D-BAUG

Department of Civil, Environmental and Geomatic Engineering

Annual Report 2006

Department of Civil, Environmental and Geomatic Engineering

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich


TCA 1800L

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Preface

After the events around the hundred-fiftieth anniversary of the ETH in 2005, the year 2006 was marked by the discussions on the paper „ETH2020“, leading to the resignation of the president, Prof. Dr. Ernst Hafen, at the beginning of November. Yet, these discussions also resulted in an unprecedented bond between the faculty, thus substantially strengthening the ETH.

The paper „ETH2020“, sent out by the management board of the ETH for internal comment in Spring 2006, contained goals and possible measures regarding teaching, promotion of young talents, financing, technology transfer, ETH-culture&communication, and organization. However, the goals and measures were not based on an analysis of the position of the ETH and no such analysis was ever provided. The lack of a thorough analysis of the position of the ETH, the unbalanced structure, the missing order according to priorities and the fuzzy wording of the paper made a serious discussion impossible. In addition, several issues addressed by the paper gave rise to deep concern, in particular the proposed composition of the management board and the abolishment of the departments, accompanied by the creation of schools and the introduction of deans.

As documented by their comments, initially, faculty and staff of the ETH were ready to cooperate but this changed to rejection and resistance after the management board decided to implement the measures sketched out in the paper „ETH2020“ on 29 August. With its decision, the management board set aside the serious and almost identical objections as well as the constructive proposals regarding fundamental issues made by the various groups of the ETH. The break with ETH‘s culture of letting fundamental decisions grow out of a broad process of participation, so that faculty and staff are able to support them, resulted in a considerable loss of trust in the management board. The withdrawal of the decisions of 29 August on 23 October couldn‘t settle the management crisis of the ETH. On 24 October, 17 professors, including the heads or deputies of 11 of the 15 departments, called upon the president to submit his resignation which then took place on 1 November.

Teaching and research were not affected by the management crisis. Via the conference of the department heads, the present management board, lead by the rector, is supported by the faculty and it enjoys its trust. The ETH board quickly established a search committee for the new president, respecting the request of the ETH faculty for adequate representation. Thus, the conditions are good for the transition period and the installation of the new president, scheduled for the summer of this year.

The ETH proved its readiness for reforms time and again in recent years. It successfully implemented the departmental autonomy and it took a leading role in the changeover from the diploma studies to the bachelor/master programs. Undoubtedly, the ETH will continue to distinguish itself by its ability to recognize necessary reforms at an early stage and to implement them independently and prudently. It will do so based on its unique culture and its self-confidence that has been strengthened through last year‘s events.

As in previous years, this annual report aims at providing an insight into our diverse activities both for our partners within the ETH domain and our external partners in Switzerland and abroad. We would like to sincerely thank our partners for the trust placed in us and the assistance rendered, and we are looking forward to their continued support.

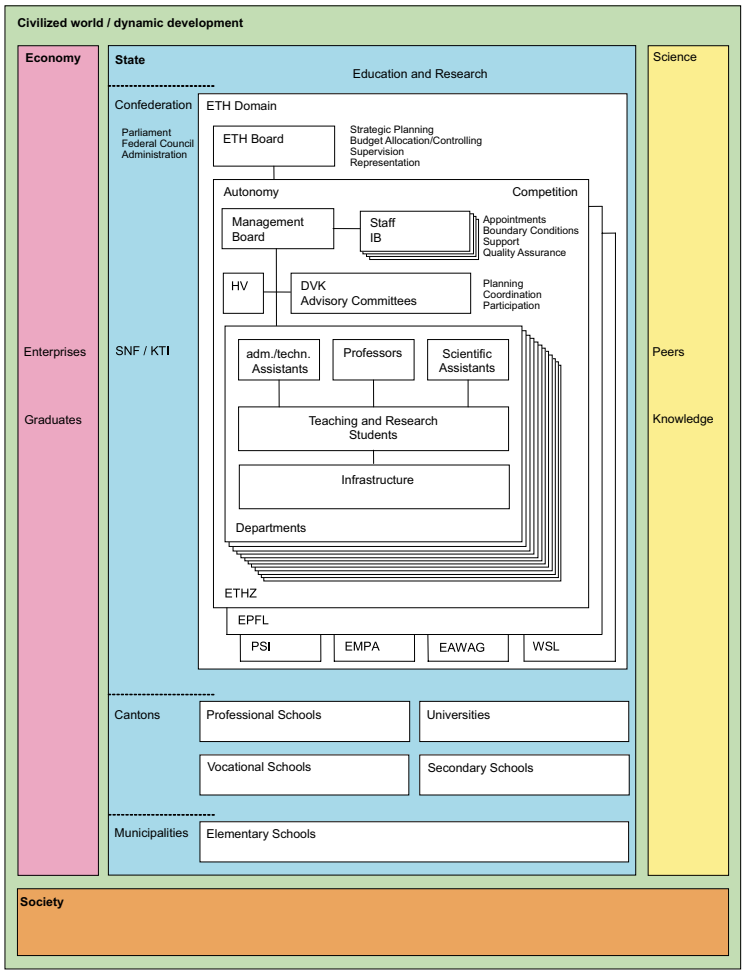
Peter Marti/February 2007

Central Points

Positioning the ETH

Last year's events give rise to deliberate on ETH's position in the national and international environment.

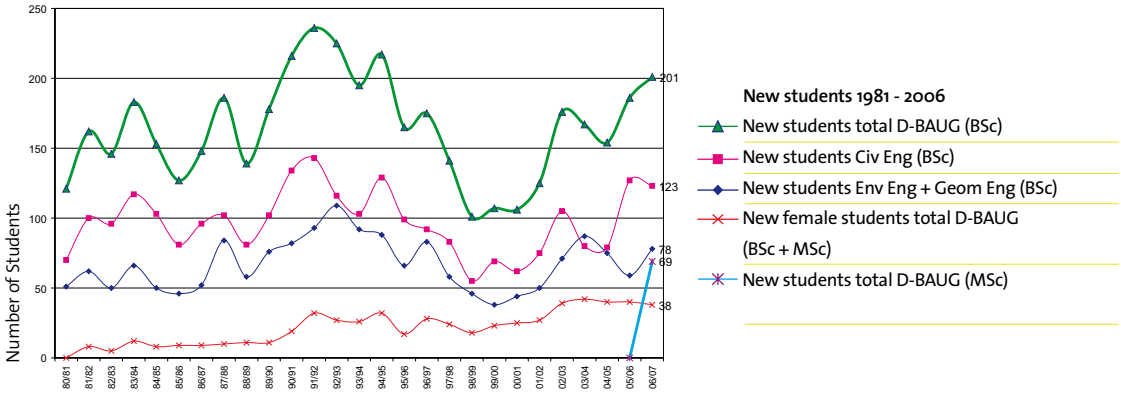
As a federal educational and research institution between the poles of science and economy, the ETH is deeply rooted in the Swiss society. It concentrates on teaching and research, i.e. the interaction of individuals with academic freedom who, in their chosen areas, prepare themselves for, or participate in, the competition of the leading engineers and scientists worldwide. The ETH compares itself with its peers and maintains close relationships with the key enterprises present in the market. It enriches science and economy through its knowledge and graduates, and it interprets its autonomy as a mission to recognize and push essential new developments, thereby continuously re-focusing its activities and adjusting its profile.



The ETH management board, in collaboration with the departments, and assisted by the staff and the infrastructure divisions (IB), bears the responsibility for appointments, boundary conditions, support, and quality assurance. It makes use of the participation of all university members, and, in its decisions, accounts for the contributions by the assembly of the university members (HV), the conference of the department heads (DVK), and the advisory committees. In this way, it ensures a suitable planning and coordination, strengthens the basis of trust, and enhances the bond within the ETH.

Within the ETH domain, manifold relationships exist between the ETHZ, the EPFL and the research institutions (PSI, EMPA, EAWAG, WSL). Similar to collaborations within the ETH, cooperations in the form of competence centres and networks within the ETH domain should be based on the free decision of the partners, and they should be subjected to the established scientific self-regulation mechanisms. Experience shows that any influence from the outside, beyond an initial encouragement, leads to friction losses, impairs the flexibility, and eventually results in mediocrity.

The ETH board is responsible for the strategic planning, budget allocation, controlling and supervision within the ETH domain as well as its representation towards the federal authorities. Similar to the ETH management board in its relationship to the departments, the ETH board is expected to support the different autonomous institutions in their individuality and diversity rather than to interfere with their operations. The ETH board's strategic mission requires a long-term view and a fine balance regarding basic financing and competitive funding, enabling a true competition without compromising basic needs. This, together with a good working relationship based on mutual respect and fairness, constitutes an essential prerequisite for a sustainable, differentiated development of the ETH domain for the



welfare of Switzerland. A second important prerequisite, the trustful, continuous support from the state and the economy, has to be legitimized again and again through outstanding performance in the dynamic global environment.

The Swiss university landscape is being reorganized. A university law, implementing the constitution's new university article passed in 2006, shall come into force in 2012. The federal council's message on the advancement of education, research and innovation in the years 2008-2011 allows to recognize the governmental intentions. The draft law proposes to concentrate all activities related to education in one department, and to create a university conference with representatives from the federation and the cantons, being responsible for the planning, steering and coordination of the universities. At present, it is unclear how the political discussion will evolve. It is clear, however, that the tendency to influence the universities from the outside is increasing and that the concentration process taking place among the professional schools and universities will intensify and expand.

In view of this situation, the ETH is well advised to concentrate on its strengths, show its profile and prove its robustness and adaptability. Highest standards in teaching and research, competition with the leading engineers and scientists worldwide, interpretation of autonomy as a mission to continuously re-focus, optimum appointments and support of chairs, commitment to scientific self-regulation, active proximity to economy, transparent and broadly based decision processes, academic diversity, respect and fairness, continuity and trust: Central points defining the identity of the ETH that need to be continuously re-established and communicated to the public and the decision-makers.

Faculty

Dr. Stefanie Hellweg was appointed associate professor of *ecological system design*, effective 1 January 2006; Dr. Hans Jürgen Herrmann was appointed professor of *computational physics of materials*, effective 1 April 2006; Dr. Bernd Scholl was appointed professor of *spatial management*, effective 1 July 2006; and Dr. Holger Wallbaum was appointed assistant professor of *sustainable construction*, effective 1 August 2006.

On 14 December 2006, the title of a professor was bestowed on Mr. Hans Peter Lindenmann, senior scientist at the Institute of Transport Planning and Systems (IVT).

Dr. Christine Giger, assistant professor of *geoinformation technologies* and Dr. Susanne Kytzia, assistant professor of *regional resource management* left the department on 31 October 2006 and 31 January 2007, respectively.

Peter Marti/February 2007

Ultra high-resolution satellite sensors for earthobservation

Armin Grün, Institute of Geodesy and Photogrammetry (IGP)

Satellite-based optical earth observation systems have made huge progress in the past years, both in terms of spectral and spatial resolution. While LANDSAT-1 MS-Scanner was operating with a 80m footprint the currently highest resolution civilian satellite (QuickBird) can produce up to 0.6 m footprint. This translates into an improvement factor of more than 100 within a period of 30 years. With this tremendous increase in spatial resolution the range of applications has also widened substantially. Can we extrapolate this development into the future. And if yes, at what rate?

Indeed, for the year 2007 the US Government has issued already licenses for 40 cm footprint satellite sensors and rumors exist that for 2008 systems with 0.25 cm are discussed. Concretely DigitalGlobe is planning for 2007 a new satellite WorldView I with the following features: 50 cm panchromatic resolution, revisit rate 1.7 times/day, collects 750 000 sqkm per day. For 2008 this system is extended to WorldView II with: 50 cm panchromatic, 1.8 m multi spectral (RGB, NIR, coastal, yellow, red edge, NIR2), revisit rate 1 times/day, coverage 950 000 sqkm per day.

Already since a number of years high-resolution satellite images at sub-5m footprint and with stereo capabilities have become available to the earth observation community and their respective clients. QuickBird for instance is collecting images at a rate of 75 Million sqkm annually. The related cameras are all using Linear Array CCD technology for image sensing. These sensors are widely used to acquire panchromatic and multi spectral imagery in pushbroom mode for photogrammetric and remote sensing applications. Spaceborne sensors like SPOT-5, IKONOS, QuickBird, ALOS/PRISM and Cartosat-1 provide not only for high-resolution (0.6 – 5.0 m) and multi spectral data, but also for the capability of stereo mapping.

All these new systems are equipped with high quality orbit position and attitude determination devices like GPS and IMU and/or startracker systems. In particular, IKONOS and QuickBird implemented the Three-Line Scanner principle in a very unique way (Fig. 1). They use only one Linear Array in one camera to form along-track stereo images by pointing to the imaging area with a forward-looking angle when approaching the area. It changes the look angle to 0° when above the area and to an afterward-looking angle when leaving the area. This agile pointing capability enables the generation of along-track stereo images from the same orbit within a very short time interval, which has a distinct advantage to cross-track stereo image acquisition because it reduces radiometric differences, and thus increases the correlation success rate in the automatic image matching process. Opposed to that ALOS/PRISM is generating 3 images over the same area by using 3 cameras simultaneously with one CCD line in each camera.

In addition to the along-track stereo capability, systems the High-Resolution-Geometry (HRG) sensors of SPOT-5 are able to collect cross-track stereo images. Unlike the traditional frame-based aerial photos, each line of the linear array image is collected in a pushbroom fashion at a different instant of time. Therefore, the perspective geometry is only valid for each line whereas it is close to a parallel projection in along-track direction, and there is in principle a different set of (time-dependent) values for the six exterior orientation elements for each line. The possible multiple view terrain coverage capability and the high quality image data (typically more than 8 bits) also result in a major improvement for data processing in terms of precision and reliability.

In summary, the processing of these kinds of images provides a challenge for algorithmic redesign and this opens the possibility to reconsider and improve many photogrammetric processing components, such as image enhancement, multi-channel color processing, georeferencing and triangulation, orthophoto and DSM generation and 3D object extraction.

If this very high spatial resolution image data is to be utilized in an efficient way the existing approaches of the remote sensing community for sensor modeling, georeferencing, image matching, etc. are

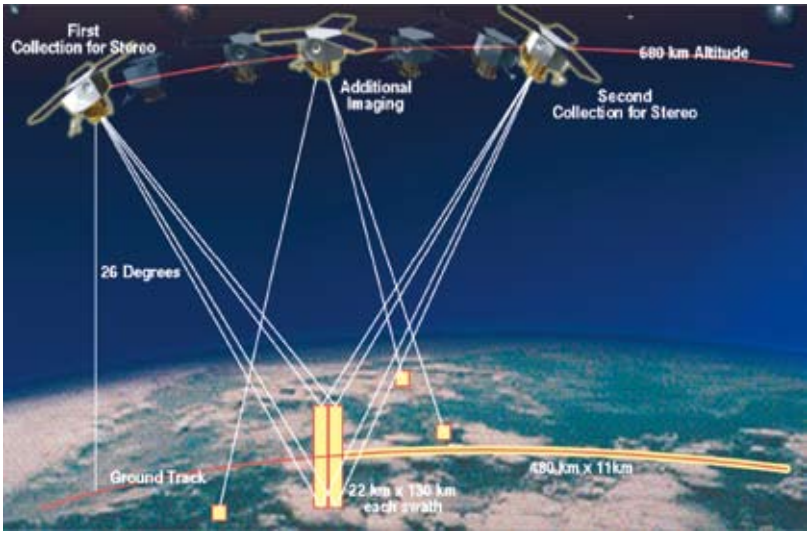


Fig. 1: Scanning principle of multiple-line stereo sensors.

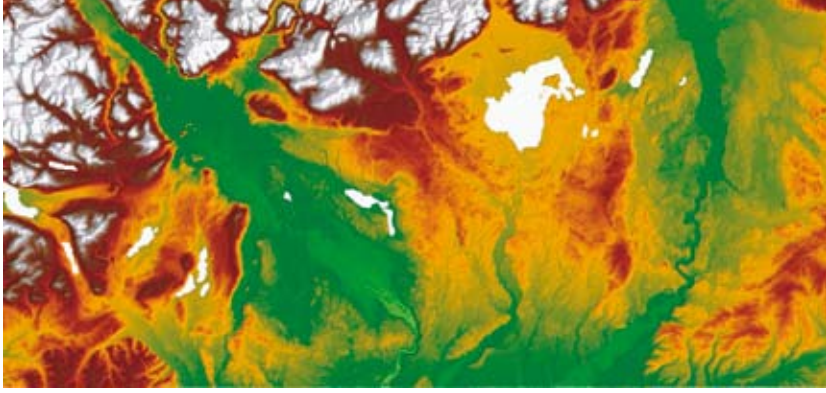


Fig. 2:
25m raster DSM generated from SPOT-5 HRS pictures with SAT-PP. The study was part of the CNES-ISPRS international tests. SAP-PP produced the most accurate DSMs (3-7 m accuracy) among all tested matching methods.

not sufficient any more. The possibility and need for accurate 3D object reconstruction requires a sophisticated camera model and new approaches for image analysis, being able to deal with such sensor geometry. We have recently developed a full suite of new methods and the related software package SAT-PP (Satellite Image Precision Processing) for the accurate processing of this kind of data. The software can accommodate images from IKONOS, QuickBird, ALOS/PRISM, Cartosat-1, SPOT-5 HRS/HRG and sensors of similar type to be expected in the future.

In our efforts of improving the capabilities of such systems we have put particular emphasis on the georeferencing and image matching functions for the generation of Digital Surface Models (DSMs) and the extraction of man-made and natural objects and features.

The software system has been verified extensively with several high-resolution satellite imagery datasets, such as the IKONOS, QuickBird, ALOS/PRISM, Cartosat1 and SPOT-5 HRS images, over different terrain types, which include hilly and rugged mountainous areas, rural, suburban and urban areas.

We will present here some of the evaluation results.

Automatic Generation of Digital Surface Models (DSMs)

We have developed an image matching approach for automatic DSM generation from linear array images, which has the ability to provide dense, precise, and reliable results.

Our image matching approach uses a coarse-to-fine hierarchical solution with a combination of several image matching algorithms and automatic quality control. The approach was originally developed for multi-image processing of the very high-resolution Three-Line-Scanner (TLS and StarImager) aerial images. Now it has been extended and has the ability to process other linear array images, e.g. satellite images of type SPOT-5, IKONOS, QuickBird, etc., as well as more traditional single frame images.

The approach essentially consists of 3 mutually connected components: the image pre-processing, the multiple primitive multi-image (MPM) matching and the refined matching procedure. The images and the given or previously estimated orientation elements are used as input. After pre-processing of the original images and production of the image pyramids, the matches of three feature types (feature points, grid points and edges) in the original resolution images are found progressively starting from the low-density features at the lowest resolution level of the image pyramid. A TIN form DSM is reconstructed from the matched features at each pyramid level by using the constrained Delauney triangulation method. This TIN in turn is used in the subsequent pyramid level for derivation of approximations and adaptive computation of some matching parameters. Finally and optionally, least squares matching methods are used to achieve more precise results for all matched features and for the identification of some false matches.

Performance Evaluation

The software system has been verified extensively with several high-resolution satellite imagery datasets, over different terrain types, which include hilly and rugged mountainous areas, rural, suburban and urban areas. We have used testfields in Bavaria, Germany (SPOT-5, see Fig. 2), Thun/Bern (Fig. 4), Switzerland (IKONOS and PRISM), Saitama, Japan (PRISM) and Piemonte, Italy (PRISM). In the following we give a summary of our results and experiences.

We act as Principal Investigator (PI) and Member of the Calibration/Validation Team for the JAXA (Japanese Space Agency) ALOS/PRISM mission and as PI for the Indian Cartosat-1 satellite. In this context, and mainly for the purpose of sensor and data validation we have set up the testfield Thun/Bern, together with ESA-ESRIN the testfield Piemonte and we are also using data from Saitama.

The set-up of a testfield for validation purposes includes the establishment of a sufficient number (more than 50) of Ground Control Points, which are used in the orientation/georeferencing process as

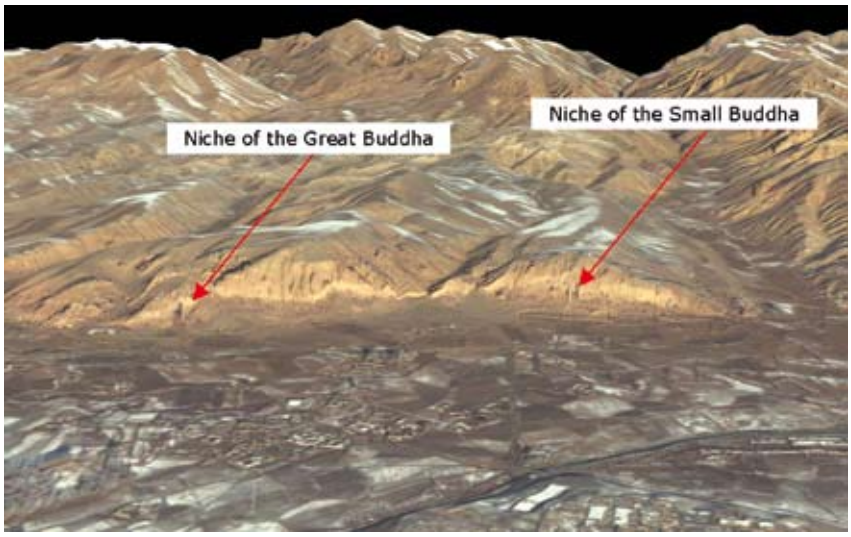
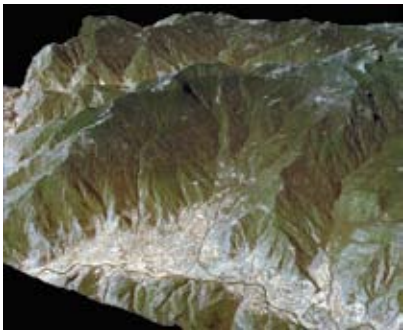


Fig. 3: DSM of the Cultural Heritage site of Bamiyan, Afghanistan. Geometric part determined from SPOT-5/HRG stereo images, texture from IKONOS orthoimage. The two now empty niches of the destroyed Buddhas are clearly visible in the rock cliff.



