EUROPEAN ATMOSPHERIC CIRCULATION CLASSIFICATIONS

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ABSTRACT

The article describes the objective classification, involving the automated systems application to section the atmospheric processes by types. The objective of typing is to split a collection of objects of a certain sample according to the maximum-distance-separable groups. The basis for objective classification includes several methods: correlation, cluster analysis, nonlinear methods, neural network method, etc.

The second half of the XX century and the beginning of XXI century are characterized by high rates of changes in climatic and circulation conditions. An occurrence of rare weather extremes is a manifestation of the transition state of the atmosphere and its instability. Often regional differences have more significant variations than global ones. Therefore, progress in the understanding of current trends of climate change is impossible without taking into account the spatio-temporal dynamics of atmospheric processes. The author considers the main principles of Grosswetterlagen (GWL) classification and investigates regional characteristics of synoptic processes in the territory of Europe based on the characteristics of the surface pressure field and displacement trajectories of the primary pressure systems.

The purpose of this paper is to explore one of the most popular classifications for the European region and to establish the possibility of its further application to the territory of Ukraine.

Research methods: a statistical description of the synoptic types for Europe for the period from September 1957 up to August 2002.

Results of the study confirm the fact that the GWL classification can be successfully used to synoptic processes and works better in the central, western and southern parts of Europe.

Keywords: classification, circulation patterns, Eastern Europe.

1. INTRODUCTION

One of the analysis methods for the characteristics of synoptic processes is typing, or the classification of synoptic processes by types, which allows finding common features of development of atmospheric processes in a large variety of synoptic situations. The objective of typing is to split a collection of objects of a certain sample by maximum-distance-separable groups.
Since the beginning of the XIX century, when the classification of synoptic processes was introduced to the practice of weather forecasting, there was published a large number of works that differ in specific methodological approaches, in a number of selected types of weather, etc. Currently, only on the territory of Europe, according to various estimates, researchers allocate from 4 to 40 types of atmospheric processes and account for up to 209 subtypes, 84 % of which is obtained by analyzing the data of surface atmospheric pressure, geopotential heights and wind characteristics [1-20]. On-scale data from 6 to 12 hours (9 %),

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daily (84 %) and monthly data (7 %) are used as output information. The spatial range varies from mesoscale (5% of classifications), regional (3 %), on an individual nationwide scale (20 %), as part of the continent (22 %) and the continent as a whole (50 %) [1].

2. TYPES OF SYNOPTIC CLASSIFICATIONS

Synoptic classifications have been developed in passing from the manual (subjective) evaluation of daily synoptic charts to automated classification based on the application of different objective criteria. Therefore, conventionally, three main types of classifications of synoptic processes can be distinguished: subjective, objective and mixed.

Subjective classifications are based on allocation of the surface and high-altitude weather maps, air masses trajectories, the position of centers of pressure systems, atmospheric front types, etc. One of the most common is the classification by Vangengeim-Girs, under which we distinguish three basic directions of air masses movement in different sectors of the Northern hemisphere: Western, Eastern and meridian (Table 1).

Table 1. Characteristics of synoptic processes classifications

Authors	Region	Number of major synoptic types
Hess – Brezowsky	Europe	10
Jenkinson Lamb	England	8
Vangengeim-Girs	The Northern Hemisphere	3
Schüepp	Switzerland	10

The objective classifications involve the application of automated systems for breaking down atmospheric processes by types. The objective classification is based on several methods: correlation, cluster analysis, nonlinear methods, neural network method etc. However, all these methods cannot be considered completely objective, because some subjective decisions (the number of allocated types, the degree of similarity, etc.) still remain. In 1880, Jenkinson Lamb developed an objective catalogue for the classification of atmospheric processes on the territory of the British Isles, and since 1950, objective synoptic classification (GWL) has been widely used in Europe and the North Atlantic.

Mixed classifications provide the joint application of subjective and objective criteria (threshold values) for analysis of synoptic objects. According to estimates, currently in Europe, objective types of classifications are applied in 45% of cases, subjective classification – in 30 % of cases, and mixed type classifications - in 25 % of the overall cases [2,3].

