Ocean Wind Speed Characteristic Over Malaysian Seas From Multi-Mission Satellite Altimeter During Monsoon Periods

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Graphical abstract

Abstract
The need for precise measurement of wind speed and growth of interest in offshore wind power has led to development of many measurements technique. This paper presents a study of wind speed characteristics during monsoon periods (north-east monsoon and south-west monsoon) over Malaysian seas using multi-mission satellite altimetry data from year 1993 to 2011. The study area covers in this study are Malacca Straits, South China Sea, Sulu Sea and Celebes Sea. From the result, the strongest winds are between Novembers to February, but on average, December is the strongest recorded wind speed at most locations. The South China Sea is the roughest region throughout the year compare to the other sea. It was concluded that using altimetry data, we can solve the disadvantage of conventional measurement in terms of spatial data distributions.

Keywords: Ocean Wind Speed; Satellite Altimeter; Monsoon Periods

Abstrak

Kata kunci: Kelajuan Angin Lautan; Altimeter Satelit; Tempoh Monsun

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1.0 INTRODUCTION

Most oceanographic research and study need the compilation of long-term databases of accurate oceanic properties such as significant wave height and wind speed. Before this, wave climate data are gathered through the deployment of oceanographic buoys and more recently through the use of numerical models (Caires et al. 2004). Both techniques have their own disadvantages. For instance, in-situ measurement using buoy clearly have limitation in terms of data coverage (spatially) and very expensive in term of deployment and maintenance.

Meanwhile, using model data actually can solve all these disadvantages but the biggest challenge for this technique relies critically on the accuracy of the model. Even though modern-day models contain sophisticated representations of wind-wave physics, the accuracy of such models are still limited (Tolman 2002). For instance, studies conducted by Dobson et al (1987) and (Monaldo1988) have shown that active remote sensing satellites, particularly Ku-band radar altimeter systems, are capable of measuring significant wave height and wind speed to an accuracy comparable to in-situ observations (e.g., buoys).
2.0 ALTIMETER MEASUREMENT CONCEPT

The basic principle of satellite altimeter is based on the pulse that is reflected at the sea surface and backscattered according to wind and waves. The pulse then will be received by the altimeter antenna after a few milliseconds. There are three main parameters in reflecting the pulse from the ocean; they are the slope of the leading edge of the returned echo for wave height determination, travel time to measure distance to sea level and the energy of the impulse response for wind speed determination (Bosch, 2010). Meanwhile, the independent tracking systems are used to compute the satellite’s three-dimensional position relative to a fixed Earth coordinate system (Din et al., 2012).

However, the situation is far more complex in practice. Several factors have to be taken into account for the corrections of altimeter range measurements such as orbit error (radial component) and instrumental effects such as electronic time delay, clock (oscillator) drift, offset antenna phase centre, troposphere (dry component) and troposphere (wet component). Other component that also can affect the signal is ocean surface such as ocean tides, earth tides; electromagnetic bias (sea state) and inverted barometer effect (Bosch, 2010). All of the effect and the correction can be refer to Figure 1.

Figure 1 Corrections for altimeter range measurements (Bosch, 2010)

The schematic diagram of satellite radar altimeter system and its principle is depicted in Figure 1. By using a similar notation to Fu and Cazenave (2001), the corrected range \( R_{\text{corrected}} \) is related to the observed range \( R_{\text{obs}} \):

\[
R_{\text{corrected}} = R_{\text{obs}} - \Delta R_{\text{dry}} - \Delta R_{\text{wet}} - \Delta R_{\text{iono}} - \Delta R_{\text{ssb}}
\]

Where,

\( R_{\text{obs}} = c \frac{t}{2} \) is the computed range from the travel time \( t \) observed by the on-board ultra-stable oscillator (USO), and \( c \) is the speed of the radar pulse neglecting refraction.

\( \Delta R_{\text{dry}} \): Dry tropospheric correction  
\( \Delta R_{\text{wet}} \): Wet tropospheric correction  
\( \Delta R_{\text{iono}} \): Ionospheric correction  
\( \Delta R_{\text{ssb}} \): Sea-state bias correction

3.0 RADAR ALTIMETER DATABASE SYSTEM (RADS)

Nowadays, altimetry data has been dispensed through agencies like NOAA, AVISO, EUMETSAT and PODAAC. Aside that, the NOAA laboratory and the Delft Institute for Earth-Oriented Space Research (DEOS) for Satellite Altimetry has been collaborating in the development of Radar Altimeter Database System (RADS). The RADS is established in a harmonized, validated and cross-calibrated sea level database from all satellite altimeter missions. In RADS, users are able to access the most present range and geophysical corrections and also can produce their own altimetry products based on their particular interest (Andersen and Scharroo, 2011).

