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VII.7 NORESS noise spectral studies - noise level characteristics

We refer to section VII.5 for description of the NORESS noise spectral system.

In this part of the NORESS noise studies, we will report the characteristic features of the seismic background noise with respect to diurnal and seasonal variations, especially at frequency ranges from 2 Hz and up. For lower frequencies a number of earlier studies are available, and microseismic long period background noise will therefore not be discussed in this summary. The features that will be emphasized in particular are those relevant to detection capability.

Figs. VII.7.1 through VII.7.3 are selected to illustrate the diurnal noise variation at NORESS. The figures show NORESS average SPZ power (MEANZ) versus time of week, for selected frequency bands. The center frequencies are identified on the plot and the bandwidth is 0.2 Hz. The weeks we have chosen as representative are week 15 , week 30 and week 31 of 1986. Week 30 is the last week of a three-week vacation period in Norway. Nearly all industry close during this period. Therefore week 30 and 31 represent summertime observations without and with industry activities, respectively. On the other hand, week 15 represent near winter-time conditions, as there is still frost in the ground during that week.

The figures show that at frequencies above 2 Hz there are pronounced peaks during working hours, whereas at lower frequencies no strong correlation with working hours can be found. Our experience is that the 0.5 Hz frequency noise level correlates well with the average unfiltered noise root-mean-squeare of SPZ instruments, thus illustrating the overall noise level.

When correlating the variations in noise power in the 0.5 Hz band, with power variations for frequencies above 2.0 Hz, we see that large fluctuations in the noise level (5 dB and more) at 0.5 Hz are not reflected at the higher frequencies. This pattern is observable for each of the three weeks displayed in Figures VII.7.1 - VII.7.3.

The typical noise pattern during working days, for most frequencies above 2 Hz, is a raise in noise power of 5 - 8 dB during normal working hours. The noise power is at a minimum level during the GMT hours 23 - 04. Then the power increases to a maximum lasting 6 - 8 hours. Thereafter, the noise power decays down to the night-time minimum.

A different pattern is seen for the frequencies 6, 12 and 18 Hz. It is down to a minimum for the same hours, but increases much more steeply to a maximum which lasts for 8 - 16 hours. In NORSAR Scientific report No. 2-85/86 we identified this as energy coming from a sawmill 15 km east of the NORESS center. In that report, details of the first working day of week 15 were plotted.

We have checked our observations against the operational times of the sawmill, and their statistics concerning days with and without activity, days with 8 and 16 hours operation, respectively, have all shown excellent correlation with our data. The sawmill operates 2 vertical ram saws, each with a mass of 5000 kg oscillating 365 times per minute (6.08 HZ). A neighboring factory also operates heavy heat-producing equipment all night through, but not during weekends. This latter information may explain the fact why the night-time minima we observe between working days always are somewhat higher than weekend minimum values.

Looking at week 30 (Fig. VII.7.2), at which time both of the above-mentioned plants have been closed, we still see a noise increase, presumably due to cultural activities, during working hours. Moreover, by comparing week 30 and 31 (Figs. VII.7.2 and VII.7.3), we note that the noise patterns are practically identical, except for the 6, 12, and 18 Hz bands and frequencies below 2 Hz. We also see that night-time minima during week 30 are closer to weekend minima.

Saturdays also indicate some day time noise increase, and this has been consistent during the reporting period. We may for some weeks also see some increase in noise level on Sundays.

The interpretation of all the data is that the NORESS noise is influenced by cultural activities during working hours, and that the pattern, when excluding the mentioned sawmill, is similar during both active and vacation periods of the nearby industry.

The noise level is increased 5 - 8 dB during 6 - 8 hours of a working day, and the sawmill 15 km east of NORESS contributes with additional 4 - 5 dB noise level increase for 6 , 12 and 18 Hz only, and extends the period to 16 hours (during periods where the sawmill has enough timber to operate two shifts).

Heavy traffic on roads may explain some of the daily cultural activity. This is not easily confirmed by the observations we have here, but we will make some comments to this source of noise: Car traffic is expected to reach maxima on mornings and around end of working hours. The noise power observed show, however, a maximum value which last for 6 hours during the middle of the working day. Car traffic is particularly heavy on the second day of Easter. Inspecting this day, we have seen that noise level for frequencies above 2 Hz increases by 3 dB during day time, whereas total noise level decreases about 3 dB, which indicates that the increase in noise level at higher frequencies may be due to peak traffic.

Noise level on Saturdays has a peak level before 12 GMT, whereas noise level on Sundays has a peak after 12 GMT (if a peak at all can be seen). This sunday afternoon effect may support the assertion that the cultural noise source is weekend traffic. However, looking at noise pattern on Friday afternoons and comparing with other days, we see no indications for weekend traffic. Thus, any correlation between car traffic and NORESS noise level, is likely to be marginal.

Seasonal variations

We have indicated that the noise level above 2.0 Hz show rather small variation when compared to the overall noise level. Figs. VII.7.4 - VII.7.6 have been chosen to document this fact.

In Fig. VII.7.4 we have plotted average SPZ noise power (MEANZ) for the selected frequencies, but only observations made at local time 02. (GMT 00 or 01). The points are connected, so lacking observations are not shown as gaps in this plot. Fig. VII.7.5 shows average SPZ noise observed at 08 local times only.

The interpretation of the data is as follows: Comparing June data with March, we may conclude that summertime observations show up to 5 dB higher noise level for frequencies above 2 Hz. Again we see that higher frequencies do not follow the larger variations in total noise level, and there is in fact a general decline in the noise level at low frequencies during summer. These effects will be investigated in more detail when a full year of observations have been collected.

A major feature of the plots is the great increase in noise power late April. This apparently is due to ice-melting in rivers close to NORESS. The effect is most clear on Fig. VII.7.6 where data for D3Z and D8Z is shown. About 100m from D8Z is a small river, and we see the highest power increase on this instrument. At the point furthest away from the river, D3Z, the power for frequencies above 5 Hz does not show this pattern. However, the data for the 3.0 Hz band show nearly the same pattern on both sides of the array. Thus, we are apparently dealing with two different noise sources, and the 3 Hz behavior is possible tied to the water flow of the large river Glomma, about 18 km east of the NORESS array.

