Physics and Chemistry of the Earth 35 (2010) 429–436

Contents lists available at ScienceDirect

Physics and Chemistry of the Earth

journal homepage: www.elsevier.com/locate/pce

Extreme values of air temperature in Poland according to different atmospheric circulation classifications

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ARTICLE INFO

Article history:
Received 29 March 2009
Received in revised form 2 December 2009
Accepted 29 December 2009
Available online 14 January 2010

Keywords:
Air temperature extremes
Circulation types
Subjective and objective classification
Poland

ABSTRACT

The paper focuses on synoptic and climate analysis with the application of circulation types based on six classification schemes, both subjective and objective. The principal goal of the study was to determine circulation types with respect to the occurrence of extreme values of air temperature. A comparison between different available classifications was also performed. Maximum and minimum daily temperatures for the 56-year study period (1951–2006) were used in the analysis. The necessary data series were obtained from 61 weather stations, relatively well spaced across Poland. Each series was checked for homogeneity and evaluated. Detailed calculations were performed for the summer (June–August) and winter (December–February) seasons. Extreme values were selected with respect to probability distribution bases. The top and bottom 5% were used for further analysis. Calculations of extreme values for particular types and classifications were the main phase of analysis. All extreme temperature values were analyzed for each type. This enabled the creation of histograms presenting types producing the highest number of particular extremes. The study showed that circulation types with an anticyclonic ridge were the most important for extremely hot days in the summer, while extremely low temperatures in the winter were usually associated with anticyclonic types with an easterly airflow. A special effort was made to identify the classification scheme yielding the best accuracy in evaluating extremes.

1. Introduction

Extreme meteorological phenomena have recently become a subject of particular interest to scientists, and especially meteorologists and climatologists. There is nothing surprising about this, given the widespread discussion on climate change in recent years, as well as increases in the frequency of extreme phenomena and their direct or indirect repercussions. This is particularly true of damage to the natural environment as well as the loss of human life and material property. Today, extreme phenomena are studied by an array of research groups, which pursue a number of monitoring and analytical projects including one at the Royal Netherlands Meteorological Institute called the "European Climate Assessment and Dataset" (ECA&D: http://www.eca.knmi.nl/). An international meteorological database has been created. Such research groups have also produced quite a few very valuable studies on the evaluation criteria and frequency of occurrence of extreme phenomena (Folland et al., 1999; Horton et al., 2001; Karl and Easterling, 1999; Klein Tank et al., 2002). Many researchers consider the atmospheric circulation factor to be of the utmost importance with regard to meteorological extremes (Huth et al., 2008; Ustrnul, 2000). Therefore, together with research on the direct causes of meteorological extreme phenomena, the impact of circulation also needs to be taken into account. Atmospheric circulation is most often described using various kinds of descriptors including circulation types.

The relationship between the occurrence of temperature extremes, circulation patterns, and classification schemes is being studied as part of the "COST Action 733" program. The working group is called "Testing methods for various applications" and its main aim is the evaluation of the usefulness of particular circulation type classifications for various purposes including extreme phenomena.

In this paper, extreme air temperatures over Poland are analyzed with respect to atmospheric circulation. The main purpose of this work is to describe the influence of circulation type on the occurrence of extreme temperature phenomena in Poland. This study also deals with the quite difficult issue of evaluating several different circulation type classifications with respect to their usefulness in the analysis of air temperature.

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doi:10.1016/j.pce.2009.12.012

2. Data

Two kinds of data were used: air temperature values and atmospheric circulation data – six circulation type classifications.

Air temperature data were obtained from 61 meteorological (synoptic) stations located all over Poland (Fig. 1). Their distribution is relatively uniform with a slightly higher density in mountain areas in the southern part of the country. This ensures a relatively good evaluation of thermal extreme variability on the mesosynoptic scale. The data cover the period from 1951 to 2006, and they were carefully prepared and checked for homogeneity. The data include daily air temperature maxima and minima from all 61 stations. There were some gaps in the data – a few dozen days missing – which were omitted from inclusion in the analyzed data set. The source data were the basis for the calculation of temperature extremes, which were then subjected to synoptic analysis. The method of calculating extremes is discussed in the next section.

