# THE BIOCLIMATIC STRESS DUE TO OVERCOOLING IN THE SOUTHERN DOBRUDJAN TABLELAND AREA

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**Key words:** bioclimatic indices, space and time distribution, bioclimatic stress due to overcooling, Southern Dobrudjan Tableland area..

**Abstract.** The present study on the bioclimatic cold stress in the Southern Dobrudjan Tableland area analyzes the time and space distribution of some specific bioclimatic indices, such as the *Wind-Chill Index* and the *Winter Scharlau Index*, revealing the area extent and intensity of the bioclimatic risk due to cold exposure. By using the monthly mean values of air-temperature ($^0$C) and humidity (%) or wind-speed (m/s) obtained from six weather stations, for a period of 30 years (1971-2000),we have calculated the corresponding specific values of the above-mentioned indices during the cold season (November-March), thus obtaining results fully concordant with the unanimously accepted global approaches, clearly showing that the bioclimatic stress due to overcooling generally intensifies with increasing wind-speeds along the Black Sea coast or with decreasing air-temperatures in central inland areas, due to the great radiative heat losses of the terrestrial active surface and the absence of the heat income from the warmer water surface of the Black Sea.

## Introduction

The analysis of the influence that various environmental factors might have on human health and behaviour is pretty often very difficult and sometimes too complex but always necessary in order to identify their actual effects on people. Out of the many environmental driving forces, the meteorological and climatic ones are, neverthelesss, the most important ones, since their most often indirect and invisible influence on man, besides their highly variable character in space and time, compose man’s everyday state of comfort or strain, which, in turn, influence his physiological and psychological responses. Human reactions due to heat or cold exposure are obviously different and it is difficult to say which is more hazardous. But any spatial and temporal analysis of the bioclimatic factors in a specific region

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might prove useful to the assessment of their risk potential on human body and well-being.

Since a higher frequency and intensity of a certain bioclimatic risk, either due to overheating or to overcooling, will always tell the difference between them and will finally point to which risk is greater and, therefore, to which risk will make human beings feel more uncomfortable.

In this respect, the bioclimatic stress due to overcooling may be considered as a serious threat to human health since, on one side, the human body has to produce large amounts of heat to compensate for the losses due to exposure in improperly heated indoor or cold outdoor environments, to the detriment of other vital physiological functions, and, on the other side, any dietary or health disorder might seriously impede this heat overproduction process and, therefore, might irreversibly affect human's physiological balance, especially in children and older or sick people which are most vulnerable.

The aim of the present study was to get a suggestive image on the potential extent and intensity of the bioclimatic risk area due to overcooling in the Southern Dobrudjan Tableland area, which is the most intense in Romania, especially due to the higher frequencies of great wind-speeds, and to identify the possible bioclimatic comfortable or uncomfortable areas and periods, which were quantitatively assessed by means of some relevant bioclimatic indices, whose critical values reveal the most hazardous periods and places in this respect.

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## 1.Data and methods

The present study, revealing the bioclimatic risk areas in the Southern Dobrudjan Tableland area, is mainly based on the analysis of the space and time distribution of some important bioclimatic indices specific of the cold season: *Wind-Chill* (and its equivalent temperature) and the *Winter Scharlau Index,* showing that their dynamics largely depends on the periodical or non-periodical variations of some relevant climatic elements. By using the monthly mean values of air-temperature ($^0$C) and humidity (%) or wind-speed (m/s) obtained from six weather stations located in the area of interest (Cernavodă, Medgidia, Adamclisi, Constanța, Mangalia and Hârşova), for a period of 30 years (1971-2000), we have calculated the corresponding specific values of the above-mentioned bioclimatic indices during the cold season (November-March), thus obtaining an extremely synthetic and suggestive image on the intensity and extension of bioclimatic risk areas due to overcooling in the Southern Dobrudjan Tableland area. The electronic calculation sheets were derived from the corresponding formulae of the bioclimatic indices, unanimously used worldwide, which were, however, adapted to the system of units currently being used in Romania (Ionac N., Ciulache S, 2008). We must also mention that the computational series strictly observed the specific limits of appliance for each bioclimatic formula and the resulting tables and graphs, giving a most direct, swift and comprehensive visual understanding of the issues under debate, may become useful tools in assessing the region's future tourism potential.

