Earth Observation (EO) data for high resolution soil moisture (SM) monitoring

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ACKNOWLEDGEMENTS:

seom scientific exploitation of operational missions Exploit-S-1 Project

esa

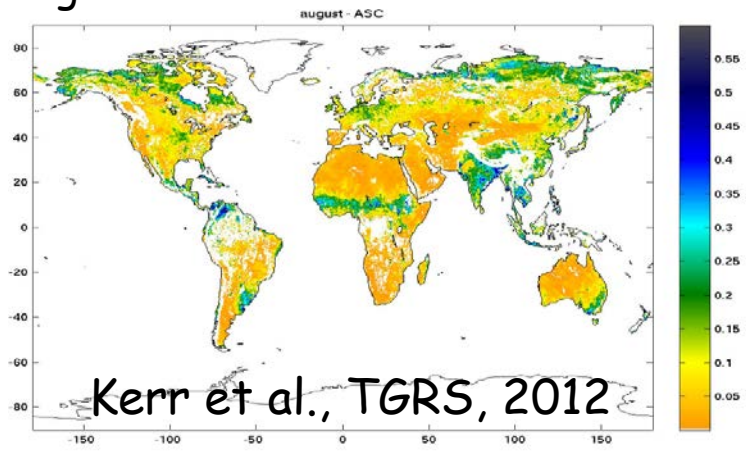
Sensagri

ASI Agenzia Spaziale Italiana

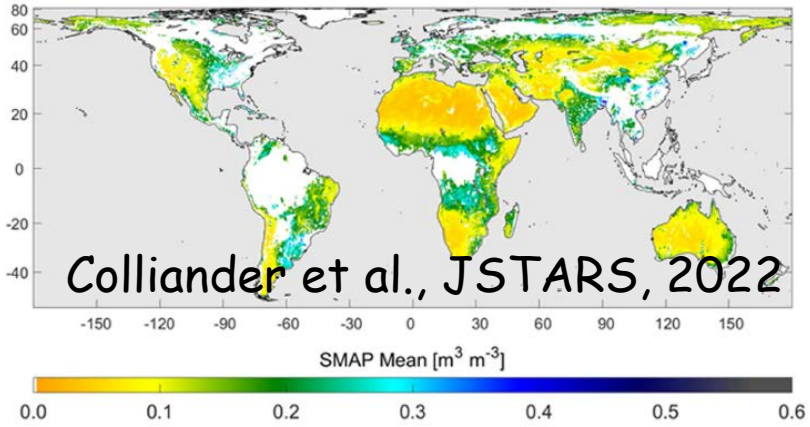
SARAGRI

Operational global coarse SM products from microwave satellites

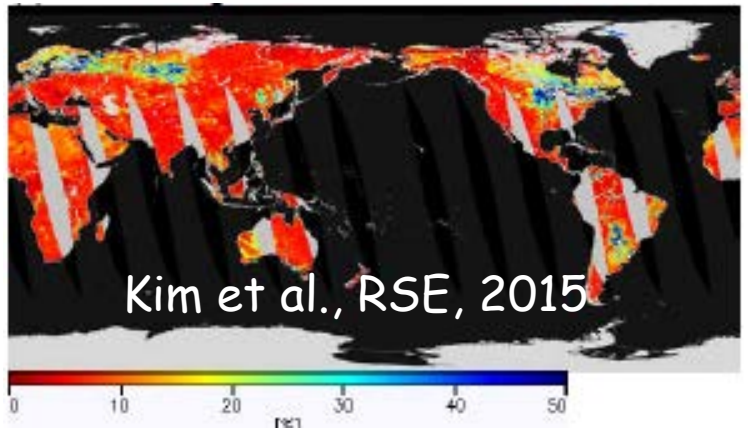
ESA/SMOS SM for the month of August 2010



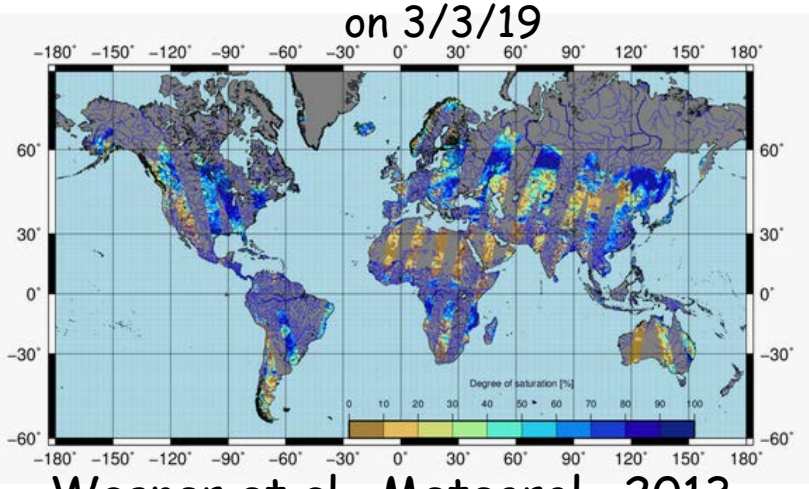
Time series 2015-2021 mean of NASA/SMAP SM



