THE VALIDATION OF SATELLITE-BASED WIND SPEED MAPS TO IN- SITU DATA RECORD

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ABSTRACT

Recently, wind-induced damages related to structure have been concerning in the community. Meanwhile, the problem rises among the structural designers because the wind speed information is scarce in some places. The satellite-based wind speed information over the sea could be found from the public domain. However the data from satellite-based is necessary to validate first. The main objective of this study is to validate the satellite-based wind speed maps to in-situ data records. The specific objectives are as follows; to obtain in-situ wind speed data from Malaysia Meteorology Department (MMD) and satellite-based wind speed from public domain, to analyse the satellite-based wind speed data at in-situ wind speed station, to compare the analysed satellite-based wind speed data with the correspond in-situ wind speed value. Data collected from both resources were tabulate based on the highest wind speed value in six consecutive days. Wind speed data from the satellite were analysed based on topography effect according to Malaysian standard MS 1553: 2002 and terrain category. The topography information had been obtained from the Shuttle Radar Topography Mission (SRTM) data product. The analysed satellite-based wind speed data were compared with correspond in-situ wind speed value. The value estimated from satellite-based and in-situ wind speed data show a very good agreement (correlation coefficient of - 4.9, 0.92, -0.17 and 1.01, for; Sultan Ahmad Shah Airport, Sultan Mahmud Airport, Sultan Ismail Petra Airport and Mersing Airport respectively) the regression line fitted through the origin has a slope of 0.787, 0.999, 0.9956 and 0.99. Therefore, wind speed data from the satellite is reliable when the topography information is available.

ABSTRAK

Baru-baru ini, kerosakan yang disebabkan oleh angin yang berkaitan dengan struktur telah terkenal dalam kalangan masyarakat. Sementara itu, masalah ini timbul dalam kalangan pereka struktur kerana maklumat kelajuan angin adalah sukar didapati di beberapa tempat. Maklumat kelajuan angin berasaskan satelit di atas laut boleh didapati dari domain awam. Walau bagaimanapun data dari satelit adalah perlu untuk disahkan dahulu. Objektif utama kajian ini adalah untuk mengesahkan peta benih angin berasaskan satelit kepada keputusan data in-situ. Objektif khusus seperti berikut; Untuk mendapatkan di-situ data kelajuan angin dari Jabatan Meteorologi Malaysia (JMM) dan kelajuan angin berasaskan satelit dari domain awam, Menganalisa data kelajuan angin berasaskan satelit di stesen kelajuan angin , Untuk membandingkan data kelajuan angin berasaskan satelit dengan data in-situ nilai kelajuan angina yang telah dianalisa. Data dikumpul daripada kedua-dua sumber adalah di rekodkan berdasarkan nilai kelajuan angin paling tinggi dalam enam hari berturut-turut. Data kelajuan angin daripada satelit dianalisis berdasarkan kesan topografi mengikut piawaian Malaysia MS 1553: 2002. Maklumat topografi telah diperoleh daripada Misi Shuttle Radar Topografi (SRTM) Produk data. Data kelajuan angin berasaskan satelit dianalisis dibandingkan dengan didefinasi in-situ nilai kelajuan angin. Nilai yang dianggarkan daripada berasaskan satelit dan data kelajuan angin di-situ menunjukkan keputusan yang amat baik (pekali korelasi - 4.9, 0.92, -0,17 dan 1.01, masing-masing) manakala data mempunyai kecerunan 0,787, 0.999, 0,9956 dan 0.99, untuk; Lapangan Terbang Sultan Ahmad Shah, Lapangan Terbang Sultan Mahmud, Petra Lapangan Terbang Sultan Ismail dan Lapangan Terbang Mersing masing-masing. Oleh itu, data kelajuan angin dari satelit boleh dipercayai apabila maklumat topografi disediakan.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Most probably every year some part of Malaysia will expected of damages caused by the windstorm. The damages will effect either to properties (roof blown off and vehicle destroyed), environment (uprooted tree) and human (people killed and injured). The losses caused by a typical damage value reach from thousand to a million ringgit. The severity and increased frequency of wind-related disaster events over the last five years in Malaysia has shifted the attention from the several researchers towards to investigate the effect of wind effect to building structure in Malaysia. The further understanding related to disastrous wind events in Malaysia are very significant to towards the improvement of national and international wind standards and building codes. The research effort produced valuable outcomes which become a references and basis for the engineer and researchers regarding wind related disaster.

