Physikalisches Institut
Heidelberg University
Germany

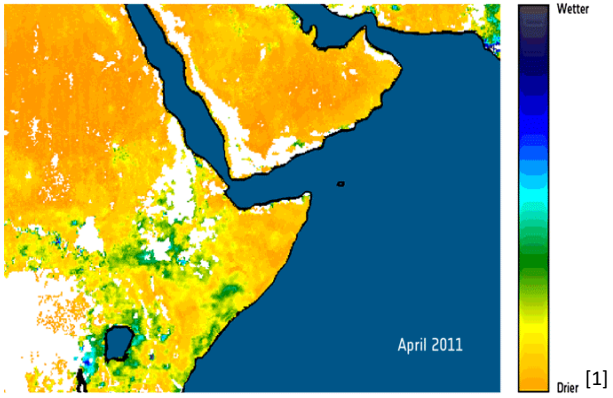
Use of CRNS for soil water management

Markus Köhli[1], Cosimo Brogi[2], Martin Schrön[3], J. Weimar[4], P. Ney[2] and Ulrich Schmidt[1]

[1] Physikalisches Institut, Heidelberg University, Heidelberg, Germany
[2] Agrosphere Institute (IBG-3), Forschungszentrum Jülich, Jülich, Germany
[3] Helmholtz Centre for Environmental Research - UFZ, Leipzig, Germany
[4] StyX Neutronica GmbH, Mannheim, Germany

Soil Moisture Measurement Gap

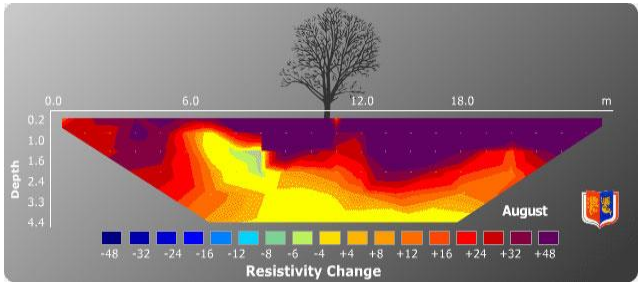
~ 1 km



[1]

via
satellite remote sensing
(optical, microwave)

< 10 m

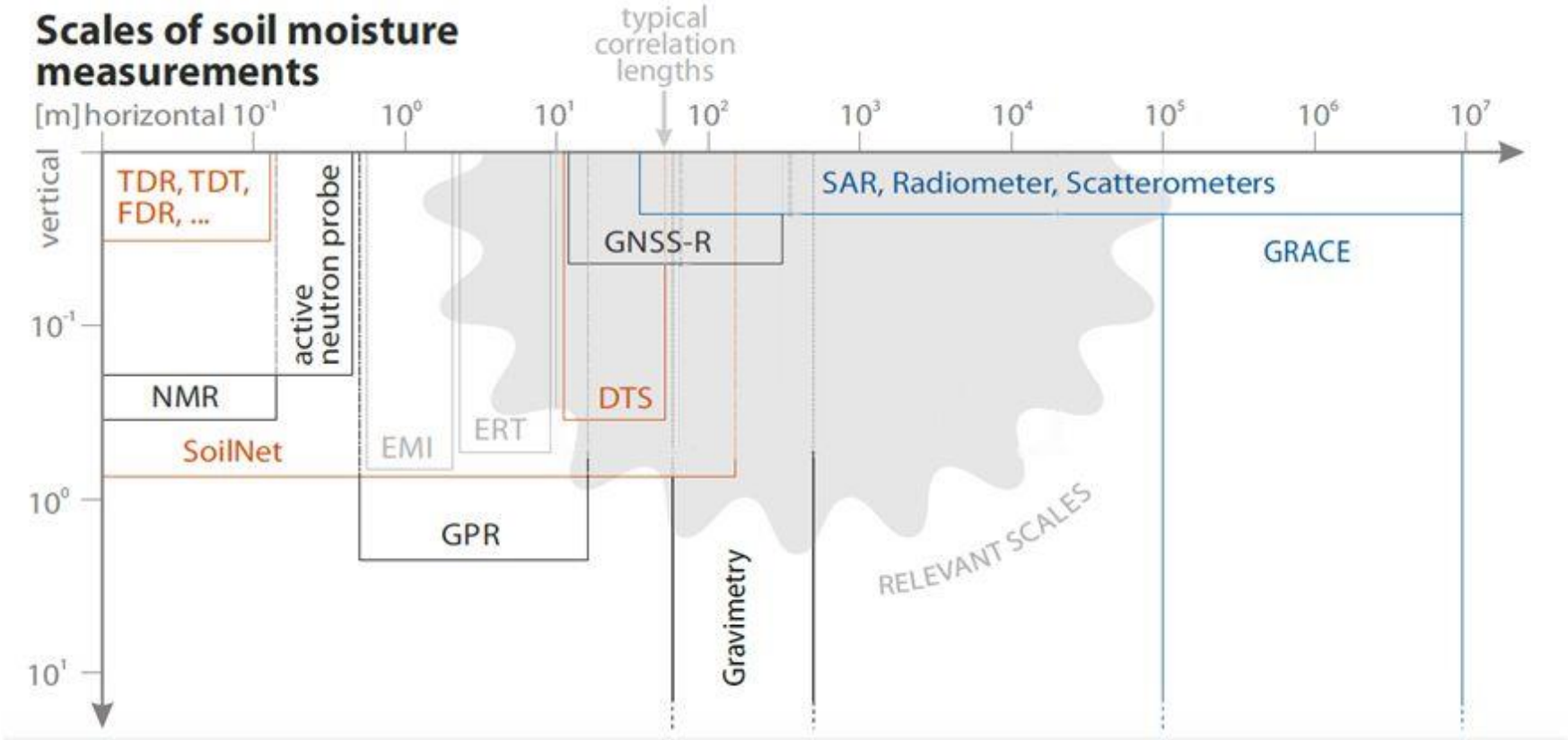


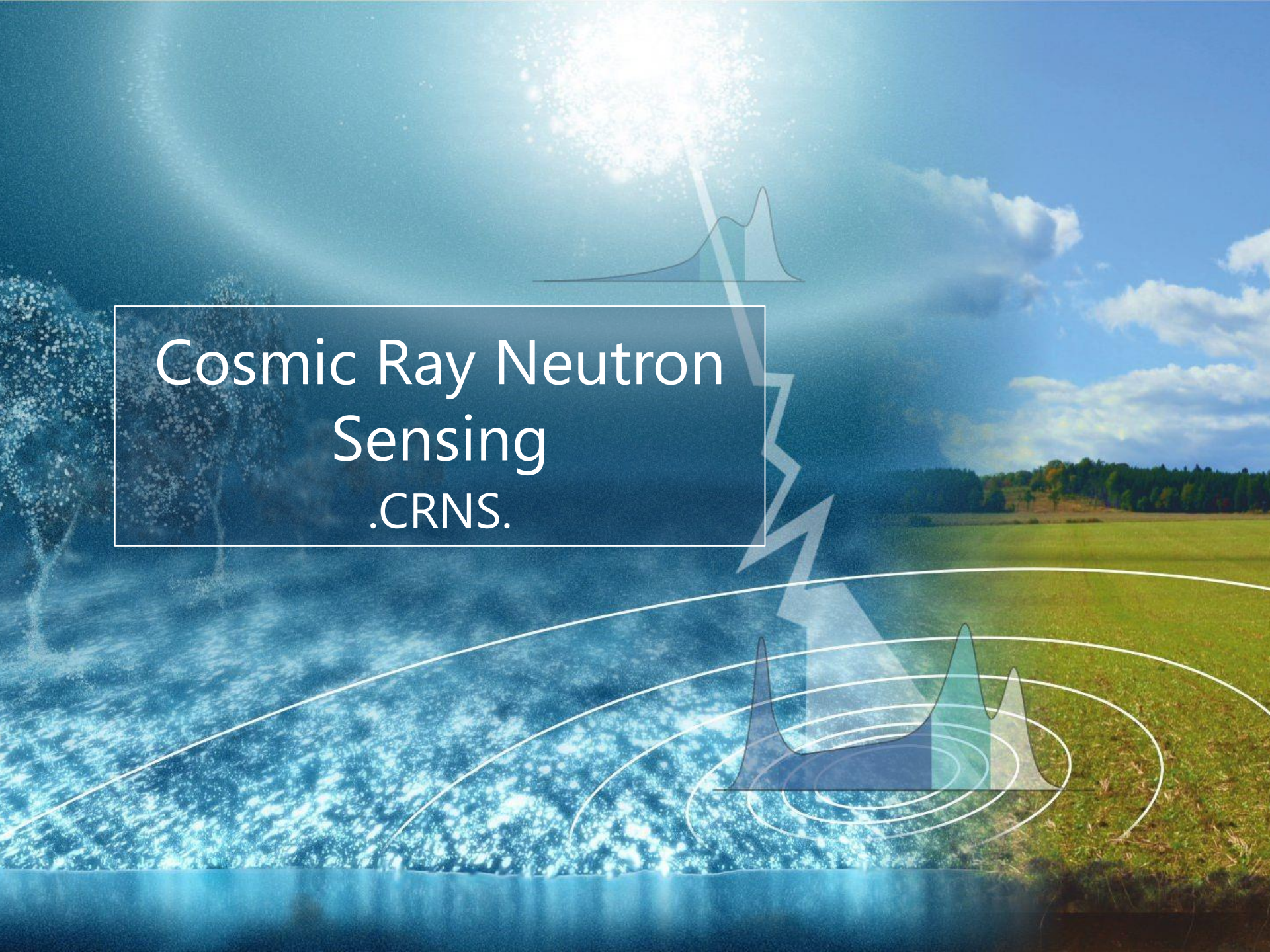
[2]

via
local techniques
(electrical resistivity, capacitance, etc)
(even neutrons…)

