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THE OPERATIONAL DROUGHT HAZARD ASSESSMENT SCHEME – PERFORMANCE AND PRELIMINARY RESULTS

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Abstract: Predicted climate change may have negative impact on many environmental components including vegetation by increase of evapotranspiration and reduction of available water resources. Moreover, a growing global population and extensive use of water for irrigation and industry result in increasing demand for water. Facing these threats, quantitative and qualitative protection of water resources requires development of tools for drought assessment and prediction to support effective decision making and mitigate the impacts of droughts. Therefore, the Institute of Meteorology and Water Management, National Research Institute has developed and implemented a set of tools for the operational drought hazard assessment. The developed tools cover drought indices estimation, assessment of sensitivity to it formation and drought hazard prediction. They are streamlined into an operational scheme combined with data assimilation routines and products generation procedures.

A drought hazard assessment scheme was designed to be implemented into the platform of a hydrological system supporting the operational work of hydrological forecast offices. The scheme was launched to run operationally for the selected catchments of the Odra River and the Wisla River basins. The crucial resulting products are presented on the website operated by IMWM-NRI: POSUCH@ (Operational System for Providing Drought Prediction and Characteristics) (http://posucha.imgw.pl/). The paper presents the scheme and preliminary results obtained for the drought event which began in August 2011.

INTRODUCTION

Climate change may have negative impact on many environmental components including vegetation by increase of evapotranspiration and reduction of available water resources. Moreover, a growing global population and extensive use of water for irrigation and industry result in increasing demand for water. Facing these threats, quantitative and qualitative protection of water resources requires development of tools for drought assessment and prediction to support effective decision making and mitigate the impacts of droughts.

A drought starts with a lack of precipitation over a large area which lasts for a longer period of time. It forms the first phase of a drought – meteorological drought. Further shortage of precipitation leads to a water deficit which propagates through the subsurface part of the hydrological cycle causing a soil drought and finally a reduction in groundwater recharge evolving into a hydrological drought. This phase causes a decrease in groundwater heads, groundwater discharges as well as leads to a streamflow decline [2, 6]. Therefore, a drought can be defined as a sustained and regionally extensive occurrence of a below average natural water availability, and can be characterized as a deviation from normal conditions [12]. According to this definition, a drought is considered to commence whenever observations indicate that current conditions fall below the long-term average for the particular time of the year. Therefore, the actual hydrological and meteorological conditions ought to be interpreted with regard to historical long-term observations. This approach is possible while characterizing droughts through relevant drought indices. Drought indices can be estimated for a different spatial and temporal scale, from regional to global applications and in relation to various impacts such as agriculture, water management or economy. Some indices are only based on one factor, i.e. precipitation for meteorological drought, soil moisture for agriculture drought or discharges or groundwater levels for hydrological drought assessment. Some are far more elaborated and use information on temperature, evapotranspiration, soil moisture, snow-cover, surface water and groundwater supplies. It is hard to find a unique drought index ideal for all regions or tasks. Therefore, it is useful to estimate multiple drought indices, complement to each other and suitable for different research or management objectives. The decision to apply the particular indicator usually depends on the aim of the application, ability to reproduce spatial and temporal features of the occurrence of drought as well as on the availability of the data required for its calculation and computation of the time regime. The latter is very crucial for operational applications [13]. Drought indicators also meet demands of novel modelling technology required for integrated management of risks related to the natural catastrophes by demonstrating such features as credibility, transparency, replicability of results, controllability, quality assurance, documentation, sharing of the results [7].

The Institute of Meteorology and Water Management – National Research Institute (IMWM-NRI) is a part of Polish national water management structure which is responsible for hydro-meteorological protection. One of the statutory tasks of the IMWM-NRI, imposed by Water Law, is a preparation and dissemination of forecasts and warnings for general public, national economy and state defense on hazardous hydro-meteorological situations. The Institute provides the users of the water management system with current information on the state of the atmosphere and the hydrosphere, forecasts and warnings both in normal as well as in emergency weather and water related situations. Consistent and timely information on drought situation is crucial for water management system, national and regional economy and the public. Therefore, the main objective of the developed system was to create a comprehensive, multipurpose application for drought hazard assessment supporting the operational work of hydrological forecasts offices. Operational drought hazard assessment scheme covers the key aspects for drought phenomena study: meteorological and hydrological drought detection, analysis of drought intensity, duration and extension as well as assessment of sensitivity to drought and drought hazard prediction. The structure of the scheme of the drought hazard assessment consists of analytical components aimed to tackle these tasks, data assimilation and flow routines and generation procedures of final products. The developed scheme was launched to run operationally for the selected catchments of the Odra River and the Wisla River basins and crucial resulting products are presented on the website operated by IMWM-NRI: **POSUCH@ (Operational System for Providing Drought Prediction and Characteristics)** (http://posucha.imgw.pl/).

The elaborated system aims to play a complementary role for the two existing systems: (i) *The Drought Monitoring System for Poland* (ADMS) that is provided by the Institute of Soil Science and Plant Cultivation – State Research Institute (IUNG-PIB) on behalf of the Ministry of Agriculture and Rural Development and (ii) *System of drought monitoring in Kujawy and the upper Notec Valley* [4]. Both systems are primary dedicated agriculture drought analysis and prediction to support decision making and activity planning in crop production, irrigation scheduling and estimation of yield losses. The new system developed by IMWM-NRI is distinctive to these two by appliance daily time step for drought hazard assessment as well as by providing combined information on meteorological and hydrological drought phases.

The paper presents rationale for the selection of a given set of indices used in drought hazard assessment procedures, architecture of the developed scheme and preliminary results of its operational application which are presented on the web-site with the results from the performance of the system during very recent drought event which started in August 2011.

