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Determination of Air Stability Parameter Threshold Value for Cumulonimbus and Thunderstorm Cloud Events at Kualanamu Meteorological Station

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ABSTRACT

Many studies have carried out calculations related to atmospheric lability as a reference in weather forecasts, especially cumulonimbus clouds, and thunderstorms. However, many air lability index values are found to be inappropriate in each region because conditions in each region are different from each other in the region. So it is necessary to use precise index thresholds to determine weather conditions. In the study, observational data and data from Showalter Index (SI), Lifted Index (LI), K Index (KI), Severe Weather Threat Index (SWEAT), and Convective data were used. Available Potential Energy (CAPE) for ten years (2013-2022), then statistical calculations and verification for one year (2022) are carried out. The results obtained are the atmospheric stability index with the best accuracy in predicting the presence of cumulonimbus clouds and thunderstorms at the Kualanamu Meteorological Station, Deli Serdang is the best LI index to predict TS 00 and TS 12, and the best KI index to predict CB 00 and CB 12.

Keywords: Cumulonimbus, Thunderstorm, Stability index, Threshold, Meteorogical Station

ABSTRAK

Banyak penelitian telah melakukan perhitungan terkait labilitas atmosfer sebagai acuan dalam prakiraan cuaca, khususnya awan cumulonimbus, dan badai petir. Namun, banyak ditemukan nilai indeks labilitas udara yang tidak sesuai di setiap wilayah karena kondisi di setiap wilayah berbeda satu sama lain di wilayah tersebut. Sehingga perlu menggunakan ambang batas indeks yang tepat untuk menentukan kondisi cuaca. Dalam penelitian tersebut digunakan data observasi dan data dari Showalter Index (SI), Lifted Index (LI), K Index (KI), Severe Weather Threat Index (SWEAT), dan data Konvektif. Energi Potensial Tersedia (CAPE) selama sepuluh tahun (2013-2022), kemudian dilakukan perhitungan statistik dan verifikasi selama satu tahun (2022). Hasil yang diperoleh adalah indeks kestabilan atmosfer dengan akurasi terbaik dalam memprediksi keberadaan awan cumulonimbus dan badai petir di Stasiun Meteorologi Kualanamu, Deli Serdang adalah indeks LI terbaik untuk memprediksi TS 00 dan TS 12, serta indeks KI terbaik untuk memprediksi CB. 00 dan CB 12.

Kata Kunci: Cumulonimbus, Badai Petir, Indeks Stabilitas, Threshold, Stasiun Meteorologi

1. Introduction

Based on the recording of the Lightning Detection device at the Class 1 Geophysical Station Deli Serdang, there were 20,390 thunderstorm phenomena in the last week or the period from October 26 to November 1, 2020, caused by unstable atmospheric conditions due to strong convection and convergence, resulting in the lifting of air masses which can then expand vertically to create convective clouds, One of them is cumulonimbus clouds that produce thunderstorms [1].

Many air lability index values are not appropriate in a region because the conditions of each region are different from one region [1], so it is necessary to calculate a threshold that has high accuracy in predicting the presence of cumulonimbus and thunderstorm clouds well in the region for an index that characterizes the potential formation of cumulonimbus and thunderstorm clouds (SI, LI, KI, SWEAT, and CAPE) [1].

Based on this background, this study was conducted to find the threshold values of the SI, LI, KI, SWEAT, and CAPE indices to find out the best index that can be used to predict the presence of cumulonimbus clouds and thunderstorms in the Deli Serdang area.

2. Method

2.1. Data

The data processing in this study is upper air and surface air observation data at the time of thunderstorms and cumulonimbus clouds from the Kualanamumu Meteorological Station for ten years from 2013 to 2022. Top air observation data were collected during thunderstorms and cumulonimbus clouds at 00 UTC and observations at 12 UTC to see SI, LI, KI, SWEAT, and CAPE index values during thunderstorms and cumulonimbus clouds.