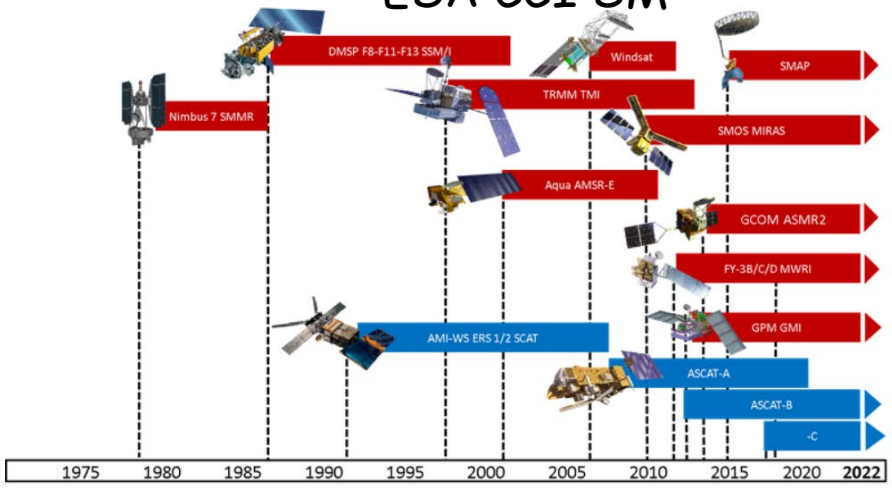
JAXA/AMRS2 SM on 20/05/13



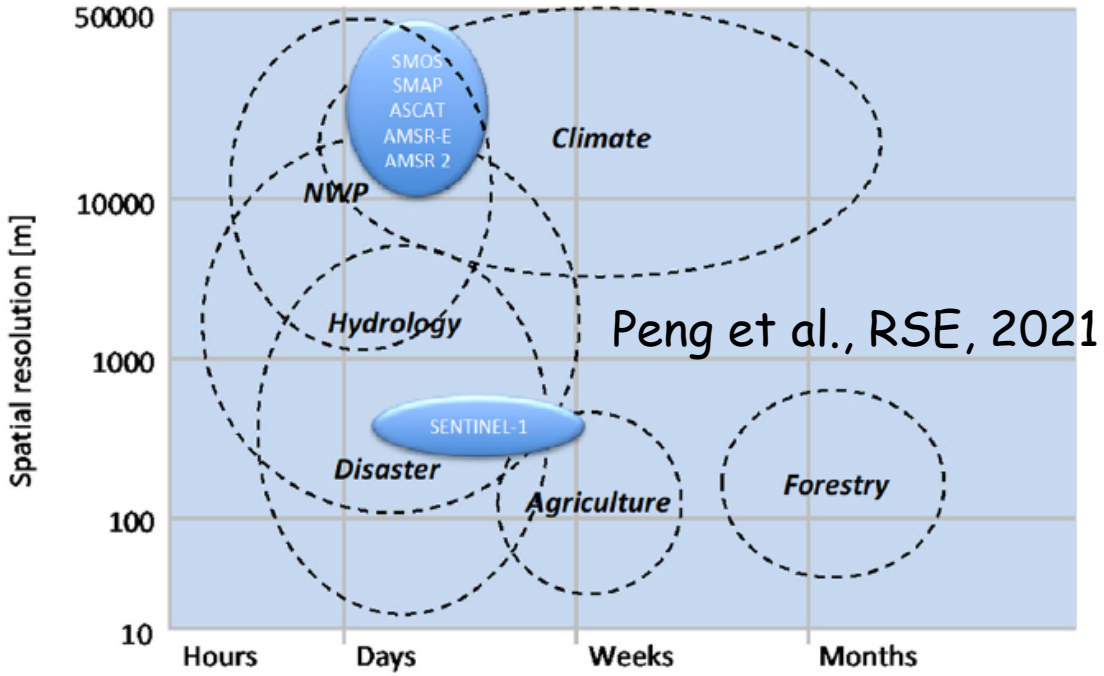
EUMETSAT/ASCAT SWI on 3/3/19



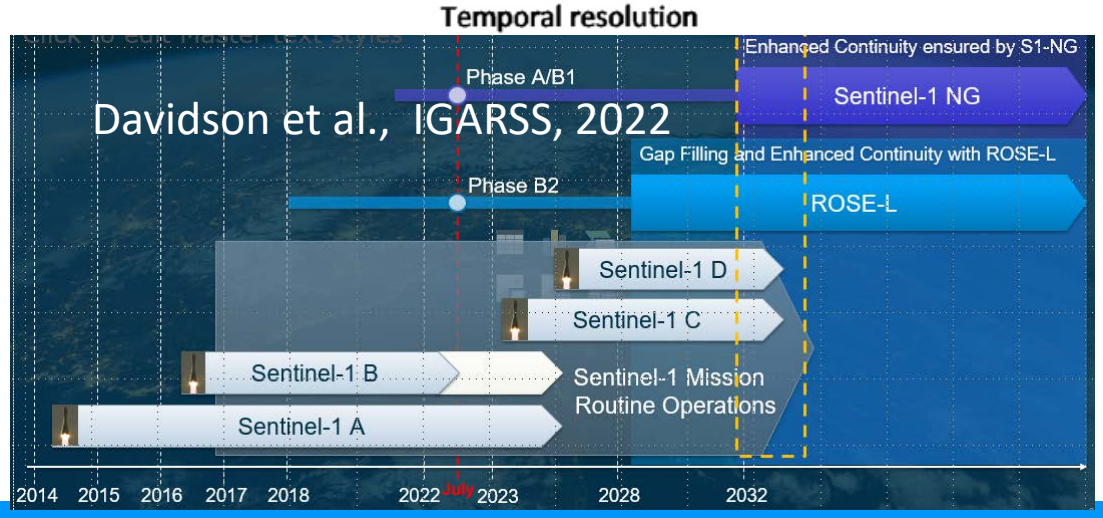
ESA CCI SM



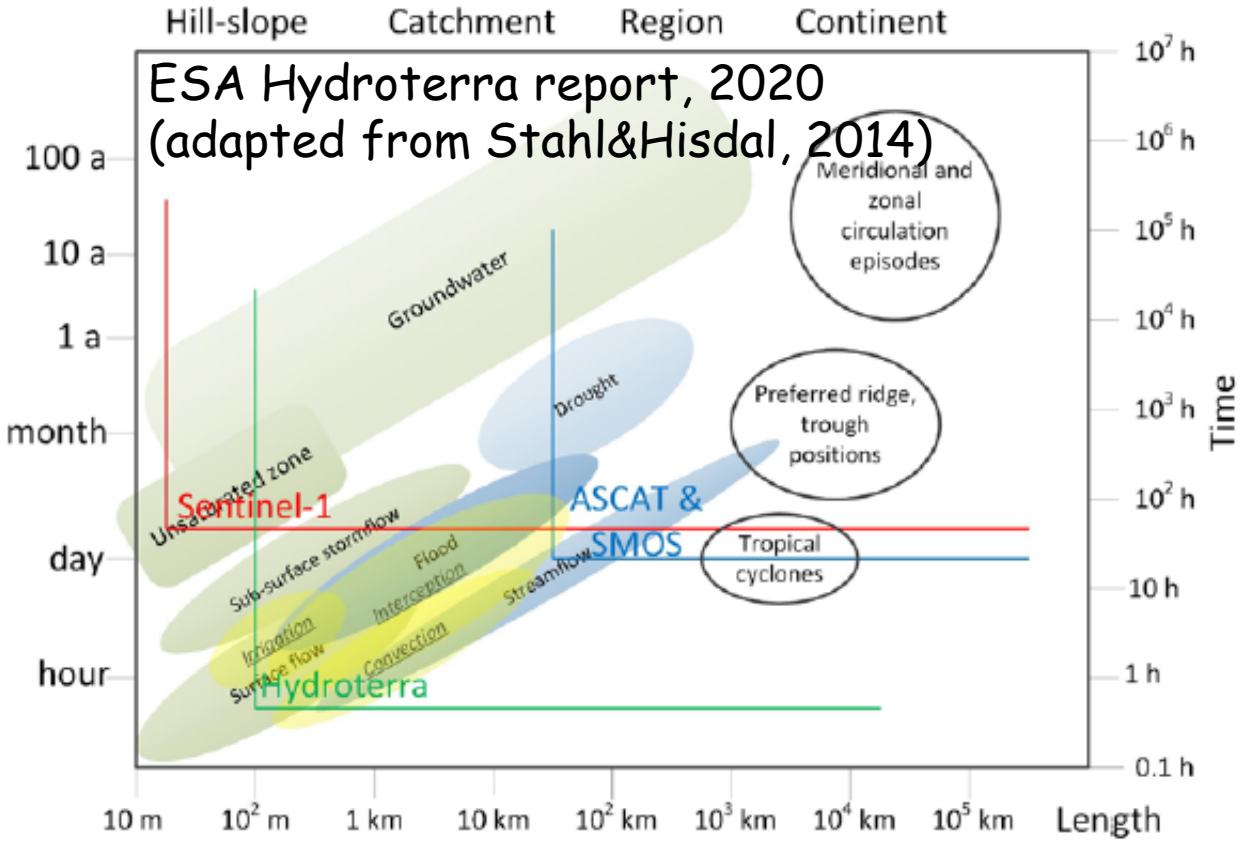
High resolution/sub-daily SM products needed



Peng et al., RSE, 2021



Davidson et al., IGARSS, 2022



- scientific interest remains to enhance the ability to resolve fine-scale surface heterogeneity and sub-daily variability

Outline

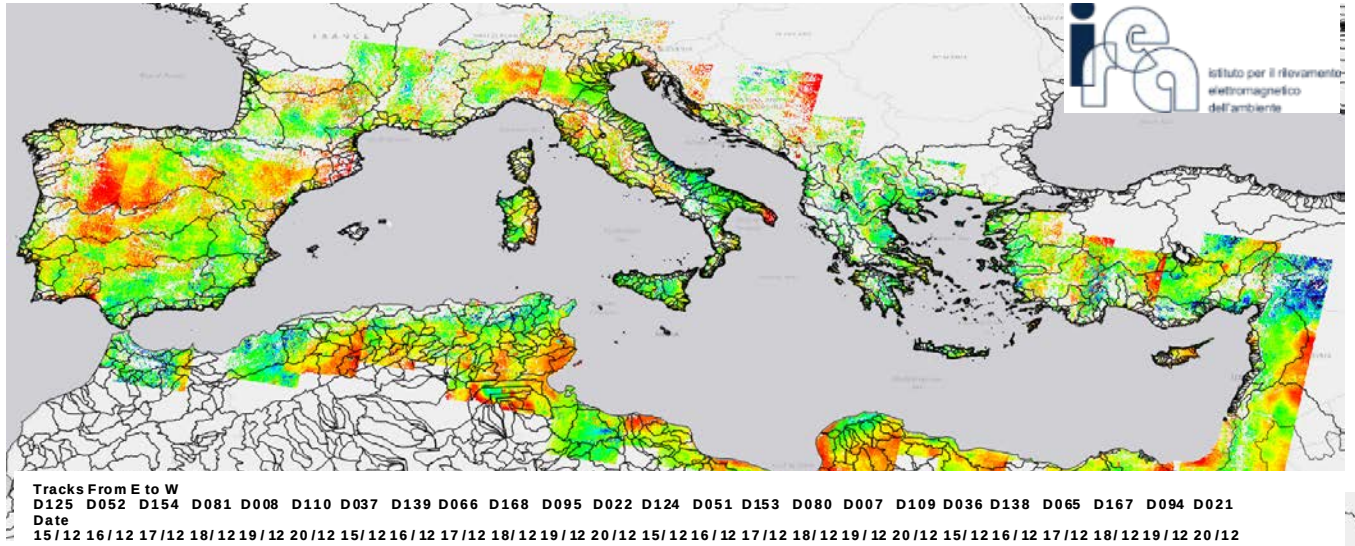
- SM product at high (0.1-1km) resolution derived from multi-platform SAR systems
  - Example of application: detection of irrigation events
  - Example of added value information stemming from SM retrieval: tillage change detection

- European Space Agency (ESA) airborne campaign carried out in Southern Italy to investigate the monitoring of rapid changes in SM

- European metrology study aiming at combining SM measured by different methods and at different spatial support, from point scale sensors, Cosmic Ray Neutron Sensing (CRNS) and satellite-based remote sensing