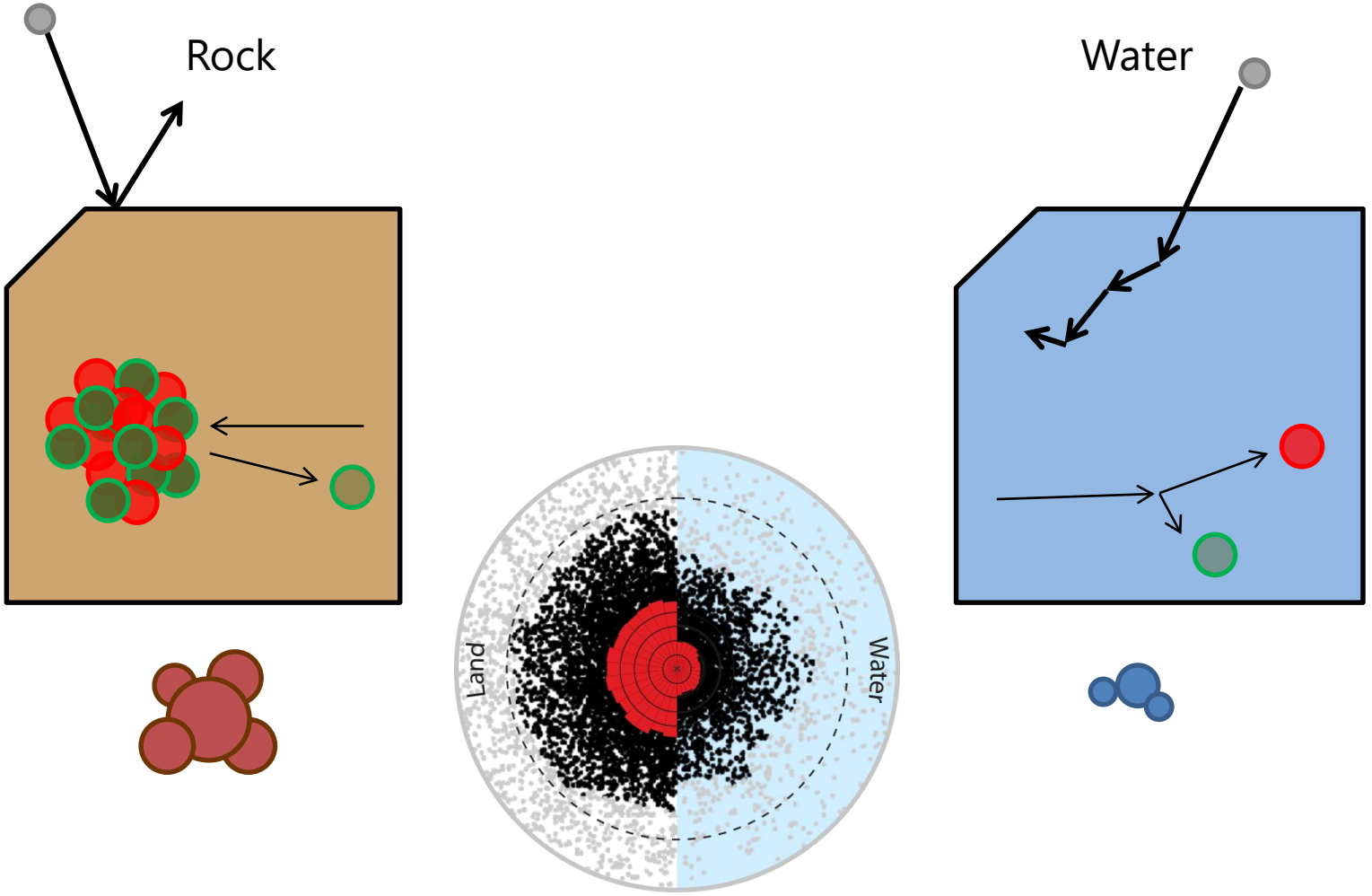
[1] ESA SMOS (http://www.esa.int/Our_Activities/Observing_the_Earth/SMOS/Horn_of_Africa_drought_seen_from_space)
[2] The Clay Research Group (http://www.theclayresearchgroup.org/images/ert.jpg)

Measurement Scales

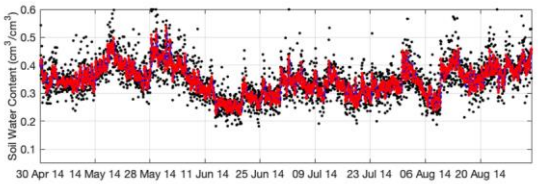


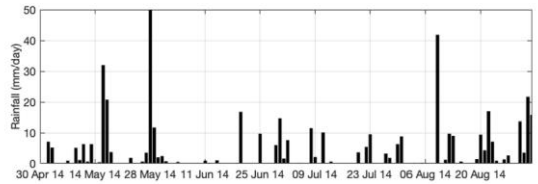

Cosmic Ray Neutron Sensing
.CRNS.

