MIDA: OPTICAL/MICROWAVE DATA INTEGRATION FOR ESTIMATING SOIL MOISTURE AND VEGETATION BIOMASS (AMSR2/3+SMAP+SENTINEL-1 +ALOS2/3)

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Introduction

- The capability of microwave radiometers as the AMSR-2 in estimating Soil Moisture (SM) has been largely proved. These sensors are characterized by high revisiting frequency that makes them very suitable for following the fast SM dynamics. The coarse spatial resolution hampers however applications at field and small basin scale.
- In this research, the soil moisture (SM) product generated at 10 km resolution by IFAC's HydroAlgo using AMSR-2 has been disaggregated up to 100 m by using Sentinel-1 (S-1) data and machine learning.
- The proposed disaggregation has been implemented and tested in an area in Northern Italy, which is characterized by a heterogeneous landscape, including agricultural, forested and urban areas. Such heterogeneity sets important constraints to the AMSR-2 potential for SM monitoring.
- Due to the unavailability of SM in-situ measurements in the area, the reference SM values for validating HydroAlgo SM at low resolution have been derived from the SMAP enhanced radiometer SM product. The validation activity pointed out a very good agreement between the two products.
- The validation of the disaggregated SM at 100m is instead in progress, however the qualitative comparison of SM maps at low and high resolution confirmed that the SM patterns at low resolution are kept with better detail at high resolution too.
- The obtained results highlight the potential of the SM generated by HydroAlgo using AMSR-2 for operational applications at regional scale, even in heterogeneous environments as Italy.

Test area

TEST AREA AND DATA

- Test on a flat agricultural area in the Po Valley for which a series of S-1 acquisitions was available
- Lon 10.9° E – 11.9°E, Lat 44.5° N – 45.5° N, extension ≃ 120Km x 120Km
- 144 nodes spaced at 0.1° x 0.1°

- **Sentinel -1,** 28 images in 2015

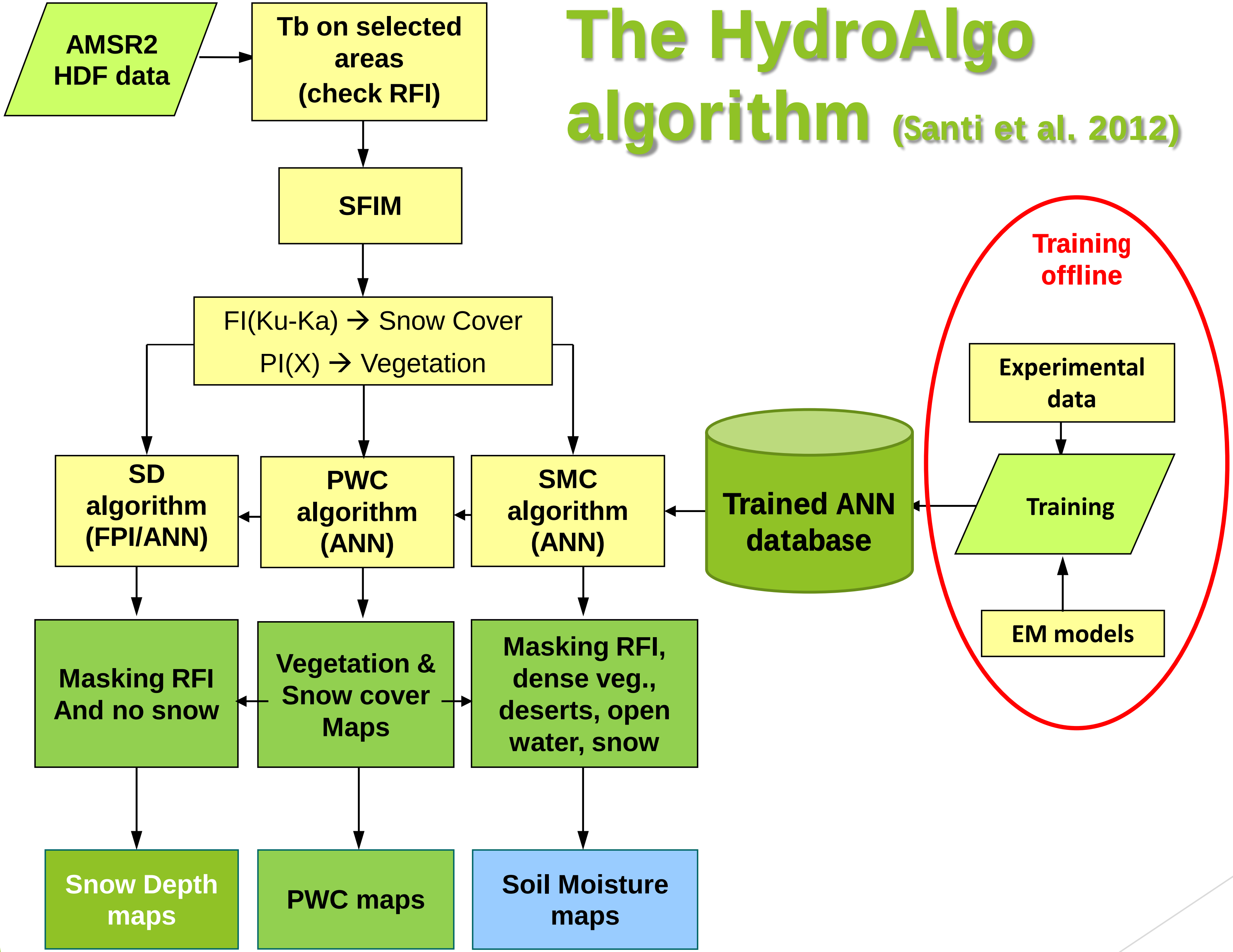
- **AMSR2 L1R V2.1**, closest date and time to S-1, A/D overpasses separated