REQUIREMENTS FOR OPERATIONAL APPLICATION

The aim of the application puts the following constrains on the developed scheme:

(a) apply methods which use standard meteorological and hydrological parameters measured within a hydrometeorological monitoring network operated by IMWM-NRI (database requirements),

(b) be incorporated into existing hardware and software infrastructure and run operationally (functional requirements),

(c) meet the expectations of the end users of hydrological forecasting offices: institutions responsible for water management, water users, crisis management centres and society (end-user requirements).

Operational application requires developing multipurpose software for drought hazard assessment which enables to run analysis and provide results in real time. In order to facilitate the work of hydrological forecast office it was beneficial to incorporate the drought indices estimations and analysis routines into the System of Hydrology (SH) which is operated at IMWM-NRI within the framework of SMOK system (the Hydrological and Meteorological Monitoring, Forecasting and Protection System). SH is a software platform aimed at data harmonization and management, data analysis and visualization, effective hydrological modeling, multi-task applications and product generation. The specific requirements for each analytical component of the developed software package for drought hazard assessment were determined by the data availability, functional objectives and requirements of end-users [14].

Database requirements

The measurements of meteorological and hydrological conditions are available within the monitoring network operated by IMWM-NRI. The data are being archived in Central Historical Database (CBDH) which consists of climatological historical database and hydrological historical database covering the period since 1951. Climatological database contains information from 350 meteorological stations and 1680 precipitation stations (with daily data from 333 stations) while hydrological historical database contains data from 900 gauge stations with records of daily discharges from around 30% of the stations. Operational data are obtained from the network of meteorological and hydrological stations supplied with telemetry facility. Meteorological and water gauge stations provide information on air temperature and humidity, wind speed and direction, precipitation and water level. These data are collected every 10 minutes, transmitted automatically and are operationally available in the SH.

In order to analyze the current meteorological and hydrological conditions in relation to their long-term meteorological and hydrological characteristics, a consistent set of meteorological and hydrological stations having both homogenous long-term daily data as well as telemetry facility had to be selected. The reference period required to estimate drought indices was set to 1966–2005. A compilation of these requirements resulted in selection of 69 gauge stations and 195 precipitation stations for 25 study basins located all over the territory of Poland (Fig. 1). The selected study basins differ in terms of climatological conditions and river regimes due to geographical location, dominant atmospheric circulation pattern as well as altitude above sea level and surface features.

Functional requirements

A review of the existing and commonly applied methods for drought assessment was performed in order to identify a set of them adjusted to the availability of the required data, facility to be defined as operational, analytical routines and ability to characterize required drought features and indicate drought hazard. The detailed functional requirements embodied (i) detection of various stages of drought including meteorological and

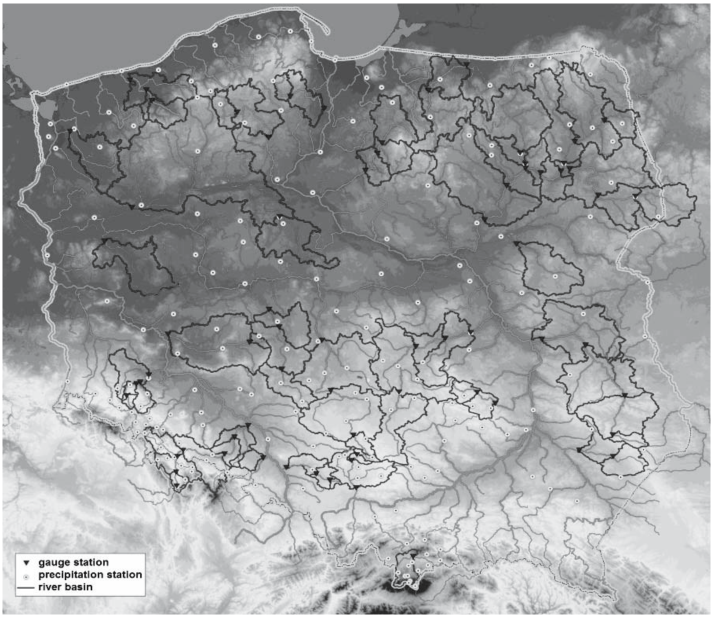


Fig. 1. Location of the selected precipitation (a) and water gauge (b) stations and river basins

hydrological drought identification, (ii) tracing temporal variability of drought up to daily time step, (iii) mapping spatial distribution of a drought, (iv) providing a standardized and dimensionless measure of drought intensity, (v) giving information on sensitivity to drought formation.

End-users communications

The form and the content of information provided within the framework of drought hazard assessment scheme is tuned to the standard groups of products generated by SH platform and conveyed to end-users of the IMWM-NRI's hydrological forecast office. Table 1 specifies the application for each of the group of products, information on drought to be obtained from a scheme of drought hazard assessment and end-users acknowledged to access this information.

Table 1. Groups of products and end-user's specification of drought hazard assessment scheme

group of products	specification of relevance	information on drought	end-user
Reports	historical and statistical reports for meteorological and hydrological yearbooks, research and development	evaluations and analysis of multi-criteria historical droughts	researchers, experienced and eligible customers
Maps & Graphs	visualization of data and results: multilayer GIS maps, temporal variability plots, presentations of web-site	values of drought indices plotted over the region at different administrative and physiographic resolution	public and society
Warnings	elaboration and distribution of forecasts, preparation of hydrological messages and issue of warnings	drought hazard communications and warnings	professional users, forecasters

DROUGHT HAZARD ASSESSMENT SCHEME

Considering data availability, functional objectives and end-users requirements, a scheme of drought hazard assessment includes the following analytical components: (i) estimation of meteorological and hydrological drought indices, (ii) evaluation of sensitivity to drought, (iii) drought hazard assessment, (iv) generation of products. The concept of operational drought hazard assessment scheme is being developed in the form of computational applications, procedures defining input and output data flow, data acquisition and dissemination routines of products.

