The complex pluri-decennial and multiphasic destabilization of the Jegi rock glacier (western Swiss Alps): historical development and ongoing crisis

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The so-called destabilization of a rock glacier is characterized by a fast motion rate of the landform (usually more than 2 meters per year (m/y)) and the development of crevasse(s) or landslide-like scarp(s) on its surface. It may concern the entire of a rock glacier or only a part of it. Such a destabilization phase is generally considered to be the result of the varying and combined influence of factors related to

i the structure and composition of the rock glacier,

ii the thermal state of the permafrost,

iii the topography of the terrain,

iv the geometrical changes of the moving landform and

v a possible local overloading in debris [Delaloye et al., 2013].

In this context, our contribution presents the historical development of the Jegi rock glacier destabilization for the last 60 years and focuses on the ongoing crisis.

The 720 m long and 100 – 150 m wide Jegi rock glacier is located between 2750 and 2450 m a.s.l. on the western flank of the Jegihorn summit (3206 m a.s.l.) and on top of a deep-seated landslide moving 1 – 3 cm/y. Downwards its rooting zone, the rock glacier consists of an upper tongue ending with a first front (2550 m a.s.l.) superimposed on a 150 m long second tongue located below. The inclination of the slope is about 20° in the rooting zone, 15° in the median part of the first tongue, 30° or more above the upper front and 10 – 15° on the lower tongue (Fig. 1). In a regional study aimed at inventorying slope movements with satellite-borne DInSAR (synthetic aperture radar interferometry), the active Jegi rock glacier was presenting in 2008 morphological and kinematical evidences of an ongoing destabilization phase [Delaloye et al., 2008, Barboux et al., 2015].

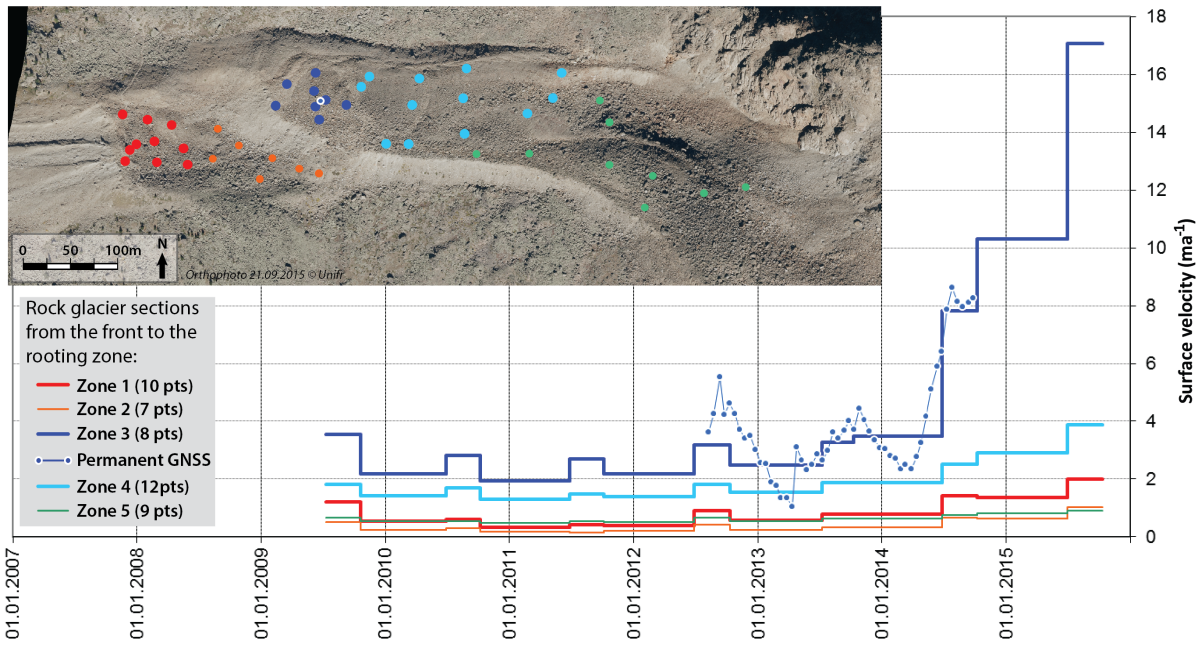

Figure 1: Surface velocities (m a^{-1}) of the 5 different zones of the Jegi rock glacier from 2009 to 2015 derived from GNSS measurements and from a permanent GNSS sensor located in the zone 3

