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ENSO (EL NIÑO-SOUTHERN OSCILLATION) INFLUENCE ON WIND AND WAVE VARIABILITY IN MALUKU WATERS

Pengaruh Enso (El Niño-Southern Oscillation) Terhadap Variabilitas Angin dan Gelombang di Perairan Maluku

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ABSTRACT

Maluku waters are among the waters in Indonesia that have a strategic location. Maluku waters encompass several seas with different characteristics, including the Banda Sea, Seram Sea, and Arafura Sea. One phenomenon that affects atmospheric conditions and Maluku waters is ENSO. The influence of ENSO on wind and wave variability in Maluku waters is the purpose of this study. This study uses ONI Index data, as well as wind and wave data from BMKG-OFS products that have a spatial resolution of 7 km and a temporal resolution of 3 hours. The ENSO neutral period occurred throughout 2013, El Niño in 2015, and La Niña in 2022. The results showed that ENSO affects wind and wave intensity. In January, the winds range between from 2 to 20 knots and moved predominantly from northwest to southeast. In February, it appears that only the El Niño period has a large enough range. In July, the maximum wind range is up to 25 knots, moving predominantly from the southeast towards the northwest. The La Niña period strengthens wave intensity, in January with a range of 0 to 1.5 meters. In July, the wave intensity is higher during the La Niña period, with wave heights reaching 3 meters. The El Niño period strengthens wind intensity, while La Niña strengthens wave intensity in Maluku waters.

Key words: ENSO, Wind, Wave, Maluku Waters.

ABSTRAK

Perairan Maluku merupakan salah satu perairan di Indonesia yang memiliki letak strategis. Perairan Maluku memiliki beberapa laut dengan karakteristik yang berbeda-beda, di antaranya Laut Banda, Laut Seram, dan Laut Arafura. Salah satu fenomena yang mempengaruhi kondisi atmosfer dan kondisi perairan Maluku adalah ENSO. Pengaruh ENSO terhadap variabilitas angin dan gelombang di perairan Maluku menjadi tujuan dari penelitian ini. Penelitian ini menggunakan data Indeks ONI, data angin, dan gelombang dari produk BMKG-OFS yang memiliki resolusi spasial 7 km dan resolusi temporal 3 jam. Periode ENSO netral terjadi sepanjang tahun 2013, El Niño tahun 2015, dan La Niña tahun 2022. Hasil penelitian menunjukkan ENSO memengaruhi intensitas angin dan gelombang. Pada bulan Januari, angin berkisar antara 2 hingga 20 knot dan bergerak dominan dari arah barat laut menuju tenggara. Pada bulan Februari, terlihat hanya periode El Niño yang memiliki kisaran cukup besar. Pada bulan Juli, kisaran angin maksimal hingga 25 knot bergerak dominan dari arah tenggara menuju barat laut. Kisaran angin terendah berada di bulan November, namun periode El Niño menguatkan intensitas angin. Pengaruh ENSO pada gelombang laut terlihat memiliki pola yang berbeda. Periode La Niña menguatkan intensitas gelombang, pada bulan Januari dengan kisaran 0 hingga 1,5 meter. Pada bulan Juli, intensitas gelombang lebih tinggi pada periode La Niña dengan tinggi gelombang mencapai 3 meter. Periode El Niño menguatkan intensitas angin, sedangkan La Niña menguatkan intensitas gelombang di perairan Maluku.

Kata Kunci: Angin, ENSO, Gelombang, Perairan Maluku.

INTRODUCTION

Maluku waters are a group of waters located in eastern Indonesia, consisting of a number of large and small islands between the Seram Sea and the Halmahera Sea and to the north of the Banda Sea. This region is famous for its extraordinary natural beauty, with clear waters, hilly and rocky islands, and underwater life that is rich in marine biota.

The strategic location of Maluku's waters, which cover several seas, gives the region its own uniqueness. The Pacific Ocean and Indian Ocean play an important role in the distribution of water masses to the waters of Maluku as one of Arlindo's routes. The influence of climate variability that affects Maluku waters is El Niño-Southern Oscillation (ENSO).

