

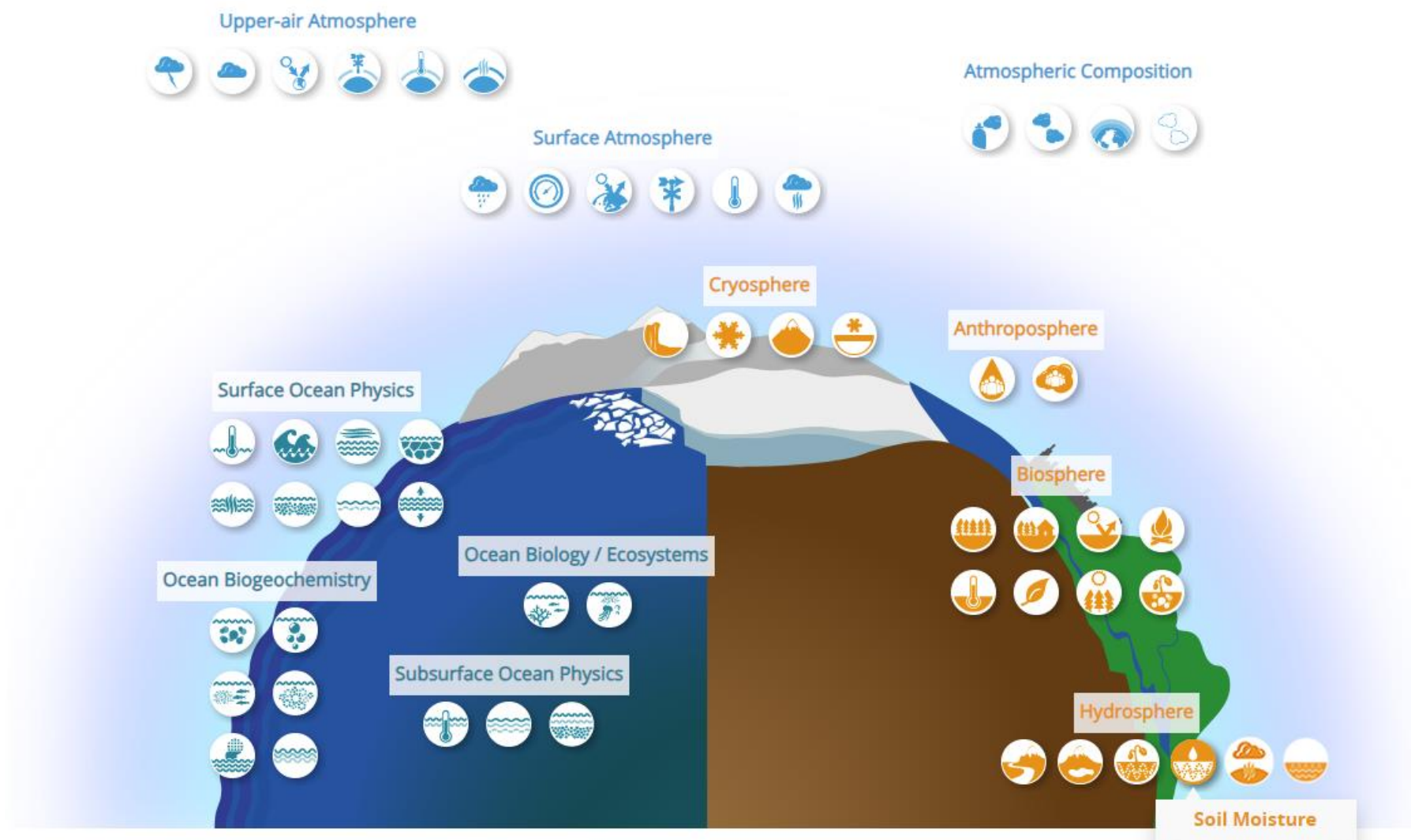
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Centro de Investigaciones Energeticas, Medioambientales y Tecnologicas (CIEMAT), Czech Metrology Institute (CMI), Danish Technological Institute (DTI), Istituto Nazionale di Ricerca Metrologica (INRIM), Institut de radioprotection et de sûreté nucléaire (IRSN), Justervesenet - Norwegian Metrology Service (JV), Slovak Institute of Metrology (SMU), Türkiye Bilimsel ve Teknolojik Arastirma Kurumu (TÜBİTAK-UME), Consiglio Nazionale delle Ricerche (CNR-IREA), Czech Technical University in Prague (CTU), Instytut Agrofizyki PAN (IAPAN), Politecnico di Milano (PoliMi), Helmholtz-Zentrum für Umweltforschung (UFZ), Ruprecht-Karls-Universität Heidelberg, Università di Bologna, Universität Potsdam, UK Centre for Ecology & Hydrology (UKCEH)

