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Application of analyzed and modelled soil moisture data for the purposes of the agricultural and hydrological forecasts

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Abstract: Soil water is part of the planet's water resource. The laws of accumulation and consumption are studied as part of the water cycle of the planet's climate system. Soil moisture resources have major role for the growth and development of the agricultural crops and orchards, as well as for all other wild plants, grasses, shrubs and trees. The content of water in the soil for agricultural purposes is defined as the humidity relative to the maximum possible (AWC). Soil moisture is taken into account by almost all numerical models used in hydrological modeling. They constantly monitor the volume of water that can be absorbed by the forecasted precipitation. Present soil moisture conditions can be determined according to: measurements from the agro-meteorological and precipitation networks of NIMH; automatic monitoring stations; satellite information, etc. Numerical models using forecasted precipitation are applied for forecasting soil water content. Information for soil moisture is provided also from large forecast centers where global and regional models are used. The use and verification of forecast information would be useful for both assessing soil moisture conditions in agricultural practice and hydrological modeling and forecasting of extreme events (floods). The aim of this study is to evaluate the possibilities of using, validating and verifying forecast and reanalysis information about soil moisture and assess the conditions for drought and overwetting.

Key words: soil moisture, contact measurements, numerical modeling, hydrological modeling, drought, overwetting of soils

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1. INTRODUCTION

Tracking the dynamics of humidity is of particular importance in the compilation of agrometeorological and hydrological forecasts. On the one hand soil water content soil ensures the realization of soil's fertility and creates an environment for the development of vegetation - cultivated and wild. Soil water has an extremely important role for the agricultural production. In this sense the soil is a water reservoir and the fuller it is the better the conditions for the growth of agricultural crops and perennials. By means of continuous up-to-date information on the conditions of moisture in the root-inhabited soil layer, management of the irrigation regime of crops and compensation of the water shortage in the soil is carried out. This is vitally necessary during the period of formation and growth of the reproductive organs of plants.

In hydrological terms the soil is also considered a reservoir, with the soil absorbing rainwater in the depth of the soil profile (Yordanova&Stoyanova, 2020). In this way the duration of the non-drainage phase when the soil is filled with water during periods with longlasting or intensive precipitation increases. When the process of filling with water is finished the formation of surface runoff begins (Stoyanova, 2020).

These features of soil water dynamics along with all its varieties of movement – vertical, horizontal, surface and subsoil runoff, evaporation and plant water uptake – require continuous monitoring of soil water content.

There are different methods for obtaining data on the water content in the soil - by direct measurement, by remote-sensing measurement and by applying numerical models, which simulate the process of movement of rainwater in the soil profile and in the root-inhabited soil layer.

The direct measurement is carried out by applying the classical weight method which is too labor- and energy-consuming. Nevertheless, it is applied in the agrometeorological practice, mainly due to the relatively high accuracy in determining water reserves. Another way of direct measurement is the use of automatic sensors for soil water content at discrete depths in the soil profile. In this approach the data obtained represents relative units that are right or inversely proportional to the water content of the soil. This is usually water vapor pressure measured in centibars (Cb), the resistance (R) or capacity (C) change by the sensors placed in the soil. Another major trend in soil water content measurements is the remote sensed data obtained through drones, aircraft and satellites. It is based on the ability of soils to change their spectral reflectance and dielectric characteristics depending on their water content.

The possibility of predicting soil moisture through the application of numerical models should also be considered. Many studies that address the issue of the integrated use of remote sensing data and model data by applying standard measurement results have been carried out since the end of the last century (Houser et al., 1998).

Within the SMEX03 experiment in 2003 (Bosch et al., 2006) a research targeting the creation of a database for temporal and spatial characterization of soil moisture thus increasing the accuracy of satellite products from remote observations. Within this experiment soil moisture characteristics were examined at three depths: 0-1, 0-3 and 0-6 cm on 49 test agricultural fields, 19 of which were pastures. The measurements were carried out with different resolution – 25, 50 and 75 km. The results of this study showed that in-situ data are suitable for long-term calibration of remotely sensed soil moisture and could be a suitable source for future satellite validation.

In the work of Wenlong Jing et al. (2018) an approach for validating multilayer soil moisture data obtained from ECMWF by reanalysis with data from ground contact measurements in the Murrumbidgee River catchment in south-eastern part of Australia is presented. According to the authors soil moisture reanalysis products can provide information on soil water content for the surface and root-inhabited soil layers, which are important for studying the water cycle in relation to climate change. The accuracy however of multi-layer soil moisture datasets derived from reanalysis products remains unclear in some areas. In the study cited soil moisture in the root habitable layer was estimated using the ERA-Interim moisture product as well as surface soil moisture based on in situ measurements from the OzNet hydrological measurement network over southeastern Australia. Overall the ERA-Interim soil moisture product shows good agreement with in-situ soil moisture values and can well reflect variations over time - correlation coefficient (R) values ranging from 0.73 to 0.84 and the RMSE variying between 0.035 and 0.060 m^3/m^3. The ERA-Interim soil moisture product overestimates the in-situ measurements at depths of 0-7 cm and 7-28 cm while the product shows underestimations compared to the in situ measured soil moisture in the 28-100 cm. Therefore the ERA-Interim soil moisture product has both high absolute and high temporal accuracy at layer 7-28 cm. Also, ERA-Interim can capture well the soil moisture dynamics except for the 28-100 cm layer during the winter months. The influence of terrain topography, vegetation cover, and soil structure on model error is identified through soil moisture estimates using the characteristics and the algorithm for a random forest type.

Another team of scientists have tried to create good practices by developing a manual for the validation of soil moisture products on a global scale, (Gruber et al., 2020). They have carried out a research of the state-of-the-art error estimation methods from all known soil moisture networks, as well as practical recommendations for reanalysis and presentation of statistical results. Their recommendations are for the use of validation protocols along with examples primarily with applications in the microwave spectrum. Questions related to the identification of white spots in the scientific research on the matter, which should be completed in the near future are also considered. In the concluding remarks all considerations related to the importance of the problem are included i.e., data reanalysis processes, soil moisture calculation metrics, literature review, statistical uncertainty, the possibilities of reconciling data obtained from different sources, continuity of data series, and accuracy are indicated of soil moisture determination.

The variety of methods for measuring the water content in soils throughout the entire root-zone layer to a depth of 1-2 m requires the creation of a justified methodology for validating and harmonizing the entire set of data obtained from different sensors, which is the main goal of the present study.

2. MATERIAL AND METHODS

Within the project framework comparative studies and analysis of data obtained from different sources were carried out. Data from standard soil moisture measurements, diagnostic and prognostic information on soil moisture by layers was used. Also model data from ECMWF, ERA 5, SURFEX and H-SAF (H14) over the territory of Bulgaria were used.

