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Fiducial Reference Measurement for Soil Moisture (FRM4SM): From ground measurement to a fully traceable satellite validation service

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Motivation

Earth observation (EO) satellites are indispensable for the global monitoring of Essential Climate Variables (ECVs). Obtaining such information is not trivial (broken uncertainty chain when satellite is launched) using in situ data as a reference (uncertainty budget untraceable or not known.

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) is one such initiative aiming to define standards for reliable and fully-traceable in situ measurements of SM. Building upon in situ datasets from the ISMN, the online validation service QA4SM and best practice guidelines (CEOS).

In situ soil moisture data

Quality Indicators (QI)

FRM protocols & procedures

Satellite data model data

FRM super sites

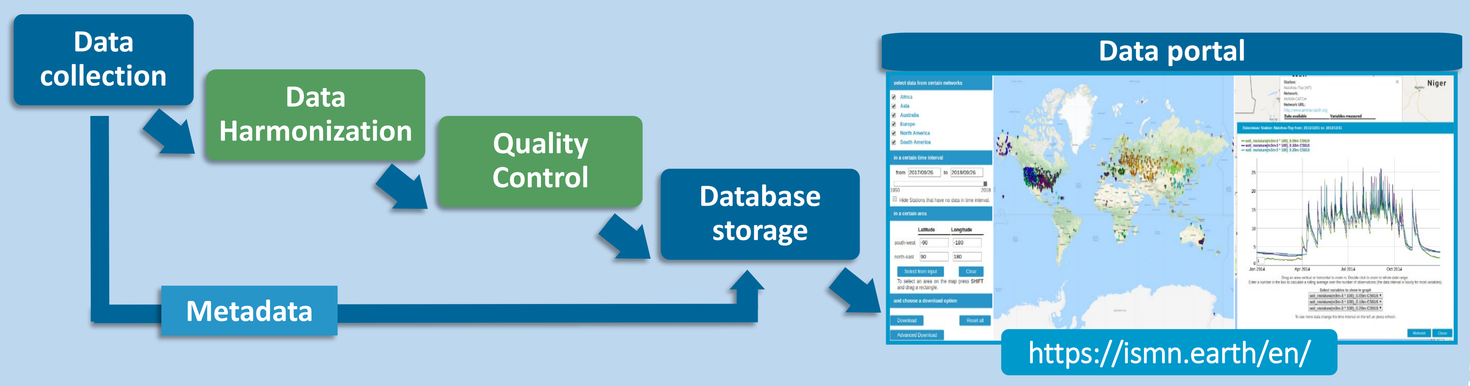
Validation good practices

Earth observation uncertainty budget

Data source: International Soil Moisture Network (ISMN)

