Modelling of the L-band brightness temperatures measured with ELBARA III radiometer on Bubnow wetland

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Introduction

Microwave radiometry has become the main tool for investigating soil moisture (SM) with remote sensing methods. ESA – SMOS (Soil Moisture and Ocean Salinity) satellite operating at L-band provides global distribution of soil moisture. An integral part of SMOS mission are calibration and validation activities involving measurements with ELBARA III which is an L-band microwave passive radiometer. It is done in order to improve soil moisture retrievals – make them more time-effective and accurate. The instrument is located at Bubnow test-site, on the border of cultivated field, fallow, meadow and natural wetland being a part of Polesie National Park (Poland). We obtain both temporal and spatial dependences of brightness temperatures for varied types of land covers with the ELBARA III directed at different azimuths. Soil moisture is retrieved from brightness temperature using L-band Microwave Emission of the Biosphere (L-MEB) model, the same as currently used radiative transfer model for SMOS. Parametrization of L-MEB, as well as input values are still under debate.

Results

One of the indices which is often used to reflect temporal changes of brightness temperatures, T_B, is polarization ratio (for a certain elevation angle θ) defined as:

$$PR_\theta = (T_{B,V,\theta} - T_{B,H,\theta})/(T_{B,V,\theta} + T_{B,H,\theta})$$

After the precipitation event *PR* increase on bare soil. It emerges directly from the change of dielectric constant of moisturized ground. On the other hand, decrease in *PR* is often related to the interception effects of vegetation or litter layer. In the fig. 1 we show spatial dependences of PR_{60} for Bubnow test-site before and after precipitation event.

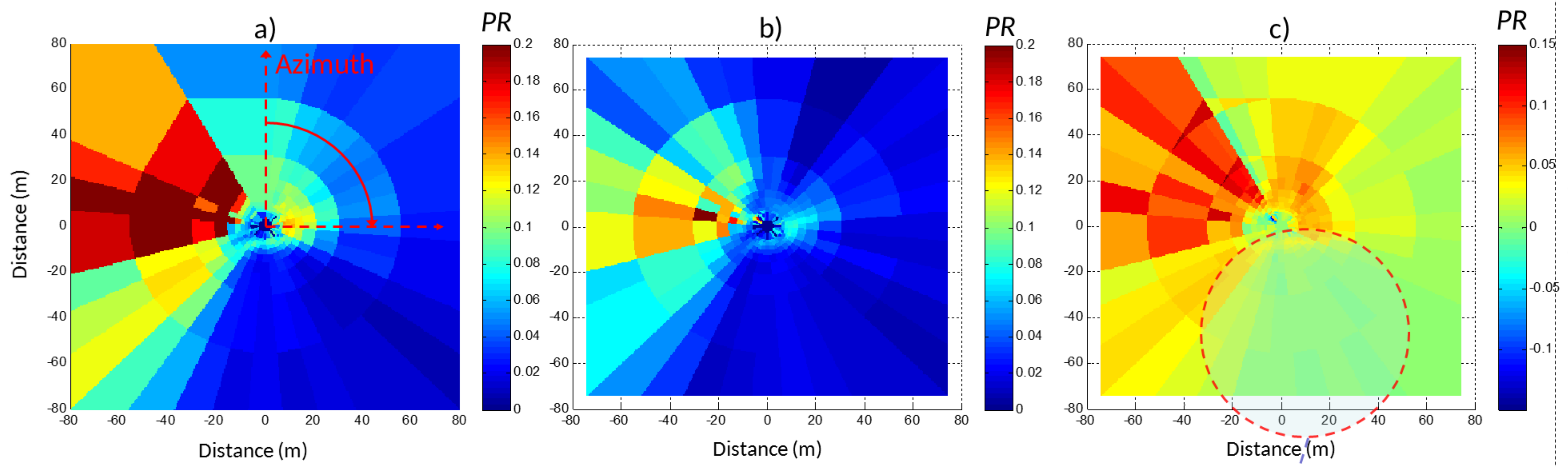

Figure 1. Spatial dependences of polarization ratio (PR) values obtained for different aziumths. Data taken for dry conditions a) and wet conditions b) for 28th July 2016. Figure 1 c) shows PR_{DRY} –PR_{WET}.

