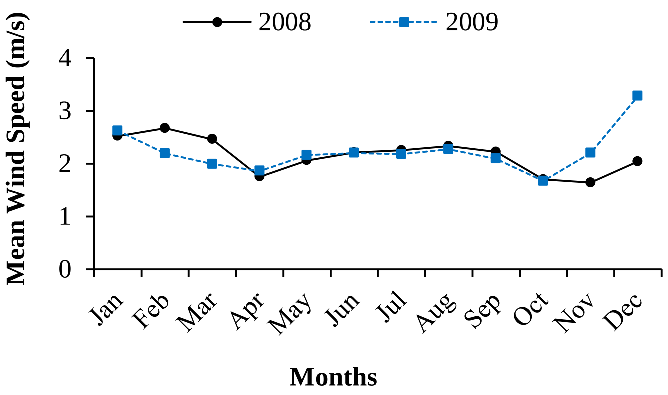

Figure 4.26 Monthly mean wind speed at Kuantan

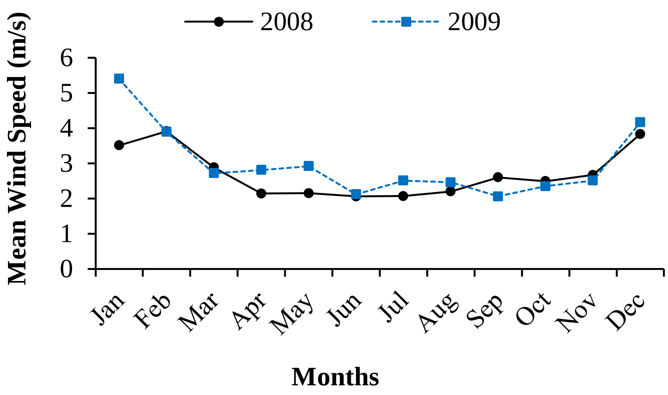

Figure 4.27 Monthly mean wind speed at Malacca

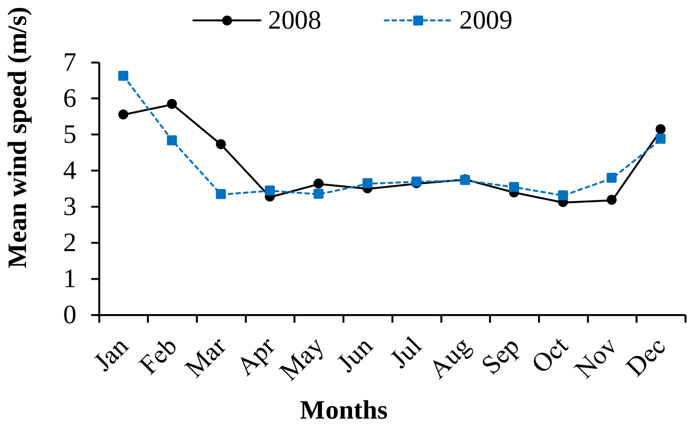

Figure 4.28 Monthly mean wind speed at Mersing

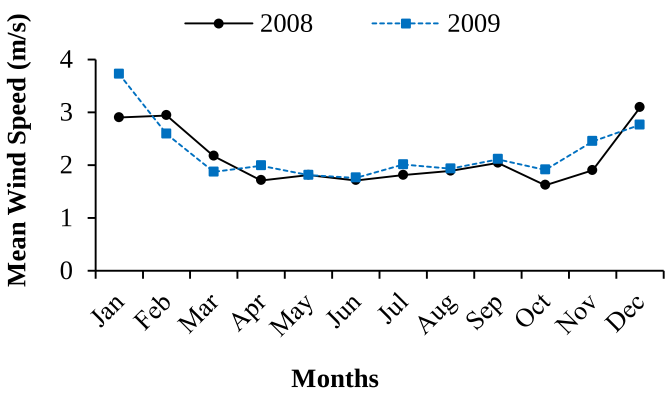

Figure 4.29 Monthly mean wind speed at Senai

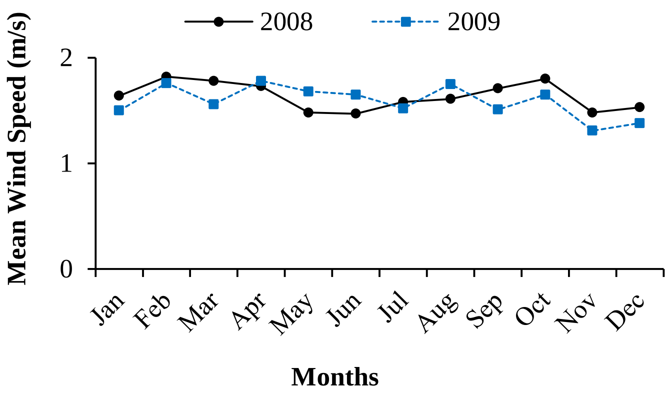

Figure 4.30 Monthly mean wind speed at Sitiawan

4.2.3 Variations of standard deviation, shape factor (k) and scale factor (c)

It is a matter of common observation that the wind is not steady all time. In order to calculate the mean power delivered by a wind turbine from its power curve, it is necessary to know the probability density distribution of the wind speed. The basic measure of the unsteadiness of the wind is the standard deviation (or root mean square) of the speed variations. A low standard deviation indicates that the data points tend to be very close to the mean, whereas the high standard deviation indicates that the data are spread out over a large range of values. The monthly and yearly standard deviation has been recorded in Table 4.1 to 4.3, which are calculated by using the Equation (3.5). By analyzing the 360 months of 15 sites, the monthly standard deviation can be found in the range of 0.57 m/s to 2.68 m/s, whereas, the yearly standard deviation range is found to be between 0.81 m/s to 2.09 m/s. From this result, it is found that the yearly standard deviation range is less than that of the monthly standard deviation which is a good sign for the generating wind power.

In order to fit wind speed data to the Weibull distribution function, we need a value for the shape factor k. This is often obtained by some form of fitting procedure to the measured probability distribution but this is unnecessarily complicated. One of the simplest ways of measuring shape factor k is to use standard deviation or root mean square of the variable (σ). As the average wind speed at a given location is a function of climate and terrain. There can be significant seasonal variations in wind speed. In general, the shape factor is more of less constant throughout the year, but there can be a large change in the scale factor and the average wind speed. The monthly and yearly values of the two Weibull parameters, the shape factor k (dimensionless) and the scale factor c (m/s) have been calculated by using Equations (3.6), (3.7) and (3.8) are shown in Table 4.1 to 4.3. It is obvious that the parameter k has a much smaller, temporal variation than the parameter c. The monthly values of k range between 0.73 and 3.81, with an average value of 1.55, whereas the yearly values of k range between 1 and 2.21 with the average value of 1.44. The lowest value of the scale parameter c is 0.69 m/s and is found in year 2009 at Chuping, while the highest value is 7.36 m/s, which occurred in the year 2009 at Mersing. Its average value is 2.54 m/s for the study period.

Table 4.1 Monthly standard deviation and weibull parameters (k, c)

Month	Parameter	Batu Embun		Bayan Lepas		Butterworth		Cameron Highlands		Chuping		Ipoh		KLIA Sepang		Kota Bharu	
		2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
Jan	$\bar{v}$	0.99	0.86	3.09	4.23	2.92	3.34	2.97	3.31	2.33	2.79	2.18	2.39	2.67	2.86	3.59	3.37
	σ	0.80	0.87	1.92	2.34	1.89	2.06	1.83	1.97	0.88	0.88	1.42	1.77	1.69	2.47	2.37	2.35
	k	1.26	0.99	1.68	1.90	1.60	1.69	1.69	1.76	2.88	3.50	1.59	1.39	1.64	1.17	1.57	1.48
	c	1.06	0.86	3.46	4.77	3.25	3.74	3.33	3.72	2.61	3.10	2.43	2.62	2.98	3.01	4.03	3.74
Fab	$\bar{v}$	0.87	0.84	3.23	2.87	3.24	2.98	3.45	2.29	2.44	2.33	2.64	2.06	2.88	1.92	4.39	3.01
	σ	0.85	0.85	2.02	2.14	1.77	2.00	1.83	1.36	0.92	1.13	1.50	1.52	1.76	1.40	2.55	2.06
	k	1.03	0.99	1.66	1.38	1.93	1.54	1.99	1.76	2.88	2.19	1.85	1.39	1.71	1.41	1.80	1.51
	c	0.88	0.84	3.61	3.15	3.65	3.31	3.89	2.57	2.74	2.63	2.97	2.26	3.24	2.11	4.99	3.34
Mar	$\bar{v}$	0.82	0.99	2.72	2.59	2.58	2.89	3.69	2.43	1.98	1.36	2.00	2.28	2.47	1.90	4.71	2.44
	σ	0.79	0.88	1.97	2.00	1.77	2.00	1.98	1.74	1.32	1.06	1.43	1.70	1.65	1.39	2.39	2.02
	k	1.06	1.14	1.42	1.32	1.51	1.49	1.97	1.44	1.55	1.31	1.44	1.38	1.55	1.40	2.09	1.23
	c	0.84	1.04	2.99	2.81	2.87	3.21	4.16	2.70	2.20	1.48	2.22	2.55	2.74	2.10	5.32	2.62
Apr	$\bar{v}$	1.01	0.92	2.61	2.41	2.82	2.78	2.18	3.00	1.28	1.20	2.30	2.40	2.18	2.05	3.07	2.73
	σ	0.82	0.81	1.91	1.96	1.68	1.86	1.34	1.99	1.04	1.21	1.30	1.55	1.23	1.65	1.69	1.79
	k	1.25	1.15	1.40	1.25	1.76	1.55	1.70	2.56	1.25	0.99	1.86	1.61	1.86	1.27	1.91	1.58
	c	1.08	0.97	2.87	2.59	3.17	3.09	2.44	3.34	1.38	1.20	2.59	2.68	2.45	2.20	3.46	3.04
May	$\bar{v}$	0.92	0.89	2.14	2.09	2.72	2.71	2.14	2.67	1.06	0.81	2.18	2.34	2.18	2.17	2.33	2.84
	σ	0.79	0.80	1.95	1.76	1.65	1.87	1.29	1.93	1.18	1.06	1.35	1.37	1.33	1.51	1.83	1.53
	k	1.18	1.12	1.11	1.21	1.72	1.50	1.73	1.42	0.89	0.75	1.68	1.79	1.71	1.48	1.30	1.96
	c	0.97	0.93	2.22	2.22	3.06	3.01	2.40	2.94	1.00	0.69	2.45	2.63	2.45	2.38	2.53	3.21
Jun	$\bar{v}$	0.94	0.90	2.20	2.19	2.47	2.67	2.26	2.08	1.00	0.90	1.95	2.19	2.41	1.68	2.67	2.49
	σ	0.84	0.80	2.08	2.00	1.80	1.64	1.50	1.65	1.09	1.21	1.44	1.28	1.32	1.39	1.56	1.38
	k	1.13	1.14	1.06	1.10	1.41	1.70	1.56	1.29	0.91	0.73	1.39	1.79	1.92	1.23	1.79	1.90
	c	0.98	0.94	2.25	2.27	2.72	3.00	2.52	2.25	0.96	0.74	2.14	2.46	2.72	1.81	3.00	2.81
Jul	$\bar{v}$	0.95	0.85	2.72	2.61	2.78	2.80	1.80	2.22	1.04	0.95	2.33	2.22	2.73	2.43	2.86	2.80
	σ	0.89	0.89	2.43	2.26	2.00	1.88	1.30	1.58	1.21	1.16	1.45	1.46	1.51	1.59	1.58	1.68

Month	Parameter	Batu Embun		Bayan Lepas		Butterworth		Cameron Highlands		Chuping		Ipoh		KLIA Sepang		Kota Bharu	
	k	1.07	0.95	1.13	1.17	1.43	1.54	1.42	1.45	0.85	0.81	1.67	1.58	1.90	1.59	1.90	1.74
	c	0.98	0.83	2.85	2.76	3.06	3.11	1.98	2.47	0.96	0.85	2.61	2.47	3.08	2.73	3.22	3.15
Aug	$\bar{v}$	0.99	0.88	2.57	2.34	3.00	2.96	1.79	2.91	1.06	1.27	2.50	2.40	2.73	2.17	2.98	2.76
	σ	0.88	0.85	2.41	1.79	1.82	1.80	1.24	1.92	1.21	1.35	1.51	1.47	1.61	1.50	1.58	1.74
	k	1.14	1.04	1.07	1.34	1.72	1.72	1.49	1.57	0.87	0.94	1.73	1.70	1.77	1.49	1.99	1.65
	c	1.04	0.90	2.64	2.55	3.37	3.33	1.99	3.24	0.99	1.24	2.81	2.69	3.07	2.44	3.36	3.07
Sep	$\bar{v}$	0.94	0.94	2.33	2.24	2.73	3.01	3.20	2.87	1.08	1.07	2.39	2.18	2.31	1.84	2.68	2.30
	σ	0.86	0.83	1.94	1.86	1.68	1.92	2.30	1.93	1.16	1.29	1.55	1.46	1.38	1.27	1.81	2.04
	k	1.10	1.14	1.22	1.22	1.70	1.63	1.43	1.54	0.93	0.82	1.60	1.55	1.75	1.50	1.53	1.14
	c	0.98	0.98	2.49	2.39	3.06	3.36	3.53	3.19	1.04	0.96	2.67	2.42	2.60	2.04	2.98	2.41
Oct	$\bar{v}$	0.92	0.97	2.22	2.18	2.86	2.91	2.62	2.55	1.05	1.08	2.17	2.46	2.11	1.79	2.74	2.62
	σ	0.74	0.78	1.78	1.72	1.69	1.66	1.71	2.03	1.06	1.17	1.52	1.55	1.34	1.27	1.66	1.55
	k	1.27	1.27	1.27	1.29	1.77	1.84	1.59	1.28	0.99	0.92	1.47	1.65	1.64	1.45	1.72	1.77
	c	0.99	1.05	2.39	2.35	3.21	3.28	2.92	2.75	1.05	1.04	2.41	2.75	2.37	1.99	3.08	2.95
Nov	$\bar{v}$	0.83	0.91	2.49	2.77	2.79	2.77	2.07	2.48	1.64	1.47	2.06	1.91	1.90	1.66	2.15	2.80
	σ	0.68	0.77	1.81	1.89	1.64	1.75	1.33	1.88	1.05	0.97	1.47	1.49	1.33	1.56	1.90	1.99
	k	1.24	1.20	1.41	1.51	1.78	1.65	1.62	1.35	1.62	1.57	1.44	1.31	1.47	1.07	1.14	1.45
	c	0.89	0.97	2.73	3.07	3.14	3.10	2.31	2.71	1.83	1.64	2.29	2.07	2.10	1.71	2.26	3.11
Dec	$\bar{v}$	0.91	0.88	3.65	3.28	3.15	2.74	2.73	3.42	2.32	2.34	2.28	1.91	2.12	2.01	2.89	4.01
	σ	0.80	0.74	2.14	2.02	1.94	1.86	1.76	2.10	0.95	0.74	1.68	1.64	1.60	1.49	1.98	2.43
	k	1.15	1.21	1.79	1.69	1.69	1.52	1.61	1.70	2.64	3.49	1.39	1.18	1.36	1.38	1.51	1.72
	c	0.96	0.94	4.10	3.68	3.53	3.04	3.05	3.84	2.61	2.60	2.50	2.01	2.31	2.21	3.20	4.51

Table 4.2 Monthly standard deviation and Weibull parameters (k, c)

Month	Parameter	Kuala Krai		Kuala Terengganu		Kuantan		Malacca		Mersing		Senai		Sitiawan	
		2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
Jan	$\bar{v}$	1.20	1.17	3.27	3.47	2.52	2.62	3.51	5.40	5.55	6.62	2.90	3.72	1.64	1.50
	σ	0.85	0.89	1.75	2.07	1.51	1.68	1.72	2.19	1.90	1.93	2.08	2.68	1.44	1.40
	k	1.45	1.35	1.97	1.75	1.74	1.62	2.17	2.66	3.20	3.81	1.43	1.43	1.15	1.08
	c	1.32	1.28	3.69	3.90	2.83	2.92	3.96	6.08	6.20	7.36	3.22	4.13	1.74	1.55
Fab	$\bar{v}$	1.37	1.32	3.41	2.59	2.67	2.19	3.91	3.89	5.84	4.83	2.94	2.59	1.82	1.76
	σ	0.57	0.97	1.83	1.41	1.72	1.71	1.97	2.09	2.18	1.74	2.34	2.25	1.57	1.70
	k	2.59	1.40	1.97	1.94	1.61	1.31	2.11	1.96	2.92	3.03	1.28	1.17	1.17	1.04
	c	1.54	1.45	3.85	2.92	2.98	2.38	4.42	4.39	6.55	5.41	3.17	2.76	1.94	1.80
Mar	$\bar{v}$	1.28	1.32	3.27	2.55	2.46	1.99	2.88	2.72	4.72	3.34	2.17	1.87	1.78	1.56
	σ	0.97	0.94	1.58	1.36	1.92	1.60	1.66	1.77	2.31	1.46	1.90	1.57	1.50	1.53
	k	1.35	1.45	2.20	1.98	1.31	1.27	1.82	1.59	2.17	2.46	1.16	1.21	1.20	1.02
	c	1.40	1.47	3.69	2.88	2.67	2.14	3.24	3.04	5.33	3.77	2.28	2.01	1.91	1.58
Apr	$\bar{v}$	1.44	1.16	2.36	2.31	1.75	1.99	2.14	2.81	3.27	3.44	1.71	1.99	1.73	1.78
	σ	1.04	0.80	1.18	1.22	1.66	1.64	1.53	1.64	1.51	1.49	1.48	1.62	1.52	1.74
	k	1.42	1.50	2.12	2.00	1.06	1.23	1.44	1.79	2.31	2.48	1.17	1.25	1.15	1.02
	c	1.60	1.29	2.66	2.61	1.79	2.13	2.36	3.16	3.69	3.88	1.80	2.14	1.82	1.80
May	$\bar{v}$	1.37	1.23	2.15	2.40	2.06	1.86	2.15	2.92	3.63	3.35	1.81	1.81	1.48	1.68
	σ	1.03	0.93	1.16	1.25	1.71	1.50	1.58	1.67	1.77	1.57	1.77	1.54	1.43	1.71
	k	1.36	1.35	1.95	2.03	1.22	1.26	1.40	1.83	2.18	2.28	1.02	1.19	1.04	0.98
	c	1.50	1.34	2.43	2.71	2.20	2.00	2.36	3.29	4.10	3.78	1.83	1.93	1.51	1.67
Jun	$\bar{v}$	1.40	1.34	2.33	2.49	2.21	2.16	2.06	2.12	3.50	3.64	1.71	1.76	1.47	1.65
	σ	0.93	0.85	1.04	1.18	1.85	1.73	1.58	1.62	1.58	1.65	1.60	1.61	1.40	1.59
	k	1.56	1.64	2.40	2.25	1.21	1.27	1.33	1.34	2.37	2.36	1.07	1.10	1.05	1.04
	c	1.56	1.51	2.63	2.81	2.35	2.33	2.24	2.31	3.95	4.11	1.76	1.83	1.52	1.68
Jul	$\bar{v}$	1.60	1.38	2.30	2.48	2.25	2.20	2.07	2.51	3.64	3.69	1.81	2.01	1.58	1.52
	σ	1.06	1.02	1.08	1.28	1.74	1.78	1.47	1.84	1.88	1.77	1.65	1.88	1.48	1.60
	k	1.56	1.39	2.27	2.05	1.32	1.26	1.45	1.40	2.05	2.22	1.11	1.08	1.07	0.95
	c	1.78	1.51	2.60	2.80	2.44	2.37	2.28	2.76	4.10	4.17	1.89	2.09	1.63	1.69
Aug	$\bar{v}$	1.58	1.30	2.42	2.60	2.33	2.18	2.20	2.46	3.75	3.73	1.89	1.93	1.61	1.75
	σ	1.11	0.92	1.18	1.35	1.87	1.87	1.69	1.79	1.81	1.82	1.76	1.66	1.64	1.78
	k	1.47	1.46	2.18	2.04	1.27	1.18	1.33	1.41	2.21	2.18	1.08	1.18	0.98	0.98
	c	1.75	1.44	2.73	2.93	2.52	2.31	2.39	2.70	4.23	4.21	1.95	2.05	1.61	1.74
Sep	$\bar{v}$	1.07	1.06	2.33	2.18	2.22	2.27	2.60	2.06	3.39	3.54	2.04	2.11	1.71	1.51
	σ	0.83	0.86	1.11	1.18	1.83	1.75	1.98	1.73	1.69	1.64	1.86	1.66	1.61	1.48
	k	1.32	1.25	2.24	1.95	1.23	1.33	1.34	1.21	2.13	2.31	1.11	1.30	1.07	1.02
	c	1.16	1.14	2.42	2.46	2.38	2.47	2.83	2.19	3.83	4.00	1.95	2.29	1.76	1.53

Month	Parameter	Kuala Krai		Kuala Terengganu		Kuantan		Malacca		Mersing		Senai		Sitiawan	
Oct	$\bar{v}$	1.32	1.09	2.35	2.21	1.70	2.09	2.49	2.35	3.12	3.31	1.62	1.91	1.80	1.65
	σ	0.89	1.00	1.19	1.12	1.55	1.62	1.88	1.71	1.26	1.47	1.48	1.52	1.63	1.57
	k	1.53	1.10	2.09	2.09	1.11	1.32	1.36	1.41	2.68	2.41	1.10	1.28	1.11	1.06
	c	1.47	1.14	2.65	2.50	1.77	2.27	2.72	2.58	3.51	3.73	2.13	2.06	1.88	1.70
Nov	$\bar{v}$	0.92	0.95	2.18	2.71	1.64	1.67	2.67	2.51	3.18	3.79	1.90	2.45	1.48	1.31
	σ	0.91	0.82	1.23	1.81	1.45	1.42	1.77	1.86	1.40	1.63	1.49	1.67	1.64	1.49
	k	1.01	1.17	1.86	1.55	1.14	1.19	1.56	1.38	2.44	2.50	1.30	1.52	0.89	0.87
	c	0.93	1.01	2.45	3.01	1.71	1.77	2.97	2.75	3.59	4.27	2.07	2.72	1.41	1.22
Dec	$\bar{v}$	1.04	1.02	3.20	3.69	2.04	2.20	3.83	4.17	5.14	4.87	3.09	2.76	1.53	1.38
	σ	0.83	0.82	1.82	1.81	1.47	1.41	2.13	2.27	2.00	1.98	2.04	2.01	1.52	1.31
	k	1.28	1.27	1.85	2.17	1.43	1.62	1.89	1.94	2.79	2.66	1.57	1.41	1.00	1.06
	c	1.12	1.10	3.60	4.17	2.25	2.46	4.32	4.70	5.78	5.48	3.47	3.07	1.53	1.42

Table 4. 3 Yearly mean wind speed, standard deviation, weibull parameters (k, c), most probable wind speed and wind speed carrying max. energy

Station	Year	Mean speed ($\bar{v}$)	Standard variation (σ)	Shape factor (k)	Scale factor (c)	Most probable wind speed	Wind speed carrying max. energy
Batu Embun	2008	0.91	0.81	1.13	0.95	0.14	2.34
	2009	0.90	0.82	1.11	0.94	0.12	2.38
Bayan Lepas	2008	2.66	2.09	1.30	2.88	0.93	5.90
	2009	2.65	2.07	1.31	2.88	0.96	5.84
Butter worth	2008	2.84	1.79	1.65	3.17	1.80	5.13
	2009	2.88	1.87	1.60	3.21	1.74	5.33
Cameron Highland	2008	2.57	1.76	1.51	2.86	1.40	5.00
	2009	2.63	1.90	1.42	2.92	1.24	5.42
Chuping	2008	1.52	1.21	1.28	1.64	0.50	3.42
	2009	1.46	1.29	1.14	1.53	0.24	3.72
Ipoh	2008	2.25	1.49	1.56	2.50	1.30	4.24
	2009	2.24	1.54	1.56	2.49	1.29	4.38
KLIA Sepang	2008	2.39	1.52	1.63	2.69	1.43	4.40
	2009	2.04	1.60	1.30	2.22	0.72	4.55
Kota Bharu	2008	3.09	2.07	1.55	3.44	1.76	3.87
	2009	2.82	1.97	1.48	3.13	1.46	5.58
Kuala Krai	2008	1.30	0.97	1.37	1.42	0.55	2.74
	2009	1.20	0.92	1.33	1.31	0.46	2.61
Kuala Terengganu	2008	2.63	1.46	1.89	2.96	1.99	4.34
	2009	2.64	1.52	1.82	2.97	1.92	4.46
Kuantan	2008	2.16	1.72	1.28	2.38	0.71	4.86
	2009	2.12	1.66	1.30	2.30	0.74	4.71
Malacca	2008	2.71	1.87	1.50	3.05	1.47	5.37
	2009	2.99	2.09	1.48	3.30	1.54	5.88
Mersing	2008	4.06	2.02	2.13	4.58	3.40	6.25
	2009	4.01	1.93	2.21	4.53	3.45	6.06
Senai	2008	2.13	1.87	1.15	2.24	1.49	5.38
	2009	2.24	1.91	1.19	2.38	0.51	5.45
Sitiawan	2008	1.64	1.54	1.07	1.27	0.10	3.40
	2009	1.59	1.59	1.00	1.59	0.02	4.77

4.2.4 Wind power and energy density

For establishing the wind power projects, the most fundamental importance is to evaluate the wind power and wind energy density at that particular region. However, one of the problems of wind power is that the power output is highly variable and reliant on the vagaries of the weather. However, whilst the power output from a turbine cannot be predicted for a particular time, it is possible to estimate the proportion of time that the turbine produces different levels of power. Monthly and yearly wind power and wind energy density have been carried out by using Equations (3.12) and (3.13) and shown in Tables 4.4 to 4.6.

It is found that the monthly highest value of wind power density was 227.1 W/m^2 at Mersing on the month of January in 2009 and the lowest value of wind power density was 1.3 W/m^2 on November in 2008 at Batu embun. The average value of the monthly wind power density was 26.76 W/m^2. The range of the values of monthly wind energy density was found to be between 11.23 to 1962 kWh/m^2/year whereas the average wind energy density was found to be 231.20 kWh/m^2/year. It can be seen, dramatic monthly changes in the wind power density was found with a maximum value (145.92 W/m^2 in January, 2009) being 7.67 times of the minimum (19.03 W/m^2 in June, 2009) at Malacca. Very similar results, 6.56 times (max. 173.8 W/m^2 in Fabruary, 2008 and min. 26.49 W/m^2 in October, 2008) for Mersing; 6.34 times (max. 94.92 W/m^2 in January, 2009 and min. 14.97 W/m^2 in May, 2009) for Senai; 6.31 times (max. 65.18 W/m^2 in July, 2009 and min. 10.33 W/m^2 in October, 2009), have been found in the study period. Such considerable amount of difference in wind power density is seen because the wind power is proportional to the cube of the wind speed. When a wind project will be assessed or designed, this significant defference from month to month will underscore the importance of distinguising different months of the year.

The results of calculated mean wind speeds, standard deviation and wind power density revealed some oddities about the wind power densities. For example, from Table 4.2 and 4.6 taking 2009 at Mersing, since the mean wind speed (3.69 m/s) is found lower in July than the mean wind speed (3.79 m/s) in November, lower wind power density can be expected in July according to the wind power density equation but it conflicts. The wind power density (53.30 W/m^2) in July is greater than the wind power density (52.45 W/m^2) in November. This can be accounted for by the difference in their standard deviations of the wind speed distributions in these months. As shown in Table 4.2, the standard deviation (1.77 m/s) in July is greater than the standard deviation (1.63 m/s) in November. With a higher standard deviation but lower mean wind speed, a higher wind power density is possible because the wind power density expressed by Equation (3.12) monotonically increases with the increase of standard deviation when the mean wind speed is given. In other words, a month with same mean wind speed but higher standard deviation will have more potentials to experience higher wind speeds, and the wind power density is proportional to the cube of the wind speed, some more wind power may be harnessed in such occasions. Considering the power density values of different months, it is clear that January 2009 at Mersing devotes the greatest values with 227.1 W/m^2. Since no wind turbo-machines could convert more than 16/27 (59.26%) of the kinetic energy of wind energy into mechanical energy, the Lanchester-Betz law (Betz, 1942) assigns a power coefficient of 0.593 for maximum extractable power from an optimum wind energy conversion system. Thus, the maximum power extractable is found to be 0.593 x 227.1 W/m^2 x A (swept area of the wind turbine) in January 2009.

