Lake Tsunamis: Causes, Consequences and Hazard investigated in a multidisciplinary project

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Context

In public perception, tsunamis are still related to marine settings and to earthquakes as direct triggers. However, tsunamis, which are generated by a sudden displacement of the water column, can occur in every aquatic system. The most prominent cases in Switzerland are:

- 563 AD tsunami wave in Lake Geneva caused by a rockfall-induced delta-collapse. Modelled wave heights reached up to 8 m.
- 1584 AD tsunami in Lake Geneva generated by an earthquake-triggered Rhone delta failure.
- 1601 AD tsunami wave in Lucerne due to earthquake-triggered sublacustrine slope failures and a rockfall at Bürgenstock. Wave heights reached 4 m in Lucerne.

The goals of this project are to understand governing mechanisms of genesis and propagation of tsunamis in lakes. Through a multidisciplinary approach involving limnogeologists, seismologists, geotechnical specialists, hydraulic engineers and hazard specialists, we are developing key concepts and factors relevant for causes and consequences of these tsunamis (Fig. 2). To reach these goals, five Work Packages (WP) exist: WP response, WP delta, WP wave, WP paleo and WP hazard.

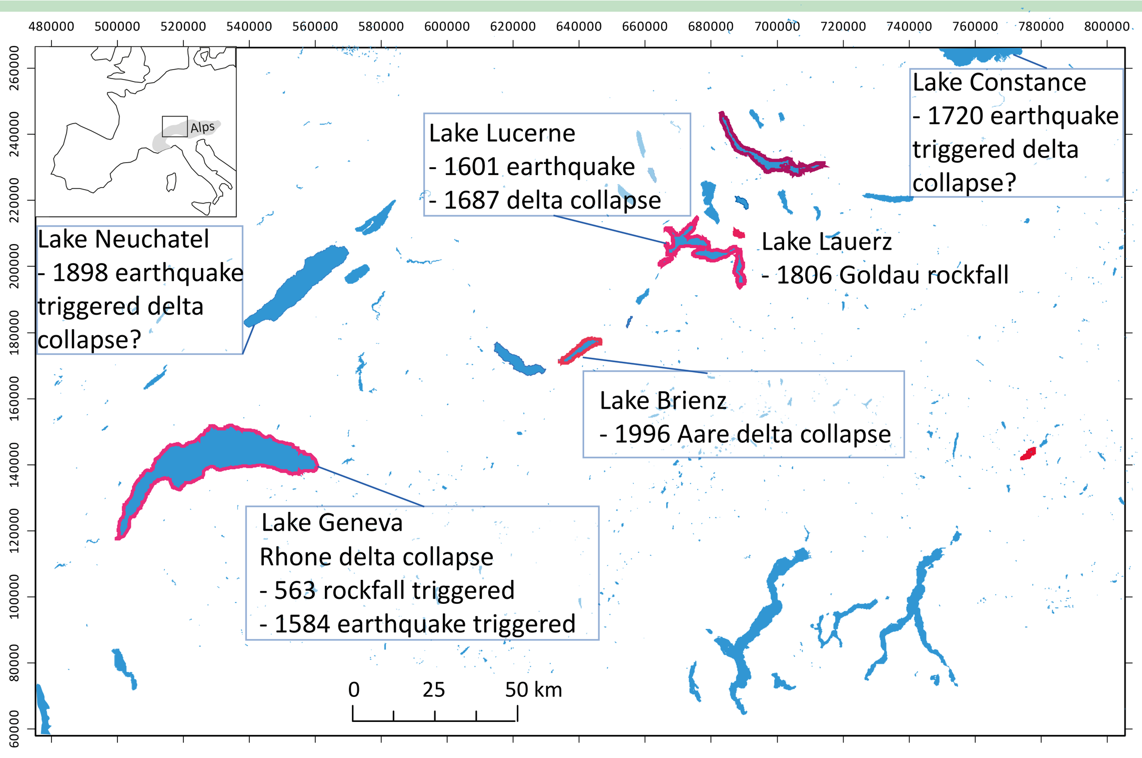

Figure 1: Historical Swiss tsunamis and their causes that have been documented in written archives. Lakes marked with a red line will be used as case study in this project in one or more work packages.

