Identification of the Sea-Land Breeze Event and Influence to the Convective Activities on the Coast of Deli Serdang

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Abstract. Located close to the sea indicates that there are influences of the sea-land breeze circulation on the weather condition in Deli Serdang. The purpose of this study is to simulate sea-land breeze occurrence and its influence on the convective activities in Deli Serdang. The research area covers the area of Deli Serdang Regency and the surrounding ocean region in the coordinates 02°57'-03°16'N & 98°33'-99°27'E where Kualanamu Meteorological Station is the centre of the research area at coordinate 03°34'N & 98°44'E and the elevation about 27MAMSL. The research time is a day with the highest rainfall in the highest peak rainy month. The raw data consist of the Himawari-8 satellite image from BMKG, FNL (Final Analysis) data from http://rda.ucar.edu, and meteorological observation data from Kualanamu Meteorology Station. This study indicates that WRF-ARW can simulate the sea-land breeze occurrence on the coast of Deli Serdang well. The existence of the convective index cover in the convergence area proves the sea-land breeze occurred in the coast of Deli Serdang can form the convergence area as the interacted result with the wind from other directions that support convective activities.

Keywords: Sea-land breeze, WRF-ARW, Heavy rainfall, Himawari-8

1. Introduction
Indonesia is a maritime country located in the tropic area which has a significant temperature difference between land and sea area. The significant temperature difference between land and sea potentially make the wind circulation known as the sea-land breeze [19]. The movement of the sea-land breeze has a correlation with convective activities in a coastal area. The convective activities can be analysed by measuring the convective index which the previous studies measure it by using the calculation of the top cloud temperature from the satellite image [12].

The wind moves due to the difference in the air pressure between two regions. Generally, it moves from the high-pressure air area (High) to the low-pressure air area (Low). The circulation of sea-land breeze can occur in areas adjacent to or near the coast. This circulation is caused by the significant temperature difference between land and sea due to the differences in heat (sunlight) absorption by land and sea [20]. In general, during the daytime, the land absorbs the heat more quickly than the sea. As the result, the air temperature over the land is higher than in the oceans so that the air pressure over the sea will be higher than the land, and it makes the wind circulation from the sea to the land which known as the sea breeze. Meanwhile, at the night when the absence of solar irradiation, the land releases the heat more quickly than the sea. As the result, temperatures over the sea will be higher than the land, so that
The air pressure over the land will be higher than the sea, and it makes the wind circulation from the land to the sea which known as the land breeze. There are two conditions expected to occur when the sea-land breeze pass through a coastal area. First, the sea-land breeze can disrupt the growth of the convective clouds. Meanwhile, the second, it can bring in convective air masses and clouds from other regions to accumulate and increase the convective activities in the sea-land breeze destination area [11].

WRF (Weather Research and Forecasting) is a mesoscale numerical weather model which is used to simulate the mesoscale meteorological phenomena for research and weather forecast activities. WRF can be used for weather simulation with a grid width of up to thousands meters [8]. WRF-ARW is a part of WRF. The use of the WRF model for each region requires the determination of parameterization schemes which the accuracy is different.

Deli Serdang is one of the regencies in North Sumatera Province. Deli Serdang is adjacent to the Malacca Strait in the north. Geographically, Deli Serdang is on the East Coast of Northern Sumatra. Located near the sea are the reason of the importance in analysing the sea-land breeze circulation over there and the influence of the weather condition in the coastal of Deli Serdang. Due to the importance of sea-land breeze influence to the weather conditions in the coastal area, further research is needed to improve the weather forecast accuracy. The purpose of this study is to know the capability of WRF-ARW model in simulating the sea-land breeze occurrence as well as to know its influence to the convective activities in Deli Serdang. And finally, the results of this study can be a reference in making the analysis and weather prediction in the coast of Deli Serdang.

