Cycles and events: Frontiers in explorations

Underwater landscapes
The last frontier of geomorphologic explorations
Flavio Anselmetti, Michael Hilbe, Stéphanie Girardclos, Katrina Kremer, Steffen Niemann, Martin Wessels, Walter Wildi
Lago Maggiore: Maggia Delta and Ticino Delta

Resolution: 1-2 orders of magnitudes difference!

High-quality bathymetry is not just about grid-resolution. It changes fundamentally the understanding of subaquatic surface processes.
The beginnings: Early efforts in bathymetric mapping

Depth soundings Lago Maggiore (1926)
Lac Léman as hotspot of developments of acoustic methods

1822: Jean-Daniel Colladen, Charles-François Sturm

The flash from the ignition was observed 10 miles away and compared with the arrival of the sound from the bell underwater heard through a trumpet-like device in the water.

In spite of these crude instruments, they managed to determine that the speed of sound under water was 1435 m/s

Acoustic revolutions in bathymetric mapping

Single-beam echosounding

Multibeam echosounder «swath bathymetry»
2007: First multibeam-bathymetric survey in Switzerland

2008: Final report of a pilot project

Bathymetric Untersuchungen in Schweizer Seen
Lever bathymétrique des lacs Suisses
Preliminary / Präsichterichts
…this was just the beginning: The new ‘cycle’ with state-of-the-art equipment
Multibeam echosounding: the data- and workflow

Simrad Kongsberg equipment with Caris software
Calculation of digital bathymetric model using sonar data

Raw data from sonar

- Model of speed of sound in water column
- Motion of ship: motion sensor, roll, pitch, and heading
- Position: GPS with Swipos-GIS/GEO (real time)

XYZ-data

- Filters, removal of bad data
- Gridding

Depth model (grid data)

- e.g. reprojection in various reference systems

Acoustic velocity in water = f (T, salinity)
Example Lake Van: Water stratification (temperature)
Water-column profiles from 2 weeks surveying Lago Maggiore

Example pilot survey Lake Lucerne

52 km² in 15 Tagen
Current status Lake Lucerne bathymetry after merging of different data vintages

Surveying not only produces morphologic data…
Our main goal: **BATHYMETRY DATA**
- Lake/oceanfloor science: processes at all spatial and temporal scales (incl. ultra high-resolution subaquatic geodetic surveys (using beacon networks), to identify tectonic lake/seafloor deformations)

Applied issues with scientific aspects
- Natural hazards (rock slides, mass movements, coastal collapses, earthquake studies)
- Waste issues (waste deposits, ammunition, tar, etc.)
- Engineering aspects (stabilities, shore constructions, etc.)
- Ship traffic (port bathymetries, navigation routes, shoaling processes, etc.)
- Natural resources (gravel and sand in deltas)
- Time series of bathymetry changes (coastal erosion, delta-progradation)
- Sedimentation processes in reservoirs
- Underwater archeological sites
- Leisure activities (mainly divers)

Examples natural hazards: Lake Zurich - Oberrieden slides
Analogy: snow avalanche

Photo: Rainer Hesse

Example Lake Lucerne
Gersau Basin Lake Lucerne
(Hilbe et al., subm.)

Traces of a magnitude 5.9 earthquake of AD1601

Engelberger Aa

Gersau basin, reflection seismic profiles
(Data by Michael Hilbe)

Engelberger Aa

total thickness

volume: ~ 50 x 10^6 m^3
area: ~ 4 km^2

0 m
209 m
Earthquake-triggered subaquatic slide as tsunami-creator
(Animation SRF)

Mass-movement and tsunami model
combine existing & freely available codes that use simplifications
use 2D models (depth averaged) on regular grids
more or less similar to other existing (published) models

Baggeroer et al. 2009

Berger et al. 2011

Governing equations: massmouv2D

\[ \frac{\partial h}{\partial t} + \frac{\partial (hu)}{\partial x} + \frac{\partial (hv)}{\partial y} = 0, \]
\[ \frac{\partial h}{\partial t} + \frac{\partial (hu)}{\partial x} + \frac{\partial (hv)}{\partial y} = -c_s \left( \frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2} \right), \]
\[ \frac{\partial \eta}{\partial t} + \frac{\partial (\eta u)}{\partial x} + \frac{\partial (\eta v)}{\partial y} = 0. \]

Governing equations: GeoClaw

\[ \frac{\partial h}{\partial t} + \frac{\partial (hu)}{\partial x} + \frac{\partial (hv)}{\partial y} = 0, \]
\[ \frac{\partial (hu)}{\partial t} + \frac{\partial (hu^2 + \frac{1}{2} rh^2)}{\partial x} + \frac{\partial (huv)}{\partial y} = 0, \]
\[ \frac{\partial (hv)}{\partial t} + \frac{\partial (huv)}{\partial x} + \frac{\partial (hv^2 + \frac{1}{2} rh^2)}{\partial y} = 0. \]
Model of mass movement (max height: 35 m) (Data by Michael Hilbe)

**Parameters**
- Rheology: Bingham viscous
- Density: 800 kg/m³
- Yield stress: 20 Pa
- Dynamic viscosity: 10 Pa s
- Internal friction angle: 15°

**Results**
- Max. velocity: 33 m/s
- Max. height: 35 m

Model of tsunami wave (max height: 10 m) (Data by Michael Hilbe)
Tsunamogenic megaslides in Lac Léman (Kremer et al., 2012)

5 km

Possible inundated area

Supplementary Figure 6: Possible inundated zone in Geneva for an 8 m wave. Aerial photographs (SITG Geneva) of Geneva showing regions that would have been submerged by an 8 m tsunami. Inundated regions were estimated (Kremer et al., 2012)

Tauredunum Event, 563 AD
Volume > 0.25 km$^3$
Rhone-channel bathymetry in Lac Léman (Sastre et al., 2010)

The Rhone channel walls photographed onboard the FA Forel submersible by Jean-Pierre Vernet in 1982 (Girardclos et al., 2012)
Comparison of multibeam-bathymetry maps of the Rhone main delta channel from February 2008 and March 2012 (Girardclos et al., 2012)
Differences in 2008 and 2012 data (Girardclos et al., 2012)
Add-on survey: Geoid measurements (Measuring of lake level using GPS)

Alain Geiger, Markus Rothacher
Inst. für Geodäsie u. Photogrammetrie ETH Zürich

Tiefenschärfe: Preliminary coverage status October 2013
Classified and sensitive data in Lake Constance – to be masked!

Pflanzenschutzmittel: Gift-Anschlag auf Bodensee-Wasserversorgung


27. Oktober 1933:
Steam ship Helvetia is drowned in Lake Constance in 200 m water depth
Lake Constance – Shallow-water areas to be mapped with airborne Lidar

Received Echo Signal

Surface Return

Bottom Return

New Airborne Scanner

Green Wavelength

Water Surface

Quelle: AWM
Lake Constance – Shallow-water areas to be mapped with airborne Lidar

Data then will be merged with multibeam data
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