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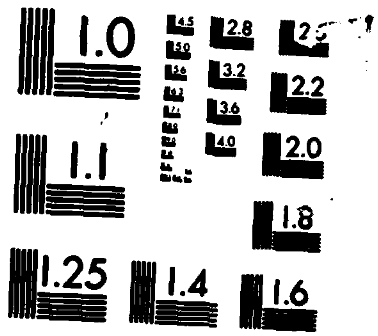

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Technical Report C86-03
March 1986

NOISE LEVELS AND DETECTION THRESHOLDS AT U.S. SEISMOLOGICAL STATIONS DURING THE GSETT

and

NOISE LEVELS AND DETECTION THRESHOLDS AT GSETT SEISMOLOGICAL STATIONS

Hans Israelsson

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Seismic noise levels and detection thresholds for teleseismic short period P-waves and long period Rayleigh waves at U.S. seismological stations, and other stations, which participated in the Technical Test (GSETT) of the Ad Hoc Group of Scientific Experts are estimated. It is concluded that the GSETT stations constitute a global network with large variations in noise and detection characteristics among the individual stations. The median value of the m_b detection threshold is 4.9. Most of the stations have a significantly higher detection capability for teleseismic short period P waves than for long period Rayeigh waves. The variation in short period detection capability among the stations is well over a magnitude unit, whereas the long period detection capbility has less variation among the stations.

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NOISE LEVELS AND DETECTION THRESHOLDS AT U.S. SEISMOLOGICAL STATIONS DURING THE GSETT

Hans Israelsson

1. INTRODUCTION

The purpose of this note is to estimate the seismic noise levels and detection thresholds for teleseismic short period P-waves and long period Rayleigh waves at U.S. seismological stations, which participated in the Technical Test (GSETT) of the *Ad Hoc* Group of Scientific Experts.

Station noise and detection thresholds are not only interesting *per se* but are also important parameters for the automatic association and location of seismic events, the so called *AA* procedure. The final processing of a seismic event in the AA involves an amplitude consistency check, which forms a maximum likelihood estimate of the body wave magnitude, m_b. As part of this check an event plausibility value is also calculated on the basis of reported station amplitudes as well as of noise values and detection thresholds at *non-detecting* stations.

2. GSETT MEASUREMENTS

Each seismic station that participated in the GSETT was assumed to measure a number of so-called Level I parameters for *all* recorded seismic signals. The data analyzed herein are limited to the following parameters which relate directly to station noise levels and signal amplitudes:

LEVEL I PARAMETERS ANALYZED				
GSETT parameter code	Amplitude and period measured			
-	Short period P		Long period Rayleigh	
-	noise	signal	noise	signal
NSZ	X			
M1X-M4X		X		
N2LZ			X	
MLRZ				X

The procedures for measuring the Level I parameters were specified in considerable detail whereas no specific criteria for signal detection were given.[1] The short period noise parameters, *(NSZ)*, consist of the maximum trace amplitude at a frequency between 1.0 and 5.0 Hz or at a frequency close to that of the signal together with the associated period. The amplitude is measured within 30 seconds before the signal onset.

The amplitude and period measurements of short period signals *(M1X-M4X)*, were also determined from the maximum trace amplitudes and measured to the maximum deflection within the intervals 0-6 s, 6-12 s, 12-18 s, 18-300 s after signal onset. In addition the character of each detected signal should be qualified as originating from an event at local *(LA,LB)*, regional *(R)* or teleseismic *(TA,TB,TC)* distances. The modifiers A, B, and C signify increasing numbers of discernable phases.

Long period Rayleigh wave parameters were usually measured only when associated with a detected short period P-wave. The noise parameters, *(N2LZ)* consisted of the largest trace amplitude with a period between 10-30 s measured on the vertical component within a 5 minute section of the recording preceding the initial P-wave. The period of the largest noise amplitude was also measured. The Rayleigh wave parameters, *(MLRZ)* consisted of the amplitude of the maximum deflection measured on the vertical component and its corresponding period.

The parameters described above are simple measurements in observational seismology. Nonetheless their extraction requires recordings with high dynamic range and time resolution as well as considerable experience with seismogram reading.

3. STATIONS, DETECTION PROCEDURES, AND DATA

Level I data extracted from recordings at the following stations are analyzed in this note:

SEISMOLOGICAL STATIONS	
Code	Location
FBA	Fairbanks, Alaska
LAC	Landers, California
LTX	Lajitas, Texas
RSNY	Adirondack, New York
RSON	Red Lake, Ontario, Canada
RSSD	Black Hills, S. Dakota

The characteristics of sites, instrumentation, detection procedures, data recording and analysis have been documented in a working paper to the GSE.[2] The three stations RSNY, RSON, and RSSD all belong to the so called Regional Seismic Test Network (RSTN) and have essentially identical characteristics apart from the geological conditions.

The amplitude response curves shown in *Fig.*1 represent the frequency bands in which the parameters described above were *measured*. The long period curves are quite similar among the stations, whereas one of the stations, LAC, has a short period curve clearly different those of the other stations. The LAC short period curve with its WWSSN response characteristics is relatively less sensitive at high frequencies.

It should be noted that the detection processor used to detect short period signals recorded by the RSTN stations used a narrow band pass (three pole Butterworth with cut-offs at 0.9 and 4.0 Hz). This band is different from the one used for measuring the Level I parameters shown in *Fig.*1. Detection of short period signals was made *automatically* at LTX (so called *Walsh transform* detector) and the RSTN stations (so called *Z* detector) and *manually* at FBA and LAC. The automatic detections were, however, reviewed by an analyst for rejection of "false alarms".

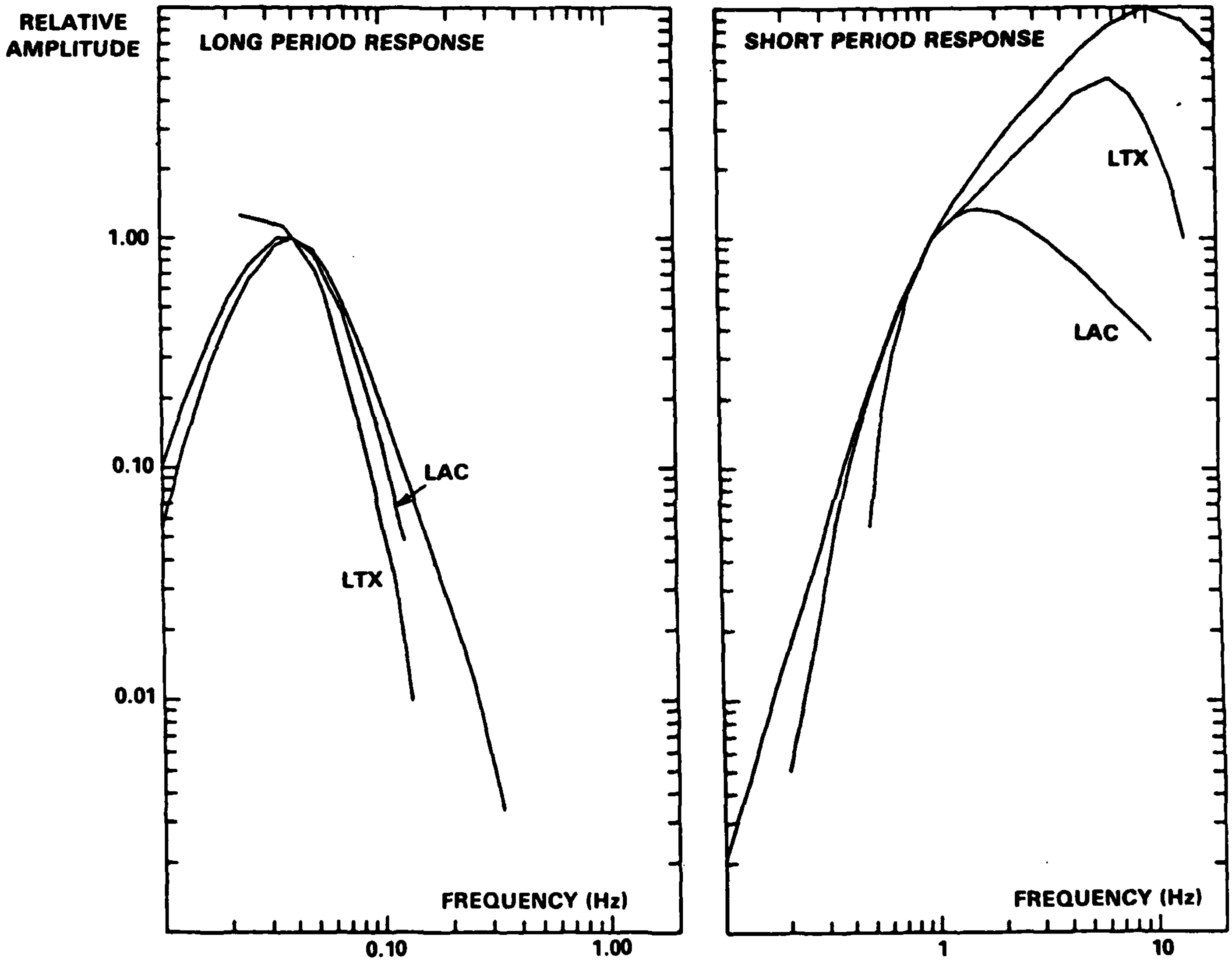

FIGURE 1. LONG AND SHORT PERIOD AMPLITUDE RESPONSE CURVES.

The number of measurements of the different parameters is summarized by the following table:

NUMBER OF MEASUREMENTS						
Parameter	Station					
-	FBA	LAC	LTX	RSNY	RSON	RSSD
NSZ	1301	491	1028	445	516	888
M1X (Teleseism)	987	299	512	169	267	333
N2LZ	194	37	52	158	248	320
MLRZ	229	35	46	98	157	174

The values for M1X refer to observations which have been classified as teleseismic (i e TA, TB, and TC) except for the station LAC for which the number refers to observations which were not classified as local (LA or LB) or regional(R).

There are differences among stations in reading long period noise data (N2LZ) as can be seen from the table above. Only the RSTN stations were analyzed for long period noise for all detected teleseisms (TA, TB, and TC). LTX reported long period noise only if Rayleigh waves were detected. This was the case also for FBA and LAC.

4. DETECTION MODEL

The analysis that follows is discussed in relation to a simple model for signal detection. This model is often used in seismological detectability studies [3] and is also the basis for the earlier mentioned amplitude consistency check of the procedure for automatic association and location of seismic events.

It is assumed that a signal with amplitude S (displacement in, say, nm) and associated period T is detected if:

$$\frac{S}{T} \geqslant SNR_{\min} \frac{N}{T}$$

Here $SNR_{\min}$ represents the minimum signal-to-noise ratio that has to be exceeded for a detection to be declared, and N denotes the amplitude (displacement) of the prevailing seismic background noise. This corresponds to signal detection of a narrow bandpass filtered signal with center frequency around $1/T$. It is assumed that the logarithms of the amplitude/period ratios for signal as well as for noise are normally distributed. That is to say that $log(S/T)$ and $log(N/T)$ belong to N(μ_S,σ_S) and N(μ_N,σ_N), respectively. The mean value μ_S for the signal amplitude/period ratio is related to the seismic event magnitude, m_b, by the standard formula:

$$\mu_S = m_b - Q(\Delta, h) + C$$

and to the station correction C and amplitude attenuation factor Q (which, in turn is a function of epicentral distance, Δ , and focal depth, h). With these assumptions the probability of detecting an event, $p(m_b)$, with magnitude m_b, becomes:

$$p(m_b)=\Phi\left\{\frac{m_b-Q+C-\mu_N-log(SNR_{\min})}{\sqrt{\sigma_S^2+\sigma_N^2}}\right\}$$

Here Φ is the standard normal distribution function. The magnitude detection threshold at 50% probability, $\tau(50)$, is:

$$\tau(50)=\Theta+Q(\Delta,h)$$

with

$$\Theta=\mu_N+log(SNR_{\min})-C$$

and for a given station the threshold $\tau(50)$ becomes a function of the correction Q and depends on the hypocenter of the seismic event. An analogous expression would hold for surface waves with the magnitude and Q correction appropriately replaced.

The subsequent analysis will focus on estimating the noise parameters, μ_N and σ_N, the minimum signal to noise ratio , $SNR_{\min}$, and the station correction C on the basis of the measured Level I parameters described above.

5. SEISMIC NOISE

Although the noise amplitude measurements represent *maximum* values in a certain time window, it is assumed that the data are observations of N, at periods, T, of the simple model described above.

5.1. Short period

The distribution of noise amplitude measurements as a function of frequency is shown in *Fig.*2. The measurements are usually concentrated in a small band with a pronounced peak. The peaking occurs between 2 to 5 Hz except for the station LTX for which the distribution peaks at about 0.6 Hz. In fact for all stations except for LTX most measurements have frequencies above 1 Hz. For FBA, RSNY, and RSSD 90% or more of the measurements have frequencies in the band 1.0 to 5.0 Hz as specified by the GSETT instructions. The percentages for LAC and RSON are about 70%, but for LTX only about 5% of the data have wave periods in this frequency band. For most of the stations there are also observations up to 10 Hz or 0.1 s period.

Some examples of empirical distribution functions of noise amplitudes for a given period are shown in *Fig.*3. They have been plotted with a vertical scaling of a normal distribution and would follow a straight line if the amplitudes were normally distributed. The hypothesis that such empirical distribution functions are normally distributed was also formally tested using the Kolmogorov-Smirnov statistic.[4] In four out of 11 cases it was not possible to reject the hypothesis on a level less than 8%, whereas in seven cases the hypothesis could be rejected at a level of 2.5% or less. It is felt that two of the rejected cases were due to the

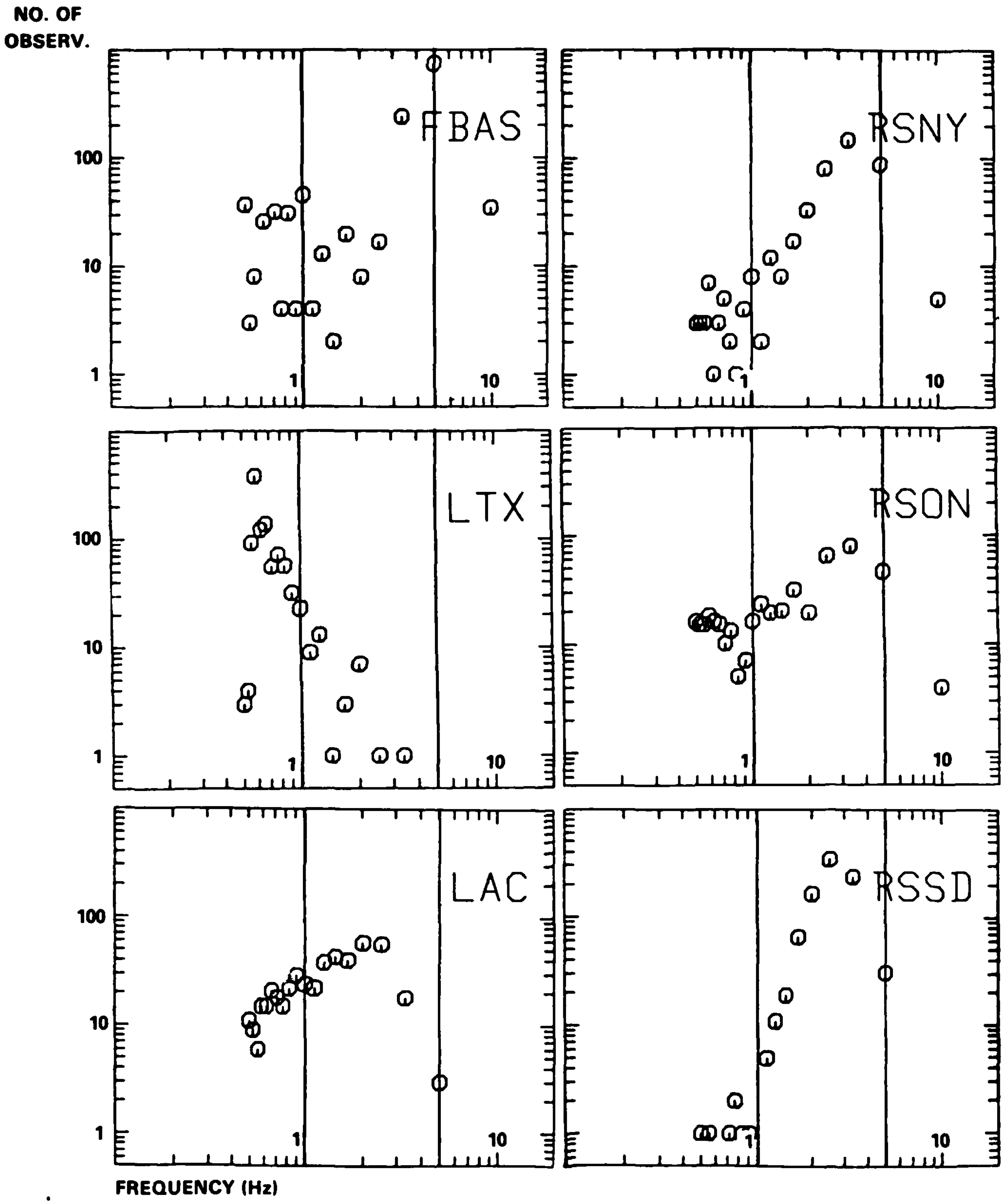

FIGURE 2. NUMBER OF SHORT PERIOD NOISE MEASUREMENTS (NSZ) AS A FUNCTION OF FREQUENCY.

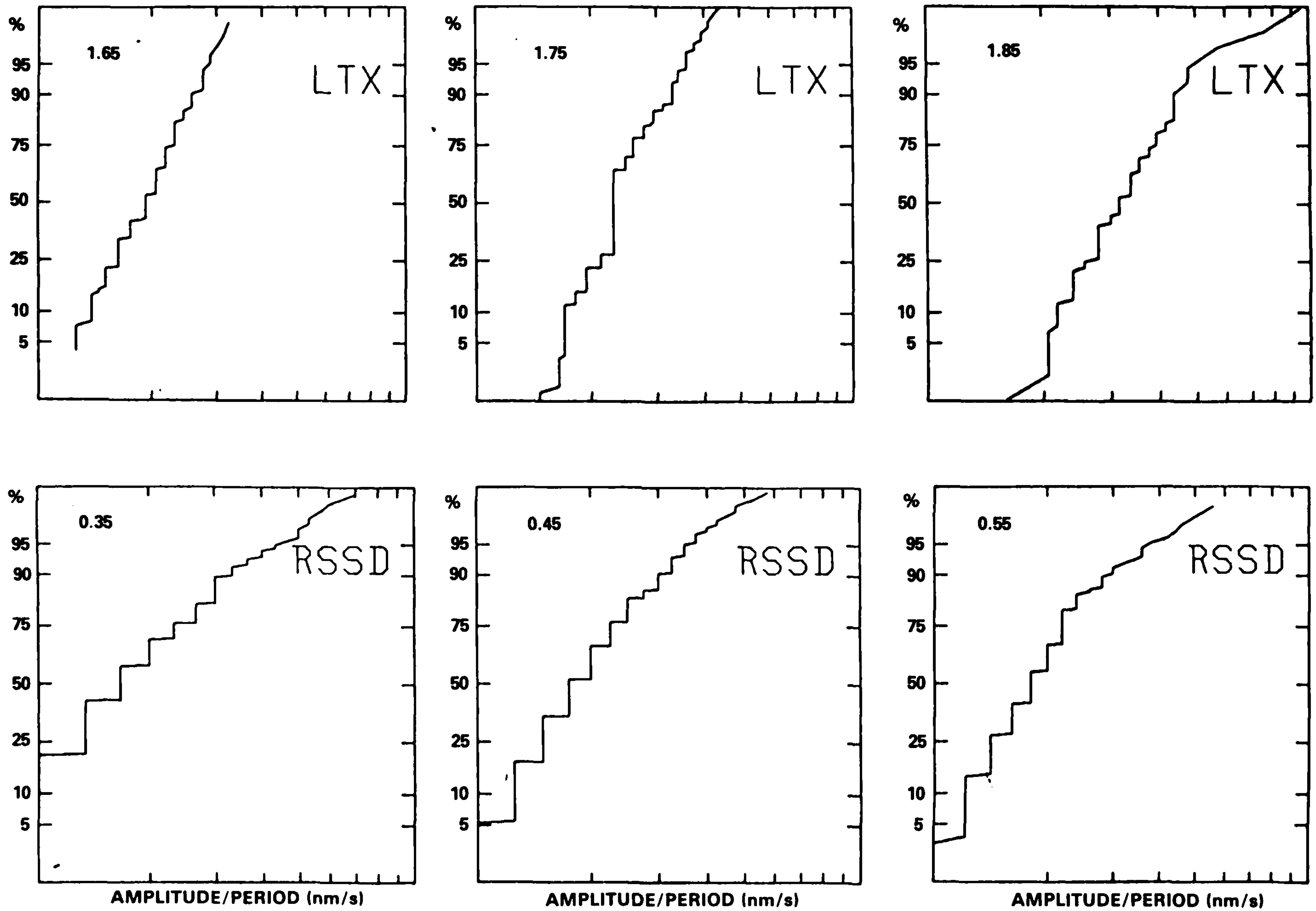

FIGURE 3. EXAMPLES OF EMPIRICAL DISTRIBUTION FUNCTIONS FOR NOISE AMPLITUDE MEASUREMENTS AT DIFFERENT PERIODS.

limited resolution of the amplitude measurements, since virtually all measurements had the same numerical values. The effect of limited resolution can be seen for one of the distributions in *Fig*.3 for LTX (period 1.7s) showing a large number of observations with equal values around the mean. It seems that about half of the cases follow a normal distribution, which justifies the simple detection model presented above and the assumptions in the subsequent analysis.

The estimates of the mean values $\mu_N(T)$ and associated 95% confidence limits are plotted in *Fig*.4 as a function of frequency (or period T) for each station. The estimates are based on straightforward assumptions of normal distribution. The estimated mean values at 1 Hz (converted to velocity) are:

NOISE AT 1 HZ			
Station Code	Mean (nm/s)	Standard deviation	No. of observ.
FBA	2.1	0.15	46
LAC	1.6	0.28	24
LTX	0.8	0.17	23
RSNY	8.5	0.17	8
RSON	5.5	0.14	16
RSSD	3.1	0.21	5

The values for the RSTN stations are significantly higher than those derived from power spectra.[5] The plotted values in *Fig*.4 can be thought of as approximate "spectra". An amplitude roll-off inversely proportional to frequency has been drawn in each figure for comparison.[6] The "spectrum" for LTX apparently drops faster at lower frequencies. Most of the "spectra" drop from lower frequencies systematically up to some frequency between 1 and 3 Hz beyond which a flattening of the amplitude level occurs. The variation of the noise mean values, μ_N , with frequency suggests that values used in the model have to be selected with regard to the period of the signal. This issue is discussed in section 6 below.

Estimated standard deviations of the noise amplitudes on a logarithmic scale, σ_N, are shown in *Fig.5* where the 95% confidence limits are also indicated. Again the values have been plotted as a function of frequency. The estimates for LAC appear in general higher than for the other stations. It can also be noted that standard deviations for lower frequencies at stations FBA, LTX, and RSON appear to be smaller than for frequencies above 1 Hz. It has been assumed that larger mean noise levels would imply also larger standard deviations.[7] It is, however, difficult to see any dependence on the standard deviations with the mean values for the stations analyzed here. Most of the estimated standard deviations are in fact compatible with the often used value of 0.2.[8]

5.2. Long period

The number of long period noise measurements, *N2LZ,* is much smaller than the number of short period noise measurements. For the stations FBA, LAC, and LTX the numbers are a factor of 10 less whereas for the RSTN stations the difference is less dramatic. Virtually all measurements (except for LAC) have a period between 10 and 30s, and most measurements were made at a period of 16s.

Examples of empirical distribution functions for measured noise amplitudes are

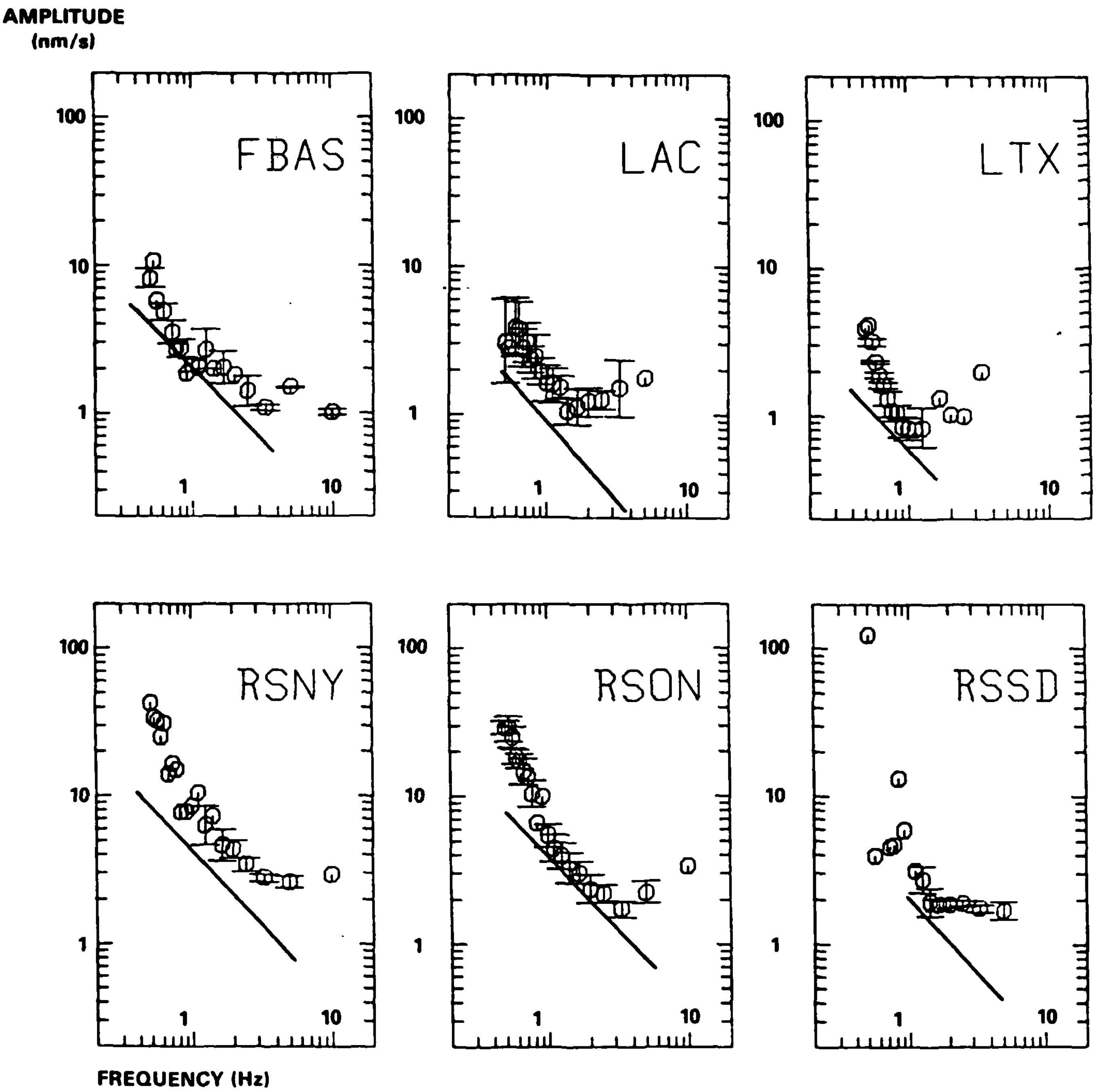

FIGURE 4. ESTIMATED MEAN VALUES OF NOISE AMPLITUDES (AMPLITUDE/PERIOD) AS A FUNCTION OF FREQUENCY. THE 95% CONFIDENCE LIMITS ARE INDICATED BY HORIZONTAL BARS IN CASES WITH SUFFICIENT NUMBERS OF OBSERVATIONS. THE SLOPING LINES CORRESPOND TO AN AMPLITUDE ROLL-OFF PROPORTIONAL TO FREQUENCY SQUARED.