Drought indices estimation

Drought indices are widely used for drought monitoring, assessment and prediction, drought early warning. Drought indices constitute useful decision-making information for policy-makers in water management. Their practical implementation allows for detection of various stages of drought including meteorological and hydrological drought identification, providing a standardized and dimensionless measure of drought intensity which is comparable for different climatological regions, tracing temporal variability of drought up to daily time step and mapping the spatial distribution of drought. A set of four drought indices was selected to be used for the scheme of a drought hazard assessment. These are:

(i) The **EDI** (**Effective Drought Index**) [1] is a measure of precipitation needed for a return to normal conditions. It is calculated with a daily time step. First step is a calculation of weighted precipitation accumulation over a defined preceding period (EP). In the study, this period is set on 365 days corresponding to duration of a hydrological year in Poland. The concept of the EDI is a standardized daily difference between EP and the climatological mean of EP (MEP) for each calendar day. EDI values are standardized, which allows for comparing drought severity at different locations regardless of climatic differences among them.

(ii) The **SPI** (**Standardized Precipitation Index**) [8] is based on a long-term precipitation record at a station fitted to a probability (gamma) distribution, which is then transformed into a normal distribution so that the mean SPI is zero. In the study, SPI is computed with 1 month time step [11]. Similar to EDI values SPI values are standardized representing deviations of the transformed precipitation totals from the mean.

(iii) The **FDC (Flow Duration Curve)** [15] represents the empirical cumulative frequency of discharges as a function of the percentage of time which the discharge value is exceeded. FDCs are constructed for each calendar day basing on long-term discharge data. Each FCD is divided into 5 classes which correspond to the humidity conditions.

(iv) The **Standardized Runoff Index** (SRI) [10] is assessed similarly to the SPI. It is used to classify hydrological drought. SRI is the unit standard normal deviate associated with the percentile of hydrologic runoff characterizing selected period of time. Computation of the SRI involves fitting a probability density function (PDF) to a given frequency distribution of monthly runoff for a gauge station. This cumulative probability is then transformed to the standardized normal distribution with mean zero and variance one, which results in the value of the SRI.

Evaluation of sensitivity to drought

In Poland, drought formation is usually observed in spring and summer period and it is associated with the high air pressure and air temperature exceeding normal values [3]. This results in increase of both the value of evapotranspiration and demand for water [2]. Therefore, the sensitivity to drought formation shows regional disparities which are mainly related to the climatic conditions (precipitation and temperature) and geomorphological features of the given basin.

Operational drought hazard assessment was preceded with the analysis of long term data in order to identify the sensitivity to drought for a particular river basin. Sensitivity to drought was evaluated in terms of two major factors triggering droughts: precipitation (climatological sensitivity) and characteristics of a discharge (streamflow sensitivity).

Climatological sensitivity was evaluated from the long-term time series (1966–2005) of monthly SPI values in selected meteorological stations. The performed analysis included development of Markovian models according to the method presented by Paulo et al. [9]. A non-homogenous Markov chain was formulated to estimate the probabilities of drought/wet states which depended on the considered month. Drought/wet states were defined according to a scale modified and adopted to Polish conditions namely the scale of SPI values by Łabędzki et al. [5]. On the basis of 7 defined classes, a drought severity is defined as a moderate drought (-0.50 to -1.49), a severe drought (-1.50 to -1.99) and an extreme drought (< -2.00). For the aim of the assessment of meteorological drought's sensitivity, this scale was compressed to three conditions: wet (SPI>0.50), normal (-0.49<SPI<0.49) and dry (SPI<-0.50). The sensitivity to drought is evaluated from transition matrix with monthly time step pending on the conditions observed in the previous month. The actual proneness to drought of a region is reflected in the probability for dry conditions and varies from month to month and from station to station.

In the same manner, the stream flow's sensitivity was estimated on the basis of the values of SRI. The adopted SRI classes were following SPI classes and hydrological drought severity levels are defined as follows: a moderate drought (-0.50 to -1.49), a severe drought (-1.50 to -1.99) and an extreme drought (< -2.00). Consequently, three types of conditions were set as a wet (SRI>0.50), normal (-0.49<SRI<0.49) and dry one (SRI<=-0.50).

Drought hazard prediction

Prediction of a drought hazard is performed twofold, as a short-term drought hazard prediction and a long-term drought hazard prediction.

A short-term prediction is based on daily time step for the need to issue warnings in case of a detection of a severe drought. Time series of EDI and FDC values calculated from daily precipitation and discharge observations are extrapolated for the next 3 days on the basis of precipitation and discharge forecasts provided by a hydrological forecast office.

A long-term drought hazard prediction is done with the use of the results obtained from a sensitivity to drought analysis. After each month, the prediction in the form of values of probability for dry, normal or wet meteorological and hydrological conditions for the next month is prepared pending on the conditions observed in a previous month.

Generation of products

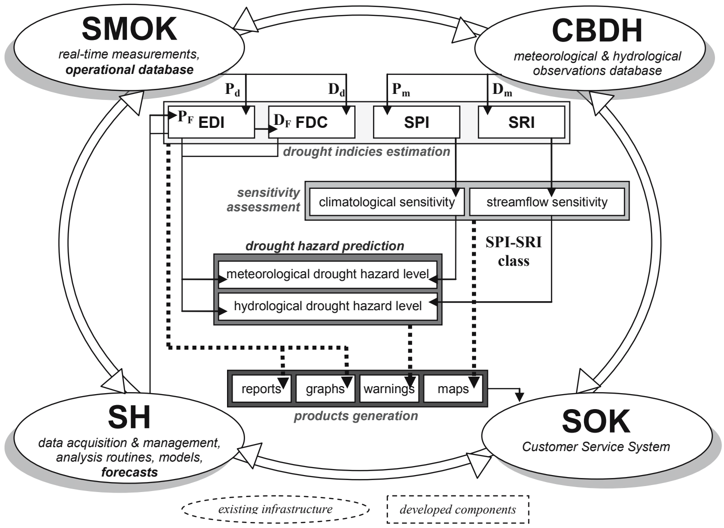
Comprehensive analysis of values of selected drought indices coupled with long-term data studies and short-term precipitation and discharge forecasts consists of the scheme of drought hazard assessment. Fig. 2 summarizes a combined scheme of operational drought hazard assessment with the interactions among existing infrastructure and developed components, communication chart and specification of the transmitted information. The indices developed within the framework of the scheme are appointed for the following applications:

