The International Soil Moisture Network (ISMN): status and pathway towards FRM

QA4EO/IDEAS Cal/Val Workshop #3

April 1st 2022

Irene Himmelbauer[A], Daniel Aberer[A], Lukas Schremmer[A], Ivana Petrakovic[A] and Wouter A. Dorigo[A]

[A] **TU Wien**
Department of Geodesy and Geoinformation
Climate and Environmental Remote Sensing
https://climers.geo.tuwien.ac.at

Overview

- Overview of the ISMN Operations
- ISMN paper: ” The International Soil Moisture Network: serving Earth system science for over a decade. Hydrology and Earth System Science, 10.5194/hess-25-5749-2021”
- ISMN transfer to new host: from TUW Austria to BfG/ICWRGC Germany
- ISMN R&D towards FRM: ESA project FRM4SM
- Outlook

Overview of the ISMN

ISMN: Overview Operations (72 networks, 2879 stations, 4000 active users)

ISMN = a global **in situ** (surface and subsurface) soil moisture database

- Established in 2009 at TU Wien
- International cooperation (ESA, WCRP GEWEX, CEOS, GTN-H, etc.)
- Funded by ESA ever since : SMOS, IDEAS+, **QA4EO — ending latest by December 2022**
- Long term funding of ISMN operations found ⇒ German Ministry (2021 - long term)
- ISMN R&D: Fiducial Reference Measurements for Soil Moisture (FRM4SM)

Idea: Reliable and consistent validation datasets ⇒ crucial for (satellite) soil moisture products
ISMN timeseries: 1952 - near real time (daily updates of 8 NRT networks, 1000 stations)

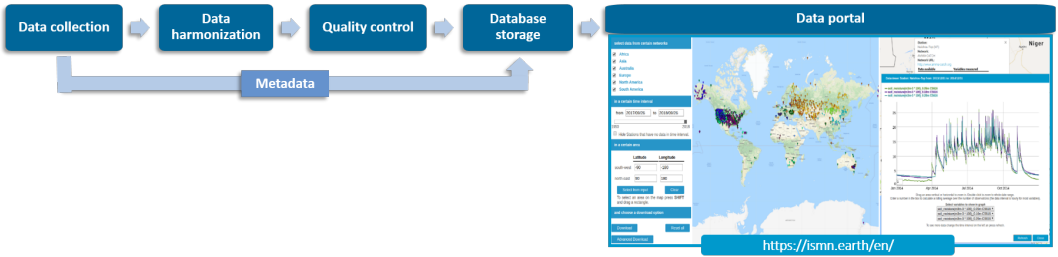
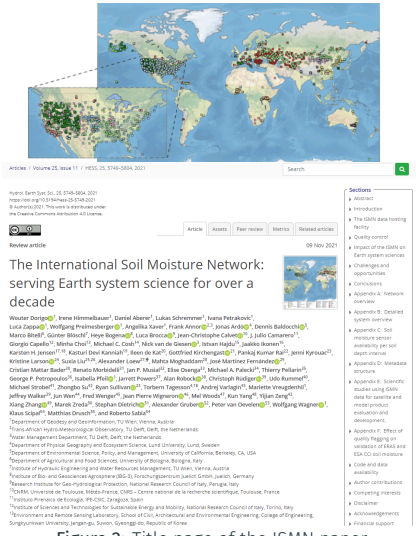


Figure 1: Diagram of workflow of the ISMN.

New ISMN paper: Over a decade of the ISMN

ISMN publication - released on 9 November 2021 (HESS) - Dorigo et al. 2021



The ISMN paper has been officially published on 9 November 2021 (HESS)
https://hess.copernicus.org/articles/25/5749/2021/

⇒ Content:

- Overview of ISMN
- New pyhton based quality control procedure

  ISMN python flag moduel – flagit: https://github.com/TUW-GEO/flagit
- Impact of the ISMN on Earth system sciences (Literature overview of studies making use of ISMN)
- Challenges and opportunities
- Recent developments (since 2013 paper)
- Summarize current shortcomings and future needs

Figure 2: Title page of the ISMN paper.

ISMN transfer to new host: from TUW Austria to BfG/ICWRGC Germany

Transfer of ISMN operations to new host: 20 months (May 2021 - December 2022)

- January 2021 - yes for take over from German Ministry of Transport and Digital Infrastructure
- New host: German Federal Institut of Hydrology (BfG) AND International Center for Water Resources and Global Change (ICWRGC, under auspicy of UNESCO and WMO), Koblenz, Germany
- 5 full time positions financed (Data management, PM, PR, IT, Science)
- May 2021 - financial approval by German Ministry for part of TUW effort
- Operations at TUW covered by QA4EO project from ESA
- 20 month transfer phase approved (May 1st 2021 - December 31st 2022)
  - Phase 1: Finances, contracts, planning, organisation, staff recruitment
  - Phase 2: Setup of technical instance at BfG
  - Phase 3: Parallel run TUW and BfG, knowledge transfer
- Delays due to:
  - Extensive delayed in staff recruitment (especially with IT recruit)

