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# Meteorological Factors in Dispersion Modelling of $SO_2$ and $NO_2$ in Baia Mare, Romania

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***Authors' contributions***

*This work was carried out in collaboration between both authors. Author CB wrote the introduction, realised and designed the graphic results and wrote the first draft of the manuscript. Author CM designed the study, managed the literature searches, performed the analysis methodology and realised the results interpretation. Both authors read and approved the final manuscript.*

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## ABSTRACT

Atmospheric dispersion characterizes the evolution in time and space of an ensemble of pollutants (aerosols, gases, dust) emitted into the atmosphere. Atmospheric dispersion phenomenon is influenced by atmospheric conditions, soil parameters and emission values. The atmospheric dispersion model is the mathematical simulation of how air pollutants disperse. Such models are used to estimate the concentration of air pollutants emitted from industrial activity, domestic, rural and difuse sources.

The paper presents the variety of atmospheric dispersion models on concentrations of $SO_2$ and $NO_2$ made according to the time variation of meteorological parameters (atmospheric pressure, relative humidity, rainfall, wind speed and solar radiation) specific to the Baia Mare urban area.

*Keywords: $SO_2$ and $NO_2$ emissions; meteorological data; dispersion modeling.*

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## 1. INTRODUCTION

Baia Mare (Romania) is located on both of the Săsar River banks, in the geological basin with the same name, on the steppes of Igniş-Gutin Mountains and sits between two major natural units: the mountain and the basin. The urban area occupies a hollow with altitudes around 220 m [1]. The city`s climate is a continental climate with Mediterranean influences. The morpho-graphical particularity of the Baia Mare Basin has generated, at the contact with the southern mountain space, perfect conditions for the occurrence of the shelter based climate [1,2].

Annual temperatures average 9.4ºC in Baia Mare city and going down to about 8ºC in the hillsides and southern areas. The annual air humidity ranges at approximately 80%, favored by the mild climate and the northern forested areas and by the multitude of green recreational spaces inside the city [3].

The precipitation average is around 870 mm/year with a maximum during summertime, snow days average at about 50 days per year and the predominant winds are blowing from the west [2,3].

The areas' geomorphology and geography, as well as the strong industrialization from the past, have concentrated the population of Baia Mare in the urban areas and in the verging neighborhoods (Băiţa, Tăuţi, Recea etc). We can state that Baia Mare is a natural nest of population.

**Fig. 1. The Baia Mare urban area**

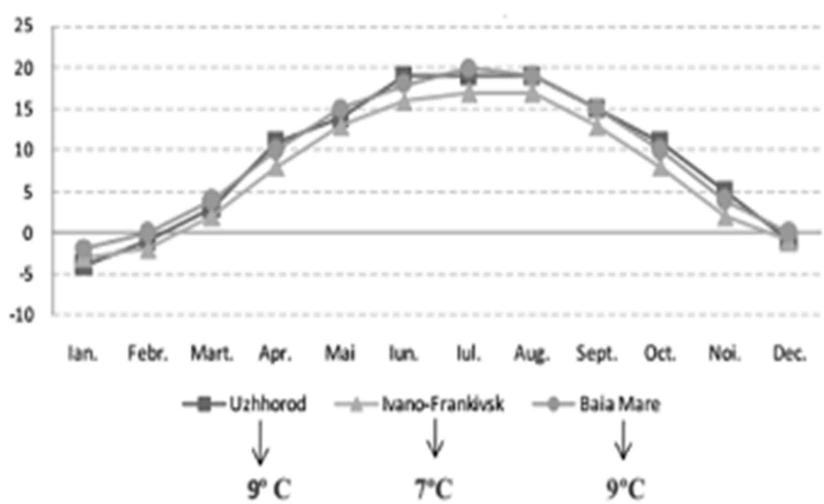



**Fig. 2. The schematic representation of annual temperatures in Baia Mare urban area**

## 2. MATERIALS AND METHODS

This paper's objective is to analyze the concentration variations of $NO_2$ and $SO_2$ recorded in Baia Mare city (Romania) urban area in correlation to climatic parameters by using the G.S. Surfer 9.0 software. It is well known that the geomorphological and climate aspects of the Baia Mare Basin favor the stagnation of atmosphere pollutants in the atmospheres' lower strata (70-120 m), but so far there has been a lack of informatics instruments to process real time data necessary for prognoses and detailed info about the atmospheres dynamic [4,2].

