Abstract Volume
10th Swiss Geoscience Meeting

Bern, 16th – 17th November 2012

19. Geoscience and Geoinformation – From data acquisition to modelling and visualisation

sc | nat

Swiss Academy of Sciences
Akademie der Naturwissenschaften
Accademia di scienze naturali
Académie des sciences naturelles

b
UNIVERSITÄT
BERN

19. Geoscience and Geoinformation - From data acquisition to modelling and visualisation

Nils Oesterling, Adrian Wiget, Massimiliano Cannata

Swiss Geological Survey
Swiss Geodetic Commission
Swiss Geotechnical Commission
Swiss Geophysical Commission
Swiss Hydrogeological Society

TALKS:

19.1 Arndt D., Bär K., Sass I., Hoppe A.: Geological structural model of the Federal State of Hesse (Germany) to evaluate geothermal potentials with consideration of parameter uncertainties

19.2 Baumberger R., Wehrens P., Herwegh M.: Large scale mapping of 3D deformation structures – a combined remote sensing and field work approach

19.3 Bozzini C., Krebs P., Conedera M.: Quantifying landscape changes through the georeferencing of single oblique historical photos

19.4 Caduff R., Kos A., Schlunegger F.: Deformation and radiometric mapping with terrestrial radar interferometry – From radar-geometry to high resolution 3d-surface maps

19.5 Jaboyedoff M., Abellan A., Carrea D., Derron M.-H., Epard J.-L., Humair F., Loye A., Matasci B., Metzger R., Michoud C., Schreiber L.: 3D geological investigations coupled to Lidar data: toward vertical geology. **(Key-Note: Aquisition)**

19.6 Matzenauer E, Mosar J.: 3D Modelling and Visualisation of the Structures within the Préalpine Nappe Stack

19.7 Nebiker S., Christen M.: 3D visualisation – state-of-the art and perspectives. **(Key-Note: Visualisation)**

19.8 Pamer R.: Getting the “logic” out of geological 3D modelling. **(Key-Note: Modelling)**

19.9 Psimoulis, P., Rothacher, M., Dalguer, L., Zhang, Y.: Development of a method for the detection of seismic events based on high-rate GNSS network measurements

19.10 Schmassmann S., Filipponi, M., Jeannin P.-Y., Parriaux A.: KarstALEA : a practical guide for the prediction of karstrelated hazards in underground works

19.11 Terrington R., Hughes L., Napier B., Ramos L.: Geoscience Data Integration and Visualisation in 3D - GeoVisionary

POSTERS:

P 19.1 Dresmann H., Huggenberger P., Epting J., Wiesmeier S., Scheidler S.: The 3D-model Basel region – a planning tool

P 19.2 GeORG-Project Team: The EU-project GeORG – products

P 19.3 Zhe Liu, Geiger A., Guillaume S., Zhenzhong Su, Häberling S. & Psimoulis P.: Small and Fast Motion Detection using GPS receiver Single-Frequency Carrier Phase Observations

P 19.4 Neyer, F.: Visualizing vector data: Clustering noisy displacement fields

19.1

Geological structural model of the Federal State of Hesse (Germany) to evaluate geothermal potentials with consideration of parameter uncertainties

Arndt Dirk[1], Bär Kristian[2], Sass Ingo[2] & Hoppe Andreas[2]

[1] *Böhringer AG, Mühlegasse 10, CH-4104 Oberwil (dirk.arndt@boe-ag.ch)*
[2] *TU Darmstadt, Institut für Angewandte Geowissenschaften, Schnittspahnstr. 9, 64287 Darmstadt, Germany*

A three dimensional structural model of the Federal State of Hesse was developed using the software GOCAD (Arndt 2012). It incorporates more than 4150 well data from the Hessian well database hosted by the Geological Survey of Hesse (HLUG) as well as from the Hydrocarbon Well Database of the German Geo-logical Surveys, hosted by the Geological Survey of Lower Saxony (LBEG).

Furthermore, all available geological cross sections from geological maps, from interpretations of seismic 2D profiles and from other literature were taken into account. Additional data such as contour maps, palaeogeographic maps, theoretical models and actual 3D models were used. In order to provide uncertainty information to third party users more easily, it was integrated for each geological unit into the model itself.

Based on the structural model, Stratigraphic Grids were created (Arndt 2012) and parameterised with geothermal reservoir parameters, such as matrix and rock mass permeability, porosity, density, thermal conductivity, thermal diffusivity, heat capacity and temperature including the temperature and pressure dependence of the different parameters (Bär 2012).

This integrated approach makes the model highly capable to evaluate geopotentials. Therefore, a new method for geopotential evaluation based on the Analytic Hierarchy Process (AHP; Saaty 1980) was developed. It uses gridded 3D objects, i.e. SGrids or Voxets (Arndt 2012). The method can identify and visualize different geopotentials from cell based objects using individually chosen sets of parameters included in the model. The hierarchical weighting of the different parameters is adjusted according to the geopotential, which shall be evaluated. Additionally, the method is able to consider parameter uncertainties if the empirical variance of the probability distribution is known from statistical analysis of the input data. An example from the Upper Rhine Graben Area is presented.

REFERENCES

Arndt, D. 2012: Geologische Strukturmodellierung von Hessen zur Bestimmung von Geopotenzialen. PhD thesis TU Darmstadt.

Bär, K. 2012: Untersuchung der tiefengeothermischen Potenziale von Hessen. PhD thesis TU Darmstadt

Saaty, T.L. 1980: The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation. McGraw-Hill, 287 p., New York.

19.2

Large scale mapping of 3D deformation structures – a combined remote sensing and field work approach

Baumberger, Roland [1,2], Wehrens, Philip[1], Herwegh, Marco[1]

[1] *University of Bern, Institute of Geological Sciences, CH-3012 Bern*
[2] *Federal Office of Topography swisstopo, Swiss Geological Survey, CH-3084 Wabern (roland.baumberger@swisstopo.ch)*

Shear zones, faults and joint systems represent important sources of geological information and allow deep insight into the formation history of a rock complex. However, the three-dimensional spatial distribution of these geological structures is a key problem while developing valid geological 3D models, particularly with increasing distance from the surface. That is especially true in regions, where only little or even no "hard" underground data (e.g. bore holes, tunnel mappings and seismics) is available.

The granitic rocks of the Haslital valley (Switzerland) provide excellent outcrop conditions to study such mechanical anisotropies. Furthermore, there is many subsurface data available (e.g. tunnel and pipeline mappings, drill holes, cross sections etc.) allowing the correlation between surface and subsurface information. The present study aims to bring together remote sensing and field data, in order to develop a methodology to improve the reliability of geological 3D models. In a first step, based on a geostatistically verified map of large-scale structural elements (shear zones, faults), a shear zone map was derived and evaluated in the field. Field work was partially done using a GPS based Slate PC and the FieldMove™ software, in order to ease the subsequent data processing. The second step focused on autocorrelation algorithms (Fernández, 2005 and Fernández et al., 2009), in order to use remote sensing results as a basis for semi-automatic three dimensional shear zone construction. In the third and last step, own field data helped to justify the former findings and to fill gaps in between automatically constructed single patches along shear zones traces.

