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Modelling and detection of present and future glacial lakes in the Swiss Alps based on digital terrain information and remote sensing

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The retreat and vanishing of mountain glaciers causes the formation of lakes in overdeepened parts of newly exposed glacier beds. Such lakes often constitute attractive landforms but can also be a source of serious flood and debris flow hazards, especially in connection with ice avalanches and rock falls from destabilized mountain slopes. In view of ongoing atmospheric warming and related deglaciation trends, early detection of sites with potential lake formation is therefore an important task of protection concepts with respect to rapidly changing high-mountain hazards. Corresponding strategies can build on GIS-based modelling of digital terrain information and satellite-based detection of of lake formation. This is illustrated with the example of the Swiss Alps.

Assuming a constant basal shear stress and, hence, slope dependent thickness change, potential future lake formation was first modelled in the Bernina massif, eastern Swiss Alps, by selecting major glacier surfaces with slopes $< 5^{\circ}$ above steeper surface slopes. Probably overdeepend parts of glacier beds were delineated at the foot of steep mountain walls below Piz Bernina (Morteratsch glacier) and Piz Palü (Pers glacier). The same procedure was then applied to the entire Swiss Alps based on the SRTM digital elevation model. As a result, the potential formation of major lakes could be determined. In combination with a GIS-based scenario of glacier shrinkage, the growth of new lake surfaces could be estimated as a function of time and warming scenario. A total of several tens of km2 may indeed form during the 21st century with about half of it developing already within the first few decades.

At the same time, methods and techniques were developed for lake detection and hazard assessment over large areas based on remote sensing data and digital elevation models (DEM). Lake detection is based on an algorithm using spectral reflectance difference of Landsat and ASTER bands. The result of this fully automatic procedure is verified in a selected area in the Upper Engadin. For assessing the effects and runout of potential outburst floods from these lakes, flow trajectory modelling is applied.

The comparison of conditions in 1985 and 2003 showed that the area of some glacial lakes as well as the number of lakes in glaciated areas increased. Also, many existing glacial lakes changed due to glacier retreat. The flow modelling has shown that some of the lakes can be problematic and should be analysed in more detail ,possibly requiring regular observation.

The strength of the here-described procedure is the fast overview over large areas and the anticipation of likely changes in landscape and hazard potential. The models are designed to facilitate subsequent more detailed investigations and field observations. They can be applied all over the world given the availability of multispectral satellite data and elevation information