JOURNAL OF APPLIED GEOSPATIAL INFORMATION

Vol 10 No 1 2026

http://jurnal.polibatam.ac.id/index.php/JAGI
ISSN Online: 2579-3608

Variability of Sea Surface Temperature and Salinity during Super El Nino 2015 and Strong La Nina 2022 in Southern Java Waters

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Received: December, 22 2026
Accepted: June 22, 2026
Published: June 30, 2026

Abstract

The southern waters of Banten and West Java constitute a seasonal coastal upwelling pathway that is highly sensitive to global climate variability. This study aims to analyze and compare the spatial-temporal patterns of sea surface temperature (SST) and sea surface salinity (SSS) during two contrasting climate extremes: the Super El Niño (2015) and the Triple-Dip La Niña (2022). Daily gridded data with a spatial resolution from the Copernicus Marine Service (CMS) were processed via cloud computing using the Xarray, Matplotlib, and Cartopy libraries. The results demonstrate a pronounced interannual contrast during the Southeast Monsoon (July-October). At the peak of El Niño (September 2015), an intensification of robust upwelling occurred, characterized by an extreme drop in minimum SST to 22–24°C and a sharp increase in SSS to 33.8–34.5 psu, driven by reduced freshwater flux and the displacement of deep, saline water masses. Otherwise, during the La Niña phase (2022), upwelling weakened significantly; SST remained warm, ranging from 27-28°C (4-5°C warmer than in 2015), while SSS remained low at 32.6–33.4 psu due to enhanced precipitation and freshwater transport through the Sunda Strait and the Indonesian Throughflow (ITF) circulation. These dynamics underscore the pivotal role of ENSO teleconnections and monsoonal winds in modulating the variability within the study area.

Keywords: Sea Surface Temperature, Salinity, Upwelling, El Niño 2015, La Niña 2022

1. Introduction

The southern waters of Banten and West Java are part of the eastern Indian Ocean system, which is oceanographically unique due to its direct exposure to a narrow continental shelf and its location within a seasonal coastal upwelling regime (Atmadipoera et al., 2020). These characteristics make the region highly responsive to regional and global climate variability, particularly the El Niño-Southern Oscillation (ENSO) phenomenon. ENSO is an ocean-atmosphere interaction in the tropical Pacific Ocean that manifests in two opposing phases: El Niño, characterized by anomalous warming in the central and eastern Pacific, and La Niña, characterized by anomalous cooling in the same region. Both phases generate teleconnection effects that influence sea surface temperature (SST), precipitation, and wind patterns across Indonesia, including the southern waters of Java (Nababan et al., 2022).

In general, during El Niño events, the southeasterly trade winds along the southern coast of Java tend to strengthen, intensifying coastal upwelling. This process is characterized by a significant decrease in SST and an increase in chlorophyll-*a* concentration (Wen et al., 2023). Conversely, during La Niña events, coastal upwelling weakens, resulting in warmer-than-normal SSTs, although La Niña is generally associated with increased rainfall over Indonesia (Alhadid & Nugroho, 2024). This negative relationship between ENSO phases and SST along the southern coast of Java has been confirmed by previous studies conducted in the southern waters of Central Java and southern Java (Prihatiningsih et al., 2022).

In addition to temperature, sea surface salinity (SSS) is another important oceanographic parameter that reflects the dynamics of water masses in the southern waters of Java, including the southern waters of Banten and West Java (Rahmawitri et al., 2026). Seasonally, surface salinity in this region is generally lower during the Northwest Monsoon (January) and the first transitional season (March) due to high precipitation and increased freshwater input from river discharge into the coastal ocean (Hu et al., 2019). In contrast, during the Southeast Monsoon (August) and the second transitional season (October), surface salinity tends to increase as rainfall decreases and high-salinity subsurface water is transported upward through coastal upwelling (Permatasari, 2020). Consequently, the seasonal variability of salinity generally exhibits an opposite pattern to that of SST, making these two parameters complementary indicators for describing water mass dynamics within the study area.

