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Long-Term Variability of Wind and Waves in the Malacca Strait Based on ERA-Interim Data from 1980 to 2014

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ABSTRACT

Wave and wind climate information can serve as basis for design, research and policy making regarding ship safety and operability, potential renewable energy exploitation, design of off-shore installation etc. The objective of this paper is to determine mean annual significant wave heights and wind speeds in the Malacca Strait. Mean annual wave height and wind speed values have been statically analyzed based on ERA-Interim reanalysis data produced by ECMWF (European Center for Medium-Range Weather Forecasts) during 34 years period. This data has been processed resulting in monthly and annual observed significant wave heights and corresponding wind speed values. The obtained results show that wave speed and the significant waves height have an increasing trend at the location studied but both trends are statistically insignificant.

KEY WORDS: *wind, wave, ERA-Interim, variability*

1.0 INTRODUCTION

Malacca Strait sea lane is an important trade route for the main world countries of Southeast Asia. Due to the Strait of Malacca linking the Indian Ocean with the South China Sea and provide sea lanes for most of world trade. Over the years, tankers and bulk carriers move large quantities of oil, coal, iron ore, and minerals to the production centers in Southeast Asia and East Asia, while tens of thousands of container flows in the opposite direction to meet the needs of consumers worldwide market, Every year, more than 71,000 ships pass through the Strait of Malacca to carry a variety of commodities, ranging from crude oil to finished products from various regions of the world [1].

Therefore, it is no exaggeration when waterway is considered as one of the busiest sea lanes simultaneously functions as an artery of the world economy. The Malacca Strait serves as a shipping route for surrounding countries and an important role waterway to increase the economic and industrial development in the Asian region.

Thorough knowledge about possible sea states in a certain area is essential for all activities related to the maritime sector (e.g. offshore installations, ship design for safety and sea keeping, shipping routes planning, vessel management etc). Every increase in knowledge in this field for the Malacca strait is important as it serves as a busy shipping route with an increasing trend. Sea state analyses are available from in-situ measurement data, numerical modeling, and various forecast models derived on empirical or mathematical models giving relations between wind and waves.

The aim of present study is to contribute to the field by further developing the statistical analysis of the data available from forecast models derived on empirical or mathematical models throughout the Malacca strait. It aims primarily to identify mean annual wave heights, and to look in more detail the zone of maximum wave heights, researching its relation to the dominant winds. Such an analysis can serve as basis for design parameters of vessels, research and policy making regarding ship safety and operability, or for data source for possible wave energy evaluation projects in the region.

2.0 STUDY AREA OF MALACA STRAIT

Figure 1: Strait of Malacca (red dot is data sampling location)

Strait of Malacca is one of the world's trade lanes most strategic as shown in Figure 1. Not only for the countries directly adjacent to the waterway, but also other countries that have strategic interests, such as China, India, Japan, and the United States. Strait of Malacca and Singapore has a length of about 520 nautical miles and is the longest strait used for international waters. The entrance located on the west coast of Indonesia and Malaysia approximately 200-mile wide strait sea. This is where the sovereign territory of Indonesia and Malaysia be overlapping. Narrowest part is in the south western tip of the Malay Peninsula has a width of only 8.4 nautical miles [2]. The narrowest distance around the Straits of Singapore is 3.2 km along 15 miles with a depth of less than 75 feet. The type of ships that crossed the straits is container ships, tankers, bulk vessels, cargo vessels, ro-ro ship, passenger ships, ship Navy and fishing vessels. In late 2010, passing ship had reached 71.359 vessels and it is expected to increase reach 320.000 vessels in 2024 and will reach 1.3 million in the year 2083 [3].

3.0 ERA-Interim REANALYSIS DATA

The present study is based on the ERA-Interim global atmospheric reanalysis data that are produced by the European Center for Medium-Range Weather Forecasts (ECMWF) [4][5]. ERA-Interim is the first re-analysis using adaptive and fully automated bias corrections of satellite radiance observations [5] and contains improvements to ERA-40 such as the complete use of four-dimensional variation data assimilation from various kinds of sources such as scatterometers, altimeters, US wind profiler data, etc. The ERA-Interim reanalysis is produced with a sequential data assimilation scheme, advancing forward in time using 12- hourly analysis cycles [5].

