Exploratory Workshops Scheme

Standing Committees for:

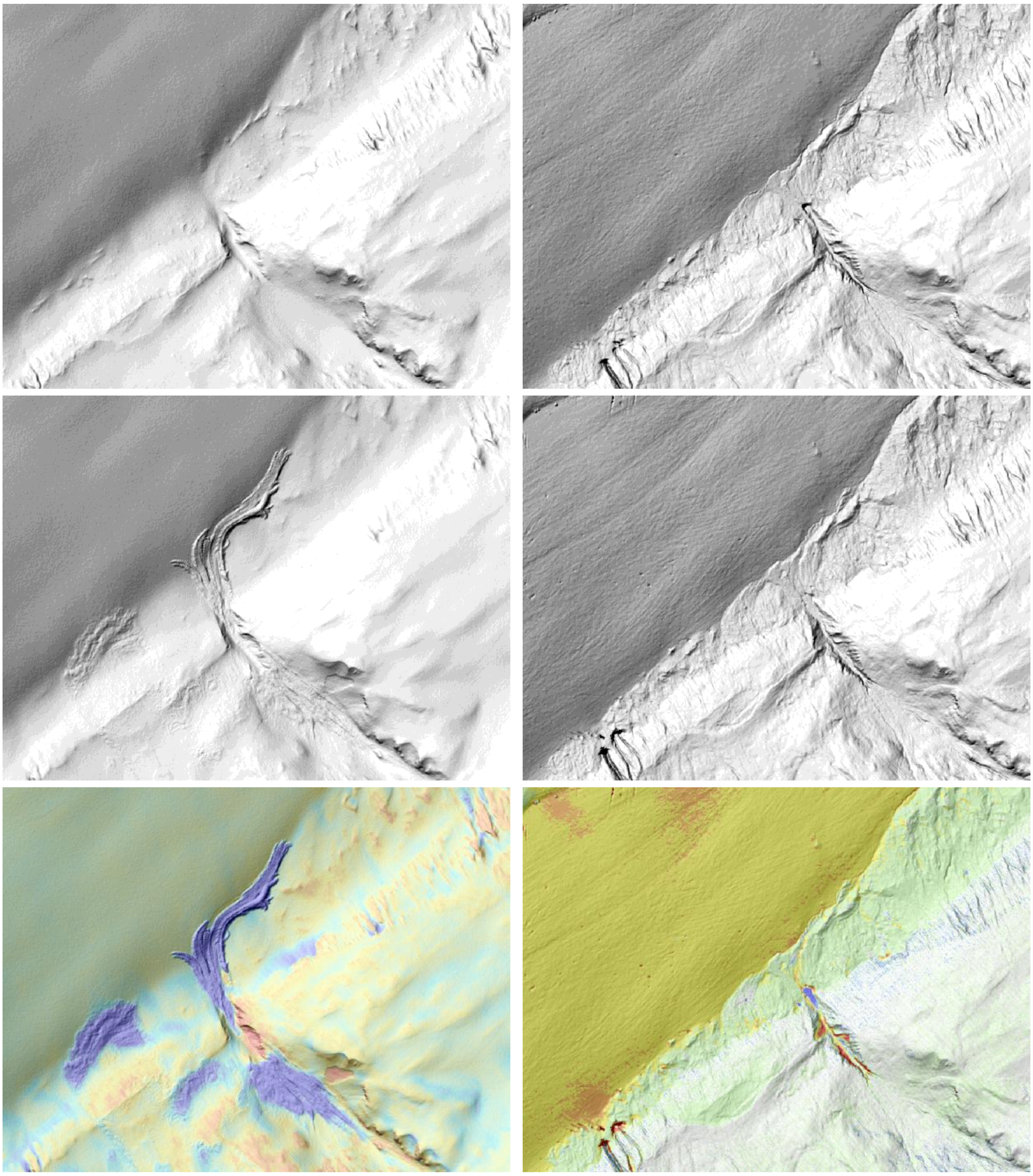
- Life, Earth and Environmental Sciences (LESC)
- Physical and Engineering Sciences (PESC)

Final Report

ESF-Exploratory Workshop

"Laser Scanning for alpine natural hazard management – Development of new Concepts"

