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Trends in daily temperature and precipitation extremes over Georgia, 1971–2010

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ABSTRACT

Annual changes to climate extreme indices in Georgia (Southern Caucasus) from 1971 to 2010 are studied using homogenized daily minimum and maximum temperature and precipitation series. Fourteen extreme temperature and 11 extreme precipitation indices are selected from the list of core climate extreme indices recommended by the World Meteorological Organization – Commission for Climatology (WMO-CCL) and the research project on Climate Variability and Predictability (CLIVAR) of the World Climate Research Programme (WCRP). Trends in the extreme indices are studied for 10 minimum and 11 maximum temperature and 24 precipitation series for the period 1971–2010. Between 1971 and 2010 most of the temperature extremes show significant warming trends. In 2010 there are 13.3 fewer frost days than in 1971. Within the same time frame there are 13.6 more summer days and 7.0 more tropical nights. A large number of stations show significant warming trends for monthly minimum and maximum temperature as well as for cold and warm days and nights throughout the study area, whereas warm extremes and night-time based temperature indices show greater trends than cold extremes and daytime indices. Additionally, the warm spell duration indicator indicates a significant increase in the frequency of warm spells between 1971 and 2010. Cold spells show an insignificant increase with low spatial coherence. Maximum 1-day and 5-day precipitation, the number of very heavy precipitation days, very wet and extremely wet days as well as the simple daily intensity index all show an increase in Georgia, although all trends manifest a low spatial coherence. The contribution of very heavy and extremely heavy precipitation to total precipitation increased between 1971 and 2010, whereas the number of wet days decreases.

1. Introduction

The globally averaged surface temperature data shows a linear warming trend of 0.85 °C [0.65 to 1.06 °C] during the period 1880–2012. The total increase between the average of the 1850–1900 period and the 2003–2012 period is 0.78 °C [0.72 to 0.85 °C], based on the single longest dataset available (IPCC, 2013). Climate extremes receive much attention as trends in extreme events react more sensitively to climate change than mean climate, and therefore have a more intense impact on natural and human systems. (Katz and Brown, 1992; Easterling et al., 1997, 2000; Kunkel et al., 1999; New et al., 2006; IPCC, 2007; Aguilar et al., 2009). The IPCC (2012) stated that there is a high confidence economic losses from weather- and climate-related disasters have increased during the last 60 years and will have greater impacts on sectors with closer links to climate, such as water, agriculture and food security, whereas the highest fatality rates and economic losses caused by hydro-meteorological induced disasters are registered in developing countries. On a global scale, temperature indices demonstrate a significant warming during the 20th century, citing the highest trends for the most recent periods and for minimum temperature indices. However, trends in extreme precipitation illustrate a much lower spatial coherence, yet on a global scale a significant wetting trend could be detected, whereas the number of consecutive dry days shows very different regional changes (Frich et al., 2002; Alexander et al., 2006). Since the 1990s, various regional studies pertaining to temperature and precipitation extreme indices have been conducted which provide strong evidence that global warming is related to significant changes in temperature and precipitation extremes. (Zhang et al., 2000; Manton et al., 2001; Peterson et al., 2002; Aguilar et al., 2005; Griffiths et al., 2005; Zhang et al., 2005b; Haylock et al., 2006;

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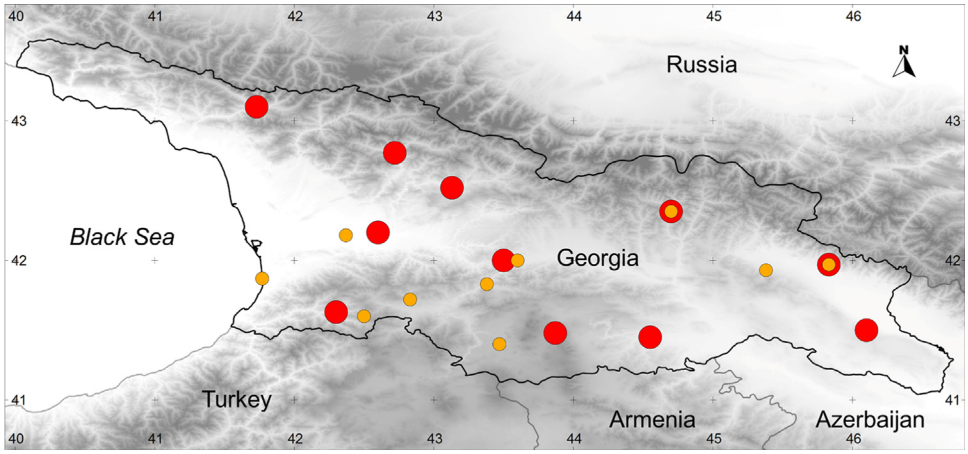

Fig. 1. Stations with daily time series of temperature minimum (orange dots) and maximum (red dots) and precipitation for the period 1971–2010.

