SNOW WATER EQUIVALENT: SURVEY ON ITALIAN TERRITORY, FIRST RESULTS.

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ABSTRACT: The Italian Avalanche Service, technical body of the Italian Alpine Club, is involved in the analysis of snow water equivalent (SWE) on a national scale. This parameter represents an important indicator in terms of climate change and evaluation of water resources. SWE is a key parameter in hydrology and meteorology and refers to the amount of water contained in a snow cover. It represents the height of water that would theoretically occur if the entire snow cover melted instantly. Extracting snow water equivalent involves the process of estimating or measuring this parameter without physically melting the snow. Estimating SWE is critical to understanding water availability, especially in regions where snowmelt contributes significantly to river flow and water supply. The second major experimental campaign is coming to an end, but in the 2023-2024 season an organization has been set up on a national scale with the involvement of all its holders and making specific agreements with the Command of the Alpine Troops of the Italian Army. With this work they want to expose the first results on the estimate and validate the rapid survey methodology, developed to facilitate weekly surveying on a large geographical scale. Furthermore, with the support of an IT platform, we want to compare the data recorded in the field and the data estimated by satellite together with the snow cover monitoring data..

KEYWORDS: Snow Water Equivalent, Monitoring, Italian Avalanche Service, climate change.

1. INTRODUCTION

The Italian Avalanche Service, hereinafter SVI, has activated a campaign to survey the depth of snow and density to integrate the measures aimed at the Snow Water Equivalent, hereinafter SWE.

Snow depth, density and SWE data are useful in many applications, including water management and climate change monitoring.

The present study aims to highlight the importance of SWE monitoring and to share an expeditious way of surveying snow depth and density measurements performed by non-professional personnel.

2. AREA STUDIO

The measurement campaign in the 2023-2024 winter season was carried out throughout the Italian territory, with some trespassing also in France and Slovenia, affecting both the Alps mountain range and the Apennine mountain range (Fig. 1).

Figure 1: Measurement sites of SVI and Alpine Troops Command.

The geographical density of the survey (Tab. 1) was not very dense, but this first measurement campaign was used to test the survey methodology.

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Mountain range	Locality	Longitude (E)	Latitude (N)	Height above sea level (m)	Catchment basin	Organization
Alpi Cozie	Pic du Glabier	6,388610	45,064000	2840	Extra Italia	SVI
Alpi Cozie	SerreOrel	6,415190	45,047780	2110	Extra Italia	SVI
Alpi Cozie	Briancon	6,709385	44,828440	2300	Extra Italia	SVI
Alpi Pennine	Saint Rhemis	7,141834	45,823497	1805	Fiume Po	SVI
Appennino Tosco Emiliano	Monte Cavalmurone	9,205129	44,653850	1626	Fiume Po	SVI
Appennino Tosco Emiliano	Corno alle Scale	10,805612	44,126612	1596	Fiume Po	SVI
Appennino Tosco Emiliano	Poggio Martino	11,718610	43,879440	1473	Fiume Unti	SVI
Alpi Giulie	Dutovlje	13,812610	45,749910	300	Extra Italia	SVI
Appennino Centrale	Passo Godi	13,924607	41,845361	1558	Fiume Aterno - Pescara	SVI
Appennino Centrale	Vastogirardi	14,255985	41,778573	1179	Fiume Trigno	SVI
Appennino Centrale	Campitello Matese	14,391453	41,464395	1458	Fiume Biferno	Truppe Alpine
Alpi Carniche	Monte Florianca	13,547011	46,486362	1649	Extra Italia	Truppe Alpine
Dolomiti	Passo Padon	11,891195	46,463387	2409	Fiume Piave	Truppe Alpine
Alpi Graie	Gressan	7,288865	45,671428	2285	Fiume Po	Truppe Alpine
Dolomiti	Col de Baldi	12,068913	46,414966	1911	Fiume Piave	Truppe Alpine
Alpi Cozie	Sestriere	6,883399	44,957553	2037	Fiume Po	Truppe Alpine
Alpi Marittime	Limone Piemonte	7,552155	44,173833	1409	Fiume Po	Truppe Alpine
Alpi Cozie	Claviere	6,765894	44,937233	1938	Fiume Po	Truppe Alpine

Tab.1: Measurement sites and related geomorphological parameters.

