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TOPOCLIMATIC AND MICROCLIMATIC DIFFERENCES IN THE PITEŞTI TOWN-AREA

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Résumé. La ville de Pitesti a, par sa surface active artificielle, déterminé, dans une manière évidente, la modification des valeurs et des régimes des principaux éléments météorologiques, engendrant ainsi, un climat urbain spécifique. Celui-ci se caractérise par des températures de l'air supérieures à celles de l'extérieur de la ville (les différences positives maximales s'enregistrent à 21 h et elles atteignent 4,7^{o}C), par des valeurs plus réduites de l'humidité relative (les différences négatives vont jusqu'au 10 – 20%) et par des vitesses plus faibles du vent (les différences négatives atteignent 3,2 m/s). Dans le périmètre de la ville il y a des aires avec des bâtiments denses et hautes, avec des maisons individuelles, aires avec des entreprises industrielles, des espaces verts, des surfaces aquatiques etc. Ces aires déterminent des microclimats distinctes, avec des effets pas du tout négligeables sur la qualité de la vie des habitants urbains.

Like many other towns of importance as regards their spatial extent and density of buildings, Piteşti exerts on all meteorological elements deeply modifying influences that turn its relatively homogenous territory as compared to the surrounding regions, into a particular space with specific value and time variations of all the respective elements.

The differences are, obviously, not very big if we compare monthly and yearly means of various climatic parameters, but those referring to the instantaneous values and the daily means are often considerable, thus greatly influencing the climatic comfort and the health status of the inhabitants. And this gets even more prominent provided that the meteorological conditions in specific time periods of the year largely favor the accumulation and the growth of the atmospheric pollutants concentration up to values largely exceeding the maximum allowable limits.

The causes of the differences creating specific urban topoclimatic conditions are numerous and refer mainly to the town's active layer surface that has been deeply modified by human intervention. This surface has physical characteristics that are substantially different from those of the adjoining field areas, also implying

different matter and energetic exchange fluxes. We must also mention that the urban active layer surface gets double since one is lying at the level of the soil surface and the other one is located at the average height of the roofs. But even if the underlying surfaces are made of asphalt, concrete etc. (as in the case of the lower surface) or tiles, bricks etc. (as in the case of the upper surface), they have in common the essential feature of being totally impermeable, thus greatly influencing the radiation budget of the urban space. Together with the presence of the sewage-disposal system, representing another specific feature, the impermeability of the urban active layer surface prevents rainfall water from infiltrating into the ground (this being almost totally taken and evacuated by the town's canalization system), thus largely reducing the heat consumption in the evaporation process. Consequently, the heat resulted from the radiation budget is mainly consumed in the process of heating the underlying surface and from here, in the process of heating the ground surface and the overlying air. This actually makes urban air warmer than the one in the surrounding areas, and also surely drier. But not only because of the previously-mentioned cause, since the marked growth of air-temperature inside the town area may also be attributed to the lower specific heat and the higher heat conductibility of the building materials out of which the town is made of, as well as to the exceptionally high increase of the contact surface between the town's emission-reception surface of radiation energy and air. And we haven't still mentioned all the factors of influence, because the artificial heating all the year round and mostly during the cold season greatly contributes to the increase of the air-temperature and the decrease of the relative humidity in the urban air. Air pollution adds to all these influences which mainly affect the radiation budget and the heat exchange fluxes, with complex and often contradictory effects, which are more difficult to be quantified.

The assessment of the specific topoclimatic conditions in Piteşti city must therefore include, as in the case of any other town, the comparative analysis of the meteorological data covering at least a 30-year long span (which is necessary to ensure the time representativeness of the data series), obtained both from the weather station of Piteşti and from another weather station located in similar physical-geographical conditions, but unaffected by the town's influence. Such ideal conditions are often hard to be found in the case of Romania's towns, as well as in the case of many other towns in the world. This is mainly because the weather station of the analyzed town is not usually located inside the town and consequently, does not provide meteorological information which may be typical of the urban active-layer, and the weather station of reference in the adjoining rural space unaffected by the modifying influence of the city, is neither located at the proper distance from the town, nor is located in somewhat different physical-

geographical conditions, nor has a similar data series in terms of synchronous time-lengths.