Here we present the results from the years 2010 – 2013, through recordings of specific climate elements and the air concentration of $NO_2$ and $SO_2$ according to Law no. 104/2011 [5]. Through the use of modern data processing software the paper underlines the connection between the pollutant concentrations and the air temperature, atmospheric pressure, rain, relative humidity, wind speed, cloud coverage and solar radiation [6].

For the first time in this region, we tried to correlate specific climatic factors with the pollution of the atmosphere, referred to data monthly and weekly fluctuations of $NO_2$ and $SO_2$. For the climatic measurement, recordings have been made on the climates' main parameters: air temperature, air relative humidity, wind speed, cloud coverage and solar radiation [6,7]. Measurements have been made between 2010 and 2013.

The raw data has been registered either from the weather stations' own software (Oregon Scientific Weather Station WMR 100) [8] or by using specific weather synthesis based on collected data from www.calitateaer.ro [9]. In the next phase, the data has been centralized so that a detailed climatic synthesis could be made, correlating weather with the pollution reports.

The concentrations of $NO_2$ and $SO_2$ have been daily measured with a professional mobile weather station (Oregon Scientific Weather Station WMR 100) [8] and compared with the collected data from www.calitateaer.ro [9]. The data have been recorded in raw format in daily averages measured in $\mu g/m^3$ for 10 different locations.

The atmospheric pollutant concentrations of $NO_2$ and $SO_2$ have been compared with the daily average limits for human health protection (60% from 75 $\mu g/m^3$ and 80% from 32 $\mu g/m^3$) specified in the Romanian and European legislation (Law no. 104/2011 Regarding the Ambient Air Quality - equivalent with Directive no. 2008/50/EC) [10]. For the 10 selected locations result viewing specialized graphic representation software called Surfer has been used. Surfer's interpolation engine transforms XYZ data into publication-quality maps [11].

Surfer provides gridding methods and control over gridding parameters, including customized variograms. A 3D surface uses shaded relief and color tones to underline the characteristics of the used data. ”Block-diagrams” are formed. After mapping the 3D surfaces the second graphic representation highlights the maximum and minimal pollutant concentration values, using ”2D isomorphic maps” [11].