Textured 3D modell of Thimpu, Bhutan.
Automatically generated from an IKONOS stereo pair.

control and check points. If the DSM generation functionality has to be checked a large number (several ten- or even hundredthousands of reference points have to be generated – mostly via aerial image processing or LiDAR survey.

Results

For the orientation/georeferencing of the stereomodels/triplets we achieved over all different sensors and all testfields consistently a planimetric accuracy of 0.3 - 0.5 pixels, which is equivalent to 30 – 50 cm in case of IKONOS and a height accuracy of 0.5 - 1 pixels.
For the automated generation of the DSMs we used our new image matching approach described above. We achieved consistently accuracies between 1 and 5 pixels, depending on the roughness of the terrain, the amount and type of vegetation and the image quality and image texture.

DTM generation of the Cultural Heritage area of Bamiyan, Afghanistan

Here we present the modeling and visualization of the Cultural Heritage area of Bamiyan, Afghanistan, using SPOT-5 and IKONOS imagery. The region is situated approximately 200 km north-west of Kabul and was one of the major Buddhist centres until the ninth century AD. The two standing Buddhas of Bamiyan belonged to some of the most famous Buddhist monuments world-wide. In 2001 they were destroyed with an act of vandalism by the Taleban militia and since 2003 the cultural landscape and archaeological remains of the Bamiyan valley are included in the UNESCO World Heritage List [http://whc.unesco.org/]. In previous reports we have already presented the 3D computer reconstruction of the Great Buddha and its currently empty niche within the Bamiyan rock cliff. Here we report briefly about the landscape modeling of the larger environment for documentation and visualization purposes. The 3D data will later be imported into GIS software and used for the generation of a cultural and tourist information system.
A 2.5 m panchromatic SPOT-5/HRG stereopair over the UNESCO cultural heritage area of Bamiyan was provided to us by the CNES/ISIS Program. Furthermore, a colour Geo level IKONOS image mosaic (1 m resolution) over the Bamiyan area was provided by Space Imaging. The images were oriented with our SAT-PP package.
The oriented SPOT stereopair was subjected to the automated DTM/DSM generation process and a point cloud of approximately 8,500,000 points was computed. Then a 20 m raster DTM for the whole area (49x38 sqkm) and 5 m raster DTM for the area covered by the IKONOS image mosaic (11x18 sqkm) were interpolated from the original irregular point cloud, produced by image matching. Figure 3 shows a view onto the textured terrain model. It is notable that the empty niches can be seen at an amazing level of detail from space from a distance of about 700 km.

3D forest canopy modeling

Over our testfield Thun an IKONOS image triplet was acquired in December 2003. The testfield consists of a steep mountainous region in the southwestern part and smooth hilly regions in the middle and northern parts. The whole area is about 11 x 20 km² and 30% is covered by forests. The site has an elevation range of more than 1600 m and the land cover is very variable.
After the IKONOS image triplets were georeferenced our matching approach was applied. The three images were matched simultaneously in order to achieve more precise and reliable results. Some areas like lakes and rivers were manually defined as “dead areas” via a user-friendly interface and were excluded from matching. The matching approach resulted in about 11 million points and 800,000 edges, of which more than 80% were labeled as highly reliable. Finally, a 5 m regular grid DSM was interpolated from the raw matching

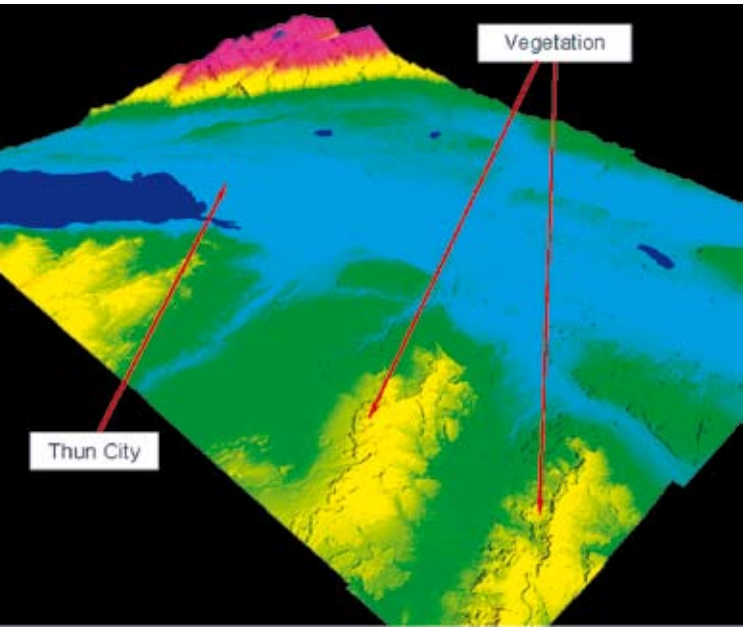


Fig. 4: The automatically generated 5m raster DSM of the Thun region in a color coded picture.

Fig. 6: 3D city model of Phoenix, Arizona, derived from QuickBird stereo images *(courtesy CyberCity AG)*.

results. Figure 5 shows the shaded DSM for one sub-area, together with the corresponding sub-image. The resulted DSM reveal that our matching approach reproduces quite well not only the general features of the terrain relief but also small geomorphological and also 3D forest canopy structures.

Man-made object extraction

We also use satellite images for the generation of 3D city models. For that purpose our semi-automated method of building extraction "CyberCity Modeler" is applied and connected to the particular sensor model of these satellite images. Figure 6 shows a city model of Phoenix, Arizona, which was derived from QuickBird stereo images and produced in cooperation with CyberCity AG. On other occasions we could also show that 3D road networks can be extracted from satellite images very efficiently.

Conclusions

Ultra high-resolution satellite images constitute an interesting tool for many new applications. In order to match the intrinsic capabilities of these images new methods for data processing had to be developed. Our new software package SAT-PP for the 3D processing of high-resolution linear array - based satellite images includes such required functionality. We have basically 3 types of sensor models for georeferencing at our disposal. As revealed from the experimental results, sub-pixel orientation accuracy (up to 1/3 of a pixel) can be achieved.

We also showed that DSMs can be produced fully automatically with a height accuracy of slightly better than one pixel in cooperative terrain. As evidenced by the visual inspection of the results, we can reproduce not only the general, but also detailed features of the relief. This also includes the determination of 3D forest canopy models, from which in turn biomass parameters may be derived.

The accuracy of the DSM depends mainly on the roughness of the terrain, the amount and kind of vegetation and the image texture. In general one can achieve an accuracy between 1 and 5 pixels.

Remote sensing history shows that hardware development has outpaced very often the development of processing techniques. Algorithmic advancements are mostly trailing behind. This is one of the reasons that the great majority of space images is not processed at all. Bigger efforts have to be made in the future in order to advance both hard- and software at a meaningful level of synchronization.

The processing techniques for ultra high-resolution satellite images approach more and more the procedures of aerial photogrammetry. This convergence of technologies will further contribute to the unification of these disciplines.

We are currently observing that photogrammetry and remote sensing have expanded their techniques very much in recent years – mostly towards the joint goal of precise georeferencing and 3D modeling. This has opened many new fields of applications.

The pressing need for modeling our 3 D environment (3D city and terrain modeling) from aerial and high resolution satellite images will have a tremendous impact in natural hazard damage monitoring, risk analysis, car navigation, Location-Based Services, virtual tourism, and in many more applications.

Already now, but even more so in the near future, we are and will be overwhelmed by huge amounts of images, emerging from satellite, aerial and terrestrial platforms. A good deal of those images will have to be processed using photogrammetric techniques. This is why we see a very bright future for a joint approach to photogrammetry and remote sensing, in research, development and with respect to practical applications as well.

(More information: *www.photogrammetry.ethz.ch* under PROJECTS).

Fig. 5: DSM generated from IKONOS image triplets over our testfield Thun.
Left: 5 m DSM visualized in shading mode; right: IKONOS subimage.
The canopy structure is clearly visible, both in the image and in the 3D model.

On the outburst of glacier-dammed lakes: A study at Gornergletscher, Valais[1]

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[1] Study funded by Swiss National Science Foundation Grants Nr. 200021-103882/1 and 200020-111892/1
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All the other authors: VAW/ETH Zurich

The release of water from glaciers in catastrophic floods poses an important threat to human activity. Such events are called *jökulhlaups*, an expression from Iceland, where spectacular outburst events originate in large water bodies impounded within ice caps. These lakes form when a geothermal area melts ice from the base. In the Alps or in glacierized mountain areas in general, glacier-dammed lakes develop in a depression resulting from a combination of topographical conditions and glacier extent. They also form in depressions on the irregular surface of debris-covered glaciers. The most famous historical cases in the Swiss Alps, where such glacier-dammed lakes suddenly drained with disastrous consequences, are *Glacier du Giétro, Allalingletscher, Grubengletscher* and *Aletschgletscher/Märjelensee*. These outbursts represent a severe threat in mountain ranges and have caused major damage and loss of life in the past.

Lakes impounded behind an ice barrier drain in a variety of ways. Among the most well known are lake outbursts associated with a catastrophic drainage due to rapid thermal enlargement of subsurface channels. But sometimes, for unknown reasons, other mechanisms occur, even at the same location, owing to the complex nature of these events. The initiation of an outburst may be of particular complexity. The ultimate challenge of this phenomenon is clearly to be able to predict the timing and magnitude of lake outbursts. In spite of recent improvements in the physical understanding of flood mechanics, such forecasts are not yet possible. This was the main motivation for the launching of a comprehensive project by the VAW, Glaciology Section, three years ago on *Gornergletscher* above Zermatt.

Observations

Gornergletscher is the second largest glacier in the Alps (Fig. 1). It consists of several tributaries and covers an area of nearly 60 km^2.
At the confluence of *Gorner-* and *Grenzgletscher*, *Gornersee* (an ice-marginal lake) has formed every spring and drained every summer for many years. In the last century *Gornergletscher* experienced a significant ice loss, especially in the lake area (150 m thinning since 1931, Fig. 2) leading to a continuously changing bathymetry. The greatest ice thickness of *Gornergletscher* is 450 m and the main glacial valley is slightly over-deepened.
A gauging station operated by the *Grande Dixence* hydropower company is situated 1 km downstream of the glacier terminus, recording hourly discharge since 1970 and additional observations of the lake drainage in the 1950s and 1960s, providing the unique possibility to carry out an assessment of glacier floods for more than half a century. Each year 1 to 5 Mill. m^3 of meltwater are impounded by the lake. In most of the cases, the lake filled to the maximum level beyond which it would give rise to a supraglacial outflow and start to drain subglacially shortly after. Since 2004, we have performed a variety of field experiments to explore the lake outburst phenomena, including:

1. velocity measurements with high temporal and spatial resolution,
2. passive seismic activity recording,
3. dye-tracing, and
4. water pressure and tilt measurements in boreholes drilled in the glacier.

In 2005 the lake drainage started subglacially with a surface water level 15 m lower than 2004, well before supraglacial outflow could occur. In 2006, the lake filled completely and drained within roughly three weeks by melting a 300 m long and 50 m deep gorge in the ice dam. The water then flowed through a *moulin* and escaped from the glacier subglacially. According to these observations, three different drainage processes occurred in three consecutive years. This indicates the difficulties encountered in attempting to forecast such events.

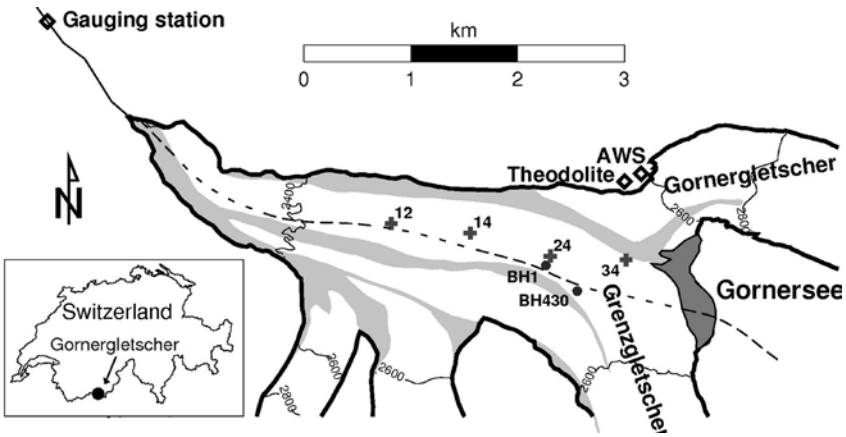


Fig. 1: Map of *Gornergletscher* (left). Dots mark two boreholes and crosses indicate the position of four stakes for ice motion measurements. The central flowline used for the profiles in Figure 2 is depicted by a dashed line. Photograph (right) taken in July 2006 showing *Gornergletscher* and its two tributaries *Grenz-* and *Gornergletscher* (right and left) and *Gornersee* (at the confluence).

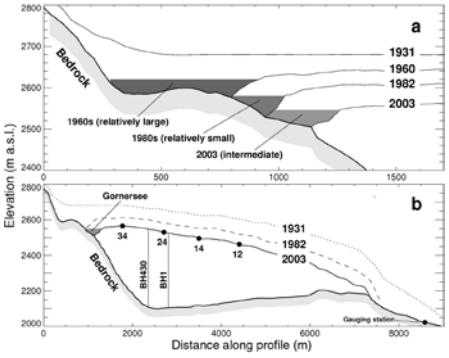


Fig. 2: (a) Schematic profile of the *Gornersee* evolution during the past decades. (b) Longitudinal profile of the *Gornergletscher* tongue. Bed topography was obtained from radio-echo soundings. Two boreholes and four stake locations are indicated.

Lake outbursts 1950-2006

The discharge from lake outbursts is superimposed on melt-precipitation induced by runoff variations. Because we have discharge records from the *Grande Dixence* gauging station only, it was necessary to conduct a hydrograph separation to identify the magnitude and timing of previous lake outbursts. We applied a distributed temperature-index melt model coupled with a linear-reservoir runoff model to compute hourly discharge from the *Gornergletscher* catchment. By subtracting the simulated melt-precipitation induced discharge from the discharge measured at the gauging station, we extracted the outburst component of the hydrograph (Fig. 3).

Significant drainage events were identified in each year except for 1984, 1991, 1995 and 2006. Figure 4a presents the evolution of the lake outburst timing revealing an obvious trend. Between 1950 and 2005, a shift of about two months was observed, moving the expected date of the event from late August to late June. In contrast, the temporal evolution of drainage volume does not show a uniform trend (Fig. 4b).

It is not clear to what extent the volume fluctuations are caused by the changing lake basin geometry or the different filling levels of the lake. Clague and Mathews (1973) first suggested that the peak discharge Q_{max} and the water volume V drained by an ice-dammed lake during the flood appears to follow a power low relation of the form $Q_{max}=K V^{b}$, where K and b are constants determined from field data. This relation can be used to estimate the flood magnitude but is not suitable for accurate predictions. Subsequent extended studies with more data revealed a greater scatter, but the value of the exponent (b=2/3) seemed robust for subglacial lake outbursts. Recently, Ng and Björnsson (2003) demonstrated the physical origin of this formula and discussed the numerical value of the exponent. By analyzing the data obtained from *Gornersee* between 1950 and 2005, we found the same relation as Clague and Mathews (1973) but with a much smaller value of K=10 instead of 75 (Fig. 5).

Considering the range of drainage volumes of Gornersee, which is much smaller than in the previous studies, the two variables show a strong correlation (Fig. 5). Nevertheless, the scatter in Figure 5 indicates that the previous relation is not yet practicable for a reliable forecast. This unique 50-year time series of annual lake outbursts demonstrates the complexity and diversity of the lake outburst process.

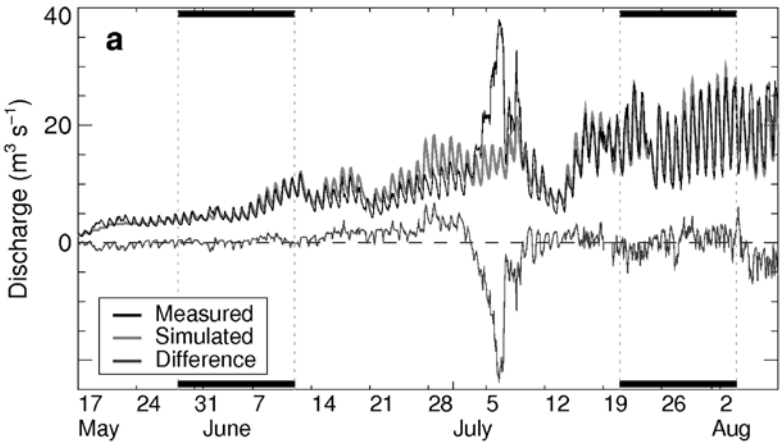


Fig. 3: Measured and simulated hourly discharges of *Gornergletscher* during summer 2004. The lake drainage event is clearly identified.

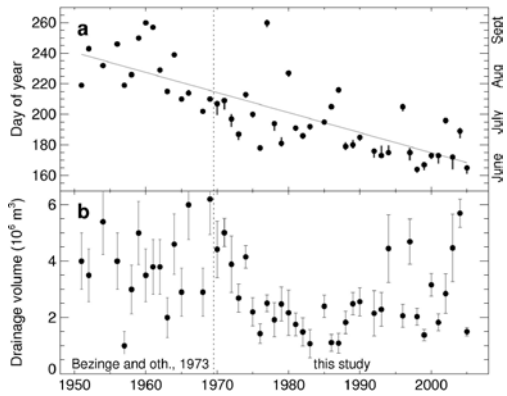


Fig. 4: (a) Evolution of lake outburst timing. (•) correspond to the dates of peak discharge. Vertical bars show the duration of the drainage events. (b) Time series of drainage volumes with corresponding error bars.

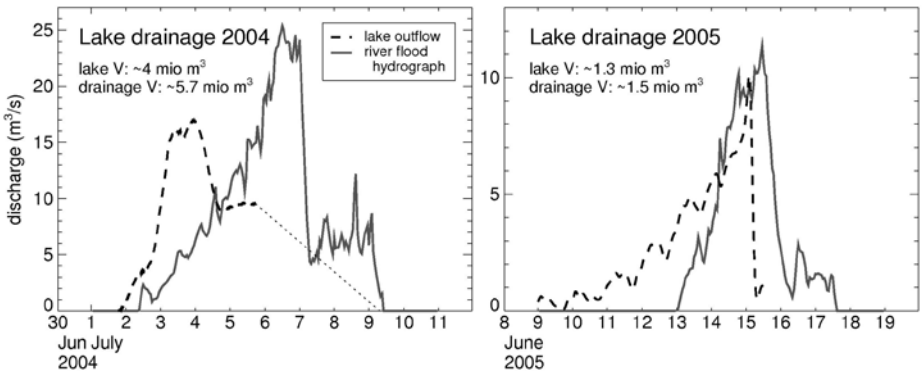


Fig. 6: Outburst from *Gornersee* and corresponding discharge record (in which the glacier melt contribution was subtracted) at the Gornera River at Grande Dixence gauging station near the glacier snout for the years 2004 and 2005. Note that after July 5 2004, no lake level records were available.

Mechanisms of lake outburst

Present theories postulate that the drainage of glacier-dammed lakes is controlled by two different processes:

- Progressive enlargement of intra- or subglacial water channels, and
- Flotation of the ice dam.

The intra- or suglacial channels have been called Röthlisberger- or R-channels since Hans Röthlisberger, VAW, first published a pioneering article on this subject in 1972. This channel enlargement process induces a gradual climb of the hydrograph. On the other hand, flotation of the ice dam produces a sharp and sudden runoff peak which happens when the subglacial water pressure exceeds the ice overburden pressure.

We were able to observe these two different drainage mechanisms on *Gornersee*. In 2004 the flood was triggered by flotation of the ice dam and in 2005 by channel enlargement. This can be seen in the two very different lake outflow hydrographs in Figure 6.
If the flood is triggered by channel enlargement, then it is conceivable that the subglacial drainage system prevailing near the ice dam can play an important role. In 2005, it was shown with dye tracer experiments that the lake drainage initiated when the drainage system became efficient near the lake. Figure 7 shows a series of injections into a *moulin* above the lake, the transition is marked by the change in breakthrough time of the dye.