(a) EDI (Effective Drought Index) – meteorological drought detection, intensity and duration analysis, temporal variability presentations, hazard evaluation;

(b) SPI (Standardized Precipitation Index) – mapping spatial distribution of meteorological drought, infer on regional sensitivity to drought;

(c) FDC (Flow Duration Curve) – hydrological drought detection, intensity and duration analysis, temporal variability presentations, hazard evaluation;

(d) SRI (Standardized Runoff Index) – mapping spatial distribution of hydrological drought, infer on regional sensitivity to drought.



$\mathbf{P_d}$ – daily precipitation, $\mathbf{P_m}$ – monthly precipitation, $\mathbf{P_F}$ – precipitation forecast
$\mathbf{D_d}$ – daily discharges, $\mathbf{D_m}$ – monthly precipitation, $\mathbf{D_F}$ – discharge forecast

Fig. 2. Concept of operational drought hazard assessment scheme

RESULTS

Crucial results obtained with the use of the operational drought hazard assessment scheme are presented on the website: http://posucha.imgw.pl/. This web-site has a public access and it is intended to provide information on drought prediction and its characteristics. It consists of three basic components: reports on historical droughts, current state of moisture conditions and drought characteristics, and finally a component of drought hazard prediction. The last two components include interactive links enabling selection of the location for which the required information is to be presented.

Current state of moisture conditions

The area of application of the operational drought hazard assessment scheme is presented in the form of maps showing locations of the selected meteorological and hydrological stations. Each location of a site on the map of meteorological stations is an interactive link which opens the figure presenting temporal variation from the last 16 weeks of daily EDI indices. The plots are useful for analyzing the current state of atmospheric moisture, detecting meteorological drought, evaluating its intensity and duration as well as tracing the temporal variability of surplus or deficit precipitation. Fig. 3 presents the pattern of EDI values developed operationally for the selected location (Bolkow) in the Middle Odra River basin from the beginning of September till the end of December 2011.

In the same manner, each location of a site on the map of hydrological stations is an interactive link which opens the Flow Duration Curves (FCD) representing 5 classes of probability of exeedence for streamflow values developed for each calendar day. Superimposing on the FCD plots the actually measured values of streamflow assimilated

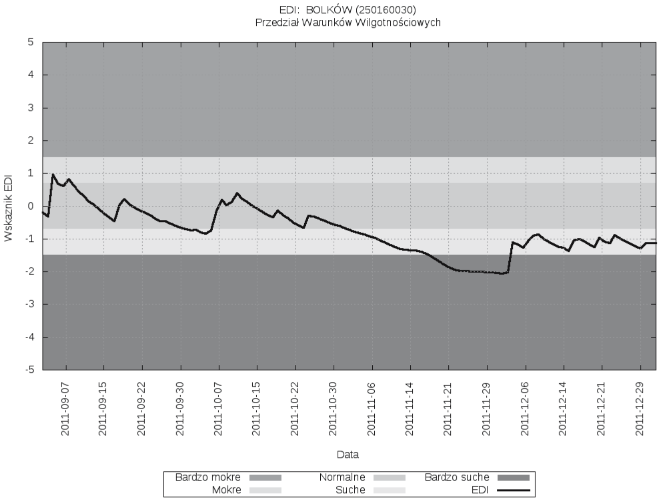


Fig. 3. Time series of EDI values from 04/09/2011 to 03/01/2012 for Bolkow meteorological station. Color codes of conditions: dark blue – very wet, blue – wet, grey – normal, yellow – dry, orange – very dry

operationally to the scheme, it is possible to interpret the current hydrological conditions. This is useful for detecting a hydrological drought, assessing its intensity and duration as well as visualizing its temporal variation. Fig. 4 presents the pattern of FDC values developed for the selected location (Bystrzyca Klodzka) from the end of September 2010 to the beginning of January 2012.

On the web-site, the spatial distribution of the meteorological drought severity is presented with the use of SPI values developed on a monthly basis. The spatial distribution is generated for each month and it is helpful to assess the spatial extension of meteorological drought and its severity. The classes of the meteorological drought divide severity into 3 classes : a moderate dry, very dry or extremely dry. Fig. 5 presents the spatial distribution of SPI values for the territory of Poland in October 2011.

Drought hazard prediction

A stochastic analysis of long-term values of SPI and SRI indicators were used to construct the transition probability matrix which is applied for a long-term drought hazard prediction. For each location, after the end of a month, the probability of moving to wet, normal or dry conditions in the next month is evaluated. The probability is conditioned by the state of the previous month. In Poland, a drought formation is usually observed in a warm period. In a cold season, other factors like a snow cover have impact on the hydrological cycle. In the case of low flows it may not be fully informative for a drought hazard assessment. Therefore, a long-term drought hazard prediction is restricted to the period from May to October. Fig. 6 presents the form of drought hazard communication with the window for the selection of the looked-for station and values of the probabilities to reach dry, normal or wet conditions in the next month. This prediction is done at the beginning of each month.

