Sentinel – 1 Supersite

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Remote Sensing Center

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Sensor types

For passive radiometers: one aboard **SMAP mission** or **MIRAS (SMOS satellite)**
the acquired brightness temperature, and consequently SM product, are of low spatial resolution (40-60 km), but relatively of high temporal sampling 3 days.

Likewise, some of the active scatterometers such as **ASCAT** – Metop's Advanced Scatterometer instrument records low resolution (25 – 50 km) data simultaneously from two SAR (Synthetic Aperture Radar) systems, which allow to obtain near global coverage in less than five days.

Other, active scatterometers such as decommissioned SAR (ERS) satellites and ASAR (ENVISAT) or SAR antenna operating aboard TerraSAR-X allow to obtain high resolution data (1-20 m) at low temporal resolution (35 days).

These characteristics affect fields of application of SM data. In general, if a high temporal sampling is needed (e.g. weather forecasting) the radiometers are more suitable as opposed to scatterometers, which are used where the high spatial resolution is required (eg. hydrological modelling, precision farming).

Solution?
This issue is going to be overcome by the new generation of Sentinel-1 (S-1) satellites.

Sentinel-1 characteristics

The Sentinel-1 satellite constellation sharing the same sun-synchronous, near-polar orbital plane consists of two platforms equipped with the C-band (5.4 GHz) SAR systems acquiring data at the spatial resolution ranging from 5x5 m to 20x40 m.

Main observing mode of the sensor denoted as interferometric wide swath (IWS) features scan width of 250 km and a footprint size of 5 x 20 m. This will allow to acquire near-global data coverage within 12 days for a single platform and 6 days for the satellite constellation.
Over Europe the revisit time will be 3-6 days.

The S-1 acquires measurements with radiometric accuracy of 1 dB at the following polarization modes: **VV+VH,HH+HV,HH,VV.**
At the incidence angles ranging from **20◦ – 45◦**.

Description of Soil Moisture (SM) retrieval algorithms suited for the S-1 data
Retrieval of SM estimates from radar data is affected by a wide range of variables such as:

- vegetation biomass,
- vegetation water content,
- atmospheric state,
- surface roughness,
- acquisition incidence angle

and radiometric accuracy of the sensor: Statistical fitting, Radiative transfer model inversion, time series analysis of radar backscatter

IGiK algorithm

The IGiK algorithm is based on **water cloud model** (Attema and Ulaby, 1978), further modified by Prevot et al. (1993) and Dabrowska-Zielinska et al. (2007).

The water cloud model expresses the total SAR backscatter from a canopy as a sum of contributions from vegetation and underlying soil.

Since the backscatter is affected by dielectric and geometrical properties of the canopy, it is possible to expand water cloud model by incorporating a robust vegetation descriptors such as: **leaf area index (LAI)**, **leaf water area index (LWAI)**, and **vegetation water mass (VWM)**.

The LWAI is defined as: LWAI = LAIW, where W is the amount of water (unitless) = a ratio of the wet and dry biomass difference to the wet biomass. This is equivalent to the amount of water present in the leaf area.

The VWM is defined as the difference between wet and dry biomass (kg/m2).

The modified cloud model was successfully applied to co-polarized (IS4 VV, IS6 HH) ENVISAT ASAR data (Dabrowska-Zielinska et al., 2009).

Validation methodology

Many approaches were proposed to validate satellite SM products based on in-situ measurements. However, most of them are related to low resolution data coming from the instruments such as SMOS, where a large sensor footprint usually covers a heterogeneous area composed of many land covers and soil types. This implies, that a single in-situ SM measurement may not correspond well with areal average over a vast terrain. This problem is significantly resolved by the S-1 SAR systems that allows retrieval of SM content at high spatial and temporal resolutions.

In order to compare satellite SM data with in-situ measurements they require the same reference in terms of spatial scale and observation time. Due to the small footprint size of S-1 radar system the satellite observations and ground measurements can be collocated using the nearest neighbor technique for temporal and spatial matching:

nearest neighbor technique, where the closest measurement to a center of SAR pixel is selected (Imbo and Baghdad, 2012). This technique works best for high resolution satellite data where there is small within-pixel variability of land cover and topography.

Quality indicators

Accuracy assessment and inter-comparison of different SM retrieval algorithms require some qualitative measures.

