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# Drought Monitoring on the CHMI Website

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## Abstract

The presented paper briefly summarizes the analysis of Drought monitoring, which is regularly performed at the Czech Hydrometeorological Institute (CHMI) during vegetation period. The system was completely innovated and significantly expanded in 2014, with many new map outputs for the region of the Czech Republic, which are the result of expert cooperation between the Prague and Brno branch offices of the Czech Hydrometeorological Institute. The outputs are published on the website in weekly intervals and contain detailed assessment of the risk of potential development or continuation of climatological, soil or hydrological drought. Apart from the actual measured values, the Drought monitoring also includes maps and graphical representations of selected agrometeorological and hydrological parameters, which can be used to characterize the current humidity situation in the landscape of the Czech Republic, particularly concentrating on the possible occurrence and duration of drought.

The presented paper only concentrates in detail on the meteorological part of drought (climatological and soil drought), not the hydrological one.

**Keywords:** drought, precipitation, evapotranspiration, balance, soil humidity

## Introduction

In meteorology, drought is an often used, yet very unspecific term, which in fact means insufficiency of water in the atmosphere, soil or plants. There are no unified criteria for quantitative definition of drought, especially with respect to various aspects of meteorological, hydrological, agricultural, pedological, bioclimatological and many other conditions, and also with respect to the damages caused in various areas of national economy. The definition of drought is therefore not unified. Based on the causes one can characterize it from various points of view (meteorological or climatological drought, agricultural or soil drought, hydrological drought, socio-economical drought).

Drought is usually a random phenomenon. It mostly occurs irregularly during periods of below-average or significantly below-average precipitation and can last for several days, but in extreme cases up to several months. In the Czech Republic, the primary cause for the development of drought is always precipitation deficit at a certain time period and at a particular location, and it often develops for example during vegetation period or during its part. Drought is often accompanied by above-average or significantly above-average air temperatures, lower relative air humidity, less cloud cover and increased number of sunshine hours. The mentioned meteorological parameters then lead to a higher rate of evaporation (evapotranspiration), which further increases the insufficient water availability in soil and in the atmosphere and this then intensifies the drought period.

Due to its unexpected and irregular occurrence in space and time, drought is a very dangerous natural phenomenon. A reliable and scientific prognosis of drought is therefore very complicated and can even be seen as problematic. A high level of importance is currently seen in special methods and approaches, which, based on operational weather information, can assess the current humidity balance in landscape, especially with respect to the fact whether some form of drought can be expected and its potential progress.

This year, Drought monitoring on the CHMI website, the subject of this paper, has undergone a substantial expansion and quality improvement in comparison to the previous years. Since 2014, apart from the meteorological part, which is concerned with the climatological and soil drought, also the hydrological part (hydrological drought) is now included. The system is a result of tight cooperation between meteorologists and hydrologists (Department for Biometeorological Applications in Prague, Meteorology and Climatology Department in Brno and Hydrology Department in Prague).

## Materials and Methods

In weekly intervals, the Drought monitoring on the CHMI website presents the results in a form of nice and easily understandable maps, graphs and texts, divided into “Climatological and soil drought” and “Hydrological drought” sections. From now on, this paper will only deal with the outputs of the “Climatological and soil drought” section, which, within the Drought monitoring, are processed in the Brno branch office or the branch is partly involved in their development.

Apart from the actual measured values (precipitation, soil humidity and evaporation from water level at selected climatological stations), the outputs include modeled data of selected agrometeorological parameters (potential evapotranspiration of grasslands, basic, i.e. potential water balance of grasslands, available water capacity in the soil profile under grass cover), which are then used to assess natural conditions and potential risk of drought development in the region of the Czech Republic.

Drought monitoring is based on two agrometeorological models – the BASET (Bilance Atmosferických Srážek a EvapoTranspirace, Atmospheric Precipitation and Evapotranspiration Balance, administered at the Department for Biometeorological Applications in Prague) and AVISO (Agrometeorologická Výpočetní a Informační SOustava, Agrometeorological and Computational Information System), which is managed by the Meteorology and Climatology Department at the Brno branch office. AVISO model, outputs of which will be described in detail later in the text, is a modified model based on the methodology of water given out by the evaporation from the surface using modified Penman-Monteith algorithm. The modeled soil humidity is based on a dual-layer model of water circulation in soil profile to the depth of active roots and both layers are separated from each other by the point of lowered availability (lentocapillary point).

The basis of the input data is formed, apart from selected phenological parameters, exclusively by measured data of basic meteorological parameters (air temperature and humidity in the form of calculated water vapor pressure, amount of sun shine, wind speed and precipitation) from 198 automated professional and voluntary climatological stations from the CHMI observation network. The source of data is then the CLIDATA database of the Czech Hydrometeorological Institute.

The AVISO model works in operational and regime manner in daily intervals. Operational assessment is regularly used in the Drought monitoring, regime analysis forms the basis for assessments of selected characteristics in long-term (in this case 1961-2010).

Apart from soil temperature and air temperature, soil humidity is one of the most important meteorological factors that influence plant growth. It is dependent on the amount, intensity and temporal distribution of precipitation, on evaporation and on the soil properties described by the so-called hydrolimits.

The basic hydrolimit for model analysis is available water capacity (AWC) as a difference between soil humidity at its field water capacity and the wilting point. It is reported in mm and the model allows two settings – standard for previously specified soil types, or a more accurate one, which classifies soil types into 5 classes. In Drought monitoring, the available water capacity in soil is set to the following values:

AWC = 70 mm/1m: light or lighter soil (sandy and loamy sand soil),
granularity 0%-20%, i.e. 0%-10% and 10%-20%);

AWC = 120 mm/1m: heavy or heavier soil (loamy clay, clay soil),
granularity 45%-75%, i.e. 45%-60% and 60%-75%);

AWC = 170 mm/1m: medium or medium-heavy soil (sandy and loamy soil),
granularity 20% -45%, i.e. 20%-30% and 30%-45%).

Drought monitoring uses the following current outputs from the AVISO model:

- Potential evapotranspiration of grasslands;

- Basic (i.e. potential) soil water balance of grasslands;
- Available water capacity in medium-heavy and heavy grass-covered soils.

The major output of the model for balancing soil humidity is the current water deficit of the soil type in mm, which characterizes the amount of available water in soil that remains to achieve field water capacity. The water capacity in soil, which in terms of the Drought monitoring is used for the analysis of the state of soil humidity, is then calculated for every day and for every calculated location (climatological station) using the current water deficit in soil and its available water capacity.

