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CONTRIBUTIONS TO THE REGIONALIZATION OF AIR TEMPERATURE IN EUROPE

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Rezumat : *Contribuții la regionalizarea temperaturii aerului în Europa*. Din bibliotecile de specialitate nu lipsesc studii, manuale şi atlase privind repartiția spațială a precipitațiilor in Europa, la nivel local, regional şi chiar european. Lucrarea noastra se justifică prin aceea că aduce unele precizări, pe care ne permitem să le apreciem ca necesare, dat fiind faptul că la ora actuală ne sunt la indemână date mai numeroase şi mai precise, inclusiv imagini satelitare. Toate acestea ne-au permis să facem o analiză mai fundamentată, in primul rând a raportului dintre originea, caracterul şi, mai ales, dinamica maselor de aer şi repartiția spațială a precipitațiilor la nivelul continentului. În lucrare au fost analizate totodată şi rolul latitudinii, reliefului, mărilor şi oceanelor vecine in explicarea fenomenului care face obiectul acestei lucrări. Pentru ilustrarea grafică a repartiției spațiale a precipitațiilor am construit un set de hărți reprezentative, folosind mijloace informatice moderne.

Key words: thermal distribution by regions, spatial distribution, automatic classification, discriminatory analysis

The spatial distribution of air temperature in Europe, as we will next present it, does not present any new, surprising and spectacular elements compared to what it is already known. However, as we have incomparably richer information than some decades ago, we could provide significant retouching. What we mean by information refers to its quality, its volume and the easier possibility to have access to it, now that we are in the era of meteorological satellites and internet. We could rely on climatic data from more than 4000 stations all over the world, out of which more than 600 in Europe, gathered in a volume and a CD edited by WMO (2004) and an approximate equal number of data which may be found in materials offered by F.A.O. (2003). We have also mentioned the number of stations outside Europe as, for us to better understand certain aspects, we have used comparative analyses based on data from other continents, from Northern America especially. The paper includes a series of graphical materials among which we should mention, first of all, maps presenting the territorial distribution of air temperature, that is the phenomenon which is the goal of our paper.

As Europe generally lies in the temperate area where, from the thermal point, 4 annual seasons may be clearly distinguished, we have drawn a map with the monthly (pluri-annual) average temperature for the most characteristic month of each season: January, April, July and October (figure 1). Another map presents the spatial distribution of annual average temperature (figure 2). We have calculated the pluri-annual averages for 30 years for all the maps.

Factors conditioning the temperature's spatial distribution

The spatial distribution of air temperature in Europe is influenced by numerous cosmic and geographical factors, among which the most important ones are:

- Latitude;
- Air masses;
- Europe's relationship with the neighbouring, maritime or continental areas;
- Relief.

The **latitude** factor is important as far as the distribution of solar radiation is concerned; however this is not a decisive factor. The temperature areas (latitudinal areas) are not parallel. The lines demarcating them do not follow the path of the geographical parallels, as it would happen on a ideal, uniform in terms of surface structure and smooth planet or with a very weak fragmentation. There are also some other important factors disturbing the astronomic factor. The influence of the other factors varies from one season to another, from one region to another or depending on both factors. For instance, in the cold season, the Mediterranean warm air goes to the north, through the gate between the Pyrenees and the Alps to the Paris region "as if it would be wrong with respect to latitude" as Max Derruaux says. This phenomenon considerably contributes to the movement to the north of the winter temperatures in this area (figure 1.a). The nature and circulation of air masses go through some important changes all through the year and from one year to another, the distribution of major relief forms is not arranged based on latitude, the ocean (sea) – land relations are very complicated and such examples may go on. However, the latitude factor generally plays an important part as far as the distribution of air temperature is concerned by means of a decrease of solar radiation and radiation balance from south to north, with some perturbations brought about by the listed factors (and some others too). The annual solar radiation ranges between about 160 kcal/cm² in the extreme southern parts of Europe (Peloponnese, Sicily, Gibraltar) and 70 kcal/cm² in the extreme northern areas (Mageröi Island). The annual radiation balance decreases in the north direction as well, from 80 kcal/cm² in the southern part of the continent to 20 kcal/cm² in the northern part. Even if the annual average values of radiation balance in Europe are positive, however, in the cold season, negative values are registered on almost the whole of the continent. The “0” isoline of radiation balance, for December and January, passes at approximately latitude 40º N, south to this parallel, in the western half of Europe and north to 40º N in its eastern half.