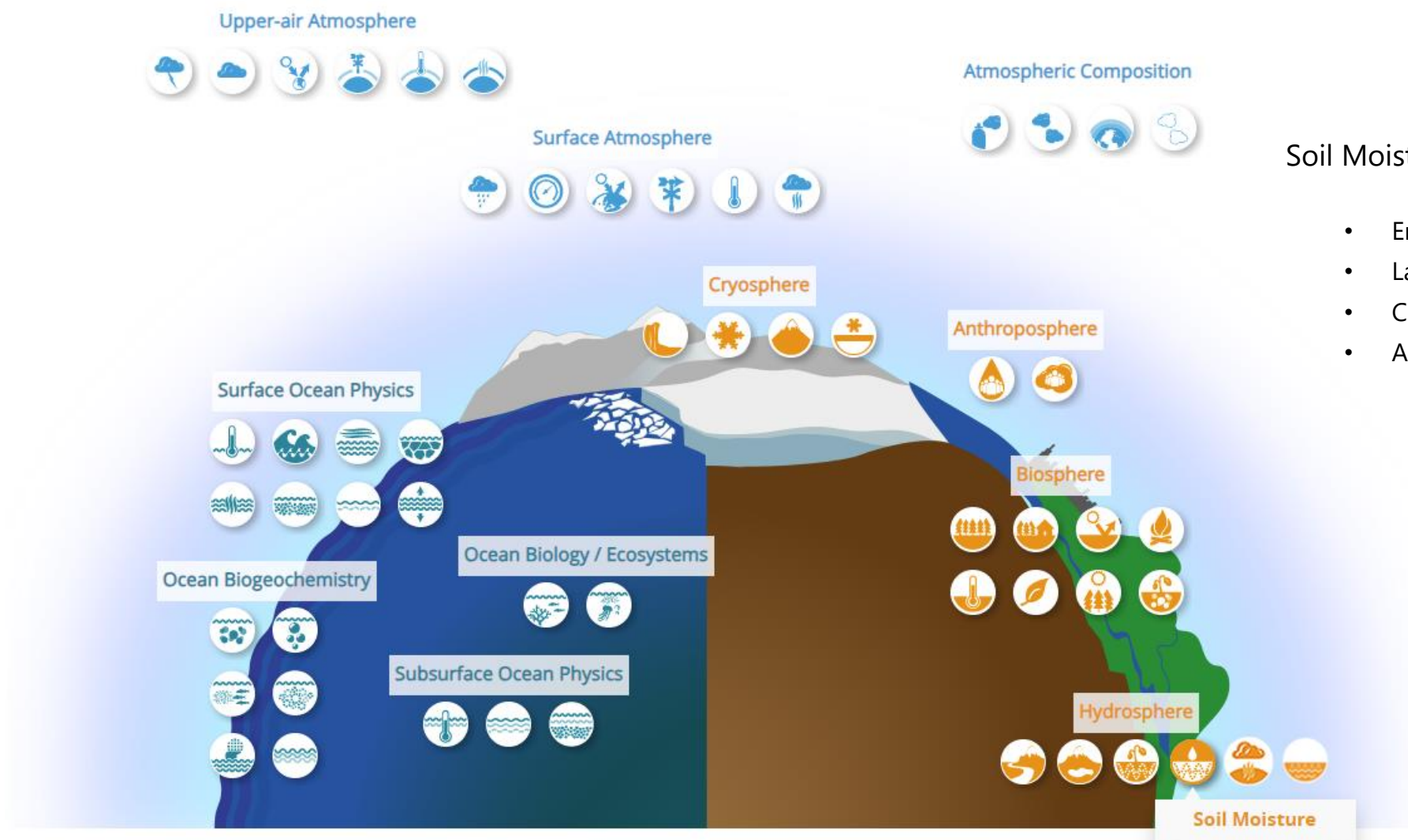




World Metrological Organization: Essential Climate Variables



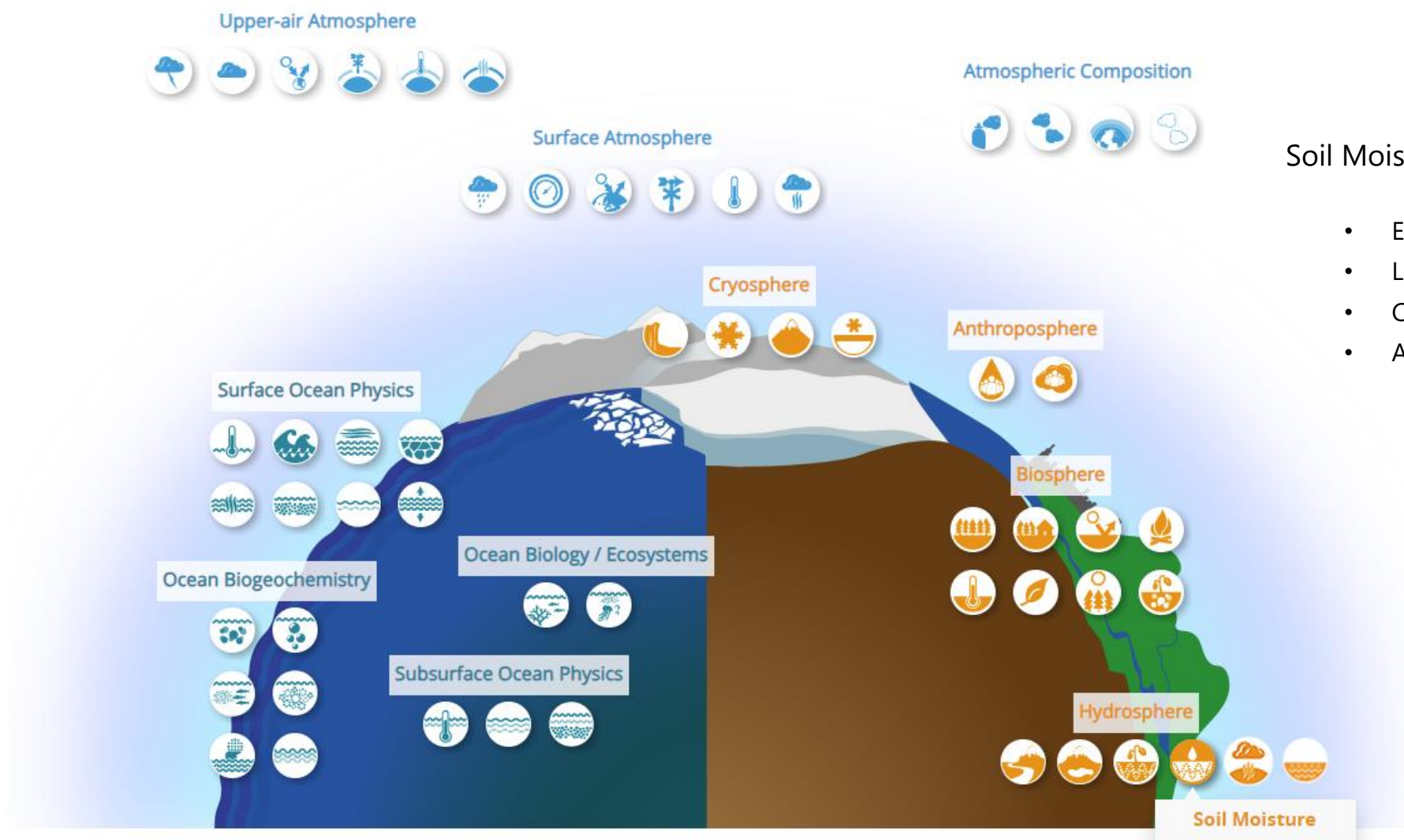
World Metrological Organization: Essential Climate Variables



Soil Moisture:

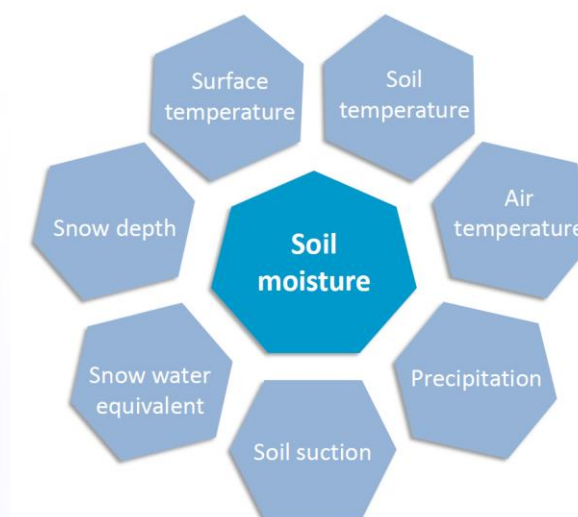
- Energy transfer
- Land-atmosphere interactions
- Climate and vegetation
- Agriculture, Forestry, ecosystem Health

World Metrological Organization: Essential Climate Variables

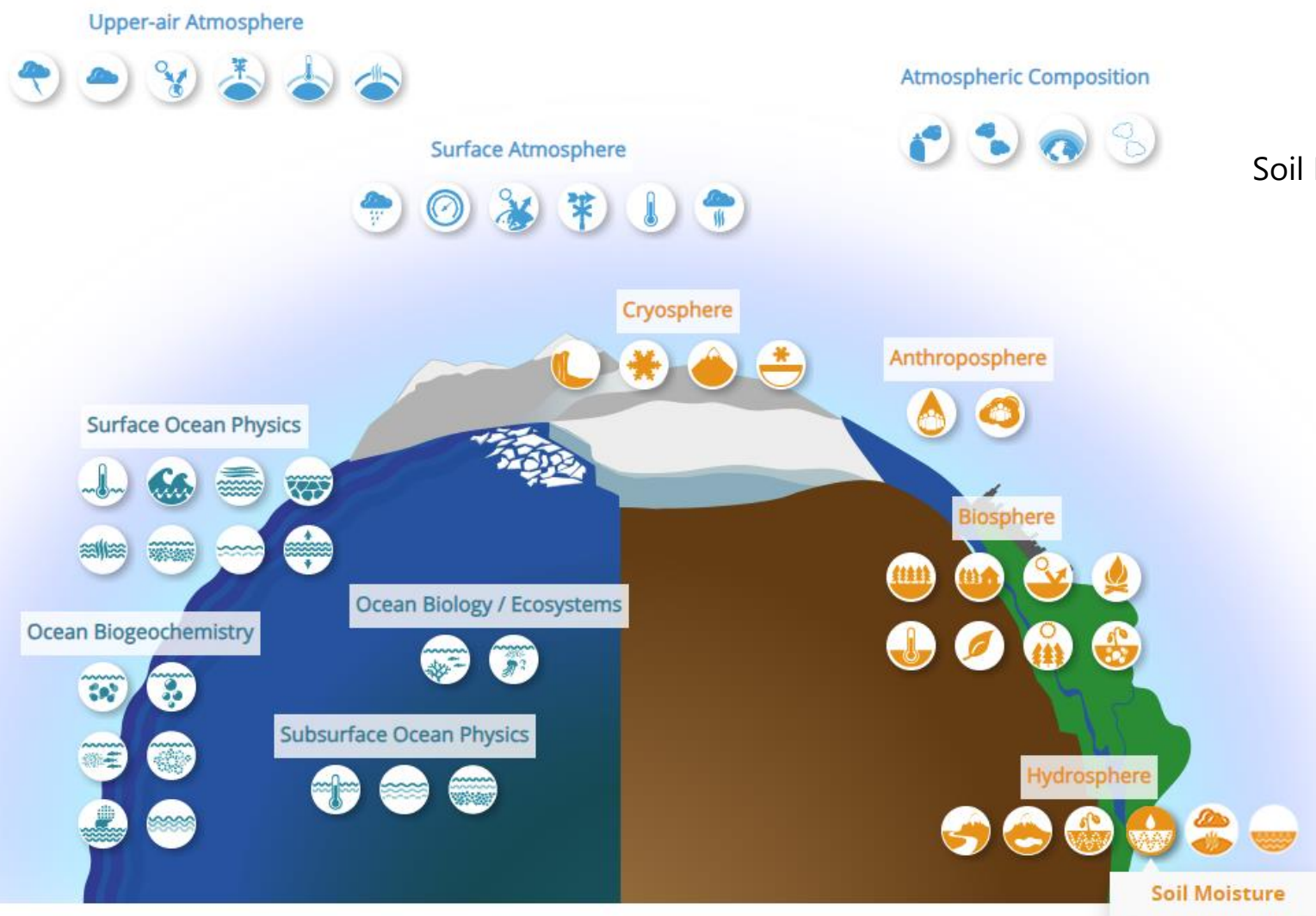


Soil Moisture:

- Energy transfer
- Land-atmosphere interactions
- Climate and vegetation
- Agriculture, Forestry, ecosystem Health



World Metrological Organization: Essential Climate Variables



Soil Moisture:

- Energy transfer
 - Land-atmosphere interactions
 - Climate and vegetation
 - Agriculture, Forestry, ecosystem Health
-
- Progressing climate change
 - Extreme events (floods, droughts)
 - Water scarcity
 - Agriculture: Water management

Global Hydrological Data

WMO action plan for Hydrology (2020 –2030)

1. No one is surprised by a flood
2. Everyone is prepared for drought
- ➔ 3. Hydro-climate and meteorological data support the food security agenda
4. High-quality data supports science
5. Science provides a sound basis for operational hydrology
- ➔ 6. We have a thorough knowledge of the water resources of our world
- ➔ 7. Sustainable development is supported by information covering the full hydrological cycle
8. Water quality is known

UNESCO IHP IX Priority areas 2022 –2029

1. Scientific Research and Innovation
2. Water Education for the Fourth Industrial Revolution including sustainability
- ➔ 3. Bridging the data and knowledge gaps
- ➔ 4. Integrated and Inclusive Water Resources Management under conditions of global change
5. Water Governance based on science for mitigation, adaptation and resilience



Global Data Management: GCOS

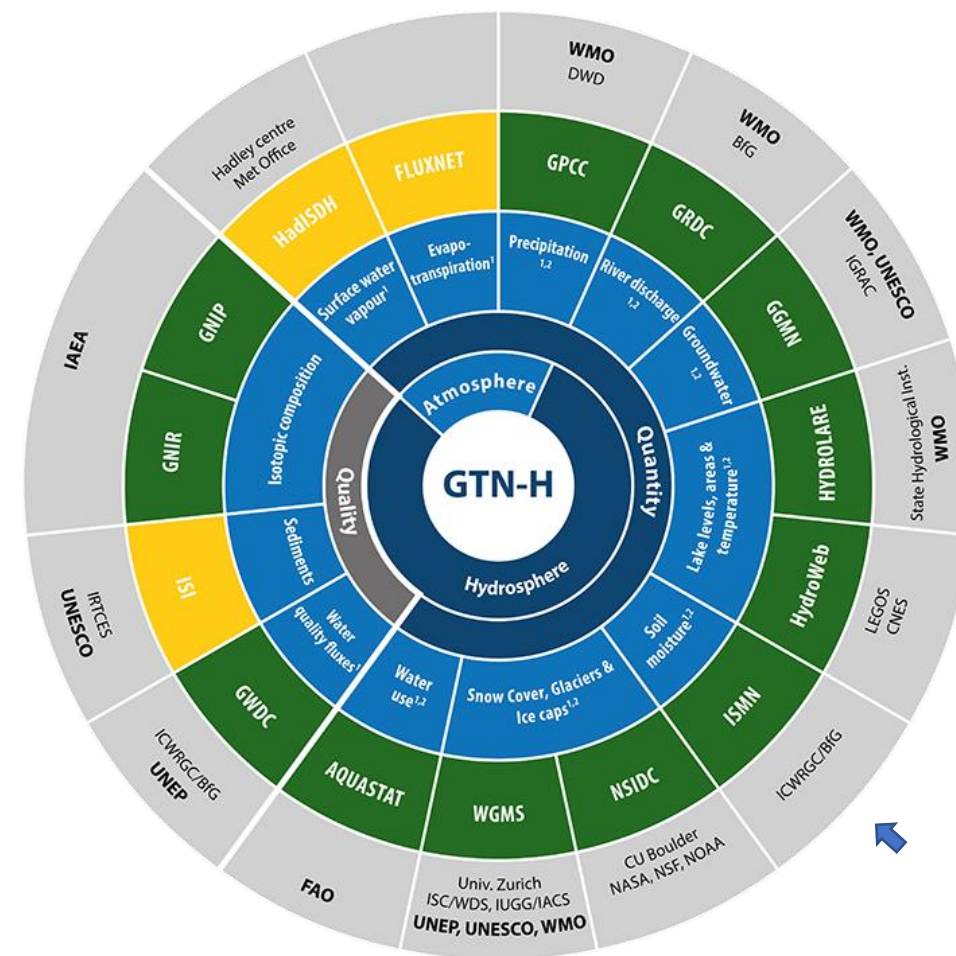


Network of the global water data centres,
In-situ focus

Joint programme of the World
Meteorological Organization (WMO) and
the Global Climate Observing System
(GCOS); implemented in 2001