**Fig. 3. The schematic representation for G.S. surfer weather modeling**

## 3. RESULTS AND DISCUSSION

### 3.1 The Cloud Coverage (0/8) and Solar Radiations Intensity (W/m$^2$) Models

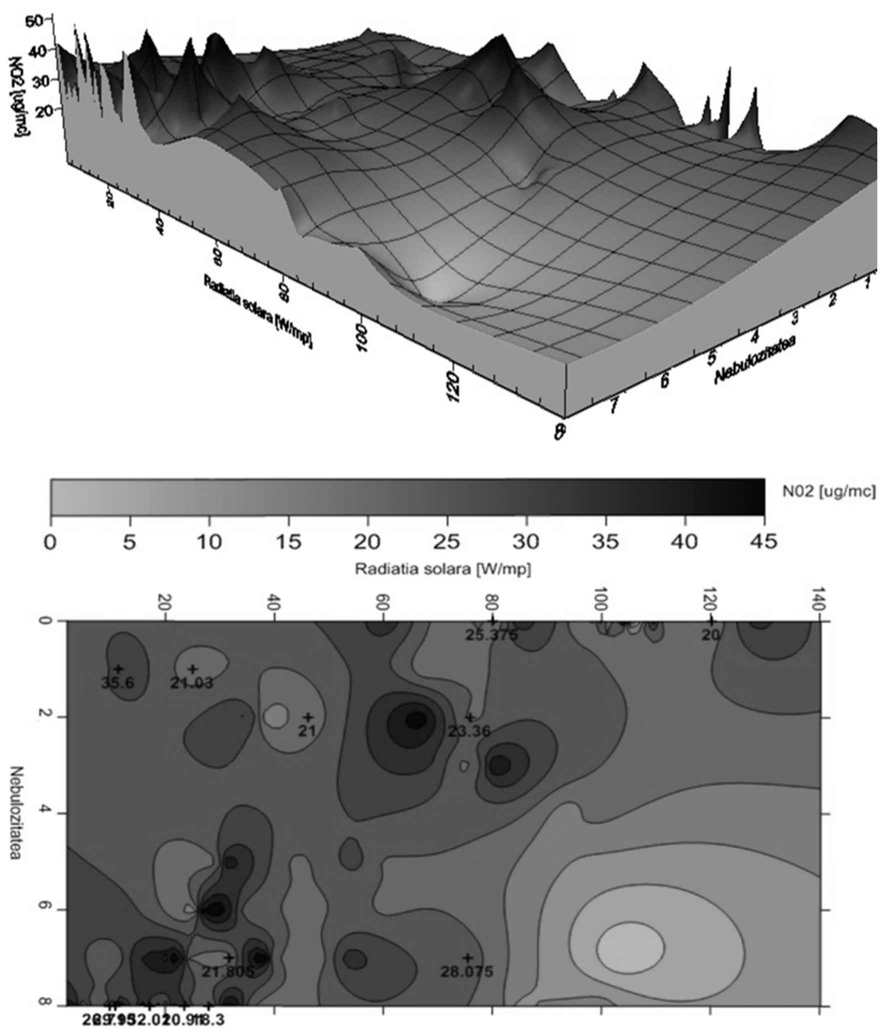
The presence of UV radiation can be a photochemical reaction catalyst for $NO_2$ reactions in the atmosphere. A cloud coverage stops penetration of solar radiation in the atmosphere's lower strata and at high values (6/8, 8/8) favors humidity accumulation.

From the graphic (Fig. 4) we can notice that the highest values of $NO_2$ during the period October - February can be divided into two sections. The first section, with the highest values 57.7 µg/m$^3$, is evident in the 15-40 W/m$^2$ interval of solar radiation intensity (common to the clouded sky) and the 5/8-8/8 parts cloud coverage.

The second section of high values of $NO_2$ concentration refers to the 60-90 W/m$^2$ interval, combined with 1/8-4/8 parts cloud coverage. A characteristic for the basin are the lower $NO_2$ values that have been recorded during the100-120 W/m$^2$ interval, combined with 5/8-8/8 parts cloud coverage.

Also it can be noticed that the highest values of $SO_2$ can be divided into two sections. The first section, with the highest values, is evident in the 20-80 W/m$^2$ range of solar radiation intensity (common for the clouded sky) and the 1/8-3/8 interval of cloud coverage.

The second section of high values of $SO_2$ concentration refers to the 40-90 W/m$^2$ interval, combined with 5/8-8/8 parts cloud coverage. Low $SO_2$ values have been recorded in the 100-120 W/m$^2$ interval, combined with 1/8-8/8 parts cloud coverage.



