ESTIMATING THE MAGNITUDE OF ELECTRIC CHARGE INSIDE ISOLATED CONVECTIVE CLOUDS.

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1. INTRODUCTION

The use of coulomb's law to study cloud structure is not new. It was employed by Jacobson and Krider, (1976) and Livingston and Krider (1978) to study the electric cloud structure of thunderstorm by using electric field network in Florida.

During November and December a network of electric field mill and data of a polarimetric radar (X-band) were used to infer the cloud structure of thunderstorms. We tried to find a isolated small thunderstorm to simplify the problem of using coulomb's law (Stolzenbourg et al 1998, Stolzenburg, and Marshall, 1994).

The approach used was to solve the inverse problem (Tarantola, 1987) of coulomb's law. This is not a trivial problem and requires the knowledge of the region were the electric charges could be, inside the thundercloud. This optimizes the computational effort because it localize the seed for start the solution of z coordinate too close of the true region. Radar images gives that seed.

2. METHODOLOGY

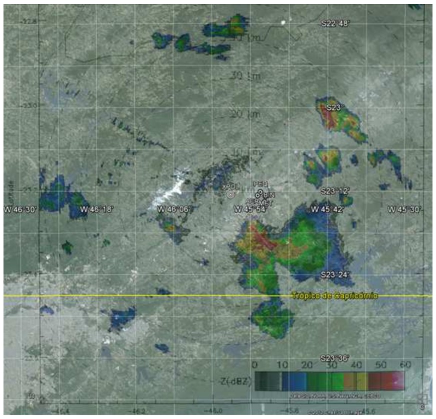
It was installed a network of electric field mill close to a polarimetric radar in São José dos Campos. Four sensors with distance varying between 1 to 2 km were installed (See Table 1). In figure 1 we see the localization of this network and the Radar, represented as a white circle with black concentric circunferences centered in a position marked as XPOL. In Figure 1 (a), we see the representation of the network and radar image. The scale of colors represents the reflectivity of the radar. In Figure 1 (b) we represent the detailed image of radar with concentric circles with radius multiple of 10 km.

The thunderstorm occurred at 19:30 GMT and was monitored by several equipments, like LINET, STARNET, LMA, BRASILDAT.

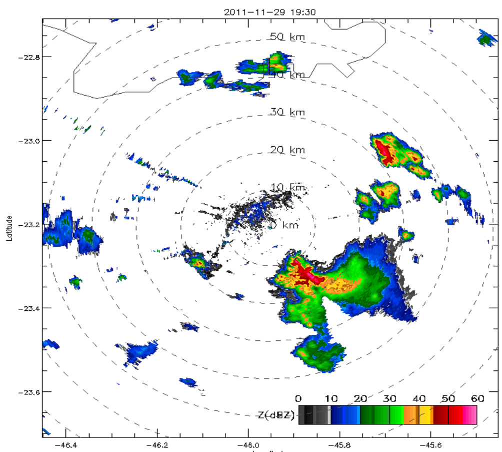
Table 1. Localization of sensor

Site - name	latitude	longitude
Meteorology (INPE) - met	- 23.211283	- 45.860278
Batalhão e Infantaria da Aeronáutica (BINFA)- bin	- 23.209431	- 45.880862
Aeroport - aer	- 23.224739	- 45.862521
Pequenópolis School - peq	- 23.201461	- 45.873773

A sequence of images like that presented at figure 1 and b were mounted at every six minutes and were used to estimate the coordinate x and y of the electrically active region of cloud (reflectivity greater than 40 dBZ).



(a)



(b)

Figure 1. a) representation of network and radar position in a georeferenced map; b) the radar reflecitivy associated to the thunderstorm of 29 nov 2011 at 19:30 GMT is shown right down.

The coordinate z of the charge centers were chosen between 2000 and 10000, and calculations of electric charge q at every center were performed by using

$$\mathbf{q} = (\mathbf{R}^T.\mathbf{R})^{-1}.\mathbf{R}^T.\,\mathbf{E} \qquad \text{eq (1)}$$

where

$$Rij := 2k\cdot\frac{(zj - zi)}{\left[(xj - xi)^2 + (yj - yi)^2 + (zj - zi)^2\right]^{\frac{3}{2}}}$$

eq (2)

R is a i x j matrix and i refers to the position of sensor on ground and j to the charge center and k= $(1/4\pi\varepsilon_o)$ with ε_o being permissivity of vacuum; **q** is a i x 1 matrix and **E** is a j x 1 matrix of measurements.

