**Nekton:** Jurnal Perikanan dan Ilmu Kelautan
Vol 6 No 1 (2026): 1–12. DOI: 10.47767/nekton.v6i1.1079
ISSN 2776-2734 (online); ISSN 2776-2742 (printed)
Publisher: Politeknik Negeri Sambas

RESEARCH ARTICLE

# Characteristics of Monsoon Current Patterns in Maluku Waters in the ENSO Period

*Karakteristik Pola Arus Muson di Perairan Maluku pada Periode ENSO*

**Yusran Abdul Gani Tuatoy** [1], **Simon Tubalawony** [1*], **Ronald Darlly Hukubun** [1]
[1]*Universitas Pattimura, Indonesia.*

**Abstract.** The hydrodynamic conditions of the Maluku waters are highly dynamic and are generally influenced by several oceanographic factors, including current patterns that are also affected by variations in monsoonal winds. At present, global climate change associated with the El Niño–Southern Oscillation (ENSO) phenomenon is suspected to have altered wind and current patterns. This study aims to examine the variations in monsoonal wind patterns and monsoonal current patterns during ENSO events in the Maluku waters, including the Seram Sea, Banda Sea, and Arafura Sea. Monthly averaged wind and current data were obtained from the Copernicus database, while ENSO index data were acquired from the National Oceanic and Atmospheric Administration (NOAA) database. The results indicate that the average maximum wind speed during the West Monsoon reaches 6.1 m/s with a southeastward direction, whereas during the East Monsoon it reaches 9.2 m/s with a northwestward direction. Based on the direction of movement, the prevailing winds are characterized as monsoonal winds. The average maximum current velocity during the West Monsoon reaches 0.8 m/s with an eastward direction, while during the East Monsoon it reaches 1.4 m/s with a dominant westward movement. The dominant direction of current movement generally follows the direction of the monsoonal winds. The influence of ENSO indicates that the average wind speed and spatial distribution of winds increase during El Niño events, whereas the average current velocity and spatial distribution of currents increase during La Niña events.
**Keywords: Maluku waters, monsoonal winds, ocean currents, ENSO.**

***Abstrak.*** *Kondisi Perairan Maluku yang dinamis secara umum dipengaruhi oleh beberapa faktor oseanografi di antaranya adalah pola arus yang juga dipengaruhi oleh variasi angin muson. Sekarang ini, dengan terjadinya perubahan iklim secara global akibat fenomena ENSO diduga menyebabkan terjadinya perubahan pada pola angin dan arus. Tujuan penelitian ini adalah untuk mengkaji variasi pola angin muson dan pola arus muson saat fenomena ENSO di Perairan Maluku yang meliputi Laut Seram, Laut Banda, dan Laut Arafura. Data angin dan arus dengan rata-rata bulanan yang digunakan diperoleh dari situs web milik Copernicus, sedangkan data indeks ENSO diperoleh dari situs web milik NOAA. Hasil penelitian menunjukkan bahwa rata-rata kecepatan maksimum angin pada Musim Barat adalah 6,1 m/s dengan arah menuju Tenggara, dan 9,2 m/s pada Musim Timur dengan arah menuju barat laut. Jika dilihat dari arah pergerakannya, angin yang berhembus merupakan angin muson. Rata-rata kecepatan maksimum arus pada Musim Barat mencapai 0,8 m/s dengan arah menuju timur, dan 1,4 m/s pada Musim Timur dengan arah pergerakan dominan ke arah barat. Arah dominan pergerakan arus mengikuti arah hembusan angin muson. Pengaruh ENSO menunjukan bahwa Kecepatan rata-rata dan area distribusi angin mengalami peningkatan saat terjadinya El Nino, sedangkan kecepatan rata-rata dan area distribusi arus mengalami peningkatan saat terjadinya La Nina.*
***Kata Kunci: perairan Maluku, angin muson, arus, ENSO.***

*Corresponding author: Simon Tubalawony
Jurusan Ilmu Kelautan, Fakultas Perikanan dan Ilmu Kelautan, Universitas Pattimura, Ambon, 97233, Indonesia.
E-mail: simontubalawony003@gmail.com



***To cite this article (APA Style):***
Tuatoy, Y. A. G., Tubalawony, S., & Hukuban, R. D. (2026). Characteristics of Monsoon Current Patterns in Maluku Waters in the ENSO Period. *Nekton*, *6*(1), 1–12. https://doi.org/10.47767/nekton.v6i1.1079

https://ojs.poltesa.ac.id/index.php/nekton
Submitted: 22 Sep 2025; Received in revised form: 13 Jan 2026; Accepted: 1 Feb 2026; Published regularly: 8 April 2026

## INTRODUCTION

The Maluku waters constitute one of the strategically important marine regions of Indonesia, characterized by high biodiversity and a significant role in the marine ecological system. This region encompasses several major marine areas, including the Banda Sea, Seram Sea, and Arafura Sea, which exhibit highly dynamic oceanographic conditions. In general, dynamic marine environments are influenced by various oceanographic factors, one of which is ocean currents (Anisa et al., 2017). According to Irawan et al. (2018), ocean currents are defined as the continuous movement of water masses driven by several factors, such as wind forcing, density differences, upwelling and downwelling processes, and long-wave motion. In Indonesian waters, current systems are generally generated by wind forcing and tidal dynamics. Ocean currents represent one of the key oceanographic parameters that play a crucial role in determining the physical characteristics and environmental conditions of marine waters (Permadi et al., 2015).

The movement of ocean currents in Indonesian waters, particularly at the surface layer of the Maluku waters, is generally influenced by monsoonal wind systems. The strategic geographical position of these waters allows seasonal monsoonal winds to develop depending on the position of the sun (Yananto & Sibarani, 2016). Persistent wind forcing throughout the year facilitates the occurrence of Ekman transport in the ocean. The Ekman mechanism is commonly used to explain the movement of water masses resulting from the interaction between wind stress and the ocean surface, which causes the deflection of surface current directions. Ekman transport develops due to current velocities generated by wind energy acting on the ocean surface and gradually decreases with increasing ocean depth (Ginanjar et al., 2020). This phenomenon significantly influences the marine environment, including nutrient distribution, upwelling and downwelling processes, which subsequently affect fish migration patterns and fisheries activities. The complex topography and extensive marine area of the Maluku waters contribute to unique oceanographic characteristics. Its strategic geographical location makes the region strongly influenced by seasonal monsoonal wind circulation. In addition, the proximity of the Maluku waters to the Pacific Ocean allows sea surface temperature anomalies associated with the El Niño–Southern Oscillation (ENSO) to influence oceanographic conditions in this region, particularly variations in wind patterns and ocean current dynamics.

The El Niño–Southern Oscillation (ENSO) is a climate anomaly characterized by fluctuations in sea surface temperature in the equatorial Pacific Ocean. One of the key indicators of ENSO events is the weakening of the Walker circulation, an east–west atmospheric circulation system across the equatorial Pacific (Yananto & Dewi, 2016). ENSO generally consists of two main phases: the warm phase (El Niño) and the cold phase (La Niña), with an additional neutral phase when neither El Niño nor La Niña conditions occur. El Niño refers to a phenomenon in which sea surface temperatures in the equatorial Pacific increase above normal conditions on a large spatial scale over an interannual time scale (Wang et al., 2017). Conversely, La Niña represents a condition characterized by a decrease in sea surface temperature in the eastern equatorial Pacific relative to its normal state (Athoillah et al., 2017). Variations in atmospheric pressure and sea surface temperature associated with ENSO events may induce changes in wind variability and surface current patterns in the Maluku waters. During El Niño events, the speed, intensity, and spatial distribution of winds in the Maluku waters tend to be greater than under normal conditions (Buton et al., 2023; Kakiailatu et al., 2024).

