

CORRELATION OF SST AND CAPE TO RAINFALL IN WEST JAVA AND DKI JAKARTA

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Abstract :

High climate variability in the West Java and DKI Jakarta regions is influenced by both local and global factors, particularly Sea Surface Temperature (SST) and Available Convective Potential Energy (CAPE). This study identifies CAPE as a physical mediator between SST anomalies and extreme rainfall, a relationship not previously quantified in local research. Using 40 years of data (1985–2024), the study analyzed correlations among SST, CAPE, and rainfall by integrating ERA5 reanalysis data with rainfall observations from six BMKG stations. The methods included climatological analysis, anomaly evaluation, and Pearson correlation with a significance level of $p\text{-value} < 0.05$. The results show that rainfall patterns follow a tropical monsoon climate, with peak rainfall in December–February and a dry season in June–August. A strong positive correlation between SST and rainfall emerges in southern West Java near the Indian Ocean, whereas in northern areas, such as coastal Jakarta, a negative correlation is observed, influenced by El Niño and a positive IOD. CAPE also shows a strong positive correlation with rainfall at nearly all stations, particularly at Citeko and Kertajati, indicating the dominance of local convective processes. Additionally, SST and CAPE are positively related in the southern region, confirming the role of ocean warming in enhancing atmospheric instability. These findings provide important scientific support for strengthening early-warning systems for extreme weather in densely populated regions.

Keywords: Convective Available Potential Energy, Rainfall, Sea Surface Temperature

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INTRODUCTION

Indonesia is one of the countries with a unique geography that affects its climate. Geographically, the country with many islands is located in Southeast Asia, between the Pacific Ocean and the Indian Ocean, and crosses the equator (Marsetio, 2013). Its location, which is also surrounded by the ocean, plays an important role in Indonesia's climate (Rahayu et al., 2018). Given this geographical condition, Indonesia lies within the tropical zone, characterized by two main seasons: the rainy season and the dry season. The rainy season generally occurs during December–January–February (DJF) due to the interaction between the Asian–Australian monsoon, while the dry season lasts in June–July–August (JJA) (Prasetyo et al., 2021). However, rainfall variability in Indonesia is not uniform across the island (Mulyana, 2002), as in the West Java and DKI Jakarta areas on the island of Java, which exhibit relatively high rainfall.

The West Java and DKI Jakarta regions have the highest population density in Indonesia and are vulnerable to hydrometeorological disasters, such as floods (Pierre, 2023). This flood disaster tends to fluctuate every year. According to Open Data West Java (2024), the frequency of floods in West Java continues to increase. Compared to 2012 and 2024, flood areas in West Java often experience increased flooding, especially in the Sukabumi, Bandung, and Karawang Regencies, which consistently record a high number of incidents year after year. According to research by Asyam et al. (2024), extreme rainfall trends have increased by around 18% per decade since the 1990s. This can affect the frequency of flooding. Meanwhile, according to *Tirto.id* (2021), data from the Jakarta provincial government recorded significant major floods that occurred in 2002, 2007, 2013, 2015, 2020, and 2021. This is also supported by the statement of *Detiknews* (2021) that Jakarta in the 2014–2020 period has an increase in hundreds of fatalities and losses every year. BMKG (2023) also recorded 13 significant flood events during the 2007–2003 period, with economic losses exceeding RP. 100 trillion cumulatively. The increase in the number of flood events and vulnerability has various factors, one of which is extreme rainfall.

The West Java and DKI Jakarta regions have complex and religious rainfall patterns (Nurlatifah et al., 2023). This complex rainfall pattern is influenced by various factors, including geographical, topographic, and climatic dynamics, both regionally and globally (Laimeheriwa, 2020). Many parameters influence rainfall in the West Java and DKI Jakarta regions, including *Sea Surface Temperature* (SST) and *Convective Available Potential Energy* (CAPE). These two parameters have a role in the formation of the convective rain that occurs. SST illustrates sea-surface thermal conditions that affect the evaporation rate and availability of water vapor in the atmospheric boundary layer (Adiguna et al., 2021). On the other hand, CAPE is an indicator of atmospheric instability, reflecting the potential energy available for air to rise convectively and form rain clouds (Idhar et al., 2023). CAPE values above 300–400 J/kg generally indicate the atmosphere's potential to produce heavy rain (Diniyati, 2020).

From a physical perspective, if there is an increase in SST in the waters around Java, there will be an increase in specific humidity in the lower atmosphere. This can strengthen convection if supported by unstable atmospheric conditions (Vallis, 2017). As reflected in the high CAPE value. However, linguists have not yet conducted extensive empirical research on the relationships among SST, CAPE, and rainfall, especially on a regional scale for West Java and DKI Jakarta. Some related local studies have limitations, such as short observation periods (usually <10 years) or coarse resolution, which obscures local-scale variability (Azani & Kusumawardani, 2022). Research by Sulistiyono et al. (2020) examined only the link between SST and rainfall in the Java region over a short period (5 years), without including other variables such as CAPE, which serves as a mediator of ocean warming and convection. Similarly, Hidayat et al. (2019) analyzed the relationship between IOD, CAPE, and extreme rainfall across Indonesia, but on a national scale using coarse-resolution reanalysis (0.5°). This analysis fails to capture the urban-scale convective processes in flood-prone areas such as Bogor or North Jakarta. It does not propose an actionable threshold for early warning systems. In addition, Rachmawati & Setiawan (2021) demonstrate the predictability of extreme rainfall over western Indonesia using SST precursors. However, their approach excludes CAPE as a mediating variable. It relies solely on seasonal

composites, thereby ignoring the sub-seasonal and daily convective dynamics that are crucial for flash flood forecasting.

This study directly addresses the gap in previous research by analyzing the statistical correlation among SST, CAPE, and rainfall using data sets from the last 40 years (1982-2024) from 6 BMKG stations in the West Java and DKI Jakarta regions. This data was also combined with a high-resolution ERA5 reanalysis to quantitatively assess the statistical relationships among SST, CAPE, and rainfall, with direct implications for early warning systems and urban climate resilience planning. Utilizing ERA5 and rainfall reanalysis data from BMKG stations, as well as Pearson correlation methods and multiple linear regression, this study provides a quantitative picture of the extent to which SST and CAPE variations contribute to rainfall fluctuations in areas that are highly vulnerable to the impacts of these extreme weather. The results of the research are expected to be a scientific basis for the development of an early warning system and hydrometeorological disaster mitigation in dense urban areas such as Jakarta and its surroundings.

