Use of multivariate techniques in the analysis of instability indices and lightning in the summer of 2008/2009

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ABSTRACT: Severe convective storms are capable of producing hail, gusty winds and lightning also accumulated significant rain. Weather systems are difficult to predict due to its short duration (hours). However, indices are used in meteorology of instability that are based on vertical profiles of temperature, humidity and wind synthesizing some thermodynamic characteristics and wind shear typical convective situations. In this work we used vertical profiles obtained at two airports in the Galeão/RJ and Campo de Marte/SP as well as the daily amount of lightning in the vicinity of the airports within a radius of 200 km, from November 2008 to March 2009. In literature there are various levels of instability each one with its proper and particular potential in predicting certain weather systems. Due to the large amount of instability indices, multivariate techniques were used to analyze these indices in order to correlate some of them that can identify a higher number of lightning associated with severe convective storms. The use of multivariate techniques is a common method to reduce the number of variables that can explain certain phenomena according to factors that are assigned to each variable. In a first analysis, the K indices, CAPE and LI seem to indicate a good correlation with the observed lightning activity at both airports.

1. INTRODUCTION

The study of severe storms has been broached in different ways related to theirs structure, formation and evolution. According to Johns and Doswell Moller [1992] and Moller [2001] the better way to define a storm is when this meteorological system is able to produce hail of 2cm or above and/or jet stream and/or tornados with lightning activity almost ever associated with it. Several techniques can be used to study the storms, depending on the goal. One of most used technics involve the calculation of instability indices that consider vertical profiles of temperature and atmospheric humidity through radiosounding or calculated by atmospheric numeric models. However, in order to improve the forecasts is necessary the use of different techniques that can refine the data without loss of information.

2. MATERIALS AND METHODS

In this work were used instability indices calculated from atmospheric temperature profile and humidity at two airports in Brazil, Campo de Marte/SP and Galeão/RJ for the period from November 2008 to March 2009. The used profiles were composed by two observations per day during the studied period.

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However, only observations from 12 UTC were used in this work.

The lightning data were provided by Brazilian lightning detection network (BrasilDat) [Pinto Jr. et al., 2006a,b, 2007]. The data are summarized to the total detected lightning to 200 km of radius around of the two cited airports. In order to verify the influence of each instability index on the number of lightning detected we used factor analysis by Principal Components Analysis. This statistic technique allows the reduction of the number of variables without loss the capacity to explain the variables in a smaller number of variables (factors).

3. RESULTS AND DISCUSSION

The Principal Component Analysis was applied to the instability indices data. The total explained variance is presented on Table 1 showing that the greatest part of total variance is explained by the two firsts components explain computing 79.1% of total variation.

Table 1 – Total Explained Variance

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5,632	56,317	56,317	5,632	56,317	56,317
2	2,279	22,795	79,111	2,279	22,795	79,111
3	,964	9,640	88,752			
4	,623	6,235	94,986			
5	,280	2,795	97,782			
6	,163	1,628	99,410			
7	,036	,360	99,770			
8	,017	,175	99,945			
9	,005	,048	99,993			
10	,001	,007	100,000			

Table 2 – Component Matrix – Extraction Method: Principal Components Analysis.

	Component	
	1	2
Showalter index:	-,932	,080
Lifted index:	-,935	,119
LIFT computed using virtual temperature:	-,937	,093
SWEAT index:	,667	,233
K index:	,875	-,199
Totals totals index:	,864	-,191
Convective Available Potential Energy:	,706	,397
CAPE using virtual temperature:	,740	,418
Convective Inhibition:	-,050	,949
CINS using virtual temperature:	-,091	,941

The first component explains well the first three indices [Showalter, Lifted Index and LIFT (virtual temperature)] due the high correlation values (values close to1 or -1). The next index with good correlation was the K index. According to the Table 2 and considering the second component, the CINE index also can be considered significant due the high correlation value (0.949).

Through factor analysis, is possible to analyze the communalities among the variables, in other words, the variation proportion of each explained variable by common factors (Table 3).

Table 3 – Communalities – Extraction Method: Principal Component Analysis.

	Initial	Extraction
Showalter index:	1,000	,874
Lifted index:	1,000	,887
LIFT computed using virtual temperature:	1,000	,886
SWEAT index:	1,000	,499
K index:	1,000	,806
Totals totals index:	1,000	,783
Convective Available Potential Energy:	1,000	,657
CAPE using virtual temperature:	1,000	,722
Convective Inhibition:	1,000	,903
CINS using virtual temperature:	1,000	,894

The similarities are significant when after the variable extraction it value is close to 1 (initial values). Values less than 0.6 should be ignored if the numbers of the sample remain constant. Therefore, the most significant indices are the CINE, Showalter, Lifted and K index.

4. CONCLUSIONS

The use of multivariate techniques allowed the reduction of variables (instability indices) that were related to the amount of lightning in the two airports in question, the Campo de Marte/SP and Galeão/RJ. It was possible to identify which the most important indices applied to the lightning activity through the explained variance to each component and commonality. According to results, the atmospheric instability indices that can be used to forecast severe storms associated with lightning are CINE, Showalter, Lifted and K index

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