CORELATION ANLYSIS OF POLLUTANT CONCENTRATIONS IN HIGH AND LOW TRAFFIC URBAN AREAS

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ABSTRACT

The paper is focusing on several episodes of continuous monitoring of the air quality in different urban areas in Timisoara. Although the city is known as city of parks, the traffic is inducing dangerous pollutants, especially to the intensive traffic, old fleet and lack of modern roads or parking places. Not only CO is a problem, but also NOx and PM10, even in green areas, that are surrounded by cross roads. Correlation between the fleet intensity, as well as between the meteorological conditions and the air quality is studied, both in high intensive traffic cross roads, as well as in parks, where one expects an improved air quality.

SHORT TIME SPECTRAL ANALYSIS AS CORRELATION METHOD

In Figure 1 some representative results concerning the air quality monitoring in the city are given.

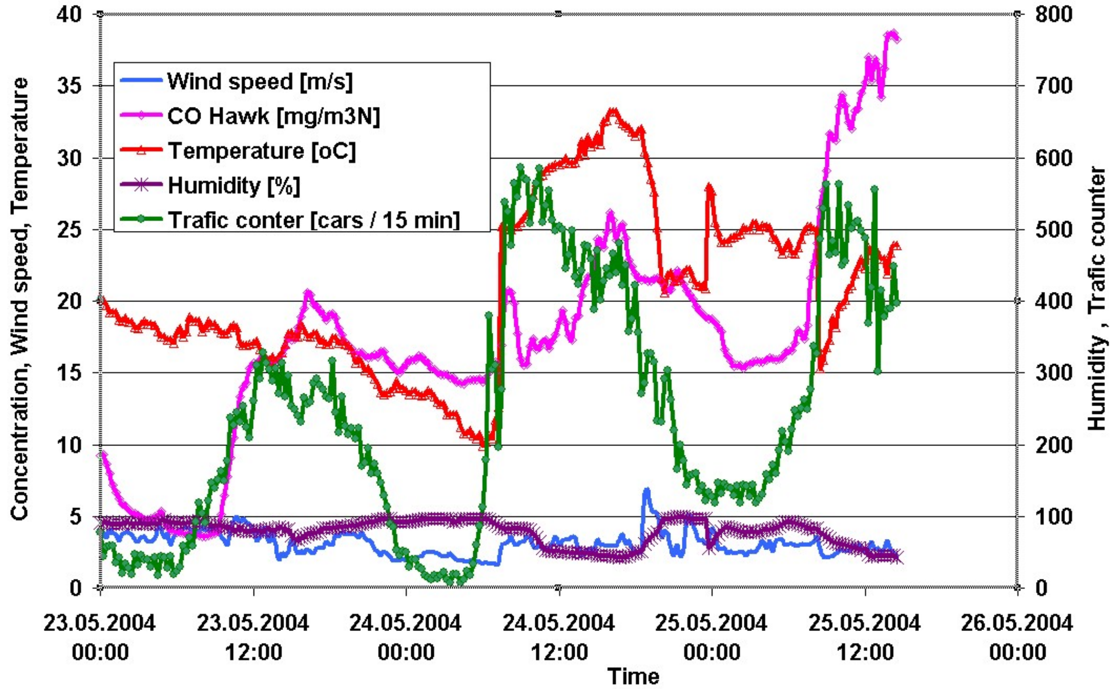

Figure 1: Time dependence of the CO concentrations, meteorological parameters & traffic.

These constitute the basis of the further analysis. From all the data of the trial one selected the day of 23.05.2004, from 00:00:00 up to 25.05.2004, at 14:44:54. Thus the sequence contains 37650 samples, measured at a sampling period of 6 sec. The frequency of the sampling is f_s = 1/6 = 0,166 Hz. According to the sampling theory, the domain for the calculated spectra will be in between f = 0 Hz ad f = $f_s/2$ =0,083 Hz.

As first impression, one notices that the fluctuations versus the mean average value are very reduced. This fact is evident also from the spectrum calculated from all the data, as presented by Figure 2. On the ordinate, one represented the log of the module of this spectra especially for putting into evidence the spectral components, at frequencies different from zero.

