JOURNAL OF APPLIED GEOSPATIAL INFORMATION

Vol 8 No 1 2024

http://jurnal.polibatam.ac.id/index.php/JAGI
ISSN Online: 2579-3608

Analysis of Strong Wind Characteristics Using Doppler Weather Radar over Kualanamu Airport Indonesia

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Received: March, 25 2024
Accepted: May 29, 2024
Published: May 29, 2024

Abstract

Strong wind is one of the weather phenomena that can be dangerous for aviation safety. According to observation data from the Kualanamu Meteorological Station, there were 61 strong winds with speeds greater than or equal to 15 knots in 2020, which indicates a high risk of strong wind over this area. This research aims to analyze the characteristics of strong winds in the Kualanamu airport area using weather Doppler radar. The data used consisted of nine cases of the strongest winds for each month in 2020. We have tested analysis methods of radar products such as VVP, CAPPI V, and PPI on nine sample dates to determine the duration, intensity, and direction of wind speed. Additionally, we used the radar's echo pattern to identify the potential impact of cumulonimbus clouds (Cb), which trigger strong winds. Three out of nine study cases, identified as the three most significant strong winds during 2020, have been subjected to echo pattern analysis. The results showed that the strong winds occur for 40 to 70 minutes, but they mostly have a duration of about 50 minutes. Overall, strong winds occurred during the night and early morning. The radar echo typically has a range between 18 and 43 dBZ. Echo patterns generally revealed a group that extended in the shape of a squall line that moved from west to east and reversed.

Keywords: Strong wind, Doppler Weather radar, Cumulonimbus clouds, Kualanamu airport

1. Introduction

High flight activity requires a high level of flight safety as well. There are many factors that affect flight safety, one of which is weather factor. Wind is one of the main weather parameters. Wind can influence the stability of an airplane. The airplane impacted by winds close to the surface while take off and landing (Fadholi, 2013). Wind data is needed during the airplane take-off and landing process. It is reported in two variables (direction and speed). Routine aviation weather reports called METAR and SPECI contains wind data. METARs are made every half hour (30 minutes), while SPECIs are made between METARs when there are significant changes in weather parameter. It is dangerous for an airplane to fly through wind gusts that change the average wind speed and direction suddenly (Gultepe et al., 2014). This wind shift can cause differences in wind direction and speed at different parts of the runway and can endanger the landing and takeoff process.

According to The Meteorology, Climatology, and Geophysics Agency (BMKG) wind is categorized as extreme if it blows at a speed above 25 (twenty five) knots. Kualanamu Airport has a Standard Operation Procedure (SOP) Number: SOP/DAT/03/09 concerning the Creation, Distribution and Cancellation of an Aerodrome Warning which states that strong winds with speeds of 15 (fifteen) knots and above are considered siagnificnt weather that requires an Aerodrome Warning. Therefore, in this research the author analyzes winds with speeds of 15 knots and above. In Tambunan et all., (2023) mention that the atmosphere conditions when tailwinds and crosswinds occur in Kualanamu Airport runway area are the unstable of air mass which results in convection processes and the growth of Cumulonimbus clouds which give rise to strong wind. Aerodrome Warning information is created by Meteorological officers to be disseminated to airport stakeholders to avoid losses that may be caused during bad weather.

In creating the Aerodrome Warning, the forecaster used Medan weather radar data. The terrain weather radar is a C Band Doppler Radar (CDR) with an outer range of up to 250 km from the radar center (EEC., 2010; Wardoyo E., 2015). This weather radar has been officially operational since April 8 2010 and is located at the Center for Meteorology, Climatology and Geophysics (BBMKG) Region I Medan. C band Doppler radar can be used to observe winds and storms or extreme weather (Holleman I., 2010, Fukao et all., 2014). The BBMKG Doppler weather radar is capable and sensitive to detect tornado events that occur in mountainous areas (Darmawan and Matondang, 2013).

From synoptic observation data from the Kualanamu Meteorological Station, in 2020 there were 61 days of strong winds with speeds greater than or equal to 15 knots. Strong wind events are dominantly accompanied by reduced visibility, thunderstorms and heavy rain (Ahrens D, 2003; Zakir et all, 2010) . Based on the description above, the author assesses that the presence of Cb clouds in the airport area requires further review. This research aims to identify strong winds in the Kualanamu airport area due to the presence of Cb clouds using weather radar.

