A multi-scalar character of droughts based on the SPEI in the Republic of Moldova

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Abstract. This study presents a detailed assessment on drought characteristics in a multi-scalar way based on the Standardized Precipitation Evapotranspiration (SPEI) in the Republic of Moldova. This study combined two SPEI datasets: (1) the global 0.5°gridded the SPEI dataset at time scales between 1 and 48 months from December 1950 to May 2013 over Moldova domain (45.01ºN-49.01ºN; 26.52ºE-30.48ºE) obtained from the SPEIbase and (2) the Chisinau climatological station as a representative station with relatively long continuous series (1945-2011) in the Republic of Moldova. The SPEIbase is based on the FAO-56 Penman-Monteith estimation of potential evapotranspiration from CRU with spatial resolution of 0.5ºlat x 0.5ºlon. The SPEI at climatological station is based on Hargreaves estimation of potential evapotranspiration (the minimum and maximum air temperature and extraterrestrial radiation). For all the time scales of the SPEI calculation during the warm season of the year (April to September), the longest duration and highest severity was occurring during the 1950s, 1960s and 2000s. These periods correspond to highest temperature and lower precipitation anomalies (i.e. more than 2.5°C associated with precipitation anomalies up to 60% below normal).

Key words

SPEIbase, time-scale, summer and winter drought

Introduction

In the last two decades, drought was one of the greatest threats for field crops farmers in the Southern and Eastern Europe. In extreme cases, the effects of drought can lead to serious damages to agricultural sector. Drier conditions and increasing temperatures already observed in many regions of Eastern Europe could lead to lower agricultural production. The Republic of Moldova is among the eastern European countries affected by extreme drought during the last decades (Potop, 2011, Potop et al., 2012a, b). Studies based on various greenhouse gas emission scenarios show that Europe is one of the Earth's most sensitive regions to global warming and the Romania and Moldova are located in a transition region for the pattern of precipitation changes (Boroneat et al., 2011).

The projected changes in summer drought characteristics in Moldova domain based on the Standardized Precipitation Index (SPI) calculated from RegCM simulations (Boroneat et al., 2011, Potop et al., 2011, Potop et al. 2012b) show less frequently dry events for almost all timescales of the SPI series during the mid-century period (2021-2050). By the end of the 21st century (2071-2100) the projections suggest that long-term droughts could become more important than it is observed during the present climate (1961-1990).

During last two decades the heat wave episodes in association with droughts in the Republic of Moldova have increased significantly due to climate variability and extremely hot years (Overcenco and Potop, 2011).

In previous studies (Potop and Soukup, 2009; Potop, 2011) we have extensively analyzed the spatial and temporal evolution of drought events in the Republic of Moldova by comparing the results from the most advanced drought indices which take into account the role of antecedent conditions in quantifying drought severity. In this study, drought was identified in a multi-scalar way using the Standardized Precipitation Evapotranspiration (SPEI) developed by Vicente-Serrano et al. (2010). The SPEI is a site-specific drought indicator of deviations from the average water balance (precipitation minus potential evapotranspiration). One of the weaknesses of the SPEI is that it requires more data than the SPI. Like the SPI, the SPEI has trouble dealing with arid climates where precipitation is near zero (Vicente-Serrano et al., 2012). However, the SPEI includes the role of temperature on drought severity by means of its influence on the atmospheric evaporation demand.

This study presents a detailed assessment on drought variability and its driving factors in the Republic of Moldova during the second half of 20th century and the first decade of the 21st century.

Material and methods

This study presents the evolution of two SPEI datasets: (1) the global 0.5°gridded the SPEI dataset at time scales between 1 and 48 months from December 1950 to May 2013 over Moldova domain (45.01ºN-49.01ºN; 26.52ºE-30.48ºE) obtained from the SPEIbase and (2) the Chisinau climatological station as a representative station with relatively long continuous series (1945-2011) in the Republic of Moldova.

The SPEIbase is based on the FAO-56 Penman-Monteith estimation of potential evapotranspiration from CRU (the Climatic Research Unit of the University of East Anglia) with spatial resolution of 0.5ºlat x 0.5ºlon. A complete description of the data and links to download the files, are provided at http://sac.csic.es/spei. In this study, gridded data of SPEIbase have been downloaded to climatological station coordinates (Figure 1).