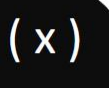
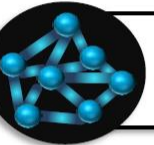





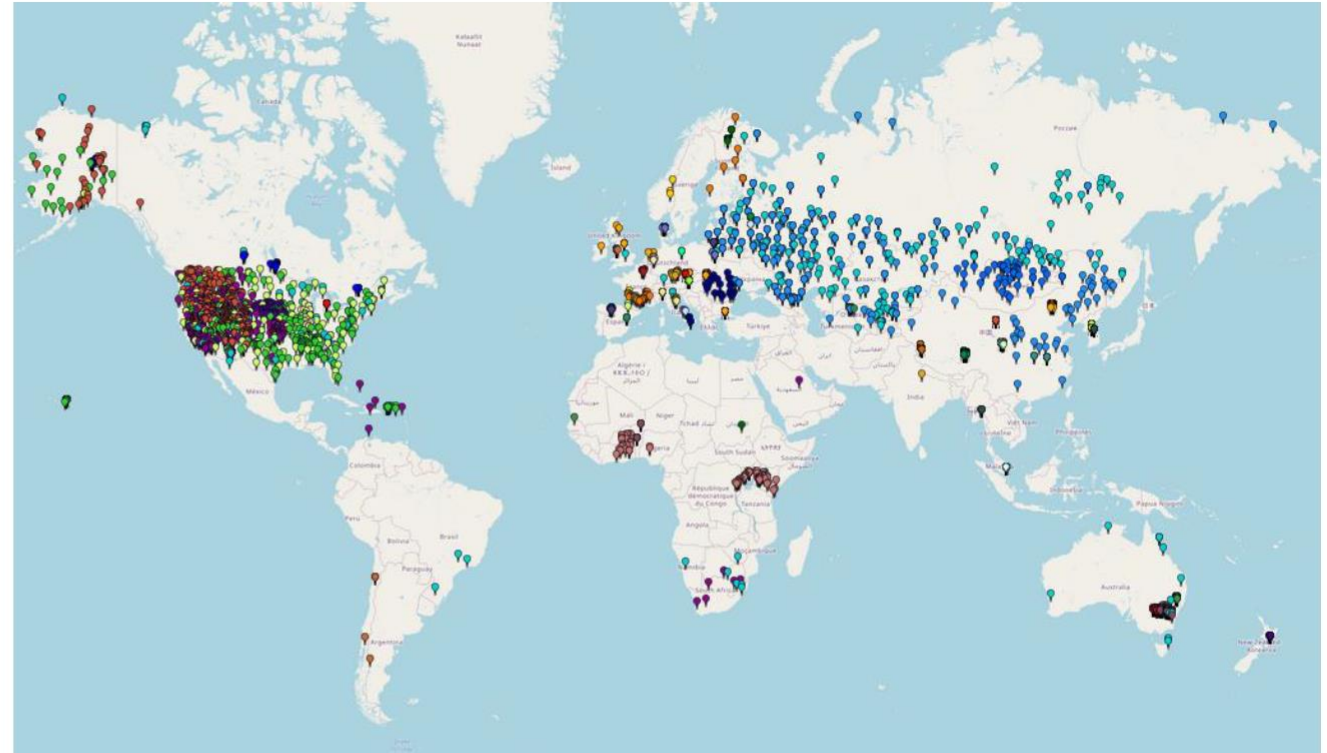
WORLD
METEOROLOGICAL
ORGANIZATION



- Variable, ¹GCOS Essential Climate Variable, ²GEO Essential Water Variable
- GTN-H member network
- Global network/identified/suggested to join GTN-H

Global Data Management: International Soil Moisture Network

-  **In situ data + metadata**
-  **Soil moisture + 7 additional variables integrated in the DB**
-  **73 networks participate (June 2022)**
-  **>2900 stations with several depths integrated (June 2022)**
-  **Time series available from 1952 up to near real time (see graph)**
-  **Daily update of 6 NRT networks → ~1000 stations (June 2022)**

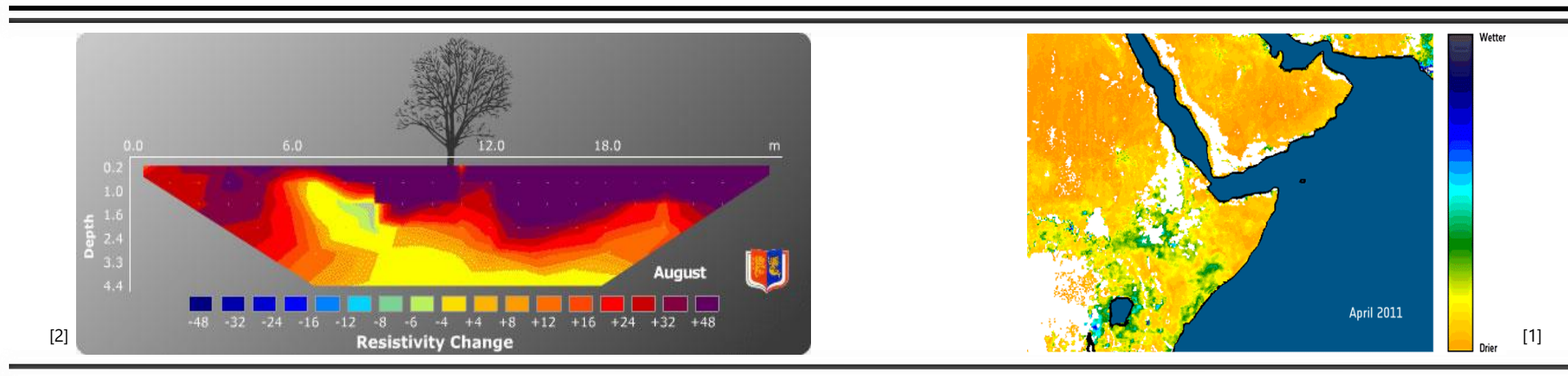


Distribution of the soil moisture stations

The scale gap

< 10 m

~ 1 km



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

via
satellite remote sensing
(optical, microwave)

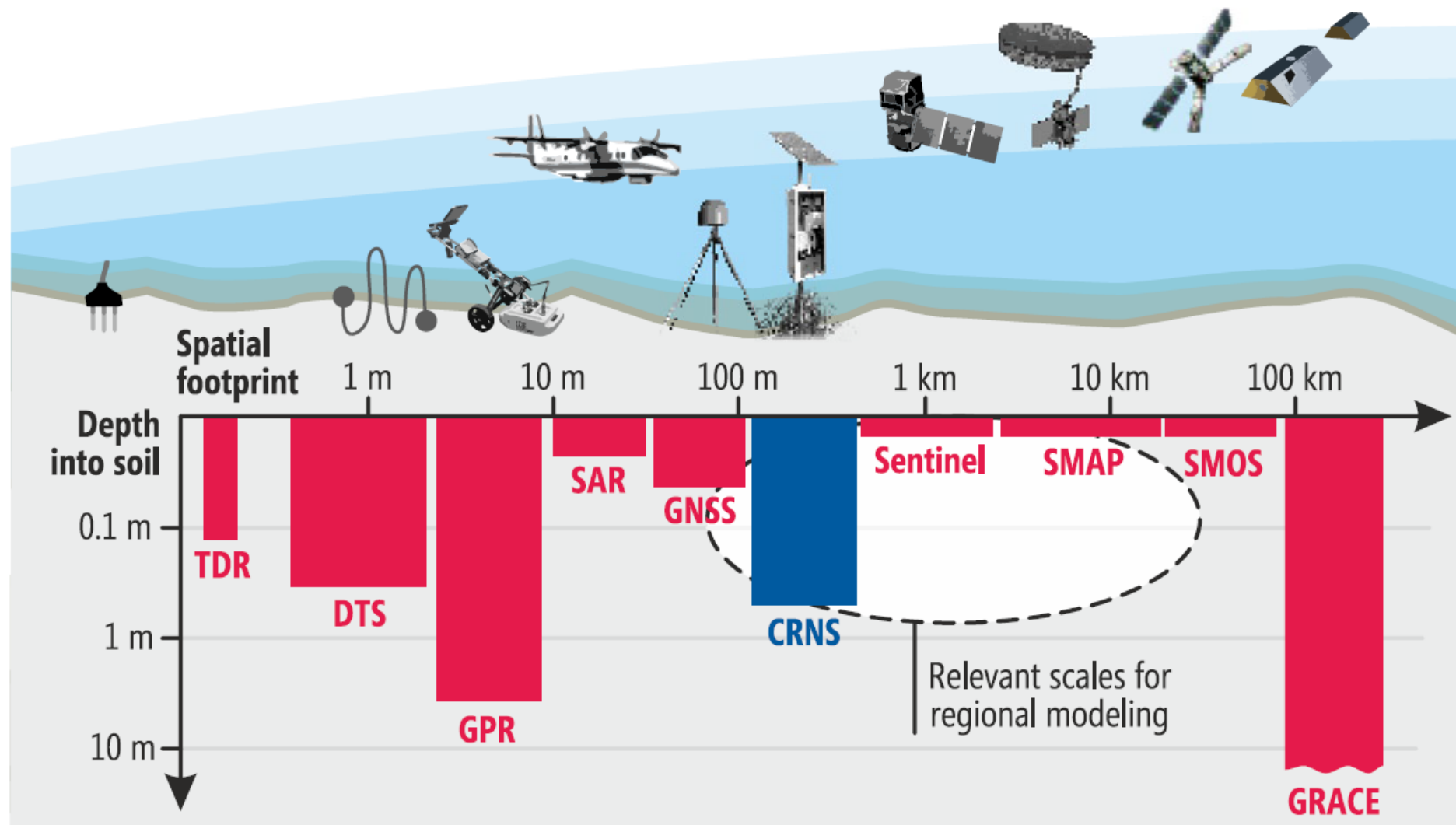
[1] ESA SMOS (http://www.esa.int/Our_Activities/Observing_the_Earth/SMOS/Horn_of_Africa_drought_seen_from_space)

