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VII.2 NORESS noise spectral studies. Noise level characteristics

The NORESS noise recording system has continued to be in operation throughout this reporting period. The system is documented in NORSAR Sci. rep. No 1-86/87, where also results from the first half-year of recording are presented. The system is used to obtain statistics on both noise suppression by beamforming, and the actual variations in the noise level.

The beam suppression results for half a year of data were documented in the referenced report. The continued observation of beam suppression has reconfirmed the conclusions made in that report. The results for the different subarray configurations are consistent and stable over time.

We will therefore not report any further on the beam suppression data, but rather concentrate on the noise level, and in particular extract features important for signal detection.

An initial assessment of diurnal and weekly variations in the NORESS SP noise spectra was given in the mentioned report. Observations from more than one year of data, generally confirm the previous results, but the expanded data base allows us to describe further the effect of cultural noise. To illustrate time-dependent varations we have chosen to use uncorrected data, with variations in power measured in dB. For illustration of the actual noise level, corrected power spectra will also be presented.

Fig. VII.2.1 displays the average NORESS SPZ noise power for a few selected frequencies, plotted versus time for the four-week period Monday, 15 December 1986, through Sunday, 11 January 1987. A vertical dotted grid line is plotted at 00 GMT for every 24 hour period. In

this figure, days which are not normal working days have been identified by hatched rectangles.

As may be seen later from the statistics on seasonal variations, the noise level during the Christmas holidays are among the lowest we have observed throughout one year of data (for frequencies above 2 hz). We note that although industrial plants are closed, there is a cyclic rise in noise power of 2 -3 dB during the day, with a minimum level at 01 GMT (local time 02).

For days with normal industrial activity the diurnal variation may range from 5 to 15 dB for frequencies above 2 Hz. However, the nightime minima during the week do not reach the minima we observe during weekends. These observations are consistent throughout one year of data.

These data represent average power from the 25 NORESS SPZ instruments and local effects from wind or other phenomena which may disturb one or a few instruments, will be smoothed out in the average spectra.

To illustrate the seasonal variations we have chosen to use observations made at particular times during each day. For nighttime statistics we have thus chosen local time 02 hours, and for daytime observations we have selected local time 13 on normal working days only. The data time period covered is 31 March 1986 through 04 May 1987. Frequencies selected are the same as used in NORSAR Sci.rep. No. 1-86/87. For each frequency we may compare observations made at 02 and 13 local time to see the effect on noise level from cultural activities. Results are presented in Figs. VII.2 and VII.2.3.

Fig. VII.2.2 shows the noise levels sampled at 02 hours local time. In the figure, each vertical dotted grid line denotes Monday 00 GMT of each week. There are 7 observations within each vertical gridline. We see the cyclic variation of noise level reaching a minimum every

weekend, and a pronounced minimum during Christmas holiday and industry vacation (07 July through 27 July). Thus, the data again show that the variations in the noise level above 2 Hz are to a large extent due to cultural effects. Below 2 Hz we see seasonal variations that are not reflected at the higher frequencies.

Easter holidays (16 - 20 April,1987), are also characterized by relatively low noise. However, an increase in noise level start off at the end of the holidays. This is because that time period coincides with the snow melting. This leads to greatly increased water flow in the rivers nearby plus transport of large ice blocks, and the corresponding effects on the seismic noise level are most clearly seen at frequencies above 1.5 Hz.

The snow melting period in Norway normally consists of two phases: first the melting of snow in the low-lands, and later when the snow from the mountains is melting. The first period strongly affects small local rivers, and implies a sharp increase especially in high frequency noise. The second period causes the large more distant rivers to have increased water flow, and the effect on NORESS is mostly confined to a band around 3 Hz.

In 1986 these periods covered the interval late April to early July. The 1987 snow melting started about 20 April. The effect of water flow in the rivers was also documented in former report.

The daytime observations are shown in Fig. VII.2.3. Many of the features are similar to those observed for the nighttime data. Thus, the snow melting period is easily detected. Also, the holidays show pronounced minima, with Christmas being the quietest period.

Otherwise, the noise level at daytime is consistently above that observed at night, even during the common vacation period. (07 July - 27 July 1986).

As displayed in Fig. VII.2.4, data from the NORESS high frequency element (here named HFZ), show the same features with respect to diurnal and weekly variations as do the standard short period instruments. We may infer from the data that above 20.0 Hz , the industrial noise is not as pronounced as for frequencies in the range 2 - 20 hz. However, as this data is from from one single instrument as opposed to the average power from 25 instruments for NORESS SPZ, the data show much more variability. Moreover, the instrument is located at the central site, closer to a road, and high frequency 'signals' from local activity are difficult to eliminate. This is more easily done among the 25 SPZ instruments, where data from each instrument is compared to the average, and excluded from consideration if interpreted as an outlier.