2.1 GROSSWETTERLAGEN CLASSIFICATION

"Grosswetterlagen" (synoptic types) define periods of days or weeks with similar atmospheric processes. The new term "Grosswetterlage" (GWL) derived from the concept of "Witterung" (German language term, no English equivalent), on the time-scale located between and clearly separating "weather" and "climate". "Witterung" is characterised by periods or seasons with similar characteristics of weather elements such as temperature or precipitation in a certain region. "Grosswetter" focus on similar atmospheric processes in a larger area, e.g. Europe. The first calendar of European Grosswetterlagen comprised 21 GWL. Baur's initial concept was further developed and extended to 29 GWL in the following decades by Hess and Brezowsky [6], therefore also known under their name. Recent updates were published by Gerstengarbe and Werner [8].

Developed for central Europe (Germany), the GWL concept works well for a much larger region, covering all of Europe(Fig. 1). GWL are allocated based on the location of dominating centres in the upper air level of 500 hPa, i.e. ridges/anticyclones, troughs/cyclones and the position of the jet stream over Europe. However, sea-level pressure is still an important aspect for the GWLc concept since only surface charts were available in Europe until 1938. Different from most other concepts of classifying atmospheric circulation, each GWL persists for at least 3 days. If the transition to another GWL takes more than 1 day, such days are allocated to the previous or the following GWL, depending on higher similarity. If pressure patterns are non-uniform, one or two undefined days might be added [4-25]. Such days do not bear any common features and are thus not used in this paper.

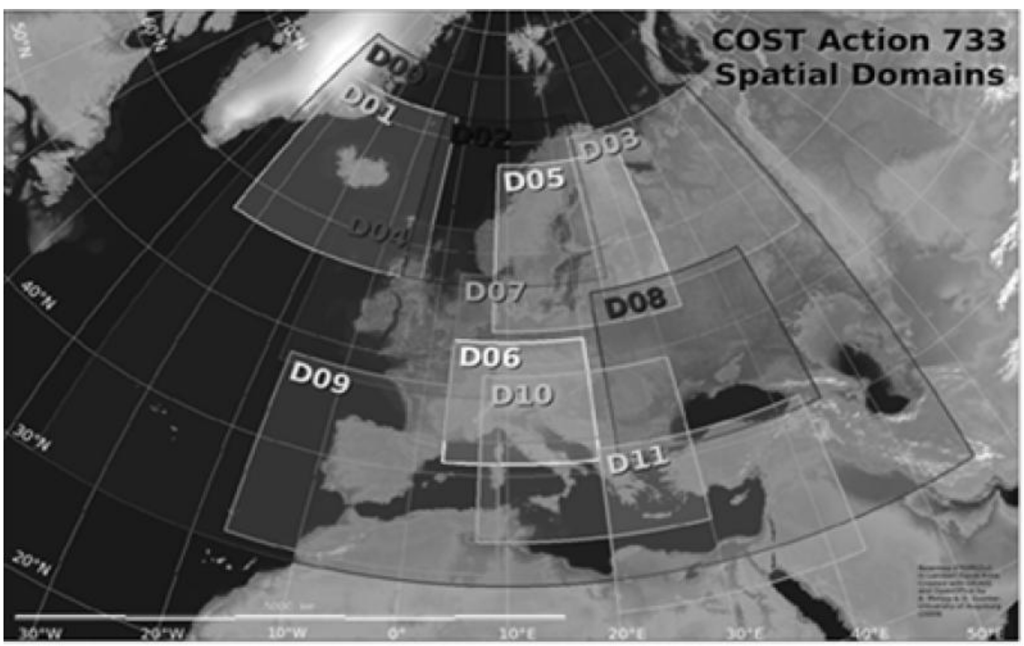


Fig. 1 - Areas for which the classification was carried out [26]

Table 2 shows the system of major and sub-classes of the GWLc. Their abbreviations follow the original German nomenclature, while their names have predominantly been adopted from James (2006, 2007). The GWL are commonly defined by (1) cyclonic and anticyclonic forms and (2) ten large-scale weather types (Grosswettertypen (GWT)), defined by eight flow directions and two types located directly over central Europe. These can (3) be further categorised into three circulation forms (zonal, half-meridional or mixed and meridional). The latter division might be useful for its high information compression, widening the central European focus while still clearly separating prevailing westerlies from other forms of circulation. Nevertheless, this division does not clearly separate inflow directions apart from zonal conditions, merging air masses of very different character into one group. Meridional conditions are difficult to apply on studies of surface climate parameters like temperature on the basis of atmospheric circulation because of the different nature of included air masses. The same is true for half-meridional conditions, a combination of warm south-westerlies and cool north-westerlies, merged with anticyclonal or cyclonal conditions over central Europe. To focus on a small number of major types with a clear spatial pattern and to assess a good comparability with the available VGc forms, a grouping into four key directions of air mass inflow (W*/west, N*/north, E*/east and S*/south) has been applied in this paper (Table 1). This regrouping was employed by James (2007) and is subsequently referred to as "Grosswetterlagen Inflow" (GWI). All GWI fully comprise the GWT they are named after, while the GWT, covering secondary geographic directions (SW, NW, NE and SE), are split between the GWI, e.g. a day assigned to the GWT SW is allocated to the GWI W* and S* in equal parts.

