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Spatial Correlation between AUSMI and WNPMI Index with Rainfall in Jabodetabek

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Abstract

The Australian Summer Monsoon Index (AUSMI) and Western North Pacific Monsoon Index (WNPMI) help analyze the relationship between zonal winds and rainfall. In Jabodetabek, rainfall is affected by monsoons, El Nino Southern Oscillation (ENSO), and Dipole Mode Index (DMI). Understanding rainfall variability helps mitigate flood and drought risks. This study evaluates the relationship between AUSMI, WNPMI, and rainfall in Jabodetabek to support monsoon-based weather prediction. The data used include 850 hPa wind data from NCEP-NCAR Reanalysis 1 and rainfall data from GPCP Monthly Analysis, processed monthly. Analysis of 850 hPa zonal winds (2000–2023) shows dominant easterlies (-1 m/s), reducing rainfall, especially in the dry season. The AUSMI index (-2.32 m/s) correlates positively (0.6) with rainfall, indicating its role in moisture transport. Meanwhile, the WNPMI index (-1.32 m/s) shows a negative correlation (-0.7), as high values bring dry air, while low values promote rain cloud formation. These indices reveal distinct monsoonal impacts on Jabodetabek's rainfall patterns.

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Abstrak

Indeks Monsun Musim Panas Australia (AUSMI) dan Indeks Monsun Pasifik Utara Barat (WNPMI) membantu menganalisis hubungan antara angin zonal dan curah hujan. Di Jabodetabek, curah hujan dipengaruhi oleh monsun, El Nino Southern Oscillation (ENSO), dan Dipole Mode Index (DMI). Analisis variabilitas curah hujan dapat membantu memitigasi risiko banjir dan kekeringan. Penelitian ini mengevaluasi hubungan antara AUSMI, WNPMI, dan curah hujan di Jabodetabek untuk mendukung prediksi cuaca berbasis monsun. Data yang digunakan meliputi data angin 850 hPa dari NCEP-NCAR Reanalysis 1 dan data curah hujan GPCP Monthly Analysis yang diolah secara bulanan. Analisis angin zonal 850 hPa (2000-2023) menunjukkan angin pasat yang dominan (-1 m/s), mengurangi curah hujan, terutama di musim kemarau. Indeks AUSMI (-2.32 m/s) berkorelasi positif (0.6) dengan curah hujan, yang mengindikasikan perannya dalam transportasi uap air. Sementara itu, indeks WNPMI (-1.32 m/s) menunjukkan korelasi negatif (-0.7) karena nilai yang tinggi membawa udara kering, sementara nilai yang rendah mendukung pembentukan awan hujan. Indeks ini menunjukkan dampak monsunal yang berbeda terhadap pola curah hujan Jabodetabek.

INTRODUCTION

Indonesia is located in the equatorial region flanked by the Pacific Ocean and the Indian Ocean. This condition causes the Indonesian region to be influenced by monsoon winds consisting of the Asian monsoon circulation and the Australian monsoon circulation (Wang et al., 2005; Yihui & Chan, 2005; Kitoh, 2017). Monsoon winds result from the interaction of heat differences between the ocean and land as a result of the zenithal march of the sun (Ding, 2004). Zonal wind data is used to obtain the Asian and Australian monsoon indices, namely the Australian Summer Monsoon Index (AUSMI) and Western North Pacific Monsoon Index (WNPMI), to see their correlation with the bulk (Wang et al., 2001).

Based on research conducted by Pandia et al. (2019) shows that there is a powerful influence of zonal winds and rainfall when zonal winds increase, there will be a decrease in rainfall and a decrease in zonal wind speed results in an increase in rainfall. The magnitude of the AUSMI index value shows that the greater the AUSMI index value, the lower the rainfall intensity, and the smaller the AUSMI index, the higher the rainfall intensity from the low AUSMI state (Pandia et al., 2019).

The Australian Summer Monsoon Index (AUSMI) performs well in describing the variability of the Australian summer monsoon for various time scales (Lisonbee et al., 2020). Meanwhile, the Western North Pacific Monsoon Index (WNPMI) is also very good at describing the conditions of monsoon activity in Southeast Asia (Ha et al., 2018). Both of these indices play a role in controlling the movement of circulating air masses that bring water vapor to Indonesia (Chen et al., 2019). The AUSMI index is related to summer westerlies from Australia, while the WNPMI index is related to wind circulation in the western Pacific Ocean that affects rainfall in the tropics (Gallego et al., 2017).

