MULTIFREQUENCY SAR DATA FOR ESTIMATING SNOW, SOIL AND VEGETATION PARAMETERS

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INTRODUCTION

- These results have been obtained within the 2019-2022 ALGORITMI project between ASI and CNR-IFAC.
- The focus of the research was the development of innovative algorithms for the estimation of geophysical parameters of soil, snow, and vegetation with the aim of monitoring soil, snow cover and agricultural crop conditions.
- The estimation of soil moisture, vegetation biomass, snow water equivalent, and crop classification was improved by using retrieval algorithms based on machine-learning approaches and temporal series of SAR images from COSMO-SkyMed (CSK) and Sentinel-1 (S-1) missions, along with optical images from Sentinel-2.

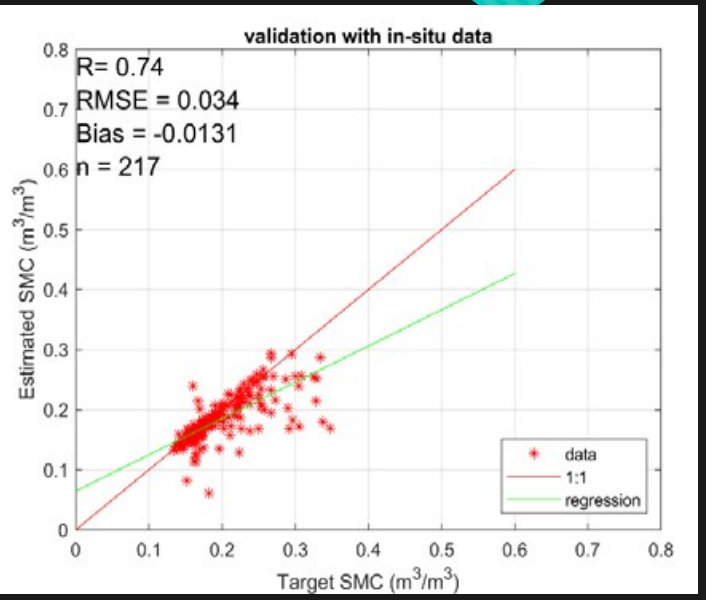
METHODS

- During the ASI – IFAC-CNR project "Development of algorithms for the estimation and monitoring of hydrological parameters from satellite and drone-ALGORITMI", algorithms for estimating SM, SWE and for crop classification have been developed and implemented.
- The test and validation activities have been performed in the investigation sites of Val d'Elsa, Mazia Valley and Alto Adige, in Italy. The project was carried out in collaboration with the Institute for Earth Observation of EURAC Research.
- The methods for the generation of accurate products of SM, SWE and crop classification maps by using SAR sensors and retrieval algorithms based on machine learning approaches are described, along with their validation results.

Soil Moisture product (SM)

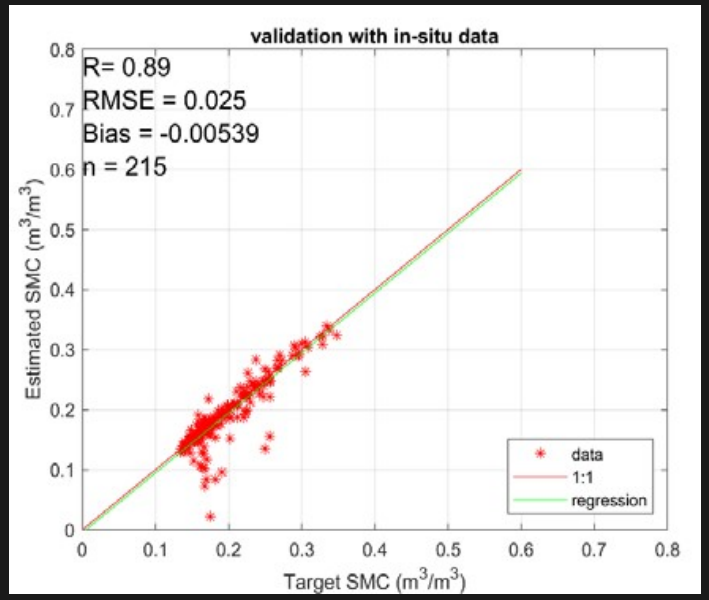
- A new algorithm for merging SMAP and S-1 data is proposed: the algorithm, which is based on ANN, has been implemented and tested on an agricultural area in Central Italy.
- In the algorithm, data from ASI's CSK X-band SAR have been integrated too, for obtaining a SM product at improved accuracy, spatial and temporal resolution that can be used for hydrological modeling in small basins
- Although a complete validation on larger areas is still in progress, the validation results obtained on the test area pointed out the algorithm capability of estimating SM at a resolution better than 100 m.