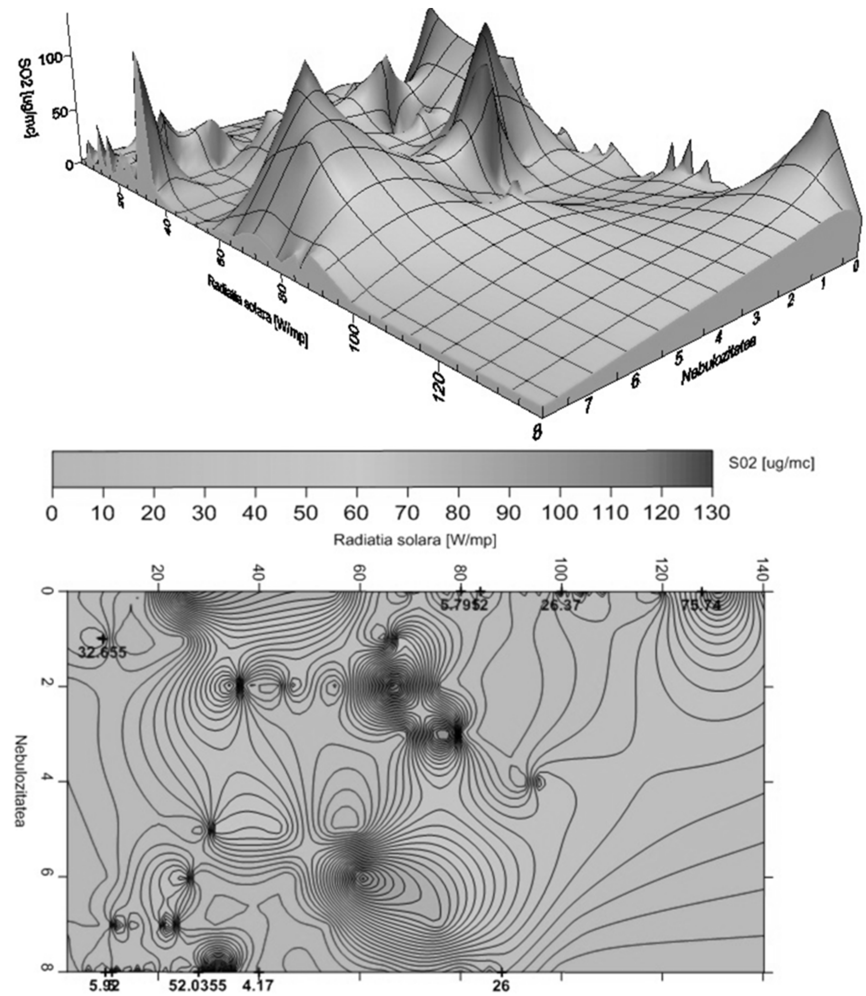



**Fig. 4. The dispersion models for $NO_2$ and $SO_2$ related to the cloud coverage and solar radiations intensity**

From the data interpretation it is clear that $NO_2$ and $SO_2$ accumulates in the cold season at lower values of solar radiation intensity and is generally lower for high values of cloud coverage.

## 3.2 Atmospheric Pressure (hPa) and Precipitation (mm) Models

A well-known fact is the tight dependence between the atmospheres' nitrous dioxide concentration and the formation of acid rain, so the hydro-climatic conditions can greatly influence the concentration of $NO_2$ and $SO_2$.

Precipitations also influence the transfer speed of atmospheric pollutants into the soil through the auto purification phenomena. Also the atmospheric pressure dictates the precipitation conditions by creating the general isobaric relief.

(Fig. 5) High concentrations of $NO_2$ (50-60% from 75 µg/m$^3$ according to Law no. 104/2011) have been recorded for the daily precipitation quantity between 0-3 mm. $NO_2$ accumulates in when there are no precipitations and normal air pressure values are 974-995 hPa.

The second section of nitrous dioxide is distributed uniformly in the area between 5-15 mm atmospheric precipitation and in values of above 995 hPa atmospheric pressure (high pressure, specific to sunny weather and stabile atmosphere). A plain surface, with very similar nitrous dioxide concentration values that vary around 15-20 µg/m$^3$ occurs at above 15 mm precipitations at normal or lower pressures.

The highest concentrations of $SO_2$ (60-65 µg/m$^3$ as compared to 80% from 32 µg/m$^3$ limit considered by Law no. 104/2011) have been mm and air pressure values between 974-990 hPa.