2.1. Description of the soil moisture spatial data

- ISBA model output: daily values in two layers – S1 (0-1 cm) and S2 - root habitable layer, [kg/kg]: 8 km resolution dataset for the period 2007-2022 covering the Maritsa-Tundzha-Arda river basin;
- SURFEX model output: daily values in three layers – S1 (0-1 cm), S2 (the root habitable layer) and S3 (below the S2 layer), [m^3/m^3] – 8 km resolution dataset for the period 2015-2022 covering the territory of Bulgaria;
- ECMWF (reanalysis and forecast data): daily values in three layers – S1 (0-7 cm), S2 (7-28 cm) and S3 (28-100 cm), [m^3/m^3] – 12 km resolution dataset for the period 2015-2018;
- ECMWF (reanalysis and forecast data): daily values in three layers - S1 (0-7 cm), S2 (7-28 cm) and S3 (28-100 cm), [m^3/m^3] – 9 km resolution dataset for the period 2018-2022;
- H-SAF, H-14 product data: daily values in three layers – S1 (0-7 cm), S2 (7-28 cm) and S3 (28-100 cm), [m^3/m^3] – 25 km resolution dataset for the period 2013-2022;
- Primary product: Soil moisture daily gridded data for the period 1978-2022 in one layaer S1 (2-5 cm), extracted for the territory of Bulgaria with a spatial resolution of 0.25 degrees, [m^3/m^3];
- Primary product: ERA5-Land hourly data for the period 2001-2022 in three soil layers – S1 (0-7 cm), S2 (7-28 cm) and S3 (28-100 cm), extracted for the territory of Bulgaria with spatial resolution of 0.1 degrees, [m^3/m^3].

2.2. Joint data, measured soil moisture

- Watermark sensors - 11 stations [cB] with measurements taken at 4 depths – 20 cm, 50 cm, 70 cm and 100 cm;
- Campbell sensors CS650 – 6 stations [m^3/m^3] with measurements taken at 2 depths – 3-10 cm, 30-60 cm;
- Sentek sensors – 4 stations [CFU] with measurements taken at 8 depths – 10, 20, 30, 40, 50, 70, 90 and 110 cm;

Data from direct measurements by gravimetric method used at NIMH agrometeorological network. The results from the measurements are in percentages by weight and afterwards are converted in (m^3/m^3) using hydrological constants from the Agrometeorological Database (AMDB) of the department of Agrometeorology at NIMH.

After analyzing the length of the rows and in accordance with the project objectives it was found that there are continuous datasets for the period 2015-2020 available from most of the sources. For carrying out the comparative analysis a database with different layers covering all data was created. For evaluating the soil moisture reserves information about hydrological constants from two sourses was used:

- ESDAC - https://esdac.jrc.ec.europa.eu/resource-type/european-soil-database-soil-properties,
- FAO - https://www.fao.org/soils-portal/data-hub/soil-maps-and-databases/en/.

3. RESULTS AND ANALYSIS

1. Verification of the diagnostic and prognostic information was performed using data from in-situ measurements from the agrometeorological network and from automatic stations soil moisture data records.
2. Verification of model input data from SURFEX, ECMWF and ERA using ground-based Campbell sensor data was performed.
3. Verification of model input data from SURFEX, ECMWF, H-SAF and ERA using ground-based gravimetric data was performed.

The contact measurements at the agrometeorological network and the data from automatic stations (Campbell sensors) were compared with modelled data from the above mentioned sources for the period 2015-2020.

Seven representative stations from the agrometeorological network at three depths (0-10, 10-30 and 30-100 cm) were used for the comparison - Glavinitsa, Dolni Chiflik, Karnobat, Yambol, Sliven, Haskovo and Kyustendil.

The following soil types are included in the experiment - chernozem, vertisols, gray forest, cinnamon and brown forest soils. Mean error (ME), standard deviation (SD) and root mean square deviation (RMSD) were determined for all measurements. The correlation coefficient (CC) for each of the rows by measurement depths with the values of ground-measured soil moisture was also determined. The obtained statistical characteristics are necessary to determine the correlation between the weighted method values and the data obtained from ERA, SURFEX, ECMWF and H-SAF.

3.1. Assessment of the degree of soil saturation

Soil moisture was estimated for hydrology and agrometeorology purposes by the saturation index (K) and Soil Water Availability (SWA) % FC:

$$K = \frac{SM - WP}{SAT - WP}; \qquad RHW = \frac{SM}{FC} * 100;$$

where SM - soil moisture; WP - wilting point; SAT-total moisture content; FC-limiting field capacity.

Given the objective of the project, model data for two dates – 05.09.2019 and 10.04.2019 was used. Based on expert assessment 05.09.2019 corresponds to a period with a well-defined drought while the second date 10.04.2019 corresponds to a period with strong humidification and overwetting in places.

3.2. Investigation of the possibility of using the values of water-physical properties for the assessment of soil moisture reserves

The results obtained showed that for these dates there are areas with saturation index values higher than 1 and lower than 0, which suggests the presence of incorrect values of the hydrological constants. For this reason a re-selection of the minimum and maximum values for each point was carried out and maps of the saturation index were drawn again.

The comparison between the model data from the mentioned sources and the automatic stations with Campbell type sensors showed very good correlation at the stations with two sensors (Chirpan and Rozhen): Chirpan between 0.8 - 0.9 and in Rozhen between 0.6-0.8, (Table 1). The results obtained at the other 4 stations are also good (Table 2).

Table 1. Statistical scores for the data from automatic stations with Campbell-type sensors at two depths and data from SURFEX, ERA and ECMWF

Statistical parameters	SURFEX			ERA			ECMWF		
	S1	S2	S3	S1	S2	S3	S1	S2	S3
Chirpan									
ME	-0.1	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.1
SD	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1
CC	0.8	0.8	0.9	0.9	0.5	0.9	0.8	0.5	0.7
RMSD	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.2
Rozhen									
ME	0.1	0.2	0.2	-0.1	0.0	0.1	0.0	0.2	0.2
SD	0.1	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0
CC	0.8	0.8	0.6	0.6	0.7	0.7	0.7	0.7	0.6
RMSD	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.2

Table 2. Statistical scores for data from automatic stations with Campbell-type sensors at one depth and data from SURFEX, ERA and ECMWF