In the lower part of Fig. VII.2.4, we have displayed uncorrected power spcectra for the high frequency element observed at 02 local time during the quiet Christmas period. The corrected spectra are shown in Fig. VII.2.5. The peaks in the spectra are due to electronic interference from fans and from the 50 Hz power supply. Fig. VII.2.5 represents a lower bound for NORESS noise level.

As the diurnal and weekly variation is well documented, and seasonal variations are mainly tied to low-frequency noise, we will document the actual noise level at the NORESS site by looking at all observations for selected time points throughout the last two half-year periods. Again we look at local time 02, and local time 13 at workdays. The spectra are corrected for system response, and reported as power density (nm**2/Hz). Figs. VII.2.6 - VII.2.8 show the results, both for NORESS average SPZ and the High frequency element. NORESS average SPZ data is generally consistent with the high frequency ele-

ment, but small variations may be detected due to the averaging of the SPZ instruments. The data has been divided into the two half-years of recording. During the first half-year, the high frequency data was sampled from the S-3 borehole seismometer at a depth of 60 meter (site F0). During the second half-year, the data is from the GS-13 seismometer, which is located in a shallow avult (site A0). Comparing the MEANZ (average SPZ data) with HFZ for the two periods, we find that the MEANZ and HFZ observations are close to equal during the period when GS-13 was used.

Comparing the upper and lower parts of Fig. VII.2.8, we see some systematic differences. Thus, for frequencies above 6.0 Hz, the surface seismometer shows 5 - 7 dB higher noise level than the borehole instrument.

