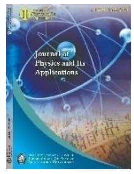
Journal of Physics and Its Applications

Journal homepage : https://ejournal2.undip.ac.id/index.php/jpa/index



Meridional variations of sea surface temperature and wind over southern sea of Java and its surroundings

I. Sofiati*, E. Yulihastin, Suaydhi, M. F. Putranto

Indonesian National Institute of Aeronautics and Space, Bandung, Indonesia

*)*Corresponding author: sofiati07@gmail.com*

A R T I C L E I N F O

Article history:
Received: 12 November 2020
Accepted: 29 November 2020
Available online: 30 November 2020

Keywords:
Sea surface temperature
Wind
Meridional variation

A B S T R A C T

Sea surface temperature (SST) plays an important role in controlling the ocean's heat content and regulating climate. The seasonal characteristics of SST and wind speed and their correlation in the southern Java are investigated using satellite observations. The method in this study is averaging hourly into monthly data for SST and wind speed during 20 years observation for period of 2000-2019, and representing it in the form of descriptive analyses of both monthly and seasonally. The study area for drawing the correlation between SST and wind speed was limited on the (0-5°S), (5-10°S), and (10-15°S). The results show that SST reached its peak in August, while wind speed reached its minimum in August. The difference in SST (wind speed) for climatological condition exhibit lower (higher) in May-October (MJJASO), and the magnitude is more fluctuating in latitude average rather than in November-April (NDJFMA). The significant results of the study describe meridional variation in SST and wind between the northern (Karimata Strait), central (Java Sea), and southern (Indian Ocean) regions. In this case, the Indian Ocean region near south of Java has the highest correlation between SST and wind for both of dry and rainy season compared to other areas.

1. Introduction

The vast Indonesian sea require monitoring and study of marine parameters to explain various phenomena that occur in the sea. One of the marine parameters that determines water quality is Sea Surface Temperature (SST). SST plays an important role in controlling the ocean's heat content and regulating climate. In the study of the temporal and spatial distribution of SST, oceanographic processes such as wind direction and speed can affect water conditions.

The correlation between SST and wind speed has been studied for decades and some researchers state sea surface temperature (SST) and wind speed are positively correlated on oceanic mesoscales in both the tropics and extra tropics [1, 2, 3]. Such a positive SST – wind relationship is mainly due to the SST's modification of stability and vertical mixing in the atmospheric boundary layer [4]. Another study [2] showed that SST and wind speed are also positively correlated in a small-scale region, and that surface winds are locally higher over warm sea and lower over cool sea. Cold water stabilizes the atmosphere boundary layer and thus decouples the winds at the sea surface from those at a greater height, whereas heating over warm water deepens and destabilizes the atmospheric boundary layer, decreasing the wind vertical shear [5-8]. Changes in wind speed and cloud fraction also affect the SST by inducing variations in heat flux at the sea surface [9]. The atmospheric variations induced by SST play an important role in modulating the propagation, life cycle, intensity, and other transient features of eddies [3, 10-12].

On the other hand, some researchers state that sea surface temperature (SST) and wind speed are not always positively related as suggested by [6, 13-15]. Generally, research has shown that SST and wind speed have a negative correlation [16-18]. It is due to the fact that the increasing wind speed would decrease the surface temperature by breaking down the surface water stratification, hence bringing the colder subsurface water to the surface. Seasonal variability of SST and wind speed was different for different regions, SST and wind speed mainly had negative correlations [19]. Another study found that sea surface emissivity (SSE) changes with wind speed, while SSE affects SST retrieval [20]. Hence, wind speed affects SST retrieval. Moreover, they found that only a high wind speed of greater than 15 m/s had a significant effect on SST retrieval. Increasing surface wind speed would result in more evaporation and more SST cooling, which result in further increase of the surface wind speed, and vice versa [7]. This wind speed-evaporation-SST feedback is interesting and can be explained in many situations.

Thus, based on several studies above, there are differences of opinion about the correlation of sea surface temperature with wind speed because it depends on each research area. The relationship between SST and wind speed is not as simple as that one is dependent on the other. Therefore, the purpose of this study is to analyze and better understand the seasonal variability and correlation of SST and wind speed in Indonesia, especially in the southern Java.