[2] The Clay Research Group (<http://www.theclayresearchgroup.org/images/ert.jpg>)

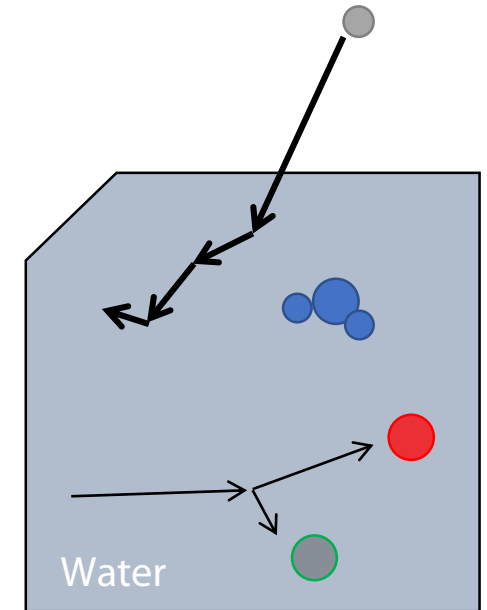
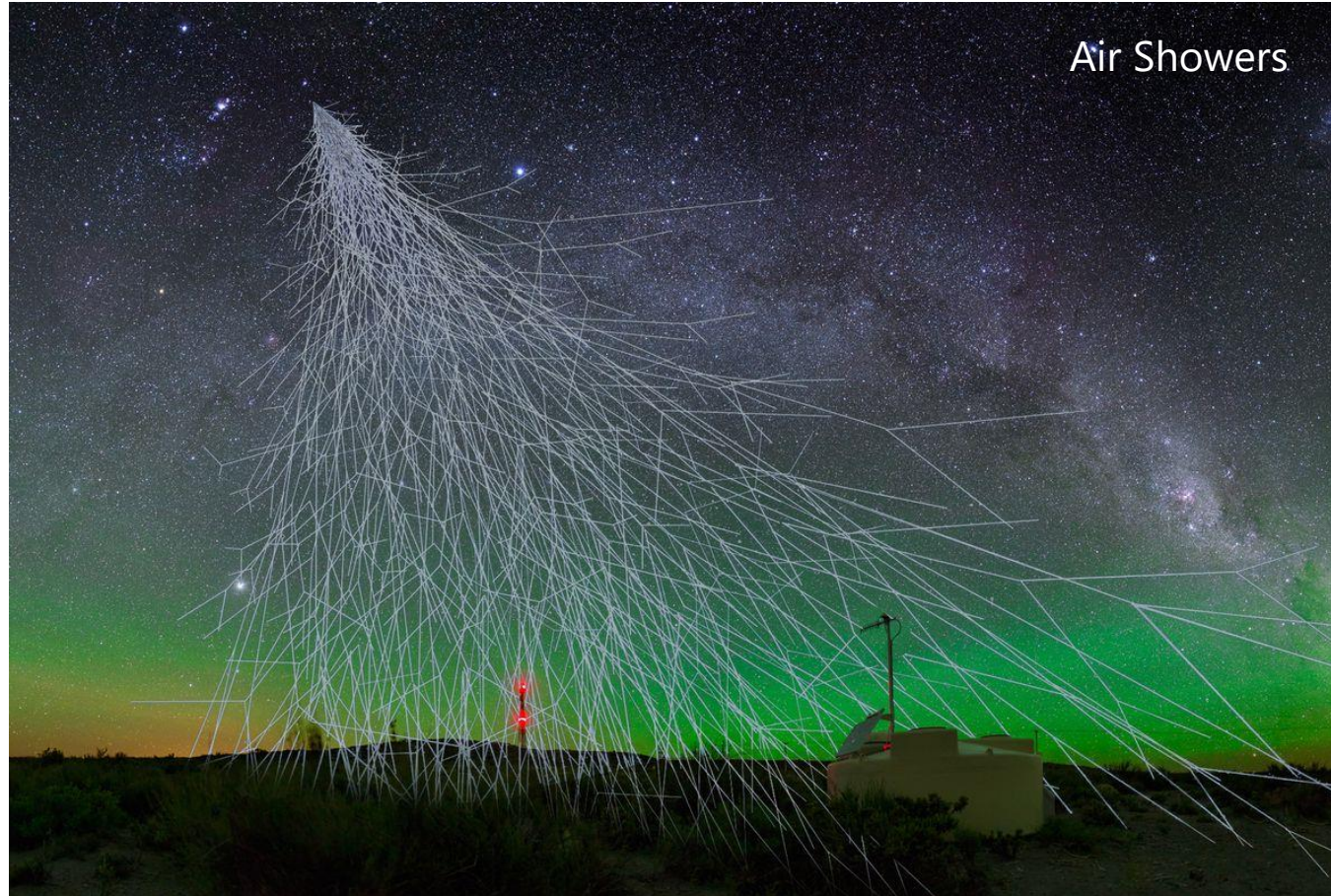
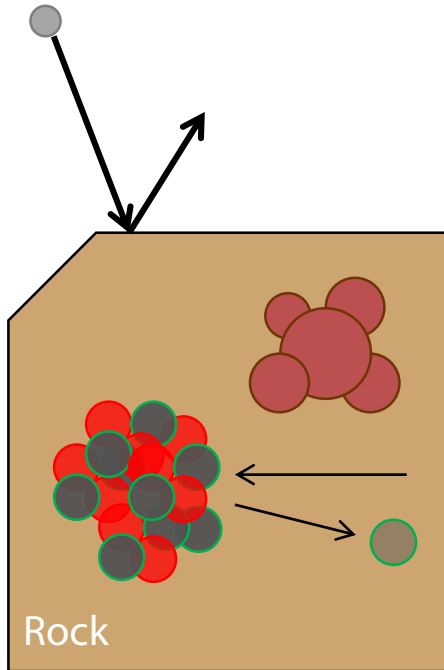
Difference between both



Soil moisture measurement methods

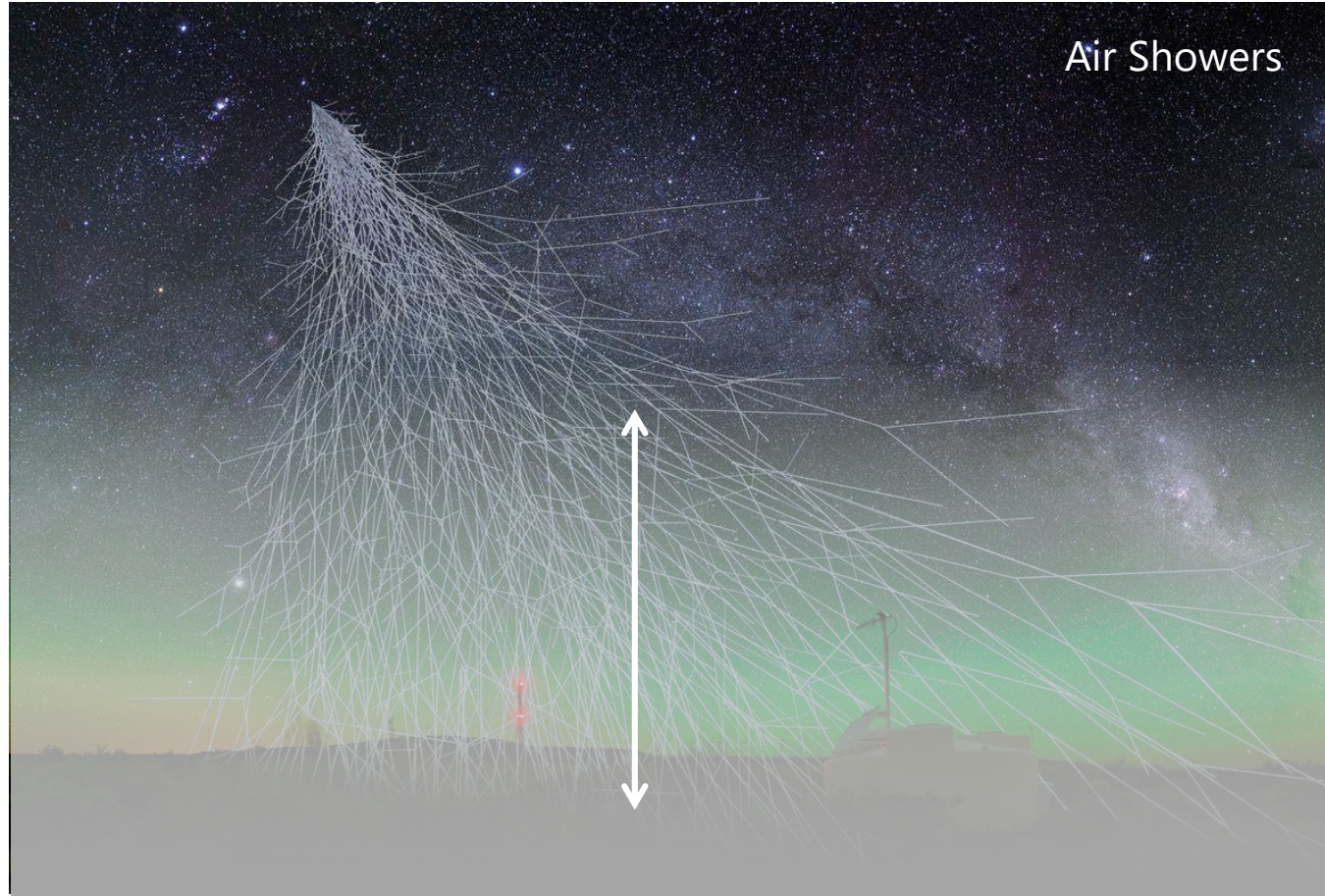
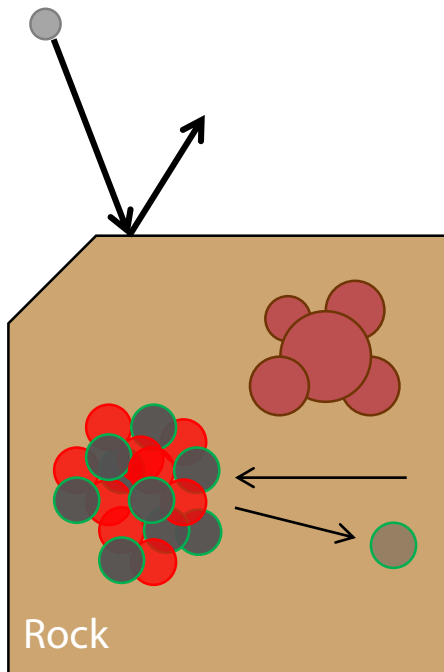


