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Lublin, 10/05/2018

SOIL MOISTURE SENSING – FROM LOCAL TO GLOBAL

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Why soil moisture is important?

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- Proper amount of water in soil is very important for effective crop production
- Information about soil moisture allows predicting floods and droughts
- Water in soil governs the energy flow and hydrologic cycle of the Earth

Problem

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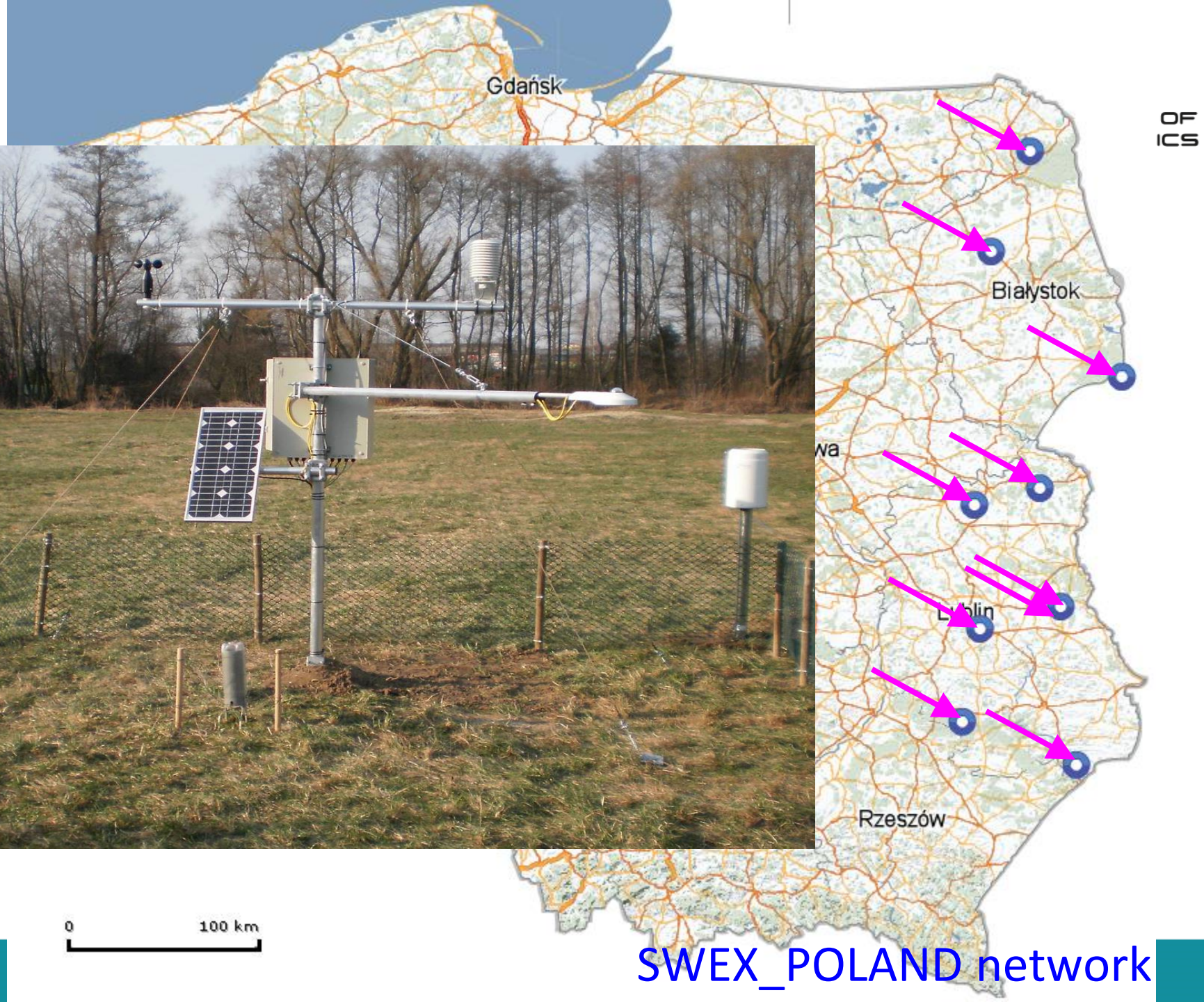
- Soil moisture can be spatially variable → *in-situ* field measurements on a large scale are very time consuming (and costly)
- Long-lasting measurement → easy to lose relevance in temporal scale and in forcing conditions
- Knowledge about soil moisture temporal behavior and spatial distribution is limited…



SWEX_POLAND network

SWEX_POLAND network (10 automatic stations)

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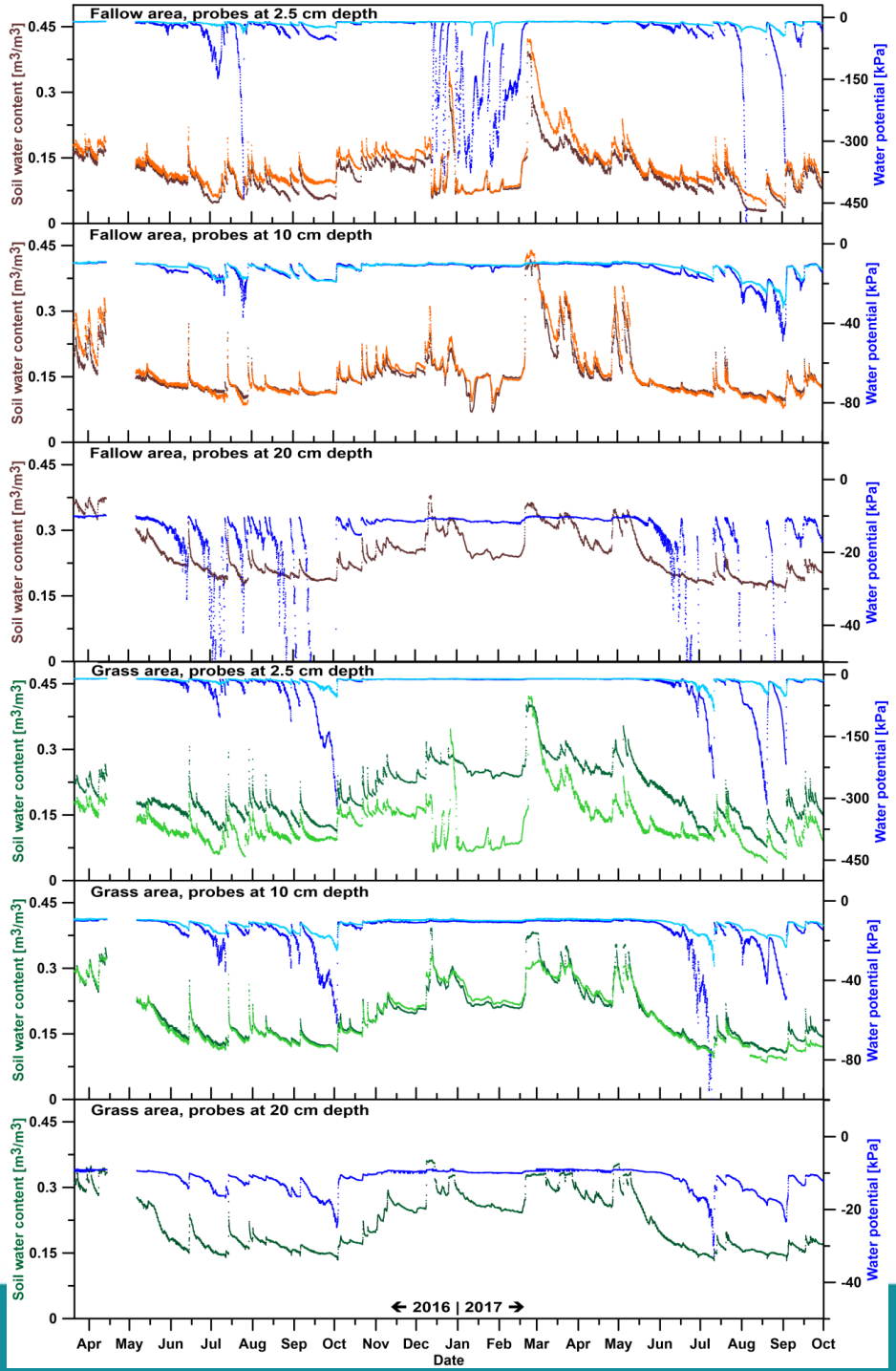
- precipitation
- air temperature
- air humidity
- wind speed
- wind direction
- barometric pressure
- energy balance
- soil moisture, temperature and salinity
- soil moisture (profile)
- soil temperature (profile)
- soil water potential and soil temperature
- radiative temperature of soil surface

Datasets are available here:
http://serwer.elbara.pl/agrostationdb/



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Field measurements

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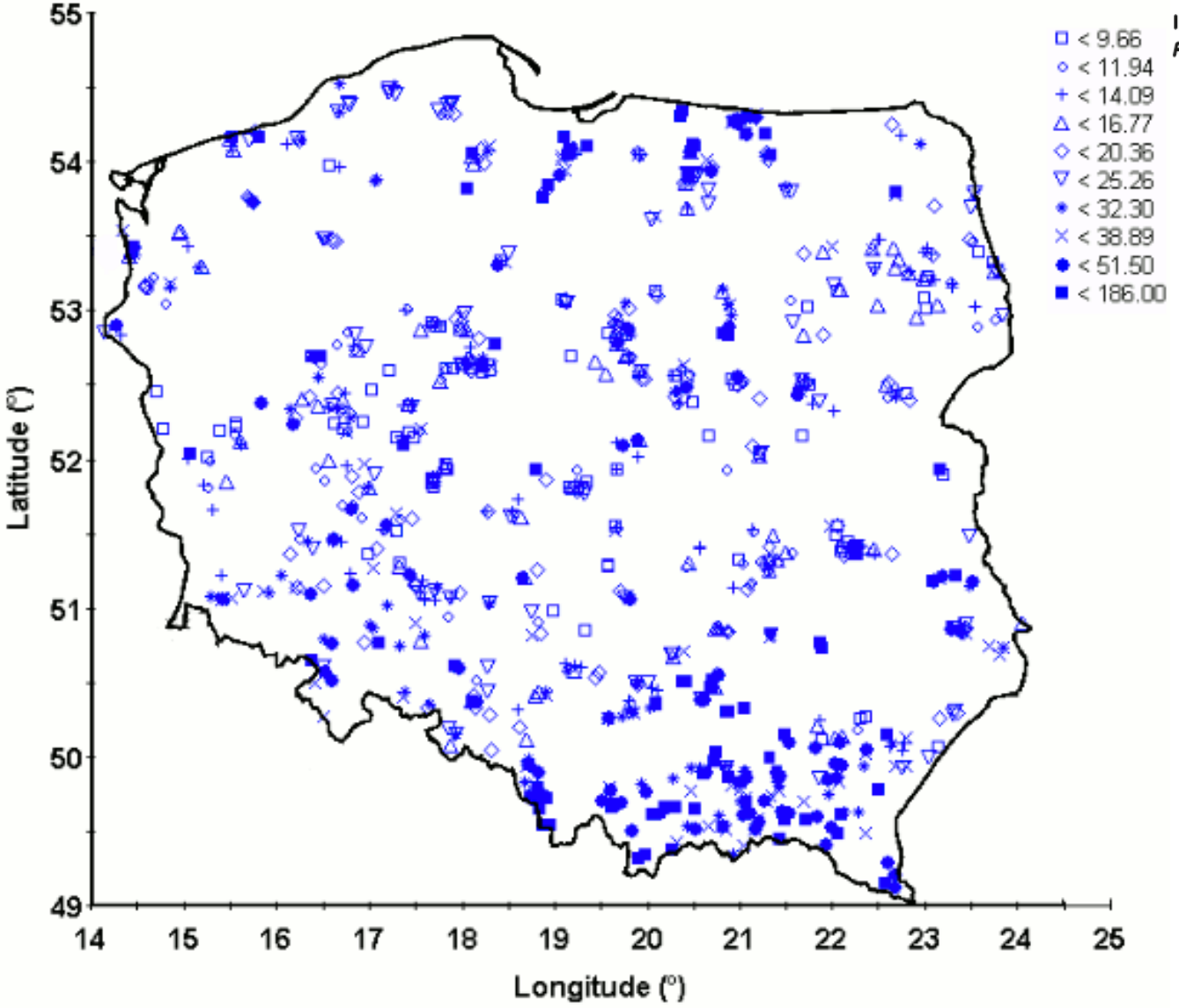
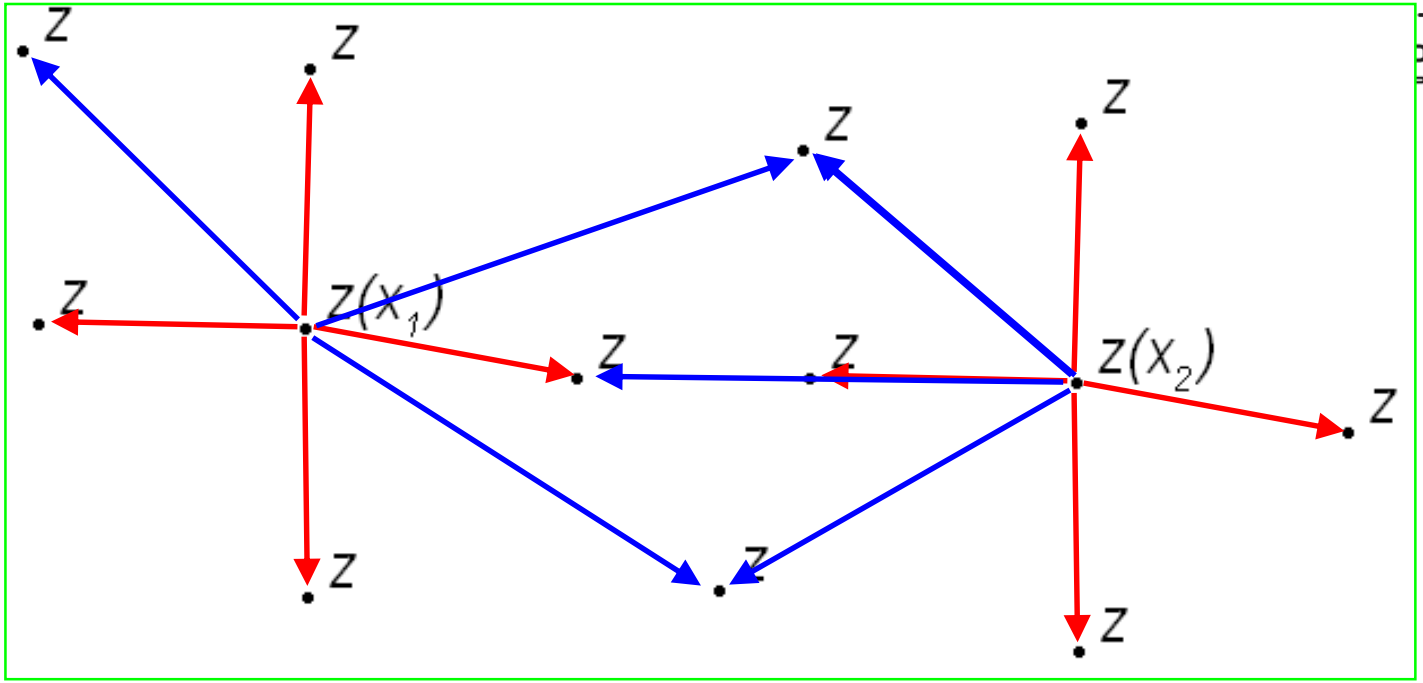


Spatial analyses – geostatistical methods



The empirical semivariograms $\gamma(h)$ for distance h were calculated from:

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

where $N(h)$ is the number of pairs of points $z(x_i)$ separated by the distance h.