The synoptic data used for the analysis of thunderstorm events and cumulonimbus clouds is the current weather code 7www1w2 with passwords 13, 17, 91, 92, 93, 94, 95, 96, 97, 98, and 99, while for cumulonimbus cloud analysis using the 8NhClCmCh section CL password with passwords 3 and 9 [2].

2.2. Processing

The data processing techniques in this study are as follows:

1) The upper erial observation data was processed using the RAOB 5.7 application to obtain SI, LI, KI, SWEAT, and CAPE index values [3].
2) Data from observations of thunderstorms and cumulonimbus clouds were then grouped with RAOB 5.7 results according to time. Then separated by periods December, January, February (DJF), March, April, May (MAM), June, July, August (JJA), and September, October, and November (SON) [4-7].
3) Determine the threshold value according to the Sturges Equation which given in equation (1) to (3) [8,9]:

$$k = 1 + 3.322 \log \log n \tag{1}$$

$$R = X_n - X_t \tag{2}$$

$$i = \frac{(R)}{(k)} \tag{3}$$

where k is number of class intervals, n is amount of observational data, r is range, X_n is big data, X_t is small data, and i is class interval length.

4) Verify the value of the air lability parameter index for weather phenomena using the new Threshold. Verification is carried out using 2022 data. In verification, a 2 × 2 contingency table is used to see the level of accuracy of weather predictions.

Tabel 1. Contingency forecast table - results of observations [8].

		OBSERVATIONS		
		Yes	No	TOTAL
FORECAST	Yes	Hits (H)	False Alarms (FA)	Forecast ’Yes’
	No	Misses (M)	Correct Negatives (CN)	Forecast ‘No’
	TOTAL	Forecast ‘Yes’	Forecast ‘No’	TOTAL

3. Results and Discussion

3.1. Threshold Value

Tabel 2. Threshold value of atmospheric stability index of Kualanamu Meteorological Station December, January, February (DJF).

	Index				
	LI	SWEAT	KI	SI	CAPE
TS 00	-1.98	190.01	34.6	-0.12	0
TS 12	-3.13	209.9	34.4	-0.08	942.33
CB 00	-2.38	191.71	32.9	-1.32	0
CB 12	-3.21	205.7	35.1	-0.78	316.4

Tabel 3. Threshold value of atmospheric stability index of Kualanamu Meteorological Station March, April, May (MAM).

	Index				
	LI	SWEAT	KI	SI	CAPE
TS 00	-3.15	200.6	32.6	-1.61	628.6
TS 12	-3.46	200.71	34.3	-1.54	699.4
CB 00	-2.75	202.81	34.1	-1.11	540.4
CB 12	-3.76	207.81	34.7	-0.88	1223.4

Tabel 4. Threshold value of atmospheric stability index of Kualanamu Meteorological Station June, July, August (JJA).

	Index				
	LI	SWEAT	KI	SI	CAPE
TS 00	-4.05	200.1	35.9	-0.56	0
TS 12	-3.42	221.58	37.3	-2.27	822.8
CB 00	-3.77	205.1	34.7	-1.17	0
CB 12	-4.05	219.78	35.9	-2.06	0

Tabel 5. Threshold value of atmospheric stability index of Kualanamu Meteorological Station September, October, November (SON).

	Index				
	LI	SWEAT	KI	SI	CAPE
TS 00	-2.36	195	35	-0.13	0
TS 12	-3.67	198.7	34.1	-0.78	932.4
CB 00	-2.36	198.3	33.8	-0.57	0
CB 12	-3.07	180.02	33	-0.08	339

The threshold value when cumulonimbus clouds begin to occur at LI values < -4.05 to -2.36; according to [10,11], this value allows very strong storms, even accompanied by tornadoes. The threshold value when cumulonimbus clouds begin to appear at SWEAT values > 180.02 to 219.78, this value is based on the category of Wirjohamidjojo and Swarinoto (2013) in the category of allowing cumulus cloud growth. Cumulonimbus clouds occur at KI threshold values > 32.9 to 35.9 in the SON period. The SI threshold value at the time of cumulonimbus clouds is SI < -2.06 to -0.08; this value has a weak level of volatility and the possibility of small storms [10]. The CAPE threshold value shows cumulonimbus clouds occur at CAPE > 0 to 1223.4, where according to Zakir, CAPE values < 1000 indicate weak atmospheric instability, while CAPE values of 1000 – 2500 indicate moderate atmospheric instability [10,12].