Then we used the calculated electric structure to recalculate electric field on ground, Ec_i, by using

$$Ec_i = \Sigma_{ij} (R_{ij} \square q_j) \qquad \text{eq.(3)}$$

and compare the measured electric field at every field mill with that calculated one, by using

$$\eta = Ec_i/E_j \qquad \text{eq (4)}$$

maintaining $0 \le \eta \le 0.1$.

We arbitrarily adopt the dipolar structure. The results are presented in next section.

3. RESULTS AND DISCUSSION

Figures 2, 3 and 4 shows the fit of the curve for 5 points.

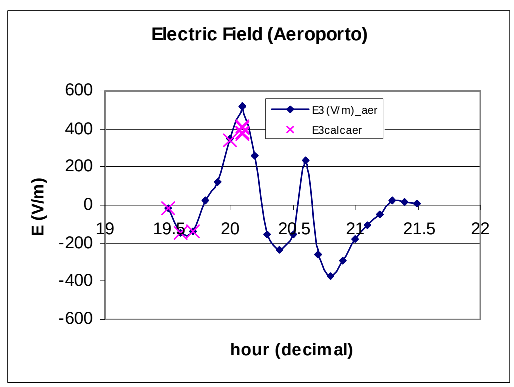


Figure 2. Measured E_i (line) versus Calculated Ec_i (x) at Aeroporto position.

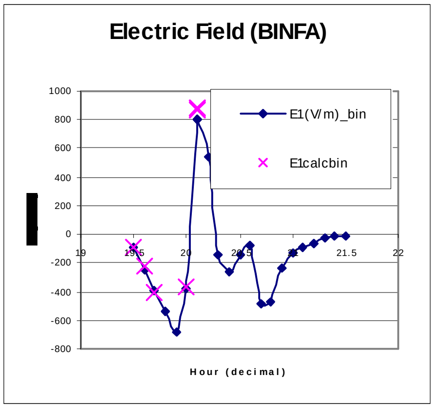


Figure 3 . Measured E_i (line) versus Calculated Ec_i (x) at BINFA position.

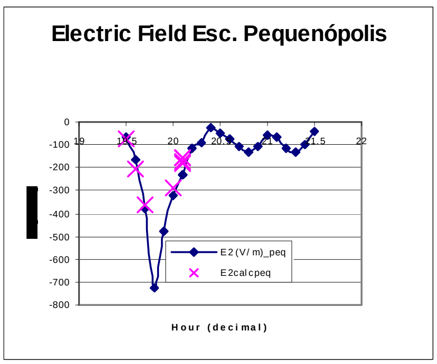


Figure 4. Measured E_i (line) versus Calculated Ec_i (x) at Escola Pequenópolis position.

The two points that were not fitted between those points of figures 2, 3 and 4 correspond to situations where it was not possible to localize precisely charge center's in radar image.It would be very difficult to find a solution that could be physically reasonable with only few measurements. The last point was poorly fitted because of the same difficulty, and several essay were proceeded. The cloud was already too complicated to get a reasonable solution.

4. CONCLUSIONS

We used data of dense electric field mill network (distance between sensors ~ 1.5 km) and data of polarimetric radar to investigate the electrical structure inside a thunderstorm cloud occured in 29 november 2011. The main conclusions are:

1. The inverse problem of Coulomb's law is a reasonable tool to find the structure of charges inside the cloud (position and magnitude of electric charges).
2. Temporal data of three sensors (BINFA, Esc. Pequenópolis and Aeroporto) were reasonably fitted by the recalculated electric field.
3. Results show a cloud with inverted dipole with electric charge varying between -13 C and -78 C (heigth from 4800 to 7900 m), and 15 C up to 54 C (height from 2800 to 5000) for negative and positive centers respectively.

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6. REFERENCES

-Jacobson, E. A., Krider, E. P., Electrostatic Field Changes Produced by Florida Lightning, Journal of Geophysics Research, p. 103, jan 1976.

- Livingston, M. J., Krider, E. P., Electric Fields Produced by Florida Thunderstorms, Journal of Geophysical Research, Vol 83, n. C1, jan 1978.

- Stolzenburg, M., W. D. Rust, and T. C. Marshall (1998), Electrical structure in thunderstorm convective regions 2. Isolated storms, J. Geophys. Res., 103 (D12), 14,079–14,096, doi: 10.1029 /97JD03547.

- Stolzenburg, M., Marshall, T. C., Testing models of thunderstorm charge distributions with Coulomb, s law, Journal of Geophysical Research,V. 99, N. D12, p.p. 25921-25932, Dec, 1994.

- Tarantola, A., Inverse Problem Theory, methods for data fitting and model parameter estimation, Elsevier, 1987