Assessment of soil surface water resources from SMOS satellite and in situ measurements in changing climatic conditions

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Introduction

The SMOS (Soil Moisture and Ocean Salinity) mission is a direct response to the current lack of global observations of soil moisture (SM) and ocean salinity which are needed to develop our knowledge about the water cycle and to contribute to better weather and extreme-event forecasting.

The SMOS mission is the ideal framework to capitalize the often fragmented efforts of the experts working in all research areas connected to climate change and regional planning. The spatial resolution of SMOS (pixel size) is about 45×45 km and revisit time on every fixed place is approximately not less than 3 days. Precision of soil moisture measurements is claimed to be 0.04 m^3 m^{-3}.

Soil moisture is inherently consistent in time and space, but its validation is still a challenge for further use in the climate and hydrology studies.

Methods

The SMOS uses observation method of soil moisture and ocean salinity, based on radiometric measurement of the brightness temperature in the spectral range 1.400-1.427 GHz.

The Institute of Agrophysics participates in the validation of SMOS by conducting ground-based measurements of soil moisture, using the SWEX_POLAND network of automatic ground monitoring stations localized in the Eastern Poland (Fig. 1).

Several methods of comparison have been used, for example the Bland-Altman method, concordance correlation coefficient and total deviation index.

Results

The resulting maps of the distribution of soil moisture for the Poland show considerable spatial variability of soil moisture.

In the central part moisture values were in the range from about 0.05 to 0.20 m^3 m^{-3}. The high moisture content, up to 0.4 m^3 m^{-3}, was observed in the regions of north-eastern and western borders of Poland.

Fig 1. SWEX_POLAND network of automatic ground monitoring stations

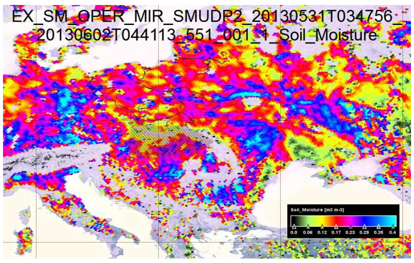


Fig 2. Weekly average of spatial distribution of surface soil moisture in the region of central Europe (starting from 31.05.2013)

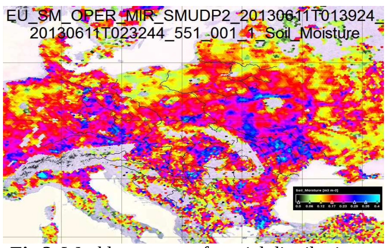


Fig 3. Weekly average of spatial distribution of surface soil moisture in the region of central Europe (starting from 11.06.2013)

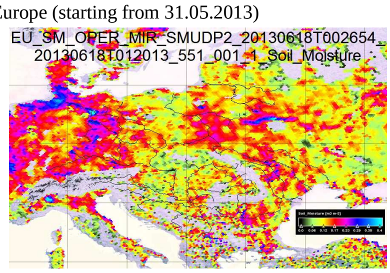
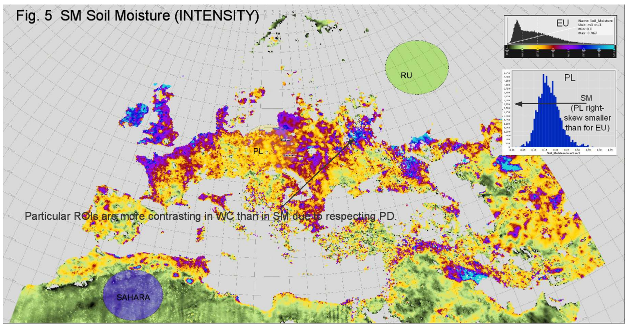