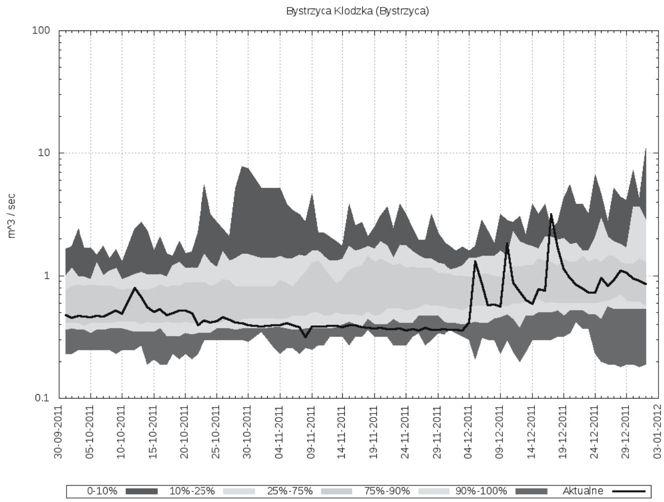


Fig. 4. Time series of FDC plots from 30/09/2011 to 03/01/2012 for Bystrzyca Klodzka gauge at the Nysa Klodzka river (the Odra River basin). Color codes of conditions: dark blue – very wet, blue – wet, grey – normal, yellow – dry, orange – very dry

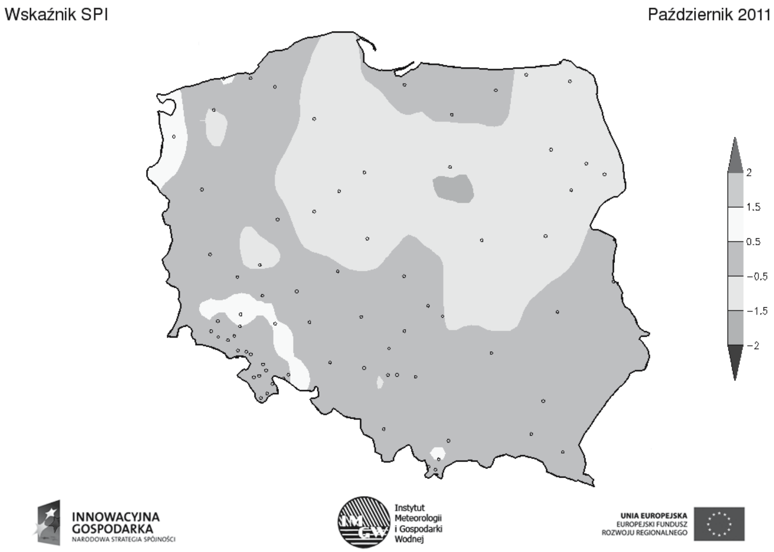
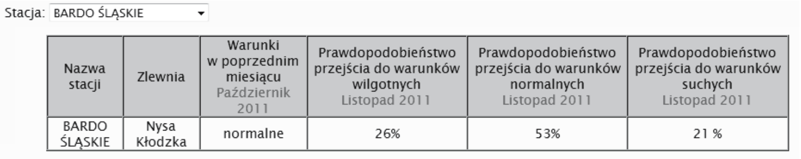


Fig. 5. Spatial distribution of SPI classes for October 2011. Color codes of conditions: dark blue – very wet, blue – wet, light blue – moderate wet, green – normal, yellow – moderate dry, orange – very dry, red – extremely dry

The short-term forecast of meteorological drought hazard is done with the use of EDI values. Time series of EDI values are extrapolated for the next 3 days basing on the information on predicted daily precipitation totals from a numerical weather prediction model Locally Model COSMO. The forecast is updated on a daily basis (Fig. 7).



Stacja: BARDO ŚLĄSKIE

Nazwa stacji	Zlewnia	Warunki w poprzednim miesiącu Październik 2011	Prawdopodobieństwo przejścia do warunków wilgotnych Listopad 2011	Prawdopodobieństwo przejścia do warunków normalnych Listopad 2011	Prawdopodobieństwo przejścia do warunków suchych Listopad 2011
BARDO ŚLĄSKIE	Nysa Kłodzka	normalne	26%	53%	21 %

Fig. 6. Example of drought hazard prediction for November 2011 done for the Bardo Slaskie location performed at the end of October 2011. Description of columns: 1 – name of the station, 2 – name of the basin, 3 – conditions recognized for the previous month, 4 – probability to move to wet conditions, 5 – probability to move to normal conditions, 6 – probability to move to dry conditions in next month

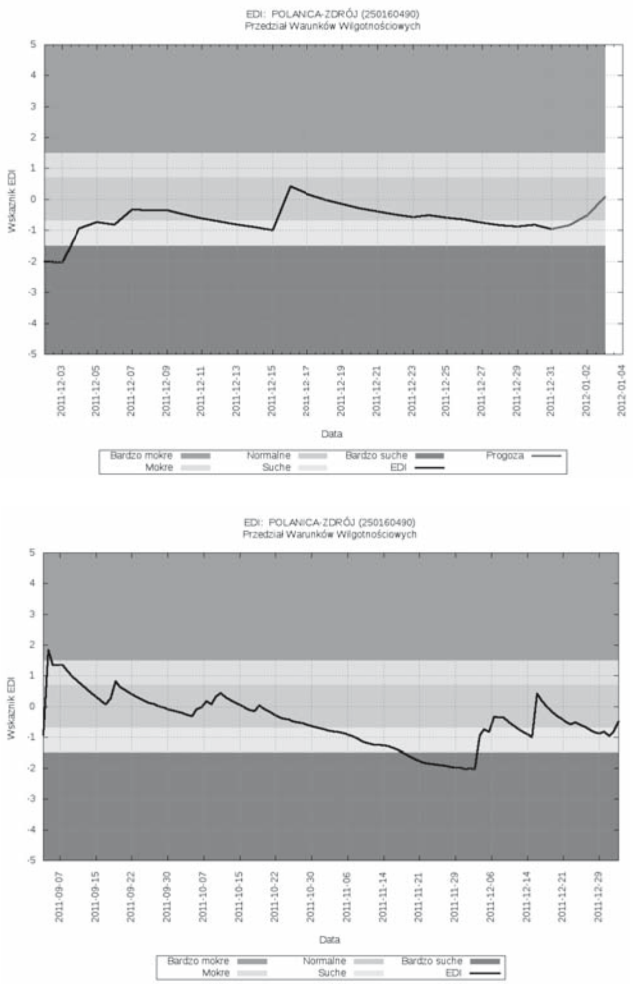


Fig. 7. Short-term prediction (30/12/2011-03/12/2011) of meteorological drought for Polanica Zdroj station (upper panel) and the actual pattern done three days later obtained from measured data (lower panel). Color codes of conditions: dark blue – very wet, blue – wet, grey – normal, yellow – dry, orange – very dry

