FRM4SM: Fiducial Reference Measurements for Soil Moisture

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Motivation

Earth observation (EO) satellites are indispensable for the global monitoring of Essential Climate Variables (ECVs). Assuring the quality of EO-based ECV retrievals is not trivial, however, because the uncertainty tracability chain breaks when a satellite is launched into space and in situ reference data also typically lack a well-described uncertainty budget.

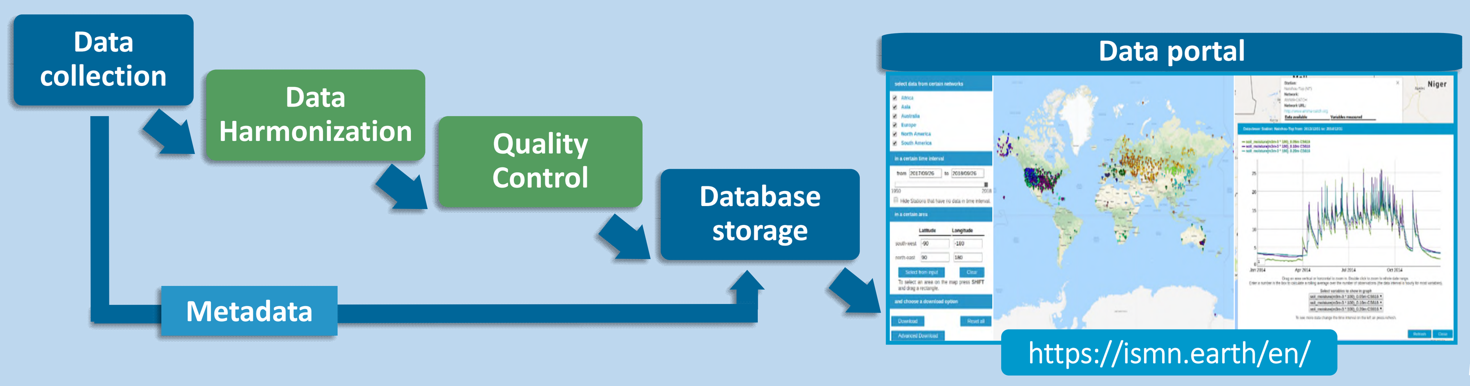
FRM for Soil Moisture
2 year project by ESA
Start: May 2021
End : May 2023

The ESA project "Fiducial Reference Measurements for Soil Moisture" (FRM4SM) aims to define standards for reliable and fully-traceable in situ measurements of soil moisture. It builds upon in situ data sets from the ISMN, the online validation service QA4SM, and best practice guidelines established by CEOS and the soil moisture community.

Data source: International Soil Moisture Network (ISMN)

Dorigo et. al. 2021

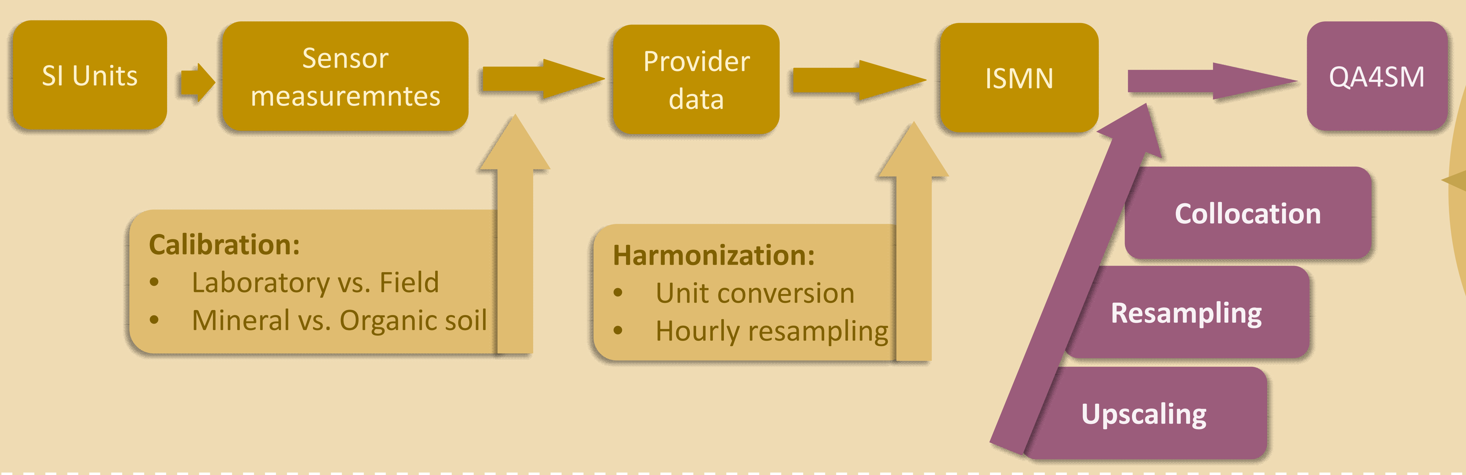
- Established in 2009
- Global in situ soil moisture datasets
- 73 networks (~3000 stations)
- Time series from 1952 up to near real time
- Free accessible https://ismn.earth/