2. Experimental method

The data used in this study is hourly time intervals of sea surface temperature (SST), speed and wind direction data from the European Centre for Medium-Range Weather Forecasts (ECMWF) with a resolution (0.25 x 0.25°). The type of ECMWF data used is ERA-Interim which is the result of reanalysis and is available from 1979 to the present, and the boundaries of the study area are southern of Java and its surroundings area with coordinates (0-15°S), (105-125°E), and the data source is https://apps.ecmwf.int/datasets/data/interim-full-daily/levtype=sfc/. The method use in this study is averaging hourly into monthly data for SST and wind speed during 20 years observation for period (2000-2019), and representing it in the form of descriptive monthly and seasonally. The detailed correlation in this research was focused on the (0-5°S), (5-10°S), (10-15°S).

3. Results and discussion

In this study the SST characteristics were analyzed both on monthly basis and 6-month average. Fig. 1 shows the 6-month average SST over 20 years period (2000-2019) in the southern sea of Java and surrounding areas. The northern region of this study area (0-5°S) is partly of subregion I (115–135°E, 3.75°S–6.25°N) which has documented as a key region for summer precipitation characteristic in the Indonesia Maritime Continent [21]. On the other hand, both of central (5-10°S) and southern part (10-15°S) are identified as a winter precipitation [22]. Interestingly, Fig. 1 pointed out that both central and southern part of the region have different pattern of high (low) SST during dry season May-October (MJJASO), while warm SST tend to homogenous during rainy season November-March (NDJFM).

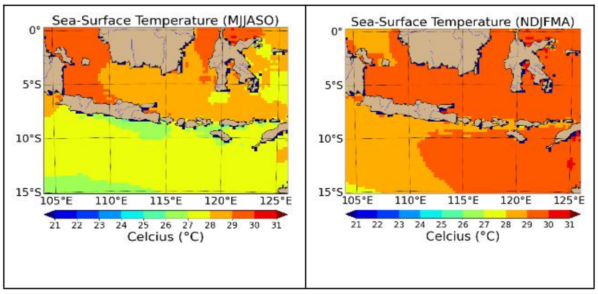


Fig. 1: Six-month average SST in May to October (MJJASO) - left and November to April (NDJDMA) - right during a 20-years period (2000-2019) in the southern sea of Java and its surroundings.

Additionally, Fig. 1 remark in detail that from November to April (NDJFMA), dominant average SST is higher with the range (28-30)°C in the eastern region compared to the western region of Indonesia with the range (27-28)°C. On the other hand, from May to October (MJJASO), the dominant average SST was lower with the range (25-27)°C in the southern region compared to the northern region of Java with the range (28-31)°C. Thus, it is clear that the difference in the 6-month average SST climatological conditions between MJJASO and NDJFMA, where SST conditions seasonally in the southern sea of Java during period of NDJFMA is relatively higher than in MJJASO.

