LOCAL WEATHER CLASSIFICATIONS FOR ENVIRONMENTAL APPLICATIONS

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ABSTRACT. Local weather classifications for environmental applications. Two approaches of local weather type definitions are presented and illustrated for selected stations of Poland and Hungary. The subjective classification, continuing long traditions, especially in Poland, relies on diurnal values of local weather elements. The main types are defined according to temperature with some sub-types considering relative sunshine duration, diurnal precipitation totals, relative humidity and wind speed. The classification does not make a difference between the seasons of the year, but the occurrence of the classes obviously reflects the annual cycle. Another important feature of this classification is that only a minor part of the theoretically possible combination of the various types and sub-types occurs in all stations of both countries. The objective version of the classification starts from ten possible weather element which are reduced to four according to factor analysis, based on strong correlation between the elements. This analysis yields 3 to 4 factors depending on the specific criteria of selection. The further cluster analysis uses four selected weather elements belonging to different rotated factors. They are the diurnal mean values of temperature, of relative humidity, of cloudiness and of wind speed. From the possible ways of hierarchical cluster analysis (i.e. no a priori assumption on the number of classes), the method of furthest neighbours is selected, indicating the arguments of this decision in the paper. These local weather types are important tools in understanding the role of weather in various environmental indicators, in climatic generalisation of short samples by stratified sampling and in interpretation of the climate change.

Keywords: weather types, climatology, factor analysis cluster analysis, Poland, Hungary

1. INTRODUCTION

Synoptic climatology i.e. classification of the endless variability of the everyday weather states according to the pressure configuration and frontal systems relative to the point, or region of interest has long history in meteorology. Its main advantage is to set a limited number of similar meteorological situations, which is the unavoidable to study any quantity or event of the environment for which its dependence on meteorological conditions should be quantified. Another advantage of this, so called, macro-synoptic classification (Peczely, 1957, Puskas, 2001) is

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that having the actual class of a given day selected, the same code can be applied for various stations or field-campaign. The price of this convenience is the limited efficiency of such circulation-based classifications for at least two reasons.

The first one is that the circulation objects and their frontal systems, related to them, often change their positions within the 24 hours of the most common classifications. Hence, the same code may hide rather different situations, indeed. The second reason is the lack of meso-synoptic object due to the large-scale nature of synoptic analysis and the otherwise reasonable trial to keep the number of the individual classes limited. (Otherwise too long samples were needed.)

The logical alternative, i.e. classification of weather according to the observed local weather elements were less popular until the recent times for various reasons. At first, for long time, the numerical weather forecasts were able to outline the synoptic situation, but not the near-surface meteorological variables. At second, there were no computing facilities to operate with multivariate diurnal samples (order of ten variables, at once). Both problems have been resolved in the recent decades as a result of the rapid development in computer technology.

2. SUBJECTIVE SYSTEMS OF WEATHER CLASSIFICATION

In complex climatology, systems of weather type classification involve a number of weather elements and each is broken down into ranges of values. Some of the most popular systems using this approach include the ones proposed by Fedorov and Chubukov (Kozłowska-Szczęsna 1965), Howe (1925), Nichols (1925, 1927), Switzer (1925), and in Poland – Woś (1999, 2010), Marsz (1992), Ferdynusa (1997, 2004), Durło (2005), Błażejczyka (2004) and Piotrowicz (2010).

When designing this type of classification system the selection of the weather elements and the number of their value ranges depends on the purpose the system is to serve. Woś (1999, 2010) designed his system to be a general one that would provide a good reflection of the climate of Poland. The author included three elements: air temperature (11 ranges), cloud cover (3 ranges) and precipitation (2 ranges). Lotko-Łozińska (1994) expanded his system by adding wind speed (3 ranges). Marsz (1992) and Ferdynus (1997, 2004) modified the original system's value ranges to adapt them to the weather structure and climate seasonality in polar areas. Durło (2005) built his own system for the purposes of phytoclimatology with 14 ranges of air temperature and 6 ranges each of relative sunshine duration and relative humidity. Błażejczyk (2004) proposed a bioclimate and meteorological system of weather type classification that he used for studying the bioclimate of Warsaw among other tasks.