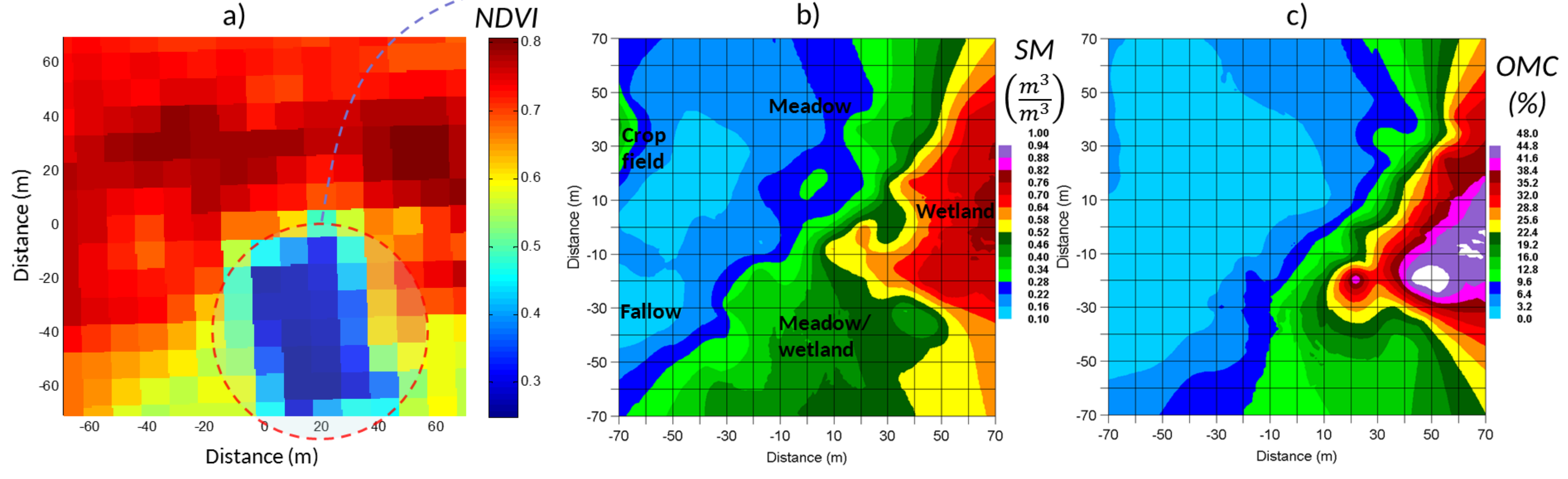

Figure 2. Characterization of the Bubnow test-site by means of a) NDVI (5th August 2016), b) soil moisture (5th May 2016) and c) organic matter content (OMC).

