Soil moisture mapping at Bubnow Wetland using L-band radiometer (ELBARA III)

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Introduction

The study of soil moisture is a scientific challenge. Not only because of large diversity of soils and differences in their water contents, but also due to the difficulty of measuring, especially in large scales. Several methods to determine the water content in soil are utilised. The basic and referential is gravimetric method, which is accurate, but time-consuming, so suitable only for small spatial scales. Indirect methods, for example those based on dielectric properties of materials (e.g. time domain reflectometry - TDR) or made from distance, e.g. remote brightness temperature measurements, are faster, but need to be validated.

In our studies, we applied spatial statistics to local soil moisture and brightness temperature mapping using ELBARA III (ESA L-band radiometer, 1.4 GHz) mounted on tower. Our measurements were carried out in natural Bubnow Wetland, near Polesie National Park in Poland. This test-site had been selected because it is part of one of the biggest wetlands in Europe, called Polesie, localized in Ukraine, Poland and Belarus. ELBARA collects data continuously (4 times per day), at area c.a. 20 000 m². This approach allows combining multiple independent measurements to one, consistent brightness temperature map. Moreover, using those techniques we can observe how soil moisture changes with time. It enables better understanding the soil moisture spatial distribution over a local area of interests, before extending assessments on larger scale.

Materials and methods

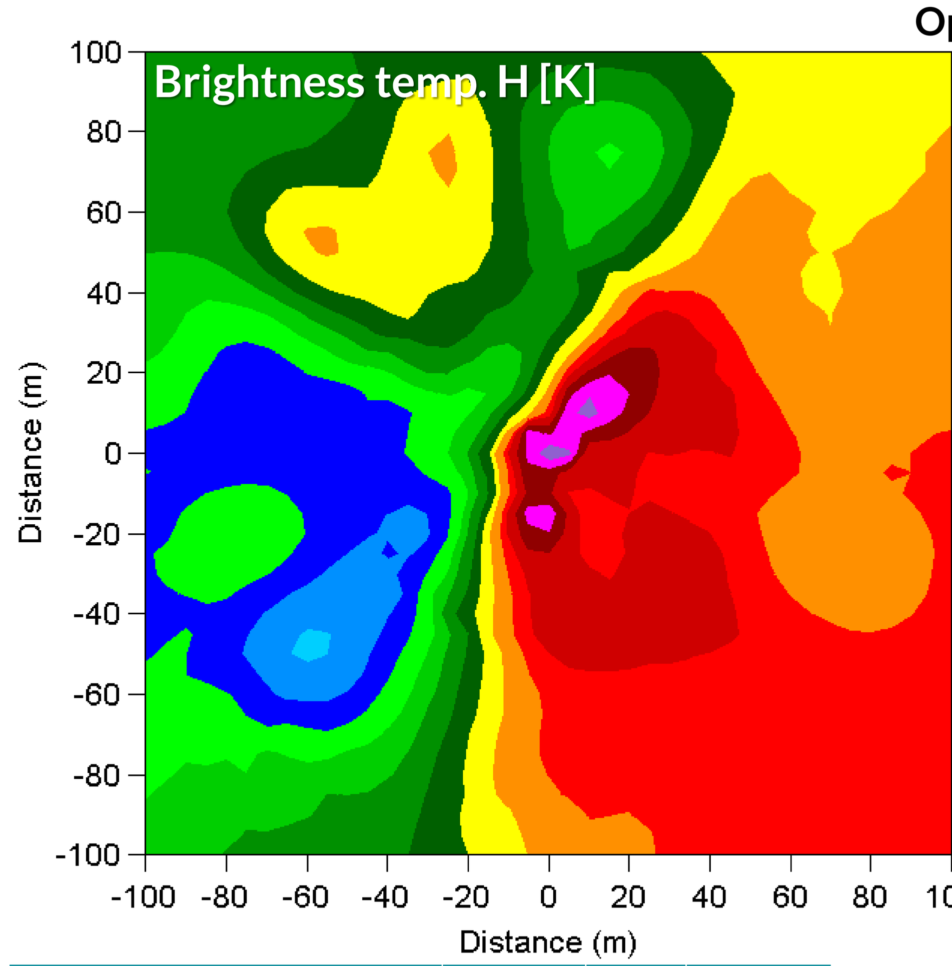
ELBARA is placed on Bubnow, at the border of different vegetation and soil types: cultivated field, meadow, marsh (peat-bog) and standing water. The expected soil moisture may vary from 0 % for mineral soil up to 95% for peat. ELBARA III azimuth rotation capability enables to observe high number of quasi-simultaneous looks to identify the most adequate footprints in support of the main research – exploring emission depth issues. In the study, the brightness temperature data obtained by ELBARA III during field campaign conducted in spring was examined. ELBARA collected data by rotating antenna in horizontal (azimuth range 0-350°) and vertical plane (incidence angle range 30-85°). Total number of overlapping footprints was 468 per session. There were 4 measuring sessions: at night (00:00 AM), in the morning (6:00 AM), noon (12:00 PM) and in the evening (6 PM). In order to validate our data, the results were compared with measurements obtained by means of the TDR method (105 samples), taken between morning and noon session, just before heavy rain. At each point soil moisture and temperature were measured by three devices with different lengths of rods; moisture contents were obtained in layers of 0-5, 0-10 and 0-17 cm. The features of soil moisture and brightness temperature distributions of the examined area were studied using methods of spatial statistics (geostatistics). The basic function of this method, which allows to describe spatial phenomenon, is the semivariogram function γ, which is equal to half of the expected difference of value of the regionalized variable $Z(x)$ in point x_i and value $Z(x+h)$ at a point distanced from x_i by separation vector h:

