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Analysis of precipitation conditions for the Carpathian Basin based on extreme indices in the 20th century and climate simulations for 2050 and 2100

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ABSTRACT

Precipitation is one of the most important elements of the hydrological cycle, and extreme events associated with precipitation are considered a key factor in several types of human activities, including agriculture, for instance. Therefore, the main objective of this paper is to evaluate extreme precipitation indices for the past century, and to analyse the possible tendency of future precipitation conditions for this century for the Carpathian Basin. Several climate extreme indices have been analysed according to the guidelines suggested by the joint WMO-CCl/CLIVAR Working Group (formed at the end of the 1990s) on climate change detection. These precipitation indices include the number of wet days using several threshold values, e.g., 20 mm (RR20), 10 mm (RR10), 5 mm (RR5), 1 mm (RR1), 0.1 mm (RR0.1), the upper quartile and the 95th percentile of daily precipitation in the base-period 1961–1990 (R75 and R95); the maximum number of consecutive dry days (CDD); the highest 1-day precipitation amount (Rx1); the greatest 5-day rainfall total (Rx5); the annual fraction due to extreme precipitation events (R95T); simple daily intensity index (SDII), etc. Our results suggest that regional intensity and frequency of extreme precipitation increased in the Carpathian Basin during the second half of the 20th century, while the total precipitation decreased and the mean climate became slightly drier during the whole 20th century. In the second part of this paper, several IPCC emission scenarios have been compared and GCM outputs have been analysed in order to project precipitation conditions in the Carpathian Basin for the 21st century. These climate simulations suggest that climate of this region may become drier in summer and wetter in winter, which highlight the importance of hydrological and agricultural planning in Hungary.

1. Introduction

First, IPCC Second Assessment Report (1995) declared the global warming trend of the last 150 years due to anthropogenic activity, which increased the annual global mean temperature by 0.7 °C. This IPCC report also concluded that changes in both the mean and the extreme climate parameters may strongly affect human and natural systems. These effects mainly appear on regional scale with high spatial variability. In order to evaluate the past and future climate tendencies of the Carpathian Basin, it is essential to monitor and analyse the mean and extreme climate conditions for the region for century-long periods. Fig. 1 summarises the asymmetric monthly distribution of precipitation anomalies in the Carpathian Basin for the whole 20th century (left panel) and the last quarter of the century (right panel). These annual cycles suggest that the largest precipitation extremes tend to occur in summer (May–June–July–August) in both cases. Large significant differences between the two diagrams cannot be observed, only slight structural changes seemed to occur. However, extreme precipitation conditions did change significantly in the Carpathian Basin, as shown in Pongrácz and Bartholy (2000), and Bartholy et al. (2003). In order to make adequate agricultural planning for the coming decades, it is essential to analyse the regional precipitation anomalies expected in this century.

Giorgi and Francisco (2000) analysed the future continental temperature and precipitation changes expected for the 21st century based on model outputs of five main Atmosphere–Ocean General Circulation Model (AOGCMs). Global continental areas were divided into 23 regions, from which two cover the European continent, namely (i) Northern Europe (NEU), and (ii) the Mediterranean region (MED). Fig. 2 summarises intensity, sign, and consistency of the GCM-based precipitation changes for these two European regions. Expected changes in precipitation conditions are presented in four small boxes for NEU and MED for 2071–2100. The upper and the lower two boxes represent expected changes in winter (December–January–February), and in summer (June–July–August), respectively. Furthermore, results for the GG (greenhouse gas only case) and GS (greenhouse gas with increasing sulphate aerosol case) scenario are shown in the left two boxes, and in the

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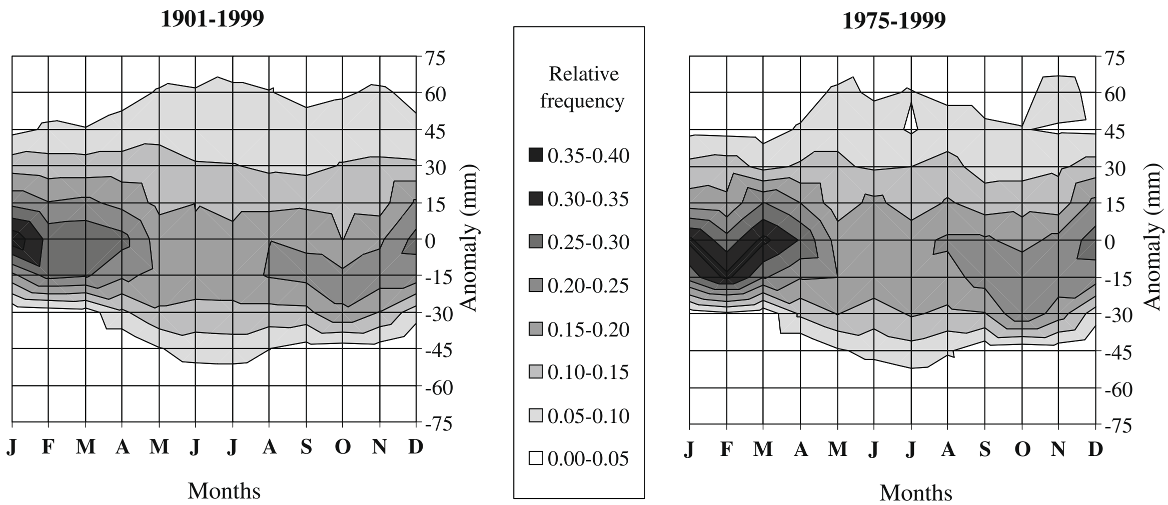