During the outburst of glacier-dammed lakes, an enormous amount of lake water drains into the glacier bed within a short period and the glacier ice flow regime is expected to change drastically during a drainage event due to the changing subglacial conditions. According to the diurnal flow variations and motion events observed in the alpine glaciers so far, a sudden water input into the bed enhances the basal ice motion by increasing the subglacial water pressure. The ice flow speed significantly increases as the pressure approaches the ice overburden pressure and the glacier sole is decoupled from the bed. Because the water flux from a lake outburst is generally much larger than the meltwater input, a lake drainage may cause flow changes that are not observable under the usual hydrological conditions. Furthermore, the ice dynamics near a glacier-dammed lake are important because of their critical role in the lake drainage process. The motion of an ice dam may control the water discharge from the lake. Therefore, knowledge of glacier dynamics in the vicinity of a lake is crucial to understanding the triggering mechanisms of an outburst.
To study the impact of the drainage of a glacier-dammed lake on glacier dynamics, high frequency ice flow measurements were carried out simultaneously with hydrological observations at Gornergletscher. During the outburst event of July 2004, the flow speed increased by 100% and the surface rose by 20 cm; these processes were triggered by 4 Mill. m³ of water drained from the lake within 5 days. The water level measured in boreholes was consistently high near flotation level, suggesting that the elevated subglacial water pressure enhanced basal ice motion and subglacial water cavity formation. The most intriguing observation was that a reversed ice motion occurred, in particular, a 180° backward ice flow was recorded at one of the surveyed stakes (Figure 8c).
The change in flow direction was attributed to the stress coupling with the accelerated ice flow at the central part of the glacier, but its reversal was difficult to explain. A plausible interpretation is the rebound of the elastic motion of the glacier. However, Young's elasticity modulus of ice is too large to explain the observed recovery of almost the entire transverse motion, suggesting that the large-scale mechanical properties of the glacier could possibly be responsible for

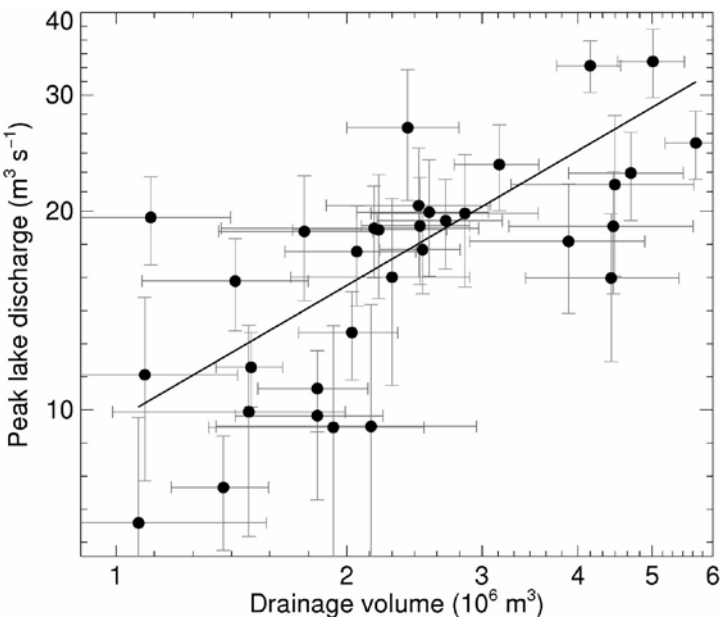


Fig. 5: Log-log-plot of drainage volumes and peak lake discharges (number of samples n=33 and correlation coefficient r^2=0.61).

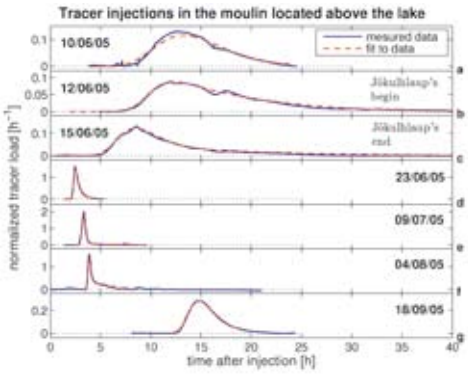


Fig.7:
A series of dye tracer experiments conducted throughout the summer 2005. The *moulin* used for the injection was situated above the lake. The evolution of the drainage system from inefficient to efficient and back is striking.

the elastic behavior. For example, the closing and opening of water-filled englacial fractures have the potential to change the macroscopic elasticity of the glacier system.
Because the reversal of ice motion was observed in the vicinity of the lake on the ice dam, it possibly played a key role in the triggering and the drainage mechanisms of the outburst. Moreover, the reversal was observed as being pervasive, from the lake vicinity to the lower reaches several kilometers below, implying that the phenomenon commonly occurs under the influence of rapidly changing stress conditions.

Conclusions

A detailed analysis of the data set obtained so far for Gornergletscher proves that a variety of different processes are involved during a lake outburst event. Our study shows the need for an integrative assessment of glacier-dammed lake floods in order to better understand the nature of these events. The dramatic dynamic response of the glacier during the lake outburst cannot be explained based on the current knowledge of glacier mechanics. Further investigations are necessary to reveal the fundamental processes triggering the initiation of a lake outburst.

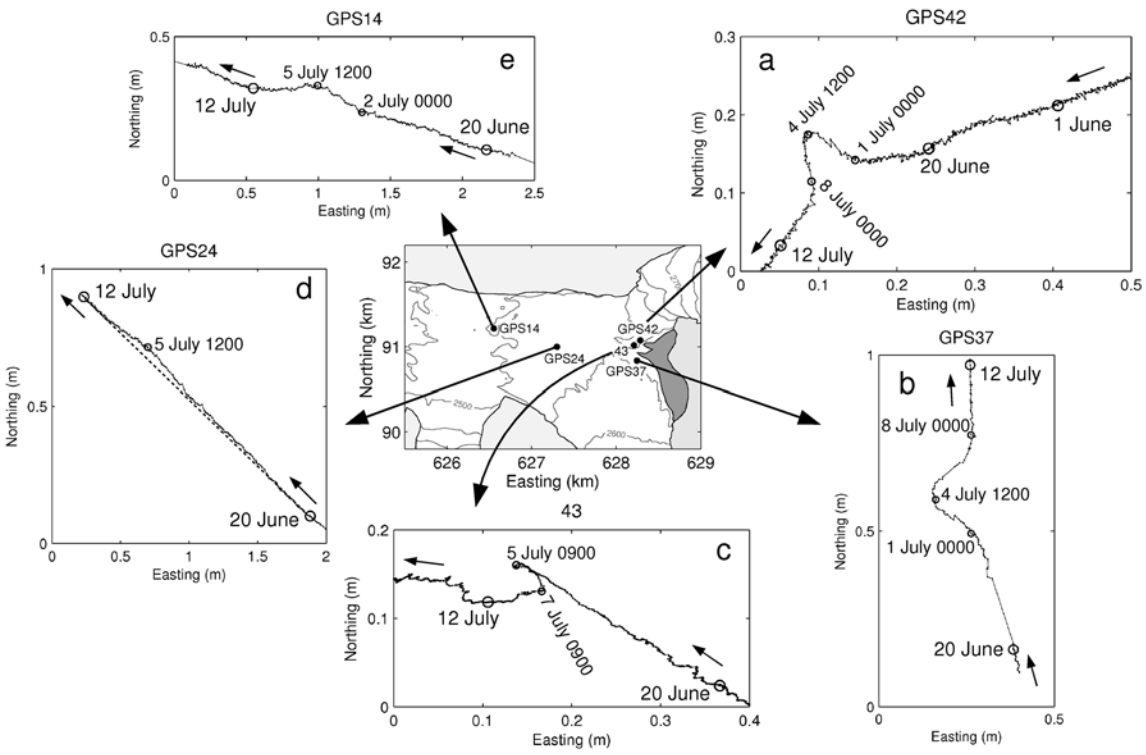


Fig. 8: Plan view of the stake motion at each survey site. The outburst began on 2 July and the water level dropped continuously until the lake emptied on July 7, 2006.

The Leaning Tower of St. Moritz – Geotechnics of construction on an active landslide

Alexander M. Puzrin, Ivo Sterba, Andreas Schmid, Sophie Messerklinger/IGT

Landslides are one of the major geotechnical hazards affecting economy and life in the subjected areas. Six percent of the area in Switzerland is prone to slope instability. Though most of the landslides take place in rural areas, they cause significant damage to the infrastructure: such as roads, railways, etc. Of major concern to the community are the landslides active in urban areas. Among these landslides, the Brattas Landslide of St. Moritz (Fig. 1a), with its most prominent landmark – the Leaning Tower of St. Moritz (Fig. 1b), is of a special interest:

- remarkably, the landslide stops in the middle of the town
- in spite of the landslide, the town has enormous real estate prices
- the town had to adopt a special construction law for the affected areas
- there is an extensive displacement monitoring program in progress
- interesting experience related to the behavior of existing structures
- original engineering solutions for construction of the new structures

Institute of Geotechnical Engineering (IGT) at the ETH Zurich, has been actively involved over the last 30 years in all geotechnical aspects of the problem, providing expert service to the community. In addition, in the last 2 years a new research program has been initiated in an attempt:

- to better understand the landslide mechanisms
- to define more accurately the boundaries of the landslide
- to make predictions of the long-term stability and displacements
- to test new monitoring and field investigation sensor technologies

Geometry, Geology and Movements

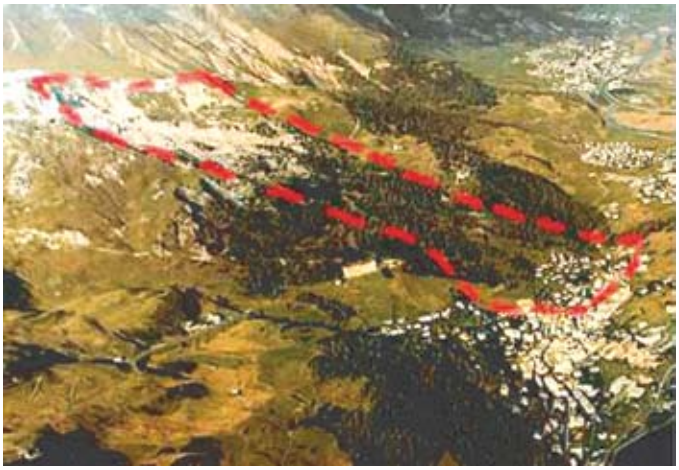
The unstable northern slope above the village of St. Moritz (Fig. 1a) may be divided into two zones (Fig. 2a, after Müller and Messina). The upper zone is the Gianda Laret rockfall, which extends from the detachment zone at the altitude of 2400 m above the see level down to the crest at an altitude of about 2100 m. The lower zone is the Brattas landslide composed of a thick soil mass, which is moving downhill, but is blocked at its foot by the Via Maistra rock ridge, after which the movement stops (Fig. 2b). It stretches from the altitude of 2100 m down to the 1800 m over a horizontal distance of 800 m. The landslide is 600 m wide and is bounded on both sides by parallel shear surfaces. The slope has an average value of 20°. The main sliding surface revealed in one boring reaches the depth of about 50 m. The sliding mass is built of soil layers of great heterogeneity, both in terms of stratigraphy and material properties.

The large-scale geologic situation of the area is seen as primary cause of the landslide: the Mesozoic sediments of the Bernina Nappe were pushed over the crystalline rock of the Err Nappe. The hydrological conditions constitute further causes of instability. Various deep aquifers were observed in the landslide, which create independent water tables. Increase in the pore water pressure due to the snow melt causes shear strength degradation, which leads to the yearly movements, but sometimes also to recurring large-scale landslide events. According to Schlüchter, there is a geological evidence of a number of these landslide events which occurred in the last 5000 years – the last one approximately 700 years ago.

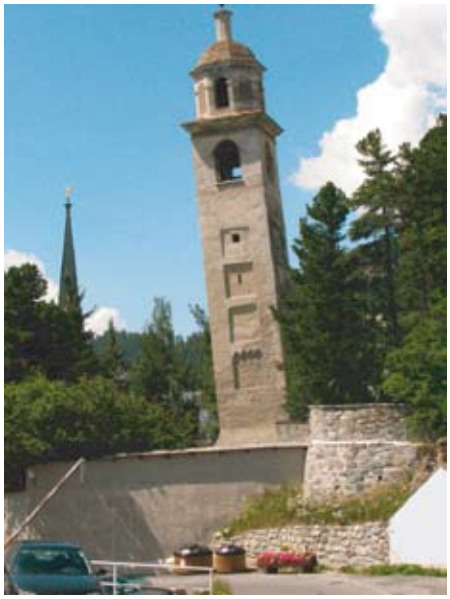
In the portion where it is approached by the landslide, Via Maistra is getting narrower by about 0.5 cm per year. Uphill from Via Maistra the displacement rate increases (Fig. 2b). The movement has only been measured in the developed areas. From these measurements it is not possible to conclude if there is any interaction between the Gianda Laret rockfall and the Brattas landslide.

The Leaning Tower of St Moritz

The Leaning Tower of St Moritz Church, which was built in the 12th century at the foot of the landslide (Fig. 3a, Schlüchter), exhibits an alarming tilt of 5°. The church itself had to be removed in 1893 because of the excessive differential settlements. Since 1908, regular tilt and displacement measurements have been carried out (Fig. 3b). Stabilization efforts in 1928 and 1968 were not successful in the long term, and an alarming re-



(a)



(b)

Fig. 1: The St. Moritz Landslide: (a) an air photo; (b) the Leaning Tower.

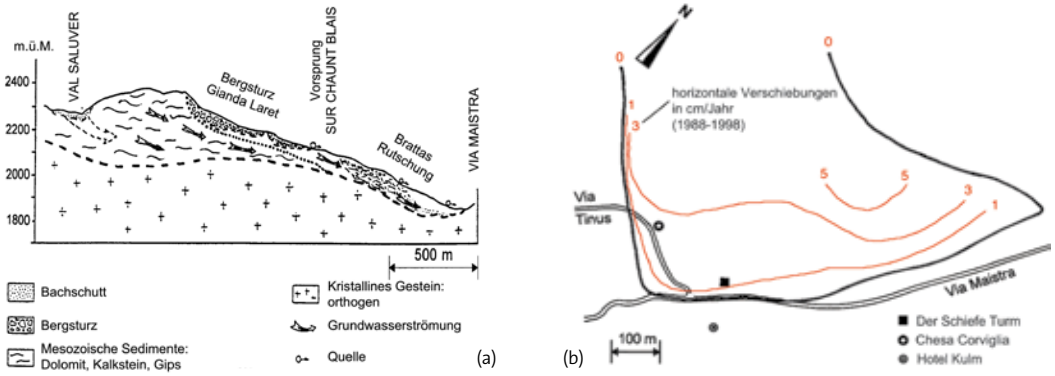


Fig. 2: The St. Moritz Landslide: (a) geological profile; (b) horizontal displacements.

action of the tower to the earthquake in Friaul on May 6, 1976 was detected. As a result it was decided to undertake an additional stabilization attempt, which was accomplished in 1983.

This stabilization procedure consisted of placing prestressed reinforced concrete collars in the area at the foot of the tower and sinking two reinforced concrete barrettes to a depth of 10 m below the original foundation level (Fig. 4a). The tower was then lifted by jack-ups and its weight (1264 tons) was placed on the foundation barrettes via 3 Teflon bearing pads (Fig 4b), and its tilt was decreased. The masonry of the tower was reinforced using vertical internal prestressing. Thus, the tower is "swimming" in the creeping mass, allowing for its tilt being periodically corrected by lifting and introducing additional plates into the bearing pads (carried out in 2005).

Construction on the active landslide

Chesa Corviglia is a terrace type structure (Fig. 5a) on the south western edge of the Brattas slope (Fig. 2b). The original building concept included a 20 m high anchored concrete pile wall (Fig. 5b) completely and permanently separated from the structure. Both the piles and the anchors were supposed to penetrate into the stable rock. Unfortunately, the prognoses concerning the location of the rock turned out to be false. As a result, both the wall and the house are moving downhill, at different speeds, causing the gap between them to close (Fig. 5c), and threatening the stability of the house. This required ingenious and expensive stabilization measures designed by Gysi Leoni Mader AG engineering firm. The wall was reinforced by additional piles, and additional anchors were placed above the original ones (Fig. 5b) in a hope to bring about identical displacements of the wall and the house, rather than to hinder the creep movement, which may be impossible.

As a consequence of the negative experiences with the Chesa Corviglia, the municipality of St. Moritz had to react. Since the only global stabilization possibility - dewatering of the entire landslide – was found not feasible, the new permit specifications were established, which regulate construction activities in the Brattas landslide. For example, during the project phase of new constructions, weight compensation and equilibrium is a priority. The base of the structure should be made as rigid as possible, and the use of the permanent ground anchors is not permitted.

Though the above regulations allow for the damage to the new structure to be significantly reduced, no predictions have been made so far for the long-term stability and displacements of the landslide.

Analysis of the long term stability

A simple model of a constrained landslide has been developed to provide an assessment for the long-term stability and displacements of the St. Moritz landslide. The unusual feature of this landslide is that it has "nowhere" to go and its downhill movement is slowing in time, which intuitively implies the landslide stability. However, exactly because the landslide is slowing, the shear strength on the sliding surface may decrease, leading to increase in compressive stresses at the landslide foot and, ultimately, to a failure.

In order to be able to apply the proposed procedure to the Brattas landslide, additional observation data from the middle and upper part of the landslide should be collected. In particular, an uncertainty with respect to interaction between the Gianda Laret rockfall and the Brattas landslide should be resolved. This will help to define more accurately the upper boundary of the Brattas landslide and the static boundary conditions on it. To collect this data an extensive field investigation program was carried out during the summer and autumn of 2006.

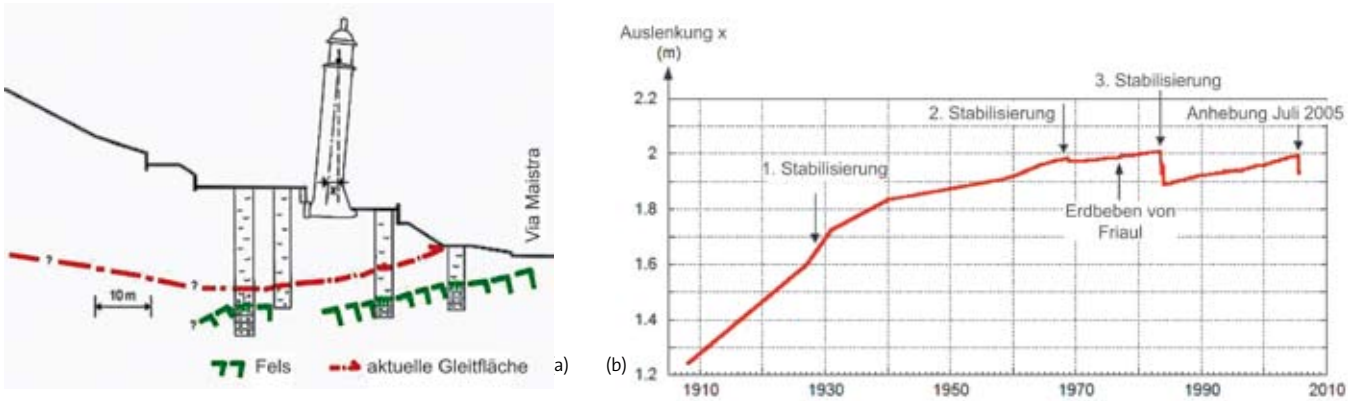
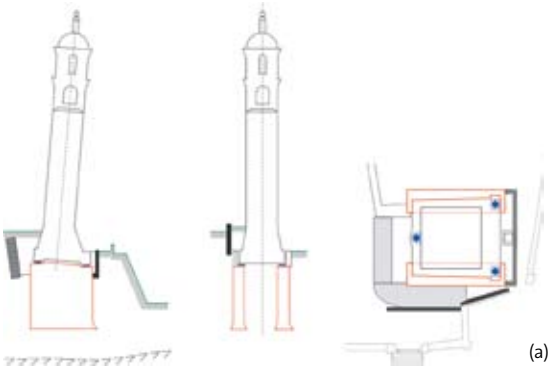


Fig. 3: The Leaning Tower: (a) geological profile; (b) inclination in time.



(a)

(b)

Fig. 4: The Leaning Tower: (a) the new foundation; (b) the jacking-up procedure.

Geodetic measurements

The major part of the field investigation program was the geodetic measurement campaign conducted in collaboration with the group of Professor Carosio, IGP. A grid of measurement points was established covering the Gianda Laret rockfall and the Brattas landslide (Fig. 6a) with a denser grid at the boundary between them. The new points were also made visible for the air photographs (Fig. 6b). The coordinates of the points were measured with a precision of up to 1 cm. The next reading will be taken in 3 years time and the movement rate of different portions of the entire slide body will be established, to be used in the inverse analysis described above.

In addition, we were incredibly lucky to discover some points with coordinates measured 80 years ago (Fig. 6c). Probability of finding them was extremely low, because they were located in a wooded area, shifted by 10-25 m from their original positions and overgrown by a thick layer of grass and tree roots. By measuring their new coordinates, it was possible to establish that the movement rate at the top of the Brattas landslide reaches 30 cm/year, while at the bottom part of the Gianda Laret rockfall – only 10 cm/year. It is, therefore, likely that the rockfall movement is stopped by a rock ridge at the attitude of about 2100 m and does not transfer earth pressures to the Brattas landslide. The upper boundary of Brattas landslide, however, is shifting upwards, with blocks from the rock ridge gradually collapsing into the sliding mass.

Dilatometer tests

Another part of the program included installation of an inclinometer and piezometer in the vicinity of the Leaning Tower. In the same borehole, two types of dilatometer tests were performed with the help of Stump ForaTec AG (Fig. 7a) to determine the soil stiffness at different depths. The first type of test involved the Cambridge dilatometer (Fig. 7b): a cylindrical probe with a cylindrical inflatable rubber membrane inserted into a predrilled borehole. The second type of test involved Marchetti dilatometer (Fig. 7c): a spade-like probe with a round flat inflatable steel membrane pushed into soil to the depth of up to 1 m from the bottom of the borehole. It is the first time that both tests were successfully implemented in such difficult soil conditions (mixture of clay and gravel).

