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7.6 Monitoring of the Indian underground nuclear tests of May 1998

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We have investigated the capability of the International Monitoring System (IMS) to monitor the Indian nuclear test site. Our approach has been to use the IMS stations with the best detection capability for this region which, in practice, determine the monitoring capability of the full IMS network. We have therefore based our investigation on data from the eleven IMS stations shown in Fig.7.6.1, which all had high SNRs for the 11 May 1998 Indian underground nuclear test. The IMS location of this event is given in Table 7.6.1.

Table 7.6.1. Event information from the REB

Origin time	Lat	Lon	Depth	m_b	Nsta	Region
1998/05/11 10:13:44.2	27.0716	71.7612	0.0	5.0	50	India-Pakistan Border Reg.

The IMS auxiliary station in Nilore, Pakistan (NIL), located 6.7 degrees away from the Indian test site, provided the P-phase with the highest SNR (937.4) for this event. NIL was the only IMS station located within regional distances, and the vertical-component recording of the Indian test is shown in Fig. 7.6.2. The highest SNR relative to the background noise level was found between 1 and 2 Hz for both the P and the Lg phase, and this filter was used prior to the calculation of STA traces. A 1.5 second STA length was used for P, and for the longer duration Lg phase an STA length of 8 seconds was used.

The remaining 10 stations used for monitoring were all located at teleseismic distances, and only P-phases were considered for calculation of the magnitude thresholds. The list of stations, and the TM processing parameters derived from the recordings of the 11 May 1998 explosion are given in Table 7.6.2.

Table 7.6.2. TM Processing Parameters Derived from the Recordings of the 11 May 1998 Indian Nuclear Test

Station	Distance (deg)	Phase	SNR in REB	Theo. ray parameter (s/deg)	Obs. slowness (s/deg)	Obs. back azimuth (s/deg)	Freq. band (Hz)	STA length	Travel time	Mag. calib.	St. dev of calib.
NIL	6.68	P	937.4	13.73	-	-	1.0 - 2.0	1.5	102.1	1.67	0.15
-	-	Lg	(3.8)	33.04	-	-	1.0 - 2.0	8.0	223.2	2.20	0.15
NRIS	43.05	P	191.1	8.10	-	-	2.0 - 4.0	3.0	482.0	3.90	0.15
FINES	45.87	P	80.3	7.90	7.34	120.37	2.0 - 4.0	3.0	505.3	3.73	0.15
GERES	49.39	P	43.3	7.65	6.95	95.05	1.0 - 2.0	1.5	532.4	4.16	0.15
ARCES	50.16	P	182.6	7.59	7.53	125.88	2.0 - 4.0	3.0	538.9	3.51	0.15
HFS	51.10	P	56.0	7.52	5.83	121.7	2.0 - 4.0	2.0	544.7	3.70	0.15
BGCA	55.19	P	174.0	7.23	-	-	1.5 - 3.5	2.0	576.1	3.87	0.15
SPITS	56.81	P	190.0	7.11	9.38	124.59	2.5 - 5.0	2.5	587.8	3.98	0.15
ASAR	78.39	P	199.3	5.53	5.67	307.3	1.0 - 3.0	2.5	724.6	4.03	0.15
ILAR	83.65	P	157.0	5.12	3.93	323.11	1.0 - 3.0	2.5	750.8	3.98	0.15
YKA	90.60	P	238.0	4.65	5.02	349.59	1.5 - 3.0	2.5	785.8	4.94	0.15

Fig. 7.6.3 shows the results from site-specific threshold monitoring of a five-hour time interval around the 11 May 1998 Indian nuclear test, using the processing parameters derived from the nuclear test itself. The top trace shows the combined network thresholds, and the following seven traces show the thresholds derived from each of seven selected stations (P-phase only). Notice the enhanced monitoring capability when NIL data are available.