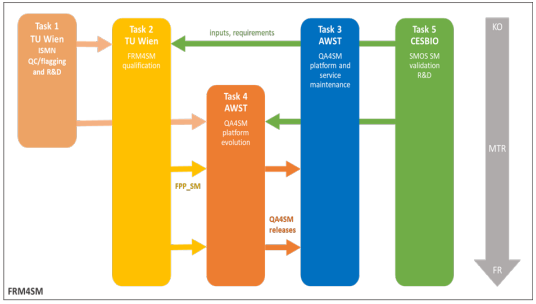
    (**Data management** Nov. 21, **PR** Dec. 21, **PM** March 22, **IT** and **Science** May 2022)
  - Elections in Germany (budget household currently frozen)
  - Corona pandemic effects on availability of personnel / hardware delivery / training / system access
  - Bureaucracy and Security instances

ISMN R&D towards FRM: ESA project FRM4SM

Fiducial Reference Measurements for Soil Moisture FRM4SM (May 2021 - May 2023)

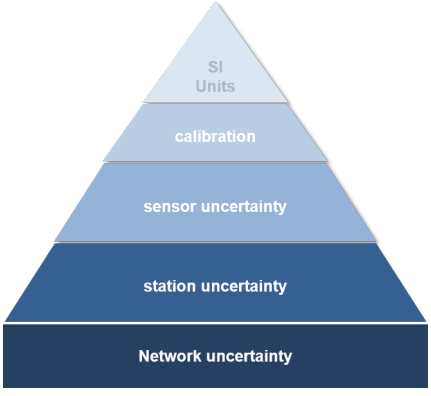
AWST … Applied Science Software Technology, Vienna, Austria

CESBIO … Centre d'Etudes Spatiales de la Biosphère, Toulouse, France



- Error characterization of soil moisture insitu data
- Towards validation of SMOS radiometer resolution
- Implementation of insitu findings into ISMN systems
- Evolution of Quality Assurance for Soil Moisture Service (QA4SM online validation service https://qa4sm.eu/ui/home)
- Implementation of FRM4SM subset of ISMN data into QA4SM
- Output: FRM Protocols and procedures for soil moisture (building upon community agreed standards)

FRM4SM Task 1 and Task 2 effecting ISMN



WP1: ISMN QC/flagging & R&D

OBJ-1: ISMN quality flags

- (REQ-1): consistent QC flags - reliable subsets of data
- (REQ-2): additional QC flags
- (REQ-3): QC with ancillary reference

OBJ-2: (REQ-4) DOIs for downloads

OBJ-3: (REQ-5) Errors & quality indicators

WP2: FRM4SM qualifications

OBJ-4: (REQ-6) FRM4SM protocols & procedures for SM

OBJ-5: Protocol application to ISMN

OBJ-6: FRM4SM super sites

$\Rightarrow$ First efforts in areas – ISMN database modification needed
– compatible with transfer (REQ-1, REQ-2, REQ-4)

$\Rightarrow$ Upcoming months: focusing more on error characterization and identification of quality indicators

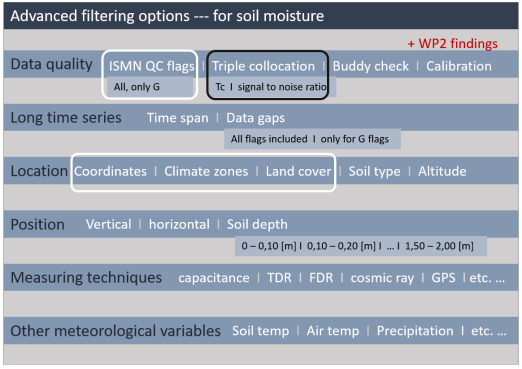


Figure 3: Example of advanced filtering option for the individual creation of reliable subsets of data.

REQ-1: consistent QC flags - reliable subsets of data

Implementation of advanced filtering options within ISMN

New results integrate able throughout the project

REQ-2: additional QC flags

Artificial water source: irrigation flag implementation

REQ-4: DOIs for ISMN downloads

Query based DOI system (concurs with ISMN Terms and Conditions)

1. Recommendations of the Working Group on Data Citation (WGDC)
2. A. Rauber et al. 2021 Precisely
3. go-fair principles

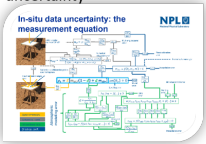
Master student working on implementation

FRM4SM WP1 and WP2: Error and quality indicators

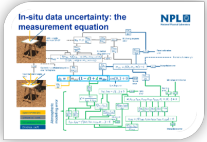
Reference standard

Calibrated sensors
Type-A
Type-B
Type-C

Sensor's uncertainty
Type-A
Type-B
Type-C



Network's uncertainty
Site-A
Site-B
Site-C



FRM4SM Dataset fully traceable to SI and fully complaint with QA4EO guidelines

FRM4SM uncertainties

FPP_SM Document domain

REQ-5: Error and quality indicators (sensor, station, network uncertainty)

- Buddy check: Sensor timeseries cross check (at same depth, same station AND near neighbourhood)
- Data gap analysis: Indication on consistency of individual timeseries

Other way around: from theoretical biggest error towards individual error sources

- Triple collocation (tc) - representativness error per sensor timeseries (Scipal et al. 2010, Gruber et al. 2016)

$$i = \alpha_i + \beta_i \cdot \theta + \varepsilon_i$$ OR

tc = insitu error + representativeness error

αi ; βi ... systematic additive and multiplicative biases of data set i

Θ .. true state

εi ... zero-mean random noise

Figure 4: Triple Collocation approach currently investigated. Statistical analysis method of three error independent data sets. Nearest neighbour method for spatial collocation. Temporal correlation of data sets to be considered.