Project description

Chat time 4th of May at 16:15-18:00 D2060

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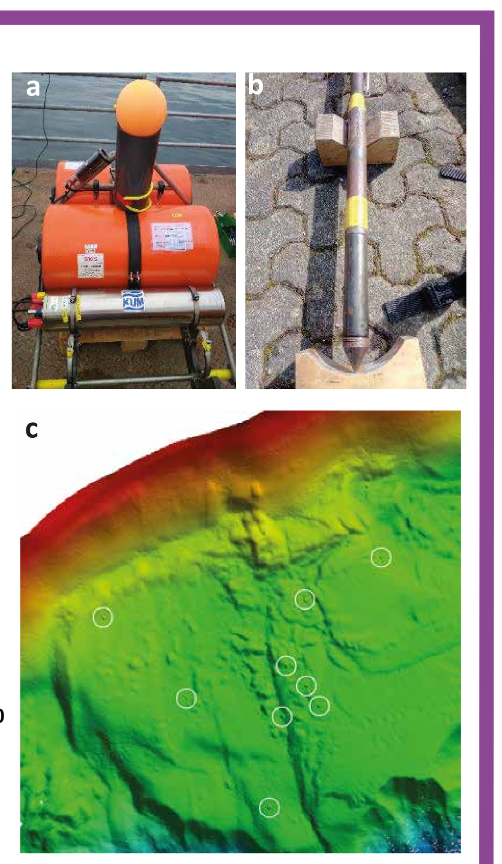
WP response

Goals:
- Evaluate the sediment-mechanical characteristics
- Estimate the volume of potentially mobile sediments
- Estimate the stability of sediments under seismic shaking

Methods:
- Ocean bottom seismometer record the seismic signal (mainly ambient vibrations and earthquake monitoring)
- Cone Penetration Test (CPT) measurements are used to define the geotechnical characteristics of the sediment.
- A new instrument combines standard OBS and piezo meter probes.



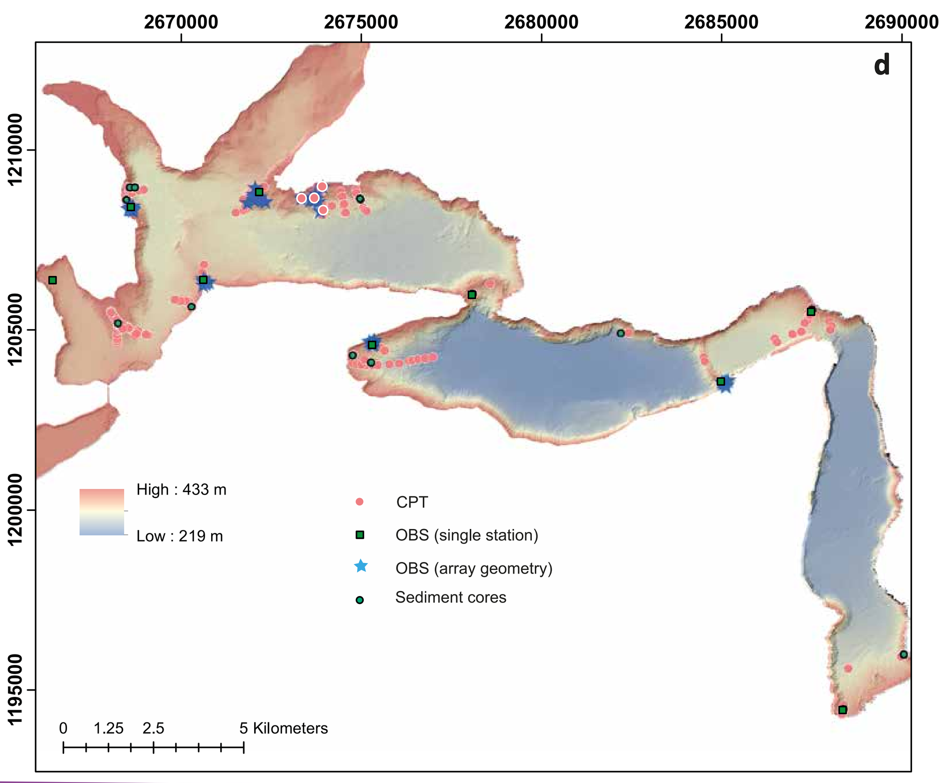


Figure 3: a) OBS - b) CPTu - c) Identification of OBS array geometry with multibeam bathymetry-

sediment mechanical characteristics & sediment volumes

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WP wave

Goals:
- Determine the governing wave generation and propagation processes in a narrow and confined lake basin.
- Select a numerical model that allows for a sufficiently detailed and efficient prediction of runup heights and inundation depths.
- Provide a set of experimental data for numerical model validation.