Spatial analyses – geostatistical methods

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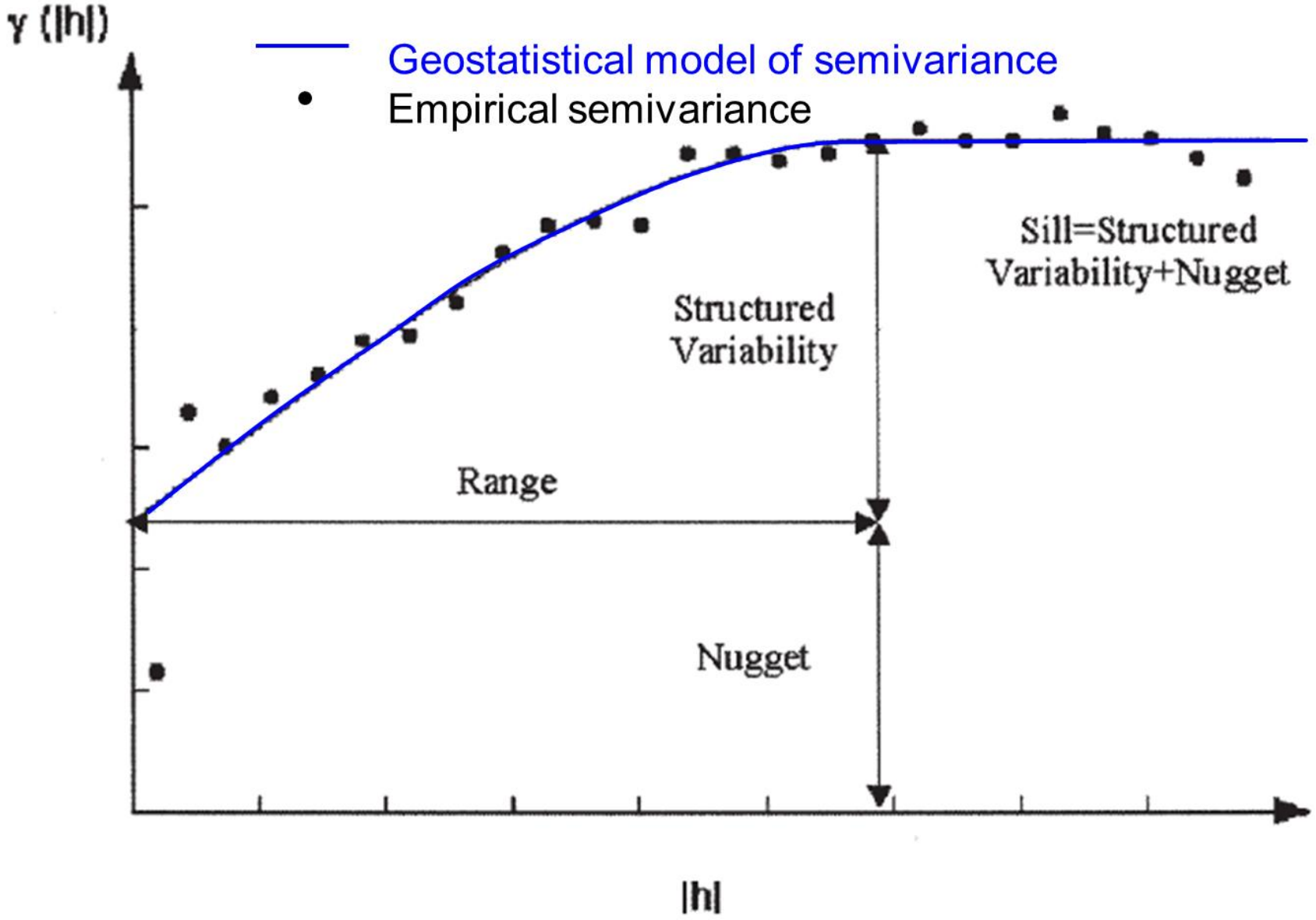

Specific Surface Area (SSA) of soil: Map of Poland

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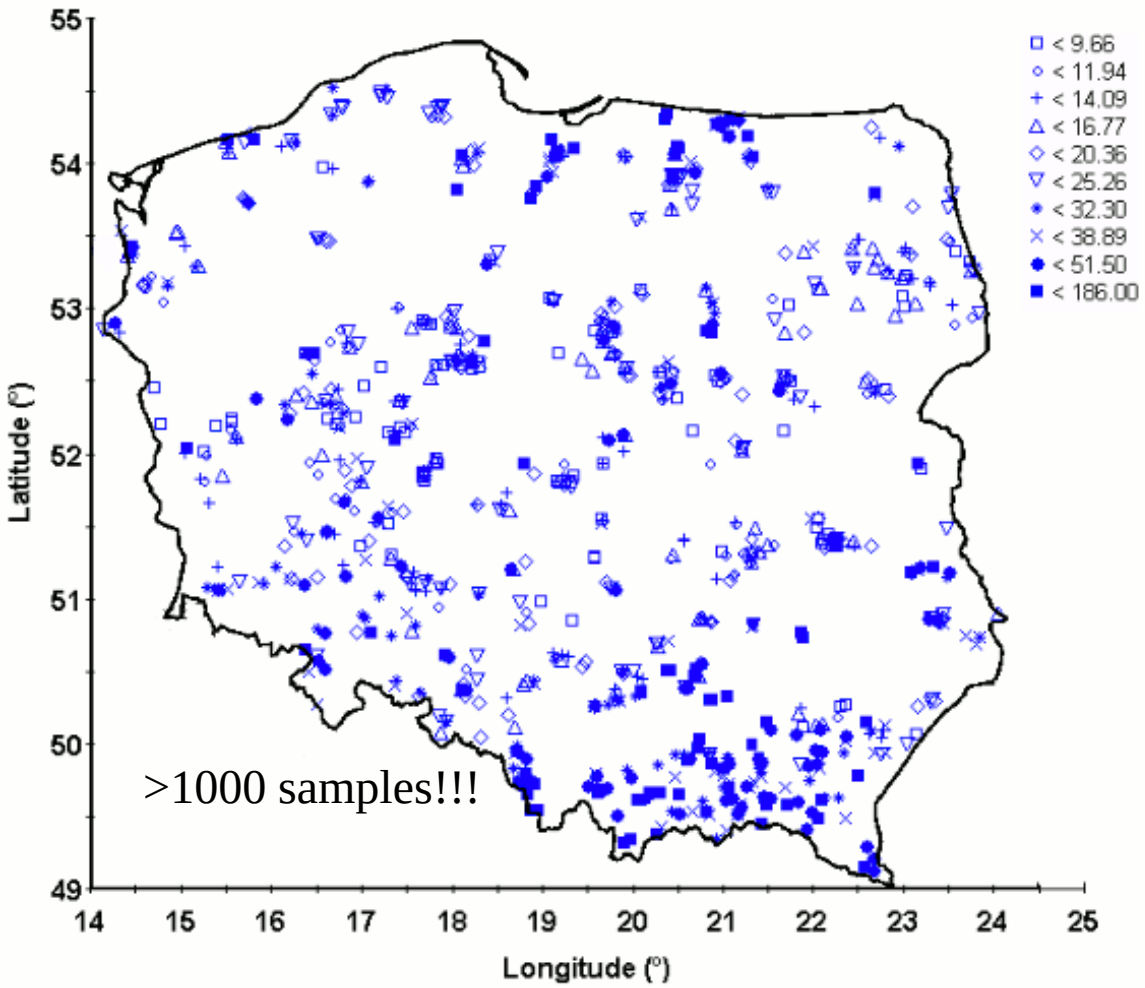

Specific Surface Area (SSA) of soil: Map of Poland

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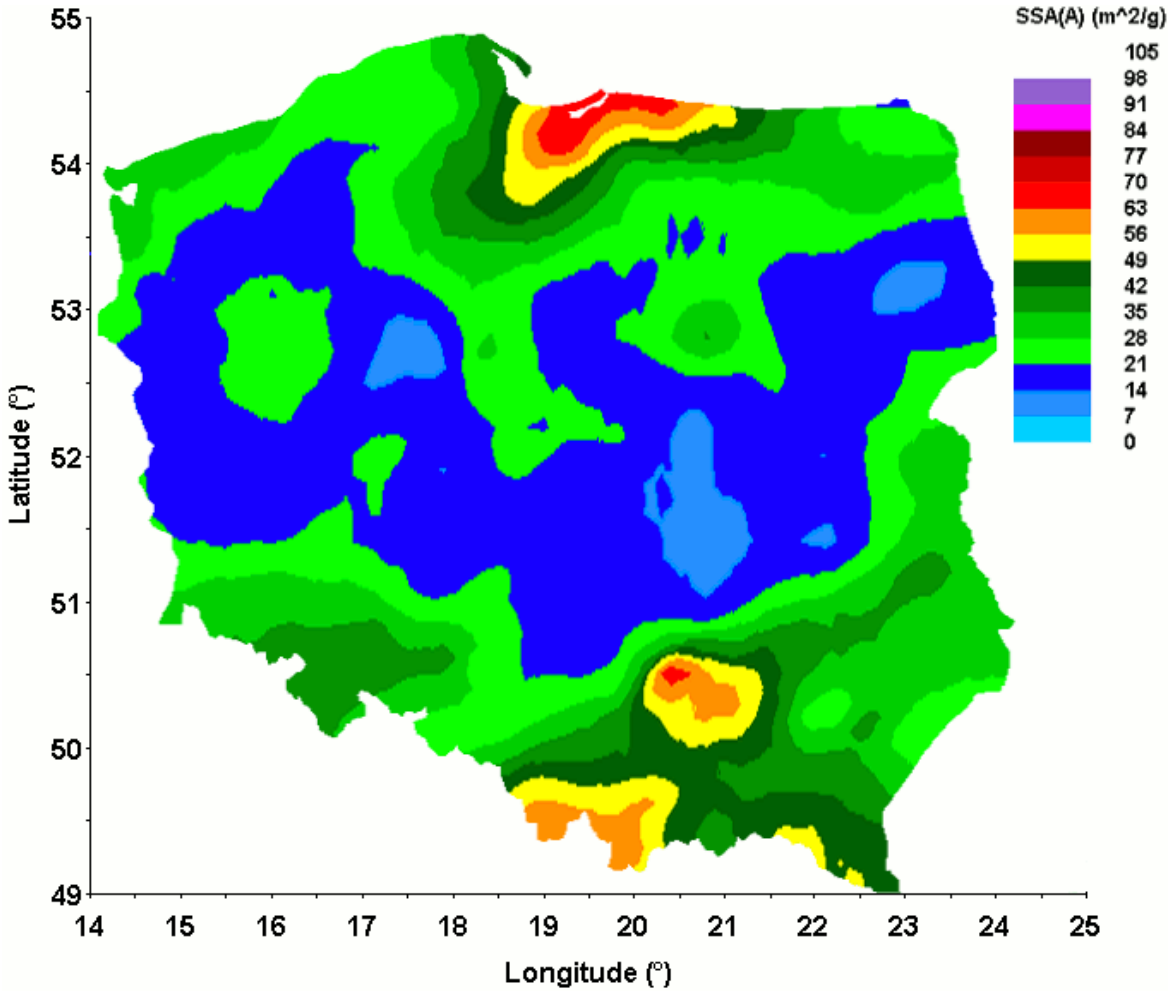

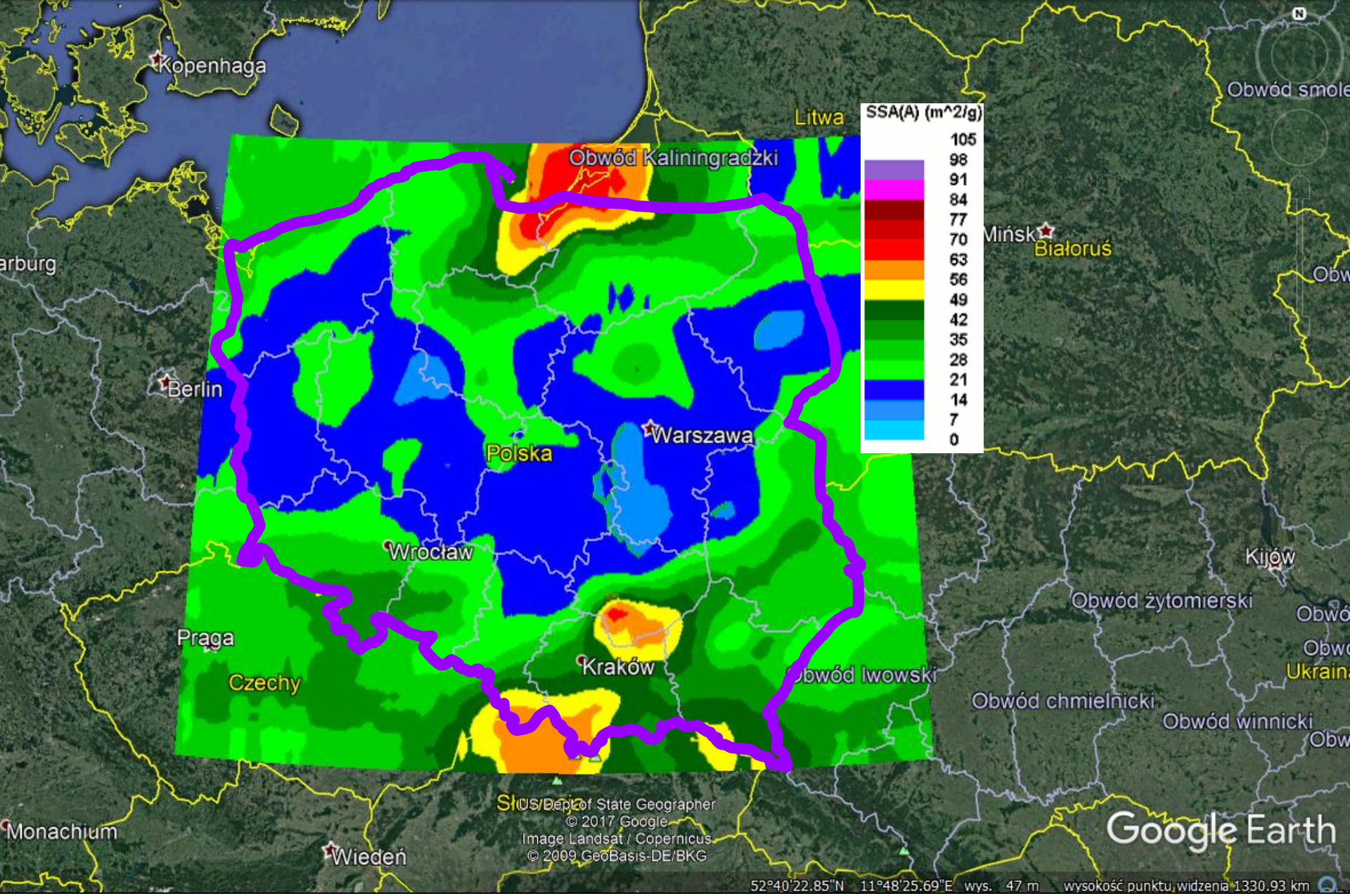

Map of soil Specific Surface Area (SSA)

Water adsorption on soil specific surface → damping of molecules movement

Field campaigns

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Date	Purpose of the visit	Details of the visit
22/03/2016	field campaign, maintenance	105 point measurements of soil moisture, soil salinity and soil temperature ×3 soil layers
06/05/2016	field campaign, maintenance	Adding pyrometer above antenna cone. 53 measurements of soil moisture, salinity and temperature ×3 soil layers. >100 measurements of soil thermal properties. 53 soil samples taken. 15 measurements of LAI and 14 of soil roughness.
18/05/2016	On-Site Acceptance Test (OSAT), field campaign	OSAT and 24 measurements of soil moisture, salinity and temperature ×3 soil layers. 48 measurements of soil thermal properties. 24 soil samples taken. 10 measurements of LAI and single of soil roughness. Pyrometer cable adjustment.
03/06/2016	field campaign, maintenance	24 measurements of soil moisture, salinity and temperature ×3 soil layers. 48 measurements of soil thermal properties. 24 soil samples taken. ELBARA's antenna cleaning.
28/07/2016	field campaign	49 measurements of soil moisture, salinity and temperature ×3 soil layers. 98 measurements of soil thermal properties. 8 measurements of LAI.
19/09/2016	field campaign	90 measurements of soil moisture, salinity and temperature ×3 soil layers. >100 measurements of soil thermal properties. 44 soil samples taken. 8 measurements of LAI and 10 of soil roughness. 4 vegetation destructive samples taken.
03/11/2016	field campaign	59 measurements of soil moisture, salinity and temperature ×2 soil layers. 118 measurements of soil thermal properties. 20 soil samples taken. 5 measurements of soil roughness.
18/05/2017	field campaign	86 measurements of soil moisture, salinity and temperature ×3 soil layers. 82 measurements of soil thermal properties. 48 soil samples taken

Soil moisture – local scale

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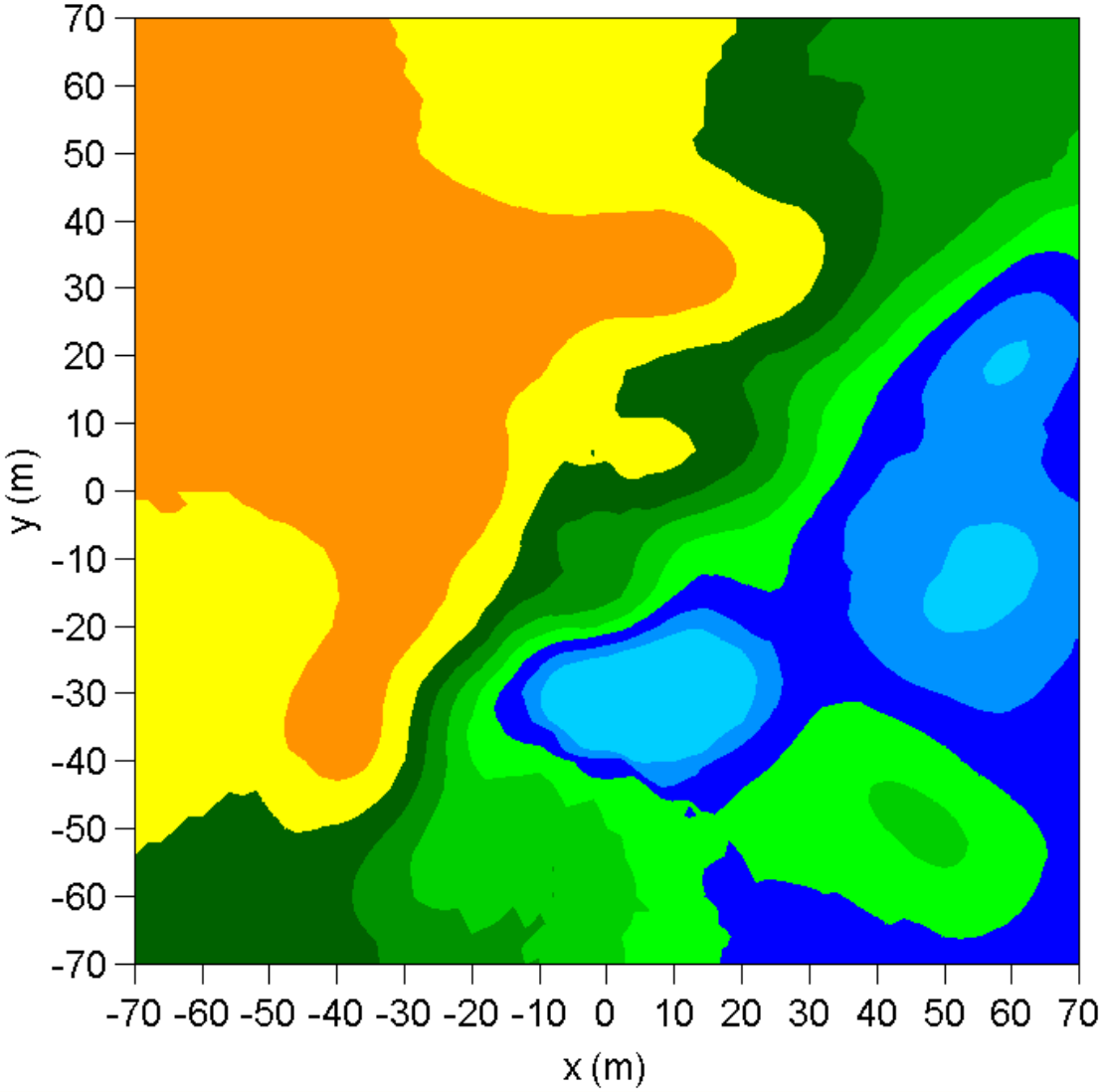