The time tolerances were set to accommodate a target area with a radius of 25 km around the explosion site. Several distinct peaks are seen on the threshold traces for the individual arrays, but for the network trace the only significant peak corresponds to the nuclear test. With available NIL data, the 90% magnitude thresholds during noise conditions vary around m_b 2.4. For time intervals without available NIL data, the magnitude thresholds increase to about m_b 2.9. We would also like to emphasize that the peak on the network threshold trace caused by the nuclear test has a value that is slightly lower than the actual event magnitude. In cases when an event occurs in the target region, the threshold calculations should be replaced by the maximum likelihood estimate of the event magnitude.

According to the Indian authorities, two explosions of 0.5 and 0.3 kt took place on 13 May 1998, with origin time 06:51 GMT. No signals were detected by the IMS stations, and we have calculated the magnitude threshold (90% upper magnitude limit) of the reported event, using the processing parameters derived from the Indian test of 11 May 1998.

Fig. 7.6.4 shows magnitude thresholds for a four-hour time interval around the announced nuclear test, using different combinations of stations. The middle trace shows the magnitude threshold calculated from all the stations listed in Table 7.6.2. From this trace we read that the reported event had an upper magnitude limit of m_b 2.4. Except for a small peak at 07:08, caused by a P-phase at NIL from an m_b 4.5 event in Java, Indonesia, the upper magnitude limit stays below m_b 2.5 for a long time interval around the reported origin time.

The magnitude thresholds calculated from NIL data only are shown in the upper trace of Fig. 7.6.4. When comparing this trace to the magnitude thresholds calculated from all stations, shown in the middle trace, we see practically no lowering of the magnitude thresholds. This implies that during background noise conditions, NIL data alone can effectively be used to place an upper magnitude limit on possible events located at the Indian test site. However, if interfering events occur, especially local events near NIL, but at sites different from the target site, the remaining stations will provide important contributions to lowering the thresholds.

The lower trace of Fig. 7.6.4 shows the magnitude thresholds calculated without using data from NIL. With this teleseismic station configuration, an upper magnitude limit of m_b 2.9 can be placed on the reported event.

The TM processing parameters derived from the 11 May 1998 Indian nuclear test can also be used for continuous assessment of the detection capability of the network. For the same four-hour interval around the announced Indian test of 13 May 1998, we have estimated the three-station detection capability of the network. An SNR of 4 was required for detection, and the capabilities were estimated at the 90% probability level.

The upper trace of Fig. 7.6.5 shows the detection capability of all stations listed in Table 7.6.2, and we find for the four-hour interval values slightly below m_b 3.5. The detection capability without the use of NIL data (teleseismic data only) is shown in the lower trace, and we find values slightly above m_b 3.5. This small difference is not surprising, since the three-station detection capability is effectively dependent on the 3rd best station. One additional good station may not make much difference.

Conclusions

From observations of the 11 May 1998 Indian nuclear test we have derived optimum processing parameters for the eleven IMS stations assumed to have the best detection capability for the Indian test site. Our results can be summarized as follows:

- The magnitude threshold of the current IMS primary network for the Indian test site is around m_b 2.9 during normal noise conditions. The stations of this network are located at teleseismic distances from the test site.
- During background noise conditions, regional data from the Nilore (NIL) station alone provides magnitude threshold of about m_b 2.4 for the Indian test site. Supplementing NIL data with data from the other teleseismic IMS stations does not lower the magnitude thresholds during normal noise conditions, but is important if interfering events occur.
- During background noise conditions, the IMS three-station detection capability vary around m_b 3.5, both with and without the use of NIL data. This illustrates that supplementing a network with one additional good station does not necessarily improve significantly the three-station detection capability of the network.

