Parametric Sub Bottom Profiler Measurements of the Subaquatic Portion of the Debris Fan of Gschliefgraben in Lake Traunsee, Austria

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SUMMARY

In winter 2007 a landslide at the shore of lake Traunsee endangered a road as well as about 45 houses. A failure of the sub aquatic portion of the debris fan was considered as a potential risk. A monitoring and an early-warning system had been developed and established in order to know the actual state of the movements and to characterize the behavior of the Gschliefgraben.

In this paper the application of the parametric sub bottom profiler (SBP) for high-resolution sediment echo sounding of the sub aquatic portion of the debris fan will be described. The work had been carried out in the framework of Innomar's Student Project 2013, an initiative of the German manufacturer of electronics and software for the marine and offshore business. Beside the SBP-survey a second ship surveyed the area of the mass movement deposit with a multi-beam echo sounder.

In the surveyed mass movement deposit, zones of different reflectivity could be identified up to 15m subsurface with the parametric sub bottom profiler. Side scan images of the debris fan surface collected at 600 kHz near the shore line - up to 40 m depth – show a high level of detail and may deliver additional information for further morphological investigations.

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1. BACKGROUND

The Gschliefgraben valley is situated on the eastern shore of Lake Traunsee in Upper Austria, at the northern rim of the Eastern Alps (Figure 1). During the last centuries, several landslides were recorded in the Gschliefgraben resulting in major events, which occur nearly periodically every 100 years, the last one in 1910. In the course of these enormous mass movements, even settlements were pushed into Lake Traunsee [2]. Geologists found out that the mass movements are caused by less permeable clayey-silty layers, which slide on more permeable silty-sandy-pebbly ones [1]. Especially after repeatedly wet and rainy periods, a huge amount of water soaks into the ground and leads to a diminished friction between the layers.