Inspecting details of all frequencies for this time period, we have found that there is a clear minimum in the noise level at the 1st of June. Thereafter the noise increases again. The increase in noise level is more dominant on the east side of the array (D3Z), and more dominant in the frequency band 2.0 - 5.0 Hz. (Peak at 3.0 Hz). On the west side we see the same pattern, but a second increase in the noise level after June 1st is seen at all frequencies. Moreover, the increase in noise level is smaller for the lower frequencies. We have correlated these observations with operational statistics made by the staff at two electrical power plants by the larger river. At the 1st of June, the river was indeed down to a minimum level. Thereafter the water flow tripled in just 5 days. Moreover, both of the plants were out of operation June 2 through 4, during which period the water flowed through a natural water fall rather than through the turbins.

NORESS High frequency element - HFSE

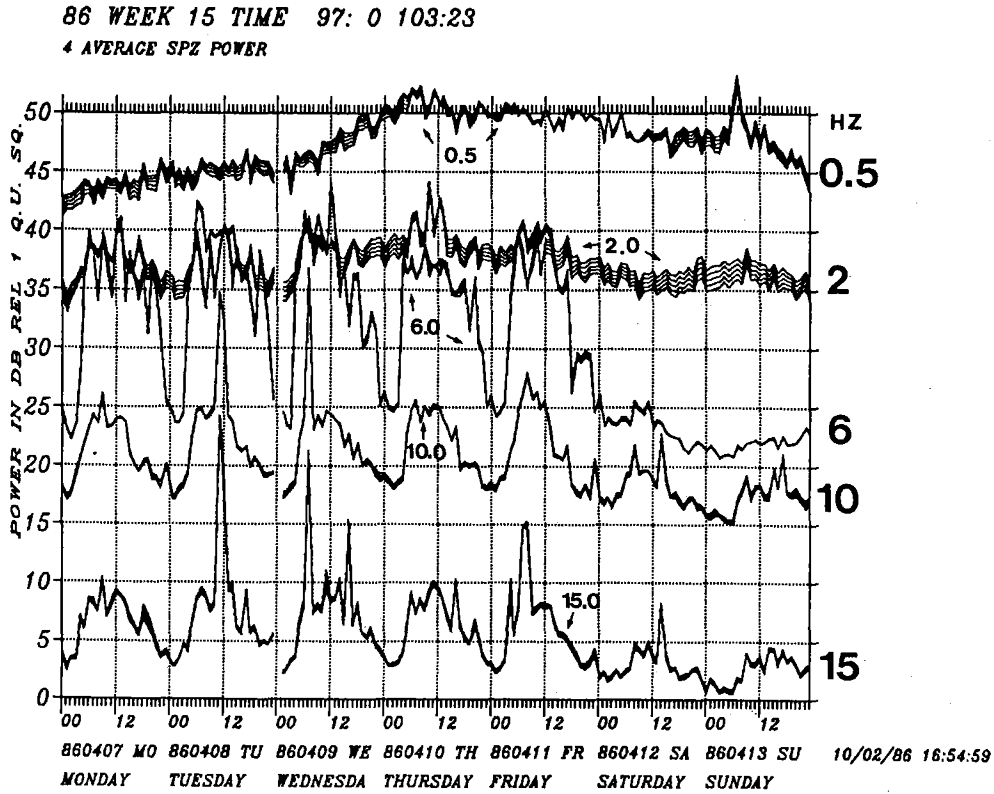
Figs. VII.7.7 - VII.7.8 are selected to show characteristic features of the high frequency system. Fig. VII.7.7 shows power as a function of time, while Fig. VII.7.8 shows all Z-component spectra for GMT hours 00 and 12, respectively, during week 15. The high frequency element is located in the NORESS central vault and therefore close to the local road. Daily activities in the area are shown very clearly on this system. Spurious high frequency noise (or near-field events) are for the NORESS array averaged out by using the average of up to 25 instruments, and excluding instruments which are outliers as compared to the other instruments. For the one HFSE instrument the data will naturally show greater variability.

As seen from Fig. VII.7.8, this may result in "outliers" among the noise spectra for HFZ. The peaks around 21 and 29 Hz are apparently due to fans in the vault. A peak resulting from the 50 Hz power supply is also commonly seen on these data.

The HFSE data confirm the results from NORESS SPZ instruments with regard to daily and seasonal variations in the noise level. Furthermore, we can see diurnal noise level variations due to cultural activities for frequencies up to around 50 Hz. (Fig. VII.7.7). In Fig. VII.7.9, this is shown by displaying power spectra for A0Z, D3Z, D8Z and HFZ corrected for system response. The data is from day 318, 00 GMT.

The studies presented here will be further expanded as more data is accumulated. In particular, we plan to evaluate in detail seasonal and diurnal noise level charactersistics at the very high frequency end of the spectrum.

