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# The ISP-CNR Ice Core Drilling System: Addressing Firn Aquifers From Arctic To High-Altitude Glaciers

Warmer summers increase the glaciers's melting and enhance meltwater infiltration into porous firn. Additionally, increased temperatures of the glacier's active layer reduce its refreezing capacity. The prolonged melt seasons associated with ongoing global air temperature rise promote the formation of perennial firn aquifers, which serve as short- and long-term water storage within glaciers.

Since spring 2023, during three field campaigns conducted as part of the Ice Memory project, the glaciology group at the Institute of Polar Sciences - National Research Council of Italy (ISP-CNR), in collaboration with Ca 'Foscari University of Venice, has encountered significant challenges in recovering shallow ice cores from wet and water-saturated firn while below freezing temperatures at the surface. These conditions were observed in both low-altitude Arctic settings (Holtedalfonna, 2023; Svalbard, 1000 m above sea level) and high-altitude Alpine environments (Grand Combin, spring 2025; Switzerland, 4150 m above sea level). The aquifers were found in the deeper firn layers, near the firn-ice transition (FIT) or the pore close-off depth.

In this study, we present the different approaches we adopted to enable ice core retrieval in partially water-filled boreholes (BH), including the use of bailing systems and fully submerged drilling techniques. Both electromechanical (EM) and electrothermal (ET) drills were used under submerged conditions. At Holtedalfonna in 2023, a large volume aquifer at a FIT depth of 24 m allows water inflow to the borehole, estimated at 2 L/min. After the borehole reached a depth of 51 m, the drilling site was relocated 140 meters uphill. However, the ice core was successfully recovered down to 51 m at the original site using a submerged electromechanical drill.

In contrast, the Grand Combin 2025 operation observed a lower water inflow rate between depths of 28 and 35 m. Drilling was carried out to a depth of 50 m using the ET drill, followed by electromechanical drilling to bedrock (~100 m) in two separate boreholes. In Svalbard and Alpine ice coring operations, to compensate for buoyancy (approximately 7 kg), the weight of the EM drill was equipped with additional weights. On the drilling site, modified bailing devices were used to remove meltwater from the BH and deploy ethanol to the borehole kerf when it was necessary. Meltwater and fluids from the BHs were removed during the operation. In these operations, we use only little amounts of environmentally friendly fluids to lubricate EM drill chip transport passages and core catchers, preventing the drill from freezing in sub-zero air temperatures at the surface. None of the drills were stuck during described field operations.

**Primary author:** ZANNONI, Daniele (Ca' Foscari University of Venice)

**Co-authors:** Dr SPOLAOR, Andrea (Institute of Polar Sciences, National Research Council, Venice, Italy); Prof. BARBANTE, Carlo (Ca' Foscari University of Venice); Dr DE BLASI, Fabrizio (Institute of Polar Sciences, National Research Council, Venice, Italy); Dr GABRIELI, Jacopo (Institute of Polar Sciences, National Research Council, Venice, Italy)

**Presenter:** ZANNONI, Daniele (Ca' Foscari University of Venice)

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