The influence of ENSO on sea surface salinity in the southern waters of Java has also been investigated in several previous studies. Arisandi et al. (2017), in their study of temperature and salinity variability in the southern waters of East Java, reported that the Niño 3.4 SST index exhibited a much stronger correlation with salinity ($r = 0.711$) than the Southern Oscillation Index (SOI) ($r = –0.05$), with greater temperature and salinity variability occurring during El Niño conditions than during La Niña events. Likewise, Kunarso et al. (2012) demonstrated that the depth and thickness of the thermocline and halocline in the southern waters extending from Java to Timor vary in response to ENSO, the Indian Ocean Dipole (IOD), and the monsoon system, indicating that ENSO plays an important role in modulating salinity structure in addition to its well-established influence on SST. Nevertheless, studies specifically addressing the relationship between ENSO and sea surface salinity in the southern waters of Banten and West Java remain relatively limited compared with those conducted in Central and East Java. Therefore, incorporating sea surface salinity as an additional parameter in this study is expected to provide a more comprehensive understanding of the oceanographic response of the study area to ENSO.

The year 2015 was recognized as one of the strongest El Niño events in recent decades (Lestari et al., 2018), whereas 2022 occurred during a prolonged La Niña episode, commonly referred to as the triple-dip La Niña, which persisted from mid-2020 to early 2023 (Alhadid & Nugroho, 2024). The marked contrast between these two years provides an excellent opportunity to investigate the influence of extreme ENSO phases on the monthly variability of SST and sea surface salinity in the southern waters of Banten and West Java (Himawa et al., 2025). Mapping the monthly mean distributions of SST and sea surface salinity for 2015 and 2022 offers empirical evidence of how these contrasting ENSO phases are expressed spatially and temporally across the study area (Atmadipoera et al., 2020).

Understanding ENSO-induced variability in SST and sea surface salinity is important not only from the perspective of physical oceanography but also for marine ecology and fisheries, as fluctuations in these parameters are closely linked to upwelling intensity, nutrient availability, primary productivity, and, ultimately, the distribution of pelagic fishing grounds in the southern waters of Java (Sukresno et al., 2018). Therefore, this study aims to analyze and compare the spatial distribution patterns and temporal variability of monthly SST and sea surface salinity during the strong El Niño year (2015) and the prolonged La Niña year (2022) in the southern waters of Banten and West Java. Furthermore, the observed patterns are interpreted in relation to the physical mechanisms of coastal upwelling and downwelling that have been widely documented in previous studies of the southern waters of Java (Rachman et al., 2024).

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2. Material and Methods

2.1 Study Area

This study was conducted in the southern waters of Java, specifically in the offshore waters south of Banten and West Java. As shown in Figure 1, the study area extends from 6.80° to 8.35° S and 105.20° to 108.80° E. The study area is directly adjacent to the eastern Indian Ocean, making it highly sensitive to both regional and global climate variability are presented in Figure 1.

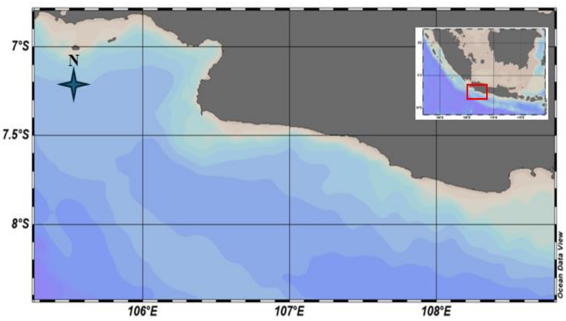

Figure 1. Location of the study

2.2 Data and Data Sources

The data used in this study were obtained from the Copernicus Marine Service (CMS). The oceanographic parameters analyzed include:

- Sea Surface Temperature (SST), derived from the *Multi Observation Global Ocean 3D Temperature, Salinity, Height, Geostrophic Current, and Mixed Layer Depth (MLD)* product, which integrates outputs from numerical models, in situ observations, and satellite observations.
- Sea Surface Salinity (SSS), derived from the *Multi Observation Global Ocean 3D Temperature, Salinity, Height, Geostrophic Current, and Mixed Layer Depth (MLD)* product, which combines numerical model outputs with in situ and satellite observations.

