GLobal Algorithms for the MOnitoring of sURface parameters (GLAMOUR)

Advances of the algorithm for generating Soil Moisture, Snow Cover and Vegetation maps by using AMSR-2 data

3-years research period

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Outline of 3-year research

- Tuning of Soil Moisture/Snow Depth/ Vegetation Biomass retrieval algorithm for AMSR2 data (HydroAlgo)
- Comparison of performance between Hydro-Algo and SCA on ARS-USDA test sites
- Snow Depth estimate on Italian Alps by using an ANN approach
- Multi-layer modeling of snow cover by using DMRT approach

The refined SMC/SD/VB Algorithm (HydroAlgo)

AMSR-E/ AMSR2 data only

Processing time=1 day
AMSR data=20min

Tb extraction and check RFI

SFIM → resolution enhancement

FI(Ku-Ka) → Snow Cover extent

Areas of interest coordinates

SMC/SD/VB retrieval algorithm

Training offline

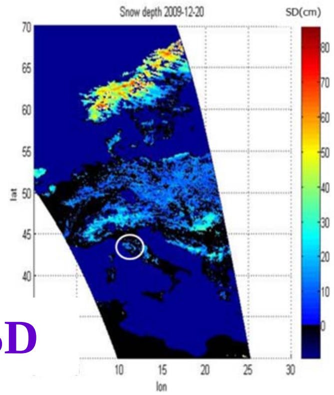
ANN Training

Experimental data

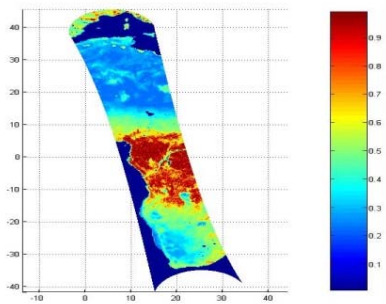
Masking RFI, dense veg., open water

4-5 levels of SMC/SD/VB (ground res.=10 km x 10 km) extracted

SMC/ SD/VB maps

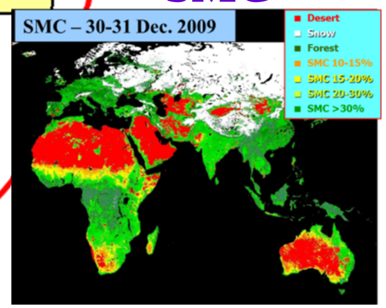


SD



VB

SMC