DROUGHT ASSESSMENT WITH THE SCHEME FOR DROUGHT EVENT 2011

The most recent drought event in Poland started in August 2011 and there are areas where drought conditions are still observed. After a period of intensive rainfalls, the next months were characterized by a lack or little amount of precipitation. Hence, the rainfall totals in August 2011 at many precipitation stations reached only 40–60% of the norm. In September, an extreme meteorological drought, with the SPI values below -2.0, affected the eastern part of Poland, in particular the Wisla River basin (Fig. 8).

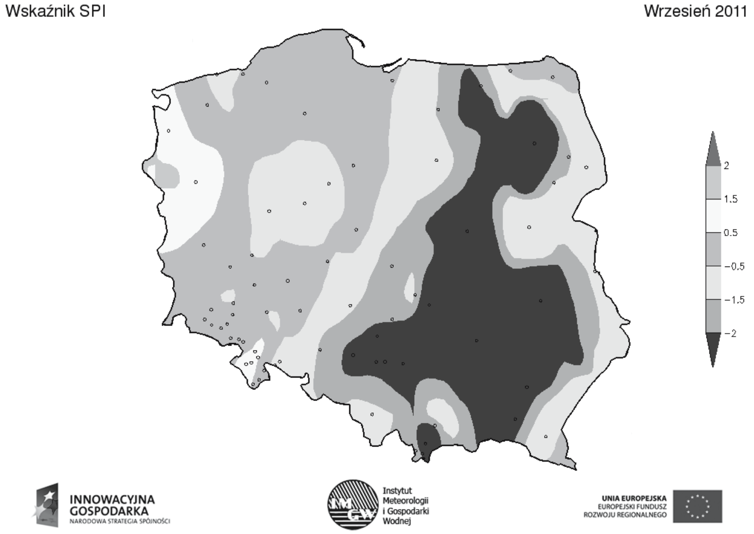


Fig. 8. Spatial distribution of SPI for September 2011. Color codes of conditions: dark blue – very wet, blue – wet, light blue – moderate wet, green – normal, yellow – moderate dry, orange – very dry, red – extremely dry

The temporal variation in EDI values observed on the example of Bielsko Biala station (the Southern part of Poland) proves, from the beginning of September, a constant decline of meteorological moisture conditions (Fig. 9). From the beginning of November 2011 and still at the beginning of January 2012 these conditions were classified as dry ones. A similar pattern of EDI values was observed for many stations in this region.

The observed precipitation deficit resulted in a reduction of water resources. Hydrological dry conditions started to be observed from the beginning of September 2011 and reached extreme values in the Wisla River basin at the end of the month. The temporal variation of FDC values from 30.09.2011 to 3.01.2012 for the water gauge station Nowy Targ (the Czarny Dunajec River – tributary of the Wisla River) demonstrates dry and extreme dry conditions with the local minimum observed in November.

In October 2011 most of the area of the Wisla River basin was still under dry meteorological conditions while for the rest of the territory of Poland, the precipitation totals were classified as normal (Fig. 5), according to the SPI classification. In turn, an extreme meteorological drought (SPI < -2) was observed in the next month on the whole territory of Poland (Fig. 11) .

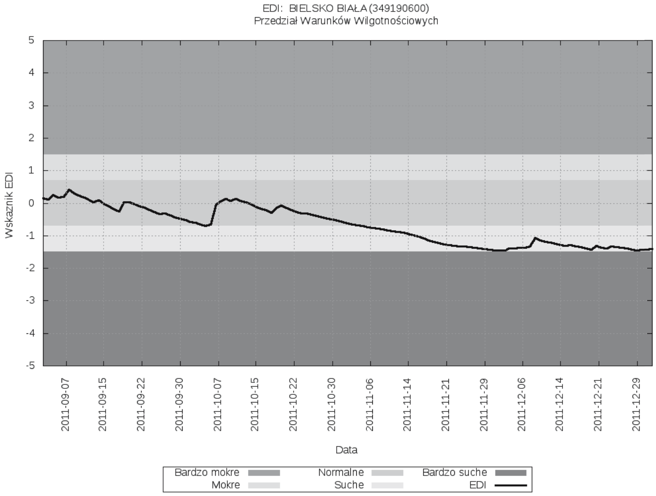


Fig. 9. Temporal variation of EDI values for Bielsko Biala station from 3.09.2011 to 3.01.2012. Color codes of conditions: dark blue – very wet, blue –wet, grey – normal, yellow – dry, orange – very dry

