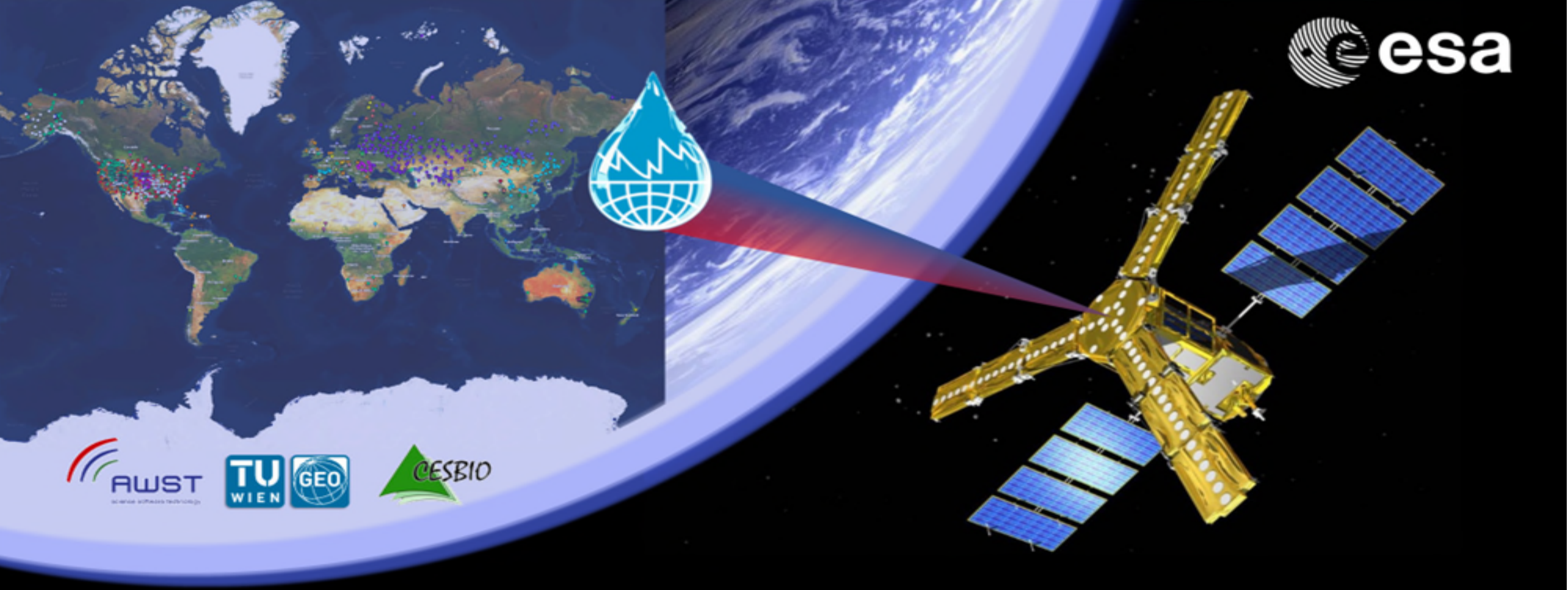

FRM4SM

Fiducial Reference Measurement for Soil Moisture II May 2021 – May 2023

Irene Himmelbauer[1], Daniel Aberer[1], Alexander Gruber[1], Wolfgang Preimesberger[1], Pietro Stradiotti[1], Wouter Dorigo[1], Monika Tercjak[2], Alexander Boresch[2], Arnaud Mialon[3], Francois Gibon[3], Philippe Richeaume[3] , Yann Kerr[3], Raul Diez Garcia[4], Raffaele Crapolicchio[4], Roberto Sabia[4], Klaus Skipal[4], Philippe Goryl[4]

Kick off SoMMet project October 12th 2022 II ISMN: ismn.earth II QA4SM: qa4sm.eu II

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[2] AWST: www.awst.at
[3] CESBIO: www.cesbio.cnrs.fr
[4] ESA: https://earth.esa.int/eogateway

Outline

1) Outline
2) FRM and FRM4SM objectives
3) FRM4SM starting point
4) Challenges to overcome
5) In situ data quality, traceability & standards - ISMN
6) SMOS validation studies
7) Providing a standatized validation system - QA4SM
8) Conclusion

FRM and FRM4SM objectives

Fiducial Reference Measurements (FRMs)

- Fully characterized & traceable in situ measurements following community-agreed guidelines (GEOS/CEOS QA4EO framework)
  - EO data easily & openly accessible
  - Data with associated Quality Indicator (QI) → to evaluate its fitness for purpose
  - Traceable QIs → internationally agreed reference standards (SI if possible)

ESA's FRM activities typically comprise activities:

- Establishing ground-based FRM networks for a particular variable
- Specify the protocols and procedures to establish and use such FRM data
- Validate relevant satellite products against established FRM data