El Niño-Southern Oscillation (ENSO) includes the El Niño phenomenon, which is the movement of warm air masses towards the central to eastern parts of the tropical Pacific Ocean, and the La Niña phenomenon, which is the movement of hot air masses towards the central to western parts of the tropical Pacific Ocean (Haiyqal *et al*., 2023; Hidayat *et al*., 2018; Santoso *et al*., 2017; Dewi *et al*., 2020).

ENSO affects the atmosphere and waters are also affected. The monsoon winds that blow in Indonesia, especially Maluku waters, have different variations. ENSO and monsoon wind circulation patterns both have a similar influence on wave heights in Indonesia (Haiyqal *et al*., 2023). Wind variations that occur also influence the height of sea waves in Maluku waters. Sea waves are formed due to generating forces acting on the sea surface (Kumar *et al*., 2019).

Waves produced by wind on the sea surface affect various human activities for survival, such as maritime transportation, offshore development projects, and tourism (Kunarso *et al*., 2023; Suroso & Firman, 2018). Efficiency and safety at sea depend heavily on fluctuations in wave height, so information regarding the characteristics of wave height in Indonesian waters is very important (Azhari *et al*., 2022).

This research uses ONI Index data and wind and wave products produced by the BMKG-OFS product. The aim of this research is to examine the influence of ENSO on wind and wave variability in Maluku waters and it is hoped that the results of this research can be used in the shipping sector for sea transportation users and fishermen and the results of this research can be used to predict future climate and oceanography.

RESEARCH METHODS

Research Data and Locations

Data processing and analysis took place at the Ambon Maritime BMKG Station, from October 2023 to May 2024. The data used in this research is secondary data including ONI Index data, wind data and wave data. ONI Index data is obtained via the page https://origin.cpc.ncep.noaa.gov with a monthly data period from 2013 to 2022. This data is used to determine the Normal phase, El Niño phase and La Niña phase. ENSO climate variability based on Niño 3.4 is classified into El-Niño and La-Niña. Sea Surface Temperature

(SST) anomalies > 0.5 °C are considered El-Niño and SST anomalies < -0.5 °C are considered La-Niña (Nurafifah *et al*., 2022).

Wind and wave data from *the Ocean Forecast System (OFS) Hindcast* system obtained from the Center for Maritime Meteorology, Meteorology, Climatology and Geophysics Agency (BMKG). This system, called BMKG-OFS, is a maritime weather modeling system that refers to *WaveWatch* III (WW3), the third generation wave model by *the National Center Environmental Prediction* (NCEP), part of *the National Oceanic and Atmospheric Administration* (NOAA) (Supriyadi, 2019). This OFS system data has a spatial resolution of 0.0625° (7km) and a temporal resolution of 3 hours main time, namely 00, 03, 06, 09, 15, 18, and 21 UTC, then using a programming language, a monthly climatology composite is carried out (Ramadhan *et al*., 2021)with the equation as follows following:

Information:

$\overline{X_m}(x,y)$ = monthly average; $\overline{X_m}(x,y) = \frac{1}{n}\sum_{i}^{n} Xi(x,y,t)$
$Xi(x,y,t)$ = composite first 3-hour data at longitude (x), latitude (y) and time (t);
n = the number of hourly composite data (1 month) and
i =1 is the ith observation period in the composite month.

The research location covers Maluku waters with a coordinate limit of 123 – 136 ° East Longitude and 1.5 – 10 ° South Latitude (Figure 1).

