Soil moisture analysis in Slovakia during storm Boris in September 2024 using H-SAF H26 product and in situ observations

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EUMETSAT H SAF SUPPORT TO OPERATIONAL HYDROLOGY AND WATER MANAGEMENT

SHMÚ SLOVENSKÝ HYDROMETEOROLOGICKÝ ÚSTAV

Introduction

Between **13th and 15th September 2024**, **Central Europe was affected by a low-pressure system named Boris**. This low-pressure system brought record-breaking rainfall and severe flooding in parts of Austria, Czechia, Hungary, Poland and Slovakia.

Storm Boris, originated as an Atlantic frontal system that formed and intensified over the exceptionally warm waters of the Mediterranean. It moved rapidly northeastward, producing very intense precipitation, with rainfall totals of 200-300 mm over vast areas and locally exceeding 400 mm.

From Slovak hydrological point of view significant floods occurred throughout Central Europe in the **Danube and Morava river basins**. In the Czech Republic, Poland and Austria, they were accompanied by high material damage and, unfortunately, loss of human life. In Slovakia, the basins in its western part were mainly affected, namely the Morava river basin and its tributaries, the Danube river basin, Kysuca and part of the Little Carpathian tributaries of the Little Danube.

This poster takes a closer look on the development of soil moisture using HSAF H26 product and analyzes how well it performed during these extreme weather conditions in comparison to in situ AWS observations of soil moisture made by Slovak Hydrometeorological Institute (SHMÚ).

Methods

For our analysis we used product H26 from H-SAF. H26 product is near-real-time root zone soil moisture profile index with **10 km resolution** in 4 different depth layers (**0-7 cm, 7-28 cm, 28-100cm, 100-289 cm**). H26 product is calculated each 24 hours with timeliness of 12 hours.

The H26 product assimilates ASCAT-B/C satellite-derived surface soil moisture into the H-TESSEL land surface model. This assimilation propagates the surface signal through the soil column to derive a four-layer root-zone soil wetness index at 10 km resolution, expressed on a 0–1 scale, which we transformed into percentage. The model accounts for three key factors: soil texture (e.g., clay, sand, loam), land cover and vegetation, and meteorological conditions (precipitation, temperature, etc.).

We compared the satellite-derived soil moisture data with ground-based observations from automatic weather stations (AWS) in Slovakia. AWS data, originally reported as ***Volumetric Water Content*** (VWC), were converted to the ***Soil Water Index*** (SWI) used by H26. This conversion required knowledge of two soil parameters:

- **Wilting point**: the minimum soil moisture level below which plants cannot extract water from soil
- **Field capacity**: the maximum amount of water soil can hold after excess water has drained

Because exact soil parameter values for each AWS site were unavailable, we used generalized values representative of each station's surrounding area.

Results

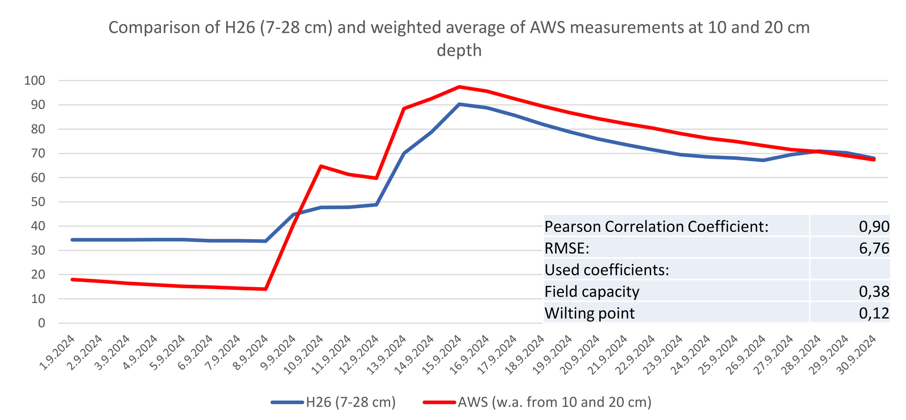

Fig. 1: Comparison of H26 soil moisture estimates (7–28 cm) with the weighted average of in situ measurements obtained from automated weather stations (AWS) at 10 cm and 20 cm depths. The graph illustrates a systematic overestimation of soil moisture by the H26 method during dry conditions, while a slight underestimation is observed during wetter periods.