CRNS Method

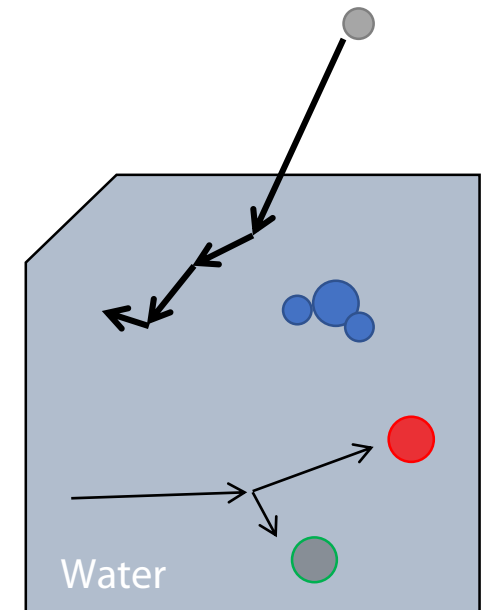


[1]

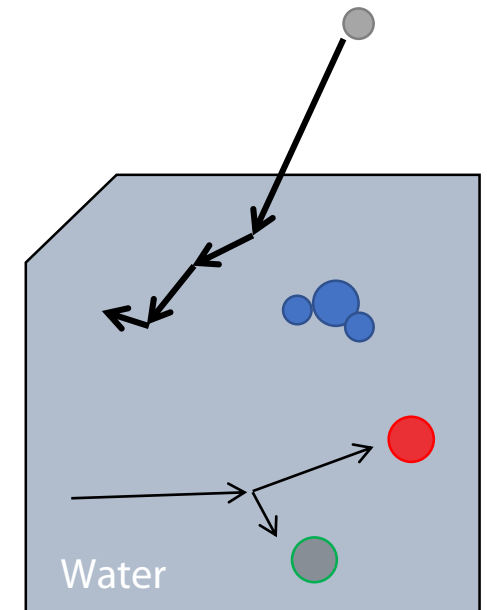
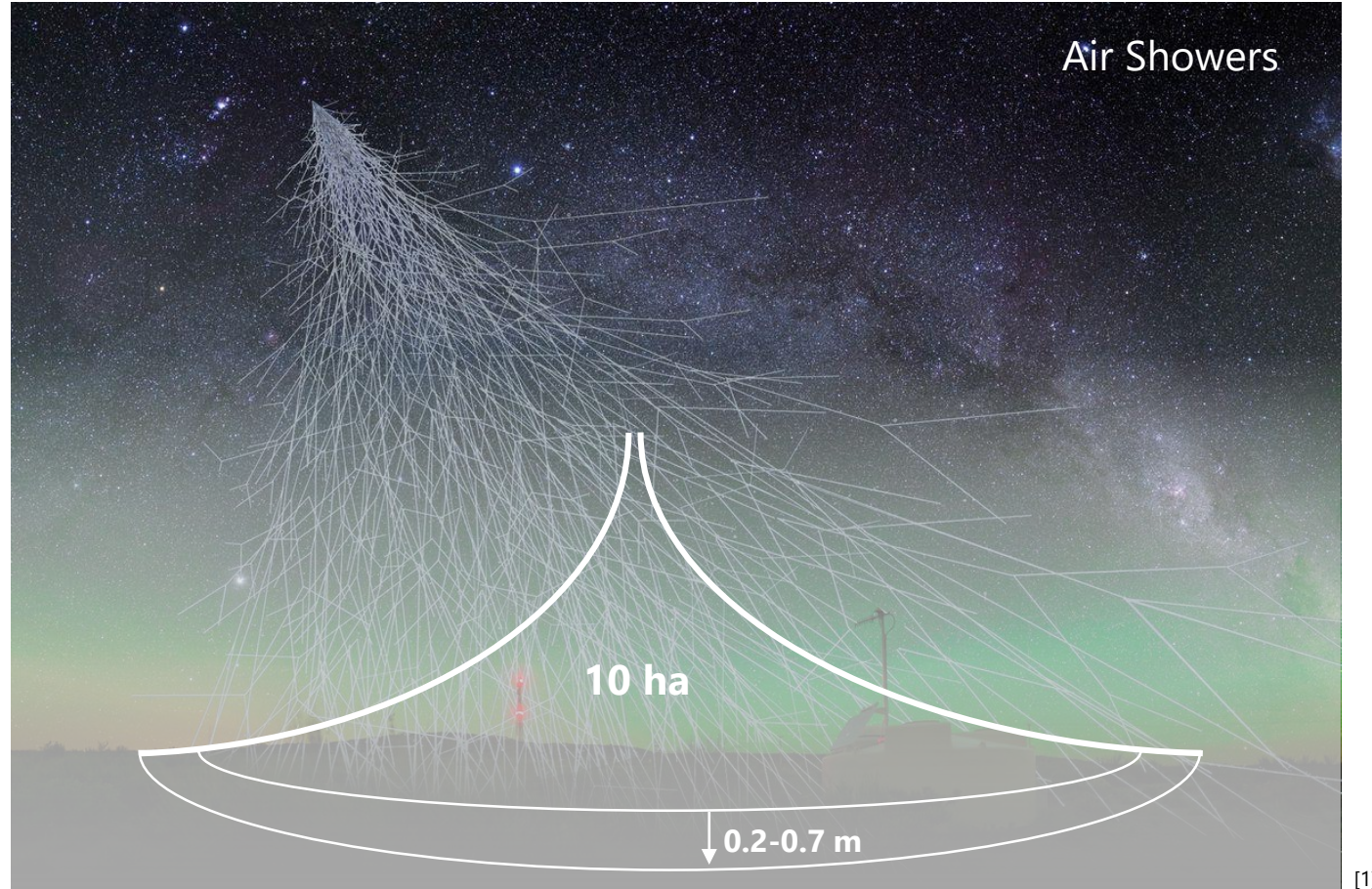
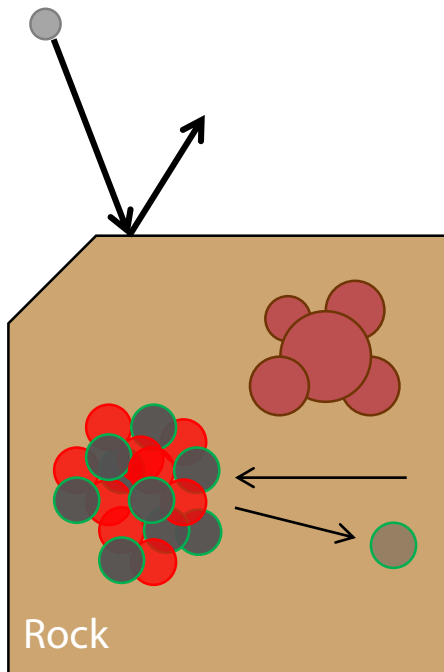
CRNS Method



[1]