In situ soil moisture data

Identification of what constitutes as FRM in situ data

Building upon standards set by the community (WMO, CEOS, etc.). All findings will be discussed and summarized within an FRM Protocols and Procedures (FPP_SM) document.



Quality Indicators (QI)

FRM protocols & procedures

Identification of Quality Indicators

Dorigo et. al. 2013

Automated flagging within the ISMN

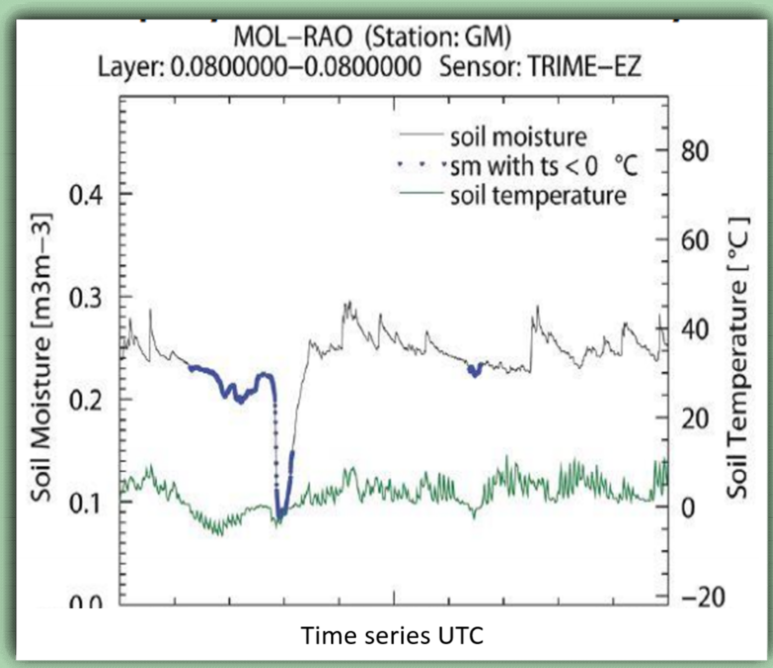


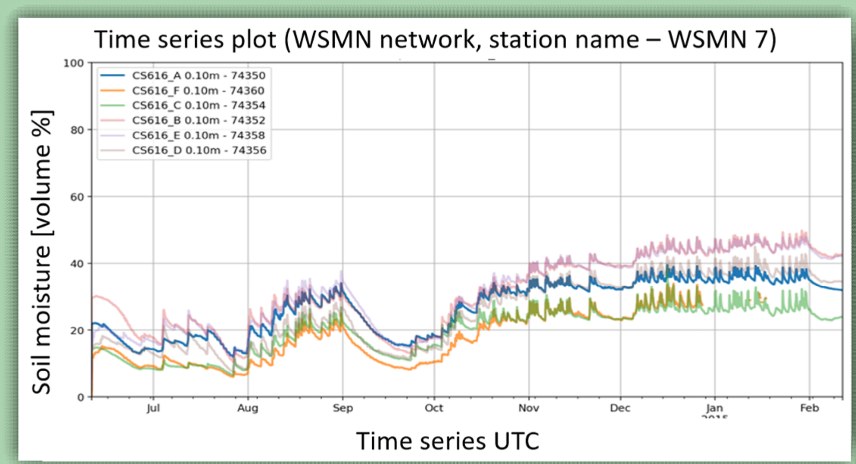
Figure: In this example soil moisture is flagged when soil temperature drops below zero degrees Celsius. .