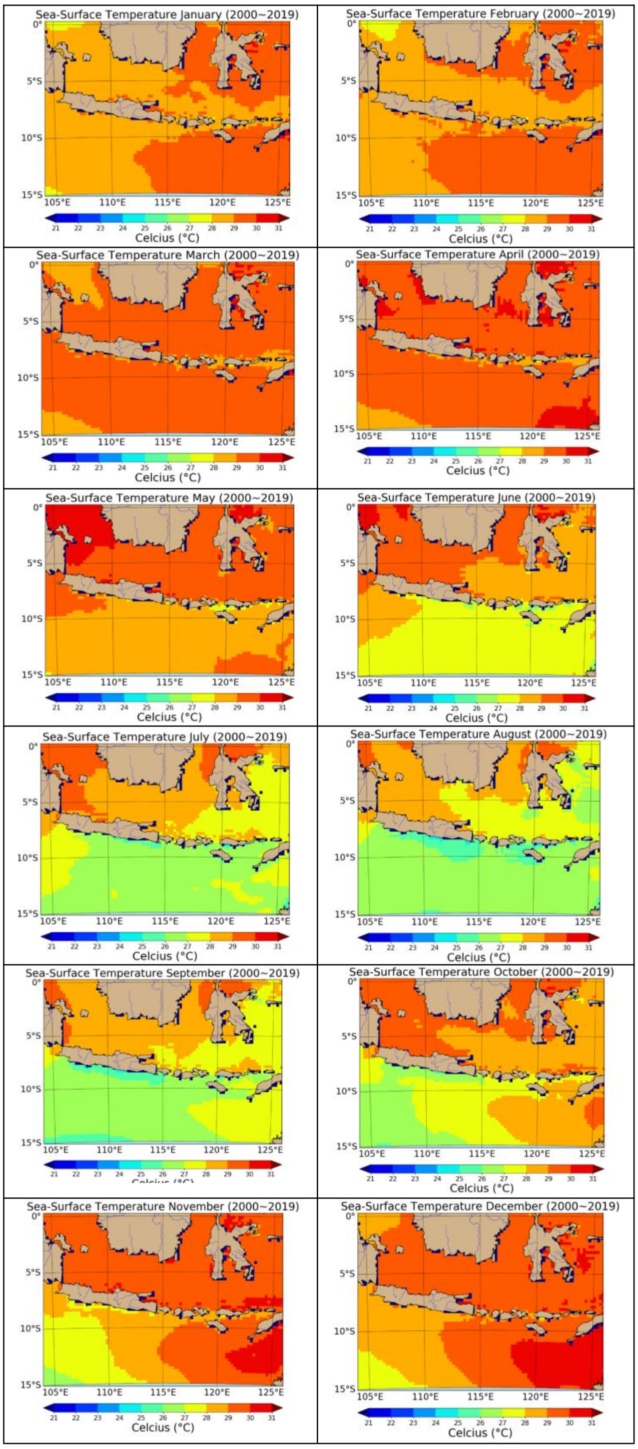


Fig. 2: Monthly average SST over the 20 years period (2000-2019) in the southern sea of Java and its surroundings.

To understand month-to-month variation of SST during both of dry and rainy season, a spatial analysis as described in Fig. 2. It can be seen that in January and February SST was warmer in the eastern Indian Ocean which was (29-30)°C compared to the western part of (28-29)°C. Furthermore, in March and April SST in the southern sea of Java was relatively homogeneous with a range (29-30)°C, while in May and June, SST began to look cooler at (27-28)°C. Meanwhile still in the southern sea of Java, the temperature decreases in July, August, September, October with a range of (25-27)°C, then there is an increase in SST to a range of (27-30)°C which reaches a maximum in the adjacent sea south of the island of Timor and at least in the sea of the Indian Ocean south of west Java. Thus, SST generally elevated from November to April and then decreased from June to October. Fig.2 also notice that in June-October, difference of SST between central and southern part of the region are large and it seems that kind of the dipole SST has role to intensify precipitation in the north-eastern part of Indonesia Maritime Continent (Sulawesi, Halmahera, Ambon, etc.) which has mentioned as in research [23]. However, reducing precipitation in southern part of the region during dry season (JJASO) also close related to Australian winter monsoon activity [24]. The changing conditions of SST in southern Indonesia are closely related to the Australian monsoon as previously studied [8, 13, 15]. This study supports previous research, where the results show that the SST in NDJFMA are seasonally higher in the southern sea of Java than in MJJASO. Conditions in NDJFMA are closely related to the occurrence of summer in Australia, which peaks in December-January-February [15]. On the other hand, when MJJASO is closely related to the occurrence of winter in Australia, the peak occurs in June-July-August [15].

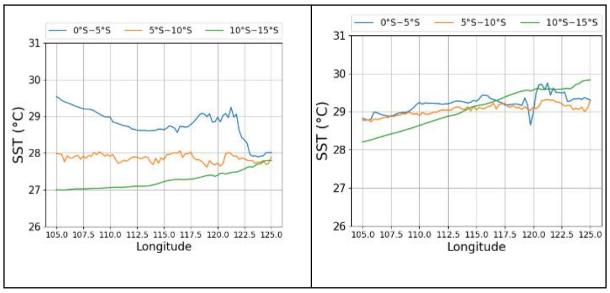


Fig. 3: SST in latitude (0-5°S), (5-10°S), and (10-15°S) for each variation in longitude for MJJASO (left) and NDJFMA (right). Horizontal-axis for longitude and the vertical-axis for SST.

Further analysis was carried out by analyzing SST on the mean month of MJJASO at each change in longitude, with the technique of averaging SST at latitude (0-5°S), (5-10°S), and (10-15°S) as shown in Fig. 3 (left). From the results, it can be seen that there are differences in SST value fluctuations, where at latitude (0-5°S) SST tends to decrease from 29.5°C at the 105°E position to around 28.2°C at 125°E, but at latitudes (10-15°S) SST tends to increase from around 27°C in position 105°E to about 28°C at 125°E, while at latitude (5-10°S) SST only fluctuates at about 28°C from position 105°E to 125°E. With the same technique, the analysis is carried out for the mean month of NDJFMA as shown in Fig. 3 (right). There is a significant difference from the previous one, where the SST tends to increase for each latitude mean, but does not fluctuate too much. At latitudes (0-5°S) SST tends to increase from 29°C at 105°E to around 29.5°C at 125°E, while at latitudes (5-10°S) SST tends to increase from 29°C at 105°E to around 29.5°C at 125°E, then at latitudes (10-15°S) SST is still the same, it is seen that it tends to increase from around 28.5°C at 105°E to around 30°C at 125°E.

