LES ORRES 10-11 May 2021

Smart Mountain for tomorrow

WATER MANAGEMENT FOR SNOW PRODUCTION - LAKE MONTAGNOLI (MADONNA DI CAMPIGLIO)

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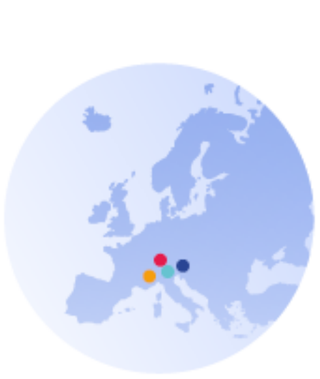
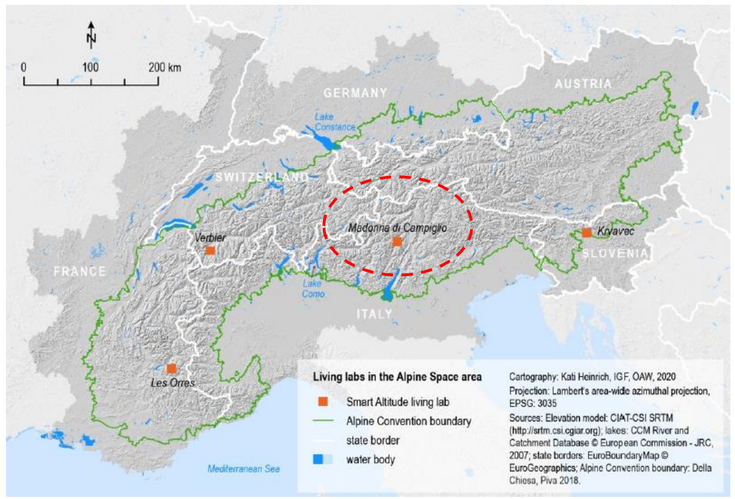
D.Viesi (Fondazione Bruno Kessler) - viesi@fbk.eu

SMART ALTITUDE – LIVING LABS



Living Labs

for testing
clean energy
innovation
in mountain
tourism
territories



Living Lab
Les Orres | France
SMART MOUNTAIN GRID
LES ORRES

Living Lab
Madonna di Campiglio | Italy
INTEGRATED ENERGY MANAGEMENT SYSTEM
SKIAREA MADONNA DI CAMPIGLIO

Living Lab
Krvavec | Slovenia
ENERGY SAVINGS
krvavec

Living Lab
Verbier | Switzerland
"CITÉ DE L'ÉNERGIE" GOLD LABEL
VERBIER

LIVING LAB MADONNA DI CAMPIGLIO

Skiarea

108 Slopes

156 km of slopes

59 Lifts

4 Snowparks

LIFTS & SLOPES | SKI MAP

MADONNA DI CAMPIGLIO

Ski slopes: 60 km
Altitudinal range: 1513-2501

Ski lifts: 35533 passengers/h
Technical snow: 1.1 Mm^3/year
Snow groomers: 20

Skier-days: 1.2 M/year
Winter turnover: 25 M€

Winter energy consumption: 15.1 GWh
Winter electricity consumption: 10.5 GWh

Winter energy cost: 2.1 M€
Winter electricity cost: 1.8 M€

LIVING LAB MADONNA DI CAMPIGLIO

OUR MISSION ZERO EMISSION

MONITORING LAGO MONTAGNOLI

WHAT IS IT?

- A set of **hi-tech sensors** installed in the artificial lake that feeds the snow production system.

WHAT DOES IT DO?

- **Data gathering** on water temperature at different depths, water surface and weather conditions.

WHY?

- **Optimize** the artificial snow production process through **energy** and **water savings** and **heat recovery.**

TRENTINOSVILUPPO
IMPRESA INNOVAZIONE MARKETING TERRITORIALE

TESTING AN INTEGRATED ENERGY MANAGEMENT SYSTEM

MONITORS WARNS FORESEES

www.ski.it/en/zeroemission2026

Electric grid
Energy consumption from the medium voltage grid

Snow production
Water, compressed air and energy consumption

Lake monitoring
Water temperatures and water surface

Snow grooming
Operational data, diesel consumption and snow-depth

Meteo
Meteorological conditions and weather forecasts

Ski lifts
Energy usage, n° of entrances, photovoltaic integration

Skiers data
Analysis of skier days

OUR MISSION ZERO EMISSION

INTEGRATED ENERGY MANAGEMENT SYSTEM FOR THE SKI RESORT MADONNA DI CAMPIGLIO

WHAT IS IT?

- **A digital platform** for the mountain environment and ski infrastructures.

WHAT DOES IT DO?

- **It monitors** plants' operations and the consumption of energy and water.
  Generate report, send notifications, make forecasts.

WHY?

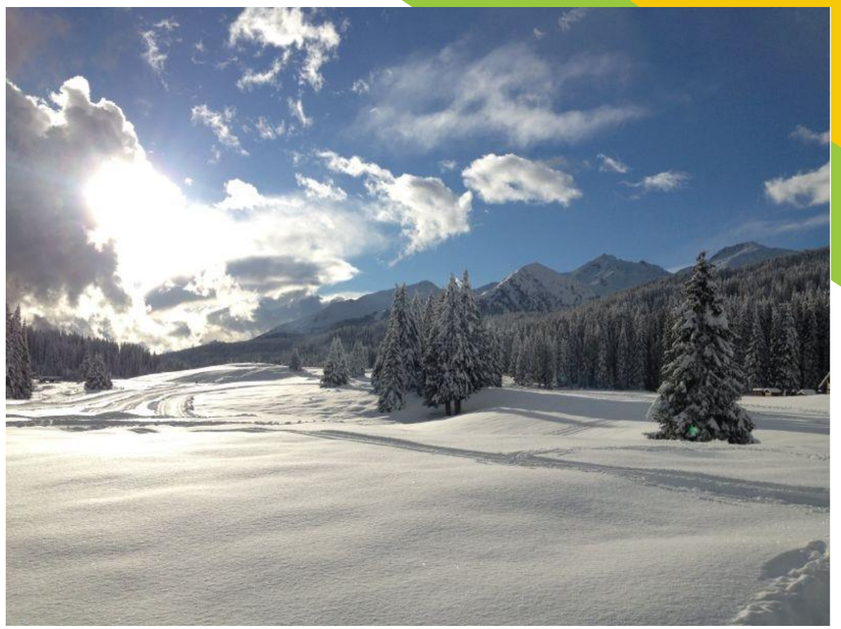
- **To have an integrated decision support system** for eco-sustainable choices.

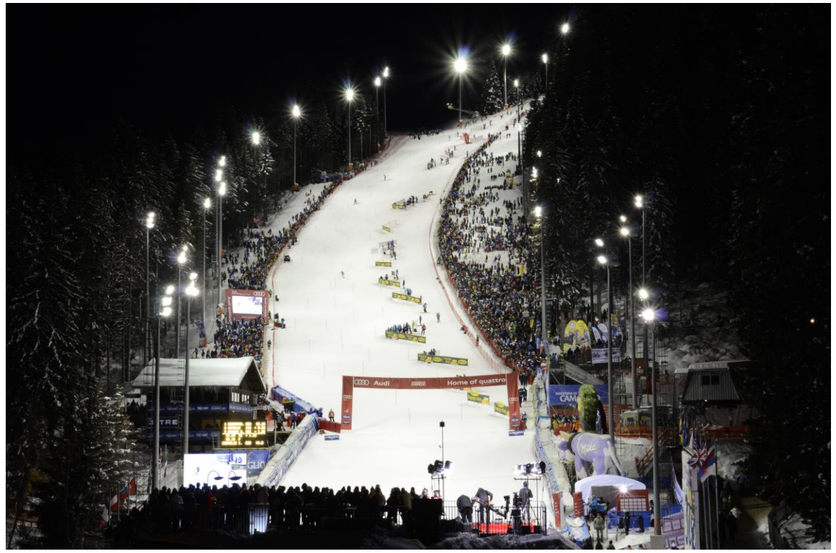
FONDAZIONE BRUNO KESSLER
FUTURE BUILT ON KNOWLEDGE

SNOWMAKING AND BASIN MANAGEMENT

- The **artificial snow production** is an essential solution for the management of modern ski areas.
- It is now a consolidated practice to form **a first layer of artificial snow on the slopes, at the beginning of the winter season**, to create an optimal base for receiving subsequent natural or artificial snow.
- The snow production is a complex discipline that requires **proper technology and an in-depth knowledge of the environment** (altitude, slope exposure, local weather, water characteristics
- The "sine qua non" condition is the lowering of environmental temperature. **Sometimes, at the beginning of the winter season, this condition occur for a limited period of time**, which entails the need to maximize the amount of snow produced in a short time.
- **Water basins represent the solution**: water storage necessary to ensure important water flows that the local environment is unable to produce.

- The **optimal conditions for snow production** occur when the air temperature drops below -4°C, the air humidity is below 80% and the process water temperature is at 2°C.
- The optimization of the process is possible by **acting on the temperature of the process water**.
- This aspect is influenced by the **initial environmental temperature** (river, lake or underground water), the ways in which the resource is conveyed by **the adduction system** (by gravity or by pumping), **the methods of storage** (climatic conditions and management).
- At the end of this process, if the liquid temperature is not optimal, **cooling systems are located before final use**, with the related energy expenditure.
- **The water storage in the basins represents a critical phase for the heat exchange with the environment.**
- Basin temperatures are **regulated by** the **climatic trend** (temperature, wind, irradiation), the **water change both in the supply and use phase**, the **plano-altimetric location of the entry/derivation point**, the **use of the boulage**.