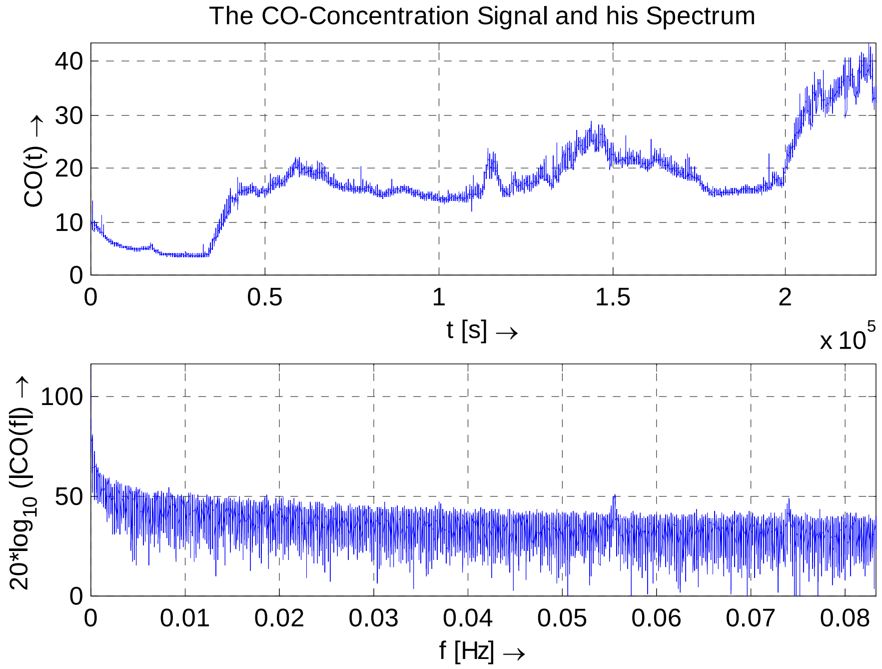

Figure 2: CO concentration signals & its spectra**.**

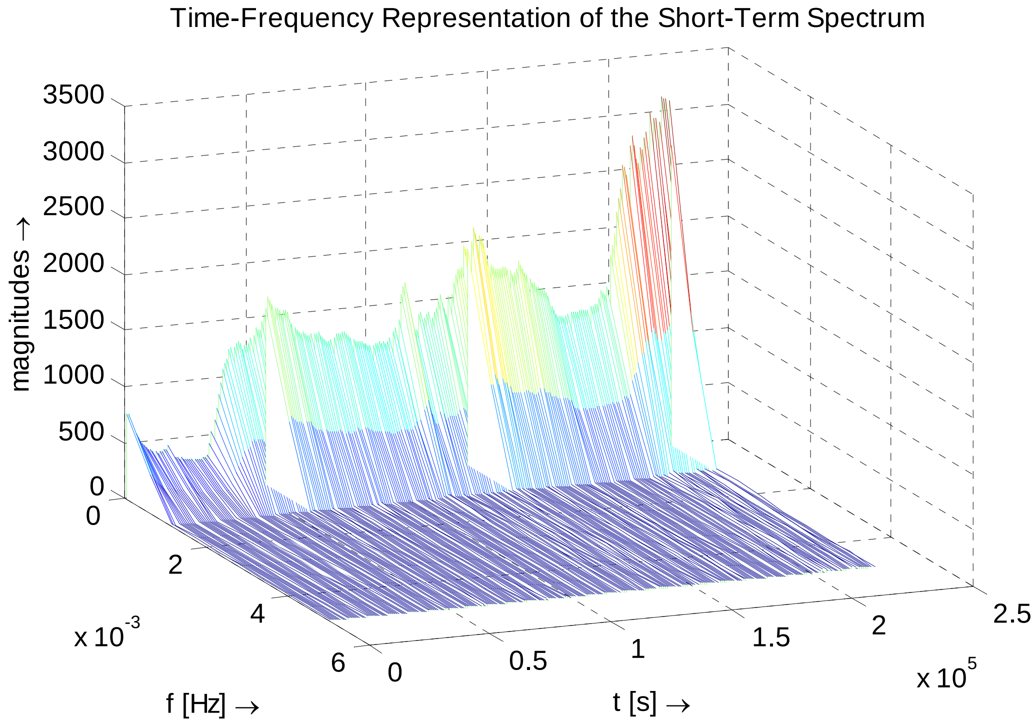

Figure 3: Time-frequency representation.

Figure 3 gives a *waterfall* representation for short-term spectra. Practically, the original signal having a duration of approximately 63 hours, was divided into 251 intervals, containing each 150 samples. The duration of such a segment is of 15 min. It contains 251 spectral profiles. Approx the first three spectral lines have evident higher values, in comparison to the rest. Thus, one decided to represent the spectra only for this first domain. The distance between two consecutive lines is of $\Delta f = (f_s/2)/150 = 5{,}5\ 10^{-3}$ Hz.

