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Log-periodic oscillations and icequakes during the breaking-off of large ice masses.

J. Faillettaz (1), M. Funk (1) and A. Pralong (1)

(1) Laboratory of Hydraulics, Hydrology and Glaciology, Swiss Federal Institute of Technology, 8092 Zurich, Switzerland (jeromef@ee.ethz.ch)

Recent in situ measurements on Weisshorn and Mönch hanging glaciers in the Swiss Alps confirm an acceleration of both motion and icequake activity of unstable large ice masses prior to their failure. The motion of a material point at the glacier surface appears to increase as a power law function of time prior to rupture. This characteristic acceleration presents a finite-time singularity at the theoretical time of failure. The icequake activity shows also a clear acceleration prior to the final rupture.

However, a close inspection of the general power law acceleration showed that it is accompanied by oscillations with a frequency decreasing logarithmically as the time of failure is approached (named 'log-periodic oscillations"). Such a trend could be explained with the anisotropic damage evolution within the basal ice. An alternative explanation is to consider these oscillations as a result of a discrete scale invariance with a preferred scale ratio λ describing a discrete hierarchical cascade. Notwithstanding types of break-off events analysed are quite different (Weisshorn 1973 and 2005, Mönch 2005), we found that $\lambda \approx 2$ in all cases, suggesting a universal value of the log-frequency in the case of hanging glaciers.

Moreover, a seismometer was installed on the side of the unstable ice mass enabling to measure and perform an icequake analysis. We found that the icequake activity of the Weisshorn hanging glacier shows a drastic acceleration three days prior the final rupture. This will open new rupture prediction possibilities, since it is a simple method that could easily be performed in real time, independently of weather conditions.

By combining the log-periodic and icequake analysis the prediction of the final break-off time will be significantly improved. This also provides useful indications on the physical mechanisms of the rupture in heterogeneous materials.