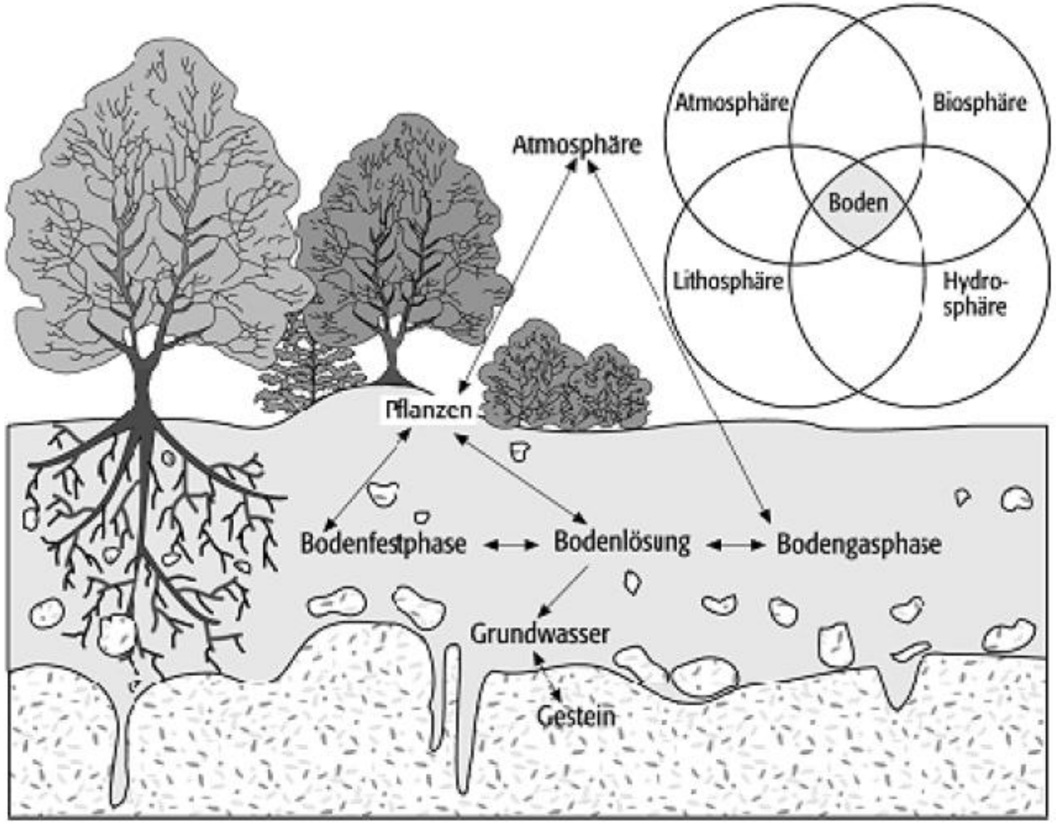
Project SoMMet
Soil Moisture Metrology

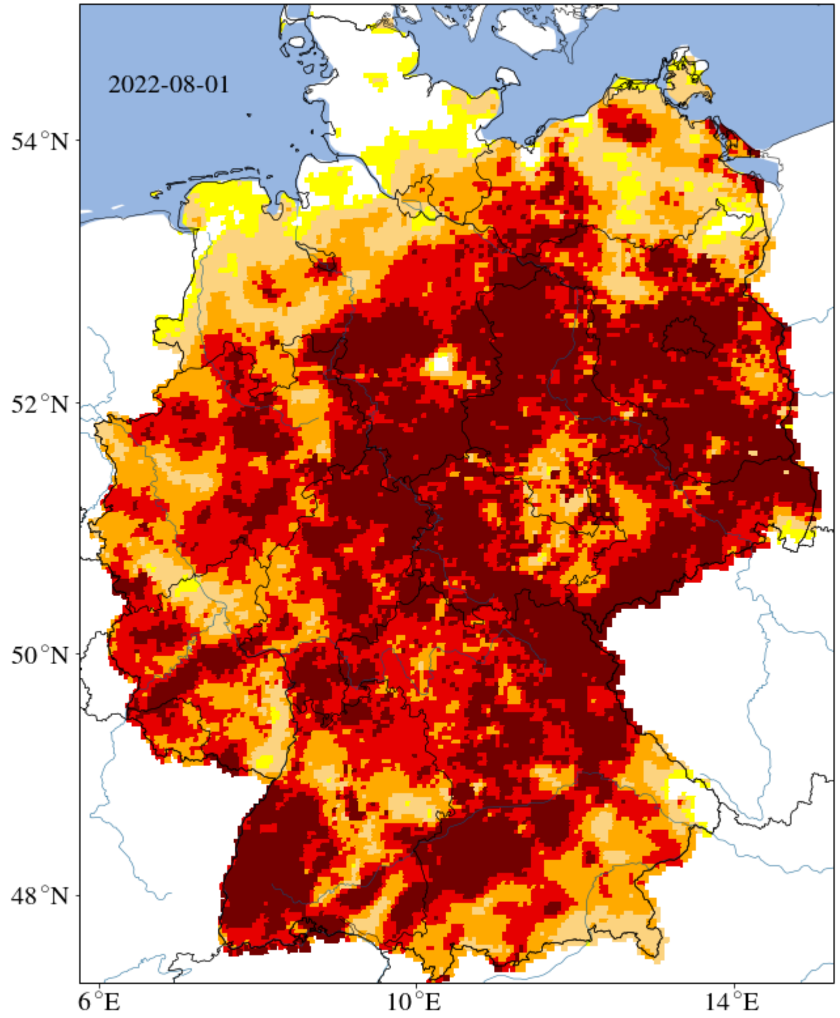
EURADOS AM 2023, Porto, 12 – 15 June 2023

Miroslav Zboril
Neutron Radiation Department of PTB
on behalf of SoMMet Consortium