1 km Sentinel-1 SM map composite over the Mediterranean basin

Dates 15/12/17 - 20/12/17



- SM variability resolved at basin scale

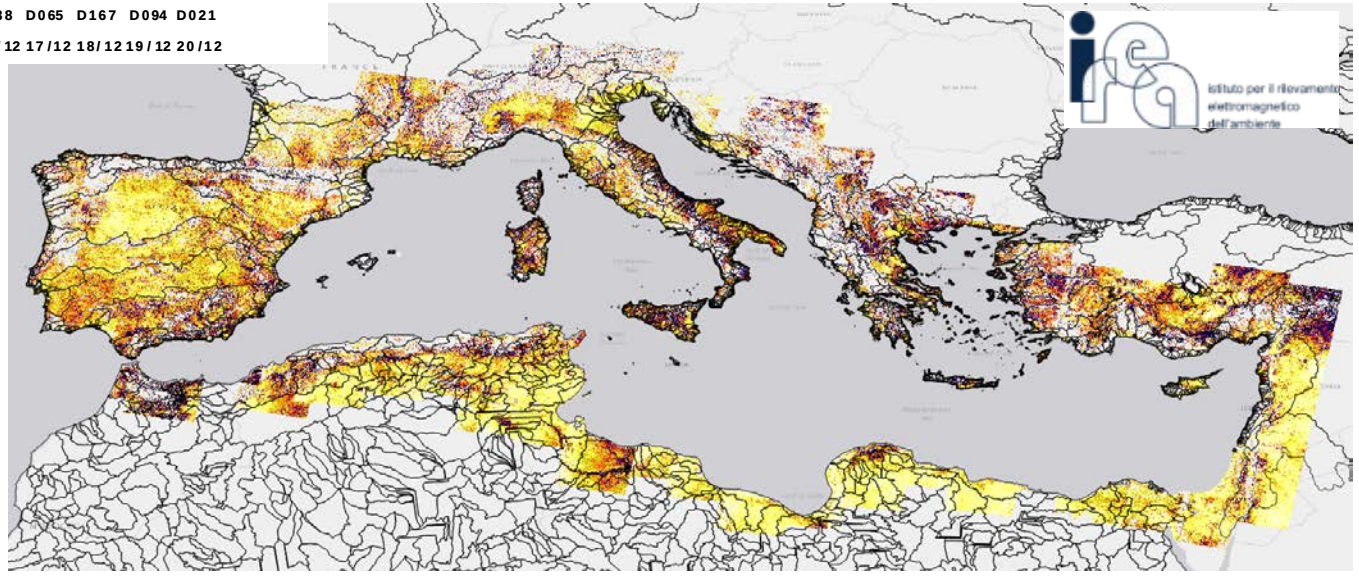
SM Mean

0.05 m^3/m^3 0.5

- std map provides **complementary information**

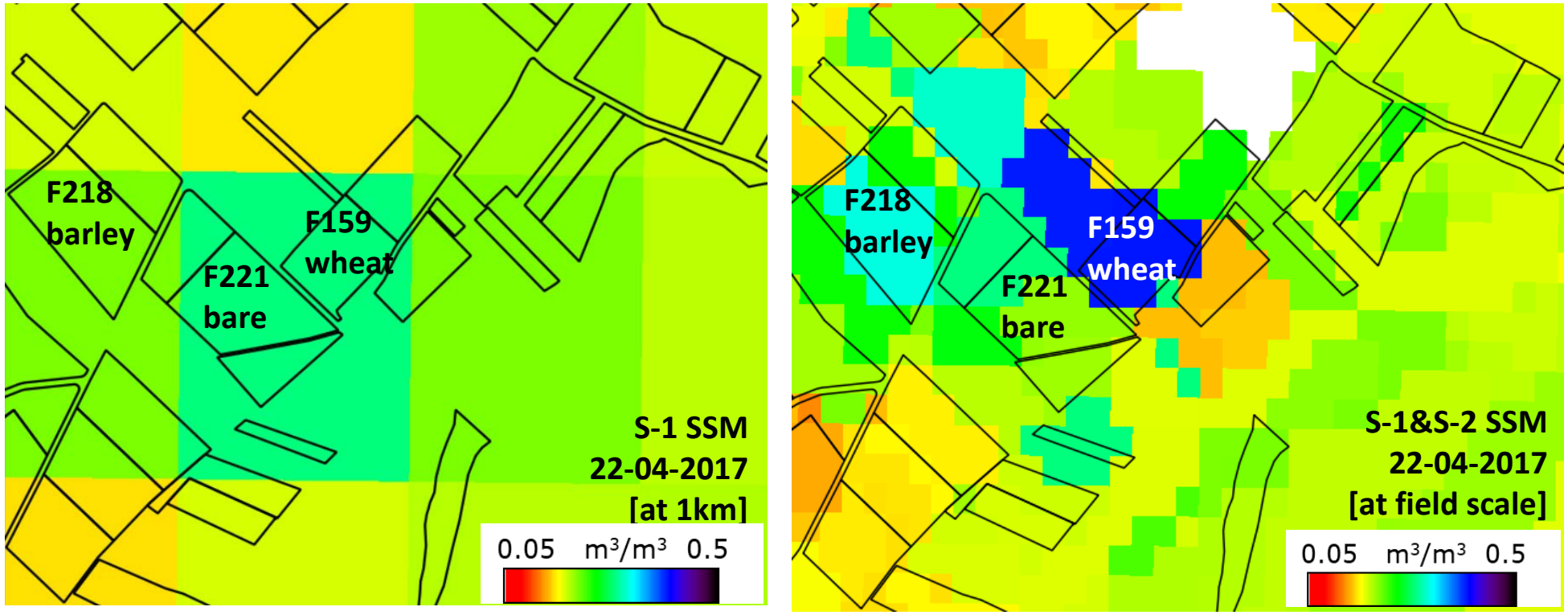
SM Std dev

0 m^3/m^3 0.1



Balenzano et al., RSE, 2021

Is 1km SM enough for agriculture applications?

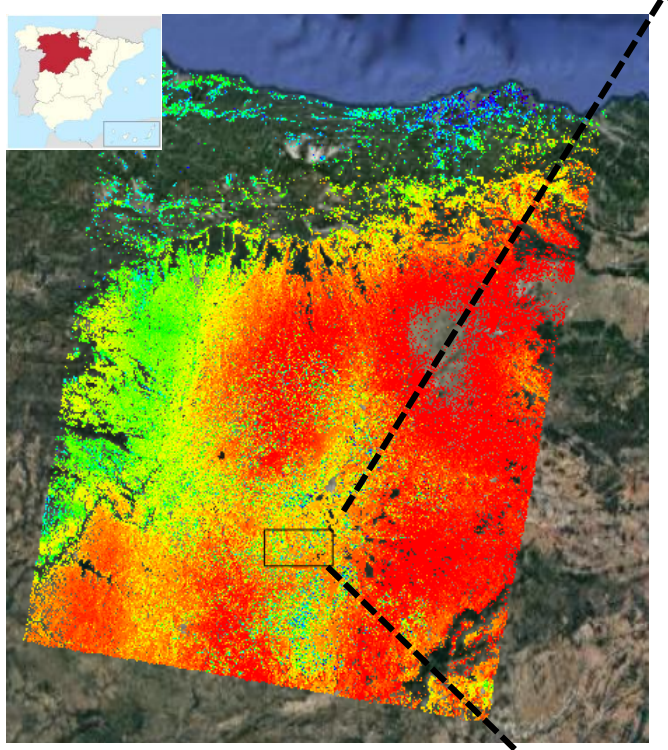


- Irrigation detection requires SM information at least at field scale.

Balenzano et al., Water, 2022

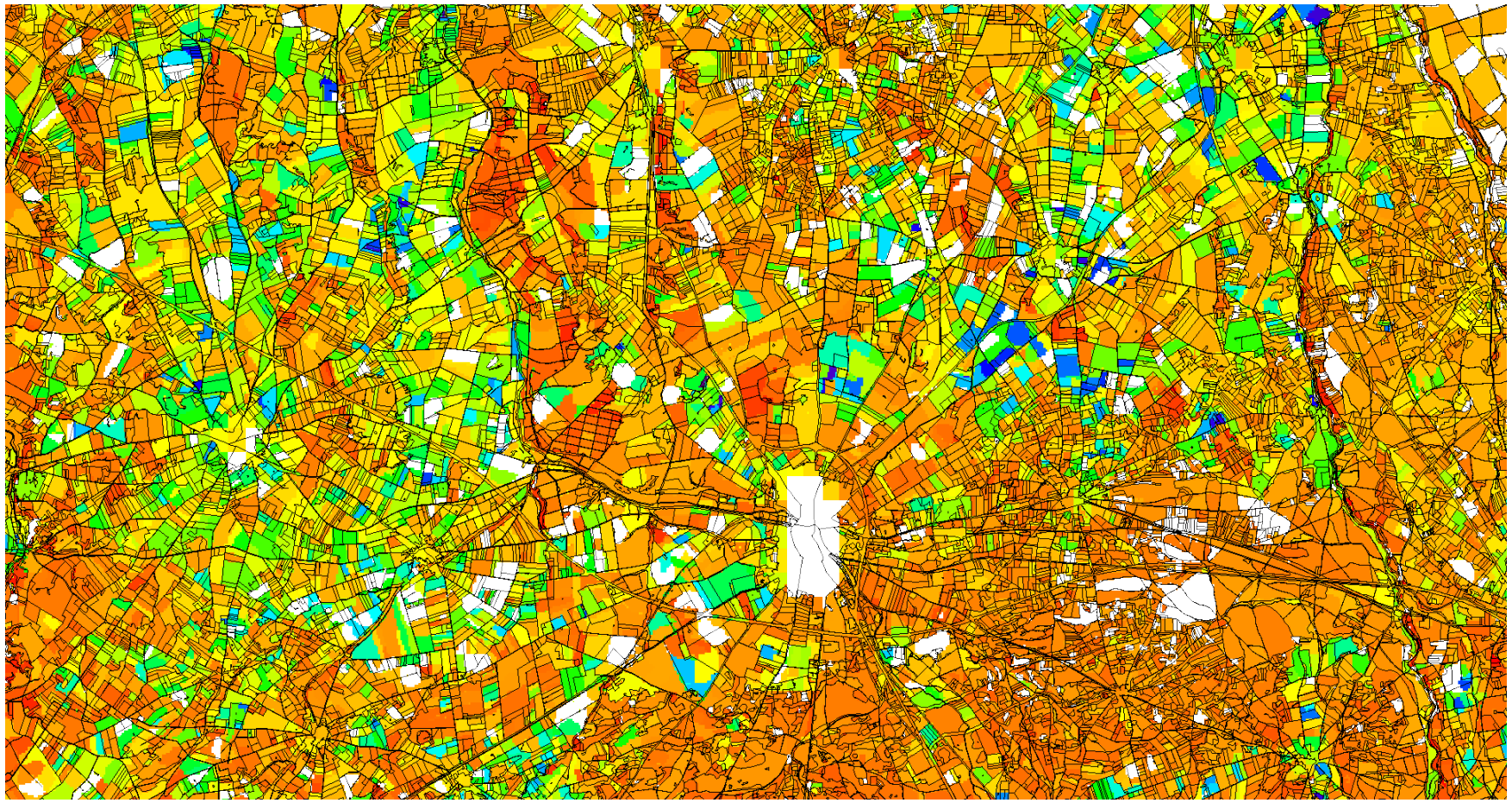
Sentinel-1 & Sentinel-2 SM at field scale

