Conference Volume	6th Symposium for Research in Protected Areas 2 to 3 November 2017, Salzburg	pages 89 - 91

The formation of glacial lakes in Austria and in the Hohe Tauern National Park since the Little Ice Age

Johannes Buckel[1], Jan-Christoph Otto[1], Günther Prasicek[1,2], Markus Keuschnig[4]

[1] University of Salzburg, Department of Geography and Geology, Salzburg, Austria
[2] Department of Earth Surface Dynamics, University of Lausanne , Lausanne Switzerland
[3] GEORESEACH Forschungsgesellschaft mbH, Wals, Austria

Keywords

glacial lake, lake inventory, lake distribution, lake formation, Little Ice Age, Austrian Alps

Introduction

The Global temperature rise in the 20th and 21st century led to massive deglaciation and the formation of numerous glacial lakes. One obvious indication for the global warming and high changing rates can be observed in rapid deglaciation in the European Alps (HAEBERLI & BENISTON, 1998; PAUL et al., 2007). The glaciated area is reduced by 50% since the end of the little Ice Age (LIA) until 2000 (ZEMP et al., 2006). The areas under rapid changes are directly influenced by creating new landscapes. Glacier lake development and lifetime are controlled by the complex interplay of climate and geological boundary conditions, geomorphological process activity and glacier dynamics. New lakes in formerly glaciated alpine areas significantly contribute to changing geomorphologic, hydrologic and ecologic conditions at high altitudes. New glacial lakes deserve a closer look referring to their different functions in high alpine environment, especially in terms of global warming.

High alpine lakes are responsible for retention and buffering of (SCHIEFER & GILBERT, 2008). In terms of sediment connectivity (HECKMANN & SCHWANGHART, 2013) geomorphic systems are decoupled within by glacial lakes by preventing coarse sediment transport. Especially sediment delivery is extremely reduced to suspended and solute sediment load (GEILHAUSEN et al., 2013). Also glacial lakes function as sediment traps, if the kind of damming (e.g. bedrock) is persistent. But glaciated high mountain environment is well known as unstable and sensible to climate (HAEBERLI & BENISTON, 1998; HAEBERLI et al., 2013), because of destabilization through melting processes.

We present an inventory of lakes in the Austrian Alps (> 1700 m a.s.l.). The inventory is a central part of the project FUTURELAKES that aims at understanding and modelling the development of glacier lakes in Austria. We intersect glacier lake locations with glacier inventory data to understand how deglaciation controls lake evolution (Figure 1).

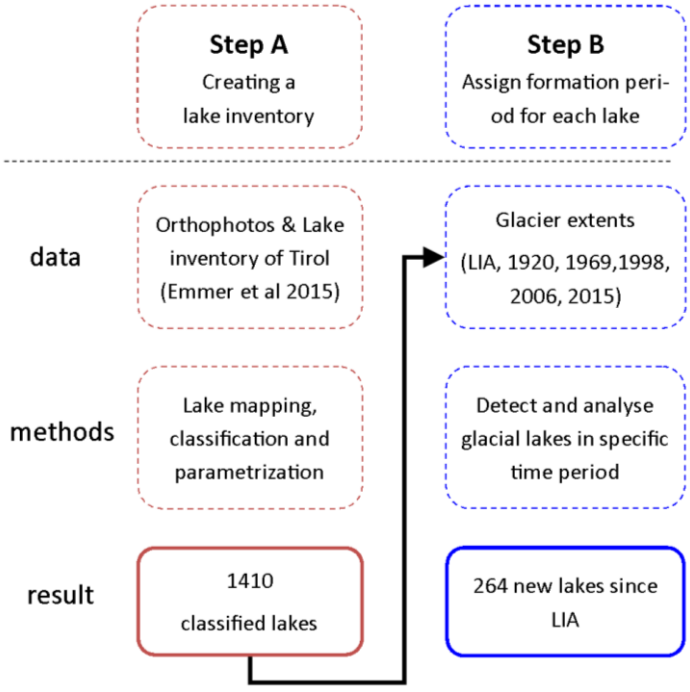

Figure 1: workflow to analyse historical lake formation in Austria

Methods

The timing of lake formation is reconstructed by comparing emerged lake area with vanished glacier area at six points in time from Little Ice Age (LIA) to 2015 – a unique timespan not covered by any other glacier lake inventory worldwide. Deglaciated area and volume for Austria is given by four different Glacier inventories (LIA, 1969, 1998, 2006 by FISCHER et al., 2015). Additional information for glacier extent around 1920 is given by (GROß, 1987) and was validated by historical maps. A recent glacier extent (2015) was mapped on google earth imagery.