## 2.Results and discussions

The critical limits of human physiological strain due to overcooling may expressively be established by means of two relevant bioclimatic indices: *Wind-chill* and *Winter Scharlau Index*.

Tab.1 – The validity terms, the value classes and the associated bioclimatic comfort of Wind-chill

| Wind-chill ( Pr - W/m$^2$ ) and Wind-chill equivalent temperature (Tpr - $^0$C) | | | |
|---|---|---|---|
| Formula validity terms: wind-speed between 2 and 24 m/s; air temperature lower than +11$^0$C | | | |
| Wind Chill (W/m$^2$) | Equivalent wind-chill temperature ($^0$C) | Bioclimatic type | Type of bioclimatic comfort |
| 200 - 400 | T > + 10 | Comfortale | Bioclimatic Comfort |
| 400 - 600 | + 10 ≥ T > - 1 | Cooling | Bioclimatic discomfort due to overcooling |
| 600 - 800 | - 1 ≥ T > - 10 | Very cooling | |
| 800 – 1 000 | - 10 ≥ T > - 18 | Cold | |
| 1 000 – 1 200 | - 18 ≥ T > - 29 | Very cold | |
| 1 200 – 1 400 | - 29 ≥ T > - 50 | Overcooling stress | |
| > 1 400 | T ≤ - 50 | Risk of instantaneous frostbites | |

The ***Wind-Chill*** is a bioclimatic index reflecting the combined influence of air-temperature ($^0$C) and wind-speed (m/s) on the heat budget of the human body. It was initially established after an experiment made by P. Siple and Ch. Passel in the Antarctic region, in 1941 (Siple P.A., Passel C.F.,1945), and expressed the equivalent temperature of air cooling power that the human body actually perceives in certain air-temperature and wind-speed conditions , starting from the premises that air motions intensify the evaporation of sweat from human skin, thus decreasing its core temperature. As the initial formula becomes totally unfunctional when air-temperature is lower than 11$^0$C and wind-speed exceeds 2 or 24 m/s, NOAA later developed a more complex *Wind-Chill Index* expressing the intensity of the heat energy (W) that a unit area of body surface (m$^2$) loses through several important heat exchange processes (radiation, convection, conductivity, evaporation etc.), that is, in simpler words, the amount of heat that the human body loses on an area of 1 m$^2$, in a time unit (min), when it is exposed to wind. In this case, wind is the most important climatic factor of influence on human well-being and, consequently, wind-speed variations either due to the general air circulation conditions or to local periodical or non-periodical winds (namely sea-breezes and blizzards, respectively) may create highly uncomfortable bioclimatic conditions, more generally and constantly perceived as rather cold conditions. And this is most often specific of the sea-side area, where wind-speeds greatly increase over the seawater's surface as the friction force of air in motion visibly decreases over the sea (Ionac N., 2007[1]). However, in order to better identify the associated bioclimatic types, Table 1 shows not only the validity terms of the *Wind-chill* formula, but also its value classes and corresponding bioclimatic comfort.