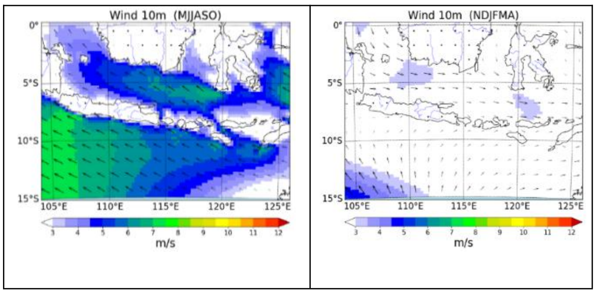
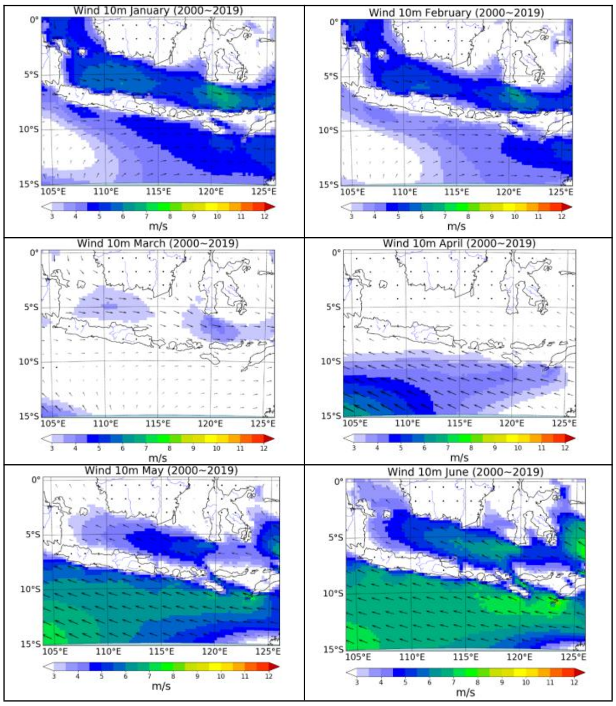


Fig. 4: Direction and speed of the 6-monthly average surface winds from May to October (MJJASO) - left and November to April (NDJFMA) - right for a period of 20 years (2000-2019) in the southern sea of Java and its surroundings.

To develop a better analysis, an analysis of wind direction and speed is carried out at the same observation location. Fig. 4 shows the spatial distribution of the 6-month average wind speed and direction in the months of MJJASO (left) and NDJFMA (right). From the results, it can be seen that the average wind speed in the month of MJJASO is relatively higher than that which occurred in the month of NDJFMA.



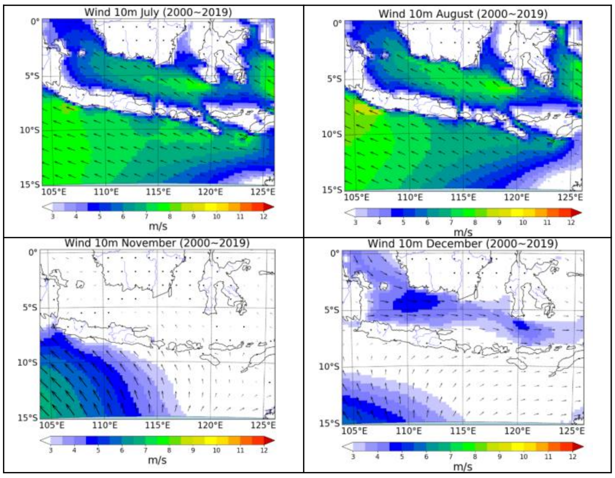


Fig. 5: Wind direction and speed monthly averaged for a period of 20 years (2000-2019) in the southern sea of Java and its surroundings.