- **SMAP_L2_SM_P Enhanced** radiometer SM product closest date and time to S-1, used as reference for HydroAlgo validation

> 4,000 co-located Tb from AMSR2, σ^0VV and VH from S-1 and SMC from SMAP

IFAC HydroAlgo

The HydroAlgo algorithm (Santi et al. 2012)

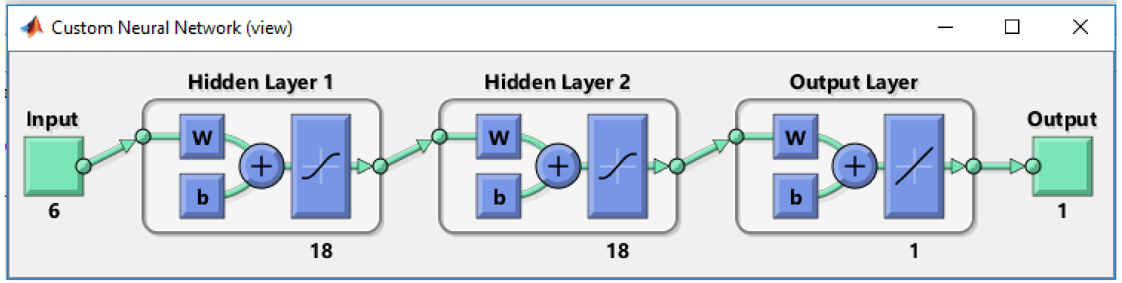


Hydroalgo for SM

- The first part of **HydroAlgo** (**SFIM** - Santi 2010) uses 37 GHz channel to improve the spatial resolution of the lower frequencies.
- Then lower frequency observations **(C, X and Ku -band)** are then used to estimate SM throughout **ANN** trained with both experimental data and the radiative transfer model **(τ–ω)**.
- Filtering and masking are based on frequency and polarization indices

Why ANN?

ANN aren’t black boxes: the input-output relationship can be written in a close way



<u>Advantages:</u>

- ANN can be trained to represent arbitrary input-output relationships
- ANN can **easily merge data from different sensors** (e.g MW sensors + optical/IR).
- Training can be updated without modifying the algorithm
- Training only is time consuming: application to new datasets is near real time

<u>Disadventages:</u>

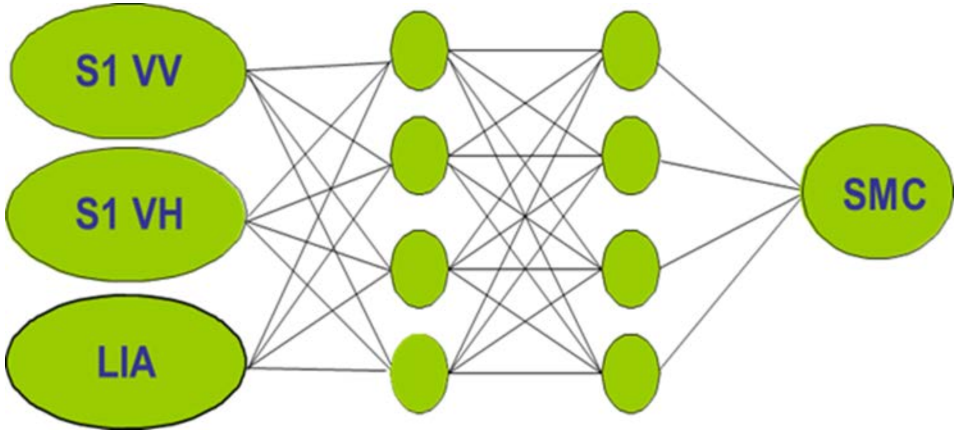
- ANN are prone to outliers→ large errors if testing data have not been properly accounted for in the training

The main constraint is represented by the statistical significance of the training set That MUST represent all the observed surface conditions.

