Diurnal variation of lightning activity based on data recorded by the global lightning location system STARNET .

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ABSTRACT: The Lightning activity is analyzed in a scale of hour, by using the lightning detection system STARNET data to build a diurnal lightning activity curve. We rebuilt Carnegie's curve by using hour averaged data of lightning incidence inside "windows" over South America, Africa and Oceania. The shape of the curve is similar to those of literature with small differences of time of peak for lightning activity. The peaks of lightning activity occurred at 08:30 over Oceania, 14:00 over Africa and 18:30 over South America

1. INTRODUCTION

The use of lightning detection system is now an important tool for research. This kind of data are used for protection purposes and for scientific research. In this paper we use it to obtain the Carnegie's curve and for study the lightning activity in a scale of hours. Carnegie's curve is a measurement of electrical activity of the planet. It can be obtained by direct averaging (in a scale of hour) measurement of electric field (Sheftel et al. 1994) , or can be obtained in the same scale of time from lightning activity (Williams and Heckman, 1993). Global frequency and distribution of lightning using Optical Transient Detector (OTD) were measured by Christian et al. (2003) and allow them to conclude that the total of lightning (cloud to ground and intracloud) around the world is about 44 flahs. s^{-1}, that approximately 78% of them occurs between 30^o S and 30^oN and that 88% of them are over continental, island and coastal regions. So we establish a methodology to rebuild the Carnegie's curve. Three windows over land area (America Africa and Oceania) were located between 30^o S and 30^oN and data of lightning activity were collected of STARNET system. To obtain the lihtning activity curve in a scale of hours we build a diurnal lihtning distribution by using data of STARNET (2010) between february 2008 and October 2009.

2. METHODOLOGY

The Carnegie's curve can be defined as a universal time (τ) dependent convolution:

$$G(\tau) = \int_0^{2\pi} S(\phi)T(\tau - \phi)d\phi \quad (1)$$

where $S(\phi)$ is a probability function of longitude, ϕ, and $T(\tau-\phi)$ is a function of the local time, $\tau-\phi$ (Williams and Heckman, 1993). Williams and Heckman used the function defined by (1), considering the temporal function $T(\tau-\phi)$, dependent only on τ . We use data of STARNET to get the function $T(\tau)$.and we established three windows that cover continental area were lightning activity is strong. The coordinates of these windows are close to those of figure 4 of Williams and Heckman (1993) that represents the function $S(\phi)$. They are (in degree): for

Africa, Latitudes: -28 to -14 Longitudes: 15.5 to 32.5; for South America: Latitudes: -28 to -14 Longitudes: -68 to -51 and for Oceania: Latitudes: -28 to 26, Longitude: 88 to 145. As the efficiency of the STARNET is too low, far from South America, to enlarge the number of discharge, we had to relocate and to take a more large window ($\Delta\phi = 57^{o}$) for Oceania, but this part of the function is relatively small compared with South America and Africa. So, we are assuming that possible error made by this choice of the large window is not too significant.

3. RESULTS

The number of spherics recorded by STARNET were 44.403 (Oceania), 91.805 (Africa) and 3.237.668. (South Africa) inside the windows of research, between fev 2008 and oct 2009. The curve of lightning activity in a scale of hour is shown in figure 1. The horizontal axis is in minute but the curve was averaged in a scale of hour and after this, normalized by mean values (Williams and Heckman, 1993). This figure shows the same shape of that one presented by MacGorman and Rust (1998) (as figure 1.8 pag 30 and 1.10 and 1.12 pag. 31), or Schonlad (1953) (as figure 6(b) pag. 28) or Markson (2007) (as figure 1) and Bailey et al. (2006) (as figure 1). Some differences are shown in figures 2 and 3 will be commented in the discussion of results, section 4.

