The definition of both the instrumental and environmental backgrounds in the electromagnetic emissions above seismic regions for CSES satellite

M. Piersanti[2], G. D'Angelo[3], P. Diego[1], I. Bertello[1], M. Candidi[1] and P. Ubertini[1]
(1) INAF-Istituto di Astrofisica e Planetologia Spaziali, Roma, Italy.
(2) INFN - University of Rome Tor Vergata, Rome, Italy.
mirko.piersanti@roma2.infn.it

Introduction.

To define a background in the electromagnetic emissions above seismic regions, it is necessary to define the statistical distribution of the wave energy in absence of seismic activity. Nemec et al. [2008], built a map of electromagnetic emissions containing the statistical description of the intensity of electromagnetic waves obtained from the entire DEMETER satellite data set. Then, they estimated the probability of occurrence of a signal during a seismic event whose intensity results to be different to the background level defined by the map.

CSES EFD Data

The orbits of the CSES satellite were sun-synchronous, had an inclination of 97.4° and a local time of 14.00 on day-side and 02.00 on night-side. The instruments were operational at geomagnetic latitudes between -65° to +65° [Shen et al., 2018]. The data from the electric field experiment EFD [Huang et al., 2018] were used in order to detect any electromagnetic waves. We selected the ELF band (from 13 Hz to 5 kHz, with a sample rate of 2.5kHz). We analysed 1 month data of the satellite observations (August 2018), focusing on L'Aquila (Italy) and Bayan (Indonesia) location, evaluating both the electric field instrumental and environmental background to be used for the detection of possible electric field signal of seismic origin. For this purpose, we applied a completely the method of Bertello et al. [2018] to determine the environmental background based on ALIF technique [Piersanti et al., 2018].

Multiscale statistics via ALIF and Standardized Mean (SM) test

The algorithm for the evaluation of the energy background is based on Adaptive Local Iterative Filtering (ALIF) technique [Piersanti et al. (2018)]. ALIF first decomposes a signal (*s(t)*) into several Intrinsic Mode Functions (IMFs), which are functions oscillating around zero, but not necessarily with constant frequencies.

$$s(t) = \sum_{\ell=1}^{m} IMF_\ell(t) + r(t)$$

Then, it performs a time--analysis on each component separately. The connection between each IMF and the scale of variability of *s(t)* have been analysed by using the method proposed by Flandrin et al. (1998):

$$s(t) = s_0(t) + \delta s(t)$$

where $s_0(t)$ is the baseline and $\delta s(t)$ are the variations around $s_0(t)$. The basic idea is that $\delta s(t)$ has a standardized mean (SM: defined as the mean divided by the standard deviation) which is close to zero and represents the fluctuating part of *s(t)*. That is:

$$\delta s(t) = \sum_{\ell=1}^{k} IMF_\ell(t) \qquad (1)$$

The k value represents the last mode index for which the reconstruction given by Eq. (1) has an SM close to zero.