Long-term values of the above mentioned agrometeorological characteristics are essential for the comparison of current state with long-term conditions at particular locations in the region of the Czech Republic. They were analyzed by the model in a regime manner using technical series of the individual meteorological parameters. In practice this means daily data from the period between 1961 and 2010.

The map data for the region of the Czech Republic are generated automatically in the GIS environment using interpolation methods of local linear regression with respect to the altitude and the measured and modeled data from the climatological stations. Spatial resolution of the output raster is 500x500 m.

In natural conditions, the primary cause of all drought types in the Czech Republic is deficit (insufficiency) of atmospheric precipitation, which is also most commonly used to define climatological drought. Climatological drought is usually defined by comparing the amount of precipitation (less often the evapotranspiration or balance conditions) of the current period with the long-term average for that same period. Precipitation deficit means a negative difference between the currently observed precipitation amount and the long-term average for a particular time period.

When classifying climatological drought it is necessary to take into account the extent of precipitation deficit including temporal precipitation distribution in a given time period. Many authors have developed various definitions of climatological drought using climatological indexes, which are derived from other meteorological parameters (air temperature, wind speed, amount of sun shine, air humidity, evaporation etc.) which can either mitigate or significantly worsen the effects of the precipitation deficit.

The basic assumption for the identification of potential climatological drought is therefore comparison analysis of values of selected climatological parameters from the current time period with their long-term average. Within the Drought monitoring, the analysis was successively performed for precipitation amount, evapotranspiration and water balance. An important prerequisite is the fact that climatological drought analysis does not take into account properties of the subsoil.

In general, the soil drought analyzed using the Drought monitoring can be defined as insufficiency of water in the root zone of the soil profile. It causes abnormalities in water regime of both agricultural crops and wild growing plants. Water deficit in the upper parts of soil horizon is caused by previous or still present climatological drought. The effects of soil drought on the individual plant species are highly variable and also to a great extent depend on the developmental stage of the plant, its water requirements, age etc.

One big disadvantage is the fact that within the region of the Czech Republic, there is a relatively low number of stations with direct measurement of soil humidity. This also means that it is necessary to suitably supplement the measured data with modeled values. It could be said that soil drought is the basic prerequisite for the development of agricultural drought.

## Results

The following text shows easily-understandable and clear maps and graphical representations that analyze the humidity-water situation in the Czech Republic during vegetation period in regular weakly intervals based on selected agrometeorological parameters (potential evapotranspiration of grasslands, basic water balance of grasslands, current water deficit, available water capacity in soil profile covered with grass) with respect to the potential development of drought. All the presented results are current as of Sunday 10th August 2014.

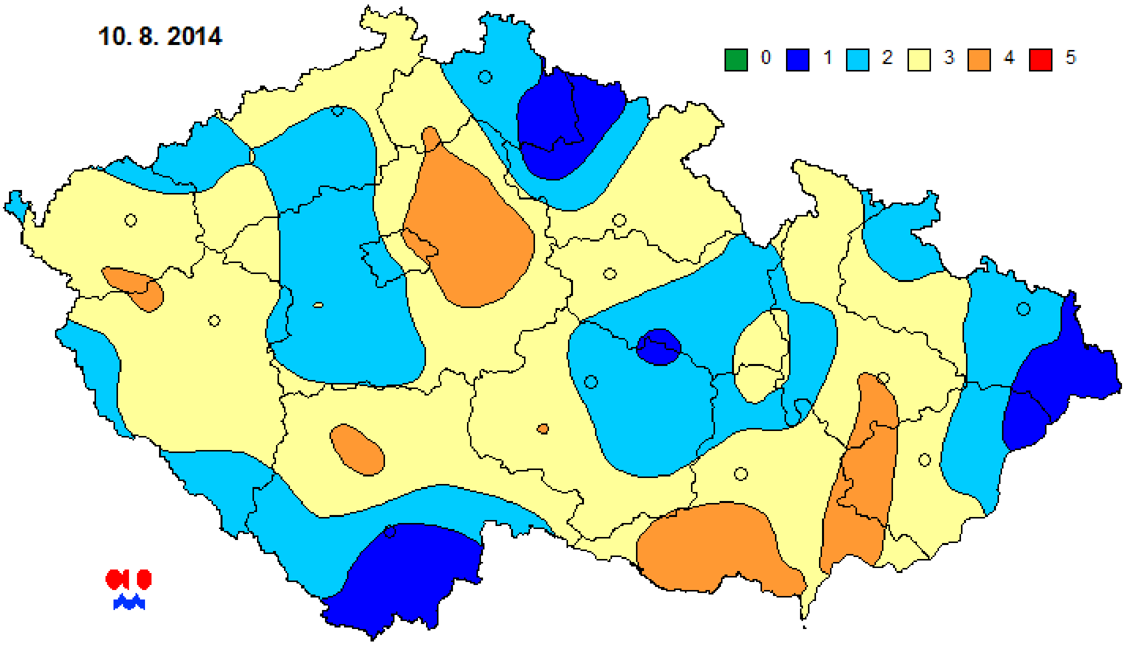


**Fig. 1** The level of risk of soil drought development at depths 0 to 20 cm in the Czech Republic as of Sunday 10th August 2014

