ANALYSIS OF A STORM THROUGH RADAR AND RAWINSONDE SOUNDING FOR EQUATORIAL REGION

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1. Introduction

The city of Belem do Para in Brazil is located on the Equatorial region (Figure 1), which has as main characteristic the high moisture content present in the atmosphere due to the Amazon Forest and the proximity to the Equatorial Atlantic Ocean, together with the high temperatures, are two sets of factors that contribute to the formation of clouds of great vertical development of type *cumuliformes*, with consequent formation of severe storms, preferably in the less rainy season in the region (southern hemisphere winter). Thus, the thermodynamic state and the dynamic is essential for growth, development and maintenance of convective activity that occurs on the study region, so necessary to carry out studies on the vertical profile of the atmosphere in order to help predict incidence of these severe storms.

It is observed that in the operational area to assist in short-term prediction, the analysis of thermodynamics, through the indices of instability provided by rawinsonde sounding upper air, to the equatorial region has been shown to be good predictors. To do this, make it necessary to use more information such as those obtained from observations by weather radar that can add to a better analysis of weather information such as the height of the cloud top, the reflectivity of clouds, as well as identifying cells storms and its displacement. Oliveira Junior (2005) conducted a study in the city of Serpong-Indonesia using radar data (L band) and CAPE (Convective Available Potential Energy) to assist in short-term prediction, finding satisfactory results when the data are analyzed together.

Therefore, the purpose of this study is to analyze the behavior of indices of instability together with radar data to assist in the short term forescast - “NowCasting” - of a storm on June 20, 2011.

Figure 01 - Location of the city of Belem in Para State-BR.

2. Materials and Methods

In this study we used observational data from weather radar, rawinsonde sounding and accumulated rainfall of the day June 20, 2011 for the city of Belem is located north of Brazil in latitude 1 º 28 'S and Longitude 48 º 29' W.

The weather radar is of type S-band Doppler, located at latitude 01 ° 24 S and longitude 48 ° 27 'W, with the following specifications described in Table 01, which uses volumetric scans with 17 elevations with a range of 240 km in time of 8 minutes. To obtain the cell characterization of rain, we used a free software TITAN, developed by researchers at the National Center for Atmospheric Research (NCAR) in Boulder, USA, which uses a methodology using geostatistics centroid of the storm as it defines regions three-dimensional reflectivity exceeding a certain threshold and combining them in a logical manner, between two consecutive radar observations.

TITAN Applying the methodology, statistical data are extracted for each convective cell, identifying the location of each, the duration of the centroid position, speed and direction of the displacements, values of reflectivity in DBZ, precipitation in mm, height of cloud top , volume, area and others who are represented on maps of the region covered by the radar. Using routine TITAN TrackGridStats through which spatialize the data cell identified by allowing the inference of environmental influence on the characteristics of those cells identified patterns that can be used for quantification and characterization system allowing to identify patterns of thunderstorms over the tropical region.

Rawinsonde sounding data were obtained from the journal entry for aircraft in two different times, the 12UTU and 00 UTC, showing the vertical profile of the atmosphere through the information of temperature, humidity and wind. These data soundings were made available by the Department of Atmospheric Science at the University of Wyoming, and treated with the help of the GrADS which is a free software and free a System Data Visualization and Analysis of Grade Point - which was used scprits to plot the vertical profile of the atmosphere and calculate the index of instability.

The accumulated rainfall was provided by the automatic stations (accumulated time) and conventional (accumulated 24 hours) of the National Institute of Meteorology - INMET.

Frequency		2.75 GHz
Wavelength(λ)		10.9 cm
Beam Width		0.95°
Potency		830 kW
Satellite Dish		4.2 m
Gain		39 dB
Polarization		Horizontal
Receiver Sensitivity		-114 dBm
Resolution		125 m
Range	of intensity	480 km
	Speed	240 km
PRF	Intensities	250 Hz
	Speed	623 Hz
Pulse Width		1µ - 2µ
Antenna Rotation		0.1 - 36 degree/s

Table 01 - Characteristics of the meteorological radar of Belem, PA.