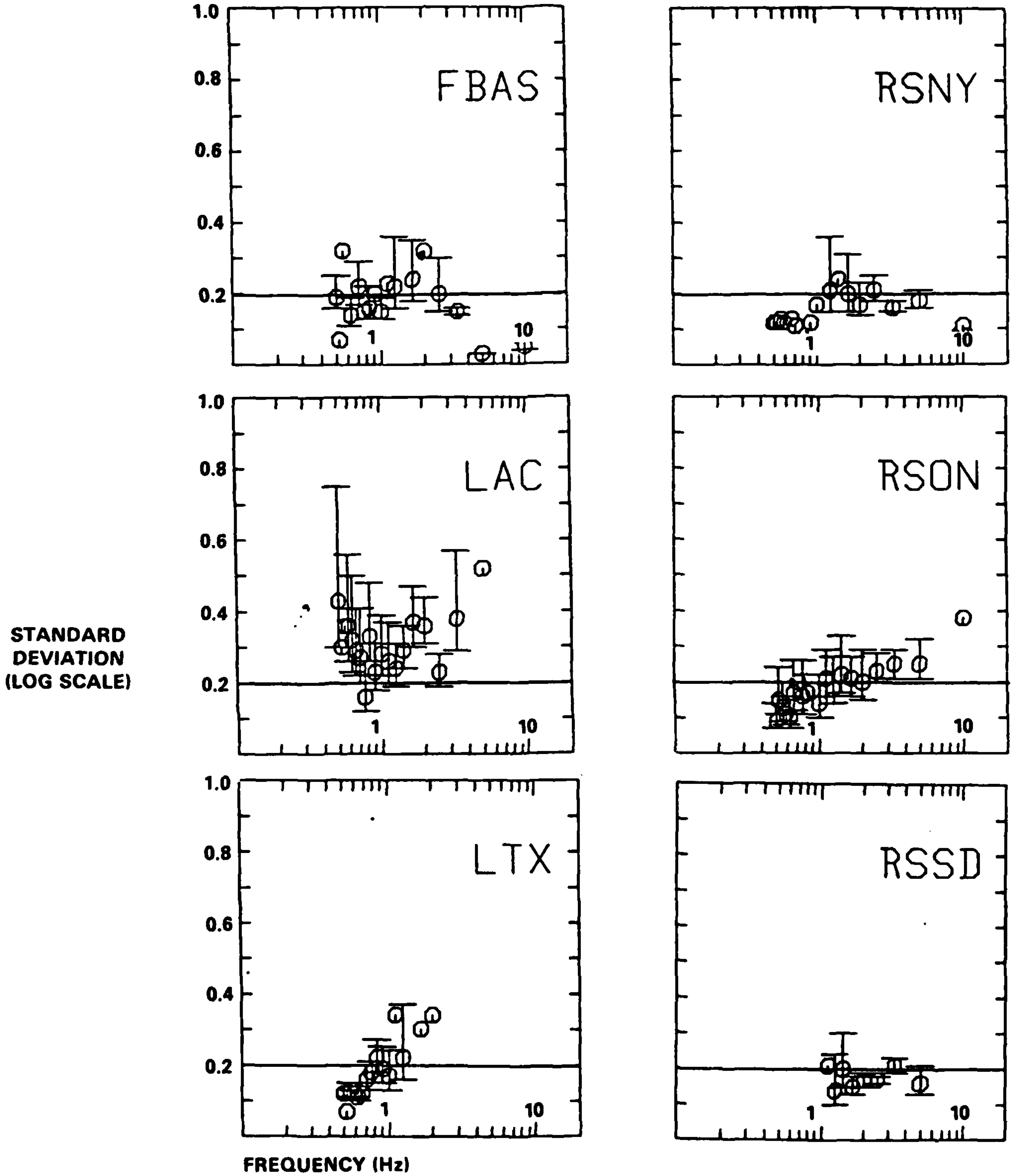

FIGURE 5. ESTIMATED STANDARD DEVIATIONS OF NOISE AMPLITUDES (AMPLITUDE/PERIOD) AS A FUNCTION OF FREQUENCY. THE 95% CONFIDENCE LIMITS ARE INDICATED BY HORIZONTAL BARS IN CASES WITH SUFFICIENT NUMBERS OF OBSERVATIONS. IN EACH CASE THE OFTEN ASSUMED VALUE OF 0.2 IS INDICATED AS A HORIZONTAL LINE.

shown in *Fig*.6. The hypothesis of normal distribution was tested as for short period noise above and only for three out of 11 cases was it possible to reject the hypothesis at a level less than 5%. It should be noted though that the numbers of observations were only between 20 and 50 whereas in the cases of short period noise more than 80 observations were used for all cases. Moreover the limited resolution of the measurements can be seen in empirical function in *Fig*.6.

Estimated mean values with associated 95% confidence limits are shown in *Fig*.7 and form "spectra" as for the short period data. A pronounced minimum near 20s (0.05 Hz) can be noted for the RSTN stations for which there are sufficient data. This can be compared with minima around 25 to 30s period (0.04 -0.03 Hz) often observed for *displacement* spectra in the long period frequency band.[9] The following values (converted to displacement amplitudes) of the means at the 16s and 20s periods were estimated:

NOISE AT 16 AND 20 S PERIODS						
Station	20 s period			16 s period		
code	mean	standard	no. of	mean	standard	no. of
-	(nm/s)	deviation	observ.	(nm/s)	deviation	observ.
FBA	58	0.18	9	54	0.24	54
LAC						
LTX	110	0.11	6	179	0.14	19
RSNY	83	0.26	6	124	0.20	24
RSON	81	0.56	8	88	0.19	30
RSSD	123	0.49	10	78	0.21	50

Estimated standard deviations and associated 95% confidence limits are shown in *Fig*.8. Although the number of observations are rather limited for firm conclusions, it appears that the values often are above the frequently used value of 0.2.[7]

6. SIGNAL FREQUENCY BANDS

As shown in the previous section the noise level both in the short and long period bands varies with frequency. To determine an operational noise level it is, therefore, necessary to also take into account the frequency distribution of the signals.

6.1. Short period

In order to discuss the variation of the dominant period of recorded teleseismic short period P waves we use the following simplistic model of the amplitude spectrum, $S(f)$, as a function of frequency (f) of a recorded wave form:

$$S(f)=EQ(f)P(f)I(f)$$

with the earthquake source spectrum, EQ , characterized by the corner frequency f_0:

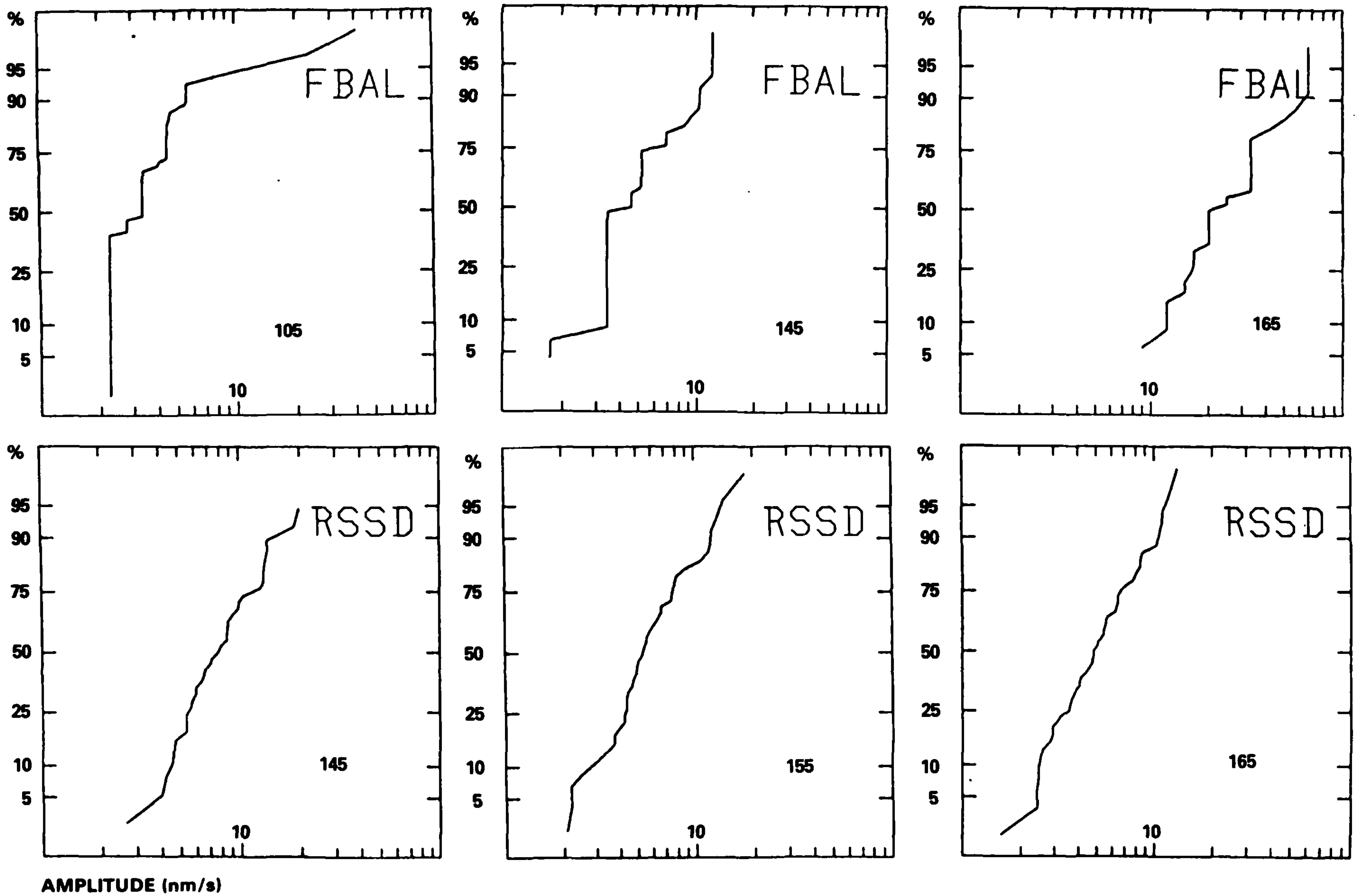

FIGURE 6. EXAMPLES OF EMPIRICAL DISTRIBUTION FUNCTIONS FOR NOISE AMPLITUDE MEASUREMENTS AT DIFFERENT PERIODS.

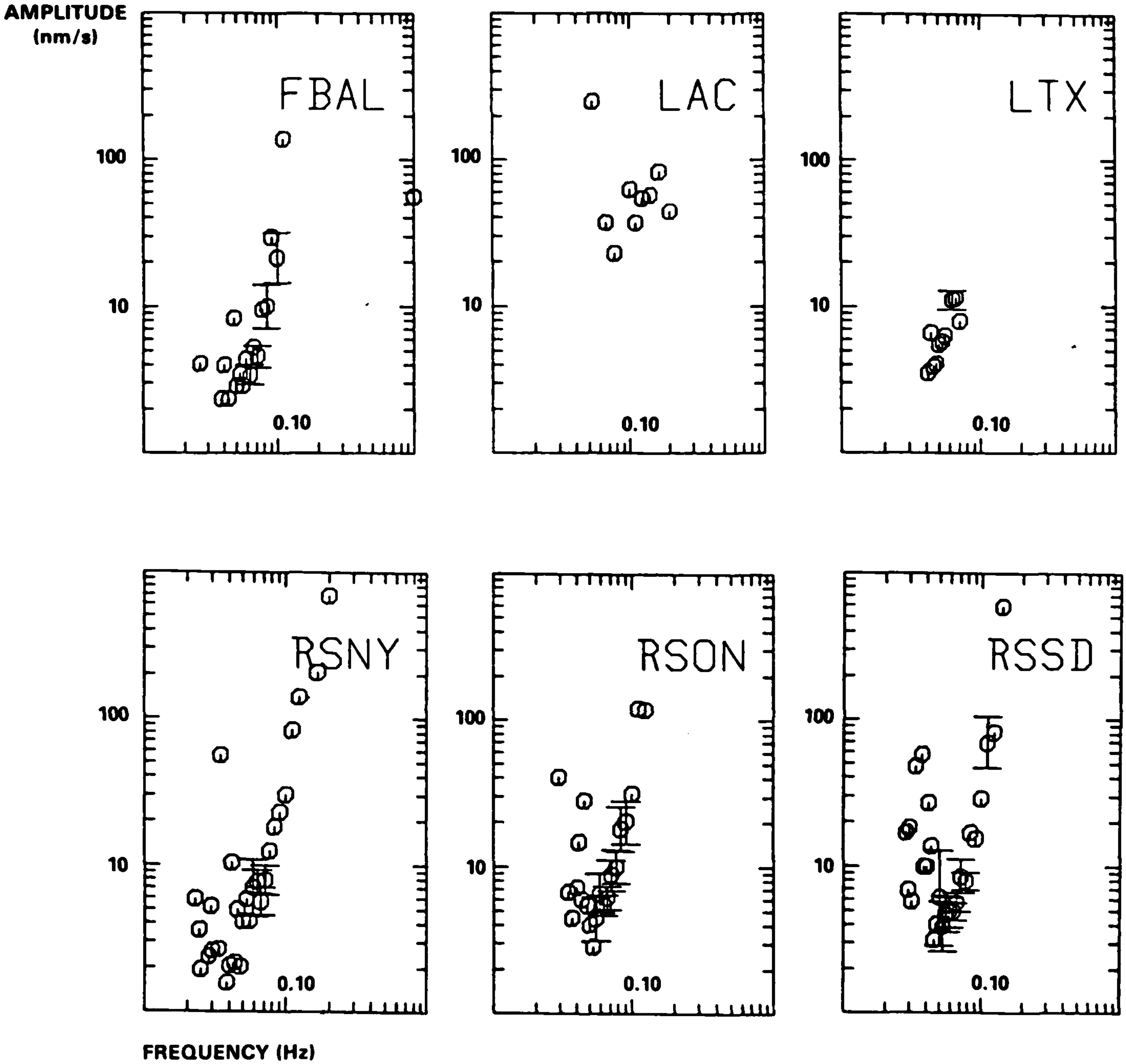

FIGURE 7. ESTIMATED MEAN VALUES OF NOISE AMPLITUDES (AMPLITUDE/PERIOD) AS A FUNCTION OF FREQUENCY. THE 95% CONFIDENCE LIMITS ARE INDICATED BY HORIZONTAL BARS IN CASES WITH SUFFICIENT NUMBER OF OBSERVATIONS.

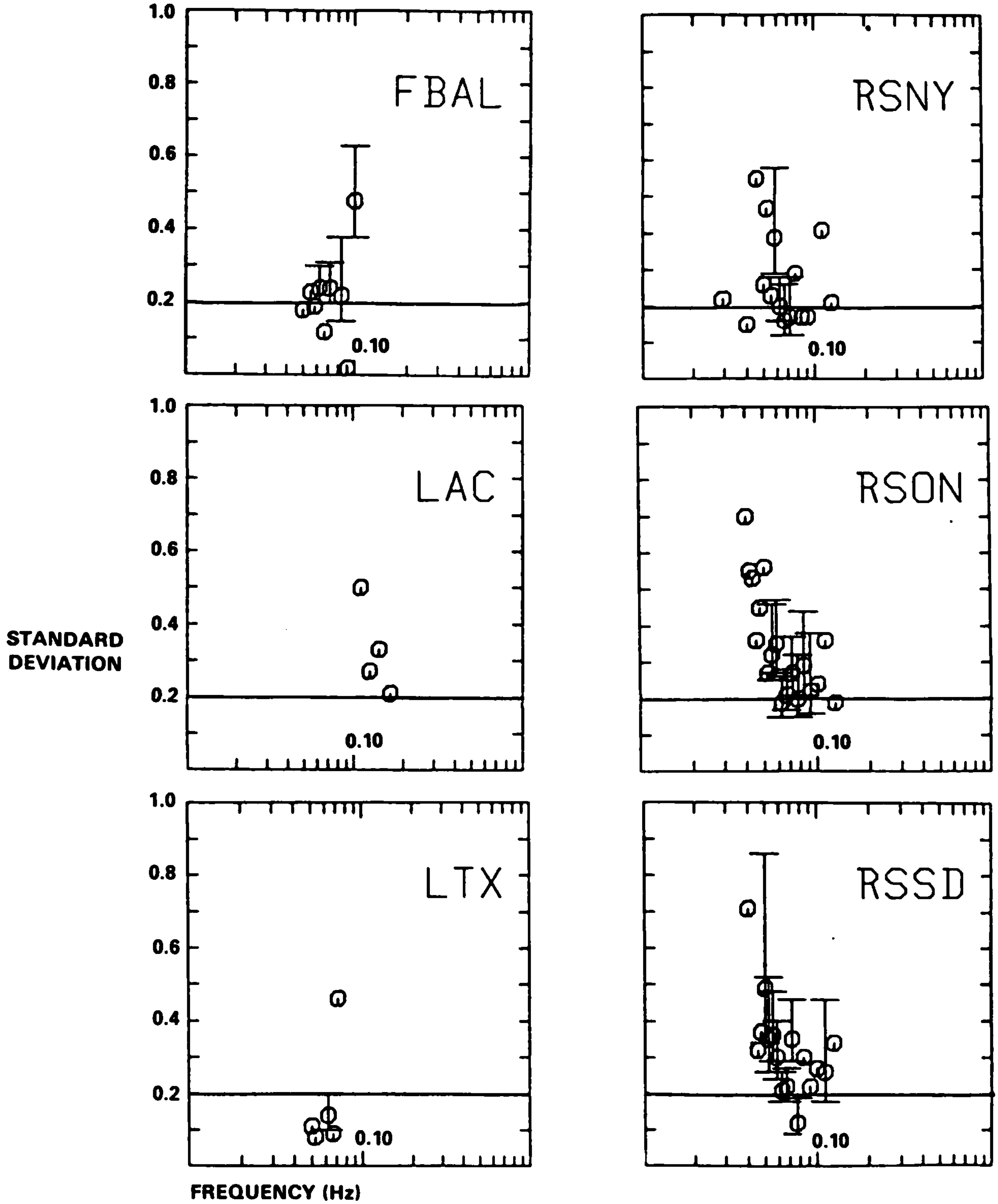

FIGURE 8. ESTIMATED STANDARD DEVIATIONS OF NOISE AMPLITUDES (AMPLITUDE/PERIOD) AS A FUNCTION OF FREQUENCY. THE 95% CONFIDENCE LIMITS ARE INDICATED BY HORIZONTAL BARS IN CASES WITH SUFFICIENT NUMBERS OF OBSERVATIONS. IN EACH CASE THE OFTEN ASSUMED VALUE OF 0.2 IS INDICATED AS A HORIZONTAL LINE.

$$EQ(f) = \left| \frac{f_0^{-3}}{(1+j(f/f_0))^3} \right|$$

with the path effect, P , characterized by the value of t^* :

$$P(f) = \exp(-\pi f t^*)$$

and with the instrument responses $I(f)$ shown in *Fig*.1. The dominant period T is assumed to be equal to $1/f$ with f denoting the frequency that maximizes the amplitude spectrum $S(f)$.

Examples of computed spectra, $S(f)$, shown in *Fig*.9, illustrate the effect of source size, path, and instrument response on the dominant period T. The source size effect of T on the data is shown in *Fig*.10, displaying measurements of the period versus magnitude for the six stations. For comparison an empirically derived linear relationship between period T and body wave magnitude, m_b, (m_b=3.24+1.32T) has also been drawn in the scatter diagrams.[10] The data have been limited to amplitudes associated with seismic events at epicentral distances between 30 and 85 degrees in order to minimize path effects. For most of the stations a source size effect is suggested by the data and, since we are interested primarily in detection of small events, the selection of the frequency band should be based on periods of signal with small amplitudes.

Clear differences in the period range of T can be seen among the stations. The period values for LAC which used an WWSSN-type response are quite large compared to the other stations where more high frequency response instruments were employed (Cf. *Fig*.1). This effect of instrument response is also implied by the simple model as illustrated in *Fig*.9 showing the dominant period for WWSSN and RSTN responses as a function of t^* and f_0 .

The empirical distributions of the period of small teleseismic amplitudes are shown in *Fig*.11. Upper limits of 30 and 10 nm have been used to define *small* amplitudes for the RSTN an non-RSTN stations respectively. The difference is motivated by the differences in amplitude levels at the two types of stations (Cf. section 9 below). The data in *Fig*.11 represent all reported detections and not just those associated with seismic events defined by the GSETT network. For most of the stations the distribution peaks between 1 and 2 Hz. LTX has a clearly lower peak and the distribution of LAC seems to be bi-modal with two peaks. It should be noted that the LAC data consist of "non"-local and "non"-regional detections and may not strictly be teleseismic.

In order to represent each station with one single noise amplitude the distribution curves of the wave period in *Fig*.11 have been combined with the earlier estimated mean noise values, $\mu_N(T)$, as a function of period T according to the following weighting:

$$\bar{\mu}_N = \sum_T n_T \mu_N(T) / \sum_T n_T$$

The weights, n_T, are the number of observed teleseisms with wave period T. The

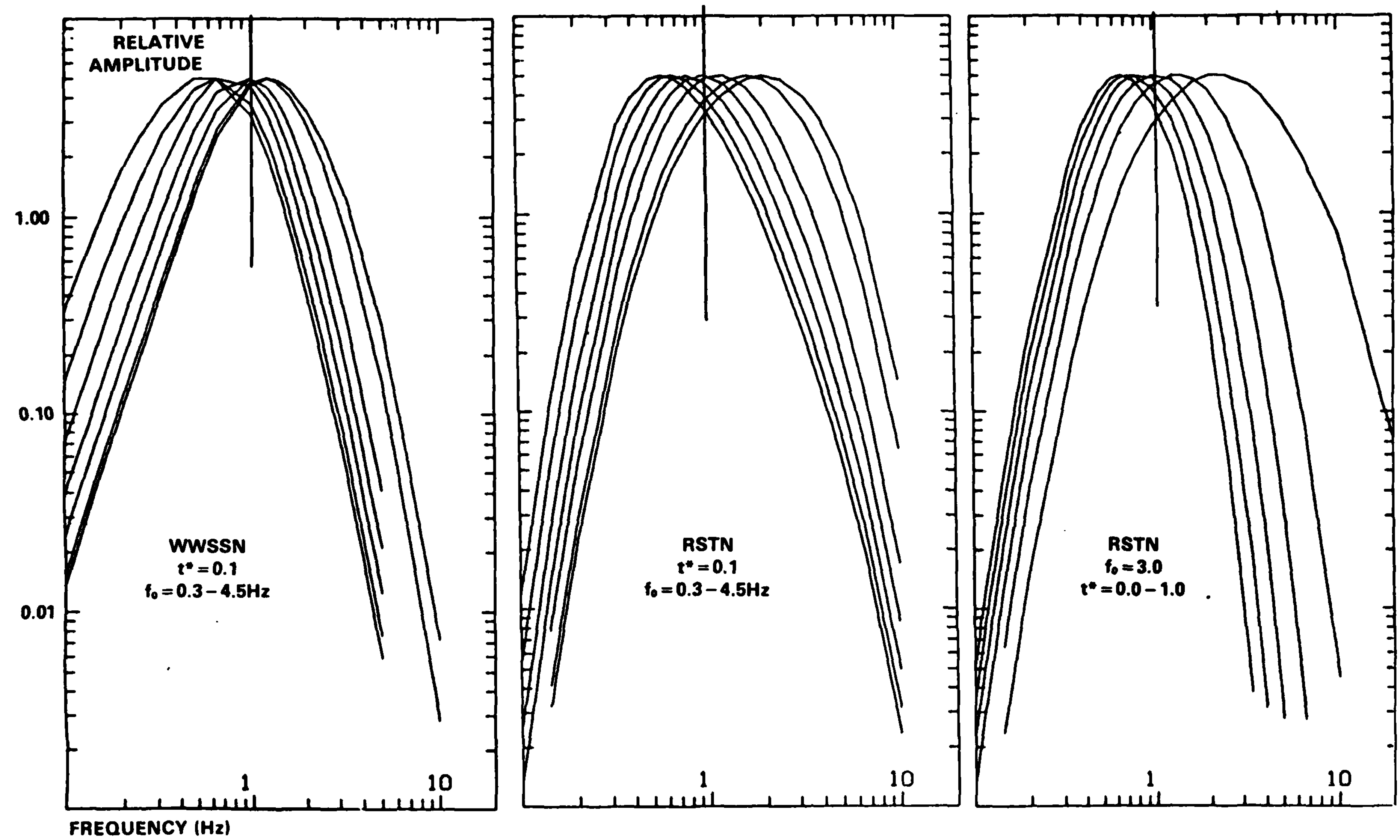

FIGURE 9. EXAMPLES OF CALCULATED RELATIVE AMPLITUDE SPECTRA IN A SIMPLE MODEL FOR SHORT PERIOD P-WAVES AS A FUNCTION OF CORNER FREQUENCY, f_o, t*-VALUE, AND INSTRUMENT RESPONSE.

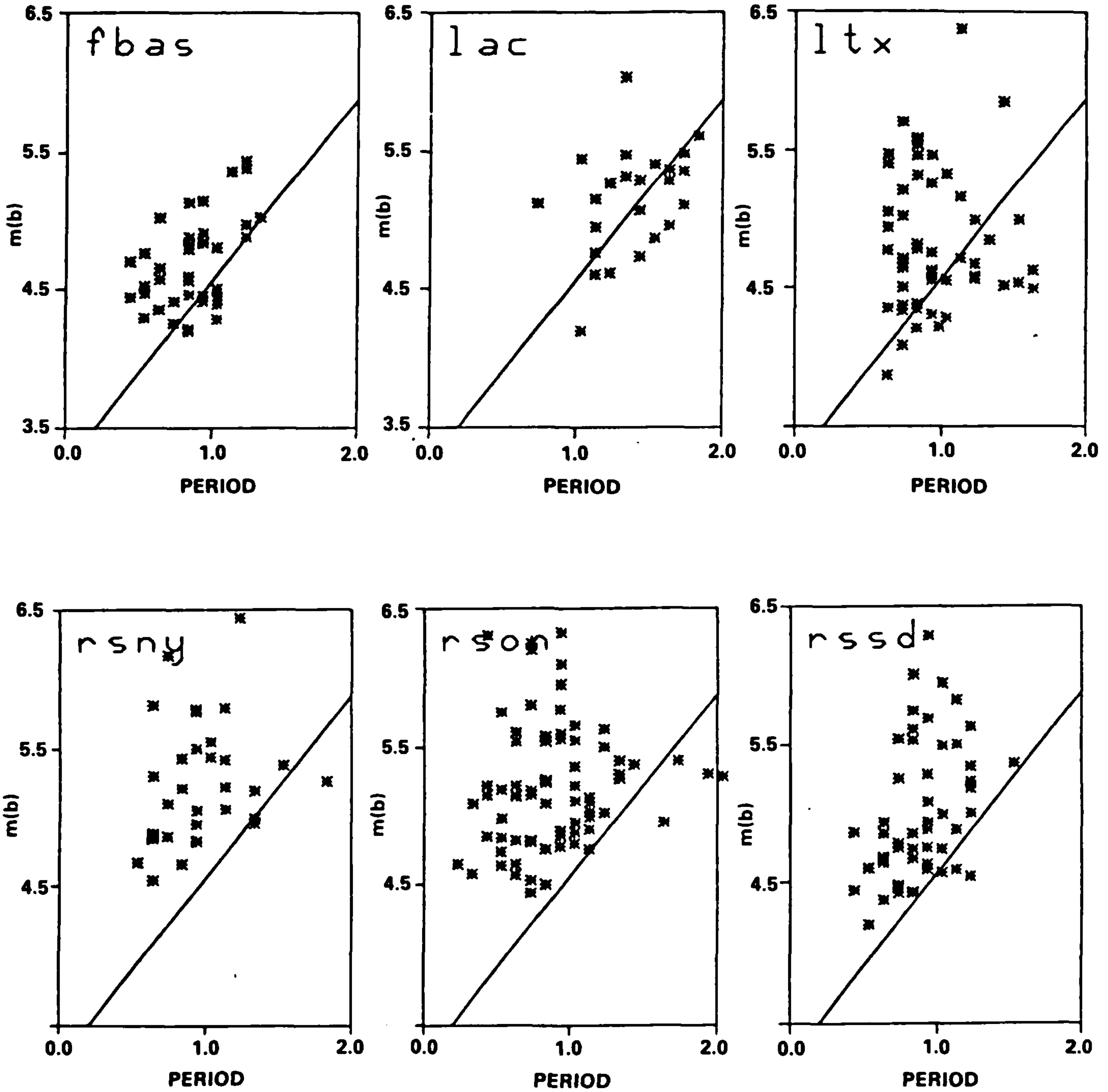

FIGURE 10. SCATTER DIAGRAMS WITH OBSERVATIONS OF BODY WAVE MAGNITUDES, m_b, AS A FUNCTION OF MEASURED WAVE PERIOD. THE EMPIRICAL LINEAR RELATION, $m_b = 3.24 + 1.32T$, IS DRAWN FOR COMPARISON.