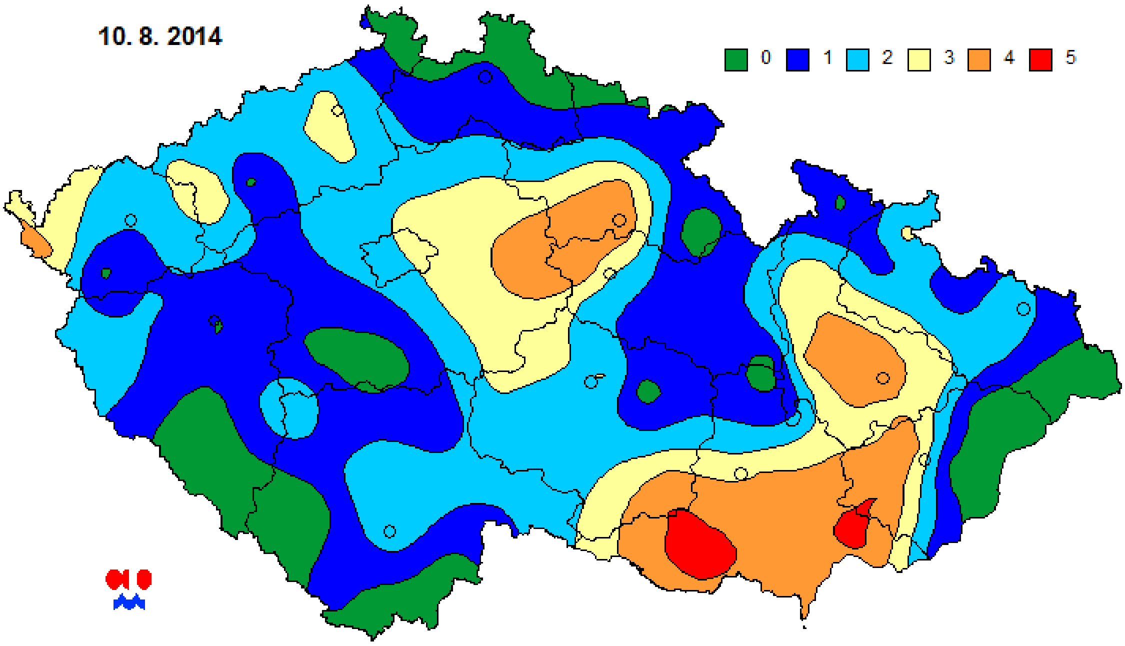


**Fig. 2** The level of risk of soil drought development at depths 0 to 100 cm in the Czech Republic as of Sunday 10th August 2014

The first two maps (**Fig. 1** and **Fig. 2**) in the meteorological Drought monitoring part show the level of risk of soil drought in grasslands. Due to substantial differences in soil humidity in the subsoil and deeper layers (for example at the beginning or end of heavy-precipitation period, or at the beginning of a period without precipitation), the level of risk of soil drought is assessed individually in two maps, one for soil profiles 0 to 20 cm (BASET model) and one for 0 to 100 cm (AVISO model). Both model approaches used to identify development of drought in various soil depths are based on a combination of measured and modeled data regarding soil humidity (measured by humidity sensors VIRRRIB or TRIFO3G, and calculated values from 198 climatological stations). Both values are given in % of available water capacity of a given soil type and are then finally analyzed and transformed into a basic scale that characterizes the level of risk of drought as follows:

| | |
|---|---|
| 0 – no risk | 3 – medium |
| 1 – small | 4 – high |
| 2 – low | 5 – very high |

The meteorological part of Drought monitoring is divided into two sections (“Climatological drought” and “Soil drought”). As was already mentioned earlier, this paper is only concerned with the model outputs that are related to the Drought monitoring regularly processed by the Brno branch office of the CHMI, or the branch office is at least partly involved.

“Climatological drought” section includes:

1) Weekly amount of precipitation – current state, measured values (Fig. 3);
2) Amount of precipitation since 1st Jan – long-term comparison, measured values (Fig. 4);
3) Evaporation from water level – current state, measured values;
4) Basic water balance of grasslands – current state, model values (Fig. 5);
5) Basic water balance of grasslands – long-term comparison, model values (Fig. 6);
6) Basic water balance of grasslands – current state at selected climatological stations at altitude below 300 m (Fig. 7);

7) Basic water balance of grasslands – current state at selected climatological stations at altitude above 300 m (Fig. 8);

8) Potential evapotranspiration of grasslands – long-term comparison, model data (Fig. 9).

“Soil drought” section includes:

1) Soil humidity under grass cover at 0 to 10 cm depth – current state, measured values;

2) Soil humidity under grass cover at 10 to 50 cm depth – current state, measured values;

3) Soil humidity under grass cover at 50 to 100 cm depth – current state, measured values;

4) Soil humidity under grass cover at 0 to 20 cm depth – current state, model values;

5) Available water capacity at medium-heavy soils under grass cover – current state, model values (Fig. 10);

6) Available water capacity at medium-heavy soils under grass cover – long-term comparison, model values (Fig. 11);

7) Available water capacity at medium-heavy soils under grass cover – current state at selected climatological stations at altitude below 300 m, model values (Fig. 12);

8) Available water capacity at medium-heavy soils under grass cover – current state at selected climatological stations at altitude above 300 m, model values (Fig. 13);

For the region of the Czech Republic, the major input to the water cycle in natural environment is atmospheric precipitation. The analysis of precipitation amount is represented in two maps, which show the current state in the form of precipitation observed in the previous week from Monday until Sunday (**Fig. 3**) and the percentage comparison of cumulative amount since 1$^{st}$ January with long-term average from 1961 to 2010 (**Fig. 4**). Unlike all the other remaining agrometeorological characteristics, these are measured, not model data.

Climatological drought is a convenient characteristic of basic (potential) water balance of grass cover, defined as the difference between precipitation and potential evapotranspiration of grass cover. It is analyzed as current cumulative amount since 1st March (**Fig. 5**) and meanwhile also in a form of a comparison with the long-term average from 1961 to 2010 (**Fig. 6**). Both values are given in mm. Higher numerical value of water balance in the current meteorological conditions (i.e. precipitation is higher than evapotranspiration) is favorable and means lower probability of potential occurrence of climatological drought at that particular location and on that particular day (and vice versa). Similar conclusions also apply for the comparison of current water balance with the long-term averages.

