Cosmic Ray Neutron Sensing
with
novel neutron detectors

UP 6.5

DPG Frühjahrstagung München

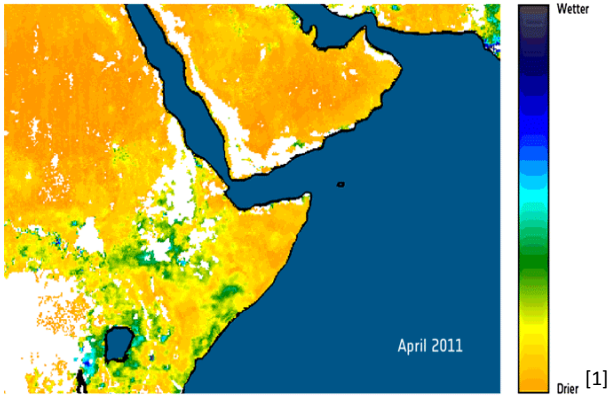
UNIVERSITÄT HEIDELBERG ZUKUNFT SEIT 1386

HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ

The Measurement Gap

1

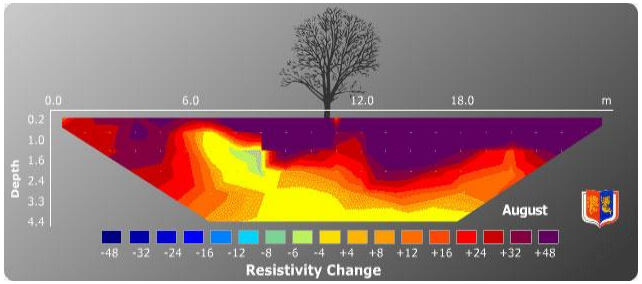
~ 1 km



[1]

via
satellite remote sensing
(optical, microwave)

< 10 m

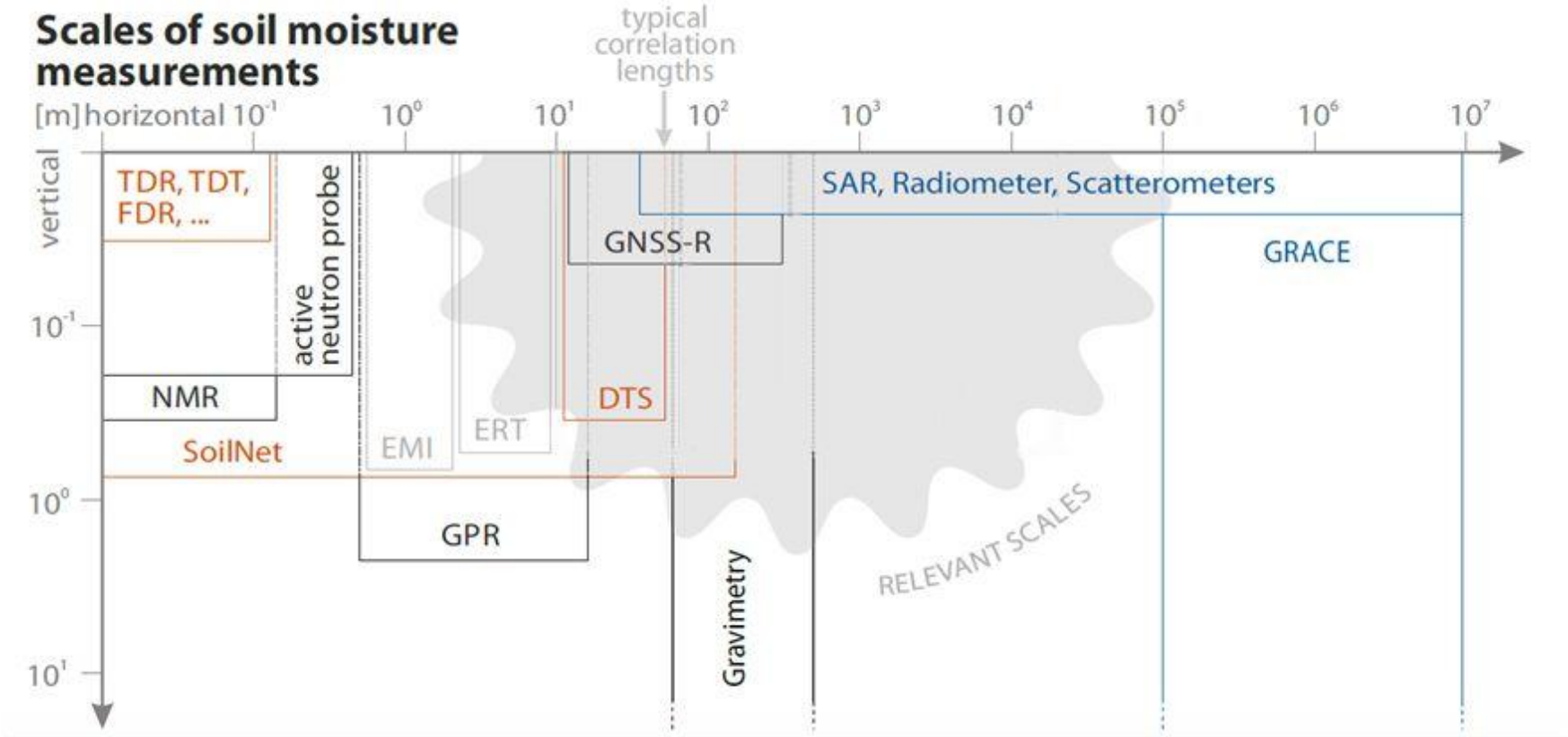


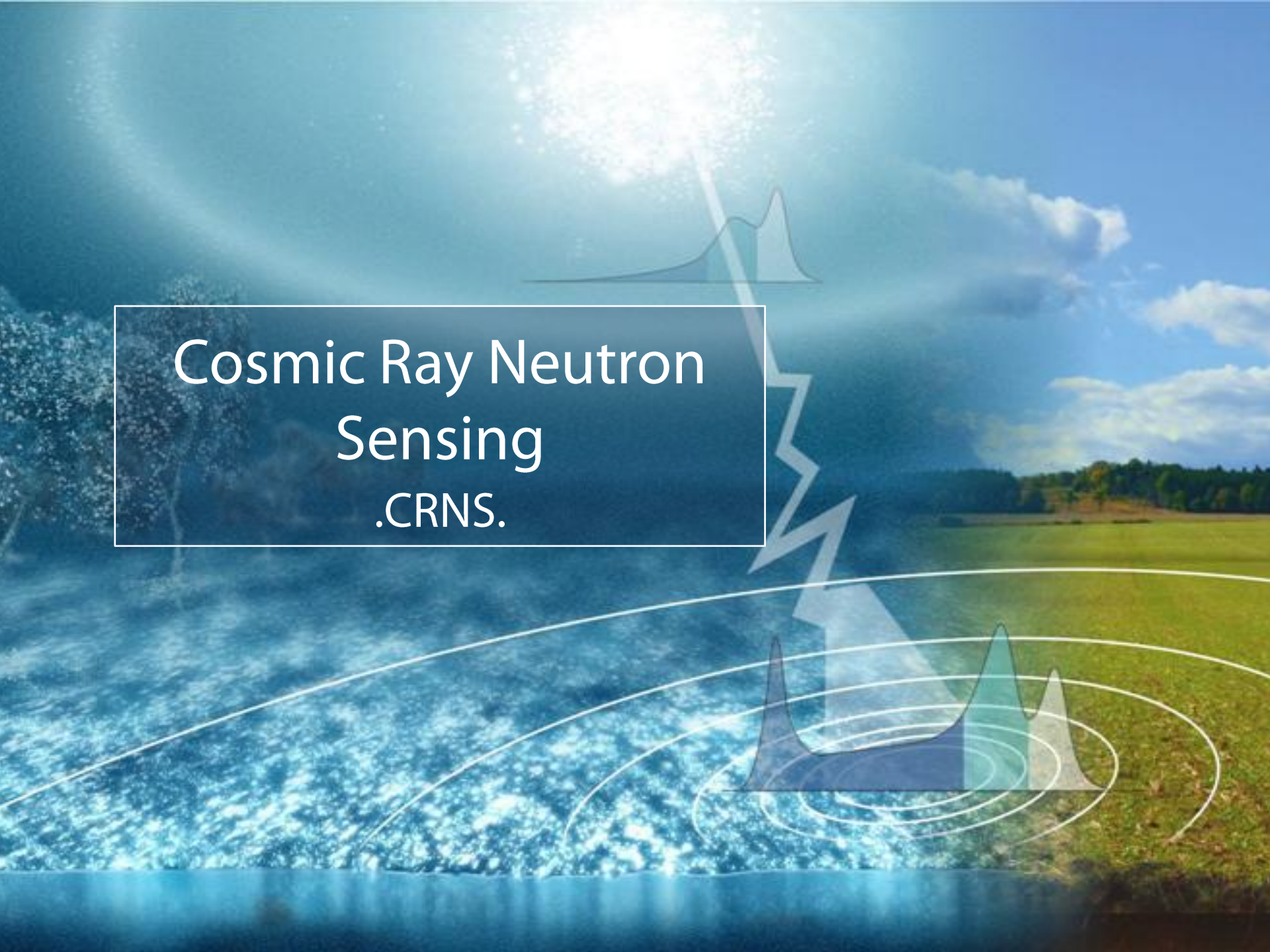
[2]

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

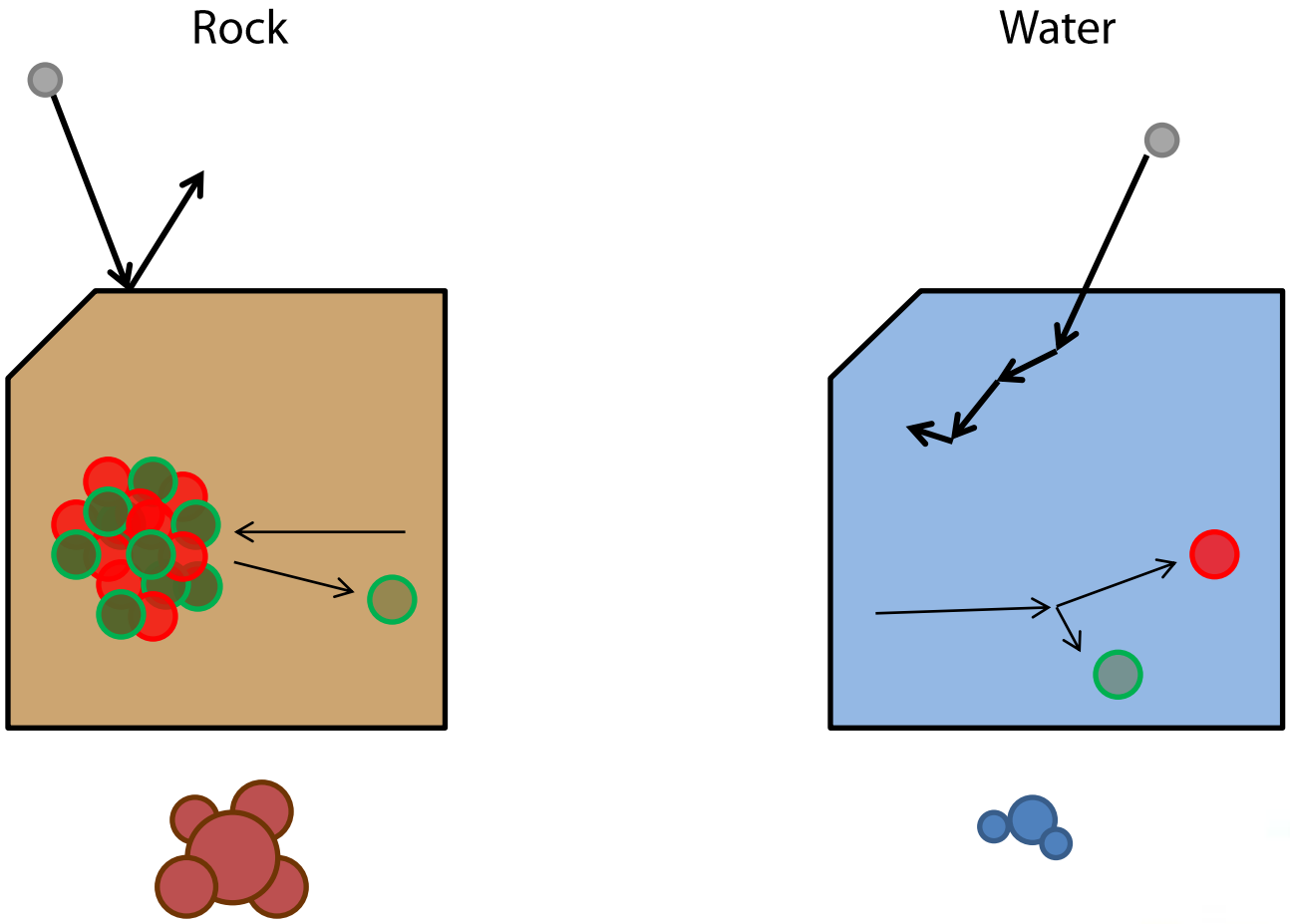
[1] ESA SMOS (http://www.esa.int/Our_Activities/Observing_the_Earth/SMOS/Horn_of_Africa_drought_seen_from_space)
[2] The Clay Research Group (http://www.theclayresearchgroup.org/images/ert.jpg)

The Measurement Gap

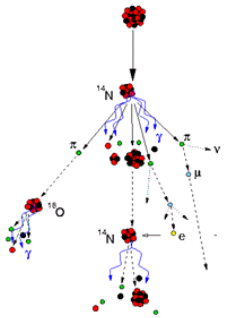



Cosmic Ray Neutron Sensing
.CRNS.

