DISCRIMINATION INFORMATION IN PHASE AMPLITUDE THRESHOLDS

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ABSTRACT

We developed a regional seismic discrimination method that uses information inherent in phase amplitudes that are unmeasurable due to small signal amplitudes and/or high noise levels. The method, Quadratic Negative Evidence Discrimination (QNED), is an enhancement to the teleseismic techniques proposed by Elvers (1974), and is extended to regional discrimination. The method is developed for a single seismic station, and makes use of the empirical evidence in the regional Pg vs Lg discriminant (see Pomeroy et al. 1983).

Key Words: negative evidence, phase threshold, discrimination

OBJECTIVE

Events observed at teleseismic distances are effectively identified with the mb vs Ms discriminant because, relative to the compression wave energy (mb) of an event, an earthquake has more shear wave energy (Ms) than an explosion. For some teleseismic events, the magnitude Ms is difficult to measure and is known only to be below a threshold. With Ms unmeasurable, the mb vs Ms discriminant cannot be formed. However, if the Ms threshold is sufficiently small relative to a measured mb, then the event is still likely to be an explosion.

A regional analog to the mb vs Ms discriminant is the Pg vs Lg discriminant (see Pomeroy et al. 1983 for a discussion of regional discriminants). As in the teleseismic setting, the Lg amplitude is difficult to measure for some regional events (especially explosions) and is known only to be below a threshold. With Lg poorly measured, we cannot form the Pg vs Lg discriminant. However, if the Lg threshold is sufficiently small relative to a measured Pg, then the event is still likely to be an explosion. This work develops a mathematical formalization of these ideas.

RESEARCH ACCOMPLISHED

We assume that poor phase amplitude measurements are caused by the noise characteristics of a region, and not by physical-basis causes such as phase blockage or event depth. Four cases of signal censoring are possible. The first case (C1) involves no censoring, that is, both Pg and Lg can be measured. In this case, classical statistical discrimination methods can be used to construct a decision rule to identify seismic events. The second case (C2) is when Pg can be measured but Lg is known only to be below a threshold. The third case (C3) is when Lg can be measured but Pg is known only to be below a threshold. The fourth case (C4) is when both Pg and Lg are buried in noise. We develop a discrimination rule for these four cases and the equations necessary to compute the station-specific missed-explosion and false-alarm error rates. These error rates depend on the required minimum signal-to-noise ratio (S/N), and can be adjusted, within

limits, to desired levels. We also show that these equations are an accurate assessment of the errors in seismic discrimination. We propose that many of the current approaches to assessing seismic discrimination errors are often overly optimistic. For some applications, this disparity can be significant. For an application to Western China regional data (Pg vs Lg (1.5 to 3 Hz)), a widely used estimate of the missed-explosion error rate is 20%, leading to the perception that explosions can be identified with an accuracy rate of 80% (see Anderson (1999)). A proper accounting of the missed-explosion error rate, using Quadratic Negative Evidence Discrimination, shows that explosions can be identified with accuracy rate of only 73%. A detailed presentation of the work can be found in Anderson (1999).

CONCLUSIONS AND RECOMMENDATIONS

QNED is a broadly applicable approach to discrimination, designed to make defensible decisions in the presence of questionable amplitude measurement accuracy. An amplitude measurement is necessary to compute a S/N ratio. However, a poor S/N casts doubt on the accuracy of the amplitude measurement. It is true that a discrimination algorithm can be based on amplitude and noise measurements devoid of S/N considerations. However, interpretability and defensibility of a decision based on such an algorithm will come into question—strong S/N is a well-reasoned requirement for high-quality amplitude measurements. Thus, the power of a QNED approach to discrimination is found in its defensibility, due to agreement with the physical theory of compression versus shear type discriminants in all measurement cases C1, C2, C3 and C4. Some specific conclusions and recommendations on the application of QNED include:

QNED should only be applied to a single geophysically distinct region. As noted above, the QNED method is based on the assumption that poor amplitude measurements are caused by the noise characteristics of a region and not by physical-basis causes such as phase blockage or event depth.

While it is possible to expand QNED methods to more dimensions, the complexity of such a multivariate extension would make clarity and interpretation quite difficult. For example, using 3 amplitudes will involve developing the mathematics for cases rather 4, and 7 OC curves with corresponding parameters. Clarity and physical basis interpretability are extremely important requirements in the seismic discrimination problem. The authors feel that QNED methods should only be applied to a single discriminant (e.g., 2 amplitudes).

The fundamental idea in QNED is the formal modeling and inclusion of the four types of data C1, C2, C3, and C4 into a seismic discrimination method. This idea can be applied to other seismic analyses.

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