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Research article

The connections between meteorological conditions and the health status of the population of Suceava municipality. A case study on respiratory afflictions throughout the years 2019-2020 in Suceava

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Abstract: Background: The present study addresses the real necessity of covering the gaps related to the actual understanding of the relationships established between weather patterns and the health status of the population. The urban area of Suceava is representative of medium-sized cities in Romania.

Methods: Respiratory pathologies manifest with a temporal offset when compared to intervals with severe weather conditions. The consultation program is one that does not take into account the severity of weather conditions. Through statistical and graphical correlations, strong direct or inverse proportional relationships were identified between meteorological elements, the multitude of meteorological elements represented by bioclimatic indices, and the number of consultations provided to patients with respiratory afflictions.

Results: In the winter season when t°C, THI, and TPr have minimum values and Pr has maximum values, the number of consultations for respiratory conditions is at an all-time high. The value of the coefficient of determination R2 between the monthly values of t° C and THI, respectively, the number of consultations for respiratory conditions exceeds the threshold of 0.7, and between the monthly values of Pr and the number of consultations for respiratory afflictions was 0.66. On days when t° C was $\leqslant$ 0° C, the average number of consultations for respiratory conditions was 6.1, decreasing to 3 on days when t°C was > 23°C.

Conclusions: Respiratory diseases have the most favorable temporal framework for occurrence in the months of the cold season. In winter in Suceava, respiratory conditions affect twice as many people as in summer.

Keywords: respiratory afflictions, meteorological elements, bioclimatic indices THI, Pr, and TPr

1. Introduction

Climate and human health is a topic increasingly addressed in scientific research after 2010. Studies specifically focus on the relationship between meteorological variables and a range of specific diseases [1]. Themes such as human thermal comfort, human morbidity and mortality have been intensely addressed [2]. *Rapid urbanization* and *climate change* are exacerbating the effects of the artificialized environment on human health [3]. Cities and their population become exponentially growing systems more vulnerable in relation to more severe weather events. There is a need to develop meteorological, environmental and climate services to help cities and their population cope with global warming and severe weather episodes in order to strengthen their resilience [4]. These biometeorological operational forecasting services can link the numerical models of meteorological forecasting with the advanced human-biometeorological models [5]. In cities, the short-term variability of said meteorological parameters can create numerous adaptation problems, discomfort and certain pathologies that primarily affect more vulnerable human groups (elderly, children, chronic patients, etc.), but also larger human groups, apparently less vulnerable to the tract of weather. Any factor or meteorological element by its extremes induces discomfort/stress or certain pathologies regardless. [6].

Weather affects the human body from a biological, emotional and behavioral sense. Emotionally stable people are less sensitive to the influence of weather on their emotions, while emotionally unstable people have a stronger response conditioned by weather characteristics [7].

Air temperature is a meteorological element that has a powerful effect on people. Temperature conditions influence the processes of thermoregulation and metabolism, alter muscle and nervous activity, and biochemical and bioelectric processes [8]. Negative temperature values can generate in the case of direct exposures chills, frostbite and Hypothermia, or in the case of indirect exposures, a wide range of conditions such as cardiovascular issues, musculoskeletal disorders, certain dermatoses. [9], [10] and most importantly respiratory diseases (colds, rhinitis, pharyngitis, laryngitis, bronchitis, broncho-pneumopathies etc.). Low air temperature strongly diminishes cognitive ability, attention and concentration by distracting awareness and increasing an active response to negative stimulus [11, 12, 13]. Sudden variations in temperature are harder to bear by the sick but also by healthy people, and the associations between low temperature, high humidity, snowfall, ice, strong wind, etc. can trigger or accentuate respiratory afflictions and other conditions [9]. The time intervals that can cause the most significant health problems for the population of Suceava due to negative temperatures are attributed to polar cold waves, especially when they occur outside the cold season.

In connection to the *relative humidity* of the air, it is known that episodes of weather that come with high humidity are harder for people to bear than those with low humidity. The high values of moisture combined with high or low temperature create difficulties in adaptability by the body. The drier atmosphere, due to high or low thermal values, is preferable to a humid atmosphere [14]. The dry and cold atmosphere favors respiratory afflictions and allergic dermatitis [9, 15], deepening unpleasant psychological states [16]. The humid and cold atmosphere favors the accentuation of the thermal perception of cold, respiratory infectious-contagious diseases, rheumatic and nervous system diseases [9]. The moist and warm atmosphere causes migraines [15] and dermatoses. High humidity and wind favor the development and dispersion of some pathogens [17] or microbial aerosols” [18]. Dry air favors the maintenance in the urban atmosphere of pollutants with the formation of dry urban fog.

Low *atmospheric pressure* slows the heart rate and increases respiratory volumes. Changes in atmospheric pressure mechanically influence circulation by constricting / dilating superficial capillaries. The *drop* in atmospheric pressure activates the sympathetic nervous system, increasing reaction time to stimulus, worsens the mood and reduces the ability to work, the cognitive performance and mental flexibility increasing the risk of neurological disorders [19]. The decrease in pressure affects patients with chronic sinusitis, nasal congestion, and increases the occurence of respiratory tract disease, and even increases the number of asmatic, renal and cardiovascular manifestations [9]. High pressure worsens the pain of ulcer patients and increases blood pressure. The rapid accentuation of pressure increases the risk of brain hemorrhages and the frequency of the pulmonary heart [14]. Increased atmospheric pressure decreases the number of leukocytes and induces activation of the parasympathetic nervous system [19].

The wind changes the body's thermal balance [19]. Wind speed, exceeding 10 m/s, negatively affects the well-being of patients [8]. On days with a strong wind, there is an increased level of anxiety in people with mental disorders, the incidence of suicides increases, and cardiac arrhythmias occur more frequently [20, 21, 22]. Foehn-type warm winds generate irritability, fatigue, headaches, mental stress and cold and wet type winds generate asthma attacks, laryngeal croup, angina attacks, negatively affect the respiratory system, the nervous system and produce many afflicts [23, 24, 25, 27, 16, 26, 28, 14].

Weather elements such as *cloud cover, sunshine duration and global radiation* or a number of *pollutants* such as carbon monoxide – CO, tropospheric ozone – O_3, nitrogen dioxide – NO_2, etc, sulfur dioxide – SO_2 and sedimentable powders PM_{10} (sedimentable particulate matter fraction 10 μm) play a special role in relation to population health or human morbidity. Air pollution, warming of the atmosphere and extreme weather phenomena lead to an increase in the number of allergic diseases such as asthma and rhinitis, but also grows the mortality rate of patients with asthma and other respiratory diseases [29]. In the polluted atmosphere of cities, particulate-suspension matter can worsen chronic respiratory diseases. The barometric field has a strong effect on pollutant levels. Pathology and patient age are important [30, 31]. When the temperature was low and levels of PM_{10}, NO, NO, NO_2, NOX, and CO were high, the number of pneumonia consultations also increased [32].