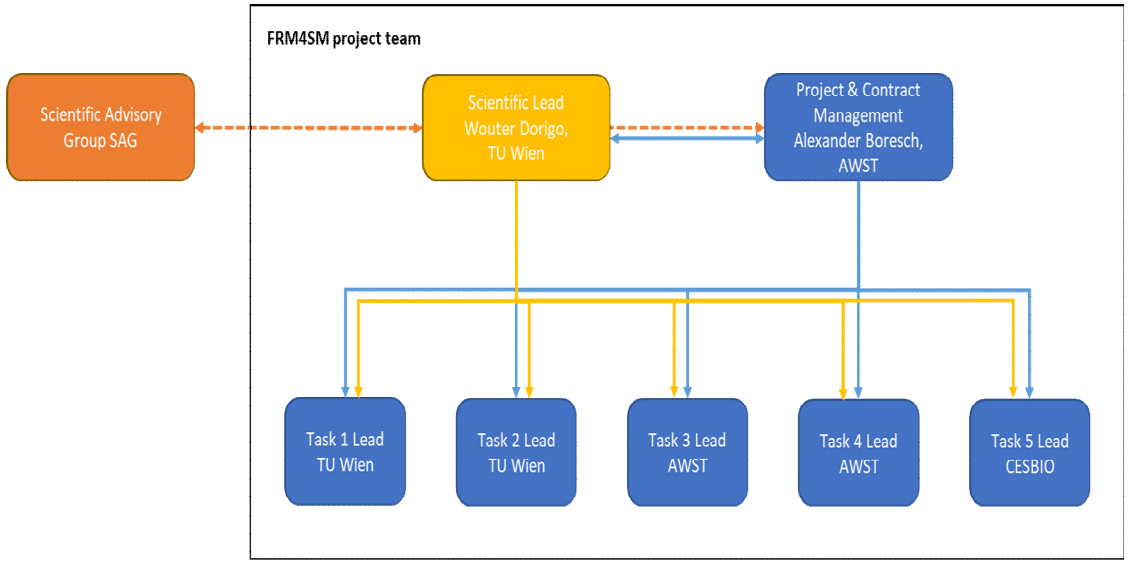
FRM4SM targets all the above goals through:

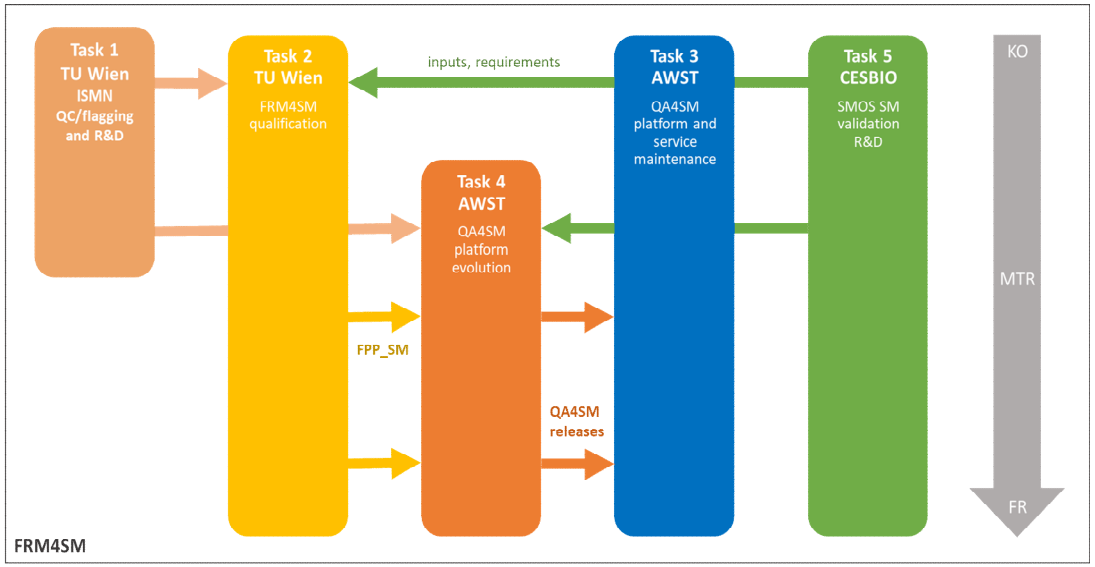
- Evolution of the International Soil Moisture Network
- Evolution of the Quality Assurance for Soil Moisture (QA4SM) platform
- Development of an "FRM Protocols and Procedures" document
- Improvement of uncertainty understanding in SSM observations — ISMN/ SMOS validation case studies

FRM4SM objectives

FRM4SM (May 2021 – May 2023)

- 4 Partners + SAG:
  - **TU Wien:** Department for Geodesy and Geoformation - Research Unit Climate and Environmental Remote Sensing, Vienna (Austria)
  - **AWST:** Applied Science, Software and Technology, private company, Vienna (Austria)
  - **CESBIO:** Center for the Study of the Biosphere from Space – SMOS Expert team, Toulouse (France)
  - **ESA:** FRM4SM comes out of the Quality Assurance for Earth Observation framework, Telespazio/Frascati (Italy)
  - **SAG:** Scientific Advisory Group (currently 10 experts) —> SoMMet a possible stackeholder?





FRM4SM Team

AWST

- **Alexander Boresch: Project Manager, Task 3 & 4 Lead**
- Monika Tercjak: Lead SW Engineer QA4SM (Task 3)
- Zoltan Bakcsa: Software & DevOps Engineer QA4SM (Task 3)

