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SEASONAL ANALYSIS OF WARM DAYS IN BELGRADE AND NIŠ

Pavle Arsenović, Ivana Tošić**[1], Miroslava Unkašević***
* Hydrometeorological Service of Serbia
** University of Belgrade-Faculty of Physics, Institute for Meteorology

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Summary: The seasonal analysis of warm days in Belgrade and Niš is presented using climate indices Warm/Dry (WD) and Warm/Wet (WW) days, which are based on the daily mean temperatures and daily precipitation. Day is conceived as warm if the daily mean temperature is greater than the 75th percentile. Day is considered as dry (wet) if the daily precipitation are below the 25th percentile (higher than the 75th percentile). Analyses are made for the period 1950–2009 for Belgrade and Niš. It is obtained that the number of WD days, as well as WW days incresed in both cities, in Belgrade more than in Niš.

Key words: climate indices, warm dry days, warm wet days, season, trend, Belgrade, Niš

Introduction

More frequent extreme temperature events can have serious impacts on our environment and society. Analyses of observed temperature in many regions of the world have already shown some important temperature changes in the climate system (Vincent et al., 2005). The mean global average surface temperature, including land and sea, has increased by about 0.6°C over the twentieth century and many areas have experienced significant warming during the last 50 years (Folland et al., 2001). This warming may not be spatially or temporally uniform, but it is projected to continue and will likely be accompanied by more extreme climate events (Vincent et al., 2005).

To better explain extreme events the Working group on Climate Change Detection of the tehnical commision for climatology of the World Meteorological Organization (WMO) proposed a list of indices meaningful over global regions, based on temperature and precipitation. Analysis of joint temperature-precipitation climate indices, that are the combination of cool/dry, cool/wet, warm/dry (WD) and warm/wet (WW) modes revealed a systematic change at nine European cities in the course of the 20^{th} century, with significant

[1] Correspondence to: itosic@ff.bg.ac.rs

declines in the frequency of occurrence of the "cold" modes and a sharp rise in that of the "warm" modes (Beniston, 2009). In this study, WD and WW climate indices will be used to analyze warm days in Belgrade and Niš.

Climate of Belgrade and Niš is continental with more precipitation during the summer than during the winter (Ducić & Radovanović, 2005). The daily mean temperatures and daily precipitation during the period 1950–2009 were used in this study. From Figure 1 it can be seen that the minimum value of the mean monthly temperatures occur in January (0.9°C in Belgrade and 0.3°C in Niš), while the maximum ones in July (22.4°C in Belgrade and 22.0°C in Niš). The highest precipitation are registered in June (92.9 mm in Belgrade and 62.3 mm y Niš), and the lowest in February (Figure 2).

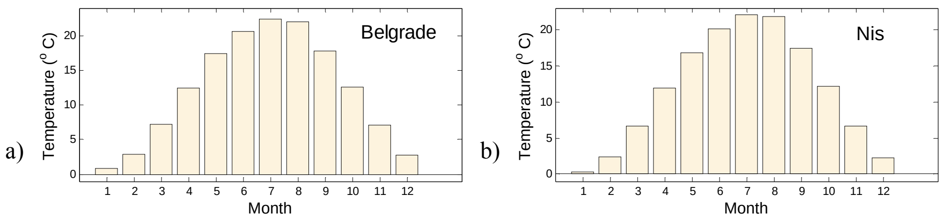

Figure 1. The monthly mean temperature (°C) in a) Belgrade and b) Niš during the period 1950–2009

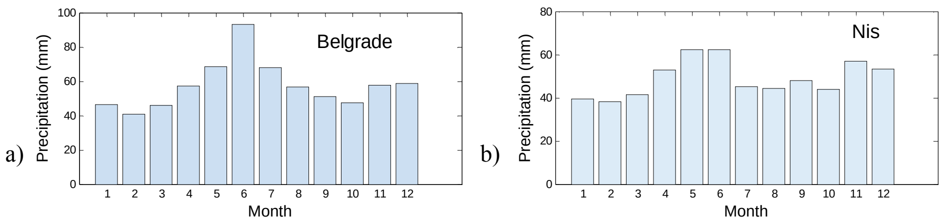

Figure 2. The monthly mean precipitation sum (mm) in a) Belgrade and b) Niš during the period 1950–2009

Method and data used

The daily mean air temperatures (measured at 2 m) and daily precipitation sums (accumulated in the period from 7 of the previous day to 7 of the current day) during the period 1950–2009 used in this study were observed in Belgrade (altitude – 132 m, latitude – 44°48' N, longitude – 20°28' E) and Niš (altitude – 201 m, latitude – 43°19' N, longitude – 21°54' E).

