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Correlation Of Atmospheric Lability Index to Vertical Wind Shear at I Gusti Ngurah Rai Airport

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ABSTRACT

Wind shear is a condition that is detrimental to aircraft because it can cause the aircraft to experience lift, especially during take-off or landing, where wind shear can occur due to bad and unstable weather, so research on the correlation of the atmospheric lability index to wind shear is very important to prevent a plane crash. This research aims to determine the magnitude of the correlation of the atmospheric lability index to the vertical wind shear that occurs at I Gusti Ngurah Rai Airport, Bali. In this research, the Wind Profiler Radar (WPR) brand scintec LAP-3000 was used to obtain wind shear data in the form of wind direction and wind speed data then radiosonde to obtain atmospheric lability index data in the form of Lifted Index (LI), Total-Totals Index (TT), K-Index (KI), and Convective Available Potential Energy (CAPE) index values for each month in 2019-2020. Wind shear measurement was carried out at an altitude of 100-3000 m and data were taken on the difference in wind direction ≥ 60^o and the difference in wind speed ≥ 10 knots. Meanwhile, measurement of the atmospheric lability index is carried out by a flying air balloon that has been equipped with a transmitter. All LI, TT, KI, and CAPE index value data and the number of wind shear events were analyzed with Pearson Product Moment correlation. The value of the correlation coefficient (r) between the LI, TT, KI, and CAPE indices was obtained for successive wind shear events of -0.786; 0,250; 0.738, and 0.713. These results show that the LI, KI, and CAPE index values can be used as a reference to predict wind shear events because they have a strong correlation, obtaining a correlation value between 0.60 to 0.79 compared to the TT index.

Introduction

I Gusti Ngurah Rai Airport has a runway that is directly adjacent to the sea. Where land and oceans have different heat capacities, causing differences in temperature and pressure between the two systems. The difference in air pressure between the two systems causes wind shear. Wind shear is defined as the change in direction and changes in wind speed per unit distance close to the surface, wind shear take on different wind directions ≥ 60^o and the difference in wind speed ≥ 10 knots [1]. The impact of wind shear that occurs on the surface layer of the runway up to an altitude of 3000 m is very important for aircraft, especially during take-off and landing [2]. Wind shear is very dangerous if it occurs in adjacent air layers because it can cause the aircraft to lose lift. If the airflow at the top and bottom of the aircraft is different, there will be a pressure difference on the top and bottom surfaces of the fuselage which can cause turbulence [3].

Information on weather parameters such as the atmospheric lability index can indicate atmospheric conditions and predict the weather to storms that can cause wind shear [4]. The way to predict atmospheric phenomena is through analysis of upper air conditions from the sounding results (vertical distribution of temperature, humidity, wind speed, and direction at a place) [5]. The sounding data recording will obtain an atmospheric lability index, this index is used to predict and estimate atmospheric phenomena such as storms that can cause wind shear [6]. So if the index value obtained is large enough within the range of values determined by the WMO, then it can be predicted that the weather will be unstable for the next 12 hours which allows storms to occur and triggers the appearance of wind shear, then the atmospheric lability index value will be very useful in preparing early warning of wind shear events due to the growth of storm clouds at I Gusti Ngurah Rai Airport.

From the description above, it is necessary to research the period of occurrence of vertical wind shear and the relationship between the atmospheric lability index and vertical wind shear at I Gusti Ngurah Rai Airport.

Observation Method

The data used in this research were radar wind profiler data and radiosonde data every day throughout 2019-2020. The research will be conducted in the city of Badung, where the research point was taken at I Gusti Ngurah Rai Meteorological Station. Wind profiler radar data in the form of wind direction and wind speed data is obtained automatically so that it can find out the incidence of vertical wind shear every day. Air observation data on radiosonde in the form of weather parameter data obtained by flying a balloon that has a transmitter installed which will analyze weather conditions so that the atmospheric lability index value is obtained which can be displayed visually using the Rawinsonde Observation Programs (RAOB). RAOB is a program used to plot rawinsonde data and calculate various indices or parameters to analyze atmospheric conditions. The atmospheric lability index values used are LI, TT, KI, and CAPE. To calculate the Lifted Index (LI), can use equation [1].

