METROLOGY FOR CLIMATE ACTION

26–30 SEPTEMBER 2022

Bureau International des Poids et Mesures

WORLD METEOROLOGICAL ORGANIZATION

Metrology for multi-scale monitoring of soil moisture

Project SoMMet (Soil Moisture Metrology)

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*The project **21GRD08 SoMMet** has received funding from the European Partnership on Metrology, co-financed by the European Union's Horizon Europe Research and Innovation Programme and by the Participating States.*

Project SoMMet (Soil Moisture Metrology)

- European Partnership on Metrology

- Call 2021: Metrology support for the Green Deal

- Project SoMMet 2022 – 2025
  - Consortium of 18 partners: 9 NMI/DI’s + 9 research institutions
  - We are looking for Collaborators!

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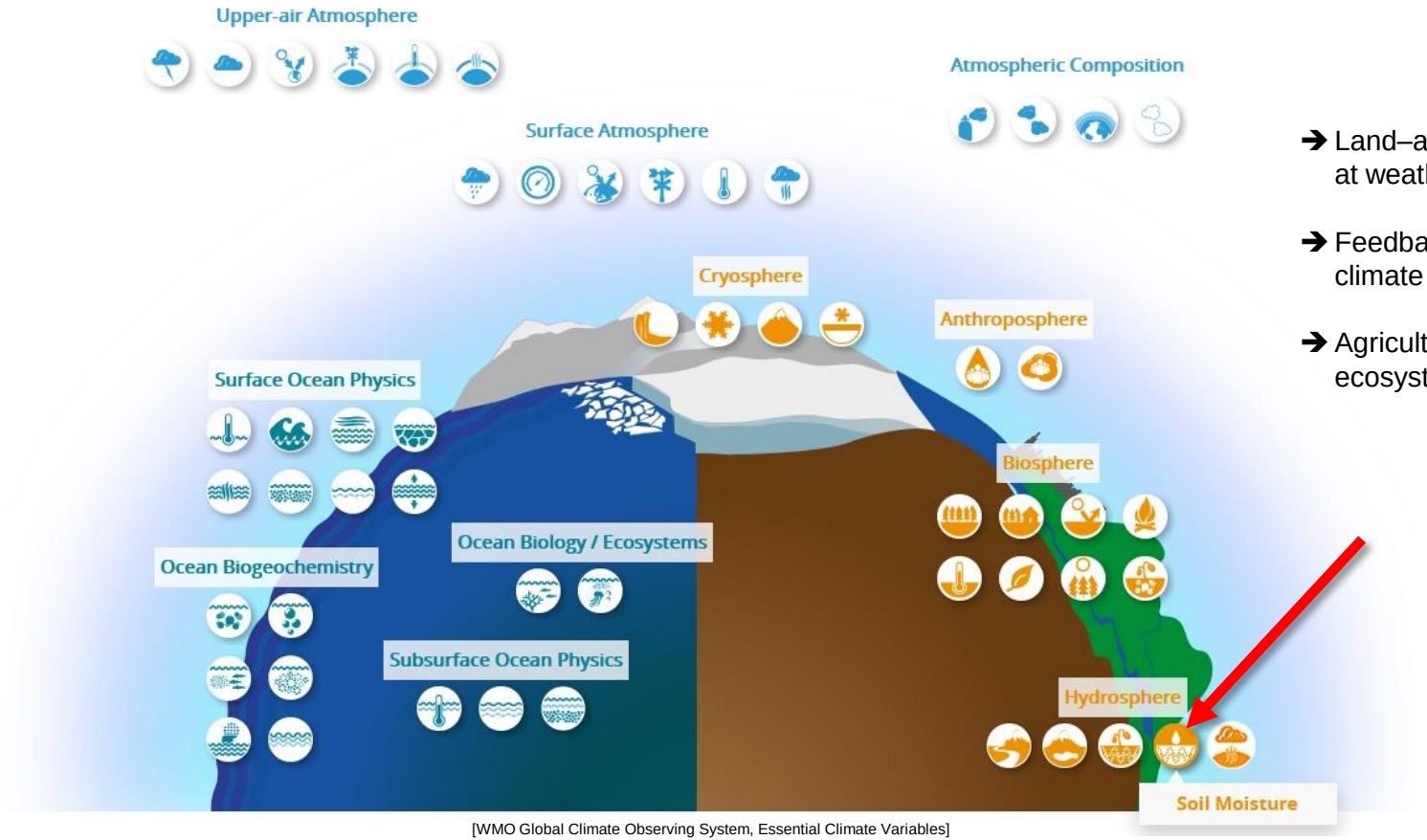
Soil moisture is Essential Climate Variable