In addition to the surveys made by the non-professional staff of the SVI, the surveys made by the Alpine Troops Command of the Italian Army were also acquired, which through a specific agreement with SVI, wanted to contribute to integrating the surveys and measurements, using the same expeditious methodology. The surveys of the Alpine Troops Command were all distributed over the Alps mountain range.

3. METHODOLOGY

The expeditious survey procedure was tested in the 2022-2023 survey campaign and tested in the 2023-2024 survey campaign through a large-scale distribution of the surveys (Fig. 2, 3).

Normally, SWE surveys are always combined with more complex snow surveys intended for evaluations of crystals, layers, resistances, etc. The goal of this experimentation is to export a quick methodology of density survey to be performed by non-professional personnel, frequenters of the mountains in fact, with few tools to carry with them. To assist the surveyor, the creation of a mobile app that facilitates the surveyor and record the data and the analyst to process the results.

Figure 2: Training of SVI staff.

Once the survey site has been fixed, free of obstacles, it will be maintained throughout the survey campaign. No itinerant surveys have been hypothesized, because the objective of the analysis is to construct a historical series. The survey is carried out in the same area every 7 days (approximately).

Figure 3: Training of SVI staff and Alpine Troops Command of the Italian Army.

Figure 4: Survey activity of SVI staff

The necessary equipment is:

- graduated probe (avalanche self-rescue kit)
- 1 dmc steel core drill
- dynamometer
- smartphone

The survey procedure involves the following steps:

- Measurement of the snowpack with the measuring probe (HS).
- recording of the total height measurement.
- construction of a hole for the density survey. The hole must not exceed the maximum height of 180 cm for operator safety reasons.
- Starting from the top, taking the snow depth data, this is divided into 20 cm blocks (example with snow depth HS=100 cm and 20cm blocks, 5 layers are obtained to be surveyed)
- Once the graduated probe has been fixed to the excavation profile, with the corer, starting from the top, 5 snow samples are taken in the center of the 5 identified layers (example HS = 100 cm, relief at 90 cm, 70 cm, 50 cm, 30 cm, 10 cm). (Fig. 5).

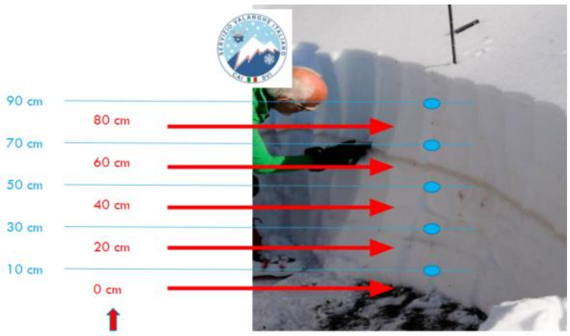

Figure 5: Survey scheme.

In the event that the height of the snowpack is not a multiple of 20 cm, the excess is added to the previous one, and the survey with the corer is carried out in the center of the block positioned higher (example with the height of the snowpack of HS = 108 cm, the survey points will be positioned at 94 cm, 70 cm, 50 cm, 30 cm, 10 cm).

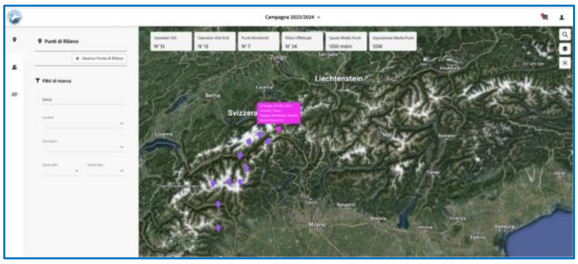

Figure 6: Web app for the management of the survey campaign and for data analysis.

The operator is supported in the survey by a mobile APP that facilitates the recording of data and indicates, once the height of the snowpack (HS) has been fixed, the altitude at which to carry out the survey to the various 20 cm blocks (Figg. 6, 7, 8).