Castilla y León

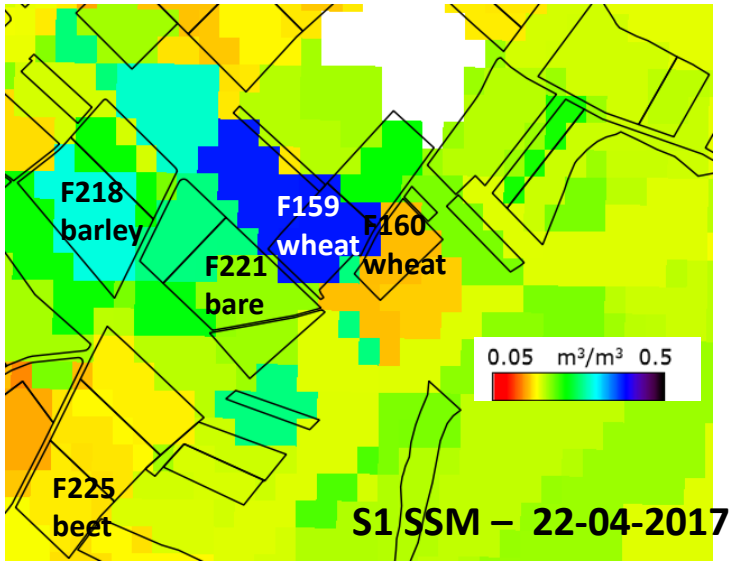


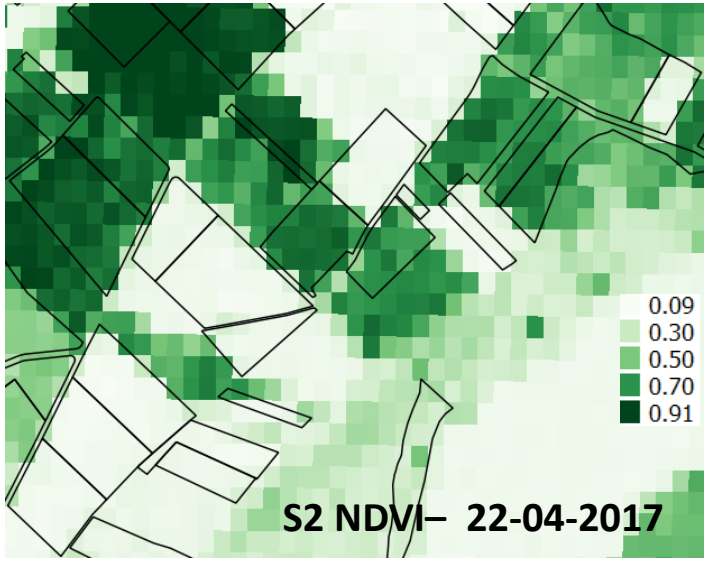
SM 0.05 m^3/m^3 0.5

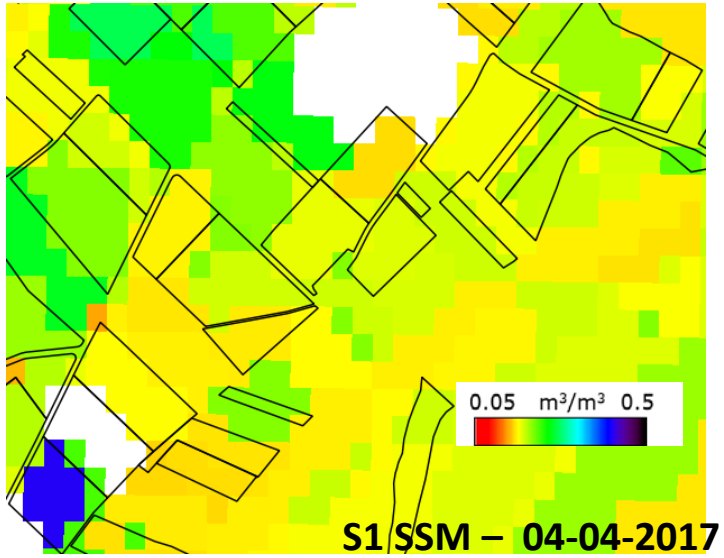
24/05/2021

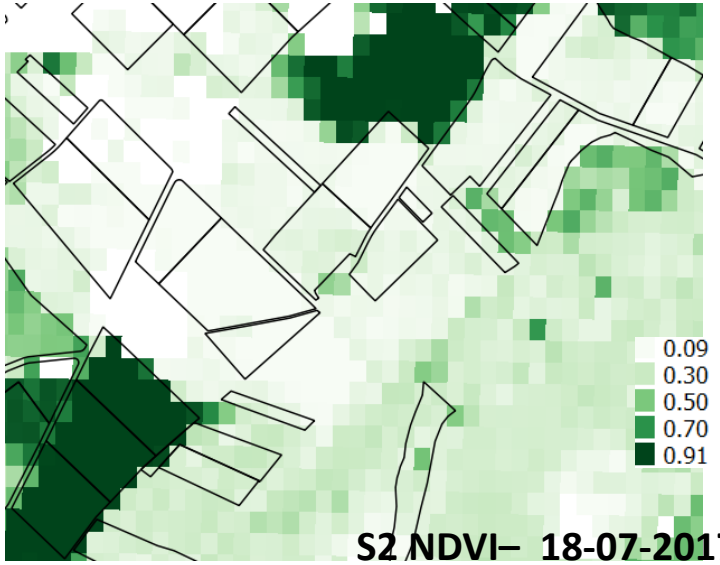


SAR and multispectral data complementarity for irrigation







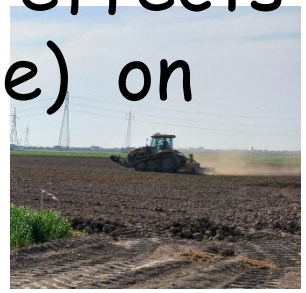


- Sentinel-1 SM → soil wetness (**irrigation event & early detection of irrigated areas**)
- Sentinel-2 NDVI → vegetation greenness (irrigated areas identified **late in the season**)

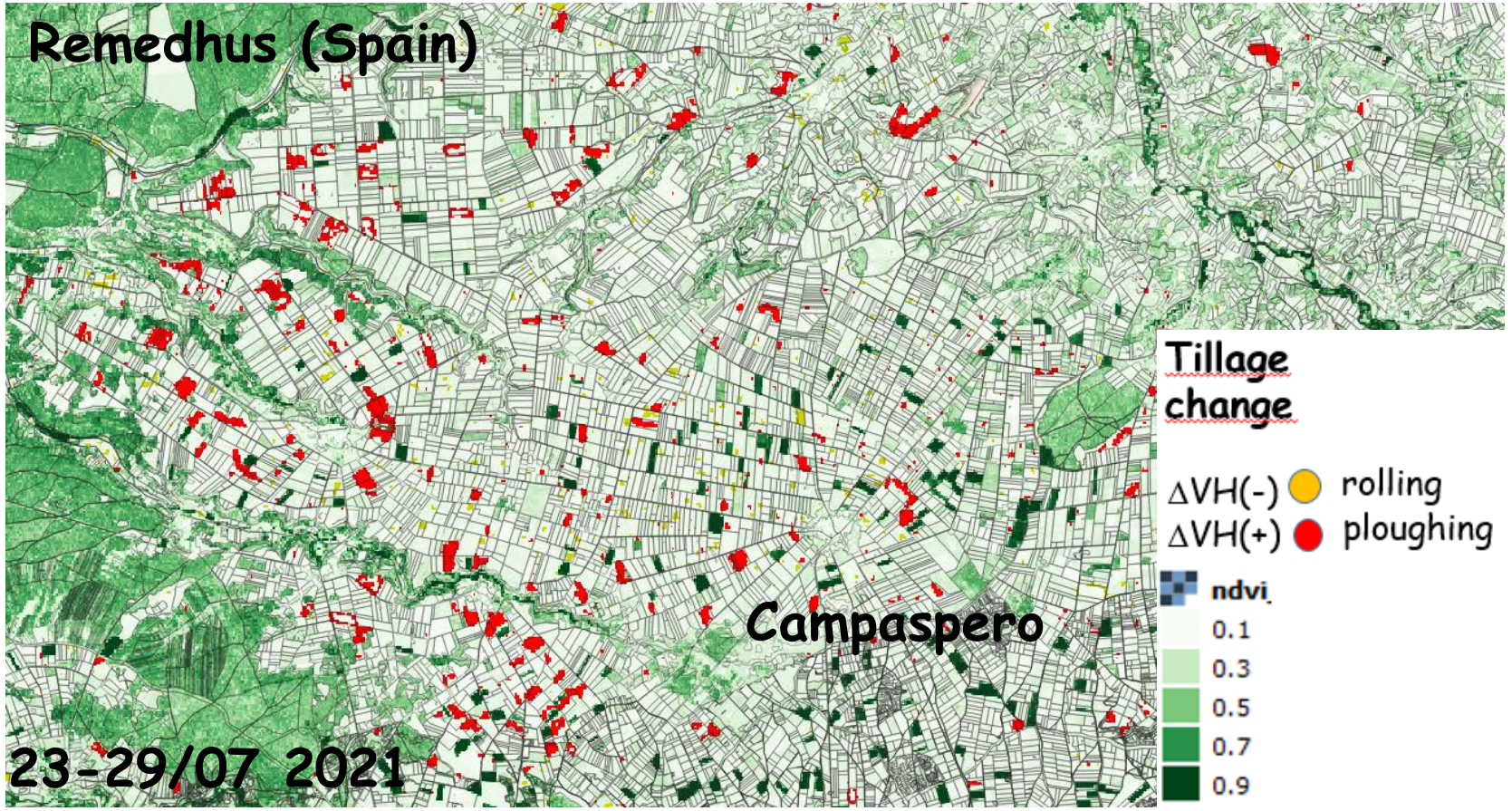
Sentinel-1 Tillage change detection

- incoherent change detection applied to S-1 **Cross-Pol** over bare soils
  (Satalino et al., 2018)

- Multi-scale approach to separate precipitation effects (medium-scale) on backscatter