TU Wien

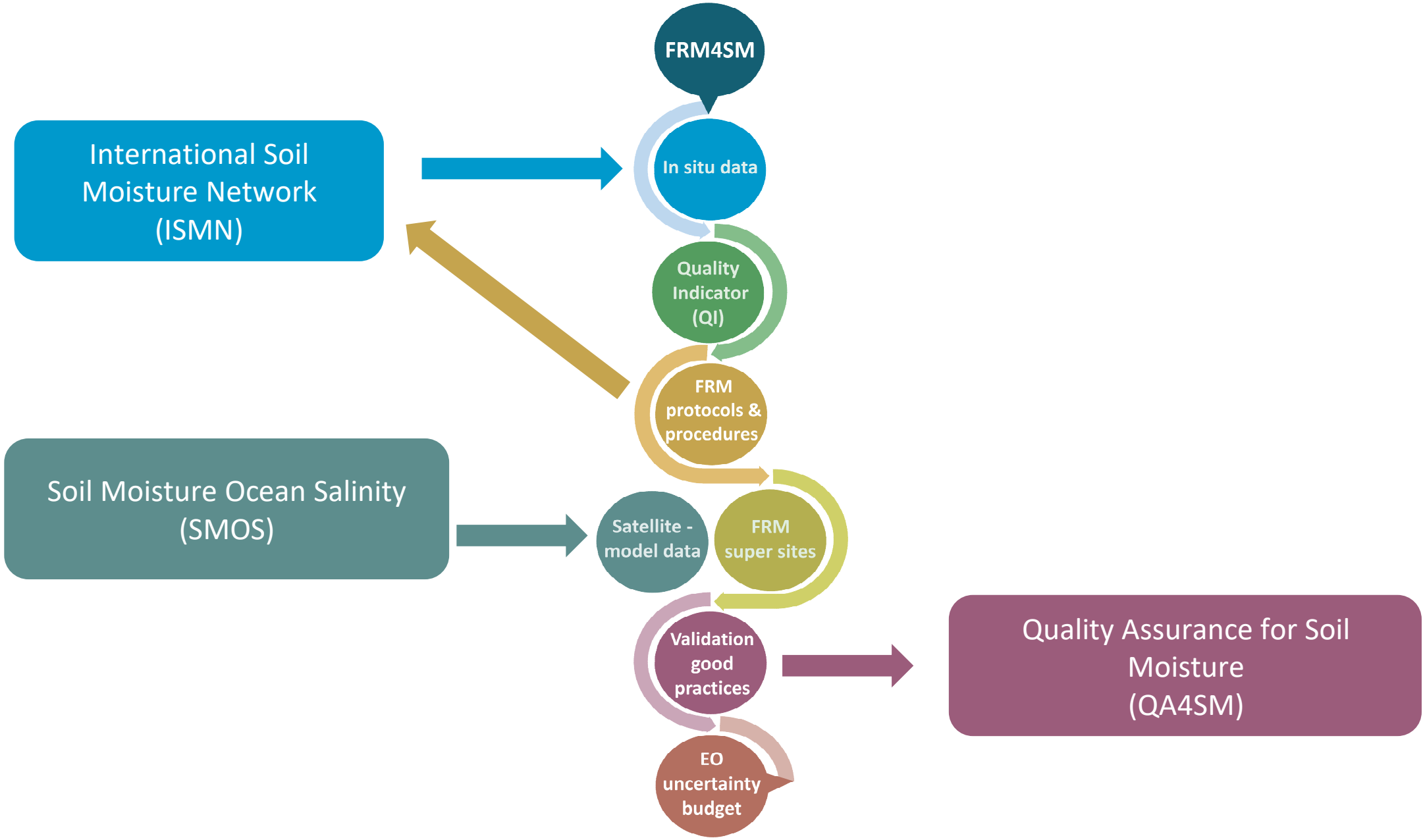
- **Wouter Dorigo: Science Lead, Task 1 & 2 Lead**
- Alexander Gruber: EO Scientist, QA Expert (Tasks 1, 2, 4)
- Irene Himmelbauer: EO Scientist & ISMN Expert (Tasks 1, 2)
- Wolfgang Preimesberger: EO Scientist (Tasks 2, 4)
- Daniel Aberer: ISMN QA Expert (Tasks 1, 2)
- Pietro Stradiotti: EO Scientists (Tasks 3, 4)

CESBIO

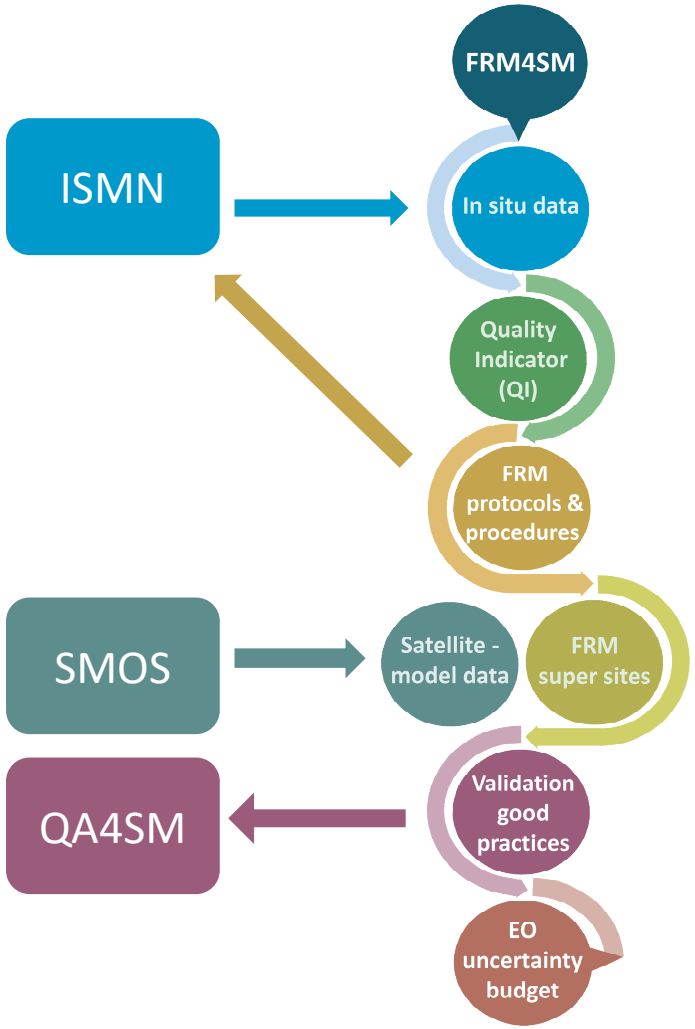
- **Arnaud Mialon: Task 5 Lead**
- François Gibon: EO Scientists
- Yann Kerr: Senior EO Scientist, SMOS Expert
- Philippe Richaume: EO Scientist, SMOS L2 Validation Expert
- Ali Mahmoodi: EO Scientists
- Nemesio Rodriguez-Fernandes: EO Scientists

ESA (funding and technical officers for the project)

- Philippe Goryl
- Raffaele Crapolicchio
- Raul Diez Garcia
- Roberto Sabia
- Klaus Scipal


