Review of data fusion methods for soil moisture obtained for multiple temporal and spatial scales

Kamil Szewczak, Mateusz Łukowski

Institute of Agrophysics, Polish Academy of Sciences, ul. Doświadczalna 4, 20-290 Lublin, Poland

1. Introduction

Soil moisture (SM) is one of the Essential Climate Variable (ECV) pointed in Global Climate Observing System by World Meteorological Organization. Current state of the environmental science gives us ability to assess SM values for a wide range of temporal and spatial scale. Using in-situ instrumentation and satellite-based remote sensing techniques, we are able to measure SM from point to global scales, with time stamp ranging from second to days. Furthermore, a new methods to provide SM data in "medium" scale are still developed and validated. One of the method providing medium, scale SM data is in-situ remote sensing including Cosmic-Ray Neutron Sensing (CRNS) stations. Taking into account the wide range of methods, their different working principles and variety in spatial and temporal characteristics, there is a strong need for developing methods of SM data fusion. In the framework of SoMMet (Soil Moisture Metrology - Metrology for multi-scale monitoring of soil moisture) project we provided a complex review of various methods that could be used in the process of data fusion for multi-temporal and multi-spatial SM data. Basing on our investigation, the most adequate data fusion approach for combining point, "medium" and global scale SM retrievals was proposed. Our interest covered a wide range of methods, from the most basic to the most complex, including those involving Neural Networks. In the results of our review we provide a advantages and disadvantages of various data fusion methods considered for application for SM data. Reviewed methods are presented regarding the abilities for SM data improvements comparing to the resources needed for the particular method evaluation. In presented work we summarized the results of performed review, giving indication for the best data fusion practice, taking into account cost-to-capabilities ratio. The advantages and disadvantages of the most effective methods were highlighted.

2. Project SoMMet : Soil Moisture Metrology (2022-2025)

- Interdisciplinary team, 9 NMI/DI's and 9 research institutions
- Novel methodology for calibration of point scale soil moisture measurement devices
- New traceability scheme and validation practices for CRNS method
- Good practice guides: calibration practices in outdoor field conditions, harmonisation and data fusion of soil moisture on multiple scales

WP1: SI-traceable measurement of soil moisture on point to field scale
WP2: Development of validation practices for CRNS methodology in outdoor conditions
WP3: Comparison and harmonisation of soil moisture observation methods on multiple spatial and temporal scales
WP4: Multi-scale and multi-disciplinary soil moisture data fusion
Task 4.1: Definition of data fusion methods for soil moisture measurements on multiple scales

3. Materials and Methods

Search criteria:

- „soil moisture" and „data fusion" terms present in title or abstract
- Date of publication – we focused on the period 2017 – 2023
- Lateral and temporal scale – we tried to select works covering the widest spatial and temporal scale
- We assume maximum 50 positions for detailed review

Literature Databases:

Scopus

PubMed

Google Scholar

Tasks:

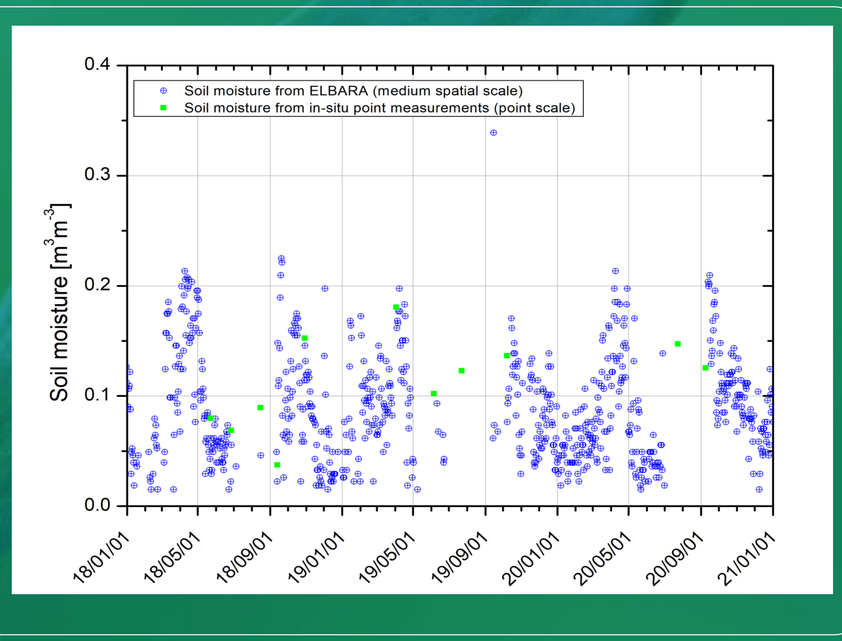
1. Review of methods
2. Selecting at least three methods
3. Applying selected methods to multi scale soil moisture data