The impacts of windstorm also could create social problem such as trauma and homeless to the windstorm victims. Victims that had been interviewed after windstorm occurrence on May 18th, 2001 at Pasir Mas, Kelantan agreed that the experience was the most frightening in their life. While, for the victims of windstorm occurrence on September 27th, 2000 at Seberang Perai Tengah, Penang, they always feel unsafe when there is a bad weather. This is due to what they had experienced (Table 1.1)

Table 1.1: Series of Windstorm Occurrence In Malaysia and It's Damages

State	Date	Damage	Estimation Loss (RM)
Perak	29 april 2000	People killed, house destroyed,.roof blown off, power pole brought down, power cable snapped and power failure.	Not stated
Kelantan	19 may 2001	House damaged and roof blown off	200, 000.00
Kuala Lumpur	31 march 2002	People killed, people injured, roof blown off, vehicle destroyed and tree uprooted.	Not stated
Kedah	10 april 2009	House collapsed, house damaged, roof blown off, roof damaged, tree uprooted and goal post blown away.	100, 000.00
Johor	25 may 2004	People injured, house collapsed, roof damaged, gate damaged, vehicle destroyed, road crashed, road closed, tree uprooted, tree trunk broken, power pole brought down, and booth blown away.	100, 000.00
Malacca	1 may 2005	Animal killed, house damaged, fence damaged, and tree uprooted.	60, 000.00
penang	1 july 2006	People injured, vehicle destroyed, and tree uprooted.	100, 000.00
Sarawak	14 january 20017	Vehicle destroyed, tree uprooted, and power pole brought down.	Not stated
Perlis	7 october 2008	House damaged and roof blown off	40, 000.00
Terengganu	30 september 2009	Uprooted tree, house collapsed, house damaged, roof blown off, vehicle destroyed, and vehicle damaged.	200, 000.00
Pahang	22 august 2010	People injured, house damaged, roof blown off, vehicle destroyed, tree uprooted and canopy blown away.	500, 000.00
Negerisembilan	30 july 2011	House damaged, roof blown off, vehicle destroyed, vehicle damaged, uprooted tree, power pole brought down, traffic light brought down, signage brought down, and canopy blown away.	1, 500 000.00
Selangor	7 february 2012	House damaged and roof blown off	250, 000.00

Source: Newspaper (2012)

Even though, injury and death is minimal, victims still suffered trauma and this is according to the eyewitnesses from those who did site investigation work after tornado occurrence. 100 families at Chukai, Kedah had to stay a few nights at school temporary until their house is repaired because their homes have been damaged by windstorm on August 18th, 2001. Most of the damaged houses were left without roofs and several trees were uprooted and fell on some of the houses. A significant increase in the number of people rendered homeless as a result of wind events in South African if more attention is being paid to underdeveloped communities and better reporting on damage in areas of mass housing and informal developments.Figure 1.1, 1.2 and 1.3 shows some of the wind-induced damage issues that happen recently in Malaysia:

Figure 1.1: Uprooted Tree in Miri Town.
Source: miri.com (26 April 214)

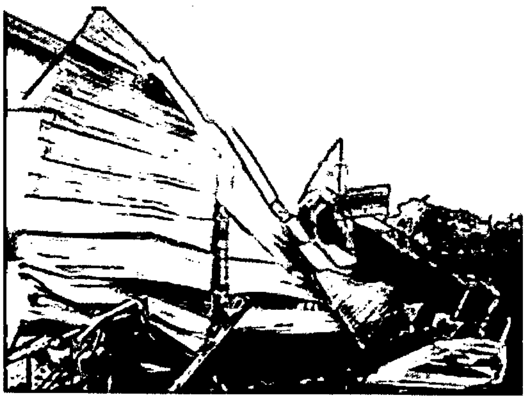

Figure 1.2: HostelRroof Collapse
Source: Sinar Harian (26 April 214)

