An International Workshop on Snow, 1st Field Campaign, MC and WG Meetings

Snow Measurements in the Italian Alps: an Overview of Operational and Research Activities

Giovanni Macelloni, Renato Zasso, Carlo De Michele, Francesco Avanzi

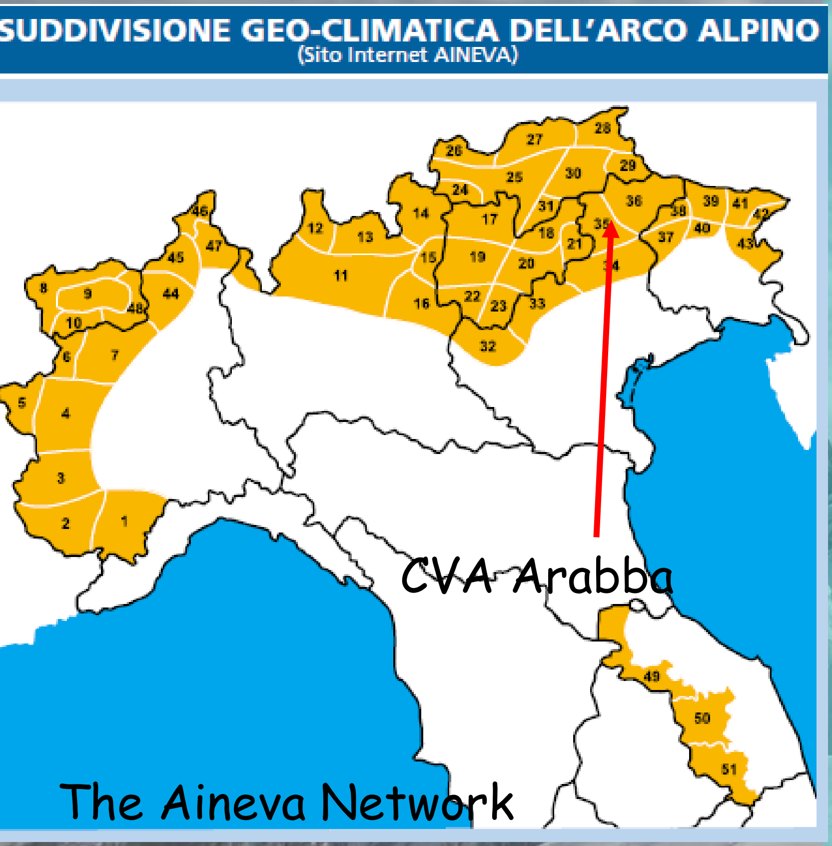
EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

Introduction

- Having more than 1/3 of his territory composed by mountains, snow is relevant for Italy :
  - Water supply for human , agricultural and industrial activities
  - Hydropower
  - Tourism
- Snow is widely monitored for both operational and scientific purposes by several entities at regional and national scale. Nevertheless a coordination at national level is not yet implemented
- Two examples will be presented today: operational service from a regional entity (ARPA-Veneto) , research acrivities at Politecnico di Milano

SWE measurements at CVA (Arrabba Avalanche Center) - Italy

The Arabba Avalanche Center (CVA) – Arabba- Italy



CVA – is part of the ARPA (Regional Agency for the Environment) Veneto and participate to the network AINEVA (Alps and Apennine Network)

CVA is the reference center for avalanche monitoring and prediction in the eastern Italian Alps

Manage Several Snow stations

Daily snow measurements and avalanche bulletin are delivered during winter season

CVA is also responsible for weather forecast in the East Italian Alps

CVA collaborates in national and international research projects

Basic Measurement: Snow Density

$$\rho = \frac{P}{V}$$

Kg /m ^{3}

The Density measurements

- Hydrology : the measurement aims to compute the water availability (vertical sampling)
- Nivology : the main objective is the snowpack monitoring for avalanches preditction (horizontal sampling)

Hydrology : Vertical Sampling

Example of measurements conducted for hydropower company

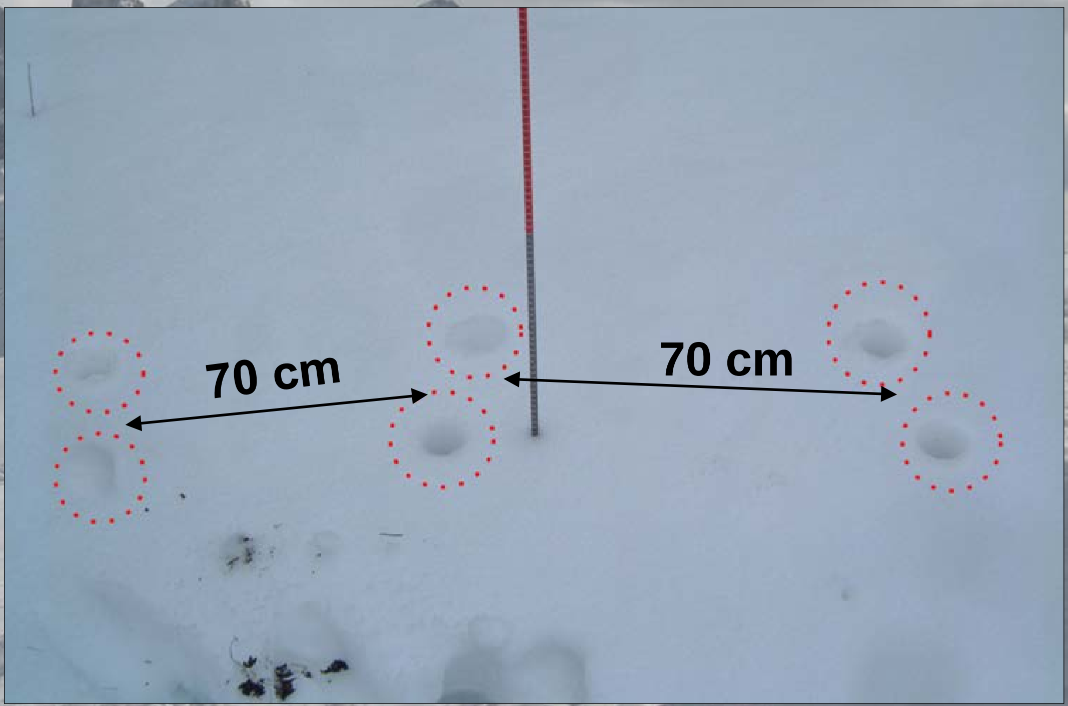
- Pristine snow
- Every 15/30 days from February to June
- 39 Sites (932 – 2635 m)
- Continuously From 2006 – 1000 samples!

Sampling Methodology

- 3 vertical cores at 70 cm distance

Selection of representing area (snow stake)

Sampling Execution



It is required to reach the soil/snow interface .
In case of deep snow , snow pits are excavated !

