Massenbewegungen und Impulswellen in alpinen Seen - ein multidisziplinärer Naturgefahren-Forschungsansatz

A MULTIDISCIPLINARY APPROACH FOR LANDSLIDE GENERATED IMPULSE WAVES ASSESSMENT IN NATURAL MOUNTAIN LAKES FROM A CASCADE HAZARD ANALYSIS PERSPECTIVE

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Abstract: This poster introduces objectives, research concept and initial preliminary results of an interdisciplinary research approach for modelling landslide-generated impulse waves in mountain lakes from a cascade hazard analyses perspective. Main focus of the poster is to explain the necessity to study this kind of phenomena and how a multidisciplinary approach concerning different sciences is useful and mandatory here. A cascade hazard perspective is proposed for a forward analysis of landslide generated impulse waves, where a series of triggers and consequences are taken in to account. The available commercial software Flow-3D is used for the simulation of the formation and the propagation of the impulse wave. To analyze the applicability and potential limitations of this software, a back analysis of the impulse wave generated in the Lituya Bay (Alaska) in 1958 is proposed. As a study case for the forward analysis in a cascade hazard perspective, the lake Achen (Achensee), located in the Eastern Alps (Tyrol, Austria), is chosen. The west slope upon that lake is investigated to verify the possibility to have any gravitational process able to generate an impulse wave. The presented project is assigned to the doctoral program “Natural Hazards in Mountain Regions” at the University of Innsbruck and funded by the University.

Research Motivation and Project Description

The management and the analysis of the hydrological and geological risk in mountain regions is considered nowadays as a priority for human and territory safety. The study of phenomena that affect these regions, like landslides or flash floods, has been and is still a challenge in continuing evolution for a better comprehension for reliable natural hazards assessment. In the last centuries the consciousness of phenomena like tsunamis in lakes or in artificial basins (also known as impulse waves) has spread since several catastrophes happened. In fact, landslides either subaquatic or subaerial can trigger devastating tsunami waves. The realization of new reservoirs in steep mountain valleys for the hydroelectric power generation has highlighted the assessment of that kind of natural hazard, especially after the Vajont disaster (10 October 1963, Italy) where a huge landslide collapsed in the down valley reservoir, generating one of the biggest impulse wave ever recorded, killing 2000 people (Paronuzzi P., Bolla A., 2012). The generation of impulse waves in lakes is often triggered by an amount of material, collapsing in the water body, with a sufficient energy in terms of mass and velocity to allow the formation and propagation of a wave. Often, large landslides, or rockslides, are triggered by intense rainfall events or earthquakes.

The study of landslide generated impulse waves in natural mountain lakes, or reservoirs, in a forward analysis, represents a hard challenge for the science world. For that purpose, a multidisciplinary approach is needed to analyze the complexity of these kinds of phenomena where different science disciplines as geology, geotechnics and hydraulics are strictly related (Fig. 1). A detailed geological, structural, geo-morphological and geo-mechanical investigation of an area allows the realization of a good geotechnical model of an unstable slope. A topography with high resolution and an accurate bathymetry of the lake floor are necessary for a good simulation of a landslide generated impulse wave. The purpose is to see the effects and the damages along the shoreline and the surrounding areas.

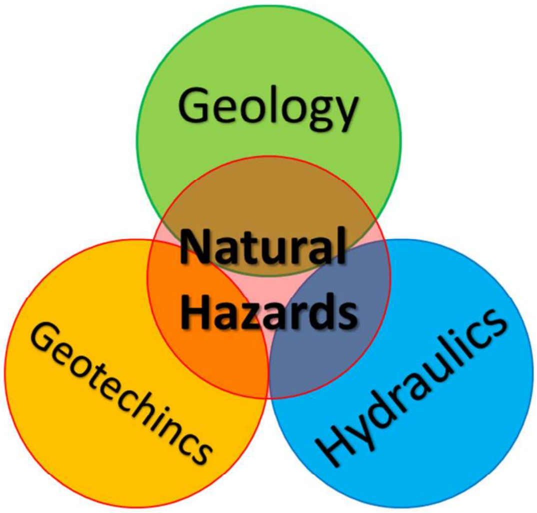

Fig.1: Multidisciplinary approach and involved science disciplines for the hazard assessment of landslide triggered impulse waves.

