Sea Breeze Observation in Bogor based on 2016 Intensive Observation Period (IOP)

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***Abstract*—Land-sea breeze circulation plays an essential role in local weather development. The different characteristics of land and sea, the air movement from and towards the sea may give different effects on convective activity and to the transport of atmospheric particulates. Observational and modeling studies on land-sea breeze circulation in Indonesia have been done to investigate various phenomena in the atmosphere. This study aimed to inspect the sea breeze circulation over the area of Jakarta, Bogor, Depok, Tangerang, Bekasi (JABODETABEK) using data from the Intensive Observation Period (IOP) in 2016. The sea breeze circulation was examined using wind and relative humidity profiles. The movement of convective cloud was observed using X-band Furuno Radar. The result showed that there had been inland propagation of sea breeze, albeit its vague effect in Bogor, West Java. The inland sea breeze may encounter another local weather system resulting in the convergence area somewhere that may result in heavy rains. However, the monsoonal wind has a distinct effect on determining the prevailing wind in one area.**

Keywords—land-sea breeze, jabodetabek, sounding, intensive observation period (IOP)

I. INTRODUCTION

Land-sea breeze is a diurnal circulation that plays a vital role in local weather and air quality. It is driven by thermal differences between two different land covers, wherein one land cover heated up faster during the day and cooled down more quickly during the night. Observational and modeling studies on land-sea breeze circulation in Indonesia have been done to investigate different phenomena in the atmosphere. Abbs & Physick (1992) explained that the vertical extension of the sea breeze in tropical areas is in 1000 m – 1400 m height range, with a maximum observed height of 2 km. The horizontal extension may, on the other hand, vary in each location which relied on several factors: the synoptic wind, the atmosphere stratification, and the geographical conditions in that area (Chiba *et al.* 1999). Hadi *et al.* (2002) showed that sea breezes from the Jakarta north coast penetrate up to 60 – 80 km inland, by observing cloud line movements caused by the Sea Breeze Front (SBF) inland. Sahla (2018) showed that the surface roughness of buildings in Jakarta's urban area have been proven to obstruct the sea breeze propagation inland.

The simulation of land-sea breeze circulation and its influence on the convective activity in Medan, North Sumatra has been studied by Saragih *et al.* (2017). By using the upper-air observation data, FNL analysis data, Himawari-8 satellite image, and the Global Satellite Mapping of Precipitation (GSMaP) data, the study showed a connection between the land-sea breeze circulation and the development of the convergence area over Medan, North Sumatra.

According to Miller *et al.* (2003), the Sea Breeze Calculation (SBC) is a mesoscale cell which rotates vertically. The sea breeze on the lower level moves towards the land, and its reverse flow heads towards the ocean on the upper level. The presence of the Sea Breeze Front (SBF) is indicated by the forming of cumulus clouds, which will be shifted away from the coastline.

The roles of SBC towards cloud propagation plays an important role in the rainfall and rain rate in the surrounding area of the coastline and intrusion area. Jakarta, as one of Asia's megacities and home to approximately 10.5 million people, is vulnerable to floods. One of the leading causes is due to heavy rain in Bogor area.

Even though Hadi *et al.* (2002) showed that the SBC develops well along the northern coast of West Java and propagates inland until its structure is deformed over the complex topography of Salak and Pangrango Mountains (Figure 1), this had only been concluded based on satellite and L-Band radar measurements carried out in Puspiptek, Serpong. Between January 21 and February 17, 2016, an Intensive Observation (IOP) was conducted in Bogor area. Several instruments were mounted to study the weather characteristics and then used the data to check sea breeze propagation in Bogor area. The study also analyzed the relationship between heavy rain that had caused flooding on February 14, 2016 with sea breeze circulation.

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II. Data and Method

A. Data

This study used the in-situ data from the Intensive Observation Period (IOP) held in Bogor, West Java on January 21 – February 17, 2016. The wind speed and wind direction were the primary data and obtained from radiosonde that was launched four times a day during the period. The in-situ wind data was obtained from the Automatic Weather Station (AWS) owned by Meteorological, Climatological, and Geophysical Agency (BMKG). These data were used to show a high-resolution diurnal variation of land-sea breeze over the study area. The radar reflectivity data was acquired from X-band Furuno Radar that was installed at the Science and Technology Research Center (Puspiptek), Serpong. This data was used to see the convective activity over Bogor area related to land-sea breeze circulation. The radiosonde and AWS data in Cengkareng were used as the reference to check the effects of the sea breeze.