The Jabodetabek region, consisting of the cities of Jakarta, Bogor, Depok, Tangerang, and Bekasi, is a five-pillar city with the center of industry, government, and national economy in Indonesia. In general, this region has a monsoonal rainfall type directly influenced by ocean and atmosphere interactions, including monsoon phenomena, El Nino Southern Oscillation (ENSO), and Dipole Mode Index (DMI) (Abay, 2021; Zulkifar et al., 2020). Therefore, it is important to conduct a more in-depth study of rainfall variability to reduce the impact of hydrometeorological disasters, such as floods and droughts that harm the community, especially in Jabodetabek (Dewi & Amri, 2022).

Several studies have examined the relationship between the Australian Summer Monsoon Index (AUSMI) and the Western North Pacific Monsoon Index (WNPMI). Research by Mulsandi et al. (2021), confirmed that the Asia-Australia monsoon activity has a significant influence on the climate in the Indonesian region, which can be represented through the Australian Summer Monsoon Index (AUSMI) and the Western North Pacific Monsoon Index (WNPMI). In addition, research by Rosyidah et al. (2022), showed that the Australian Summer Monsoon Index (AUSMI) has a strong correlation with rainfall in the September-October-November (SON) period, where the west wind (positive monsoon index) increases rainfall, while the east wind (negative index) decreases it.

This study aims to identify the spatial correlation between the AUSMI and WNPMI indices and rainfall in the Greater Jakarta area. In addition, this study evaluates the correlation strength of the AUSMI and WNPMI indices to determine how much influence each index has on rainfall. This research is expected to contribute scientifically to weather and climate studies and the development of a monsoon index-based weather prediction system in Indonesia.

METHOD

The research is in the Jabodetabek (Jakarta, Bogor, Depok, Tangerang, and Bekasi), which is located in the data used consisting of wind and rainfall data with a range of 2000 - 2023. The wind data used is the wind at an altitude of 850 hPa obtained from the National Centers for Environmental Prediction - the National Center for Atmospheric Research (NCEP-NCAR) Reanalysis 1 (https://psl.noaa.gov/mddb2/makePlot.html?variableID=158538). Rainfall data is obtained from the Global Precipitation Climatology Project (GPCP) Monthly Analysis Product, which can be accessed at the following link: https://psl.noaa.gov/mddb2/makePlot.html?variableID=1631. Wind data and rainfall data are in the form of monthly averages. The resolution of wind data and rainfall data is 2.5º x 2.5º global grids, respectively.