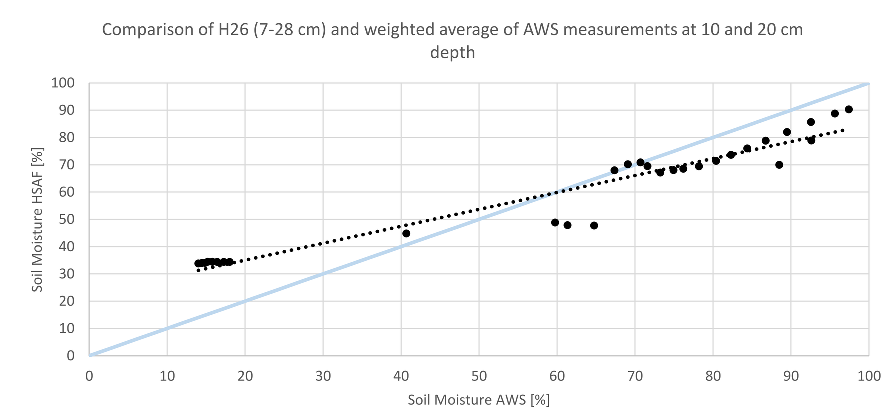

Fig. 2: Comparison of H26 (7-28 cm) and weighted average from in situ measurements from depths 10 and 20 cm. Points from H26 product connected with linear trend line, should be a little bit steeper to fit the in situ measured data.

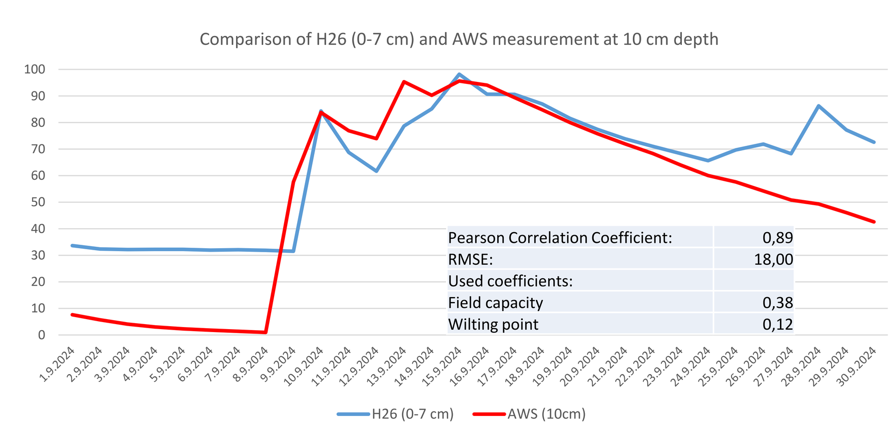

Fig. 3: Comparison of H26 (0-7 cm) with in situ measurement at 10 cm depth. 0-7 cm depth H26 product fits better in situ measurements in wet conditions than 7-28 cm product, but overestimates soil moisture even more during dry periods.

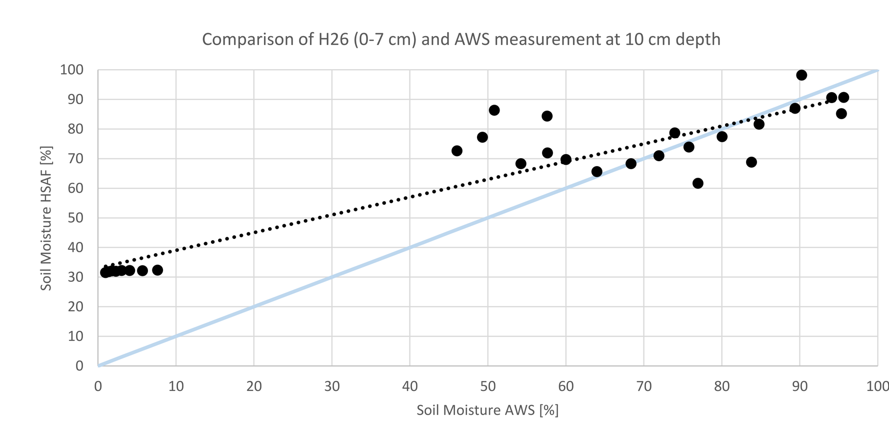

Fig. 4: Comparison of H26 (0-7 cm) with in situ measurement at 10 cm depth. Visualisation of better fit of H26 data to in situ measurements during wet periods in this depth, but strong overestimation during dry periods.