This surface based approach was amended by the integration of subsurface data taken from mappings from underground facilities. Some ten kilometers of geological maps of tunnels and pipelines were evaluated. Firstly, shear zones and faults were digitized and subsequently served as a source for the construction of small-scale planes representing segments of shear zones and faults. Secondly, surface shear planes were projected to depth and were correlated with the subsurface data.

First results show a good fit between the two approaches mentioned above. It becomes evident that (1) several different shear zone generations are present, which dip in two main directions, (2) shear zones often follow lithological boundaries, (3) the number and spatial density of shear zones increases in the southern part of the working area and (4) own large-scale data fits very well with small-scale structures provided by recent studies in the same area.
Nevertheless, there are some difficulties to be mentioned: (1) Due to ongoing erosion, the traces of the structures is not always obvious, even on high resolution digital elevation models and aerial photos, and partially need to be unraveled by interpretation, (2) the amount of subsurface structures that could be taken into account exceeds by far the number of surface structures obtained by remote sensing and own field work, which complicates the above-mentioned correlation task and (3) the digitization quality of the remote sensing part of the task is crucial and lowers modeling complexity in subsequent steps of the workflow.

The combined use of surface and subsurface data helped to predict their trend with increasing distance from the surface, bypassing a height difference of partially more than 2000m. Yet, the exact interplay of these structures in terms of orientation, kinematics and evolution is not clear. Additional analysis is needed in order to gain more detailed insight into the deformation history of the rocks in the study area (see Wehrens et al. 2012, this volume).

REFERENCES
Fernández, O. (2005): Obtaining a best fitting plane through 3D georeferenced data, Journal of Structural Geology 27, 855-858
Fernández, O., Jones, S., Griffiths, P., Armstrong, N., Johnson, G., Ravagila, A., Muñoz, J. A. (2009): Automated tools within workflows for 3D structural construction from surface and subsurface data, Geoinformatica 13, 291-304

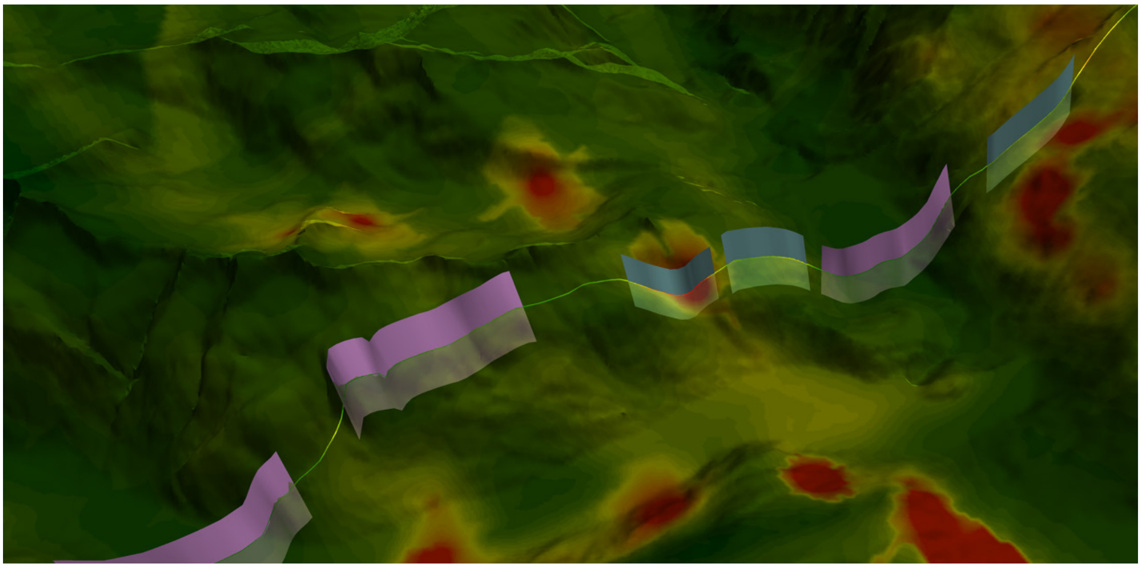

Figure 1: Coloured overlay (kriging interpolation) over digital elevation model discriminates regions of automatically correlated shear zone construction (green areas, pink patches, based on relief differences) and manual construction of shear zones (red to yellow areas, light blue patches, based on own field data). Transitions between different types of planes are not shown; Dimensions: 7x5km.

19.3

Quantifying landscape changes through the georeferencing of single oblique historical photos

Bozzini Claudio[1], Krebs Patrik[1] & Conedera Marco[1]

[1]Swiss federal Research Institute WSL, Insubric Ecosystem Group, via Belsoggiorno 22, CH-6500 Bellinzona (claudio.bozzini@wsl.ch)

Since its invention in the early 1800ies, the photography assumed a leading role as an effective instrument of documentation of the real world. With the improvement of the techniques the photography developed into photogrammetry giving the opportunity of georeferencing and mapping landscape elements starting from stereo-couples of photographs. With the introduction of the aerial photography, terrestrial oblique photogrammetry became obsolete and was almost completely abandoned as basic technique for the cartographic survey. Nevertheless, it is unquestioned that terrestrial historical pictures presents a lot of advantages such as the terrestrial landscape perspective of the daily live, the better view on the landscape in mountain regions, the high resolution and detail level, as well as the existence of an extended bulk of photographic material dating back in the late 1800ies and early 1900ies, much time before the onset of the aerial photography.

In recent times, the improvement of the computing power and the production of high resolution Digital Elevation Models (DEM) made the spatial georeferincing of single oblique terrestrial picture (monoplotting) more approachable. We started in 2009 by developing a tool for georeferencing common single historical terrestrial pictures. The basic requirements that have to be feed in the system are the digital version of the historical picture, the DEM of the depicted landscape, and the world coordinates of a suitable number of control points unambiguously recognizable on the picture. In this contribution we will illustrate the present version of the tool and some examples of practical applications we achieved so far, discussing the future developments as well as other potential fields of application. For the analyzed study cases the tool is found to be effective for reconstructing with precision the landscape changes. In particular it allow to georeference and quantify the features of former landscapes simply by mapping it directly on the available historical pictures.

The experimentations that we achieved in two alpine valleys, using photographic views that cover large portions of the opposite side of the valley, allow us to provide the first estimation of the precision of this new mono-photogrammetric approach. By comparing the cartographic results with measurements collected through an accurate topographic survey, we can assess precisely the error for every control point. The accuracy of the method depends on many conditions (e.g. high precision of the DEM, high resolution of the picture, low lens distortion), and if these conditions are respected the mean error in 3D localization can be reduced even below one meter.

