# Review of Offshore Wind Energy Assessment and Siting Methodologies for Offshore Wind Energy Planning in Malaysia

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## Abstract

*Malaysia is new to offshore wind energy. There are a few studies and experiments carried out to gauge the wind potential of Malaysia. The exploration of wind energy as one of the renewable sources has gained more attention as the fossil fuel problems of the country become more serious both economically and environmentally. This paper presented numerous wind assessment methods and argues for offshore wind energy potential in Malaysia as well as the method that is suitable and available for future research. A quick reference was made to QuikSCAT and WindSat to highlight the offshore wind potential of Malaysia. An annual wind speed of 6-7m/s at 50m and the existence of more than 10 knots at 10m throughout the year should be a good incentive for further research.*

**Keywords:** Offshore wind farm, Offshore wind energy assessment, Offshore wind farm siting, Siting Criteria, QuikSCAT, WindSat, Malaysia

## *1.0 Introduction*

Malaysia being a heavy fossil fuel dependant country generates its power not without cost to the environment as well as the economy. The United States Energy Information Administration (2011) showed that in year 2009 alone Malaysia emitted 149.6 million metric tons of carbon dioxide to the atmosphere due to energy consumption. On the other hand, the fuel price hike is increasingly choking the country's economy. The most recent and immediate issue affecting the power generation in Malaysia is the insecure gas supply which leads to more dependent on coal and more import of gas, all that contribute to more green house effect.

At the same time the national's main power producer, TenagaNasionalBerhad (TNB) is facing cash shortages and recorded less profit due to the instable gas supply,a dire situation for a nation's monopoly power producer(Yap, 2011).These are typical power generation problems affecting not only Malaysia but most part of the worldin different conditions and they are mounting to an alarming rate.

The threat of fossil fuel availability, rising oil prices, air pollution emissions, and global warming was highlighted by the Kyoto Protocol back in 1997.Therefore there is an immediate and urgent need to find the solution, partially or fully and they have to be fast, economically sound and environmentally safe. Clean, emissions free wind power is increasingly important as part of the solution to the twin global crises of energy security and climate change apart from creating new jobs and economic opportunities at an extraordinary pace (GWEC, 2008). The harvesting of wind energy would only produce comparatively low $CO_2$ emissions during its construction, maintenance and decommissioning stage. The lifetime $CO_2$ emissions of a wind farm project ranges from 8.1 to 123.7g/kWh contrary to that of newest fossil fuel energy plants in a range of 344 and 846g/kWh (Punt et al., 2009).

For the third year in a row, Asia was the world's largest regional market for wind energy, with capacity additions amounting to more than 19GW (GWEC, 2011). There are tremendous wind power potentials in this region and China is taking the lead in utilizing the renewable resource. Others including India, Japan, Taiwan, South Korea, Philippines, Thailand, Bangladesh, Indonesia, Sri Lanka and Vietnam have started their wind energy installation. Malaysia will not be excluded and there are huge offshore wind potentialsespecially with the Monsoon wind carrying lots of renewable energydespite its seasonal occurrences. However, any large scale installation of wind turbinesor expansion of wind farms would inevitably involve planning constraints and environmental conflicts, all associated with the siting of the new wind farms (see Moller, 2011, p. 511, Bishop and Stock, 2010, p.2348).

Offshore wind farms are explored due to the openness of sea areas with less turbulence and less wind shear plus steadier winds thus allows larger wind farms but not with negative effects like higher investments costs for wind turbine foundation, the underwater cabling for electrical grid and the challenging maintenance posed by the sea conditions. At the same time, offshore wind farm can be beneficial (act as artificial reefs and no-take zone creating spill-over effects) or detrimental (causes avian collisions, underwater noise and electromagnetic field) ecologically depending on its location (Punt et al., 2009, Jay, Stephen, 2010, Beaucage et al., 2011).The trade off between the economic (revenue from the wind farms) and ecological (impact on wildlife and marine ecosystem)consideration is not only complicated but of significant importance and therefore must be thoroughly analysed during the planning and siting of any offshore wind farm.

Conventionally, the development of onshore wind farms globally had been extensively covered by the regulations of the local planning system which mostly ends at border near shore. However any activity offshore would falls under the jurisdiction of the central government (Nielsen, 1994) departments overlooking matters related to international boundary, exclusive zones and other maritime sectors. References between the departments are often limited, with none of the more comprehensive approach to planning considerations onshore.Therefore the local planning authority in which the offshore wind farms are related must develop a capacity to siting and planning of them (Sperling et al., 2010). "Siting" is equivalent to "siting policy" which refers to a policy that deals with local issues related to the siting of wind power infrastructures (Nadai, 2007, p.2716); thus there must be local collaboration and a comprehensive planning approach to siting offshore wind farms.

The Netherlands had a bad experience of expending their offshore wind by relying on the market to freely lead the siting of offshore wind farms which produced unsatisfactory and disorganized siting regardless of the environmental consequences of such actions (Jay, 2010). Such system was gradually closed to give way to proper siting.Therefore there exists a definite need to construct the spatial planning system offshore in order to have a comprehensive and proper planning of offshore space. The development and planning of wind farms are related to site selection, initial and detailed wind assessment, feasibility, construction and operation. Wind resource is the most important consideration for a wind energy plant (Ozerdem et al., 2006) and therefore initial wind energy assessment is normally carried out for a wider area to scout for potential wind energy resource.This paper will give an overview of the initial wind energy resource assessment and the siting of offshore wind farm. It will also look into the wind energy planning in Malaysia. The following section discusses the various methodologies used for offshore wind energy assessment.