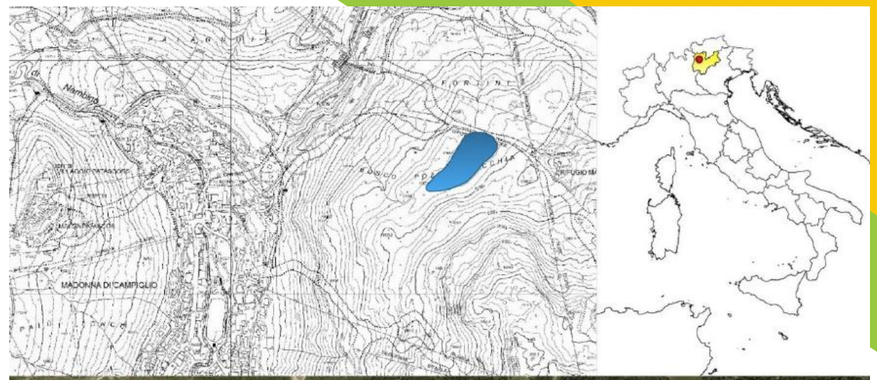


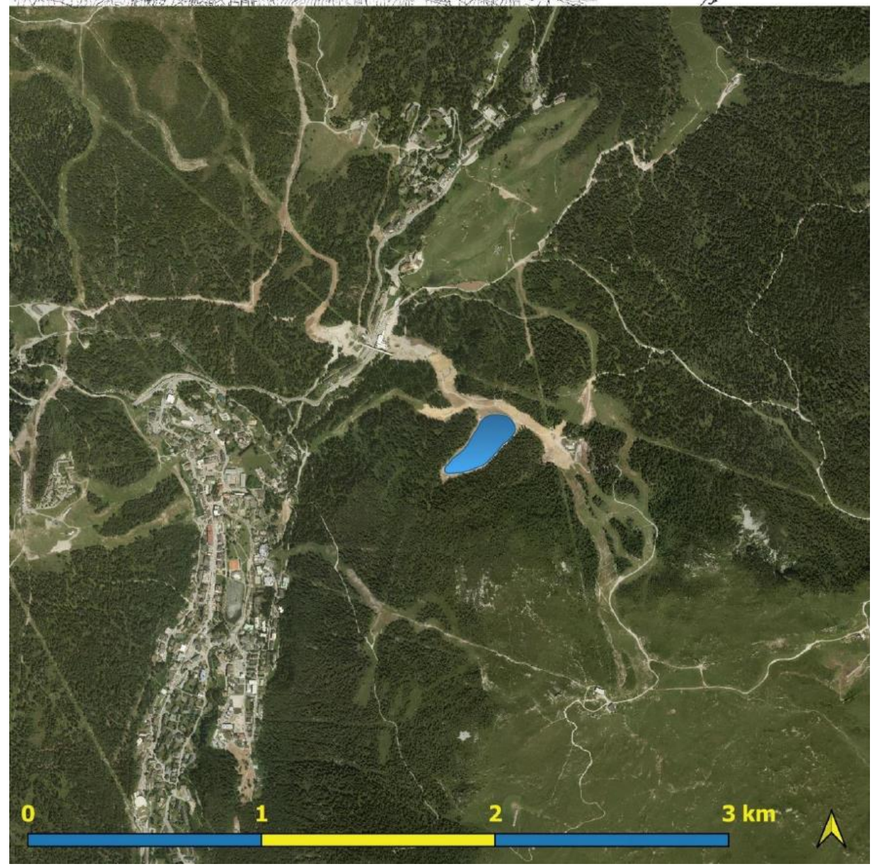
LAKE MONTAGNOLI

Artificial lake

Investment 10 Meuro

Inaugurated in 2015





LAKE MONTAGNOLI is **an artificial water basin to support snow production** in the Madonna di Campiglio ski area (Province of Trento - Italy).

Capacity **199,249 m³**

Maximum height overflow **1775.4 m.a.s.l.**

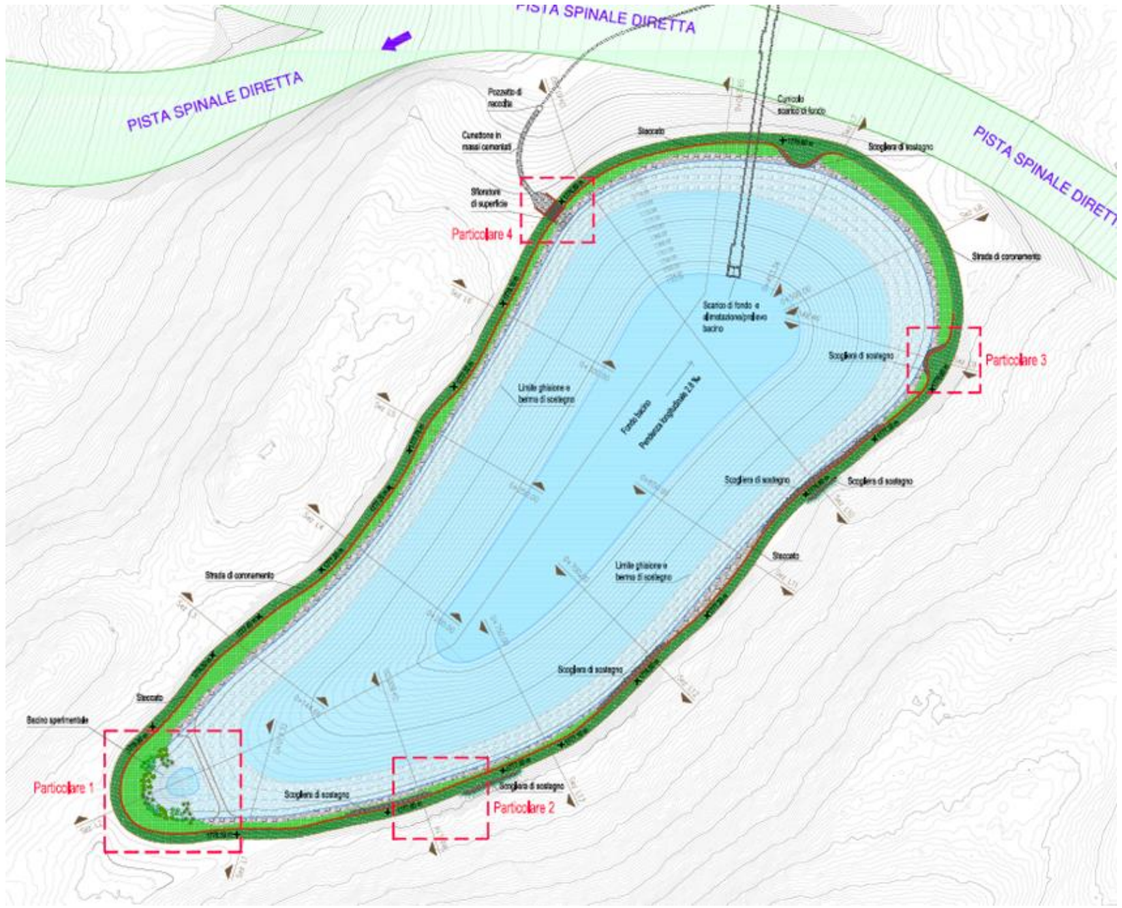
Maximum depth **11.7 m**

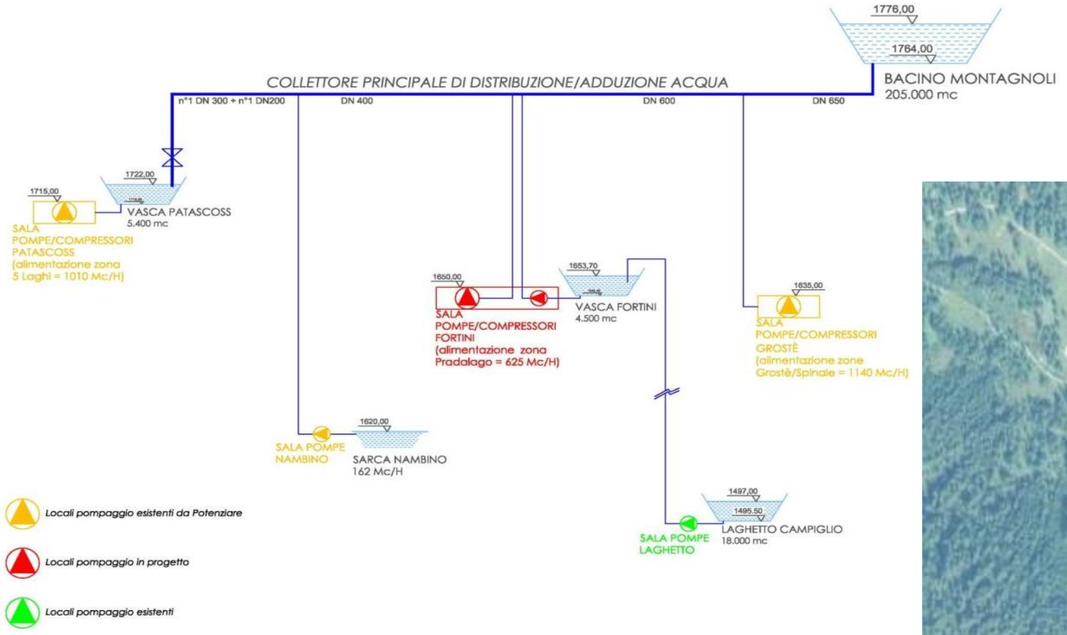
It has an elongated shape in a north-east-southwest direction

The section consists of a bottom with a slight longitudinal slope (0.28%), internal banks with slopes of 35% that reach the crown with a lower slope protected by scree.

The filling / emptying flow takes place from a single entry / emission point located at the foot of the north bank on the bottom of the water body.

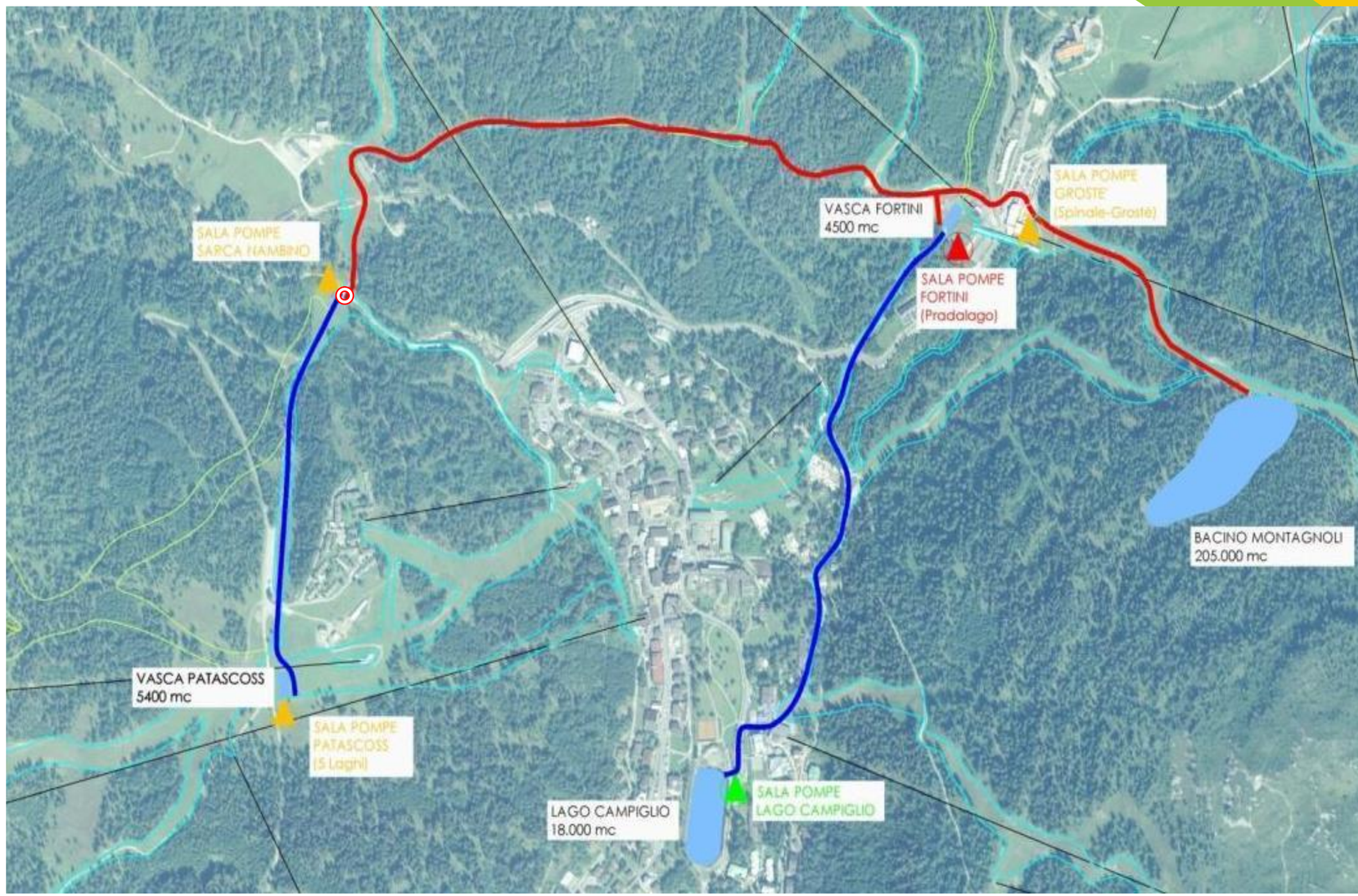
The lake is equipped with a boulage for mixing the water





- The adduction is ensured by pumping from the river Sarca di Nambino (altitude 1647 m asl), from the storage of Fortini (altitude 1654 m asl), from Lake Campiglio (1498 m asl).
- The system is able to **adduce a flow rate equal to 297 l/s** and is able of **delivering 858 l/s to the slopes**.