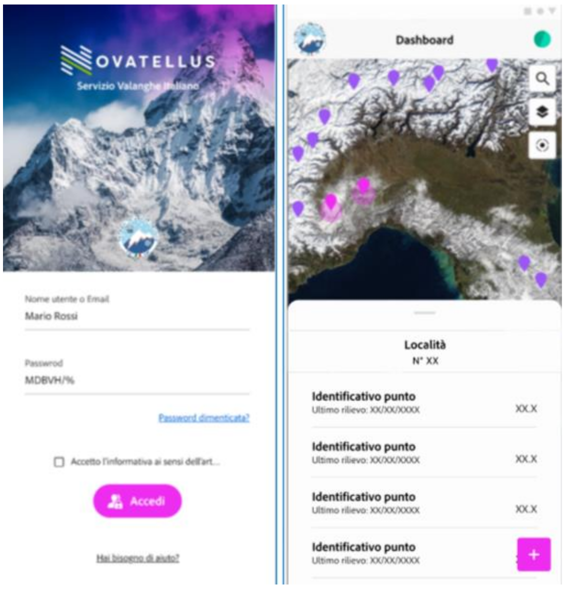

Figure 7: Some screenshots of the mobile APP to support the relevant activities.

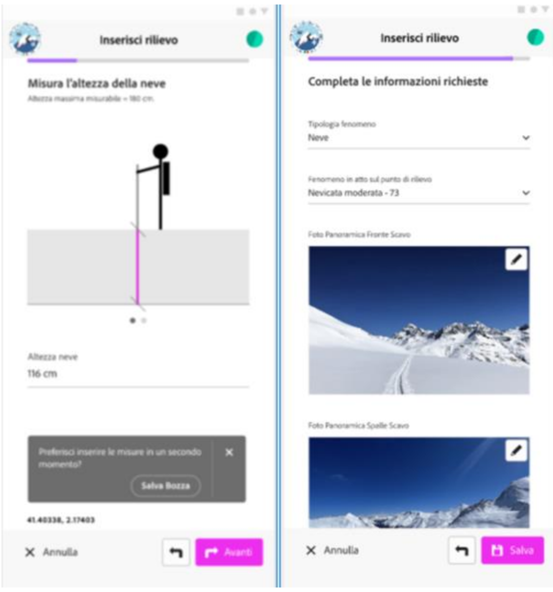

Figure 8: Some screenshots of the mobile APP to support the relevant activities.

4. RESULTS

The first Snow Water Equivalent measurement campaign of the Avalanche Service has highlighted numerous strengths and some weaknesses to be improved in the coming season.

Among the critical points, the spatial distribution of the surveys is not homogeneous throughout the Italian territory, but the SVI, aware of this criticality, wanted to test an expeditious methodology of the SWE survey in order to be able to compare it with other data from different sources, both direct (METEOMONT surveys) and indirect (satellite estimates – COPERNICUS).

From the analysis of the data collected in this first measurement season, the 2023-24 winter season was characterized by irregular snowfall in the Alps. After a winter with very little snow, especially below 1400 m., spring was very snowy and cold.

Below are the HS graphs of two relief points, one positioned in the central-eastern Alps, in the locality of Col de Baldi in the Dolomites, at an altitude of 1920 m asl (Fig. 9), the other positioned in the central Apennines, in the National Park of Abruzzo, Lazio and Molise, in the locality of Passo Godi at an altitude of 1558 m asl (Fig. 10).

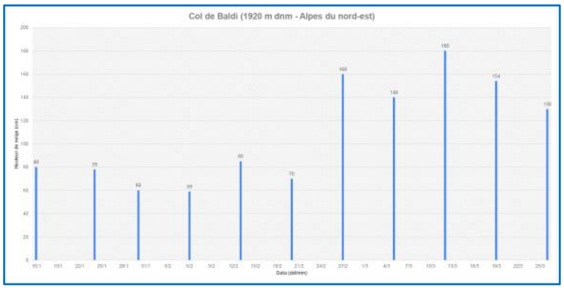

Figure 9: HS measurement at Col de Baldi (Alps).