Circulation type data for the 56-year period of interest (1951–2006) were obtained using six different classification schemes. They are the following: (1) Grosswetterlagen classification based on work by Hess and Brezowsky (GWL) on large-scale weather systems with a focus on air mass advection and location of pressure systems (Gerstengarbe et al., 1999), (2) an objective version of Grosswetterlagen according to James (GWL-O), where mean-sea-level pressure (MSLP) patterns and 500 hPa geopotential height fields were calculated for winter and summer separately for each of the 29 GWLs, employing a sequence of logical filtering steps to remove transient features in order to construct a daily catalogue (James, 2007), (3) Lityński (LIT) classification where zonal and meridional circulation indices as well as air pressure were taken into account and each index has been divided into three equally probable classes (Lityński, 1969), (4) Osuchowska-Klein (OS-K) classification where circulation macrotypes (patterns) are distinguished according to the direction and nature of air mass advection (Osuchowska-Klein, 1978), (5) Niedźwiedź (TN) classification, based on air mass advection and type of pressure system (Niedźwiedź, 1981), and (6) Ustrnul (ZU) classification where circulation types are determined on the basis of predominant air advection as expressed by a geostrophic wind vector calculated for different grids as well as types of pressure systems, defining cyclonic and anticyclonic types (Ustrnul, 1997). A detailed description of all the classification schemes can be found in the cited literature and they are all available for the entire research period of interest. It should be mentioned here, that while three of the classifications are objective or automatic (GWL-O, LIT, ZU), the remaining three are subjective (OS-K, GWL, TN). Each classification scheme has a different number of classes, which creates an additional problem

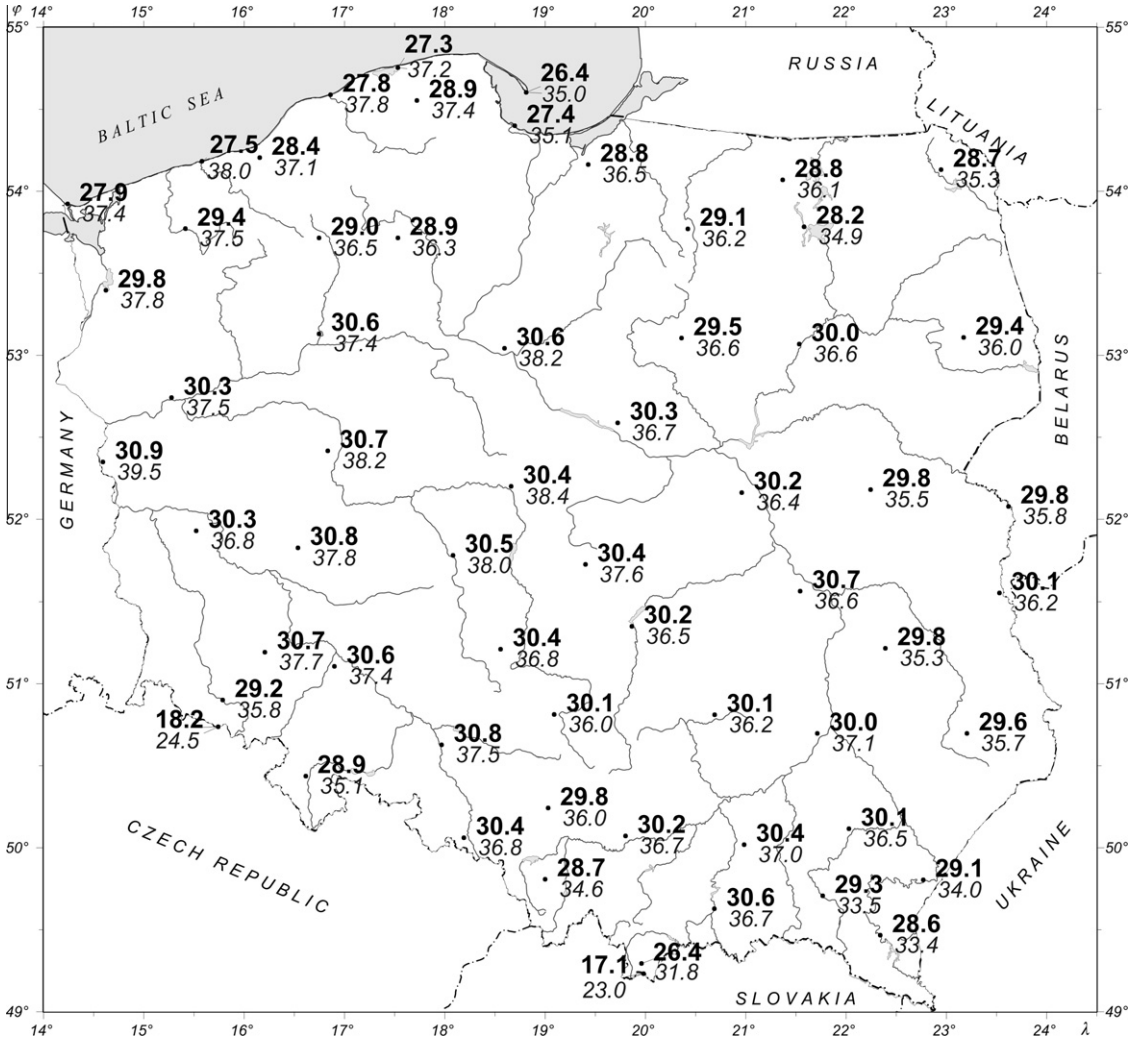

Fig. 1. Spatial distribution of the 95th percentile extreme temperature threshold values (°C) (in bold) and absolute maximum air temperature values (in italics) – summer (June–August).