Neutron interaction with water

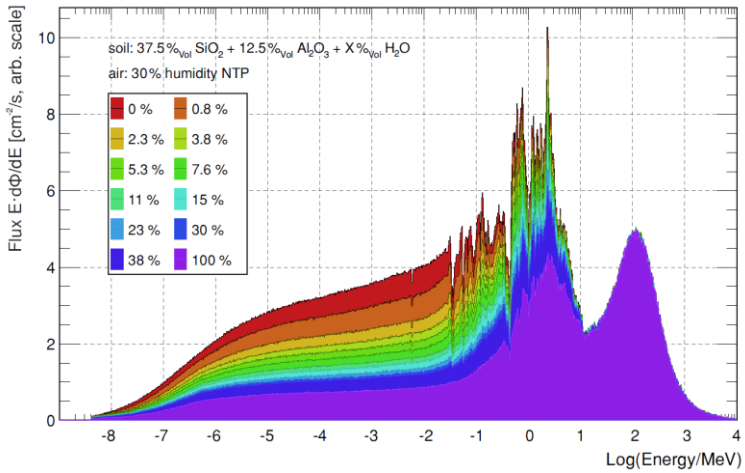


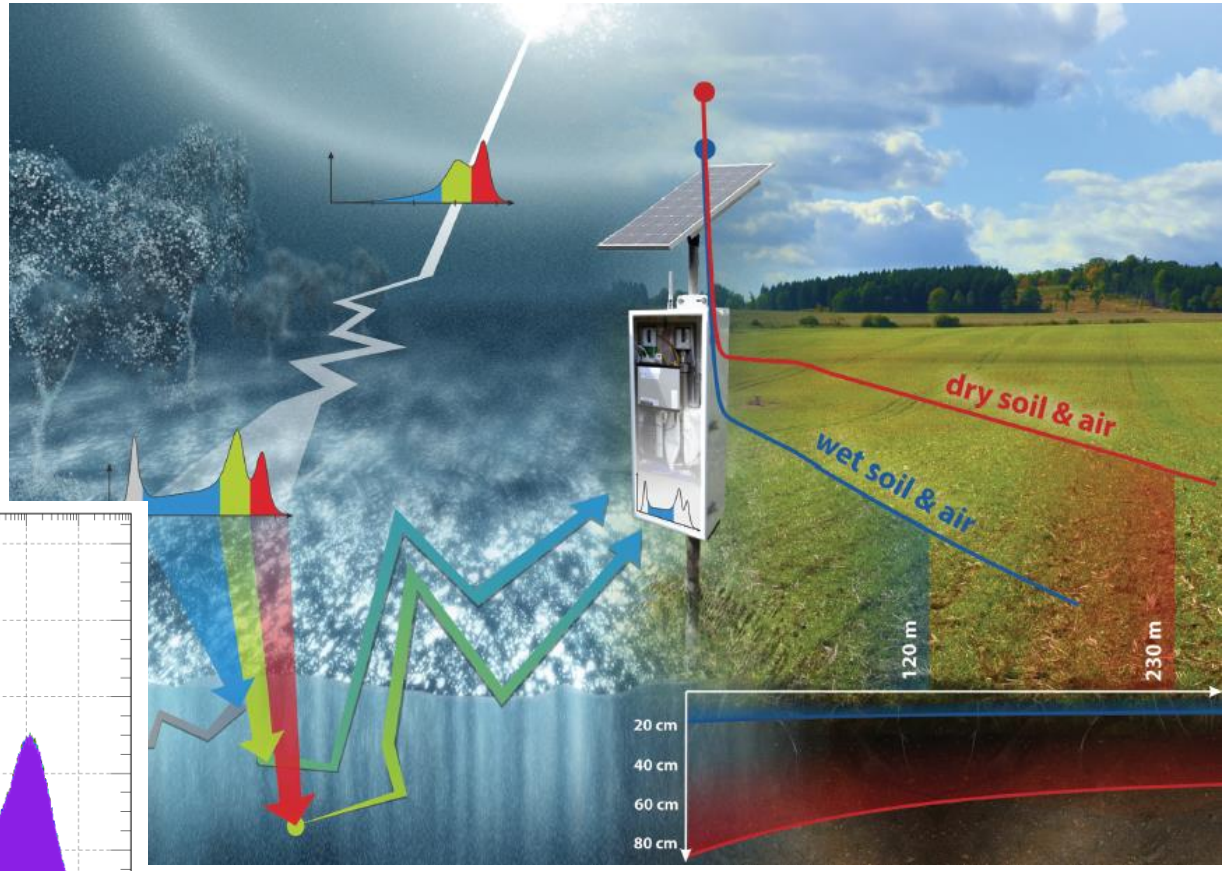
CRNS Overview





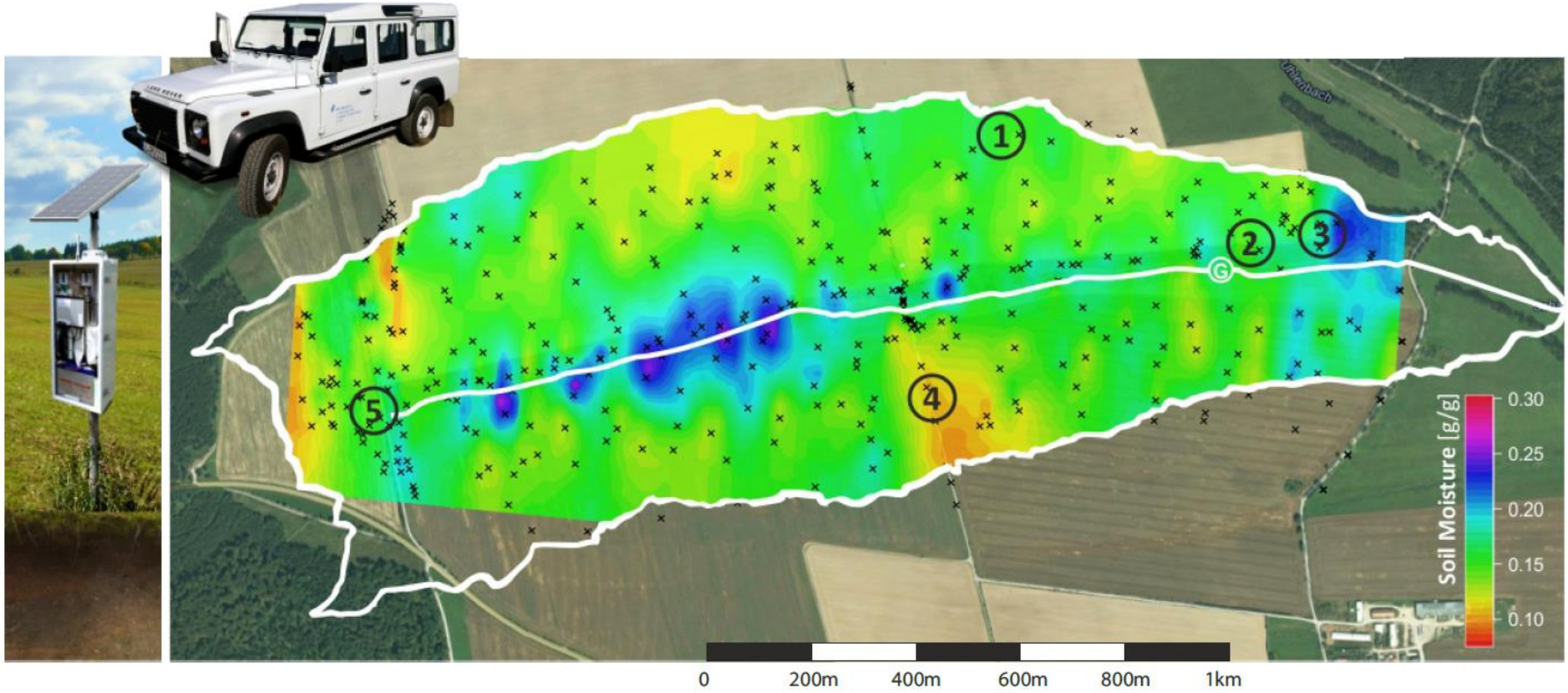
[1]



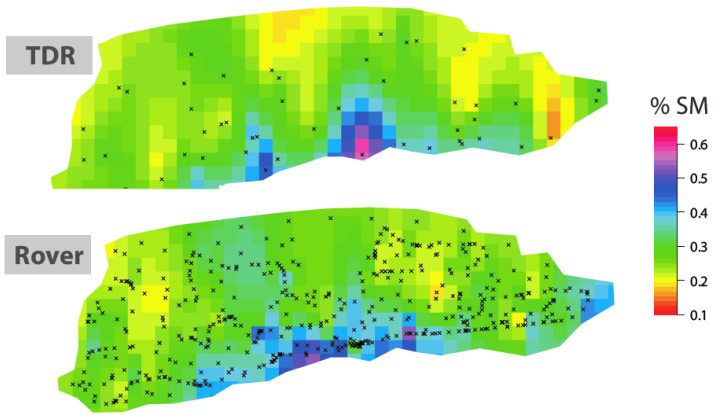


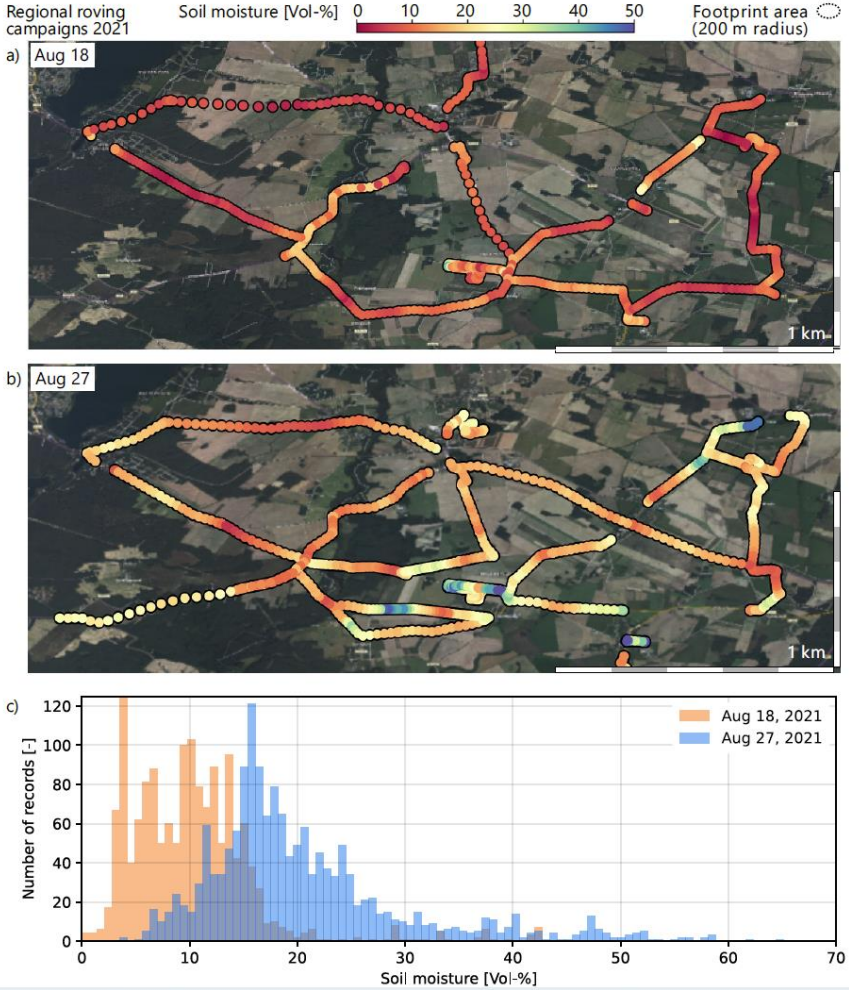
[1] T. Franz et al., Practical Data Products From Cosmic-Ray Neutron Sensing for Hydrological Applications, Front. Water, 2020

Stationary and Roving



Roving across scales



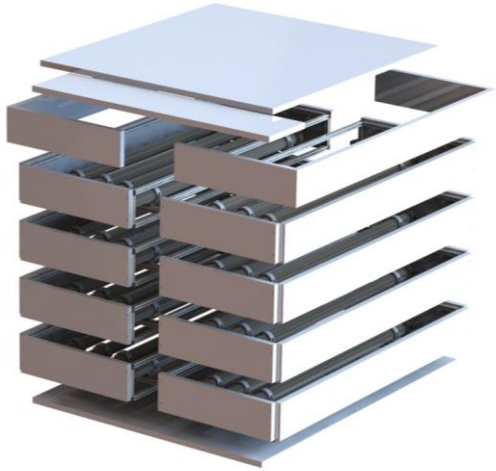


Two-days measurement campaign with the mobile detection system on Aug 18th (a) and Aug 27th (b), 2021. Credit: Martin Schrön, UFZ Leipzig, Germany.

