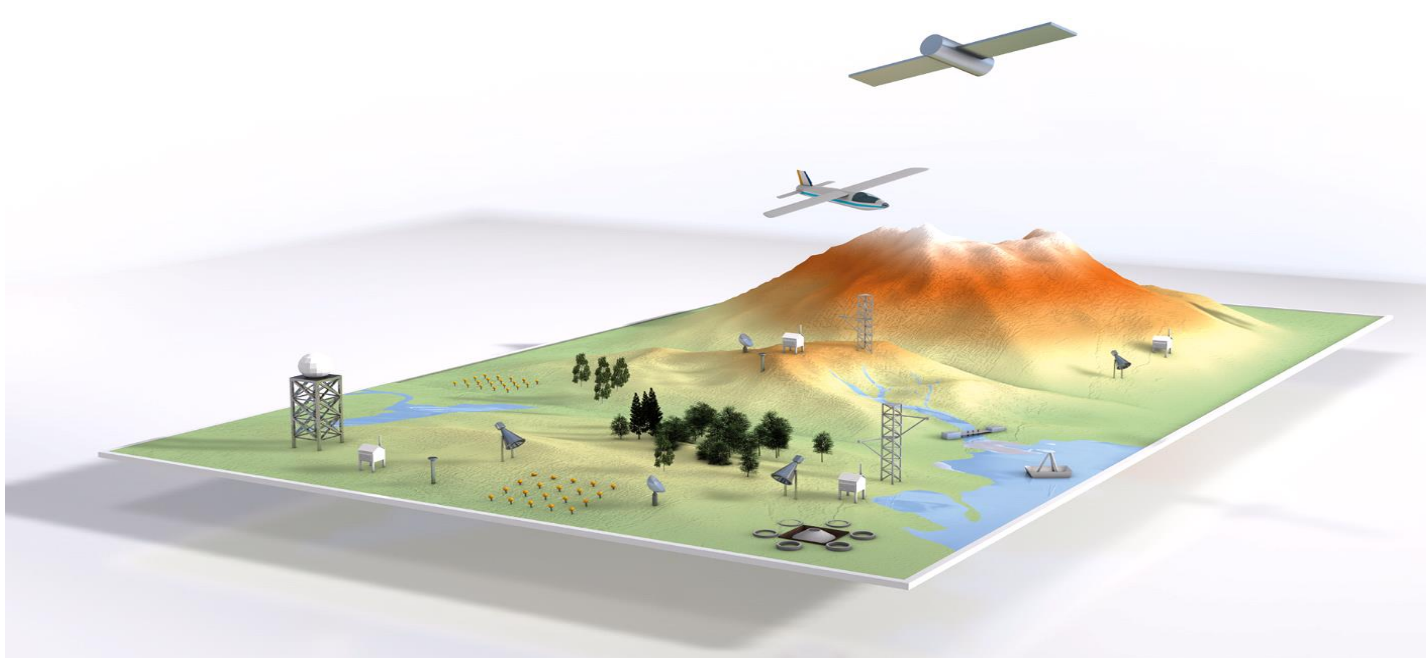


TERENO NETWORKS

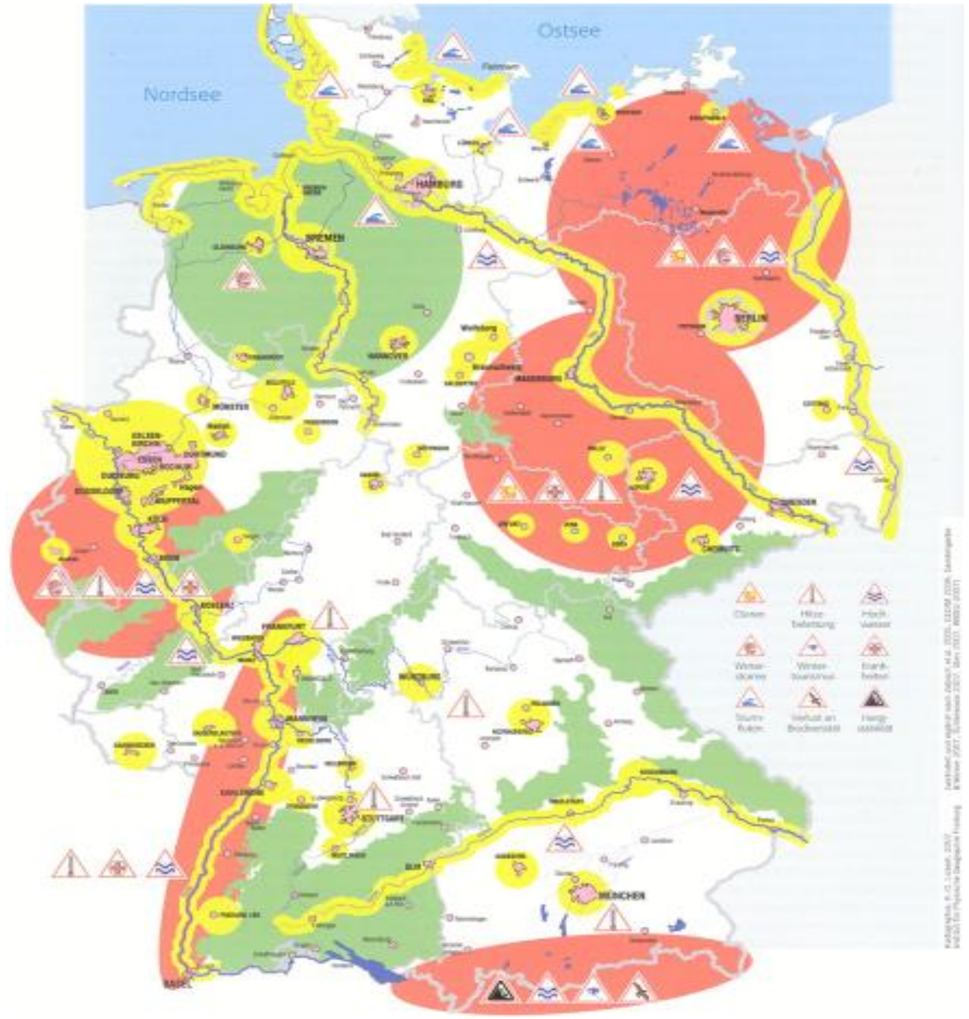
Soil moisture monitoring in German observatories