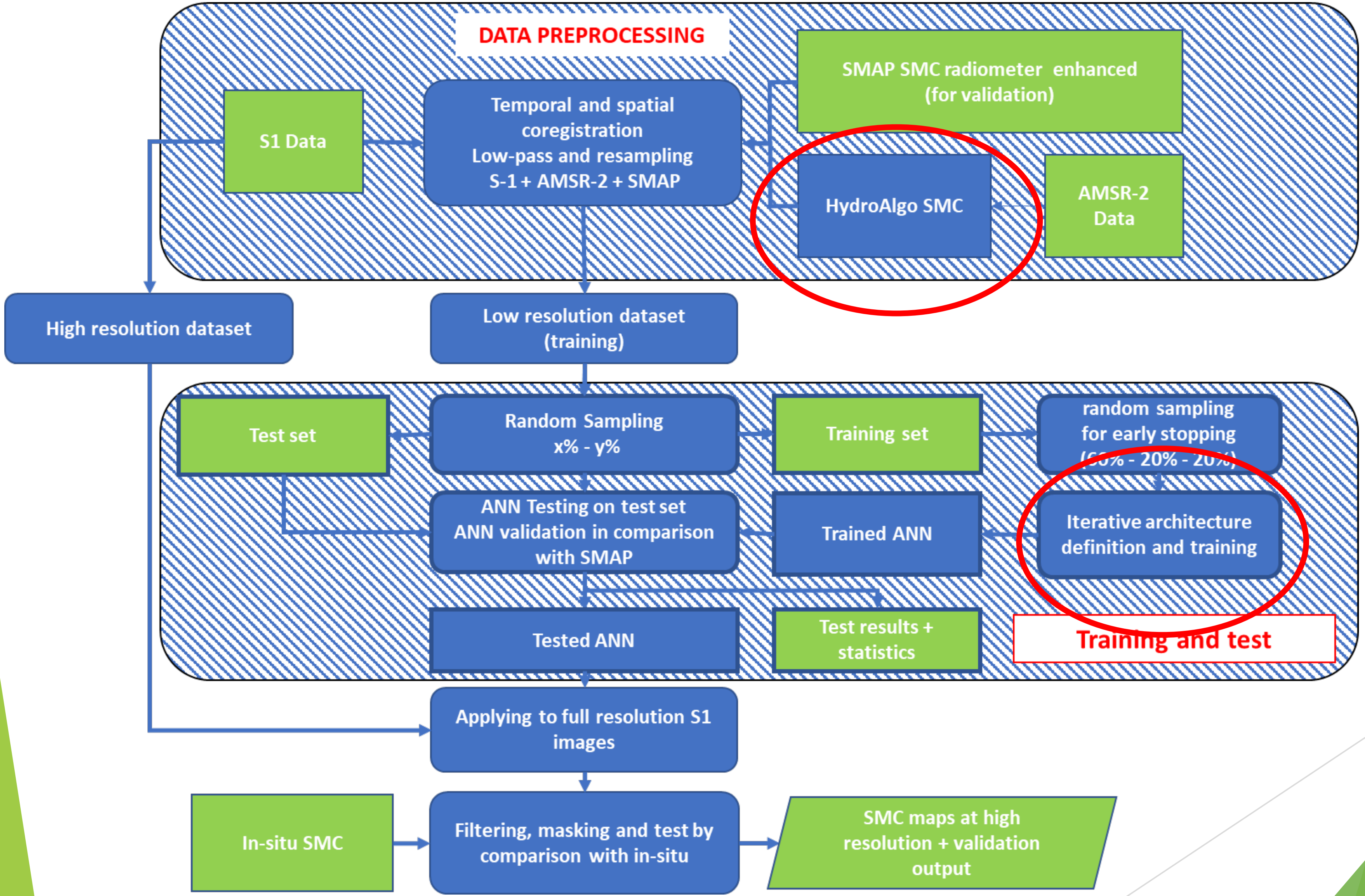
ANN disaggregation algorithm

Algorithm concept

- Beside being the core of HydroAlgo, ANN have been also applied for disaggregating the SMC product up 100 m by using S-1 acquisitions:
- S-1 data in VV and VH pol. are downsampled to the AMSR-2 HydroAlgo SM resolution (10 km) and used as inputs for training the ANN
- The corresponding HydroAlgo SM values are used as target for training
- The trained ANN is then applied to the S1 images at full resolution for estimating SM at an improved spatial scale (100m)



The ANN disaggregation algorithm



«**data driven**» approach: only based on **EO data**

Algorithm inputs:

- S1 backscattering (2 pol.)
- Local Incidence Angles (LIA).