In this respect the following quality indicators are commonly used (Imbo and Baghdad, 2012), where ***P:*** S-1 SM estimate, ***O:*** in-situ SM measurement, and ***n:*** number of collocated SAR/in-situ observations:

- Pearson correlation coefficient

$$r = \frac{\sum_{i=1}^{n}(O_i-\bar{O})(P_i-\bar{P})}{\sqrt{\sum_{i=1}^{n}(O_i-\bar{O})^2}\sqrt{\sum_{i=1}^{n}(P_i-\bar{P})^2}}$$

- Bias

$$Bias = n^{-1}\sum_{i=1}^{n}(O_i - P_i)$$

- Mean Absolute Error

$$MAE = n^{-1}\sum_{i=1}^{n}|O_i - P_i|$$

- Root mean square error

$$RMSE = \sqrt{n^{-1}\sum_{i=1}^{n}(O_i - P_i)^2}$$

- Index of agreement

$$IOA = 1 - \left[\frac{\sum_{i=1}^{n}(O_i-P_i)^2}{\sum_{i=1}^{n}\left(\left|P_i-n^{-1}\sum_{i=1}^{n}O_i\right|+\left|O_i-n^{-1}\sum_{i=1}^{n}O_i\right|\right)^2}\right], 0 \leq IOA \leq 1$$

Biebrza National Park

The Biebrza Wetlands are one of the largest area in the entire EU with marshes, swamps, and wet meadows.
This is still one of the wildest areas with limited anthropogenic pressure. However, in the recent decades some hazardous factors disturbing the natural water conditions and lowering the groundwater level have occurred, such as: scrub encroachment, fires, and changes of the farming activity. Therefore to protect this unique area the Biebrza National Park (BNP) covering 59 233 ha has been established since 1993.

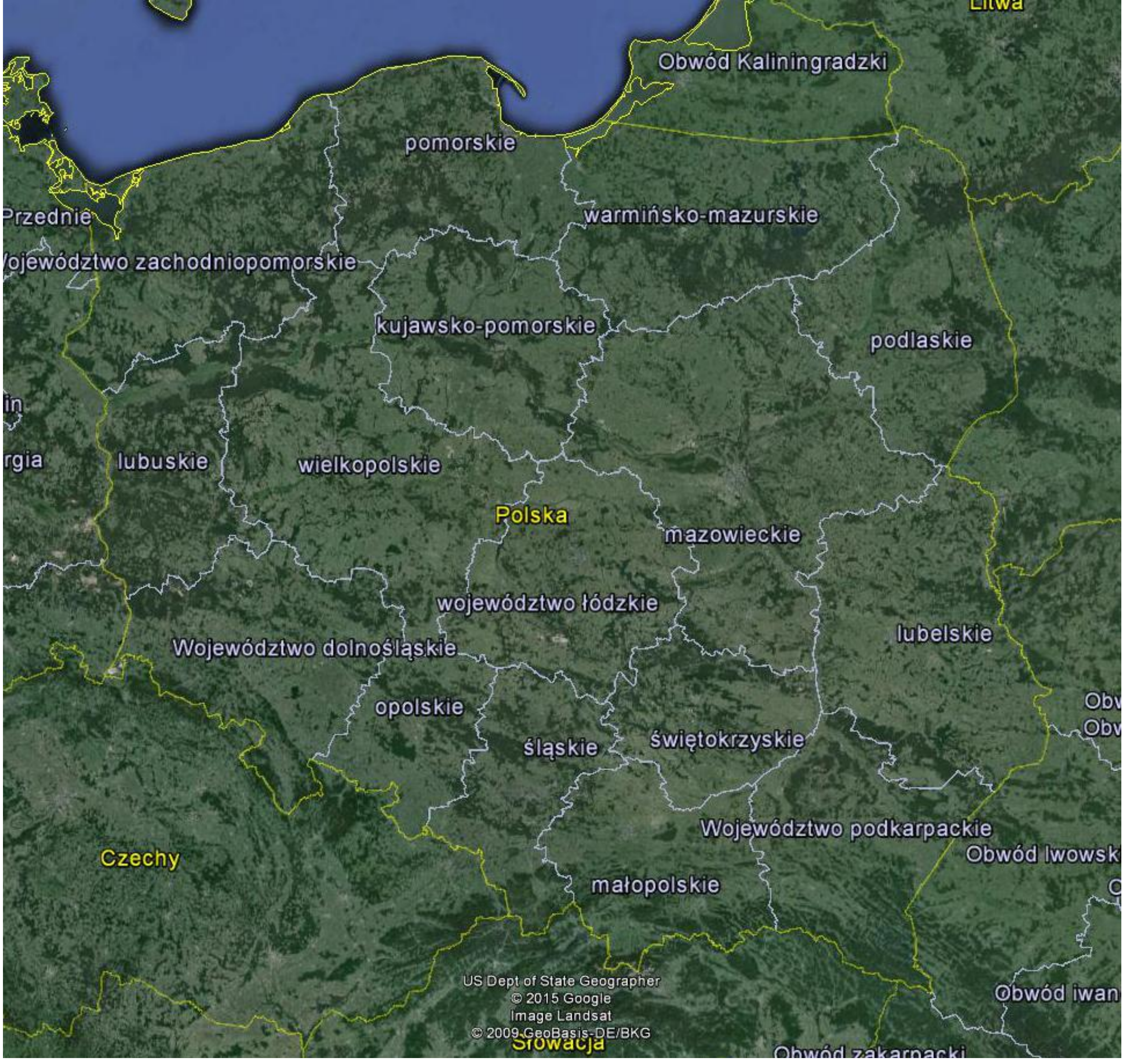
The BNP includes 15 547 ha of forests, 18 182 ha of agricultural land, and 25 494 ha of wetlands - the most valuable habitats of the park which are further protected under RAMSAR and Natura 2000 regulations. The Biebrza Wetlands are flat with an average altitude around 105 m above see level (a.s.l.).
The main river of this area is Biebrza with the mean flow of 35.3 m^3s^{-1}, which spans over 155 km and flows out near the eastern border of Poland. Its watershed covers the area of 7051 km2.