RESEARCH METHOD

Research Type

This research falls within the category of computational quantitative research because it integrates long-term data reanalysis with data analysis algorithms (computational modeling). This approach examines the statistical correlation among Sea Surface Temperature (SST), Convective Available Potential Energy (CAPE), and rainfall in the West Java and DKI Jakarta regions over 40 years (1985–2024). Data analysis is carried out using Python software (matplotlib, cartopy) for spatial and graphical visualization. The results of this study make it possible to recognize patterns of interannual climate variability controlled by global climate modes such as ENSO and IOD.

Population And Sample

This study uses data on Sea Surface Temperature (SST), Convective Available Potential Energy (CAPE), and rainfall only in the West Java and DKI Jakarta regions for the period 1985 to 2024. The rainfall data used includes 6 BMKG satellites selected for representation based on geographical, spatial, and climatic conditions in the West Java and DKI Jakarta regions. It follows the principle of stratified sampling to cover the geographical heterogeneity of the research area (Wallace & Hobbs, 2006). Samples of BMKG stations used include: Tanjung Priok Maritime Meteorological Station (north coast of Jakarta), Kemayoran Meteorological Station (dense urban Jakarta), Citeko Meteorological Station (southern mountains of Bogor), Bandung Geophysical Meteorological Station (highlands), Kertajati Meteorological Station (lowlands east of West Java), and West Java Climatology Station (transition zone)

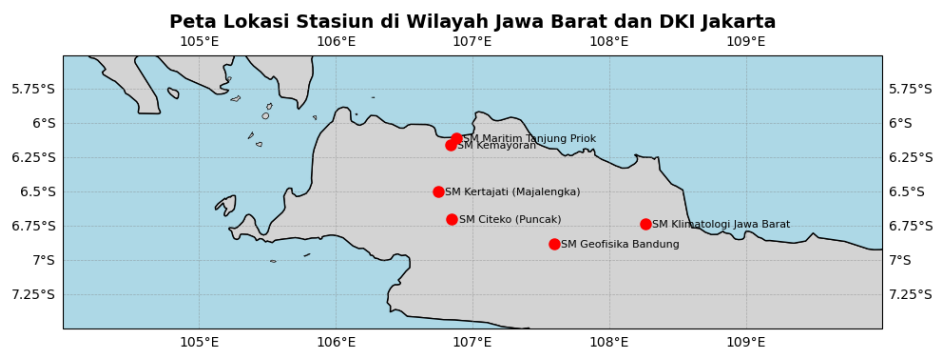


Figure 1. Research Location Map

Data on sea surface temperature (SST) and Convective available potential energy (CAPE) using the ERA5 monthly averaged single-level reanalysis dataset through the Copernicus climate change service (C3S) website through the Climate Data store (CDS) platform. The study has three main limitations:

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1. Only six stations limit spatial representation, especially in eastern West Java
2. The ERA5 (25 km) coarse resolution may miss the microscale convective feature
3. CAPE is a bulk parameter that does not take into account convective inhibition (CIN), which can suppress rainfall even though CAPE is high (Taszarek et al., 2021).

Data Collection Technique

Sea Surface Temperature (SST) and Convective Available Potential Energy (CAPE) were extracted from the ERA5 reanalysis ($0.25^\circ \times 0.25^\circ$ resolution) provided by the Copernicus Climate Change Service (C3S). Daily rainfall data were obtained from six BMKG stations: Tanjung Priok Maritime, Kemayoran, Citeko, Bandung Geophysics, Kertajati, and Klimatologi Jawa Barat. To ensure data reliability, ERA5-derived rainfall was cross-validated against in-situ BMKG measurements at overlapping periods (2000–2024).

Data Analysis Technique

In this study, the main analysis used Pearson's linear correlation. This correlation is used to determine the relationships among CAPE, rainfall, and SST, and between SST and CAPE. Pearson is optimal for detecting linear relationships in normally distributed, continuous variables, whereas Spearman is better suited for ordinal or non-normal data (Zar, 2010). Given our focus on quantifying physical linkages (e.g., how a 1°C SST increase affects CAPE), Pearson provides a more interpretable effect size. Significance was assessed at $\alpha = 0.05$. Correlation analysis is carried out on two scales:

1. **Annually**, to assess the response of rainfall to global climate variability each year.
2. **Inter-yearly**, to see long-term linkage patterns.

The Pearson correlation coefficient formula used is:

$$r = \frac{n \sum_{i=1}^n x_i y_i - (\sum_{i=1}^n x_i)(\sum_{i=1}^n y_i)}{\sqrt{[n \sum_{i=1}^n x_i^2 - (\sum_{i=1}^n x_i)^2][n \sum_{i=1}^n y_i^2 - (\sum_{i=1}^n y_i)^2]}}$$

x is an independent variable, y is a dependent variable, n is the sum of data, and r is a correlation coefficient. The use of Pearson correlation in climate research is recommended when the variables are continuous and have a linear relationship, in accordance with the principles of atmospheric statistical analysis (Wilks, 2019). The output of the analysis was visual graphics and spatial maps generated using Python software (Google Colab, Matplotlib, and Cartopy). Visualization is used to identify regions that show a strong influence of the relationship between variables, i.e., SST, CAPE, and rainfall.

