Inverse Problem of Coulomb's Law: Preliminary results on Belém Campaign.

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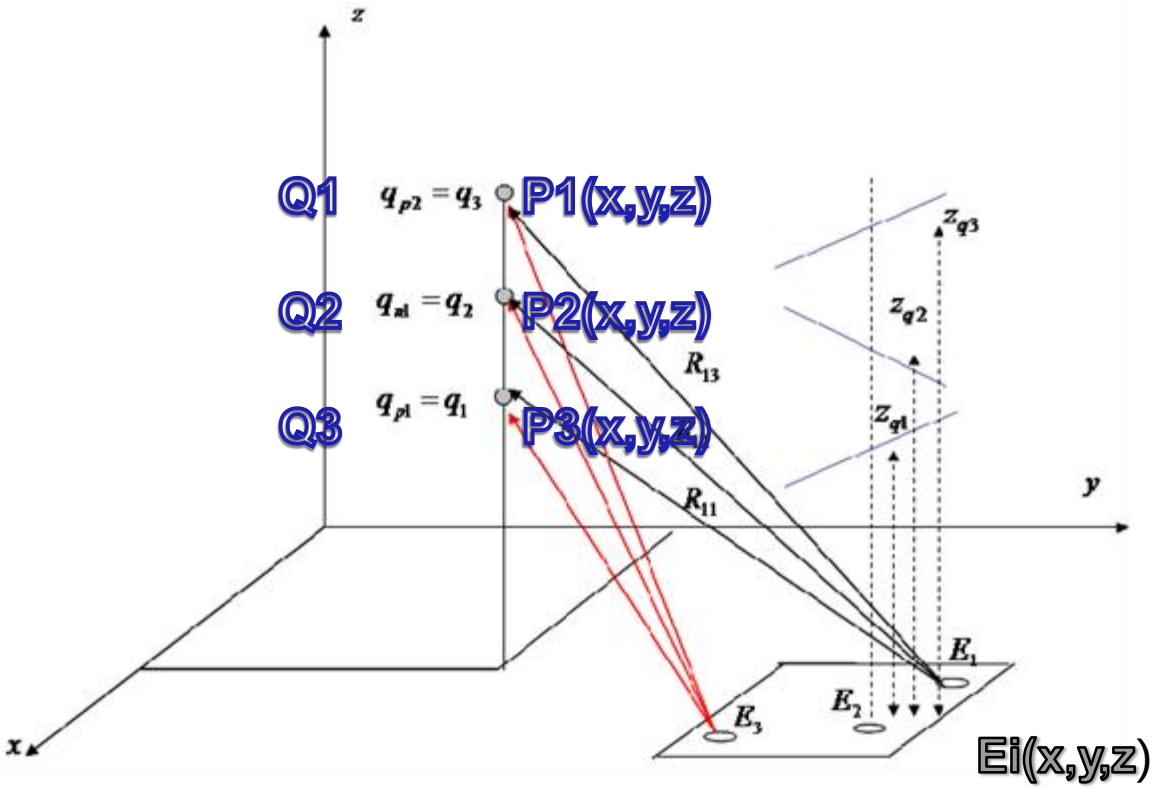
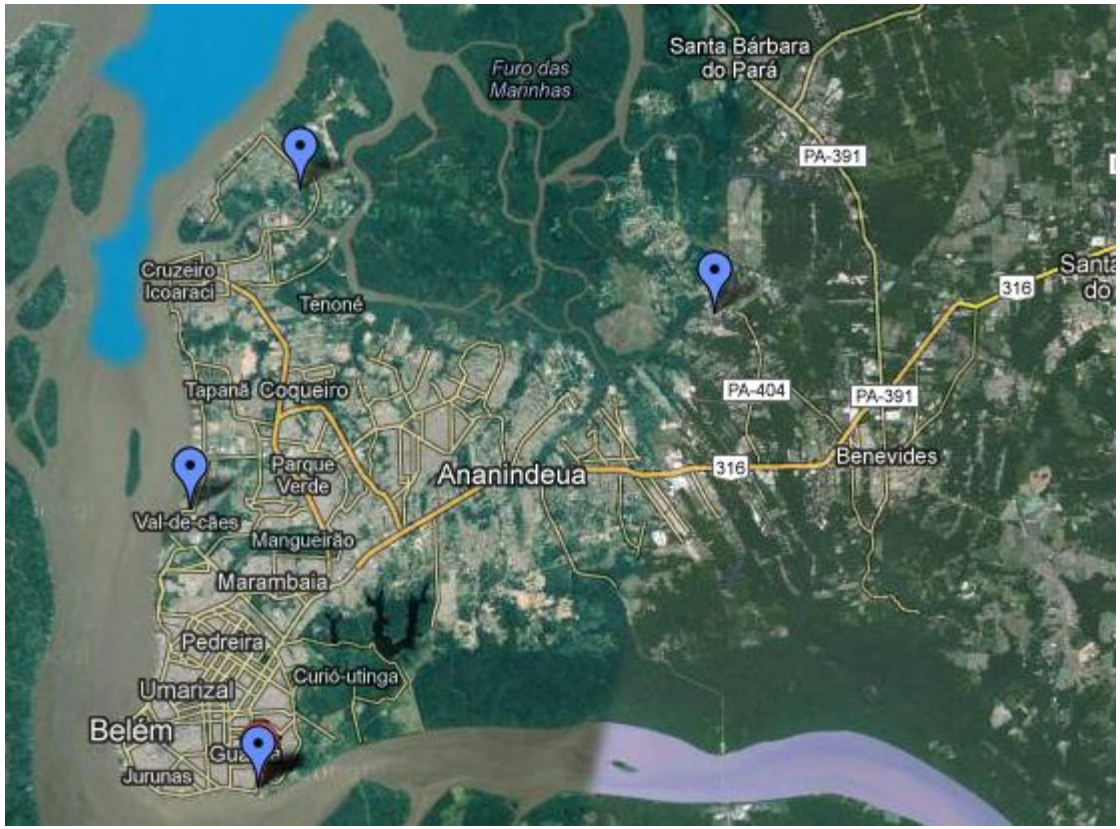
The inverse problem