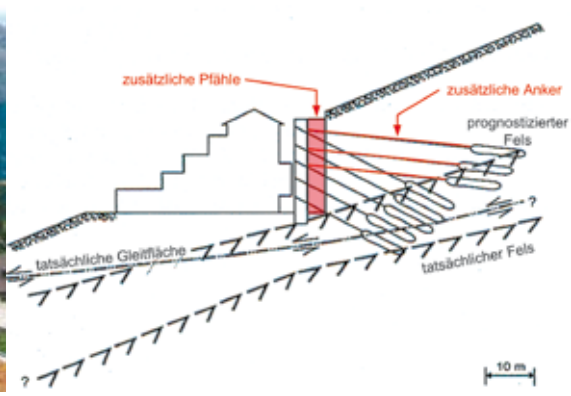
Infra-red filming from the air

Additional purpose of the field program was testing of new applications of the state-of-the-art sensor technologies. In particular, both digital and infra-red air filming of the landslide was performed from a helicopter by the PERGAM AG (Fig. 8a). The digital photos (Fig. 8b) will be used by the group of Professor Grün, IGP, to create a 3D model of the landslide. The infra-red photos (Fig. 8c) have been used to study the ground water pattern along the landslide. For example, the slope in Fig. 8b is not accessible by foot, and to identify the water stream coming out of it is not easy. While in the infra-red photo in Fig. 8c, the water is clearly visible thanks to the temperature difference of almost 15°C with the surrounding stones.

Fiberoptic strain measurements

Another novel application is using fiberoptic sensing for more accurate definition of the lateral boundaries of the landslide. Because of the municipality regulations, the new construction within the landslide area is significantly more complex and expensive than outside this zone. The western boundary of the landslide crosses the town and cannot be clearly identified from the geodetic measurements. This creates a legal and technical uncertainty when the owners of the boundary properties initiate a new construction. To resolve this problem it was decided to use Via Tinus road, which crosses the boundary (Fig. 9a) as a gigantic strain gage, by equipping it with a 82 m long fiberoptics cable (Fig. 9b), glued within a 7 cm deep trench in the asphalt (Fig. 9c). After 1-2 years of landslide movement it will be possible by propagating light waves in the cable to detect its relative elongation in the zone of the shear boundary of the landslide.

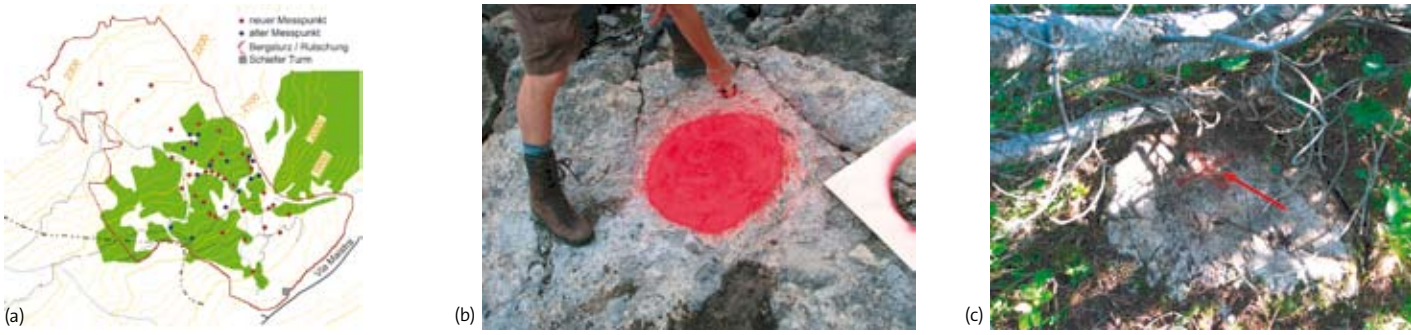
(a)



(b)

(c)

Fig. 5: Chesa Corviglia: (a) the building; (b) the retaining structure (after Gysi); (c) the closing gap between the retaining wall and the building.



(a) (b) (c)

Fig. 6: Geodetic measurement points: (a) the plan; (b) new; (c) 80 year old.

Acknowledgements

The authors would like to thank the municipality of St. Moritz, and in particular Mr. Pietro Baracchi, for their kind assistance during the field program. The collaboration with Professors Carosio and Grün and their co-workers is highly appreciated. The research has been partially supported by a VSS/ASTRA grant "Road-landslide interaction".

(a) (b) (c)

Fig. 7: Dilatometers: (a) the drilling; (b) Cambridge probe; (c) Marchetti probe.

(a) (b) (c)

Fig. 8: Air photos: (a) the helicopter; (b) digital; (c) infra-red.

(a) (b) (c)

Fig. 9: Fiberoptics: (a) the location; (b) the street view (c) the cross-section.

Highlights
Structures

Fig. 3:
Quicksand in the Lençois Maranhenses, a natural park in the North-East of Brazil.

Fig. 5:
Vic-2D-image of a specimen for tensile shearing, showing the deformation after the experiment started.

Simulation of Damage and Healing in Fatigue Fracture of Asphalt

H.A. Carmona, F. Kun, H.J. Herrmann / IfB

Asphalt exhibits a peculiar behavior when it comes to failure. Especially in fatigue damage due to mechanical load cycles, micro-cracks can not only form but also completely heal again when crack surfaces get in contact under compression. It is obvious that the competition between microscopic damage accumulation and the healing of defects finally determines the lifetime of a costly highway construction - but how does this relate to specific asphalt mixtures? Until recently this issue of material design mostly relied on experimental observations since theoretical approaches had shortcomings in capturing all the relevant mechanisms involved in the fatigue failure process such as damage growth, relaxation due to creep, and healing in particular.

By comparing their calculations to experiments (Fig. 1), researchers of the computational physics of materials group demonstrated the validity of so-called fuse and fiber bundle models with a continuous damage approach to describe the fatigue failure of asphalt. These simulations revealed novel scaling laws for the fatigue failure due to the competition of damage accumulation and healing of micro-cracks. This could also be found by a Discrete Element Simulation with damage accumulation and healing of cohesive elements. By this approach, the detailed process of damage, fracture and failure of the solid is revealed (Fig. 2), providing an excellent agreement with experiments, and even more important an open access for material design and improvement.

Fig. 1: Brazilian test on an asphalt sample under periodic compression.

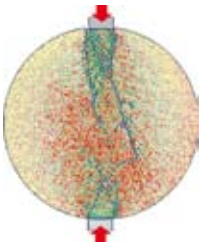


Fig. 2: Virtual Brazilian test on a Discrete Element Model with damage accumulation and healing.

The Nature of Quicksand

D. Kadau, H.J. Herrmann, J.S. Andrade Jr. / IfB

The nature and danger of quicksand has been disputed since a long time. Researchers of the computational physics of materials group investigated a specific type of quicksand at the shore of drying lagoons. Cyanobacteria form an impermeable crust, giving the impression of stable ground. After breaking the crust a person rapidly sinks to the bottom of the field (Fig.3).

Before destroying the crust the measured shear strength is essentially constant up to the bottom of the basin and then it rapidly increases. After the system collapsed the shear strength linearly increases with depth.

To undermine our point that objects lighter than water can be swallowed in the quicksand, we simulated a model in which we constructed a tenuous granular structure representing the unpertubated soil (Fig. 4, left). The initial structure consists of cohesive disks put together by ballistic deposition and settled by gravity using Contact Dynamics. Pushing in an object leads to breaking of cohesive bonds. The soil collapses irreversibly and traps the intruder inside a dense soil (Fig. 4, right). Unlike quicksand fluidized by an increase of pore pressure, in this specific soil no lifting force or buoyancy can push the object to the surface again. Instead, a high force for pulling out is needed.

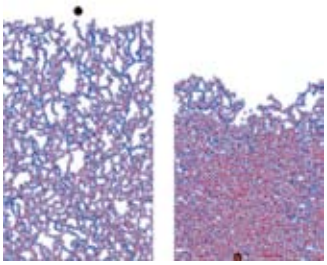


Fig. 4: Computer model of experimentally investigated quicksand. An object pushed inside gets trapped under the collapsing grain structure.

Investigation of structure – property dependencies in 1K-PUR adhesives

O.Kläusler, S. Clauss, P. Niemz / IfB

In timber construction one-component polyurethane adhesives (1K-PUR) are used for the production of glue-laminated timber trusses. Within the scope of a joint research project with Purbond AG (Sempach-Station, CH) and Bayer MaterialScience AG (Leverkusen, D) the influence of several chemical structural parameters on the properties of the glued joint is tested. The forces which act upon the glued joints vary with the static properties of the buildings structural design as well as with the predominant ambient conditions. The glued joints within the truss of an indoor swimming pool (humidity) have to endure different exposures than those within a production hall (temperature) or within a bridge construction (climatic changes). The companies Bayer and PURBOND have been working for years on the development of polyurethane adhesives for timber constructions. Switzerland is today one of the leading countries concerning the utilisation of PUR for glued timber constructions. Within the scope of a joined research project further fundamental studies on structure-property-relationships of polyurethane adhesives for wood joints shall be conducted.

The research project aims at the specific alignment of the composition of the adhesive to certain exposure types, which act upon the construction. Experiments on the shearing strength of the glued joints in alternating ambient conditions, under temperature stress and after storage in water will be conducted as well as on the strain distribution and aging. Furthermore the failure mechanism and the penetration behaviour of the adhesive in the wood will be ascertained (Fig. 5, 6).

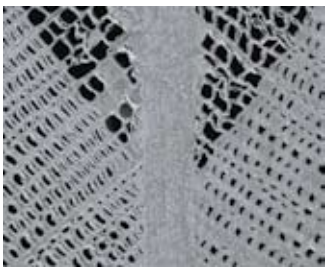


Fig. 6: SEM-image (exemplary) of spruce wood with a PUR glue line (perpendicular in the middle).

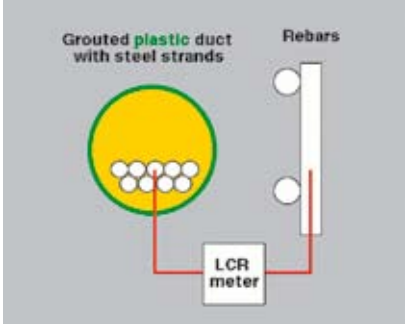


Fig. 9: Schematic representation of the electrically isolated tendons (EIT) and the measuring principle.

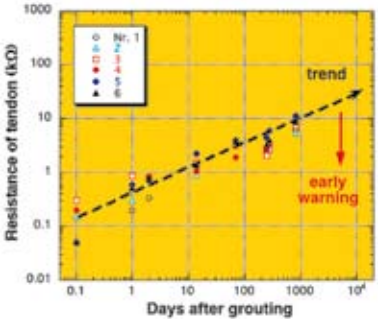


Fig. 10: Evolution of the electrical resistance R of several tendons with time (not the log log plot).

Research on the mechanisms of sound propagation in trees

F. Bächle, S. Schubert, S. Clauss, P. Niemz / IfB; H.R. Maurer / IG; J. Dual / IMES; D. Gsell / EMPA Dübendorf

Trees in urban areas add highly to the quality of life. Nevertheless human safety must be considered because falling tress or branches are dangerous. The utilisation of ultrasound measuring makes it possible to ascertain if a tree is infected with a tree rot and how far this rot has grown. The same method can principally be used for measuring rot in timber constructions or the detection of delamination in glue-laminated timber. The run-time of sound waves depends strongly on the orthotropic properties of wood. Within the scope of an interdisciplinary project between the Institute for building Materials (wood physics), the Institute of Geophysics and Institute for mechanical Systems of the ETH and the Structural Engineering Research Laboratory of the EMPA experimental research on sound propagation in stems was conducted. For the simulation of the sound propagation in stems with and without damages geophysical models were used. The research led to an increased understanding of the sound propagation in wood samples and allows the implication of better models for tomograms of sound propagation in wood. The experimental outcomes were consistent with the results of the model calculations. It showed that a correction factor (to eliminate the influence of oblique the year rings) was necessary to obtain a correct image of the cross section. The implementation of this method allows to detect decay in tomograms. Examples can be seen in Figure 7 and 8.

In a second part of the research project the sound propagation in radial-tangential direction has been calculated and illustrated using the finite element method. This numerical simulation provides likewise reliable data of the cross section area of a tree. A dissertation on numerical simulation is in work.

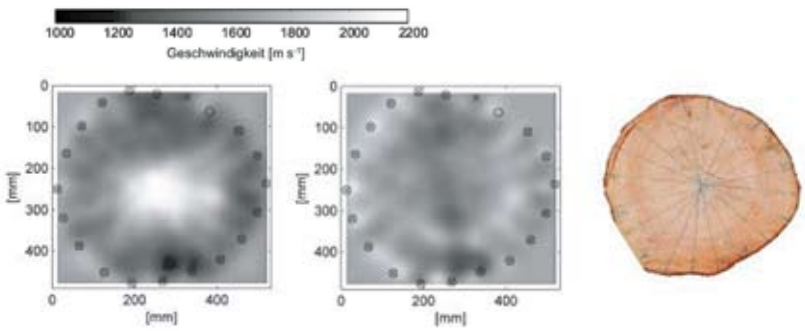


Fig. 7: Left: Without the correction procedure the center velocities are too high and the border velocities are too low / middle: corrected tomogram / right: examined trunk.

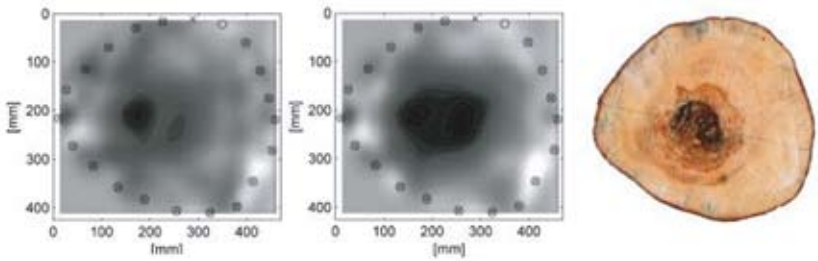


Fig. 8: Left: only a weak disturbance can be detected when not using the correction procedure / middle: clearly visible disturbance by using the correction procedure / right: examined trunk.

Durability monitoring of post-tensioning tendons

B. Elsener, M. Suter / IfB

At present, high strength steel is the only cost effective material that can be used for post-tensioning tendons of large span railway and highway bridges. The high strength steel is prone to corrosion that leads to fracture of the tendons. Despite an overall good long term behavior there occurred tendon failures and collapses. The problem is that in the traditional tendons with metallic ducts no reliable method exists to detect corrosion of the high strength steel.
Industry developed tendons with plastic ducts and electrically isolated anchorages (EIT). This allows for the first time to get information on the degree of protection of the high strength steel by measuring the electrical impedance between the normal rebar and the high strength steel (Fig. 9). Based on laboratory tests, mathematical simulations and an increasing number of post-tensioned structures limiting values for the electrical resistance could be defined. This is applied as a quality control of the tendons 28 days after grouting.

Concrete and the cementitious grout in the ducts hydrate and dry out. The electrical resistance of the tendons increases according to a square root law with time (Fig. 10). This can be used for the long term monitoring of the tendons: a continuous increase indicates corrosion protection of the tendon, a decrease of the electrical resistance instead is an early warning for the ingress of water (and associated chlorides) at a defect in the duct.

Fig. 11: Left: 3D reconstruction of the steel fibres only of a fibre reinforced concrete specimen from a CT-scan. Right: Three different slices through the same reconstructed specimen.

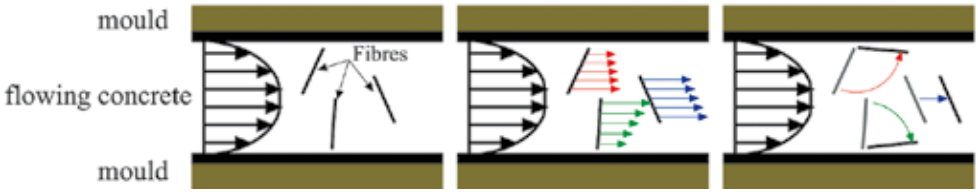


Fig. 13: Simplified model for fibre alignment in flowing concrete.

Fibre orientation and fibre distribution of Fibre Reinforced Concrete

P. Stähli, R. Custer, J.G.M. van Mier / IfB

For improving the mechanical properties of fibre reinforced concrete one can either increase the fibre content, use hybrid fibre systems, or one can attempt to align fibres in the direction of stress. In this project, it is attempted to use the flow-properties of the fresh (self-compacting) concrete to change the fibre distribution and orientation. Using a single mixture of fibre reinforced concrete, containing 3 % of 30 mm long straight steel fibres. The fibre distribution and orientation was determined in three different parts of a U-shaped specimen where the concrete could flow in three different directions. The prisms are marked „A“, „B“ and „C“ for the 'falling' 'horizontal' and 'rising' parts of the 'U-specimen' respectively. The fibre distribution and orientation for various mixtures that only differed in their viscosity (achieved by changing the amount of superplasticizer only), were determined from CT-scans at the Universitaets Spital in Zurich (Fig. 11). Flexural tests show that the mechanical behaviour depends on the fibre distribution and orientation, which can be affected by changing the viscosity of the fresh mixture (Fig. 12). Figure 13 shows a simple model of how the fibre can align in the flowing fresh concrete.

Development of high-strength foamed concrete

D. Meyer, J. G. M. van Mier / IfB

Foamed concrete is a light-weight material with a high porosity (up to 80%). Due to the low weight the compressive and bending strengths are rather low. An additional negative factor is the relatively big scatter of the mechanical and physical properties. This scatter is caused by the used proteins and by the applied foaming methods.

By using an alternative method for the foam production – foaming with membranes – it is possible to reduce the scatter caused by the foam behaviour to very low levels. At the same time the method of foaming with membranes gives us the opportunity to influence directly the foam and its properties.

To improve the strength of the foamed material polymer fibres were added. This brought a remarkable increase of the bending strength, with values up to five times higher as the reference mixtures without fibres. Likewise the ductility also rises to respectable strains, depending to the length of the added fibres.

The compressive strength was not influenced by the added fibres; neither affected were other physical properties like low weight, vapour diffusion and thermal conductivity (Fig. 14, 15).

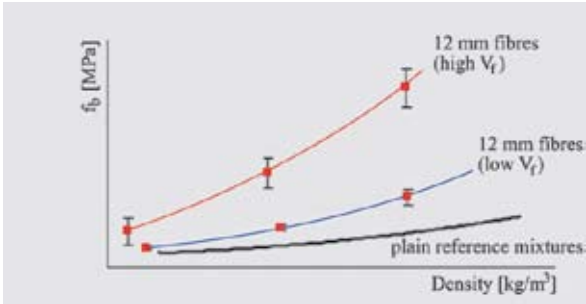


Fig. 14: Bending strength-density diagrams for foamed concrete containing various amounts of fibres.

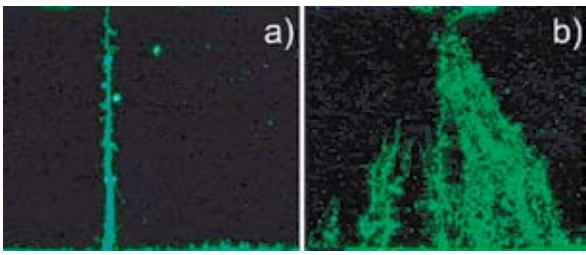


Fig. 15: Crack patterns in polymer fibre reinforced foamed cement paste can vary between a) single localised crack to b) multiple cracking, only by varying the added fibre volume.

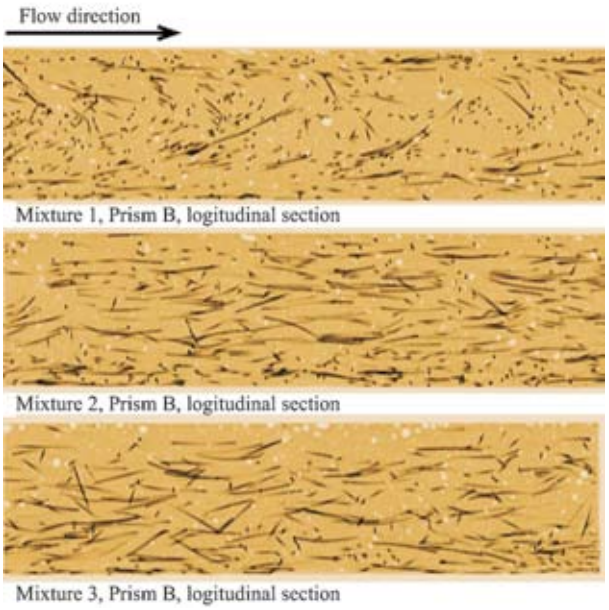


Fig. 12: Longitudinal centre sections of the prisms "B" for concretes with different viscosity.

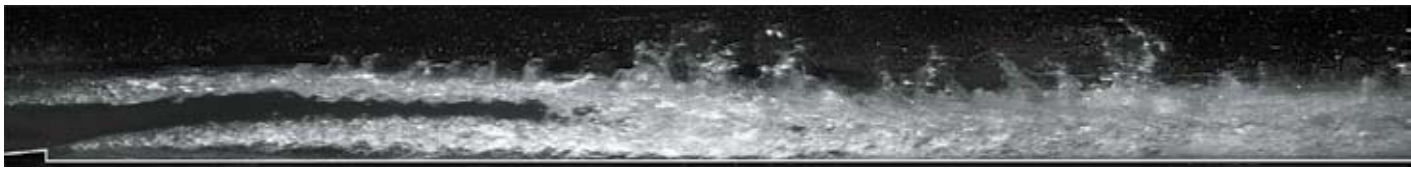


Fig. 18: Flow structure downstream of chute aerator. The jet surface disintegrates with increasing flow distance and finally results in a typical two-phase flow.