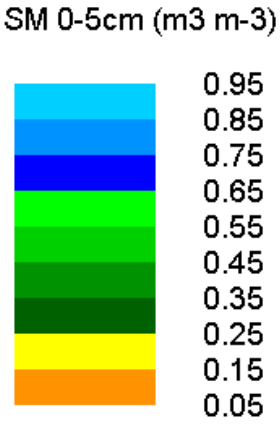

ELBARA Poland – Bubnow Wetland

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ELBARA Poland – Bubnow Wetland

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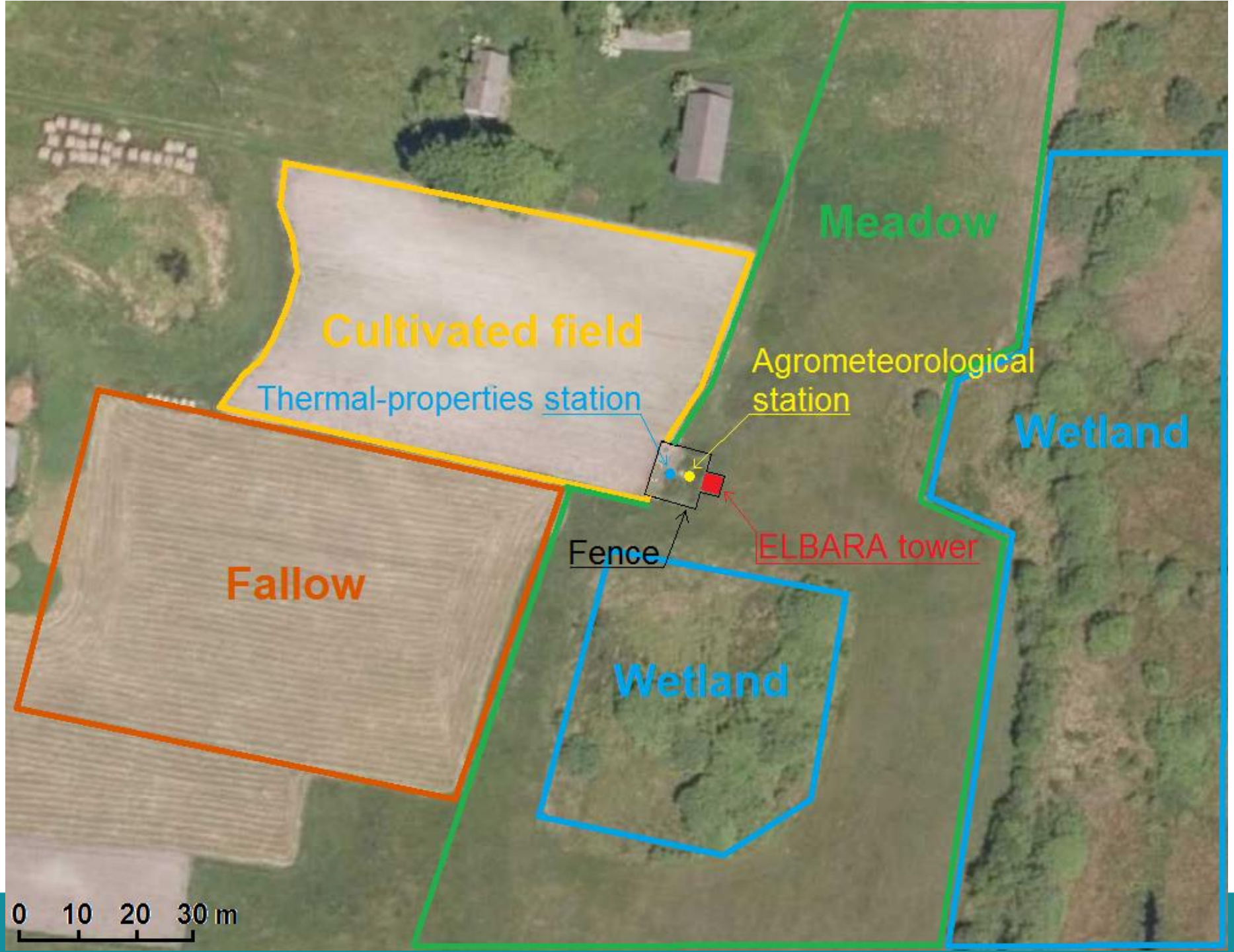
Meadow
Cultivated field
Thermal-properties station
Agrometeorological station
Wetland
Fence
ELBARA tower
Fallow
Wetland
0 10 20 30 m

ELBARA III – azimuthal and vertical

(+improved electronics)

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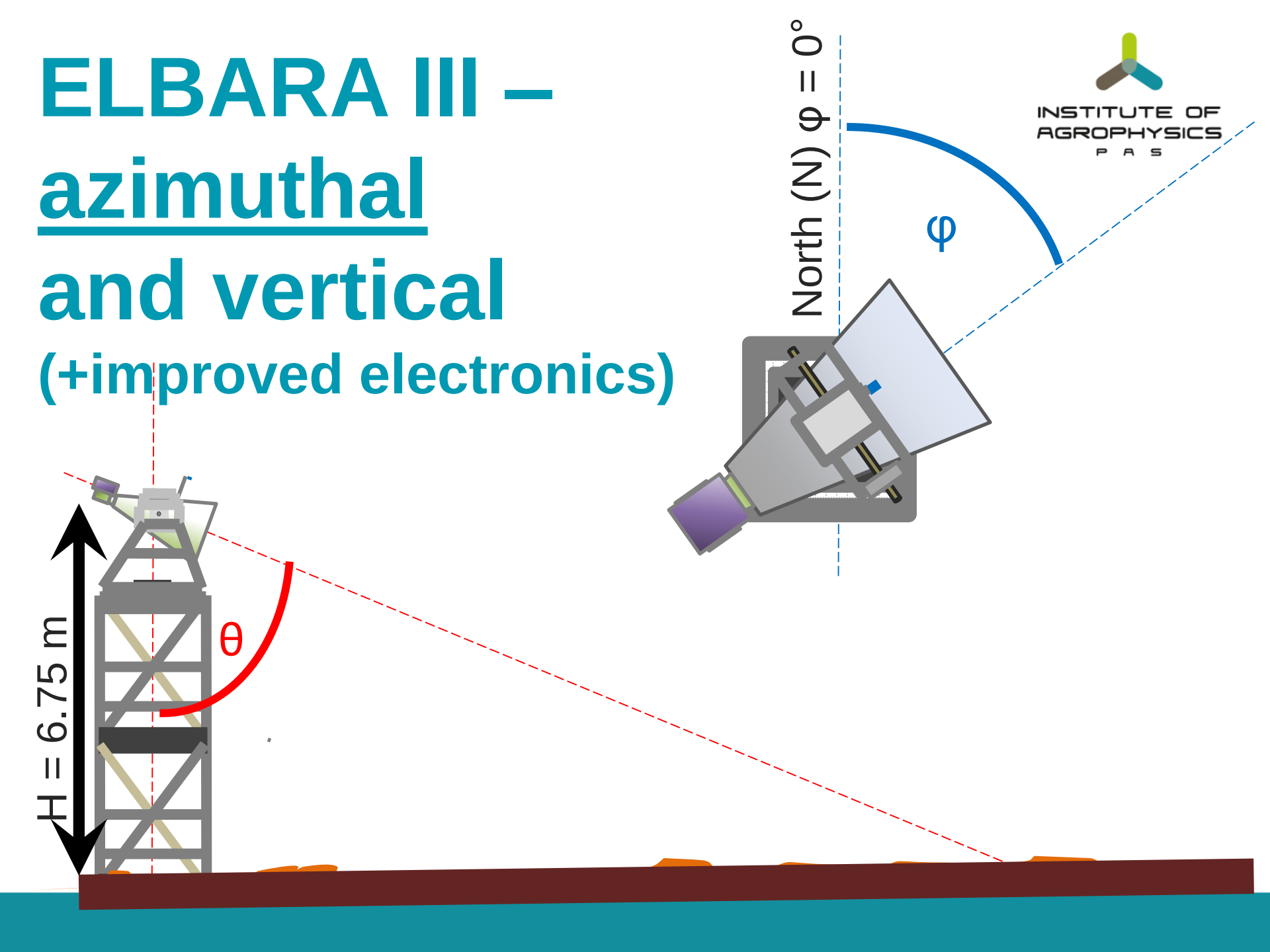

Bubnow Wetland

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Brightness temperature around ELBARA's tower

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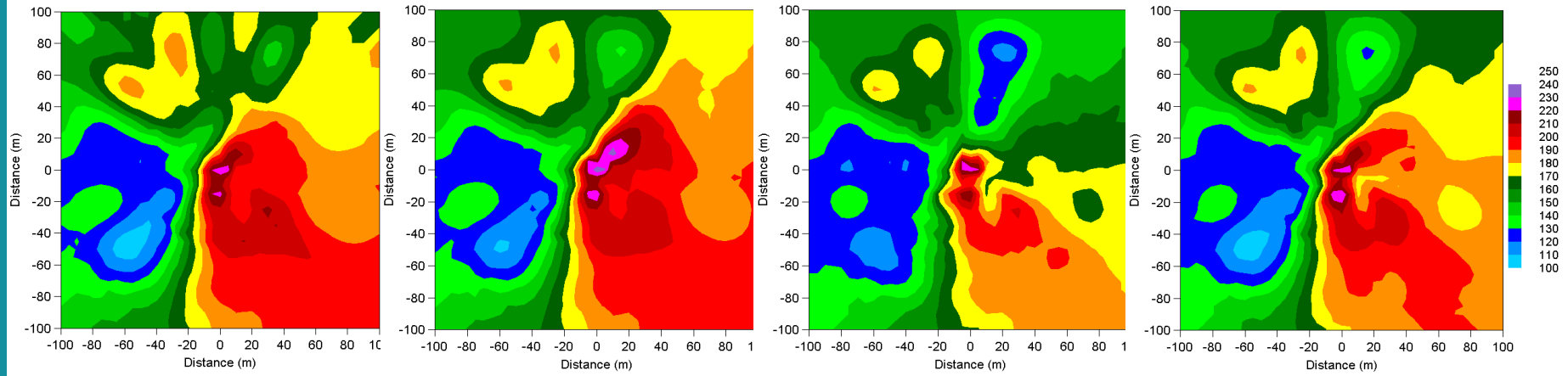
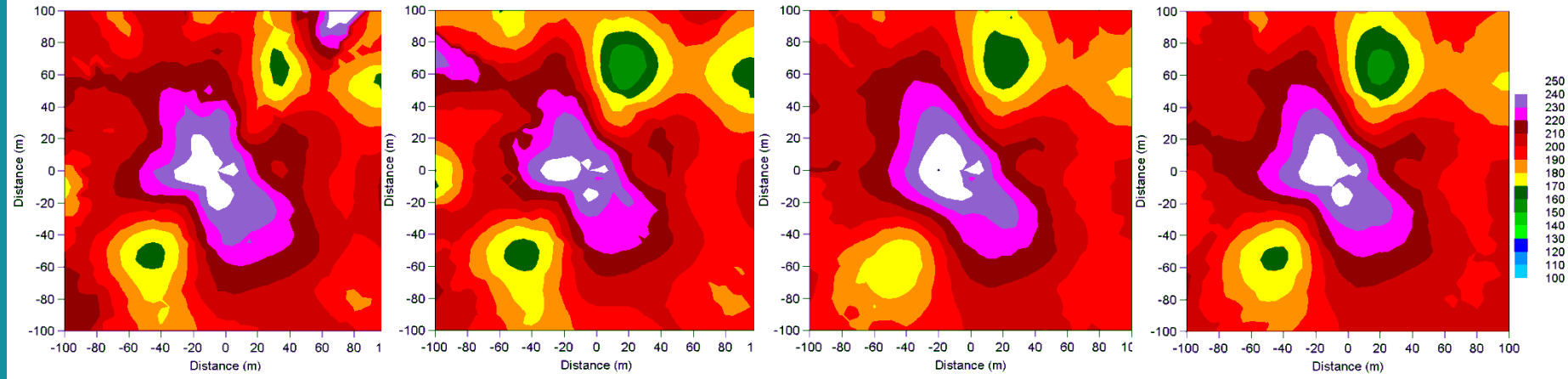
NIGHT	MORNING	NOON	EVENING

Brightness temp. H [K]



Brightness temp. V [K]



Brightness temperature around ELBARA's tower – dataset

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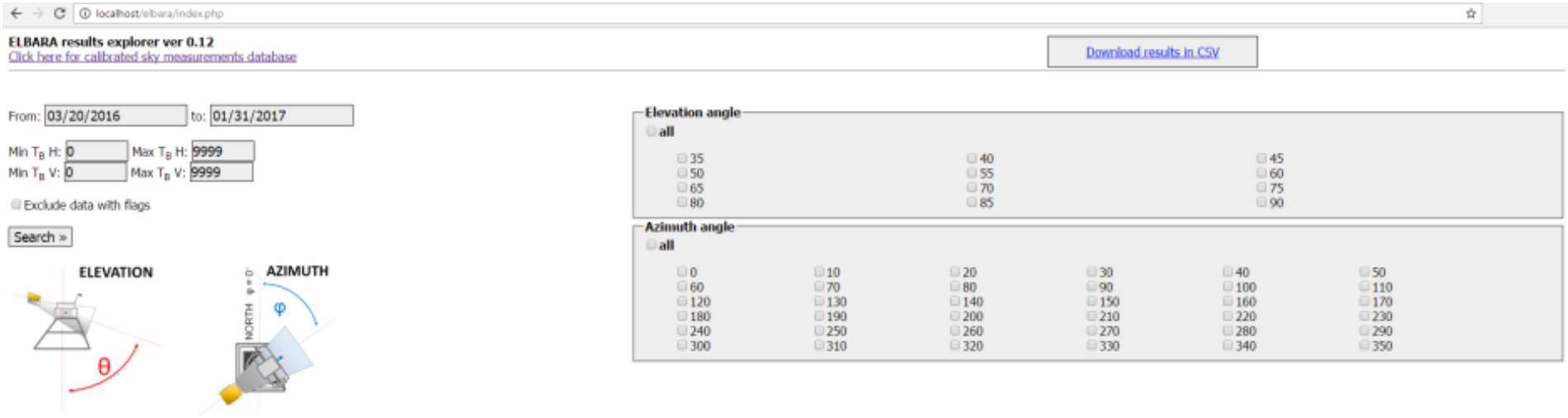

Date	Time	Elev	Azi	TB_HP	Flag_HP	TB_VP	Flag_VP	SysTempDiff	T_ext	T_set
2017-02-01	16:15:00	35	0	253.9806	0	271.654	100	-0.001	272.15	277.15
2017-02-01	16:16:00	40	0	235.6615	0	258.8013	100	0.012	272.15	277.15
2017-02-01	16:16:00	45	0	224.355	0	259.5751	100	0.01	272.15	277.15
2017-02-01	16:17:00	50	0	213.912	0	260.7098	0	0.005	272.15	277.15
2017-02-01	16:17:00	55	0	207.3839	0	264.5647	0	-0.002	272.15	277.15
2017-02-01	16:18:00	60	0	206.2457	0	263.8867	0	-0.006	272.15	277.15
2017-02-01	16:18:00	65	0	207.3291	0	260.7176	0	-0.008	272.15	277.15
2017-02-01	16:19:00	70	0	204.0235	0	254.0143	0	-0.007	271.95	277.15
2017-02-01	16:19:00	75	0	188.6469	0	242.4835	0	-0.007	271.95	277.15
2017-02-01	16:20:00	80	0	169.4713	0	222.6541	0	-0.006	271.95	277.15
2017-02-01	16:20:00	85	0	154.158	0	192.594	0	-0.003	271.85	277.15
2017-02-01	04:20:00	35	0	254.0873	100	272.9211	100	-0.003	269.55	277.15
2017-02-01	04:21:00	40	0	232.9013	0	259.0178	100	0.012	269.55	277.15
2017-02-01	04:21:00	45	0	220.5495	0	259.5512	100	0.012	269.55	277.15
2017-02-01	04:22:00	50	0	210.3312	0	260.8662	100	0.005	269.55	277.15
2017-02-01	04:22:00	55	0	204.3852	0	265.3677	0	0.001	269.55	277.15

http://serwer.elbara.pl/elbaradb/

Brightness temperature around ELBARA's tower – time series

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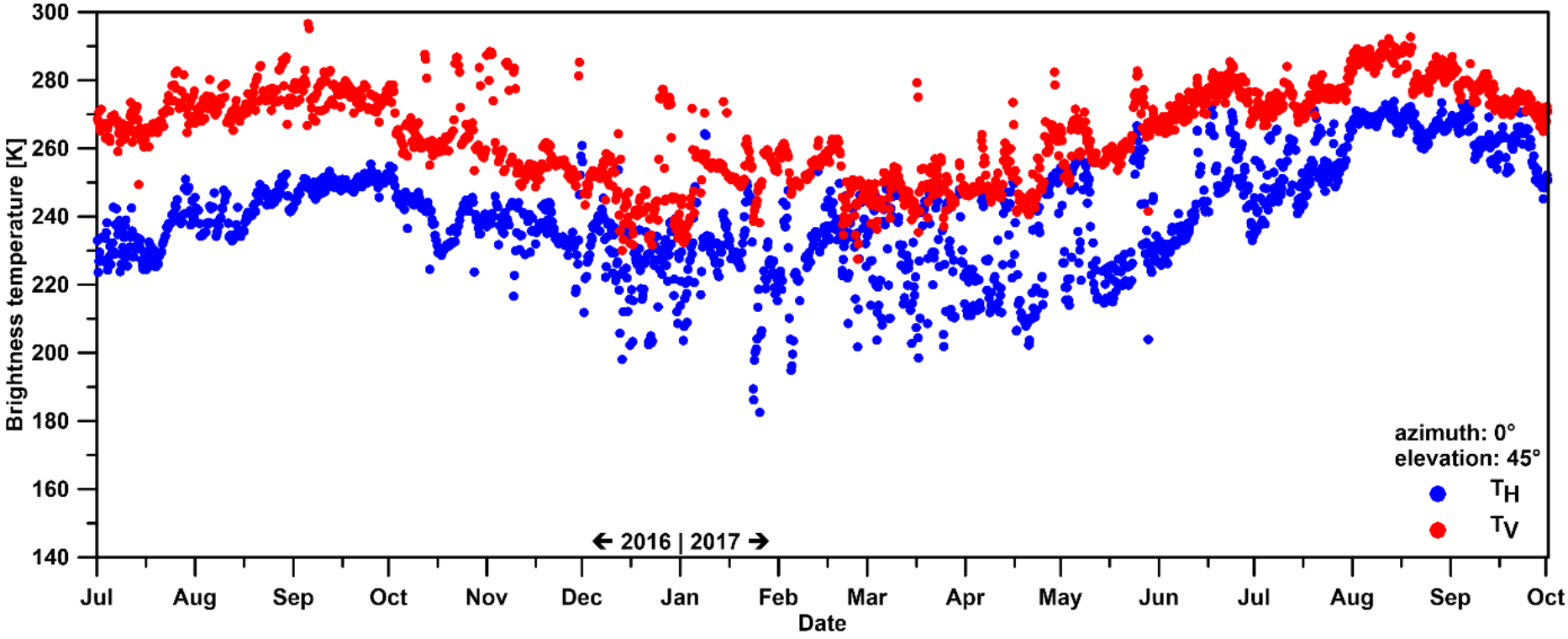

Time series of calibrated brightness temperatures of soil (exemplary footprint azimuth=0°, elevation=45°).