In Romania, correlative studies to link weather, climate and human health are few. A study conducted by a group of researchers [33] for the areal of Bucharest comprised data between October 2011 - December 2012 on the influence of the weather on people with acute cardiovascular diseases and revealed that the highest number of cases with acute cardiovascular disease occurred in February 2012, which was an abnormally cold month and also significant positive correlations were noticed between the number of female patients diagnosed with unstable angina and THI, respectively air temperature. Another group of researchers [34], in a study on the perceived influence of weather conditions over rheumatic conditions in Romania, reported that their pain intensified as the weather worsened, especially when the nebulosity and humidity rose sharply (83.8 % and 82.0 %, respectively), the air temperature dropped suddenly (81.5 %), as well as in fog or rain conditions (81.2 %).

The research of urban biometeorology aspects in *Suceava* is in its infancy [35]. At their onset are also studies that try to identify obvious and statistically proven links between weather factors, elements and phenomena and the health of the population of Suceava [6]. Due to the lack of profile studies, the present study is necessary, especially as it addresses a topic of real interest for a population of 142.844 inhabitants, the number for the urban agglomeration of Suceava, which relies on the healthcare services provided by Suceava's physicians and the healthcare network of the urban sprawl..

The general objective of the study is to identify relevant temporal and statistical connections between a series of meteorological elements (air temperature, air humidity, vapor pressure, atmospheric pressure, wind speed, cloudiness, and precipitation), bioclimatic indices (THI, Pr, TPr), and the number of specialized medical consultations provided to patients with respiratory conditions in two medical facilities in the municipality of Suceava. In cases where data were available from the Ambulance Public Service, we analyzed the annual morbidity regime related to respiratory conditions using such data. A case study complements our analysis, consolidating the achievement of the proposed objective.

2. Data and methods

2.1. Tools and methods

The logical hypothesis underlying our research is that that intervals with unpredictable weather will generate higher morbidity rates. These connections between weather and pathology were comparatively analyzed over time with samples ranging from seasonal level to a daily one. The study correlates by graphical and statistical means two large categories of data sets: meteorological/biometeorological data and medical data. The weather - pathology connections are captured by comparing weather data with those provided by two entities belonging to the healthcare infrastructure of Suceava. Medical data no longer pertain to the laws of nature as the meteorological ones do, their computable measurable vectors being influenced by a multitude of factors such as: the work schedule of the medical offices (available Monday to Friday), public holidays, religious and bank holidays when no consultations are conducted, with patients resorting to only calling the medical emergency system, taking into consideration the temporal or financial constraints to which individuals are subject to, and which often lead to the long postponement of a medical consultation, etc. [6]. Although these two large categories of data are not obtained with the same periodicity and are not entirely synchronous, graphical and statistical modeling allowed us to identify strong relationships and correlations between them. The modelling and analyses in this present study were carried out in a consistent manner for all 8 major categories of afflictions for which patients were presented at medical consultations during 2019 and 2020. Among the 8 categories of diseases we chose to detail the relationship between the weather elements course /biometeorological indices and respiratory diseases.

Biometeorological indices (wind chill index – hereinafter denoted as Pr, equivalent temperature of wind chill index – hereinafter denoted as TPr, and thermo-hygrometric index – hereinafter denoted as THI) were calculated using formulas **[1 - 3].**

The calculation formula for Pr **[1]** was proposed in 1945 [36] and modified in 1974[37].

$$Pr = \left(12.1452 + 11.62222\sqrt{v^1} - 1.16222 \cdot v^1\right) \cdot 33 - T_{dry} \qquad \textbf{[1]}$$

where:

- T_{dry} – dry bulb temperature (°C);
- v – wind speed (ms^{-1}).

The scale for interpreting Pr values is shown in **Table 1**

Table 1. The cooling power of the wind (kcal m^{-2} h^{-1}) and the significance of the biostress index skin

The cooling power of the wind (kcal/m-^{2}h^{-1})	Indices of stress skin	Character (significance)	Type of stress
0-149	-2	hypotonic	stress by triggering thermolysis during the summer
150-299	-1	hypotonic	stress by triggering thermolysis during the summer
300-599	0	relaxing	not require thermoregulation
600-899	+1	hypertonic	stress by triggering thermogenesis in winter
900-1199	+2	hypertonic	stress by triggering thermogenesis in winter
1200-1499	+3	hypertonic	stress by triggering thermogenesis in winter
>1500	+4	hypertonic	stress by triggering thermogenesis in winter

The calculation formula for TPr **[2]** was proposed in 1945 [36] and modified in 1974 [37] (studies cited in sources consulted by us in 1989 [38] and in 2002 [16]).

$$Tpr = (33 + (T_{dry} - 33) \times (0.474 + 0.454\sqrt{v_1} - 0.0454v_1)) \quad \textbf{[2]}$$

where:

- T_{dry} – air temperature measured by the dry bulb thermometer (°C);
- v_1 – wind speed expressed in m/s.

The calculation formula for THI **[3]** was proposed in 1994 [39].

$$THI\ ℃ = T_{dr} \;\; - (0.55 - 0.0055 \cdot Rh) \cdot (T_{dry} - 14.5) \quad \textbf{[3]}$$

where:

- T_{dry} – air temperature in °C measured by the dry bulb thermometer
- Rh – relative humidity (%)

Table 2. The THI threshold values (°C) a), bioclimatic conditions b) and the relationship with the thermal sensations felt by the human body c) – [40]

a) THI index (°C)	b) Bioclimatic conditions	c) Type of bioclimatic comfort/discomfort
-20 < THI ≤ -10	Excessive cold	Bioclimatic discomfort due to overcooling
-10 < THI ≤ -1.8	Very cold	
-1.8 < THI ≤ +13	Cold	
+13 < THI ≤ +15	Cool	
+15 < THI ≤ +20	Comfortable	Bioclimatic comfort
+20 < THI ≤ +26.5	Warm	Bioclimatic discomfort due to overheating
+26.5 < THI ≤ +30	Very hot	
THI > 30	Torrid	

The scale for interpreting THI values is shown in Table 2.

2.2. Data used

We used hourly meteorological and air quality data from the Suceava meteorological station, as well as data from the air quality monitoring stations SV1 and SV2. Data from all these 3 stations was used to calculate mean values and extract extreme values for the study area. This is the basis for calculating bioclimatic indices. For air quality information, hourly data from SV1 and SV2 stations were averaged. Hourly data was transformed into daily, monthly, and seasonal data.

Medical data were obtained from two family doctor offices in Suceava. They correspond to the days when subject doctors involved in the study conducted medical consultations. The consultations were mainly conducted on weekdays, with exceptions on weekends (Figure 2).

In total, in the span of two years, the doctors conducted a cumulative number of 18,704 consultations, averaging 26.4 consultations per day. Medical consultations for distinct categories of conditions are presented in Table 3.

For the years covered in the study, the number of consultations given per day and week is depicted in Figure 2.

Table 3. The total number of medical consultations for different categories of conditions conducted by the medical team participating in the study in the years 2019-2020.

