17th International Conference on
Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes
9-12 May 2016, Budapest, Hungary

ANALYSIS OF THE DAILY CYCLES IN THE DATA ON AIR POLLUTION THROUGH THE USE OF ADVANCED ANALYTICAL TOOLS

Marija Zlata Božnar[1], Boštjan Grašič[1], Primož Mlakar[1], Dejan Gradišar[2] and Juš Kocijan[2,3]

[1]MEIS d.o.o., Mali Vrh pri Šmarju, Slovenija
[2]Jožef Stefan Institute, Ljubljana, Slovenija,
[3]University of Nova Gorica, Nova Gorica, Slovenija,

Abstract: From a temporal viewpoint, air pollution has significant daily patterns/cycles of behaviour. Daily patterns are highly expressed especially in case of ground-level ozone pollution, pollution caused by the domestic heating with solid fuels (in particular in the event of the exploitation of wood biomass in various forms), and in case of pollution caused by traffic, when it comes to traffic due to commuters.

These cycles are partly conditioned by anthropogenic reasons as is the case with traffic and domestic heating systems, and partly by natural phenomena. In both cases, a detailed observation and an understanding the daily cycles rules or daily patterns of air pollution can be significant and at the same time can contribute to more effective measures to reduce the harmful impact of air pollution on human health. The measures are more effective when they are designed more targeted to specific parts of the population and for concrete measures of avoiding the harmful effects of air pollution.

In this article, we will first present the advanced analytical tools, the "sunflower" graph, which was developed for the analysis of the characteristics of the daily cycles of meteorological data, data on air pollution and other related content. The "sunflower" graph is a double radial frequency diagram, which allows the plotting of samples for analysed time periods of different lengths. The key advantage is the ease of understanding the result and the ability to present information in the form of a graphic pattern, allowing the user to quickly understand the content that would otherwise be required to be represented by a plurality of unclear numerical data.

Using the "sunflower" tool, we will present an analysis of the meteorological parameters that are important for the understanding of air pollution and air pollution data for different locations in Slovenia.

Key words: *daily cycles, analysis tool, sunflower, air pollution flower, weather flower, wind flower*

INTRODUCTION

Numerous processes in nature have a diurnal cycle. Firstly, this applies to basic meteorological processes that describe the processes in the atmosphere. These processes subsequently also affect the processes of atmospheric pollution. When exploring the entire atmospheric pollution cycle, many emissions already have a distinctive diurnal cycle (such as emissions from traffic and domestic heating sources). Moreover, everyone is already familiar with the diurnal cycle of the ozone, when we speak about the concentrations in the lower atmosphere. In order to understand, and subsequently reduce the bad influence of pollutants on the health of people, it is necessary to recognize such diurnal cycles with concentrations in the atmosphere, and to present them in a manner which is easily understandable to the lay public. An understandable presentation of atmospheric pollution is one of the preconditions for people to be able to organize their daily activities in a way to minimize our exposure to polluted air, if we cannot eliminate the pollution entirely.

Researchers of atmospheric pollution usually dedicate too much attention to the aspect which is interesting merely to us, namely the statistical analysis and the presentation of the concentration of pollutants in the atmosphere. This aspect is mainly dictated by regulatory requirements (e.g. EU directives), and we keep forgetting the aspect of presenting the statistics to the final users (exposed population). Thus, MEIS has defined a new way of a graphical method of analysis, which is suitable for a statistical analysis of diurnal cycles. We called the basic graph the “sunflower”. In this paper, we will firstly present this graph, and subsequently demonstrate a few cases, how this graph may be useful in statistical analysing, and for the presentation of the data about the concentration of pollutants in selected locations.

METHODOLOGY

We firstly encountered the problem, i.e. seeking an appropriate presentation of diurnal cycles, when we studied the meteorological variables – global solar radiation. We defined a new way of a graphical method of analysis, which we called the “sunflower”. A detailed definition of the method is available in the paper (Božnar et al., 2015). The objective of this chart is an explicit graphical presentation of the characteristics of the diurnal cycle of the observed environmental parameter. A graphical display of the characteristics allows a quick perception of the information. It is even more important that people are mainly trained in a way that they are able to easily find both similarities and differences in the details between two more or less similar images. Such similarities and differences are of course noticed much faster on an image than in a numerical table chart.