The Biebrza Valley mainly consists of hydrogenic soils such as peat soils in various stages of mouldering. The spongy structure of the peat turns the valley into a huge reservoir of fresh water which is restored every summer when Biebrza floods. The process of peat-forming is still active over areas covered by sedges, reeds, rushes, moss, scrubs, and grasses. The Biebrza Valley is naturally divided into three basins: the Upper Basin, the Middle Basin and the Lower basin.

Description of Biebrza S-1 validation supersites

Both sites are located in Biebrza wetlands administrated by the Biebrza National Park and situated in the northeastern part of Poland. The marshland site has a regular 500 m x 500 m measuring grid composed of 9 SM stations equipped with 5 probes each, measuring at depths of 5 (2 probes), 10, 20, 50 cm. The grassland site has analogous instrumentation with the stations arranged in two rows, one with 4 SM stations and second with 5 SM stations. This rectangular shape was selected due to the structure of a cadaster to fit plots rented for experiment duration.

The marshland site is located on the property of the Biebrza National Park and the access to the site and permission to collect biomass and install SM probes has been officially granted for the duration of the project by the Polish Ministry of the Environment and the Biebrza National Park. The grassland site also lays within the administrative borders of the BNP, however it is a private property of two farmers.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rgia
lubuskie
wielkopolskie
Polska
mazowieckie
województwo łódzkie
lubelskie
Województwo dolnośląskie
opolskie
śląskie
świętokrzyskie
Województwo podkarpackie
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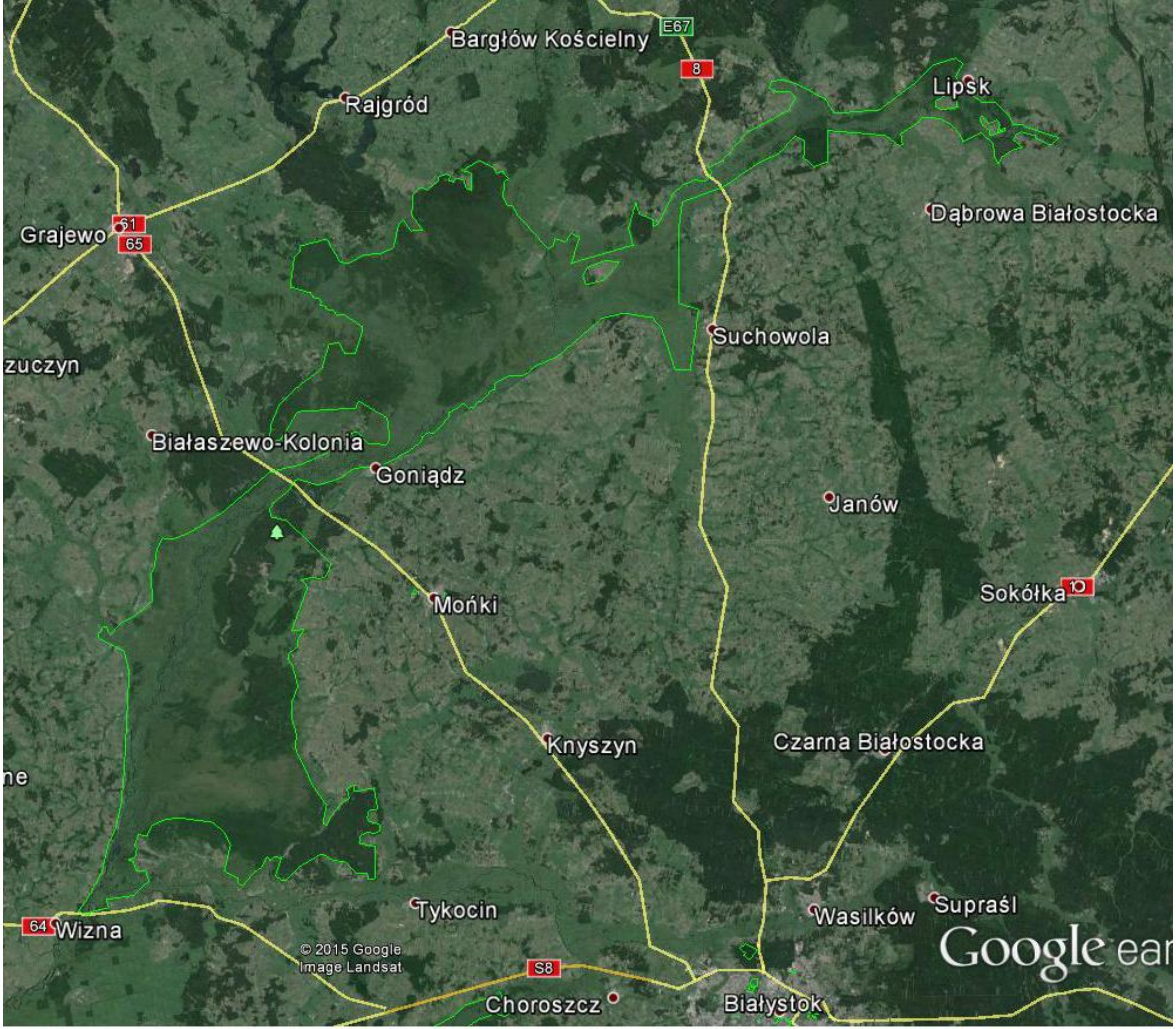

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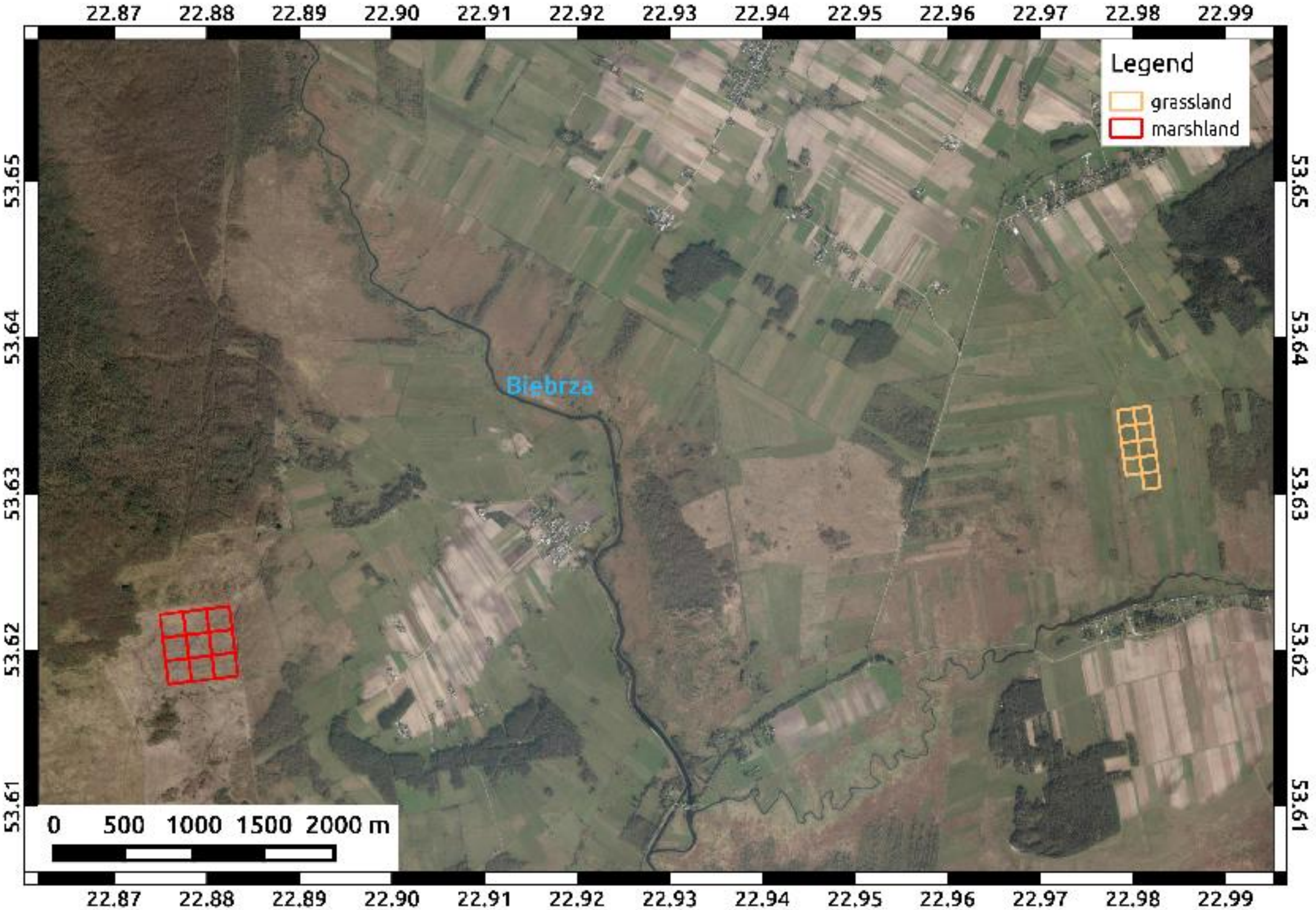
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Legend
grassland
marshland
Biebrza
0 500 1000 1500 2000 m