ANN is **trained on LR dataset** (AMSR-2 resolution)

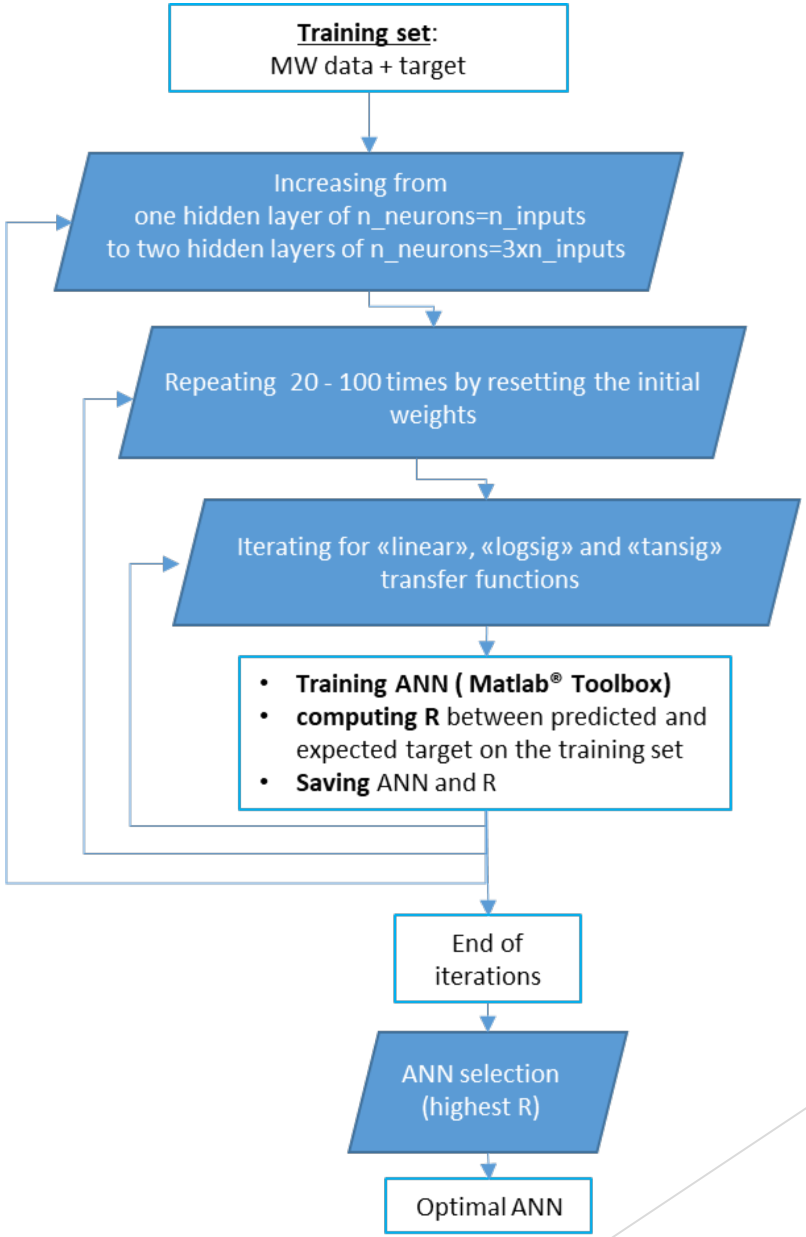
After training, the **ANN is applied to the HR dataset (**S-1 images at 100 m resolution) to generate high resolution SMC maps

Iterative architecture definition to avoid overfitting and underfitting (next slide)

Early stopping rule also applied.