More precisely, a steep section above the upper front was spotted moving in the order of 2 – 3 m/y since at least 1995, with larger velocities in summer than in winter [Delaloye et al., 2008]. Since then, its surface motion has been under investigation. First, in order to assess more precisely the pattern of the rock glacier flow field and its temporal evolution, GNSS measurements campaigns have been held twice a year since June 2009 (network of about 80 measurement points). Detailed investigations on the seasonal kinematical behavior of the rock glacier have also been conducted using DInSAR technologies between 2011 and 2013 [Barboux et al., 2015]. Moreover, a permanent GNSS sensor is installed in the center of the fast moving zone since July 2012. At the moment, aerial images available since 1958 are being photogrammetrically analyzed to recognize and reconstruct earlier stages of the destabilization development.

Our study points out so far that the Jegi rock glacier has suffered a minimum of two destabilization phases in his history. The first one already occurred before 1958, as indicated by the aerial image of that year showing morphological signs of a previous surge-like crisis: a longitudinal depression surrounded by two lateral levees is connecting the rooting zone to the median part of the upper tongue and an important transversal crevasse has developed on its frontal part. These morphological features witness the last stage of a formerly developed destabilization process, which affected the main part of the upper tongue.

This crisis was apparently caused by the pressure exerted by the rapid accumulation (overloading) of rock material collapsed from the headwall located above the rock glacier rooting zone. From 1958 to 1995, no further significant sign of destabilization is visible. Around 1995, a fast moving zone was detected on the terminal section of the upper rock glacier tongue. Between 2009 and 2013, the rock glacier flow field pattern was organized as follows: the rooting zone (zone 5, Fig. 1) was moving at a rate of 0.5 m/y; the median part of the upper tongue (zone 4), including the former depression and levees, was moving at a rate of 1 – 2 m/y, independently of the rock glacier surface morphology; the terminal part of the upper tongue (zone 3) was the fastest of the rock glacier with velocities of 2 – 3 m/y; finally the lower tongue (zones 1 and 2) was moving quite slowly (0.5 m/y).

Since the winter 2013/2014, dramatic changes of the rock glacier kinematical behavior have occurred. The landform has indeed entered into a new destabilization phase marked by a strong velocity increase in all zones: in comparison to the 2009 – 2013 mean, the annual velocity change reached in 2014/15 +50 % in the rooting zone, +100 % in zone 4, +200 % in zones 1 and 2 and +400 % in zone 3. At the time of writing this abstract (November 2015), the zone 3 was moving at a critical rate of about 5 centimeters per day (17 m/y). The new (and ongoing) destabilization phase can be considered as affecting this time only a smaller part of the rock glacier, namely the zone 3, whose area is about 0.01 square kilometers for a maximum volume of about 100'000 cubic meters. In less than 2 years, a 5 – 8 m high scarp has developed at the upper edge of the rapidly moving zone and rock falls from the destabilized frontal part have become frequent.

No specific meteorological or earthquake event has triggered the current destabilization phase and a sediment surcharge is excluded as a contributing factor. The ongoing destabilization has to be considered as resulting from the combination of

i the local steepness and convexity of the topographical slope (which in turn conducts to an extensive flow of the rock glacier),

ii the long-term geometrical changes of the moving mass (about 50-100 m advance of the upper tongue in 50 years), and

iii the pluri-decennial permafrost warming trend that has been particularly pronounced in the Swiss Alps for the 5 previous years (increasing rock glacier velocity values observed in most monitoring sites).

Thereby, one has to consider:

i that the destabilization of the Jegi rock glacier is a pluri-decennial, multiphasic and complex process, which is not always affecting the same section of the landform,

ii that the ongoing destabilization phase is in a preparation stage since 20 years at least (concomitance of the outline of the fastest zones in 1995 and 2015) and, because the whole rock glacier is simultaneously suffering a widespread and severe acceleration,

iii that the current phase has been doubtless thermally (climatically) triggered.

References

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