1) **Geophysical dynamic range** (e.g., plausible limits?)
2) **Geophysical consistency** (e.g., sm rise without rainfall?)
3) **Spectrum based approach** (detection of spikes, plateaus, …)

Time series buddy check

Investigation of neighbouring in situ sensors.

Dirmeyer et. al 2016



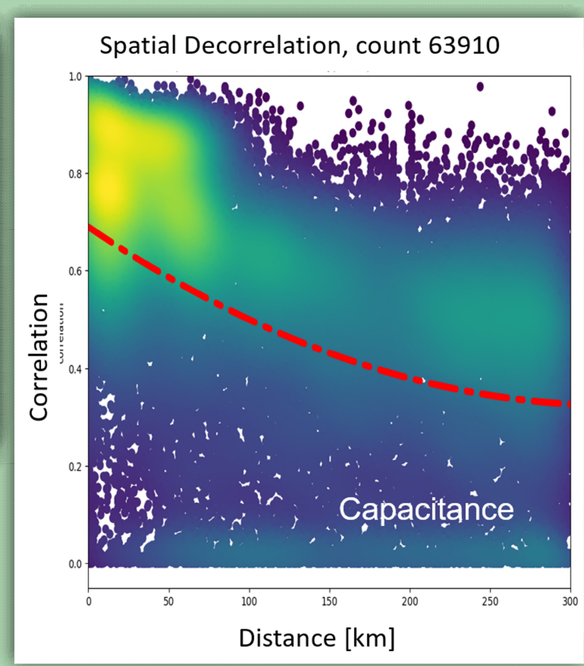


Figure (left): Correlation of sensor time series at the same station in the same depth. **Figure (right):** Sensor time series correlation in distance relationship. In this example all capacitance measuring sensors of the ISMN database are investigated .