The SPEI series at Chisinau station was calculated as follows: i) the parameterization of potential evapotranspiration (PET) based on monthly minimum (Tmin) and maximum air temperature (Tmax) and extraterrestrial radiation; ii) a simple monthly water balance, calculated as the difference between monthly precipitation (P) and potential evapotranspiration (PET) and iii) normalisation of the water balance into a log-logistic probability distribution to obtain the SPEI series at time scales between 1 and 24 months.

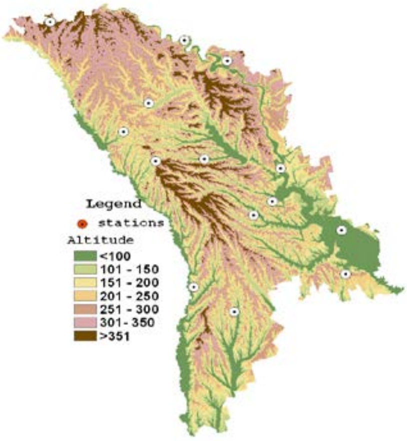

Figure 1. Location of the 15 meteorological stations and their elevation (m a.s.l.) situated in the Republic of Moldova.

Results and discussion

Hovmoller-type diagram provides a visualisation of the spatiotemporal evolution of the 0.5°gridded the SPEIbase series at time scales between 1 and 48 months for the period 1950-2013 over Moldova domain (Figure 2). The large differences between the SPEIbase series and SPEI series at climatological stations did not detected (Figures 2, 4).

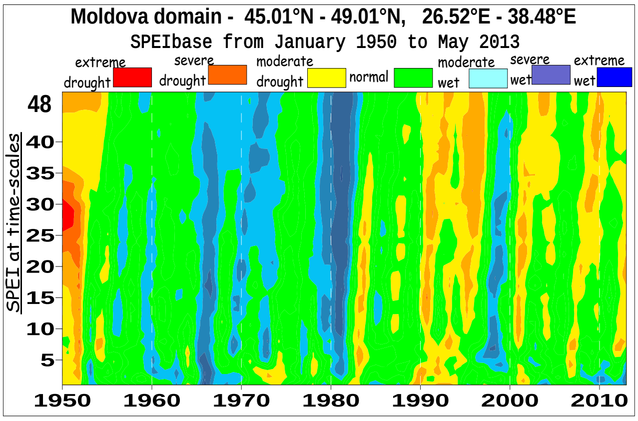

Figure 2. Spatiotemporal evolution of the 0.5°gridded the SPEIbase series at time scales between 1 and 48 months for the period 1950-2013 over Moldova domain (45.01°N-49.01°N; 26.52°E-30.48°E).

For all the time scales of the SPEI calculation during the warm season of the year (April to September), the longest duration and highest severity was identified during in the mid 1940s-1950s, 1960s and 2000s. These periods correspond to the association of the highest temperature and lowest precipitation anomalies (i.e., more than 2.5°C associated with precipitation anomalies up to 60% below normal) (Figure 3). The largest impact on water deficit during the last three decades was found to be mainly due to the increase of maximum temperature (+0.7°C decade^{-1}) and minimum temperature (+0.5°C decade^{-1}) associated with decreased precipitation (20 mm decade^{-1}). The increasing trend of extreme temperatures in the Republic of Moldova has particularly affected Tmin (the highest positive deviation was ranging between 1.5°C to 3.5°C) during warm season of the year and the increasing water deficit in this season.