## *2.0 Methodologies for offshore wind energy assessment*

It is commonly accepted that the best method to determine wind energy potential for an area is to carry out wind measurement for several years provided the measurement site is of sufficient representation of the wind condition of the areas concerned (Burlando et al., 2009).However it would be very complicated to carry out that kind of measurement by adding meteorological or measurement stations and buoys to measure a large water area offshore. Therefore there exist numerous methodologies to assess wind energy according to different situation.

### 2.1 Spatially Continuous Resource Economic Assessment Model for Offshore Wind Energy

Based on a few predecessors, Moller (2011) presented a model called Spatially Continuous Resource Economic Assessment Model for Offshore Wind Energy (SCREAM-offshore wind) based on GIS and supply cost curve analysis. SCREAM was developed as a continuous regional or national offshore planning tool with capability to analyse cumulative offshore wind energy production and its marginal cost. There are three main elements in SCREAM, i.e. wind power production calculator (MWh/km$^2$) presented in wind power density map, the real cost of producing one energy unit ($/km$^2$) and exclusion of offshore areas not suitable for wind farms. The result is an exclusion overlay map useful to the energy plannerslooking at available space for developing offshore wind farms. At the same time, a cost-supply analysis provides a good scenario to gauge the potential wind power production (TWh/yr) versus marginal production cost ($/MWh). Based on those, the model is able to quantify the available areas for offshore wind farms as well as its energy production and production cost. Nevertheless, the model is able to calculate as well the opportunity costs if the best location is not used for offshore wind farms. On the other hand, the cost and production input could also be used to look into the scale of the wind farms to enable more positive results (near shore location versus higher production cost). This model is a planning tool suitable for the above mentioned purpose but not the actual siting of a wind farm. It identifies available areas but not to the extent of pinpointing the exact location mainly due to its coarse raster resolution (model elements outputs per area unit: 1km$^2$).

### 2.2 Accessible and inexpensive method

Another method was used by Dhanju et al. (2008) in assessing offshore wind resources taking the US state of Delaware (ocean area of 4777km$^2$) as area of study. Three steps constituted their method which were developed based on the principles of having an assessing method suitable for ocean use rather than adopting from land methodologies; using existing data but not on-site measurement; high accessibility without purchasing new equipment or proprietary software; useful for large areas and accurately depicting annual wind fluctuations and pricing. First, the bathymetric map based on turbine tower technology (GE 3.6 as example) showing available water sheet areas is calculated. After that the power production is calculated based on available area to determine the location and count of turbines. Later the wind data (buoy and meteorological stations data) are extrapolated to turbine height (along with turbine output curve) to establish the expected electric power production on an hourly basis. Lastly the market value based on the nearest electric grid node is calculated. This method does not requires constructing any modelling or proprietary software (which is costly and takes relatively longer time) thus it is more accessible and inexpensive for the energy planner, education institution or any organization to carry out initial assessmentfor offshore wind resource, at the very least.

### 2.3 Numerical weather prediction

The previous method proves to be inexpensive and more accessible but not with riskand constrains associated with using data of meteorological departments. The reason as highlighted by Sultan Al-Yahyai et al. (2010) includes that of costly installation of new weather stations; coarse resolution of wind measurement which is not suitable for wind energy assessment; original function of weather station is to serve meteorological applications which is intended for places like airport, ports or close to urban areas (contrary to wind turbines which are mostly placed away from the mentioned areas); estimations errors from extrapolation methods to suit wind data to turbine hub (above 50m, where few measurements are available at typical meteorological stations); data from meteorological stations (not fully digitized) are not readily suitable for researchers use especially those from old weather stations; and at least a minimum one-year data (Sultan Al-Yahyai et al., 2010, Ozerdem et al., 2006)is needed for seasonal variation assessment (or ten-years for more reliable results for long term variability) for any newly added station.

Numerical Weather Prediction (NWP) model provides alternative accurate wind data and it is largely used for wind resource mapping (Beaucage et al., 2011). NWP is a computer program calculating the equations which describes the atmospheric processes including its time variation. The weather prediction model is based on the assumption of the significance correct initial value to produce accurate predictions, all on numerical approximation. The model works by dividing the atmosphere into 3D cubes with grid points in the middle of each cubewhich solves weather parameters within it. The minimum distance between grid points represents the horizontal model resolution while the atmosphere is vertically divided into layers. More layers provide better prediction but require more computation. NWP models are divided into global models (for global predictions, will not be discussed in this paper) and limited areas models (LAM) such as HRM, ETA, mesoscale model MM5, weather research forecast WRF, ALADIN and Consortium for Small scale Modelling COSMO. Different LAMs (according to numerical formulation, assumptions, especially hydrostatic assumption and equation simplifications) are available for research and operational use. NWP models are typically run twice a day providing wind speed and direction as typical output parameters.A combination of satellite mapping (QuickSCAT), LAM (HIRLAM) and MM5 can be used in a 'one way nesting' technique to produce an offshore wind atlas (see Mederos et al., 2011).Alternatively, Dvorak et al. (2010) also runs MM5 in a one way nested domain in assessing California offshore wind energy potential.

