Geophysical Research Abstracts
Vol. 12, EGU2010-10856-1, 2010
EGU General Assembly 2010

Airborne LiDAR based Mapping of Alpine Permafrost Distribution

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Recent global climate change findings show an acceleration of melting of glaciers, ice-sheets and ice caps. Extended remote sensing and in-situ measurements demonstrate that glaciers are losing mass at an increasing rate. In contrast to glaciers with large mass losses (about 5 m per year at the lower parts of the glacier tongue of Hintereisferner, Ötztal Alps, Tyrol, Austria), moderate to small changing rates (centimetres to decimetres per year) characterize the surface variations caused by permafrost degradation in high mountain areas. For a reliable mapping of the spatial permafrost distribution advanced remote sensing techniques with a high degree of vertical accuracy have to be applied.

Recent studies have shown that airborne LiDAR survey in mountainous regions provide high-resolution spatial data with a vertical accuracy range of centimetre to decimetre. This prediction is based on a world wide unique dataset of 18 airborne LiDAR campaigns covering the Hintereisferner region . Furthermore, the according multi-temporal dataset offers the opportunity to identify surface changes (altitudinal changes) outside glaciated areas, which have not been observed until now. Excluding gravitational induced processes these altitudinal changes have to be assigned to alpine permafrost degradations, although detailed information from prominent permafrost features like rock glaciers are missing. Beyond the detection of the climate induced permafrost degradation, based on the multi-temporal LiDAR data set, the method (point based and avoiding point to raster conversions) will be applied to identify altitudinal changes and displacement rates of prominent rock glaciers in the Stubai and Ötztal Alps (Tyrol, Austria). In contrast to the multi-temporal approach, with at least one LiDAR terrain model per ablation period (June to September), the analysis of the rock glacier features is based on a data set of only two LiDAR campaigns, which were carried out with a time shift of four years (2006 and 2009 respectively).

The very high vertical and horizontal accuracy of airborne LiDAR derived digital terrain models is expected to yield greater precision of permafrost distribution and its changes as derived from existing modelling approaches and enables the exploration of novel approaches in methodology (modelling) and mapping products. Both, the methodology progress as well as the advanced mapping products will give new impetus on climate change impact research. The authors present the error estimation, which is the basis for the subsequent analysis, as well as the results of the LiDAR based investigation on altitudinal changes of perennial alpine permafrost as well as of rock glaciers and their displacement rates, which are about ten times smaller then displacement rates of alpine glaciers.