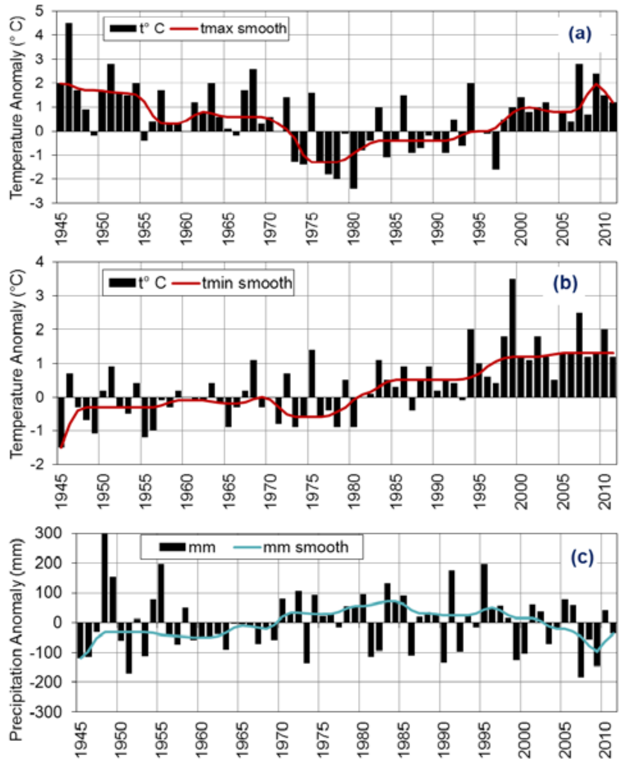

Figure 3. Temporal evolution of air anomalies of maximum temperature (a), minimum temperature (b), and precipitation totals (c) during the warm season of the year from 1945 to 2011. The long-term changes in both temperature and precipitation series were represented by a smoothed filter 5-year seasonal extreme temperatures deviation and precipitation, respectively, from the baseline climate (1961-1990).

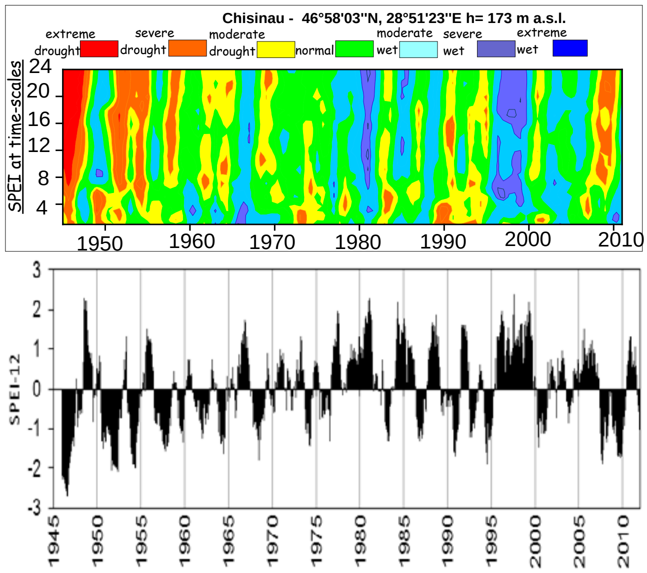

Figure 4. Temporal evolution of the SPEI at time scales from 1 to 24 months (upper panel) and the SPEI at 12-month lag for Chisinau station (bottom panel).

The majority of the hottest and driest summers since 1945 were precede by winter and spring precipitation deficit over Moldova (e.g. 1946, 1953, 2000 and 2007) (Figure 6).

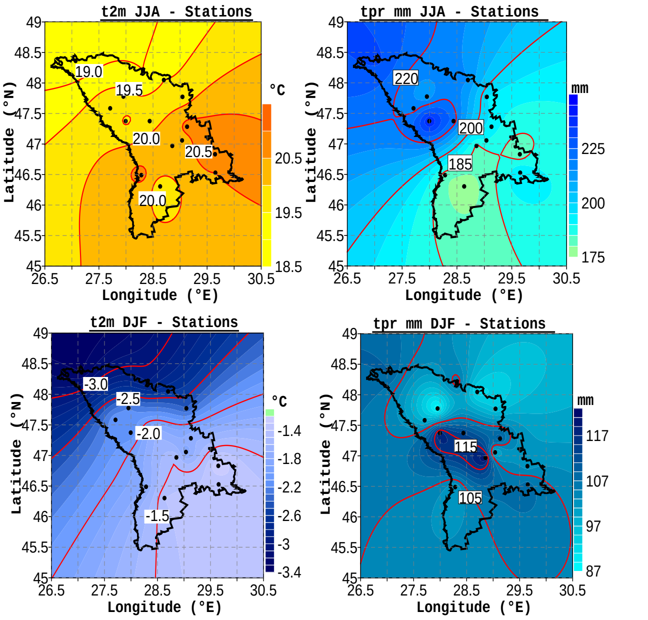

Figure 5. *Summer (JJA) and winter (DJF) temperatures mean and precipitation totals (1960-1997) in the Republic of Moldova.*

The summer and winter mean of air temperatures and total precipitations in the Republic of Moldova was calculated from monthly data from 15 meteorological stations for the period 1961-1997 (Figures 5).