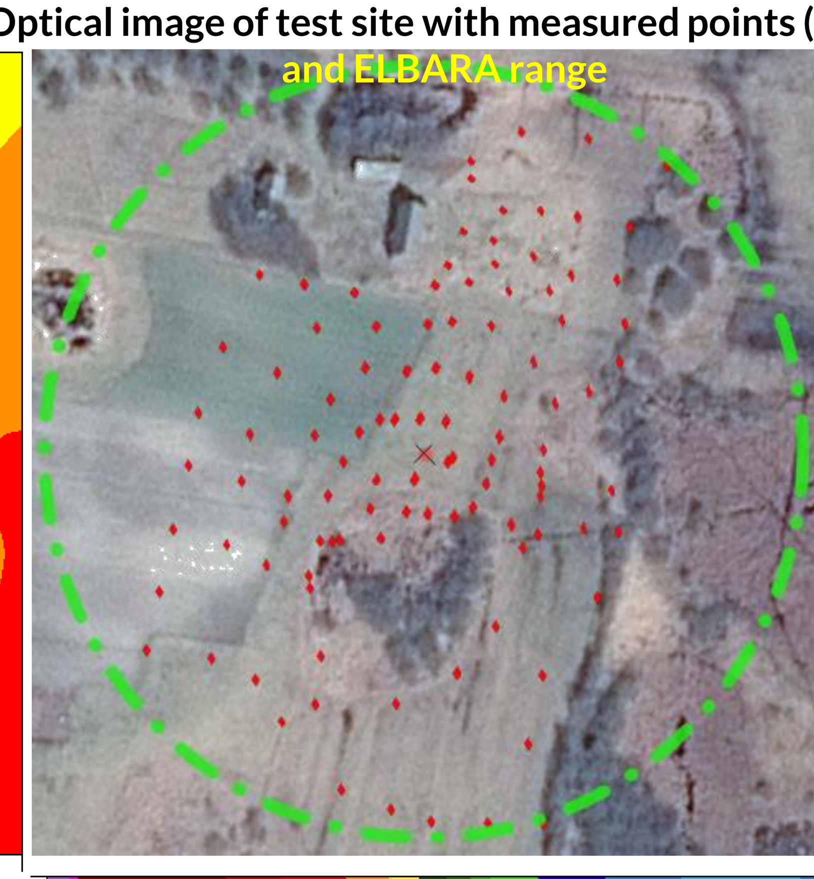
$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} [z(x_i) - z(x_i + h)]^2$$

