Systematic mobile L-band passive microwave radiometry measurements over agricultural fields in the Netherlands and Belgium

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Introduction

For more than forty years passive microwave radiometers have been used to derive soil moisture from the subsurface (e.g. Schmugge, 1974). Most of these soil moisture studies were satellite oriented which resulted in the current abundance of several coarse scale (~50 km) microwave soil moisture products. Due to this low spatial resolution, these data products seem to be of less interest for local/ regional hydrological studies. However, ground based radiometers can overcome this problem, because they can measure at a much higher spatial resolution up to one meter. The objective of this study was to determine if high quality, high resolution soil moisture data of agricultural fields can be delivered using a mobile L-band radiometer. These unique datasets and systematic measurement approach offer an outstanding opportunity for the calibration and/or validation of current and future satellite derived soil moisture products, including those from Sentinel-1, SMAP, SMOS and AMSR-2.

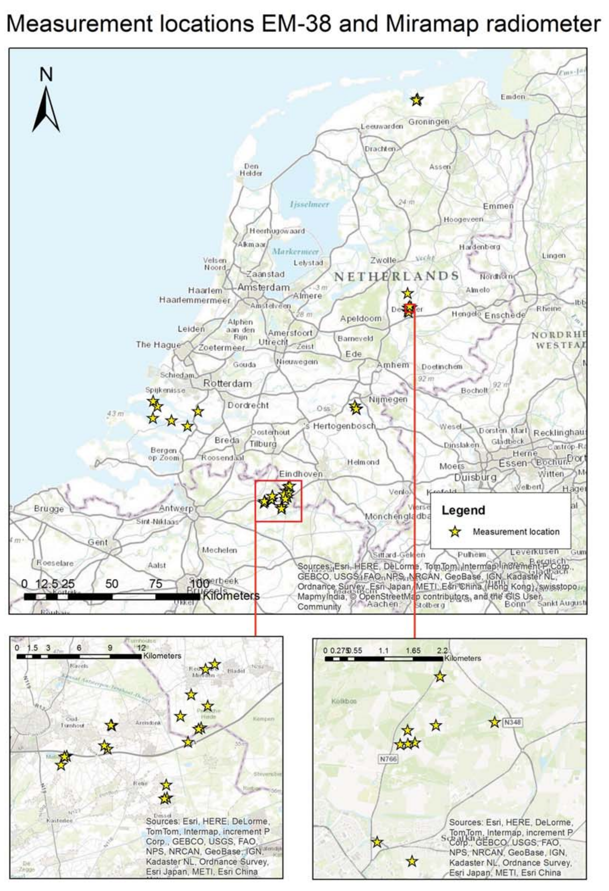
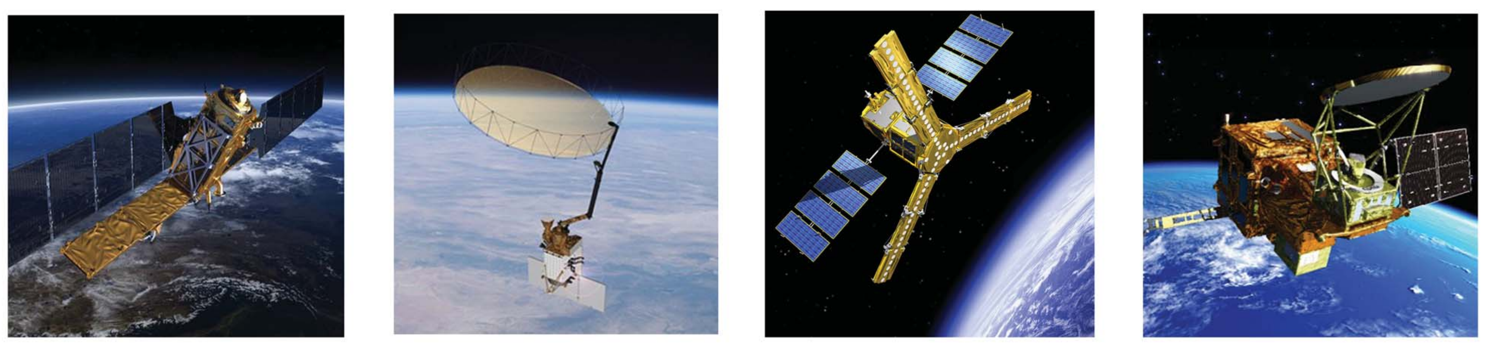


