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Glacier Bonnard (Switzerland) a complex permafrosted site source of debris flows : necessary monitoring for prediction of the dynamic and its evolution

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The Bonnard "Glacier" is over 2800 m (in the lower fringe of the possible permafrost altitude limit), at the source of two streams where debris flows are common, in the upper part of Anniviers valley (Valais, Switzerland). We describe it as a mix of rock debris with variable content of ice showing different flow features on the surface. This paraglacial feature shows signs of deterioration (significant loss of volume) and is located on an unfavourable topography (a flat creeping part reaching a steep slope).

As the debris flows in the 2 streams appear to have originated mainly from the Bonnard "Glacier", urbanization pressure, the burden of maintaining protection infrastructure downstream and the issue of recent climate warming, authorities have determined to undertake a major study.

To determine the impact (and the direction of its evolution) of permafrost degradation on the danger of debris flows downstream, it appeared that we need to:
• determine the volumes of the creeping material,
• determine the composition of these volumes (including the ice content),
• know the characteristics of mass displacement
• get a feel for the water's dynamic on the triggering areas.
To answer these questions a series of sensors and methods have been chosen.

To determine the volumes, 11 lines of seismic refraction, 6 GPR profiles and 14 boreholes were done and geometrically checked on a 3D software. Information from these data also helped better understand the composition of the mass lying between the bedrock and the surface topography. In addition, a surface temperature sensor network (operating in WiFi), two meteorological stations, and a chain of thermistors were deployed at the site. The flow characteristics have been determined by periodic measurement of more than 100 DGPS points (6 periods), the installation of three permanent GPS antennas and 5 inclinometers. Water dynamic has so far been investigated by mapping and dye tracers.

Through this network of observations, the description of the studied feature has been greatly refined. However, the complexity of this structure was greater than initially expected and after 4 years of observation, it remains difficult to know the detailed characteristics of the current "Glacier" Bonnard. This observation, prompted us to look for new methods (including geophysical and exploitation of 3D data).