The dataset has a spatial resolution of 1/8° × 1/8° and a daily temporal resolution. The analysis covers two contrasting climatic periods: 2015, representing the Super El Niño event, and 2022, representing the Triple-Dip La Niña event.

2.3 Data Preprocessing

The data analysis was conducted within the cloud-based Google Collab computing environment using the xarray library to load, organize, and consolidate multidimensional oceanographic datasets stored in NetCDF (.nc) format into an xarray.Dataset structure. The xarray package provides efficient data structures and analytical tools specifically designed for labeled multidimensional scientific datasets, making it widely applicable in geoscience and oceanographic research (Hoyer & Hamman, 2017).

To ensure visual consistency and facilitate reliable interannual comparisons between 2015 and 2022, identical visualization settings, including color scales, map projections, and contour intervals, were applied throughout the analysis. Monthly mean distributions of Sea Surface Temperature (SST) and Sea Surface Salinity (SSS) were subsequently visualized using the Matplotlib library together with the Cartopy package, which provides cartographic projections and geospatial visualization capabilities for Earth science applications.

The subsequent analysis employed a spatial area-averaging approach over the study domain to evaluate large-scale temporal variability throughout the annual cycle. In this method, all spatial grid cells within the study area were averaged to produce a representative monthly mean value for each parameter during 2015 and 2022. This approach effectively reduces spatial variability while preserving the dominant temporal signal, thereby enabling robust comparisons of seasonal and interannual variability. The resulting datasets were then presented as separate two-dimensional time-series plots for SST and SSS to illustrate differences between the Super El Niño (2015) and Triple-Dip La Niña (2022) conditions.

3. Result and Discussion

3.1 Sea Surface Temperature Characteristics in the Southern Waters of Banten and West Java During the 2015 Super El Niño and 2022 Strong La Niña Periods

Spatial comparisons of sea surface temperature (SST) characteristics during the 2015 El Niño period are presented in Figure 2. The 2015 monthly mean SST distribution map exhibits a distinctive seasonal pattern, characterized by a sharp temperature contrast between the northwest and southeast monsoons. During the January-June period, SST in the southern waters of Banten and West Java was relatively warm, ranging from 28°C to 31°C. The peak of this warming trend occurred in April, marked by the dominance of dark red shading across nearly the entire study area and a 29.4°C isotherm extending far offshore. This condition is consistent with the northwest monsoon period and the downwelling mechanism commonly observed in the southern waters of Java during this season.

A drastic shift became observable starting in July, signaled by the emergence of a ~27°C contour near the coast, which subsequently expanded and cooled further in August (with a contour of ~26°C). The cooling reached its climax in September 2015, as evidenced by a widespread cold-water mass with 24–25°C contours extending significantly westward along the southern coast of West Java toward Banten, with minimum SST values dropping near 22–23°C at the core of the cold-water mass. This sharp cooling pattern during the July–September period indicates intensive coastal upwelling, aligning with the general trend of enhanced upwelling intensity in the southern waters of Java during the southeast monsoon, which was further amplified by easterly wind anomalies during the El Niño event. September displayed the most extreme cooling, during which SST plunged to 22–24°C (indicated by dark blue contours) and spread far from the coast into the open ocean. Atmadipoera et al. (2020), who noted that during the strong 2015 El Niño, the 25–26°C isotherms breached the surface, signifying a robust upwelling zone extending from the coastal area up to approximately 195 km offshore. The SST gradually recovered throughout October and November (with contours around ~26–27°C) before uniform warming returned in December 2015. Ultimately, the strong 2015 El Niño induced an anomalous climate pattern characterized by increased heat content across Indonesian waters (Nurdiati et al., 2022).