Quasi-simultaneous observations of several footprints under the same meteorological conditions

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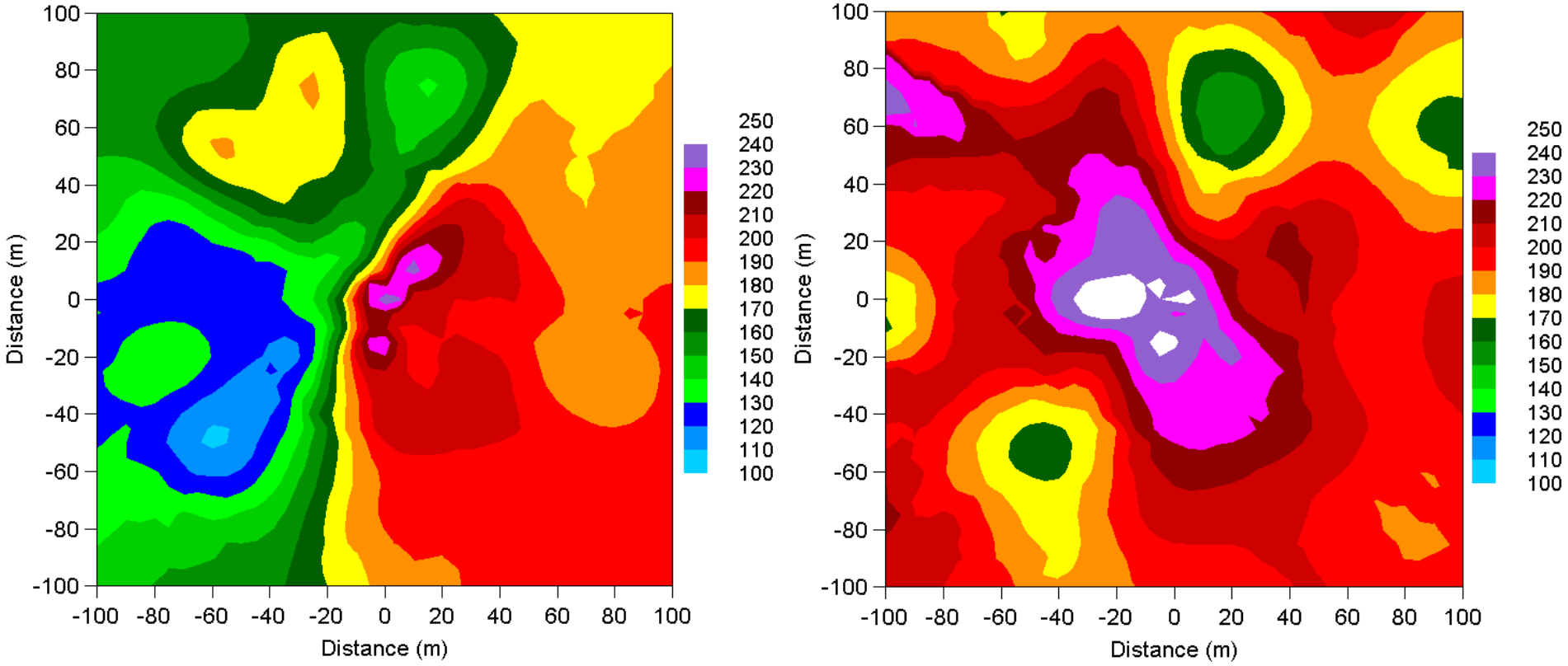
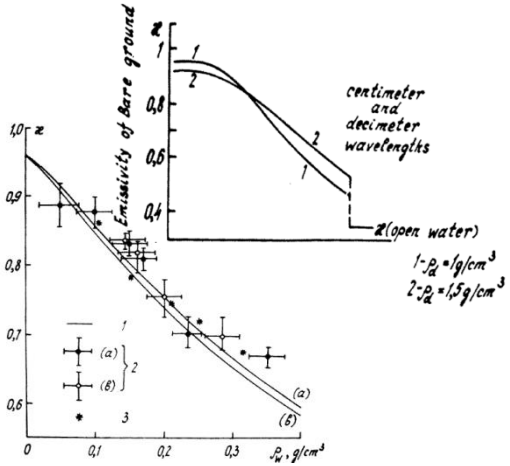
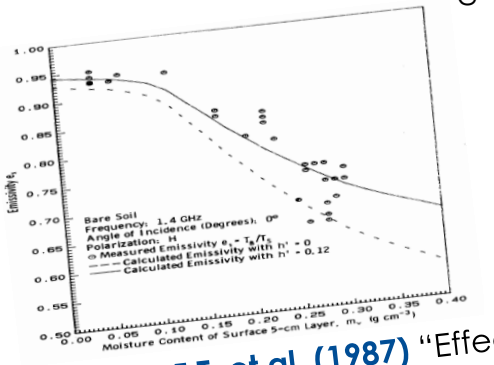


Exemplary brightness temperatures (in Kelvins) of the test-site, measured by ELBARA (localized in 0,0 point of plot). Left-hand panel – horizontal polarization, right-hand panel – vertical. Data collected 22/03/2016.

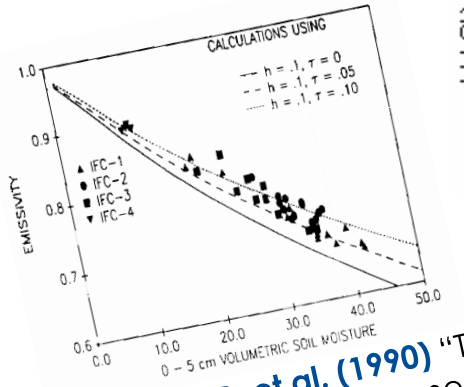
Soil moisture vs. brightness temperature



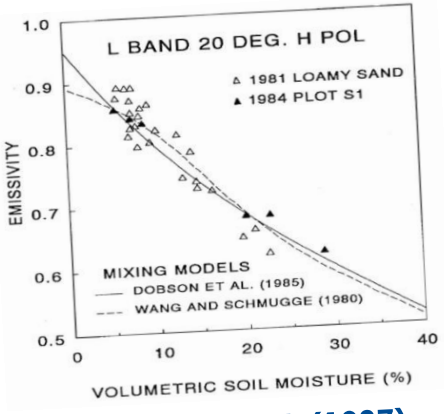
Shutko, A. M. (1982) "Microwave radiometry of lands under natural and artificial moistening."



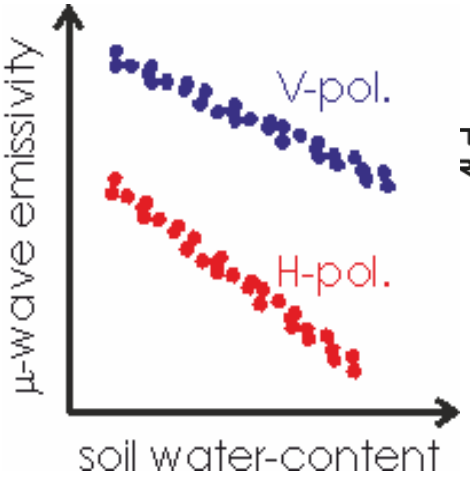
Ulaby, F.T. et al. (1987) "Effects of vegetation cover on the microwave radiometric sensitivity to soil moisture"



Wang, J.R. et al. (1990) "The L-band PBMR measurements of surface soil moisture in FIFE"



Jackson, T.J. et al. (1987) "Salinity effects on the microwave emission of soils"



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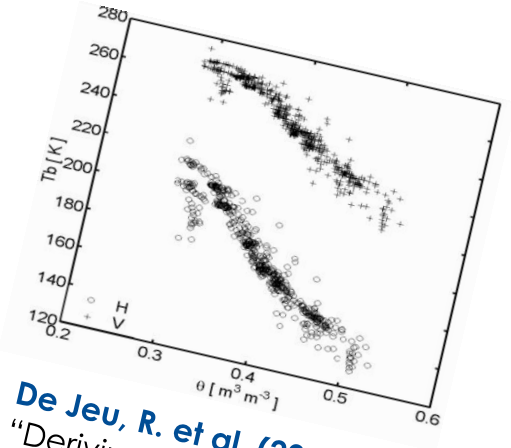
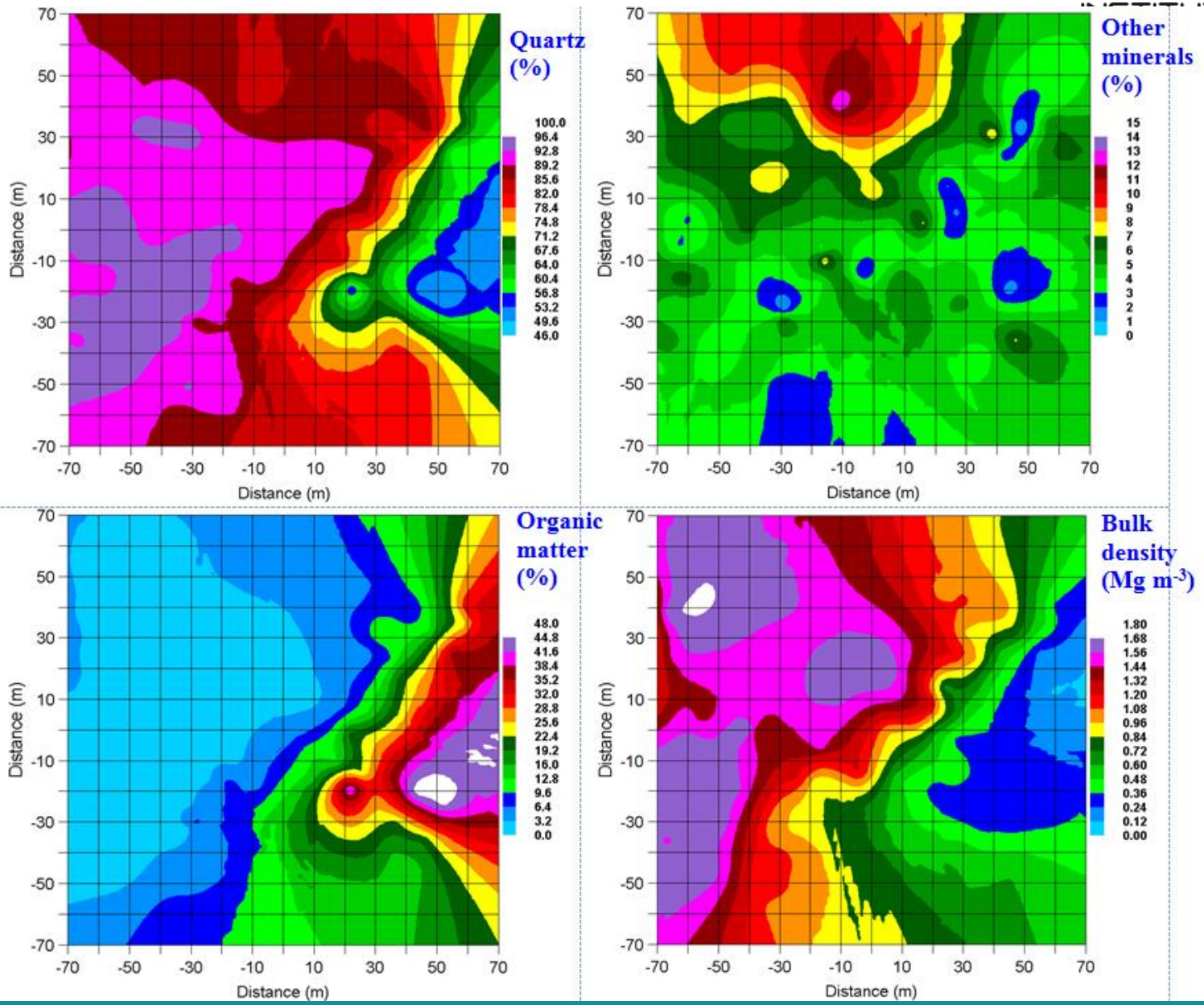
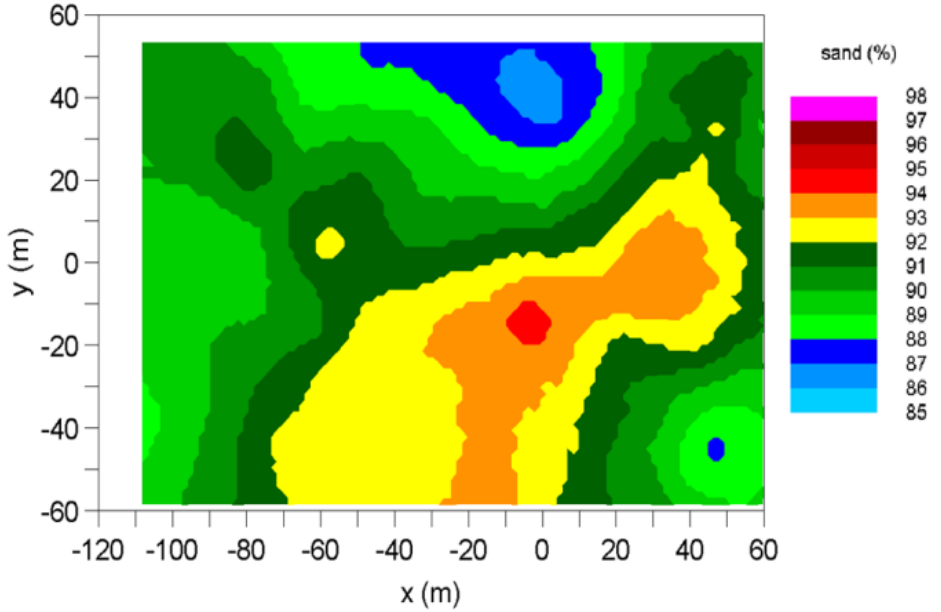


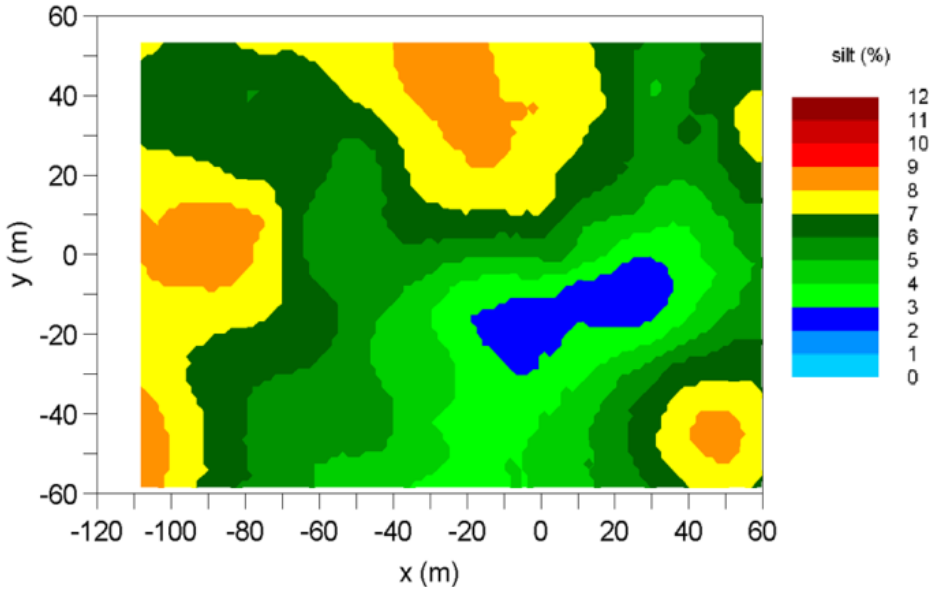
De Jeu, R. et al. (2004) "Deriving land surface parameters from 3 different vegetated sites with the ELBARA 1.4 GHz passive microwave radiometer."