J. Fyen



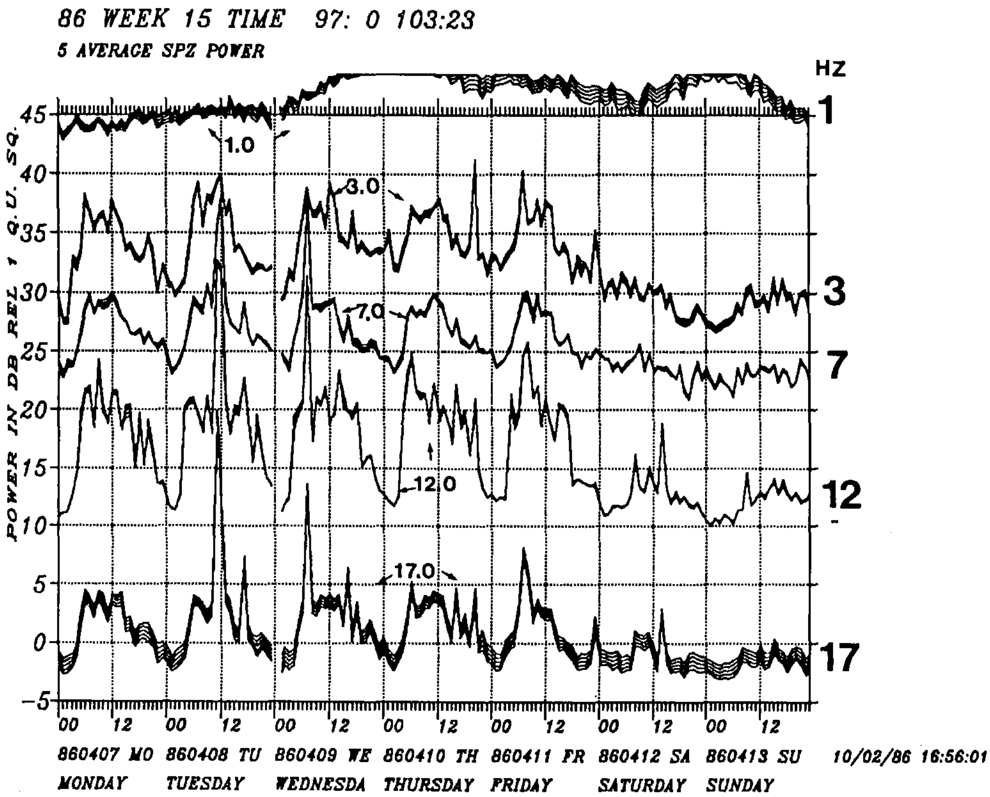
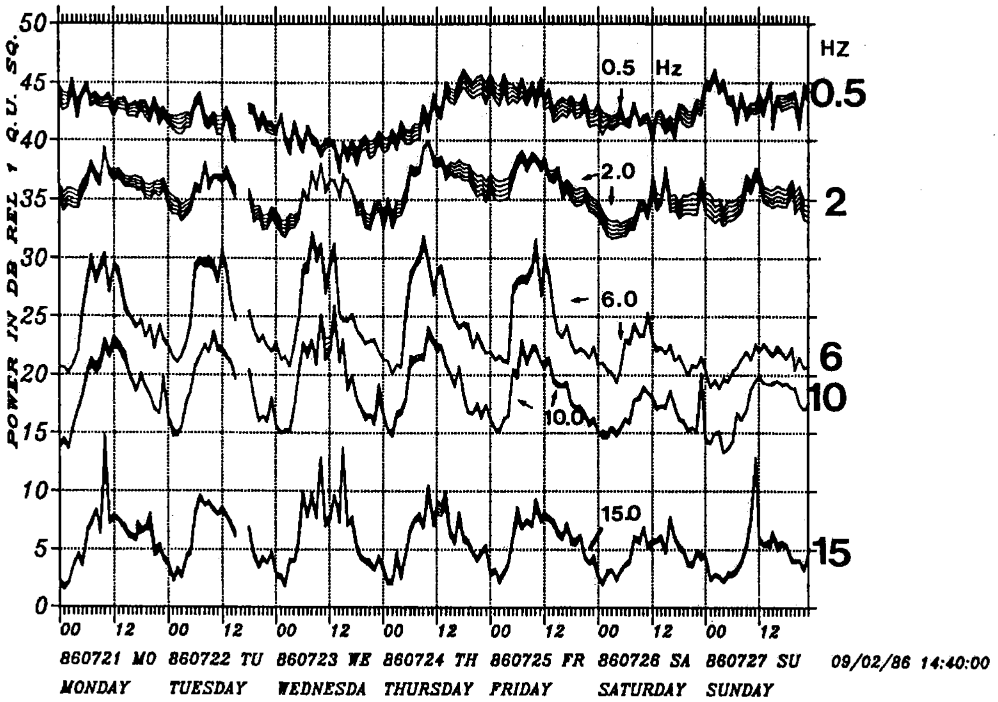


Fig. VII.7.1 Average NORESS SPZ spectral levels plotted on an hourly basis for a one-week period (week 15, 1986). The plots show a sequence of narrow frequency bands (+/- 0.1 Hz around the indicated center frequency). For better legibility, the data are shown in two separate diagrams, (top and bottom) with 5 frequency bands in each.

86 WEEK 30 TIME 202: 0 208:23
AVERAGE SPZ POWER



86 WEEK 30 TIME 202: 0 208:23
AVERAGE SPZ POWER

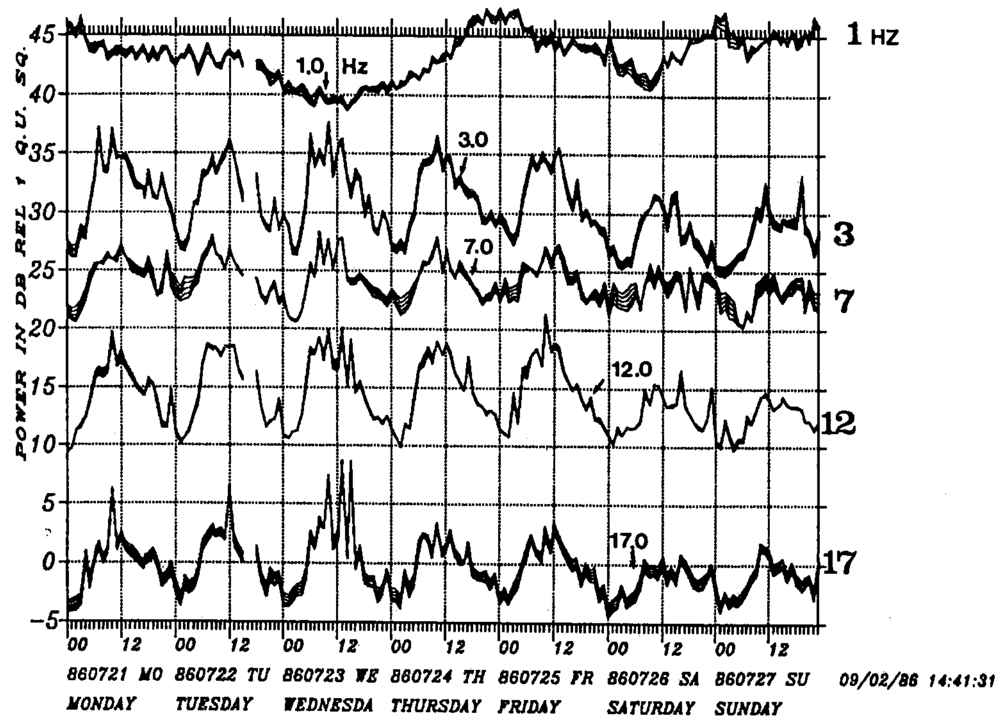
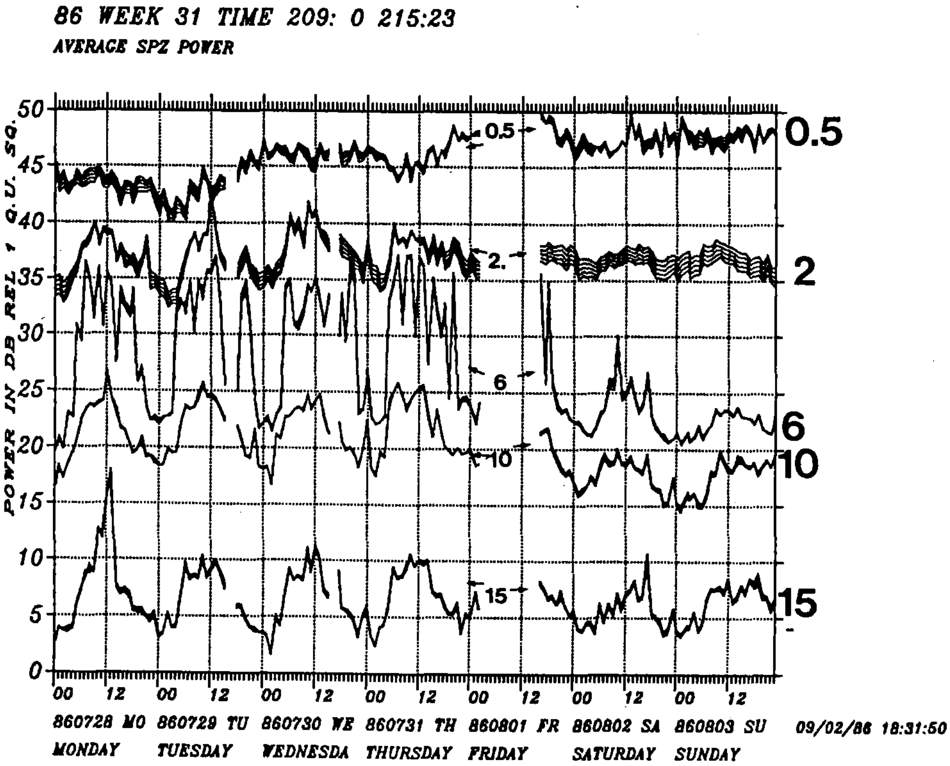