In this study, wind speed and significant wave heights (SWH) downloaded for the period 34 years from 1984 to 2014 at 6-hourly intervals. Monthly and annual mean of wind speed and SWH were calculated from 6-hourly data to describe the variability of the wave climate over 34 years period. The annual mean of wind speed ($\overline{U_{10}}$) and significant wave height ($\overline{H_s}$) were derived from the mean of the 12 concsecutive monthly mean of the data.

$$\overline{U_{10}} = \frac{\sum_i^n U_{10_i}}{n} \qquad \overline{H_s} = \frac{\sum_i^n H_{s_i}}{n}$$

where *n* is sample data.

4.0 RESULTS

Variation in wind speed from 1980-2014

Temporal variation in monthly maximum and mean wind speed is plotted in Figure 2 and 3 for 34 years. Monthly maximum wind speed shows a decreasing trend from April to May as shown in Table 1. Other months show an upward trend in monthly maximum wind speed. The highest upward trend in maximum wind speed is observed during December with increasing of 5.93 cm s−1 year−1. Meanwhile, the monthly mean wind speed shows an increasing trend in all months, with higher values during January (2.23 cm s−1 year−1) and lower values observed during November with increasing trends of 0.05 cm s−1 year−1.

Table 6 and 7 show the result from temporal variation of annual maximum and mean wind speed from 1980-2014, respectively. An upward trend of 1.41 cm s−1 year−1 is observed for annual maximum wind speed in Figure 6 and an increasing trend of 2.1 cm s−1 year−1 is observed for annual mean wind speed as shown in Figure 7. The statistical trend analysis of annual maximum wind speed and mean of wind speed show statistically insignificant as shown in Table 2.

Table 1. Trend in wind speed and significant wave height (SWH) from 1980 to 2014

Month	Wind speed (cm/s/year)		SWH (cm/year)	
	Mean	Max	Mean	Max
January	2.23	5.33	0.20	2.31
February	1.73	0.76	0.20	-0.03
March	1.16	5.83	0.20	1.97
April	0.52	-4.16	-0.18	-0.81
May	0.80	-0.90	-0.19	-0.09
June	0.54	2.59	-0.37	-1.23
July	1.43	2.67	-0.29	-1.63
August	0.89	4.77	-0.27	-1.35
September	1.20	0.05	-0.20	-0.85
October	0.81	5.89	-0.84	-0.95
November	0.05	3.01	0.07	0.40
December	1.10	5.93	-0.45	3.06

Variation in wave height from 1980 to 2014

The monthly maximum and mean values of significant wave height (SWH) for 34 years are presented in Figure 4 and 5, respectively. The monthly mean SWH shows decreasing trends from April to October and during December, whereas during other months an upward trend is observed as indicated in Table 1. A maximum decreasing trend is observed during October with trend of 0.84 cm year−1. The west monsoon period (November to April) showed an upward trend in mean SWH, with an exception during December, and the upward trend is observed in the range 0.07–0.2 cm year−1.

Similar to monthly mean SWH, the monthly maximum SWH shows a downward trend for most of the months except during November, December, January and March as shown in Table 1. The monthly maximum SWH showed a higher downward trend, with a maximum during July (1.63 cm year−1). The increasing trend during November, December, January and March is observed in the range 0.4–3.06 cm year−1.

Table 8 and 9 show the result from temporal variation of annual maximum and mean SWH for period 34 years, respectively. The annual mean SWH shows a slight upward trend, with an increase of 0.11 cm year−1, whereas an increasing trend of 0.58 cm year−1 is observed for annual maximum SWH (Fig. 8), but both trends are found to be statistically insignificant as presented in Table 2.