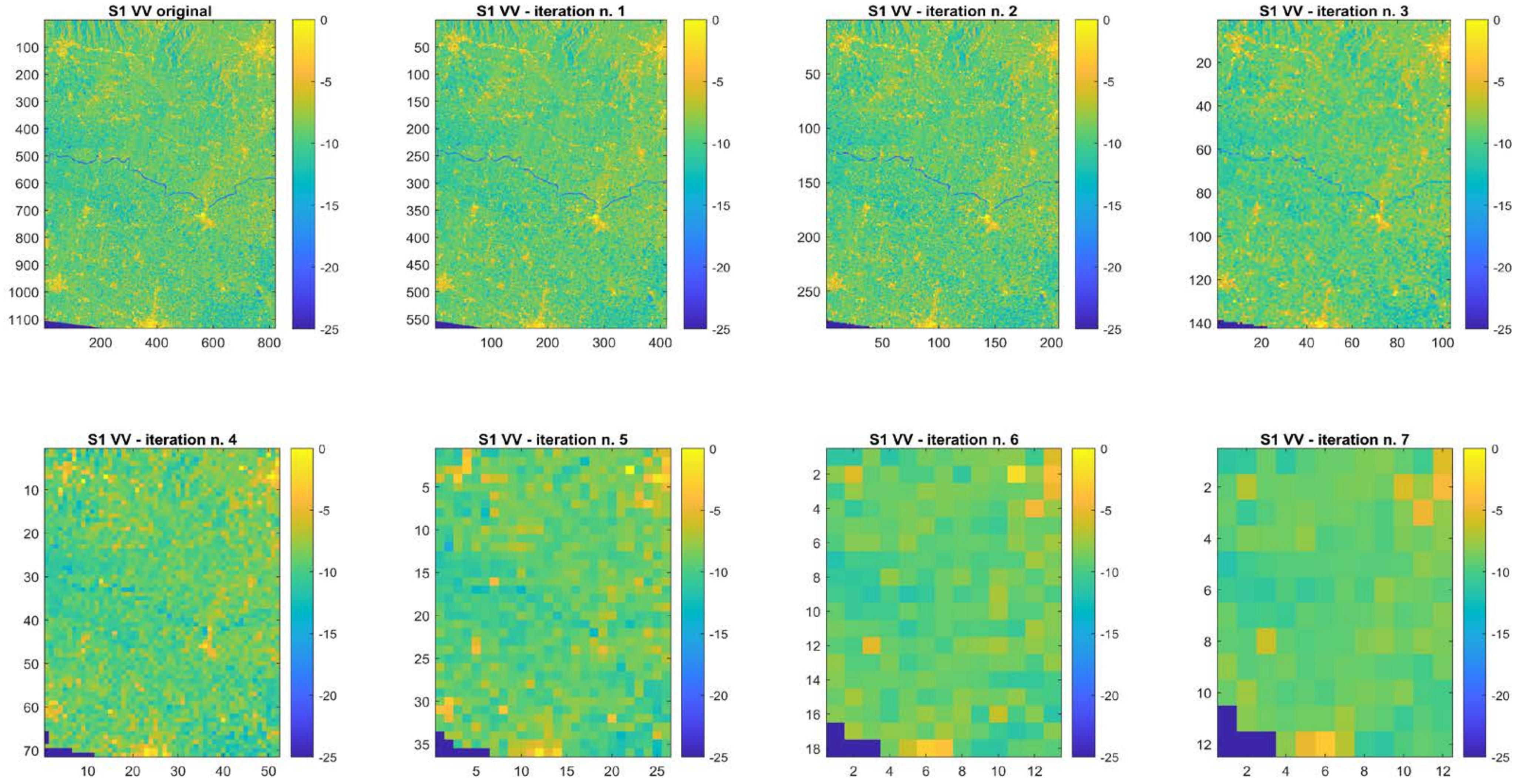
ANN «optimal» architecture

- **Optimal ANN** architecture (number of neurons and hidden layers) is defined iteratively (IFAC code)
  - **Start**: one hidden layer n. neurons = n. inputs
  - **Stop**: two/three hidden layers of n. neurons = 3 x n. inputs
- **Training** repeated 20 - 100 **times** for each architecture, by resetting each time the initial weights.
- **Training also** repeated for each **transfer function** available (linear, tansig and logsig)
- **Output is** the "optimal" ANN architecture for the given problem in terms of R, RMSE and BIAS.
- Scope is **to prevent** both **overfitting** and **underfitting**



Downsampling S1 at AMSR-2 resolution

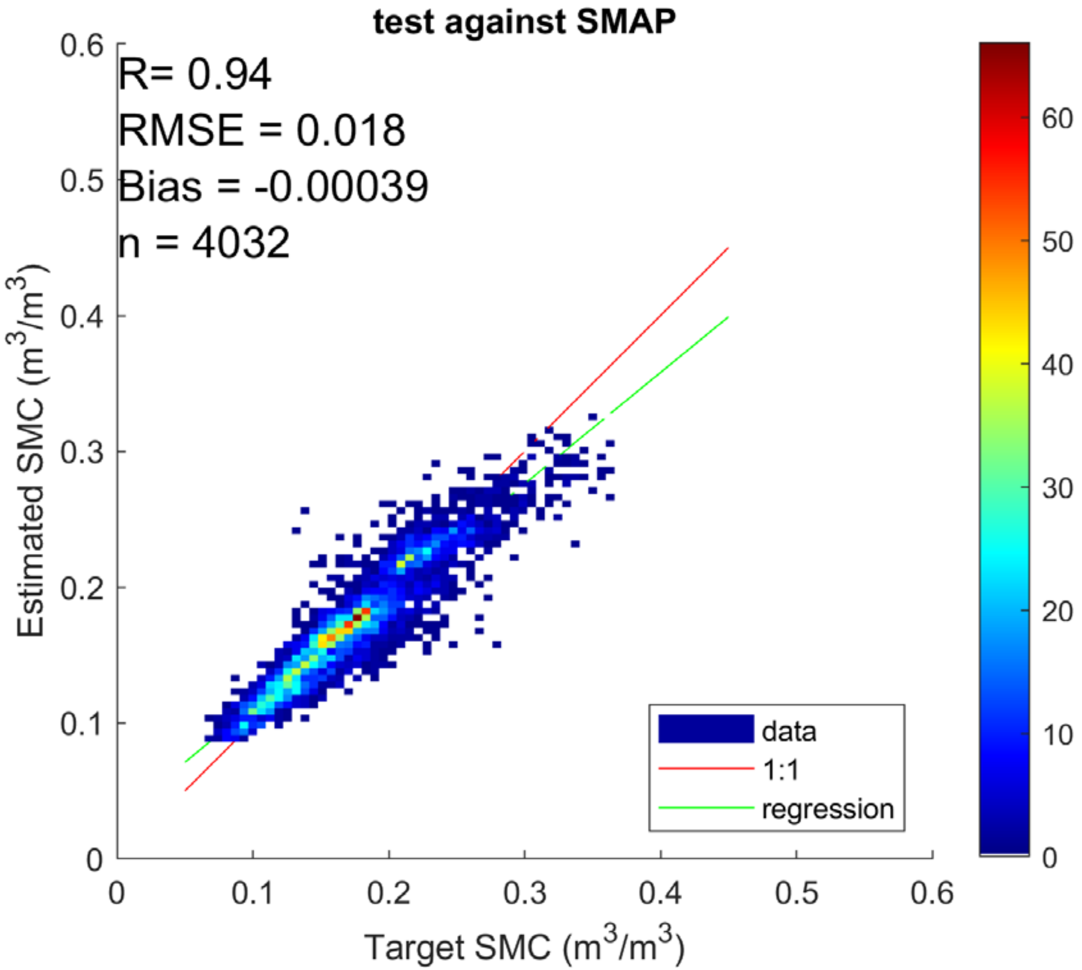
- «Single pass» downsampling from 100 m to 10 km does not work
- iterative downsampling implemented: each S1 image is iteratively resampled at half resolution till the SM AMSR-2 10 km