Fig. VII.7.2 NORESS average SPZ power as in Fig. VII.7.1, but for week 30, 1986. Note that week 30 is during industry vacation period.



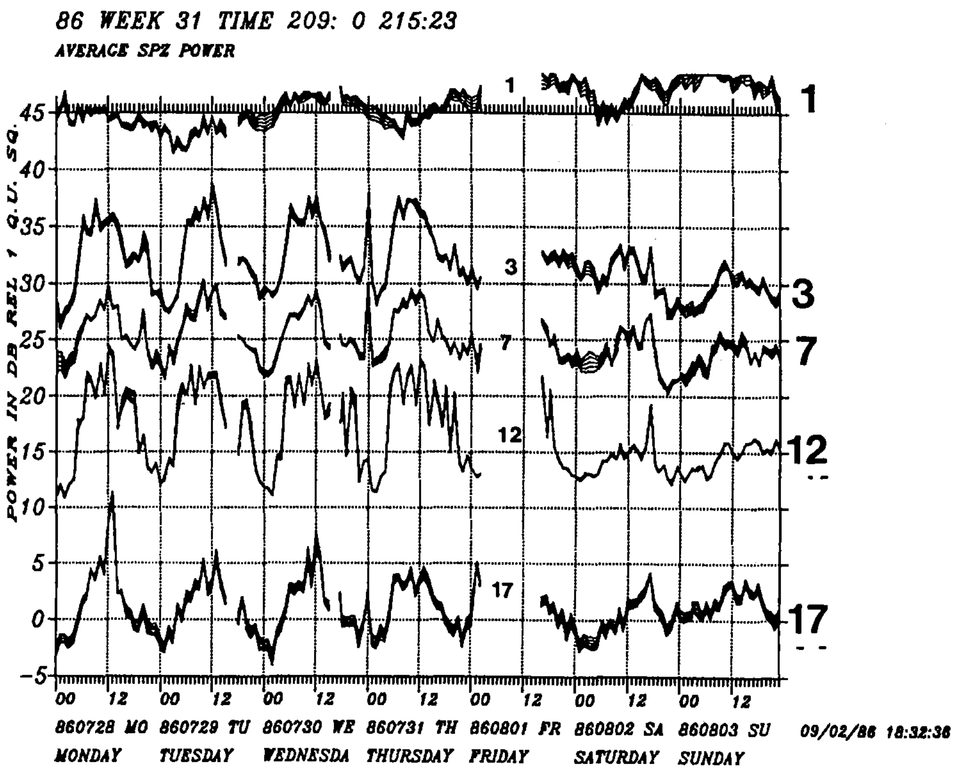
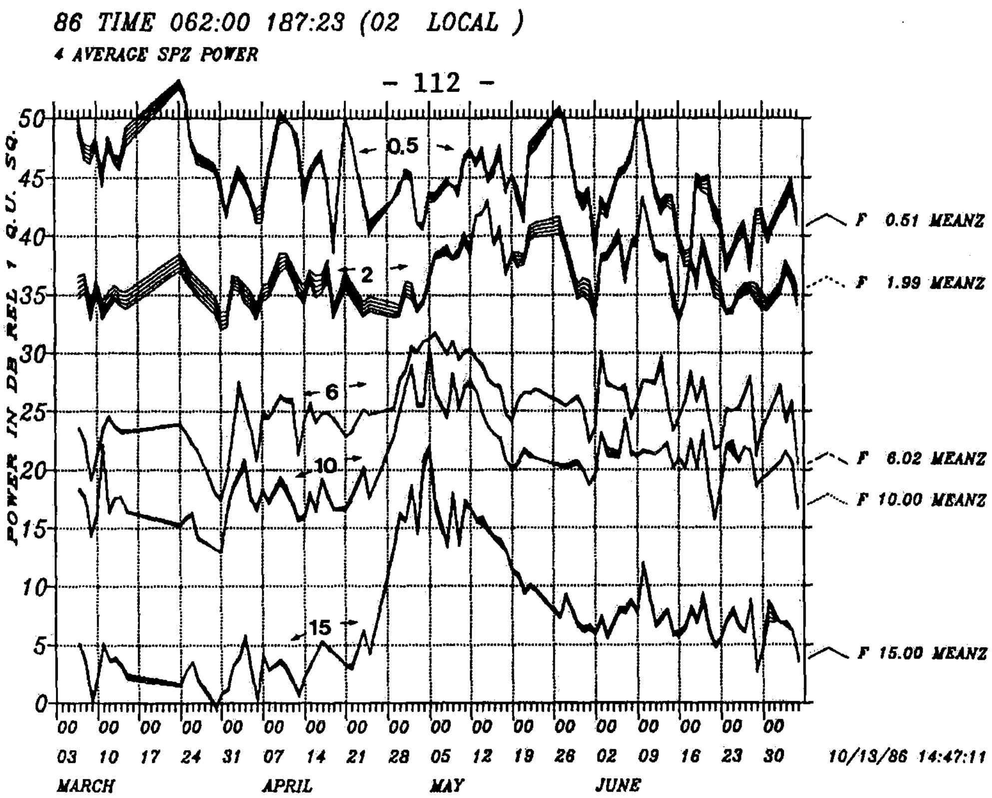


Fig. VII.7.3 NORESS average SPZ power as in Fig. VII.7.1, but for week 31.