The air masses circulating above Europe play a very important part in the explanation of the territorial distribution of air temperature. Europe it is under the influence of 4 main types of air masses: polar-Atlantic, polar-continental, Arctic and tropical. The first two types are also the most important ones.

The polar-Atlantic masses, formed at medium latitudes above the Atlantic Ocean, are the most voluminous ones, they are warm enough and they generate rains. They move on the western-eastern direction within the western flow (*Westerlies*). Their speed is periodically accelerated by the presence of some stronger cyclones in the chain of cyclones which is formed and circulates along the polar front simultaneously with stronger anticyclones which are formed and move on the western-eastern direction within the band of high pressure of dynamic origin from the subtropical area. This flow is the most important one in Europe. It entirely crosses the continent, going to Asia as well.

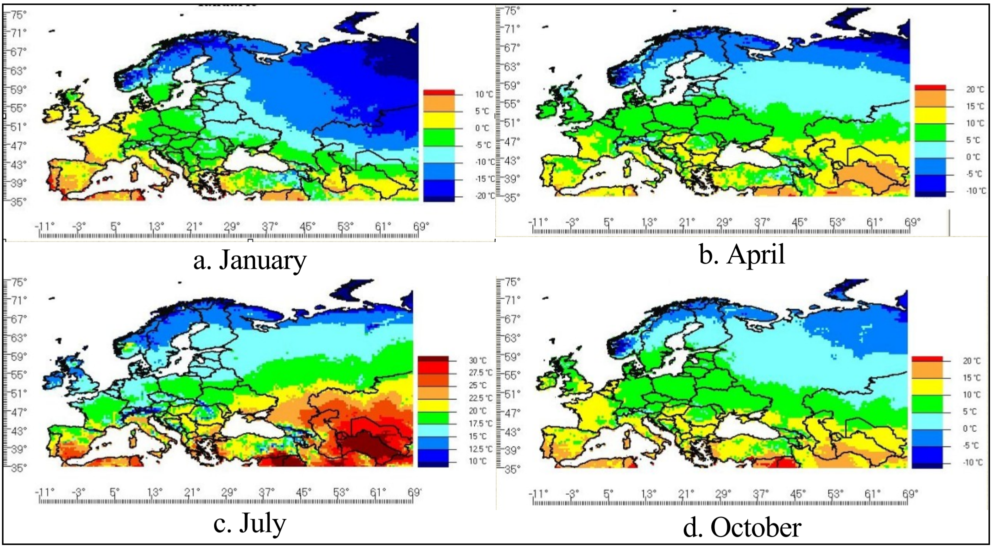

Figure 1. *The spatial distribution of air temperature in the extreme and the transition months*

The second type of air masses considerably participating in the spatial distribution of temperatures in Europe is the *polar-continental* type, coming from the east, from Asia, including the air masses of the same type which are formed above Europe, mainly above the eastern sector of the continent, that is where the continental mass is the most extensive. These air masses are generally dry, cold in winter and hot in summer.

