COSMIC-RAYS NEUTRON SENSING AS A NOVEL APPROACH TO MEASURE SNOW WATER EQUIVALENT, KEY TO HYDROELECTRIC POWER

E. Gazzola[1], L. Stevanato[1], M. Lunardon[1,2], L. Morselli[1], B. Biasuzzi[1], A. Belleville[3], P. Carrier[3], J. Lebrun[3], M. Valt[4]
[1] *Finapp srl, Via del Commercio 27, 35036 Montegrotto Terme, Padua, Italy*
[2] *Department of Physics and Astronomy, University of Padova, Via Marzolo 8, 35131 Padova, Italy*
[3] *Électricité de France (EDF-DTG), Chemin de l'Etang 134, 38950 Saint Martin le Vinoux, France*
[4] *Regional Environmental Protection Agency – Veneto (ARPAV), Via Pradat 5, 32020 Livinallongo del Col di Lana (BL), Italy*

INTRODUCTION

Hydroelectric power is significantly affected by the natural variability of available water. Snow, being the main storage of water over the mountains, represents a key variable to manage hydroelectric power plants. To improve efficiency of renewable power production it is therefore critical to achieve accurate estimations of the water content within the snowpack, i.e. the Snow Water Equivalent (SWE), in relevant areas. Cosmic Ray Neutron Sensing (CRNS) is an emergent technology which allows to provide a direct evaluation of SWE over large areas in continuous operation regime, overcoming the challenges related to the complex layering and high temporal and spatial variability of the snowpack. We developed a new generation of compact, autonomous CNRS probes and report the results of our tests on two experimental sites.