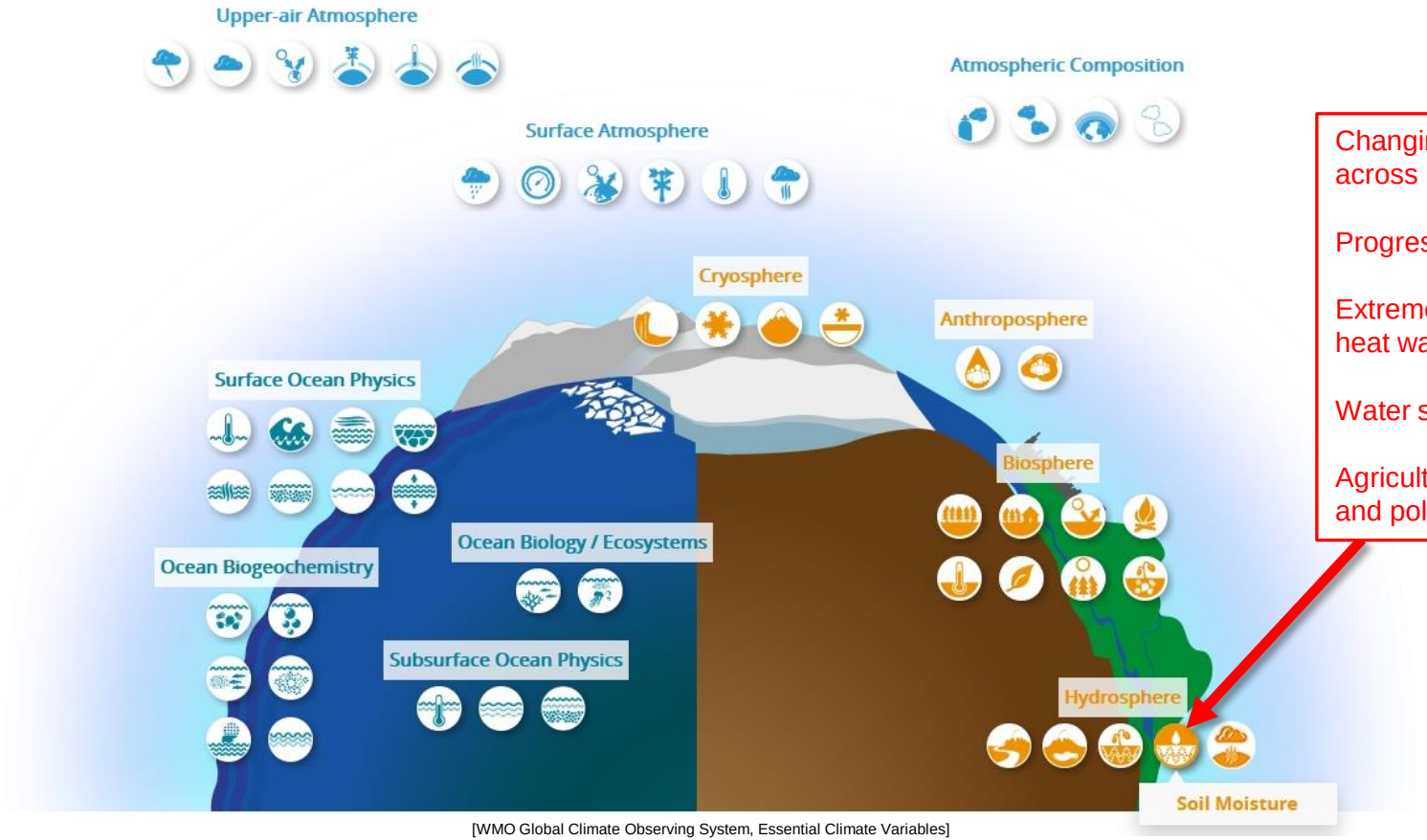
[WMO Global Climate Observing System, Essential Climate Variables]

➔ Land–atmosphere interactions at weather and climate timescales

➔ Feedback-loops between climate and vegetation

➔ Agriculture, forestry, ecosystem health

Soil moisture is Essential Climate Variable



[WMO Global Climate Observing System, Essential Climate Variables]

Changing trends of soil moisture across Europe

Progressing climate change

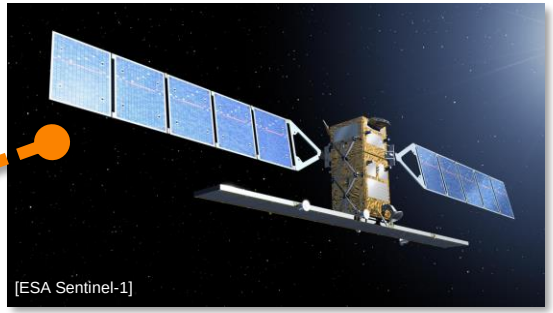
Extreme events: floods, droughts, heat waves, wildfire