Some previous studies, it was still rare to use the velocity (V) radar products. Where the V product is a radar product that shows the wind speed and direction in an area observed by the radar . VVP can use to see the vertical wind profile in certain time interval (Mujiasih et all., 2016). Radar can also see vertical wind speed and direction. In this research, the author intends to conduct a study of the echo radar characteristics that cause strong winds in the Kualanamu airport area. The aim is to determine the echo pattern, duration, intensity and wind speed produced which indicates the potential for strong winds.

2. Data and Methods

2.1 Data

There are 2 data used in this research, namely:

a) Surface air observation data, METAR and SPECI reports of the 9 date maximum wind speed in each month from Kualanamu Meteorological Station for 2020. Then choose the 3 dates of the most powerful wind speed event as shown below.

Table 1. Synoptic Wind Data

No	Date	Wind Direction	W. Speed (knot)
1	Apr 26 2020	250	21
2	May 07 2020	190	26
3	Jun 10 2020	260	26
4	Jul 29 2020	190	26
5	Aug 31 2020	170	20
6	Sep 14 2020	260	26
7	Oct 19 2020	270	28
8	Nov 16 2020	110	36
9	Dec 12 2020	220	25

b) Raw weather radar data for 2020. Weather radar data obtained from Central BMKG Jakarta.

2.2 Methods

The method in this research is analyzing VVP, CAPPI V, and PPI radar products in Kualanamu Airport area. There are two weather radar products used for wind speed analysis, namely VVP (Vertical Velocity Processing) and CAPPI V (Constant Altitude PPI Velocity). Vertical Velocity Processing (VVP) is a radar product that can display estimates of horizontal wind direction and speed from a vertical column above the radar location in a time series. This product displays the wind profile, direction and wind speed in the form of a wind barb, starting from a layer of 0 meters to 13 km or as needed. We can see by looking at the horizontal wind trend at each altitude layer, we can determine when strong winds occur. Make use of VVP to determine the ten minutes per day at which strong winds occur. To produce VVP product output, the author sets the settings as shown in the picture.

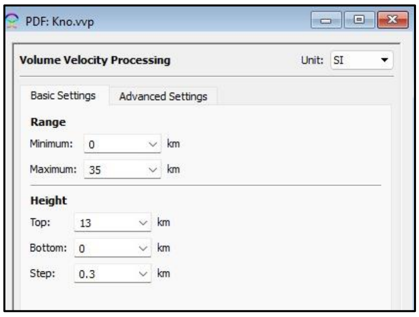


Figure 1. VVP settings

CAPPI V or Constant Altitude PPI is chosen to determine the movement of air masses, whether they are moving away from the radar with a red indication or conversely approaching the radar with a green legend. The author uses pseudo CAPPI at an altitude of 500 meters. This height is the closest distance to the earth's surface that can be observed by radar. Pseudo CAPPI was chosen because the output at altitudes that have empty data is produced from interpolated values of the surrounding (Wardoyo E., 2015).

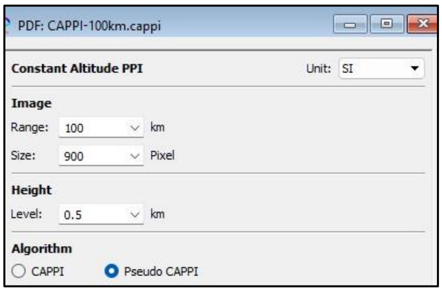


Figure 2. CAPPI V settings

Compare the results of wind speed analysis using VVP and CAPPI V radar data with the actual wind speed (observation data) at the Kualanamu Meteorological Station. Once it is known when and the intensity of strong winds that are similar to synoptic winds, the PPI is created at that time. Plan Position Indicator (PPI) is a radar product that shows radar's echo at specific elevation only (Wardoyo E., 2015). PPI was selected because it is the quickest output that can be monitored by forecaster in radar monitoring without product processing. This is the level that is closest to the surface of the earth, sweep 1 or 0.5 degrees of elevation is the PPI data that is used (Mujiasih et all., 2016). So it is hoped that by maximizing the function of this radar product, forecasters can make the Aerodrome Warning rapidly and accurate.