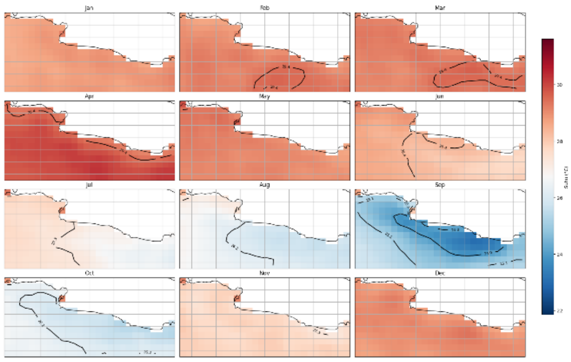

Figure 2. Monthly average sea surface temperature during Super El Nino in 2015

The SST patterns in 2022 exhibited vastly different characteristics compared to those in 2015. Throughout January-June 2022, the SST remained warm within the range of 29-31°C; although the ~29.4°C contour emerged several times, it tended to be confined near the coast and did not reach the extreme warmth observed in April 2015. The most striking feature was the pattern during the southeast monsoon period (July-October), which typically serves as the strongest upwelling period during normal and El Niño years. In 2022, the observed cooling was much more moderate: the contours only ranged around ~28.4°C (July-October) and ~27°C (September), with a complete absence of dark blue shading or contours below 27.3°C throughout the entire year. The minimum SST in 2022 was recorded at approximately 27-28°C, which is significantly warmer than the 2015 minimum SST that dropped to around 22-24°C.

This pattern confirms that coastal upwelling off southern Banten and West Java during the 2022 La Niña year was considerably weaker than during the 2015 El Niño year. The persistently warm SST throughout the 2022 southeast monsoon aligns with the physical mechanism of La Niña, namely the weakening of the southeasterly trade winds and the reduced intensity of Ekman divergence along the southern coast of Java; consequently, the ascent of cold-water masses from the thermocline to the surface was not as intensive as under El Niño conditions. The warm conditions enduring throughout 2022 also correspond with the regional triple-dip La Niña phenomenon that spanned from mid-2020 to early 2023, which is generally associated with enhanced precipitation and warmer-than-normal SSTs across Indonesian waters.

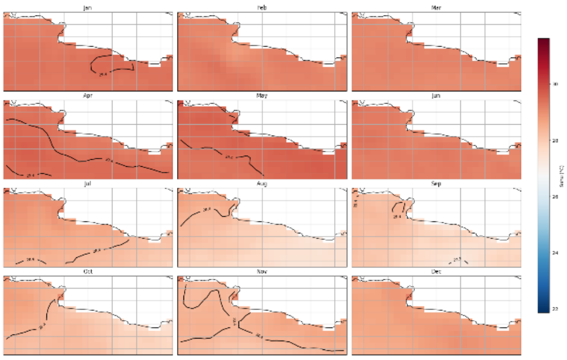

Figure 3. Monthly average sea surface temperature during Strong La Nina events in 2022

A comparison between these two years reveals a sharp contrast during the southeast monsoon period (July-October), specifically in the minimum SST difference between 2015 and 2022, which reached approximately 4-5°C. This contrast provides robust spatial evidence of how the ENSO phase modulates upwelling intensity along the southern coast of Java. A study by Sukresno et al. (2018) utilizing Aqua MODIS satellite imagery in the southern waters of Java demonstrated that upwelling intensity increases during El Niño periods, followed by a decrease in SST and an increase in chlorophyll-a concentration; conversely, during La Niña periods, upwelling intensity declines, leading to elevated SST and decreased chlorophyll-a concentrations. Quantitatively, the maximum area of high-intensity upwelling during La Niña only reached 1,952 km (August), whereas under normal and El Niño conditions, it was far more extensive, reaching 14,432 km and 29,120km in September, respectively (Rahayu et al., 2023).