Time to snow the entire ski area is **80-100 hours**

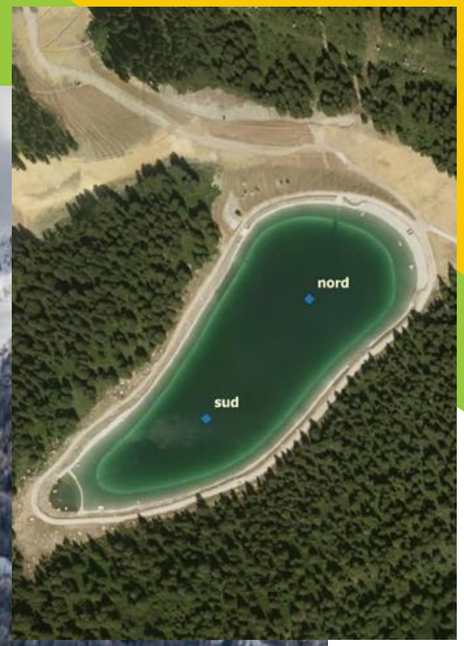


The **use of the lake** consists of:

- filling from August-September after emptying for maintenance;
- a first use of the water when the external temperatures are suitable for the production of artificial snow (October-November);
- subsequent filling and emptying during the winter season according to the snowmaking needs.

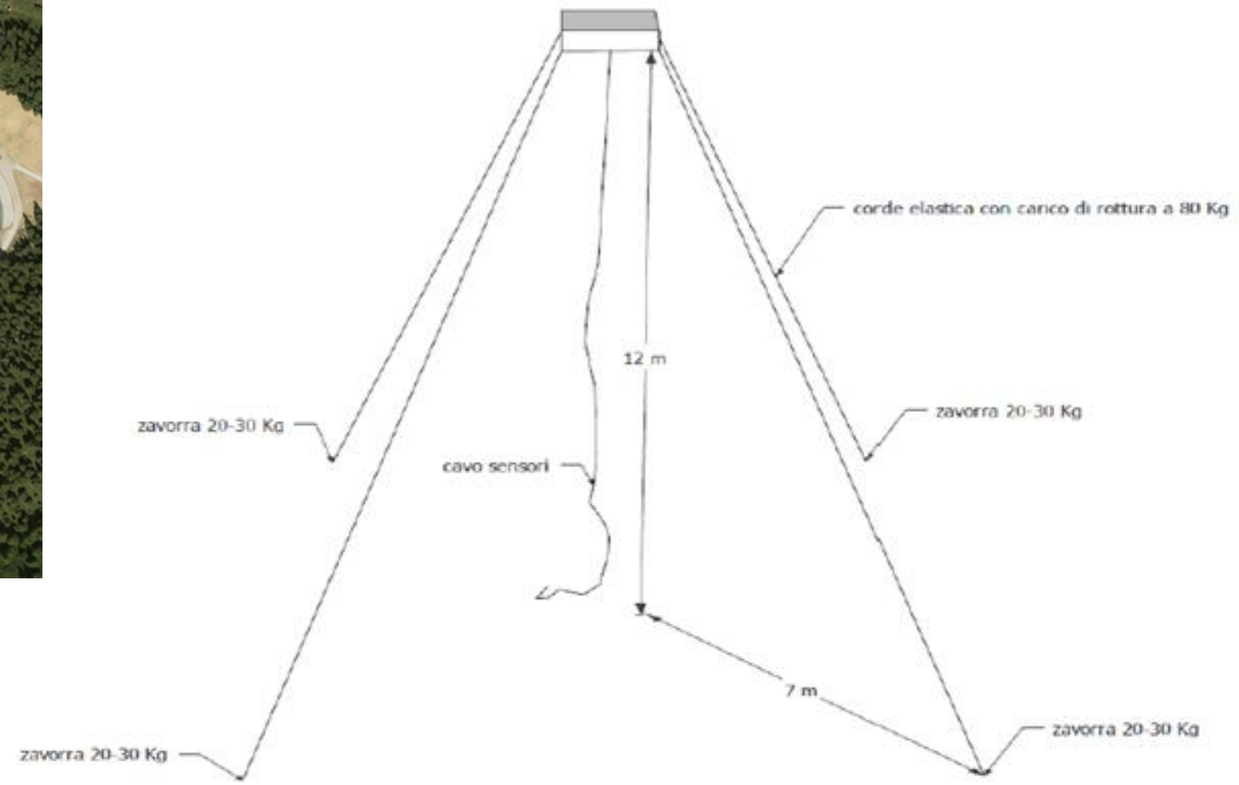
Depending on the seasonal trend, it may happen that the late-summer filling generates water temperatures incompatible with the efficiency of the first snow production. The Smart Altitude monitoring is aimed at knowing the lake thermal trend over time to understand this phenomenon.

THE SMART ALTITUDE MONITORING SYSTEM



The monitoring was carried out by setting up **two buoys** capable of **detecting weather data, water levels** and **water temperatures from the bottom to the surface**

Each buoy is equipped with **4 weights** for its fixing**, a cable for the thermal sensors, a monitoring station and photovoltaic power supply**

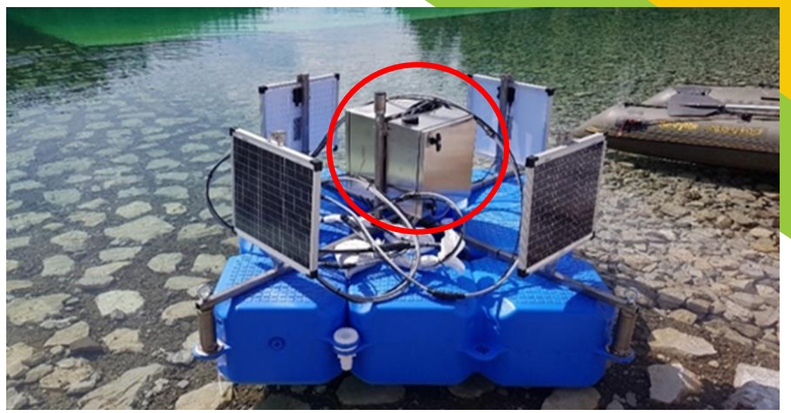


ing. **Giorgio Marcazzan**
(freelance)

Corr-Tek Idrometria Srl

Characteristics of the monitoring stations

Support	Floating platform in polyethylene 150x150 capacity 350 kg/m^2
Data logger	OTT netDL500 data logger with integrated modem, photovoltaic power supply panel, IP66 stainless steel house
Thermistors	Watertight thermometric chain with PT100 4 wires thermistors every meter
Level sensor	OTT PLS ceramic level sensor
Weather station	Weather station composed of compact WS501 weather sensor, WS100 precipitation sensor, temperature sensor



Each buoy is equipped with a thermometric chain, one of the two is also equipped with a weather station and a level sensor.

THE SMART ALTITUDE MONITORING CAMPAIGN

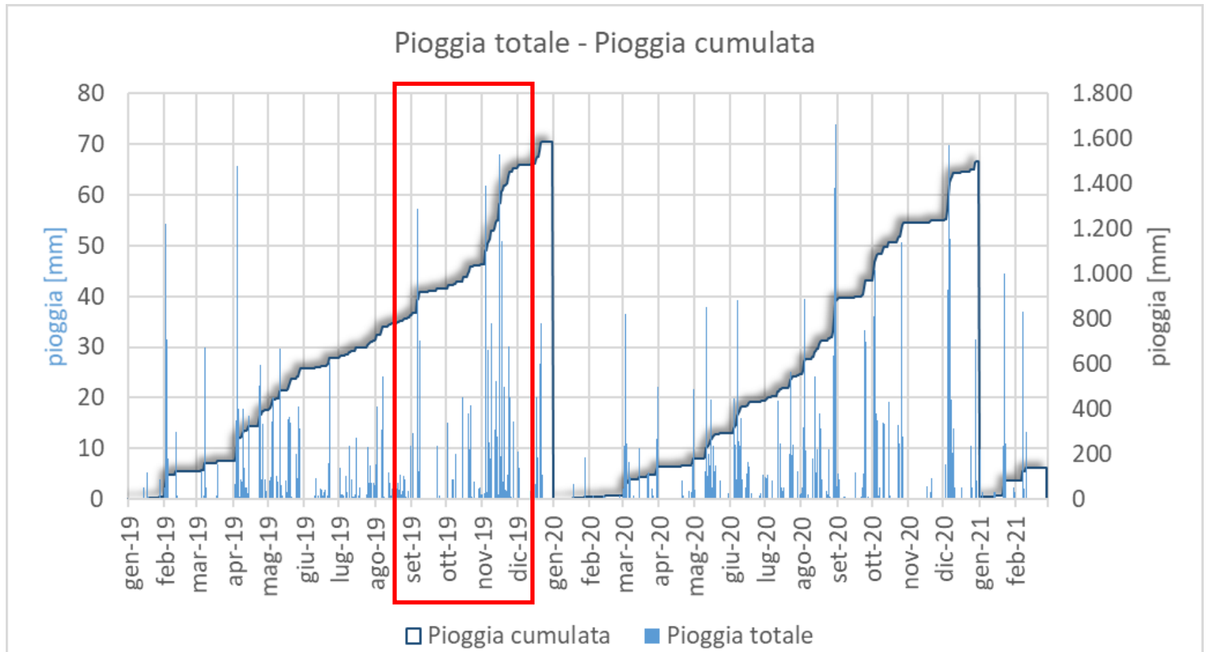
The first monitoring campaign started on 26/9/2019 and ended on 26/11/2019 (autumn period up to the first snow cover)