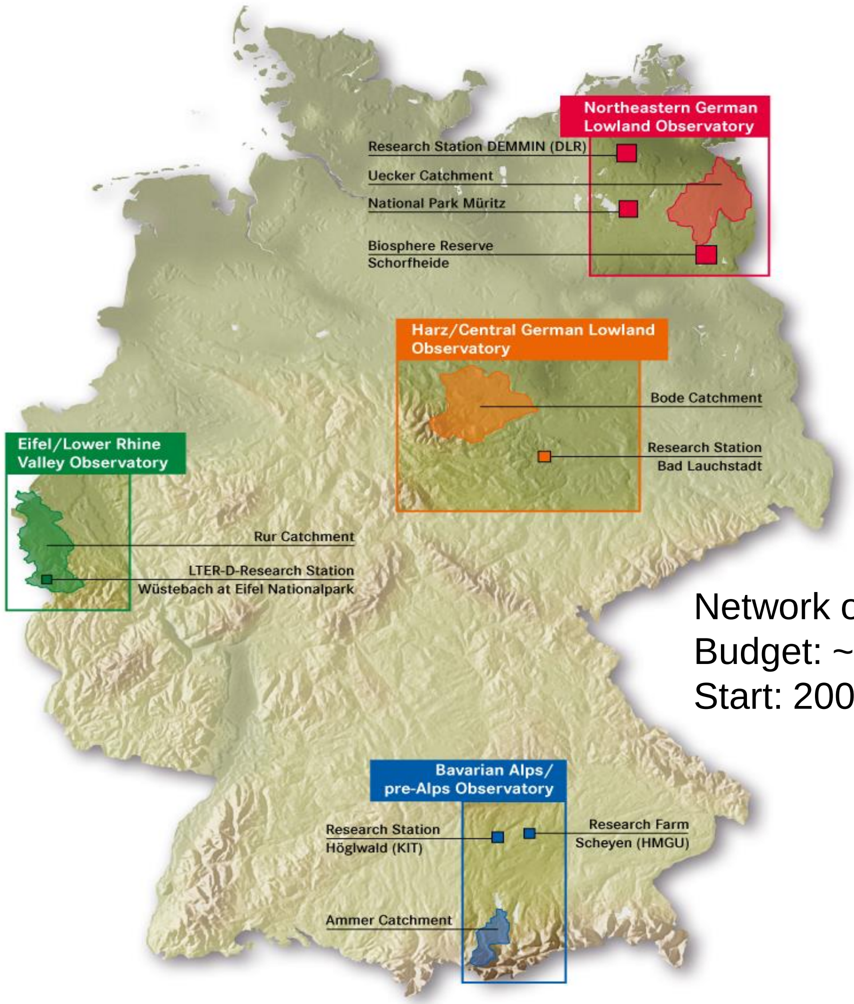
CARSTEN MONTZKA, HEYE BOGENA, HARRY VEREECKEN

JÜLICH
Forschungszentrum

CLIMATE CHANGE IN GERMANY

Identified high risk regions

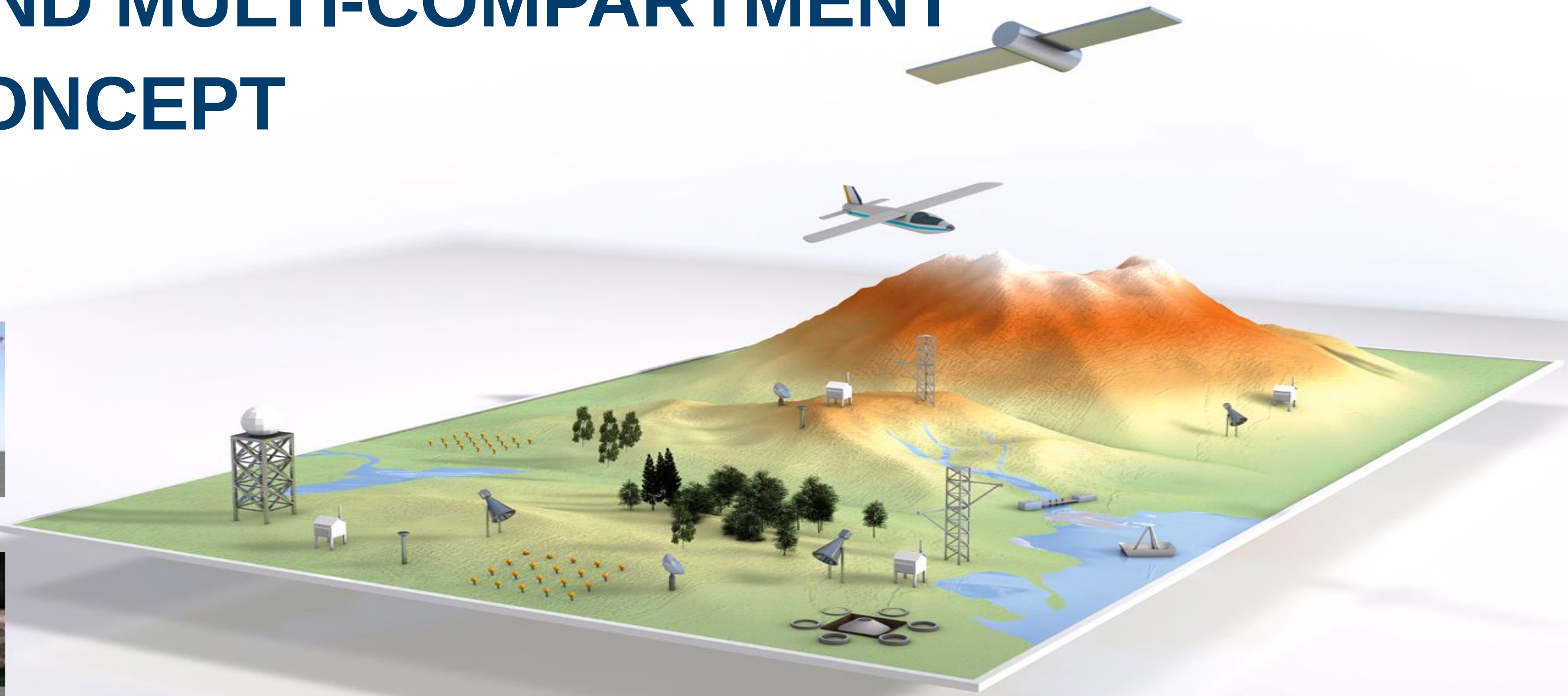




Network of TERENO Observatories
Budget: ~20 Mio. €
Start: 2008

Source: R. Glaser 2008: Klimageschichte Mitteleuropas – 1200 Jahre Wetter, Klima, Katastrophen mit Prognosen für das 21. Jahrhundert.