Water scarcity

Agriculture: water overuse and pollution, food security

Problem of scales

Satellite remote sensing



- Only topmost soil layer (5 cm)
- Validation practices based on point-scale data

➔ **Need for effective, representative ground-based methods**

“ gap ”

Point-scale *in situ* measurements

[https://soilsensor.com]

- Invasive, affected by immediate surrounding
- Sensor networks ➔ maintenance & repair costs

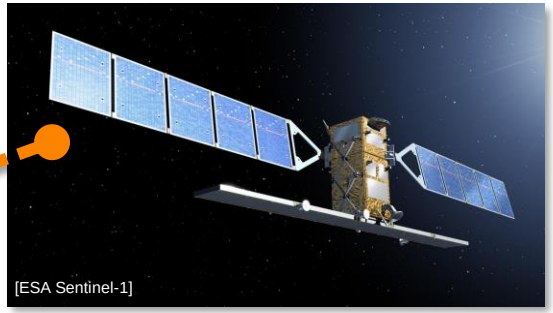
➔ **Need for harmonization of methods**

➔ **Need for traceable transfer standards**

(10^{-1} – 10^{1}) m — *Horizontal scale* — (10^{3} – 10^{4}) m

Problem of scales

Satellite remote sensing



Need for harmonized data

Point-scale *in situ* measurements

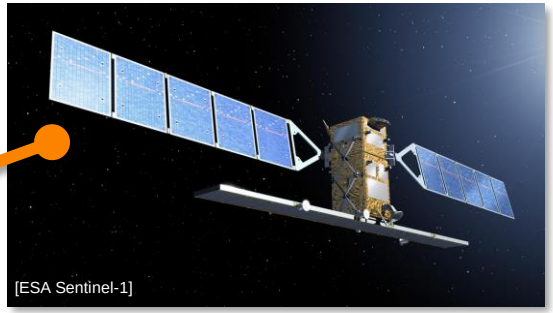
[https://soilsensor.com]

Graphics from
[EMN COO: Stakeholder Needs Review Report, 2021]

$(10^{-1} – 10^{1})$ m — *Horizontal scale* — $(10^{3} – 10^{4})$ m

Problem of scales ➔ Our approach

Satellite remote sensing



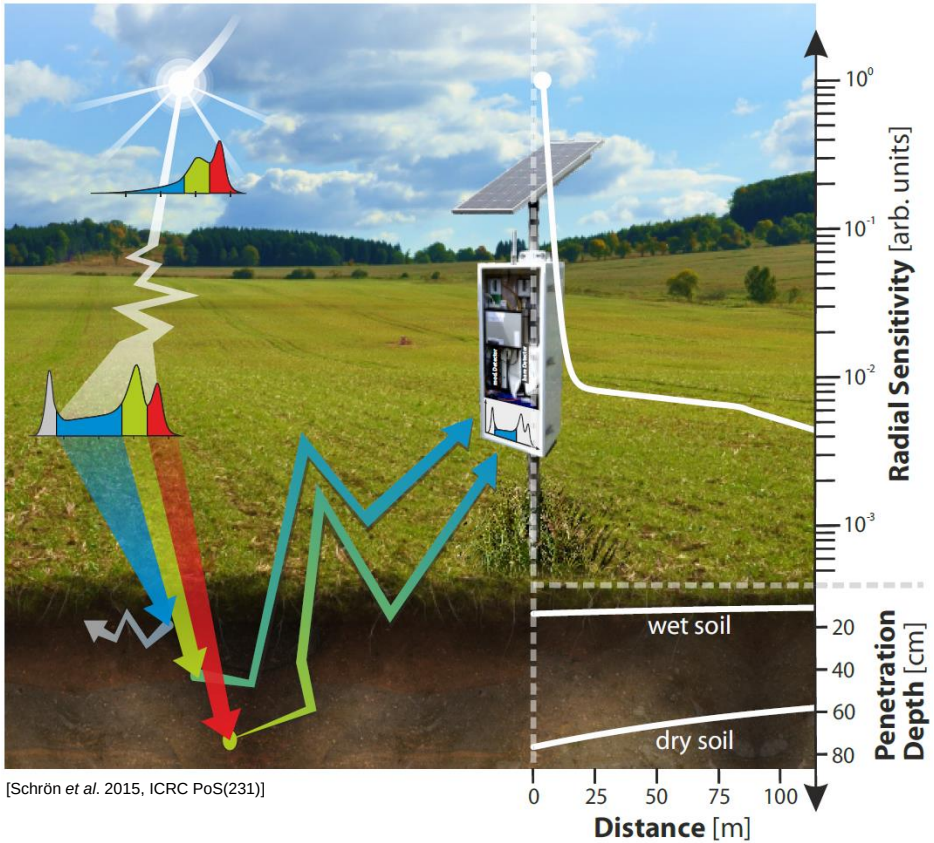
Cosmic-ray neutron sensing

Point-scale *in situ* measurements

[https://soilsensor.com]