Despite some inherent difficulties, the urban topoclimatic characteristics may well enough be evidenced by means of the data obtained from coupled weather-stations, which had obviously been compared to episodic measurements simultaneously made in specific observation points located both inside and outside the towns of reference.

In the present study, we have used the climatic data spanning over a common and synchronous period of 32 years (1971-2002) from Piteşti (295 m) and Morăreşti (548 m) weather stations; the latter being located 20-km from the former. These data series were later completed with further data obtained from episodic measurements performed between 2004 and 2006, in various observation points located quite downtown (that is the *Central Square Area*) and outside the town-area (at the *Confluence* of the Argeş and Doamna rivers), for the topoclimatic analysis, or in some representative locations inside the city area (the *Trivale and Prundu districts* and the bank of the *Piteşti lake*), for the microclimatic analysis.

The analysis of the available data reveals a convincing image of the climatic individuality that the town has created on the general climatic background of the high plain in which it was settled and developed in time, even if some values are largely highlighted or attenuated by physical-geographical factors like altitude and landforms, the presence of relatively extensive water basins in the nearest proximity of the town area, the forest cover etc. The image of the intertwining microclimates inside the town-area is also convincing, even if the objective instrumental data which had been used for their demarcation were not very numerous and fail to span over all the seasons and potential weather types throughout the year.

At the level of the topoclimatic analysis, the mean monthly and annual air-temperatures are conclusive, although they include the influence of the absolute altitude, which juxtaposes in the same direction. As Table 1 reveals, both the mean monthly and the annual air-temperature values are sensibly higher at Piteşti than at Morăreşti. Since the mean annual air-temperature value at Piteşti (10.1^0C) is 0.9^0C higher than at Morăreşti (9.2^0C), one might draw the conclusion that the respective difference is the sole result of the particular way in which the town absorbs and uses the solar radiant energy. And the conclusion gets more self-evident if taking into account that the respective difference maintains within the acceptable limits of variation for middle-sized towns like Piteşti.

The same conclusion comes out of the analysis of the monthly and annual absolute maximum air-temperatures as well (Table 2); the values recorded at Piteşti keeping in all cases higher than at Morăreşti. The highest positive difference (2.5^0C) is characteristic of the hottest month-July. The examples may well continue

with the mean annual number of freezing days, which is lower at Piteşti (99.7) and higher at Morăreşti (102.9). However, the difference is not too large but it fully confirms that the town-area is warmer than the nearby rural settlement areas.

Tab. 1 - Mean monthly and annual air-temperatures (^{0}C)
at Piteşti and Morăreşti weather-stations (1971-2002)

Weather station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Y
Piteşti	-0.6	0.6	4.8	10.0	15.6	18.9	21.2	20.3	16.0	10.4	4.4	0.2	10.1
Morăreşti	-1.2	-0.9	3.9	9.0	14.3	17.8	19.7	19.9	14.9	9.3	3.8	0.1	9.2

Tab. 2 - The highest maximum monthly and annual air-temperatures (^{0}C)
at Piteşti and Morăreşti weather-stations (1971-2002)

Weather station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Y
Piteşti	19.9	20.7	24.4	28.2	32.7	36.7	39.8	36.9	34.2	30.7	23.5	21.5	39.8
Morăreşti	17.0	19.3	23.9	25.6	29.7	34.0	37.3	33.4	32.5	28.8	22.4	18.4	37.3

Nevertheless, we may easily doubt about these proofs by simply admitting the fact the respective thermal differences are not due to the influence of the previously-mentioned urban factors, but to the general rule of air-temperature decrease by altitude. Because, as we have just mentioned, the Morăreşti weather station (548 m) is lying at an absolute altitude which is 241 m higher than the Piteşti station (307 m).