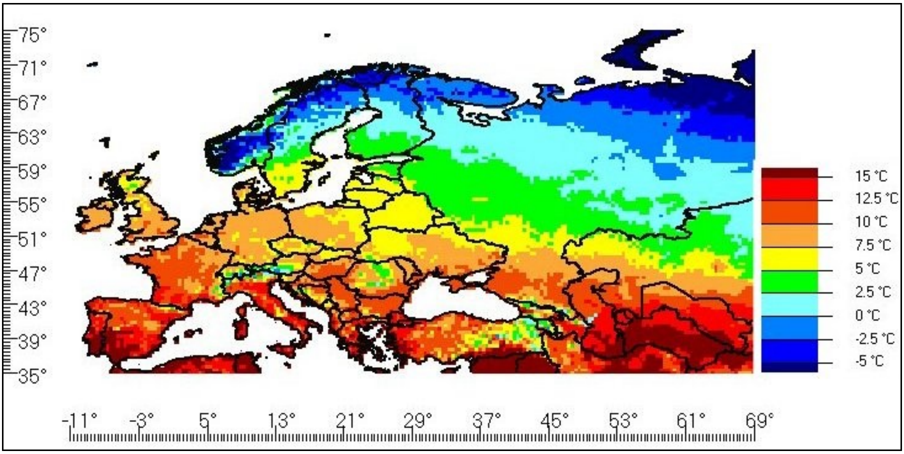

Figure 2. *The spatial distribution of the mean annual temperature*

The air masses of *Arctic* type, which are cold and moist, sporadically enter the European territory, especially in the cold season of the year. Considering the establishment of a cyclonal area in the northern half of Russian Plain and of an anti-cyclonic area in the north-eastern part of the Atlantic Ocean, this type of air may reach the Alps-Carpathians frontier.

The southern half of Europe is under the influence of air masses of *tropical* type. These are dominant in the warm season. Their influence is but rarely found north to Pyrenees-Alps-Carpathians frontier. Their influence is manifested by the high temperatures in summer, the warm waters of the Mediterranean Sea which embrace the three large peninsulas in the Southern Europe also contribute to these temperatures.

The dominant movement of air masses in Europe is from the west, with its components: north-west and south-west. The movement from the east with its components: north-east and south-east is much lower. The statistical data show a ratio of 7/3 for the two main directions. We should note here that the air movement on the ground is sometimes considerably different from the rest of the air mass. These distortions are caused by local or regional geographical factors, out of which relief is the most important one. We shall detail some aspects regarding the involvement of the relief factor.

On the other hand, the air masses which entirely move on a certain direction bring cyclones or anticyclones which cause very complex intrinsic dynamics. We considered the general dynamics of air masses as it has an important part when it comes to explaining the geometry and the geographical positions of the temperature regions in Europe.

The continent-ocean (sea) relationship

The presence of the massive Asiatic continent in the east and of the Atlantic Ocean in the west plays an important part in redirecting the temperature regions of Europe from their orientation as bands with the separation lines relatively loyal to parallels (figure 2). This impact is highlighted very well by comparing the situation in the middle of winter – January (figure 1.a) to that in the middle of summer – July (figure 1.c). We observe that, due to the different influences exercised by the two factors mentioned above, the thermal bands corresponding to the 2 months do not follow the direction of parallels, as they are oriented west- south-west – east – north-east in summer (July) and west- north-west – east – south-east in winter (January). Moreover, the width of these bands is larger in west in summer and larger in east in winter. Besides the Atlantic Ocean and Asia, the dimensions and orientation of the temperature bands are also established by the Mediterranean Sea in south and Arctic Ocean in north. However, their influence is much weaker and is more frequently expressed by the fringement of the external limit, especially in the area of contact with the Mediterranean Sea.

The **relief** of Europe is complex, which may be explained by the complex evolution of geological processes, with the succession of numerous orogenetic cycles, spectacular changes of climate, especially in Pliocene-Quaternary stage and wide spread of glaciation in Pleistocene. The surface of Europe is generally characterised by an increased fragmentation, with mountains higher than 4000 m and plains lying under the general level of seas. The territorial distribution of mountains and plains is not uniform. The Southern Europe is mostly mountainous and in the western half of the continent, taken in its totality, all the mountains are concentrated whereas the eastern half is a vast territory of plain. Neither mountainous regions nor the plain ones are homogenous. Some systems of mountains have indistinct contours and small relief energies (Caledonian and Hercynian groups of mountains); others consist of vigorous tops with great relief energies (chains of the Alps-Carpathian system). Some plains have a smooth relief, with flat surfaces (Inferior Danube Plain) whereas some others are characterised by a complex relief (Eastern Europe Plain). The mountainous chains are differently oriented: The Pyrenees, Alps, Carpathians partially, Balkans are oriented west-east whereas the Apennines, Scandinavian Mountains, Dinaric Mountains etc are generally oriented north-south. These shown differences have an important impact on climate.