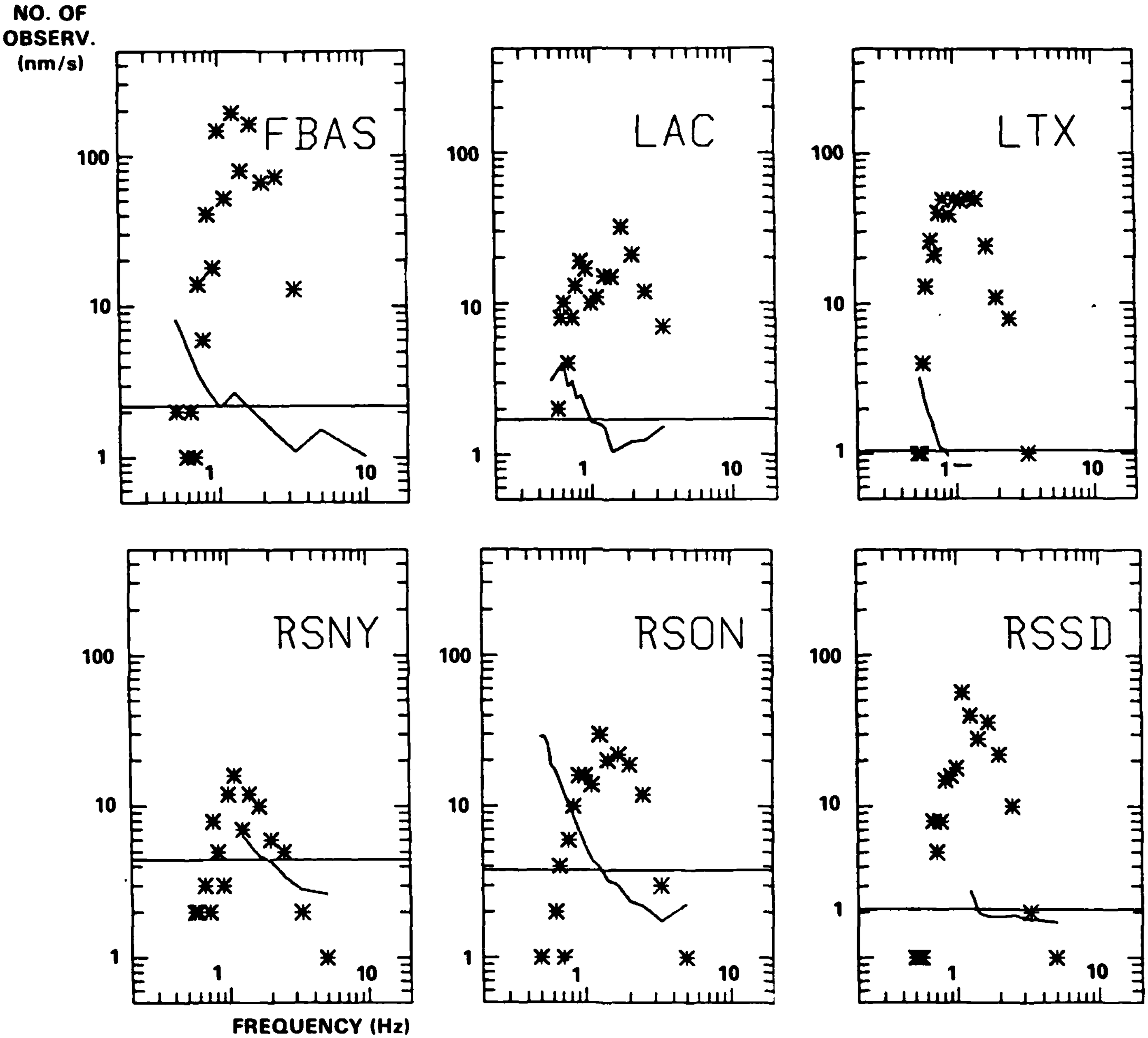

FIGURE 11. NUMBER OF DETECTED SHORT PERIOD TELESEISMIC P-WAVES WITH SMALL AMPLITUDES AS A FUNCTION OF MEASURED DOMINANT FREQUENCY. THE MEAN NOISE LEVELS HAVE BEEN DRAWN FOR COMPARISON, AND ESTIMATED 'OPERATIONAL' NOISE LEVELS AS DEFINED IN SECTION 6.1 ARE DRAWN AS HORIZONTAL LINES.

weighted values $\bar{\mu}_N$ represent velocity rather than displacement. The weighting procedure is graphically illustrated in *Fig.*11. To comply with the detection procedures at the stations the summation over the periods should be limited to the frequency band used for *detection* which may be different from the band in which *measurements* of amplitudes and periods actually were made (Cf. section 3 above). It can be seen from *Fig.*11 that for the RSTN stations summation is limited essentially to the pass band 0.9 to 4.0 Hz. The following values were obtained:

"OPERATIONAL" NOISE VALUES		
Station Code	Mean (nm/s)	Standard Deviation
FBA	2.2	0.20
LAC	1.6	0.30
LTX	1.0	0.18
RSNY	4.5	0.19
RSON	3.8	0.19
RSSD	2.1	0.16

These "operational" noise levels are generally lower than the values at 1 Hz.

6.2. Long period

Since the number of detected and reported measurements for long period noise and Rayleigh waves is comparatively limited, in particular for the non-RSTN stations, the analysis of the long period data has been restricted to the RSTN stations for which the distributions of dominant signal periods are shown in *Fig.*12. Many of the recorded Rayleigh waves have their period around 20 s, close to the minimum of the noise "spectra". "Operational" noise values have been estimated in s similar way as for the short period stations. The following values converted to amplitudes at 20 s period were obtained for RSNY, RSON, and RSSD respectively 94, 141, 120 nm.

7. MINIMUM SIGNAL TO NOISE RATIO

One important parameter of the detection model described in section 4 is $SNR_{\min}$ or the minimum signal to noise ratio which has to be exceeded to declare a detection. It is often assumed that this value is 1.5. In our case the signal to noise ratio is strictly speaking the signal plus noise divided by noise and the effect of addition of signal and noise amplitudes depends on their relative phase. For the purpose of the simplified approach here we assume however that the reported amplitude values of signals correspond to the amplitudes S of the detection model.

Upper limits of the minimum signal to noise ratio, or $SNR_{\min}$, can then at least theoretically be estimated from the amplitude/period measurements for noise and signals using cases where the two amplitudes have equal periods. In most cases however the period of noise and signals are different as shown by the table below which summarizes the minimum values of the signal to noise ratio for cases with

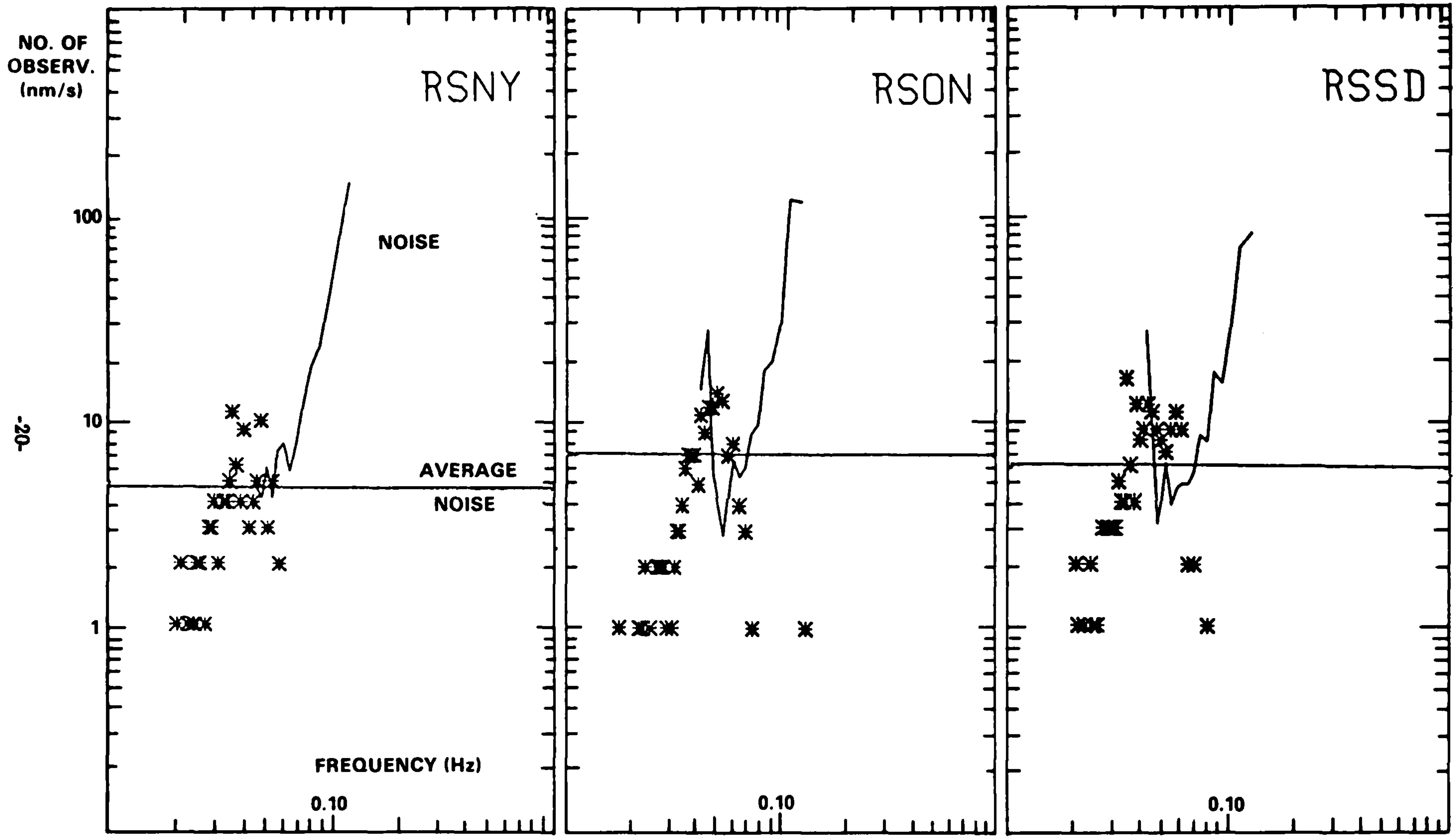

FIGURE 12. NUMBER OF DETECTED RAYLEIGH WAVES AS A FUNCTION OF MEASURED DOMINANT FREQUENCY. THE MEAN NOISE LEVELS HAVE BEEN DRAWN FOR COMPARISON, AND ESTIMATED 'OPERATIONAL' NOISE LEVELS AS DEFINED IN SECTION 6.2 ARE DRAWN AS HORIZONTAL LINES.

equal period for noise and signal for short period as well as for long period data:

UPPER LIMITS OF MINIMUM SIGNAL TO NOISE RATIO				
Station Code	Short Period		Long Period	
	SNR	No.of Observ.	SNR	No.of Observ.
-	-		-	
FBA	2.0	32	2.0	7
LAC	1.1	79	23.2	1
LTX	2.3	17		
RSNY	5.3	14	4.3	4
RSON	2.8	12	1.9	6
RSSD	1.6	25	4.9	2

The short period signal amplitude values are based on the maximum of the M1X and M2X measurements since in some cases the maximum signal amplitude occurs more than 6 s after signal onset. The SNR values in the table above represent only *upper limits* of the station thresholds. For example, the value 5.3 for short period RSNY data only means that the station threshold at RSNY is equal to or less than this value.

The minimum values of the signal to noise ratio are equal to or above 1.6 except for short period data at LAC which has the minimum value of 1.1. This may be an outlier since if this value really represents a minimum, a large number of observations would have values below 2.0, which is the case for only 5 observations at LAC.

Considering the inherent difficulty of the definition of the signal to noise ratio and the limited amount of data, it is difficult to estimate the parameter $SNR_{\min}$ on the basis of the upper limits in the table above. It seems reasonable to conclude however that the upper limit is somewhere between 1.0 and 2.0 and quite likely is below 2.0.

8. AMPLITUDE THRESHOLDS

Station and network detection thresholds can be estimated on the basis of the observed magnitude distribution of reported earthquakes.[11] The observed magnitude distribution is assumed to be the result of an exponential and a normal distribution, the latter of which expresses the detection probability (Cf. model in section 4). Maximum likelihood techniques for estimation of the parameters of the exponential distribution and the mean and standard deviation of the normal distribution have been developed.[11] The mean value of the normal distribution corresponds to the 50% detection threshold of the model in section 4, and the standard deviation corresponds to the variation of the noise level (σ_N).

This approach has been applied here to the reported amplitude/period ratios. In terms of the model used here we estimate the signal amplitude detection threshold, which in our notation is equal to:

$$\mu_N + \log(SNR_{\min})$$

and the standard deviation of this threshold, which should be equal to standard deviation of for the noise σ_N .

The approach of using the amplitude/period ratios is partly justified by using only reported teleseismic observations, in which case one may assume that the distance correction term (Q) for a large sample of earthquakes would average out. The cumulative curves are shown in *Fig*.13 which display reasonable resemblance to exponential distributions and have shapes similar to standard magnitude recurrence curves.

The following threshold values and standard deviations (std.) were obtained:

AMPLITUDE THRESHOLDS			
Station code	Threshold (nm/s)	std.	Ratio threshold/oper. noise
FBA	3.3	0.18	1.5
LAC	11.5	0.34	7.3
LTX	3.2	0.18	3.2
RSNY	12.0	0.16	2.6
RSON	10.0	0.22	2.6
RSSD	4.7	0.18	2.2

Estimated threshold values have also been drawn in *Fig*.13 together with the estimated "operational" noise levels (Cf. section 6.1). The estimated standard deviations show reasonable agreement with the independent estimates for the "operational" noise levels. In fact the standard deviation varies among stations between 0.16 and 0.34, but the differences between the two kinds of estimate of σ_N are 0.04 or less.

The estimated "operational" noise levels can be compared with the estimated thresholds and the ratios between the two should be a measure of the signal to noise ratio. The ratio values listed in the table above are all equal to or greater than the commonly assumed value of 1.5.

It is felt that the long period data are not sufficient for estimating amplitude thresholds. Moreover the criteria for detection (i e the condition on a P wave detection) makes it necessary to modify the maximum likelihood technique for actually estimating the thresholds which is beyond the scope of this report.

9. STATION CORRECTIONS

The term C entering the magnitude detection threshold of the model in section 4 namely:

$$\tau(50) = Q + C - \mu_N + log(SNR_{\min})$$

is referred to as a station correction or station magnitude bias.[12] This correction describes the amplitude reduction or amplification associated with the local conditions at the seismological station. The following simple model has been used to estimate corrections, C_j, for the six stations:

$$m_{ij} = m_i + C_j$$

Here m_{ij} denotes the magnitude computed at station j for event i . The term m_i is then the "event" magnitude. For computational reasons it is also assumed that $\sum C_j = 0$.

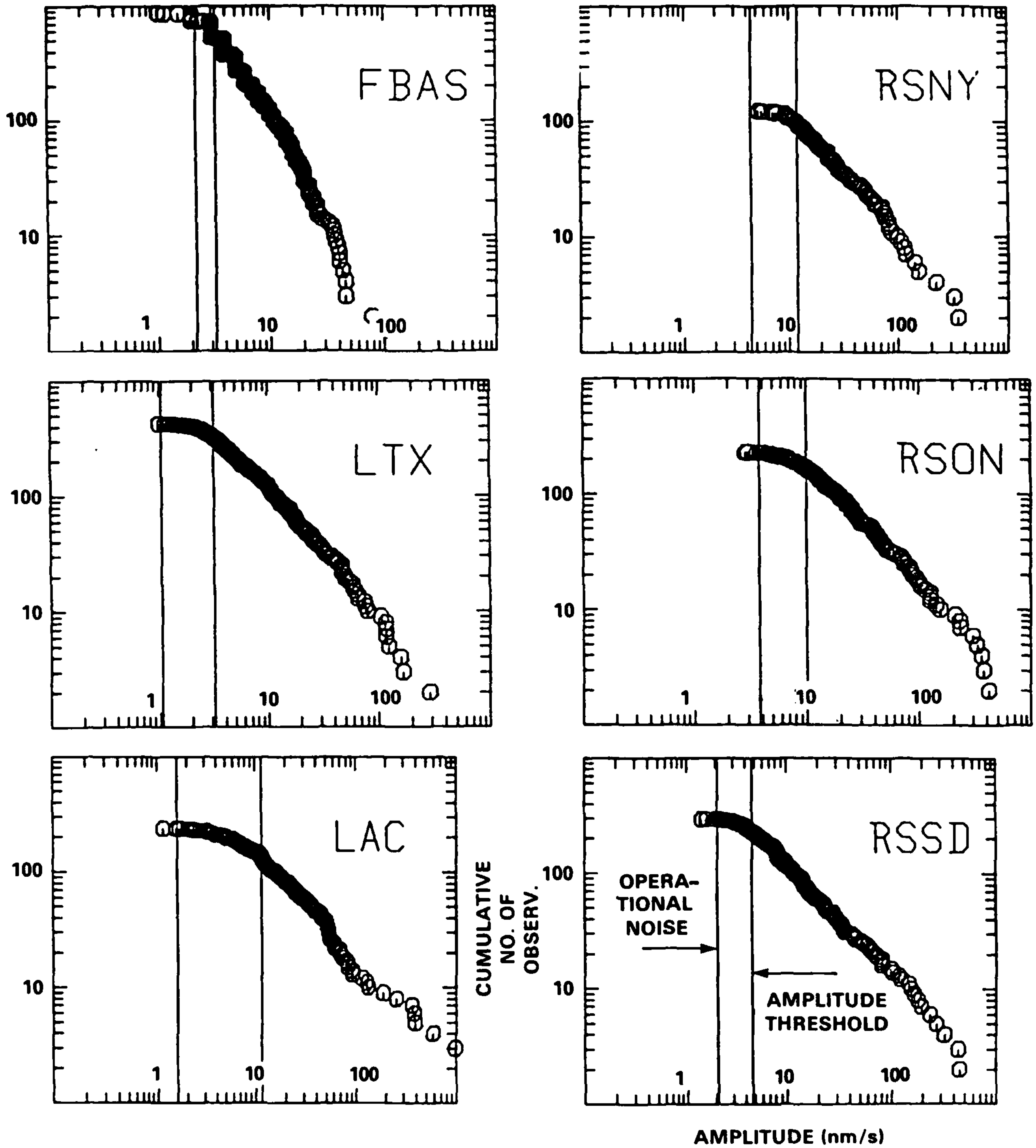

FIGURE 13. CUMULATIVE NUMBER OF DETECTED SHORT PERIOD TELESEISMIC P-WAVES AS A FUNCTION OF THE AMPLITUDE PERIOD RATIO. ESTIMATED AMPLITUDE DETECTION THRESHOLDS AND 'OPERATIONAL' NOISE LEVELS AS DEFINED IN SECTIONS 6 AND 8 ARE DRAWN AS VERTICAL LINES FOR COMPARISON.

This model was applied to 107 events for which magnitudes could be computed during the GSETT at two or more the of the six stations. In order to minimize propagation path effects only station magnitudes based on epicentral distances in the interval 30 to 85 degrees were used. The amplitude distance curve changes slowly in this interval. In all this gave 288 station magnitude observations for the events analyzed. Estimates were obtained by standard least squares techniques, and the computations were iterated twice rejecting outlying observations during the second iteration. An outlier was defined as an observation the absolute value of which exceeded 0.5 magnitude units. About 10 observations had to be truncated according to this criterion. The number of observations above refers to that after truncation.

The following values with estimated standard deviations (std) were obtained:

SHORT PERIOD STATION CORRECTIONS				
Station -	Correction (log)	Std (log)	No. of observ.	Pn vel (km/s)
FBAS	-0.16	0.05	41	8.07
LAC	-0.04	0.06	28	7.8
LTX	-0.20	0.05	55	7.9
RSNY	0.14	0.05	35	8.2
RSON	0.27	0.05	73	8.2
RSSD	-0.00	0.05	56	8.0

Station corrections are often correlated with local P_n -wave velocities, [13] and values for the stations obtained from a map compiled for North America [14] and data published for Alaska [15] are included in the table above. There is also a clear correlation for the corrections estimated here which increase with increasing P_n velocity as shown by *Fig.*14, which also compares the estimates with an empirical relation established for seismological stations in North America.[13]

10. MAGNITUDE DETECTION PROBABILITIES

The estimated values of the noise mean and standard deviation, the amplitude detection threshold, and station correction can be used to calculate magnitude detection probabilities for a given distance (i.e., the Q value) using the model described in section 4. *Fig.*15 shows the probability curves as a function of m_b and M_s using Q -values of 3.73 and 3.19 respectively corresponding to average values in the distance interval 30 to 85 degrees.

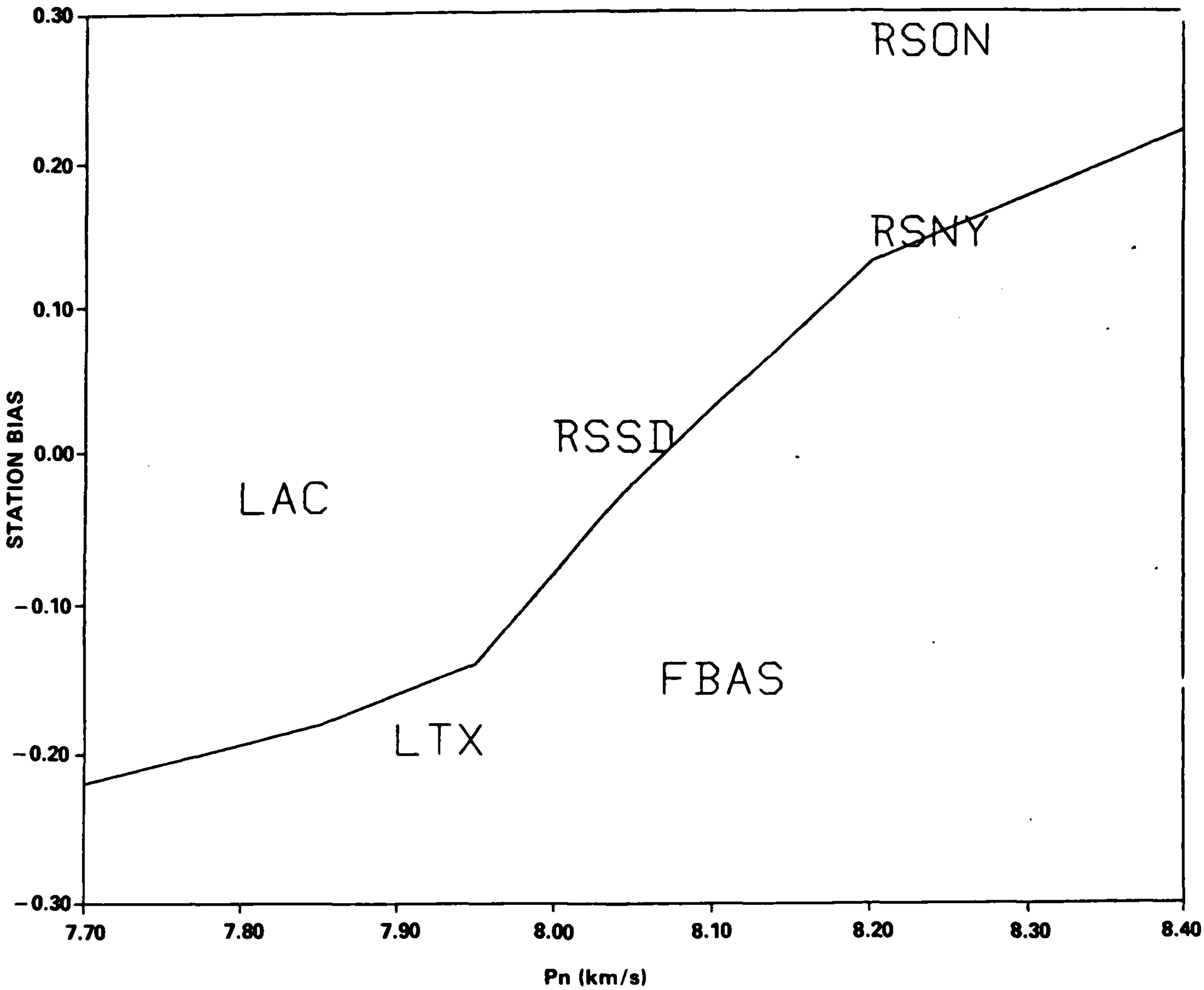

FIGURE 14. ESTIMATED STATION CORRECTIONS FOR AMPLITUDE PERIOD RATIOS PLOTTED AGAINST AVAILABLE ESTIMATES OF Pn VELOCITIES. THE CURVE IS AN 'EYE-BALL' FIT TO INDEPENDENTLY DERIVED DATA FOR SEISMOLOGICAL STATIONS IN NORTH AMERICA.

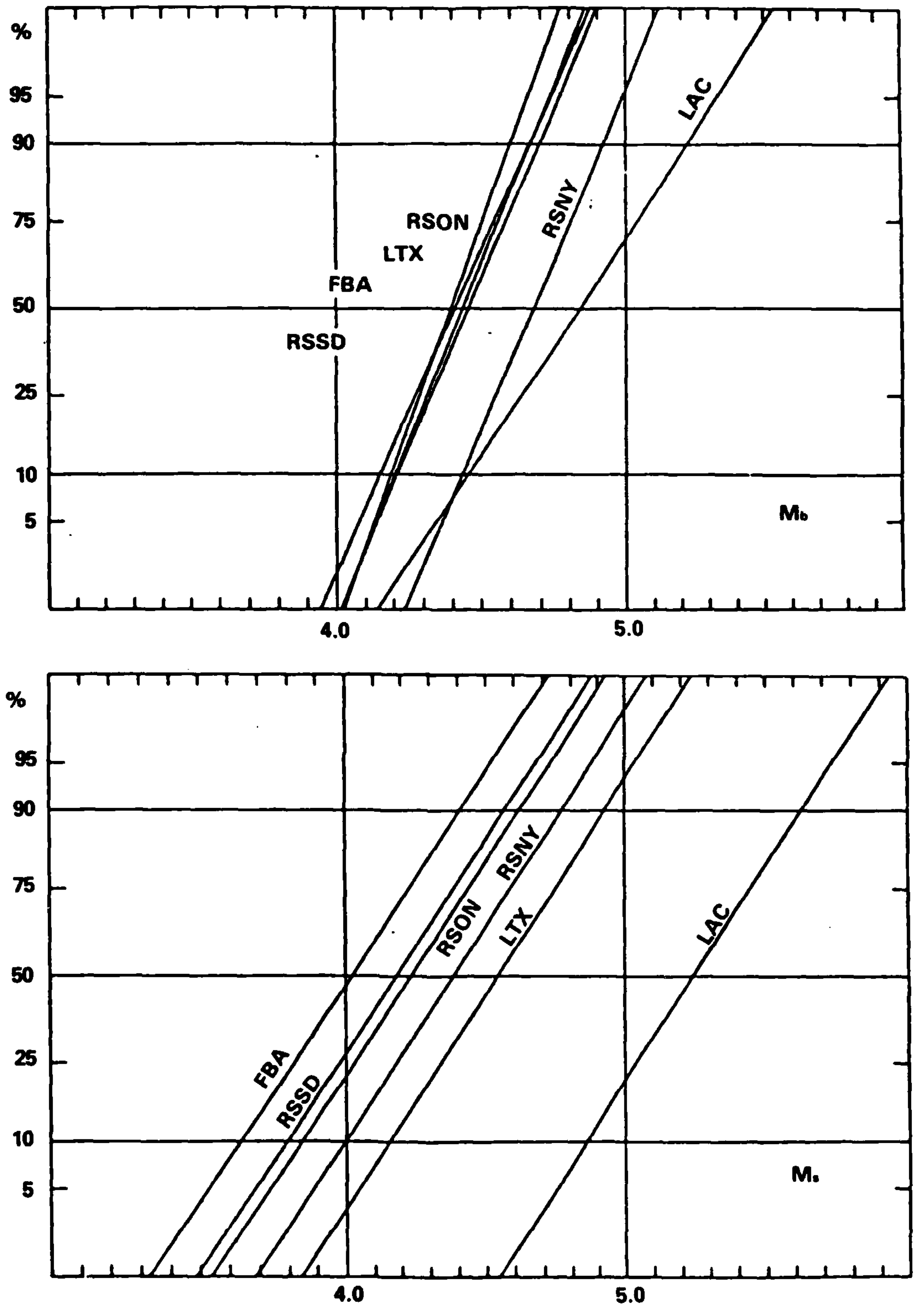

FIGURE 15. DETECTION PROBABILITY CURVES AS A FUNCTION OF MAGNITUDE FOR SHORT PERIOD TELESEISMIC P-WAVES AND LONG PERIOD RAYLEIGH WAVES BASED ON THE ESTIMATED DETECTION THRESHOLDS, NOISE LEVELS, AND STATION CORRECTIONS.