(Obergurgl, Nov, 15th to Nov, 17th 2007)



1. Executive summary

The ESF workshop on *“**Laser Scanning for alpine natural hazard management – Development of new Concepts**”* was held from Nov, 15th to 17th, 2007 at the University Centre Obergurgl (Austria) with twelve participants from four countries. This workshop aimed at discussing and developing new concepts in using high resolution and high-accurate topographic information gained with laser scanning technology for running operational process simulation models with a special focus on natural hazard management tasks in alpine areas.
Four key-note presentations gave information on the state of the art, showing both potentials and limitation thus stimulating intensive discussions.
In the first presentation on status of laser scanning and expectations towards this rather new technology (by Norbert Pfeifer), a comparison on the two available techniques, airborne (ALS) and terrestrial laser scanning (TLS) with other remote sensing technologies was given, regarding the measuring principles, the kind of objects to be observed and the data quality. At present, there is no other remote sensing technology that can provide area-wide data on the topography which are comparably accurate and precise. New technological developments promise multi wavelength laser scanners (for bathymetry), satellite based laser scanners (for atmospheric studies), and full-waveform laser scanners (another leapfrog in information density).
Although these further developments may open new scientific horizons, there are still many open questions in the up-to-date technology. It is the discussion of raster vs. point cloud data sets, the detection and modelling of objects (e.g. buildings, trees, geomorphological features).

The key-note on Geo-ICT and disaster management (by Sisi Zlatanova) gave insight into modern disaster management structures and highlighted the need for detailed geo-data in all phases of the disaster management circle, i.e. prevention and mitigation, preparation, response and recovery. Thus 3D models derived from laser scanning data can contribute to better simulations and training, and to improved analyses. Multi-temporal analysis of information from laser scanning data may be a new standard for estimation of damages resulting from natural hazards, e.g. earthquakes, land slides or fire.

In the other two key-notes the natural hazard process side and modelling aspects were discussed, a) on hydrological processes (by Friedrich Schöberl) and b) on geomorphological processes (by Rainer Bell).
The knowledge on hydrology and hydraulics of runoff, respectively flooding processes is based on long and intensive experience, thus related models are very sophisticated. Nevertheless, there is some need to improve the in put data, i.e. the transition from the point information (with low density) to an area-wide representation of parameters, a better and reproducible information on surface and vegetation roughness and improved bed structure information in higher resolution. Furthermore, input on topography (transects, break-lines, features) might also be improved.
Based on research on different geomorphological processes, it was shown how laser scanning data can be utilised for mapping of landforms as well as indicators for specific process types in a semi-automatic user controlled way. On the basis of a detailed delineation and due to their spatial distribution and their position among each other, mapped landform, i.e. land slides, can be classified towards a relative age of their genetic event. Furthermore, laser scanning data can be used for modelling geomorphological processes and, when multi-temporal information is available, for quantification of changes, thus allowing for erosion or accumulation rates.

As shown by the specific discussions on laser scanning from a hydrological and a geomorphological point of view, there is a strong demand for high quality topographic data in modern natural hazard management, e.g. as basic input for process simulation modelling. But the availability of these improved data sets is also challenging, as more detailed and more precise input parameter will force new calibration of models, respectively calls for totally new models.

In a summing-up discussion the following conclusions could be stated:

1. It is recognized that laser scanning science and technology has the capacity to make a significant contribution to improve natural hazard management in mountain areas at a variety of scales in space and time.

2. Opportunities exist in a tighter integration of information derived from laser scanning into natural hazard process models, for example parameterisation of vegetation for flooding simulation.

3. In order to be able to exploit the full potential and define standards for the next generation of topography driven process models existing obstacles due to information deficits and different semantics have to be overcome.

4. A continuation of dialogue, and subsequent interdisciplinary research, between the natural hazard and the laser scanning communities at a pan-European level will lead to a paradigm change in natural hazard and risk management.

5. Wider acceptance, both in scientific research and practical application, requires an integrated approach including other disciplines contributing to natural hazard management.

6. To address the findings of the workshop, participants agreed to establish a network to enable improvement in natural hazard risk management in European mountain areas under global climate change conditions.