The underlying physical mechanisms driving this contrast are linked to variations in monsoon wind patterns and the Coriolis force along the southern coast of Java. During the southeast monsoon, alongshore southeasterly winds drive offshore Ekman transport, which is subsequently replaced by cold, nutrient-rich water masses from the subsurface layer. During an El Niño year such as 2015, the strengthening of the easterly winds and the shoaling of the thermocline along the southern coast of Java induced by coastal Kelvin waves propagating from the eastern Indian Ocean amplify this upwelling process, causing a sharp drop in SST during September as depicted on the map. On the other hand, during a La Niña year such as 2022, the deepening of the thermocline and the weakening of the easterly wind component suppress upwelling efficiency; consequently, despite the ongoing southeast monsoon, the reduction in SST remains highly constrained. Furthermore, Yoga et al. (2014) explained that the distribution of high SST in southern Java is also putatively linked to a negative Indian Ocean Dipole Mode (IODM) and La Niña, which cause Indonesian waters, including southern Java, to exhibit higher SSTs than normal. Nababan et al. stated in their study that when a positive IOD and El Niño co-occur, they generally induce a significant positive chlorophyll-a anomaly and a corresponding negative SST anomaly. This indicates that the drastic temperature changes in the southern waters of Java are not purely driven by ENSO, but are also substantially impacted by the positive IOD factor that occurred in 2015.

This mechanism is additionally associated with the role of the Indonesian Throughflow (ITF / ARLINDO). Atmadipoera et al (2020) explained that the ITF plays an essential role in modulating upwelling in southern Java, where the upwelling intensity during El Niño periods is stronger, yet during La Niña periods, it is weaker than normal conditions. When El Niño is active, the weakening of the ITF reduces the supply of warm Pacific water masses into Indonesian waters; as a result, the local upwelling process along the southern coast of Java-Sumatra becomes more dominant, elevating cold water masses from the thermocline to the surface. Conversely, during La Niña, the strengthening of the ITF increases the influx of warm water masses into this region, which contributes to the suppression of the upwelling process.

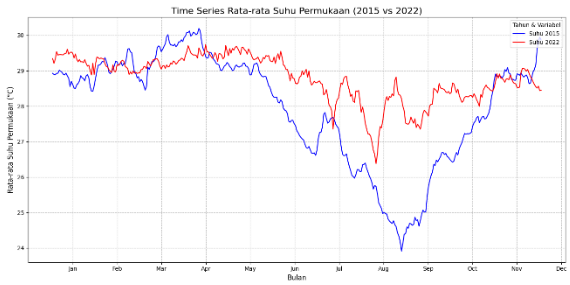

Figure 4. Time-series of Sea Surface Temperature in the Southern Java Waters during Super El Nino 2015 (Blue Line) and Strong La Nina (Red Line)

The SST time series (Figure 4) substantiates the patterns observed in the monthly spatial distribution maps while uncovering fine-scale dynamics that are typically masked in monthly aggregated data. During the January-February period, the 2022 SST (red line) was consistently warmer, ranging from 29.2°C to 29.6°C, compared to the 2015 SST (blue line), which hovered between 28.5°C and 29.3°C. The curves for both years subsequently converged within a similar warm range (~29-29.3°C) during the February–March transition, prior to a sharp spike in the 2015 SST that culminated in its annual peak of approximately 30.0-30.2°C in early April exceeding the 2022 annual peak, which only reached about 29.3-29.7°C during the same interval.

In 2015, the sea surface temperature experienced a steep and steady decline from May through early August, plunging to an extreme minimum of approximately 23.9°C in early August, representing a total temperature drop of over 6°C from its annual peak. Conversely, the 2022 SST exhibited a much more gradual decline over the same period, characterized by a double-dip pattern (two local minimum troughs) in early July and early August, ultimately reaching its lowest point at approximately 26.4°C. This minimum remained roughly 2.5°C warmer than the corresponding 2015 minimum during the same period. Intriguingly, the timing of the minimum temperatures in both years occurred relatively close to each other (early August), indicating that the peak intensity of seasonal upwelling is climatologically locked to the same timeframe, whereas ENSO modulations dictate the magnitude and depth of the cooling rather than its temporal occurrence.