Soil moisture

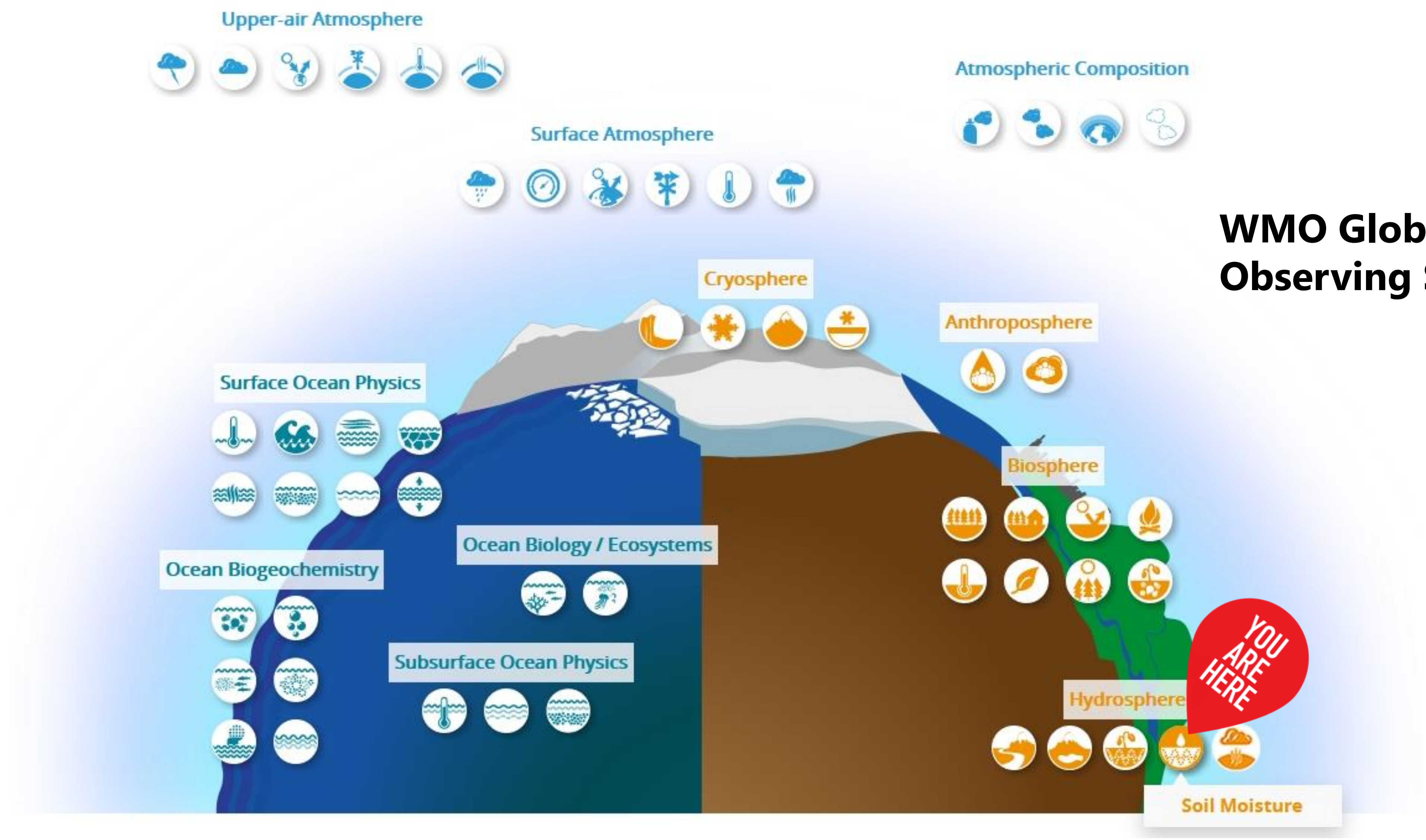


Soil moisture



Drought monitor
UFZ Helmholtz Centre for Environmental Research, Leipzig, Germany

Soil moisture is *Essential Climate Variable*

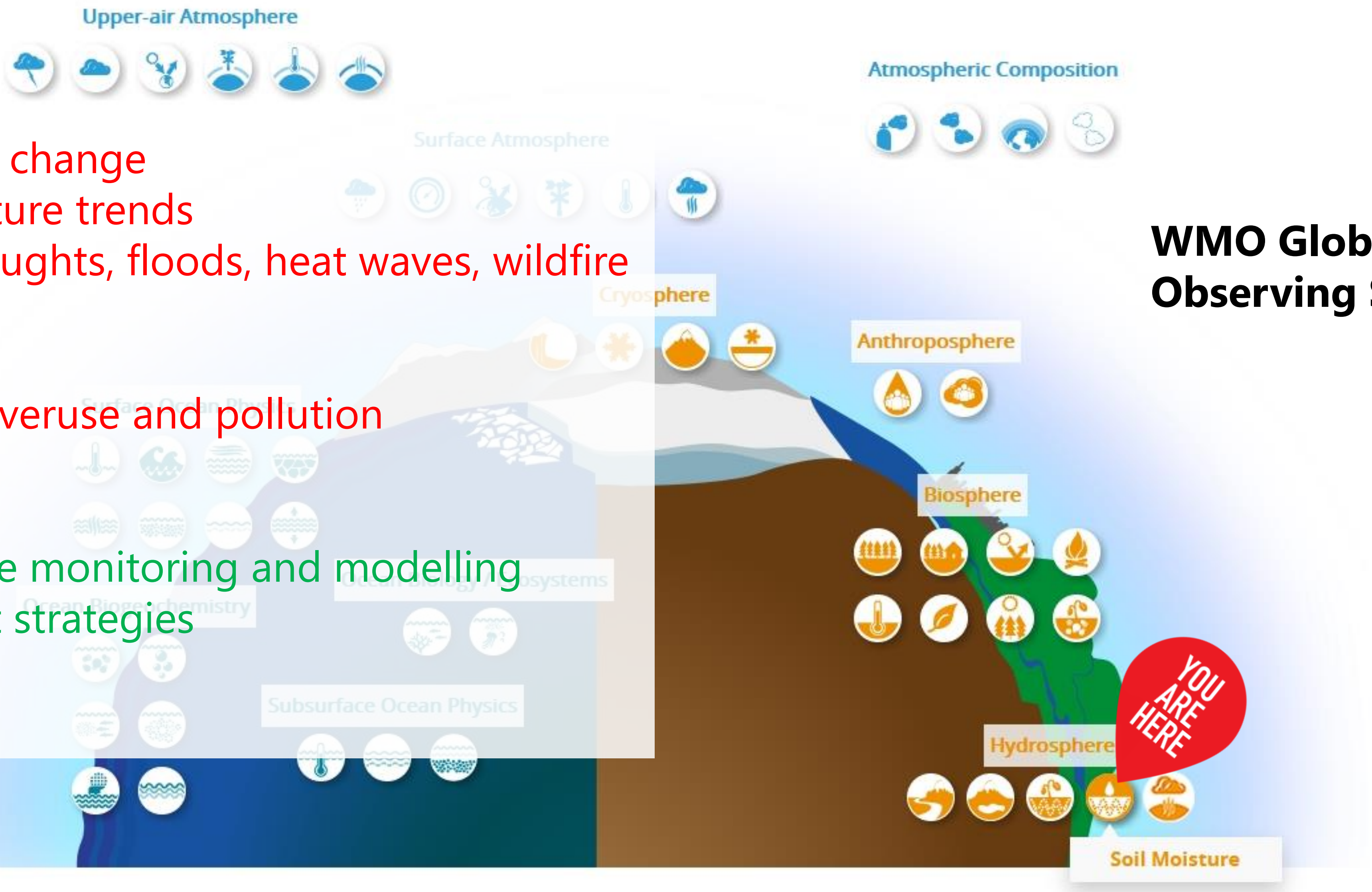


WMO Global Climate Observing System

Soil moisture is *Essential Climate Variable*

Progressing climate change
Changing soil moisture trends
Extreme events: droughts, floods, heat waves, wildfire
Water scarcity
Soil erosion
Agriculture: water overuse and pollution
Food security

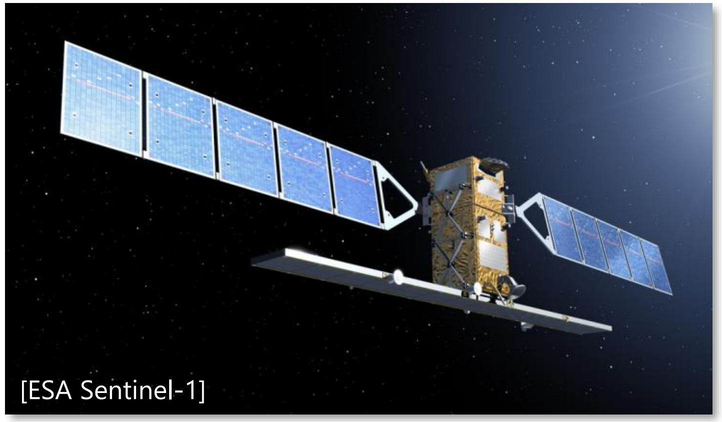
Weather and climate monitoring and modelling
Water management strategies
Precision farming
Soils as CO_2 sink