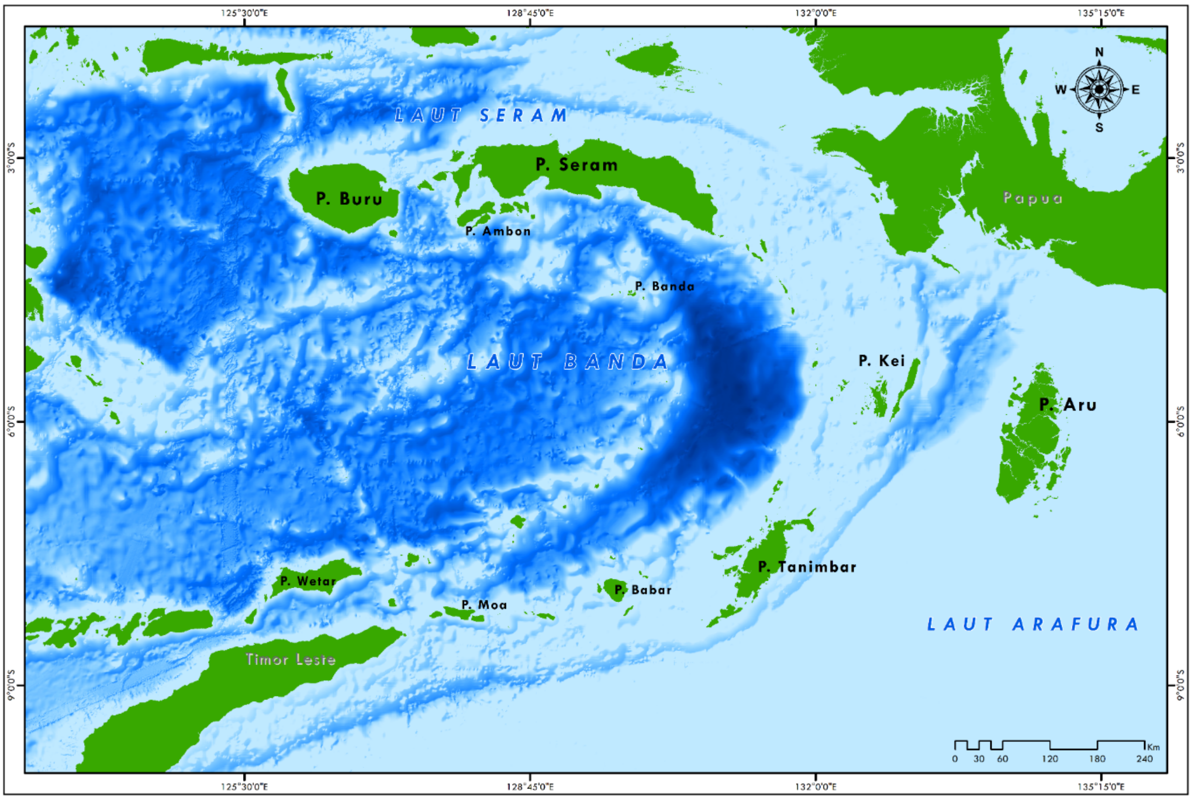

Figure 1. Research location (Maluku waters)

RESULTS

Determination of the ENSO Period

The Neutral period which occurred throughout the year in 2013, the El Niño period which occurred throughout the year in 2015 and the La Niña period which occurred throughout the year in 2022 were identified. The month, year and phenomenon of the ENSO phase from the observations became notes for subsequent analysis (Table 1).

Table 1. Nino Index

Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2010	1.5	1.2	0.8	0.4	-0.2	-0.7	-1.0	-1.3	-1.6	-1.6	-1.6	-1.6
2011	-1.4	-1.2	-0.9	-0.7	-0.6	-0.4	-0.5	-0.6	-0.8	-1.0	-1.1	-1.0
2012	-0.9	-0.7	-0.6	-0.5	-0.3	0.0	0.2	0.4	0.4	0.3	0.1	-0.2
2013	-0.4	-0.4	-0.3	-0.3	-0.4	-0.4	-0.4	-0.3	-0.3	-0.2	-0.2	-0.3
2014	-0.4	-0.5	-0.3	0.0	0.2	0.2	0.0	0.1	0.2	0.5	0.6	0.7
2015	0.5	0.5	0.5	0.7	0.9	1.2	1.5	1.9	2.2	2.4	2.6	2.6
2016	2.5	2.1	1.6	0.9	0.4	-0.1	-0.4	-0.5	-0.6	-0.7	-0.7	-0.6
2017	-0.3	-0.2	0.1	0.2	0.3	0.3	0.1	-0.1	-0.4	-0.7	-0.8	-1.0
2018	-0.9	-0.9	-0.7	-0.5	-0.2	0.0	0.1	0.2	0.5	0.8	0.9	0.8
2019	0.7	0.7	0.7	0.7	0.5	0.5	0.3	0.1	0.2	0.3	0.5	0.5
Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2020	0.5	0.5	0.4	0.2	-0.1	-0.3	-0.4	-0.6	-0.9	-1.2	-1.3	-1.2
2021	-1.0	-0.9	-0.8	-0.7	-0.5	-0.4	-0.4	-0.5	-0.7	-0.8	-1.0	-1.0
2022	-1.0	-0.9	-1.0	-1.1	-1.0	-0.9	-0.8	-0.9	-1.0	-1.0	-0.9	-0.8
2023	-0.7	-0.4	-0.1	0.2	0.5	0.8	1.1	1.3	1.6	1.8	1.9	2.0