But this argument alone is not enough, since it may be opposed to the argument that the mean number of frost nights (Table 3) and the mean number of winter days (Table 4) are somewhat greater at Piteşti than at Morăreşti. As far as these two parameters are concerned, it comes out that air-temperatures in Piteşti are lower than in Morăreşti, this meaning that air-temperature increases with altitude. This deviation from the rule of air-temperature decrease with altitude may easily be explained on account of the more frequent and longer thermal inversions in Piteşti, during winter. Although they are quite insignificant and can hardly be reflected by the means of the minimum air-temperature values during the winter months, meaning that the influence of the town-area cannot be denied since it obviously counteracts the role of thermal inversions. Besides, the fact that the air-temperature decrease with altitude, combining with its increase as result of the specific influence that urban factors have on the general climatic characteristics, fails to create higher differences between the two weather stations, is mainly due to the

fact that the Piteşti weather station is not located inside the town-area, but in the town's outskirts, close to the Trivale stadium. Moreover, this weather station had formerly been located in the area of the Piteşti airdrome, lying at a 4-km distance, to the South, from the center of the town.

Tab. 3 - The mean monthly and annual number of frost nights ($t_{min} < 10\ ^0C$) at Piteşti and Morăreşti weather-stations (1971-2002)

Weather station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Y
Piteşti	3.4	2.3	0.5	-	-	-	-	-	-	-	0.4	2.1	8.7
Morăreşti	2.9	2.3	0.6	-	-	-	-	-	-	-	0.3	2.0	8.1

Tab. 4 - The mean monthly and annual number of winter nights ($t_{max} < 0\ ^0C$) at Piteşti and Morăreşti weather-stations (1971-2002)

Weather station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Y
Piteşti	9.1	4.5	1.0	-	-	-	-	-	-	-	1.0	5.2	20.8
Morăreşti	5.3	2.6	2.4	-	-	-	-	-	-	-	2.5	6.3	19.1

Finally, the role of the urban climatic factors cannot be neglected since it is objectively revealed by the episodic measurements which have been made throughout several years, in representative observation points inside the town area (the *Central Square Area*, on a specific active surface paved with crimson-red tiles) and outside the town area (the *Confluence* zone lying to 40-km away, to the North, from the confluence point of the Argeş and Doamna rivers, on a grass-covered surface). Out of all the measurement data, we have selected those which were made on 8 consecutive days in August, on the same type of weather conditions (that is high-pressure field with calm and clear skies), for which we computed the hourly means given in Table 5. The data included in this table point to a mean difference of 1.1^0C in favor of the *Central Square* observation point, all through the daily period from 8.00 to 21.00.

The value of the difference changes over the day, according to the specific interaction between the two types of active surfaces and the solar energy flows which downwardly penetrate through the atmosphere, the vertical movements of air and the relief altitude. For example, at 8.00 a.m., the value of the difference is pretty small and negative (0.4^0C), then gradually decreasing and becoming positive as the values of the radiation budget increase, however failing to reach maximum values in the interval of the highest maximum air-temperatures (12.00-15.00). The highest positive differences occur at 20.00 (3.3^0C) and 21.00 (4.7^0C), when, on one

side, the radiative cooling of the open field outside the town area already reduces air-temperature values to 19.1-17.1^{0}C, and, on the other side, in the Central Square Area, the crossed infrared (heat) radiation of the buildings and the heat flow released through conductibility, from the deeper layers of the ground , to the surface, still keep air-temperature to pretty high values (22.4-21.8^{0}C). During the first morning hours, air-temperature inside the town-area gradually gets lower than outside the town – area, on identical high-pressure synoptic conditions. However, the fact that the *Confluence* observation point is lying at an altitude about 10-m lower than the *Central Square* observation point, favors the accumulation of the cold air in the floodplain area between the two rivers, thus greatly diminishing the negative thermal differences specific of the town's adjoining areas.

