Changes of extreme precipitation in Southern Russia

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Abstract. Features of extreme precipitation and their long-term changes over Southern Russia were analysed in the paper using daily precipitation data from 21 hydrometeorological stations in 1950 – 2010. Two climate indices for extreme precipitation (RX1day and RX5day) and concentration index data series for the study period were calculated and analysed. It was defined that precipitation extreme changes are characterized by spatial and temporal variability. It was found the tendency to wetter in extreme anomalies, however, the trends are mainly negligible. Spatial distribution of precipitation concentrations demonstrates that the northern, southern and western regions are characterized by moderate values, while the coast of the Caspian Sea and the territory of Caspian Depression has shown high values of CI.

1. Introduction

The temperature and precipitation behavior has significantly changed during past centuries. It is confirmed by IPCC report – "It is certain that Global Mean Surface Temperature has increased since the late 19th century" and "averaged over the mid-latitude land areas of the Northern Hemisphere, precipitation has likely increased since 1901 (medium confidence before and high confidence after 1951)" [1]. This also applies to the extreme values of temperature and precipitation – "It is very likely that the numbers of cold days and nights have decreased and the number of warm days and nights have increased globally since about 1950" and "It is likely that since about 1950 the number of heavy precipitation events over land has increased in more regions than it has decreased" [1].

Events with extreme precipitation may lead to catastrophic consequences, e.g. drought, floods and others. A graphic example is the floods in Krasnodar Krai of Russia in early July 2012, when the equivalent of two-five months precipitation norm fell in short time [2, 3]. Droughts in many Russian regions and following them forest fires caused great disasters in 2010 and 2012. In this work we used daily data because only daily resolution can provide information about the frequency, number of rainy days, or gaps in precipitation series. The south of Russia is a large and world famous agricultural and recreational region. The territory is characterized by diverse climate and complex orthography (Crimean Mountains, Caucasus Mountains, deltas of large rivers, coastal zone of the Sea of Azov, the Black Sea and the Caspian Sea). These factors together with natural variability of meteorological parameters can lead to the above-mentioned catastrophic events.

Thus, the aim of the paper is to study the typical characteristics of extreme precipitation in Southern Russia in 1950 – 2010 and its temporal distribution.

2. Data and method

Daily precipitation totals data observed at 21 meteorological stations in period 1950 – 2010 were analyzed. These data were obtained from the KNMI Climate Explorer (http://climexp.knmi.nl) and National Oceanic and Atmospheric Administration (NOAA, http://www.ncdc.noaa.gov). Stations names and their locations are presented in table 1 and in figure 1.
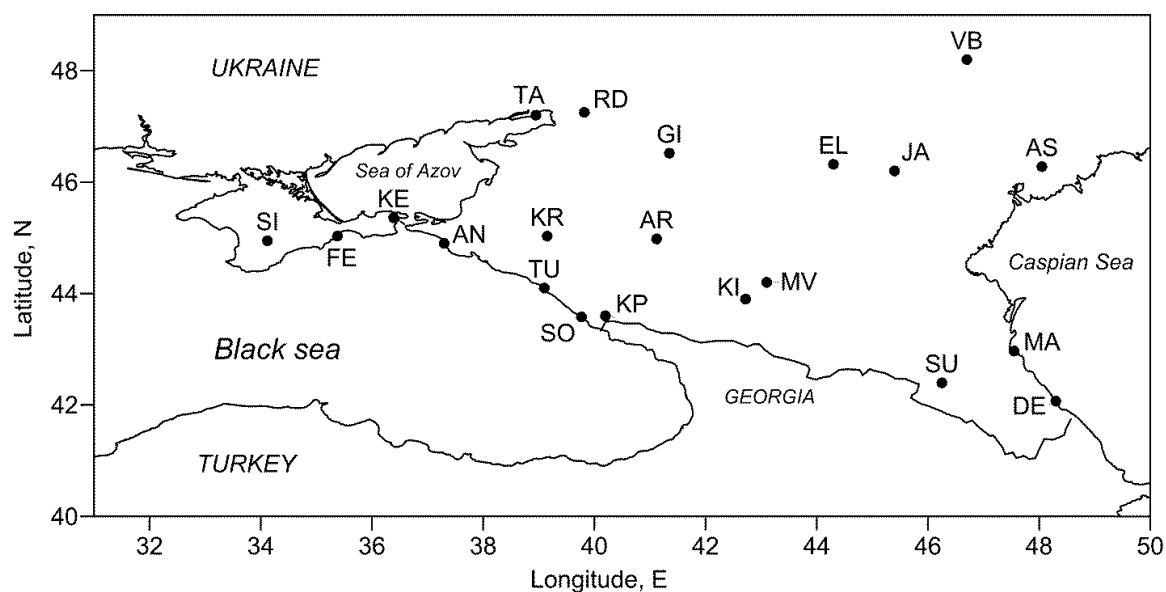
Figure 1. Study region. The black points mark stations location.

