

Multiscale soil moisture (SM) comparison and fusion in the SoMMet project

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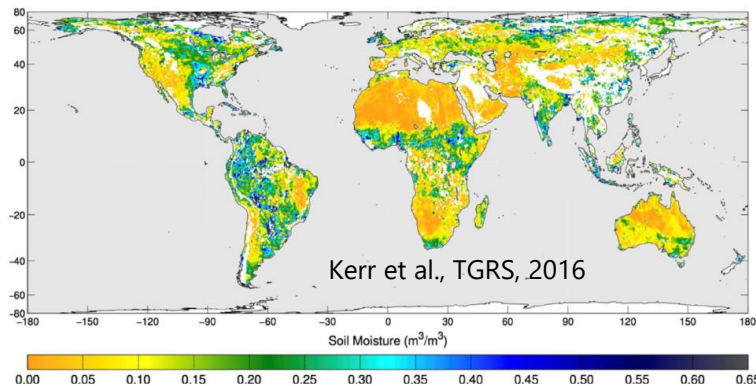
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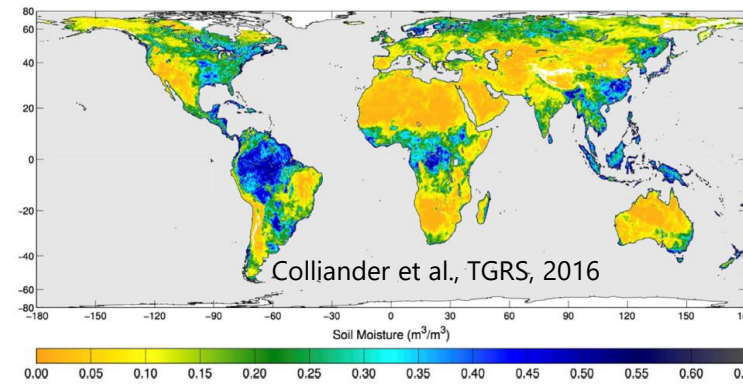
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Operational SM products from satellites

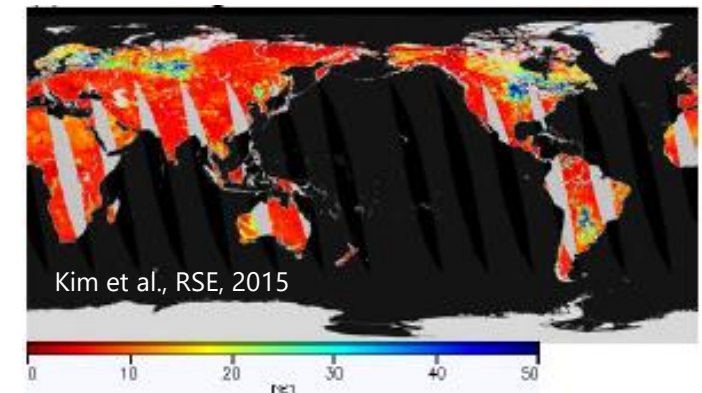
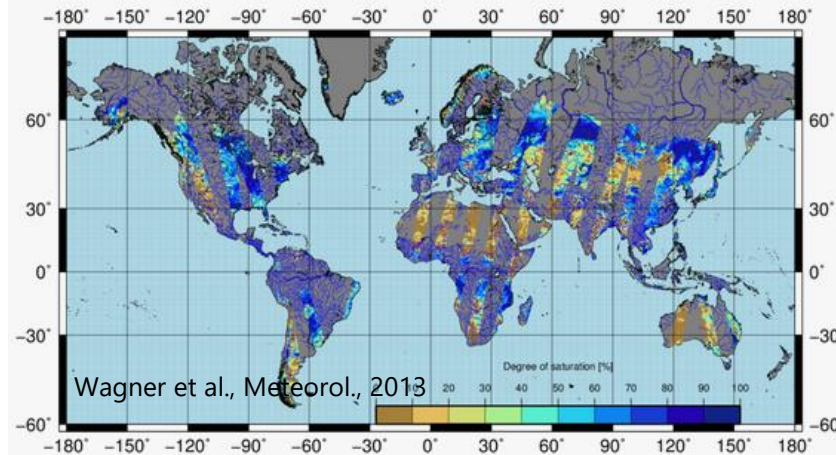
ESA/SMOS SM, 1-7/06/2015



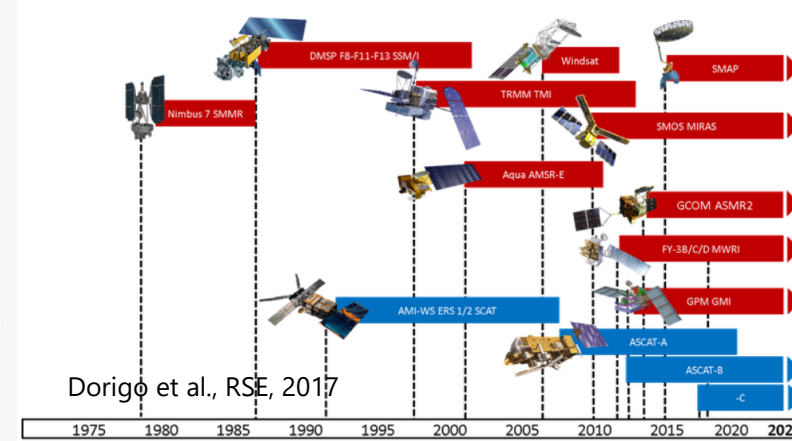
NASA/SMAP SM, 1-7/06/2015



JAXA/AMRS2 SM on 20/05/13

EUMETSAT/ASCAT SWI
on 3/3/19

ESA CCI SM



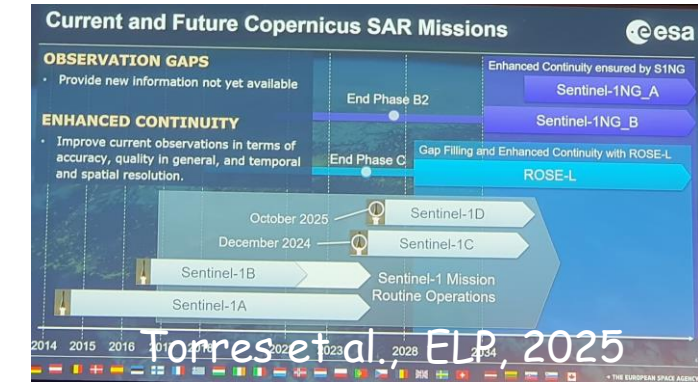
Dorigo et al., RSE, 2017

ESA CCI soil moisture v08.1 product utilizes 5 active and 12 passive microwave sensors

Context

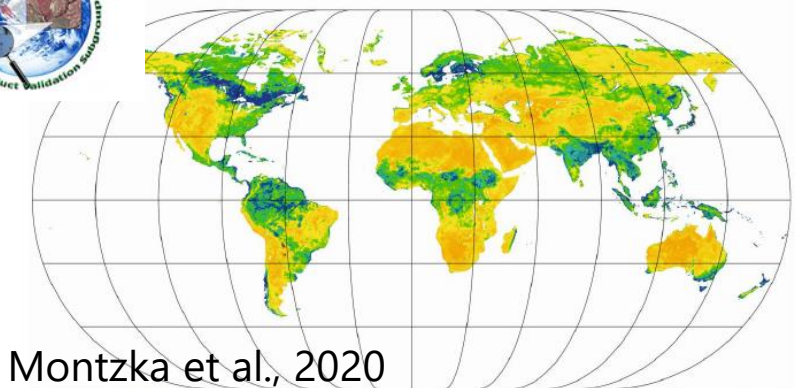
- ❑ The European Radar Observatory Sentinel-1 (S-1), the forthcoming S-1 Next Generation and ROSE-L satellites have motivated the development of operational land surface monitoring at high spatial resolution, such as surface soil moisture (SSM) monitoring.
- ❑ Significant efforts have been made to define protocols, identify reference measurements (RMs), and address the spatial mismatch between Earth Observation SSM products and RMs, which are typically point-scale (PS) measurements from hydrologic networks.
- ❑ Interest is increasing for other soil moisture measurements methods, such as the cosmic ray neutron sensors (CRNS) with wider support ($\sim 0.1 \text{ km}^2$).