MULTI-SCALE AND MULTI-COMPARTMENT MONITORING CONCEPT




Modelling Platform


Remote Sensing


Geophysics


Groundwater monitoring


Wireless soil moisture sensor network


Lysimeters


Biodiversity monitoring

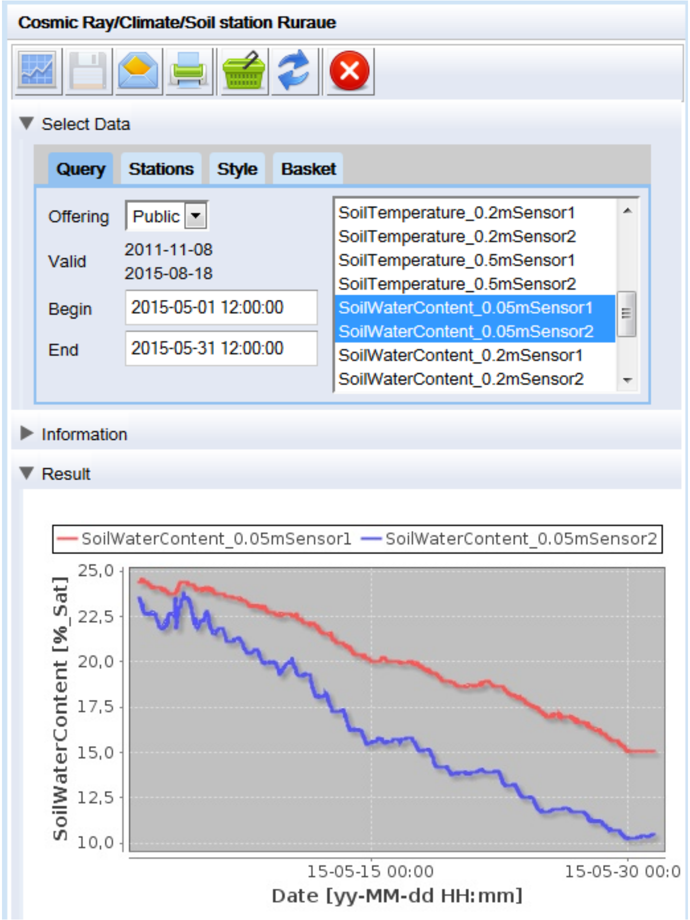

Mobile Mesocosms


Water quality monitoring


Eddy-Flux-Tower


Rainscanner

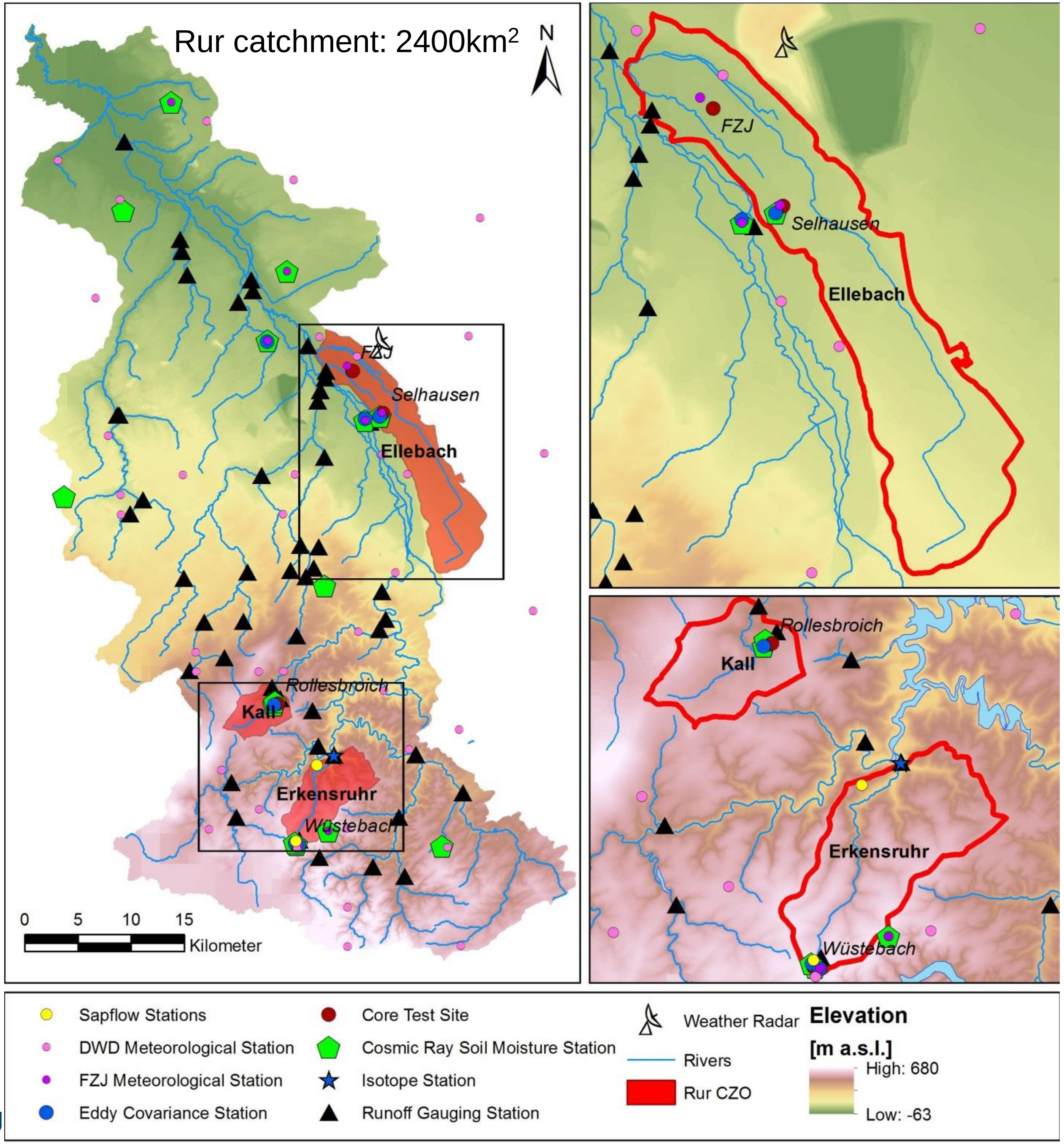
TERENO DATA MANAGEMENT



Some soil moisture data also transferred to ISMN

TERENO RUR

- 12 Cosmic ray soil moisture stations including SMT100
- 2 High density soil moisture networks
  - Grassland site Rollesbroich
  - Forest site Wüstebach

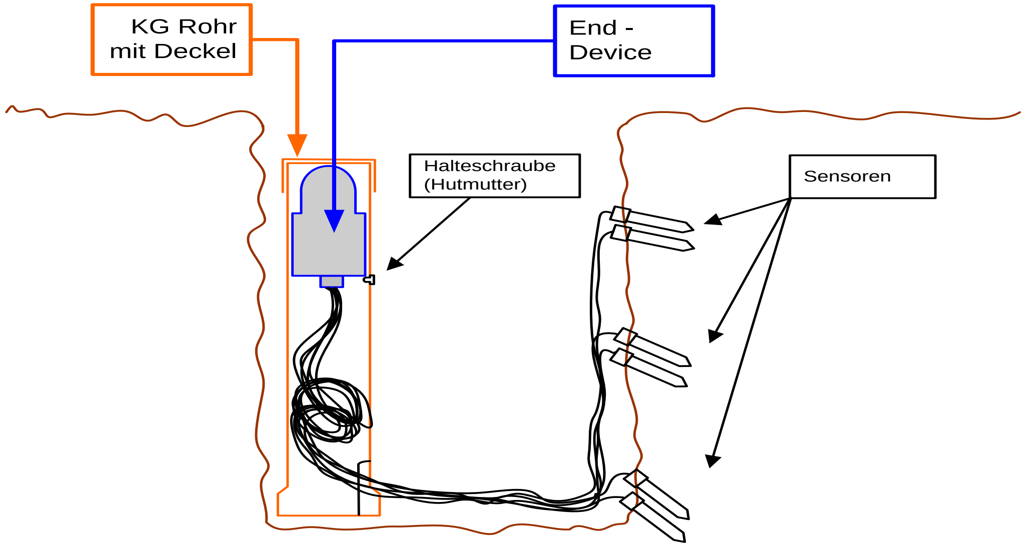


SOILNET

Subsurface wireless sensor network

Advantages:

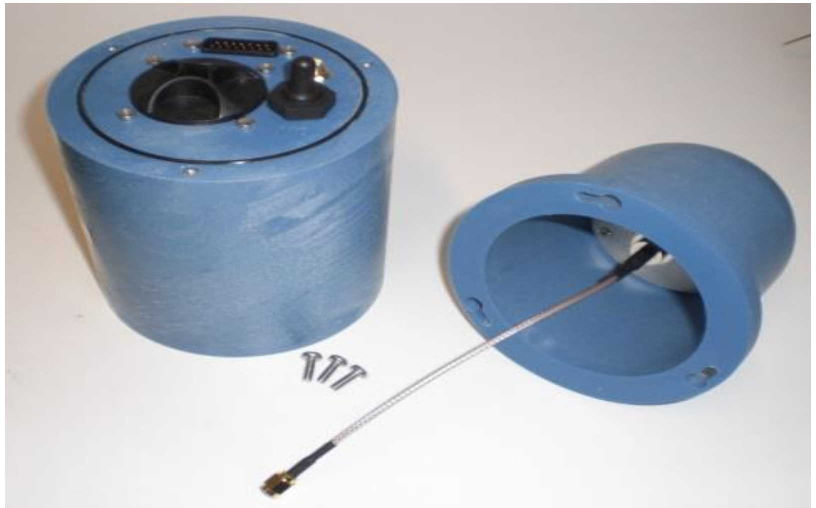
- Low visibility
- Protection against vandalism, animals etc.
- Protection against temperature changes
- No interference with agricultural practices (grassland)