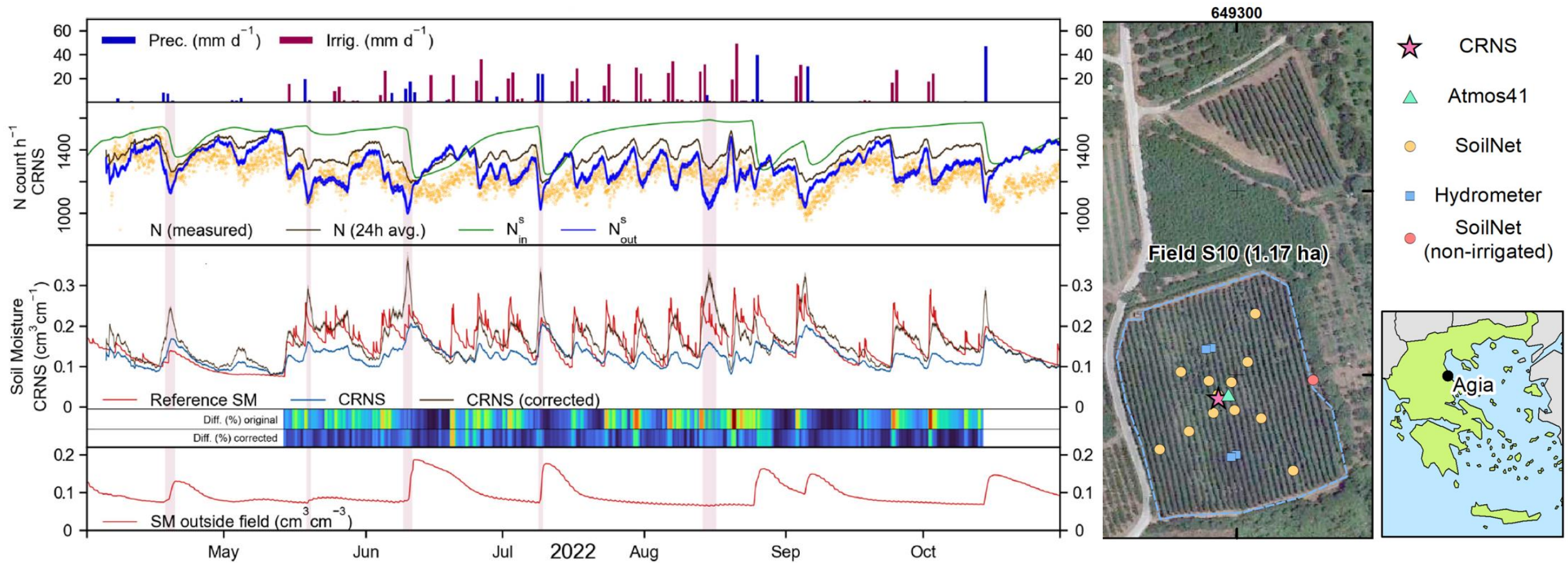
CRNS Method



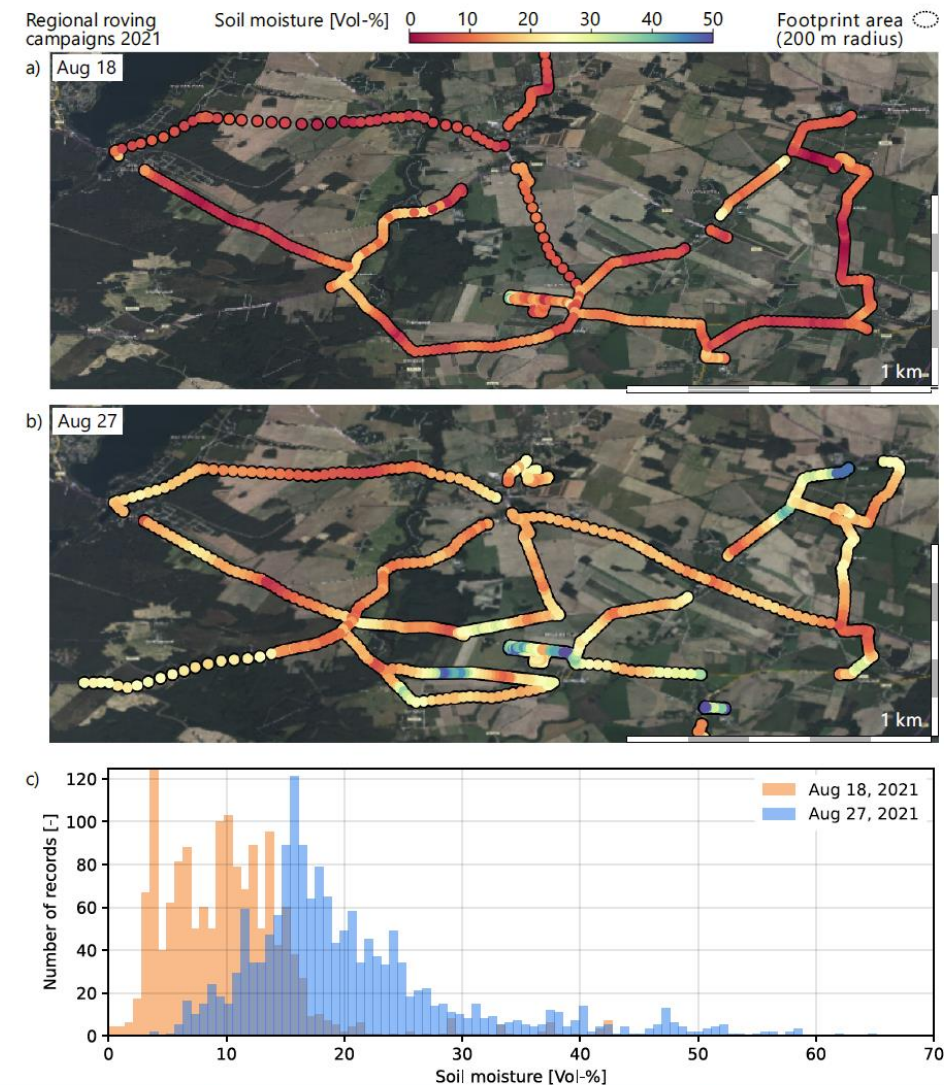
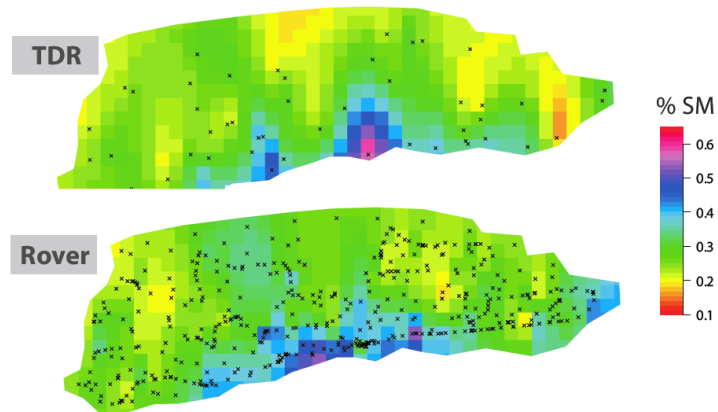
CRNS Sensors



CRNS Example: Irrigation



CRNS Example: Roving



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

PROJECT PARTNERS

EXPERIMENTAL SITES

PROJECT PARTNERS

PTB
Coordination, Lead WP6

IRSN
INSTITUT DE RADIOPROTECTION ET DE SÛRETÉ NUCLÉAIRE

Universität Potsdam
Lead WP2

UK Centre for Ecology and Hydrology

IMPACT

Google My Maps

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IMPACT

Google My Maps

PROJECT PARTNERS:



Coordination, Lead WP6



Lead WP5



Justervesenet

TÜBİTAK



Lead WP

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

Lead WP3



POLITECNICO
MILANO 1863



Lead WP4



UK Centre for
Ecology & Hydrology



HELMHOLTZ
Zentrum für Umweltforschung



INSTITUTE OF
AGROPHYSICS
P A S

IMPACT & SUPPORT:



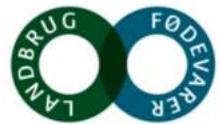
**Agenzia
Spaziale
Italiana**

United Nations
Educational, Scientific and
Cultural Organization

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

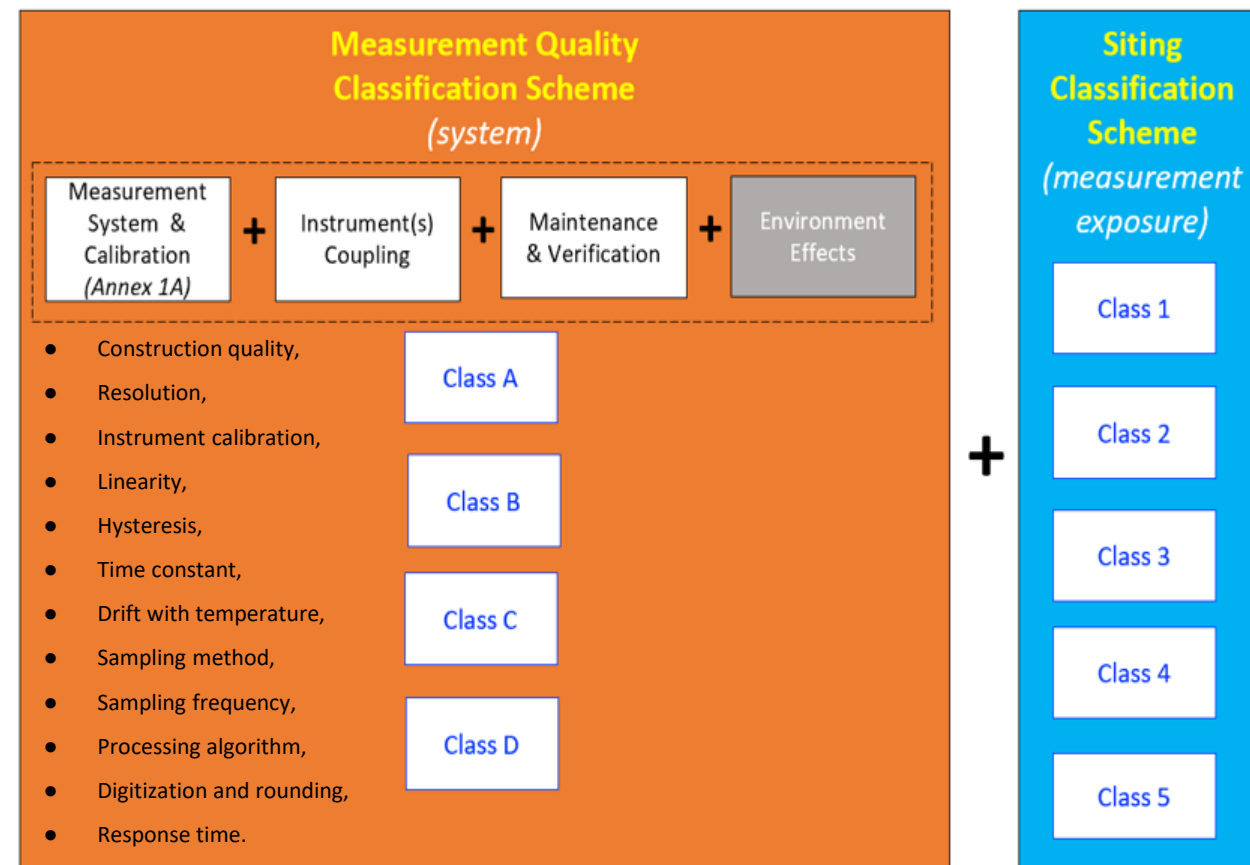
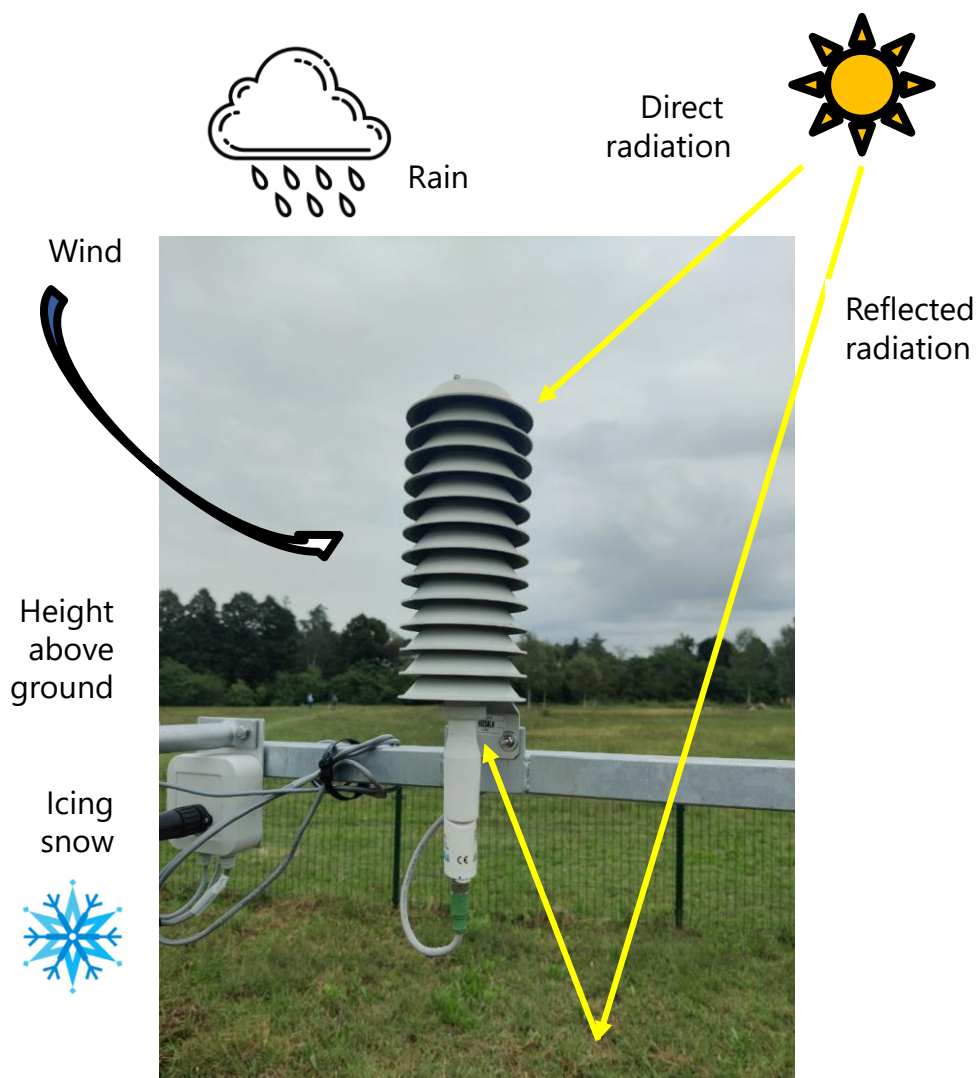


Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Norwegian University
of Life Sciences

SI-tracable measurement on the point scale

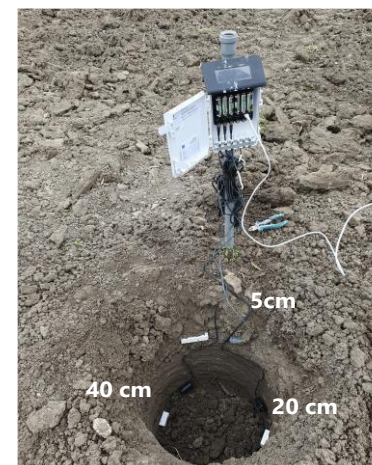
WP1: **Traceability** WP3: Harmonization
WP2: Validation WP4: Data fusion



SI-tracable measurement on the point scale

- Calibration facilities for point scale sensors
 - Primary measurement methods and transfer standards
 - Provide a tracability scheme to CRNS

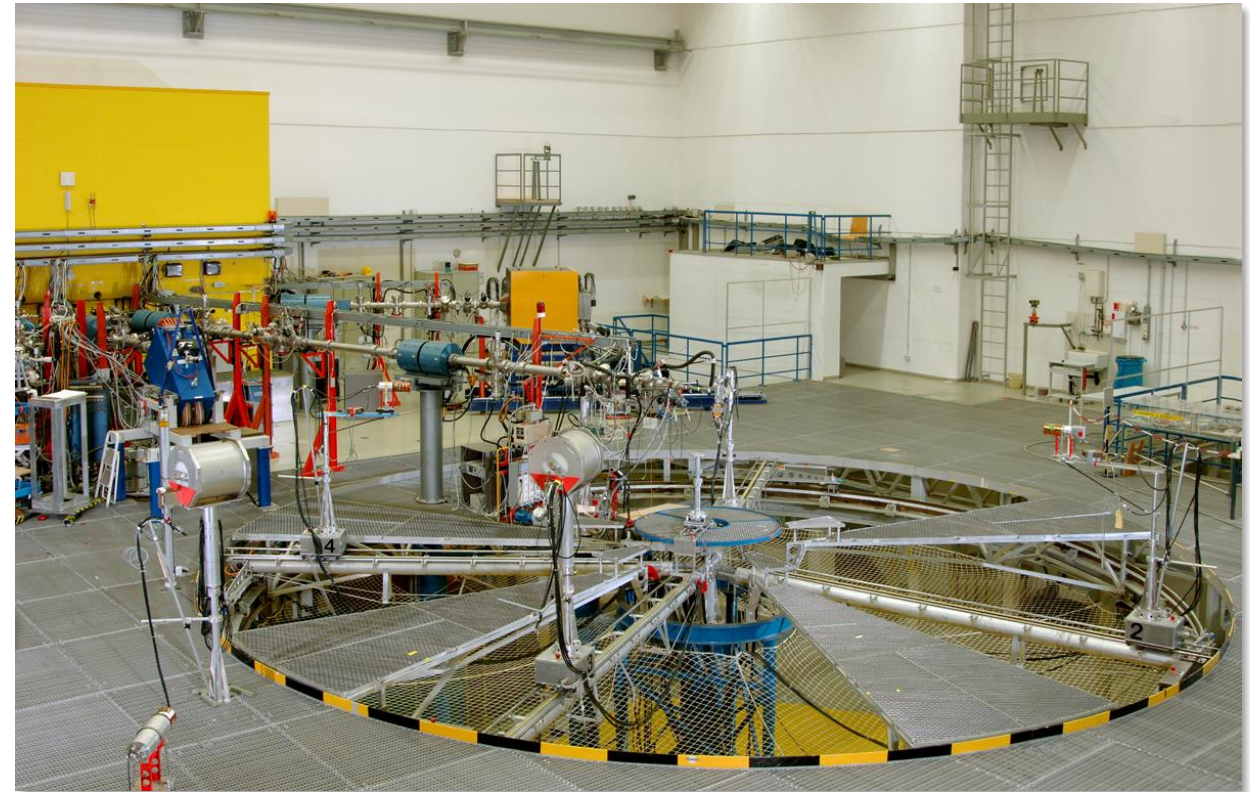
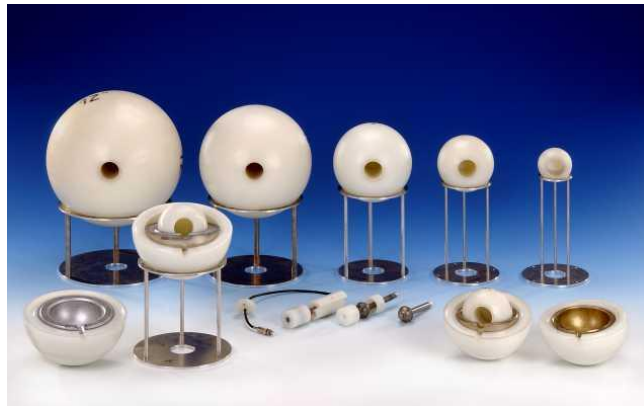
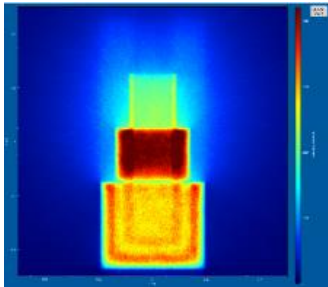
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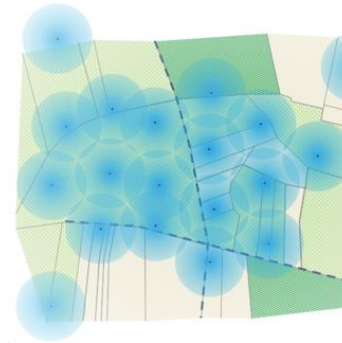
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WP1: **Traceability** WP3: Harmonization
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Development of CRNS validation practices

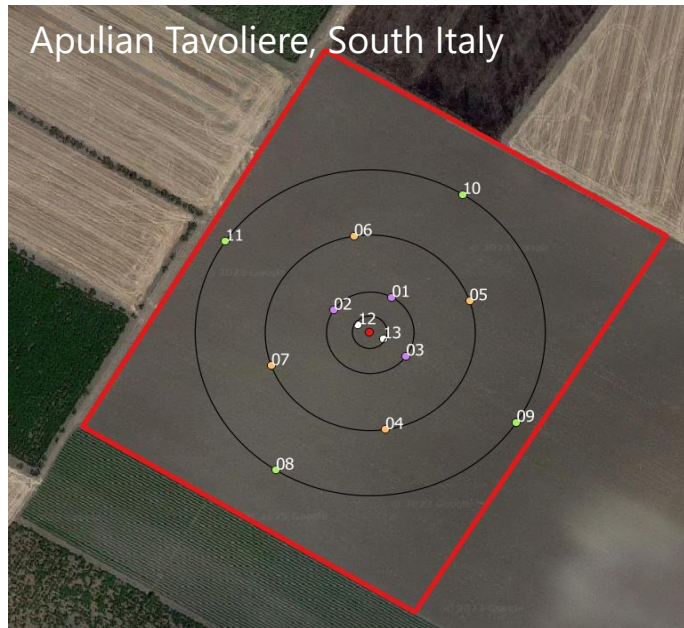
- Three 'high level' test sites selected
- Characterized, equipped with in-situ sensors
- Validation of neutron transport models
 - Uncertainty evaluation under environmental conditions (heterogeneity, changing vegetation, irrigation)