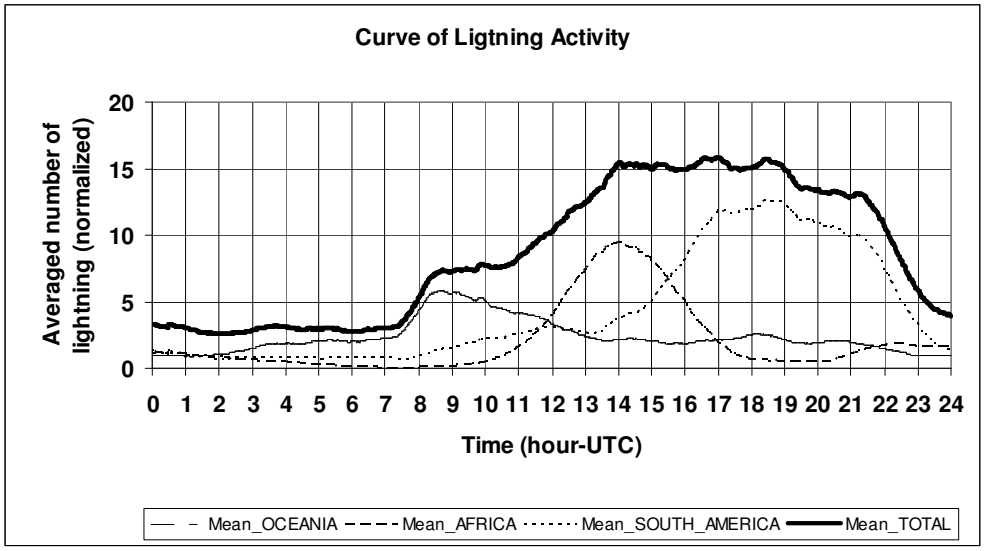


Figure 1. Carnegie's curve. Oceania curve (dash-dot), Africa curve (dashed), South America (dot) and total (solid line).

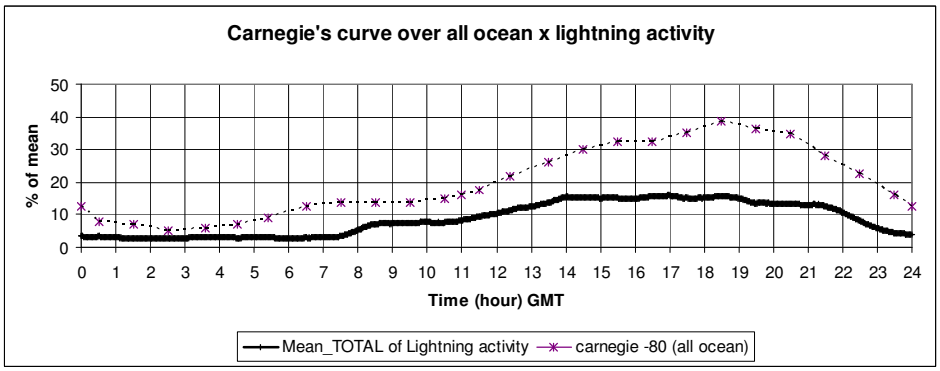
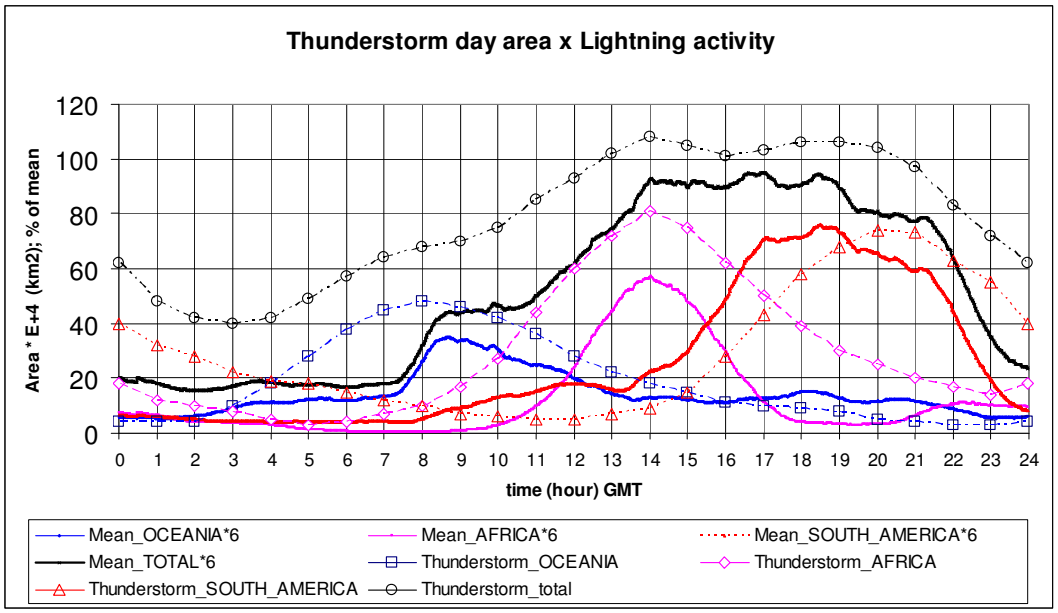