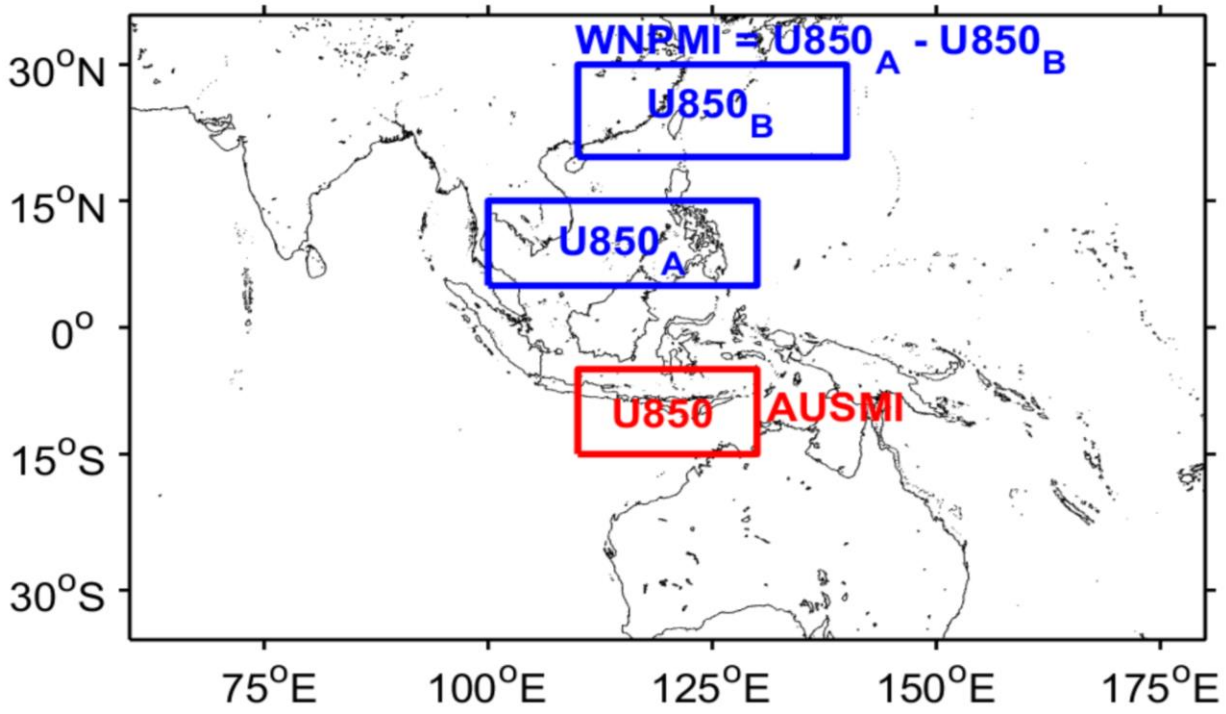

Figure 1. Region Used to Determine the AUSMI Monsoon Index (red box) and WNPMI Monsoon Index (blue box)

The index data used is the monsoon index consisting of the AUSMI and WNPMI indices. The WNPMI index is the difference between the average value of the west wind at an altitude of 850 hPa located in the northern equatorial region A with astronomical lines 5° - 15° N, 100° - 130°E, and in the northern equatorial region with line B with astronomical lines 20° - 30° N, 110° - 140°E (Mulsandi et al., 2021; Figure 1). Furthermore, the AUSMI index is the average wind in the zonal wind region with astronomical lines 5° - 15°S, 10° - 130°E, as shown in Figure 1. The WNPMI calculation uses the formula in Equation 1.

$$WNPMI = U850_A - U850_B \quad (1)$$

The correlation method is used in analyzing the relationship between the AUSMI and WNPMI indices and rainfall. Pearson correlation calculation used is presented in Equation 2 as follows.

$$r_{xy} = \frac{n\sum xiyi - (\sum xi)(\sum yi)}{\sqrt{(n\sum xi^2 - (\sum xi)^2) - ((n\sum yi^2 - (\sum yi)^2)}} \quad (2)$$

where r is the pearson correlation, x is the AUSMI and WNPMI indices, y is the rainfall value, and n is the number of data used.

The strength of the relationship between parameters is then measured by the correlation value R (Asuero et al., 2006). The following are correlation values that describe the strength of the relationship between parameters (Table 1).

Next, to see the performance of the two indices in describing the monthly monsoon cycle in the Jabodetabek region using graphs together with the monthly average data of the AUSMI and WNPMI indices (Kajikawa et al., 2010).

Table 1. Correlation Coefficient Between AUSMI and WNPMI Indices and Rainfall

R Value	Description
0.000 – 0.199	Very weak
0.200 – 0.399	Weak
0.400 – 0.599	Moderate
0.600 – 0.799	Strong
0.800 – 1.000	Very strong

RESULT AND DISCUSSION

Effect of Zonal Winds on Monsoon Index and Rainfall

The results of zonal wind data processing at the 850 mb level in the Jabodetabek area have an average value of -1 m/s. This shows that the east wind is more dominant in the Jabodetabek region during the period 2000-2023. This condition indicates that zonal winds influence the intensity of rainfall in the Jabodetabek area, showed in Figure 2 as follows.