The table above shows the division of ENSO periods which are marked as colorless (Neutral period), red (El Niño period) and blue (La Niña period). Analysis of wind and wave variability is focused on the year ENSO occurs throughout the year, namely as follows:

a. Neutral : January - December 2013
b. El Niño : January - December 2015
c. La Niña : January - December 2022

El Niño is one phase of ENSO. During the El Niño phase, there is significant warming of sea levels in the central and eastern parts of the tropical Pacific Ocean. This resulted in major disruptions to global weather patterns, including excessive rain, drought, strong tropical storms, and air temperature anomalies in various regions of the world (Larkin & Harrison, 2005).

On the other hand, La Niña is another phase of ENSO. In the La Niña phase, there is significant cooling of sea surfaces in the central and eastern parts of the tropical Pacific Ocean. This phenomenon also influences global weather patterns, with opposite impacts to El Niño, such as abundant rain, a more active monsoon, and increased tropical storm activity in some regions (Larkin & Harrison, 2005).

ENSO has a broad and significant impact on weather and climate conditions in Maluku waters. Therefore, understanding and monitoring this phenomenon is very important for various fisheries sectors.

Wind Variability During the ENSO Period

The influence of ENSO is felt in Indonesia with unpredictable weather conditions including varying wind conditions. Specifically for the Maluku region, wind variations are quite varied every month. The image below shows the monthly wind variability in the year of ENSO (a) Neutral Period, (b) El Niño Period, and (c) La Niña Period.

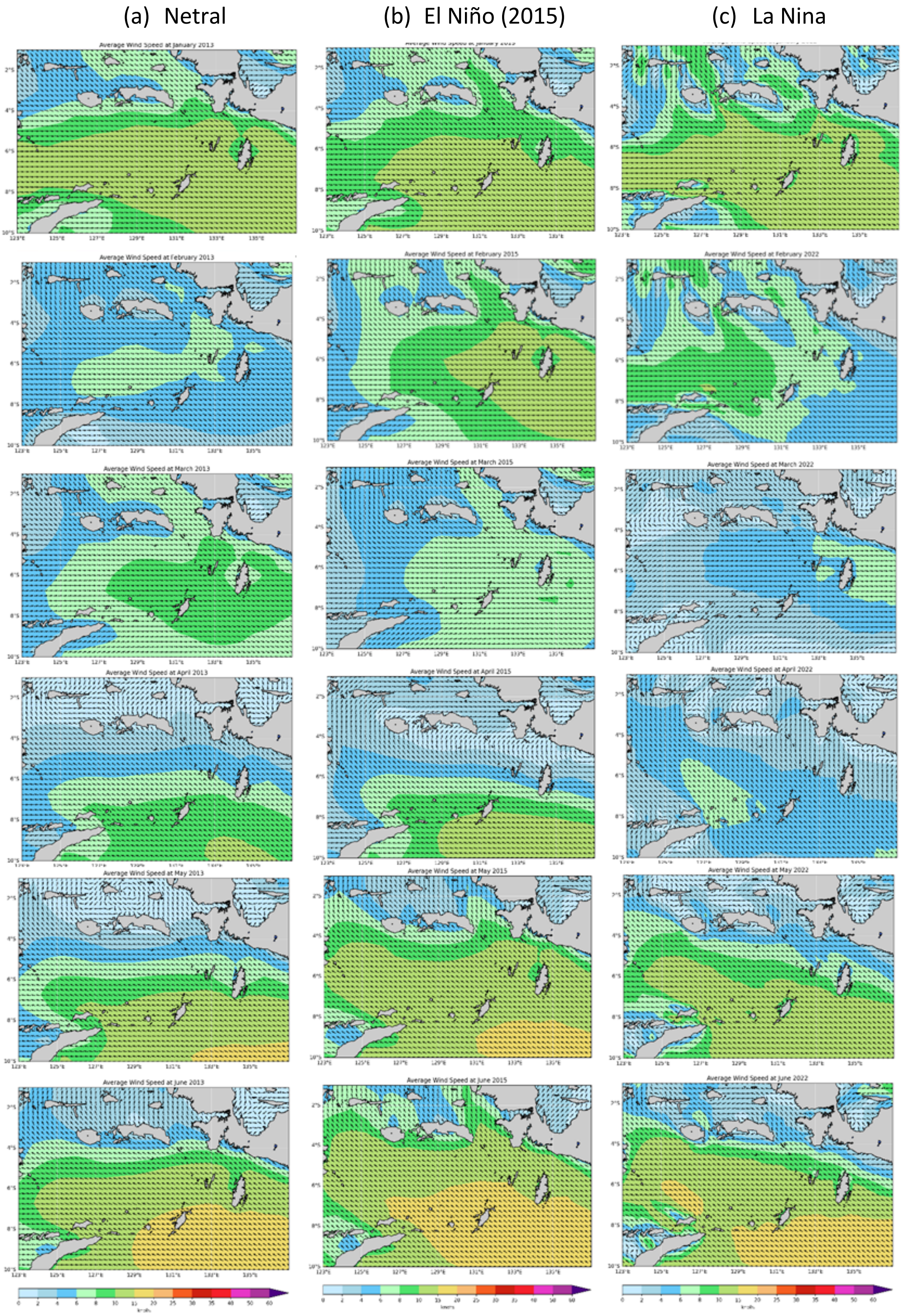
(a) Netral
(b) El Niño (2015)
(c) La Nina