MAGNITUDE THRESHOLDS		
Station Code	P wave mb	Rayleigh wave Ms
FBA	4.41	4.02
LAC	4.84	
LTX	4.44	4.54
RSNY	4.68	4.38
RSON	4.45	4.23
RSSD	4.39	4.18

The signal standard deviation, σ_S, has been set equal to zero in the computations. The m_b thresholds are based on the amplitude detection thresholds and station corrections in sections 8 and 9 respectively. The M_s thresholds are based on the noise values at the 16 s period in section 5 and an assumed SNR_{min} of 2.0, and the standard deviation of the noise, σ_N , is assumed to be 0.3.

The m_b and M_s thresholds are plotted in the scatter diagram in *Fig.16* together with a linear relation between m_b and M_s for earthquakes (m_b=0.62M_s+2.03).[16]

11. NUMBER OF DETECTED SIGNALS

The magnitude detection thresholds in the previous section can be compared with the numbers of detected signals listed in section 3. It appears that stations with similar detection thresholds reported different numbers of events. This is partly due to differences in location relative to the occurring seismic events. If it is assumed that the population of seismic events defined during GSETT is a representative sample of the geographical distribution of seismicity, average $\overline{Q}$ values can be computed for the stations:

NUMBER OF DETECTED SIGNALS				
Station Code	Daily No. of Detections	mb -	Q -	Estimated no. of Detections
FBA	16.1	4.41	3.63	9.3
LAC	5.4	4.84	3.83	2.7
LTX	8.4	4.44	3.88	5.2
RSNY	2.8	4.68	3.94	
RSON	4.4	4.45	3.94	4.5
RSSD	5.5	4.39	3.89	5.6

Presumed and announced explosions and small (below m_b =3.0) events in Europe have been eliminated from the GSETT event population. The $\overline{Q}$ values have been computed for an amplitude distance correction curve which has been extended to 180 degrees.[17,18] As shown in the table above, the $\overline{Q}$ -value varies among the stations by more than 0.3 magnitude units.

The total number of events, n_j , detected by a station, j , with the threshold Θ_j , noise standard deviation σ_{Nj} ,and distance correction $\overline{Q}_j$ can be written as:[11]

$$n_j=\exp(a-b(\Theta_j+\overline{Q}_j)+b^2\sigma_{Nj}^2/2)$$

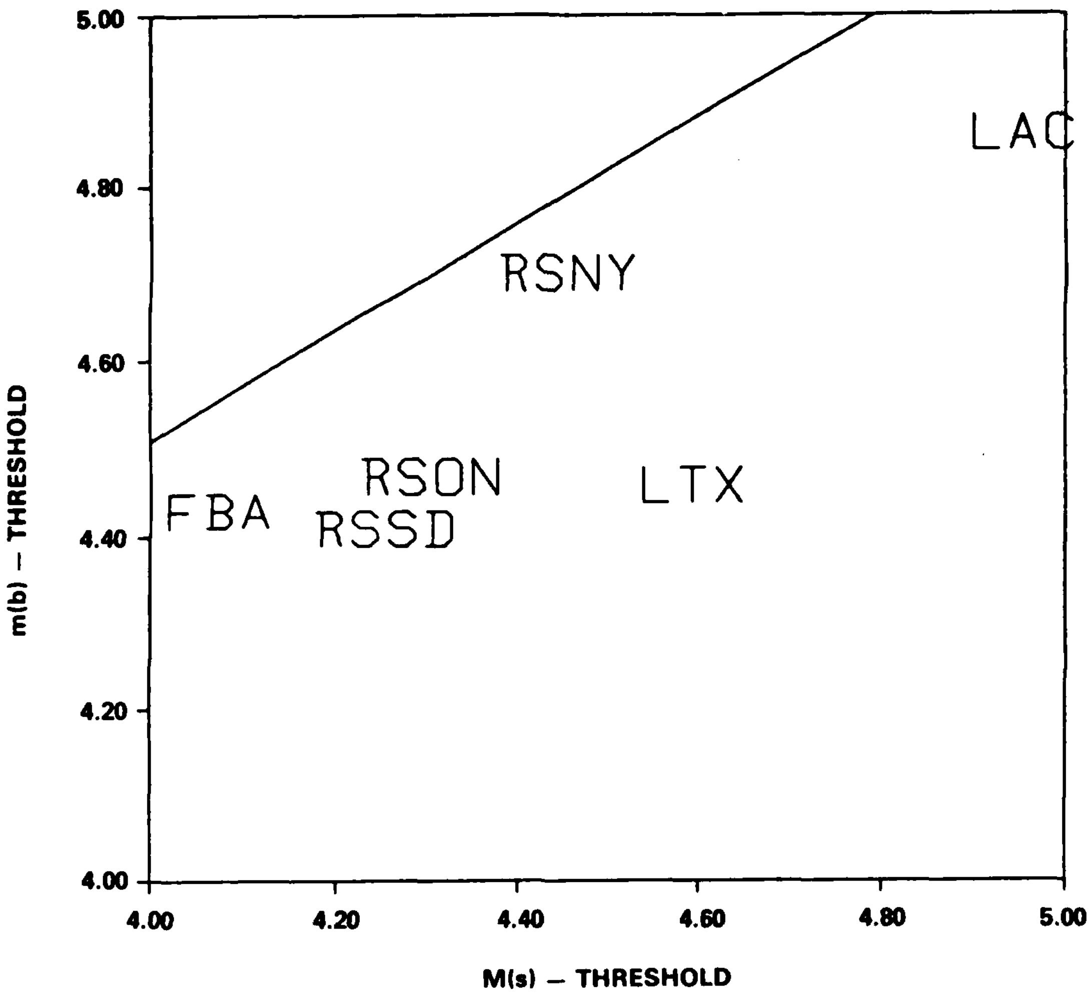

FIGURE 16. THE 50% m(b) and M(s) DETECTION THRESHOLDS. THE LINEAR RELATION, $m(b) = 0.62M(s) + 2.03$, IS DRAWN FOR COMPARISON.

The parameters a and b are the standard seismicity parameters for the exponential distribution of magnitudes. Using this formula the *relative* number, n_{ij} , of seismic events (earthquakes) detected by two stations (i,j) becomes:

$$n_{ij}=n_i/n_j=\exp(-b(\Theta_i-\Theta_j+\overline{Q}_i-\overline{Q}_j)+b^2(\sigma_{Ni}^2-\sigma_{Nj}^2)/2)$$

This formula can be used to calculate the relative number of detected events for the six stations, and the results are given in the table above with the station RSNY as a reference. The value of b is assumed to be 2.07 (i e 0.9 in 10 log base).[8] The values for the RSTN stations are reasonably consistent.

12. CONCLUSIONS

The data analyzed in this note are based on simple measurements of recorded waveforms. Even so it is found that several conclusions can be drawn about the seismic noise levels and event detection thresholds.

-For most of the stations it was possible to measure most of the short period noise amplitudes in the frequency band 1.0 to 5.0 Hz.

-The noise amplitudes follow approximately normal distributions.

-The short period noise amplitudes decrease as a function of frequency up to a certain limit between 2 to 5 Hz, beyond which the level stays almost constant.

-The variation of the short period noise amplitudes is compatible with a standard deviation of 0.2.

-The dominant period of recorded P-wave signals usually is between 1 and 2 Hz. Systematically lower periods at one of the stations (LAC) could be attributed to differences in instrumental response.

-The minimum signal-to-noise ratio establishing a threshold below which a station does not detect a signal seems to be around 2 or above rather than 1.5 as usually assumed.

-Reported amplitude/period ratios follow exponential distributions reasonably well which makes it possible to estimate amplitude detection thresholds.

-Preliminary estimates of station corrections have been made which correlate to published determinations of local P_n wave velocities.

-Magnitude detection thresholds at 50% probability based on noise, signal-to-noise ratios, and station corrections vary between m_b=4.4−4.8 and M_s=4.0−4.5 .

-The numbers of reported short period detections are, in particular for the RSTN stations, reasonably consistent with the estimated magnitude detection thresholds.

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NOISE LEVELS AND DETECTION THRESHOLDS AT GSETT SEISMOLOGICAL STATIONS

Hans Israelsson

1. INTRODUCTION

This note contains a compilation of seismic noise level measurements and detection thresholds for short period teleseismic P-waves and long period Rayleigh waves at the seismological stations that contributed to the Technical Test of the *Ad Hoc* Group of Scientific Experts *(GSETT)* carried out from 15 October through 14 December 1984.

The compilation is based primarily on data recorded during the GSETT and received at the Center for Seismic Studies.[1] In cases for which sufficient GSETT-data were not available at the Center, estimates published in the seismological literature are used. The compiled data are also compared with a list of tentative noise values included in the document describing the procedures for the GSETT.[2]

Apart from the assessment of detection capabilities of the individual GSETT stations the compiled noise levels and thresholds can be used for the amplitude consistency check in the procedure for Automatic Association *(AA)* and location of seismic events [3] as well as for simulation of network capabilities of detection and location of seismic events.[4]

2. SHORT PERIOD NOISE

A large number of waveform parameters were measured at the participating seismological stations during GSETT. According to the procedures for the test the short period *noise* parameters, *(NSZ)*, should consist of the maximum trace amplitude at frequencies between 1.0 and 5.0 Hz, or at a frequency close to that of the signal, together with the associated period. The amplitude should be measured within 30 seconds before the onset of each P wave.[2]

Table 1 summarizes NSZ data received at the Center from the GSETT stations. In all there are data from 51 stations. Sub stations of arrays (like GRA1, GRAB1, and GRAC1 for GRF) have been treated separately in the table since noise conditions may vary across the arrays. Table 1 gives for each station the total number of measurements, average of amplitudes measured at 1 Hz, and the mean value and range of variation of the measured period.

The total number of measurements (which partly reflects the signal detectability at a station) varies between 6 and 1276, and there are more than 100 observations from 34 of the stations.

2.1. Amplitudes at 1 Hz

Table 1 lists amplitudes for the noise data which had a measured period of 1

TABLE 1 NSZ MEASUREMENTS							
Station	Total No.	Amplitudes at 1 Hz			Frequency		
Code	-	Mean	Std	No. of	Mean	Low	High
-	-	(nm)	(log)	-	(Hz)	(Hz)	(Hz)
APO	594	4.3	0.57	13	1.8	0.5	10.0
ASPA	999	0.9	0.27	459	1.0	0.5	5.0
BDF	28	15.5	0.53	3	0.7	0.5	5.0
BUD	76	33.9		1	1.6	1.0	3.3
COP	34	61.7	0.19	13	1.1	0.8	2.5
CTAO	763	3.2	0.21	520	1.0	0.5	2.5
DAG	227	3.5	0.20	20	0.7	0.5	5.0
DKM	62	46.8	0.26	26	1.0	0.5	5.0
EKA	140	2.9	0.27	39	1.1	0.8	2.5
ENN	195	4.6	0.26	59	0.9	0.5	2.0
FBAS	1276	2.1	0.15	46	2.4	0.5	10.0
GAC	369	6.9	0.29	26	0.9	0.5	5.0
GBA	428	4.4	0.12	101	0.9	0.6	10.0
GDH	19	38.0	0.07	5	0.8	0.6	1.1
GRA1	243	6.0	0.09	17	1.0	0.5	2.5
GRB1	113	6.6	0.08	4	1.3	0.5	2.5
GRC1	36	4.0	0.10	3	1.3	0.5	2.0
HFS	666	9.1	0.25	10	1.8	0.6	10.0
IR4	9				0.6	0.5	0.8
JOS	186	3.0		1	1.9	1.0	2.5
KBA	281	3.4	0.14	54	1.3	0.5	5.0
KHC	555	3.4	0.14	165	1.2	0.8	2.0
LAC	463	1.6	0.28	24	1.1	0.5	5.0
LOR	283	4.2	0.20	194	1.0	0.5	5.0
LSZ	102	2.0	0.17	3	0.7	0.5	1.7
LTX	1015	0.8	0.17	23	0.7	0.5	3.3
MAT	616	8.9	0.12	139	0.9	0.5	3.3
MAW	373	1.0	0.22	120	0.8	0.5	5.0
MBC	589	5.1	0.09	212	1.4	1.0	5.0
MLR	67	4.0		1	1.8	1.0	3.3
MNS	31	5.0		2	0.7	0.5	3.3
MOX	240	3.3	0.16	240	1.0	1.0	1.0
NAO	75	1.0	0.	0	1.4	1.1	1.7
NB2	426	0.9	0.20	6	1.4	0.7	2.5
NNA	47	24.5	0.41	24	1.1	0.5	5.0
NUR	67	13.8	0.11	44	1.0	0.7	1.7
WAO	209	6.2	0.26	76	1.3	0.7	3.3
OBN	96	13.8	0.06	3	1.8	0.5	2.5
PMO	7	22.4	0.26	4	0.9	0.7	1.0
PRU	391	6.6	0.23	82	1.1	0.5	5.0
PSZ	134	6.8		1	2.0	1.0	3.3
RSNY	433	8.5	0.17	8	2.2	0.5	10.0
RSON	451	5.5	0.14	16	1.2	0.5	10.0
RSSD	885				2.4	0.5	5.0
SBA	6	6.6	0.24	3	1.0	0.7	1.7
SLL	624	5.1	0.50	9	1.6	0.5	10.0
SUF	69	4.5	0.13	17	1.3	1.0	2.0
TBY	251	5.8	0.23	7	1.8	0.5	5.0
VTS	233	4.2	0.19	50	1.2	0.5	3.3
WEL	19	125.9	0.12	9	1.0	0.6	5.0
YKA	412	2.3	0.26	43	0.8	0.5	10.0

second giving mean, standard deviation, and number of observations. The amplitude at 1 Hz for each station is often used in both AA programs and simulations of seismological network capabilities. For 36 of the stations there are more than five observations available at 1 Hz and their mean values range from 0.8 (LTX) to 125.9 nm (WEL). Four stations have values equal to or below 1.0 nm (ASPA, LTX, MAW, NB2), and 26 stations have values below 10 nm. The median value of the 36 stations is close to 5 nm.

The mean of the 36 standard deviations of the noise amplitudes at 1 Hz is 0.21 (+- 0.11). This mean agrees well with the commonly assumed value of 0.2 magnitude units for the variability of short period seismic noise. It has been suggested (CCD/558) that a high mean value of the noise amplitude would also give a large standard deviation, but there is no correlation between mean amplitudes and standard deviations for the data used here.

2.2. Periods

The mean values of the measured periods associated with the noise amplitude have been transformed into frequencies in Table 1. This mean value varies from 0.7 (LTX) to 2.4 Hz (FBAS) and it is above 1.0 Hz for 33 of the stations.

Lower and upper frequency values of period measurements have also been included in the table as an indication of the range of variation and for comparison with the measurement interval 1.0 to 5.0 Hz mentioned above. These lower and upper frequencies were obtained from the maximum and minimum respectively of the measured period values. Only measured periods less than or equal to 2 s (0.5 Hz) have been included in the analysis here. The range of variation represented by the reported lower and upper frequencies varies from 0 (MOX) to 3.1 octaves (FBAS) and the mean value of the frequency range for the stations is about 1 octave. The differences in period range among the stations is probably mainly due to differences in seismogram reading practices at the stations.

2.3. Amplitude as a function of frequency

The noise amplitudes vary significantly with period or frequency as can be seen from *Fig.1,* where mean amplitude/period ratios have been plotted as a function of frequency for each of the 51 stations. The mean values have been calculated from the logarithm of the amplitude/period ratios and the 95% confidence limits are indicated with bars in cases with more than 10 observations. The shapes of these "spectra" vary significantly from station to station. It is often assumed that the noise amplitude (ground motion, nm) decreases in proportion to frequency squared.[5] Some of the "spectra" in *Fig.1* (e.g., FBAS, KBA, MAW) do indeed fall off systematically with frequency even if not exactly like frequency squared. Others (e.g., stations GAC, HFS, and RSSD) decrease with frequency up to a certain value, often between 1 and 3 Hz, beyond which the amplitude stays almost constant. There are also cases where the "spectra" appear to have a minimum, as for the stations GRA1, LAC, LOR, and PRU. Indeed, there are also stations for which the "spectra" appear to systematically increase with frequency such as BUD and MBC.

The noise amplitudes plotted as a function of frequency in *Fig.1* are of course not

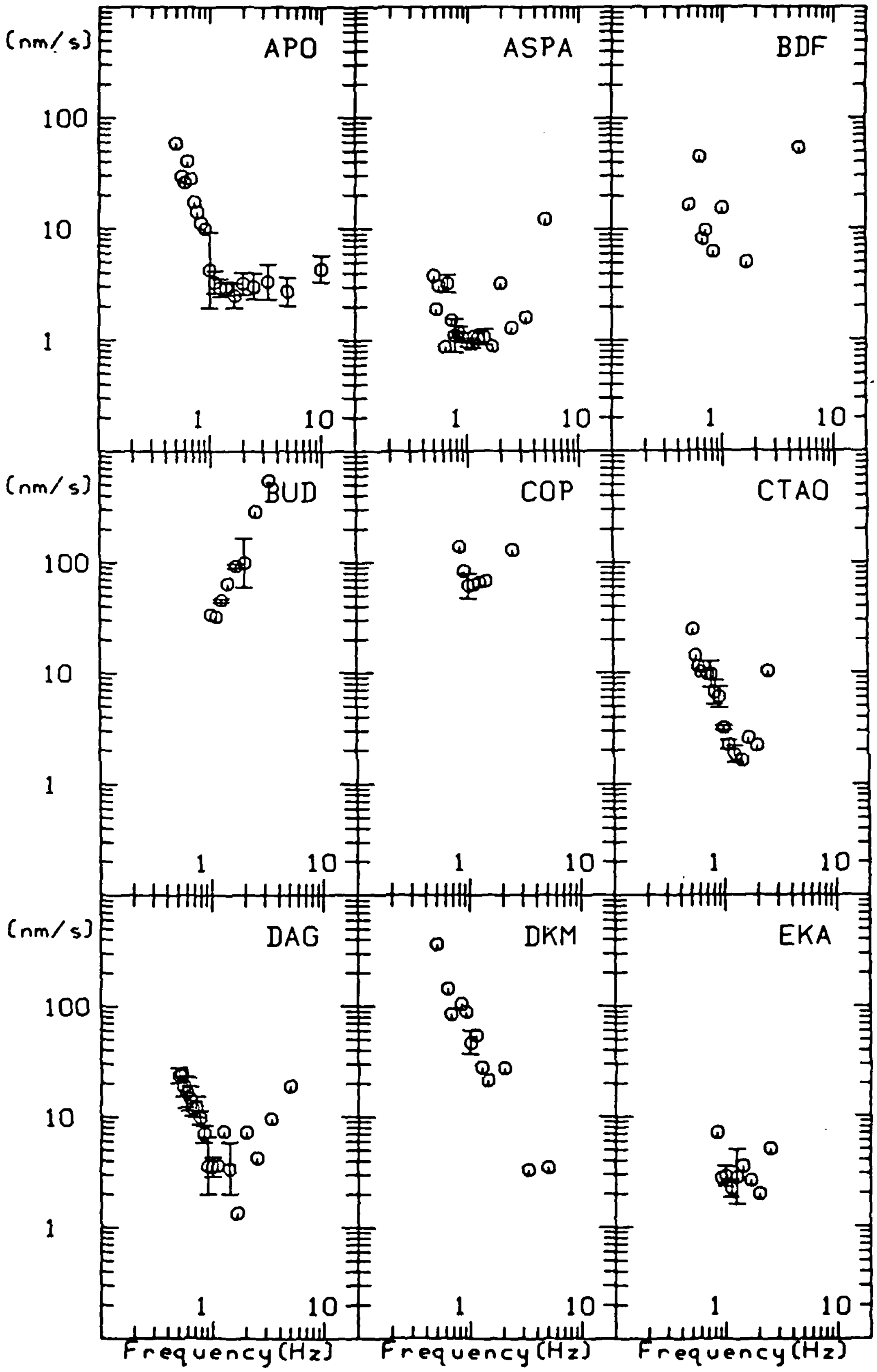


Fig.1 **Short period noise as a function of frequency. Each data point represents an estimated mean value of the amplitude divided by the period, and the 95% confidence limits are indicated with bars in cases with more than 10 observations.**

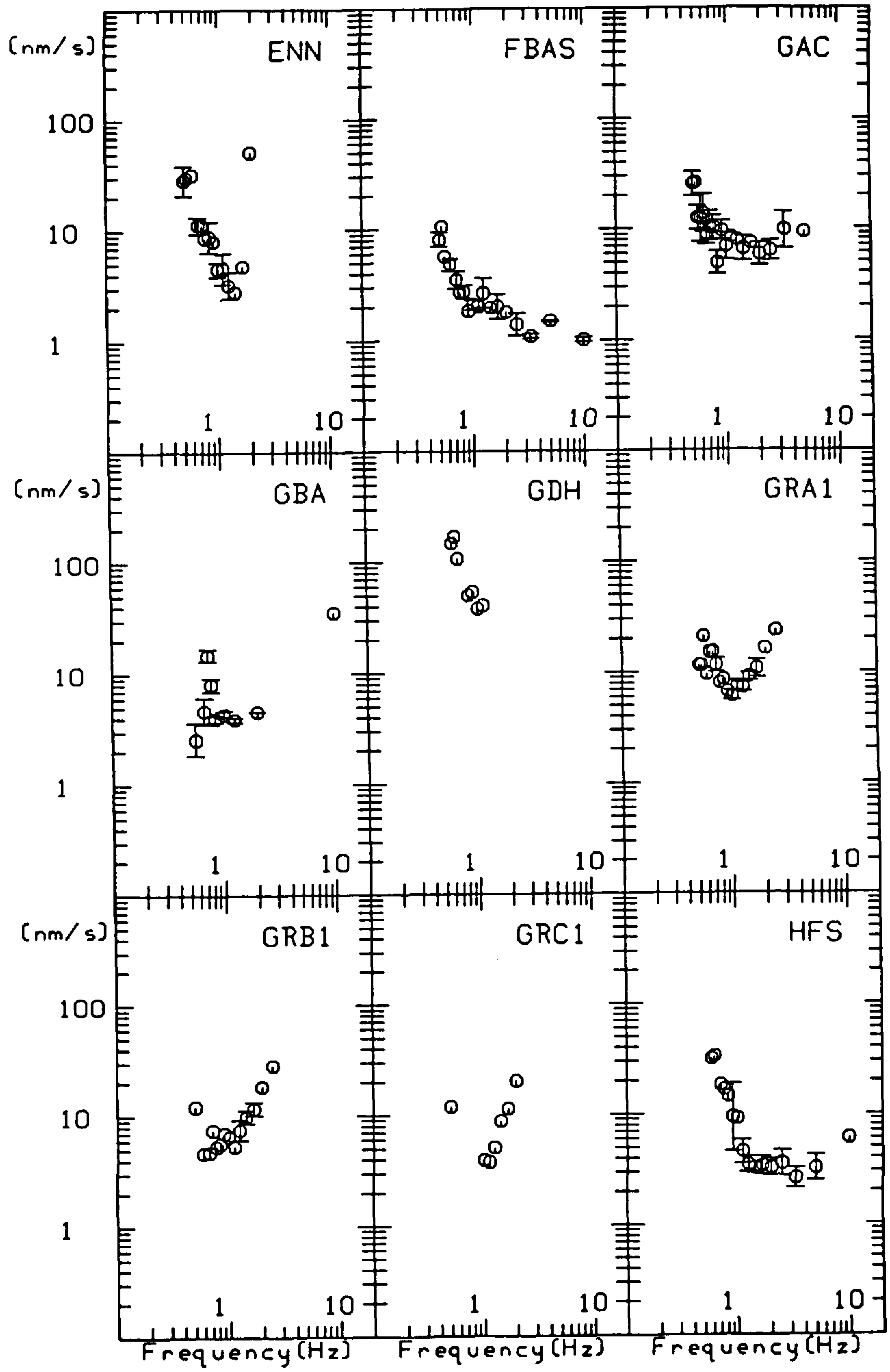


Fig.1 **Short period noise as a function of frequency. Each data point represents an estimated mean value of the amplitude divided by the period, and the 95% confidence limits are indicated with bars in cases with more than 10 observations.**

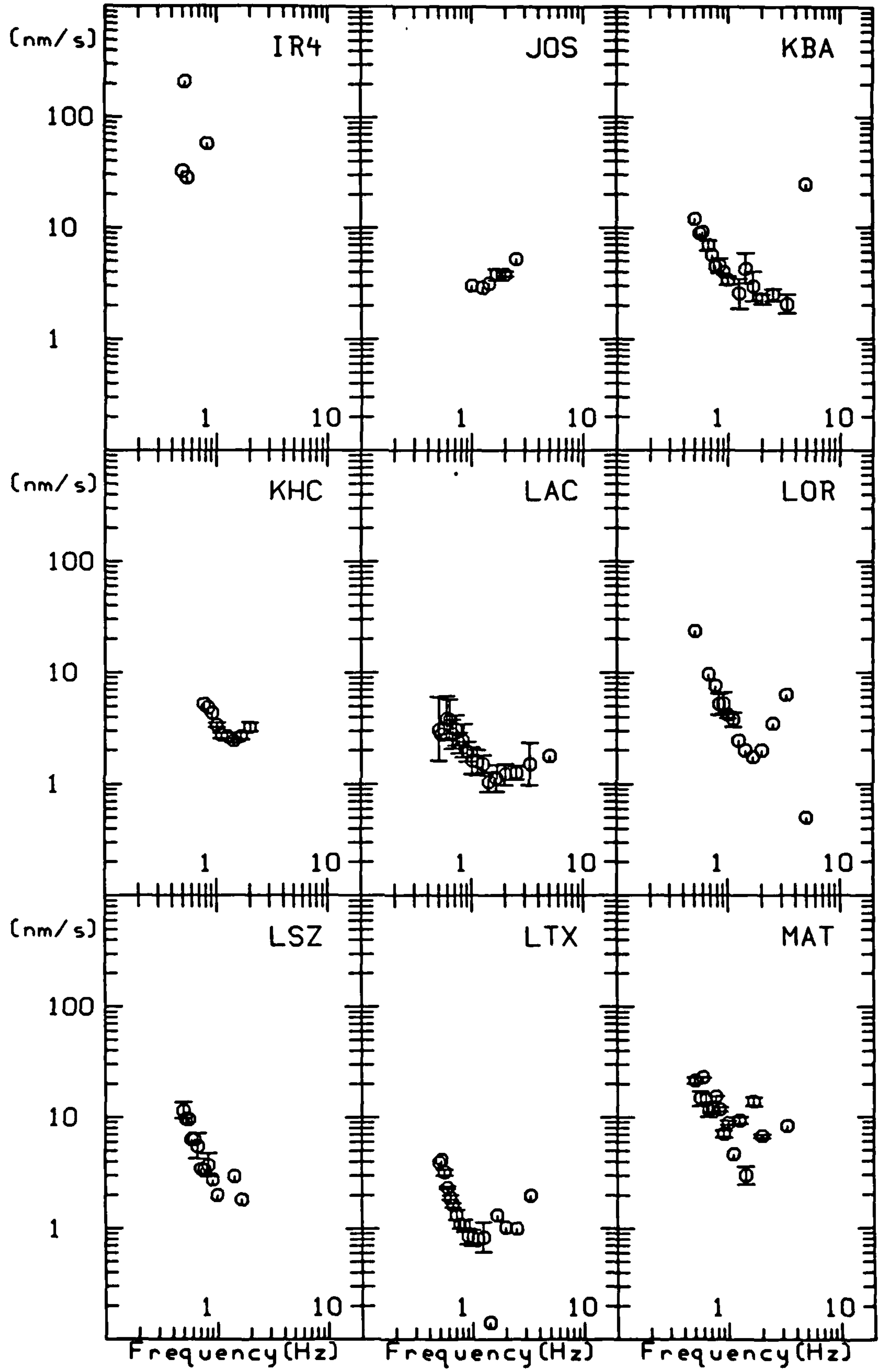


Fig.1 **Short period noise as a function of frequency. Each data point represents an estimated mean value of the amplitude divided by the period, and the 95% confidence limits are indicated with bars in cases with more than 10 observations.**