19.4

Deformation and radiometric mapping with terrestrial radar interferometry – From radar-geometry to high resolution 3d-surface maps

Caduff Rafael[1,2], Kos Andrew[3,4], Schlunegger Fritz[1]

[1] *Institut für Geologie, Universität Bern, Baltzerstrasse 1+3, CH-3012 Bern (rafael.caduff@geo.unibe.ch)*
[2] *GAMMA Remote Sensing AG, Worbstrasse 225, CH-3073 Gümligen.*
[3] *Institute for Geotechnical Engineering, ETH Zurich, Wolfgang-Paulistrasse 15 CH- 8092 Zurich.*
[4] *Terrarsense Switzerland AG, CH 9470, Werdenberg*

Early detection and quantification of surface deformation on rock slopes is a central element in hazard assessment. In recent years, radar interferometry using ground based systems has demonstrated the capability to measure deformation at mm- to sub-mm scales, thereby opening new possibilities for the early detection of instabilities. Radar interferometry complements existing remote sensing techniques such as photogrammetry and laser scanning, however very few methods exist for data integration between the different approaches. We describe a new methodology for data-acquisition and visualization, using a new portable radar-interferometer (GPRI, Gamma Portable Radar Interferometer), incorporating lidar-based terrain models and photogrammetry (Figure 1).

Ground-based radar-interferometric sensors combine the advantages of resolution and accuracy with flexibility regarding the viewing geometry and repeat measurement period. Deformation analysis of steep and/or overhanging rockwalls is possible with this type of sensor. For terrestrial observations however, simple map geometry for localization and visualization of displacements is not adequate (as is simple image draping on digital terrain models). Therefore we developed a method to locate the 2D-radar image (range and azimuth) in orthogonal 3D space. This was possible with the use of high-resolution elevation data (from photogrammetry and laser scanning data sources), fused with other thematic data (e.g. quantitative displacements) obtained from different sources and sensors.

The GPRI is a fully coherent real aperture radar operating at Ku-band (17.4-1-17.3GHz). Scenes are acquired by rotation of fan-beam antennas with horizontal opening of 0.4 deg around its vertical axis. The 2d radar images (range/azimuth) store quantitative phase and intensity information of the backscattered radar-echo. This Information allows determination of the radiometric signature of the target area and its materials on one hand, as well as information about coherence and phase shifts of objects on the other. The phase shifts allow determination of deformation with accuracies of up to 1/8 mm (1mm for larger distances and/or repeat measurements). In comparison to existing instruments, the advantages of the GPRI lie in its portability (setup at virtually any location), fast image acquisition (seconds rather than minutes), lack of defocussing when imaging moving targets, reduced setup and take-down time and large operational range. The single point suspension allows high reposition accuracy as well as simple geodetic control of the setup.

Several measurement campaigns were successfully conducted where different targets such as an ice glacier, rock glacier, unstable rock slopes, bridge vibrations, flowing river, and corner reflector displacements were investigated.

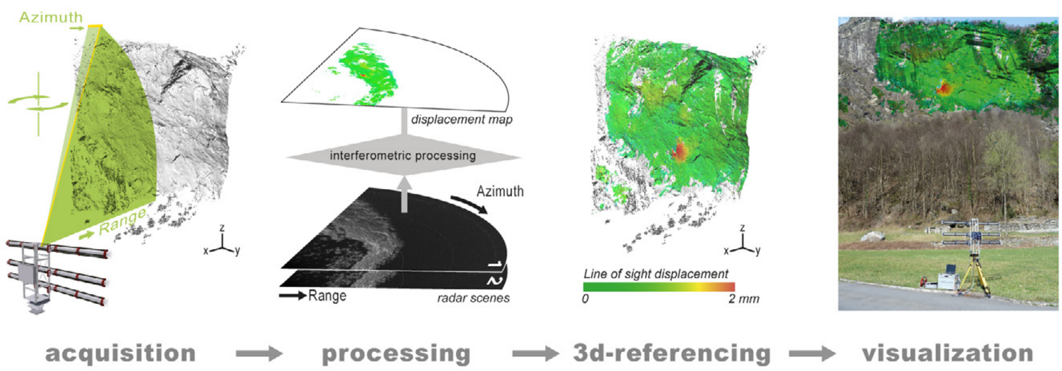

Figure 1. Schematic workflow from radar-data acquisition to visualization of data products.

19.5 3D geological investigations coupled to Lidar data: toward vertical geology

Jaboyedoff Michel[1], Abellan Antonio[1], Carrea Dario[1], Derron Marc-Henri[1], Epard Jean-Luc[2], Humair Florian[2], Loye Alexandre[1], Matasci Battista[1], Metzger Richard[3], Michoud Clément[1], Schreiber Lucien[4]

[1] *Research Centre for Terrestrial Environment (CRET), University of Lausanne, CH-1015 (Michel.jaboyedoff@unil.ch)*
[2] *Institute of Earth Sciences (ISTE), University of Lausanne, CH-1015*
[3] *Terr@num, 35 bis rue de l'Industrie, CH-1030 Bussigny*
[4] *CREALP (Research Center on the Alpine environment), Rue de l'Industrie 43 CH-1950 Sion*

The acquisition of LiDAR 3D data together with the advent of powerful computers, new graphic cards, etc., are making easier fundamental geological tasks such as mapping and structural analysis. LiDAR devices use an oriented laser beam, measuring the time of flight of successive pulses to obtain the 3D topography relatively to the device location. The acquired data can be subsequently geo-referenced (using for example differential GPS), coupled or not with inertial measurement units.

Currently, Airborne Laser Scanner (ALS) data can provide 2.5D Digital Elevation Models (DEM) of high resolution (HRDEM), i.e. more than 3-4 pts/m^2. Based on these data, the location of structures (large faults as well as the main discontinuity sets) and geological limits are almost perfectly georeferenced (Fig. 1), being the geological mapping consequently improved.
Nevertheless, the main recent improvement comes from Terrestrial Laser Scanners (TLS), which provide high accuracy and high resolution data acquisition (up to more than 1000 pts/m^2) of the terrain surface, allowing in addition vertical mapping. By analyzing surfaces, the structural features can be identified in inaccessible areas and in a more precise way than by classical fieldwork. This opens new perspectives in analyzing the real 3D structures (Jaboydoff et al., 2007). In addition to these capabilities, the use of the intensity return value allows distinguishing some of the rock contrasts (Franceschi et al., 2009).

Although some applications are still in development, this technique is already broadly used in many Geosciences disciplines: structural geology, engineering geology, stratigraphy, etc. For instance in landslide applications, LiDAR permits to characterize mass movements volumes and shapes in 3D and allows to monitor movements and deformations (Oppikofer et al., 2008; Jaboyedoff et al., 2012). Recent studies (e.g. Buckley et al., 2010) show how accurate stratigraphic profiles as well as sedimentary bodies can be defined based on LiDAR 3D data. Using both ALS and TLS can monitor Debris-flows and rockfalls. The rockfall activities show a clear link with freeze and thaw cycles, and their locations are controlled by preexisting discontinuities. Geological natural hazard mapping is also greatly improved by using Lidar data.