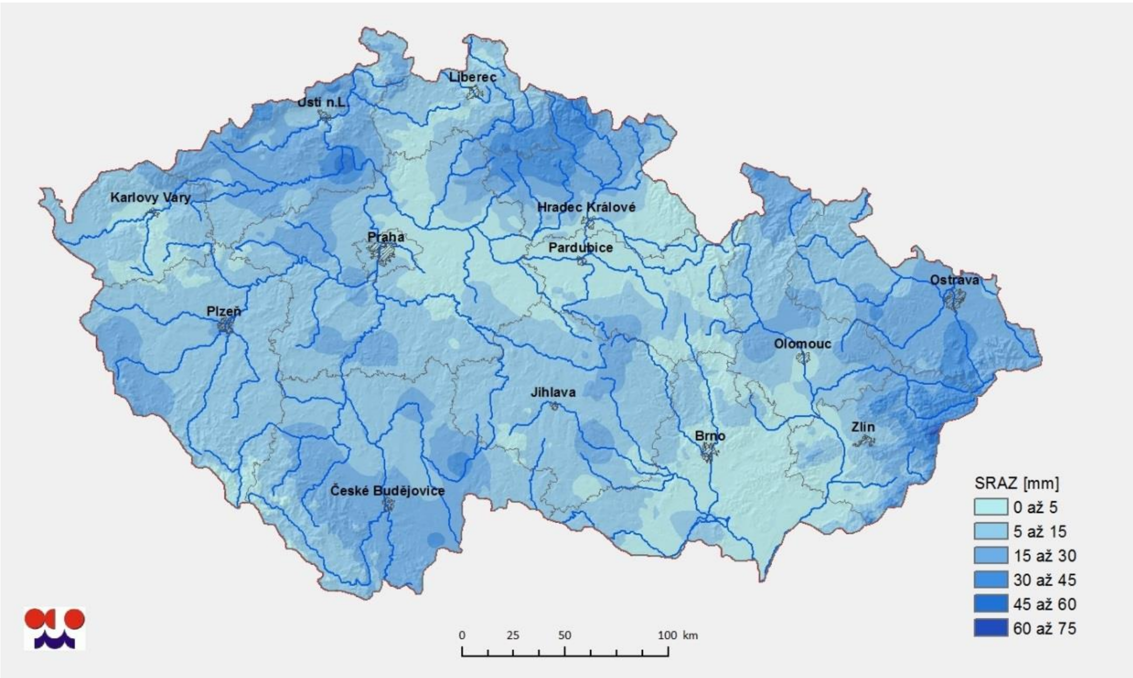


**Fig. 3** Precipitation amount in the Czech Republic from 4th August to 10th August

Current state of water balance of grass cover on selected climatological stations at altitudes below 300 m above sea level (Doksany 158 m, Dyjákovice 201 m, Semčice 234 m, Kroměříž 233 m, Ostrava-Poruba 239 m and Hradec Králové 278 m) and at altitudes above 300 m (Temelín 503 m, Vatín 555 m, Vrchlabí 482 m, Košetice 534 m, Rýmařov 578 m and Kralovice 468 m) are presented using graphs in **Fig. 7** and **Fig. 8**.

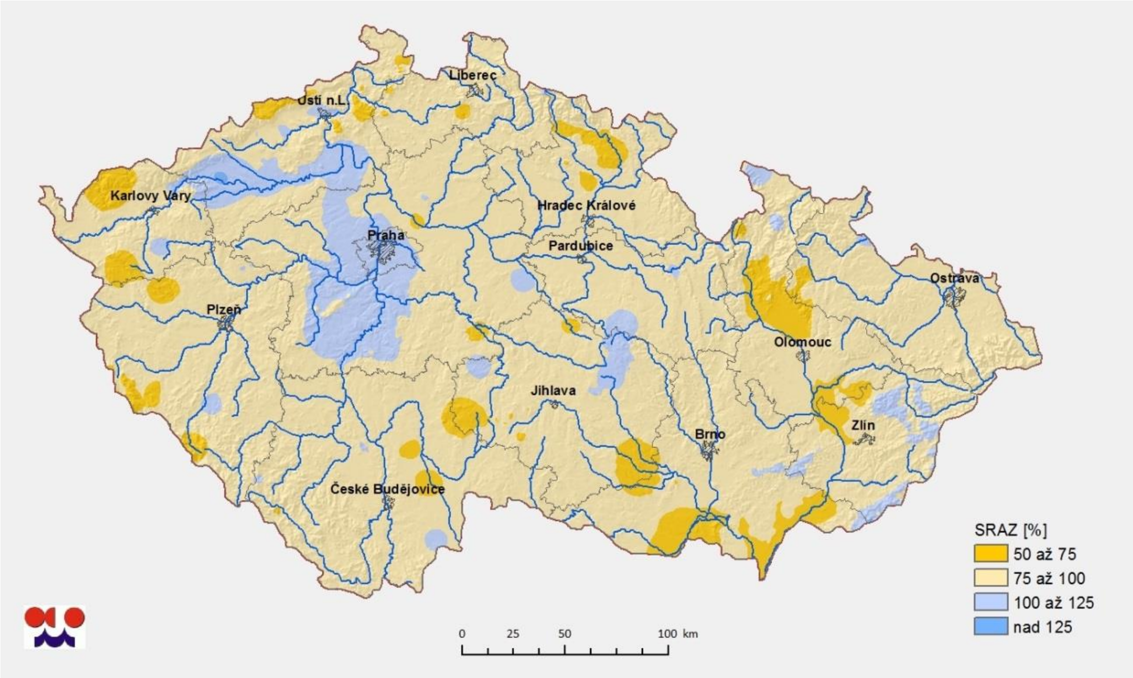


**Fig. 4** Comparison of the precipitation amount in the Czech Republic from 1st January to 10th August 2014 with the 1961-2010 long-term average.

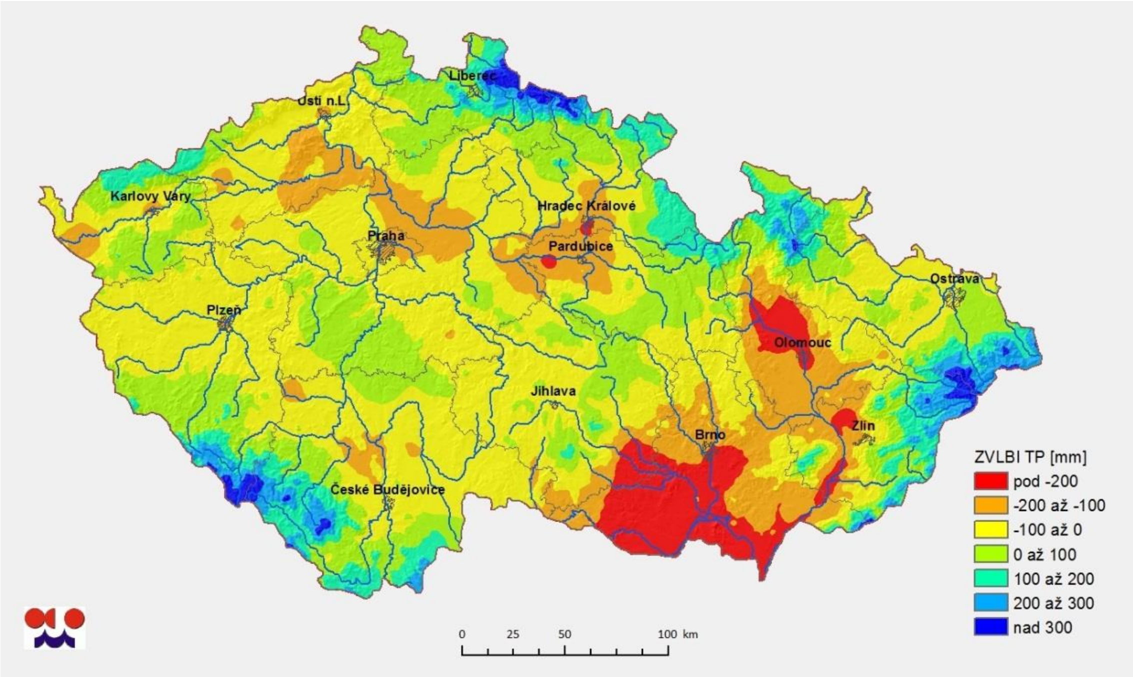


**Fig. 5** Basic water balance of grasslands (difference between precipitation and potential evaporation) in the Czech Republic from 1st March to 10th August 2014