Climate indice Warm/Dry (WD) is defined as a number of days when the daily mean temperature was above the 75th percentile and simultanously the precipitation were below the 25th percentile during the period of observation. Indice Warm/Wet (WW) is defined as a number of days when the daily mean temperature and precipitation were above the 75th percentile as noted in the summary.

The discussion here focuses on the exceedances of the joint quantiles of temperature and precipitation using the 25% and 75% quantile levels. According to the IPCC report (2007) the 10% and 90% quantiles define an extreme events. The values are set here at 25% and 75% in order to capture a larger number of events. The chosen thresholds enable to focus on particular modes of variability that can have perceptible impacts on environmental and managed systems that the use of the 50% quantile would not.

Analyses were done for the period 1950–2009 for the winter (December, January, February), spring (March, April, May), summer (June, July, August) and autumn (September, October, November) season.

Temperature percentiles were calculated for each day in a year. For example, all temperatures for the first January are selected, the series is then sorted in ascending order and finally, the 75th percentile was determined.

Precipitation percentiles were calculated for each season. For example, winter precipitation (December, January, February) were sorted in ascending order for all years, and the 25th percentile was determined for the WD indice (i.e., 75th for the WW indice). Percentiles for the other seasons were determined analogously. In this way, the values of percentiles were obtained for both indices and cities. It is considered that the precipitation day is defined as a day when precipitation greater than 1 mm were registered.

Finally, a number of days were calculated for each year in the case when both conditions were satisfied (air temperatures above the 75th percentile and precipitation bellow the 25th percentile – WD indice, air temperatures and precipitation above the 75th percentile – WW indice).

Trend determination

The nonparametric Mann–Kendall test was used to detect any possible trend in temperature series, and to test whether such trends are statistically significant. The Mann–Kendall rank correlation statistic τ (Kendall & Stuart, 1976; Mališić, 2002) is defined as

$$\tau = \frac{4\sum n_i}{N(N-1)} - 1,$$

where n_i is the number of values larger than the *i*th value in the series subsequent to its position in the series of *N* values. To apply this statistic to evaluate significance, a comparison is made with:

$$(\tau)_t = \pm t_g \sqrt{\frac{4N+10}{9N(N-1)}}$$

where, t_g is the desired probability point of the normal distribution with a two-sided test (WMO, 1966), which is equal to 1.96 for the 5% level of significance, Using a two-sided test of the normal distribution, null hypothesis of absence of any trend in the series is rejected if $|\tau| \geq |(\tau)_t|$ for the desired level of significance. The linear regression coefficients are determined using the least square method.

Analysis of the results

Climate indices WD and WW were analyzed for each season during the period 1950–2009. The linear regression coefficients of indices considered along with trends are presented in Table 1. A coefficient is bolded if there is a trend at the 5% level of significance.

From Table 1 it can be seen that there is an increasing tendency of WD with greater value in Belgrade than in Niš. Applying the Mann–Kendall test to the WD indice, the positive trend at the 5% level of significance is obtained for the spring and summer season in Belgrade. The climate indice WD is represented by solid line in Figure 3, and the trend by the dashed line. The minimum value of 5 days is registered in 1981, while the maximum of 42 days in 2001.

The greatest increase of WD is recorded in Belgrade during the summer and presented in Figure 4. The rapidly rise of WD is observed in the second half of 1980s. The minimum value of 5 days is registered in 1977, and the maximum of 47 days in 2008. Such distribution of WD is caused by air temperature. In the most European countries, and in Serbia (Unkašević & Tošić, 2009), the minimum of temperature is observed in 1970s, while maximum in 1940s and during the first decade in 21th century (IPCC, 2007).

