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DEVELOPMENT AND TESTING OF SEISMIC REGIONAL DISCRIMINANTS

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INTRODUCTION

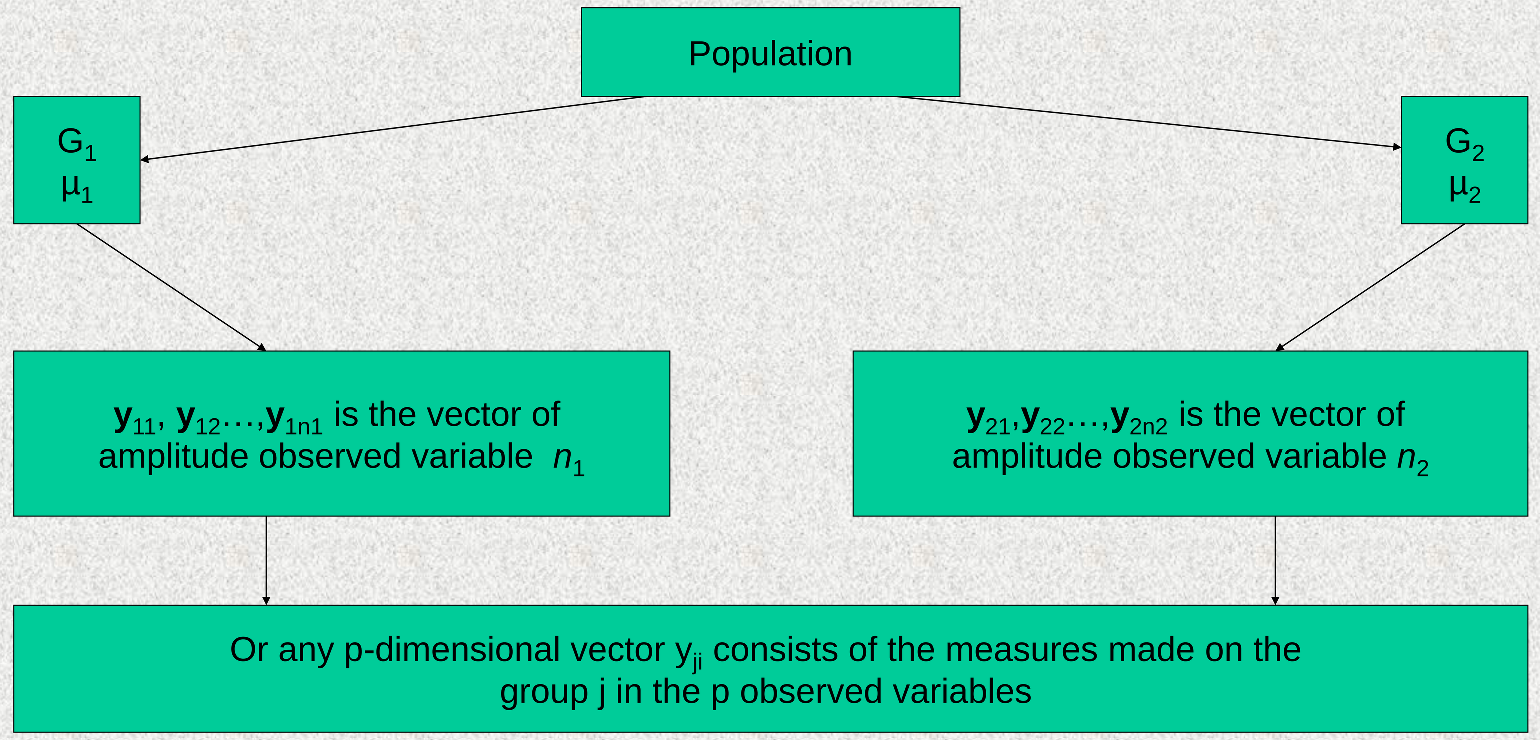
The routine process of the IMS data at the CTBTO International Data Center (IDC) is aimed at identifying in the seismological bulletins all the seismic events the source of which is certainly natural. This process, named screening out, is carried out on several tens of earthquakes per day. It is important that the methods used for the screening process are as reliable and efficient as possible, so as substantially reducing the number of suspicious events without classifying any explosion as natural events.

The principal identification method applied at the CTBTO IDC is based on the difference between the *Ms* magnitude, computed from the amplitude of the surface Rayleigh waves with period close to 20 s, and the *mb* magnitude computed from the amplitude of the body waves with period close to 1 s. The applicability of this method is, however, limited by the difficulty of detecting surface waves for events of low *mb* magnitudes, so as to allow the computation the *Ms* magnitude for such events, which are very numerous.