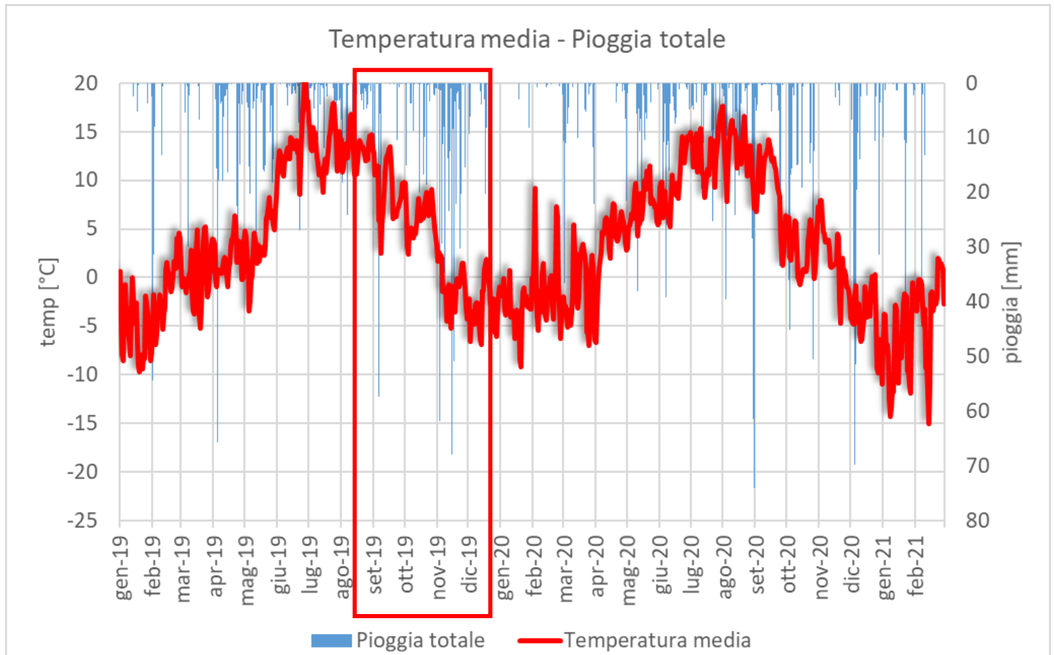
Were collected: (I) **data from the new lake monitoring system (2 buoys)**; (II) **data from the snowvisual (TechnoAlpin Liberty)** used for the management of the ski area

Acquisition frequency is **10 minutes**

The **climatic trend during the first monitoring campaign** was characterized by:

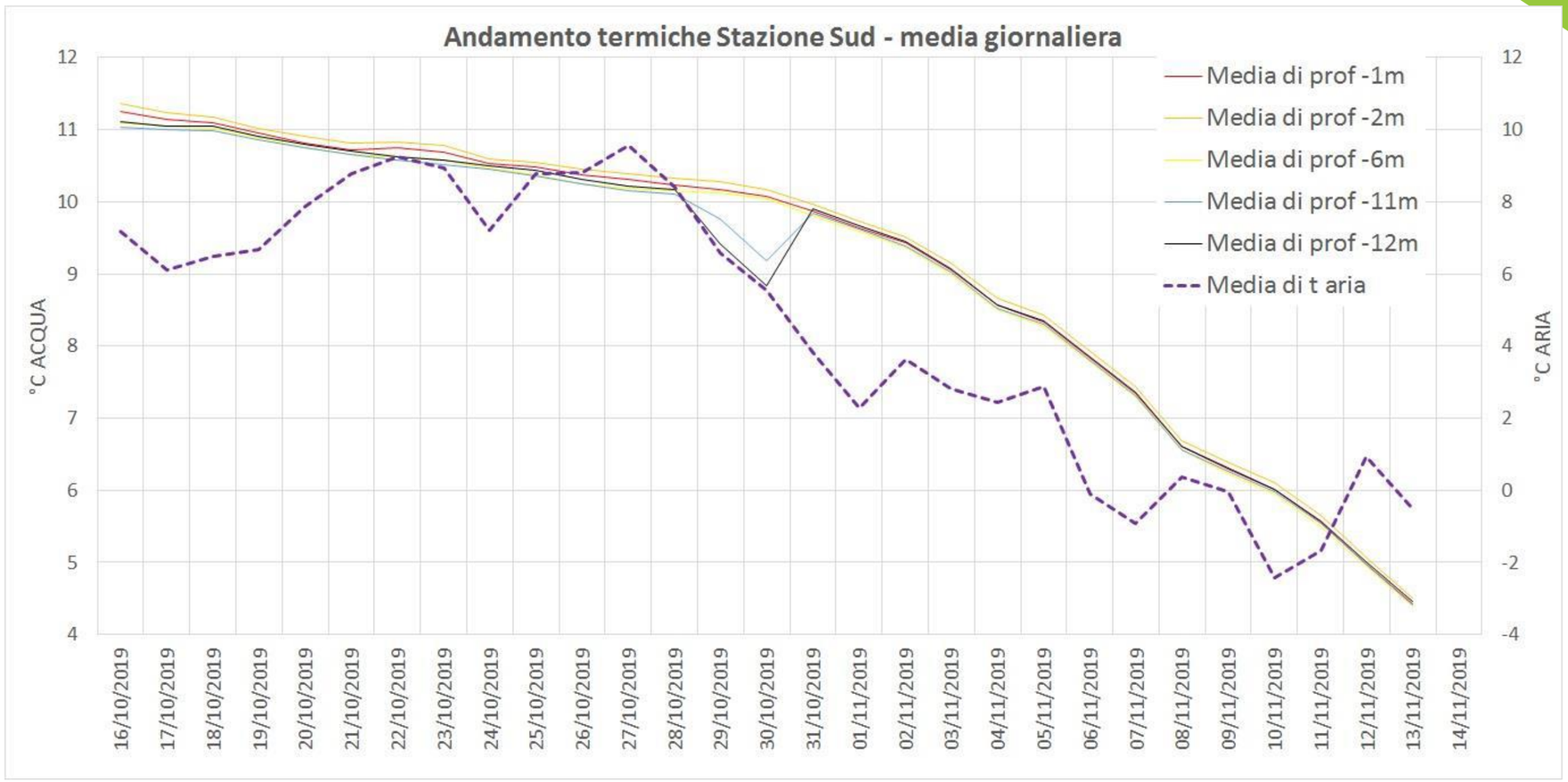
- September and October (particularly in its second half) warmer than average, precipitations in line with the average
- November exceptionally rainy/snowy (426 mm)





The **reading of the lake data must be accompanied by the interpretation of the mutation of the boundary conditions** influencing the temperatures trend. In particular:

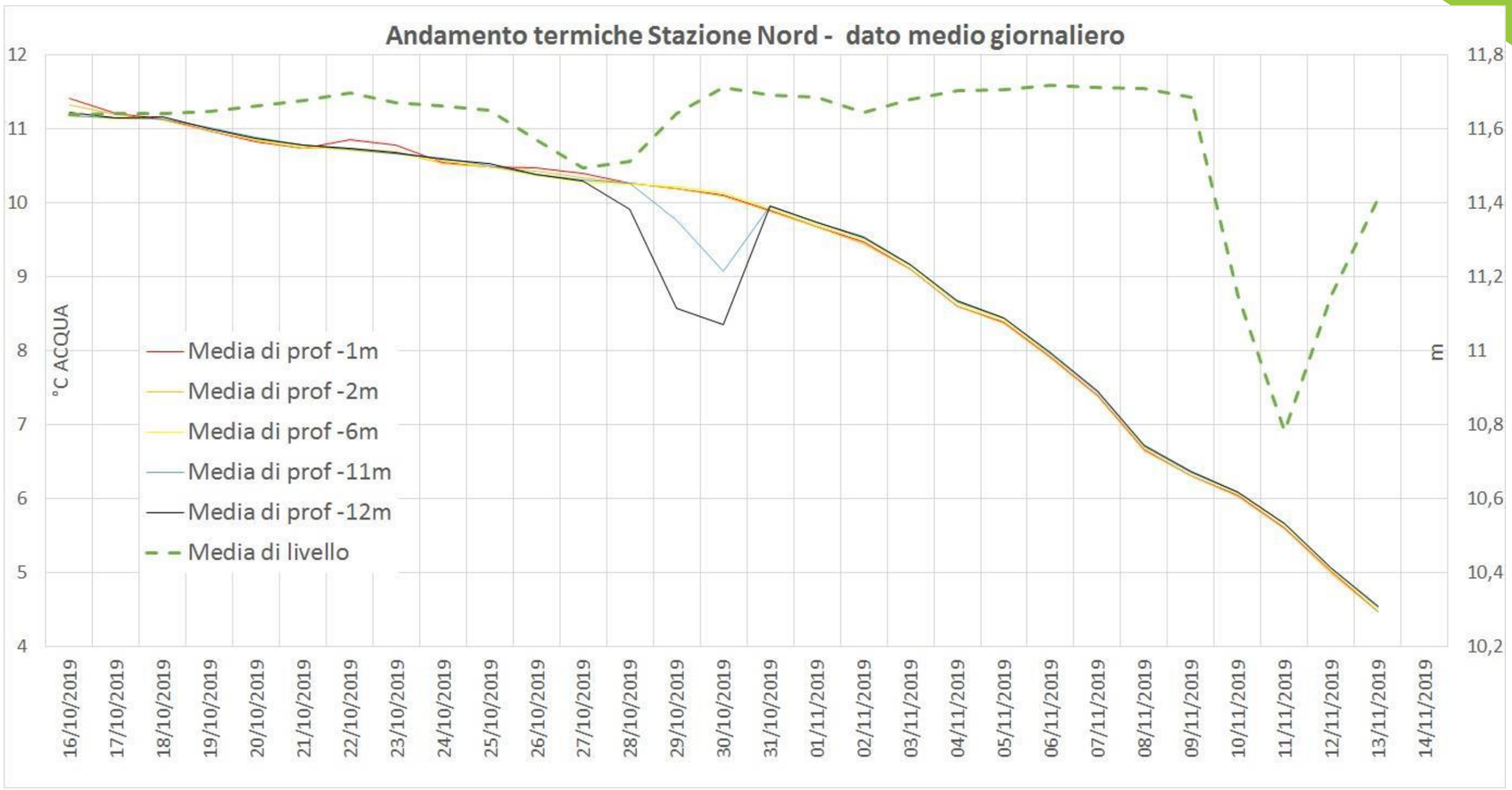
- **Atmospheric temperature:** The weather trend affects the temperature of the lake waters by means of the heat exchange with the surface. The water body, with a certain inertia, adjusts to external temperatures. The efficiency of the exchange is conditioned by ventilation and the presence of surface ice
- **Irradiation:** Exposure to solar radiation is able to affect the temperatures of the most superficial layers
- **Use of water:** The water withdrawal represents a condition capable of altering the lake thermals and the thermal balance
- **Water introduction:** In a similar way to use, the filling of the lake influences the distribution of temperatures. The water introduced will also tend to occupy the thermal layer of competence in relation to its density
- **The boulage:** The effect of the boulage is to cause the mixing of the water by interrupting any thermal stratification of the water body



The **south station** is **equipped with an air thermometric sensor**.