Table 1. List of hydrometeorological stations, their WMO (World Meteorological Organization) number, latitude, longitude and altitude (m).

Station name	WMO no.	Latitude (N)	Longitude (E)	Altitude (m)
Anapa (AN)	37001	44.90	37.30	30.0
Armavir (AR)	37031	44.98	41.12	159.0
Astrakhan (AS)	34880	46.28	48.05	-23.0
Derbent (DE)	37470	42.07	48.30	-19.0
Elista (EL)	34861	46.32	44.30	151.0
Feodosia (FE)	33976	45.03	35.38	22.0
Gigant (GI)	34740	46.52	41.35	79.0
Jaskul (JA)	34866	46.20	45.40	-7.0
Kerch (KE)	33983	45.36	36.39	49.0
Kislovodsk (KI)	37123	43.90	42.72	890.0
Krasnaja poljana (KP)	37107	43.60	40.20	566.0
Krasnodar (KR)	34927	45.03	39.15	29.0
Makhachkala (MA)	37472	42.97	47.55	28.0
Mineralnye vody (MV)	37054	44.20	43.10	316.0
Rostov-na-Donu (RD)	34730	47.25	39.82	66.0
Simferopol (SI)	33946	44.95	34.12	181.0
Sotchi (SO)	37099	43.58	39.77	57.0
Sulak (SU)	37461	42.40	46.25	2927.0
Taganrog (TA)	34720	47.20	38.95	30.0
Tuapse (TU)	37018	44.10	39.10	41.0
Verkhnij Baskuncak (VB)	34579	48.20	46.70	35.0

Two methods to analyze extreme precipitation were used. First of them is climate indices. The extremes precipitation indices were selected from the list of climate indices recommended by the World Meteorological Organization–Commission for Climatology (WMO–CCL) and the Research Programme on Climate Variability and Predictability (CLIVAR) Expert Team on Climate Change Detection, Monitoring and Indices (ETCCDMI) [4, 5]. The main function of these indices is to assess the changes in the intensity, frequency and duration of precipitation events [6]. Climate extreme indices that were used in the paper are presented in table 2. Selected indices represent frequency of extreme precipitation. Data quality control and extreme climate indices calculation were done using standardized software RClimDex (freely available at http://etccdi.pacificclimate.org /software.shtml), developed by ETCCDMI.

Table 2. List of ETCCDI climate indices used in the work.

Index	Definition	Units
Rx1day	Maximum 1-day precipitation total	mm
Rx5day	Maximum 5-day precipitation total	mm

Annual and monthly time series of selected climate indices for each station were calculated. Annual indices distribution, their first, second and third quartiles, maximum and minimum values were analysed using box-and-whiskers plots approach [7, 8].

Next, the concentration index (CI) method was applied. This index allows evaluating the contribution of very rainy days to the total amount, because a few daily events produce a high percentage of total monthly, seasonal or annual precipitation. The methodology proposed by Spanish climatologist J. Martin-Vide and described in [9]. Later this methodology was applied to investigation of precipitation concentration in many regions – for the territory of Europe [10], in China [11], in northern Africa [12], in USA [13] and around the world [14].

3. Results
To show the features of extreme precipitation at the first step of study we consider the spatial distribution of typical precipitation extremes over the Southern Russia territory in period 1950 – 2010 and their long-term changes using selected indices.

3.1. Climate indices
A graphical representation of the annual RX1day and RX5day indices distribution on the basis of box-and-whiskers plots are demonstrated in figure 2. The bottom and top of the box are the first and third quartiles; the band inside the box is the second quartile (the median). The dashes at the end of whiskers show maximum and minimum values, the dots show outliers

The box plot of extreme precipitation events in short periods of time (RX1day) is presented in figure 2a. The index shows monthly maximum 1-day precipitation. Minimum values of RX1day range from 8.3 mm·day^{-1} in eastern part of region to 48.5 mm·day^{-1} for the Black sea coastal stations. Maximum values vary from 50.5 mm·day^{-1} in Jaskul to 179.5 mm·day^{-1} in Tuapse. Annual median values of RX1day index ranges from 22.5 mm·day^{-1} in the northeastern part to 82 mm·day^{-1} on the Black Sea coast. The biggest values of index RX1day are typical for the Black sea coastal stations.