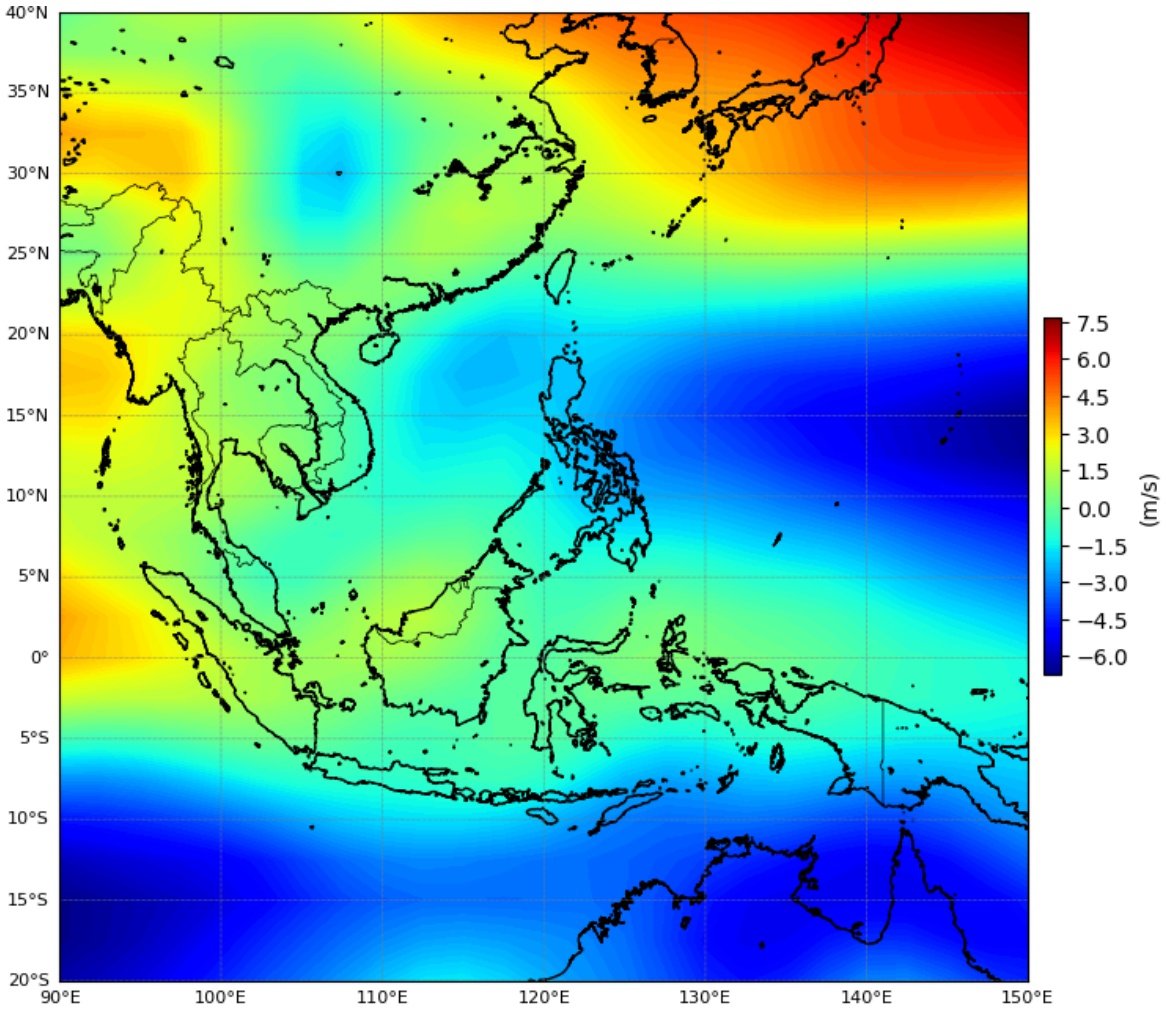

Figure 2. Average Speed of 850 mb Zonal Winds During the Period 2000-2023

Based on Figure 2, air masses moving from eastern Indonesia will significantly affect weather conditions and cause a decrease in the value of rainfall (dry) in the Jabodetabek area. Furthermore, the zonal wind value in the AUSMI index region is -2.32 m/s. This shows that the wind moves dominantly from the east to the west by carrying warmer air masses, causing the Jabodetabek area to be drier. At the same time, the zonal wind value in the WNPMI index area of -1.32 m/s is smaller than the zonal wind value in the AUSMI index. The negative zonal wind value indicates that the dominant wind moves from the east to the west. These two indices, based on the resulting values, will affect weather and climate conditions in the Jabodetabek area, especially in determining the intensity of rainfall. Additionally, this phenomenon can bring several impacts, such as dry seasons, increased temperatures and low humidity, decreased air quality, effects on agriculture, risk of drought, and more extreme El-Nino.

We then plot the AUSMI, WNPMI, and monthly average rainfall indices in the same layer to measure each month's peak season phase. The AUSMI, WNPMI, and monthly average rainfall indices are presented in Figure 3.