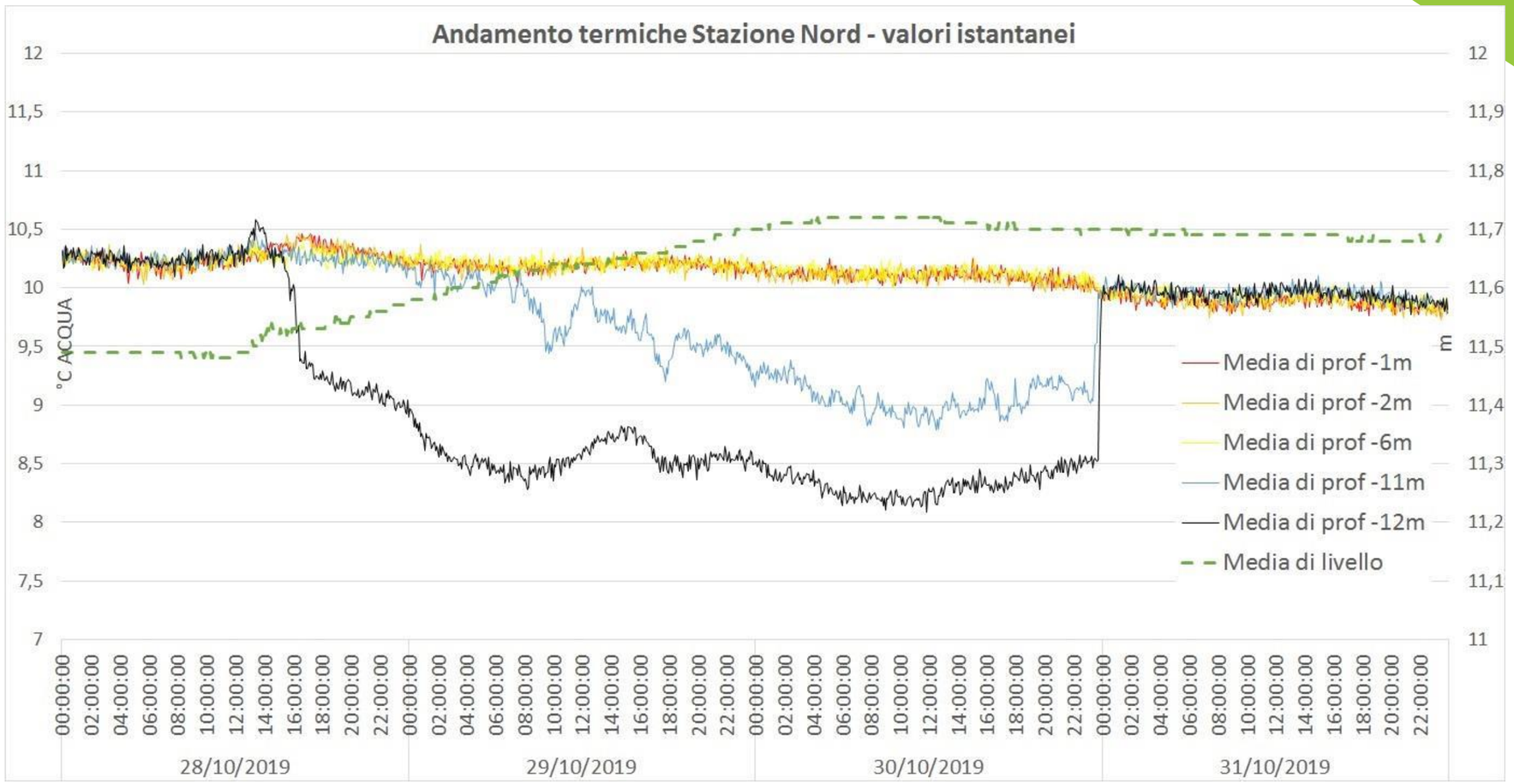
The average daily data show the **influence of the external atmospheric temperature** on the water body.

The lake has **no stratification**, **the activation of the boulage causes the continuous mixing of the waters**. An exception is the period at the **end of October** where **a stratified period linked to the introduction of colder water** is evident.



The graph relating to **the north station compares the water thermals with the level trend**.

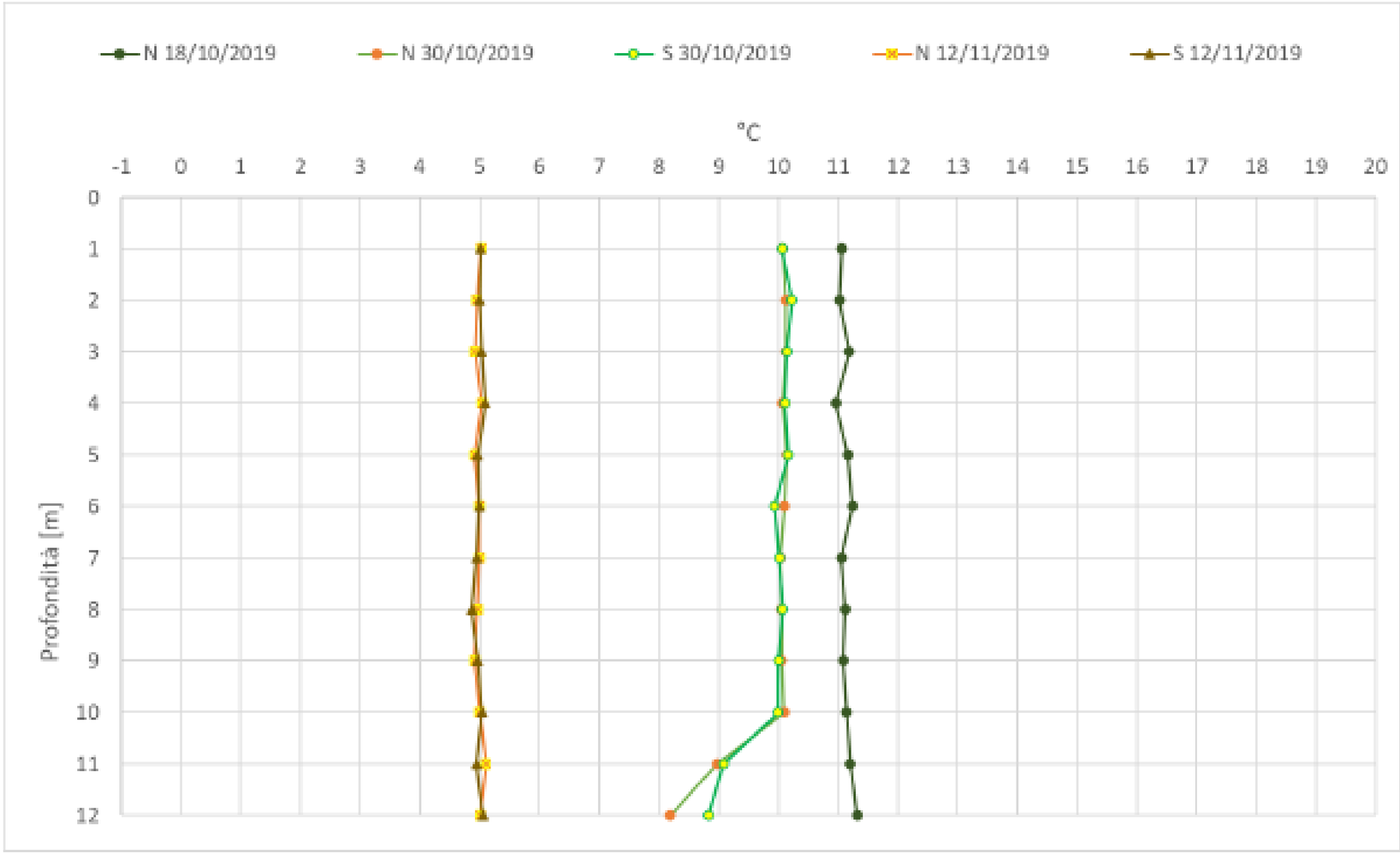
At the **end of October**, the **effect of the introduction of water at lower temperatures** than those of the lake was highlighted.



This graph shows in detail the four days in which the lake was fed with colder waters than those contained.

The sudden alteration of the thermals is evident with the lowering of the temperature of the layers -11 and -12 m. The subsequent activation of the boulage causes the instant mixing of the water.

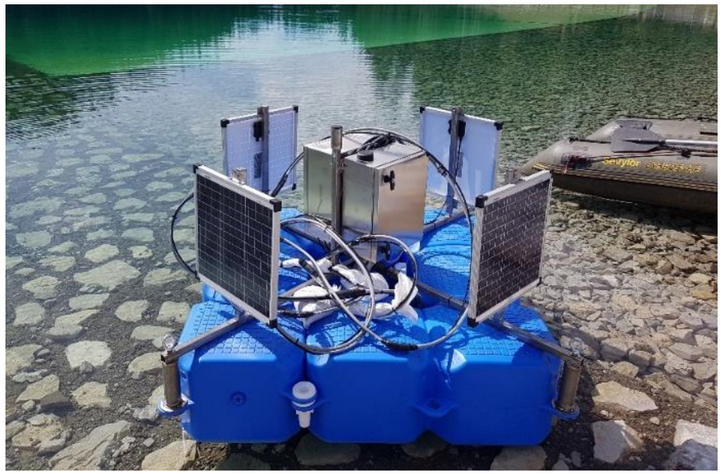
Vertical thermal profiles 2019

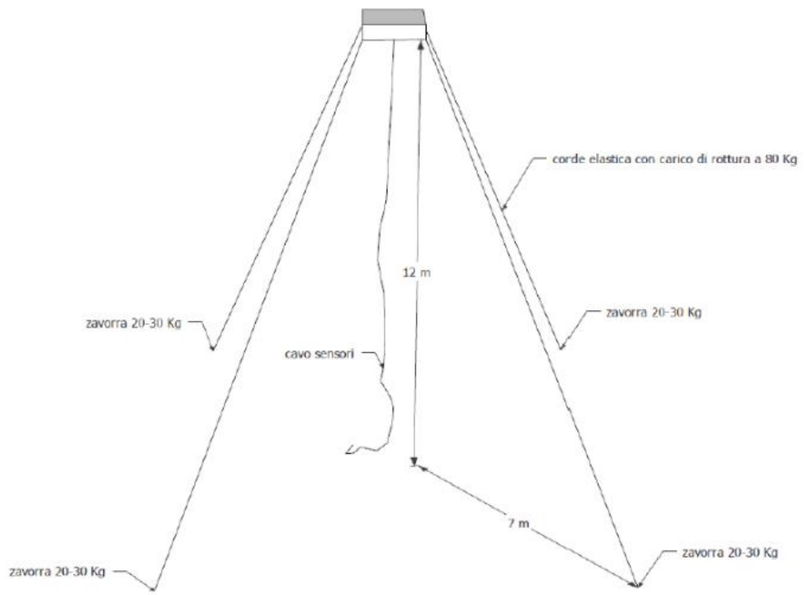


The **second monitoring campaign** took place in the period **September 2020 - February 2021** with the aim of:

- **integrate the data from the start of the autumn season** as they have shown a great influence on the behavior of the set model
- **analyze the phenomena that are triggered on the thermals immediately before and after the boulage**