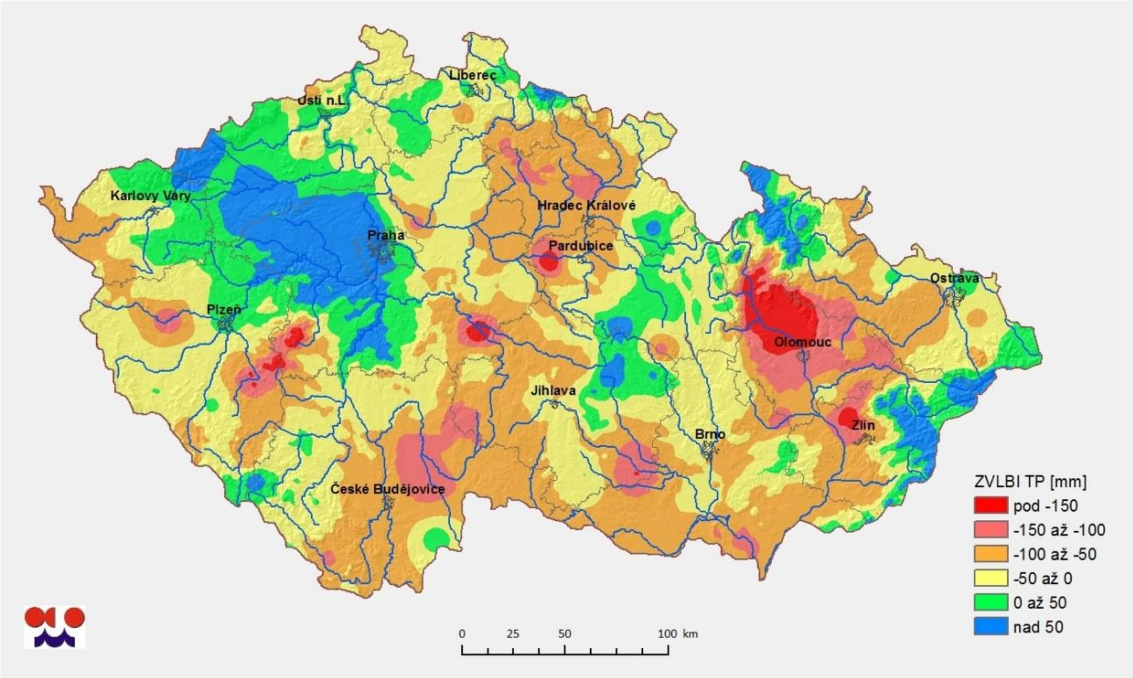


**Fig. 6** Basic water balance of grasslands (difference between precipitation and potential evaporation) in the Czech Republic, comparison of the period from 1st March to 10th August 2014 with the 1961-2010 long-term average

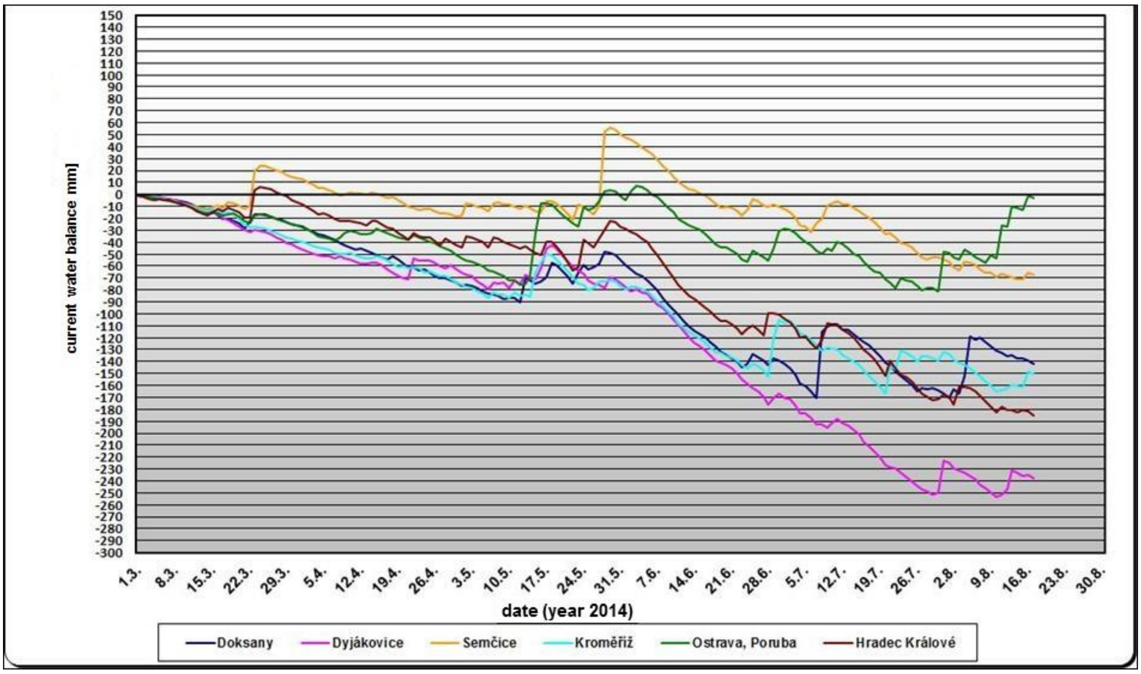


**Fig. 7** Basic water balance of grasslands, current conditions at selected climatological stations in the Czech Republic at altitudes below 300 m above sea level, as of Sunday 10th August 2014.