SCA & HydroAlgo comparison

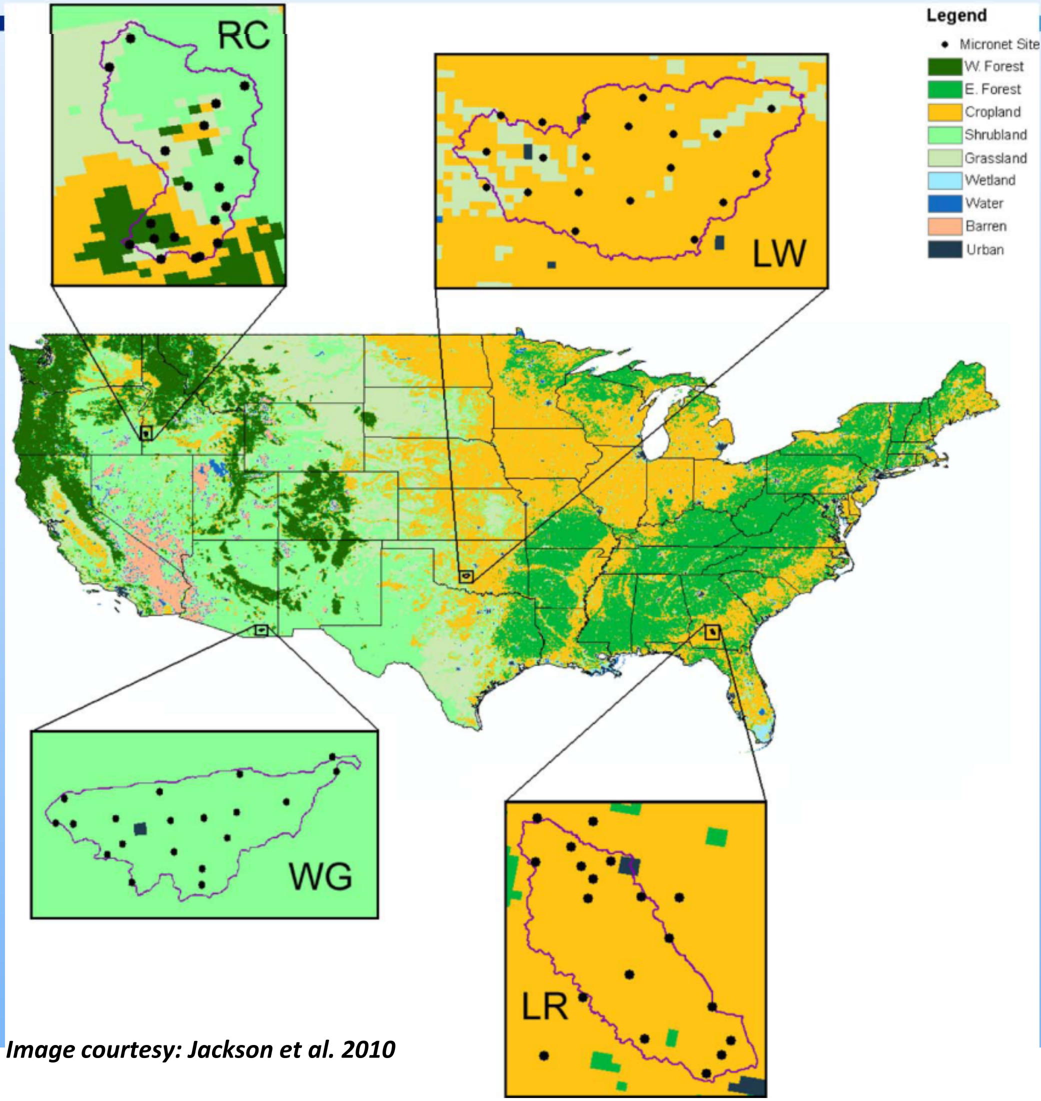


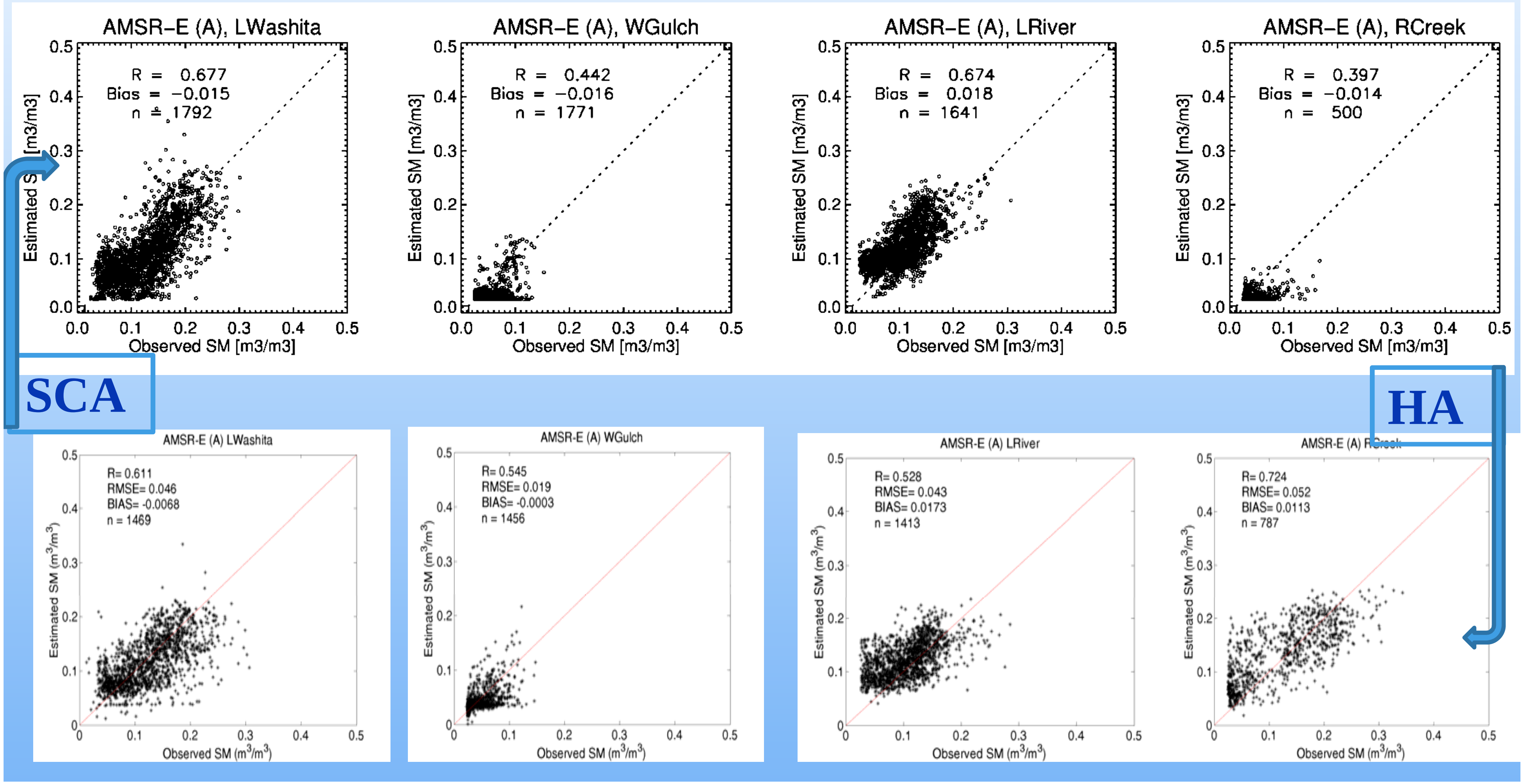
Image courtesy: Jackson et al. 2010

- **ARS watersheds:**
  - **Little Washita, OK**
  - **Little River, GA**
  - **Walnut Gulch, AZ**
  - **Reynolds Creek, ID**
- **Advantages:**
  - **Well-instrumented**
  - **Core sites for several AMSR-E validation campaigns**
  - **Provide**
    - **Long-term *in situ* data**
    - **Several stations within the satellite footprint**
    - **Wide range of ground conditions and precipitation regimes**

Jackson et al. (2010), Validation of Advanced Microwave Scanning Radiometer Soil Moisture Products, *IEEE TGRS,* 48(12), 4256–4272.

ARS watershed sites

SCA & HydroAlgo-*In situ* Comparisons



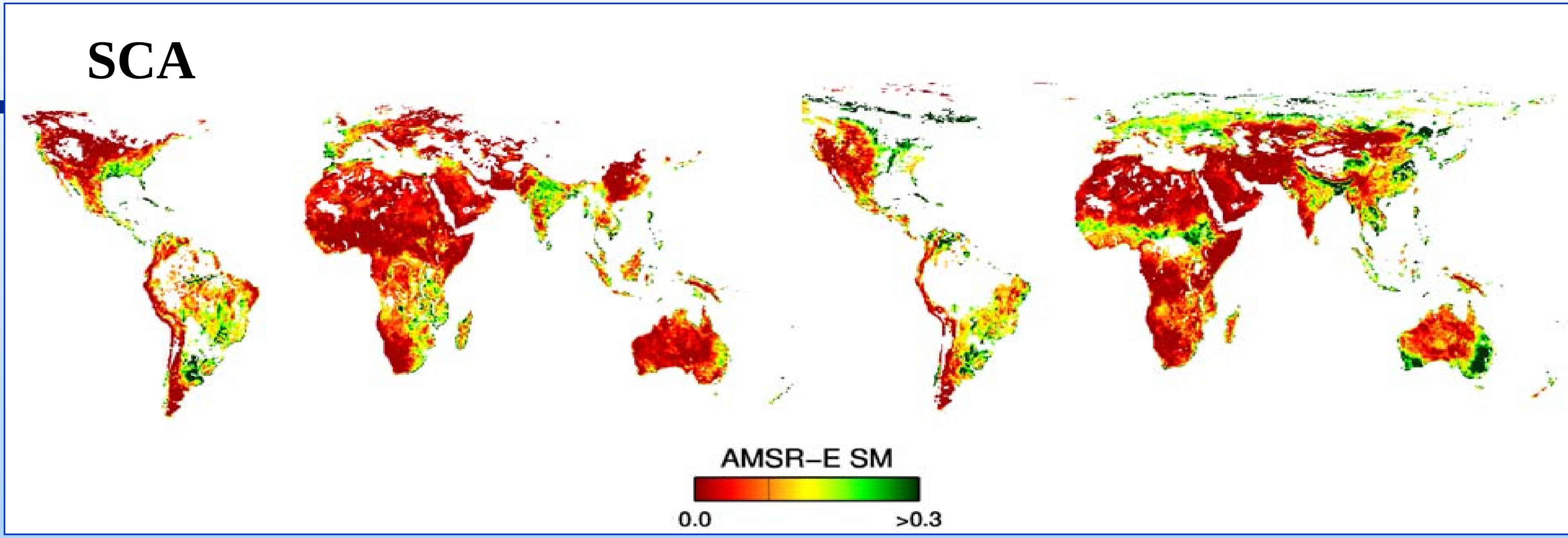
Little Washita   Walnut Gulch   Little River   Reynolds Creek

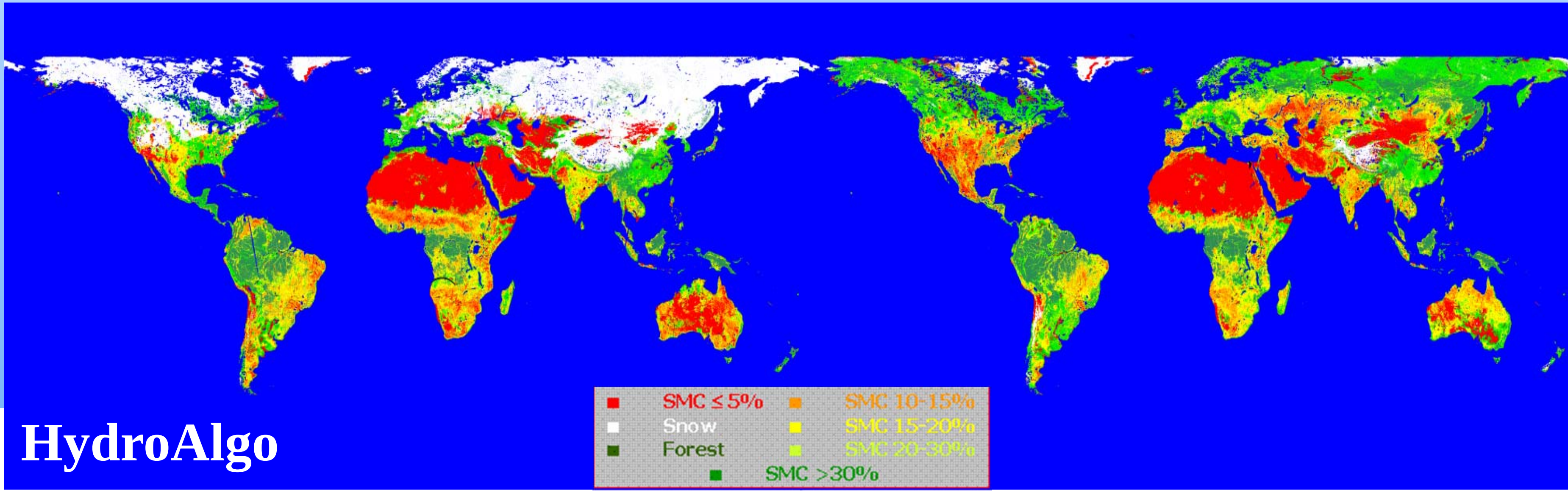
SCA & HydroAlgo (HA) comparison

Ascending	R		RMSE		Bias	
	SCA	HA	SCA	HA	SCA	HA
Little Washita	0.677	0.611	0.047	0.046	−0.015	−0.006
Walnut Gulch	0.442	0.545	0.026	0.019	−0.016	−0.0003
Little River	0.674	0.528	0.038	0.043	0.018	0.017
River Creek	0.397	0.724	0.025	0.052	−0.014	0.011