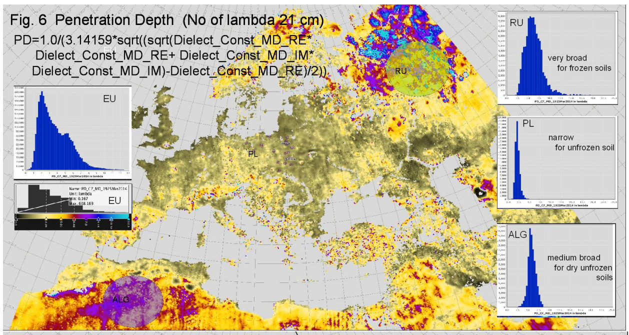
Fig 4. Weekly average of spatial distribution of surface soil moisture in the region of central Europe (starting from 18.06.2013)

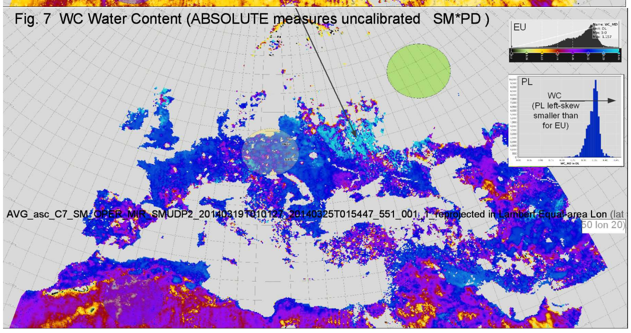
In 2013, Germany, Poland, Czech Republic and Slovakia, as many other countries in Europe, had experienced long and snowy winter. Spring thaw led to soaked soils, which are clearly depicted by SMOS image taken at the end of May 2013 (Fig. 2).

Soil moisture in central Germany, reached even up to 0.4 m^3 m^{-3} (the highest ever observed on this area). Then heavy rains occurred, which caused catastrophic floods in Germany and Czech Republic. Figure 3 shows surface soil moisture the week after. The next week (starting from 18.06.2013) was drier, especially in Czech Republic and Slovakia, but some floods on Elbe (Labe) river were still visible (Fig. 4).

Only the soil moisture (Fig. 5) is not sufficient information to obtain absolute surface water mass, because the exact depth (”Penetration Depth” - PD) to which SMOS ”sees” soil moisture is not known. Penetration Depth depends on many factors, such as the soil physical parameters and soil moisture itself. By the principle of thermodynamic equilibrium, Penetration Depth should be definitively achievable from the identity of values for emissivity=absorptivity. Basing on that assumption, spatial distribution of PD was obtained (Fig. 6).







Penetration Depth values are expressed in the number of wavelengths (=21 cm) and seems to be exaggerated because in Europe and unfrozen soils fall in the range 40 – 50 cm. Penetration Depth for permafrost in Russia can fall in the range up to 55 lambda in winter conditions, and gain 5 to 8 lambda for dry areas of deserts. Unfrozen soils in wet and very wet areas, indicate Penetration Depth equal to about 2 lambda. All that proves that Penetration Depth values are varying in proper directions but seems to be untruthful yet for ice and wet snow media. This is the reason for our attempt with ELBARA – the instrument that is capable to validate obtained PD’s. ELBARA is L-band radiometer, similar to SMOS satellite antenna, but has only 1 receiver instead of SMOS’s 69 and is mounted on tower, few meters above examined soil surface.

By multiplying Soil Moisture by Penetration Depth we obtained absolute, but not calibrated spatial distribution of surface Water Content (Fig. 7). Histograms for contrasting regions of interest (ovals in Fig. 5-7: RU-Russia, PL-Poland, ALG-Algieria) were chosen to derive histograms and compare them to the area of whole Europe (EU). Particular regions of interests are more contrasting in Water Contents than in Soil Moistures due to different Penetration Depths.

Conclusions

Different comparison methods confirmed a moderately good agreement of SMOS data and soil moisture network observations on the ground.

The gathered results are the most representative source of current information of water resources in the soil surface layer. The data are valuable for climate change modelling, hydrology, environmental evaluations, assessments of droughts and floods in regional planning.

Results are countable from intensity measures and for practical purposes should be adopted to absolute measures as soon as possible.

Acknowledgments

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