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Natural Hazards and Earth System Sciences

Preface

"LIDAR and DEM techniques for landslides monitoring and characterization"

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The present state

Since the emergence of laser scanning techniques in the 90's, the importance of high resolution digital elevation model (HRDEM) analysis has steadily increased for landslide studies until now. This is corroborated by the growing interest of the geological community during the general assembly of the European Geosciences Union (EGU), where a session "LIDAR and DEM techniques for landslides monitoring and characterization" is hold since 2005 in the natural hazards division. The nine papers of this special issue were presented in April 2008 in the frame of this session.

Historically, a turning point was reached about ten years ago when datasets from airborne and groundbased laser scanners (or LIDAR) were released from remote sensing specialists' computers to be used by geoscientists experienced in slope processes and landslide investigations. The Fig. 1 shows the increasing number of yearly publications about LIDAR in geosciences and of yearly citations related to landslide and LIDAR.

In landslide studies, HRDEMs were first used as support for geomorphologic mapping and qualitative surface characterization. Then came the estimation of moving volumes comparing scans of different ages (for example before and after a specific event). Presently an important part of LIDAR applications for landslides is dedicated to rock cliff stability: discontinuities and fractures analysis, kinematics tests from point cloud. Finally, improvements in know-how and equipments have made possible the emergence of two new topics of research related to landslide investigation and HRDEM: 1) monitoring of instabilities and detection of precursory movements, and 2) laser scanning from mobile groundbased or seabased devices.

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The collection of the 2008 EGU contributions presented in this special issue covers these various facets of the HRDEM related landslide research, including some of the first applications on cutting-edge topics such as monitoring or mobile scanning:

Trevisani et al. (2009) use an airborne HRDEM to develop a quantitative spatial continuity index, based on a directional variography, to characterize and map the morphological features in a mixed environment of screes, debris flows, rockfalls and snow avalanches deposits in the Dolomite.

Sturzenegger and Stead (2009) compare and combined terrestrial LIDAR and photogrammetry to characterize rock mass discontinuities, stressing the effects of the observation scales on orientation and persistence measurements. Both techniques are applied to the site of Franck slide (Alberta, Canada).

Abellan et al. (2009) demonstrate the potential of LIDAR to detect rockfall precursory movements of millimetre magnitude by using post-processing filtering. Results from a controlled experiment on an artificial surface and from a natural cliff in Catalonia (Spain) are presented.

Corsini et al. (2009) produce a time series analysis of airborne high resolution DEM of two landslides in the Northern Apennines (Italy) to identify depletion and accumulation zones on the landslides bodies and to quantify mass wasting processes during the reactivation events.

Lato et al. (2009) have used mobile LIDAR devices along transportation corridors in Canada, along both roads and rail tracks. A workflow for engineering monitoring of rockcuts is proposed and comparisons between mobile terrestrial and static LIDAR data collection and analysis are also presented.

In Oppikofer et al. (2009), the Aaknes rockslide (35 M m^3; Norway) was monitored during two years with a terrestrial LIDAR. A very detailed 3-D analysis is produced distinguishing translational and rotational components of blocks