Sample Weigth and Report

A detailed report is filled for each sample

Numero stazione	Località stazione	Codice e quota stazione	Data rilievo (gg/mm/aaaa)	Altezza neve (m)				Peso neve (Kg)				S.W.E. (mm) Area di base (cm) 25				Densità neve (Kg/dm^3)			
				Ril H1	Ril H2	Ril H3	Valore medio	Ril P1	Ril P2	Ril P3	Valore medio	SWE 1	SWE 2	SWE 3	Valore medio	DEN 1	DEN 2	DEN 3	Valore medio
1	Ra Vales	ARP10 - 2615	01/02/2016	0,22			0,22												
2	Lagazuoi	ARP11 - 2531	02/02/2016	0,30	0,31	0,30	0,30	0,20	0,21	0,20	0,200	80	82	78	80	0,267	0,265	0,260	0,264
3	Monte Piana	ARP14 - 2265	01/02/2016	0,15			0,15												
4	Passo Giau	ARP09 - 2140	02/02/2016	0,13	0,12	0,13	0,13	0,08	0,08	0,08	0,077	32	30	30	31	0,246	0,250	0,231	0,242
5	Faloria	VBB35 - 2120	27/01/2016	0,29	0,29	0,29	0,29	0,13	0,13	0,13	0,125	50	50	50	50	0,172	0,172	0,172	0,172
6	Passo Falzarego Km 109	VBB39 - 1985	01/02/2016	0,19	0,19	0,18	0,19	0,11	0,12	0,11	0,112	44	46	44	45	0,232	0,242	0,244	0,239
7	Casera Coltrondo	ARP07 - 1950	01/02/2016	0,21			0,21												
8	Col dei Baldi	ARP01 - 1900	28/01/2016	0,25	0,24	0,25	0,25	0,14	0,14	0,14	0,135	54	54	54	54	0,216	0,225	0,216	0,219
9	Casera Doana	ARP08 - 1899	01/02/2016	0,12			0,12												
10	Passo Tre Croci	VBB23 - 1800	02/02/2016	0,10	0,09	0,11	0,10	0,08	0,07	0,08	0,075	32	28	30	30	0,320	0,311	0,273	0,301
11	Misurina	ARP13 - 1750	02/02/2016	0,07	0,08	0,09	0,08	0,08	0,09	0,07	0,077	30	34	28	31	0,429	0,425	0,311	0,388
12	Malga Dignas	VBB08 - 1676	01/02/2016																
13	Passo M.C.Comelico	ARP12 - 1650	01/02/2016	0,25	0,22	0,25	0,24	0,16	0,15	0,17	0,158	64	60	66	63	0,256	0,273	0,264	0,264
14	Monte Siera	ARP06 - 1630	28/01/2016	0,18	0,20	0,25	0,21	0,11	0,12	0,13	0,118	44	48	50	47	0,244	0,240	0,200	0,228
15	Passo Duran	ARP02 - 1590	01/02/2016	0,00	0,00	0,00	0,00												
16	Pocol	ARP04 - 1540	01/02/2016	0,00	0,00	0,00	0,00												
17	Forcella Cibiana	ARP05 - 1520	01/02/2016	0,00	0,00	0,00	0,00												
18	Passo S.Antonio	VBB19 - 1486	01/02/2016	0,11	0,09	0,10	0,10	0,11	0,09	0,10	0,098	42	36	40	39	0,382	0,400	0,400	0,394
19	imabanche Ospitale SS 51 km 114,	ARP03 - 1450	01/02/2016	0,00	0,00	0,00	0,00												
20	Malga d'Oten	VBB32 - 1387	01/02/2016	0,00	0,00	0,00	0,00												
21	Corte di Cadore - C.V.	VBB55 - 1286	01/02/2016	0,00	0,00	0,00	0,00												
22	Cretta Sappada	VBB03 - 1265	01/02/2016	0,00	0,00	0,00	0,00												
23	Padola	VBB14 - 1255	01/02/2016	0,00	0,00	0,00	0,00												
24	Centrale Frison	VBB13 - 1178	28/01/2016	0,08	0,08	0,09	0,08	0,04	0,04	0,05	0,040	16	14	18	16	0,200	0,175	0,200	0,192
25	Cortina Costeana	VBB36 - 1142	02/02/2016	0,00	0,00	0,00	0,00												
26	Fusine Sponda Destra	VBB56 - 1125	01/02/2016	0,06	0,05	0,07	0,06	0,04	0,04	0,05	0,043	16	16	20	17	0,267	0,320	0,286	0,291

Example of snow samplers (vertical)

Plexiglass tube

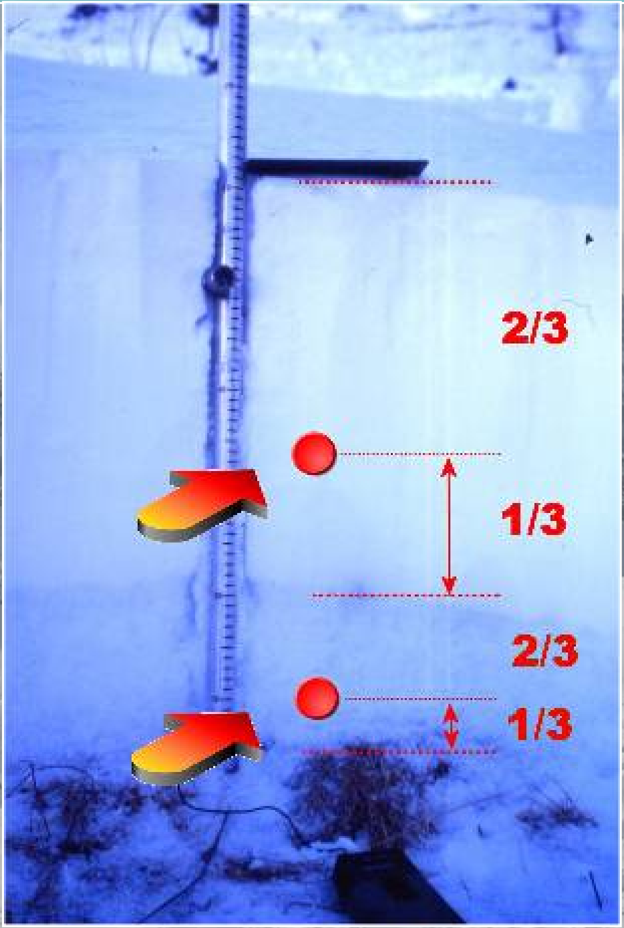
Metallic Extendable tube

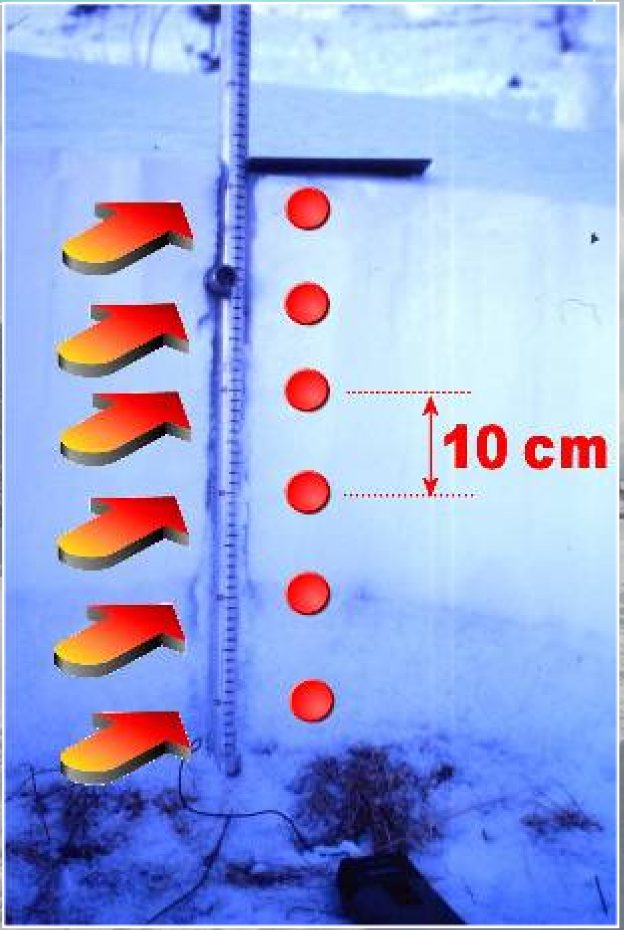
Plexiglas Vertical tube

- Plexiglas Tubes:
  da 50 cm, 100 cm e 140 cm

Field Experience demonstrated that Plexiglas tubes provide better performances in term of measurement reliability and accuracy

Horizontal Sampling





- Per layer
- 1/3 of the layer (average density)
- Only if layer thickness > sampler diameter

- Every 10 cm
- Better for SWE
- Worst for stability

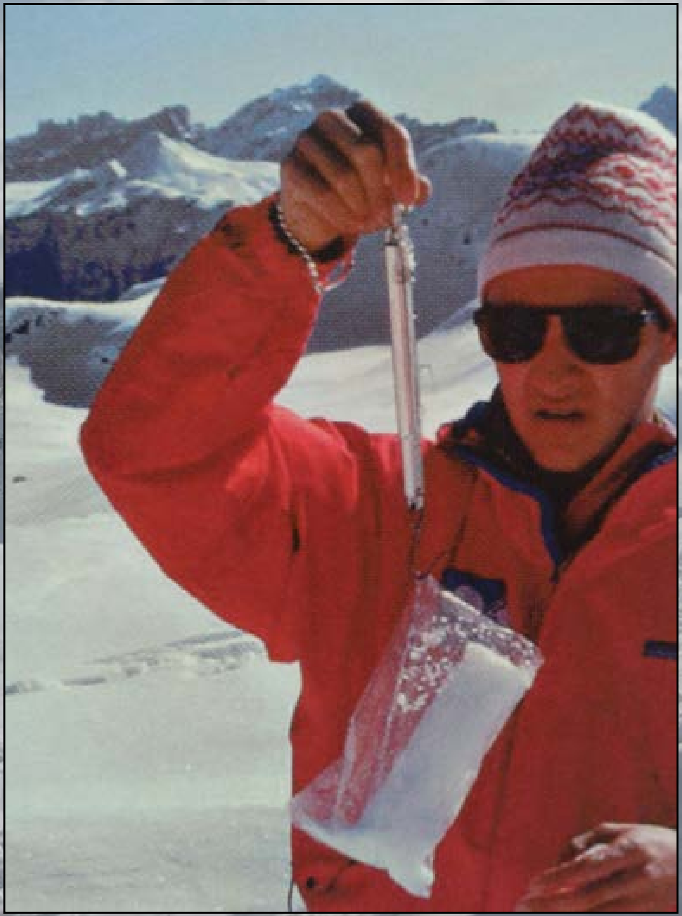
Examples of snow samplers

- da 0,0005 m^3 (different lenght 19-17-13 cm)