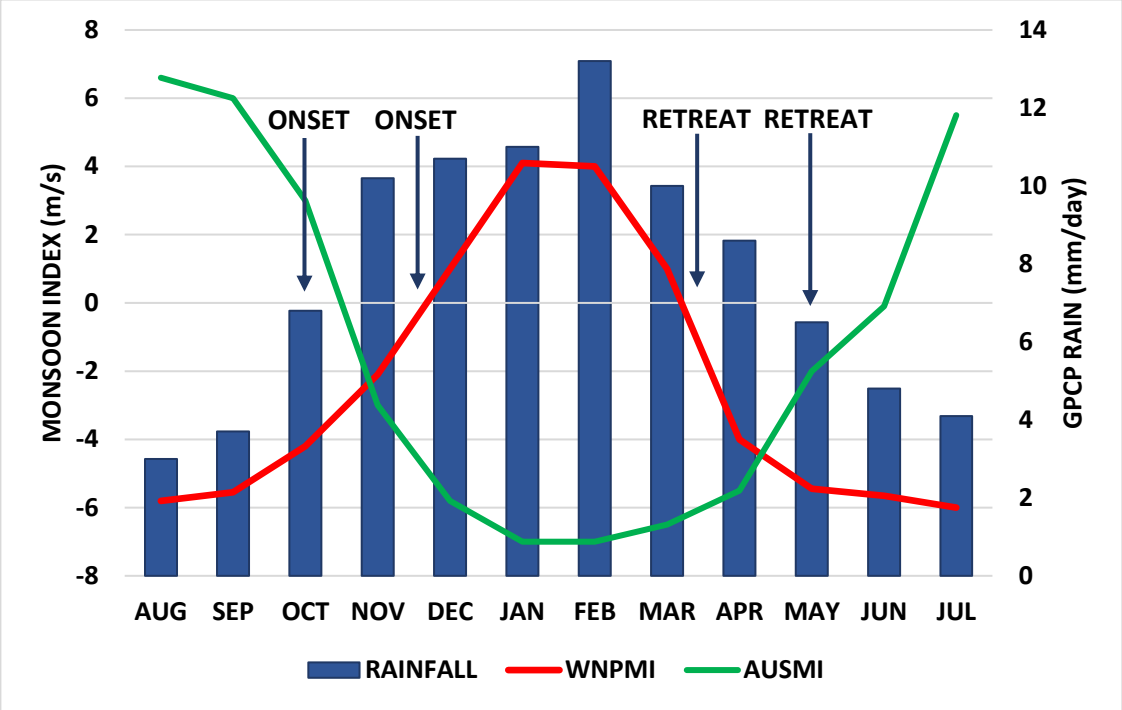

Figure 3. Graph of AUSMI Index, WNPMI Index and Monthly Average Rainfall Over the Period 2000-2023

Based on Figure 3 shows graphs of the AUSMI index, WNPMI index, and monthly average rainfall over the period 2000-2023. The AUSMI index has an inverse value to rainfall. In August, the AUSMI index value is 6.5 m/s, but the rainfall intensity value is low. Conversely, in February, when the AUSMI index is -7 m/s, the value of rainfall intensity is high. Based on this, it is clear that the AUSMI index cannot be used to monitor monsoon activity in the Jabodetabek area because the monsoon index and rainfall have different peak phases of the rainy season (Figure 3).

Next, the WNPMI index has a value that is in line with rainfall. This shows that the dynamics of the monsoon circulation described by the WNPMI index shows a change in the direction of the east wind (dry) to the west wind (rain), which indicates the beginning of the rainy season (onset) in October. Meanwhile, a change in wind direction from the west to the east, indicating the end of the rainy season (retreat), occurs in May (Figure 2). When the WNPMI index value increases, the intensity of rainfall in the Jabodetabek area also increases. Conversely, when the WNPMI index value decreases, the intensity of rainfall in the Jabodetabek area decreases. This condition is caused by the Asian Monsoon effect which affects the circulation of air masses in carrying water vapor in the Jabodetabek area (Schrier, 2022).

Spatial Correlation of AUSMI Index with Rainfall

The results of the spatial correlation between the AUSMI index and rainfall have a positive correlation coefficient in the Jabodetabek area, as shown in Figure 4. The resulting correlation value is 0.6. Based on the correlation value in Table 1, this correlation falls into the strong category. This indicates that there is a strong relationship between the two variables in the Jabodetabek area over a period of 23 years (2000-2023).