2. Scientific content of the event (1 page min.)

The ideas summarised here refer to a publication in print by Thomas Geist, Bernhard Höfle, Martin Rutzinger, Norbert Pfeifer, and Johann Stötter on *"Laser scanning – a paradigm change in topographic data acquisition for natural hazard management"*. They comprise most of the scientific discussion of the ESF workshop on *"**Laser Scanning for alpine natural hazard management – Development of new Concepts**"*.

In modern natural hazard management remote sensing data are used in manifold ways and are especially valuable in inaccessible terrain. A wide spread application of remote sensing is the mapping and monitoring of area-wide impacts of natural hazards and the analysis of process disposition and triggering factors. Current research demands include the development of operational monitoring methods and the development of support tools based on automated analysis algorithms, both aiming to reduce the time gap between data acquisition, processing and data application, with real-time user-tailored data availability as the main goal for the future.

Laser scanning, a remote sensing method for the acquisition of topographic data, can meet these demands, allowing the calculation of high resolution and high-accurate digital elevation models and, additionally, providing information on characteristics and properties of the surface. This technology has been developed into an operational and reliable airborne method in recent years. Due to the availability of commercial off-the-shelf sensors and an increased awareness of the advantages of laser scanning by end-users, the use of airborne laser scanning data has grown rapidly and, consequently, the development of a wide variety of applications is under way. Therefore, applied research in the field of laser scanning is embedded in a dynamic and challenging frame. Fundamental knowledge about the technical accuracy of this method and the quality of produced digital elevation datasets has evolved in recent years. At the moment a paradigm change is taking place, with laser scanning replacing image-based photogrammetry as the standard method for acquiring topographic data.

Laser scanning is an active remote sensing technology for directly measuring 3D coordinates of points on surfaces, including the terrain and objects thereupon (e.g. houses or trees). It is operated from airborne and terrestrial platforms.
Airborne laser scanning is also referred to as airborne LIDAR (LIght Detection And Ranging) or LADAR (LAser Detection And Ranging). First applications of laser altimetry were based upon the so-called laser profiling technology, designed to collect data following a virtual single line on the observed (recorded) surface.
An ALS system is a multi-sensor measurement system that incorporates the following time-synchronized components (Figure 1):

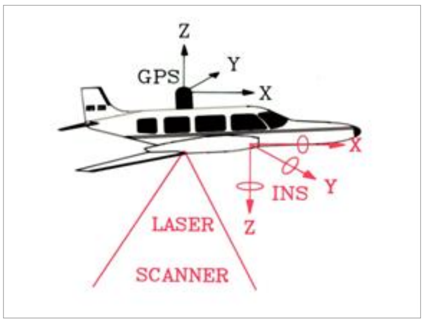


Figure 1: Airborne laser scanning system components, schematic illustration (left) and laser scanning device (right).

- The satellite global positioning system (GPS), which is used to determine the absolute position (x, y, z) of the sensor platform in a differential mode using ground reference stations.
- The inertial measurement unit (IMU) is used to determine the angular attitude of the platform (roll, pitch, and heading). The flight path of the platform is calculated from combined analysis of the GPS and IMU data.

The laser scanner itself, consisting of the laser range finder, measuring the distance from the sensor on the airborne platform to a reflecting surface, and a beam deflection device, that deflects the laser beam perpendicular to the flight direction (±20° as common value). The laser range finder operates by measuring the two-way travel time required for a pulse of laser light (commonly in the infrared section of the electromagnetic spectrum) to travel to the location of reflection, and back to the receiver. The distance r can be computed from the travel time Δt by the known speed of light c ($r = c \cdot \Delta t/2$). Current systems are capable of operating up to 5000 m above ground level. Range measurements provide pulse repetition rates up to 150 kHz. Some experimental systems utilize continuous wave lasers and examine phase differences between the transmitted and the reflected radiation.

Mountainous regions are especially affected by geomorphodynamic processes causing damage, loss of property and human life. The mapping of the processes according to their surface properties and geomorphological structure and the analysis of their characteristics is the basis for risk and vulnerability analysis. The applicability of remote sensing methods for natural hazard assessment is predominantly governed by the following factors:

- *spatial resolution*, which determines the degree of detail that can be detected from the data.
- *spatial coverage*, which is the area that can be included in the assessment procedure.
- *temporal resolution* or *revisit time*, which has to be in agreement with the rate of hazard development or changes observed.