The threshold value of thunderstorm events began to occur at LI < -3.67 in the SON period up to -2.96, where according [13–15], the value of 0 < LI < - 2 indicates that storms can occur and require good storm support mechanisms and -3 < LI < -5 indicates an unstable atmosphere and allows storms to occur. The threshold value for thunderstorm events began to occur in SWEAT > 190.01 to 221.58; this value is based on the categories of [12] and included in the category of enabling cumulus cloud growth. Thunderstorm events occur at KI threshold values > 32.6 to 34.3 in the MAM period, where according to Wirjohamidjojo and Swarinoto (2013), KI values in the range of 31-35 allow thunderstorms with a percentage of events of 61 to 80% and KI with a range of 36-40 allow thunderstorms to occur. Thunderstorms percentage is 81 – 90%.

The SI threshold value at the time of a storm is SI < -0.13 to -2.27; this value has a weak level of volatility, according to Zakir [10]. The CAPE threshold value indicates that storms occur at CAPE > 0 to 942.33, whereas according to Zakir, this value indicates weak atmospheric instability [9,10].

3.2. Verification

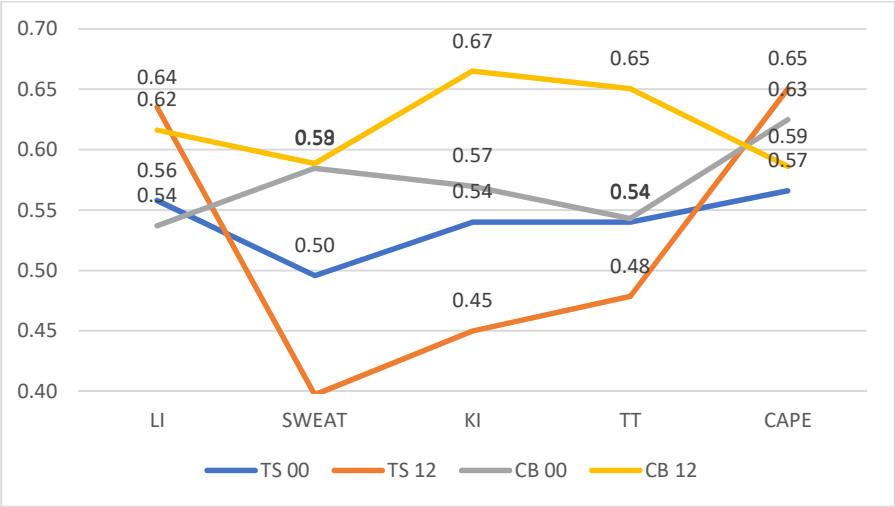


Figure 1. The accuracy value of the atmospheric stability index when cumulonimbus clouds are present at the Kualanamu Meteorological Station.

The verification results show the accuracy value of each atmospheric stability index. At 00 UTC during the cumulonimbus cloud, the CAPE index showed the highest accuracy value compared to other atmospheric stability indices with an accuracy value of 0.63, and the thunderstorms also had the same highest accuracy value, the CAPE index of 0.57. At 12 UTC for cumulonimbus cloud events, the highest accuracy index value was the KI index with an accuracy value of 0.67, and the thunderstorm event was the CAPE index with an accuracy value of 0.65.

4. Conclusion

The difference in threshold values during TS 00, TS12, CB 00, and CB 12 events in the period December,January, February (DJF), March, April, May (MAM), June, July, August (JJA), and September, October, November (SON) at the Meteorological Station Kualanamu Meteorological Station, Deli Serdang illustrates different index values influenced by atmospheric conditions in each period and atmospheric stability index with the best accuracy value in predicting the presence of cumulonimbus clouds and thunderstorms in Kualanamu Deli Serdang Meteorological Station is the best LI index for predicting TS 00 and TS 12. The KI index is best for predicting CB 00 and CB 12.

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