- da 0,0001 m^3 (useful for thin layers)

Sampling collection

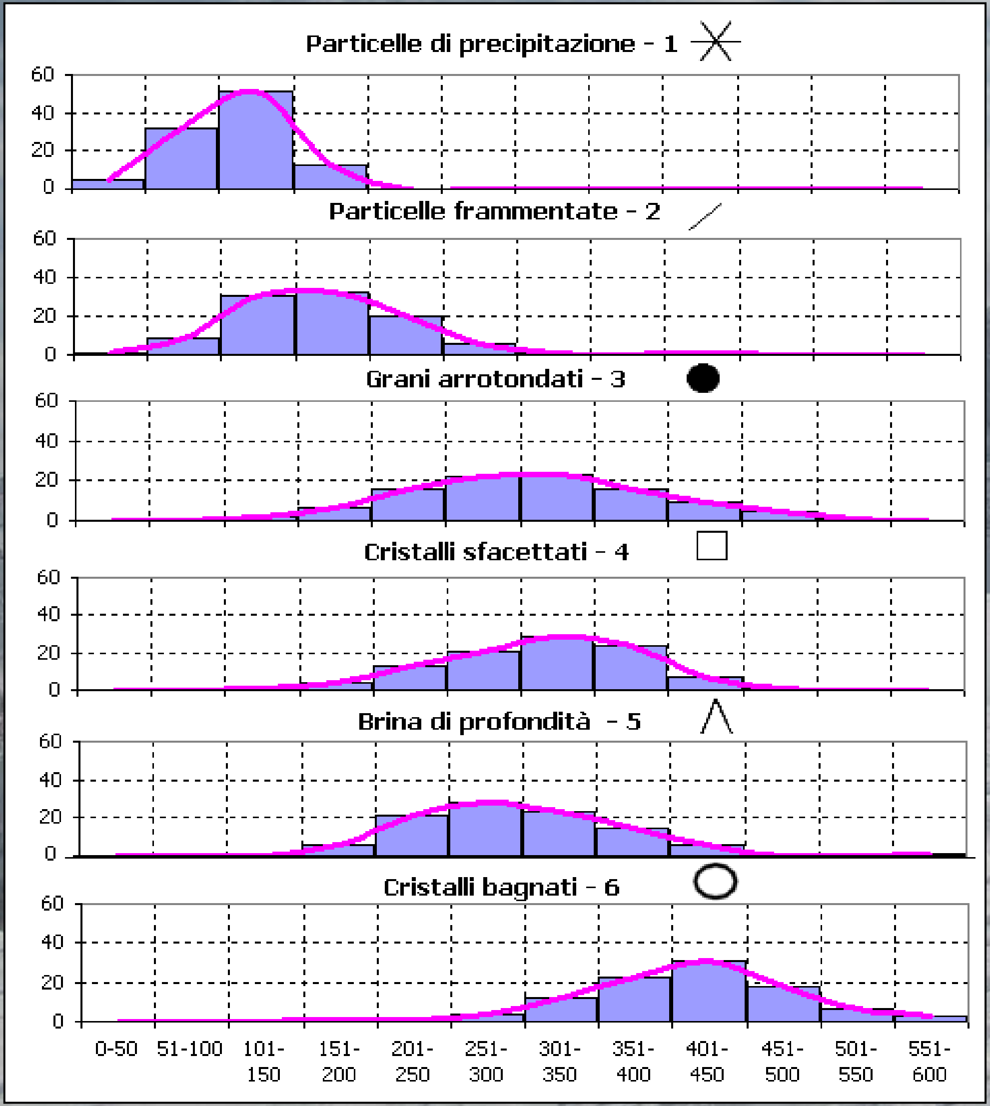
Sampler in the snow (no compact the snow!)



Sample weight

Example of snow weight directly using the snow sampler

Snow Density Results



Density depends on snow metamorphism and grains type

Examples of snow density distribution is provided here

A new tool for snow hardness measurement : The AVATECH 2 probe

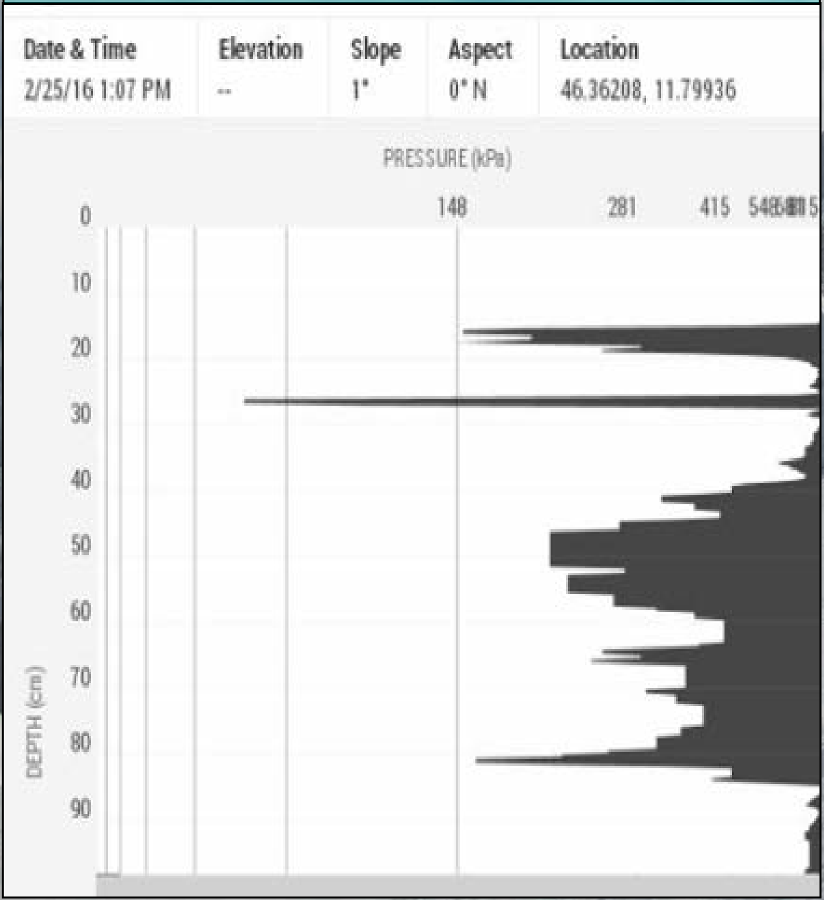
- Snow Penetrometer measure the snow resistance to penetration
- 3 IR sensors provide to the distance measurement (thickness layer)
- Data are directly acquired in a WEBGIS platform