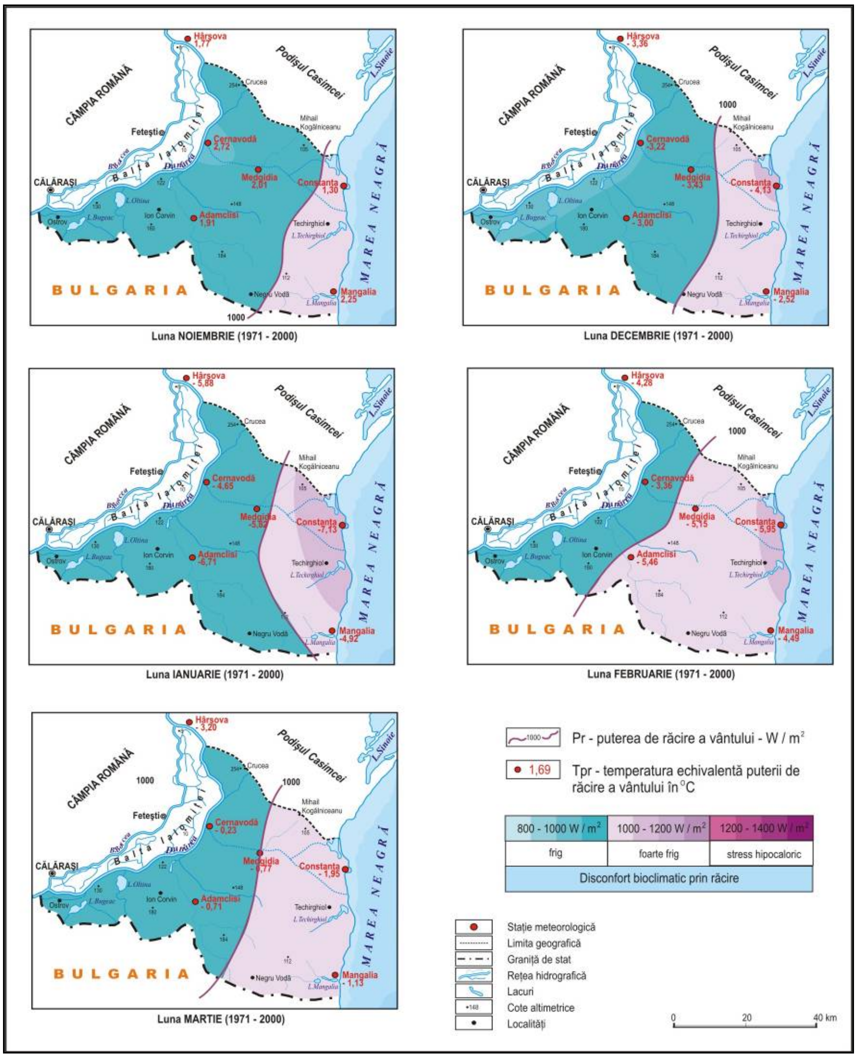


Fig.1 – Spatial distribution of Wind-Chill (Pr - W/$m^2$) and its Equivalent Temperature (Tpr - °C) Indices in the Southern Dobrudjan Tableland Area (1971 – 2000)

By analyzing the maps depicting the spatial distribution of the Wind-chill and its equivalent temperature Indices (Figure 1), one may easily notice that all the Southern Dobrudjan Tableland area is generally characterised by a bioclimatic stress due to overcooling all through the cold season lasting from November to March (Grigore E., 2011).

A closer look at the maps above will reveal that the Wind-chill equivalent temperature (Tpr) values are directly dependent on the Wind-chill (Pr) values but indirectly proportional to the wind-speed, that is they increase as the cooling power of wind gets weaker, namely the wind-speed decreases, and decrease as the cooling power of wind gets stronger, namely the wind-speed increases; reflecting the active role of wind in regulating the heat exchange processes between the human body and its surrounding environment. One may also notice that the area of reference is divided into two important zones of bioclimatic discomfort: the eastern seaside-exposed zone is characterised by *very cold* bioclimatic conditions, while the western inland zone, extending to the Danube River right banks, is characterised by milder bioclimatic conditions, describing only a *cold* environment.

In fact, if analyzing the variation of Wind-chill (Pr) values from one month to another, it is also obvious that the bioclimatic conditions turn *very cold* in February and March, on more than half of the central inland zone and on all the eastern seaside zone, along the Black Sea coast, but they keep *cold* from November to January, especially in the western inland area. This is mainly due to two opposing factors of influence. On one side, in winter, the Black Sea waters have pretty high positive temperatures, giving off, to the air above, important amounts of heat through various radiative and turbulent processes, thus largely increasing air-temperatures on the seaside area, which keep positive all the year round, January included. On the other side, although air-temperatures along the Black Sea Coast are higher in winter than everywhere else in the country, the higher wind-speeds, resulting from a significant decrease of air’s friction force with the plane surface of the Black Sea waters, seriously increase the cooling power of wind, thus reducing the effective temperature that the human body actually perceives and turning the bioclimatic sensations colder than they are really felt (Ciulache S., Ionac N., 2004).