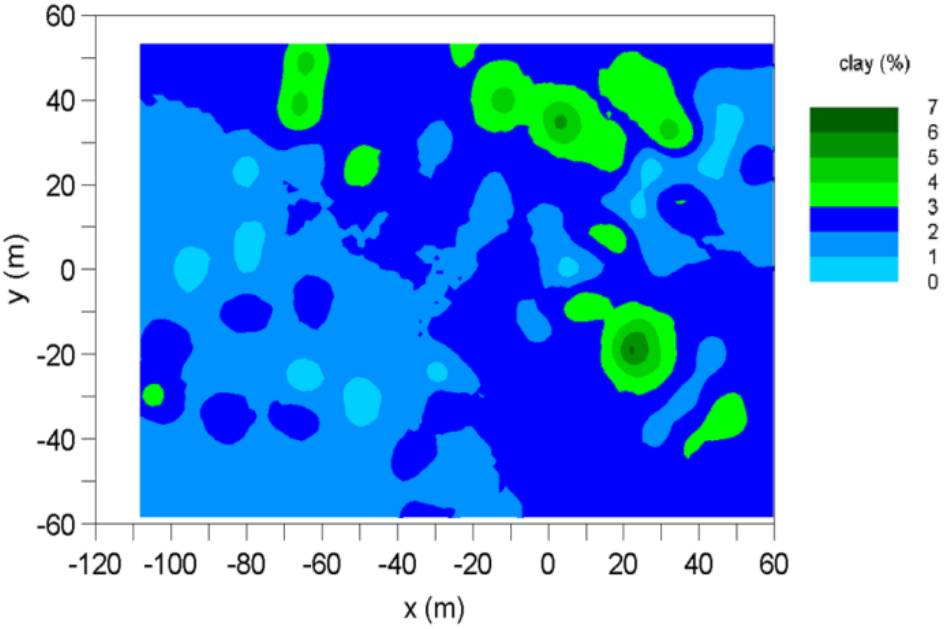
Soil texture and mineralogical composition

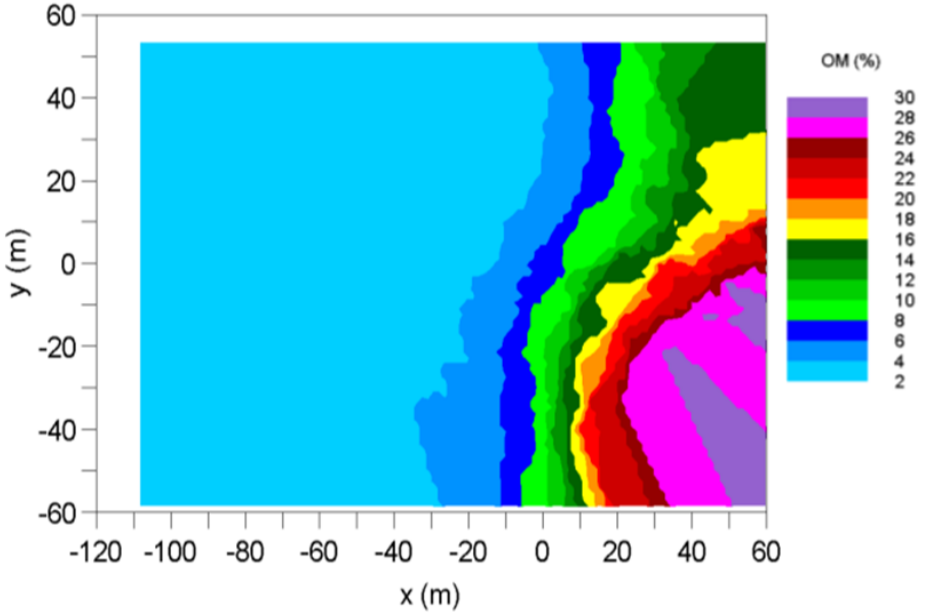


Soil properties – local scale









Measurements of soil moisture distribution in layers

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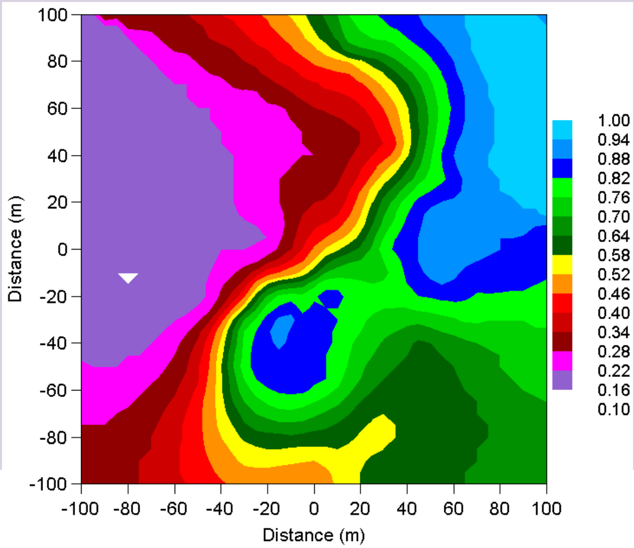
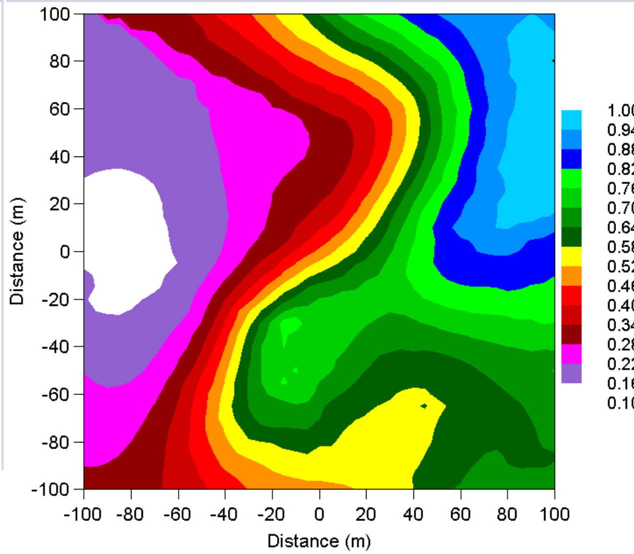
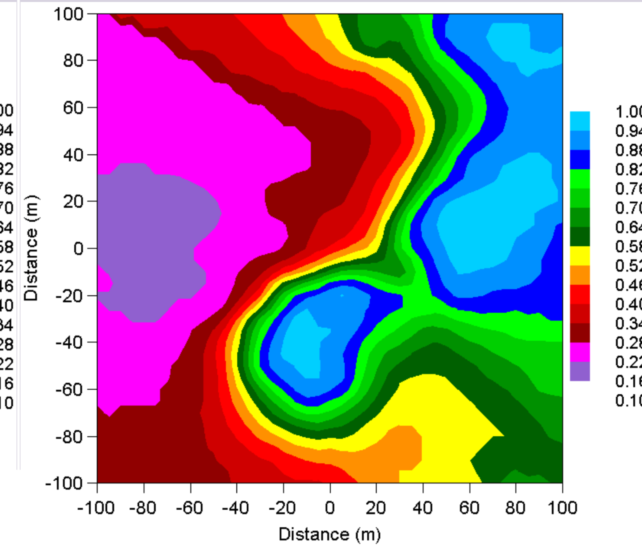
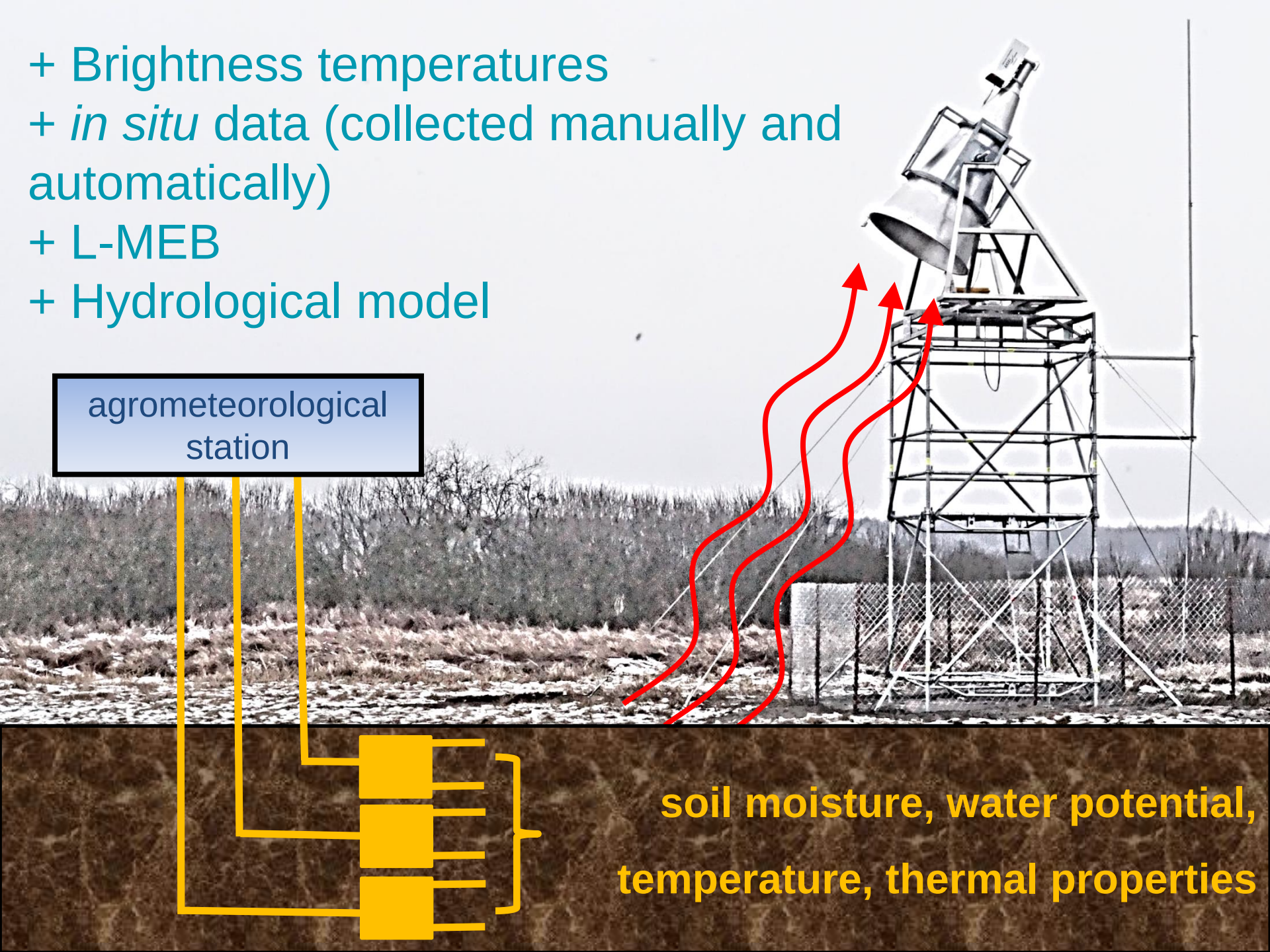
Soil moisture (0-5 cm) [$m^3\ m^{-3}$]	Soil moisture (0-10 cm) [$m^3\ m^{-3}$]	Soil moisture (0-17 cm) [$m^3\ m^{-3}$]

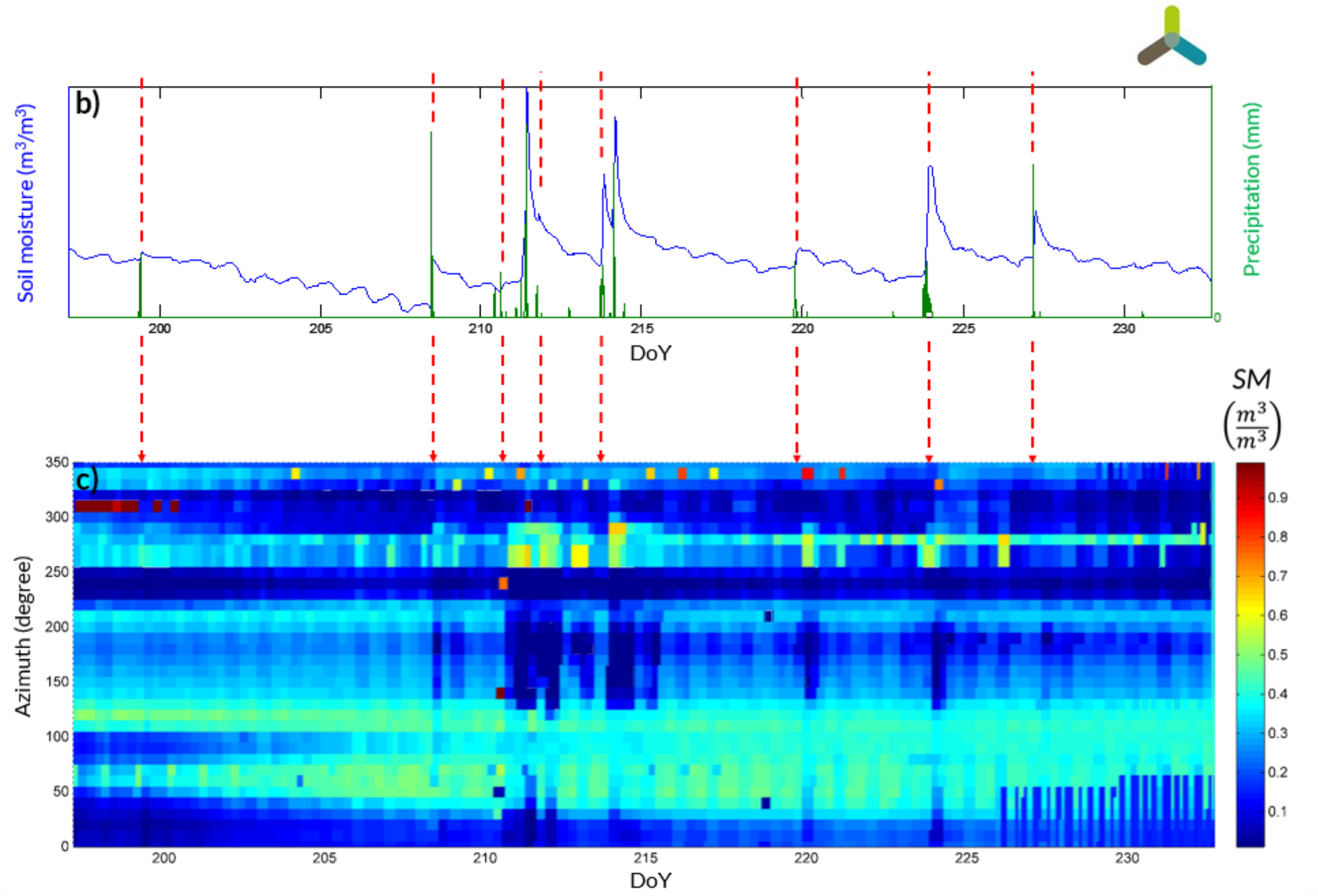






+ Brightness temperatures
+ *in situ* data (collected manually and automatically)
+ L-MEB
+ Hydrological model




b)
Soil moisture (m³/m³)
Precipitation (mm)
0
200
205
210
215
220
225
230
DoY
SM
(m³/m³)
c)
Azimuth (degree)
350
300
250
200
150
100
50
0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
200
205
210
215
220
225
230
DoY

Soil Moisture retrieved with L-MEB model (from Brightness Temperature)

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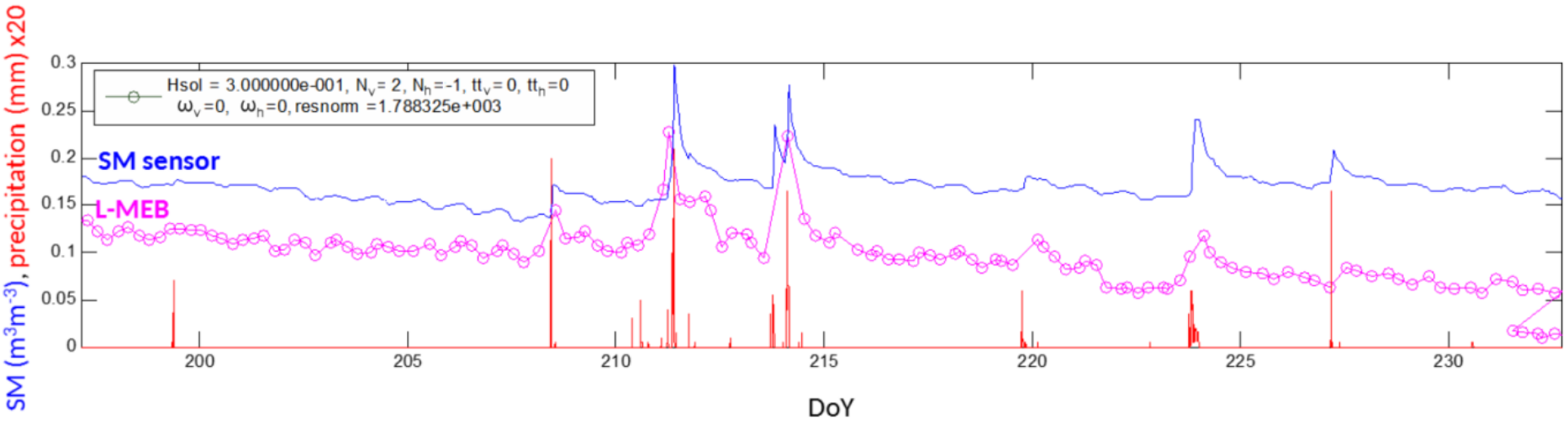

Temporal dependences of SM measured with a sensor and retrieved with L-MEB model. Red, narrow vertical lines indicate precipitation events. SM values were obtained from microwave brightness temperatures measured at azimuth angle 290º. The retrieval has been done assuming T_{GC}, τ_{nad} and SM as free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

Mesoscale – KBW

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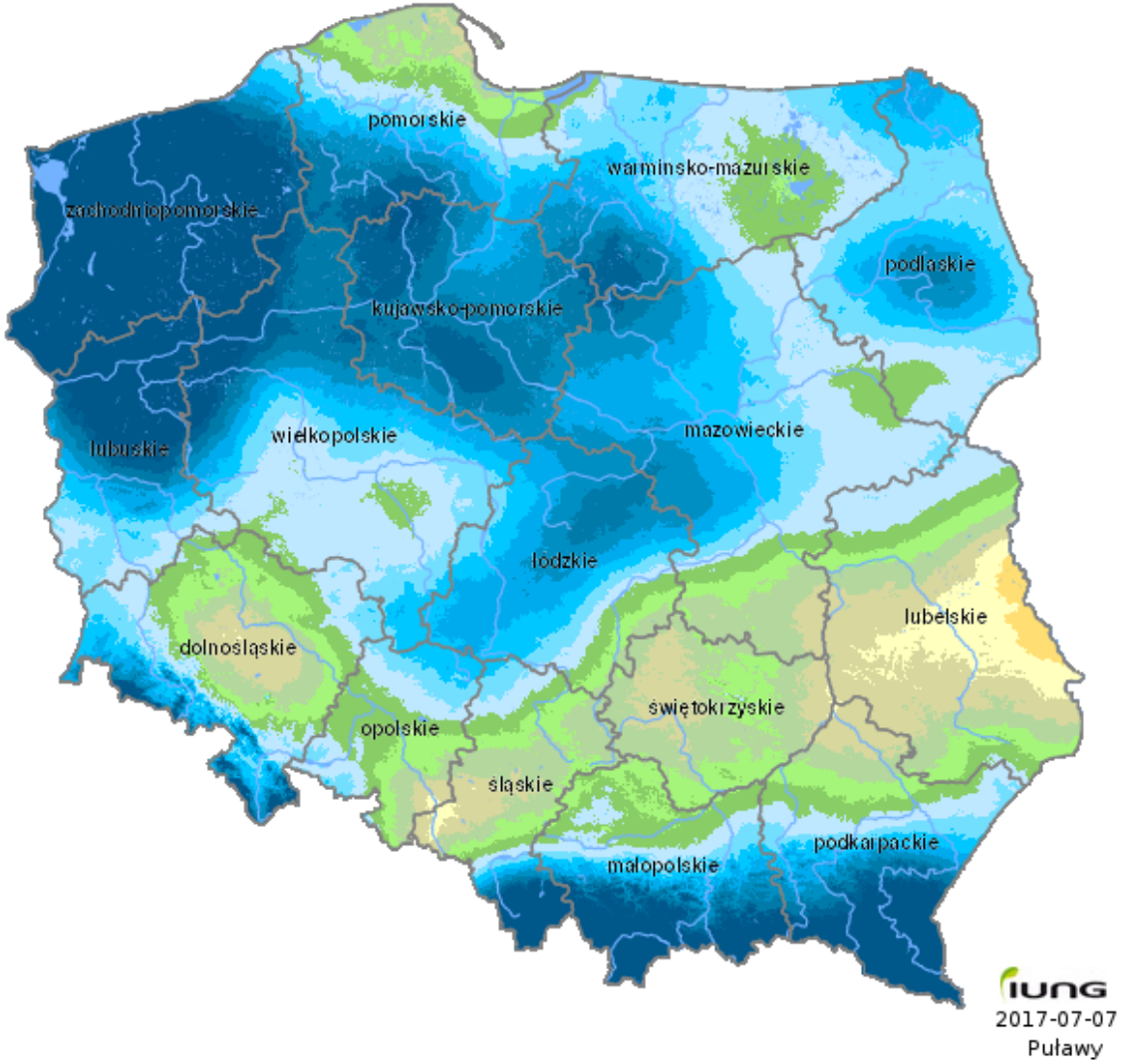