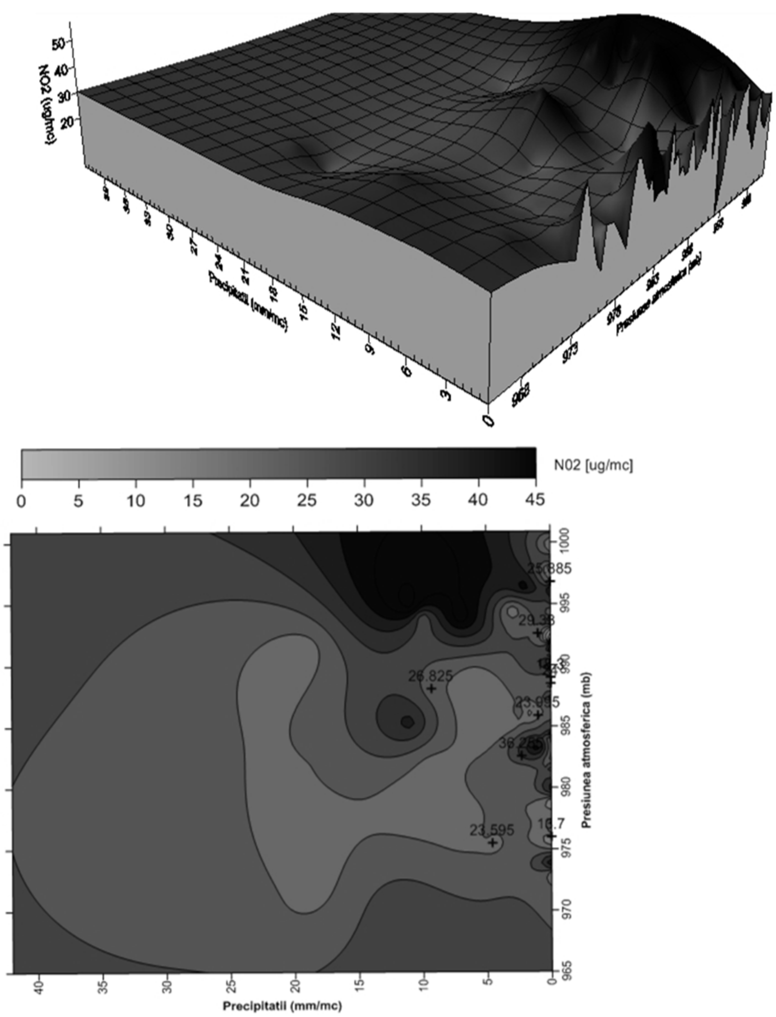
Similar to $NO_2$, a plain surface of lower $SO_2$ values we find at 12-25 mm atmospheric precipitation and 965-985 hPa atmospheric pressure. In this case the atmospheres' auto purification and the chemical transformation of $NO_2$ and $SO_2$ are favored by the two climatic parameters.

### 3.3 Temperature (°C) and Humidity (%) Models

The airs' humidity percentage is greatly influenced by the daily variations of air temperature. In turn, humidity influences the persistence (accumulation) of $NO_2$ in the atmosphere. Because of the atmospheres' water components, notably the hydroxyl radical (OH-), recorded for daily precipitation quantities of 0-4 water takes part directly in the formation of $NO_2$ and intensification of the acid rain phenomena.

From Fig. 6 we can see that the dispersion of high concentration of atmospheric pollutants is in this case" cluster based" unevenly across the surface of the graphic. Although the clusters do not follow any general rule, the peaks can be grouped into two sections in relation to their maximums.

The first clusters are between (-10)-(+5)°C (daily average temperature for the cold season) and 45-80% air relative humidity [6]. The second section contains an even surface between the interval of 0-11°C air temperature and 25-35% humidity. It is difficult to pronounce what humidity and temperature conditions favor the accumulation of $NO_2$ and $SO_2$ in the lower atmosphere strata.