Global climate variability associated with ENSO can alter monsoonal wind circulation, which subsequently leads to modifications in ocean current patterns, particularly in the Maluku waters. These changes may significantly influence the oceanographic dynamics of the region, highlighting the importance of conducting further investigations on this topic. Research on wind and ocean current variability is also essential for understanding climate change issues, as wind patterns and current systems may respond to variations in global temperature. Based on the background described above, this study aims to identify and analyze the monsoonal current patterns in the Maluku waters, with particular emphasis on how ENSO events influence the formation and movement of monsoonal winds and ocean currents in the region. A comprehensive understanding of monsoonal current patterns is expected to provide deeper insights into the marine and coastal dynamics of the Maluku waters, including the Banda Sea, Arafura Sea, and Seram Sea.

## MATERIAL AND METHODS

The study area is located in the Maluku waters, Indonesia, within the geographical coordinates of 124°E–140°E and 1°S–11°S, covering several major marine regions, including the Banda Sea, Arafura Sea, and Seram Sea. This study was conducted by analyzing wind and ocean current data during monsoonal periods under different ENSO conditions. The observation periods were selected based on the Oceanic Niño Index (ONI) to represent three climate conditions: December 2012 – November 2013 (neutral ENSO conditions), December 2014 – November 2015 (El Niño event), and December 2021 – November 2022 (La Niña event). For each period, the analysis was conducted according to the four monsoonal seasons in the Indonesian region: West Monsoon, Transition Season I, East Monsoon, and Transition Season II.

The wind data used in this study consist of 10-m wind velocity above sea level with a spatial resolution of 0.25° × 0.25° and monthly temporal resolution, obtained from the Copernicus Climate Change Service (C3S) database, accessible at: https://climate.copernicus.eu/. Ocean current data with a spatial resolution of 0.083° × 0.083° and monthly temporal resolution were obtained from the Copernicus Marine Service database, available at: https://marine.copernicus.eu/. In addition, the ENSO index data were used to identify the occurrence and intensity of ENSO events during the study period. The collected datasets were subsequently analyzed to describe the variability of wind patterns and ocean current patterns, as well as to evaluate the influence of ENSO phenomena on the dynamics of monsoonal winds and currents in the Maluku waters.

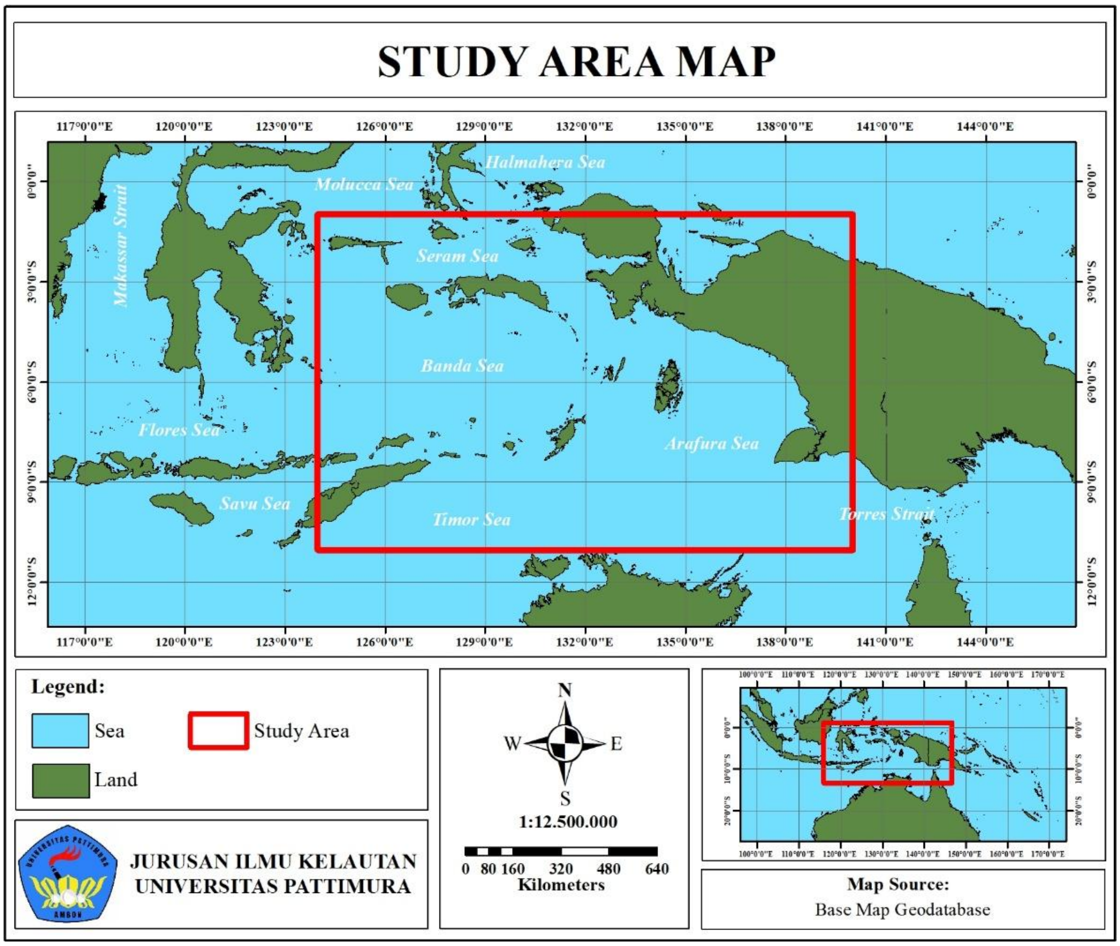


Figure 1. Study Area Map.

## RESULTS AND DISCUSSION

### Wind Pattern Variability

During the West Monsoon (Figure 2), the wind direction over the Maluku waters was generally consistent. Winds predominantly blew from the west (Flores Sea) and northwest (Molucca Sea) toward the southeast (Arafura Sea), passing through the Maluku waters, including the Seram Sea, Banda Sea, and Arafura Sea. Wind speed reached its peak in January in the Banda Sea, with maximum velocities of 7.9 m/s during the El Niño period, 7.0 m/s during neutral conditions, and 7.5 m/s during the La Niña period. Based on the direction of the wind flow during the West Monsoon, the dominant wind system corresponded to the Asian Monsoon (Northwest Monsoon), which is consistent with the findings of Haiyqal et al. (2023).

This wind movement is driven by the air pressure gradient, where atmospheric pressure in the western and northwestern regions is higher than that in the eastern and southeastern regions due to the apparent motion of the sun, causing areas near the equator to become pathways for wind circulation (Rifai et al., 2020). During the West Monsoon, the El Niño period exhibited stronger wind speeds, particularly over the Banda Sea and Arafura Sea, compared to the Seram Sea. However, wind speeds during the La Niña period were also relatively strong. According to Buton et al. (2023), this occurs because the Asian Monsoon (Northwest Monsoon) exerts a stronger influence than ENSO forcing, resulting in a more dominant north–south atmospheric circulation over Indonesia compared with the east–west circulation changes associated with ENSO.