Consultations for patients with cardiovascular conditions	Consultations for patients with respiratory conditions	Consultations for patients with locomotory disorders	Consultations for patients with digestive conditions	Consultations for patients with neurological conditions	Consultations for patients with renal conditions	Consultations for patients with psychiatric conditions	Consultations for patients with metabolic-endocrine conditions
8789	1954	2430	1704	1285	1121	882	539

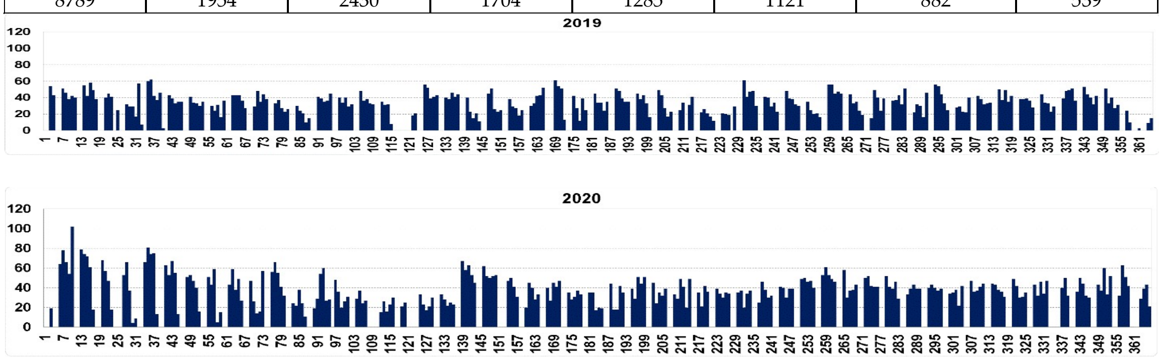


Figure 2 (above). Variation over the years 2019 and 2020 of the daily number of consultations provided to patients with various conditions by the team of doctors participating in this study

3. Study Area

The Municipality of Suceava (and the homonymous urban agglomeration) is located in the northeast of Romania, in the middle of Suceava Plateau, being situated in the central direction of WNW-ESE by the Suceava river valley. North of the Suceava river valley is the Dragomirna Plateau, and to the south the Falticeni Plateau.

On the valley of the Suceava river the relief altitudes drop slightly below 280 meters, and on the plateaus and hills to the north and to the south the altitude rises over 400 meters (Figure 3). The spontaneous vegetation consists of deciduous forests and forest-steppe. Anthropogenic actions on the surrounding land is increasing, with built-up areas and ur-ban high density zoning gaining in importance over time.

Studied data shows that the total of areas that have undergone changes between 1980 and 2020 represent 9.08 % of the total area of the urban sprawl with the construction and increase of zoning for residential and commercial areas at an increase of the 864.3 ha, converted mostly from farming zones (758.8 ha) [41].

The quality of life of over 140.000 inhabitants of the municipality depends directly on the physical and chemical peculiarities of the environment and air quality, and the socio-economic activities are conditioned to varying degrees by them. The climate of Suceava is temperate, with high variability of weather patterns. In the summer, tropical weather episodes occur with an incidence of 1.5 % per average per year. During the cold season, cold weather outburst are quite frequent over the region, lasting 8% of the time.

From a bioclimatic point of view, the climate of Suceava has more demanding features than passive ones [42, 43, 44].

4. Results

4.1. A brief analysis of the meteorological conditions throughout the years 2019-2020 in Suceava

In the two years of the analysis period, the weather in the urban agglomeration of Suceava was marked by rythmic variability. Statistical processing and graphical representations allow us to highlight certain patterns of the annual variation, which present similarities with those already known and resulting from processing of climate data over long periods (since 1960, for example).

Average monthly air temperature values were minimal in the winter months (dropping at -3.6°C in January 2019) and maximum in the summer months (they peak up to 20.5°C in august 2020). The montly sunshine duration was at its lowest in the winter months (in January and December 2020 it dropped to 25 hours) and presented the highest values in the summer months (in August 2020 exceeded the 300-hour threshold). Global radiation values have increased from 20 Watt per square meter per day in winter days (January 2019, as reported, to December 2020) to over 200 Watt per square meter per day on summer days (June 2019) (Figure 4a). The precipitaton amount was highly variable, being highest in late spring and early summer months - May and June (reaching almost 150 mm in June 2019), and lowest in the late winter and early spring months (only 5 mm in January and April 2020) and in the late summer and autumn months (only 7 mm in November 2020).