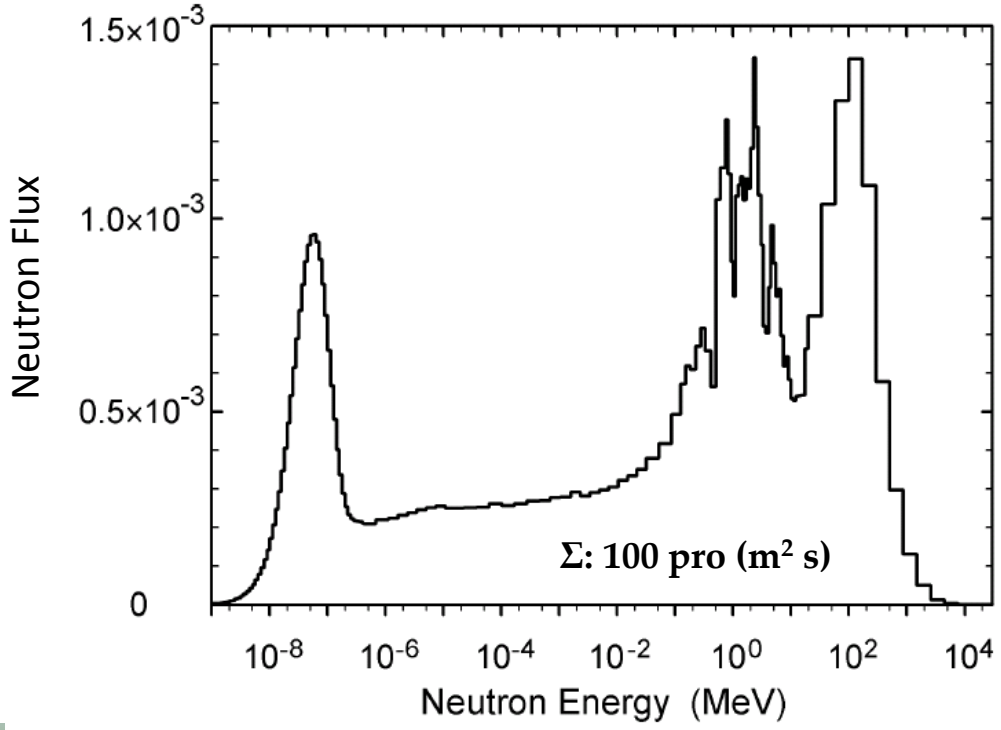
Neutron Response to Water



The Cosmic Neutron Spectrum



soil



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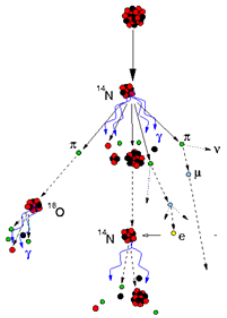

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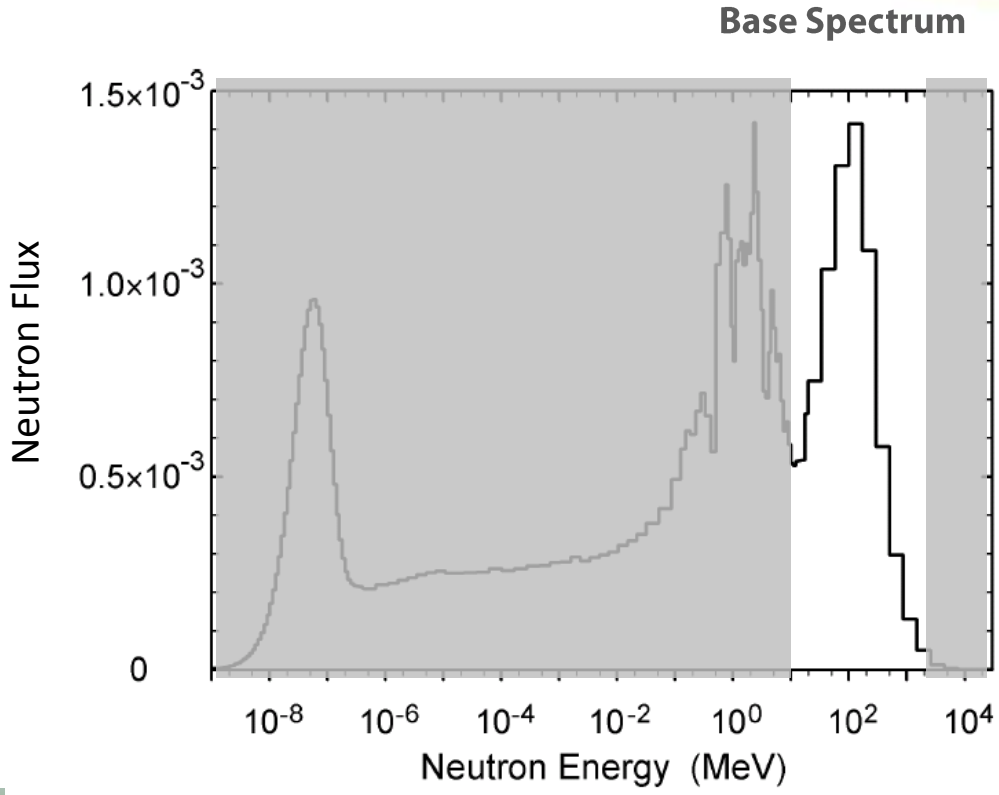

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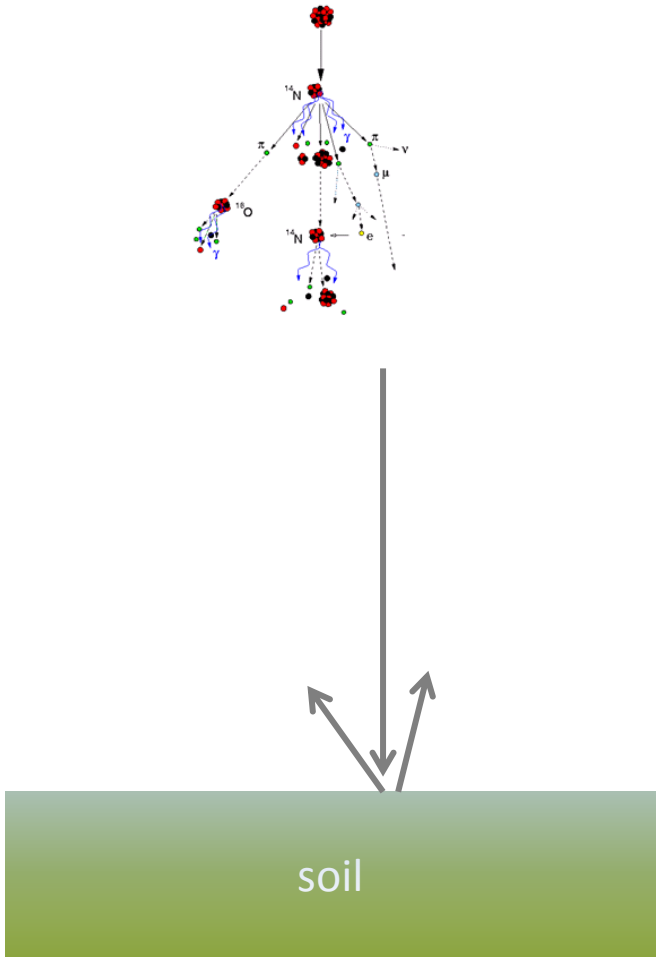

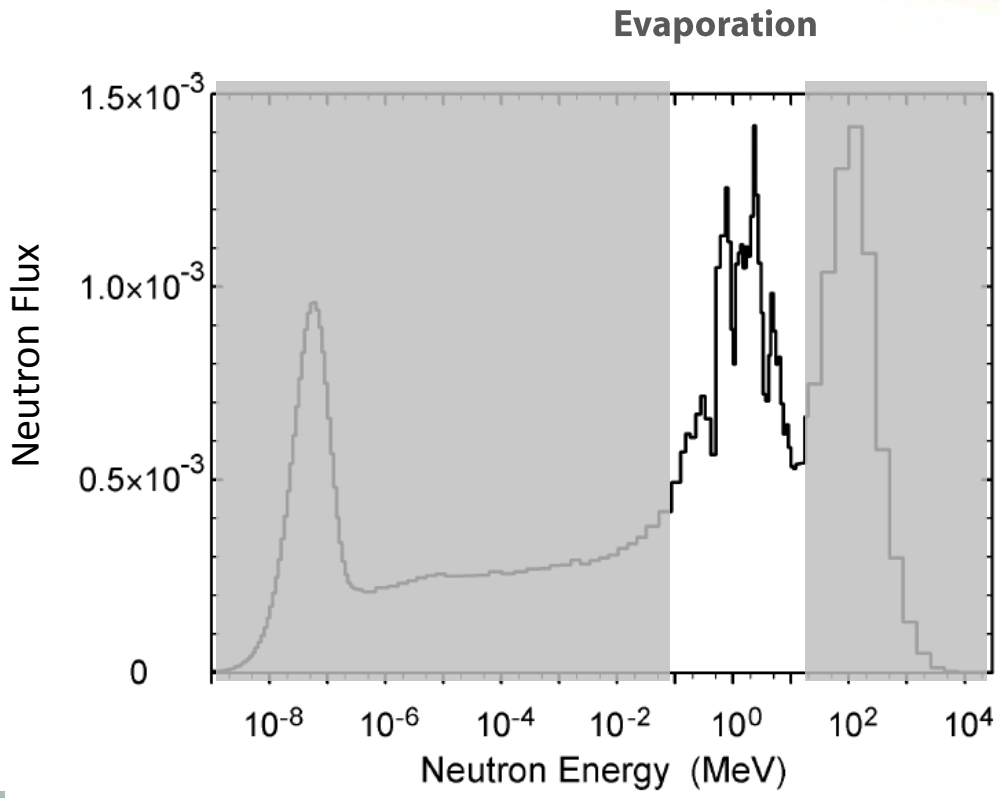

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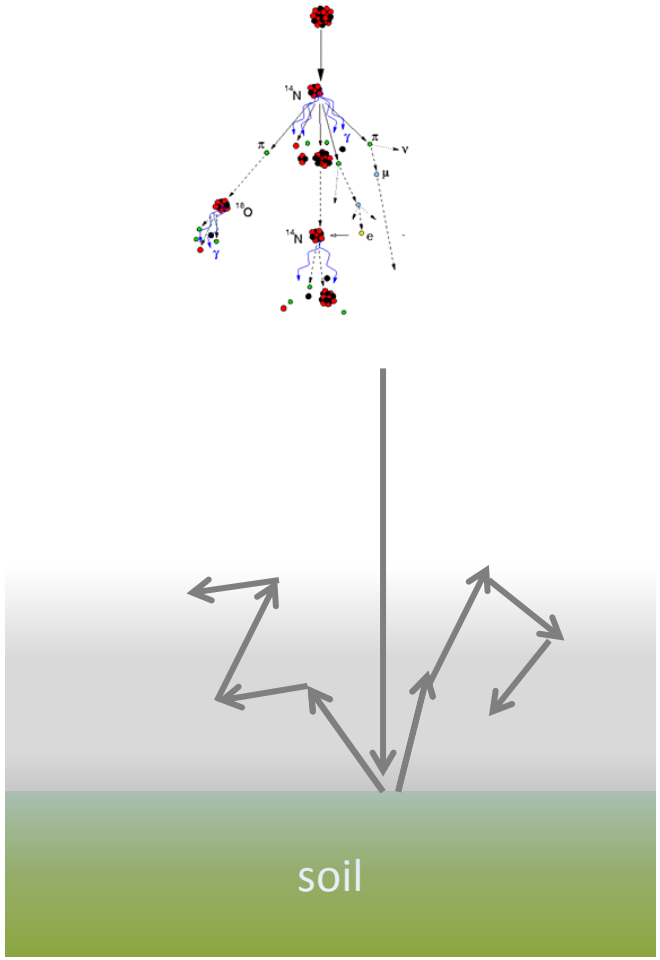

