Conference Volume | 3rd Symposion of the Hohe Tauern National Park for Research in Protected Areas | pages 15-18
September 15th to 17th, 2005, Castle of Kaprun

Monitoring modification of alpine environments: New techniques and perspectives

Michael Avian [1,3], Arnold Bauer [2], Gerhard Lieb [1]
(1) Institute of Geography and Regional Sciences, University of Graz
(2) Institute of Digital Image Processing, JOANNEUM Research, Graz
(3) Institute of Remote Sensing and Photogrammetry, University of Technology, Graz

Abstract

The modification of high alpine environments due to climate warming was a topic of increasing importance of research in the 90`s of the last century and is the main objective of research in recent years. Several disciplines use different techniques to draw a comprehensive picture of environmental dynamics. Terrestrial laser scanning is a quite new technique for monitoring glaciers and natural hazards. The ability to acquire high-resolution 3D data of surface structures makes long-range laser scanners a very interesting instrument for measuring geomorphodynamics. The Pasterze glacier in the Hohe Tauern National Park (Central Alps, Austria) is object of a comprehensive monitoring network beginning in 1879. Since the middle of the last decade the glacier retreat increases dramatically, as a consequence a massive modification of the proglacial areas is in progress. To quantify these landscape dynamics with an accurate resolution, terrestrial laser scanning has been used the last years beginning in 2001. In 2004 we started to increase the temporal resolution with two measurements in the summer period to get a better picture of the interannual ablation dynamics.

Keywords

Pasterze Glacier, Terrestrial laser scanning, Landscape modification, Climate change

Introduction and objectives

The Pasterze Glacier (Glockner Mountains, Central Alps) represents the longest glacier in the Eastern Alps and is located S of the main crest of the Hohe Tauern Range (12°44'E, 47°04'N). The glacier`s dimension changed from 1852 to 2002 as follows: length 11.4km to 8.4km (-26%) and area 26.5km² to 18.5km² (-30%). First measurements observing changes at the glacier terminus were carried out by Ferdinand Seeland beginning in 1879 (SEELAND 1880) leading to one of the longest records of annual measurements in the Alps. Annual measurements are carried out in the last decades within the framework of glacier measurements coordinated by the Austrian Alpine Association (OeAV) which now include (a) location of glacier terminus, (b) surface velocity, and (c) surface elevation changes (e.g. WAKONIGG & LIEB 1996). The dramatic loss of ice in the last decades is documented in a comprehensive modification of this alpine environment which is furthermore made available for public in form of the nature trail "Gletscherlehrweg", new adapted and reopened in 2004 (LIEB & SLUPETZKY 2004). Quantification of these changes such as spatial measurements of glacier surface changes are a primary task in the last 20 years with new remote sensing techniques using photogrammetric analyses (e.g. KAUFMANN & LADSTÄTTER 2004), Airborne laserscanning (e.g. GEIST et al. 2003) and radar-interferometry (e.g. KAUFMANN et al. 2005). This article discusses first results of annual terrestrial laserscanning campaigns beginning in 2001 within the monitoring of the glacier tongue of the Pasterze. This monitoring network furthermore consists of additional annual GPS measurements of glacier outline and profile points.

Methods

For the past few years, terrestrial 3D laser scanning (TLS) systems have been employed very successfully in the design and manufacturing industries as well as in industrial surveying (PFEIFER et al. 2004). Further development in terms of measurement speed, accuracy, range, field-of-view, and data sampling rate allow TLS to be applied in terrain surveying (BAUER et al. 2001, 2004, and 2005). The ability to acquire high-resolution 3D data of surface structures makes this technique a very interesting instrument for measuring glacier (AVIAN et al. 2005, KELLERER-PIRKLBAUER et al. 2005) as well as rock glacier dynamics (BAUER et al. 2003, 2005). The integrated measurement

Contribution received at: 08.08.2005

system is capable of describing 3D motion and deformation of glacier surface within a single day's measurement campaign including logistics and evaluation. It is a time-of-flight system that measures the elapsed time of the pulse emitted by a photo-diode until it returns to the receiver optics. Maximum range depends on the reflectivity of surface (which is very good for snow and rock covered terrain), and atmospheric visibility (best for clear visibility, bad for haze and fog). A measuring range of up to 2000m allows hazardous sites to be easily measured from a safe distance. Since each single measurement consists of a multitude of laser-pulses, different measurement modes ("first pulse", "last pulse", "strongest pulse") give proper results even on bad weather conditions and surfaces that may otherwise lead to ambiguous measurements like vegetated, moist or roughly structured terrain.