WMO Global Climate Observing System

Soil moisture – problem of scales

Satellite-based remote sensing



[ESA Sentinel-1]

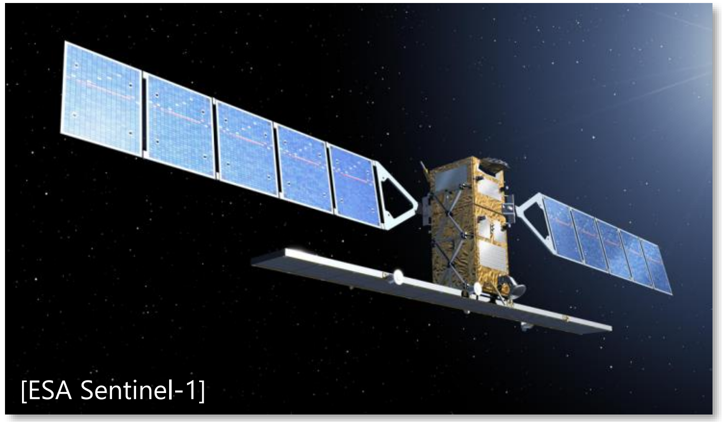
Point-scale sensors

[https://soilsensor.com]

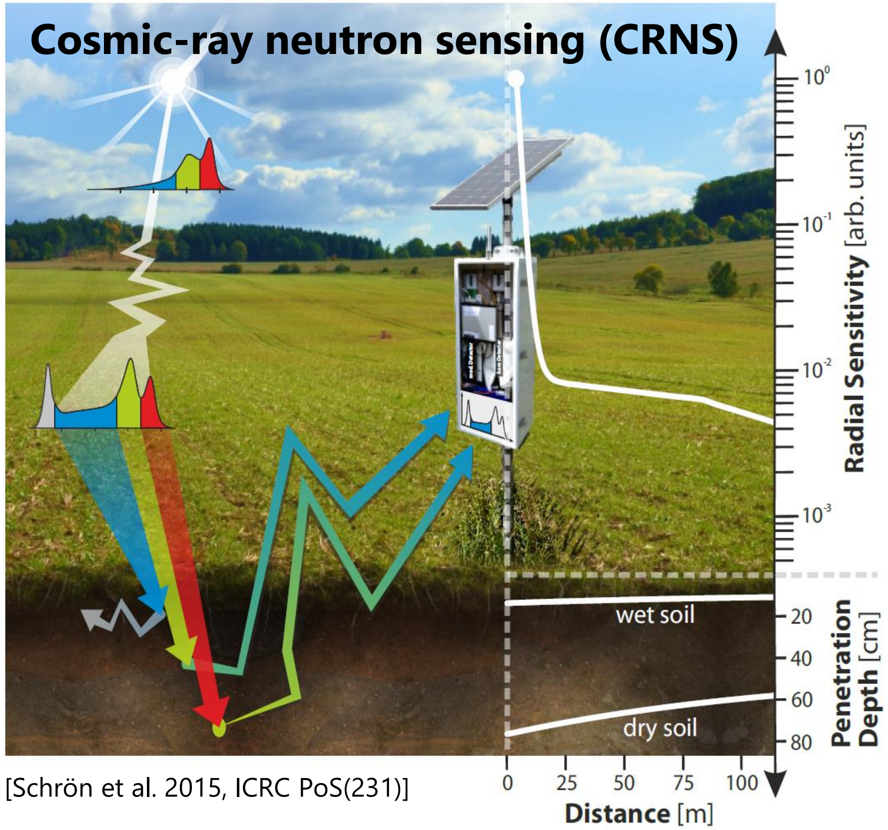
(10^{-1} – 10^{1}) m
(10^{2} – 10^{3}) m
Horizontal scale
(10^{3} – 10^{4}) m

Soil moisture – problem of scales

Satellite-based remote sensing



Cosmic-ray neutron sensing (CRNS)



[Schrön et al. 2015, ICRC PoS(231)]

Point-scale sensors

[https://soilsensor.com]

$(10^{-1} – 10^{1})$ m

$(10^{2} – 10^{3})$ m

Horizontal scale

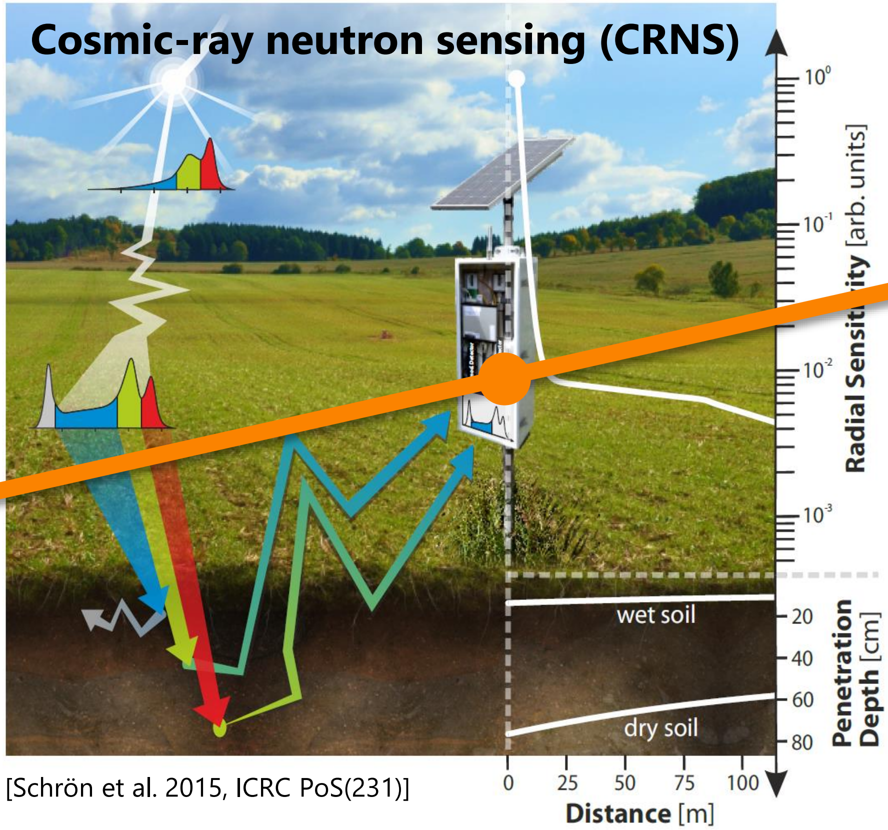
$(10^{3} – 10^{4})$ m

Main goal of SoMMet

Calibration establishes ***traceability*** which in turn improves ***comparability*** of different methods across scales.