Table 4.4 Monthly wind power and energy density

Month	Para meter	Batu Embun		Bayan Lepas		Butterworth		Cameron Highlands		Chuping	
		2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
Jan	P/A	2.13	2.43	42.03	93.07	37.74	52.87	37.32	48.56	11.11	17.33
	E/A	18.40	21.00	363.1	804.1	326.1	456.8	322.4	419.6	95.99	149.7
Fab	P/A	2.24	2.26	48.70	44.99	41.10	42.43	48.31	16.01	12.85	13.59
	E/A	19.35	19.53	420.8	388.7	355.1	366.6	417.4	138.3	111.0	117.4
Mar	P/A	1.77	2.65	36.35	35.33	28.67	40.92	59.53	26.04	12.33	5.28
	E/A	15.29	22.90	314.1	305.3	247.7	353.6	514.3	225.0	106.53	45.62
Apr	P/A	2.30	2.10	33.01	31.71	30.05	34.15	14.41	42.45	4.80	6.59
	E/A	19.87	18.14	285.2	274.0	259.6	295.1	124.5	366.8	41.47	56.94
May	P/A	1.94	2.00	27.94	21.78	28.08	33.41	13.38	34.55	5.96	4.83
	E/A	16.76	17.28	241.4	188.2	242.6	288.7	115.6	298.5	51.49	41.73

Month	Para meter	Batu Embun		Bayan Lepas		Butterworth		Cameron Highlands		Chuping	
Jun	P/A	2.27	1.96	33.98	30.95	27.86	26.79	18.23	19.33	4.80	7.04
	E/A	19.61	16.93	293.6	267.4	240.7	231.5	157.5	167.0	41.47	60.83
Jul	P/A	2.72	2.57	55.86	45.72	38.61	35.19	10.55	19.75	6.57	5.80
	E/A	23.50	22.20	482.6	395.0	333.6	304.0	91.15	170.6	56.76	50.11
Aug	P/A	2.65	2.32	52.86	25.59	34.93	36.19	9.75	38.33	6.45	8.95
	E/A	22.90	20.04	456.7	221.1	301.8	312.7	84.24	331.2	55.73	77.33
Sep	P/A	2.48	2.22	30.07	26.59	28.43	40.19	59.27	37.98	5.48	7.90
	E/A	21.43	19.18	259.8	229.7	245.6	347.2	512.1	328.2	47.35	68.26
Oct	P/A	1.70	2.38	23.91	22.02	31.00	31.56	27.60	35.67	4.42	5.79
	E/A	14.69	20.56	206.6	190.3	267.8	272.7	238.5	308.2	38.19	50.03
Nov	P/A	1.30	1.86	28.16	34.56	29.01	31.02	13.21	30.11	6.57	4.97
	E/A	11.23	16.07	243.3	298.6	250.7	268.0	114.1	260.2	56.76	42.94
Dec	P/A	2.03	1.65	64.17	50.37	44.45	33.56	30.59	56.18	11.65	20.02
	E/A	17.54	14.26	554.4	435.2	384.1	290.0	264.3	485.4	100.66	173.0

Table 4.5 Monthly wind power and energy density

Month	Param eter	Ipoh		KLIA Sepang		Kota Bharu		Kuala Krai		Kuala Terengganu	
		2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
Jan	P/A	15.91	25.67	27.88	59.30	73.76	66.00	2.99	3.18	41.55	56.68
	E/A	137.5	221.8	240.9	512.4	637.3	570.2	25.83	27.48	359.0	489.7
Fab	P/A	23.27	16.47	33.54	13.00	114.9	45.19	2.42	4.26	47.19	21.04
	E/A	201.1	142.3	289.8	112.3	992.9	390.4	20.91	36.81	407.7	181.8
Mar	P/A	14.48	23.87	23.81	12.93	118.1	33.93	4.15	4.16	37.24	19.75
	E/A	125.1	206.2	205.7	111.7	1020	293.2	35.86	35.94	321.8	170.6
Apr	P/A	15.32	20.75	12.97	18.65	35.52	31.49	5.57	2.63	14.53	14.48
	E/A	132.4	179.3	112.1	161.1	306.9	272.1	48.12	22.72	125.5	125.1
May	P/A	14.95	16.94	14.50	17.01	26.88	27.55	5.00	3.64	12.04	15.97
	E/A	129.2	146.4	125.3	147.0	232.2	238.0	43.20	31.45	104.0	138.0
Jun	P/A	13.99	13.86	17.13	11.19	25.14	19.03	4.33	3.63	12.59	16.17
	E/A	120.9	119.8	148.0	96.68	217.2	164.4	37.41	31.36	108.8	139.7
Jul	P/A	18.30	16.89	25.23	65.18	28.83	30.06	6.43	4.87	12.70	17.34
	E/A	158.1	145.9	218.0	563.2	249.1	259.7	55.56	42.08	109.7	149.8
Aug	P/A	21.47	19.31	27.12	17.97	31.13	30.31	6.83	3.84	15.33	20.03
	E/A	185.5	166.8	234.3	155.3	269.0	261.9	59.01	33.18	132.5	173.1
Sep	P/A	20.99	16.41	16.79	10.40	31.28	33.00	2.49	2.70	10.42	12.49
	E/A	181.4	141.8	145.1	89.85	270.3	285.1	21.51	23.32	90.03	107.9
Oct	P/A	17.83	21.78	14.02	10.33	29.71	24.06	3.76	3.92	14.59	12.25
	E/A	154.1	188.2	121.1	89.25	256.7	207.9	32.49	33.87	126.1	105.8
Nov	P/A	15.89	14.45	11.80	14.39	27.22	39.43	2.85	2.24	12.97	31.27
	E/A	137.3	124.9	102.0	124.3	235.2	340.7	24.62	19.35	112.1	270.2
Dec	P/A	22.30	17.26	18.50	15.54	39.34	89.90	2.41	2.33	41.44	54.63
	E/A	192.7	149.1	159.8	134.3	339.9	776.7	20.82	20.13	358.0	472.0

Table 4.6 Monthly wind power and energy density

Month	Parameter	Kuantan		Malacca		Mersing		Senai		Sitiawan	
		2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
Jan	P/A	21.80	26.69	46.78	145.92	143.0	227.1	44.99	94.92	12.13	10.45
	E/A	188.4	230.6	404.2	1261	1236	1962	388.7	820.1	104.8	90.29
Fab	P/A	28.53	21.96	66.64	70.48	173.8	96.98	54.63	45.72	15.88	18.47
	E/A	246.5	189.7	575.8	608.95	1502	837.9	472.0	395.0	137.2	159.6
Mar	P/A	31.01	17.17	31.04	31.15	114.1	36.43	26.72	16.17	14.17	13.46
	E/A	267.9	148.4	268.2	269.1	985.7	314.8	230.9	139.7	122.4	116.3
Apr	P/A	17.11	18.23	17.39	29.38	36.00	39.71	12.68	17.89	13.88	19.90
	E/A	147.8	157.5	150.3	253.8	311.0	343.1	109.6	154.6	119.9	171.9
May	P/A	20.74	14.31	18.36	32.06	51.92	39.04	20.91	14.97	10.90	18.46
	E/A	179.2	123.6	158.6	277.0	448.6	337.3	180.7	129.3	94.18	159.5
Jun	P/A	25.83	22.16	17.76	19.03	43.41	48.90	15.66	16.22	10.86	15.01
	E/A	223.1	191.5	153.5	164.4	375.1	422.5	135.3	140.1	93.83	129.7
Jul	P/A	23.13	23.81	15.54	29.36	54.46	53.30	17.24	25.61	12.47	21.76
	E/A	199.8	205.7	134.3	253.7	470.5	460.5	149.0	221.3	107.7	188.0
Aug	P/A	28.03	26.20	21.57	27.25	56.09	56.22	20.80	18.31	16.54	20.88
	E/A	242.2	226.4	186.4	235.4	484.6	485.7	179.7	158.2	142.9	180.4
Sep	P/A	25.68	23.81	34.98	20.91	43.01	45.86	18.94	19.93	15.69	12.22
	E/A	221.9	205.7	302.2	180.7	371.6	396.2	163.6	172.2	135.6	105.6
Oct	P/A	14.16	18.63	30.20	23.77	26.49	35.92	15.57	14.99	16.97	14.65
	E/A	122.3	161.0	260.9	205.4	228.9	310.3	134.5	129.5	146.6	126.6
Nov	P/A	11.79	11.51	29.85	29.93	31.74	52.45	14.72	24.04	16.71	12.07
	E/A	101.9	99.44	257.9	258.6	274.2	453.2	127.2	207.7	144.4	104.3
Dec	P/A	15.35	15.96	70.12	87.76	123.0	106.8	47.09	40.05	13.16	8.54
	E/A	132.6	137.9	605.8	758.3	1063	923.1	406.9	346.0	113.7	73.79

The most probable wind speed and wind speed carrying maximum energy is calculated by using Equations 3.9 and 3.10 are shown in Table 4.7. It is observed from Table 2.40 that the yearly highest values of the most probable wind speed and wind speed carrying maximum energy are 3.45 m/s and 6.25 m/s respectively. The yearly average values of the most probable wind speed and the wind speed carrying maximum energy are found to be 1.18 m/s and 4.59 m/s respectively. The yearly wind power and wind energy density are evaluated, respectively by Equations (3.11) and (3.12) and shown in Table 4.7. Clearly, the yearly highestt value of wind power density was in 2008 followed by 2009 at Mersing while the lowest one was found to be in 2008 at Batu Embun. The highest value of the yearly wind energy density was found to be 659.28 kWh/m^2/year in 2008 at Mersing. As it can be seen in Table 4.7, the values of power and energy related to meteorological prediction are fairly greater for some years and smaller for some years than those of Weibull prediction. The discrepancies are almost considerable may be due to low wind speed values in these sites. This is in close agreement with the findings of Zhou et al. (2006) who suggested that the discrepancies between the Weibull function predictions and the wind speed data are much wider as the wind speed approaches its lower limit. However, for the purpose of estimating wind power potentials, the difference may always be ignored for the wind turbines where little or even no energy output under such low wind speeds are provided. For higher wind speeds, Weibull distribution function can be coincided with the wind data very well. The maximum wind power and wind energy density for Weibull prediction were found to be 73.56 W/m^2 and 635.56 kWh/m^2/year respectively at Mersing, whereas for meteorological prediction, they were 75.26 W/m^2 and 650.24 kWh/m^2/year respectively.

Table 4.7 Yearly wind power density and wind energy density

Station	Year	Meteorological		Weibull		V_{mp}	$V_{max,E}$
		P/A	E/A	P/A	E/A		
Batu Embun	2008	1.84	15.90	2.07	17.88	0.14	2.34
	2009	1.83	15.81	1.95	16.85	0.12	2.38
Bayan Lepas	2008	36.40	314.50	39.65	342.58	0.93	5.90
	2009	36.16	312.42	38.92	336.27	0.96	5.84
Butter worth	2008	32.61	281.75	33.36	288.23	1.80	5.13
	2009	35.65	308.02	36.47	315.10	1.74	5.33
Cameron Highland	2008	28.30	244.51	28.37	245.12	1.40	5.00
	2009	33.96	293.41	33.85	292.46	1.24	5.42
Chuping	2008	6.49	56.08	4.65	40.18	0.50	3.42
	2009	6.88	59.44	4.23	36.55	0.24	3.72
Ipoh	2008	17.91	154.74	17.80	153.79	1.30	4.24
	2009	18.63	160.96	17.59	151.98	1.29	4.38
KLIA Sepang	2008	20.36	175.91	20.63	178.24	1.43	4.40
	2009	17.73	153.19	18.16	156.90	0.72	4.55
Kota Bharu	2008	44.80	387.07	47.12	407.12	1.76	3.87
	2009	36.60	316.22	38.69	334.28	1.46	5.58
Kuala Krai	2008	4.54	39.22	4.21	36.37	0.55	2.74
	2009	3.64	31.44	2.66	22.98	0.46	2.61
Kuala Terengganu	2008	23.02	198.89	22.56	194.92	1.99	4.34
	2009	24.73	213.67	23.91	206.58	1.92	4.46
Kuantan	2008	20.66	178.50	21.69	187.40	0.71	4.86
	2009	19.05	164.59	20.20	174.53	0.74	4.71

Station	Year	Meteorological		Weibull		V_{mp}	$V_{max,E}$
		P/A	E/A	P/A	E/A		
Malacca	2008	33.76	291.69	34.76	300.33	1.47	5.37
	2009	43.79	378.35	45.34	391.74	1.54	5.88
Mersing	2008	75.26	650.24	73.56	635.56	3.40	6.25
	2009	70.79	611.63	68.89	595.21	3.45	6.06
Senai	2008	23.64	204.25	25.88	223.60	1.49	5.38
	2009	26.48	228.79	28.07	242.52	0.51	5.45
Sitiawan	2008	12.13	104.80	5.90	50.98	0.10	3.40
	2009	12.47	107.74	14.23	122.95	0.02	4.77

4.2.5 Weibull distribution and cumulative distribution

The strength of wind varies, and an average value for a given location does not alone indicate the amount of energy a wind turbine could produce there. To assess the frequency of wind speeds at a particular location, a probability distribution function is often fit to the observed data. Different locations will have different wind speed distributions. The Weibull model closely mirrors the actual distribution of hourly wind speeds at many locations. Wind distribution profile is one of the main keys to wind energy resource assessment for a region of a particular country. If a graph is plotted of the number of times, or frequency, with which winds occur at various speeds throughout the year, it is found that there are few occurrences of no wind and few occurrences of winds above hurricane force. Most of the time wind speeds fall some where in between these extremes. The Weibull distribution can be presented in two forms: the ‘probability density function’ and the ‘cumulative distribution function’. The probability density function produces the most intuitive results and so is most commonly used.

The cumulative distribution function can be used for estimating the fraction of time ‘T’ the turbine will be turning. This may be a very important consideration if a turbine is to feature in a prominent position in the urban landscape or be considered iconic. In the case of a cut-in speed of 3 m/s and cut-out speed of 25 m/s, the following equation can be used:

$$T = e^{-(3/c)^k} - e^{-(25/c)^k} \qquad (4.1)$$

The probability density and cumulative distribution functions of the wind rigimes, following the Weibull distribution are shown in Figures 4.31 to 4.60. The k and c values for these sites are shown in their respective probability distribution functions. The Equations (3.2) and (3.3) have been used to evaluate the Weibull probability distribution function and Weibull cumulative distribution function respectively. As the peak of the probability density curve indicates the most frequent wind velocity in the particular regime, it can be easily seen from the curves that the range of the most frequent wind speed values is between 1 m/s to 3.5 m/s.

The result shows that, Mersing is the most 'windy' place with the largest scale parameter c, and its most frequent wind speed is 3.5 m/s. The result also shows that, the Kuala Terengganu is in the second position with the scale parameter value of 2.97 m/s and most frequently wind speed value of 3.00 m/s. For other most of the sites, the most frequent wind speeds are below the 2.5 m/s. Generally wind turbines are designed with a cut-in speed, or the wind speed at which it begins to produce power, and a cut-out speed, or the wind speed at which the turbine will be shut down to prevent the drive train from being damaged. For most wind turbines, the range of cut-in speed is 3.0 ~ 4.50 m/s, and the cut-out speed can be as highly as 25 m/s. So from the probability distribution function, it is found that the Mersing and Kuala Terengganu are the two most probable wind energy generating sites in Peninsular Malaysia.

From Weibull probability density function, it can be seen that the maximum percentage of error between Weibull wind speed frequencies and observed frequencies occurs at 3 m/s or more than 3 m/s is almost insignificance with the highest value of the error is 20%. On the other hand, for wind speed less than 3 m/s the error between the Weibull density function and observed density function are larger with the maximum error value is around 46 %. This is because Weibull distribution function is unable to represent the probabilities of observing zero or very low wind speed. It is observed that Weibull distribution fits the observed distribution reasonably well in the higher wind speed range. Previous studies have also concluded that the Weibull distribution fits the actual wind speed frequencies quite well at the larger wind speed (Keyhani et al., 2010; Morgan, 1995).

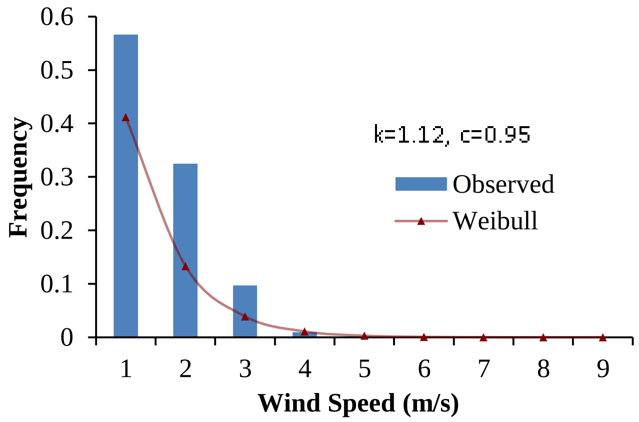

Figure 4.31 Weibull and observed wind speed frequencies at Batu Embun

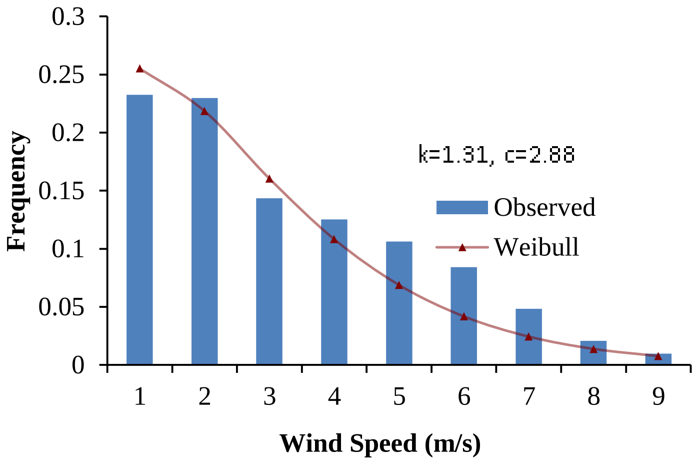

Figure 4.32 Weibull and observed wind speed frequencies at Bayan Lepas

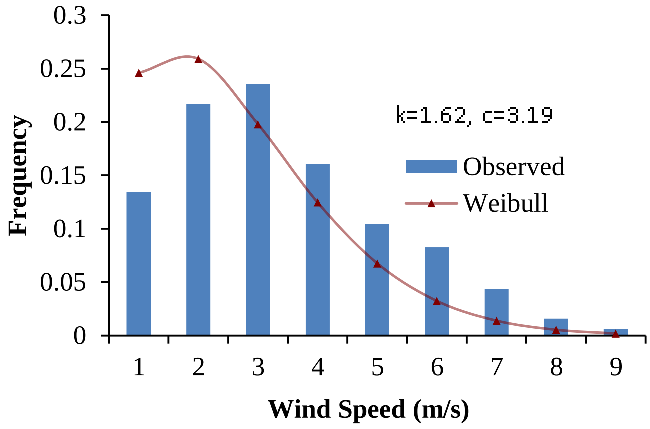

Figure 4.33 Weibull and observed wind speed frequencies at Butterworth

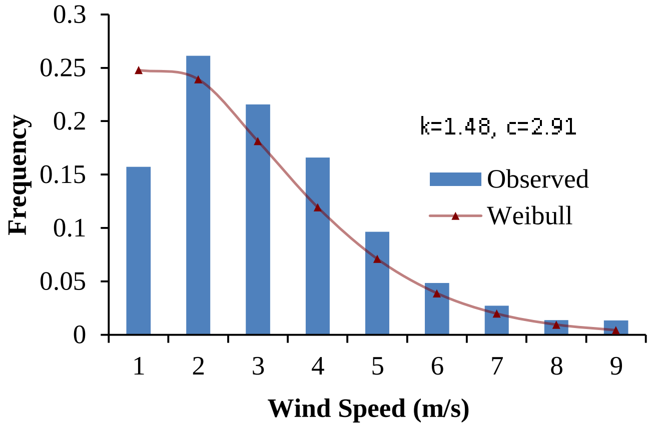

Figure 4.34 Weibull and observed wind speed frequencies at Cameron Highland

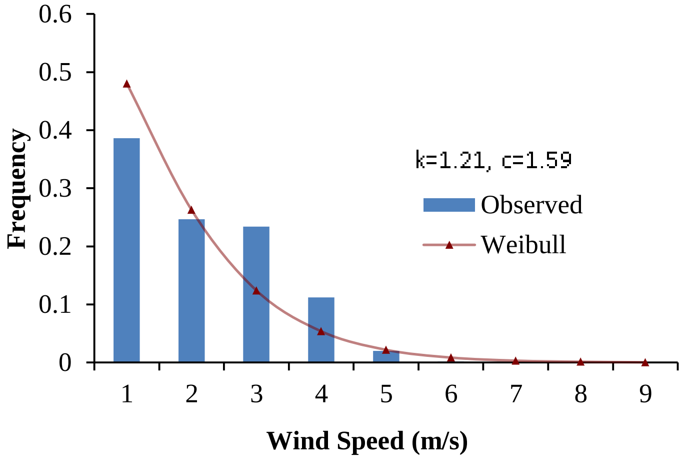

Figure 4.35 Weibull and observed wind speed frequencies at Chuping

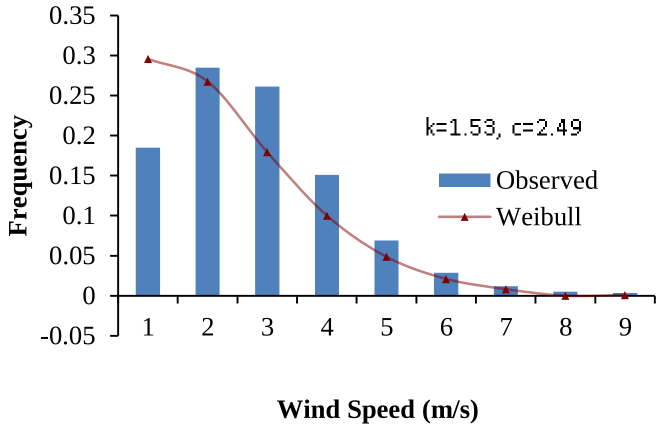

Figure 4.36 Weibull and observed wind speed frequencies at Ipoh

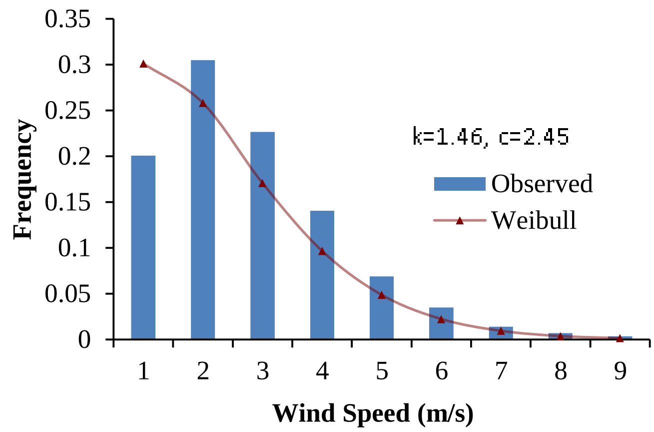

Figure 4.37 Weibull and observed wind speed frequencies at KLIA Sepang

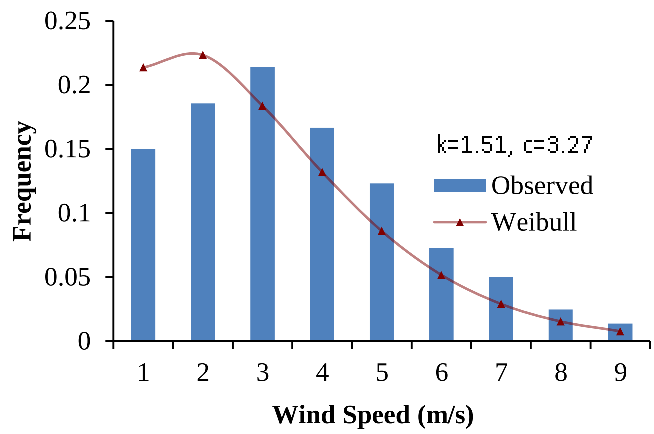

Figure 4.38 Weibull and observed wind speed frequencies at Kota Bharu

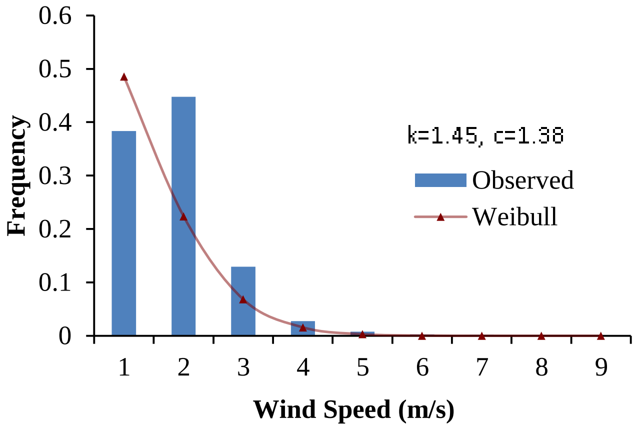

Figure 4.39 Weibull and observed wind speed frequencies at Kuala Krai

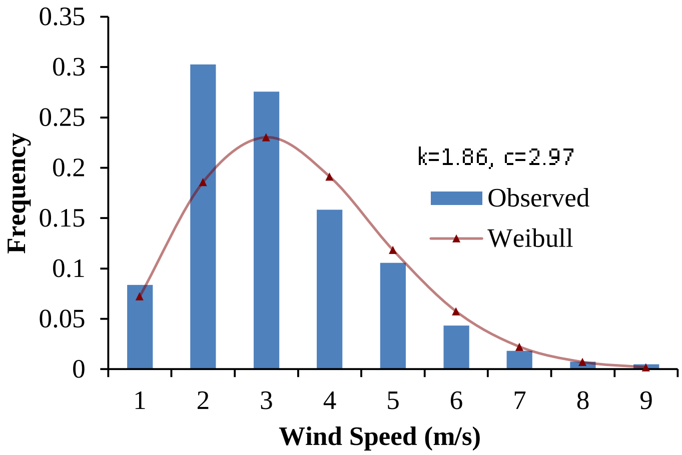

Figure 4.40 Weibull and observed wind speed frequencies at Kuala Terengganu

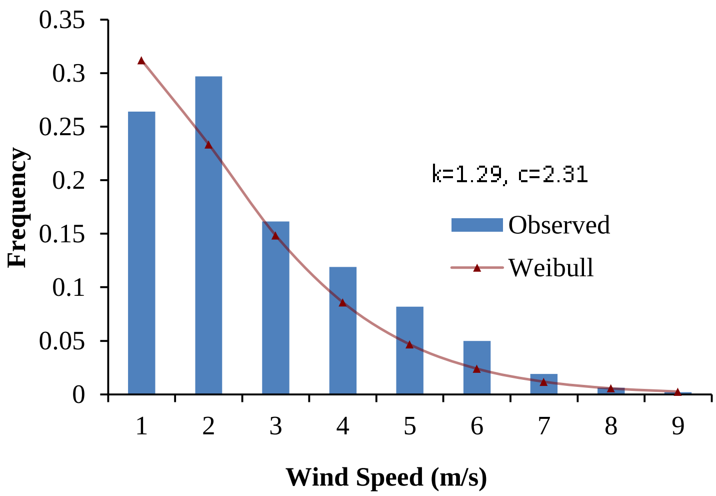

Figure 4.41 Weibull and observed wind speed frequencies at Kuantan

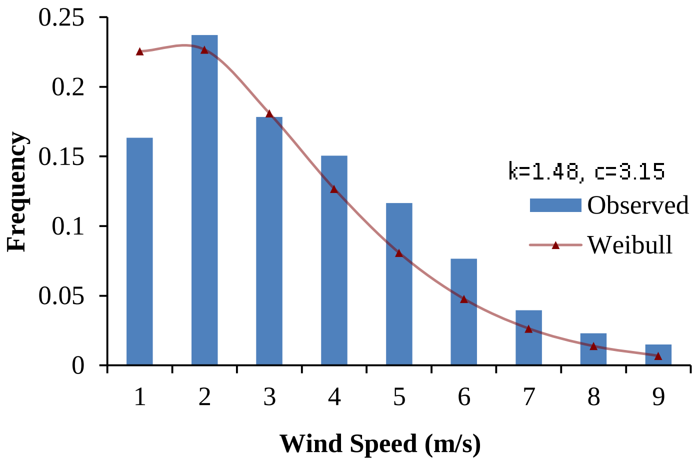

Figure 4.42 Weibull and observed wind speed frequencies at Malacca

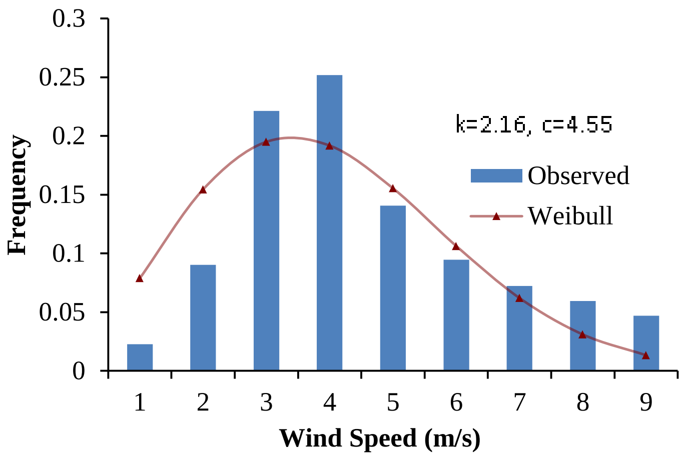

Figure 4.43 Weibull and observed wind speed frequencies at Mersing

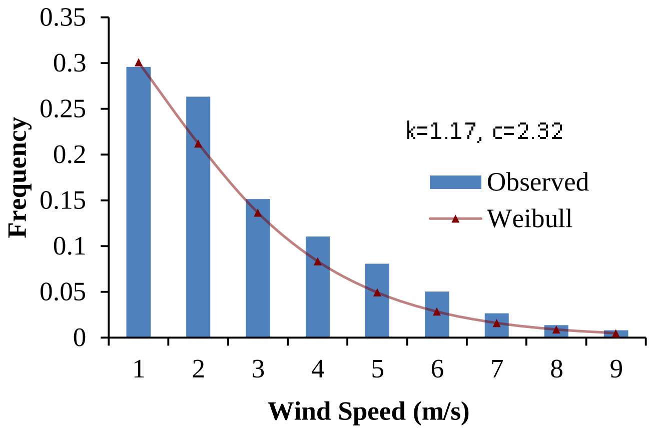

Figure 4.44 Weibull and observed wind speed frequencies at Senai

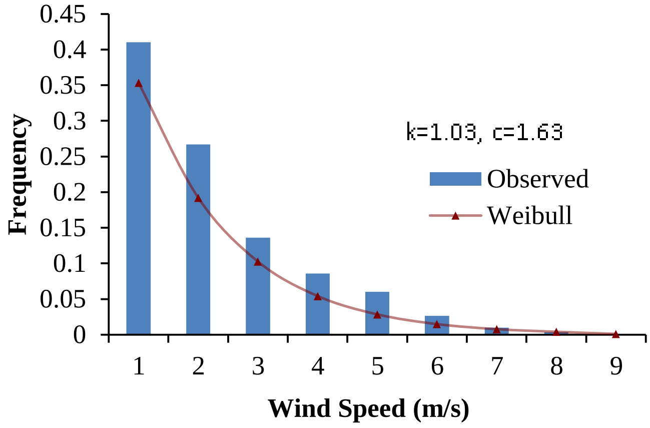

Figure 4.45 Weibull and observed wind speed frequencies at Sitiawan

It is observed that the Weibull cumulative frequency disributions are closer to the observed cumulative frequency distributions. The cumulative distribution function can be used for estimating the time for which wind is within a certain velocity interval. If 3.0 m/s and 25 m/s are used as the cut-in and cut-out speeds, as for example from Equation (4.1), it is found that Mersing will have the highest operating possibility of 67% (around 5789 hours per year), Kota Bharu, Butterworth, Malacca and Kuala Terrengganu will have 42% (around 3629 hours per year), 40% (around 3456 hours per year), 39% (around 3370 hours per year) and 36% (around 3110 hours per year) respectively.