Methods:
- Laboratory experiments (Fig. 4) to allow a better insight into the underlying physical processes and act as a benchmark for simulation models.
- Numerical modelling to compute tsunami scenarios for entire lakes at prototype scale (Fig. 5)

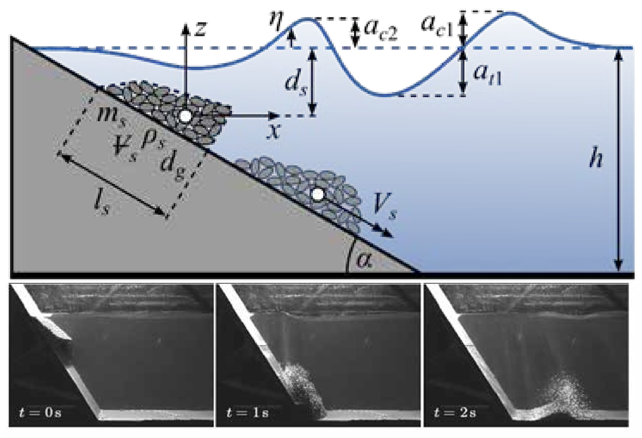


Figure 4: Wave generation by a subaqueous landslide in the VAW laboratory.

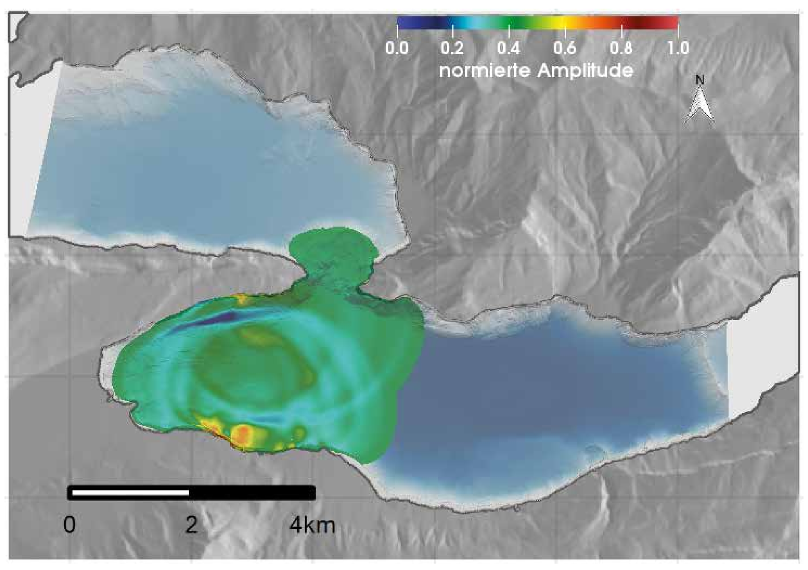


Figure 5: Numerical simulation of wave propagation

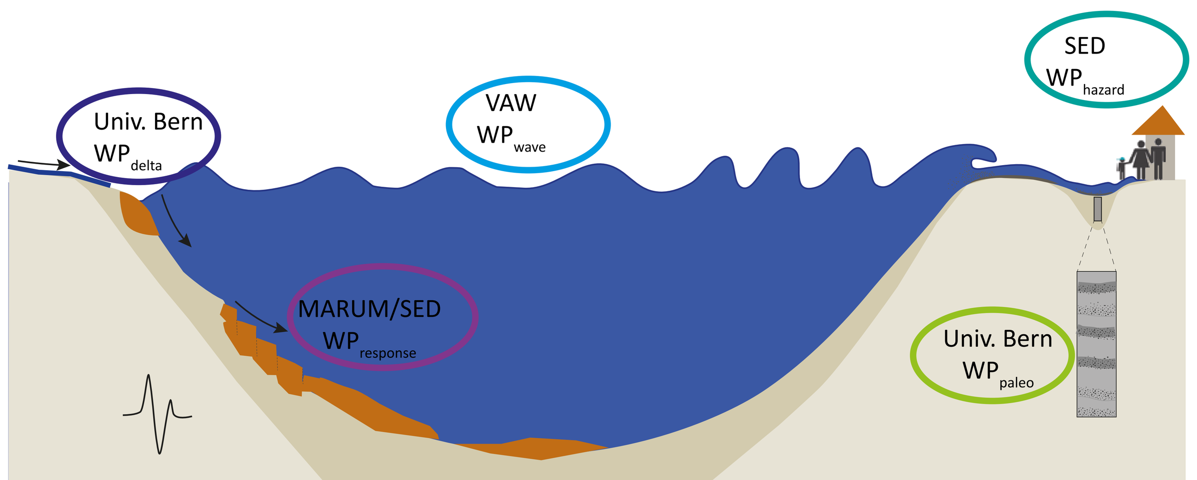


Figure 2: Sublacustrine mass movements (at deltas or hemipelagic slopes) do generate tsunamis. This sketch shows the lake-system approach adopted in this project and the focus