## 3.4.10. Air Flow Oscillations

### 3.4.10.1. Existence of Oscillating Air Movements

Many attempts were made during cave visits to detect eventual periodic reversals of airflow direction or periodic changes of the magnitude of wind velocity. Analyses with smoke using incense sticks often showed that the direction of airflow reversed within one or two minutes; the readings of the anemometers also varied often periodically at the same rythm. To get a clearer picture of this phenomen, we did several fast measurement campaigns by using sampling intervals much shorter than the usual one hour interval.

The first of these campaigns was done in 1992, when neither the differential pressure sensor nor the external weatherstation were installed. As no direct measurement of air flow directions or external gusts are available, the needed information has to be inferred in an indirect manner.

If external wind blows into the cave, the difference $\Delta\rho_{12}$ between the outside air density and that at station 2 (situated only 12 m from the entrance) becomes very small; as the fresh air inflow does not extend up to station 4, the corresponding difference $\Delta\rho_{14}$ is not affected and does not change accordingly in an appreciable manner.This means that $\Delta\rho_{12}$ and $\Delta\rho_{14}$ differ much when there exists an outside gust; conversely, when $\Delta\rho_{12}$ is close to $\Delta\rho_{14}$, no external wind blows into the cave, and the only air movements are those driven by differences of air densities.

Flow direction can be detected by looking for the algebraic sign of $\Delta\rho_{14}$: a positive sign means outside air entering the cave (winter) and vice-versa. If no external gust exists, another clue is given by the variations of air temperature at station 2: if air blows out of the cave, this temperature is nearly constant, which is not the case if fresh air enters the cave.

The check for possible periodicities is done mainly by calculating its power spectral density (PSD) or the autocorrelation function: they are among the best tools available for analysing frequency spectra or common periodicities. The original FFT algorithm demands that the series length be equal to a power of two. Even if the DADiSP software used can compute the FFT for series of arbitrary length, tests have shown that in theses cases a small but noticeable spectral smearing may occur. To avoid all problems resulting from the padding of series, we always use for our analysis subsets whose lengths are a power of two. As wind velocity and pressure differences vary very quickly, we systematically apply a digital lowpass FIR (finite impulse response) filter to block out the too fast variations. A 100 point FIR with a 3dB passband ripple and a 40dB stopband attenuation is computed using the digital filter package of the DADiSP software (version 3.01b). The cutoff frequency will usually be 0.05 Hz, which means that periods shorter than 20 seconds will be discarded. Before computing the PSD, or autocorrelation, the mean is substracted and a Hamming window is routinely applied (in the case of the PSD) to the low-pass FIR-filtered signal. The following figures show this FIR filter, the magnitude of its frequency response and the result of applying the filter to a velocity sampled at 0.25 Hz.