ESA S-1 & ROSE-L long term scenario



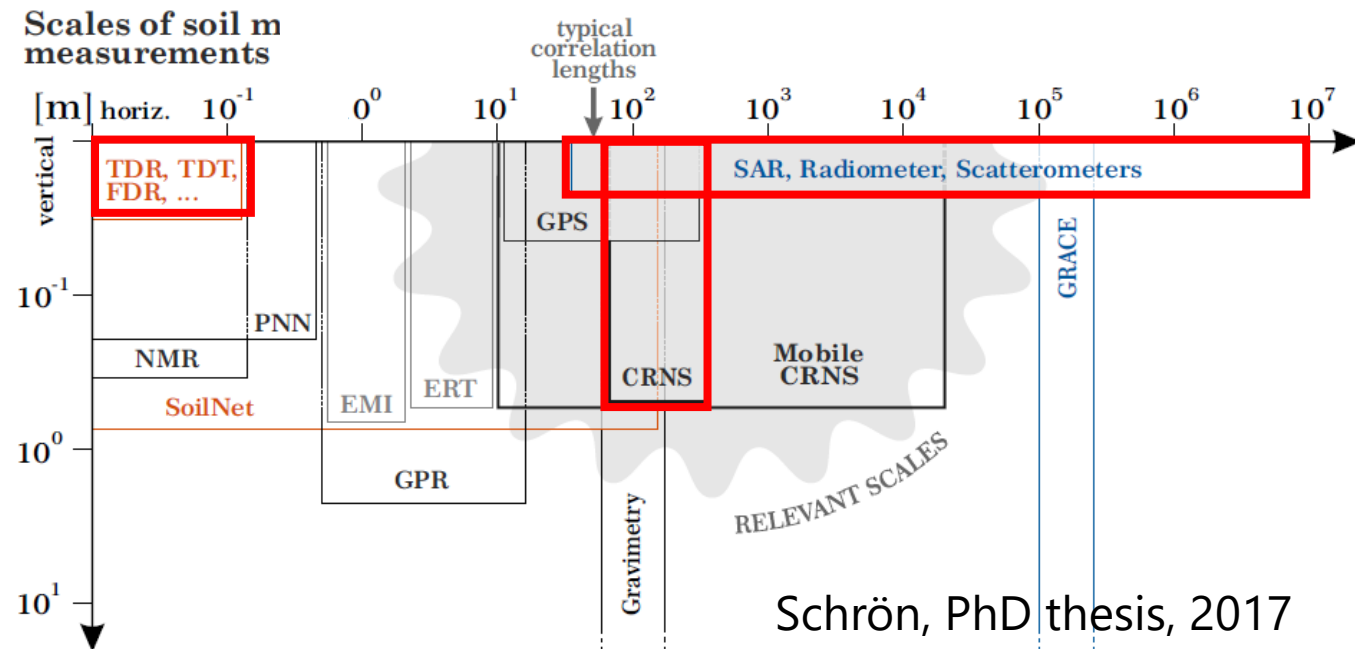
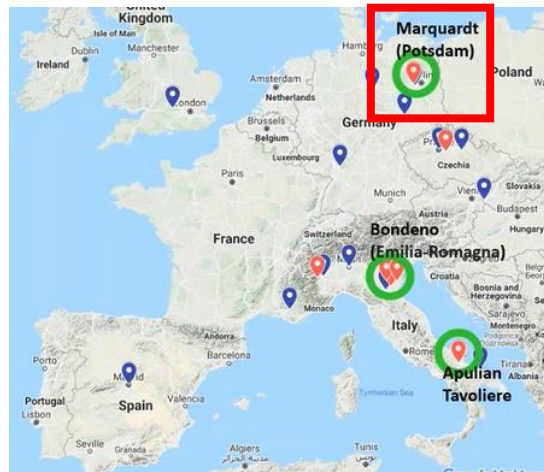
Soil Moisture Product Validation Good Practices Protocol

Version 1.0 – October 2020



SoMMet project

- SoMMet project aims to establish a metrological basis, harmonization in SM measurements across scales, from point scale to remote sensing, through CRNS, and data fusion.

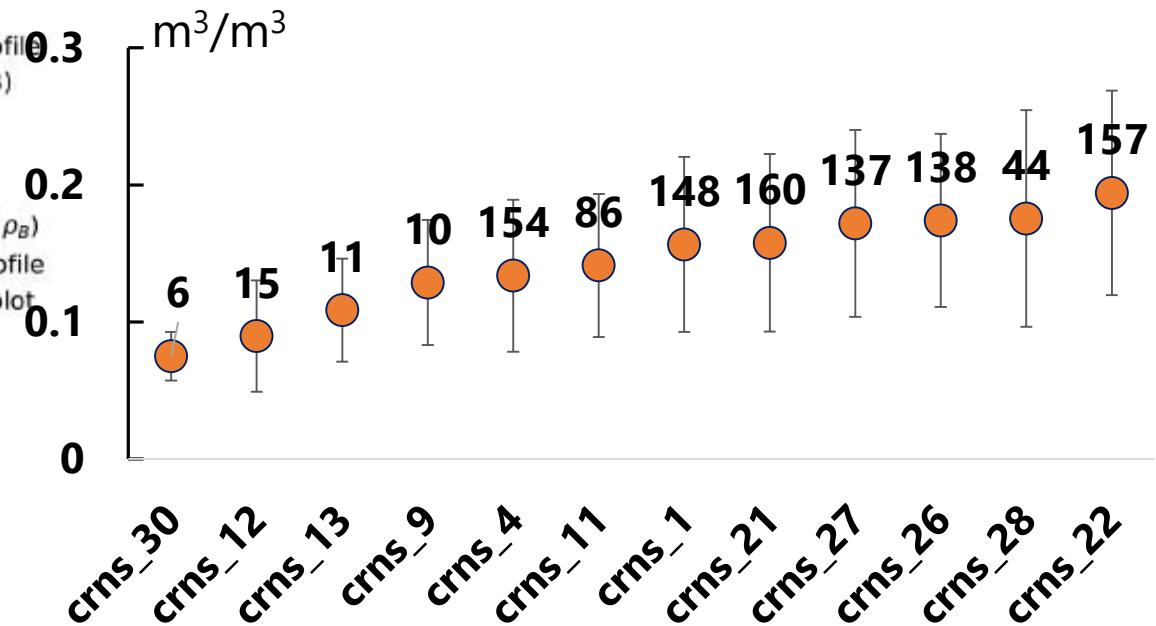
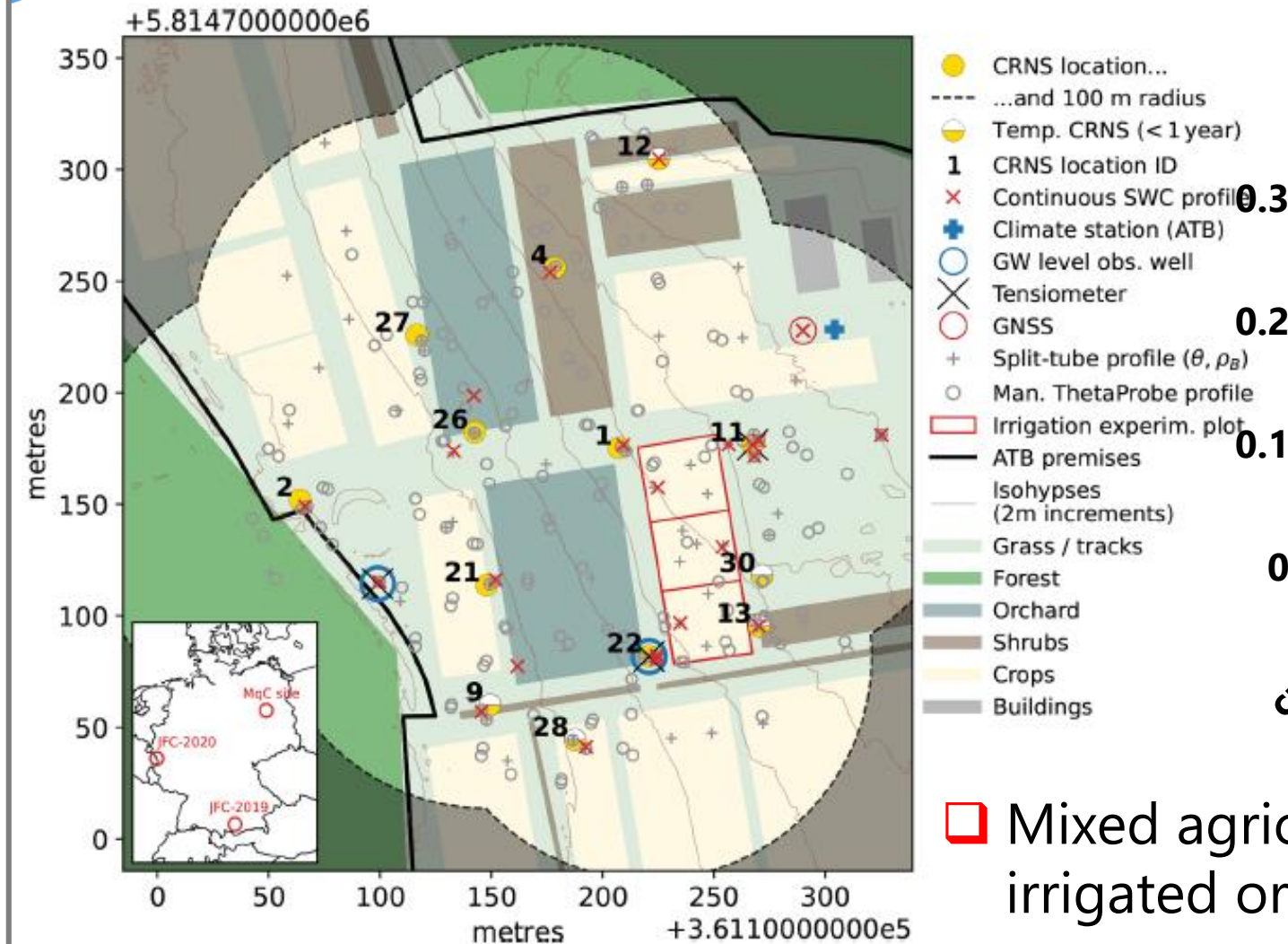