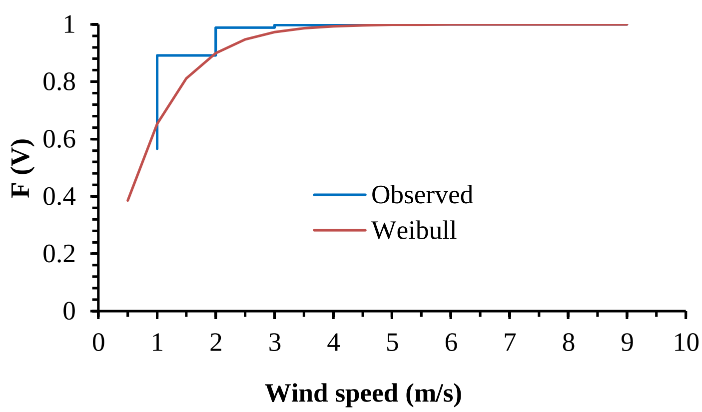

Figure 4.46 Cumulative distribution function at Batu Embun

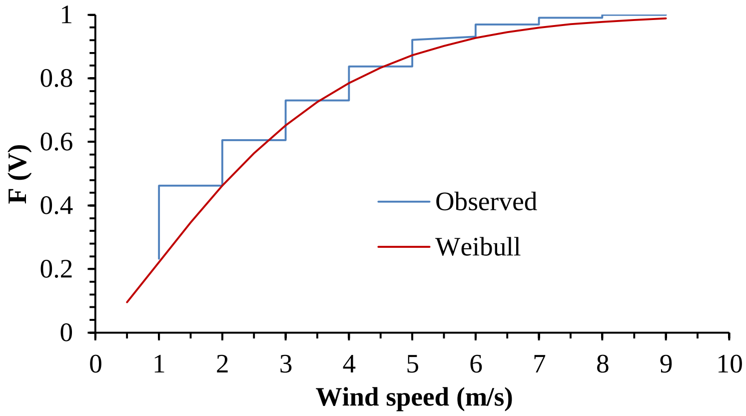

Figure 4.47 Cumulative distribution function at Bayan Lepas

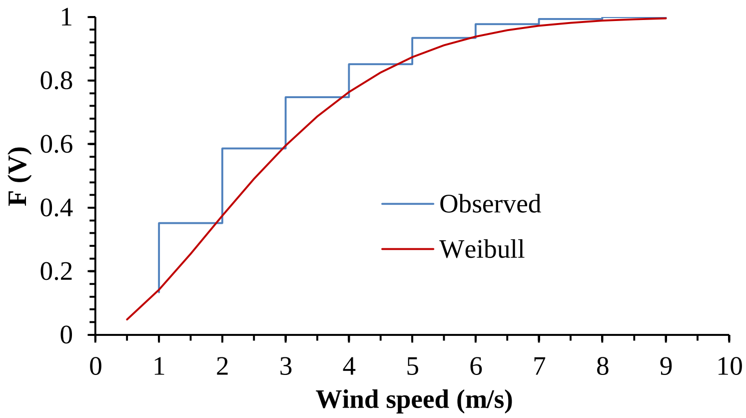

Figure 4.48 Cumulative distribution function at Butterworth

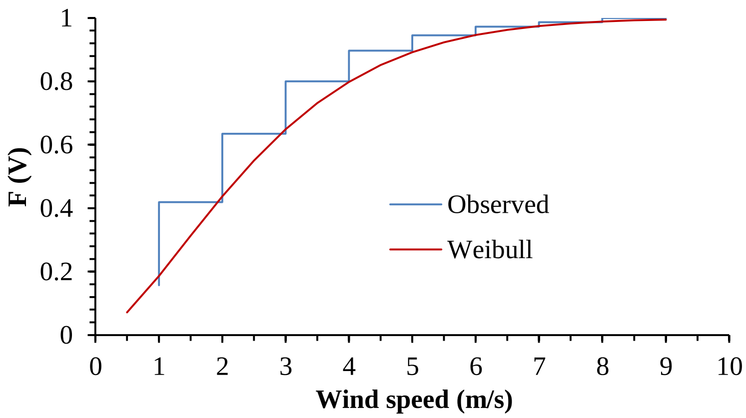

Figure 4. 49 Cumulative distribution function at Cameron Highland

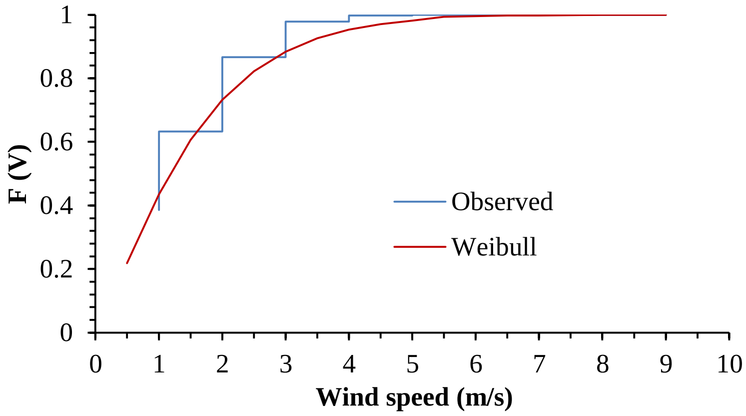

Figure 4.50 Cumulative distribution function at chuping

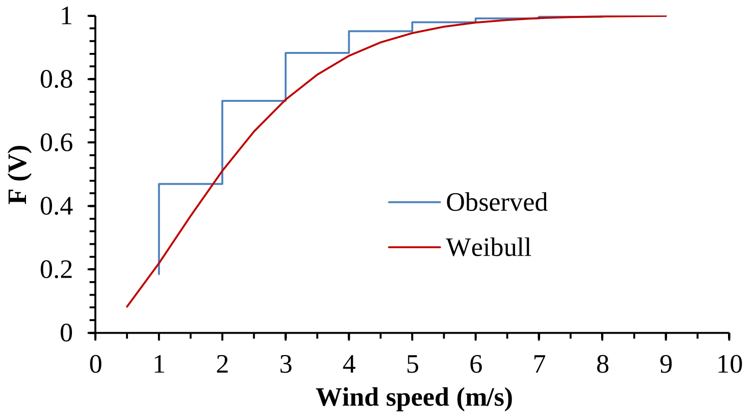

Figure 4.51 Cumulative distribution function at Ipoh

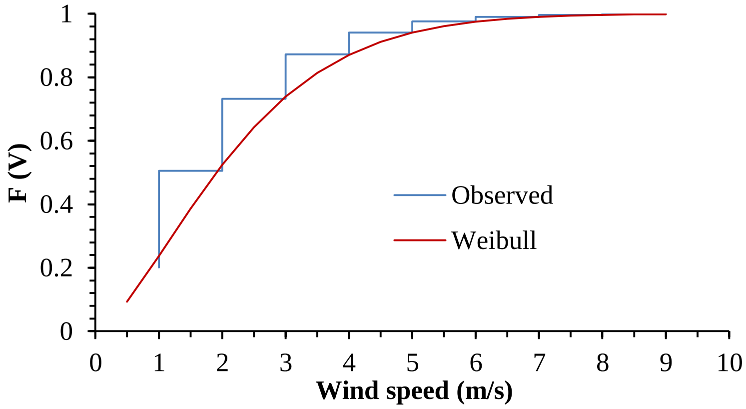

Figure 4.52 Cumulative distribution function at KLIA Sepang

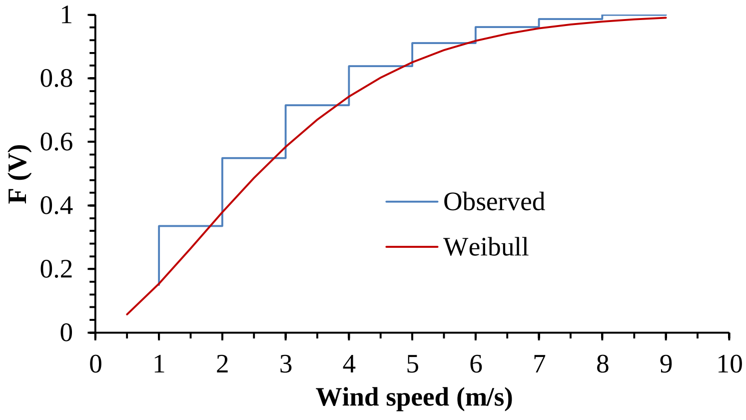

Figure 4.53 Cumulative distribution function at Kota Bharu

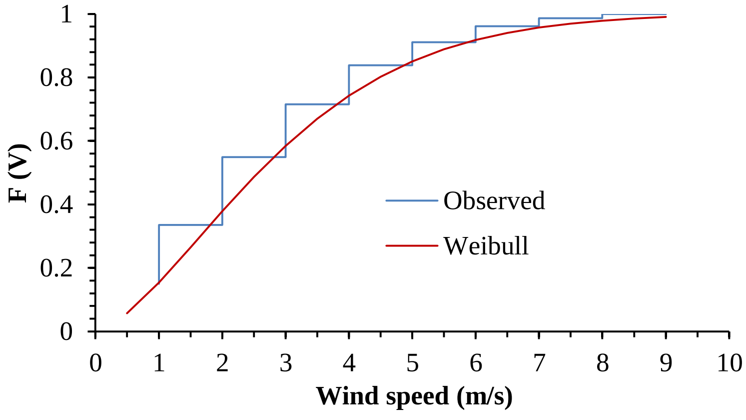

Figure 4.54 Cumulative distribution function at Kuala Krai

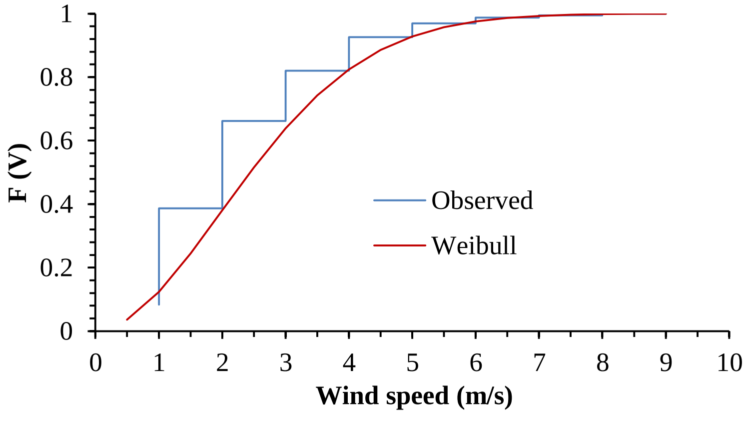

Figure 4.55 Cumulative distribution function at Kuala Terengganu

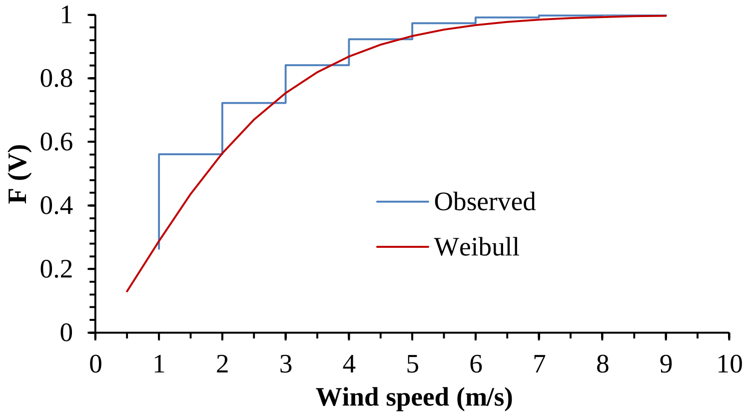

Figure 4.56 Cumulative distribution function at Kuantan

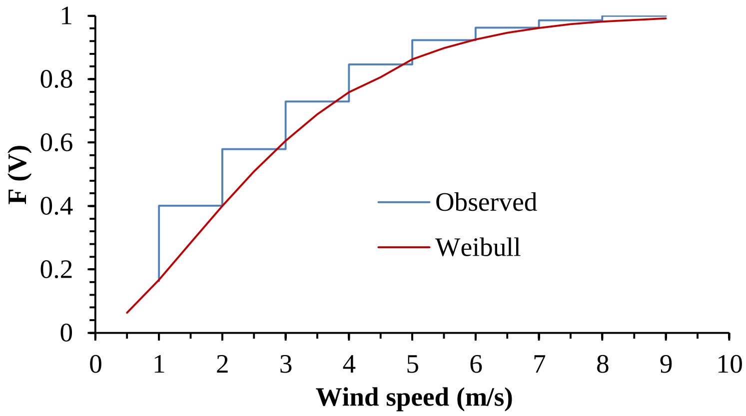

Figure 4.57 Cumulative distribution function at Malacca

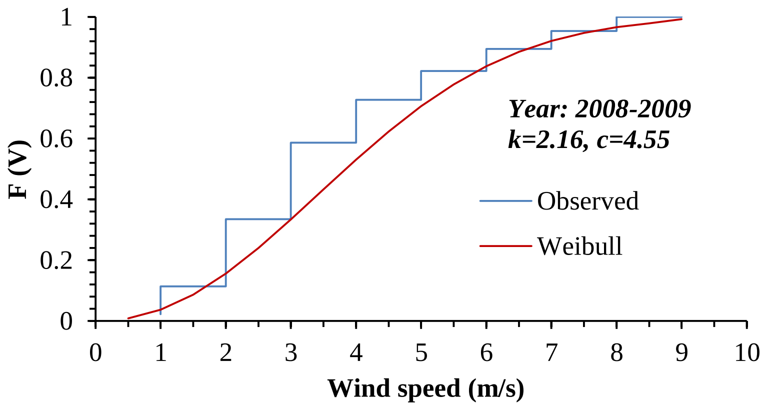

Figure 4.58 Cumulative distribution function at Mersing

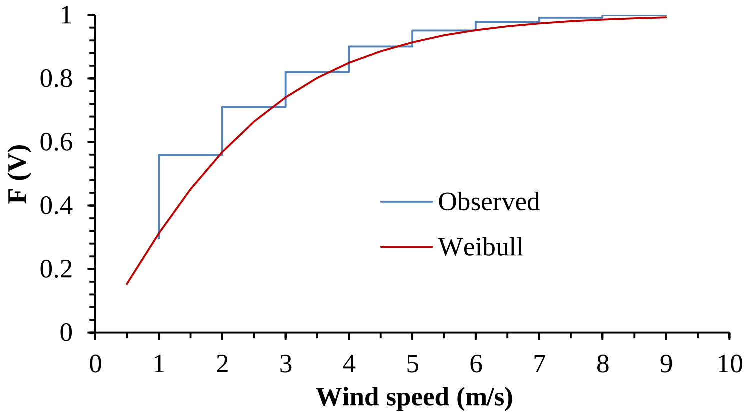

Figure 4.59 Cumulative distribution function at Senai

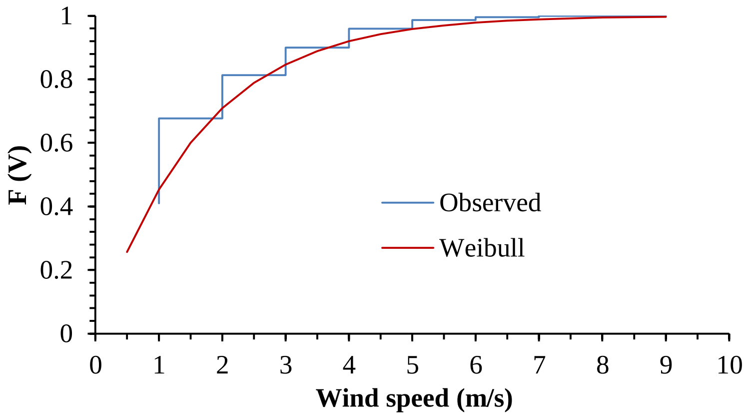

Figure 4.60 Cumulative distribution function at Sitiawan

4.2.6 Polar diagrams

Determining wind speed according to wind direction is important to conduct wind energy researchers and displays the impact of geographical features on the wind. Although the wind direction may not be a major concern for wind farm development in open-field areas, it can prove very important when considering urban wind energy and assessing the suitability of a particular location. Analyzing the average energy content of the wind from the various wind directions gives an appreciation of where the dominant high energy flows originate. This information can be related to the proposed location to determine an optimal turbine position or, at least, to avoid obstacles such as tall buildings and trees upstream of the turbine. In the case of building- integrated turbines, knowledge of directionality can be even more important as the buildings will often be designed to accelerate winds from certain key directions.

In order to use the wind energy properly, it is very essential to determine the wind direction with other parameters. WRPLOT software is used to draw the polar diagram of wind speed to show the wind direction. The circular diagram displays the relative frequency of wind directions in 8 or 16 principal directions. The wind direction is illustrated in polar diagrams and is measured clockwise in degrees. The cycle (360˚), which represents the cardinal points, is devided into 16 sectors and each of them covers an arc of 22. 5°. Based on the wind dirrection data collected from the meteorological department, the frequencies (%) are plotted in polar diagrams with respect to the cardinal point, from which the wind blows. The observed wind speed data directions are plotted in polar diagrams with respects to the cardinal point to show the wind direction in Figuress 4.61 to 4.75. It is noticed that the direction of wind blow in tha same area of different years is characterized by a significant stability.

As for example, if Mersing is considered, It can be found that the most probable wind direction for the two-year period is on 247. 5˚ and the second most probable wind direction is on 0˚. From the resultant vector, the most probable wind direction for the study period is on 270˚, i.e. west winds. The prevailing winds are due 247.5˚ on a percentage is around 18.5%, wlhereas the second most prevailing winds are due 0˚ and the resultant vector winds due 270˚ are around 15.8% and 24% respectively. In the quadrants, which correspond to the south-east, the wind frequency appears to be very low. On the other hand, for the study period the wind speeds less than 3 m/s are only 11.3%, which are not suitable for generating wind energy. If we consider the 15 study sites, the most probable wind directions are varying considerably. For all the sites, the prevailing winds from the most probable wind directions on the percentage ranging from 15 to 41% and the wind speeds less than 3 m/s are ranging from 11.2-89.2%.