One observes, that the evolution versus time of the amplitudes for the spectral lines at a frequency of $f = 0$ corresponds (in-between a proportional approximation) to the evolution of the mean value of the measured CO signal. This representation time – frequency has the advantage that it indicates how intensively the measured values are affected by the measuring noise. In the considered case the noise is minor.

On the other hand, it shows the time dependent evolution of the mean values of the signals, as well as its spectra. The 251 values for the amplitude of the spectra at zero frequency might be further correlated with the meteorological parameters, in order to depict, which of them have larger effect on the measured pollutant concentration.

Figure 4 gives the six pairs of signals that will be correlated further (concentration, temperature, wind; velocity, traffic intensity). The level of pollution is indicated by the spectral amplitude at zero frequency (Zero-Frequency Amplitude).

The traffic influence is given by the number of vehicles/lane that has been counted during the correspondent time interval, in 15 minutes distance.

The CO concentration is given in $mg/m^3{}_N$, temperature is given in degree C, humidity in %.

The last two parameters represent the velocity of the wind along the open path direction, respectively perpendicular component versus the same direction. These projections have been calculated taking into account the 35 degrees existing between the axis of the open path instrument and the S-N direction, taken as reference by the sensor of the wind rose. Both parameters are measured in m/sec.

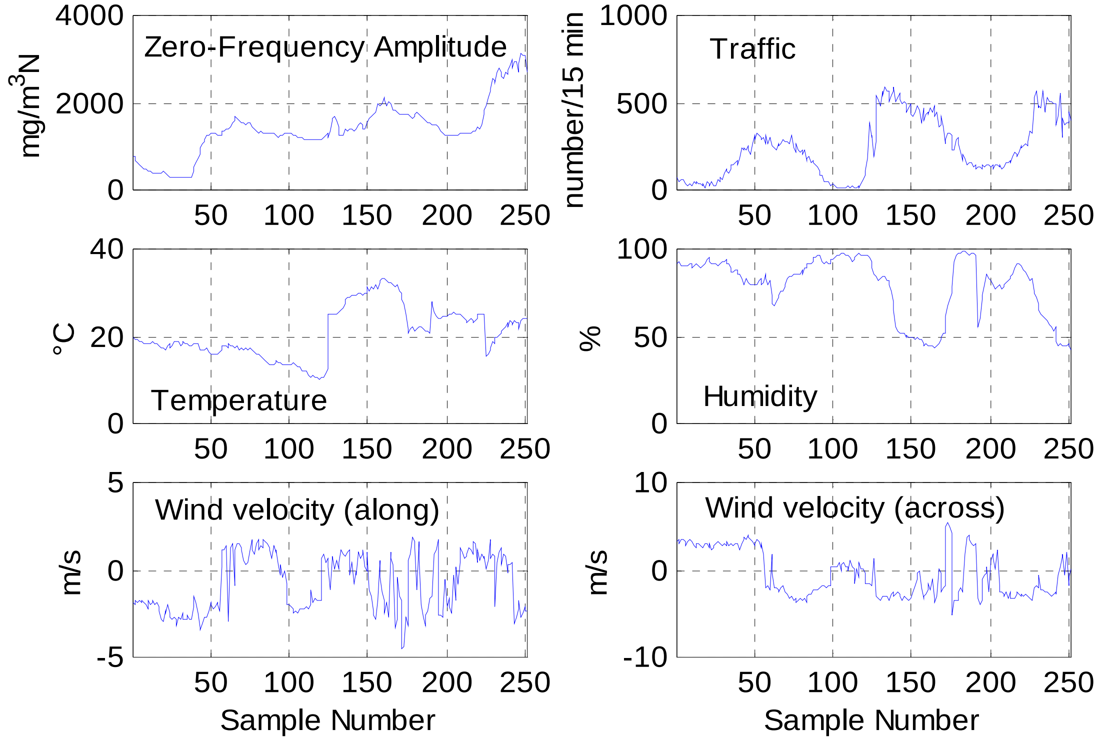

Figure 4: Pairs of parameters to be correlated.

