
Climate Characteristics of the Makassar Coastal Based on FKLIM Data

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ABSTRACT

The sea is the most extensive part of the earth and the most developed place in the world, as well as Makassar City in Indonesia. Moreover, the mainstay of the coastal city relies on the economic sector related to the sea, which is strongly influenced by land-sea wind circulation. Although it has long been known as an area that is influenced by land-sea winds, identification of changes in land-sea winds is still very rare. The purpose of this study was to identify the characteristics of the land-sea wind in Makassar using FKLIM data. Moreover, windrose graph is used to analyze the influence of sea breezes on rainfall, humidity, temperature, solar radiation, wind direction, and speed. The result shows that the circulation of land and sea winds influences Makassar City since appearing of changes in wind direction. Based on its location, the west to the north wind is identified as a sea breeze, while the land wind appears as an east or southeast wind. The appearance of these two wind directions throughout the year shows the influence of land and sea winds. Both of the factors affect other weather parameters, such as rainfall, temperature, and humidity. Moreover, the occurrence of rain does not always dominate by the Asian monsoon, but sometimes by the easterly wind which is probably the sea breeze. Meanwhile, high humidity is found in both wind directions and the presence of sea breezes can keep the temperature in this city always warm.

Keywords: climate characteristics, land-sea breeze, coastal, Makassar, Paotere

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1. INTRODUCTION

The sea is the largest part of the earth, with a surface area covering 72% of the earth's surface area. The sea and land borders or coastal areas are the most inhabited places by humans. More than 600 million people or about 10 percent of the world's population live in this area and an estimated 2.4 billion people or 40% live in an area 100km from the coast [1]. Almost all cities in the world develop on the coast or upstream of rivers, including big cities in Indonesia. It is noted that Jakarta, Surabaya, Semarang, Makassar, Palembang, Medan and other big cities are the places where millions of people live along the coast. In Indonesia, coastal cities started as ports and coastal areas which later became centers of trade and city government activities. The development of this city is very rapid, starting from the edge of the water, then extending to other lands where the dominant development becomes more rapid. This city has become part of the route and gateway for international trade, cultural exchange of the nation, and a symbol of the nation's prosperity and people's welfare, thus playing an important economic and socio-cultural role in the cultural development of the archipelago.

Coastal areas have their own climatological characteristics, where the weather pattern is a meeting of land and sea that is different from other areas. Coastal weather conditions are recognized in several ways, namely the presence of sea breezes during the day, land breezes at night, temperatures that are quite warm throughout the year, the appearance of coastal fog and high rainfall on the coast compared to land. Characteristics of coastal areas where temperatures are warm compared to the surrounding area will be increasingly unclear at high latitudes or near the tropics.

Land-sea wind circulation is one of the main characteristics of the existence of coastal areas. This pair of wind movements is widely used by fishermen in looking for fish in the sea, returning time and determining trading times so that coastal areas generally develop rapidly. The emergence of large ports, markets and government centers cannot be separated from the use of this land-sea wind cycle.

Sea breezes are the result of differences in the nature of the earth's surface in receiving solar heat. During the day, both land and ocean heat up, but land warms more quickly than ocean waters. As you will soon discover, it is important to note that although the ocean takes longer to warm up, it is also able to retain heat longer than the land. When the soil heats up, it heats the air at the surface. Warm air rises and expands leaving less air at the surface, creating a low pressure system above the ground. Because the water above the ocean takes longer to warm up, it allows the air above it to maintain a higher pressure. Since air always flows from a high-pressure system to a low-pressure system, air from the sea flows to the land. These form the sea breezes we are so familiar with, which usually occur in the late afternoon and evening. Depending on the temperature difference between the land and the sea, the wind blowing from the sea can vary from a light breeze to a relatively strong gale.

At night, the opposite happens. The land cools much faster than the ocean, which retains heat, absorbed throughout the day, longer. (The reason why I highlighted this capability of the ocean in the previous section.) As a result, cooler air over land forms a high-pressure system, while warm air over seawater rises and creates a low-pressure system. The wind now blows from areas of high pressure on land, to areas of low pressure over the sea. This is how a breeze is formed, which usually occurs in the late afternoon and early morning. To find out how high and low pressure systems form and how they affect the weather, you can read more about them in this article.

Makassar City is the capital city of the province of South Sulawesi and is the largest metropolitan city in the Eastern Indonesia region which is one of the four main growth centers in Indonesia, along with Medan, Jakarta and Surabaya. In the 16th century, Makassar became the dominant trading center in Eastern Indonesia, as well as being one of the largest cities in Southeast Asia. The Makassar kings implemented a strict free trade policy, in which all visitors to Makassar had the right to do business there and rejected the VOC's (Dutch) attempts to obtain monopoly rights in the city. Paotere Harbor is a port since the days of the Gowa-Tallo kingdom which is still used as a port for people's boats such as Phinisi and Lambo as well as a commercial center for fishermen.

The coastal area which is the border of sea and land is influenced by diurnal circulation in the form of sea breezes and land breezes. Coastal cities in Indonesia are generally dominantly influenced by daily rain cycles and wind circulation [2]. The sea-land wind causes changes in the character of the meteorological variables. The existence of sea breezes and land breezes is strongly influenced by the topography of an area [3]. The existence of sea breezes is influenced by interactions with other heat-induced flows such as mountain valley winds, heat circulation from settlements, and other sea breeze circulation [4], [5]. The daily heat cycle over hilly coastal areas is a strong combination of daily heating and cooling over higher terrain and sea-land heat differences [6].