Figure 2a. Wind variability during the ENSO period (January to June)

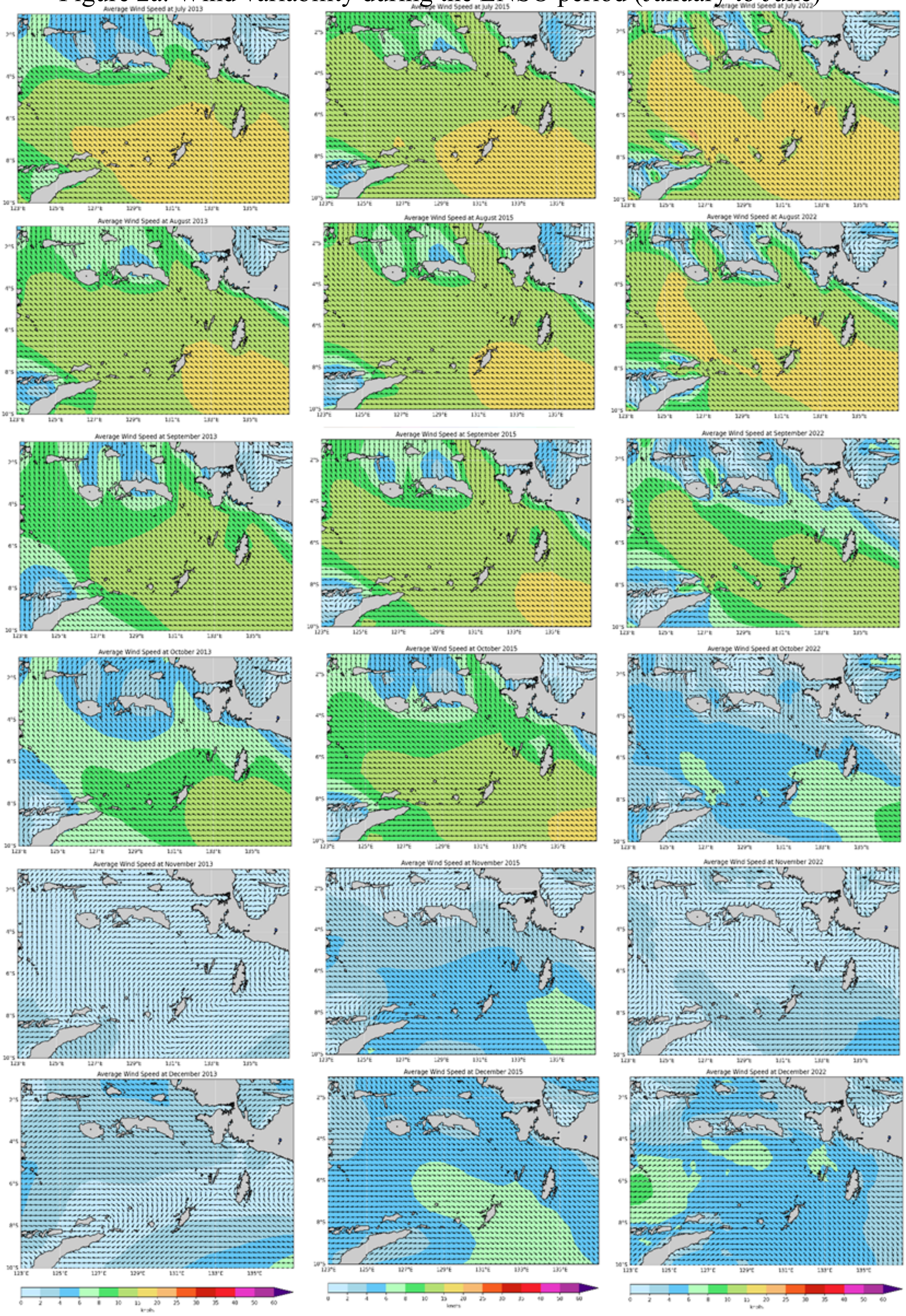

Figure 2b. Wind variability during the ENSO period (July to December)

Wave Variability During the ENSO Period

One of the oceanographic parameters that is affected by ENSO is sea waves. Sea wave height is strongly influenced by monthly wind variations. If monthly winds are influenced by ENSO, it is assumed that this influence also occurs on wave height (Haiyqal *et al*., 2023). It is very important to analyze how big the influence of ENSO is on wave height in order to provide information for sea transportation users and fishermen, especially in Maluku waters about the dangers of wave height.