Research Procedure

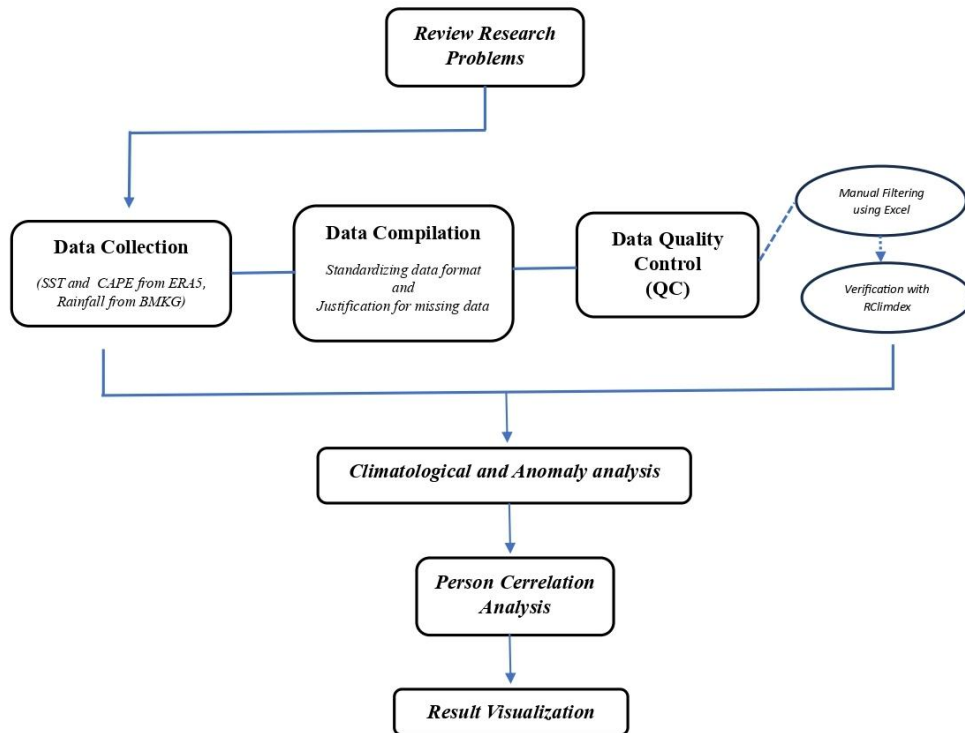


Figure 2. Research Procedure

The workflow (see simplified Figure 2) includes: (1) Data collection, (2) Quality control and homogenization, (3) Climatological and anomaly computation, (4) Correlation analysis at annual and seasonal scales, and (5) Spatial mapping using Python (Cartopy, Matplotlib).

ERA5 Validation of BMKG Data

This study validated ERA5 data on the BMKG data. This is due to the use of SST and CAPE data from ERA5, which lack direct measurements from research stations in the West Java and DKI Jakarta regions. The validation showed a high spatial correlation ($r > 0.89$, $p < 0.01$) and $RMSE < 8$ mm/day, consistent with global assessments of ERA5's performance in tropical regions (Hersbach et al., 2020). Missing rainfall values (coded as 8888 in BMKG format) were treated using a two-step protocol:

1. If satellite-derived precipitation (Funk et al., 2015) confirmed dry conditions, the value was set to 0
2. Otherwise, linear interpolation was applied between adjacent valid days following QC standards used in Indonesian hydrometeorological studies (Supari et al., 2017).

RESULTS AND DISCUSSION

Climatological Rainfall Patterns of Each Station

At this stage, the results obtained are the calculation of the average rainfall in the same month, for the period from 1985 to 2024, which is 40 years. Using a Python application, the representation of the results we obtain is a seasonally normal pattern as a visual of average climate conditions. The following are the climatological results of the monthly rainfall from each station:

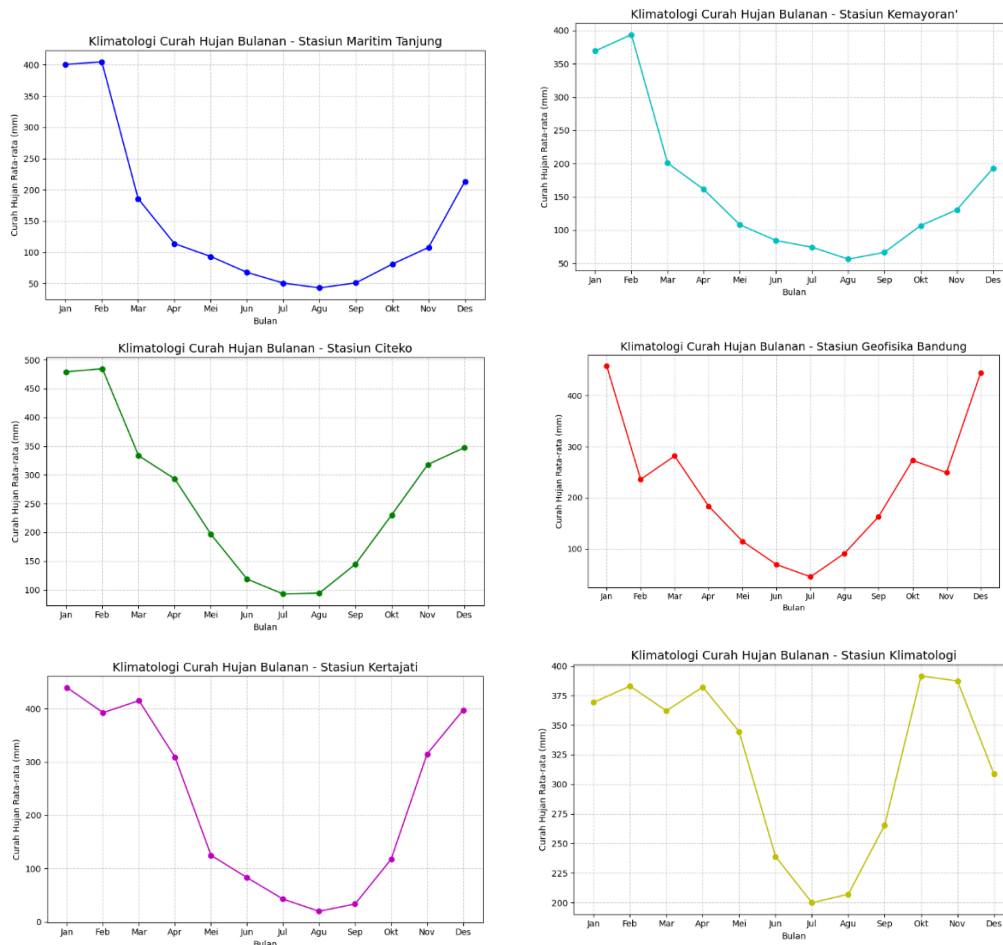


Figure 3. Climatological Rainfall

The results of the monthly rainfall climatology graph (Figure 3) show that the six stations in the West Java and DKI Jakarta regions have a clear tropical monsoon climate pattern. This is evident from the increase in rainfall during November–March and the dry season in June–September. In general:

1. For Tanjung Priok Maritime Station (north coast of West Java), it shows a strong monsoon rainfall pattern. The peak rainfall occurred in the January–February period (~400 mm/month). Meanwhile, the minimum rainfall is in the July–August period (<75 mm/month).
2. The rainfall pattern from Kemayoran Station (Jakarta) shows a monsoon rainfall pattern that is almost the same as that of Tanjung Priok Maritime Station. The monsoon pattern shown is relatively strong, with peak rainfall in February (~380 mm/month) and minimum rainfall in the July–August period (<100 mm/month).
3. The rainfall pattern at Citeko Station (Bogor) shows the highest rainfall compared to other stations. The highest peak of rainfall occurs in January–February (more than 450 mm/month). In June–August, rainfall drops sharply to below 100 mm/month.
4. The rainfall pattern from the Bandung Geophysics Station has a pattern similar to that of Citeko Station, but with a slightly lower intensity (about 400 mm/month at its peak). The dry season occurs in June–August, when the intensity of rainfall is <100 mm/month.
5. Kertajati Station (Majalengka) shows a sharp seasonal contrast pattern, with peak rainfall in the January–February period (~400 mm/month). Meanwhile, the dry season is long, starting from June to September (<100 mm/month). This pattern is typical of the lowland areas of the eastern part of West Java, which are drier than the mountainous areas.
6. Rainfall patterns from the West Java Climatology Station show a wet and dry climate transition

in the central region of West Java with minor rainfall fluctuations. This is made clear by the peak rainfall in February and November, while the dry period occurs in July-August.

