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REASERCH OF ELECTRICAL STRUTURE OF A THUNDER CLOUD OVER SÃO PAULO CITY BY USING FIELD MILL RECORDS, RADAR DATA AND LIGHTNING LOCALIZATION SYSTEM (LLS).

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Abstract – In this paper we present preliminary results of the study of thundercloud structure over urban area. The sensors were developed by LCA-UFMS team and are operated now by IAG-USP team. To solve Coulomb's law by using the records of two electric field mill (EFM) (at rate of one second) we developed a computational code that calculates second by second the magnitude and localization of charges main centers. This methodology allows to find results with good precision. Analyzing the solutions of Coulomb's law, surprisingly we noticed that there are inversion of the sign of charges from positive to negative or negative to positive in those regions where the centers were located in a scale of several seconds. We don't have definitive explanation about this but it is possible that fast discharges inside the cloud are responsible for this behavior.

1 - INTRODUCTION

The solution of Coulomb's law with recordings of a EFM net (Cape Canaveral - Florida) was first used to calculate the charges annihilated for lightning discharge to ground [1][2][3][4][5]. Jacobson and Krider[1] obtained solutions of point and dipole discharge that fit well most of their data by fixing two coordinates (x and y) and calculating the charge magnitude and localization (q and z). They minimized a chi-squared function to find those solutions. They conclude that there is a negative and a positive center between 6 and 9.5 km and a small positive center (0.5 to 4C) between 1 and 3 km. In our work we used a cloud dipolar structure to fit data of two EFM by solving Coulomb's Law every second by minimizing another mathematical function. Previously, Lacerda et al.[7] published some results by using similar methodology for three minutes of data. This work is an application of this methodology to a larger period of time. This implies in a more expensive use of computer because the algorithm is computationally dependent of the number of points used to get solution. Stolzenburg and Marshall[6], testing Coulomb's law for fixing calculated electric field to data, used the equation 1 like to calculate electric field for all the space.

2 – METHODOLOGY

We used an stochastic method to solve equation 1, considering equation 2 and equation 3.

$$Ec_j = \left[\sum_{i=1}^{Nq} \frac{1}{4\pi\varepsilon} \frac{Q_i \cdot \left[(x-x_i)\hat{U}x + (y-y_i)\hat{U}y + (z-z_i)\hat{U}z \right]}{\left[(x-x_i)^2 + (y-y_i)^2 + (z-z_i)^2 \right]^{3/2}} \right] + \mathrm{Etb}.\hat{U}z$$

(eq.1)

ErrFMj = [(│Emj│-│Ecj│)/│Emj│ i=1,2 (eq. 2)

$\varepsilon = \sum_j$ ErrFMj (j=1,2) (eq. 3)

Were x, y and z are the coordinates where the electric field measurement were made, xi, yi and zi are the coordinates of the i-th charge center, Ux, Uy and Uz are unitary vectors, Nq is the number of centers of charge (in this case 2), Ecj is the calculated Electric field for the j-th field mill (in our case 2), ErrFMj is the error of the j-th EFM, E_{tb} is the fair weather electric field, Qi is the charge at i-th center and ε is the maximum error allowed.

The stochastic method consists in choosing the variables z an q randomly in a interval that we believe that there is a solution, calculating the electric field using eq 1 and than using eq. 2 and eq. 3 as criteria for accepting or rejecting the solution.

The EFM were located at coordinates P1 = (-23.65123, -46.622337) and P2= (-23.559295, -46.733315).

To minimize the number of variables we used a radar image showed in Figure 1 (Lacerda et al. 2010), where the center of circle is the coordinates of radar of São Roque (considered the origin O =(0,0,0).

The figure 1 shows the content inside the cloud obtained for several ranges of radar reflectivity (up and right side of figure) and the localization of those regions. The red color corresponds to the reflectivity between 50 and 60 dBz. The cloud is part of a front that occurred in 23/04/2010 and data analyzed corresponds to the period of time from 23:18:55:11 to 23:19:28:44 (day:hour:minute:second).

The Figure 1 allows to obtain the coordinates x and y for the regions were the center is probably located. The cloud presented no lightning activity to ground, only inside the cloud as shown in Figure 2.

In Figure 2 (Lacerda et al. 2010) we see the region of the front where lightning occoured (black regions up left) according data of STARNET that is the LLS used in this work.