RADAR		BENE		OUT		AERO	
-48.4583	-1.4749	-48.3017	-1.3167	-48.447	-1.2673	-48.4824	-1.3845

BENE = Benevides, OUT = Outeiro, AERO = Aeroporto.



Field mill network

R. Cap. Barata, 219-303
Benevides - PA, 68795-000

Passagem da Fab, 197-399 - Itaiteua
Belém - PA, 66842-050

Rod. Artur Bernardes, 5694-7000 - Val-de-cães
Belém - PA, 66115-000

R. Augusto Corrêa, 1311-1591 - Guamá

methodology

- Step1. Analize radar image to localize the possible centers of charge **Pj(xj, yj, zj).**
- Step2. Construct the function Ri,j, where the index *i* refers to the position of field mill and *j* refers to the center of charge.

$$R21 := 2k \cdot \frac{(z2 - zn1)}{\left[(x2 - xn1)^2 + (y2 - yn1)^2 + (z2 - zn1)^2\right]^{\frac{3}{2}}}$$

. Step 3.Calculate column vetor $q := \left(R^T \cdot R\right)^{-1} \cdot R^T \cdot E$

- . Step 4 . Use Coulomb's Law to calculate the direct value
- $Ec_i = \Sigma_{ij} (R_{ij} \cdot q_j)$ for fitting data