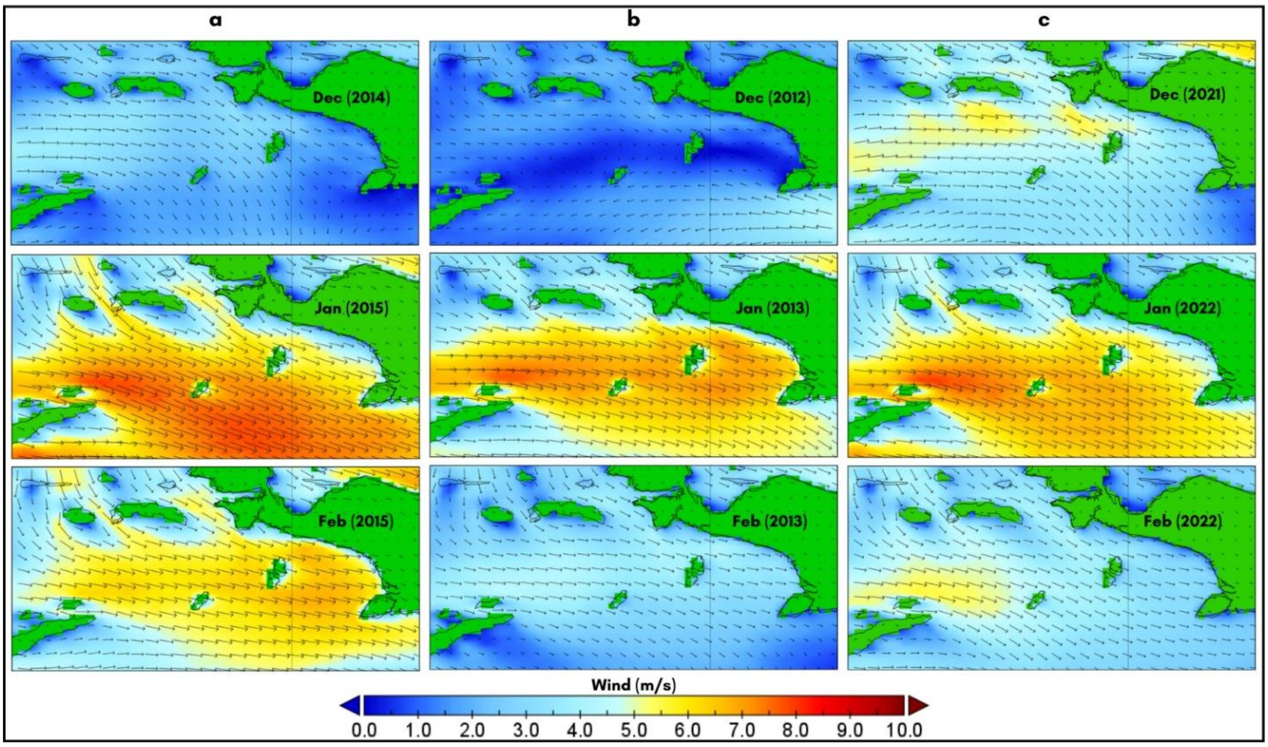


Figure 2. Wind pattern variability during the West Monsoon under El Niño (a), neutral (b), and La Niña (c) conditions in the Maluku waters.

During Transition Season I (Figure 3), wind movement in the Maluku waters varied from month to month. According to Marpaung et al. (2015), Transition Season I represents the transitional phase between the West Monsoon and the East Monsoon. Consequently, the wind direction gradually shifts from northwest–southeast to southeast–northwest (Buton et al., 2023). In March, winds still predominantly moved from northwest to southeast, reflecting the Northwest Monsoon, as the seasonal transition had just begun. By April and May, the wind direction shifted toward southeast to northwest, indicating the influence of the Southeast Monsoon. During this season, May recorded the highest wind speeds, reaching maximum values of 8.0 m/s during El Niño, 8.6 m/s during neutral conditions, and 6.4 m/s during La Niña, particularly in the

Arafura Sea. The southern position of the Arafura Sea allows winds to flow directly into the Maluku waters. Changes in wind direction during this period indicate the seasonal transition occurring in the Maluku waters, driven by winds originating from the Australian continent (Rinekso et al., 2023). During this transition, wind patterns become irregular because the sun moves across the equator (Utami et al., 2018). The results showed that during Transition Season I, the El Niño period exhibited higher average wind speeds compared with neutral and La Niña conditions, as indicated by the broader spatial distribution of wind intensity.

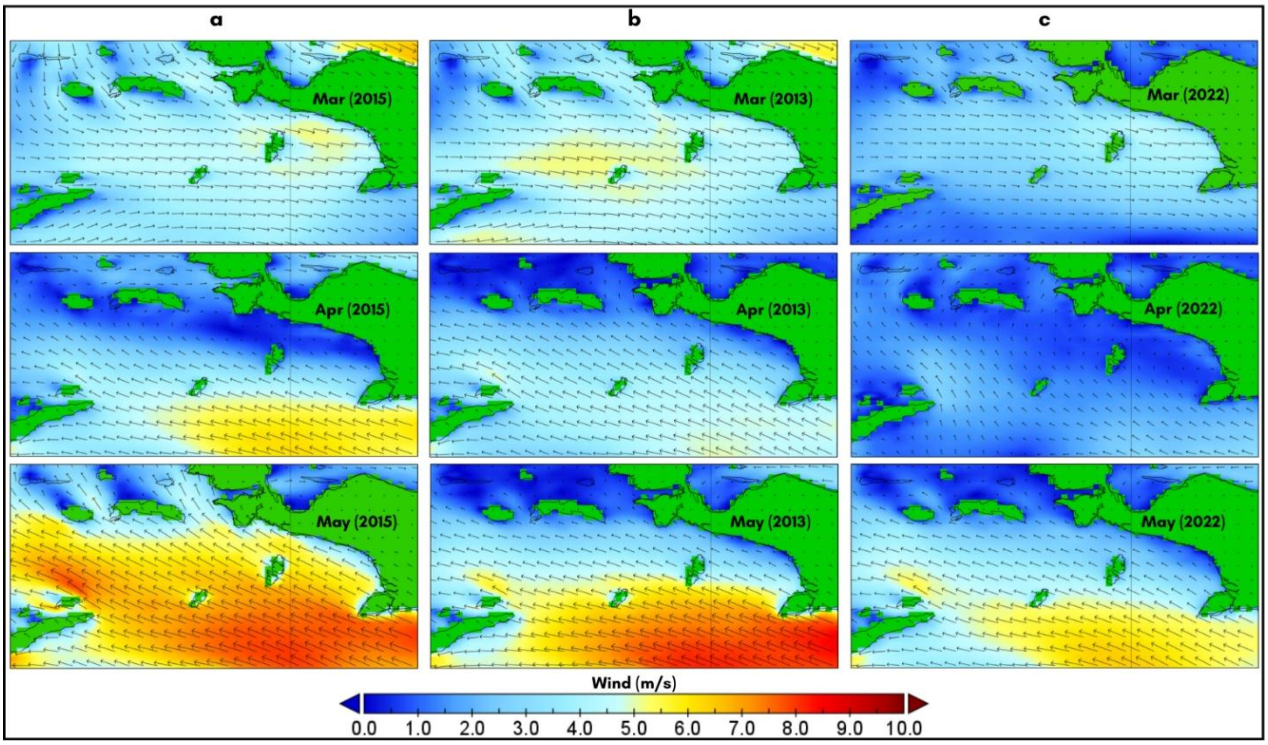

Figure 3. Wind pattern variability during Transition Season I under El Niño (a), neutral (b), and La Niña (c) conditions in the Maluku waters.

During the East Monsoon (Figure 4), wind movement in the Maluku waters showed relatively uniform patterns. Winds generally blew westward toward the Flores Sea and northwestward toward the Molucca Sea, originating from the southeast (Arafura Sea) and passing through the Maluku waters. Wind speeds during the East Monsoon were also relatively high across all ENSO phases. The maximum wind speeds were recorded during June in the El Niño period (9.3 m/s), July under neutral conditions (10.1 m/s), and July during the La Niña period (9.2 m/s).