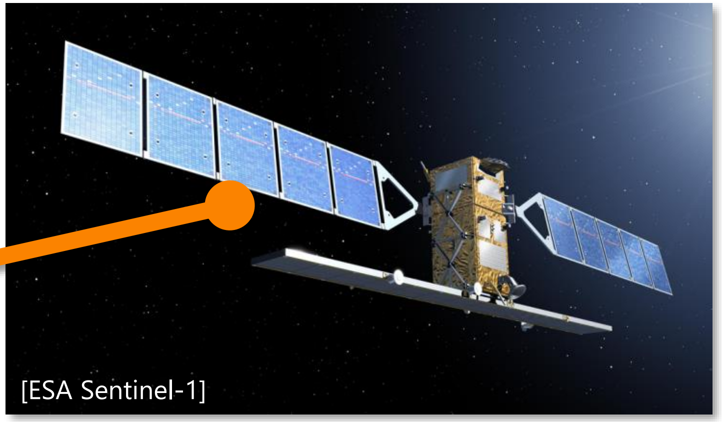
Point-scale sensors

[https://soilsensor.com]



[Schrön et al. 2015, ICRC PoS(231)]

Satellite-based remote sensing



[ESA Sentinel-1]

$(10^{-1} - 10^{1})$ m

$(10^{2} - 10^{3})$ m

Horizontal scale

$(10^{3} - 10^{4})$ m

Organisational

- European Partnership on Metrology, 2021 Green Deal Call
- 21GRD08 SoMMet: 10.2022 – 09.2025
- 18 Funded partners: 9 NMI/DI's + 9 Research institutions
- Coordinated by Neutron Radiation Department of PTB
- Total budget 2.5 M€

WP1: **Traceability**
WP2: **Validation**
WP3: **Harmonization**
WP4: **Data fusion**
WP5: **Impact**
WP6: **Coordination**

www.sommet-project.eu

PROJECT PARTNERS:

PTB — Coordination, Lead WP6

Ciemat — Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

CMI — Czech Metrology Institute

Danish Technological Institute — Lead WP1

TÜBİTAK

IRSN — Institut de Radioprotection et de Sûreté Nucléaire

SMU

INRiM — Istituto Nazionale di Ricerca Metrologica — Lead WP5

Justervesenet

Universität Potsdam — Lead WP2

Alma Mater Studiorum Università di Bologna — Lead WP3

CTU — Czech Technical University in Prague

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

Politecnico Milano 1863

UK Centre for Ecology & Hydrology

UFZ — Helmholtz Zentrum für Umweltforschung

Institute of Agrophysics PAS

SUPPORT & STAKEHOLDERS

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

Norwegian University of Life Sciences

AHDB — Agriculture & Horticulture Development Board

ECMWF

MeteoSwiss

Landbrug & Fødevarer

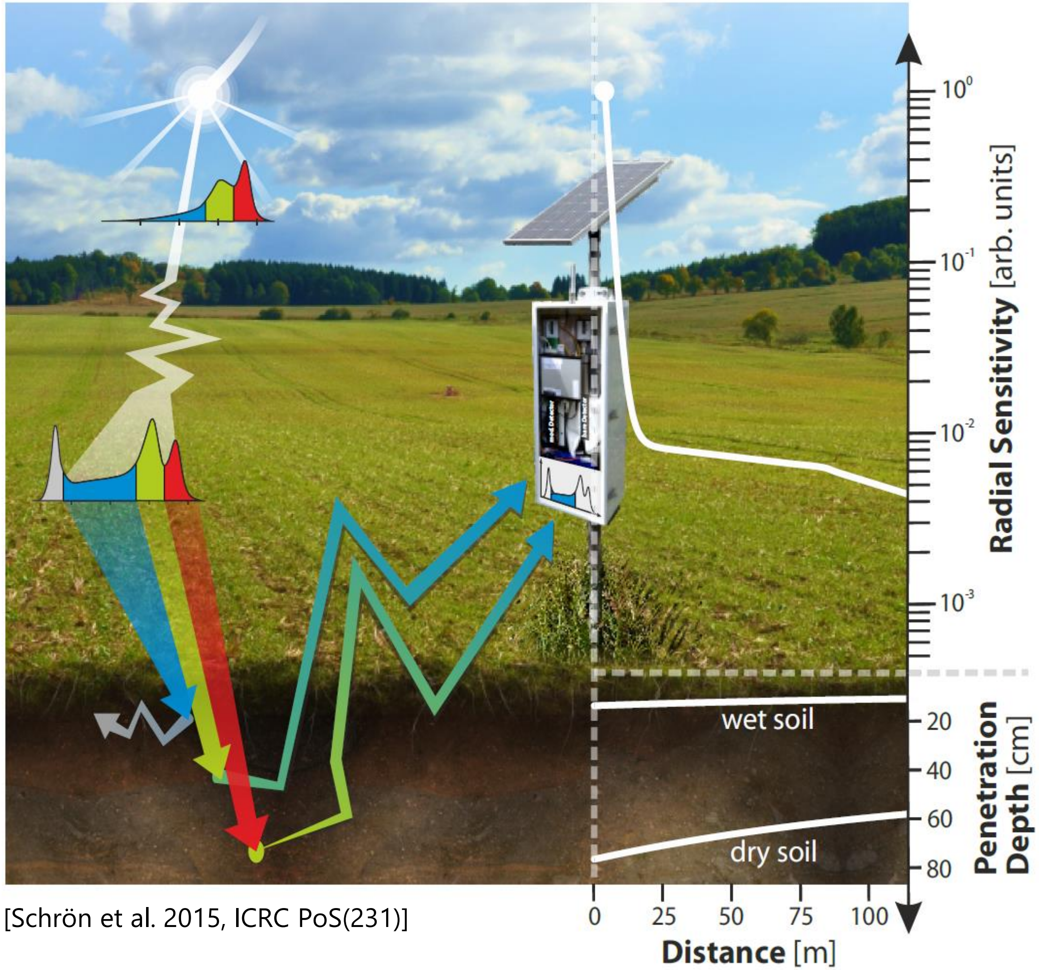
TU Wien

Jülich Forschungszentrum

NIBIO — Norwegian Institute of Bioeconomy Research

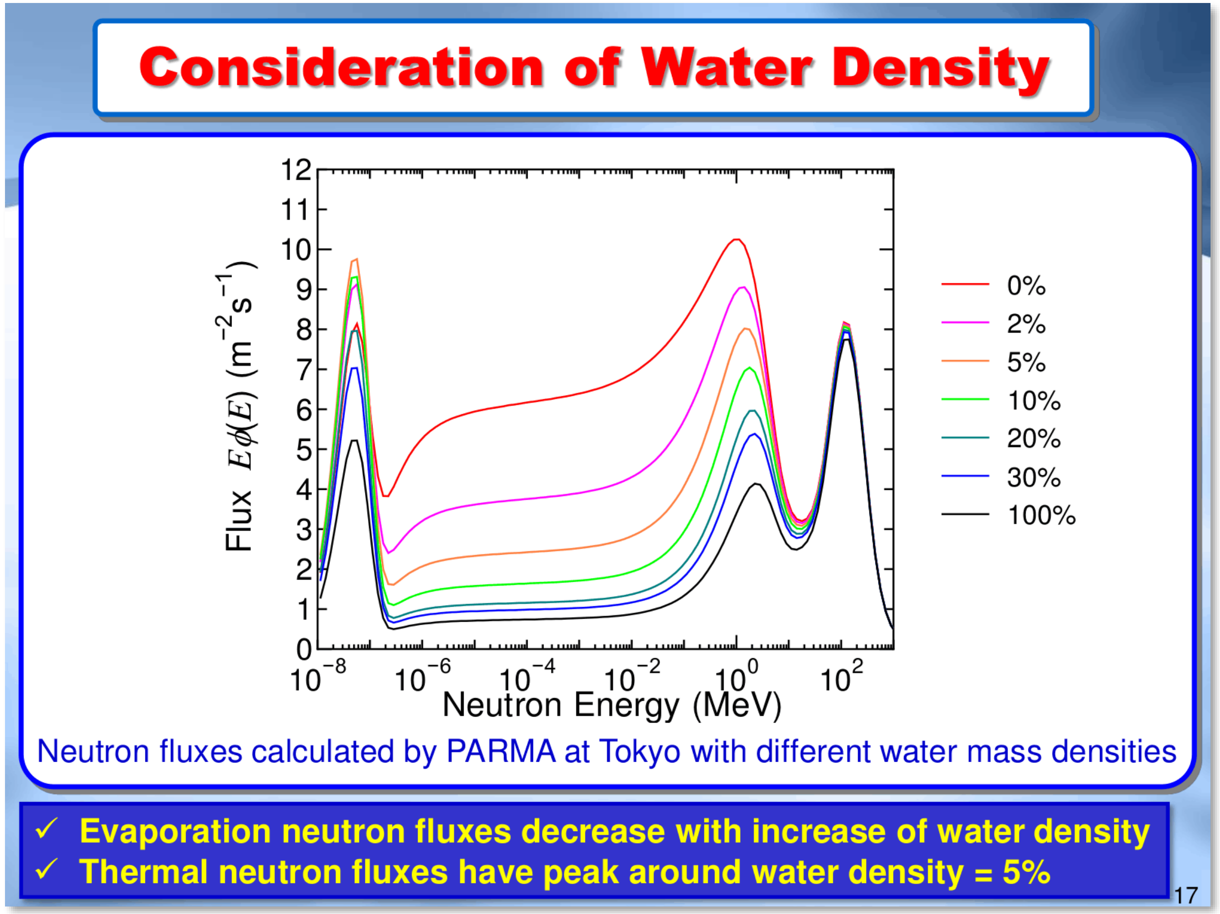
The University of Arizona

CRNS: measurement methodology



[Schrön et al. 2015, ICRC PoS(231)]

[T. Sato, COSMOS Workshop, 2020]

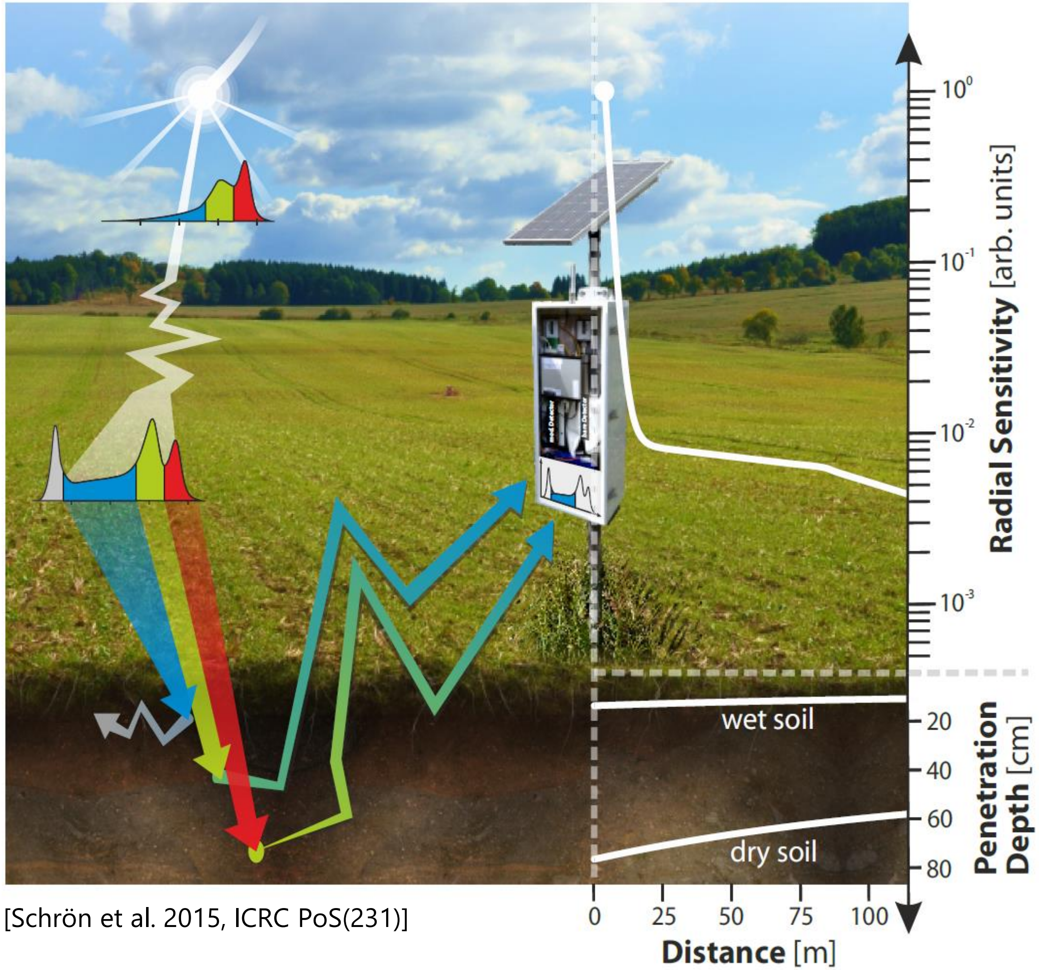


PARMA: PHITS-based analytical radiation model in the atmosphere

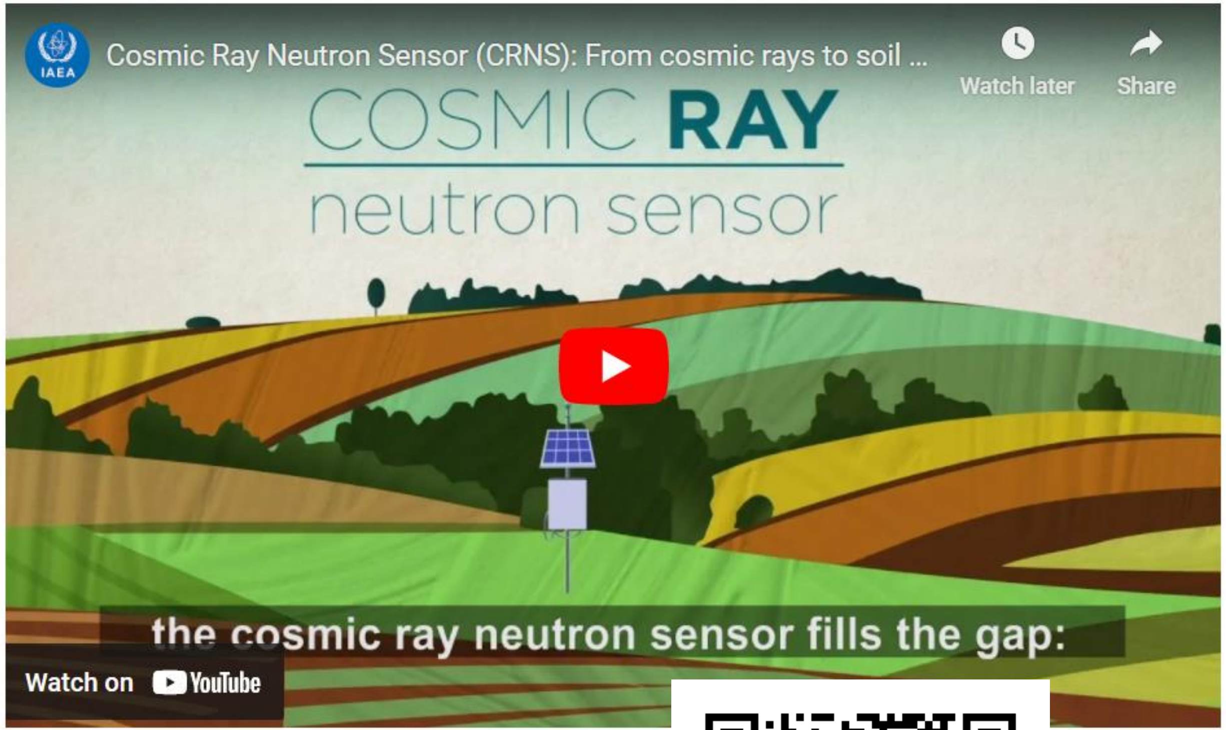
[T. Sato et al., Radiat. Res. 170(2):244-259 (2008)]