Research on the characteristics of land and sea breezes in Indonesia is still very rare, even though most of the economic activities and population are located in coastal areas in Indonesia. This paper aims to identify the influence of land-sea winds in Makassar during the Asian monsoon and Australian monsoon based on daily data at the Paotere Maritime Meteorological Station.

2. METHOD

Makassar City has a strategic position since located at the intersection of traffic lanes from the south to north in the Sulawesi Island, and from the West to the East of Indonesia. Moreover, this city area has astronomical coordinates 119 degrees east longitude and 5.8 degrees south latitude with elevation varies between 1-32 meters above mean sea level. Makassar City include a flat coastal area with a slope of 0 - 5 degrees to the west, flanked by two river mouths, namely the Tallo river which empties into the northern part of the city and the Jeneberang river which empties into the south of the city. The total area of Makassar city is approximately 175.77 Km² of land and includes 11 islands in the Makassar Strait plus a water area of approximately 100 Km². The topography of Makassar City is relatively gentle with elevation variations between 0-25 meters above sea level. In general, the air temperature in this city is between 20⁰ C to 39⁰ C. A quick overview of the location and geographical conditions of Makassar is shown in Figure 1.

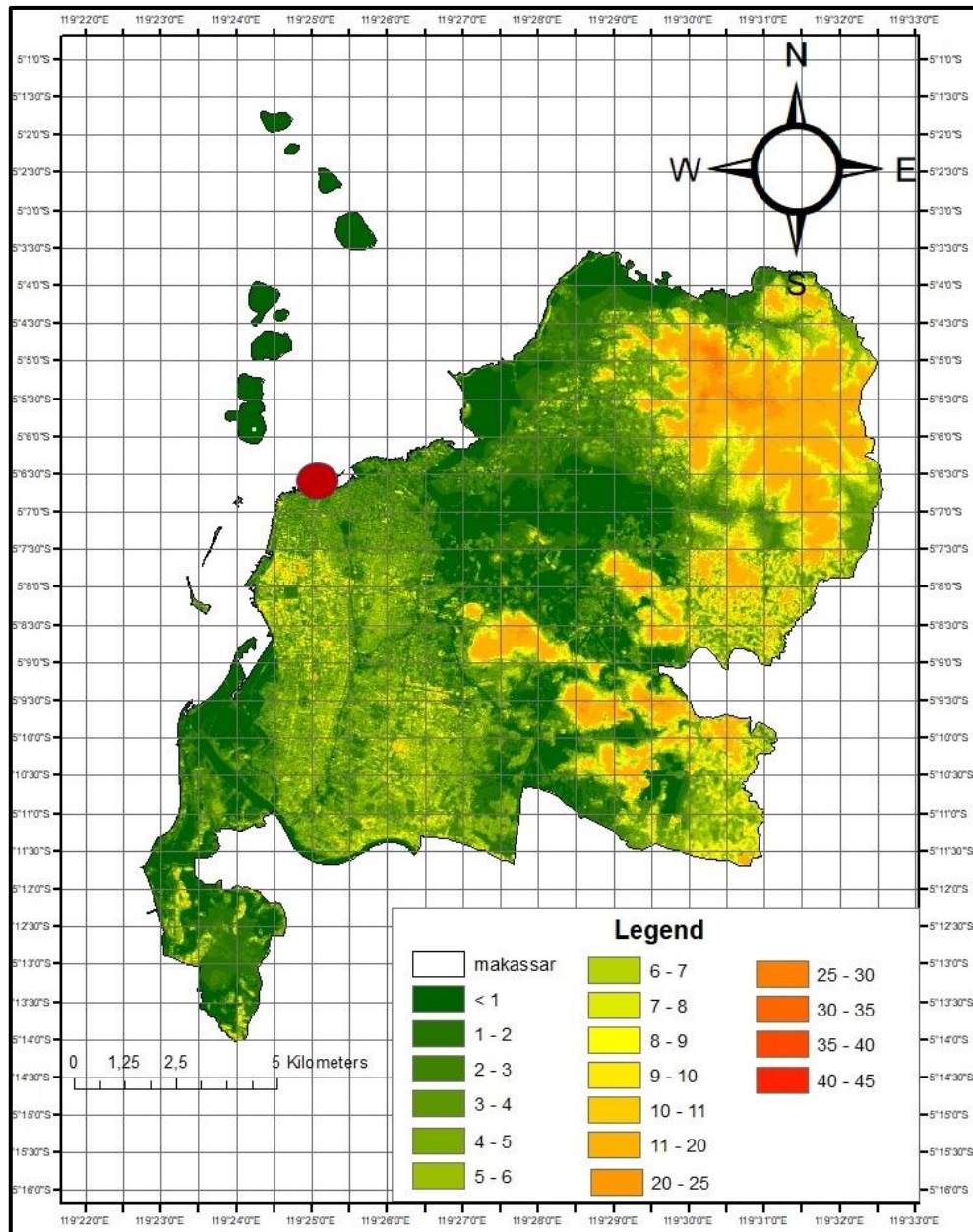


Figure 1. Topography of Makassar City and position of Paotere Maritime Meteorological Station

The data used for this research is the daily average data in meteorology is reported in FKLIM. The FKLIM form in meteorology is widely used to determine seasonal forecasts containing data on temperature and relative humidity or RH at 07:00, 13:00, and 18:00 local time. The average of these two parameters uses the three recording times by giving a weight of 1 to the data at 07:00 and 18:00 and 2 to the data record at 13:00. The average of this data is calculated by adding up the multiplication results and then dividing by 4. In addition to these two weather parameters, FKLIM also records data on average wind direction and speed, daily rainfall, minimum temperature, maximum temperature, duration of sunlight, pressure, wind direction, and maximum wind speed. This study uses a graphic visualization of windrose or wind roses. Windrose identification is very simple and easiest to understand when the relation of a parameter is associated with the dominant wind direction. Daily weather parameter data recorded in FKLIM will be grouped according to the wind direction. Then the classification of each weather parameter is carried out in a certain wind direction and the results are displayed in a windrose graph. In this study, the visualization of windrose is divided into season groups, namely the rainy season (December–February) and the dry season (June – August). Between these two seasons, they are grouped into a transitional season, namely the transition from the rainy

season to the dry season (March-May) and the transition from the dry season to the rainy season (September–November).