The upper magnitude limit of the announced Indian nuclear test of 13 May 1998 is estimated at:

- m_b 2.4 using NIL data (distance 700 km) either alone or in combination with teleseismic IMS data
- m_b 2.9 using teleseismic IMS data only

Except for a small threshold peak caused by a P-phase at NIL from an m_b 4.5 event in Java, Indonesia, the upper magnitude limit stays below m_b 2.5 for several hours around the reported origin time of the 13 May 1998 event.

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References

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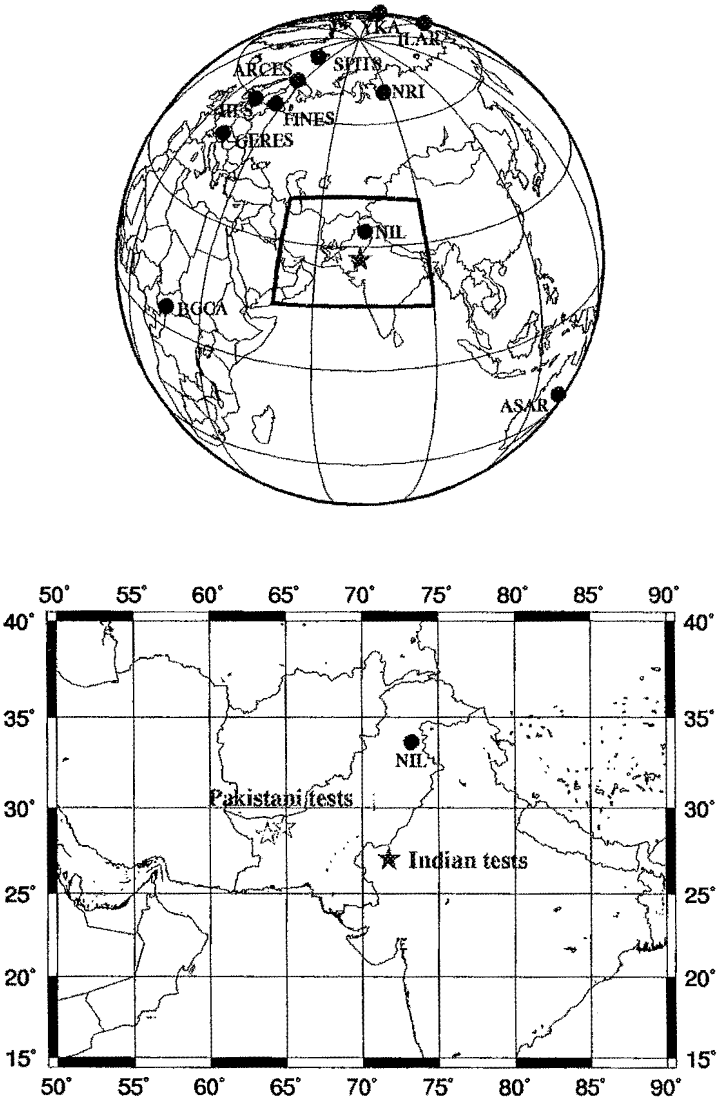

Fig. 7.6.1. The upper map shows the locations of the stations used for threshold monitoring of the Indian nuclear test site. The area within the rectangle is expanded in the lower map, where the filled star indicates the location of the Indian explosions, and the open stars indicate the location of the Pakistani explosions of 28 May and 30 May 1998.