J. Fyen

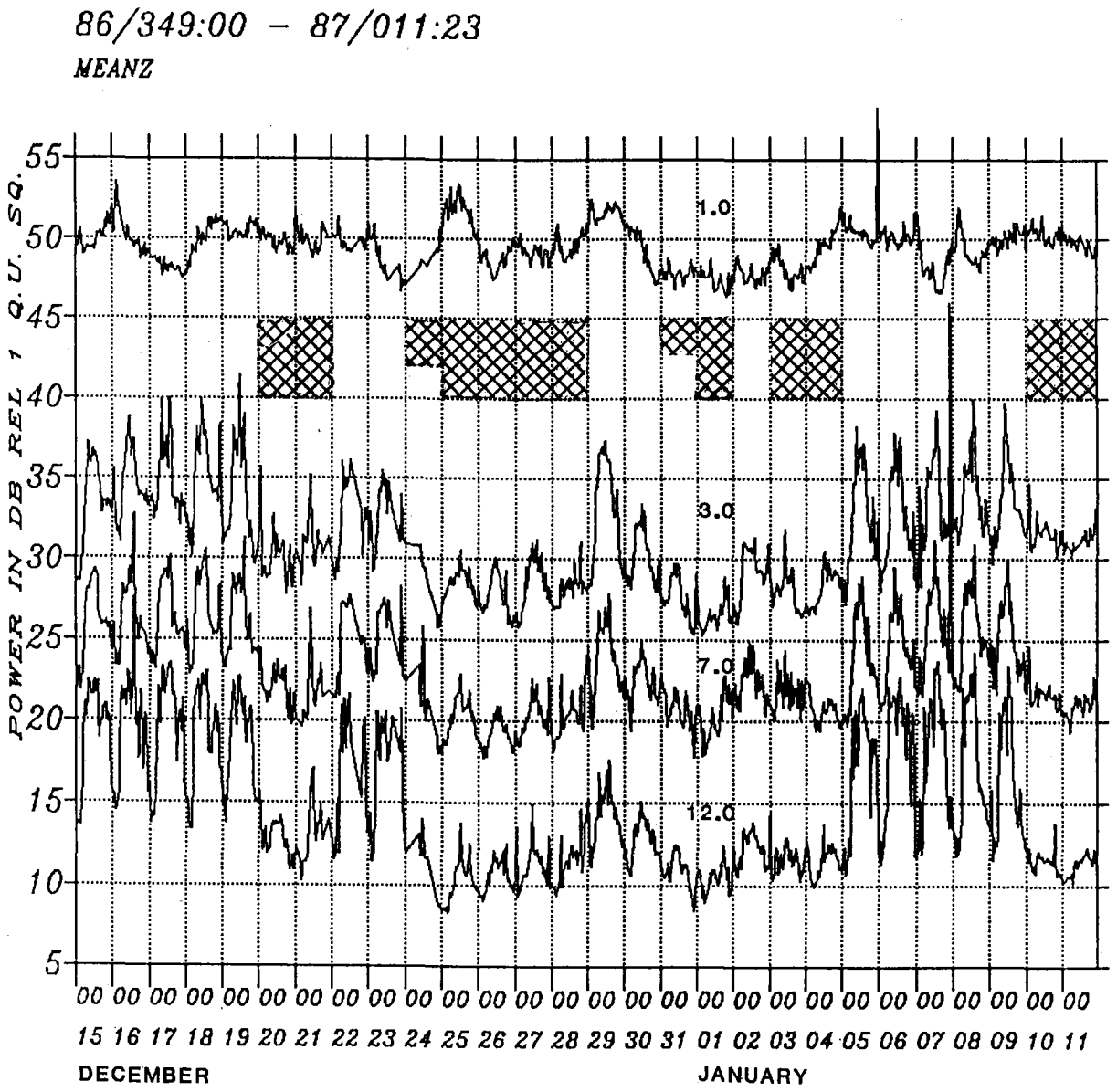


Fig. VII.2.1 Average NORESS SPZ spectral levels plotted on an hourly basis for the four-week period 15 december 1986 through 11 January 1987. Based on the complete noise spectra sampled each hour, the plot shows the power versus time for frequencies within narrow bands (± 0.1 Hz). Center frequency for each band is printed on the plot. A vertical dotted grid line is plotted at 00 GMT each day (01 local time). Hatched squares indicate days which are not normal working days.

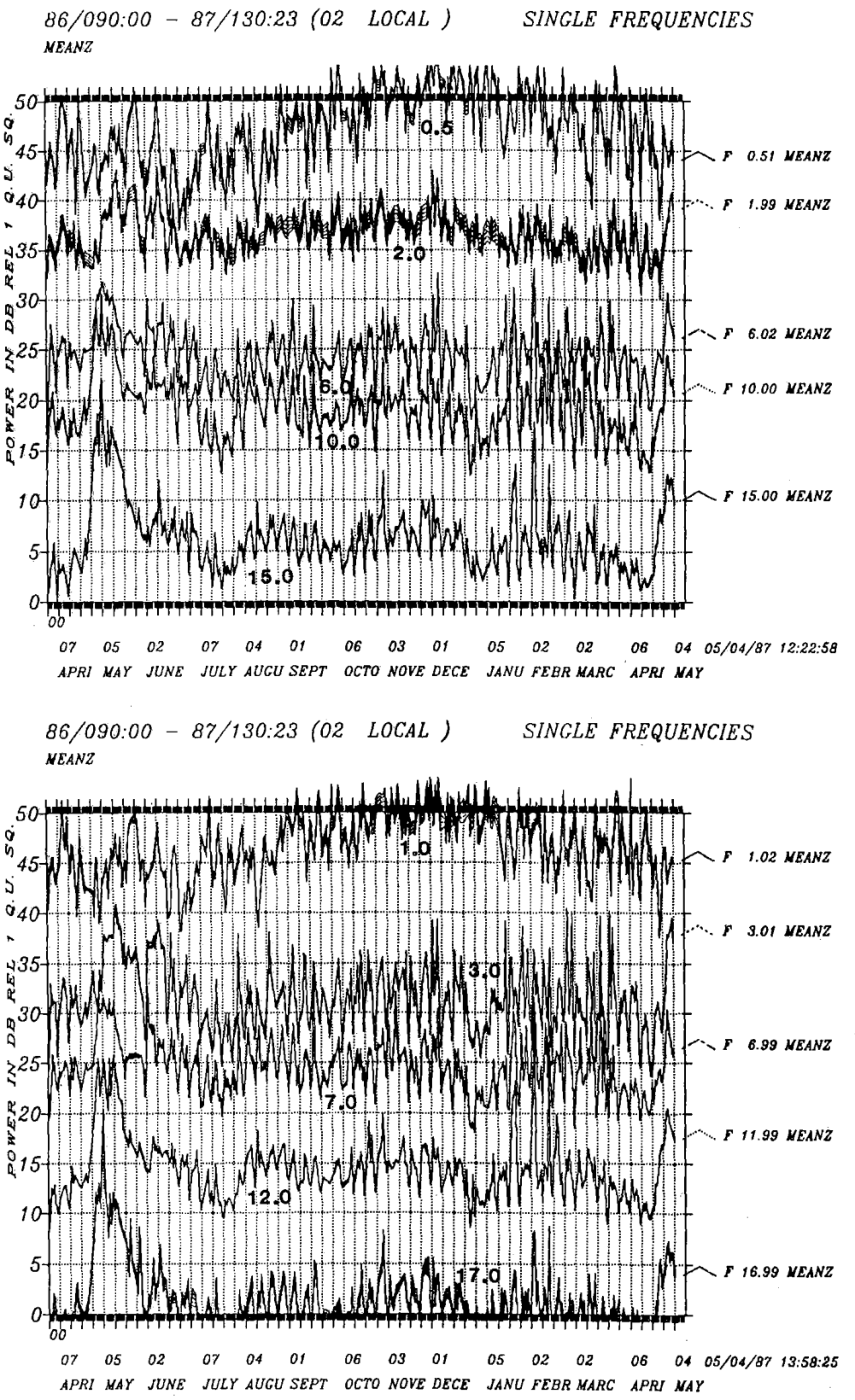
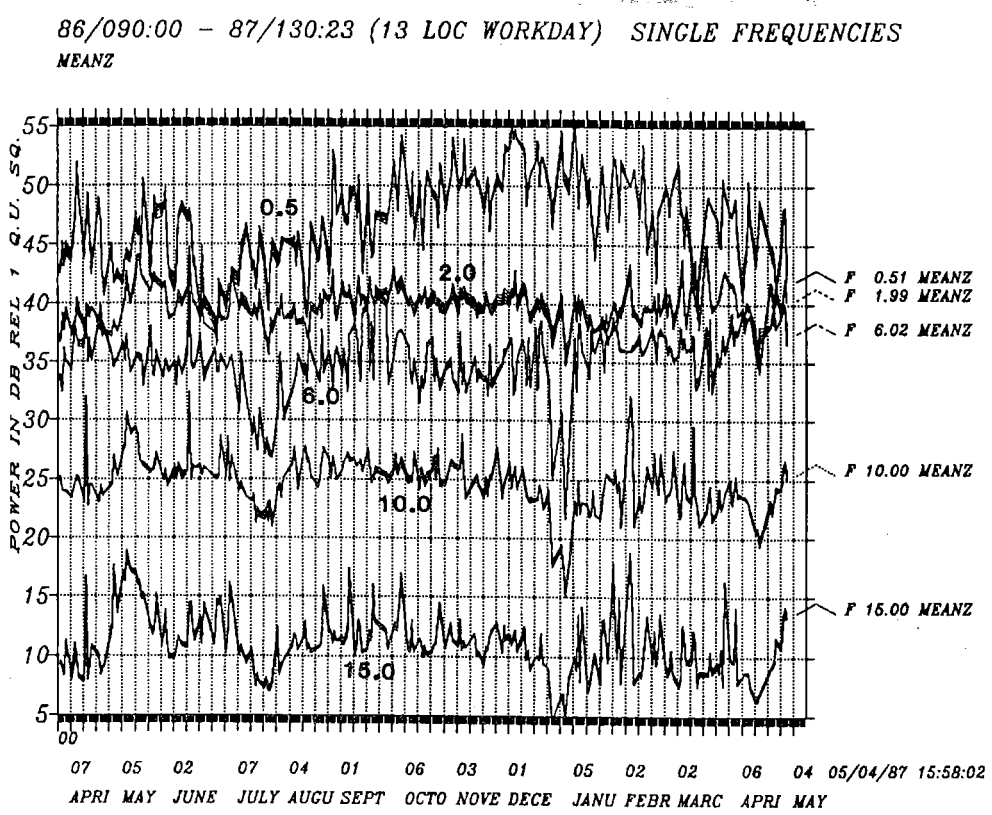