$(10^{-1} – 10^{1})$ m $(10^{2} – 10^{3})$ m *Horizontal scale* $(10^{3} – 10^{4})$ m

Cosmic-ray neutron sensing (CRNS)



[Schrön *et al.* 2015, ICRC PoS(231)]

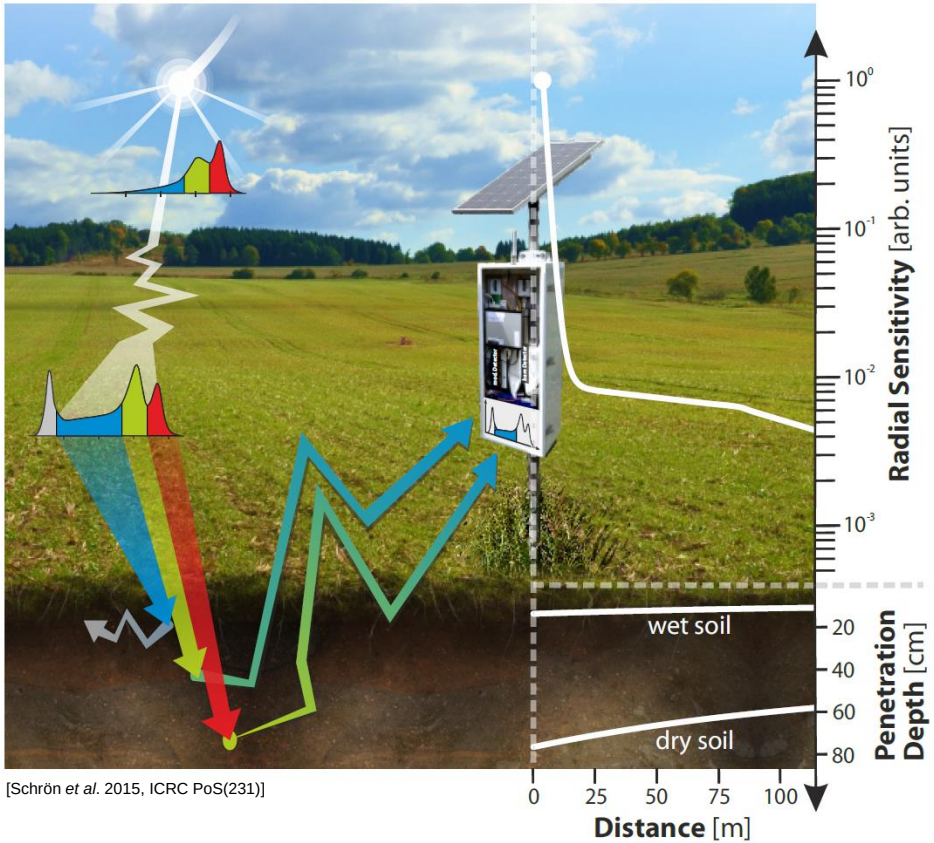
Soil moisture ➔ Count rate of albedo neutrons

- Deep-sensing method: soil moisture in root zone
- Area-averaged soil moisture measurand
- Continuous, automated measurement ➔ Networks

➔Need for metrology principles

Metrology of neutron radiation
Metrology of temperature and moisture

Cosmic-ray neutron sensing (CRNS)



[Schrön *et al.* 2015, ICRC PoS(231)]

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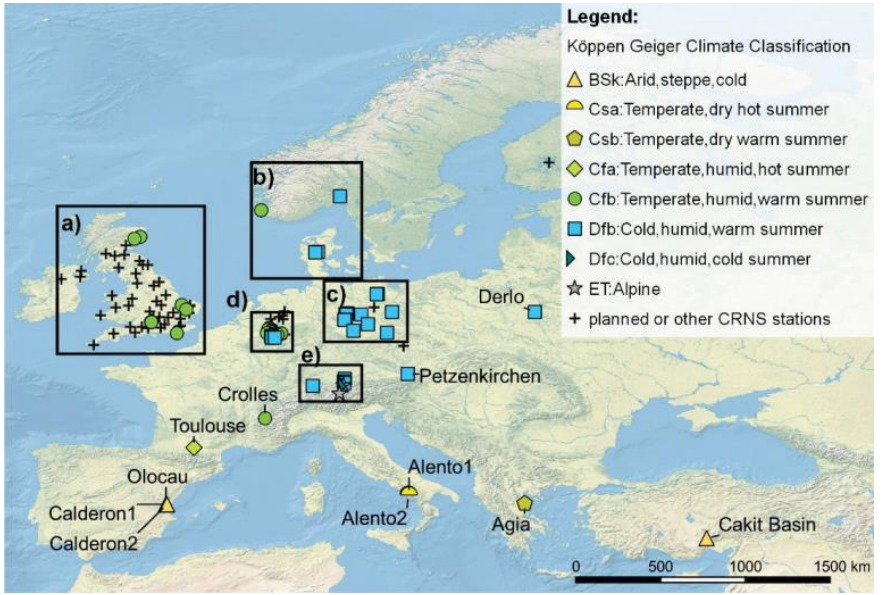