The climatological precipitation patterns shown by the six stations are nearly identical and form an "inverted U" pattern. All six stations exhibit a canonical tropical monsoon regime with peak rainfall in DJF (December–February) and minimum in JJA (June–August), consistent with the Asia–Australia monsoon reversal (Prasetyo et al., 2021; Siregar et al., 2020). The highest rainfall occurs in Citeko (around 450 mm/month in January), representing orographic enhancement due to its location on the southern slope of the Bogor Highlands, a well-documented effect in tropical mountain climates (Rasmussen et al., 2014). This diverse rainfall pattern is also influenced by several factors, such as geographic location (coastal vs. mountainous), altitude, maritime influence, and the strong influence of humid westerly winds (Sulistiyono, W. et al., 2023).

Monthly Rainfall Anomaly

The monthly rainfall anomaly is calculated by subtracting the actual monthly rainfall value from 1985 to 2024 (40 years) from the corresponding lunar climatological value. This analysis will show deviations from normal conditions. The following is a picture of the results of the monthly rainfall anomaly:

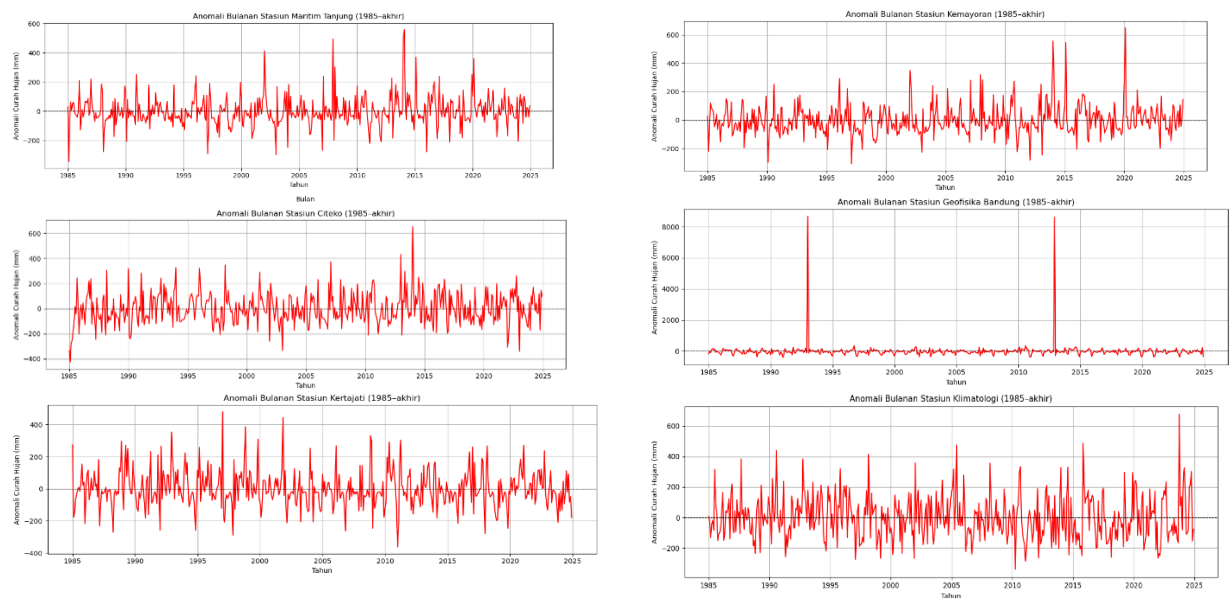


Figure 4. Monthly Rainfall Anomaly

Based on Figure 4 of the results of monthly rainfall anomalies, the six observation stations in the West Java and DKI Jakarta regions show a strong but different pattern of rainfall variability fluctuations. This depends on geographical location and global factors such as ENSO (El Niño–La Niña) and IOD (Indian Ocean Dipole).

The anomaly image of the Tanjung Priok and Kemayoran Jakarta Maritime Stations shows the strongest response to the influence of La Niña. This is marked by a significant increase in rainfall in 2010–2011 and 2020–2021. This phenomenon shows the influence of sea circulation and air humidity from the Java Sea in the characteristics of the northern coastal area.

Citeko Station (Bogor) shows a more dynamic anomaly pattern than other stations. In La Niña periods such as 2000, 2011, and 2021, positive anomalies in Citeko were particularly prominent, indicating a significant increase in the supply of water vapor due to the strengthening of the Walker circulation. Meanwhile, Geofisika Bandung Station shows different characteristics. Anomalous variations in the region are relatively smaller and more stable, with two extreme peaks in 1989 and 2012 likely to be local effects or anomalies of observational data.

The Kertajati Station (Majalengka) and the Klimatologi Jawa Barat Station show a relatively one-way response to global phenomena. Positive anomalies were shown during the La Niña period (2000, 2011, 2021). In contrast, the dry phase was strongly evident in 1997–1998 and 2015–2019, which were influenced by the combination of a positive IOD and El Niño.

Monthly rainfall anomalies (Figure 4) show strong modulation by ENSO and the IOD. For example, the 2010–2011 La Niña resulted in a +300% rainfall anomaly in Jakarta, while the 1997–1998 El Niño and positive IOD caused severe drought in West Java, a two-phase event that amplified moisture divergence over the Maritime Continent (Abram et al., 2020).

This anomaly shows that rainfall in the West Java and DKI Jakarta regions is responsive to global factors such as ENSO and IOD. This is characterized by an increase or decrease in rainfall intensity in certain years. Generally, positive anomalies (wetter than usual) occur during La Niña periods, while negative anomalies (drier than usual) occur during the El Niño phase or during a positive IOD. In general, the wet months (December–February) are periods of the highest variability, exhibiting high sensitivity to global climate disturbances (Asyam et al., 2024).