Objectives:

- ❖ to present the comparison of SM measurements from a cluster of CRNS and 1km S-1 SSM at the Potsdam test site in Germany
- ❖ to provide an example of data fusion

Potsdam site

CNRS SM temporal mean & std (2019-2022)



□ Mixed agricultural land use (crops, meadows, irrigated orchards, some bushland, some forest)

S-1 SMOSAR SSM product

Physical approximations: Short Term Change Detection Retrieval Model

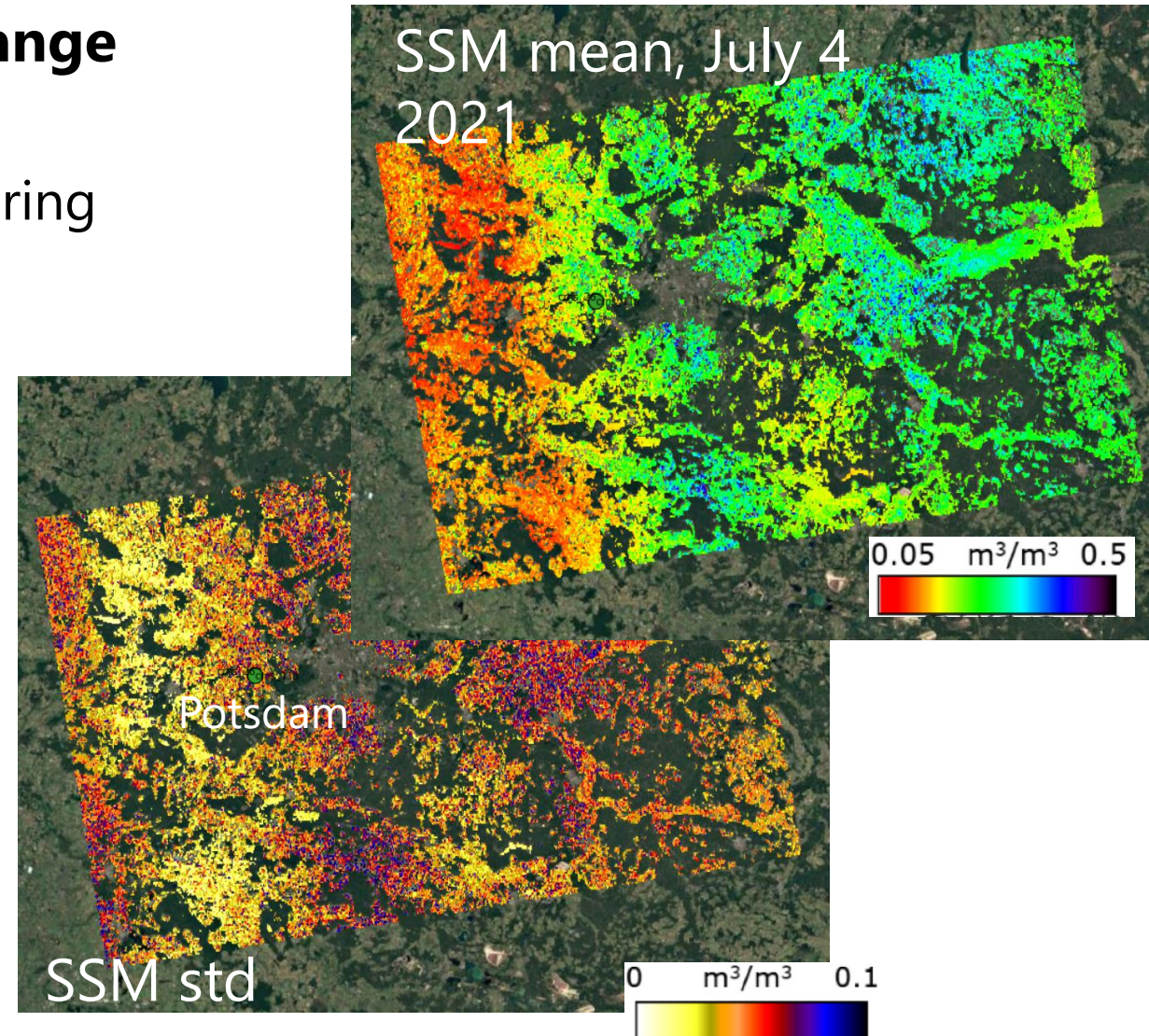
- surfaces dominated by soil attenuated scattering (Satalino et al., GRSL, 2014)

$$\sigma_0 \approx \tau^2 \cdot \sigma_0^{soil} \approx \tau^2 \cdot |\alpha_{pp}(\vartheta, \epsilon)|^2 \cdot F(\Omega, \vartheta, \lambda)$$