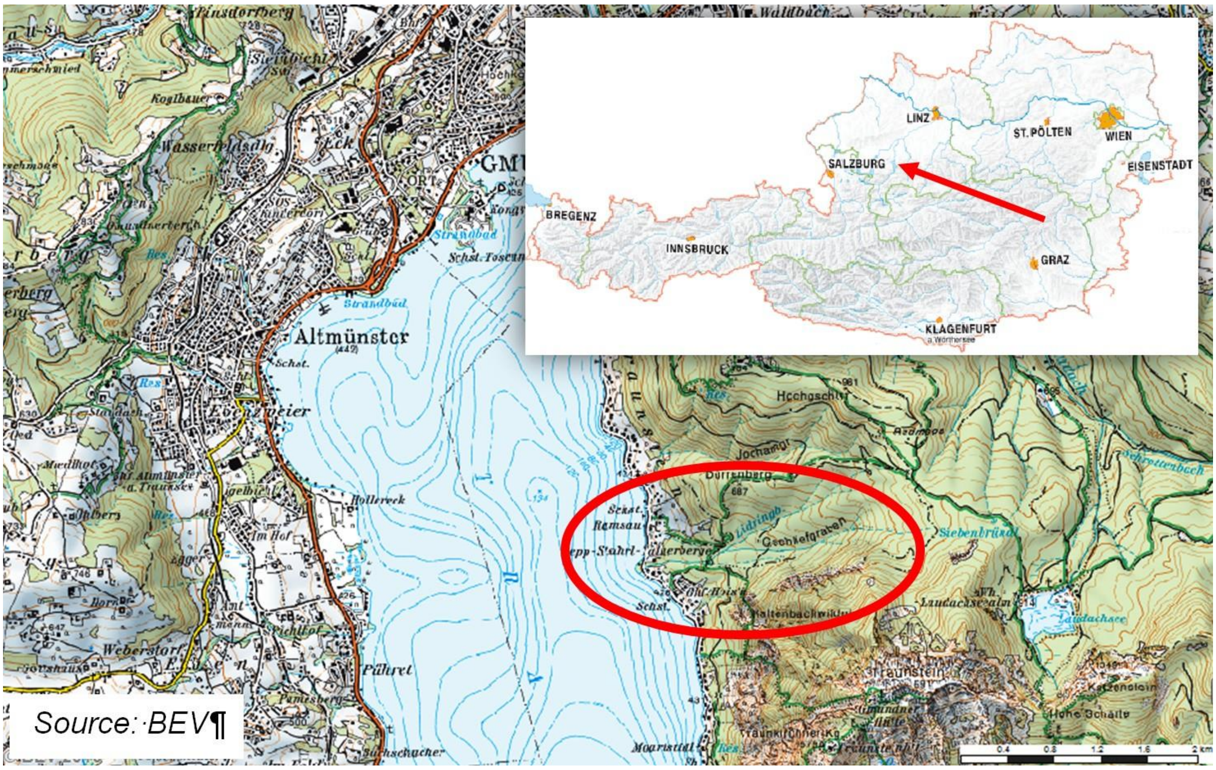

Figure 1: Location of the landslide area of Gschliefgraben at Lake Traunsee

The last major event took place in winter 2007. Due to humid weather, a mudslide of 22 ha in area and of 4 million m³ in volume was reactivated. As the mudslide moved with a maximum displacement velocity of 4.7m/day, it endangered a road as well as about 45 houses which were located at the alluvial fan. Thus, the Austrian service for torrent, erosion and avalanche control executed several mitigation measures (e.g. installation of drainages and trenches, removal of material, construction of wells), which led to a deceleration of the process, thus the mudslide is in a stable condition [1]. A failure of the sub aquatic portion of the debris fan was considered a potential risk, but the results of echo sounding measurements in January, February, May and December 2008 showed only local erosion and a general, minor accumulation at the flanks of the fan, no signs of a large-scale failure could be detected [2]. A monitoring and an early-warning system had been developed and established in order to know the actual state of the movements and to characterize the behavior of the Gschliefgraben in the near future.

2. MOTIVATION

In 2013 a bathymetry case study at Lake Traunsee had been initiated due to new kinds of hydrographic survey equipment capable of providing substantially higher data density, resolution and accuracy than the traditional sounding methods.
The aim of this ongoing project is to explore the usability of different bathymetric systems for monitoring the subaquatic portion of the debris fan, which includes:

- Multibeam echo sounding (MBES) for a precise mapping of the topography
- Side scan sonar imaging (SSS) for high resolution imaging of the lake floor and
- Parametric sub bottom Profiler (SBP) for surveying the sediment structure.

In this paper the application of the parametric sub bottom profiler (SBP) for high-resolution sediment echo sounding of the Gschliefgraben will be described. The work had been carried out in the framework of Innomar's Student Project 2013, an initiative of the German manufacturer of electronics and software for the marine and offshore business. The first and the second author of this paper had been selected out of 20 participants to be supported by the company with a SES-2000 parametric sub-bottom profiler and side scan sonar system to perform the scientific survey.
The main objectives of the SBP survey were to determine:

- if it is possible to acquire highly accurate bathymetry and sediment data with this parametric sub-bottom profiler, in particular as the slope is fairly steep
- if critical zones, which might reactivate the mass movement, can be discovered
- if the data can be used for monitoring purposes.

Beside the SBP-survey a second ship surveyed the area of the mass movement deposit with a multi-beam echo sounder (Fig.2). This survey had been realized in cooperation of our department and VERBUND Austrian Hydro Power AG (VHP), the owner of the MBES survey vessel.