Satellite data model data

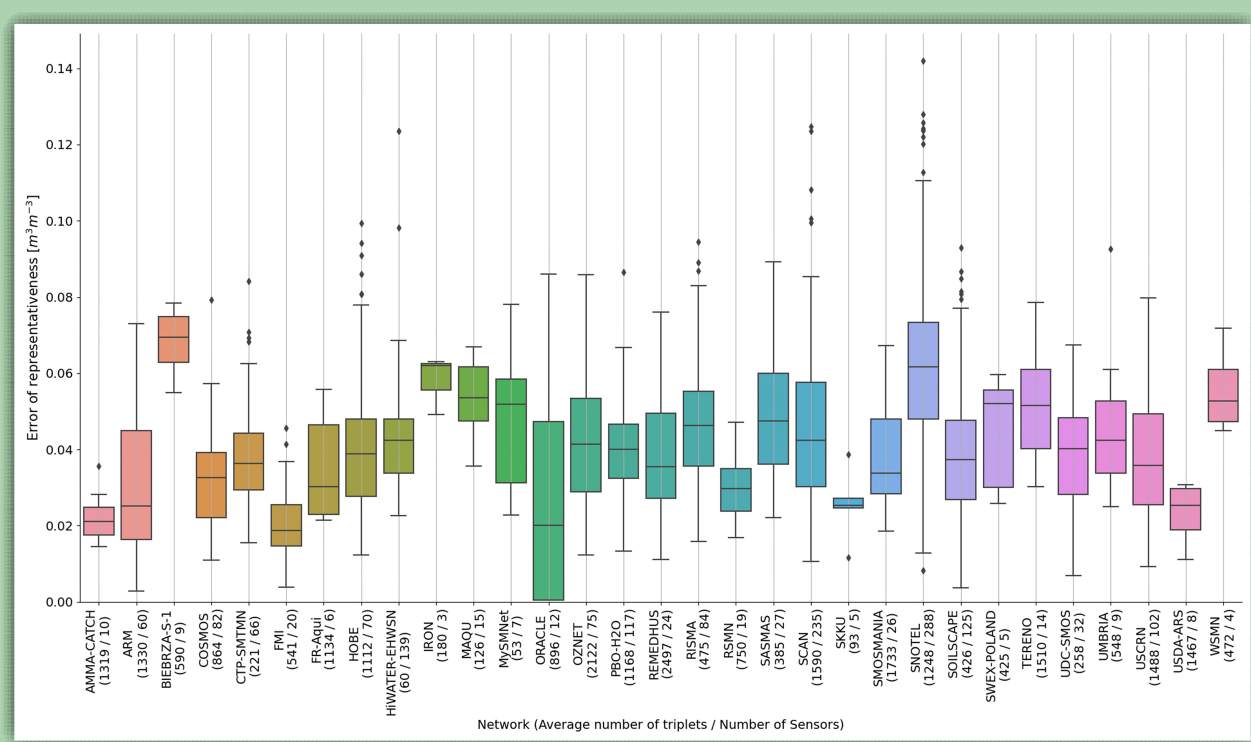
FRM super sites

Representativeness estimation

Gruber et. al 2013

Investigating in situ station representativeness error w.r.t. the satellite grid scale based on triple collocation analysis

Figure: Representativeness error estimates for Different ISMN networks



4 to 5 QI classes will be created considering:

1) **Representativeness error** (triple collocation based)
2) **Confidence interval** (bootstrapping)
3) **Sample size**

Community-based validation good practises

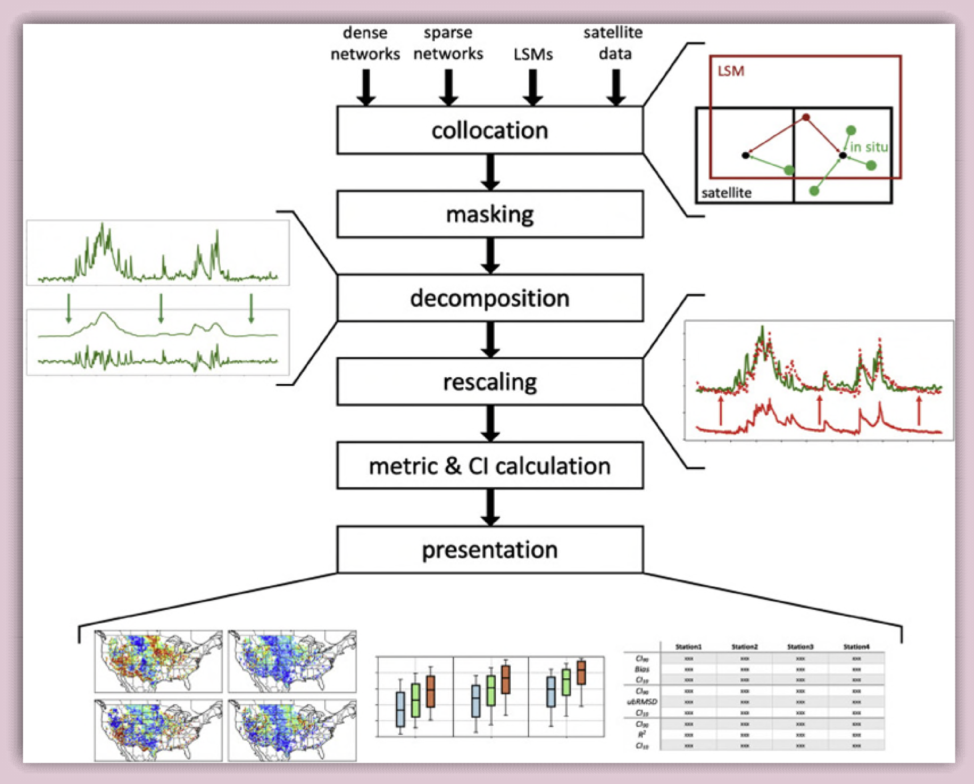


Figure (left): Validation good practice protocol illustration (Source: figure 3 of Gruber et. al 2020 paper).