The second monitoring campaign envisaged the **reinstallation of the thermometric chain in the deepest area of the lake (north area)**.




corde elastica con carico di rottura a 80 Kg
12 m
zavorra 20-30 Kg
zavorra 20-30 Kg
cavo sensori
7 m
zavorra 20-30 Kg
zavorra 20-30 Kg

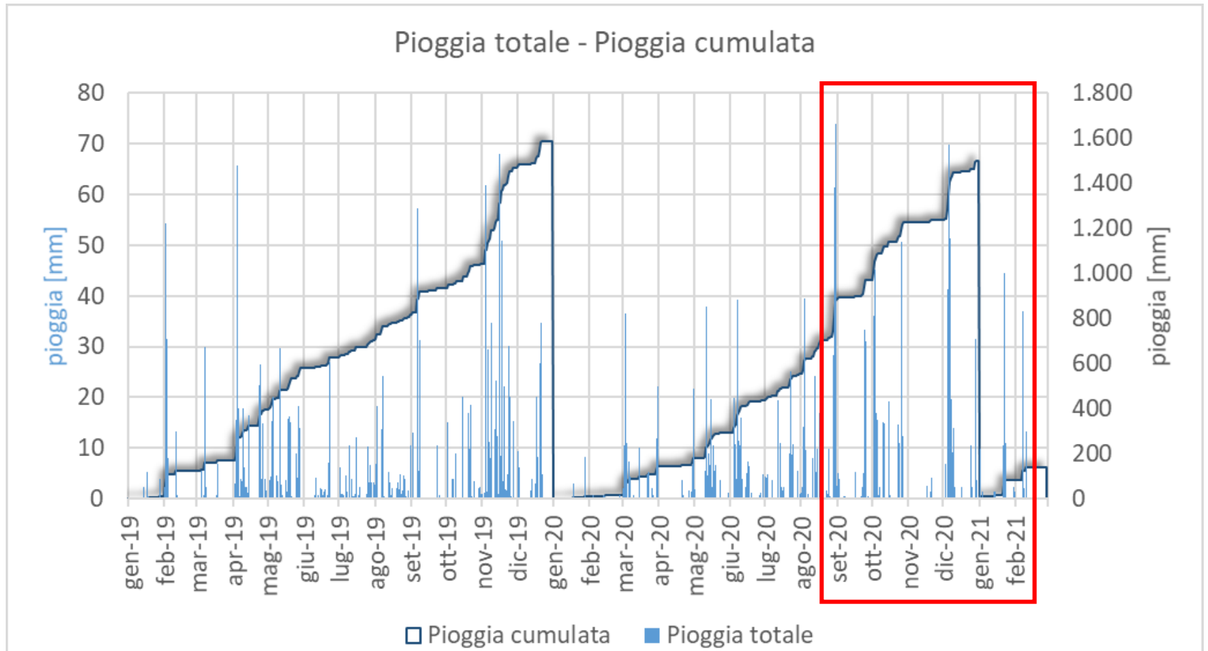

nord
sud

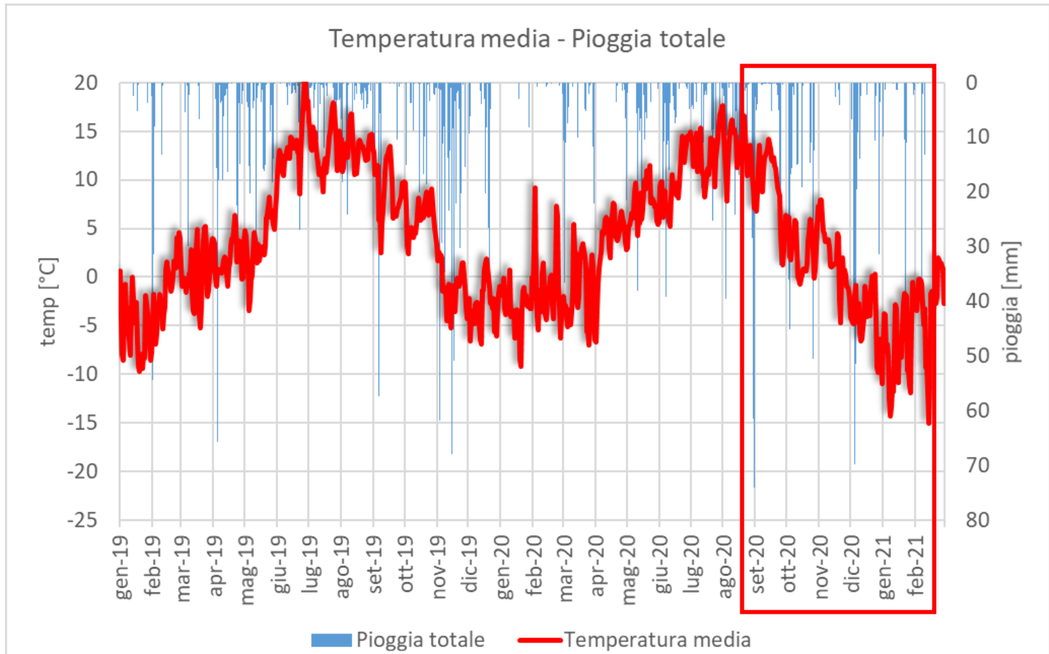
The **objectives** set by the second monitoring campaign were:

- **raise the level of research deriving from the reading of the data** and have the output phase as precise as possible in the critical and sensitive areas highlighted in the first monitoring campaign
- **remodeling the automatic operation of the boulage** so as not to affect the natural stratification of the water during the first snow cover
- **provide design indications aimed at improving the efficiency of future artificial basins**: (I) **indications to design artificial basins** already **equipped with on-board sensors for monitoring** (II) **indications of a technical nature** (positioning, irradiation, depth, slope of the lake shores, etc ...).

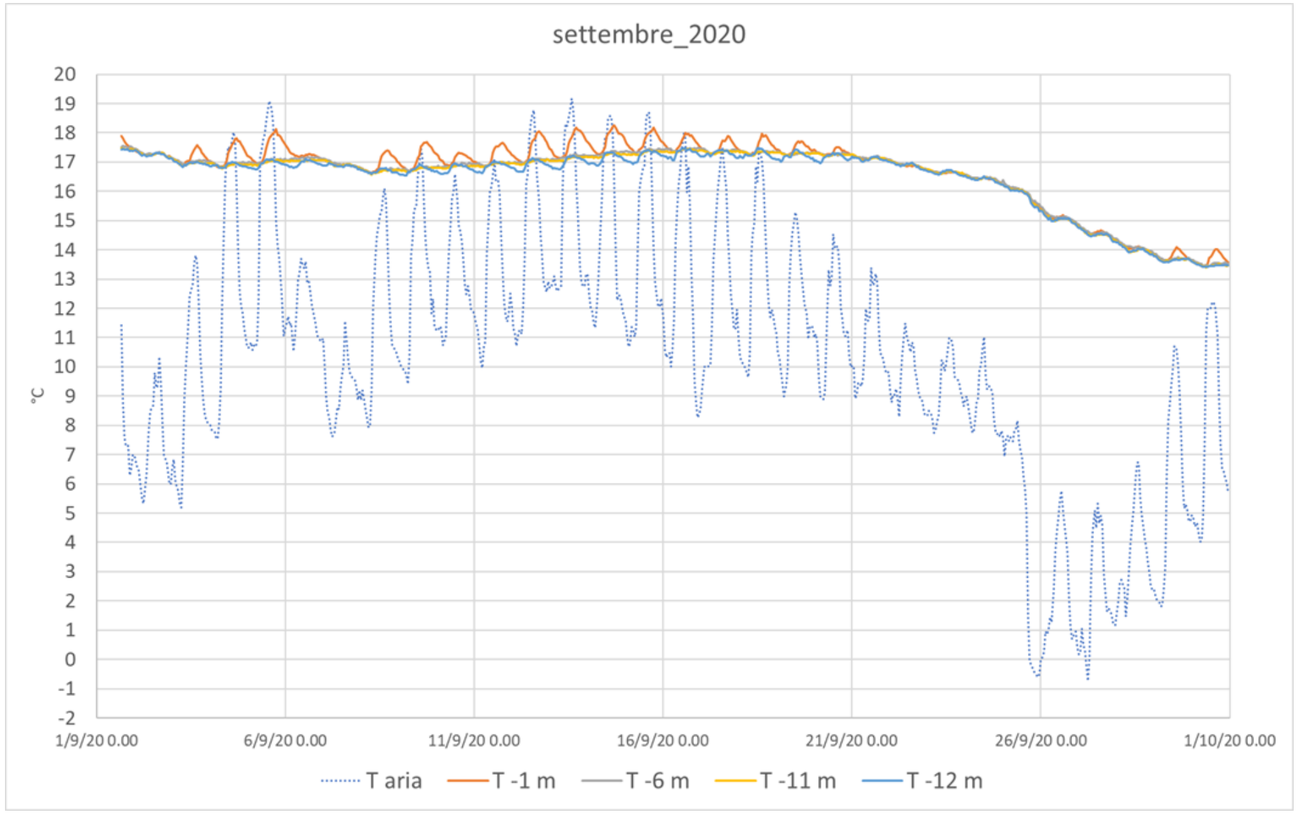
The **climatic trend during the second monitoring campaign** was characterized by:

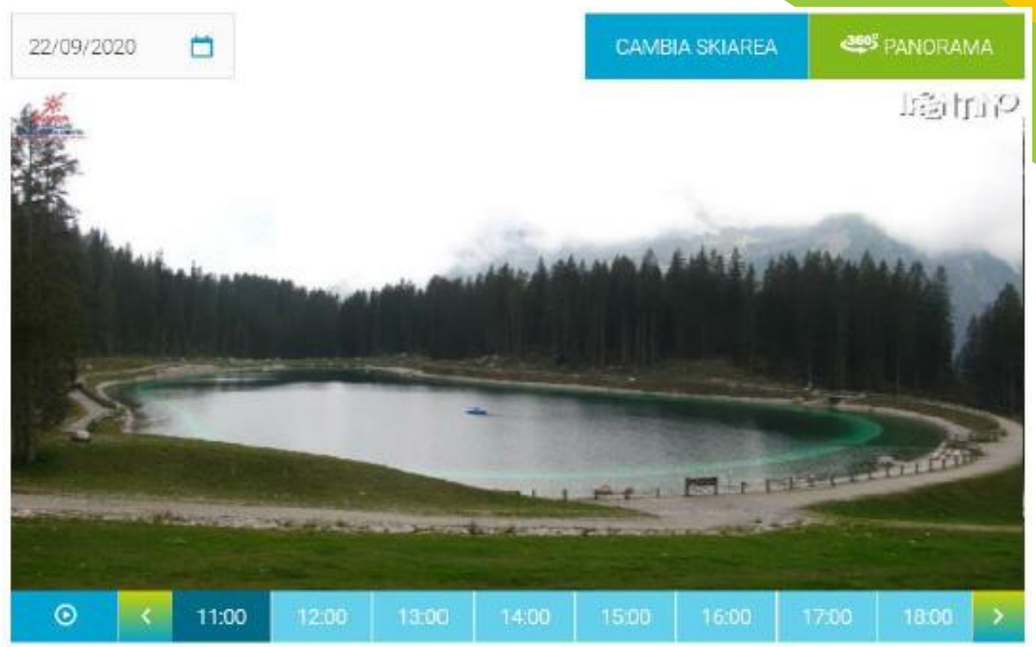
- In September, temperatures remained at fairly high values for the season with average daily values between 12-13 °C. Starting from September 25th, a sudden thermal drop determines average daily thermometric values just above zero.
- October is characterized by an important temporary thermal drop that determines nighttime values below the average during the first two decades.
- In November, conditions of weather stability, low rainfall and temperatures on the period-average, that leads to minimum values below zero at the end of the month.
- Heavy rains took place in December, particularly from 4th to 6th.
- Significant precipitations also during January.