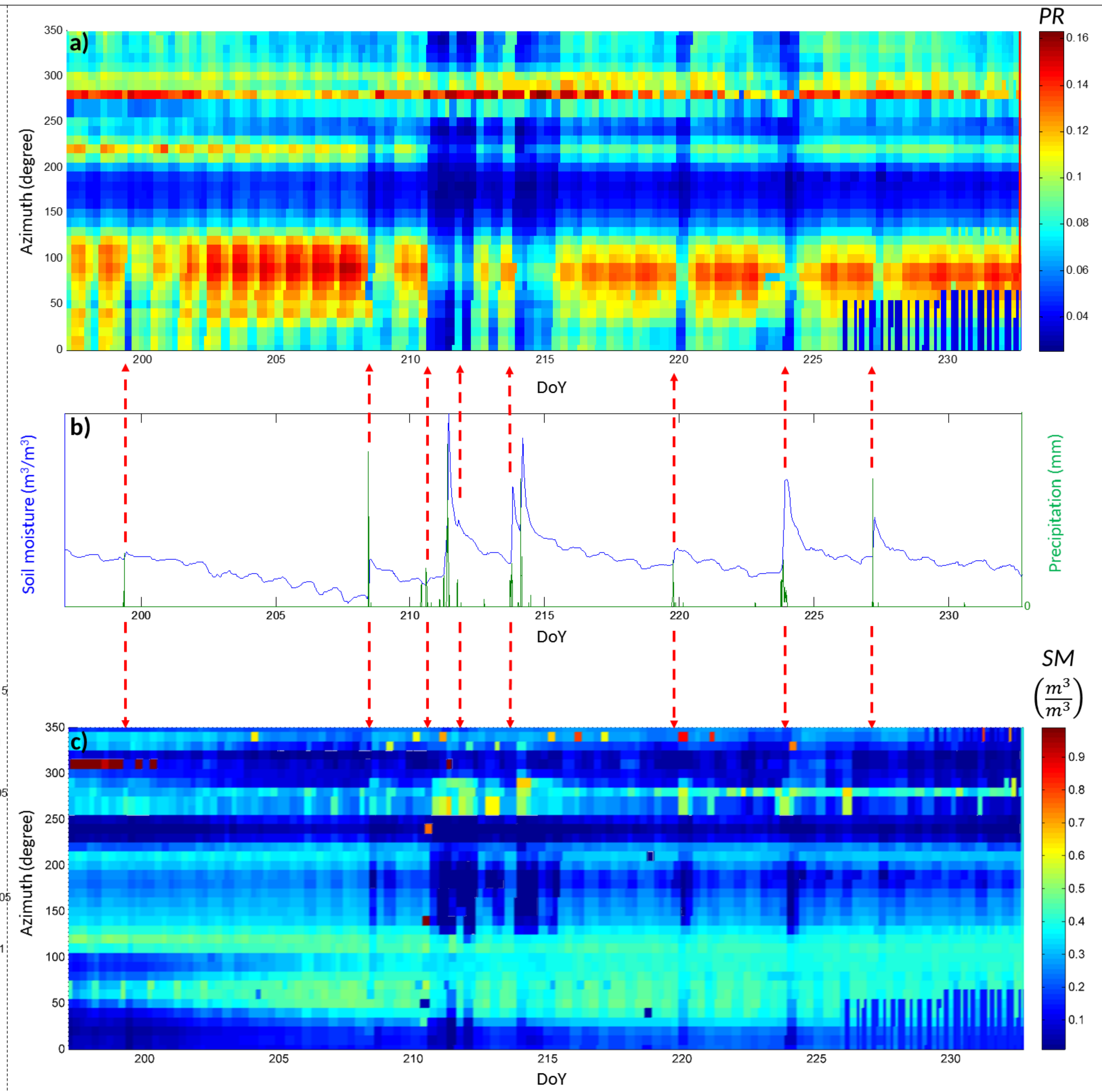

Figure 3. Spatio-temporal dependences of PR_{60} values obtained for different aziumths a) related to the temporal changes of soil moisture and precipitation b). Figure c) shows spatio temporal evolution of soil moisture (SM) retrieved from L-MEB (SRP) model depending on the azimuth angle. The elevation angles used for L-MEB studies are 45°-70°.