$$LI = T_{500} - T_{P\,500} \quad (1)$$

Where T_{500} is the atmospheric temperature to the surface at a pressure of 500 mb (°C), T_{p500} is the temperature of the atmospheric parcel to the surface at a pressure of 500 mb (°C). To calculate the Total-Totals Index (TT), can use equation [2].

$$TT = (T_{850} - T_{500}) + (T_{d\,850} - T_{500}) \quad (2)$$

Where T_{850} is the atmospheric temperature to the surface at a pressure of 850 mb (°C), T_{500} is the atmospheric temperature to the surface at a pressure of 500 mb (°C), $T_{d\,850}$ is the dew point temperature at a pressure of 850 mb (°C). To calculate the K-Index (KI), can use equation [3].

$$KI = (T_{850} - T_{500}) + \left(T_{d\,850} - (T_{700} - T_{d\,700})\right) \quad (3)$$

Where T_{850} is the atmospheric temperature to the surface at a pressure of 850 mb (°C), T_{500} is the atmospheric temperature to the surface at a pressure of 500 mb (°C), $T_{d\,850}$ is the dew point temperature at a pressure of 850 mb (°C), T_{700} is the atmospheric temperature to the surface at a pressure of 700 mb (°C), $T_{d\,700}$ is the dew point temperature at a pressure of 700 mb (°C). To calculate the Convective Available Potential Energy (CAPE) Index, can use equation [4].

$$CAPE = \int_{Z_{LFC}}^{Zmax} g \frac{T_{parcel}-T_{env}}{T_{env}} dz \qquad (4)$$

Where Z_{max} is maximum height (m), Z_{LFC} is level free convection (m), g is gravity (m/s²), T_{parcel} is air parcel temperature (°C), and T_{env} is environment temperature (°C).

After data processing, an analysis of the vertical wind shear occurrence and the correlation of the atmospheric lability index value to the vertical wind shear was carried out, strong atmospheric lability index correlation value can be used as a reference for predicting vertical wind shear events. A Pearson Product Moment correlation analysis was carried out to see how strong the correlation between the atmospheric lability index value was obtained with the vertical wind shear that occurred throughout 2019-2020 using the software IBM SPSS Statistics 26. To calculate the Pearson Product Moment correlation coefficient (r), can use equation [5].

$$r = \frac{\sum_{i=1}^{n}(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i-\bar{x})^2 \sum_{i=1}^{n}(y_i-\bar{y})^2}} \qquad (5)$$

Where x is the atmospheric lability index, y is wind shear events, and n is the amount of data.

Result and Discussion

Based on this research, data on wind shear events for 2019-2020 were obtained from radar wind profiler data presented in Figures 1 to 3.