Stationary and Roving Instruments

Stationary - small

Stationary - large



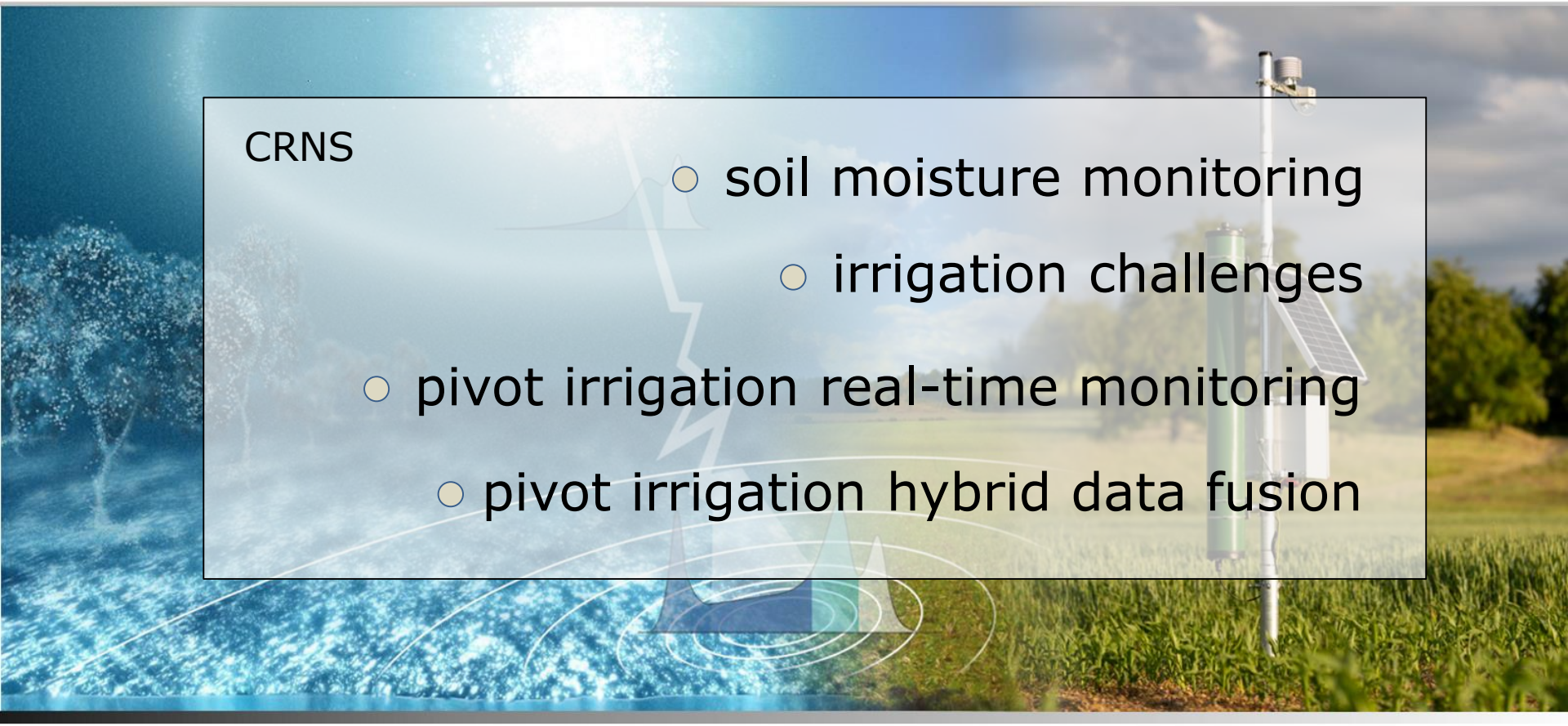
Roving

Physikalisches Institut
Heidelberg University
Germany

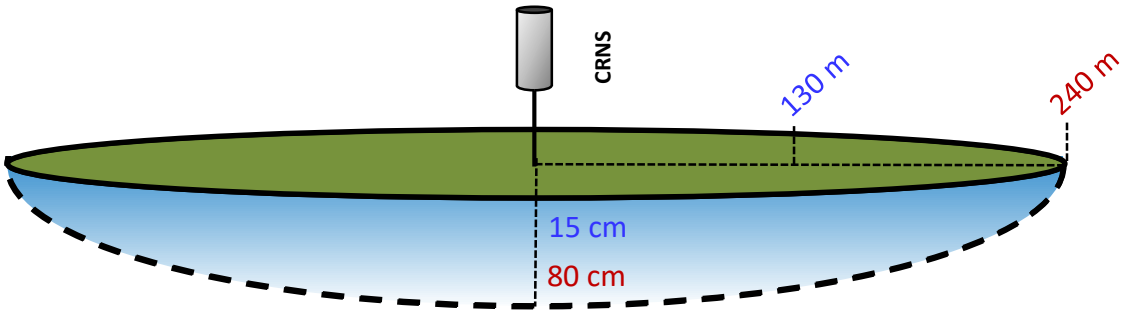
Use of CRNS for soil water management

Markus Köhli[1], Cosimo Brogi[2], Martin Schrön[3], P. Ney[2] and Ulrich Schmidt[1]

[1] Physikalisches Institut, Heidelberg University, Heidelberg, Germany
[2] Agrosphere Institute (IBG-3), Forschungszentrum Jülich, Jülich, Germany
[3] Helmholtz Centre for Environmental Research - UFZ, Leipzig, Germany

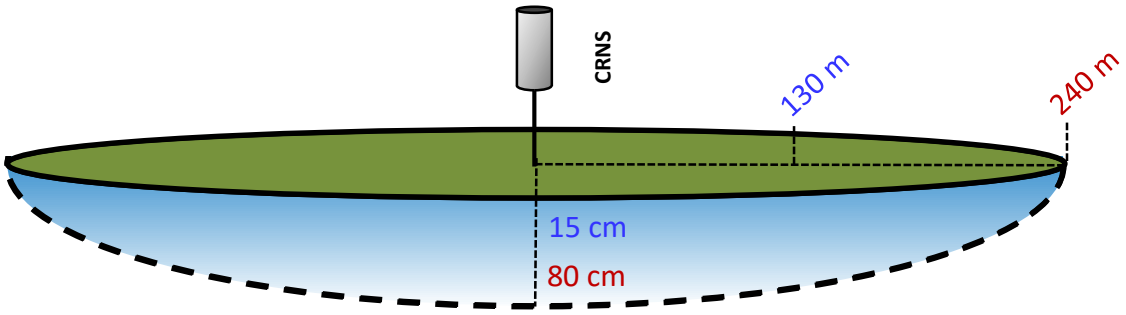


Motivation for Smart Agriculture



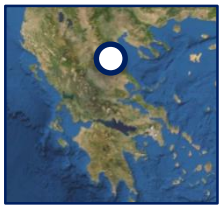
- ✓ One sensor per field
- ✓ Large measured volume
- ✓ No removal during management
- ✓ Low maintenance

Motivation for Smart Agriculture



- ✓ One sensor per field
- ✓ Large measured volume
- ✓ No removal during management
- ✓ Low maintenance

Challenges Sprinkler Irrigation



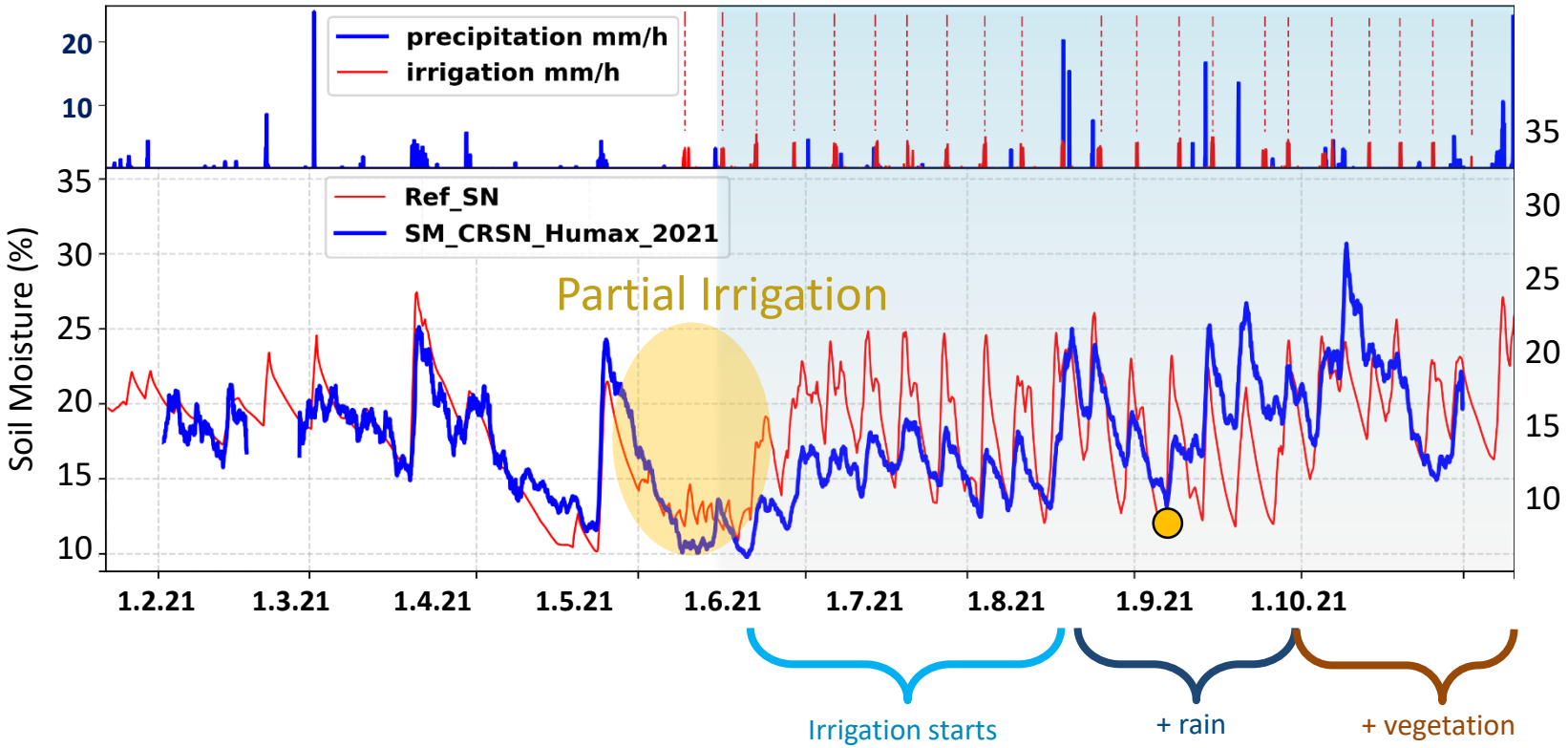
In collaboration with
C. Brogi
FZ Jülich

ATLAS
AGRICULTURAL INTEROPERABILITY AND ANALYSIS SYSTEM

Timeseries of irrigation

Before irrigation, the soil moisture obtained with the CRNS well match the reference data.