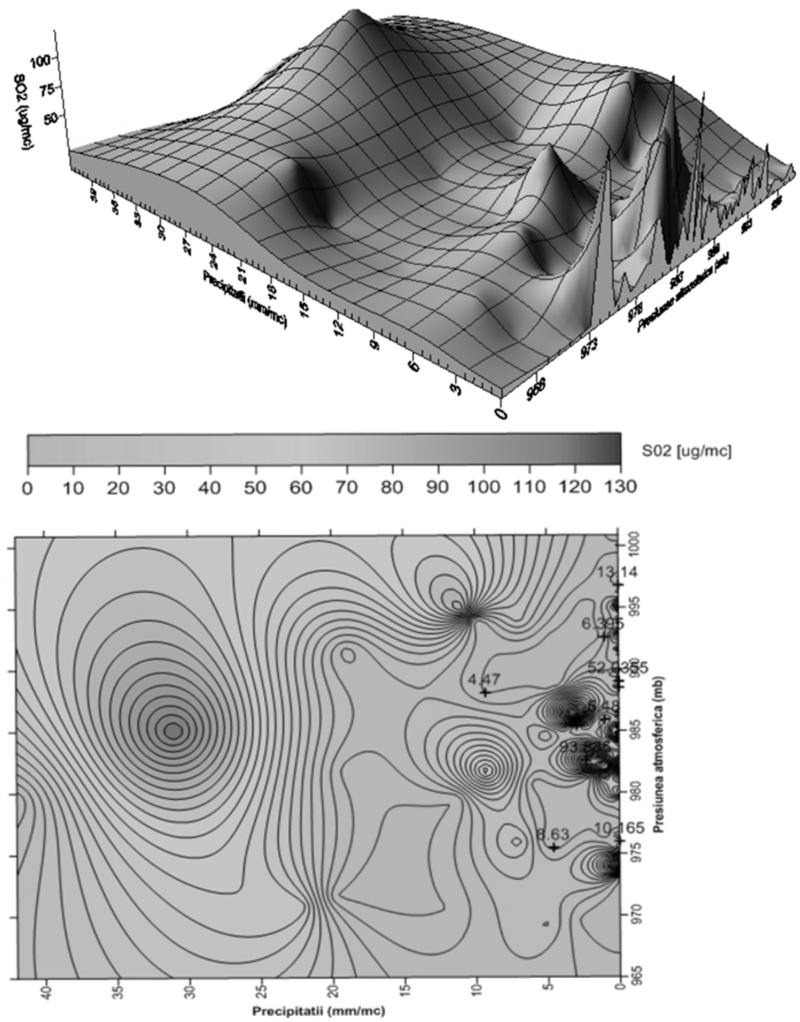



**Fig. 5. The dispersion models for $NO_2$ and $SO_2$ related to the atmospheric pressure and precipitation**

The accumulation of pollutants is in relation with other climate parameters that have not been included in the present research. It can be estimated that $NO_2$ and $SO_2$ accumulates in winter at lower humidity values and at lower daily temperature averages.

## 3.4 Wind Speed (m/s) and Humidity (%) Models

The dispersion of the pollutant emission is greatly affected by wind conditions in the atmosphere. The absence of wind can determinate a temporary accumulation of pollutants in a certain area.

When taking into account this two climatic factors, wind speed (m/s) recorded at 125 m and humidity (%), $NO_2$ accumulation on the graphic (Fig. 7) occurs in an area of interest between 20-80% humidity and 0-1.30 m/s wind speed.

The pollutants concentration values are tightly connected to the values of wind speed and start to decrease after 1.30 m/s, establishing the minimum value for the beginning of atmospheric dispersion and reduction of $NO_2$ concentrations at the monitoring points through natural washing. A small basin is formed at humidity levels below 40% (dry air) and for daily wind averages of 1.30-2 m/s. These are the lowest pollutants concentration values recorded, averaging 0.1-5 μg/m$^3$.

Similar to the $NO_2$ concentrations, we find a piedmont with lower $SO_2$ values formed at humidity levels below 50 % (dry air) and for daily wind averages of 1.10-2.40 m/s. Also we noticed that $SO_2$ accumulation is present between 20-90% humidity and 0.20-1.40 m/s wind speed.