In the month of MJJASO, the maximum average wind speed occurs in the Indian Ocean which reaches 7.5 m/s, with the dominant wind direction from the southeast. Meanwhile, in NDJFMA the average wind speed in the southern sea of Java decreases compared to what happened in the month of NDJFMA with an average speed of only 3 m/s, and the maximum speed is around 4.5 m/s, while the dominant wind direction is from the south.

The conditions of monthly average wind speed & direction for 20 years are also analyzed in this paper, as seen in Fig. 5. From the results it can be seen that in January and February in both the northern and southern waters of Java, the dominant wind direction is from the east with from 4 to 6 m/s. Meanwhile, in March at the same location, the wind speed decreases with a speed of below 3 m/s, and the dominant direction is from the south. In April, the wind speed in the southern waters of Java began to rise again, ranging from 3 to 6 m/s, and the direction was dominant from the West. Then the speed increases from May to October with a maximum speed of up to 10 m/s which occurs in the south of West Java in August. While the wind direction from May to August is dominant from the west, while from September to November it is dominant from the southeast. In December the wind again decreases its speed which only reaches a maximum of about 5 m/s around the Indian Ocean, and its direction is dominant from the south.

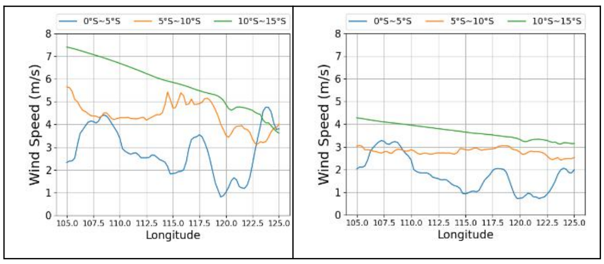


Fig. 6: Wind direction and speed at latitude (0-5°S), (5-10°S), and (10-15°S) for each variation in longitude in MJJASO (left) and NDJFMA (right). Horizontal-axis for longitude and the vertical-axis for wind speed.

Using the same analysis technique as SST, this paper analyses the wind direction and speed at a 6-month average in the month of MJJASO at each change in longitude, with the technique of averaging wind direction & speed at latitude mean (0- 5°S), (5-10°S), and (10-15°S) as shown in Fig. 6 (left) and month of NDJFMA (right). From the results, it can be seen that in the month of MJJASO, there is a difference in wind speed fluctuation, where at latitude (0-5°S) the wind speed is very fluctuating, from decreasing speed from 2 m/s at 105°E to around 4 m/s at 125°E, but at latitude 120°E wind speed is only around one m/s. Then at latitude (10-15°S) the wind speed tends to decrease from about 7.5 m/s at 105°E to about 3.5 m/s at 125°E, while at latitude (5-10°S) wind speed fluctuates from about 5.5 m/s from position 105°E to 4 m/s at 125°E, but at latitude 120°E wind speed is only around one m/s. Then at latitude (10-15°S) the wind speed tends to decrease from about 7.5 m/s at 105°E to about 3.5 m/s at 125°E, while at latitude (5-10°S) wind speed fluctuates from about 5.5 m/s from position 105°E to 4 m/s at 125°E.

With the same technique, the analysis is also carried out for the average month of NDJFMA as shown in Fig. 6 (right). Wind speeds tend to fall for each latitude average, but do not fluctuate too much. At latitude (0-5°S) wind speed tends to fall from 3 m/s at 107.5°E to about one m/s at (120-122°E), while at latitude (5-10°S) wind speed is still seen to be down from 3 m/s at 105°E to around 2.5 m/s at 125°E, then at latitudes (10-15°S) the wind speed is still the same, it seems that it tends to drop from about 4 m/s at 105°E to around 3 m/s 125°E.

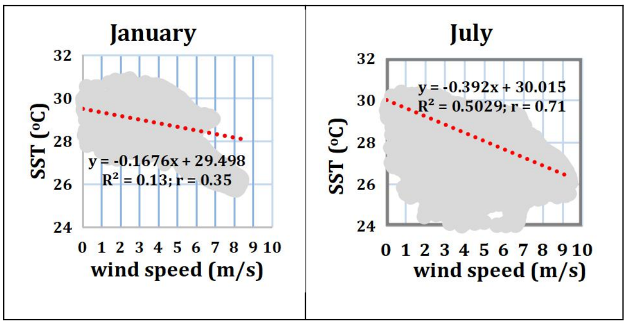


Fig. 7: Correlation of SST with wind speeds monthly average in January (left) and July (right) during a period of 20 years (2000-2019) in the southern sea of Java and its surroundings (0-15°S); (105-125°E).