FRM4SM
International Soil Moisture Network (ISMN)
In situ data
Quality Indicator (QI)
FRM protocols & procedures
Soil Moisture Ocean Salinity (SMOS)
Satellite - model data
FRM super sites
Validation good practices
EO uncertainty budget
Quality Assurance for Soil Moisture (QA4SM)

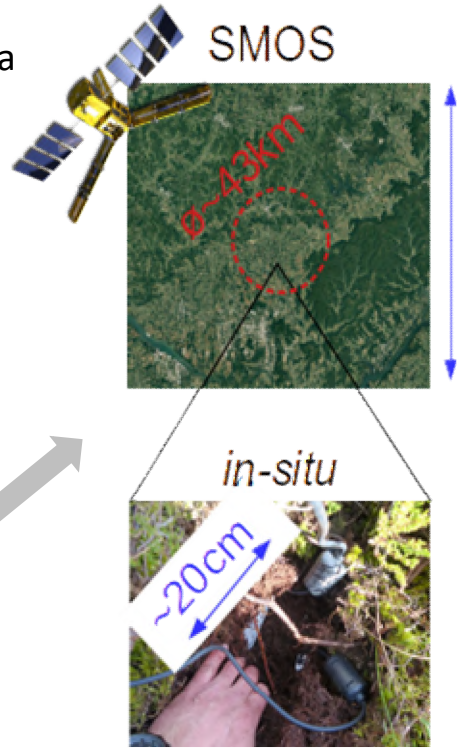
FRM4SM starting point



ISMN as a base:

- The ISMN does not operate ground measurements – purely collection of data
- Standard metadata available / applied
  - Challenge: no information about calibration
- Automated ISMN developed QC procedures are applied
- Challenge: myriad of different measuring techniques and brands included
- Simple traceability of data in place

Dorigo et al. (2013): *"Global Automated Quality Control of In Situ Soil Moisture Data from the International Soil Moisture Network"*. DOI: 10.2136/vzj2012.0097



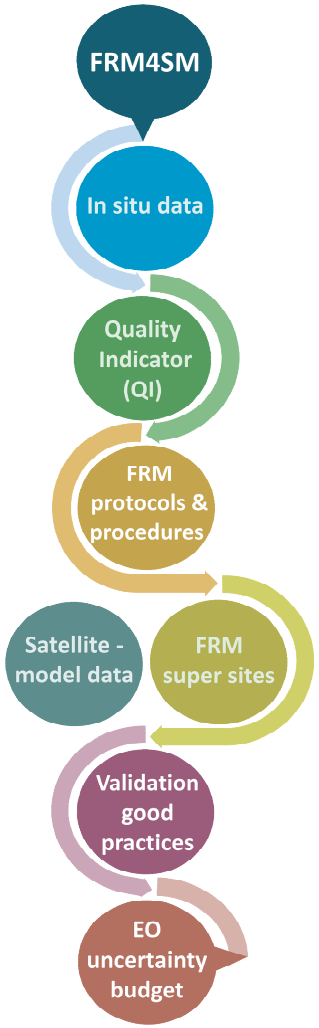
SMOS satellite data as a first validation case:

- Soil penetration until max. 10 cm depth
- Spatial resolution of SMOS footprint 35 km at center of field of view

QA4SM online validation service:

- Following the guidelines and protocols endorsed by CEOS LPV https://lpvs.gsfc.nasa.gov/
- In situ data (ISMN), model data (ERA5, GLDAS) and Satellite data (ESA CCI, SMAP, SMOS, Sentinel-1, ASCAT, ...)
- Box plots and maps created & comparisons to other runs
- Zenodo integration → publishing results & get a DOI