Single time-of-flight measurements with distance accuracy of better than 5 cm are automatically combined to a measurement grid. Although the data generated by the measurement devices can in principle be directly used for measurement and further visualization, several methodological, technical, and logistic problems are to be encountered when establishing an integrated monitoring system. In case of the Pasterze area this method was selected due to several reasons and advantages: the steep terrain is unfavourable for airborne or satellite data resulting in a better resolution of terrestrial data, a perfect accessibility keeps costs low respectively.

For scanner parameters and values of the used instrumentation cf. Tab.1 in KELLERER-PIRKLBAUER et al. 2005 in this volume.

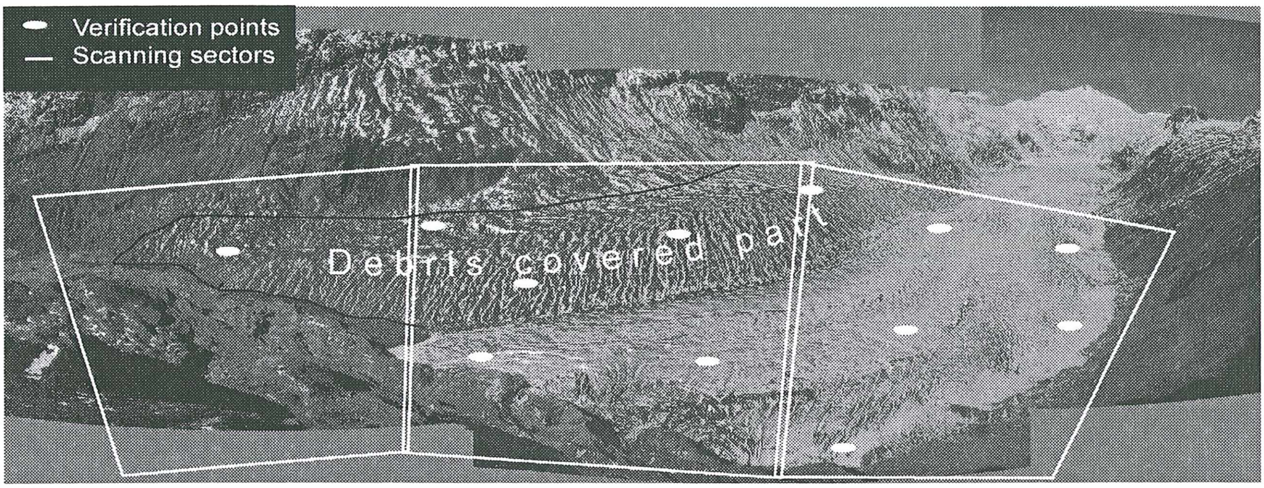

Fig. 1: Situation and scanning sectors (Image: KELLERER-PIRKLBAUER 2003)

Results

Mass losses and deglaciation were successfully measured five times resulting in four data-sets of surface elevation changing rates (xy-resolution 1m, z-resolution 5cm). As expected from simultaneous tachymetric measurements all data sets show a clear trend in spatial distribution of glacier retreat. There is a significant distribution of mass loss from the SW to the NE which also increases towards the glacier terminus on the bare ice glacier part. Quantitative rates begin with about -2m/a on the right boundary increasing to ~-4.5m/a at the boundary of the two glacier parts. Here we can observe a clear leap in mass loss difference between the two obviously different glacier parts from ~-1.5m/a in the upper part to more than -3m/a in the lowest part where absolute rates of ~-7m/a occur. Debris cover with a thickness of at least 5cm is a significant protection against incoming short wave radiation (cf. BENN & EVANS 1998, NAKAWO et al. 2000, KELLERER-PIRKLBAUER et al. 2005, in this volume) as well as less potential radiation in the summer period due to the shadowing effect of the adjacent Großglockner ridge may be a reason as well.

Near the left boundary of the entire glacier the ice body is beginning to collapse in several areas. The lowermost event is already visible in the last years with a dramatic landscape modification near the fenced off touristic area. Following the glacier upwards two further small basins are developing with a distance of 500m. The sinking of the surface occurs with rates of -7.5 to -8.0m/a in 2001/02 and increased to -9.2 to -9.5m/a in 2003/04, 2.0 -2.5m/a above the sinking rates of the surrounding areas. The lower part of the adjacent slope facing to the "Gamsgrubenweg" is also getting increasingly unstable which is observable in mass losses already above dead ice. This part has not been measured consequently in the last years, no comparable rates are calculated.