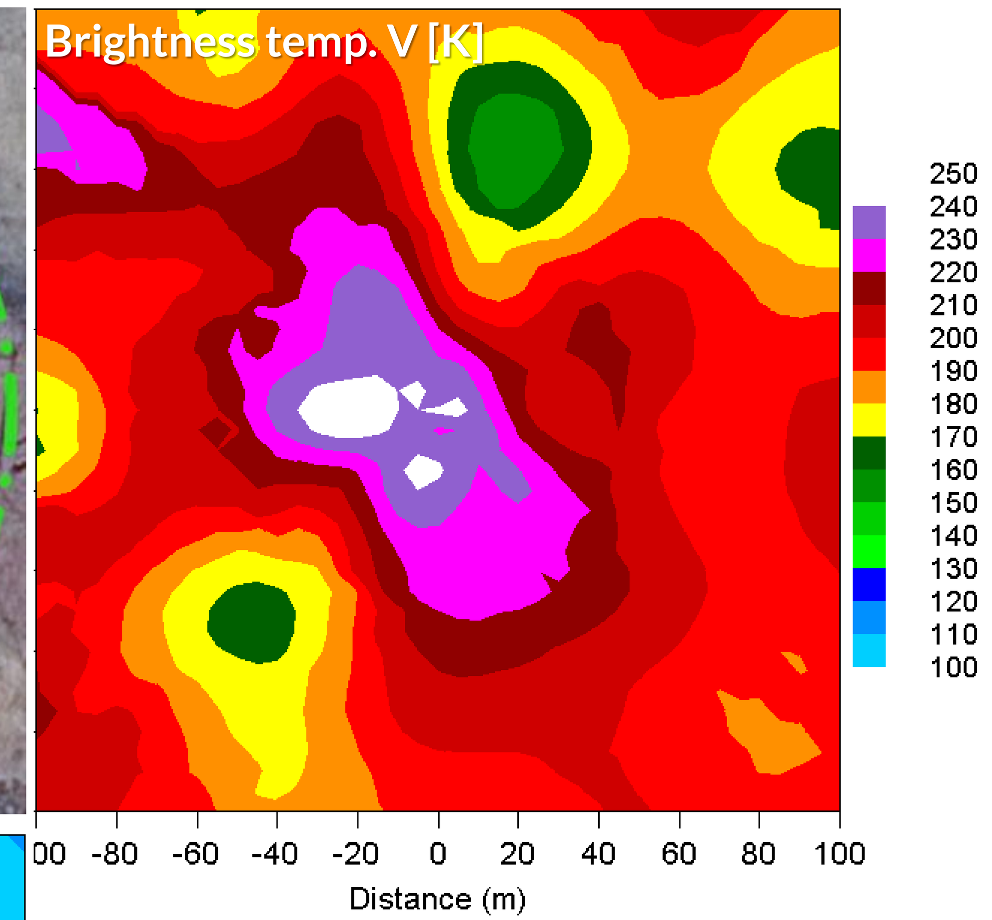
Thanks to the geostatistical methods, by employing semivariance analysis, it was possible to get the information about the nature of spatial dependences (geostatistical models), their lengths (ranges), directions of the smallest anisotropy and estimate continous distribution from point measurements.