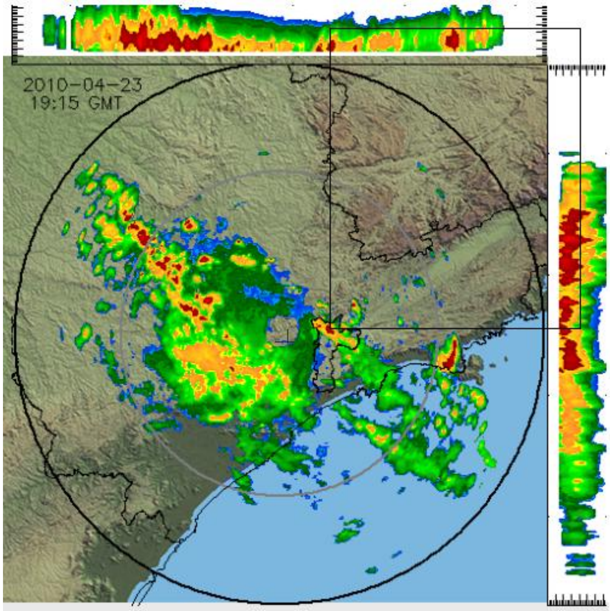

Figure 1. Localization of lightning activity centers.

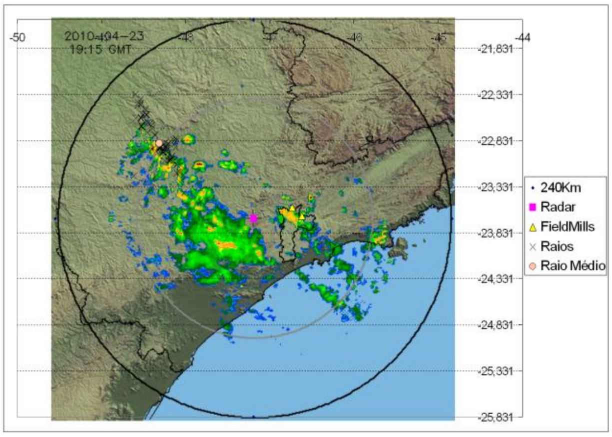

Figure 2. Localization of Field Mill, radar and lightning activity.

3. – RESULTS.

The figure 3 shows the result of computed solutions for several criteria of acceptance. In this figure, the regions of curves are numbered from down to top as 1, 2, 3 and 4. Region 1 corresponds to the field mill record subtracted 2000 (to allow visualization together with the other curves), region 2 corresponds to the solution for the charge multiplied by 50 (to allow visualization together with the other curves), region 3 is the lower charge position and region 4 is the corresponding region for the upper charge position.

The figure 3 is the superposition of the solutions obtained for variable criteria of acceptance and number of run of the algorithm. The color black and red for the larger curves correspond to the more restrictive criteria what includes $\varepsilon \leq 0.0001$ and number of runs, n, 1000000 times. This choice implies in 4.5 hours of processing computational time. The several other colors are the other curves with variable criteria. The most roughly criteria was $\varepsilon \leq 0.01$, n=10000.

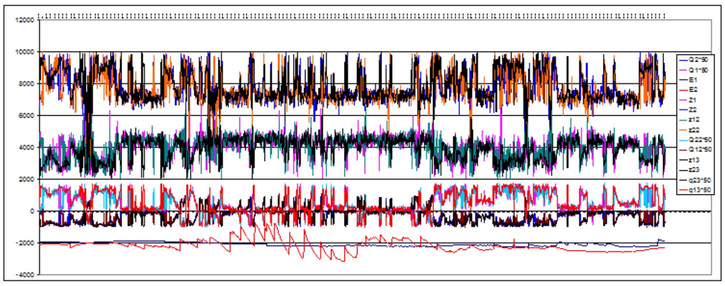

Figure 3. Solutions obtained by using the described methodology for the interval of time 23:18:55:11 to 23:19:28:44

4. DISCUSSION OF RESULTS

The figure 3 shows EFM data (region 1) and calculated parameters z and q for the interval of time 23:18:55:11 to 23:19:28:44. Notice the oscillations of curves of region 2. The black large curve in region 2 (relative to the charge at center 2, around 8000 m, region 4) starts from negative values and sometimes cross the zero line becoming positive, during lightning activity as showed in the curves of EFM data below (region 1). The opposite charge behavior is observed in the large red curve of region 2 that shows the behavior of the charge relative to center of charge 1. The calculated position of center of charge 1 is the region 3 (curves around 4000 m).

5 – CONCLUSIONS

The preliminary results of this study about thundercloud structure over urban area using EFM, data of radar and lightning localization system, are presented. These results show that the solution of Coulomb's law by using the records of two electric field mill allows calculate the magnitude and localization of charges main centers, with good accuracy. The mean values relatives to the most restrictive case calculated were: z1 = 3898 m, q1= 11 C, z2 = 7893 m and q2= -5.9 C, for the charges and z coordinate for lower and upper charge centers. Analyzing the solutions of Coulomb's law, we noticed that there are inversion of the sign of charges from positive to negative or negative to positive in those regions where the centers were located in a scale of several seconds. We don't have definitive explanation about this but it is possible that fast discharges inside the cloud are responsible for this behavior.

7 - REFERENCES

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