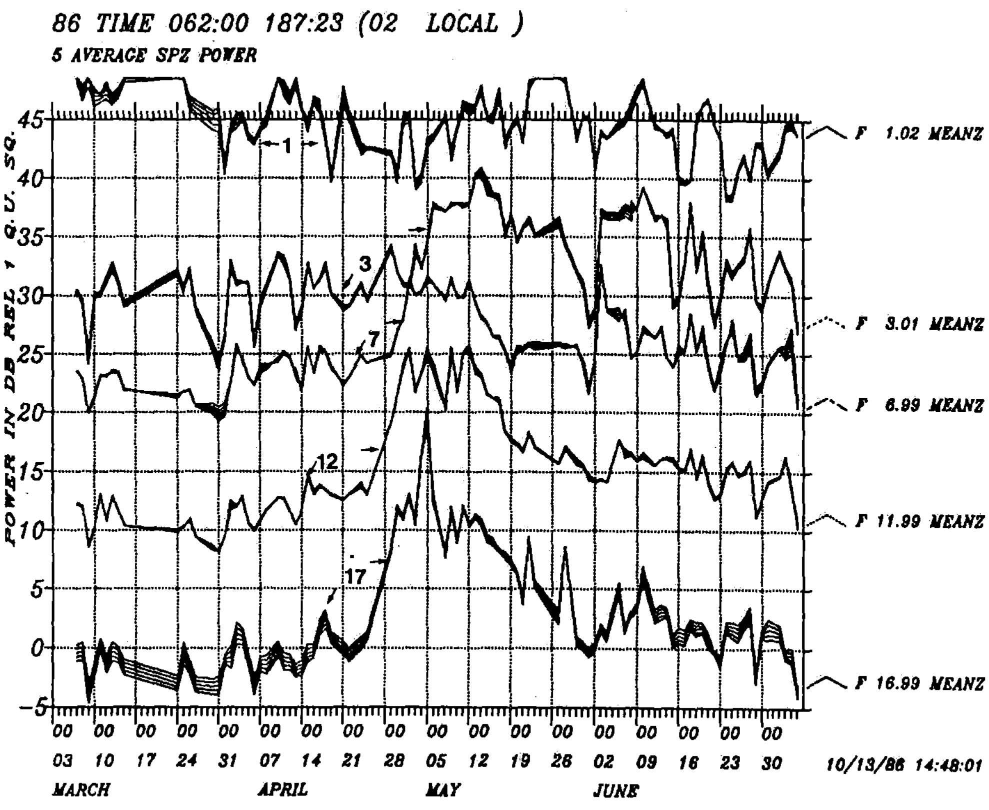
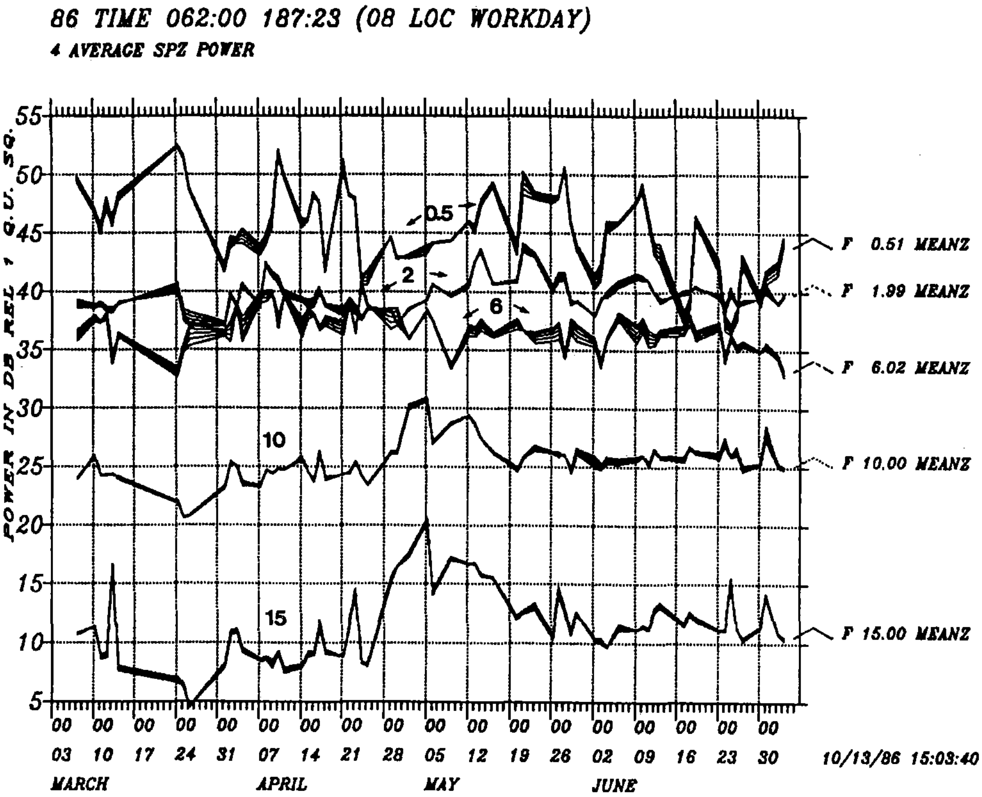


Fig. VII.7.4 NORESS average SPZ power observed at 02 local hours only, for the period day-of-year 062 through 187. There is one data point per day. Minor ticks on time axis is one day. The numbers identify frequency in Hz and the data is observed at these frequencies +/- 0.1 Hz. Points are connected, so lacking observations are not shown. The upper and lower parts of the figure corresponds to different sets of frequencies.