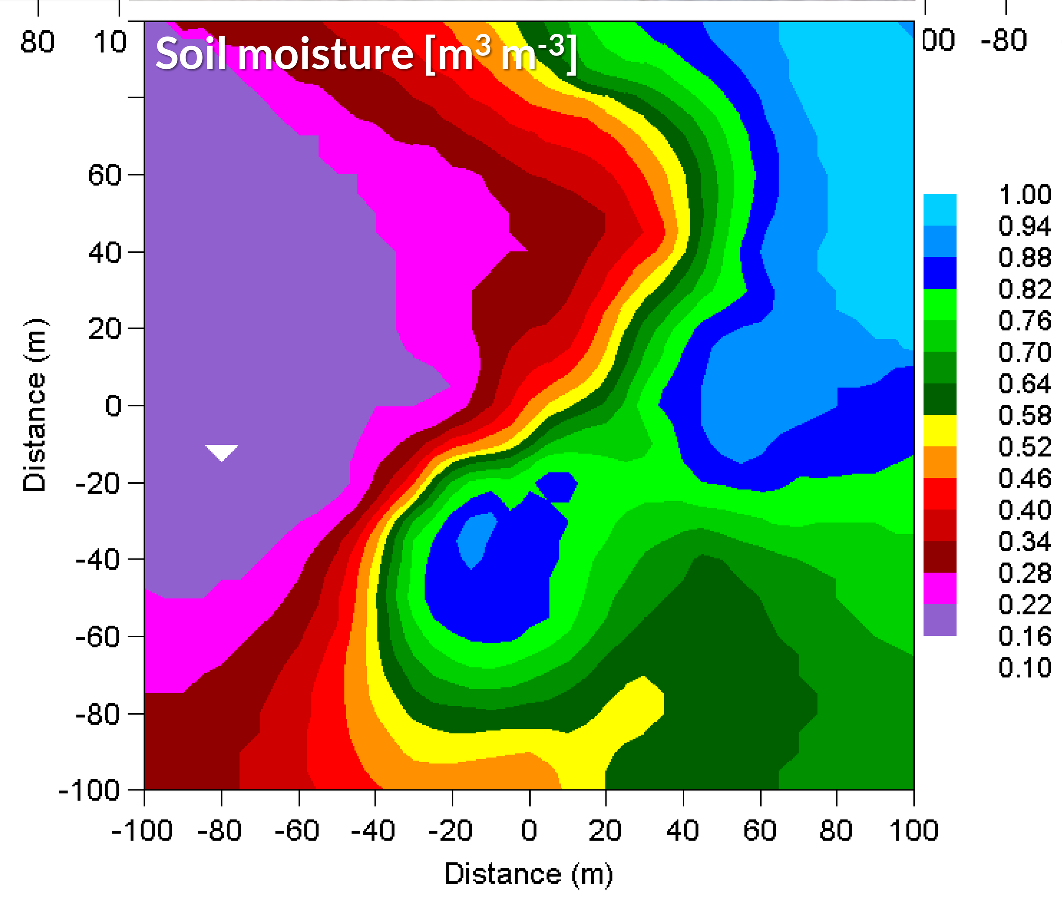
Results

Optical image of test site with measured points (TDR) and ELBARA range









RANGE [m]	night	morning	noon	evening
Brightness temp. H	34	36	31	40
Brightness temp. V	70	60	82	70
Soil moist. (0-5 cm)	-	89		-
Soil moist. (0-10 cm)	-	89		-
Soil moist. (0-17 cm)	-	85		-

MIN. ANIS. [°]	night	morning	noon	evening
Brightness temp. H	9	9	144	23
Brightness temp. V	159	155	157	155
Soil moist. (0-5 cm)	-	37		-
Soil moist. (0-10 cm)	-	37		-
Soil moist. (0-17 cm)	-	39		-

