# Magnetotelluric response estimates under the equatorial electrojet in Brazil.

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**Abstract**

Magnetotelluric responses of soundings under the equatorial electrojet in Brazil have been estimated for four distinct locations at the north and south of the Magnetic Equator. It has been observed that the effect of the concentrated ionospheric currents (electrojet) in equatorial zones is added to the electromagnetic data and act as source. The difference between daytime and nighttime data indicates that source boosted by the electrojet, mainly observed at daytime, provides better estimation of the earth response functions even for lower frequencies (<0.01Hz).

**Introduction**

Magnetotelluric (MT) method provides information about the deep resistivity composition of the crust. The main assumption underlying the method is that the source field is a plane wave (Tikhonov 1950, Cagniard 1953) which may not be applicable in regions with concentrated ionospheric currents (e.g. equatorial and auroral zones).
The ionospheric currents at the equatorial zone is called electrojet (EEJ) phenomena, described as a non-uniform east-west flowing current, effective during most of the day time, in a belt of some 600 km width centered close to the dip equator at an altitude of about 110 km (e.g. Padilha et al., 1997). The effect of such current on the ground is observed as an amplification of the northward components of the electromagnetic field on both sides of the magnetic equator.

The source effect of ionospheric currents on MT studies at these regions have been discussed in the literature both theoretically (e.g. Mareschal 1986; Pirjola 1992; Carrasquilla & Rijo, 1998) and experimentally (e.g. Padilha et al. 1997, Padilha 1999). Theoretical studies suggested that inhomogeneous source may become effective and disturb MT responses at 10 s and above while experimental studies show that such effect does not cause any problem even at larger periods.

The experimental and theoretical results contradict each other. Experimental studies may be conducted in different ways and, therefore, different results may easily be obtained. Generally, multiple MT stations are deployed around the magnetic dip equator, and, the data are recorded continuously for a period covering both day and night times which are thus associated with the EEJ source effects and its absence, respectively. By using MT data measured along a profile crossing the EEJ in Brazil, the earth response functions (ERF) are calculated for daytime and nighttime in this study to assess the EEJ influence, using both conventional and robust methods.

A distinct approach was followed and the conventional least square technique (e.g. Vozoff 1991) was employed to estimate the ERF for daytime and nighttime without any stacking. The ERFs were estimated for 9-hours long individual time segments. The starting times of the segments in Universal Time are 09:00 AM, daytime, and 09:00 PM, nighttime.

**The data**

The long period MT (LMT) data are being recorded as part of a national project run by Observatory Nacional, Rio de Janeiro, Brazil. The time variations of two horizontal electrical fields (Ex and Ey) and three magnetic fields (Hx, Hy and Hz) were recorded with one second sampling interval using LEMI instruments of LVIV Center of Institute for Space Research, Ukraine. The x-direction is aligned to magnetic north while y- direction is perpendicular to x.

The sample time series (TS) of four stations are considered here for the testing purpose (Figure 1). Stations are Sao Joaquim do Pacui (SJP), Tatuoca (TTA), São Geraldo do Anagua (SGA), Centenário (CEN) and the dates of the TS are from 25.06.2009 to 30.06.2009

6-day long sample TS, from all stations, is presented in Figure 2. SJP TTA SGA and CEN data are given with green, blue magenta and red, respectively. All curves are presented after detrend application. The graphs are, from top to bottom, the three components of the magnetic field, Hx, Hy and Hz. The bottom graph has markers (dashed lines) which indicate 9 AM and 9 PM at every day. It is clear that there is an additional variation on all daytime curves while the nighttime periods are very quite.


*Figure 1. LMT stations simultaneously recorded between 26.06.2009 and 09.07.2009.*

Two horizontal components from all stations presents identical fluctuation without any significant amplitude variations while vertical components have amplitude variation and sign reversal, as Rigoti et al. (1999, Figure 3) presented, between the stations northern and southern side of the Equatorial dip.

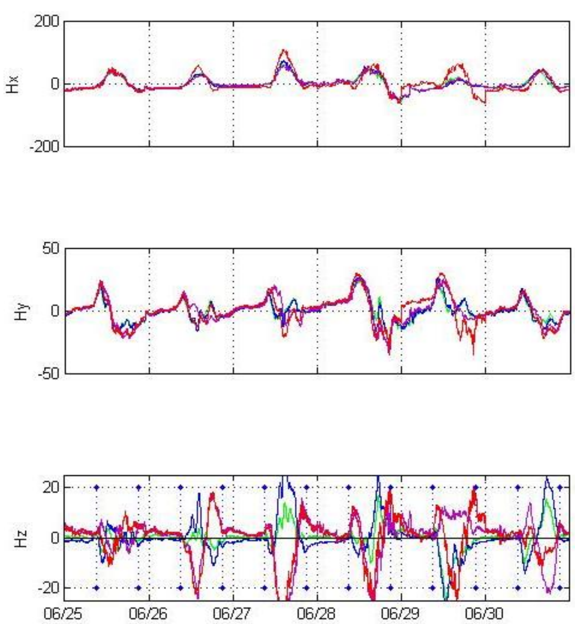


*Figure 2. 6 days time series from all four stations. Green blue magenta and red are from NW to SE, respectively. The three components of magnetic field are presented versus time. The mark lines on lower graph (Hz) indicate 9 AM and 9 PM everyday. Day markers are at midnights.*