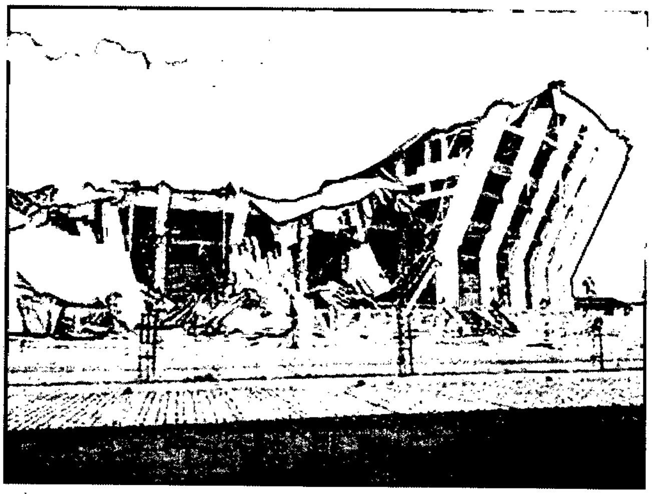

Figure 1.3: Terengganu Stadium Collapse
Source : The Star (26 April 214)

Currently in Malaysia, wind related disasters are not being given priority due to lack of expertise and awareness among the Malaysian. Incidences of damaged houses have been reported in daily Newspapers. a. The climate change in the world has resulted in significant increasing in the numbers of incidences of freak wind storm in Malaysia. It is of vital that study be carried out to under the characteristics of such freak wind storm. The lack of information regarding wind hazard are rigorously needed in order to reduce the risk reduction. One of the reasons why damages due to wind storm happened in Malaysia is because there is no specific data on wind speed value at that particular moment of incidence. The reason why the research was carried is to validate the wind speed data from the sea and get the specific wind speed value on the location of wind damage incident.

1.2 PROBLEM STATEMENT

Recently, wind-induced damages related to structure have been concerning in the community. Meanwhile, the problem rises among the structural designers because the wind speed information is scarce in some places.

The satellite-based wind speed information maps over the sea could be found from the public domain. However the data from satellite-based is necessary to validate first.

1.3 OBJECTIVE OF STUDY

The main objective of this study is to validate the satellite-based wind seed maps to in-situ data results. The specific objectives this study was as follow:

i. To obtain in-situ wind speed data from Malaysia Meteorology Department (MMD) and satellite-based wind speed from public domain
ii. To analyse the satellite-based wind speed data at in-situ wind speed station.
iii. To compare the analysed satellite-based wind speed data with correspond in-situ wind speed value.

1.4 SCOPE OF STUDY

Data collected from both resources will be tabulate based on the highest wind speed value in six consecutive days. Wind speed data from the satellite will be analyses based on topography effect according to Malaysian standard MS 1553: 2002. The topography information will be obtained from the Shuttle Radar Topography Mission (SRTM) data product. The analysed satellite-based wind speed data will be compare with correspond in-situ wind speed value.

Figure 1.4: Peninsular Malaysia East Coastal Area
Source : www.ecerdc.com.my/(26 April 214)

1.5 THESIS STRUCTURE

This research consists of five chapters. Chapter one comprises the introduction section. It states the study background, problem statement, objectives of study and lastly scope of study. For chapter two, describe the key term in- purpose of these research and comprises the literature review that related and suitable for these research. Chapter three explains the research methodology that used for planning research type of data collected and the method of data analysis to be employed. For chapter four present the result that obtained from the study area and year of study and discussed the result from analysis. Finally, chapter five comprises the conclusion from the overall chapter and relates some recommendation for future work on research field.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Wind is the flow of gases on a large scale. On the surface of the Earth, wind consists of the bulk movement of air. In meteorology, winds are often referred to according to their strength, and the direction from which the wind is blowing. Short bursts of high speed wind are termed gusts. Strong winds of intermediate duration (around one minute) are termed squalls. Long-duration winds have various names associated with their average strength, such as breeze, gale, storm, hurricane, and typhoon. Wind occurs on a range of scales, from thunderstorm flows lasting tens of minutes, to local breezes generated by heating of land surfaces and lasting a few hours, to global winds resulting from the difference in absorption of solar energy between the climate zones on Earth. Trade winds also one of the effect of the wind movement thorough the earth. The trade winds or trades are the prevailing pattern of the easterly surface winds founds in the tropics, within the lower portion of the earth's atmosphere, in the lower section of the troposphere hear the earth's equator. The trade winds blow predominantly from the northeast in the Northern Hemisphere and from the southeast in the Southern Hemisphere