B. Method

To check the inland propagation of sea breeze in Bogor area, the study area was limited to JABODETABEK as seen in Figure 1. The methods used to check the inland progression of SBF was based on Hadi et al. (2000) (1) across-shore wind near the surface and (2) return flow aloft; (3) decrease in temperature and (4) increase humidity. Sea Breeze Circulation (SBC) was detected by observing meridional and zonal wind components from AWS, which was then composited to 24 hours to define the diurnal pattern. The observational wind data from AWS in Cengkareng and Bogor were first broken down into two components, *u* and *v* using the following formula:

$$u = -\,\text{mag} \times \sin(\text{dir} \times \pi/180) \quad (1)$$

$$v = -\,\text{mag} \times \cos(\text{dir} \times \pi/180) \quad (2)$$

in which *u* is the zonal wind component, *v* is the meridional wind component, *mag* is the wind speed, and *dir* is the wind direction (0°-360°).

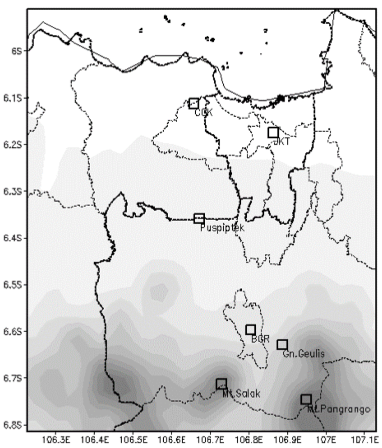

Figure 1 Area of study

Next, the presence of SBC would further confirmed by the intercomparing of vertical profile data and surface measurements. The time-height cross-section of meridional wind from the sounding data would be plotted to analyze the vertical profile. The study calculated the wind anomaly to eliminate dominant or gradient wind factors from the data. Sea breeze and its reverse flow would be further observed by analyzing the meridional wind speed data at 0.5-0.75 km and at 1.5-2.5 km. Temperature and humidity data from the AWS and sounding data would be plotted to inspect its time evolution. Cloud lines and the developments from the frontal region through Bogor area would be used to investigate and verify the inland spreading of SBC (Simpson, 1994). The reflectivity (dbz) value from the radar would be used to analyze the cloud over Jakarta and Bogor area.

III. Results and Discussion

A. Sea Breeze Identification

Wind characteristics in Cengkareng and Bogor were checked using AWS data from BMKG. The data on wind speed and wind direction were converted into meridional and zonal wind components. The wind components were then composited into 24-hour periods to check the diurnal pattern. Figure 2 describes the diurnal variation of the wind components at two meteorological stations, Cengkareng and Gunung Geulis (Bogor area). Cengkareng chart shows the positive zonal wind components (u) throughout the day. The positive value means the wind moved west (from the west toward the east) which corresponds to wind gradient in wet season of December-January-February (DJF). The meridional wind component (v) showed negative value starting at 0000 UTC (0700 LT) to 1200 UTC (1900 LT), which indicated that the wind moved from the north to the south. This value verified the sea breeze effect in Cengkareng. The AWS station data in Bogor (Gunung Geulis) showed the calm zonal wind component. It explains that the location had not been affected by the westerly monsoon wind. The meridional wind component showed moving air from the north at 0000 UTC to 0900 UTC, which was assumed as the sea breeze. The wind directions were then reversed, starting at 0900 UTC, shifting to the land breeze. Although not significant, it can be assumed from AWS data that the sea breeze propagation reached the area of Gunung Geulis, Bogor. The figure also indicated that the sea breeze effect in Cengkareng is quite dominant during wet season (Asian Monsoon). This was pointed out by the massive gap between the meridional wind speed during the day and night. On the other hand, the diurnal pattern in Gn. Geulis showed that the land breeze effect during the night had been more dominant than the sea breeze effect during the day.

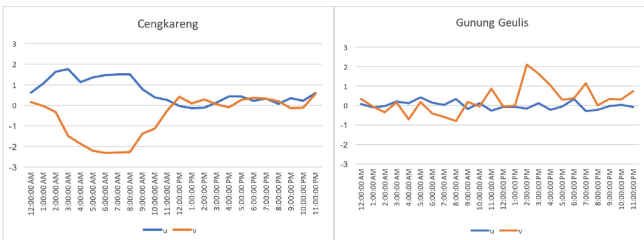

Figure 2 The composite of observational wind (m/s) in Cengkareng (left) and Gunung Geulis (right) during the 2016 Intensive Observation Periods (time in UTC)