The spatial distribution of the mean annual Wind-chill (Pr) values describes a rather *cold* bioclimate, with heat losses between 800 and 1,000 W/m$^2$, on most of the Southern Dobrudjan Tableland territory and a smaller, more isolated *very cold* bioclimatic area, with heat losses greater than 1,000 – 1,200 W/m$^2$, on the North-Eastern corner of the area of study, more specifically in the town-area of Constanța city, as result of the more constant action of the powerful sea-breezes on the central region of the Black Sea Coast area (Ciulache S., Torică V., 2007).

If analyzing the variation of Wind-chill equivalent temperature (Tpr) values from one month to another, one may notice that they are positive only in

November, when ranging between +1,30°C (at Constanța) and +2,72°C (at Cernavodă), and then they seriously decrease from December to the beginning of spring (March), keeping negative all through the cold season. Moreover, the value differences are pretty high not only from one month to another but also from one one weather station to another. For instance, the negative Wind-chill equivalent temperatures (Tpr) range from -1,13°C (at Mangalia, in March) to -7,13°C (at Constanța, in January), resulting a difference of more than 6,0°C.

Tab.2 – The annual variation of Wind-chill (Pr - W/m$^2$) and Wind-chill equivalent temperature (Tpr - $^0$C) values in the Southern Dobrudjan Tableland area, 1971 – 2000

| Period | month | Measurement unit | Western Danubean Zone | | Central Continental Zone | | Eastern Seaside Zone | |
|---|---|---|---|---|---|---|---|---|
| | | | ***HARŞOVA*** | **CERNAVODĂ** | ADAMCLISI | MEDGIDIA | **CONSTANŢA** | MANGALIA |
| 1971 - 2000 | XI | Pr (W / m²) | 941,11 | 927,03 | 945,85 | 955,81 | 1031,24 | 1011,30 |
| | | Tpr ( °C) | 1,77 | 2,72 | 1,91 | 2,01 | 1,30 | 2,25 |
| | XII | Pr (W / m²) | 953,73 | 950,15 | 977,39 | 979,28 | 1053,36 | 1016,42 |
| | | Tpr ( °C) | -3,36 | -3,22 | -3,00 | -3,43 | -4,13 | -2,52 |
| | I | Pr (W / m²) | 972,14 | 950,50 | 977,76 | 985,64 | 1060,79 | 1013,15 |
| | | Tpr ( °C) | -5,88 | -4,65 | -6,17 | -5,82 | -7,18 | -4,92 |
| | II | Pr (W / m²) | 992,52 | 966,38 | 1004,90 | 1004,95 | 1061,68 | 1019,93 |
| | | Tpr ( °C) | -4,28 | -3,36 | -5,46 | -5,15 | -5,95 | -4,49 |
| | III | Pr (W / m²) | 994,95 | 995,73 | 992,80 | 1002,48 | 1041,62 | 1014,56 |
| | | Tpr ( °C) | -3,20 | -0,23 | -0,71 | -0,77 | -1,95 | -1,18 |
| Annual Mean | | Pr (W / m²) | 970,89 | 957,96 | 979,74 | 985,63 | 1049,74 | 1015,07 |
| | | Tpr ( °C) | -2,99 | -1,74 | -2,69 | -2,63 | -3,58 | -2,17 |

Interesting findings are also revealed by Table 2, presenting the highest (maximum) and the lowest (minimum) Wind-chill (Pr) and Wind-chill equivalent temperature (Tpr) values respectively, during the cold season (from November to March), all through the period of analysis (1971-2000). For instance, the lowest Wind-chill (Pr) value recorded on the Southern Dobrudjan Tableland territory in the 1971-2000 period, was 927,03 W/m$^2$ at Cernavodă (in November) and the highest corresponding value reached 1061,68 W/m$^2$ at Constanța (in February). However, the range of the extreme Wind-chill (Pr) values from one weather station to another and from one month to another reflects rapid and abrupt shifts of bioclimatic conditions on the Black Sea Coast but slow and little changes of bioclimatic features on the western and central parts of the region of study. The mean annual Wind-chill (Pr) values range from 957,96 W/m$^2$ at Cernavodă to 1,049.74 W/m$^2$ at Constanța throughout the entire period of analysis (1971-2000). In fact, the multi-annual variation of Wind-chill (Pr) values reflects an evident bioclimatic stress due to overcooling conditions for more than 67% of the period of reference. Table 2 also presents the corresponding monthly extreme Wind-chill equivalent temperature (Tpr) values, ranging from –7,18˚C at Constanța (in