Numerous NWP models are available freely from internet downloads. They can run in very high resolution (even to 2-3km providing more accurate predictions) depending on the capability of the computer. The extrapolation issues which raised estimations error can be countered by solving the equation within each grid point. At the same time, the vertical layers are typically configurable input parameter for the model thus able to produce predictions at different altitudes. When dealing with real data measurement issues, NWP allows for a rerun for any period of time thus allowing flexibility unlike one cannot go back in time. On the other hand, NWP saves time, effort and money when for example a year of data can be produced within a shorter period of time depending on the computational speed. Nevertheless NWP do work with real world measurements, at least at the initial stage (main assumption as discussed earlier) to predict for the future.

Many wind assessment studies were carried out using the NWP model wind data (see Burlando et al., 2009) however limitations do exist for these models. The model structure of having horizontal and vertical resolution plus the time integration remains an approximation of reality which is subject to conditions unpredictable. This is also true in a sense of simplifications of atmospheric physical processes which are not sufficiently understood to be represented in equation format. The uncertainty in initial datamay render the whole prediction insignificant. The same goes to the lateral boundary conditions in LAMs when they are mathematically represented meteorological conditions but coarsely related to the global model, which influence the quality of the LAM output. Lastly there exist some uncertainties when vegetation type, soil type and vegetation fraction are group in more general categories having similar characteristics due to computational limitations (Sultan Al-Yahyai et al., 2010).

### 2.4 Synthetic aperture radar (SAR)

Many studies have shown that SAR approach is a suitable tool for wind energy assessment as well as wind mapping for offshore areas besides validating and improving NWP and its results (Beaucage et al., 2011). The SAR satellite method uses snapshots of the sea surface roughness to provide measurements of sea surface winds. The density of the SAR image database will determine the reliability of the wind statistics. The only drawback with SAR is that of the large scene sample required to accurately calculate wind statistics.That is particularly true for a random sampling where it is found that a minimumof 75 and 175 (or more) wind observations are required to accurately estimate the Weibull scale and shape parameters respectively. However, in an effort to save cost on wind mapping, Beaucage et al. (2011) uses a strategic sampling approach requiring a relatively smaller number of observations to obtain a precise estimation of wind resources. This can be done by fitting the SAR wind data to a reference Weibull distribution, using an existing long term wind distribution as a reference.In this case, less than 30 SAR scenes are needed to accurately estimate the Weibull scale parameter, which is comparatively less compared to a random sampling.

## *3.0 Methodologies for siting offshore wind farm*

Good location is fundamental for successful wind farms. Three key factors influencing the location of wind farms are wind energy output, grid availability and construction conditions (Ozerdem et al., 2006). On the contrary, there are limiting factors like technical, economic, social and environmental considerations which presents the siting difficulty prompting a variety of methodologies to mitigate them. Siting difficulty is defined as any combination of obstacles in the wind turbine siting process, including environmental, topographic, and geographic constraints; public opposition; local, state, and federal regulatory barriers to permitting, investment, and/or construction (Tegou et al., 2010). Conflicting use among different activities further complicates offshore wind farm siting, among them and primarily the aesthetic impacts of offshore wind farm on the seascape (Ladenburg and Dubgaard, 2009). Therefore siting offshore wind farm becomes a complicated task requiring the measurement of preferences on the choice of the location of the offshore wind farm and the factors influencing it. This section will discuss the various methodologies related to the siting of offshore wind farms.

### 3.1 Analytical hierarchy process

The Analytical hierarchy process (AHP) method was first developed by Saatyin the 1970s to be a flexible and simple Multi-criteria Analysis (MCA) and it has been largely explored in literature related to locating facilities. AHP is recognised in its ability to consider tangible and intangible criteria in giving solutions to a multi-criteria problem. There are two distinct character of AHP, i.e. the ability to assign a hierarchy structure and conducting pair-wise comparisons between different criteria (attributes are ranked against each other to assess their relative importance); at the same time it is able to screen out inconsistent judgements by running a consistency test (see Tegou et al., 2010). AHP is found to be the most popular technique based on a study of literature review on multi-criteria decision making on sustainable energy planning (Pohekar, 2004).

Application of AHP starts with the structuring of the decision problem in a hierarchy with the objectives on top level followed by the criteria affecting the decision at the intermediate level, and the decision options at the lower level. Thereafter the pair-wise comparison of criteria will be carried out. The decision makers will be able to quantify their opinion about the criteria importance by having comparison of a pair of criteria at a time. The individual judgements or preferences are basically represented by a nine point's scale measurement which creates a reciprocal ratio matrix, where the number of rows and columns is defined by the number of criteria (Tegou et al., 2010). However the pair-wise comparison can only be carried out for a relatively small number of elements at each decision hierarchy therefore any large amount of alternatives would requires the criteria weights (at the criteria level) to be assigned to the criteria map layers and processed in the GIS environment (spatial-AHP method). GIS will then produce an overall suitability map for the location of wind farms.