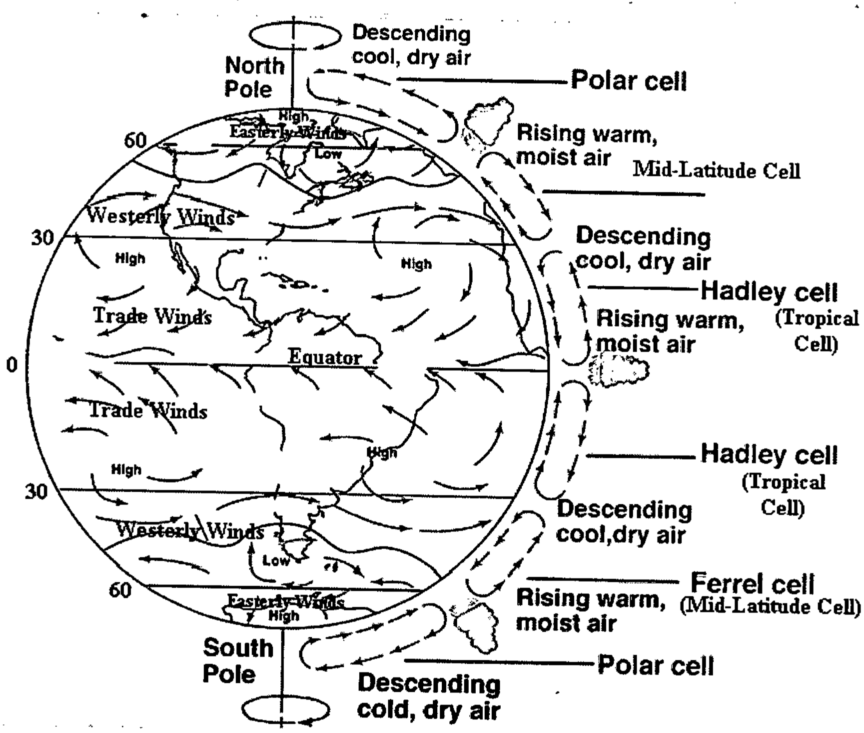

Figure 2.1: Large-Scale Atmospheric Wind Circulation

Source: geology.campus.ad.csulb.edu (26 April 214)

2.2 CHARACTERISTIC OF WIND

The earth's atmosphere can be modeled as a gigantic heat engine. It extracts energy from one reservoir (the sun) and delivers heat to another reservoir at a lower temperature (space). In the process, work is done on the gases in the atmosphere and upon the earth-atmosphere boundary. There will be regions where the air pressure is temporarily higher or lower than average. This difference in air pressure causes atmospheric gases or wind to flow from the region of higher pressure to that of lower pressure. These regions are typically hundreds of kilometers in diameter.

2.2.1 WIND DIRECTION

Wind direction is reported by the direction from which it originates. For example, a northerly wind blows from the north to the south. Wind direction is usually reported in cardinal directions or in azimuth degrees. For example, a wind coming from the south is given as 180 degrees; one from the east is 90 degrees. There are a variety of instruments used to measure wind direction, such as the windsock and wind vane. Both of these instruments work by moving to minimize air resistance. The way a weather vane is pointed by prevailing winds indicates the direction from which the wind is blowing. The larger opening of a windsock faces the direction that the wind is blowing from; its tail, with the smaller opening, points in the direction the wind is blowing. Modern instruments used to measure wind speed and direction are called anemometers and wind vanes respectively. Figure 2.2 shows the wind compass describing the sixteen principal bearing used to measure wind direction.

