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'Unterer Eisbodensee' - a good example for the future evolution of glacial lakes in Austria?

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Abstract

Lake Unterer Eisbodensee, located in Stubach Valley, Hohe Tauern National Park, Austria, is a good example for one of the most visible consequences of climate change in high alpine areas, i.e. the formation of glacial lakes. The visual appearance of its 1.66 km² catchment has, due to glacier retreat, dramatically changed since the lake first appeared at the terminus of Stubacher Sonnblickkees in 1987.

Repeated terrestrial laser-scanning and bathymetry using dGPS and echo-sounders mounted on an inflatable boat, showed that the lake doubled its surface area to 6,6 ha between 2010 and 2016 and the lake's calculated maximum extension, based on subglacial DEMs interpolated from GPR data and bathymetry in 2011, has now almost been reached.

During the same time span, the volume almost multiplied fourfold whilst the maximum depth increased from 20.4 m to 27.1 m. The volume of the lake will gradually be reduced by sediment input in the next decades, but due to the gneiss bedrock and the morphology of the catchment, not as fast as other newly-emerged glacial lakes e.g. Obersulzbach See, which first appeared in 1989.

Time series from the automatic gauging stations have shown a slight change in discharge and temperature patterns since the beginning of observations in 2002. This is mainly due to a reduced proportion of the glaciated catchment area. In order to investigate alterations in the pristine freshwater system, repeated hydro-biological probing will be carried out in the future.

Keywords

Glacier retreat, glacial lake, climate change, hydrology, discharge, sediment, Hohe Tauern

Introduction and aim

Monitoring and analysing the water cycle of glaciers and lakes in high alpine regions is, amongst others, one of the main tasks of the Hydrological Service, especially as lakes and headwaters are faced with severe environmental changes at present e.g. rising water temperatures and possible discharge regime changes.

New proglacial lakes, like Unterer Eisbodensee, can also have a great influence on the downstream geomorphological system, due to discharge modifications, decoupling effects, sediment trapping and long-term sediment storage.

They also represent the development of new pristine freshwater ecosystems and therefore, hydro-biological probing and monitoring was also of interest in the multidisciplinary monitoring programme.

Study site

Unterer Eisbodensee, located in the Hohe Tauern Range (Eastern Alps) in the south of the Province of Salzburg, lies within the boundaries of Hohe Tauern National Park. Stubacher Sonnblickkees, a small east-facing slope glacier with an actual size (2016) of 0.93 km² compared to 1.7 km² in the 8Os, has an important influence on the lake's hydrology.

The first signs of this new proglacial lake appeared in 1987 and in 1990 it was surveyed and outlined on the map 'Granatspitze' scale 1: 5000 (SLUPETZKY 1997).

In 2009 around 70 percent of the lake's total catchment area of 1. 66 km² was covered by glaciers (WIESENEGGER & SLUPETZKY 2009).

Methods

Several interdisciplinary methods were used to monitor and analyse the various ongoing processes at Unterer Eisboden See:

- Geodetic survey to determine lake surface area (1994)
- Repeated terrestrial laser-scanning (since 2003)
- Repeated GPS surveys of the terminus of Stubacher Sonnblickkees and the shoreline of Unterer Eisboden See (since 2003)
- Simple bathymetry by means of a perpendicular (1998)
- Bathymetry using dGPS and echo-sounders mounted on an inflatable boat (2010; 2016)
- Subglacial DEMs based on ground penetrating radar (GPR) measurements of SSK (2010)
- Water temperature, conductivity, water level and discharge registration at automatic gauging stations (since 2002)
- Hydrobiological sampling to assess biocenosis and ecosystem development (2010)

Results

Due to glacial retreat of Stubacher Sonnblickkees, the proglacial lake has continuously increased its size (Fig. 1) and volume since it first appeared in 1987 (Tab. 1).