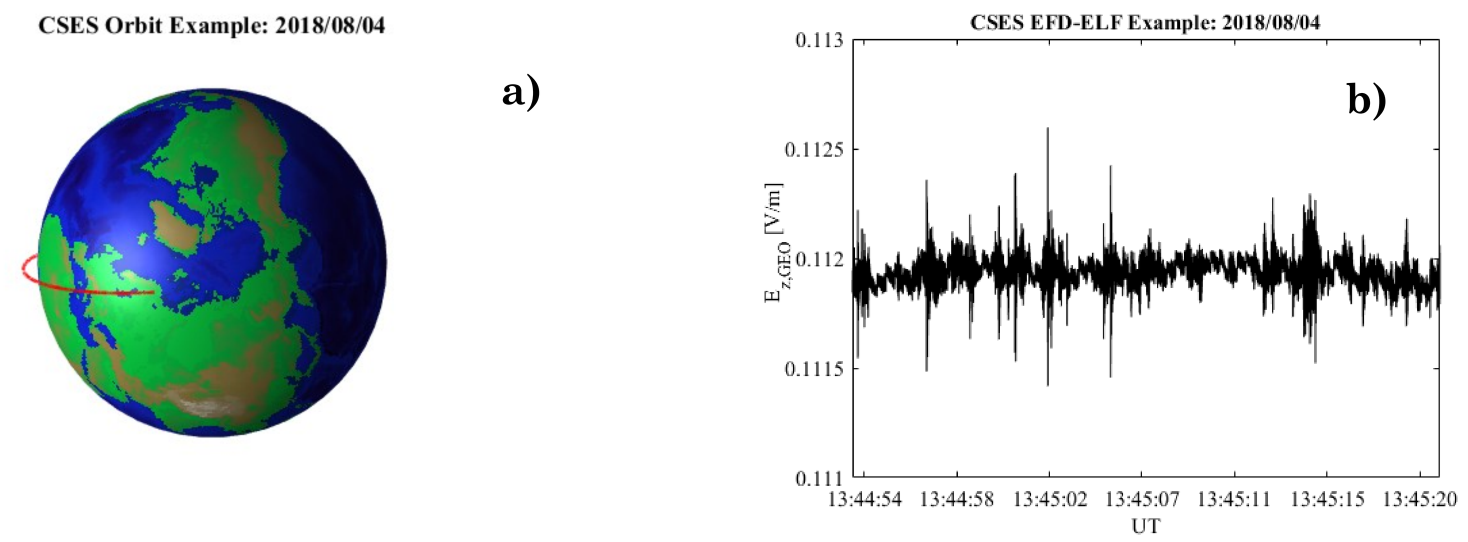

Figure 1: a) Display of one CSES orbit passing through l'Aquila geographic position **b)** Example of the electric field observations over l'Aquila on August 4, 2018 from 13:44 to 13:45 UT, along the E_z component. Here, we used the geographic reference frame.

As in Bertello et al., 2018, we evaluated, for each component the relative, $\epsilon_{rel}(\ell)$, defined as the ratio between the square L_2 modulus of the single IMF and the total energy *s(t)*. In our case the scale ℓ corresponds to the peculiar frequency of each IMF component of the electric field observations. To accomplish this task, we create a 2°x 2° latitude/longitude cell centred at the geographical position of L'Aquila and Bayan. The we divided the period in Solar Quiet (SQ) and Storming (GS). Finally, we divided the dataset into 2 subsets depending on the local time sector of the satellite orbit (i.e. dayside or nightside). Each subset has been again divided into 2 more subsets characterized by different seismic conditions. The first one (M_L) is defined for low seismic activity (M≤3, M being the earthquake magnitude) and the second (M_H) for high seismic activity (M>3).

References.
Bertello et al., *Ann. Geophys,* 36, 1483–1493, doi:10.5194/angeo-36-1483-2018, 2018 .
Flandrin, P.: Time-frequency/time-scale analysis, Vol. 10, *Academic press*, 1998.
Nemec, F., Santolik, O., Parrot, M., and Berthelier, J. J.: *Geophys. Res. Lett.*, doi:10.1029/2007GL032517, 2008.
Piersanti M., et al., *Journal of Geophysical Research: Space Physics*, doi:10.1002/2017JA024153, 2018.
Shen X., et al., *Earth and Planetary Physics*, 2, 439-443. doi:10.26464/epp2018041, 2018.
J.P. Huang et al., *Earth and Planetary Physics*, 2(6): 469-478. doi:10.26464/epp2018045, 2018.