Results: STEP1

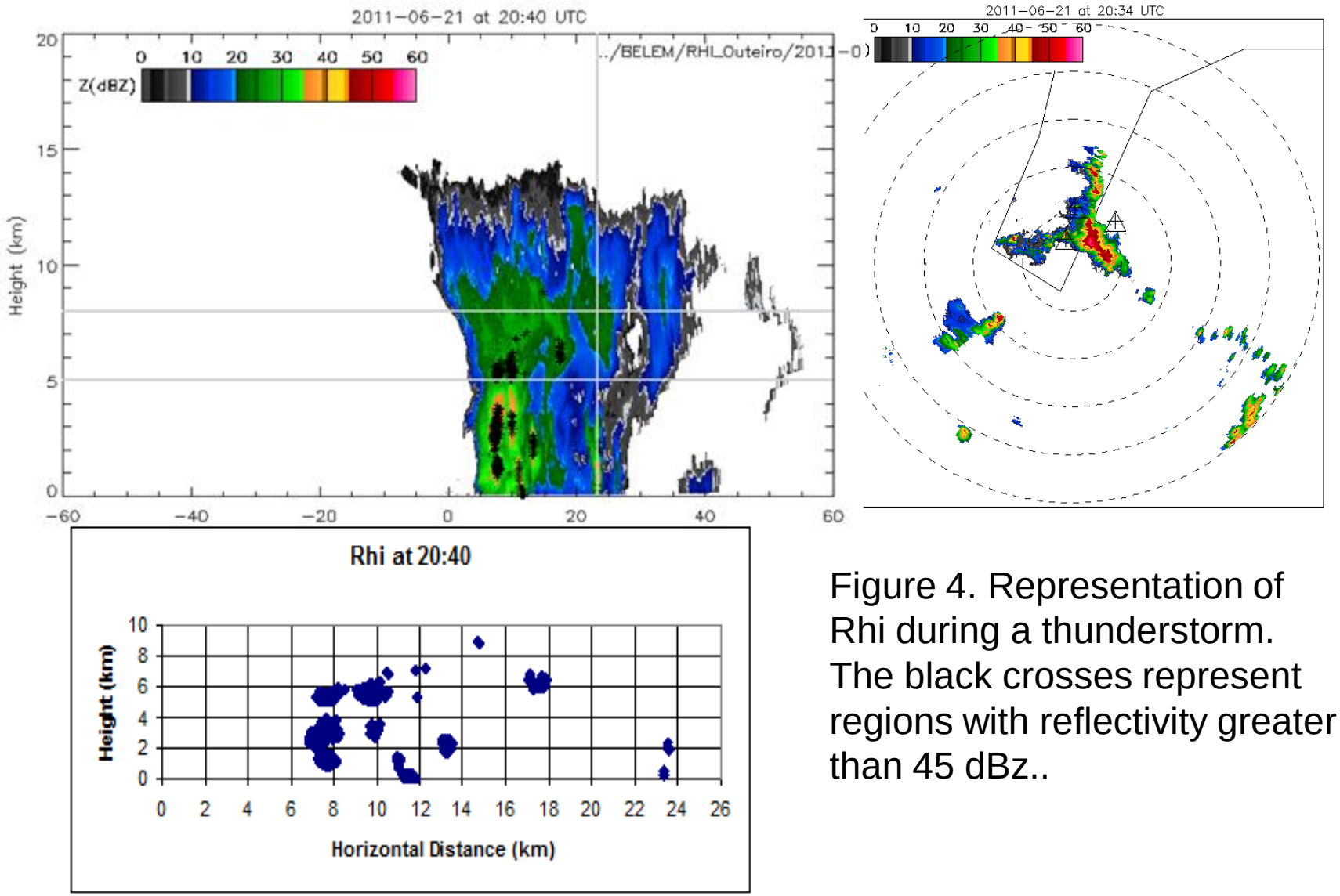


Figure 4. Representation of Rhi during a thunderstorm. The black crosses represent regions with reflectivity greater than 45 dBz..

Step 2 and 3

$$R = \begin{matrix} & R11 & R12 \\ & R21 & R22 \\ & R31 & R32 \end{matrix} \qquad E := \begin{pmatrix} E1 \\ E2 \\ E3 \end{pmatrix} \qquad q := \left(R^T \cdot R\right)^{-1} \cdot R^T \cdot E$$

$$R = \begin{pmatrix} 52.8996 & 62.9145 \\ 19.2823 & 30.3041 \\ 32.577 & 45.049 \end{pmatrix} \quad E = \begin{pmatrix} 925.4 \\ 2829.769 \\ 1276 \end{pmatrix} \quad \left(R^T \cdot R\right)^{-1} \cdot R^T = \begin{pmatrix} 0.0968 & -0.1077 & -0.0627 \\ -0.0663 & 0.0883 & 0.0554 \end{pmatrix} \quad q = \begin{pmatrix} -295.2618 \\ 259.1926 \end{pmatrix}$$