The system included seven types and 27 subtypes of weather and eight weather classes defined using the subjective temperature index, intensity of radiation stimuli, physiological strain, intensity of sultriness, air temperature amplitude, precipitation and snow cover thickness. The author claims that his system can be useful both for the study of detailed weather conditions and as a source of basic information on the potential attractiveness for leisure activities of any period (day, month or season) and/or area (Błażejczyk 2004). Piotrowicz (2010) proposed a system that modified the systems by Woś (1999) and by Błażejczyk (2004) and she used it to analyse the seasonality of Krakow's climate variability.

This study presents the results of research on the frequency of weather types in Krakow (Poland) and Debrecen (Hungary) during the period 1961-2010 using a modification of the classification systems of Woś (1999) and Piotrowicz (2010) (Table 1). The study identified 12 thermal weather types, 9 subtypes involving only relative sunshine duration and precipitation, 16 weather classes determined using air humidity and wind speed and, finally, weather types that took into account all five weather elements. The weather on each single day was coded to simplify subsequent analysis.

Table 1. Classification of weather types and their frequency [%] in Krakow and Debrecen (1961-1990). E.g. 10_10_21 – very warm day, sunny, no precipitation, wet air, weak wind

	Code	Partition	Names of weather	Krakow	Debrecen
		Air temperature			
Thermal weather types	11	t_{mean}>25.0°C; t_{min} & t_{max}>0.0°C	hot	0.2	1.0
	10	t_{mean} 15.1-25.0°C; t_{min} & t_{max}>0.0°C	very warm	28.5	35.4
	09	t_{mean} 10.1-15.0°C; t_{min} & t_{max}>0.0°C	warm	19.7	17.2
	08	t_{mean} 5.1-10.0°C; t_{min} & t_{max}>0.0°C	moderately warm	15.0	13.1
	07	t_{mean} 0.1-5.0°C; t_{min} & t_{max}>0.0°C	cool	8.3	5.7
	06	t_{mean}>5.0°C; t_{min}≤0.0°C; t_{max}>0.0°C	ground-frost, moderately cool	2.0	1.8
	05	t_{mean} 0.1-5.0°C; t_{min}≤0.0°C; t_{max}>0.0°C	ground-frost, very cool	10.1	10.4
	04	t_{mean} -5.0-0.0°C; t_{min}≤0.0°C; t_{max}>0.0°C	ground-frost, moderately cold	6.7	7.2
	03	t_{mean} <-5.0°C; t_{min}≤0.0°C; t_{max}>0.0°C	ground-frost, very cold	0.2	0.1
	02	t_{mean} -5.0-0.0°C; t_{min} & t_{max}≥0.0°C	moderately frosty	3.8	3.7
	01	t_{mean} -15.0÷-5.1°C; t_{min} & t_{max}≥0.0°C	fairly frosty	5.2	4.2
	00	t_{mean} <-15.0°C; t_{min} & t_{max}≥0.0°C	very frosty	0.3	0.2
		Relative sunshine duration			
Subtypes	0-	≤33%	cloudy	58.7	43.1
	1-	33.1-67%	sunny	26.6	26.8
	2-	≥67.1%	very sunny	14.7	30.1
		Precipitation			
	-0	< 0.1 mm	day without precipitation	52.8	63.6
	-1	0.1-4.9 mm	day with a slight precipitation	35.9	26.8
	-2	≥5.0 mm	day with high precipitation	11.3	9.6
		Relative humidity			
Classes	0-	≤55%	dry air	2.1	3.7
	1-	55.1-70.0%	moderate wet air	19.6	27.8
	2-	70.1-85,0%	wet air	48.2	41.1
	3-	≥85.1%	very wet air	30.1	27.4
		Wind speed			
	-0	0.0-0.2 m/s	windless weather	3.7	0.4
	-1	0.3-4.9 m/s	weak wind	93.0	99.2
	-2	5.0-8.5 m/s	moderate wind	3.1	0.4
	-3	8.6-14.0 m/s	strong wind	0.2	-

The study found that the number of types of weather that occurred in Krakow was 434 and in Debrecen 302. The most frequent types included very warm (10_--_--), very sunny or sunny without precipitation (10_20_-- or 10_10_--), and moderately wet (10_20_11 and 10_10_11) or wet air with weak wind (10_20_21 or 10_10_21).