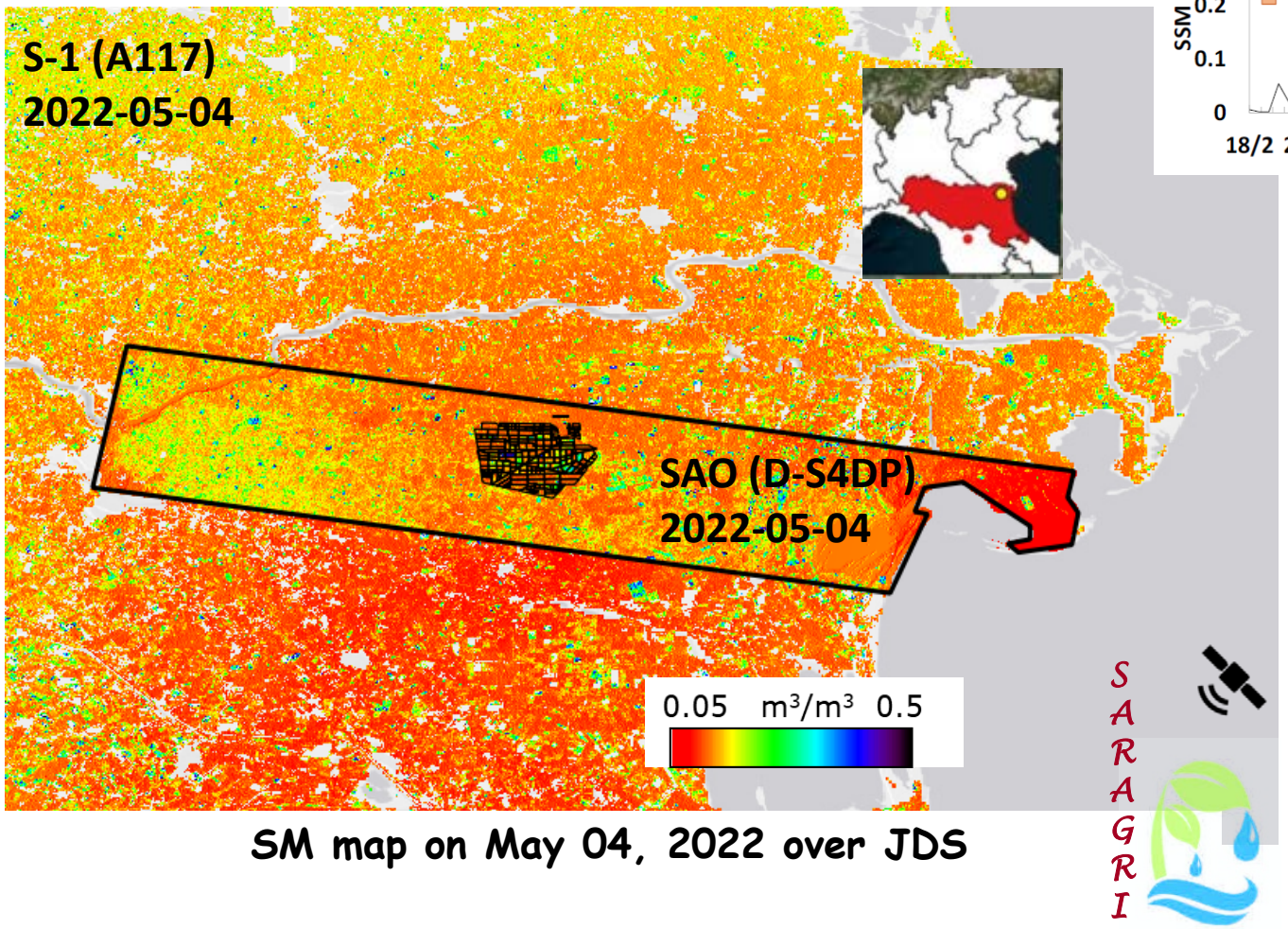


Example of tilled/non-tilled fields by (S-1) cross-pol change and S-2 NDVI (<=0.3) @100m scale

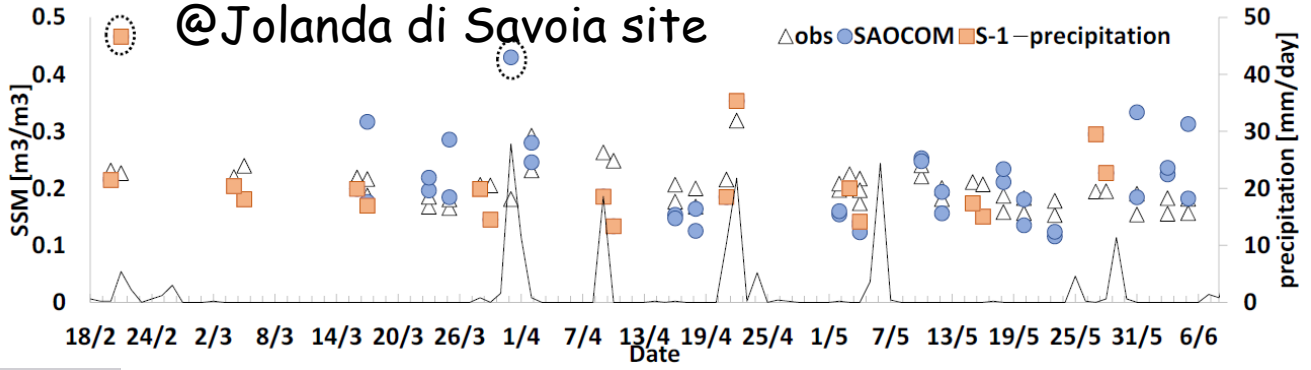


Combining multi-platform SAR observations for frequent SM

SM retrieval from SAR data by the Short term Change Detection (STCD) method



SM map on May 04, 2022 over JDS



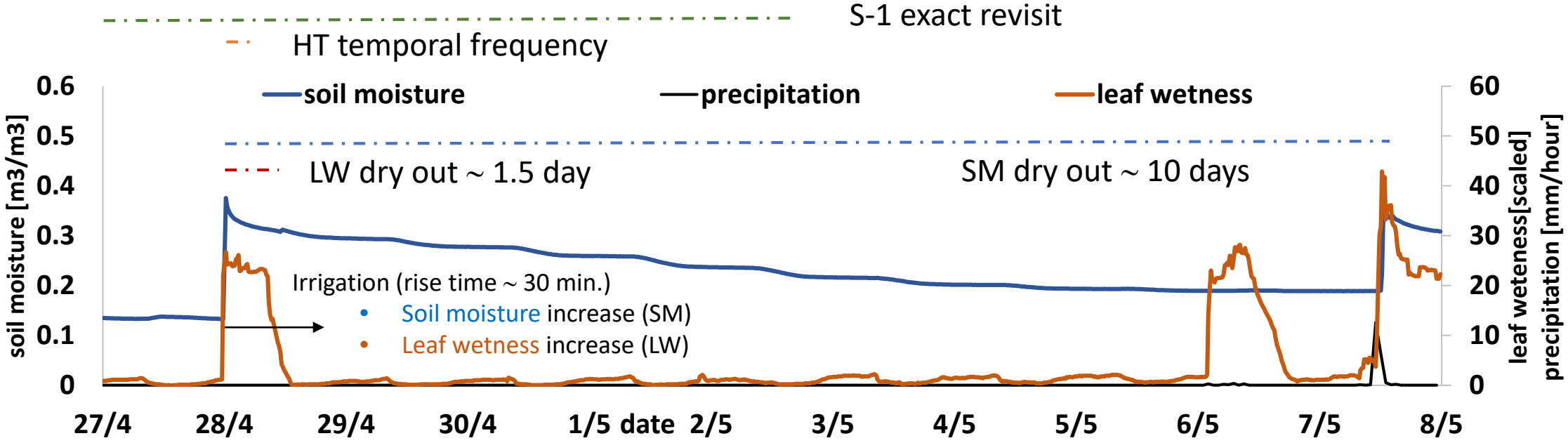
N= 169, RMSE 0.058m³/m³ (2 sites)

- Integration of multi-frequency & multi-platform SAR measurements for a consistent and harmonized SM retrieval at higher temporal resolution

Agenzia Spaziale Italiana

Monitoring the rapid (few hours to few days) land water cycle processes

- to improve the understanding of:
  - formation and dynamics of Mesoscale Convective Systems which cause extreme rainfall, and related flooding and landslide
  - the diurnal water cycle related to soil moisture and snow melt/re-freeze

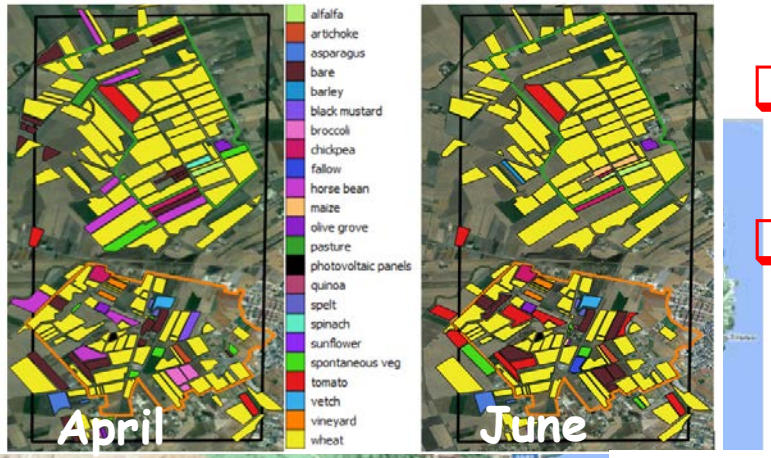


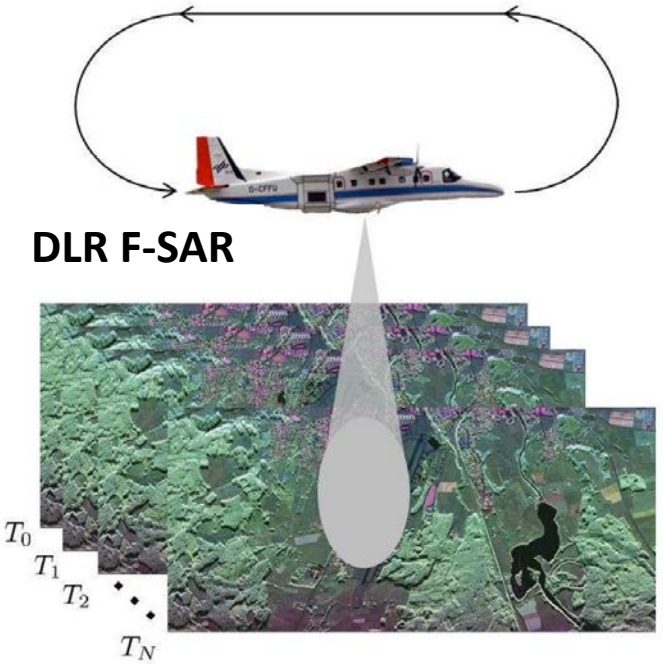
The research is funded by the ESA through the project "Simulation of Hydroterra SAR System Performance in the Mediterranean and the Alps Based on Experimental Airborne SAR Data" (SARSimHT-NG), contract no. 4000134680/21/NL/FF/an.