In the fragmented (mountainous) regions, the distribution of temperature is more colourful compared to the plain areas or hills. This is a normal situation. However, the mountains of Europe have a different role with respect to the establishment of the annual average temperature, depending on latitude, on the orientation of the great mountainous chains, on their internal macro morphology (the presence of the great intra-mountain depressions, great valley couloirs) and other less important morphological factors. We should note here that latitude by itself is not involved in these spatial differences with respect to relief. A more important fact is that the southern Europe is, most of the year, under the influence of poorly moist air masses which decreases the value of the temperature gradient, whereas the Northern Europe is under the influence of moist air masses which increases the value of the temperature gradient.

We may note in this respect a south-north gradation. The mountains located in the extreme southern parts of Europe practically do not create any isles with thermal values significantly different compared to the area where they lie. The mountains located at medium latitudes (the Alps, Carpathians, Pyrenees to a smaller extent) create isles of lower but sufficiently moderate annual average temperatures. However, the Scandinavian Mountains which practically bathe in very moist air masses all over the year appear as an isle with a monthly average temperature lower by 7-8º C compared to the low area of Sweden. With respect to the orientation of the mountainous chains, this becomes an important factor for the distribution of air temperature if it is more or less perpendicular to the movement direction of air masses. A clear example in this respect is the Scandinavian Mountains chain. As here the dominant movement direction of air masses is west-north-west – east-south-east, that is perpendicular to the direction of mountains, they have to climb this wall which enables the föehn to actively participate in the distribution of air temperature in the vast hilly area between the Scandinavian Mountains and border of the Baltic Sea. In this vast area, temperatures are higher by 8-10º C compared to the western slope of the Scandinavian Mountains. We need to specify that it is compared to the western **slope** and not to the western, Atlantic **border** of this peninsula where there is a completely exceptional situation, a thermal anomaly which was analysed by our team in another paper (*Hârjoabă I., Erhan Elena, Patriche C.V.*, 2006, *Erhan Elena, Hârjoabă I., Patriche C.V.*, 2006).

The large intramountainous depressions, such as those in the Carpathians or large valley couloirs, such as those in the Alps, bring about important discontinuities in the spatial distribution of air temperature in Europe. Their entry in the thermal picture of the continent is different. Depressions give rise, especially in the cold season, to what the Russian climatologists expressively called “cold lakes”. Some valley couloirs with a high frequency of foehn register higher temperatures even in winter (at Bludenz, Austria, 18º C was registered in February!). The Rhone valley (Valais) is famous for its long and warm summer in favour of vine and fruit trees, even apricot trees.

This paper has not analysed all the factors which participate, in one way or another, in the territorial distribution of air temperature in Europe, as it has focussed on those with a visible role. We hope to have the opportunity in a near future to pay the due attention to the less visible ones which have secondary and, especially, local roles.

It comes out from the presentation of the 4 basic factors listed above, with their specific contribution to the territorial distribution of air temperature that Europe has some geometry and spatial distribution of its various temperature units which are far more complex compared to the other continents, except for Asia which Europe actually belongs to.

The temperature regionalization

The temperature regionalization was performed on the basis of statistical methods, following 3 main stages:

- the spatialisation of temperature parameters by *residual kriging*;
- integration of temperature fields by methods of *automatic classification*;
- assessment of the quality of regionalization by *discriminant analysis*.