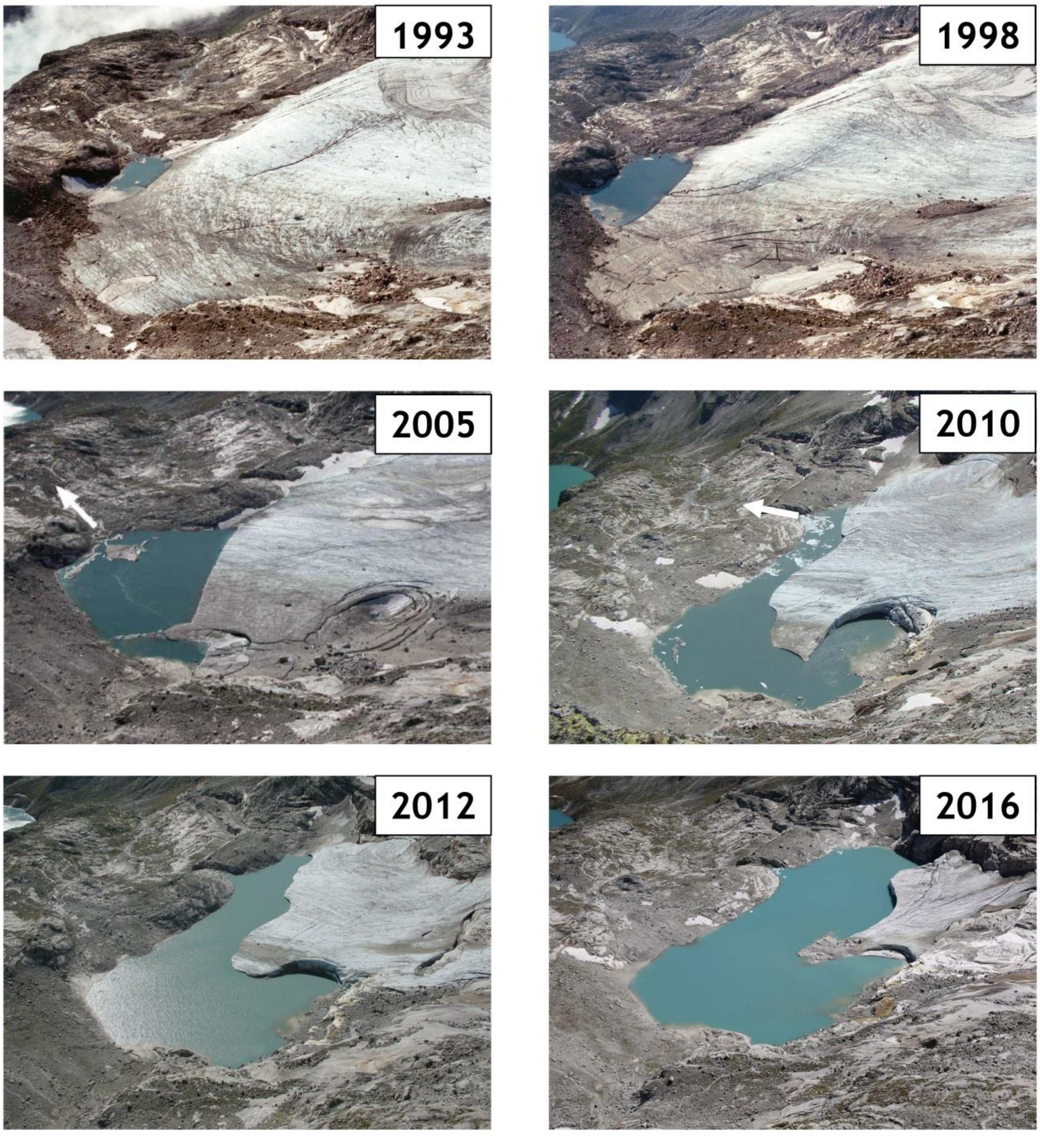

Figure 1: Spatio-temporal evolution of Unterer Eisboden See within the proglacial zone of the Stubacher Sonnblickkees (view to south-east). Note the change of outflow location between 2005 and 2010

	1994	1998	2005	2010	2016
max. length [m]	80	132	200	370	436
max. width [m]	30	62	125	206	210
area [ha]	0.470	0.627	1.90	3.10	6.6
max. depth [m]		7.8		20.3	27.1
volume [m³]		12,340		138,550	551,500

Table 1: Temporal development of characteristic figures of Unterer Eisboden See

The original hydrological system of Unterer Eisbodensee was rather complex, with two outlets (Eislbach, Keesbach) at different levels. In July 2006 a glacier outburst flood (GLOF) lowered the lake's surface by approx. 6 m and shifted the outlet to its present and steady position (WIESENEGGER & SLUPETZKY 2009).

Results of the 2016 bathymetry (KUM 2016) show, that the calculated maximum extension of Unterer Eisbodensee, based on subglacial DEMs interpolated from GPR data and bathymetry (GEILHAUSEN 2011) has almost been reached (Fig. 2).

