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Monitoring concept for observing the activity of alpine rock glacier at a regional scale

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By supplying loose blocky materials, rock glaciers - and more generally the creep of perennially frozen ground - are potentially the source of slope instability processes (rock fall, debris flow) on steep valley sides in a mountain environment. Any change in the rate of permafrost creep is susceptible to affect both the frequency and magnitude of slope instabilities. Such an assertion is well illustrated for instance by the recent crisis that occurred in 2004 and 2005 on the south-eastern flank of Mont-de-l'Etoile in the western Swiss Alps: a dramatic increase of rock fall and debris flow activities was consecutive to the destabilisation of a mantle of frozen blocky sediments perched on top a steep gully. The event was synchronous with a documented period of maximal intensity of rock glacier motion consecutive to the extremely warm year 2003. The understanding of the processes involved in such a kind of event as well as the management of natural hazards related to periglacial slopes require to-date information on the permafrost creep activity and point out on the importance to develop a concept for the monitoring of rock glacier activity at a regional level. Studies on rock glacier dynamics have shown that three types of variability in surface motion occurring with different time-scales can be envisaged. (a) The rock glacier flow may suffer a seasonal rhythm, that is an annual amplitude of velocity, which has appeared to be very variable depending on the rock glacier (0 to more than 50 %) but rather constant with time. (b) Changes in annual displacement are occurring from year to year. Ongoing surveys in the western Swiss Alps show that these inter-annual changes are similar and synchronous for most rock glaciers since the beginning of the observation in 2001. (c) Seasonal rhythm and annual changes are superimposed on a decadal to pluri-decadal trend. In the whole Alps, the recent trend has consisted in a general and significant increase of the rock glacier activity since about the 1980s. Taking account

of these potential sources of variability, the monitoring strategy for the survey of rock glacier dynamics that we are trying to develop at a regional scale is based on five interconnected levels of observation. Additional data on ground (sub-)surface temperature evolution is also necessary. (1) A regional inventory of rock glaciers activity can be more or less well provided by satellite analysis (e.g. SAR interferometry). (2) For the last decades, the long-term trend and velocity field can be determined for most rock glaciers by photogrammetric analysis. (3) A reduced number of rock glaciers are selected as control sites for the documentation of annual changes. Field survey (e.g. by differential GPS) has to be carried out at the same date every year. (4) For other sites of interest, a field survey of the annual changes during 3-4 years is suggested (same date every year) in order to check the correlation with the control sites. (5) To understand the seasonal rhythm of individual sites, several field surveys have to be carried out during an annual cycle on a reduced - but however as large as possible - number of measurement points. A fixed differential GPS can also be used. Particularly observations issued from levels (2) and (3) have to be connected to large-scale monitoring networks.