4. Results

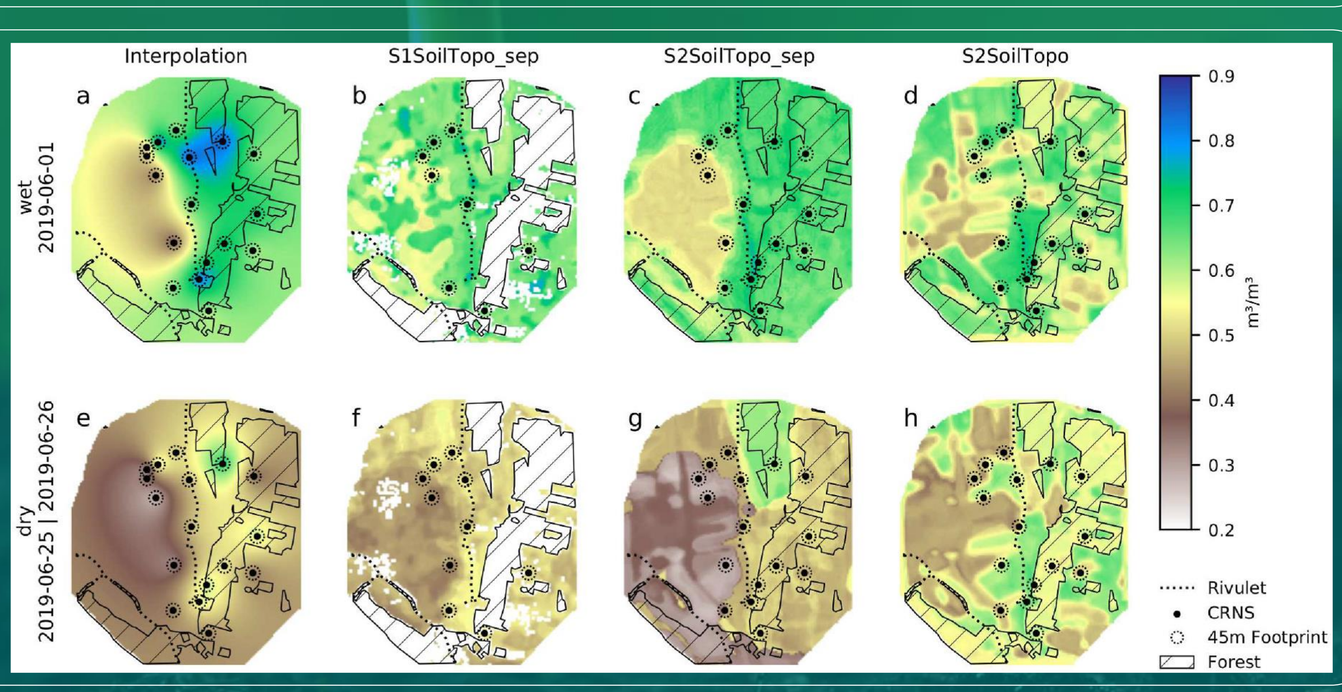
AD 1. The most common data Fusion methods applied for soil moisture retrievals:
- Machine Learning: 13
- Neural Network: 10

AD 2. Three data fusion methods used for Cosmic-ray Neutron Sensing (CRNS) data were selected for following research in the project framework:
- Random Forest Regression (RFR)
- Point-Surface Collaborative Inversion (PSCI)
- Generalized Regression Neural Network (GRNN)

AD 3. Point and medium scale soil moisture data from Sęków test site in Poland (2018-2021) were prepared for selected data Fusion methods application



Example for RFR application for multi scale soil moisture: Comparison of CRNS soil moisture content with RFR modeled Sentinel-1 and Sentinel-2 data depending on the input data set for RFR models [Veronika Döpper, Thomas Jagdhuber, Ann-Kathrin Holtgrave, Maik Heistermann, Till Francke, Birgit Kleinschmit, Michael Förster, Following the cosmic-ray-neutron-sensing-based soil moisture under grassland and forest: Exploring the potential of optical and SAR remote sensing, Science of Remote Sensing, Volume 5, 2022, 100056, https://doi.org/10.1016/j.srs.2022.100056]



Acknowledgements

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.

INSTITUTE OF AGROPHYSICS PAS