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Confirmation of sea breeze effect in Bogor area was conducted by plotting the time-height cross-section of the sounding data in Bogor. The anomaly of meridional wind clearly described the diurnal variation up to 500 m, marked by the shifting of the shaded area from blue to red according to its time evolution (See Fig.3). In general, there had been a reversing wind above 700 m high, but there had been some days that the sea breeze penetrated up to 1.5 km or 2 km (January 31, February 2, February 12). Even though most of the cross-section plot indicated diurnal variation in level 500m, Bogor area had not been affected by the sea breeze throughout the observation period. It was proven by part of the dominant meridional wind components, shown in Figure 2 by the dominating blue shade, up to the maximum height of 5 km. In those cases, it could be interpreted that the monsoonal wind as the background wind had been stronger than the sea breeze as there had not been any return flow. The vertical profile of the average value of meridional wind during 00 and 06UTC showed that during IOP the wind originated from the north during the day and then started shifting at around 3000m high. The sounding profile also pointed out that the sea breeze reached Bogor area at 06UTC. This assumption was based on the tremendous difference of the 00 and 06UTC meridional wind speed near the surface level.

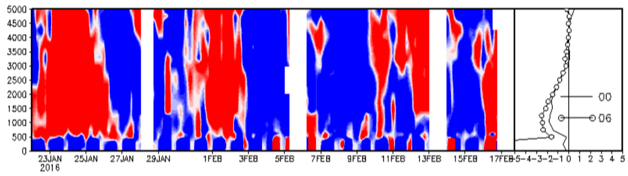

Figure 3 The meridional wind profile from radiosonde data during the IOP and the vertical profile of the meridional wind average value at 00 and 06 UTC. (Blue shade indicate northerly wind, on the other hand red shade indicate southerly wind).

Relative humidity profile vaguely pointed out the diurnal variation at the lower level. It was also hard to analyze the increasing value of humidity from its time evolution, but the vertical profile of the 00 and 06 sounding data showed that humidity started to change at around 1500m, which favored the return flow of the sea breeze circulation (See Fig.4).

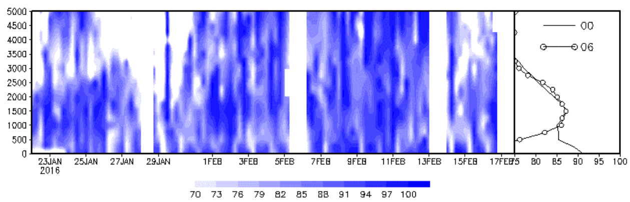

Figure 4 The relative humidity profile from radiosonde data during the IOP for Cengkareng (left) and Bogor (right)

Further observation of the SBC's backflow was conducted by averaging both of meridional wind and humidity data at 500-750 m to define the sea breeze and at 1500-2500 m to inspect the reverse flow. Despite the diurnal pattern showed by both of the meridional wind and relative humidity which indicated the wind were northerlies, most days in Bogor area were not affected by the sea breeze circulation. This was pointed out by having no return flow or that the 0.5-0.75 km wind did not originate from the north (Eg. 22-26 Jan, 3Feb, 13-15Feb). The relative humidity plot on several dates also pointed out the decreasing value of humidity throughout the day (Eg. 25-27Jan, 12-13Feb). However, some of the dates successfully pointed out that the penetration of sea breeze effect from the north coast inland had reached Bogor area (See Fig. 5).

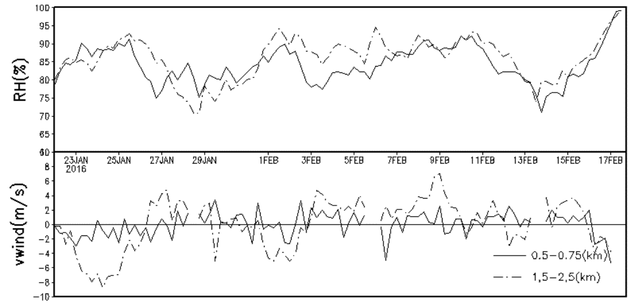

Figure 5 The averaged relative humidity and meridional wind components

B. Sea Breeze role towards the February 14, 2016 flood

The recorded heavy rain that occurred on February 14, 2016 caused floods in locations in east Jakarta, 6 locations in south Jakarta, 11 fallen trees in east Jakarta, and some minor damage at the toll gate (BNPB, 2016). Other sources from GIS BPBD Jakarta also showed flooded areas in several Jakarta sub-districts.