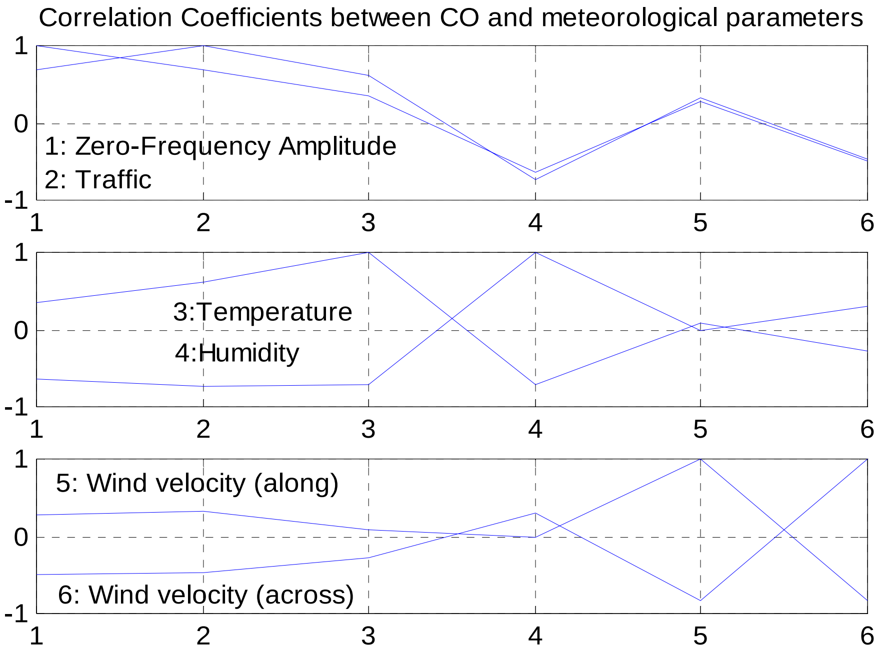

Figure 5: Correlation analysis.

In order to put into evidence of the connection between the pollution level and the meteorological parameters the correlation analysis was applied. The calculated values are given in the graphs from Figure 5.

Following comments are given:

✓ The first conclusion is that temperature and humidity are strongly negative correlated, that is very good scientific conclusion already known, from thermodynamics. The two wind components (along and cross the open path direction) are also negative correlated. This fact is found under the special conditions for overrunning 15 km/h for the wind velocity, meaning that from this value on, one may count on anti-correlation between the two wind velocity.

✓ The most evident positive correlation (0.6752) is between the traffic intensity and the level of CO pollution. Both parameters are correlated to the temperature (positive) and (negative) to the humidity. These results are also normal, as during night, the temperature decreases, humidity increases and traffic goes down, so less pollution levels are occurring [Bisorca, D., & all, 2004].

✓ The pollution level is positive correlated to the wind direction along the optical path direction, and negatively to the cross component. These influences should be interrelated regarding the open path instrument position. The explanation is that the wind component acting along the open path direction is carrying new polluting agent into the open path, and that opposite, the cross component is diluting the pollution.

✓ The short term spectral analysis is a worth full instrument, as start point for further correlation between meteorological data and pollution levels. In the second level of the analysis, one may continue on to use correlation. The excellent correlation between the traffic intensity (number of vehicles) and the pollution level is of great importance.

✓ Other factors influencing the level of pollution are temperature and the wind component along the open path direction. Contrary, humidity and the perpendicular (across) component of the wind velocity are acting in the sense of reducing the pollution (dilution) [Ionel, Ioana & all, 2004b].

RESULTS OF THE LOW PASS (LP) AND HIGH PASS (HP) FILTERING OF COMPARATIVE MEASURED CONCENTRATION SIGNALS

One will refer to another trial, accomplished in a large area, where normally no instantaneous sources interfere. Still, one had the surprise of registering with HAWK peaks, that were explained but unexpected emitting sources. HAWK did not registered them because also by its position, but also because the wind was not dispersing the CO flag towards its punctual sensor.

Due to the different measuring principles utilized by the two instruments, they do actually not measure the same physical quantity. Taking also into account the random character of the CO-concentration signals, it becomes clear that the only comparison of the measured sequences may occur only by means of a statistical one.

One will demonstrate that the correlation coefficient can be, in this case, an adequate mathematical tool. However, if one wants to reveal the common average variations of the CO-concentration levels measured by the two instruments, as well as diurnal repeatability of such tendencies, it is appropriate to calculate the correlation coefficients only for the low-pass (LP) spectral components of these signals. Using direct and inverse FFT (Fast Fourier Transformation), an ideal LP and HP filtering of the signals was performed. The cutting frequency was empirically chosen: f_c = 2 cycles/hour. As result, the LP part of the signals contains frequencies between 0 and f_c = 2 cycles/hour, while in the HP part, frequencies between f_c = 2 cycles/hour and f_{max} = 300 cycles/hour. Note that the maximal frequency f_{max} (the Nyquist frequency) corresponds to the half of the sampling frequency f_s = (1/6) Hz. The LP and HP parts of the signals are shown in the Figures 8, 9. The HP and LP of the signals are processed separately. For example *PNH1-low* and *PNH1-high* represent the LP and HP part of the signal *PNH1*. One can restore the original signal by adding the corresponding LP and HP sequences obtained after ideal filtering: *PNH1*=(*PNH1-low*) + (*PNH1-high*).