ALS data deliver high quality topographic information in a spatial resolution that is unprecedented; the availability of data (spatial coverage) is steadily increasing. That revisit time can be actively decided, was proven, for example, by the Austrian Federal State of Vorarlberg who acquired ALS data for several river catchments after the flood event in August 2005 in order to compare it with data that were acquired before the flood in the course of an area-wide data acquisition for the entire state. These data are an important source for process models of different types (empirical, numerical and probabilistic). Most outputs of these models are highly sensitive to DTM characteristics such as resolution, level of detail, and vertical or horizontal errors.

Terrain elevation changes over time, i.e. vertical differences between repeated DTMs are indicators for geomorphodynamic processes. Thus, their detection is an important step in hazard assessment and disaster mapping. In general, changes in terrain elevation are derived by subtracting repeat DTMs. The accuracy of such-derived vertical changes is, in principle, on the order of the accuracy of the single DTMs that are used. If the DTMs represent independent measurements, the root mean square error (RMS error) of an individual elevation change can be estimated from the RMS errors of the DTMs involved.

The application of ALS data in natural hazard management is highlighted by two process categories, i.e. land slides and debris flows as examples of gravitation controlled processes and

Landslides are mass movements, which are triggered by geologically instable zones, heavy rainfalls leading to high soil water pressure, or earthquakes. The processes can be continuous creeping movements or are initiated spontaneously. The spatial and temporal distribution of landslides is of high interest because not only single buildings or infrastructure but whole settlement areas can be affected. In high resolution DTMs undisturbed terrain appears smoother than the mass movement area. Derived morphometric parameters from ALS DTMs are used to locate and map landslides. The process itself can be described and characterized in terms of spatial distribution and activity and age. Parameters used for landslide description are for example surface roughness coefficients, first and second order derivatives like slope, aspect and curvature. The relation between surface properties and activity of certain terrain parts makes it possible to distinguish kinematic units of mass movements (McKean and Roering 2004). Furthermore, active landslides can be distinguished from old, inactive ones by the analysis of surface roughness values. Current investigations show that active landslides are characterized by higher surface roughness (Glenn et al. 2006). A similar approach is used to investigate the spatial distribution of debris flow deposition on alluvial fans, which is necessary to understand the process itself. Selected fans are investigated towards their curvature and gradient properties. To suppress noise caused by fine-scale surface forms like levees, lobes, debris dams, and channels formed from past events, a calculation window larger than these forms is used for parameter calculation. Curvature and height gradients derived from high resolution laser scanning DTMs can be used to define sub-fan sections representing different levels of internal shear strength (Staley et al. 2006).

The last 15 years have been marked by severe flooding in many parts of Europe. For example, large parts of Central Europe were hit in August 2002 by two consecutive flood events, which caused significant damage to buildings and infrastructure. ALS has been evolved to an attractive technology for the acquisition of useful data for various river management tasks, e.g. floodplain vegetation classification for hydraulic modeling, the determination of soil volume, the determination of riverbed morphology (at low water levels) and measuring water levels and wave pattern parameters (Brügelmann and Bollweg 2004). DTMs form the basis for distributed hydrologic models as well as for two-dimensional hydraulic river flood models. Two-dimensional hydraulic surface flow models are mostly constrained by inadequate parameterization of topography and roughness coefficients, primarily due to insufficient or inaccurate data. DTMs and their derived parameters such as slope, aspect and drainage network form a fundamental input for the models mentioned. In addition to the topographical information, nDSMs have the advantage of offering the possibility to estimate object heights (vegetation, buildings). Detailed land cover maps can be derived in conjunction with the complementary information provided by high resolution color-infrared orthophotos.

Important tasks which can be supported by laser scanning data are the delineation of flood prone areas and the determination of landscape roughness as the standardized input parameter in two-dimensional river flood models.