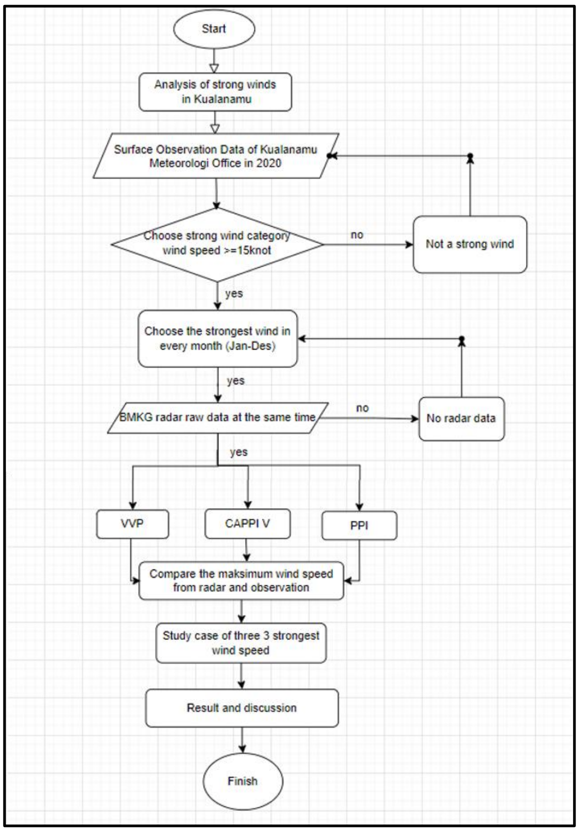


Figure 3. flowchart

3. Results and Discussion

3.1 Analysis of 9 dates of strong wind events

Figure 4 shows a comparison of the maximum wind speed resulting from synoptic and radar estimates on 9 dates of strong wind events (>15 Knots) in 2020. Radar estimated wind direction and speed were obtained from VVP and CAPPI V product processing. Results analysis shows that the two types of data do not provide the same results. However, both of them assessed that the strong winds were more than 15 knots. Wind speed values from synoptics are generally greater than radar estimates. From the graph above, it can be seen that the CAPPI V estimated wind speed is closest to the observation results. Meanwhile, for the wind direction elements, both VVP and CAPPI V are in accordance with surface air observations.

This proves that the combination of VVP and CAPPI products can be used to determine the time and duration of strong winds that occur. We can also know the vertical direction and speed of the wind in various layers. So when VVP and CAPPI V the radar shows a wind speed greater than 15 knots, forecasters can immediately make an early Aerodrome warning of strong winds. From the 9 date strong winds generally occurred between 10.00 UTC – 18.00UTC (17.00 WIB – 01.00 WIB) in the afternoon until early morning but the dominant occure in afternoon to night time (7date). There is a time difference between the observation wind and the radar wind of around 10-20 minutes. The duration of the strong winds was around 40-60 minutes. Strong winds generally occur first, followed by heavy rain.

It is accordance with Saragih (2020) mention that the rain typical in the North Sumatra seaside region dominant occur around evening to early morning time. There are several reasons why there may be more chances of rain in the afternoon / night compared to the early morning. One of the reason is diurnal heating during the day, the sun heats the Earth's surface, causing the air near the ground to warm up. This warming leads to the air rising and instability (Supangkat, 1994). The instability of the atmosphere can give the favourable support for the covective clouds (Cb) formation that may produce strong wind and rain (Bayong T., 1999; Ahrens D., 2003). In coastal areas, sea and land breezes are the local winds which can contribute to the formation of convective clouds (Zakir et all., 2010)

Echo patterns generally revealed a group that extended in the shape of a squall line that moved from west to east and reverse. The echo direction is related to the sea breeze and land breeze in Deli Serdang coast. In Saragih et all (2017) stated that sea and land breeze influence the convective movement in Deli Serdang coast. Sea breeze moves from the sea to land during the day. And in the evening time, the land is cooler than the ocean. When the air moves from land to the sea, it is called land breeze (Supangkat, 1994). Radar echo intensity generally ranges from 18-45 dbz and forms slight to heavy rain.