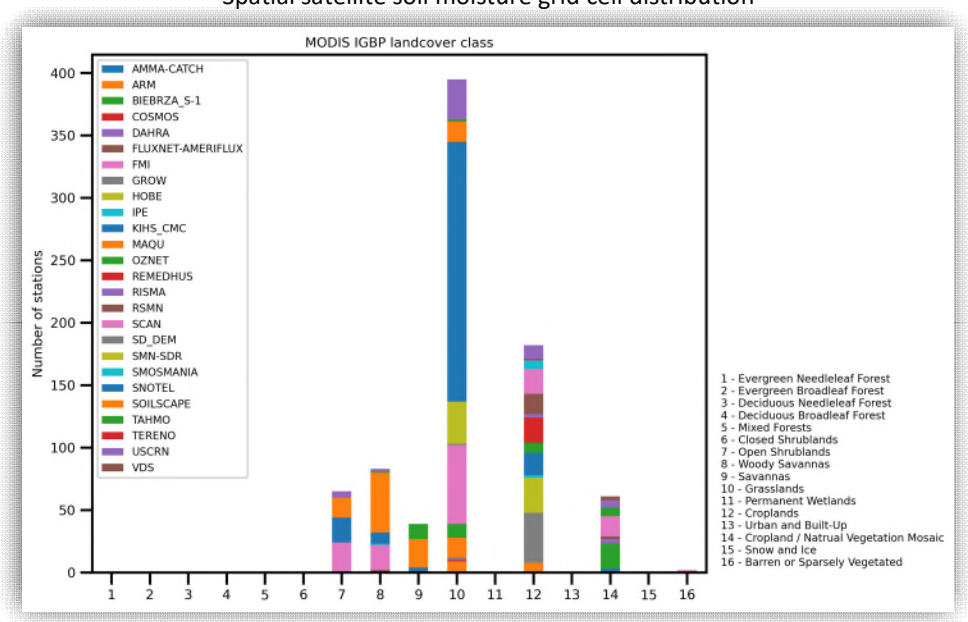
Challenges to overcome



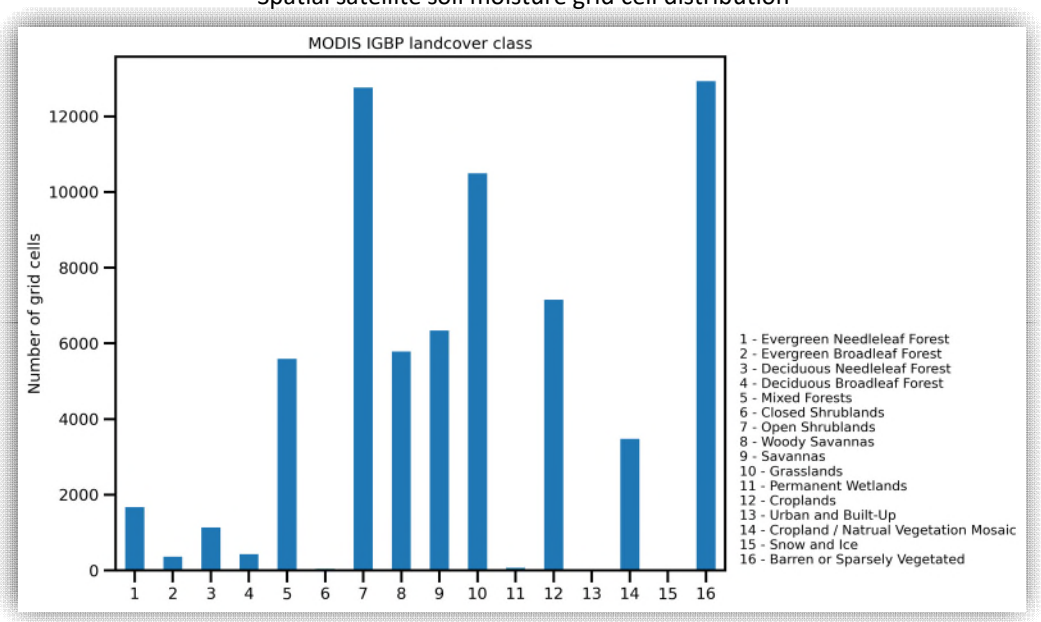
"FRMs ought to be *fully characterized* and *traceable* ground measurements to *support satellite Cal/Val*"

- **Issue 1:** Most in situ data providers do not provide any uncertainty information
- **Issue 2:** Missing standards to calculate in situ sm uncertainty budget → output FRM4SM data
- **Issue 3:** Upscaling to the satellite scale typically breaks traceability
- **Issue 4:** In situ networks have a strong spatial bias and thus cannot fully capture satellite uncertainty variations
- **Issue 5:** FRMs could differ for individual satellite missions

Spatial satellite soil moisture grid cell distribution



Spatial satellite soil moisture grid cell distribution



In situ data quality, traceability & standards: ISMN https://ismn.earth

In situ soil moisture data

Quality Indicators (QI)

FRM protocols & procedures

ISMN evolution:

- Creation of open source QC: https://github.com/TUW-GEO/flagit
- DOI systematic: current development and implementation
- New filter options for ISMN dataviewer

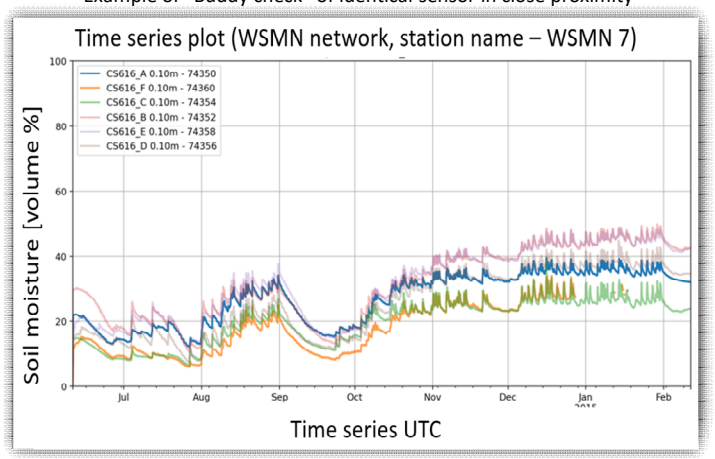
DOI references building system upon:

[1] Recommendations of the Working Group on Data Citation (WGDC)
[2] Rauber et. al 2021; https://doi.org/10.1162/99608f92.be565013
[3] FAIR principles

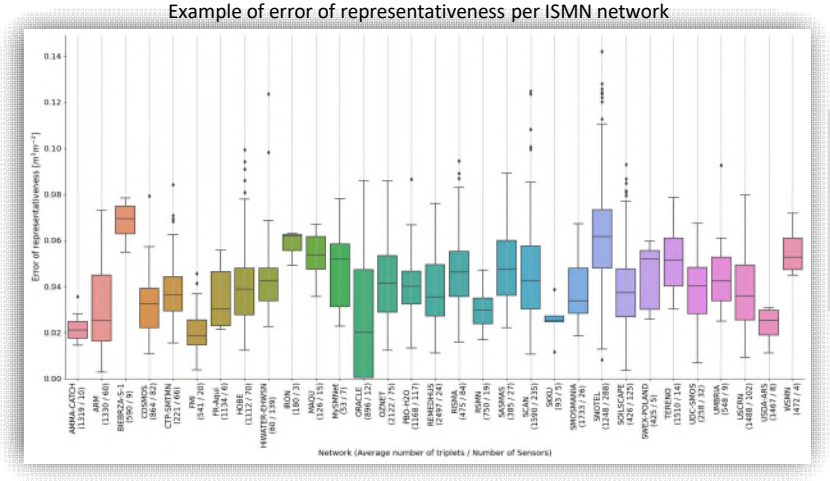
In situ QI R&D:

- Estimates of spatial representativeness based on triple collocation analysis
- „Buddy check" with identical sensors in close proximity
- Spectrum-based estimates of (random) sensor uncertainty
- Uncertainty budget calculation: Parameters? Missing standards? (calibration, field, etc.)