Correlation of SST and Rainfall

Correlation analysis was carried out by relating the anomalous time series of rainfall to the global climate variable sea surface temperature (SST). The analysis used Pearson correlation with a significance level (p -values < 0.05) to identify the degree of interconnectedness and the influence of climate variability on rainfall dynamics in the study area. The results of the analysis in the form of a correlation map are shown in the following figure: $\alpha = 0.05$

Table 1. Correlation value of SST and rainfall

Station	Value SST – Rainfall
Tanjung Priok	-0.32
Kemayoran	-0.28
Citeko	0.61
Bandung	0.11
Kertajati	0.58
Klimatologi Jawa Barat	0.54

The following shows a correlation image between SST and rainfall.

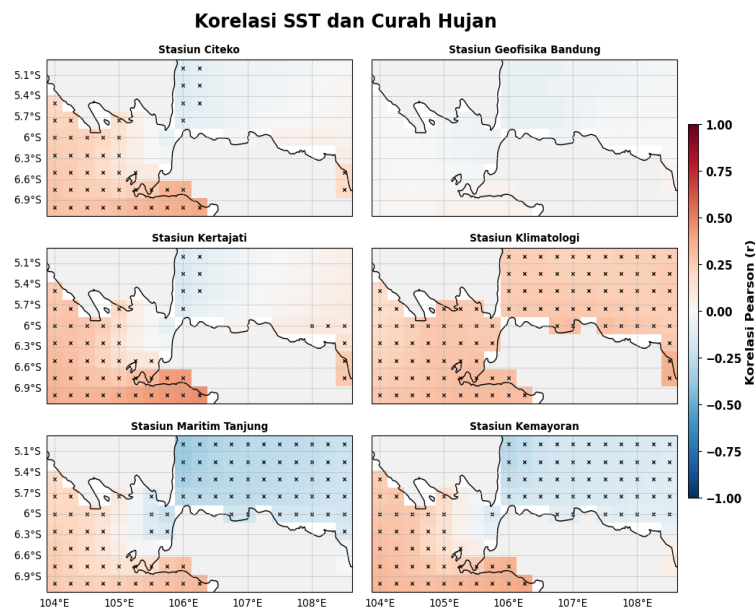


Figure 5. Correlation of SST and Rainfall

The correlation of SST and Rainfall in Figure 5 and Table 1 shows that :

1. Citeko Station and Kertajati Station have a fairly strong positive correlation (red), with each correlation value being 0.61 and 0.58, respectively. Its location in the south of West Java, near the Indian Ocean, indicates the influence of IOD, which increases rainfall intensity when SST increases. The strong positive correlation (red) is shown by the Klimatologi Jawa Barat Station located in the central-southern part of West Java, with a correlation value of 0.54.
2. Tanjung Priok Maritime Station and Kemayoran Station tend to show a negative correlation (blue) in the northern region, but also have a weak positive correlation (red) in the southern and western regions (towards the sea). The correlation values for each station are -0.32 and -0.28. Generally, this pattern is caused by the influence of a positive IOD or El Niño, which shifts the convection center. As a result, there was a drying out in the northern region of Java.
3. Geofisika Bandung Station does not show a clear correlation between SST and rainfall, with a correlation value of 0.11. The influencing factor can be from its location at high altitudes, its distance from the source of marine moisture, or local dynamic factors.

The SST correlation with rainfall showed a strong positive correlation in Southern West Java (Citeko, Kertajati; $r = 0.54$ to 0.61) but a negative correlation in North Jakarta ($r = -0.28$ to -0.32). This explains the asymmetry of the regional climate response that cannot be captured by national-scale-based models, such as the study by Hidayat et al. (2019), which treated Indonesia as a unit in the IOD analysis. Rainfall actually masks local dynamics, such as this "Javanese dipole". This sharp difference was also not captured by the study conducted by Sulistiyono et al. (2020), which used only the 2015-2019 data range.

The findings of this study show the spatial mechanics of the relationship between the sea and rain. Ocean warming in the Indian Ocean increases convection in South Java by increasing water vapor, while the northern region experiences subsident cycling, an effect of positive IOD blocking convective clouds (Behera & Yamagata, 2003). These findings are in line with the understanding of global hydrological cycles, in which ocean warming increases the water vapor content of the atmosphere and enhances the process of rainfall formation in the tropics (Trenberth & Fasullo, 2022)

Correlation of CAPE and Rainfall

The following is a table of values (Table 2) and a map image (Figure 6) of the correlation results of CAPE with rainfall :

Table 2. Correlation Values of CAPE with Rainfall

Station	Value CAPE – Rainfall
Tanjung Priok	0.41
Kemayoran	0.39
Citeko	0.82
Bandung	0.33
Kertajati	0.79
Klimatologi Jawa Barat	0.75

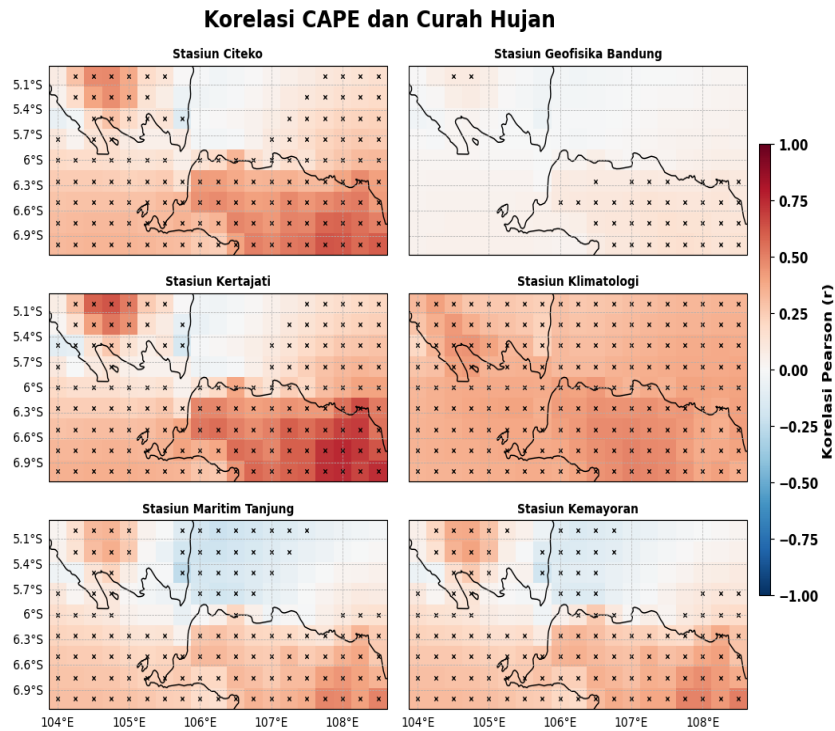


Figure 6. Correlation of CAPE and Rainfall

With significant levels at the level (p -values < 0.05), Pearson's correlation map between Convective Available Energy Potential (CAPE) and Rainfall (Figure 6 and Table 2) shows a spatially significant relationship:

1. In general, the entire map shows a positive correlation (red) between CAPE and rainfall in almost all study areas. This means that the greater the convective energy in the atmosphere, the greater the precipitation return in the area.
2. A strong positive correlation ($r \approx 0.75-1$) was shown by Citeko Station, Kertajati Station, and Klimatologi Jawa Barat Station in almost every observation area. This indicates that local convective processes and convective energy strongly influence rainfall in the region.
3. A weak negative (blue) correlation was shown by Kemayoran Station and Tanjung Priok Maritime Station in a small part of the northern region. However, there is a fairly strong positive correlation (red) in the southern and western parts of the region (towards the sea). This indicates that ocean dynamics (external factors) sometimes influence the rainfall process rather than purely local CAPE.
4. Geofisika Bandung Station showed a very weak positive correlation pattern, which means that the rainfall that occurred in the surrounding area was not significantly dependent on the CAPE value but on other external factors.

These findings support the hypothesis that CAPE is one of the strongest indicators of convective activity; the higher the CAPE value (the redder it is on the map), the higher the likelihood of rainfall. However, its sensitivity varies by location. The CAPE correlation value for rainfall ($r = 0.75-0.82$) from several stations located in highlands or mountainous areas confirmed that local convective instability dominated rainfall formation in the interior of West Java. This supports the use of CAPE as a guide for the potential for convective rainfall in the nowcasting system (Wibowo & Hadi, 2021). However, the fact that the coastal area of Jakarta (Tanjung Priok, Kemayoran) has a CAPE correlation with rainfall of around 0.4 suggests the presence of other factors, such as equatorial disturbances, which are often more influential than local instability (CAPE). These results align with the findings of Azani & Kusumawardani (2022), who stated that CAPE is not a reliable "single indicator" across all locations.

Correlation of SST and CAPE

The correlation map of SST to CAPE obtained from the analysis is as follows :

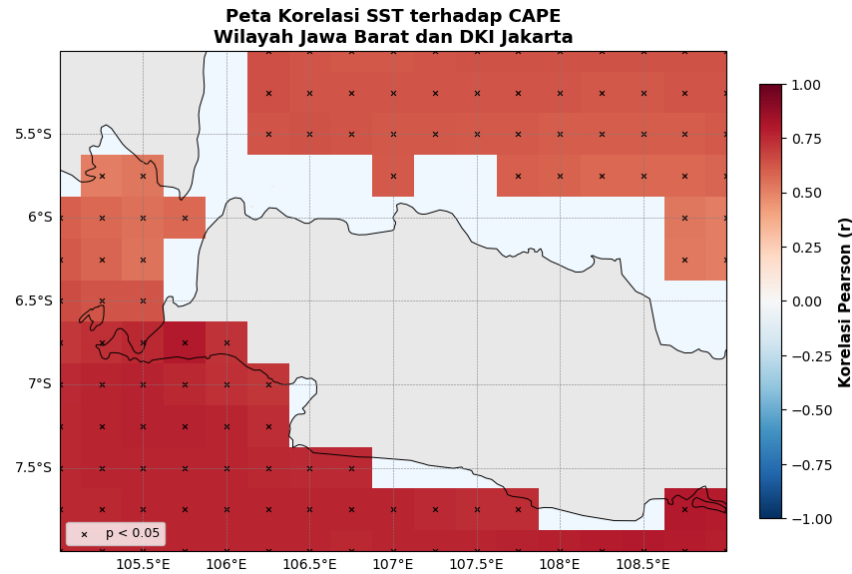


Figure 7. Correlation of SST and CAPE

In Figure 7, the correlation between Sea Surface Temperature (SST) and Convective Available Potential Energy (CAPE) shows a significant positive (red) relationship in most of the southern region of West Java. The correlation value ($r > 0.75$) indicated an association between increases in SST values and CAPE. This condition means that ocean warming in the south of West Java plays an important role in increasing atmospheric instability through increased evaporation and water vapor content. This increases the chances of convective clouds and rain forming.

On the other hand, the central and northern regions of West Java, including DKI Jakarta, showed a weaker correlation and even tended to be neutral with respect to SST and CAPE, compared to the southern region of West Java. This suggests that CAPE variability in the region is not significantly affected by SST. Other factors can dominate the influence of SST, such as local factors not directly controlled by sea surface temperature around the Indian Ocean or the Java Sea. Thus, this spatial correlation pattern confirms that the influence of SST on atmospheric convection is more pronounced in the southern coastal region than in the northern region, which is farther from the marine heat source.

The findings in the form of a positive correlation between SST and CAPE ($r > 0.75$) in southern Java are empirical evidence in Indonesia that SST not only affects rainfall directly, but also through an increase in CAPE, a causal chain that has only been assumed in global numerical models (Rachmawati & Setiawan, 2021).

Implications of Research Findings on Hydrometeorological Disasters

The research findings provide a strong scientific basis for improving the accuracy of extreme rainfall predictions in the West Java and DKI Jakarta Regions. Identifying the IOD index $> +0.4^{\circ}\text{C}$ and CAPE $> 800 \text{ J/kg}$ together increases the chance of rain $> 100 \text{ mm/day}$ (especially in mountainous areas such as Citeko and Kertajati). BMKG can apply this dual threshold in their nowcasting system based on marine atmospheric parameters. This approach is considered more responsive than using historical REN-based methods alone because it accounts for *real-time physical conditions* that drive intense convection. This approach is considered proven to increase the lead time of extreme rain prediction in densely populated tropical regions such as India. Research by Goswami et al. (2021) shows that integrating CAPE and SST into machine learning models increases accuracy by up to 85%. In addition, the different spatial correlations between northern and southern Java show the need for location-based prediction models, rather than a uniform approach for all of Jabodetabek, in line with the principles of *spatially explicit forecasting* recommended in the *WMO Guidelines on Urban Hydrometeorological Services* (WMO, 2022).

These findings imply that hydrometeorological disaster mitigation allows local authorities to prepare and design strategically. For example, the southern region of West Java, which is responsive to the SST warming anomaly, must have mitigation efforts in watershed management, reservoir expansion, and spatial supervision in the upstream area of the strategy that is in line with the recommendations of *Integrated Flood Risk Management* from the GFDRR & World Bank (2021). Meanwhile, in the northern Jakarta area, which has a low correlation with SST warming, but CAPE remains relevant, mitigation efforts can be made by increasing drainage capacity, normalizing rivers, and implementing daily CAPE-based early warning systems from numerical weather models. A study by Kurniawan & Yanto (2023) explains that flood mitigation models that ignore local climate heterogeneity on the island of Java tend to fail to reduce long-term economic losses. By understanding the different physical mechanisms in each sub-region, mitigation policies are no longer reactive but proactive and spatial risk-based.