The dominant wind system during this period was the Southeast Monsoon, which develops due to the higher atmospheric pressure gradient in the southeastern region compared to the western and northwestern regions, driven by the apparent motion of the sun (Buton et al., 2023). Wind speeds were strongest in the Arafura Sea, followed by the Banda Sea, while the Seram Sea experienced relatively calmer conditions. This difference is influenced by the geographical position of the Seram Sea, which lies north of Seram Island and is partially shielded by topographic barriers that reduce wind intensity.

When the Southeast Monsoon prevails, wind stress over the sea surface can induce Ekman transport (Putri et al., 2023). This process causes the displacement of surface water masses, resulting in water divergence and the upward movement of deeper water masses, leading to upwelling. Similar processes occur in the Maluku waters. During the Southeast Monsoon, upwelling has been observed in the Banda Sea, Arafura Sea, and Kei waters (Hukubun & Tubalawony, 2024; Tristianto et al., 2021; Wattimena & Tubalawony, 2023). In contrast, according to Gordon et al. (1999) cited in Tristianto et al. (2021), upwelling and downwelling alternate annually in the southern and northern parts of Seram Island. Thus, when upwelling occurs south of Seram Island and in the

Banda Sea during the East Monsoon, downwelling occurs in the Seram Sea north of the island.

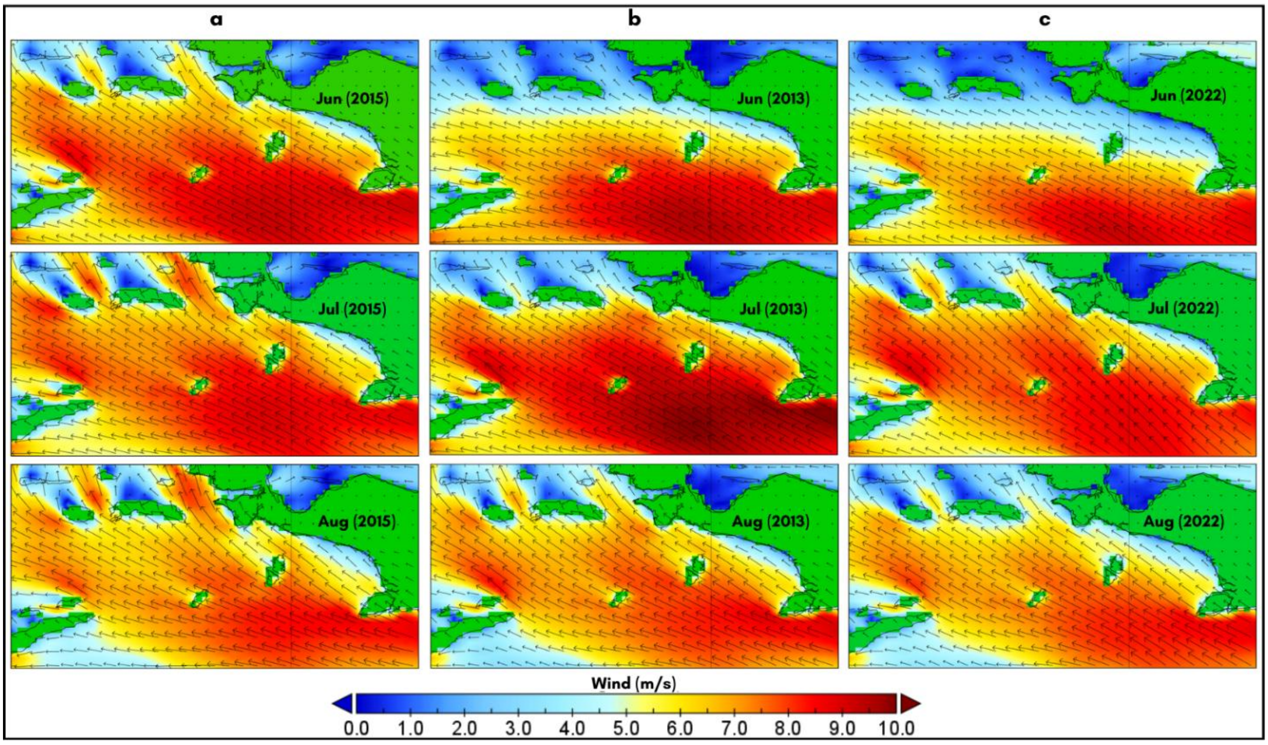


Figure 4. Wind pattern variability during the East Monsoon under El Niño (a), neutral (b), and La Niña (c) conditions in the Maluku waters.

During Transition Season II (Figure 5), wind direction and speed in the Maluku waters became more variable. In September and October, winds were still dominated by the Southeast Monsoon, whereas in November, wind speeds weakened and directions became more variable. The highest wind speeds occurred in September, reaching 9.4 m/s during El Niño, 8.5 m/s under neutral conditions, and 7.4 m/s during La Niña.

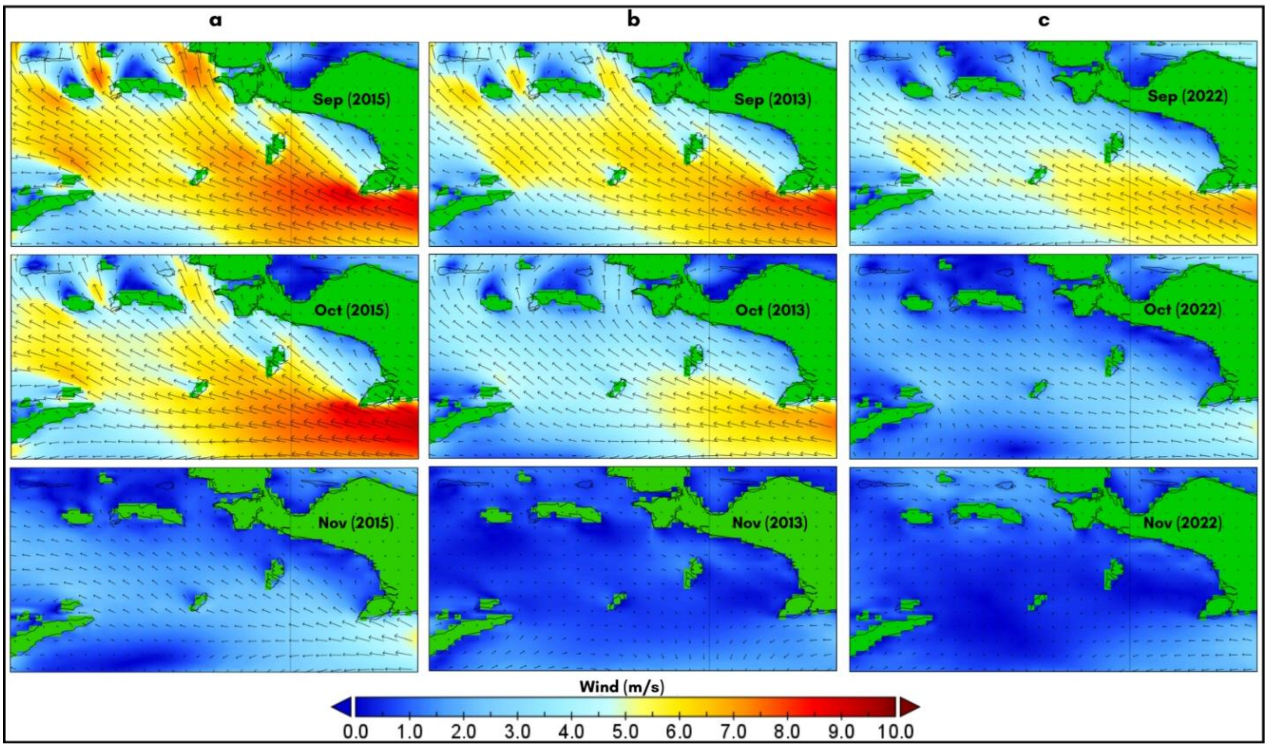


Figure 5. Wind pattern variability during Transition Season II under El Niño (a), neutral (b), and La Niña (c) conditions in the Maluku waters.