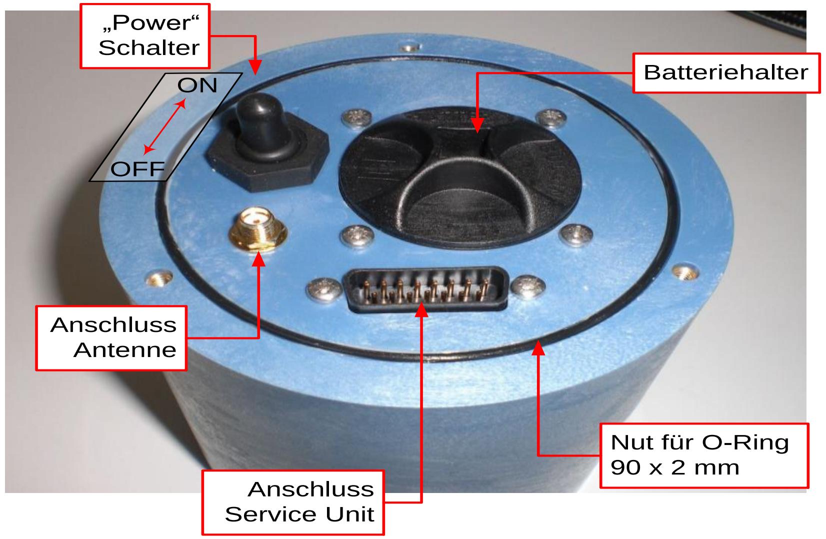


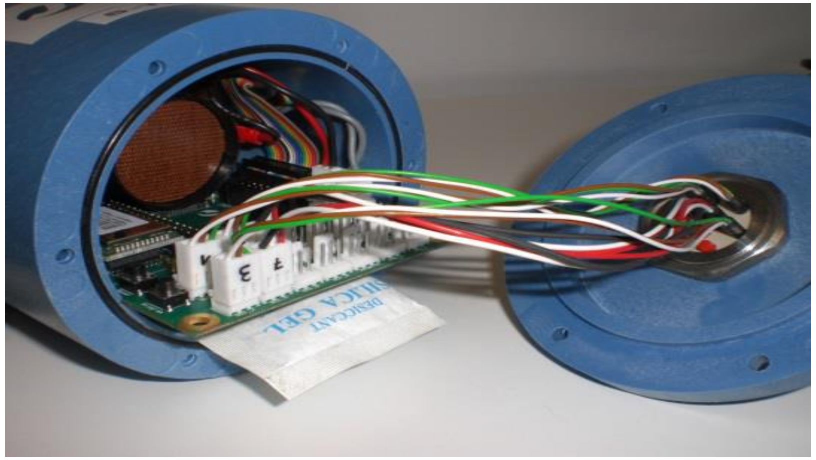
SOILNET

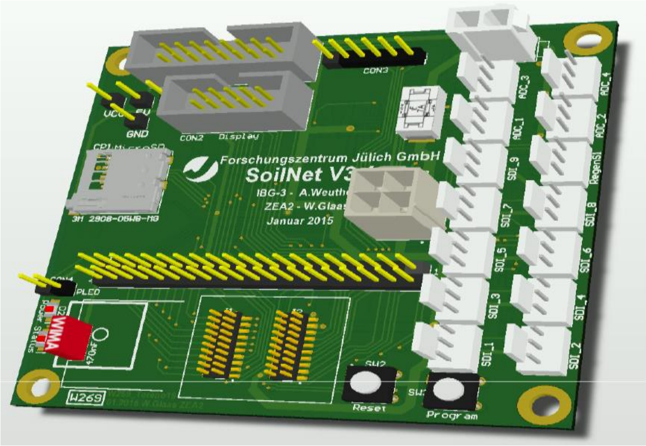
SoilNet

Subsurface wireless sensor network







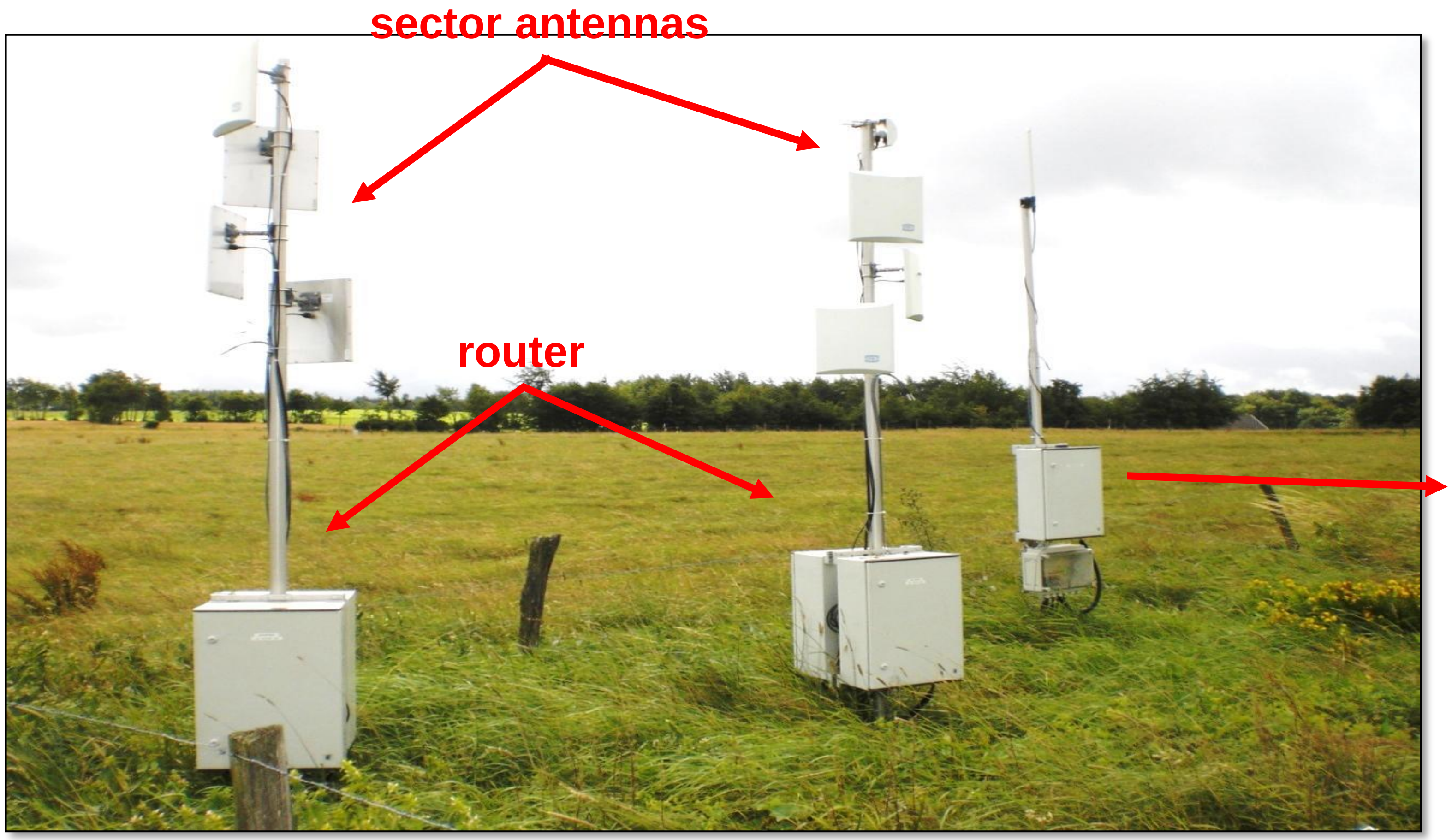


Zigbee standard, a LoRa standard is under development

SOILNET

SoilNet

Router and coordinator



Sensor network Rollesbroich

Coordinator with GSM modem

SOILNET

SoilNet

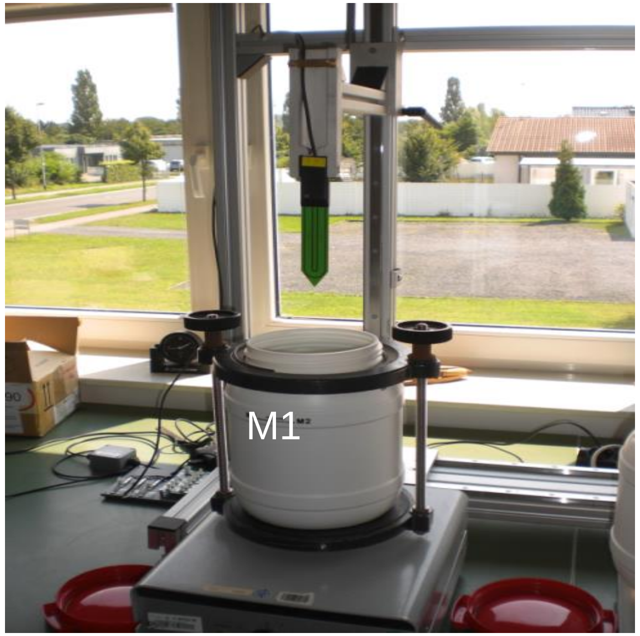
Sensor examples

Name	Variable	Interface	Company
SMT100	Soil moisture, soil temperature	SDI-12	truebner.de
MPS-6	Water potential	SDI-12	decagon.com
GS3	Soil moisture, soil temperature, el. conductivity	SDI-12	decagon.com
5TE	Soil moisture, soil temperature, el. conductivity	SDI-12	decagon.com
CTD-10	Water level, temperature, el. conductivity	SDI-12	decagon.com
RT-1	Soil temperature	SDI-12	decagon.com
EC-5	Soil moisture	analogue	decagon.com
RG2501	Precipitation	pulse	omega.com

SMT100 MPS-6 GS3 5TE CTD-10 RT-1 EC-5 RG2501

SOILNET CALIBRATION

Fist step: Relationship between sensor output and permittivity



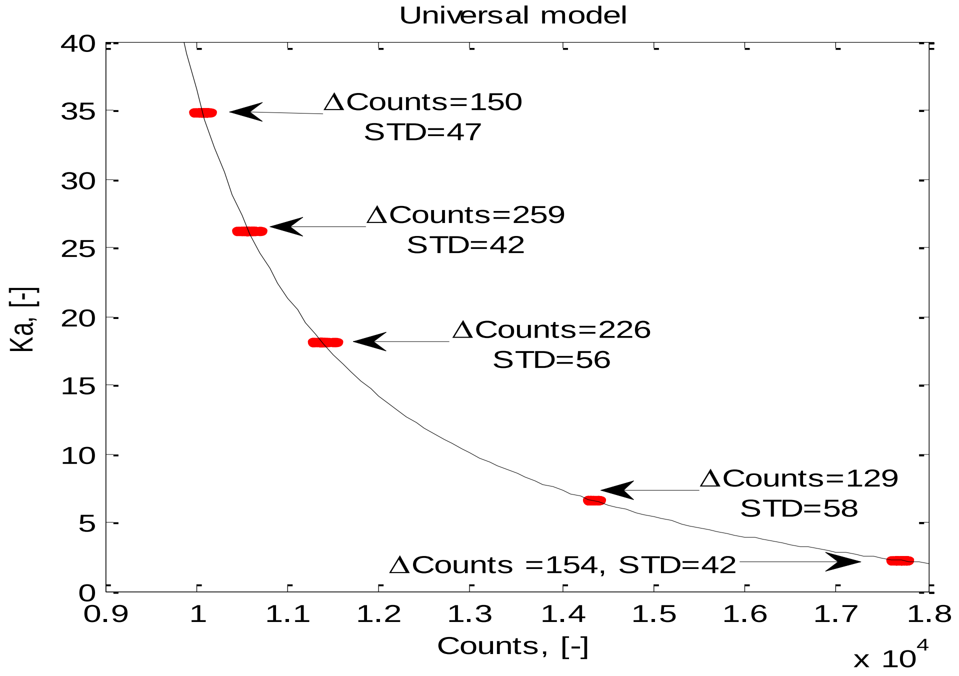
M1: Air (έ=1)
M2: Dry sand (έ=3)
M3: (2-Isopropoxyethanol, έ ~ 18.1)
M4: (2-Isopropoxyethanol, έ ~ 26.3)
M5: (2-Isopropoxyethanol, έ ~ 34.8)