Mesoscale – SPI

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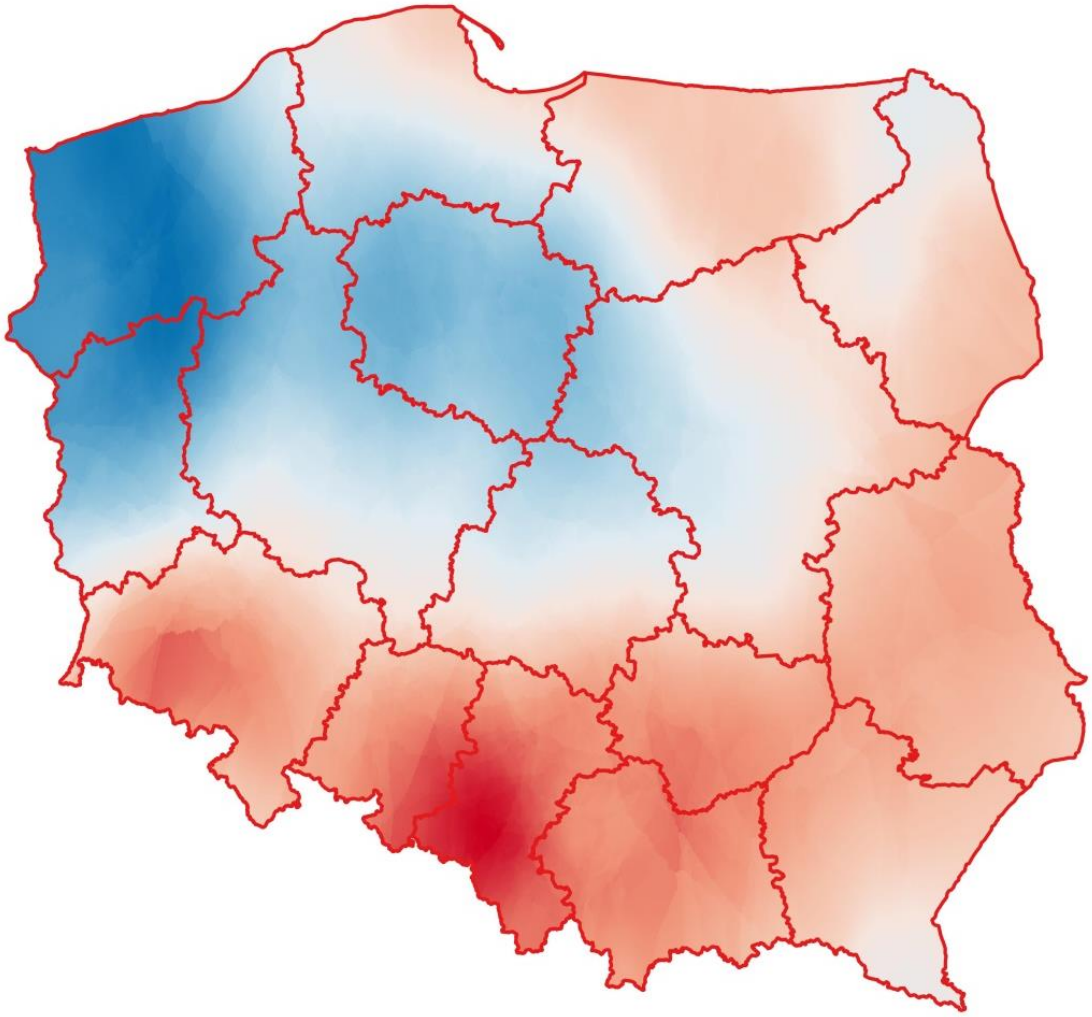

Satellite data

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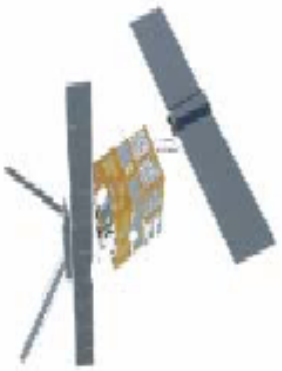
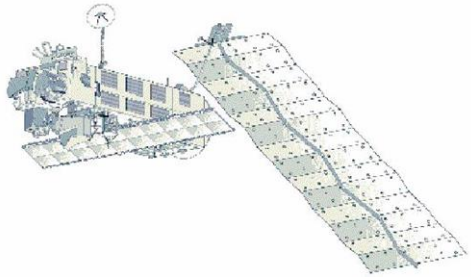
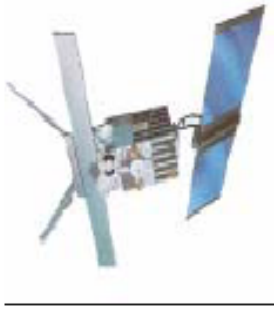
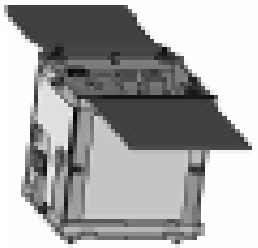
- Large region of measurement (meso- and global scale)
- Spatial continuity
- Consistency
- Cost effectiveness

Mesoscale – KBW_MODIS

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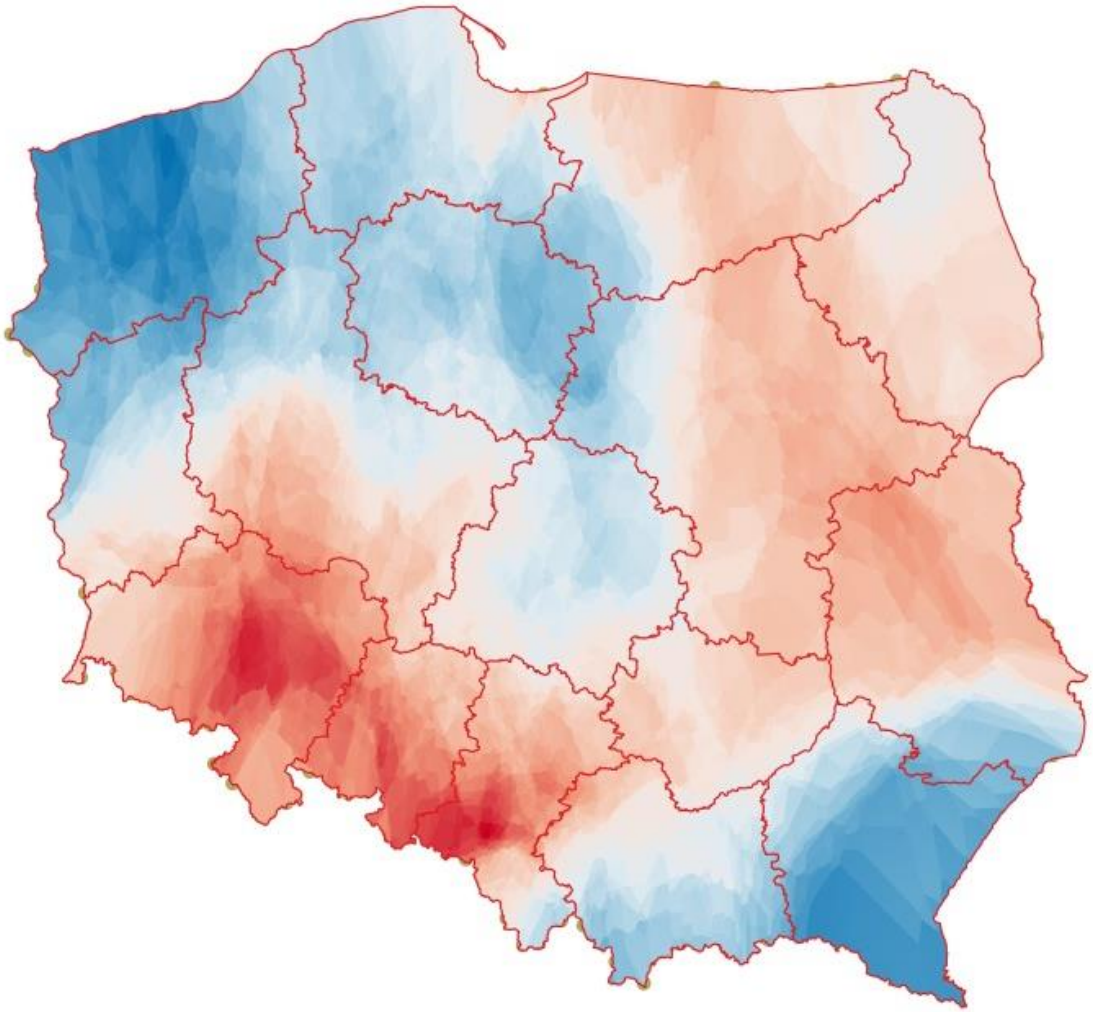

KBW_MODIS vs. SPI

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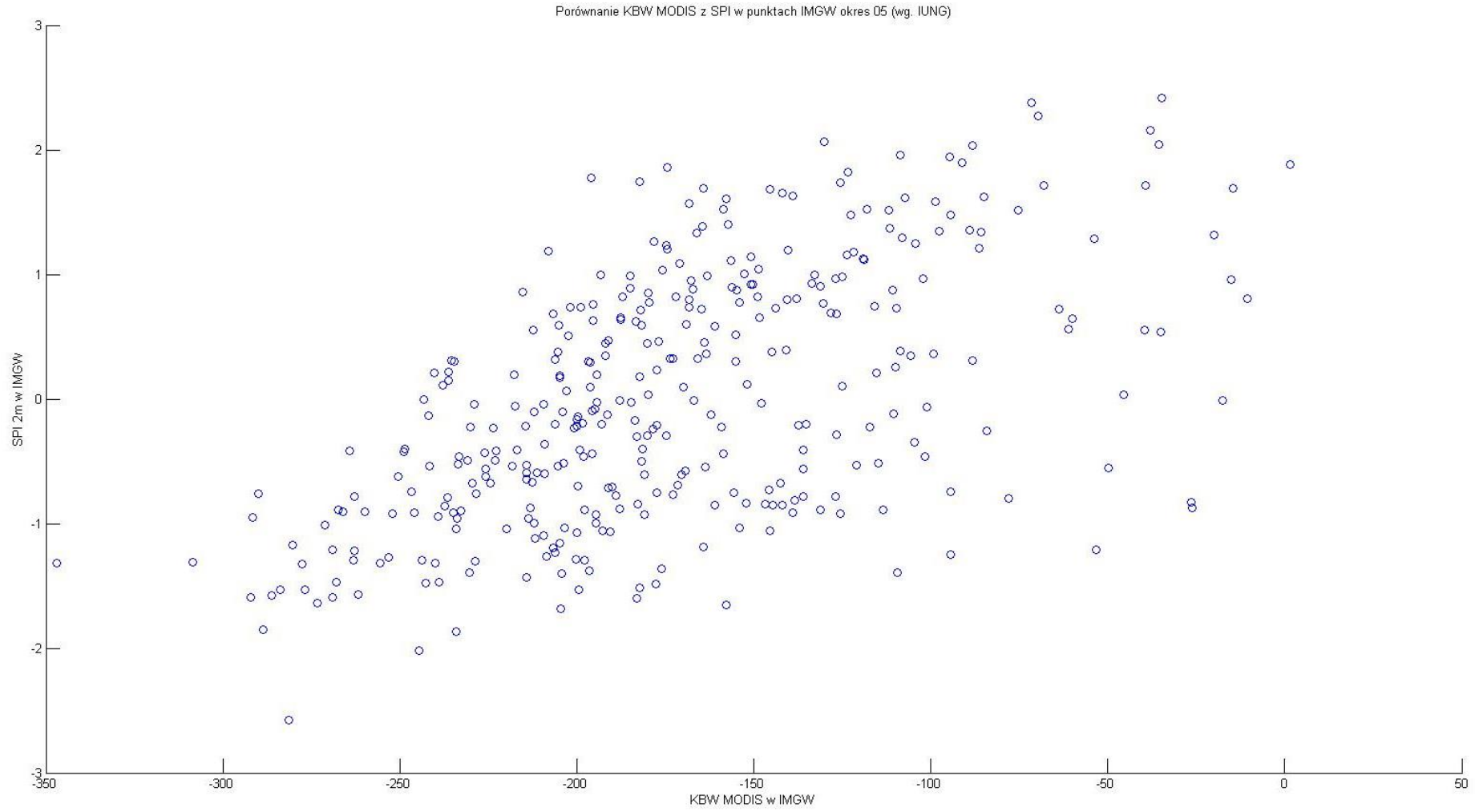


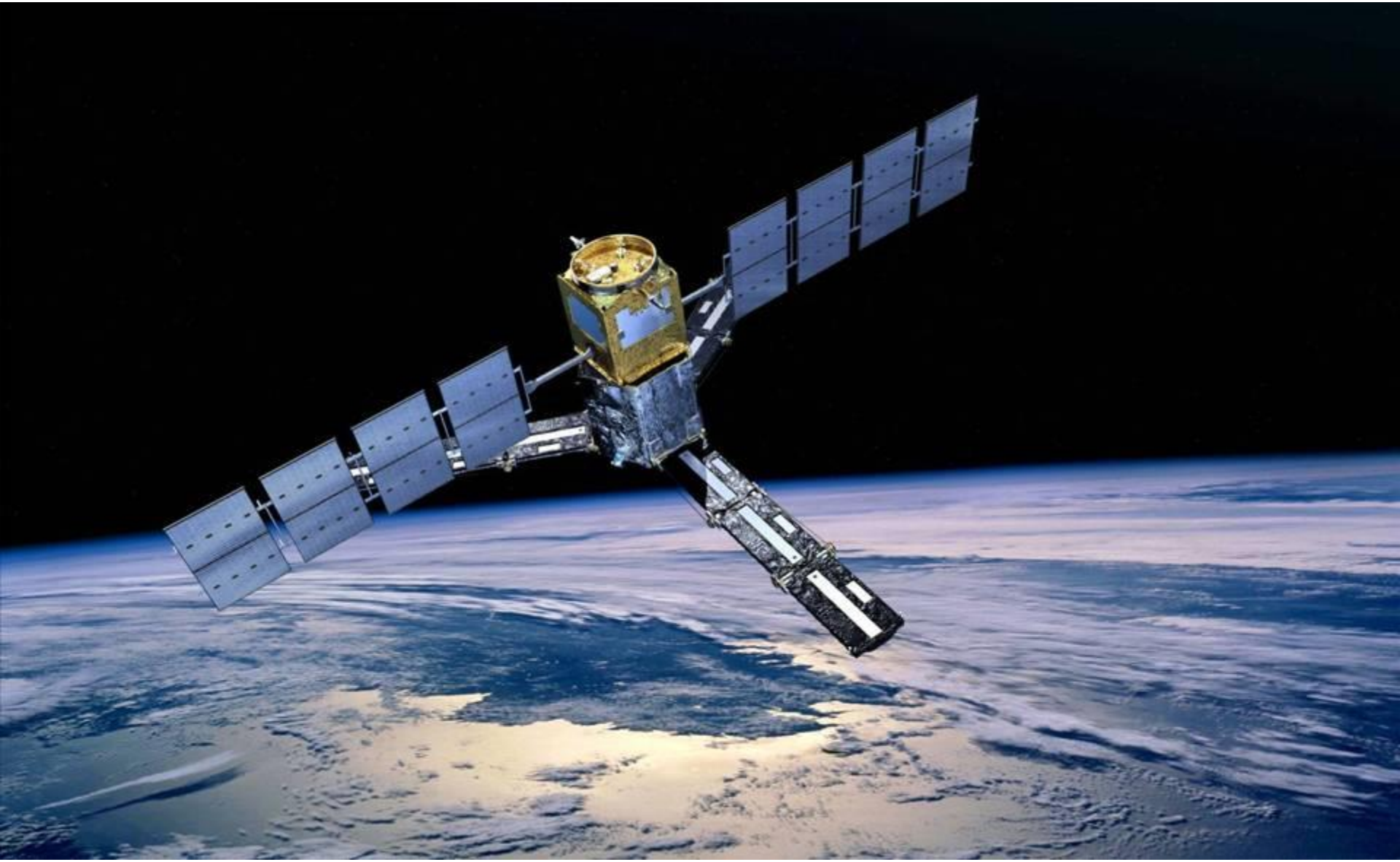
Soil Moisture and Ocean Salinity (SMOS)

INSTITUTE OF AGROPHYSICS PAS

Launched in November 2009

Parameters:

- Precision: 4% volumetric water content
- Pixel area: 40x40 km
- Revisit period: twice a day