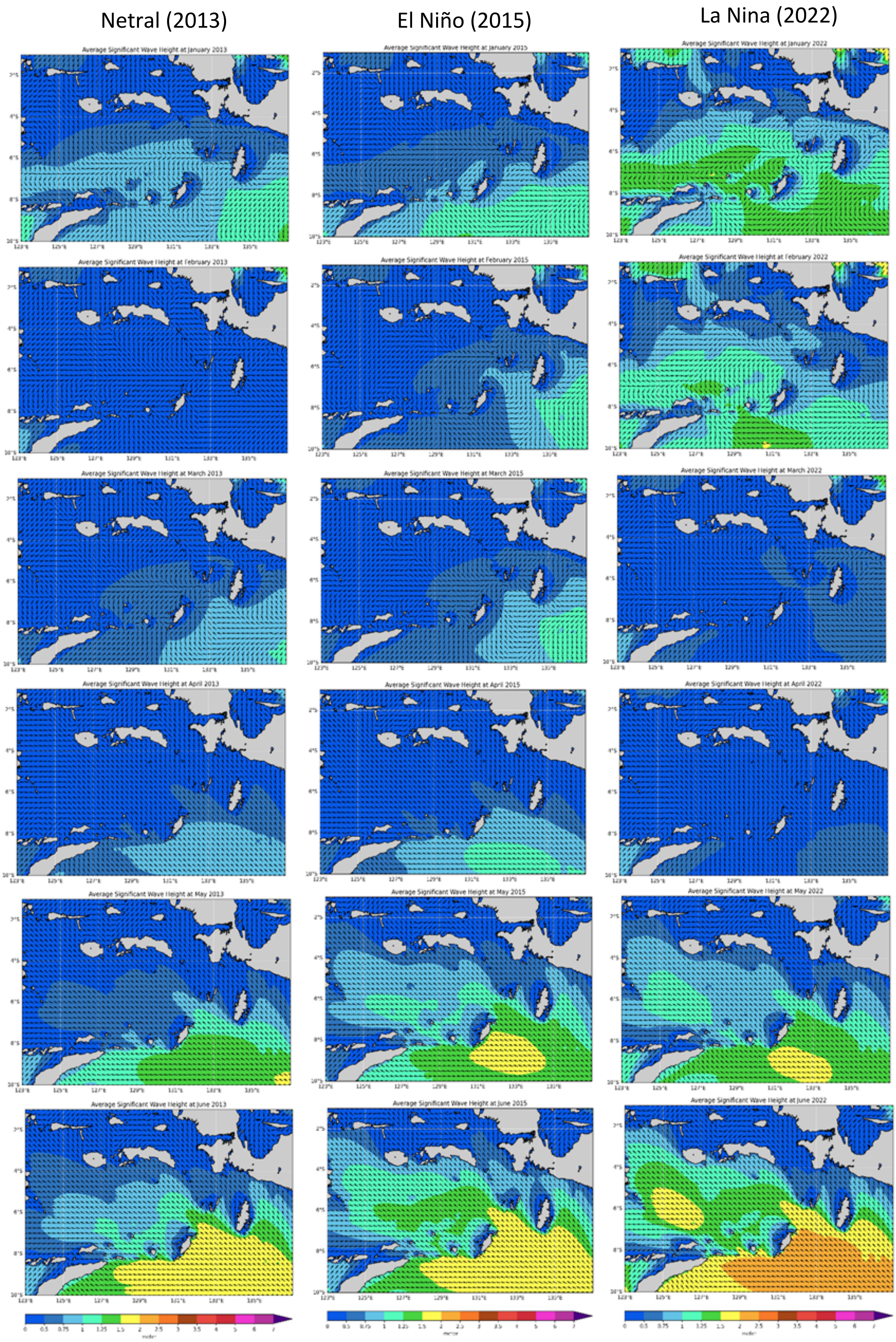

Figure 3a. Wave variability during the ENSO period (January to June)