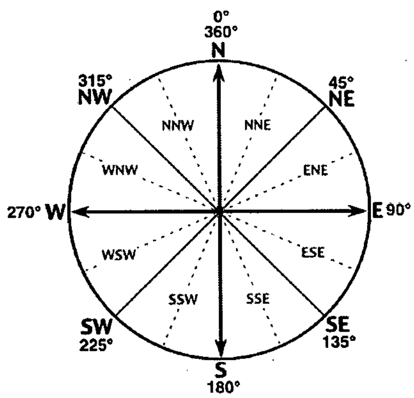

Figure 2.2: Wind Compass Describing The Sixteen Principal Bearings Used to Measure Wind Direction.

Source: physicalgeography.net (26 April 214)

2.2.2 WIND SPEED

Wind speed, or wind velocity, is a fundamental atmospheric rate. Wind speed is caused by air moving from high pressure to low pressure. Wind speed affects weather forecasting, aircraft and maritime operations, construction projects, growth and metabolism rate of many plant species, and countless other implications. Wind speed is now commonly measured with an anemometer but can also be classified using the older Beaufort scale which is based on people's observation of specifically defined wind effects.Wind speed is affected by a number of factors and situations, operating on varying scales (from micro to macro scales). These include the pressure gradient, Rossby waves and jet streams, and local weather conditions. There are also links to be found between wind speed and wind direction, notably with the pressure gradient and surfaces over which the air is found. Pressure gradient is a term to describe the difference in air pressure between two points in the atmosphere or on the surface of the Earth. It is vital to wind speed, because the greater the difference in pressure, the faster the wind flows (from the high to low pressure) to balance out the variation. The pressure gradient, when combined with the Coriolis Effect and friction, also influences wind direction. Rossby waves are strong winds in the upper troposphere. These operate on a global scale and move from West to East (hence being known as Westerlies). The Rossby waves are themselves a different wind speed from what we experience in the lower troposphere. Local weather conditions play a key role in influencing wind speed, as the formation of hurricanes, monsoons and cyclones as freak weather conditions can drastically affect the velocity of the wind.

2.3 METHOD ON HOW TO GET WIND CHARACTERISTIC

Regular data on wind speed and wind direction is required not only by meteorological stations throughout the world, for general forecasting and weather records, but specifically by airport and marine authorities, civil engineers and contractors on major projects, agriculturists, sport and outdoor event promoters, holiday tour operators, resort managers and many more. There are a few examples on method to find wind characteristic such as:

1. Weather balloon
2. Satellite data

2.3.1 WEATHER BALLOON

The invention of the weather balloon inaugurated the age of remote sensing , the ability to collect information from unmanned sources. Use of weather balloons is now common in advanced atmospheric research. High altitude weather balloons have also been used by astronomers and cosmologists seeking to take readings of certain particle frequencies or gather light readings free of excessive disturbance from Earth's relatively thick lower atmosphere (troposphere).

The first observation balloon was launched immediately before the first manned balloon flight by Frenchmen Jean-François de Rozier and the Marquis d'Aalandes on November 21, 1783, for a pre-flight wind reading. Later, French meteorologist Leon Teisserenc de Bort (1855-1913) pioneered the use of weather balloons, handily proving their utility. With balloon-acquired data, he determined the existence of a lower level of the atmosphere, which he termed the troposphere or "sphere of change," where weather takes place. Since the 1930s, when radio tracking systems were invented, balloons have been used as complete floating weather stations, employing such instruments as thermometers, barometers, hygrometers, cameras, and telescopes.