ESA SARSimHT-NG experiment for GEOSAR concept study

- 2 missions: 1) 28-29 April and 2) 15-16 June 2022
- 4 flights per mission: morning & afternoon
- For each flight 11-12 passages every 10 minutes approx., except afternoon of the second day (only 4-5 passages)

Crop maps

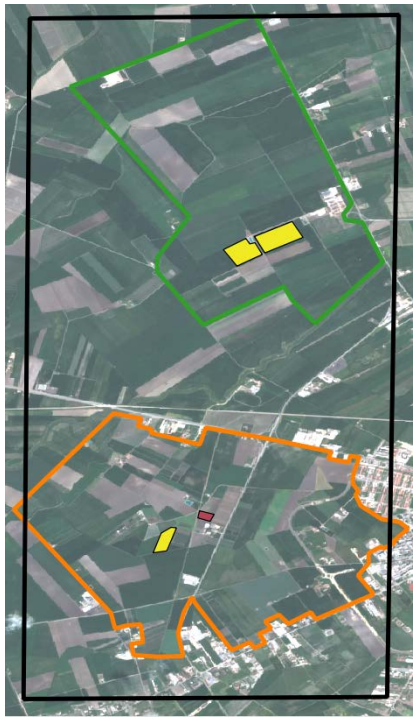


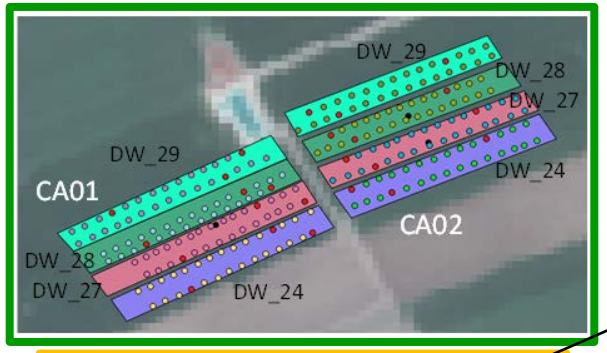


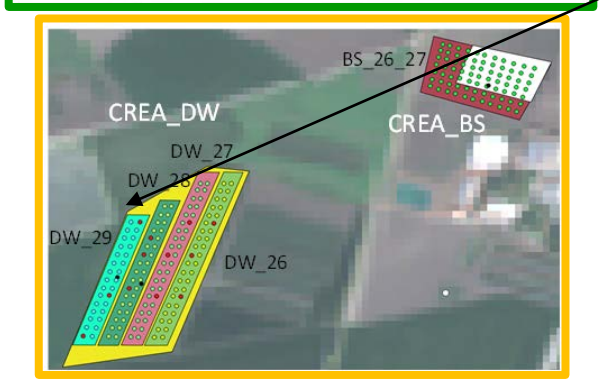
- 2 Polarimetric and interferometric acquisitions at L-band (1.325 GHz) and C-band (5.3 GHz)
- Incidence angle range: 20-60 degrees off-nadir

Irrigation experiment

RGB Sentinel-2 image on April 27



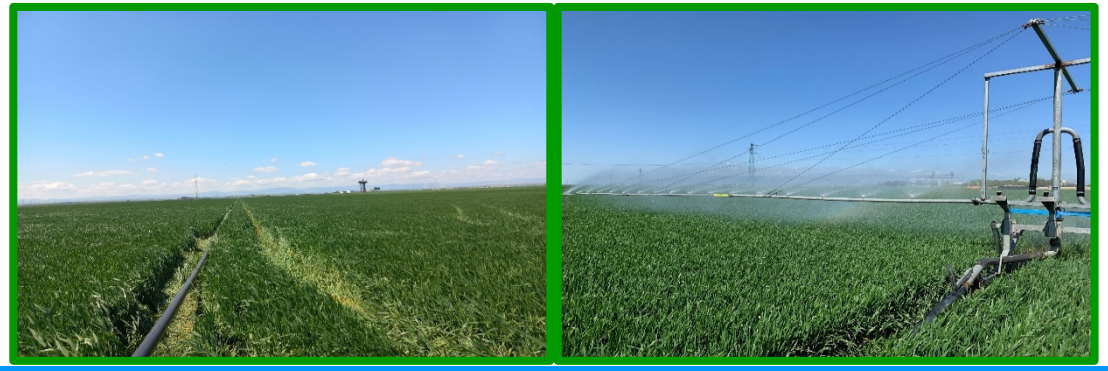




Example of irrigation strategy over different areas of wheat field «CREA_DW»

- CREA_DW_26 irrigated on 26 (2 days before the flights)
- CREA_DW_27 irrigated on 27 (1 day before)
- CREA_DW_28 irrigated during the first day of flight
- CREA_DW_29 irrigated during the second day of flight

Caione fields «CA01» and «CA02»: wheat irr. with mobile boom



CREA fields «CREA_DW» and «CREA_BS»: wheat with mobile boom and bare with drip

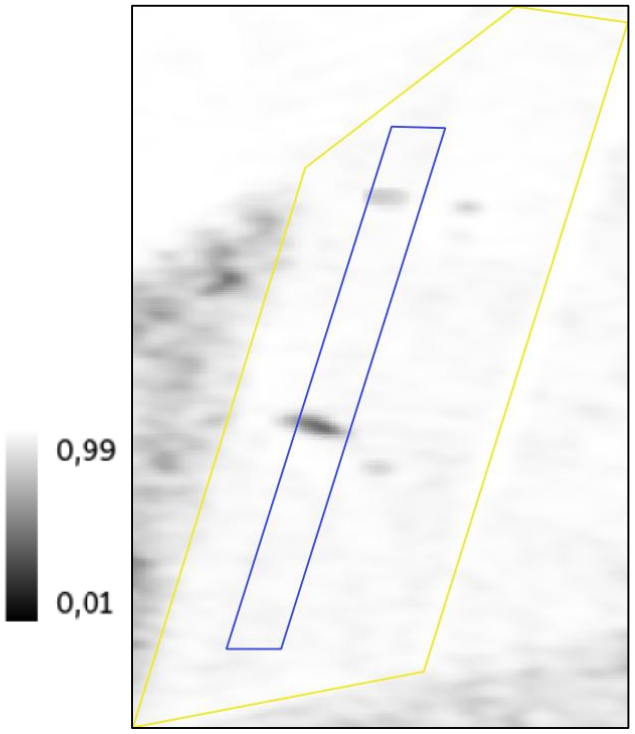
Irrigated wheat

- **L-band** analysis, VV polarization
- Wheat field «CREA_DW»
  - ➢ Stripe DW_28 irrigated during flight 09:00-15:00

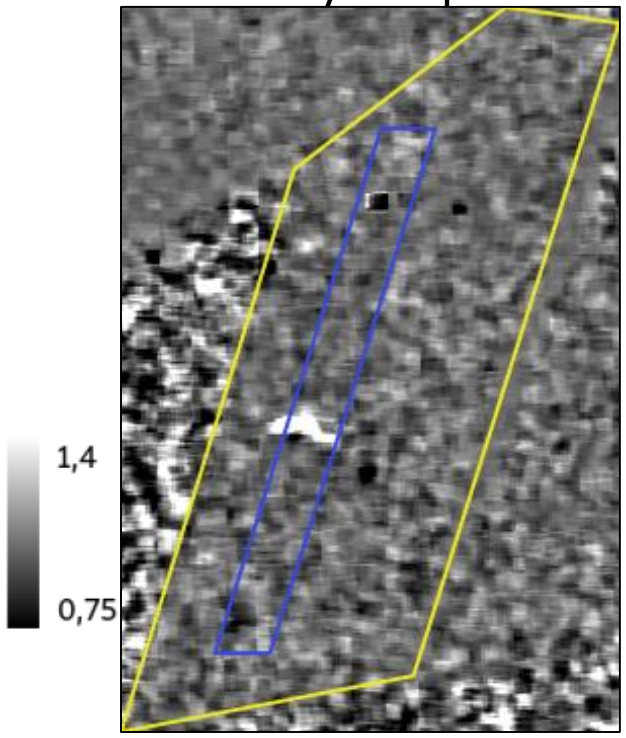
Field «CREA_DW»: mobile boom irrigation
Controlled experiment

FL01PS04 (09:42) – FL01PS05 (09:53)

Coherence



Intensity temporal ratio



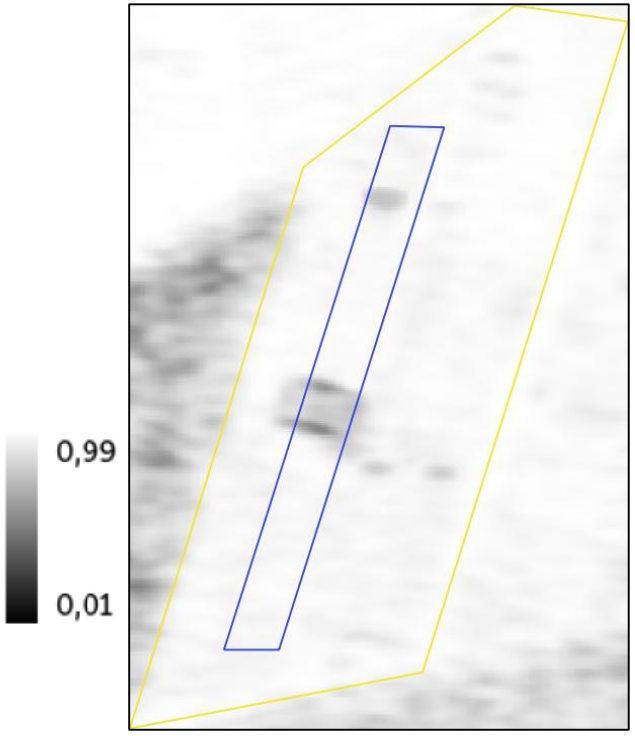
Irrigated wheat

- **L-band** coherence analysis, VV polarization
- Wheat field «CREA_DW»
  - ➢ Stripe DW_28 irrigated during flight 09:00-15:00