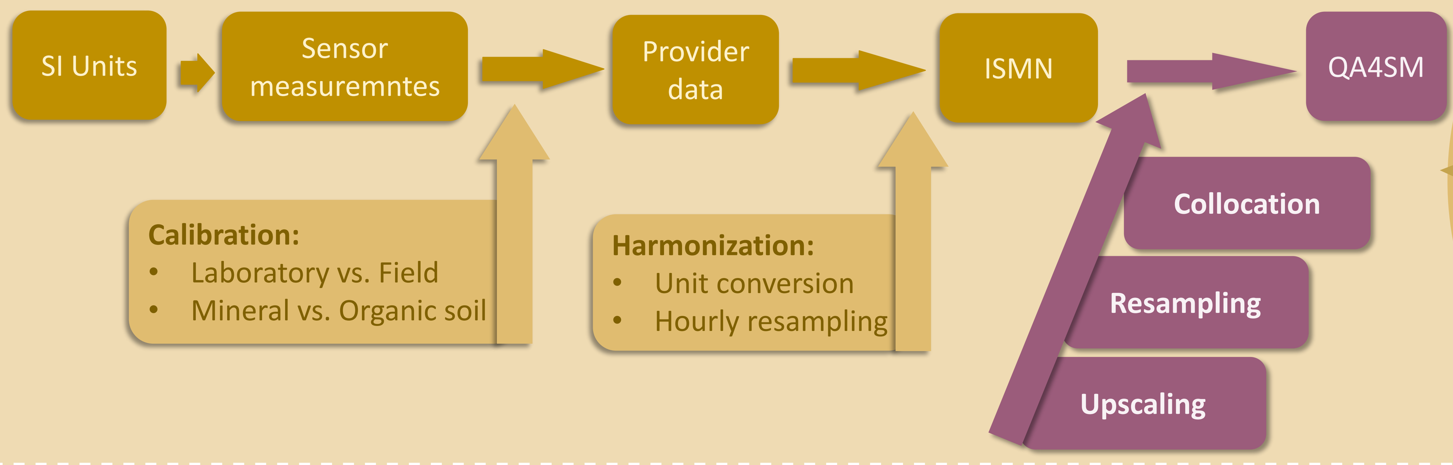
Dorigo et. al. 2021

- 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/en/



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.