2.3.1 SATELLITE

Microwave sensors aboard satellites can provide coverage for large areas but just a few observations during the day. Also, since satellite sensors operate at microwave frequencies, they can measure surface winds during nighttime and cloudy conditions. Both active (radar) and passive (radiometer) microwave sensors have been shown capable of determining the ocean surface wind speed, with active microwave instruments being used to derive the wind direction. Recently, radiometer systems have been shown capable of determining the wind direction using polarimetric and multi-look observations. Development and refinement of instrumentation and algorithms for ocean surface wind retrieval is an ongoing process being conducted in both the active and passive areas

Using an instrument called a scatterometer an orbiting satellite beams microwave radiation (which penetrates cloud cover) at the surface of the ocean. By measuring the amount of this radiation reflected back from the surface at different angles the Satellite can deduce the direction and speed of travel of the tiny wind generated capillary waves on the surface of the ocean. Knowing how these waves are moving in turn allows the Satellite to calculate the strength and direction of the wind at the sea surface – the critical bit of information we need to then forecast the generation of waves, swell and ultimately, surf.

2.4 EFFECT OF TERRAIN AND TOPOGRAPHY TOWARDS WIND CHARACTERISTIC

Wind speed increases with increasing height above the ground, starting from zero due to the no-slip condition.The wind speed values vary according to the ground level. The higher the roughness of the earth surface, the more momentum is lost at the ground. Therefore, the offshore wind speed is higher than the wind speed on the ground.Surface friction forces the surface wind to slow and turn near the surface of the Earth, blowing directly towards the low pressure, when compared to the winds in the nearly frictionless flow well above the Earth's surface.

This layer, where surface friction slows the wind and changes the wind direction, is known as the planetary boundary layer. Daytime solar heating due to insolation thickens the boundary layer as winds at the surface become increasingly mixed with winds aloft. Radiative cooling overnight decouples the winds at the surface from the winds above the boundary layer, increasing vertical wind shear near the surface, also known as wind gradient.

2.5 EFFECT OF WIND TOWARDS STRUCTURE

Wind direction, speed and frequency will influence the building design including bracing requirements, roof and wall cladding selection, weather tightness detailing, building entry locations, window size and placement and provision of shelter for outdoor spaces. Wind forces can break the building's load path or punch a hole in the building envelope. Sometimes the actual force of high winds can cause a door or window to break open.

Other times nearby debris can be picked up in the wind and projected against the building envelope. Roof shingles from a neighbor's home, branches from fallen trees, or unsecured yard furniture are examples of potentially dangerous wind-borne debris.

Once wind forces create an opening in the building envelope, the dangers of structural failure greatly increase. Water intrusion is another damaging effect of wind-driven rain.

2.6 SUMMARY

Wind characteristic such as the wind speed and wind direction can change due to topography and terrain effect. Therefore it is important to get the wind speed data by using recent technology in order to design a structure.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter describes the phases involved in achieving the study objectives. There were FOUR (4) phases, namely; i) data collecting, ii) pre-processing, iii) processing, and iv) results and analysis (Fig. 3.1). Data collecting, pre-processing and the processing will be explained in the following sections in this chapter. While the results and analyses are described in Chapter 4.

The research will be starting with collecting in-situ wind speed data from the Malaysia Meteorology Department (MMD). The data product of the satellite-based offshore wind speed will be obtained from the public domain (www.windfinder.com).Variation of topography profile will be obtained from Shuttle Radar Topography Mission (SRTM) (www.cgiar-csi.org/data). And lastly the Terrain category will be determined based on Google Map.