Fig. VII.2.2 Average NORESS SPZ spectral levels observed at 02 local time only, for the period day 090, 1986 through day 130, 1987. There is one point per day per frequency value, and vertical dotted grid lines indicate Monday 00 GMT each week. Frequencies used are identified by the center frequency, and observations that are within ± 0.1 Hz of center frequency are used. For better legibility, the data are shown in two separate diagrams (top and bottom) with 5 frequency bands in each.



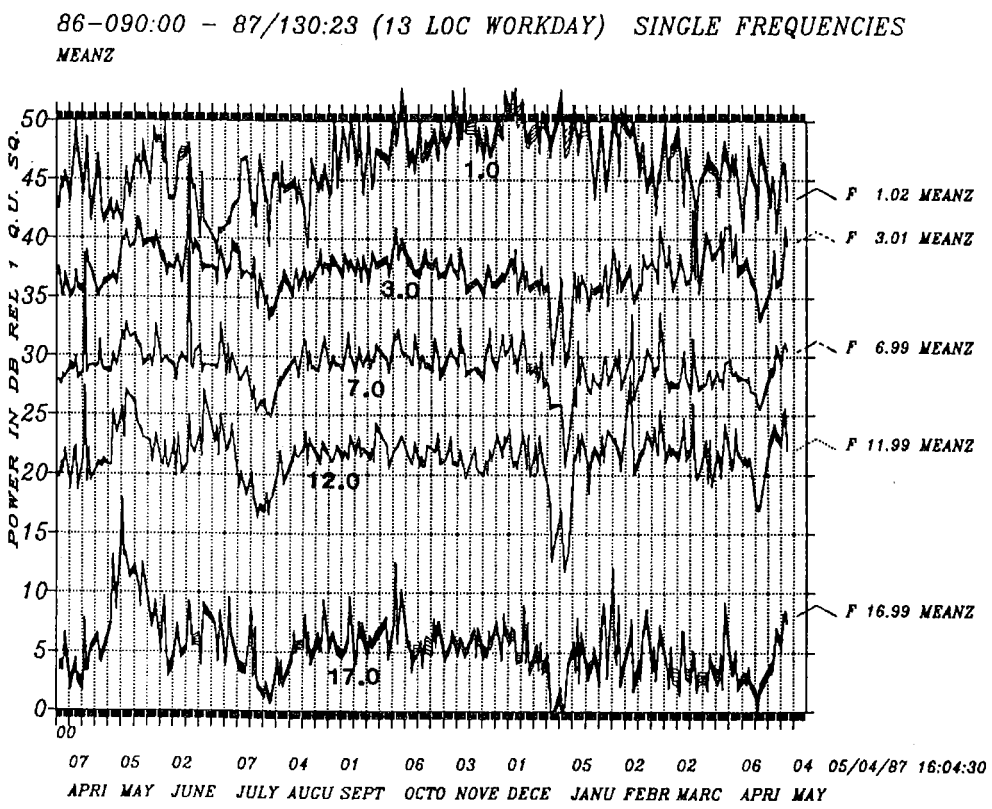


Fig. VII.2.3 Average NORESS SPZ spectral levels as in Fig. VII.2.2, but observed at 13 local time on working days only.