January) and +2,72˚C at Cernavodă (in November). The corresponding (Tpr) mean annual values range between -1,74˚C at Cernavodă and -3,58˚C at Constanța.

**The *Winter Scharlau Index*** (SI), experimentally established by K. Scharlau (Scharlau K., 1950) in order to assess the physiological strain due to cold exposure, that is to measure the intensity of the human overcooling stress, clearly reflects the fact that, in the absence of wind, the wet and cold climatic conditions may be harmful to the unacclimatized people, due to the intensification of radiation and evaporation exchange rates of the human body, with serious negative consequences on its thermo-regulating processes. Actually, the values of this index, currently being calculated only on condition that air-temperature values keep between -5$^0$C and +6$^0$C and relative humidity values maintain higher than 40%, describe the bioclimatic comfortable or discomfortable sensations due to cold exposure but also indicate the *critical temperatures*, representing the corresponding air-temperature values **below** which, at certain air-humidity values, the human body effectively feels uncomfortable because of the intense physiological cooling processes due to radiative and evaporation heat losses from the exposed skin (Ionac N., Ciulache S., 2008). In this respect, Table 3 shows not only the validity terms of the *SI* formula, but also its value classes and corresponding bioclimatic comfort.

Tab.3 – The validity terms, the value classes and the associated bioclimatic types of the Scharlau Index (SI)

| Winter Scharlau Index (SI - units) | | |
|---|---|---|
| Formula validity terms: air-temperature between -5$^0$C and + 6$^0$C; relative humidity over 40% | | |
| SI - units | Bioclimatic type | Type of bioclimatic comfort |
| IS ≥ 0 | Comfort | Bioclimatic Comfort |
| - 1 < IS < 0 | Slightly uncomfortable | Bioclimatic discomfort due to overcooling |
| - 3 < IS ≤ -1 | Moderately uncomfortable | |
| IS ≤ -3 | Highly uncomfortable | |

According to its formula validity terms, the *Winter Scharlau Index* could be calculated only for the cold season months (November – March) of the period of reference (1971-2000), but its actual values show that the wet and cold unfavourable bioclimatic conditions of the given geographical region are dominant only in December, January and February, that is only during the winter months. For instance, in November, the entire Southern Dobrudjan Tableland territory is characterised by pretty comfortable bioclimatic conditions, which are more pronounced in the western Danubean and central inland areas and less intense on the eastern seaside area; the SI values ranging from 2.18 units at Hârşova to 4.76 units at Mangalia, where they reach the highest values in the entire period of analysis (Figure 2). In December, the bioclimatic conditions are largely differentiated since the area of bioclimatic comfort along the Black Sea coast