After passing their minimum thresholds, both years demonstrated a gradual warming trend toward the end of the year. The 2015 SST only caught up with and surpassed the 2022 SST in mid-November, marked by a sharp surge approaching 30°C in late November, while the 2022 SST remained relatively stable within the 28.5–29°C range until the end of the data period. The stark contrast between the two years from June to August is closely tied to the role of the Southeast Monsoon (East Monsoon), which climatologically blows from the southeast along the southern coast of Java-Sumatra during this period. These winds generate alongshore wind stress that drives offshore Ekman transport, thereby displacing the warm surface water layer with cold subsurface water from the thermocline as a process defined as coastal upwelling (Rachman et al 2024).

The integrated results of the spatial and time-series analyses clearly demonstrate that even though the 2022 La Niña was in a decaying phase of a prolonged episode rather than its peak intensity, it successfully suppressed the seasonal cooling signal to the point of near invisibility. This further strengthens the argument that ENSO modulation over SST in these waters is highly consistent and robust, operating independently of the absolute peak strength of the active ENSO phase.

3.2 Sea Surface Salinity Characteristics in the Southern Waters of Banten and West Java During the 2015 Super El Niño and 2022 Strong La Niña Periods

The southern waters of Banten and West Java directly face the eastern tropical Indian Ocean, featuring a narrow and steep continental shelf that allows deep ocean water masses to readily ascend to the surface when triggered by appropriate dynamic drivers. The east-west orientation of the coastline makes this region highly sensitive to alongshore winds, which act as the primary forcing mechanism driving offshore Ekman transport and the subsequent upwelling of lower-temperature, higher-salinity water masses from the subsurface layer. Spatial analyses of sea surface salinity (SSS) in 2015 and 2022 reveal a consistent seasonal pattern. During the January–May period, surface salinity was relatively low, ranging within ~32.5-33.5 psu. A sharp increase in salinity toward 33.8-34.5 psu occurred from June to November, reaching its climax in September. The salinity subsequently declined during the transition to the northwest monsoon in December. The intensification of monsoonal winds exerts a significant impact on variations in sea surface physical parameters. Generally, the salinity in the southern waters of Banten and West Java tends to remain within the open-ocean range of approximately 33-35 psu (Iskandar & Suga, 2022), before decreasing near the coastlines, bays, estuaries, and during the rainy season (Aji et al., 2022; Bahiyah et al., 2019); its primary pattern is governed by monsoons, the South Java Current (SJC), precipitation, river runoff, and upwelling dynamics.

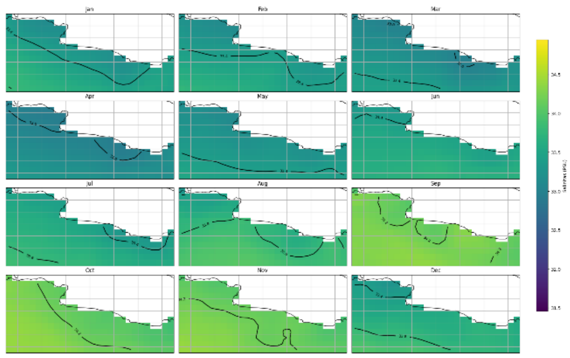

Figure 5. Monthly average sea surface salinity during Super El Nino in 2015

The ENSO phenomenon exerts a profound influence on precipitation and evaporation processes, as well as the intensification of the developing upwelling. During the 2015 El Niño period, the sea surface salinity distribution along the southern coast of Banten and West Java tended to increase progressively each month in accordance with seasonal transitions. Under El Niño conditions, a reduced freshwater flux resulting from a deficit in precipitation inherently tends to elevate salinity levels (Zhi et al., 2019). This reduction in freshwater flux directly corresponds to diminished terrestrial runoff, which subsequently prevents the coastal zones from becoming fresher. Throughout this period, the interplay among local forcing, ENSO modulation, and monsoonal winds enhanced the occurrence of upwelling. A significant surge in salinity was clearly observed upon entering the southeast monsoon, with a salinity increment reaching approximately 0.8 psu in September 2015.