3. RESULT AND DISCUSSION

3.1. Direction and Wind Speed Angin

Based on calculations, the dominant wind in Makassar City always has two opposite directions, namely west to north and east to southeast. During the rainy season, the first dominant wind comes from the west, while during the dry season the first dominant wind comes from the southeast as can be seen in Figure 2. Interestingly, the second dominant wind or the second-highest wind direction actually comes from the opposite direction, namely east or southeast.

Rain in Indonesia in general and Makassar City, in particular, comes from Asian water vapor carried by the Asian monsoon winds from west to north. This wind will dominate in the rainy season so it can be said that if the westerly wind comes, the rainy season has arrived. On the other hand, during the dry season, the dry wind that crosses this region is the wind that comes from Australia which is dry because it does not pass through a very wide ocean like the Asian monsoon. This wind will appear as an east or southeast wind which will dominate in the dry season. However, based on the windrose in Figure 2, it shows that although during the rainy season the wind is dominant from the west to the north, the easterly wind also often appears as the second most abundant wind. Likewise, during the dry season where the dominant wind comes from the east or southeast, but west to north winds also often appears as the second most abundant wind.

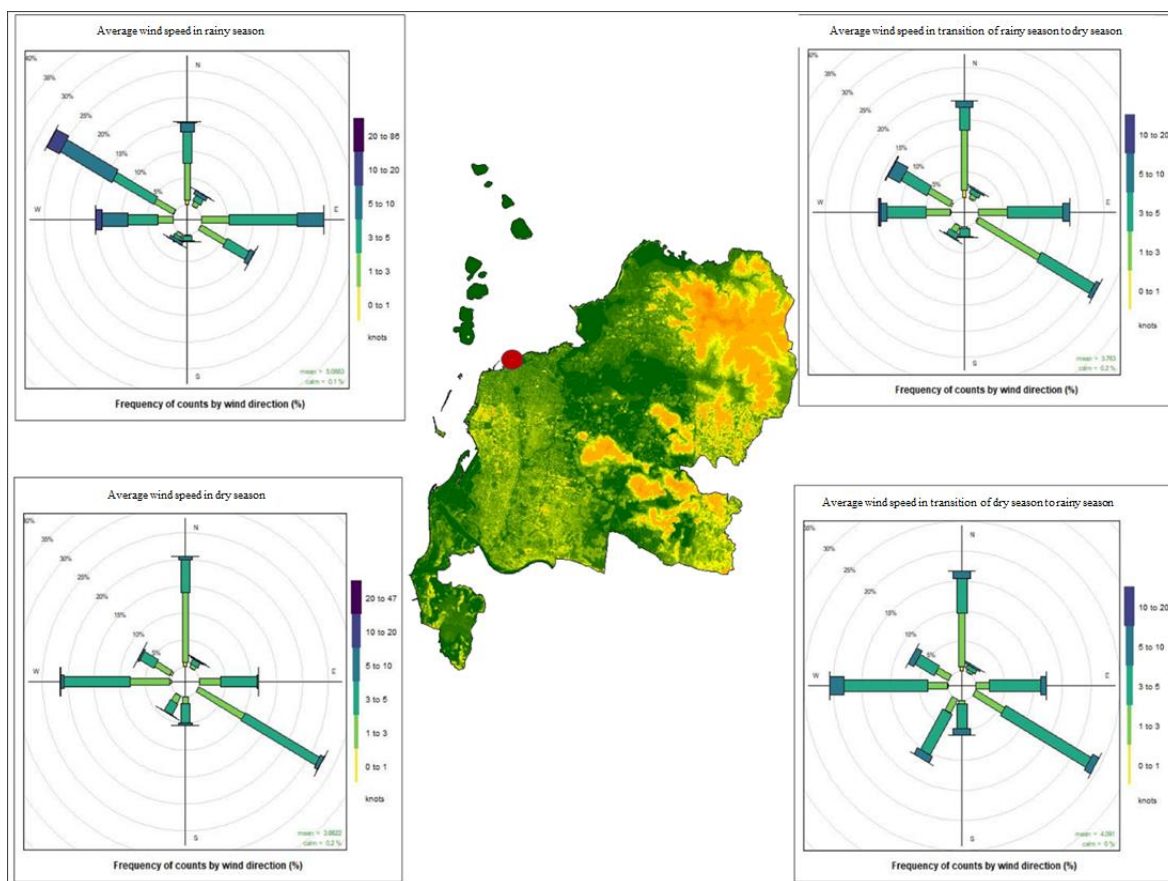


Figure 2. Average direction and wind speed windrose at the Paotere Maritime Meteorological Station during the rainy season (top left), the transition from the rainy season to the dry season (top right), the dry season (bottom left) and the dry season to the rainy season (bottom right)

The change from the rainy season to the dry season is also followed by a change in the dominant wind, where the number of the west to north winds is getting less so that the amount is balanced with the east to southeast winds. Compared to the transition from the dry season to the rainy season, the dominant wind during the transition from the rainy season to the dry season is more

focused between the west and north. At the time of the transition from the dry season to the rainy season, although the southeast direction is stronger, there are also quite a lot of other wind directions, except for winds from the west and northeast.

