Geophysical Research Abstracts
Vol. 21, EGU2019-9208, 2019
EGU General Assembly 2019

Lake volume and mean depth estimation from a large bathymetry data set in the Cordillera Blanca, Peru

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Glacier lake research is motivated by their potential for water storage on the one hand, and their potential for glacier lake outburst floods (GLOF) on the other hand. Most of these lakes are located in remote places, with difficult access, limiting their monitoring through remote sensors. Therefore, most glacier lake inventories include only basic characteristics such as area, length and width, whereas bathymetric information, such as mean depth and volume, typically are missing.

In this regard, several ways to estimate the lake mean depth and volume have been developed in the literature, most approaches use lake area to estimate mean water depth and volume. These area –depth relations are established on the basis of lake depth measurements, and most previous studies are based on small data sets of around 20 lakes from very diverse regions and dam types.

In Peru, the Unidad de Evaluación de Glaciares y Lagunas (UEGL) of the National Water Authority (ANA), has been responsible for the monitoring of glaciers and glacier lakes. Since its creation in 1941, the office has done measurements for glacier and glacier lake inventories including a large number of bathymetric studies on selected lakes. To date, detailed bathymetric measurements are available for 250 different glacier lakes in Peru, out of which 121 are located in the Cordillera Blanca. The lakes were selected according to their water storage potential or hazard level for downstream inhabitants. Here, we present this unique bathymetry data set of the Cordillera Blanca with detailed information obtained between 2005 and 2016, which make this the most extensive data set in the world.

We use this large data set to establish new relations between different topographic lake characteristics (area, length, width, elongation) and measured mean lake depths, and compare the performance of different existing empirical relations for mean depth and volume estimations. Furthermore, we use these findings to estimate the mean depth, volume and peak discharge for the entire, remote, sensing based lake inventory of the Cordillera Blanca (860 lakes), including an assessment of related uncertainties.

We found that the total water volume of all glacier lakes in the Cordillera Blanca is about 1.5 x 109 m3. These results provide information about the order of magnitude of the water volume storage for water resources management. However, our findings also indicate that lake volume cannot be accurately estimated from 2D lake parameters, entailing uncertainties of up to $\pm$50% for estimates of individual lake mean depth and volumes due to high variability of lake morphometry.