"On-air" probe for Areal SWE measurements

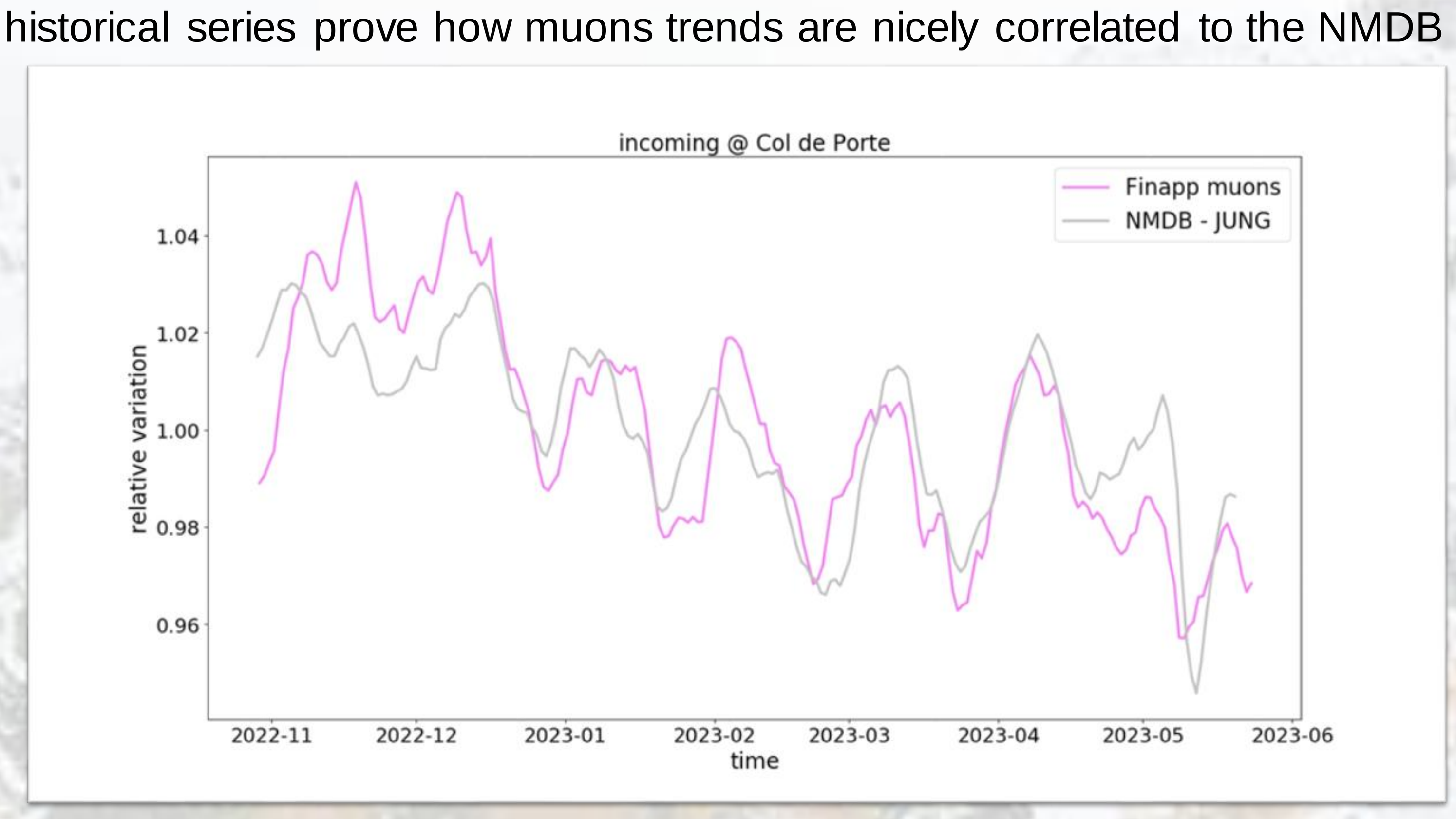
FINAPP COSMIC-RAYS NEUTRON SENSING (CNRS) TECHNOLOGY

Finapp measures water using cosmic rays. Neutrons coming from space interact with soil and snow and are finally detected by our probe. Since neutrons mainly interact with hydrogen, they carry information about the amount of water (soil moisture) or SWE present within the detector footprint. A Finapp probe can work remotely and autonomously in continuous and real-time operation. It can be placed under snow (on-ground configuration) or mounted up above ("on air" configuration) thus obtaining different performances in terms of footprint (up to twenty hectares with an on-air probe) and saturation level (up to 2000 mm SWE with the on-ground probe).