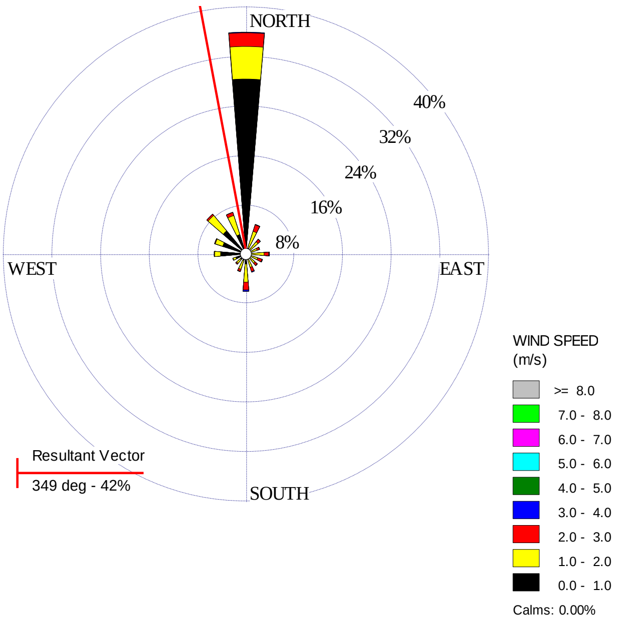

Figure 4.61 Wind rose-wind direction for the years 2008-2009, Batu Embun

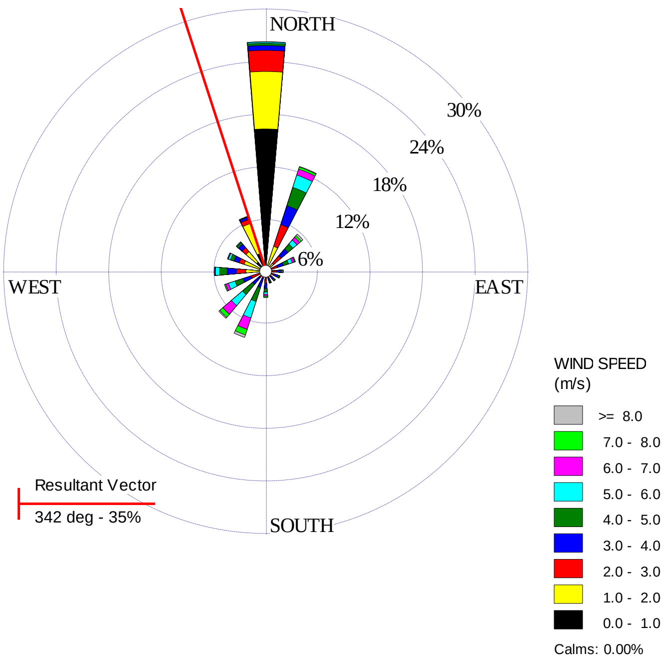

Figure 4.62 Wind rose-wind direction for the years 2008, Lepas

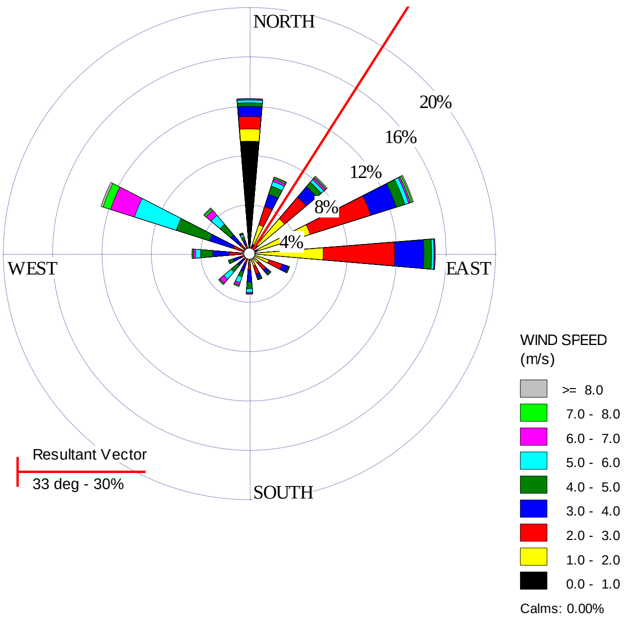

Figure 4.63 Wind rose-wind direction for the years 2008-2009, Butterworth

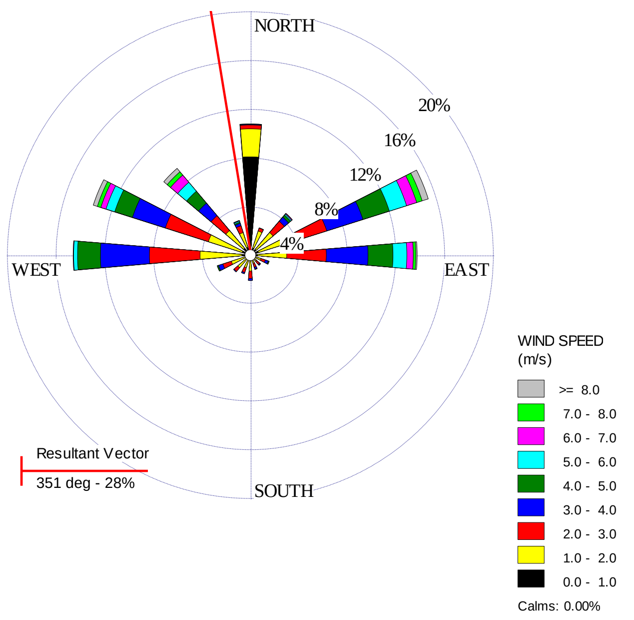

Figure 4.64 Wind rose-wind direction for the years 2008-2009, Cameron Highland

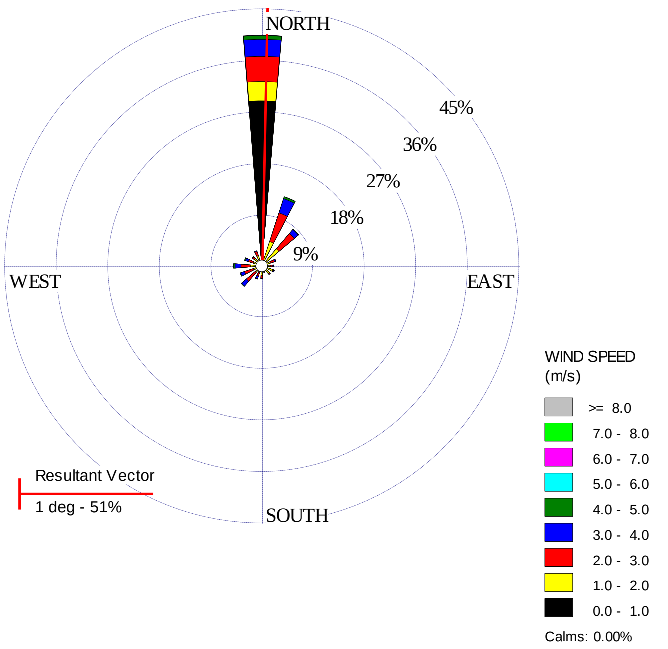

Figure 4.65 Wind rose-wind direction for the years 2008-2009, Chuping

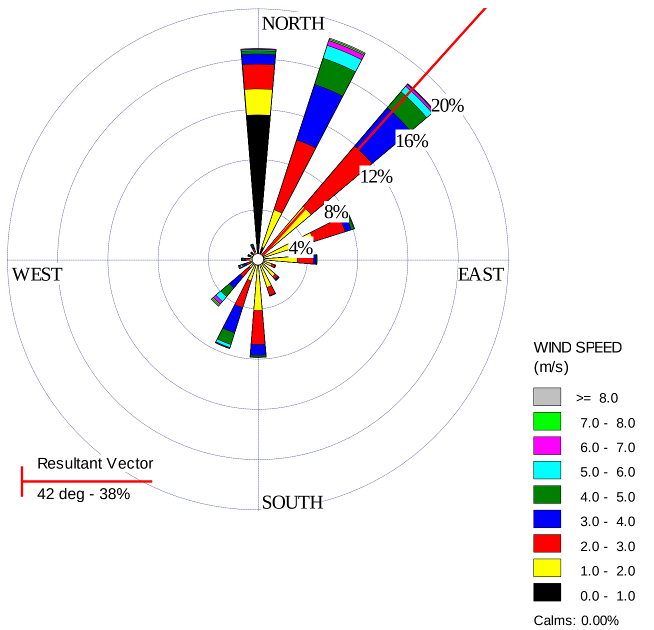

Figure 4.66 Wind rose-wind direction for the years 2008-2009, Ipoh

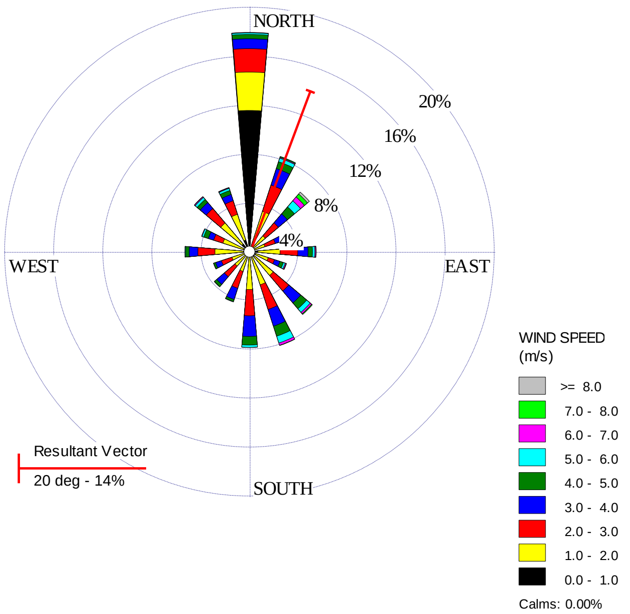

Figure 4.67 Wind rose-wind direction for the years 2008-2009, KLIA Sepang

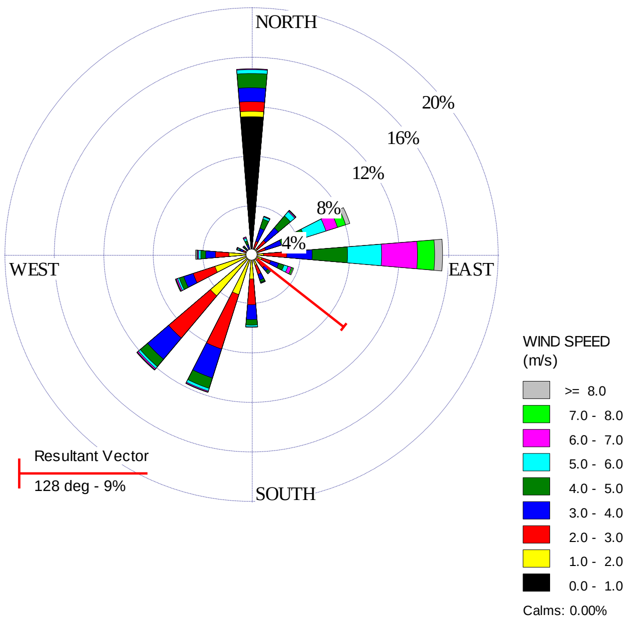

Figure 4.68 Wind rose-wind direction for the years 2008-2009, Kota Bharu

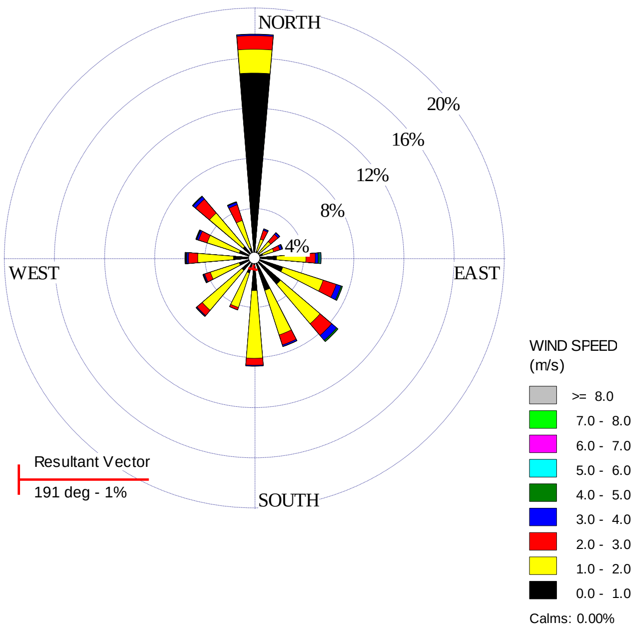

Figure 4.69 Wind rose-wind direction for the years 2008-2009, Kuala Krai

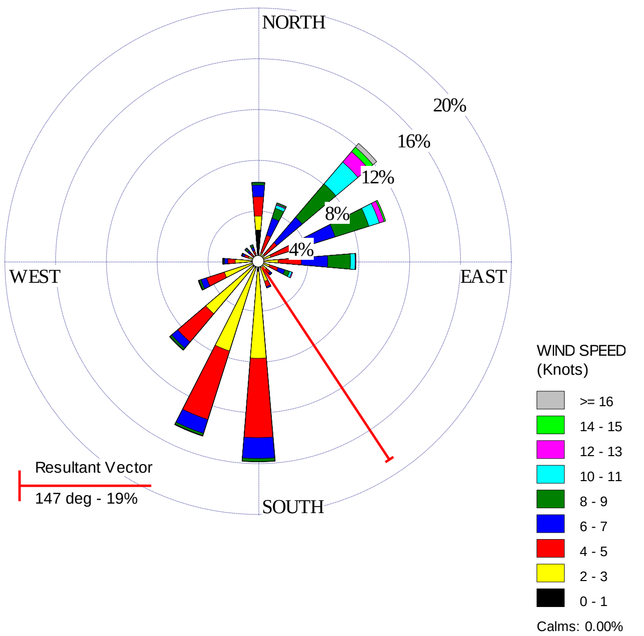

Figure 4.70 Wind rose-wind direction for the years 2008-2009, Kuala Terengganu

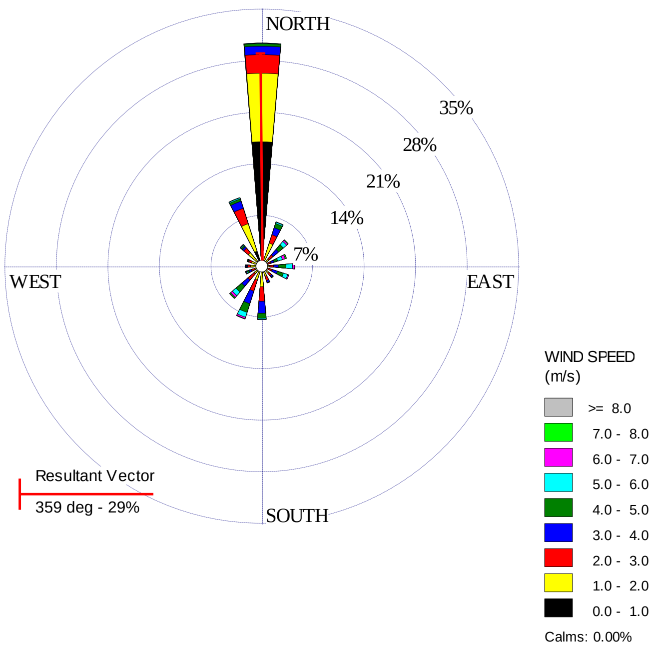

Figure 4.71 Wind rose-wind direction for the years 2008-2009, Kuantan

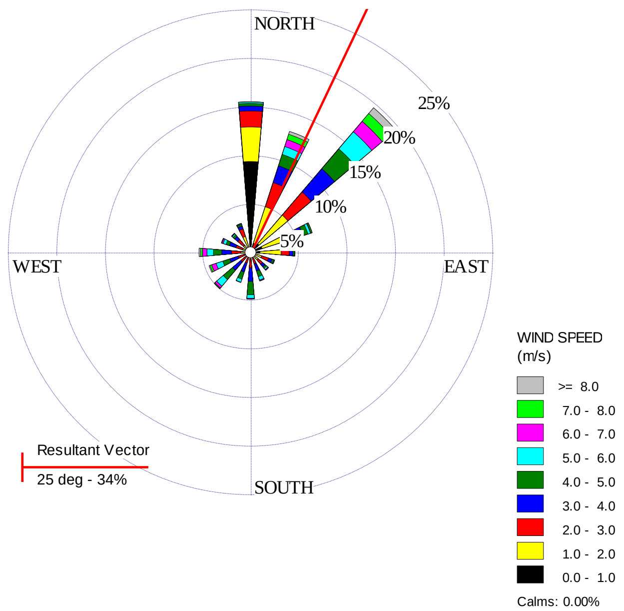

Figure 4.72 Wind rose-wind direction for the years 2008-2009, Malacca

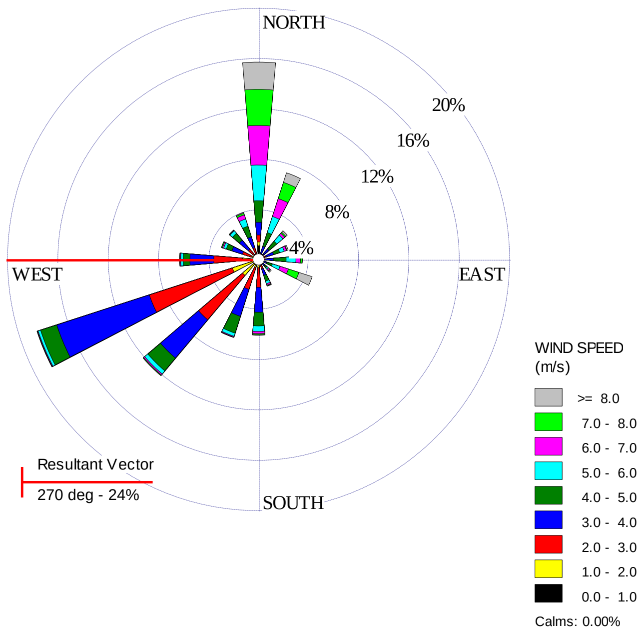

Figure 4.73 Wind rose-wind direction for the years 2008-2009, Mersing

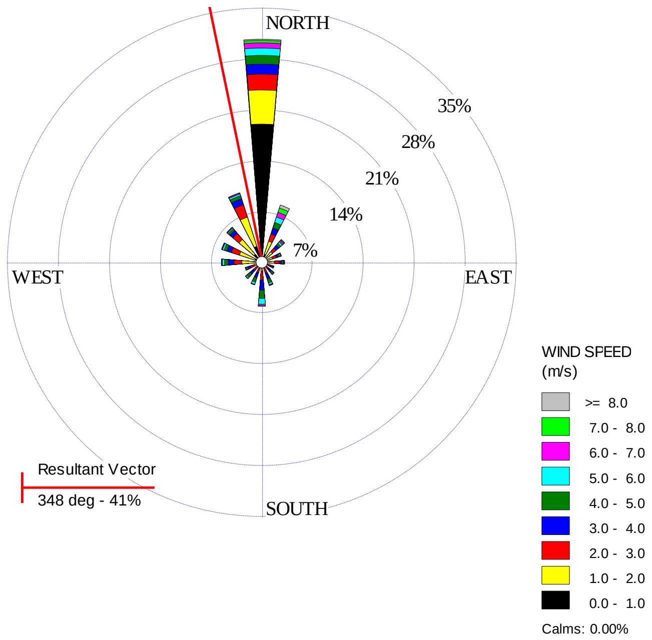

Figure 4.74 Wind rose-wind direction for the years 2008-2009, Senai

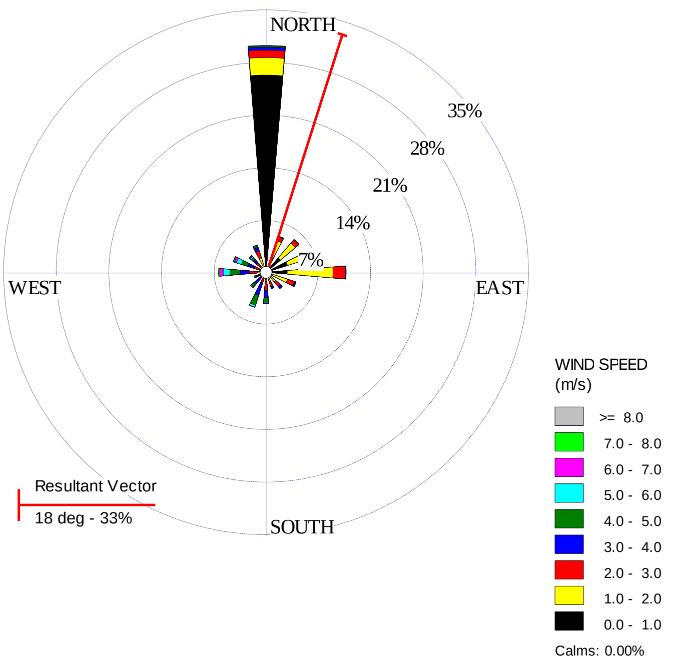

Figure 4.75 Wind rose-wind direction for the years 2008-2009, Sitiawan

4.3 Contour mapping of mean wind speed in Peninsular Malaysia

The National Renewable Energy Laboratory (NREL) has developed an automated technique for wind resource mapping to aid in the acceleration of wind energy deployment. The new automated mapping system was developed with the following two primary goals: (1) to produce a more consistent and detailed analysis of the wind resource for a variety of physiographic settings, particularly in areas of complex terrain; and (2) to generate high quality map products on a timely basis. Regional wind resource maps using this new system have been produced for areas of the United States, Mexico, Chile, Indonesia (1), and China. Countrywide wind resource assessments are under way for the Philippines, the Dominican Republic, and Mongolia. Regional assessments in Argentina and Russia are scheduled to begin soon. Malaysia is still so far from this idea and though the government of Malaysia includes RE as the fifth fuel in the energy mix the advancement is a nonentity. One of the key things to know about wind speed is that the amount of energy which wind can generate is not a one to one function. Rather energy increases by the cube of the wind speed. If we double the wind speed, we will get eight times the energy. That is one reason that looking at wind maps is so useful. Even a small difference in wind speed within a given area can have a big impact on the amount of energy a wind turbine can generate. If the wind speed increases even a few m/s by varying the wind turbine position the energy generation potential goes way up. That is why a wind resource potential map is a very useful resource for evaluating a site for its wind energy potential.

From the wind energy map, anyone could easily understand the wind speed and prevailing area of that wind speed. In this study, with the assessment of wind energy the wind energy map has been generated by the geographical parameters (latitude, longitude, and altitude), and months of the year were used as input for the development model to predict the monthly mean wind speed from January to December. The predicted monthly mean wind speeds for the Peninsular Malaysia are presented in the form of monthly maps using the Geographical Information System (GIS) ArcGIS 9.3 software. Predicted monthly mean wind speed maps are shown in Figures 4.76 to 4.87, whereas the predicted yearly mean wind speeds' map is shown in Figure 4.88. From the monthly mean wind speed map, it can be seen that the southern part of Peninsular Malaysia is windier than that of the other parts. The range of the monthly mean wind speeds is found to be 0.80 m/s to 6.0 m/s whereas the range of the yearly mean wind speeds is estimated to be 0.9 m/s to 3.9 m/s. From the map, it can be easily understood that Mersing is the most promising wind energy site in Peninsular Malaysia with the monthly mean wind speed range from 3.00 m/s to 6.0 m/s. Mersing has been also reported as the most promising wind energy site in Malaysia by Sopian et al. (1995). In the present technology, this site is suitable for a year round small-scale wind energy production. Some other sites like Malacca, Johor, Kuala Terengganu and Bayan Lepas are suitable for small-scale electricity generation around the quarter of the year.

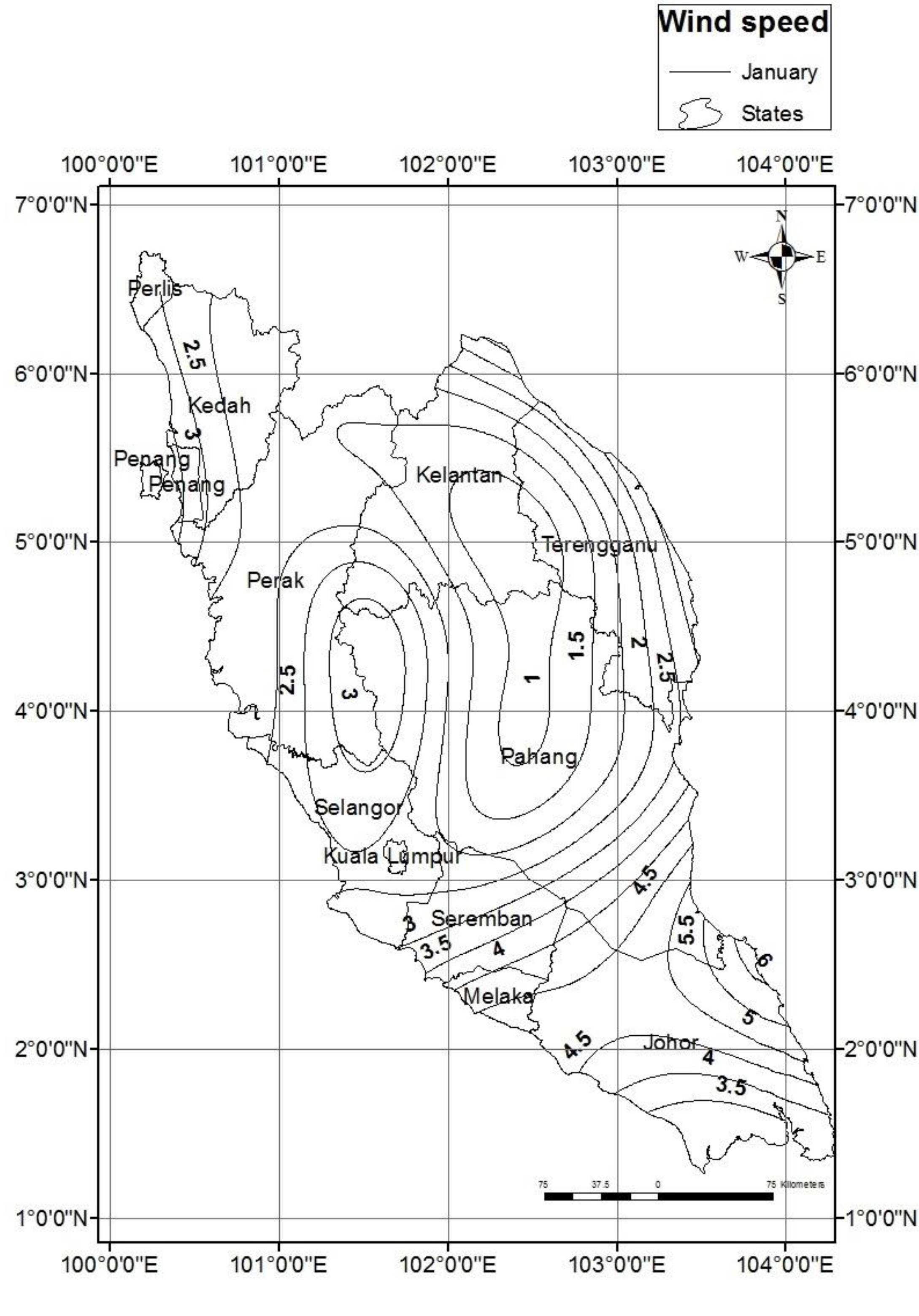

Figure 4.76 Contour Map on predicted monthly mean wind speed (m/s) for January

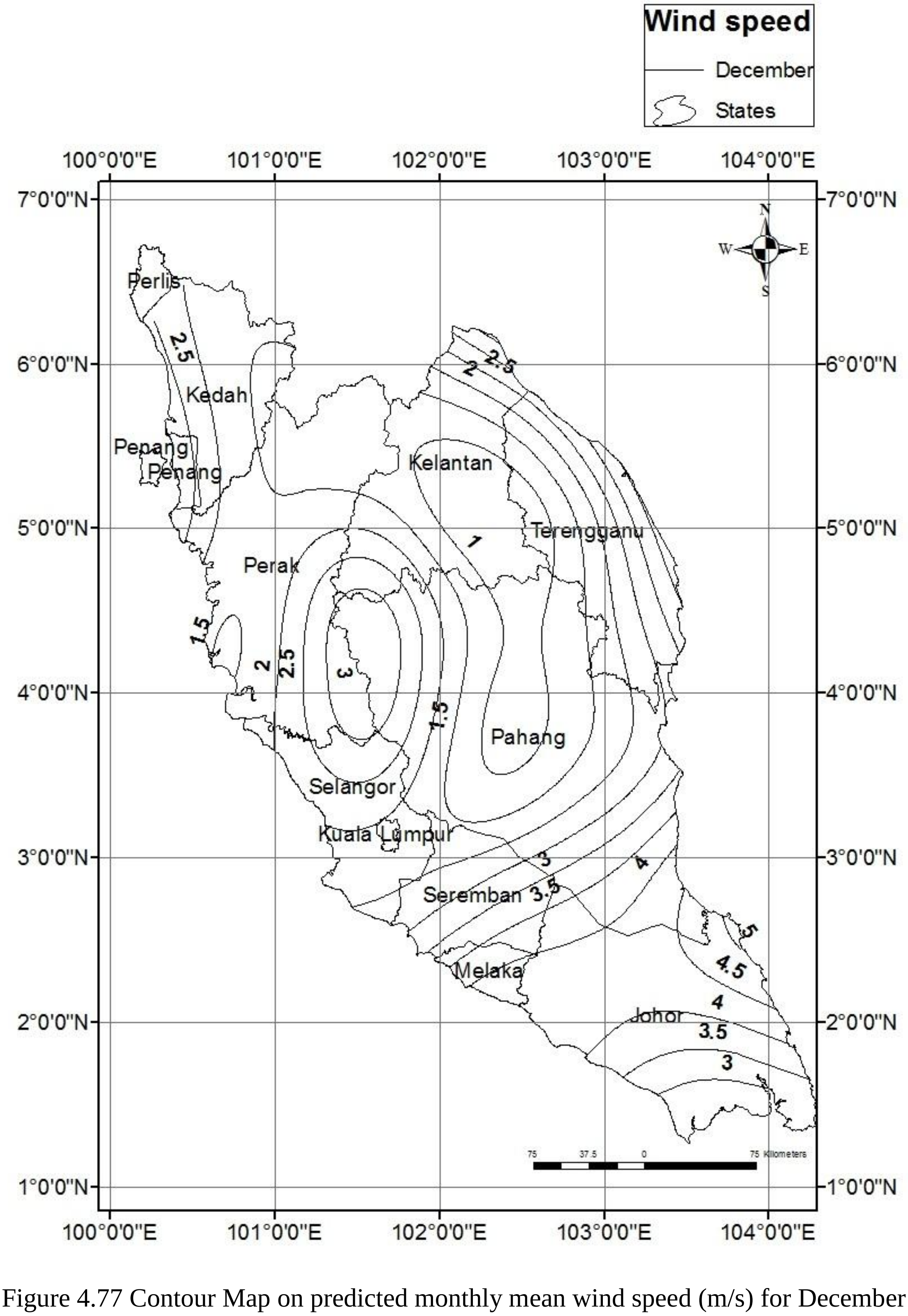

Figure 4.77 Contour Map on predicted monthly mean wind speed (m/s) for December

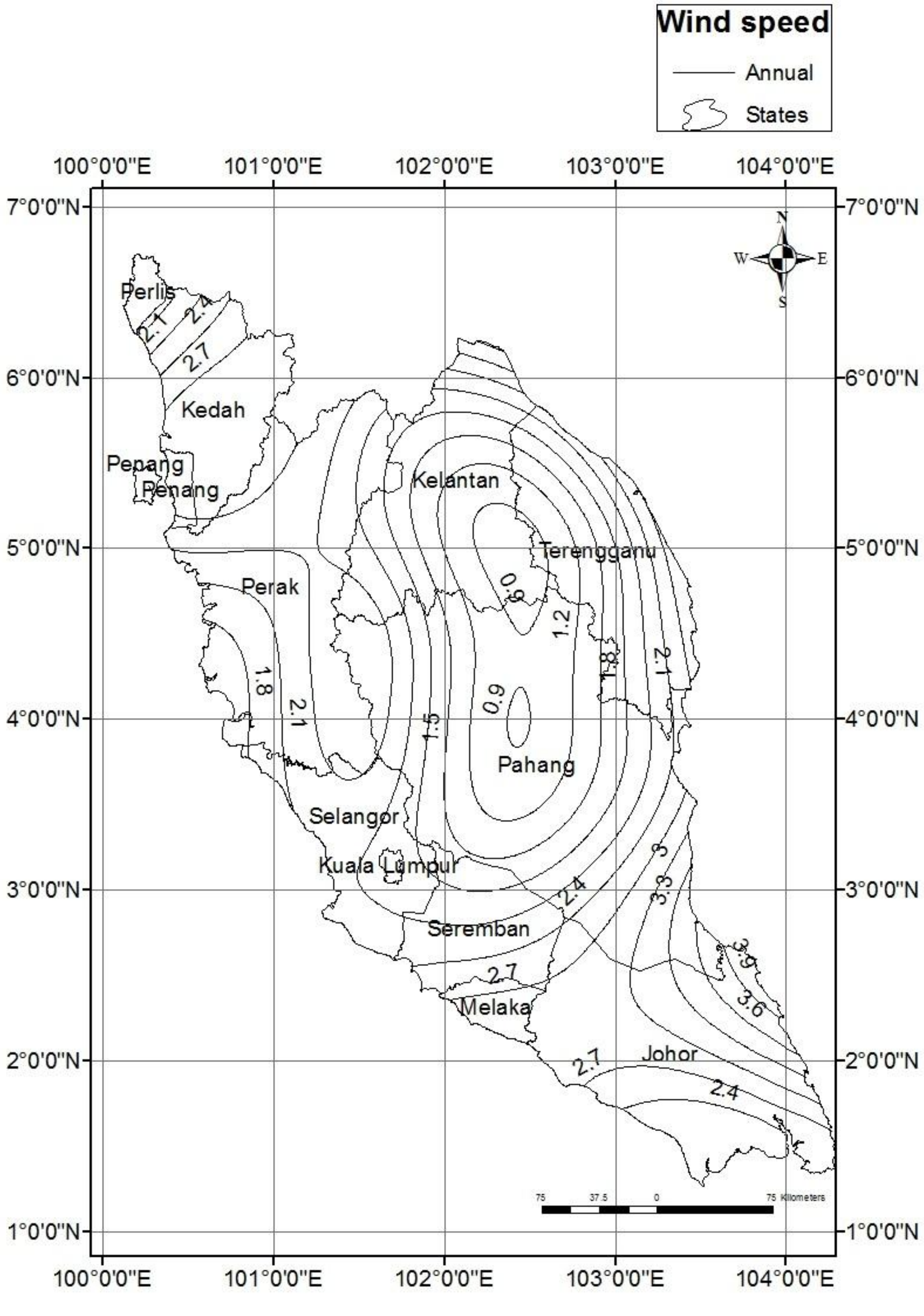

Figure 4.78 Contour Map on predicted yearly mean wind speed (m/s)

CHAPTER 5: CONCLUSIONS AND SUGGESTIONS

5.1 Introduction

The rapid industrialization and technological development have raised a global energy crisis in the current power utilization, which has emerged as one of the major concerning issues. The various sources for large-scale power generation are the fossil fuels, nuclear and minerals are found in the earth's crust. These fossil fuels, nuclear and minerals are not renewable and will be exhausted someday. The increase rate of depletion of fossil energy resources in one hand and growing energy demand, on the other hand, has initiated considerable research activity worldwide to explore means for tapping of renewable energy resources. Wind energy due to its freely availability, clean and renewable character is found as the most promising renewable energy resource that could play a key role in solving the worldwide energy crisis. There is no doubt that wind energy has already achieved its standards in power generation, from the fact that the major technology developments facilitating the wind power commercialization have already been made.

This dissertation performed the assessment of wind energy potentiality and wind energy mapping of Peninsular Malaysia based on the hourly surface mean wind speed from 15 meteorological stations. In this chapter, the main outcome of this dissertation and suggestions for the future work will be discussed.

5.2 Assessment of wind energy potentiality

In assessment of wind energy potentiality, hourly mean wind speed data for two years of each station were statically analyzed. The wind energy potential of these stations has been studied based on the Weibull distribution function. The probability density distributions, cumulative distribution, wind directions were derived and most importantly the distribution parameters were identified. The most important outcomes of the study can be summarized as follows:

- The values of the hourly mean wind speed ranges are between 0.32 m/s to 5.67 m/s.
- The daytime, from 8 am to 6 pm, is windy for all the years round, while the nighttime is relatively calm.
- At all stations, the highest average wind speeds are observed at 3 pm for the study period.
- During the study period for Bayan Lepas, Cameron Highland, Chuping, Kota Bharu, Kuala Terengganu, Kuantan, Malacca, Mersing and Senai, it is found that the month of December to March is windier than that of the remaining months in a year.
- Most of the monthly mean wind speed values are between 1.5 m/s to 4.5 m/s, but some are over 4.5 m/s and few are under 1.5 m/s. While January 2009 at Mersing shown the highest mean wind speed value with 6.62 m/s, May 2009 at Chuping shown the minimum wind speed value with 0.81 m/s.
- The mean wind speeds for all the years are lower than 4.5 m/s and the range of the yearly mean wind speed values is from 0.90 to 4.06 m/s.
- The monthly standard deviation can be found in the range of 0.57 m/s to 2.68 m/s whereas, the yearly standard deviation range is found to be between 0.81 m/s to 2.09 m/s.
- The parameter k has a much smaller, temporal variation than the parameter c. The monthly values of k range between 0.73 and 3.81, with an average value of 1.55, whereas the yearly values of k range between 1 and 2.21 with the average value of 1.44. The lowest value of the scale parameter c is 0.69 m/s and is found

in year 2009 at Chuping, while the highest value is 7.36 m/s, which occered in the year 2009 at Mersing.

- The monthly highest value of wind power density was 227.1 W/m^2 at Mersing on the month of January in 2009 and the lowest value of wind power density was 1.3 W/m^2 on November in 2008 at Batu embun.
- The average value of the monthly wind power density was 26.76 W/m^2.
- The range of the values of monthly wind energy density was found to be between 11.23 to 1962 kWh/m^2/year whereas the average wind energy density was found to be 231.20 kWh/m^2/year.
- Dramatic monthly changes in the wind power density was found with a maximum value (145.92 W/m^2 in January, 2009) being 7.67 times of the minimum (19.03 W/m^2 in June, 2009) at Malacca.
- The maximum power extractable is found to be 0.593 x 227.1 W/m^2 x A (swept area of the wind turbine) at Mersing in January 2009.
- The yearly highest values of the most probable wind speed and wind speed carrying maximum energy are 3.45 m/s and 6.25 m/s respectively. The yearly average values of the most probable wind speed and the wind speed carrying maximum energy are found to be 1.18 m/s and 4.59 m/s respectively.
- The maximum wind power and wind energy density for Weibull prediction were found to be 73.56 W/m^2 and 635.56 kWh/m^2/year respectively at Mersing, whereas for meteorological prediction, they were 75.26 W/m^2 and 650.24 kWh/m^2/year respectively.
- From the Weibull distribution curves, it is found that the range of the most frequent wind speed values is between 1 m/s to 3.5 m/s. Mersing is the most 'windy' place with the largest scale parameter c, and its most frequent wind speed is 3.5 m/s. The result also shows that, the Kuala Terengganu is in the

second position with the scale parameter value of 2.97 m/s and most frequently wind speed value of 3.00 m/s.

- The maximum percentage of error between Weibull wind speed frequencies and observed frequencies occurs at 3 m/s or more than 3 m/s is almost insignificance with the highest value of the error is 20%. On the other hand, for wind speed less than 3 m/s the error between the Weibull density function and observed density function are larger with the maximum error value is around 46 %.
- From cumulative distribution function, it is found that Mersing will have the highest operating possibility of 67% (around 5789 hours per annum), Kota Bharu, Butterworth, Malacca and Kuala Terrengganu will have 42% (around 3629 hours per annum), 40% (around 3456 hours per annum), 39% (around 3370 hours per annum and 36% (around 3110 hours per annum respectively.
- It is noticed polar diagram that the direction of wind blow in tha same area of different years is characterized by a significant stability.
- The prevailing winds from the most probable wind directions on the percentage ranging from 15 to 41% and the wind speeds less than 3 m/s are ranging from 11.2-89.2%.

5.3 Contour maps

Geographical Information System (GIS) is potentially well suited for identifying wind energy potential zones as it can manage and analyze the diverse multidisciplinary spatial and temporal data needed in this application. This is useful as a planning tool as it provides the user with the freedom to use their individual expertise in analyzing the local conditions and in the decision making process. The wind potential zone maps can be used easily to assist in making appropriate decisions. The GIS also helps in integrating additional relevant layers of information, such as prevailing wind, terrain, adjacent terrain, vegetation, proximity to residential areas, noise and appearance and public satisfaction, which are to be taken into consideration while locating wind farm sites. This also would help in locating the most suitable site among several of the ‘‘ideal’’ sites from the spatial data by assessing their suitability on an individual basis considering various constraints.

- From the monthly mean wind speed map, it is found that the southern part of Peninsular Malaysia is windier than that of the other parts in Peninsular Malaysia.
- The range of the monthly mean wind speeds is found to be 0.80 m/s to 6.0 m/s whereas the range of the yearly mean wind speeds is estimated to be 0.9 m/s to 3.9 m/s.
- Mersing is the most promising wind energy site in Peninsular Malaysia with the monthly mean wind speed range from 3.00 m/s to 6.0 m/s.
- Mersing is suitable for a year round small-scale wind energy production. Some other sites like Malacca, Kota Bharu, Kuala Terengganu and Bayan Lepas are suitable for small-scale electricity generation around the quarter of the year.

5.4 Suggestions for future work

Because of the relative simplicity of wind energy systems and the availability of wind resources, wind power is expected to play a significant role in meeting some of the future energy needs. With this, there are number of problems to be resolved if the wind resource is to be used effectively and efficiently. For the development of wind energy in Malaysia the following works can be done in the future:

- In this study, initial assessment of wind energy potentiality in Peninsular Malaysia has been done; collecting two-year data from Malaysian

Meteorological Station (MMD) for each station. From literature review, it has been found that for reliable assessment of wind energy potentiality, at least 30 years wind speed data is needed. So, in the future, anyone can collect the 30 years hourly surface mean wind speed data and make this research work stronger.

- Moreover, in Peninsular Malaysia there are around 32 meteorological wind stations; among them only 15 stations have been selected for this study. For better contour mapping, station-station distant should be within 50 km; otherwise, that contour map may contain some inaccuracy at the time of interpolation and extrapolation. So, in the future, during development of any wind energy project this should be considered.
- For the wind energy project, cost analysis is much more important. So anyone can analyze the initial cost site by site and can give the feed back period and make the decision, whether it would be viable or not.
- Turbine selection is a very important in the wind energy project so after detail assessment attention should be given to select the suitable wind turbine. Generally, wind turbine selection depends on the characteristics of wind speed, topography, etc.
- In Peninsular Malaysia, the wind speed is not so strong. Therefore, to produce economically viable wind energy, manufacturing facilities for wind machines could also be created an adequate distribution, installation, operation and maintenance infrastructures must be developed in the country.
- Resource and development work is still required to develop cost effective and reliable windmills of varying types and sizes, made of local materials.

- Due attention should be paid in selecting an appropriate site for the installation of windmills so that they can perform satisfactorily over a reasonable period requiring little maintenance.
- In case of power generation, major obstacles such as energy storage need to be overcome by linking wind generators as a bypass with conventional electric grid.
- With the variety of applications of wind energy, short and long term research program may be undertaken for the utilization of wind energy in Peninsular Malaysia, especially in those areas where the wind speed is favorable. These programmes may be started in accordance with the local needs, conditions and facilities available.

If these problems are solved, wind energy may be harnessed to provide power in many remote and isolated villages and areas, which are not electrified and where the relatively small amount of power is needed. In view of encouraging results of this study for future wind energy utilization, windmills and small scale wind generations could be used to provide the basic needs which are not commensurate to the requirements of main electrical supply.