CRNS: measurement methodology

[IAEA]

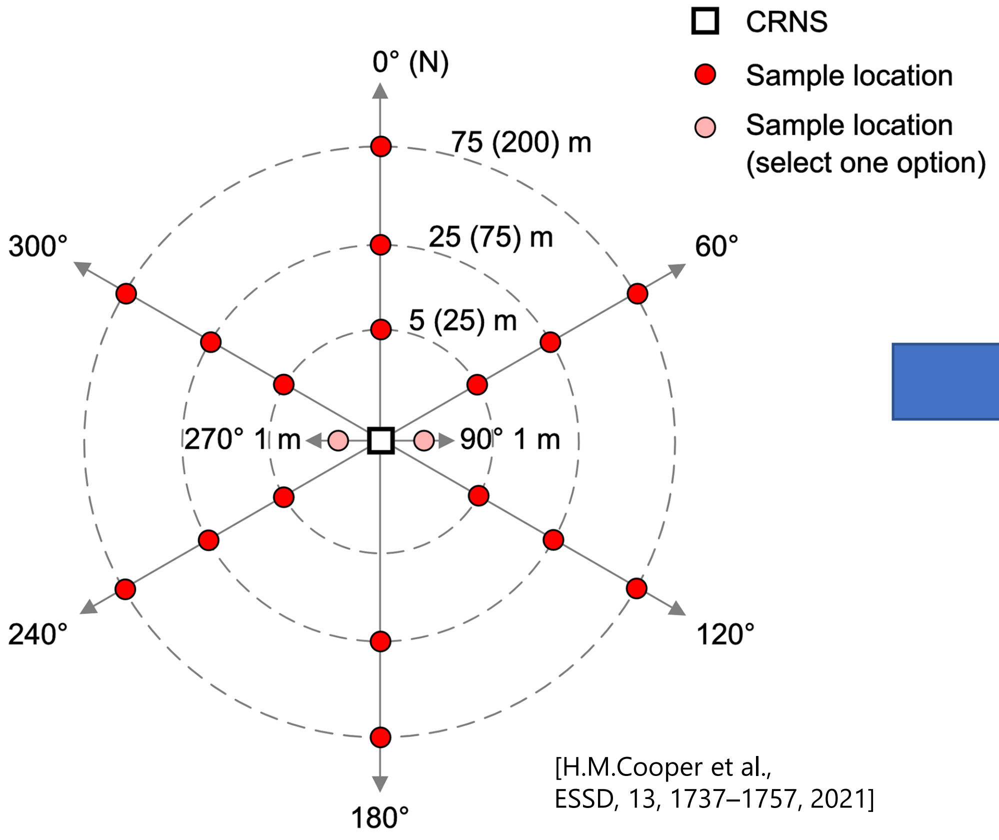


[Schrön et al. 2015, ICRC PoS(231)]



CRNS: measurement methodology

Calibration* in real world conditions: from albedo neutrons count rate to soil moisture



[H.M.Cooper et al.,
ESSD, 13, 1737–1757, 2021]

Field sampling of CRNS footprint:
Point-scale soil moisture measurements and neutron modelling