2.1 Indices of instability

The indices of instability parameters are based on information of the vertical profile of temperature, humidity and wind from the atmosphere and serve to assist in the short term forecasts operational centers. Examples of such indices are the K-TT Total Totals, Showalter - SH, Severe Weather Threat - SW instability by survey (Lifted Index) - LI, Cross Totals - CT, Vertical Totals - VT, convective available potential energy - CAPE , Energy Inhibition Convection - CINE Index and Tropical - IT, introduced by Perreira (2010), for the Tropical region. But for this work we used the following indexes:

a.) Index-TT Total Totals:

Using data obtained from rawinsonde sounding, it combines three basic information: the lapse-rate of average levels, the ambient humidity and ambient temperature in 850hPa at 500hPa.

TT analyzed separately to estimate is not appropriate for the prediction as a lapse-rate high in middle levels may lead to an average TT high even without the supply of moisture at low levels.

$$TT = T_{850} + T_{d850} - 2(T_{500}) \quad \text{eq. (1)}$$

where T850 is the air temperature of 850 hPa, 850 Td is the temperature of dewpoint in 850hPa and T500 is the air temperature at 500 hPa.

Total-Totals Index (°C)	***Interpretation***
< 43	stable weather
≥ 44	scattered storm
≥ 50	scattered and severe storm
> 56	severe storm

Tab. 02 – Critical values of the index TT . Fonte: https://twister.sbs.ohio-state.edu

b.) Index K

This index can be interpreted as a measure of thunderstorm potential based on the rate of vertical temperature change (lapse-rate), the moisture content in the lower atmosphere and the vertical extent of the moist layer. Being widely used to assess heavy rainfall, because the presence of moist layer at 850 and 700hPa implies quite precipitable water.

$$K = (T_{850} - T_{500}) + T_{d850} - (T_{700} + T_{d700}) \quad \text{eq.(2)}$$

where T850 is the air temperature at 850hPa, T500 is the air temperature at 500hPa, Td850 is the temperature of dew point in 850hPa, T700 is the air temperature at 700 700hPa and Td is the temperature of dewpoint in 700hPa .

K Index(°C)	*Interpretation*
20 - 25	Cb formation isolated
25 - 30	very scattered Cb formation
30 - 35	Cb formation scattered
> 35	formation of numerous Cb

Tab. 03 – Critical values of the index K. Fonte: https://twister.sbs.ohio-state.edu

c.) Lifted Index – IL:

This index analyzes the degree of atmospheric instability, especially when combined with the CAPE, where:

$$IL = T_{500} + T'_{500} \quad \text{eq. (3)}$$

where T500 is the ambient air temperature at 500 hPa eT500' is the temperature of an air parcel at 500 hPa after ascend.

Lifted Index (°C)	*Interpretation*
negative values of IL	unstable weather
< -5	very unstable
> -10	extremely unstable

Tab. 04 – Critical values of the index IL.

d.) Convective Available Potential Energy – CAPE:

Is the area of the positive and thermodynamic diagram can be used to check the condition of instability of the atmosphere. In other words, is the area between the pseudo-adiabatic and sounding, which is proportional to the kinetic energy that the air parcel gains of the environment. According to William and Renno (1993) CAPE evaluates the energy required to ascend an air parcel vertically and pseudo adiabatically the Level of free Convection to the level of neutral bouyancy.

According to Craven et al (2002) the CAPE should be calculated for two samples of the air parcel that ascends, since convection is not always triggered by parcel of surface . Thus were analyzed CAPE surface, referring to 100hPa from the surface layer and the CAPE unstable, that is covering the first 300hPa from the surface. Concluded that the CAPE where the surface is more representative of the convection initiated boundary layer, whereas the more unstable is best suited for high convection.

$$CAPE = \int_{NCE}^{NE} g\left(\frac{T_{vp} - \overline{T_v}}{\overline{T_v}}\right) dZ \quad \text{eq. (4)}$$

Where NCE is the level of spontaneous convection, NE equilibrium level, T_{vp} is the virtual temperature of an air parcel, T_v is the virtual temperature of the environment and g is the gravitational constant of Earth.

CAPE (J/Kg)	*Interpretation*
0	stable
0 - 1000	somewhat unstable
1000 - 2500	moderately unstable
2500 - 3500	very unstable
> 3500	extremely unstable

Tab. 05 – Critical values of CAPE. Fonte: https://twister.sbs.ohio-state.edu

The indices Showalter - SH and SW Severe Weather Threat were not analyzed in this study because there were good correlations with rainfall events, in other words, are not good predictors for the study region in the short term.