APENDICES

Appendix A Predicted monthly basis hourly surface wind speed data

Table A1 Monthly basis hourly surface wind speed data at Butterworth in 2009

Month / Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hourly Mean
1	2.27	1.68	1.57	1.94	1.71	1.33	1.72	2.10	1.53	1.60	1.97	1.74	1.76
2	2.06	1.57	1.38	1.84	1.22	1.56	1.40	1.67	1.88	1.87	1.84	1.98	1.69
3	1.84	1.60	1.54	1.40	1.87	1.64	1.45	1.80	2.54	1.91	1.59	1.71	1.74
4	2.17	1.51	1.63	1.53	1.91	1.65	1.93	1.86	2.53	1.96	1.90	1.26	1.82
5	2.05	1.74	1.96	1.77	1.83	1.69	1.57	2.01	2.41	1.78	1.84	1.30	1.83
6	1.81	1.53	1.65	1.68	1.70	1.52	1.80	2.00	2.14	2.18	1.44	1.55	1.75
7	1.51	1.09	1.51	1.63	1.92	1.42	1.73	2.32	2.28	1.75	1.55	1.69	1.70
8	1.84	1.13	1.70	2.10	2.14	1.56	1.80	2.24	2.13	1.97	2.01	1.25	1.82
9	2.46	2.22	1.89	2.50	2.46	2.40	2.10	2.29	2.60	2.48	2.44	2.49	2.36
10	4.06	2.94	2.31	2.12	2.55	2.67	2.51	2.49	2.39	2.77	2.57	3.23	2.72
11	4.01	2.61	2.48	2.85	2.91	2.51	2.92	2.47	2.45	2.39	2.76	3.73	2.84
12	4.79	3.34	3.13	3.54	3.04	3.15	3.57	3.14	3.40	3.22	3.19	3.57	3.42
13	4.70	4.81	4.06	4.05	3.74	4.13	4.30	4.40	4.56	4.24	3.94	3.86	4.23
14	5.29	5.42	5.06	4.40	4.22	4.85	4.62	5.00	5.15	4.65	4.40	4.16	4.77
15	5.61	5.72	5.70	5.09	4.89	4.73	5.03	5.13	4.81	4.55	5.04	4.59	5.07
16	5.63	5.65	5.53	5.12	4.77	5.07	5.14	4.78	4.79	4.98	4.97	4.96	5.12
17	5.27	5.30	5.29	4.18	4.62	4.73	4.69	4.93	4.55	4.77	4.38	4.58	4.77
18	4.57	4.31	4.91	4.13	4.26	3.89	3.92	4.04	4.36	4.35	4.04	4.26	4.25
19	3.52	3.64	3.97	3.34	3.55	3.41	3.45	3.38	3.70	3.94	3.27	3.19	3.53
20	3.36	3.82	3.20	3.03	2.63	2.94	2.86	3.16	3.00	2.92	3.02	2.81	3.06
21	3.20	2.89	2.56	2.42	2.06	2.20	2.59	2.73	2.77	2.58	2.42	2.03	2.54
22	2.93	2.44	2.47	2.03	1.81	2.10	2.13	2.71	2.22	2.40	2.28	1.82	2.28
23	2.53	2.51	2.00	2.13	1.83	1.57	1.96	2.45	2.18	2.48	1.92	1.95	2.13
24	2.57	2.02	1.85	1.88	1.38	1.46	2.01	2.00	1.84	2.06	1.62	1.96	1.89
Monthly Mean	3.34	2.98	2.89	2.78	2.71	2.67	2.80	2.96	3.01	2.91	2.77	2.74	

Table A2 Monthly basis hourly surface wind speed data at Cameron Highland in 2008

Month / Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hourly Mean
1	2.83	2.82	3.95	2.21	1.87	2.03	1.49	1.12	3	2.71	2.32	2.75	2.43
2	2.65	2.94	3.56	2.27	1.51	2.36	1.54	1.27	3.13	2.59	2.01	3.13	2.41
3	2.69	2.54	3.08	2.22	1.79	2.13	1.19	1.22	2.64	2.7	2.29	3.06	2.30
4	2.97	3.1	3.41	2.11	1.61	2.09	1.49	1.19	3.1	2.4	1.99	2.66	2.34
5	2.95	3.17	3.4	2.15	1.95	1.91	1.62	1.32	3.84	2.6	1.85	2.93	2.48
6	2.97	3.29	3.38	2.03	1.7	2.07	1.41	1.51	3.24	2.78	1.74	2.34	2.37
7	2.99	3.46	3.8	2.15	1.97	1.75	1.48	1.69	3.16	2.85	1.56	2.88	2.48
8	3.04	3.56	3.79	2.03	1.77	1.67	1.36	1.55	2.97	2.48	1.61	2.89	2.39
9	3.16	3.61	4.09	2.07	1.76	1.84	1.36	1.4	2.93	2.52	2.07	2.78	2.47
10	3.63	4.24	4.07	2.48	2.31	2.29	1.51	2.34	3.67	2.87	2.37	3.15	2.91
11	3.95	4.46	4.3	2.49	2.56	2.73	2.31	2.25	3.85	2.86	2.61	3.3	3.14
12	3.63	4.15	3.95	2.71	3.01	2.97	2.51	2.48	3.82	3.33	2.59	3.29	3.20
13	3.26	4.21	3.93	2.86	3.14	3.17	2.65	2.8	3.64	3.38	2.61	2.96	3.22
14	3.29	3.56	3.89	2.98	3.41	3.22	2.84	3.08	3.77	3.13	2.41	2.74	3.19
15	2.91	3.45	3.57	2.54	3.13	2.97	2.56	2.91	3.73	2.79	2.44	2.26	2.94
16	2.52	3.29	3.78	2.23	3.21	2.63	2.43	2.53	3.66	2.84	2.26	1.9	2.77
17	2.49	3.28	3.63	1.71	2.52	2.93	2	2.31	3.21	2.29	1.89	2.45	2.56
18	2.63	3.12	3.73	1.52	2.18	2.27	2.16	1.97	2.98	2.36	1.61	2.52	2.42
19	2.27	3.38	3.37	1.68	1.64	1.85	1.5	1.26	2.72	1.99	1.65	2.52	2.15
20	2.48	3.24	3.75	1.77	1.6	1.88	1.51	1.35	2.56	2.21	1.74	2.74	2.24
21	3.11	3.28	3.4	1.79	1.64	1.77	1.35	1.3	2.79	2.22	2.04	2.68	2.28
22	3.13	3.52	3.6	2.02	1.58	1.87	1.61	1.48	2.81	2.27	2.23	2.55	2.39
23	3.01	3.63	3.79	2.2	1.82	1.75	1.78	1.18	2.73	2.29	1.95	2.57	2.39
24	2.75	3.44	3.44	2.04	1.71	2.02	1.55	1.41	2.81	2.48	1.85	2.48	2.33
Monthly Mean	2.97	3.45	3.69	2.18	2.14	2.26	1.80	1.79	3.20	2.62	2.07	2.73	

Table A3 Monthly basis hourly surface wind speed data at Cameron Highland in 2009

Month / Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hourly Mean
1	3.19	1.81	2.30	2.56	2.82	1.73	2.07	2.87	2.44	2.50	2.27	3.21	2.48
2	2.98	1.74	2.30	2.78	2.12	1.65	2.16	3.22	2.82	2.61	2.25	2.99	2.47
3	3.22	1.59	2.25	2.82	2.30	1.55	1.95	3.00	3.24	2.45	2.27	3.11	2.48
4	2.63	1.72	1.81	2.76	2.40	1.49	2.02	2.68	2.22	2.22	1.70	3.11	2.23
5	2.87	1.66	1.91	3.09	2.16	1.52	1.73	2.39	2.79	2.27	2.10	3.12	2.30
6	2.94	1.66	2.13	2.81	2.74	1.31	1.91	2.57	2.78	2.38	2.09	3.70	2.42
7	3.40	2.12	2.23	2.98	2.62	1.52	2.21	2.26	2.63	2.14	2.30	3.39	2.48
8	3.68	2.00	2.08	2.86	2.43	1.15	2.02	2.50	2.76	2.16	1.94	3.32	2.41
9	3.27	1.77	1.85	2.99	2.56	1.27	1.75	2.62	2.37	2.03	1.79	3.60	2.32
10	3.68	2.32	2.69	3.27	2.87	2.08	2.03	2.78	2.94	2.73	2.88	3.78	2.84
11	3.89	2.87	2.88	3.55	3.21	2.82	2.73	3.20	3.21	2.90	2.81	4.04	3.18
12	3.82	3.00	3.39	3.71	3.47	3.09	2.60	3.11	3.38	3.39	2.88	3.47	3.27
13	3.89	3.22	3.41	3.61	3.52	3.47	2.88	3.29	3.74	3.64	3.09	3.56	3.44
14	3.48	3.45	3.03	3.77	3.62	3.69	3.46	3.35	3.51	3.73	2.78	3.55	3.45
15	3.18	3.13	3.29	3.63	3.30	3.60	3.16	3.53	3.09	3.39	2.74	3.17	3.27
16	3.11	3.10	2.91	3.32	3.18	3.43	2.86	3.23	3.50	2.86	2.90	2.91	3.11
17	3.02	2.47	2.22	2.80	2.78	2.67	2.40	3.57	3.46	2.50	2.28	2.85	2.75
18	2.91	2.23	1.96	2.69	2.40	1.99	1.76	3.23	2.89	2.39	2.22	3.05	2.48
19	3.08	1.82	1.95	2.44	2.08	1.39	1.77	3.02	2.26	2.04	2.53	3.12	2.29
20	3.36	2.01	2.48	2.60	2.17	1.34	1.59	2.95	2.48	1.97	2.72	4.02	2.48
21	3.51	2.33	2.51	2.76	1.96	1.38	2.01	2.38	2.51	2.25	2.89	3.94	2.54
22	3.58	2.42	2.49	2.71	2.48	1.96	2.24	2.35	2.54	2.04	2.88	3.88	2.63
23	3.33	2.41	2.08	2.72	2.39	1.76	1.91	2.87	2.91	2.32	2.74	3.67	2.59
24	3.34	2.02	2.16	2.81	2.51	1.97	2.17	2.91	2.43	2.36	2.55	3.45	2.56
Monthly Mean	3.31	2.29	2.43	3.00	2.67	2.08	2.22	2.91	2.87	2.55	2.48	3.42	

Table A4 Monthly basis hourly surface wind speed data at Chuping in 2008

Month / Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hourly Mean
1	2.01	2.29	1.63	0.76	0.19	0.27	0.22	0.30	0.28	0.41	1.36	2.16	0.99
2	2.01	2.43	1.61	0.59	0.23	0.37	0.33	0.15	0.27	0.44	1.26	2.17	0.99
3	1.92	2.43	1.78	0.83	0.22	0.27	0.13	0.32	0.23	0.32	1.52	1.97	1.00
4	2.21	2.20	1.87	0.69	0.23	0.22	0.28	0.20	0.34	0.38	1.33	2.17	1.01
5	2.26	2.35	1.76	0.78	0.34	0.47	0.19	0.29	0.55	0.23	1.29	2.14	1.05
6	2.03	2.22	1.78	0.56	0.22	0.28	0.16	0.29	0.46	0.49	1.38	1.95	0.98
7	2.17	2.15	2.04	0.55	0.17	0.23	0.13	0.07	0.35	0.29	1.29	2.03	0.96
8	2.23	2.29	2.01	0.76	0.08	0.28	0.37	0.30	0.25	0.44	1.20	1.93	1.01
9	2.38	2.23	1.88	1.06	0.63	0.67	0.58	0.81	0.77	0.75	1.38	2.23	1.28
10	2.35	2.40	2.06	1.41	1.17	1.03	1.02	1.05	1.29	1.38	1.75	2.34	1.60
11	2.59	2.69	1.96	1.68	1.62	1.45	1.89	1.74	1.58	1.62	1.89	2.48	1.93
12	2.50	2.56	2.17	1.76	2.12	1.87	2.30	2.15	1.96	1.77	2.10	2.52	2.15
13	2.88	2.96	2.34	1.81	2.56	2.40	2.56	2.64	2.30	2.09	2.14	2.48	2.43
14	2.56	3.00	2.10	2.02	2.69	2.58	2.81	2.82	2.65	2.23	2.17	2.67	2.52
15	2.55	2.89	2.50	2.24	2.87	2.58	2.63	2.80	2.56	2.59	2.24	2.77	2.60
16	2.59	2.80	2.64	2.55	2.86	2.65	2.70	2.74	2.65	2.39	2.24	2.77	2.63
17	2.38	2.47	2.54	2.29	2.59	2.13	2.43	2.34	2.47	2.02	1.97	2.96	2.38
18	2.65	2.36	2.00	2.20	1.84	1.62	1.86	1.90	1.92	1.37	2.02	2.67	2.03
19	2.35	2.29	2.13	1.51	1.15	0.83	1.07	1.06	1.09	1.04	1.18	2.44	1.51
20	2.19	2.29	1.97	1.10	0.55	0.55	0.24	0.30	0.37	0.72	1.50	2.11	1.16
21	2.34	2.26	1.87	1.00	0.36	0.33	0.31	0.19	0.72	0.78	1.45	2.16	1.15
22	2.24	2.58	1.69	0.97	0.17	0.38	0.24	0.28	0.23	0.72	1.58	2.11	1.10
23	2.19	2.24	1.53	0.93	0.26	0.26	0.17	0.46	0.26	0.42	1.75	2.20	1.06
24	2.22	2.23	1.55	0.76	0.26	0.29	0.24	0.15	0.24	0.29	1.47	2.28	1.00
Monthly Mean	2.33	2.44	1.98	1.28	1.06	1.00	1.04	1.06	1.08	1.05	1.64	2.32	

Table A5 Monthly basis hourly surface wind speed data at Chuping in 2009

Hour \ Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hourly Mean
1	2.55	1.83	0.86	0.63	0.20	0.06	0.16	0.52	0.36	0.36	1.21	2.22	0.91
2	2.49	1.84	0.84	0.49	0.27	0.00	0.10	0.39	0.24	0.40	1.01	2.01	0.84
3	2.42	1.97	0.91	0.47	0.31	0.03	0.13	0.32	0.31	0.34	1.08	1.95	0.85
4	2.56	1.98	0.85	0.58	0.23	0.13	0.15	0.34	0.36	0.38	1.33	2.16	0.92
5	2.43	1.74	0.92	0.63	0.26	0.09	0.23	0.47	0.40	0.50	1.27	2.01	0.91
6	2.43	1.73	1.07	0.47	0.22	0.07	0.18	0.36	0.39	0.46	1.35	2.17	0.91
7	2.33	1.60	0.96	0.51	0.12	0.06	0.22	0.41	0.31	0.44	1.07	2.32	0.86
8	2.34	1.75	1.22	0.72	0.22	0.06	0.20	0.45	0.34	0.48	1.05	2.19	0.92
9	2.57	1.92	1.15	0.93	0.38	0.21	0.42	0.91	0.59	0.67	1.36	2.32	1.12
10	2.89	2.36	1.56	1.29	0.76	0.62	0.84	1.39	1.13	1.13	1.60	2.30	1.49
11	2.96	2.55	1.87	1.75	1.10	1.39	1.74	2.17	1.69	1.74	1.64	2.56	1.93
12	3.13	2.77	2.02	1.94	1.51	2.03	1.87	2.48	2.07	1.99	1.77	2.77	2.20
13	3.18	3.00	1.99	2.24	1.97	2.40	2.26	2.66	2.16	2.29	1.76	2.70	2.38
14	3.27	2.94	1.95	2.47	2.21	2.85	2.52	2.71	2.34	2.49	2.27	2.85	2.57
15	3.13	3.06	2.22	2.77	2.06	2.89	2.62	2.91	2.59	2.80	2.08	2.54	2.64
16	3.21	3.25	2.25	2.39	2.10	2.87	2.40	3.08	2.67	2.56	1.93	2.37	2.59
17	3.17	3.00	2.10	2.64	1.90	2.37	2.30	2.68	2.40	2.14	1.81	2.06	2.38
18	2.95	2.77	1.37	1.92	1.45	1.97	1.92	2.26	1.90	1.68	1.58	2.38	2.01
19	2.89	2.61	1.27	1.50	0.86	1.06	1.05	1.58	1.21	1.01	1.28	2.31	1.55
20	2.69	2.47	0.82	0.80	0.43	0.22	0.42	0.93	0.77	0.42	1.49	2.28	1.14
21	2.82	2.24	0.98	0.48	0.33	0.04	0.47	0.49	0.51	0.38	1.58	2.45	1.06
22	2.88	2.21	1.33	0.29	0.14	0.00	0.17	0.39	0.35	0.35	1.28	2.49	0.99
23	2.86	2.31	1.19	0.38	0.15	0.05	0.24	0.29	0.32	0.43	1.29	2.46	1.00
24	2.89	1.88	0.99	0.52	0.17	0.08	0.13	0.30	0.23	0.39	1.22	2.33	0.93
Monthly Mean	2.79	2.33	1.36	1.20	0.81	0.90	0.95	1.27	1.07	1.08	1.47	2.34	

Table A6 Monthly basis hourly surface wind speed data at Ipoh in 2008

Month / Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hourly Mean
1	1.63	1.75	1.74	1.79	1.98	1.55	1.75	2	1.88	1.82	1.9	1.93	1.81
2	2.05	2.11	1.51	2.47	1.78	1.57	1.94	2.04	1.8	1.95	1.63	1.56	1.87
3	2.13	2.36	1.74	2.19	1.78	1.74	2.21	2.01	1.97	2.02	1.82	1.79	1.98
4	2.30	2.56	1.55	2.19	1.87	1.74	2.22	2.19	2.43	1.95	1.67	2.14	2.07
5	2.12	2.44	1.48	2.08	2.11	1.71	2.08	2.11	2.55	1.75	1.55	2.34	2.03
6	2.06	2.24	1.74	2.09	1.94	1.43	2	2.52	2.42	2.19	1.32	2.36	2.03
7	2.66	2.7	1.66	2.11	2.11	1.91	1.88	2.38	2.15	1.91	1.61	2.34	2.12
8	3.36	3.1	1.65	2.38	2.09	2.14	2.32	2.18	2.5	2.09	1.83	2.55	2.35
9	4.21	3.97	2.64	3.23	2.7	3.05	2.79	2.68	3.23	2.65	2.92	3.45	3.13
10	3.29	4.75	2.56	2.91	2.56	2.58	2.45	2.63	3	2.33	2.93	3.71	2.97
11	2.38	3.82	1.91	2.16	2.04	1.54	1.85	1.99	2.16	1.75	2.27	3.06	2.25
12	2.51	2.6	1.86	2.26	2.08	1.95	2.61	2.69	2.53	2.17	1.94	2.33	2.29
13	2.89	2.49	2.35	2.62	2.71	2.41	3.18	3.1	2.84	2.31	1.92	2.03	2.57
14	3.17	2.63	2.66	2.63	3	2.99	3.35	3.66	3.78	2.67	2.65	2.11	2.94
15	3.05	2.53	2.87	3.26	2.87	3.21	3.4	3.85	3.17	3.11	2.8	2.49	3.05
16	3.44	2.89	2.56	3.45	3.38	2.31	3.51	3.52	3.34	3.07	3.75	2.92	3.18
17	3.17	3.1	2.86	2.91	2.88	2.58	2.73	4.25	3.12	3.23	2.99	2.24	3.00
18	2.53	3.57	3.29	2.29	2.74	2.33	2.58	3.38	2.21	2.47	2.86	2.47	2.73
19	2.13	3.97	2.46	2.01	2.04	1.78	2.36	2.36	2.3	1.85	1.92	2.12	2.28
20	2.05	2.4	1.73	1.66	1.55	1.21	1.59	1.92	1.76	1.43	1.16	1.79	1.69
21	1.75	1.51	1.39	1.49	1.4	1.21	1.64	1.65	1.35	1.48	1.27	2.02	1.52
22	1.44	1.28	1.06	1.59	1.58	1.57	1.81	1.51	1.59	1.91	1.43	1.92	1.56
23	1.72	1.15	1.35	1.85	1.54	1.12	1.72	1.68	1.62	1.84	1.71	1.61	1.58
24	1.08	1.5	1.41	1.67	1.67	1.27	1.96	1.56	1.72	2.04	1.5	1.5	1.57
Monthly Mean	2.46	2.64	2.00	2.30	2.18	1.95	2.33	2.50	2.39	2.17	2.06	2.28	

Table A7 Monthly basis hourly surface wind speed data at Ipoh in 2009

Month / Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hourly Mean
1	1.18	1.52	1.72	2.18	2.39	1.55	1.90	1.80	1.82	2.20	1.53	1.16	1.75
2	1.73	1.81	1.85	1.76	2.33	1.66	2.20	2.33	2.07	2.18	1.43	1.24	1.88
3	2.26	1.65	1.69	2.17	2.31	1.97	2.31	2.24	2.15	2.17	1.55	1.52	2.00
4	2.01	1.92	1.70	1.80	2.10	2.71	2.20	2.06	2.35	2.26	1.89	1.63	2.05
5	2.43	1.78	1.91	2.20	2.17	2.15	2.12	2.17	1.86	2.00	1.58	1.91	2.02
6	2.67	1.65	1.93	1.76	1.99	2.21	2.10	2.12	2.16	2.32	1.81	2.37	2.09
7	2.81	1.94	2.10	1.71	2.11	2.40	2.35	2.12	1.87	2.38	2.11	2.12	2.17
8	2.97	2.02	2.00	2.39	2.11	2.37	2.05	2.15	2.40	2.56	2.17	2.21	2.28
9	3.91	2.87	2.51	3.43	3.01	2.92	2.25	2.97	2.75	2.78	3.06	3.07	2.96
10	4.76	3.57	2.40	3.22	3.04	2.60	2.38	2.56	2.46	2.37	2.80	3.57	2.98
11	3.83	2.64	1.70	2.60	2.38	1.74	1.71	2.22	2.13	1.84	2.10	2.87	2.31
12	2.93	1.58	1.63	2.55	2.24	1.88	2.33	2.38	2.15	1.94	1.83	2.10	2.13
13	2.22	1.90	2.28	2.50	2.39	2.35	2.52	2.74	2.30	2.77	2.39	2.28	2.39
14	1.99	2.38	3.01	2.97	2.72	2.64	3.12	2.74	2.82	3.29	2.43	2.24	2.69
15	2.08	2.32	3.45	3.15	2.84	2.70	3.01	3.33	2.91	3.75	2.29	2.44	2.85
16	2.68	2.95	4.25	3.50	3.04	2.89	3.30	3.13	2.84	4.34	2.63	2.70	3.19
17	3.88	2.99	3.93	3.80	2.91	2.78	2.92	3.58	2.62	3.50	2.71	2.61	3.18
18	2.12	3.29	3.60	3.19	2.78	2.77	2.26	3.26	2.45	3.10	1.90	2.25	2.75
19	2.43	3.45	2.65	2.08	2.32	2.46	2.18	2.39	2.05	1.87	2.19	1.80	2.32
20	1.69	1.66	2.24	2.09	1.66	1.84	1.63	1.96	1.47	1.95	1.44	1.13	1.73
21	1.39	1.06	1.66	1.83	1.51	1.59	1.34	1.79	1.52	1.52	1.23	0.82	1.44
22	1.12	0.75	1.48	1.79	1.71	1.42	1.41	1.62	1.89	2.00	1.23	0.63	1.42
23	1.20	0.60	1.54	1.46	1.98	1.23	1.73	1.89	1.78	2.09	1.42	0.35	1.44
24	1.09	1.13	1.62	1.47	2.21	1.77	1.91	2.02	1.46	1.90	1.59	0.71	1.57
Monthly Mean	2.39	2.06	2.29	2.40	2.34	2.19	2.22	2.40	2.18	2.46	1.97	1.91	

Table A8 Monthly basis hourly surface wind speed data at Kuala Terenganu in 2008

Month / Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hourly Mean
1	2.63	2.94	2.47	1.39	1.65	1.84	1.96	2.19	1.96	1.78	1.94	2.67	2.12
2	2.46	3.05	2.34	1.67	1.64	1.76	1.79	2.17	2.06	1.86	1.99	2.42	2.10
3	2.62	2.71	2.34	1.93	1.75	1.76	1.67	1.87	1.93	1.80	1.90	2.43	2.06
4	2.49	2.60	2.56	1.82	1.95	1.83	1.83	1.82	1.91	1.82	1.89	2.36	2.08
5	2.41	2.31	2.29	1.89	1.79	2.00	1.77	2.34	1.98	1.66	1.99	2.61	2.09
6	2.35	2.14	2.45	1.91	1.70	2.03	1.85	1.65	2.06	1.76	1.56	2.57	2.00
7	2.36	2.13	2.44	1.75	1.99	2.08	1.73	2.03	1.60	1.82	1.58	2.50	2.00
8	2.38	2.33	2.74	2.17	2.00	2.05	1.99	2.16	2.05	1.98	1.64	2.53	2.17
9	2.48	2.60	3.06	2.41	2.34	2.59	2.48	2.40	2.44	2.31	1.96	2.48	2.46
10	2.74	3.10	3.18	2.44	2.05	2.55	2.62	2.48	2.27	2.21	2.08	3.27	2.58
11	3.18	3.86	3.82	2.21	2.07	2.49	2.49	2.18	2.53	2.13	2.19	3.57	2.73
12	3.85	4.36	4.17	3.14	2.69	3.23	2.69	2.80	2.84	3.18	2.43	3.92	3.28
13	4.35	4.74	4.52	3.61	2.91	3.29	3.16	3.15	3.29	3.60	2.60	4.10	3.61
14	4.59	4.91	4.86	3.86	3.38	3.42	3.20	3.36	3.60	3.71	3.03	4.29	3.85
15	4.21	4.54	4.87	4.09	3.29	3.54	3.27	3.71	3.64	3.88	3.15	4.10	3.86
16	4.37	4.63	4.80	3.98	3.10	3.05	3.43	3.58	3.23	3.60	3.03	4.04	3.74
17	4.30	4.44	4.58	3.71	2.88	2.87	3.05	3.39	2.97	3.13	2.79	3.89	3.50
18	4.08	4.07	3.99	3.02	2.05	2.46	2.57	2.91	2.54	2.77	2.24	3.65	3.03
19	3.83	3.67	3.50	2.04	1.84	2.13	2.19	2.28	1.97	2.19	1.83	3.71	2.60
20	3.83	3.43	2.98	1.75	1.54	1.87	1.94	2.01	1.89	2.18	2.19	3.31	2.41
21	3.40	3.46	2.74	1.48	1.61	1.87	1.96	1.96	1.82	1.80	2.15	3.27	2.29
22	3.27	3.43	2.64	1.47	1.88	1.79	1.67	1.88	1.59	1.72	1.92	3.25	2.21
23	3.14	3.31	2.65	1.25	1.85	1.85	1.83	1.55	1.90	1.82	2.16	2.97	2.19
24	3.15	3.00	2.52	1.62	1.58	1.62	1.95	2.23	1.93	1.62	2.09	2.95	2.19
Monthly Mean	3.27	3.41	3.27	2.36	2.15	2.33	2.30	2.42	2.33	2.35	2.18	3.20	

Table A9 Monthly basis hourly surface wind speed data at Kuala Terenganu in 2009

Month / Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hourly Mean
1	3.23	1.71	2.08	2.09	1.73	1.71	1.88	1.69	1.65	1.79	1.96	3.45	2.08
2	3.19	1.72	1.93	1.85	2.19	2.07	1.67	1.92	1.77	1.95	2.60	3.22	2.17
3	2.76	1.51	2.06	1.82	2.02	2.08	1.74	1.74	1.97	1.66	2.69	3.17	2.10
4	2.74	1.47	1.87	1.98	2.02	1.87	1.57	1.70	2.10	1.65	2.69	3.39	2.09
5	2.70	1.48	1.72	1.79	2.21	1.81	1.87	1.93	1.87	1.52	2.41	3.19	2.04
6	2.67	1.51	1.83	1.88	1.95	1.96	1.87	2.07	1.73	1.59	2.45	3.13	2.05
7	2.40	1.68	1.96	1.77	1.81	1.83	1.91	1.90	1.61	1.69	2.45	2.95	2.00
8	2.49	1.82	1.86	1.94	2.04	2.20	2.17	2.05	1.90	2.05	2.67	3.07	2.19
9	3.01	1.88	2.17	2.21	2.49	2.50	2.45	2.40	2.26	2.21	2.66	2.97	2.43
10	3.12	1.82	1.91	2.27	2.52	2.62	2.52	2.53	2.10	2.15	2.72	3.41	2.47
11	3.55	2.66	2.48	2.31	2.08	2.28	2.52	2.44	2.05	2.00	3.12	3.95	2.62
12	3.89	3.76	2.90	2.78	2.70	3.18	3.08	3.25	2.60	2.70	3.29	4.35	3.21
13	4.16	4.19	3.61	3.35	3.43	3.61	3.51	3.73	3.35	3.31	3.43	4.27	3.66
14	4.17	4.35	4.00	3.51	3.74	4.12	3.84	4.24	3.60	3.55	3.18	4.43	3.90
15	4.13	4.41	4.31	3.58	3.76	4.20	3.92	4.22	3.49	3.35	3.24	4.47	3.92
16	4.38	4.42	4.32	3.60	3.53	3.72	3.90	4.26	3.28	3.15	3.41	4.46	3.87
17	4.31	4.14	3.73	3.26	3.27	3.43	3.81	3.88	2.83	2.62	3.30	4.42	3.58
18	4.20	3.78	3.21	2.54	2.56	2.95	3.09	3.44	2.20	2.29	2.80	4.04	3.09
19	3.91	3.22	2.66	2.29	2.48	2.31	2.39	2.68	1.88	2.12	2.57	3.86	2.70
20	3.93	2.80	2.30	1.79	1.63	2.09	2.32	2.60	1.39	1.71	2.32	3.76	2.39
21	3.73	2.29	2.14	1.57	2.30	1.68	1.81	2.11	1.69	1.88	2.15	3.65	2.25
22	3.56	1.96	2.16	1.61	1.75	1.95	1.72	1.78	1.69	2.24	2.21	3.67	2.19
23	3.56	1.81	2.00	1.96	1.70	1.82	1.87	2.02	1.75	2.19	2.25	3.67	2.22
24	3.40	1.72	1.99	1.82	1.69	1.81	2.18	1.91	1.58	1.69	2.57	3.58	2.16
Monthly Mean	3.47	2.59	2.55	2.31	2.40	2.49	2.48	2.60	2.18	2.21	2.71	3.69	

Table A10 Monthly basis hourly surface wind speed data at KLIA Sepang in 2008

Month / Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hourly Mean
1	2.88	2.81	2.1	1.94	1.79	1.68	2.59	2.08	1.83	1.93	1.19	1.99	2.07
2	2.74	2.92	2.13	1.66	1.43	1.85	2.16	1.96	1.86	1.79	1.17	1.81	1.96
3	2.37	2.8	2.23	1.64	1.3	1.75	2.23	2.22	1.71	1.6	1	1.81	1.89
4	2.8	2.35	1.49	1.69	1	1.9	1.83	1.78	1.5	1.26	1.11	1.91	1.72
5	2.09	2.52	1.65	1.81	1.41	1.6	2.03	1.87	1.51	1.42	1.09	1.64	1.72
6	2.13	2.41	1.09	1.59	1.22	1.74	1.69	1.74	1.53	1	1.02	1.5	1.55
7	1.91	2.69	1.59	1.46	1.5	1.76	1.99	1.45	1.58	1.25	1.02	1.3	1.63
8	1.64	2.96	1.55	1.69	1.75	2.02	1.65	1.62	1.46	1.46	1.54	1.42	1.73
9	2.19	3.24	2.02	2.27	2.12	2.23	2.49	2.33	1.84	2.09	1.81	2.09	2.23
10	2.39	3.56	2.96	1.9	2.36	2.83	3.37	3.26	2.37	2.42	2.06	2.86	2.69
11	3.26	3.87	3.39	2.14	3.04	3.2	3.81	3.63	2.99	2.58	2.55	2.96	3.12
12	3	3.95	3.41	2.32	3.39	3.22	3.63	3.59	3.51	2.9	2.41	2.97	3.19
13	3.37	3.57	3.6	2.84	3.62	3.59	3.95	4.1	3.77	3.07	2.75	2.92	3.43
14	3.42	3.49	3.78	3.07	3.52	3.73	4.07	4.25	3.86	3.02	2.73	3.01	3.5
15	4.1	3.59	3.6	3.15	3.55	3.69	4.06	4.08	3.63	3.28	3	2.95	3.56
16	3.17	3.68	3.21	3.26	3.27	3.66	3.61	4	3.41	3.04	2.95	3.12	3.37
17	3.03	3.65	3.07	2.88	2.63	2.97	3.33	3.86	3.04	2.49	2.4	2.74	3.01
18	2.7	2.56	2.69	2.7	2.09	2.35	2.57	3.3	2.51	2.12	2.34	2.35	2.52
19	2.23	1.72	2.57	2.5	1.85	2.27	2.46	2.61	2.15	1.94	2.16	1.8	2.19
20	2.09	1.94	2.08	2.29	2.09	2.15	2.31	2.31	2.03	2.3	1.99	1.45	2.09
21	2.31	1.68	1.89	2.15	2.04	1.91	2.47	2.43	1.95	1.9	2.02	1.47	2.02
22	2.72	2.08	2.56	1.68	1.86	1.88	2.49	2.46	1.77	2.04	1.78	1.35	2.06
23	2.6	2.34	2.27	1.77	1.56	2.01	2.26	2.48	1.9	2.07	1.76	1.59	2.05
24	2.83	2.69	2.34	1.82	1.81	1.77	2.39	2.21	1.81	1.62	1.73	1.93	2.08
Monthly Mean	2.67	2.88	2.47	2.18	2.18	2.41	2.73	2.73	2.31	2.11	1.9	2.12	

Table A11 Monthly basis hourly surface wind speed data at KLIA Sepang in 2009

Month / Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hourly Mean
1	2.91	1.42	1.62	1.20	1.24	1.33	1.61	1.68	1.27	1.22	0.39	1.87	1.48
2	2.94	1.25	1.51	1.20	1.42	1.02	1.81	1.36	1.49	1.49	0.79	2.13	1.53
3	2.41	0.99	1.26	1.29	1.67	1.13	1.49	1.2	1.45	1.3	0.9	1.52	1.38
4	2.23	0.83	0.88	1.24	1.65	1.40	2.04	1.06	1.25	1.16	0.91	1.81	1.37
5	2.25	0.81	1.01	1.44	1.53	1.14	1.69	1.46	1.37	1.03	1.07	1.47	1.36
6	2.15	1.14	0.88	1.41	1.38	0.93	2.00	1.10	1.39	0.97	0.72	1.20	1.27
7	2.39	0.67	1.37	1.16	1.43	1.03	1.45	1.56	0.98	1.23	0.76	0.98	1.25
8	2.29	1.18	1.29	1.21	1.26	1.09	1.80	1.24	1.08	1.35	0.98	1.36	1.34
9	2.89	2.27	1.44	1.71	1.89	1.46	2.59	1.87	1.73	1.93	1.64	2.00	1.95
10	3.89	2.43	1.85	2.46	2.84	2.15	3.13	2.22	2.30	2.18	2.00	2.26	2.48
11	4.27	2.50	2.01	2.74	3.05	2.41	3.36	2.93	2.23	2.21	2.25	2.81	2.73
12	4.03	2.64	2.44	2.93	3.13	2.81	3.66	3.07	2.72	2.44	2.64	2.33	2.9
13	4.15	2.93	2.78	3.16	3.35	2.84	3.78	3.37	2.67	2.74	2.82	2.65	3.1
14	3.81	2.86	2.91	3.39	3.24	3.17	3.99	3.48	2.97	2.96	2.53	2.63	3.16
15	3.69	3.22	3.21	3.47	3.6	3.12	3.78	3.64	3.09	3.02	3.28	2.76	3.32
16	3.48	3.39	2.44	3.44	3.88	2.79	3.47	3.4	2.83	2.85	2.62	2.85	3.12
17	2.96	3.04	2.99	2.93	3.5	2.42	3.35	3.08	2.37	2.37	2.69	2.53	2.85
18	2.83	2.73	2.56	2.85	2.53	1.68	2.5	2.61	1.63	1.48	2.08	2.23	2.31
19	2.05	1.79	1.95	1.88	1.7	0.78	1.85	2.15	1.52	1.25	1.77	1.66	1.70
20	1.60	1.66	1.80	1.87	1.46	1.28	1.84	2.05	1.83	1.47	1.95	2.00	1.73
21	2.16	1.29	2.22	1.58	1.51	1.32	1.79	2.00	1.99	1.66	1.65	2.19	1.78
22	2.06	1.63	1.92	1.67	1.55	1.07	1.66	1.85	1.52	1.77	1.54	1.95	1.68
23	2.50	1.81	1.57	1.66	1.69	0.82	1.76	1.94	1.32	1.45	0.99	1.50	1.58
24	2.69	1.50	1.58	1.43	1.60	1.06	1.91	1.69	1.07	1.43	0.95	1.56	1.54
Monthly Mean	2.86	1.92	1.90	2.05	2.17	1.68	2.43	2.17	1.84	1.79	1.66	2.01	