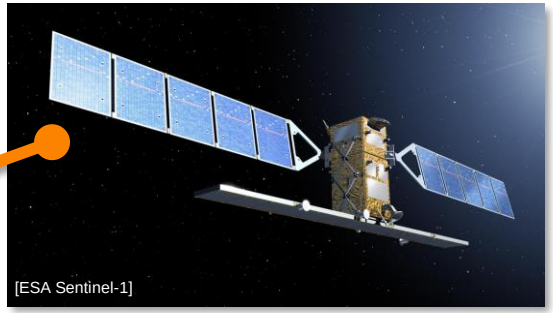
[Bogena et al., ESSD, in review, 2021]

> 100 CRNS sensors in Europe

Towards harmonized soil moisture measurements on multiple scales

SoMMet

Satellite remote sensing



Cosmic-ray neutron sensing

[M. Schrön, PhD Thesis Uni Potsdam]

Point-scale *in situ* measurements

[https://soilsensor.com]

$(10^{-1} – 10^{1})$ m $(10^{2} – 10^{3})$ m *Horizontal scale* $(10^{3} – 10^{4})$ m

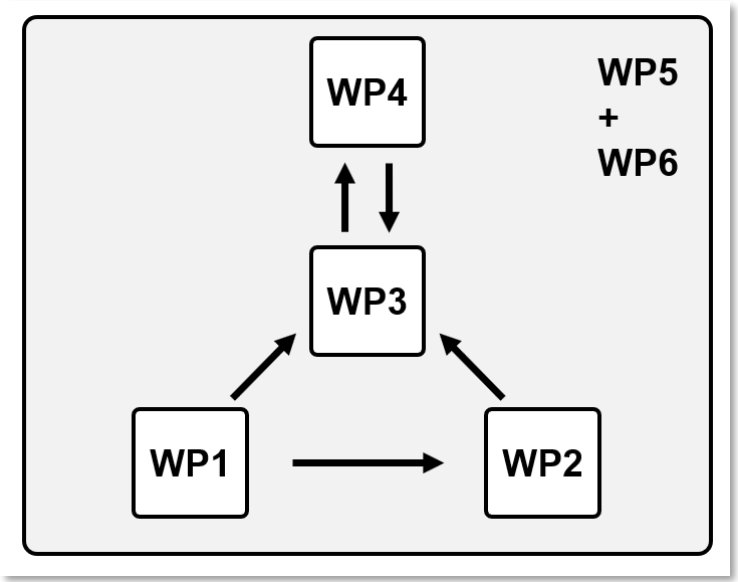
Objectives ➔ Technical Work Packages

1. Development of metrologically traceable methods for point-scale soil moisture measurements with uncertainties of 5 % under laboratory conditions. Development of metrological framework for validation of CRNS devices under laboratory conditions.

2. Development of validation practices for CRNS devices for use in outdoor conditions. Application and validation of neutron transport models used in CRNS. Standardization of CRNS on-field calibration procedure for soil moisture assessment.

3. Investigation of constraints and accuracy of soil moisture measurement methodologies using intercomparison campaigns on local and remote sensing. Development of procedures to overcome temporal and spatial differences regarding the sensing domains of soil moisture measurement methods.

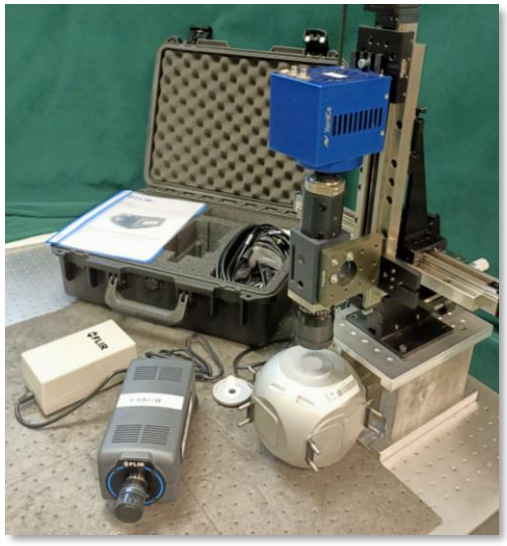
4. Development of multi-scale metrological system for soil moisture monitoring, covering lateral scales ranging from 10^{-1} m to 10^{3} m and to depths of up to 1 m, and temporal scales ranging from hours to days, to assess the soil moisture with traceable relative uncertainty of 20 % or better.