The grassland validation site is located close to Suchowola village on intensively mowed, drained meadow with semi-organic soil, which will allow to retrieved SM from S-1 data all year round due to low biomass (<2kg/m2).

The sites are located around 6.5 km apart

The marshland validation site is located within the Biebrza National Park and covers extensively mowed (once pear year) sedges with more moist, organic soil. Due to the natural character of the site with dense vegetation (biomass >2kg/m2), the SM retrieval from S-1 data will be possible only during a part of a year.

For the rest of time the C-band SAR signal is expected to be more related to biomass, which will be investigated in depth by IGiK.

Temporal sampling and data transmission

Temporal sampling of soil moisture and meteo measurements will be set to 15 minutes and the data transmission via GPRS to Decagon and IGiK servers will be done 3 times per day (to limit battery drainage). The CO2 fluxes and 3d wind field will be measured at the 20 Hz frequency, which inhibits GPRS transmission due to the large data amount. Therefore, those variables will be stored on the SD card and downloaded to laptop during field campaigns.

Additional measurements performed during cyclic field campaigns

Every 2-3 weeks a filed campaign will be conducted over the validation sites to inspect the instrumentation status, download data, and to perform additional measurements related to: LAI, biomass, chlorophyll content, TDR SM measurement, soil pH, and CO2 fluxes measured with the chamber method.