Table A12 Monthly basis hourly surface wind speed data at Kota Bharu in 2008

Month / Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hourly Mean
1	2.37	3.8	3.81	1.62	1.22	1.63	1.83	2.22	1.43	1.85	1.3	2.68	2.15
2	2.21	3.49	3.22	1.92	1.34	1.66	1.62	2.13	1.65	1.87	1.7	2.19	2.08
3	2.36	3.13	3.16	1.77	1.1	1.76	2.02	2.38	1.64	1.83	1.65	2.22	2.09
4	2.39	2.94	2.96	2.05	1.2	1.62	1.95	2	1.76	1.7	1.41	2.07	2
5	1.9	2.07	2.87	2.01	1.15	1.77	2.05	1.92	1.69	1.66	1.19	1.73	1.83
6	1.79	1.87	2.5	1.68	1.27	1.6	1.99	2.14	1.7	1.84	1.46	1.68	1.79
7	1.69	1.91	2.78	1.78	1.11	1.6	2.19	2.26	2.04	2.04	1.31	1.64	1.86
8	1.97	1.86	3.16	2.17	2	2.24	2.25	2.51	2.08	2.37	1.67	1.96	2.19
9	2.63	2.81	4.12	3.21	2.47	2.88	3.13	3.34	2.98	2.78	2.23	2.57	2.93
10	3.59	3.77	4.79	3.3	2.79	3.05	3.78	3.76	3.41	3.31	2.43	3	3.42
11	4.34	4.96	5.6	3.15	2.62	2.86	3.45	3.67	3.38	2.81	2.36	3.8	3.58
12	5.04	5.96	6.4	3.85	2.52	3	3.22	3.14	3.64	3.39	3	3.74	3.91
13	5.3	6.32	6.76	4.75	3.21	3.58	3.46	3.61	4.29	4.12	3.13	3.92	4.37
14	5.28	6.57	6.69	4.99	3.99	4.03	3.7	4.35	4.5	4.49	3.29	4.02	4.66
15	5.65	6.55	6.93	5.15	4.16	4.24	4.42	4.25	4.47	4.47	3.43	3.93	4.8
16	5.45	6.57	7.04	5.38	4.13	4.32	4.32	4.43	4.72	4.64	3.4	3.98	4.87
17	5.35	6.72	6.89	4.86	4.37	4.21	4.23	4.52	4.54	3.92	3.03	3.73	4.7
18	5.29	6.02	6.35	4.68	3.71	3.76	3.98	4.02	3.49	3.6	2.57	3.27	4.23
19	4.31	5.35	5.73	3.64	3.2	3.35	3.67	3.5	2.5	2.67	1.87	3.43	3.6
20	3.73	4.74	4.95	2.99	2.15	2.43	2.97	2.63	1.97	2.56	1.82	2.84	2.98
21	3.79	4.84	4.56	2.78	1.51	1.86	2.19	2.14	1.58	2.12	1.85	2.96	2.68
22	3.64	4.68	4.13	2.37	1.37	2.79	2.22	2.14	1.96	1.91	2.16	2.89	2.69
23	3.12	4.38	3.82	2.13	1.45	2.17	1.87	1.97	1.44	2.08	1.69	2.54	2.39
24	2.88	4.11	3.89	1.42	1.79	1.73	2.12	2.5	1.39	1.77	1.59	2.6	2.32
Monthly Mean	3.59	4.39	4.71	3.07	2.33	2.67	2.86	2.98	2.68	2.74	2.15	2.89	

Table A13 Monthly basis hourly surface wind speed data at Kota Bharu in 2009

Hour \ Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hourly Mean
1	2.21	1.38	1.12	1.58	2.2	1.49	2.05	1.92	1.14	1.81	1.94	3.26	1.84
2	2.16	1.34	0.95	1.36	2.02	1.58	1.78	1.73	1.2	1.77	2.3	3.21	1.78
3	2.15	1.21	0.96	1.75	2.01	1.62	1.7	1.61	1.58	1.85	1.99	2.65	1.76
4	1.91	0.95	1.16	1.72	2.01	1.7	1.79	1.46	1.35	1.9	2.42	2.78	1.76
5	1.81	1.05	1.11	1.45	2.16	1.69	1.8	1.65	1.63	1.92	2.53	2.28	1.76
6	1.65	0.97	1.34	1.62	1.95	1.83	1.96	1.78	1.66	1.78	2.29	2.47	1.77
7	1.64	1.1	1.14	1.67	1.99	1.86	2.22	1.65	1.53	2.04	2.32	2.32	1.79
8	1.74	1.26	1.18	1.86	2.32	2.35	2.46	2	1.88	2.36	2.65	2.48	2.05
9	2.18	2.02	1.86	2.72	2.81	3.11	2.99	2.64	2.54	2.98	3.52	3.12	2.71
10	3.01	2.54	2.39	2.98	3.17	3.37	3.39	3.2	2.76	3.09	3.47	3.95	3.11
11	3.85	3.34	2.76	2.87	3.06	3.04	3.3	3.26	3.13	2.86	2.97	4.86	3.27
12	4.93	4.64	3.26	3.23	2.87	3.16	3.1	3.29	2.86	3.23	3.14	5.44	3.6
13	5.05	5.42	4.13	4.12	3.56	3.42	3.84	3.99	3.46	3.35	3.85	5.18	4.11
14	5.08	5.54	4.18	4.35	3.98	3.79	4.26	4.38	3.55	3.79	3.72	5.78	4.37
15	5.24	5.68	4.6	4.71	4.15	3.85	4.22	4.95	3.69	4.13	3.81	5.68	4.56
16	5.03	5.56	4.86	4.77	4.64	3.65	4.26	4.57	3.72	4.57	3.56	5.61	4.57
17	5.03	5.41	4.87	4.54	4.34	3.73	4.13	4.24	3.85	4.32	3.31	5.61	4.45
18	4.79	5	4.46	4.09	4.04	3.6	3.88	4.32	3.2	3.48	3.15	5.4	4.12
19	4.64	4.2	3.13	3.16	3.47	2.54	3.22	3.2	2.12	2.57	2.48	4.66	3.28
20	3.76	3.41	2.52	2.75	2.51	1.94	2.26	2.55	2.06	1.73	2.35	4.43	2.69
21	3.79	2.95	2.2	2.75	2.34	1.88	2.33	2.1	1.59	1.94	2.72	4.33	2.58
22	3.6	2.66	1.73	1.98	2.29	1.7	2.49	1.95	1.63	1.42	2.47	4.05	2.33
23	3.15	2.58	1.09	1.85	2.09	1.26	1.98	1.71	1.61	1.88	2.2	4.34	2.15
24	2.44	2.14	1.52	1.77	2.22	1.57	1.88	2.02	1.44	2.07	1.99	3.59	2.06
Monthly Mean	3.37	3.01	2.44	2.73	2.84	2.49	2.8	2.76	2.3	2.62	2.8	4.06	

Table A14 Monthly basis hourly surface wind speed data at Kuala Krai in 2008

Month / Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hourly Mean
1	0.78	0.69	0.75	1.1	1.03	1	1.13	1.11	0.69	1.06	0.62	0.56	0.88
2	0.63	0.69	0.59	0.9	1.04	0.85	1.03	0.99	0.79	0.71	0.4	0.67	0.77
3	0.69	0.65	0.6	0.83	0.88	1.06	1.02	0.92	0.57	0.77	0.41	0.5	0.74
4	0.53	0.77	0.6	0.82	0.7	0.99	1.09	0.98	0.54	0.81	0.47	0.47	0.73
5	0.55	0.71	0.41	0.92	0.89	1	1.12	0.87	0.72	0.72	0.28	0.64	0.74
6	0.7	0.74	0.56	0.99	0.92	0.91	1.17	0.99	0.63	0.86	0.31	0.6	0.78
7	0.54	0.65	0.72	0.95	1.04	0.97	1.18	1.06	0.62	0.84	0.57	0.55	0.81
8	0.54	0.57	0.75	0.87	0.79	1.14	1.23	1.16	0.73	1.11	0.57	0.63	0.84
9	0.7	0.91	0.77	1.38	1.26	1.27	1.45	1.34	0.96	1.23	0.65	0.6	1.04
10	0.94	1.26	1.13	1.57	1.52	1.48	2.17	1.91	1.31	1.71	0.84	0.82	1.39
11	1.15	1.41	1.34	1.73	1.68	1.94	2.41	2.08	1.35	1.63	0.96	1.05	1.56
12	1.3	1.76	1.54	1.74	1.76	2	2.42	2.42	1.55	1.5	1.14	1.3	1.7
13	1.66	1.89	1.87	1.76	1.88	1.96	2.48	2.37	1.38	1.82	1.24	1.67	1.83
14	1.86	2.02	2.03	2.12	1.88	1.99	2.34	2.24	1.71	1.72	1.62	1.65	1.93
15	1.98	1.97	2.15	2.43	1.63	1.71	2.41	1.99	1.47	2.02	1.82	1.76	1.94
16	2.02	2.4	2.38	2.65	1.6	1.46	1.69	1.94	1.59	2.08	1.71	2.05	1.96
17	1.91	2.29	2.47	2.2	1.93	1.89	1.5	1.9	1.48	1.66	1.75	1.8	1.9
18	2.05	2.23	2.16	1.83	1.79	1.29	1.36	2.24	1.36	1.58	1.34	1.51	1.73
19	1.81	1.95	1.74	1.54	2.05	1.7	1.96	1.92	1.19	1.75	1.42	1.28	1.69
20	1.78	1.85	1.6	1.57	1.62	1.58	1.83	1.79	1.12	1.61	1.13	1.32	1.57
21	1.57	1.82	1.29	1.22	1.42	1.93	1.6	1.87	1.19	1.42	1.07	1.08	1.46
22	1.3	1.53	1.36	1.31	1.41	1.22	1.48	1.62	1.07	1.26	0.61	1.04	1.27
23	0.99	1.13	0.99	1.05	1.22	1.09	1.24	1.08	0.82	1.19	0.51	0.76	1.01
24	0.87	1.09	0.85	1.02	1	1.19	1.07	1.09	0.83	0.73	0.63	0.76	0.93
Monthly Mean	1.2	1.37	1.28	1.44	1.37	1.4	1.6	1.58	1.07	1.32	0.92	1.04	

Table A15 Monthly basis hourly surface wind speed data at Kuala Krai in 2009

Month / Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hourly Mean
1	0.72	0.74	0.89	0.88	0.96	0.95	0.78	0.83	0.82	0.69	0.7	0.79	0.81
2	0.69	0.64	0.87	0.73	0.89	0.93	0.75	0.89	0.7	0.77	0.55	0.61	0.75
3	0.45	0.54	0.78	0.69	0.85	1	1	0.72	0.67	0.66	0.53	0.5	0.7
4	0.47	0.61	0.78	0.53	0.84	0.87	0.83	0.7	0.84	0.78	0.61	0.52	0.7
5	0.47	0.46	0.81	0.76	0.96	0.78	0.82	0.75	0.75	0.51	0.62	0.39	0.67
6	0.5	0.58	0.68	0.88	0.9	0.72	0.68	0.76	0.66	0.62	0.61	0.41	0.67
7	0.58	0.4	0.74	0.81	0.81	0.99	0.98	0.89	0.55	0.72	0.6	0.35	0.7
8	0.53	0.55	0.83	0.59	0.8	1.11	1.07	1.03	0.7	0.83	0.74	0.52	0.78
9	0.55	0.6	1.02	1.28	0.98	1.14	1.34	1.3	0.75	1	0.88	0.55	0.95
10	0.96	0.87	1.29	1.23	1.48	1.5	1.56	1.62	1.19	1.06	1.16	0.82	1.23
11	1.21	1.21	1.39	1.51	1.67	1.72	1.98	1.84	1.36	1.29	1.08	0.99	1.44
12	1.38	1.55	1.41	1.48	1.61	1.77	2.32	1.94	1.39	1.49	1.47	1.27	1.59
13	1.75	1.89	1.8	1.63	1.64	2.02	2.14	1.98	1.45	1.56	1.37	1.46	1.72
14	1.98	2.15	1.91	1.55	1.61	1.95	2.1	2.02	1.66	1.69	1.52	1.86	1.83
15	2.2	2.48	2.06	1.76	1.55	1.72	1.76	1.95	1.24	1.43	1.54	1.66	1.78
16	1.96	2.47	2.44	1.66	1.88	1.7	1.56	1.75	1.21	1.48	1.53	1.89	1.8
17	2.08	2.26	1.93	1.75	1.4	1.49	1.74	2.01	1.34	2.48	1.49	1.7	1.81
18	1.82	1.9	1.97	1.48	1.84	1.35	1.45	1.68	1.41	1.15	0.99	1.6	1.55
19	1.62	2.06	1.78	1.58	1.41	1.49	1.53	1.43	1.26	1.6	0.95	1.43	1.51
20	1.74	2.01	1.54	1.32	1.54	1.54	1.61	1.54	1.63	1.38	0.94	1.48	1.52
21	1.58	1.94	1.55	1.05	1.16	1.68	1.36	1.14	1.17	1.06	0.9	1.25	1.32
22	1.05	1.71	1.28	1.12	1.13	1.6	1.56	0.98	1.14	0.76	0.7	1.17	1.18
23	1.11	1.17	0.96	0.79	0.91	1.07	1.27	0.77	0.9	0.74	0.7	0.66	0.92
24	0.66	0.95	0.95	0.79	0.81	1.04	1.03	0.82	0.67	0.48	0.62	0.68	0.79
Monthly Mean	1.17	1.32	1.32	1.16	1.23	1.34	1.38	1.3	1.06	1.09	0.95	1.02	

Table A16 Monthly basis hourly surface wind speed data at Kuantan in 2008

Month / Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hourly Mean
1	1.43	1.56	1.31	0.82	1.09	1.22	1.10	0.80	1.07	0.87	0.89	1.24	1.12
2	1.57	1.64	1.13	0.77	0.99	0.95	0.84	0.83	1.05	0.73	1.04	1.21	1.06
3	1.59	1.65	1.10	0.40	1.12	0.90	0.94	0.90	1.01	0.72	0.71	1.18	1.02
4	1.69	1.56	0.92	0.49	0.77	0.50	1.09	1.14	1.08	0.51	0.99	1.22	1.00
5	1.62	1.53	1.02	0.50	0.57	0.76	1.13	1.13	1.01	0.81	1.04	1.15	1.02
6	1.72	1.32	1.10	0.38	0.55	0.92	1.27	1.13	0.81	0.48	0.88	1.07	0.97
7	1.63	1.17	1.03	0.49	0.58	0.70	1.18	1.01	0.73	0.70	0.63	1.08	0.91
8	1.57	1.19	1.23	0.57	0.64	1.40	0.96	1.20	0.94	0.89	0.71	1.31	1.05
9	2.28	2.16	1.77	1.10	1.13	1.67	1.60	1.65	1.73	0.92	1.15	1.88	1.59
10	2.63	2.62	2.30	1.93	2.69	2.96	2.98	2.91	2.55	1.57	1.71	2.40	2.44
11	3.01	3.08	2.52	2.50	3.41	3.24	3.85	3.79	3.60	2.04	2.12	3.39	3.05
12	3.07	3.36	3.38	2.59	3.66	3.48	4.04	3.99	4.09	2.19	2.34	3.16	3.28
13	3.35	4.02	4.17	3.09	3.65	3.54	3.95	3.85	3.78	2.67	2.64	3.29	3.50
14	4.14	4.58	4.79	3.05	3.73	3.74	3.76	3.89	3.67	3.12	2.75	3.13	3.70
15	4.48	4.82	5.14	3.81	3.36	3.62	3.54	4.13	3.86	3.13	3.03	3.37	3.86
16	4.85	5.29	5.65	4.24	3.86	4.06	3.95	3.97	3.83	3.86	3.19	3.37	4.18
17	4.46	5.21	5.42	3.88	4.24	3.97	4.14	4.20	4.15	3.69	2.80	3.13	4.11
18	4.04	4.41	4.57	3.63	3.90	3.73	3.79	4.15	3.62	2.99	2.59	2.97	3.70
19	3.01	3.84	3.17	2.40	2.46	3.79	2.51	3.34	2.39	1.98	1.55	2.30	2.73
20	1.85	2.51	2.07	1.14	1.62	2.03	2.23	2.44	1.99	1.37	1.91	1.70	1.91
21	1.74	1.61	1.38	0.83	1.52	1.55	1.66	1.67	1.90	1.98	1.44	1.47	1.56
22	1.50	1.70	1.50	1.34	1.56	1.58	1.31	1.51	1.57	1.54	1.08	1.38	1.47
23	1.69	1.65	1.31	1.11	1.25	1.35	1.02	1.12	1.64	1.02	1.26	1.29	1.31
24	1.47	1.62	1.16	0.92	1.12	1.44	1.10	1.30	1.15	0.98	1.00	1.36	1.22
Monthly Mean	2.52	2.67	2.46	1.75	2.06	2.21	2.25	2.33	2.22	1.70	1.64	2.04	

Table A17 Monthly basis hourly surface wind speed data at Kuantan in 2009

Month / Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hourly Mean
1	1.20	0.98	1.15	1.12	1.49	1.33	0.99	0.92	1.36	1.48	0.73	1.33	1.17
2	1.44	1.09	1.07	0.81	1.11	1.17	1.12	0.76	0.95	1.12	0.90	1.27	1.07
3	1.26	0.83	1.07	0.79	1.24	1.32	1.13	0.78	1.11	1.17	1.14	1.35	1.10
4	1.52	0.91	1.20	0.78	0.89	0.86	1.14	0.94	0.91	1.08	1.04	1.42	1.06
5	1.46	0.97	0.98	0.78	0.81	0.83	1.01	0.90	0.90	0.91	0.86	1.28	0.98
6	1.52	0.75	0.87	0.89	0.99	0.89	0.91	0.79	1.07	0.83	0.71	1.51	0.98
7	1.42	0.72	0.73	0.79	1.08	1.14	1.10	0.86	1.06	0.69	0.78	1.35	0.98
8	1.56	0.73	0.71	0.96	1.03	0.72	1.12	0.91	1.33	0.98	1.09	1.31	1.04
9	2.08	1.42	1.42	1.09	1.01	1.58	1.58	1.42	1.94	0.94	1.51	2.05	1.50
10	3.13	2.34	1.91	2.01	1.58	2.86	2.94	2.57	2.67	1.95	1.58	2.71	2.35
11	3.56	3.02	2.11	2.76	2.03	3.16	3.54	3.24	3.68	2.74	2.11	3.01	2.91
12	3.95	3.25	2.35	2.70	2.31	3.49	3.81	3.73	3.86	3.19	2.10	2.93	3.14
13	4.39	3.32	2.78	2.81	2.61	3.68	4.13	3.68	4.16	3.79	2.73	3.21	3.44
14	4.14	3.58	3.34	3.26	3.18	3.39	4.29	4.21	4.05	3.65	2.95	3.82	3.65
15	4.79	4.59	3.88	4.10	3.54	3.65	3.91	4.01	3.90	3.65	3.06	4.03	3.93
16	4.77	4.73	4.63	4.58	3.45	4.06	3.45	4.38	3.64	4.02	3.09	3.69	4.04
17	4.45	4.86	4.22	4.39	3.39	3.88	3.82	4.12	4.04	3.78	2.82	3.55	3.94
18	4.11	4.45	3.46	3.65	3.09	3.55	3.69	4.06	3.55	3.15	2.27	3.08	3.51
19	3.43	3.17	2.94	2.16	2.19	2.98	2.86	2.91	2.59	2.47	1.63	2.28	2.63
20	2.39	2.01	1.97	1.86	1.39	1.82	1.26	1.55	1.84	2.08	1.72	1.73	1.80
21	1.82	1.40	1.59	1.61	1.61	1.25	1.44	1.65	1.69	2.17	1.54	1.34	1.59
22	1.63	1.25	1.30	1.24	1.43	1.80	1.23	1.45	1.44	1.52	1.27	1.67	1.43
23	1.40	1.21	1.04	1.41	1.69	1.24	1.24	1.32	1.57	1.39	1.20	1.44	1.35
24	1.48	1.01	1.07	1.15	1.52	1.13	1.16	1.12	1.28	1.40	1.13	1.50	1.25
Monthly Mean	2.62	2.19	1.99	1.99	1.86	2.16	2.20	2.18	2.27	2.09	1.67	2.20	

Table A18 Monthly basis hourly surface wind speed data at Lepas in 2008

Hour \ Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hourly Mean
1	1.69	1.35	1.30	1.45	0.79	1.03	0.75	1.16	1.40	1.20	1.60	3.49	1.44
2	1.91	1.79	1.40	1.64	0.82	0.85	0.87	0.93	1.44	1.36	1.45	3.52	1.50
3	2.00	2.59	1.60	1.84	0.64	1.07	0.87	0.85	1.16	1.31	1.91	2.88	1.56
4	2.53	2.66	1.83	1.33	0.78	0.75	1.03	0.88	1.36	0.86	1.58	3.00	1.55
5	2.20	2.69	1.64	1.28	0.79	0.71	0.94	1.26	1.00	1.15	1.39	3.25	1.52
6	2.43	2.78	1.50	1.39	1.01	1.01	0.91	0.87	1.12	1.00	1.47	3.31	1.57
7	2.57	2.41	1.64	1.37	0.98	0.69	1.22	0.66	1.26	1.36	1.50	2.89	1.55
8	2.54	2.19	1.61	1.40	0.88	0.85	0.78	1.26	1.60	1.22	1.60	2.71	1.55
9	3.15	3.33	2.41	1.89	1.52	1.79	1.54	1.91	1.86	1.65	2.78	3.91	2.31
10	3.82	4.07	2.56	2.54	2.39	2.24	2.88	2.90	2.43	2.08	3.42	4.81	3.01
11	3.86	4.23	3.24	3.66	3.28	3.51	3.83	3.62	3.53	3.04	4.10	4.94	3.74
12	4.32	4.15	3.83	3.85	3.84	3.89	4.17	4.42	3.65	3.70	3.94	4.84	4.05
13	4.28	4.59	4.55	4.60	4.10	4.20	4.85	4.82	4.64	4.14	3.78	4.82	4.45
14	4.78	4.93	5.42	5.12	4.56	4.80	5.21	5.36	4.65	4.77	3.98	4.93	4.88
15	5.37	5.31	5.55	4.85	4.49	4.54	5.43	5.87	4.64	4.54	4.25	4.71	4.96
16	5.19	5.27	4.82	4.78	4.44	4.83	5.54	5.88	4.22	4.40	4.13	4.53	4.84
17	5.31	5.17	4.56	4.61	3.81	4.02	5.31	5.57	3.76	3.68	3.31	3.80	4.41
18	3.96	4.50	3.69	3.66	3.25	3.61	4.69	4.49	3.16	2.68	2.75	3.87	3.69
19	3.06	3.75	3.18	2.84	2.37	2.54	4.02	3.12	2.28	2.00	2.07	2.63	2.82
20	1.90	2.71	2.23	2.74	1.55	1.58	3.10	1.95	1.63	1.30	1.66	2.12	2.04
21	1.69	1.91	2.04	1.76	1.27	1.01	2.49	1.20	1.36	1.46	1.77	2.76	1.73
22	1.82	1.76	1.82	1.46	1.41	1.41	2.01	1.13	1.30	1.21	1.54	2.96	1.65
23	1.85	1.34	1.70	1.22	1.34	1.10	1.51	0.74	1.23	1.58	1.98	3.17	1.56
24	1.90	2.03	1.21	1.37	0.98	0.82	1.22	0.93	1.29	1.49	1.72	3.75	1.56
Monthly Mean	3.09	3.23	2.72	2.61	2.14	2.20	2.72	2.57	2.33	2.22	2.49	3.65	

Table A19 Monthly basis hourly surface wind speed data at Lepas in 2009

Month / Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hourly Mean
1	3.72	1.37	1.35	1.54	1.15	0.90	1.22	1.13	0.82	1.22	1.70	2.00	1.51
2	3.39	1.44	1.52	1.23	1.17	0.85	1.04	1.35	0.96	1.02	1.93	2.36	1.52
3	3.80	1.39	1.02	1.24	1.23	0.70	1.30	1.28	1.17	0.90	1.54	2.69	1.52
4	3.87	1.56	1.78	1.18	1.34	0.99	1.62	1.30	1.14	1.25	1.59	2.85	1.71
5	4.13	1.75	1.77	0.91	1.34	1.01	1.32	1.44	1.28	1.27	1.68	2.77	1.72
6	4.07	1.94	1.33	0.94	0.79	0.97	1.50	1.75	1.10	1.35	2.01	3.20	1.74
7	3.86	1.79	1.15	1.61	1.39	1.01	1.49	1.37	1.30	1.21	1.78	3.03	1.75
8	3.96	1.80	1.26	1.23	1.30	1.20	1.43	1.35	1.26	1.30	1.81	3.30	1.77
9	5.10	2.03	1.22	1.91	1.65	1.43	1.56	2.21	1.34	2.22	2.55	3.25	2.21
10	5.03	3.38	2.21	2.90	2.42	2.09	2.10	2.51	2.64	3.12	3.38	4.32	3.01
11	5.44	3.75	3.30	3.41	3.10	3.23	3.29	3.01	2.91	2.97	4.00	4.53	3.58
12	5.85	3.78	3.79	3.22	3.56	3.31	3.78	3.52	3.68	3.68	3.79	3.98	3.83
13	6.03	4.80	4.71	4.42	3.54	4.52	4.81	3.88	4.23	4.05	4.39	4.32	4.47
14	6.02	5.66	5.04	4.70	4.07	4.93	4.89	4.40	4.74	4.39	4.89	4.83	4.88
15	5.69	6.05	5.56	5.08	4.41	4.94	5.07	4.31	4.85	4.03	4.74	5.22	5.00
16	5.13	5.91	5.01	4.58	3.82	4.74	5.23	4.44	4.37	3.86	4.24	5.04	4.70
17	5.08	5.01	4.34	4.06	3.45	4.35	5.17	3.98	3.93	3.08	3.92	4.43	4.23
18	4.43	4.14	3.95	3.46	3.08	3.61	4.67	3.35	3.03	2.53	3.38	3.37	3.58
19	3.00	3.42	2.64	2.78	2.34	2.62	3.39	2.39	2.32	2.05	2.74	2.76	2.70
20	2.35	2.39	1.83	2.21	1.39	1.54	2.43	1.50	1.93	1.81	2.53	2.05	2.00
21	2.89	1.64	2.42	1.40	1.08	1.18	1.46	1.93	1.70	1.11	2.22	2.04	1.76
22	2.57	1.25	1.90	1.24	1.02	0.78	1.38	1.33	1.20	1.49	2.08	2.03	1.52
23	2.85	1.12	1.86	1.32	0.78	0.86	1.35	1.34	0.87	1.22	1.89	2.16	1.47
24	3.20	1.52	1.22	1.16	0.86	0.89	1.12	1.16	0.90	1.16	1.66	2.25	1.43
Monthly Mean	4.23	2.87	2.59	2.41	2.09	2.19	2.61	2.34	2.24	2.18	2.77	3.28	

Table A20 Monthly basis hourly surface wind speed data at Malacca in 2008

Month / Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hourly Mean
1	3.22	3.61	2.61	1.48	1.39	1.64	1.21	1.16	1.60	1.46	2.09	3.13	2.05
2	3.14	3.55	2.68	1.33	1.44	1.02	1.18	1.22	1.80	1.28	2.04	3.25	2.00
3	3.09	3.19	2.44	1.36	1.35	1.59	1.00	1.35	1.53	1.27	1.78	3.28	1.94
4	3.24	3.37	2.06	1.35	1.22	1.24	1.19	1.01	1.40	1.55	1.77	3.13	1.88
5	2.87	3.19	2.16	1.33	1.33	1.32	1.37	1.08	1.24	1.38	2.02	2.88	1.85
6	2.56	3.03	2.05	1.04	1.14	1.08	1.18	0.96	1.41	1.37	1.64	2.91	1.70
7	2.53	3.42	1.85	1.04	1.24	1.37	1.13	1.04	1.45	1.17	1.34	2.41	1.67
8	2.57	3.33	2.13	1.22	1.21	1.26	1.39	1.43	1.37	1.32	1.68	2.69	1.80
9	3.63	4.12	3.14	1.63	1.73	1.55	1.72	1.70	2.00	2.13	2.13	4.04	2.46
10	4.69	4.87	4.19	2.38	2.48	2.02	2.21	2.39	2.89	2.58	2.78	4.54	3.17
11	5.06	5.49	3.89	2.91	3.30	2.76	3.27	3.17	3.95	3.13	3.28	5.08	3.77
12	5.25	5.59	4.37	2.84	3.52	3.53	3.88	4.26	4.66	3.63	3.50	5.44	4.21
13	4.93	5.36	4.26	3.75	4.17	4.03	3.91	4.31	4.70	4.62	3.77	5.32	4.43
14	4.36	5.53	4.03	3.88	4.34	4.23	3.78	4.36	4.93	4.99	4.11	5.25	4.48
15	4.96	5.40	4.29	3.92	4.14	3.90	3.73	4.51	5.13	5.39	4.80	5.33	4.62
16	4.34	4.91	4.02	3.94	3.93	3.54	3.66	3.95	4.85	4.88	4.34	4.95	4.28
17	4.07	5.00	3.64	3.52	3.42	3.34	3.13	3.58	4.14	4.31	4.25	4.73	3.93
18	4.32	4.16	2.83	2.81	2.94	2.82	2.83	2.95	3.30	3.14	3.67	4.07	3.32
19	3.11	2.92	2.45	2.08	2.07	1.99	2.12	1.86	2.57	2.36	2.69	3.83	2.50
20	2.22	2.28	1.71	1.74	1.21	1.25	1.55	1.40	1.83	1.88	2.21	3.06	1.86
21	2.46	2.43	1.86	1.39	0.86	0.88	1.09	1.01	1.43	1.63	1.97	3.00	1.67
22	2.38	2.46	2.14	1.57	1.04	0.97	1.17	1.20	1.46	1.41	2.08	3.07	1.75
23	2.37	3.16	2.05	1.47	1.13	1.04	0.94	1.56	1.47	1.22	2.20	3.24	1.82
24	2.80	3.41	2.20	1.41	1.05	1.06	1.10	1.22	1.27	1.61	1.99	3.24	1.86
Monthly Mean	3.51	3.91	2.88	2.14	2.15	2.06	2.07	2.20	2.60	2.49	2.67	3.83	