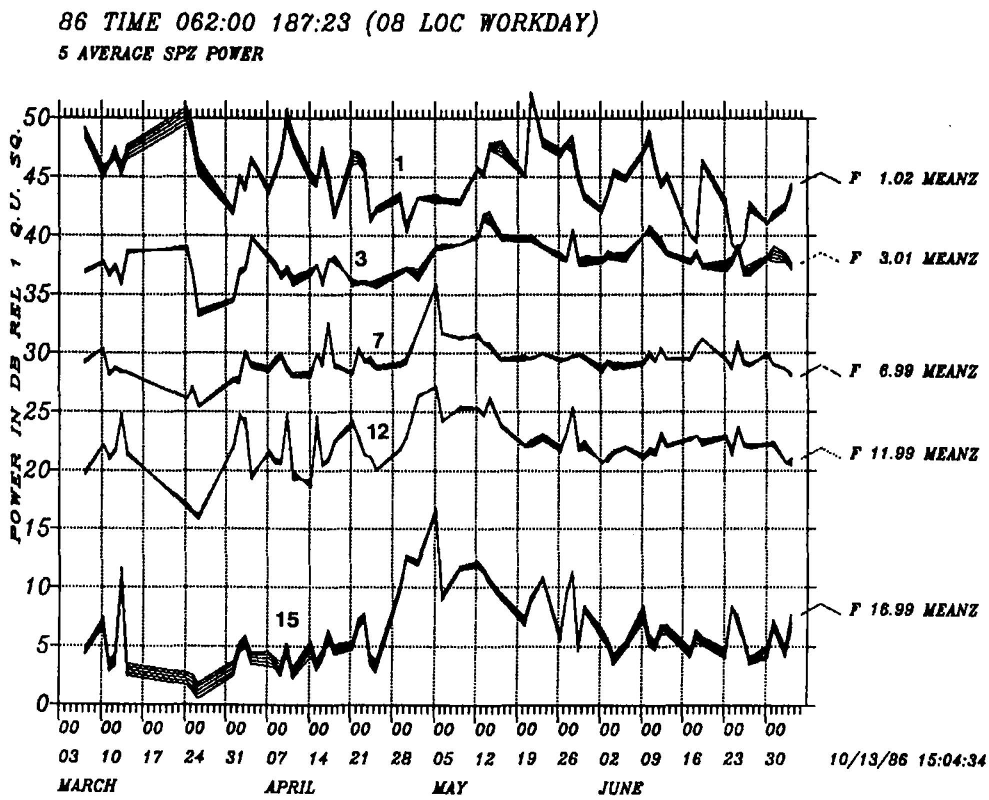
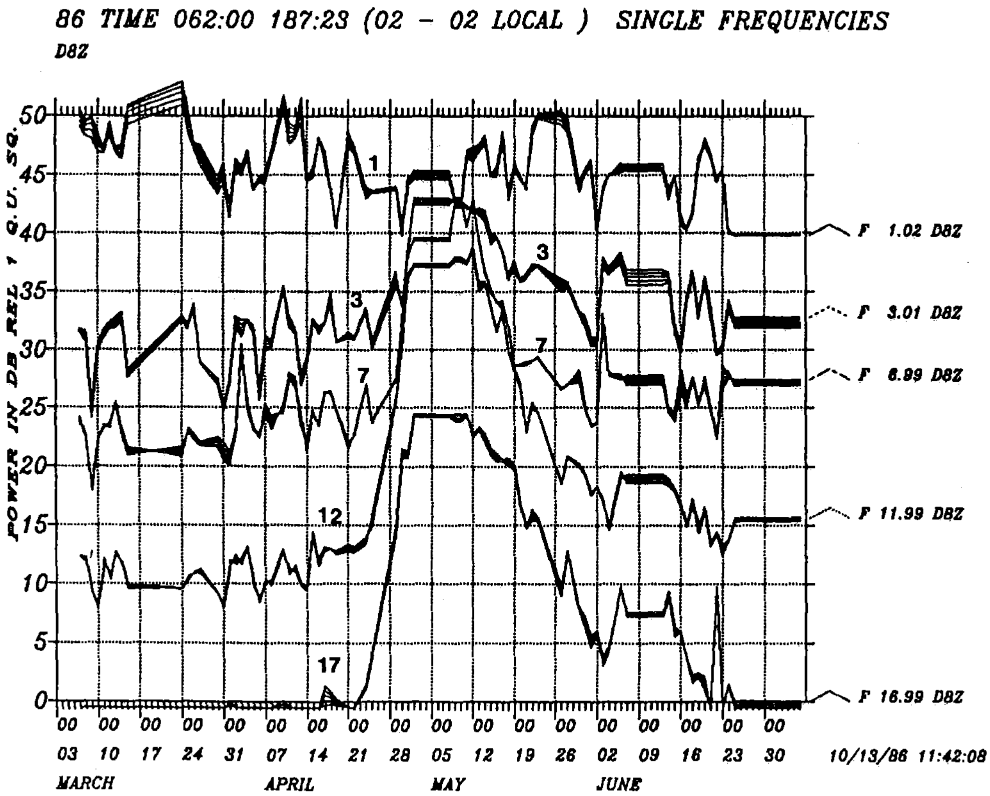


Fig. VII.7.5 NORESS average SPZ power as in Fig. VII.7.4, but observed at 08 local hours only.