Analysis of the wettest consecutive five days (RX5day) is presented in figure 2b. Distribution of the annual maximum five-day precipitation accumulation is similar to distribution of RX1day index. Minimum values range from 10.8 to 106.2 mm for the eastern part of region and the Black sea coastal zone respectively. Mean values range from 32.3 mm in the northeast of territory to 162.5 mm for the Black Sea coastal zone. The maximum values of RX5day index is typical for the Black Sea coastal stations and reached 285.1 mm during the studied period. The smallest change of RX5day index is typical for Elista station (continental climate) and the largest for Tuapse. Summarizing the results of precipitation extremes analysis it can be concluded that the maximum values of indices are typical for the Black Sea coast and the minimum for the northeastern part of the region.
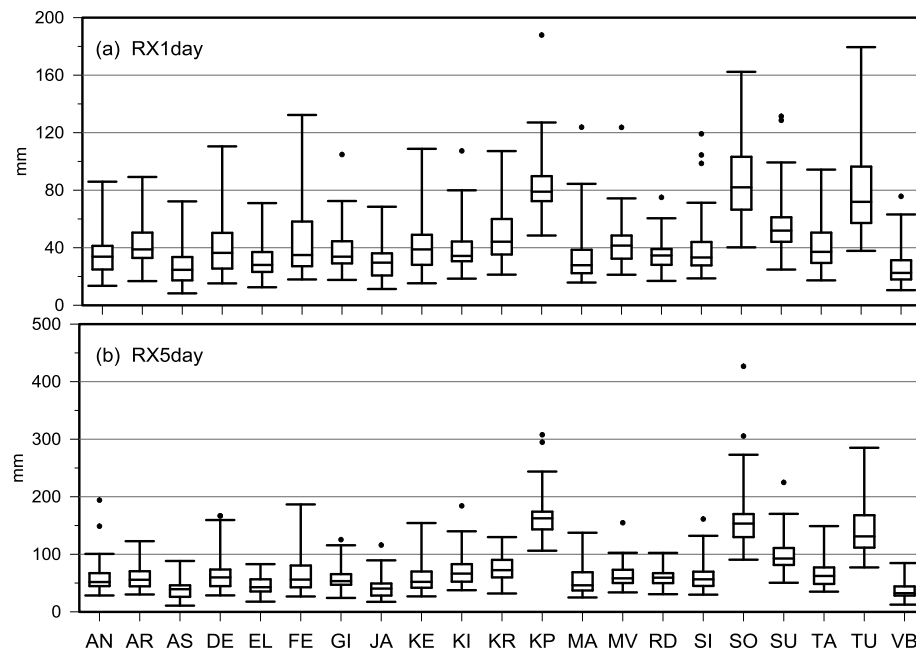
Figure 2. The box plots of the RX1day (a) and RX5day (b) indices for the period 1950 – 2010.

Distribution of extreme precipitation trends is characterized by strong spatial variability. Spatial distribution of trends RX1day index is shown in figure 3a. Linear trends are predominantly positive and range from 0.1 mm·(10 years)$^{-1}$ (the southeastern part of studied region) to 3.5 mm·(10 years)$^{-1}$ (the coastal zone of Black Sea). But there are only several significant ($p < 0.05$) trends. Negative trends are typical of the north-western part of the studied region, coastal zone of the Sea of Azov (continental part of Russia). Trend coefficient varies between 0.04 and 1.8 mm·(10 years)$^{-1}$, but all of them are not significant. Analysis of long-term changes of the wettest consecutive five days (RX5day) are presented in figure 3b. Upward changes are typical for the region under consideration. Positive trends ranges have the values between 0.5 and 5.4 mm·(10 years)$^{-1}$. Negative trends are few in number and not significant. So, the analysis of long-term precipitation changes generally demonstrates insignificant increase to wetter conditions.
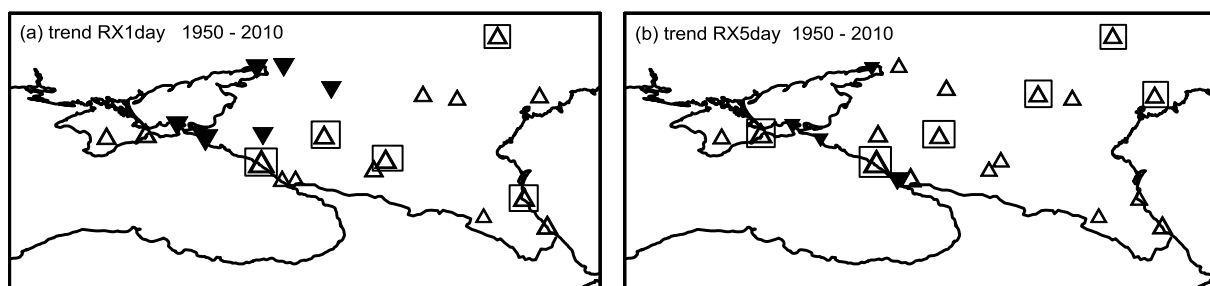