During transitional seasons, wind patterns and associated parameters are generally less stable compared to the main monsoon seasons (Hendrayana et al., 2023). Wind conditions in September and October remained influenced by the Southeast Monsoon, while in November winds weakened and became more variable, indicating the upcoming transition toward the Northwest Monsoon. Based on the apparent solar movement, during Transition Season II the sun moves from the equator toward the Southern Hemisphere, passing over the Maluku waters, which results in more variable wind patterns. The results also indicated that wind speeds during the El Niño period were generally higher than those observed under neutral and La Niña conditions.

**Ocean Current Pattern Variability**

During the West Monsoon (Figure 6), current movement in the Maluku waters showed considerable spatial variability, although the dominant current direction was eastward. The highest current velocities were observed in the Banda Sea, which is directly connected to the Flores Sea. According to Assir et al. (2017), during the West Monsoon winds blowing toward the southeast generate currents that transport water masses from the Flores Sea toward the Arafura Sea through the Banda Sea. During the La Niña period, current velocities were higher, reaching 0.9 m/s in December and January, and 1.0 m/s in February. In contrast, the Seram Sea and Arafura Sea exhibited relatively weaker and more variable current movements. This condition is likely influenced by the southern position of the Arafura Sea and the relatively smaller spatial extent of the Seram Sea. The accumulation of water masses transported from the Flores Sea into the Banda Sea and Arafura Sea may also trigger downwelling processes in these regions.

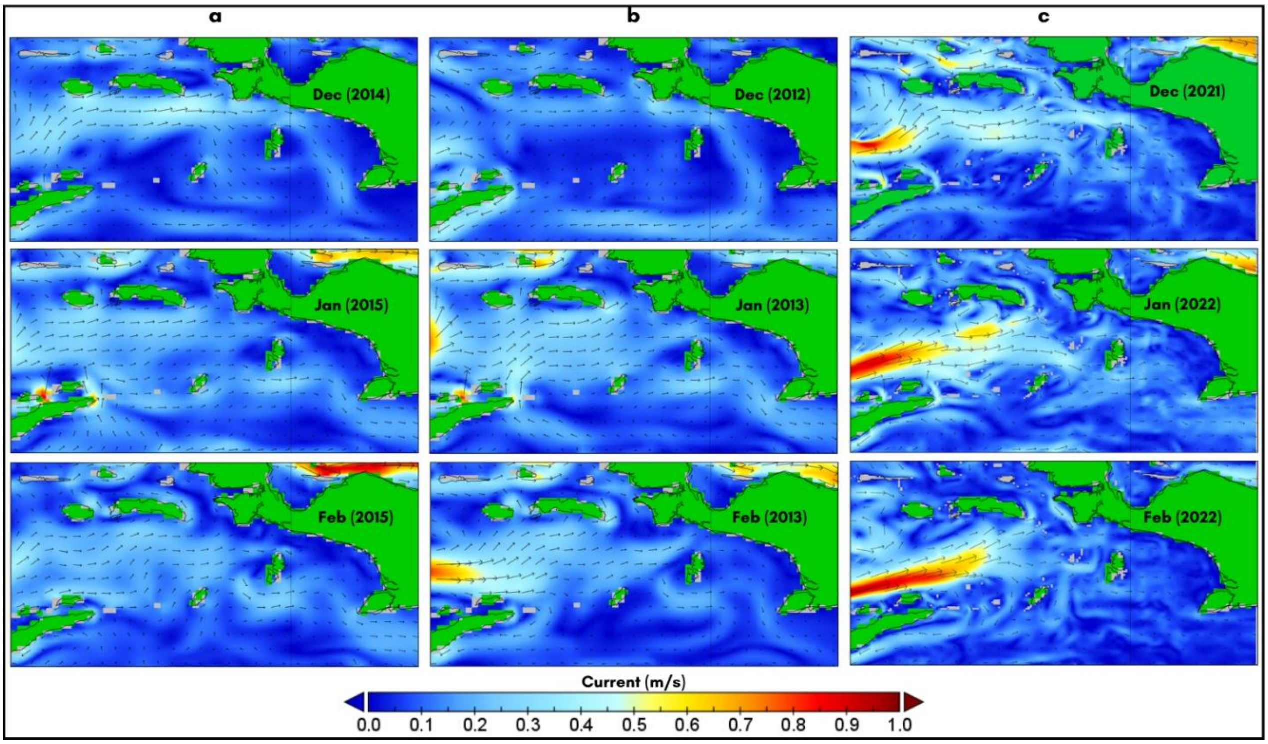


Figure 6. Current pattern variability during the West Monsoon under El Niño (a), neutral (b), and La Niña (c) conditions in the Maluku waters.

Unlike the West Monsoon, which shows a dominant eastward current pattern, Transition Season I (Figure 7) exhibits more variable current movements. In March, currents predominantly flowed eastward, whereas in May the direction shifted westward. This shift indicates that ocean current directions change concurrently with the reversal of monsoonal wind patterns across the Maluku waters. In addition to wind forcing, pressure gradient differences also influence current movement, since surface currents generally move from high-pressure regions toward low-pressure regions (Sari et al., 2020). However, during Transition Season I, the sun crosses the equator, reducing pressure gradients over the Maluku waters and resulting in more variable current patterns. In addition to wind forcing, pressure gradient differences also influence current movement, since surface currents generally move from high-pressure regions toward low-pressure regions (Sari et al., 2020). However, during Transition Season I, the sun crosses the equator, reducing pressure gradients over the Maluku waters and resulting in more variable current patterns.

During this season, an eddy formation was observed in the western Banda Sea in April, characterized by a counterclockwise (anticyclonic) rotation. Eddy formation in the Banda Sea is influenced by several factors, including local wind forcing near the ocean surface and the geographical position of the Banda Sea. The variability of wind directions during transitional seasons promotes eddy formation. Additionally, the Banda Sea is connected to several surrounding seas, allowing water masses from different regions to converge and generate rotational circulation. Darmawan et al. (2020) reported that eddies in the Banda Sea tend to be spatially widespread. During this season, La Niña exhibited higher current velocities with broader spatial distribution, reaching 0.8 m/s in March, 0.5 m/s in April, and 0.6 m/s in May.