The spatialisation of temperature parameters was carried out by *residual kriging* by means of the NewLocClim 1.03 software[1] at a spatial resolution of 0.4º, this one being the finest resolution allowed by the programme at the level of the working scale (European continent). The application of this method followed 3 stages:

- estimation of the temperature parameters based on the local vertical and horizontal gradients established by regression (deterministic component);
- interpolation of residues by ordinary kriging (stochastic component);
- addition the deterministic component up with the stochastic one resulting in the final spatial model.

The integration of spatial models of the analysed climatic parameters (*temperature regionalization*) was carried out by automatic classification, by

[1] NewLocClim – Local Climate Estimator, developed by Jürgen Grieser, FAO/SDRN, 2005

means of *fuzzy k-means* method within the TNTmips 6.4 software[2]. The resolution of spatial models was improved to 1x1 km through the interpolation, in TNTmips by means of the minimum curvature method, of the grids imported from NewLocClim.

The fuzzy k-means method is an unsupervised automatic classification method which defines the likelihood of a value's belonging to a certain class. The classification aims at minimizing the intra-class variance and maximizing the inter-class variance, as well as minimizing the likelihood of values' belonging to other classes. The classification used as input data the initial (untransformed) variables (the temperature parameters themselves) as well as the first 2 principal components derived from the application of the *principal component analysis* (PCA) on the initial variables.

Using the principal components in the automatic classifications presents 2 main advantages: the principal components are not correlated, therefore the issue of the Euclidian distances between classes' averages is solved; the values of the principal components are comparable, the scale issue of values is therefore solved. The main disadvantages refer to the difficulty of defining the principal components and establishing the role of initial variables in defining classes.

The classification was gradually carried out, from 3 classes to 10 classes, their spatial evolution being observed. The minimum number of classes for the temperature regionalization was established to be 9 considering the fact that at this level the arid Mediterranean area is separated within the classification based on initial data. We note significant differences between classifications based on initial data (figure 3.a) and those based on PCA scores (figure 3.b).

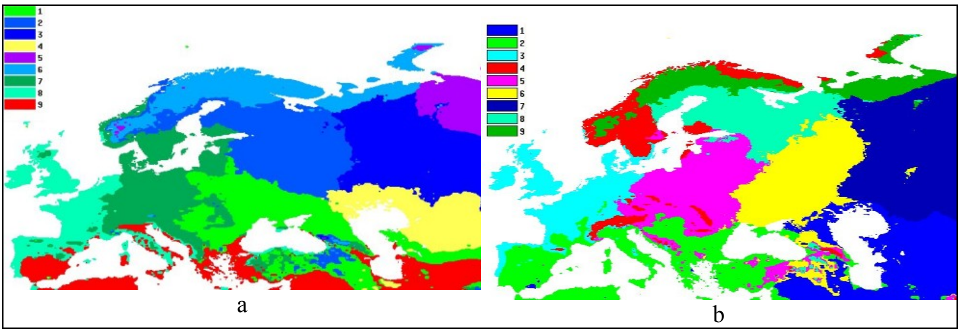

Figure 3. *Comparison between the two statistically-based regionalisation of air temperature, based on the initial variables (a) and the PCA transformed variables (b)*

[2] TNT Map and Image Processing System, Lincoln, Microimages Inc.

For us to decide which of the regionalisation is optimal from the statistical point of view, we applied the *discriminant analysis* by means of the XLSTAT module (table 1). The results show that the percentages of those points which were wrongly classified are smaller if initial variables are used, being minimum for the grouping of 9 classes. Moreover, the Euclidian distances among the 9 classes are larger if the classification is based on initial data, compared with the use of PCA scores, showing a better discrimination of classes in the first case.