Figure 2. Carnegie's curve over all ocean x lightning activity . We subtract 80 form values of the Carnegie's curve to allow a best comparison. Carnegie's curve was adapted from Markson (2007).



- Figure 3. Thunderstorm day area x Lightning activity. Thunderstorm day area was adapted from Markson (2007).

4. DISCUSSION

The peaks of lightning activity for individual windows, showed in Fig. 1 are quite similar to those showed in Fig. 1 of Markson (2007) were he presented diurnal variation of electric field over ocean (Carnegie's curve) and over thunder areas (countries) (reproduced from Chamlers, 1967), i. e., 08:30 x 08:00 for Oceania, 14:00 x 14:00 for Africa and 18:30 x 20:00 for South America, for ours and Markson's figures, respectively. These peaks are closed to those presented for Bailey et al. (2006) The total curve in our case tends to form four plateaus, one of them between 00:00 and 04:00, P1, another between 08:30 and 10:30, P2, and another between 14:00 and 19:00, P3, and finally the last one between 19:30 and 21:30, P4. P1 represents the lower level of lightning activiy, P2, medium, P3 the highest and P4 a high level.

The Curve of figure 1 of our work is more similar to that one over thunder areas of figure 1 of Markson's work (2007) and that one presented by Bailey et al (2006) than the Carnegie's curve over all ocean (see figures 2 and 3). Clearly South America and Africa dominates the peak of activity.

Bailey et al. (2006) rebuilt the curves of lightning activity and obtained similar curves, closed to our results. The curves for Australia and for Phillipines and Asia, obtained for Bailey et al (2006), have peak at 08:00 UT and 10:00 UT, respectively. Considering that the window of Oceania in our work covers part of Asian continent and Australia, our result shows a kind of median value of the results of those authors. Africa and South America together contributes for the existence of the high level of activity from 14:00 UT to 21:00 UT.

Because we have used separated small windows through continental area of the globe, where lightning activity is stronger, limited in a short longitudinal interval, and we are supposing that the function $T(\tau-\phi) \sim T(\tau)$ (therefore separable of integral of Eq (1)), the function $\int S(\phi)d(\phi)$, in the same interval of the windows, would be computed in a first approximation as single peak that multiply $T(\tau)$ and has no strong importance if we normalize it to the mean value. So, in terms of Eq. (1), for plotting $G(\tau)$, the shape of curve of figure 1 would be maintained,

and only small changes in locations and magnitude of peak values would be waited. This effect can be noticed in figures 11 and 12 of the paper of Williams and Heckman (1993) were G(τ) is plotted.

Markson (2007) following Whipple and Scrase (1936) arguments that Carnegie's curve closely resembled the average UT variation of of global thunderstorm activity. Inversely, in our work using only lightning activity over continental area we obtain Carnegie's curve. This is equivalent of using air current or direct measurement of electric field under fair weather conditions. This is essentially the evidence of the existence of a global electrical circuit (Bailey et al., 2006, Markson, 2007).

5. CONCLUSIONS

In this paper we present the analysis of lightning activity in a scale of hours. Data of STARNET were used to obtain curve of lightning activity in a scale of hour to rebuild the Carnegie's. The main conclusions are:

a) The curve of lightning activity was obtained and compared with Carnegie's curve, and it is in good agreement with the literature;

b) the peaks of lightning activity occurred at 08:30 h (UT) over Oceania, 14:00 h (UT) over Africa and 18:30 h (UT) over South America .

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