Global and Planetary Change 118 (2014) 85–96

Contents lists available at ScienceDirect

Global and Planetary Change

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

Climate variability in the Carpathian Mountains Region over 1961–2010

Sorin Cheval, Marius-Victor Birsan *, Alexandru Dumitrescu

National Meteorological Administration (Meteo Romania), 97, Sos. Bucuresti-Ploiesti, 013686 Bucharest, Romania

ARTICLE INFO

Article history:
Received 14 October 2013
Received in revised form 19 February 2014
Accepted 22 April 2014
Available online 29 April 2014

Keywords:
Carpathian Mountains
climate change
monthly trends
maximum temperature
wind speed
relative humidity
vapor pressure
snow depth

ABSTRACT

The Carpathian Mountains Region (CMR) lies over parts of the territories of seven Central and Southeastern European countries, and the mountain chain induces major changes in the temperate climate specific to the latitudes between 43° and 49°N. Different administrations govern the long-term meteorological networks; the infrastructure, collection protocols, and storage capacities are specific to each country, so that a comprehensive study on the climate of the area has met considerable difficulties along time. Climate of the Carpathian Region (CARPATCLIM) is a regional initiative developed between 2010 and 2013 aiming to enhance the climatic information in the area by providing comprehensive, temporally and spatially homogenous data sets of the main meteorological variables. Based on daily data aggregated to a monthly scale at 10-km resolution, this study exploits and promotes the results of the CARPATCLIM project, documenting the variability of the main climatic variables over 1961–2010. For each month, the significant increasing or decreasing trends were identified, mapped and placed in the context of previous studies and climate change perspectives. The study has revealed several patterns in the climatic variability, i.e., positive or negative trends prevailing over the entire area, very distinct delineation between various trends induced by the Carpathian Mountain chain, and pledges for further scientific approaches, i.e., causes of the variability and applications in other domains.

1. Introduction

The Carpathian Mountains Region (CMR) extends in Central and Southeastern Europe, over parts of the territories of the Czech Republic, Slovakia, Hungary, Poland, Ukraine, Romania, and Serbia. The rectangular-shaped frame of the CMR also includes some areas of Croatia, Bosnia and Herzegovina, and Austria despite the fact that they have no direct connection with the geography of the Carpathians. The mountain chain dominates the geographical context with altitudes exceeding 2500 m, but other forms of relief also contribute to the variety of the landscape, i.e., intra-mountainous depressions, sub-mountainous hills and lowlands. The CMR is a European biodiversity hotspot (Björnsen Gurung et al., 2009) which congregates major economical interests and derives social and political attention, demographic and land cover changes, and the climatic diagnosis and future projections have always made the scientific agenda. The latest IPCC report mentions significant climatic changes in the 2071–2100 perspective (Christensen et al., 2007), so that the climate monitoring services may have an authentic practical meaning in the CMR. The administrative, economic, and political changes that took place in the region along the recent history left behind a heterogeneous meteorological network, with numerous and significant changes between countries. The density of the national networks, the instruments, and the timing of the measurements and observations have been different, and they are not fully harmonized yet. A large number of studies, projects, and initiatives have tackled environmental issues and climate-related topics in the area at regional or country scale (Ruffini et al., 2006; UNEP, 2007; Villarini, 2011), but no valid description of the climate of the Carpathian Region has been available until very recently (Szalai, 2012). As a consequence, the outputs have been generally limited to local or country scales (Björnsen Gurung et al., 2009), with inherent difficulties whenever an integrated view was necessary.

Climate of the Carpathian Region (CARPATCLIM) is one of the most recent international projects over the area, developed with the joint effort of National Meteorological Services (NMS) from all the Carpathian countries. It was contracted by the European Union represented by the Joint Research Centre (JRC), it ran between 2010 and 2013, and it aimed at enhancing the climatic information in the region by providing comprehensive, temporally and spatially homogenous, data sets of the main meteorological variables, and the corresponding metadata. The project was an excellent opportunity to address the inventory of the data sets available in each country, their gaps, quality, and homogeneity. Some project outputs have already been published recently (Lakatos et al., 2013; Spinoni et al., 2013), while many others are prepared to be turned to good account.