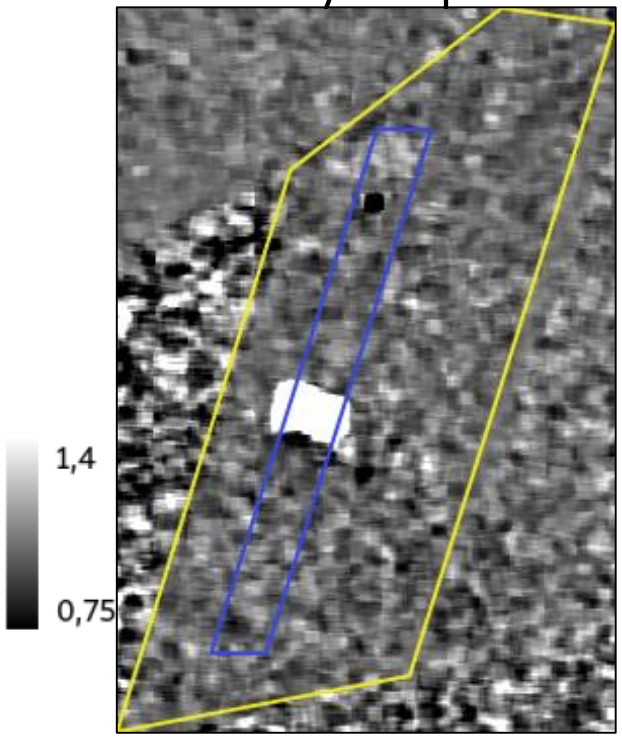
Field «CREA_DW»: mobile boom irrigation
Controlled experiment

FL01PS04 (09:42) – FL01PS10 (10:45)

Coherence



Intensity temporal ratio



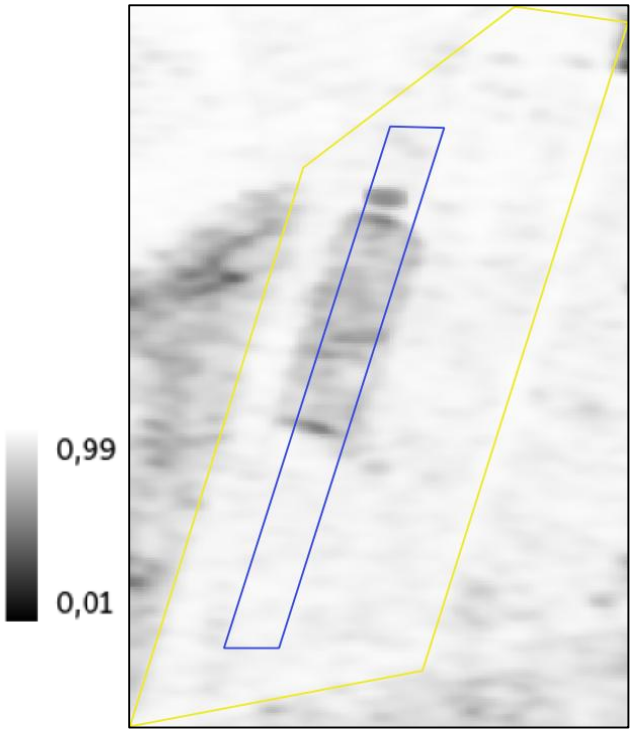
Irrigated wheat

- **L-band** coherence analysis, VV polarization
- Wheat field «CREA_DW»
  - ➢ Stripe DW_28 irrigated during flight 09:00-15:00

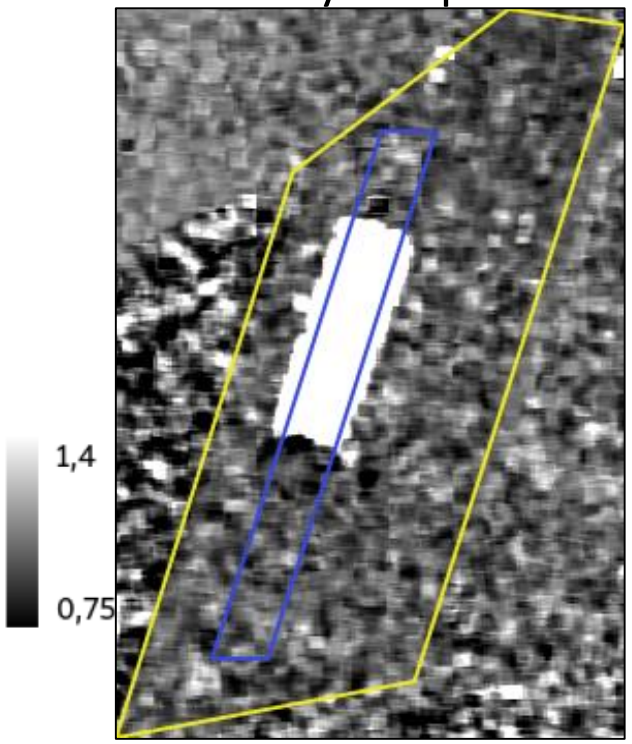
Field «CREA_DW»: mobile boom irrigation
Controlled experiment

FL01PS04 (09:42) – FL02PS04 (14:46)

Coherence



Intensity temporal ratio



- High coherence over wheat allows to follow soil moisture change
- Temporal ratio shows high sensitivity to soil moisture change

Metrology for multi-scale monitoring of soil moisture

Satellite remote sensing

(10^3) m

Cosmic-ray neutron sensing

[M. Schrön, PhD Thesis Uni Potsdam]

$(10^2 - 10^3)$ m

Point-scale *in situ* measurements

[https://soilsensor.com]

$(10^{-1} - 10^1)$ m

SoMMet

Co-funded by the European Union

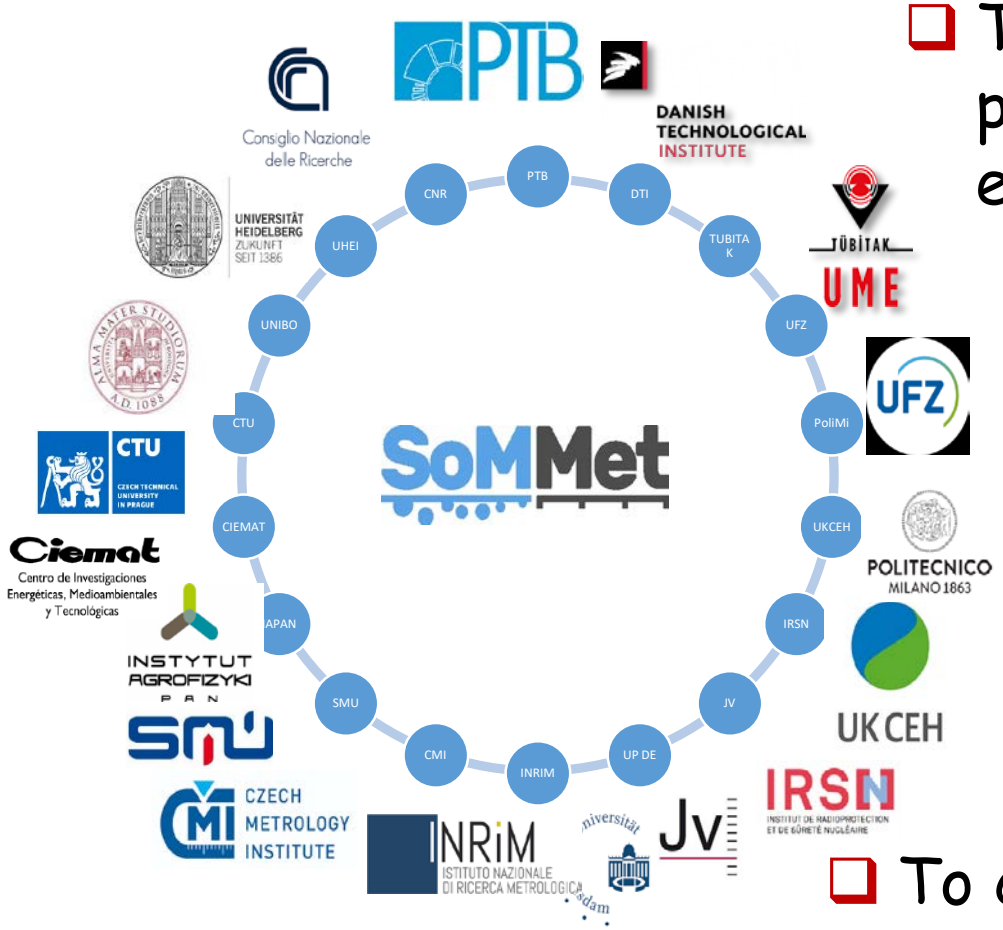
European Partnership

METROLOGY PARTNERSHIP

EURAMET

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 from by the Participating States