AHP is commonly applied and it would be a more complete tool if the negative criteria such as risks and cost can be considered simultaneously by associating AHP with benefits, opportunities, costs and risks (BOCR). Lee et al. (2009) claimed that there are only two literatures (to their understanding) has ever considered and analysed BOCR simultaneously. It is interesting to note that the association of AHP and BOCR increased the analysis scope of AHP (positive criteria conventionally) to cover the negative criteria and process them simultaneously thus producing a more holistic and realistic view on the wind farm siting issues.At the same time, Punt et al. (2009) modelled the trade-off between economics and ecological considerations in relation to spatial context of locating offshore wind farm, though there was no clear identification of BOCRor any use of AHP.

### 3.2 Geographic information system (GIS)

Experiences showed that initial identification of suitable offshore wind farm site involves the usage of geographic information system (GIS) to show the constraint and opportunity of a particular area. The Danish Energy Agency used a GIS-based decision support system to identify potential and conflicting areas related to the siting of wind farms in a projection to year 2025. However, the mapping is not in a continuous state but rather highlights the possible offshore areas one-off.

UK experience as highlighted by Baban and Perry (2000) reveals the siting considerations accompanying the development and expansion of wind farms. Siting criteria were developed and applied in GIS layers to determine site suitability for wind farms (see also Beata and Vogt, 2011, Rodman and Meentemeyer, 2006). Two different methods were used for site determinant.

One equates all the criteria layers equally while another grouped the criteria layers and graded them according to perceived importance. The latter suggested more geographical extent in most suitable sites due to its flexibility and freedom in incorporating individual expertise in the decision making process. The analysis could go into detail and further scrutinize the most suitable site among the favourable sites by assessing their suitability on an individual basis. All these could be done by using GIS as a database for the in situ data collected from each site.

Janke (2010) also used GIS model with multicriteria input to identify suitable areas for wind farms in Colorado. His methods involved the identification of variables including wind speed classes, landcover, population density, federal lands, location of roads, transmission lines and cities. The criteria were rescaled from 0 to 1 by dividing the maximum value in the grid. Each data set was resampled to 1500m using an averaging filter. Each variable was given a weight based on its relative importance to one another. This GIS overlay technique enables the analysis of relationship between variables therefore provides a better view of each variable's importance and influence on the result. In that sense, it could be flexibly adjusted or improved to allow for better decision making. Variables such as local acceptance, natural landscape/seascape, ecological sensitivity, etc. can be considered in the model.SimilaryTegouet al. (2010) used a raster GIS with overlay capabilities in its study although both raster and vector based could be used but raster was selected due to its wider mathematical capabilities.

However according to Densham (1991) GIS can be integrated into a Spatial Decision Support System (SDSS) to help decision makers solve complex and semi-structured spatial problems because GIS lack the analytical modelling capabilities and do not support multiple decision-making strategies. As Hendriks and Vriens (2000, p. 86) put it, GIS look at data, while SDSS look at problem situations. Numerous literatures (see Simao et al., 2009, p.2029, Tegou et al., 2010) suggested one particular type of SDSS focuses on Multi-criteria Evaluation (MCE). The MCE techniques was developed to ease decision making by allowing the exploration and problem solving that requires trade-offs between multiple and conflicting objectives. In order to support the planning process, MCE techniques have been embedded into SDSS, creating Multi-Criteria SDSS. MC-SDSS is used to articulate decision objectives, and evaluate criteria, forming and articulating preferences, finding feasible decision alternatives and evaluating these alternatives so that better decision options can be identified. The only drawback as highlighted by Simao et al. (2009) is its lacking capacity to support discussion: there is no clarification on the reasons behind stated preferences, nor any assessment on the interests and concerns of the stakeholders.

Recently GIS is used together with virtual environment to analyse the placement and siting of wind turbines. The virtual environment software includes that of VGIS (ERDAS), ArcScene (ESRI), extension of landscape animation packages (for example Scene Express extension of Visual Nature Studio), specific purpose products such as Polytrim, Len-né3D and Biosphere3D. At the same time, game engines are gaining popularity in virtual environment analysis. Game engines for example Garagegames' Torque Games Engine, CryEngine2, Virtools and Quest3D are used in different environmental situation and analysis. These engines provide additional audio dimension to the analysis. Normally the turbine planning process starts in GIS as a 2D map but later develop to 3D in virtual environment. The planning participant including layman and community which the wind turbine project comes into contact explore and scrutinize the project in the visual simulation. The corrections or alternatives from the experience may be updated in the GIS(2D) and reflected in the virtual environment or it may be edited in the virtual environment as an immediate comparison to the previous proposal. Bishop and Stock (2010) used SIEVE (Spatial Information Exploration and Visualisation Environment) to assess a real wind turbine site of the Challicum hills in Victoria, Australia.

### 3.3 Siting Criteria

The planning and successful implementation of wind farms project requires not only economic viability and acceptance but also of the socio aspect which cannot be neglected (Sperling et al., 2010), neither the environmental considerations. The first step towards that could be the development of siting criteria in order to identify the suitable location for wind farms.

Jay (2010) highlighted the UK's wind energy development experience where the planning perspective was incorporated into the development of offshore wind energy. Legitimate issues like landscape/seascape, marine wildlife, seabed archaeology, leisure activities, fisheries, cumulative effects, socio-economic advantages, tourism, etc. were considered in the process.