Statistical parameters	ECMWF		SURFEX		ERA	
	S2	S3	S2	S3	S2	S3
Kardzhali						
ME	-0.01	-0.01	-0.07	-0.07	0.01	0.01
SD	0.08	0.09	0.09	0.09	0.08	0.08
CC	0.70	0.56	0.68	0.73	0.64	0.62
RMSD	0.29	0.08	0.19	0.19	0.31	0.08
Dam Yasna Polyana						
ME	-0.02	-0.02	-0.18	-0.18	0.35	-0.02
SD	0.05	0.04	0.09	0.09	0.38	0.04
CC	0.84	0.74	0.45	-0.29	0.76	0.67
RMSD	0.35	0.05	0.18	0.18	0.36	0.04
Kurtovo						
ME	0.17	0.17	0.00	0.06	0.16	0.16
SD	0.04	0.03	0.05	0.04	0.03	0.03
CC	0.76	-0.32	0.29	-0.43	0.78	0.82
RMSD	0.36	0.17	0.18	0.05	0.36	0.17
Shindara						
ME	-0.04	-0.04	-0.09	-0.09	0.02	0.02
SD	0.06	0.06	0.02	0.06	0.05	0.04
CC	0.64	0.44	0.50	-0.30	0.81	0.67
RMSD	0.28	0.08	0.19	0.10	0.34	0.05

- Soil moisture values from the four models are lower than those measured by the weight method at the agrometeorological network of NIMH and only the values from H-SAF are slightly higher than the measured ones (Table 3). Analyzing the Campbell sensors data such regularity is not observed.
- The prevailing value of the standard deviation when comparing with gravimetric data is 30%. The lowest value of this deviation is obtained by ERA and H-SAF at G. Chiflik, Karnobat, Yambol and Sliven, where the predominant soils are vertisols. When compared with Campbell sensors data the SD is much smaller, 8-9% (Table 3).

Table 3. Statistical scores for data from gravimetric measurements by location with modelled data and soil layers (S1; S2; S3)

	SURFEX			ERA			HSAF			ECMWF		
	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
Glavinitsa												
ME	-0.3	-0.3	-0.2	-0.3	-0.3	-0.2	0.1	0.0	0.1	-0.3	-0.2	-0.2
SD	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.4	0.3	0.3	0.3	0.2
CC	0.14	0.33	0.34	0.4	0.5	0.5	0.0	0.2	0.5	0.1	0.1	0.4
RMSD	0.4	0.4	0.3	0.4	0.4	0.3	0.4	0.4	0.3	0.4	0.4	0.3
G. Chiflik												
ME	-0.3	-0.2	-0.2	-0.2	-0.2	-0.3	0.2	0.2	0.2	-0.2	-0.2	-0.1
SD	0.2	0.2	0.2	0.2	0.2	0.3	0.1	0.1	0.2	0.2	0.1	0.2
CC	0.4	0.7	0.46	0.7	0.4	0.6	0.7	0.8	0.6	0.6	0.6	0.2
RMSD	0.4	0.3	0.3	0.2	0.2	0.4	0.2	0.2	0.3	0.2	0.2	0.2
Karnobat												
ME	-0.3	-0.2	-0.2	0.0	-0.1	0.0	0.1	0.1	0.1	-0.1	-0.1	-0.1
SD	0.2	0.2	0.2	0.2	0.2	0.0	0.2	0.2	0.1	0.2	0.3	0.2
CC	0.2	0.6	0.8	0.5	0.7	0.9	0.4	0.6	0.7	0.0	0.1	0.1
RMSD	0.4	0.3	0.2	0.2	0.2	0.0	0.2	0.2	0.2	0.2	0.3	0.3
Yambol												
ME	-0.2	-0.1	0.0	-0.2	-0.1	-0.1	0.1	0.1	0.2	-0.3	-0.3	-0.2
SD	0.0	0.2	0.1	0.2	0.2	0.1	0.2	0.2	0.1	0.3	0.3	0.1
CC	0.5	0.7	0.5	0.4	0.5	0.6	0.1	0.5	0.7	0.5	0.1	-0.4
RMSD	0.3	0.3	0.1	0.3	0.3	0.1	0.2	0.2	0.2	0.4	0.4	0.3
Sliven												
ME	-0.3	-0.3	-0.2	-0.2	-0.2	-0.2	0.1	0.1	0.0	-0.2	-0.2	-0.2
SD	0.2	0.2	0.2	0.2	0.3	0.3	0.2	0.2	0.2	0.2	0.3	0.3
CC	0.4	0.5	0.4	0.6	0.5	0.6	0.6	0.5	0.5	0.7	0.5	0.5
RMSD	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.3	0.4	0.4
Haskovo												
ME	-0.3	-0.1	-0.1	-0.2	-0.1	-0.1	0.0	0.2	0.2	-0.1	-0.1	-0.1
SD	0.2	0.3	0.3	0.2	0.3	0.3	0.0	0.3	0.2	0.2	0.3	0.3
CC	0.6	0.7	0.6	0.6	0.5	0.5	0.6	0.6	0.5	0.7	0.4	0.3
RMSD	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Kyustendil												
ME	-0.3	-0.3	-0.3	-0.1	-0.2	-0.2	0.1	0.1	0.0	-0.3	-0.3	-0.3
SD	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.3	0.3	0.2	0.2	0.3
CC	0.6	0.8	0.7	0.8	0.9	0.7	0.8	0.7	0.3	0.7	0.8	0.1
RMSD	0.4	0.4	0.4	0.3	0.3	0.3	0.2	0.2	0.3	0.4	0.4	0.4

- The highest correlation values are registered for the data from ERA model. Very good correlation values between measured and H-SAF values are observed for Kyustendil, where cinnamon and brown forest soils are the predominant soil types. Slightly lower, yet statistically significant, are the correlation coefficient at Haskovo, where there is a well-expressed variety of soils - cinnamon, brown and resin soils.

3.3. Verification of the diagnostic and forecast information

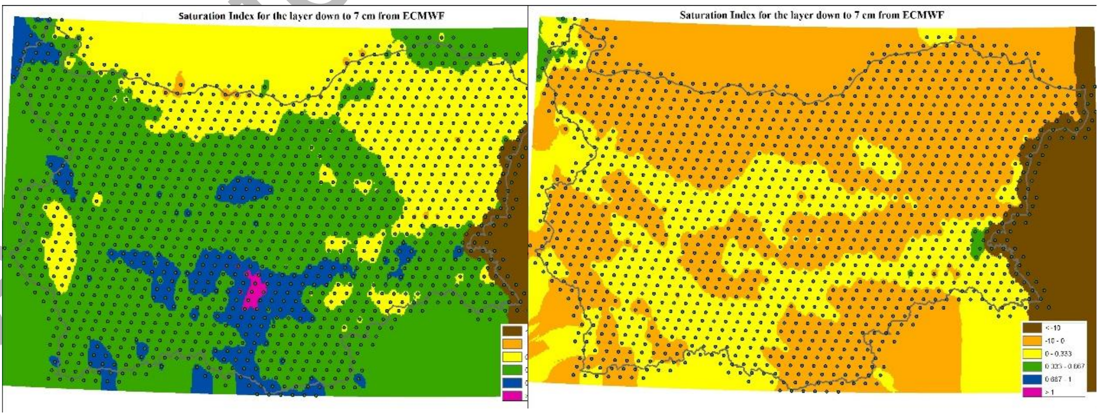
The received diagnostic and forecast information was compared with gravimetric data from the Agrometeorological network and from automatic stations measurements. The statistical scores are presented in Table. 4.