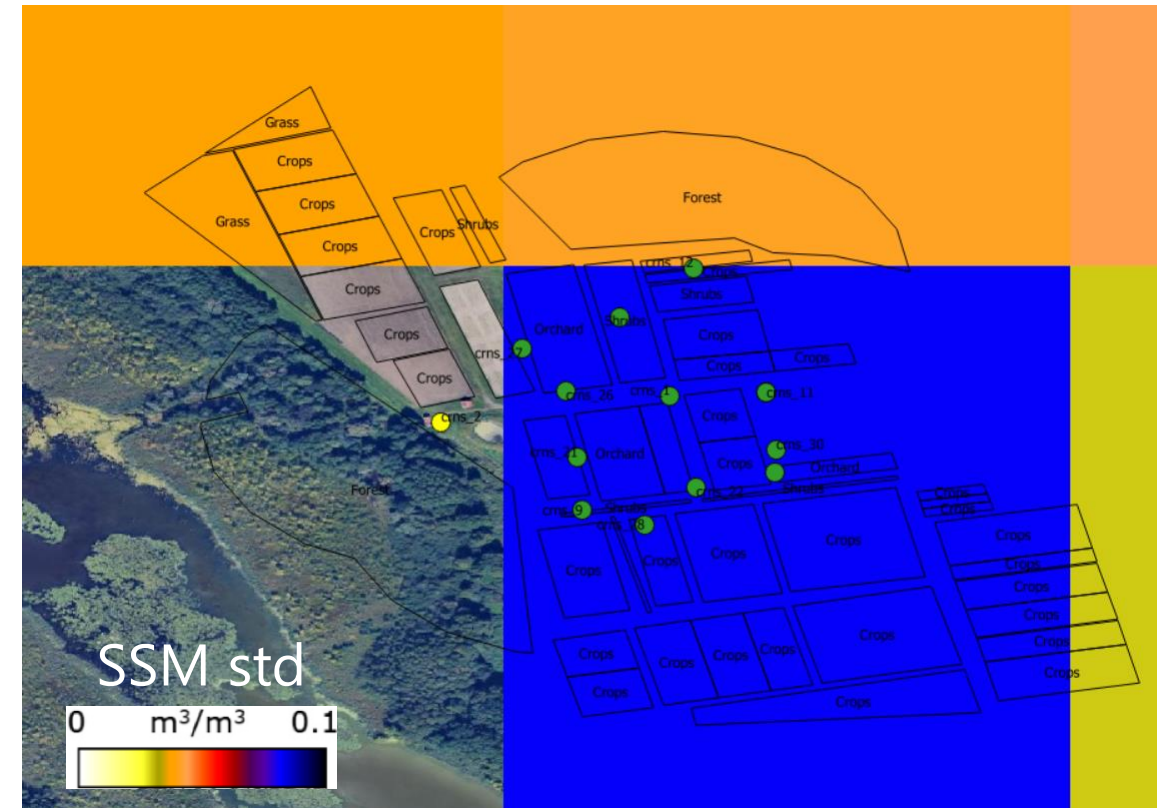
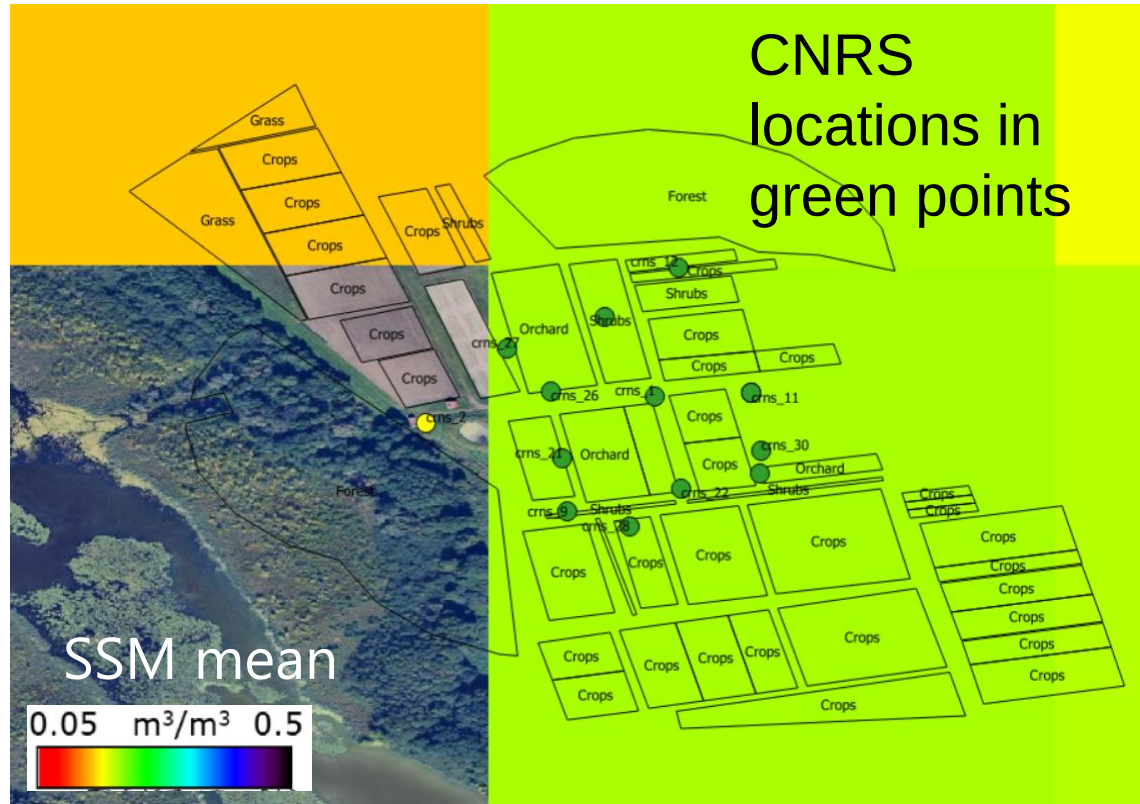
- σ_0 temporal change depends solely on SSM (Balenzano et al., EuJRS, 2013)

$$\frac{(\sigma_0)_{DoY(i+1)}}{(\sigma_0)_{DoY(i)}} \approx \frac{|\alpha_{pp}(\vartheta, \epsilon)|^2_{DoY(i+1)}}{|\alpha_{pp}(\vartheta, \epsilon)|^2_{DoY(i)}} \approx \frac{SSM_{DoY(i+1)}}{SSM_{DoY(i)}}$$

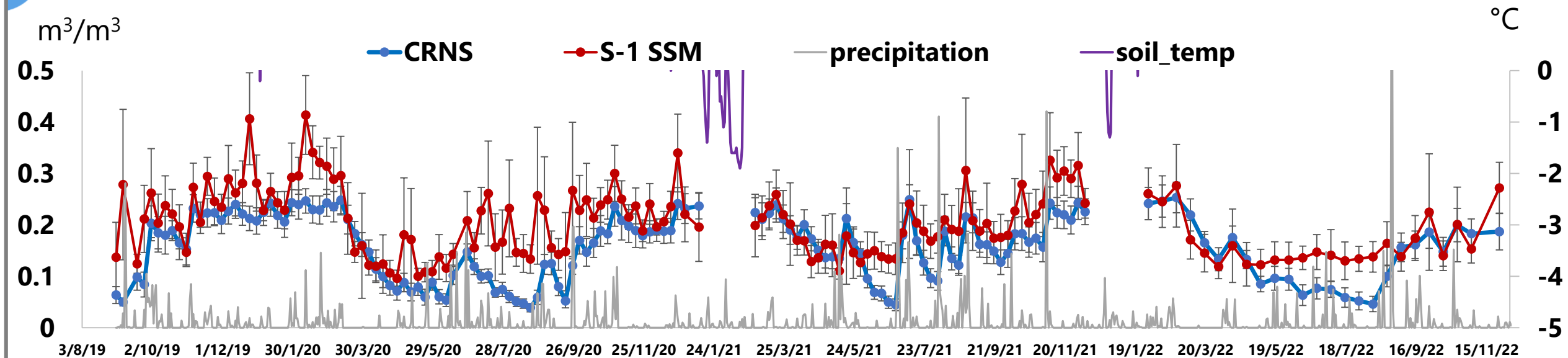
S-1 SSM mean and std at ~1 km resolution



S-1 SMOSAR SSM at Potsdam site



CRNS cluster and S-1 SMOSAR SSM @1km



❑ S-1 SSM from S-1 IW ASC 146 (17:00 UTC)