of the different research sub-projects. The institutes responsible for the individual work packages are also mentioned.

inundation extend & flow characteristics -> calibration of the model

sediment-mechanical characteristics of deltas

WP delta

Goals:
- Understand the causes of delta collapses
- Distinguish between delta collapse turbidites and other turbidites (floods)

Methods:
- Repeated multibeam bathymetry surveys of deltas
- Sediment cores (in different lakes such as Lake Lucerne and Lake Brienz; Fig. 6)

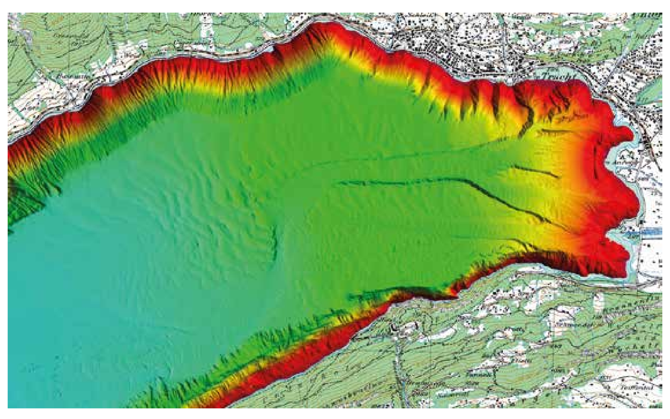
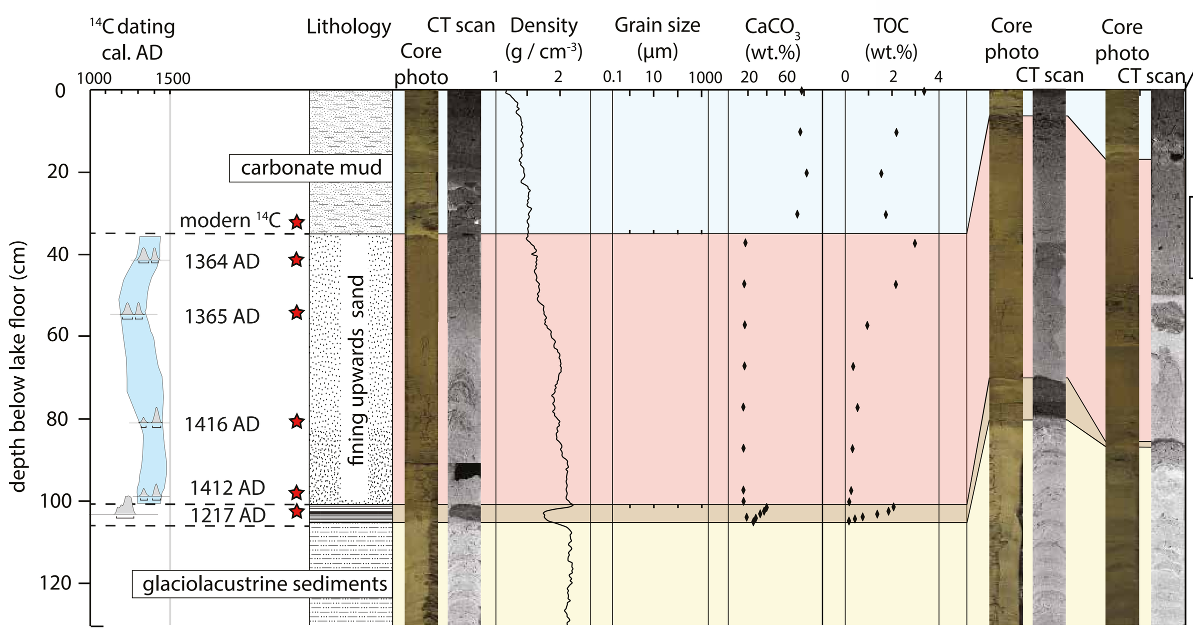


Figure 6: Multibeam bathymetry map of the Aare delta that collapsed in 1996.