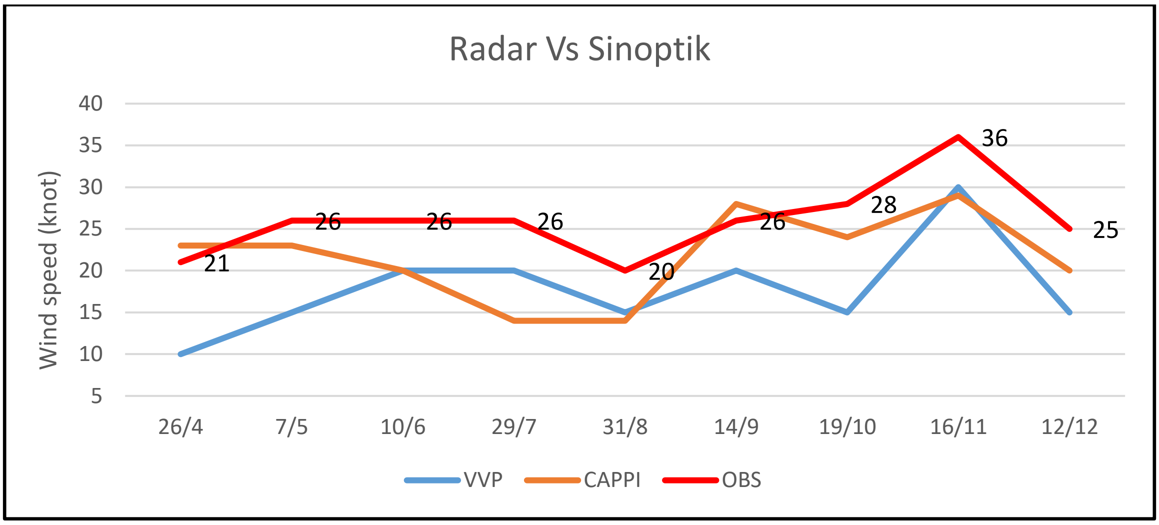


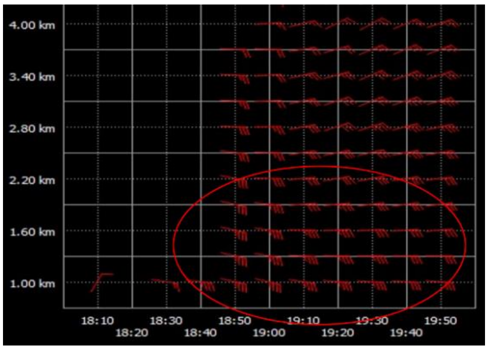
Figure 4. Comparison of wind data from radar and synoptics.

3.2 Echo pattern analysis of 3 date of the strongest wind events

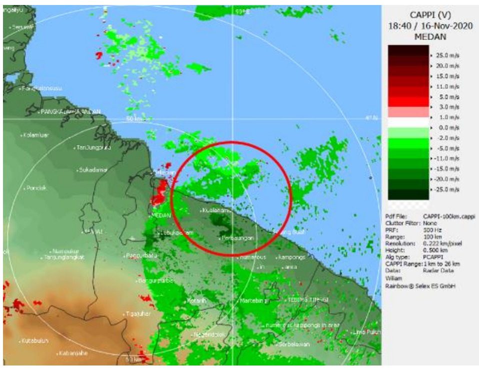
1. November 16 2020 (wind speed 36 knot)

Figure 5 shows the VVP, CAPPI V, and PPI products on November 16 2020. In figure 5a the peak of strong winds occurred at 18.40UTC or 01.40 WIB and lasted until 19.50UTC or 02.50 WIB (early morning) in the atmospheric layer at a height of 1 Km – 2 Km. The duration of the strong winds lasted 70 minutes. Strong winds blowing at a speed of 15-30 knots, consistent and uniform wind direction moving from East to Southeast. From figure 5b of the CAPPI V product during the strong wind incident on 16 November 2020, a green dot can be seen at 18.40UTC or 01.40 WIB (early morning) in the Kualanamu area. The Strong wind is green, which means the wind direction is approaching the radar with a maximum wind speed of 15 m/s or 30 knots.

