CONCLUSION VERSUS BEST PRACTICE OF OPTICAL AND POINT MEASURING AIR QUALITY MEASURING INSTRUMENTS, UNDER TRAFFIC CONDITIONS

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Abstract: *The authors determined differences of the concentrations levels measured by two techniques, one nominated as optical remote sensing method, and the other as point source system. These divergences are caused by different volumes being scanned by the two methods: the remote-sensing method measures over a distance of 20-80 m, while the point-measurement method is focussing only in the middle position of the monitoring path, thus reflecting the local level of pollution, on this special location. This means that mobile pollutant sources are affecting the sensors of both instruments, at different time The IR DOAS long-path method reflects more the pollution along the path, while the stationary measuring point (NDIR) records the pollution in one point.*

Keywords: remote sensing evaluation, point source measuring instruments, air quality, trafiic, correlation factors, best practice

Introduction

Ever since the publication of Limits to Growth, there has been no excuse for not recognising that exponential growth in energy consumption on industrial, energetic and traffic domain, population and pollution can not be sustained in a world with finite resources and a finite capacity to digest the waste products of our civilisation. Yet people desperately want growth and are not content to reach steady state at current levels. Illness or premature death due to wholly or in part to air pollution places a great burden upon society by way of increased costs of medical treatment and through the loss of manpower. In addition, air pollution adversely affects soil, water, crops, vegetation, human-made materials, buildings, animals, wildlife, weather, climate, and transportation, as well as reducing economic values, personal comfort and well being.One of the criteria set for the country to enter the European Community consists specially in solving environmental protection issues and equalising the national standards to European ones. As part of this initiative a European consortium has been formed within Framework 5’s Competitive and Sustainable Growth program to carry out a project on Remote Optical Sensing Evaluation (ROSE) [5]. The University of Timisoara was one of the partners, mainly involved in accomplishing comparative measurements with a point source instrument and an optical one [10], [6] and brought its contribution within the general spirit.

General description of the measuring method

One organised eleven campaigns, planning where to measure & locate the instruments, using the numerical modeling [1], [2], [4], [8], [9], [10]. The trials referred to continuous field monitoring. In order to make an interpretation of the results, one used the correlation analysis, to get reliable information about the trust. All national and European legislation has been respected, for mounting and selecting the instruments and their analyzing methods [3], [6], [7].Of great help was the data acquisition system with 16 analogue channels, consisting of a special hardware and a PC, that were able to register in real time, and simultaneously, the inputs from the:

(i) Meteorological sensors: temperature, wind rose and speed, air humidity, solar radiation, atmospheric pressure, (ii) Traffic counters VEK M4C-E with 4 coupling loops,

(iii) Air quality monitors: SO_2, NO, NO_2, NO_X, with special concern paid to parallel CO monitoring, using a ND-IR analyser & an IR DOAS instrument (optical paths 20-80 m).

The used point measuring instruments were:

(i) The NO_x measuring apparatus Monitor Labs 8840 working with chemiluminiscence,

(ii) The Monitor Labs 8850S for SO_2, working in UV,

(iii) Particle sampler LVS3 for PM10,

(iv) HORIBA APMA-350E monitor for CO, working ND in IR (called classic) and working according to ISO 4224.

For remote control one used the IR Hawk instrument from Siemens Environ. Systems configured to detect CO, representing an open path monitor working in infrared (IR) and applying Differential Optical Absorption Spectroscopy (DOAS). Optical paths ranging from 26 to 50 m have been successfully used. The relative positioning between the point source detection and the long path optical length was different, one tried to place it as much more in the middle, but it was not possible because of lack of cables and restriction imposed by the trial or averaging-measuring condition, in respect to the Romania legislation.

In Figure 1 a schematic of the assembly is presented. Figure 2 gives images of the meteorological mast, and the screen shoot of the monitor indicating the data acquisition, in real time, continuously, as well as details of the instruments, inside the station.