The recent advances in remote sensing such as hyperspectral images (Kurz et al., 2011), coupled with Lidar data may provide rock type identification. This will lead in a close future to real vertical geology and more precise 3D maps.

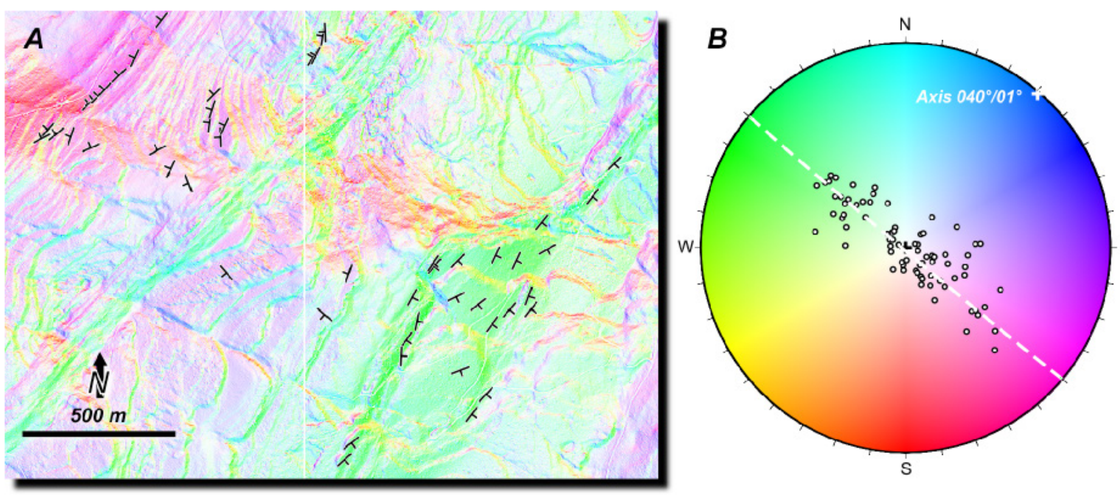

Figure 1. Structural analysis with ColtopGIS based on a swisstopo HRDEM in Jura Mountains. (A) Map with colour scheme indicating the orientations. (B) Stereonet extracted from the HRDEM represented in A.

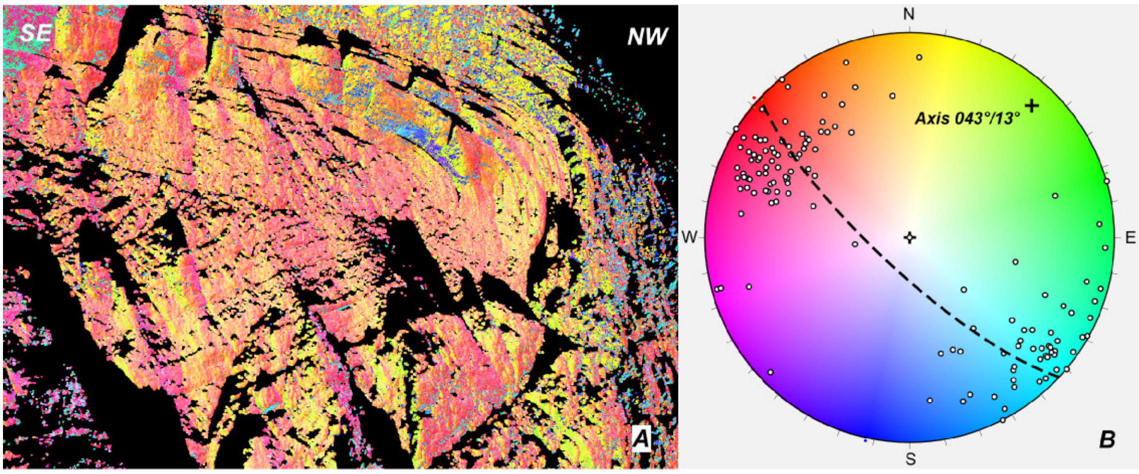

Figure 2. Folds analysis based on TLS scan of the Dents du Midi northwest face (A: Coltop3D view; B: Stereonet extracted from the 3D point cloud in Coltop3D).

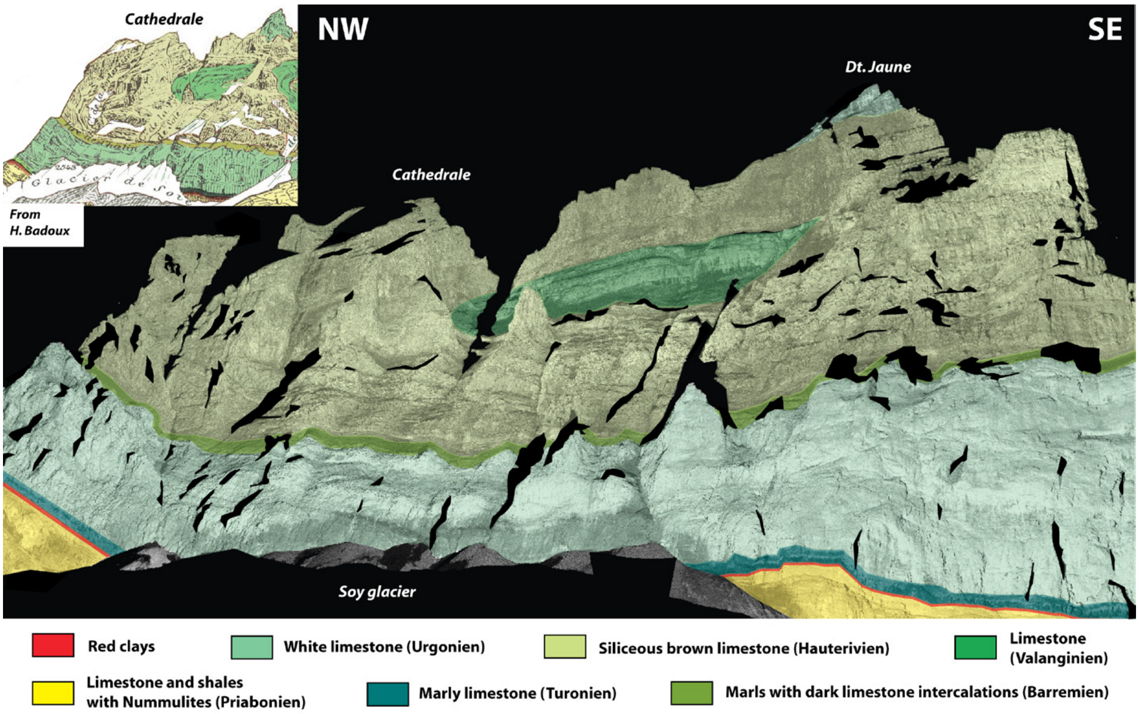

Figure 3. Vertical 3D geology of the Dents du Midi in the Morcles Nappe.