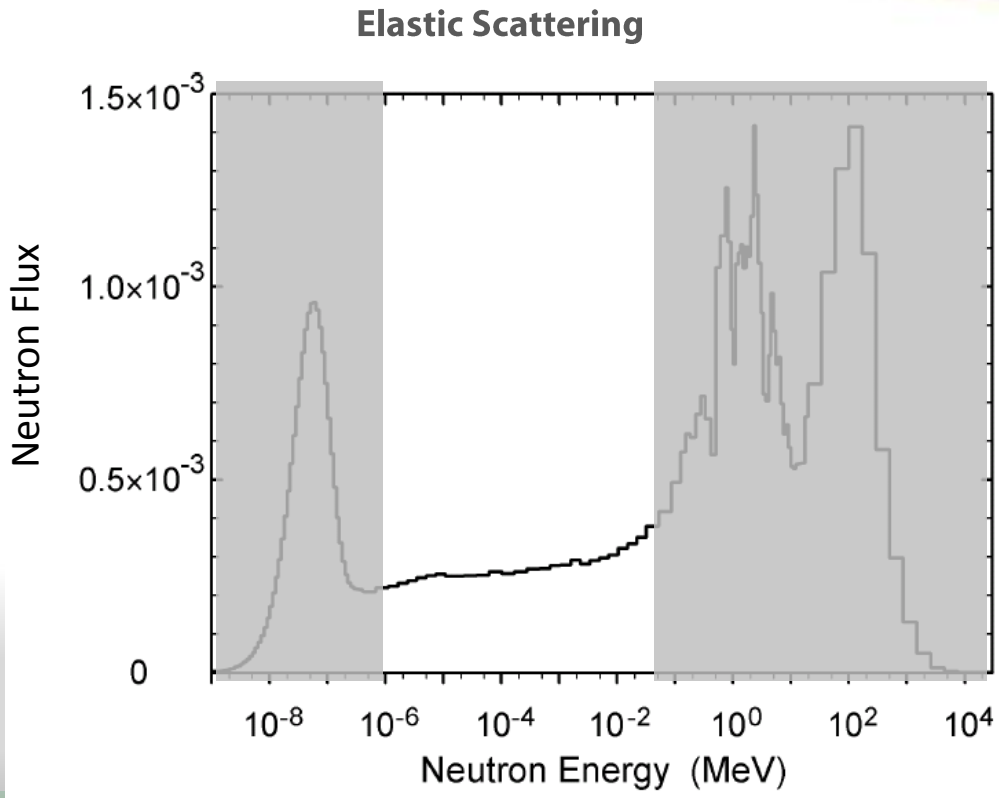

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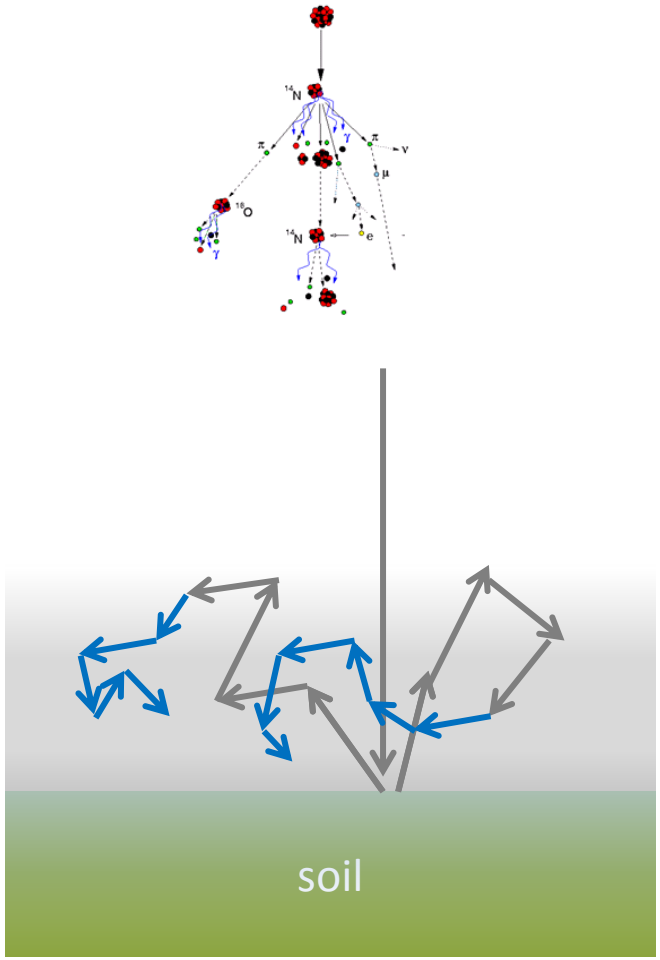

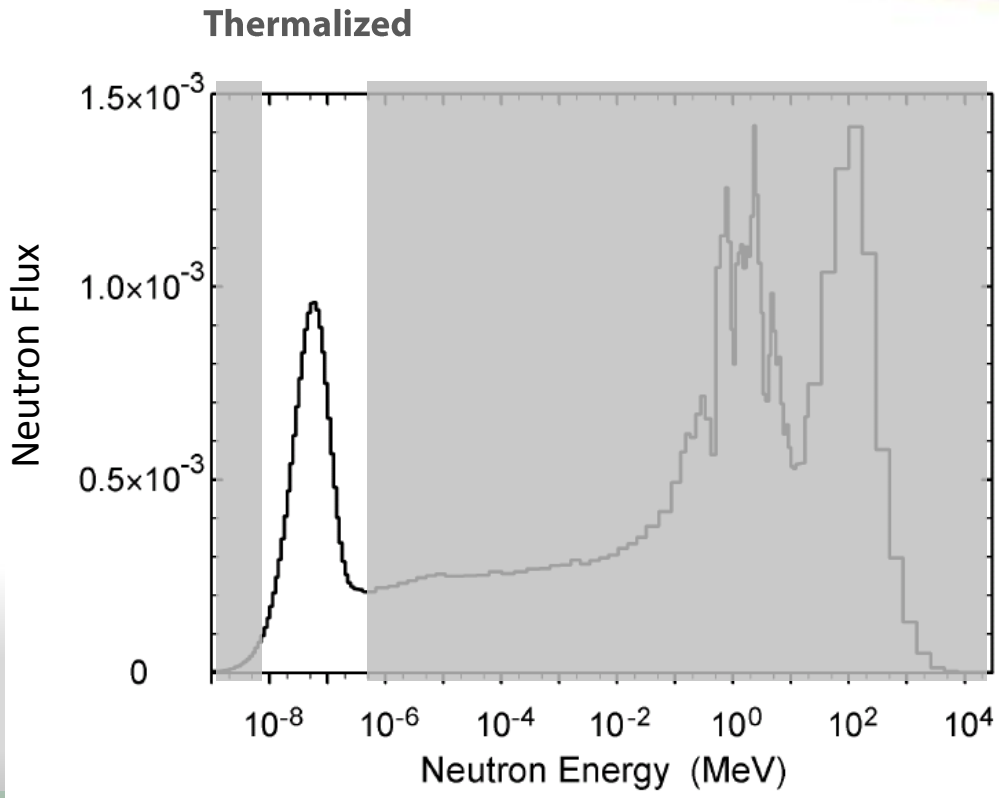

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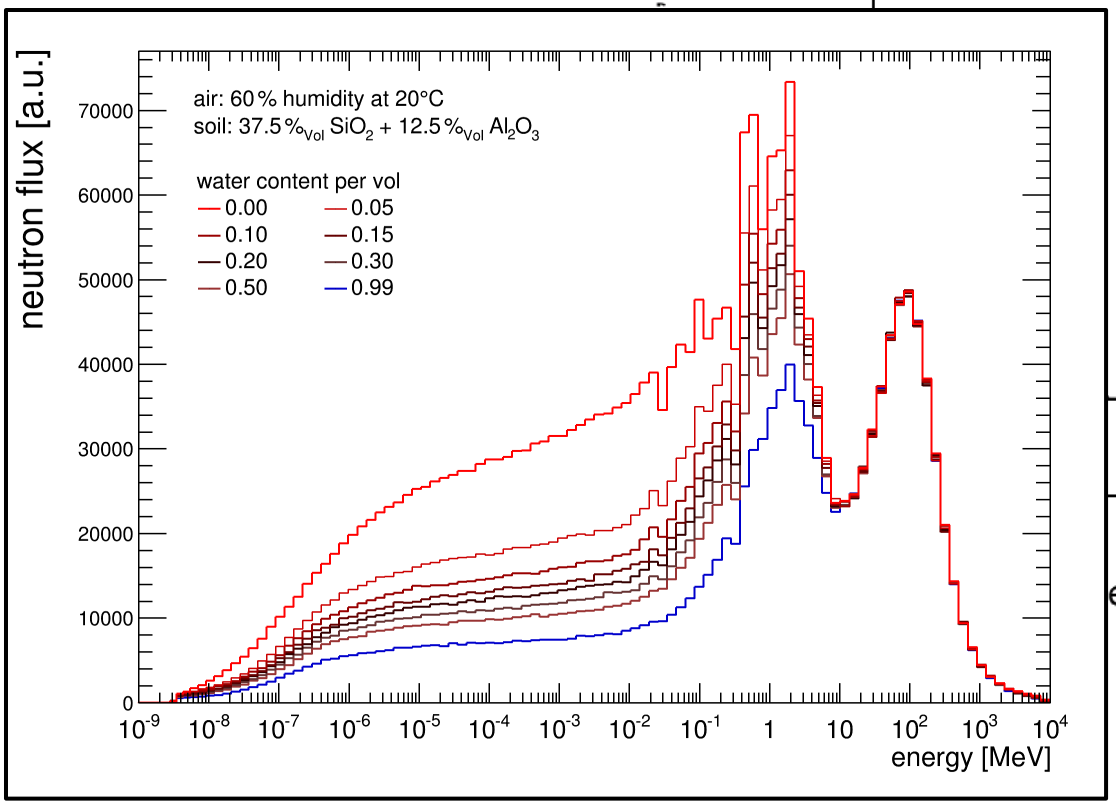