Table A21 Monthly basis hourly surface wind speed data at Malacca in 2009

Month / Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hourly Mean
1	4.76	3.27	2.16	2.05	2.23	1.34	1.84	1.72	1.07	1.62	1.42	3.46	2.25
2	5.00	3.43	2.34	2.02	2.41	1.21	1.74	1.62	1.29	1.83	1.33	3.46	2.31
3	5.04	3.37	1.97	1.79	2.52	0.82	1.90	1.53	1.50	1.33	1.36	3.35	2.21
4	4.88	3.38	2.15	1.86	2.28	1.27	2.08	1.16	1.33	1.68	1.43	3.23	2.23
5	4.82	3.50	1.61	1.70	2.42	1.20	1.86	1.13	1.15	1.75	1.38	2.91	2.12
6	4.88	3.27	1.36	1.96	1.86	1.23	1.46	1.30	1.31	1.18	1.63	2.74	2.01
7	4.40	3.50	1.63	1.56	1.72	1.14	1.61	1.26	0.87	1.12	1.24	2.78	1.90
8	4.72	3.39	1.71	1.74	1.92	1.31	1.37	1.31	0.63	1.14	1.31	2.95	1.96
9	5.45	4.00	2.26	2.53	2.47	1.90	1.62	1.85	1.39	2.20	2.26	4.05	2.66
10	6.53	5.14	2.80	3.08	2.63	2.88	2.21	2.62	2.30	2.69	3.02	5.36	3.44
11	7.70	5.47	3.03	3.92	3.38	3.00	3.34	3.69	3.31	3.43	3.66	5.91	4.15
12	7.66	5.10	3.28	4.10	3.68	3.51	4.32	3.98	3.95	3.82	4.02	6.23	4.47
13	7.34	4.94	3.84	4.60	4.20	3.98	4.74	4.15	4.20	4.19	4.42	5.93	4.71
14	6.73	4.89	4.34	4.43	4.60	3.85	4.53	4.48	4.19	4.11	4.42	5.68	4.69
15	6.29	5.21	4.38	4.50	4.59	4.00	3.99	4.34	3.94	4.12	4.13	5.59	4.59
16	6.19	5.24	4.51	4.11	4.69	3.54	3.71	4.21	3.66	4.02	4.21	4.95	4.42
17	5.94	4.73	4.36	4.19	4.32	3.27	3.43	3.78	3.07	3.47	3.82	5.08	4.12
18	5.25	4.54	3.70	3.60	3.65	2.78	3.03	3.36	2.80	2.84	3.55	4.71	3.65
19	4.43	3.65	2.84	2.91	2.69	2.13	2.82	2.99	2.16	1.96	2.40	3.86	2.90
20	3.75	2.51	2.44	2.50	2.54	1.58	1.81	2.26	1.43	1.52	1.89	3.56	2.32
21	4.03	2.10	2.21	2.34	2.27	1.22	1.74	1.61	1.02	1.93	2.05	3.45	2.17
22	4.76	2.77	2.35	2.10	2.34	1.33	1.63	1.58	1.07	1.66	1.89	3.67	2.26
23	4.56	2.85	1.80	2.04	2.21	0.97	1.78	1.52	0.97	1.16	1.67	3.69	2.10
24	4.61	3.06	2.11	1.91	2.34	1.30	1.56	1.65	0.86	1.51	1.83	3.49	2.19
Monthly Mean	5.40	3.89	2.72	2.81	2.92	2.12	2.51	2.46	2.06	2.35	2.51	4.17	

Table A22 Monthly basis hourly surface wind speed data at Mersing in 2008

Month / Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hourly Mean
1	5.12	5.75	4.62	2.68	2.98	3.05	3.10	2.95	2.99	2.83	2.95	4.33	3.61
2	5.18	5.36	4.30	3.20	3.21	3.31	3.18	2.93	3.09	2.89	3.05	4.87	3.71
3	4.95	5.44	4.34	3.28	3.28	3.20	3.34	3.08	3.05	2.91	2.91	4.85	3.72
4	5.37	5.38	4.09	3.31	3.35	3.35	3.05	3.26	3.04	3.00	2.79	4.76	3.73
5	5.56	5.23	4.26	2.97	3.34	3.00	3.04	3.26	2.96	2.90	3.03	4.56	3.67
6	5.38	5.53	3.87	3.15	3.45	3.21	2.90	3.32	3.07	2.83	3.00	4.73	3.70
7	4.82	5.70	3.71	3.25	3.24	3.46	2.85	3.36	2.79	2.98	2.96	4.65	3.65
8	4.57	5.59	3.62	2.63	2.94	3.07	2.57	3.16	2.76	2.60	2.66	4.52	3.39
9	4.51	5.70	3.52	2.18	2.22	2.65	2.60	3.06	2.62	2.13	2.39	4.28	3.15
10	5.25	5.80	4.12	2.08	2.56	2.39	2.80	2.91	3.05	2.32	2.57	5.04	3.41
11	5.63	6.06	4.26	2.56	3.44	3.19	3.30	3.97	3.73	2.39	3.00	5.30	3.90
12	5.75	6.07	4.83	3.78	3.96	3.53	4.13	3.90	3.64	3.43	3.56	5.72	4.36
13	6.19	6.88	5.56	4.35	4.81	4.17	4.72	4.79	4.29	3.67	3.98	6.00	4.95
14	6.05	7.10	6.03	4.56	5.48	4.86	5.60	5.87	4.30	3.99	4.39	5.95	5.35
15	6.65	7.03	6.01	5.16	5.66	5.66	5.26	5.79	4.65	4.41	4.29	6.05	5.55
16	6.46	6.77	6.06	4.72	5.62	5.81	5.51	5.75	4.69	4.08	3.84	5.81	5.43
17	6.27	6.31	6.14	3.96	4.89	4.39	5.42	5.42	4.49	4.31	3.73	5.91	5.10
18	5.97	5.87	5.53	3.55	4.01	3.22	4.98	4.08	3.57	3.82	3.69	5.61	4.49
19	5.97	5.52	5.17	2.72	3.42	2.84	3.98	3.73	3.26	3.04	2.98	5.09	3.98
20	5.84	5.43	4.97	2.86	3.55	3.04	3.05	3.37	2.99	2.95	2.89	5.37	3.86
21	5.48	5.21	4.58	2.88	2.85	3.14	3.02	3.05	3.11	2.82	2.87	5.21	3.68
22	5.32	5.39	4.63	2.42	2.94	3.22	2.82	2.96	2.97	2.74	2.76	5.19	3.61
23	5.70	5.62	4.66	3.00	2.87	3.16	3.06	2.94	3.12	2.90	2.99	4.92	3.75
24	5.25	5.44	4.33	3.17	3.12	3.18	3.12	3.09	3.18	2.85	3.02	4.64	3.70
Monthly Mean	5.55	5.84	4.72	3.27	3.63	3.50	3.64	3.75	3.39	3.12	3.18	5.14	

Table A23 Monthly basis hourly surface wind speed data at Mersing in 2009

Month / Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hourly Mean
1	6.61	4.08	3.01	3.29	3.04	3.34	3.09	3.10	2.83	2.65	3.63	4.92	3.63
2	6.34	4.29	3.00	2.78	3.03	3.02	3.15	3.06	2.93	3.15	3.71	4.82	3.60
3	6.36	4.32	2.90	3.00	3.09	2.95	3.40	3.09	3.09	2.89	3.50	4.69	3.61
4	6.21	4.31	2.96	2.59	3.24	3.11	3.16	3.29	3.14	2.78	3.57	4.18	3.54
5	6.08	4.30	3.17	2.83	3.08	3.13	3.10	3.32	3.00	2.85	3.55	4.43	3.57
6	6.06	4.17	2.96	2.87	3.04	3.33	3.21	3.47	3.24	3.03	3.67	4.41	3.62
7	5.89	3.79	3.24	2.97	2.92	3.03	3.11	3.45	3.22	3.11	3.69	4.25	3.56
8	5.78	3.82	2.82	2.54	2.82	2.91	3.28	3.06	2.80	2.56	2.85	4.32	3.30
9	5.78	3.97	2.17	1.98	2.18	2.40	2.88	2.69	2.54	2.22	2.94	4.23	3.00
10	6.28	4.62	2.48	2.55	2.69	2.68	2.90	3.08	3.00	2.30	2.97	4.69	3.35
11	6.64	4.87	3.00	3.21	3.43	3.43	3.73	3.74	3.66	2.73	3.55	4.97	3.91
12	7.03	5.27	3.53	4.32	4.09	4.38	4.16	4.37	3.89	3.47	4.28	5.25	4.50
13	7.12	5.94	3.97	4.67	4.34	4.83	5.04	4.73	4.70	4.37	4.26	5.30	4.94
14	7.39	5.95	4.19	4.97	4.63	5.69	5.24	5.31	5.40	4.64	4.63	5.53	5.30
15	7.50	6.44	4.75	4.66	5.07	5.56	5.95	6.35	6.38	5.27	4.59	5.50	5.67
16	7.10	6.01	4.73	4.78	4.96	5.37	5.85	5.99	5.48	4.70	5.00	5.70	5.47
17	7.10	5.88	4.29	4.54	4.30	5.20	4.97	5.12	4.20	4.52	4.33	5.40	4.99
18	7.10	5.55	4.03	4.42	3.60	4.02	4.09	4.21	3.50	3.71	4.01	5.20	4.45
19	6.68	5.06	3.85	3.54	3.14	3.51	3.55	3.38	3.16	3.49	3.85	4.94	4.01
20	6.73	5.04	3.34	3.28	2.66	2.99	2.91	3.09	2.69	3.04	3.66	5.04	3.71
21	6.76	4.84	3.07	3.20	2.67	2.91	2.95	3.03	3.03	3.01	3.92	4.71	3.68
22	6.99	4.61	2.93	3.26	2.78	3.07	2.87	2.91	3.20	2.92	3.76	4.80	3.67
23	6.72	4.49	2.87	3.12	2.87	3.16	3.03	2.75	2.86	3.00	3.44	4.79	3.59
24	6.57	4.36	2.85	3.12	2.81	3.26	3.05	2.82	2.97	2.93	3.52	4.89	3.60
Monthly Mean	6.62	4.83	3.34	3.44	3.35	3.64	3.69	3.73	3.54	3.31	3.79	4.87	4.01

Table A24 Monthly basis hourly surface wind speed data at Senai in 2008

Month / Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hourly Mean
1	1.33	1.22	0.9	0.63	0.48	0.52	0.56	0.97	0.51	0.8	1.15	1.57	0.89
2	1.3	1.02	0.92	0.7	0.36	0.36	0.73	0.64	0.9	0.86	0.94	1.65	0.87
3	1.52	1.1	0.86	0.71	0.63	0.61	0.62	0.62	0.75	0.71	1	1.56	0.89
4	1.6	1.1	0.84	0.84	0.68	0.62	0.63	0.75	0.72	0.71	0.78	1.76	0.92
5	1.51	1.41	0.95	0.71	0.61	0.66	0.59	0.52	0.5	0.77	1.11	1.88	0.93
6	1.39	1.33	0.66	0.8	0.6	0.74	0.33	0.47	0.83	1.04	1.22	1.68	0.92
7	1.44	1.28	0.7	0.67	0.75	0.68	0.67	0.63	1.07	0.8	1.02	1.45	0.93
8	1.56	1.26	0.8	0.86	0.84	0.51	0.68	0.58	0.92	0.95	1.43	1.73	1.01
9	2.68	2.17	1.41	1.37	1.05	0.79	0.95	0.9	1.83	1.45	2.06	2.96	1.63
10	4.17	3.65	2.59	1.99	2.97	1.96	2.33	2.3	2.81	2.13	2.37	4.37	2.8
11	4.57	5.08	3.31	2.41	3.34	2.81	3.24	3.17	3.39	2.38	3.05	5.01	3.48
12	4.91	5.13	3.3	2.78	3.58	3.16	3.56	3.66	3.61	2.34	3.2	5.51	3.73
13	4.88	5.15	3.97	2.66	3.58	3.12	3.52	3.74	4.12	2.97	3.39	5.35	3.87
14	5.07	5.77	4.37	3.23	4	3.46	3.89	4.17	4.3	3.54	3.34	5.26	4.2
15	5.25	5.49	4.26	4.27	4.23	3.76	4.03	4	4.5	3.63	3.37	5.21	4.33
16	5.25	5.38	4.52	3.58	3.83	3.75	3.67	4.11	4.2	3.25	3.42	5	4.16
17	4.65	5.69	3.97	2.99	3.2	3.49	3.27	3.36	3.55	2.51	2.91	4.48	3.67
18	4.1	4.67	3.15	2.42	2.58	3.01	2.87	2.62	3.33	1.89	2.72	3.92	3.11
19	3.36	3.76	2.87	1.99	2.02	2.15	2.08	2.39	2.4	1.53	2.12	3.08	2.48
20	2.39	2.74	2.3	1.4	1.1	1.74	1.85	1.72	1.57	1.15	1.31	2.72	1.83
21	1.7	1.99	1.72	1.43	0.78	0.95	1.3	1.54	1	1.03	1.08	2.61	1.43
22	1.79	1.64	1.59	0.85	0.78	0.87	0.91	0.78	0.82	0.88	0.82	2.04	1.15
23	1.65	1.32	1.08	0.88	0.87	0.69	0.57	0.78	0.63	0.69	0.88	1.71	0.98
24	1.52	1.28	0.94	0.74	0.56	0.68	0.63	0.94	0.68	0.75	0.87	1.61	0.93
Monthly Mean	2.9	2.94	2.17	1.71	1.81	1.71	1.81	1.89	2.04	1.62	1.9	3.09	

Table A25 Monthly basis hourly surface wind speed data at Senai in 2009

Hour \ Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hourly Mean
1	1.73	0.89	0.88	1.13	0.45	0.61	0.52	0.79	0.88	0.85	1.38	1.44	0.96
2	1.66	0.93	0.82	0.97	0.44	0.57	0.39	0.61	0.95	1.04	1.36	1.21	0.91
3	1.43	0.82	0.96	0.86	0.73	0.73	0.52	0.9	1.08	0.93	1.71	1.22	0.99
4	1.36	0.7	0.86	0.9	0.91	0.64	0.64	0.97	1.04	0.84	1.45	1.16	0.96
5	1.25	0.61	0.94	0.89	0.97	0.65	0.69	1.09	0.85	0.88	1.43	1.11	0.95
6	1.31	0.85	0.87	0.7	1.22	0.78	0.88	0.99	0.85	1.04	1.48	1.31	1.03
7	1.38	0.77	1.04	0.79	0.9	0.5	1.05	0.68	1.06	0.99	1.39	1.15	0.98
8	1.09	0.65	0.95	0.88	1.11	0.69	0.78	1.01	1.4	1.17	1.74	1.38	1.07
9	2.77	1.53	1.58	1.54	1.39	0.87	1.12	1.22	1.46	1.79	2.4	2.46	1.68
10	5.2	3.52	2.39	2.42	2.3	1.95	1.96	1.78	2.61	2.29	3.15	4.09	2.81
11	6.16	4.93	2.58	3.19	2.69	2.84	3.03	3.08	3.1	2.61	3.72	4.72	3.55
12	6.52	5.03	2.96	3.55	3	3.2	3.92	3.3	3.82	3.32	3.95	4.95	3.96
13	6.63	4.67	3	3.71	3.07	3.85	4.72	3.65	4.12	3.43	4.19	4.63	4.14
14	6.76	4.94	3.01	3.48	3.22	4.29	4.51	3.87	4.36	3.94	4.1	4.98	4.29
15	6.66	4.84	3.47	4.12	3.43	3.82	4.34	3.9	4.6	3.96	4.2	5.34	4.39
16	6.96	5.07	3.82	4.04	3.43	3.46	4.23	3.85	3.89	3.6	4.11	5.06	4.29
17	6.51	4.86	3.64	3.49	3.17	2.97	3.9	3.52	3.57	2.98	3.59	5.03	3.94
18	5.83	4.12	2.91	3	3.02	2.79	3.34	2.82	3.35	2.66	2.89	3.8	3.38
19	4.63	3.12	2.39	2.17	2.59	2.19	2.56	2.35	2.52	2.15	2.1	3.04	2.65
20	3.86	2.7	1.71	1.49	1.56	1.5	1.71	1.79	1.51	1.37	2.03	2.2	1.95
21	2.75	2.28	1.22	1.39	1.24	1.27	1.29	1.39	1.26	1.02	1.6	1.89	1.55
22	2.57	1.81	1.16	0.9	1.14	0.85	0.78	0.92	0.98	1.02	1.71	1.63	1.29
23	2.12	1.41	0.95	1.11	0.84	0.56	0.61	0.83	0.77	0.98	1.81	1.26	1.1
24	2.06	1.16	0.74	1.07	0.64	0.56	0.69	0.95	0.72	0.98	1.42	1.26	1.02
Monthly Mean	3.79	2.65	1.92	2.03	1.86	1.81	2.07	1.97	2.18	1.95	2.5	2.83	

Table A26 Monthly basis hourly surface wind speed data at Sitiawan in 2008

Hour \ Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hourly Mean
1	0.89	0.6	0.65	0.71	0.22	0.56	0.43	0.44	0.66	1.02	0.21	0.82	0.6
2	0.69	0.51	0.67	0.61	0.41	0.24	0.51	0.44	0.45	0.91	0.11	0.69	0.52
3	0.56	0.54	0.71	0.62	0.43	0.28	0.62	0.4	0.79	0.64	0.14	0.53	0.52
4	0.56	0.64	0.8	0.79	0.43	0.48	0.33	0.44	0.8	0.95	0.4	0.51	0.59
5	0.5	0.6	0.55	0.77	0.42	0.52	0.43	0.35	0.73	0.78	0.53	0.24	0.54
6	0.49	0.58	0.6	0.61	0.56	0.38	0.59	0.52	0.63	0.89	0.58	0.4	0.57
7	0.46	0.72	0.65	0.84	0.54	0.35	0.51	0.49	0.6	0.5	0.53	0.29	0.54
8	0.51	0.68	0.87	0.95	0.57	0.63	0.65	0.59	0.77	0.73	0.34	0.42	0.64
9	1.42	1.52	1.29	1.62	1.56	1.33	1.31	1.29	1.47	1.39	1.46	1.19	1.4
10	1.53	1.93	1.71	1.96	1.65	1.69	1.87	1.77	1.8	1.79	1.69	1.54	1.74
11	1.63	2.22	1.81	1.99	2.09	2.06	2.48	2.34	2.37	1.89	1.86	1.67	2.04
12	1.89	2.14	2.03	2.27	2.31	2.37	2.49	2.69	2.92	2.49	2.15	1.98	2.31
13	2.29	2.62	2.73	2.77	2.75	2.82	2.95	3.15	3.33	3.04	2.61	2.48	2.79
14	2.91	3.03	3.49	3.46	3.04	3.18	3.27	3.64	3.59	3.58	3	3.09	3.27
15	3.54	4.07	3.95	4.41	3.48	3.26	3.62	4.1	4.01	4.13	4.09	3.48	3.84
16	3.91	4.23	4.58	4.14	3.59	3.48	3.84	4.15	3.9	4.26	4.11	4	4.02
17	4.06	4.28	3.93	3.61	3.4	2.93	3.57	3.69	3.37	3.7	3.78	3.68	3.67
18	3.49	4.09	3.34	2.66	2.71	2.7	2.91	2.89	2.72	3.26	2.93	3.04	3.06
19	2.71	3.16	2.43	1.83	1.89	2.04	1.88	2.13	1.9	2.18	1.95	2.12	2.19
20	1.54	1.85	1.65	1.3	1.26	1.38	1.19	1.1	1.36	1.31	1.14	1.43	1.38
21	1.11	1.31	1.24	1.14	0.7	0.83	0.63	0.6	0.96	1.12	0.81	0.89	0.94
22	0.77	0.76	1.09	0.97	0.61	0.64	0.67	0.65	0.65	0.93	0.53	0.55	0.73
23	0.93	0.7	0.9	0.79	0.56	0.53	0.64	0.45	0.75	0.64	0.31	0.87	0.67
24	0.95	0.9	0.99	0.8	0.42	0.71	0.53	0.45	0.53	0.96	0.23	0.83	0.69
Monthly Mean	1.64	1.82	1.78	1.73	1.48	1.47	1.58	1.61	1.71	1.8	1.48	1.53	

Table A27 Monthly basis hourly surface wind speed data at Sitiawan in 2009

Month / Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hourly Mean
1	0.58	0.51	0.8	0.64	0.43	0.28	0.37	0.61	0.49	0.51	0.28	0.31	0.48
2	0.6	0.39	0.54	0.79	0.45	0.49	0.16	0.69	0.56	0.47	0.32	0.43	0.49
3	0.35	0.28	0.43	0.25	0.69	0.37	0.49	0.43	0.35	0.59	0.42	0.5	0.43
4	0.5	0.55	0.51	0.44	0.54	0.44	0.81	0.36	0.56	0.56	0.38	0.44	0.51
5	0.54	0.35	0.68	0.52	0.52	0.54	0.74	0.39	0.57	0.72	0.26	0.35	0.52
6	0.37	0.65	0.48	0.44	0.65	0.38	1.09	0.37	0.72	0.87	0.4	0.44	0.57
7	0.3	0.4	0.44	0.41	0.53	0.53	0.66	0.55	0.63	0.87	0.31	0.51	0.51
8	0.45	0.48	0.51	0.52	0.65	0.43	0.71	0.76	0.63	1.06	0.72	0.39	0.61
9	1.39	1.21	1.21	1.44	1.23	1.24	1.3	1.05	1.29	1.65	0.91	1.28	1.27
10	1.67	1.73	1.42	1.74	1.79	1.93	1.93	1.55	1.72	1.86	1.37	1.68	1.7
11	1.89	2.01	1.71	2.52	1.94	2.07	2.38	2.26	2.12	1.95	1.39	1.8	2
12	1.79	2.14	1.8	2.65	2.23	2.33	2.61	2.66	2.08	2.1	1.6	1.71	2.14
13	1.85	2.5	1.97	3.09	2.6	2.66	2.72	3.03	2.16	2.63	2.32	2.23	2.48
14	2.49	3.28	2.61	3.78	3.17	3.16	3.02	3.72	2.85	3.48	3.15	2.65	3.11
15	3.18	4.31	3.51	4.4	4.08	3.69	3.23	4.43	3.27	3.92	3.97	3.27	3.77
16	3.67	4.68	3.91	4.62	4.43	4.4	3.56	4.8	3.51	3.91	3.73	3.55	4.06
17	3.91	4.49	4.01	3.79	4.13	4.05	3.28	4.01	3.65	3.56	2.91	3.22	3.75
18	3.3	3.9	3.44	3.14	3.3	3.68	2.82	3.29	2.79	2.73	2.06	2.78	3.1
19	2.59	2.87	2.5	2.51	2.6	2.76	1.74	2.15	1.96	1.83	1.29	2.12	2.24
20	1.4	1.93	1.51	1.73	1.56	1.52	0.85	1.56	1.19	1.43	0.93	1.13	1.4
21	1.03	1.08	1.34	1.14	1.17	0.85	0.66	1.2	1.2	0.94	0.97	0.58	1.01
22	0.78	1	0.8	0.76	0.82	0.71	0.44	0.87	0.58	0.68	0.84	0.7	0.75
23	0.65	0.78	0.83	0.73	0.36	0.63	0.41	0.8	0.67	0.56	0.49	0.58	0.62
24	0.81	0.7	0.58	0.71	0.34	0.41	0.43	0.52	0.59	0.65	0.43	0.46	0.55
Monthly Mean	1.5	1.76	1.56	1.78	1.68	1.65	1.52	1.75	1.51	1.65	1.31	1.38	