Algorithm test
(comparison with SMAP)

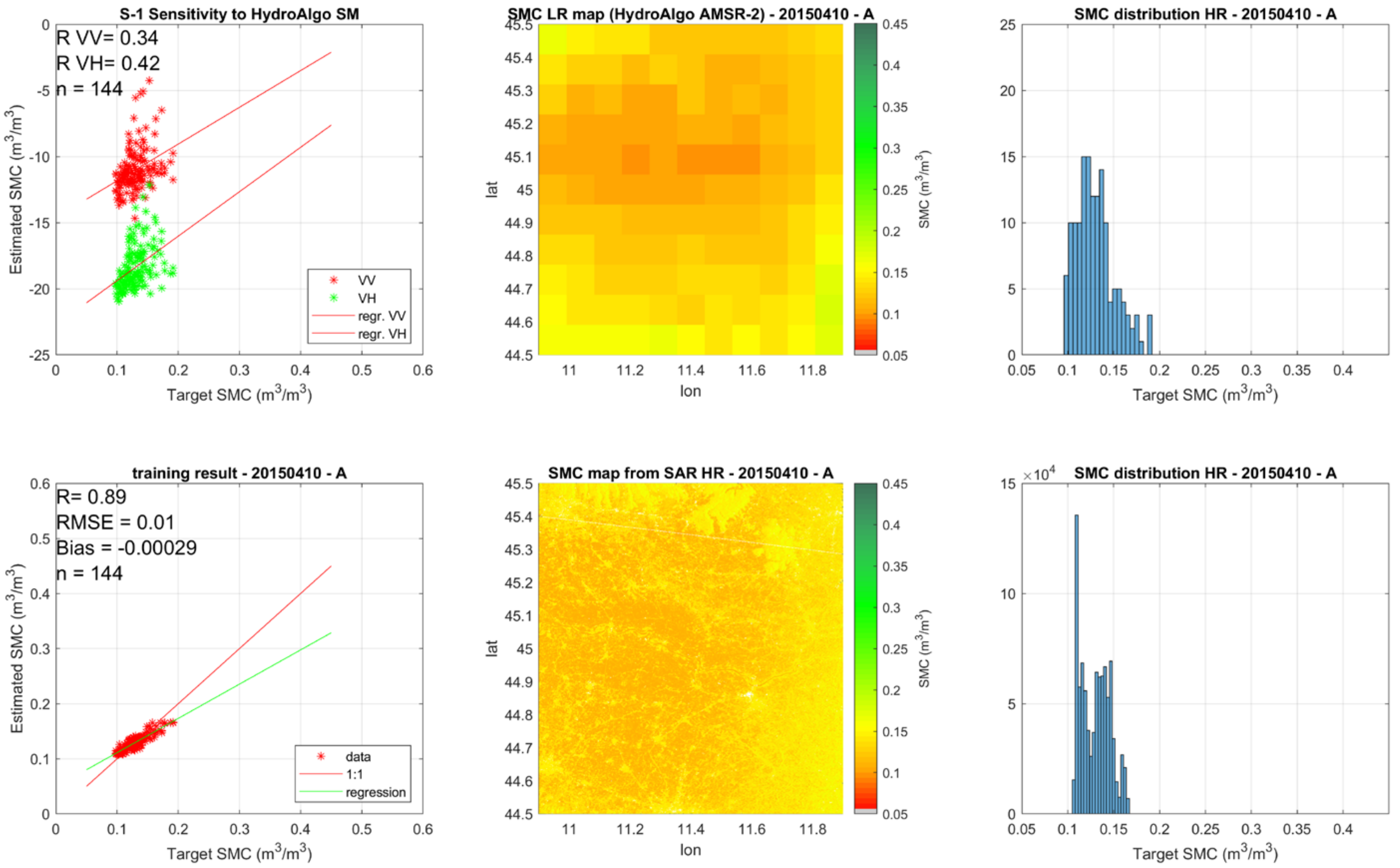
Algorithm test (HydroAlgo vs. SMAP)