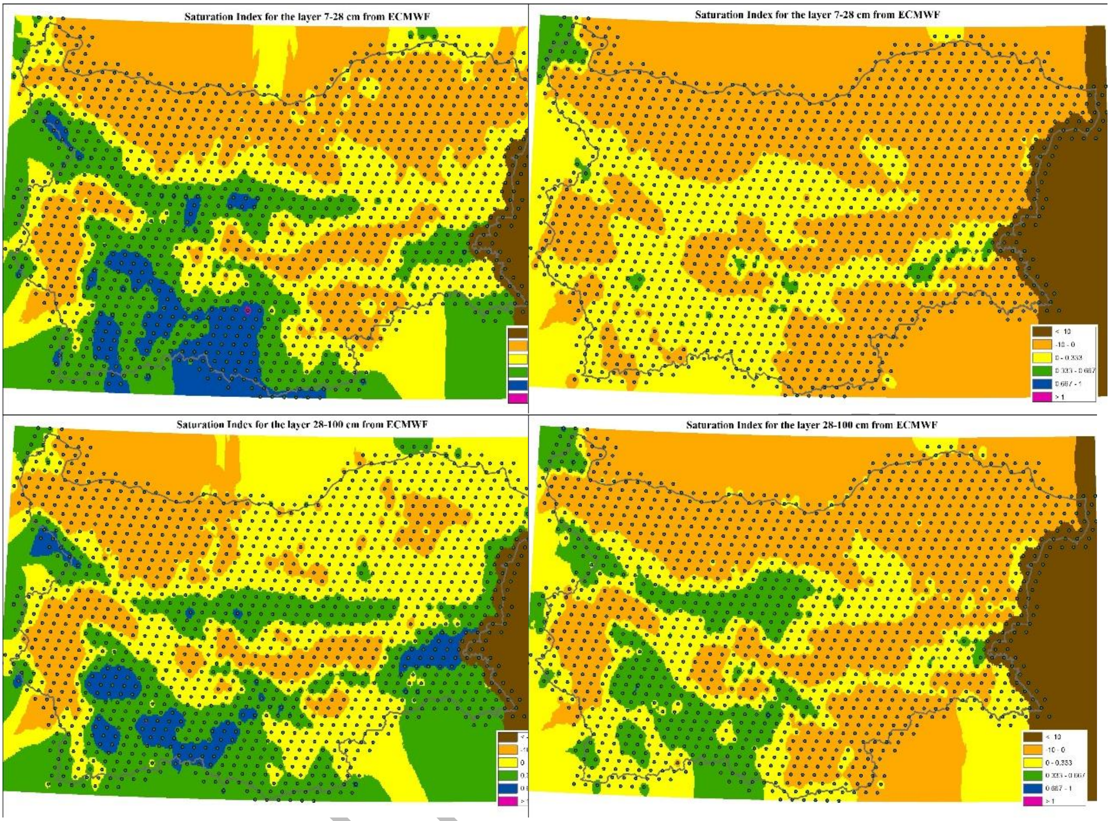
Table 4. Statistical scores of the comparison of data from gravimetric measurements with model data – averaged

	SURFEX			ERA			HSAF			ECMWF		
	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
ME	-0.28	-0.22	-0.15	-0.15	-0.19	-0.18	0.10	0.09	0.11	-0.21	-0.21	-0.20
SD	0.25	0.25	0.21	0.22	0.23	0.22	0.18	0.23	0.21	0.24	0.25	0.23
CC	0.40	0.61	0.47	0.60	0.56	0.64	0.47	0.54	0.53	0.40	0.35	0.22
RMSD	0.37	0.33	0.25	0.27	0.29	0.28	0.26	0.26	0.25	0.31	0.34	0.32

3.4. Evaluation of the soil saturation by Saturation Index and Soil Water Availability (%FC).

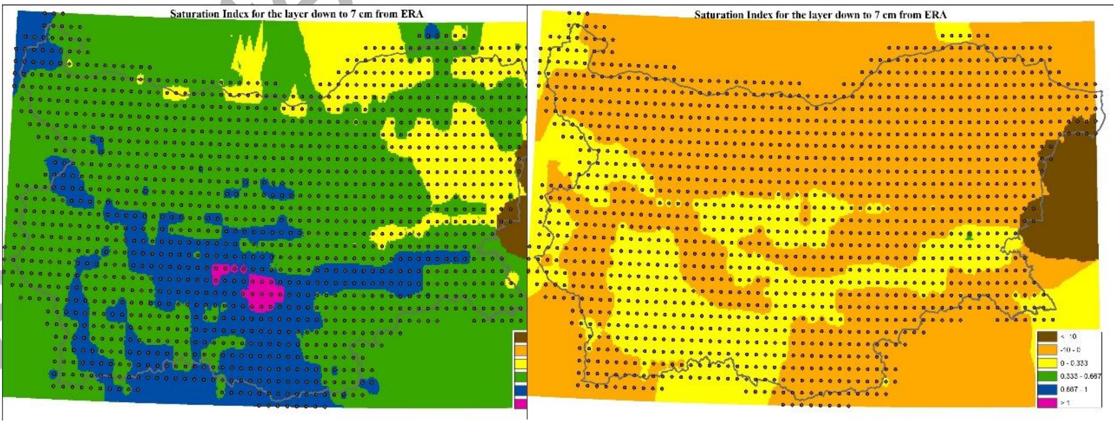
The graphical representation of the calculated level of soil saturation and relative soil moisture for different soil layers is shown on Figures 1-6.