The position of Makassar City, which is located adjacent to the vast waters of the Makassar Strait, clearly affects changes in the wind. Sea breezes that cause wind movement from the sea to the mainland, in Makassar City are manifested as winds coming from the west to the north. This condition is affected the west to the north of Makassar City has a vast ocean. On the other hand in the northeast to southeast of this city is a wide plain to the high mountains of Malino. Its influence on wind changes in Makassar City can be seen in the appearance of the west to north winds and east to southeast winds throughout the year.

Interestingly, the sea breeze which appears to be west to the north wind in Makassar City appears more than a wind that comes from the west and north than the northwest wind. This is probably due to the existence of a group of islands in the northwest that are thought to affect the wind direction in this city, although it must be proven using more detailed data.

The rainy season is the time when the wind speed in Makassar City increases, where this month the wind speed of more than 10 knots is quite a lot. The rainy months, namely December to February, are the months when many cumulonimbus clouds appear. The process that occurs in it where there is an updraft, downdraft, microburst will cause sudden high-speed gust or wind. Likewise, the influence of the movement of other rain clouds on a large scale will cause a pressure difference, resulting in an increase in wind speed. During the rainy season, tropical cyclones also appear in the Australian area which is relatively close to Makassar, which may also affect the increase in wind speed in this city.

Maximum wind data is the highest wind speed on a given day. In contrast to the average wind which is the result of the average wind in 24 hours or 24 times of recording, the maximum wind can occur outside the hours of observation. This means that the maximum wind data may be different from the average wind results in Figure 2. Based on the calculations depicted in the form of a windrose in Figure 3, it shows that the maximum wind in Makassar City generally comes from the west wind.

In the rainy season, it is clear that the highest wind speeds come from the Asian monsoon or westerly winds that carry a lot of water vapor. The growth of rain clouds starts from the west and moves to the east, where the maximum wind speed turns out to accompany the growth of these rain clouds. However, in the dry month or dry season, the maximum wind speed also comes from the west and southwest winds. In the transition season from the rainy season to the dry season, the maximum winds come from the west to the northwest. Meanwhile, during the transition from the dry season to the rainy season, the maximum wind incidence comes from the southwest to the west. Judging from the magnitude of the maximum wind, the value is similar to the average wind, where the highest maximum wind value occurs during the westerly wind or the rainy season as shown in Figure 3.

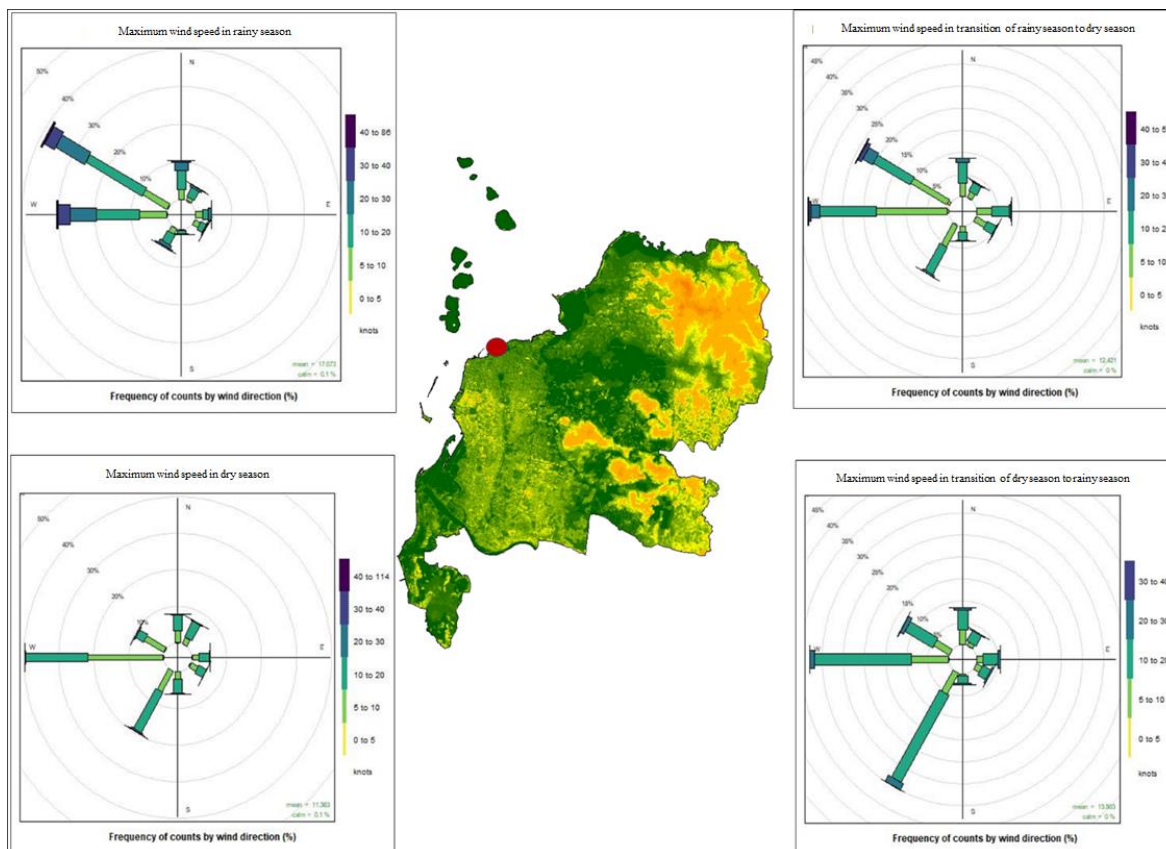


Figure 3. Maximum wind speed windrose at the Paotere Maritime Meteorological Station during the rainy season (top left), the transition from the rainy season to the dry season (top right), the dry season (bottom left) and the dry season to the rainy season (bottom right)

Based on the maximum wind rose, all of which are dominated by southwest to northwest winds, it can be concluded that the maximum wind incidence is more influenced by the Asian monsoon wind and sea breeze. Even though the seasons change, whether the rainy season, dry season or transitional season, it is found that the maximum wind is still dominant from the west. This means that the maximum wind in Makassar City is strongly influenced by its location on the edge of the sea.