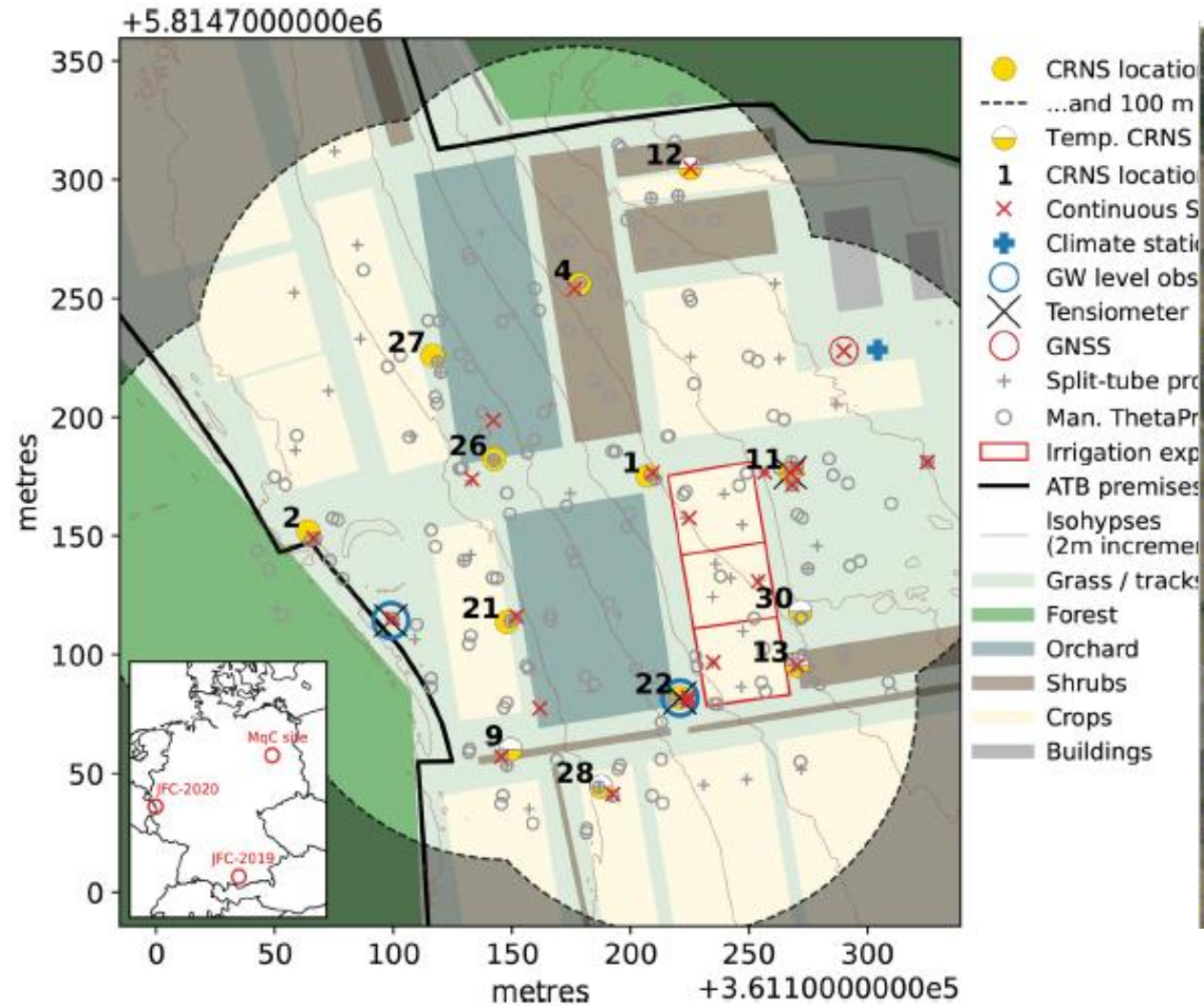
❑ CNRS daily average and a deeper penetration depth (e.g. 26.3 ± 7.7 cm on average, Köhli et al., 2015; Bogena et al., 2022)

❑ Data filtering -> dates with frozen soil removed

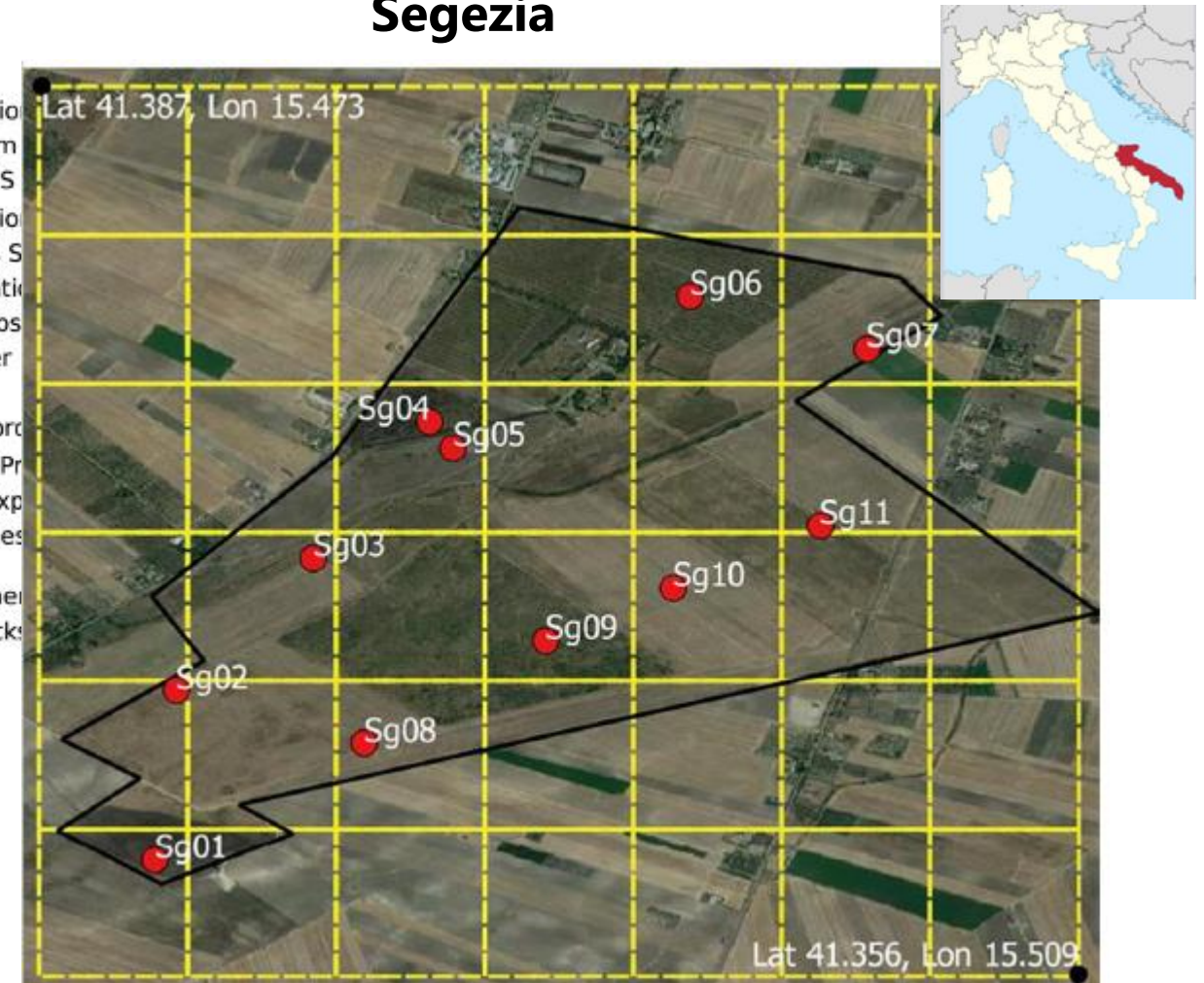
N of dates	bias [m ³ /m ³]	rmse [m ³ /m ³]	ubrmse [m ³ /m ³]	R
154	-0.046	0.067	0.049	0.7