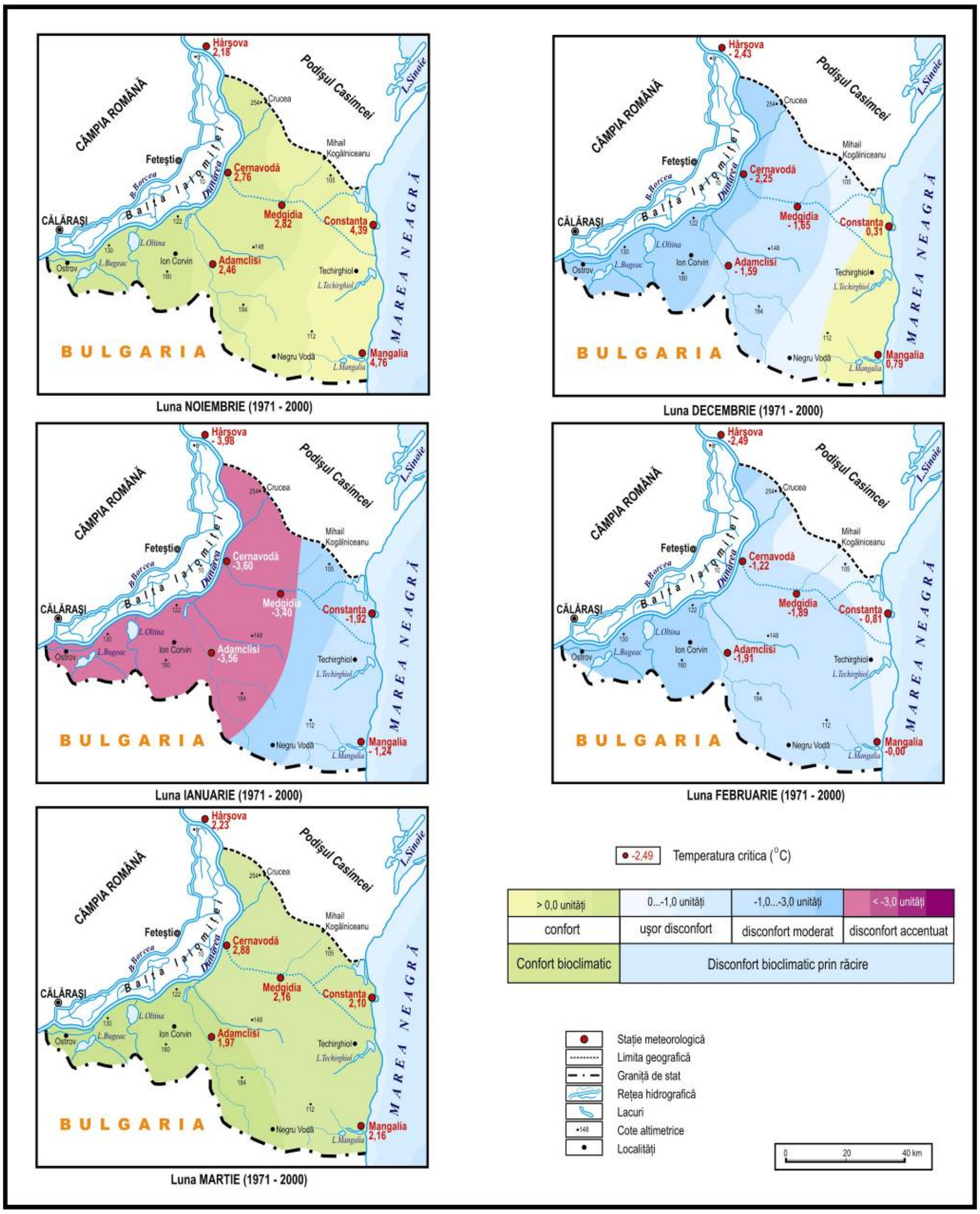


Fig.2 - Spatial distribution of Winter Scharlau Index (SI)
in the Southern Dobrudjan Tableland Area (1971 – 2000)

clearly opposes to the area of bioclimatic stress due to overcooling on the rest of the territory (Grigore E., 2011). In this case, since the SI formula is based only on the air-temperature and relative humidity input data, it is self evident that the bioclimatic type depends mainly on air-temperature values and, consequently, the lower the air-temperatures get, the more uncomfortable the bioclimatic sensations become on conditions of cold exposure. And this is best reflected by the more intense stress due to overcooling in the western and central inland areas, where the great radiative heat losses of the terrestrial active surface and the absence of the heat income from the warmer water surface of the Black Sea significantly reduce air-temperatures and thus, turn the local bioclimatic conditions into highly uncomfortable sensations of cooling (Ionac N., 2007[2]).