Discussion

H26 product reflected well the high precipitation in central Europe during storm Boris. We can observe the development of SWI on the sequence of images provided below on *Fig.5*. The upper soil level (0-7 cm) SWI value started rising on the 13th of September, which was the first day of heavy rainfall from storm Boris.

On the other hand, it can be observed that deeper soil level (28-100 cm) has a delay of approximately 3 days, as we see the SWI rising in the west part of Slovakia in the Little Carpathians region on the 16th of September.

When we look at the deepest level (100-289 cm), there are barely measurable changes in H26 derived SWI and we can not compare these to our in-situ measurements, as in situ data are only available up to 50 cm depth.

Looking at figures 1 to 4 we see graphical comparison of SWI derived from satellite measurements and from AWS. In *Fig.1* and *Fig.2* we used **weighted average** of 10 and 20 cm in-situ measurements by AWS so we could compare these values with H26 (depth 7-28 cm). The values of SWI from H26 were overestimated for dry period at the beginning of the month and slightly underestimated during the heavy rainfall period. The Pearson correlation coefficient for this comparison method is **0,90.** On *Fig.3* and *Fig.4,* where we **directly compared** H26 (0-7 cm) with our 10 cm AWS observations, we observe even bigger overestimation of SWI by H26, however during wet period of the month, with SWI above 60%, H26 fits very well values from AWS, with Pearson correlation coefficient **0,89**.

On *Fig.6* (bottom-left) we observe temporal evolution of spatial distribution of soil moisture classes across Slovakia

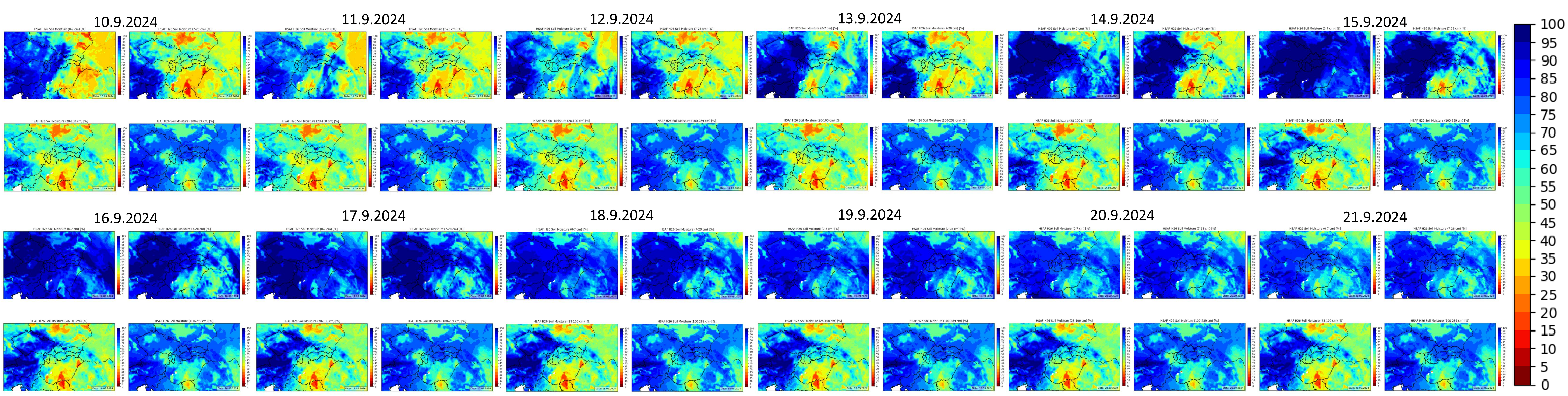

Fig. 5: This sequence of map visualizations of H26 product over Slovakia and neighboring countries displays the development of soil moisture from 10th of September 2024 until 21st of September 2024. For each day we have 4 images showing soil moisture from different depth level: Top-left –> 0-7 cm; top-right -> 7-28 cm; bottom-left -> 28-100 cm; bottom-right -> 100-289 cm. The color scale is in percentage of SWI and you can see it on the right-hand side.