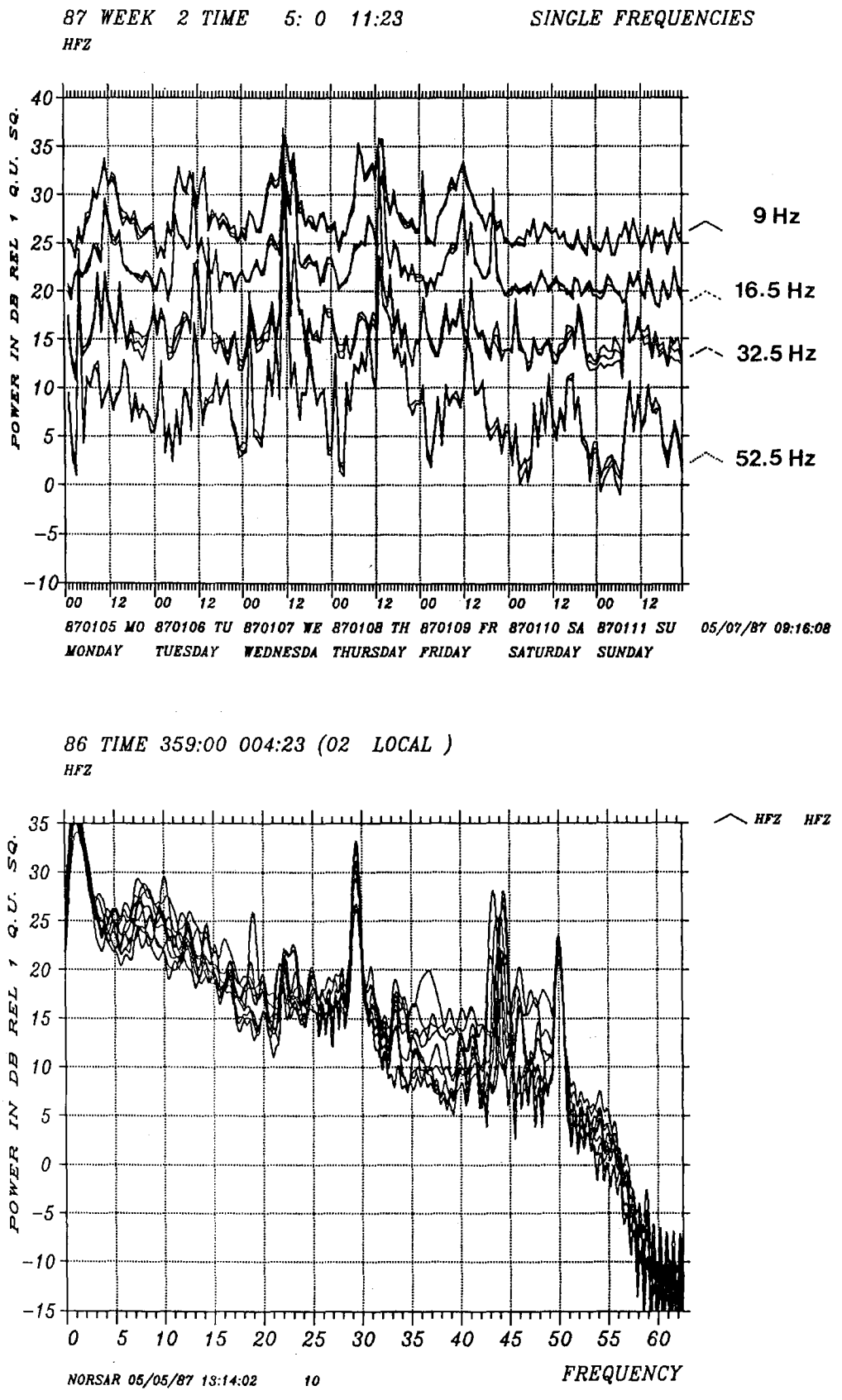


Fig. VII.2.4 NORESS noise power level as in Fig. VII.2.1, but for the High Frequency Element HFZ. The time period is week 2, 1987 for the upper part of the figure. The lower part show the full spectra for the Christmas holiday period day 359, 1986 through day 004, 1987 at 02 local time only. The spectra have not been corrected for system response.