This paper promotes and places the CARPATCLIM results in the context of similar reports on the topic, so that brief overviews are presented. The main objective of the study is to document the climatic

* Corresponding author at: National Meteorological Administration (Meteo Romania), Department of Climatology, 97, Sos. Bucuresti-Ploiesti, 013686 Bucharest, Romania. Tel.: +40 748 105 045 (GSM).
E-mail addresses: sorin.cheval@meteoromania.ro (S. Cheval), marius.birsan@gmail.com, marius.birsan@meteoromania.ro (M.-V. Birsan), alexandru.dumitrescu@gmail.com, dumitrescu@meteoromania.ro (A. Dumitrescu).

http://dx.doi.org/10.1016/j.gloplacha.2014.04.005
0921-8181/

variability in the CMR, based on the parameters considered in the project, in order to identify significant trends in the present climate as a base for further in-depth investigations. To our knowledge, this is the first endeavor tackling the subject unitarily, at the scale of the Carpathian region, based on high quality, homogenous monthly data sets, aggregated and validated by an international consortium including all the NMSs in the area. Since many publications report on the future climate projections according to various IPCC scenarios, and the most common control period is 1961–1990, this study also represents a good opportunity to evaluate the track of the estimations, as it refers to the period 1961–2010.

2. Regional setting

Fig. 1 shows the altitudes within the area of interest. There is no unanimous agreement regarding the geographical extension and margins of the CMR. Ruffini et al. (2006) report a surface of about 210,000 km^2 for the Carpathian Ecoregion and propose principles for delimitating the Carpathian Convention area. UNEP (2007) places the limits at 43°28′ and 49°47′N; 16°58′ and 26°38′E, summing up an area of about 161,000 km^2. Ruffini and Ptaček (2008) define a Carpathian Macroregion using administrative criteria. Following the JRC Tender Specification, the spatial area of interest for the CARPATCLIM project covered "the area between latitudes 50°N and 44°N, and longitudes 17°E and 27°E, approximately". As regards the main sub-units, UNEP (2007) divides the CMR in Northwestern, Northeastern, Eastern, and Southeastern Carpathians, around the Pannonian and Transylvanian Depressions. The CMR has a temperate climate, with a rather continental regime, increasingly intensive eastwards. The Carpathians are more humid than the surrounding lowlands, and the average annual precipitation amounts register about 700–800 mm in the western parts, 350–400 mm in the south, and 1000–1200 mm in the mountain area (Ruffini and Ptaček, 2008). The altitude, the compact arrangement and the shape of the Carpathian Chain introduce important disturbances in the zonal climate and in the general atmospheric circulation (UNEP, 2007). For the Romanian Carpathians, Cheval et al. (2011) report variations of the thermal vertical lapse according to the aspect, slope and land cover, and one can assume those are reflected in the local conditions and in the other meteorological variables, such as relative humidity, wind speed, and snow cover.

The land cover and hydrology have little influence on the regional climate of the CMR. Deciduous and conifer forests, steppe and cropland dominate the land cover, while the Danube River practically collects the waters of all the Carpathian hydrographical basins.

3. Materials and methods

This study exploits the results of the project CARPATCLIM. Details about the objectives, methodology, metadata, input and output data of the project are easily available at www.carpatclim-eu.org (accessed on February 2014). Spinoni et al. (2013) describe the concepts and methods used for building a reliable climatologic database in the Carpathian Region. For the sake of brevity, we provide here only general information on the data and methodology.