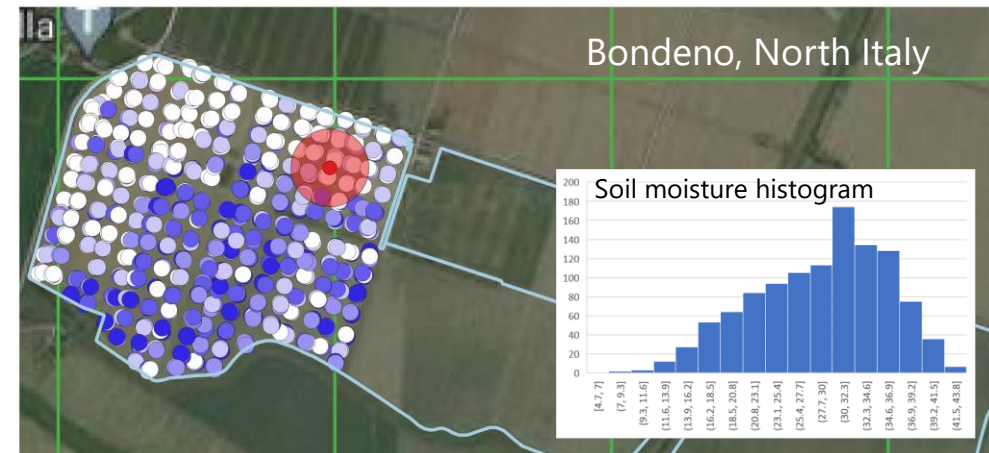
WP1: Traceability WP3: Harmonization
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ATB Marquardt, Potsdam



Apulian Tavoliere, South Italy



Bondeno, North Italy

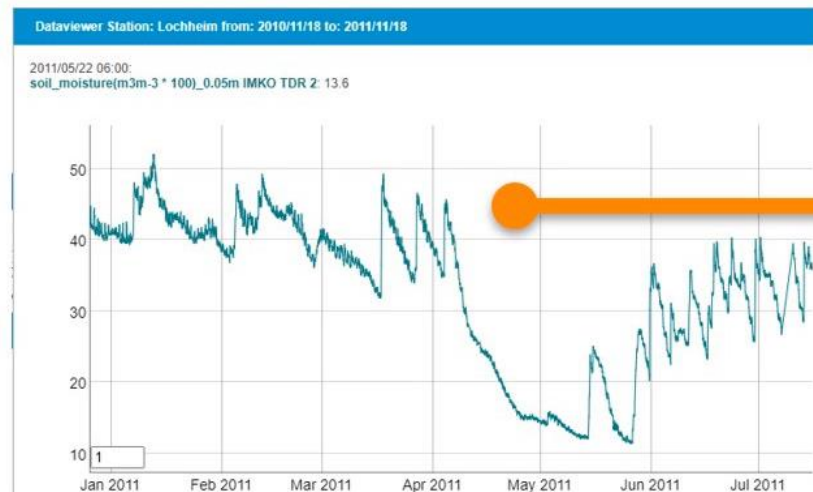
Comparison and harmonization of soil moisture measurement methods at multiple spatial and temporal scales

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

- Comparison of methods, their constraints and different spatial and temporal characteristics
- Development of an approach to harmonize point scale, field scale and remote sensing

Point-scale *in situ* measurements

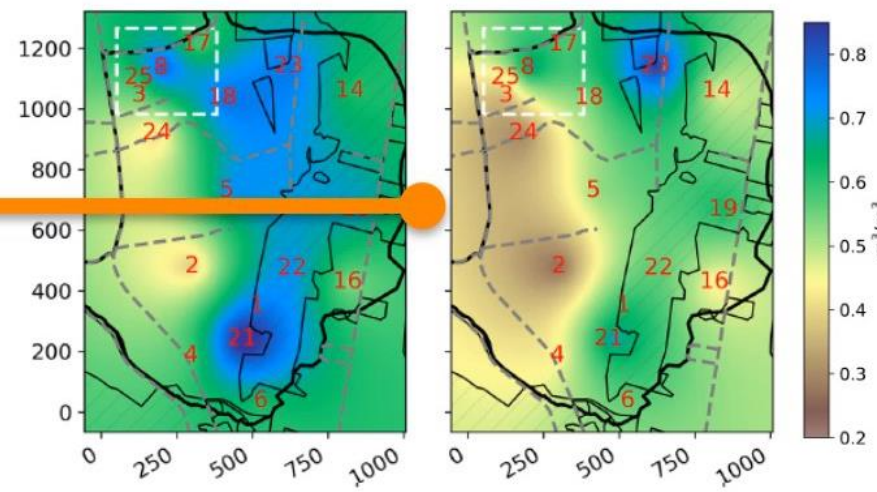
Example: Time series of a single sensor



[International Soil Moisture Network]

Cosmic-ray neutron sensing

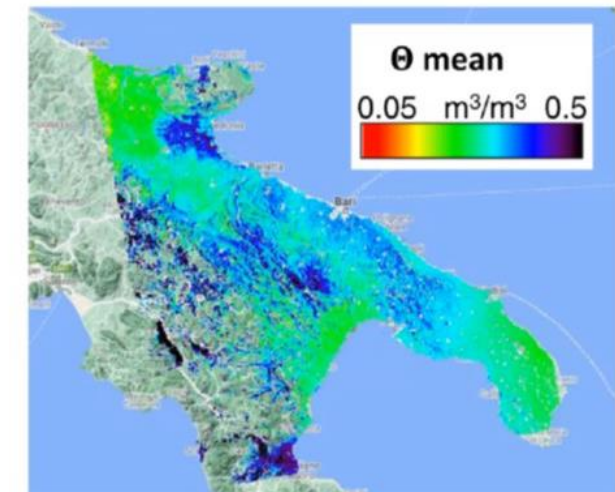
Example: Daily average soil moisture at catchment scale



[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]

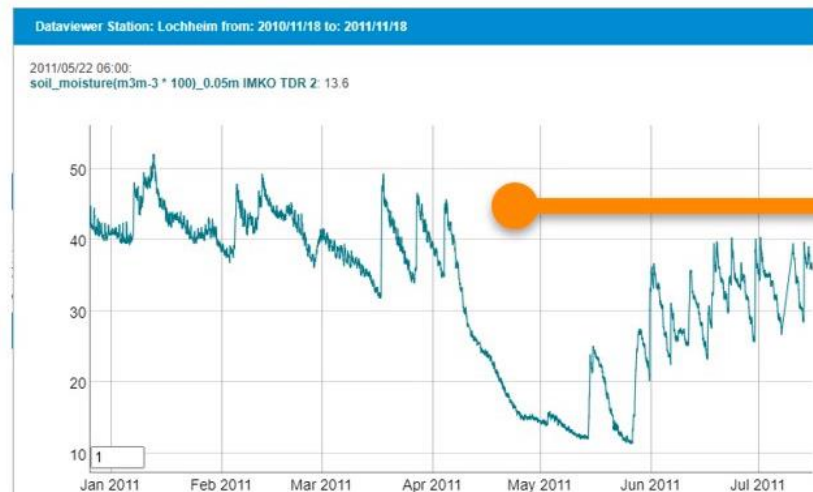
Multi-scale and multi-disciplinary data fusion

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

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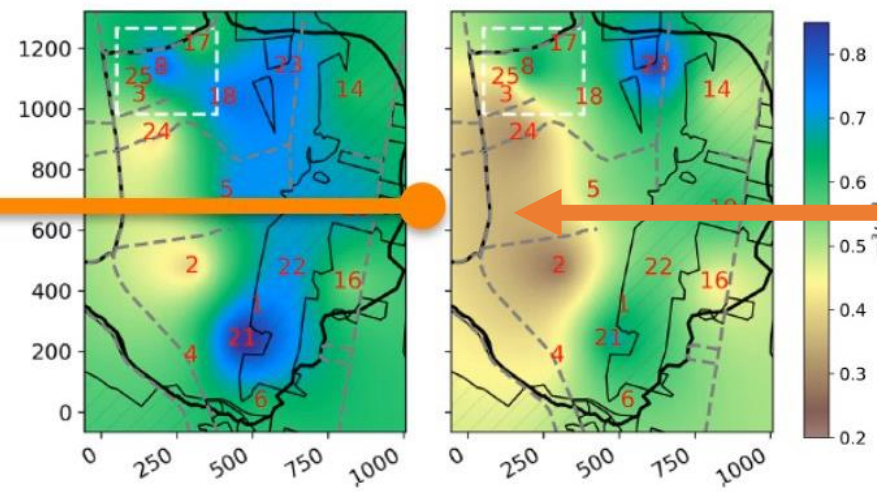
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[International Soil Moisture Network]

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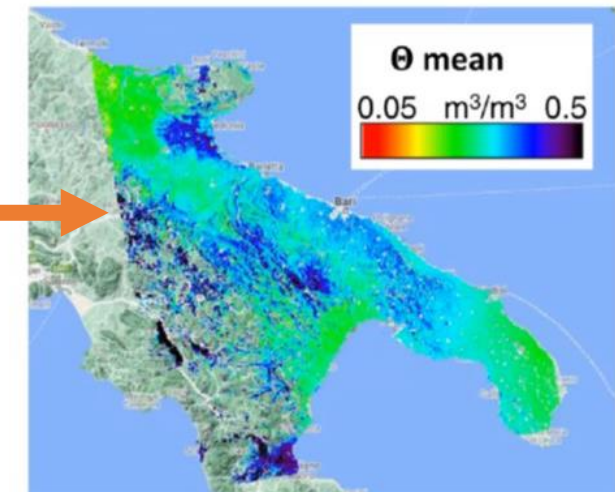
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Metrology for multi-scale monitoring of soil moisture

'Soil Moisture Metrology' (SoMMet) – a project within framework of the European Partnership on Metrology



European Partnership

Co-funded by the
European Union

**METROLOGY
PARTNERSHIP**



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.

Gefördert durch



Deutsche
Forschungsgemeinschaft

FOR 2394

Markus Köhli for the SoMMet collaboration:

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- On the point scale (10^{-1} m - 10^1 m): primary and secondary standards of measurements, specifically for soil samples

Traceability – Validation - Harmonization - Data fusion



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- On the intermediate range (10^2 m - 10^3 m): establish the metrological basis of the CRNS in laboratory and outdoors
- On the large scale (10^3 m - 10^4 m): utilize satellite-based remote sensing products

Traceability – Validation - Harmonization - Data fusion



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