The cross-shore gradient reveals a lower coastal salinity pattern relative to the open ocean. Semi-enclosed areas, such as bays and estuaries, exhibited lower salinity levels (<33 psu), which were dictated by the influx of terrestrial freshwater runoff. A study by Wardani et al. (2014) in the southern waters of Java demonstrated that salinity concentrations during the southeast monsoon increase continuously, culminating in Transition Season II (September-November). Furthermore, the eastern tropical Indian Ocean is actively influenced by the presence of the Indian Ocean Dipole (IOD).

The co-occurrence of a positive IOD and a strong El Niño event delivers a highly significant impact. During a positive IOD event, the eastern Indian Ocean tends to be colder than normal, thereby suppressing precipitation over the Indonesian region.Influence of radar distance

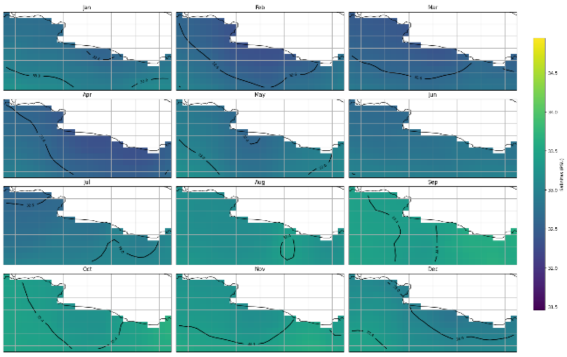

Figure 6. Monthly average sea surface salinity during Strong La Nina in 2022

The year 2022 marked the third year of the "Triple-Dip" La Niña phenomenon, characterized by three consecutive years (2020-2023) of persistent La Niña conditions. Although 2022 was toward the tail end of this La Niña event, its existence nonetheless exerted a significant influence on climate variability, particularly on sea surface salinity (SSS) variations. The monthly mean SSS spatial visualization for 2022 (Figure 6) exhibits a distinctly different pattern compared to the salinity distribution in 2015. During this La Niña period, sea surface salinity ranged between 32.6 and 33.4psu. The Northwest Monsoon and Transition Season I were dominated by relatively low salinity levels compared to the Southeast Monsoon (June-July-August) and Transition Season II. The 32.6psu contour encompassed a highly extensive area when compared to the corresponding months in 2015. This observation aligns with the intensification of monsoonal winds and the overarching influence of La Niña. During La Niña, the enhancement of precipitation across the Indonesian region is driven by warmer sea surface temperatures, which promote convective cloud development, thereby increasing both terrestrial runoff and net precipitation relative to normal conditions. During La Niña events, the weakening of the easterly trade winds suppresses the intensity of coastal upwelling in the southern waters of Java, significantly reducing the supply of highly saline subsurface water masses ascending to the surface layer (Hafiz et al., 2024). This condition is further corroborated by Sukresno et al. (2018), who stated that during La Niña periods, the decline in upwelling intensity is accompanied by an increase in sea surface temperature and a corresponding decrease in salinity and chlorophyll-a values, standing in stark contrast to the conditions observed during El Niño periods.

In the coastal zone parallel to the shoreline, the western part of southern Banten (proximal to Ujung Kulon) exhibited a consistently low salinity pattern during the Northwest Monsoon and Transition Season I (January-May). This pattern is dynamically linked to the seasonal circulation within the Sunda Strait, which acts as a crucial exchange pathway for water masses between the Java Sea and the Indian Ocean. During the northwest monsoon, a net outflow of water masses occurs from the Java Sea which is significantly diluted by high precipitation and heavy river runoff from large rivers in Sumatra, Java, and Kalimantan passing through the Sunda Strait into the Indian Ocean. Concurrently, the monsoonal influx from the north brings warmer waters that further modify the upper-layer salinity. At the peak of the Southeast Monsoon through Transition Season II, the influence of the Sunda Strait diminishes, and the monsoonal wind forcing drives a significant increase in salinity, with values along the coastal zones of southern Banten and West Java rising to 34.2psu. This localized salinity suppression is also potentially modulated by the Indonesian Throughflow (ITF / *ARLINDO*); as explained by Gordon et al. (1997), the ITF transport can carry relatively cool, low-salinity freshwater masses into the eastern Indian Ocean.