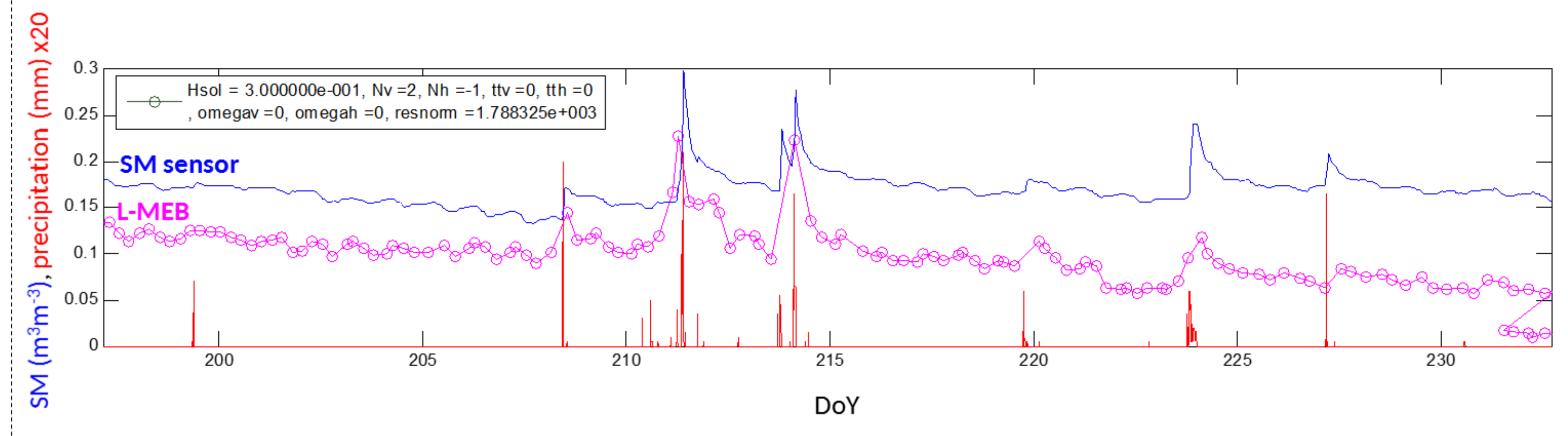

Figure 4. Temporal dependences of SM measured with a sensor and retrived with L-MEB model. Narrow vertical lines indicate precipitation events. SM values obtained from microwave brightness temperatures measured at azimuth angle 290°. The retrieval has been done assuming T_{GC}, τ_{nad} and SM as free parameters while H_r = 0.3.

<u>L-MEB model</u>

The current discription of microwave radiative transfer used for SMOS soil moisture retrieval is based on L- band Microwave Emission of the Biosphere model. Brightness temperatures emitted by soil covered by vegetation layer can be expressed as:

$$T_{B,P} = (1-\omega_P)(1-\gamma_P)(1+\gamma_P\Gamma_{GP})T_C + (1-\Gamma_{GP})\gamma_P T_G.$$

Assuming the scattering albedo ω_P = 0 (P=H,V), T_C (canopy temperature) = T_G (ground) the equation can be rewritten as follows:

$$T_{B,P} = \left(1-{\gamma_P}^2\Gamma_{GP}\right)T_{GC}.$$

Where T_{GC} is a ground-canopy effective temperature, and γ_P is vegetation transmissivity derived from the Beer law:

$$\gamma_P = \exp\left(-\frac{\tau_{nad}(\sin^2\theta\, tt_P + \cos^2\theta)}{\cos\theta}\right),$$

Γ_{GP} is Fresnel equation for specific polarization P modified by roughness parameter H_r:

$$\Gamma_{GP} = \Gamma^*_{GP}\exp\left(-H_r \cos^{N_P}\theta\right).$$

Combination of vegetation and roughness effects assumes N_P =-1 and tt_P = 1, then T_r = τ_{nad}+H_r/2 (Simplified Roughness Parametrization – SRP approach). Dielectric constant of soil, as input to Fresnel equations are calculated using Mironov model using clay percentage, temperature and soil moisture.

Discussion

The values of PR shown in Fig. 1 indicate diverse character of the ground depending on the chosen azimuth around the radiometer. Most of the azimuths revealed a decrease in *PR* value after precipitation events what infers strong interception or/and litter effects. Azimuths for which we found the lowest PR values are less sensitive to precipitation events by means of microwave emission changes what is reflected in Fig. 1 c). Microwave emission (by means of PR) from the certain azimuths can be compared with NDVI, SM and OMC (Figs. 2 a) b) c)). The lowest sensitivity to the precipitation events can be connected with the local NDVI drop (Fig. 2a)). In this case dense partially dried vegetation effectively screens the microwave response from the ground. Furthermore, OMC-related water holding ability may have a significant impact on *PR* behaviour by contribution to the interception effects.

Temporal changes of brightness temperatures has been used to retrieve SM for each azimuth (Fig. 3 c)) using SRP simplification to L-MEB model. For most azimuths modeling revealed a decrease in soil moisture after rainfall, as compared with Fig. 3 b). It arises from earlier mentioned interception/litter effects found in PR_{60} results. Nevertheless, SRP modelling revealed an increase in SM for azimuth angle 290° visible in Fig. 3 c) aiming at cultivated field with relatively low OMC and SM values comparing to other azimuth's footprints (Fig. 2). Particularly, for this azimuth (290°) we have performed optimization of L-MEB parameters and the result is depicted in Fig. 4. The modelling reflects well the increase in SM after precipitation events. However, the modelled values seems to be underestimated comparing to SM sensor data. It can be a result of different locations of the sensor (near the radiometer) and the footprints at the investigated azimuth.

To conclude the spatio-temporal analysis of L- band microwave emission form the Bubnow test-site can be used for extensive studies of liter/interception effects, oragnic-rich soils as well as mineral cultivated fields in order to improve the current SM retrievals.

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