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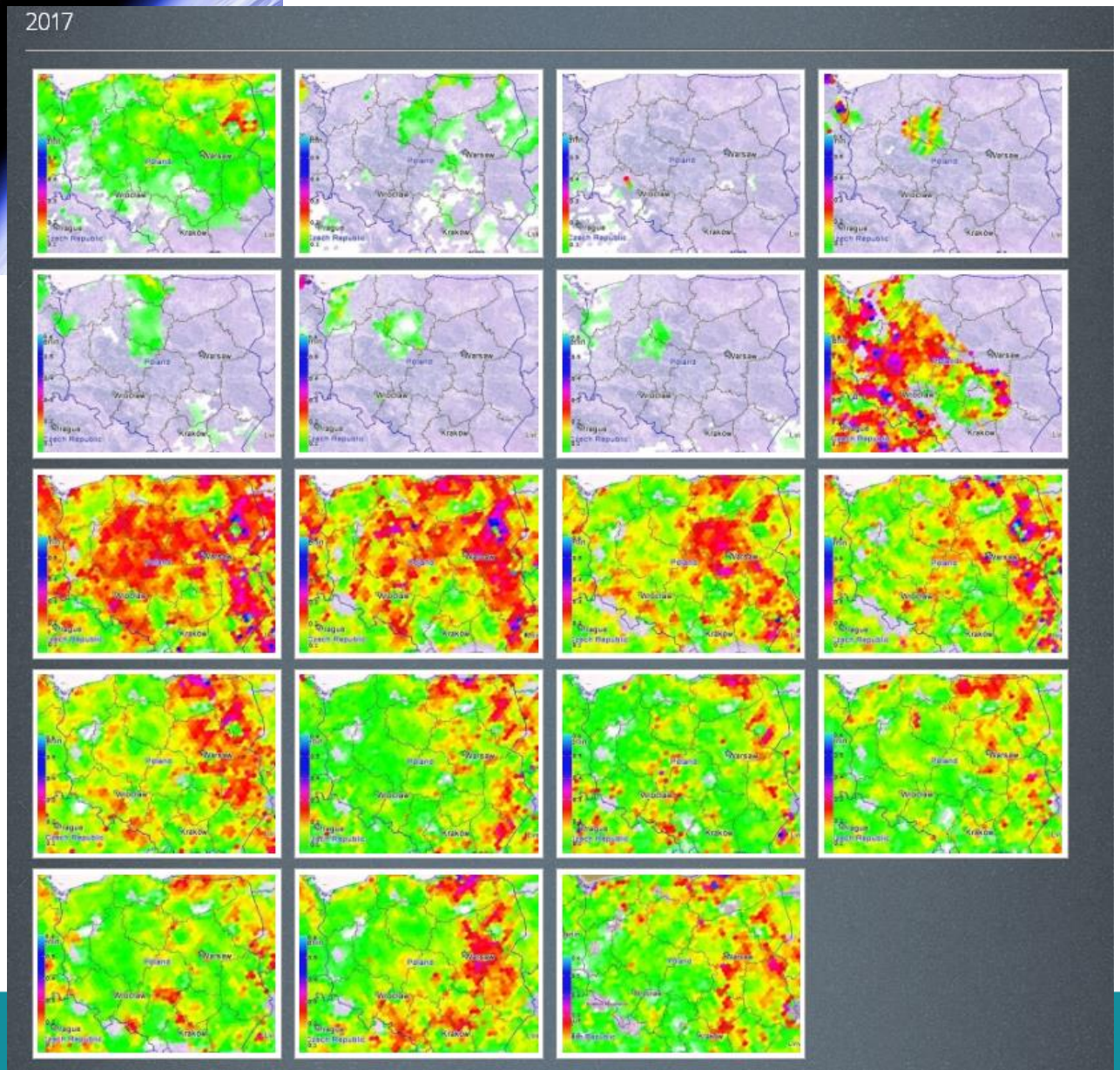

Mesoscale – SMOS

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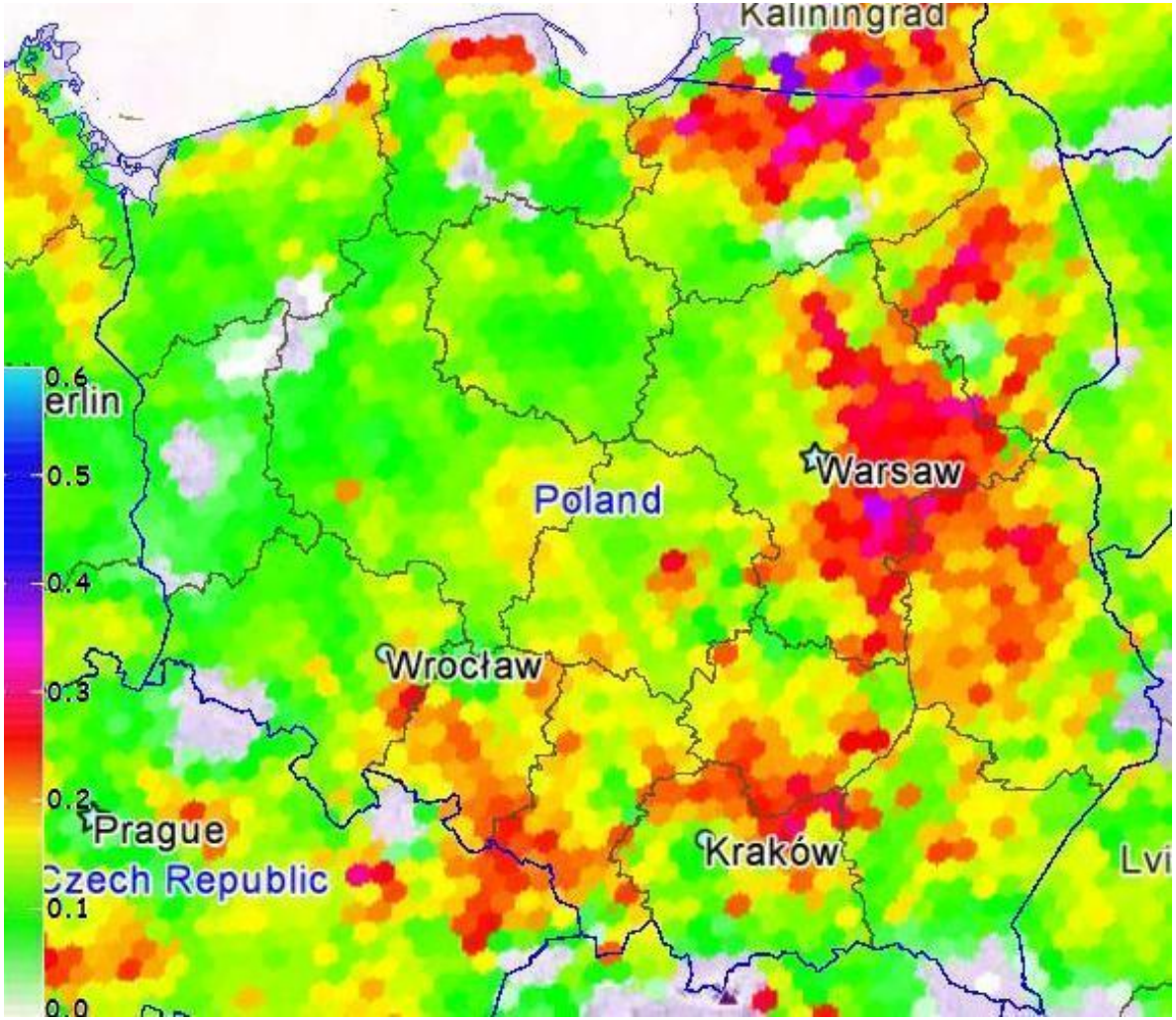

Mesoscale – KBW

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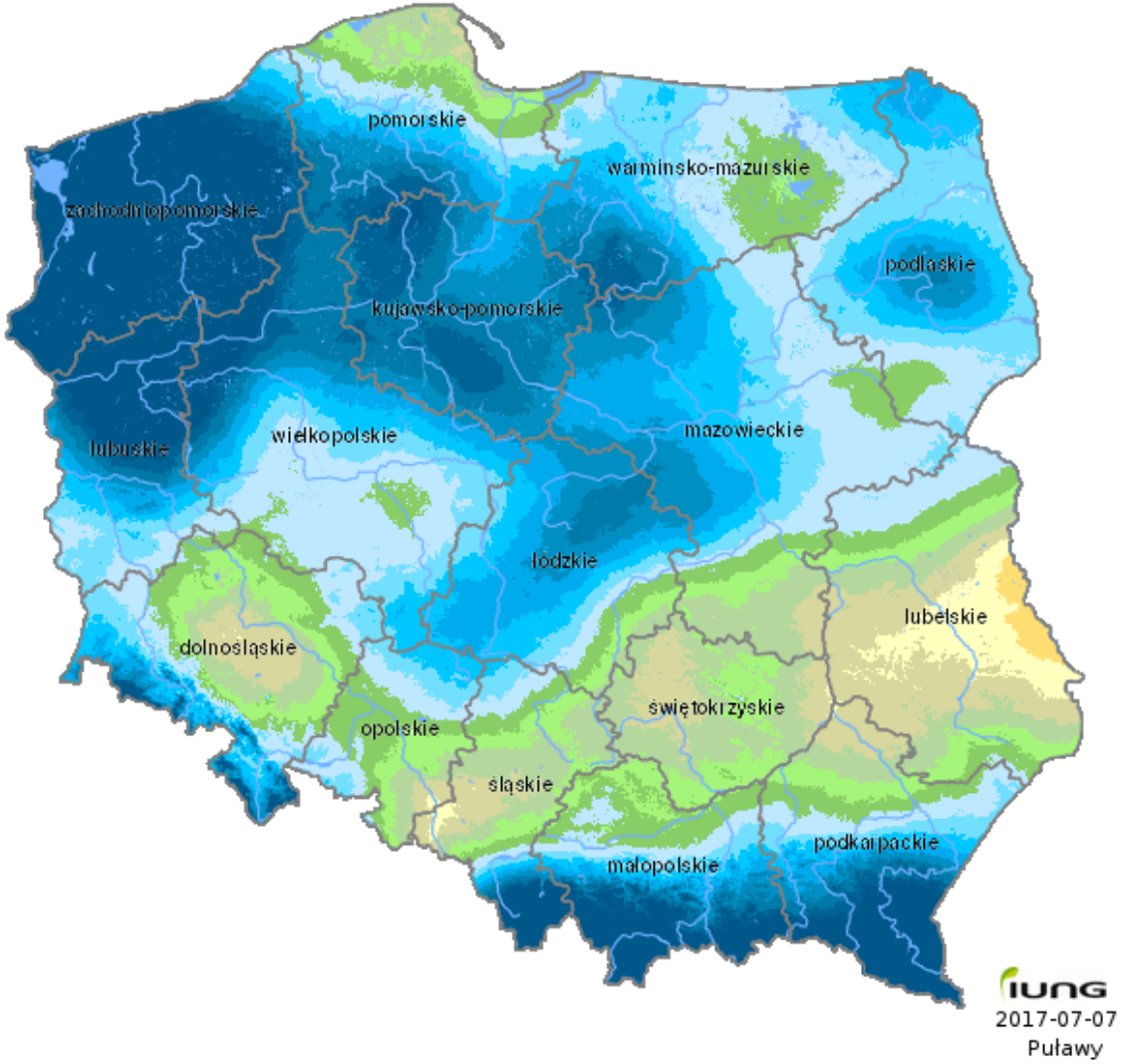
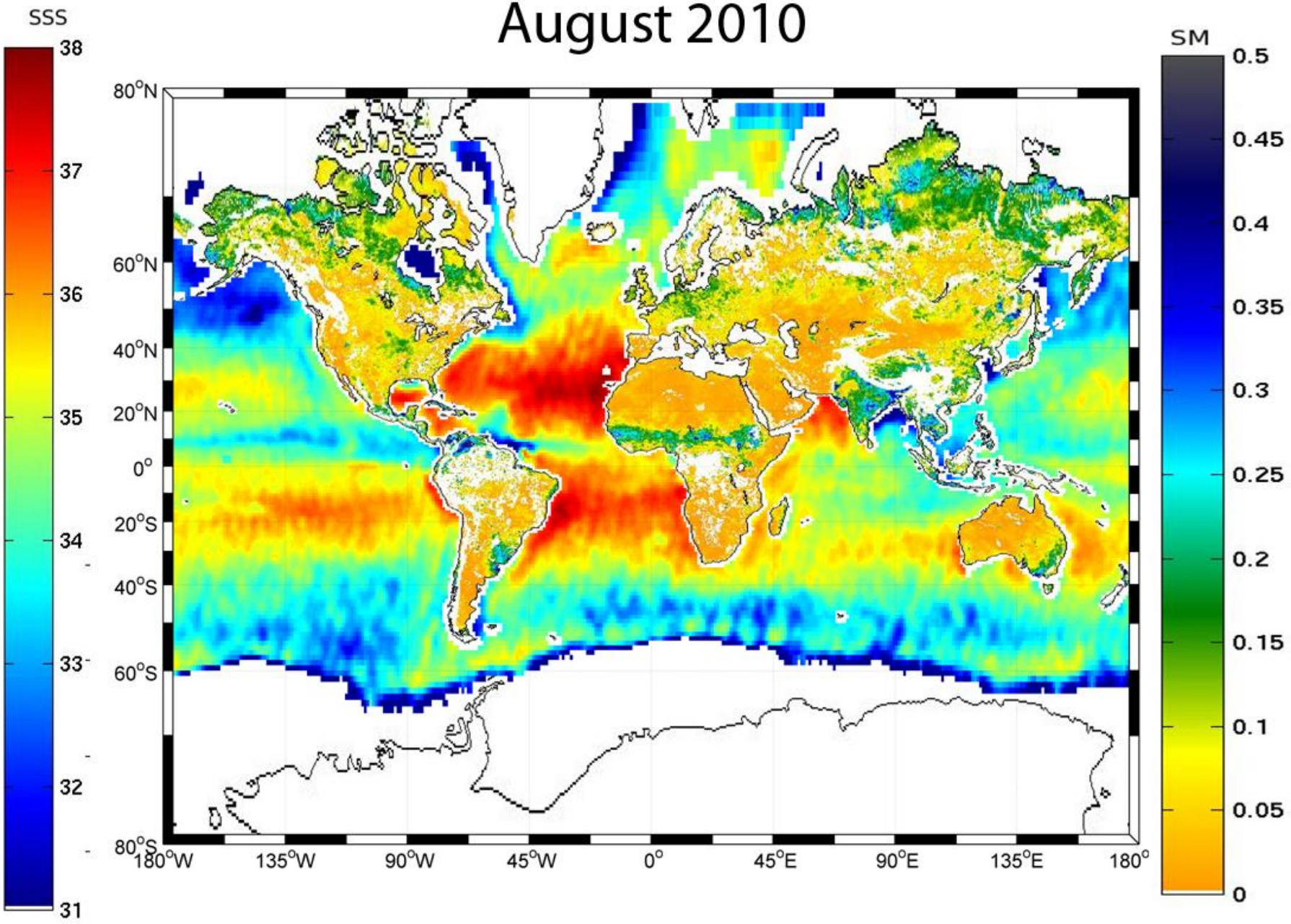


August 2010

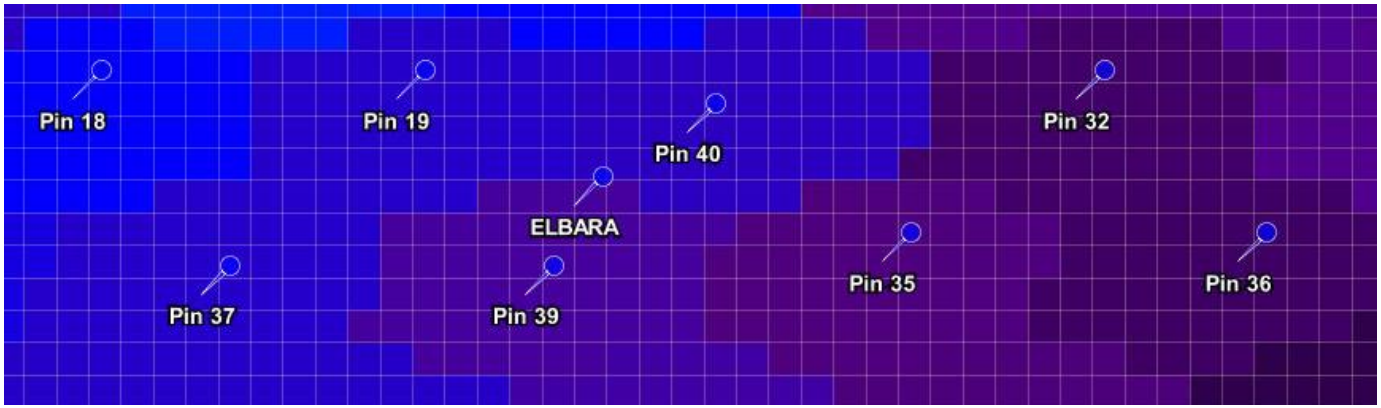


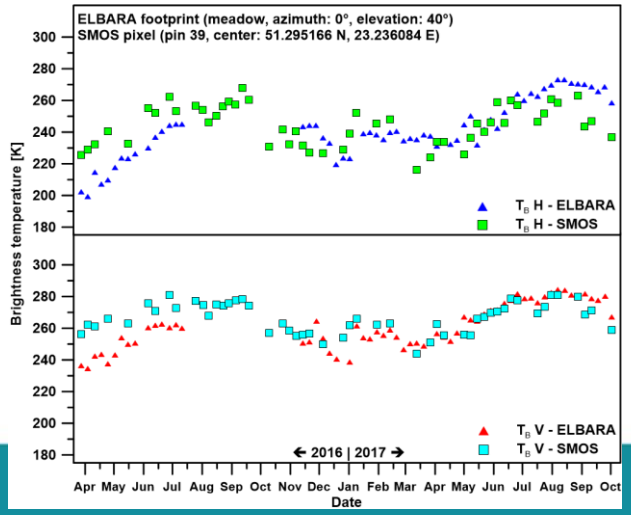
http://www.esa.int

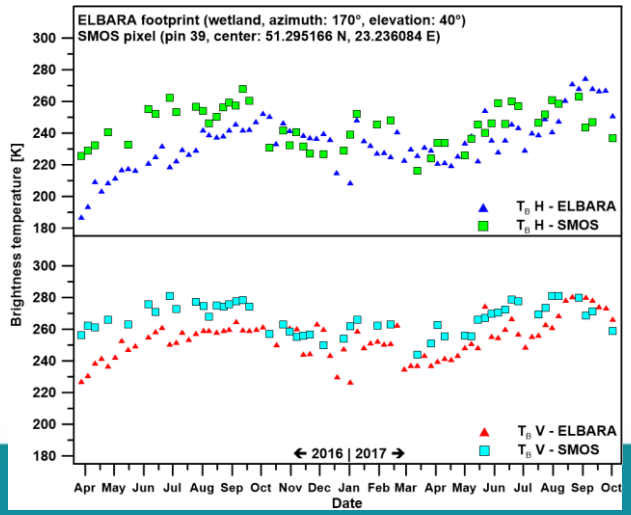
ELBARA – ”single SMOS antenna”