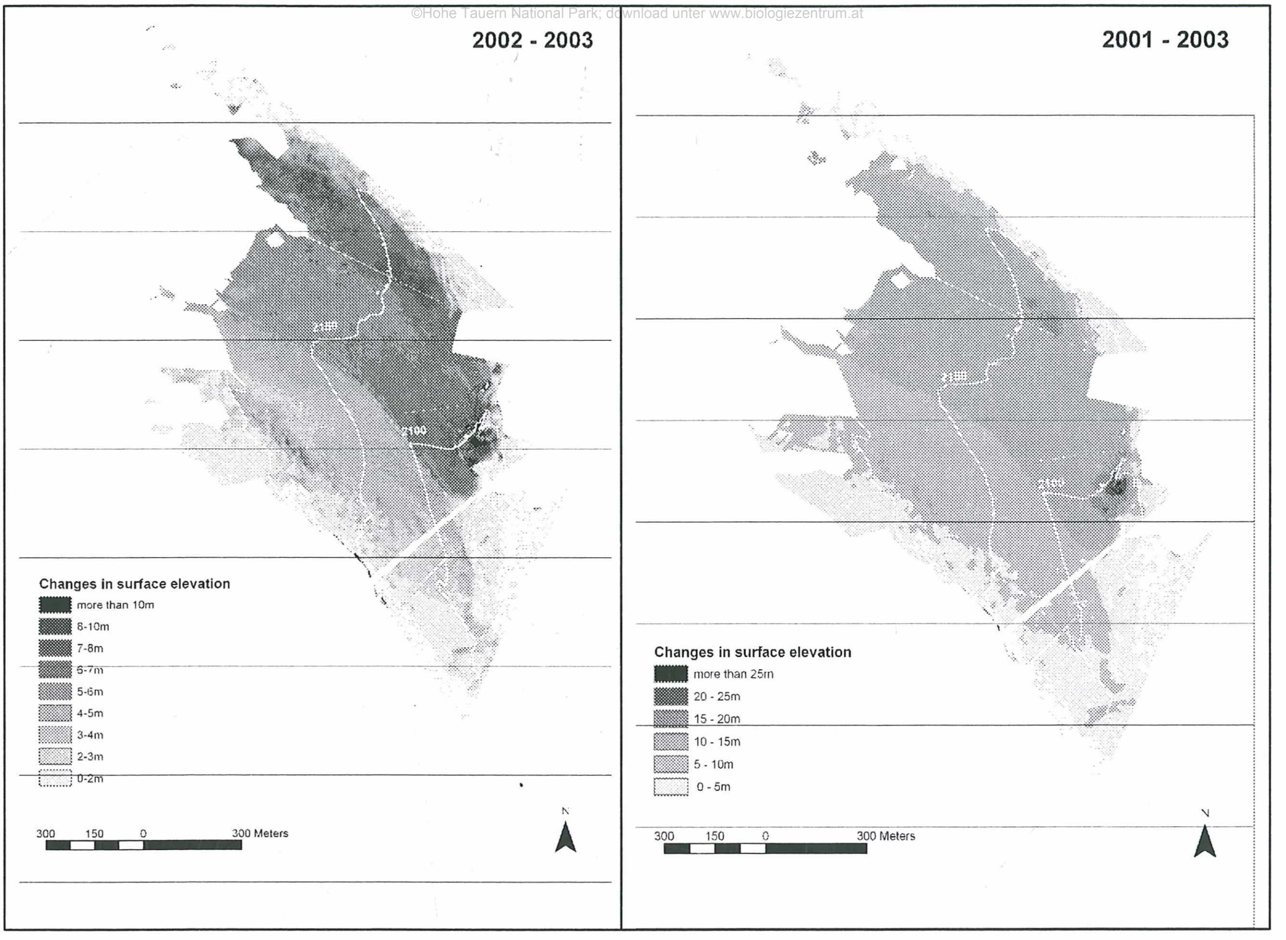

Fig. 2: Results of measurements of the periods 2002/03 and 2001/03

Discussion and Conclusion

The experimental setup at the Pasterze glacier turned out to be very economic in time and costs. The scanner is installed at the Franz-Josefs-Höhe where an appropriate infrastructure in terms of accesibility, power supply, and safety is avaiblable. As a consequence only one person is needed to carry out the measurements within a single day campaign. This TLS measurement system provides nearly real time data for monitoring, whereas protected areas in very sensitive high alpine regions (e.g. National Park Hohe Tauern) and close to intensive tourist utilisation area are of special interest for research and public.

Results from the last five years lead to following future activities:

(1) Interannual measurements at at least three epochs (June, July, and September)
(2) Additional measurements in the upper part of the glacier tongue
(3) Scanning of special areas of interest with higher resolution (e.g. proglacial areas in the vicinity of hiking trails and tourist areas).

All these tasks will lead to new information about:

(1) Area wide information on elevation variation on the glacier tongue;
(2) Spatial surface velocity distribution;
(3) Analysis of different ablation rates (debris cover – bare ice).