3.2. Relative Humidity

Throughout the year the water vapor content calculated in relative humidity or RH in the atmosphere of Makassar City is above 50%, with the maximum water content in the rainy season. From December to February, the water vapor content is above 70% from all cardinal directions. In the rainy season, the most water vapor content is not only carried by the wind blowing from the west to the north but also the wind coming from the east. This can be suspected as an orographic influence by the presence of mountains next to Makassar City. The amount of water vapor is still quite a lot in the transition season from March to May with a slight change, namely an increase in the amount of water coming from the southeast. RH 70% to 80% starts to increase in percentage in this transitional season and is increasingly dominant in the dry season and the transition from dry to rainy season as shown in Figure 4.

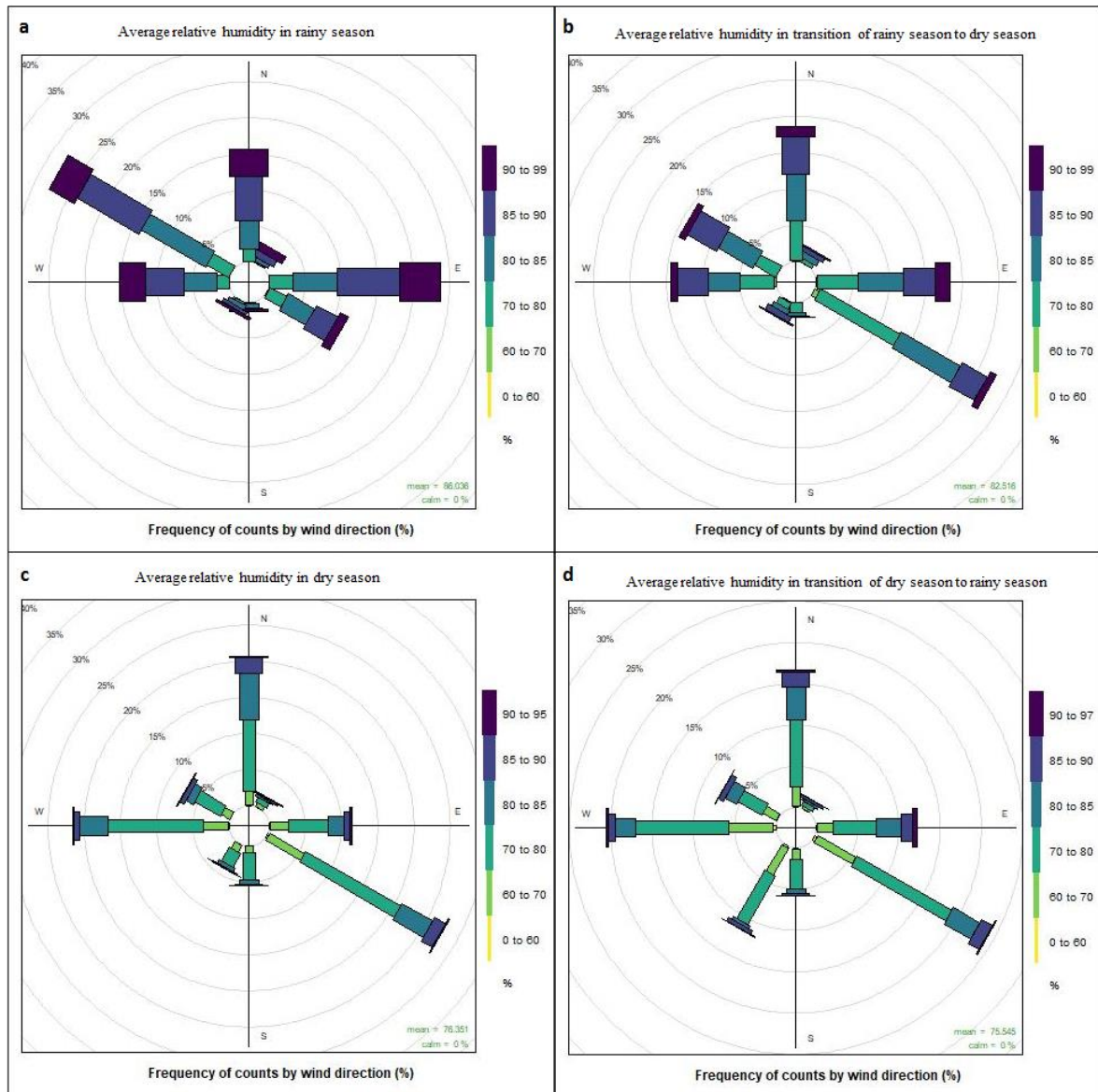


Figure 4. Windrose Humidity at the Paotere Maritime Meteorological Station during the rainy season (a), the transition from the rainy season to the dry season (b), the dry season (c) and the transition from dry to rainy season (d)

In the dry season and the transition from the dry season to the rainy season there are more than 20% RH values more than 80%, even occasionally found RH values more than 90%. This condition shows that Makassar City as part of the continental maritime area always has a fairly large water vapor content throughout the year [7].