On the other hand, the Dutch while planning for their North Sea wind farms looked into sectors like oil and gas, cables and pipelines, shipping, military training, nature conservation, etc.Offshore wind energy development opinion study from Cape Cod, U.S. showed some negative concerns about the ocean view, community harmony, fishing industry, recreational, wildlife and ecosystem, and tourism (Firestone and Kempton, 2007). The German is facing complex siting issues mainly relating to that of energy efficiency, economy gain, aesthetic, emotional arguments and nature conservation both tangible and intangible from some vociferous local opposition (Gee, 2010).Interestingly, bothKempton(2007) and Gee (2010) found aesthetic reason to be a similar consideration in siting offshore wind farm. They also found that the oppositions from the opponents are always greater than the supports from the supporters. On the other hand, Dan van der Horst and Toke(2010) refers to siting controversial characteristics related to distance and people. On average, the more influential opponents with certain socio-economic and demographic profile are mostly living nearby a wind farm project. Socio-economic and demographic profile are found to have strong association with that of wind farms development, especially offshore wind farm as the seascape is both tangible and intangible asset, related to human activities, economic matter as well as emotionally and psychologically (see also Cowell 2010).

Most literature suggested that visual impact and ocean aesthetic or seascape is of great concern mostly to the respondents of the studies carried out. Nadaiand Dan (2010) found that wind farms development so far is inevitably seen to invite arbitration between a 'globalised' public good (less $CO_2$) and a 'localised' public bad (impact on landscape or seascape). Bishop and Miller (2007) in his study on the offshore wind farm 7km off the coast of Walesfound the importance of visual impact related to siting. Ladenburg (2009) also found the same in conducting survey for Nysted and Horns Rev offshore wind farms 10km and 14km from the coast respectively.The 2001 Wadden Sea wind project (the largest wind project ever proposed) in the Netherland was cancelled due to opposition out of seascape impacts as well as lack of community participatory during the planning stage of the project (Wolsink, 2010). Therefore, it is suggested thatdistance from the shore, of offshore wind farms might be closer to the coast areas with little recreational activities compared to coastal areas with a higher level of recreational activities (Ladenburg and Dubgaard, 2009).

All these could very well be further developed into siting criteria which allows for a comprehensive and systematic identification of offshore wind farm sites. Specific offshore wind farms siting criteria adopted in the North Sea siting as reported by Jay (2010) stated that wind farms should be located relatively close to the coast and potential grid connections, covering a minimum area of 80 $km^2$ to ensure the cost-effectiveness of the projects; it should be minimum 12 miles from the coast mainly for minimal impact to the seascape; beyond two nautical miles from international shipping lanes and 500m from oil and gas platforms for safety reasons; outside of any strategic military areas; excluding any ecological sensitive areas; in a dispersed pattern of large arrays to prevent cluttering of the seas as well as to allows for an integration of complementing activities like fishing, aquaculture and recreation.All these are part of the decision making process which influence the way in which physical space is used.

## *4.0 Offshore wind energy planning in Malaysia*

Malaysia has been considering wind energy as one of the alternative source of power generation (Zuhairuse et al., 2009). Several studies and actual wind turbine installation had been carried out as a preliminary assessment of offshore wind energy potential mostly at the East coast in the South China Sea as well as the coast off Sabah, East Malaysia.In 2005, a 150kW wind turbine was installed in the TerumbuLayang-layang and subsequently two 100kW wind turbines were installed as part of a hybrid system at PulauPerhentian in 2007. The two turbines contributed about 50% of the total load required with an average wind speed of 7.26m/s. Zuhairuseet al. (2009) reported findings from National University of Malaysia on the wind speed for the period of 2003-2005 in PulauPerhentian as having a range from 2m/s to 13m/s. In the contrary, Ali (2010) argued that Malaysia is not economically feasible to install offshore wind turbine based on a study by Chaing et al. (2003).

Chiang et al. (2003) conducted a study to gauge the potential of renewable wave and offshore wind energy sources in Malaysia and found the highest potential of wind energy is located in the East coast of peninsular Malaysiawith an annual vector resultant wind speed of 4.1m/s. The offshore characteristics were reportedly stronger than that of the coast with wind speed more than 5m/s during the northeast monsoon (September to March) but low for the rest of the year.

However, it is noticed that the data collected for the study was largely based on marine surface observation reported by ships which participated in the World Meteorological Organization Voluntary Observation Ships (VOS) Scheme together with that of oilrigs and lighthouse as well as monthly summary of marine meteorological observations published by the Malaysian Meteorological Service (MMS), for the period of 1985-2000. Chiang et al. (2003) acknowledged the possibility of errors arising from heavy dependant on VOS data. Furthermore Azami et al.,(2009) stated that they are only two fully equipped climatological stations in Malaysia namely the University of Malaya station and the University of Terengganu station. This implies that the data used previously by Chiang et al. (2003) from the MMS need further verification on its reliability to accurately presentthe wind energy potential. Nevertheless, there are certain areas off the coast of Terengganu state such as PulauPerhentian that are left out in the Chiang et al. study.

Figure 1 shows QuikSCAT for 2005 offshore wind in Malaysia's water facing South China Sea to have more than 6m/s annual wind speed when extrapolated to 50m height(Swera, 2011).The satellite measurements are subjected to certain uncertainties with regards to biases due to rain and also of wind shear adjustment from 10m to 50m. However QuikSCAT is able to assess wind resource for close to shore areas and in shallow water, an advantage for near shore wind farm planning. The QuikSCAT estimates of ocean wind are derived from scatterometer measurements of the state of the ocean surface (calm or turbulent state of ocean surface for area beneath the satellite) assuming a neutrally stratified atmosphere. This ocean surface data is then converted to an estimate of the winds 10m above the ocean surface. The accuracy of an annual average wind speed is estimated to be about ±1 m/s. The adjustment from 10m to 50m was applied with a power law exponents of 0.10 which translated to a multiplicative factor of 1.17 for wind speed. The implication is that Malaysia water facing South China Sea is having an annual wind speed of about 6m/s at 50m.