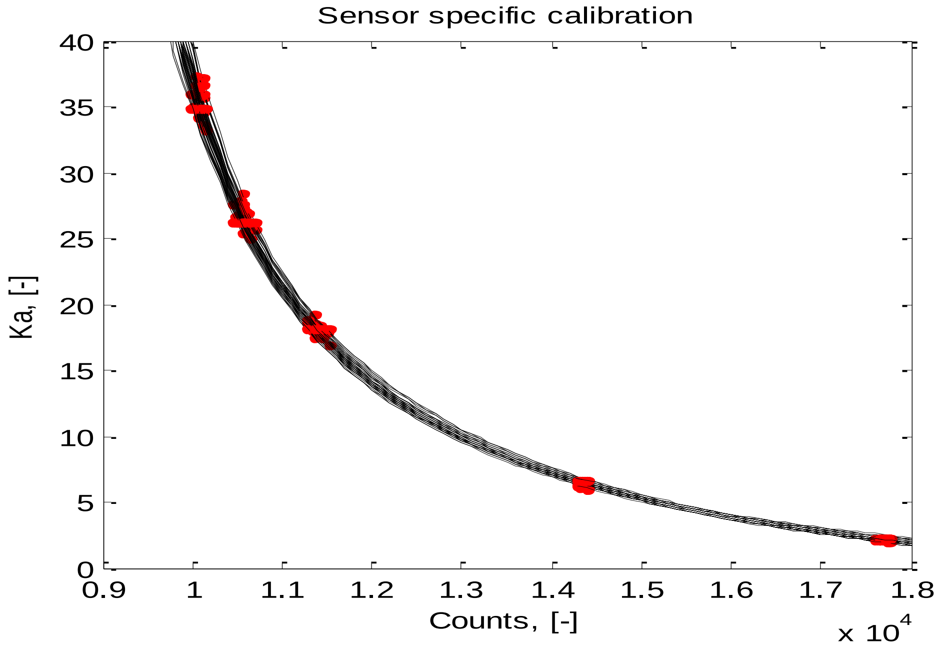
SOILNET CALIBRATION

SoilNet

Fist step: Relationship between sensor output and permittivity

$$K_a = \gamma + \frac{1}{\alpha + \frac{\beta}{(18000 - counts)/_{5000}}}$$





SOILNET CALIBRATION

SoilNet

Second step: Relationship between SWC and permittivity

- Empirical models (e.g. Topp et al., 1980) -> not universal

$$\Theta_v = -5.3 \cdot 10^{-2} + K_c \cdot 2.92 \cdot 10^{-2} - K_c^{\,2} \cdot 5.5 \cdot 10^{-4} + K_c^{\,3} \cdot 4.3 \cdot 10^{-6}$$

Θ_v: Volumetric soil water content
K_c: Measured apparent soil permittivity

- Physically based models:
  - Three component model CRIM (Roth et al., 1990)

$$\theta = 100 \cdot \frac{K_a^{\,\beta} - (1-\eta) \cdot K_s^{\,\beta} - \eta K_{air}^{\,\beta}}{K_w(T)^{\beta} - K_{air}^{\,\beta}}$$

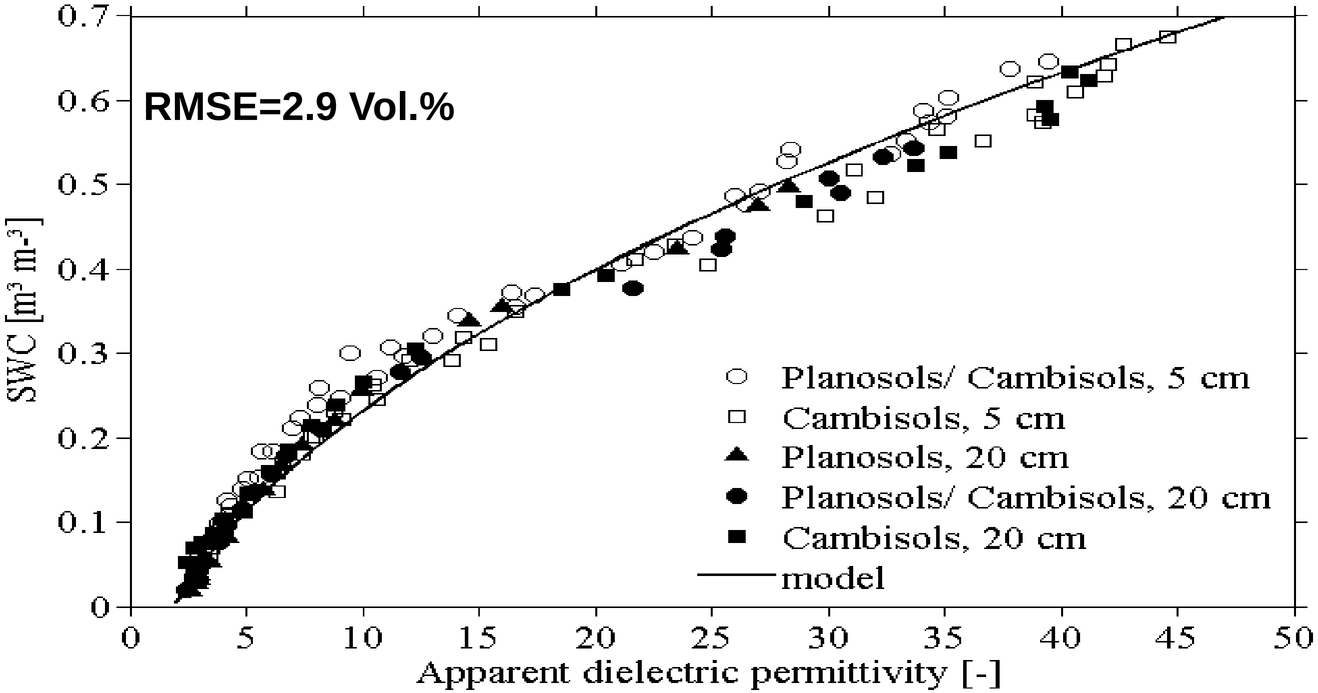
K_a: Apparent permittivity
K_s, K_w, K_{air}: Relative permittivities of the solid, water, and air phases
η: Porosity
ß: Shape factor

SOILNET CALIBRATION

Soil-specific calibration

CRIM Modell:

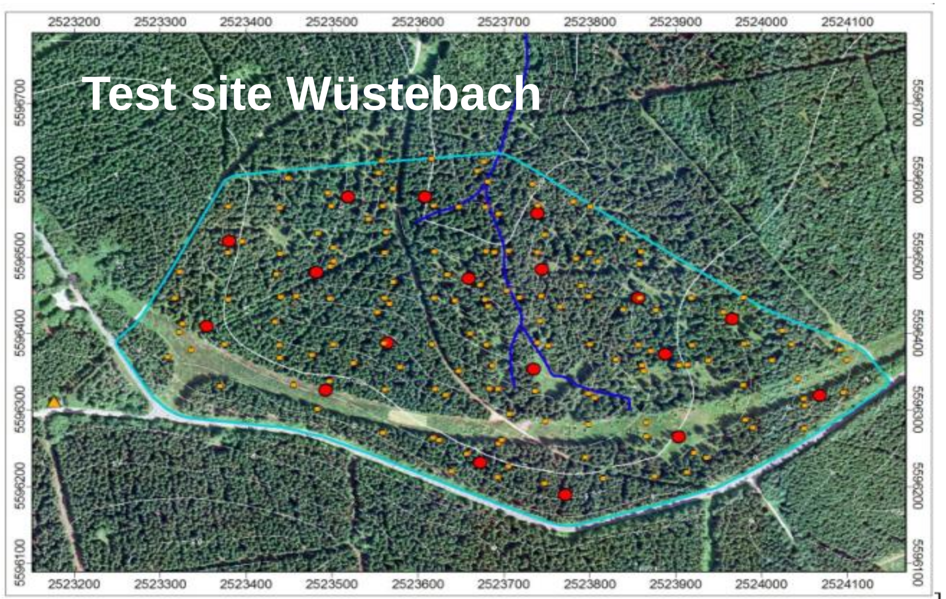
$$\theta = \frac{K_a^{\ \beta} - (1-\eta)\cdot K_s^{\ \beta} - \eta K_{air}^{\ \beta}}{K_w(T)^{\beta} - K_{air}^{\ \beta}}$$