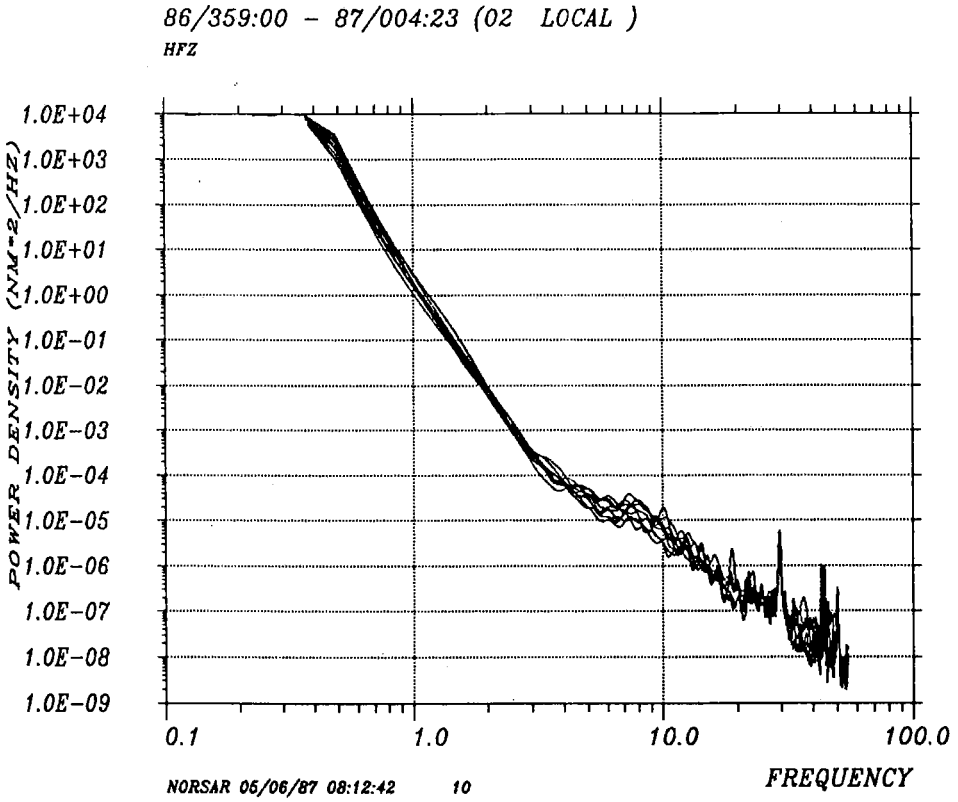


Fig. VII.2.5 NORESS corrected noise power spectra based on data from High Frequency Element. The data are from the period day 359, 1986 through day 004, 1987, observed at 02 local time only.