Based on the results of the previous analysis, the SST correlation with wind speed is analyzed on a monthly and 6-monthly basis. Fig. 7 shows the correlation of SST with monthly mean wind speed for 20 years of observational data. It can be seen that the SST correlation with the monthly average wind speed in January (left) shows a negative correlation, with a correlation coefficient of 0.35, while in July (right) the correlation coefficient is 0.71.

The largest correlation was in October, with a correlation coefficient of 0.88, while the smallest correlation was in January with a correlation coefficient of 0.35. Seen on an average for each month, the correlation between SST and wind speed is quite good, with an average correlation coefficient of 0.67. Complete result of correlation between SST and wind speed for monthly averages during the observation period is shown in Table 1.

Table 1. Correlation between SST and monthly average wind speeds from December to November over a 20 years period (2000-2019) in the southern sea of Java and its surroundings (0-15°S); (105-125°E).

No.	Month	Corr. coef.
1	D; J; F	0.60; 0.35; 0.44
2	M; A; M	0.63; 0.66; 0.81
3	J; J; A	0.80; 0.71; 0.60
4	S; O; N	0.70; 0.88; 0.86

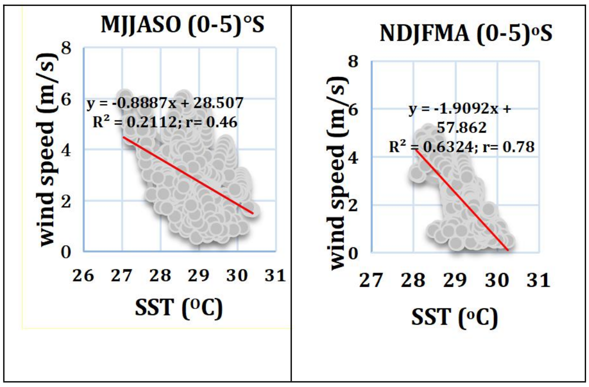


Fig. 8: Correlation of SST with 6-month wind speed for MJJASO (left) and NDJFMA (right) for a 20-years mean (2000-2019) at (0-5°S) for each variation in longitude.

Furthermore, the one of SST correlation with wind speed for 6-month on (0-5°S) is analyzed as shown in Fig. 8. At (0-5°S) for the month of MJJASO, SST with wind speed has a negative correlation with a correlation coefficient of 0.46, while for the month of NDJMA the correlation coefficient was 0.78. Whereas at (5-10°S) for MJJASO the correlation coefficient is 0.44, while for the month of NDJMA it is 0.69. Complete results of SST correlation with 6-month wind speeds at (0-5°S), (5-10°S), and (10-15°S) for each variation in longitude can be seen in Table 2.

Table 2. Correlation between SST and 6-month wind speed of the average of MJJASO, NDJFMA over a period of 20 years (2000-2019) in the southern sea of Java for each variation in longitude.

No.	Latitude Av	MJJASO Av	NDJFMA Av
1	(0-5˚S)	0.20	0.68
2	(5-10˚S)	0.19	0.26
3	(10-15˚S)	0.99	0.98

Based on the results shows that the correlation between SST and wind speed on a monthly and six-monthly basis are the highest during the dry season on average and lower in the wet season. SST and wind speed exhibited a strong negative correlation at various temporal, where from the average latitude, the highest correlation occurs at latitude (10-15°S) both in MJJASO and NDJFMA. These results can be seen also in Fig. 3 and 6, where SST and wind speed correlate very strongly at longitude (10-15°S), whereas it is relatively weak correlation for both of the interval (0-5°S) and (5-10°S). SST in MJJASO and NDJFMA tends to decrease (Fig. 3), while the wind speed is the opposite as seen in Fig. 6.

Table 1 depicted that northern part has a strong influenced by Asian winter monsoon (NDJFMA) which is characterized by westerly wind. For central region, which is also denoted as transition region, weak correlation between SST and wind speed is clearly documented in this study. Interestingly, SST and wind speed in southern region seems a positive feedback each other in both rainy and dry season. However, this part was explained in previous study has strong relation with Australian winter monsoon which is identified as a strong easterly wind [24].

On the other hand, the lower correlation between wind speed and SST was depicted during January and February (Table 2), while Asian winter monsoon activity strong influenced rainy season in southern part of the region [22]. It also noticed that strengthen of convective activity during January-February in entire region [25] tend to diminished horizontal wind speed [26].