3. Analysis thermodynamic and dynamic

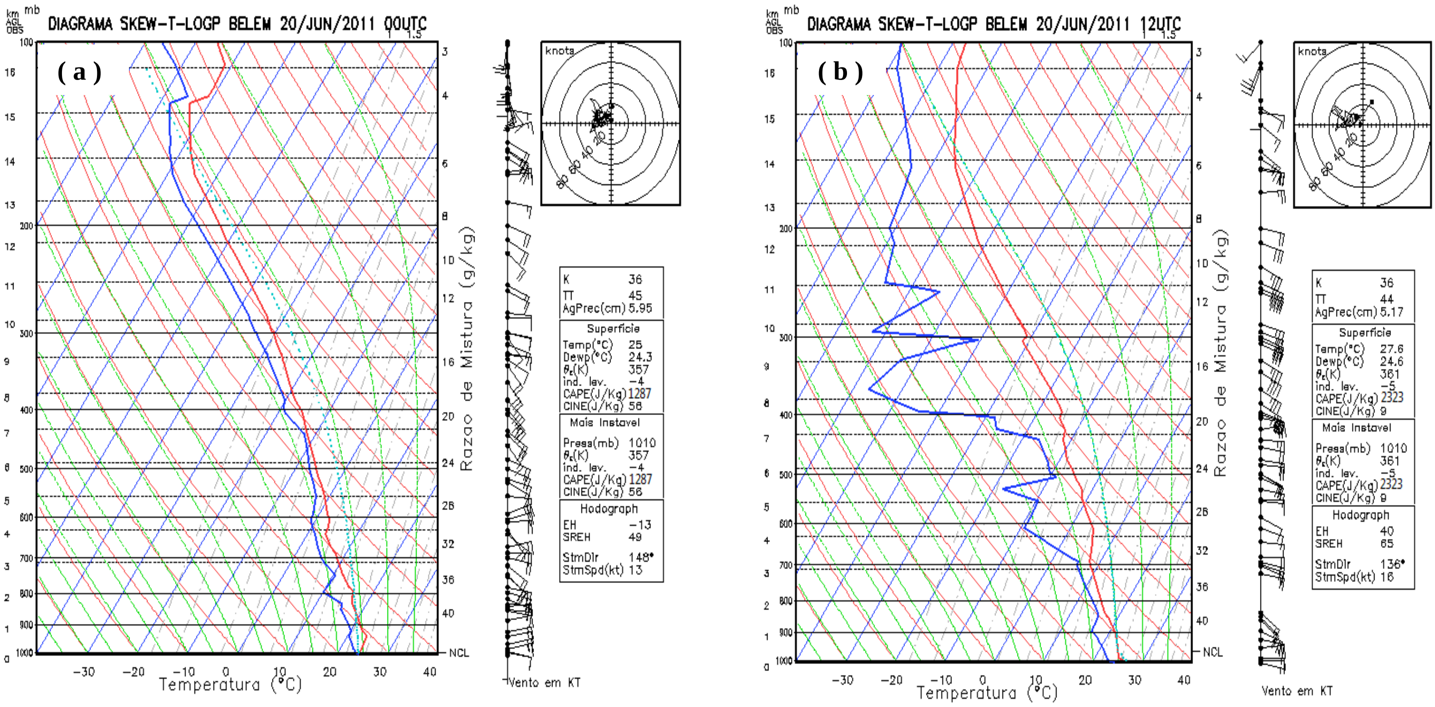

Figure 02 –Sounding of Belem-PA for the 00UTC (a) and 12UTC (b) 20 day of June 2011.

You can confirm the sounding of the day before 00UTC already showed a moderately unstable atmosphere with CAPE in 1287J/Kg throne (Fig. 02 - a). And launched the 12UTC (09HL - local time) - Fig.02 (b) of June 20, showed that the atmosphere was still very unstable and moist up to about 700hPa, since the curves of air temperatures (T-right) and dewpoint (Td - left) were very near, and above 700hPa has a dry areas, thereby indicating the possibility of severe storm. Moreover, indices of instability TT IL K and were significantly elevated, with values respectively 44, 36 and -5.3 (both layer unstable as the surface), namely was above the IL-5, showing a atmosphere very unstable, according to tab.04 as well as two other indices which indicate the formation of large clouds of vertical development - tab.02 and 03.

Added to this, the CAPE also indicated a very unstable atmosphere (according to tab.05), since its value was 2323J/Kg, both as to the surface layer more unstable. That is, as the CAPE represents how much power the air is available for the formation of convection, to this day that the atmosphere had sufficient energy to high cloud vertical development and hence the formation of storm. In conjunction to this, in the field of wind direction and speed, it was observed that the winds were weak and with little shear in the lower and middle levels, demonstrating that if the storm does not have the possibility of strong winds and rains will be accumulated high, conditions observed on the second region (Assumption, 2000).