Tab. 5 - The hourly air-temperature mean values recorded in summer, on calm and clear skies, in the Piteşti town-area (2004-2006)

Observation point	8	9	10	11	12	13	14	15	16	17	18	19	20	21	M
Central Square	18.1	19.3	20.6	21.8	23.0	24.7	26.4	25.3	24.5	23.9	23.4	23.0	22.4	21.8	22.7
Confluence	18.5	19.5	20.8	21.7	22.4	24.0	25.6	24.4	23.6	22.9	22.2	21.2	19.1	17.1	21.6
Lake	18.0	19.0	20.3	21.6	22.6	24.0	25.4	24.0	23.2	22.4	21.2	20.1	19.0	18.1	21.3
Trivale	18.7	19.8	21.0	22.4	22.9	24.5	26.0	25.1	24.3	23.6	23.0	22.8	22.0	21.2	22.6

The topoclimatic differences between the inner and the outer parts of the Piteşti town are also evident when comparatively analyzing the relative humidity data between then two weather stations. And since this is somewhat inversely proportional to air-temperature, its actual values re generally lower in the *Central Square*, than in the *Confluence* zone. However, the directly proportional dependence of relative humidity to the vapor pressure, the elongated shape and the existence of wide-open spaces with sparse buildings, which roughly characterize the city's environment, do not yield highly conclusive data during episodic measurements.

The topoclimatic differences of wind-speed are, nevertheless, highly expressive; they become evident even in the absence of objective, instrumental measurements. The analysis of the wind-speed data obtained in synoptic situations with moderate winds (in August, 2004-2006) reveals that the mean values in the *Central Square* (1.1 m/s) are 1.4 m/s lower than those which had been recorded in the *Confluence* zone (2.5 m/s), outside the town-area. In some cases with very strong winds, the momentary differences reached as high as 3.2 m/s (1.9 m/s in the *Central Square* and 5.1 m/s at the *Confluence*).

The microclimatic analysis highlights the existence of several active surface-types with different features, quite inside the town-area. For example, the

downtown areas, with dense and tall buildings, as well as with artificial pavements in the streets, determine greater changes in the daily and monthly variations of all meteorological elements than the peripheral districts with individual houses, surrounded by smaller or larger open-field spaces over which the soil and the vegetation cover actively interact with the meteorological elements.

There are also green spaces (parks), although not very large, and water areas (like the reservoir lake on the Argeş river) in the town's outskirts, which, on their turn, differently interact with the meteorological elements. These active-layer surfaces with distinct features actually compose a highly-erratic pattern of microclimates, especially on calm weather. Some meteorological elements are significantly modified, so that their specific influence becomes evident even on their long-term (monthly or annual) variations. The results of the episodic air-temperature measurements which have been made at the standard 2-m height above the ground, fully confirm the microclimatic differences between the various relatively homogenous areas inside the city (Table 5).

Therefore, the air-temperature value averaged over the 14 hours, in the four distinct observation points, is, as it was to be expected, obviously higher in the *Central Square* (22.7^0C) and in the *Trivale district* with dense block-of-flats (22.6^0C) and lower on the banks of the *Piteşti Lake* (21.3^0C).

All through the whole daily measurement interval, the hourly air-temperature mean differences are relatively low between the observation points in the *Central Square* and the *Trivale district*, both lying in densely-settled areas with tall block-of-flats. The fact that, in the central downtown area, the buildings are more compact and should have determined higher positive differences, is compensated, and maybe even overcompensated, by the fact that the heart of the city lies at an altitude, which is 51 m lower than the *Trivale district*, thus determining frequent and persistent thermal inversions during the high-pressure periods. This fact is also reflected by the mean hourly air-temperature values from 8.00 (0.6^0C) to 11.00 (0.4^0C).

The highest differences occur between the Central Square (22.7^0C) and the *Piteşti Lake* (21.3^0C) mainly because of the fundamental differences of the heating and cooling processes over the two types of active surface. The mean difference of 1.7^0C of the whole time-series has been much over-exceeded by the mean hourly differences. These differences do not reach maximum values at 14.00 -15.00, in the daytime, but at 20.00 (3.3^0C) – 21.00 (3.7^0C) in the evening, when the downtown areas of the city, which had accumulated great heat amounts during the day, slowly cool down mainly because of the crossed infrared radiations and of the heat flow transmitted by conductibility from the deeper layers of the ground.

Water also cools down more slowly because of the higher specific heat and conductibility values, but during the summer months, its superficial temperatures

keep high enough to favor an active evaporation process, with notable consequences in decreasing the air-temperature values within the microclimatic layer.

More detailed researches may highlight further microclimates, thus greatly contributing to the identification of the most favorable areas for the health and well-being of the town's inhabitants.

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