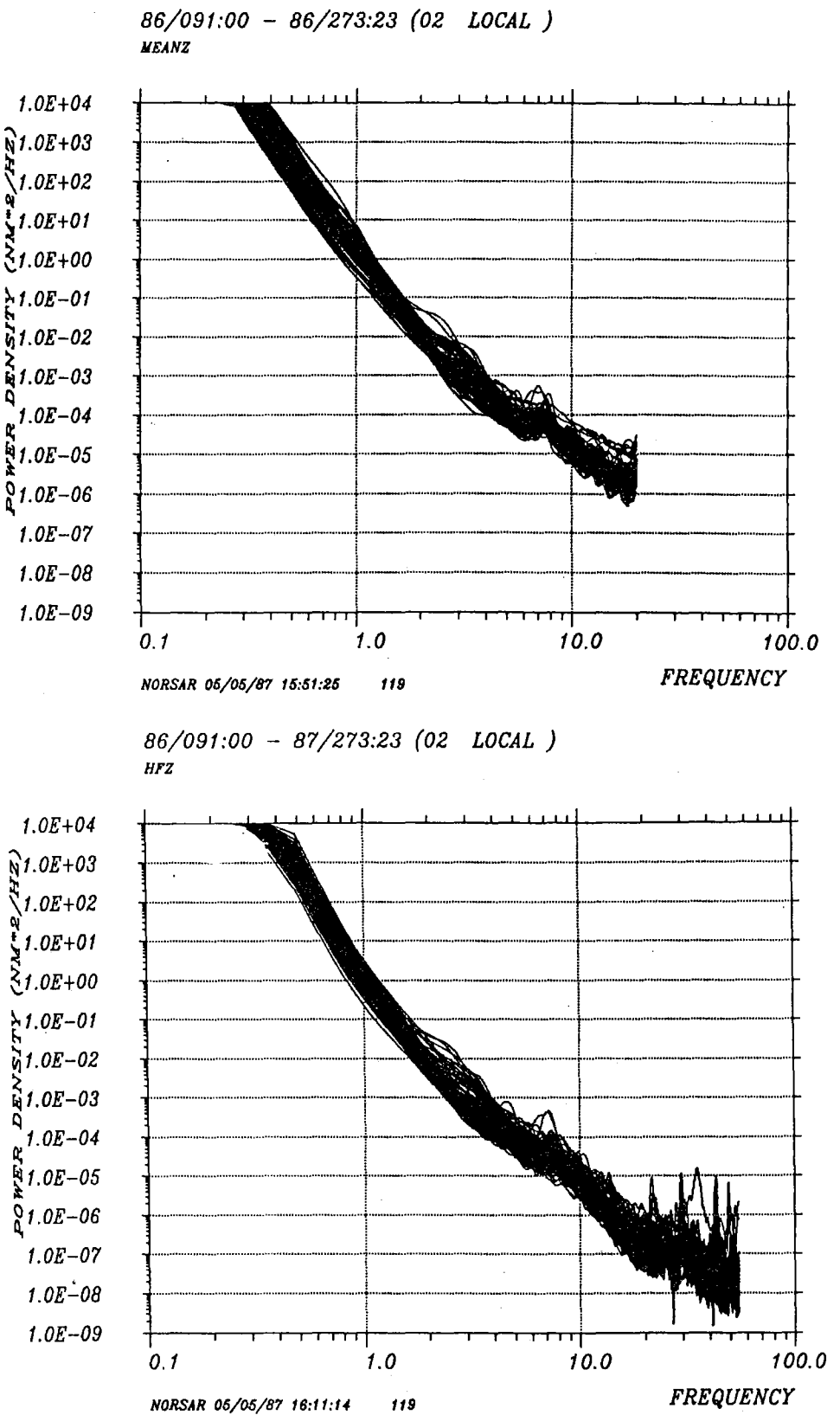


Fig. VII.2.6 NORESS corrected noise power spectra from average of SPZ instruments (upper part) and from NORESS high frequency element (HFZ) on lower part. All spectra observed at 02 local time are displayed. The data are from the period day 091, 1986 through day 273, 1986.