A more detail analysis of SST and wind speed for review of differences in latitude is very important and interesting as described in Fig. 1, Fig. 3, Fig. 4, and Fig.6, because differences in SST can depend on several factors. As we knew, SST is affected by incoming solar radiation (insolation), monsoon, and topography. Equally important, SST is also influenced by meteorological parameters such as wind speed, humidity, air temperature, cloud cover, and sea level pressure. Fig. 3 (left) show that at the time of MJJASO the SST distribution at latitude (0-5°S) was clearly dominated by the influence of insolation, topography, Asian summer and Australian winter monsoon which brought the cold air period, so that the previously warm SST was seen to decrease, but inversely for wind speed as shown in Fig. 6 (left). Then at latitude (5-10°S), SST is still heavily influenced by insolation, topography, and Australian winter monsoon. With a high wind speed (5-7) m/s from the southeast, SST looks cooler and constant. At latitudes (10-15°S), the SST is heavily influenced by the Australian summer monsoon, ocean dominance and high wind speeds, so that the SST looks cooler to warmer. Furthermore, in NDJFMA, at positions (0-5°S), (5-10°S), SST is warmer and relatively constant throughout most of the area, while at latitudes (10-15°S), SST which was previously cold, continues to warm. It can be seen that the SST was influenced by the Australian summer monsoon which experienced a decrease in southerly wind speeds with a lot of warm air.

Further study in improving better understanding of SST vs. wind speed and its direction is necessary. It can also be developed to the wider interval or area from Aceh to Papua. The method to analyze is not only restricted for average monthly or yearly, but also investigate in a single time or area that could be the reasons of climate differences in the last 20 years.

4. Conclusions

From the results of the analysis it can be concluded that the difference in SST climatological conditions and (wind speed) in monthly and 6-month averages, in MJJASO it is lower (higher) and the magnitude is more fluctuating in latitude average, compared to NDJFMA month. The correlation between SST and wind speed on a monthly basis are the highest average during the dry season. Meanwhile, from the average latitude, the highest correlation occurs at latitude (10-15°S) both in MJJASO and NDJFMA. The significant results obtained are regarding the differences in SST and wind variations with respect to latitude between the northern [Karimata strait, (0-5°S)], center[Java sea (5-10°S)] and southern [Indian Ocean(10-15°S)] regions. In this case, the Indian Ocean region south of Java has the highest correlation between SST and wind during the dry and rainy season compared to areas in the north and center.

Acknowledgment
This research was supported by the Indonesian Educational Endowment Fund (LPDP) through the Mandatory Productive Innovative Research program under National Research Priority, Decree Number: 252/Menteri Ristek/Ka BRIN/E1/PRN/2020.