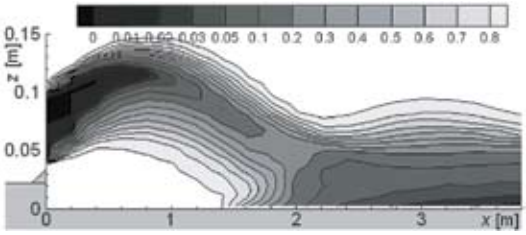


Fig. 19: Contour plot of measured air concentrations with a stretched *z*-axis.

Bed stability of steep open channels

R. Weichert / VAW

Flood events in mountainous regions have caused significant damages in Switzerland during the recent years (Fig. 16). Consequently, there is a considerable demand for the quantification of flood risks in mountain streams and torrents. In close connection to the damages in steep open channels are processes that are related to the mobilisation of sediment. In this context, the assessment of the bed stability is of special significance. Flume experiments were carried out at the VAW that focussed on naturally developed beds on the one hand and on nature-oriented bed stabilisation measures on the other hand. Within the present investigation, a new stability approach was derived that takes into account the self-stabilisation potential of the bed in different geomorphologic scales. This approach combines the existing stability of the bed with potentially occurring channel bed degradations at larger discharges. Nature-oriented, man-made structures gained in importance recently (Fig. 17). The investigated connection between discharge, slope, bed morphology and channel bed degradation can be applied to design naturally developed step-pool reaches. In this case, appropriate material is dumped into a specific reach and the river is left to its own resources to construct a stable and natural structure.

Fig. 16: Sediment deposited in the *Schächen* near the mouth into the *Reuss*-river (Photo: BAFU).

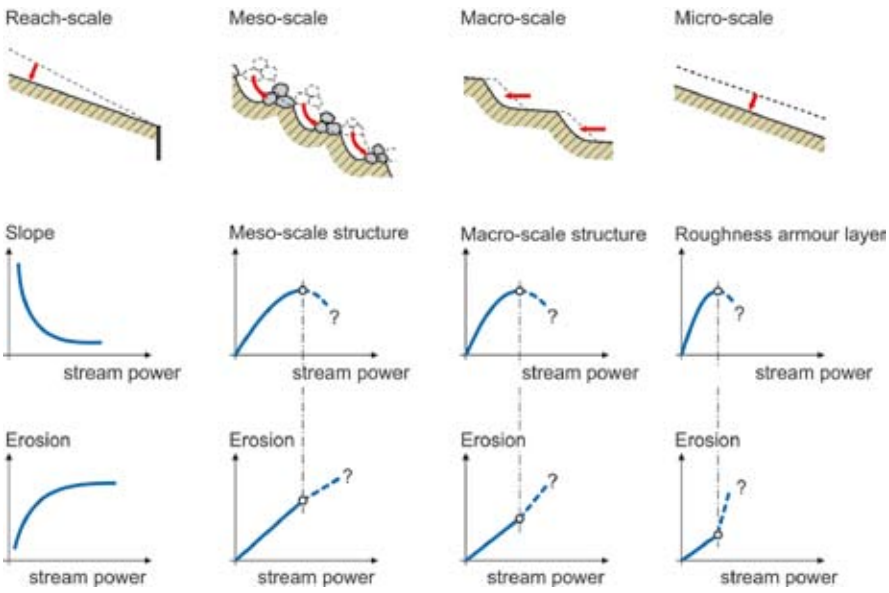


Fig. 17: Idealised description of the self-stabilisation potential of steep open channels in different geomorphologic scales.

Air transport downstream of chute aerators

M. Pfister, W.H. Hager / VAW

In the 1940s, when the tunnel spillways of Hoover Dam (USA) were taken into operation, damages of the chute concrete surface were detected. An analysis of the phenomena pointed to cavitation. Thereafter, cavitation damage was prevented by aerating the flow using chute aerators consisting of a deflector and a drop. In general, the aerator efficiency is specified by the ratio of entrained air discharge to the water discharge. However, this value does not describe the air concentration distribution within the flow downstream of an aerator. As cavitation damage mainly occurs at the bottom of a chute, the knowledge of the bottom air concentration is of prime interest. The present investigation intends to provide this information.

Experimental tests were conducted to measure local air concentrations using a fiber-optical probe. Fig. 18 shows a photo of the flow downstream of a chute aerator. As can be seen, the water surface disintegrates along the free jet. The flow appears more and more white, indicating an increasing air concentration. Downstream of the jet re-attachment point, the flow color changes to grey as the flow undergoes significant de-aeration. Especially the bottom air concentration is reduced downstream of the re-attachment point. This trend is also visible from Fig. 19 showing the measured air concentrations. At location x=3.8 m the bottom air concentration is only 1.6%.

Highlights
Infrastructure Systems

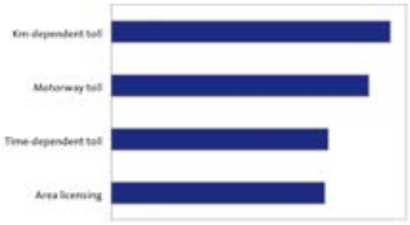


Fig. 22: Supporters and opponents of the road pricing scheme by type of road pricing.

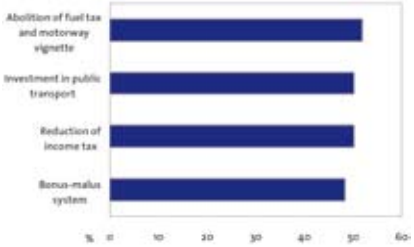


Fig 23: Supporters and opponents of the road pricing scheme by use of the revenues.

Strategies for Increasing Intermodal Transport Between Eastern and Western Europe

N. Fries, J. Wichser, U. Weidmann / IVT
Sponsor: DANZAS Stifung für Logistik

The purpose of this project is to develop market-oriented strategies for better serving Central and Eastern Europe with intermodal freight transportation. Countries in this area of Europe, both, those recently admitted to the European Union and potential candidate countries, are experiencing rapid economic growth. This growth is creating demand for additional mobility and intelligent logistics solutions.
In addition to rapid economic growth, transport networks (road, rail, and intermodal facilities) are poorly developed in Eastern Europe. Rapidly growing traffic demand is causing organisational and infrastructure bottlenecks leading to major congestion problems.
Given the increasing demand and relatively underdeveloped network, major transport providers are considering how best to serve Central and Eastern Europe. Thus, this research project was initiated to collect background data on conditions in Central and Eastern Europe, and use this information to help identify potential markets, cost structures and strategies for providing successful intermodal transport between Eastern and Western Europe (Fig. 20).
The first step in the research was to collect and analyze background data from different countries and economic areas (several nations). The second step was to eliminate unpromising transportation corridors and markets based on economic, legal, geographic, and transport logistic limitations.
The third step in the research was to prepare a more detailed analysis of the most promising corridors, the corridor running from Germany through Austria/Czech Republic to Hungary. This analysis estimated costs for shipments and identified key problems in intermodal transport on this corridor. The final step in the project was to develop different business strategies for operating intermodal transport in this market. This step combined information from the research and the characteristics of intermodal transport.

Social nets and traffic

A.R. Frei, K.W. Axhausen / IVT

Travel is the price we pay to be with other people, at least it is a very substantial part of the generalized cost of meeting others. If we accept this proposition, and consider that the vast majority of travel serves activities with others, then one has to wonder, why the social content of activities and the constraints arising from coordination with others has received so little attention so far in transport research. The capture of the social content of activities serves ideally to improve the trip generation in micro simulations, to deepen our understanding of planning and organization of joint leisure travel and trips, to inform the development of new tools, which can evaluate the effects of political measures, as well as to account for the amount and structure of the social capital of a society. To realize these goals, this project supplements the previous extensive qualitative research by further quantitative surveys, so that the effects of social contacts on travel behavior and vice versa can be quantified. A first result is the measurement of the geographical distribution of the members in egocentric social nets using confidence ellipses (Fig. 21) and further parametric geometries.

Design elements of road pricing schemes and their acceptability

M. Vrtic, N. Schüssler, A. Erath, K.W. Axhausen / IVT

One key factor for the successful introduction of a road pricing scheme is its electoral acceptability, which is in turn strongly affected by its design. This is especially true in Switzerland, where any major policy change has to be approved in a referendum. An extensive stated preference (SP) survey about the acceptability of different design elements was included in a study about the impact of possible transport pricing schemes on travel behaviour conducted on behalf of the Swiss Federal Roads Authority.

Fig. 20: Intermodal transport between Eastern and Western Europe.

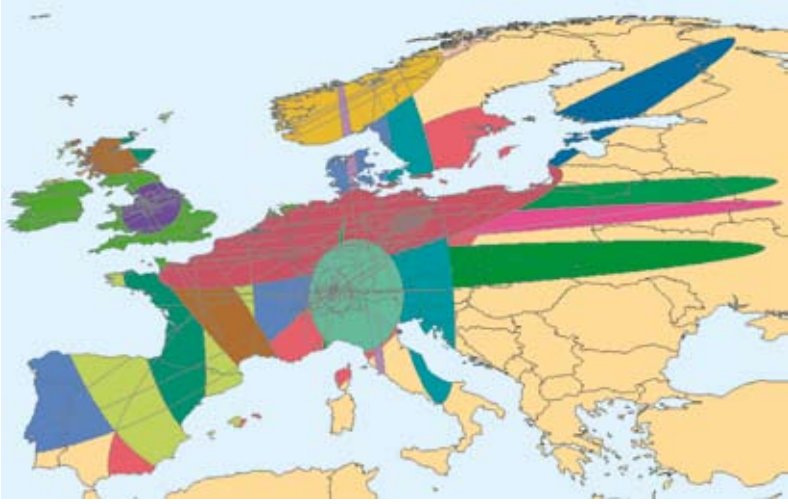


Fig. 21: Geographical distribution of social contacts described by confidence ellipses.

Fig. 24: Water flows over the stepped chute end and plunges as a free falling jet into the deep canyon (physical model at a scale of 1:45).

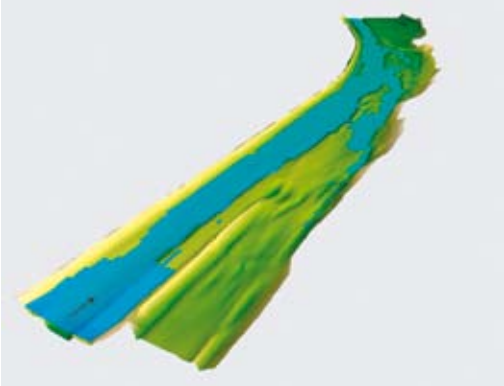


Fig. 27: Two dimensional simulation with BASEplane: The depicted result was computed for the same investigation as the one of BASEchain. The advantages of the two dimensional model are the better resolution of the terrain and of the hydrodynamics, which enables a more detailed simulation of morphological processes.

The aim of the study was to assess the influence of various scheme elements on acceptability. The proposed charging level is the most important factor. Distance-based motorway tolls and km-dependent tolls for all roads are the preferred pricing types, in contrast to area licensing and time-dependent tolls (Fig. 22). With regards to the use of the revenues, replacing the existing pricing mechanisms, the fuel tax and motorway vignette, was the least liked option even though it would lower costs for the individual. Investment in public transport was favoured above reductions in income tax and a bonus-malus system that redistributes the revenues directly back to the Swiss population (Fig. 23).

Model investigation of Kárahnjúkar Dam Spillway (Iceland)

Th. Berchtold, M. Pfister, A. Lais / VAW

A flood flowing into an already filled reservoir is usually discharged on a spillway. Thereby, the additional water is conveyed into the downstream river without causing any damages on the dam or on other hydraulic structures. During the design phase of the Kárahnjúkar hydroelectric power plant in Iceland, the Laboratory of Hydraulics, Hydrology and Glaciology (VAW) was committed to optimize the uncontrolled spillway with a physical model. The Kárahnjúkar spillway consists of a 420 m long chute, wherein water discharges from the reservoir into a very narrow, 100 m deep canyon (Fig 24). Therein, the jet should hit neither the opposite nor the spillway sided canyon flank. A two-stepped chute end was developed to handle the range of jet throw lengths and to pool their impact points in the middle of the canyon. In case of high discharges the water falls direct over the upper step into the canyon; otherwise, it impinges firstly upon the lower platform and drains over the second step into the canyon thereafter. For enlarging the impact area of the jet and reducing thereby its energy-density leading to reduced pressures on the canyon floor, the upper step is equipped with seven baffles, which vertically fan out the jet. Additionally, the continuously widened chute provides a wider cross-sectional area of the footprint. With pressure measurements on the canyon bottom the effects of the measures were evaluated quantitatively (Fig 25). Start of operation of the hydroelectric water plant will be in 2007.

BASEMENT – An object-oriented software system for numerical simulation of natural hazards

R. Fäh, D. Farshi, R. Müller, P. Rousselot, D. Vetsch, H.-E. Minor / VAW

The software system BASEMENT – BAsic Simulation EnvironMENT for computation of environmental flow and natural hazard simulation – provides a framework for the numerical simulation of river flow and sediment transport processes involved.

In the year 2002, the research project was launched as part of the trans-disciplinary "Rhone-Thur" project and with co-financing of the federal office of the environment. This gave opportunity to build a new simulation environment from scratch. Furthermore, it allowed for the combination of state-of-the-art approaches with the experience gained out of existing codes. With the objective of a transparent and sustainable software package, an object-oriented development process has been chosen.

The software system BASEMENT at its current state comprises two main sub modules: The one dimensional tool named BASEchain is thought for the simulation of river reaches based on cross-sections (Fig. 26) and the two dimensional module BASEplane allows for the computation of flood plains based on a digital terrain model (Fig. 27). Both sub modules are able to trace morphological changes due to active hydrodynamic forces. The further development of the software particularly tends to new approaches for sediment transport.

On October the 6th this year, the first version of the software system has been presented to the public within the scope of a workshop at VAW. The software package and its extensive documentation are available free of charge online at our project website: *www.basement.ethz.ch*.

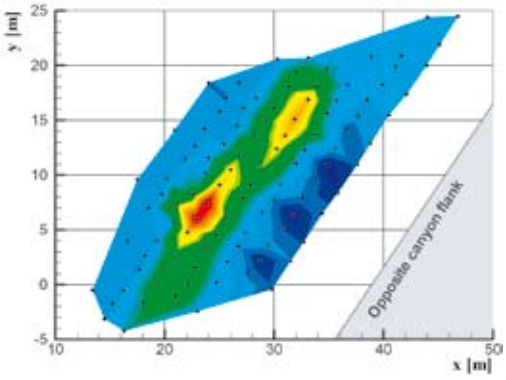


Fig. 25: Pressure measurements in the canyon. The 'footprint' of the jet is visible in terms of high pressure values.

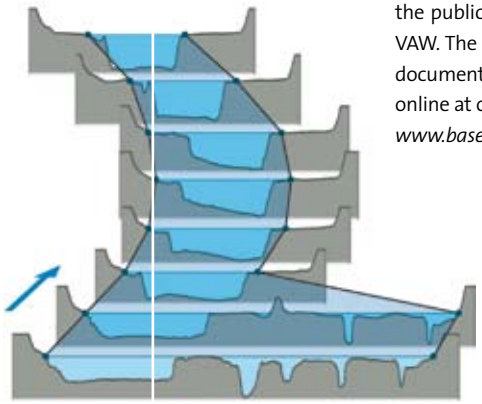


Fig. 26: One dimensional simulation with BASEchain: Shown is a result of an ongoing investigation on the effect of flood events to the widening of the river *Thur* near *Altikon*.

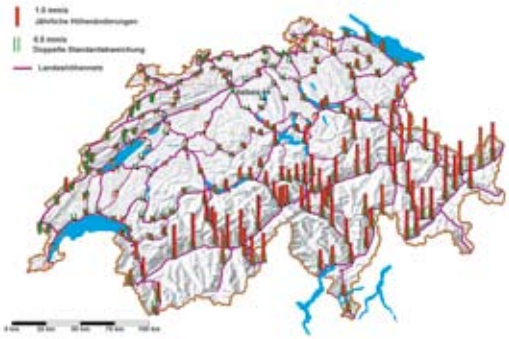


Fig. 28: Recent vertical crustal movements along the lines of the vertical control network. The ongoing Alpine uplift is clearly visible, reaching 1.7 mm/a, relative to the reference station Aarburg. A trend of subsidence of up to -0.4 mm/a has been observed in the Swiss Jura mountains.

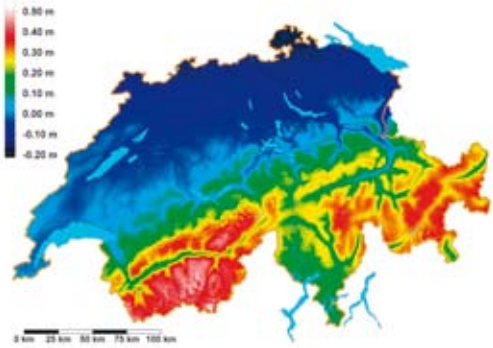


Fig. 29: Differences between the new heights of LHN95 and the official heights LN02. The discrepancies range between -20 and 50 cm.

The new vertical reference network of Switzerland LHN95

A. Schlatter, A. Geiger, H.-G. Kahle / IGP

In collaboration with the Federal Office of Topography (swisstopo), the Geodesy and Geodynamics Lab (GGL) has modernized the over 100-year-old vertical network of Switzerland. This proved to be a necessary step for adapting the national survey to the possibilities of modern satellite-based surveying methods and for designing a practical network. The so-called „official heights LN02" were replaced by the new orthometric heights LHN95, which are strictly correlated to the gravity field. Together with the geoid undulations and the ellipsoidal heights, which result from GPS observations, they define the consistent vertical reference system for the new national control network in Switzerland (LV95). Thus it is possible to determine heights directly from satellite observations with an accuracy of a few centimeters. The calculation of this (geopotentially) rigorous vertical frame is primarily based on the first order levelling observations since 1902. In addition, repeatedly observed measurements of the bench marks provided important insights into recent crustal movements (Fig. 28). LHN95 has already been successfully applied to the survey of the two new Alpine railway tunnels Lötschberg and Gotthard. Based on the analysis of the differences between LHN95 and LN02 (Fig. 29) for 1400 bench marks of the vertical network, the transformation software *HTRANS* was developed. This software tool allows the transformation between the two vertical frames. In practical surveying HTRANS is mainly used for transforming the GPS observations into the official vertical reference LN02.

Precision Navigation for Environmental Monitoring

Ph. Kehl, A. Geiger, H.-G. Kahle / IGP
J. Staehelin, Institute for Atmospheric and Climate Science (IAC)

Dedicated air pollutant measurements have been carried out in the interdisciplinary feasibility study «Dynamic Environmental Monitoring» of the D-BAUG. The campaign has been conducted on a streetcar of the public transport Zürich (Fig.30). GPS has been chosen as a position and time reference. Dynamic, precise and reliable positioning is a challenge in an urban environment.

GPS outages or reduced precision occur as a consequence of poor satellite visibility because of buildings or trees and unfavourable satellite constellations. Techniques have been developed to provide steady positions with reasonable accuracy for the streetcar and the measurements, respectively.

A Kalman filter has been tuned with respect to the expected movements of the streetcar. The filtered navigation solutions have been transformed into precise positions using a projective map-matching technique which takes the limited mobility of the streetcar and the known track geometry into account.

Missing positions have been interpolated using a specially developed technique. While many outages lasted only a second or two outages lasting up to a few dozens of seconds have been observed regularely. Since the streetcar follows a fixed schedule characteristic path-time relations can be determined for individual parts of the track. These standard curves form the basis for the interpolation. As a result all air pollutant measurements could be georeferenced with a high precision. First results from the analysis of the measurements validate the feasibility of operational dynamic air pollutant measurements (Fig.31).

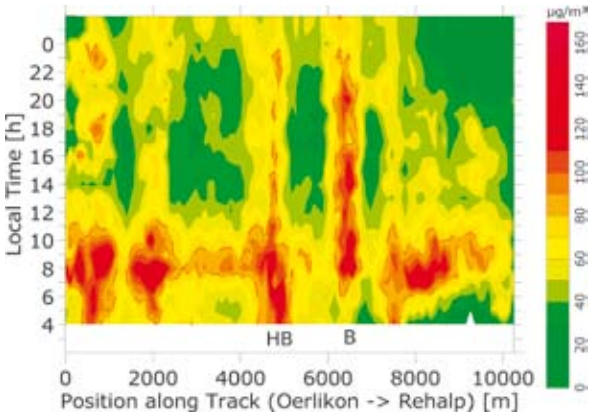


Fig. 31: Average fair weather diurnal variations of nitride oxide concentrations (NO_x). High concentrations are clearly seen near Central Station (HB) and around Bellevue (B) during the whole day.