Environmental Background

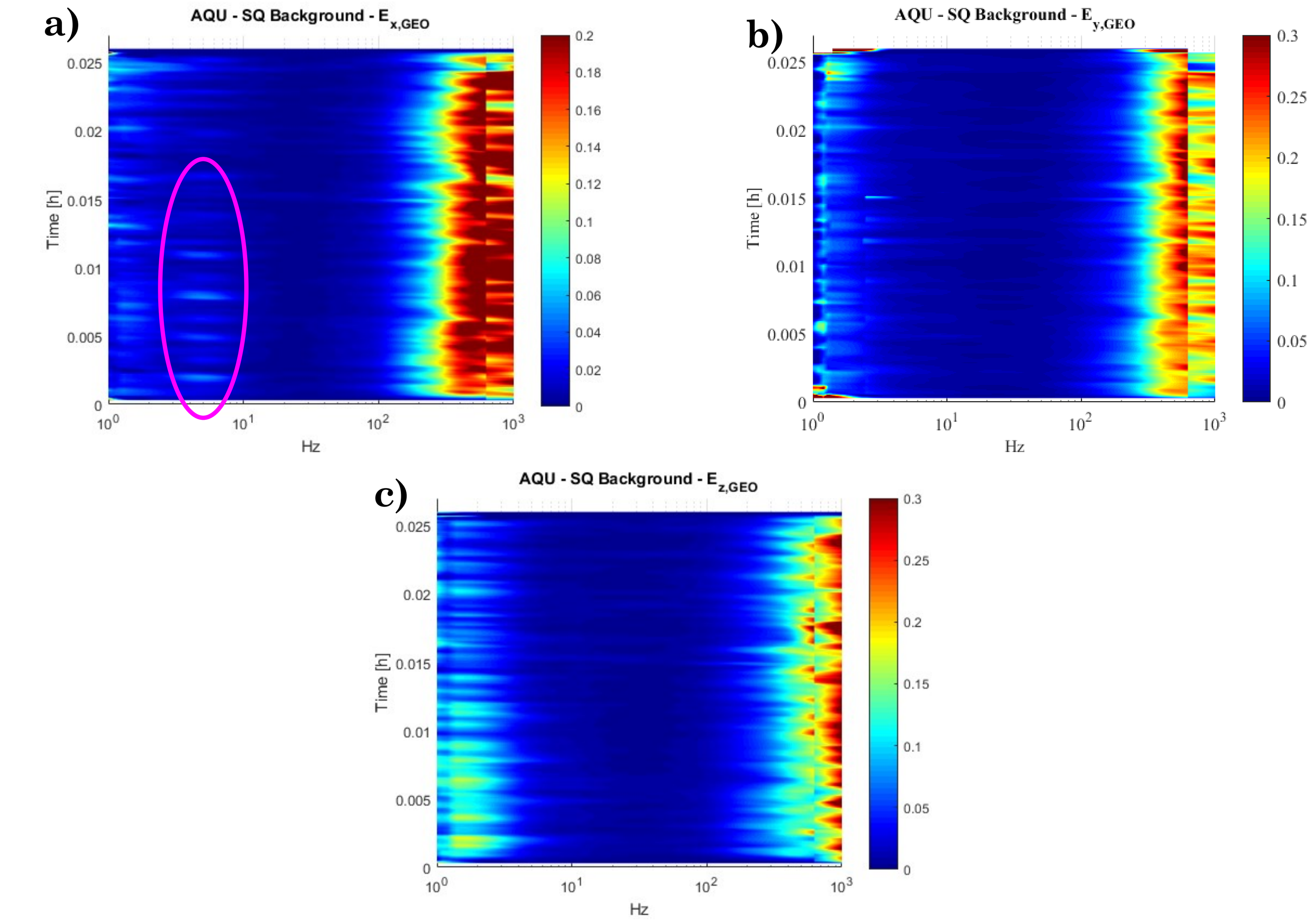

Figure 2: EFD SQ environmental background over l'Aquila. The EM energy wave background over l'Aquila cell for the E_x component (panel a), for the E_y component (panel b) and for the E_z component (panel c). A signature at f≈8 Hz (pink circle), related to the Schumann ionospheric resonance at CSES orbit, is visible at in the E_x components. The peaks detected at frequency around 2 Hz are due to the VxB electric field present in the ELF band.

