International Baltic Earth Secretariat Publication No. 12, March 2018

MedCORDEX-Baltic Earth-COST Workshop

Regional Climate System Modelling for the European Sea Regions

Universitat de les Illes Baleares, Palma de Mallorca, Spain
14 - 16 March 2018

Programme, Abstracts, Participants

Med CORDEX

Baltic Earth
Earth System Science for the Baltic Sea Region

Future droughts in Southern Ukraine – reasons and possible consequences for water resources and agriculture

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1. Introduction

The frequency and severity of droughts in Ukraine has considerably increased since 1980s. This feature is especially pronounced in the southern regions of Ukraine, which are the areas with intensive agriculture but mainly have not irrigation systems. Preliminary analysis has showed (Khokhlov and Yermolenko, 2014) that the Southern Ukraine is the region with considerably increasing number of droughts. As the temperature will most probably rise in further it is reasonable to consider what peculiarities of future droughts in Ukraine we can expect.

2. Methodology

We used the standardized precipitation evapotranspiration index (SPEI) to investigate spatiotemporal droughts variability caused by the climate change. The SPEI is the multi-scalar drought index and allows determining the onset, duration and severity of drought conditions on different time scales. It is common practice to assess the meteorological droughts on the time scale 1–2 months, agricultural ones – 3–12 months, and hydrological ones – 13–24 months. The monthly SPEIs were calculated using the data on the temperature and precipitation. The two periods – nearest-past 1981–2010 and nearest-future 2011–2040 – were used to reveal a climate change impact. The index for the first period was calculated using the 0.5 degree grid reanalysis data. The future conditions were estimated using the outcomes from the CORDEX Project – the 14 runs of 5 regional climate models (RCM). For the latter period, the SPEIs were calculated for each RCM and then were averaged to obtain a single ensemble-mean value.

The mean value and standard deviation of the SPEI are 0 and 1, respectively. This index is the standardized value and can be compared with similar values in other sites and for other time periods. The table shows the drought category for the valued of the SPEI:

SPEI values	Drought category
0 to −0.99	mild drought
−1.0 to −1.49	moderate drought
−1.5 to −1.99	severe drought
≤ −2.0	extreme drought

3. Future Temperature and Precipitation

In Figure 1, the box plots visualize min/max, 25/75-percentile, median and mean (dots) by the 14 runs of RCMs. It shows rising temperature (about 0.8 °C per 30 years) and precipitation (about 40 mm per 30 years) during the 2021-2050 in the Southern Ukraine. Let's note that precipitation will usually decrease in Ukraine and southern region is rather exception to the rule. In this Figure, we can see (i) changeable increase of temperature and sharp decrease of precipitation during the 2023-26; (ii) sharp increase of temperature following decrease of precipitation during the 2028-31; and (iii) sharp decrease of temperature against the steady precipitation background during the 2037-40.

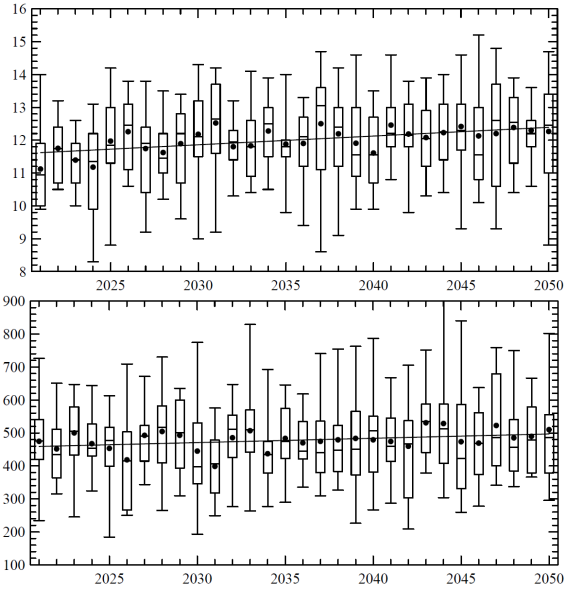

Figure 1. Annual mean temperature (°C; upper panel) and total precipitation (mm; lower panel) in Odessa estimated using the outcomes from the CORDEX Project

4. Future Droughts in Southern Ukraine

The analysis of nearest-future SPEI time series showed (Fig. 2) that the trend to drier conditions will be expected for whole Ukraine, and this trend will be remarkable for its southern part. It is noteworthy that the model ensemble reveals the drought in 2014–16, especially pronounced in Southern and Eastern Ukraine, i.e. the current drought; this result is rather surprising. The next long and severe droughts can be registered about 2025 and after 2030. Moreover, we can expect in all likelihood that the period 2031-2040 will be driest, and duration of drought in Southern Ukraine will be a few year.

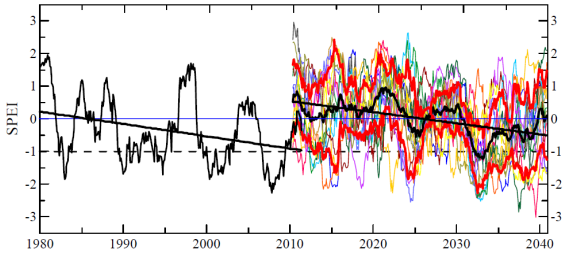

Figure 2. SPEI24 in Odessa estimated using reanalysis data and outcomes from the CORDEX Project

Considering Figs. 1 and 2, the drought of 2025 will develop by reason of decreasing precipitation, the prolonged drought starting from 2035 will arise from joint impact of high temperature and low precipitation. Also, the latter drought will terminate due to decreasing temperature.

5. Consequences for Water Resources

We also considered a connection between time series of SPEI24, i.e. the SPEI on the 24-month time scale, and annual runoff on a few hydrological sites in the drainage basin of Southern Buh – the river is sourcing in Western Ukraine and flowing into the Black Sea. As a result we can note that the SPEI24 can explain high and low water discharge on the annual time scale (Fig. 3).

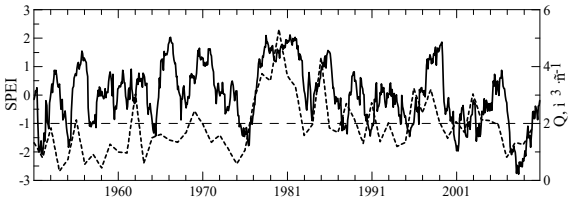

Figure 3. SPEI24 vs. annual mean water discharge (dotted line) in Katerynka gauge site (the Southern Buh River) from 1951 to 2010.

In the past, the strong positive trend exists up to the end of 1970th in the water flows for all sites, and the strong trend with opposite sign was registered from the end of 1970th up to the now. Also, the temporal features of water flow changes are in close agreement with the SPEI24 during the first 30-year period – all years with high water flows were registered during the wet years, i.e. the absence of atmospheric droughts. For example, the droughts were not registered during five years resulting in the maximal water flow in the 1980. During the second 30-year period, the minimal annual water flows and the atmospheric droughts coincided not always. This fact can be explained by intensive water-management activities at the Southern Buh catchment during the last years.

6. Conclusion

Our results show that a vulnerability of different community in Southern Ukraine to the droughts in the nearest future will be rather high (Pietrapertosa et al., 2018). This hazard will impact both the water-management and agricultural sector (Yermolenko and Khokhlov, 2014). The future droughts together with the undeveloped irrigation system will result in negative effect on the cereals, the main crop in Ukraine.

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