Figure 3. Annual trends for the (a) RX1day (mm/10 years) and (b) RX5day (mm/10 years) indices for the period 1950 – 2010. White upward triangles mean positive linear trend, black downward triangles mean negative linear trend. Significant precipitation trends ($p < 0.05$) are indicated by external square. The sizes of triangles are proportional to the trend values.

3.2. Precipitation concentration
The concentration index was calculated for 21 meteorological stations for the period 1950 – 2010. According to the previous studies CI > 0.61 is high, 0.55 < CI < 0.61 is moderate and CI < 0.55 is low.

The minimum value of CI is typical for north-eastern part of the region and for Anapa station. High values of CI are found in the Caspian Sea coast and the Caspian Depression.

The northern part of the region is characterized by sufficiently high values of the CI (0.58 – 0.59). The climate of this region is moderate-continental, with a short, cold, snowy winter and a long, hot, dry summer. In Ciscaucasia and the northern part of the Greater Caucasus index values vary within 0.58 to 0.6. This is explained by the uniform distribution of rainy days throughout the year. As it was said above high values of concentration index are observed on the coast of the Caspian Sea and in the territory of the Caspian Depression. It can be explained by geographical location and the atmospheric circulation over this region. In winter and summer precipitation regime is irregular, which leads to high values of the CI. High value of CI was also found in the eastern part of the Crimean peninsula.
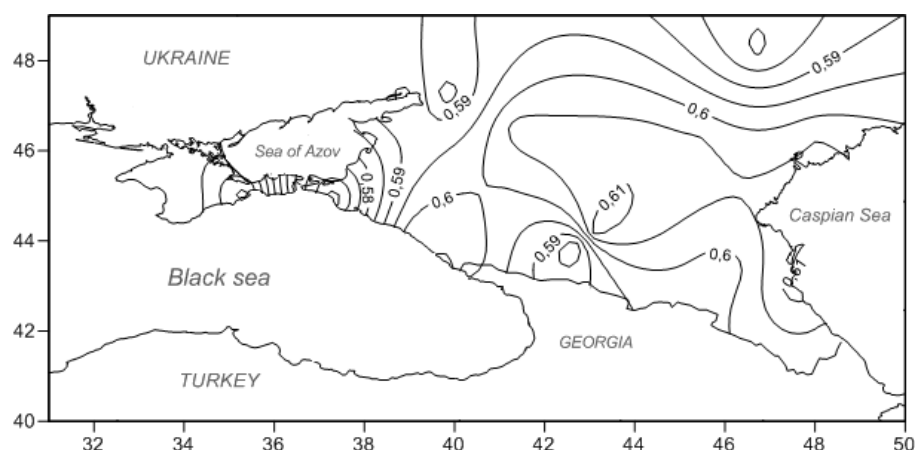

Figure 4. Spatial distribution of concentration index values.

4. Conclusions

The study of precipitation extremes distribution in Southern Russia and their long-term changes in 1950 – 2010 showed the following results. The maximum values of climate indices (RX1day and RX5day) are typical for the Black Sea coastal zone. Linear trends of precipitation indices are predominantly positive, but only a part of them is significant. Analysis of precipitation concentrations made it possible to identify several regions with different regimes. The eastern part of the region showed the highest concentration of precipitation, whilst the northern, southern and western parts exhibit relatively regular precipitation. The highest CI values were found on the coast of the Caspian Sea and in the territory of the Caspian Depression.

Acknowledgments

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