Cluster of CRNS and cluster of PS sensors

Potsdam

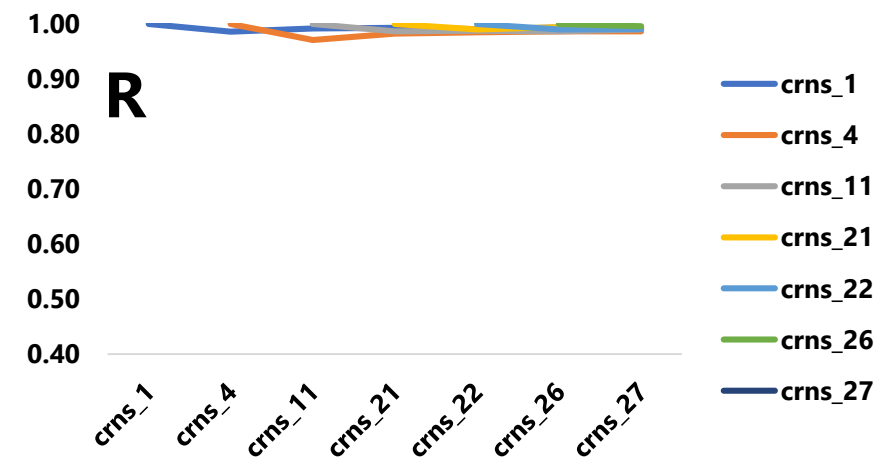
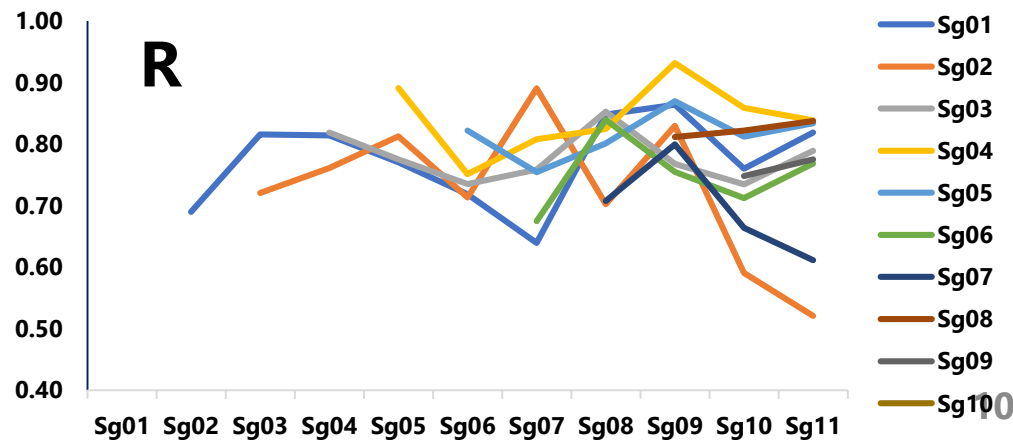
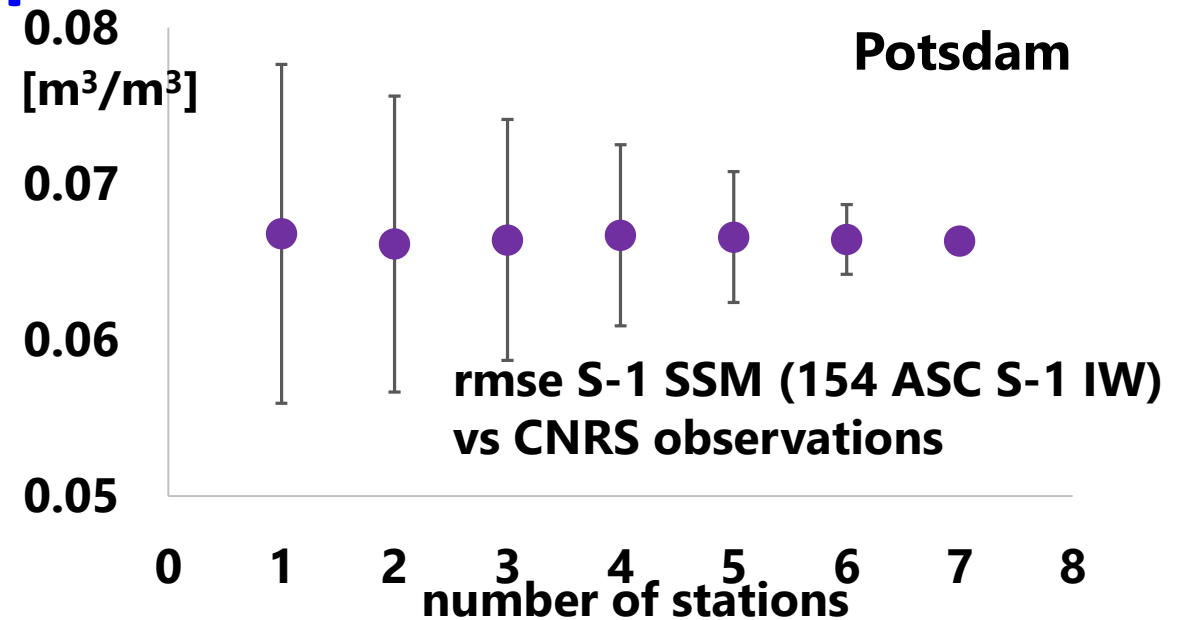
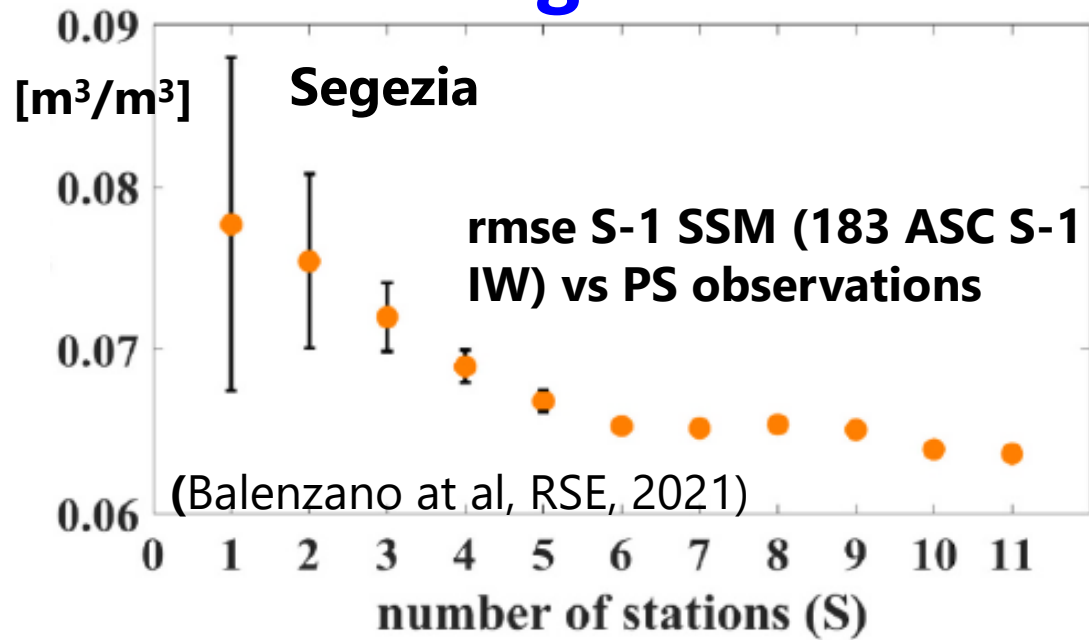


Segezia



11 stations cover a total area of $\sim 1.6 \times 1.6$ km²

Impact of spatial representativeness error on validation of high resolution SM product: rmse and R