Using the correlation coefficients between the LP part of the signals measured under similar conditions (the same place and time interval for one signal pair; however, different days for different signal pairs), one can compare the tendencies of the CO-concentrations measured with the Horiba and Siemens devices, respectively. The pair of signals correspond to the "channel"-pairs (1, 2), (3, 4) and (5, 6). Correlation coefficients of the LP part of the air pollution signals represent also a good measure of the "diurnal" repetition of the CO-concentration level. This correlation is meaningful since the pair of signals were measured on consecutive days (nights) starting at the same hour.

Figure 6 presents the correlation coefficients computed for the signals PN**-low, by night.

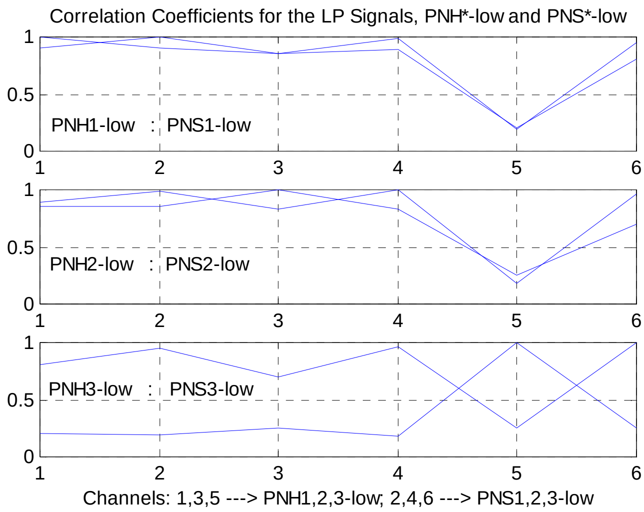

Figure 6: The correlation coefficients computed for the park signals PN**-low, by night, for both instruments.

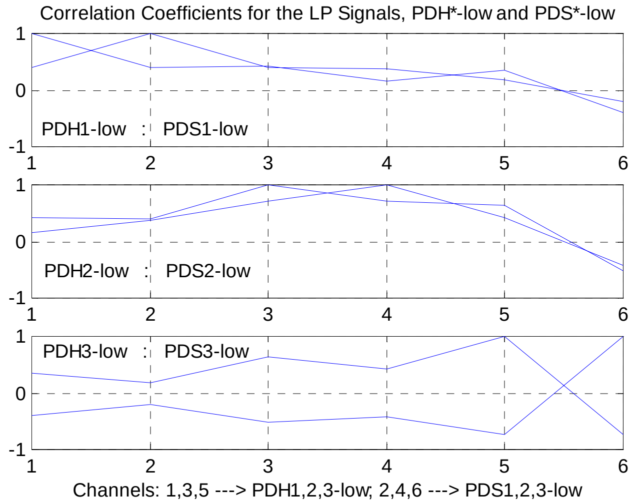

Figure 7: The correlation coefficients computed for the park signals PD**-low, by day, for both instruments.

Figure 7 highlights the correlation coefficients between the signals PD**-low, by day. The coefficients have moderate positive values with a single exception: the signal PDS3 (Channel 6) follows a decreasing tendency, in contradiction with the other five sequences.
Figure 8 indicates that there is no correlation between the signals CNH*-low, by night. The independence of these signals proves the absence of diurnal repetition of the concentrations measured with Horiba instrument. The signal CNS1-low is negatively correlated with all other sequences. However, the correlation between Channels 4 and 6 is very high, denoting good diurnal repetition.