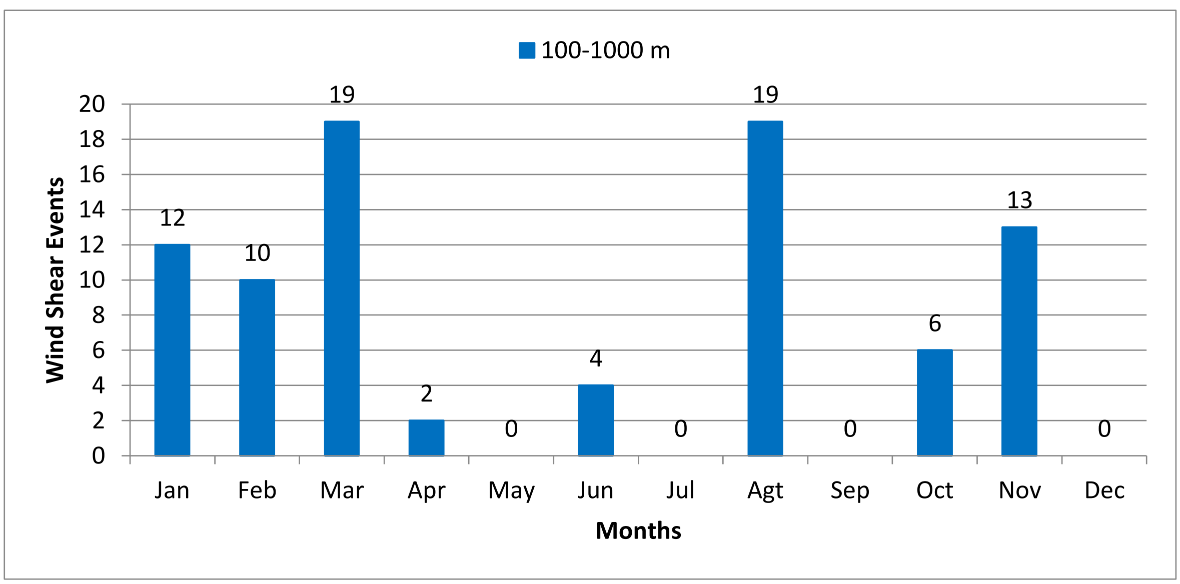

Figure 1. Graph of wind shear occurrence at the height of 100-1000 m in 2019-2020.

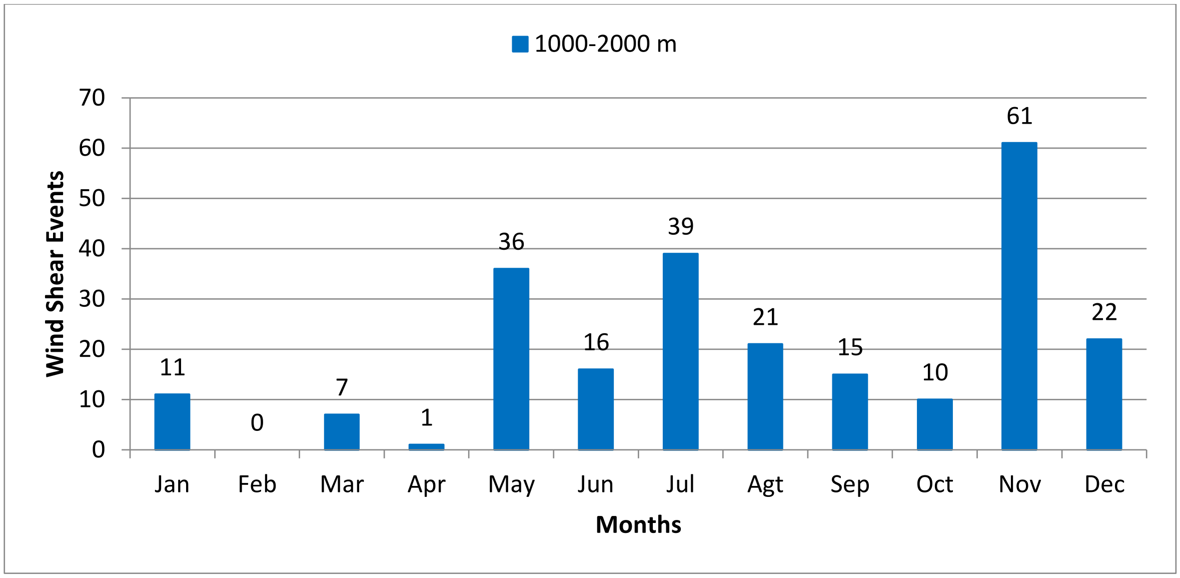

Figure 2. Graph of wind shear occurrence at the height of 1000-2000 m in 2019-2020.