Previous studies [12][15] have been done to analyse the convection and convergence patterns in Indonesian Maritime Continent (BMI). Convection and convergence patterns can be analysed by utilizing the results of the infrared channel of Himawari-8 satellite imagery (previously used MTSAT satellites). The cloud top temperature measured using 10.4μm satellite channel data is used to calculate the convection index over the research area. Sakurai has undertaken the formulation of convective index calculations as follows [15].

\[ CI = \begin{cases} 230 - T_b, & \text{if } T_b \leq 230K \\ 0, & \text{if } T_b \geq 230K \end{cases} \]

Which CI is the convective index, Tb (Brightness Temperature) is the measured cloud top temperature and K (Kelvin) is the unit value of the cloud top temperature.

2. Data and methods
2.1. Research area
The research area covers the area of Deli Serdang Regency and the surrounding ocean region which located at coordinates 02°57'-03°16'N & 98°33'-99°27'E, where Kualanamu Meteorological Station is the centre of research area located at coordinates 03°34'N & 98°44'E and elevation about 27MAMSL (metres above mean sea level).

![Figure 1. Map of Deli Serdang Regency (Google Maps Views)](Source: https://www.google.co.id/maps/place/Bandara+Int.+Kualanamu/)
2.2. Research data

2.2.1. Meteorological observation data. This study uses the meteorological observation data from 2014 to 2016 obtained from the Kualanamu Meteorological Station. These data consist the surface air (synoptic) and the upper air observation data (radiosonde). This study uses the rainfall data (CH) to determine the distribution of the daily and monthly rainfall in Deli Serdang.

2.2.2. FNL (Final Analysis) data. This study uses the FNL data accessed from http://rda.ucar.edu which have 10x10 spatial resolution and 6 hours temporal resolution. This FNL data is the 24-hours data on 1 September 2016 with the spin-up time for 12 hours before and after the main data hours.

2.2.3. The infrared channel of the Himawari-8 satellite image. This study uses the infrared (10.4 mm) channel of Himawari-8 satellite image obtained from BMKG. This satellite image data are used to calculate the convective index value over the research area.

2.2.4. GSMaP data. GSMaP (Global Satellite Mapping of Precipitation) is consists of the rainfall data measured by the satellite which has the 1-hour temporal resolution and 0.1°x0.1° spatial resolution. The GSMaP data accessed from ftp://hokusai.eorc.jaxa.jp.

2.3. Data processing

2.3.1. Research time identification. The research time is determined based on rainfall data from 2014 to 2016 obtained from Kualanamu Meteorological Station. In this study, the research time is a day with the highest rainfall in the highest peak rainy month. Based on monthly rainfall data, it is indicated that the highest peak of rainfall occurred in September. Meanwhile, the rainfall data from 2014 to 2016 represent that on 1 September 2016 occurs the highest daily rainfall about 101mm so that 1 September 2016 set as the research time.

2.3.2. Running process of the WRF-ARW model. The mesoscale model used in this study is the WRF-ARW Version 3.8.1 model. The WRF-ARW model run by using the Mercator map projection and be divided into two domains. 1st Domain (DO1) located in coordinate -4.82°-11.89°N & 90.32°-107.135°E with a horizontal resolution of 21km. Meanwhile, the 2nd Domain (DO2) located in coordinate 1.15°-5.98°N & 96.31°-101.15°E with 7km horizontal resolution. Here are the domains and parameterization settings used in this study.

![Figure 2. Display of domains used in WRF-ARW model](image-url)
Table 1. WRF-ARW configuration used in the research.

|                          | Domain 1 | Domain 2 |
|--------------------------|----------|----------|
| Type Projection          | Mercator |          |
| Centre Point Lon         | 98.73°   |          |
| Centre Point Lat         | 03.57°   |          |
| Horizontal Dimension X   | 91       |          |
| Horizontal Dimension Y   | 91       |          |
| Grid-Point Distance      | 9km      | 3km      |
| Graphics Data Resolution | 10m      | 5m       |
| Time Step                | 60       |          |
| Microphysics Option     | WRF Single-Moment 3-class scheme |
| Cumulus Parameterization Option | Kain-Fritsch scheme |
| Shortwave Radiation Option | Dudhia scheme |
| Longwave Radiation Option | RRTM scheme |
| Boundary-Layer Option    | YSU scheme |

2.3.3. Verification. This study compares the selected meteorological parameters of the output of WRF-ARW model and meteorological observation data from Kualanamu Meteorological Station to verify the accuracy of the output of WRF-ARW model.