The duration of weather types is an important measure as it describes their impact on the environment, human body or economic activities (Piotrowicz 2010). The adaptive response of humans, animals and plants is different when the weather remains the same for several days to when it changes dramatically overnight. When the weather is stable, it is important to know what type of weather it is. Stability itself tends to be beneficial for human well-being, but when the weather involves strong stimuli, such as hot and humid weather, its stability can be detrimental.

January and February were found to be the most variable in terms of weather, while July and August were the most stable, which was measured by the number of different weather types measured in each day (Fig. 1). The highest number (28) of weather types was recorded in Krakow on 15 January and on 3 and 27 February and in Debrecen on 24 February. The lowest number of weather types occurred on 14 July in Krakow (11 types) and on 15 August in Debrecen (9). Figure 1 an illustration of variability and seasonal cycle of climate. Finally, it is worth noting that the number of weather types occurring during each year of the study period was falling (Fig. 2) i.e. weather is becoming more stable in both cities.

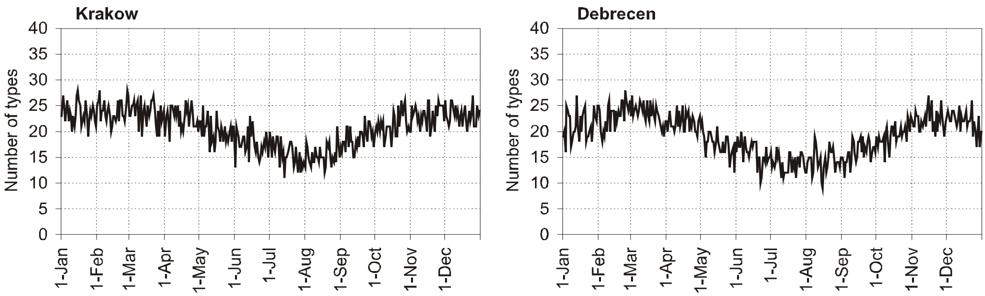

Fig. 1. ***Number of weather types in individual days of the year in Krakow and Debrecen in the period 1961-1990***

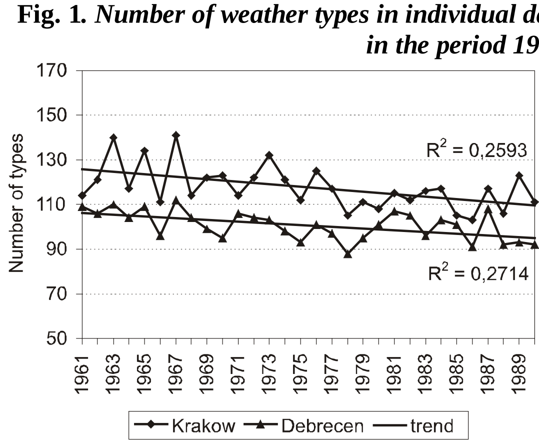

Fig. 2. ***Number of weather types in Krakow and Deberecen in the period 1961-1990***

3. OBJECTIVE STATISTICAL WEATHER CLASSIFICATION

Eight stations from Poland and five stations from Hungary and 30 years periods (1966-1995 for Poland and 1961-1990 for Hungary) were selected with 8 weather elements (see below). The stations are Łeba, Suwałki, Olsztyn, Warszawa-Okęcie, Zielona Góra, Wieluń, Rzeszów-Jasionka, Bielsko-Biała-Aleksandrowice for Poland and Szombathely, Pécs, Budapest, Szeged, Debrecen for Hungary.