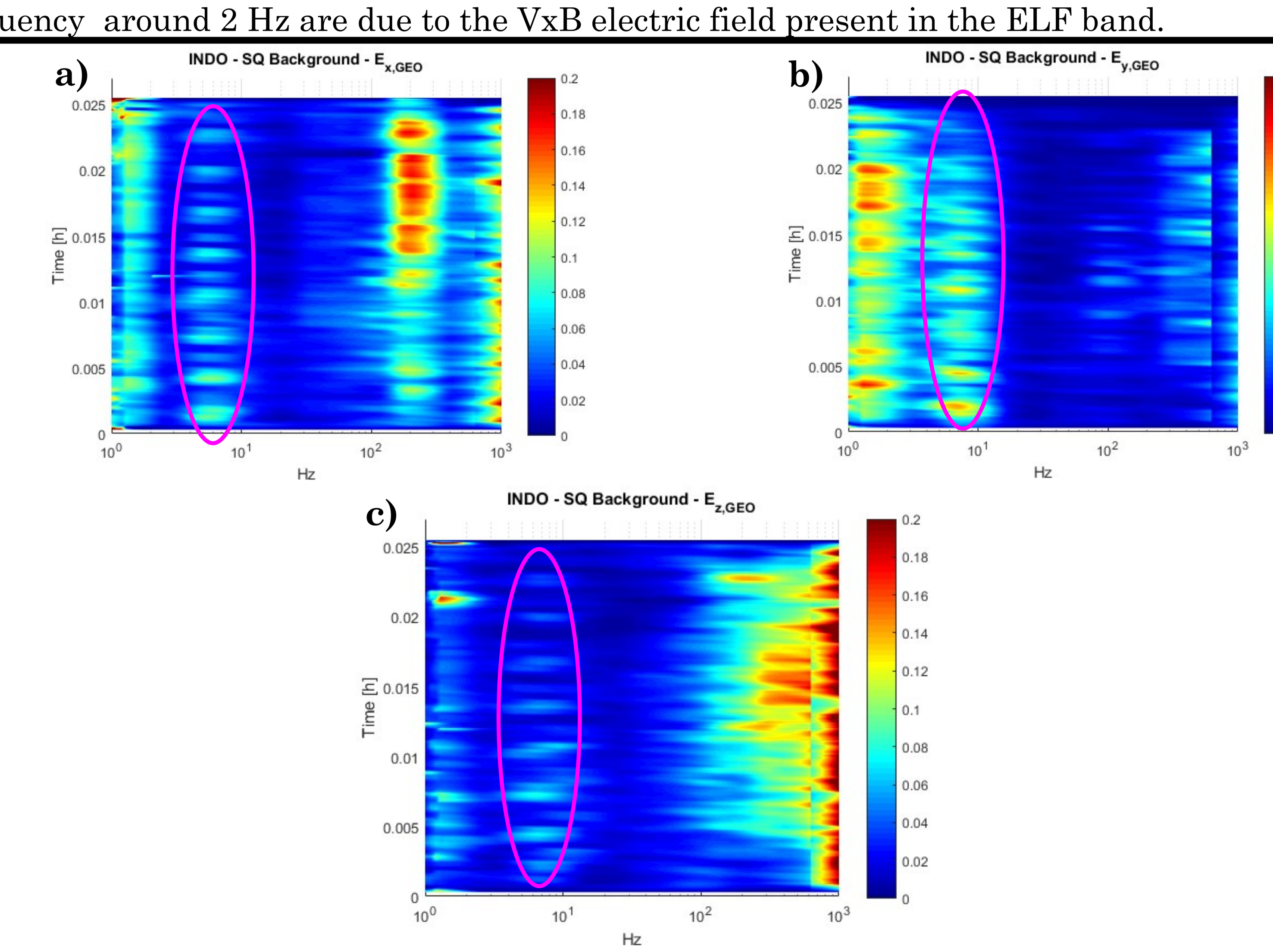

Figure 3: EFD SQ environmental background over Bayan. The EM energy wave background over l'Aquila cell for the E_x component (panel a), for the E_y component (panel b) and for the E_z component (panel c). A signature (pink circle) at ≈8 Hz is visible at all components, related to the Schumann ionospheric resonance at CSES orbit. The peaks detected at frequency around 2 Hz are due to the VxB electric field present in the ELF band.

Bayan EQ—August 5, 2018—A tentative

Figure 4: Display of one CSES orbit passing near the EQ epicentre geographic position (left); EQ location, magnitude and UT (from http:\\www.ingv.it—right panel). Red circle identifies the EQ epicentre