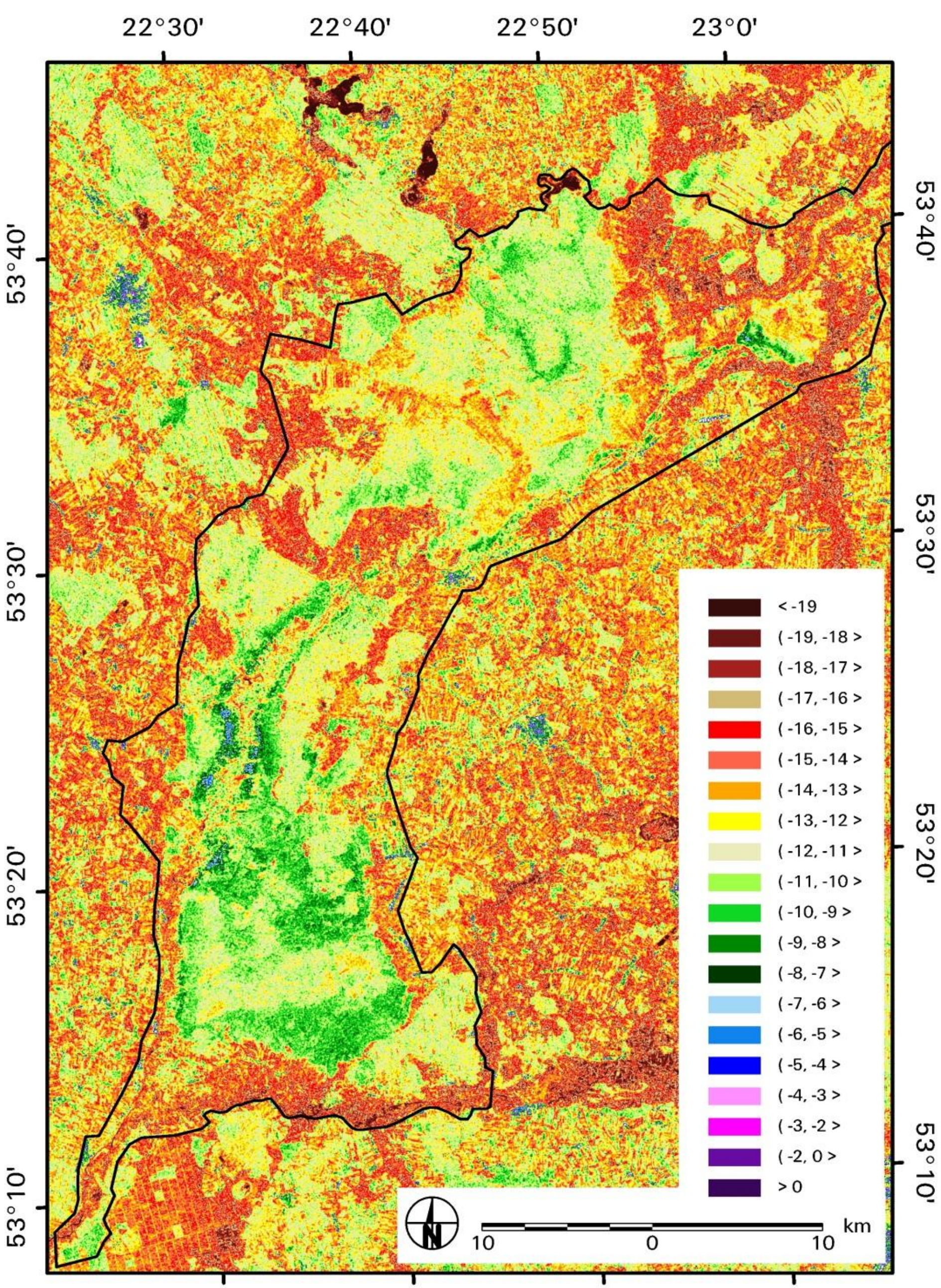
This complementary material will expand the SM validation analysis with ancillary information about the variables influencing SAR signal (biomass, vegetation condition) and will provide one more reference SM dataset acquired by means of the TDR technique. Furthermore, these additional data sets will be used for the analysis of water, carbon and heat fluxes within the wetland environment.

Variable	Level [m]	Number of samples	Frequency	Measuring instrument
soil moisture	-0.05,-0.10,-0.20,-0.50	90	15 min	Decagon GS3 probe
soil temperature	-0.05,-0.10,-0.20,-0.50	90	15 min	Decagon GS3 probe
soil electrical conductivity	-0.05,-0.10,-0.20,-0.50	90	15 min	Decagon GS3 probe
SAR backscatter	0	18	each sat. overpass	S-1 satellite
SAR SM products	0	18	each sat. overpass	S-1 satellite
soil silt fraction	-0.05,-0.10,-0.20,-0.50	72	once	in labolatory
soil clay fraction	-0.05,-0.10,-0.20,-0.50	72	once	in labolatory
soil sand fraction	-0.05,-0.10,-0.20,-0.50	72	once	in labolatory
soil organic matter	-0.05,-0.10,-0.20,-0.50	72	once	in labolatory
soil porosity	-0.05,-0.10,-0.20,-0.50	72	once	in labolatory
TDR soil moisture	-0.10	variable	field campaign	IMKO TRIME probe
soil temperature	-0.10	variable	field campaign	Tlead TP3001
soil pH	-0.05	variable	field campaign	ISFET probe
LAI	0	variable	field campaign	Licor LAI-2000
surface temperature	0	variable	field campaign	100BX-MTS radiometer
chlorophyll content	0	variable	field campaign	CCM-200+
biomass	0	variable	field campaign	in laboratory