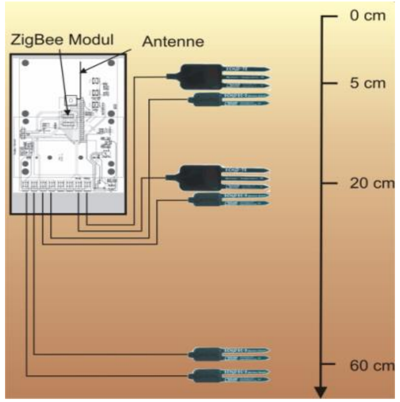


Rosenbaum et al. (2012)

THE WÜSTEBACH NETWORK

Forest hydrology research (27ha)





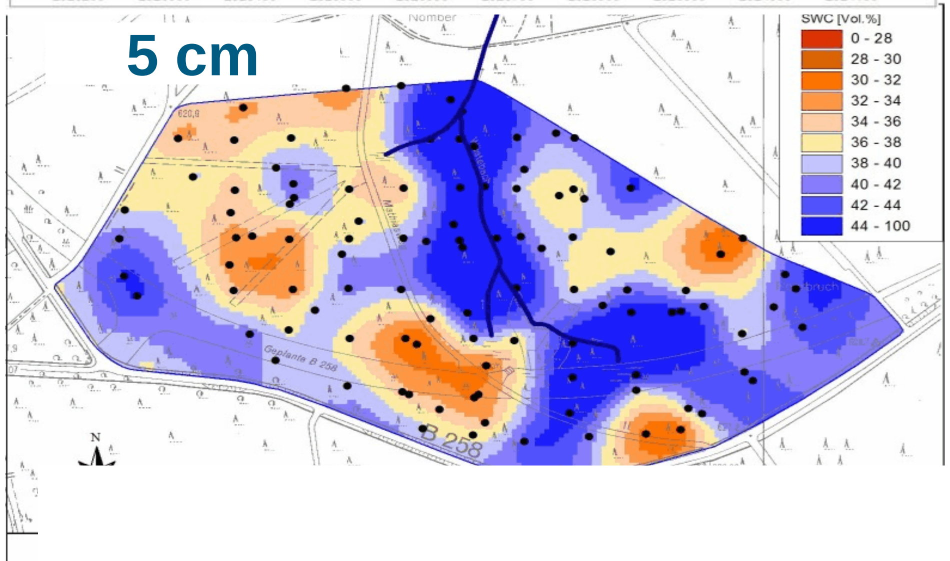
150 Sensor units

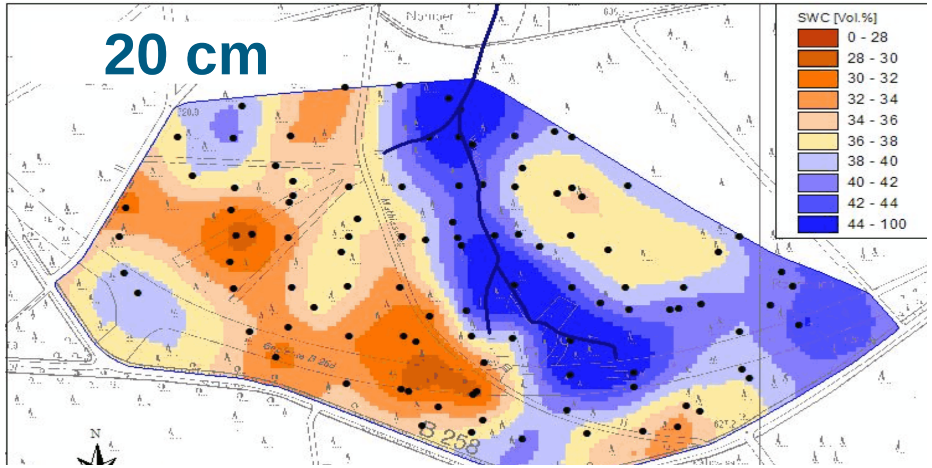
18 Router units

900 Soil moisture sensors

300 Temperature sensors

455 days: ~10 Mio. hourly measurements!

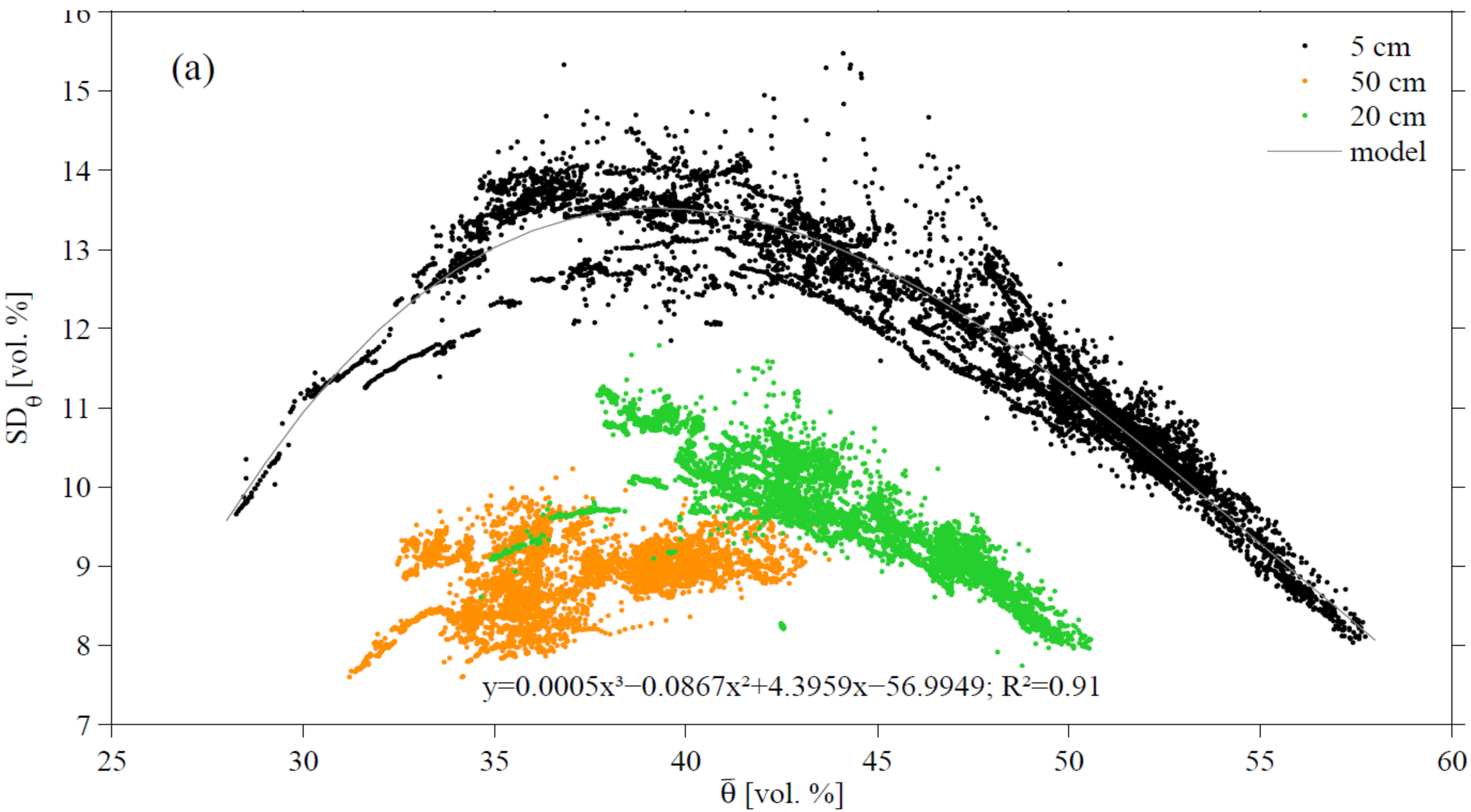




Bogena et al. (2010)