However, the bioclimatic stress due to overcooling gets weaker to the wet island areas formed between the Danube River arms, in the West, where the SI values in December go as low as – 2.53 units at Hârşova, and it consequently gets stronger to the eastern seaside strip along the Black Sea Coast, where the SI values keep positive (0.79 units at Mangalia). In January and February, the bioclimatic stress due to overcooling prevails over the entire Southern Dobrudjan Tableland area, getting most intense in the western and central inland areas, in January, when the lowest SI values have been recorded (- 3.98 units at Hârşova). In March, the bioclimatic conditions turn comfortable all over the territory of reference, since the SI values keep positive, yet very different from one place to another (1.97 units at Adamclisi and 2.88 units at Cernavodă).

Tab.4 – The annual variation of *Winter Scharlau Index* values (units) in the Southern Dobrudjan Tableland area, 1971 – 2000

| Period | IMonth | Western Danubean Zone | | Central Continental Zone | | Eastern Seaside Zone | |
|---|---|---|---|---|---|---|---|
| | | ***HARŞOVA*** | **CERNAVODĂ** | ADAMCLISI | MEDGIDIA | CONSTANŢA | MANGALIA |
| 1971 - 2000 | I | -3,98 | -3,60 | -3,56 | -3,40 | -1,92 | -1,24 |
| | II | -2,49 | -1,22 | -1,91 | -1,89 | -0,81 | -0,00 |
| | III | 2,23 | 2,88 | 1,97 | 2,16 | 2,10 | 2,16 |
| | XI | 2,18 | 2,76 | 2,46 | 2,82 | 4,39 | 4,76 |
| | XII | -2,53 | -2,25 | -1,59 | -1,65 | 0,31 | 0,79 |
| Annual Mean | | -0,91 | -0,28 | -0,52 | -0,39 | 0,81 | 1,29 |

The variation of the *Winter Scharlau Index* values from one month to another, all through the period of analysis (1971-2000), is very large on the Southern Dobrudjan Tableland area, the most extreme values ranging from – 3.98 units at

Hârşova (in January) to +4.76 units at Mangalia (in November). Table 4 actually gives the SI values for each weather station taken into consideration in this study, showing, in case of mean annual SI values, for instance, that they ranged from -0.91 units at Hârşova, to +1.29 units at Mangalia. In fact, the mean multi-annual variation (1971-2000) of the SI values reflects that the bioclimatic stress due to overcooling is characteristic of 53.3% of the cold season (November-March) interval, while the comfortable bioclimatic conditions are felt only during the remaining 46.7% of the time. The comfortable bioclimatic conditions are dominant all over the Southern Dobrudjan Tableland area in November and March, and also on the seaside area, in December only.The rest of the territory is characterised by uncomfortable bioclimatic conditions due to overcooling, which are more intense in January (at Hârşova, Cernavodă, Adamclisi and Medgidia); only moderate in January (Constanța and Mangalia), February and December (Hârşova, Cernavodă, Adamclisi and Medgidia); and weaker in February (at Constanța and Mangalia).

**Conclusions**

The present paper-work, mainly based on the analysis of the space and time distribution of some important bioclimatic indices specific of the cold season: *Wind-Chill Index* (and its equivalent temperature) and the *Winter Scharlau Index*, identified the bioclimatic risk areas due to overcooling in the Southern Dobrudjan Tableland area, showing that their dynamics largely depends on the spatial and time variations of some important radiative, dynamic and physical-geographical climatic factors. In case of *Wind-chill Index* (Pr), wind is the most important climatic factor of influence on human bioclimatic comfort and, consequently, wind-speed variations either due to the general air circulation conditions or to local periodical or non-periodical winds (namely sea-breezes and blizzards, respectively) may create highly uncomfortable bioclimatic conditions, making people feel at stress due to the overcooling power of air in motion, especially on the seaside area, all through the cold season (November-March). In case of the *Winter Scharlau Index* (SI), which is basically calculated only in function of air-temperature and relative humidity input data, the wet and cold uncomfortable bioclimatic conditions, namely the bioclimatic stress due to overcooling of the given geographical region are dominant only in December, January and February, when it gets more intense in the western and central inland areas, due to the great radiative heat losses of the terrestrial active surface and the absence of the heat income from the warmer water surface of the Black Sea.

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