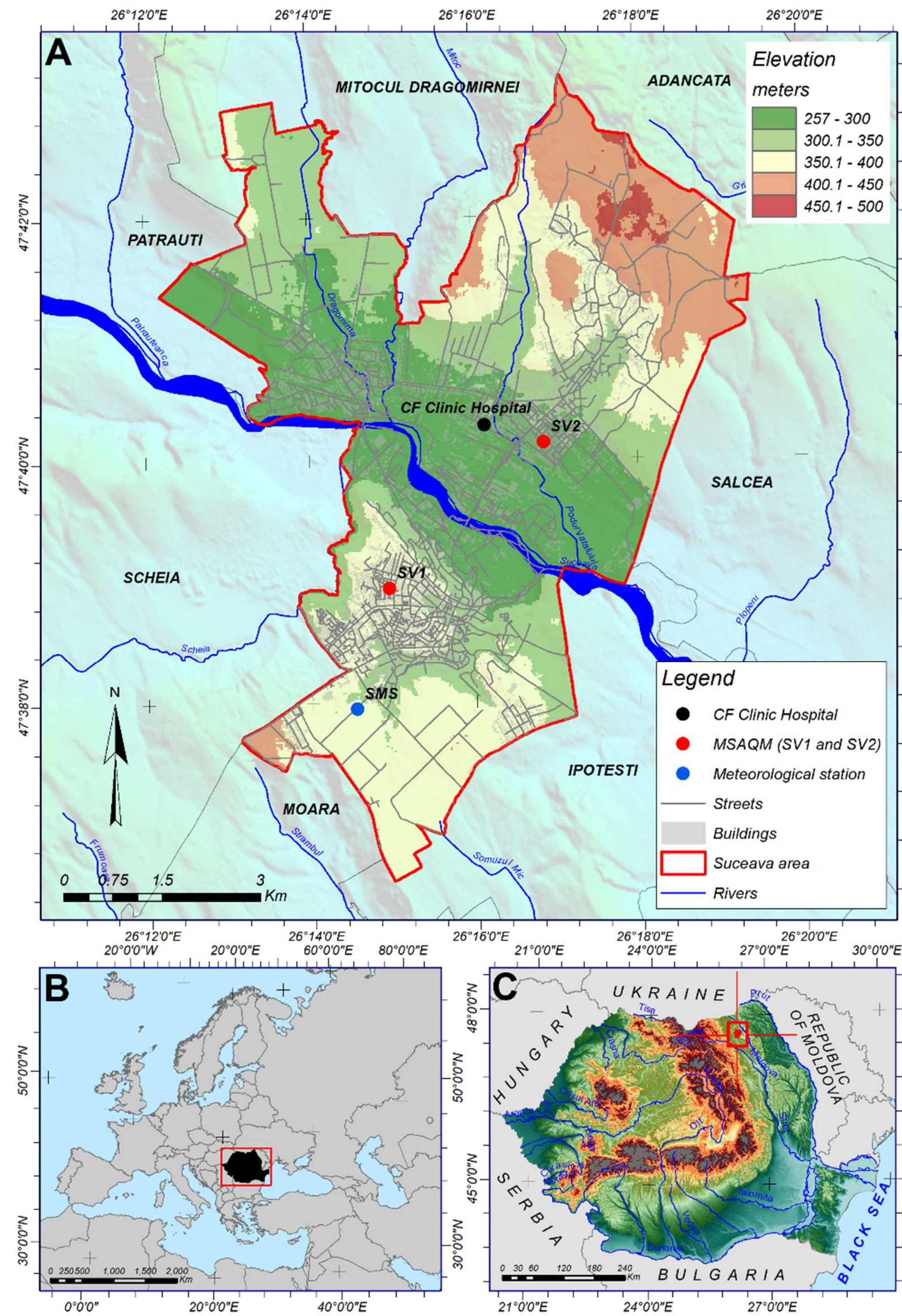


Figure 3 The positioning of Romania within the continent of Europe (B) and the urban agglomeration of Suceava within Romania (C). Detailed geographic framework of the urban agglomeration of Suceava with the location of the weather stations from which we used meteorological data and the medical clinic that provided us with medical statistics detailing respiratory conditions (A)

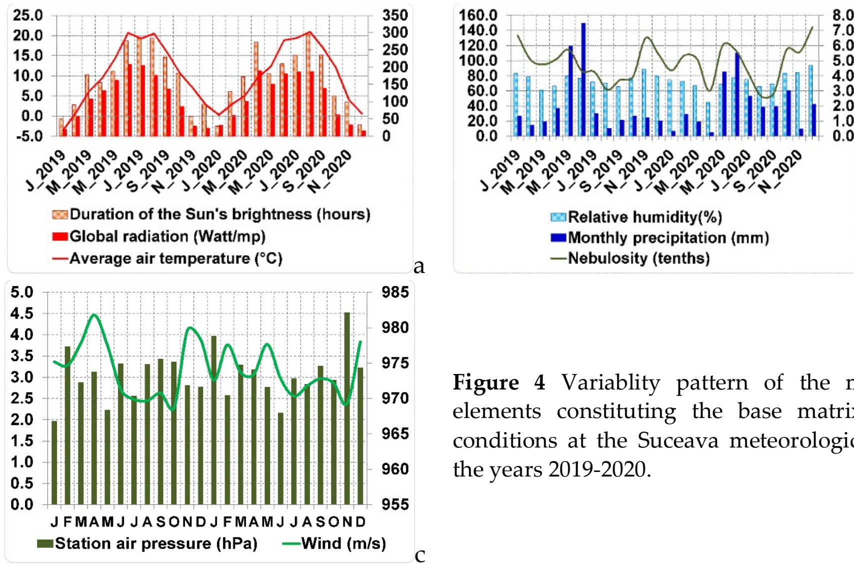


Figure 4 Variablity pattern of the meteorological elements constituting the base matrix of weather conditions at the Suceava meteorological station for the years 2019-2020.

Nebulosity was maximum in the winter months (7.1 oktas in December 2020) and minimum in the months of August-September (less than 3 oktas in August and September 2020). Relative humidity rose to averages of 94 % in December 2020 and dropped to 45 % in April 2020 (Figure 4b).

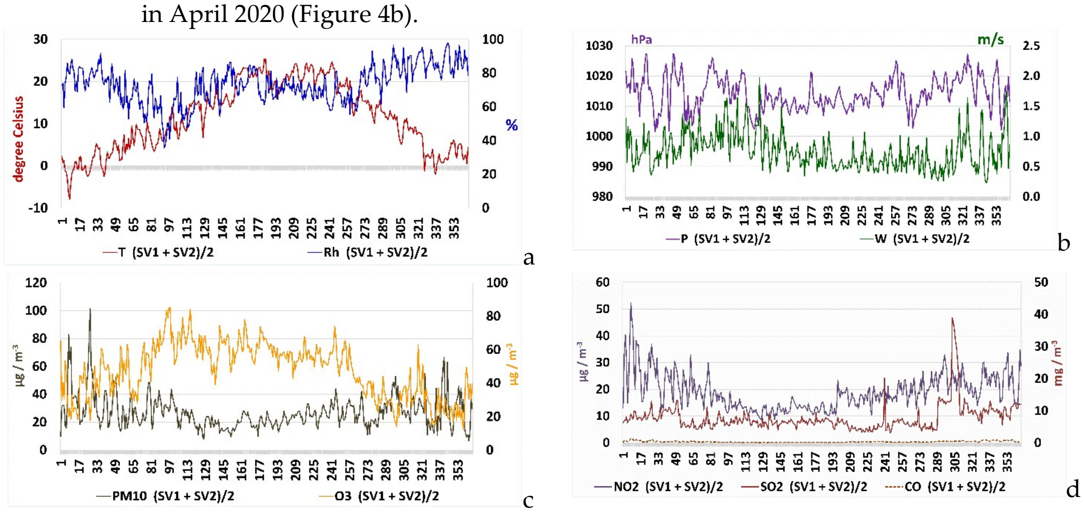


Figure 5 The annual variability pattern for the main meteorological elements (T - air temperature, Rh - relative humidity, P - atmospheric pressure, W - wind speed) and atmospheric pollutants (PM_{10} - particulate matter with a diameter of 10 μm, O_3 - tropospheric ozone, NO_2 - nitrogen dioxide, SO_2 - sulfur dioxide, CO - carbon monoxide) in the years 2019 and 2020 in Suceava.

The wind blew strongly in the spring and winter months (in April 2019 the average wind speed was 4.5 meters per second) and had lower speeds in the summer months and in the autumn (in October 2019 the average speed was 2.3 meters per second). Atmospheric pressure at the station ranged from an average of 967 hPa in January 2019 to 982.5 hPa in November 2020 (Figure 4c).

Daily, the average annual trend (2019-2020) of the physical and chemical parameters of the urban atmosphere (mean values for SV1 and SV2 stations) shows the following (Figure 5): *i)* diurnal values of air temperature decreased to -8°C in January and reached 25°C in July; *ii)* relative humidity had diurnal values which decreased up to 30 % in April and climbed up to 98 % in December (Figure 5a); *iii)* in the city, sheltered by buildings the diurnal wind speed climbed up to 2 meters per second, on spring days and descended below 0.5 meters per second on certain summer and autumn days; *iv)* sea-level air pressure exceeded the threshold of 1025 hPa and dropped to nearly 1000 hPa on certain winter days (Figure 5b); *v)* on certain days in the cold (winter) season the sedimentable PM_{10} particulate matter exceeded the daily limit value for human health protection of 50 μgm^{-3} [45], but during the spring days – summer was below the threshold of threshold of 30 $\mu g\ m^{-3}$; *vi)* the average daily O_3 values did not exceed the public information threshold (>180 $\mu g\ m^{-3}$) by legislation standards [45] [46], but they slightly exceeded the 100 $\mu g\ m^{-3}$ threshold in a few days in April – May, dropping on many days during autumn and especially winter below the daily threshold of 30 $\mu g\ m^{-3}$ (Figure 5c); *vii)* NO_2 emissions, SO_2 and CO had the highest values during winter and autumn days, but they were below the thresholds endangering human health (the daily limit value for the protection of human health for the SO_2 pollutant is 125 $\mu g\ m^{-3}$; and for CO, it is 10 mg m^{-3}) [45].