Appendix B Predicted contour mapping on mean wind speed

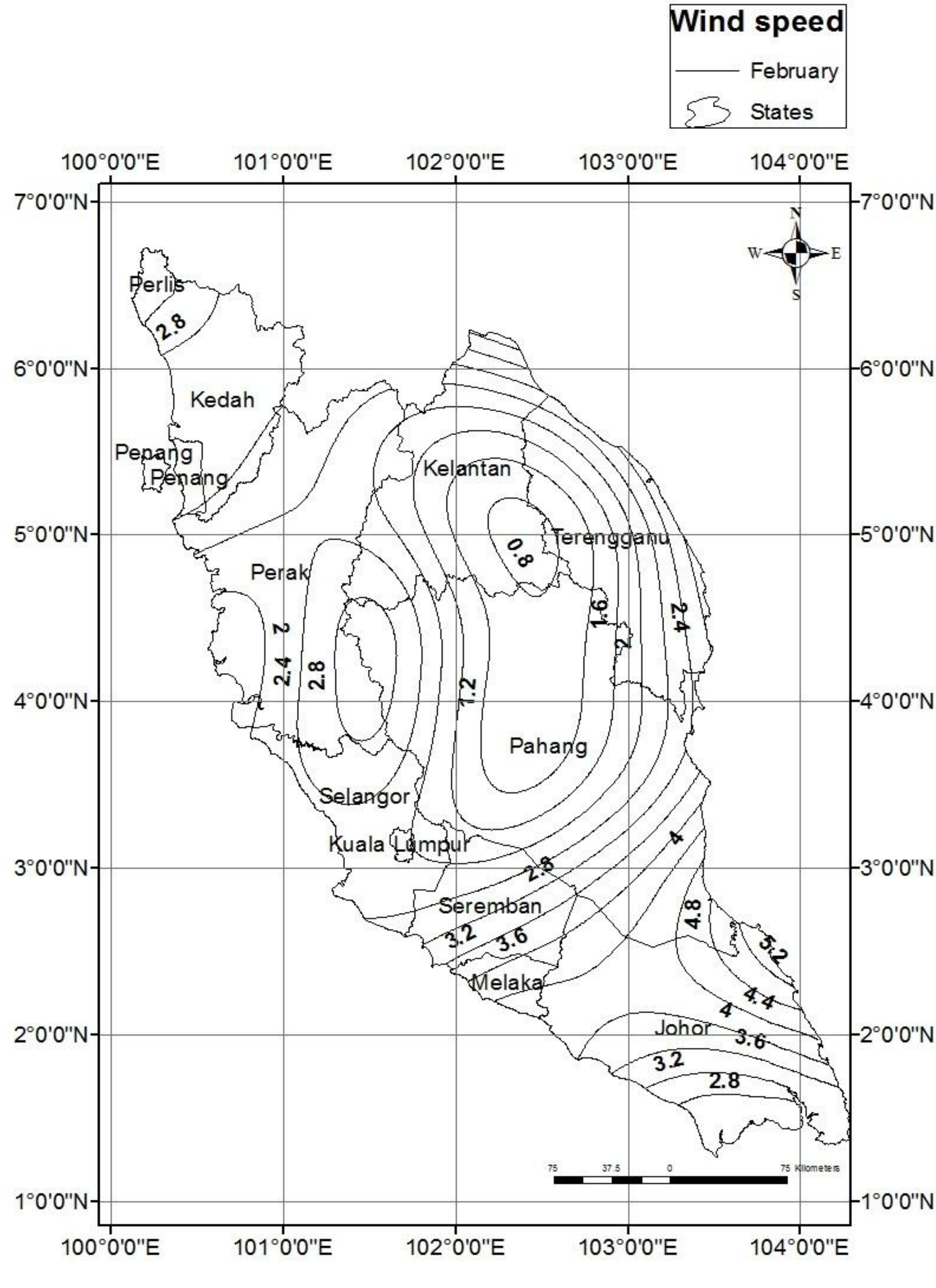

Figure B1 Contour Map on predicted monthly mean wind speed (m/s) for February

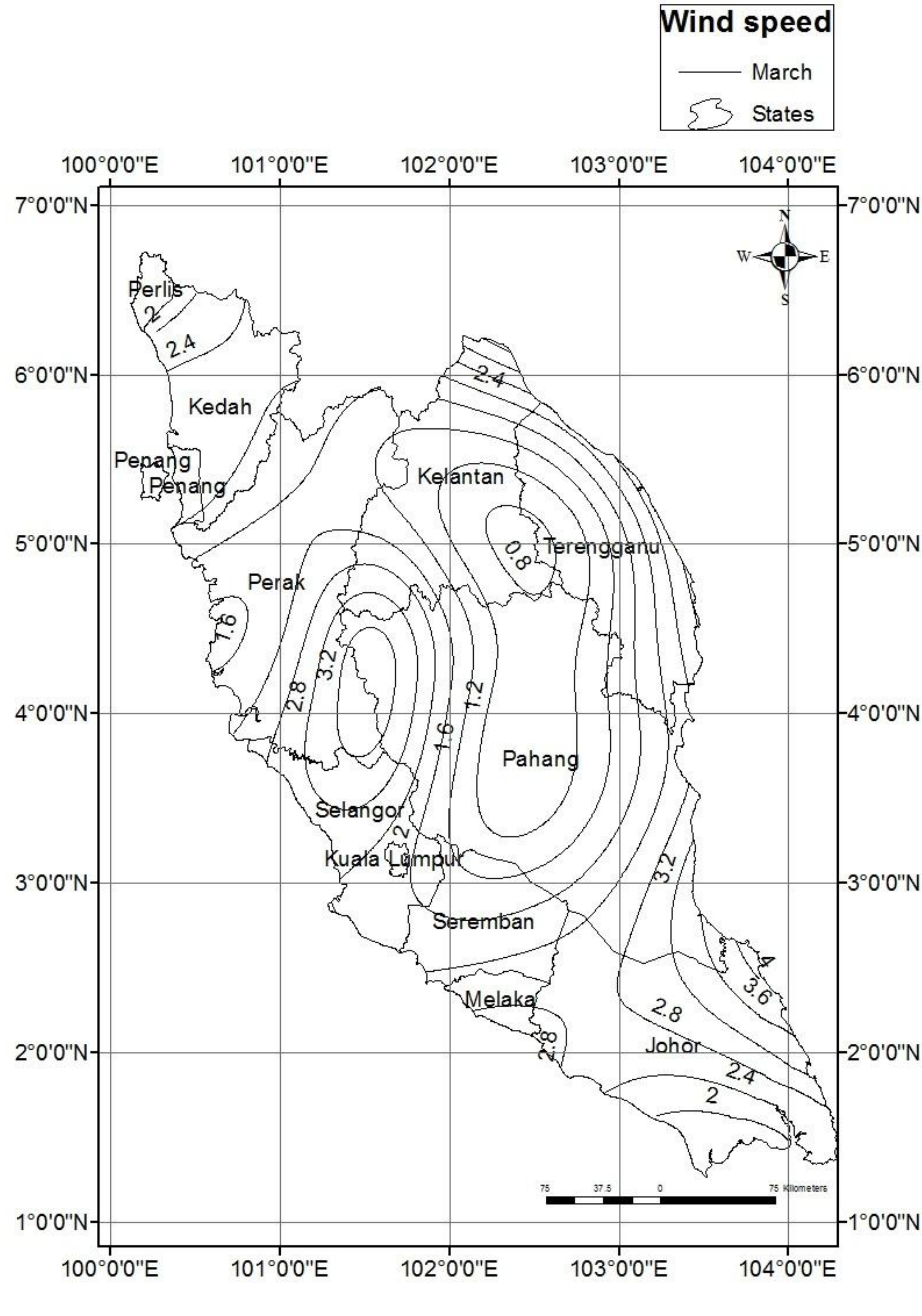

Figure B2 Contour Map on predicted monthly mean wind speed (m/s) for March

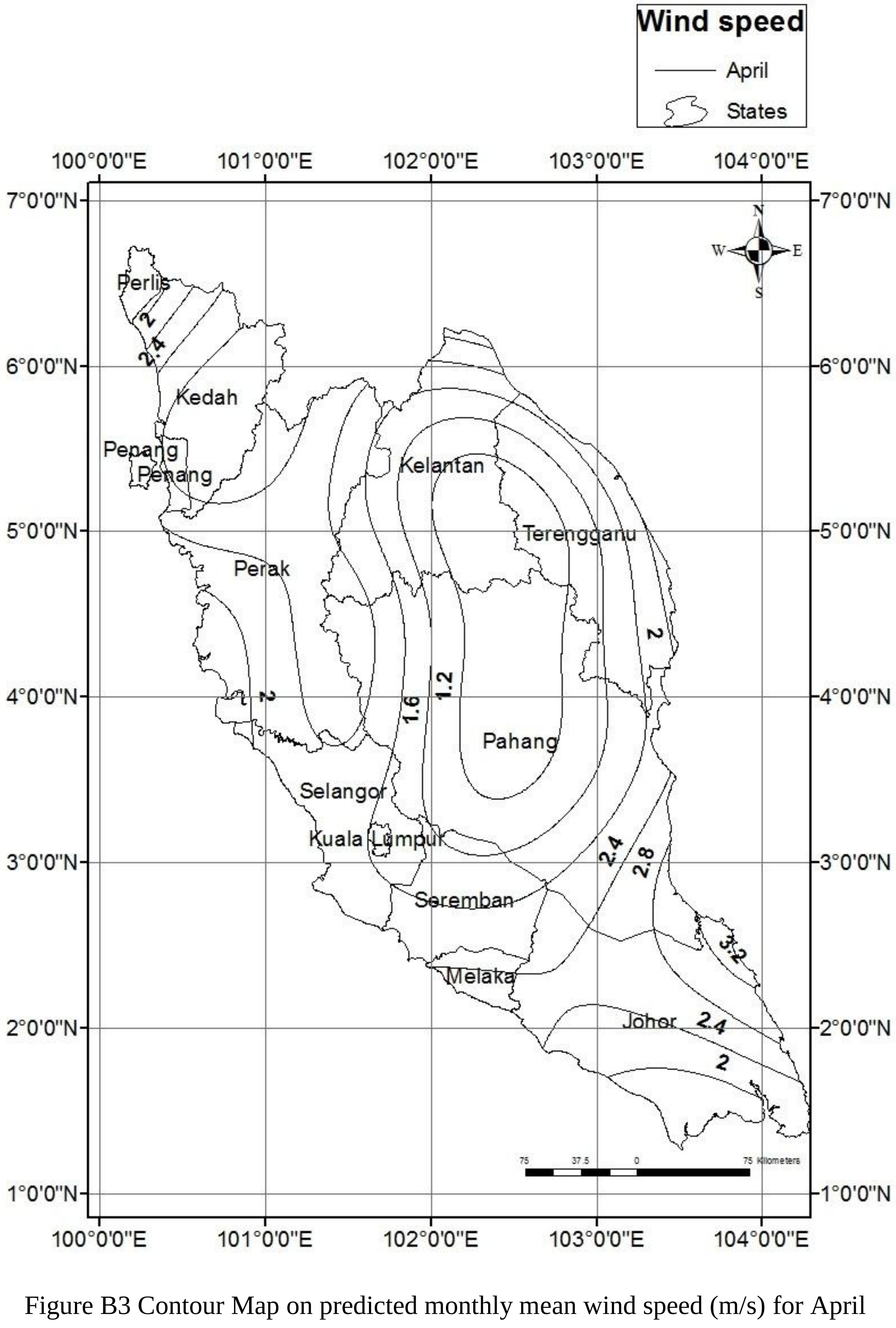

Figure B3 Contour Map on predicted monthly mean wind speed (m/s) for April

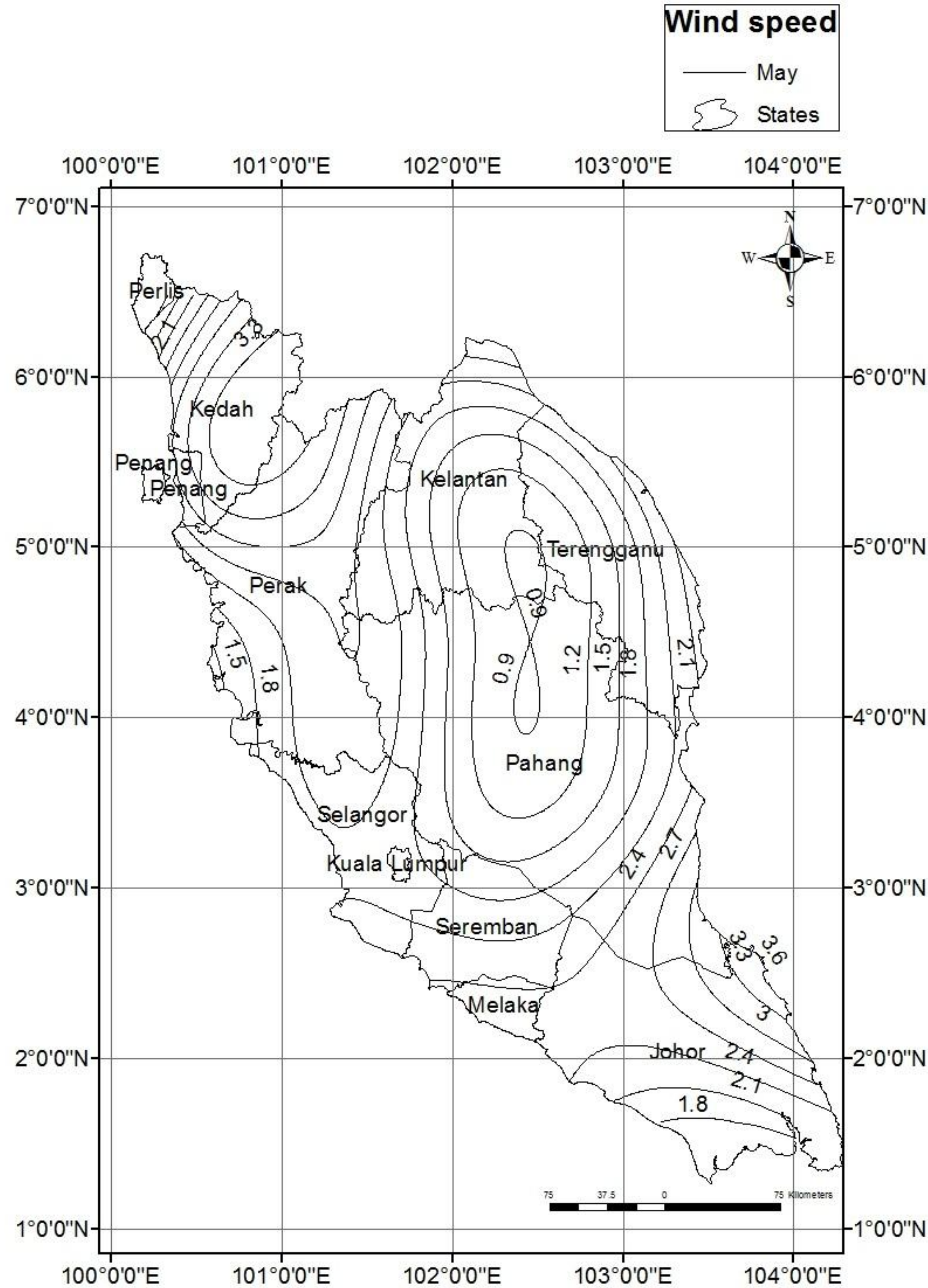

Figure B4 Contour Map on predicted monthly mean wind speed (m/s) for May

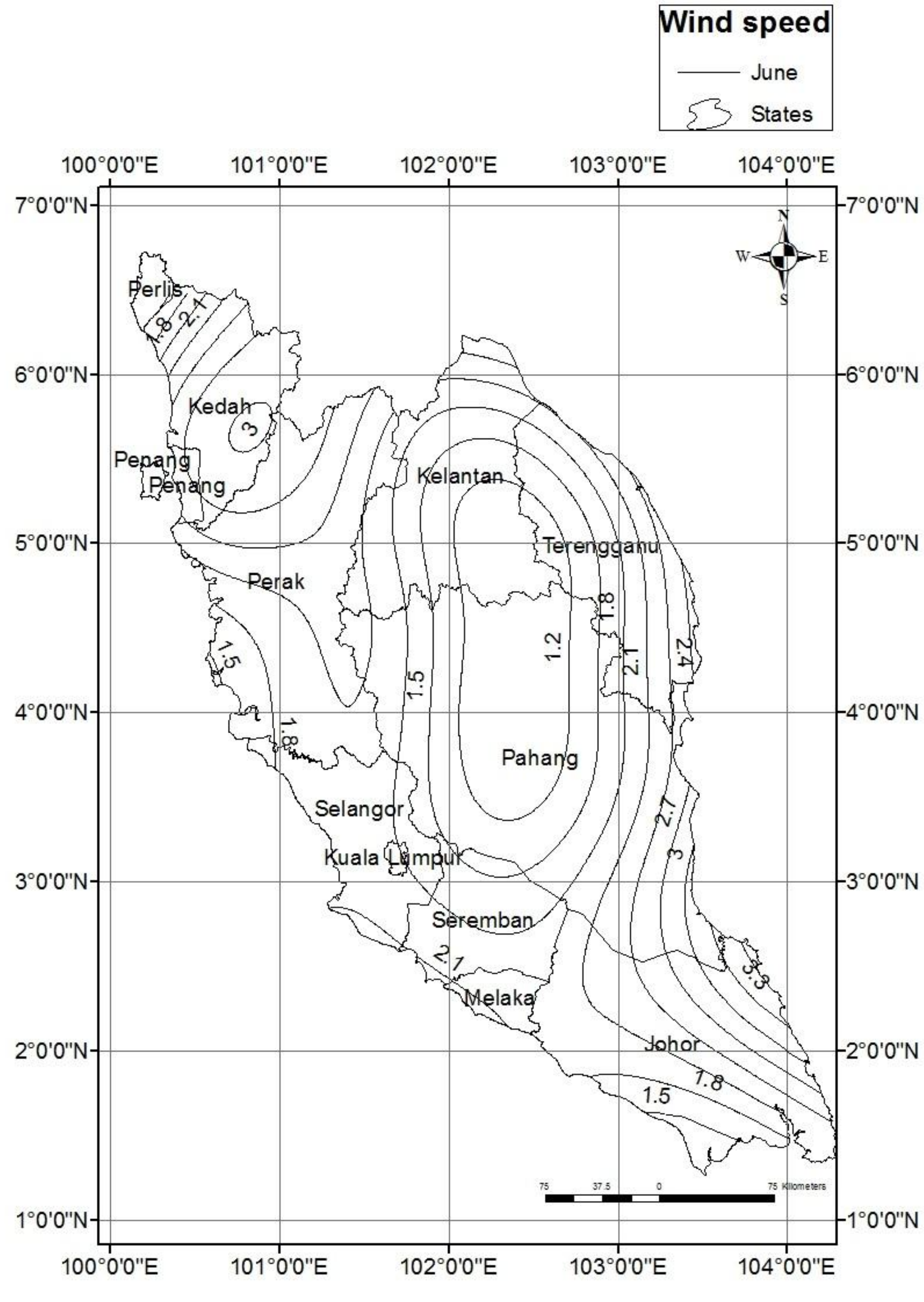

Figure B5 Contour Map on predicted monthly mean wind speed (m/s) for June

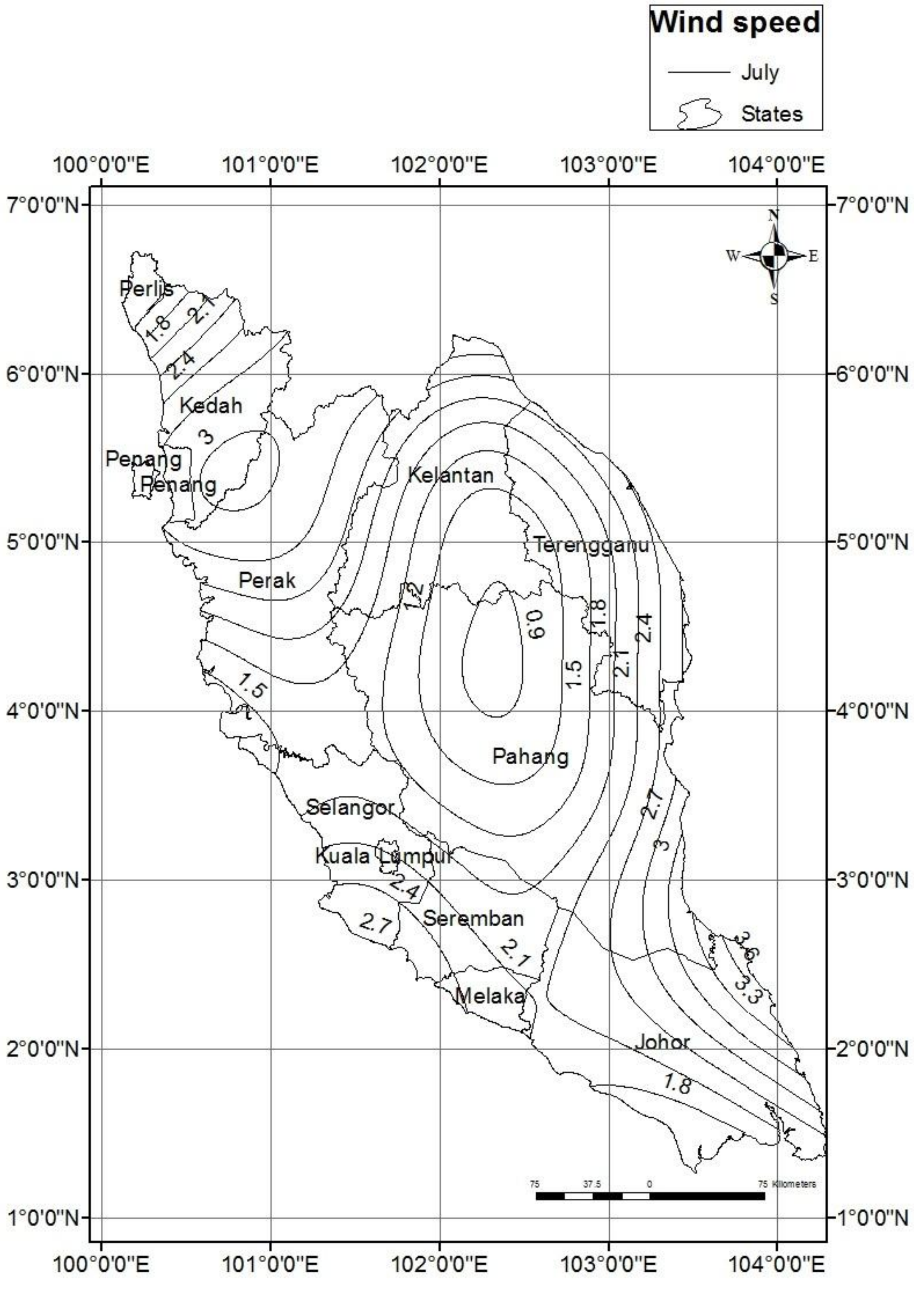

Figure B6 Contour Map on predicted monthly mean wind speed (m/s) for July

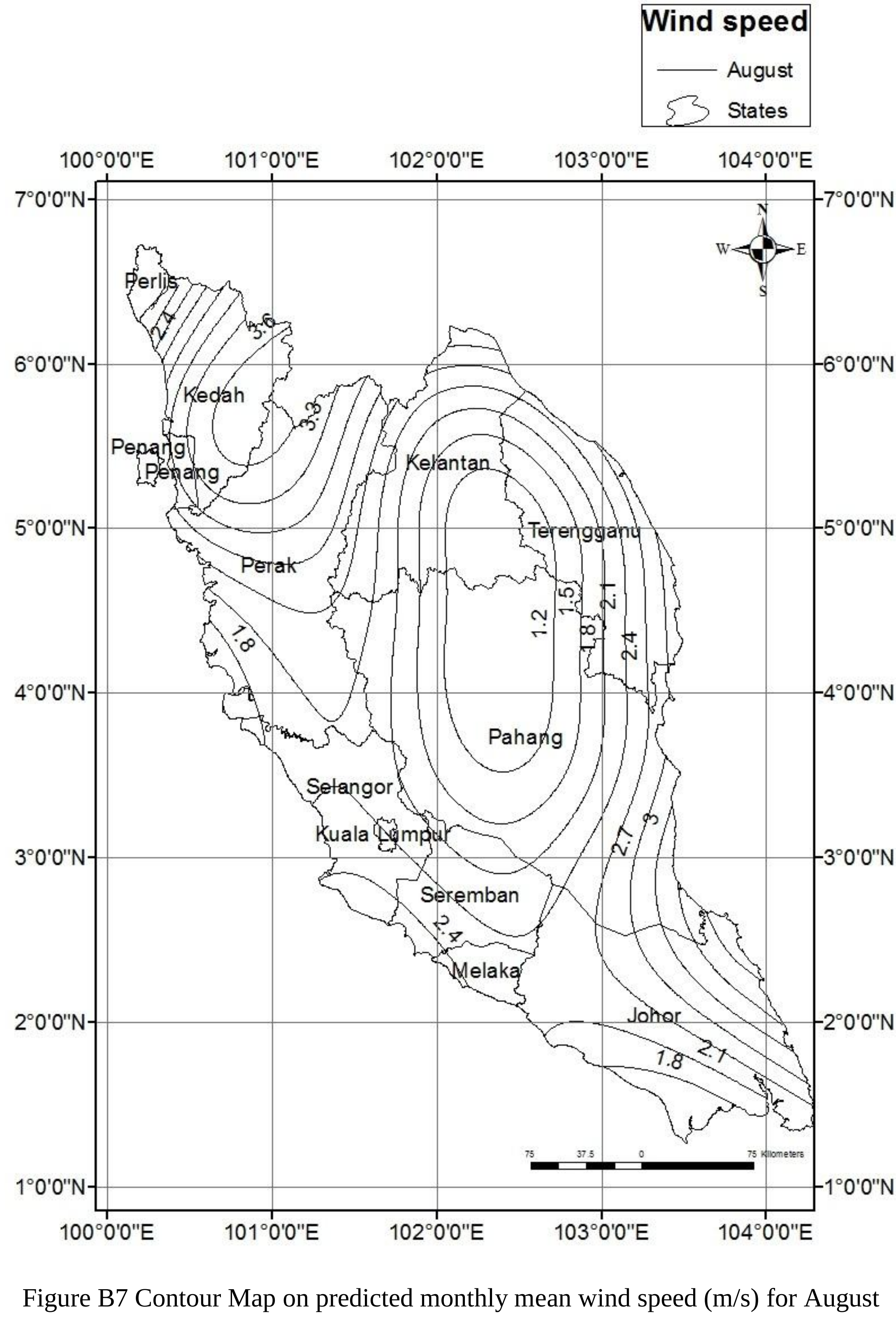

Figure B7 Contour Map on predicted monthly mean wind speed (m/s) for August

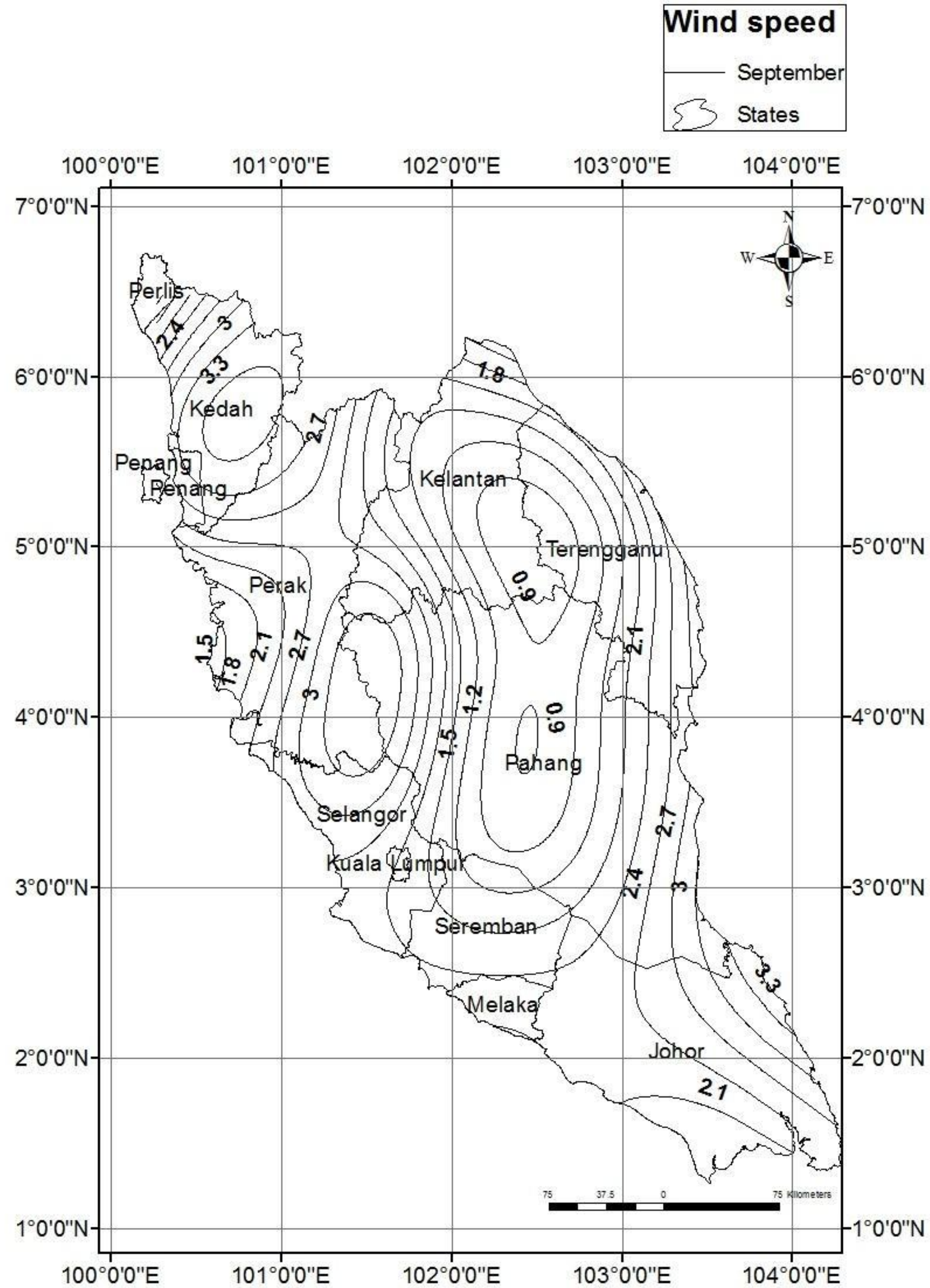

Figure B8 Contour Map on predicted monthly mean wind speed (m/s) for September

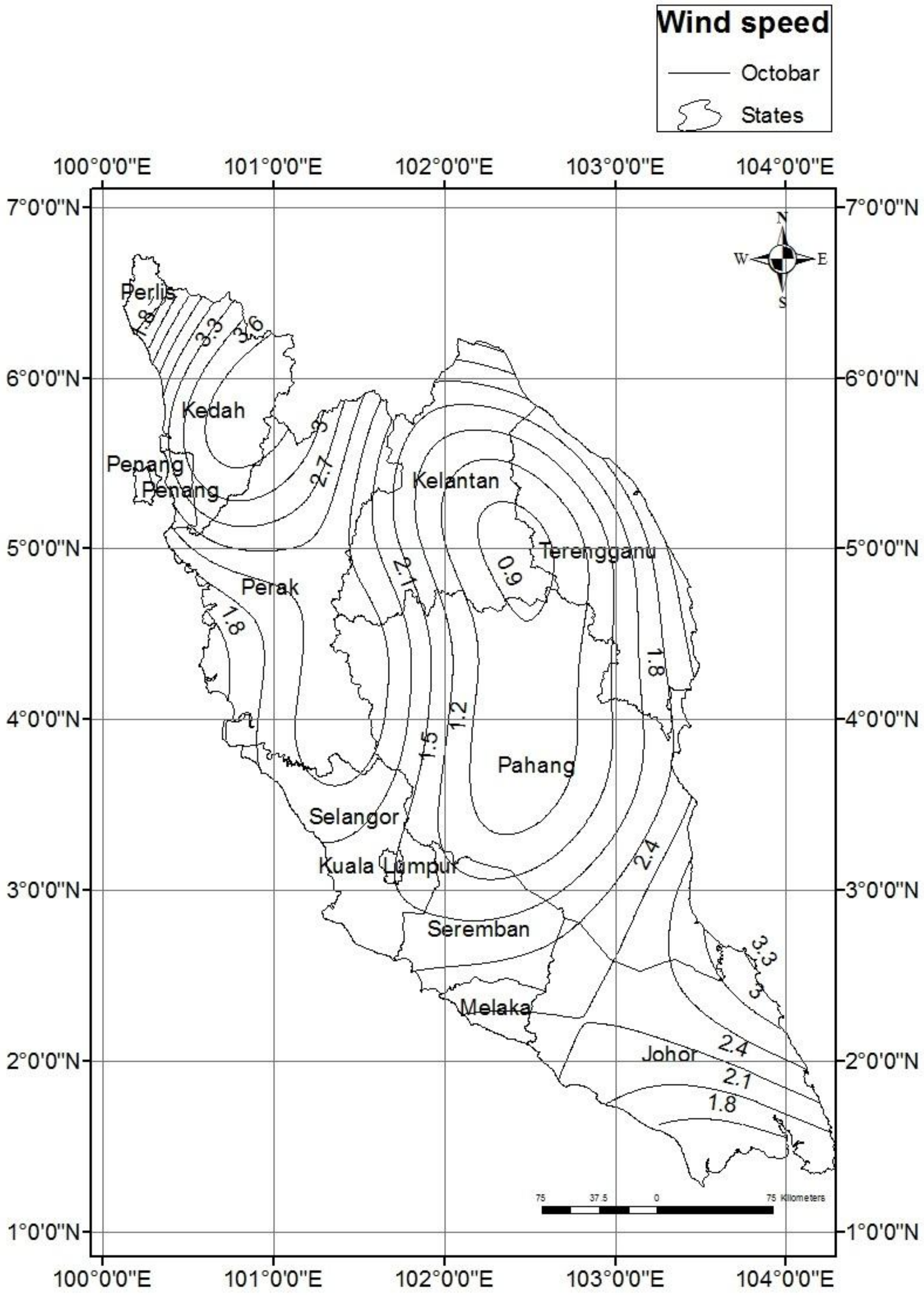

Figure B9 Contour Map on predicted monthly mean wind speed (m/s) for October

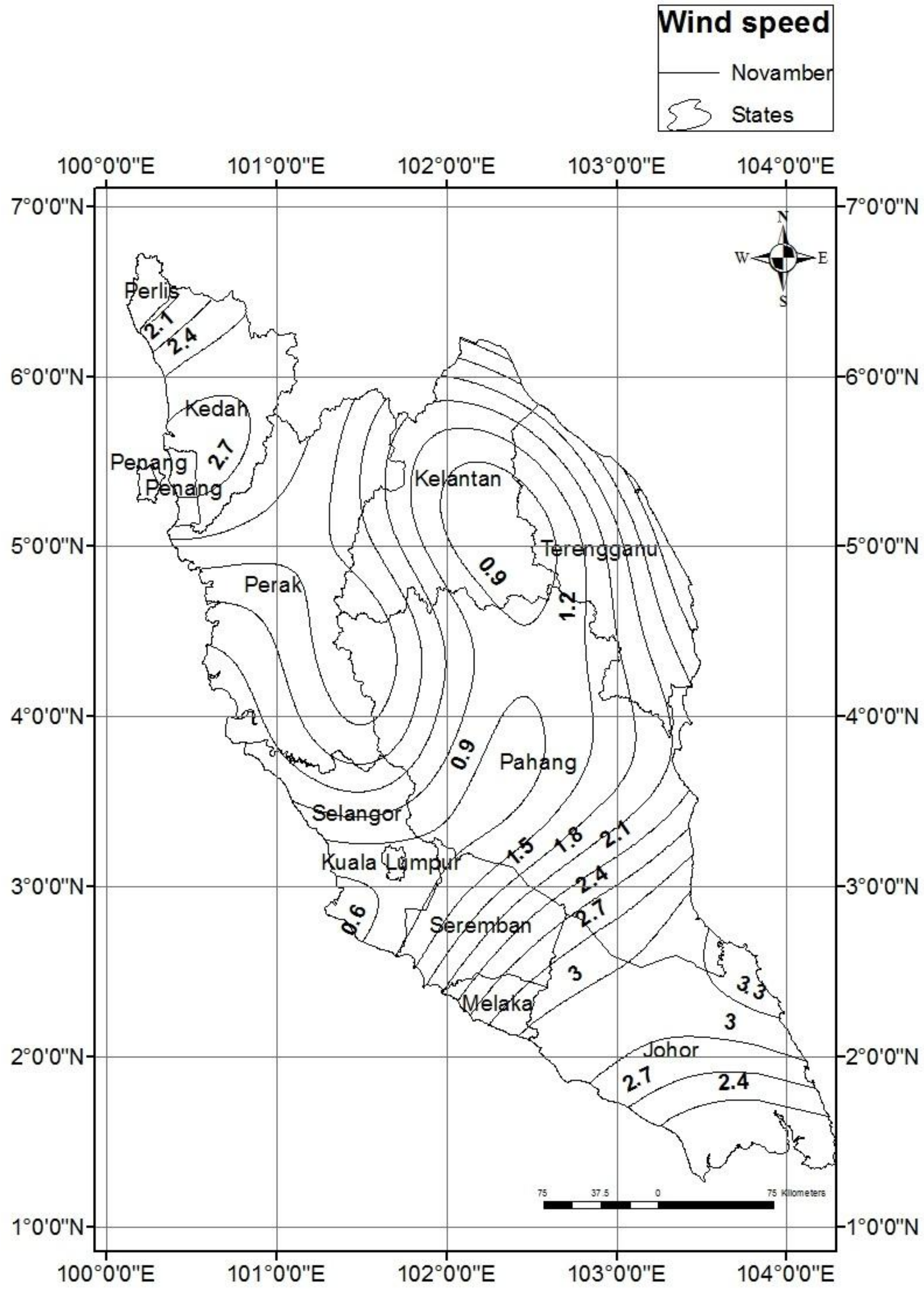

Figure B10 Contour Map on predicted monthly mean wind speed (m/s) for November

Appendix C Relevant publications

Journal Articles

1. **M.R. Islam**, R. Saidur and N.A. Rahim (2010). Assessment of Wind Energy Potentiality At Kudat And Labuan, Malaysia: Using Weibull Distribution Function. *Energy, 36(2), 985-992.*

2. R. Saidur, **M.R. Islam**, N.A. Rahim and K.H. Solangi (2010). A Review on Global Wind Energy Policy. *Renewable and Sustainable Energy Reviews*, 14(7), 1744-62.

3. R. Saidur, N.A. Rahim, **M.R. Islam** and K.H. Solangi, and (2010). Environmental Impact of Wind Energy. *Renewable and Sustainable Energy Reviews*, 15(5), 2423-2430.

4. **M.R. Islam**, R. Saidur and N.A. Rahim (2010). Assessing Wind Energy Potentiality for Selected Stations in Malaysia. *Energy Education Science and Technology Part A: Energy Science and Research. (**Under review**)*

Conference Papers

1. **M.R. Islam**, R. Saidur, N. A. Rahim and K. H. Solangi. Assessment and analysis of wind energy potential at mersing, Malaysia, 3rd international conference on science & technology (ICSTIE), Penang, Malaysia, 16-17 December, 2010, Paper No. 13.

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