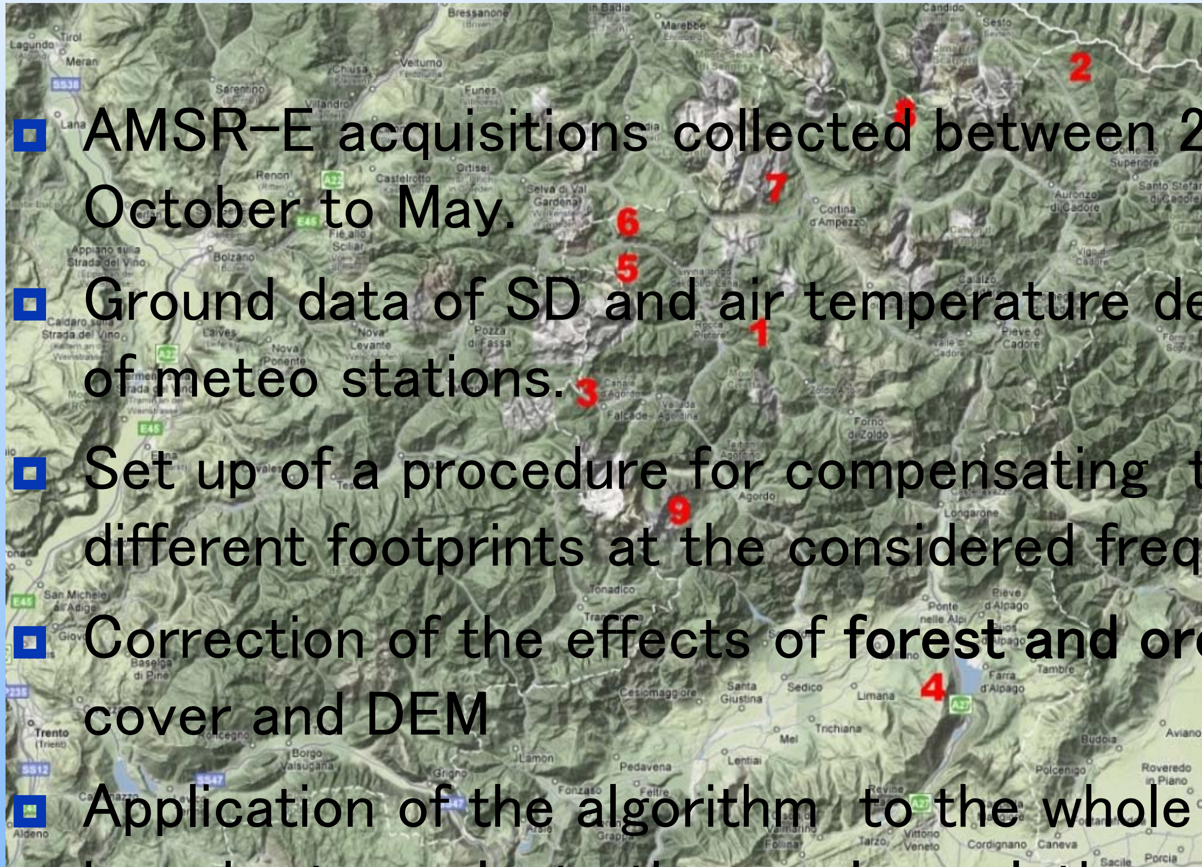
- The algorithms were compared by using the large dataset collected over the ARS watershed sites.
- Results demonstrated that both algorithms perform within a specified accuracy with RMSE ≤0.05 m3/m3.
- The two algorithms gave approximately the same results in terms of R and Bias.
- Ascending orbits (early-morning) provided better results than Descending orbits (early afternoon)
- A comparison on a very large scale was also performed

Winter / Summer





Application of HydroAlgo for estimating Snow Depth (SD) to an alpine Italian test area (Dolomites)



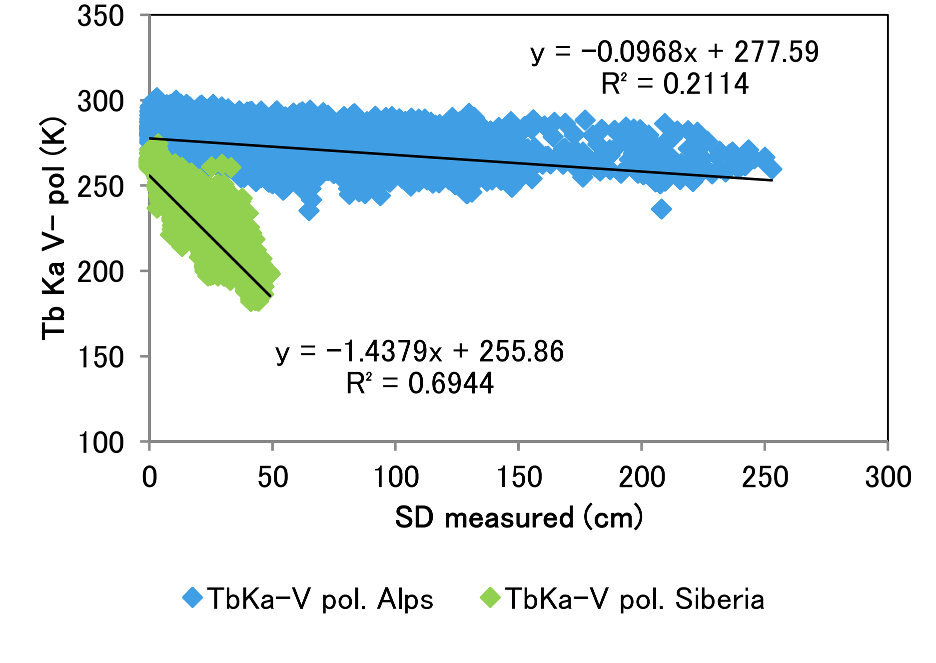
- AMSR-E acquisitions collected between 2002 and 2011 from October to May.
- Ground data of SD and air temperature derived from a network of meteo stations.
- Set up of a procedure for compensating the effect of the different footprints at the considered frequencies (SFIM).
- Correction of the effects of forest and orography basing on land cover and DEM
- Application of the algorithm to the whole extent of Italian Alps, in order to evaluate the yearly evolution of snow depth.

	Stations	Altitude
1	Col dei Baldi (BL)	1900
2	Casera Soltrondo (BL)	1899
3	Cima Pradazzo (BL)	2200
4	Faverghera (BL)	1605
5	Monti Alti di Ornella (BL)	2250
6	Cherz (BL)	2100
7	Ravales (BL)	2615
8	Monte Piana (BL)	2265
9	Malga Losch (BL)	1735

100 Km

Sensitivity analysis: TbKu, Ka → SD

- The comparison between SD estimated from AMSR-E data and SD measured on ground, on Siberia and Italian Alps, showed a strong underestimation, with maximum estimated value of about 30 cm for a corresponding SD of about 200 cm.

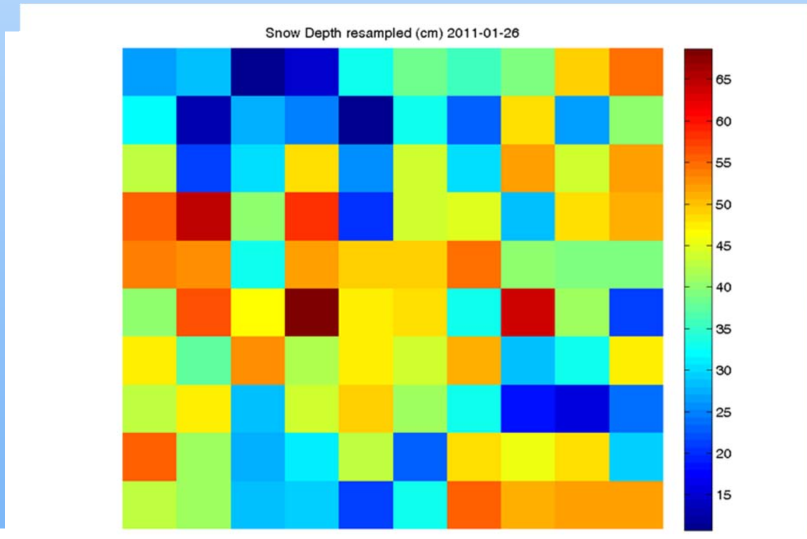


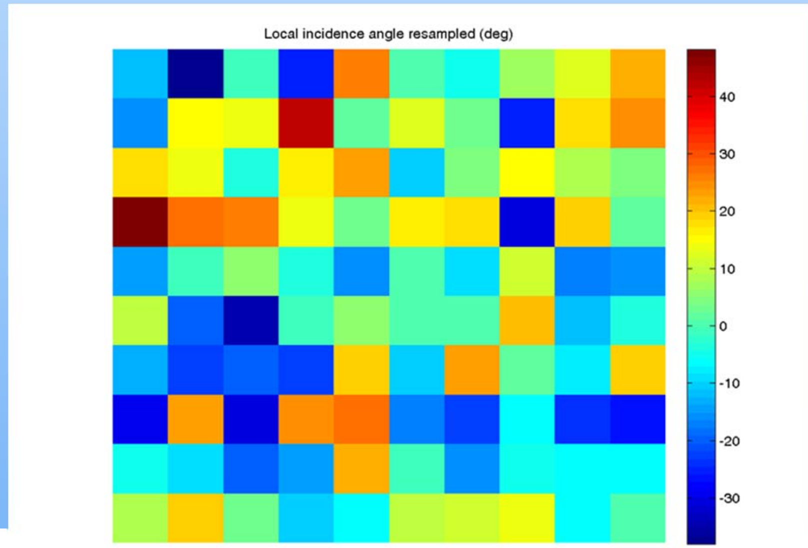
(K/cm)	Siberia		Alps	
Band	V	H	V	H
X	−0.13	−0.09	−0.05	−0.04
Ku	−0.46	−0.44	−0.07	−0.06
Ka	−1.44	−1.42	−0.1	−0.09