Figure 1: locations of measurements of EM-38 and passive radiometer during March 2014

Figure 2: From left to right the Sentinel-1, the SMAP, the SMOS and the AMSR-2 satellite



Materials and methods

At the beginning of 2014 forty-one agricultural bare soil sites were measured simultaneously in the Netherlands and Belgium (see Figure 1) with both a L-band radiometer and an EM 38 sensor. Both sensors are sensitive to soil moisture. However, the L-band radiometer is more sensitive to soil moisture of the first centimeters whereas the EM 38 is more sensitive to soil moisture at 40-50 cm depth. Regardless the difference in sensing depth both observations are independent and both would potentially give us the spatial variability of soil moisture.

Figure 3: Kubota equipped in front with the mobile passive radiometer developed by Miramap and pulling the EM 38 over a bare soiled field

During this study, a mobile passive radiometer developed by Miramap was used (Figure 3). The radiometer observed microwave brightness temperatures at a 1.4 GHz frequency with an accuracy of 1 Kelvin and at an incidence of 40 degrees. The radiometer was mounted on an agricultural vehicle (Kubota) at an elevation of approximately 1 m, which resulted in an observation footprint of about 1m^2. The data was linked to a GNSS system with a location accuracy of about 10 cm. The radiometer measured with a sampling frequency of 1 second.

The EM-38 measured the bulk apparent electrical conductivity (EC_a) of the soil in mS/m. The EC_a is the bulk value of the material in the subsurface below and may be considered a function of the soil solids, soil solution (e.g. soil moisture content and salinity) and soil temperature. The bulk electric conductivity can be described as a quadratic function of the volumetric water content (Rhoades et al., 1976):

$$EC_a = a * EC_w * \theta_v{}^2 + b * \theta_v EC_w + EC_c$$

where θ_v is the volumetric water content, EC_w is the electrical conductivity of the soil water, EC_c is the surface electric conductivity, which is dependent on the type of soil and *a* and *b* are regression parameters related to soil texture. The penetration depth of the EM-38 was approximately 1 meter with the highest contribution of the top 40 cm of the soil. The EM-38 also measured with a sampling frequency of 1 second and was directly linked to the GPS system (Figure 3).