Fig. 30: Measurement system maintenance on the roof of the streetcar.
Source: TA-Bild/Sophie Stieger

Highlights
Resources

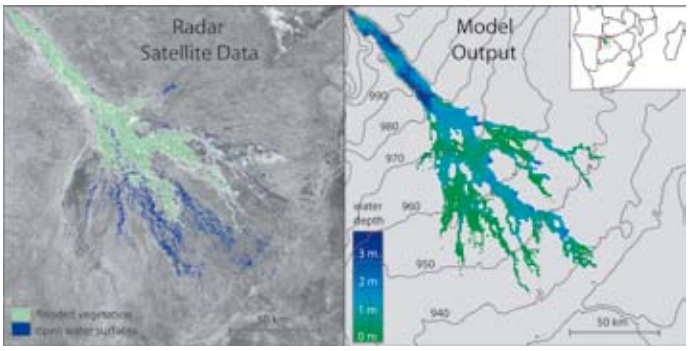


Fig. 33: Flooding patterns from radar satellite image (left) and the hydrological model (topography from Shuttle Topography Mission).

Relevance of Environmental Tracers in Groundwater Modelling

G. A. Onnis, W. Kinzelbach / IfU

Man-made nuclide releases from nuclear bomb experiments and nuclear fuel reprocessing plants resulted in the emission of radionuclides into the atmosphere and, through precipitation, into the hydrological cycle. The study of these *Environmental Tracers* can yield valuable information about the water dynamics in the subsurface. Well measurable amounts of the environmental tracers 85Kr, 3H (Tritium) and 3He are found in young groundwater dating back no more than 50 years. While Kr and He are noble gases diffusing in the soil air and dissolving in soil or ground water, the Tritium atom is bound to the water molecule and from the beginning moves with the water in the subsurface. The passage entails a delay and a smoothing of the tracer input signals at the groundwater table, which is different for the two types of tracers. A model accounting for the unsaturated zone processes as well as transport in the saturated zone, leads to a description of the tracer dynamics in the subsurface, which can be compared with the observations. A flow and transport model for a small catchment at Baltenswil near Zurich showed that these variations in concentration are a consequence of the time-variations of recharge that feeds the aquifer. Especially in the hot summer of 2003 very old groundwater was mobilised and pumped in the wells. The correlation between recharge and tracer concentration can in turn be used to calibrate recharge, one of the most poorly characterized parameters in groundwater modelling. New evaluation methods for this parameter are of primary importance for a successful management of renewable water resources (Fig. 32).

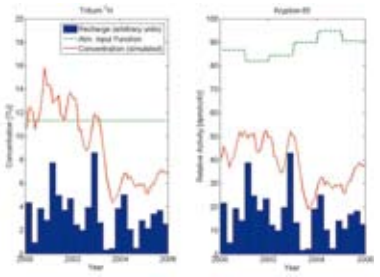


Fig. 32: Recharge vs. Simulated Tracer Concentration at Pumping Station Baltenswil.

Flooding patterns of the Okavango

Ch. Milzow , P. Meier, W. Kinzelbach / IfU

The Okavango Delta is a large wetland situated in Botswana, Southern Africa. Its ecological significance resides in its biodiversity of both fauna and flora. The delta is threatened by water abstractions for agriculture and households in all riparian states of the basin. Moreover, climate change will probably lead to reduced rainfall and increased temperatures. A hydrological model with 1km resolution has been build to study the impact of different management and climate scenarios. One of the model outputs are inundation patterns and the associated water depths (Fig. 33, right). The patterns show strong seasonal and annual variations correlated to past and present river inflow and meteorological conditions. Because of these variations a verification of the model against inundation patterns derived from satellite images is promising. From active radar sensors (ENVISAT-ASAR, Fig. 33, left) inundated areas can be differentiated into flooded vegetation and open water surfaces at a resolution of 150m. The high potential of the sensor lies in the radar wavelength (6 cm), which - unlike all sensors in the visible range - is not attenuated by clouds and does not depend upon solar light. Comparison of lengths and distribution of the arms of the delta shows good agreement. The quantitative comparison of flooded areas is still challenging and involves scaling issues.

Study of turbulent entrainment through 3D-SPTV

M. Holzner, W. Kinzelbach / IfU

A striking feature of many turbulent flows is the sharp interface that exists between turbulent and surrounding non-turbulent flow regions. Examples of such flows are free shear flows (jets, plumes, wakes, mixing layers), penetrative convection in the atmosphere and in the ocean, gravity currents, avalanches and clear-air turbulence. An important property of these flows, commonly referred to as ‚turbulent entrainment', is the process of transition of fluid from laminar to turbulent state through the boundary between the two regions. One physically qualitative distinction between turbulent and non-turbulent regions is that turbulent regions are rotational, whereas the non-turbulent ones are (practically) irrotational. The mechanics of such interfaces are up to now poorly understood and a deeper investigation is of fundamental importance for example for the understanding of turbulent mixing.

The present study uses the *3D-Scanning Particle Tracking Velocimetry* (3D-SPTV) technique recently developed at IfU. It is an optical method which follows the movement of a large number of tracer particles in the flow and determines the evolution of the full tensor of velocity derivatives along their trajectories. First the turbulent interface is detected and its properties are studied using time-resolved three dimensional measurements of vorticity. Then particle trajectories are selected, which cross the sharp interface between turbulent and non-turbulent regions. They allow to analyze the role of vortex stretching versus viscous diffusion for the amplification of vorticity during the transition. As an illustrative example the figure 34 shows the detected turbulent/non-turbulent interface as measured by 3D-SPTV at 2 different instances in time.

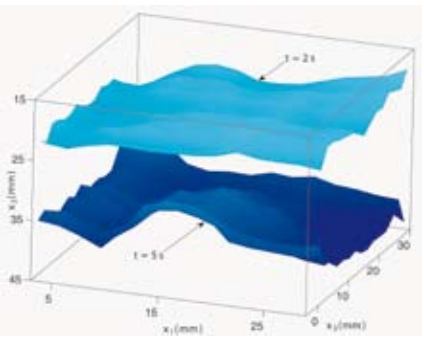


Fig. 34: Detected turbulent/non-turbulent interface as obtained from 3D-SPTV for 2 time instances.

Fig. 35: Lateral Erosion event: left) at the river *Muota* (*canton Schwyz*) after the 2005 flood event; right) physical model.

Lateral Erosion in Gravel Bed Rivers – actual issue at floods events

P. Requena, H.-E. Minor / VAW

In August 2005 several regions of Switzerland were hit by severe floods. Floods, land slides, lateral erosions and sedimentations caused damage about 2.5 billions CHF. During this flood event, large lateral erosions at some rivers like *Engelberger Aa* or *Muota* (Fig. 35, left) have been observed. Since lateral erosion can cause severe damages, it is an essential task to advance our knowledge about its fluvial dynamics process.

In order to understand the morphological dynamics of the lateral erosion process, physical model investigations have been carried out at the VAW (Fig. 35, right). The aim of this research project is to describe and quantify the spatial and temporal evolution of the lateral erosion process as well as the influence of the relevant parameters, such as discharge, bed slope, sediment supply and grain size distribution. The results of these hydraulic simulations will be compared with available field data of lateral erosion events on different rivers in Switzerland.

In this project, a method to analyze the evolution of the lateral erosion was developed. The digital cameras installed above the flume automatically took vertical photos at one minute intervals. Based on an edge detection algorithm, the program "Edge Detection" was developed to analyze the photos and to identify the position of the laterally eroded banks automatically (Fig. 36). These lines are detected by identifying the different contrast values of the wetted and the dry bed zone respectively. With this method, the position of the left and right eroded bank is known for any time during the experiment. This allows analysis of the spatial and temporal evolution of the lateral erosion with a high time resolution as well as quantification of lateral erosion velocities with precision.

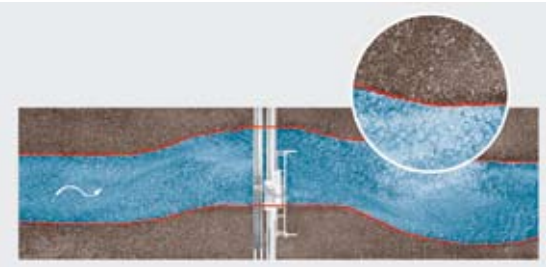


Fig. 36: Eroded bank lines (red), detected from the digital photos.

Alpine Water Resources

R. Dadic, J.G. Corripio, P. Burlando / IfU

The project Alpine WAter Resources monitoring and modelling through continuous Simulation of ice and snow cover mass balance – AWAS – aims at improving the detailed understanding of the processes of snow accumulation and ablation on Alpine environments, as well as their climatic sensitivity. The main task is assessing water resources in snow covered and glaciated basins through continuous modelling of distributed snow and ice mass balance. The research site is the Haut Glacier d'Arolla in south-western Switzerland. The intention is to use a highly instrumented site in the Alps for testing and implementation of process based mass and energy balance models, which could be applied in other mountain regions of the world. We now have a continuous series of meteorological measurements since 2000.

Aside from our continuous measurements, which contain 3 automatic weather stations, 2 automatic cameras and ablation/accumulation stakes (Fig. 37), we also evaluated digital elevation models from 1999 and 2005 in order to estimate total ice loss for this period.

The estimated ice volume loss for this period (Fig. 38) is about 40 million m^3 (10% accuracy), which is around 25% of the total runoff for this period. The rest of 75% available water comes from snow (60%) and rain (15%). The net specific mass balance for the glaciated areas is -7.5 m.

It is therefore important for water resources management to understand the distribution of snow in the basin, as it seems to be controlling factor for the form of the discharge hydrograph, and therefore the availability of water throughout the melt season.

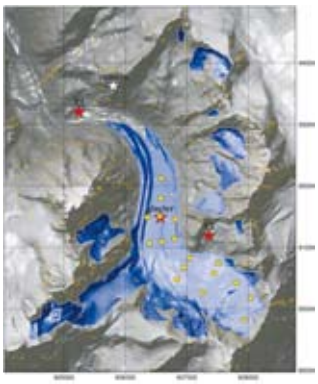


Fig. 37: Digital elevation model of the Haut Glacier d'Arolla basin. Indicated in blue is the glaciated area (5.3 km^2). In red is the locations of automatic weather stations, in white the location of the automatic camera and in yellow the locations of accumulation/ablation stakes. The total area of the catchment is 13 km^2 and the elevation range is from 2500-3800 masl.

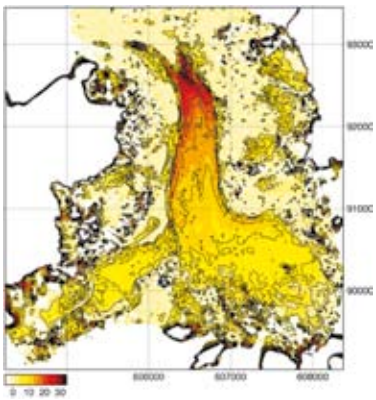


Fig. 38: Difference [m] in elevation on Haut Glacier d'Arolla from 1999-2005, estimated from DEM's. The accuracy is 2 m in non-glaciated areas and 1 m in glaciated areas. Maximum ice loss is at the glacier tongue with 34 m. The average ice loss is 7.5 m.

Assessing the impact of climatic variations on water resources from highly glacierised basin: modelling melt and runoff in the Aconcagua river basin

F. Pellicciotti, P. Burlando / IfU

Water resources originating from high mountains are a crucial source of water in large regions of the world. Because glaciers and perennial snow covers have undergone retreat in the past and have been affected by climatic variations (e.g. IPCC, 2001), water availability from highly glacierised basins has also changed. Combined with population growth, this will likely lead to increasing competition among water use for agriculture, industry and domestic activities in some areas of the world. The Chair of Hydrology and Water Resources Management, in cooperation with several international partners, has undertaken a project to study changes in water availability in mountainous regions of the world where water resources originate almost solely from glaciers and snow covers, and their scarcity is either leading to enhanced conflict of uses or is a potential source of conflicts. The case study selected for this investigation is the Aconcagua river basin in the dry Andes of Central Chile. A study on the analysis of trends in streamflow, precipitation and temperature in the basin has shown that the region is experiencing decreasing contribution of runoff from the upper glacierised basin, which cannot be explained by similar trends in precipitation (Fig. 39). Statistically decreasing trends in runoff are linked to the glacier extension in the basins: the higher the glacier area coverage is, the higher the magnitude and statistical significance of negative trends is. These results seem to point to the fact that glaciers in the dry Andes of Chile are already in a phase of reduced runoff production. To understand the behaviour of the glaciers in the area, the reconstruction of volume changes in the past decades from aerial pictures is being carried out. In addition, an extensive field campaign in one of the accessible glaciers in the area, Juncal Norte glacier, has been organised (Fig. 40). Measurements of glacier runoff, surface meteorological variables, snow and ice ablation, observation of glacier velocity, accurate GPS measurements and photos from an automatic camera allow us to understand and model the glacier-climate interaction and to support the modelling effort, which will provide a detailed insight in the evolution of water resources in the area. This campaign represents for the dry Andes area an unprecedented effort for its duration and the comprehensive character of the experimental setup.

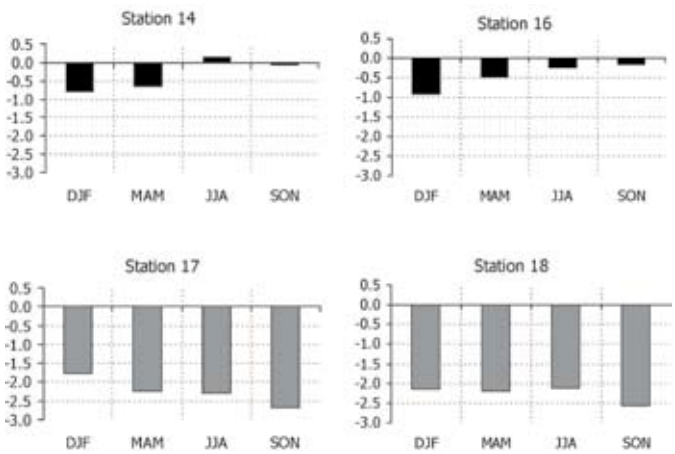


Fig. 39: Trend test statistics for seasonal streamflow totals at four gauging stations in the basin. The sign of Z indicates trend direction. In grey are the statistically significant trends, in black the statistically not significant trends. Analyses are for the common period of record (1970-2002).

Fig. 40: Photograph of Juncal Norte glacier showing some of the instrumentation that was part of the measurement setup, maintained from December 2005 to February 2006.

Highlights
Geo-, Structural and Environmental Data

Swiss-style colored relief shading by digital means

B. Jenny, L. Hurni / IKA

Maps with Swiss-style colored relief shading represent topography in a particularly vivid and descriptive manner. Carefully modulated illumination and shading shown in continuous color tones simulate the third dimension of topography, helping map-readers to easily conceive the terrain's important landforms. Since the end of the 19th century, cartographers have developed a wide variety of color and illumination schemes for terrain maps, culminating in the high standard developed by Eduard Imhof, the founder of the Institute of Cartography at ETH. In this spirit a new computer-based method for colorizing grey shaded relief has been developed. An interactive software application allows the map author to place color reference points on a gray shaded relief. The color reference points are then used in combination with a digital elevation model to modulate color with elevation and exposure to illumination. The new method is particularly user-friendly and permits the coloring of traditional high-quality hand-shaded reliefs, as well as modern shadings computed from digital elevation models. It bridges the gap between traditional analog techniques and the digital realm, allowing for time effective comparison and selection of alternative color schemes (Fig. 41 - 45).

Open Architecture and Spatial Data Infrastructure for Risk Management

I. Iosifescu, M. Hugentobler, D. Isenegger, L. Hurni / IKA

The overall aim of the Integrated EU Project ORCHESTRA (Open Architecture and Spatial Data Infrastructure for Risk Management) is to improve the efficiency in dealing with risks. This aim is achieved by developing an open service architecture designed to cover the need for coordination and collaboration of the risk management community.

During the past two years the ORCHESTRA consortium has created a very robust and open reference model for a service-oriented architecture based on de-facto and de-jure standards. Special attention is paid to an integrated service and data approach including their spatial, temporal and thematic characteristics.

The ORCHESTRA architecture (Fig. 46) delivers to users and applications integrated spatial and non-spatial information services. These services should allow the users to identify and access information in an interoperable way from a wide range of sources (from local to global level), for a variety of uses, mainly focusing on the risk management area.

Fig. 46: ORCHESTRA Architecture Layers.
In risk management, various numerical or GIS-based assessment methods have a cartographic output. In this respect, thematic maps are of interest as a decision support tool that visually communicate spatial phenomena as risk-related data distributions, variations and aggregations (e.g. distribution of risk levels, comparisons between the number of occurrences of various hazards, population densities, etc.).
ETH Zurich contributes to the project and develops the architecture of the ORCHESTRA Map and Diagram Service by improving the well-known OGC WMS (Web Map Service) standard (ISO/DIS 19128). According to the Map and Diagram Service design, future implementations of map servers should be able to dynamically produce complex thematic web maps that fulfill the requirements of risk management applications.

Fig. 41

Fig. 42

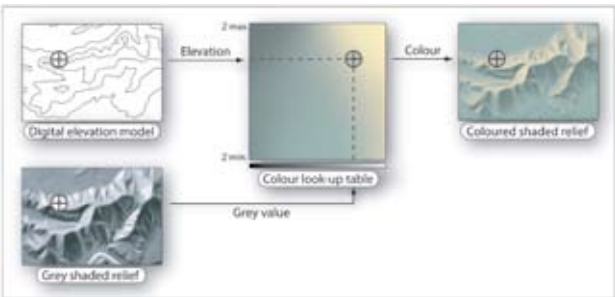


Fig. 43

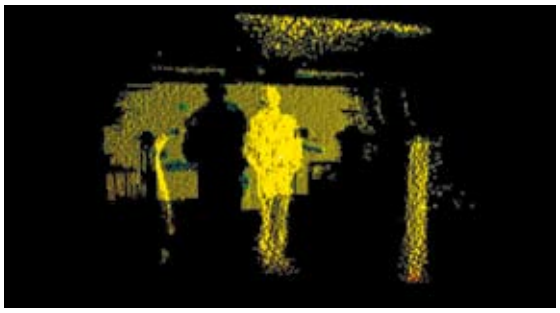


Fig. 47: Multi sensor navigation module „remap“ developed in cooperation with the ZHW (left). The module contains several navigation sensors (e. g. a RIM camera) and works autonomously. RIM cameras are able to capture their environment fast and with high resolution (person in a room; right). The possibilities and the security of construction machinery can be increased.

Range Imaging Technology: Successful Collaboration between ETH and ZHW

T. Kahlmann, H. Ingensand / IGP

Range Imaging (RIM) is a new suitable choice for capturing the environment in many different applications. RIM is a fusion of two different technologies within a single sensor. According to the terminology, it integrates distance measurement as well as imaging. Each imaging pixel is able to store also the distance towards the corresponding object point. Therefore 3D capturing of the environment with up to about 50 Hz and high resolution with several thousand pixels is possible. Recently, the calibration of different RIM cameras has been focused at the Institute of Geodesy and Photogrammetry.

RIM is an outstanding technology for the fast capturing of the environment. In cooperation with the ZHW (Zürcher Hochschule Winterthur) a multisensor module has been developed. This module is equipped with different navigation supporting sensors, like a RIM camera, and can be mounted on a robot, for example (Fig. 47). The goal is to capture the closer environment with high resolution in three dimensions in order to support rescue robots, in future. The module works autonomously and can be linked via WLAN. Therefore, the use in dangerous, contaminated environments is possible. Beyond this, construction machines can be equipped to increase the possibilities and the security of automatic construction, significantly.

GPS-derived co-seismic displacements induced by the M6.2 Lefkada 2003 earthquake (Greece)

Ch. Hollenstein, H.-G. Kahle / IGP

Greece is presently the seismo-tectonically most active region of Europe. This is reflected in the occurrence of more than 4500 intermediate-size earthquakes during the last 30 years, with several large and destructive events among them. In order to understand the geodynamical processes in such a hazardous area, the Geodesy and Geodynamics Lab (GGL) (professorship Kahle) has carried out GPS measurements in Greece since the late eighties. Reoccupation and continuous measurements not only enable the calculation of longer-term rates but also allow to determine earthquake-related displacements. Fig. 48 shows co-seismic displacements of GPS sites in the vicinity of the Lefkada 2003 earthquake (M=6.2). The regions to the east of the Kefalonia Fault Zone (KFZ) shifted by up to 7 cm towards south/southwest during the earthquake. Furthermore, an uplift of about 5 cm was found in the north of the island of Lefkada, while the GPS sites at the southernmost point of the island subsided by about 2.5 cm. On the island of Antipaxi (APAX) - about 50 km to the northwest of the KFZ - a small displacement of about 8 mm towards northwest was found. Improved coordinate time series, which made the detection and quantification of such small displacements possible, are displayed in Fig. 49.

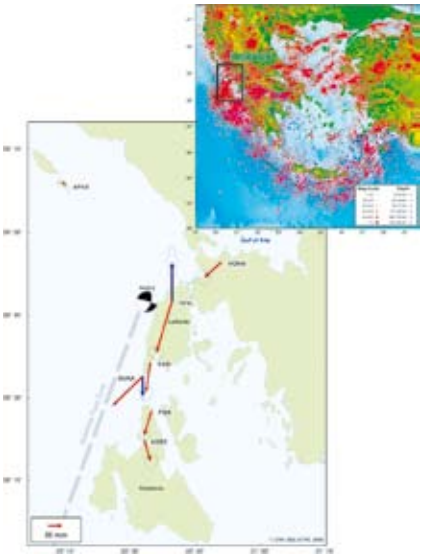


Fig. 48: Co-seismic displacements caused by the Lefkada 2003 earthquake. Red arrows: horizontal displacements; blue arrows: vertical displacements. The error ellipses represent the 1-sigma confidence region. Fault plane solution: Global CMT catalog; earthquake location: USGS-NEIC. The displacements of Lefkada and Kefalonia, compared to APAX, are a clear indication that the KFZ is a prominent boundary zone between the southwestward moving Aegean microplate and the stable Eurasian plate. Top right: Seismicity of Greece, 1973-2004 (USGS-NEIC).