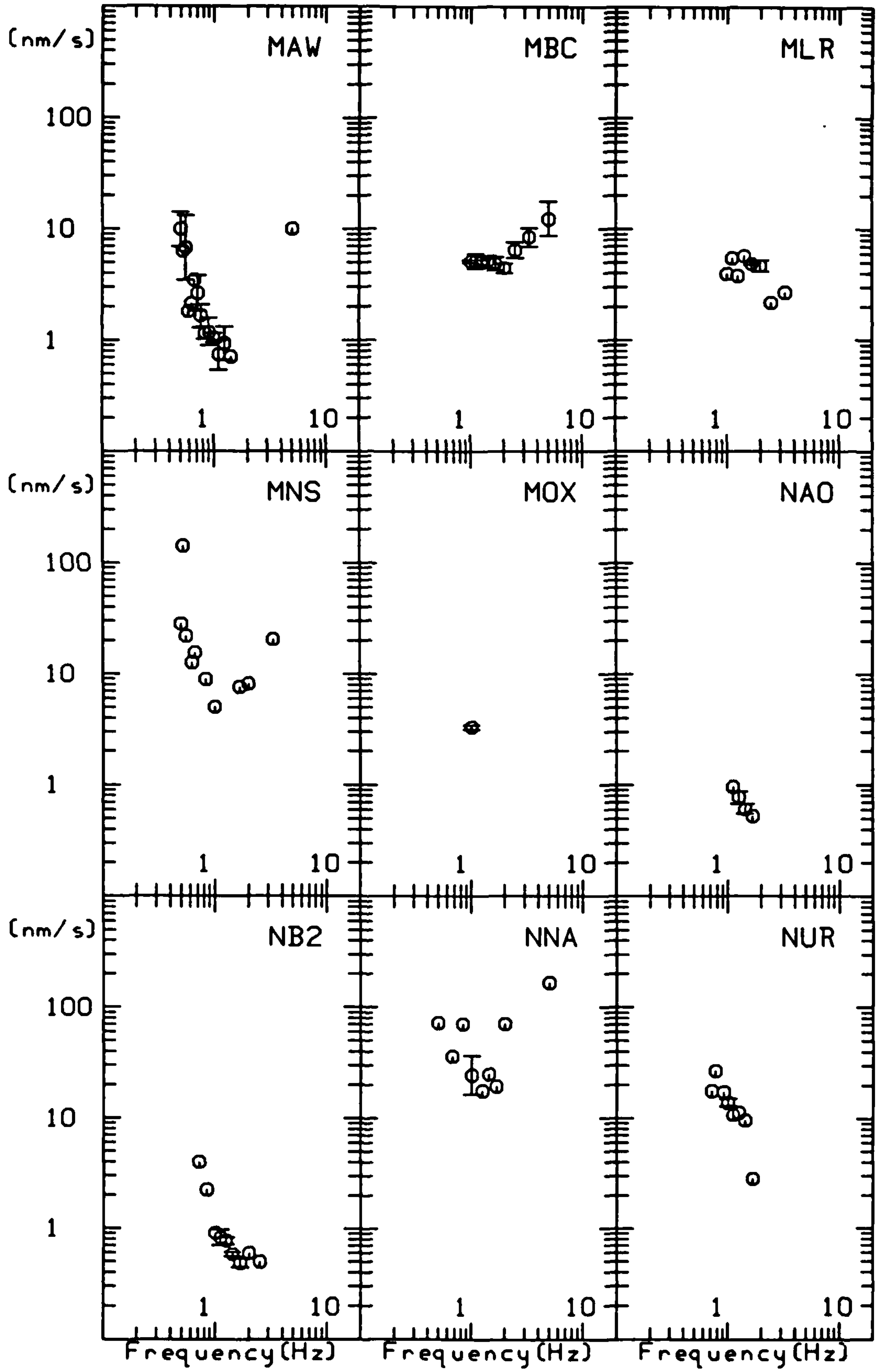


Fig.1 **Short period noise as a function of frequency. Each data point represents an estimated mean value of the amplitude divided by the period, and the 95% confidence limits are indicated with bars in cases with more than 10 observations.**

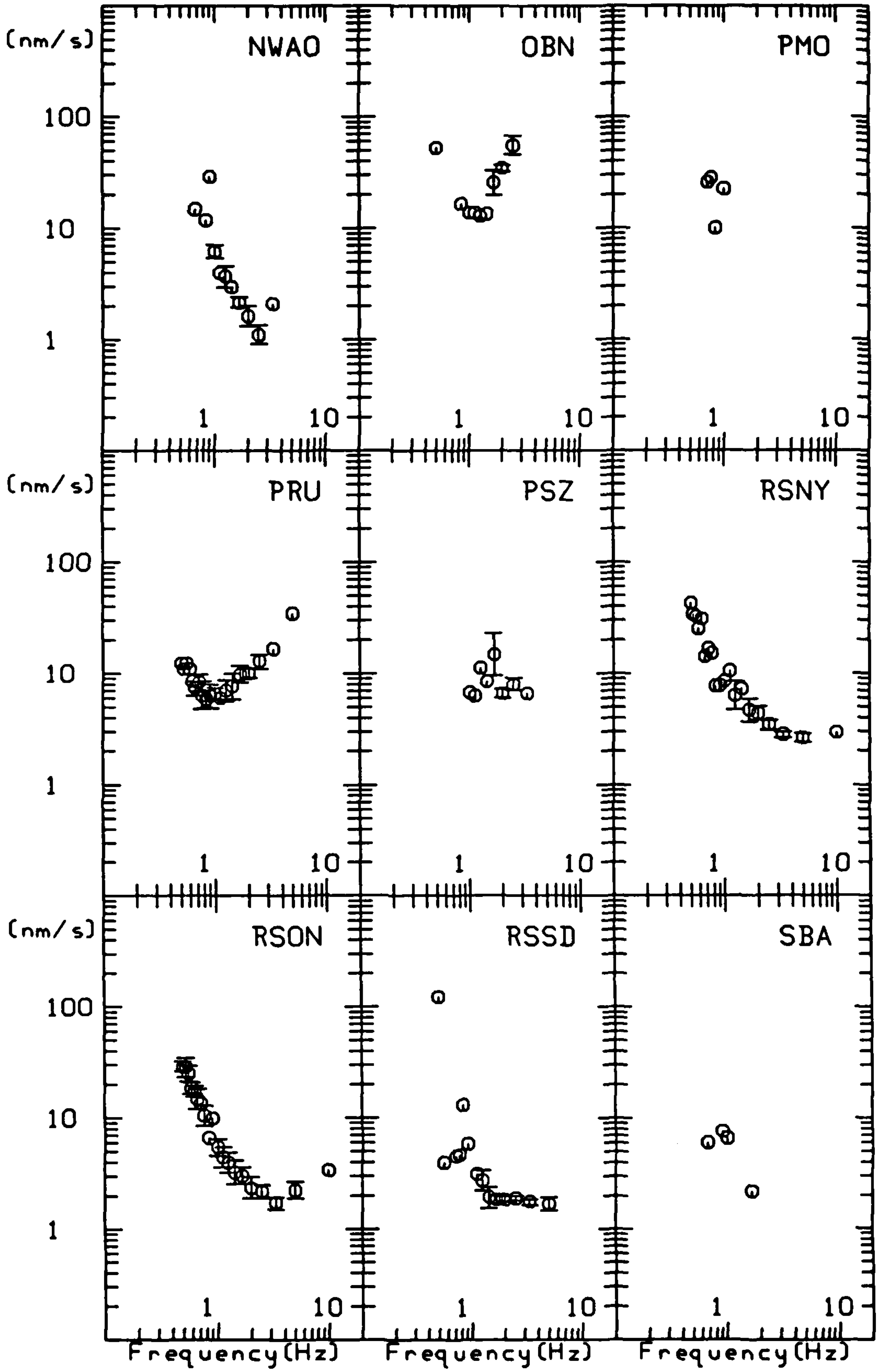


Fig.1 **Short period noise as a function of frequency. Each data point represents an estimated mean value of the amplitude divided by the period, and the 95% confidence limits are indicated with bars in cases with more than 10 observations.**

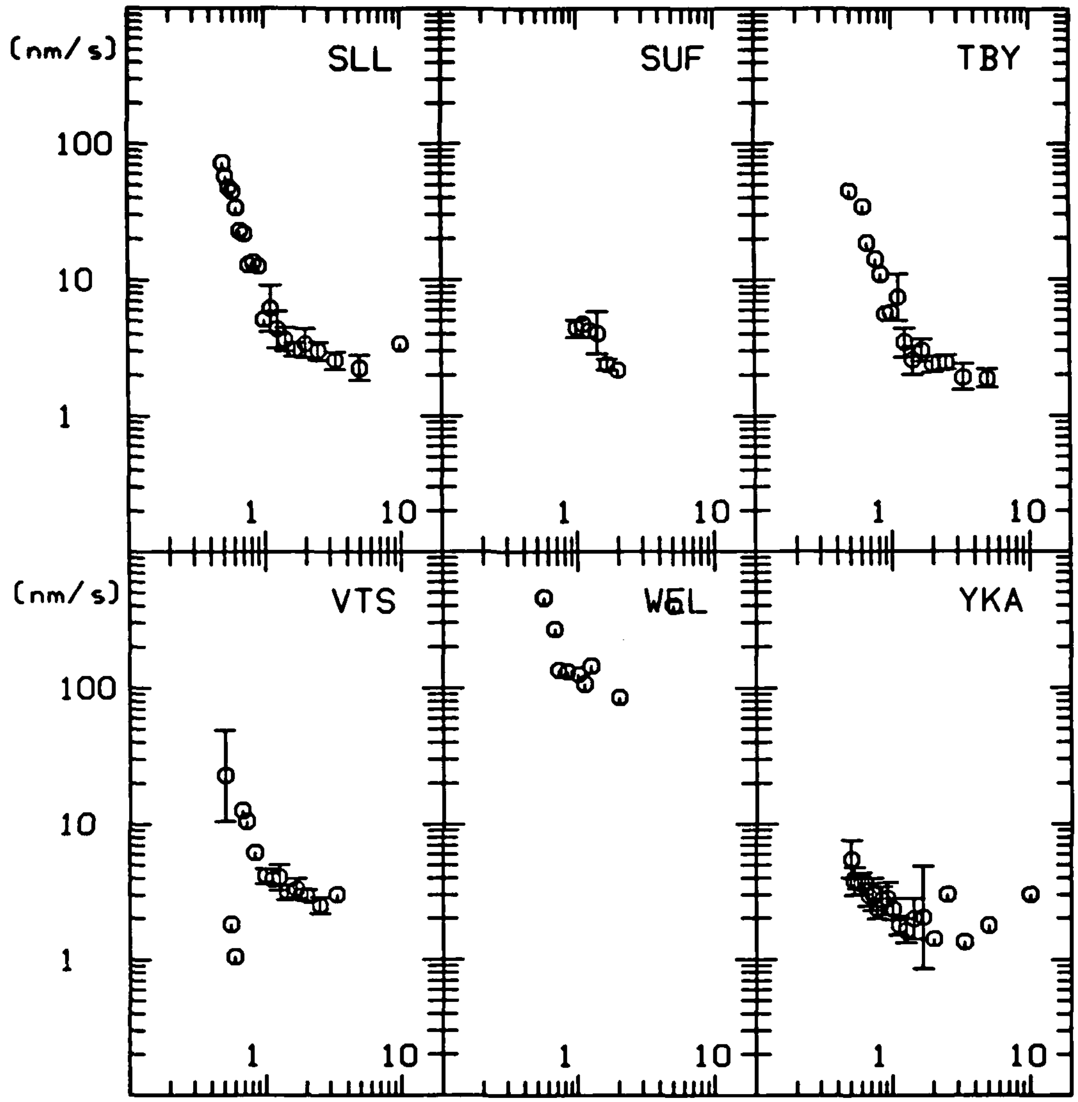


Fig.1 **Short period noise as a function of frequency. Each data point represents an estimated mean value of the amplitude divided by the period, and the 95% confidence limits are indicated with bars in cases with more than 10 observations.**

true amplitude spectra since they are derived from *maximum* trace amplitudes in a certain time window. The high amplitudes at high frequencies for some of the stations are probably due to transient local "cultural" noise bursts.

3. SIGNAL FREQUENCIES AND NOISE IN THE TELESEISMIC FREQUENCY BAND

Because the seismic noise in the short period band varies quite significantly with frequency as illustrated by the "spectra" in *Fig.1,* the amplitude at 1 Hz or any other single frequency may not always adequately reflect the noise level limiting a station's detection capability for teleseismic signals. A more representative number for deducing the detection threshold is the average noise across the entire frequency band for teleseismic P-waves.

The signal amplitude measurements referred to as *M1X* during the GSETT consisted of the maximum trace amplitude within the 0 to 6 s time interval after signal onset. In addition the character of each detected signal should be broadly qualified as to epicentral distance of the originating seismic event : local *(LA,LB)*, regional *(R)* or teleseismic *(TA,TB,TC)*. For the purpose of this study amplitude data were not used for local and regional distances, i.e., signals classified as LA,LB or R. Since it was noted that some stations did not always classify signals as teleseismic, P-waves from events having no label designating distance were assumed to be teleseisms in this study, as well as those labeled as teleseisms.

The number of such *M1X* measurements have been plotted in *Fig.2* as a function of frequency for each station, showing the distribution of the signal frequencies of the non-local and non-regional signals. For a few of the stations (e.g., LOR) the data may be influenced by non-teleseismic observations. Moreover, a selection of *small* amplitudes might have been more appropriate from a theoretical point of view, considering the scaling effects of seismic sources. Comparisons of various ways of selecting the teleseismic signal periods for the data of the US GSETT stations showed small differences in resulting noise estimates as discussed below. Hence a simplified procedure was used here for selecting the data on signal amplitudes.

Some of the characteristics of the signal frequencies are summarized in Table 2 for 49 of the GSETT stations. The table includes the number of measurements of "teleseismic" P-waves, together with mean, low, and high frequencies of the amplitude measurements. The number of observations varies between 6 (SBA,WEL) and 1155 (FBAS), and there are more than 100 observations for 31 of the stations. The mean value of the signal frequency ranges from 0.7 (MOX) to 1.9 Hz (HFS), and 37 of the stations have their mean values above 1.0 Hz. The median frequency for all the stations in Table 2 is 1.2 Hz. Without correction for instrument response (characteristics which may vary among the stations), the peaking frequencies listed in Table 2 are difficult to compare. The variation or spread in the signal frequencies is indicated by the low and high frequency limits listed in Table 2 which were computed in the same way as the periods of the noise measurements described in the preceding section. The frequency range has a median value of 1.0 octave and varies from 0.6 (MOX) to 1.6 octaves (GAC).

The "spectra" of the short period noise amplitudes from *Fig.1* have been included

TABLE 2 SIGNAL FREQUENCIES AND NOISE IN TELESEISMIC BAND					
Station Code	Signal Frequencies				Noise Amplitude (nm)
-	No. of Obs.	Mean (Hz)	Low (Hz)	High (Hz)	
APO	593	1.9	1.2	3.8	3.2
ASPA	860	1.4	1.0	2.3	1.3
BDF	57	1.0	0.7	1.4	10.7
BUD	44	0.8	0.6	1.1	35.5
COP	15	1.1	0.8	1.5	67.6
CTAO	617	1.2	0.9	1.7	3.0
DKM	53	1.3	0.9	2.4	26.3
EKA	139	1.2	0.9	1.7	2.9
ENN	210	1.1	0.8	1.6	6.3
FBAS	129	1.4	1.0	2.3	1.9
GAC	156	1.4	0.9	2.8	7.8
GBA	14	1.4	1.2	1.8	4.4
GRA1	265	1.1	0.8	1.8	8.9
GRB1	123	1.1	0.9	1.5	7.4
GRC1	36	1.2	0.9	1.7	6.5
HFS	663	1.9	1.3	3.6	3.5
IR4	10	1.2	0.9	1.6	57.5
JOS	92	0.9	0.7	1.2	3.0
KBA	153	1.2	0.8	2.0	3.3
KHC	340	1.0	0.8	1.3	3.3
LAC	235	1.1	0.8	1.9	1.7
LOR	252	1.3	0.9	2.4	2.6
LSZ	190	1.1	0.8	1.7	2.6
LTX	514	1.0	0.8	1.5	0.8
MAT	241	1.4	1.0	2.6	7.9
MAW	131	1.2	0.9	1.7	0.9
MBC	558	1.4	1.0	2.0	5.0
MLR	59	1.2	0.8	1.9	4.4
MNS	29	0.9	0.7	1.5	7.9
MOX	97	0.7	0.6	0.9	3.3
NAO	59	1.2	1.0	1.6	0.7
NB2	387	1.3	1.0	1.7	0.7
NNA	44	1.5	1.1	2.3	35.5
NUR	35	1.4	1.1	1.9	7.6
NWAO	170	1.5	1.2	2.2	2.4
OBN	91	0.8	0.7	1.1	15.8
PMO	7	0.8	0.7	1.0	21.4
PRU	130	0.8	0.6	1.0	7.4
PSZ	54	0.9	0.7	1.4	7.6
RSNY	143	1.0	0.7	1.7	4.2
RSON	249	1.1	0.8	1.9	3.4
RSSD	316	1.1	0.9	1.7	2.2
SBA	6	1.1	1.0	1.3	6.6
SLL	631	1.8	1.2	3.5	3.5
SUF	44	1.8	1.4	2.6	2.6
TBY	171	1.6	1.1	2.8	3.0
VTS	116	1.4	1.0	2.4	3.5
WEL	6	1.5	1.0	2.8	131.8
YKA	556	1.2	0.9	1.9	2.0

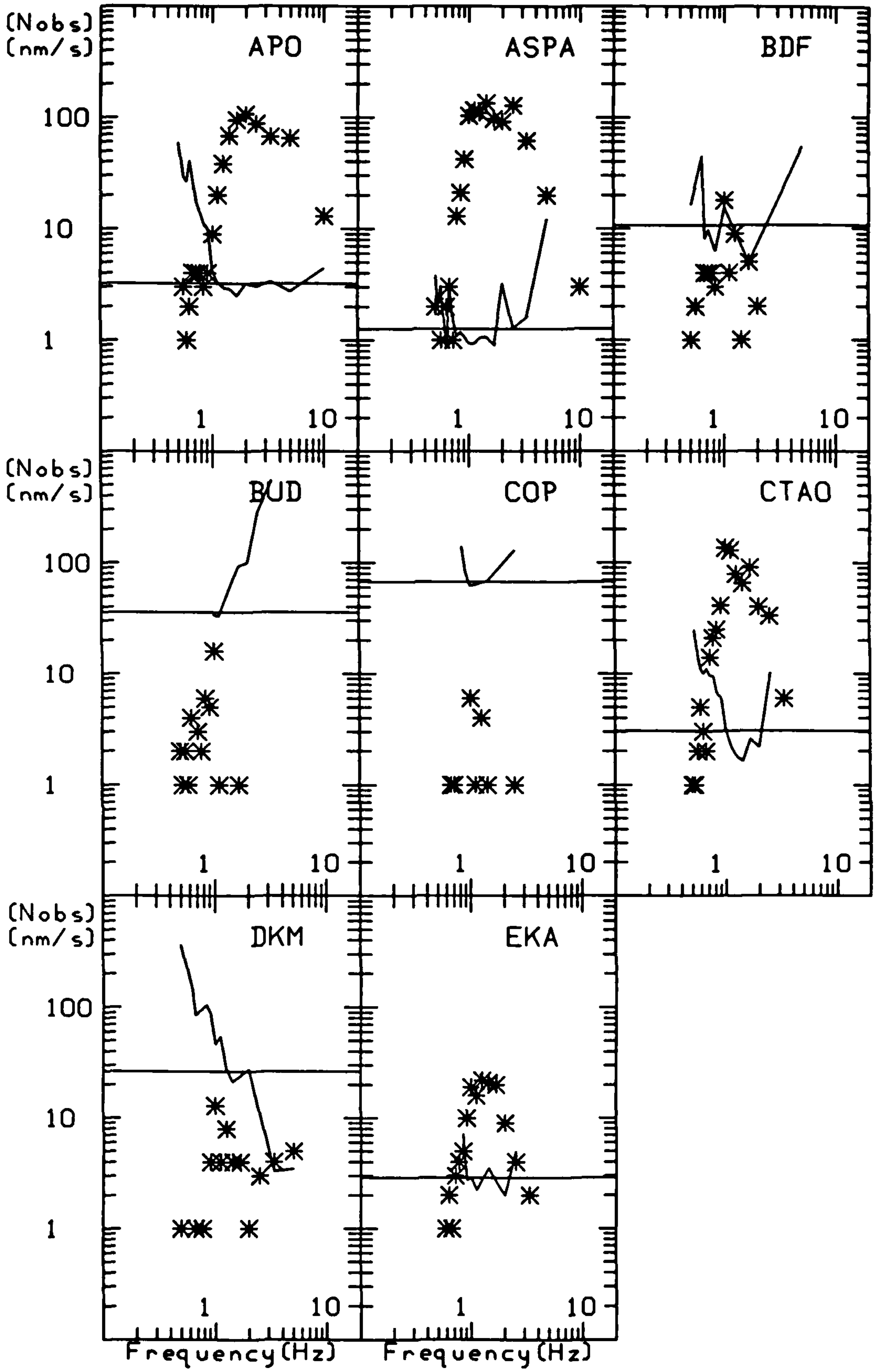


Fig.2 **The stars represent the number of observed teleseismic signals plotted as a function of signal frequency. The non horizontal lines represent the mean noise level as defined in *Fig.1*. The horizontal lines represent the estimated noise in the teleseismic frequency band as defined in Section 3.**

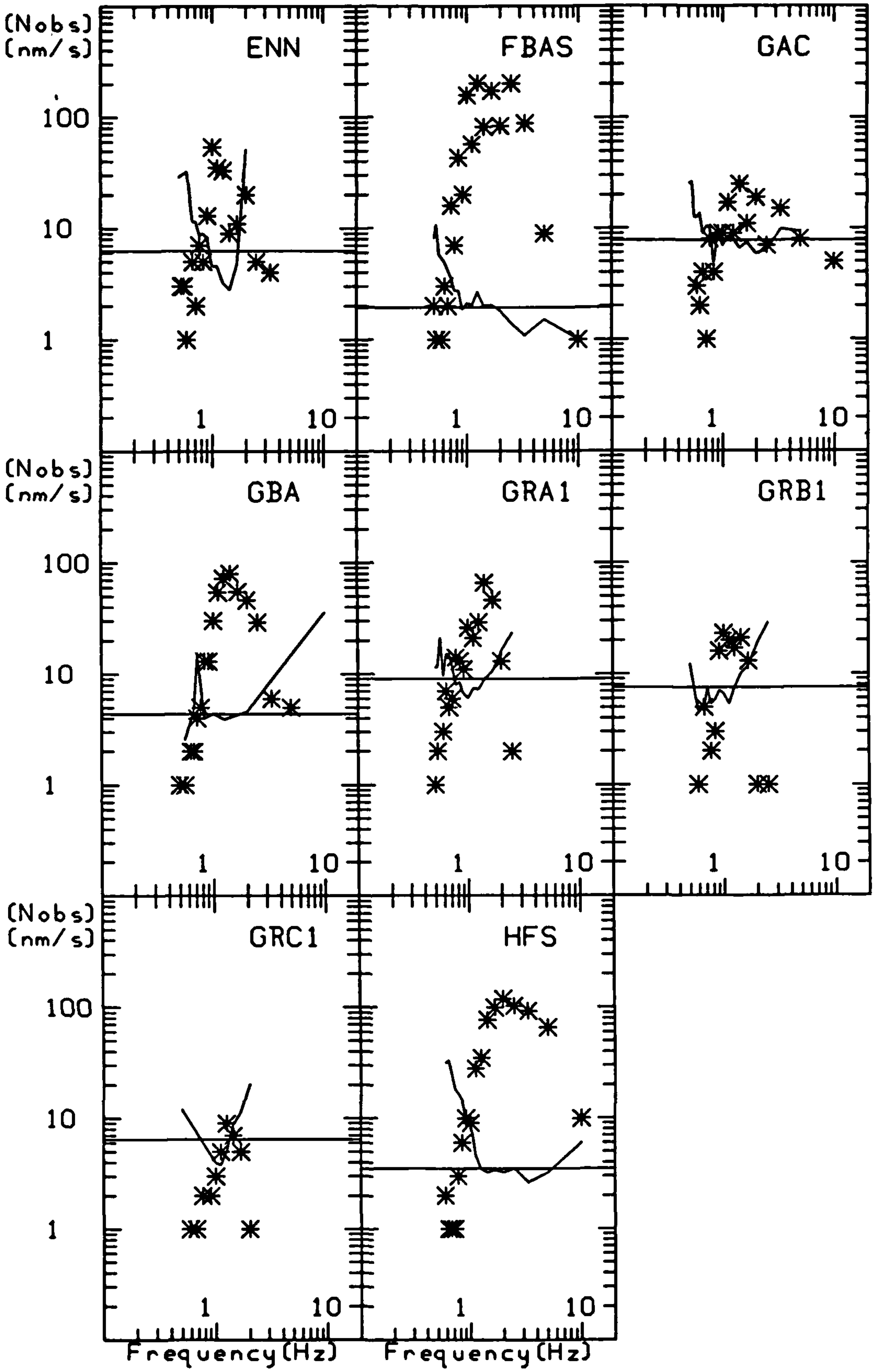
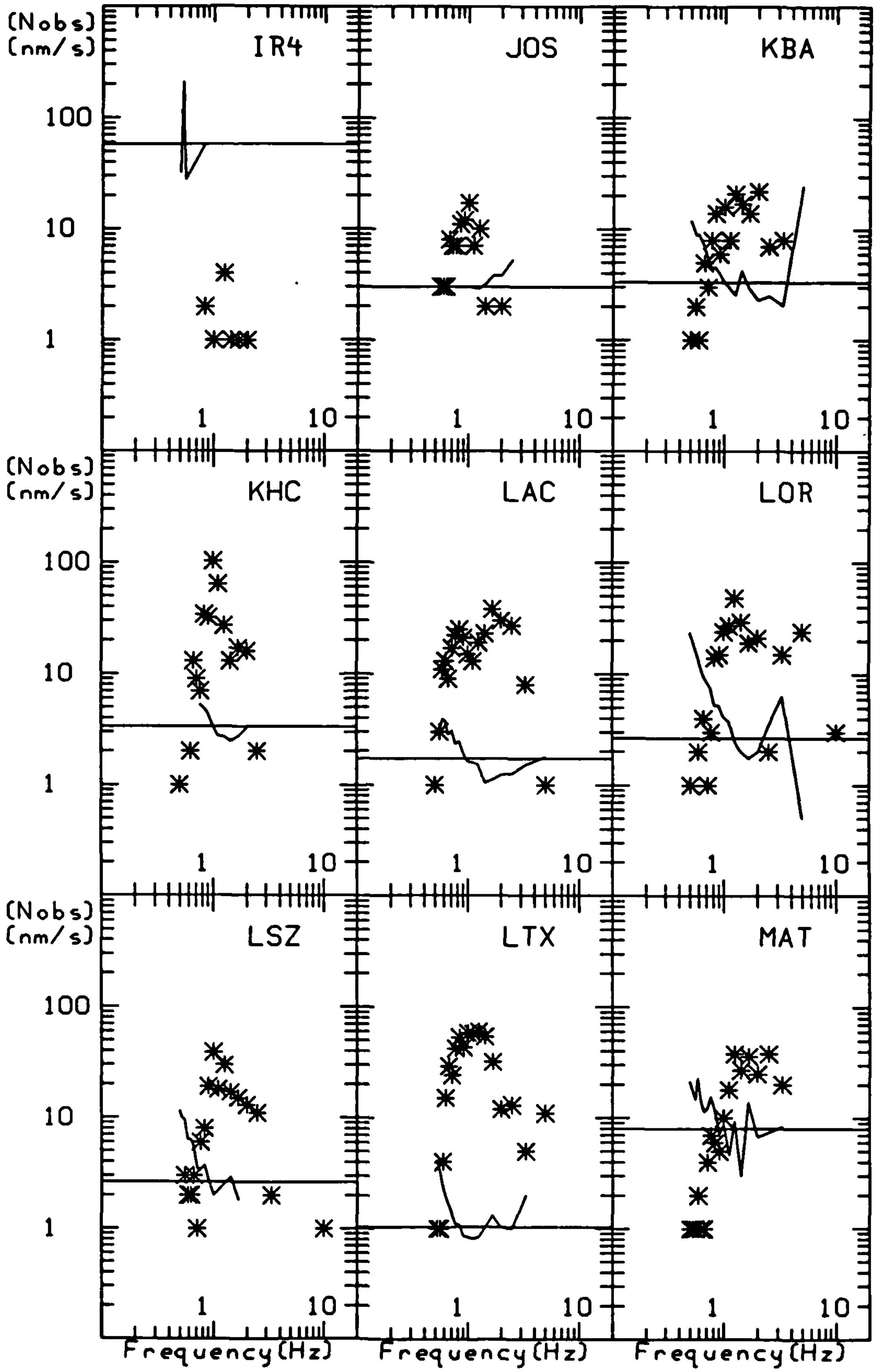


Fig.2 The stars represent the number of observed teleseismic signals plotted as a function of signal frequency. The non horizontal lines represent the mean noise level as defined in *Fig.1*. The horizontal lines represent the estimated noise in the teleseismic frequency band as defined in Section 3.