4.2. The consultations provided to patients with respiratory afflictions. Emergency responses conducted by the Suceava County Ambulance Service in relation to patients with respiratory afflictions. Meteorological conditions and their influence on these patients.

During the two years of medical examinations, the doctors and nurses we collaborated with, gave a total of 1954 consultations to chronic or acute patients suffering from respiratory diseases which were localized to the upper respiratory tract (nose, sinuses and throat) or lower tract (respiratory pathways and lungs). In the 1954 cases consulted we targeted patients with chronic (obstructive: emphysema, chronic bronchitis, asthma, cystic fibrosis, and restrictive: pulmonary fibrosis and other more serious conditions such as sarcoidosis, lung cancer) and infectious diseases (pneumonia, tuberculosis).

In the winter months of 2019-2020, given the average wind cooling power values of 813 W/m² and temperature equivalent to the wind cooling power of - 3.9°C, the, the number of patients examined for respiratory afflictions was 689, and during the two summers the number of consultations related to these diseases was 340, given that the average of the wind cooling power index was 312 W m^{-2} and a temperature equivalent to the wind cooling power of 18.8°C (Figures 6a and 6b).

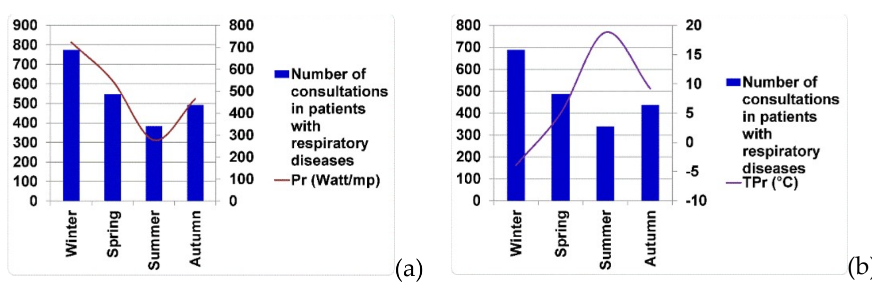


Figure 6. The seasonal variational trend of the cumulative number of examinations provided to patients with respiratory afflictions and Pr – (a) respectively, examinations given to the same patients and TPr – (b) in Suceava throughout 2019-2020

Analyzing the monthly number of examinations conducted for respiratory afflictions and the value cycle of the two bioclimatic indices used, we discovered some relevant aspects. In January when the value of the Pr index is maximum (920 W m^{-2}) indicating significant thermal losses by the human body, and the value of the TPr index is minimal (-5.4°C) indicating a chill atmosphere and real thermal discomfort for people by cooling the number of consultations for patients with respiratory afflictions increased to a total sum number of 281 (January 2019 + January 2020). In August, the value of Pr decreased on average to 284 W m^{-2}, the value of TPr climbed to 20.1°C, this thermo-caloric and meteorological ambience thus leading to a decrease of 105 of the cumulative number of examinations for patients with respiratory afflictions (Figures 7a and 7b).

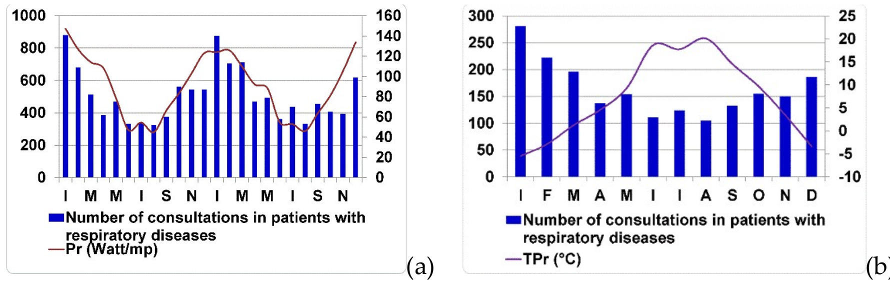
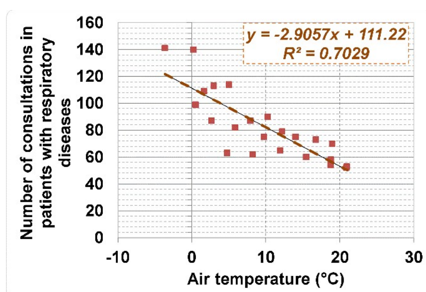
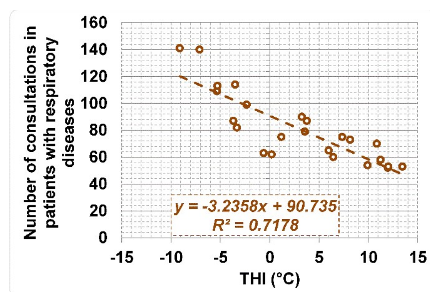


Figure 7. The monthly variational trend of the number of examinations provided to patients with respiratory afflictions and Pr – (a), as well as the cumulative number of consultations provided to the same patients and TPr – (b) in Suceava throughout 2019-2020.

In the wet, cold, windy days of winter or on the contrary with thermal inversions that favor the creation of fog and frosts, respiratory diseases increase in number. Of the total number of 1954 respiratory afflictions requiring consultations, 35 % were recorded in the winter months. Autumn and spring reduced their percentage to 22.4 and 22.9 % respectively, and summer to 17.4 %. In the summer, when thermal comfort is dominant and weather conditions do not put a strain on the body, we measured for Suceava an annual minimum of respiratory ailments.



(a)



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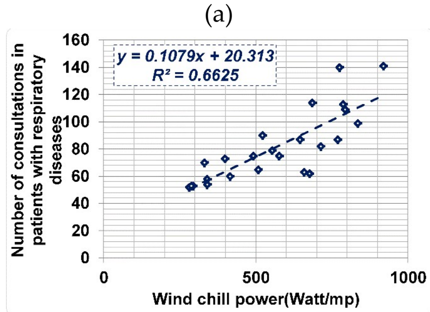


(c)

Figure 8 The mean lines, regression equations, and dispersion indices related to the correlations between the monthly number of examinations provided to patients with respiratory afflictions and air temperature – (a), THI – (b), and Pr (c) (2019-2020).

By maintaining the analysis at the monthly level, we discover a strong correlation between the decrease in air temperature - Figure 8a, respectively THI – Figure 8b and the increase in the number of cases of respiratory afflictions that required medical consultations in Suceava. Regression equations indicate inverse connections between the number of consultations and air temperature / THI, and determination coefficients R^2 show that these correlations are strong: we have identified that 49.5 % the consultations correlate numerically with the air temperature (Figure 8a) and 51.5 % with THI (Figure 8b). We also highlight a strong and direct proportionality between the increase in the value of Pr and the number of consultations for patients with respiratory diseases. 43.9 % the consultations correlate numerically with Pr - Figure 8c.