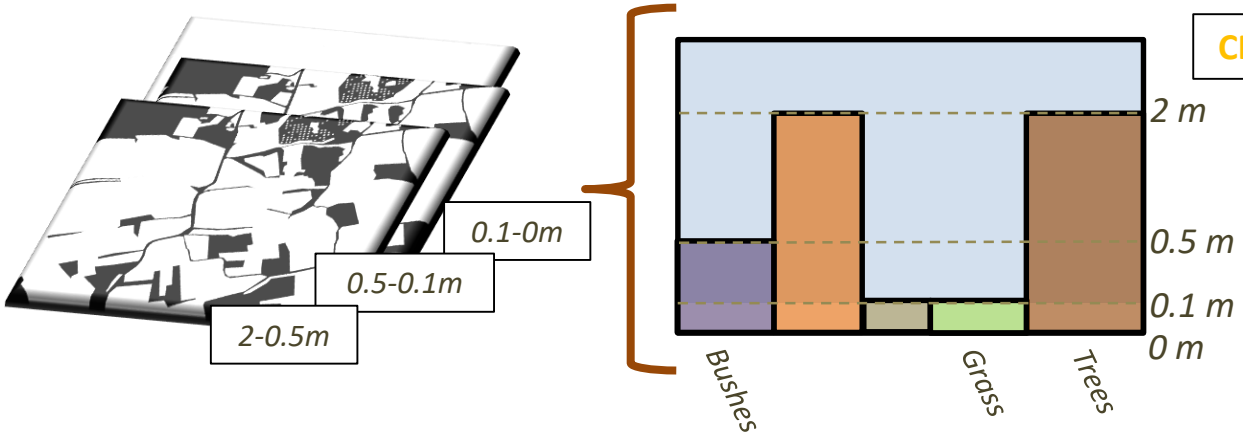
With irrigation, only the temporal dynamics are partially represented.



Agia Neutron Simulation

Setup of the actual scenario simulations:

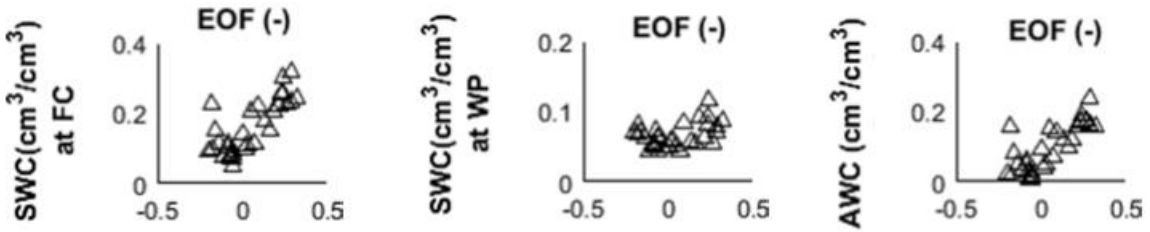
- 600x600 meters domain (center CRNP)
- Irrigation area coincident with field S10
- 8 layers covering 1000 meters of air and 1.6 meters of soil.
  - 4 layers of air (with source/detector)
  - 3 layers of vegetation/air
  - 3 layers of soil (0-0.125, 0.125-0.35, 0.35-1.6)

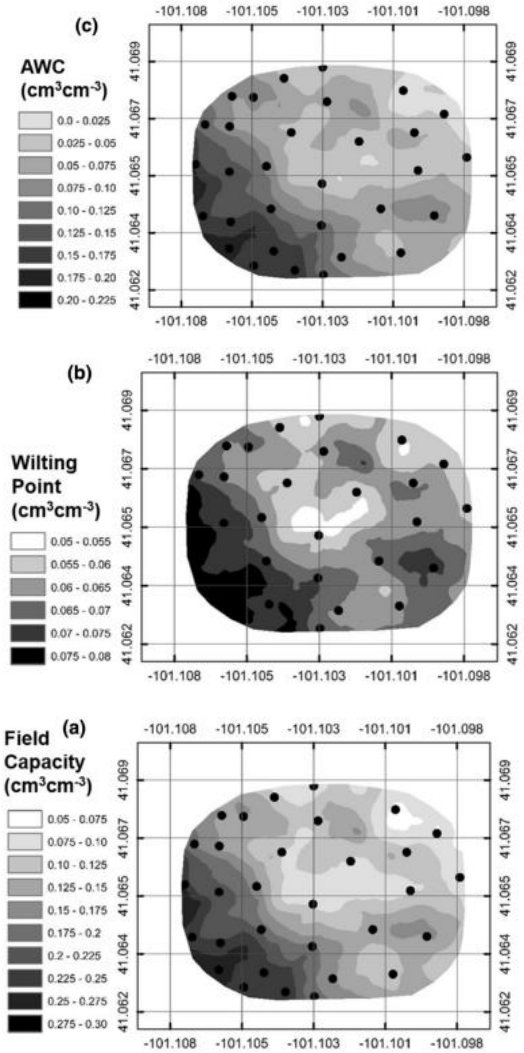


Pivot Irrigation Hybrid CRNS

Soil hydrological properties evaluation by CRNS Roving

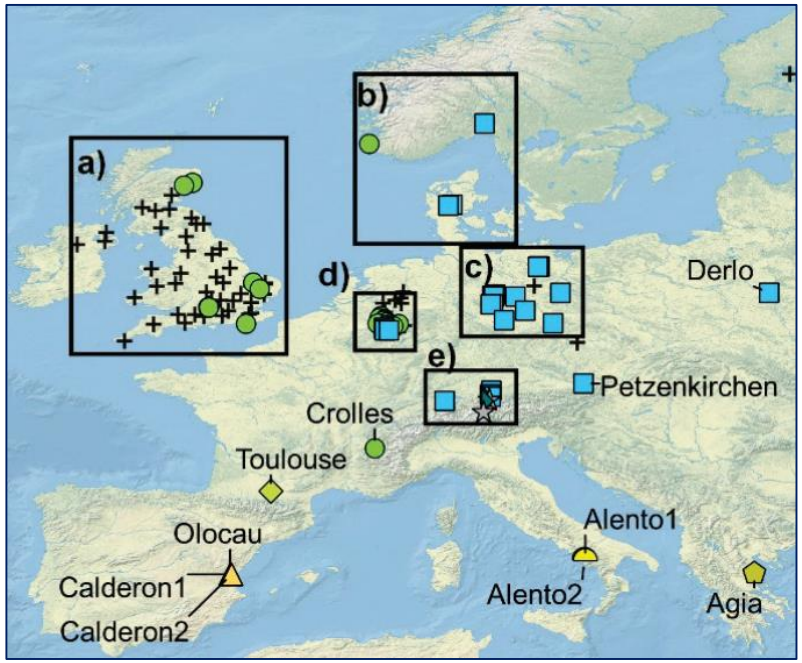
(53 ha)





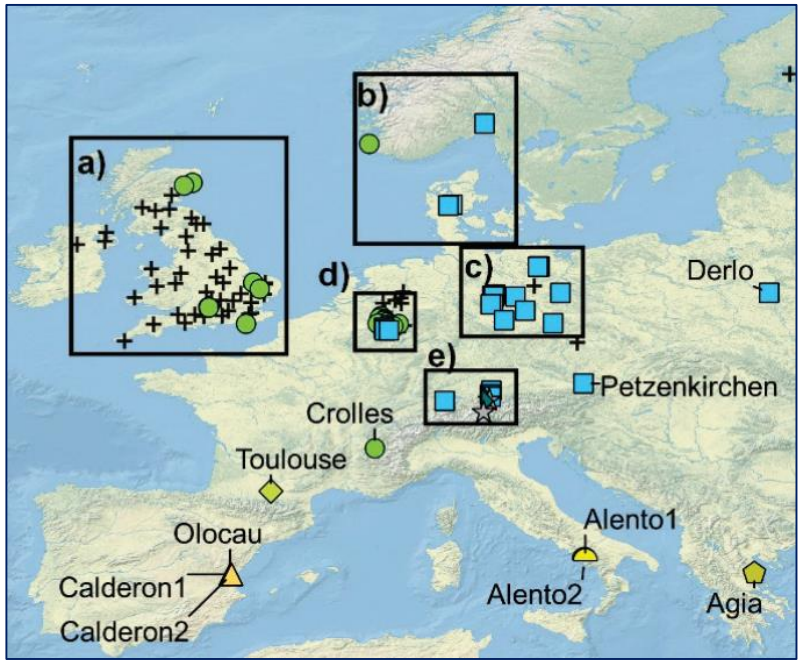
Finkenbiner et al. Integration of hydrogeophysical datasets and empirical orthogonal functions for improved irrigation water management
Precision Agric (2019) 20:78–100