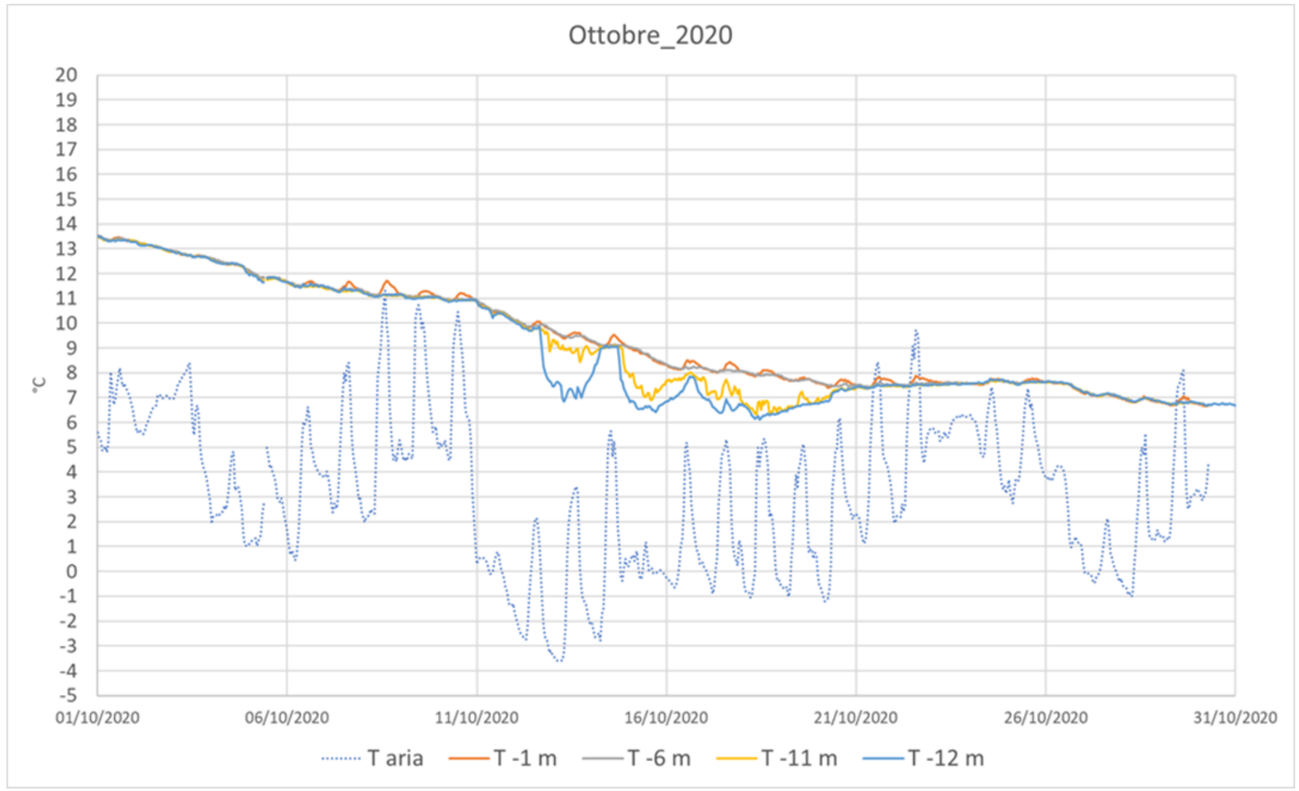
September 2020: Initial conditions

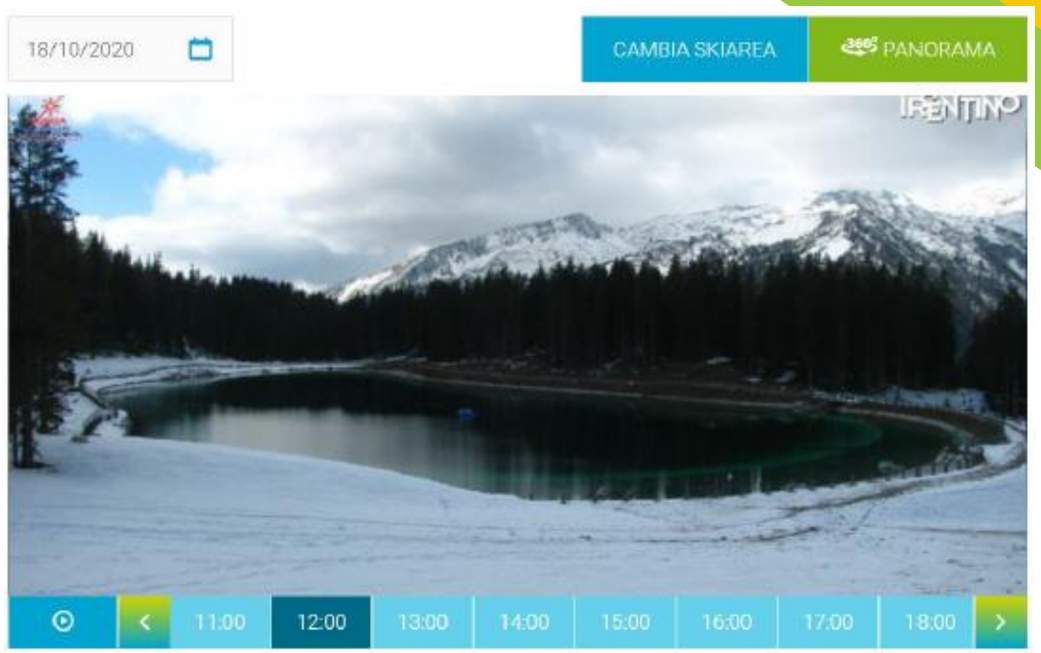




- At the end of the 2020 summer season the thermals show a substantially non-stratified vertical distribution with temperatures of about 17°C.
- The surface is affected by the day / night temperature range. Indeed, the surface temperature tends to increase by about one degree in the hottest hours.
- This hot-phase ends on day 25th when the decrease in air temperatures of 6-7°C leads to a reduction in water temperatures of 3-4 °C