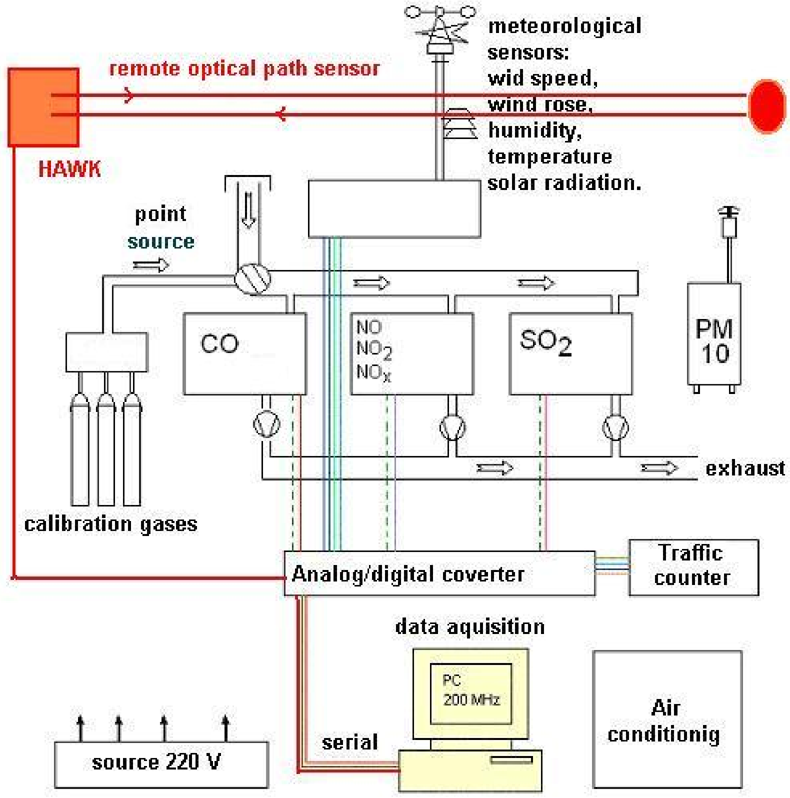

Figure 1: Schematics of the entire monitoring station.

One of the most representative trial refers to a cross road situated at the entrance-exit from Timisoara (Figure 3). On several lanes one installed traffic counters, that recorded the number of vehicles, in order to allow further on a correlation between traffic data and pollution levels.

Figure 2: images of the meteorological mast and the screen shoot of the monitor indicating the data acquisition, in real time & continuously.

Figure 3: Details considering the localisation of the trial and the wind rose, mounting of the instruments and the traffic counter.

Results and Short time spectral analysis

In Figure 4 some representative results are given.

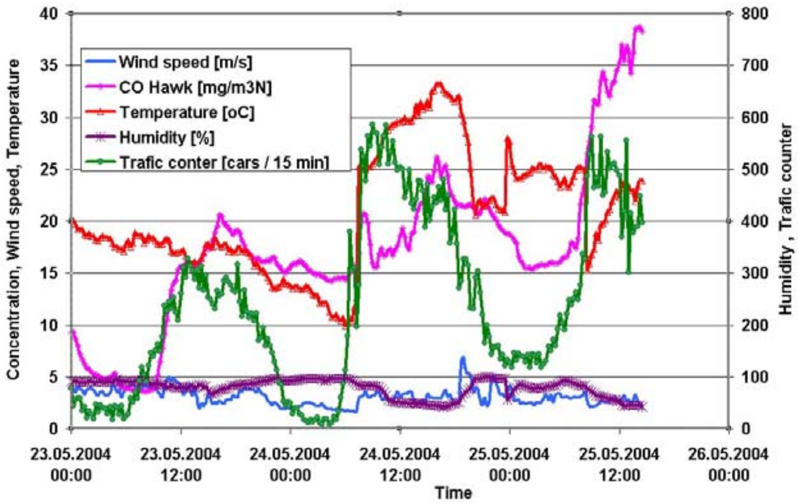

Figure 4: Time dependence of the CO concentrations, meteorological parameters & traffic.

From all the data of the trial one selected thouse from the day 23.05.2004, strating 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.
Figure 5 gives the six pairs of signals that were correlated further according the concentration, temperature, wind; velocity, and traffic intensity.

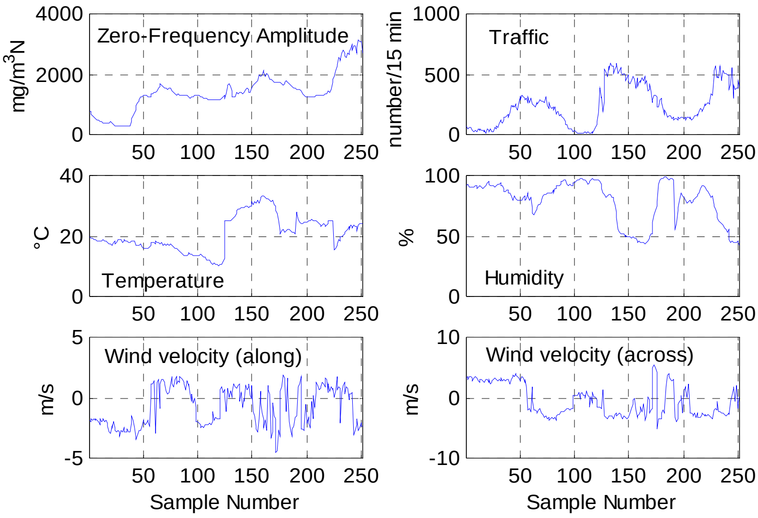

Figure 5: Pairs of parameters to be correlated.