CRNS Networks

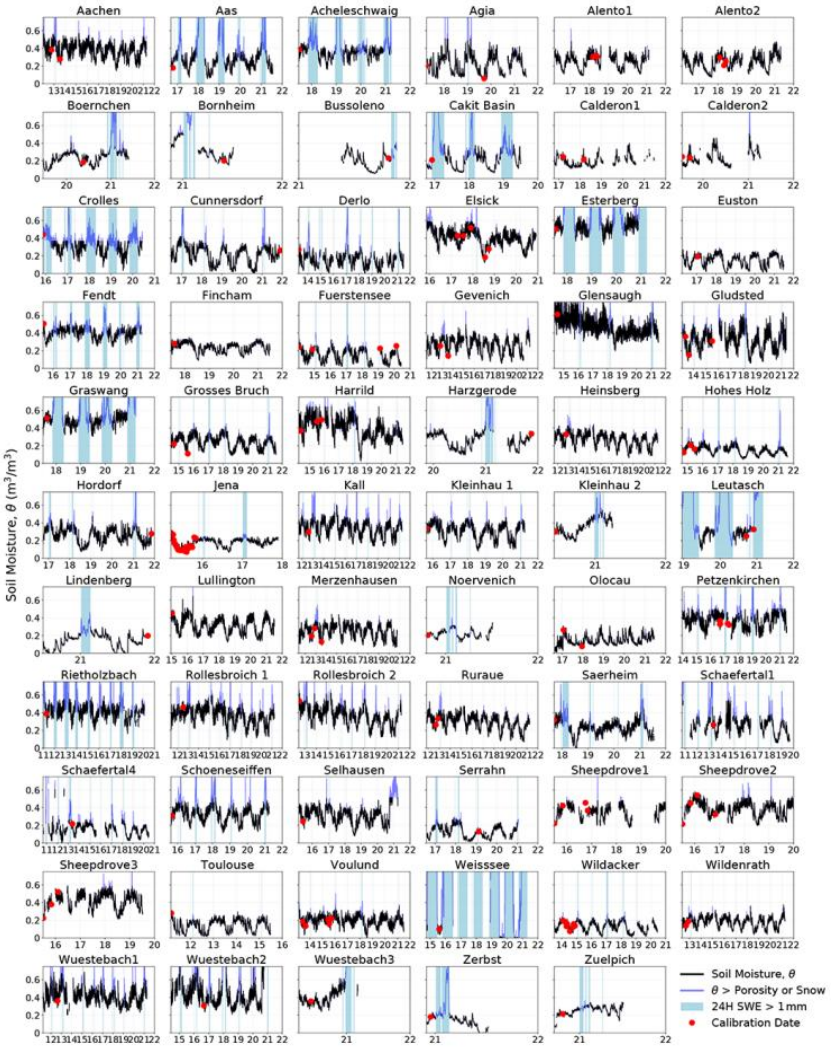


COSMOS-Europe sites (Bogena 2021, ESSD)

CRNS Networks

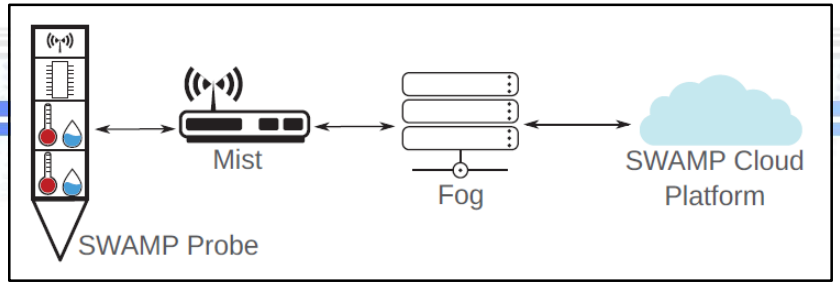


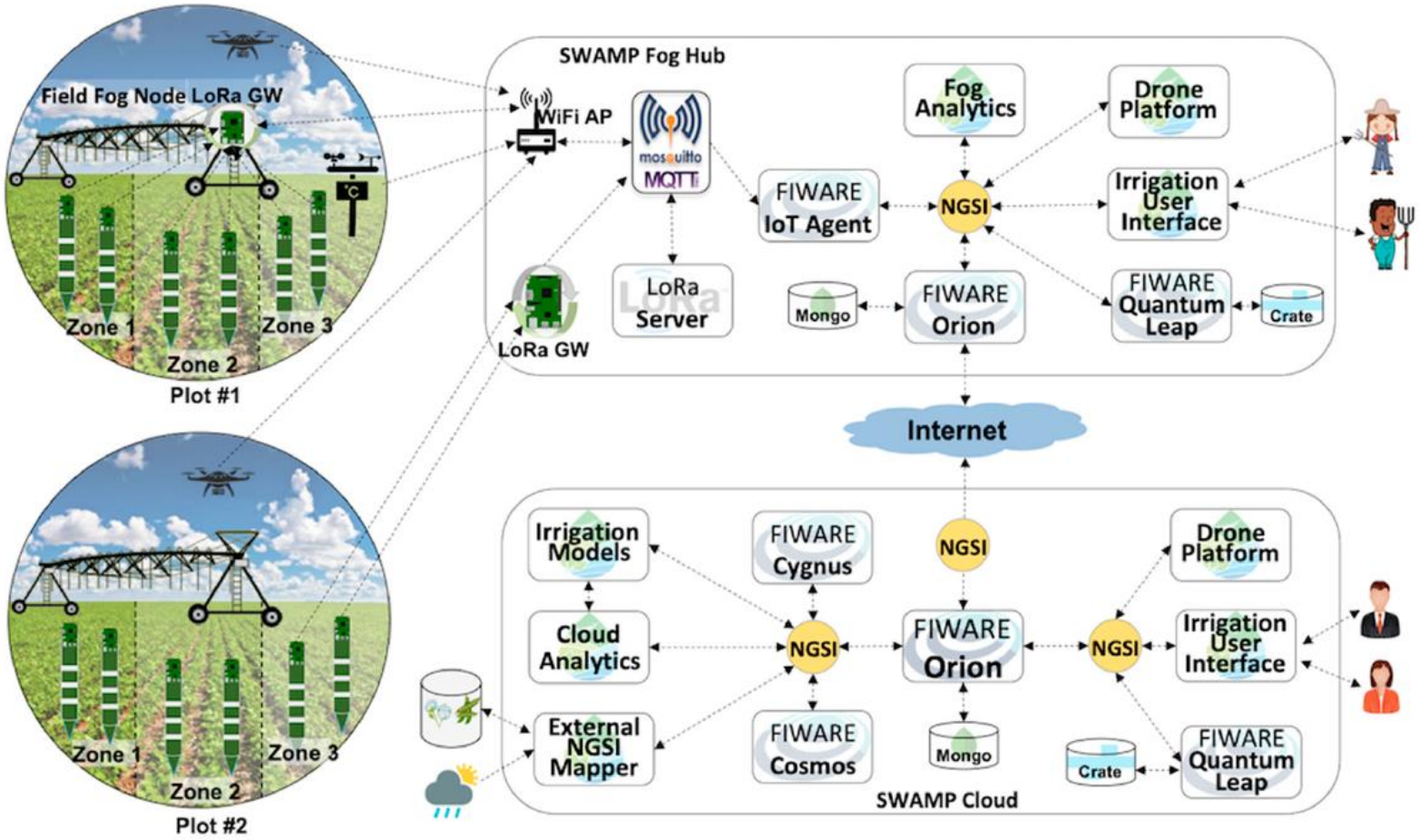
COSMOS-Europe sites (Bogena 2021, ESSD)



H.R. Bogena et al., COSMOS-Europe: a European network of cosmic-ray neutron soil moisture sensors, Earth Syst. Sci. Data, 14, 1125–1151, 2022

