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Changes in precipitation extremes in Romania

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A B S T R A C T

Changes in daily extreme precipitation have been identified in many studies conducted at local, regional, or global scales. In Romania, little research on this issue has been done. The present study focuses on the analysis of the trends in daily extreme precipitation indices over a period of 53 years (1961–2013). Data sets of daily precipitation recorded in 34 weather stations were analyzed. Among them, three are located in the Carpathians and four on the Black Sea Coast. The main goal was to find out changes in extreme daily precipitation using a set of 13 indices adopted from the core indices developed by ETCCDMI adapted to suit to the studied area. The series of indices and their trends were generated using RClimDex software. The trends have been calculated by employing modified Mann–Kendall test and Sen's slope. Generally, the climate of Romania has become wetter over the 53-yr period considered, especially in the northern regions, although the spatial distribution of the significant trend slopes in the area is extremely irregular. Based on fixed threshold indices analysis, extreme precipitation events are characterized by a decreasing in the total number of precipitation days (R0.1), and a dominant increasing trend for the number of isolated days with moderate and heavy precipitation (R5, R10).

1. Introduction

During the last decades, recent and future climate change has attracted international attention and has become one of the most important topics in climatic research. Changes in temperature and precipitation and their impact have been studied worldwide. Regarding precipitation, scientists recorded an increase both in the magnitude, frequency and probability of extreme precipitation events (Sen Roy and Balling, 2004; Bengtsson and Rana, 2013; Wang et al., 2013; Du et al., 2014). Those events usually trigger, at local or regional scale, extreme hydrological events like floods, flash-floods or drought, with strong social and economic impact, especially in developing countries, implying serious damages on settlements and agriculture, the main source for income and subsistence in many cases (Alexandrov et al., 2006; Nandintsetseg et al., 2007; Toreti and Desiato, 2008; Choi et al., 2009; Dos Santos et al., 2011; Wang et al., 2012). Moreover, changes in precipitation have been considered as one of the most important topics in global climate change, due to concerns related to the negative impacts on natural vegetation and ecosystems, water supply and management, river discharges, as well as human welfare and regional political stability (Radinović and Ćurić, 2009; Estrela and Vargas, 2012; Capra et al., 2013; Wan et al., 2013).

Most of the existing studies investigated the changes in annual and seasonal precipitation rates, but recently, changes in extreme precipitation events expressed by different indices based on historical data or on simulations of the regional climate models (RCMs) outputs have become attractive in research. Some previous papers on extreme temperature and precipitation events have been at large scale, such as global or hemispheric (Frich et al., 2002; Alexander et al., 2006; Fang et al., 2008), mid-scale, as the European continent (Klein Tank and Können, 2003; Moberg et al., 2006) or at small/regional scale. In Europe, significant positive trends in annual precipitation extremes were detected in different regions (Brunetti et al., 2004; Ramos and Martínez-Casasnovas, 2006; Bartholy and Pongracz, 2007; Łupikasza et al., 2011). Some other papers focused on this topic over Eastern Europe, as it is a region that could be significantly impacted by possible future changes in rainfall, temperature and evaporation (Ivanova and Alexandrov,

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2012; Villarini, 2012). Some other studies conducted in Southeastern Europe considered the areal-accumulated convective precipitation. Ćurić and Janc (2011a,b) focused on this topic for a 15-year period over mountainous and flat land areas. They also performed comparisons between observations and three model samples. The statistical analysis shows that the model version most closely matches observations better for the flat land area (with a correlation coefficient of 0.94) than for the mountainous area (correlation coefficient is 0.89).

Generally, statistical tests have shown changes in precipitation indices that were consistent with a wetter climate. The results indicate that the widespread global warming and wetting detected in the last 50 years or so, is likely to be part of a much longer-term trend. Moreover, the evidence suggests complex changes in precipitation extremes that support a generally wetter world. Numerous studies reported increasing heavy precipitation trends in many regions of the world (Frich et al., 2002; Alexander et al., 2006; Fang et al., 2008).

Although in different areas of the world extreme precipitation were investigated in detail at larger or smaller scales, in Romania only a few studies have been conducted. Some previous studies focused on precipitation extremes, but they covered small areas (Croitoru, 2006; Bartholy and Pongracz, 2007) or considered very few indices (one to four) (Dragotă, 2006; Busuioc et al., 2010; Villarini, 2012).