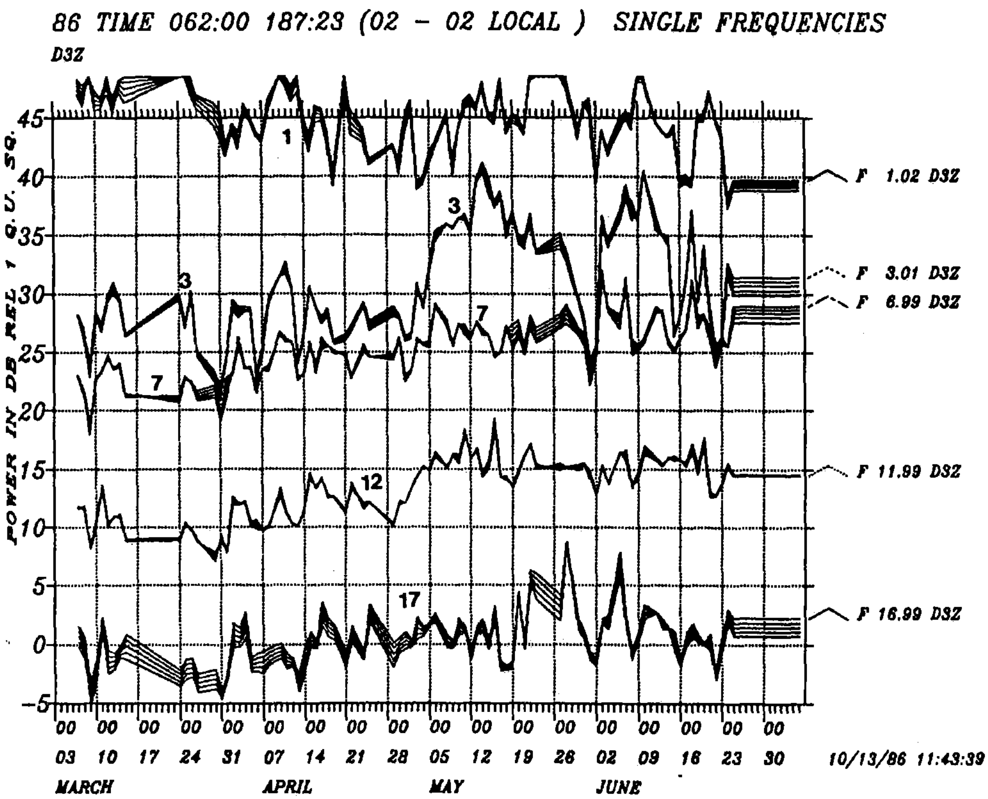
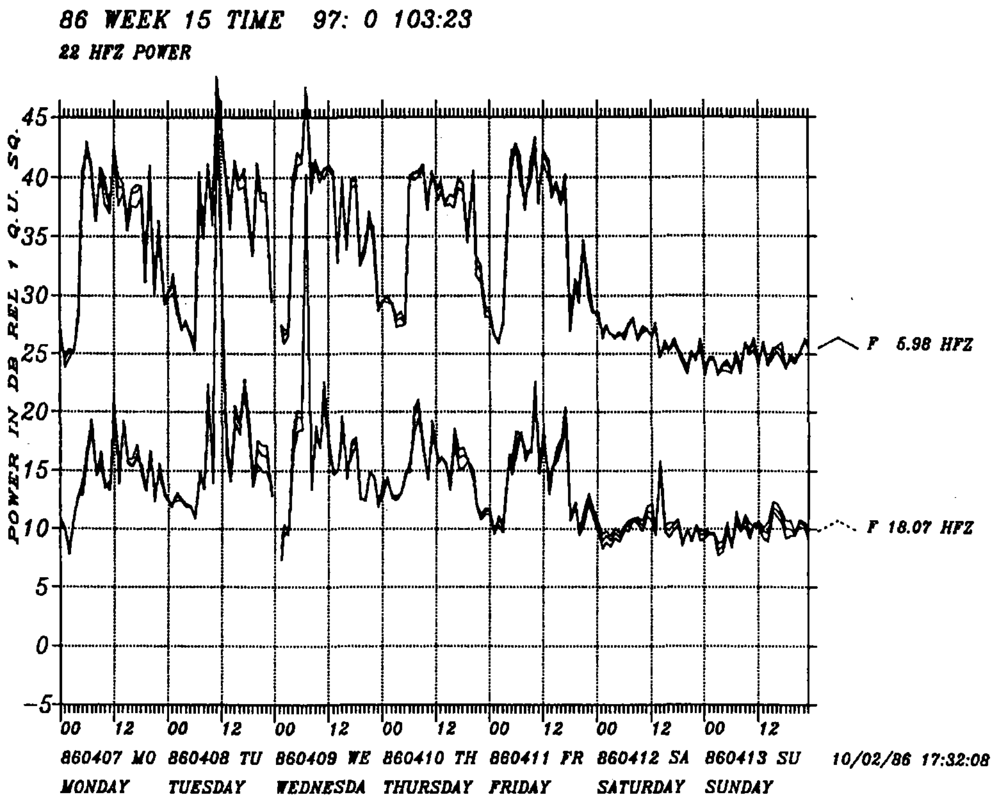


Fig. VII.7.6 NORESS SPZ power for two instruments: D8Z (top) and D3Z (bottom) observed at 02 local hours only.



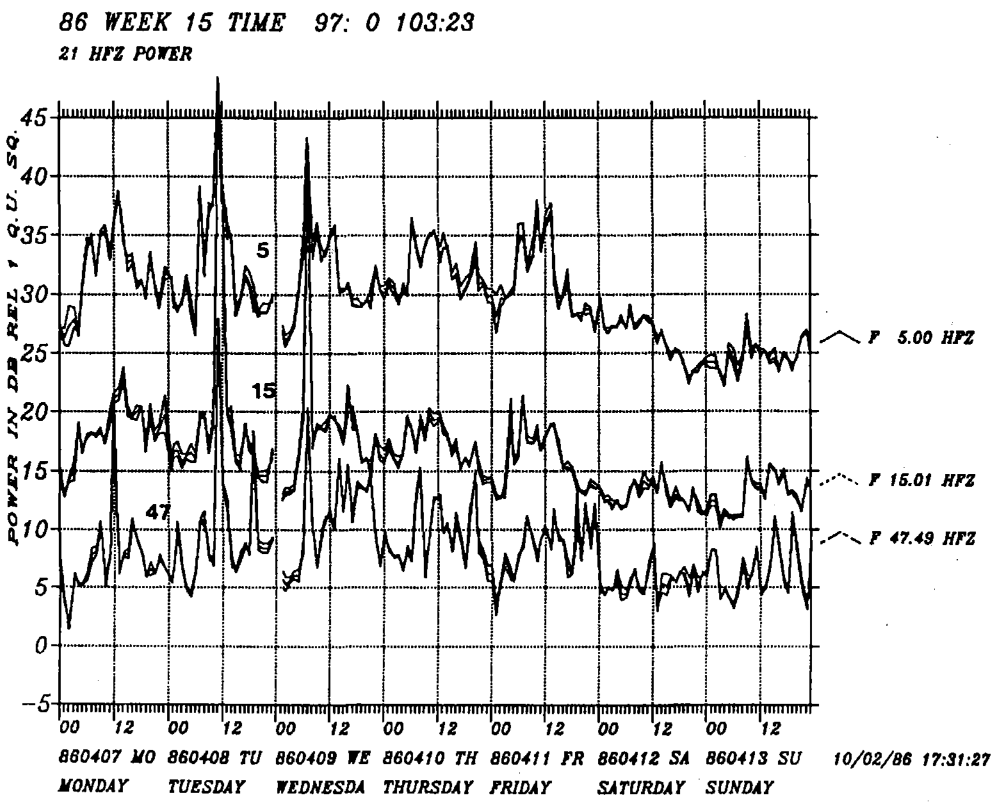
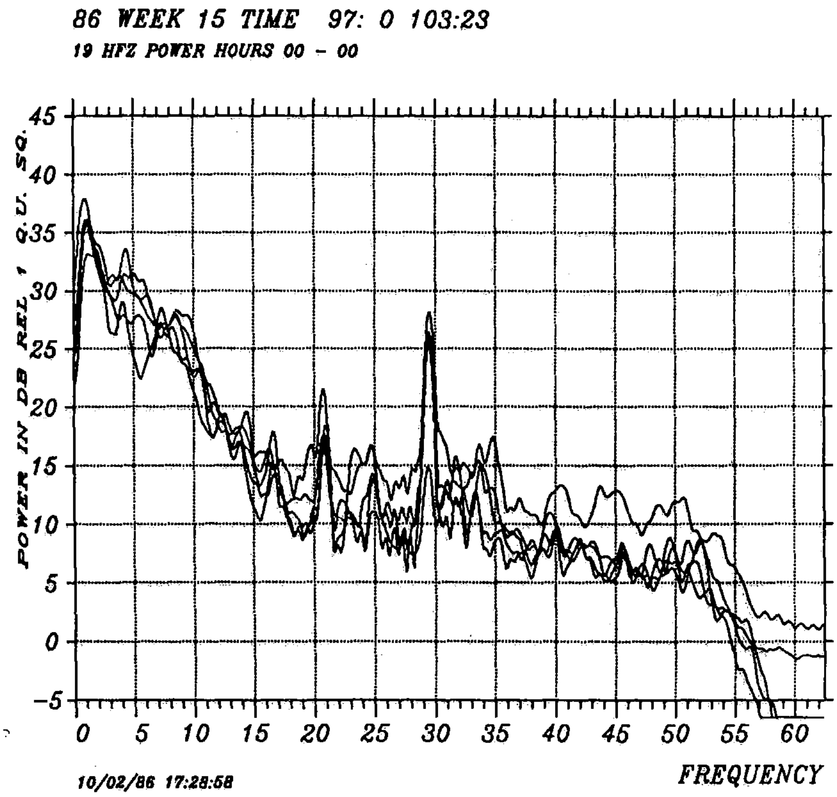