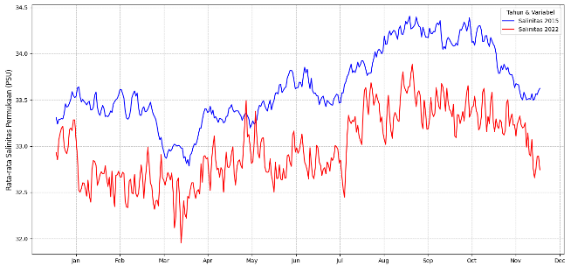

Figure 7. Time-series of Sea Surface Salinity in the Southern Java Waters during Super El Nino 2015 (Blue Line) and Strong La Nina (Red Line)

In addition to upwelling dynamics, the decrease in salinity during the 2022 La Niña was further amplified by positive precipitation anomalies, which are a hallmark characteristic of this phase across the Indonesian region. More specifically, Destyano et al. (2025) reported that under La Niña conditions, sea surface temperatures across the Indonesian seas become warmer, frequently leading to rainfall well above normal thresholds, with the most pronounced impact occurring at the onset of the dry season (June-November). This pattern provides a relevant mechanism explaining why the 2022 salinity reduction remained clearly discernible even during months that are climatologically dry (June-October). Nonetheless, both years consistently exhibited a similar seasonal curve, characterized by a salinity minimum in March-April (the peak of the rainy season/northwest monsoon) and a maximum in August-September (the peak of the dry season/southeast monsoon and upwelling). A gradual increase in salinity began to take place, where a significant surge reaching 34.4psu was observed in August. In other words, ENSO does not induce a novel seasonal pattern, but rather amplifies (during El Niño) or dampens (during La Niña) the intensity of the pre-existing seasonal cycle.

4. Conclusion

The ENSO phenomenon significantly modulates the hydro-oceanographic dynamics in the southern waters of Banten and West Java through distinct variations in the thermohaline structure (temperature and salinity) between the Super El Niño (2015) and the Triple-Dip La Niña (2022) periods. During the Southeast Monsoon (July-October) of 2015, the strengthening of southeasterly trade winds coupled with climate anomalies triggered an extreme intensification of coastal upwelling, marked by a drop in minimum sea surface temperature (SST) to 22-24°C and a surge in sea surface salinity (SSS) to 33.8-34.5psu due to the upwelling of deep, saline water masses and deficit precipitation. Conversely, during the La Niña year of 2022, the upwelling mechanism was remarkably suppressed, causing the SST to remain warm at around 27–28°C (approximately 4-5°C warmer than in 2015) and maintaining a depressed SSS range of 32.6–33.4psu as a result of elevated precipitation, river runoff, and the intrusion of fresher water masses from the Java Sea via the Sunda Strait and the ITF (*ARLINDO*) circulation. Furthermore, the positive phase of the IOD also plays a pivotal role in modulating the surface temperature and salinity structures off southern Banten and West Java. Consequently, the co-occurrence and concurrent combination of ENSO and IOD exert a profound impact on variations in both SST and sea surface salinity. The fluctuations of these two parameters reveal an inverse yet complementary seasonal relationship, reflecting a complex interplay among local monsoon forcing, regional Indian Ocean dynamics, and global climate teleconnections that ultimately govern nutrient availability and pelagic fishing grounds in the study region.

Further studies investigating the combined interaction of IOD and ENSO during their neutral, positive, and negative phases are highly warranted to elucidate their comprehensive impacts on temperature and salinity variability, thereby strengthening the understanding of their hydro-oceanographic implications in the southern waters of Banten and West Java.

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