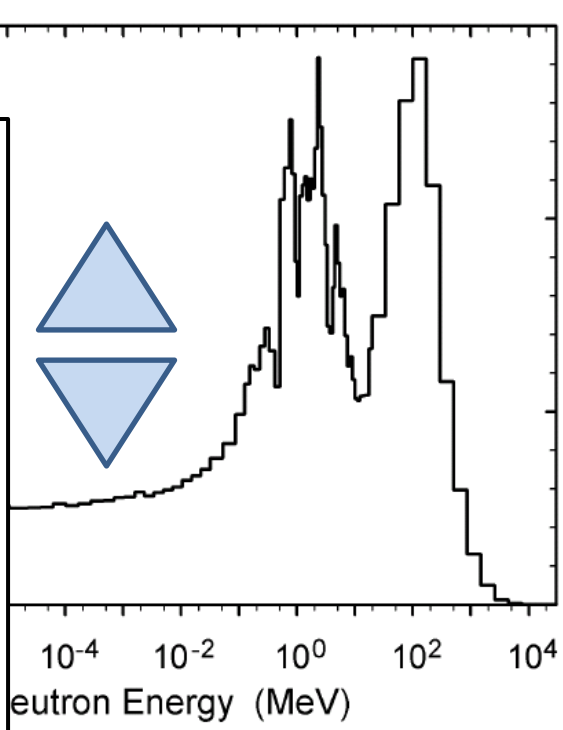

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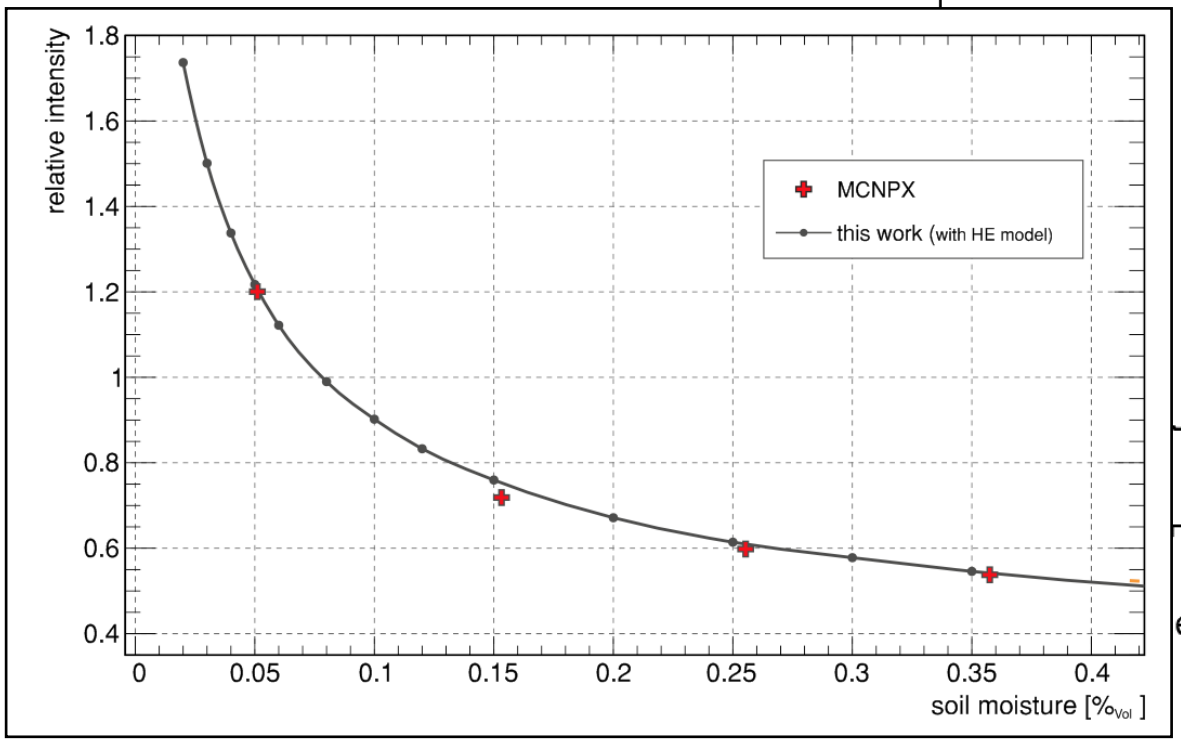
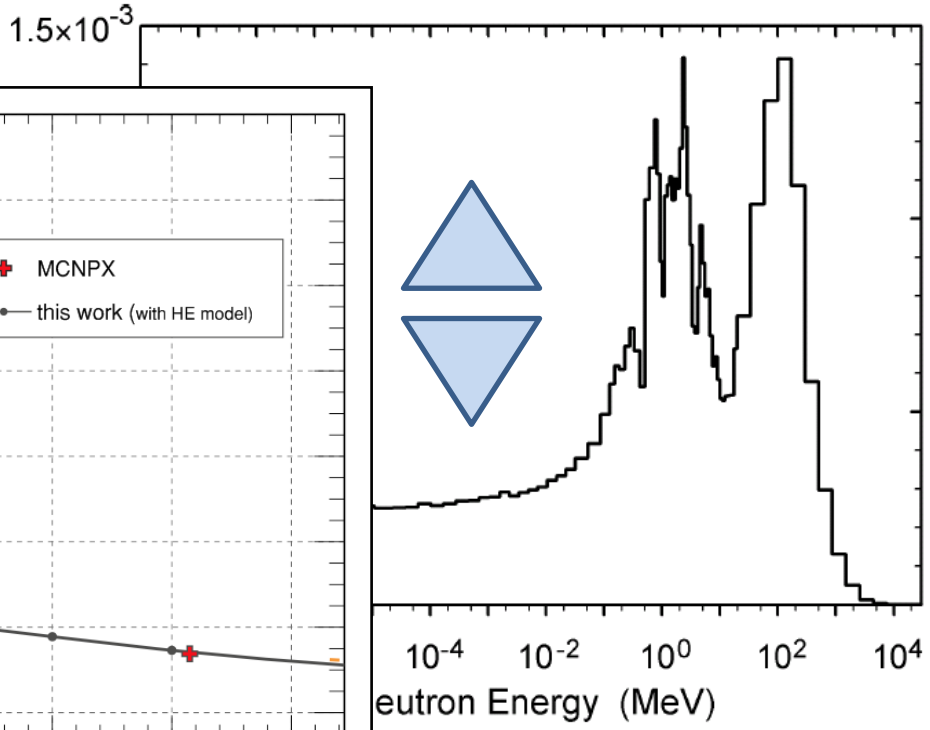
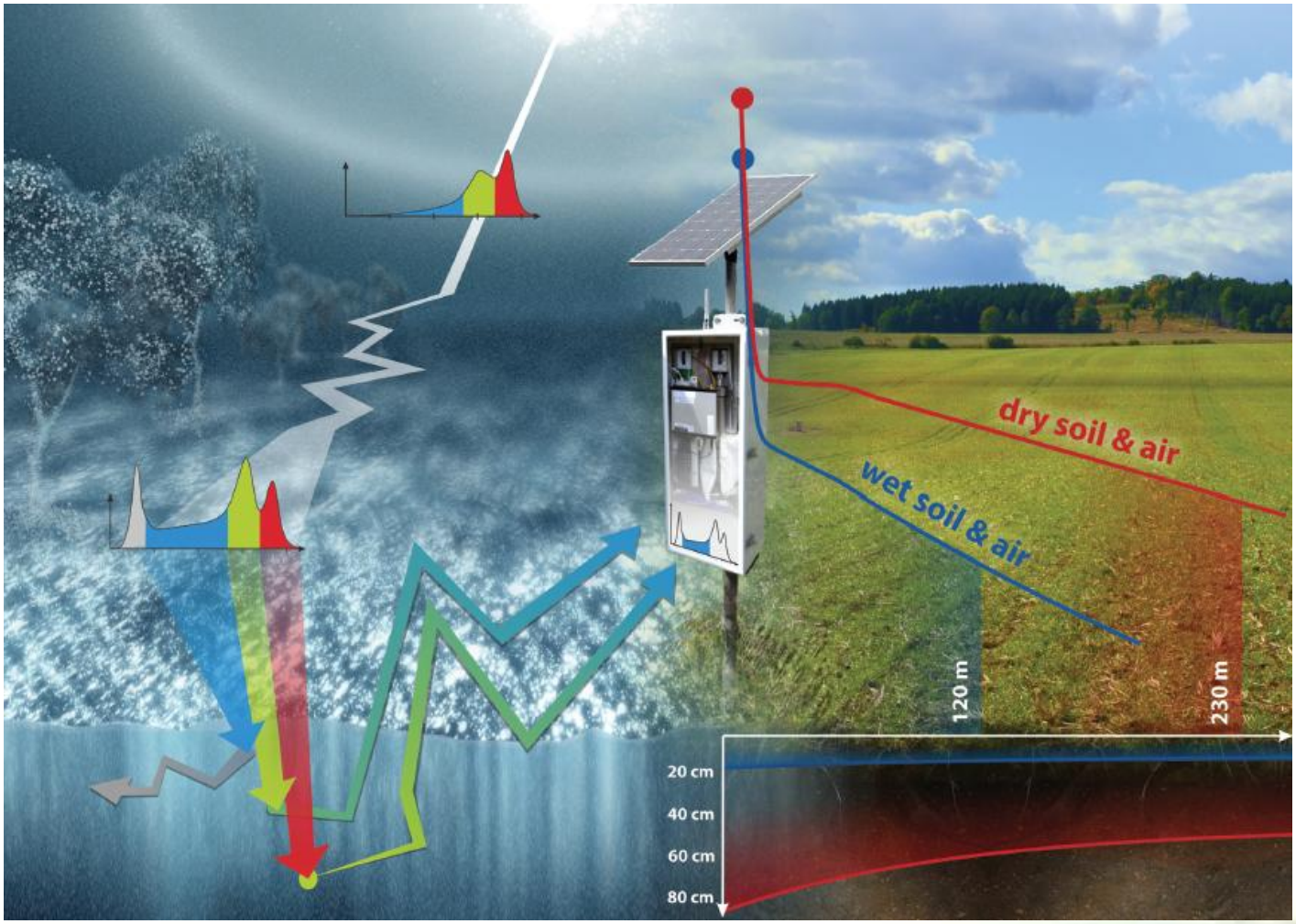




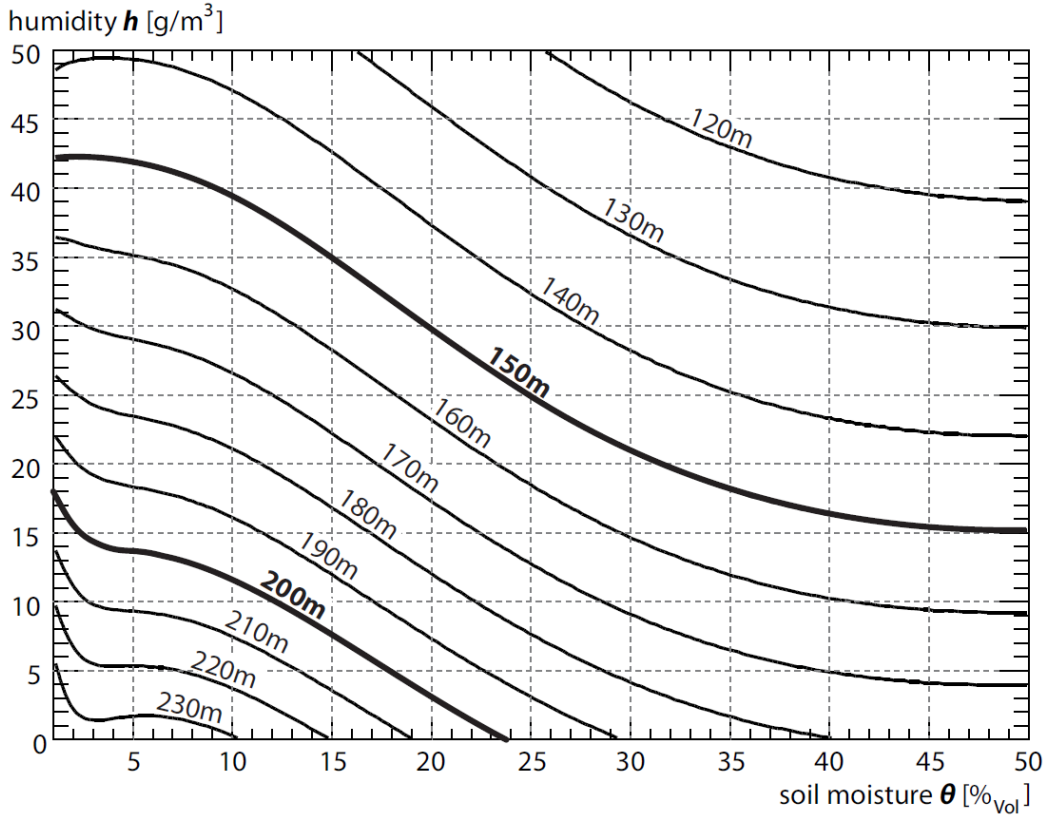
The Footprint

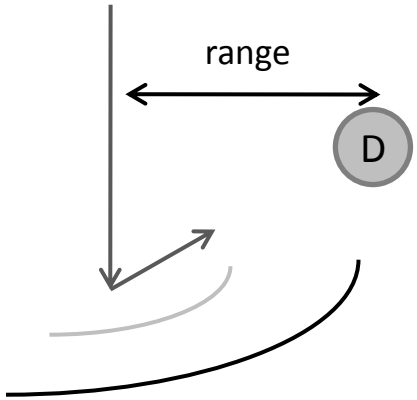
How far do reflected neutrons travel?



The Footprint in 2015

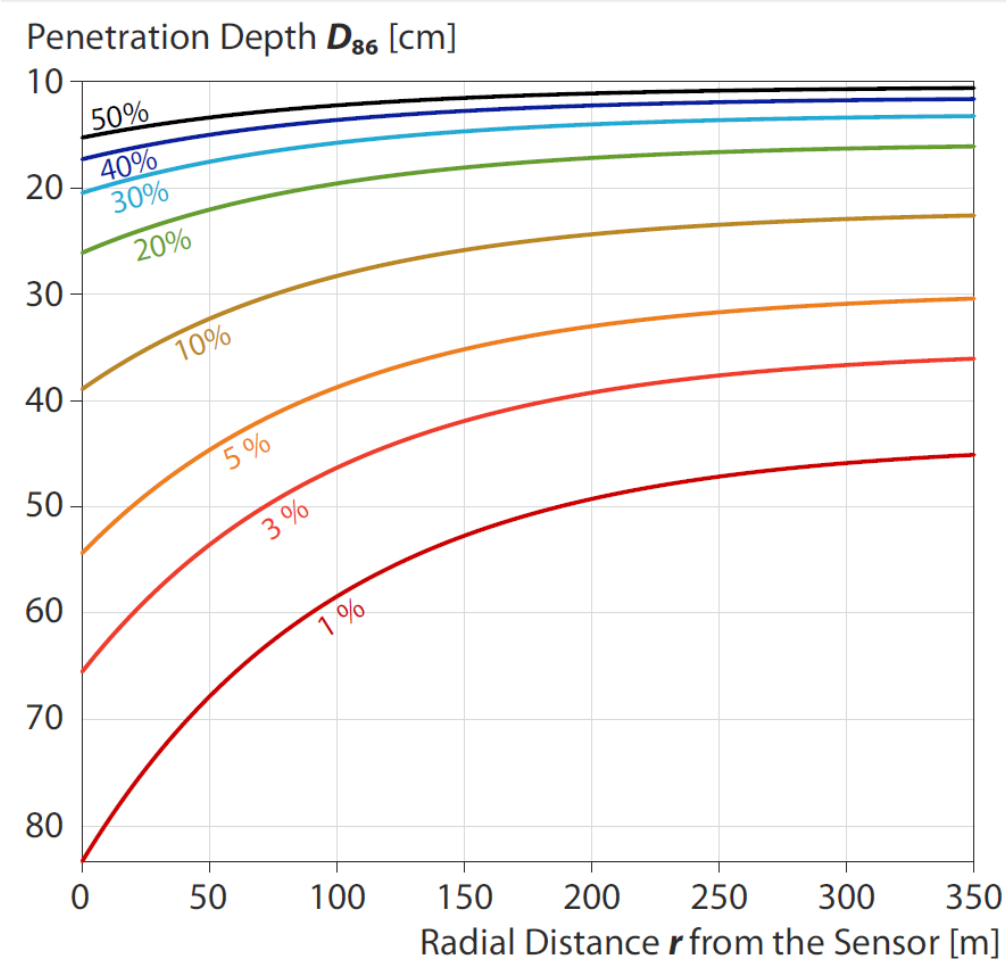
How far do reflected neutrons travel?