Fig. 1. Annual variation of relative frequencies of precipitation anomalies observed in 10 Hungarian stations (1901–1999).

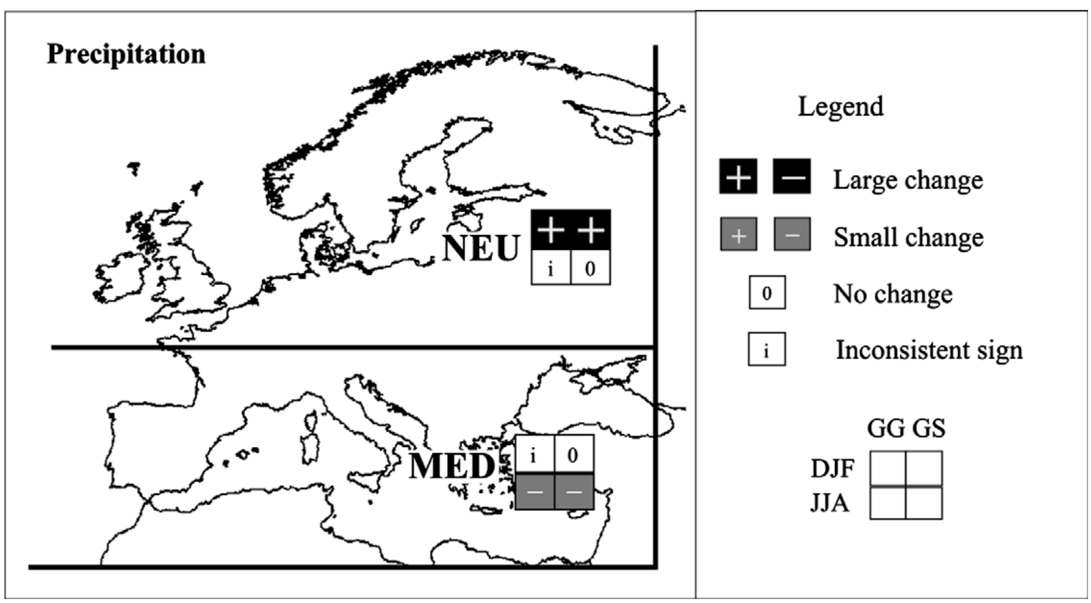

Fig. 2. Summary of precipitation trend analysis for Northern Europe (NEU) and the Mediterranean region (MED) for two seasons (winter and summer) and for two climate scenario (GG, GS) based on inter-model consistency analysis of Giorgi and Francisco (2000).

right two boxes, respectively. "+" and "–" signs appearing in the small boxes indicate the intensity of precipitation change compared to the base-period 1961–1990. Black and grey colors imply large (greater than 20%) and small (between 5% and 20%) average change, respectively. "0" indicates no change (between −5% and +5%), while in case of model disagreement sign of inconsistency ("i") appears in the small box. Results of Giorgi and Francisco (2000) suggest that winters in Northern Europe are tend to become considerably wetter, and Mediterranean summers are likely to become drier than today for both GG and GS scenario. Estimations of the five main AOGCM are inconsistent for NEU summers and MED winters for the GG scenario, while they do not indicate significant changes for the GS scenario. The Carpathian Basin is located at the border of these two main regions, NEU and MED, therefore even the sign of expected precipitation changes is uncertain for the basin. That is why detailed analysis of past and future precipitation conditions occurring in the area, is necessary and presented in this paper.

Section 2 of our paper presents the analysis of regional extreme precipitation indices for the Carpathian Basin based on the daily precipitation observations in the 20th century. Then, Section 3 summarises the regional precipitation projections on annual and monthly scales for the 21st century. Finally, Section 4 highlights the main conclusions of the paper.

2. Extreme climatological analysis of the Carpathian Basin for the 20th century

In 1998, a joint WMO-CCl/CLIVAR Working Group formed on climate change detection (Peterson et al., 2002). One of its task groups aimed to identify the climate extreme indices (Table 1) and completed a climate extreme analysis on all part of the world where appropriate data was available (Frich et al., 2002). Some results of this working group also appeared in IPCC Third and Fourth Assessment Reports (2001, 2007). In the frame of this international