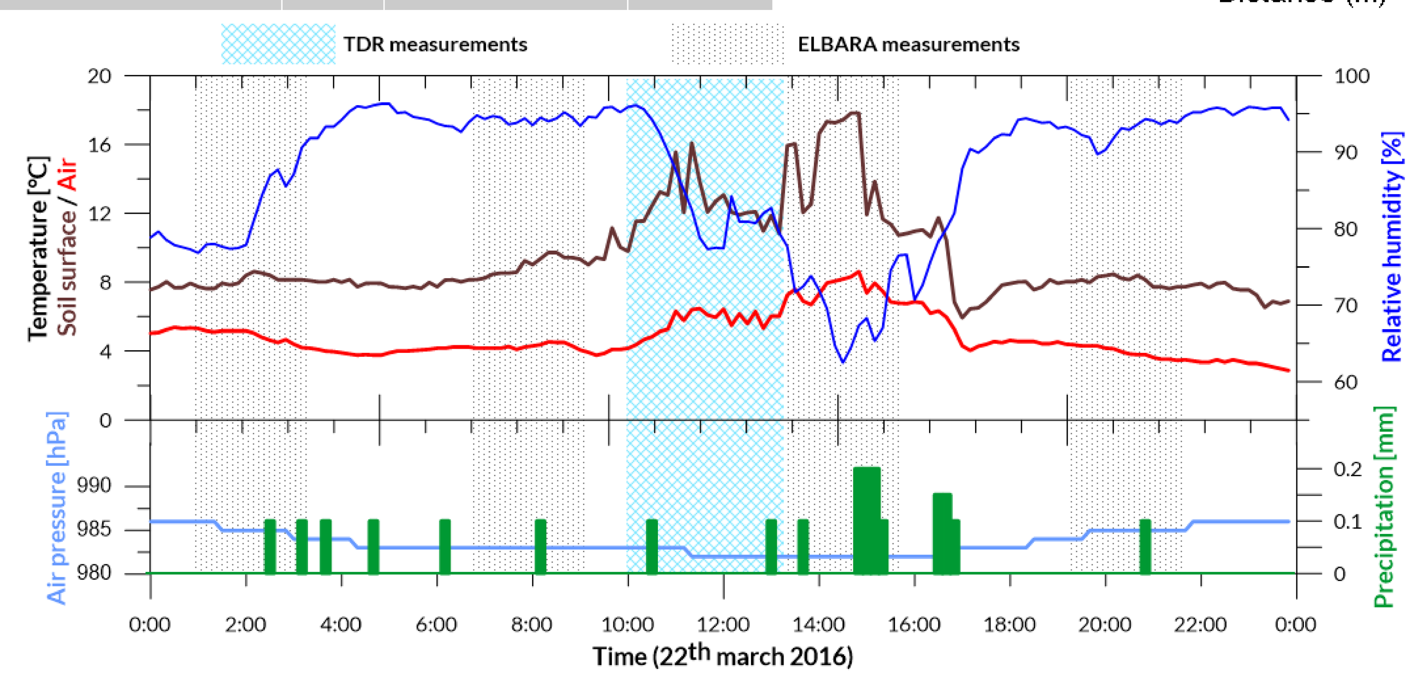


Fig. Weather data from Bubnow-Sekow station in the day of field campaign

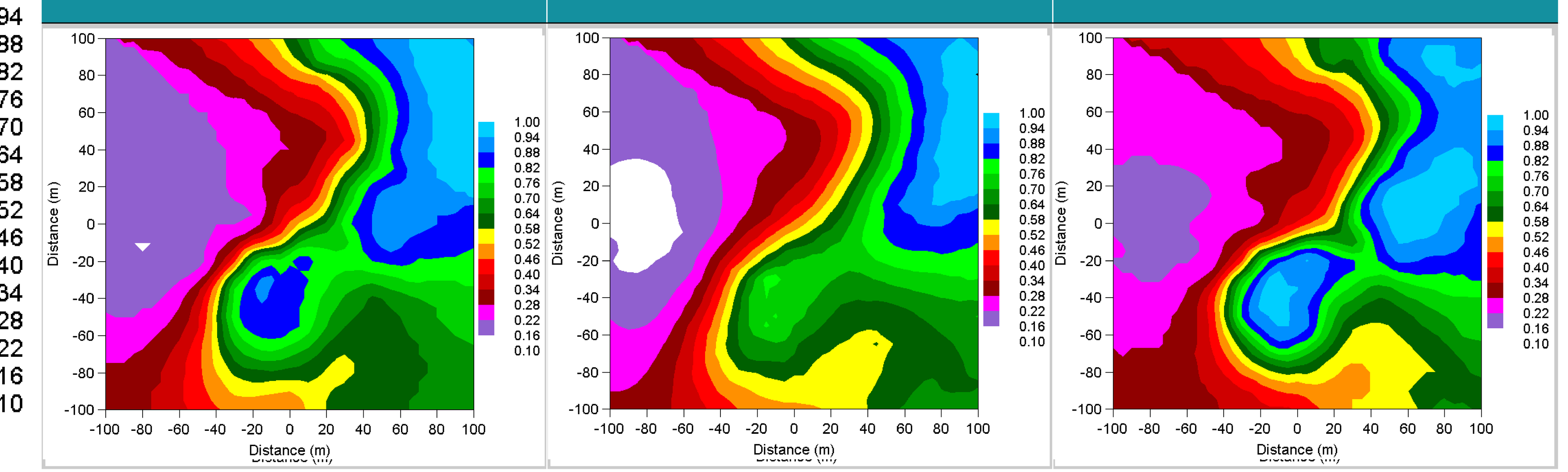


Fig. Spatial distributions of soil moisture obtained by TDR method. ELBARA location is [0,0]