2.3.4. Research flowchart

![Research Flowchart](image-url)

**Figure 3.** Research flowchart
3. Result and discussion

3.1. Research time identification

**Figure 4.** Graphic of 3-hour rainfall average in Kualanamu Meteorological Station from 2014 to 2016

**Figure 5.** Graphic of 10-day rainfall average in Kualanamu Meteorological Station from 2014 to 2016

**Figure 6.** Graphic of 3-hour rainfall average in Kualanamu Meteorological Station in September 2016
Based on rainfall data from 2014 to 2016 obtained from Kualanamu Meteorological Station can be produced the graphic of 3-hour [Figure 4] and 10-day [Figure 5] rainfall average in Kualanamu Meteorological Station from 2014 to 2016 and also the graphic of 3-hour rainfall average [Figure 6] and the daily-rainfall total [Figure 8] in Kualanamu Meteorological Station in September 2016. Meanwhile, based on GSMaP data can be produced the spatial average of rainfall in the research area (Deli Serdang) during September 2016 [Figure 7]. Figure 4 and 5 indicate that September is the month which has the highest rainfall of the rainfall peak in Kualanamu. Figure 8 represents that 1 September 2016 is the day which has the highest rainfall, about 101mm/day. Meanwhile, Figure 6 and 7 indicate that from 12:00UTC to 24:00UTC there is the significant variation of in the amount of the rainfall in September 2016, while the highest rainfall occurs in the period of 18:00UTC to 21:00UTC. Thus, based on analysis of rainfall data from 2014 to 2016, 1 September 2016 is determined as research time.

3.2. Data validation
Figure 9. Graph of upper air temperature (T), dew point temperature (TD), and relative humidity (RH) comparison of WRF-ARW model output with observation data in Kualanamu Meteorological Station on 1 September 2016 {00:00UTC [Left] and 12:00UTC [Right]}. 

In this study, the validation of WRF output data is done by comparing it with the meteorological observation data obtained from Kualanamu Meteorological Station. Based on Figure 9, the RMSE (Root Mean Square Error) value of upper air parameters such as temperature (T) and dew-point temperature (TD) at 00:00UTC and 12:00UTC are 0.93 & 1.04 and 3.12 & 2.91 respectively. For the temperature comparison, these RMSE values categorized well. Meanwhile, the comparison of relative humidity (RH) at 00:00UTC and 12:00UTC are 17.23 and 13.81 respectively, which can be categorized as good enough.

Figure 10. Graph of surface air temperature (T), dew point temperature (TD), relative humidity (RH), and wind speed (WS) comparison of WRF-ARW model output with observation data in Kualanamu Meteorological Station on 1 September 2016.

Based on Figure 10, the graphs indicate that the RMSE value of surface air parameters such as T, TD, RH, and wind speed (WS) from 00:00UTC to 23:00UTC are 4.39, 2.19, 10.03, and 4.97, which all of these values statistically can be categorized better. Thus, the comparison value of the surface air parameters is better than the upper air parameters. And as the result, it can conclude that the WRF-ARW model used in this study can describe the weather parameters condition in Deli Serdang well.
3.3. Analysis of Atmosphere Condition

Figure 11. Zonal (02.57°N to 04.57°N 98.73°E) [Left] and meridional (03.57°N 97.73°E to 99.73°E) [Right] wind in the research area on 1 September 2016.

Figure 12. The divergence [Left] and the vertical velocity [Right] values in the research area on 1 September 2016.