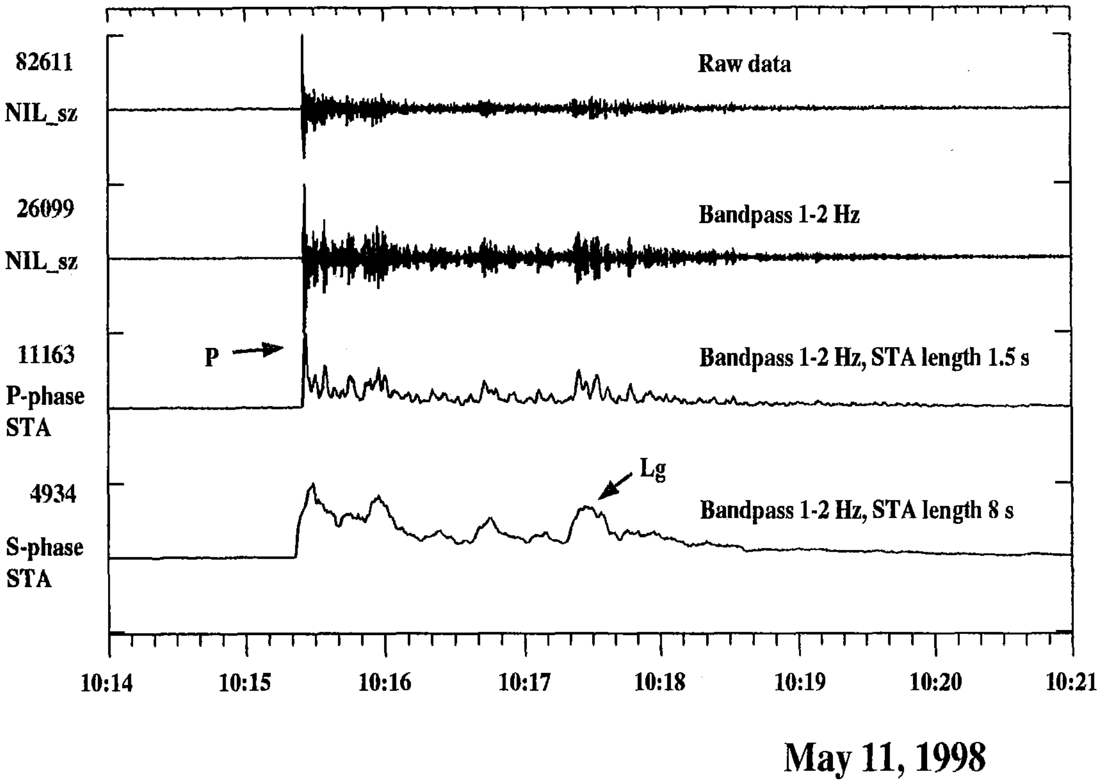

Fig. 7.6.2. Panel showing Nilore recording of the Indian nuclear test of 11 May 1998. The upper trace shows the raw data of the vertical-component sensor, and the second trace shows the same data filtered in the band 1-2 Hz. The two lower traces show the STA traces used for representing the amplitudes of the P and Lg phases. Notice that different STA lengths were used for P and Lg.