SM results



S-1 data

S-1 and CSK data



- Validation of SM algorithm: SM estimated by ANN against in situ measurements,
  - a) using S-1 only, and
  - b) using S-1 and CSK.
- The statistics, for a sample of 217 points, are
  - R=0.74 and RMSE=0.034 m3/m3 for S-1 alone and
  - R=0.89 and RMSE=0.025 m3/m3 for S-1 + CSK

Snow Water Equivalent (SWE)

- The potential of X-band SAR to monitor SWE was exploited by using time series of CSK images, collected on South Tyrol (Italy) from 2012 to 2021. Although the frequency of X-band is not the optimal one for snow applications, X-band proved to be capable in providing key information for snow cover monitoring, also thanks to the short revisit time and high spatial resolution.
- The CSK acquisitions were compared with SWE in-situ measurements to evaluate the sensitivity of σ° to the target parameters, obtaining good correlation if data from ascending and descending orbits are processed separately.
- For interpreting the scattering mechanisms, the experimental data were compared with model simulations based on the DMRT–QMS model.
- The SWE retrieval from CSK images was based on ANN, trained by using experimental data and AMUNDSEN (Alpine MUltiscale Numerical Distributed Simulation ENgine) simulations. After training and testing, the algorithms were applied to the available CSK images to generate SWE maps of the entire area covered by the SAR acquisitions.
- The results were encouraging, although more analysis and validation are needed to exploit the potential and to assess the limits of CSK application to snow parameters retrieval.

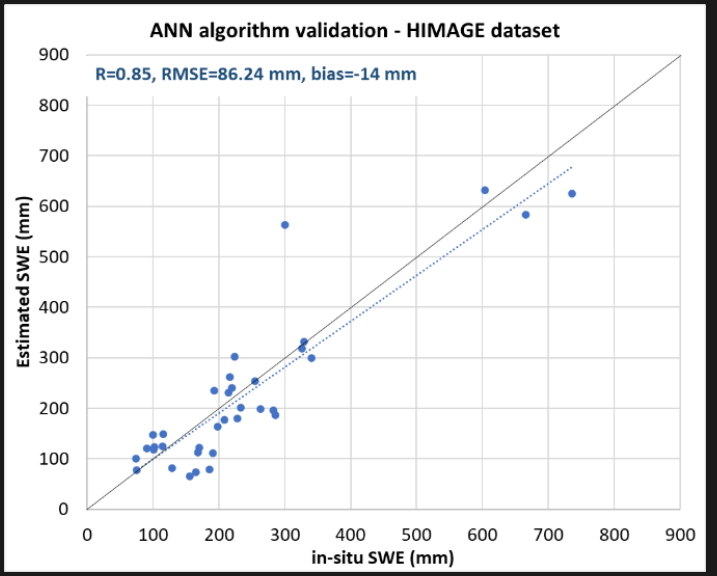
SWE Results

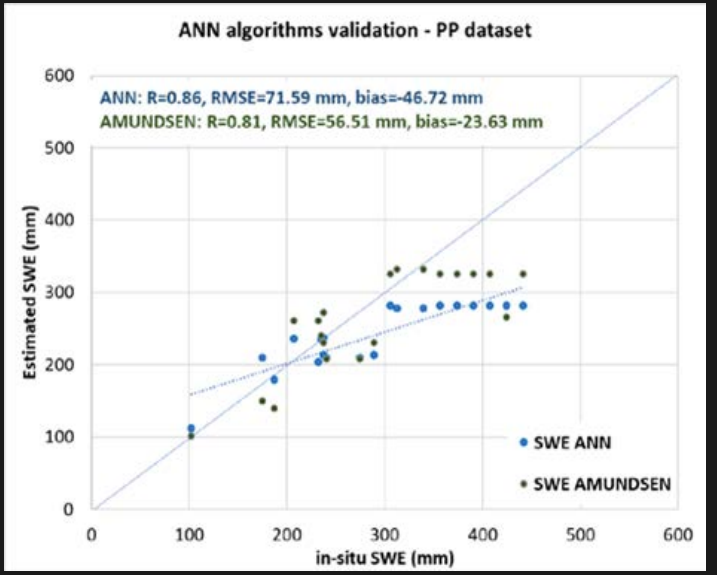
Two sets of CSK acquisitions were considered :

The first dataset of 25 CSK single-look complex images in HH polarization (StripMap HIMAGE mode) on the entire South Tyrol, in January and February from 2013 to 2015

The second was collected over the Val Senales using 50 CSK images dual polarization VV+VH (StripMap PingPong mode – PP) in the winter 2019-2020, from November to March, plus other 4 in the winter 2020-2021

- For building a robust dataset for training and validating the ANN algorithm an "experimental + model driven" approach was proposed, training the ANN with SWE maps simulated by the AMUNDSEN model
- The validation of the algorithm was performed by comparing the ANN outputs with SWE data collected on site.
- For HIMAGE the obtained results were R=0.85 with RMSE=86.24 mm,
- For PP R=0.86 with RMSE=71.59 mm.





