Modelling Global Seismic Network Detection Threshold
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Abstract

The seismic network of the International Monitoring System (IMS) operated by CTBTO has a global coverage but its detection capability is inevitably non-uniform. Network detection capability can be quantified in terms of an “event location threshold” that marks the magnitude of the smallest seismic event that could occur at a location and have a specified probability of being detected and located. Network detection capability can be modelled by numerical methods that use knowledge of seismic station response characteristics and background noise conditions to produce global maps of event location thresholds. Such methods may be used to simulate the performance of the current network and to predict the consequences of station outages or future modifications of the network. Data are presented from the NetSim seismic network simulation system for a series of ninety-one-day periods from 2003 to 2010. NetSim takes information describing the locations of stations in the IMS seismic network that were active at the relevant time, and using data describing background noise measured at those stations specific to the time period under study. Predictions of event location threshold are then made. NetSim predictions are compared with predictions made by the IDC Threshold Monitoring subsystem and with “Magnitude of Completeness” values calculated for the Reviewed Event Bulletin over the same period.

Note that not all the events in the REB conform to a simple “3-primary Stations” detection rule – this is an approximation to network detection that makes modelling possible.

Figure 1. Binned histogram (blue bars) of number of events as a function of magnitude. Red line shows the predicted empirical POD with fitted functional form.

Figure 2. Example TM data

NetSim

NetSim is a network simulation tool. It predicts network detection threshold (in seismic magnitude units) for a network with station types, locations and noise conditions described by the user. Event magnitude and received signal level are related by amplitude-distance relationships. The level of detection is specified in terms of the number of stations at which a station-specific signal-to-noise ratio must be exceeded in order to achieve a specified probability of detection. To simulate IMS seismic network detection performance, a 0.90 probability of detection on three or more primary stations is normally used.

Threshold Monitoring

Threshold monitoring (TM) is a real-time network monitoring tool. Signals received from IMS seismic stations are used to determine local noise conditions and these are used to calculate a signal level necessary to achieve a specified probability of detection (0.90) at each station. Amplitude-distance relationships are then used to calculate the event magnitude at each point on a global grid required to achieve detection. Network detection threshold at a given location is set to the third smallest magnitude required for detection at that location.

Figure 3. Global averaged event location thresholds predicted by NetSim and TM calculated from REB data

Practical calculation of }_{M} is difficult because catalogue completeness is approached asymptotically More reliable estimates of }_{M} can be found for levels of completeness less than 100%. Here, }_{M} and }_{M} completeness measures of }_{M} and }_{M} were calculated. First, a magnitude-dependent probability of detection (POD) was calculated from the 91-day period of global REB data by estimating the parameters a and b then calculating the ratio between the observed and predicted numbers of events. An error-function form was then fitted to the empirical POD and values for 0.90 and 0.99 POD were accepted from it. A third descriptor of the magnitude beyond which the REB is effectively complete was calculated from the binned distribution above. As the central magnitude of bias decreases so the number of events in the bias increases there are more earthquakes with similar magnitudes. This behaviour continues until a network POD begins to fall and not all events are detected. If the change in POD between two adjacent bin-values is large enough then the number of events is the lower bin will be smaller than the higher bin. Thus, a magnitude one bin-width higher than the centre of the bin which shows the largest number of events can be used as a simple estimate }_{M} of the magnitude of completeness.

Magnitude values quoted are calculated using IDC procedures. These differ by between 0.3 and 0.5 magnitude units from values calculated by seismological surveys and data centres.

Magnitudes

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Conclusion

When NetSim was run using measured noise data, its predictions were shown to agree to within 0.1 magnitude units of the magnitude completeness of the REB, based on a 0.99 probability of detection. The thresholds predicted by the threshold monitoring subsystem of the IDC processing were observed to be 0.5 magnitude units higher. These values are normally used in terms of }_{m} as calculated using IDC processing. It is important to note that these metrics are based on different methods of estimating event magnitude and the averaging process involved in the production of seismic activity and the spatial averaging used in the production of }_{M}.

The 2010 globally averaged }_{m} magnitude completeness of the REB was observed to lie between 3.4 and 3.5 magnitude units above the threshold derived from the REB data and was more representative of a 0.9996 probability of detection, although there is no suggestion that they were deliberately calculated at this level. A likely cause of the difference between the thresholds predicted by the NetSim and TM lies in the different ways in which probability of detection at the station level is converted to probability of detection at three or more stations.

Note that the simple measure of }_{m} magnitude completeness, }_{M} is stable throughout the period of study but }_{M} and }_{M} sharpen in response to peaks of background activity, e.g., Jan 2005, due to changes in the estimated values of the slope parameters.

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Magnitude-frequency relationships


Calculation of Magnitude of completeness


Differences between IDC and other agencies’ calculations of }_{m}


Figure 4. Global averaged event location thresholds predicted by NetSim, TM and calculated from REB data

Figure 2. Example TM data

Results

The 2010 globally averaged }_{m} magnitude completeness of the REB was observed to lie between 3.4 and 3.5 magnitude units above the threshold derived from the REB data and was more representative of a 0.9996 probability of detection, although there is no suggestion that they were deliberately calculated at this level. A likely cause of the difference between the thresholds predicted by the NetSim and TM lies in the different ways in which probability of detection at the station level is converted to probability of detection at three or more stations.

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