REFERENCES

Buckley, S.J., Enge, H.D., Carlsson, C., Howell, J.A. 2010: Terrestrial laser scanning for use in virtual outcrop geology. The Photogrammetric Record: 25, 225-239.

Franceschi, M., Teza, G., Preto N., Pesci, A., Galgaro, A. and Girardi S. 2009: Discrimination between marls and limestones using intensity data from terrestrial laser scanner. ISPRS Journal of Photogrammetry and Remote Sensing, 64, 522–528.

Jaboyedoff M., Metzger R., Oppikofer T., Couture R., Derron M.-H., Locat J. Turmel D. 2007: New insight techniques to analyze rock-slope relief using DEM and 3D-imaging cloud points: COLTOP-3D software. In Eberhardt, E., Stead, D and Morrison T. (Eds.): Rock mechanics: Meeting Society's Challenges and demands (Vol. 1), Taylor & Francis. pp. 61-68.

Jaboyedoff, M., Oppikofer, T., Abellán, A., Derron, M.-H., Loye, A., Metzger, R., Pedrazzini, A. (2012): Use of LIDAR in landslide investigations: a review. Natural Hazards, 61:5–28, DOI 10.1007/s11069-010-9634-2.

Kurz, T., Buckley, S.J., Howell, J.A., Schneider, D. 2011: Integration of panoramic hyperspectral imaging with terrestrial lidar data. The Photogrammetric Record, 26, 212-228.

Oppikofer, T., Jaboyedoff, M. and Keusen, H.-R. 2008. Collapse of the eastern Eiger flank in the Swiss Alps. Nature Geosciences, 1, 531-535.

19.6

3D Modelling and Visualisation of the Structures within the Préalpine Nappe Stack

Matzenauer Eva[1], Mosar Jon[2]

[1] *Federal Office of Topography swisstopo, Swiss Geological Survey, Seftigenstrasse 264, CH-3084 Wabern (eva.matzenauer@swisstopo.ch)*
[2] *Département de Géosciences Université de Fribourg, Chemin du Musée 6, CH-1700 Fribourg*

Within the scope of a PhD thesis on the tectonic and neotectonic structures of the Préalpes Klippen, five 3D models of different scales were calculated to represent the complex structures of the allochthonous nappe stack of the Préalpes Romandes, as well as the fold-and-thrust structures of the Préalpes Médianes. The focus of this modelling approach lies in the visualisation of the interpreted structures, applying different specialised software to create not only geologically correct models, but also to develop attractive and easy understandable graphics, useful for professional and didactical purposes.

The 3D models were generated by the 3D GeoModeller Editeur Géologique© program, developed by the BRGM (Bureau de Recherches Géologiques et Minières, France) and the Australian company Intrepid Geophysics. Within the general 3D model of the préalpine nappes, a compilation of existing cross-sections and seismic lines, as well as the crystalline basement topography were used to constrain the model, but still leave much room for interpretation. Therefore, the presented 3D visualisation is not a reproduction of unknown structures at depth, but rather gives a suggestion of a possible solution taking into account all available data.

After the creation of a complete 3D Model in 3D GeoModeller, the TSurf Export feature was used to calculate and export TSurf surface models, where each geological unit appears in a unique TS file. Since the graphical export method generates exclusively contact surfaces instead of the entire volume, the 3Dmodel becomes "lighter" and therefore easier to handle. One disadvantage of this export method are interfering contact surfaces at out-thinning layers, which provoke errors such as vacant and redundant facets in the triangular mesh. For this reason the exported model requires a cleaning of the model impurities by the use of a post-processing freeware, such as MeshLab v1.3.0. The purified layers were then reassembled in Paraview and NX Unigraphics for final visualisation (crosssections, exploded views, animations).

The final visualisation of the 3D model was established with a powerful CAD software normally used for engineering purposes. NX7.5 has a several sophisticated visualisation tools allowing dynamic cross-sectionning, smoothing of the triangular mesh structure and fly-through views. In this way it was possible to create aesthetic views of a complex structural context.

The generation of 3D pdfs created in Adobe Acrobat allow a further dissemination of the 3D models regardless whether specific modelling software is available, since these models can be opened by everyone using the free Adobe pdf viewer.

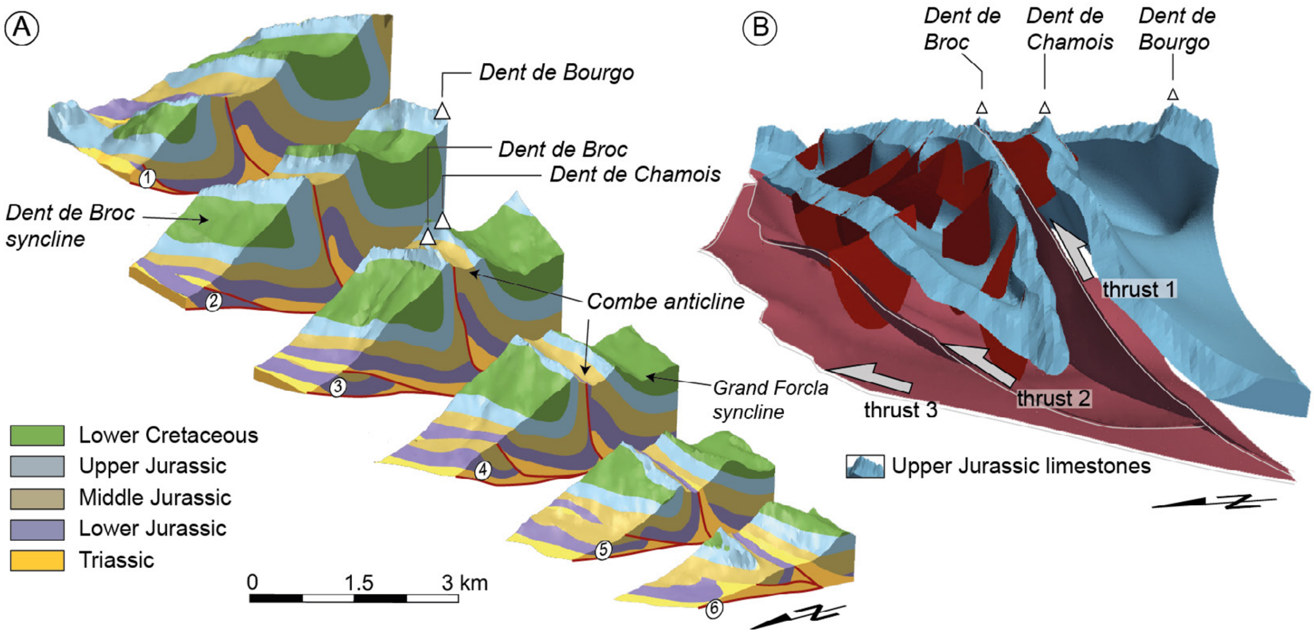

Figure 1. Two 3D representations of the Dent de Broc area generated by 3DGeoModeller. On the left, a view of different sections is exposing the internal structures, and on the right an illustration of the three thrust planes and the normal faults with most influence in this area.