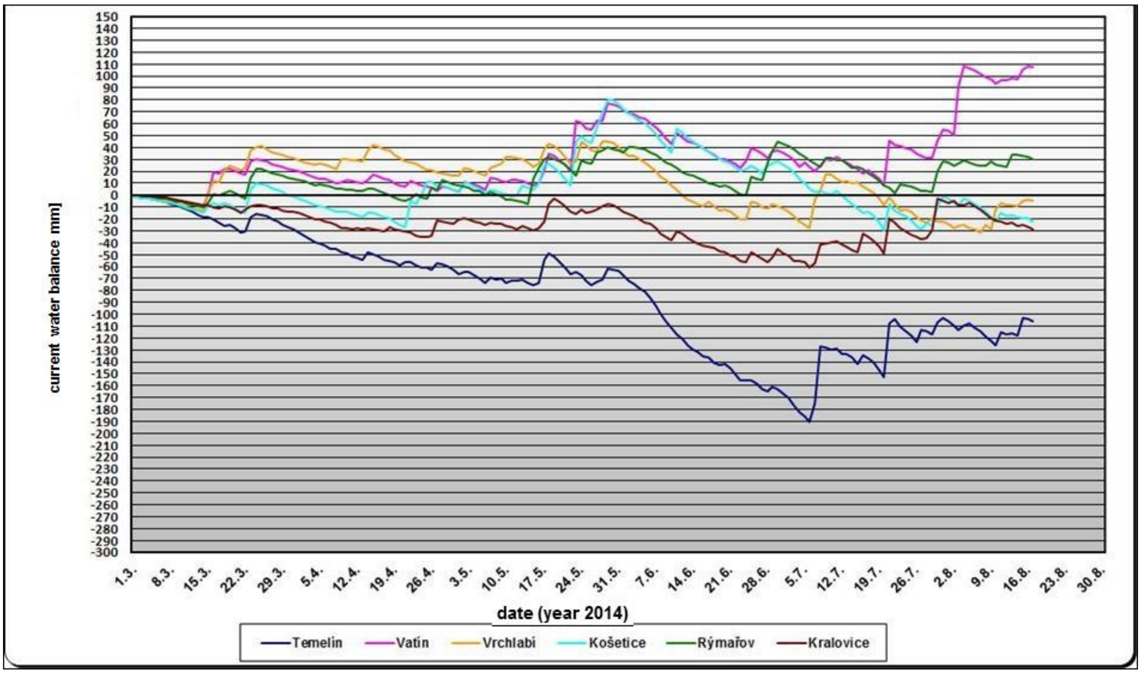


**Fig. 8** Basic water balance of grasslands, current conditions at selected climatological stations in the Czech Republic at altitudes above 300 m above sea level, as of Sunday 10th August 2014.

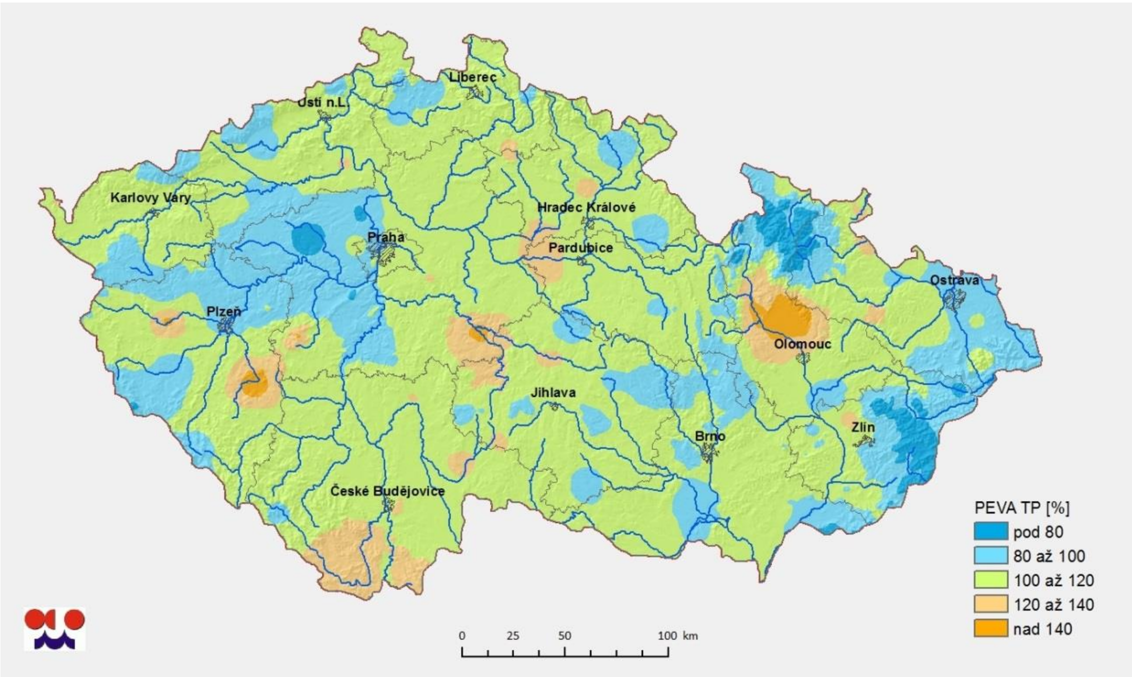


**Fig. 9** Potential evapotranspiration of grasslands in the Czech Republic, comparison of the amount from the period from 1st March to Sunday 10th August 2014 with the 1961-2010 long-term average.

The final characteristic of this section is the potential evapotranspiration of grass cover, which is calculated using modified Penman-Monteith algorithm. The current state is not included, instead only the percentage comparison with the long-term average from 1961 to 2010 is given (**Fig. 9**). The higher the final % value (i.e. currently calculated potential evapotranspiration is higher than the corresponding long-term average), the less favorable the water balance situation is and means a higher probability of potential occurrence of climatological drought and its effects in that particular location on that particular day (and vice versa).