THE WÜSTEBACH NETWORK

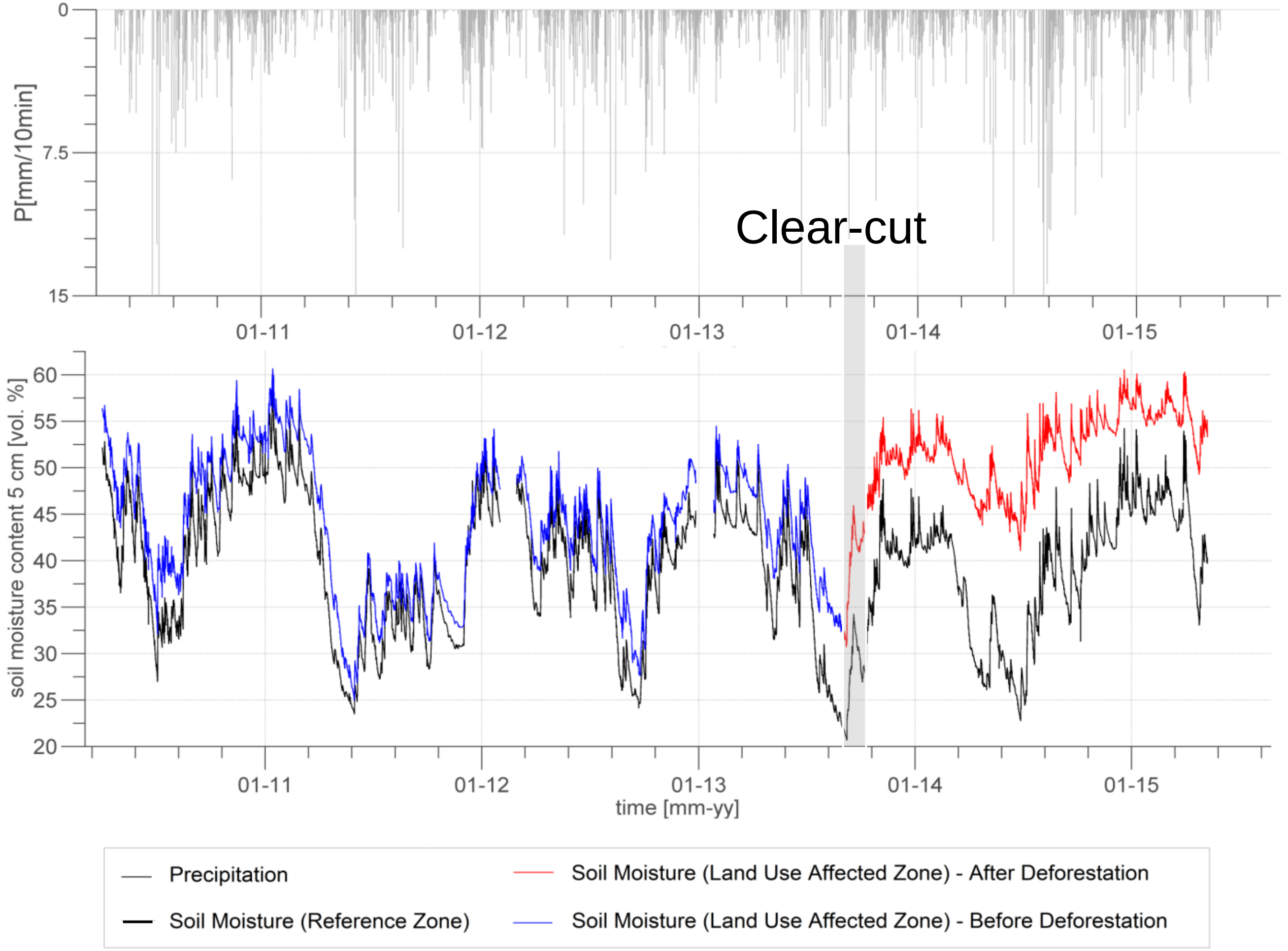
Spatial variability vs. mean soil moisture

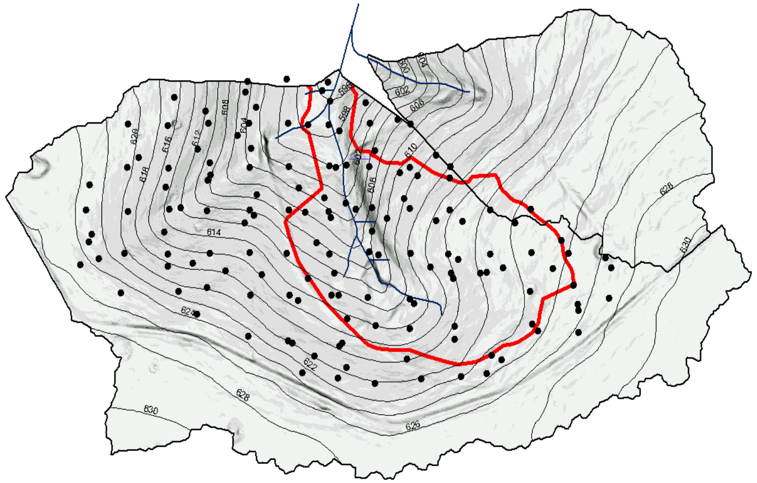


- Highest soil moisture variability as well as scatter is observed in 5 cm.
- SD peaks in the intermediate soil moisture range.

THE WÜSTEBACH NETWORK

A clear-cut experiment



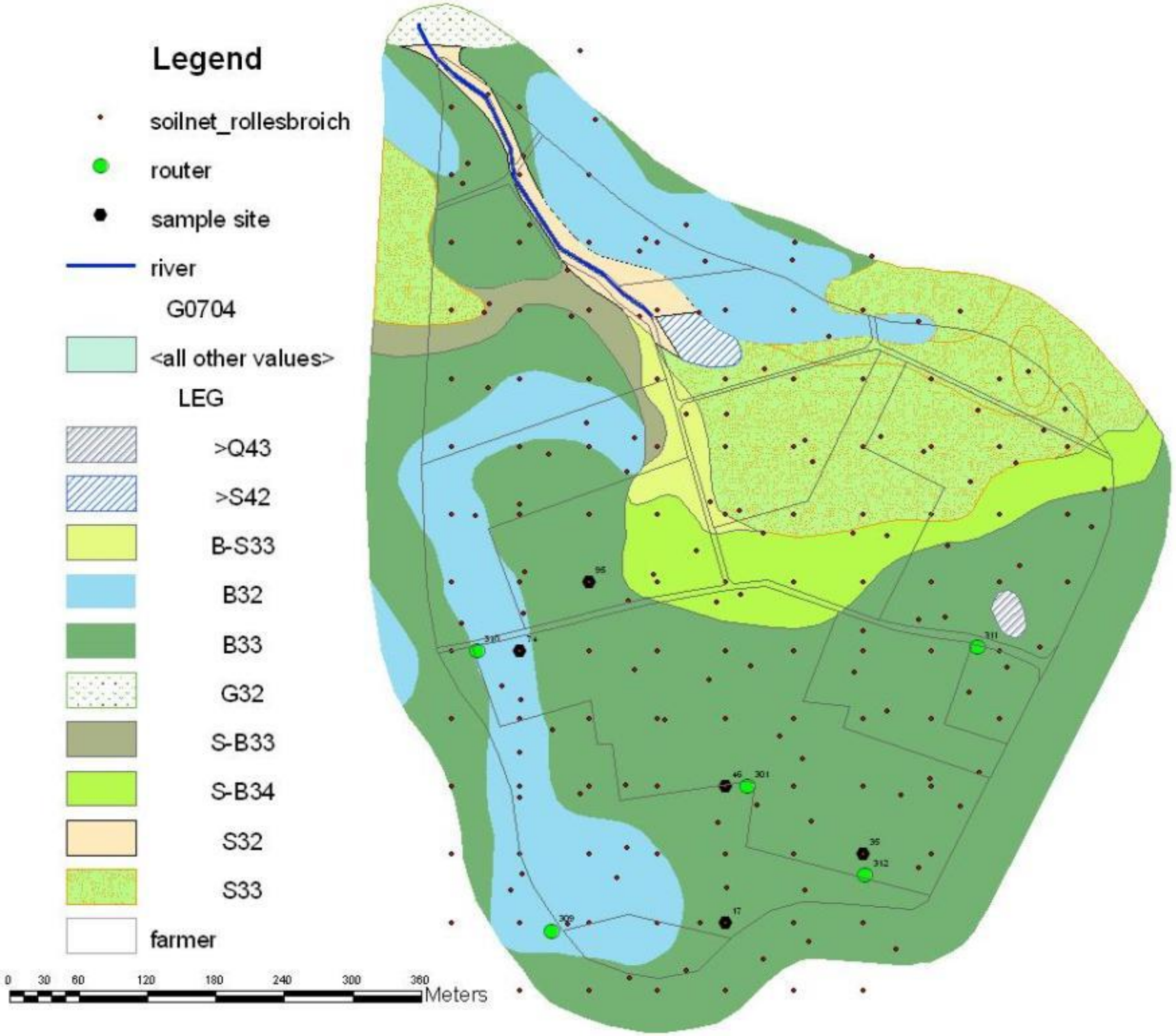


	SM	
	Reference area	Clear-cut area
Before	39.5 (7.6)	43.6 (7.2)
After	38.6 (6.9)	51.2 (4.9)