Gruber et. al. 2020

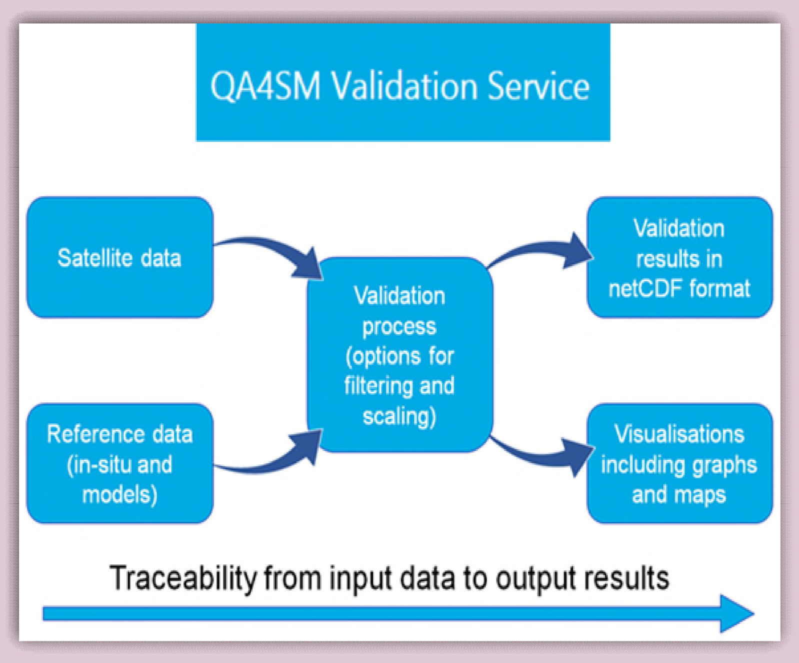
Montzka et al. 2021

Validation good practices

Quality Assurance for Soil Moisture (QA4SM)

- Online validation service following good practices
- Interactive, easy-to-use tool and GUI
- Traceable and shareable validation results (DOI capability)
- Free accessible https://qa4sm.eu

Earth observation uncertainty budget



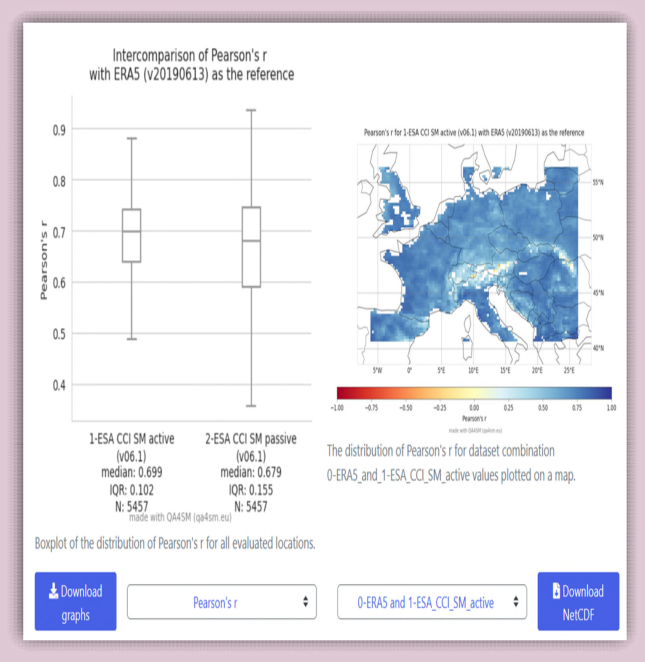


Figure (left): Workflow of the QA4SM validation tool. **Figure (right): Example of output from the** QA4SM service. All calculation and metadata are listed and a DOI can be created

GOALS

1) Develop a set of QIs describing in situ data uncertainty
2) Definition of protocols to obtain fully traceable uncertainty budgets
3) Calculate QIs and apply developed protocols for identifying FRM super sites
4) Use selected FRMs within QA4SM to validate ESA´s SMOS mission (case study)

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