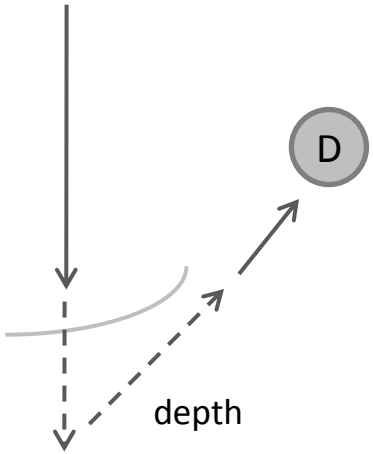




M. Köhli et al.
Footprint characteristics revised for field-scale soil moisture monitoring with cosmic-ray neutrons
Water Resources Research, **51**, 5772-5790 DOI: 10.1002/2015WR017169

Penetration Depth





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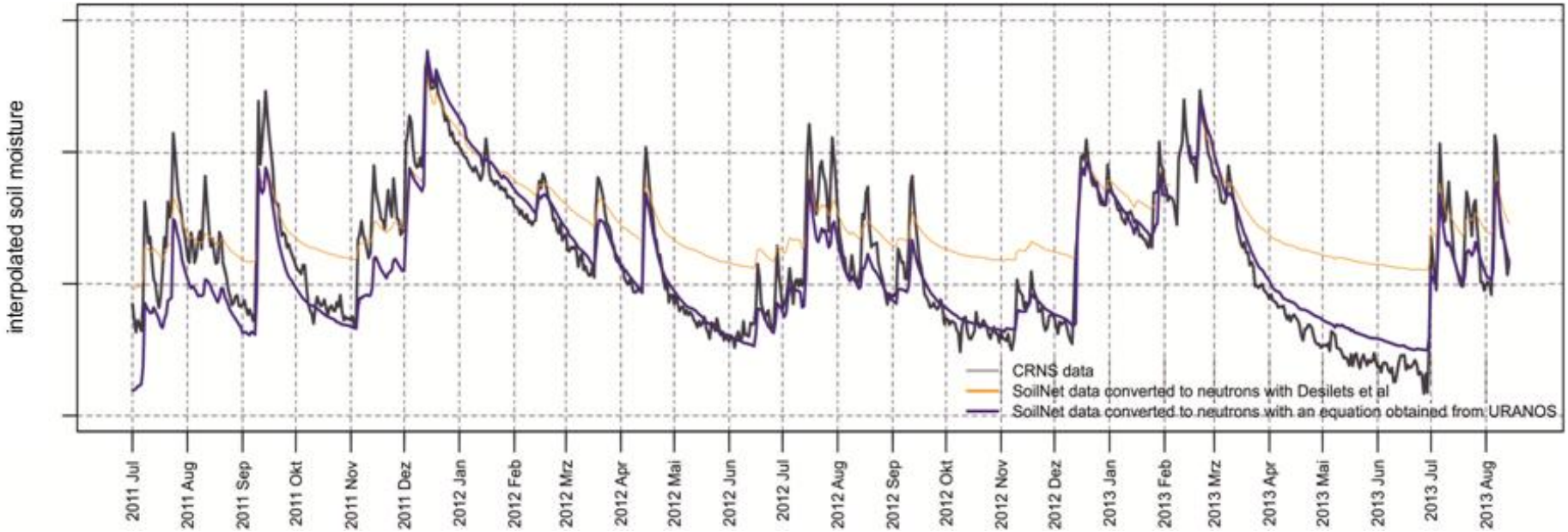
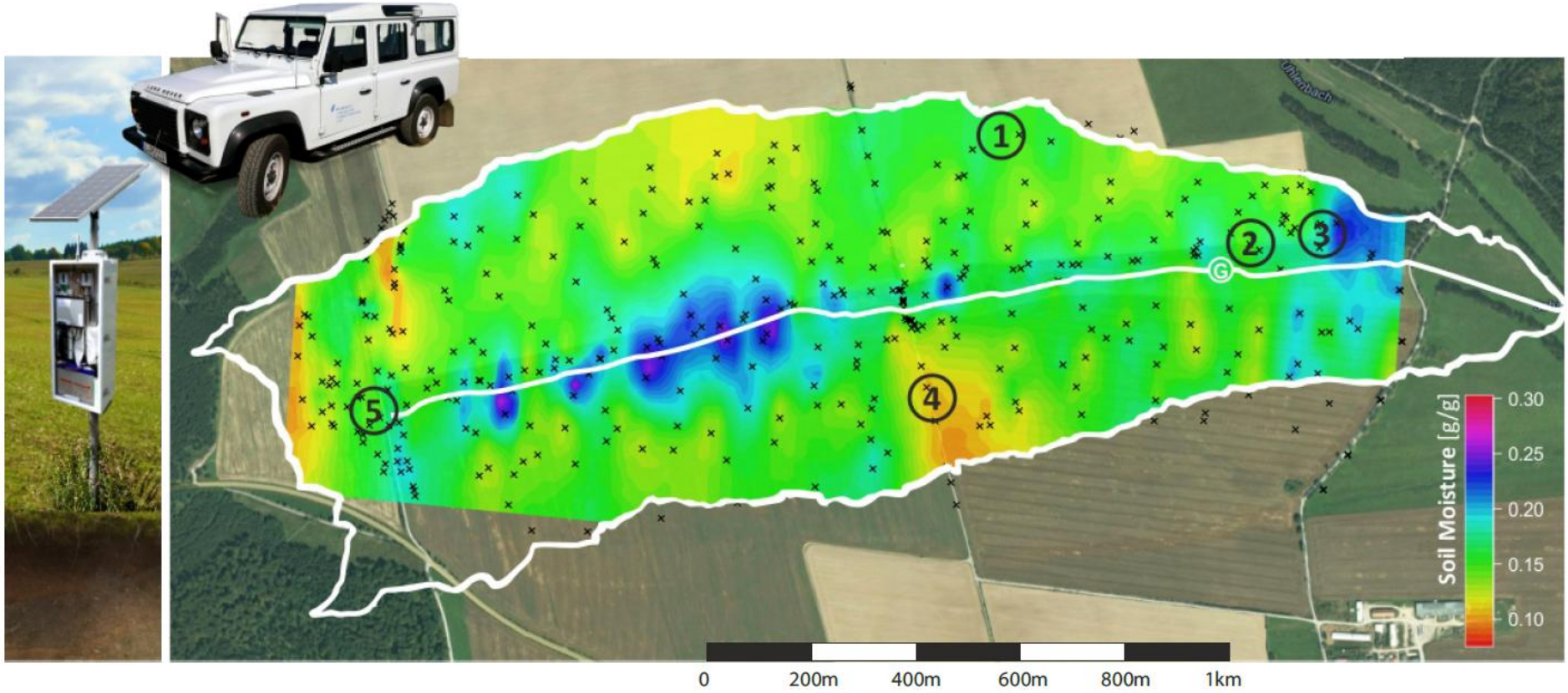
Precipitation Events



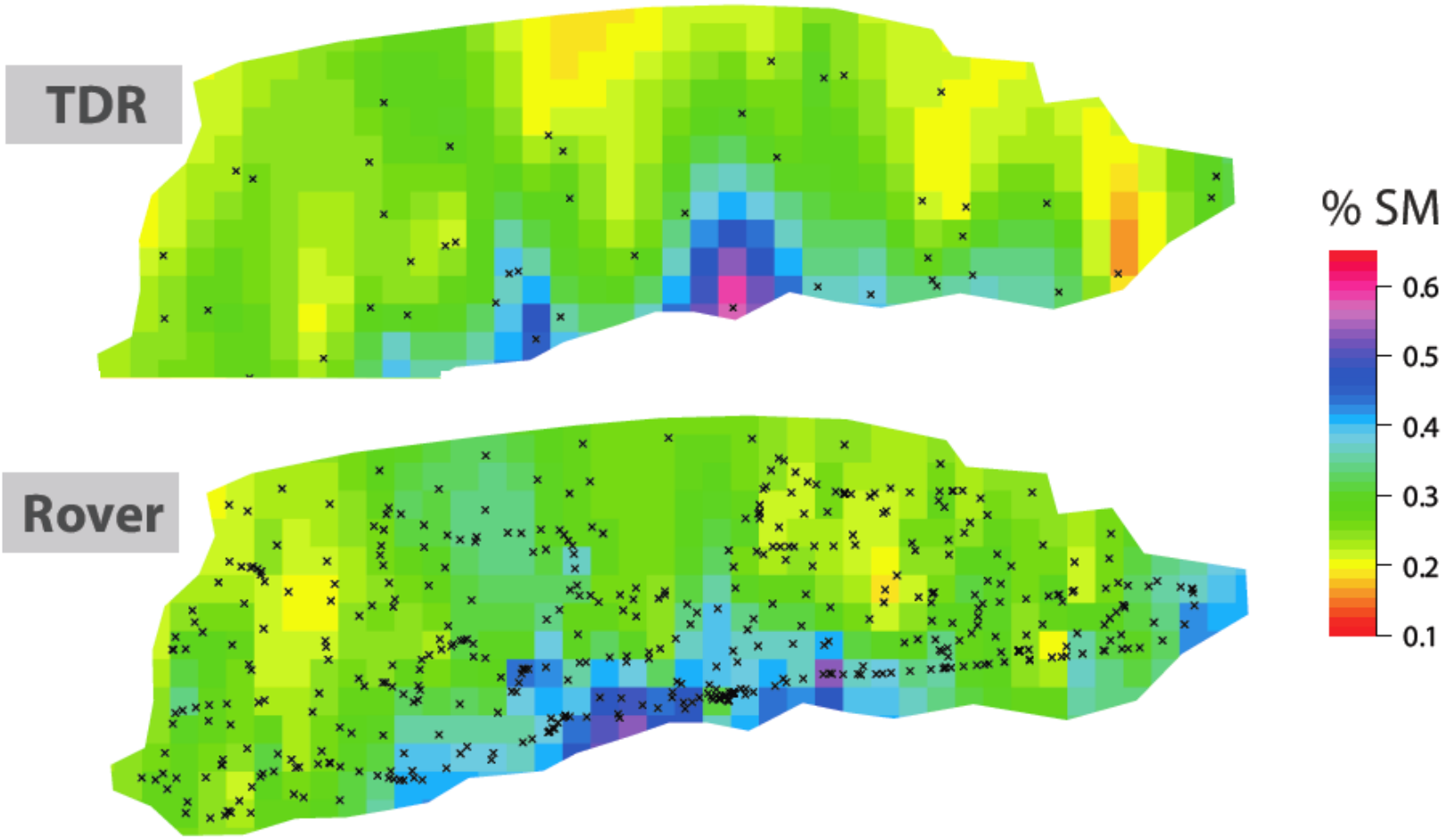
raw data from T. Franz, Santa Rita Site, refined by URANOS

Mobile CRNS



UFZ Site Schäfertal

Mobile CRNS




URANOS
Ultra Rapid Adaptable Neutron-Only Simulation
for Environmental Research
Physikalisches Institut
Heidelberg University
HELMHOLTZ
CENTRE FOR
ENVIRONMENTAL
RESEARCH – UFZ

URANOS

URANOS - The Cosmic Neutron Soil Moisture Simulator

Simulate | Pause | Stop | Clear | #neutrons: maximum: 400000000 | Refresh every 1000 neutrons | Export

Physical Parameters | Computational Parameters | Detector | Setup | Export & Display

Soil Water Content [Vol%] 8 %

Soil Porosity [Vol%] 50 %

Air Humidity 2.33 g/m³

Atmospheric depth 1020g/cm²

Topological presets (water, land)

- None
- River, width [m] 10
- Coast at x [m] 0
- Island, diameter [m] 10
- Lake, diameter [m] 10

Layers are arranged in the vertical direction, representing different materials or 2D gridded patterns
Position z denotes the depth below surface (z=0) in [m] and refers to the upper edge of the layer
Layers override topological presets

Layers

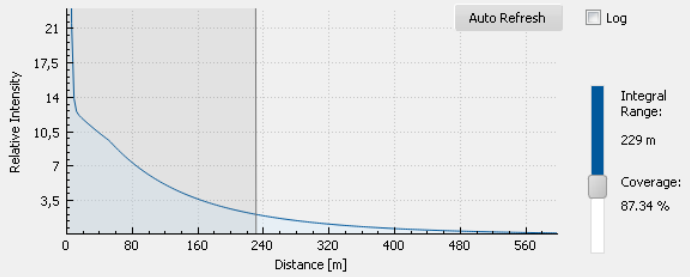
	Position	Height	Material	Matrix
1	-1000	920	11	
2	-80	30	11	
3	-50	20	11	
4	-30	10	11	4.png (1800)
5	-20	16	11	5.png (1800)
6	-4	2	11	6.png (1800)
7	-2.25	0.25	11	
8	-2	-1.9	11	8.png (1800)
9	-0.1	0.1	11	9.png (1800)
10	0	0.1	20	10.png (1800)
11	0.1	0.1	20	11.png (1800)
12	0.2	3	20	12.png (1800)

Load Minimal Config | - | +

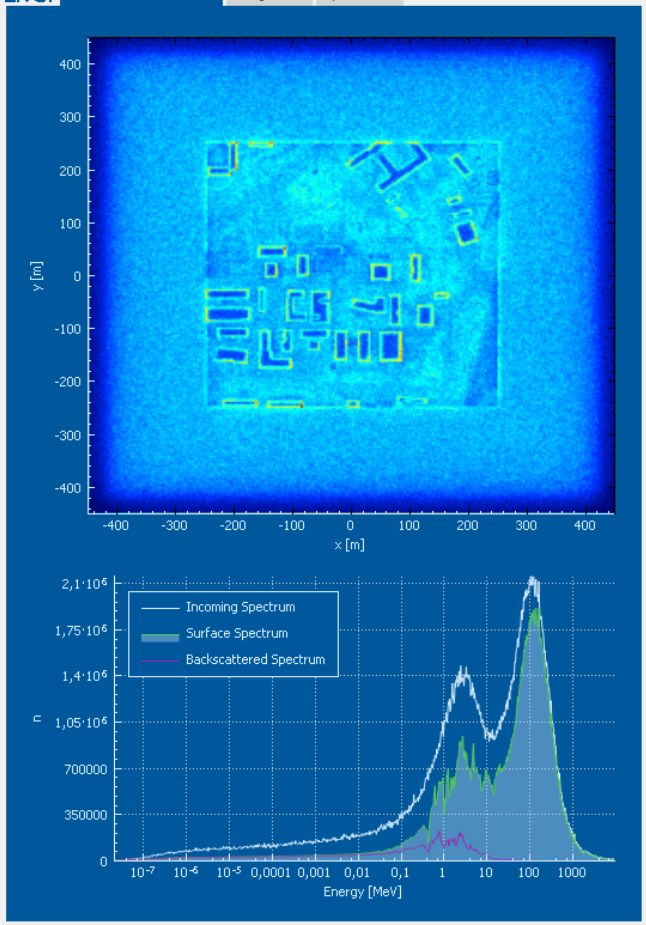
Source Layer 2 | Detector Layer 7 | Ground Layer 10