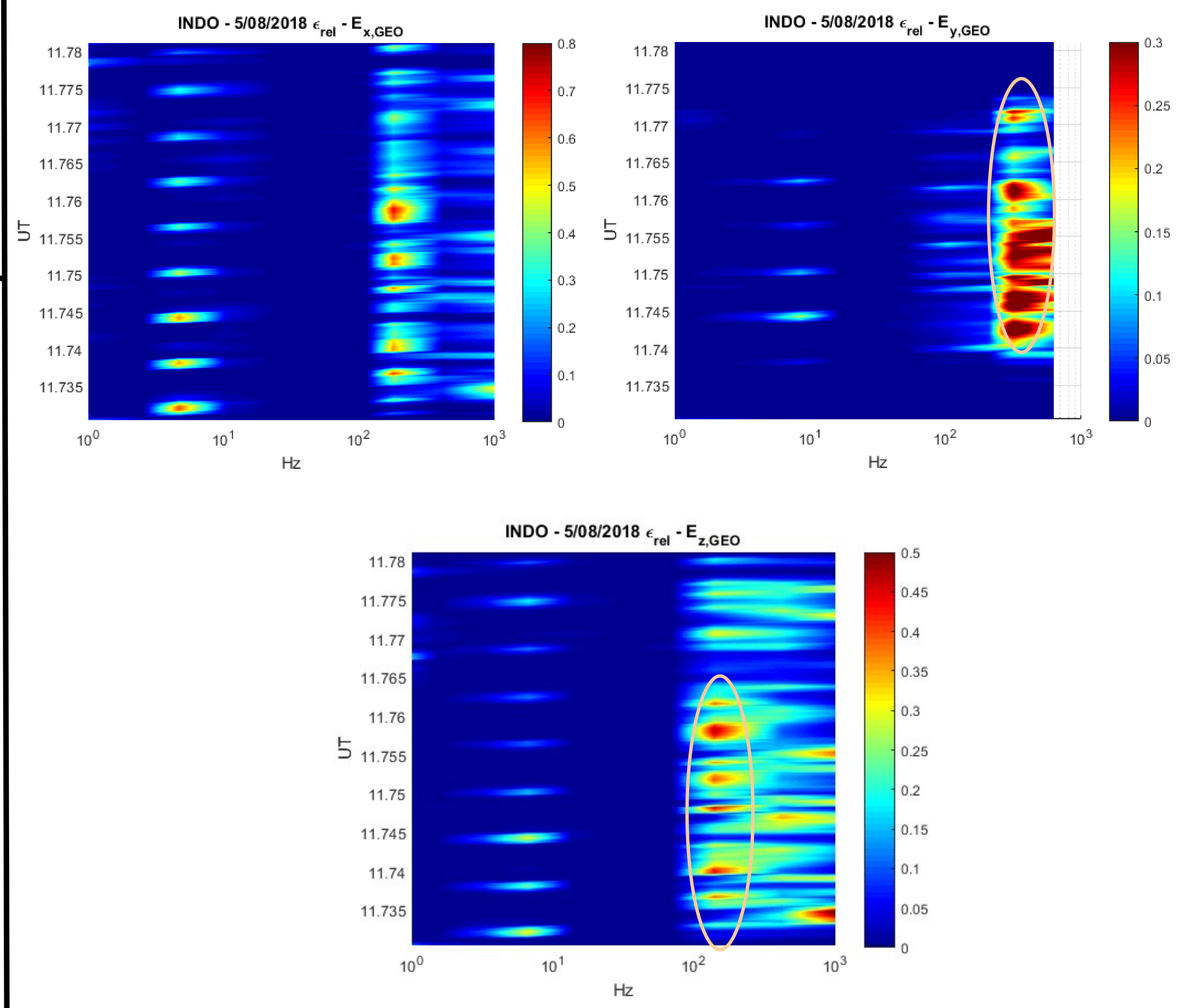

Figure 5: The EM energy wave background over Bayan cell during the 05/08/2018 EQ for the E_x component (panel a), for the E_y component (panel b) and for the E_z component (panel c). A clear peak at ≈8 Hz is visible at all components, related to the Shuman ionospheric resonance at CSES orbit. Anomalous peaks (brown circles) at 210 Hz (E_z component) and at 535 Hz (E_y component) with respect to the background has been detected.

Conclusions.

- To define a background in the electromagnetic (EM) emissions above seismic regions, it is necessary to define the statistical distribution of the wave energy in absence of seismic activity.
- Bertello et al. [2018] evaluated EM background for the entire DEMETER satellite mission using an algorithm based on a new data analysis technique, called ALIF [Piersanti et al., 2018];
- Here we evaluated the EM background using Bertello et al. [2018] algorithm for the first observations of EFD on board CSES satellite over l'Aquila (Italy) and Bayan (Indonesia) geographic positions.
- Our results shows a signature of the Schumann resonance, whose amplitude is higher at Bayan then at l'Aquila. This is probably due to the close to equatorial position of Bayan.
- Interestingly, we repeated our analysis for Bayan EQ occurred on August 5, 2018 at 11:46 UT. CSES orbit was close to the EQ epicentre. Two anomalous frequency peaks has been detected at 210 Hz and 535 Hz along Ez and Ey, respectively.
- A further analysis is in progress to identify the origin of those anomalous EM signals.

Acknowledgment.
The authors thank the Italian Space Agency (ASI) for the financial support under contract ASI "LIMADOU scienza" no. 2016-16-H0.