19.7
3D visualisation – state-of-the art and perspectives

Nebiker Stephan[1], Christen Martin[1]

[1] *Institut Vermessung und Geoinformation, FHNW Fachhochschule Nordwestschweiz / Institute of Geomatics Engineering, FHNW University of Applied Sciences and Arts Northwestern Switzerland, Gründenstrasse 40, CH-4132 Muttenz (stephan.nebiker@fhnw.ch, martin.christen@fhnw.ch)*

The visualisation of multi-dimensional geospatial objects, phenomena and processes has been the focus of research for several decades and in different scientific domains. Subsequently, often highly specialised 3d visualisation software solutions have been developed and extensively used by the different domain experts in the geospatial and geoscience communities. However, the rapid emergence of commercial virtual globes such as Google Earth has brought the subject of web-based 3d geovisualisation to the attention of the mass media and the consumers as well as to a much wider spectrum of scientists. In our presentation we discuss some recent developments in the fields of interactive web-based 3d geovisualisation and virtual globes. A particular focus is placed on the creation, dissemination and exploitation of massive 3d geospatial environments and on recent developments and technologies such as cloud computing, HTML5 and WebGL. Based on the OpenWebGlobe project, an open source virtual globe technology, we discuss current shortcoming of large commercial virtual globes – also from a geoscience and geological perspective – and give an outlook on ongoing and future developments addressing some of these shortcomings.

Virtual globes can be characterized as distributed software environments capable of streaming and interactively displaying large amounts of geo-referenced spatial contents. These contents consist of elevation data, ortho-imagery, 3d objects, points of interest (POI), and possibly 2D vector layers. More recent work integrates 3d point cloud data or data from mobile geo-sensors such as UAV-based videos into virtual globes. Some first examples also include subsea surfaces and some limited support for subsurface structures. However, since virtual globes were and still are predominantly based on 2.5d data and data structures, supporting complex and large geological datasets creates a number of (new) challenges. These challenges are discussed based on the following key functionalities of virtual globes:

- An accurate underlying mathematical model of a global geodetic reference framework – permitting the integration of geodata and geosensor data from different reference systems down to the sub-meter accuracy level.
- Global spatial indexing of very large and complex geo-data sets – supporting the rapid, often highly parallelized production of large geospatial databases and ensuring highly efficient data access over medium bandwidth networks.
- Level-of-detail and/or multiple representation support for all types of geospatial content – providing view-dependent loading and displaying of geospatial contents at suitable aggregation levels.
- Internet-based streaming support for multiple users – enabling the constant access to potentially very large public or private geospatial data repositories.
- Smooth interactive visualization – permitting the asynchronous dynamic loading of 3D scene contents and spatial partitions.

This functionality and the special requirements of geological data are illustrated using the OpenWebGlobe technology. The open source project OpenWebGlobe (www.openwebglobe.org) was initiated by the Institute of Geomatics Engineering of the FHNW University of Applied Sciences and Arts Northwestern Switzerland (IVGI). It started in April 2011 following nearly a decade of 3d geobrowser development at the Institute.

Core of the project is the OpenWebGlobe SDK consisting of two main parts: first, the Viewer part, based on HTML5 and WebGL, allowing the integration of the OpenWebGlobe into custom web-applications. Second, the Processing Tools, a bundle of tools for bulk data processing, e.g. tiling or resampling of large geospatial data sets. OpenWebGlobe was one of the first projects employing WebGL, a cross-platform, royalty-free web standard for a low-level 3D graphics API based on OpenGL ES 2.0 (Khronos 2012). The first version of WebGL was released in March 2011. Today WebGL – and OpenWebGlobe – runs in desktop and mobile web-browsers like Mozilla Firefox, Google Chrome, Safari, and Opera. Thus, OpenWebGlobe might be the technology of choice for creating future interactive 3d visualisation solutions in geology and in geosciences in general.

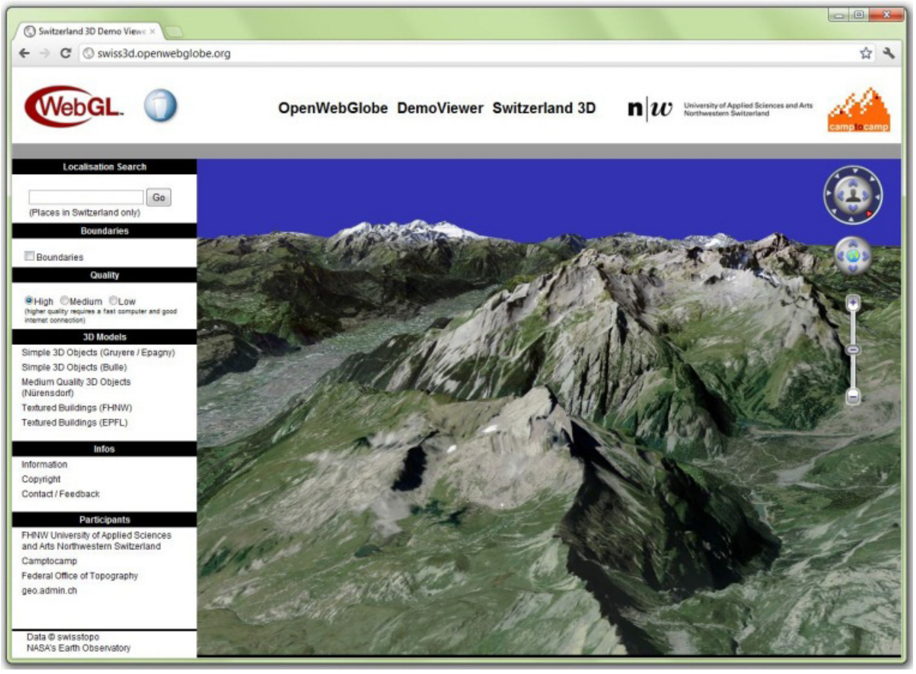

Figure 1. Demonstrator 3D Geoportal “Swiss3D” based on the OpenWebGlobe technology (http://swiss3d.openwebglobe.org)

REFERENCES

Christen, M., Nebiker, S., Loesch, B. 2012: Web-Based Large-Scale 3D-Geovisualisation Using WebGL: The OpenWebGlobe Project. International Journal of 3-D Information Modeling (IJ3DIM). 2012;1(3):16–25.