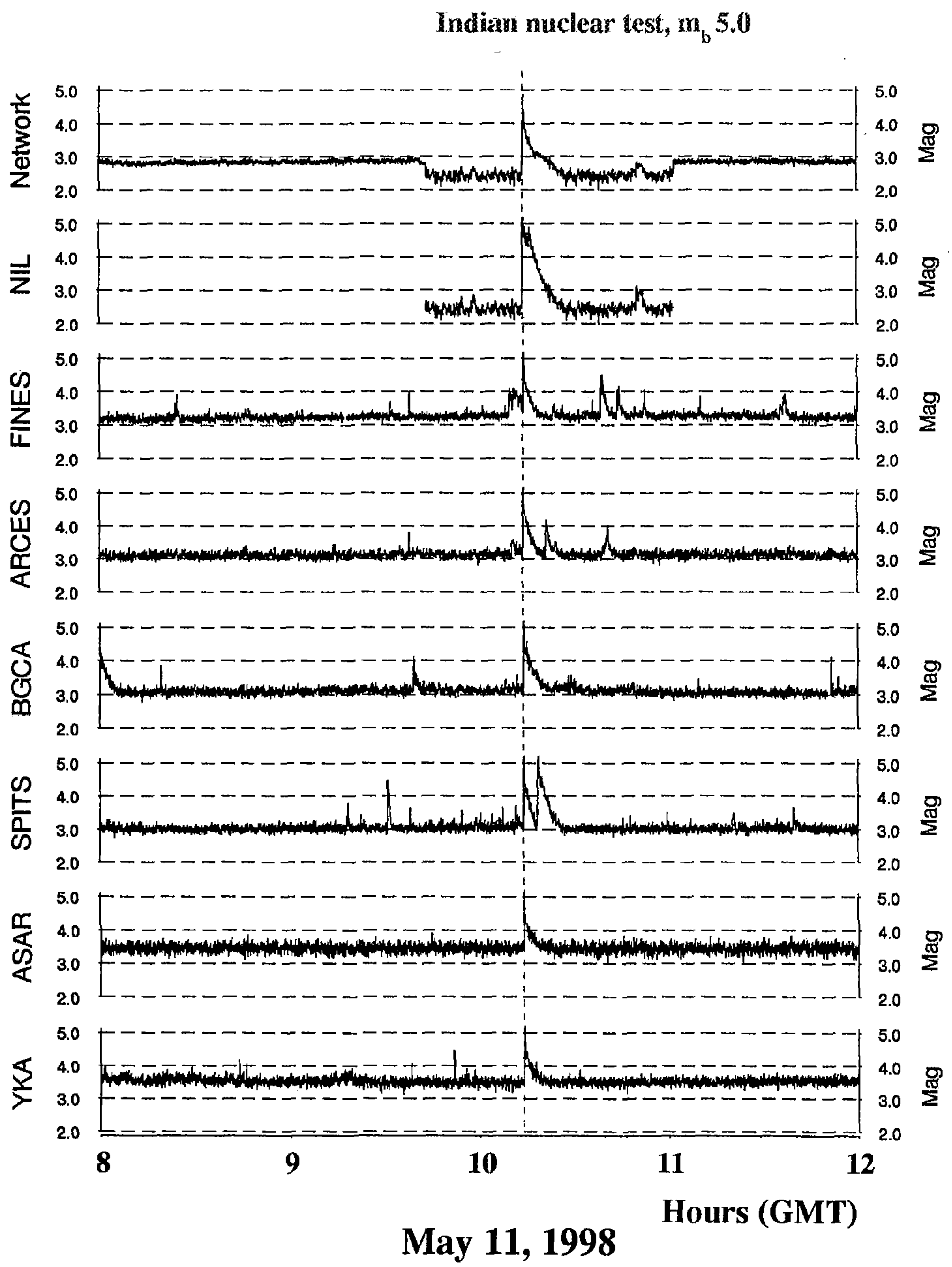

Fig. 7.6.3. Site-specific Threshold Monitoring of a 5-hour time interval around the Indian nuclear test, using the processing parameters given in Table 7.6.2. The plot shows the individual P-phases (STA traces) for 7 selected stations, with the combined network threshold trace on top. The time tolerances were set to accommodate a target area with a radius of 25 km around the explosion site. Notice the improved monitoring capability when NIL data are available. The only significant peak on the network threshold trace corresponds to the nuclear test.