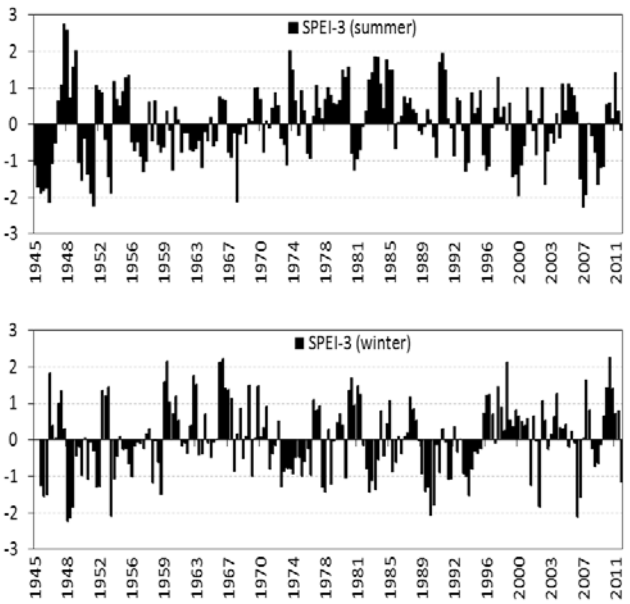

Figure 6. *Evolution of the SPEI at 3-month lag during summer from June of 1945 to August of 2011(upper panel) and during winter from December of 1946 to February of 2011 at Chisinau climatological station (bottom panel).*

The summer mean air temperature ranges between +18.5ºC and +21.0ºC (upper panel of Figure 5). The hottest summer was recorded in 2007 with Tmean ranging 22.0 to 25.0ºC (exceeding the norm with 3.0-4.0ºC). The absolute maximum was reached the value of +41.5ºC (on 21 July 2007 at Kamenka stations, according to Moldova's State Hydrometeorological Service source).

The total precipitation ranging from 235 mm in the north and 175 mm in the south and the lowest was reached the value of 37 mm (Cahul, 1924). The hierarchy of the driest summers according to the SPEI at 3-month lag are as follows: 2007, 1946, 1951, 1968, 2000, 1953, 1951, 1945, 2003 and 2009. The longest dry periods during summer season were 1945-1947, 1950-1951 and 1999-2000 (upper panel of Figure 6). Extreme drought (*SPEI≤-2*) occurs in the summer months when the extreme water balance (D) values come close to -150 mm (e.g. in July of 2007, D = -179 mm, P = 4 mm, Tmean = 25.8°C and Tmax = 32.3°C, PET = 183 mm, whereas SPEI at 3-month lag = -2.3) (Potop et al., 2012a).

The winter air temperatures mean ranges between -1.4 and -3.4ºC (bottom panel of Figure 5*).* The coldest winter was recorded in 1953/1954, with *Tmean* ranging -8.0 to -9.0ºC (6.0-7.0ºC lower than the norm according to Moldova's State Hydrometeorological Service). The warmest winter was recorded in 2006/2007; with *Tmean* ranging +1.0ºC to +3.0ºC (exceeded the norm with 4.0-5.0ºC). The high variability of the air temperature during winter season is one of the climatic particularities of Moldova.

The winter total precipitation was on average 104 mm or 16-20% of the annual amount. The hierarchy of the driest winters according to the SPEI at 3-month lag are as follows: 1948, 1949, 2006, 1953, 1990, 1949, 2002, 1990, 2007, 1946, 1994 and 1959. The longest dry periods during winter season were 1948-1954, 1958-1959, 1977-1978, 1989-1990, 2001-2002 and 2006-2007 (bottom panel of Figure 6).

Conclusions

The salient results are summarized below:

a) Although lack of precipitation is the principal driving factor for drought conditions, the rapidly increasing of minimum temperature in this region could also play a notable role in drought through increasing its severity as a consequence of water loss by evapotranspiration.

b) High summer temperatures are also responsible for the large extent of the drought conditions in summer during the last two decades (e.g., 1994, 2003, 2007 and 2009).

c) Two SPEI data sets and two different method of parametrization of potential evapotranspiration were used to compare ability of gridded SPEIbase to reproduce the spatial and temporal evolution of drought at the territory of the Republic of Moldova.

d) The approach to drought characterisation based on the global 0.5°gridded SPEIbase calculated for various accumulation periods provides comprehensive results on the complexity of drought phenomena in the Republic of Moldova.
e) The 0.5°gridded SPEIbase is also suitable for the detection, monitoring, and assessment of drought conditions at the regional scale.

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