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 (Stolzenboung et al 1998, Stolbenoburg, 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.

It was installed a network of electric field mill close to a polarimetric radar in Sao 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 circles 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.

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).

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

\[ q = (R \cdot R)^{-1} \cdot R \cdot E \]  

(1)

\[ R_{ij} = 2k \left( \frac{(x_i - x_j)}{d^2} \right) \]

\[ d = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2 + (z_i - z_j)^2} \]

\( R \) is a \( i \times j \) matrix and \( r \) refers to the position of sensor on ground and \( / \) to the charge center and \( k = (144 \mu F) \) with \( \epsilon_0 \) being permittivity of vacuum; \( q \) is a \( j \times 1 \) matrix and \( E \) is a \( j \times 1 \) matrix of measurements.

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

\[ E_c = \left[ \frac{q}{R \cdot R} \right] \]

(3)

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

\[ \eta = \frac{E_c}{E_m} \]  

(4)

maintaining \( 0 \leq \eta \leq 0.1 \).

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

2. RESULTS

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.

3. DISCUSSION

1. The methodology is strongly dependent of the localization of the charge centers that requires the use of another technique.
2. The choice of the cloud structure is arbitrary and depends on the information given by another technique.
3. The polarity and magnitude of electric field remains the same for different choices of center’s position for a set of Ek (measurements \( E \) for every sensor in a instant \( t \)), but the magnitude of electric charge varies.
4. The choice of charge magnitude depends of another technique.
5. This technique may be preferentially used for small thunderclouds localized close the field mill network.

CONCLUSIONS

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).

Temporal data of three sensors (BINFA, Esc. Pequenópolis and Aeroporto) were reasonably fitted by the recalculated electric field.

Results show a cloud with inverted dipole with electric charge varying between -13 C and -78 C (height 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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