All the countries covering the CMR contributed to CARPATCLIM with relevant data and expertise, except for Bosnia and Herzegovina. Daily data sets from ground based meteorological stations, covering the period 1961–2010, refer to the following variables: maximum and minimum air temperature (Tmax and Tmin); precipitation amount (PP); average and maximum wind speed (WSave) and Wmax); sunshine duration (SD); cloud cover (CC); global radiation (GR); relative humidity (RH); air pressure (AP); water vapor pressure (VP); and snow depth (SwD). Within the project, each data set was quality controlled (QC), harmonized at the national borders and homogenized using the Multiple Analysis of Series for Homogenization (MASH v3.03) method and software (Szentimrey, 1999, 2008, 2011; Lakatos et al., 2013), and further combined at approximately 10-km resolution using the Meteorological Interpolation based on the Surface Homogenized Data Basis software (MISH v1.03; Szentimrey and Bihari, 2007).

Homogenization was one of the main objectives of the CARPATCLIM project, so that it is worthy to present here the main details of the homogenization process and the quality of the resulting data set. MASH v3.03 was selected due to its demonstrated performance (Venema et al., 2012), and to the project partners' knowledge and skills. It is a relative homogenization method developed by Tamas Szentimrey from the Hungarian Meteorological Service, which makes no *a priori* assumption regarding the data homogeneity, and it uses an exhaustive searching scheme to detect and adjust the most probable breaks, and regime shifting points in the data series from each weather station. The distribution of the examined meteorological element is taken into account for using a multiplicative or additive model, depending on the

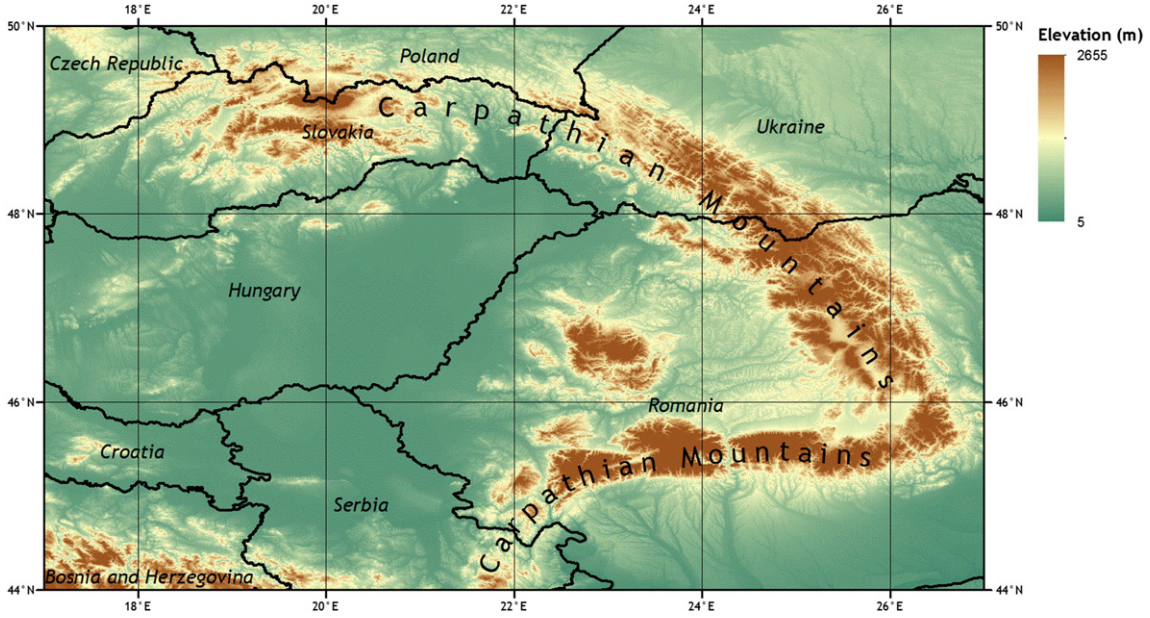

Fig. 1. Digital elevation model of the Carpathian Mountains Region.