For CTBT verification, in case of events of small magnitude, the use of stations at regional distances from the epicenter, is crucial. In this context, another category of seismological screening, the so-called regional discriminants, can be applied. This method is based on the amplitudes of the surface waves (*Lg*) at much higher frequencies (8-12 Hz). Unfortunately, these high-frequency waves are not easily detectable, and the method requires regional calibration curves for each specific site, calibrations that are not available on a global scale.

DISCRIMINANT ANALYSIS

A discriminant method should be optimized and tested by means of rigorous statistical methods. In our work, we adopt a mathematical theoretical framework named "Discriminant Analysis". The Discriminant Analysis is known as a statistical tool in a variety of applications for classifying single observations in two or more sets through the search of the optimal linear functions of the parameters describing the observed data. In the learning phase, this method allows the adjustment of the contribution of each single parameter to the discrimination algorithm.



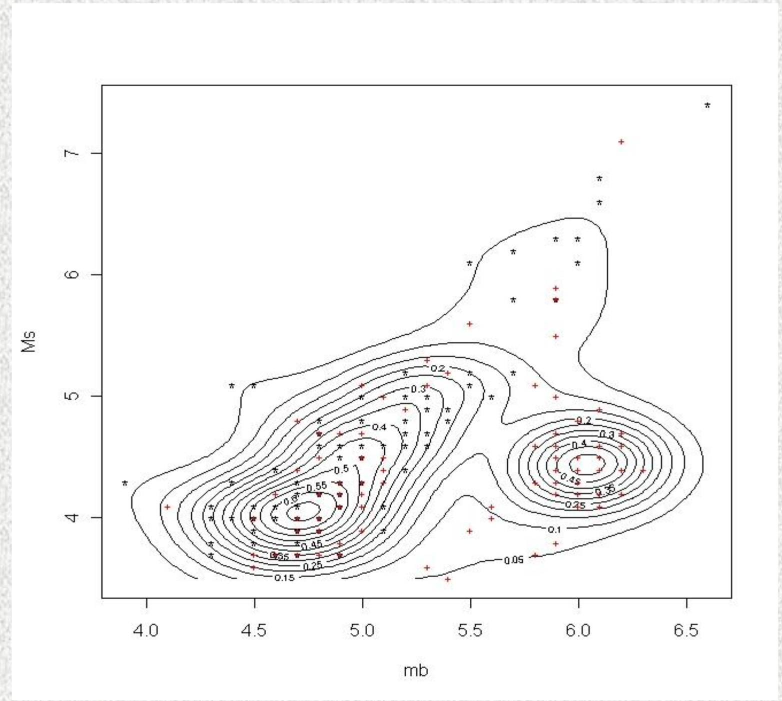
The Discriminant Analysis allows you to find the perfect separation between the two groups G_1 and G_2, looking for the carrier that maximizes the standardized difference (the problem of maximum bound)

$$\frac{(\bar{z}_1 - \bar{z}_2)^2}{s_z^2} = \frac{\left[\mathbf{a}'(\bar{\mathbf{y}}_1 + \bar{\mathbf{y}}_2)^2\right]}{\mathbf{a}' S_p^2 \mathbf{a}} \qquad \mathbf{a} = S_p^{-1}(\bar{\mathbf{y}}_1 - \bar{\mathbf{y}}_2)$$

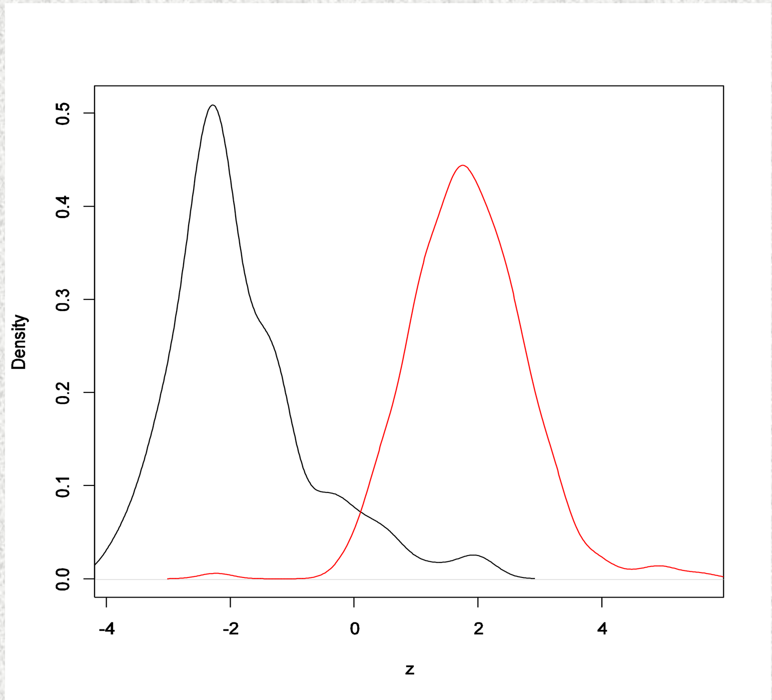
LEARNING

For the learning phase of the Discriminant Analysis we have taken *mb*, *Ms* and depths from the NEIC reports for 105 known explosions in former nuclear test sites (China, India, Pakistan, Nevada and Kazakhstan) and 263 natural earthquakes belonging to these areas or neighbouring regions