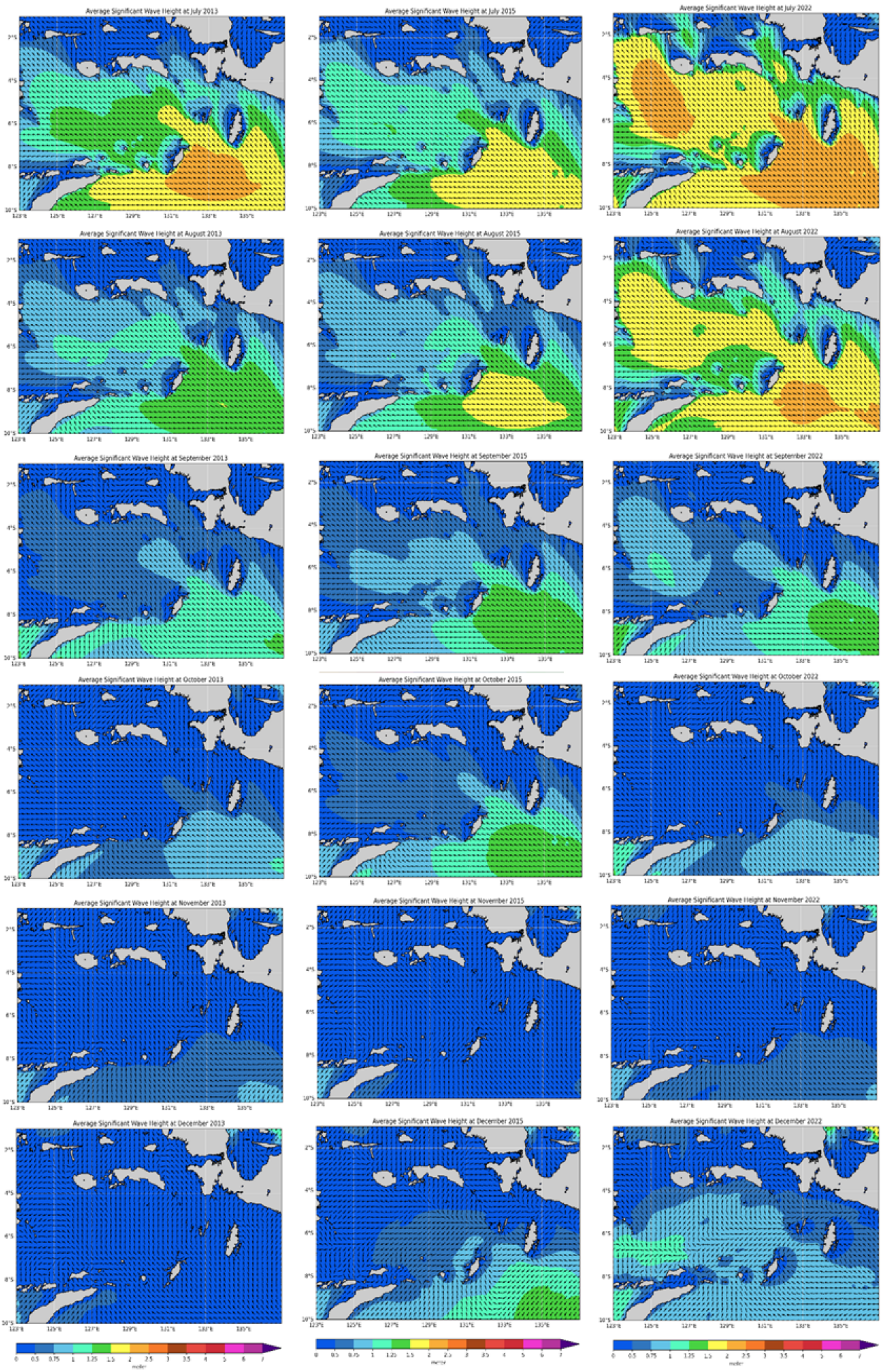

Figure 3b. Wave variability during the ENSO period (July to December)

DISCUSSION

El Niño-Southern Oscillation (ENSO) has 3 phases, namely the neutral phase, which is a condition where there are no significant anomalies in sea surface temperature in the equatorial region of the central and eastern Pacific, the El Niño phase is the warm phase of ENSO which is characterized by an increase in sea surface temperature in the central and eastern tropical Pacific Ocean and the last is the La Niña phase which is the opposite phase of El Niño where there is a decrease in sea surface temperature in the central and eastern tropical Pacific Ocean(Santoso *et al*., 2017)

The research results show that ENSO influences wind and wave intensity. In January, the wind pattern ranges from 2 to 20 knots and moves predominantly from the northwest to the southeast. Areas of wind distribution with greater intensity are during the El Niño period.

In February, it appears that only the El Niño period has a fairly large wind range followed by its distribution. In March, the wind speed can be seen decreasing, but in May the wind speed starts to increase, where the El Niño period has greater wind speeds and their distribution until August with a maximum wind speed value reaching 25 knots.

In September, the wind speed appears to decrease, but the El Niño period still has a large and wide intensity and distribution of wind speed. In December, the wind speed decreases for 3 periods, but during the El Niño period, the wind speed is seen from the southeast, but during the La Niña period, large wind speeds are seen moving from the west. In general, large wind speeds move from the southeast to northwest and vice versa, and large wind speeds move from the southeast.

The influence of ENSO on wind also influences the height of sea waves so that they appear to have different patterns. The La Niña period strengthens the wave intensity, in January with a range of 0 to 1.5 meters. The southern part of Maluku waters has quite high wave heights, including Wetar Island, Moa Island, Babar Island, Tanimbar Island, Kei Island, and Aru Island.

In July, the intensity of the waves increases to a higher level. The La Niña period has wave heights reaching 3 meters compared to the Neutral and El Niño periods. The southeast side of Tanimbar Island has a significant impact, the southern part of Buru Island also has large wave heights so people are strongly advised to be careful when using sea transportation in that area.

CONCLUSION

This research provides an illustration that ENSO greatly influences the wind and waves in Maluku waters, where during the El Niño period the wind intensity increases, while during the La Niña period the wave intensity increases to be higher so that during the La Niña period, people are advised to be more careful via sea transportation.

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