Two station were selected for the further process; distant one (Centenário) and closest one (Tatuoca). First attempt is to see the amplitude variations between the daytime and the nighttime segments. The spectrograms for vertical components for 6-day data are given in Figure 3.

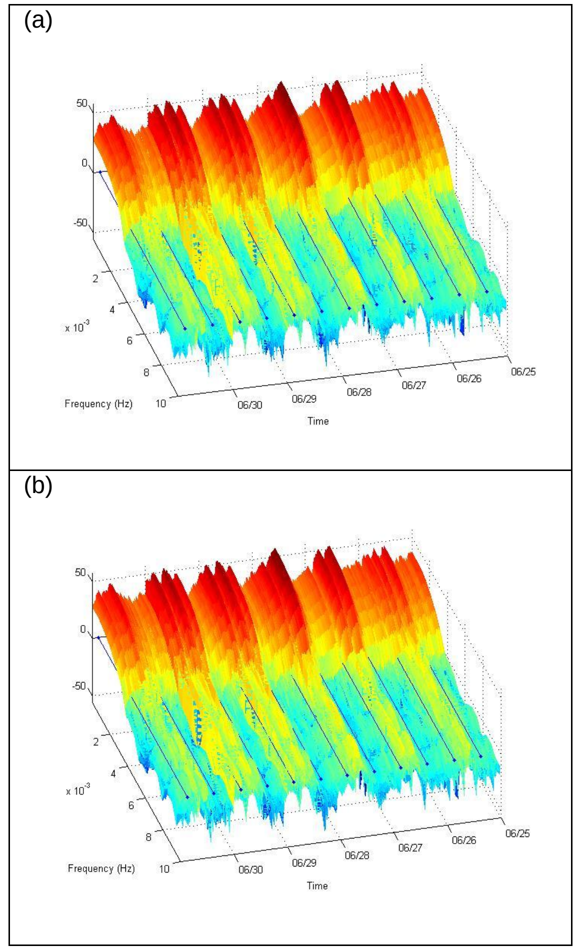


*Figure 3. Spectrograms of Hz component for (a) Centenário and (b) Tatuoca stations. The mark lines indicate 9 AM and 9 PM everyday.*

20 linearly spaced frequencies, between 0.01 and 0.00001Hz, are considered here. The Centenário data, for higher frequencies (>4e-3Hz), have relatively lower amplitude than the Tatuoca data. The daytime data has additional highs and it covers all frequency range of interest. Additionally, Figure 2 indicates that fluctuations appear in other component in the same time intervals. Therefore, it may be taken as an additional source, as long as the plane wave assumption is not violated.

The day and the night time segments are evaluated separately to see the effect of additional source. The ERFs are estimated by processing a single time segment, separately, from the daytime (Figure 4a) and the nighttime (Figure 4b). Hx and Hy are the references for the impedance estimation (e.g. Vozoff 1991). The right panels are the apparent resistivity (top) and phase of impedance (bottom) obtained from conventional method (e.g. Vozoff 1991). The left panels are the coherencies between the components of the EM field except that bottom one; two curves are the analytic (astr) and tipper (tstr) strike.

The ERFs for all segments were expected to present same behavior. The northward component of the magnetic field (Hx) and its associated electrical filed (Ey) produced better estimations from daytime segments. The nighttime segments and other components suffer from lower signal strength.

The diurnal east-west EEJ currents should have strong effect on the northward magnetic components (Padilha 1999). As a consequence, the coherencies between Ey and Hx (Rx) are higher in both cases. It is a fact that the high coherency could also be a sign of coherent noise rather than coherent signal. Since this condition resulted in better estimation of apparent resistivity curve (yx) than other direction, the high coherency meant coherent signal rather than noise. Some directional noise or low signal strength corrupted the result in perpendicular direction.