Parameter	2010	Bedrock model	Sediment model	2016
max. shoreline [m]	1,362	1,480 (+111/-45)	1,495 (+7/-5)	1420
max area [m²]	31,050	74,790 (+644/-991)	71,730 (+802/-824)	66,100
max. depth [m]	20.3	22.3 (+-/0.4)	22.3 (+-/0.4)	27.1
max volume [m³]	**138,550**	**533,900** (+3920/-7735)	**497,130** (+5510/-5760)	**551,500**

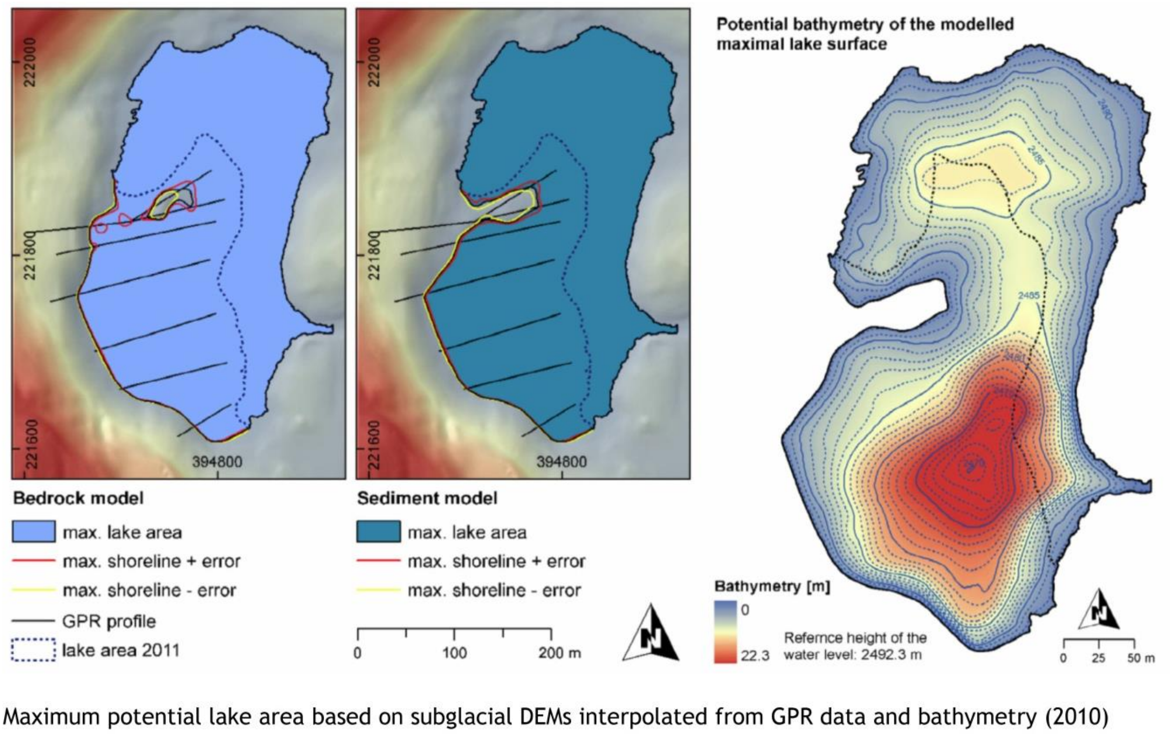

Figure 2: Unterer Eisbodensee potential development calculated 2010 compared to present situation

Between 2010 and 2016, the lake doubled its surface area, its volume almost multiplied fourfold and the maximum depth increased from 20.4 m to 27.1 m (Fig. 3).

Hydrological observations, which started in 2002, at 3 automatic gauging stations, show a slight change in discharge and temperature patterns, due to a reduced proportion (approx. 56 % in 2016 compared to approx. 70 % in 2009) of the glaciated catchment area.