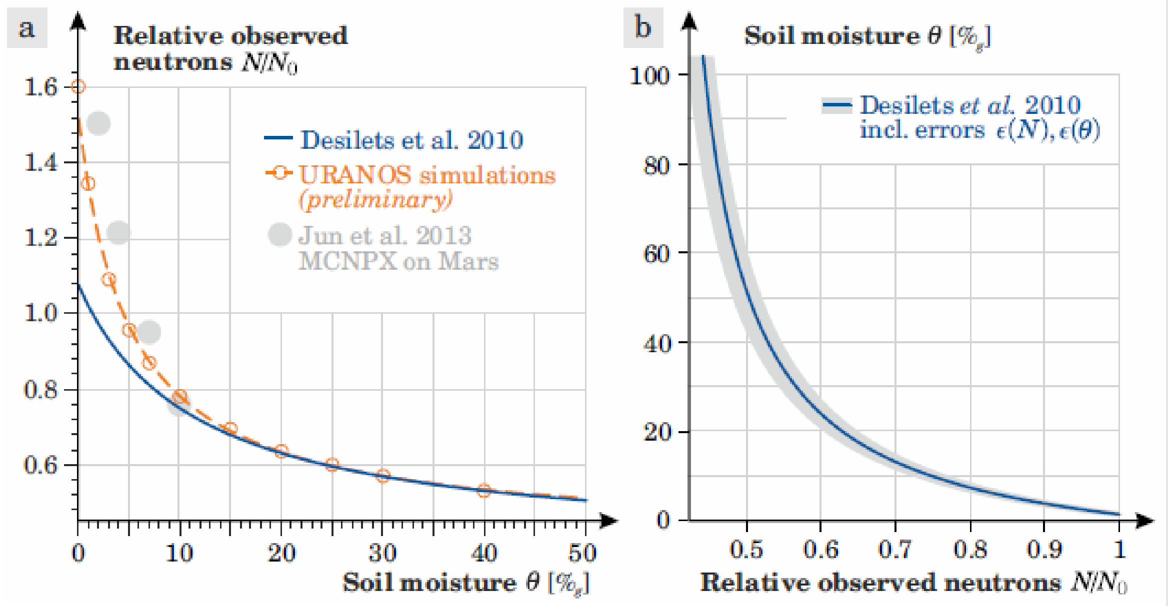


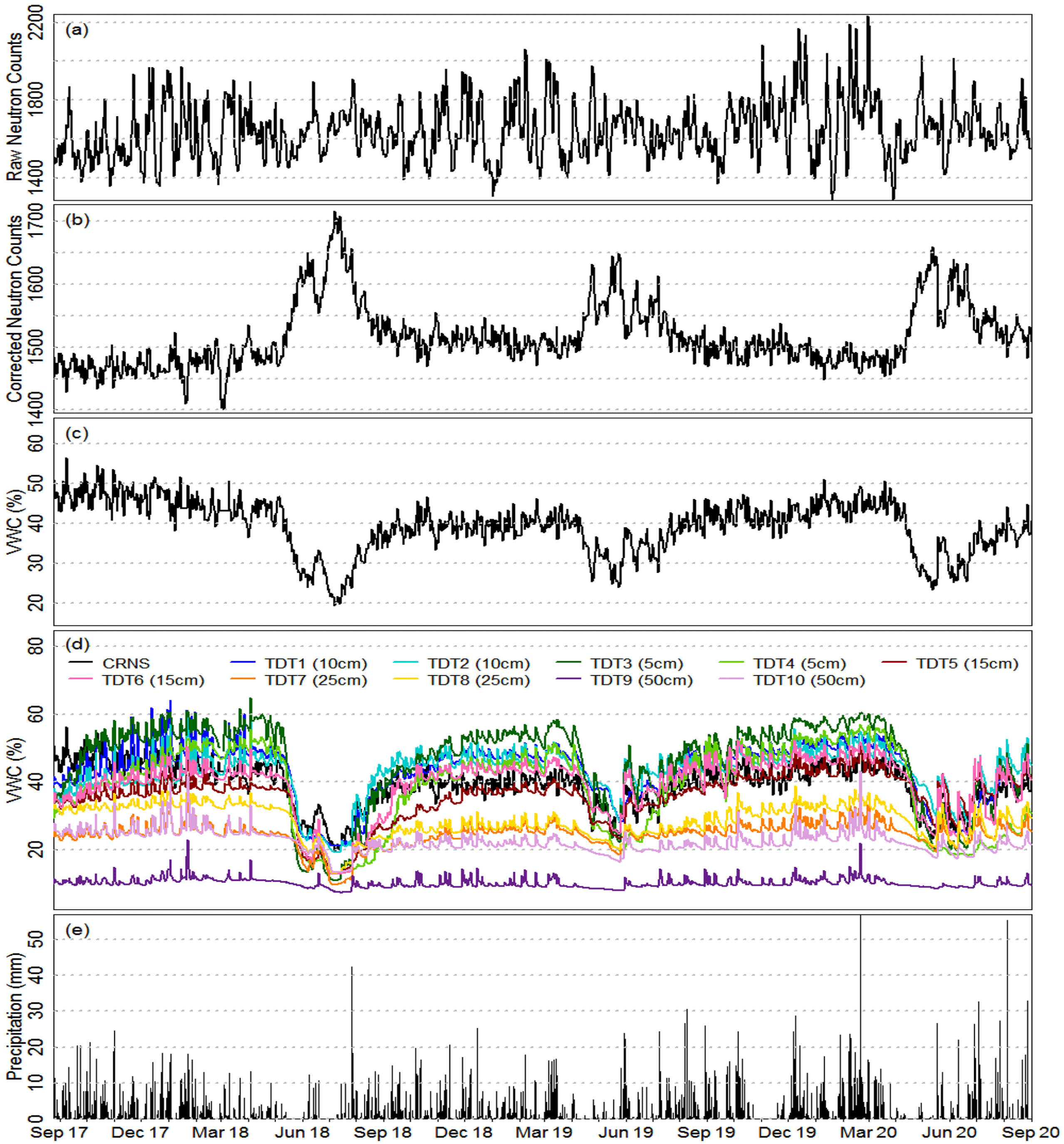
Fig. 3.6: From neutrons to soil moisture and back. a Two different approaches, Desilets et al. (2010) and simulations with URANOS (by M. Köhli, private communication), both normalised to $\frac{1}{2}N_0$ at 50 $\%_g$, and compared with approaches from space science (Jun et al. 2013). b Soil moisture as a function of neutron counts, including an error band for signal uncertainty $\epsilon(N)$ and propagated uncertainty $\epsilon(\theta)$ (see section 3.7.2).

[M. Schrön, PhD Thesis Uni Potsdam, 2017]

CRNS: time series

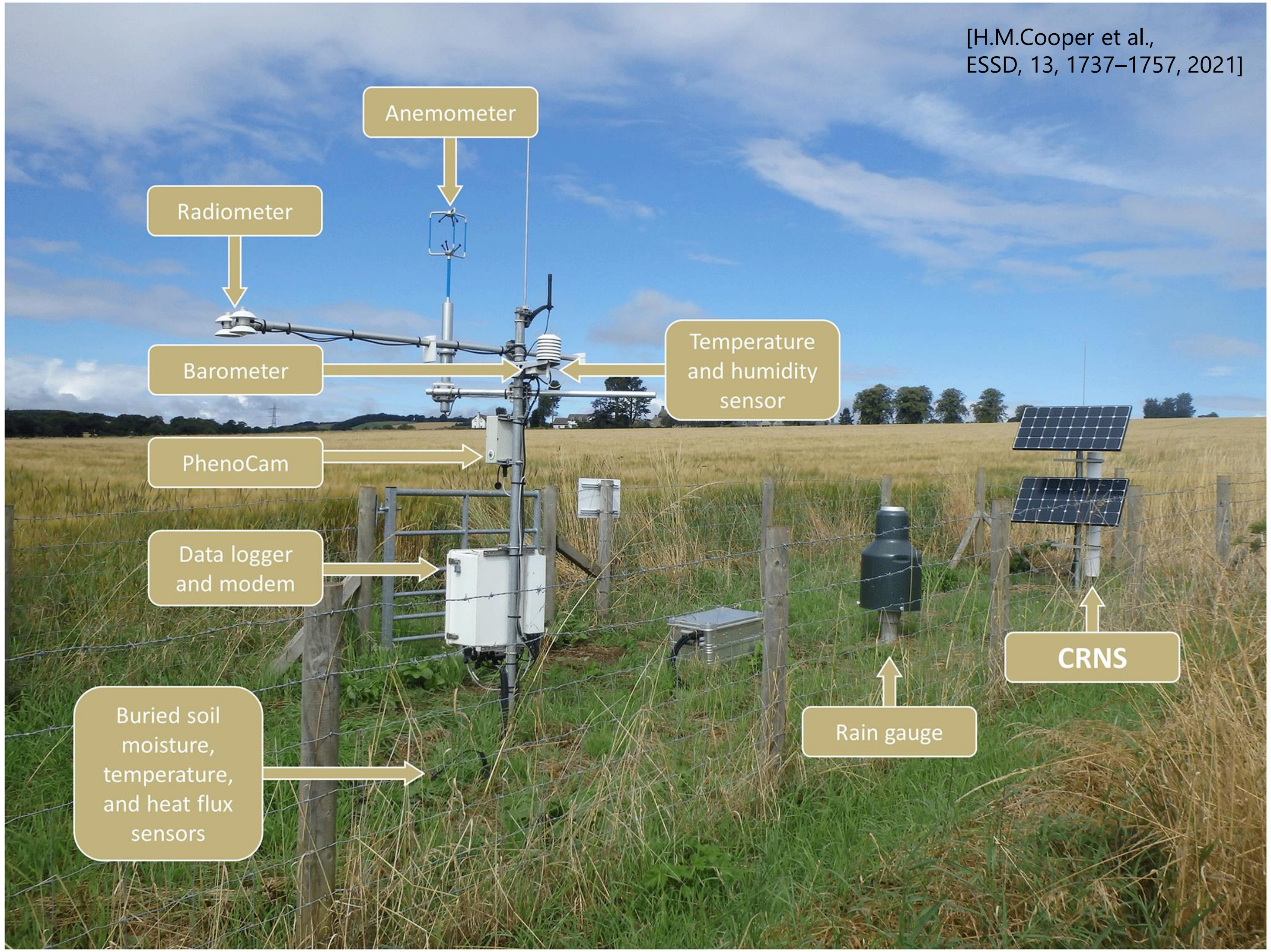
Exemplary 3-years time series of CRNS data and comparison to point-scale soil moisture measurements

[H.M.Cooper et al., ESSD, 13, 1737–1757, 2021]



CRNS: typical instrumentation

[M. Schrön et al.,
Geosci. Instrum. Method. Data Syst., 7, 83–99, 2018]