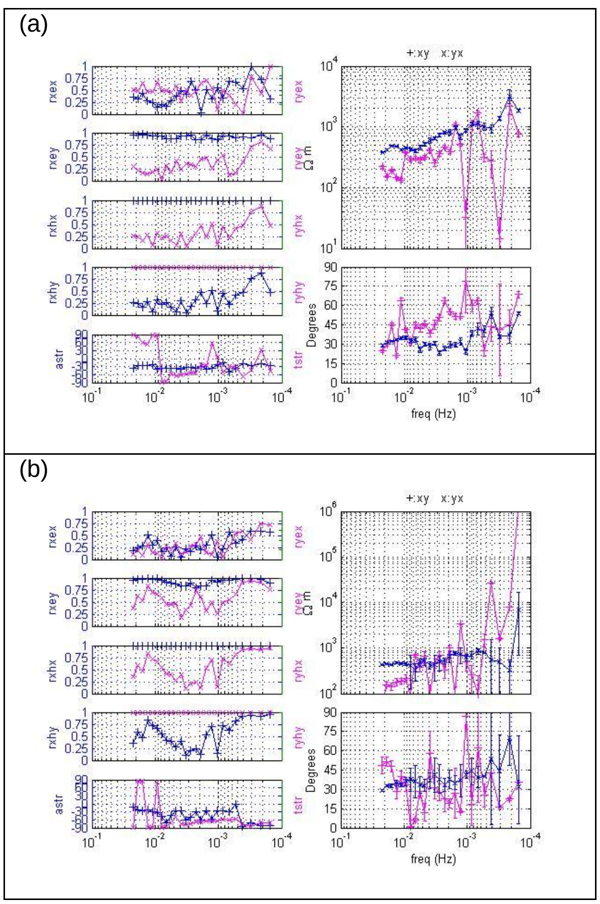


*Figure 4. ERF from (a) a single daytime segment (09:00:00 30/06/2009 - 18:00:00 30/06/2009) and (b) a single nighttime segment (21:00:00 29/06/2009 - 06:00:00 30/06/2009) at Centenário stations*

The next stage is to compare the results from independent time segments. Only YX (Ey and Hx) component of the apparent resistivity and the phase of impedance are considered. The daytime and the nighttime time segments are evaluated individually and the resulted curves are compared (Figure 5).

Figure 5a and 5b evidenced that the nighttime segments are noisier than the daytime segments. The difference is much significant in equatorial zone. When the period of interest approaches to 10,000 s, the noise level in the ERFs increases rapidly. When the processing scheme uses stacking or robust methods, apparently, the nighttime segments becomes weaker and the daytime segments are dominant on estimation of ERFs. This results confirm former results (Padilha, 1999); the day time recordings provide better estimations.

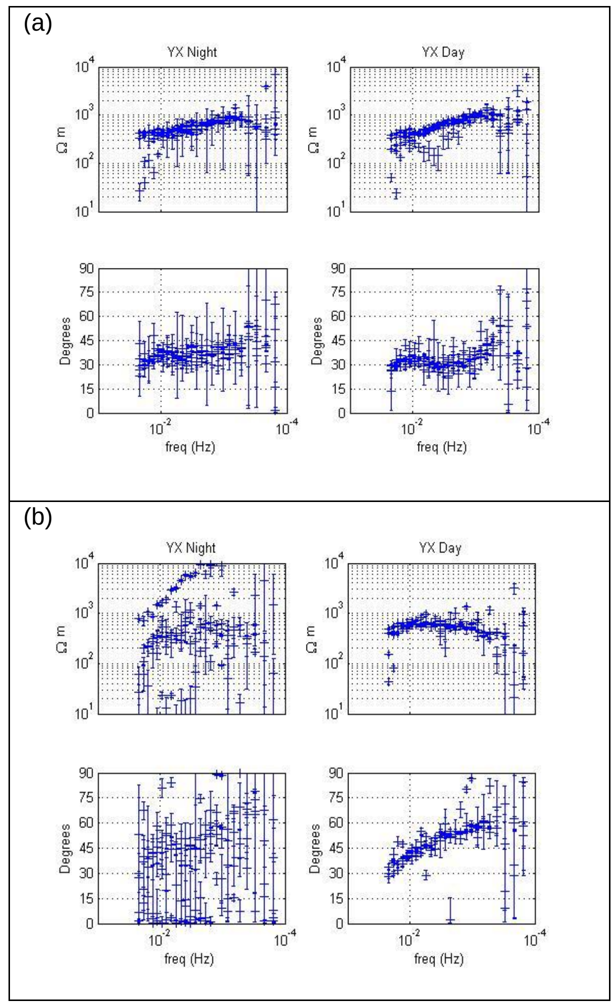


*Figure 5. Apparent resistivity (Top) and phase of impedance (bottom) from all night (left panels) and day (right panels) time segments (25/06/2009 - 30/06/2009) at (a) Centenairo stations and (b) Tatuoca stations.*

**Conclusions**

Three is a distinct difference between the daytime and the nighttime time segments in terms of noise content which assigned to EEJ due to its nature and appearance time. This present study has shown that MT response estimates for daytime were more realistic and less noisy than nighttime estimates. Longer recording time provides an opportunity to utilize such source.

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