Material Codes | Use layer maps | View layer maps | Load | Save

Estimated Radial Neutron Distribution at Sea Level

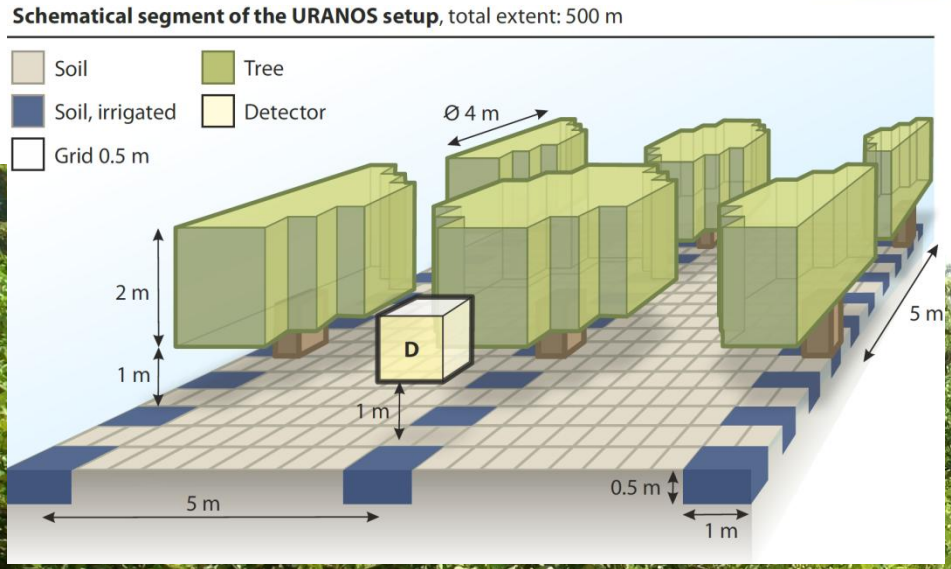


Live: Birds-eye View & Spectra | Range View | Spatial View



Recent Studies

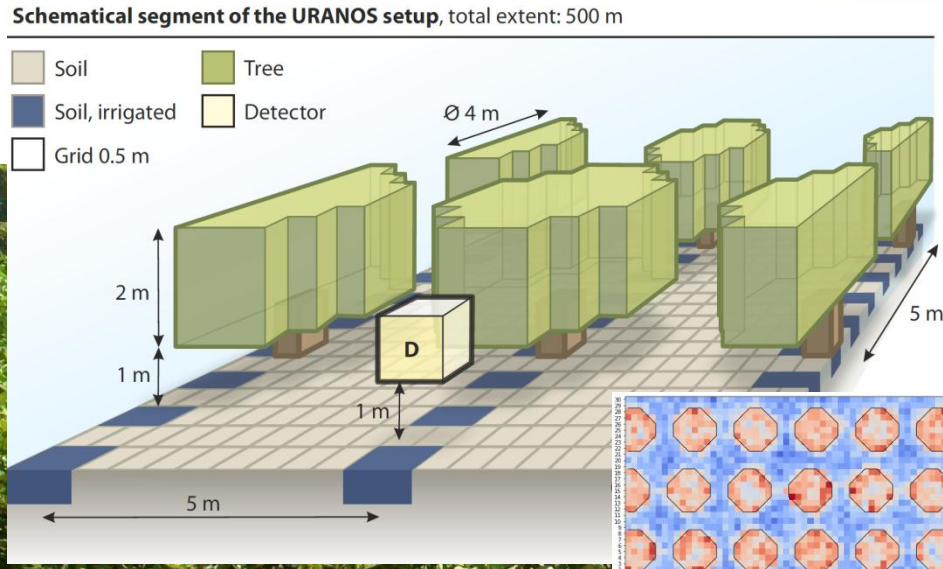
Drip Irrigation in Valencia

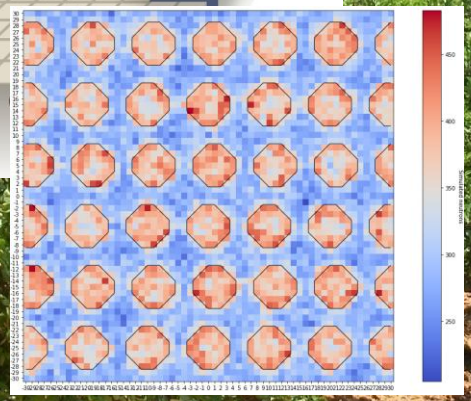


In collaboration with
Dazhi Li
FZ Jülich

D. Li et al., to be published

Drip Irrigation in Valencia





In collaboration with
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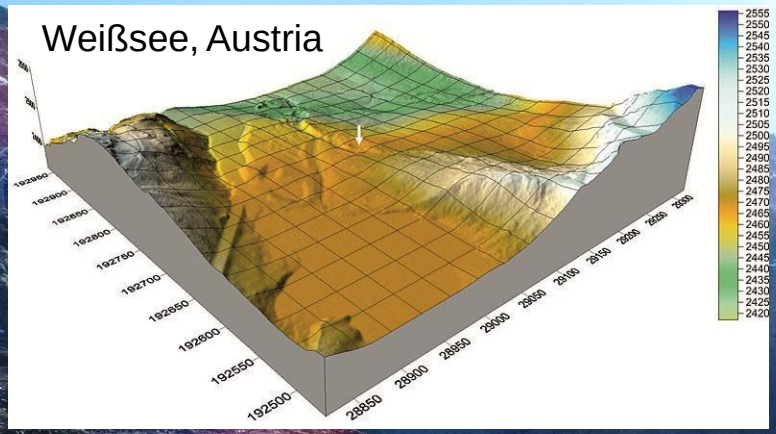
D. Li et al., to be published

Glacier landscapes and snow cover



In collaboration with
Paul Schattan
Uni Insbruck

P. Schattan et al., to be published

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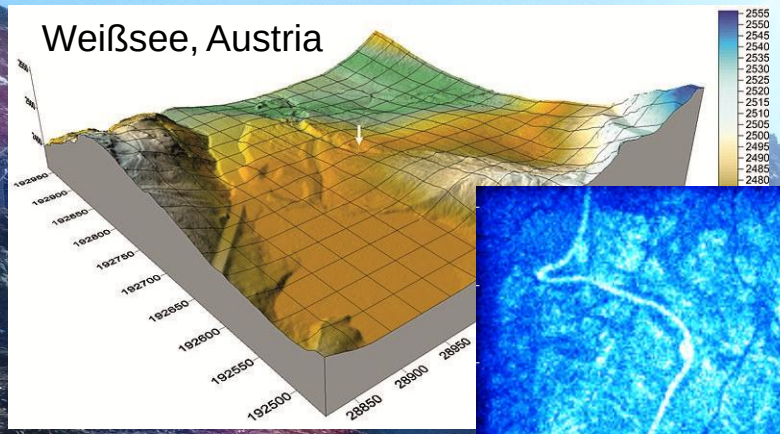

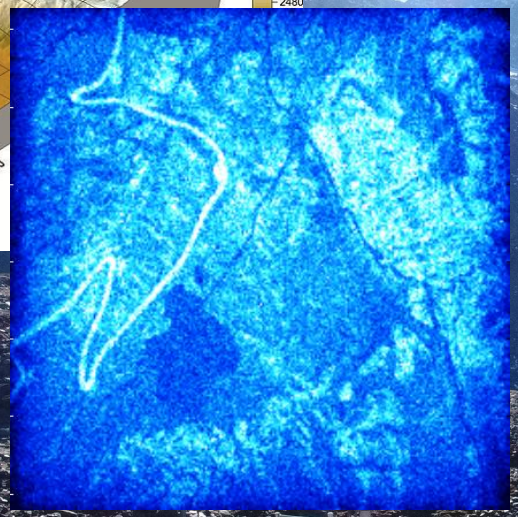

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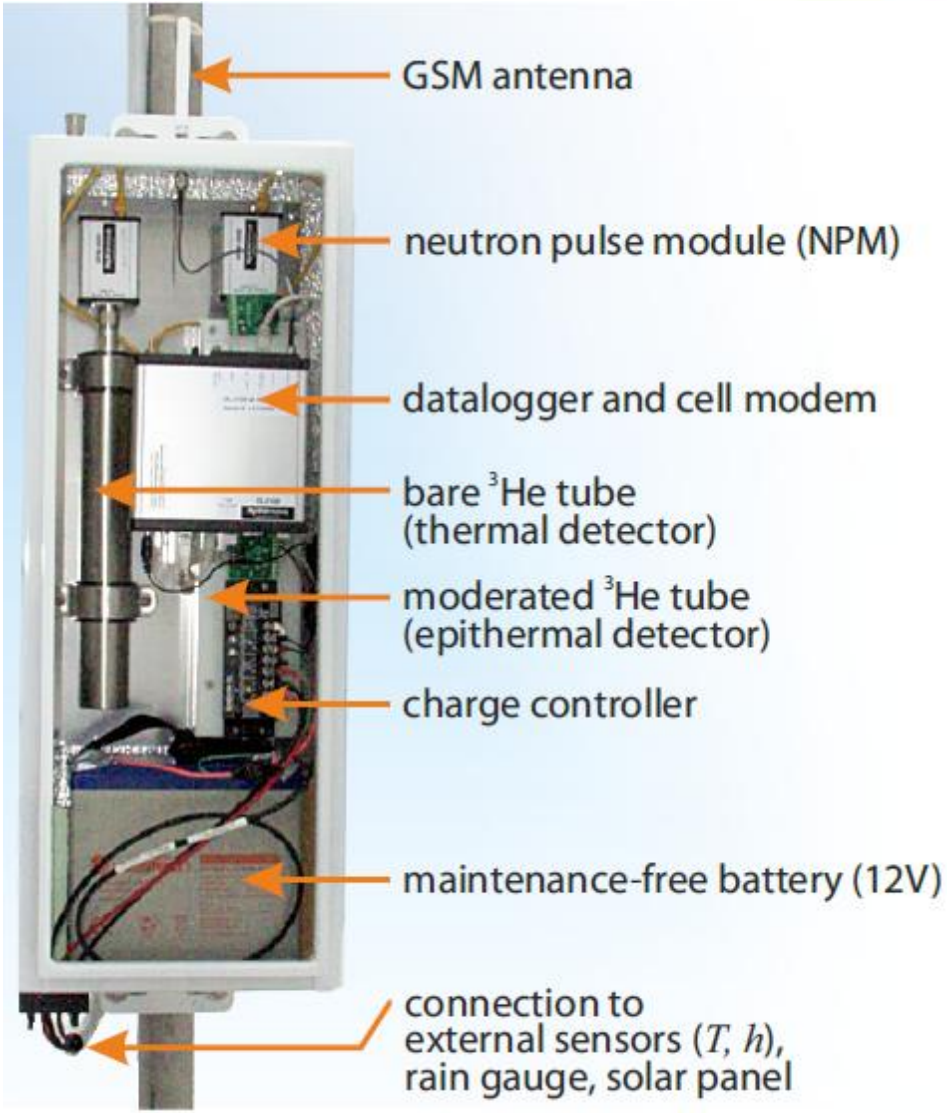
Uni Insbruck

P. Schattan et al., to be published

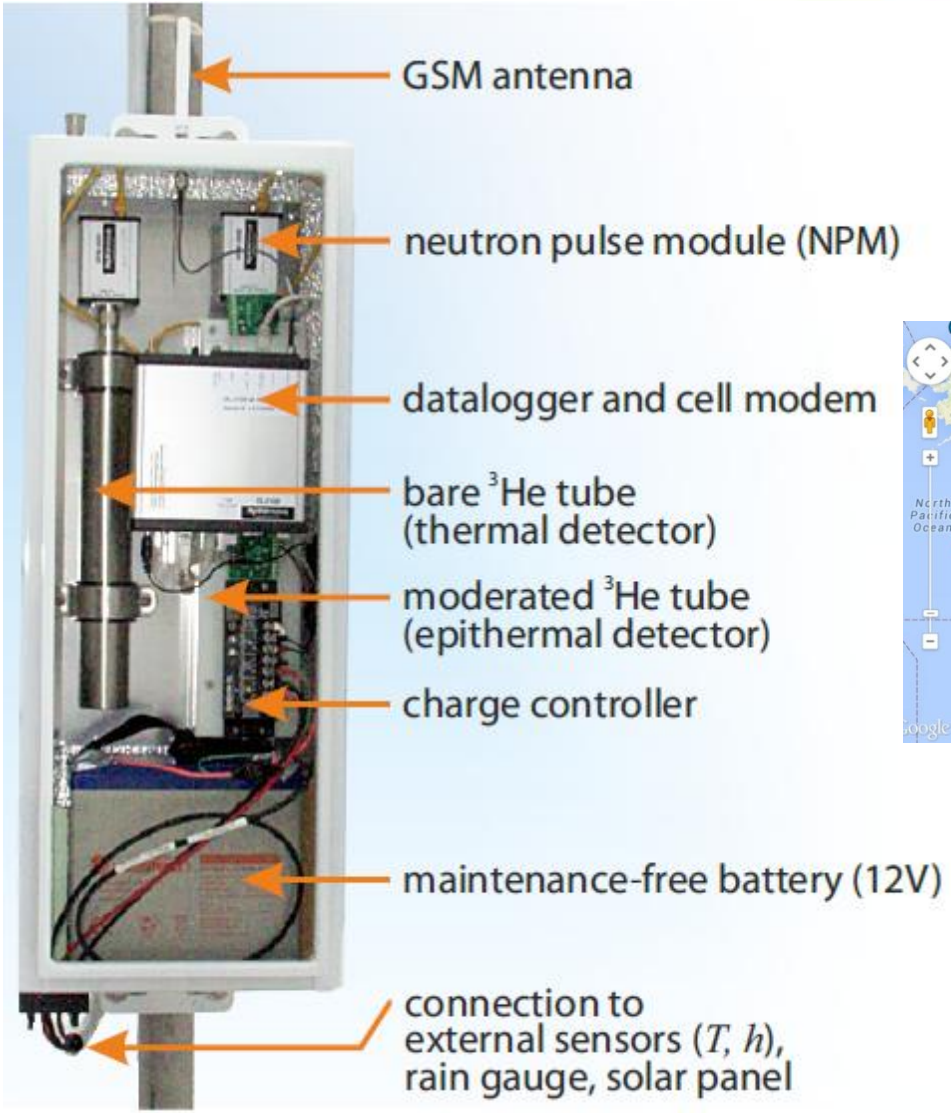
The Equipment

The CRNS Sensor



M. Schrön et al.
Intercomparison of cosmic-ray neutron sensors and water balance monitoring in an urban environment
Geosci. Instrum. Method. Data Syst. **7**, 83-99 DOI: 10.5194/gi-7-83-2018

The CRNS Sensor



M. Zreda et al. (CRNS Website)

From large-scale research…

[1]

[1] Bernhard Ludewig @ BMBF Großgeräte: Die Forschungs-Neutronenquelle FRM II
[2] Mateo Zlatar - http://www.oshwa.org/open-source-hardware-logo

From large-scale research...