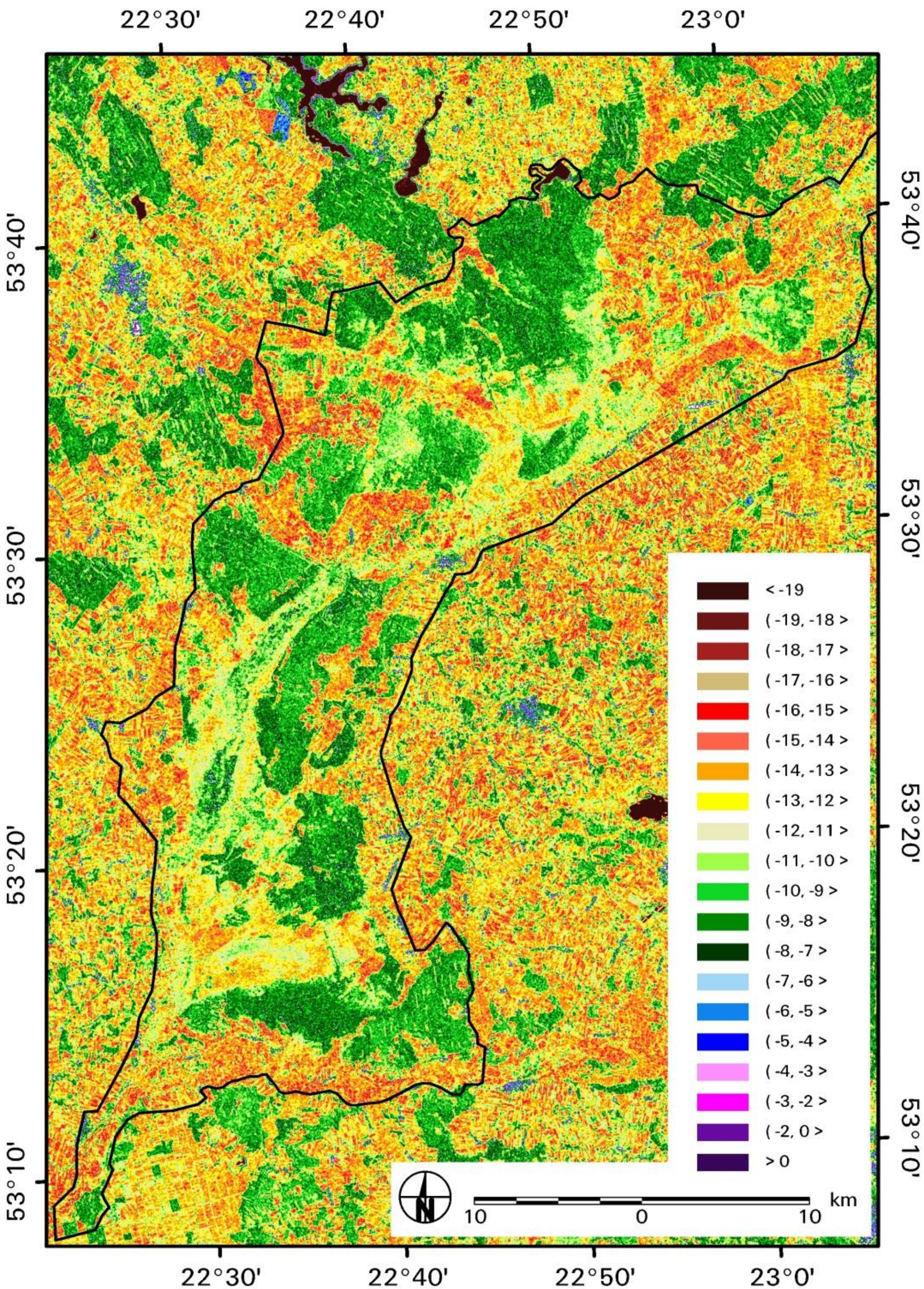
Table 4: Variables to be measured at each SM station enclosed within the first NetCDF-4 file.

Variable	Level [m]	Number of samples	Frequency	Measuring instrument
air temperature	2	2	15 min	Decagon VP-3/Campbell 083E-L
air humidity	2	2	15 min	Decagon VP-3/Campbell 083E-L
air pressure	2	1	15 min	Vaisala CS106
wind speed	2	2	15 min	Decagon Davis/Campbell 05103-L
wind direction	2	2	15 min	Decagon Davis/Campbell 05103-L
upwelling shortwave radiation	2	1	15 min	Hukselflux NR01
downwelling shortwave radiation	2	2	15 min	Hukselflux NR01/Decagon pyranometer
upwelling longwave radiation	2	1	15 min	Hukselflux NR01
downwelling longwave radiation	2	1	15 min	Hukselflux NR01
upwelling PAR radiation	2	1	15 min	Decagon PAR
downwelling PAR radiation	2	1	15 min	Decagon PAR
canopy transmitted PAR	0	1	15 min	Decagon PAR
3h rain amount	2	2	3 h	Decagon ECRN-100
6h rain amount	2	2	6 h	Decagon ECRN-100
12h rain amount	2	2	12 h	Decagon ECRN-100
24h rain amount	2	2	24 h	Decagon ECRN-100
soil heat flux density	-0.02 m	1	15 min	Hukselflux HFP01SC-L
leaf wetness	0	1	15 min	Decagon PAR

Table 5: Variables to be measured at meteo stations enclosed within the second NetCDF-4 file.