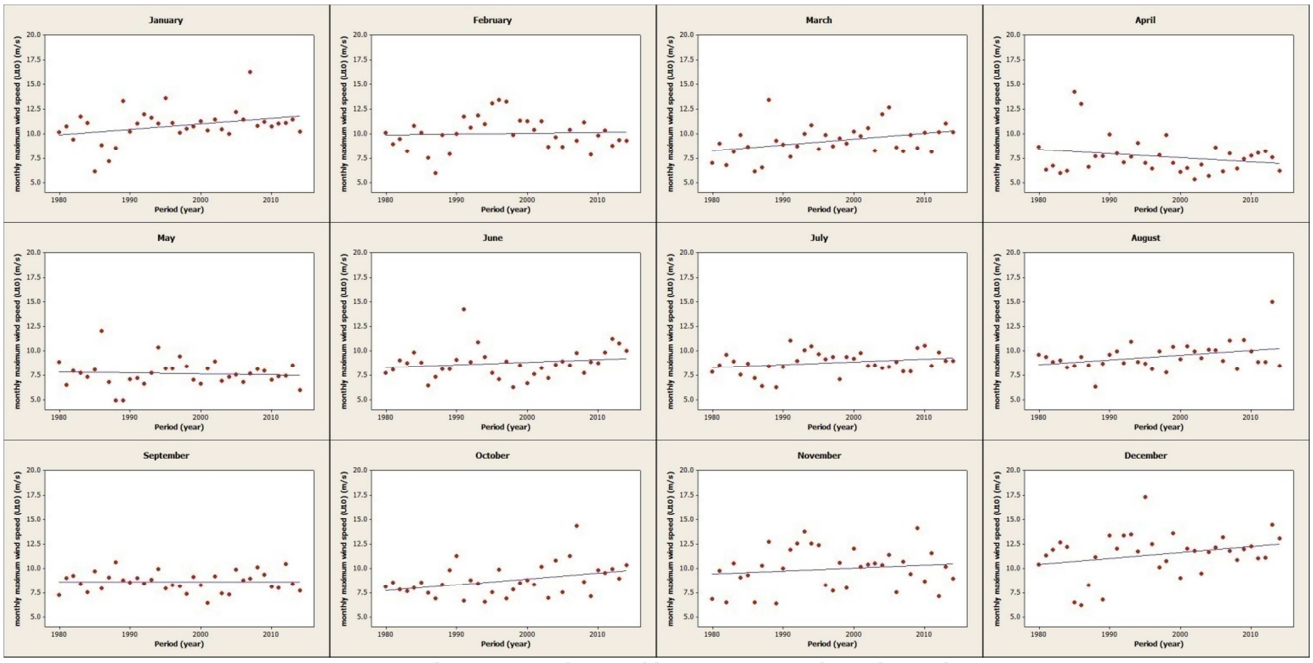

Figure 2: Temporal variation in the monthly maximum wind speed at Malacca strait

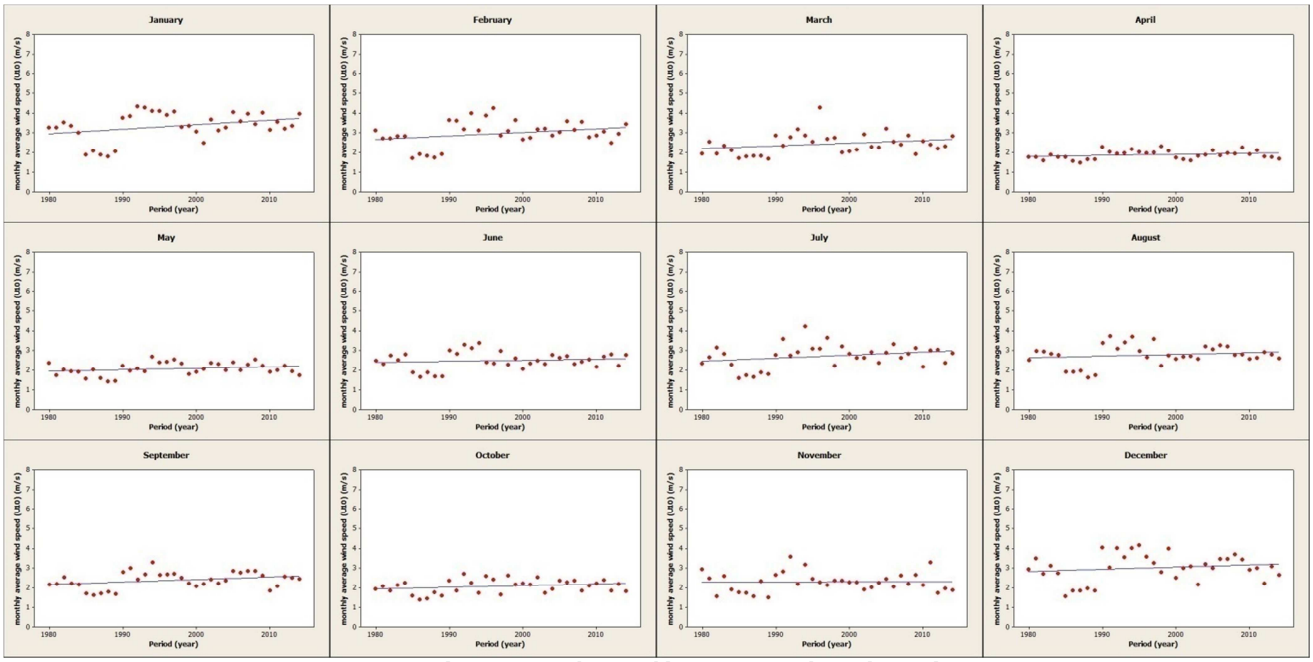

Figure 3: Temporal variation