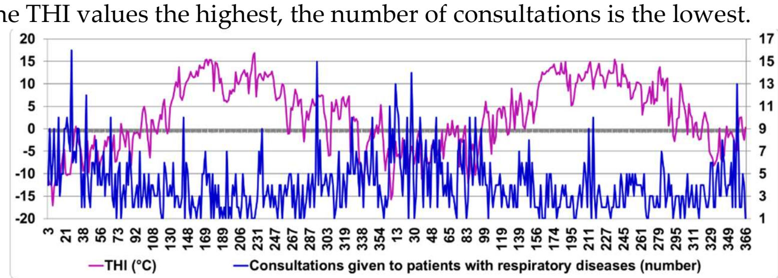
The breakdown of the number of diurnal examinations on a daily analysis level, whose thermal averages were within different thermal intervals (Table 4), revealed to us that on days when t°C was < 0°C the average number of consultations was 6.1, furthermore, as the diurnal thermal averages climbed, the median daily number of consultations for respiratory diseases decreased to less than half (for example on days when t°C was > 23°C, the average daily number of consultations decreased to 3.0).

Table. 4 Statistical information regarding examinations for respiratory afflictions, separated into four temperature intervals, based on the diurnal average temperature of the day in which the examination was conducted (2019-2020).

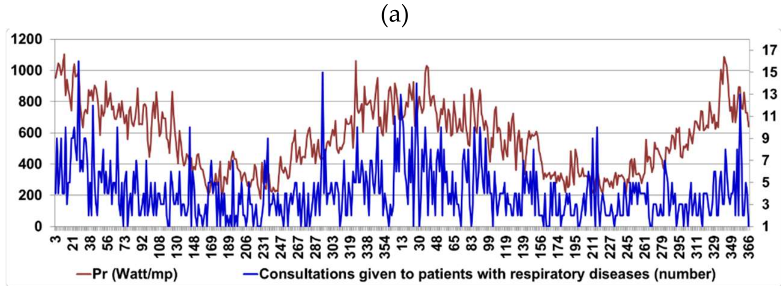
Parameter	t°C < 0°C	t°C between 0 and 17,9°C	t°C between 18 and 23°C	t°C > 23°C
The average temperature for analyzed day-type category	-3,5	8,5	20,3	24,0
The total number of consultations within the analyzed temperature range	274	1332	317	30
The number of days on which patients with cardiovascular conditions were examined	45	324	102	10
The average number of consultations on days when patients with respiratory conditions were examined	6,1	4,1	3,1	3,0

These statistical data are a strong argument of the inverse relationship of proportionality between the increase in the incidence of respiratory diseases and the decrease in air temperature.

The inverse and direct proportionality correlations can also be noted from the analysis of the inter-diurnal variability of the examinations and the inter-diurnal regime of the TCI (Figure 9a) and Pr (Figure 9b), respectively. On winter days when the Pr values are high and the TCI values are low, the number of consultations is, beyond the inter-diurnal variability, higher, and on summer days when the Pr values are the lowest and the THI values the highest, the number of consultations is the lowest.



(a)



(b)

Figure 9. The inter-diurnal variation throughout 2019 and 2020 of the number of consultations provided to patients with respiratory afflictions and THI (a), respectively Pr (b). Only the days when patients with respiratory afflictions were examined is represented.

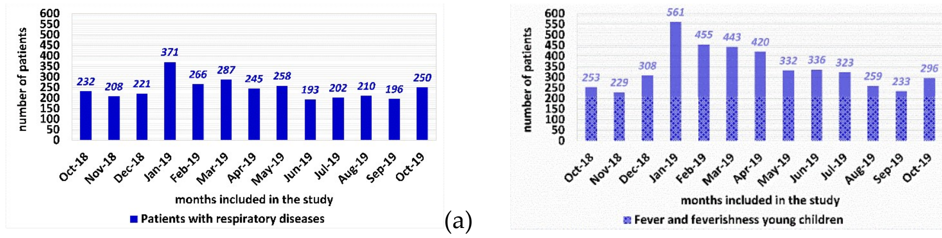


Figure 10. The monthly number of emergency responses by medical teams on the ambulances of the Suceava County Ambulance Service for requests from patients with respiratory afflictions (a) and fever and febrile conditions in young children within the service's coverage area between October 2018 and October 2019.

As discovered even in the emergency medical system, the analysis on two shorter periods (october 2018 – October 2019) highlights the fact that during the months between January and May, ambulance calls by dialing the emergency number 112 for respiratory afflictions (Figure 10 a), fever and febrile conditions in young children (Figure 10b) was higher than in other months of the year.

4.3. Case study for the period of January 4-26, 2020, regarding the influence of meteorological conditions on the number of medical consultations provided for various conditions, including respiratory afflictions.

Between the 4th and the 28th of January 2020, during 14 working days at the medical offices of the doctors participating in our study, a total of 858 medical examinations were conducted. This meant 61.3 / working day examinations were conducted, compared to 26.4 / working day examinations between the 1st of January 2019 and 31st of December 2020.

Table. 5 A concise overview of the air circulation above Suceava during the period of January 4th - January 26th, 2020.

	The direction of air circulation above the Suceava urban area. AMSv	The frequency in number of days of the baric types during study	The percentage frequency of days with the baric types during the study interval.
1_Wc	Circulation from the North Atlantic and Central Nordic Atlantic	1	4.4
2_SWc	Circulation from the Central Atlantic		
3_NWc	Circulation from the Baltic Sea over Central and Eastern Europe	2	8.7
4_Nc	Circulation from the Baltic Sea over Poland, Belarus, and western Ukraine	1	4.4
5_NEc	Circulation from Ukraine and western Russia		
6_Ec	Circulation from the Black Sea over Ukraine and Moldova	1	4.4
7_SEc	Circulation from the Southeast, from the Balkan, Anatolian, Pontic, and Dobrujan spaces		
8_Sc	Circulation from the Aegean Sea, Greece, Bulgaria		
9_Wa	Circulation from Central Europe		
10_SWa	Circulation from the Italian and Balkan Peninsulas		
11_NWa	Circulation from Germany and Poland	4	17.4
12_Na	Circulation from Belarus and the Baltic countries	1	4.4
13_NEa	Circulation from Ukraine, Belarus, and the westernmost part of Russia		
14_Ea	Circulation from central Ukraine and southwestern Russia		
15_SEa	Circulation from the northern Black Sea, Bugeac, Moldova		
16_Sa	Circulation from the southern Black Sea, Anatolian Peninsula, eastern Bulgaria, Dobruja	1	4.4
17_L	Cyclone centered in AMSv, intense circulation		
18_H	Anticyclone centered in AMSv, weak circulation or calm weather	12	52.2