Flood risk areas are modeled by delineating inundated land surfaces for different water levels. For this task, ALS data has become the preferred data source. Laser DTMs have a sufficient vertical accuracy for the modeling of design events. An additional requirement is the consideration of micro-topography effecting the flow routing. Certain structures like dams, ditches, levees, embankments and old channels are represented in laser DTMs. Grenzdörffer et al. (2002) compared ALS data with data from terrestrial surveying for the specific task of flood risk area delineation and found significant deviations in areas with a high surface roughness (e.g. bush, reed) seeing as the automatic ALS filtering methods reached their limits here. As the quality of the derived DTMs is often not completely sufficient for the modeling of inundation patterns in the case of flooding, approaches to extract hydraulically relevant breaklines have been a main focus in recent research efforts (Briese and Attwenger 2005). The determination of landscape roughness is of significant importance. In the case of flooding the flow of water in the floodplain of a river is influenced by the spatial distribution of forests, grasslands, agricultural fields and infrastructure like roads and houses. ALS data have a significant potential for assessing landscape roughness and vegetation structure (height, layering, spatial arrangement). This information is useful for determining relevant model parameters, such as the coefficient of friction. For flood modeling the *Manning coefficient* of roughness is often used. Asselman et al. (2002) estimated hydraulic roughness of flood plain vegetation in the Netherlands while Smith et al. (2004) assessed the potential of using ALS data in analyzing the landscape for the estimation of roughness coefficients and compare ALS data with data derived from aerial photography/photogrammetry. They proposed automated techniques for a more objective estimation. Major advances are expected from upcoming full-waveform laser scanner systems (e.g. Wagner et al. 2004). The overall goal is a spatially distributed parameterization of friction as the standardized input parameter in two-dimensional river flood models. These model types are core elements in flood prediction systems.

Cobby et al. (2003) used ALS data for improving such models by decomposing a finite-element mesh to reflect floodplain vegetation features, such as hedges and trees having different frictional properties to their surroundings, and significant floodplain topographic features having high curvature values. The decomposition is achieved by using an image segmentation method that converts the ALS data into separate data sets of surface topography and vegetation height at each point. The derived vegetation height map is used to estimate a friction factor at each node, which results in a physically based, spatially distributed friction parameterization. Methodologies were developed to convert vegetation heights to friction coefficients (Mason et al. 2003). The use of the decomposed mesh also allows the prediction of velocity variations in the neighborhood of vegetation features such as hedges. These variations can consequently be used for predicting erosion and deposition patterns. Thoma et al. (2005) used multitemporal ALS data for riverbank erosion assessment by quantifying volume and mass changes. A study in Iceland (Smith et al. 2006) showed how multitemporal ALS data can support the estimation of sediment erosion and deposition in sander plains after a glacier outburst flood (jökulhlaup). French (2003) considered the application of ALS data for the provision of elevation data at accuracies and spatial densities in accordance with the current generation of high resolution hydraulic models. He specifically addressed the quality of the data via multi-scale calibration against surveyed sections and supplementary control points, and the use of image processing techniques for identifying regions of interest. He concluded that ALS provides topographic information at an accuracy and resolution close to the present limits of model representation. Charlton et al. (2003) discussed the derivation of representative cross-profiles of river channels.
The summarized advantages of ALS data for hydrodynamic modeling are as follows:

- adequate vertical accuracy
- adequate horizontal accuracy and data density
- potential for the derivation of breaklines
- potential for the derivation of land use classification and roughness coefficient
- increasing data availability

Most studies until now were constrained to small test sites. Hollaus et al. (2005) summarized the experiences to process ALS data for large mountainous regions, demonstrating the applicability for hydrological applications. In 2003 the Christian Doppler laboratory *Spatial data from laser scanning and remote sensing* was founded at the Technical University of Vienna with the goal of exploiting airborne laser scanning for hydrologic applications, whereby the extreme topographic environment of Austria is taken into consideration as a challenging boundary condition. One point of focus is also the development of new and advanced methods combining ALS with radar remote sensing and digital photogrammetry. In Bavaria the project *Floodscan* started in 2006. The goal of the project is the optimization of ALS data processing for hydrodynamic modeling with the development of data thinning techniques.

Asselman N, Middelkoop H, Ritzen M, Straatsma M (2002) Assessment of the hydraulic roughness of river flood plains using laser altimetry. IAHS publication 276: 381-388.