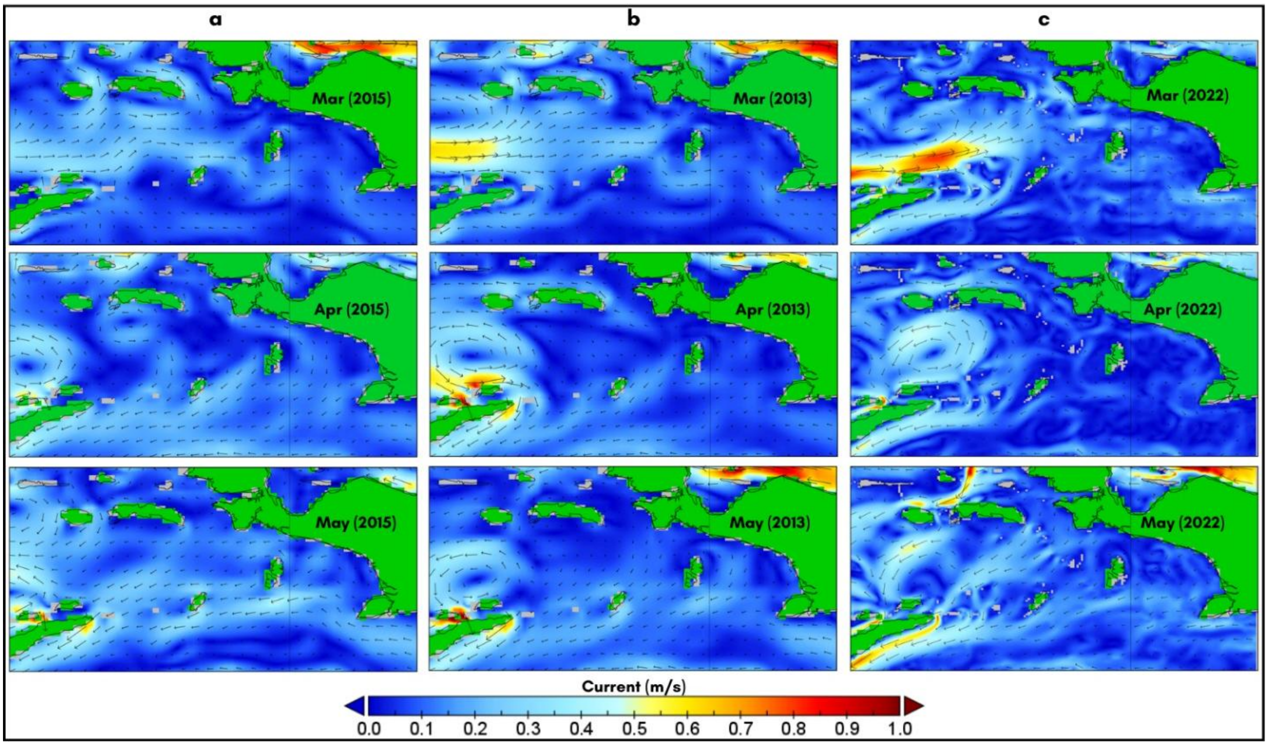


Figure 7. Current pattern variability during Transition Season I under El Niño (a), neutral (b), and La Niña (c) conditions in the Maluku waters.

In general, current movement in the Maluku waters during the East Monsoon (Figure 8) followed the direction of the Southeast Monsoon winds. According to Assir et al. (2017), during the Southeast Monsoon winds blowing from east to west transport water masses from the Arafura Sea toward the Java Sea through the Banda Sea and Flores Sea. Surface current movement in the Banda Sea creates divergence of surface water masses, which triggers upwelling during the East Monsoon (Nurafifah et al., 2022). A similar process occurs in the Arafura Sea, where strong Southeast Monsoon winds transport warm and low-salinity surface waters offshore, promoting upwelling processes (Wattimena & Tubalawony, 2023). These processes increase the productivity of the Maluku waters, particularly through enhanced chlorophyll-a concentrations associated with upwelling events.

During the La Niña period, water mass inflow from the Halmahera Sea into the Seram Sea was observed. This inflow indicates an increase in water volume in the western Pacific Ocean during La Niña conditions. Increased rainfall over the western

Pacific during La Niña events increases water mass accumulation, which subsequently flows toward the Indian Ocean through the Indonesian seas, including the Halmahera and Seram Seas. Under these conditions, current velocities in the Seram Sea reached 0.7 m/s in June, 0.7 m/s in July, and 0.9 m/s in August.

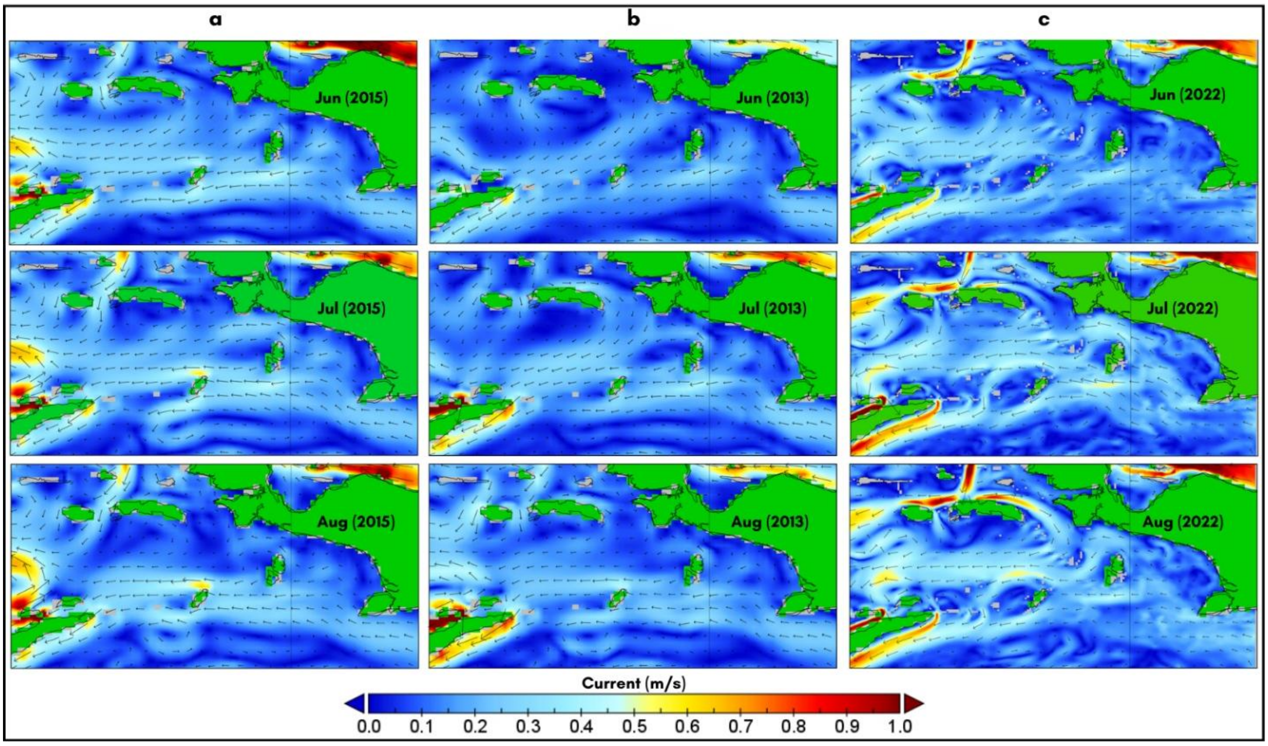


Figure 8. Current pattern variability during the East Monsoon under El Niño (a), neutral (b), and La Niña (c) conditions in the Maluku waters.

During Transition Season II (Figure 9), current movement was highly variable in both speed and direction. In September and October, current patterns generally followed the Southeast Monsoon wind direction, while in November current velocities weakened before the onset of the West Monsoon. This variability results from the transition between the Southeast and Northwest Monsoon systems, which alters atmospheric pressure patterns and wind circulation, subsequently influencing ocean current dynamics in the region. Surface currents during Transition Season II were generally weaker than those observed during the main monsoon seasons.

Similar to Transition Season I, eddy formation in the Banda Sea was also observed during this period. Eddy formation during transitional seasons is strongly influenced by local wind forcing, which becomes more dominant during periods of weak large-scale circulation (Chen et al., 2020), consistent with the findings of Darmawan et al. (2020). During the El Niño and neutral periods, anticyclonic eddies were observed in the Banda Sea, whereas during the La Niña period, cyclonic eddies were more dominant. In September, both cyclonic and anticyclonic eddies were observed simultaneously. Overall, November exhibited calmer current conditions compared to the other months.