Effect of orography: altitude & incidence angle

- Each AMSR-E footprint includes a heterogeneous landscape, from valleys to peaks → the SD measurements at ground stations (1500-2600 m a.s.l.) cannot be considered as representative of the average SD.
- A linear relation between SD and elevation was assumed, accounting for a 20% variation of SD depending on the orientation of the slopes

- The average observation angle of each pixel differs from the AMSR-E incidence of 55° .
- A map of local slopes was computed at 100x100m2 for each orbit considering DEM and satellite track averaging for each 10x10 km2 pixel.
- Averaged slopes were used for computing the effective LIA and compensating Tb





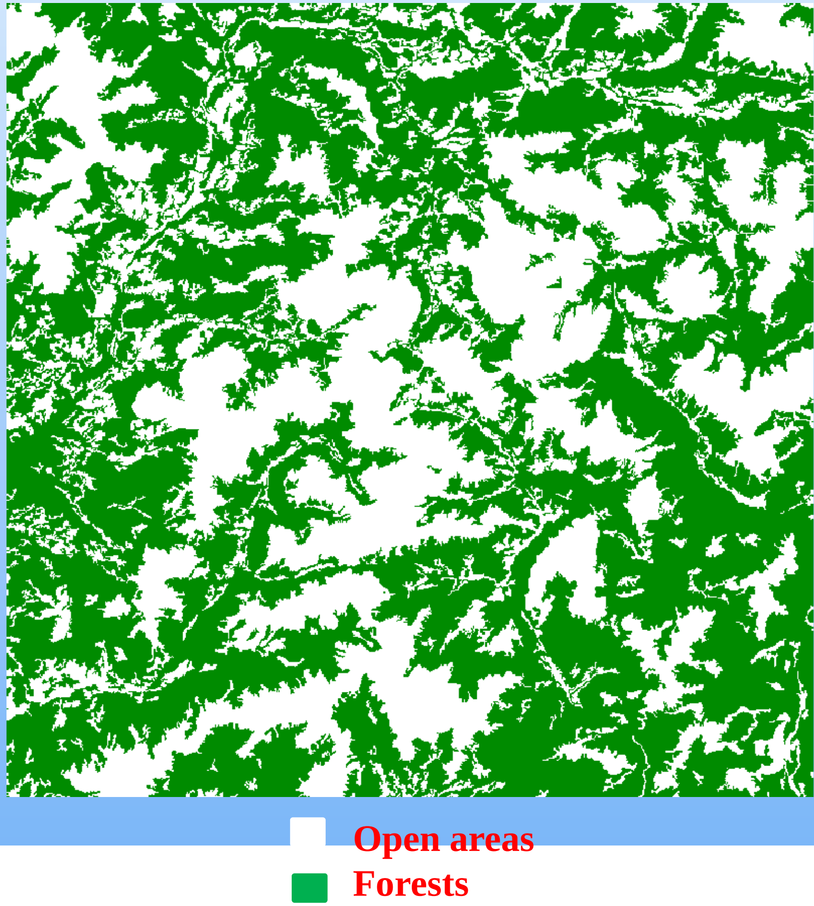
Effect of forests

A large part of the test area is covered by forests characterized by an high and quite stable emission that is poorly affected by the snow presence.

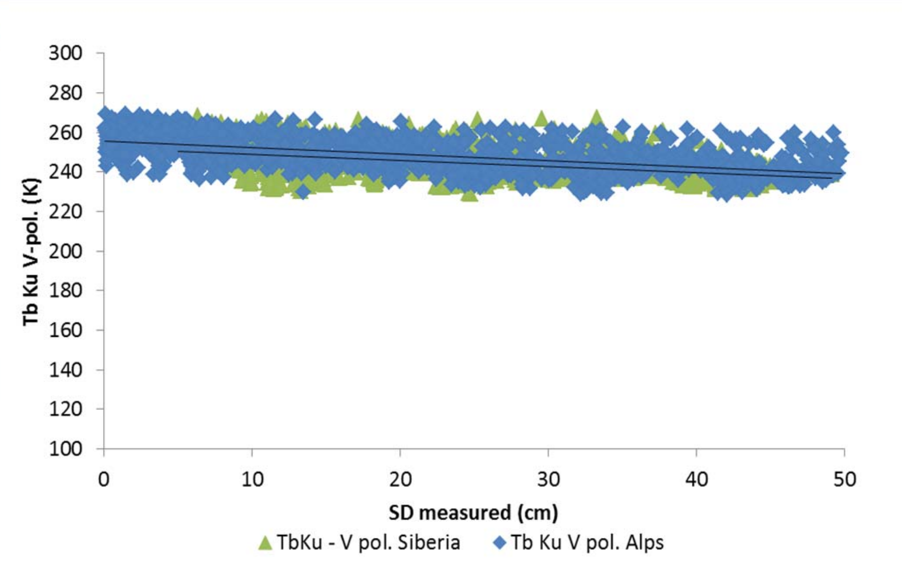
- Land use map at 100 m resolution from Corine allowed to compute the fraction of each AMSR-E pixel covered by forests.
- The Tb of the open areas covered by snow (Tbsnow) has been derived from the AMSR-E acquisition as follows:

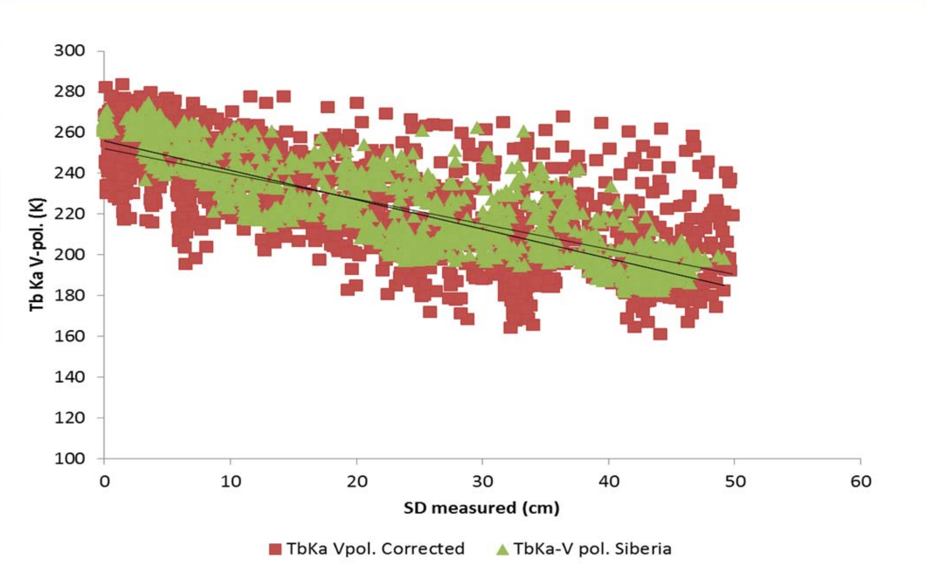
$$Tb_{snow}=(Tb_{meas}-cf*emiss*T_{phys})/(1-cf)$$

cf is the fraction of each pixel covered by forests.
T_{phys} is the physical temperature of the target (derived from meteo stations air temperature).
Tb_{meas} is the brightness measured by AMSR-E.
emiss is the emissivity of forested areas