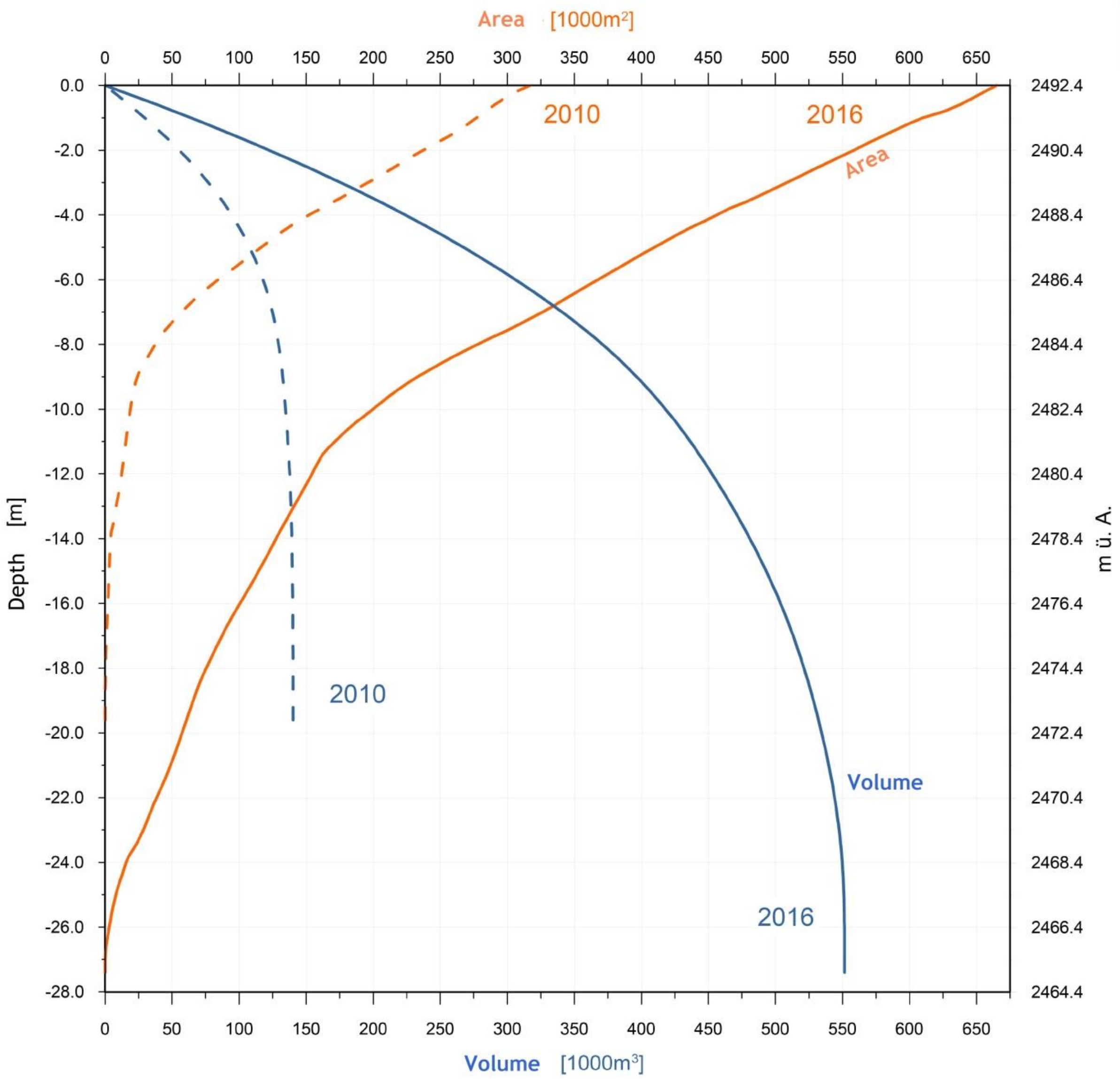

Figure 3: Unterer Eisbodensee – comparison of characteristic figures: max. depth, surface and volume

Conclusions and perspectives

In its genesis up to the present state, Unterer Eisboden See has shown interesting hydrological behaviour and it took some time to understand the ongoing processes (subglacial drainage, shift of outlets, glacier outburst flood, rhythmical water level changes etc.). The lake has now almost reached its potential maximum size and volume with its permanent outlet water level situated at 2,493 m.a.s.l.

The volume of the lake will gradually be reduced by sediment input in the next decades, but due to the gneiss bedrock and the morphology of the catchment, not as fast as other newly emerged glacial lakes e.g. Obersulzbach See, which first appeared in 1989. The results of the 2016 measurement campaign, showing no essential sedimentation, underline this assumption and repeated bathymetry surveys in the future (every 5 years) are planned to check this process.

The hydrological monitoring, in order to analyse changes in the lake's behaviour, will be prolonged and hydrobiological monitoring and sampling will be repeated every 5 years.

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