The four key weather elements of classification have been selected by factor analysis from the 8 candidates. Considering the skewed distribution of precipitation, its logarithm was further considered (with a 0.1 mm correction to keep the zero precipitation in the sample). All these elements have been standardised against the standard deviation within the monthly samples.

Table 1 indicates approximate results of the factor analysis for Budapest. The main conclusion is that 3 or 4 factors are enough, and, except precipitation, the climate elements belong to the same factors in majority of bimonthly sub-samples.

The selected elements are

- diurnal mean temperature (Tm: °C),
- cloudiness (Cl: % of sky),
- wind speed (Ws: m/s) and
- relative humidity (Rh: % of saturation).

The omitted (redundant) elements are precipitation (Pcp: mm/d), sunshine duration (Sd: hour/d), diurnal temperature amplitude (ΔT: °C), water vapour pressure (Wvp: hPa). These omitted elements serve for basis of independent quantification of classification efficiency.

The monthly sampling has been decided after analysing the standard deviation as a function of the duration of the sample from the annual (1 sample, no separation) to the daily (365 samples, no separation) amalgamation.

The hierarchical cluster analysis has been performed based on the selected four variables with 4-9 clusters in each month and station. The method of furthest neighbours has been selected for rules of joining the groups, based on Euclidean distance, after having tried several other possibilities. No Mahalanobis distance has been applied since the retained four elements have no strong cross-correlations.

Table 1. ***Results of factor analysis between the eight elements. The numbers indicate the factors. The serial numbers have no specific meaning.***

Budapest	Tm	Wvp	ΔT	Cl	Sd	Rh	Ws	Pcp
J-F	**1**	**1**	*2*	*2*	*2*	**3**	**3**	*4*
M-A	**1**	**1**	*2*	*2*	*2*	**3**	*4*	*2*
M-J	**1**	**1**	*2*	*2*	*2*	**3**	*4*	**3**
J-A	**1**	**1**	*2*	*2*	*2*	**3**	*4*	**3**
SZ-O	**1**	**1**	*2*	*2*	*2*	**3**	*4*	*2*
N-D	**1**	**1**	*2*	*2*	*2*	*2*	**3**	*4*

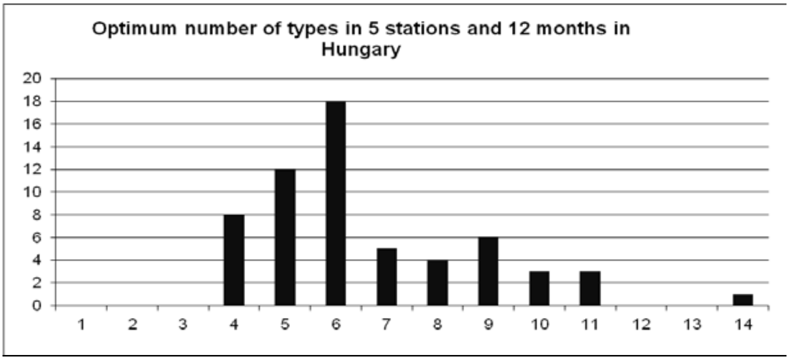

Fig. 3. ***Optimum number of objective weather types in Hungary according to the applied cluster analysis for 5 stations and 12 months for the applied 30 years period (1961-1990)***

Since the frequency distribution of optimum numbers has a steep maximum at six classes, further we fixed this number of classes (i.e. weather types) for each station and month. *Fig. 3* indicates it for the Hungarian stations. There has no seasonal cycle been observed in the optimum number of monthly samples. The optimum number of the clusters was established when (i.) after using this number of clusters, the standardized average intra-group variance would be less than 70 % of the original variance of the four variables without clustering, (ii.) the difference between variances of the selected number of classes and of the by one smaller number of classes differs by more than 2 %, but (iii.) the same between the selected number and the by one more clusters differ already by less than 1 %.