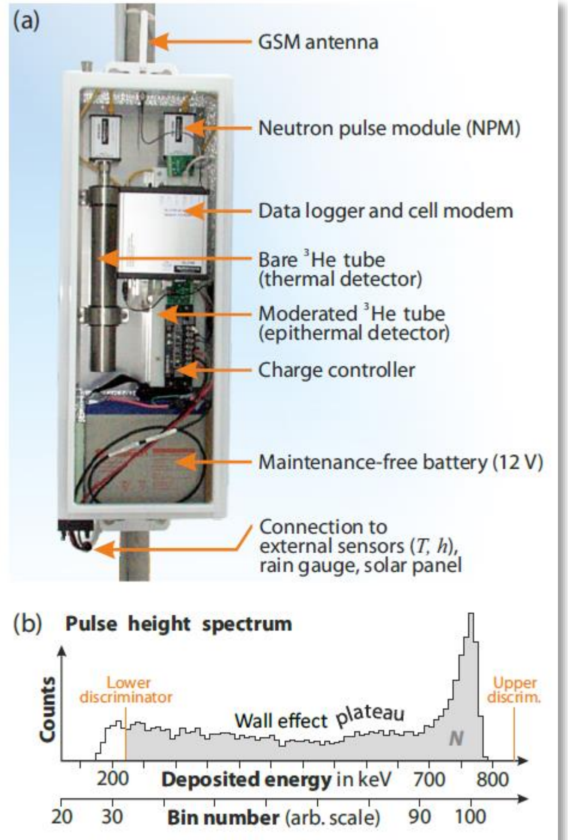


Figure 1. (a) Inside view of the cosmic-ray neutron sensor (CRNS) of type "CRS1000". The moderated tube (surrounded by a white polyethylene block) mainly detects epithermal neutrons and is thus sensitive to water in the environment. (b) A typical, measured pulse height spectrum (PHS) shows the deposited energy in the gas tube. Upper and lower discriminators (orange) delimit the region (grey) in which events are interpreted as neutron counts N. Illustrated discriminator positions are examples. The internal representation of released energy as bin numbers is a specific feature of the sensor.

CRNS: open problems

1. Neutron detectors: instrumental effects, stability, response functions
2. Measurand definiton: sensing domain („footprint“) & penetration depth
3. Site-specific calibration procedure of CRNS detectors
4. Influence of hydrogen-rich volumes in footprint on CRNS signal
5. CRNS relies on neutron transport calculations ➔ benchmarking needed
6. Systematic effects (air pressure, humidity, incoming neutron flux intensity)
7. Reliable estimates of uncertainties

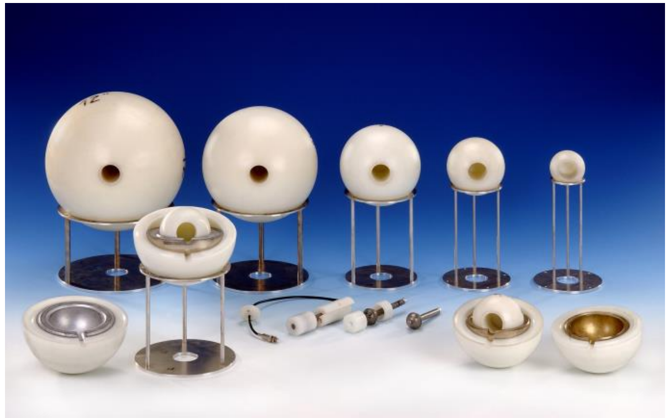
➔ Needs for metrology and traceability

Metrology of temperature and humidity

Metrology of neutron radiation

Neutron metrology in SoMMet

- Characterisation of CRNS detectors in metrology labs
- Benchmarking of MC codes for neutron transport calculations
- Neutron spectrometry in real world with Bonner sphere spectrometers
- Traceability scheme for CRNS methodology, from laboratories to the real world

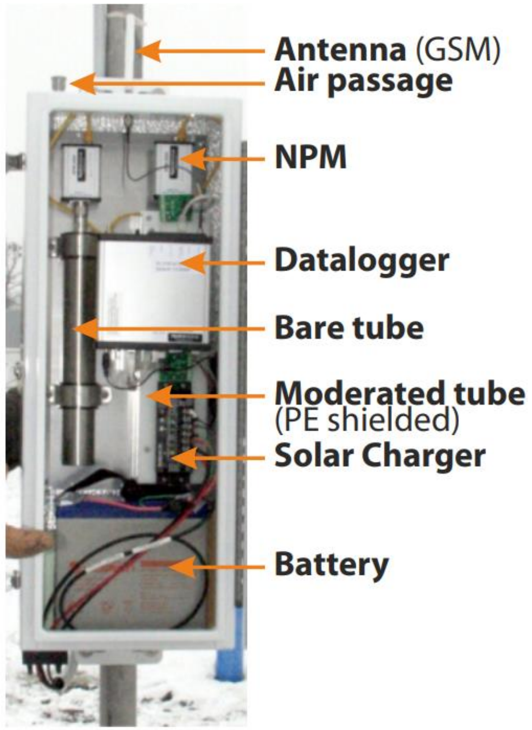


Neutron metrology in SoMMet

- Characterisation of CRNS detectors in metrology labs
  ➔ Examples of instruments:

^{3}He(n,p)
^{10}B(n,α)
^{6}Li(n,α)

Hydroinnova, USA



StyX Neutronica, DE

FINAPP, IT

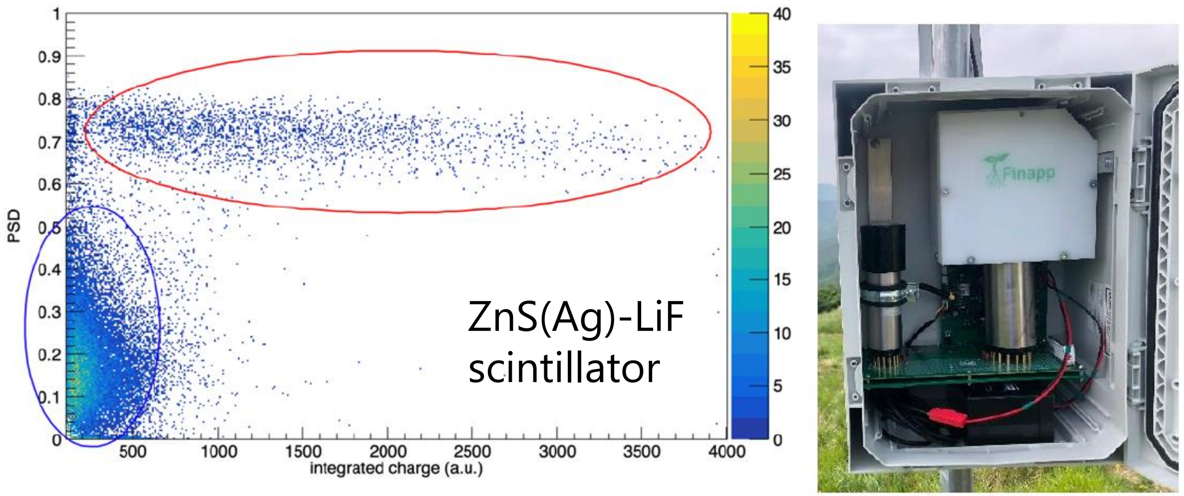


Figure 1: (left) typical PSD *vs.* integrated charge plot for a FINAPP3 detector. Red and blue ovals indicate the neutron and muon region respectively; (right) scintillator-based sensor FINAPP3 with board, photomultiplier, and the two main detectors.

[S. Gianessi, under review]

Summary & Outlook

We are interested in Collaborators!

- Addressing the needs for metrological basis and harmonization in soil moisture measurement across the scales and communities
- Development of primary & secondary standards for calibration of point-scale soil moisture sensors
- Metrologically establishing the CRNS method in labs & real world
- New calibrated data from comparison campaigns ➔ the aim is: point-scale + CRNS + drone-borne hyperspectral methods + satellite-based microwave remote sensing

Acknowledgment

- I acknowledge all Colleagues
  of the SoMMet Partners
  and the funding by the European Union.

Kick-off Meeting @PTB, October 2022

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or EURAMET. Neither the European Union nor the granting authority can be held responsible for them.

EUROPEAN PARTNERSHIP

Co-funded by the European Union

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

METROLOGY PARTNERSHIP

EURAMET