Level curves



Distribution of non-parametric density estimated by kernel estimators in the two groups E (black curve) and T (red curve)



For the test, we have considered *mb*, *Ms* and depths reported in REBs from 806 natural earthquakes distributed on the whole globe. Of these, the Discriminant Analysis has classified 798 events as earthquakes and left 8 events classified as explosions. The "false alarm" rate is quite smaller than that achieved by the standard IDC screening procedure, although we can not guarantee that the number of explosions missed by the method would be zero.

Results obtained

On the basis of the rule obtained by discriminating the events are allocated as follows

earthquakes	explosions
8	798

Distribution of a-posteriori probability in the two groups for the set of uncertain events

	earthquakes	explosions
minimum	0.0000	0.1947
first quartile	0.0000	0.9862
median	0.0000	0.9980
mean	0.0278	0.9722
third quartile	0.0138	0.9997
maximum	0.8053	1.0000

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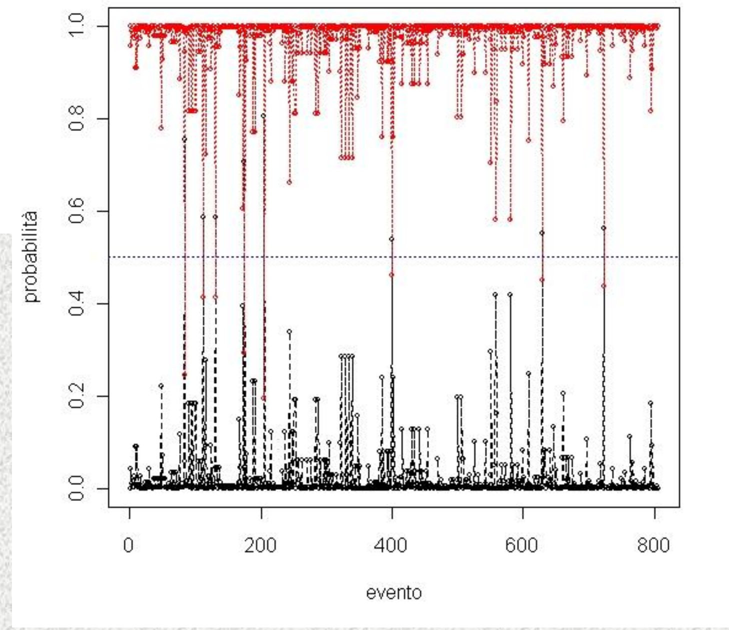
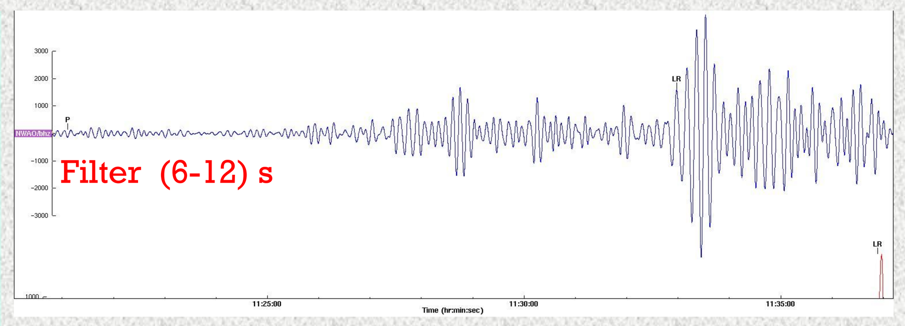
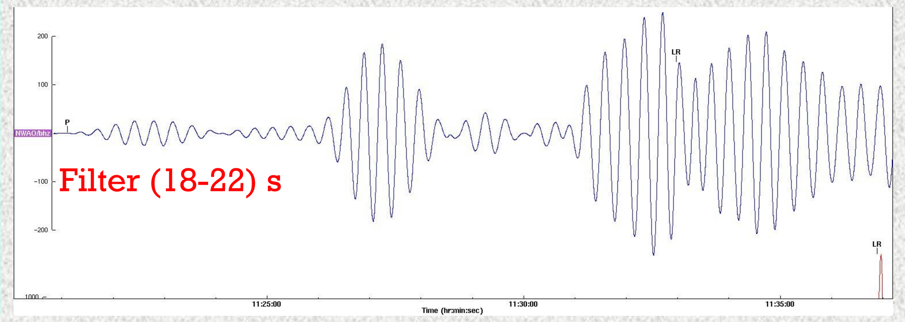