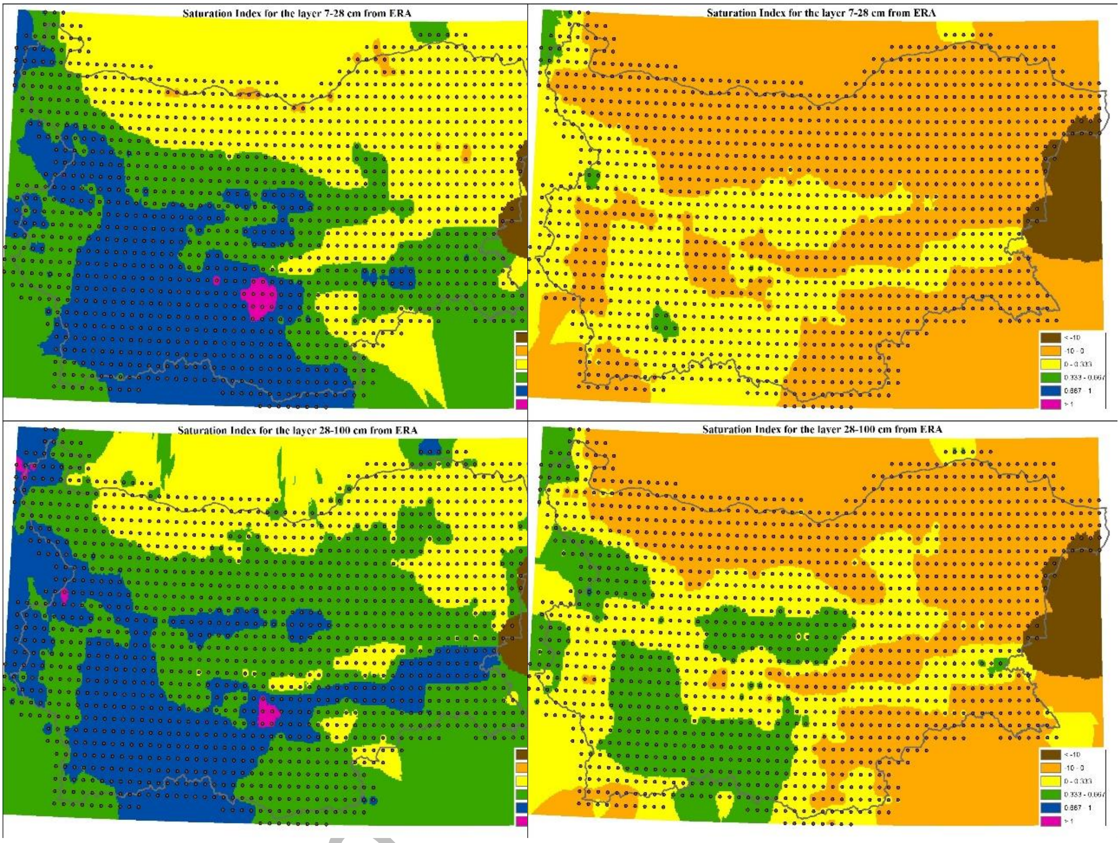




10.04.2019 05.09.2019

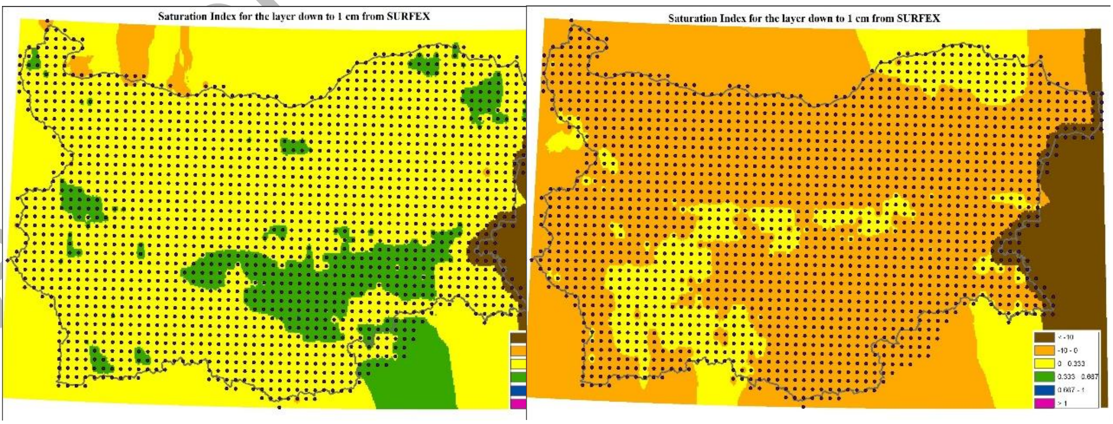
Fig. 1. Distribution of the Saturation Index with data from ECMWF for a wet date (10.04.2019) and a dry date (05.09.2019) for three depths – 0-7 cm, 7-28 cm and 28-100 cm