Statistically, this correlation shows that changes in the value of the AUSMI index tend to go hand in hand with changes in the value of rainfall intensity in the region. When the AUSMI index value increases, rainfall in Jabodetabek tends to increase, although this relationship is not deterministic. In the context of Jabodetabek, this positive relationship can be caused by the contribution of the monsoon to the supply of moisture and convective cloud formation, which is the main mechanism in the process of rainfall. This is in line with the research of Satyawardhana & Yulihastin (2015), showing the spatial correlation value between

AUSMI and rainfall using TRMM data on the island of Java between 0.5-0.6.

However, the correlation value of 0.6 also indicates that although the AUSMI index has a significant influence, there are still other factors that contribute to rainfall variability in Jabodetabek. These factors may include local phenomena such as the topography of the region, the effects of urbanization, as well as regional and global scale atmospheric variability, including the influence of ENSO, DMI, and Madden-Julian Oscillation (MJO) (Habibullah & Tarya, 2021). For example, Jabodetabek often experiences the impact of the interaction between global and local factors that cause rainfall anomalies, both in the form of heavy rainfall and drought. Thus, this correlation value of 0.6 not only illustrates the linear relationship between the AUSMI index and rainfall but also shows the complexity of the atmospheric system in the tropics involving many interacting variables.

Temporally, this relationship is likely to show significant differences in wet and dry periods, such as the wet and dry seasons. In the wet season, when monsoon activity in the Australia-Indonesia region tends to be stronger, the contribution of AUSMI to rainfall in Jabodetabek may be more dominant, thus strengthening the correlation. Conversely, in the dry season, the influence of AUSMI may be weaker as the role of other factors, such as local wind circulation and pressure anomalies, becomes more significant. The AUSMI index in the SON period increases rainfall, and the ENSO phenomenon also affects sea level during the June-July-August (JJA) period, which can affect the coastal conditions of Semarang City (Rosyidah et al., 2022).