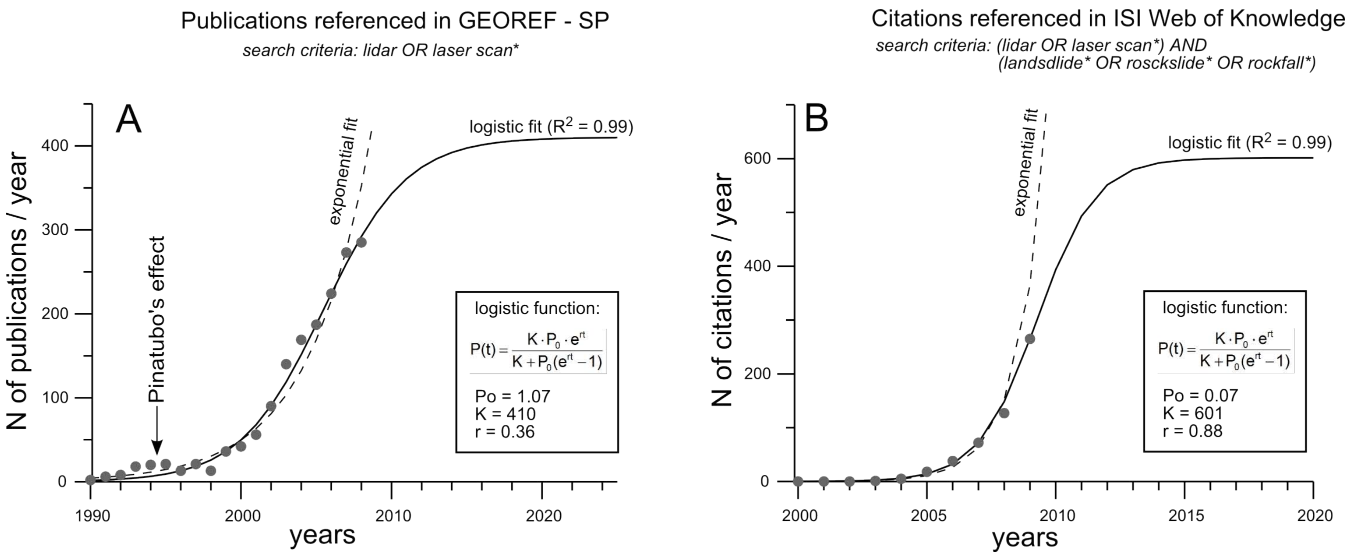

Fig. 1. (A) Number of publications per year (dots) registered in GEOREF that are related to LIDAR or laser scanning. The line is the best fit logistic function of the dots, with $t = 0$ in 1990. The small increase of papers published in the mid 90's is due to the use of LIDAR to study aerosols from the 1991 Pinatubo's explosion. **(B)** Number of citations per year (dots) registered in ISI Web of knowledge that are related to LIDAR AND landslide. The line is the best fit logistic function of the dots, with $t = 0$ in 2000. Po is the annual number of publications or citations at time $t = 0$, K is the upper limit of the number of publications or citations per year and r is the growth rate.

displacements. The results are compared with independent GPS and laser measurements, and integrated in a model of instability.

Avian et al. (2009) have monitored over 8 years a rockglacier in the Austrian Alps with a terrestrial LIDAR. The surface elevation changes are then used to describe the movements patterns of the rockglacier and to propose a dynamical model of its evolution related to the local permafrost conditions.

In a brief communication, Gigli et al. (2009) shows how LIDAR scanning can be used for cultural heritage preservation. These authors have extracted from laser scans the cracks distribution and some deformation patterns for the historical city of Mdina (Malta) which is built on a landslide.

Prokop et al. (2009) have used a small landslide in Austria to compare laser scanning with tachymetry. Accuracy tests on target positions, determination of displacements vectors and an analysis of erosion/deposition were carried out.

Any future?

This special issue is then a valuable benchmark to understand the present state-of-the art of HRDEM analysis for slope processes. It provides some ideas about future developments of the LIDAR techniques for the geohazards research. But we think that LIDAR techniques and HRDEM analysis are by far not at maturity, and that they still have a large potential of development. To illustrate this point, the annual productions of publications and citations of Fig. 1 were fitted with logistics functions. It was already proposed to use logistics functions to describe the growth of knowledge through the production of publications (Gupta and Karisiddappa, 2000) because they represent properly the different stages of this evolution: (1) a period of low production but increasing steadily, (2) a stage of exponential-like growth of the number of publications, (3) a stabilization of the production to a plateau and (4) an decline of the absolute production of publications. During the stage (2), an exponential growth can be excluded as the reservoir of persons interested by a specific subject is limited.

LIDAR techniques are too young to show the full path of evolution. Then to illustrate our point we have selected two older technical methods in the area of geosciences: the *K/Ar* and *Ar/Ar* thermochronological dating techniques (Fig. 2a). These methods were chosen because they are historically linked: the *K/Ar* method was progressively replaced by the *Ar/Ar* one.