Dry conditions prevailed over most of the country, with around two-thirds of the territory falling within the 30–40 % soil moisture class at the beginning of the month. On 13th of September an abrupt increase in soil moisture was observed—up to 90 % of the area reached saturation levels within the 90–100 % class. This reflects the impact of a widespread and intense precipitation event. In the following days, soil moisture conditions remained elevated, predominantly within the 60–90% range.

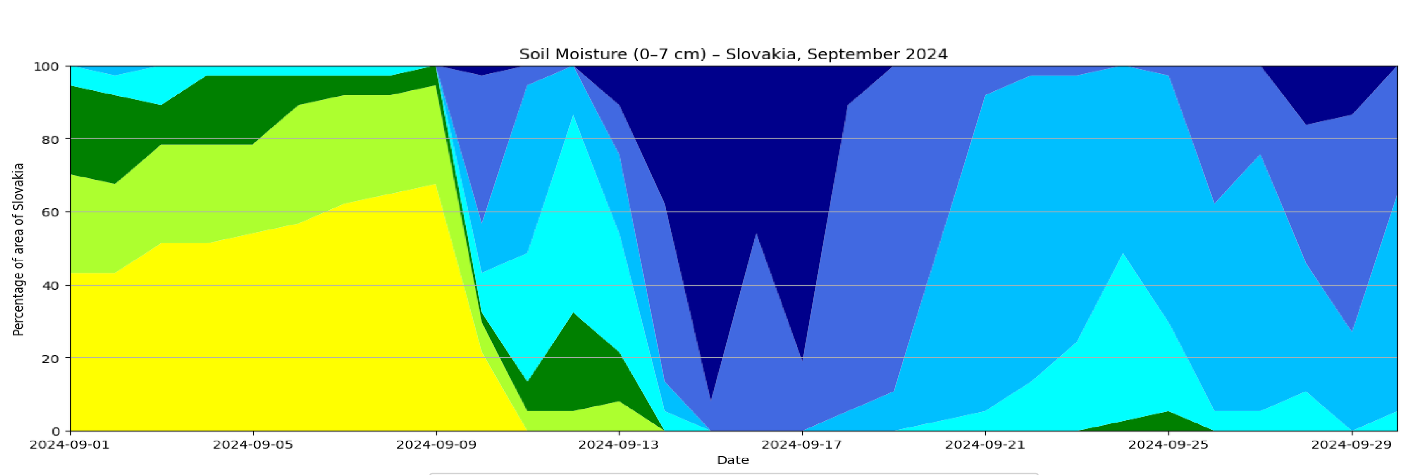

Fig. 6: Temporal evolution of the spatial distribution of soil moisture classes in the surface layer (0-7cm) across Slovakia

Conclusion

This study investigates the temporal and spatial variability of soil moisture across Slovakia during September 2024, focusing on the impact of storm Boris, using the newest EUMETSAT H-SAF H26 soil moisture product and in situ measurements from automated weather stations (AWS). The H26 product assimilates ASCAT-B/C satellite-derived surface soil moisture into the H-TESSEL land surface model.

The analysis captures a sharp transition from dry conditions dominating early September to widespread saturation of soil moisture levels in Slovakia following storm Boris around 9 September.

Comparative analysis with AWS measurements (10 and 20 cm depths) indicates systematic overestimation of soil moisture by H26 during dry conditions and closer agreement during wet periods. The surface layer (0–7 cm) of the H26 product showed the best correlation with in situ data under wet conditions, while still overestimating in dry scenarios.

These findings confirm the utility of the H26 product for high-resolution, near-real-time monitoring of soil moisture (timeliness of 12 hours), and highlight its potential for operational hydrology and landslide potential detection —particularly under wet conditions—while also pointing to the need for adjustments or bias corrections in drier regimes over Central Europe.