Qp2=0

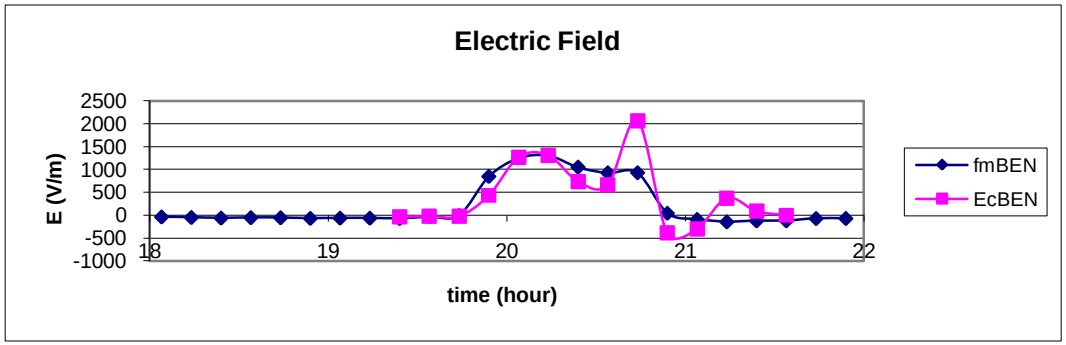
$$E1c := \left[2k \cdot qp1 \cdot \frac{(zp1 - z1)}{\left[(xp1 - x1)^2 + (yp1 - y1)^2 + (zp1 - z1)^2\right]^{\frac{3}{2}}}\right] + \left[2k \cdot qn1 \cdot \frac{(zn1 - z1)}{\left[(xn1 - x1)^2 + (yn1 - y1)^2 + (zn1 - z1)^2\right]^{\frac{3}{2}}}\right] + \left[2k \cdot qp2 \cdot \frac{(zp2 - z1)}{\left[(xp2 - x1)^2 + (yp2 - y1)^2 + (zp2 - z1)^2\right]^{\frac{3}{2}}}\right]$$

$$E2c := \left[2k \cdot qp1 \cdot \frac{(zp1 - z2)}{\left[(xp1 - x2)^2 + (yp1 - y2)^2 + (zp1 - z2)^2\right]^{\frac{3}{2}}}\right] + \left[2k \cdot qn1 \cdot \frac{(zn1 - z2)}{\left[(xn1 - x2)^2 + (yn1 - y2)^2 + (zn1 - z2)^2\right]^{\frac{3}{2}}}\right] + \left[2k \cdot qp2 \cdot \frac{(zp2 - z2)}{\left[(xp2 - x2)^2 + (yp2 - y2)^2 + (zp2 - z2)^2\right]^{\frac{3}{2}}}\right]$$

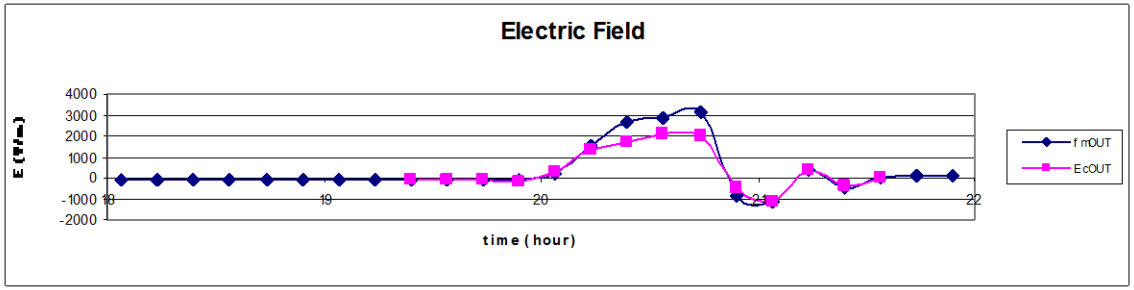
$$E3c := \left[2k \cdot qp1 \cdot \frac{(zp1 - z3)}{\left[(xp1 - x3)^2 + (yp1 - y3)^2 + (zp1 - z3)^2\right]^{\frac{3}{2}}}\right] + \left[2k \cdot qn1 \cdot \frac{(zn1 - z3)}{\left[(xn1 - x3)^2 + (yn1 - y3)^2 + (zn1 - z3)^2\right]^{\frac{3}{2}}}\right] + \left[2k \cdot qp2 \cdot \frac{(zp2 - z3)}{\left[(xp2 - x3)^2 + (yp2 - y3)^2 + (zp2 - z3)^2\right]^{\frac{3}{2}}}\right]$$

$E1c = 687.734$ $E1 = 925.4$ $E2c = 2161.2655$ $E2 = 2829.769$ $E3c = 2057.6156$ $E3 = 1276$