	Fuzzy k-means with the initial variables		**Fuzzy k-means with PCA scores**	
	9 classes	10 classes	9 classes	10 classes
Wrongly classified points (no)	**1133**	1268	1433	1601
Wrongly classified points (%)	**9,25%**	10,35%	11,7%	13,7%
lambda de Wilks	0.0134	0,0099	0,0177	0,0154

Table 1. *Results from discriminant analysis*

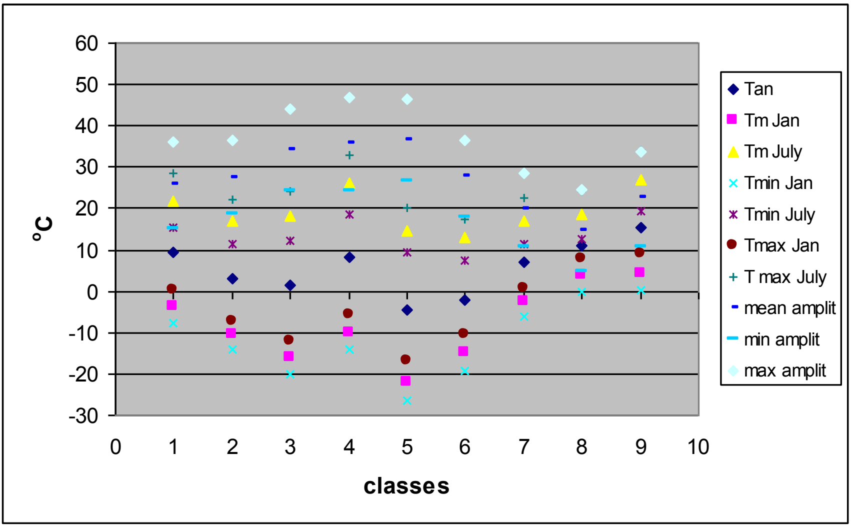

Figure 4. *The mean values of the temperature parameters for the 9 classes regionalization based on initial variables*

Note: 1 – Central and South Eastern Europe, 2 – Central-Northern Europe (Western Russian Plain, Finland), 3 – Eastern Europe (Eastern Russian Plain), 4 – Caspian Sea region, 5 – North-Eastern Europe (arctic region), 6 – Northern Europe (Scandinavia, White Sea, Barents Sea shores), 7 – Central-Western Europe, 8 – Western Europe, 9 – dry Mediterranean region

For this temperature regionalization we have reallocated the points which were wrongly classified and corrected the classification. We note here class 3, corresponding to the Eastern Europe (eastern half of the Russian Plain) as the most stable one, that is better defined, characterised by a minimum percentage of points which were wrongly classified. At the opposite pole, we may find class 1 with a percentage of wrong points of about 18%, corresponding to the Central and Southern-Eastern Europe.

References

Alisov B.V., Poltaraus B.V. (1974) – *Klimatologhia*, Ed. Univ. Moscova.

Derruaux M. (1971) – *L'Europe*, Collection H. U., Paris.

Erhan Elena, Hârjoabă I., Patriche C.V. (2006) – *Specific Aspects Regarding the Air Temperature Distribution in Europe, Along the Meridians*, Lucr. Sem. Geogr. „D. Cantemir", nr. 26/2005.

Hârjoabă I. (autor şi coordonator, 1982) – *Geografia continentelor – Europa*, Ed. Did. Şi Ped., Bucureşti.

Hârjoabă I., Erhan Elena, Patriche C.V. (2006) – *Air temperature in Europe along the parallels*, An. Şt. Univ. „Al. I. Cuza" Iaşi, serie nouă, tom LII, s. II-C, Geogr.

Kendrew W.G. (1982) – *The climates of the continents*, ed. a 4-a, Clarendon Press, Oxford.

Vlasova T.V. (1965) – *Geografia fizică a părţilor lumii*, ed. a 2-a, Ed. Lumina, Moscova.

* * * (2004) – *Climatological normals (CLINO) for the period 1961-1990*, WMO, Geneva.

* * * (1964) – *Fizico-geograficeschii Atlas Mira*, Ac. Nauc. SSSR, Moscova.

* * * (2000) – *Reference manual for the TNT products V6.4*, Lincoln, Microimages Inc.

* * * (2003) – *FAOCLIM-2. World-wide agroclimatic database v.2.02*, FAO/SDRN, 2003.