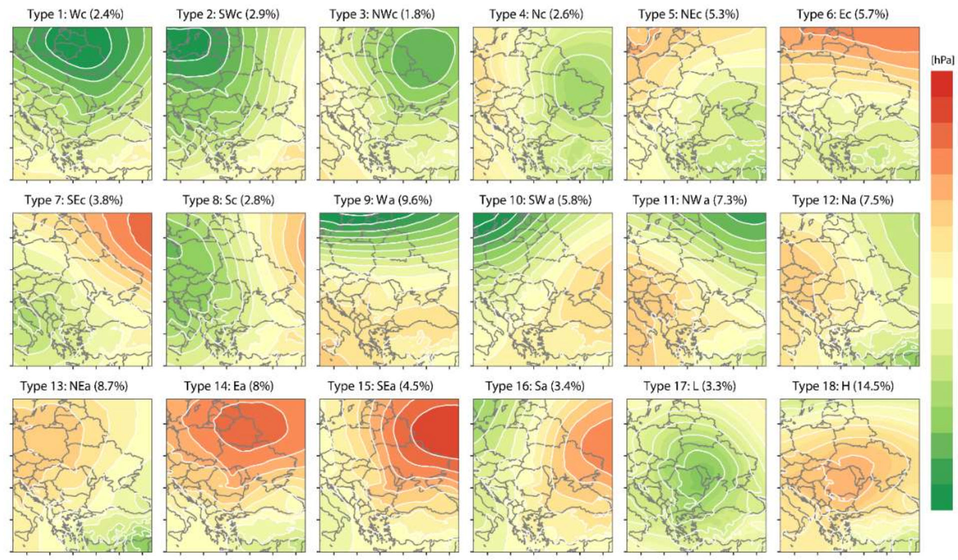


Figure. 11. The average annual frequency (% of total days) of baric types influencing atmospheric dynamics above Suceava in the years 1979 - 2021 [47]

During the period of January 4-26, 2020, an anticyclone centered above the urban area of Suceava dominated for 52.2 % of the time (baric type 18, anticyclonic – Table 5 and Figure 11) . The anticyclone generated relative stable weather and nighttime frost. It was followed by the presence of an anticyclonic dorsal ridge for 17.4 % of the time, as an extension of a cyclone centered over in the Central Europe (baric type 11, a, northwest anticyclonic – Table 5 and Figure 11). Air circulation from Germany and Poland generated cold, cloudy and humid weather. The anticyclonic circulation, which gave the weather more stability, lasted a total of 78.7 % of the time, and the cyclonic one that occurred in 21.3 % during the analyzed period, came with disturbances (wind intensification, snow precipitation). For anti-cyclonic circulation in that representative range is Figure 12 from the 20th of January, showing how extensive and powerful the anticyclone was. It generated stability and overcooling of the air during the nights in depression areas or valleys such as the Suceava River valley and surrounding neighborhoods: Burdujeni, Itcani, and Șcheia.

The meteorological characteristics of the period from January 4th to the 28th, 2020, included predominantly cloudy sky (the total average period nebulosity was 4.8 oktas). The period was a cold one with the average temperature equal to -0.6°C, the minimum temperature descending to -13.1°C, and the maximum one climbing to 18.0°C. The thermal variability was high, with diurnal thermal amplitudes ranging from 1.3 to 23.4°C.

The period was very humid, with an average relative humidity of 80.1 %. Atmospheric pressure was very high (period average was 1027 hPa, the minimum was 1016.1 hPa, and maximum was 1040.3 hPa on 20 January 2020). Precipitation was moderated to quantitatively weak (a total of 5.35 mm). Snow cover was deposited on only 8 days during the period, with a maximum thickness of 4 cm. The ground surface was slippery and moist. Details of the values of the meteorological elements from January 4th up until January 26th, 2020 can be captured in Figure 13a, b and c.

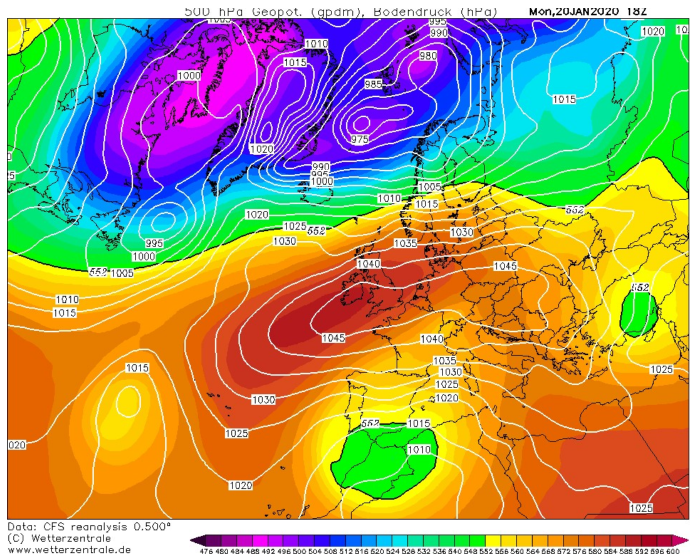
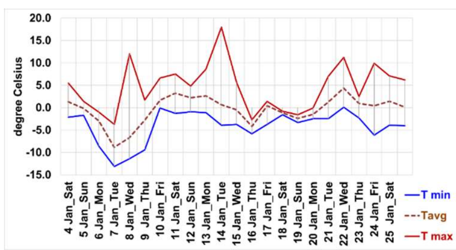
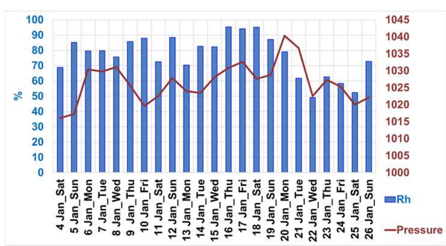


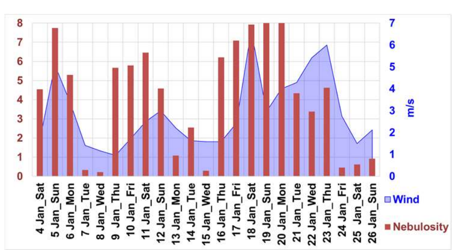
Figure. 12 The distribution of the baric field at the surface and at the level of the 500 hPa isobaric surface (approximately 5000 - 5500 m) on January 20, 2020, at 18 UTC is notable. It's evident that the municipality of Suceava was within the influence area of a vast anticyclonic baric formation, with its core (at 1045 hPa) stretching from the southeast of the British Isles to the east of Romania. https://www.wetterzentrale.de/reanalysis.php?jaar=2020



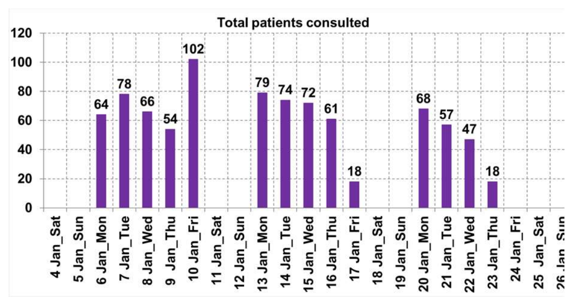
a



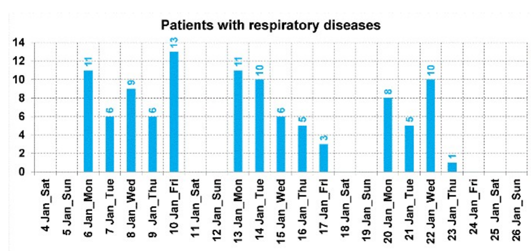
b



c



d



e

Figure 13. The daily variation in air temperature (minimum, average, and maximum values – (a), relative humidity (%) and atmospheric pressure (hPa) – (b), as well as wind speed (ms^{-1}) and total cloud cover (oktas) – (c) at the Suceava Meteorological Station (SMSv) during the period from January 4th to January 26th, 2020; the daily variation in the total number of consultations provided to patients with various conditions – (d) and with respiratory conditions – (e) by the medical team participating in the study during the period from January 4th to January 26th, 2020.