The Mann-Kendall test was not applied to the WW indice, because of the small number of warm/wet days in Belgrade and Niš during the spring, summer and autumn. The number of WW days was observed each year during the winter (up to 12 days) in Belgrade and (up to 6 days) in Niš. The trends of this indices were insignificant.

Table 1. The regression coefficients for WD and WW indices for Belgrade and Niš during the seasons

Station	season	indice	regression coefficient
Belgrade	Winter	WD	0.06216
		WW	0.00204
	Spring	WD	**0.19697**
	Summer	WD	**0.24032**
	Autumn	WD	0.08199
Niš	Winter	WD	0.00497
		WW	0.01794
	Spring	WD	0.10486
	Summer	WD	0.17799
	Autumn	WD	-0.04026

Coefficients being significant at the 5% level are indicated by bold

It is likely that feedback effects between heat availability and the presence or absence of moisture explain both the trends in mean temperature and temperatures associated with the WD modes and the increases of precipitation during WW modes. Warmer temperatures associated with little or no rainfall lead to enhanced warming in the WD mode because of the positive feedback effects of drier land-surface conditions. However, the changes in precipitation during the WW mode are related to changing availability of heat close to the ground that may on occasion contribute to an amplification of convective instability and hence greater to precipitation potential (Beniston, 2009).

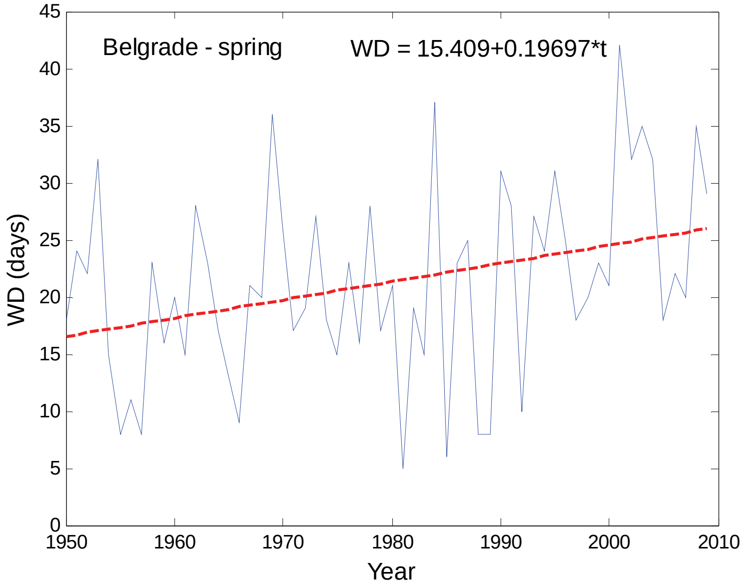

Figure 3. Number of warm/dry (WD) days during the spring in Belgrade during the period 1950–2009