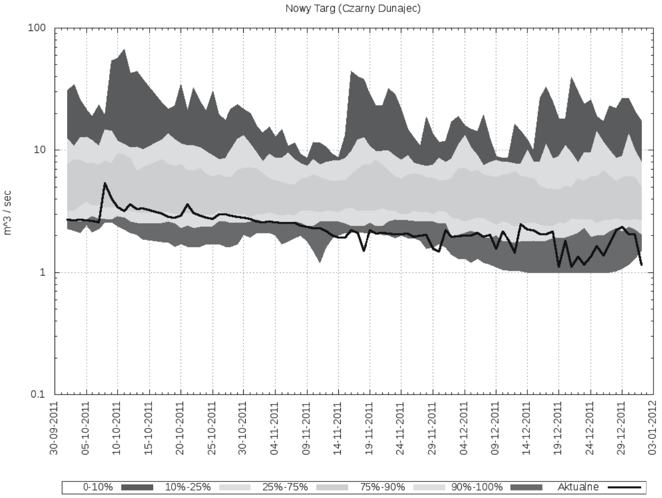


Fig. 10. Temporal variation of FDC values for water gauge station Nowy Targ (the Czarny Dunajec River) from 30.09.2010 to 3.01.2012. Conditions of color codes: dark blue – very wet, blue – wet, grey – normal, yellow – dry, orange – very dry

Temporal variation in EDI values in the Odra River basin acknowledged a rapid decline of meteorological conditions of the moisture which since the very beginning of November have been classified as dry and locally very dry. This is illustrated in Fig. 3 and Fig. 7 (lower panel) representing the pattern obtained for Bolkow and Polanica Zdroj precipitation stations respectively (the south part of the Odra River basin).

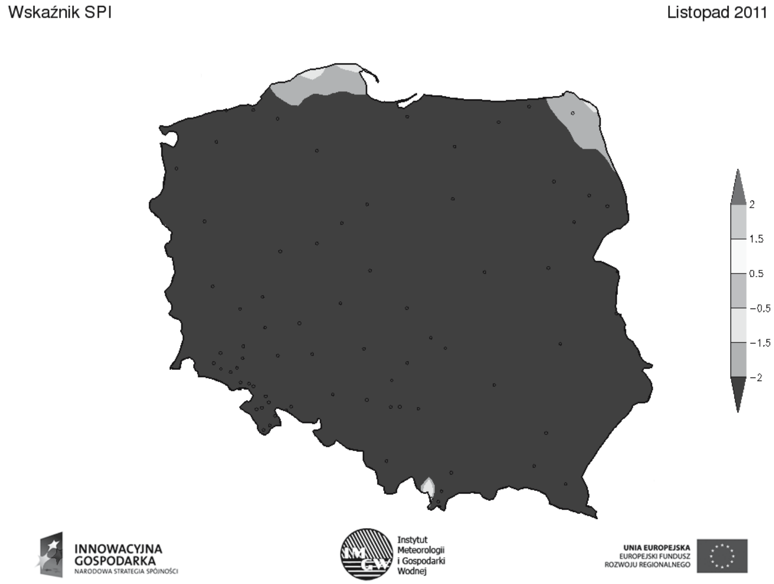


Fig. 11. Spatial distribution of SPI for November 2011. Color codes of conditions: dark blue – very wet, blue –wet, light blue – moderate wet, green – normal, yellow – moderate dry, orange – very dry, red – extremely dry

Dry and extremely dry meteorological conditions in November were accompanied by the dry hydrological conditions. The FDC plot for the Biala Ladecka (the Odra River tributary) proves that since the beginning of November the most of the streamflows values have been classified as low flows (Fig. 12) denoting a hydrological drought.

In December, the majority of the territory of Poland returned to normal meteorological conditions according to SPI (Fig. 13). However, the hydrological drought was still observed at most of the water gauge stations. Fig. 14 presents SRI values for selected stations in the Odra River and the Wisla River basins. The increasing intensity of hydrological drought reached the maximal values in November but dry conditions were still observed in December. This provides the confirmation for the temporal shift between meteorological and hydrological drought which is characteristic for the climate regime of Poland. Returning to normal hydrological conditions requires refilling the retention of the river basin. This is obtained through the sufficient amount of precipitation and usually takes a longer period of time.

CONCLUSIONS

The paper presents assumptions, functioning and application together with the preliminary results of a scheme of drought hazard assessment. The scheme for operational drought hazard assessment for a real time drought monitoring system was developed within the framework of the project “Environmental, economic and social impacts of climate change” (KLIMAT) [POIG.01.03.01-14-011/08]. The scheme was launched to run operationally in November 2010 and is operated by the Institute of Meteorology and Water Management

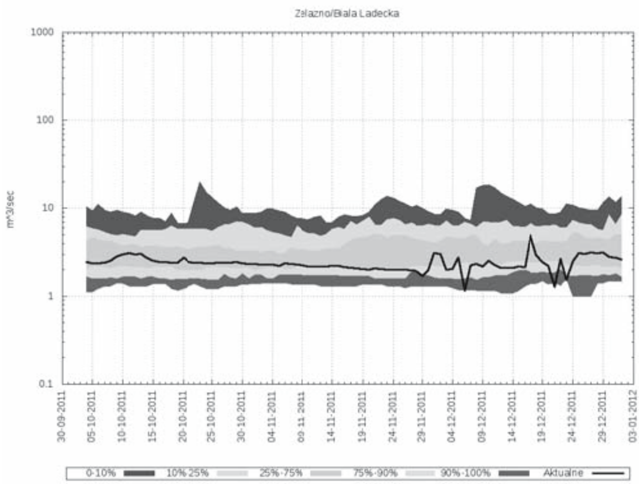


Fig. 12. Temporal variation of FDC values for water gauge station Zelazno (the Biala Ladecka River) from 30.09.2010 to 3.01.2012. Color codes of conditions: dark blue – very wet, blue –wet, grey – normal, yellow – dry, orange – very dry