Table 2. GWLc sub-classes (GWL) and major types (GWT)

Type number	GWL	GWT
1	Anticyclonic Westerly	W West
2	Anticyclonic South-Westerly	SW Southwest
3	Anticyclonic North-Westerly	NW Northwest
4	High over Central Europe	HME Central Europe High
5	Low (Cut-Off) over Central Europe	TME Central Europe Low
6	Anticyclonic Northerly	N North
7	Anticyclonic North-Easterly	NE Northeast
8	Scandinavian High, Ridge Central Europe	E East
9	Anticyclonic South-Easterly	SE Southeast
10	Anticyclonic Southerly	S South
11	Undefined	U

Next, we consider features of the objective Hess-Berezovsky classification for Europe for the period from September 1957 up to August 2002 (Fig. 2).

Regional features of synoptic processes on the territory of Europe were considered, based on characteristics of the surface pressure field and displacement trajectories of the main pressure systems [27-29].

Exploring the nature of synoptic processes in Europe, there was revealed the dominant influence of a high-pressure belt over the entire territory of Europe, Ukraine (type 1) the part of which account for on average 4447 days in the period studied.

The fourth (2665 times) and the sixth (2459 times) types meet with almost identical frequency and take a second place. The 10th and the 8th types in 1595 and 1378 cases are of rare occurrence.

Almost equally often happened the 2nd (1175 times) and the 3rd (1151 times) GWL types. Less common are the 9th (555 times), the 7th (487 times) and the 5th (339 times) types of circulation.(Fig. 2)

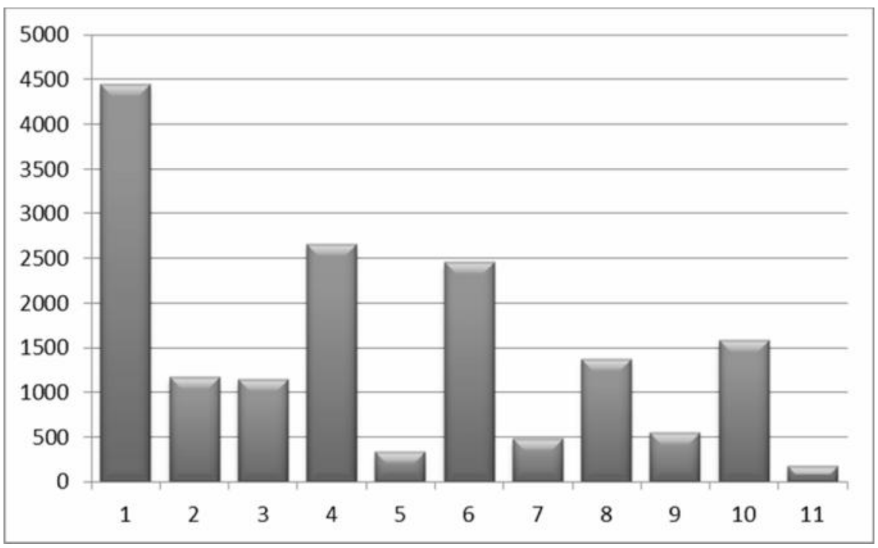


Fig. 2. Number of days with different circulation patterns over Eastern Europe

The duration of GWL circulation patterns ranges from one day up to 7.5 days (Fig. 3). The most lasting effect on the territory of Eastern Europe has the first type of circulation and it lasts more than a week. Total distribution by the duration coincides with the distribution by frequency of GWL types occurrence. About the same duration demonstrate the 6th, the 8th and the 4th types at 5.9 , 5.8 and 5.7 days, respectively. The second, third and tenth types last from 5 to 5.4 days, whereas the 5th, the 7th and the 9th GWL types last for 4.7 days.