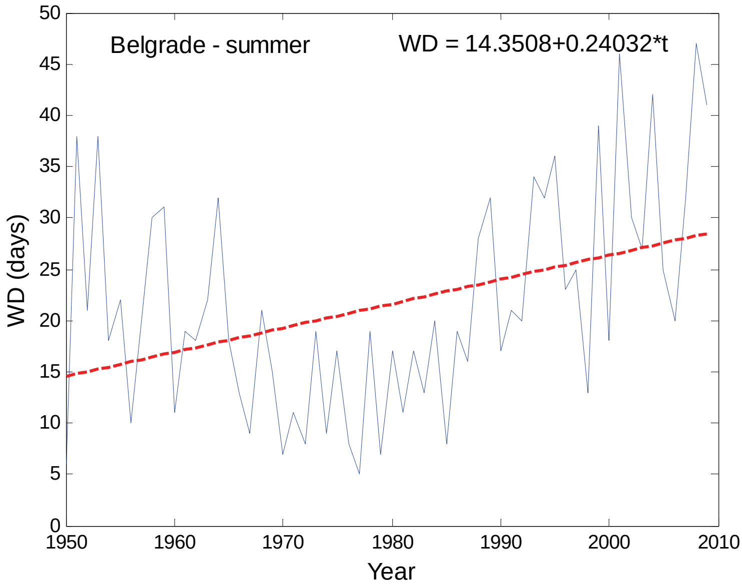

Figure 4. As in Figure 3, but for the summer season

Analyzing the WD indice for the European cities with the Mediterranean (Lisbon, Lugano, Madrid), maritime (Copenhagen, Dublin, Paris) and continental climate (Hannover, Vienna, Zurich), Beniston (2009) found an increase of WD for all climate types, with the most increase in Lisbon. The increse of WD is evidenced in the Mediterranean stations exhibiting a rate of change that is twice as fast as that of the continental or maritime locations (Beniston, 2009).

Analysis of heat waves (time period of at least 5 consecutive days with the daily maximum temperature higher than 5°C according to the mean maximum temperature during the 1961-1990 reference period) indicated a rise of number of heat wave in Belgrade and Niš (Drljača, Tošić & Unkašević, 2009) that was in accordance with obtained trend of warm indices. Unkašević & Tošić (2013) made comprehensive analysis of the temperature indices and determined an increase of warm nights (i.e. the number of days per year with the daily minimum temperature higher than the 90th percentile) and warm days (i.e. the number of days per year with the daily maximum temperature higher than the 90th percentile) in Serbia for all seasons. It is noticed that there was a positive air temperature trend at the other region of the World. For southern Canada, the findings show increasing trends in the 5th and 95th percentiles of the daily minimum and maximum temperature over 1900–1998 (Bonsal et al. 2001). Warming was identified in various parts of Brazil (Marengo 2001, Sansigolo et al. 1992). Over Australia and New Zealand, the frequency of warm days and nights has increased while the frequency of extreme cool days and nights has decreased since 1961 (Plummer et al. 1999). An investigation of the trends in temperature indices over Europe has indicated a symmetric warming of the cold and warm tails of the daily minimum and maximum temperature distributions during 1946–1999 (Klein Tank and Können 2003).

The temporal variability of air temperature and precipitation in Europe is known to be largely influenced by variability in the atmospheric circulation (Moberg & Jones, 2005). The relationships are particularly strong in the winter season, where numerous studies have linked changes in the North Atlantic oscillation (NAO) to changes in temperature and precipitation in Europe (Marshall et al., 2001; Hurrell et al., 2003). Hurrell and Folland (2002) discussed a possible link between sea-level pressures (SLP) averaged over the southern action centre for the NAO in summer and precipitation in Europe. They showed that a trend of SLP calculated over 1921–1999 was positive, indicating increased anticyclonic conditions over the period. Considering the extreme temperatures, Unkašević and Tošić (2013) found that the EA pattern dominated the variability of Serbian extreme temperatures during the summer in Serbia. The EA consist of a north–

south dipole of anomaly centres but displaced southeastward with respect to the NAO (Barnston and Livezey, 1987). It is found that when the EA pattern was in the positive phase, the temperatures over Europe and Serbia were above normal (Knežević et al., 2013). In summer, it is found that the relationships are weaker and other factors than circulation also play important roles. Cloud amount, for example, has been found to be strongly correlated with summer temperatures at Stockholm and Uppsala (in Sweden) back to 1780 (Moberg et al., 2003).

Conclusions

In this study, the analysis of warm/dry and warm/wet days using climate indices WD and WW for the period 1950-2009 is presented. The analysis was done for Belgrade and Niš for all seasons (spring, summer, autumn and winter). The following can be concluded:

- The increase of WD days is observed in both cities for all seasons, except in Niš during the autumn;
- The greatest increase is evidenced during the summer with greater value in Belgrade than in Niš;
- The significant trend of the WD indice is recorded during the spring and summer for Belgrade (at the 5% level of significance);
- The number of WW days is small in both cities for all seasons.

Taking into account, it can be concluded that the greatest increase of number of warm/dry and warm/wet days was observed during the summer in Belgrade. The increase of warm/dry days is also obtained by Beniston (2009) analyzing the WD indice for several European cities.

The presented results are just starting point of future work, which will include a link with cloud amount and weather types, depending on the season.

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