Briese C, Attwenger M (2005) Modellierung dreidimensionaler hydrologisch und hydraulisch relevanter Geländekanten aus hochauflösenden Laser-Scanner- Daten. In: Bundesanstalt für Gewässerkunde (ed): Praxisorientierte und vielseitig nutzbare Fernerkundungseinsätze an der Elbe: 35-45.

Brügelmann R, Bollweg A (2004) Laser altimetry for river management. International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences 35 (B2): 234-239.

Charlton M, Large A, Fuller I (2003) Application of airborne LiDAR in river environments: the River Coquet, Northumberland, UK. Earth surface processes and landforms 28 (3): 299-306.

Cobby D, Mason D, Horrit M, Bates P (2003) Two-dimensional hydraulic flood modelling using a finite-element mesh decomposed according to vegetation and topographic features derived from airborne scanning laser altimetry. Hydrological Processes 17: 1979-2000.

French J (2003) Airborne LiDAR in support of geomorphological and hydraulic modelling. Earth surface processes and landforms 28 (3): 321-335.

Geist T, Höfle B, Rutzinger M, Pfeifer N, Stötter J (in press) Laser scanning – a paradigm change in topographic data acquisition for natural hazard management. – Veulliet E, Stötter J, Weck-Hannemann H (eds.) Contributions to a sustainable natural hazard management.

Glenn NF, Streutker DR, Chadwick DJ, Thackray GD, Dorsch SD (2006) Analysis of LiDAR-derived topographic information for characterizing and differentiating landslide morphology and activity. Geomorphology 73: 131-148.

Grenzdörffer G, Foy T, Bill R (2002) Laserscanning und andere Methoden zur Ausweisung potenziell gefährdeter Hochwasserbereiche der Unteren Warnow. In: Strobl J, Blaschke T, Griesebner G (eds) Angewandte Geoinformatik 2002 - Beiträge zum 14. AGIT-Symposium Salzburg: 133-138.

Hollaus M, Wagner W, Kraus K (2005) Airborne laser scanning and usefulness for hydrological models. Advances in Geosciences 5: 57-63.

Mason D, Anderson G, Bradbury R, Cobby D, Davenport I, Vandepoll M, Wilson J (2003) Measurement of habitat predictor variables for organism-habitat models using remote sensing and image segmentation. International Journal of Remote Sensing 24 (12): 2515-2532.

McKean J, Roering J (2004) Objective landslide detection and surface morphology mapping using high-resolution airborne laser altimetry. Geomorphology 57: 331-351.

Smith M, Asal FFF, Priestnall G (2004) The use of photogrammetry and Li- DAR for landscape roughness estimation in hydrodynamic studies. International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences 35 (B3): 714-719.

Staley DM, Wasklewicz TA, Blaszczynski JS (2006) Surficial patterns of debris flow deposition on alluvial fans in Death Valley, CA using airborne laser swath mapping data. Geomorphology 74: 152-163.

Thoma D, Gupta S, Bauer M, Kirchoff C (2005) Airborne laser scanning for riverbank erosion assessment. Remote Sensing of Environment 95 (4): 493-501.

Wagner W, Ullrich A, Melzer T, Briese C, Kraus K (2004) From single-pulse to full-waveform airborne laser scanners: potential and practical challenges. International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences 35 (B3): 201-206.

3. Assessment of the results, contribution to the future direction of the field

The ESF workshop on *"**Laser Scanning for alpine natural hazard management – Development of new Concepts**"* was certainly successful.

It stimulated scientists of different disciplines, one group from a technological side, the other group from an application side, to discuss about potentials and limitations in merging their activities. It turned out that such an interdisciplinary activity may create somewhat like a win-win situation. On the one side, among the scientists representing the fields of geomorphological natural hazard processes, sincere needs of improved data were highlighted, i.e. high resolution, high precision data for both a better understanding of the processes and further developed modelling. On the other side the developers of the rather new technology of laser scanning gain for applications of their technique that contribute to really existing problems.

Bringing together very experienced scientists with young post-docs and graduates working on their PhD project, made this workshop an interesting platform for exchange of ambitious ideas and research desires on the one side, and knowing of potentials, limitations and well-experienced needs on the other side, which might e seen as another win-win aspect of the workshop.

