Lightning and Precipitation Produced by Severe Weather Systems, over Belem, Brazil

W.M.N. Ribeiro[1], J.R.S. Souza[1]; M.N.G. Lopes [2]; J.L.M. Lopes [2] ;V.A.Teixeira[1], V.H.M. Paca [3]

1. Meteorology Faculty – Federal University of Pará, Av. Augusto Corrêa nº1, Belém, Pará, 66075-110, Brazil, emails:wandaribeiro10@hotmail.com, jricardo@ufpa.br; vat.24@hotmail.com
2. The Amazonia Protection System – SIPAM .Belém, Pará, 66617-020, Brazil, e-mails: marcio.lopes@sipam.gov.br, jorge.lopes@sipam.gov.br

3- Mineral Resources Prospecting Company – CPRM, Av. Dr. Freitas, nº 3645, Belém, Pará, 66095-510, Brazil, e-mail: victor@be.cprm.gov.br

ABSTRACT: Lightning variables monitored by a LDN which included 12 LPATS IV VAISALA sensors distributed over eastern Amazonia, were analyzed during five severe rainstorm occurrences in Belem-PA-Brazil, in 2007. For the analysis of the days of severe storms, data from a high time resolution pluviometer, operated by CPRM in Belem, were also used. These case studies referred to rainfall events, which produced more than 40 mm of precipitation totals, registered by a tipping bucket automatic pluviometer located at 1°24' S, 48°26' W. Centered at this location, a 30 km radius circle was drawn by means of a geographic information system, and the data from lightning occurrences within this area, were set apart for analysis. The associated CG lightning events do not show a recognizable displacement pattern over the neighboring area. Instead, they occur almost simultaneously over the surrounding area, covered by meso scale convective systems. These case studies constitute a basis for future warnings of severe rainfall in Belem, and other locations, in the Region. Additionally, this work also showed that, the large- scale meteorological conditions also has a large influence on the intensity of the storms cases studied. This was clearly demonstrated, when the ZCIT and LI`s were acting and enhancing the precipitation and lightning occurrences observed around Belem.

1. INTRODUCTION

Belem is a city located at the confluence of the Guamá River with the Guajará Bay, about 150 km away from the Atlantic Ocean, along the southern shore of the mouth of the Amazon River. The level of its surrounding water masses is significantly determined by tides, which during the trimester March to May, may exceed the 2.5 m amplitude. This period coincides with part of the local rainy season, when the precipitation is strongly influenced by the inter-annual variability of the atmospheric general circulation, accumulating most of its nearly 3,000 mm annual average total. (Figueroa and Nobre, 1990). The rainy period in Belem is largely modulated by the drift of the Inter Tropical Convergence Zone (ITCZ) over this equatorial latitude (Ferreira, 1998), frequently producing severe lightning and rain storms , from January to May. The combined effect of the simultaneous high tides with severe rainfall, is the overflow of the drainage channels of the city, resulting in serious traffic jams and economic losses to its population. At present, no real time flood warning system is available to mitigate these situations, through the local Civil Defense and communications media. This work represents an attempt to contribute to the development of a low cost intense rainfall warning method, based on the knowledge of the relationship between the lightning frequency of occurrences and the associated rainfall, during severe storm events, in Belém. For this purpose, lightning detecting and rainfall measuring data of observations made by local institutions were used, through a joint effort which will be described bellow.

2- MATERIALS AND METHODS

In order to analyze the severe lightning storm events, a 30 km radius circle was defined to draw a sub set of data from the Amazonia Protection System – Lightning Detection Network (SIPAM –LDN). This área was centered at one digital tipping bucket pluviometers, from a surface meteorological station (belonging to CPRM) installed at the 4th Naval District, located in Belém, with coordinates: latitude -1°:47':53'' and longitude -48°:30':16" . A similar pluviometer, located about 8 km away from this position, and operated by the Brazilian Institute of Meteorology (INMET) , was also used for rainfall data information .

The SIPAM – LDN included up to12 LPATS IV – VAISALA sensors with a space configuration described in Rocha et al 2008, which covers part of the eastern Amazon region, including the city of Belem.

Besides these lightning and rainfall data, the analyses were complemented by means of satellite images and data provided by Brazilian National Institute for Space Research (INPE), the Climanalise Bulletin, and the Para State Meteorology and Hydrology Forecasts Network (RPCH).

2.1 Storm selection

The storms selected for study, fell under the severity criterion established by the Brazilian Aeronautics Guide nº 105-2 , Aeronautical Routes Directorate (1964), which considers a rainfall event with accumulated precipitation between 25.1 and 50.0 mm, as intense; and precipitation beyond 50.0 mm as a severe event. In this study the accumulation rate of the rainfall was also considered, so that it was required that the selected events registered more than 25.0 mm per hour or more than 40 mm in two hours. Under these guidelines, four days of storms were chosen to display the time and space distributions, of lightning and rainfall around Belém. Additionally, the atmospheric situation in those days was analyzed in a larger scale, to find out the meteorological contexts which produced those extreme local storms.