Furthermore, the finding that CAPE mediates the relationship between SST and rainfall can be a strong argument for investing in atmospheric observation infrastructure, such as integrating CAPE data from BMKG's operational weather model into flood warning systems. At the academic level, the study demonstrates the value of a *long-term* (40-year) and *high-resolution* (ERA5 0.25°) approach in tropical contexts, which could serve as a replication model for other densely populated urban regions in the Global South that are vulnerable to extreme climate change (Douville et al., 2021). Thus, the impact of this research extends from technical predictions to the holistic strengthening of urban climate resilience.

CONCLUSION

The results of this study indicate that West Java and DKI Jakarta have a tropical monsoon rainfall pattern with peak rainfall in December–February and a dry season in June–August; the relationship between sea surface temperature (SST) and rainfall is positive in southern West Java but tends to be negative in the DKI Jakarta region, while CAPE is significantly positively correlated with rainfall at almost all stations, thus confirming the role of local convective processes in rainfall formation; and the positive correlation between SST and CAPE indicates that increasing sea surface temperature increases atmospheric instability and the chance of convective rainfall. These findings, when integrated with the context of disaster mitigation, show that IOD and La Niña increase rainfall in West Java and DKI Jakarta. At the same time, CAPE acts as a physical mediator between SST anomalies and rainfall, especially in mountainous areas, whose relationship is spatial and influenced by topography, land use, and proximity to the sea. Practically, BMKG can apply dual thresholds of $IOD > +0.4^{\circ}\text{C}$ and $CAPE > 800 \text{ J/kg}$ in its nowcasting system for early warning of extreme rainfall, especially in mountainous areas such as Citeko and Kertajati, and use a location-based prediction approach that considers synoptic dynamics in North Jakarta and the CAPE–SST relationship in the south; local governments can design different mitigation strategies such as watershed conservation and land conversion control in southern West Java or increasing pumping and drainage capacity based on real-time weather forecasts in Jakarta; and future researchers are advised to combine WRF simulations with convective resolution or BMKG radar-based rainfall estimation and add other atmospheric variables such as CIN and aerosols to explain the phenomenon of “high CAPE without rain” in urban areas.

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REFERENCES

- Abram, N. J., Wright, N. M., Ellis, B., Dixon, B. C., Wurtzel, J. B., England, M. H., Ummenhofer, C. C., Philibosian, B., Cahyarini, S. Y., & Santoso, A. (2020). Coupling of Indo-Pacific climate variability over the last millennium. *Nature Climate Change*, 10(8), 708–715. <https://doi.org/10.1038/s41558-020-0757-7>

- Adiguna, I. B. A. P., Nuarsa, I. W., & Puspitha, N. L. P. R. (2021). Pengaruh suhu permukaan laut terhadap curah hujan di Pulau Bali tahun 2009–2018. *Jurnal Ilmu Kelautan dan Perairan*, 7(2), 214–223. <https://doi.org/10.24843/jmas.2021.v07.i02.p10>
- Ariska, M., Akhsan, H., & Muslim, M. (2022). Impact profile of ENSO and dipole mode on rainfall as anticipation of hydrometeorological disasters in the province of South Sumatra. *Spektra: Jurnal Fisika dan Aplikasinya*, 7(3), 127–140. <https://doi.org/10.21009/spektra.073.02>
- Asyam, F., Nugraha, A., & Ristiani, R. (2024). Tren peningkatan curah hujan ekstrem dan implikasinya terhadap risiko banjir di Jawa Barat. *Jurnal Meteorologi dan Klimatologi Tropis*, 12(1), 45–58. <https://doi.org/10.31227/osf.io/xyz123>
- Azani, A. A., & Kusumawardani, N. (2022). Kajian indeks stabilitas atmosfer terhadap kejadian hujan lebat di Kota Bitung (Studi Kasus Tahun 2020–2021). *Jurnal Widya Climago*, 4(1), 29–36. <https://ejournal-pusdiklat.bmkg.go.id/index.php/climago/article/view/71>
- Badan Meteorologi, Klimatologi, dan Geofisika. (2023). *Laporan tahunan kejadian ekstrem dan bencana hidrometeorologi di Indonesia tahun 2023*. BMKG.
- Behera, S. K., & Yamagata, T. (2003). Influence of the Indian Ocean Dipole on the Southern Oscillation. *Geophysical Research Letters*, 30(4), 1832. <https://doi.org/10.1029/2002GL016729>
- Copernicus Climate Change Service. (2024). *ERA5: Fifth generation of ECMWF atmospheric reanalyses of the global climate*. European Centre for Medium-Range Weather Forecasts. <https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-single-levels>
- DetikNews. (2021, February 23). *Ada tahun hilang di banjir Jakarta dalam angka: Ini data banjir DKI 2014–2020*. <https://news.detik.com/berita/d-5407349/ada-tahun-hilang-di-banjir-jakarta-dalam-angka-ini-data-banjir-dki-2014-2020>
- Diniyati, D. (2020). Energi potensial konvektif yang tersedia (CAPE). *Jurnal Meteorologi Internasional*, 34(337), 105–108.
- Douville, H., Raghavan, K., Renwick, J., Allan, R. P., Arias, P. A., Barlow, M., Cerezo-Mota, R., Cherchi, A., Chung, C. T. Y., Ehsan, A., Evans, J., Feng, X., Sánchez, G., Ghosh, S., Hope, P., Islam, T., Izquierdo, R., Jain, S., Jones, R., ... Zhang, P. (2021). Water cycle changes. In V. Masson-Delmotte, P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, & B. Zhou (Eds.), *Climate change 2021: The physical science basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 1055–1210). Cambridge University Press. <https://doi.org/10.1017/9781009157896.010>
- Funk, C., Peterson, P., Landsfeld, M., Pedreros, D., Verdin, J., Shukla, S., Husak, G., Rowland, J., Harrison, L., Hoell, A., & Michaelsen, J. (2015). The climate hazards infrared precipitation with stations—A new environmental record for monitoring extremes. *Scientific Data*, 2, Article 150066. <https://doi.org/10.1038/sdata.2015.66>
- Global Facility for Disaster Reduction and Recovery (GFDRR) & World Bank. (2021). *Integrated flood risk management: A guide for practitioners*. World Bank. <https://www.gfdr.org/en/publication/integrated-flood-risk-management-guide-practitioners>
- Goswami, P., Hazra, A., & Ghosh, S. (2021). Convective instability indices for extreme rainfall prediction over India using machine learning. *Atmospheric Research*, 262, 105769. <https://doi.org/10.1016/j.atmosres.2021.105769>
- Hersbach, H., Bell, B., Berrisford, P., Hirahara, S., Horányi, A., Muñoz-Sabater, J., Nicolas, J., Peubey, C., Radu, R., Schepers, D., Simmons, A., Soci, C., Abdalla, S., Abellan, X., Balsamo, G., Bechtold, P., Biavati, G., Bidlot, J., Bonavita, M., ... Thépaut, J.-N. (2020). The ERA5 global reanalysis. *Quarterly Journal of the Royal Meteorological Society*, 146(730), 1999–2049. <https://doi.org/10.1002/qj.3803>
- CORRELATION OF SST (Azizah Putri Berimah) pp:347-361