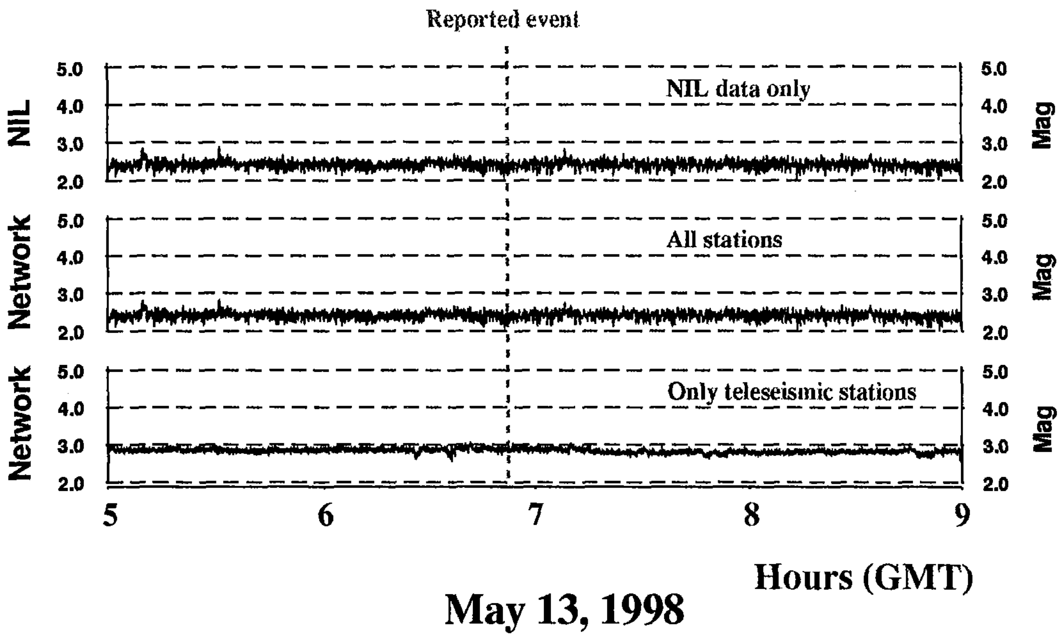

Fig. 7.6.4. The plot shows magnitude thresholds for a four-hour time interval around the announced Indian nuclear test of 13 May 1998. The upper trace shows the magnitude threshold calculated from NIL data only, using the P and Lg processing parameters derived from the 11 May event. The middle trace shows the magnitude threshold calculated from all stations listed in Table 7.6.2. The lower trace shows the magnitude threshold calculated without using data from NIL (i.e., teleseismic stations only).

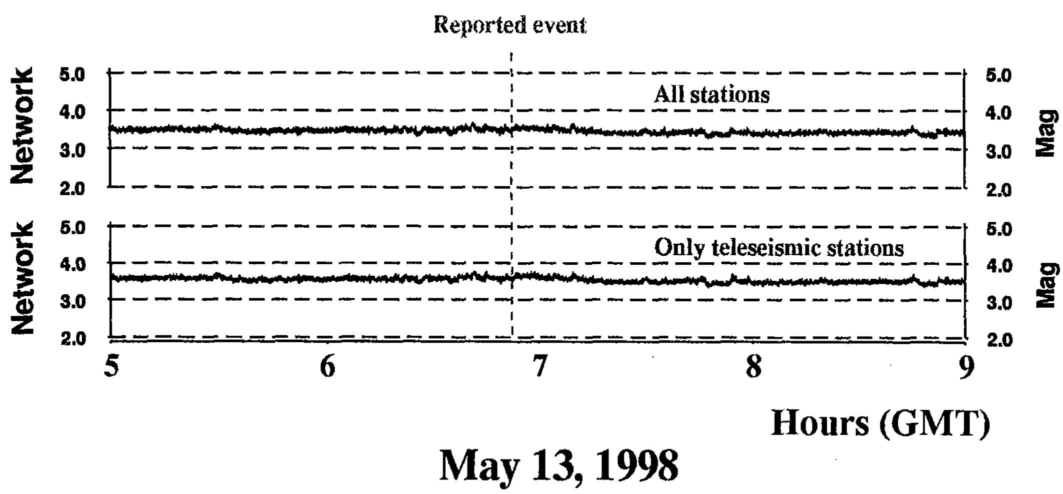

Fig. 7.6.5. The plot shows the three-station detection capability at the 90% level for a four-hour time interval around the announced Indian nuclear test of 13 May 1998. An SNR of 4 was required for detection. The upper trace shows the detection capability of all stations listed in Table 7.6.2, whereas the lower trace shows the detection capability estimated without the use of NIL data (teleseismic data only).