The example of two sunflower graphs is presented in Figure 1. On the left, we can see the analysis of the measured half-hour data for January 2015, for the global solar radiation at the Pustice station in the continental part of Slovenia. On the right, we can see the same analysis for July 2015. The sunflower is actually a double circular histogram. The course of preparation of this chart will be presented with the case of global solar radiation measurements. Firstly, we have to sort all the measurement values into groups for each hour of the day, namely into groups from 1 to 24, whereby a measurement must be sorted in the interval (each interval is independent), when the measurements were actually taken, and the interval mark is the full hour mark at the end of the interval. Each given group is then separately presented in the form of a spike (segment) on the sunflower graph in the direction from the centre towards the appropriate time. Measurements performed within one class for each individual hour are subsequently sorted into classes by values. We selected 8 value classes with solar radiation, which are presented on the graphical legend besides the graph. The boundaries between the classes are chosen so that they are reasonably adapted to the problem under consideration. In this case the values under $5W/m^2$ are sorted in the class “darkness”, which is presented in the centre of the diagram as a share in %. This central class consists of all the values which are not interesting for the analysis of the daily cycle (darkness in this case, when there is no solar radiation). In the other classes, which are presented on a spike, we sort out the values on a scale from the lowest borderline to the highest expected value, however, the last class may be left open in the upward direction (as is the case in the figure for the values above $1,100W/m^2$), when we expect only a few very large values. Each individual value class on the figure is presented as a spike section of a clock in its own time class. Hereby, all the individual spike parts are aligned on a virtual radial line running from the centre point to the mark of the corresponding time on the outer circle of a circular graph. Each value class has its own codifying colour, in the event potentially black/white image reproductions, we present the values also with the width of the spike section. The length of the spike section is proportional to the percentage of the class in comparison to the whole. The whole is identified as a number of all (mark besides the graph: “all”) measurement intervals, which occur from the beginning of the statistical interval until the end. This interval for the statistical treatment is written beside the graph in the form of a date. Specifically, it makes sense to also write how many of the used measurement values were useful (“good”) and how many of them were unknown and incorrect (“unknown”).

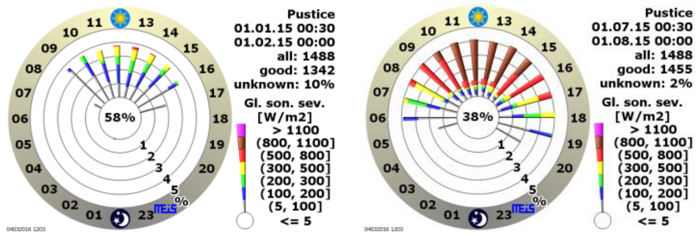


Figure 1. On the left, we can see the analysis of the measured half-hour data for January 2015, for the global solar radiation at the Pustice station in the continental part of Slovenia. On the right, we can see the same analysis for July 2015.

In the final figure (case of the left or right image in Figure 1) we may clearly see the representation of individual global solar radiation value classes by the hours of the day. In the winter month of January, we have a relatively short period of the light of the day (from 7a.m. to 5p.m.), thus interesting value classes are visible only in these hours. We do not indicate clock spikes during the night time, but present their measurement values together for all the hours as a part of the whole, indicated in the centre of the graph. However, the bright part of the day in the July sunflower is evidently longer, according to the colour scale, we can also see the highest values. The representation of the value classes by individual hours determines the natural course of the global solar radiation deviations from the theoreticaly expected course. It indicates when on average a cloud or fog reduces the global solar radiation, which penetrates to the ground. On the way, as we have just described the presentation of the global solar radiation on the "sunflower" graph, we can introduce other variables. Unlike traditional wind rose, with the help of this wind flower we are able to give the wind speed (i.e. categorization of absolute speed in classes and by hours without considering the direction of the wind) or any other data on the concentration of atmospheric pollutants for the chosen location and the pollutant. It is also important that the statistical interval expressed with the sunflower is at least a day long if possible, but it does not have any limitations regarding the duration (day, week, month, quarter as a season, year, several years etc.). The sunflower graph and the air pollution flowers are very appropriate for the comparison of the daily statistics not only between various periods of time but also between various locations (e.g. for the same month between various locations across the country). Such cases will be shown below.