in the monthly average wind speed at Malacca strait

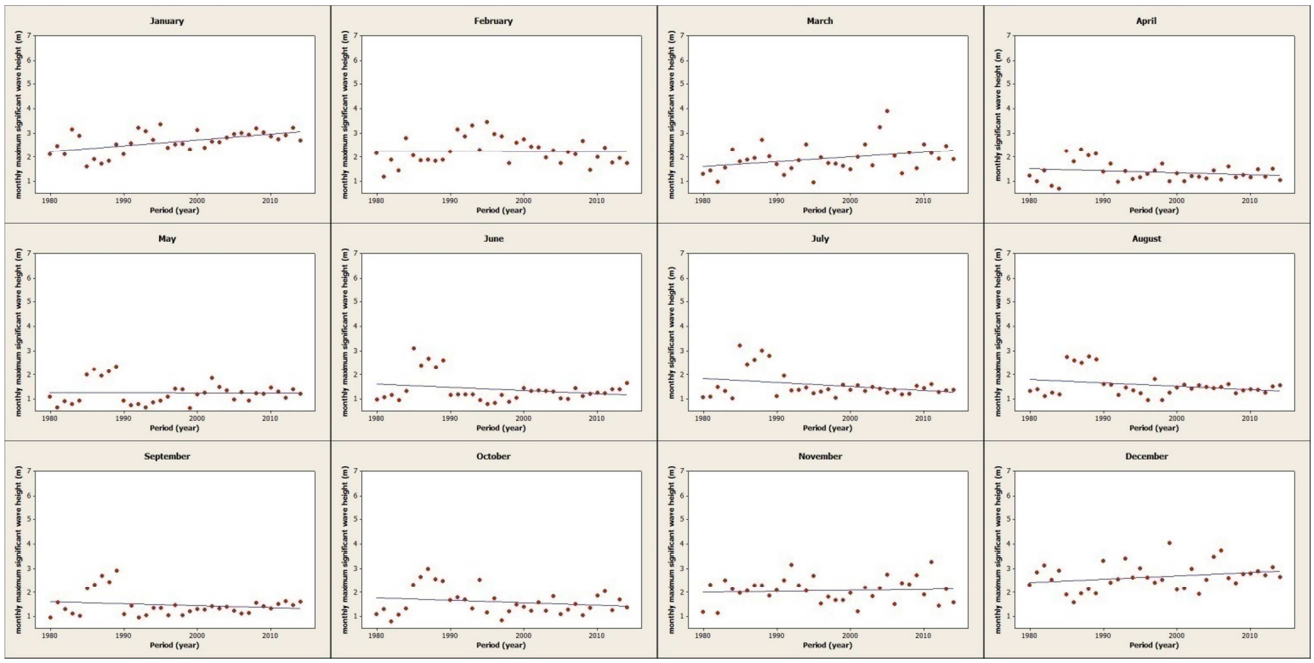

Figure 4: Temporal variation in the monthly maximum significant wave height (SWH) at Malacca strait