AVATECH 2

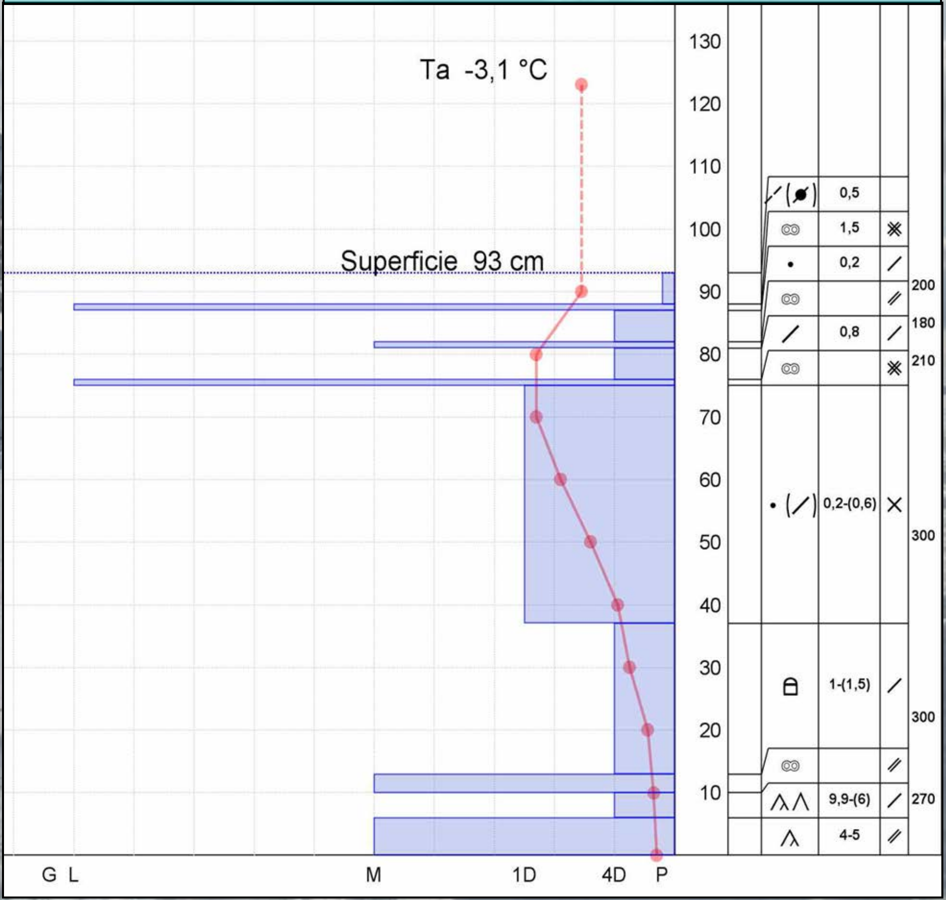
- Data are available in real time
- Probe evaluation and validtion is in progress

Example of Profile

- AVATECH 2



- Traditional Profile



Snow measurements @ Polimi (Italy)

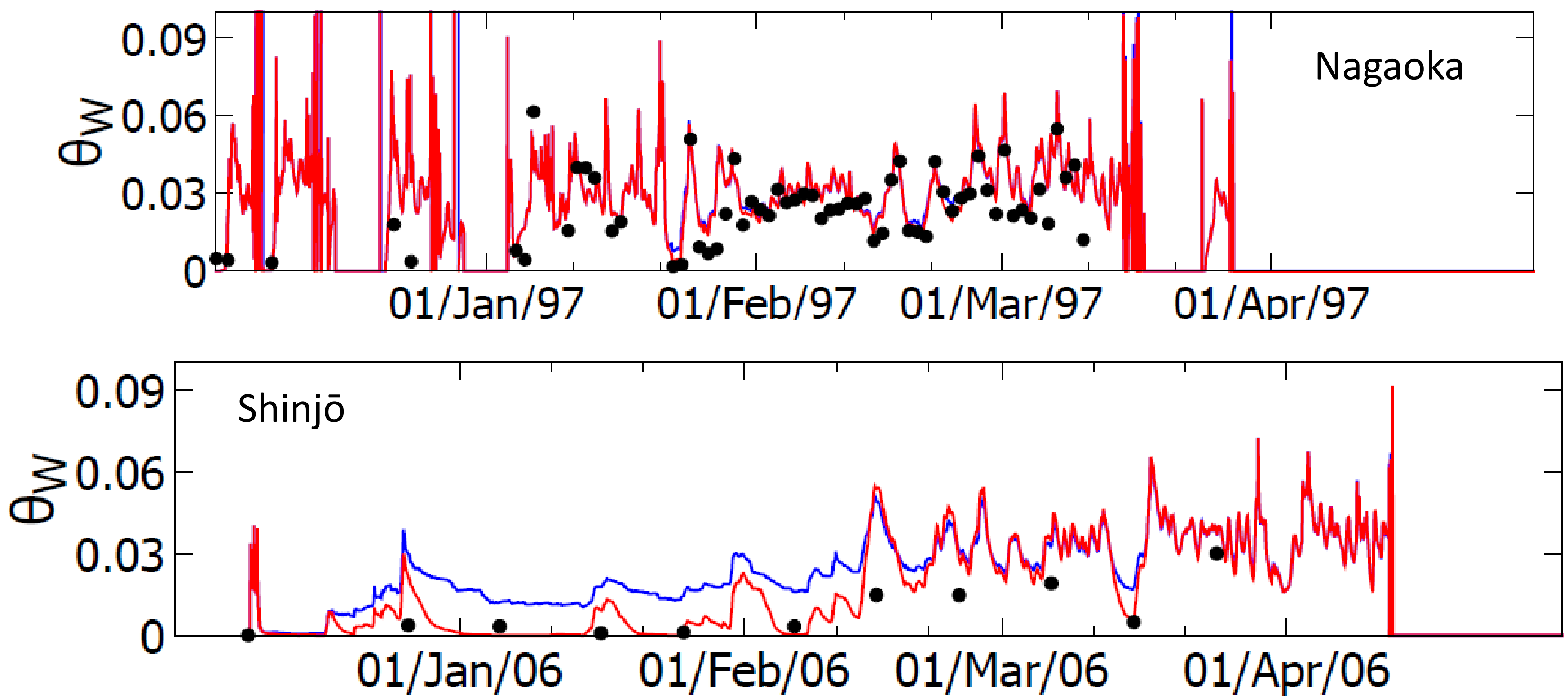
- ....
- ....
- Liquid water content (continuous in time)
- Snow depth (spatial variability)
- ....

Why continuous-time measurements of liquid water content?

1) Need data to validate a model of snow dynamics in wet conditions (see De Michele et al. 2013, Avanzi et al. 2015)

2) Most techniques are destructive and need a pit to be excavated. Non-destructive techniques are still not widespread.

Why measurements continuous in time of liquid water contents?

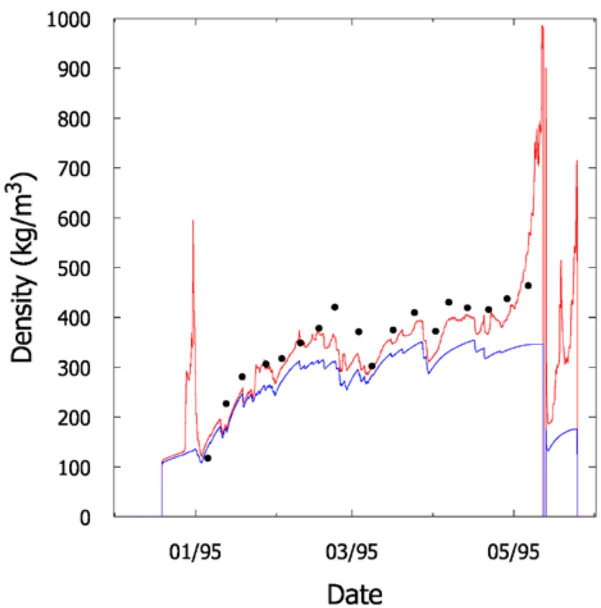


Black: data (manual), **Red**: HyS (with MF), **Blue**: HyS (without MF)

Avanzi, F., Yamaguchi, S., Hirashima, H., De Michele C. 2015. Bulk volumetric liquid water content in a seasonal snowpack: modeling its dynamics in different climatic conditions. *Advances in Water Resources*.

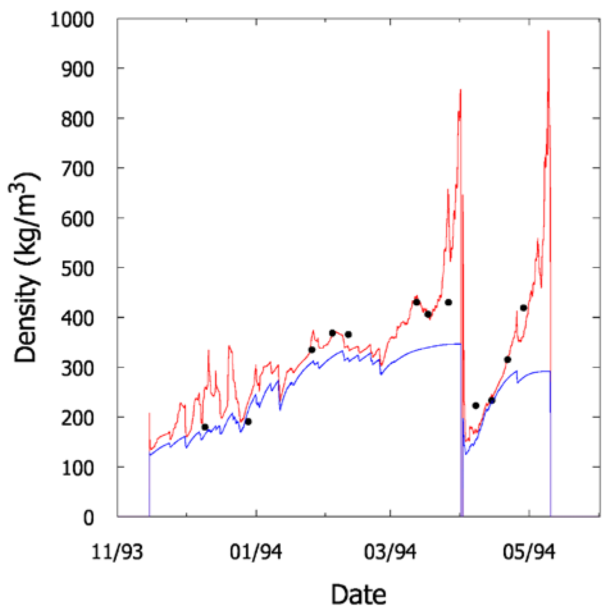
Why measurements continuous in time of liquid water contents?