"On-ground" probe for Local SWE measurements

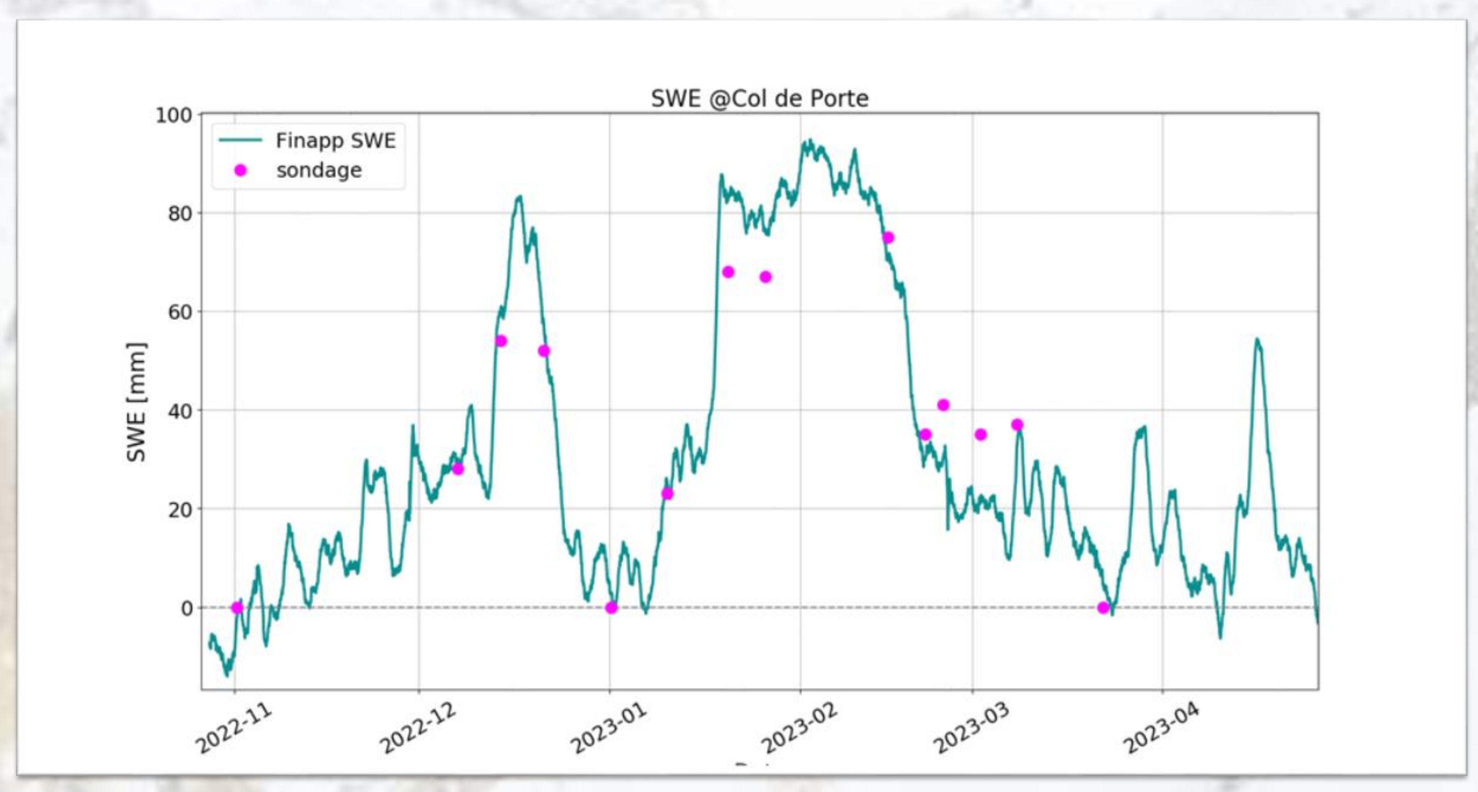
INNOVATIVE ABILITY OF MONITORING INCOMING FLUX

CRNS systems do not use artificial sources of radiation: neutrons originated by cosmic rays in the atmosphere are used instead. For this reason, the natural variability of the incoming flux needs to be monitored and compensated for. The established way to do that is referring to a network of reference stations scattered around the world: the Neutron Monitor Database (NMDB). Finapp includes a patented innovative, alternative solution. Its unique ability of contextually detect muons, another species of particles generated by cosmic rays, allows an autonomous, site-specific and real-time monitoring of the incoming flux. Our historical series prove how muons trends are nicely correlated to the NMDB trends:



LOCAL SWE MEASUREMENT IN FRENCH ALPS

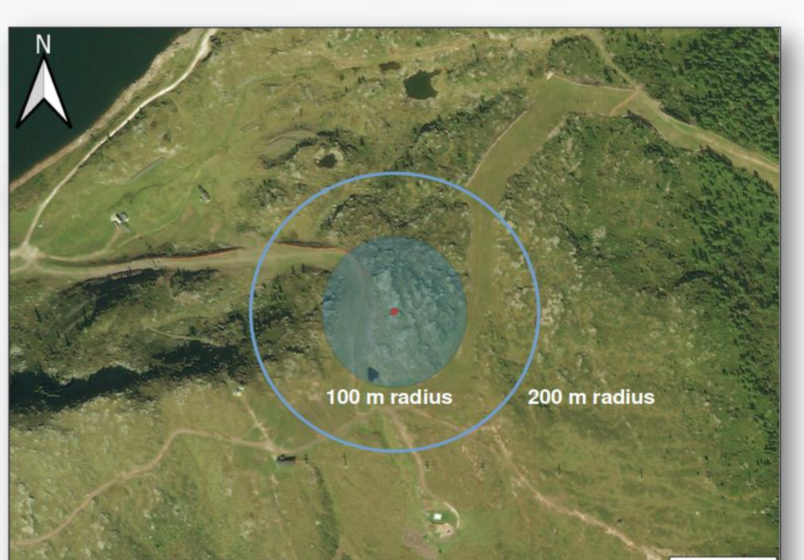
Local SWE is the evaluation obtained by the on-ground Finapp probe. SWE is calculated with a custom formula correlating the variation of neutrons counts with respect to the reference value collected before the first snowfalls. It embeds a footprint radius up to 25 m and a saturation level of 2000 mm SWE. In order to monitor the incoming flux by measuring muons unperturbed by the snow, a separate muon detector is mounted on a pole above. A configuration of this kind is installed in collaboration with EDF at the Col de Porte site (Grenoble). The resulting trend is compared to data points obtained by in-situ manual sampling (coring) operated by Meteo-France, showing a good correlation with differences that can be attributed to the effect of the footprint.