Fig. VII.7.7 NORESS HFSE Z-component power observed during week 15. See the text of Fig. VII.7.1.



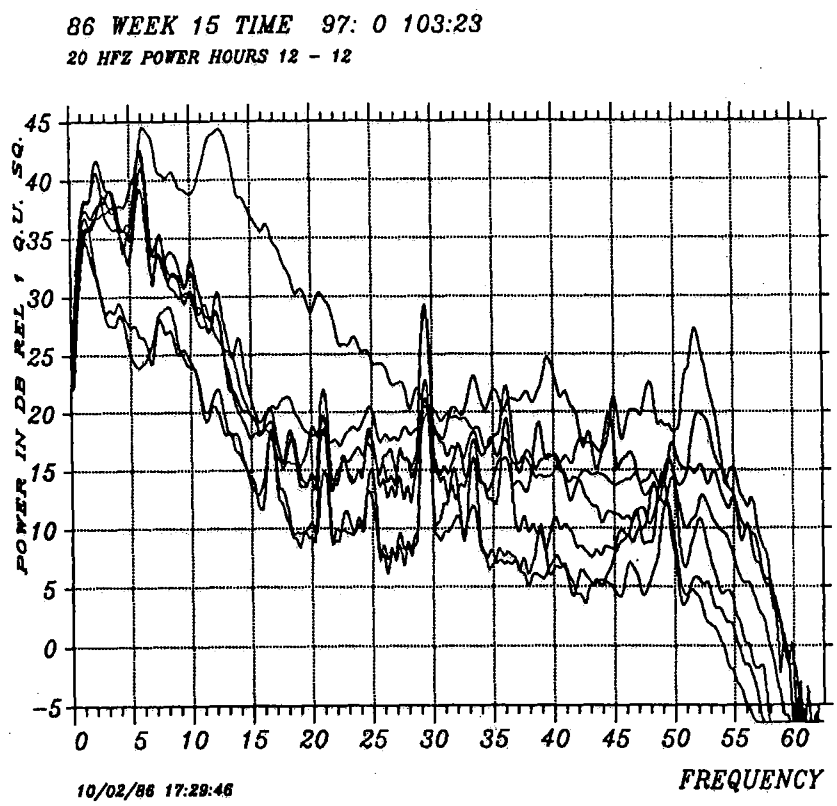


Fig. VII.7.8 NORESS HFSE Z-component spectra observed at two fixed times of day, during week 15, 1986. The top part corresponds to 00 hours GMT, the bottom part to 12 hours GMT.

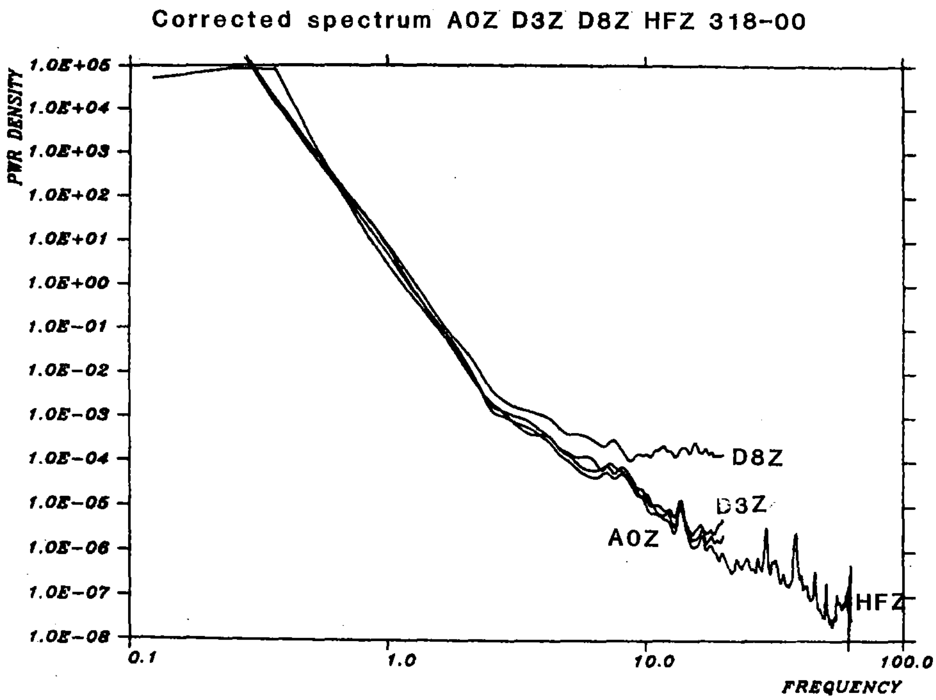


Fig. VII.7.9 Corrected noise spectra for A0Z, D3Z, D8Z, HFZ observed day 318 at 00 GMT. The power density unit is nm^2/Hz.