Example of "Buddy check" of identical sensor in close proximity



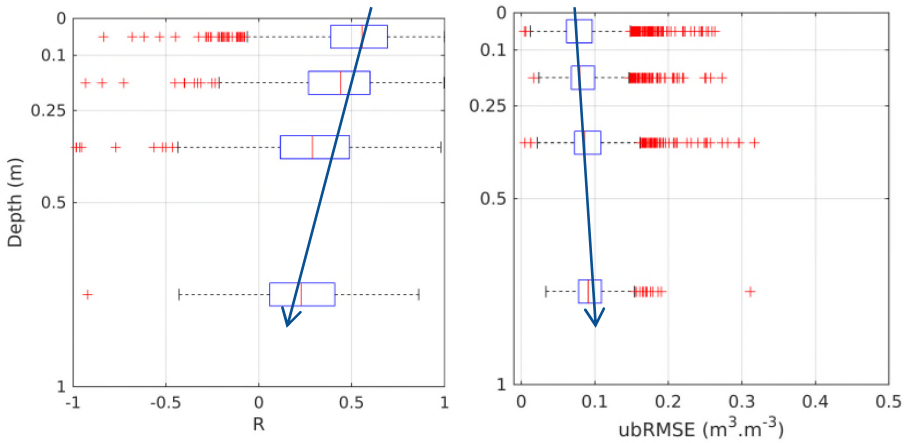
Example of error of representativeness per ISMN network



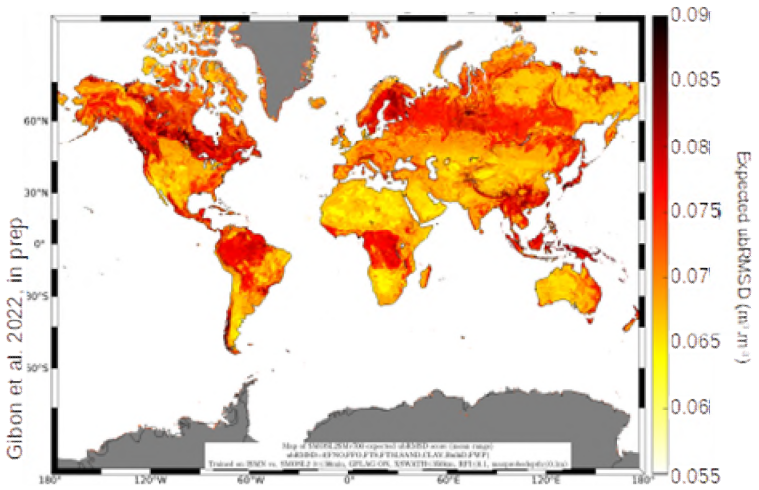
Gruber et al. (2013): *"Characterizing Coarse-Scale Representativeness of in situ Soil Moisture Measurements from the International Soil Moisture Network".*
DOI: 10.2136/vzj2012.0170

SMOS validation studies

In situ probe depth influence on SMOS validation. Better agreement in surface area.



Map of expected SMOS uncertainties at global scale



Surface condition influence SMOS performance are expected better whit no/low vegetation, open water and topography within its footprint (Gibon et al. 2022, in prep).

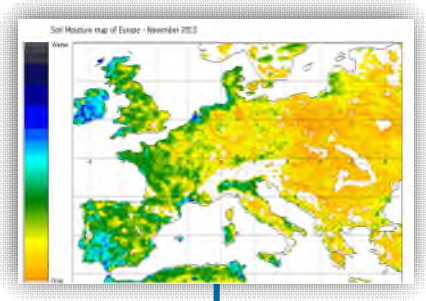
- **SMOS accuracy regarding different surface conditions** (within its footprint)
  - vegetation, topography, soil characteristics (sand/clay and bulk density)…
- **Influence of the in-situ probes features** on the validation:
  - depth, technology, calibration,…
- **Differences in spatial collocation strategies** (SMOS versus in situ):
  - nearest neighbor (point-scale), dense network average,...
- **Differences in temporal collocation strategies** (SMOS versus in situ)
  - +/- 30min, rolling window,...
- **Influence of high soil organic for validation**:
  - probes calibration, dielectric modeling,..
- **Quantifying land cover spatial heterogeneity/uniformity** (within SMOS footprint)
  - spatio-temporal scale mismatch with the in-situ probes (m^2 vs km^2)

Providing a standardized validation system: QA4SM https://qa4sm.eu

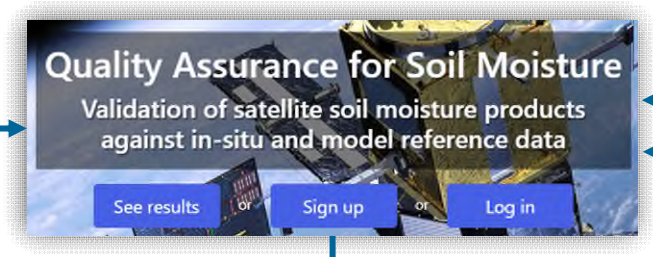
Quality Assurance for Soil Moisture (QA4SM) = online validation service

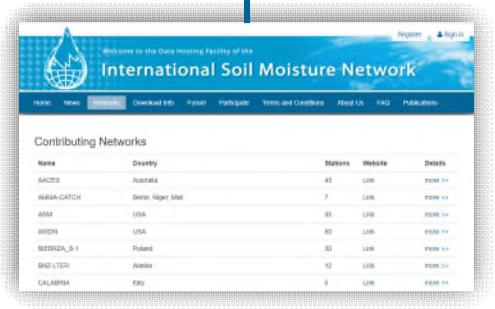
- Feature to upload own datasets in development
- Providing access to “Fiducial” Reference data sets
- Implementation of further developed community agreed standards
  - Preprocessing: data filtering, matching, scaling, ...
  - Metric calculation (R, ubRMSD, Bias, SNR, ...)