WP1: **Traceability**
WP2: **Validation**
WP3: **Harmonization**
WP4: **Data fusion**

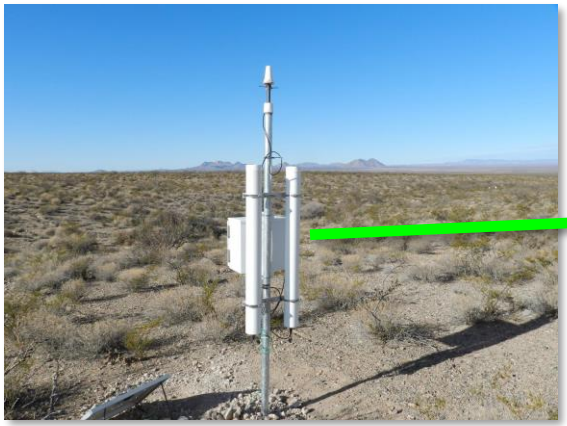
WP1: SI-traceable measurement of soil moisture on point to field scale

- Definition of the needed **metrological framework** ← **Stakeholders**
- **Calibration facilities** for point-scale sensors and transfer standards



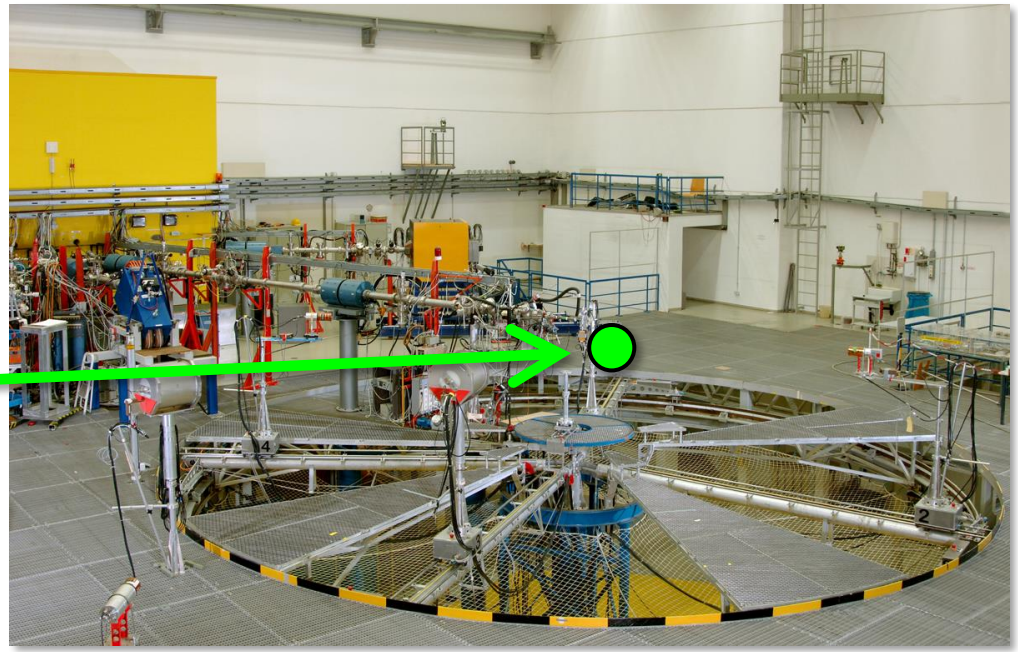
WP1: SI-traceable measurement of soil moisture on point to field scale

- Definition of the needed **metrological framework** ← **Stakeholders**
- **Calibration facilities** for point-scale sensors and transfer standards
- **Calibration procedures** for neutron detectors of CRNS methodology



[Arizona State University]

[PTB Ion Accelerator Facility (PIAF)]

