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A study about 3D magnetotelluric response of a simple topographic feature

Jéssica Brito (Universidade Federal do Pará), Vinícius Neves (Universidade Federal do Pará), Cícero Régis (Universidade Federal do Pará)

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Abstract Summary

The 3D magnetotelluric homogeneous halfspace response of several truncated cone-shaped models with varying dimensions was simulated in a range of 10^{-3} Hz to 10^{4} Hz. We have compared the sounding results to the halfspace-expect response and identified a relationship between the skin depth of frequency which the phase deviation from 45° plane response is maximum, and the horizontal dimensions of the models. We also noticed that the response behavior at low frequencies is similar to the galvanic distortion due to near-surface inhomogeneities.

Introduction

In real-world MT surveys, one of the main features that influences the MT response (Vozoff, 1991), (Tikhonov, 1985) is the topography. This influence has been verified by Wannamaker et al. (1986) on 2D magnetotelluric data, which concluded that the H_x component parallel to the strike is more susceptible to topographic features than the horizontal. Meanwhile, Nam et al. (2007), for 3D data, noticed that topography induces galvanic effects in both TM and TE modes, with these effects increasing with terrain slope. Both studies were done for the MT response on simple models with halfspace conductivity, this method has allowed the observation of the response only due to the topography. In order to further broaden the understanding on the behavior of the MT response in non-plane terrains, we have modelled the 3D MT response for a station in the top center of a simple truncated cone hill, varying the slope (the angle of the vertical surface to the horizontal xy plane), the ratio relation between the base radius and the top radius (that determines the distance of the vertical surface to the station) and its proportional size.

Truncated Cone Hill Models

The behavior of the MT response was tested for several Truncated Hill Models, which were built with 3 types of slope, 3 types of ratio radius and 3 proportions the slope α and the β ratio radius is calculated respectively as

$$\alpha = \frac{H}{(R_b - R_t)}\text{[a]} \qquad \beta = \frac{R_t}{R_b}\text{[b]}, \tag{1}$$

where H is the height, R_t is the top radius and R_b is the base radius.

The models with the highest slope were based on the trapezoidal hill model modeled in (Wannamaker et al., 1986), as seen in figure 1 which is 450 m tall, 450 m wide at the top and 2000 m wide at the base. Its proportions α and β are the first line of both following tables,

α	H(m)	R_t(m)	R_b(m)
0.58	450	225	1000
0.29	450	225	1775
0.15	450	225	3225

Table 1: α values, with example H,R_b and R_t.

β	H(m)	R_t(m)	R_b(m)
0.225	450	225	1000
0.127	450	225	2000
0.067	450	225	3225

Table 2: β values, with example H,R_b and R_t.

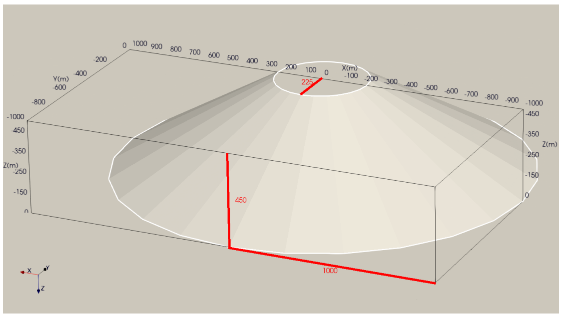

Figure 1: Truncated cone hill model example.

For each model type, we have tested scaled at 1x (original size), 0.5x (half the original size), and 0.1x (10 % of the original size).

3D MT Modelling

The 3D MT syntheic response was generated by the program mMT3D-TIV, which was implemented using the finite edge element (Jin, 2015). It was developed and validated by Professor Anderson Piedade (UFOPA) inside the research project *Estudos de Métodos Eletromagnéticos Aplicados à Exploração de Hidrocarbonetos*, which seeks to develop human and technical resources applied to the oil and gas industry.

Evaluation Method

For each type of model, with a set α and β, we verified the frequency at which the apparent phase is further from 45°, which corresponds to the apparent phase response of the homogeneous plain halfspace. Then, using the conductivity of the model's halfspace, we calculated the skin depth δ for this frequency as

$$\delta(m) \approx 503\sqrt{\frac{\rho}{F}}. \quad (2)$$

Each skin depth δ was related to the Base radius R_b of the model, where we observed an approximate linear relationship for each type of model.