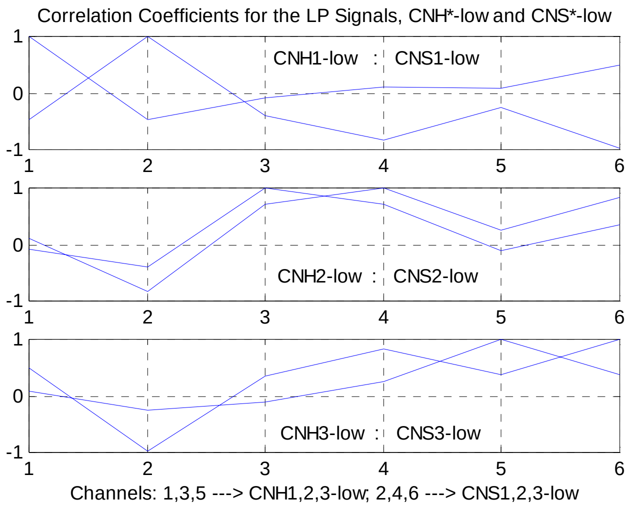

Figure 8: The correlation coefficients computed for the cross road signals CNH**-low, by night, for both instruments**.**

The correlation coefficients for the signals CD**-low by night are presented in Figure 9. As in the precedent case, the signals measured with Horiba instrument are statistically independent (absence of diurnal repetition). The signals measured with the Siemens HAWK instruments are highly correlated, denoting a diurnal repetition of CO-concentration.

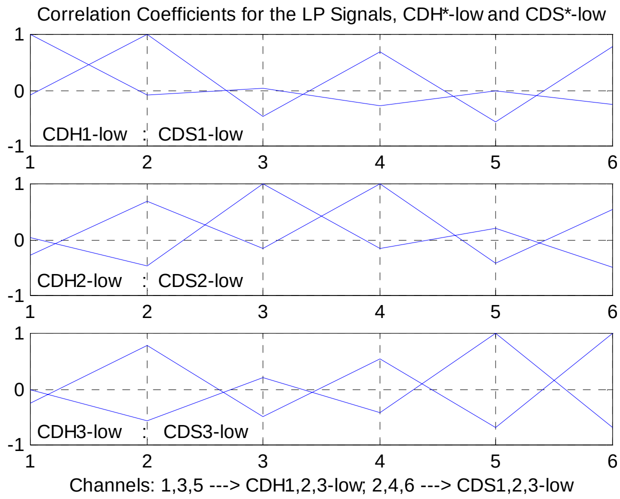

Figure 9: The correlation coefficients computed for the cross road signals LP**-low, by night, for both instruments.

Following conclusions are expressed:
(i) The pairs of signals measured in a place with low air-pollution level (park), are, with some exceptions, positively correlated. In such environments, the measured signals put into evidence diurnal repetition of the concentrations levels.
(ii) The signals measured with the point source instrument in a crossroad (high polluted medium) are practically independent, denoting absence of diurnal periodicity. In such environment, the CO-concentrations measured with the optical devices, show diurnal repetition. This is explained by the fact that concentrations measured by the open path instruments are average values, i.e. signals in which the low frequencies (denoting diurnal periodicity) are accentuated.
(iii) The HP components are having generally a stationary mean value, approximated along a zero value, as it contains both the real fluctuations of the measured signals but also the registered noise.

General conclusions

✓ One can general conclude that the correlation coefficient, when applied to the LP spectral components of measured traffic induced CO-concentrations, is a valuable tool for revealing diurnal repetition of the air-pollution levels as well as possible correlations between the CO-concentrations measured with different devices [Ionel, Ioana & all, 2004a];
✓ Another general conclusion is that the analysis of the HP part of the measured signals can bring insight into the characteristics of the measuring instruments and suggest some improvements regarding measurement planning and signal processing. However, since the coherence of the fluctuations in the signals measured with the two devices is negligible, only the analysis of the LP part of the signals can reveal correlations between the CO-concentrations measured with the two instruments;
✓ The most evident positive correlation is between the traffic intensity and the level of CO pollution. Both parameters are correlated to the temperature (positive) and (negative) to the humidity;
✓ The short term spectral analysis is a worth full instrument, as start point for further correlation between meteorological data and pollution levels;
✓ Other factors influencing the level of pollution are temperature and the wind component along the open path direction;

- ✓ Contrary, humidity and the perpendicular (across) component of the wind velocity are acting in the sense of reducing the pollution (dilution);
- ✓ Analysis of results should be done after low and high filtering (FFT) and correlation;
- ✓ HAWK is very well correlating between itself, for different episodes, at same hour. The higher the concentrations, the better the correlation;
- ✓ In urban areas where the influence of walls is larger, the noise is of less importance, because of the high influence of the air induced;
- ✓ HORIBA shows a weaker similar correlation;
- ✓ The interpretation must be made according to national standards and methods of averaging. Romania has such a legislation, with European levels.

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