3.3 Air Temperature

Characteristics of coastal areas that are always warm can be seen in Figure 5, where the temperature throughout the year in Makassar City is more than 25°C. The average temperature value in this city is in the range of 27°C to 29°C which is warm enough for humans to live in.

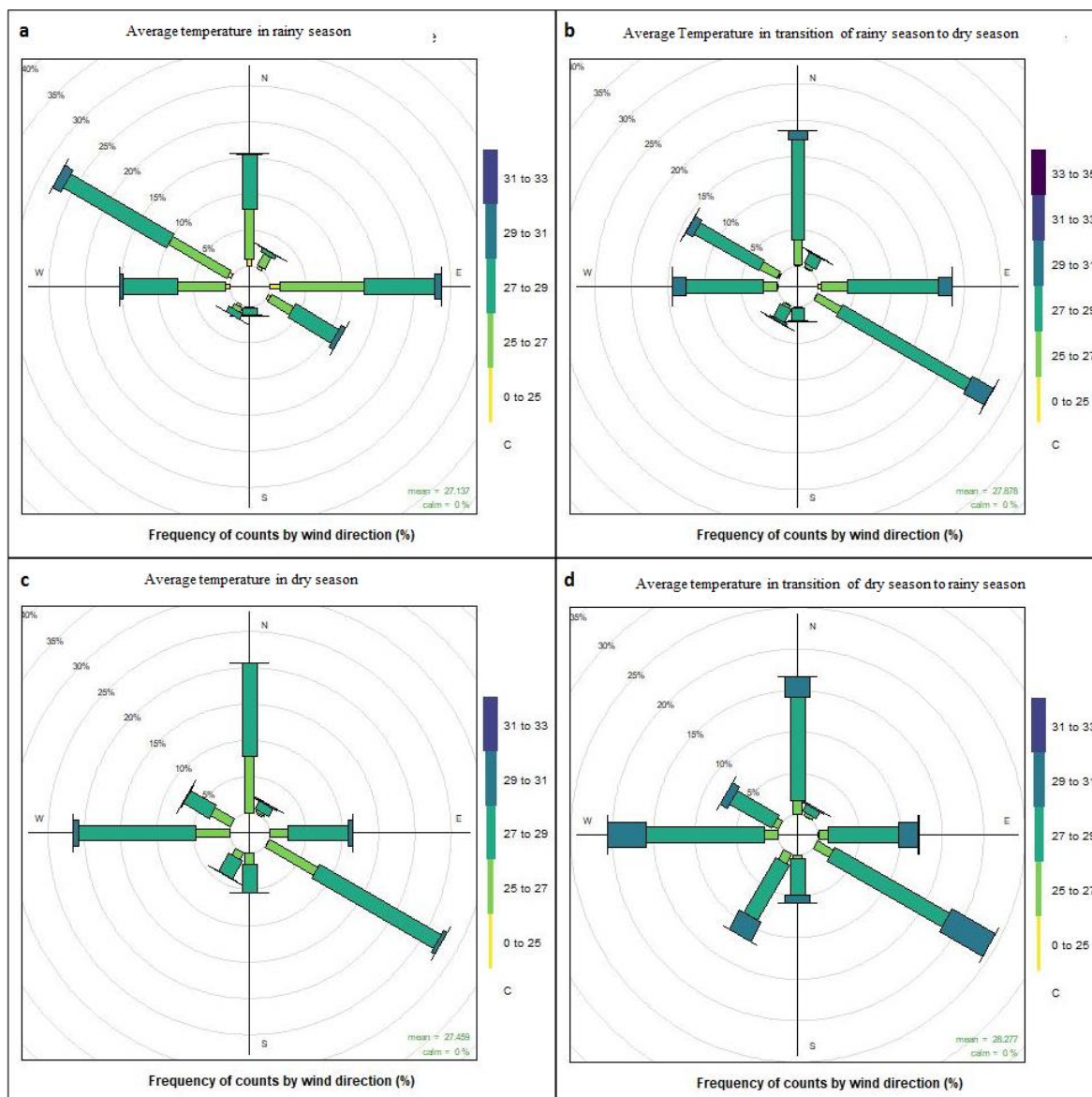


Figure 5. Windrose temperature at the Paotere Maritime Meteorological Station in the rainy season (a), the transition from the rainy season to the dry season (b), the dry season (c) and the dry to rainy season transition (d)

The lowest temperature occurs in the rainy season which can be seen with a temperature percentage of 25°C to 27°C and the temperature is found below 25°C around 5%. It is possible that in the rainy season there will be days where it rains all day so that the penetration of sunlight to the earth's surface does not reach. Interestingly, the dry season is not the season where the average temperature in Makassar City is the highest, the hottest average temperature occurs in the transition season between the dry season and the rainy season. The average temperature range in this transitional season reaches 27°C to 31°C which automatically in September to November is probably the least comfortable time according to the heat index [8].

3.4 Rainfall and Sun Shine Duration

In the maritime continent area, rain occurs throughout the year as can be seen in Figure 5 where rain occurs both in the rainy season, dry season, and in the transition season. The difference in the nature of the rain between these seasons is only in the intensity. In the rainy season from December to February, the intensity of rainfall is generally above 5 mm/day. Meanwhile, the intensity of rain is very light, which is below 5 mm/day, overall

less than 20% (Figure 6a). Rain with high intensity that is more than 100mm/day that occurs in the rainy season does not always come from the west to the north, but also from the east.