Figure 12 shows the divergence value [Left] and vertical velocity value [Right] on 1 September 2016 from 00:00UTC to 23:00UTC at 1000hPa to 100hPa. The positive divergence-value indicate the spread of air masses, whereas the negative divergence-value indicate the buildup of air mass or commonly known as convergence. In the left part of Figure 11, the negative and positive divergence patterns appear less regular. Strong negative divergence occurs in the lower layers at the level of 1000hPa to 900hPa while strong positive divergence occurs at 200hPa. The presence of convergence in the lower layers and divergences in the upper layer indicates the occurrence of a strong convective event that is always identical with the less friendly weather condition. The vertical velocity value is related to the direction of vertical wind movement. In the right part of Figure 11 presents the vertical velocity pattern that varies every hour on 1 September 2016. At 00:00UTC to 12:00UTC is not seen the significant vertical velocity value. At 12:00UTC, the positive vertical velocity, about 0.05 to 0.35, indicate the upward vertical air movement (updraft). This condition occurrence until 15:00UTC which indicating any convective activities or the formation of convective clouds (rain clouds) over the area. At 17:00UTC until 21:00UTC, the negative vertical velocity value looks to be dominant, in the range of values from -0.05 to -0.25. It shows the occurrence of vertical downward movement (downdraft) which indicates the occurrence of rain over the area in this time span.
Figure 11 indicates the wind pattern during the rain peak on 1 September 2016. The condition at 03:00UTC shows that the transition of land breeze currents into the sea breeze has begun. The condition at 06:00UTC shows that the moving of sea breeze is quite fast, about 10-14kt, which entered the West Coast of Sumatra including the region of Deli Serdang. The condition at 09:00UTC shows that the sea breeze is getting louder and finally began to weaken at 12:00UTC. The condition at 12:00UTC shows that there is an encounter-wind in the opposite direction but its speed is relatively low. The condition at 15:00UTC shows the beginning of the rising of the land breeze speed and the weakening of the sea breeze speed. Visible land breeze speeds are increasing and occur until at 24:00UTC. If analysed from its convective activities, from 00:00UTC until before 09:00UTC, there is no significant convective activities even though the sea breeze flows at a relatively strong speed. This has occurred because of the absence of the wind from the opposite direction that blocks the sea breeze to form the convergence area. It is because in September the Eastern wind (Easterly) was occurred in Deli Serdang, so the sea breeze is reinforced by the movement of the wind from the north (Asia). At 12:00UTC, the convective activities began to appear. The land breeze that flows from the south meets the Eastern winds moving from the north to form a convergence area scattered in the area around Deli Serdang. This is increasingly evident at 18:00UTC where in addition to meeting the wind from the opposite direction, the land breeze is influenced by the surface topography and make the wind shear around the Deli Serdang area. At 21:00UTC, it is shown that the Eastern wind is weakening and the land breeze is clearly visible. In

Figure 13. Spatial average of GSMaP rainfall in the research area on 1 September 2016
general, it is seen that the wind that blows from land to sea on the coast of Deli Serdang began clearly visible from 18:00UTC to 03:00UTC which the speed is about 2-12kt. The wind patterns shown are in accordance with the theory of sea-land breeze circulation where the land breezes usually occur about three hours after sunset and increase in speed until sunrise and still continue to occur in a few hours after sunrise. Meanwhile, the sea breeze appears near the shore a few hours after sunrise and reach the maximum condition when the difference between land and sea temperature reaches the maximum value. However, this is not entirely consistent with Riehl’s theory [14] where ideally the direction of the wind circulation of the sea breeze is perpendicular to the shoreline. Besides that, observed the existence of convergence that occur between two of sea breeze and between sea breeze and the wind from other direction blowing from the north (Eastern wind), this is in accordance with the theory of Wirjohamidjojo and Sugarin [21].

4. Conclusions
The conclusions of this study are as follows. In general, the occurrence of sea-land breeze over the coast of Deli Serdang can be simulated well by WRF-ARW model with the configuration used in this research. The sea breeze tends to be stronger than the land breeze. The sea breeze speed can reach about 10-16kt while the speed of the land breeze only about 6-10kt. The sea-land breeze that occurs on the coast of Deli Serdang can be the convergence form in the transition time or when the encountering-wind from another direction and it will support the convection activity at Deli Serdang. This is evidenced by the high value of the convective index in the convergence area. The recommendation of this study is the research time needs to be done in other months and not on the heavy rain occurrence, so it will be known the variation of the influence of the sea-land breeze circulation on the convective activities on the coast of Deli Serdang.

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