Validation best practises – community agreed

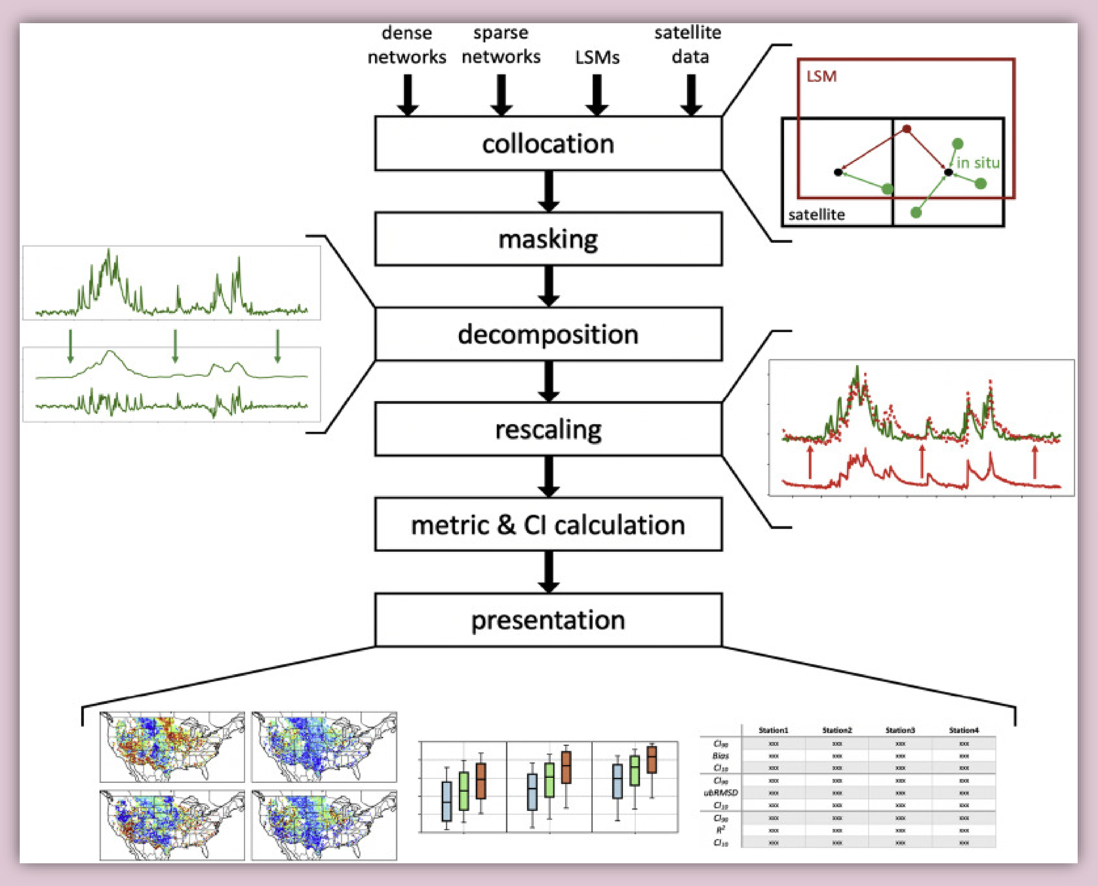


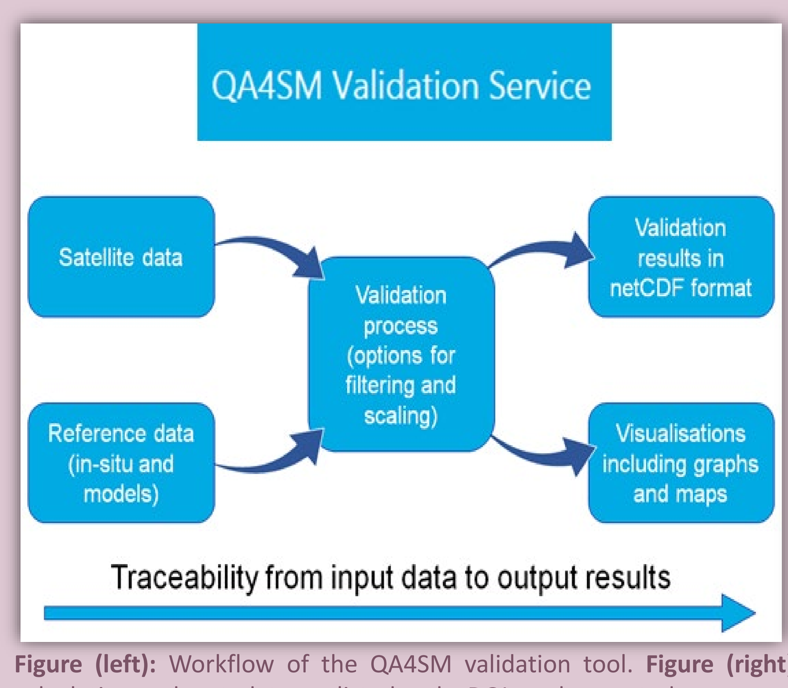
Figure (left): Validation good practice protocol illustration (Source: figure 3 of Gruber et. al 2020 paper).

Gruber et. al. 2020

CEOS LPV 2021

Quality Assurance for Soil Moisture (QA4SM)

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



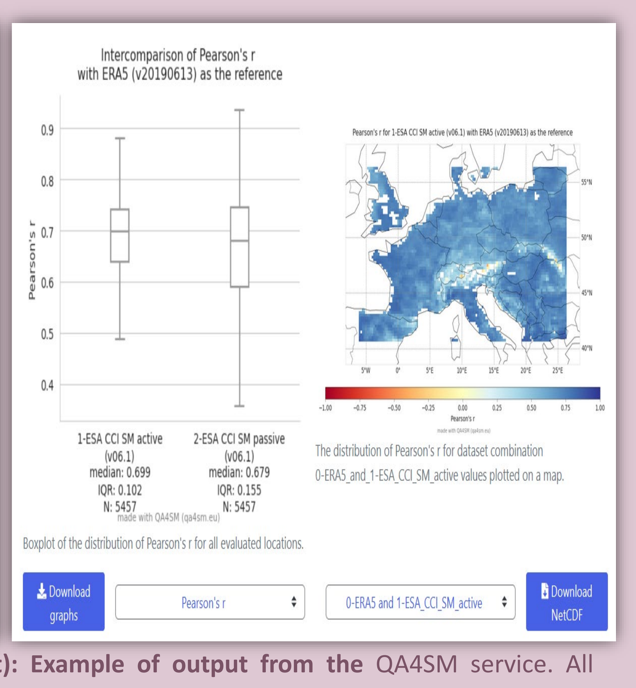


Figure (left): Workflow of the QA4SM validation tool. Figure (right): Example of output from the QA4SM service. All calculation and metadata are listed and a DOI can be created

Identification of Quality Indicators --- Approaches

Flagging systematic at ISMN instance (in situ data source)