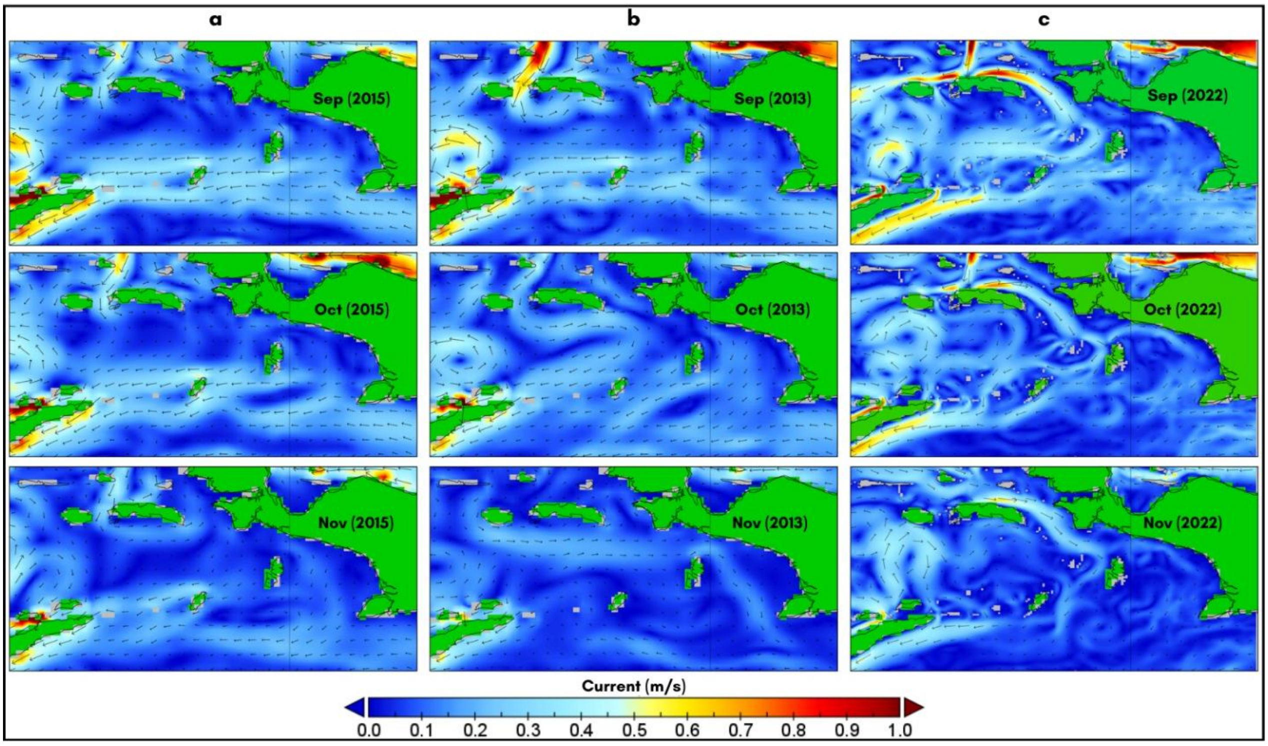


Figure 9. Current pattern variability during Transition Season II under El Niño (a), neutral (b), and La Niña (c) conditions in the Maluku waters.

**Influence of ENSO on Wind and Current Variability**

The analysis of wind variability in the Maluku waters indicated that wind speeds increased during the El Niño period (2014–2015), particularly during the primary monsoon seasons, namely the East Monsoon and West Monsoon. This finding is consistent with Kakiailatu et al. (2024), who reported that ENSO significantly influences wind and wave intensity, with stronger and more extensive wind distributions during El Niño events. Although wind speeds may decrease in certain months, the El Niño period generally exhibits stronger wind intensity and broader spatial coverage. However, wind movement in the Maluku waters is also influenced by other factors, particularly the atmospheric pressure gradient between the Northern and Southern Hemispheres. According to Buton et al. (2023), north–south atmospheric circulation associated with the monsoon system exerts a stronger influence than the east–west circulation anomalies associated with ENSO.

In contrast to wind variability, the analysis showed that current velocities increased during the La Niña period (2021–2022), particularly in the Seram Sea. During La Niña, the central and eastern Pacific Ocean experience lower-than-normal sea surface temperatures, while atmospheric pressure decreases in the western Pacific region (Ismiati, 2022). This condition results in increased rainfall over the western Pacific Ocean (Rodysill et al., 2019). High rainfall increases water mass accumulation in the western Pacific, leading to higher sea levels compared to the Indian Ocean. To maintain oceanic balance, water masses from the Pacific Ocean flow toward the Indian Ocean through the Indonesian seas, including the Halmahera Sea and subsequently the Seram Sea, resulting in stronger current velocities in the region.

## CONCLUSION

The variability of wind patterns in the Maluku waters indicates that during the West Monsoon, winds predominantly move toward the southeast with an average speed of 6.1 m/s, whereas during the East Monsoon, winds move toward the northwest with an average speed of 9.2 m/s. Meanwhile, ocean current patterns in the Maluku waters exhibit considerable variability. However, the dominant current direction generally follows the direction of the prevailing monsoonal winds. During the Northwest Monsoon (West Monsoon), currents predominantly flow eastward with a maximum velocity of 0.8

m/s, whereas during the Southeast Monsoon (East Monsoon), currents mainly move westward with a maximum velocity of 1.4 m/s. The differences in intensity observed across the analyzed periods suggest that the El Niño–Southern Oscillation (ENSO) exerts a significant influence on the variability of wind patterns and ocean current dynamics in the Maluku waters.

## AUTHOR CONTRIBUTIONS STATEMENT

The authors declare that their respective contributions to this manuscript are as follows: YAGT served as the primary contributor, responsible for designing the research; ST acted as the corresponding author, providing linguistic revisions and manuscript improvements; and RDH, as a co-author, also contributed to language editing and manuscript refinement. The authors have submitted a signed Author Declaration Statement.

## CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest with any party regarding the publication of this article.

## REFERENCES

Anisa, M. N., Purwanto, P., & Prasetyawan, I. B. (2017). Studi Pola Arus Laut di Perairan Tapaktuan, Aceh Selatan. *Journal of Oceanography*, *6*(1), 183–192.

Assir, A., Palo, M., Jaya, I., & Sari, R. K. (2017). Komposisi Jenis Hasil Tangkapan Bagan Perahu yang Beroperasi di Laut Flores Kabupaten Kepulauan Selayar pada Musim Angin Muson Barat. *Jurnal IPTEKS Pemanfaatan Sumberdaya Perikanan*, *4*(7), 108–111. https://doi.org/10.20956/jipsp.v4i7.3138

Athoillah, I., Sibarani, R. M., & Doloksaribu, D. E. (2017). Analisis Spasial El Nino Kuat Tahun 2015 dan La Nina Lemah Tahun 2016 (Pengaruhnya terhadap Kelembapan, Angin dan Curah Hujan di Indonesia). *Jurnal Sains & Teknologi Modifikasi Cuaca*, *18*(1), 33-41. https://doi.org/10.29122/jstmc.v18i1.2140

Buton, I., Tubalawonya, S., & Wattimena, M. C. (2023). Variabilitas Hidrometeorologi Permukaan Laut Arafura pada saat Fenomena ENSO. *Jurnal Laut Pulau*, *2*(2), 32-50, 32–50. https://doi.org/10.30598/jlpvol2iss2pp32-50

Chen, B., Xie, L., Zheng, Q., Zhou, L., Wang, L., Feng, B., & Yu, Z. (2020). Seasonal Variability of Mesoscale Eddies in the Banda Sea Inferred from Altimeter Data. *Acta Oceanologica Sinica*, *39*(12), 11–20. https://doi.org/10.1007/s13131-020-1665-2

Darmawan, L. K., Pranowo, W. S., Harsono, G., Sukoco, N. B., & Putra, I. (2020). Purwarupa Informasi untuk Keselamatan Pelayaran Berdasarkan Karakteristik Eddy di Laut Banda. *Jurnal Chart Datum*, *6*(2), 33–39. https://doi.org/10.37875/chartdatum.v6i2.195

Ginanjar, S., Syach, M. F., & Wulandari, S. (2020). Kajian Pengaruh Siklon Tropis Mangga Terhadap Curah Hujan, Transpor Ekman, Viskositas Eddy dan Tinggi Gelombang di Perairan Selatan Jawa pada 20-25 Mei 2020. *Jurnal Meteorologi Klimatologi Dan Geofisika*, *7*(2), 15–23.