Calibration year (1994/1995)



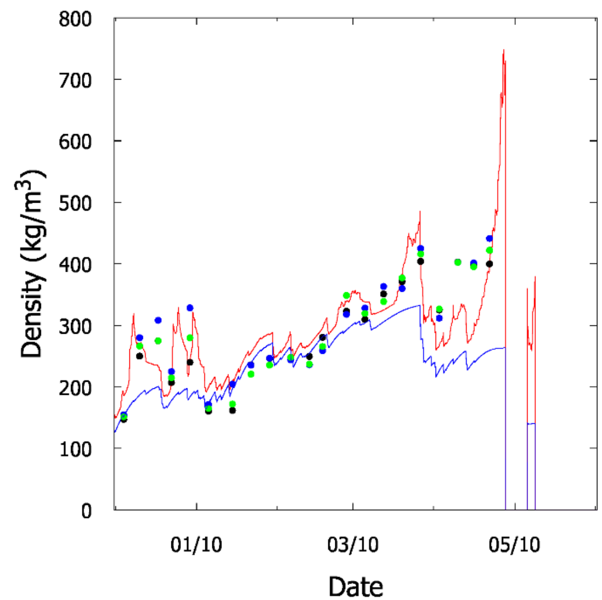
1 pit/week available

An example of validation (1993/1994)



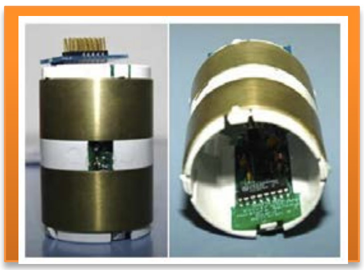
1 pit/week available

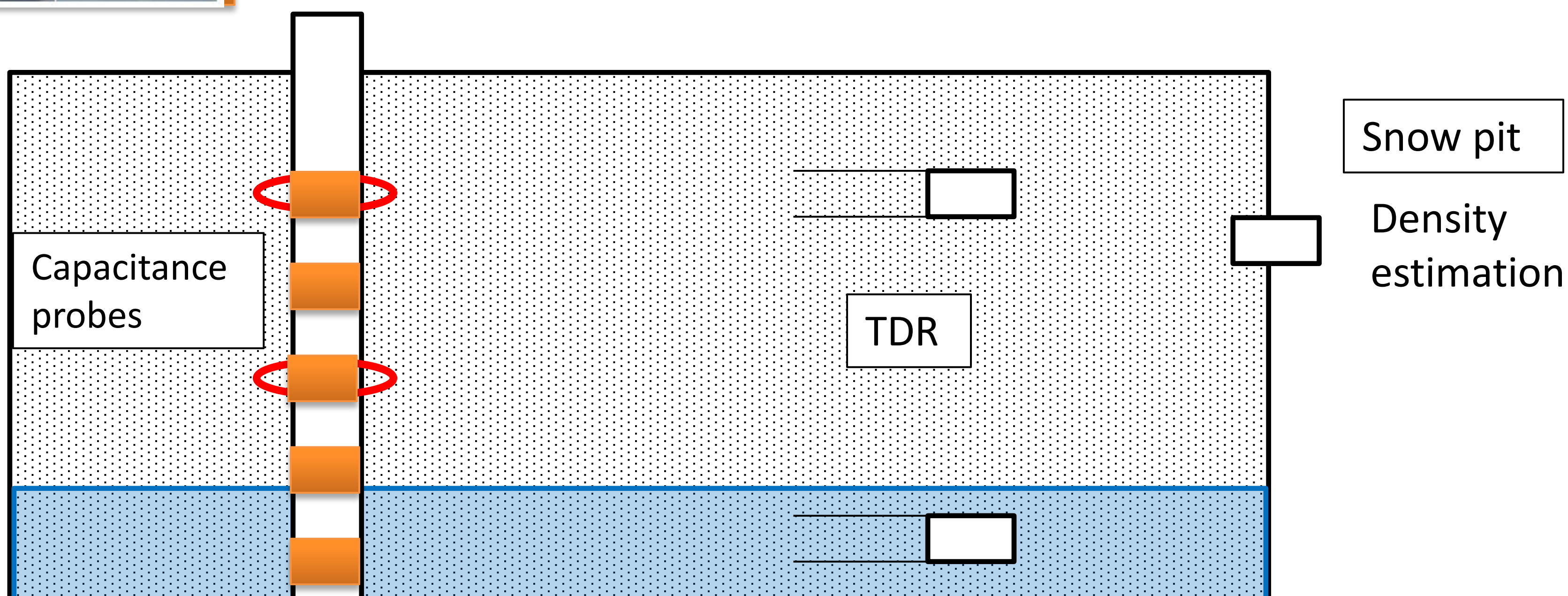
An example of validation (2009/2010)



3 pits/week available

Measuring LWC using capacitance probes





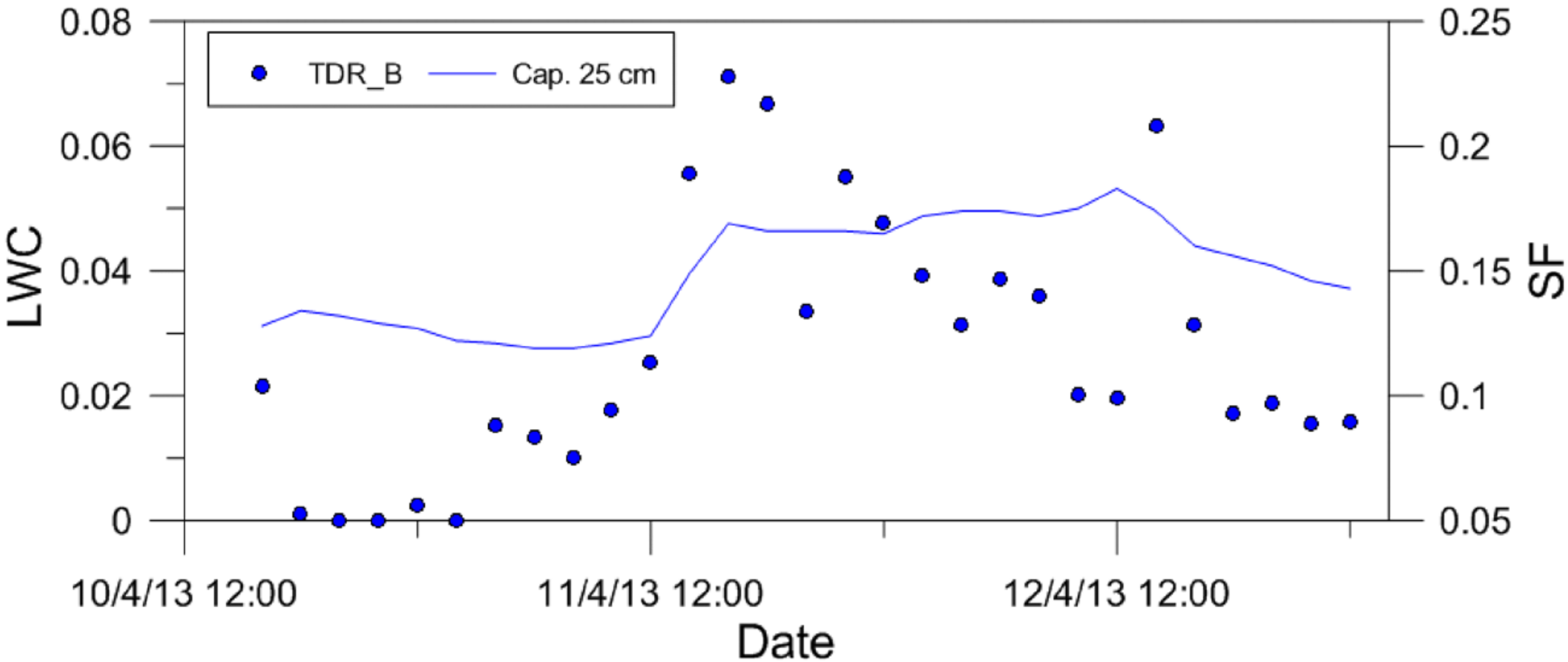
Avanzi et al. (2014) Continuous-time monitoring of liquid water content in snowpacks using capacitance probes: a preliminary feasibility study, Advances in Water Resources.