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.

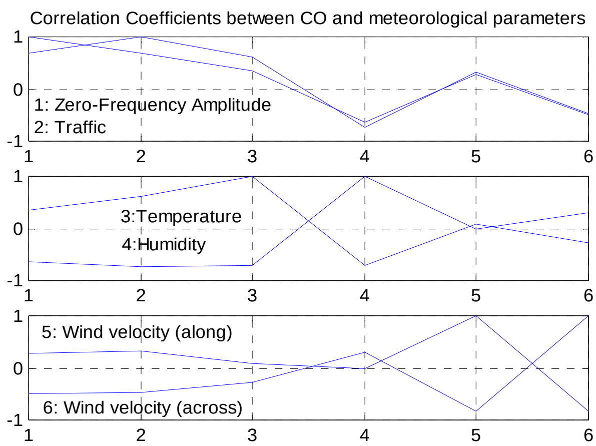

Figure 6: Correlation analysis.

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 6. Details for the used method and theory are given in [13], [5], [9], [14].

Conclusions driven from the correlation analysis

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 [11].
- 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) [14].

Conclusions versus the air quality

The incidence of motor vehicles has emerged as a critical source of urban air pollution. The associated human health and welfare costs run into a huge value of €, and far exceeds the prevention costs in terms of the control measures [17]. Figure 7 and 8 give main results concerning the air quality (represented by the CO concentrations) measured with both systems, in urban area, during summer, winter, spring or autumn episodes, as achieved in the city of Timisoara. In accordance also to other measurements of the authors reported in [14], [15], [7] one concludes:

1. Air quality in the city is determined generally by traffic. Peaks over the limits are recorded for short intervals.
2. Parks are much cleaner areas, but they might be also affected and endangered by high traffic from vicinity.
3. Calibration needed was different for the two systems.
4. Optical instruments are much more appropriate for rapid air quality modifications.
5. Point sources are referring only to this special area, even if all indications from air quality measurement standards are used.
6. In order to get best results one has to analyse in advance the location of the instruments.
7. For analysing, suitable intervals have to be selected, in order to get concluding and meaningful results.