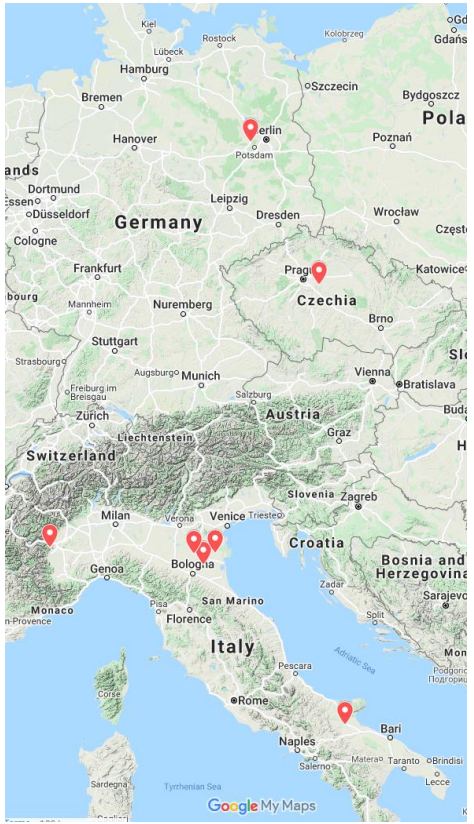


WP2: Development of validation practices for CRNS methodology in outdoor conditions

- **Selection** of high-level test field sites
- **Validation** of neutron transport models
- **Standardization** of CRNS on-field calibration procedure

➔ Uncertainty evaluation of measurements under environmental conditions

➔ Study of quantities of influence

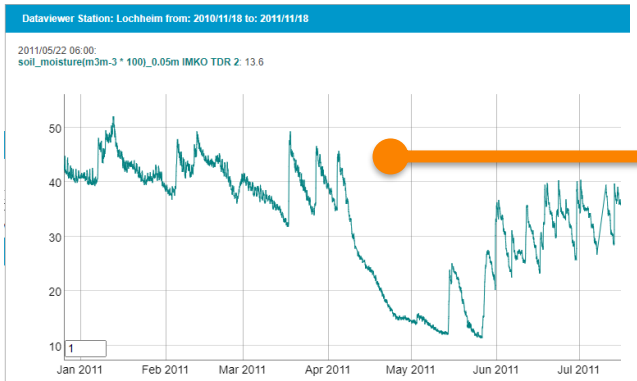


WP3: Comparison and harmonization of soil moisture observation methods on multiple spatial and temporal scales

SoMMet

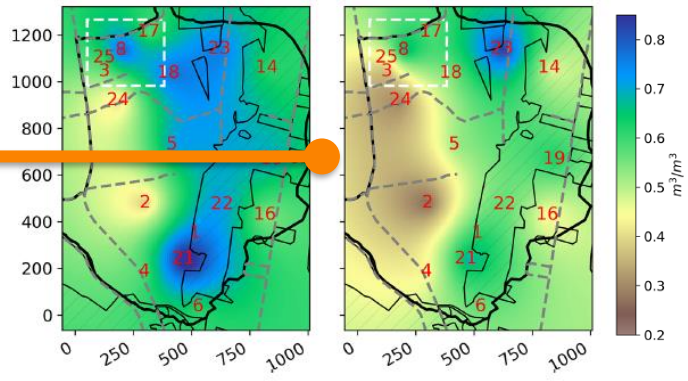
- **Comparison** of methods, their constraints and different spatial and temporal characteristics
- Development of the **harmonization approach**

Point-scale *in situ* measurements
Example: Time series of a single sensor



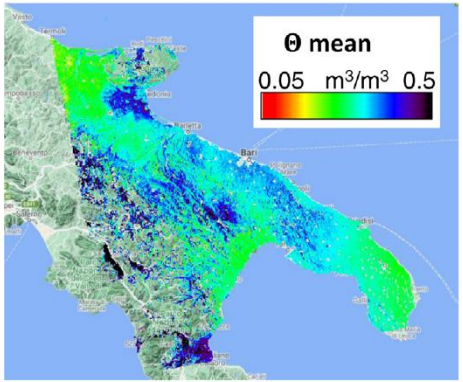
[International Soil Moisture Network]

Cosmic-ray neutron sensing
Example: Daily average soil moisture at catchment scale



[Heistermann, HESS 25 (2021) 4807]

Satellite remote sensing
Example: Sentinel-1 surface soil volumetric water content product

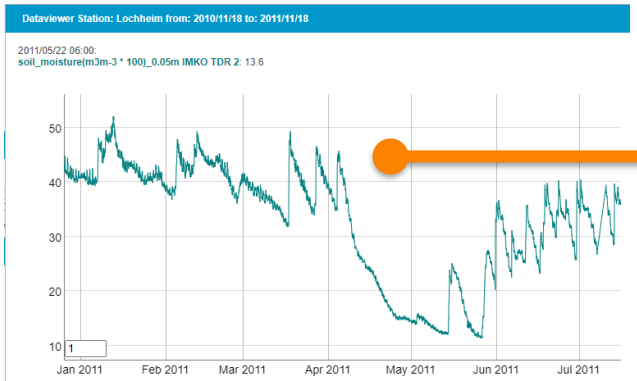


[Balenzano *et al.*, Data in Brief 38 (2021) 107345]