WP paleo

Goals
- Identification of lake tsunami deposits

Methods:
- Sedimentological analysis on on- & off-shore sediment cores (Fig. 7)



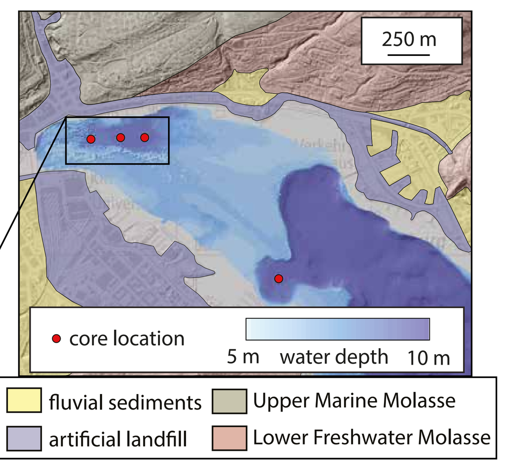


Figure 7: Right: Sediment core location at Lake Lucerne (Bay of Lucerne). Left: Transect along recovered sediment cores show a fining upwards sand sequence. Based on radiocarbon dating of coniferous needles, the fining upward sandois interpreted to be reworked and deposited during the 1601 Lake Lucerne tsunami.

Modelling of high risk areas in greater detail

Frequency of delta collapses? - delta stability model

Frequency of tsunamis

WP hazard

Goals:
- Evaluate the tsunami potential of Swiss lakes
- Produce a first generation of intensity maps for relevant return periods (case studies for some lakes such as Lake Lucerne, Lake Brienz, Lake Zurich, Lake Constance, Fig. 8)
- Evaluate the technologies related to warning

Methods:
- Simple classification of the tsunami potential on Swiss lakes, using geospatial analyses
- Creation of conceptual workflow for the rapid estimation of the tsunami hazard (Strupler et al. 2019)
- Probabilistic modelling of tsunami effects

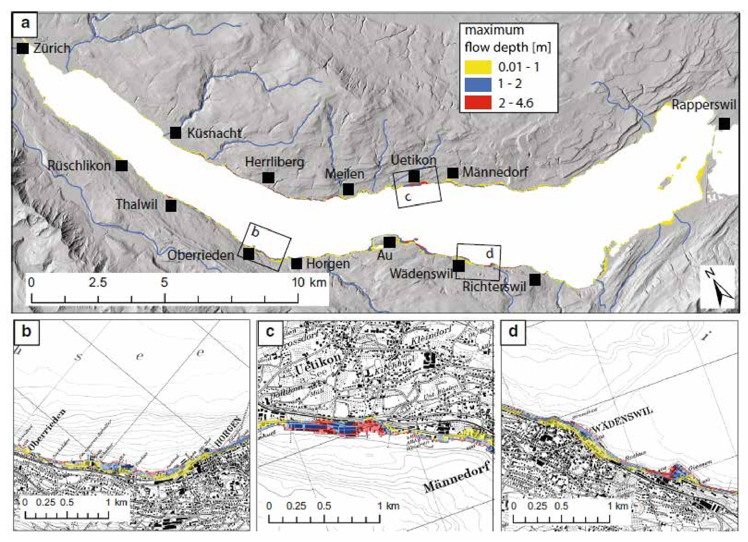


Figure 8: Example of the flow depth alongshore Lake Zurich, calculated for tsunamis that are expected to be caused by landslides triggered by earthquakes with an occurrence probability of 0.5% in 50 years (Strupler et al. 2018, Swiss Journal of Geosciences)

References
Strupler, M., Anselmetti, F. S., Hilbe, M., Kremer, K., and Wiemer, S. (2019). A workflow for the rapid assessment of the landslide-tsunami hazard in peri-alpine lakes. Geol. Soc. London, Spec. Publ.

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