4. DISCUSSION

Derivation of the local weather types, either by subjective, or by objective approach, opens new perspectives in various applications. Moreover, these new scientific tools can be used to detect climate change in terms of diurnal weather, i.e. the process will be better transformed into everyday life of the society.

A sub-topic of these applications, the identification of extremes in terms of these newly defined weather types, also contributes to express our continuous process of man-made climate change in terms of probability of the harmful weather events that may occur at the mid-temperate latitudes.

Finally, education of meteorology and climatology for various professions, including geography and environmental sciences may gain a brain new scientific approach and methodology to express the local weather in less abstract and probably more efficient terms than circulation types.

At present it was too early to judge if the objective or the subjective approach is more fruitful. The authors intend to continue their activity and comparison of the newly discovered tools to sum up the experiences at a later time.

Acknowledgements. The authors are grateful to the Polish-Hungarian bi-lateral project, TÉT_10-1-2011-0037 for the partial support.

REFERENCES

1. Błażejczyk, K. (2004), *Bioklimatyczne uwarunkowania rekreacji i turystyki w Polsce*. Prace Geograficzne 192, 1-291.
2. Durło, G. (2005), *Typologia warunków pogodowych na potrzeby fitoklimatologii*.Woda-Środowisko-Obszary Wiejskie 5(14), 129-136.
3. Ferdynus, J. (1997), *Główne cechy klimatu morskiego strefy subpolarnej północnego Atlantyku w świetle struktury stanów pogód*. Wyższa Szkoła Morska, Wydział Nawigacyjny, Gdynia.
4. Ferdynus, J. (2004), *Roczna struktura stanów pogody w Hornsundzie (SW Spitsbergen)*. Polish Polar Studies, XXX International Polar Sympsium, Gdynia, 81-94.
5. Howe, G.F. (1925), *The summer and winter weather of selected cities in North America*. Monthly Weather Review 10, 427-429.
6. Kozłowska-Szczęsna, T. (1965), *New Soviet Publications in the Field of "Complex Climatology"*. International Journal of Biometeorology 9, 261-265.
7. Lotko-Łozińska, A. (1994), *Założenia i kryteria klasyfikacji stanów pogody występujących w Poznaniu w latach 1920-1990*. Badania Fizjograficzne nad Polską Zachodnią 45, Seria A, 68-80.
8. Marsz, A.A. (1992), *Struktura pogód i roczna sezonowość klimatu Stacji Arctowskiego*. Problemy Klimatologii Polarnej 2, 30-49.
9. Mika J., Ivady A., Patkos Cs. and Razsi A. (2012): Trial to derive statistically objective local weather types. In: “The atmosphere as risk and resource” Eger 23. November, 2012 (Mika J., Wypych A., Razsi A., eds.) CD-ROM (in prep).
10. Nichols, E.S. (1925), *A classification of weather types*. Monthly Weather Review 10, 431-434.
11. Nichols, E.S. (1927), *Frequencies of weather types at San Jose*. Monthly Weather Review 9, 403-405.
12. Péczely G. (1957): Grosswetterlagen in Ungarn. Kleinere Veröffentl. der Zentralanstalt für Meteorologie No. 30., Budapest
13. Piotrowicz, K. (2010), *Sezonowa i wieloletnia zmienność typów pogody w Krakowie*, IGiGP UJ, Kraków.
14. Puskás J. (2001): New weather front types and catalogue for the Carpathian Basin. In. Nowinszky L. [ed.]: Light trapping of insects influenced by abiotic factors. Part III. Savaria University Press Szombathely 87-118.
15. Switzer, J. (1925), *Weather types in the climate of Mexico, The Canal Zone, and Cuba*. Monthly Weather Review 10, 434-437.
16. Woś, A. (1999), *Klimat Polski*. PWN, Warszawa.
17. Woś, A. (2010), *Klimat Polski w drugiej połowie XX wieku*, Wydawnictwo Naukowe UAM, Poznań.