Furthermore research activities and results have been made avaible for public in form of:

(1) Media
(2) Journal of Austrian Alpine Association (OeAV)

References

AVIAN M. & BAUER A., 2005. The use of long range laser scanners in terrestrial monitoring of glacier dynamics, Pasterze glacier (Hohe Tauern, Austria). Geophysical Research Abstracts, Vol. 7, 06779, European Geosciences Union General Assembly, Vienna, Austria. April 24–29, 2005.

BAUER A., PAAR G. & KAUFMANN V., 2003. Terrestrial laser scanning for rock glacier monitoring. Phillips M., Springman S.M., and Arenson L.U. (eds.) Proceedings of the 8th International Permafrost Conference, Zurich, p.55-60.

BAUER A., PAAR G., 2004. Monitoring von Schneehöhen mittels terrestrischem Laserscanner zur Risikoanalyse von Lawinen. In *Proc. of the 14th Int. Course on Engineering Surveying. Zurich, Switzerland. March 15-19, 2004.*

BAUER A., PAAR G., KALTENBÖCK A., 2005. Mass Movement Monitoring Using Terrestrial Laser Scanner for Rock Fall Management. In *Proc. of the First International Symposium on Geo-information for Disaster Management. Delft, The Netherlands. March 21-23, 2005.*

BAUER A., KELLERER-PIRKLBAUER A., AVIAN M. & KAUFMANN V., 2005. Five years of monitoring the front slope of the highly active Hinteres Langtal rock glacier using terrestrial laser scanning: A case study in the Central Alps, Austria. Terra Nostra, 2nd European Conference on Permafrost, Potsdam, 91.

BENN D.I. & EVANS D.J.A, 1998. Glaciers and Glaciation. Arnold, London, 734p.

GEIST, TH., E. LUTZ, J. STÖTTER, 2003. Airborne laser scanning technology and its potential for applications in glaciology. In: *Proceedings of the ISPRS Workshop on 3-D reconstruction from airborne laserscanner and INSAR data*, Dresden, p101-106.

KAUFMANN, V., KENYI, L.W. & AVIAN, M., 2005. Messung der Fließgeschwindigkeit von Gletschern mittels satellitengestützter Radar-Interferometrie in der Schobergruppe (Nationalpark Hohe Tauern, Kärnten). Endbericht zum Forschungsprojekt des Kärntner Nationalparkfonds, Institute of Remote Sensing and Photogrammetry, TU Graz, 59p.

KAUFMANN V. & LADSTÄTTER R., 2004. Documentation of the retreat of a small debris-covered cirque glacier Goessnitzkees, Austrian Alps by menas of terrestrial photogrammetry. Proceedings of the 4th ICA Mountain Cartography Workshop, Vall de Nuria, Catalonia, Spain, 30th September – 2nd October 2004.

KELLERER-PIRKLBAUER A., BAUER A. & PROSKE H., 2005. Terrestrial laser scanning for glacier monitoring: Glaciation changes of the Gößnitzkees glacier (Schober group, Austria) between 2000 and 2004. Third Symposion of the Hohe Tauern National Park for Research in Protected Areas. Kaprun, Austria. September 15-17, 2005.

LIEB, G. K., & SLUPETZKY, H., 2004: Gletscherweg Pasterze. – Naturkundlicher Führer zum Nationalpark Hohe Tauern, Bd. 2, Innsbruck, 122p.

NAKAWO M., RAYMOND C.F. & FOUNTAIN A. (eds.), 2000. Debris-covered glaciers: Proceedings of the international workshop held at the University Of Washington at Saettle, Washington, USA, 13-15 September 2000, IAHS publication, 288p.

PFEIFER N. & LICHTI D., 2004. Terrestrial Laser Scanning: Developments, Applications and Challenges. GIM International, December 2004, p.50-53.

SEELAND, F. (1880). Studien am Pasterzengletscher. - Z. d D.u.Ö.A.V. 11, p.205-208.

WAKONIGG H., & LIEB G.K. (1996). Die Pasterze und ihre Erforschung im Rahmen der Gletschermessungen. – Kärntner Nationalparkschriften 8, Großkirchheim, p.99-115.

Contact

Mag. Michael Avian
m_avian@yahoo.com

Institute of Remote Sensing and Digital Photogrammetry
Graz University of Technology
Steyrergasse 30
A 8010 Graz
Austria

Zeitschrift/Journal: Nationalpark Hohe Tauern - Conference Volume

Jahr/Year: 2005

Band/Volume: 3

Autor(en)/Author(s): Avian Michael

Artikel/Article: Monitoring modification of alpine environments: New techniques and perspectives 15-18