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Mapping basin-wide subaquatic slope failure susceptibility as a tool to assess regional seismic and tsunami hazards

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With increasing awareness of oceanic geohazards, submarine landslides are gaining wide attention because of their catastrophic impacts on both offshore infrastructures (e.g. pipelines, cables and platforms) and coastal areas (e.g. landslide-induced tsunamis). They also are of great interest because they can be directly related to primary trigger mechanisms including earthquakes, rapid sedimentation, gas release, glacial and tidal loading, wave action, or clathrate dissociation, many of which represent potential geohazards themselves. In active tectonic environments, for instance, subaquatic landslide deposits can be used to make inferences regarding the hazard derived from seismic activity. Enormous scientific and economic efforts are thus being undertaken to better determine and quantify causes and effects of natural hazards related to subaquatic landslides. In order to achieve this fundamental goal, the detailed study of past events, the assessment of their recurrence intervals and the quantitative reconstruction of magnitudes and intensities of both causal and subsequent processes and impacts are key requirements.

Here we present data and results from a study using fjord-type Lake Lucerne in central Switzerland as a “model ocean” to test a new concept for the assessment of regional seismic and tsunami hazard by basin-wide mapping of critical slope stability conditions for subaquatic landslide initiation. Previously acquired high-resolution bathymetry and reflection seismic data as well as sedimentological and in situ geotechnical data, provide a comprehensive data base to investigate subaquatic landslides and related geohazards. Available data are implemented into a basin-wide slope model. In a Geographic Information System (GIS)-framework, a pseudo-static limit equilibrium infinite slope stability equation is solved for each model point representing reconstructed slope conditions at different times in the past, during which earthquake-triggered landslides occurred. Comparison of reconstructed critical stability conditions with the known distribution of landslide deposits reveals minimum and maximum threshold conditions for slopes that failed or remained stable, respectively. The resulting correlations reveal good agreements and suggest that the slope stability model generally succeeds in reproducing past events. The basin-wide mapping of subaquatic slope failure susceptibility through time thus can also be considered as a promising paleoseismologic tool that allows quantification of past earthquake ground shaking intensities. Furthermore, it can be used to assess the present-day slope failure susceptibility allowing for identification of location and estimation of size of future, potentially tsunamigenic subaquatic landslides. The new approach presented in our comprehensive lake study and resulting conceptual ideas can be vital to improve our understanding of larger marine slope instabilities and related seismic and oceanic geohazards along formerly glaciated ocean margins and closed basins worldwide.