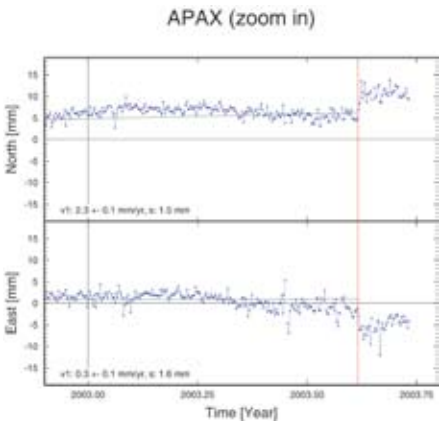


Fig. 49: Improved GPS time series of daily coordinates (relative to Eurasia) of the site APAX, showing co-seismic displacements (about 8 mm) caused by the Lefkada 2003 earthquake (50 km away). The vertical red line marks the time of the seismic event. The gray lines represent the weighted linear fits.

Fig. 44

Fig. 45

Fig. 50: Location of an analyzed profile across the northern Sporades (compare Fig. 51).

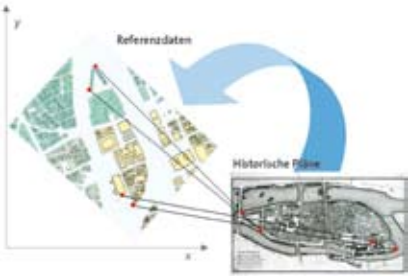


Fig. 52: Fitting an historical plan into the desired geographical coordinate system using today's reference data.

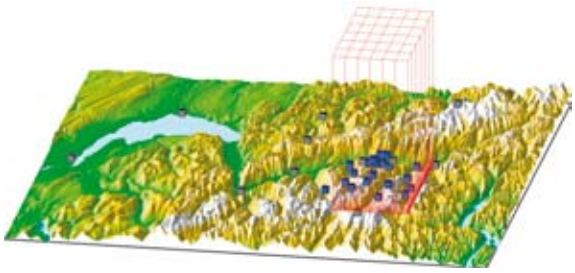


Fig. 53:
Campaign setup in the area of „Oberwallis". GPS permanent stations (black), campaign stations (blue). The 3 dimensional grid model is also displayed.

Detailed measurements of the deflections of the vertical in the North Aegean Sea

A. Somieski, B. Bürki, H.-G. Kahle / IGP

Dedicated measurements of Deflections of the Vertical (DoV) at 30 stations in the northern Aegean have been analyzed and compared with other data available for this region. Of particular interest is the North Aegean Trough which is interpreted as a continuation of the seismically active North Anatolian Fault Zone (Fig. 50). One data set is formed by the local "*Limpach geoid*" determined by marine GPS measurements. In addition, the altimetric as well as the gravimetric geoid model of Greece (Department for Geodesy and Surveying, Aristotle University of Thessaloniki, Greece) were used for a validation. The DoV were transformed to geoid height differences along different profiles through dedicated Zenith Camera stations.

Fig. 51 shows a representative example for a geoid profile through eight stations along the Sporades islands (Fig. 50). It is clearly seen, that the geoid height differences based on DIADEM, GPS and satellite altimetry correspond very well. In contrast, the gravimetric geoid reveals a significant discrepancy of up to 70 cm. This is mainly due to existing gravity data gaps in the marine area. Therefore, an important goal of the project is the improvement of the geoid using all available data sets. Only by a highly precise knowledge of the geoid it is possible to quantify potential sea level changes.

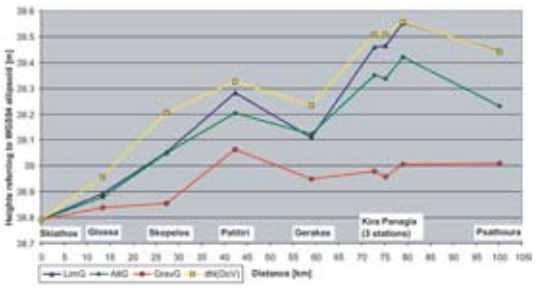


Fig. 51: Comparison of the geoid undulations of available data along the profile (Fig. 50). All heights refer to the same level based on the Limpach geoid.

Knowledge Center in GIS

A. Carosio / IGP

In recent years the use of Geo Information Systems has intensified in various disciplines. This resulted in the GIS group being asked to provide technical support in many different projects and activities. An interesting co-operation was developed in 2006 with the Institute for History and Theory of Architecture in the seminar "Urban transformations in Rome and London" held by Professor Lampugnani.

The development of cities like Rome and London was investigated and analyzed in the seminar, which was an experiment in inquiry learning for planning and building processes in city development studies.

Professor Christine Giger tutored the first phase of the project within the framework of a semester assignment. In the winter semester 2006/2007 our GIS group was also asked to provide technical support for the students in the Master's course in architecture. One of the goals was to better familiarize the students with the use of GIS tools to enable them to georeference old city maps.

Very demanding in this type of project is the separation between the scientific problems and the application of the technical tools required to solve them.

In this particular case it was necessary to develop the mathematical model required for the definition of different map projections and distortions in the representaion. This fundamental model enables one to overlay maps dating from different epochs using today's reference systems (Fig. 52).

This interesting collaboration shows the increasing need for interdisciplinary work between the arts and technology and stresses once more the relevance of a knowledge center in GIS.

(Participants in this work: dipl. Forst. C. Dolci, dipl. Geogr. S. Brugger, dipl. Engineer D. Salvini, dipl. Forest. R. De Filippi)

High-resolution GPS-tomography to improve forecasting of natural disaster

M. Troller, S. Lutz, A. Geiger, H.-G. Kahle / IGP

Severe weather conditions, floodings and storms have more and more increased in recent times. Precise forecasting has become of major interest to protect human being and to mitigate high damage of properties. Especially the parameter humidity has to be determined with a much higher spatial and temporal resolution than it is possible today. In principle, high-resolution GPS-tomography is able to determine humidity profiles and monitor their temporal change.

GPS signals propagating through the atmosphere are influenced by the humidity. Their delay is proportional to the integrated amount of water vapor along the GPS ray path. Applying a tomographic method, the spatial distribution of the water vapor can be determined.

In the frame of an SNF-project currently pursued at the Institute of Geodesy and Photogrammetry (group of Prof. Hans-Gert Kahle), two dedicated GPS field campaigns have been conducted in the „Oberwallis" (Fig. 53). The GPS-derived water vapor profiles are validated with radiosondes and the current weather forecasting model of MeteoSwiss (Fig. 54). Compared to conventional methods, the density of humidity profiles can be increased substantially. Therefore, the implementation of GPS-tomography in real-time should allow to forecast natural disaster earlier and more accurately.

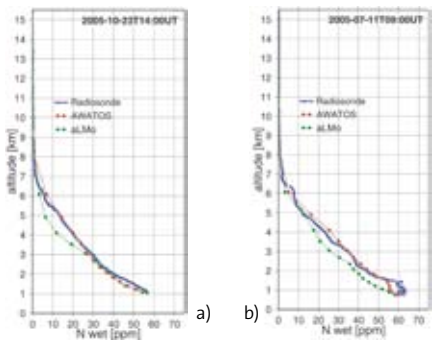


Fig. 54: Water vapor profiles of GPS data, radio soundings and data of the numerical weather model aLMo. The figure shows a profile above Susten (a) and St. Niklaus (b). The quantity „wet refractivity" (N wet) plotted is proportional to the amount of tropospheric water vapor.

Highlights
High-Tech Measuring Systems

Fig. 57: (Left) Two ETH-radiometers monitoring water vapor at the Geo-Fundamental station Hartebeesthoeck (HARTRAO) near Johannesburg (South Africa). (Right) GGL-Solar Spectrometer at the marine base Ajaccio, Corsica (France), during a calibration/validation campaign for the JASON satellite.

Development of a 3D Laser Scanning System for Cavern Inspection

H.-M. Zogg, H. Ingensand / IGP

The survey of special buildings in the field of Water and Sewage Engineering is getting more and more important. On the one hand, geometrical data is needed as planning basis for restoration work, and on the other hand, the data is the basis for establishment and complementation of pipe cadastre systems. Conventional measurement methods are based on the use of measurement tapes or laser distance meters. These methods require an on-site inspection of the caverns by a crew member. The access to the special buildings is a shaft with a length of 3 to 4 meters. The development of a new measurement system based on laser scanning technology is driven by the increased importance of three dimensional data and the costs and dangers of an inspection by a person (Fig. 55).

The Institute of Geodesy and Photogrammetry (IGP) in collaboration with Geomatik + Vermessung Stadt Zurich (GeoZ) is developing a cavern inspection system for three dimensional acquisitions of special buildings. The central part of the 3D-measurement system is a laser scanner, which is guided into a shaft headfirst in order to acquire the environment touch-less. A full 3D-acquisition of a cavern takes about two to three minutes. The result is a so-called point cloud, which contains more than two million 3D-points (Fig. 56). The 3D-vector model, consisting of objects like pipes or gullies, is generated afterwards with special post-processing software. The 3D-model can be imported into any CAD-software.

High Tech Measurement Systems for Monitoring Water Vapor: Radiometry and Solar Spectrometry

B. Bürki, A. Somieski, H.-G. Kahle / GGL

Microwave based satellite measuring systems have taken over an important role in the context of the research of our planet. Microwaves penetrate the earth's atmosphere independently from daytime, visibility and weather. Important environmental parameters such as the thickness of the polar caps and sea level changes can be monitored by means of dedicated environmental satellites. Also in radio astronomy where very faint signals emitted by extremely distant objects (quasars) are detected, the analysis of signal propagation properties plays an important role. Microwaves are delayed due to their interaction with water vapor molecules. In order to calibrate the measuring systems aboard the satellites, the water vapor content has to be known with high accuracy. Since this parameter cannot be modelled adequately it has to be measured with advanced instruments. Suited measuring systems for this task are water vapor radiometers and solar spectrometers (Fig. 57). Such high-tech instruments are being developed at the Geodesy and Geodynamics Lab (GGL). They are deployed in several International measuring campaigns including the NASA/CNES Ocean Surface Topography Mission (OSTM).

Fig. 55: Cavern inspection system developed at the Institute of Geodesy and Photogrammetry (IGP). The 3D-laser scanner can be guided upside down through shafts into caverns for water and sewage systems.

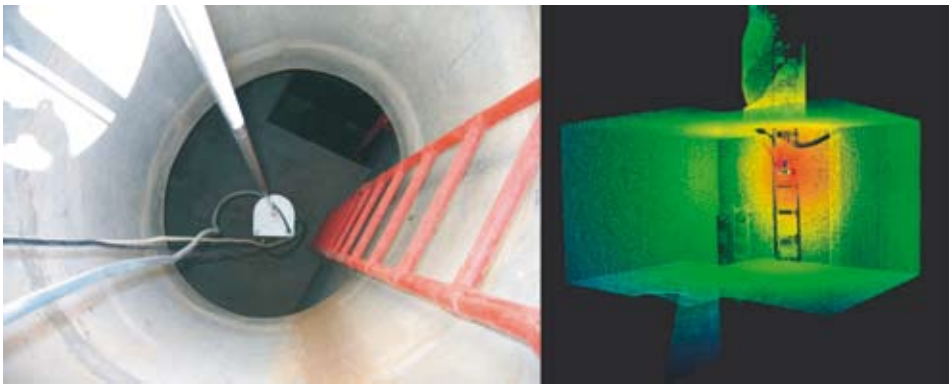
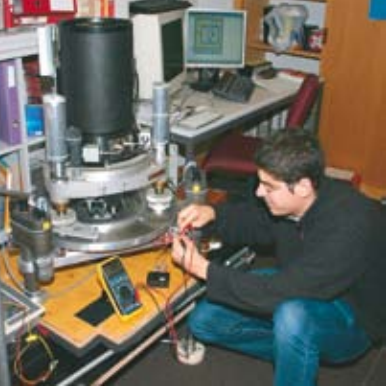


Fig. 56: (Left) 3D-Laserscanner is acquiring a cavern. (Right) The result of a scan is a point cloud which contains more than 2 million points.



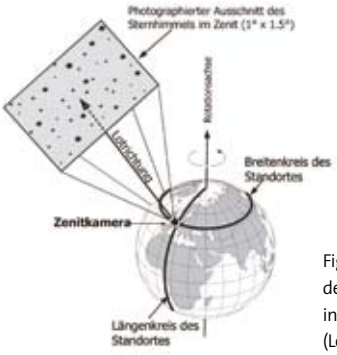


Fig. 58: (Right) Principle of Zenith camera system: determination of the direction of the local plumb line in terms of astronomical longitude Λ and latitude Φ. (Left) Zenith camera in the lab.

Astrometry and Vector Gravimetry

B. Bürki, St. Münch, H.-G. Kahle / IGP

Research of the Earth's gravity field and its variations represents an important issue in the context of global change. In addition to satellite based measuring techniques the importance of geodetic-astronomical methods is steadily growing. On one hand they serve as validation tools for satellite gravity field missions, on the other hand they form a link between satellite navigation systems and terrestrial measuring techniques. Precise knowledge of the geoid as an equipotential surface of the Earth's gravity field is mandatory. CCD technology provides essential progress in digital astro-geodesy. Currently the question is to what extent the measuring process in the field can be automatized and the determination of the local plumb line in terms of astronomical longitude and latitude can be carried out in real-time with high accuracy. The alignment of the instrument into the direction of the local gravity vector and hence the highly accurate levelling process represent an important task in the context of the measuring procedure. In the frame of a diploma thesis a new system has been developed ideally fulfilling the objectives of a field proven system. The new two-step control circuit allows an automated, highly precise and time optimized measuring process in the field (Fig. 58).

JASON-1 satellite radar altimeter calibration with GPS-equipped buoys

P. Limpach, H.-G. Kahle / IGP

Satellite radar altimeter missions are the basic means for global-scale sea surface height monitoring with a dense and homogeneous coverage in space and time. A result of major concern is the evidence of global sea level rise provided by continuous spaceborne radar altimeter observations over the last 15 years. Other important features detected are pronounced anomalies in the gravity field as seen in large-scale undulations of the equipotential surfaces (Fig. 59). Due to the increasing requirements in the accuracy and long-term integrity of spatiotemporal monitoring, it has become mandatory to validate and calibrate the satellite systems. In this context, in situ measurements of the sea surface in the open sea are of particular interest. For this purpose, the Geodesy and Geodynamics Lab (GGL) has developed and deployed lightweight buoys and ultra-sonic sensors equipped with high-frequency GPS receivers (Fig. 60). Dedicated sea surface height surveys were successfully performed in the Eastern Mediterranean Sea, along ground-tracks of the radar altimeter satellite JASON-1 (Fig. 59). These investigations are being pursued in the framework of the NASA/CNES space mission OSTM (Ocean Surface Topography Mission). They substantially contribute to the improvement of sea level monitoring and provide precise information on the short-wave structure of the marine gravity field.

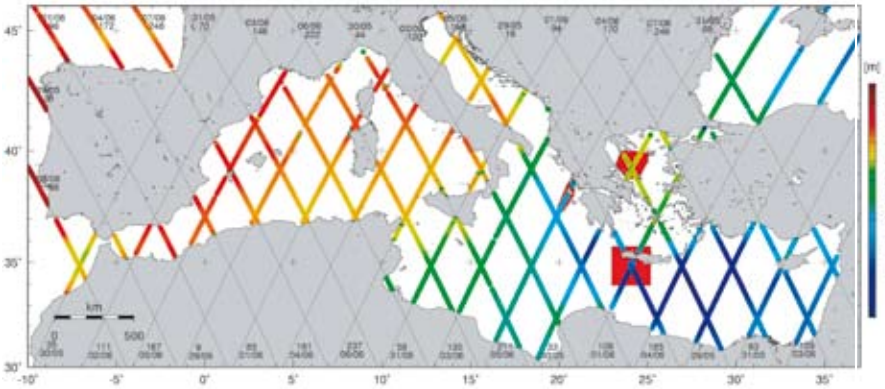


Fig. 59: JASON-1 satellite ground-tracks in the Mediterranean Sea. The color-coded sea surface heights determined from radar altimeter data are referenced to the global ellipsoid. The pronoun-ced regional slope of the surface of the Mediterranean Sea is clearly seen, ranging from 50 m in the Balearic Sea down to 5 m in the southern Aegean Sea. The three red surfaces are showing the survey areas in the vicinity of JASON-1 tracks in the Eastern Mediterranean.

Fig. 60: High-precision measuring systems used to provide ground-truth observations of the absolute sea surface heights: GPS equipped buoy (bottom), ultra-sonic distance sensor coupled with GPS (middle) and one of the four GPS antennas mounted on the ship (top).

Fig. 61: Prof. P. Petroscevicius, head of the Institute of Geodesy (VGTU) and Prof. H. Ingensand (IGP) signing the agreement of scientific and educational collaboration in Vilnius.

Fig. 62: Young scientists of VGTU visiting the AlpTransit construction site.

First Lithuanian Swiss Geodetic Science Week, 2 – 6 October 2006, ETH Zurich

S. Naldi, A. Ryf, H. Ingensand / IGP

In July 2006 the Institute of Geodesy and Photogrammetry (IGP) of ETH Zurich and the Institute of Geodesy of Vilnius Gediminas Technical University (VGTU) have signed a collaboration agreement that aims to establish scientific research and educational cooperation in Geodesy and Geomatics.
The start of the close collaboration was initialised by six young scientists of VTGU who participated in the „First Lithuanian Swiss Geodetic Week“, which was a seminar that took place between 2 and 6 October 2006 at ETH Zurich. Both institutes presented their own scientific research projects and teaching activities. Furthermore, the Lithuanian delegation reported on the topics in Lithuanian geodesy and the procedures for calibration of geodetic instruments. The main focus, however, was the exchange of information to lay the basis for further collaboration.
The IGP will support Vilnius Gediminas Technical University by providing technical infrastructure such as measurement instruments and calibration equipment. On the teaching side it is planned to enter the Erasmus Programme that allows the exchange of students between VGTU and ETH Zurich.

The next steps foreseen in the collaboration activities are the participation of Lithuanian students in the Geodetic Projects Course in summer 2007 in Sedrun and the organisation of the „Second Lithuanian Swiss Geodetic Science Week” in Lithuania in autumn 2006 with the participation of ETH scientists (Fig. 61, 62).

The collaboration is financially supported by the GEBERT-RÜF FOUNDATION / Swiss Baltic Net.

Studying at the Department of Civil, Environmental and Geomatic Engineering

I completed my studies in geomatics at the ETH Zurich in the Winter Semester 2004 / 2005. For almost two years now I have been working as an assistant to Prof. Dr. Willy A. Schmid at the Institute for Spatial and Landscape Development IRL.

What does an assistant like me actually do? What were my experiences as a student? What were the positive aspects of my student life and what were the negative ones? What is my opinion today of the courses in geomatic engineering? What induced me to study geomatics? I would like to reflect on all these questions in the following paragraphs.

Let us start with the time before my studies: When I was at secondary school I knew that I would like to study one of my favourite subjects at that time, which were history, geography and mathematics. Furthermore, the course of studies had to be related to engineering practice, guarantee a wide-ranging education and enable me to choose a profession in which one can work with other people, in which a knowledge of foreign languages is useful, which includes work in the open air and not just in the office in front of a computer screen. In addition to studying one of the secondary school subjects mentioned above, earth sciences and geomatics also struck me as being quite interesting and worthwhile.

All this sounds very structured and well thought-out, but the decision to study geomatics was rather intuitive; when the time of applying for the university studies got closer, I simply had the feeling that geomatics was the field of study which interested me most.

The basic courses, which bored many students, were also hard for me, but at the same time it was quite exciting because an insight into various subjects was provided. I also tried to follow a wide range of studies in the specialisation and optional subjects by choosing lectures in geodesy and geo-informatics as well as in planning, land use management and landscape development. Therefore I am a somewhat disappointed that there are always people who demand that the compulsory basic lectures of the different specialization subjects should be voluntary, because in my opinion, the wide range of subjects is one of the biggest advantages in geomatics and planning.

The small number of students, in our semester we were only about 15, had a positive effect on the classroom spirit and also on the quality of the lectures, because sometimes they were more a case of interactive learning units between lecturers and students than pure lectures. Nevertheless, it has to be hoped that in future the number of students will increase because only with a bigger number of students the courses in geomatics have a long-term perspective.

The events of GUV (Association of Geomatic and Environmental Engineering Students) was one of the pleasant sides of student life. The excursions, parties, sporting activities and international student meetings helped one to forget the stress of studies for a while. However, for some people they give the impression of a happy-go-lucky or even lazy student life, which does not in fact correspond to studies at the ETH Zurich at all.

Naturally the studies were not only fun: In the sixth semester I had just about enough of lectures and exercise classes and so I greatly looked forward to the compulsory practical training. For about four months I worked in an engineering firm in the Bernese Oberland in the fields of engineering geodesy, photogrammetry and hydraulics. I was surprised how much of what I learnt at the ETH could be used directly in practice. In many cases long-term experience is missing, but especially if new technologies are in demand the knowledge acquired at the ETH can be put into practice directly.
Unfortunately, since the Bologna System was implemented a compulsory program of practical training no longer exists. Nevertheless, I hope that there will be plenty of students who can manage to find a practical job during their studies, either in the semester holidays or in a gap year between bachelor and master studies. Practical training is essential, since it breaks up the studies, gives fresh motivation and provides useful experience for the remaining period of study and is also of benefit in ones future professional life.