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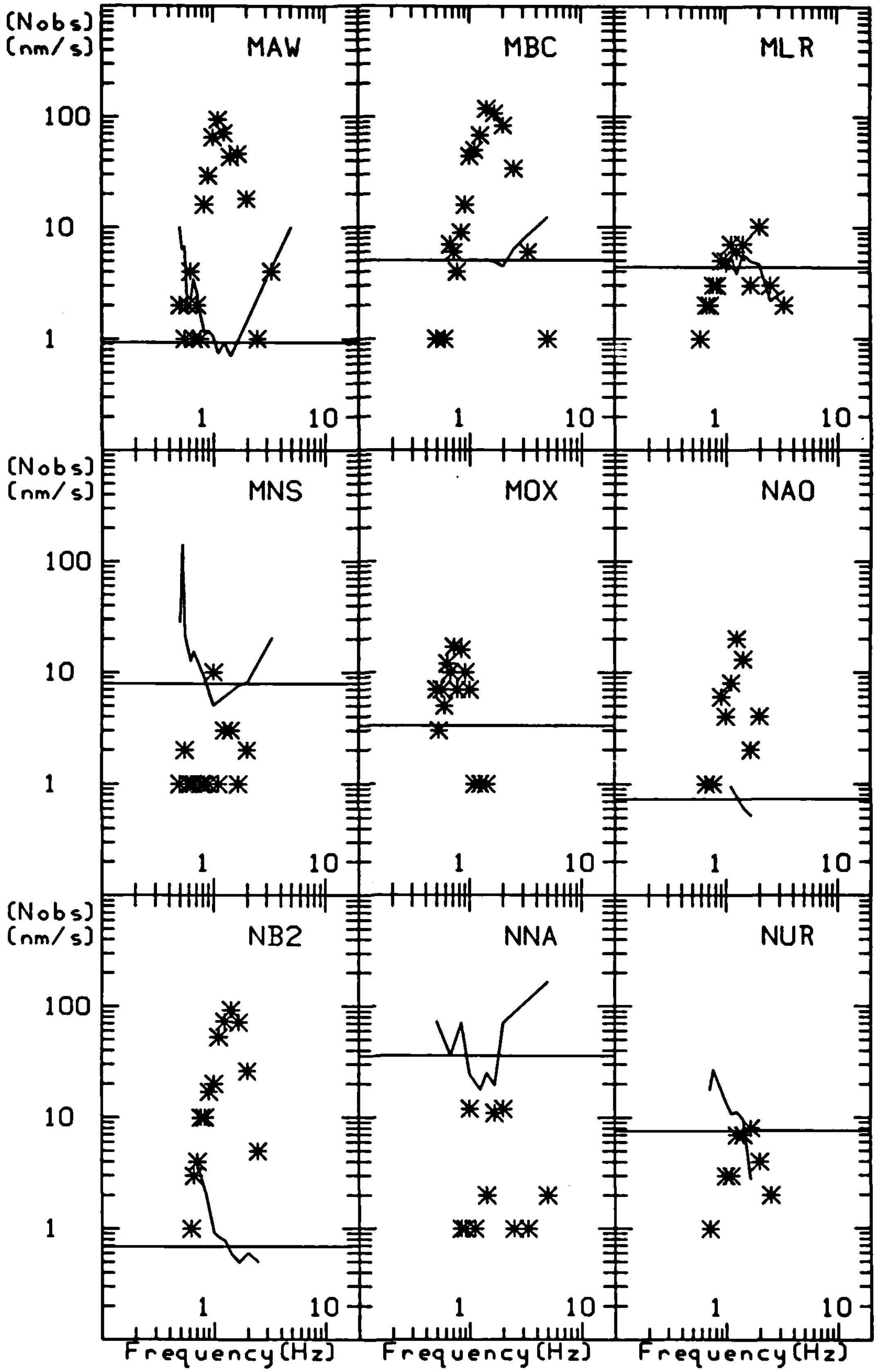

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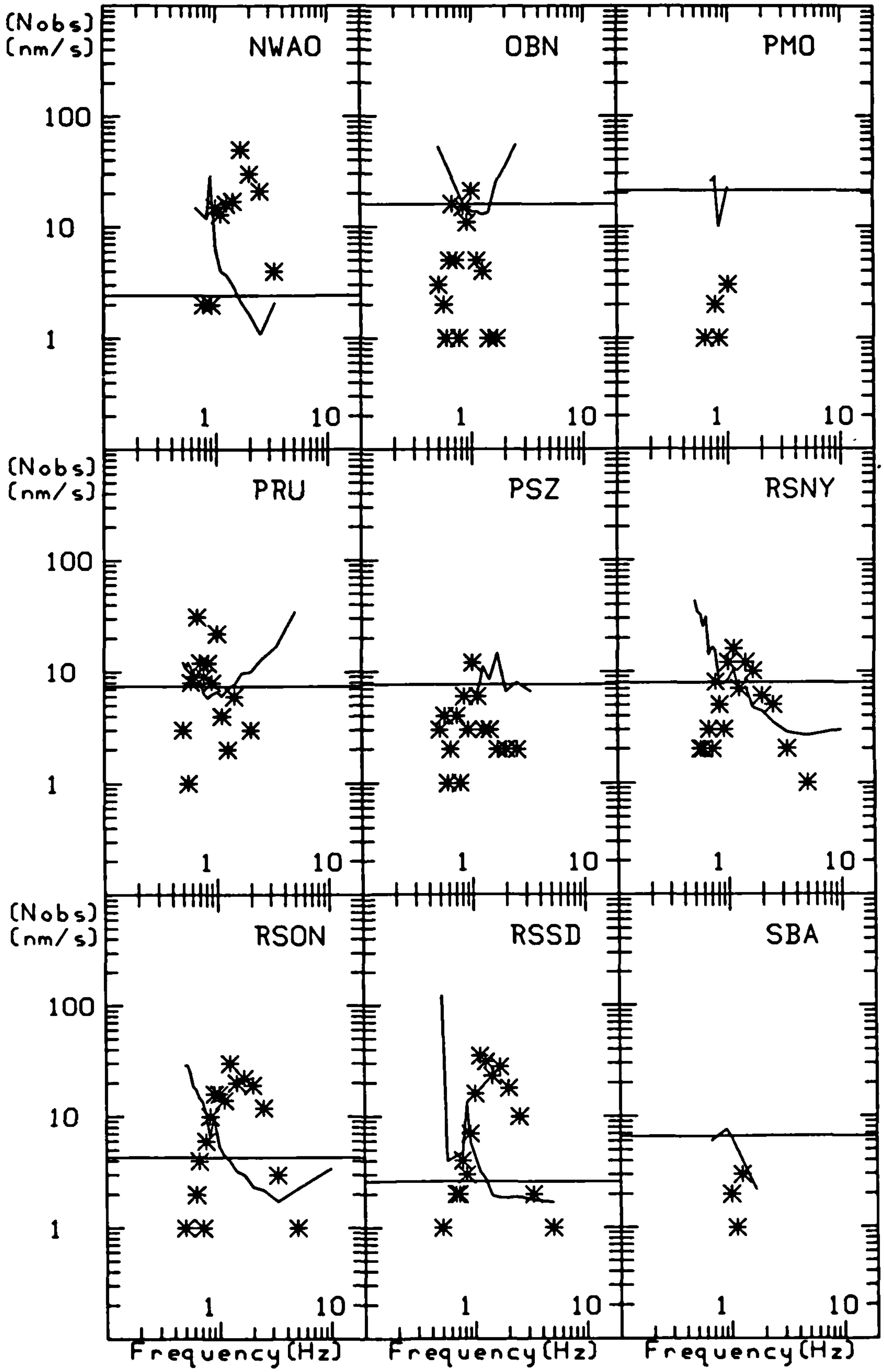


Fig.2 The stars represent the number of observed teleseismic signals plotted as a function of signal frequency. The non horizontal lines represent the mean noise level as defined in *Fig.1*. The horizontal lines represent the estimated noise in the teleseismic frequency band as defined in Section 3.

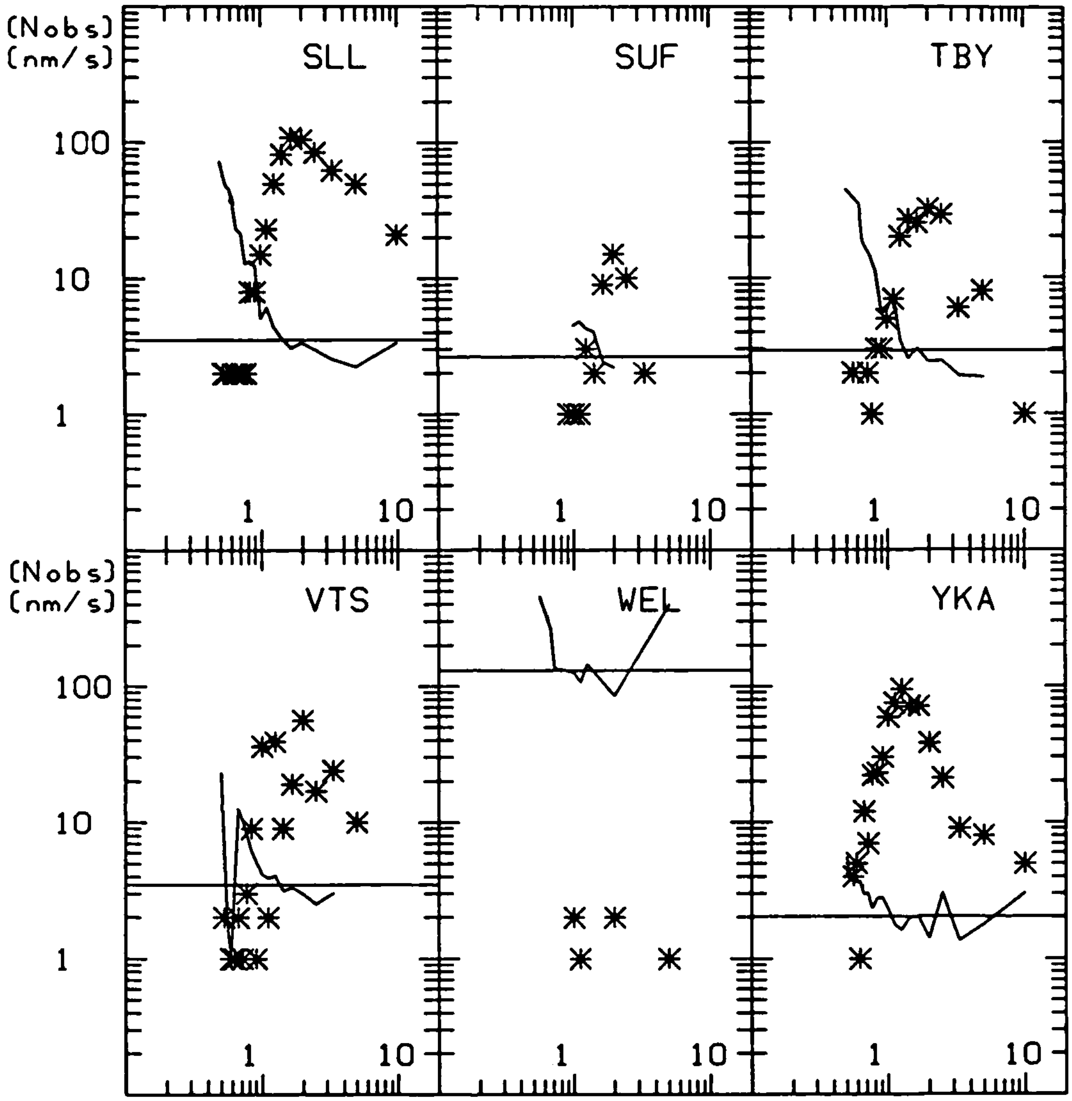


Fig.2 The stars represent the number of observed teleseismic signals plotted as a function of signal frequency. The non horizontal lines represent the mean noise level as defined in *Fig.1.* The horizontal lines represent the estimated noise in the teleseismic frequency band as defined in Section 3.

in *Fig.2* for comparison. The distribution of the signal frequencies has been used to estimate a noise level in the teleseismic band as a weighted average of the noise amplitude values at each frequency. The relative number of observed signals at each frequency was the weighting. The resulting noise levels (nm/s) are listed in Table 2 and are graphically shown in *Fig.2* as horizontal lines across the amplitude-frequency diagrams.

For most of the stations these noise values in the "teleseismic" band are rather close to the values at 1 Hz listed in Table 1. For about 20 per cent of the stations, however, the values are significantly lower.

4. SIGNAL AMPLITUDE DETECTION THRESHOLDS

The amplitude detection threshold for a seismological station can be estimated from the distribution of the logarithm of the amplitude/period ratios of recorded earthquake signals, if the station has recorded a large representative sample of earthquakes. A plot of the cumulative number of recorded earthquake signals against the logarithm of the amplitude/period ratio would then resemble a recurrence curve for the distribution of earthquake magnitudes.

This approach has been attempted for the GSETT amplitude/period data which have been plotted in *Fig.3*. This figure shows the amplitude/period data for each of the stations and the data is limited to the M1X measurements discussed in the preceding section. That is to say, amplitudes associated with identifiable local or regional events have been omitted.

A maximum likelihood procedure [6] was used to estimate detection thresholds and associated standard deviations which are listed in Table 3. Estimates which are based on data that clearly deviate from the exponential shape of the cumulative curve have been placed within parentheses in Table 3 to indicate that they are poor. The estimated threshold values are also graphically illustrated in *Fig.3* as vertical straight lines. The estimated noise values in the teleseismic band discussed in Section 3 have been included in the figure for comparison and are drawn in a way similar to the thresholds, which are usually slightly higher than the noise values. This is discussed further in the following section.

Table 3 also gives amplitude detection thresholds based on two other data sets for the stations considered here. One is taken from a study on estimating station magnitude detection thresholds,[7] which in Table 3 have been transformed into equivalent amplitudes (nm/s) assuming a Q-value of 3.73. The second kind of estimate in Table 3 is from a study where the amplitude thresholds were actually estimated.[8] Both of these studies covering several years of data are based on much larger sets of observations than the GSETT.

Comparisons between the thresholds obtained from the GSETT data and those from the two earlier studies can be made for nine of the stations. The agreement between the GSETT thresholds and those obtained from the study on amplitude detection thresholds (denoted Ringdal A in Table 3) is usually within 0.1 magnitude unit except for the stations MOX and LOR for which the difference is about 0.3 magnitude units. There are somewhat larger differences between the GSETT thresholds and those obtained from the study on magnitude thresholds (denoted

TABLE 3
AMPLITUDE DETECTION THRESHOLDS

Station Code	This study		Ringdal A		Ringdal B	
-	Mean (nm/s)	Std (log)	Mean (nm/s)	Std (log)	Mean (nm/s)	Std (log)
APO	(3.5)	(0.16)				
ASPA	(3.6)	(0.22)				
BDF	(10.0)	(0.12)	9.1	0.38	5.0	0.54
BOG					16.6	0.38
BUD	(40.7)	(0.02)			17.8	0.34
BUL			7.6	0.31	5.0	0.31
CHG			11.5	0.43		
COP	(234.4)	(0.22)			25.1	0.29
CTAO	6.6	0.22				
DAG			6.9	0.35	6.2	0.40
DBN					44.7	0.28
DKM	(87.1)	(0.24)				
EKA	(21.9)	(0.24)	11.0	0.39	12.0	0.41
ENN	8.5	0.22				
FBAS	3.3	0.18				
GAC	20.4	0.30				
GBA	10.5	0.24	12.6	0.51	9.3	0.49
GDH			20.4	0.42	22.9	0.37
GRA1	9.8	0.14				
HFS	3.5	0.14	4.7	0.41	2.5	0.82
HLW					31.6	0.30
IR4	(41.7)	(0.02)				
JAY			35.5	0.42		
JOS	14.8	0.24			10.7	0.33
KBA	6.6	0.20				
KHC	5.8	0.14	7.1	0.33	5.0	0.36
LAC	(11.0)	(0.34)				
LOR	5.0	0.24	9.3	0.41	8.3	0.32
LPB			9.8	0.41	3.7	0.42
LSZ	8.9	0.28				
LTX	3.2	0.18				
MAT	17.4	0.12	14.4	0.42	8.3	0.38
MAW	(14.1)	(0.32)	13.8	0.41	17.4	0.64
MBC	4.8	0.08	4.6	0.44	1.9	0.80
MLR	(21.9)	0.22				
MOX	16.6	8	8.1	0.28	5.5	0.37
MNS	(66.1)	(0.32)				
NAI					27.5	0.41
NAO	(2.6)	(0.20)	3.0	0.41		
NB2	(2.8)	(0.18)				
NNA	(32.4)	(0.26)			44.7	0.41
NUR	(14.5)	(0.12)	7.4	0.49	3.5	0.51
NWAO	13.2	0.26				
OBN	(51.3)	(0.26)	8.7	0.37	7.1	0.32
PMO	(83.2)	(0.34)			45.7	0.42
PRU	18.2	0.26			6.5	0.30
PSI			14.4	0.40		

TABLE 3
AMPLITUDE DETECTION THRESHOLDS

Station Code	This study Mean (nm/s)	This study Std (log)	Ringdal A Mean (nm/s)	Ringdal A Std (log)	Ringdal B Mean (nm/s)	Ringdal B Std (log)
PSZ	(20.4)	(0.08)			14.8	0.38
QUE			8.3	0.49	6.3	0.40
RAR					93.3	0.37
RMP					30.2	0.32
RSNY	12.0	0.16				
RSON	10.0	0.22				
RSSD	4.7	0.18				
SBA	(12.0)	(0.14)			11.5	0.58
SLL	3.6	0.14				
SMY					83.2	0.44
SPA			11.2	0.48	1.2	0.68
SUF	4.4	0.12				
TBY	(4.0)	(0.14)				
UCC					35.5	0.23
VTS	10.5	0.22				
WEL	(43.7)	(0.02)			61.7	0.35
YKA	3.0	0.26				

Ringdal A[1]

Ringdal B 2

1. F. Ringdal, *Study of magnitudes, seismicity and earthquake detectability using a global network*, NTNF/Norsar, Kjeller, Norway (1984).

2. F. Ringdal, E.S. Husebye, J. Fyen, "Earthquake detectability for 478 globally distributed seismograph stations," *Physics of the Earth and Planetary Interiors* 15 pp. P24-P32 (1977).

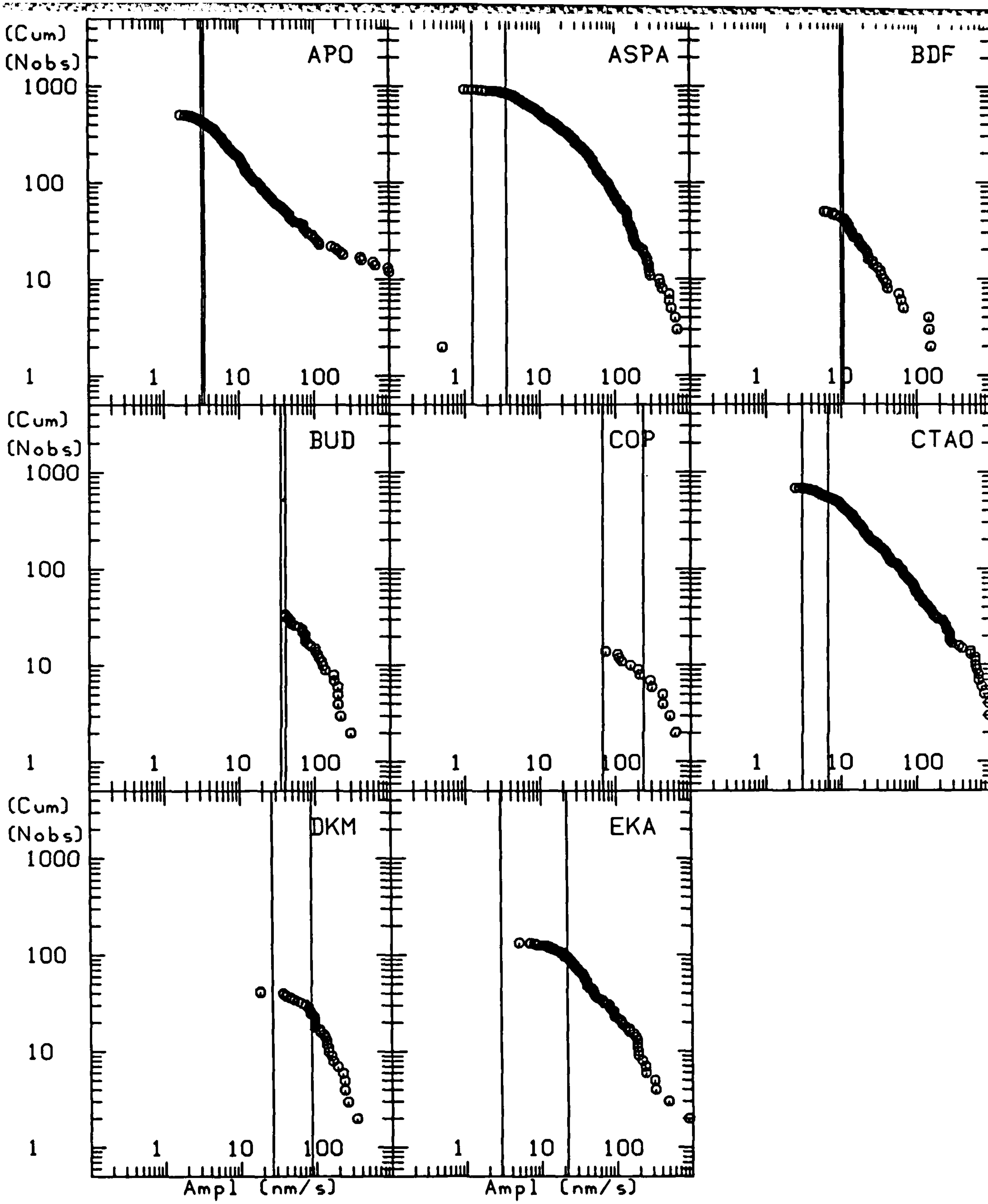
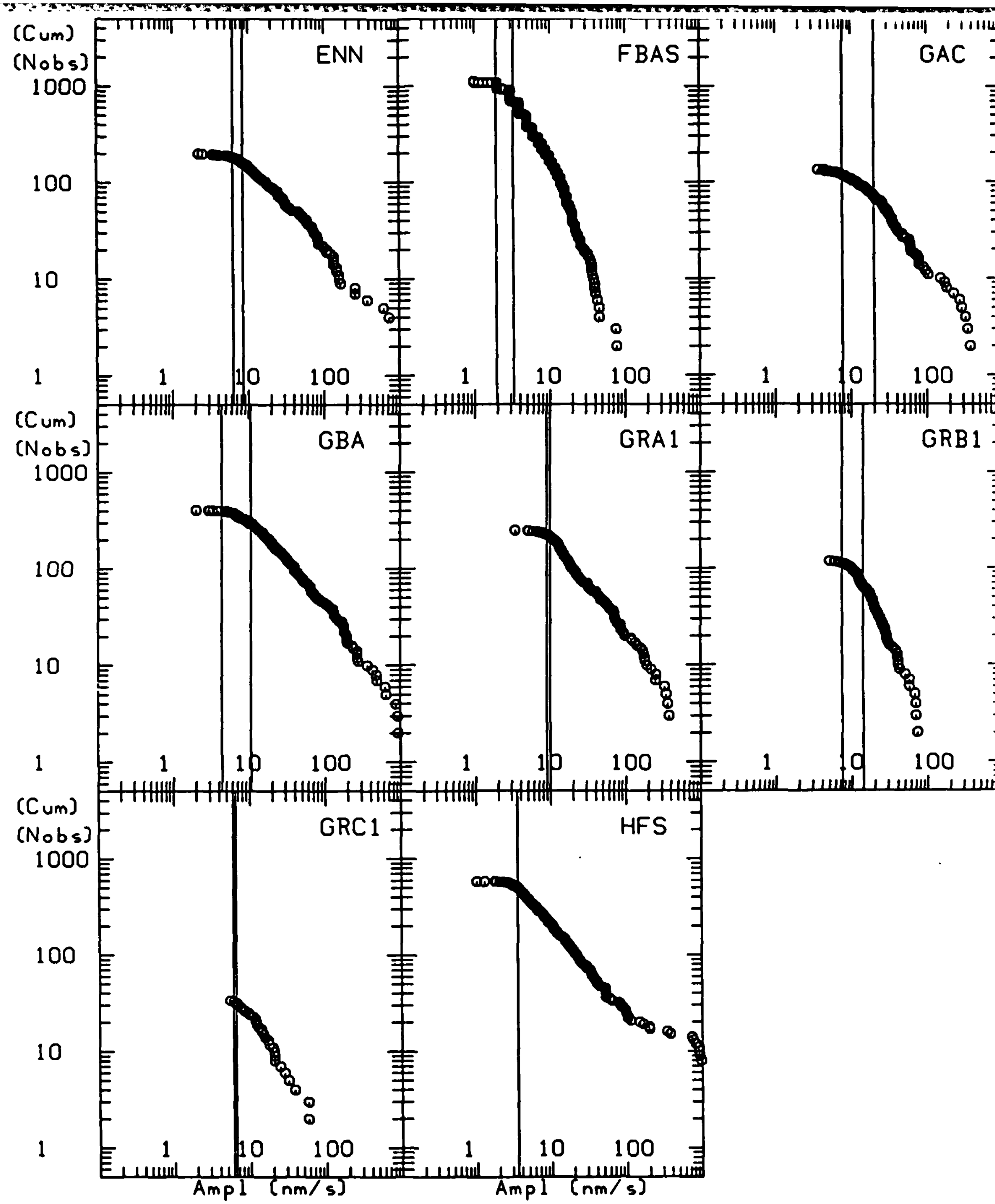