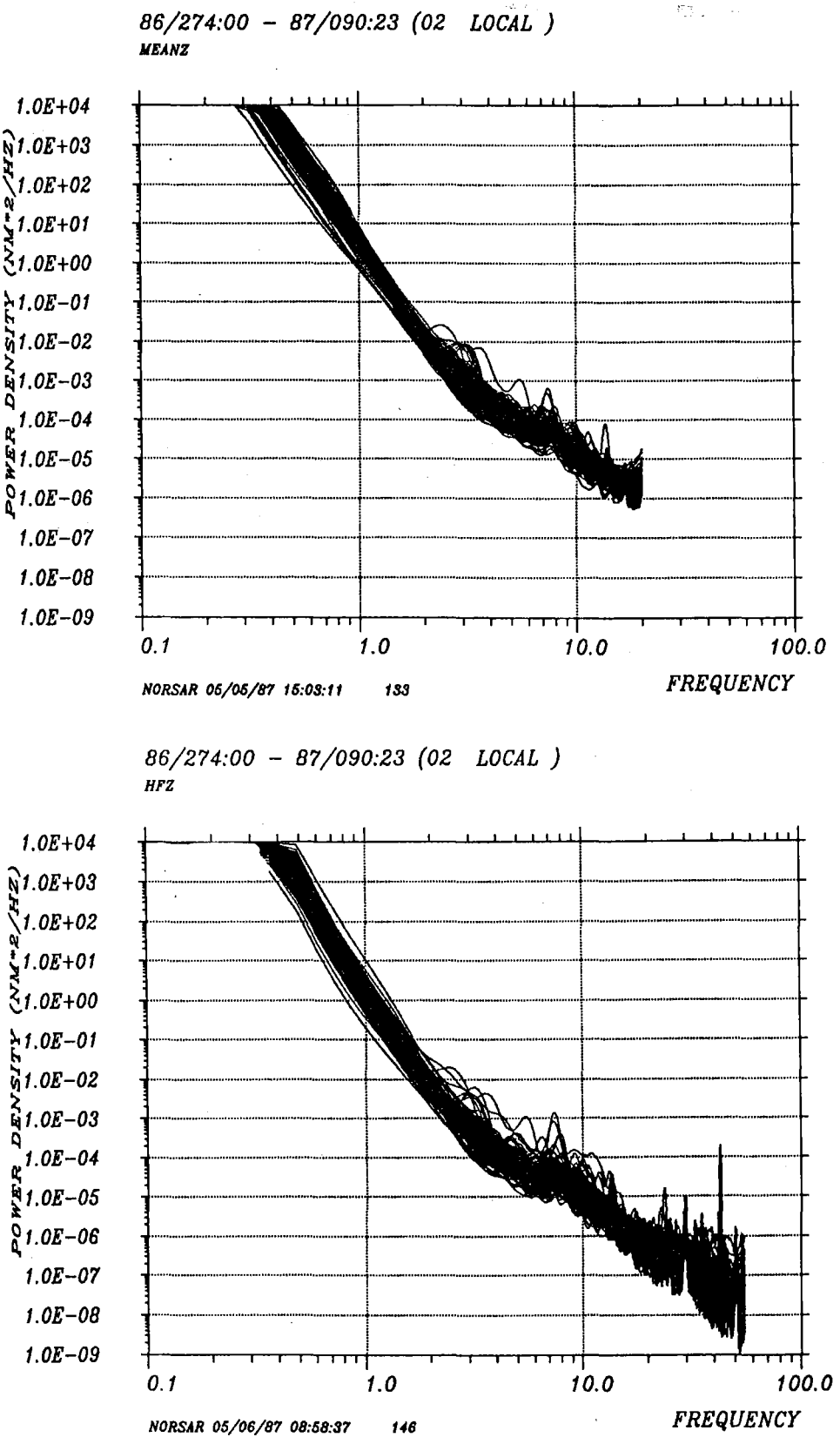


Fig. VII.2.7 NORESS corrected noise power spectra as in Fig. VII.2.4. The data are from the period day 274, 1986 through day 090, 1987.

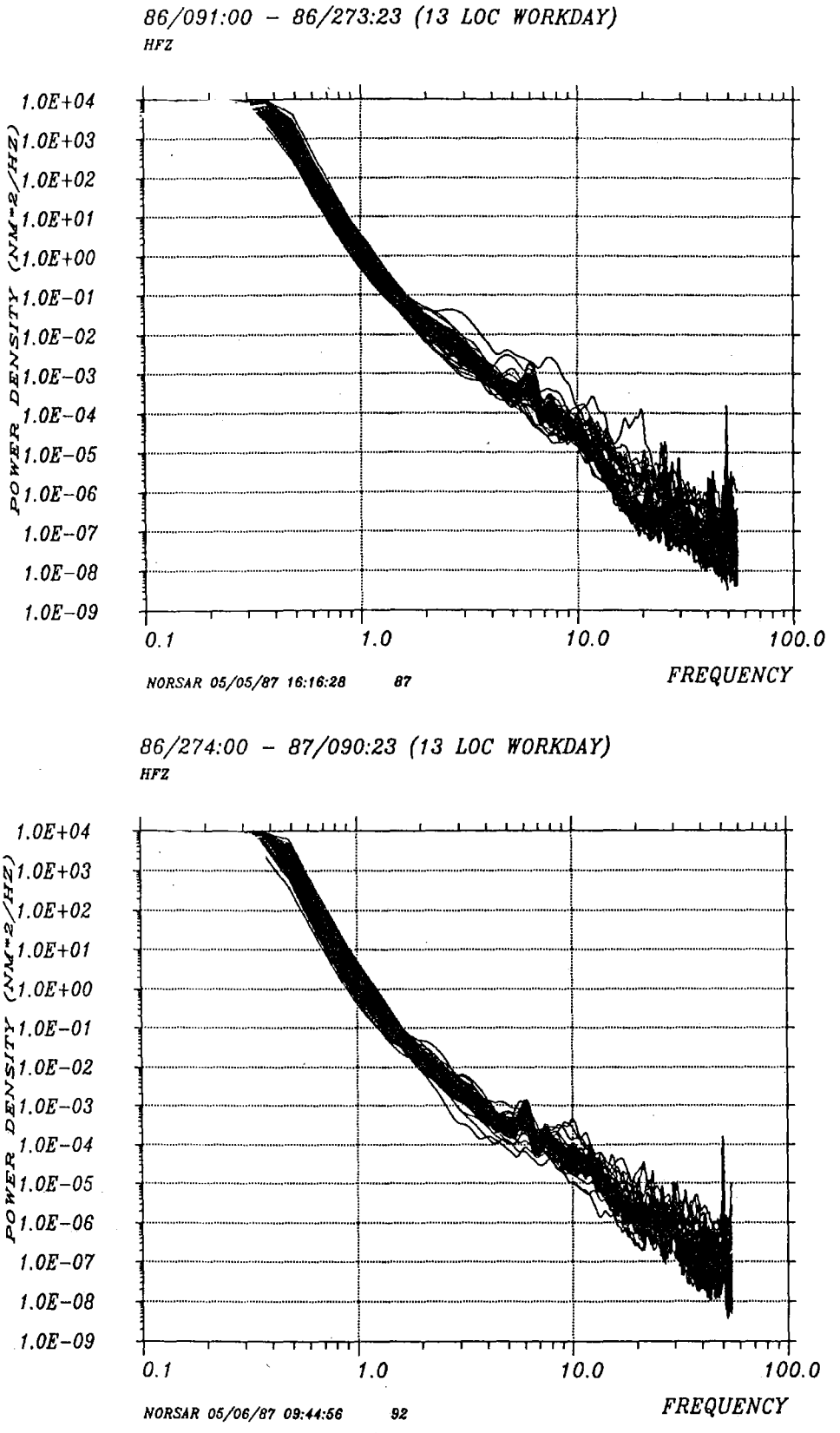


Fig. VII.2.8 NORESS corrected noise power spectra as in Fig. VII.2.4, but for local time 13 and working days only. The data are from the period day 091, 1986 through day 273, 1986 (upper part), and day 274, 1986 through day 090, 1987 (lower part).