Khronos, 2012: WebGL - OpenGL ES 2.0 for the Web. http://www.khronos.org/webgl/ (last accessed: 7 Oct 2012)

Nebiker, S., Bleisch, S., Christen, M. 2010: Rich point clouds in virtual globes – A new paradigm in city modeling? Computers, Environment and Urban Systems. 2010;34(6):508–517.

19.8

Getting the “logic” out of geological 3D modelling

Pamer Robert[1]

[1] Bayerisches Landesamt für Umwelt (BayLfU), Abt. 10 Geologischer Dienst, Bürgermeister-Ulrich-Str. 160, D-86791 Augsburg (robert.pamer@lfu.bayern.de)

Working fully in digital 3D is creating an immense surplus for understanding as well as for raising public and political awareness of geology - not only as an academic science but also as a need to envisage the outstanding societal challenges in environment protection, clean energy and risk prevention. Geological survey organisations (GSOs) are going their way towards dynamic 3D underground cadastres that allow rapid and comprehensive, even probabilistic statements about the possibilities and risks of the subsurface.

Some years ago the main focus in geological modelling was on developing 3D-software and tools for handling geological data, visualise it in real-time and in “real” 3D and constructing static geological 3D models. With software becoming more powerful and affordable to a wider geological community like universities and geological survey organisations (GSOs) outside the e & p industry, seamless data exchange and integration of various data sets of different types and formats have become an issue. This could be summarized by the slogan: Better be detailed than coarse!

From a medium size GSO’s point of view the challenge now is to step ahead towards dynamic models that can be recycled and refreshed rapidly in order to reflect new data or different model versions. With provoking words: Better be fast than complex – GSOs have to give advise on decision makers who have (often too impatiently) to decide now and not tomorrow – like it or not, there is no time for waiting new boreholes to be drilled or another study to be underway.

Once that data is harmonised (in its semantics, format and structure) and software is interacting in a dynamic and user-defined way automation is nearby! Running predefined procedures takes modelling to its very core: To establish an exhaustive set of possible solutions to a set of comparatively sparse information about the barely accessible subsurface (e.g. Wellmann et al. 2011). So, what does one have by adding up a bulk of possibilities? Call it a probability map – in this case it should better be called a 3D probability model. Many off-the-shelf software already include tools for handling uncertainty, versions, dynamic updates and stochastics (e.g. stochastic simulation) - better be comprehensively fast than vague!

Revising these developments reveals many parallels to the progress that has been done in the well known field of 2D-GIS. Still, geological 3D modelling is more restricted to a smaller user community but the technological investment is not standing much behind and both worlds are converging more and more: 3D City models, 3D-viewers, 3D data formats, databases and so on.

The technical aspect of geological 3D modeling reflects this history: Early software was very specific regarding data formats and import/export capabilities. Originally developed by the e & p industry it was very focused on seismic data and the construction of models from huge data sets but without taking into account the full set of geological rules and constraints. Having responsibilities at the shallower subsurface as is the case for GSOs, all these tools had to be added with extra workflows, workarounds and programming to be able to utilize a field mapper's inhomogeneous database. However, this time consuming and error prone procedure was not very suitable for any re-modelling triggered by new data or alternative concepts. Furthermore, severe limitations arose from incompatible software, data-formats or databases when working within a regional or (even worse!) national context like projects or overview models. How to take over work on a third party's model? How to include its base data?

Interoperability is therefore a prerequisite for any capitalization of models beyond small problem-driven ones. To achieve this, many parallel activities had to be started with some of them still being ongoing. GSOs have taken over a substantial part by pushing forward technical standards for 3D databases, data formats, semantic and by harmonizing databases resp. data content, stratigraphic correlations etc. (Berg et al. 2011). Also more "geological thinking" by software has been welcome of course. However, the central issue is still to establish formats and standards to store and utilize complete models independently of the software that was used to build them, including the uncomplicated dissemination via the web. Having learned hard lessons on how to bridge the gap between the 2D and the 3D worlds opened concepts and new ideas on how to utilize GIS as a central data hub being able to manipulate, generate and transform all kind of data and handle it through to constrain generic 3D models (Pamer & Diepolder 2010).

The example of generating a state wide 3D model of Bavaria/Germany gives an idea about the complexity of this approach. It shows one way of how to use the automatisms of ArcGIS® to harmonise borehole databases, structure geological maps and generate hypothetic geometries to make them ready to use in any 3D modelling software. It is also used as a script generator to preset the whole model environment within the modelling suite SKUA®.

The concept reveals that most work has to be done apart the modelling task itself. In this example this effort is invested not in the preparation of the data itself but in the algorithms to make it fit!

REFERENCES

Berg, R., Mathers, S., Kessler, H., Keefer, D. (Eds). 2011: Synopsis of Current 3D Geological Mapping and Modeling in Geological Survey Organizations, Illinois State Geological Survey Circular 578

Pamer, R., Diepolder G. 2010: 3D geological modelling in Bavaria – state-of-the-art at a State Geological Survey, Z. dt. Ges. Geowiss., 161/2, 189-203.

Wellmann, F., Horowitz, F., Regenauer-Lieb, K. 2011: Towards a quantification of Uncertainties in 3-D Geological Models, In: Mathematical Geosciences at the Crossroads of Theory and Practice, Proceedings IAMG conference 2011 Salzburg, 746-759.

19.9

Development of a method for the detection of seismic events based on high-rate GNSS network measurements

Panos Psimoulis[1], Markus Rothacher[1], Luis Dalguer[2], Youbing Zhang[2]

[1] *Geodesy and Geodynamics Lab., Inst. of Geodesy and Photogrammetry, ETH Zurich, Schafmattstr. 34, 8093, Zurich (panos.psimoulis@geod.baug.ethz.ch; markus.rpthacher@geod.baug.ethz.ch)*
[2] *Swiss Seismological Service (SED), ETH Zurich, Sonneggstr. 5, 8092 Zurich (dalguer@sed.ethz.ch; youbing.zhang@sed.ethz.ch)*

Strong earthquakes, among the major natural hazards globally, occur in Switzerland on average every 80 years, with the last strong event taking place in Sarnen in 1964 (Mw=5.3). Furthermore the development of GNSS technology, e.g. the availability of high-frequency receivers recording at a rate of up to 100Hz and the many different systems (GPS, GLONASS, Galileo, Compass, etc.), allow the application of GNSS receivers to accurately monitor the seismic ground motions (Häberling, et al., 2011) and not only to estimate coseismic displacements. This study here is a first attempt by GGL-ETHZ in collaboration with SED to detect strong earthquakes based on high-rate measurements of a GNSS network covering the area of seismic interest.