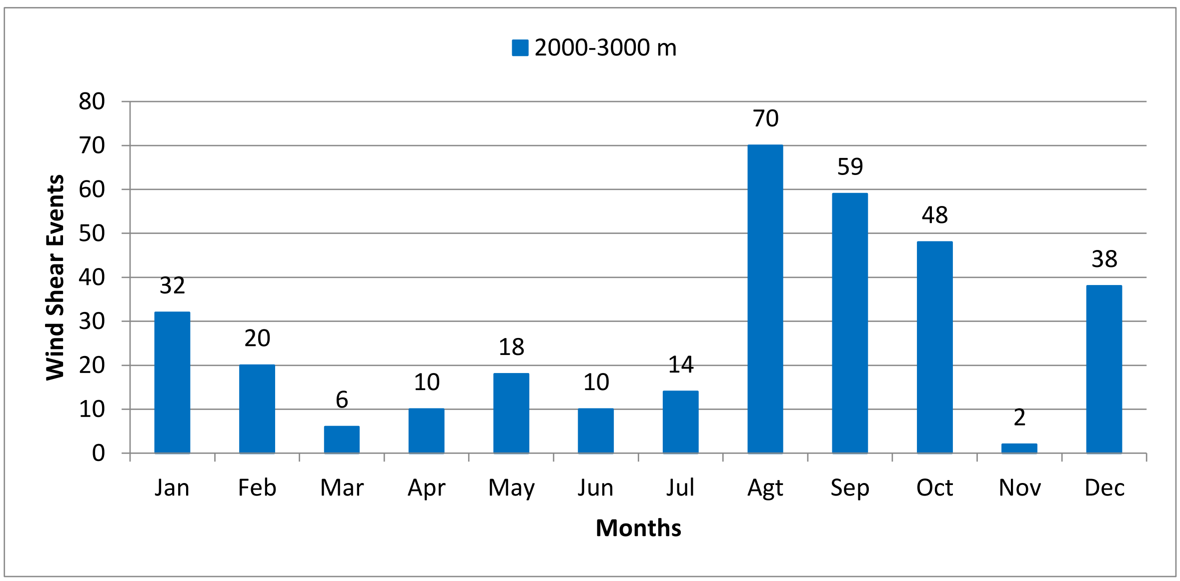

Figure 3. Graph of wind shear occurrence at the height of 2000-3000 m in 2019-2020.

In Indonesia, the division of seasons is carried out based on the annual phase into four parts, namely December-January-February (DJF) which is the rainy season that is influenced by the movement of the western monsoon wind that crosses Indonesia by bringing cold and humid air, March-April-May (MAM) which is the transition season (transition from the rainy season to the dry season), June-July-August (JJA) is a dry season influenced by the movement of eastern monsoon winds that cross Indonesia that bring hot and dry air, and September-October-November (SON) which is the transition season (transition from dry to the rainy season) [6]. From the results shown in Figure 1, many vertical wind shear events at an altitude of 100-1000 m occurred in 2019-2020 in March and August, as many 19 incidents. Then in Figure 2 vertical wind shear events at an altitude of 1000-2000 m occur a lot in November, as many 61 events. Meanwhile, Figure 3 the wind shear event that occurred in 2019-2020 often occurred in August at an altitude of 2000-3000 m from the ground level. This is because the JJA (June, July, August) seasonal period occurs easterly winds that carry a little water vapor so that there is a dry season and the peak occurs in August. In the dry season, there is a rise in sea surface temperature which produces very strong winds that trigger a wind shear [7]. Meanwhile, wind shear events in April are very rare. This is because the seasonal period of MAM (March, April, May) is a transition condition from the rainy season to the dry season those wind shear events due to storms rarely occur [8]. Data on the atmospheric lability index for 2019-2020 were obtained from radiosonde data presented in Figure 4.