- Due to the unavailability of in-situ data, test has been carried out by comparison with SMAP
- ≃4000 data at 10 km resolution

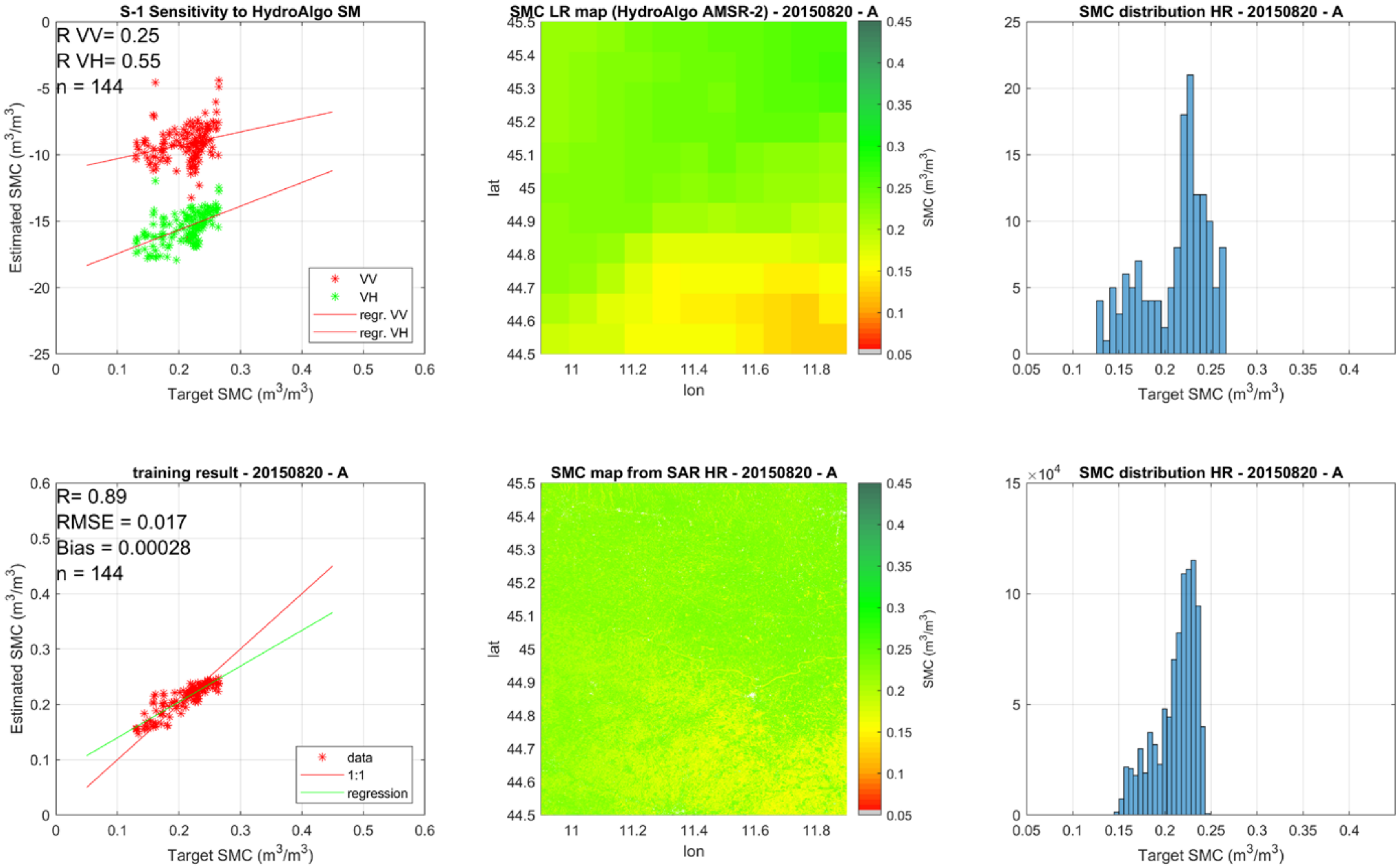


Example of results

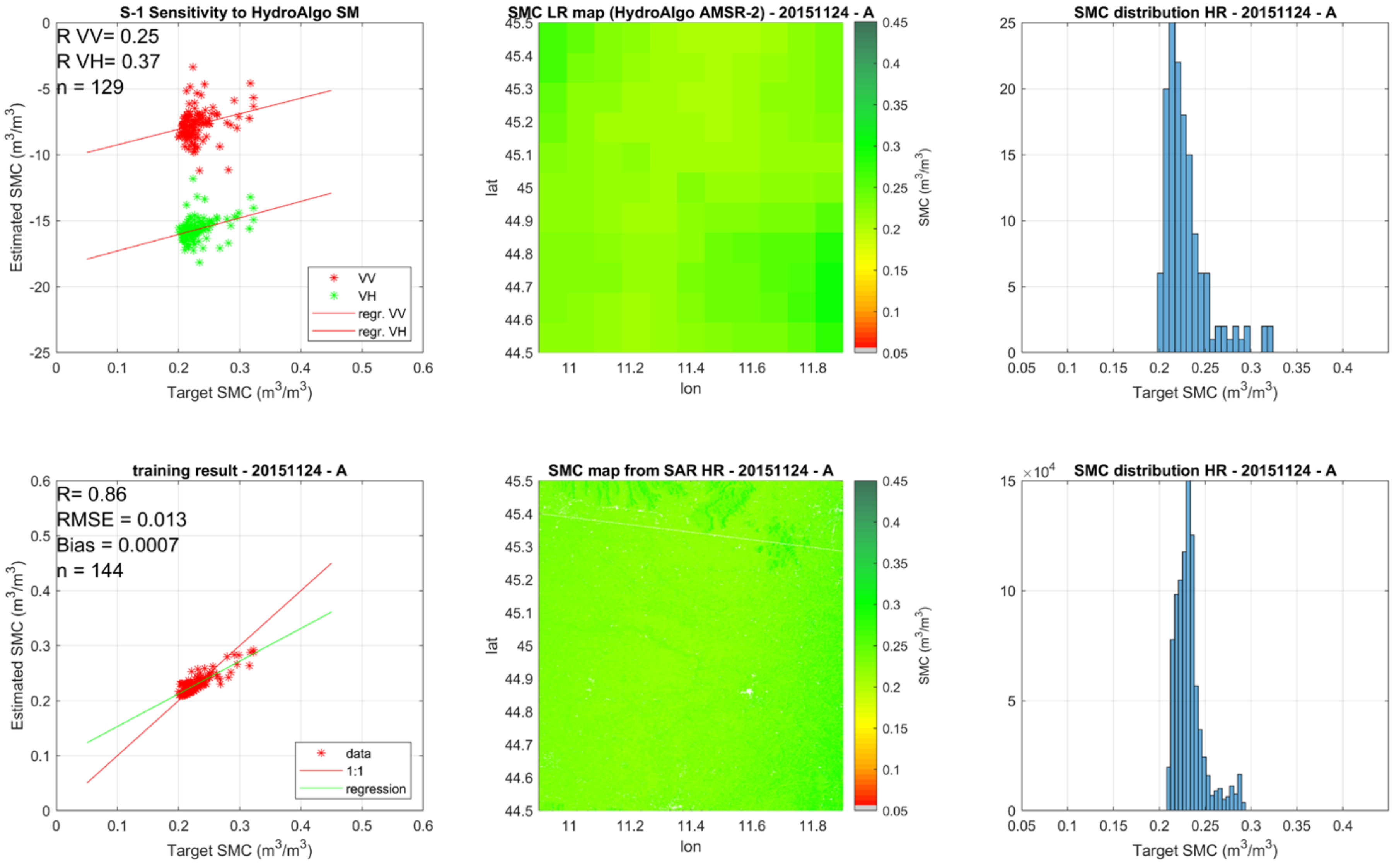
Example of results (April 2015 – mid-low SM)



Example of results (August 2015 - mid SM)



Example of results (November 2015 - mid-high SM)



Conclusions

- This study aimed at defining a method to improve the spatial resolution of HydroAlgo AMSR-2 SM from 10 km up to 100 m.
- Test and validation carried out so far pointed out that the proposed disaggregation concept is effective to this scope.

ADVANTAGES

- Although the method has been tested with S-1 and AMSR-2, the concept is valid for other combinations of radiometric and SAR data (e.g. ALOS+AMSR-2).
- Given the of ANN characteristics, changing I/O data to other combinations of sensors is quite straightforward.
- Computational cost is not an issue if using recent machines.

OPEN POINTS

- The temporal frequency is linked to SAR revisiting: in principle it could be possible to use different SAR sensors for improving the revisiting.

FUTURE ACTIVITY

- Extending test and validation by including more areas and involving in-situ data sources (ISMN?)

Thank you

Acknowledgment

Contacts

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