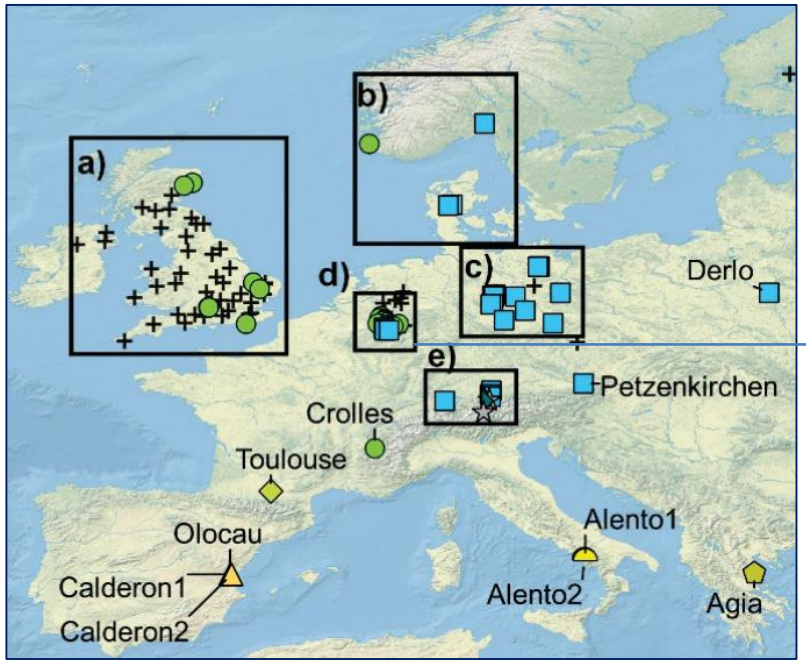
Cosmic SWAMP



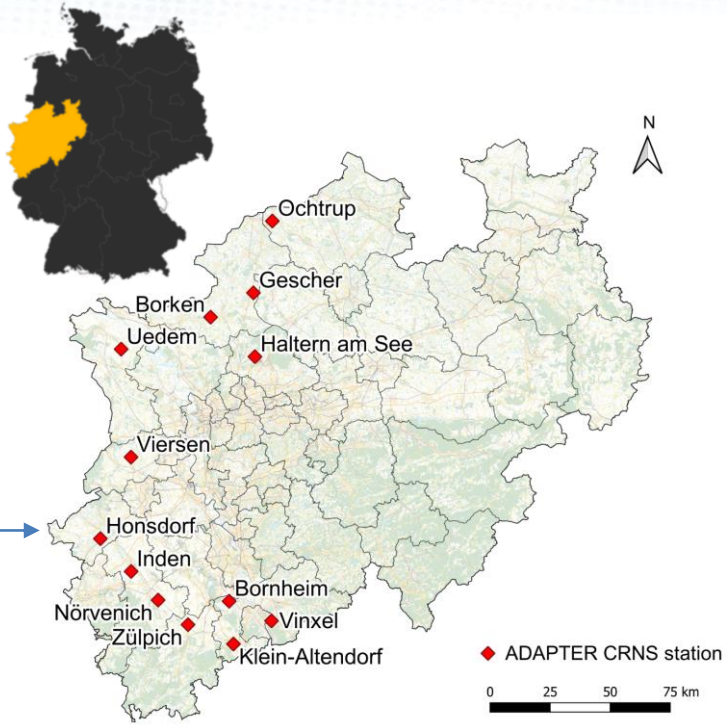


C. Kamienski et al., Smart Water Management Platform: IoT-Based Precision Irrigation for Agriculture, *Sensors* **2019**, *19*(2), 276

CRNS Networks

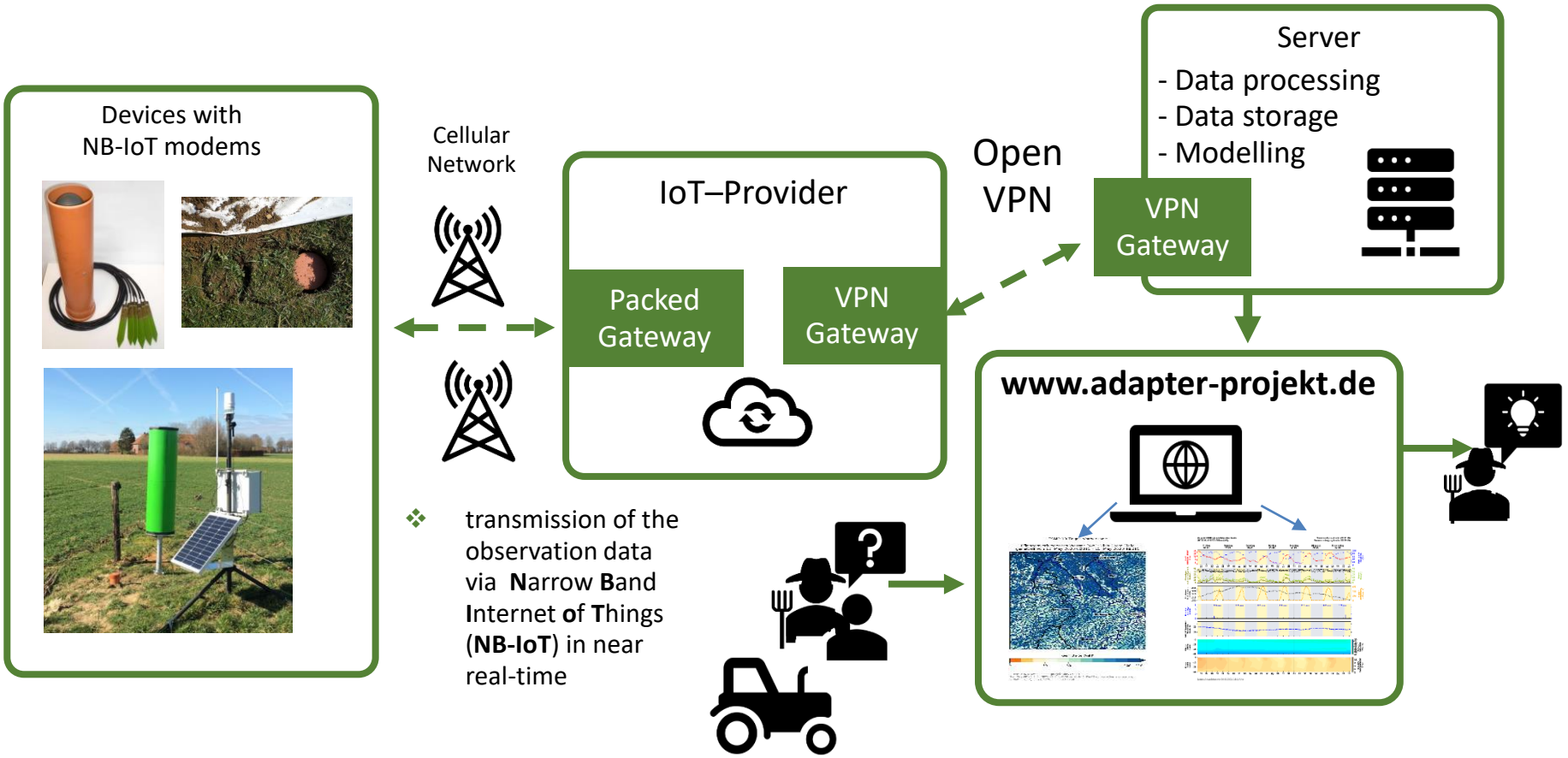


COSMOS-Europe sites (Bogena 2021, ESSD)



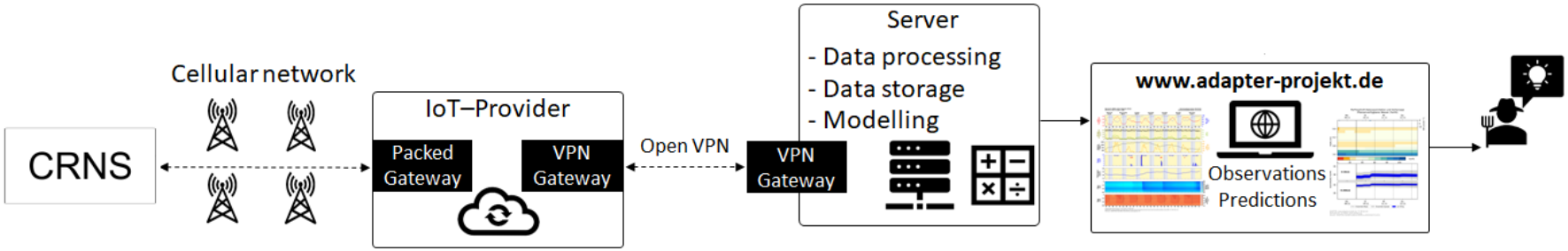
ADAPTER sites (Ney 2021, MetroAgriFor)