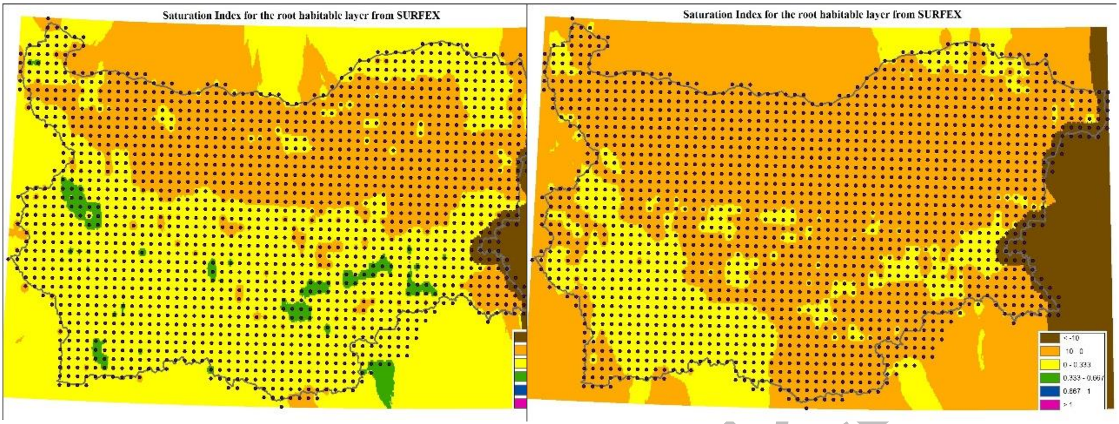




10.04.2019 05.09.2019

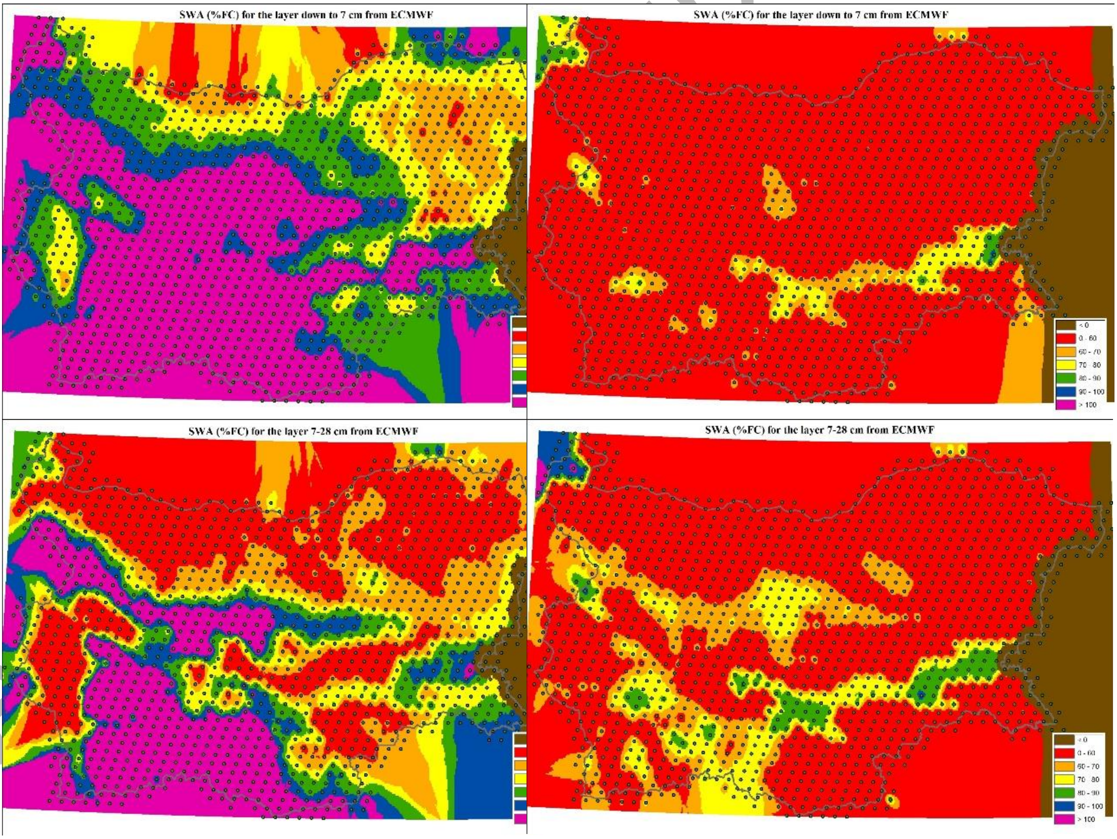
Fig. 2. Distribution of Saturation Index data from ERA for wet (10.04.2019) and dry date (05.09.2019) for three depths: – 0-7 cm, 7-28 cm and 28-100 cm

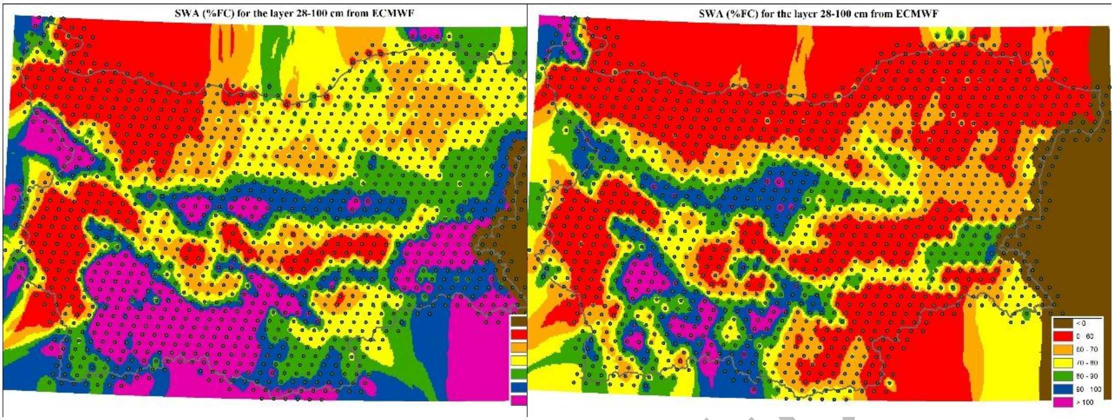




10.04.2019 05.09.2019

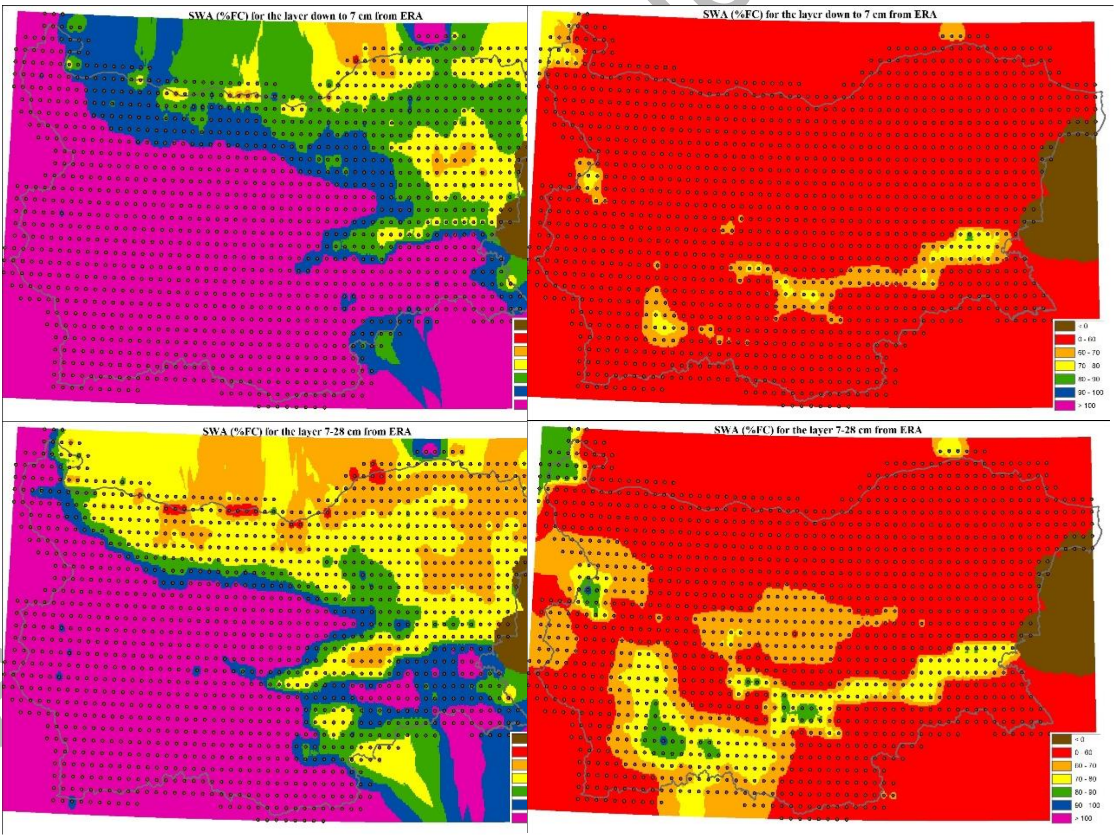
Fig. 3. Distribution of Saturation Index with data from SURFEX for a wet (10.04.2019) and a dry date (05.09.2019) for two depths – 0-1 cm, and a root layer