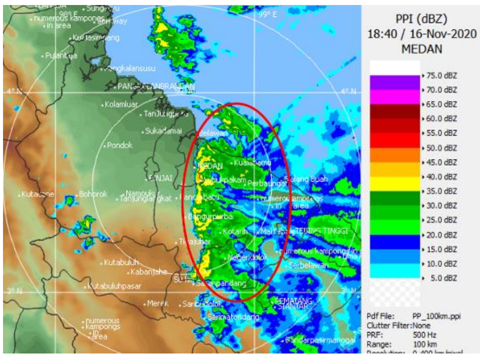
Strong winds on the surface were observed in the SPECI report at 18.18 UTC with a wind direction from the East (110°) and a wind speed of 26 Knots Gusty 36 Knots. The winds on the radar are observed 20 minutes later than the synoptic observations. In Figure 5c, the echo pattern shows a collection of clouds that are elongated in the form of a line moving from east to west. The radar echo intensity ranges from 15-45 dbz. This echo pattern is known as a squall line (Bluestein, et all., 1985). This cloud pattern has the potential for strong winds, heavy rain and hail.



(a) VVP Nov 16 2020 at 14.20 -16.00 UTC



(b) CAPPI V Nov 16 2020 at 18.40 UTC

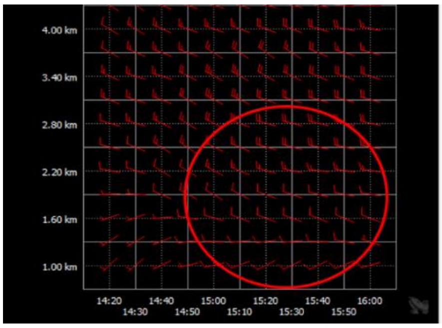


(c) PPI Nov 16 2020 at 18.40 UTC

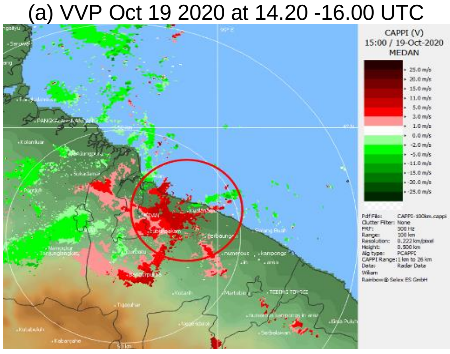
Figure 5. Radar Product November 16 2020

2. October 19 2020 (wind speed 28 knot)

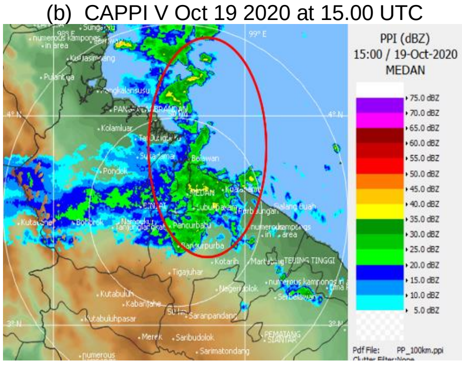
Figure 6 shows the VVP, CAPPI V, and PPI products on October 19 2020. In figure 6a the atmospheric layer at a height of 1 - 2 km strong winds begin to appear at 15.00 UTC or 22.00 WIB and last until 15.50 UTC or 22.50 WIB (at night). The wind is blowing at a uniform speed of 10 - 15 knots from the West to East. The duration of the strong winds lasted for 50 minutes. In figure 6b of the CAPPI V product at an altitude of 500 meters at 15.00 UTC, a wind speed of 10 - 22 knots is observed with the wind direction away from the radar (red) in the Kualanamu airport area. Strong winds on the surface were observed in the METAR report at 15.00 UTC with wind direction from the West (270°) and wind speed 12 Knots Gusti 28 Knots. Radar can read strong winds at the same time with synoptic observations. In figure 6c. The echo pattern shows an elongated grouped cloud pattern shaped like a squall line. This echo pattern is known as a squall line (Bluestein, et all., 1985). This cloud pattern has the potential for strong winds, heavy rain and hail. The radar echo intensity ranges from 15-40 dbz.