Measuring LWC using capacitance probes

Location: around 2000 m a.s.l. (Cancano, Lombardia, Italy)

Dates: April 2013

Measuring LWC using capacitance probes



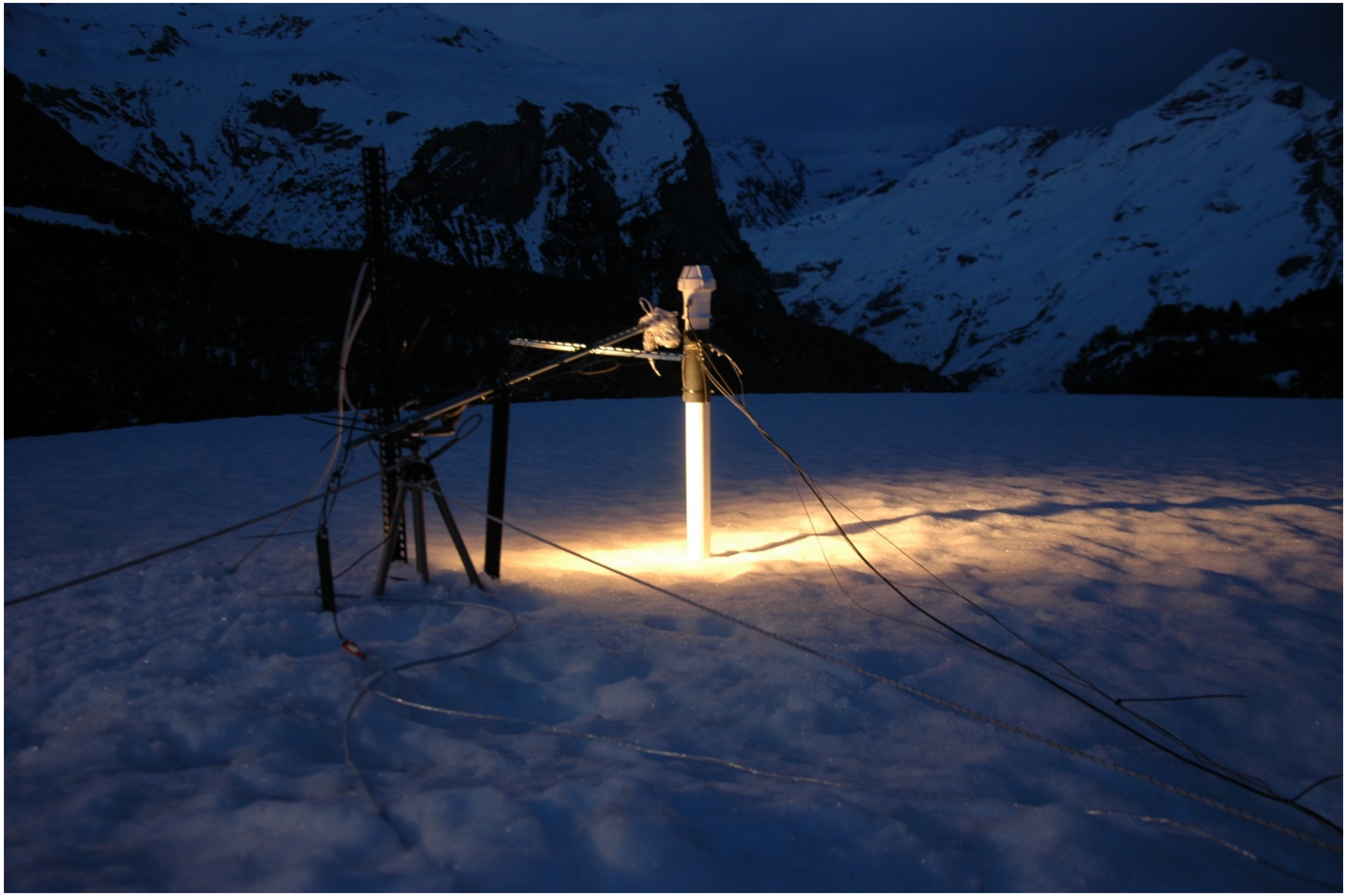
Measuring LWC using capacitance probes

Problems

Air gap development when placed in snow, after hours

Shielding effect + localized melting = Difficulty in MR registering

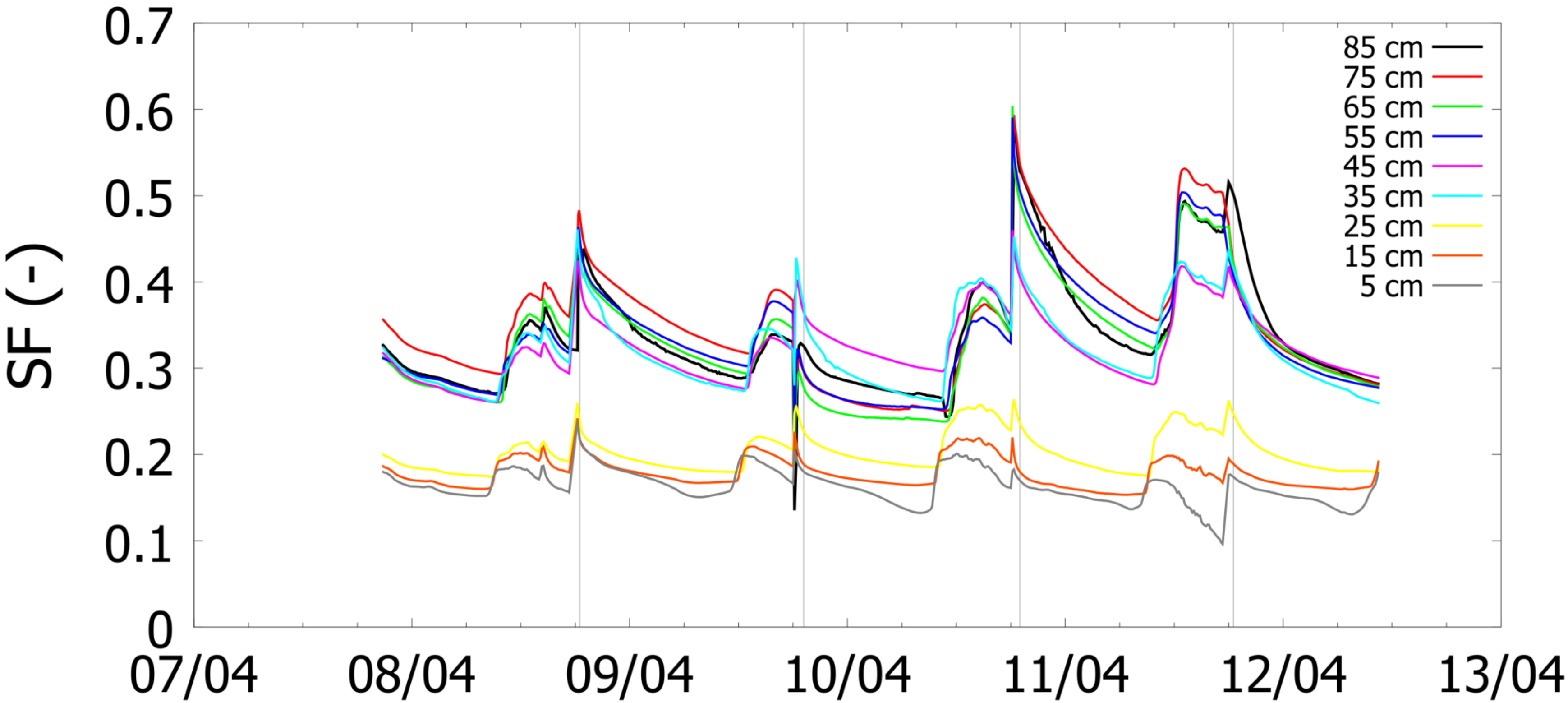
Measuring LWC using capacitance probes



Location: around 2000 m a.s.l. (Cancano, Lombardia, Italy)