Application of this approach means also to analyze this kind of phenomena from a cascade hazard perspective, since we are talking about a “domino effect”. Like a chain reaction of triggers and consequences, a quake could destabilize a slope that at the end of its collapsing process impacts a water body, like a lake, generating an impulse wave, whose propagation damages the banks surrounding the impact area. A good knowledge of the possible triggers (e.g. in terms of rainfall or seismic hazard) concerning a specific mountain area is needed. Information, like the local acceleration if an earthquake is taken into account, can be used as input for stability and stress-strain analysis of a slope to understand the possibility of an unstable volume to collapse in a lake or in a reservoir. Starting from the outputs obtained from the previous analysis, a landslide run out simulation is considered as process boundary condition of the hydraulic model simulating formation and propagation of the impulse wave and any related hydraulic consequences.

Recently, the most used commercial-available software for the simulation of impulse waves in alpine lakes and reservoirs is the computational fluid dynamics (CFD) model Flow-3D, which is based on a three-dimensional numerical modelling approach (Vasquez, J.A., 2017, Das K. et al, 2009). This software solves the Reynolds-Averaged-Navier-Stokes-(RANS)-Equations. It uses the Volume-of-fluid-(VOF)-method to track the free surface and the Fractional Area/Volume Obstacle representation (FAVOR) to define the solid bodies. Several tools and parameter modules are useful to simulate a body sliding along a slope and impacting a water basin, in function also of which kind of gravitation process is going to be simulated (rock fall, rock slide, rock avalanche or as well snow avalanche).

A task of this project is also to test the capacity of Flow-3D and its limits with regard to the extent of the computational domain, the grid resolution, the corresponding computation times and as well the accuracy of modelling results. For that purpose, a back analysis of the past event of the Lituya Bay (1958, South Alaska, maximum run up recorded is 524 m above the sea level; Miller D., 1960) is proposed, since a lot of information and data are available for that study and the comparison with already existing data and publications (eg Basu D. et al, 2009; Ward S.N., Day S., 2010; Gonzales-Vida J.M. et al., unpublished) is possible. First a detailed analysis of the tsunami formation and run-up in the impact area is accomplished with the numerical model (Fig. 3). Then the model will be enlarged along on the entire bay to simulate the propagation of the wave. Since no bathymetry is available, a new interpretation of the Lituya Bay bathymetry before the event is proposed, starting from the available cartography and from the free data obtained from the National Ocean Service (Hydrographic Survey with Digital Sounding). The shape of the bay, as a narrow and long fjord, and the gravitational process that generated the impulse wave (a rock avalanche) represent a situation that can be easily found also in a common mountain region as the Alps (Figs. 2 and 4).