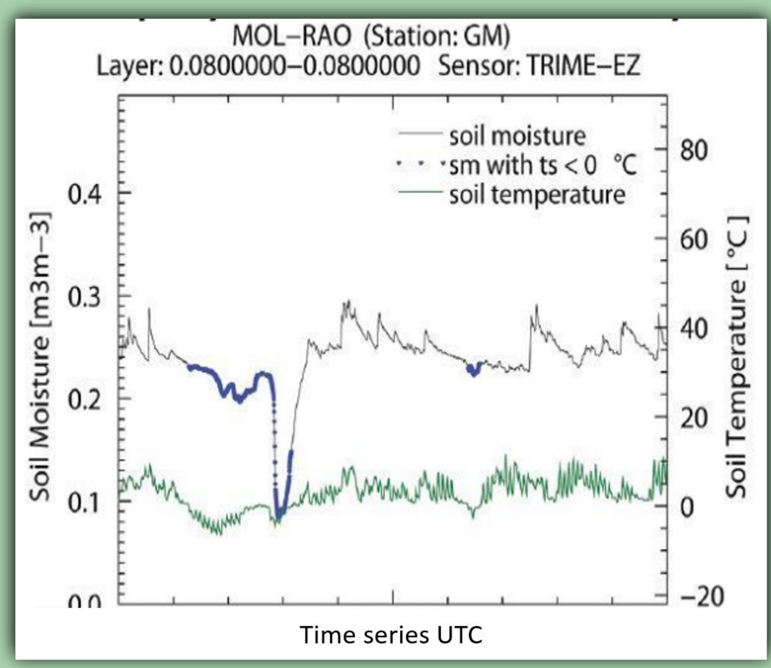


Figure: In this example soil moisture is flagged when soil temperature drops below zero degrees Celsius.

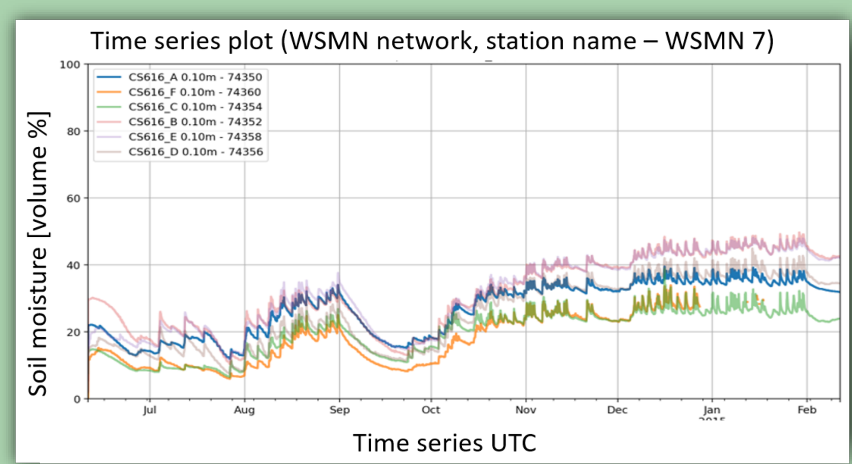
1) **Geophysical dynamic range** (threshold based)
2) **Geophysical consistency** (NASA`s GLDAS Noah used to flag soil moisture data)
3) **Spectrum based approach** (spikes, plateaus detection)

Dorigo et. al. 2013

Time series buddy check

Investigation of neighbouring in situ sensors.

Dirmeyer et. al 2016



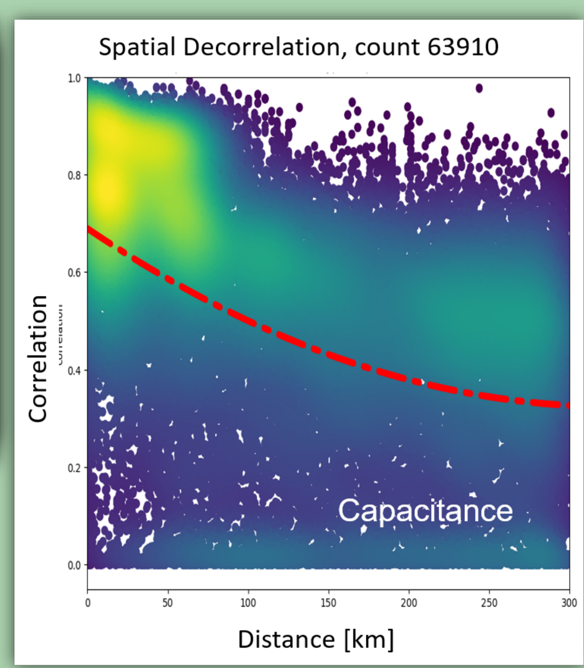


Figure (left): Correlation of sensor time series at the same station in the same depth. Figure (right): Sensor time series correlation in distance relationship. In this example all capacitance measuring sensors of the ISMN database are investigated .

