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Thicknesses and volumes of glaciers in the Andes of Peru estimated with satellite data and digital terrain information

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The glaciers in the tropical Andes of Peru have been melting at an unprecedented rate in recent years and generally after the Little Ice Age, a cold period that lasted from the 16th to the 19th century. Knowledge of glacier thicknesses and volumes is necessary for evaluating possible future scenarios of glacier shrinkage and of water supply to the Andean populations under conditions of continued warming.
Calculation of glacier volumes for 19 mountain ranges in Perú has been based on two ice- thickness modeling methods including an area-related approach with different parameterizations and a slope-dependent approach. Both methods allow for rapid treatment of regional data obtained from satellite imagery and a Digital Elevation Model, integrated into a Geographic Information System. In addition, glacier outlines were obtained from the glacier inventory compiled by the Unit of Glaciology and Water Resources (UGRH) - National Water Authority (ANA) that used satellite imagery (ASTER, SPOT and LISS III from 2003 to 2010) and topographic information acquired from the cartography of the National Geographical Institute (IGN).
The volume-area scaling approach resulted in glacier volume of 35.00 km3 and a total volume of 34.39 km3 resulted from the slope-dependent thickness with a thickness approximately 30 m. Estimated results also show a loss of the total ice surface $\sim$42% and glacier volume loss about $\sim$38% in both methods based on the first Glacier Inventory of Peru (from aerial photographs 1962 -1970) performed by HIDRANDINA SA. The results also indicate that volume estimations are subject to large uncertainties.
Field measurements of glacier thickness are scarce and locally restricted due to rugged topography, high altitude and heavy crevassing of glaciers. Possibilities of calibrating and validating the applied model approaches are therefore limited. New possibilities nevertheless come into play with slope-dependent approaches, which lead beyond area-related average thicknesses but enable calculation of detailed bed topographies as a function of local surface slopes as contained in DEMs. Such detailed bed topographies in turn make it possible to directly compare local measurements, for instance with ground penetrating radar, with calculated local ice thicknesses. This step is underway now in view of providing important information to decision makers for adapting to the evolution of landscapes, water resources and natural hazards in the Andes of Peru with their rapidly shrinking glaciers.