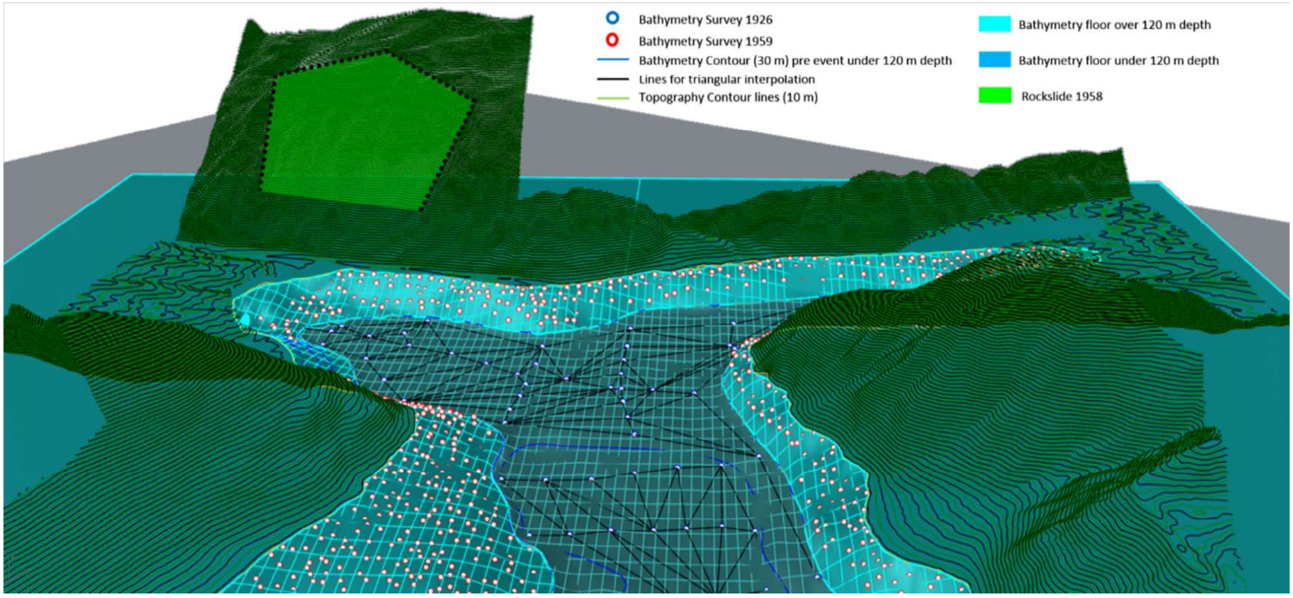

Fig.2: Reconstruction of the Lituya Bay bathymetry 1958 based on data from U.S. Coast and Geodesic Survey: Survey id: H04608, 1926 and Survey id: H08492, 1959. DTM available from DGGS Elevation Portal of Alaska.

For a cascade hazards forward analysis, a real study case in the Eastern Alps is chosen. The lake Achen (Achensee) in the north-eastern part of the Tyrol region, Austria, represents an interesting case for this project, since it is the greatest lake in the Tyrol region and a lot of information on the surrounding slopes and bathymetry is available thanks to several previous and ongoing projects (eg Ortner, H., Gruber, A., 2011, Oswald P., unpublished) (Fig. 4). Of particular interest for this case is the west slope upon lake Achen which seems to be affected by hard erosional processes and deformation after the glacier retreat. The purpose is to understand if any possible gravitational process could lead the generation of an impulse wave in this lake, and so simulate the formation and the propagation of the wave. To verify the reliability of the results of this forward analysis, a comparison with the results obtained by the empirical equations for subaerial landslide generated impulse waves provided by Heller et al. (2010) will be proposed.