The air pollution level above Suceava was average, especially in the night hours. During the whole period studied the average levels of PM_{10} were 35.4 μgm^{-3} and the maximum went up to 83.2 with 33.3 μgm^{-3} exceeding the daily limit allowed for protection human health. The levels of the other pollutants were not high enough in order to be directly responsible in creating problems for patients in general, neither for those with respiratory conditions in particular.

During the 3 weeks pertaining to our case study, the number of daily consultations for all conditions (61.3) exceeded the daily one for the entire period of 2019-2020 (26.4) by 132 %. The number of daily examinations given to patients with respiratory diseases (7.4) exceeded the average daily one for the entire studied period of 2019-2020 (3.8) by 97.6 % (Figures 13 d and e). The case study period recorded such a high number of patients due to varied factors involved, for example: remaining unresolved pathological remanences, delays during the holidays, but also due to the great thermal variability (with minimums dropping below -10°C and maximums that climbing to over 10°C), in addition, increased baric fluctuations (10 hPa from one day to another; 20 hPa over the entire interval), fluctuating nebulousness, but high overall cloud cover combined with atmospheric moisture, many days with averaging over 80 %, atmospheric calm or days with low wind speeds (1 - 2 ms^{-1}) followed by days with wind intensifications leading to averages of over 5 ms^{-1} (Figures 13 a, b, and c). This significantly high variability of meteorological elements, ranging from very low to very high levels, challenges the body's thermoregulatory mechanisms, lowers immunity, and makes the human organism vulnerable to a number of external infectious agents.

5. Discussions

Our study demonstrates, like other profile studies [1], that between weather variables (t°C, moisture, pressure, wind) biometeorological variables (THI, THI, Pr TPr) and respiratory conditions exist direct and measurable links to account.

Our endeavor demonstrated that weather extremes besides inducing discomfort/stress have a direct effect on certain pathologies [6]. In our work the focus is on respiratory diseases, these afflictions recur during weather extremes or episodes with high meteorological variability. More severe weather episodes with high concentrations of particulate matter suspended in the air, or sedimentable dusts in the atmosphere, measured between January 4 and 26, 2020 that are responsible for the increase in overall morbidity, but also on the component of respiratory diseases [32] which must be forecasted [5] and well managed through weather and medical services appropriate to crisis situations [4]

Negative temperature values generated during the cold seasons of 2019-2020 respiratory diseases (colds, rhinitis, pharyngitis, laryngitis, bronchitis, broncho-pneumopathies) in many patients [9], [10]. The cold season and especially the winter days are create the perfect meteorological climate that is at the basis for the resurgence of respiratory diseases. Sudden variations in temperature are triggers and exacerbate respiratory conditions [9]. On days with negative average temperature values in Suceava, the number of consultations granted to patients with respiratory afflictions was on the whole of the analyzed indicators double compared to the situations in which the average daily temperature exceeded the threshold of 18°C. The humid and cold atmosphere was a catalyst for respiratory diseases [9]. High humidity and wind favored the development and dispersion of some pathogens [17] or, "microbial aerosols" [18]. The drop in atmospheric pressure affected patients with chronic sinusitis, nasal congestion and favored respiratory tract disease and asthmatic episodes [9].

One of the methodological struggles in our scientific endeavor was the difficulty with which meteorological and medical databases are only incidentally compatible at a diurnal level. A substantial effort was dedicated into correlating continuous weather information, without interruptions, with medical information that was lacking a certain rigor of continuity. In order to better correlate medical data with meteorological data in the future, it is necessary to work on improving medical statistics, in order to bring them to a daily level of analysis including several subcomponents, such as: medical offices, ambulance services, emergency responses, health insurance providers, crisis management actors, etc. Although it is reassuring to see patient confidentiality policies properly implemented and enforced, it is our recommendation that anonymous big data information should be accessible to researchers interested in making correlations towards the medical field in formats that do not affect individual patients personal data. In this way, research could contribute to the development of meteorological alerts and services useful for the medical [4] and weather prognostic fields [5] absolutely necessary for the population in general and especially for the population in urban agglomerations. We can express our hope that studies similar to ours will multiply and that they will be able to create the framework for solving many prediction and prevention problems for the population and streamline policies for authorities of Suceava or other cities of Romania.[6]

Conclusions

In the winter months and days, when the air temperature is negative, the wind exceeds the threshold of 3 m/s, the air humidity passes the 80 % threshold, the atmospheric pressure exceeds the normal threshold of 1013.25 hPa, the wind chill power also drops below 800-900 Wm^{-2}, and the equivalent temperature of wind chill descends below -5°C, the number of patients consulted for respiratory afflictions was twice as high as during the months and summer days, when the air temperature frequently exceeds the threshold of 18°C, with the humidity dropping below 60 %, the wind speed is below 1 - 1.5 ms^{-1}, the average wind chill power index was 280-320 Wm^{-2}, respectively, and the equivalent temperature of wind chill rises to 19-21°C.

Of the total number of consultations for respiratory diseases (a number of 1954), 35 % were conducted at medical offices during the winter months of the studied interval (2019-2020). During the autumn and spring their percentage reduced to 22.4 - 22.9 %, while in the summer it was at the lowest of all seasons (17.4 %).

The regression equations indicate inverse proportionality correlations between the number of consultations and air temperature / THI and of direct proportionality between the increase in the value of Pr and the number of consultations for patients with respiratory diseases. The R^2 determinants show that these links are strong: we have identified that 49.5 % of respiratory afflictions examinations correlate with air temperature, 51.5 % with THI, and 43.9 % the consultations correlate with Pr. Specifically, the proportions outlined, explain the extent to which respiratory afflictions examinations are influenced by air temperature, THI, Pr, and TR.

In the case study period from January 4th to 26th, the number of daily consultations for all afflictions exceeded the daily reference by 132 %. The number of daily examinations granted to patients with respiratory diseases exceeded the daily reference one by 97.6 %. Severe, variable weather was largely the main cause of the increase in the number of conditions and examinations for respiratory afflictions.

Contributions of the Authors: "Conceptualization, DM; methodology, MȚC, DM, PIB, CSS; software, PIB and SL; validation, DM and SCS; formal analysis, MȚC and AM; investigation, AM; resources, MȚC; data curation, DM, PIB, SL, SCS; writing—original draft preparation, DM; writing—DM, LGLA, MȚC, PIB and CSS, visualization, LGLA; supervision, MȚC, DM and CSS. All authors have read and agreed to the published version of the manuscript."

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