- Hidayat, R., Syamsudin, F., & Aldrian, E. (2019). Linkages between Indian Ocean Dipole, CAPE, and rainfall extremes in Indonesia. *International Journal of Climatology*, 39(12), 4852–4865. <https://doi.org/10.1002/joc.6103>
- Idhar, J., Suryadi, M., & Fauzi, A. (2023). Analisis badai petir berdasarkan nilai indeks labilitas atmosfer. *Jurnal Digital Teknologi Informasi dan Komunikasi*, 3(2), 21–30. <https://doi.org/10.56757/djtc.v3i2.123>
- Kurniawan, R., & Yanto, M. (2023). Spatiotemporal analysis of extreme rainfall and flood risk under climate variability in Java Island. *Natural Hazards*, 117(2), 1425–1448. <https://doi.org/10.1007/s11069-023-05942-1>
- Martinson, D. G. (2018). Empirical orthogonal function (EOF) analysis. In *Quantitative methods of data analysis for the physical sciences and engineering* (pp. 495–534). Cambridge University Press.
- Narulita, I. (2020). Pengaruh ENSO dan IOD pada variabilitas curah hujan di DAS Cerucuk, Pulau Belitung. *Jurnal Tanah dan Iklim*, 41(1), 45–60. <https://doi.org/10.21082/jti.v41n1.2017.45-60>
- Open Data Jawa Barat. (2024). *Jumlah kejadian bencana banjir berdasarkan kabupaten/kota di Jawa Barat*. <https://opendata.jabarprov.go.id/id/dataset/jumlah-kejadian-bencana-banjir-berdasarkan-kabupatenkota-di-jawa-barat>
- Pierre Rainer. (2023). *Distribusi penduduk Indonesia berdasarkan pulau/area*. GoodStats. <https://data.goodstats.id/statistic/distribusi-penduduk-indonesia-berdasarkan-pulauarea-sKtCH>
- Prasetyo, A., Hadi, T. W., & Nugroho, D. (2021). Karakteristik musim hujan di Indonesia berdasarkan interaksi monsun Asia-Australia. *Jurnal Sains dan Teknologi Modifikasi Cuaca*, 21(2), 67–78. <https://doi.org/10.29122/jstmc.v21i2.4231>
- Rachmawati, L., & Setiawan, I. (2021). Seasonal predictability of extreme rainfall in western Indonesia using SST precursors. *Climate Dynamics*, 57, 2105–2120. <https://doi.org/10.1007/s00382-021-05793-7>
- Rahayu, N. D., Sasmito, B., & Bashit, N. (2018). Analisis pengaruh fenomena Indian Ocean Dipole (IOD) terhadap curah hujan di Pulau Jawa. *Jurnal Geodesi Undip*, 7(1), 57–67.
- Rasmussen, K. L., Houze, R. A., Jr., & Zuluaga, M. D. (2014). Extreme convection and rainfall in the tropical Andes. *Nature Geoscience*, 7, 787–792. <https://doi.org/10.1038/ngeo2269>
- Saji, N. H., Goswami, B. N., Vinayachandran, P. N., & Yamagata, T. (1999). A dipole mode in the tropical Indian Ocean. *Nature*, 401(6751), 360–363. <https://doi.org/10.1038/43854>
- Siregar, D., Siregar, M. Z., & Hadi, T. W. (2020). *Karakteristik iklim hujan di wilayah Indonesia berdasarkan data reanalisis*. BMKG Press.
- Sulistiyono, A., Wijaya, K., & Gunawan, D. (2020). The role of sea surface temperature anomalies in modulating extreme rainfall over Java Island during the 2015–2019 El Niño. *Atmospheric Research*, 245, Article 105073. <https://doi.org/10.1016/j.atmosres.2020.105073>
- Supari, Tangang, F., Juneng, L., & Aldrian, E. (2017). Observational evidence of Indonesia's rainfall response to the Madden–Julian Oscillation and its modulation by ENSO and IOD. *Climate Dynamics*, 48(11–12), 3899–3914. <https://doi.org/10.1007/s00382-016-3318-1>
- Taszarek, M., Brooks, H. E., & Czernecki, B. (2021). Sounding-derived parameters associated with convective hazards in Europe. *Monthly Weather Review*, 149(4), 1251–1273. <https://doi.org/10.1175/MWR-D-20-0384.1>
- Tirto.id. (2021, February 22). *Rincian data banjir Jakarta dari tahun ke tahun versi Pemprov DKI*. <https://tirto.id/rincian-data-banjir-jakarta-dari-tahun-ke-tahun-versi-pemprov-dki-gayq>
- Trenberth, K. E., & Fasullo, J. T. (Eds.). (2022). *The global water cycle: Observations and modeling*. American Geophysical Union.

- Vallis, G. K. (2017). *Atmospheric and oceanic fluid dynamics: Fundamentals and large-scale circulation* (2nd ed.). Cambridge University Press.
- Wibowo, A., & Hadi, T. (2021). Pengaruh CAPE terhadap pembentukan hujan konvektif di wilayah Jakarta. *Jurnal Sains Atmosfer Indonesia*, 3(2), 67–78. <https://doi.org/10.28932/jsai.v3i2.559>
- Wilks, D. S. (2019). *Statistical methods in the atmospheric sciences* (4th ed.). Academic Press.
- World Meteorological Organization. (2022). *Guidelines on urban hydrometeorological, climate and water services* (WMO-No. 1291). https://library.wmo.int/doc_num.php?explnum_id=11483
- Zar, J. H. (2010). *Biostatistical analysis* (5th ed.). Pearson Prentice Hall.