References
[1] D. B. Chelton, S. K. Esbensen, M. G. Schlax, N. Thum, M. H. Freilich, F. J. Wentz, C. L. Gentemann, M. J. Mc Phaden, and P. S. Schopf, "Observations of coupling between surface wind stress and sea surface temperature in the eastern tropical Pacific," *J. Climate*, **14**, 1479–1498, (2001).
[2] S.-P. Xie, "Satellite observations of cool ocean–atmosphere interaction," *Bull. Amer. Meteor. Soc.*, **85**, 195–208, (2004).
[3] R. J. Small and Coauthors, "Air–sea interaction over ocean fronts and eddies," *Dyn. Atmos. Oceans*, **45**, 274–319, (2008).
[4] S. Sun, Y. Fang, Y. Zu., B. Liu, Tana, and A. A. Samah, "Seasonal Characteristics of Mesoscale Coupling between the Sea Surface Temperature and Wind Speed in the South China Sea," *J. Climate*, **23**, 625-638, (2020).
[5] S. P. Hayes, M. J. Mc Phaden, and J. M. Wallace, "The influence of sea-surface temperature on surface wind in the eastern equatorial Pacific: Weekly to monthly variability," *J. Climate*, **2**, 1500–1506, (1989).
[6] J. M. Wallace, T. P. Mitchell, and C. Deser, "The influence of sea-surface temperature on surface wind in the eastern equatorial Pacific: Seasonal and interannual variability," *J. Climate*, **2**, 1492–1499, (1989).
[7] C. Wang, R. H. Weisberg, and H. Yang, "Effects of the wind speed-evaporation-SST feedback on the El Niño-Southern Oscillation," *J of Atmospheric Sciences*, **56**, 1391-1403, (1999).
[8] M. L. Griffiths, R. N. Drysdale, M. K. Gagan, J.-x. Zhao, L. K. Ayliffe, J. C. Hellstrom, W. S. Hantoro, S. Frisia, Y.-x. Feng, I. Cartwright, E. St. Pierre, M. J. Fischer, and B. W. Suwargadi, "Increasing Australian–Indonesian monsoon rainfall linked to early Holocene sea-level rise," *Nature Geoscience*, **2**, 636–639, (2009).
[9] I. N. Frenger, N. Gruber, R. Knutti, and M. Münnich, "Imprint of Southern Ocean eddies on winds, clouds and rainfall," *Nat. Geosci.*, **6**, 608–612, (2013).
[10] W. B. White, and J. L. Annis, "Coupling of extratropical mesoscale eddies in the ocean to westerly winds in the atmospheric boundary layer," *J. Phys. Oceanography.*, **33**, 1095–1107, (2003).
[11] X. Jin, C. Dong, J. Kurian, J. C. McWilliams, D. B. Chelton, and Z. Li, "SST–wind interaction in coastal upwelling: Oceanic simulation with empirical coupling," *J. Phys. Oceanography.*, **39**, 2957–2970, (2009).
[12] H. Seo, A. J. Miller, and J. R. Norris, "Eddy–wind interaction in the California Current system: Dynamics and impacts," *J. Physics Oceanograph.*, **46**, 439–459, (2016).
[13] N. Nicholls, "A system for predicting the onset of the north Australian wet season". *Int. J. Climatol.*, **4**, 425–436, (1984).
[14] M. A. Alexander, I. Blade, M. Newman, J. R. Lazante, N. C. Lau, J. Scot, "The Atmospheric Bridge: The Influence of ENSO Teleconnections on Air–Sea Interaction over the Global Oceans," *J. Climate*, **15**, 2205-2231, (2002).
[15] Y. L. Duan, H. W. Liu, W. Yu, L. Liu, G. Yang, and B. Liu, "The Onset of the Indonesian–Australian Summer Monsoon Triggered by the First-Branch Eastward-Propagating Madden–Julian Oscillation," *J. Climate,* **32**, 5453-5470, (2019).
[16] J. Shukla and B. M. X. Misra, "Relationships between sea surface temperature and wind speed over the central Arabian Sea, and monsoon rainfall over India," *Monthly Weather Review*, **105**, 998-1002, (2005).
[17] T. Qu, Y. Du, J. Strachan, G. Meyers, and J. Slingo, "Sea surface temperature and its variability in the Indonesian region," *Oceanography*, **18**, 50–61, (2005).
[18] C. Huang and F. Qiao, "The relationship between sea surface temperature anomaly and wind energy input in the Pacific Ocean," *Natural Science*, **19**, (2009).
[19] B. Qu, A. J. Gabric, J. N. Zhu, D. R. Lin, F. Qian , M. Zhao, "Correlation between sea surface temperature and wind speed in Greenland Sea and their relationships with NAO variability," *Water Sci. Eng.*, **5**, 304-315, (2012).
[20] H. G. Ng, M. Z. Mat Jafri, K. Abdulah, and C. J. Wong, "The effect of wind speed on SST retrival," *Proceedings of Aerospace Conference*, (2009).
[21] Q. Xu, Z. Guan, D. Jin, D. Hu, "Regional Characteristics of Interannual Variability of Summer Rainfall in the Maritime Continent and Their Related Anomalous Circulation Patterns," *J. Climate*, **32**, 4179-4192, (2019).
[22] C.-P. Chang, Z. Wang, J. Mc Bride, C. H. Liu, "Annual Cycle of Southeast Asia-Maritime Continent Rainfall and the Asymmetric Monsoon Transition," *J. Climate*, **18**, 287-301, (2005).
[23] E. Aldrian and R. D. Susanto, "Identification of Three Dominant Rainfall Regions within Indonesia and Their Relationship to Sea Surface Temperature," *Int. J. Climatol*. **23**, 1435–1452, (2003).
[24] Y. Kajikawa, B. Wang, J. Yang, "A• multi-time scale Australian monsoon index," *Int. J. Climatol.*, **29**, 1114–1120, (2009).
[25] C. S. Ramage, "Monsoon Meteorology,"

Academic Press, **296**, (1971).
[26] J. Matsumoto, "The Seasonal Changes in Asian and Australian Monsoon Regions," *J. Meteorology. Soc. Japan*. **70**, 257-273, (1992).