# Using Unmanned Aerial Vehicles for monitoring glacial moulins

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The exploration of cavities on glaciers has always represented a fascinating activity that attracts scientists and researchers since many decades.

Several explorations performed by speleologists and scientists since 1985 on the Gorner Gletscher (Mount Rosa group, SW Switzerland) have allowed to survey more than 40 endoglacial caves and some marginal tunnels of this glacier, which is the most interesting in the Alps for its supraglacial and englacial pseudo-karst forms. In recent years, the study of these caves has led to the distinction of two morphological and genetic types: marginal tunnels, that generally forms at the contact between ice and lateral moraine, and swallow holes (moulins) which are vertical shafts where a supraglacial stream sinks into the ice.

During the first International glacier-caving camp organized in October 2014 as part of the project "Inside the glaciers" which had the main objective to explore the cavities of this glacier and to study the cryo-karstic processes that lead to the formation of deep shafts, an unmanned aerial vehicle (UAV) equipped with camera and GPS system was used for the first time to perform photogrammetric surveys on three different areas. This technique allowed to derive detailed 3D models with very high resolution and accuracy of the entrance of the main moulins and other interesting parts of this glacier.

Thanks to the acquisition of geo-referenced images and post-processing the acquired data (i.e. motion corrections), with the realized 3D point clouds and mesh models it was possible to obtain geo-referenced ortophoto and digital surface models which have been used to calculate contour lines and calculate the difference of position of the same moulins detected during the last years expeditions. Moreover, the data acquired have allowed to perform other different type of surface analysis and obtain an excellent photographic database that will surely be useful for further comparisons in future, proving the importance of the use of UAV's as an effective system to study and monitor the short life evolution of glacial moulins.