The four stages of evolution described above are very well recorded by the annual production of *K/Ar* related publications, including its decline phase when the *Ar/Ar* method took over. The *Ar/Ar* related production has now reached a maximum and already shows the beginning of a decline. The growth rate of the publication production for *K/Ar* ($r = 0.38$) was higher than the growth rate related to *Ar/Ar* publications ($r = 0.29$). That may indicate that *K/Ar* was more innovative than *Ar/Ar*, which came principally as a substitute of the former technique. The plateau values of the annual production of publications is lower for *K/Ar* ($K = 418$) than for *Ar/Ar* ($K = 619$), following the general increase of scientific literature production during these last 20 years.

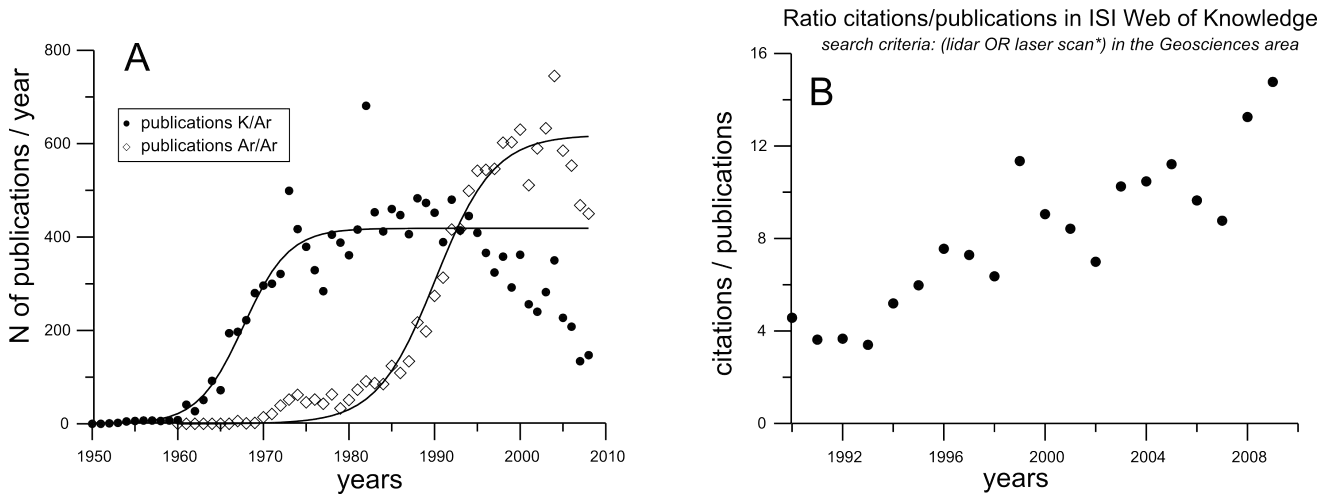

Fig. 2. (A) Number of publications registered in GEOREF per year for the thermochronological techniques *K/Ar* and *Ar/Ar*, and associated best fit logistic functions ($K = 418$ and $r = 0.38$ for *K/Ar*, $K = 619$ and $r = 0.29$ for *Ar/Ar*). **(B)** Ratio of the number of citation to the number of publication per year (from ISI Web of knowledge), related to LIDAR or laser scanning in the subject area of Geosciences.

About the production growth related to LIDAR techniques in geosciences, we infer from the logistics curves of Fig. 1 that the annual production of publications is now at about half way, and that it should reach a plateau in 5 to 10 years (with $K = 410$). The growth rate of publication ($r = 0.36$) is very similar to the one observed for the *K/Ar* technique. In addition, from 1990 until now, the average number of citations per publications related to LIDAR in geosciences has steadily increased (Fig. 2b).

Conclusions

The increasing production of publications and the evolution of the ratio of citations to publications indicate that a scientific community (even small) is presently building an innovative and useful knowledge, and that it should last for the next 5 to 10 years. Moreover, in the same way that the *Ar/Ar* technique replaced the *K/Ar* one during the 80's, we cannot exclude that a major technical improvement will take over the LIDAR technology as we know it nowadays. There is then a stimulating challenge for geoscientists to take part to this trend, proposing new methods and developing new tools able to take advantage of these high quality data. Then, welcome on board!

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