The lake inventory contains 1410 mapped lakes with a minimum size of 1000 m² covering an area of more than 17 km². All lakes were classified according to their damming material (bedrock, debris, ice, Tab. 1). The dominant lake type is bedrock-dammed (55.1%), followed by debris-dammed lakes (44.5%). Six lakes ice-dammed lakes have been observed during the time of mapping in Austria. Bedrock-dammed lakes store two-third of lake water area above 1700 m a.s.l..

material	Number (percentage) of lakes	sum area [km²]
bedrock	777 (55.1)	11.51
debris	627 (44.5)	5.61
ice	6 (0.4)	0.04

Table 1: Dam types of glacial lakes in Austria

Results

In Austria, 264 lakes have formed since LIA. Both the total number of glacial lakes and total lake area increased exponentially from LIA to 2015, while glacier area shrunk correspondingly. The number of new lakes per year grew from 0.8 (LIA-1920) to 6.5 (2006-2015) and new lake area per year increased from 7,423 m² (LIA-1920) to 78,534 m² (2006-2015).

Within the National Park Hohe Tauern 309 lakes have been mapped (Figure 2). Equally, bedrock-dammed lakes prevail over debris-dammed lakes. Lake formation dynamics are slightly lower in the National Park area compared to the entire Austrian Alps with a seven-fold increase of new lakes per year since the LIA. In contrast to the picture from the entire Austrian Alps, in the Hohe Tauern region lake formation peaked in the period of 1998-2006 and stagnated or slightly decreased in the most recent period (Tab. 2).