RESULTS

In Figure 2 we present an analysis of the PM_{10} measured values for the town of Zagorje on a complex terrain in central Slovenia. The analysis comprises daily cycles which were measured every 30 minutes for a period of one year. We created air pollution flowers for each individual month. Thus, we are able to quickly determine the information on various daily pollution patterns for various parts of the year. Zagorje is a place in a narrow half-closed valley, which partly expands to a basin, the winds are weak and thermal inversions are common during the winter. Particle pollution comes from the traffic, local heating sources, and the production of lime (Božnar et al., 2014, Mlakar et al., 2012). The figures show in a very clear and graphical way the following information about typical daily air pollution regimes with PM_{10}: Firstly, the yellow and brown spikes present relatively high concentrations; green, blue and grey spices consequentially show more and more clean air. Very clean air as a share in every interval is also presented in the centre of each air pollution flower. Firstly, we see that during the winter months from December to February inclusively, the pollution is pronounced during the entire day, the highest values in December and January occur in the late afternoon and last until midnight, or an hour longer, which indicates that they are most likely due to heating (people start the heating when they return home from work). The opposite of this are the months of June, July and August, when the air is more or less clear for the major part of the day, a few higher concentrations may be noticed in the late afternoon, from 3p.m. to 8p.m., which indicates the influence of the traffic (the station is located very close to the main road through the town). In the spring and autumn, we can notice the transition from one described daily pollution pattern to another. Figure 3 presents the measurements for 8 individual consecutive days for PM_{10} in the town of Celje, which also lies in central Slovenia. If we use the air pollution flower graph for individual days, we are able to monitor very precisely when in a day and in a week, high and low concentrations occurred, and are thus more able to find the reasons for them (or confirm the hypotheses about their origin when we do not have a spatial model in a sufficiently precise spatial and time resolution). The lay public may use it for planning when to let fresh air into their houses, and outdoor activities.

Figure 4 presents the air pollution flower graph for ozone and NO_2 for two selected months; both graphs indicate these two pollutants in Celje, where the station is located in the centre of the town, where the impact of urban transport is felt. The scales on the display for ozone and NO_2 are chosen in a way that we notice only increased concentrations. A daily pollution with NO_2 is clearly visible both for April and September, and the elevated values follow the expected increase in the urban traffic during rush hours both in the morning and late afternoon. However, the picture is complementary with the ozone, as is apparent from the well-known cycle of formation and decomposition of ozone due to solar radiation and ozone precursors, among which, NO and NO_2 are also very important. The two graphs for ozone and NO_2 for the same month show the complementarity between the ozone and NO_2. Exceedingly high concentrations of both are not present together at the same time. The air pollution flower graph for NO_2 and ozone vary from the PM_{10} air pollution flower graphs, indicating that the elevated concentrations hardly occur during some hours of the day, which is clearly visible by the fact that the spikes at these hours are significantly shorter than those when the pollution is significant (if the concentrations occur in the clean air class, their presence on the graph is indicated in the numerically written share in the middle of the circle, however, they are not present as parts of the spikes).

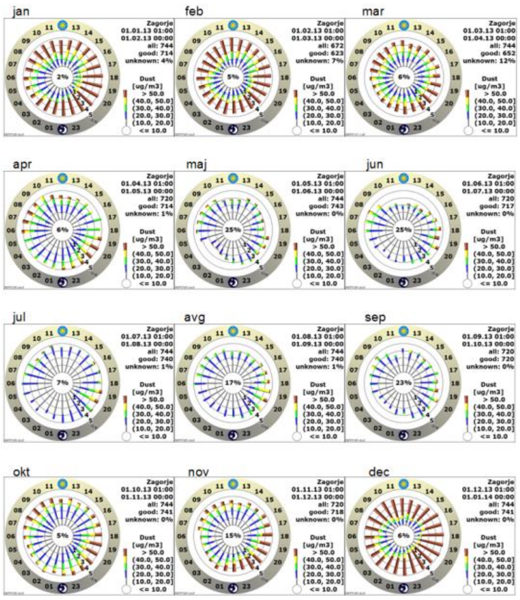


Figure 2. Analysis PM_{10} measured values (dust) for Zagorje on a complex terrain in central Slovenia. The analysis comprises the daily cycles which were measured every 30 minutes for a period of one year (2013). We created air pollution flowers for each individual month.

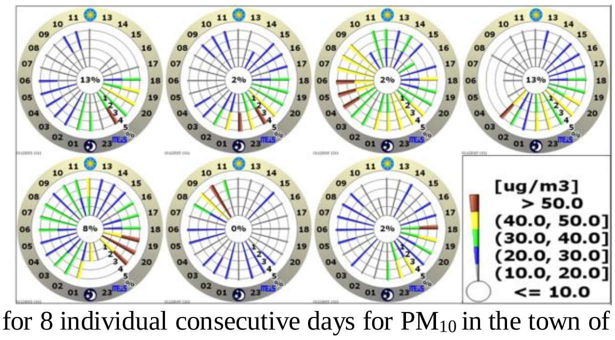
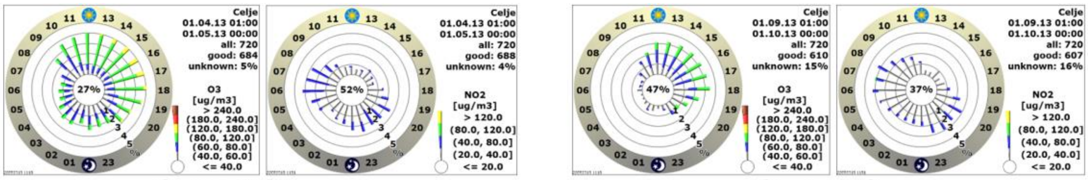