The large - scale analysis included displays, through the GRADS software, of the wind circulation configurations at 850 hPa and 200 hPa pressure levels. The zonal and meridian wind components during the selected days were drawn from the NCEP/NCAR site (Kalnay et al. 1996), through a consistent system of data assimilation used for its Global Circulation Model (GCM) with T621.28 resolution, i.e., approximately 210 km in latitude and longitude, plus 28 vertical levels.

The long wave radiation figures were derived from data collected by polar orbiting meteorological satellites (Liebmann et al., 1996), available over a 2.5º by 2.5º, latitude versus longitude regular grid.

3-RESULTS AND DISCUSSION

3.1. Space and time distributions of lightning and rainfall during the case study days.

The Figure 1 (a,c,e,g) shows the hourly distributions of rainfall at one of the two pluviometer sites and the number of CG lightning detected within the 30 km radius circle over Belém. The case study days chosen were: 11 Dec, 2006, 02 and 09 Jan, 2007 and 14 Feb, 2007, respectively.

One may observe that the most intense electrical activity in these cases, occurred at 16 hours LT on 11 Dec , 2006; when 101 such discharge events happened in 15 minutes. In the same day, 636 CG lightning flashes were detected between 16 and 18 hours LT, i.e.,an average of nearly 70 events per 15 minute interval.

The pluviometer data from INMET registered rainfall at hourly intervals, while the other three cases were analyzed from a CPRM pluviometer data, with rainfall totaled at 15 minute intervals. Considering this

greater uncertainty on the time when the rainfall rates reached their peak values, for the case of INMET data, the peak was supposed to occur at the half hour, in the middle of the maximum hour record of rainfall.

On 11 Dec, 2006, rainfall started at 14 hours LT, but reached its maximum rate of 41.8 mm/hour, at 18 hours LT of that day. This was the largest rainfall rate observed among the four cases analyzed.

This Figure shows that for all cases analyzed, the lightning peaks preceded the time of occurrence of the rainfall rate maxima. This fact has been a common feature in several other cases of lightning versus rainfall observed by the authors, in this region. The delay interval between the lightning and rainfall peaks, may be approximately estimated as: 90 , 60, 30, and 45 minutes, respectively, for the sequence of the four case days exhibited in Figure 1.

The Figure 1 (b,d,f,h) shows that the CG lightning intense activity occurred between 13 and 19 hours LT, period which coincides with the hours of most intense air convection over the area. Additionally, this figure indicates that for the first case day, lightning exceptionally starts to occur over the Guajara Bay and later drifts eastward toward Belem. For all three subsequent cases, the electrical activity starts over land surfaces at east and northeast of the area, and drift westward as usually occur with the cloud systems which approach Belém, driven by the prevailing northeast winds at this local.

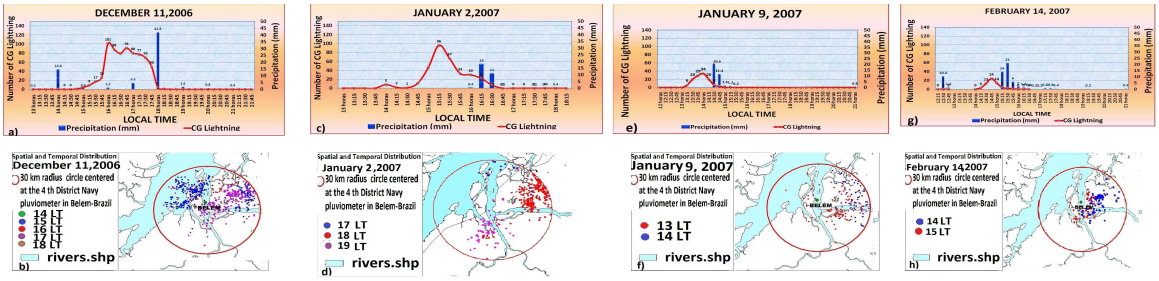

Figure 1 (a,c,e,g)- Time distributions of the lightning occurrence rate and precipitation in Belém. Case study days: 11/Dec/2006 (INMET data), 02 and 09/Jan/2007 + 14/Feb/2007 (CPRM data) .
Figure 1 (b,d,f,h)- Space and hourly distribution of the CG lightning occurrences during the same storms.

3.2. Meteorological Analysis Summary

On a larger scale, the Figure 2 (a,c,e,g) exibits the precipitation distribution and the atmospheric circulation at low levels (850 hPa level vectors), and Figure 2 (b,d,f,h) displays the long wave radiation plus the high level atmospheric circulation (200 hPa level vectors), over the area of interest.