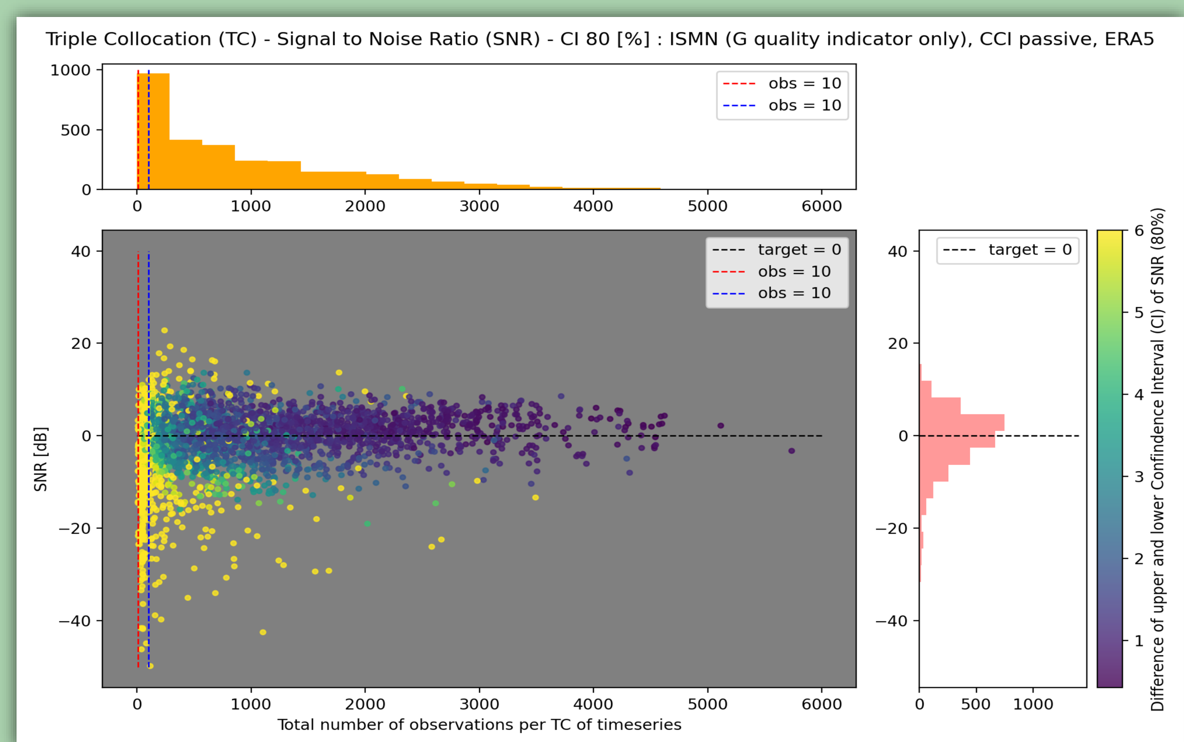
Representativeness Indication

Triple collocation = in situ error + representativeness error

Gruber et. al 2013

Investigating in situ station representativeness against a satellite mission and its time series availability and spatial distribution at a satellite pixel.

Figure: Scatterplot of signal to noise ratio (triple collocation of ISMN, CCI passive and ERA5 land) in comparison with total number of observations of ISMN time series. Bootstrapping applied and scatterplot coloured within confidence interval (CI) of 80%.



4 to 5 categories will be created considering:

1) **Signal to noise ratio** (triple collocation based)
2) **Confidence Interval** (bootstrapping)
3) **Sample size**

GOALS

1) Develop a set of QIs fully describing uncertainty characteristics
2) Definition of protocols: fully traceable uncertainty budget (metrological principles)
3) Calculate QIs and apply developed protocols for assessment of FRM stations
4) Validate selected FRMs with QA4SM (ESA´s SMOS mission)

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