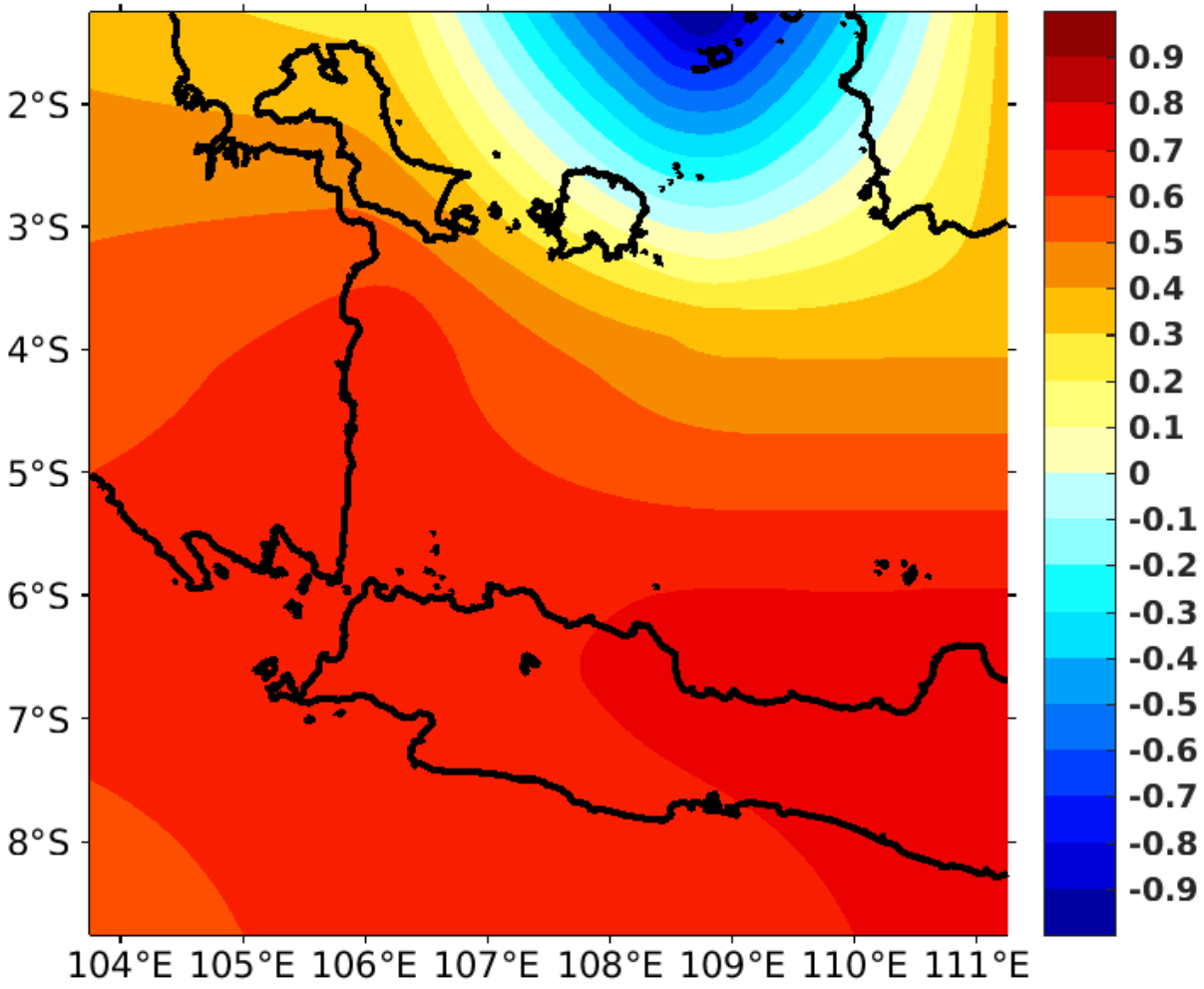

Figure 4. Correlation between AUSMI Index and GPCP Rainfall

Spatial Correlation of WNPMI Index with Rainfall

The results of the spatial correlation of the WNPMI index with rainfall have a negative correlation coefficient in the Jabodetabek area, as shown in Figure 5. The resulting correlation value is -0.7. Based on the correlation value in Table 1, this correlation falls into the strong category. However, this condition shows a strong but opposite negative relationship between the two variables in the Jabodetabek area for 23 years (2000-2023). When the WNPMI index value is high, the rainfall intensity is low, and vice versa when the WNPMI index value is low, the rainfall intensity is high in the Jabodetabek area. The resulting negative correlation can be explained through the process of convection pattern mechanism due to the interaction of monsoon winds with local weather systems in Jabodetabek.