The great demand for knowledge of predictors that signal the onset of severe storms is intended to assist in the "nowcasting", which has a major ally of the use of meteorological radar, which help identify, at the microscale, the formation and displacement of storm cells. According to Byers and Braham (1949), convective storms are related to their development and size.

The routine analysis of TITAN identified for the day June 20, 2011 a total of 263 storm cells distributed throughout the area covered by the radar. At around 19:21 UTC (Fig. 03 - a) the radar has indicated the formation of storm cells that can be observed by the field of reflectivity, ranging from 22 to 52 dBz. According to Visser (2001) convective cells above 55 dBz are considered severe storm and between 45 and 50 are considered moderate and 30 to 40 low, however this condition was analyzed for Southern Africa. Noting further the evolution of convective cells which at approximately 20:33 UTC (Fig. 03 - b), the system had already been organized and toward the city of Belem, with reflectivity above 45 dBz, the 22:21 UTC (Fig. 04) the system has reached the city, promoting the event of heavy rain, where the cumulative record at the station 24HL conventional INMET was 37.7mm and lasted approximately six hours, but there was no record of strong winds over the region in accordance as INMET and METAR.

The spatial distribution of storm cells can be observed in fig. 5 a and b represent the variability of the top of the convective 263células mapped by routine TITAN TrackGridState and by variation of the reflectivity in the area encompassing the radar, respectively. The maximum recorded was the top 17Km what happened to 22:21 UTC, the minimum being at 4 km and the average value of about 7 km, values that are considered relatively high compared (Queiroz 2009), which analyzed cases of tops severe storms to the southeast region of Brazil tops with minimum and maximum 6-12 km respectively. The maximum was 52 dBz occurred a few hours before the rain and the minimum 23 and average around 38 dBz.

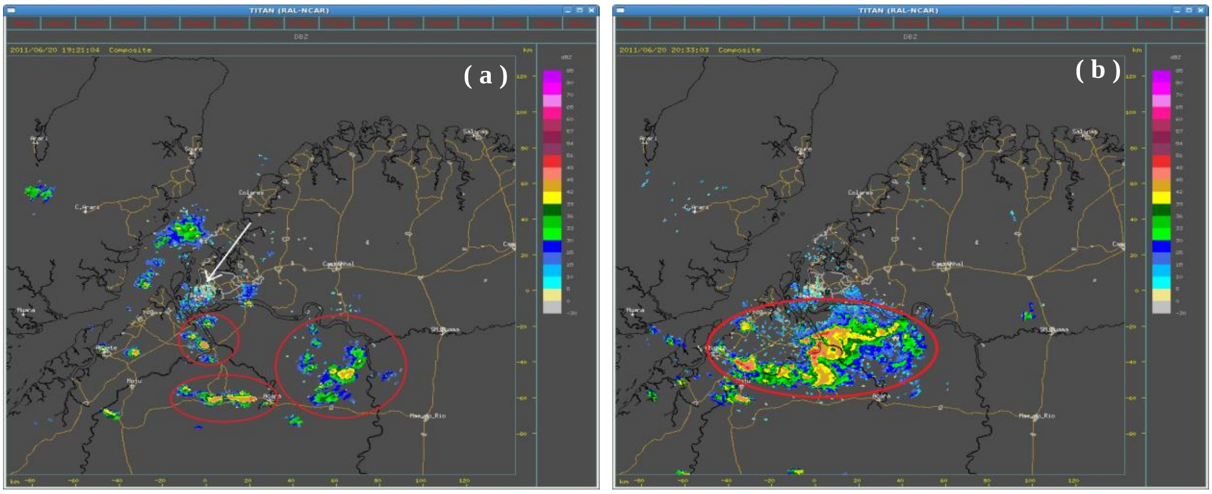

Figure 03 - Field of radar reflectivity in dBz of Belem-PA, to June 20 to 1921UTC (a) and 2333UTC which shows the maximum 52dBz (b). The white arrow indicates the city of Belem and red circles the storm cells.