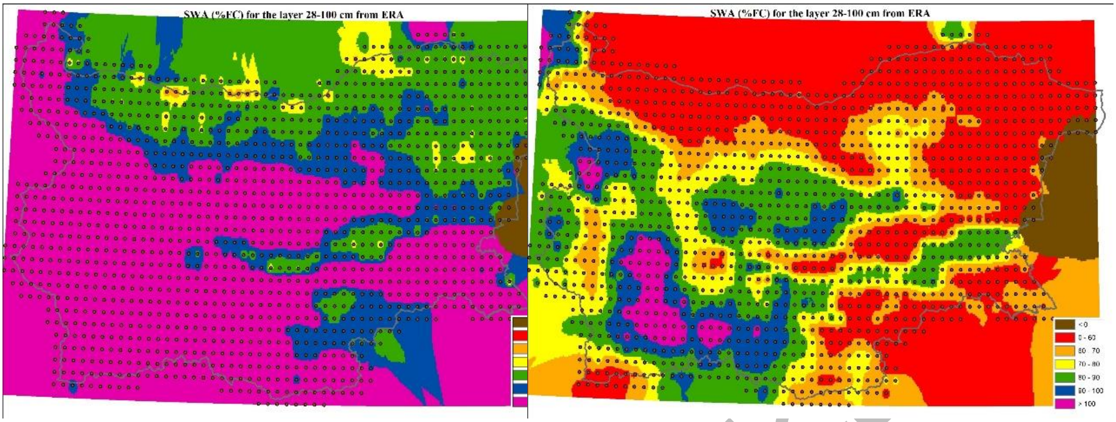




10.04.2019 05.09.2019

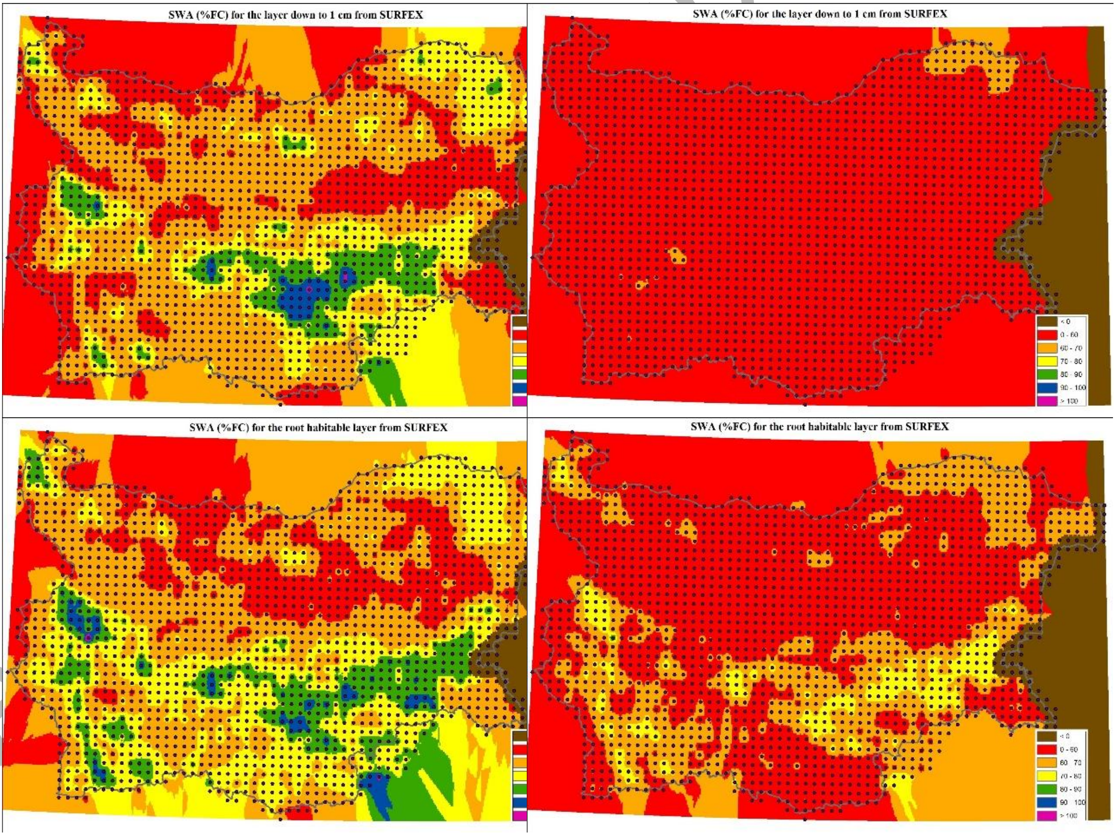
Fig. 4. Distribution of Soil Water Availability (%FC) with data from ECMWF for a wet (10.04.2019) and dry date (05.09.2019) for three depths – 0-7 cm, 7-28 cm and 28-100 cm





10.04.2019 05.09.2019

Fig. 5. Distribution of Soil Water Availability (%FC) with data from ERA for wet (10.04.2019) and dry date (05.09.2019) for three depths – 0-7 cm, 7-28 cm and 28-100 cm



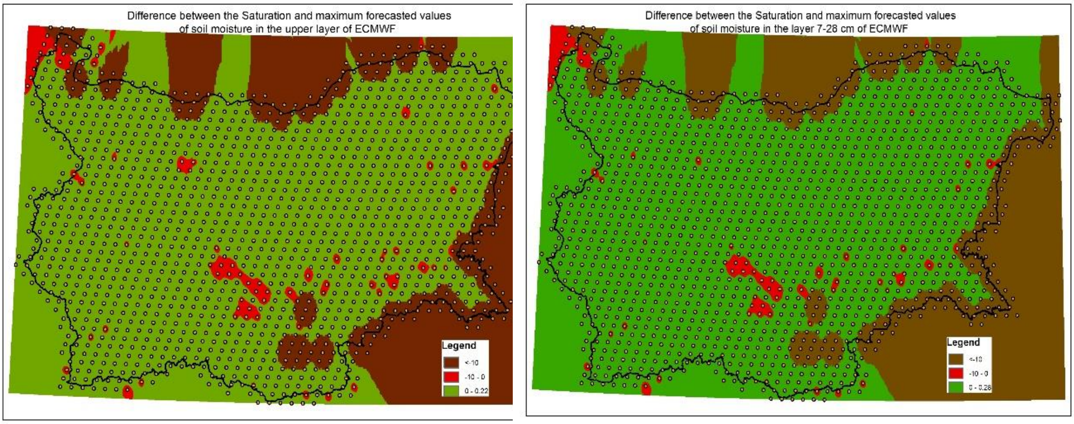
10.04.2019 05.09.2019

Fig. 6. Distribution of Soil Water Availability (%FC) with data from SURFEX for wet (10.04.2019) and dry date (05.09.2019) for two depths - 0-1 cm and root layer

The analysis of the results regarding the degree of saturation on 10.04.2019 and 05.09.2019 shows that Saturation Index successfully represents the case of high humidity (10.04.2019) with both ERA and SURFEX data for the surface layer, except some regions in the Thracian valley (Figure 1-6). The SWA represents the dry cases (05.09.2019) comparatively well, except in the mountain regions.