Combining LWF with IDW interpolation

$$\frac{\sigma_{i+1}^0}{\sigma_i^0} \approx \left| \frac{\alpha_{VV}^{i+1}(\varepsilon, \theta)}{\alpha_{VV}^i(\varepsilon, \theta)} \right|^2 \approx \frac{\varepsilon^{i+1}}{\varepsilon^i} \approx \frac{SSM^{i+1}}{SSM^i}$$

$$\vec{\alpha}_{PP}^* = \alpha_{min} \cdot \max_{i=1, \dots, N} \left(\sqrt{\frac{\sigma_{0(N)}}{\sigma_{0(i)}}} \right) \cdot \left[\sqrt{\frac{\sigma_{0(1)}}{\sigma_{0(N)}}}, \sqrt{\frac{\sigma_{0(2)}}{\sigma_{0(N)}}}, \dots, \sqrt{\frac{\sigma_{0(N)}}{\sigma_{0(N)}}} \right]$$

$$\varepsilon(interp) = \varepsilon_{SAR} w_{SAR} + \varepsilon_{GRD} w_{GRD}$$

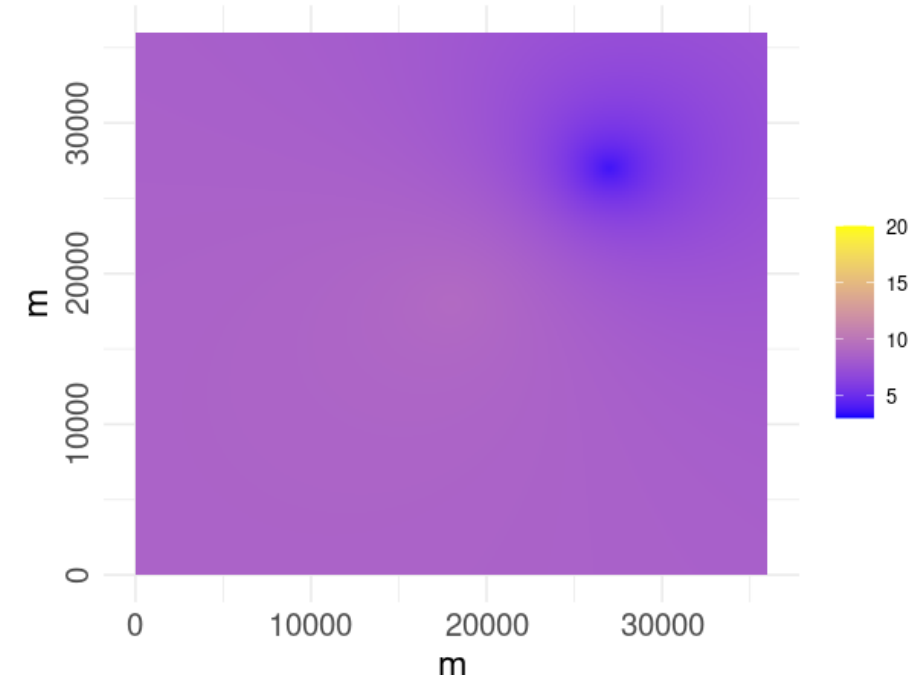
$$w_{SAR} = \frac{1}{d^a} \frac{1}{\Delta \varepsilon_{SAR}}$$

$$w_{GRD} = \frac{1}{d^b} \frac{1}{\Delta \varepsilon_{GRD}}$$

IDW interpolation - 2019-09-07

SAR eps = 9.16, In-situ eps = 3.70

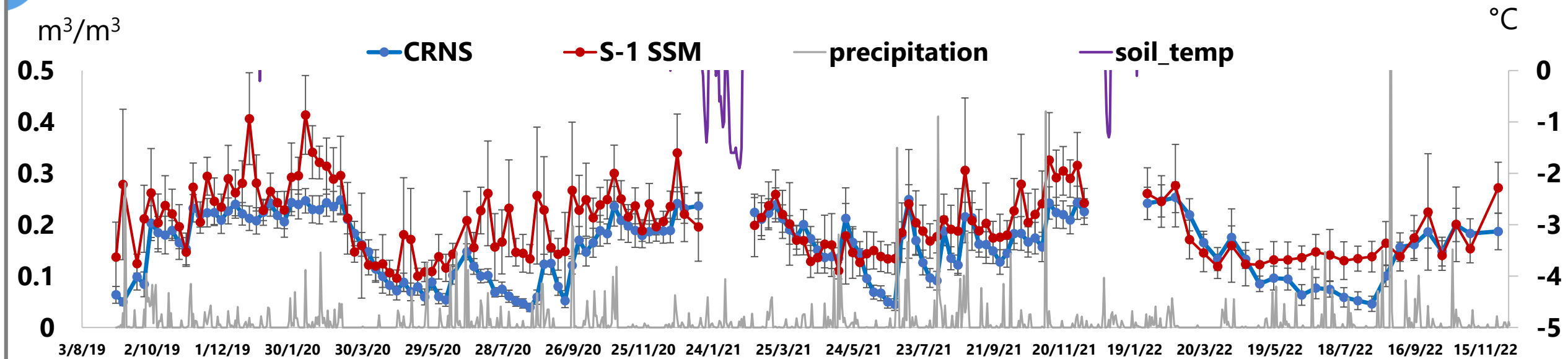
SAR err = 1.10, In-situ err = 0.28



LWF = **Linear Weighted Fusion**

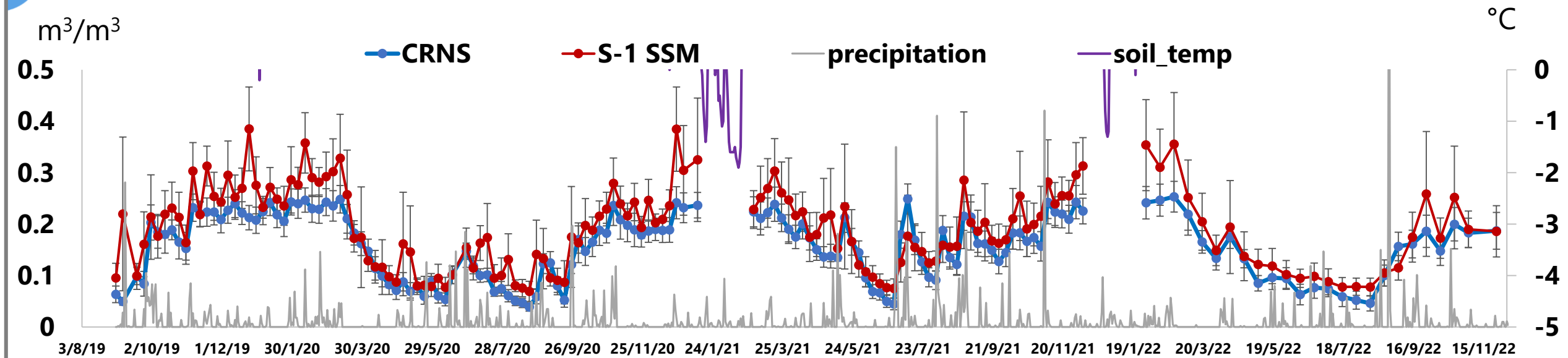
IDW = **Inverse Distance Weighting**

CRNS cluster and S-1 SMOSAR SSM @1km



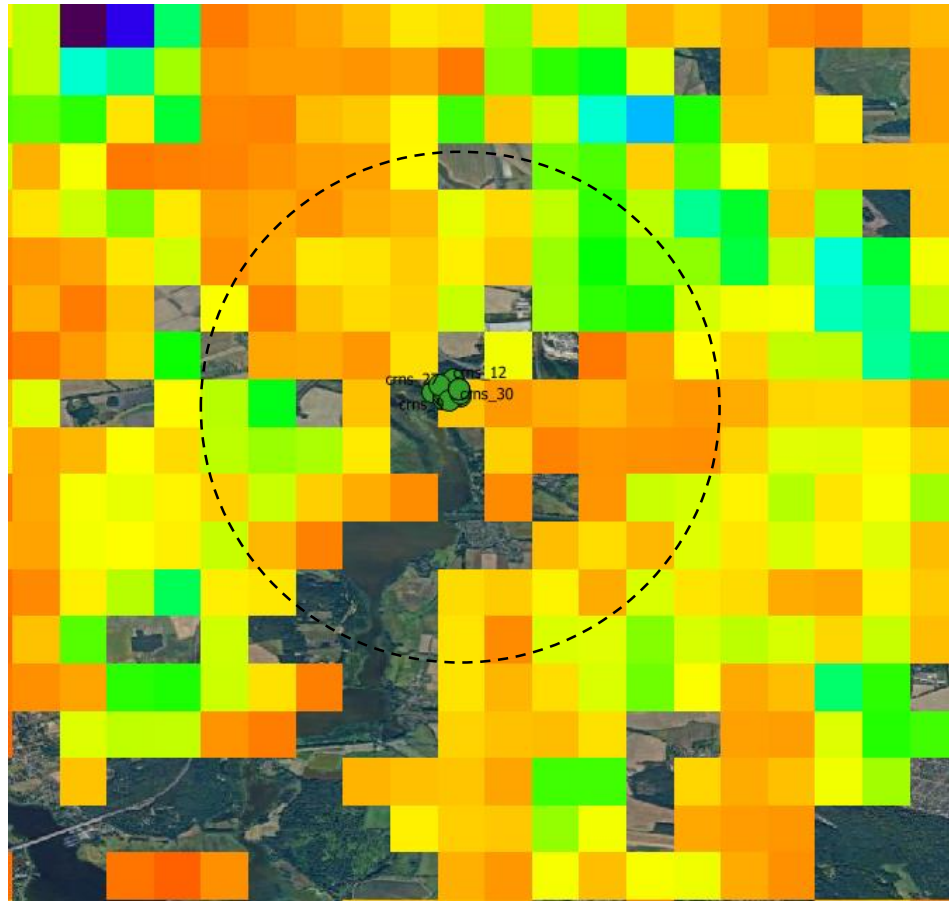
N of dates	bias [m^3/m^3]	rmse [m^3/m^3]	ubrmse [m^3/m^3]	R
154	-0.046	0.067	0.049	0.7