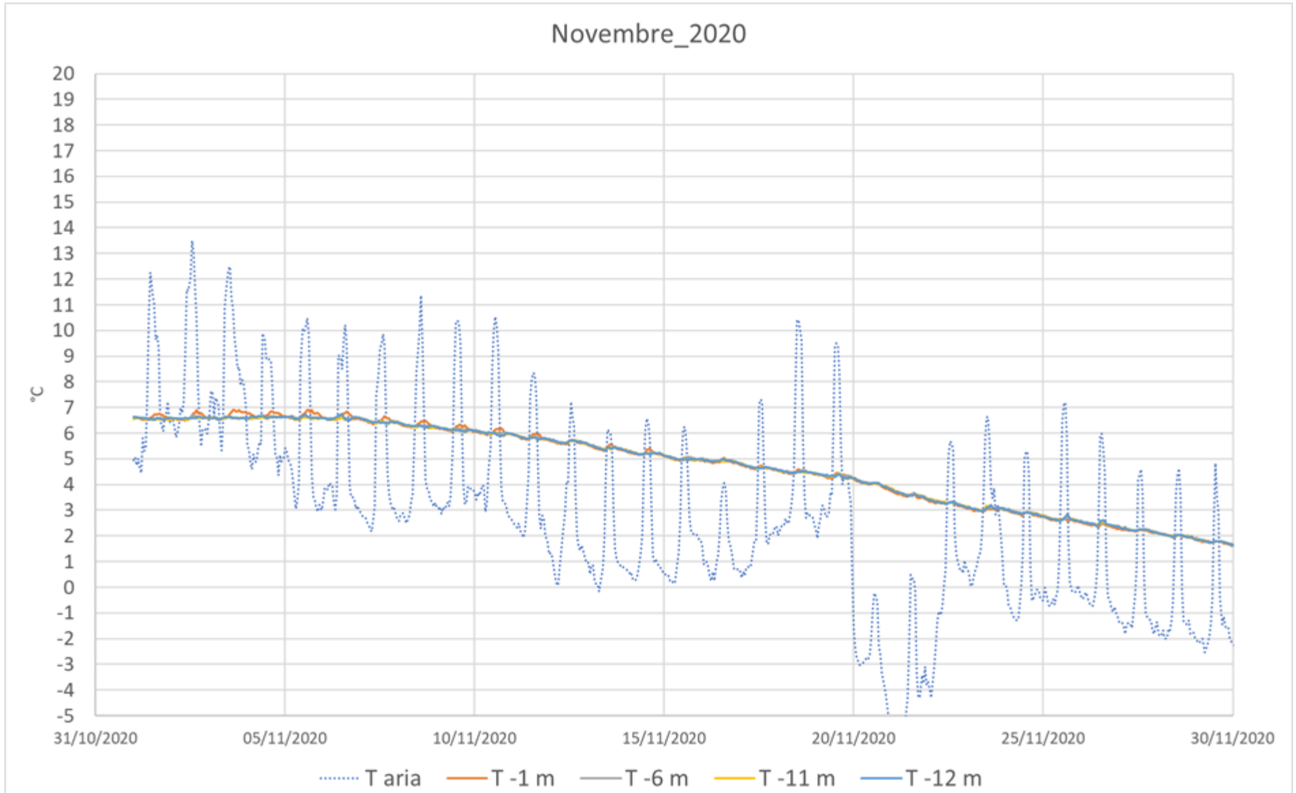
October 2020: First use of water





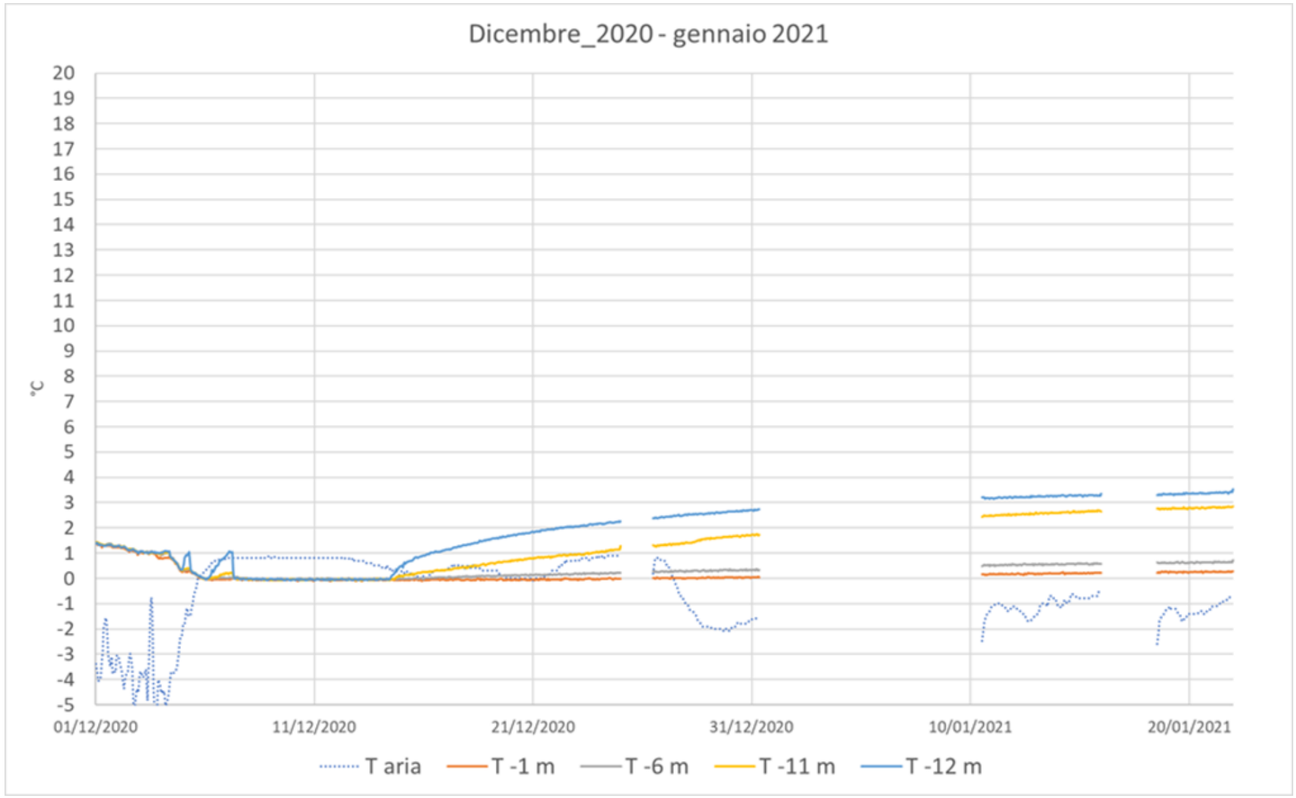
- The non-stratified trend continues until October 12th when the Montagnoli is subject to three successive filling phases
- The cooling of the water in the deeper layers where the newly introduced waters (at 4.4 °C) are positioned is evident
- The boulage was activated starting from October 23th and therefore did not play a role during the filling phases of mid-October.
- The three filling phases show the tendency to spontaneous mixing of the waters.

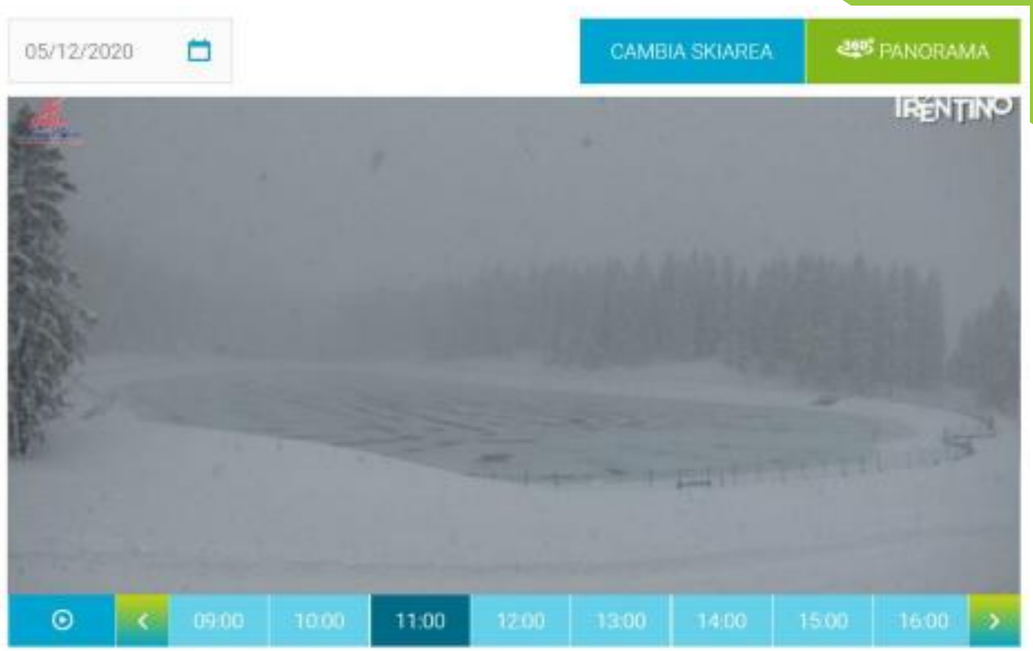
November 2020: Overall thermal drop



- The use of water in the second half of the month and the lowering of the minimum environmental temperatures, from average daily values of 7.2 °C to 1.5 °C, determine a decrease in the overall temperature of the basin which remains thermically mixed and passes from average values of 6.6 °C at the beginning of the month to 1.4 °C.
- The boulage is used starting from November 7th.

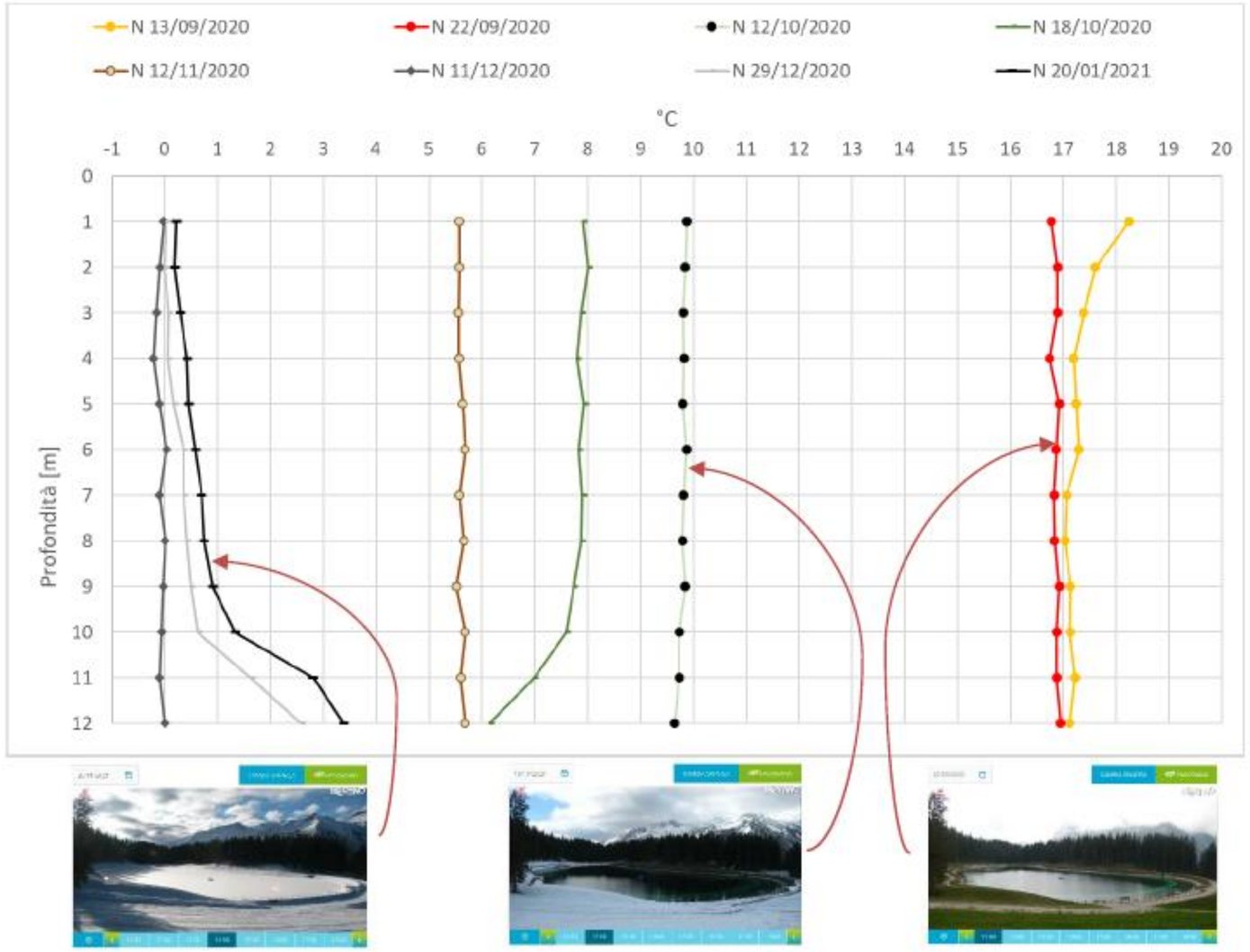
December 2020 - January 2021: Confining of the water





- In the first days of December the constant lowering of temperatures to levels below zero leads to the formation of surface ice.
- This condition substantially frees the trend of water temperatures from the weather.
- The buoy is incorporated into the ice and covered by snow measures false air temperature (erroneously indicate values above zero).
- On December 14th, a stratification process begins which determines the positioning of the less cold waters towards the bottom of the basin, those are close to the point of maximum density (about 4°C).

Vertical thermal profiles 2020-2021



The inflections at the extremes of the diagrams indicate three different phenomena:

- in September, daily irradiation tends to heat the more superficial layers;
- in October, the use and introduction of new water cools the deeper layers;
- in December-January the isolation of the water body involves the heating of the water in the deeper areas

GOOD MANAGEMENT PRACTICES

- **A late lake filling can limit the activities aimed at cooling the water** (use of boulage, water exchange, water cooling before use)

- Furthermore, **it can make an energy saving carrying out a filling for subsequent steps such as to ensure that:**
  - the last waters introduced, the coldest, are kept at the bottom of the reservoir and are the first to be used;
  - the simultaneous lowering of the air temperature reduces the temperature of the water stored in the surface layers which will have more time to cool down;
  - the subsequent filling of the reservoir will consist of colder waters;
  - the boulage is activated only in long cold periods.

PROJECT GUIDELINES FOR ENERGY SAVING

- **Microclimate:** The location of the reservoir has a decisive influence on the trend of the thermals inside it (Altitude, Exposure, Irradiation, Wind, Trend of local air temperatures).

- **Water supply:** Although often the water derivations are mandatory choices by local hydrology, it is useful to check the thermal characteristics of the water withdrawals and their alteration due to pumping or temporary storage.

- **Provision for environmental monitoring:** It is simple and inexpensive to integrate in the design phase a lake monitoring such as that of Smart Altitude, this allows better management of the water resource and better energy efficiency in snow production.

Smart Mountain for tomorrow

THANK YOU FOR YOUR ATTENTION

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