During all storm days selected, it is evident the influence of the Bolivian High and a low pressure zone over the Brazilian northeast. This situation leads to bi-directional winds at different levels and high level cyclonic vortices (HLCV) episodes. The low values of the observed long wave radiation, indicate the presence of cold cloud tops of deep convective systems over the region. This characterizes the occurrence of large and intense cumulonimbus cloud systems, which led to the production of the studied local storms. Specifically in Figure 2.b one may observe a cloudiness band with a NW to SE orientation, which characterizes the presence of the SACZ acting from western Amazonia to the Brazilian southeast. The SACZ and the HLCV placed over the Atlantic ocean, may have contributed to the formation of Instability Lines which led to the severe storms observed over Belem. The low level air circulation showed the occurrence of low level jets from the north and prevailing winds from the northeast quadrant, transporting humidity from the Atlantic to the continent. Finally, it should be pointed out that, the exceptional lightning storm observed on 11 Dec, 2006; was the result of the

presence and coupling of several large-scale meteorological systems, such as : the ITCZ, Bolivian High and SACZ, acting over Belém.

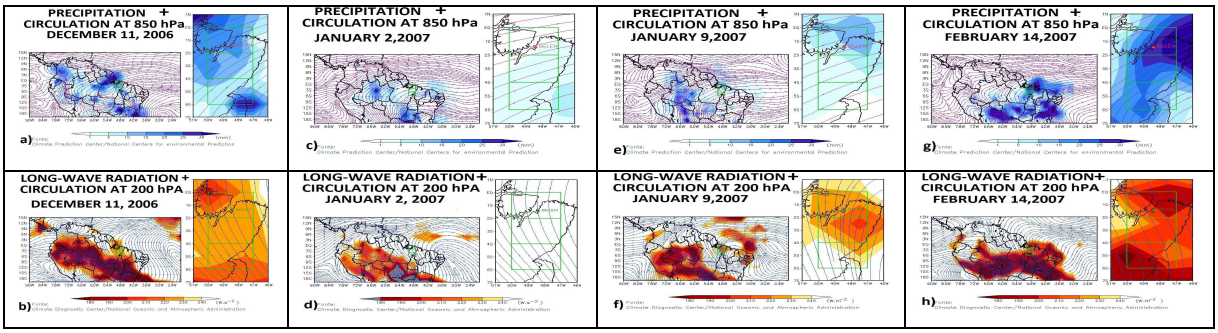

Figure 2 (a,c,e,g) shows de wind flow lines ($m.s^{-1}$) at the 850 hPa pressure level, and precipitation during the case study days. Figure 2 (b,d,f,h) displays the wind flows ($m.s^{-1}$) at the 200 hPa pressure level and the long wave radiation - LWR ($W.m^{-2}$) during the same days. One may note the influence of the ITCZ and SACZ as well as the anti cyclonic circulation known as the Bolivian High (BH), over the area . Source**: NCEP**.

CONCLUSIONS

For all storm cases studied, the occurrence rate of CG lightning flashes in Belém, peaked between 30 to 90 minutes before the precipitation rate reached it maxima values. Since this type of observation has also been verified for other severe storms in this area, there is reason to expect that the CG lightning frequency rate observed by existing lightning detection networks, might become a low cost alternative to radar, for example, to subsidize real time warning of imminent severe rainfall, to the local population. With an exception, most storms reached Belém, coming from the northeast quadrant, driven by the prevailing low level winds. This work also analyzed the larger scale climatic and weather configurations such as the ITCZ, SACZ and the Bolivian High, which especially when acting simultaneously, periodically produce intense convergence of moist air masses over this area, resulting on the formation of intense cumulonimbus cloud systems. Further analysis of these system configurations may provide a longer warning time frame, for the local severe lightning and rain storms.

ACKNOWLEDGMENTS

The authors wish to thank the financial support granted by FINEP to the REMAM 2 Project, and to the CNPq for a fellowship awarded to the first author. They are also grateful to SIPAM, INPE, INMET, CPRM and NCEP, for the data made available and used in this work.

REFERENCES

Ferreira, N.S. A Zona de Convergência Intertropical**.** In: NOBRE, Carlos Afonso. **Climanálise Especial 10 Anos**. São José dos Campos, 1996.

Figueroa, S.N.; Nobre, C.A. Precipitation distribution over central and western tropical South America. **Climanálise**, v. 5, p. 36-45, 1990.

Kalnay, E. et al. The NCEP/NCAR 40-year reanalysis project. ***Bulletin of the American Meteorological Society*****,** v.77, n.3, p437-471. 1996.

Liebmann, B.; Smith, C. A. Description of a complete (interpolated) outgoing Long Wave Radiation dataset. ***Bulletin of the American Meteorological Society***, v.77, p.1275-1277. 1996

Rocha, B. R. P. ; Pereira, C. S. ; Souza, J. R. S. ; Monteiro , J.H.A. . Lightning Variables Seasonal Changes over Eastern Amazônia. In: **Proceedings of the 29th International Conference on Lightning Protection**- 26th 29th June, 2008. Uppsala, Sweden., 2008. v. 1. p. 1-8.