After finishing practical training, together with a friend I worked out a guiding plan for the Shaxi Valley, a remote mountain valley in the southern part of the Himalayas in the Chinese Province of Yunnan. The work was a semester thesis at the Institute for Spatial and Landscape Development, supervised by Prof. Dr. Willy A. Schmid and Dr. Jacques P. Feiner. In order to do the essential field work, we had the possibility of visiting China for about one month. There we realized that, on the one hand, collaboration in an international project is very interesting and, on the other hand, it involves a lot more difficulties than a conventional task. In addition to the language problems, which lead unavoidably to misunderstandings, with loss or distortion of data, there were also problems in collecting the data. Frequently, the required planning and statistical data was not available because it did not exist, it could not be found or it was kept under lock and key by the appropriate authorities.
Nevertheless, I have good memories of this semester thesis. The team of the Shaxi Rehabilitation Project and the local population supported our work wholeheartedly. Besides the lessons learned, the cultural experience was the biggest profit from this work.

As a diploma thesis, I worked out a detailed tourism development strategy for the Shaxi Valley. In future tourism will be one of the most important sources of income in the Shaxi Valley. Both the wonderful scenery with meandering rivers and creeks, brightly coloured fields, steep hillsides and a unique cultural heritage such as temples, Buddha statues, decorated tombs and the last existing stop-over on the ancient Tea and Horse Caravan Trail between Yunnan and Tibet are the main tourist attractions of the Shaxi Valley.

After submitting my diploma thesis I completed all my military service in one piece, because I avoided the compulsory repetition courses during my university studies. This four-month period of service was a good thing in every respect; due to the longer deployment, I was able to do a more responsible and more meaningful job than in the normal military repetition course. And now I have finished my all my military duties.

In the meantime, Gusti Nussbaumer, the person responsible for teaching at the Institute for Spatial and Landscape Development IRL, asked if I would like to work as an assistant at IRL. After considering it for a while I accepted. My desire, to work somewhere else after five years at Hönggerberg was the sole reason holding me back.
Now, however, after two years as an assistant, I see things in a positive light: I like my job immensely; the combination of teaching and project work is ideal for me. I was able to collaborate on the final assignments of the Shaxi Rehabilitation Project and for teaching duties I am involved in the preparation of lectures, exercises and semester theses. This gives me the opportunity to pass on my knowledge and to work together with the students. All the things I found fault with lecturers and assistants as a student, I can now try to improve on; e.g. devoting more time to students' questions, explaining the subject material better and fixing the dates for handing in exercises more appropriately.

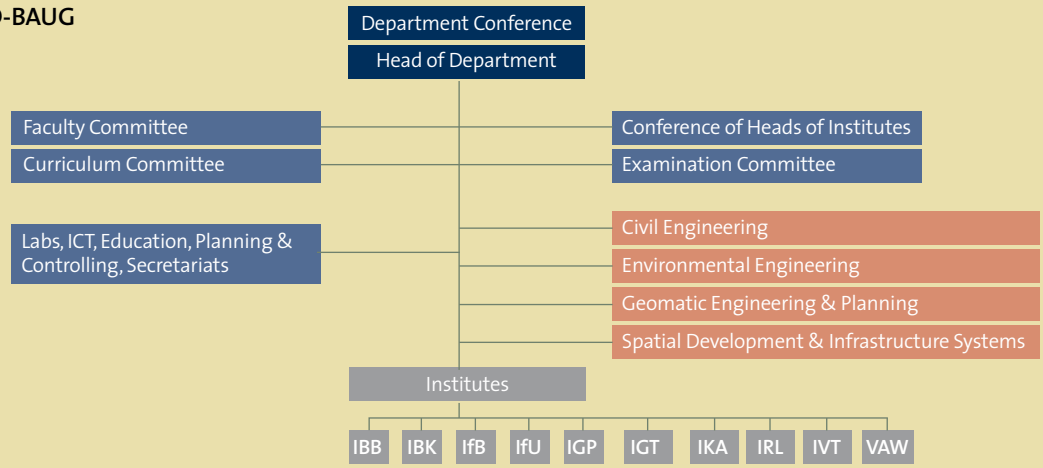
In addition, one can continue the learning process: All the subject material of the lectures I did not take as a student now has to be understood in depth in order to be able to answer students' questions competently. A further advantage of my work as an assistant is the excellent working atmosphere at the Institute for Spatial and Landscape Development IRL.

Thus, I believe I made the right decisions by choosing the course of studies in geomatics and then starting work as an assistant at the Institute for Spatial and Landscape Development. Both of them offer a wide range of interesting subjects with exciting opportunities for the future.

Patrick Bertschi, Dipl. Geom. Ing. ETH / IRL

Facts & Figures

Organisation Chart D-BAUG



Institutes

IBB Institute for Construction Engineering and Management
Proff. G. Girmscheid, H.R. Schalcher, H. Wallbaum

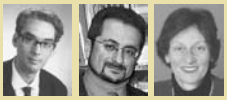
IBK Institute of Structural Engineering
Proff. M.H. Faber, M. Fontana, P. Marti, T. Vogel, A. Dazio

IfB Institute for Building Materials
Proff. H. J. Herrmann, J.G.M. van Mier, P. Niemz, B. Elsener

IfU Institute of Environmental Engineering
Proff. P. Burlando, W. Gujer, S. Hellweg, W. Kinzelbach, M. Boller, H. Siegrist, F. Stauffer

IGP Institute of Geodesy and Photogrammetry
Proff. A. Carosio, A. Grün, H. Ingensand, H.-G. Kahle, A. Geiger

IGT Institute for Geotechnical Engineering
Proff. G. Anagnostou, A. Puzrin, S.M. Springman



IKA Institute of Cartography
Prof. L. Hurni

IRL Institute of Spatial and Landscape Planning
Proff. W.A. Schmid, B. Scholl

IVT Institute of Transport Planning and Systems
Proff. K.W. Axhausen, U. Weidmann, H.P. Lindenmann, P. Spacek

VAW Laboratory of Hydraulics, Hydrology and Glaciology
Proff. H.-E. Minor, M. Funk, W. Hager

Faculty

Retirements and Demissions

Prof. Dr. Christine Giger	Geo-Information Sciences	October 31, 2006
Prof. Dr. Susanne Kytzia	Spatial and Landscape Planning	January 31, 2007

Appointments

Prof. Dr. Stefanie Hellweg	Ecological System Design	January 1, 2006
Prof. Dr. Hans Jürgen Herrmann	Computational Physics for Engineering Materials	April 1, 2006
Prof. Dr. Bernd Scholl	Spatial Development	July 1, 2006
Prof. Dr. Holger Wallbaum	Sustainable Construction	August 1, 2006

Students (Date: December 31, 2006)

	BSc		MSc[1)]		Total			PhD Students			Doctorate		
Curricula	♂	♀	♂	♀	♂	♀	♂+♀	♂	♀	♂+♀	♂	♀	♂+♀
Civil Engineering	267	48	102	16	369	64	433	82	22	104	10	3	13
Environmental Engineering	101	42	38	17	139	59	198	23	10	33	4	1	5
Geomatic Engineering & Planning	48	20	30	10	78	30	108	34	13	47	3	2	5
Spatial Development & Infrastructure Systems	-	-	3	0	3	0	3	0	0	0	0	0	0
Total	416	110	173	43	589	153	742	139	45	184	17	6	23

[1)] including diploma students

Staff D-BAUG (Date: December 31, 2006)

	P	AP	TP	Scientific Staff	Technical Staff (incl. ICT)	Administrative Staff	Apprentices	D-BAUG Staff total (Capita)
Department	0		0	0	6	10	0	16
IBB	2	1	0	21	2	2	0	28
IBK	4	1	0	42	6	6	3	62
IfB	2	0	2	22	6	5	1	38
IfU	4	0	3	39	4	4	0	54
IGP	4	0	1	45	3	5	3	61
IGT	3	0	0	28	14	4	0	49
IKA	1	0	0	29	5	2	0	37
IRL	2	1	0	31	6	3	0	43
IVT	2	0	2	42	4	3	0	53
VAW	1	0	2	33	20	3	1	60
Total	25	3	10	332	76	47	8	501

P = Professor, AP = Assistant Professor, TP = Titular Professor
Scientific Staff = PhD students, Post-Docs, (Senior) Assistants, Senior Scientists (no P, AP, TP)
Figures without Student Assistants, Hourly Wage Employees, Trainees, "occupied Workplaces"

Master of Advanced Studies (MAS), Postgraduate Courses (ZLG), Courses

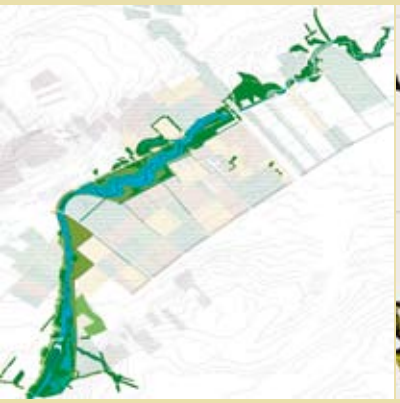
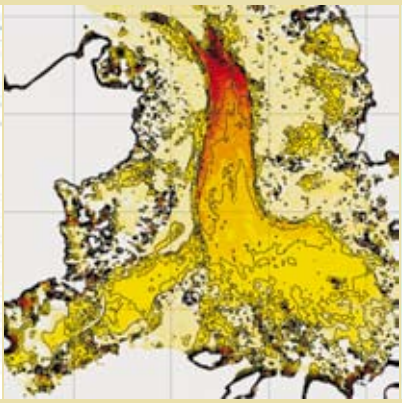
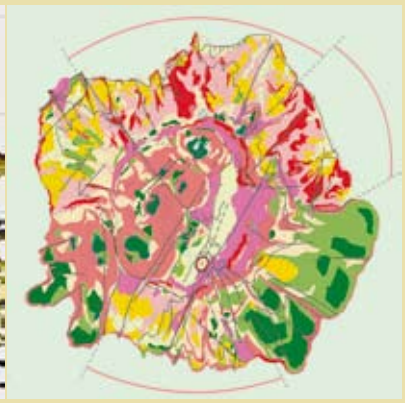
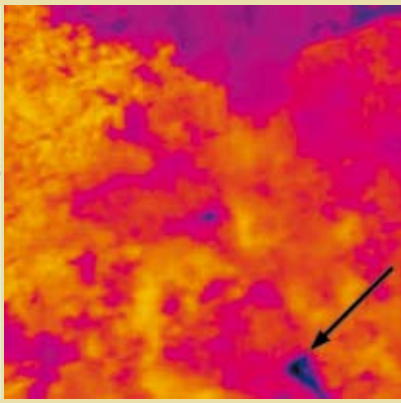
	Institute	Title
MAS ETH	IRL / IVT / NSL	Spatial Planning
MAS ETH	VAW / IfU + EPFL	Water Resources Management and Engineering
ZLG ETH	IGP / IKA	Spatial Information Systems
ZLG ETH	IRL / NSL	Spatial Development
ZLG ETH	IBK / IVT et al.	Risk and Safety of Technical Systems (responsible body: D-MAVT)
Course (MAS)	IBB / College of Architecture and Urban Planning, Tongji University	Urban Facility Management
Course	IBB	3rd International Summer Academy Project Management
Course	IBB	Construction Company Management
Course	IBB	Blasting Excavation Methods
Course	IBB / IFZ	Public Private Partnership
Course	IfB	Building Materials: different topics with (partly) external lecturers
Course	IGP	Study week: Under direction of IGP for college scholars
Course	IGP	Public presentation: TBM drill the Alps. Who shows the correct path?
Course	IGP / geomETH	First Lithuanian Swiss Geodetic Science Week
Course	IGT	Finite Element Analysis in Geotechnical Engineering
Course	IVT	Big Projects, Big Effects? Current Experience
Course	IVT	Optimization of Transport Systems
Course	VAW	Spillways
Course	VAW	River Diversion during Construction
Course	VAW	Bottom and Irrigation Outlets
Course	VAW	Planning Phases
Course	VAW	Fluviale und glaziale Prozesse in der Geomorphologie

Workshops, Symposia, Congresses

Event	Institute	Topic	Date (in 2006)
Conference	IBK / Bureau Veritas	The hazard potential of the built environment and industrial facilities for the safety of persons in Switzerland: identification and mitigation	January 10
Colloquium	IRL	„Leistungen der Natur: eine Risiko-basierte Bewertung“	January 25
Symposium	IRL	Preventing Urban Sprawl through Market-Oriented and Planning Instruments	March 16
Conference	IVT	Transport Engineers Day	March 23
Conference	IGP / geomETH	Society for the Calibration of Geodetic Instruments	March 23 - 24
Seminar	IVT	Geographic Systems and Quality Protection in Scheduling and Service	March 30
Workshop	IRL	„Spatial and Environmental Planning in Switzerland“ with PhD students from Asian Institute of Technology (AIT, Thailand)	April 3 – 7
Seminar	IGP	International GIS-cooperation Graz-Munich, Zurich	April 20 - 21
International Summer School	IGP	Digital Recording and 3D Modeling	April 24 - 29
Workshop	IRL	„Spatial Planning Practice in Switzerland“ and „Kunming Municipality: Regional City Network Master Plan“ with experts from the Kunming Urban Plannning and Design Institute (KUPDI, China)	April 24 / May 7 June 26 - July 3
Conference	IBK / University of Calgary	IFED, 2. Forum, „ Decision Making Involving Spatially Distributed Systems“	April 26 - 29
Congress	IGP / GGL	Research Day Nav, Location Based Services	April 27
Workshop	IGT	8th GEO-DACH Meeting	May 25 – 27
Seminar	IGP / ISPRS	Extraction of Geospatial Information from High Spatial Resolution Optical Satellite Sensors	June 3
Workshop	IGP	ISPRS Student Consortium Summer School „Satellite Data Processing and Spatio-Temporal Analysis for Resource and Disaster Mapping, Monitoring and Management“	June 19 - 26
Seminar	IVT	Optimization of Transport Systems	June 22
Symposium	IGP / ISPRS	Caravan Student Tutorial „Thesis and Proposal Writing“	June 27 - 30
Workshop	VAW	Meeting of the German-Sino Group of Unsteady Sediment Transport (Gesinus)	July 27 – 28
Workshop	IBK	China meets Switzerland	August 16 - 18
Symposium	IBK	fib-CH Betontag	August 18
Symposium	IBK	6th International PhD Symposium in Civil Engineering 2006	August 23 - 25
Workshop	IBK	Interdisciplinary Workshop on Management of Earthquake Risks	August 28 - 29
Symposium	IBB	New Stadia - secure Experiences?	September 6
Workshop	IVT	Introduction in Estimating and Modeling Transport Demand	September 20 - 22 October 19 - 20
Conference	IRL	„Landmanagement und Infrastruktur“ (co-organized with geosuisse, IGS, sia VSVAK, BLW and CH-AGRAM)	September 16
Workshop	IRL	Kunming Municipality: Regional City Network Master Plan“ with experts from the Kunming Urban Planning and Design Insitute (KUPDI, China)	September 26
Seminar	IGP / ISPRS	Information extraction, with emphasis on DSM generation, from high resolution optical satellite sensors	September 26
Workshop	IBK / IGP/ Nideco	Community based Risk Management Workshop	October 3 - 5
Workshop	VAW	River Widening - Potentials and limitations	October 4
Symposium	IBK / Holcim	12th Holcim Concrete Symposium „Concrete in Composite design“	October 5
Workshop	VAW	Block Ramps - Requirements and Design	October 5
Conference	IGP / ACRS	Writing and Presentation Techniques	October 5 - 6
Workshop	VAW	Numerical Modelling of Natural Hazards with the Software System Basement	October 6
Conference	IGP / ACRS	3D Mapping with high Resolution Satellite Imagery (ALOS-PRISM)	October 6 - 8 / 11
Workshop	IBK / IVBH	Composite Structures, workshop with Japanese Experts - Prof. Takanashi	October 9
Workshop	IBK	Steel, Timber and Composite Structures - Information on Ongoing Research Projects	October 30
Conference	IBB et al.	„Immobilien und Services erfolgreich entwickeln: Wertschöpfungspotenziale in einem komplexen Umfeld”	November 1
Forum	IVT et al.	Public Transport Forum 2006: Connected or broken networks?	November 2 - 3
Congress	IRL	Perspectives for Spatial and Railway Development at the North-South-Transversale for Europe	November 2 - 4
Symposium	IRL	City and Region on discussion	November 9 - 10
Congress	IBK / SAH	38th Congress of the Swiss Association for Timber Research	November 9 - 10
Conference	IGP / geomETH	20 Years GEOMATICS NEWS	November 14
Symposium	IBB	Innovations in blasting Techniques	November 30
Symposium	IRL	City Development in Europe	December 1
Seminar	IGP	Comitato Scientifico italo-svizzero per la Geoinformazione (EPFL, ETHZ, Polimi)	December 1 - 2
Workshop	IBK	Multi-storey Buildings in Timber Construction / Switzerland and Japan	December 5
Seminar	IVT	Big Projects, Big Effects? Current Experience	December 7
Workshop	IfU	Extreme Precipitation, Multisource Data Measurements and Uncertainty	December 7 - 11
Colloquium	IRL	The Visualisation Tool for Research and Praxis	December 13

Honours

Name	Institut	
Prof. Dr. Elsener Bernhard	IfB	Titular Professor ETH Zurich
Prof. Dr. Grün Armin	IGP	Member of the Fourth Academic Committee of the State Key Laboratory of Information Engineering in Surveying, Mapping and Remote Sensing (LIESMARS) , Wuhan University, China
Prof. Dr. Grün Armin	IGP	Member of the Executive Committee of the International Digital Earth Society, Beijing, China
Prof. Dr. Grün Armin	IGP	Fellow Professor of the National Central University, Taiwan
Prof. Dr. Gujer Willi	IfU	„Owl 2006 VSETH“ for best lecturing Professor in D-BAUG
Prof. Dr. Hager Willi H.	VAW	2006 Borland Lecture Award
Prof. Dr. Hurni Lorenz	IKA	Corresponding Member of the German Geodetic Commission
Prof. Lindenmann Hans Peter	IVT	Titular Professor ETH Zurich
Prof. Vogel Thomas + Dipl. Ing. Fricker Stephan	IBK	NDT Award, 11th International Conference on „Structural Faults & Repair - 2006“, Edinburgh, UK. Paper: „Acoustic Monitoring of Post-Tensioned Bridges“
Dr. Brunner Philip	IfU	ETH Medal for an excellent Doctoral Thesis
Dr. Eisen Olaf	VAW	SCAR Research Fellowship 2006/07
Dr. Pralong Antoine	VAW	ETH Medal for an excellent Doctoral Thesis
Dr. Weichert Roman	VAW	Research Award of PLANAT (National Platform for Natural Hazards)
Huss Matthias	VAW	Best Poster Presentation by a Student (1st price). IUGG Commission for the Cryospheric Sciences (UCCS)
Kienzler Peter	IfU	Best Poster Award EGU, Vienna
Schellenberg Kristian	IBK	Conference Award, 3rd International Conference on Protection of „Structures against Hazards“, Venice, Italy. Paper: „Rockfall-falling weight tests on galleries with special cushion layers“
Anhorn Karin	IBK	Culmann Award for excellent Diploma Thesis
Binetti Andrea	IBK	Culmann Award for excellent Diploma Thesis
Blumer Samuel	IfB	Hatt-Bucher-Price (1st position), „Moisture induced stresses and deformations in parquet floors - An experimental and numerical study“
Etter Stephan	IBK	Hatt-Bucher Award: „Composite Hypar-Schalen“
Foglia Amilcare Santino	IfB	Willi-Studer-Price for the best graduate of completed studies in 2006 and Medal of ETH Zurich for the excellent diploma thesis „Investigations on selected factors influencing the water vapour resistance of wood-based materials“
Furrer Patrick	VAW	Maggia Price
Heinzmann Daniel	IBK	ETH Silver Medal, Willi Studer Award and Civil Engineering Curriculum Award: „Rissbildung und zugversteifende Mitwirkung des Betons“
Künzler Philipp	IBK	Culmann Award for excellent Diploma Thesis
Martini Fabiano	IBK	Young Engineers‘ Symposium 2006 by ivbh.ch (1 of 3 awardees): „Drei Werke von Pier Luigi Nervi“
Münch Stefan	IGP/GGL	ETH Diploma Medal for excellent Diploma Thesis
Pfister Stefan	IfU	ETH Diploma Medal for excellent Diploma Exam
Reifler Jan	IBK	Culmann Award for excellent Diploma Thesis
Rousselot Patric	VAW	Willi-Studer Price for best Alumnus of the Year 2006: „Numerical Simulation of highly unsteady problem, dam erosion“
Saurer Erich	IGT	Culmann Award for excellent Diploma Thesis
Schmid Andreas Matthias	IGT	Culmann Award for excellent Diploma Thesis
Steiner Francis	VAW	Hatt-Bucher-Price (3rd rank)
Zeller René	IVT	Swiss Transport Association Prize for Masters Thesis

Addresses

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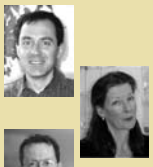

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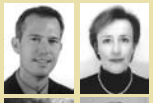

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