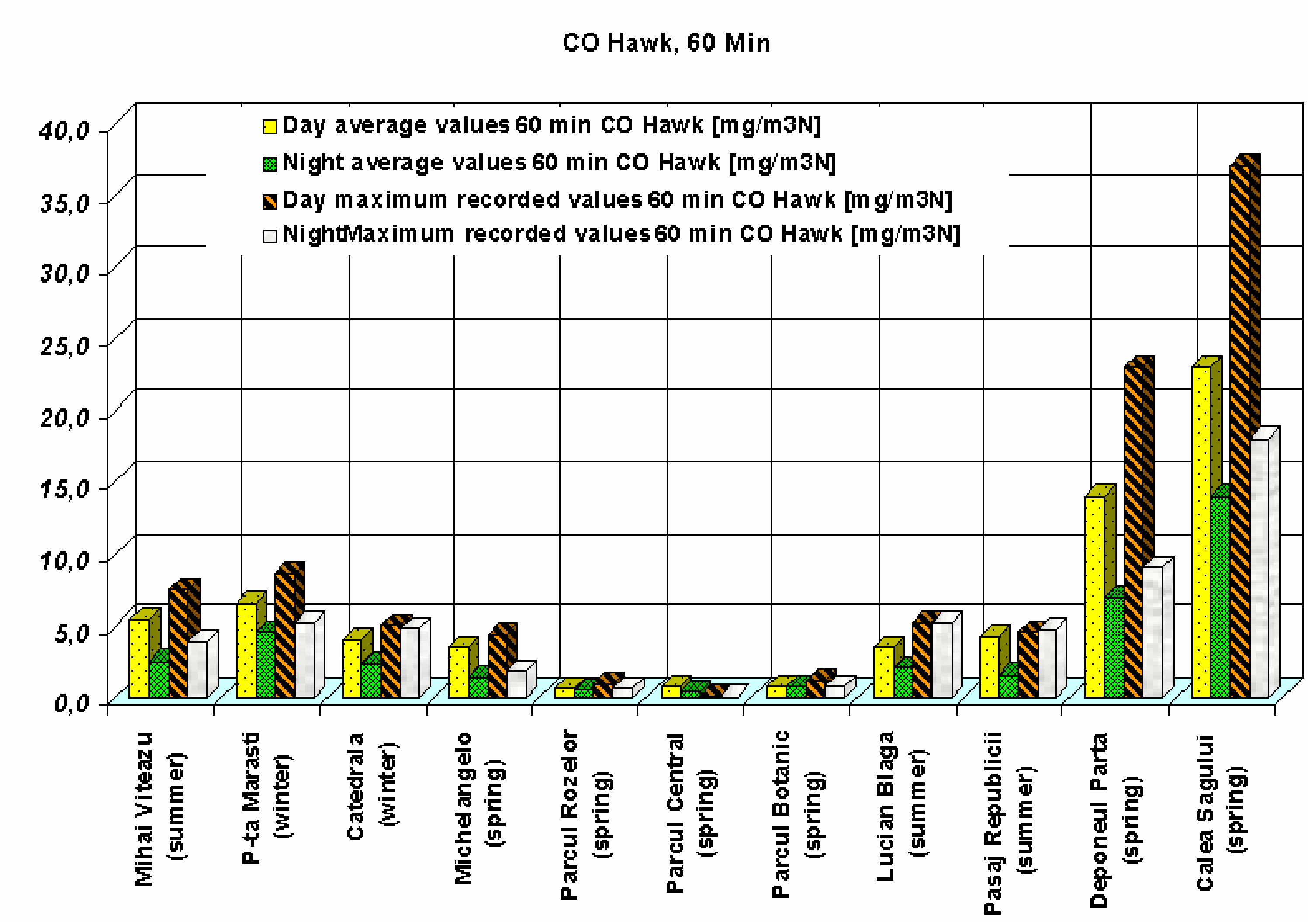

Figure 7: CO mean values for 60 min, and maximal values, indicated by the optical path instrument HAWK, during various campaigns accomplished n Timisoara, consisting of over 120 days of continuous on line measurements.