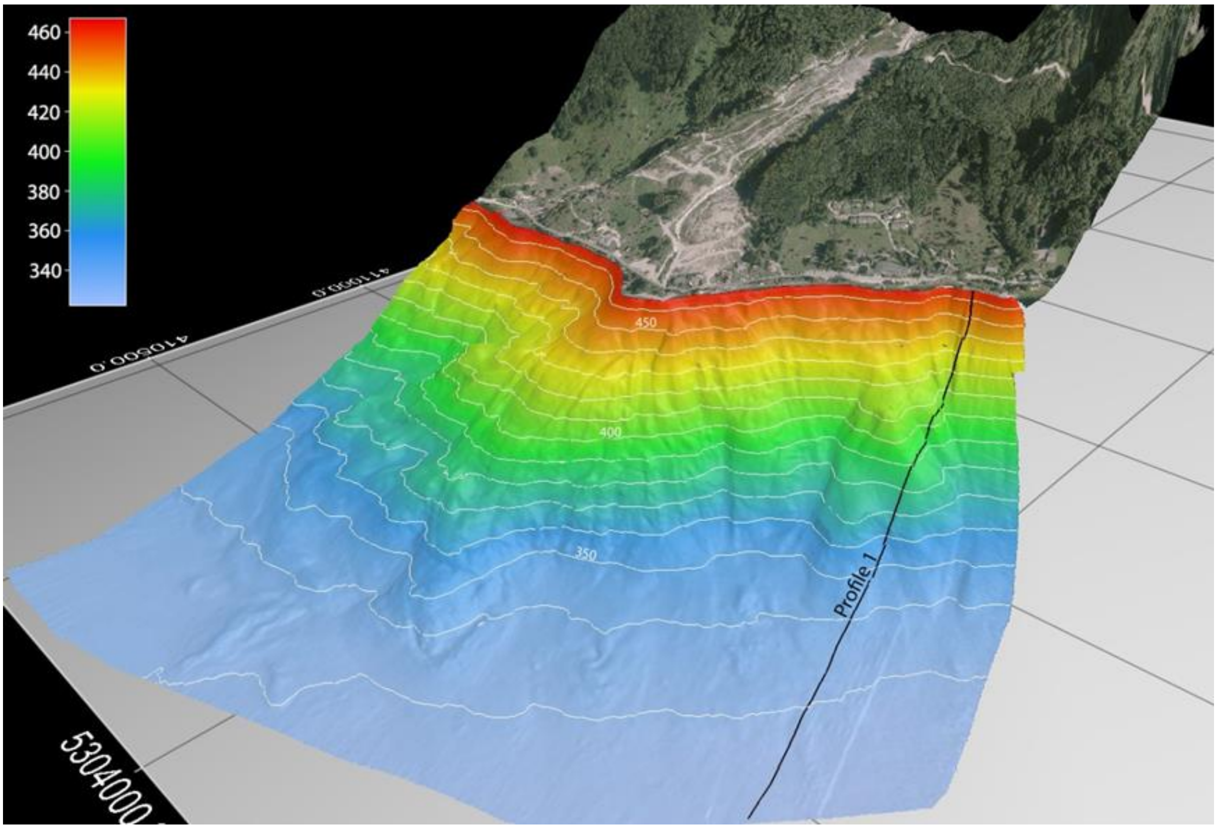

Figure 2: Visualization of the debris fan of Gschliefgraben based on multi-beam echo sounder and airborne laser scan data

3. DATA ACQUISITION AND DATA PROCESSING

The field work of the survey of the debris fan was carried out in April 2013. The survey vessel had been equipped with the following measuring instruments (Fig.3):

- Innomar's SES-2000 light plus combined sub-bottom profiler and side scan sonar system
- Innomar's inertial measurement unit MRU-Z
- One GPS rover, which worked with virtual reference stations, provided by BOKU
- Two additional GPS antennas to determine the ship's heading
- Valeport's sound velocity profiler owned by BOKU
- Additionally a narrow beam 200kHz single beam echo sounder (Kongsberg EA400)

After installing the system components at the survey vessel, the calibration process of the hydrographic surveying unit had to be undertaken. For this purpose profiles at areas with differing depth were surveyed, due to the fact, that the height of subaquatic portion of the debris fan is about 140m. This procedure was supervised by Mr. Jens Lowag from Innomar because of its complexity (for unexperienced users) and the risk of producing wrong results.

Figure 3: Arrangement of the instruments at the survey vessel

For navigation purposes, a grid consisting of perpendicular and parallel lines to the coast line, was created and imported into the hydrographic data acquisition, navigation and processing software package QINSy. All in all, 60 lines perpendicular and five lines parallel to the coast as well as three side scan lines along the coast were surveyed, covering in total an area of approximately 800 m times 600. Some of the profiles were measured in both directions in order to discover and eliminate remaining errors of the sensor calibration. Furthermore, sound velocity profiles were recorded each day of the survey.
The frequencies used for sub-bottom profiling were 10 kHz for penetrating the lake bed and 100 kHz for water depth calculations. In contrast to the side scan line farther away from the coast, which was recorded with 400 kHz, the signals for the side scan images closer to the coast were emitted at two frequencies of 400 kHz and 600 kHz with the aim of benefiting from different side scan resolutions.
The post-processing of Innomar's data was carried out with the computer programs ISE and Simple Side Scan Processor, respectively. With regards to the measurements of the parametric SBP system, the following procedure was performed for each file:

1) The water depth was calculated based on the high frequency (100 kHz) data. Each profile was corrected according to the corresponding sound velocity profile and outliers (spikes) were manually edited.
2) The echograms of the processed low frequency data (10 kHz) were geo-referenced and stored as vertical image (curtain), where the image is not flat but follows the track of the ship that collected the imagery. This type of visualization class is very useful for imaging the vertical cross-section of the sediment subsurface.
3) To be able to compare the results of the bathymetry of 2013 with those from previous measurements, the height provided by GNSS system (ETRS89) had to be translated to the national reference sea level given by the water level of Lake Traunsee was used

instead of the. Also the horizontal coordinate system was converted from UTM 33N to the Austrian coordinate system GK M31.