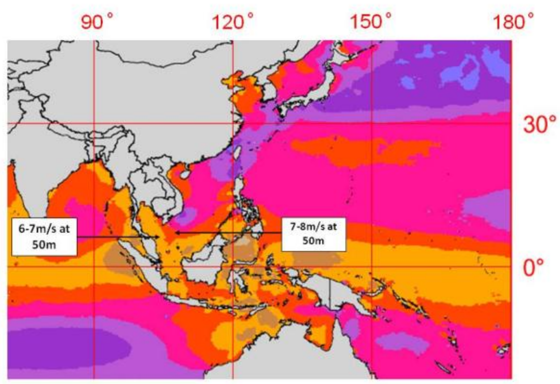
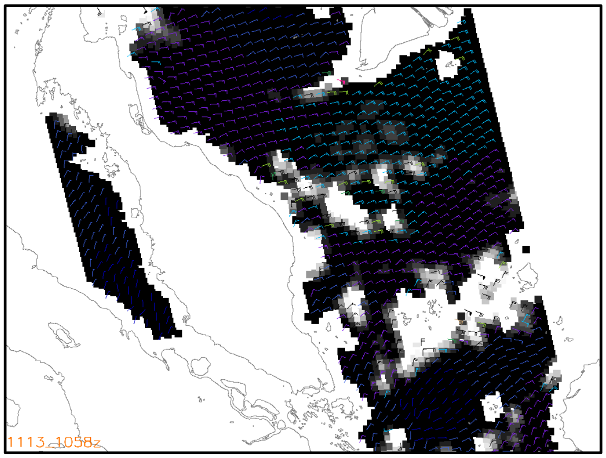


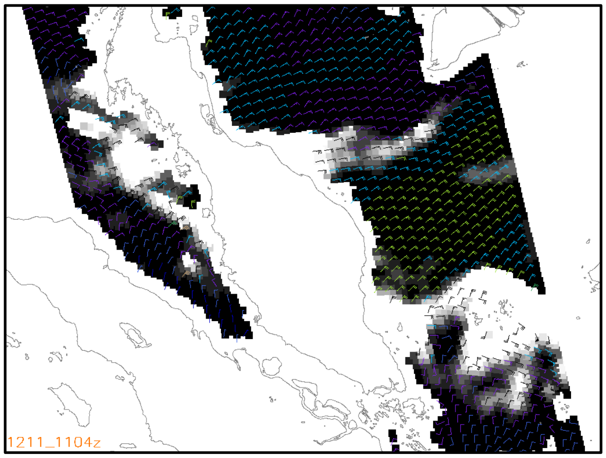

Fig. 1.QuikSCAT - Annual wind speed map (at 50m) of South East Asia for 2005 [100]

Another quick reference was made by using WindSat to look at the water of peninsular Malaysia for the period of 12 months from November 2011 to October 2012. WindSat is the first radiometer to measure wind direction due to its polarimetric capabilities. It was launched on January 6, 2003 by the United States Department of DefenseCoriolis satellite capturing 10m surface wind speed and directions. Figure 2 shows that for a period of twelve month, different water areas of peninsular Malaysia having at least 10knots (5.14m/s) ocean surface wind speed at 10m. A 100kW wind turbine will be able to generate electric power from wind speed in a range of 5m/s to 15m/s (Zuhairuse et al, 2009).

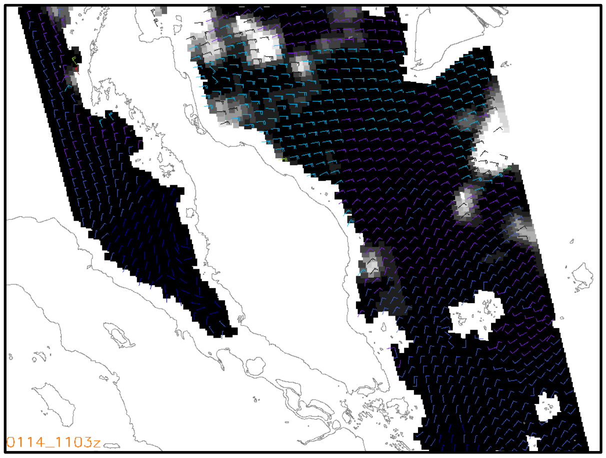
Based on the wind speed reported by QuikSCAT and WindSat at 50m and 10m height respectively, it can be concluded that there is huge potential for offshore wind in Malaysia supplying continuous renewable resource. Therefore, the argument by Ali (2010) is insignificant in that sense and offshore wind in Malaysia should be fully explored and utilised. A further deployment of buoy at strategic Malaysia water will be able to validate the satellite record.