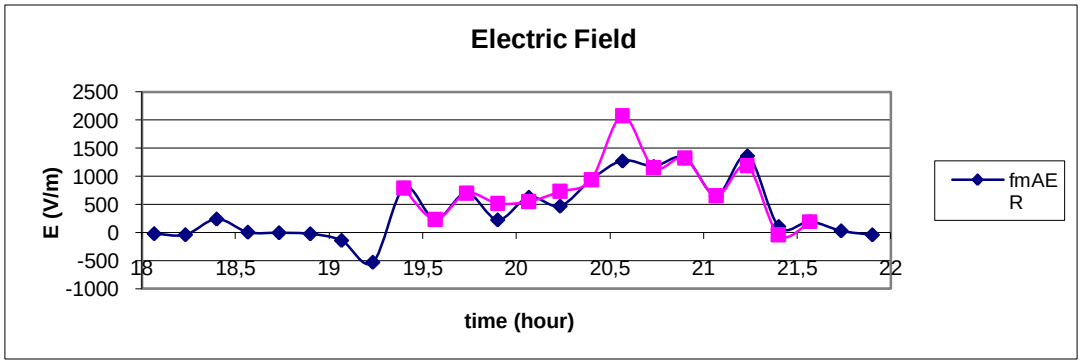
STEP 4



Benevides



Outeiro

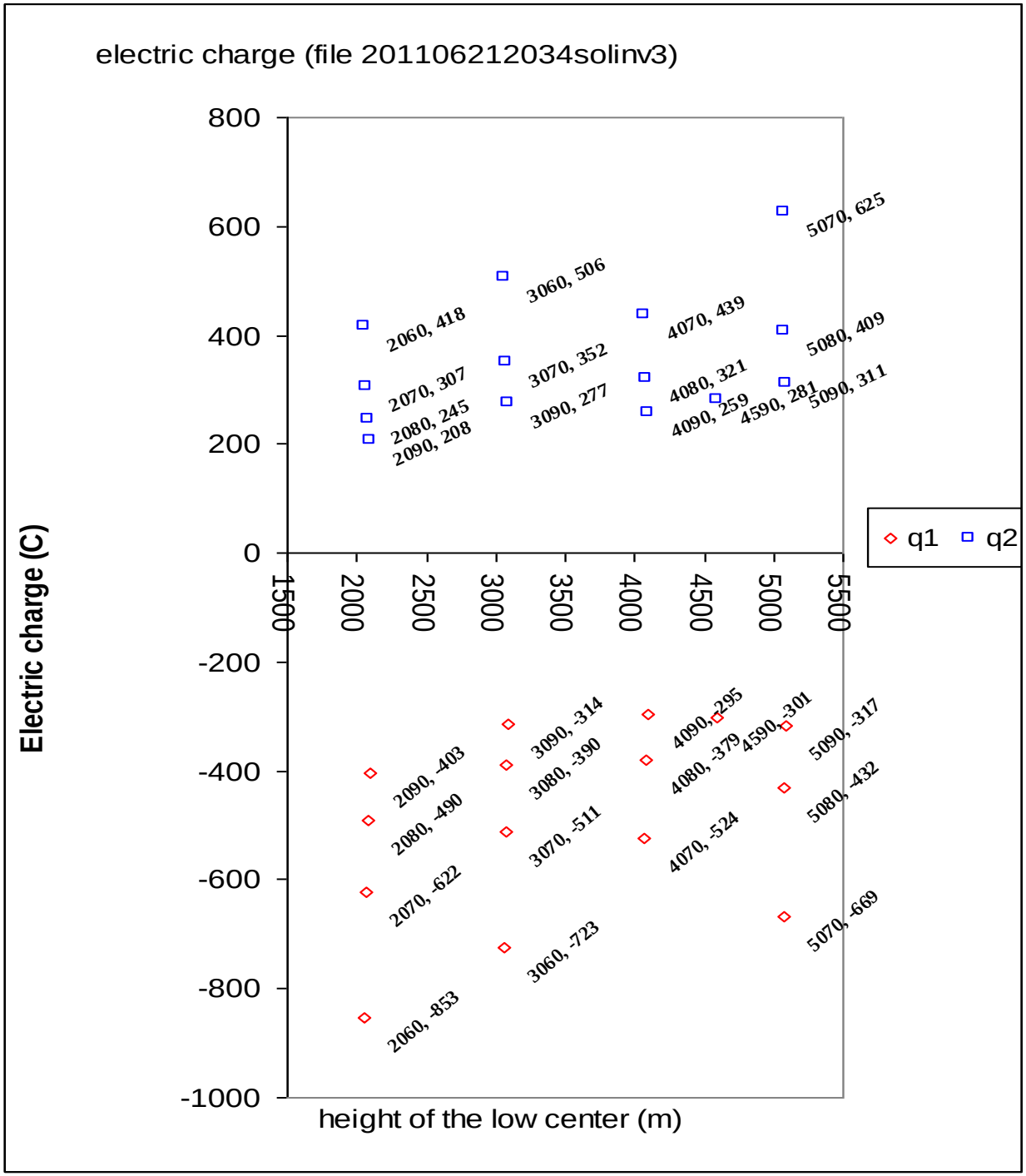


Aeroporto

Calculated results 1 (matrix)

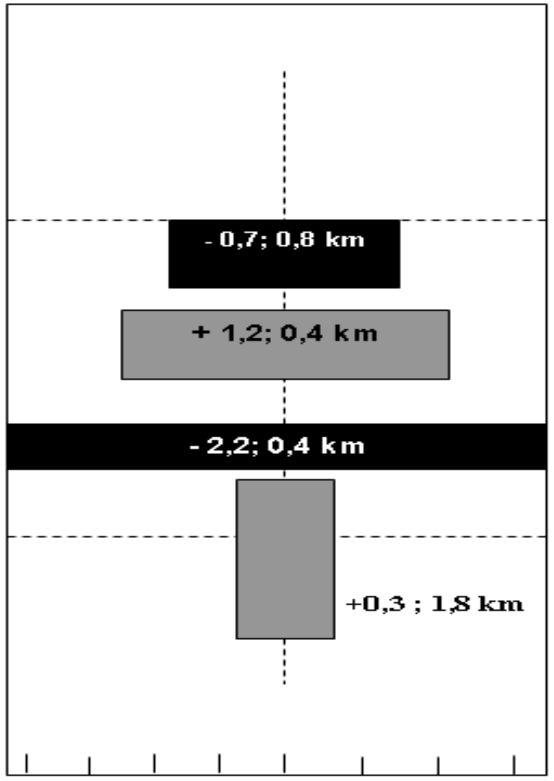
file	h1 (m)	h2 (m)	h1+h2/100	q1 (C)	q2 (C)	
1a	2000	6000	2060	-853	418	
1	2000	7000	2070	-622	307	
2	2000	8000	2080	-490	245	
3	2000	9000	2090	-403	208	
6b	3000	6000	3060	-723	506	
4	3000	7000	3070	-511	352	
5	3000	8000	3080	-390	273	
6	3000	9000	3090	-314	277	
7	4000	7000	4070	-524	439	
8	4000	8000	4080	-379	321	
9	4000	9000	4090	-295	259	
9a	4500	9000	4590	-301	281	
10	5000	7000	5070	-669	625	
11	5000	8000	5080	-432	409	
12	5000	9000	5090	-317	311	
mean	3433	7800		-481.53	354.14	

2.(grafic)


electric charge (file 201106212034solinv3)
800
600
400
200
0
-200
-400
-600
-800
-1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
Electric charge (C)
height of the low center (m)
q1
q2
2060, 418
3060, 506
4070, 439
5070, 625
2070, 307
3070, 352
4080, 321
5080, 409
2080, 245
3090, 277
4090, 259
4590, 281
5090, 311
2090, 208
2090, -403
3090, -314
4090, -295
4590, -301
5090, -317
2080, -490
3080, -390
4080, -379
5080, -432
2070, -622
3070, -511
4070, -524
2060, -853
3060, -723
5070, -669

discussion

- This methodology is not closed because
- of the nature of the inverse problem that
- has infinite solutions.
- The increasing knowledge of position and
- sign of charges means more confidence in charge magnitude.
- This knowledge can be given by balloons
- (Stolzenburg et al. 1998a, b and c).
- For a more detailed discussion on some
- improvement of this methodology see for
- exemple, Lacerda et al 2012b.



Conclusions

- In this paper we present a methodology for calculating charge structure in convective clouds. The electric field measured by a network of field mill is fitted by calculated field and seems be in reasonable agreement. The magnitude and location of charge centers were calculated and charge magnitude is of order of 4 $x10^2$ C
- q(3433) = -481.53 C q(7800)= 354.14 C
- This result is greater than values presented in literature. For a better improvement of this methodology we recommend the use of other techniques that allow detect the position of centers and the sign of charges in that center.

- Thanks

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