SENTINEL-1 16.02.2015 VV



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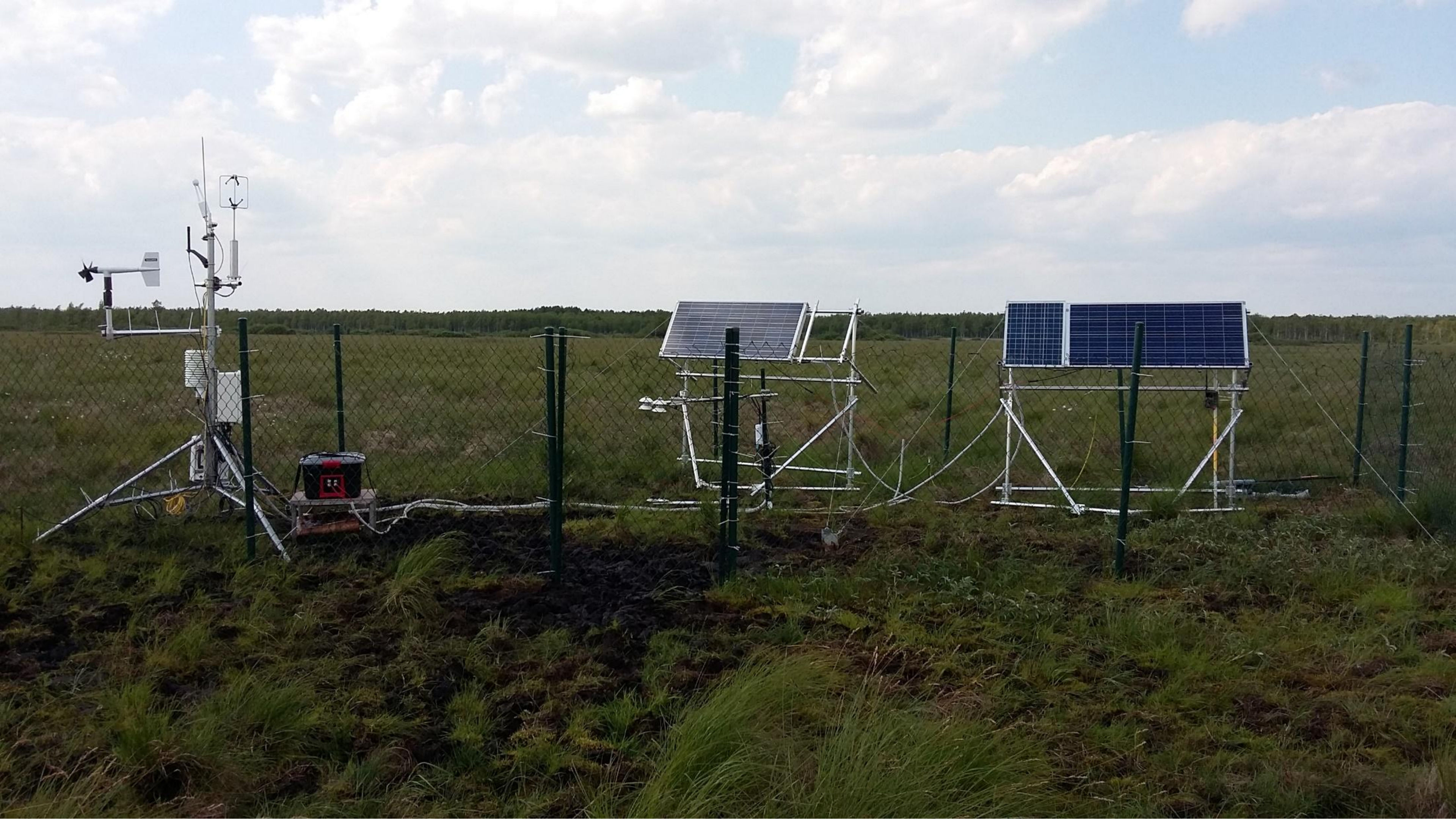


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