During the transition from the rainy season to the dry season, the intensity of very light rain increases in number. Changes also occur from the increased amount of rainfall brought by the southeast wind direction. However, the intensity of heavy and very heavy rain in this transitional season is still quite a lot coming from the west, northwest, north, east, and southeast winds as can be seen in Figure 6b. This is presumably due to the influence of land-sea wind circulation which can supply water during the transition from the rainy season to the dry season.

In the dry season and the transitional season from dry to rainy season, days are dominated by non-rainy days with the number of rainy days only 14% and 23%, respectively. Based on the windrose calculation, the amount of rainfall that occurs in the dry season is generally very light, coming from the west, north, and east winds. However, sometimes high-intensity rainfall occurs from June to August, although the occurrence is very rare. This condition still continues in the transitional season from the dry season to the rainy season, but with slight changes, namely increasing rainy days and the distribution of winds that bring more rain. In these months the frequency of westerly and southwest winds began to increase which caused rain as can be seen in Figures 6c and 6d.

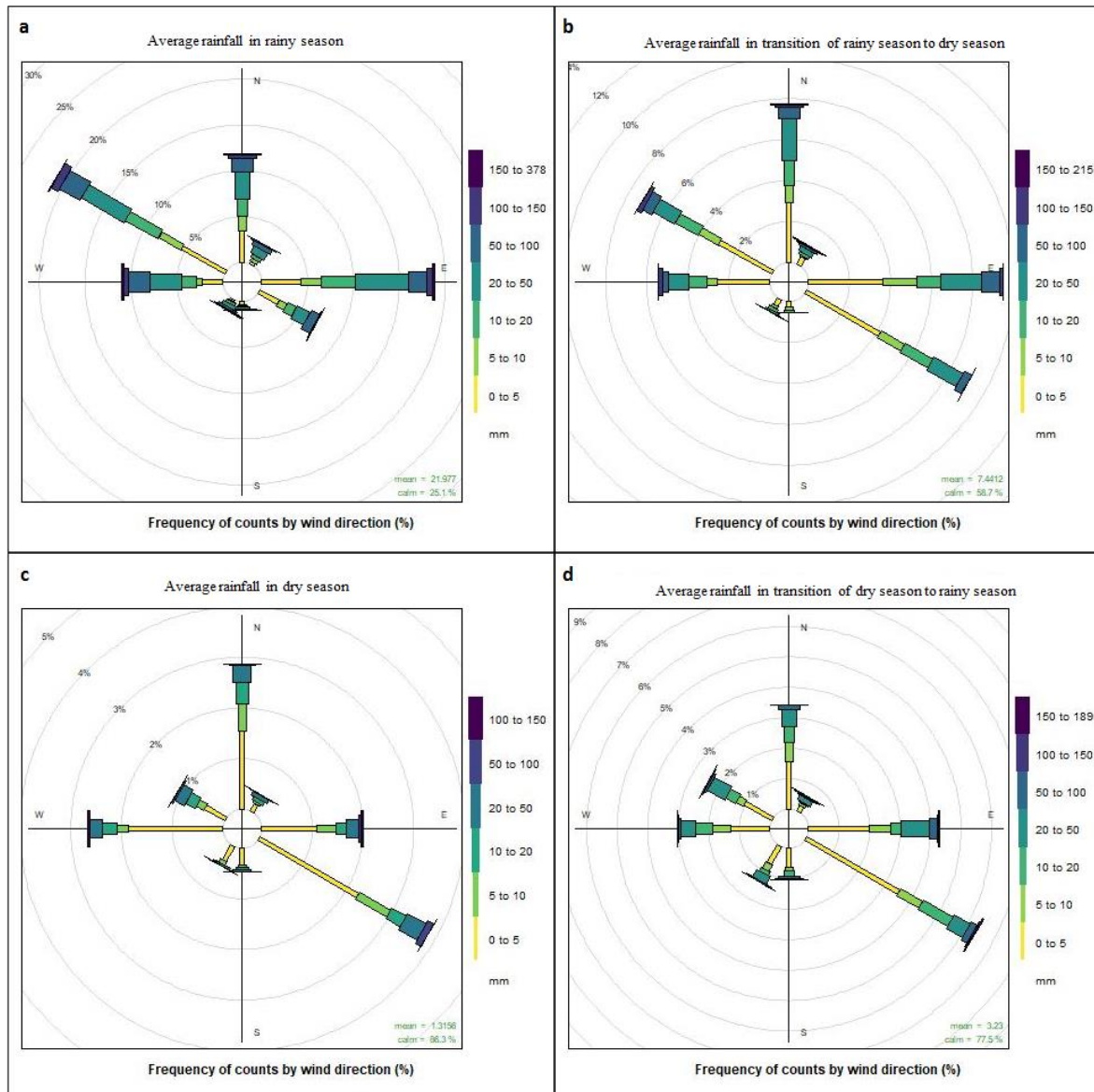


Figure 6. Windrose rainfall at the Paotere Maritime Meteorological Station in the rainy season (a), the transition from the rainy season to the dry season (b), the dry season (c) and the dry season to the rainy season (d)

The equatorial region is famous for its high intensity of solar radiation. Sunlight can reach the earth's surface throughout the year and generally about 10 to 12 hours a day. However, there are variations in the duration of solar radiation from time to time. During the rainy season the amount of sunlight is generally less than 6 hours / day because clouds often appear that block the penetration of sunlight. Figure 7a shows that the rainy season in Makassar City still allows for long periods of sunlight or more than 10 hours/day even though there is a lot of rain in these months.