....after data fusion

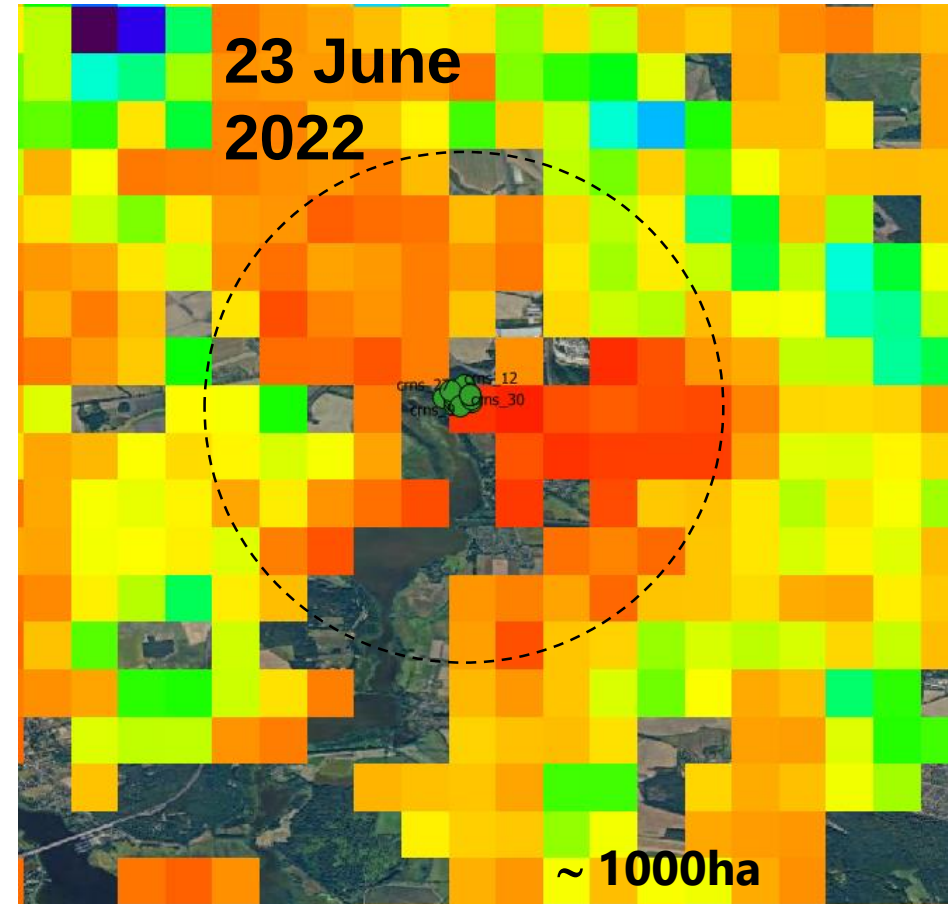


N of dates	bias [m^3/m^3]	rmse [m^3/m^3]	ubrmse [m^3/m^3]	R
154	-0.034	0.049	0.035	0.89

Perspective for precision farming



BEFORE



AFTER

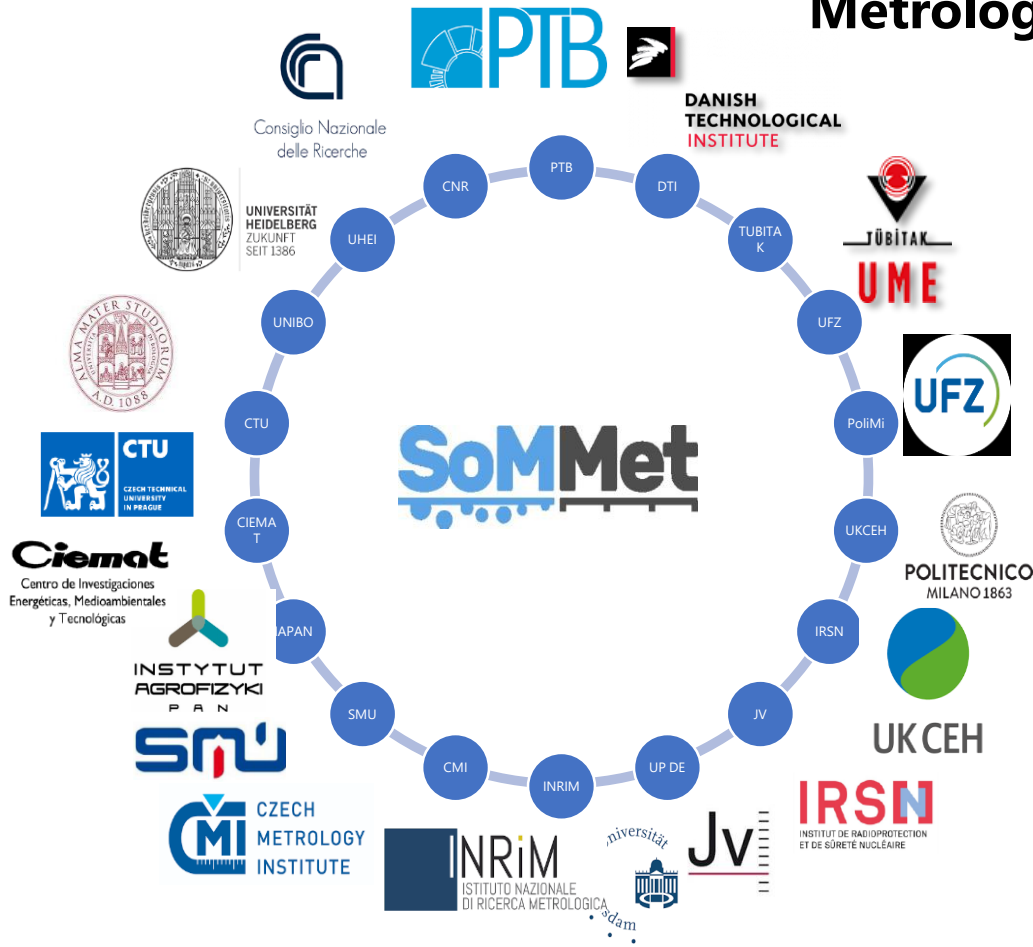
Summary

- ❑ SoMMet project: harmonisation in soil moisture measurements across scales, from point scale to remote sensing, through CRNS.
- ❑ Three years (**2019-2022**) comparison between CNRS measurements and S-1 SMOSAR SSM products at 1 km resolution (bias=-0.034 m³/m³; rmse=0.049 m³/m³; R=0.89).
- ❑ Characterization of spatial representativeness error: CNRS vs PS.
- ❑ Integrating CRNS and S-1 SM results in very accurate SM maps at high resolution (~ 1ha) and local scale (e.g., ~1000-5000 ha), which is **promising for precision farming and landslide monitoring**

Thank you!

Metrology for multi-scale monitoring of soil moisture (SoMMet)

www.sommet-project.eu



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**METROLOGY
PARTNERSHIP**



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