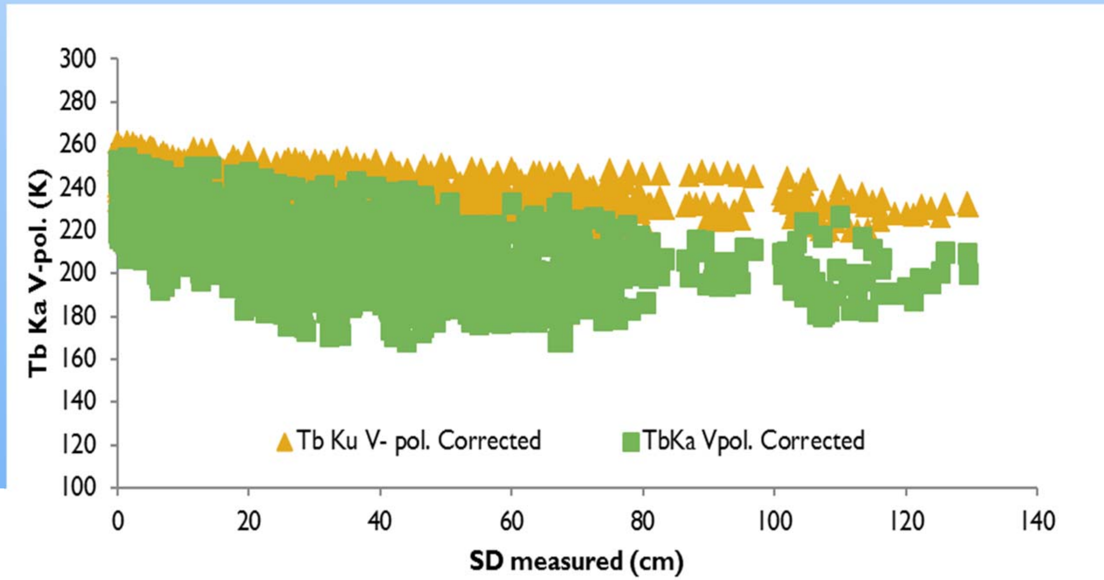


Correction results:
comparison with the Siberian dataset



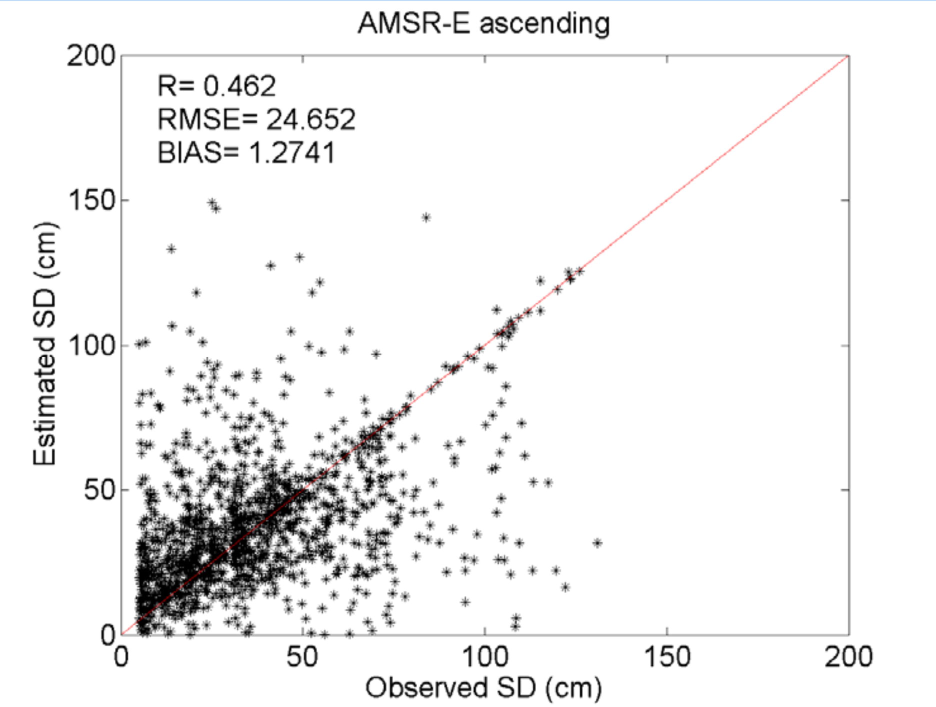


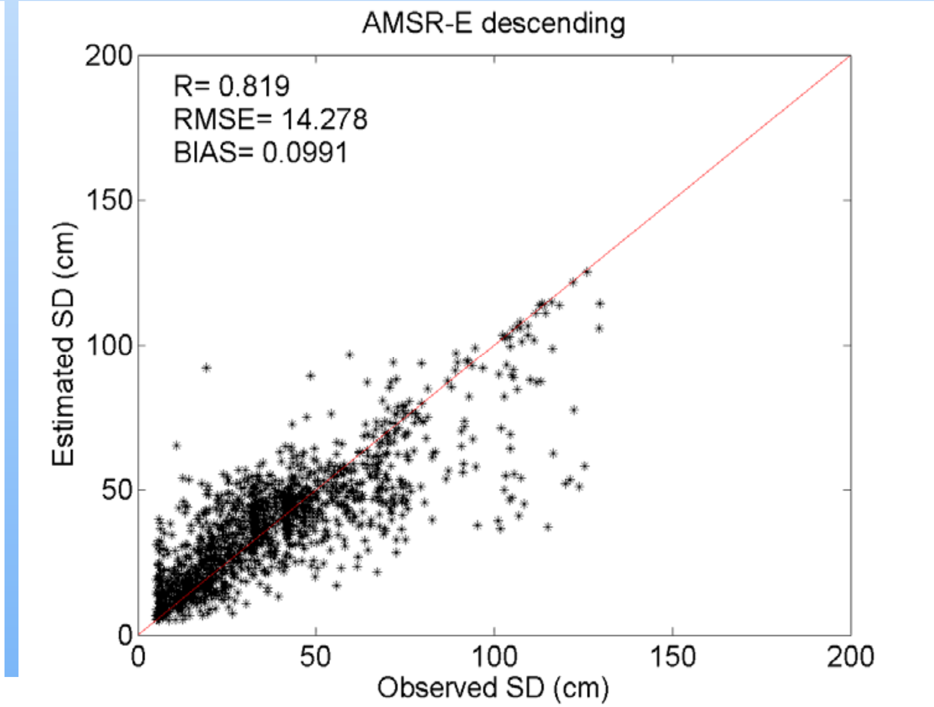
- Comparison limited to the common SD range (0-50 cm)
- Saturation for higher SD, mainly at Ka band.



Algorithm validation: Dolomiti

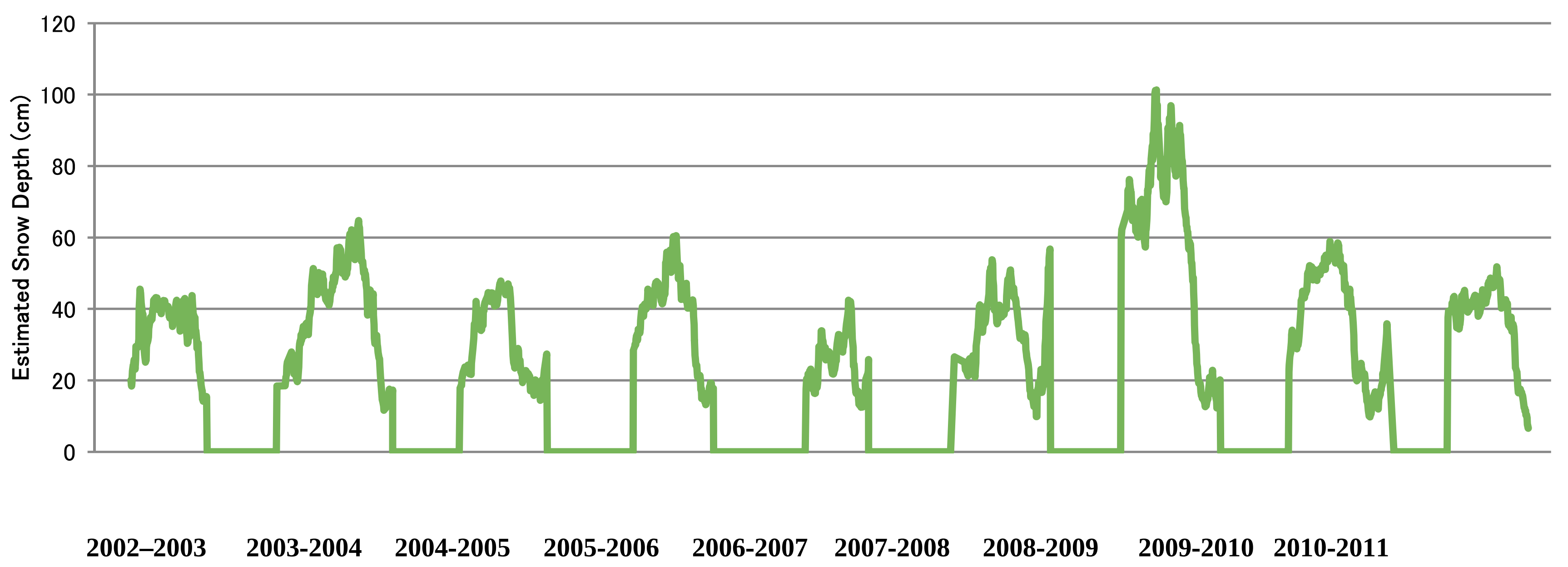
- The retrieval of SD was performed separately for ascending and descending orbits
- Ascending orbits showed a worse retrieval, due to the poor correlation between Tb and SD for diurnal observation (ascending orbits)