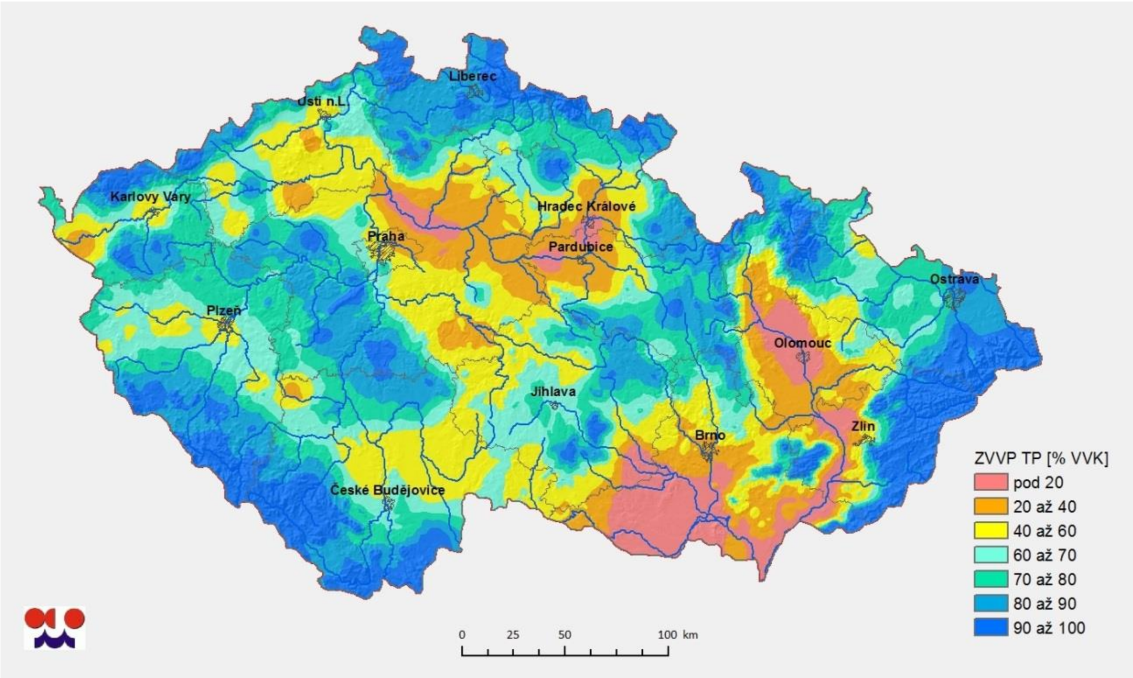


**Fig. 10** Amount of usable water in loam soils (AWC = 170 mm/1 m of soil profile) under grass cover in the Czech Republic, current state as of Sunday 10th August 2014.

The basic agrometeorological parameter for the analysis of soil drought within the Drought monitoring is the amount of available water capacity in soil profile under grass cover. It is shown as modeled values given in % of available water capacity and calculated for medium-heavy soils with available water capacity 170 mm / 1 m of soil profile. The current state is monitored (**Fig. 10**) and also a comparison with long-term average from 1961 to 2010 is given (**Fig. 11**). Higher values of available water capacity in soil at the current meteorological conditions mean more favorable humidity conditions of soil and therefore lower probability of potential occurrence of soil drought in that particular location on that particular day (and vice versa). Similar conclusions also apply for the comparison of the current state of available water capacity in soil with long-term conditions.

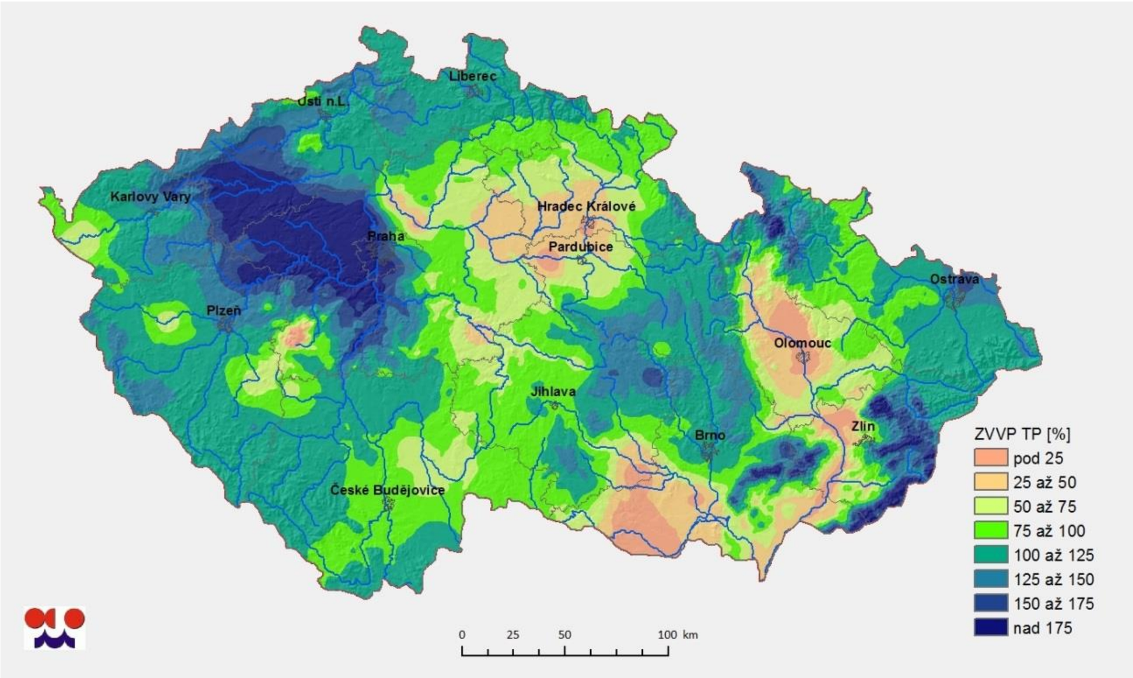


**Fig. 11** Amount of usable water in loam soils (AWC = 170 mm/1 m of soil profile) under grass cover in the Czech Republic, comparison with the 1961-2010 long-term average, as of Sunday 10th August 2014

Current state of available water capacity in soil under grass cover for selected climatological stations with altitude below 300 m above sea level (Doksany 158 m, Dyjákovice 201 m, Semčice 234 m, Kroměříž 233 m, Ostrava-Poruba 239 m and Hradec Králové 278 m) and at altitudes above 300 m (Temelín 503 m, Vatín 555 m, Vrchlabí 482 m, Košetice 534 m, Rýmařov 578 m and Kralovice 468 m) are presented in graphs in **Fig. 12** and **Fig. 13**.