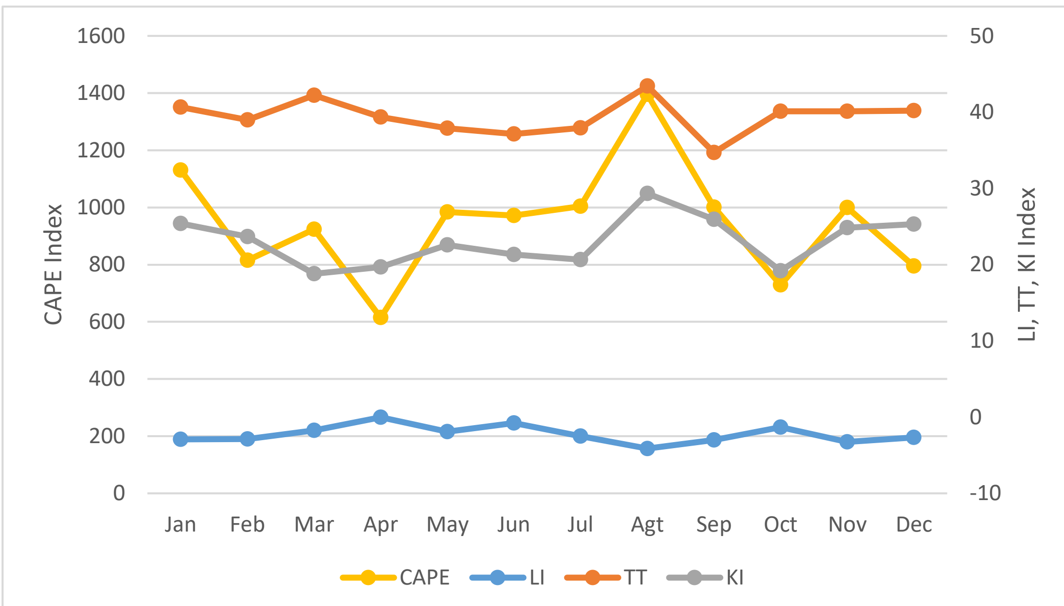

Figure 4. Graph of the atmospheric lability index for 2019-2020.

The results showed that the atmospheric lability index in August 2019-2020 indicated that the atmosphere was unstable enough to trigger the appearance of storms that could cause wind shear. The average value of the LI index in August throughout 2019-2020 was -4.13^{o}C which indicates the difference in atmospheric parcel temperature with a large enough ambient temperature stating that weather conditions are quite unstable [9]. Meanwhile, the average value of the TT index is 43.43^{o}C which shows the difference in temperature and humidity that occurs between the atmosphere triggering a storm [10]. For the average KI index value throughout 2019-2020, it was obtained at 29.33^{o}C which shows the convective motion of the cloud due to the temperature difference between the atmosphere so that the potential for the appearance of storm clouds is quite high [11}. The average value of the CAPE index obtained at 1395.25 J/Kg shows that the convection process of air masses rises vertically warmer than the surrounding air, causing atmospheric instability [12].

The calculation of the correlation coefficient is used to find out how much the correlation between the wind shear that occurs and the values of the atmospheric lability index, the wind shear data used is the data at all altitudes shown in Figure 1-3 and the atmospheric lability index values are shown in Figure 4. So that the results of calculating the correlation coefficient are shown in Table 1.

Table 1. The correlation coefficient of the LI, TT, KI, and CAPE indices to wind shear events in 2019-2020.

Atmospheric Lability Index	Correlation Coefficient (r)	Parameters	Description
LI (^oC)	-0,786	Strong	Negative
TT (^oC)	0,250	Weak	Positive
KI (^oC)	0,738	Strong	Positive
CAPE (J/Kg)	0,713	Strong	Positive

Based on the results obtained the value of the correlation coefficient (r) between the LI, TT, KI, and CAPE indices to successive wind shear events of -0.786; 0,250; 0.738, and 0.713. The value of the correlation coefficient of -0.786 indicates that the correlation between the LI index and wind shear events includes a strong correlation and is negative, meaning that the smaller the LI index, the greater the number of wind shear events [13]. Furthermore, the value of the correlation coefficient of 0.250 on the TT index indicates that the strength of the correlation of the TT index with the wind shear event is weak [14]. Then the values of the correlation coefficients of 0.738 and 0.713 indicate that the correlation of the KI and CAPE indices to the wind shear event is strong, so from the results obtained, it can be stated that the LI, KI, and CAPE indices can indicate atmospheric conditions that have the potential to trigger the emergence of storms that cause vertical wind shear [15].

Conclusion

Based on the research that has been done, it is obtained that vertical wind shear events that occurred at I Gusti Ngurah Rai Airport in 2019-2020 occurred more frequently in August at an altitude of 2000-3000 m. This is because, during the JJA seasonal period, there are east winds that carry a little water vapor resulting in a dry season and the peak occurs in August. In the dry season, there is an increase in sea surface temperature which results in very strong winds that trigger wind shears. In addition, the values of the LI, KI, and CAPE indices in August were quite large indicating that wind shear events occurred more frequently during 2019-2020 due to unstable weather. So wind shear events occur more often so that they have a stronger correlation between wind shear events and LI, KI, and CAPE index values compared to the TT index.

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