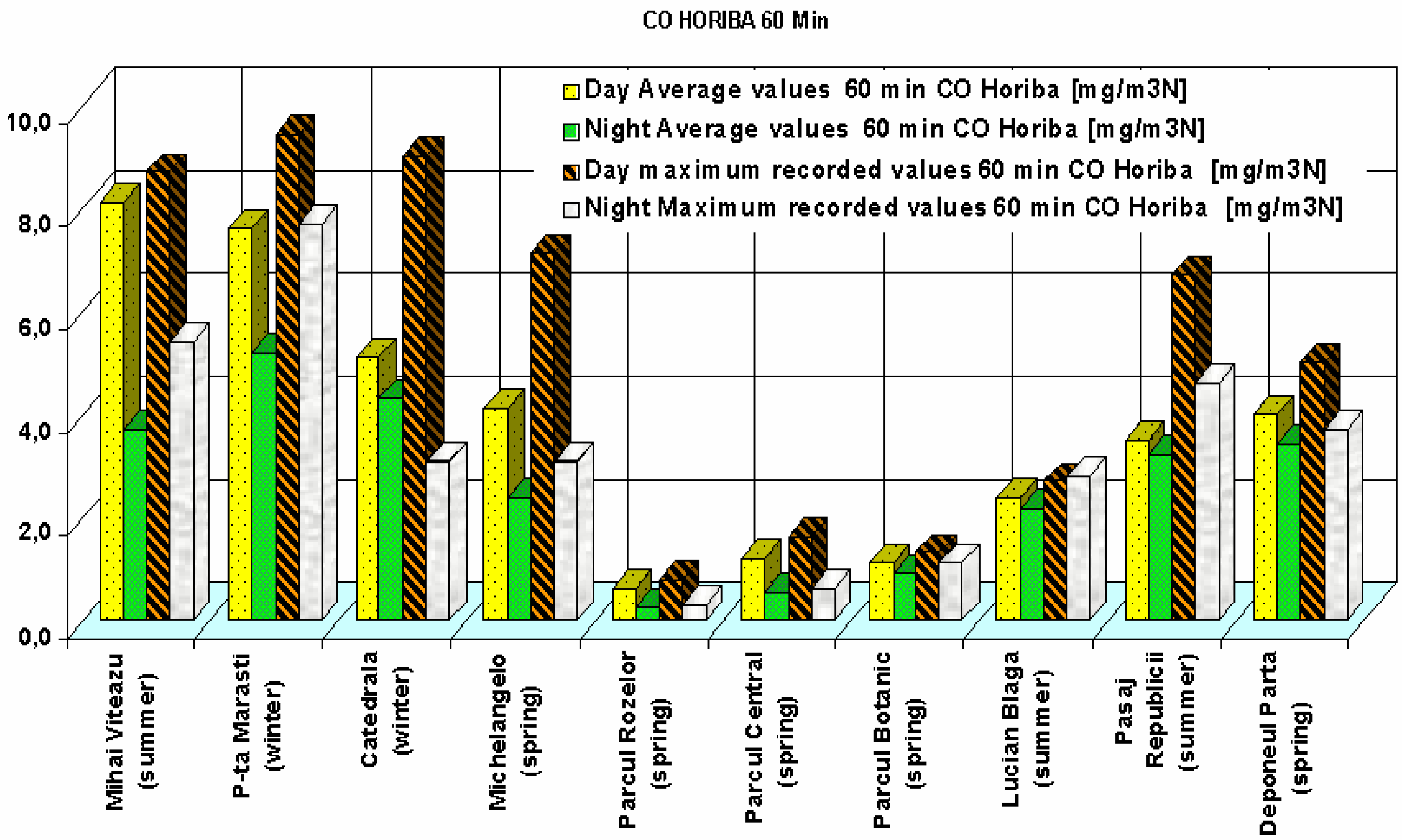

Figure 8 CO mean values for 60 min, and maximal values, indicated by the classic point source instrument HORIBA, during various campaigns accomplished in Timisoara, consisting of over 120 days of continuous on line measurements.

Conclusion versus best practice

One demonstrated thus, that the main *advantages of open path instruments* are:

- Reduced price for calibration, maintenance and buying of the open path instrument, comparative to classical instruments;
- No calibration gases needed during regular campaigns;
- Identification of a spatial distributed pollution value trough the open path methods;
- Selectivity at high accuracy;
- Real time measurements, appropriate for accidental alarming in case of special events of dangerous components release, even if the intensity is of reduced extension;
- Possibility of working in open or closed spaces, as well monitoring for vertically and horizontally applications, if turbulences are known;
- Higher the open path, more accuracy for the measuring results obtained;
- Minimal interference chance to other components, once an apparatus is working for a specific range;
- Sufficient good correlation, sometimes better, with classical methods, when using the intervals for mean values, as the legislation is indicating;
- No great influence regarding radiation, temperature or pressure variation in an urban area;
- Appropriate for urban area air quality measurements, not sensible to air temperature fluctuation, need of constant acclimatisation of the van;
- Good correlation for the repeatability of the signals (better as for classic apparatus).

Disadvantages of open path instruments were also noticed and concluded in the following:

- For a good result a very careful positioning of the optical apparatus is needed, influence of turbulences, distribution of the pollutant clouds, etc., depending on the topography and meteorological conditions, on spot;
- Canyon streets are not very suitable if the position is not very clearly analysed, better industrial area, analysis of traffic induced pollution (superficial sources), parks, gardens are more appropriate examples;
- Manual alignment is necessary and this gets lost at vibrations, meteorological changes, thus a periodic check is recommended;
- Only one (unique) specie is identified;
- Appropriate sampling frequency;
- Sensibility to humidity variation (fog), to the instability of the climate (humidity, vibration), corrections are needed currently when turbulent factors occur;
- A very stable support for the entire instrument is needed;
- Qualified personnel for establishing the position of the optical paths and instrument, alignment, survey, data recording and interpretations;
- If in the open path interferences with particle loaded clouds or other mechanical turbulences, results are obstructed;
- HAWK is very sensible to vibrations, its alignment is destroyed, and then the signals are distortional;
- The extreme temperatures (very high and very low), that occurred during the campaigns are to be avoided by air conditioning (heating or cooling) so that inside the tent, where the data acquisition system and also the classic CO Horiba recorder are placed, the temperatures should not exceed the interval +5 to +15 ºC;
- Humidity in excess (fog) is introducing artefacts, for both apparatus, H2O is interfering in the output signal.

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