Detecting signals of ecological drought events in Poland during the last decades

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ABSTRACT

1. Motivation

The water resources in Poland are characterized by high seasonal variability and uneven spatial distribution. They are the basis for economic functioning and development. The "green water" is an important element of water resources defined as water stored in the unsaturated soil layer. It is used by plants contributing to the evapotranspiration flux in the hydrologic cycle. Recent observations reveal a widespread soil moisture drying across Europe which concerns also Poland. Considering the growing recognition that adaptation to changing conditions in the Anthropocene is required, there is a need to identify recent severe and extreme drought events. Recently introduced concept of ecological drought emphases the importance of the effects that drought has on ecosystems (Crausbay et al., 2017). When trying to capture the signals of ecological drought propagation, several soil moisture and vegetation indices are used to reveal the deficiency of water available for plants. The approach taken here was to detect the occurrence of widespread ecological drought events in Poland as a consequence of substantial deficit in precipitation during the summer season.

2. Data and methods

Here, using the dataset produced by the GLEAM (Global Land Evaporation Amsterdam Model) version 3.3b, the impact of precipitation deficit on ecological drought occurrence in Poland is investigated. The GLEAM provides surface and root-zone soil moisture, potential evaporation and evaporative stress conditions (Martens et al., 2017; Miralles et al., 2011), approximately spanning the 16-year period 2003–2018. Two indices of water stress in plants are applied, namely the Soil Moisture Index, SMI (Hunt et al., 2009), and the Evaporative Stress Index, ESI (Anderson et al., 2011). By design, SMI represents the normalized soil moisture between maximum and minimum values, and then scaled between –5 and 5. Moderate, severe, extreme and exceptional drought conditions occur when SMI is within the range –2 to < –1, –3 to < –2, –4 to < –3, and –5 or less, respectively. By definition, ESI reflects the anomaly of actual evapotranspiration to potential evapotranspiration ratio. In this case, drought is classified as moderate, severe, extreme and exceptional when ESI lies between 11-20th, 6-10th, 3-5th and 0-2nd percentile, respectively (McEvoy et al., 2016).

Distinct ecological drought events are identified across two large river basins in Poland, namely the Vistula and Oder River basins. In order to enhance the sequence of dry years, the data are smoothed over a 2-year moving window using the tool MASH, introduced by Anghileri et al. (2014). Annual precipitation anomalies, organized in water years, are derived from monthly data provided by ERA5 (2017).

3. Results and conclusions

Negative precipitation anomalies were detected in the years 2003, 2004, 2005, 2015 and 2018 (Table 1). Consequently, distinct ecological drought events have occurred in these years. The propagation of drought

Table 1. Precipitation anomalies in selected water years over the Oder and Vistula River basins derived from ERA5 (2017)

Year	Precipitation Oder (mm)	Anomaly Oder (mm)	Relative Precipitation Oder (%)	Precipitation Vistula (mm)	Anomaly Vistula (mm)	Relative Precipitation Vistula (%)
2003	523	-190	70	619	-132	82
2004	628	-85	84	730	-21	97
2005	674	-39	90	666	-85	89
2015	544	-169	72	603	-149	80
2018	611	-102	81	688	-63	92
(2003-2018)	713			751		

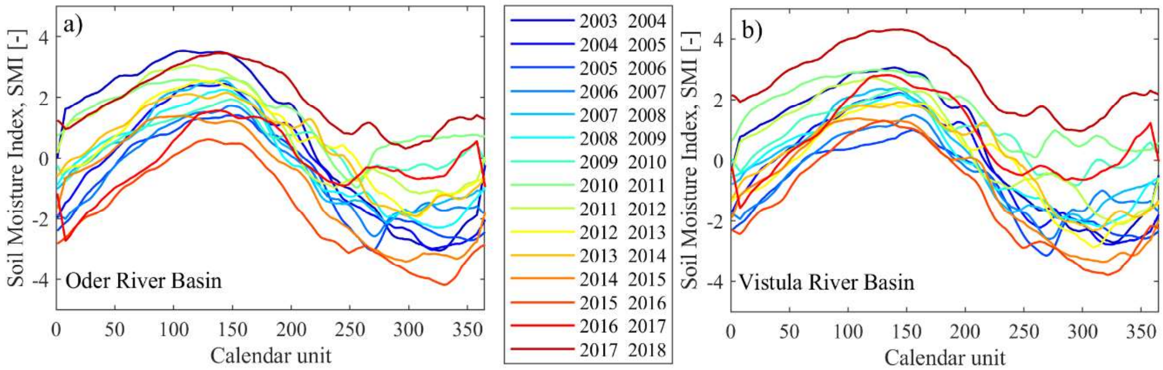

Fig. 1. MASH results for SMI time series across the river basins of Oder (a) and Vistula (b)

through the hydrological system took place not only in separated years, but also it was marked in consecutive years (Fig. 1). Extremely dry conditions occurred in late September/October in 2014-2016, as well as in 2003-2006. Time series of ESI for the water years 2003-2018 give similar picture (Fig. 2).