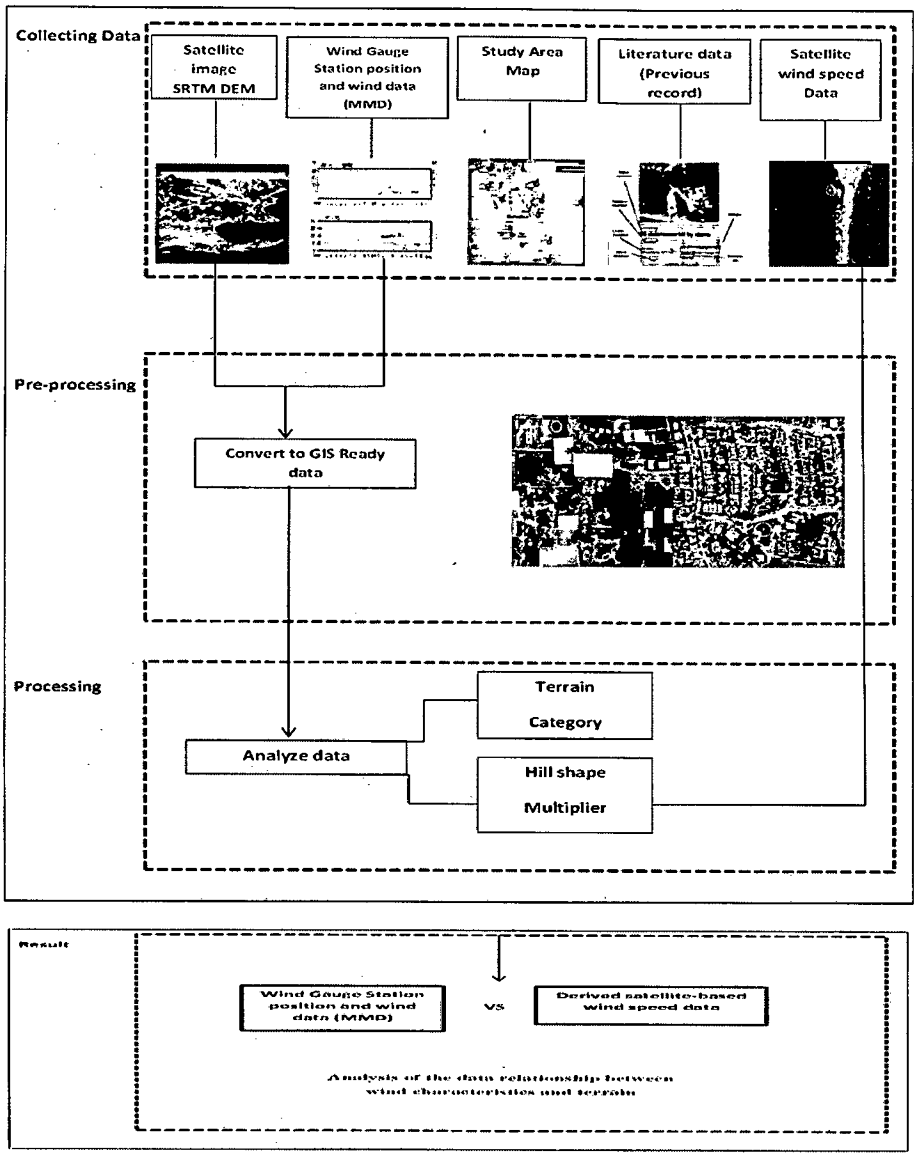

Figure 3.1: Methodology flow chart

3.2 DATA COLLECTING

Data collected are the value of highest Wind speed data in 6 days collected by Malaysia Meteorology Department (MMD) by using SRTM collect. Instruments used for measuring the surface wind speed are called anemometers. It is usually located around Malaysian airports, thus the data collected involve four main airports in east Malaysia:

1. LapanganTerbang Sultan Ismail Petra, Kelantan
2. LapanganTerbang Sultan Mahmud, Terengganu
3. LapanganTerbang Sultan Ahmad Shah, Kuantan
4. LapanganTerbangMersing, Johor

The satellite data of wind speed in the exact time and date of the location is also recorded from the public domain. Table 3.1, Table 3.2, Table 3.3 and Table 3.4 show the recorded value of wind speed data in a consecutive of 6 days around east coast Peninsular Malaysia.

Table 3.1: Wind speed data of LapanganTerbang Sultan Ahmad Shah, Kuantan

No	Date	Time	Wind Speed Value (mmd)	Wind Speed Value (satellite)
1	17 April	1700	15 km/h (90 E)	14.8 km/h (90 E)
2	18 April	1600	20 km/h (250' WSW)	20 km/h (250' WSW)
3	19 April	1700	17 km/h (100 E)	16.7km/h (90 E)
4	20 April	1500	13 km/h (100 E)	13 km/h (90 E-180S)
5	21 April	1700	15 km/h (110 ESE)	14.8 km/h (110 ESE)
6	22 April	1600	17km/h (90E)	16.7 km/h (90E)