Satellite & model data

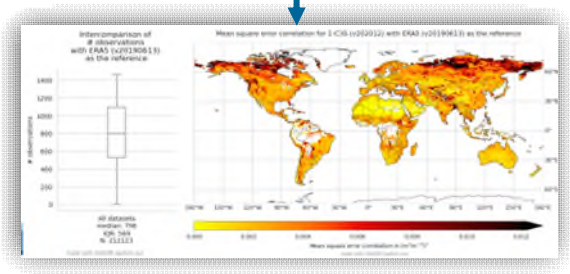


‘FRM super site’ selection based on QIs and **FRM Protocols and Procedures (FPP_SM)** developed in FRM4SM





In situ data



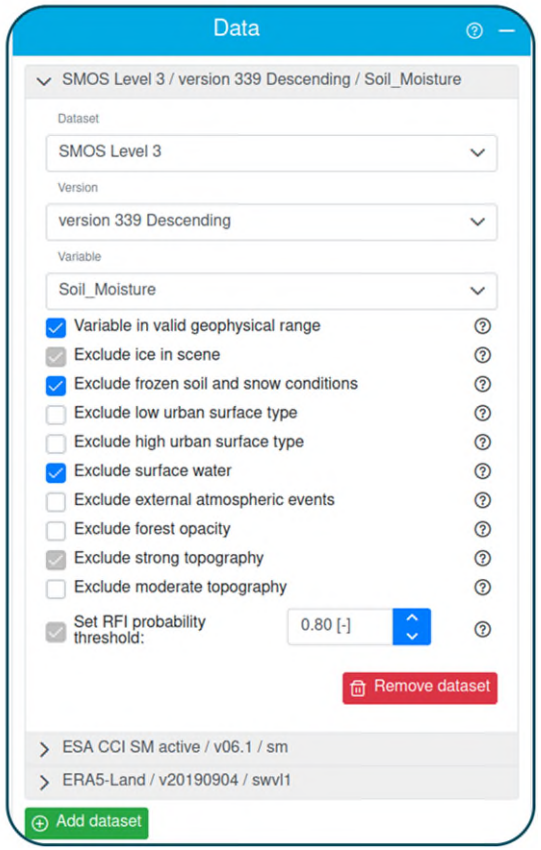
Standardized validation and inter-comparison reports

Gruber et al. (2020): *“Validation practices for satellite soil moisture retrievals: What are (the) errors?”*. DOI: 10.1016/j.rse.2020.111806

Montzka et al. (2020). *“Soil Moisture Product Validation Good Practices Protocol”*. CEOS WGCV LPV. DOI: 10.5067/doc/ceoswgcv/lpv/sm.001