Results

All the results were analyzed for the xy polarization; due to the symmetry at the station position, the results for both polarizations are equal. For the trapezoidal hill based on the model from (Wannamaker et al., 1986), the sounding curves for apparent resistivity ρ_{ap} shows a different behavior than the phase in figure 2, where the first has the maximum deviation from the halfspace response at a period tending to infinity. In contrast, the latter has a specific frequency for each model where the deviation is maximum. We also notice a translation on the frequency axis related to the size of the truncated hill cone.

For low frequencies, the behavior of the apparent resistivity is similar to the static shift distortion shown at some MT soundings due to near-surface conductivity inhomogeneits.

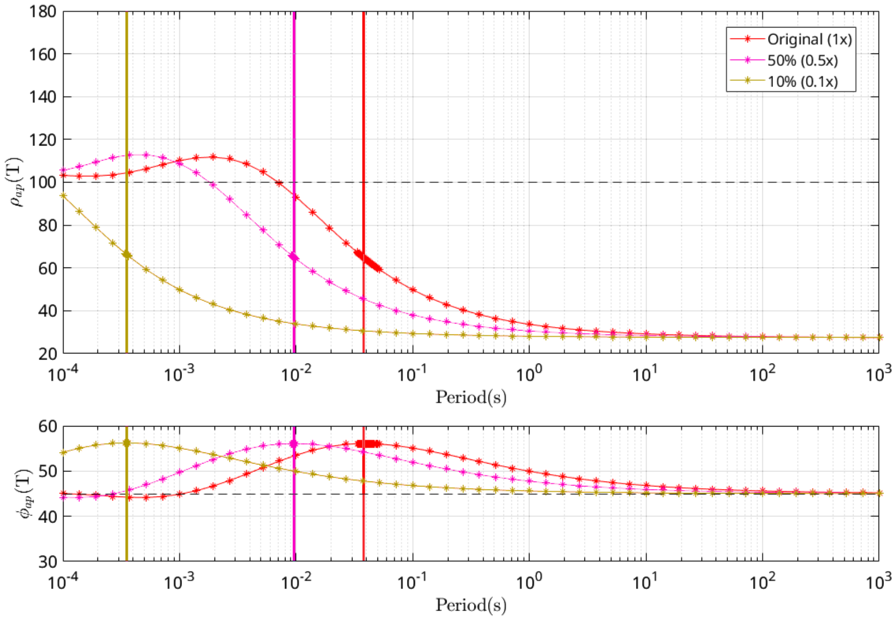

Figure 2: Apparent Resistivity and Phase curves for the models with $\alpha = 0.58$ and $\beta = 0.225$. The skin depth of maximum deviation of the phase for 1x is $\delta = 981$ m, for 0.5x is $\delta = 491$ m and 0.1x is $\delta = 94.35$ m.

By gathering the results for each model and relating them to the base radius R_b, the relation for each type of model could be fit by a line, as seen in figure 3. The analysis of models with the same slope $\alpha = 0.58$ shows that the inclination of each line increases with the ratio β.

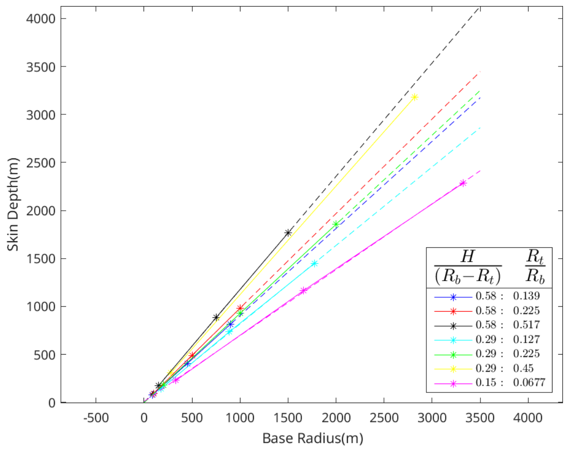

Figure 3: Relationship between the Skin depth δ and the Base Radius R_b for each model type, characterized by α and β.

Conclusion

This is an ongoing research. Our findings indicate the existence of galvanic distortion at high periods of the survey, where the apparent resistivity reduces while the phase remains at 45°. We also notice that the simulated soundings indicate a common behavior among the different tested models, which is linked to the proportions α and β of each kind of model.

Acknowledgments

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