(a) 13 November 2011

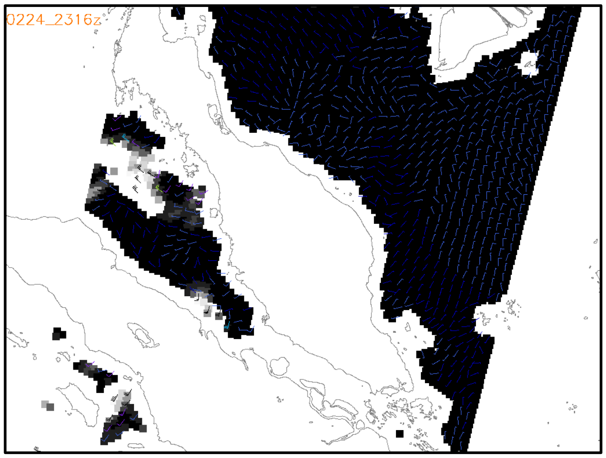



(b) 11 December 2011

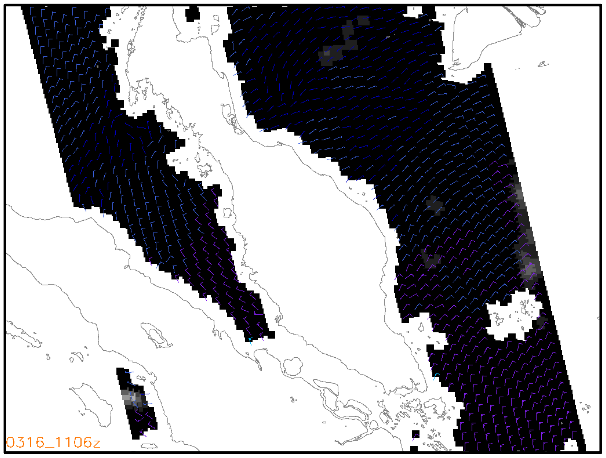



(c) 14 January 2012

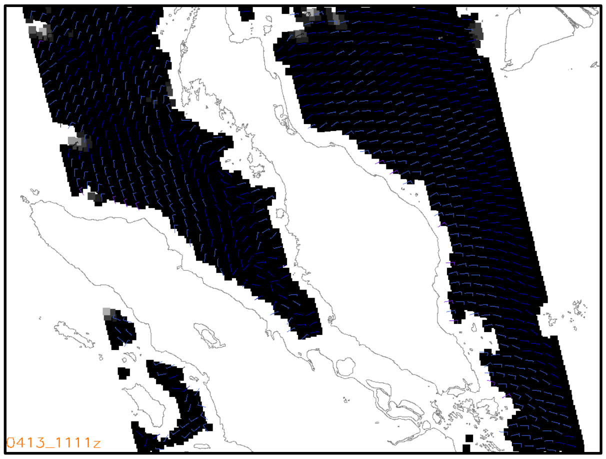
Fig. 2. (*Continued*)




(d) 24 February 2012

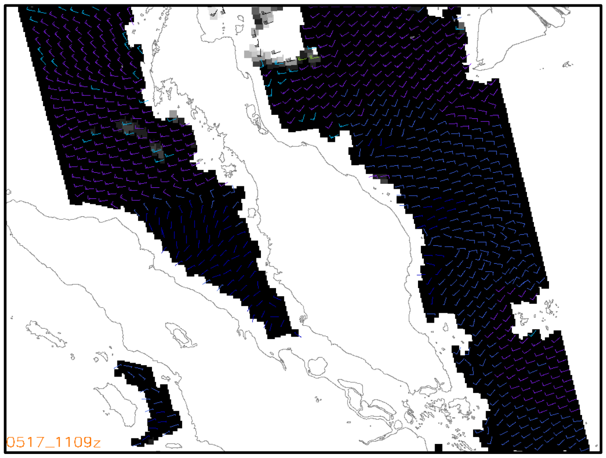



(e) 16 March 2012

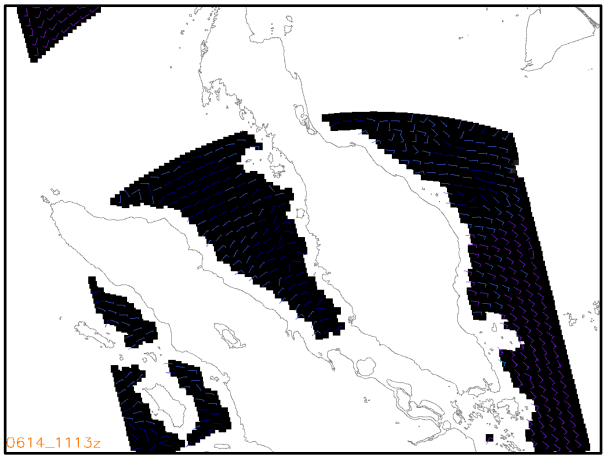



(f) 13 April 2012

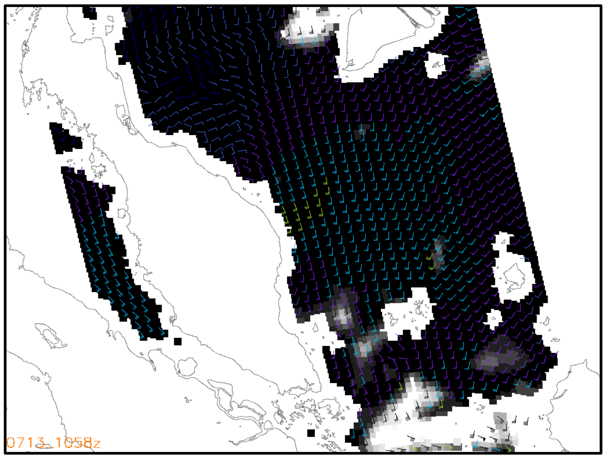
Fig. 2. (*Continued*)