Figure 3. Measurement for 8 individual consecutive days for PM_{10} in the town of Celje (22–29 November 2015), also in central Slovenia.



Ozone, NO_2
April 2013, Celje

Ozone, NO_2
September 2013, Celje

Figure 4. Presents the air pollution graph for ozone and NO_2 for two selected months, both graphs indicate these two pollutants in Celje, where the station is located in the centre of the town, and you can feel the impact of urban transport.

To conclude the presentation of the broad possibilities of using the sunflower graph, we present a weather flower graph in Figure 5, which is slightly modified version of sunflowers. This graph presents three main parameters of weather forecast, namely one individual day on each separate graph. These concentric rings indicate the forecast for cloudiness, which is the nearest to the centre of the graph, the following ring indicates solar radiation, and the last ring indicates the predicted precipitation based on the same principle as the sunflower graph. Figure 5 shows an example of the use with a pictorial legend. With such a presentation, we are able to show a much more detailed weather forecast without using numerous pictograms or line charts, which are not close to all the lay public.

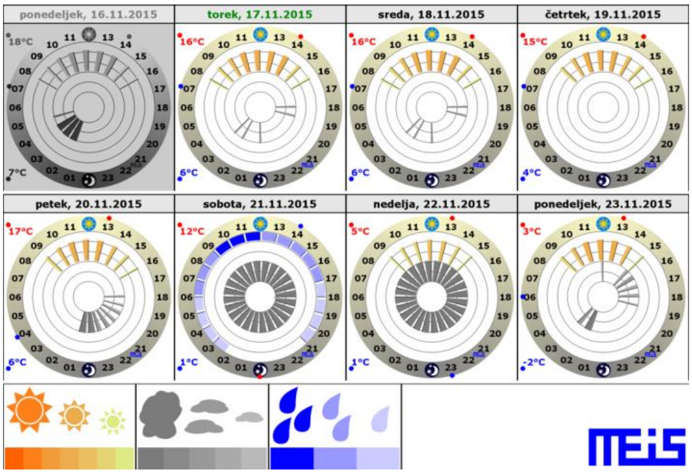


Figure 5. Example of a weather flower graph, presentation example of a selected location at Krško for eight days (previous day, current day, following 6 days)

CONCLUSION

The paper presents our new analytical tool, the "sunflower" graph, which is suitable both for basic meteorological parameters, as well as an analysis of daily concentrations of air pollutants. Some of possible examples of the application are defined in detail in the Results, however, they are not only limited to these kinds of application, a few additional options are described in the paper Božnar et al. 2015.

ACKNOWLEDGEMENT

This research was supported by the Slovenian Research Agency Projects No. L1-4154(A), L2—5475(C) and L2—6762(B). We are grateful to Slovenian Environment Agency for measured data from Zagorje and Celje.

REFERENCES

Božnar, M. Z., B. Grašič, P. *Mlakar*, J. R. Soares, A. P. de Oliveira and T. S. Costa, 2015: Radial frequency diagram (sunflower) for the analysis of diurnal cycle parameters: solar energy application. *Applied energy*, **154**, 592-602, doi: 10.1016/j.apenergy.2015.05.055.

Božnar, M. Z., B. Grašič and P. Mlakar, 2014: The problem of limit values exceedances detection in complex terrain using measurement and models. *16th International Conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes*, 8-11 September 2014, Varna, Bulgaria. BATCHVAROVA, Ekaterina (ur.), KIROVA, Hristina (ur.), HRISTOVA, Elena (ur.). HARMO 16: proceedings. [Sofia]: National Institute of Meteorology and Hydrology, Bulgarian Academy of Sciences, 5 pages

Mlakar, P., M. Z. Božnar, B. Grašič, and G. Tinarelli, Gianni, 2012: Zasavje canyon regional online air pollution modelling system in highly complex terrain **-** description and validation. *International Journal of Environment and Pollution*, **50**,. 22-30.