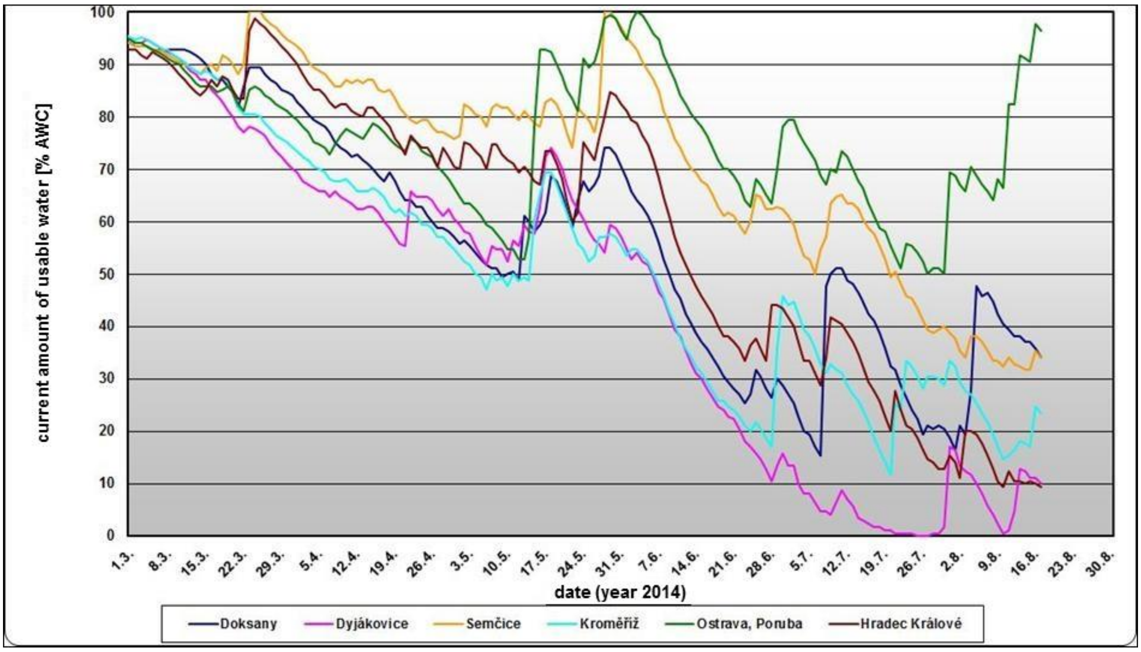


**Fig. 12** Amount of usable water in loam soils (AWC = 170mm/1 m of soil profile) under grass cover, current state at selected climatological stations in the Czech Republic with altitude below 300 m above sea level, as of Sunday 10th August 2014

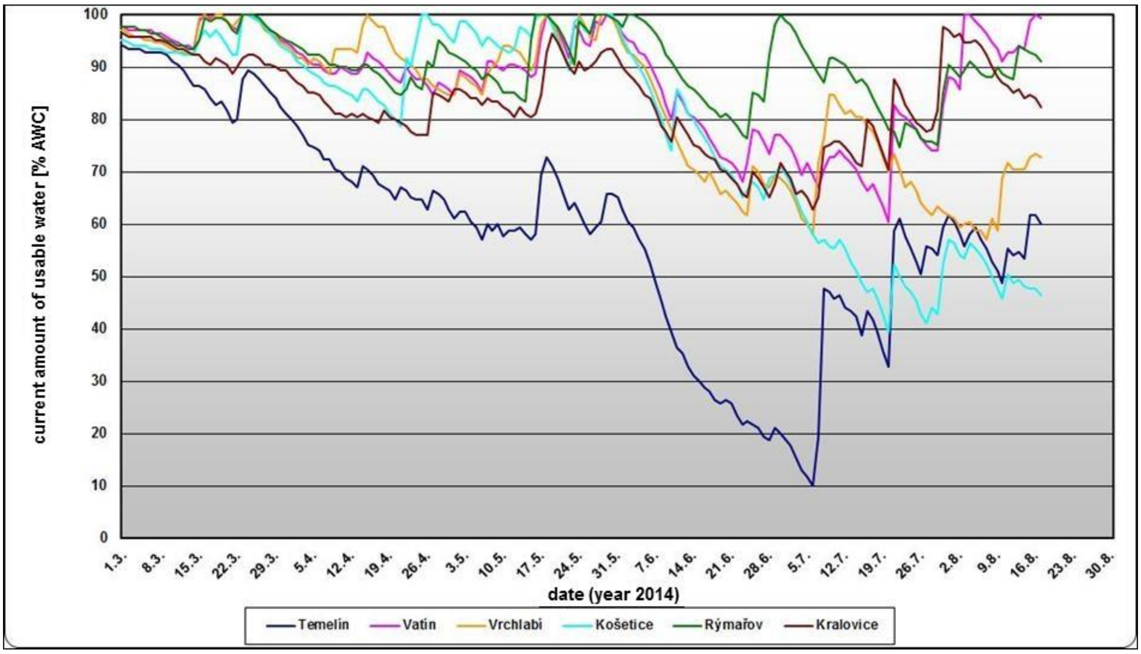


Fig. 13 Amount of usable water in loam soils (AWC = 170mm/1 m of soil profile) under grass cover, current state at selected climatological stations in the Czech Republic with altitude above 300 m, as of Sunday 10th August 2014

## Discussion

Drought can be described as one of natural weather extremes with irregular and unexpected occurrence in space and time. Due to the fact that it is a dangerous natural phenomenon with far-reaching consequences for national economy, it is very important to monitor weather conditions in real-time with particular focus on analysis of those agrometeorological parameters, which can be used to identify potential development and duration of drought.

This paper briefly describes Drought monitoring, which has undergone a substantial innovation and expansion compared to previous years. During vegetation period, the outputs are available at the CHMI website.

Both general public and scientific community would definitely welcome a drought forecast. It is however a very complicated issue even when trying to make medium- or short-term prognosis. If modified, and especially with the pre-requisite of using prognosis data of basic meteorological parameters, the AVISO model could be used for making forecasts and this can be seen as one of the key activities in the upcoming future to further enhance the quality of the Drought monitoring project.

## Conclusion

The presented paper briefly introduces the Drought monitoring regularly performed during vegetation period at the Czech Hydrometeorological Institute. In 2014, the entire system has undergone a substantial innovation and expansion in comparison to the previous years and now includes many map outputs for the region of the Czech Republic, which are the result of expert cooperation between the Prague and Brno branch offices of the Czech Hydrometeorological Institute. The outputs are published weekly on the CHMI website and contain detailed analysis of potential development or duration of climatological, soil and hydrological drought. Apart from the actual measured values, Drought monitoring also includes maps and graphical representations of selected agrometeorological and hydrological characteristics, which can be used to describe the current water situation in the Czech Republic, with particular focus on potential occurrence and duration of drought.

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**Summary**

Předkládaný příspěvek se stručně věnuje analýze Monitoringu sucha pravidelně provozovaného ve vegetačním období na Českém hydrometeorologickém ústavu. V roce 2014 byl celý systém oproti rokům předcházejícím inovován a výrazně rozšířen o řadu mapových výstupů pro území České republiky, které jsou výsledkem odborné spolupráce mezi pracovišti Praha a Brno Českého hydrometeorologického ústavu. Výstupní sestavy publikované v týdenních intervalech na webových stránkách obsahují podrobná hodnocení týkající se možného nástupu či trvání případného klimatického, půdního a hydrologického sucha. Monitoring sucha vedle měřených hodnot obsahuje mapová a grafická zpracování vybraných agrometeorologických a hydrologických charakteristik, pomocí nichž lze charakterizovat aktuální vlhkostní situaci v krajině na území České republiky, a to se zvláštním zřetelem na možná výskyt a trvání sucha.

Předkládaný příspěvek se podrobněji zabývá pouze částí meteorologickou (klimatické a půdní sucho), nikoliv částí hydrologickou.

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