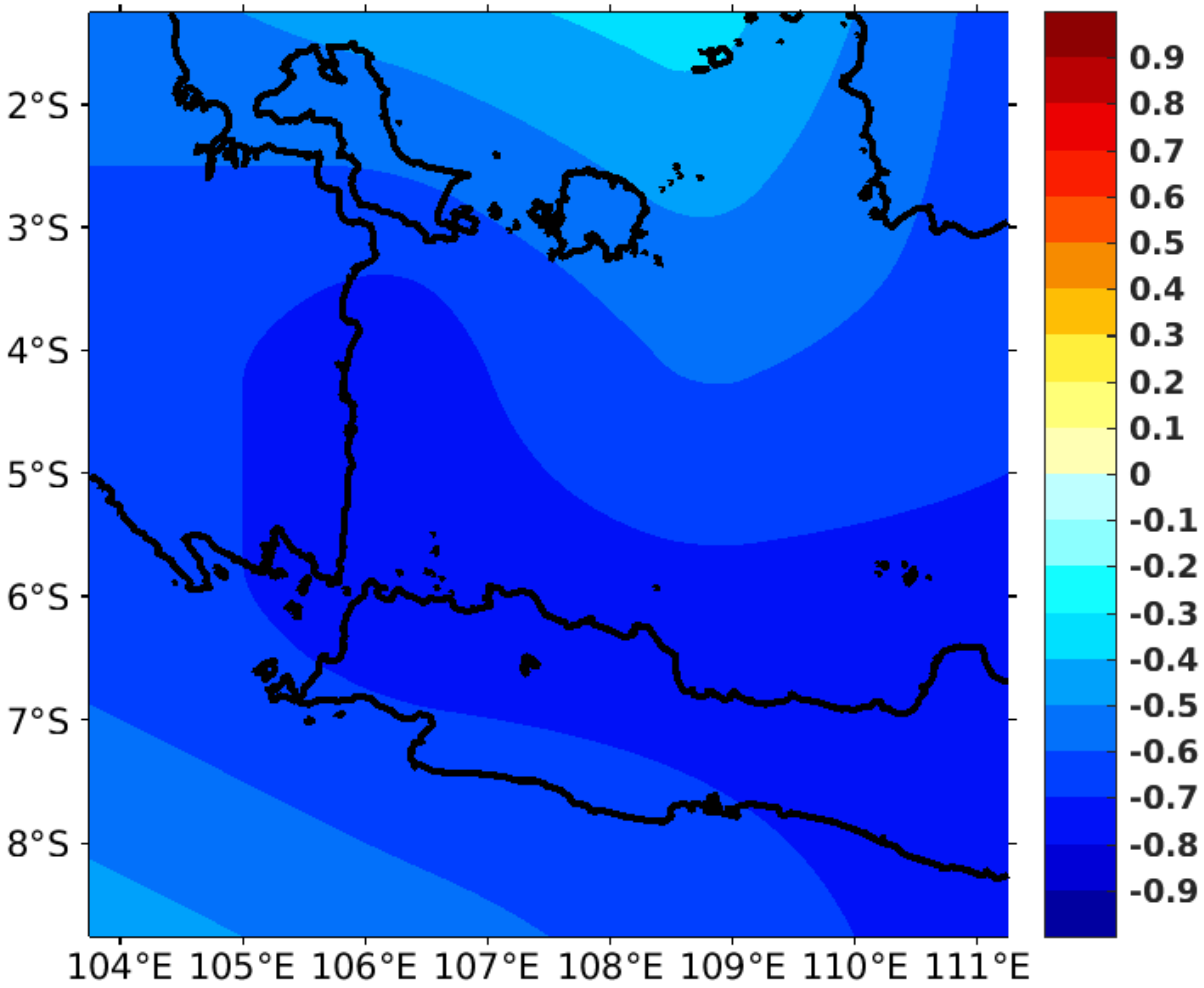

Figure 5. Correlation between WNPMI Index and GPCP Rainfall

When the WNPMI index is high, monsoon winds from the northwest tend to be stronger, bringing relatively dry air masses to the Greater Jakarta area. This inhibits the formation of convective clouds needed to produce rainfall, especially during the wet season. Conversely, a low WNPMI index may indicate weakening monsoon winds, allowing local seasonal wind influences, such as sea breezes, to dominate, thus favoring air mass lift and rain cloud formation. Therefore, this negative correlation value underscores the important role of large-scale atmospheric dynamics in controlling rainfall patterns in the Greater Jakarta area.

This study has several limitations that need to be considered. In terms of concepts and theories, this study only focuses on the relationship between the monsoon indices (AUSMI and WNPMI) and rainfall in Jabodetabek without considering in depth other

atmospheric factors, such as the influence of ENSO, DMI, and MJO which also play a role in rainfall variability. This limitation can be overcome by integrating a multi-variable analysis that includes these factors to provide a more comprehensive understanding. In terms of methodology, the use of reanalysis data from NCEP-NCAR and GPCP with a spatial resolution of 2.5° x 2.5° can be an obstacle in describing local rainfall variations in detail, especially in areas with complex topography such as Jabodetabek. To overcome this, additional analysis can be done with observational data from local meteorological stations or data products with higher resolution to make the research results more representative. In addition, this study only uses the Pearson correlation method without testing the causal relationship between the monsoon index and rainfall, so it cannot explain the physical mechanism in depth.

More robust approaches, such as regression analysis or atmospheric numerical models, could be used to strengthen the results. Although the correlation found is quite strong, this study has not tested how significant the influence of the monsoon index is on various time scales, such as seasonal or inter-decade. Therefore, long-term trend analysis and additional statistical tests can help in understanding the broader changes in atmospheric dynamics and improve the reliability of interpreting the results of this study.

CONCLUSION

Analysis of 850 mb zonal winds shows the dominance of easterly winds in Jabodetabek with an average of -1 m/s during 2000-2023, causing a decrease in rainfall, especially during the dry season. The AUSMI index with an average zonal wind of -2.32 m/s shows a strong positive relationship (coefficient 0.6) with rainfall. This correlation suggests that the Australian monsoon plays a more dominant role in bringing moisture to the Greater Jakarta area. In contrast, the WNPMI index with an average zonal wind of -1.32 m/s has a strong negative correlation (-0.7) with rainfall. High WNPMI values reduce rainfall as northwest winds bring dry air, while low values favor rain cloud formation. These different patterns illustrate the unique role each index plays in influencing rainfall in the Greater Jakarta area.

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