Klein Tank et al., 2006; Alexander et. al, 2006, Skansi et al., 2013). Climate extreme indices have also been computed and analyzed for projected future climate conditions based on simulations by Global Climate Models (GCMs) (Sillmann, 2013a and 2013b; Russo and Sterl, 2011; Tebaldi et al., 2006; Alexander and Arblaster, 2009; Kharin et al., 2007; Orlowsky and Seneviratne, 2012). Extreme precipitation and extreme warm temperature are both predicted to increase while extreme cold temperatures will become more moderate. The results also suggest that climate models cannot overcome uncertainties for projecting future changes in extreme events, especially concerning the regional scale with complex physiographic conditions. For that reason, analyzing changes in extreme climate events based on observation data is essential. Developing and transition countries such as Georgia face a number of political, financial and institutional barriers for a proper climate data monitoring system, including limitations on funding, technology and human resources (Page et al., 2004). After the collapse of the Soviet Union in the early 1990s the number of meteorological stations in Georgia rapidly decreased and the lack of station maintenance caused large measuring gaps. The quality and quantity of accessible climate series still limit our understanding of the observed changes in climate extremes in Georgia. So far, studies on changes in climate and climate extremes have been carried out based on monthly temperature data and associated weather and climate phenomena, such as drought, hurricanes and frost (Elizbarashvili, 2007, 2009, 2011, and 2012). Elizbarashvili (2013) discovered that the frequency of extremely hot months during the 20th century increased, especially over Eastern Georgia, whereas extremely cold months decreased faster in the Eastern than in the Western region. In addition, highest rates for positive trends of mean annual air temperature can be observed in the Caucasus Mountains. The aim of this study is to provide a better understanding of recent changes in the variability, intensity, frequency and duration of climate extreme events across Georgia by investigating trends in selected daily temperature and precipitation extreme indices between1971 and 2010 using the software RClimDex 1.1 (Zhang and Yang, 2004). This is achieved by calculating a set of 25 ETCCDI climate extreme indices from homogenous daily weather data and estimating linear trends. Standardized anomalies of those trends are also investigated. The indices of temperature and precipitation extremes considered in the present study are recommended by the Expert Team on Climate Change Detection Indices (ETCCDI). Section 2 of the current study describes the study area, the quality criteria of the data selection, quality control, homogenization, the climate extreme indices and the analytical methods used in this study. Section 3 presents and discusses the observed regional trends for the analysis period 1971–2010 as averaged regional trends from anomalies and regional trends per decade for each index. Section 4 summarizes the conclusions.

2. Data and methods

2.1. Study area

Georgia is located in the Southern Caucasus between 41 and 44°N and 40 and 47°E and covers an area of 69.700 km² (Figs. 1 and 2). It borders Russia to the North, Azerbaijan to the Southeast and Armenia and Turkey to the South. The topographic patterns throughout Georgia are very diverse. The relief declines from the Greater Caucasus Range in the North, with an elevation range of 1500–5000 m and the Lesser Caucasus with altitudes up to 3500 m in the South towards Transcaucasia, which stretches from the Black Sea coast to the Eastern steppe. The Surami mountain chain with a maximum altitude of 1000 m connects the Lesser Caucasus with the Greater Caucasus and divides Transcaucasia into eastern and western lowlands (0–500 m). The Greater Caucasus represents an important climatic parting line towards Russia. It protects Transcaucasia from arctic high-pressure systems in winter originating from the Central Asian Region. The Southern Caucasus inhibits the summer heat from the Southeast. The Surami mountain chain avoids wet air masses circulating from the Black Sea towards the Caspian Sea causing high temperatures and humid climate at the Western coast, continental climate in inner Transcaucasia up to very dry climate with high temperatures in the eastern lowlands. Due to the complex annual large-scale circulation and diverse physiographic patterns, large spatial and temporal differences of temperature and precipitation over Georgia can be observed. In general, the west of Georgia is characterized by mild winters and hot summers with mean annual air temperatures of 13 to 15 °C and high annual precipitation values (1200–2400 mm). The climate in eastern Georgia is continental with much lower annual precipitation (500–600 mm in the lowlands) and a mean temperature between 10 and 13 °C. In the mountainous areas mean temperature covers a range of −5 to 10 °C and precipitation varies from 800 to 1400 mm (World Bank, 2006).

2.2. Data, quality control and homogeneity testing

Daily minimum and maximum temperature and daily precipitation for 88 stations were kindly provided by the National Environmental Agency of Georgia (NEA). The analysis period 1971–2010 was chosen to investigate recent change in extreme