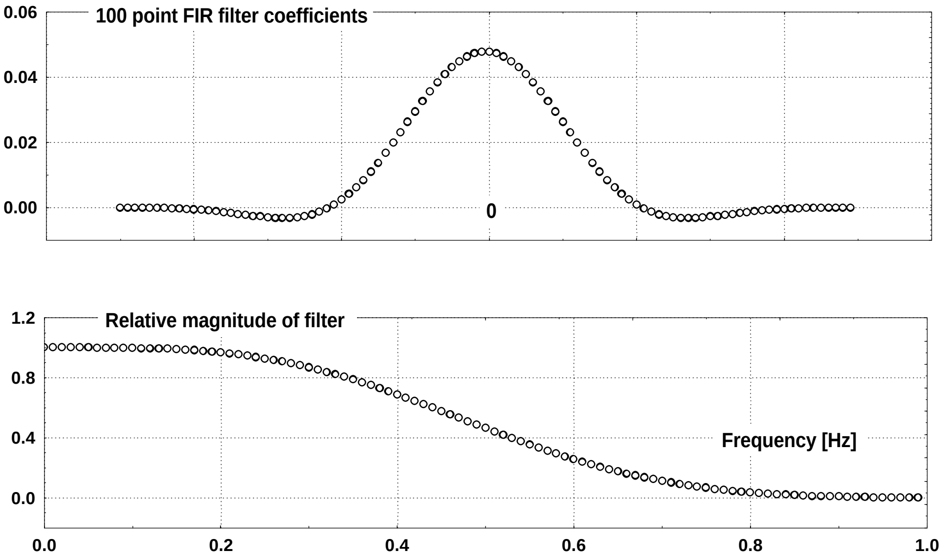


*Fig. 3.4.17. FIR digital filter: coefficients and relative magnitude*

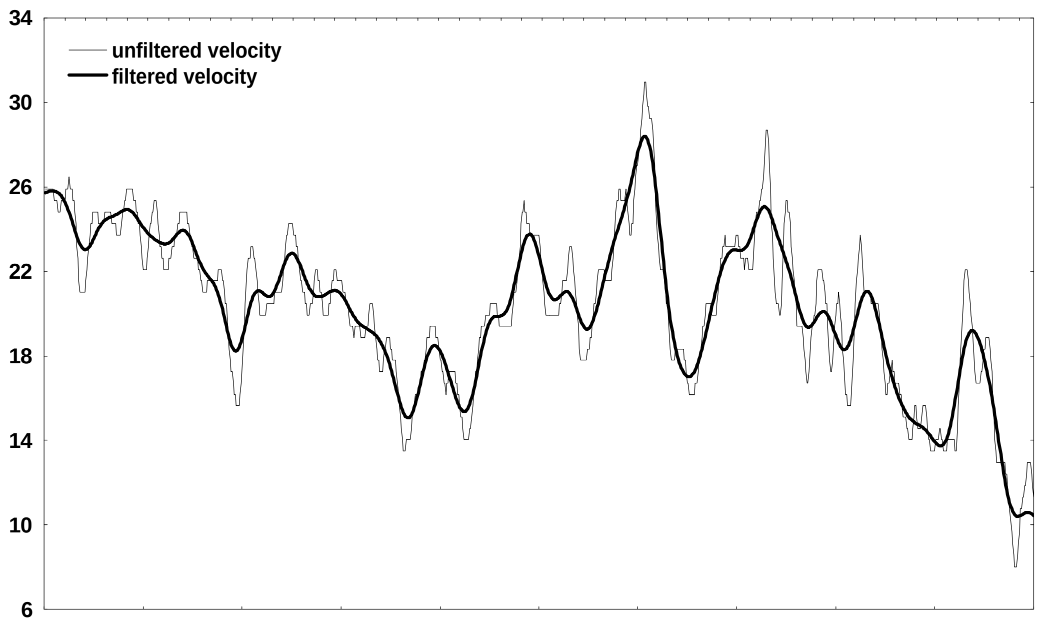


*Fig. 3.4.18. Result of digital filtering on velocity data(sampling frequency 0.15 Hz)*

### 3.4.10.2. Results of the Eight Fast Measurement Campaigns

We will now look in more detail at the 8 different fast measurement campaigns, and try to detect features common to all.

| **campaign #1** | | |
|---|---|---|
| date: | | 28 to 29 February 1992 (start: 14:30 UTC) |
| sampling rate: | | 15 Hz |
| number of samples: | | 13500; 8192 used for FFT |
| duration: | | 900 s |
| signal sampled: | | $v_2$ velocity at station 2 |
| mean outside temperature: | | 13.1°C |
| mean temp. at station 2: | | 9.1°C probably inflow |
| mean $\Delta\rho_{12}$ | -0.01650 kg/m$^3$ | negative means **inflow** |
| mean $\Delta\rho_{14}$: | -0.01248 kg/m$^3$ | small difference between $\Delta\rho_{12}$ and $\Delta\rho_{14}$ suggests no external gust |

Visual inspection of $v_2(t)$ suggests a possible periodicity; the power spectrum has two very distinct peaks at about 90 s and 48 s.

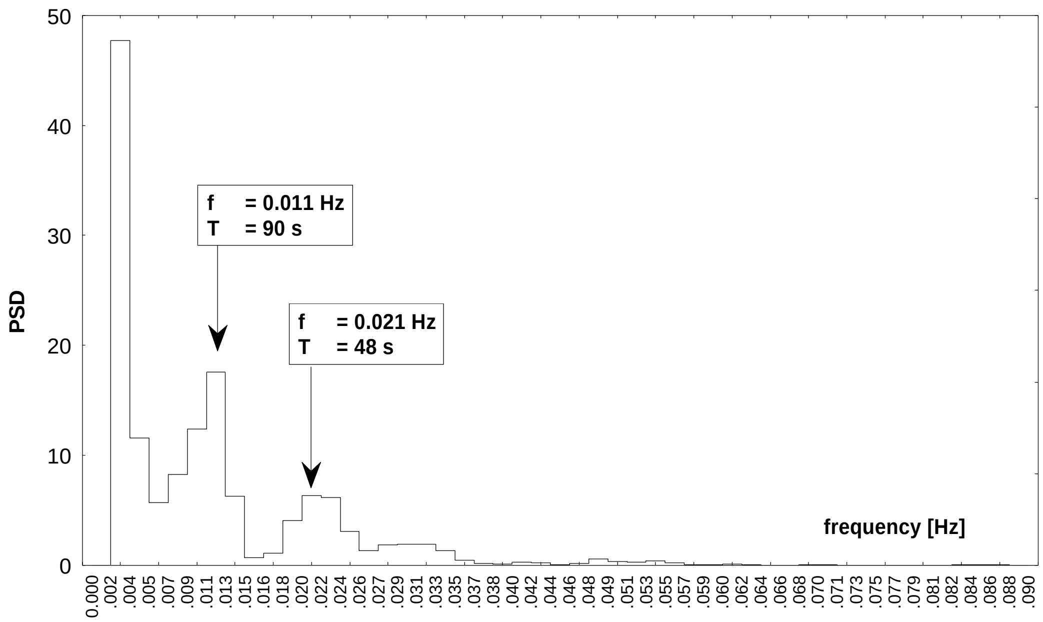


*Fig. 3.4.19. Power spectral density of velocity at station 2 shows peak at 90 s*