Fig.3 **Cumulative number of signal detections as a function of amplitude/period ratio. Estimated amplitude detection thresholds and noise levels as defined in Sections 4 and 3, respectively, are drawn as vertical lines for comparison.**



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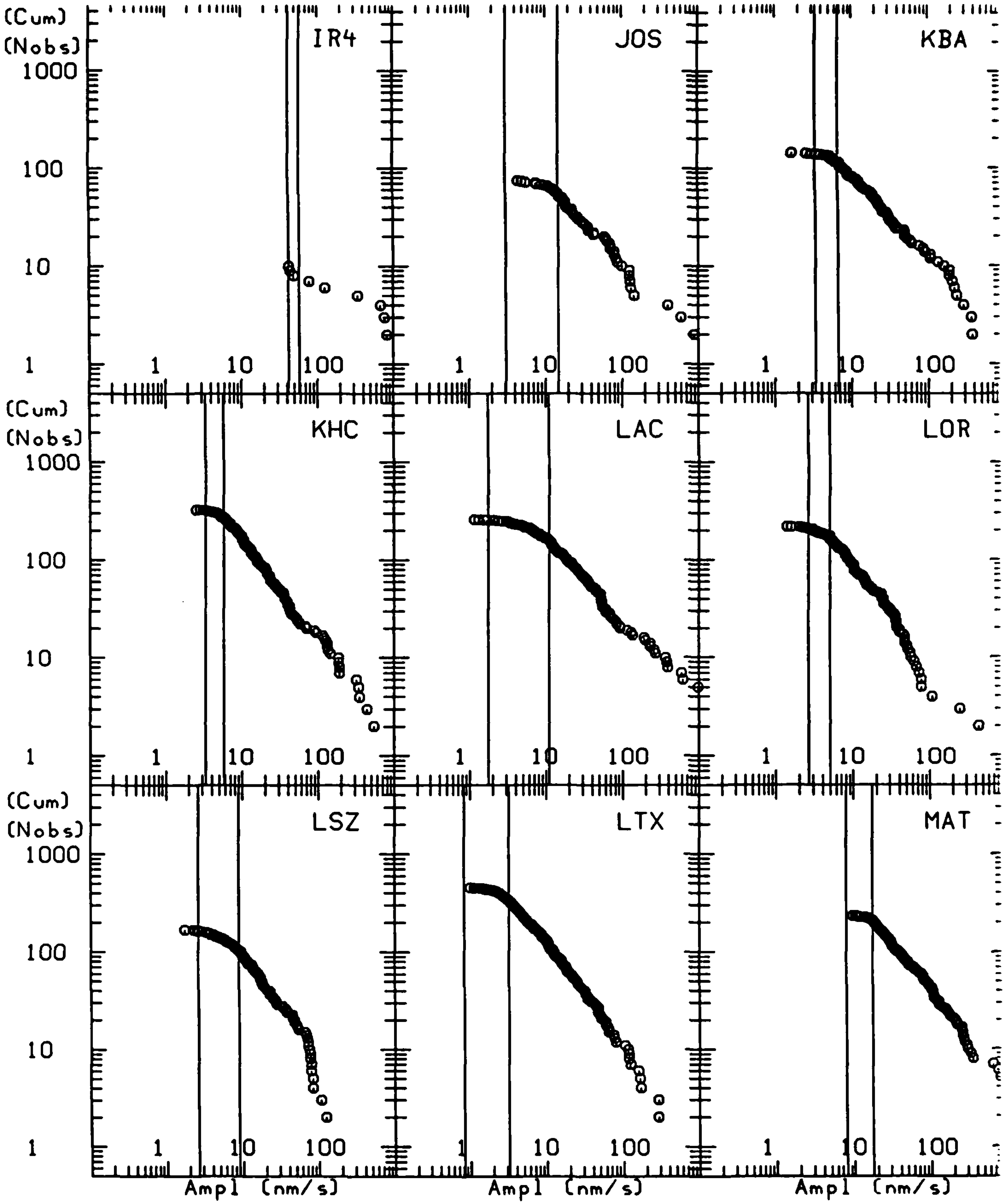

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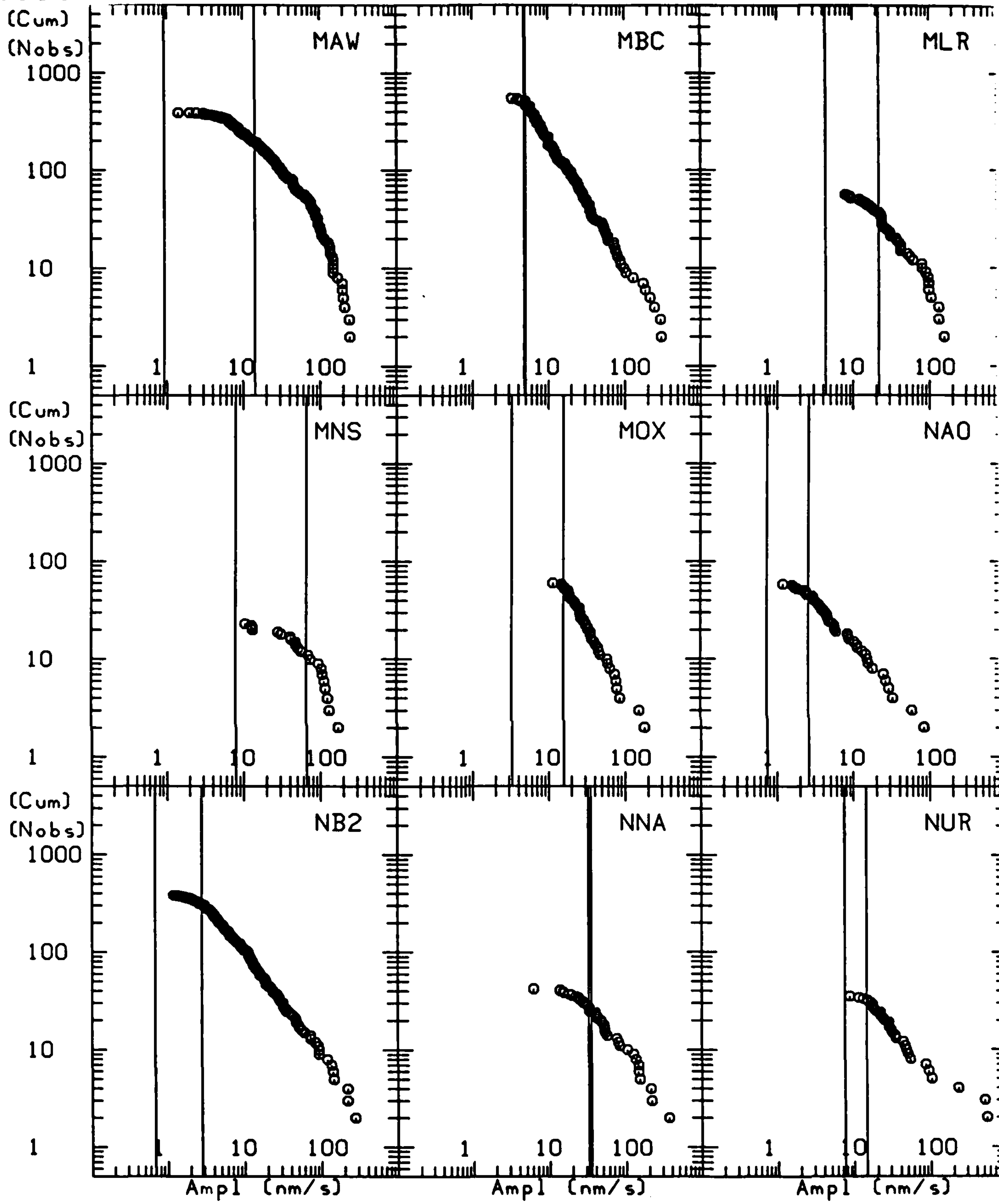

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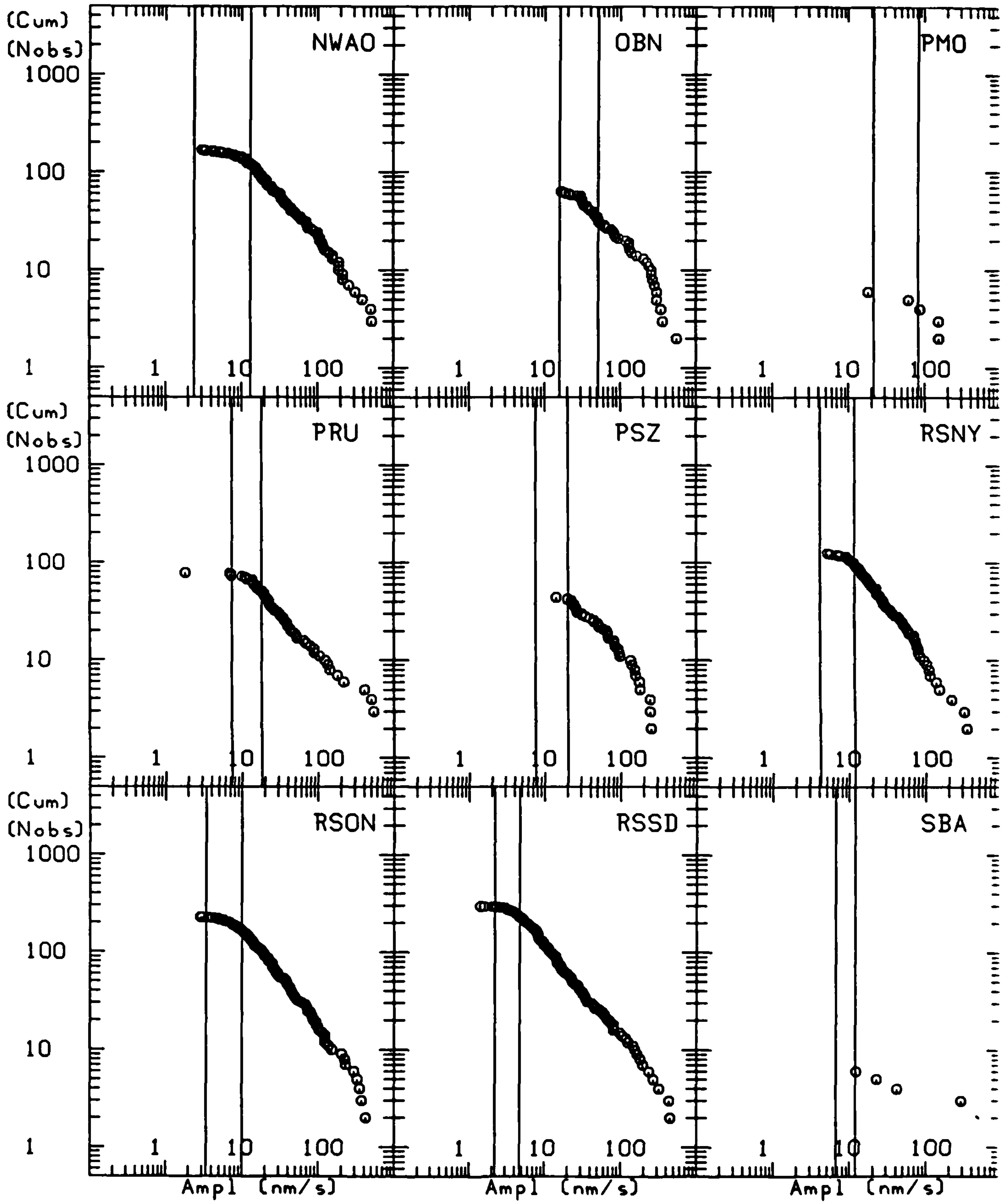

*Fig.*3 Cumulative number of signal detections as a function of amplitude/period ratio. Estimated amplitude detection thresholds and noise levels as defined in Sections 4 and 3, respectively, are drawn as vertical lines for comparison.

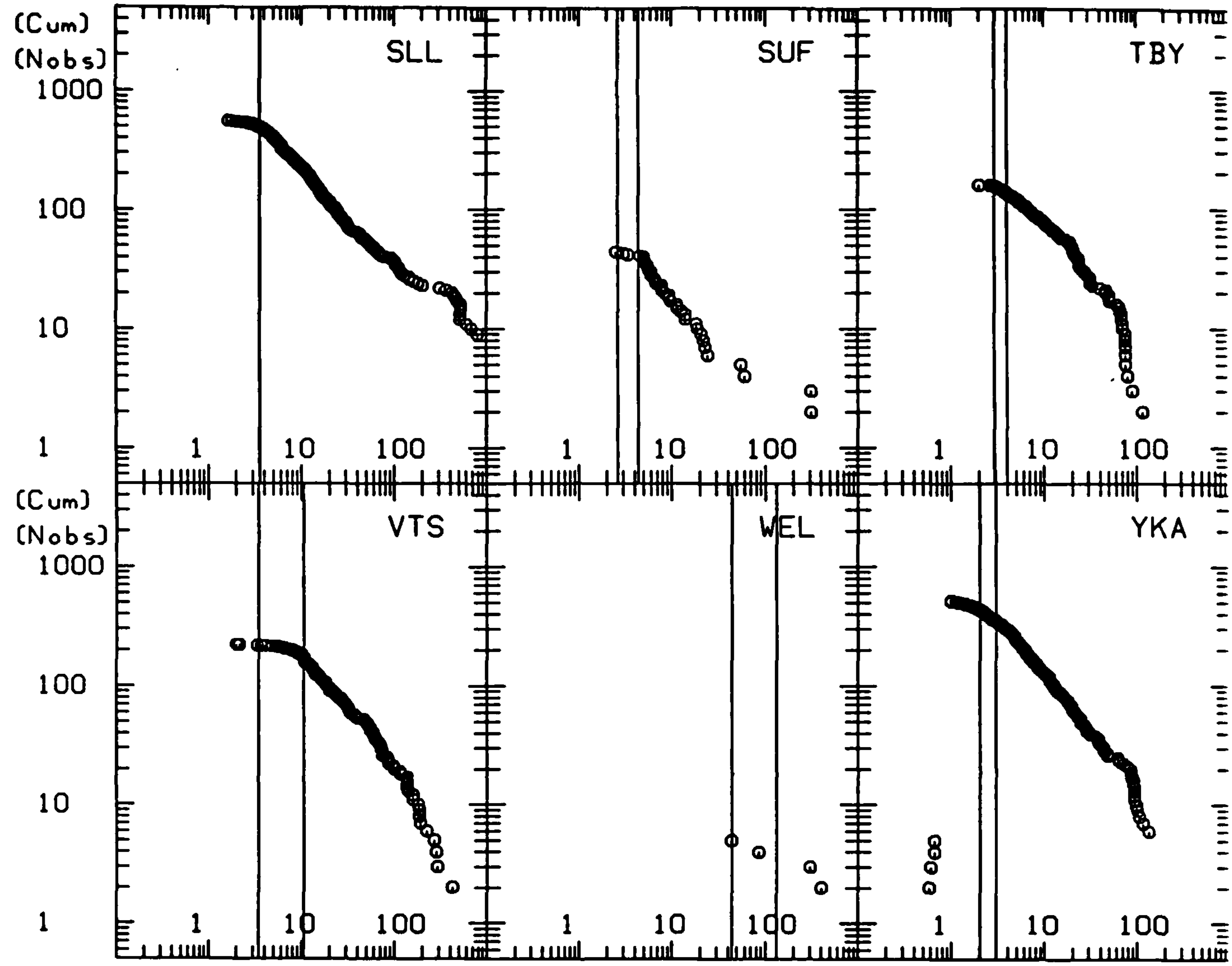

Fig.3 **Cumulative number of signal detections as a function of amplitude/period ratio. Estimated amplitude detection thresholds and noise levels as defined in Sections 4 and 3, respectively, are drawn as vertical lines for comparison.**

Ringdal B) in Table 3.

5. MINIMUM SIGNAL TO NOISE RATIO

The minimum signal-to-noise ratio for signal detection is often assumed to be 1.5. This minimum value can be compared with the ratio of the amplitude detection threshold and noise in the teleseismic frequency band discussed in the two preceding sections. Values of this ratio are listed in Table 4 for 14 of the stations. The stations listed have a significant number of observations on which the noise value is based, a reasonable agreement (0.05 or less) between standard deviations estimated for noise and threshold, and a reasonable appearance of the cumulative distribution curve for the measured amplitude/period ratios.

All ratio values are between 1.1 and 4.0, and the median value is 2.2. Two of the stations (ENN, GRA1) have values less than 1.5. Considering the inherent difficulty of the definition of such a parameter as the minimum signal-to-noise ratio for detection, the ratios in Table 4 can only be interpreted in broad terms. These ratios suggest, however, that there may be clear differences among stations in the signal-to-noise criterion used to declare a signal. The ratios also indicate that the often used value of 1.5 may be too low as a standard value for the "average" station even if there may be stations that operate at minimum signal-to-noise ratios around this value.

6. LONG PERIOD NOISE

Long period noise and Rayleigh wave parameters were usually measured only when associated with a detected short period P-wave. The *noise* parameters, *(N2LZ)*, consisted of the largest trace amplitude with a period between 10 to 30 s measured on the vertical component within 5 minutes of the section of the recordings preceding the initial P wave. The actual period associated with this amplitude was also measured. The *Rayleigh wave* parameters, *(MLRZ)*, consisted of the amplitude of the maximum deflection measured on the vertical component and its corresponding period. The number of long period measurements is for most of the stations much smaller than the number of short period measurements, usually in rough terms about ten times smaller. Long period measurements were reported to the Center from only 35 stations.

Noise amplitudes are plotted in *Fig.4* as function of frequency for each station. Most of the amplitudes have periods between 10 and 30 s. For many of the stations the "spectra" in *Fig.4* have a pronounced minimum around the 20 s period which is often found for true amplitude spectra.[9]

Amplitude values at a period of 20 s and periods close to 20 s for the 21 GSETT stations with a comparatively large number of observations are listed in Table 5. Only eight stations have noise amplitudes below 100 nm, five of which (ASPA, EKA, FBAL, LOR, NWAO) have values around 50 nm. It is difficult to define noise levels for some of the stations since the reported noise had periods far away from 20 s.

TABLE 4 SIGNAL-TO-NOISE RATIOS					
Station	Noise		Threshold		Ratio
Code	Ampl.	Std.	Ampl.	Std.	-
-	(nm/s)	(log)	(nm/s)	(log)	-
CTAO	3.0	0.18	6.6	0.22	2.20
ENN	6.3	0.23	8.5	0.22	1.35
FBAS	1.9	0.19	3.3	0.18	1.50
GAC	7.8	0.26	20.4	0.30	2.61
GRA1	8.9	0.15	9.8	0.14	1.10
KBA	3.3	0.17	6.6	0.20	2.00
KHC	3.3	0.11	5.8	0.14	1.76
LTX	0.8	0.19	3.2	0.18	3.20
MAT	7.9	0.09	17.4	0.12	2.20
NB2	0.7	0.15	2.8	0.18	4.00
RSNY	4.2	0.17	12.0	0.16	2.60
RSON	3.4	0.23	10.0	0.22	2.60
RSSD	2.2	0.17	4.7	0.18	2.20
VTS	3.5	0.17	10.5	0.22	3.00

TABLE 5 LONG PERIOD NOISE AMPLITUDES							
Station	20 s period			Period with max obs.			
Code	Ampl(nm)	Std	Nobs	Period(s)	Ampl(nm)	Std	Nobs
APO	155	0.26	8	17	115	0.35	16
ASPA				16	25	0.38	18
EKA				18	54	0.31	17
FBAL	57	0.18	10	16	54	0.24	55
GAC	70	0.32	62				
GRA1				15	124	0.37	16
GRB1				12	109	0.15	18
HFS				15	108	0.23	56
LAC				6	499	0.21	9
LOR	42	0.15	25	19	38	0.17	266
LTX	109	0.11	7	16	179	0.14	20
MOX	166	0.22	205				
NAO	186	0.43	11				
NB2	174	0.39	63				
NWAO	55	0.28	27	16	65	0.30	49
OBN	632		2				
RMP	276		1	40	459		4
RSNY	83	0.26	7	17	120	0.39	18
RSON	81	0.56	9	18	80	0.32	33
RSSD	123	0.49	11	18	84	0.36	33
SLL				15	104	0.33	65

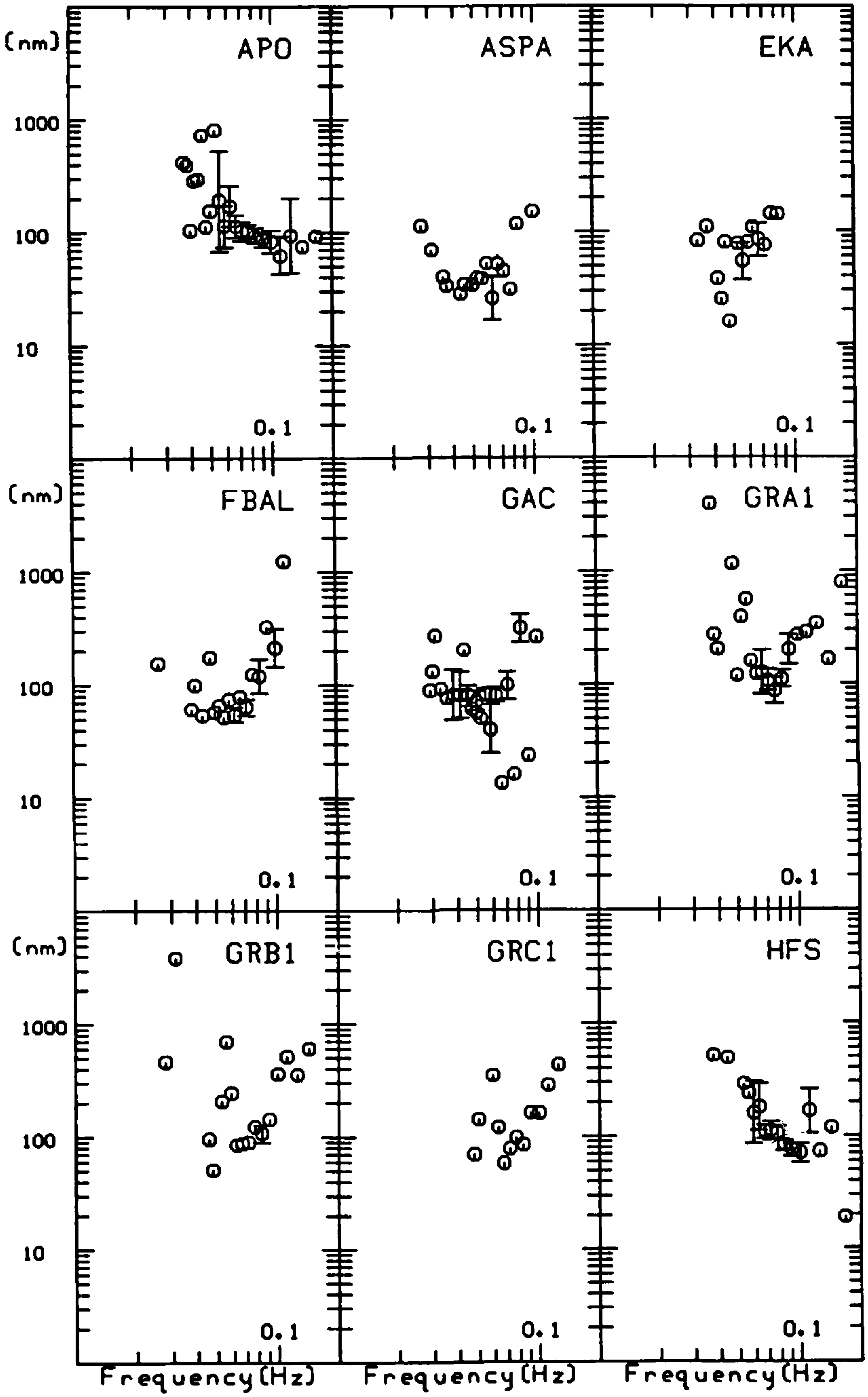

Fig.4 **Estimated mean values of long period noise levels as a function of frequency. The 95% confidence limits are indicated by horizontal bars in cases with more than 10 observations.**

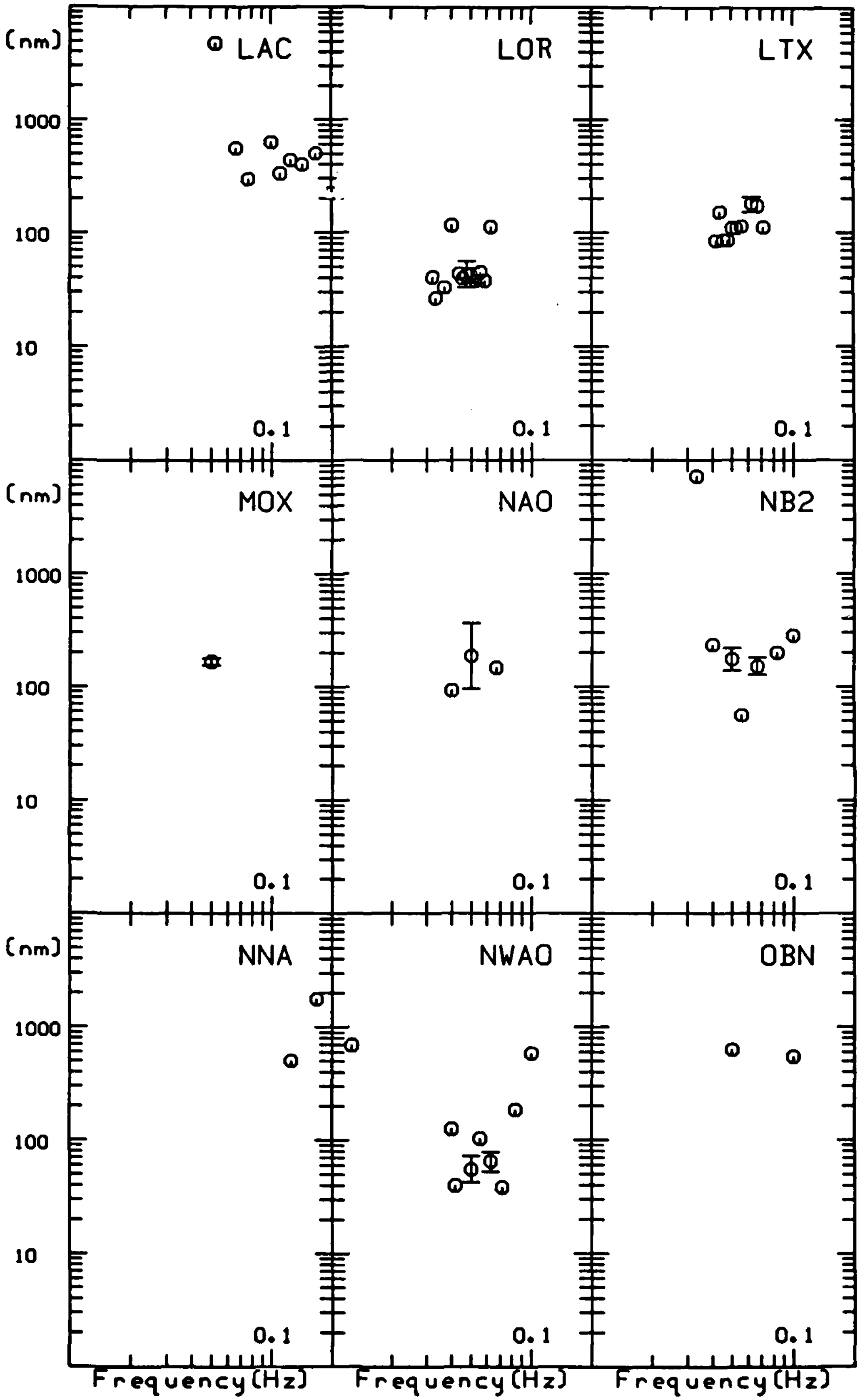

Fig.4 **Estimated mean values of long period noise levels as a function of frequency. The 95% confidence limits are indicated by horizontal bars in cases with more than 10 observations.**