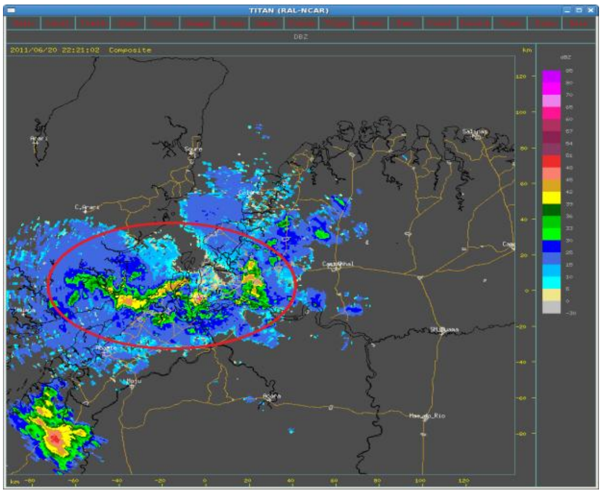

Figure 04 - Field of reflectivity in dBz radar Belem-PA, on the 20th of June, 2221UTC, which shows the convective cell over the city of Belem-PA.

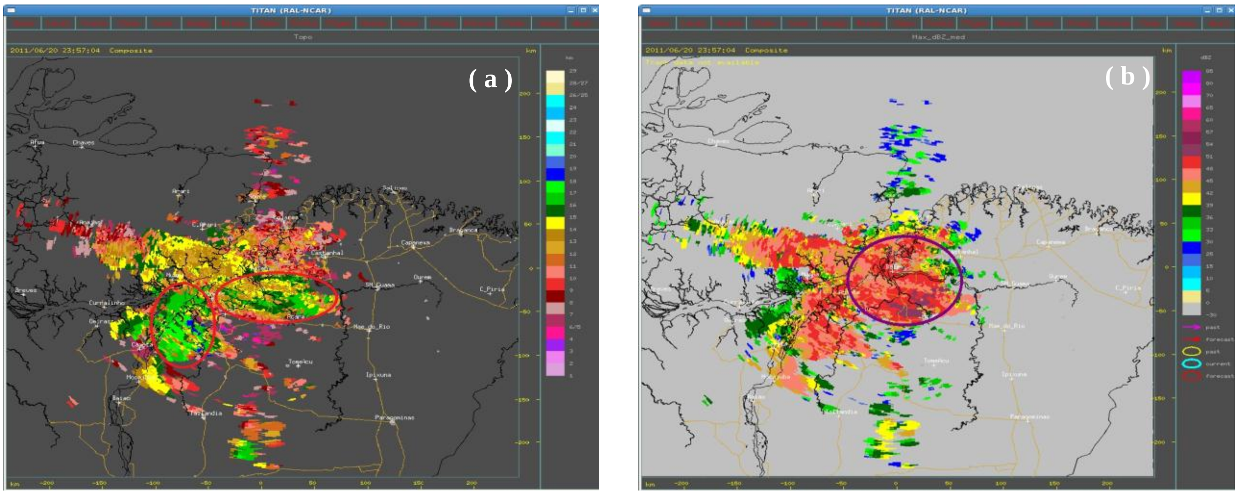

Figure 5 - Geographical distribution of the top (a) and reflectivity (b) of the storm cells for the day June 20, 2011 on the city of Belem, PA. The circles show the top and the maximum reflectivity.

4. Conclusions

In general the indices of instability TT, K and IL proved to be good predictors to aid in the prediction of severe storms for the region under study. But the CAPE did not get the same result, because in spite of its value be 2323J/Kg indicating a moderate instability for the event that occurred, we expected a value of greater magnitude, since CAPE values between 1000 and 2500J/Kg these are common to the region, both during the wet season (summer in the Southern Hemisphere) and as for the dry season (winter in the Southern Hemisphere) and are not always associated with precipitation. Thus, a need to do a more detailed study on this index for the equatorial region as well as adaptation and introduction of new indices that help in the short term forecast. An example is the index Tropical (IT) created by Pereira (2006) for the Brazilian Northeast is that proved reasonably satisfactory.

But to have a more accurate prognosis is also necessary, too, the use of meteorological radar data, as indicated in advance the formation of storm cells, thru the reflectivity in dBz and the height of top of clouds, and inform the displacement of these cells. And as can be seen the field of high reflectivity and the top already indicated the formation of storm cells moderate for the day in question, with values above 40 dBz.

In view of this, we can conclude that the thermodynamic analysis done together with the analysis of microscale can assist in the short term forecast - “NowCasting” - which is used by operational centers, and thus help in preventing meteorological alerting society greater natural disasters.

5. References

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