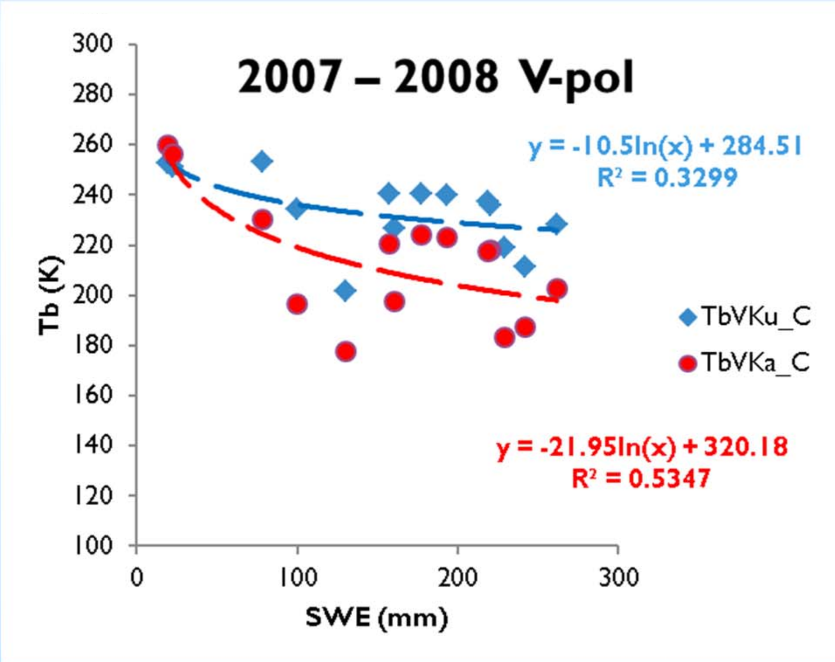


Temporal trend on the Alps

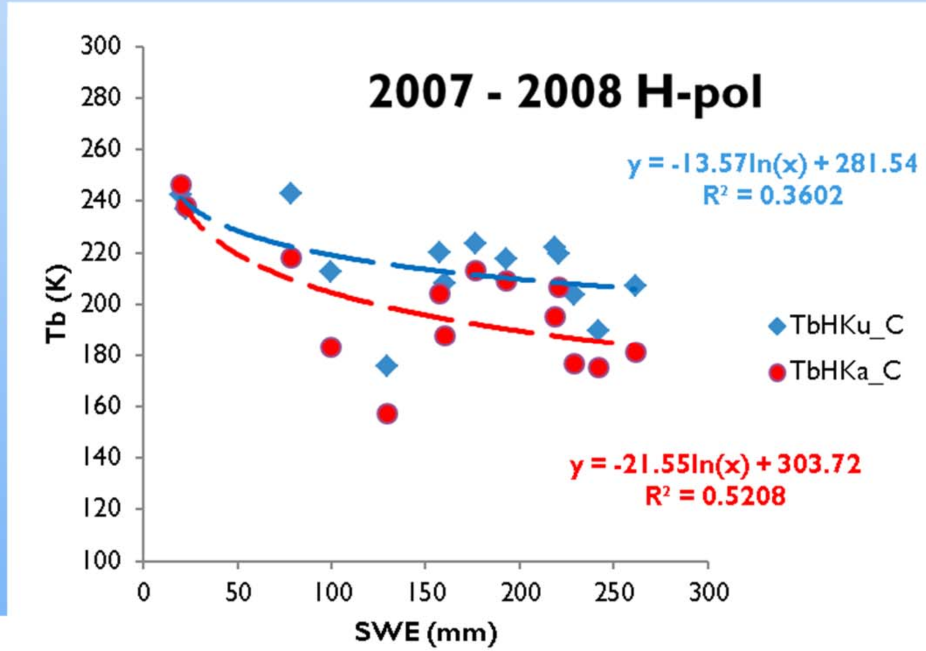
- The algorithm was then applied to the AMSR-E data collected on the whole extent of Italian Alps, in order to evaluate the temporal trend of snow
- The diagram represents the temporal trend of SD estimated by the algorithm from the available AMSR-E data collected during the winter seasons between 2002 and 2011, considering only the descending orbits: in this case, the SD values returned by the algorithm have been averaged weekly



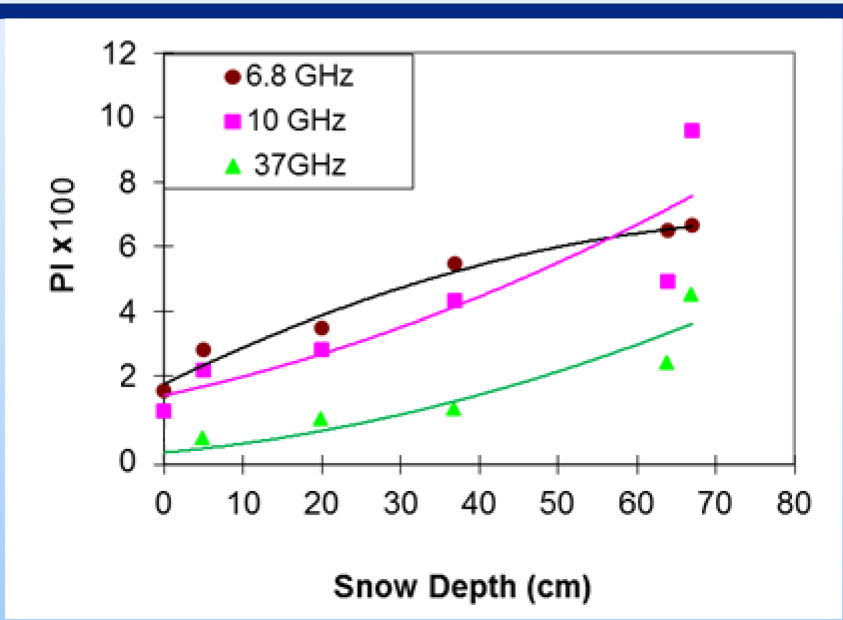
Investigating the sensitivity of microwave indexes to snow parameters



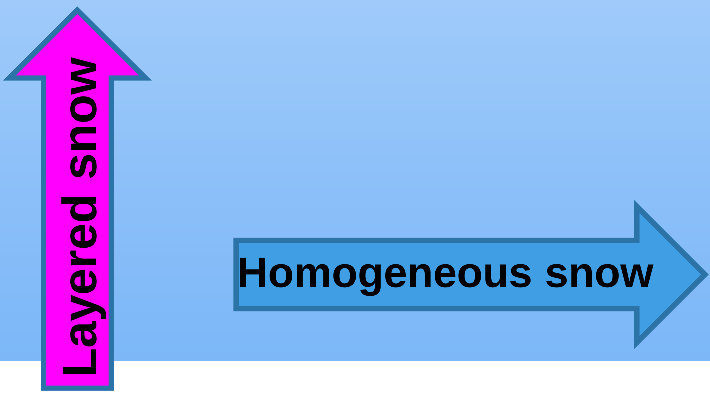
- Tb at Ku and Ka bands are sensitive to snow presence and decrease when snow accumulates
- And show similar trends in H and V polarizations