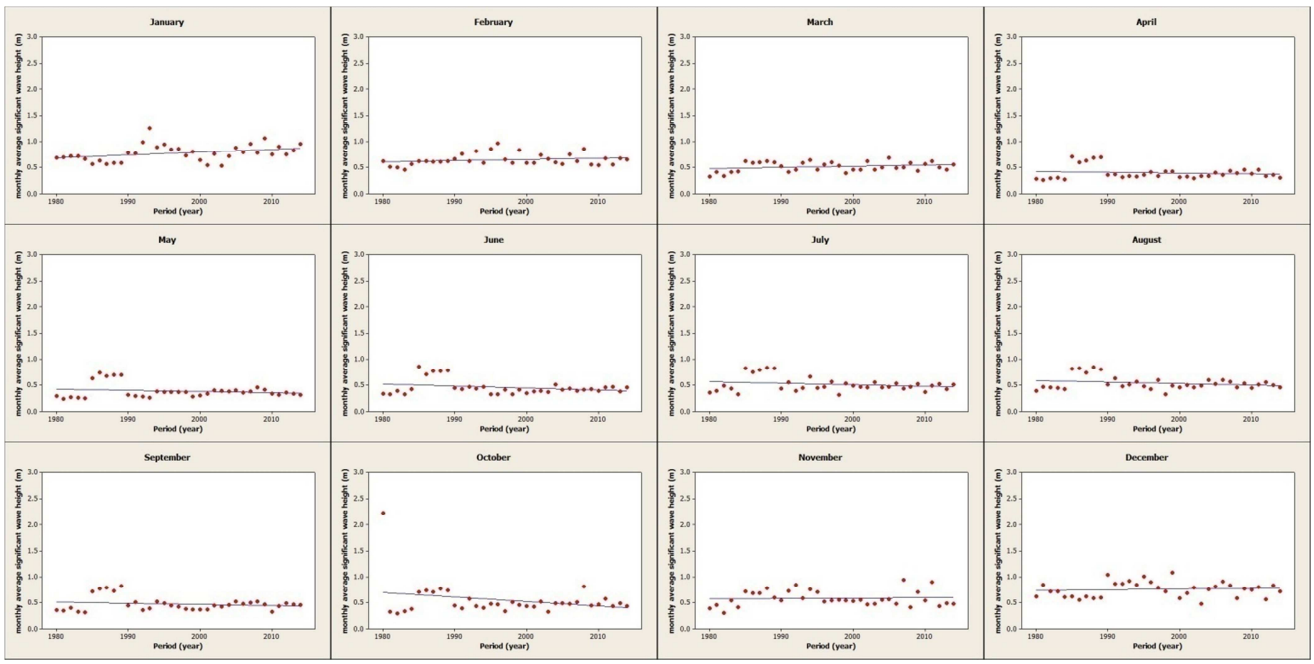

Figure 5: Temporal variation in the monthly average significant wave height (SWH) at Malacca strait