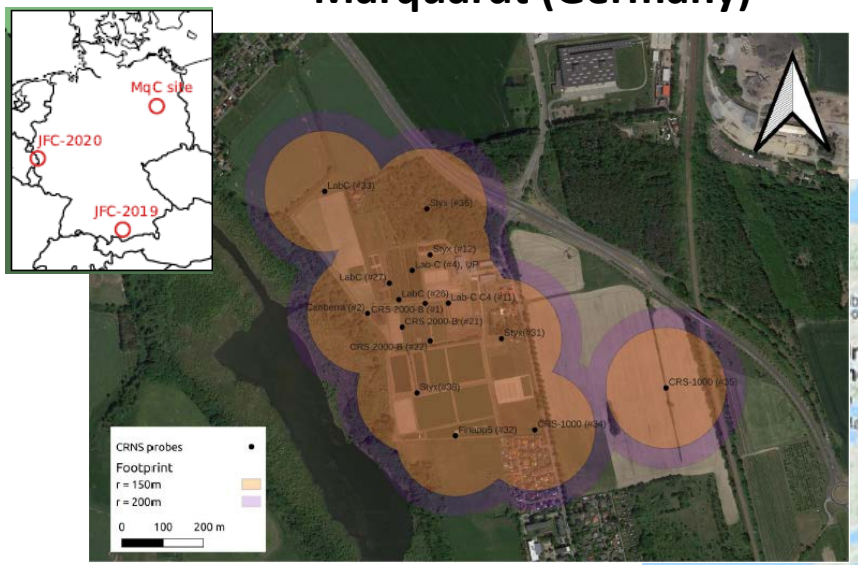
Consortium & Objectives



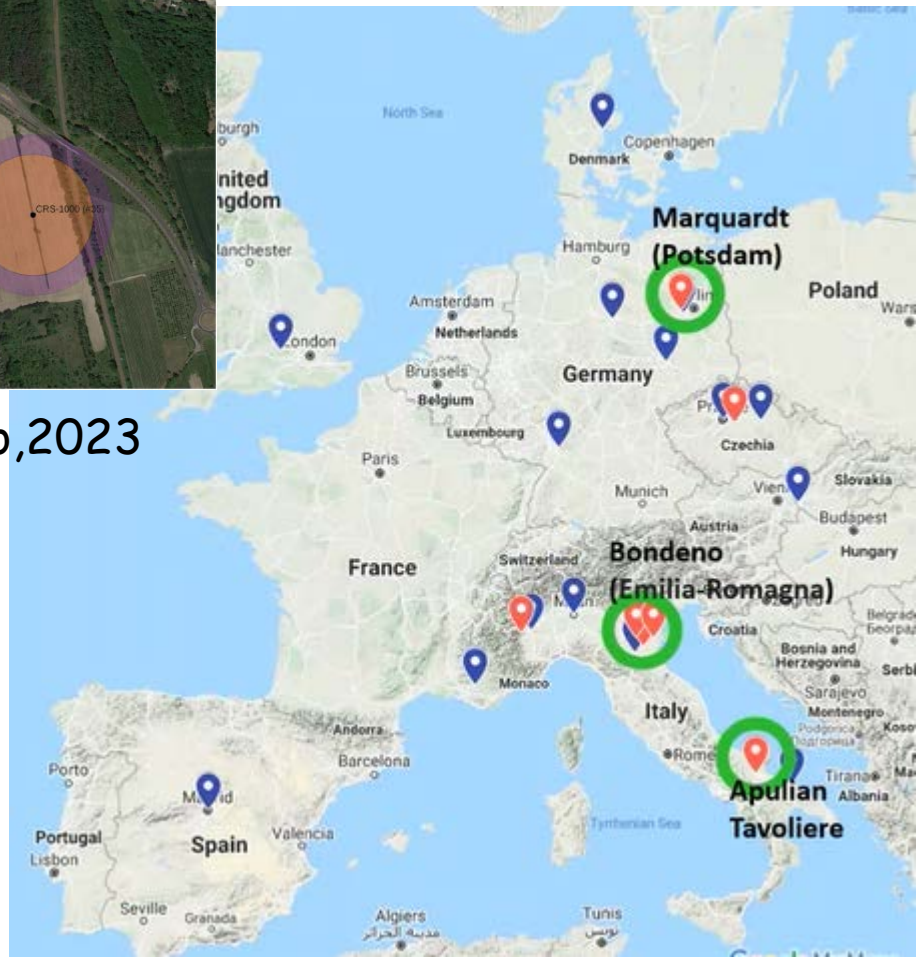
- To develop metrological framework, including primary and secondary transfer standards, to ensure SI-traceable point-scale SM measurements
- To develop validation practices for CRNS methodology for use in outdoor conditions
- To compare and harmonize SM measurements on multiple spatial and temporal scales, with better understood uncertainties and sensing volumes
- To cooperate with user communities to define design criteria for future hydrological/meteorological SM networks using the combination of point-, intermediate- and large-scale methods.

SoMMet test sites

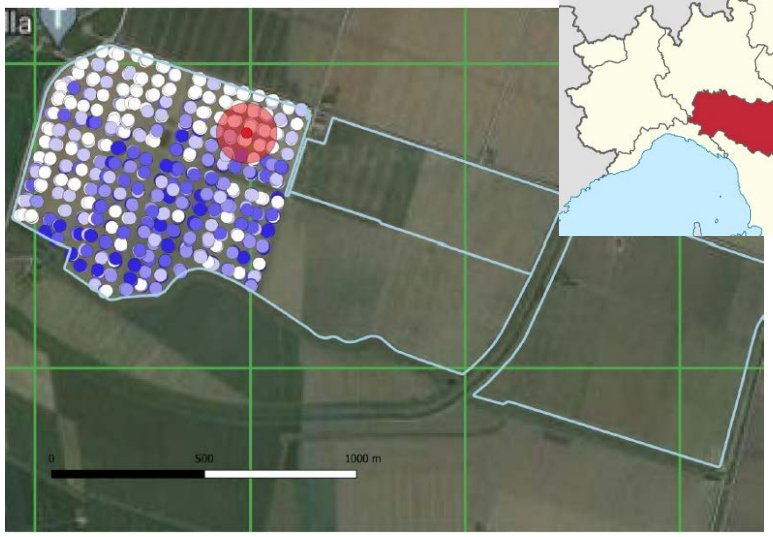
Marquardt (Germany)



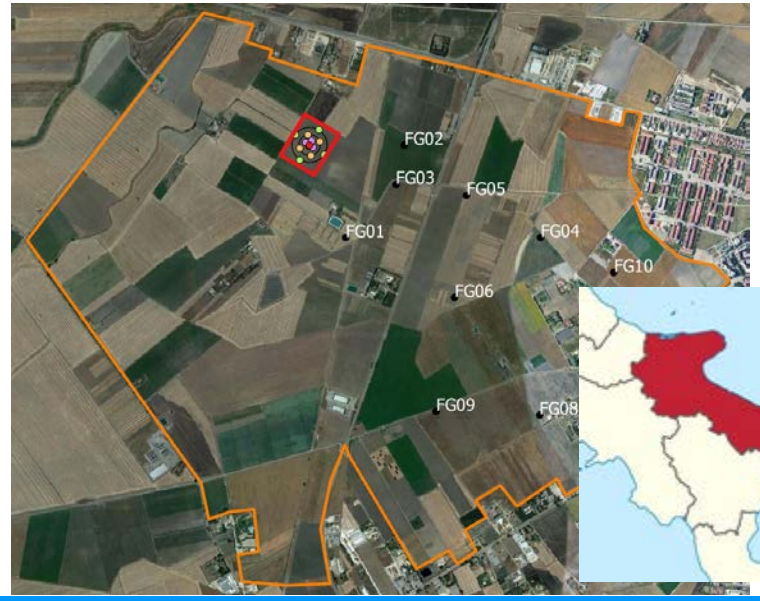
Oswald et al., GC8/Hydro,2023



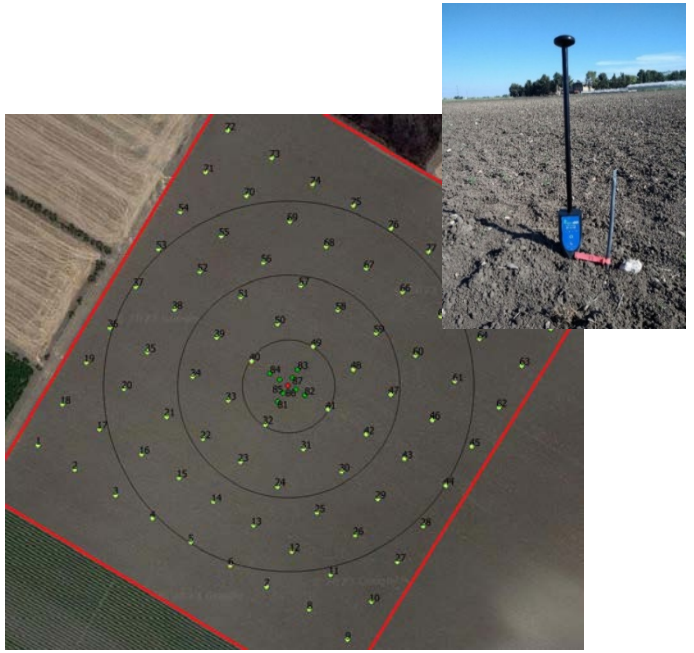
Bondeno (Northen Italy)

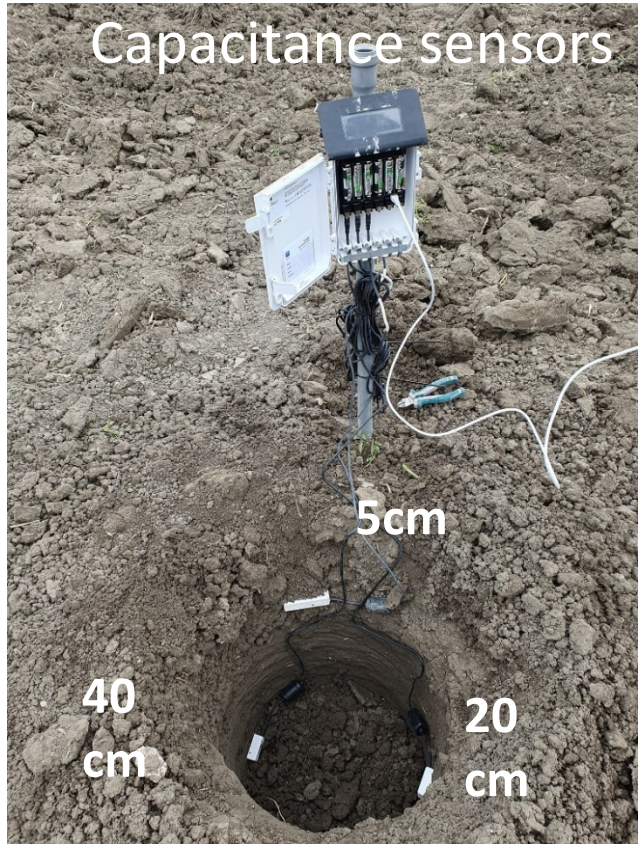


Apulian Tavoliere (Southern Italy)



Ground stations and CRNS at Apulian Tavoliere: Apr-July 23





Summary

- Satellite SM products at high spatial (1km) and moderate temporal (6days) resolution are currently available using Copernicus S-1 data
- Significant scientific interest remains to enhance the ability to resolve fine-scale surface heterogeneity and sub-daily variability
- Improvements in the temporal resolution of SM products will come combining multi-platform/multi-frequency data, e.g. ESA S-1/S-1 NG/Rose-L missions
- Further improvements in SM product performance are expected from GEOSAR systems
- Working link among different SM communities is needed for high-quality (metrologically traceable) and harmonised data on SM on multiple scales