Accepting the fact that extreme precipitation trends strongly depend both on the study period and on other climatic and non-climatic factors (global warming, changes in circulation patterns, changes in land cover, urbanization), an approach that considers the large spatial and temporal variability of precipitation in Romania is needed. The objective of this article is to provide an analysis of detected changes in precipitation extremes over the whole territory of Romania. The study aims at identifying if the weather is getting more extreme in terms of precipitation by determining the spatial and temporal variability of annual series trends in extreme precipitation indices over a period of 53 years by using 13 extreme precipitation indices.

2. Data and methods

2.1. Study area

Romania is located in Eastern Europe in a temperate climate in transition from western maritime climate to arid continental climate. The Carpathian Mountains divide the Romanian territory into two groups: intra-Carpathian regions and extra-Carpathian regions. The first group includes the areas located inside the mountain chain as well as those located westward from the mountains (the Transylvanian Depression and the Western Plain and Hills). The extra-Carpathians regions are located southward and eastward from the Carpathians (the Romanian Plain, the Moldavian and Dobrudja tablelands) (Fig. 1). From the climatic perspective, such a division mirrors the spatial variability in the climatic features of the two groups of regions: the first group is dominated by western moist air masses, while the second group is more influenced by the southern tropical or eastern continental air masses.

The studied area extends over more than 4° of latitude (between 43°40′ and 48°11′N) and 8° on longitude (between 22°39′ and 29°41′E). The topography of the area is very complex, including plains, hills, highlands, and mountains. The altitude ranges between 0 and 2544 m. Thus, dominant continental (eastern) conditions are more specific to Eastern Romania, while the southeastern region is particularly affected by the Black Sea maritime influences; the western regions are open to the air masses originated over the Atlantic Ocean. At the same time, southwestern Romania seems to receive the influence of the Mediterranean Sea weather conditions against those of the Black Sea (Sandu et al., 2008). Under these circumstances, in the intra-Carpathian regions, floods generated by heavy precipitation are quite common, whereas in extra-Carpathian areas, droughts are more frequent and stronger, but floods are not excluded.

In the present study, we investigated the specific regional behavior of the extreme precipitation in Romania and identified changes in different extreme precipitation indices. The annual amounts of precipitation generally decrease eastward, from more than 550 mm/yr in the Western Plain to less than 300 mm/yr along the northern half of the Black Sea coast. The amounts increase considerably with altitude, reaching up to 986 mm/yr at 2500 m in the Carpathians.

2.2. Data

2.2.1. Data description

Changes in precipitation extremes indices were identified by using daily precipitation time series recorded in 34 weather stations, which belong to the Romanian National Meteorological Administration network. Among them, one is located on a summit (34), two in the intra-Carpathian depressions (20, 21) and four on the Black Sea Coast (11, 19, 25, 28). All the other locations cover plain and hilly areas. The datasets cover a period of 53-years (1961–2013). The data sets recorded in eight locations (13, 16, 19, 24, 25, 27, 30, 33) were provided by the Romanian National Meteorology Administration (RNMA), while the rest of the series were freely downloaded from ECA&D project database (Klein Tank et al., 2002).

The weather stations used in the study benefit from a reasonable spatial coverage, including all types of topography and all climatic regions in Romania (Fig. 1, Table 1). Thus, the regional features in the variability of the precipitation extremes in Romania could be detected.

Table 1
Geographical coordinates of the weather stations considered.

Code	Weather station[a]	Latitude (N)	Longitude (E)	Elevation (m)	Region
1.	Arad	46°08′ 15″	21°21′13″	117	Intra-Carpathians West
2.	Bacau	46°31′ 54″	26°54′45″	184	Extra-Carpathians East
3.	Bistrita	47°08′ 56″	24°30′49″	367	Intra-Carpathians Center
4.	Botosani	47°44′ 08″	26°38′40″	161	Extra-Carpathians East
5.	Bucuresti Baneasa	44°31′00″	26°05′00″	90	Extra-Carpathians South
6.	Bucuresti Filaret	44°25′00″	26°06′00″	82	Extra-Carpathians South
7.	Buzau	45°07′ 57″	26°51′05″	97	Extra-Carpathians South
8.	Calarasi	44°12′ 22″	27°20′18″	19	Extra-Carpathians South
9.	Caransebes	45°25′ 01″	22°13′30″	21	Intra-Carpathians West