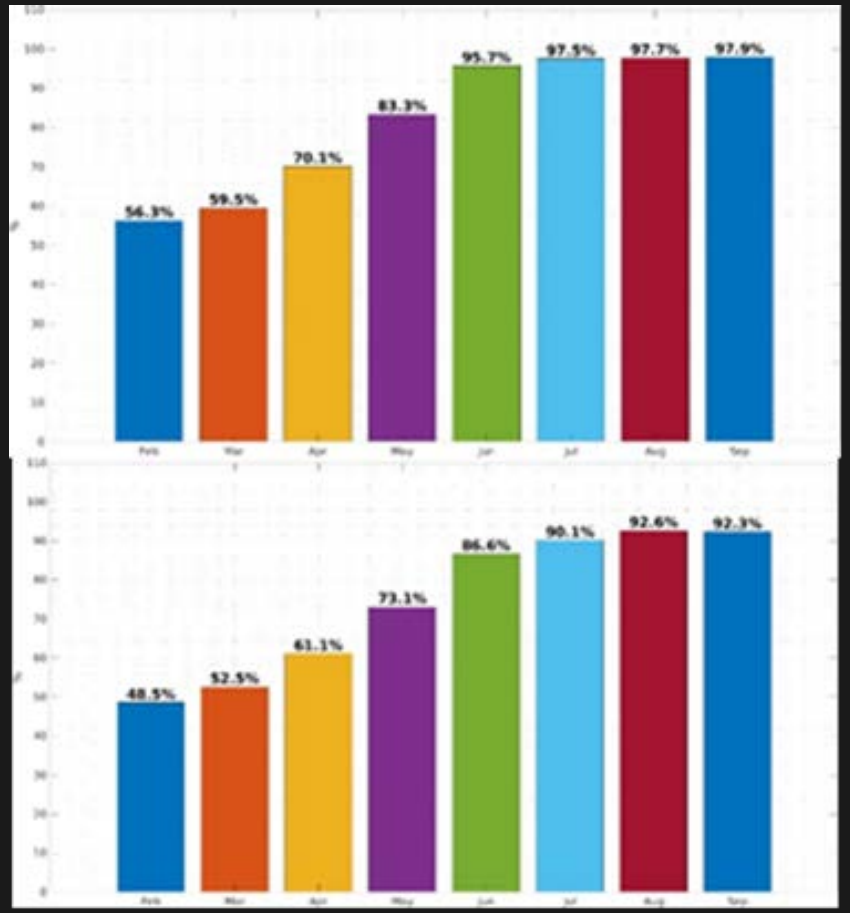
Crop Classification

- The investigation was carried out in two areas in Tuscany region (Italy) where dedicated measurement campaigns were carried out in spring/summer 2020.
- 12 CSK StripMap HIMAGE, HH pol. scenes were acquired from January to September 2020 on the two test sites. This time period was divided in eight monthly time frames to test the early mapping scenarios. Backscatter and ground data were used to implement a database used for training the classifier and validating the produced maps.
- A fully supervised classification approach was chosen based on convolutional neural networks (CNN) to correctly classify the two agricultural areas, by using multi-temporal CSK data with two different CNN architectures: one operating on pixel-basis along the time series (called 1D) and the other one operating on patch basis and performing convolution on both space and time (called 3D), respectively
- An accurate analysis of the opportunity to generate a crop map in the early agricultural season was also carried out to boost our methodology in providing predictive agricultural information for water, pesticides, and fertilizer management at regional scale.

Crop Classification Results

Overall accuracy in early crop classification attained progressively in 8 months in 2020 using a deep learning- based classifier and CSK SAR data in Capannoli (top) and Montopoli (bottom) test area

- An almost monotonic progression in overall accuracy is found over time and with the increase of available images as input to the classifier. 3D architecture CNN always provides better performance, with encouraging accuracy obtained already at the end of May.
- Results of crop mapping in Capannoli are always better than those attained in Montopoli, due to the balance of dataset and representativeness of each class..



CONCLUSIONS

- The results obtained in the framework of the “ALGORITMI” project confirm the capability of multi-frequency SAR data in retrieving the main parameters of soil, snow and vegetation with good accuracy and improved spatial resolution with respect to single-frequency approaches.
- The use of retrieval algorithms based on machine-learning approaches allowed integration of data collected from different sensors, confirming the optimal performances of these methods.

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