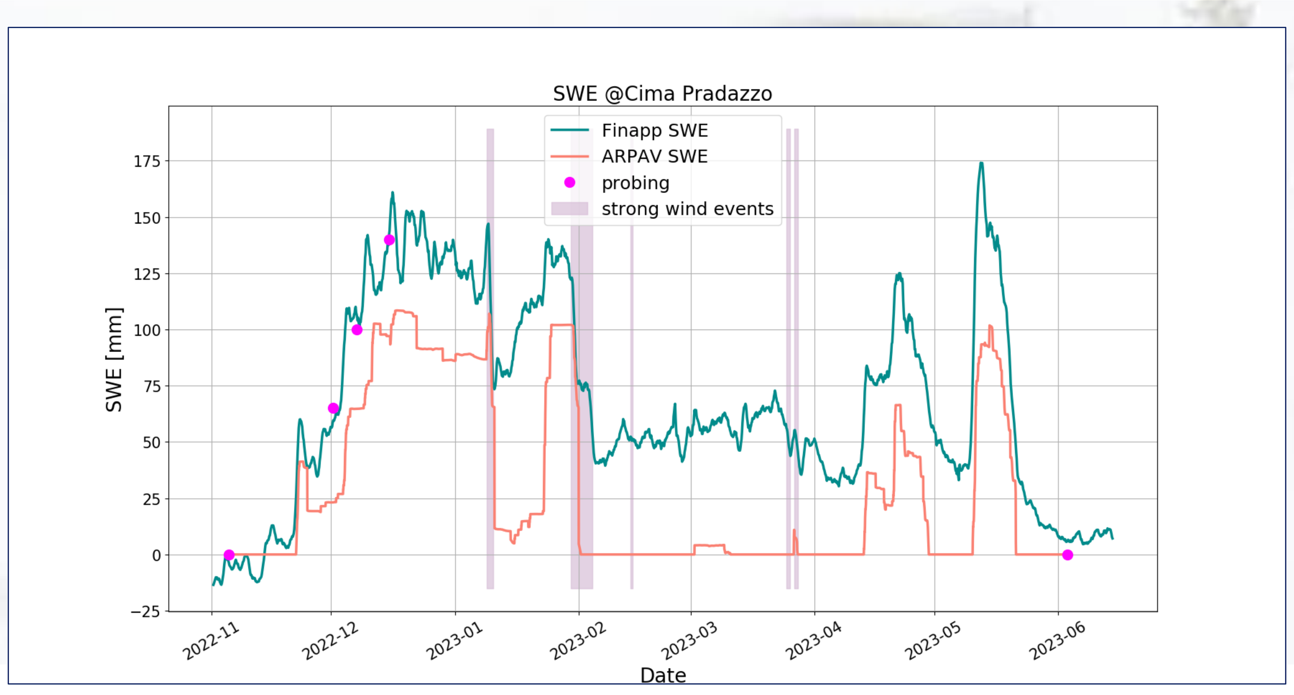


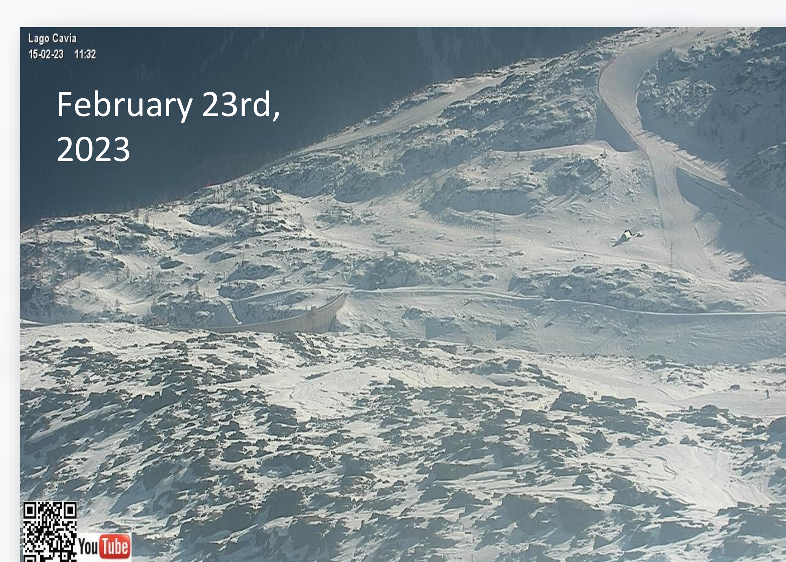
AREAL SWE MEASUREMENT IN ITALIAN ALPS

Our probe at the ARPAV-managed site of Cima Pradazzo, nearby Passo Valles (the Dolomites), is mounted in the on-air configuration and can therefore provide, through the application of a different custom formula, Areal SWE measurements. It offers a large footprint (up to 250 m radius) amid a lower saturation limit (500 mm SWE). It simultaneously measures neutrons and muons and it's therefore self-referenced for incoming correction.

The trend is compared to local observations of the snow layer (pink dots) and to the SWE evaluation provided by the automatic ARPAV nivometer. Strong wind events are also marked because the site is frequently wind-swept with removal of snow mass that is moved away. In February the local nivometer could not detect any snow because the top of the site was completely swept; however, as testified by nearby webcams, there was plenty of snow along the slopes and in fact Finapp was still able to detect it: this is the footprint effect.







CONCLUSIONS AND PERSPECTIVES

Measuring the amount of snow on mountain basins is a challenging task but crucial to improve the prediction and management of resources. Finapp CRNS probes in different configurations offer the capability of measuring SWE representative of large areas of tens to hundreds meters radius, while operating continuously, autonomously and real-time even in remote areas. Our results show the advantages of this technology when compared to point-scale measurements in site with complex morphology.

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