Dates: April 2014

Measuring LWC using capacitance probes



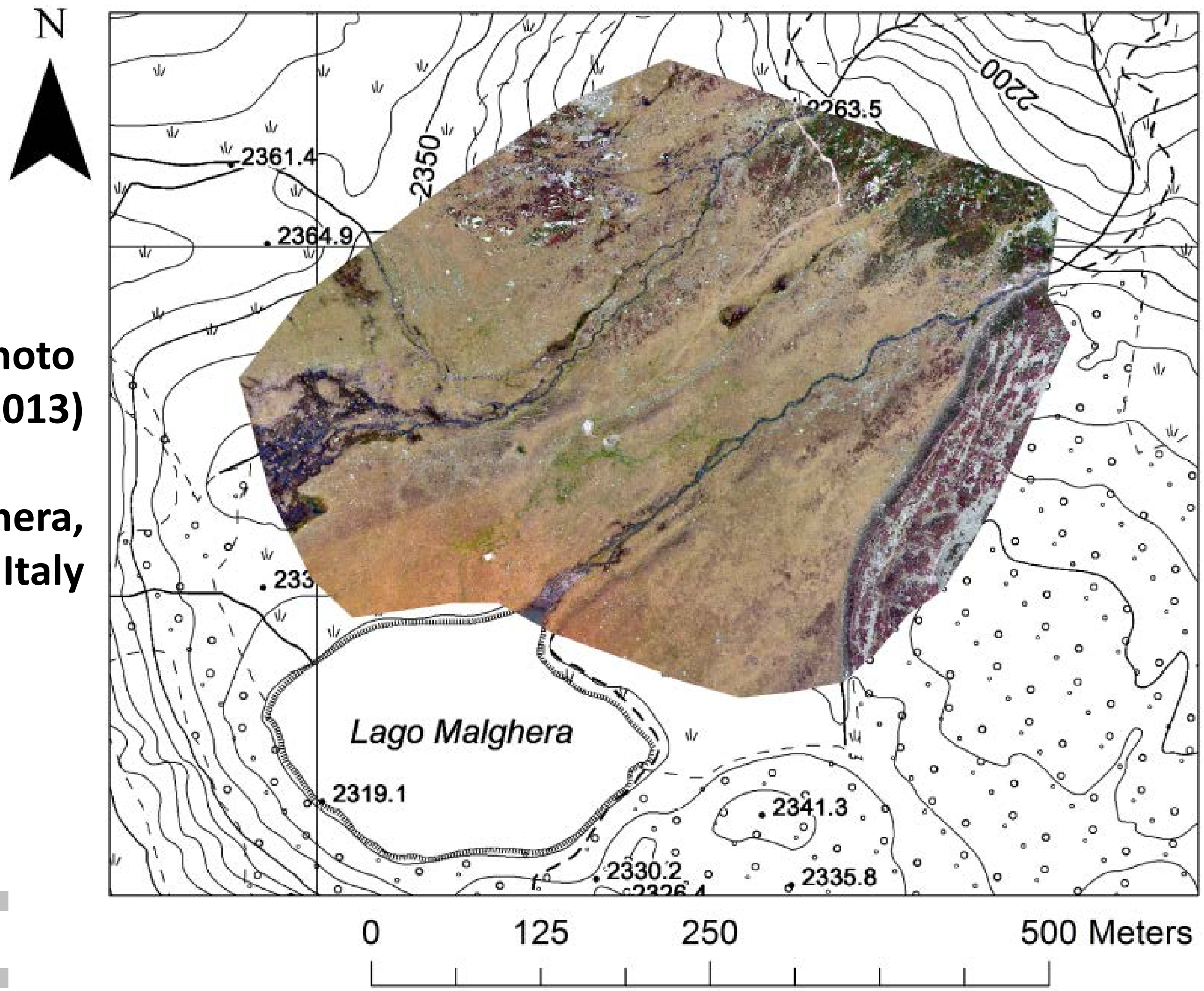
Mapping snow depth using UAS systems

De Michele et al. (2016), Using a fixed-wing UAS to map snow depth distribution: an evaluation at peak accumulation, The Cryosphere, 10, 1–12, 2016.

Mapping snow depth using UAS systems

Orthophoto (Autumn 2013)