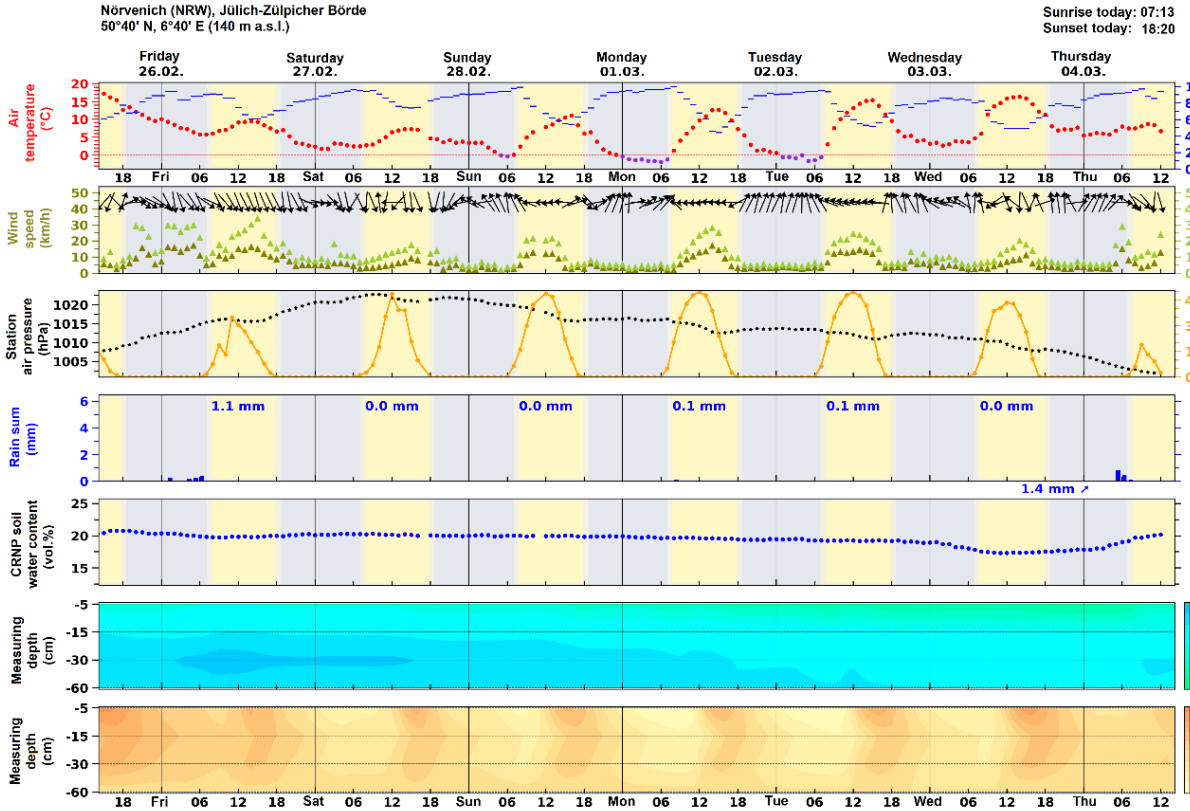
The ADAPTER Network



In collaboration with
Patrizia Ney
FZ Jülich

Telemetry Integration





air temperature

wind speed

air pressure

precipitation rate

CRNP
soil water content

relative humidity

wind gust

solar radiation

SoilNet
soil water content

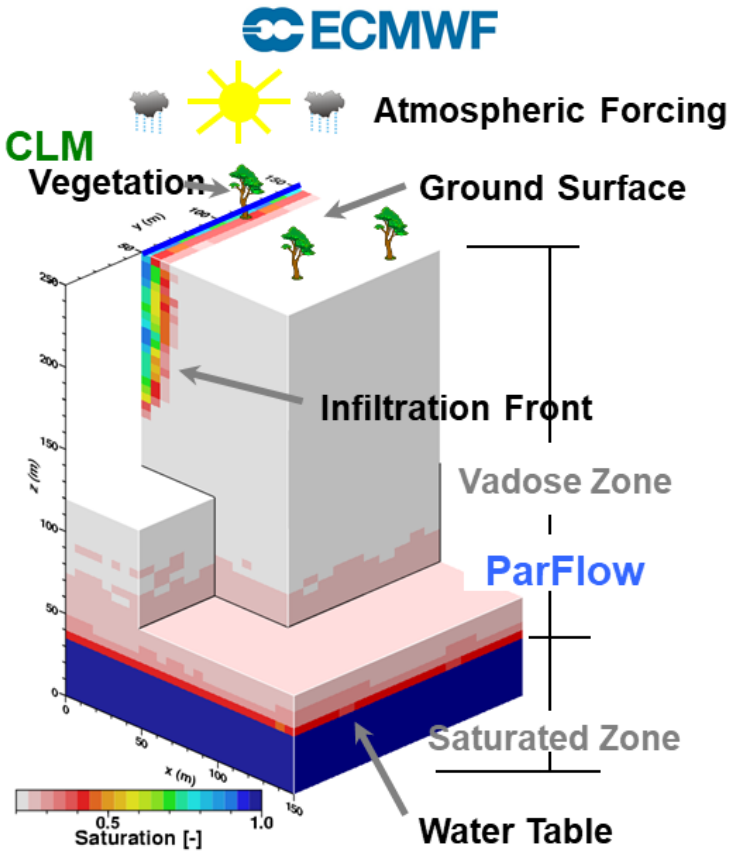
soil temperature

Forcast Model

High-resolution soil moisture forecast

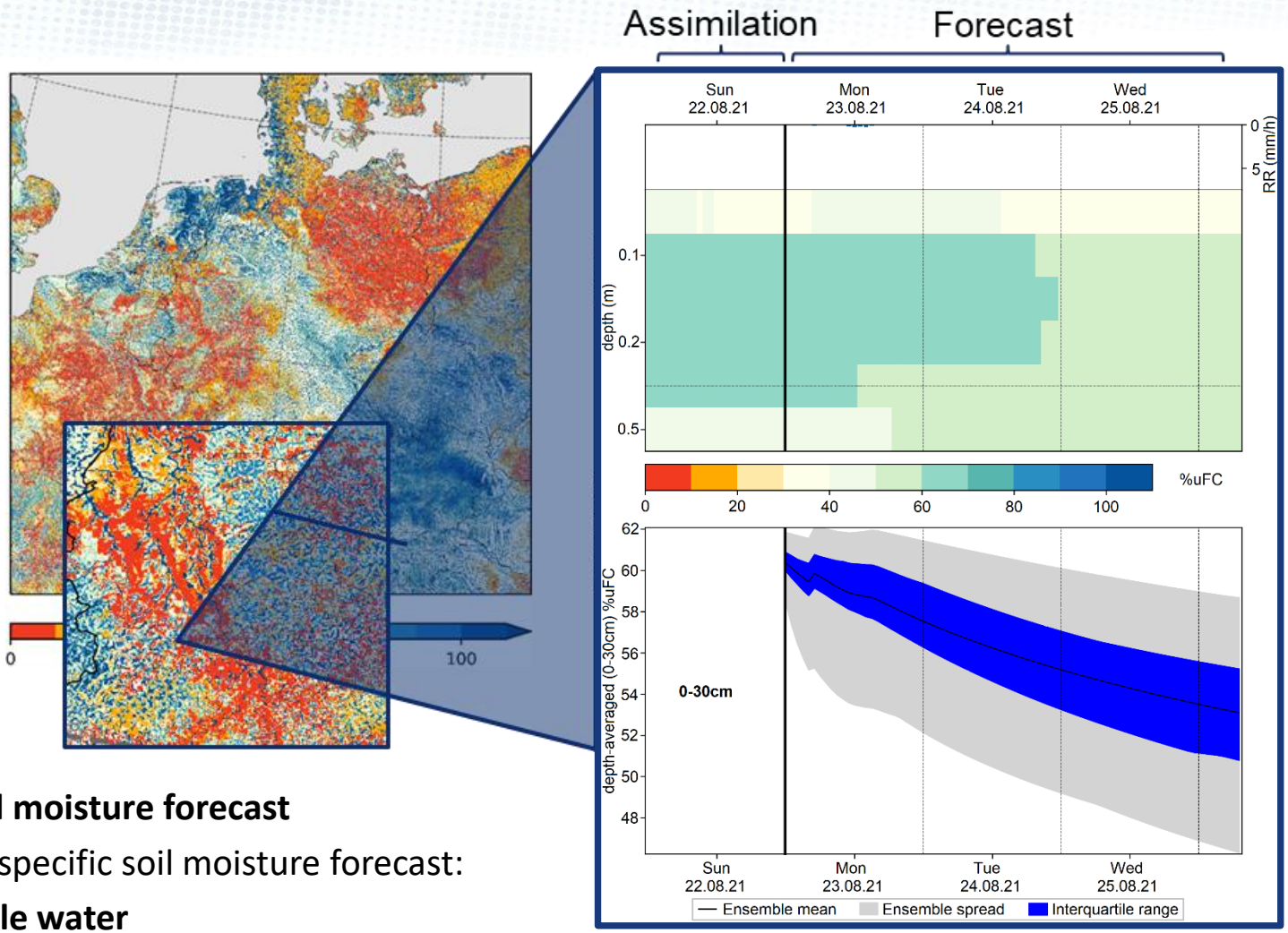
- Focus on **soil water states** and **fluxes**
- **ParFlow** hydrological model for the complete dynamical representation of the subsurface and surface hydrological processes, coupled with
- **CLM** (**C**ommon **L**and **M**odel) for the interactions at the surface
- Atmospheric forcing: forecasts from ECMWF
- Assimilation of observed soil moisture

→ **Initialization closest to reality**



An interdisciplinary spin-off

Model: ParFlow/CLM
Forcing: ECMWF HRES

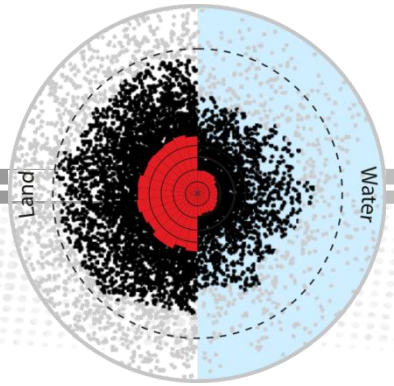


High-resolution soil moisture forecast

- Prototype: site specific soil moisture forecast:
  e.g., **plant available water**
- Ensemble accounts for **uncertainty** due to heterogeneity of soil hydraulic properties

CRNS – non-invasive soil moisture measurement



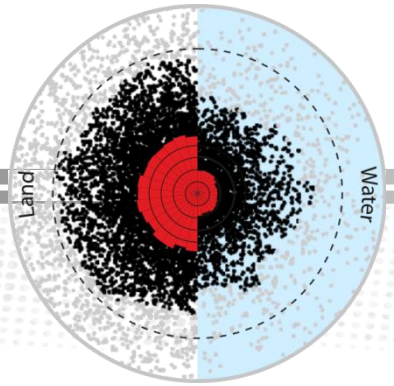



Physikalisches Institut
Heidelberg University
Germany

CRNS – non-invasive soil moisture measurement

CRNS is an emerging technology

- **Bridges the scale** between remote sensing and local probes
- Provides an **area-averaged soil moisture** estimate on **10 ha** and around 50 cm depth
- **Stationary: real-time data, Roving: snapshot of km^2 scale**
- Different Networks (COSMOS, UK, EU, Germany) - different telemetry solutions
- IoT-Integration for precision farming facilitated by
  - Independent, non-invasive sensor operation and low maintenance
- **Forcast models** based on weather station data in development, possible combination with **scheduled irrigation**



Physikalisches Institut
Heidelberg University
Germany