Wiekenkamp et al., 2016

THE ROLLESBROICH NETWORK

Grassland hydrology (40ha)

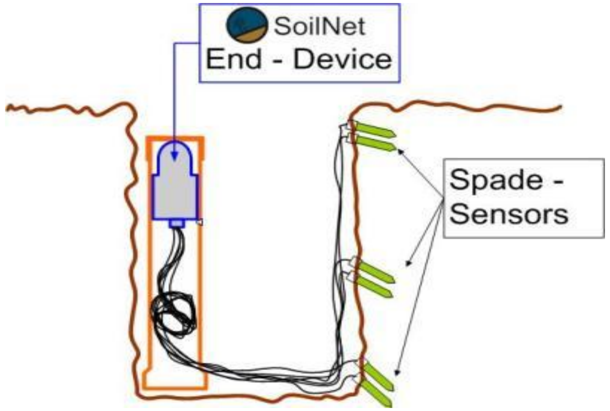


200 Sensor units

18 Router units

1200 Soil moisture sensors

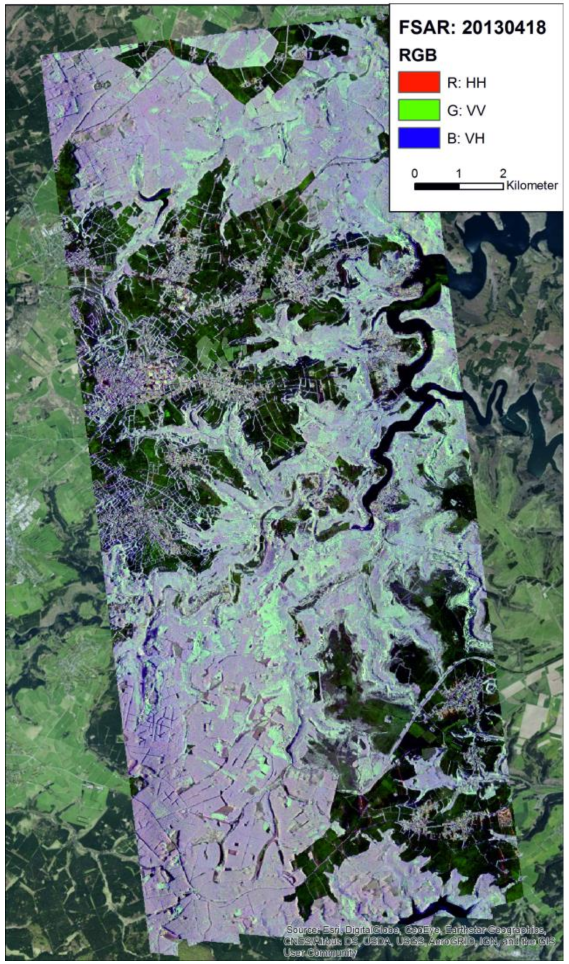
300 Temperature sensors

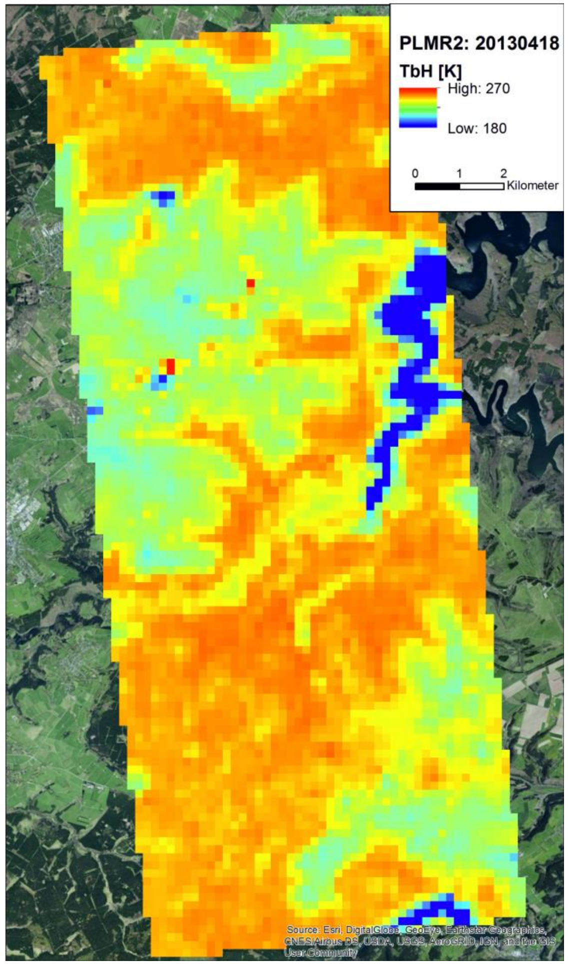


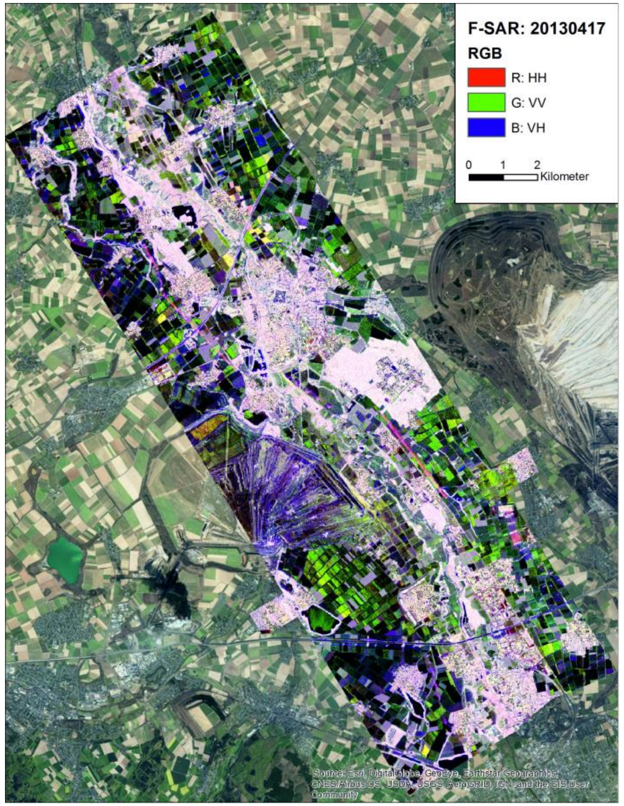
Long-term L-band radiometer measurements

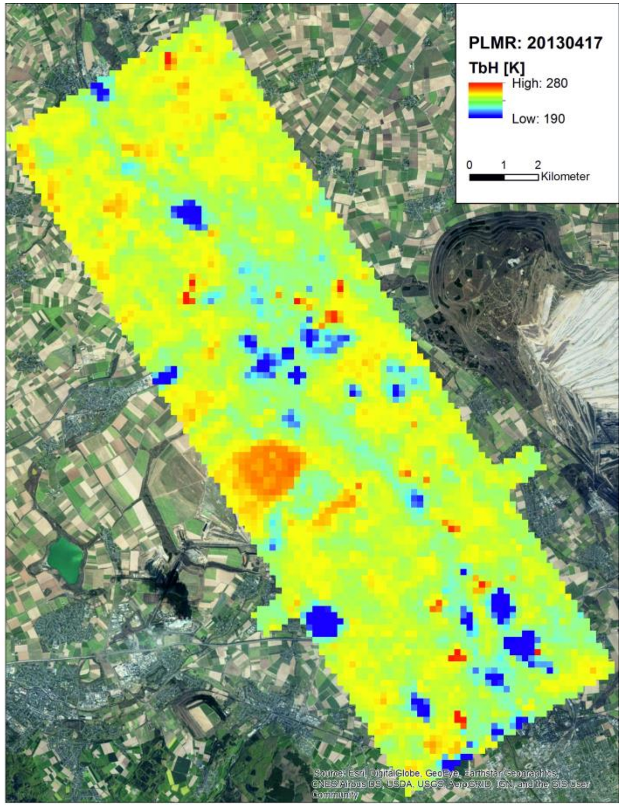
AIRBORNE CAMPAIGNS

L-band SAR (DLR F-SAR) and radiometer measurements (PLMR2)









JÜLICH Forschungszentrum

CONCLUSIONS AND OUTLOOK

- To get closest to real spatiotemporal variability of soil moisture with in situ sensors, wireless sensor networks have some advantages
- SoilNet applications since 9 years mainly for soil water dynamics research
- SoilNet is restricted to small catchments
- SoilNetLoRa makes monitoring of larger catchments possible (e.g. 100 km²)
- 2 step SM sensor calibration is TERENO standard
- TERENO Rur observatory (ag site Selhausen) will be location of a test campaign for the ESA Copernicus L-band SAR candidate mission