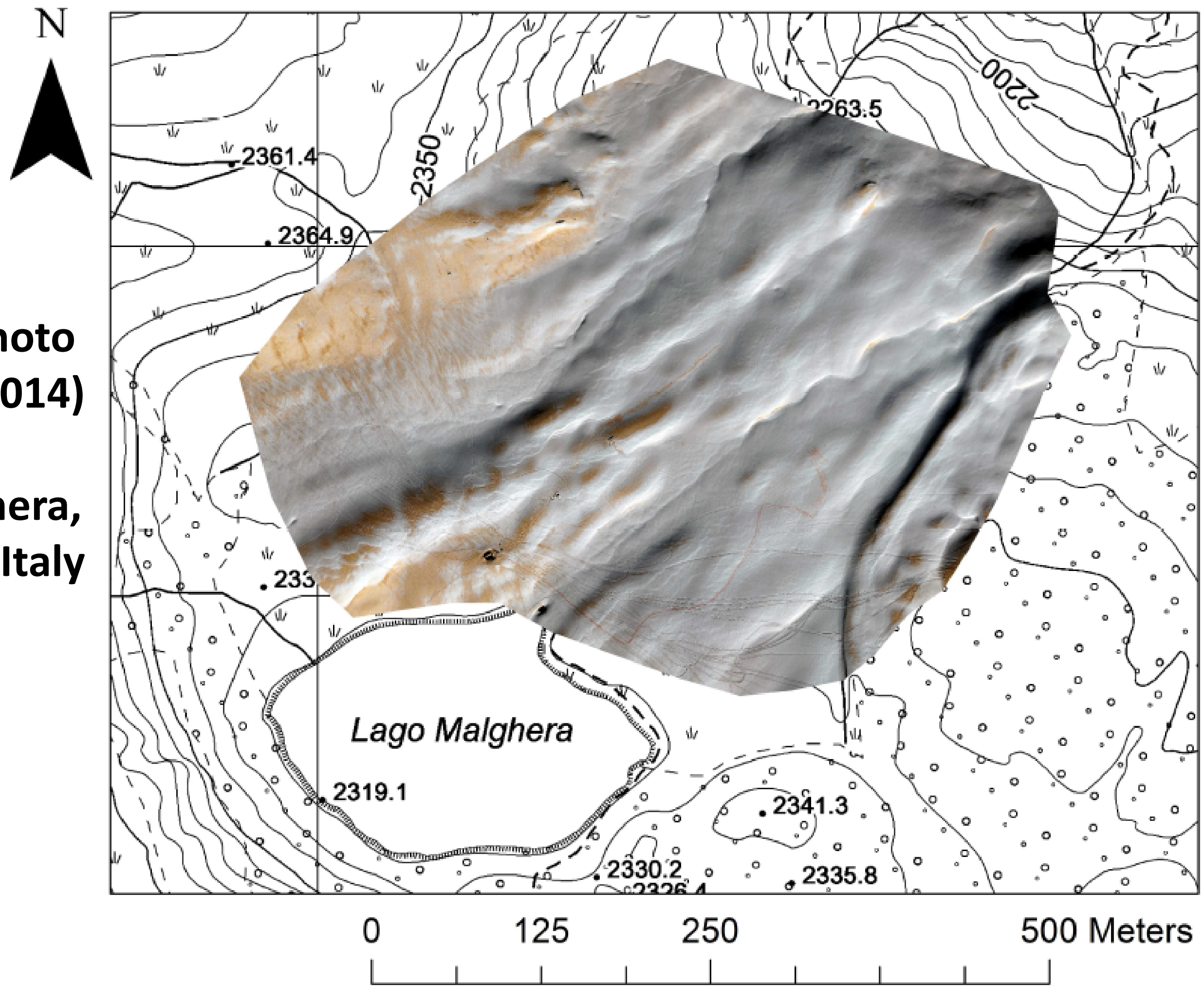
Location: Malghera, Lombardia, Italy



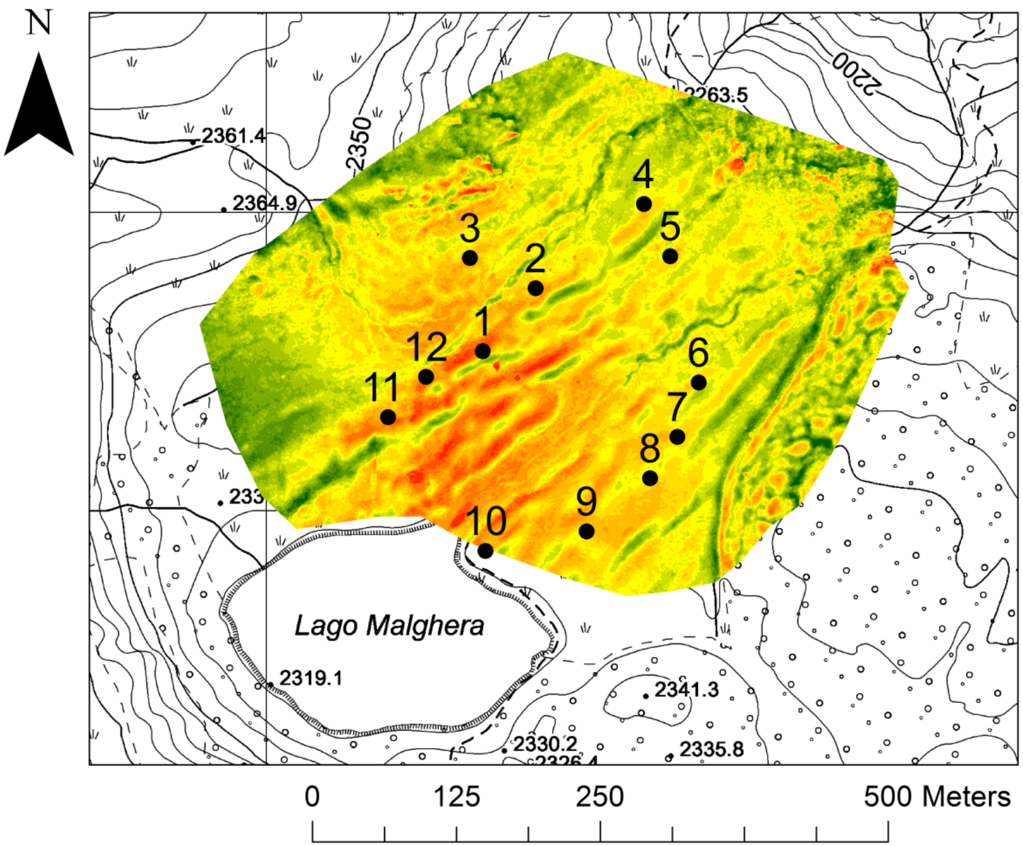
Mapping snow depth using UAS systems

Orthophoto (Spring 2014)

Location: Malghera, Lombardia, Italy



Mapping snow depth using UAS systems



Snow depth map

Legend

- Probes data

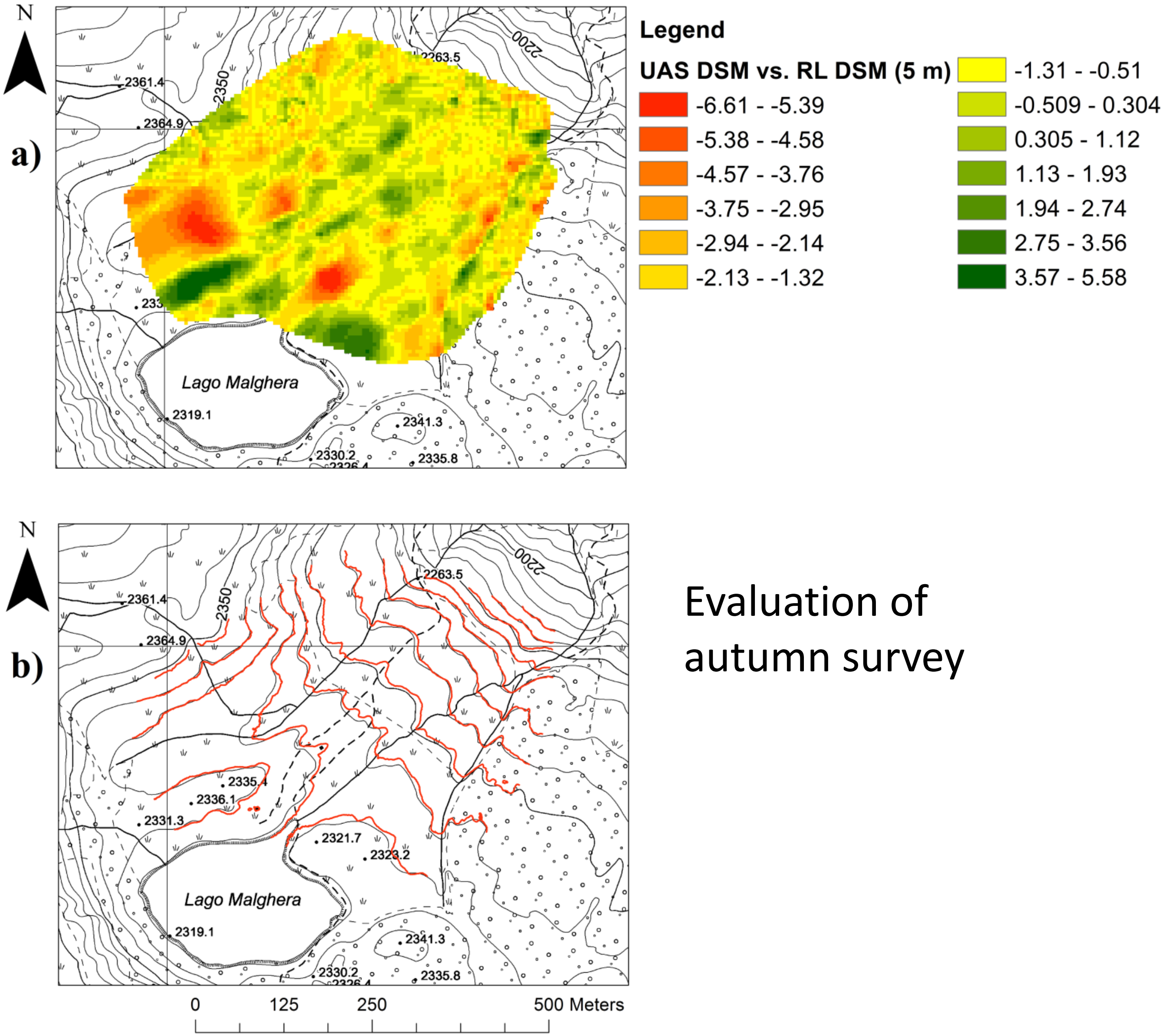
Snow Depth (m)	
0 - 1.2	2.2 - 2.3
1.3 - 1.4	2.4 - 2.5
1.5 - 1.6	2.6 - 2.7
1.7 - 1.8	2.8 - 2.9
1.9 - 2	3 - 3.1
2.1 - 2.1	3.2 - 3.3
	3.4 - 4.4

EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

Mapping snow depth using UAS systems

ID	H_M [m]	$H_{U.A.S.}$ [m]	$H_M - H_{U.A.S.}$ [m]	$H_{U.A.S.}/H_M$
1	1.48	1.40	0.08	94.6%
2	2.07	2.06	0.01	99.5%
3	1.75	1.96	-0.21	112%
4	1.88	2.05	-0.17	109%
5	1.68	1.93	-0.25	114%
6	1.85	2.13	-0.28	115%
7	1.96	2.03	-0.07	103%
8	2.11	2.17	-0.06	102%
9	1.91	1.96	-0.05	102%
10	1.89	1.81	0.08	95.7%
11	1.45	1.49	-0.04	102%
12	1.60	1.52	0.08	95.0%
Average difference [m]			-0.073	
St. dev. difference [m]			0.128	
RMSE [m]			0.143	

Mapping snow depth using UAS systems



Evaluation of autumn survey

Mapping snow depth using UAS systems

Technique	V_T (m^3)	$V_{UAS} - V_T$ (m^3)
Arith.c mean	369 146.3	94 505.9
IDW	368 216.9	95 435.3
Thiessen	363 400.5	100 251.7
Kriging	368 433.1	95 219.2


Greetings from
Dolomites !