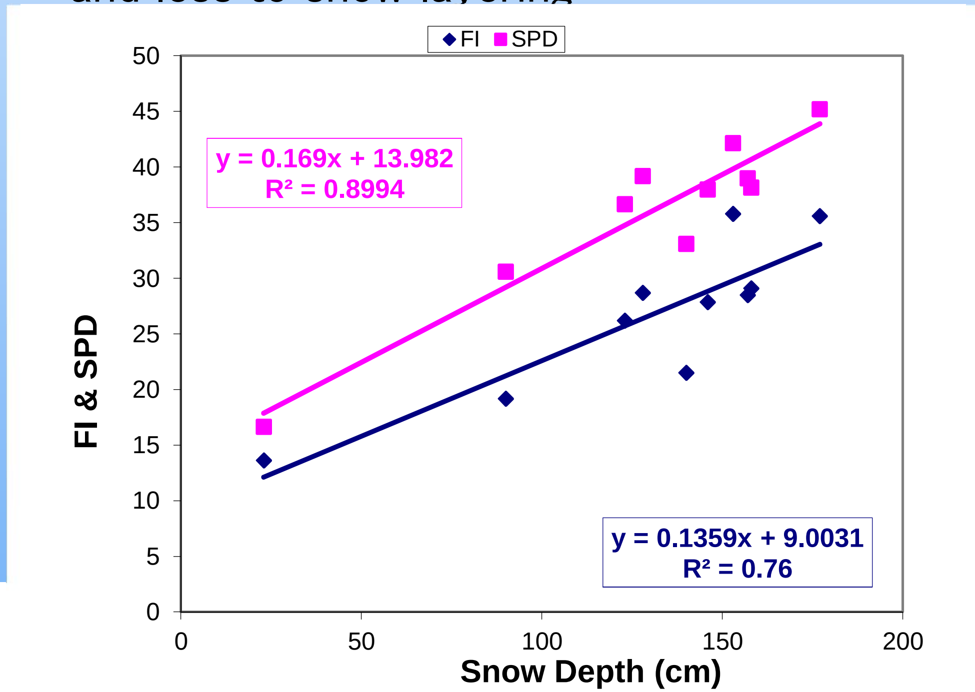


Polarization, Frequency, and mixed (SPD) indexes vs. Snow Depth



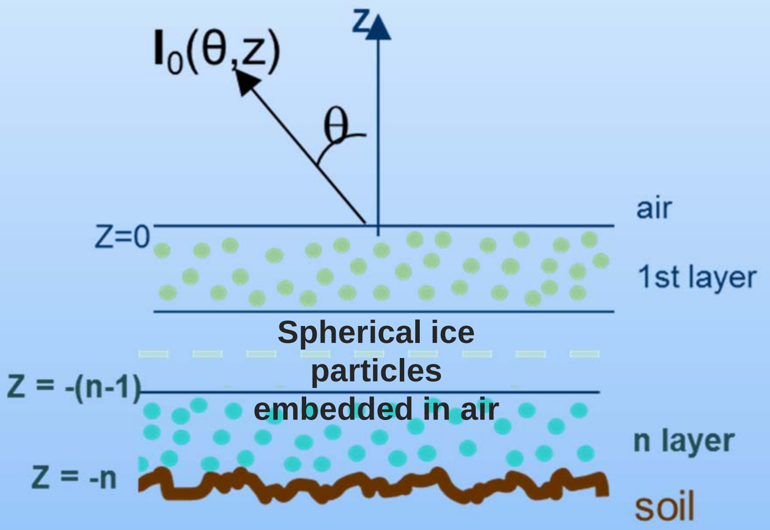
- PI are sensitive to snow presence and change rapidly from bare to snow-covered soils.
- However, the characteristics of snow cover significantly affect their behavior
- FI & SPD seem indeed more related to SD and less to snow layering





DMRT–QCA MULTI-LAYER MODEL

Snow: DMRT–QCA (Dense Medium Radiative Transfer Model, Quasi Crystalline Approximation) (*Tsang et al. 2007*)



Soil: Advanced Integral Equation Method (Chen et al., 2004)

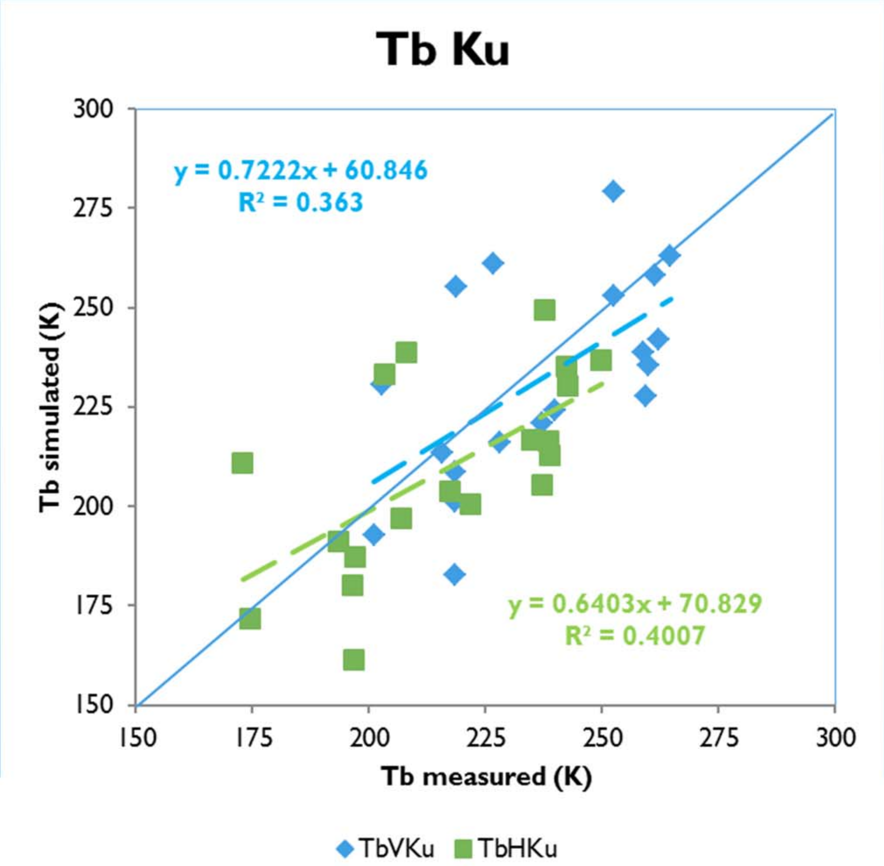
- The DMRT describes the scattering in a medium with particle fractional volume >10% (independent scattering is not valid)
- DMRT equations are derived from Dyson's equation under the QCA approx. and from the Bethe Salpeter eq. under the ladder approx. of correlated scatterers
- The correlation of particle position described by the pair distribution function of the Percus–Yevick approximation
- For each layer the radiative transfer equation was solved by using the Discrete-order Eigenvalues Method. The boundary were determined by using a cubic spline interpolation

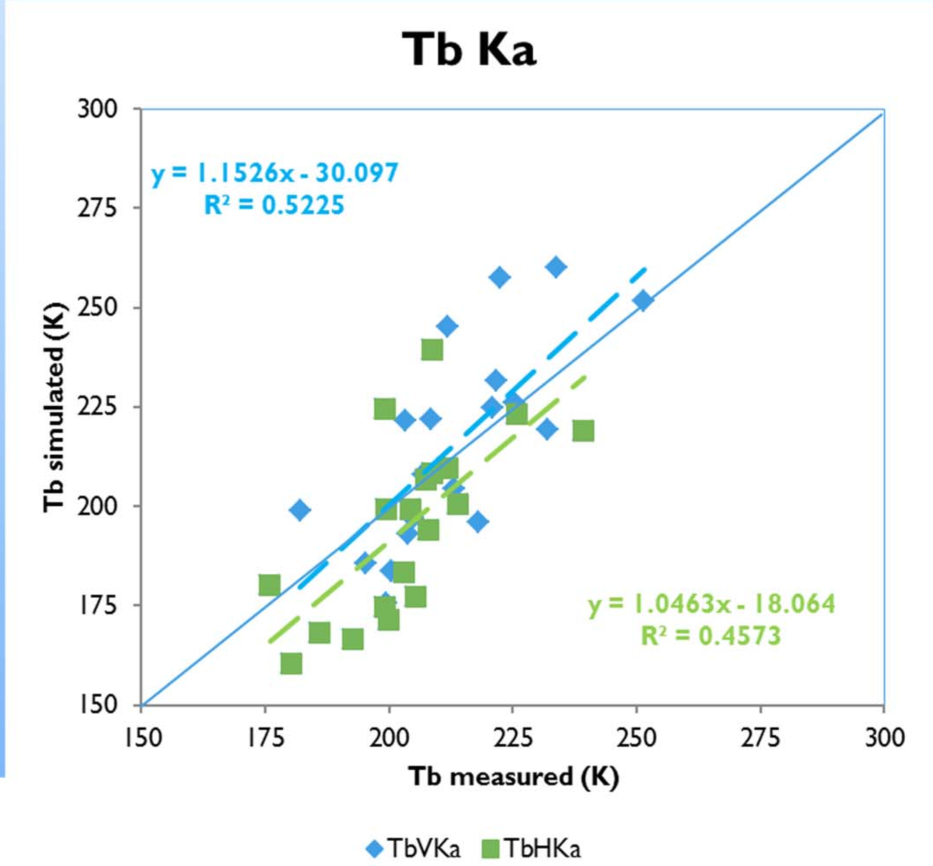
e.m. model → DMRT multilayer + AIEM

Frequency	19 and 37 GHz
Incidence angle	55°
n. of snow layers	between 3 and 15, derived from the ground measurements
Density of each layer	Between 100 and 400 Kg/m^3, from the ground measurements
Grain radius	Deff = 1.5(1− exp (−1.5 · Dobs))
Stickiness	fixed =0.2
Snow temperature	Derived from the ground measurements
snow volumetric wetness (%)	=0%, only dry snow has been considered
Snow thickness of each layer	Between 2 and 40 cm, from the ground measurements