On the maps there are areas with saturation index values higher than 1 and lower than 0, which suggests there are incorrect values of the hydrological constants. That is why a selection on the minimum and maximum values for each point was done and maps were drawn for the Saturation Index (Figure 7). Zones with values greater than those of the FC are outlined mainly in Northwestern Bulgaria. Zones with valus lower than the WP are located mainly in central and eastern part of Southern Bulgaria. The former are fewer and the latter cover vast areas.

The maximum and minimum values of the forecasted data from ECMWF and the diffrence between SAT and WP were selected. In Figure 7 the results of those differeces for the upper two layers are presented. These results were obtained with the information about the hydrological constants (SAT, WP and FC) obtained from the FAO database.



a) b)

c) d)

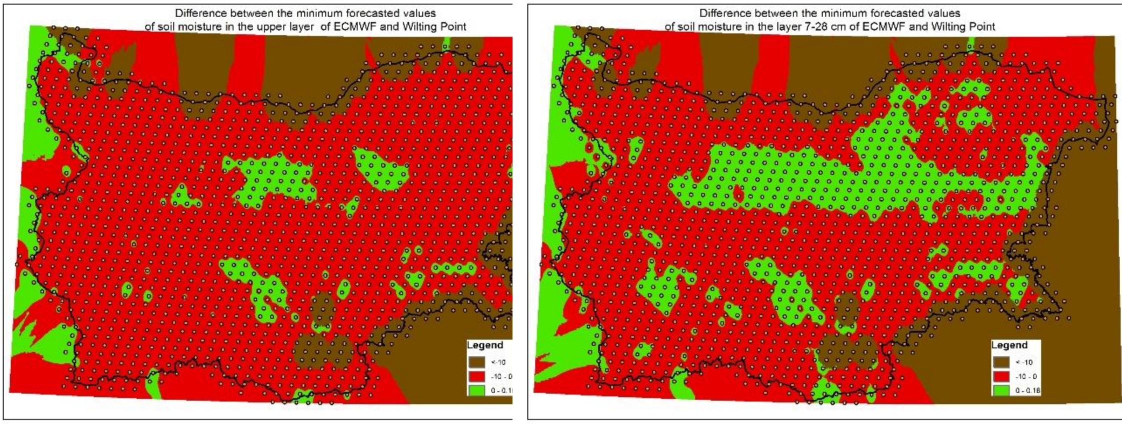


Fig. 7. Differeces for the two upper layers between: (a) and (b) SAT constants and the maximum ECMWF forecasted data values; (c) and (d) minimum forecasted ECMWF data values and WP constants

The spatial distribution of the differences between minimum and maximum forecasted values and SAT and WP shows that the minimum values are smaller for almost all the country. Better results are obtained with the data for SAT constants and the maximum values (Figure 7a and Figure 7b). Most of the territory with negative differences is in Southern Bulgaria. This could be explained with the fact that much of this territory consists of water body covearage (lakes and dams). When the maximum forecasted values exceed the SAT constant, both values are very close to each other.

The results for the differences between FC and the maximum ECMWF values are not presented as they are negative for the whole country.

A comparison with hydrological constants derived from the other database (ESDAC) was also done, showing good statistical results as well. In order to use the ECMWF forecast data in the operational practice at NIMH additional analyses and data processing of the forecasted values and the soil phisical charcteristics should be performed.

4. CONCLUSIONS

The results obtained within this study certainly define a solid basis to expand the research in this field. The application of data from ERA, H-SAF, SURFEX and ECMWF in the operational practice for the purposes of agrometeorological and hydrological forecasts for soil moisture in the root layers and assessment of the occurrence and development of drought and floods should broaden.

For improving the correlation between contact, contactless and numerical methods for determining the soil water content the following key remarks should be considered:

- improving the accuracy of soil moisture definition for all layers, SURFEX model for 0-1 cm layer and root habitable layer, HSAF in the 0-7 cm layer and ECMWF data in all layers in particular. The accuracy in the determination of soil moisture should be near or better than 0.04 m³/m³;

- updating the values of the hydrological constants for the soil types in Bulgaria;
- the updated values of the hydrological constants (FC and WP) to become available through the national and European soil database – ESDAC.

REFERENCES

EUROPEAN SOIL DATA CENTRE (ESDAC), ESDAC. JRC. EC. EUROPA. EU, European Commission, Joint Research Center, https://esdac.jrc.ec.europa.eu/

Bosch, D.D., Lakshmi, V., Jackson, T.J., Choi, M., Jacobs, J.M. (2006) Large scale measurements of soil moisture for validation of remotely sensed data: Georgia soil moisture experiment of 2003, Journal of Hydrology, 323 (1–4), 120-137, https://doi.org/10.1016/j.jhydrol.2005.08.024

Gruber, A., De Lannoy, G., Albergel, C., Al-Yaari, A, Brocca, L., Calvet, J.-C., Colliander, A., Cosh, M., Crow, W., Dorigo, W., Draper, C., Hirschi, M., Kerr, Y., Konings, A., Lahoz, W., McColl, C. Montzka, J. Muñoz-Sabater, J., Peng, R., Reichle, P., Richaume, C., Rüdiger, T., Scanlon K., van der Schalie, R., Wigneron, J.-P., Wagner, W. (2020) Validation Practices for Satellite Soil Moisture Retrievals: What Are the Errors? J. of Remote Sensing of Environment, vol. 244, 2020, https://doi.org/10.1016/j.rse.2020.111806

Houser, P. R., Shuttleworth, J. W., Famiglietti, J. S., Gupta, H., Syed, K. H., Goodrich, D. (1998) Integration of Soil Moisture Remote Sensing and Hydrologic Modelilg Using Data Assimilation, Water Resources Research, 34 (12) 3405-3420, DOI: 10.1029/1998WR900001

Panagos, P., Van Liedekerke, M., Jones, A., Montanarella, L. (2012) European Soil Data Center: Response to European Policy Support and Public Data Requirements, Land Use Policy, 29 (2), 329-338. DOI: 10.1016/J.landusepol.2011.07.003

Stoyanova, S. (2021) Hydrological Modelling for Water Balance Components Assessment, XXIX Conference of the Danubian Countries, Sep. 6-8, 2021, Brno, Conf. Proc., Prague 2021, p. 119-120.

Wenlong Jing, Jia Song and Xiaodan Zhao (2018) Validation of ECMWF Multi-Layer Reanalysis Soil Moisture Based on the Oznet Hydrology Network, MDPI, Water 2018, 10, 1123; DOI: 10.3390/W10091123

Yordanova, V. and Stoyanova, V. (2020) Modeling floods with a distributed hydrological model in a river catchement, 20th International Multidisciplinary Scientific Geoconference, Volume 2020 (3.1) 249-255