Gordon, A. L., Susanto, R. D., & Ffield, A. (1999). Throughflow within makassar strait. *Geophysical Research Letters*, *26*(21), 3325-3328. https://doi.org/10.1029/1999GL002340

Haiyqal, S. V., Ismanto, A., Indrayanti, E., & Andrianto, R. (2023). Karakteristik Tinggi Gelombang Laut pada saat Periode Normal, El Nino dan La Nina di Selat Makassar. *Jurnal Kelautan Tropis*, *26*(1), 190–202. https://doi.org/10.14710/jkt.v26i1.17003

Hendrayana, H., Wulan, A. C., & Winanto, T. (2023). Pola Pertumbuhan Ikan Teri (S*tolephorus* sp.) di Perairan Tegal pada Musim Peralihan II. *MAIYAH*, *2*(1), 33–40. https://doi.org/10.20884/1.maiyah.2023.2.1.8311

Hukubun, R. D., & Tubalawony, S. (2024). Variabilitas Klorofil-a di Perairan Kepulauan Kei, Maluku Tenggara. *Biofaal Journal,* *5*(1), 034–043. https://doi.org/10.30598/biofaal.v5i1pp034-043

Irawan, S., Fahmi, R., & Roziqin, A. (2018). Kondisi Hidro-Oseanografi (Pasang Surut, Arus Laut, Dan Gelombang) Perairan Nongsa Batam. *Jurnal Kelautan: Indonesian Journal of Marine Science and Technology*, *11*(1), 56–68. https://doi.org/10.21107/jk.v11i1.4496

Ismiati, M. (2022). Implikasi El-Nino Dan La-Nina terhadap Perubahan Iklim Wilayah Indonesia. *NIHAIYYAT: Journal of Islamic Interdisciplinary Studies*, *1*(1), 93–100.

Kakiailatu, J. S. H., Masrikat, J. A., & Tubalawony, S. (2024). Enso (El Niño-Southern Oscillation) Influence on Wind and Wave Variability in Maluku Waters. *Jurnal Perikanan Unram*, *14*(2), 887–897. https://doi.org/10.29303/jp.v14i2.857

Marpaung, F. F., Pranowo, W. S., Purba, N. P., Yuliadi, L. P. S., Syamsudin, M. L., & Setyawidati, N. A. R. (2015). Kondisi Perairan Teluk Ekas Lombok Timur pada Musim Peralihan. *Jurnal Akuatika, 6*(2), 198–205.

Nurafifah, U. O., Zainuri, M., & Wirasatriya, A. (2022). Pengaruh ENSO dan IOD terhadap Distribusi Suhu Permukaan Laut dan Klorofil-a pada Periode Upwelling di Laut Banda. *Indonesian Journal of Oceanography, 4*(3), 74–85. https://doi.org/10.14710/ijoce.v4i3.14971

Permadi, L. C., Indrayanti, E., & Rochaddi, B. (2015). Studi Arus pada Perairan Laut di Sekitar PLTU Sumuradem Kabupaten Indramayu, Provinsi Jawa Barat. *Jurnal Oseanografi, 4*(2), 516–523.

Putri, E. M. J., Wirasatriya, A., & Marwoto, J. (2023). Pengaruh Ekman Mass Transport dan Ekman Pumping Velocity terhadap Upwelling di Perairan Selatan Pulau Bali-Sumbawa. *Indonesian Journal of Oceanography, 5*(3), 118–130. https://doi.org/10.14710/ijoce.v5i3.15244

Rifai, A., Rochaddi, B., Fadika, U., Marwoto, J., & Setiyono, H. (2020). Kajian Pengaruh Angin Musim Terhadap Sebaran Suhu Permukaan Laut (Studi Kasus : Perairan Pangandaran Jawa Barat). *Indonesian Journal of Oceanography, 2*(1), 98–104. https://doi.org/10.14710/ijoce.v2i1.7499

Rinekso, T. O., Widagdo, S., & Bintoro, R. S. (2023). Karakteristik Cuaca Maritim untuk Keselamatan Pelayaran di Perairan Popoh, Tulungagung. *Jurnal Riset Kelautan Tropis (Journal Of Tropical Marine Research) (J-Tropimar), 5*(1), 34–50. https://doi.org/10.30649/jrkt.v5i1.70

Rodysill, J. R., Russell, J. M., Vuille, M., Dee, S., Lunghino, B., & Bijaksana, S. (2019). La Niña-driven flooding in the Indo-Pacific warm pool during the past millennium. *Quaternary Science Reviews*, 225. https://doi.org/10.1016/j.quascirev.2019.106020

Sari, Y. N., Wirasatriya, A., Kunarso, K., Rochaddi, B., & Handoyo, G. (2020). Variabilitas Arus Permukaan Di Perairan Samudra Hindia Selatan Jawa. *Indonesian Journal of Oceanography, 2*(1), 1–7. https://doi.org/10.14710/ijoce.v2i1.6785

Tristianto, G., Wulandari, S. Y., Suryoputro, A. A. D., Handoyo, G., & Zainuri, M. (2021). Studi Variabilitas Upwelling di Laut Banda. *Indonesian Journal of Oceanography, 3*(1), 25–35. https://doi.org/10.14710/ijoce.v3i1.9764

Utami, I. R., Jumarang, M. I., & Apriansyah, A. (2018). Perhitungan Potensi Energi Angin di Kalimantan Barat. *Prisma Fisika, 6*(1), 65–69. https://doi.org/10.26418/pf.v6i1.23617

Wang, C., Deser, C., Yu, J.-Y., DiNezio, P., & Clement, A. (2017). El Niño and Southern Oscillation (ENSO): A Review. *Springer Science Publisher, 8*, 85–106. https://doi.org/10.1007/978-94-017-7499-4_4

Wattimena, M. C., & Tubalawonya, S. (2023). Variasi Parameter Oseanografi di Utara Laut Arafura pada Tahun Super La Nina 2010 dan El Nino 2015. *Journal of Coastal and Deep Sea: Juni, 1*(1), 42–50.

Yananto, A., & Dewi, S. (2016). Analisis Kejadian El-Nino Tahun 2015 dan Pengaruhnya terhadap Peningkatan Titik Api di Wilayah Sumatera dan Kalimantan. *Jurnal Sains & Teknologi Modifikasi Cuaca*, *17*(1), 11–19.

Yananto, A., & Sibarani, R. M. (2016). Analisis Kejadian E-Nino dan Pengaruhnya Terhadap Intensitas Curah Hujan di Wilayah Jabotabek (Studi Kasus : Periode Puncak Musim Hujan Tahun 2015 / 2016). *Jurnal Sains & Teknologi Modifikasi Cuaca, 17*(2), 65–73.