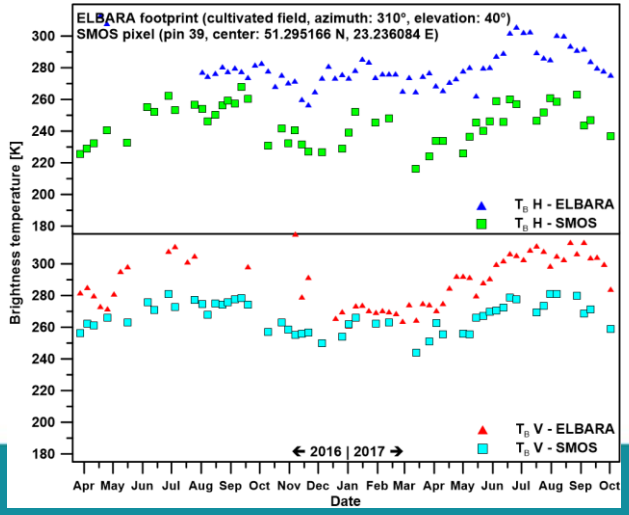
SMOS vs. ELBARA comparison

INSTITUTE OF AGROPHYSICS PAS









SMOS vs. ELBARA comparison

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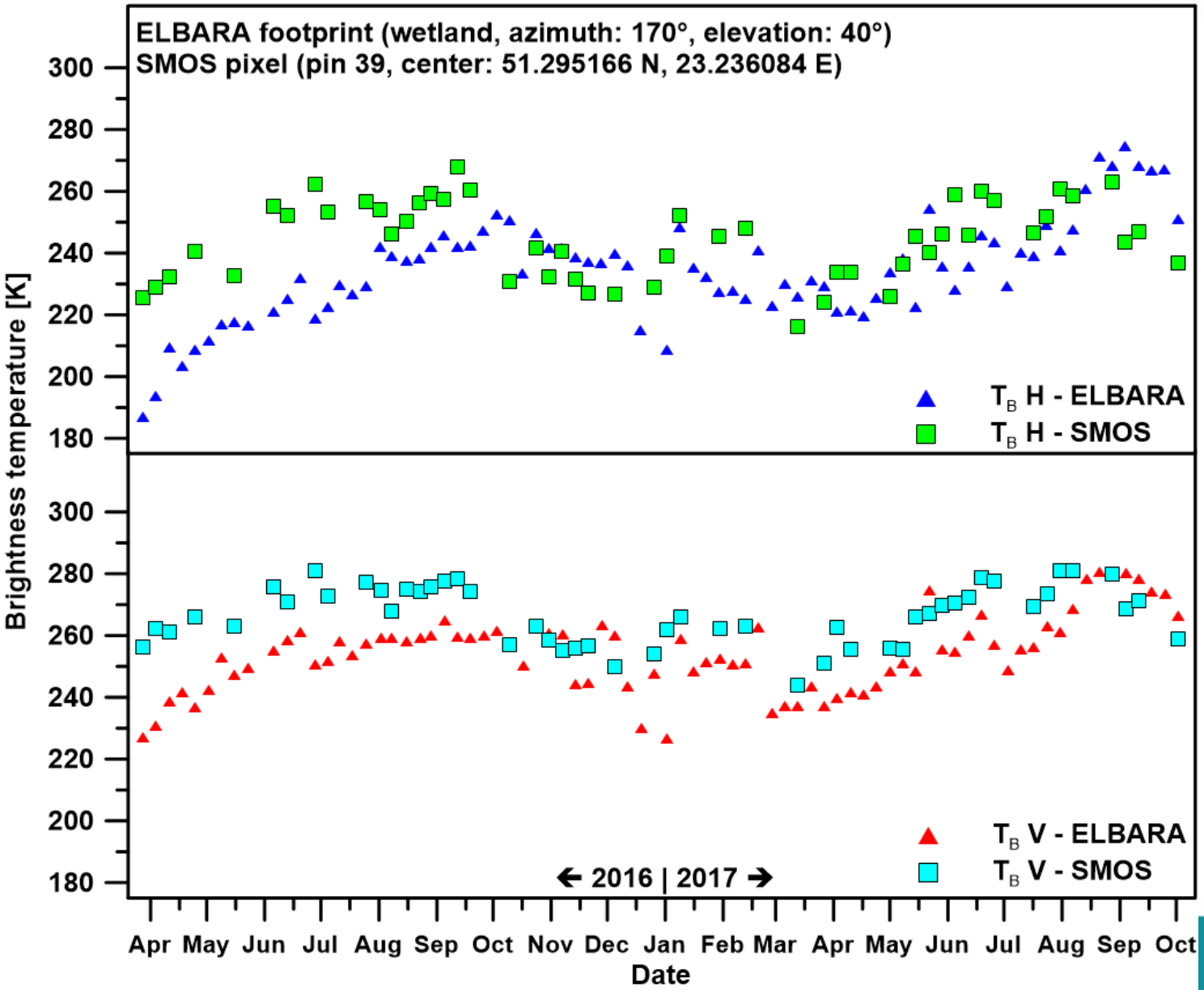

SMOS vs. ELBARA comparison

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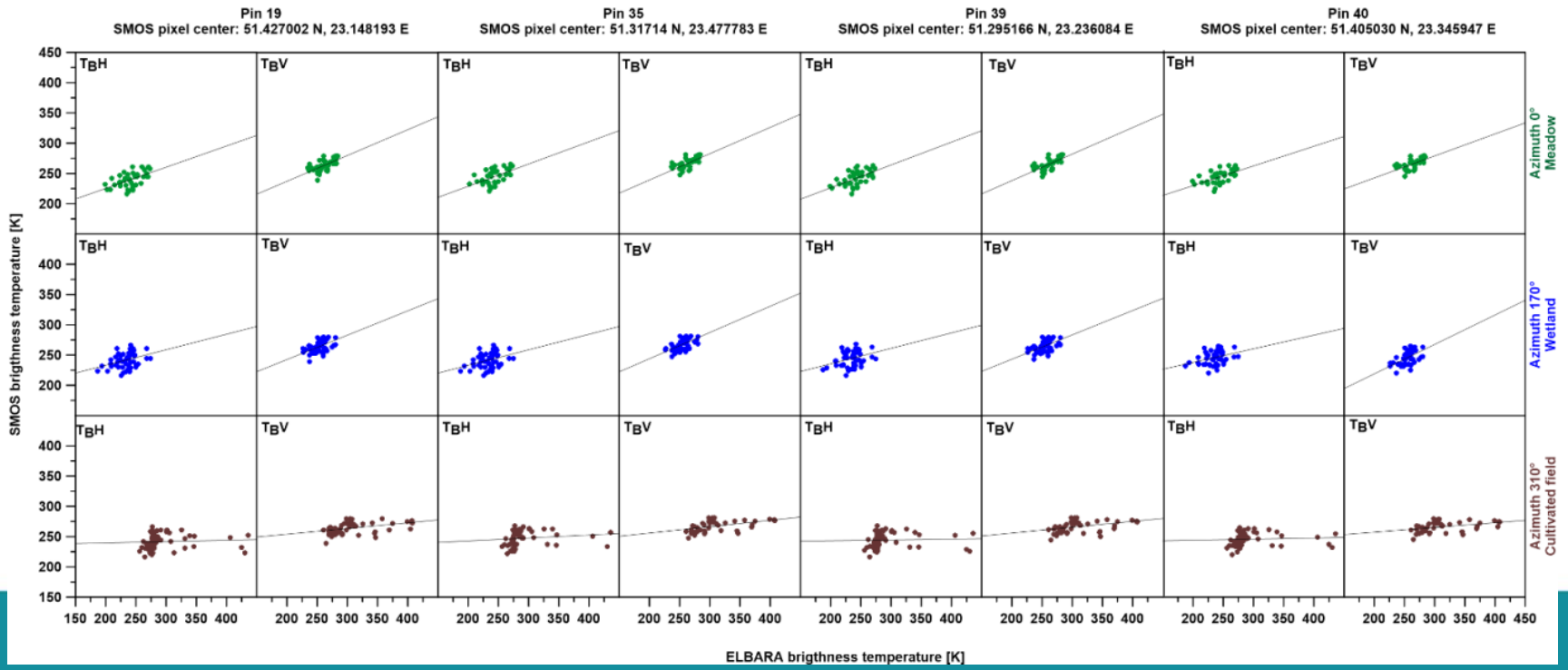
Coefficients of determination (R^2)

SMOS	Pin 19		Pin 35		Pin 39		Pin 40	
ELBARA	T_B H	T_B V	T_B H	T_B V	T_B H	T_B V	T_B H	T_B V
Azimuth 0° (meadow)	0.31	0.39	0.28	0.43	0.32	0.42	0.32	0.37
Azimuth 170° (wetland)	0.12	0.30	0.12	0.33	0.11	0.27	0.12	0.27
Azimuth 310° (cultivated field)	0.08	0.16	0.02	0.21	0.00	0.17	0.00	0.15



ELBARA_PD (Penetration Depth)

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HR EXCELLENCE IN RESEARCH

- The team: Mateusz Łukowski, Bogusław Usowicz, Jerzy Lipiec, Edyta Rojek, Radosław Szlązak, Łukasz Gluba, Joanna Sagan, *Wojciech Marczewski, Ewa Słomińska, Jan Słomiński, Andrzej Kotarba, Krystyna Stankiewicz*
- **II 2013 – II 2015** (CCN1→VIII 2016, CCN2→VII 2017)
- Financed from PECS (Plan for European Cooperating States, between Government of Poland and European Space Agency)

Technical Support for the fabrication and deployment of the radiometer ELBARA-III in Bubnow, Poland

INSTITUTE OF AGROPHYSICS PAS

HR EXCELLENCE IN RESEARCH

- The team: Mateusz Łukowski, Bogusław Usowicz, Jerzy Usowicz, Edyta Rojek, Radosław Szlązak, *Andreas Wiesmann, Mike Schwank, Charles Werner*
- **II 2015 – VII 2016**
- Financed by European Space Agency
- The ELBARA instrument goes from one research team to another under a loan agreement with ESA. Thanks to this project ELBARA III was built specifically for Poland!

GAMMA REMOTE SENSING

esa

Soil Moisture and Ocean Salinity (SMOS) – 7 years on orbit

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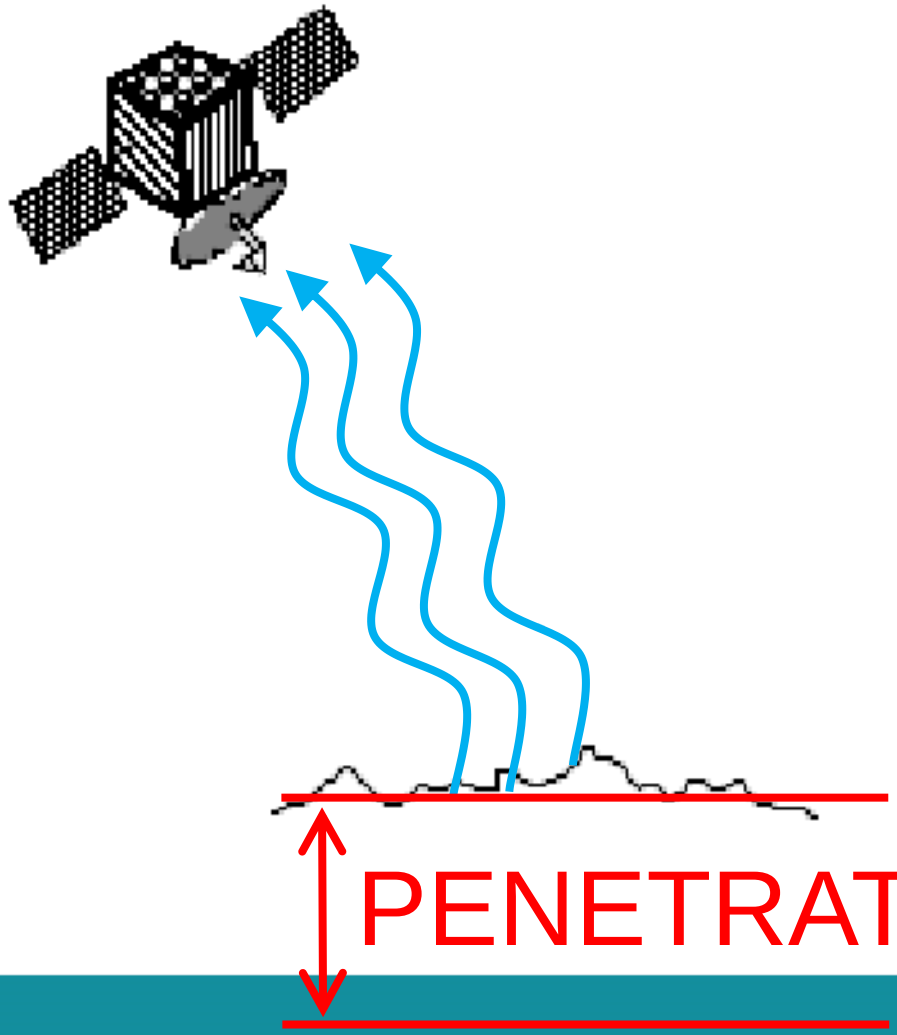
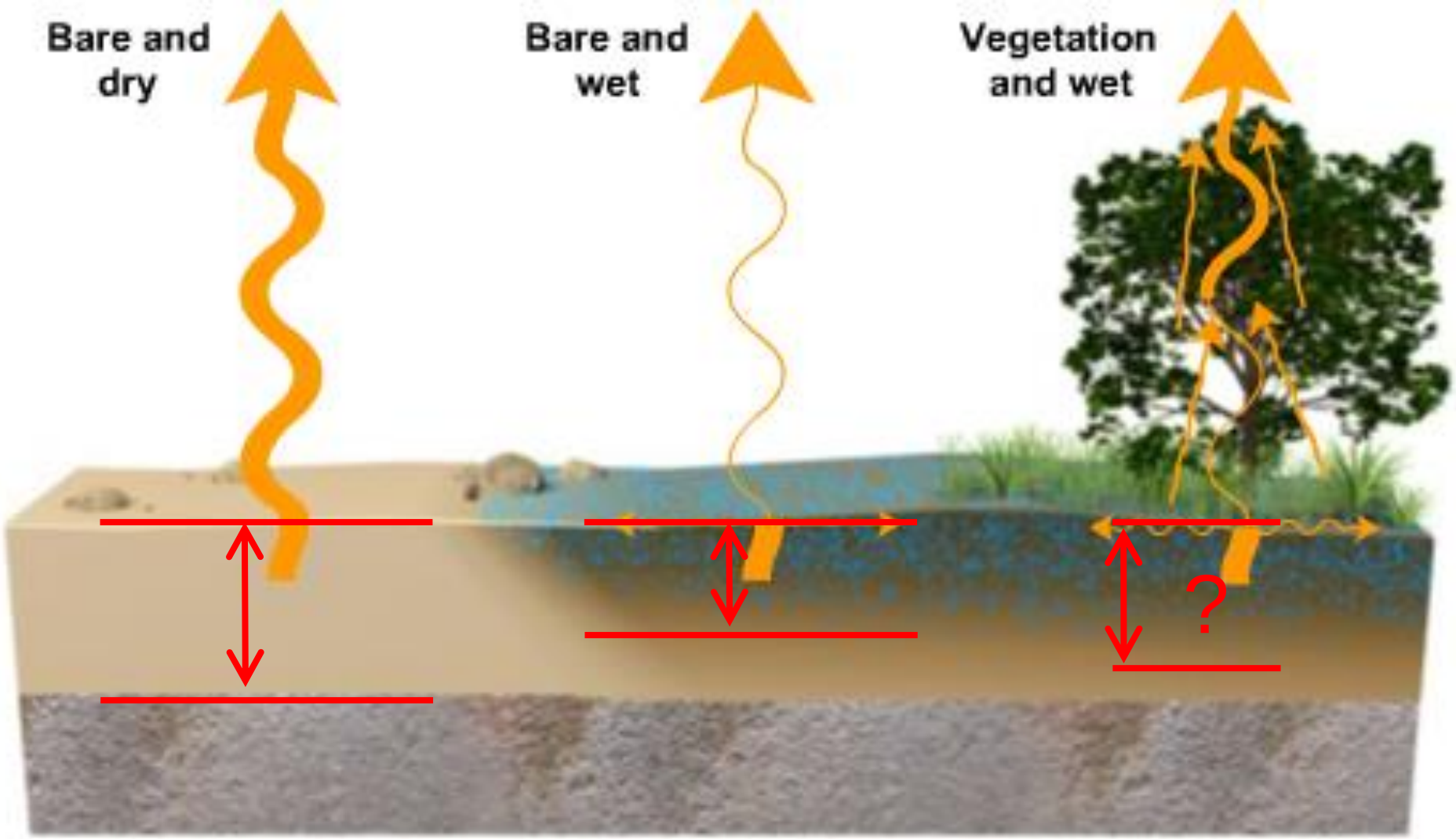


The purpose of the projects is to obtain:

1. The radiometric characteristics of wetlands
2. "Penetration Depth" for the L-band



Posters

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- *Snow melting effect on L-band brightness temperature*
- *ELBARA: Low altitude L-band radiometer for soil moisture retrieval*
- *Compatibility of soil moisture remote sensing data of SMOS with ELBARA instrument results – the comparison on long time scale*

Websites:
elbara.pl
soilaqchar.pl

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THANK YOU FOR YOUR ATTENTION!