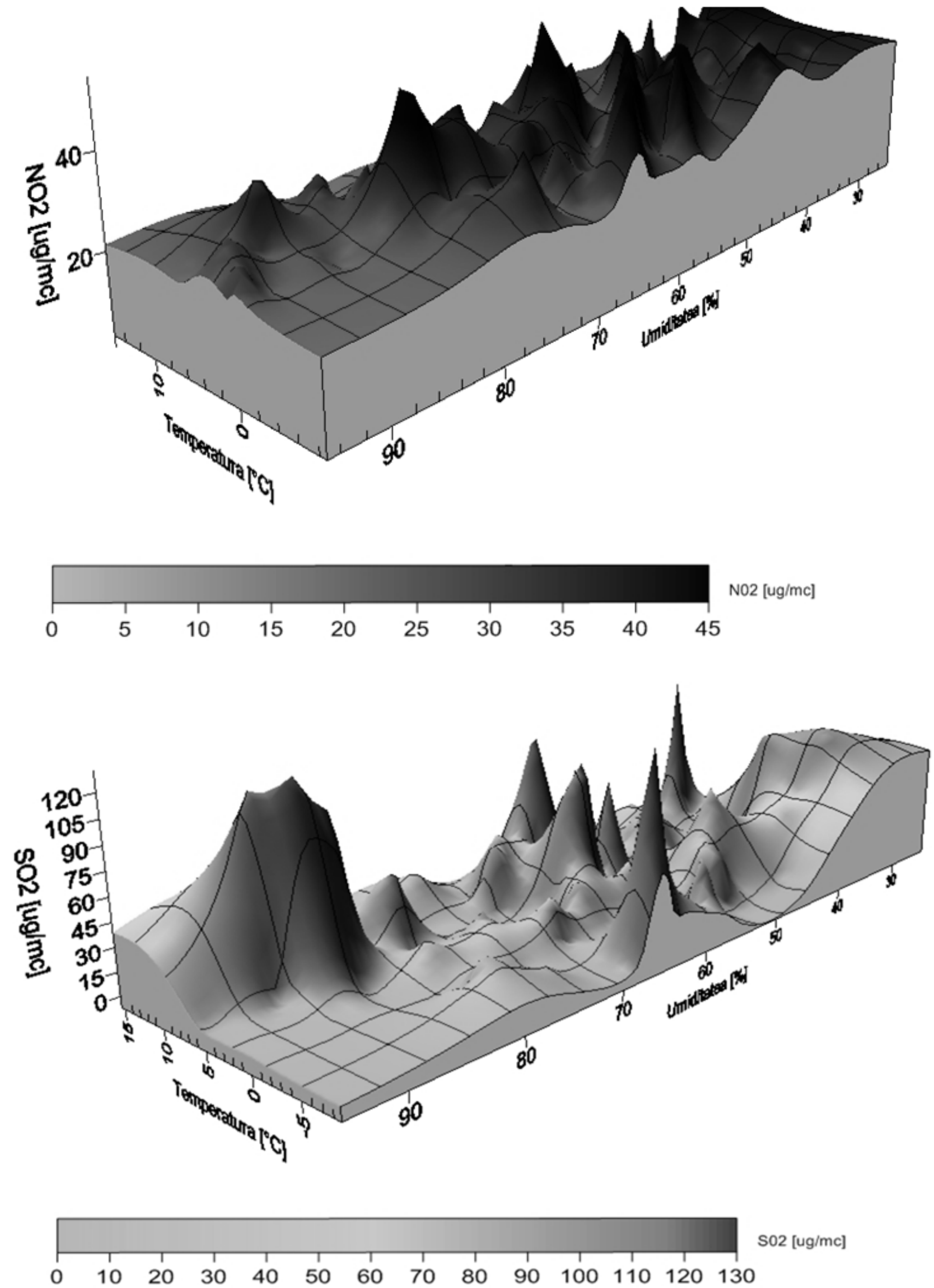



**Fig. 6. The dispersion models for $NO_2$ and $SO_2$ related to the temperature and humidity**

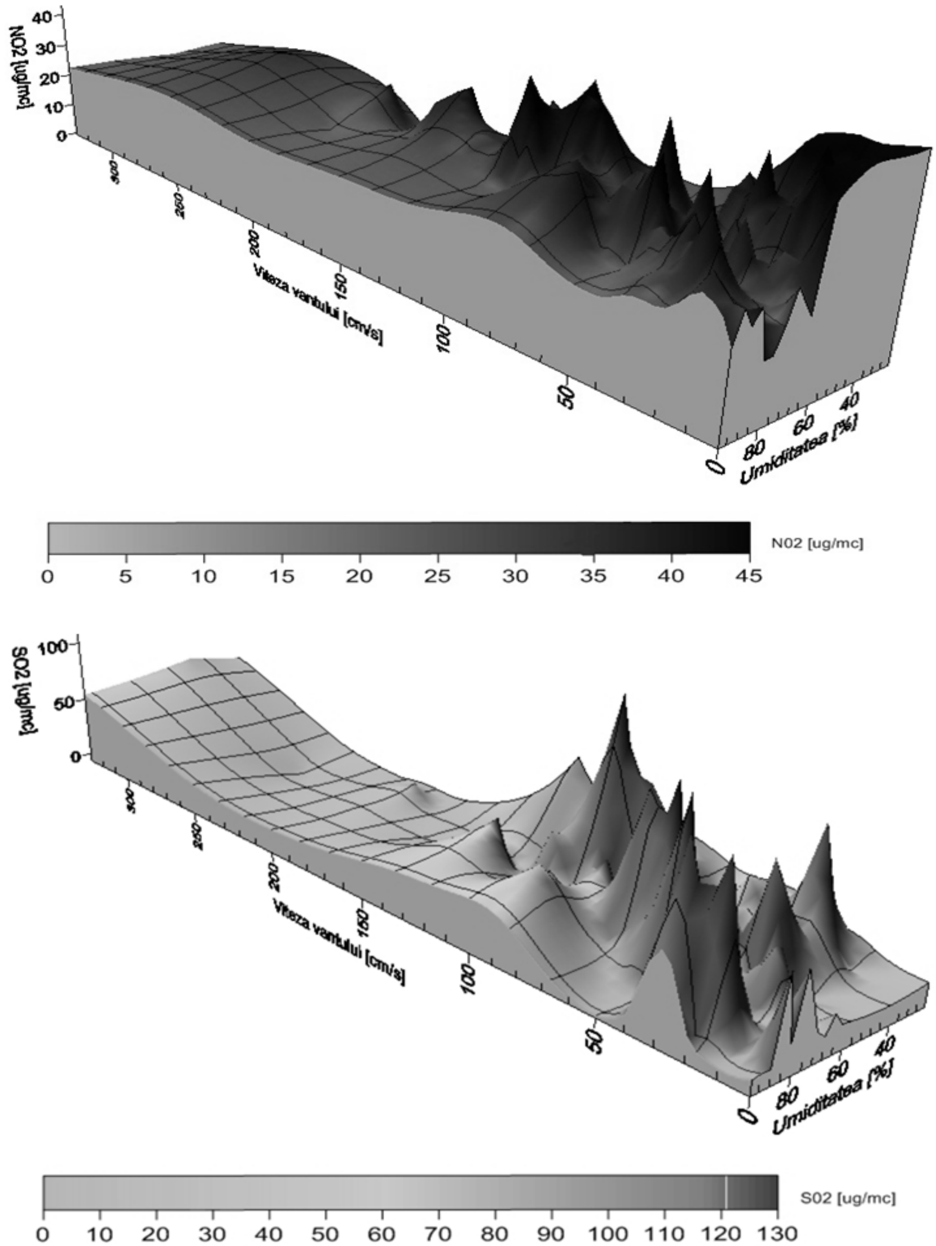



**Fig. 7. The dispersion models for $NO_2$ and $SO_2$ related to the wind speed and humidity**

## 4. CONCLUSION

The specific climate factors (influenced in turn by the geomorphologic display of Baia Mare City) lead to a poor dispersion of pollutants and stimulate concentration in the Baia Mare Depression, which is a demographic agglomeration.

We correlated specific climatic factors with the pollution of the atmosphere, referred to data monthly and weekly fluctuations of $NO_2$ and $SO_2$. For the climatic measurements, recordings have been made on the following parameters: Air temperature, air relative humidity, wind speed, cloud coverage and solar radiation. Measurements have been made between 2010 and 2013, and interpreted using the models offered by G.S. Surfer software.

The use of G.S. Surfer software in climatic studies is useful because it creates a great precision graphic representation for everyone interested in having an idea about climate and related pollution issues regarding a specific urban area.

## ACKNOWLEDGEMENT

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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