4) In a final step, data from three different sources (sub-bottom profiler, single beam echo sounder and multi-beam echo sounder) were merged and displayed with the help of the 3D Visualization and Analysis Software Fledermaus (Fig.4).

4. RESULTS

Regarding the water depth calculation, there is just a marginal difference between the depth calculated with Innomar's SES-2000 light plus system and the one based on Kongsberg's EA 400. Also the data fits perfectly in the bathymetry layer, which was created with the help of the multi-beam echo sounder's information. Thus, it can be assumed that all three measuring systems provide highly accurate bathymetry data, although the survey region's gradient was rather steep (within approximately 500 m from the coast line, the water depth increased from circa 2 m up to nearly 140 m).

Innomar's SES-2000 light plus also provides detailed sub-bottom profiles from the debris fan. In general it was possible to identify three zones in the mass movement deposit (Figure 4):

- The upper part (from water level to ca. 60 m) consisting of highly reflective material (red colour in echogram) with a layer thickness of up to 5 m.
- The middle part (from ca. 60 m to ca. 130 m), which is made up of less reflective material (solid rock, blue colour in echogram) characterized by morphological distortions in which layers of sediments could be found in basins.
- The lower part (below ca. 130 m) with stratified sediment layers in which the signal could penetrate the bottom up to 15 m.…

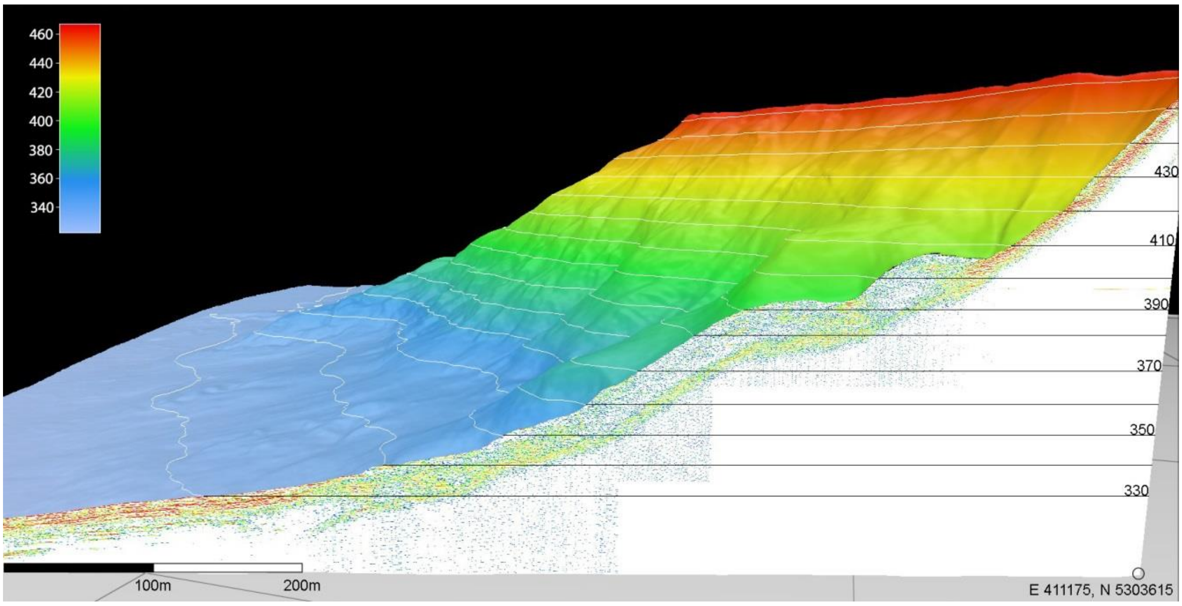

Figure 4: Sub-bottom profiler echogram of Profile 1 embedded in the multi-beam echo sounder image (vertical exaggeration factor 2)

CONCLUSION

At the subaquatic portion of the debris fan it was possible to acquire highly accurate bathymetry and sediment layer information with Innomar's SES-2000 light plus measuring system. In the surveyed mass movement deposit, zones of different reflectivity could be identified up to 15m subsurface. Side scan images of the debris fan surface collected at 600 kHz near the shore line - up to 40 m depth – show a high level of detail and may deliver additional information for further morphological investigations.

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