Charts characterizing the pressure field distribution comply with each of the circulation patterns depicted in figures 4 A – 4 J

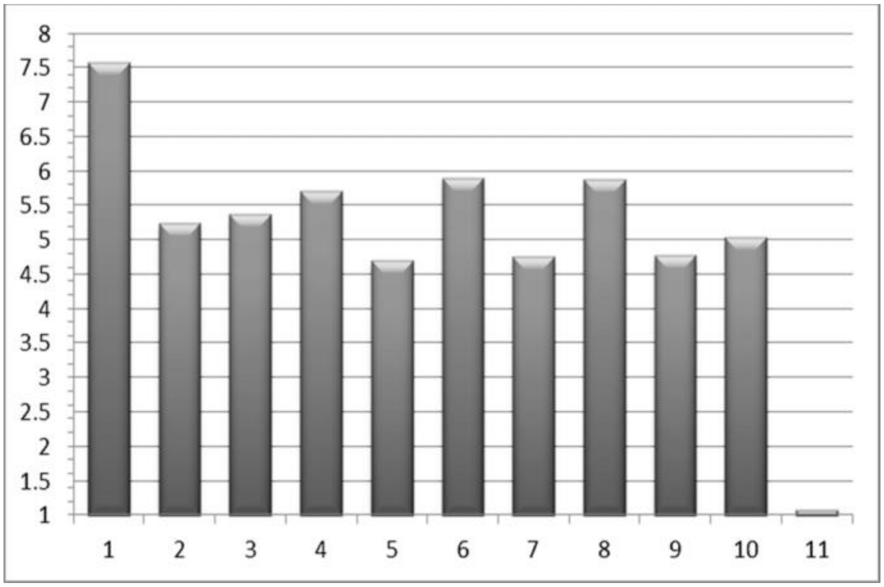
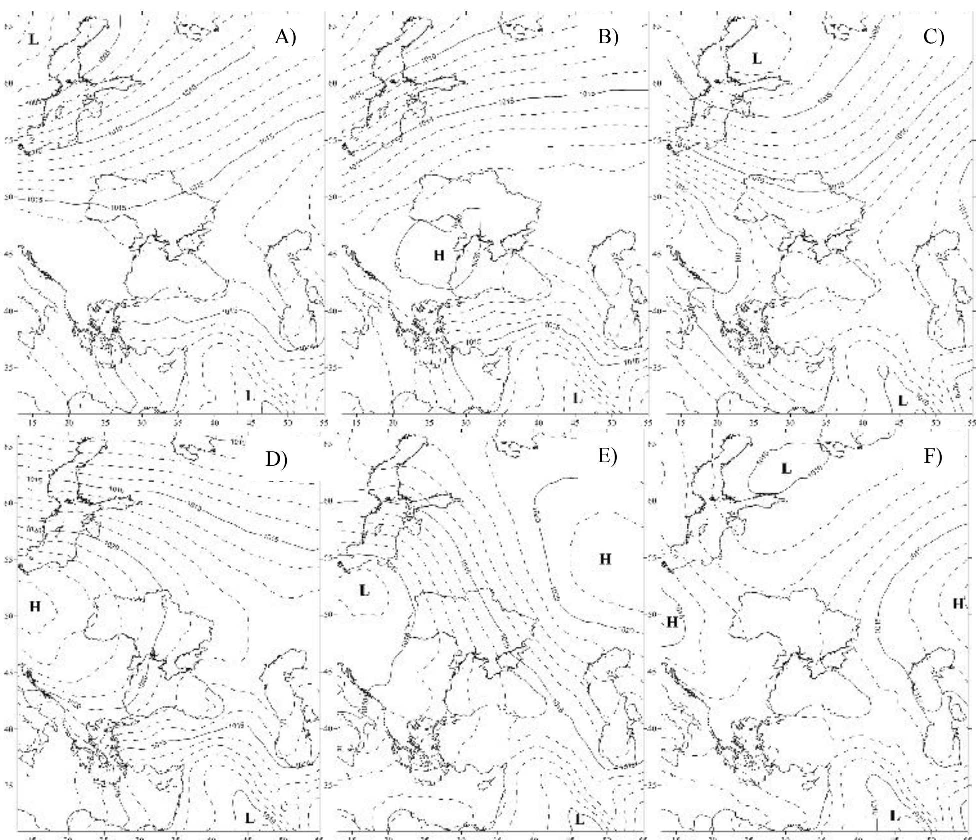