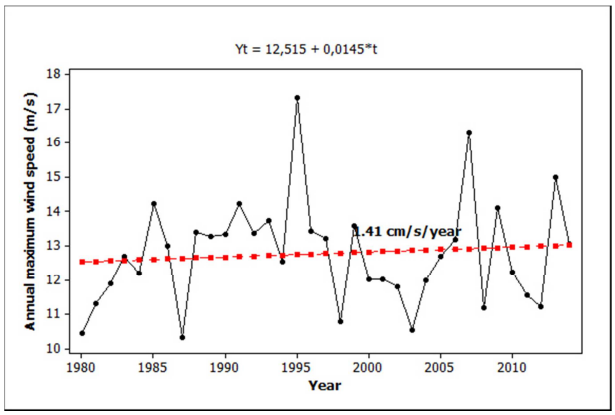

Figure 6: Temporal variation of annual maximum wind speed from 1980-2014

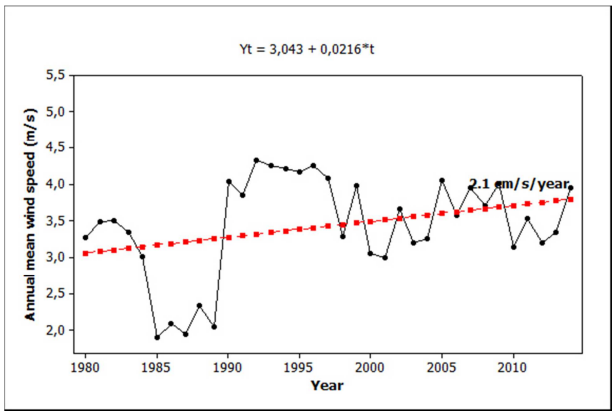

Figure 7: Temporal variation of annual mean wind speed from 1980-2014

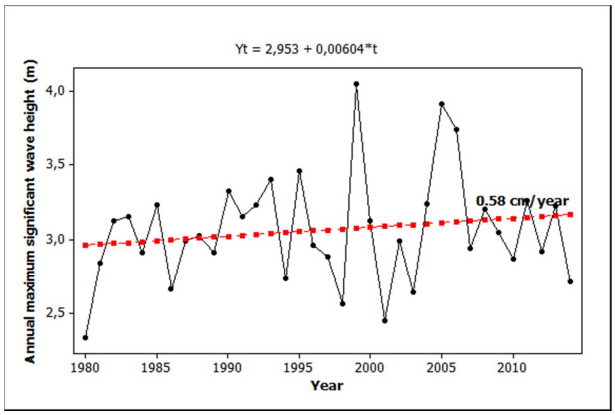

Figure 8: Temporal variation of annual maximum significant wave height from 1980-2014

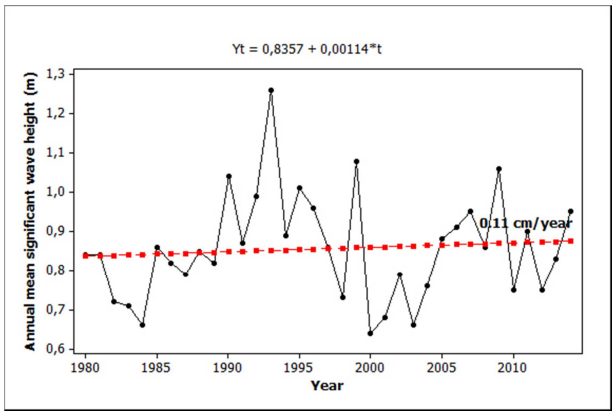

Figure 9: Temporal variation of annual mean significant wave height from 1980-2014

Table 2. Mann-Kendall test for trend analysis

Parameter	Variance	Mean	Standard Deviation	Mann-Kendall test		
				Sen slope	ρ value	Significance
Annual max wind speed	2.393	12.777	1.547	0.00767	0.3827	Not Significant
Annual mean wind speed	0.479	3.431	0.692	0.01133	0.2009	Not Significant
Annual max SWH	0.136	3.062	0.369	0.00392	0.2257	Not Significant
Annual mean SWH	0.072	0.896	0.269	0.00105	0.3558	Not Significant

5.0 CONCLUSION

In this study, a long-term trend in wind speed and significant wave height in the Malacca strait is analyzed using the ERA-Interim data set. This study is based on the data covering 34 years from 1980 to 2014. The study shows that during 34 years period, the annual maximum wind speed was characterized by a slight increasing trend (1.4 cm s−1 year−1), whereas the annual mean wind speed displays a small upward trend of 2.1 cm s−1 year−1. For the annual maximum and mean significant waves height from 1980 to 2014 has an increasing trend of 0.58 and 0.11 cm year −1, respectively. Overall, the results show that wave speed and the significant waves height have an increasing trend at the location studied but both trends of wind speed and significant wave height are statistically insignificant.

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