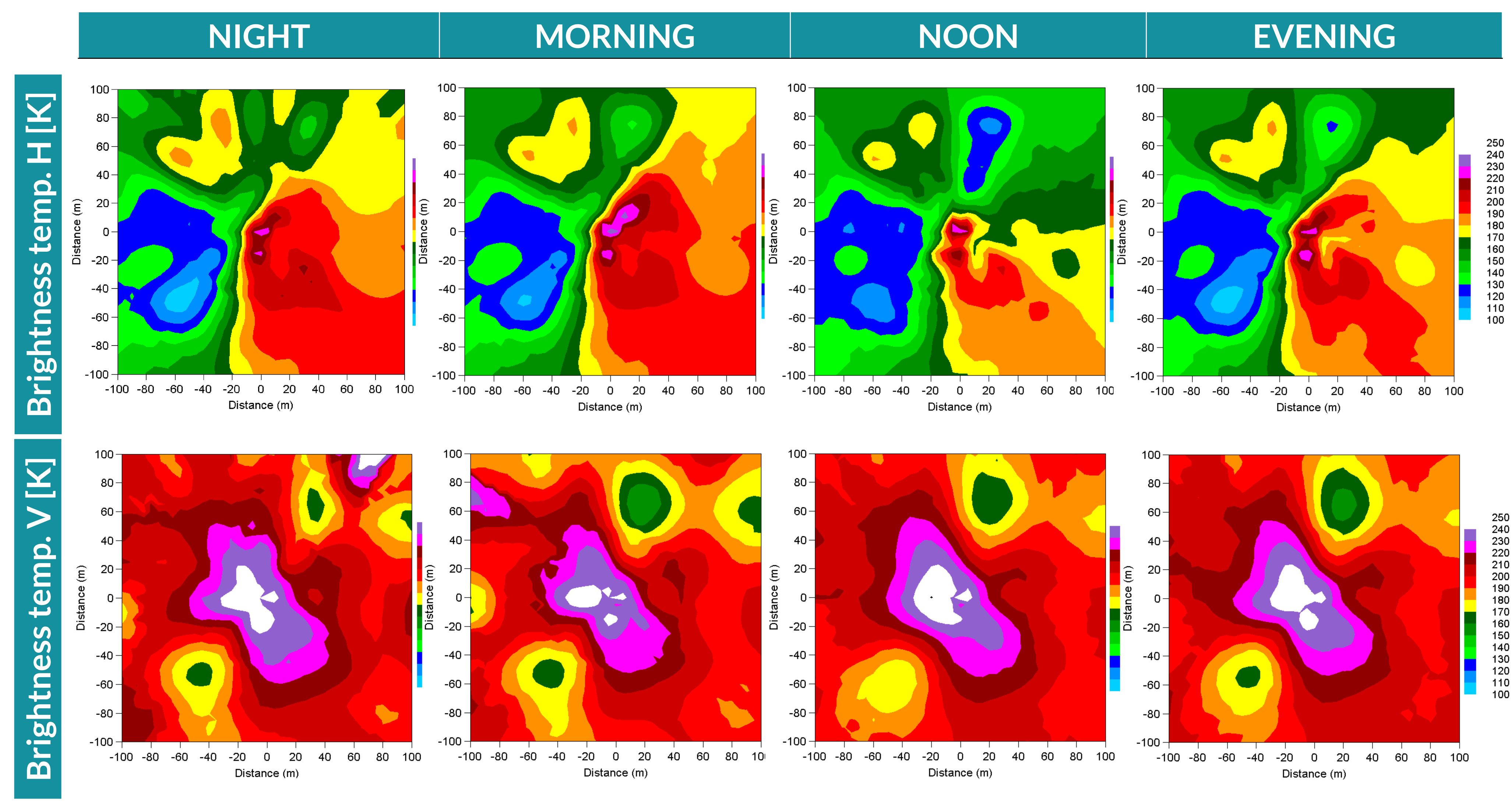


Fig. Spatial distributions obtained by kriging method. ELBARA location is [0,0] –the center of plots

Summary and Conclusions

Using ELBARA, TDR and geostatistical methods brightness temperature and soil moisture maps were obtained.

Brightness temperature maps represent well the land cover (vegetation, soil type, etc.) and distribution of soil moisture, as confirmed by *in situ* TDR measurements. It was noticed, that brightness temperature is in some relation with the color patterns of the ground visible on the optical images. That might be associated with the spatial distribution of organic matter and granulometric fractions contents and bulk density.

Soil moisture measured in the 0-5 cm layer was on average higher than measured in 0-10 cm layer, which may be connected to the increase in water content due to light rain before measurements. The soil moisture in the deepest layer (0-17 cm) was again higher, as usually on the wetland site.

Spatial dependences for soil moisture distributions were ca. 90 m, for brightness temperature in horizontal polarization 30-40 m and 60-70 m long for vertical.

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