(g) 17 May 2012

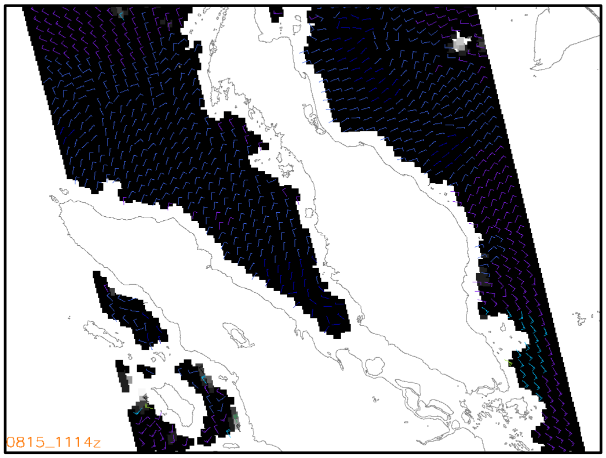



(h) 14 June 2012

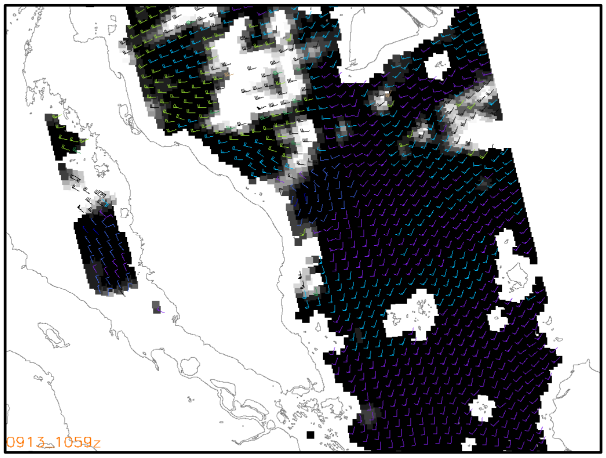


(i) 13 July 2012

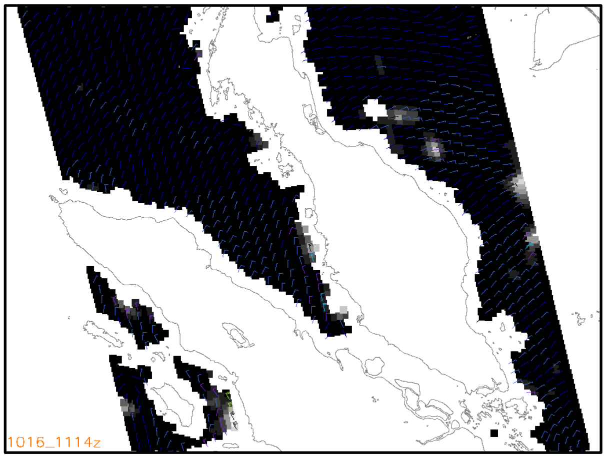
Fig. 2. (*Continued*)




(j) 15 August 2012



(k) 13 September 2012




(l) 16 October 2012

Fig. 2. Monthly wind speed (knots) and direction (arrows)of Peninsular Malaysia from November 2011 to October 2012(www.nrl.navy.mil/WindSat/) (Refer to the web version to interpret the colour in this figure)

## *5.0 Conclusion*

This paper has presented various methodologies for preliminary wind energy assessment that can be appliedaccording to the different constraints of offshore wind energy development. Firstly the trade off between economic and ecology is given emphasis as they depend on the inputs given by the politics, investors as well as the affected local. The manner SCREAM presents the wind assessment is more towards economic gain after taking away areas deemed not suitable for offshore wind farm development. The main principle of having a continuous assessment by regular updating of data is commendable for the long run. Contrary to that is the accessible method which allows for a quick and inexpensive way to assess wind energy resource be it a preliminary or just as a gross checking on any claims for wind energy potential. However there is no sufficient reliable buoy and meteorological data in Malaysia offshore water that can be of use for this method.

The development of NWP, SAR, scatterometer, radiometer and etc. presents a wide range of tools to suit different assessment scenario. Some requires computational capability to process while some are easily available through the internet. The easier accessibility to these tools means wind energy assessment can be carried out easier and faster. This will eventually contribute to more wind farm development and thus more renewable energy. Malaysia can easily tap into the availability of wind map produced by scatterometer or radiometer such as QuikSCAT and WindSat.

At the same time, when the planning and development of offshore wind farm is progressing, there is a definite need to develop siting criteria suitable to Malaysia condition. The criteria includes different but holistic aspect of consideration consist mainly of economic, social, environment as well as aesthetic reason which proved to be argumentative elsewhere. These criteria can then be applied in AHP to determine a ranking of importance among them. Last but not least, the criteria can become input to GIS in order to provide a spatial dimension for siting purpose. It is clear that Malaysia like the rest of the Asian countries can also tap into wind energy if there is more research done to support such an endeavour.

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