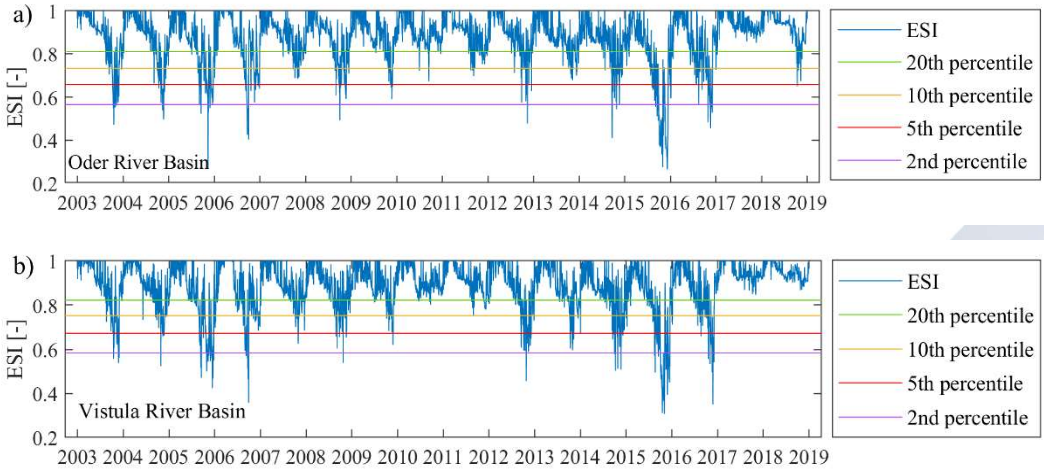

Fig. 2. Time series of ESI across the river basins of Oder (a) and Vistula (b) for the water years 2003-2018

In general, the indicators provided similar interannual and seasonal patterns. Seasonal cycle comprises the recharge of soil water storage in months October-February/March and depletion in April to September. The most extreme droughts occur in late summer/early fall. The GLEAM dataset provides the valuable alternative to sparse ground data.

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References

Anderson MC, Hain C, Wardlow B, Pimstein A, Mecikalski JR, Kustas WP (2011) Evaluation of drought indices based on Thermal remote sensing of evapotranspiration over the continental United States, Journal of Climate, 24, 2025–2044, doi:10.1175/2010JCLI3812.1

Anghileri D, Pianosi F, Soncini-Sessa R (2014) Trend detection in seasonal data: from hydrology to water resources, Journal of Hydrology, 511, 171–179, doi: 10.1016/j.jhydrol.2014.01.022

Crausbay SD, Ramirez AR, Carter SL, Cross MS, Hall KR, Bathke DJ, Betancourt JL, Colt S, Cravens AE, Dalton MS, Dunham JB, Hay LE, Hayes MJ, McEvoy J, McNutt CA, Moritz MA, Nislow KH, Raheem N, Sanford T (2017) Defining ecological drought for the twenty-first century, Bulletin of the American Meteorological Society, 98, 2543–2550, doi:10.1175/BAMS-D-16-0292.1

ERA5 (2017) Fifth generation of ECMWF atmospheric reanalyses of the global climate, Copernicus Climate Change Service Climate Data Store (CDS), accessed 15.09.2019, https://cds.climate.copernicus.eu/cdsapp#!/home

Martens B, Miralles DG, Lievens H, van der Schalie R, de Jeu RAM, Fernández-Prieto D, Beck HE, Dorigo WA, Verhoest NEC (2017) GLEAM v3: satellite-based land evaporation and root-zone soil moisture, Geoscientific Model Development, 10, 1903–1925, doi:10.5194/gmd-10-1903-2017

McEvoy DJ, Huntington JL, Hobbins MT, Wood A, Morton C, Anderson M, Hain C (2016), The evaporative demand drought index. Part II: CONUS-wide assessment against common drought indicators, Journal of Hydrometeorology, 17, 1763–1779, doi:10.1175/JHM-D-15-0122.1

Miralles DG, Holmes TRH, de Jeu RAM, Gash JH, Meesters AGCA, Dolman AJ (2011) Global land-surface evaporation estimated from satellite-based observations, Hydrology and Earth System Sciences, 15, 453–469, doi: 10.5194/hess-15-453-2011