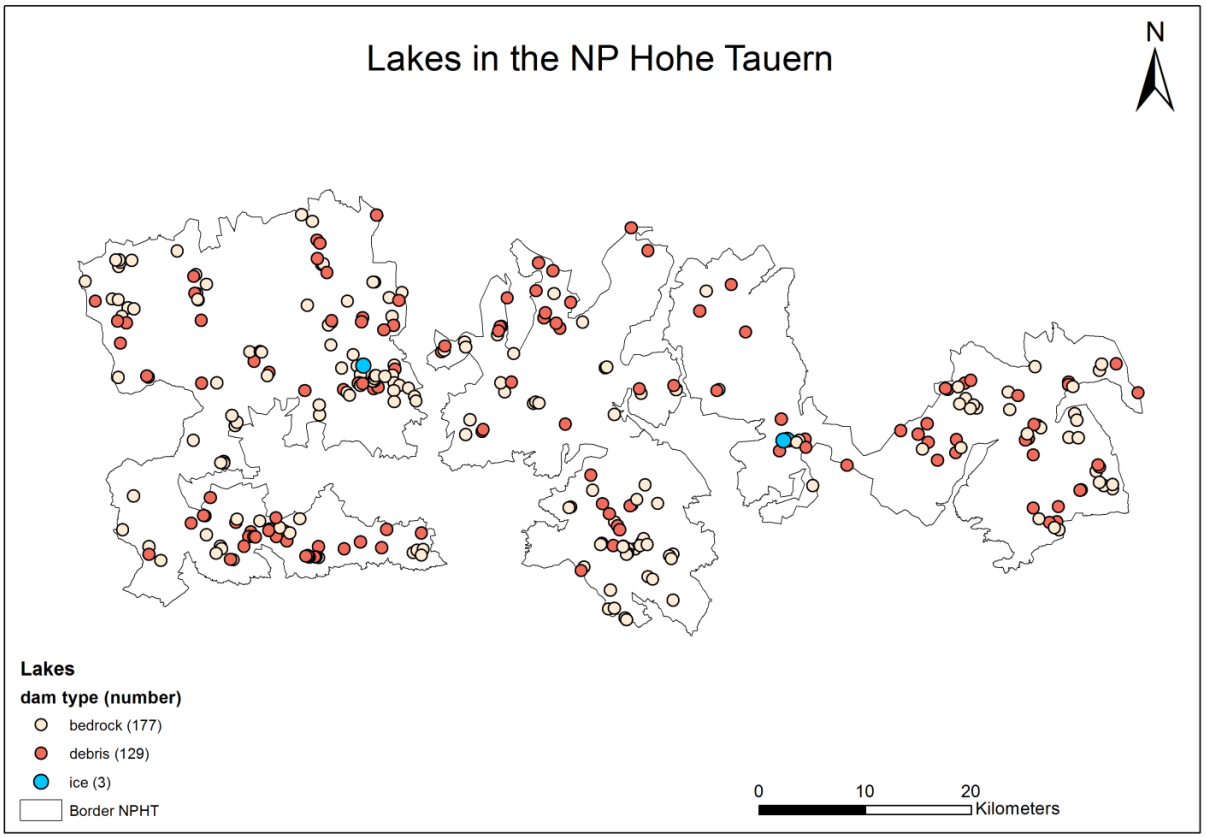

Figure 2: Lakes in the NPHT, classified by dam type

	1850-1920	1920-1969	1969-1998	1998-2006	2006-2015
n lakes	18	27	19	19	20
new lakes per year	0.3	0.5	1.5	2.4	2.2

Table 2: Lake formation over different time periods

Conclusion

We analyzed the formation of glacial lakes in the Austrian Alps combining a detailed lake inventory with an extensive record of glacier retreat since LIA. The formation of glacial lakes reflects glacier erosional and depositional dynamics in the study area. From LIA to 2015 264 new glacial lakes developed following glacier retreat and rising temperatures. Lake formation has been subject to constant acceleration throughout the entire observation period in Austria. This observation is in concordance with glacier retreat and can be related to increasing positive temperature trends within the last 35 years. Within the National Park Hohe Tauern, lake formation peaked in the early 2000s and stagnated since then. We consider the lake inventory a valuable database for further analysis ranging from applications in hazard research and hydrology to hydropower generation or other fields.

References

FISCHER, A., SEISER, B., STOCKER-WALDHUBER, M., MITTERER, C. AND ABERMANN, J., 2015. The Austrian Glacier Inventories GI 1 (1969), GI 2 (1998), GI 3 (2006), and GI LIA in ArcGIS (shapefile) format. In: A. FISCHER (Ed.), Supplement to: FISCHER, ANDREA; SEISER, BERND; STOCKER-WALDHUBER, MARTIN; MITTERER, CHRISTIAN; ABERMANN, JAKOB (2015): Tracing glacier changes in Austria from the Little Ice Age to the present using a lidar-based high-resolution glacier inventory in Aust. PANGAEA, 10.1594/PANGAEA.844988.

GEILHAUSEN, M., MORCHE, D., OTTO, J.-C. AND SCHROTT, L., 2013. Sediment discharge from the proglacial zone of a retreating Alpine glacier. Zeitschrift für Geomorphologie, Supplementary Issues, 57(December 2012), 29-53.

GROß, G., 1987. Der Flächenverlust der Gletscher in Österreich 1850-1920-1969. Zeitschrift für Gletscherkunde und Glazialgeologie, 23(2), 131-141.

HAEBERLI, W. AND BENISTON, M., 1998. Climate change and its impacts on glaciers and pemafrost in the Alps. Ambio, 27(4), 258-265.

HAEBERLI, W., HUGGEL, C., PAUL, F. AND ZEMP, M., 2013. Glacial Responses to Climate Change. In: J.F. SHRODER (Ed.), Treatise on Geomorphology. Academic Press, San Diego, pp. 152-175.

HECKMANN, T. AND SCHWANGHART, W., 2013. Geomorphic coupling and sediment connectivity in an alpine catchment - Exploring sediment cascades using graph theory. Geomorphology, 182, 89-103.

PAUL, F., KÄÄB, A. AND HAEBERLI, W., 2007. Recent glacier changes in the Alps observed by satellite: Consequences for future monitoring strategies. Global and Planetary Change, 56(1–2), 111-122.

SCHIEFER, E. AND GILBERT, R., 2008. Proglacial sediment trapping in recently formed Silt Lake , Upper Lillooet Valley , Coast Mountains , British Columbia. Earth Surface Processes and Landforms, 33, 1542-1556.

ZEMP, M., HAEBERLI, W., HOELZLE, M. AND PAUL, F., 2006. Alpine glaciers to disappear within decades? Geophysical Research Letters, 33(13), 6-9.

Contact

Johannes Buckel
johannes.buckel@sbg.ac.at
University of Salzburg
Department of Geography and Geology
Hellbrunnerstr.34
5020 Salzburg
Austria