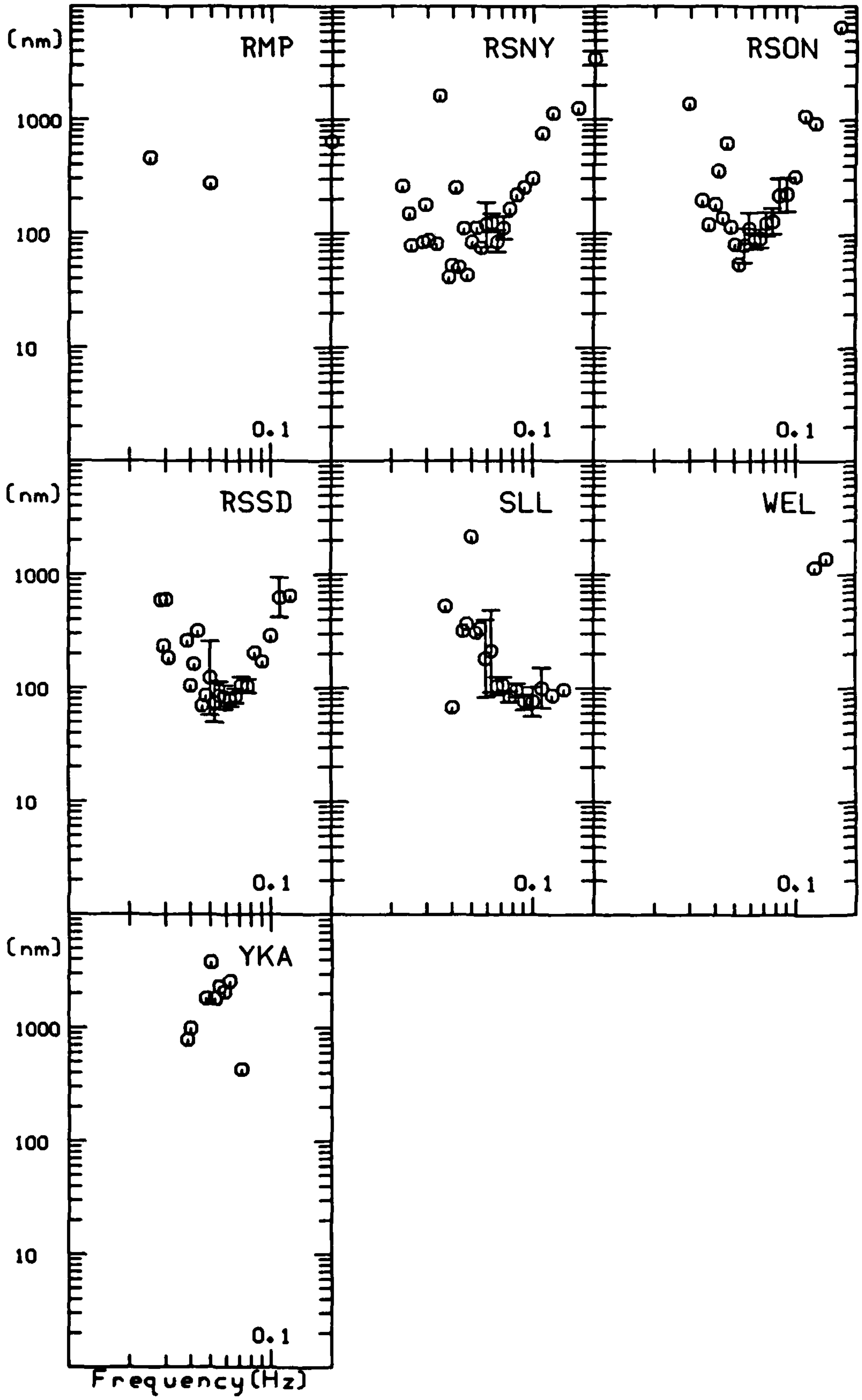

Fig.4 **Estimated mean values of long period noise levels as a function of frequency. The 95% confidence limits are indicated by horizontal bars in cases with more than 10 observations.**

The reported Rayleigh wave amplitudes can theoretically be used to estimate amplitude detection thresholds as with the short period data. The cumulative amplitude curves do not, however, represent the same type of distribution as short period data described above since long period measurements were usually made only in relation to short period detections. Nevertheless, the number of reported Rayleigh wave measurements is a crude measure of the detection capability. In *Fig.5* this number has been plotted against the noise amplitudes for stations with available data and shows a clear correlation between these two parameters. A linear relation between noise and number of detected Rayleigh wave signals has been fitted by eye to the data in *Fig.5* and used to estimated noise at the stations. The values obtained in this approximate and simplified way are listed in Table 6, which also gives minimum reported values of signal amplitudes at periods around 20 s for comparison. The noise values estimated from the number of Rayleigh wave detections are reasonably consistent with the estimates based on noise data and the minimum signal amplitudes.

7. REVISED NOISE VALUES

The list of noise values for the GSETT stations compiled in the procedures for the test were in many instances only of a preliminary nature. The short and long period noise levels were taken from CCD/558, or from the seismological literature if a more recent estimate had been published. If noise levels were not available from either of these sources, the short period noise was set at 10 nm and the long period noise was estimated from that of the nearest station at which a long period noise estimate was available.

Table 7 lists revised values for the GSETT stations based on the results and analyses presented above. Sub stations of arrays are not included in Table 7, which contains data for 72 stations. For comparison, values listed in the procedures for GSETT have also been included when available.[2]

The short period values consist of estimates based on amplitude thresholds and noise values discussed earlier, or of estimates calculated from published detection thresholds. For the remaining stations for which no information was available an arbitrary noise value of 50 nm was assumed.

Short period noise was estimated for 48 of the stations using the GSETT data. The GSETT based noise values are of two kinds. The estimated thresholds discussed in Section 4 were used to the maximum extent possible and these values were divided by 1.5 which is equal to the often assumed minimum signal-to-noise ratio. If adequate amplitude thresholds could not be obtained, the noise values in the teleseismic band discussed in Section 3 were used as revised values. The revised short period noise values in Table 7 differ for most of the stations from the values listed in the procedures of the GSETT. In fact only eight of the stations have similar values in the two cases. For 16, or one third of the stations, the revised estimates are significantly higher and for 18 stations they are significantly lower than the preliminary values. Most of the stations which have lower revised values had preliminary values of 10 nm, which is the value assigned to stations for which no noise information was available when the preliminary list was compiled.

Long period noise values are given in Table 7 for 26 stations and these are all

TABLE 6 LONG PERIOD NOISE AND SIGNAL THRESHOLDS							
Station	Noise			Signal detections		Min. ampl.	
Code	Ampl.	Per	Ampl(20)	#	Equiv.noise	Ampl.	Per
-	(nm)	(s)	(nm)	-	(nm)	(nm)	(s)
APO	115	17	153	91	148	251	18
ASPA	25	16	31	131	107	127	21
COP				48	262	179	20
CTAO				143	99	274	19
DBN				43	289	399	24
DOU				39	314	950	18
EKA	54	18	60	266	57	31	21
FBAL	57	20	57	219	68	49	20
GAC	70	20	20	310	49	33	18
GBA				89	151	8	21
GRA1	124	15	165	85	157	162	20
HFS	108	15	144	152	93	167	18
KHC				37	330	620	19
LAC				35	346	107	20
LOR	38	19	40	338	46	39	20
LTX	179	16	223	45	277	292	20
MAT				47	267	895	20
MBC				107	128	280	20
MOX	166	20	166	54	235	496	22
NB2	174	20	174	145	97	83	20
NUR				115	120	170	19
NWAO				93	145	220	20
OBN				65	200	500	20
PRU				69	189	455	20
RMP				102	133	110	20
RSNY	120	17	141	98	138	105	20
RSON	80	18	89	156	92	63	20
RSSD	84	18	93	173	83	78	19

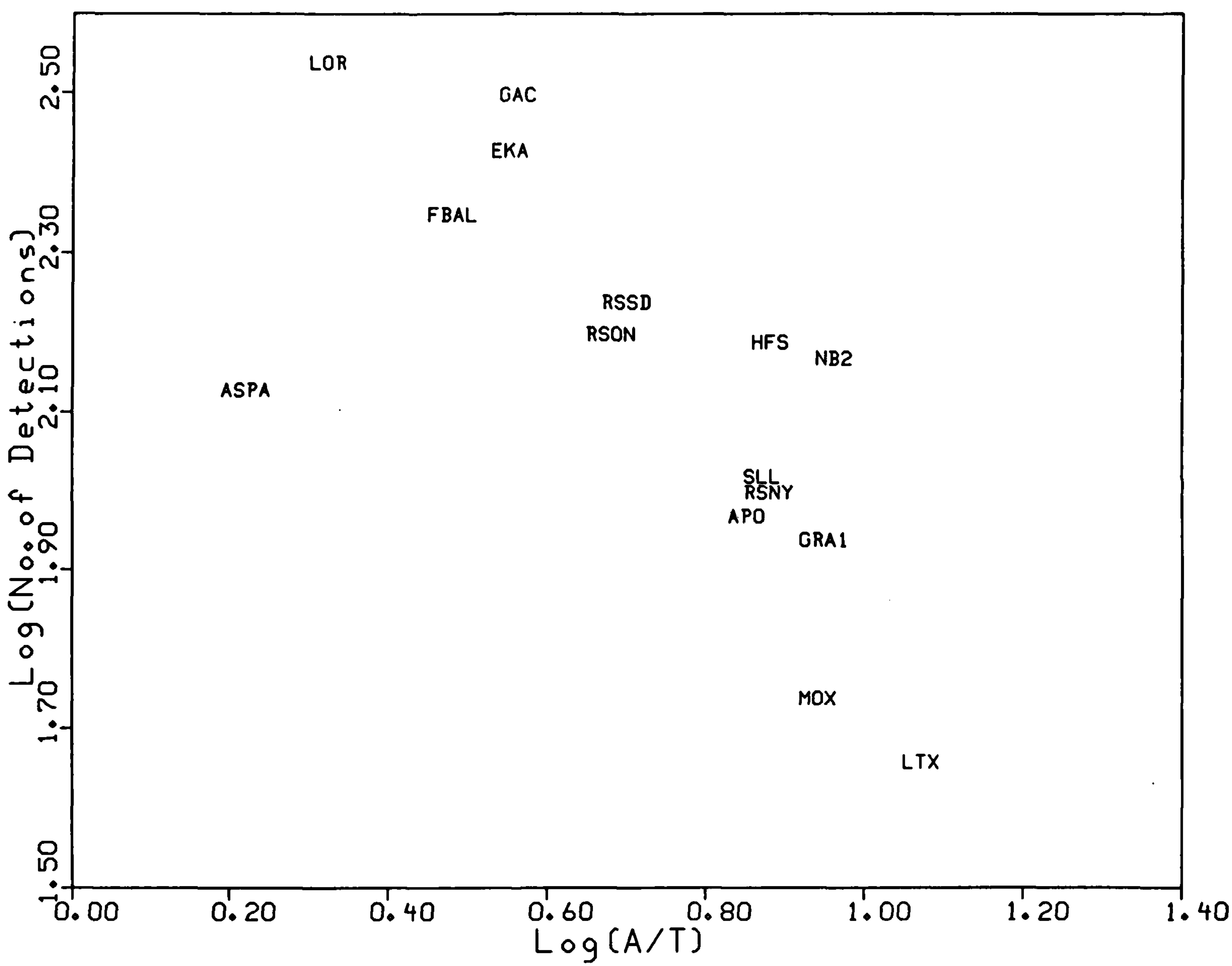

Fig.5 **Number of detected Rayleigh waves plotted against long period noise amplitudes around the 20 s period.**

TABLE 7
NOISE AMPLITUDES AND DETECTION THRESHOLDS

Station	Noise					Magnitude	
-	Short Period			Long Period		-	-
-	Ampl(nm)		Source	Ampl(nm)		-	-
-	Revised	CRP/134	-	Revised	CRP/134	mb	Ms
AAI	50.0	(10.0)	Assumed value				
APO	3.2	(2.0)	GSETT-noise	153	(50)	4.4	4.6
ASPA	1.3	(3.0)	GSETT-noise	107	(40)	4.0	4.4
BAA	50.0		Assumed value				
BDF	10.7		GSETT-noise			4.9	
BMA	50.0		Assumed value				
BOG	11.1		Ringdal B			5.0	
BUD	35.5	(17.0)	GSETT-noise			5.5	
BUL	7.6		Ringdal A			4.8	
CHG	5.1		Ringdal A			4.6	
COP	67.6	(25.0)	GSETT-noise	262	(100)	5.7	4.8
CTAO	4.4	(5.0)	GSETT-thres	99	(40)	4.5	4.4
DAG	4.6	(12.0)	Ringdal A		(300)	4.6	
DBN	29.8		Ringdal B	289	(400)	5.4	4.8
DKM	26.3		GSETT-noise			5.3	
DOU			GSETT	314		4.9	
EKA	14.6	(8.0)	GSETT-thres	57	(30)	5.1	4.1
ENN	5.7	(10.0)	GSETT-thres			4.7	
FBA	2.2	(10.0)	GSETT-thres	58	(40)	4.2	4.1
GAC	13.6	(2.0)	GSETT-thres	49	(40)	5.0	4.1
GBA	7.0	(3.0)	GSETT-thres	151	(100)	4.8	4.5
GDH	38.0	(16.0)	GSETT-thres			5.5	
GRA1	6.5	(2.0)	GSETT-thres	165	(50)	4.7	4.6
HFS	2.3	(2.0)	GSETT-thres	93	(50)	4.3	4.3
HLW	21.1	(15.0)	Ringdal B			5.2	
IR4	57.5		GSETT-noise			5.7	
JAY	23.7	(23.7)	Ringdal A			5.3	
JOS	9.9	(10.7)	GSETT-thres			4.9	
KBA	4.4	(10.0)	GSETT-thres			4.5	
KHC	3.9	(3.0)	GSETT-thres	330	(200)	4.5	4.9
KSI	50.0	(10.0)	Assumed value				
KUG	50.0	(10.0)	Assumed value				
LAC	7.8	(10.0)	GSETT-thres	346	(50)	4.8	4.9
LOR	3.3		GSETT-thres	40		4.4	4.0
LPB	6.5		Ringdal A				4.7
LSZ	5.9	(10.0)	GSETT-thres			4.7	
LTX	2.1	(10.0)	GSETT-thres	223	(50)	4.2	4.7
MAT	11.6	(10.0)	GSETT-thres	267	(260)	5.0	4.8
MAW	4.3	(10.0)	GSETT-thres			4.5	
MBC	3.3	(6.0)	GSETT-thres	128	(80)	4.4	4.5
MLR	14.6	(2.0)	GSETT-thres			5.1	
MNS	7.9	(10.7)	GSETT-noise			4.8	
MOX	10.5	(4.0)	GSETT-thres	235	(200)	4.9	4.7
NAI	18.3		Ringdal B			5.2	
NB2	1.9	(0.8)	GSETT-thres	97	(10)	4.2	4.4

TABLE 7
NOISE AMPLITUDES AND DETECTION THRESHOLDS

Station	Noise					Magnitude	
-	Short Period			Long Period		-	-
-	Ampl(nm)		Source	Ampl(nm)		-	-
-	Revised	CRP/134	-	Revised	CRP/134	mb	Ms
NNA	35.5	(44.8)	GSETT-noise			5.5	
NUR	9.6	(4.9)	GSETT-thres	120	(100)	4.9	4.4
NWAO	8.8	(4.0)	GSETT-thres	145	(44)	4.9	4.5
OBN	15.8	(6.0)	GSETT-noise	200	(50)	5.1	4.7
PMO	21.4		GSETT-noise			5.2	
PRU	12.1	(10.0)	GSETT-thres	189	(200)	5.0	4.6
PSI	9.4	(9.6)	Ringdal A			4.9	
PSZ	7.6	(14.8)	GSETT-noise			4.8	
QUE	5.5		Ringdal A			4.6	
RAR	62.2	(93.3)	Ringdal B			5.7	
RMP	30.2		GSETT-thres	133	(100)	5.4	4.5
RSNY	7.8	(10.0)	GSETT-thres	141	(50)	4.8	4.5
RSON	6.6	(10.0)	GSETT-thres	89	(50)	4.7	4.3
RSSD	3.1	(10.0)	GSETT-thres	93	(50)	4.4	4.3
SBA	6.6	(11.5)	GSETT-noise			4.7	
SLL	2.4	(2.0)	GSETT-thres	139	(50)	4.3	4.5
SMY	55.4		Ringdal B			5.6	
SOB1	50.0		Assumed value				
SPA	7.5		Ringdal A			4.8	
SUF	2.9	(2.0)	GSETT-thres			4.4	
TBY	3.0	(3.0)	GSETT-noise			4.4	
TRT	50.0	(10.0)	Assumed value				
UCC	23.7	(35.5)	Ringdal B		(100)	5.3	
VAO	50.0		Assumed value				
VTS	7.0	(10.0)	GSETT-thres			4.8	
WEL	131.8	(30.0)	GSETT-noise		(100)	6.0	
YKA	2.0	(3.0)	GSETT-thres	151	(50)	4.2	4.5

Ringdal A[1]

Ringdal B[2]

CRP/134[3]

1. F. Ringdal, *Study of magnitudes, seismicity and earthquake detectability using a global network*, NTNF/Norsar, Kjeller, Norway (1984).

2. F. Ringdal, E.S. Husebye, J. Fyen, "Earthquake detectability for 478 globally distributed seismograph stations," *Physics of the Earth and Planetary Interiors* 15 pp. P24-P32 (1977).

3. GSE 1984a, *PROCEDURES FOR THE GSE TECHNICAL TEST (GSETT) 1984*, Conference Room Paper 134/Rev. 1, GSE, Conference of Disarmament (15 August 1984).

based on GSETT data according to the simplified and approximate estimation procedure outlined in Section 6. The revised values are for most of the stations (21) higher than the original values and only in five cases are the values similar. This systematic difference could partly be due to the seasonal variation of long period noise, which is more pronounced than for the short period noise, and the fact that the GSETT was carried out during a time of high noise levels in the Northern Hemisphere.

8. MAGNITUDE DETECTION THRESHOLDS

The revised noise values in Table 7 have been used to infer magnitude thresholds which are also listed in the table. These thresholds have been estimated from a standard magnitude formula assuming a constant Q - value (3.73 and 3.19 for short and long period, respectively) corresponding to an average value of Q in the interval 30 to 85 degrees. A minimum signal-to-noise ratio of 1.5 has also been assumed for signal detection. These thresholds only apply to the GSETT period and have been computed here to illustrate in a simple way the variation in detection capability among stations and between wave types.

The thresholds are also graphically illustrated in *Fig.6* and *Fig.7*. *Fig.6* shows the m_b and M_s for all stations. The M_s values have been transformed into equivalent m_b thresholds for earthquakes assuming the relation m_b=0.62M_s+2.03.[10] The median value of the m_b threshold is 4.9. The figure shows the difference in detection capability of the GSETT network of short period body and long period surface waves. There are no stations with surface wave thresholds below m_b=4.5 , whereas there are 13 stations with short period body wave thresholds below 4.5. There is also a much larger variation of the short period than of the long period detection capability among the stations.

Fig.7 shows the geographical variation of the short period station detection thresholds. There are only 21 stations in the Southern Hemisphere and only one of them has a threshold below 4.5. The concentration of stations with low detection thresholds in Europe is also clear with seven stations having thresholds below 4.5. This means that more than half of the most sensitive GSETT stations are located within an area less than 10% of the earth's surface.

9. CONCLUDING REMARKS

The following general conclusions can be drawn from the discussion above:

The amplitude and period measurements reported during the GSETT could be used for to estimate short period noise levels and amplitude thresholds for about 50 (or two thirds) of the participating stations. Corresponding long period information could be compiled from the GSETT data for about 30 of the stations.

Comparisons between short period noise estimates obtained from GSETT data and earlier published estimates based on much larger sets of observations could be made for about 10 of the stations and showed reasonable agreement.

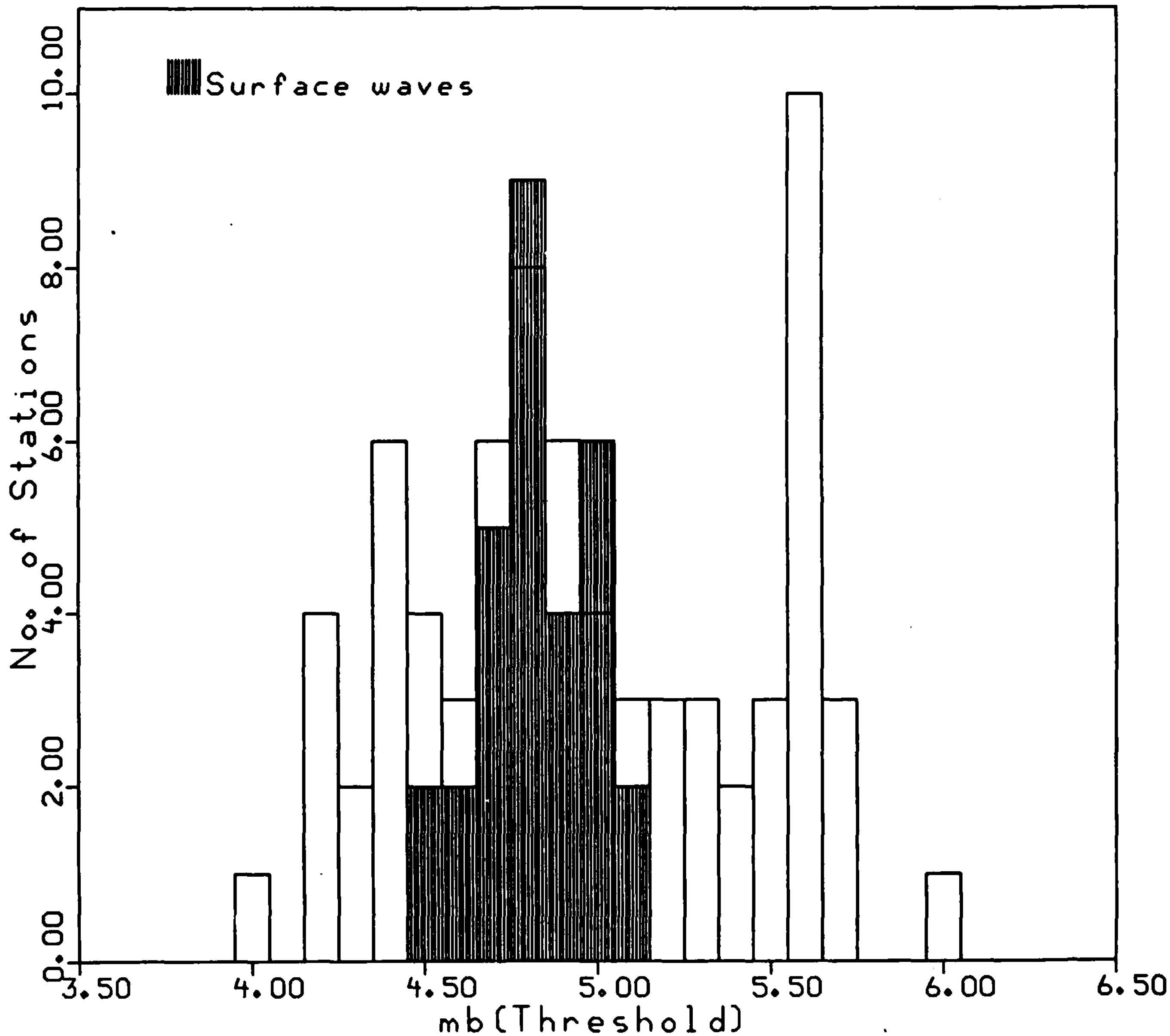

Fig.6 Magnitude detection thresholds for the GSETT stations for short period P waves and long period Rayleigh waves.

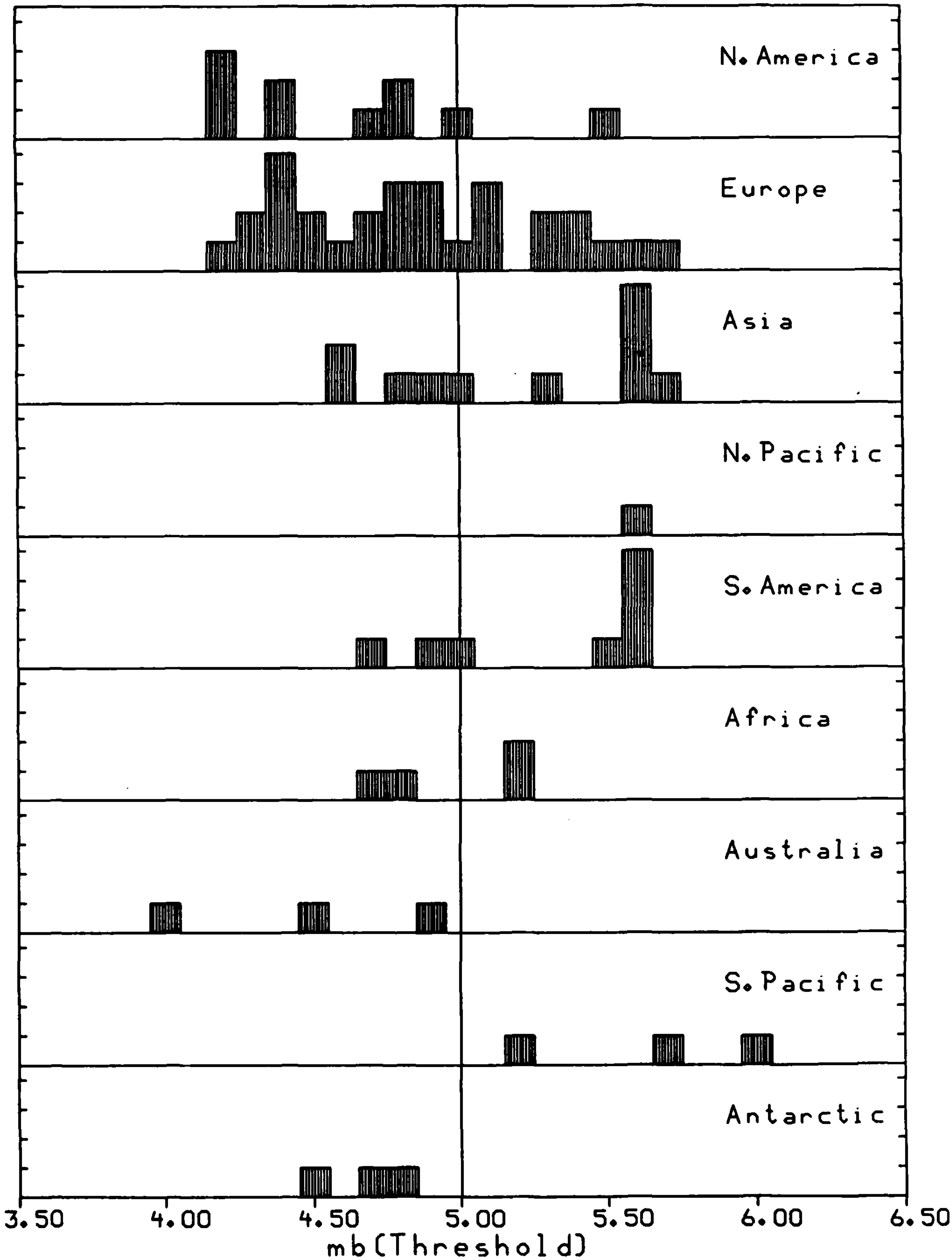

Fig.7 **Geographical distribution of station magnitude detection thresholds for short period P-waves of the GSETT stations.**

The revised noise values differ significantly from the preliminary values assumed or reported before the GSETT. The revised short period values are either significantly lower or significantly higher than the preliminary values for most of the stations. The revised long period values are generally much higher than the preliminary values.

The GSETT stations constitute a global network with large variations in noise and detection characteristics among the individual stations. The median value of the m_b detection threshold measurements as defined above is 4.9, a rather high value. Most of the stations have a significantly higher detection capability for teleseismic short period P waves than for long period Rayleigh waves. The variation in short period detection capability among the stations is well over a magnitude unit, whereas the long period detection capability has less variation among the stations.

The network of GSETT stations also follows the well known geographical distribution with most of the stations concentrated in the Northern Hemisphere and in Europe in particular. Stations in the Northern Hemisphere have generally lower magnitude thresholds than stations in the Southern Hemisphere. More than half of the more sensitive GSETT stations were located in Europe.

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