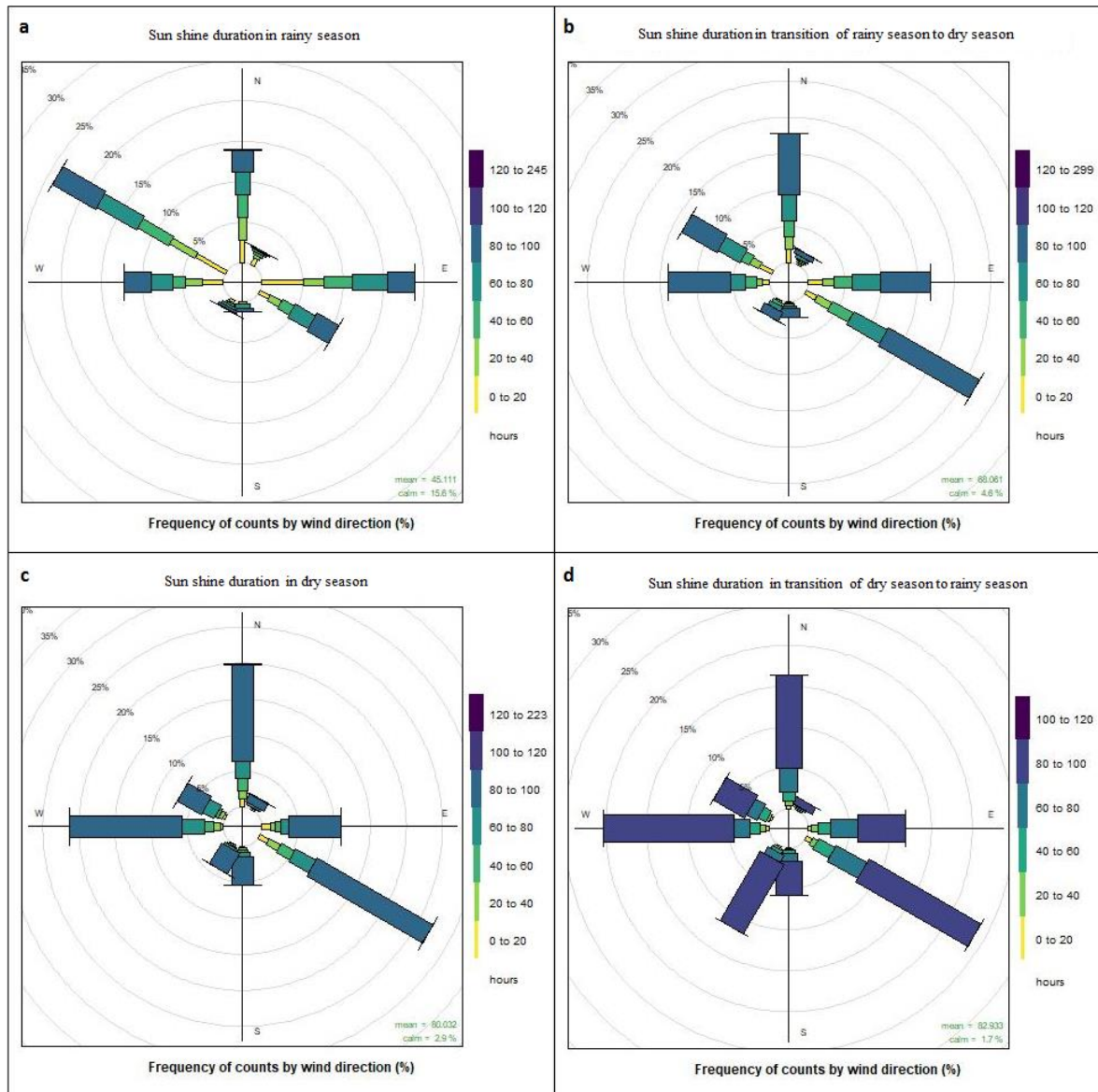


Figure 7. Windrose duration of solar radiation at the Paotere Maritime Meteorological Station is in the rainy season (a), the transition from the rainy season to the dry season (b), the dry season (c) and the transition from dry to rainy season (d). Hours of sunshine are calculated by dividing the value on the windrose by 10.

The number of sunshine duration increases in the transitional and dry seasons. However, the longest duration of sunshine does not occur in the dry season, but in the dry season transition to the rainy season from September to November. According to its astronomical location where Makassar City is located at latitude $5^{\circ}6'$ south latitude or not exactly at the equator, it will cause the duration of solar radiation will not be exactly the same. The apparent movement of the sun back and forth from $23.5^{\circ}LU$ - $23.5^{\circ}LS$ reaches the equator in March and September. Areas south of the equator will take longer to wait for the sun to reach above it when the sun moves from horse latitude in the north to horse latitude in the south. This causes the sun's rays to be received longer by areas south of the equator during summer in the northern hemisphere. This is what causes the duration of sunlight in Figure 7d to be longer than in other months. Because the position of the sun is relatively unchanged throughout the day, it appears that changes in wind direction do not affect the duration of solar radiation.

4. CONCLUSION

Makassar City, which is bordered by wide waters, is influenced by the circulation of land and sea winds. It appears that the wind changes in this city are dominant only from 2 directions, namely the west and east winds throughout the year. Sea breezes in this city are manifested as westerly winds, while land breezes appear as east or southeast winds. The occurrence of these two wind directions throughout the year shows the influence of land and sea winds in this city. Land breezes and sea breezes affect other weather parameters, such as rainfall, temperature and humidity. Rain events are not always dominated by westerly winds, but sometimes by easterly winds. Likewise, high humidity is found in both wind directions and the presence of sea breezes can keep the temperature in this city always warm, despite its tropical location.

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