REQ-5: Calibration of Sensors – SI traceabilty

- Multiple different measuring techniques
  - Capacitance
  - Cosmic ray
  - Droplet spectrometer
  - GPS
  - Hygrometer
  - Resistance
  - Time Domain Reflectrometry (TDR)
  - Time Domain Transmissometry (TDT)
- Lab versus field calibration
- Mineral versus organic carbon calibration functions

Outlook

ISMN: Participating in workshops/assemblies/symposiums

European Geoscience Union Assembly 2022 (May 23^{rd} - 27^{th}):

- Two oral presentations (ISMN operations and transfer): session HS6.1, Remote Sensing of Soil Moisture, room 2.31 on Thursday, May 26^{th} 2022

Living Planet Symposium (LPS, May 23^{rd} - 27^{th} 2022) poster presentations:

- ISMN: session A5.02 The role of Earth Observation in climate services
- FRM4SM: session B1.07 Analysis Ready Data: are we there yet?

6^{th} Satellite Application and Validation Workshop (June 7^{th} - 9^{th}):

- FRM4SM abstract submitted
- **QA4SM half day user workshop organized (June 7^{th} 9am - 12am): Register**

ISMN: Outlook ISMN

- Operations funded until April 30th 2022 by ESAs QA4EO CCN
- Proposal sent for additional ISMN operational funding until end of December 2022 - QA4EO Phase 2 project funds
- Implementation of irrigation flags
- Understanding what error characteristics can be met within ISMN (traceability chain inclusion in ISMN system)
- Going online with beta version of new filtering systematic
- By end of 2022:

  ISMN operational transfer concluded
  Implementation of DOI system completed

Thank you for your attention!

ISMN: https://ismn.earth
CLIMERS: https://climers.geo.tuwien.ac.at

Contact:
irene.himmelbauer@tuwien.ac.at; wouter.dorigo@tuwien.ac.at OR ismn@tuwien.ac.at; ismn@bafg.de

Dorigo, W., Himmelbauer, I., Aberer, D., Schremmer, L., Petrakovic, I., Zappa, L., Preimesberger, W., Xaver, A., Annor, F., Ardö, J., Baldocchi, D., Bitelli, M., Blöschl, G., Bogena, H., Brocca, L., Calvet, J.-C., Camarero, J. J., Capello, G., Choi, M., Cosh, M. C., van de Giesen, N., Hajdu, I., Ikonen, J., Jensen, K. H., Kanniah, K. D., de Kat, I., Kirchengast, G., Kumar Rai, P., Kyrouac, J., Larson, K., Liu, S., Loew, A., Moghaddam, M., Martinez Fernandez, J., Mattar Bader, C., Morbidelli, R., Musial, J. P., Osenga, E., Palecki, M. A., Pellarin, T., Petropoulous, G. P., Pfeil, I., Powers, J., Robock, A., Rüdiger, C., Rummel, U., Strobel, M., Su, Z., Sullivan, R., Tagesson, T., Varlagin, A., Vreugdenhil, M., Walker, J., Wen, J., Wenger, F., Wigneron, J. P., Woods, M., Yang, K., Zeng, Y., Zhang, X., Zreda, M., Dietrich, S., Gruber, A., van Oevelen, P., Wagner, W., Scipal, K., Drusch, M., and Sabia, R. (2021). The International Soil Moisture Network: serving Earth system science for over a decade. Hydrology and Earth System Sciences, 25, 11, 5749–5804. 10.5194/hess-25-5749-2021

Dorigo, W. A., Wagner, W., Hohensinn, R., Hahn, S., Paulik, C., Xaver, A., Gruber, A., Drusch, M., Mecklenburg, S., van Oevelen, P., Robock, A., and Jackson, T. (2011). The International Soil Moisture Network: a data hosting facility for global in situ soil moisture measurements, Hydrol. Earth Syst. Sci., 15, 1675-1698, https://doi:10.5194/hess-15-1675-2011; https://hess.copernicus.org/articles/15/1675/2011/hess-15-1675-2011.pdf.

Dorigo, W.A. , Xaver, A. Vreugdenhil, M. Gruber, A., Hegyiová, A. Sanchis-Dufau, A.D., Zamojski, D. , Cordes, C., Wagner, W., and Drusch, M. (2013). GlobalAutomated Quality Control of In situ Soil Moisture data from the International Soil Moisture Network. Vadose Zone Journal, 12, 3, https://doi:10.2136/vzj2012.0097, https://acsess.onlinelibrary.wiley.com/doi/abs/10.2136/vzj2012.0097