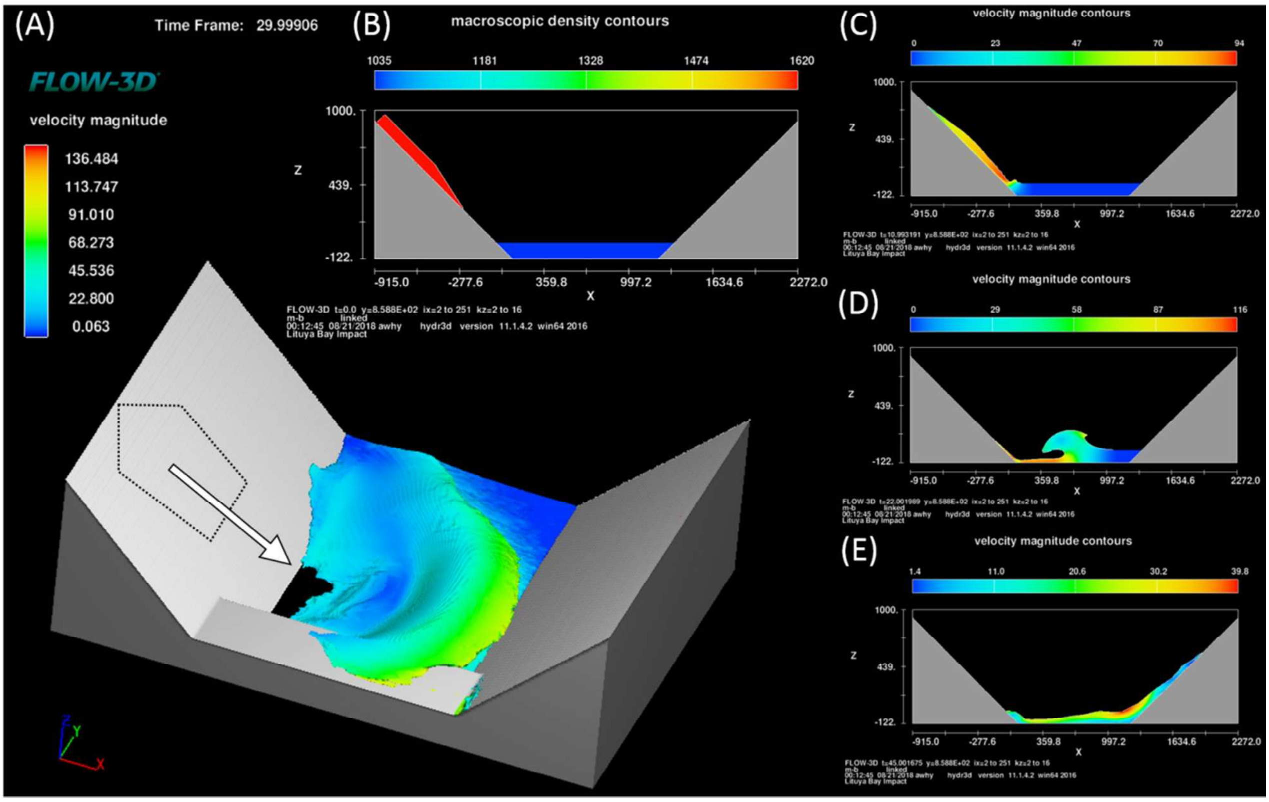

Fig.3: Lituya Bay 1958 landslide-generated impulse wave simulation using Flow-3D. A) impact area, a simplified topography is used for preliminary simulations; propagation of the wave before impacting the opposite slope; B) position of the rock slide before the failure (red); C) moment of the initial impact in the water body, the rock slide reaches a velocity of 94 m/s; D) formation and propagation of the wave; E) run-up at the opposite slope.