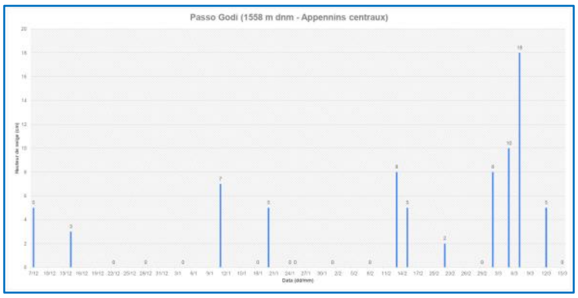

Figure 10: Measurement of HS at Passo Godi (Apennines).

An initial estimate of seasonal accumulations showed that they were on average aligned with the 1991-2020 Clino as regards the western and eastern Alps, in the central Alps by about 20%. Snowfall was extremely rare in the Apennines, especially in the northern sectors. There was no shortage of snowy days, but the average contributions for each event were always very low and limited to altitudes above 1500 m.

Through the data of the MODIS – NASA satellite it is also possible to estimate the SCA (Snow Cover Area), in this first campaign we have not focused on this spatial aspect, but from next season we will also implement with the support of the platform, the analysis of snow cover at the hydrographic basin scale (Fig. 11).

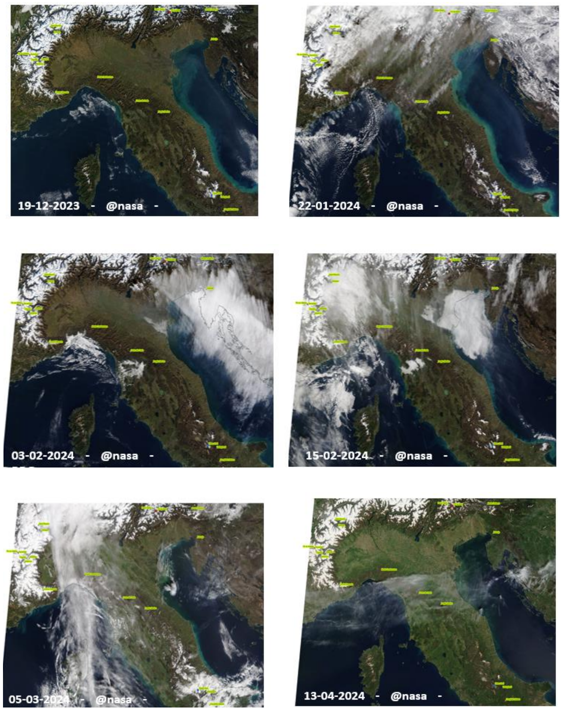

Figure 11: Sequence of satellite images (MODIS – NASA) in which the areas covered by snow are highlighted. in the first part of the winter season, northern Italy characterized by little snowfall, in the final part of the winter season and in the spring, a lot of snowfall affected northern Italy. in central-southern Italy, there was a winter with little snowfall.

The analysis of the applied methodology suggests that we are on the right path towards a rapid but effective method of surveying density and therefore snow water equivalent. As already widely stated, the analysis of snow water equivalent finds application in many sectors, having data available and collected in a database possibly spatialized at the scale of a hydrographic basin (the real limit of the methodology), has a high value from the scientific point of view and of the knowledge of the availability of water resources, especially in an era affected by the climate emergency.

5. CONCLUSIONS

In this work we have presented the first results of the first snow water equivalent survey campaign. We wanted to present the rapid survey methodology for a parameter with high scientific value such as snow water equivalent, capable of influencing any decision support system tools.

We started the activities on the methodology already in the previous winter season, that of 2022-2023, but based on the critical issues encountered we improved the methodology applied in Alpine and Apennine contexts of Italy and above all, carried out by lay personnel (not professionals in the sector). This first survey campaign has demonstrated how it is possible to acquire important useful information in numerous sectors such as Snow Water Equivalent, even through hasty surveys carried out by citizens with minimal training. The Italian Avalanche Service intends to pursue this objective by improving the information and results to make them available to the scientific community, in a niche area, but of very high scientific value, also through modern support technologies such as the web and mobile app for managing survey campaigns. Knowing the amount of water available and potentially usable during periods when overall signs of reduced rainfall are evident is essential.

ACKNOWLEDGEMENT

We thank the Italian Army - Troops Command Alpine - Meteomont, ARPA Valle d'Aosta for the technical comparison and the related methodology, finally ARPES srl for the technical support for the creation of the APP.

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