[1]

+

open source hardware

[2]

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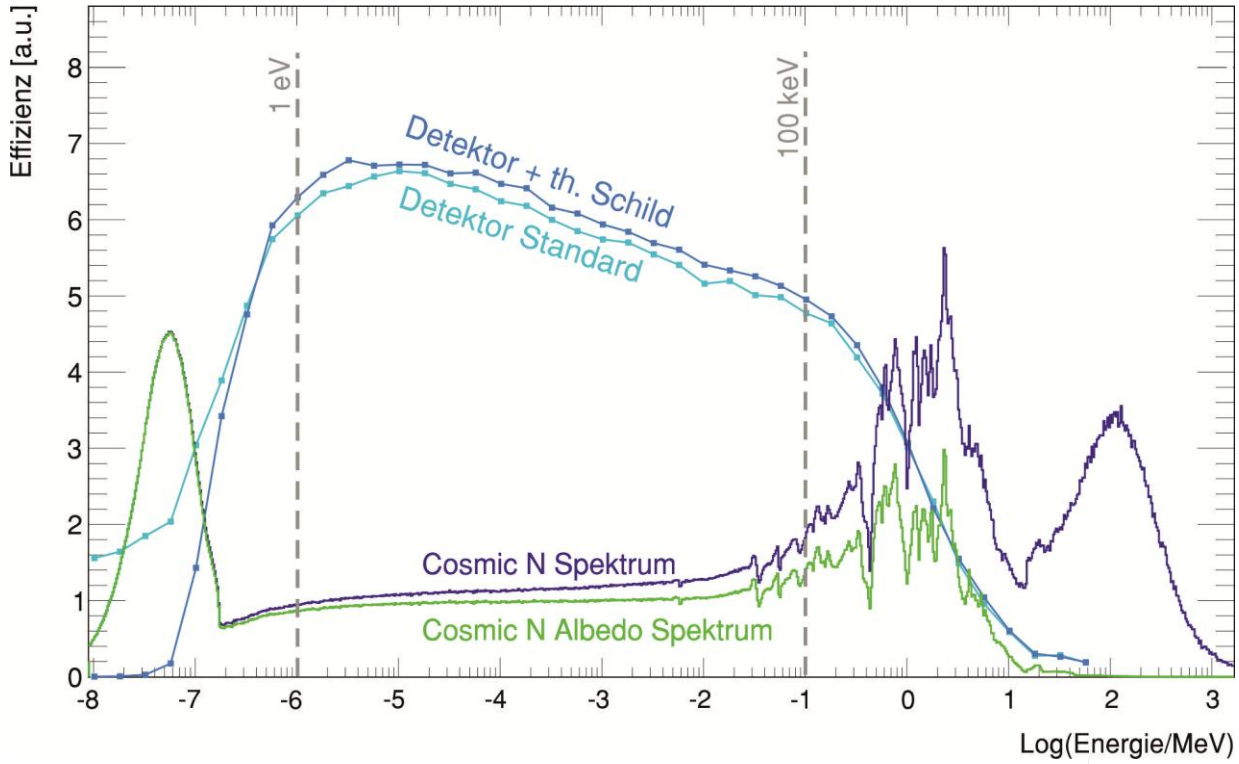
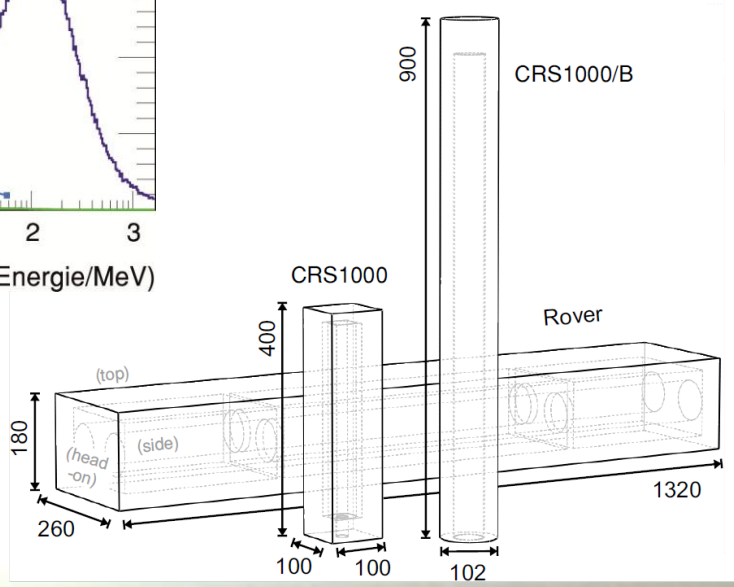
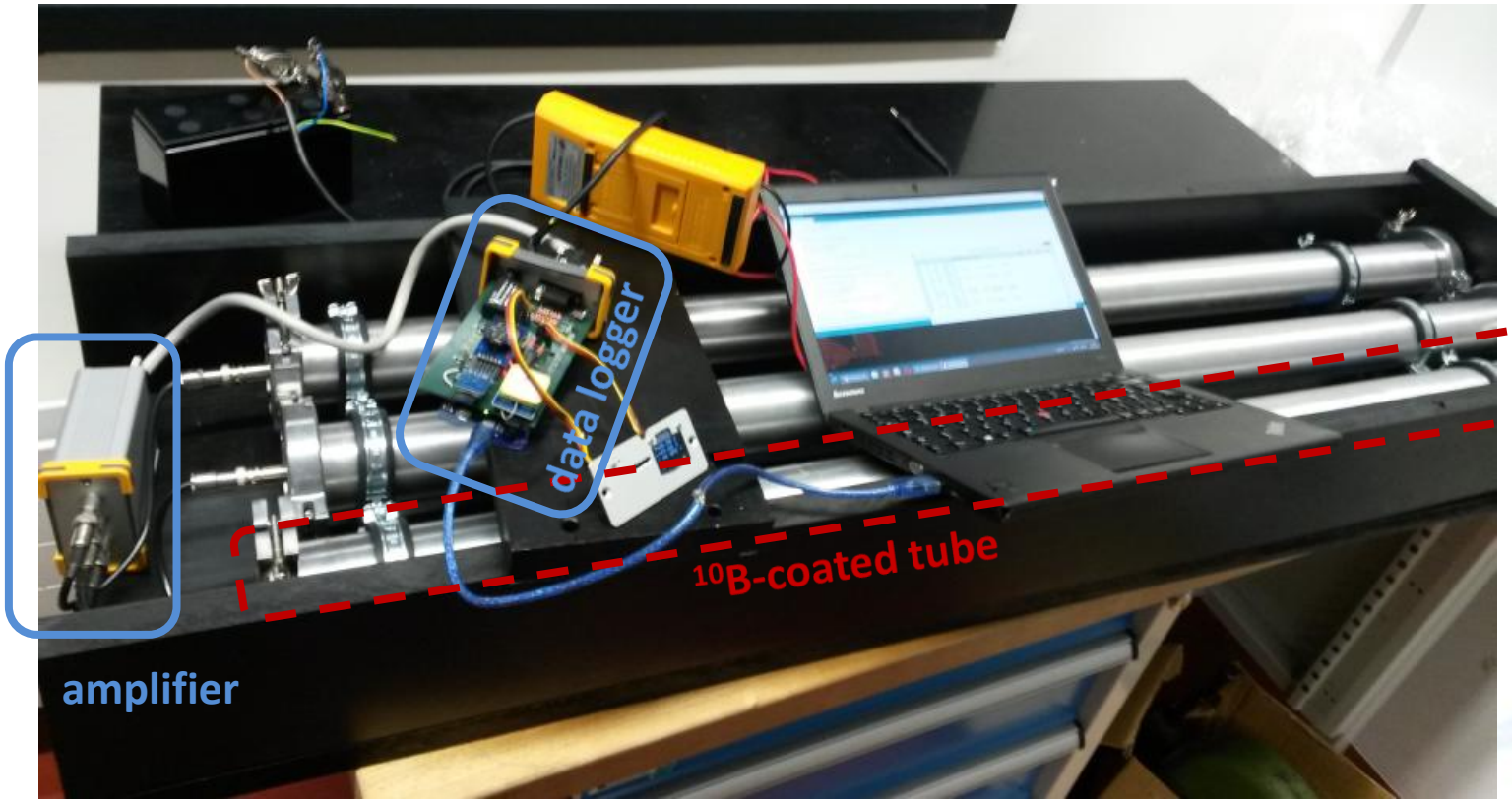
The CRNS Sensor Response



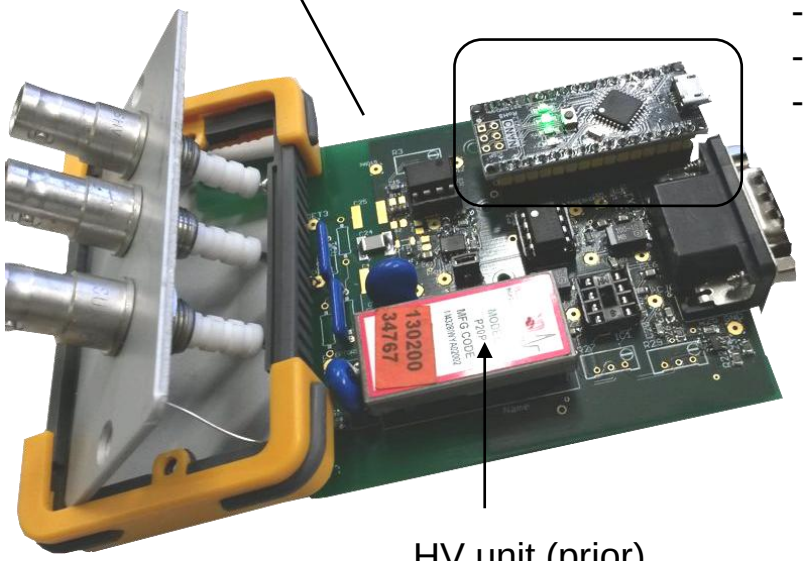


The new Heidelberg CRNS Sensor



Open Hardware Readout Electronics

nCatcher (Pulse Analyzer + Digitizer)