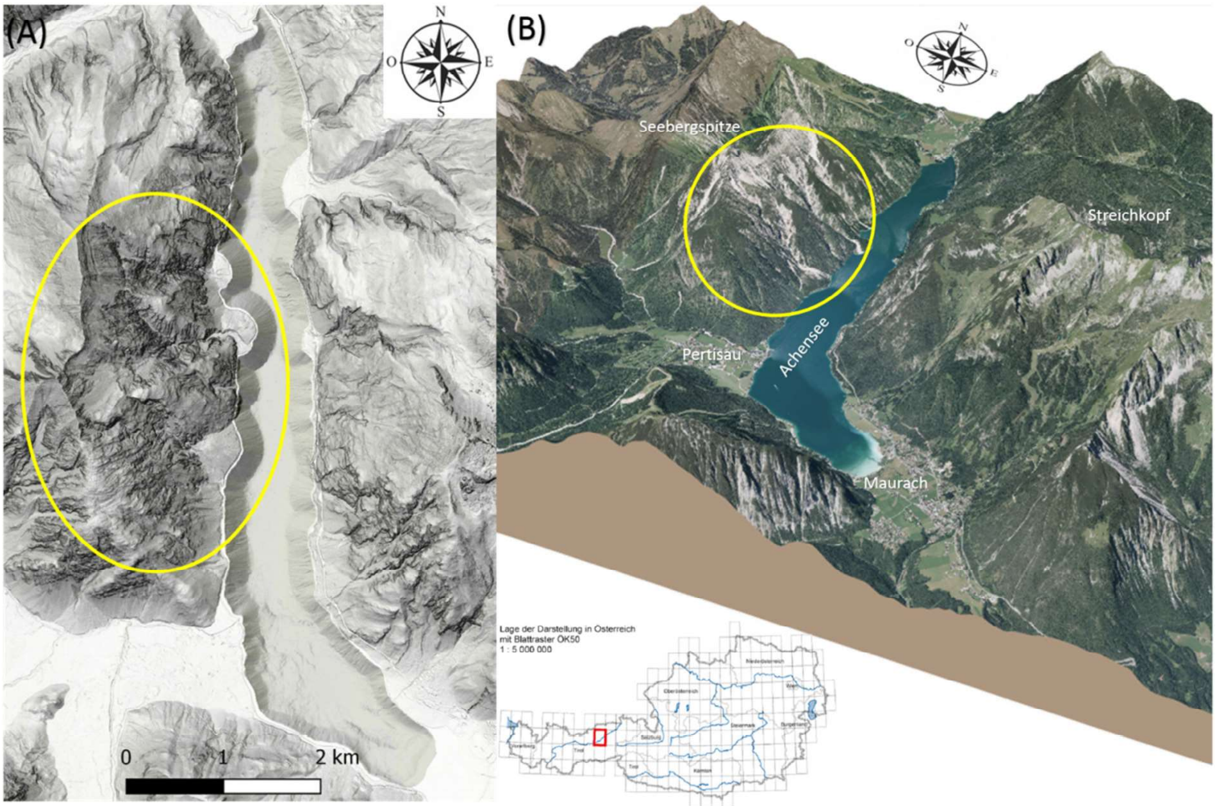

Fig.4: View of lake Achen and the west slope as a subject of investigation (yellow area). A) digital terrain model of slopes (Anleitung zur Einbindung von Geodatendiensten 2017) and lake bathymetry (Oswald P., 2017); B) panorama view of the lake Achen region.

References

Anleitung zur Einbindung von Geodatendiensten (2017): https://gis.tirol.gv.at

Basu, D., Green, S., Das, K., Janetzke, R., Stamatakos, J. (2009): Numerical Simulation of Surface Waves Generated by a Subaerial Landslide at Lituya Bay, Alaska. Proceedings of OMAE2009, 28th International Conference on Ocean, Offshore and Arctic Engineering, May 31 - June 5, Honolulu, pp 14.

Das, K., Janetzke, R., Basu, D., Green, S., Stamatakos, J. (2009): Numerical Simulations of Tsunami Wave Generation by Submarine and Aerial Landslides Using RANS and SPH Models. Proceedings of OMAE2009, 28th International Conference on Ocean, Offshore and Arctic Engineering, May 31 - June 5, Honolulu, pp 14.

DGGS Elevation Portal, Division of geological and geophysical survey: https://elevation.alaska.gov

Gonzales-Vida, J.M. Macías J., Castro M. J., Sánchez-Linares C., de la Asunción M.: The Lituya Bay landslide-generated mega-tsunami. Numerical simulation and sensitivity analysis. In review for Geophys. J. Int., pp 25.

Heller, V., Hager, W.H. (2010): Impulse Product Parameter in Landslide Generated Impulse Waves. Journal of Waterway, Port, Coastal and Ocean Engineering, 145-155.

Miller, D. (1960): Giant Waves in Lituya Bay, Alaska: A Timely Account of the Nature and Possible Causes of Certain Giant Waves, with Eyewitness Reports of Their Destructive Capacity. Professional paper, U.S. Gouvernement Printing Office.

Ortner, H., Gruber, A. (2011): 3D-Geometrie der Strukturen zwischen Karwendel-Synklinale und Thiersee-Synklinale. Arbeitstagung der Geologischen Bundesanstalt 2011, Achenkirch, Proceedings, 51-67.

Oswald P. (2017): Achensee Surveys 2017. Expedition report, University of Innsbruck, unpublished.

Paronuzzi P., Bolla A. (2012): The prehistoric Vajont rockslide: an update geological model. Geomorphology, Volumes 169-170, 165-191.

U.S. Coast and Geodesic Survey: Survey id: H04608, 1926.

U.S. Coast and Geodesic Survey: Survey id: H08492, 1959.

Vasquez, J.A. (2017): Modelling the generation and propagation of landslide-generated landslide. CSCE SCGC, Leadership in Sustainable Infrastructure, Annual Conference, May 31 - June 3, Vancouver, pp 10.

Ward S.M., Day S. (2010): The 1958 Lituya bay landslide and tsunami – A tsunami ball approach. Journal of Earthquake and Tsunami, Vol. 4, No. 4, 285-319.