Tb simulated vs Tb measured on ground

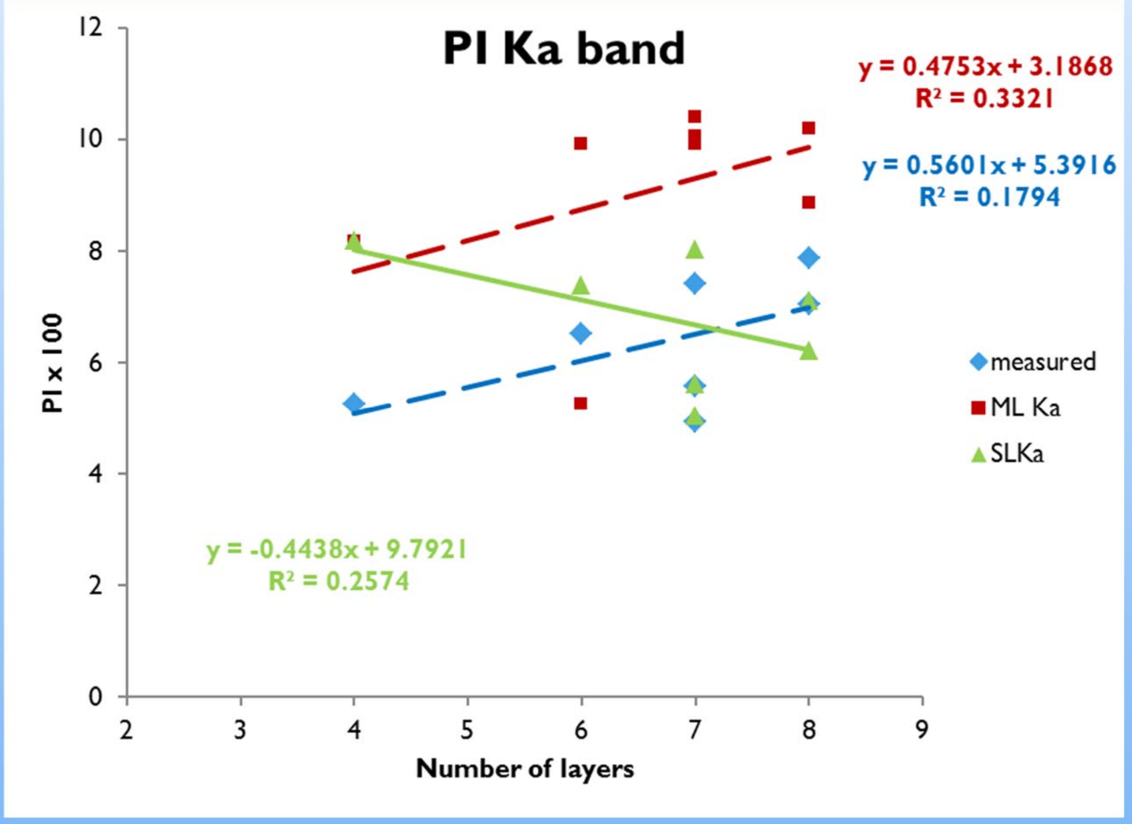
- Model simulations have been compared with the ground measurements of Tb at Ku– and Ka– bands, showing a reasonable agreement at both polarizations





Sensitivity to snow layering – Polarization Index

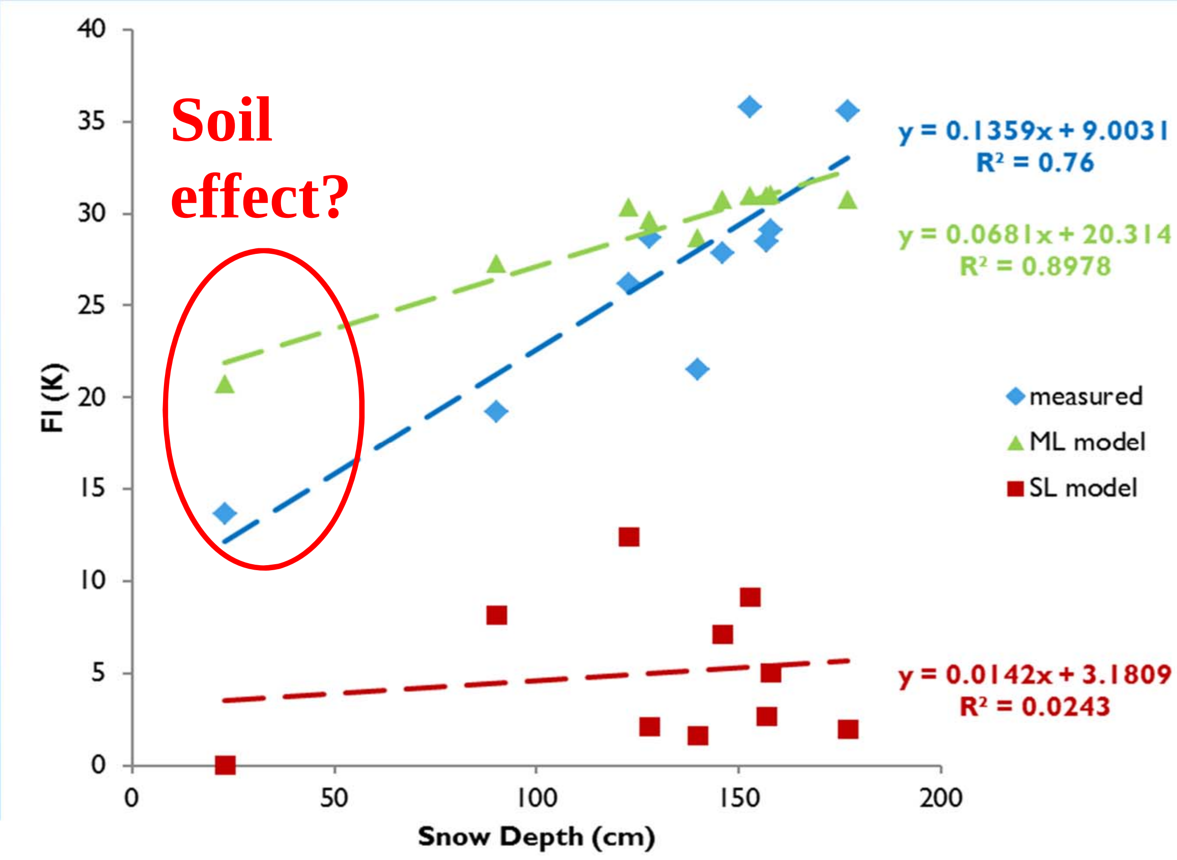
- measured and simulated (SL and ML) PI at Ka band as a function of the number of layers.



Density 230-270 kg/m^3 Depth 50 -100 cm

Sensitivity to Snow Depth

- **FI as a function of the measured snow depth for the winter season 2008 – 2009 measured, and ML model**



Summary

- The comparison between simulated and measured brightness temperatures at Ku and Ka band showed a rather satisfactory agreement, considering the complicated snow layering and the difficulties in measuring accurately the various snow parameters.
- In general the multilayer model is able to account for complex stratigraphy (up to 15 layers), simulating the measured Tb with an higher accuracy than the single layer one
- Model simulation confirmed the sensitivity of PI at Ku and Ka bands to the snow stratigraphy and of FI and SPD to the Snow Depth that can be successfully considered for the retrieval of the latter parameter

Some conclusions and future activities

- The HydroAlgo algorithm demonstrated to be able to separate 4–5 levels of SMC, SD and VB at a nominal ground resolution >= 10 km x 10 km.
- SMC and SD are retrieved by using two ANN trained with a large set of experimental data (for SMC, ANN training is enriched by $\tau-\omega$ model simulations).
- The algorithm has been successfully tested at several spatial scales over different regions of the Earth and compared to SCA (Tom Jackson)
- Recent research was devoted to improve some aspects related to SD retrieval
- The ANN algorithm was used to estimate SD on Italian Alps
- DMRT model in the multilayer version was used to simulate different trends of Tb, PI and FI for stratified snow cover
- Detailed ground data of snow cover are necessary for improving the validation of the model
- Moreover, additional tests on different areas and seasons will be necessary to properly evaluate the operational capabilities of the implemented code.

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Arigato!


Thanks
for the attention