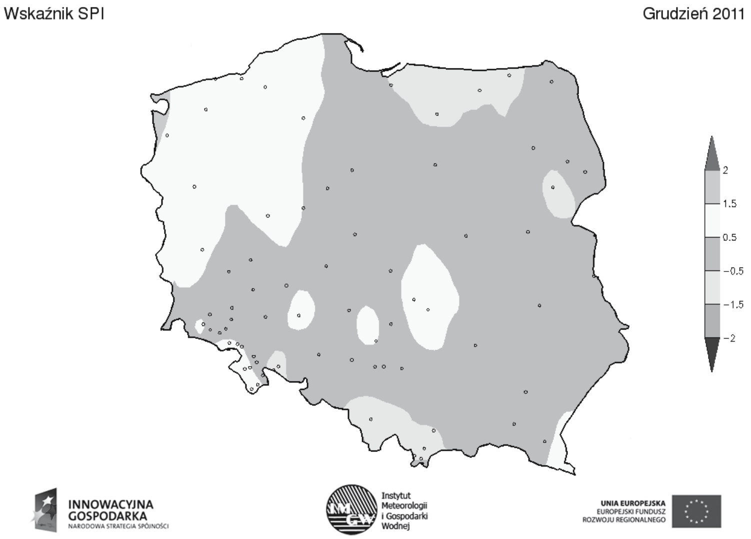


Fig. 13. Spatial distribution of SPI for December 2011. Color codes of conditions: dark blue – very wet, blue –wet, light blue – moderate wet, green – normal, yellow – moderate dry, orange – very dry, red – extremely dry

– National Research Institute. The crucial results are available to the public on the website: http://posucha.imgw.pl. The assessment of the scheme for a drought hazard is aimed to present a holistic approach capable of recognizing sensitivity to drought on the one hand and short-term drought prediction on the other hand. A big advantage of the developed scheme is the multi-criteria assessment of a drought involving elements of a hydrological

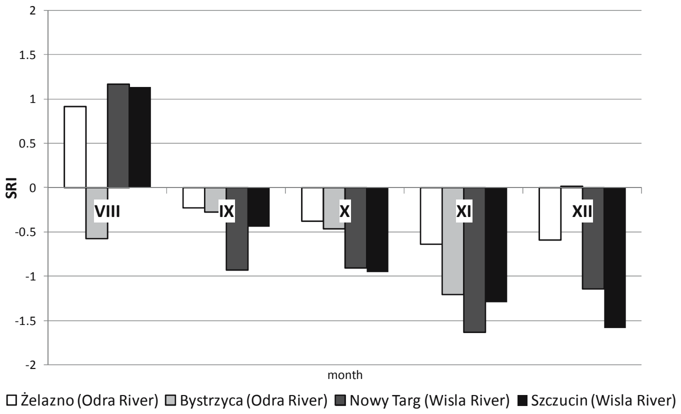


Fig. 14. Values of monthly SRI developed for selected stations Zelazno and Bystrzyca in the Odra River basin and Nowy Targ and Szczucin in the Wisla River basin from August to December 2011

circle subject to a formation of drought phases: a meteorological and hydrological one. Moreover, the application of daily time step allows for a precise diagnosis of the current state of drought.

A preliminary evaluation of the system functionality was done for the very recent drought event in Poland which started in August 2011. The performed analysis allowed to recognize spatial extension and intensity of the meteorological and hydrological drought as well as for the detailed investigation of the development and evolution of the specified drought phases. As a result, the proposed system containing tools for drought hazard assessment was used to track, in real-time, the spatiotemporal severity of meteorological and hydrological droughts during the drought event, provide short-term forecasts of drought along with the utility for the analysis of a posteriori drought event. The preliminary results and assessment of the system's functionality reveal a few requisite improvements mainly in terms of visualization techniques of the developed products as well as the need for further scheme development. The latter concerns introducing a module which employs the analysis of long-term Standardized Runoff Index values to the component of drought hazard prediction.

The quality of the operational data assimilated to the scheme conditions the functionality of its components and is the main reasons for the malfunctions of the system. Operational data are inherently subject to various sources of errors including sensor breakdowns, transmission failure, etc. To obtain more robust results of the system's performance, the evaluation will be continued over a longer period of time as well as for the events of different spatial and temporal scales.

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OPERACYJNY SYSTEM OCENY ZAGROŻENIA SUSZĄ – FUNKCJONOWANIE I WYNIKI

Prognozowane zmiany klimatu mogą niekorzystnie oddziaływać na wiele komponentów środowiska w tym na wegetację roślin poprzez zmiany wielkości parowania i dostępnych zasobów wodnych. Dodatkowo wzrost gospodarczy oraz wzrost populacji powoduje coraz większe zapotrzebowanie na wodę. W obliczu takich zagrożeń, ilościowa i jakościowa ochrona zasobów wodnych wymaga opracowania skutecznych narzędzi do oceny i prognozy zagrożenia suszą oraz wspomagania procesów podejmowania decyzji w celu przeciwdziałania skutkom suszy. W odpowiedzi Instytut Meteorologii i Gospodarki Wodnej Państwowego Instytutu Badawczego opracowali i wdrożyli system narzędzi od operacyjnej oceny zagrożenia suszą. Opracowany system zawiera narzędzia wskaźnikowe do oceny suszy, podatności na jej pojawianie się oraz do prognozowania zagrożenia suszą. System przystosowany jest do operacyjnego działania, co wiąże się z procedurami asymilacji danych z różnych źródeł oraz generowaniem produktów ukierunkowanych na odbiorcę.

System oceny zagrożenia suszą został zaprojektowany do współdziałania z platformą hydrologiczną wspomagającą codzienną pracę Biur Prognoz Hydrologicznych w IMGW PIB. **P**rognostyczno-**O**peracyjny **S**ystem **U**dostępniania **Ch**arakterystyk Suszy POSUCH@ został uruchomiony w operacyjnym trybie pracy dla wybranych zlewni Odry i Wisły, a wyniki prezentowane są na stronie internetowej http://posucha.imgw.pl. Artykuł przedstawia system oraz wstępne wyniki i ocenę suszy, która pojawiła się w sierpniu 2011.