Against this background, the conclusions that where drawn at the end of the workshop are understood as kind of fundamental declaration for a co-operative future research programme explaining the present situation and pointing out research goals. It should be mentioned here that all participants agreed on the positive feedback and stimulating character of this interdisciplinary workshop.

Nevertheless, some remarks about potential improvements on the basis of the experience with this workshop should be made. There is no doubt that the very small number of twelve persons enabled a very intensive and fruitful discussion, but that might also be understood as a sub-critical mass. Furthermore, the gender balance might be seen as worrying even though the responsible organiser tried their best to get more female researchers to this workshop.

Regarding further future activities, e.g. applying ESF Science Synergy or Science Management programme lines, it has to be stated that in times in which universities are meant to develop company-like structures thus evaluating success barely on the basis of figures, any application activity has to be questioned considering cost-benefit options. As a consequence that means that all applications with a statistically rather high probability of success have to be of primary interest for university institutes. Thus a head of an institute has to encourage scientific staff to focus on such programme lines when applying for research funding.

That means, although it was discussed among the participants and with the ESF representative who gave very helpful advices, to prepare an application for the EOROCORES Programme, such an activity has not yet been realised due to the fact that other options seem to have a higher probability for success.

4. Final programme

The final programme of the ESF workshop had to be change rather spontaneously due to cancellation of one of the key-note speakers (Saana Kaasalainen) by rather short note. As a consequence the first impulse on the state of the arts of laser scanning technology was given by Norbert Pfeifer.

	Thursday, 15 th		Friday, 16th		Saturday, 17th	
7.30			Breakfast		Breakfast	
8.30			Modelling in Hydrology/Hydraulics	Fritz Schöberl	Strategy and Concept Discussion	Norbert Pfeifer/ Hans Stötter
9.15			Geomorphology – State of the Art	Rainer Bell		
10.00			Coffee break		Coffee break	
10.30			Discussion		Further Activities Conclusions	Norbert Pfeifer/ Hans Stötter
11.15.	Arrival					
12.00			Lunch and Walk		Lunch	
13.00	Lunch					
14.00	Opening	Norbert Pfeifer/ Hans Stötter Hefin Jones (ESF) Thomas Geist (FFG)	Working group discussions WG 1: Laser Scanning - Hydrology WG 2: Laser Scanning – Mass Movements	Norbert Pfeifer, Hans Stötter	Departure	
	Expectations					
15.00	Laser Scanning Technology - State of the Art	Norbert Pfeifer				
15.30	Discussion					
16.15	Coffee break		Coffee break			
16.45	Laser Scanning and Disaster Management	Sisi Zlatanova	Reporting of Working Group 1	Group 1		
17.30	Discussion		Reporting of Working Group 2	Group 2		
18.30	Aperitif		Dinner			
19.00	Dinner					
	Fireplace Discussions		Fireplace Discussions			

5. Statistical information on participants (age structure, gender, repartition of countries of origin, etc.)

The statistical information is given
A) for the overall number of participants (twelve) and
B) for the number of participants without the ESF observer an the observer of the FFG (ten)

Age Structure

Age	**Group A**	**Group B**
20-30	4	4
31-40	3	2
41-50	2	2
51-60	3	2

Gender

Gender	**Group A**	**Group B**
female	1	1
male	11	9

Countries of Affiliation

Country	**Group A**	**Group B**
Austria	7	6
Netherlands	2	2
Italy	1	1
United Kingdom	2	1

Countries of Origin

Age	**Group A**	**Group B**
Austria	4	4
Netherlands	1	1
Italy	1	1
United Kingdom	2	1
Czech Republic	1	1
Germany	3	2

6. The Final list of participants (full name and affiliation)

Dr. Rainer Bell	Vienna, AT
Dr. Thomas Geist	Vienna, AT
Dr. Bernhard Höfle	Wien, AT
Professor T. Hefin Jones	Cardiff , UK
Professor Jon Mills	Newcastle upon Tyne, UK
Dr. Sander Oude Elberink	Enschede, NL
Professor Norbert Pfeifer	Vienna, AT
Mr. Martin Rutzinger	Innsbruck, AT
Dr. Marco Scaioni	Milano, IT
Professor Friedrich Schöberl	Innsbruck, AT
Professor Johann Stötter	Innsbruck, AT
Dr. Sisi Zlatanova	Delft, NL