NEW METHOD

In this study we explore the capacity of a new discriminant, applying the classical *mb-Ms* method to surface waves of periods shorter than 20 s (6-12 s), more easily observable at regional distances. Rather than using the *Ms* magnitudes, this discriminant is directly based on the surface wave amplitudes, by comparison with the amplitudes expected through a theoretical model of explosive source. According to the study of Taylor and Patton, (BSSA 2006) this method is expected to reduce the false-alarm rate, i.e. the number of events detected but not screened out.

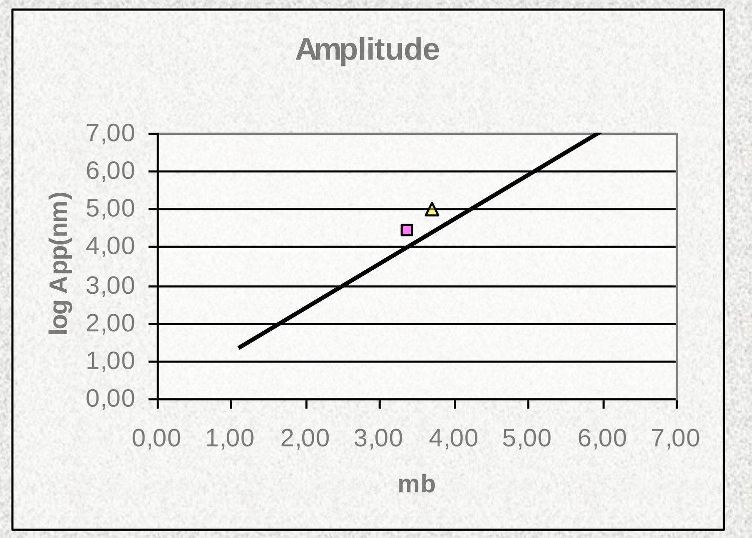


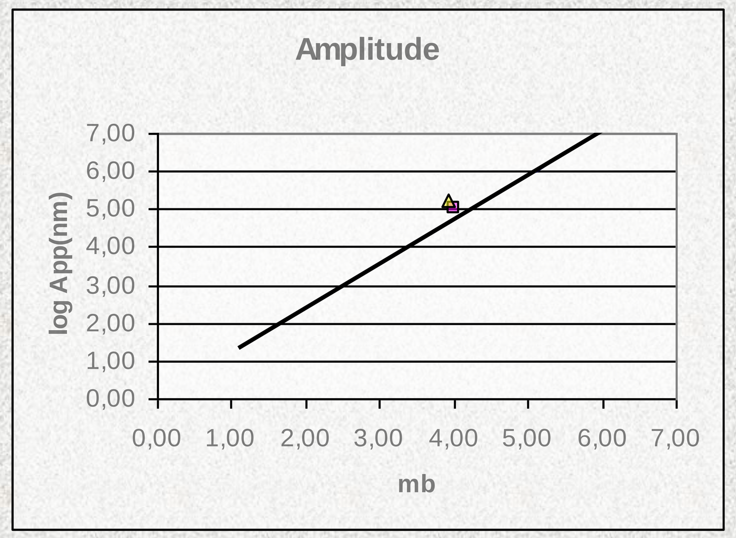


$$A_{pp}^X = 3 \cdot \frac{M_0^X}{\rho\, \alpha^{7/2} \sqrt{T\, r_0 \sin\Delta}} \cdot \sqrt{\frac{(f_h - f_l)}{T_W}} \cdot A_T \cdot K_Q$$

For comparison with the classical *mb-Ms* method, the new regional discriminant method, based on the theoretical surface wave amplitudes, has been applied to waveform data from 10 events selected in Indonesia, Kyrgyzstan, Greece, China (Xinjiang), China (Sichuan), Japan (Honshu), India, Kaukasus and Iran. In most cases, the regional investigation has led to a better detection of the seismic waveform, and then to a better event identification.

Observed surface wave amplitudes versus mb magnitudes computed by the theoretical model





CONCLUSIONS

Our results show that these new methodologies seem capable of bringing advantages in the identification of seismic events, and that the development and testing of such procedures could be usefully implemented in the future verification system