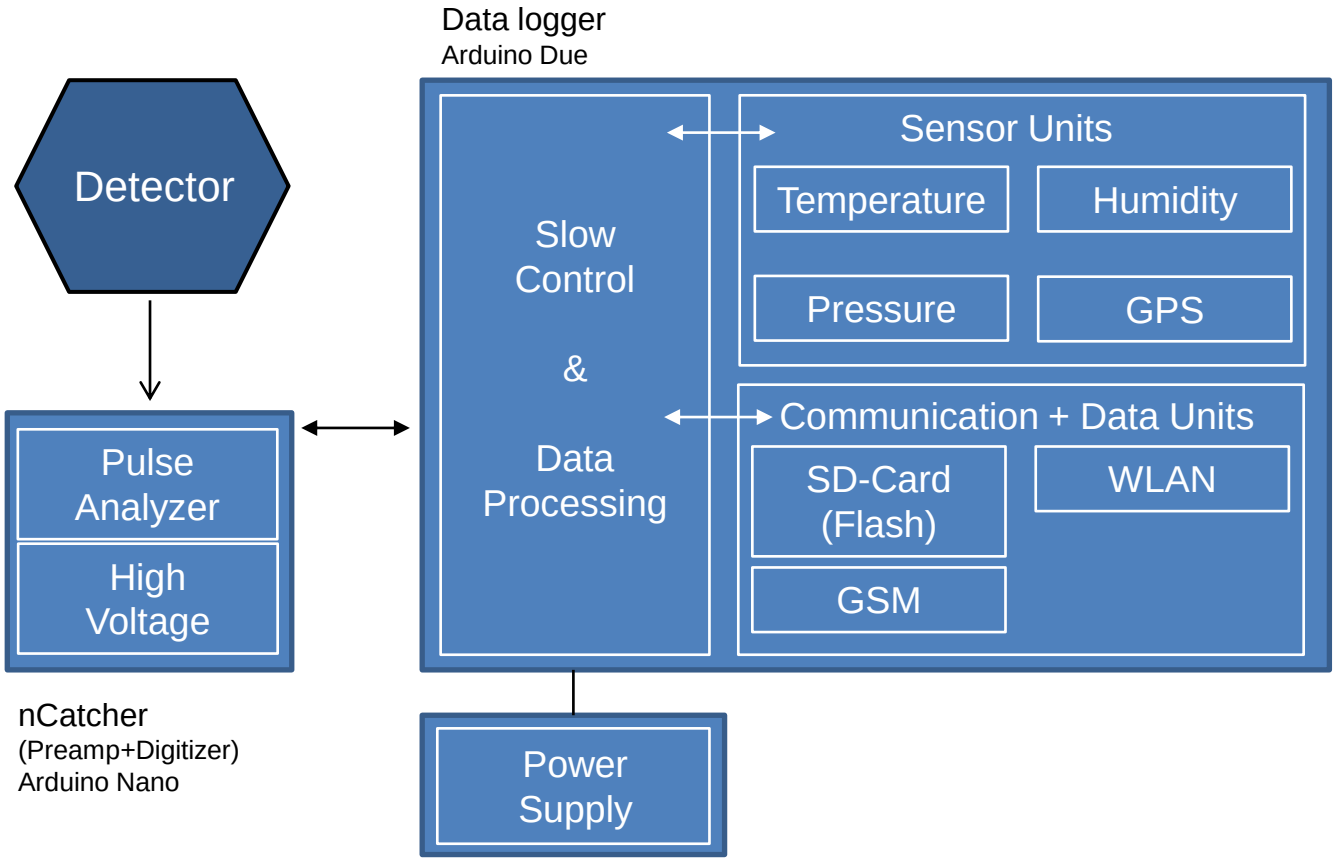


Arduino Nano
- ADC: pulse height measurement
- Time over threshold: pulse length measurement
- Communication with data loggers possible via I^2C

Analog ouput and serial communication allows for read-out and control

HV unit (prior)

Open Hardware Readout Electronics



New:
- upgrade to Due (larger)
- GSM Modem
- shielded design for nCatcher

Webinterface

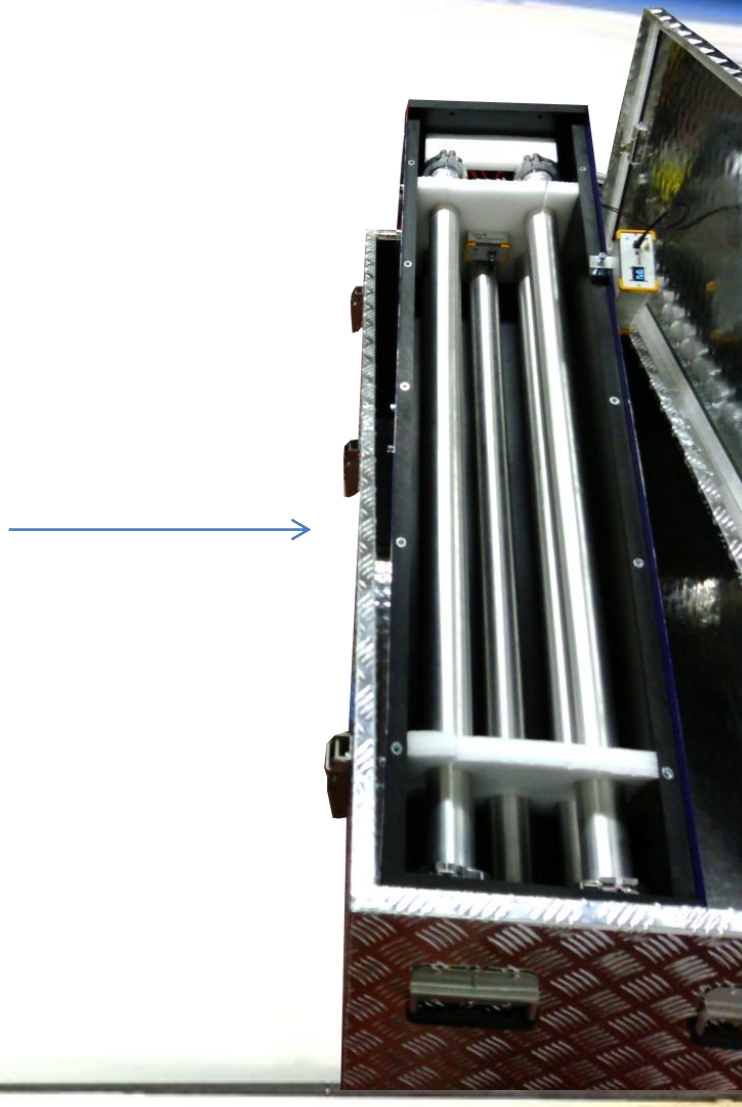
Live-Display for Webbrowser

GSM-Modem
+
MQTT-Server
(Internet of Things)
+
Influx-DB
(Time series data base)
+
Grafana
(Frontend)

CRNS Sensor tests

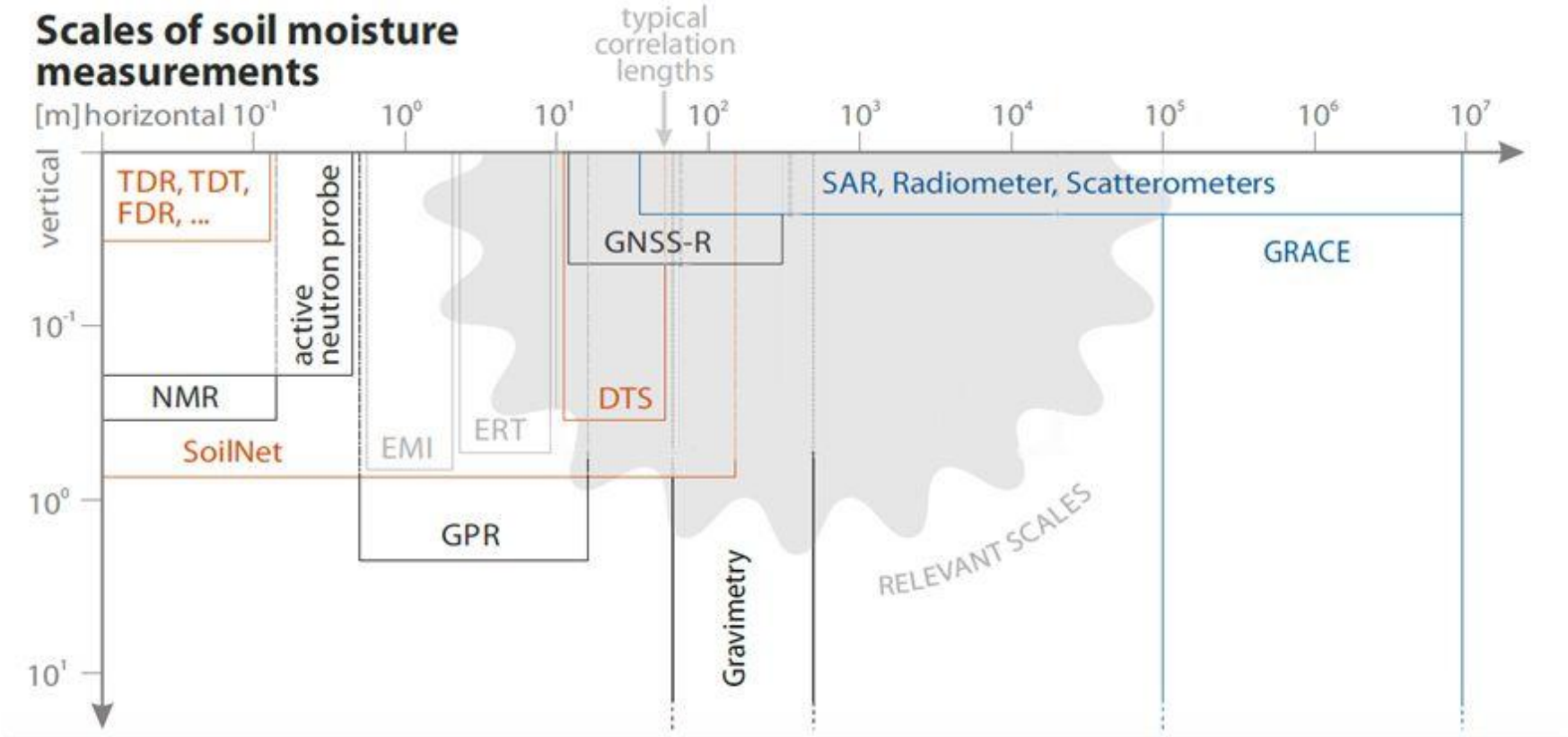
In collaboration with
Heye Bogena and Jannis Jakobi
FZ Jülich

Measurements @ Wüstebach (Eifel)



Summary

The Measurement Gap



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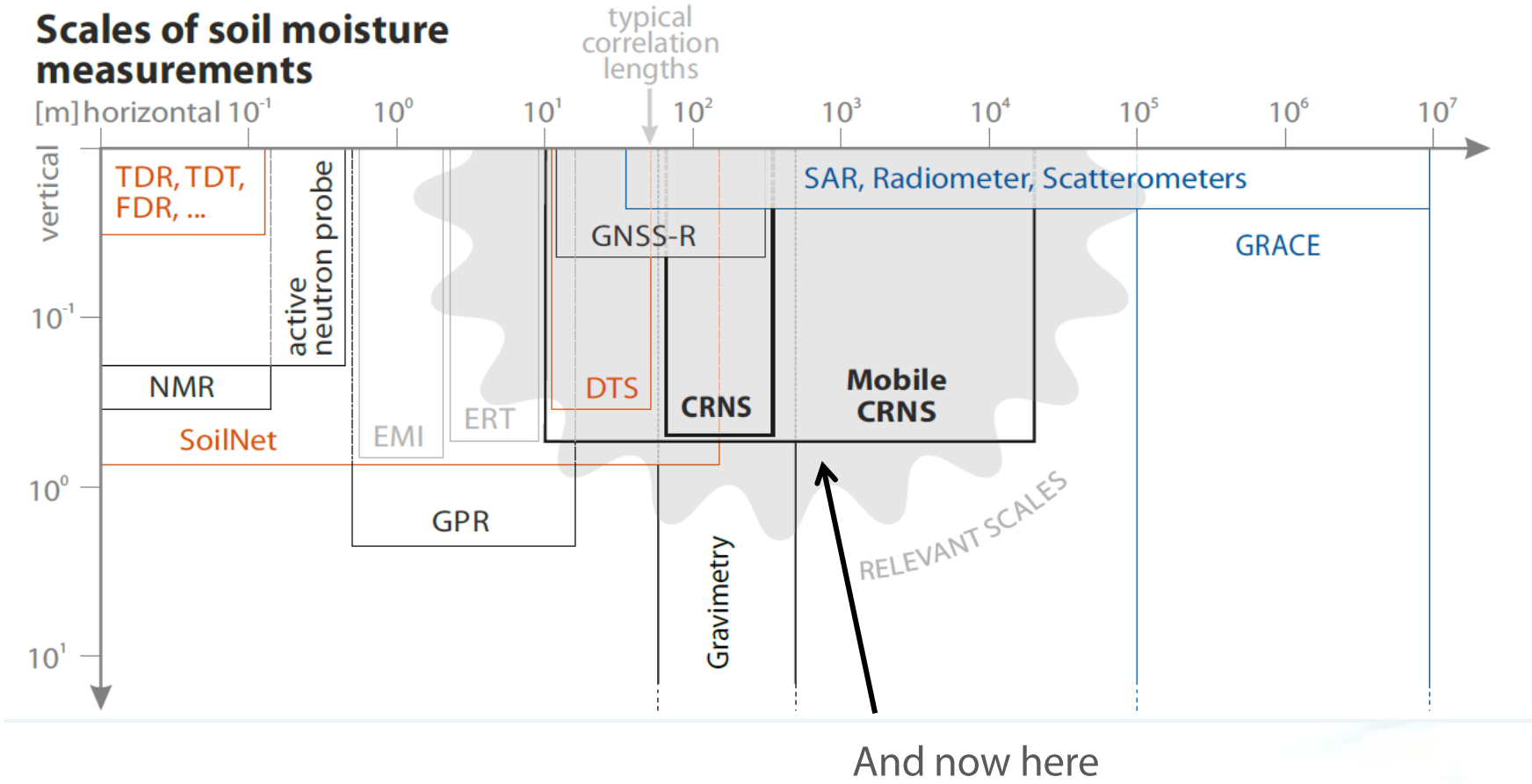

Summary

- Cosmic-Ray Neutron Sensing
- New CRNS Sensor
- Outlook

Summary

Cosmic-Ray Neutron Sensing

- provides an average soil moisture measurement over **several hectares** and **0.5 m in depth**
- can be understood by Monte Carlo transport modelling
- small scale variations, inhomogeneous soil moisture patterns can now be **understood**

New CRNS Sensor

Outlook

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- First prototypes based on **boron coatings** and **Open Hardaware** readout electronics developed and successfully tested
- **Outperforms** existing systems by approx. factor 3

Outlook

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Outlook

- development of **larger detectors** for mobile sensing