(a) VVP Oct 19 2020 at 14.20 -16.00 UTC



(b) CAPPI V Oct 19 2020 at 15.00 UTC

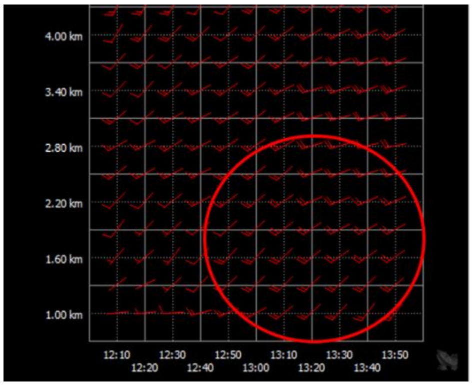


(c) CAPPI V Oct 19 2020 at 15.00 UTC

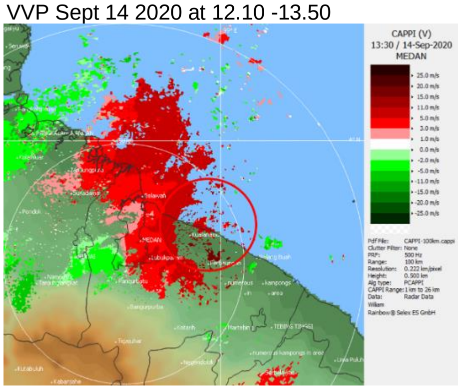
Figure 6. Radar Product October 19 2020

3. September 19 2020 (wind speed 28 knot)

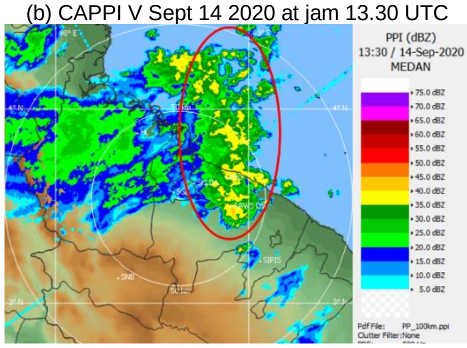
Figure 7a shows that the peak of strong winds occurred at 13.00 UTC or 20.00 WIB and lasted until 13.50 UTC or 20.50 WIB (at night) in the atmospheric layer at a height of 1-2 km. The wind moves uniformly from the West - Southwest direction at a speed of around 10-20 Knots. The duration of the strong winds lasted for 50 minutes. In figure 7b of the CAPPI V product at an altitude of 500 meters at 13.30 UTC, wind is observed with a speed of 13.9 m/s or around 28 Knots with the wind direction away from the radar (red) in the Kualanamu airport area. Meanwhile, from synoptic observations, strong winds on the surface were reported in SPECI at 13.10 UTC with winds blowing from the west (260°) at a speed of 26 Knots. Radar can read maximum winds about 10 minutes faster than synoptic observations. Meanwhile in figure 7c. The echo pattern shows elongated grouped clouds shaped like lines (Bluestein, et all., 1985). The radar echo intensity ranges from 15-40 dbz.



(a) VVP Sept 14 2020 at 12.10 -13.50



(b) CAPPI V Sept 14 2020 at jam 13.30 UTC



(c) PPI 2020 Sept 14 at 13.30 UTC

Figure 7. Radar Product September 14 2020

4. Conclusion

Weather radars can predict strong winds, which can cause significant damage. VVP and CAPPI V products can be used to determine strong winds that occur in Kualanamu. VVP effectively monitors the vertical wind profile. Meanwhile, horizontally, CAPPI V is capable of properly analyzing Kualanamu's maximum wind speed. The PPI sweep 1 product can be used to view echo squall line patterns. Strong wind events in Kualanamu in 2020 predominantly occurred at afternoon, night until early morning but dominant in afternoon to night time. It's because of the diurnal heating during the day, instability of atmosphere and the influence of sea/land breeze. The duration of strong winds lasts around 50-70 minutes. Wind speed observations using radar tend to be of smaller value than observation results. So when VVP and CAPPI V the radar shows a wind speed greater than 15 knots, forecasters can immediately make an early Aerodrome warning of strong winds.

Acknowledgements

We thank to Meteorological Climatology and Geophysical Agency (BMKG) for providing the radar raw data. We also thank colleagues of BMKG Kualanamu for the synoptic data and support.

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