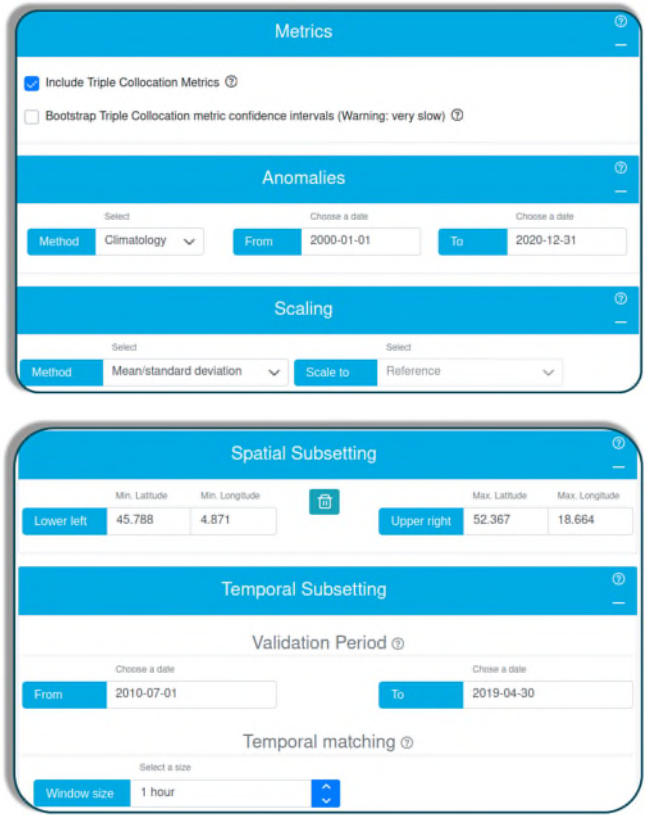
QA4SM workflow https://qa4sm.eu

1) Data Selection



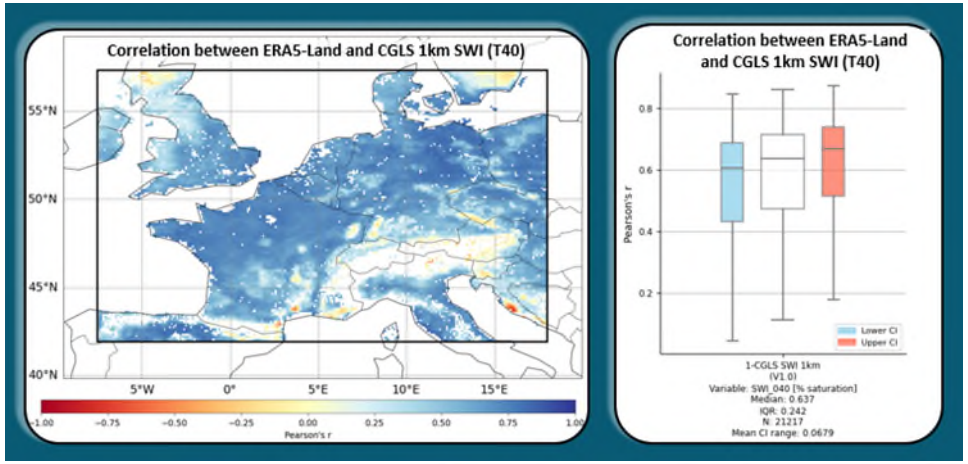
Up to 5 satellites + 1 reference

2) Customize Settings



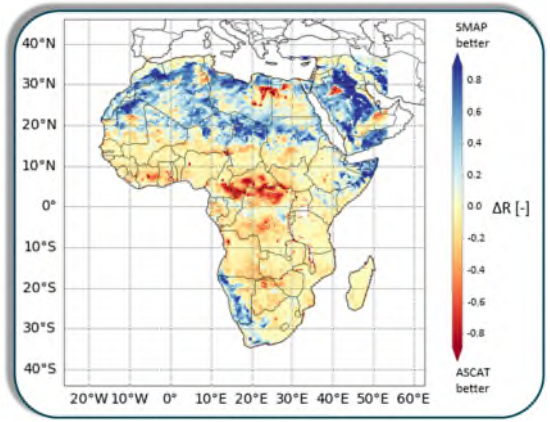
Temporal / spatial subsets, validation metrics + CIs, anomaly computation, ...

3) Process, visualize, share & download



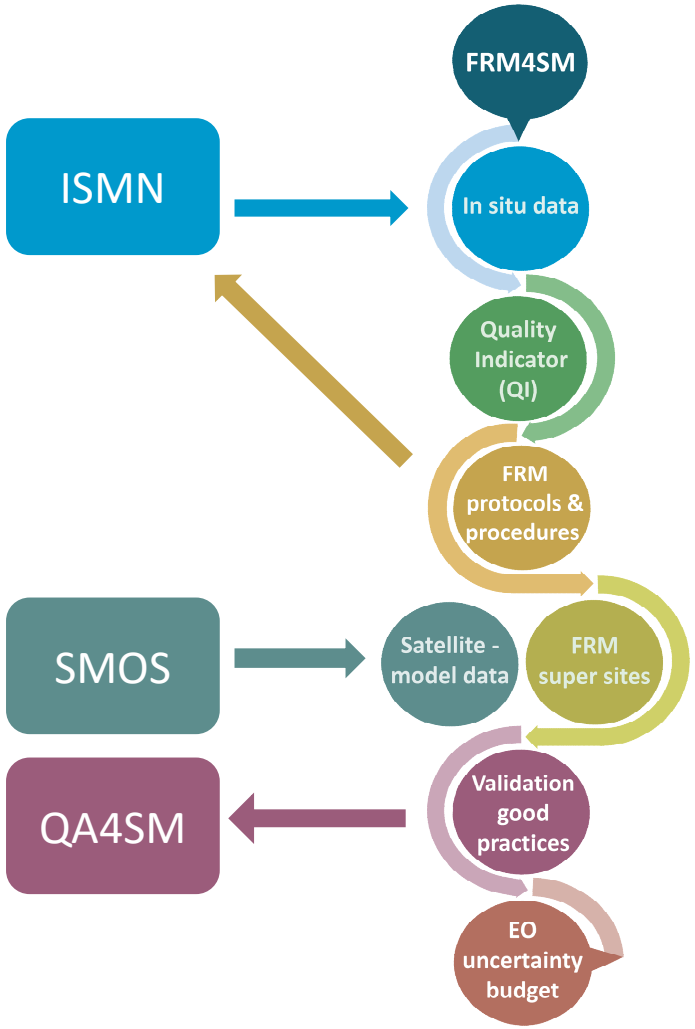
Validation metrics ↑
tables, maps, box plots,...

Comparisons →
difference maps,
ISMN metadata based comparisons, ...



Public example: Published Validation of C3S Soil Moisture with ERA5 https://qa4sm.eu/ui/validation-result/e9a9d43a-deac-4ea5-bbcb-855065fbbeb8

Conclusion

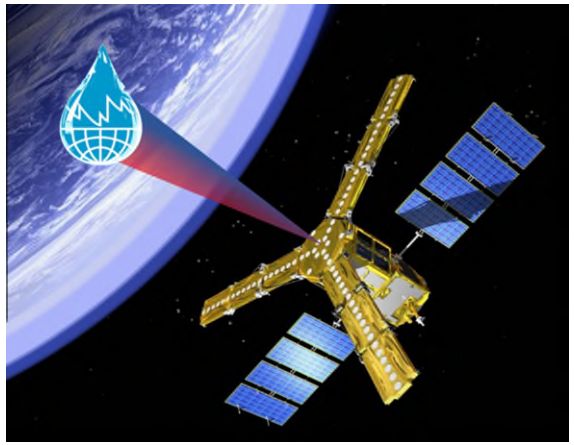


FRM4SM is currently committed to

- Developing "**FRM Protocols and Procedures**"
  - Guidelines for the correct identification and use of soil moisture FRM sites
- Developing **improved QIs** for characterizing ISMN soil moisture networks
- Implementing developed methods into **QA4SM online validation** platform
- Identifying a set of select "**FRM super sites**"
- Demonstrating the project findings in a **SMOS validation case study**

Open issues and future directions

- Uncertainty budget calculation
  - No calibration information in ISMN → no standards for calibration available
    - Potential future work: quantification of the **uncertainty associated with (lacking) calibration**
- ISMN data coverage strongly biased toward cropland and grassland
  - Goal to provide guidelines for **setup and maintenance of future climate reference networks**
- In situ spatial distribution -- influences of soils
- Upscale/ Downscale challenges
- Validation good practice guidelines
  - Continuously evolving in response to new challenges and developments
  - Co-evolving of protocols within FRM4SM e.g., for validating high-resolution products



Thank you for your attention!

https://project-frm4sm.geo.tuwien.ac.at/

Contact

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