WP4: Multi-scale and multi-disciplinary soil moisture data fusion

- Definition of **data fusion** practices for soil moisture measurements on multiple scales
- **Implementation** of data fusion of soil moisture measurements on multiple scales

Point-scale *in situ* measurements
Example: Time series of a single sensor



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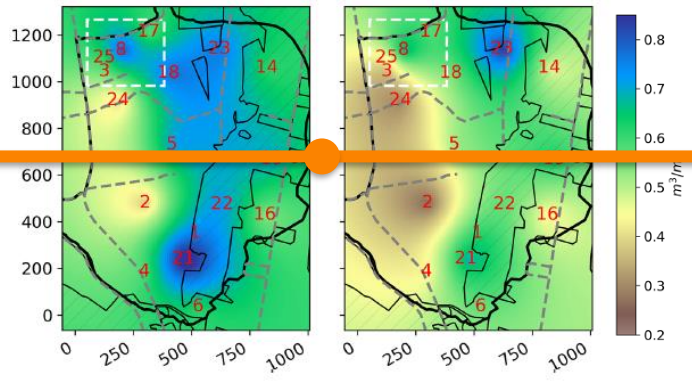

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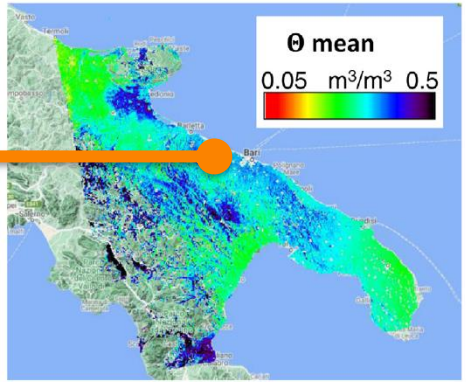

[Balenzano *et al.*, Data in Brief 38 (2021) 107345]

WP5: Creating impact

Project outputs

- **NEW**: Methodology for calibration of soil moisture sensors. Primary method + transfer standards.
- **NEW**: Traceability scheme and validation practices for CRNS method.
- **NEW**: calibrated data from comparison campaigns on local and remote sensing.
- Good practice guides.
  Scientific publications.
  Conference contributions.
  Engagement with Stakeholders and programmes, networks.
  Conference + training course.
  Soil Moisture Workshop.

Outcomes

- Point-scale soil moisture sensors: traceable calibrations, reliable uncertainties. New services (NMI, DI).
- CRNS method: "*emerging*" ➔ **established**
- Remote sensing: More efficient and representative validation practices.
- Better soil moisture data with better comparability across scales and communities.
- Input for experts of EMN COO, WMO, ESA, ISMN and other relevant bodies.
- Engagement with end-users: remote sensing, agriculture, weather and climate monitoring, modelling and forecasting.

Wider impacts

- Better soil moisture products for users, more efficient, more reliable modelling.
- Hydrological modelling, numerical weather predictions.
- Improved flood forecasting, drought monitoring and prediction.
- Better models and understanding of global water cycle under progressing climate change.
- Agriculture: smart technologies for water management.
- Better understanding of soil contributions to GHG inventories on global scale.

PROJECT PARTNERS:

PTB — Coordination, Lead WP6

Ciemat — Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

CMI — Czech Metrology Institute

Danish Technological Institute — Lead WP1

INRiM — Istituto Nazionale di Ricerca Metrologica — Lead WP5

IRSN — Institut de Radioprotection et de Sûreté Nucléaire

SMU

Justervesenet

TÜBİTAK

Universität Potsdam — Lead WP2

CTU — Czech Technical University in Prague

Alma Mater Studiorum Università di Bologna — Lead WP3

POLITECNICO MILANO 1863

ISA — istituto per il rilevamento elettromagnetico dell'ambiente — Lead WP4

UK Centre for Ecology & Hydrology

UFZ — Helmholtz Zentrum für Umweltforschung

Institute of Agrophysics PAS

IMPACT & SUPPORT:

esa

ASI — Agenzia Spaziale Italiana

UNESCO — United Nations Educational, Scientific and Cultural Organization

International Centre for Water Resources and Global Change under the auspices of UNESCO

WMO

eLTER

Deutscher Wetterdienst — Wetter und Klima aus einer Hand

DWD

ECMWF

The University of Arizona

AHDB — Agriculture & Horticulture Development Board

Landbruk Føderaser

NMBU — Norwegian University of Life Sciences