Results

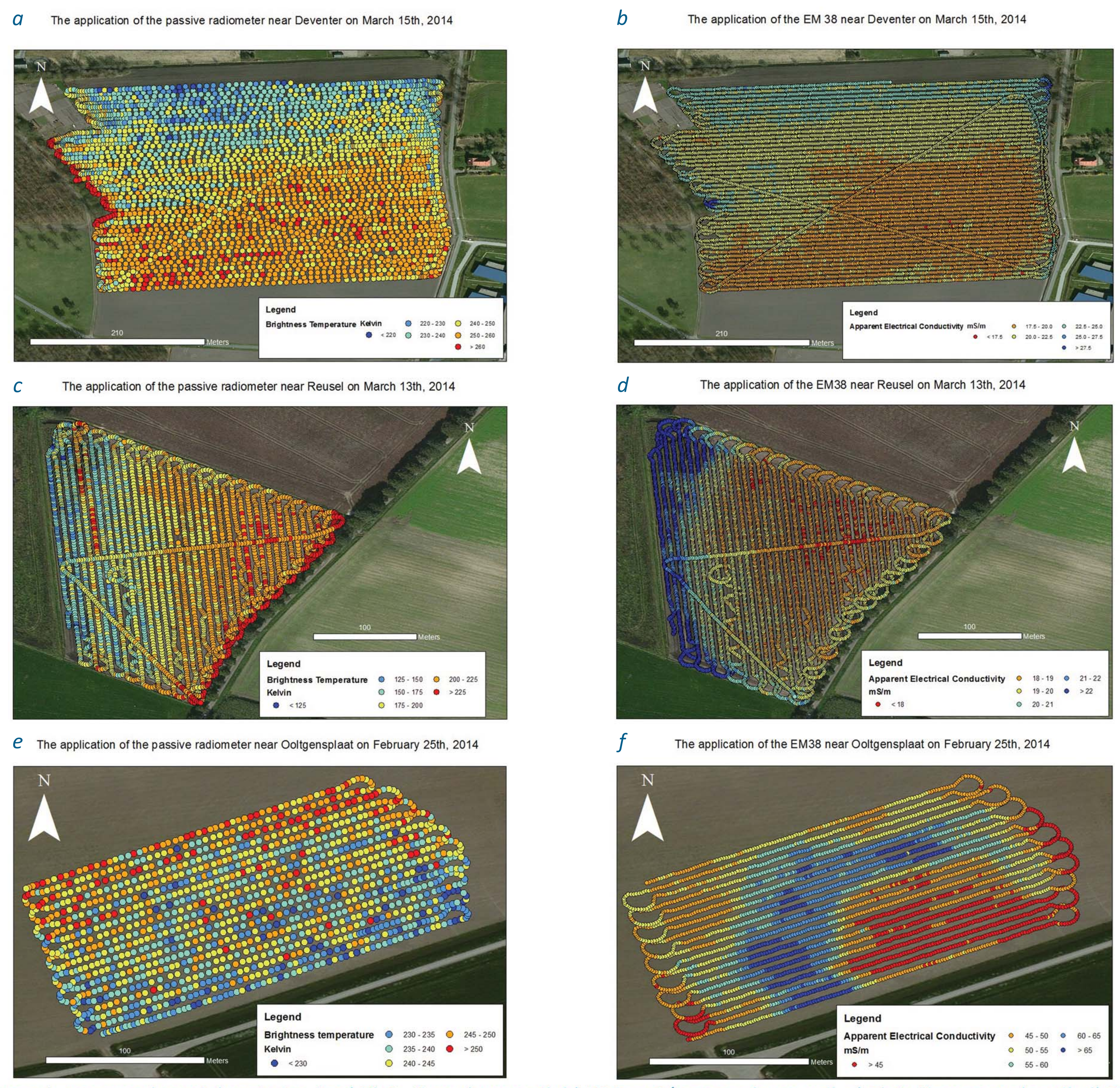


Figure 4: measured spatial variation in a) Tb in K on clayey soil, b) EC in mS/m on a clayey soil, c) Tb in K on a sandy soil, d) EC in mS/m on a sandy soil, e) Tb in K on clayey soil and f) EC in mS/m on a clayey soil near the towns of Deventer, Reusel and Ooltgentsplaat. Correlation coefficients between a & b, c & d and e & f are -0.71, -0.57 and 0.07 respectively.

In a two-month time period forty-one fields were measured including 23 sandy soils and 18 clay soils. Figure 4 shows the patterns of 3 fields. In general both sensors give similar patterns with low brightness temperatures/high conductivity values for wet soils and high brightness temperatures/low conductivity values for dry soils. The correlation between the two observations is therefore also negative. No significant differences were observed between sandy and clay soils. In several occasions the spatial patterns in soil moisture in the EM38 were more pronounced compared to the brightness temperatures (e.g. see Figure 4e and f). This is most likely due to the smaller spatial variability of soil moisture in the top 5 cm compared to deeper layers.

Conclusion

Using the mobile passive microwave radiometer system, agricultural fields across the Netherlands and Belgium were systematically measured. The resulting data are high resolution geo-referenced soil moisture maps with 1-meter ground sample distance. The spatial patterns of L-band radiometer measurements correspond with simultaneously measured EM38 patterns. This gives confidence in the reliability of the mobile passive microwave radiometer system and demonstrates the potential use for high resolution soil moisture mapping. As a next step, the same method will be applied at different vegetation growth stages. This follow-up study should reveal the impact of vegetation on the microwave signal.

Acknowledgements

Partial funding for this research was provided by the Topsector Agri&Food - Food & Nutrition Delta Program, Dutch Department of Commerce, grant nr. FNDM130067. In addition, we acknowledge Jacob van den Borne for his support in the field and his data collection efforts.

Reference

- J.D. Rhoades, P.A.C. Raats and R.J. Prather, 1976. *Effects of liquid-phase electrical conductivity, water content, and surface conductivity on bulk soil electrical conductivity*. Soil Sci. Soc. Am. J. 40: 651-655
- T. Schmugge, P. Gloersen, T. Wilheit, F. Geiger, 1974. *Remote sensing of soil moisture with microwave radiometer.* J. Geophys. Res., 79 (2) (1974), pp. 317-323

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