Another method to detect sea breeze circulation is by observing roll clouds along the coastline that have been caused by the sea breeze front. The reflectivity image at Februari 14, 2016 was interpreted by xband radar and showed that there had been sea breeze fronts, marked by the roll cloud at 0600 UTC (Fig. 6). At the same time, convective clouds were also formed due to the topography effect in the southern area. Roll clouds originated from the SBF moved inland while the cloud from the south expanded to the north. Tokairin *et al.* (2010) explained that Jakarta develops low-pressure areas during midday and these convergence areas cause heat transfer in the surrounding areas of Jakarta to enter Jakarta.

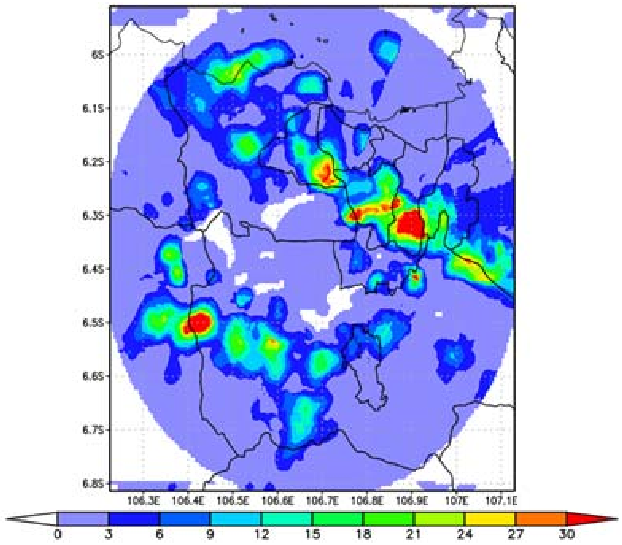

Figure 6 Sea breeze front, observed by the X-band Furuno Radar.

Sea breeze intrusion and its effects toward heavy rain that had caused severe flooding in Jakarta were analyzed using cloud movement from the radar data. To check the inland expansion of cloud lines from the north coast, the study plotted the time latitude section of the reflectivity data. The reflectivity data was then averaged in the 106.5-

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107 longitude. Figure 6 shows the distribution of radar reflectivity of X-band Furuno Radar during 1000 LT until 1900LT for the latitude -6.7 to -6.0. The radar reflectivity from X-band radar represents convective clouds over the study area. The hövmoller (time-latitude cross-section) diagram is used to detect the influence of cloud line movement evolution. According to Figure 7, the convective clouds moved toward the south because of the sea breeze. Meanwhile, the convective clouds that originated in Bogor moved from the south toward the north during midday. The air parcels from the north coast while the mountainous area in the south started to dissipate at around 14LT, which then emerged and moved north until it fully dissipated at around 18LT. The movement of the air parcel from the south was presumably affected by the convergence area around 6.4 S. These movements converged the convective clouds into the Jakarta area and produced the heavy rain over Jakarta.

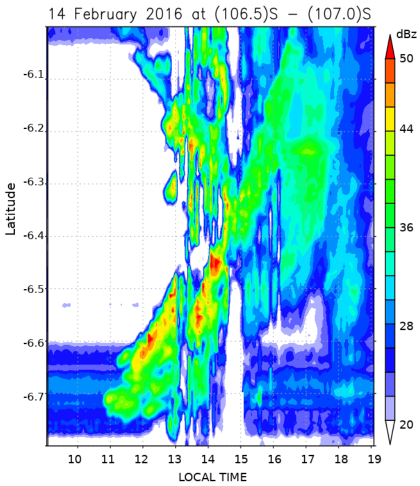

Figure 7 The hövmoller diagram of radar reflectivity on February 14th, 2016.

IV. Conclussion

The AWS mounted in Cengkareng area in Tangerang and Gunung Geulis in Bogor successfully pointed out the diurnal variations of meridional wind. The intercomparing supports this interpretation that used sounding data collected from Bogor. The cross-section plot of meridional and relative humidity albeit vaguely showed the inland propagation of sea breeze circulation in Bogor area. The wind data that originated from the north and the reverse flow at the higher level above 700 meters supported this conclusion. Analysis of the Jakarta flood on February 14, 2016 showed that the heavy rain in the JABODETABEK area was influenced by sea breeze circulation in addition to the inland propagation of convective clouds that have developed from the sea breeze front. Cloud movements pointed out that during wet seasons (DJF), heavy rains in Bogor concluded as one of the main causes of floods in Jakarta had not been affected by the SBC. Heavy rains from Bogor came about due to topography effects and regional or global factors.

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