Fig. 3.The average duration of GWL types (in days)



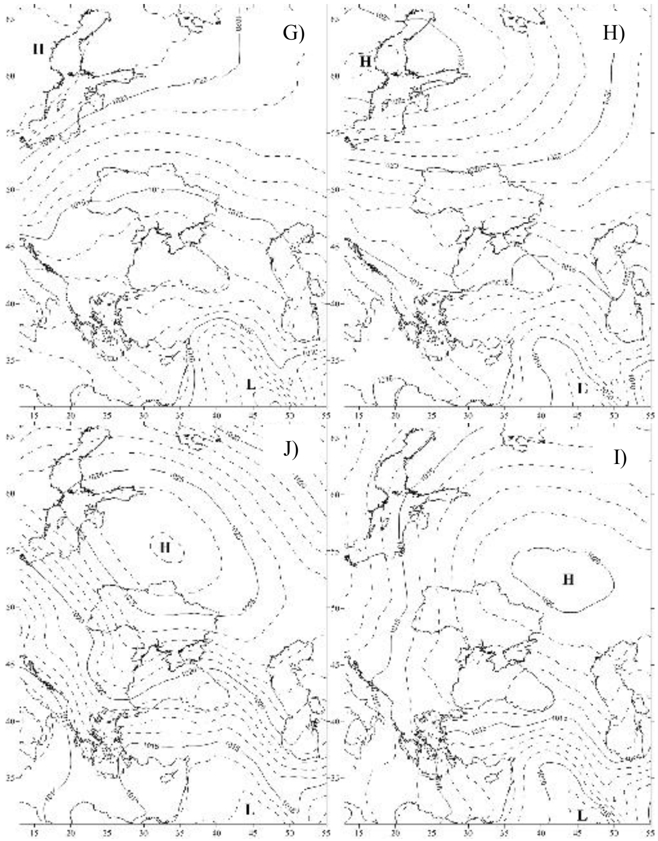


Fig.4.Synoptic situations (sea-surface maps) with different types of GWL : A – 1th type, B – 2th type, C – 3th type, D – 4th type, E – 5th type, F – 6th type, G– 7th type, H – 8th type, I – 9th type, J – 10th type

It was interesting to explore and identify interannual variability of GWL circulation patterns. As it turned out, the first circulation type determines weather conditions most often in winter, but in summer and autumn it is almost the same repeatability, and the lowest in spring (Table 3).

But, despite this, the first GWL type of circulation has a dominant influence on atmospheric processes in Eastern Europe throughout the year. The 4th type has an active influence on the weather in winter, but in spring the 6-type GWL shows greater repeatability. In summer and autumn, the 4th type again takes a second place by repeatability. The 5th and the 7th types less often occurs in winter. The 5th type of circulation less likely to affect weather conditions in spring. The smallest frequencies of occurrence demonstrate the 5th and the 9th types in summer, and the 5th and 7th GWL types in the fall.

Table 3 - Repeatability of GWL types by season

Season	1th type	2th type	3th type	4th type	5th type	6th type	7th type	8th type	9th type	10th type	11th type
Winter	1350	315	305	679	56	562	56	274	205	228	31
Spring	794	289	307	543	146	704	154	478	166	505	54
Summer	1124	217	288	713	63	661	221	393	41	372	47
Autumn	1179	354	252	730	74	532	56	233	143	490	53

Year	4447	1175	1151	2665	339	2459	487	1378	555	1595	185

4. CONCLUSION

Climatic variability, especially at the regional level, is determined primarily by the nature of atmospheric processes on a territory. The predominance of a particular mode of circulation within individual months and seasons forms a particular temperature and precipitation regime, which subsequently defines features of the regional climatic variability.
One of the methods for large-scale atmospheric process analysis is their classification, which allows finding common features of the development of large-scale processes at a large variety of synoptic situations [1]. In general, the task for classification is to divide a collection of objects of a certain sample by maximum different against each other groups.
The objective classifications involve the application of automated systems for distinguishing the atmospheric processes by types. The objective classification is based on several methods: correlation, cluster analysis, nonlinear methods, neural network method etc.
In 1880, Jenkinson Lamb developed an objective catalogue for the classification of atmospheric processes on the territory of the British Isles, and since 1950 objective synoptic classification (GWL) has been widely used in Europe and the North Atlantic. This paper shows that the GWL classification can be used for Eastern Europe.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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