In the frame of RADS, the DEOS is developing a database that incorporates validated and verified altimetry data products. Besides, the database is also consistent in accuracy, correction, format and reference system parameters. The capability of such a database will attract users with less satellite altimeter expertise like advisory councils, water management authorities and even high schools (Naeije et al., 2000). This system also caters for the needs of scientists and operational users to have value-added sea level data readily at one’s disposal (Lucy Mathers, 2005). Currently, RADS enables users to extract the data from several present and past satellite altimeter missions like Geosat, ERS-1, ERS-2, ENVISAT, TOPEX/Poseidon (T/P), JASON-1 and JASON-2. The current status and detail information of the altimetry data in the RADS is shown in Table 1.

Table 1 Status of RADS (Source: http://rads.tudelft.nl/rads/status.shtml)

<table>
<thead>
<tr>
<th>Altimeter Phase</th>
<th>Time</th>
<th>Cycles</th>
<th>Passes</th>
<th>Records</th>
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<td>B 08 Nov 1986 - 30 Dec 1999</td>
<td>032 - 045</td>
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<td></td>
<td>C 21 Mar 1990 - 30 Sep 1991</td>
<td>001 - 021</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ERS-1</td>
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<td>001 - 046</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>D 24 Dec 1993 - 10 Apr 1994</td>
<td>103 - 138</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>E 10 Apr 1994 - 28 Sep 1994</td>
<td>139 - 159</td>
<td></td>
<td></td>
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<tr>
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<td>B 05 Jul 2011 - 31 Jan 2012</td>
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<tr>
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<tr>
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</table>

In Universiti Teknologi Malaysia (UTM), the RADS system has been installed since 2005 in the frame of the SEAMERGES project, an EU funded project (AUNP) that aimed for knowledge, methods and data exchange related to satellite altimetry, InSAR and GPS (www.deos.tudelft.nl/seamerges). Several universities and research group from France, Netherland, Malaysia, Indonesia and Thailand are participating in this geodetic education and geodetic research project. The main goal of the SEAMERGES project is to accomplish the knowledge transfer, expertise and technology from Europe to South East Asia. This is to locally enable the geodetic research at higher-level and to initiate the implementation of these technologies in the water management and risk assessment applications. It also aims at encouraging the scientific cooperation and collaboration among South East Asia countries.
4.0 MATERIALS AND METHODS

This research utilises data from six satellite missions TOPEX, ERS-2, ERS-1, JASON-1, JASON-2 and ENVISAT from year 1993 until year 2011. These data were combined to produce wind speed characteristics. In order to densify our data points, monthly average of the data were gridded on a 0.25° x 0.25° square block.

Furthermore, to study the seasonal variation effect, the wind speed from January 1993 until December 2011 were averaged based on monsoon season period, Northeast Monsoon (November, December, January and February), Southwest Monsoon (May, June, July and August), first Inter-monsoon (March and April) and second Inter-monsoon (September and October).

5.0 RESULTS

In a single year, the strongest wind speed vary usually between November to February, but on average, December is the strongest recorded wind speed at most locations, especially at the open sea such as the South China Sea.

The average of wind speed in each of monsoon seasons and two inter-monsoon periods are shown in figure 2 to figure 5. In these figures, the South China Sea is the roughest region throughout the year, while more sheltered regions, for example around Malacca Straits, Sulu Sea and Celebes Sea are relatively calm. The seasonality varies slightly from region to region. For example, the Northeast Monsoon tends to be rougher than the other monsoon season period, for the inter-monsoon it is usually calmer period for all over the sea.

6.0 CONCLUSIONS

Remote sensing satellite technology is very useful and has a very huge potential in terms of measuring the dynamics of the earth either in ocean or on land. Satellite Altimeter or RADS technology fall within this concept. It provides a series of continuous data for years and can cover up for almost every part of the sea. This means that this technology can be used as a complementary tool to account for the limitations of the conventional win speed measurements techniques. In conclusion, RADS and altimeter are extremely helpful in research, education and sea management. It is not only helpful for researchers but also for sea fearers, fisherman, and engineers as well as for local authorities especially for coastal management.

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