The methodology is based on an algorithm, which analyses the high-rate GNSS kinematic coordinates to detect possible ground motions and displacements in each GNSS station. Based on the detection of the seismic motion the time of arrival at each station, the maximum coseismic displacement etc. can be derived. The algorithm developed is based on three steps:

I) the estimation of the measurement noise level for each component (north, east, up) and each station based on the measurements recorded several minutes before the event,

II) the comparison of the measurements of each station for the examined time interval with the corresponding noise level

III) if the apparent displacement in one of components is greater than the estimated noise level then this displacement express seismic motion and the corresponding time express the arrival time of the seismic motion at the current station.

In order to avoid possible wrong detections of seismic events caused by other phenomena (e.g. landslides) or outliers in the measurements, several GNSS stations covering the broader area of seismic interest are used in the algorithm.

The method has been assessed based on simulated velocity records corresponding to simulated strong seismic events (Mw>6.0) varying in fault (normal, reverse) and rupture mechanism (depth, angle slip, etc.). These high-rate velocity values were computed from the seismic simulation models for a total of 168 sites covering symmetrically the broader area of 100kmx80km around the epicenter (Dalguer and Mai, 2011). The velocity records were integrated into displacement records and subsequently transformed into series of geocentric coordinates thereby locating the epicenter in the area of the Valais, an area of high seismicity in Switzerland. Using the Bernese GPS Software 5.1 simulated GPS observations were then generated for the 168 simulated stations with their ground motions.

The processing of the simulated GPS data resulted in series of kinematic coordinates, to which the detection algorithm was applied. The ground motion was accurately detected (error < 0.1 sec) for 30% of the stations and with error < 0.5sec for the 43% of the stations (Fig.1).

Thus, these preliminary results indicate that the developed methodology can be applied for the earthquake detection based on a high-rate GNSS network. It is clear that the algorithm still needs to be improved for a refined, more reliable detection of seismic motions by limiting possible measurement errors and outliers.

REFERENCES

Dalguer, L.A. and Mai, P.M. 2011: Near-source ground motion variability from M~6.5 dynamic rupture simulations. Proc of 4th IASPEI/IAEE International Symposium: Effects of surface geology on seismic motion (in CD), August 23-26, 2011, CA, USA.

Häberling, S., Rothacher, M., Zhang, Y. 2011:.Assessment of shake table generated earthquake ground motions recorded using high-rate GPS. 25th International Union of Geodesy and Geophysics General Assembly (IUGG), 2011.

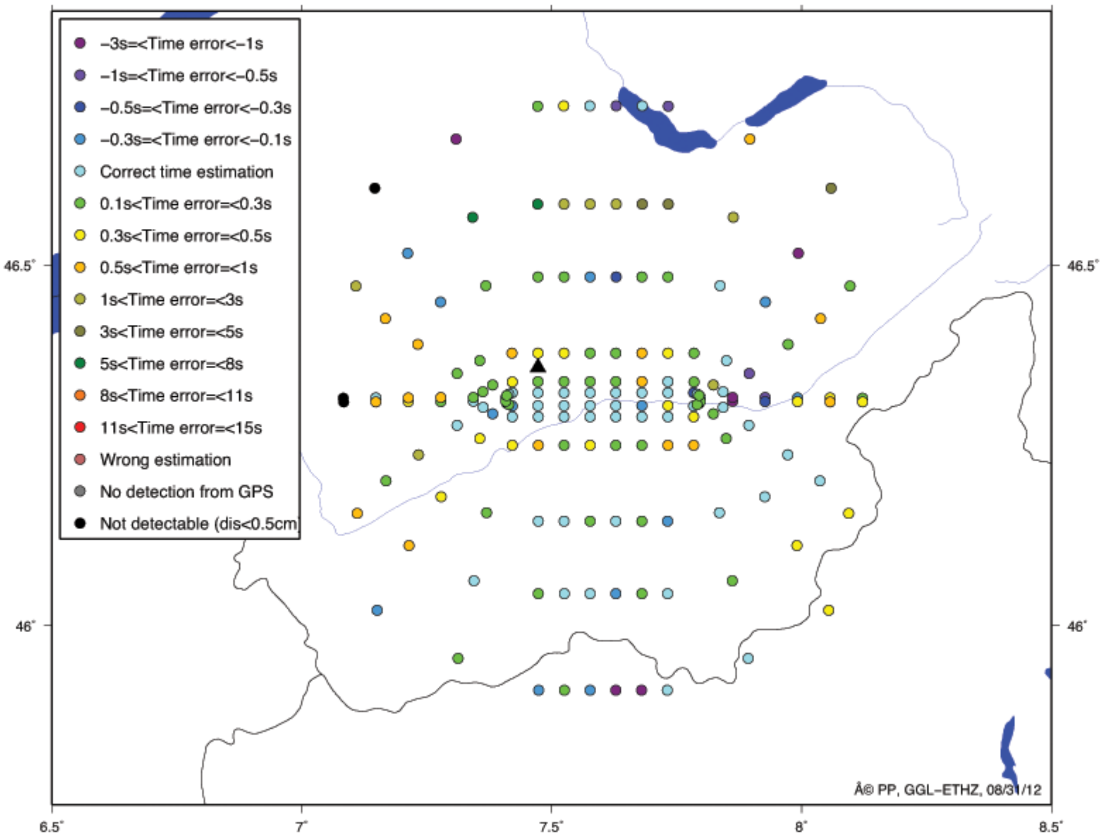

Figure 1. Determination of the time of arrival of the ground motion at the stations of the simulated GNSS network, covering the area of Valais. The triangle marks the epicenter of the simulated earthquake and color scale indicates the accuracy of the estimated time of arrival for each simulated GNSS station.

19.10

KarstALEA : a practical guide for the prediction of karstrelated hazards in underground works

Schmassmann Silvia[1], Filipponi, Marco[2], Jeannin Pierre-Yves[1], Parriaux Aurel[2]

[1] *Swiss Institute of Spelology and Karst Studies, case postale 818, 2301 La Chaux-de-Fonds (silvia.schmassmann@isska.ch)*
[2] *Ecole polytéchnique fédérale de Lausanne EPFL, ENAC ICARE GEOLEP*

Excavation of tunnels in karst environments commonly meets problems with severe and costly consequences.

The practical guide “KarstALEA” (meaning KarstHazard; Filipponi et al. 2012) aims to provide a practical method for the assessment of ground conditions in karst massifs. This method is an addon to the SIA 199 code and guidelines for tunnels in karst, and is designed for use by geologists involved in underground works. The results are then presented in a longitudinal profile of the tunnel to give clear indications of the probabilities of occurrences of karst voids and conduits within respective sections of the tunnel; they also indicate probable characteristics of the anticipated karst features.

The KarstALEA method synthesizes academic knowledge on karst and combines this in a way to address practical questions related to the underground works. It is based first on the observed fact that karst conduits preferentially develop along a restricted number of geological horizons, known as “inception horizons”. Typically, 70% of the conduits may develop along 3 to 5 discrete horizons within the scale of a tunnel project (Filipponi, 2009). A second input factor is that conduit density varies within the karst massif depending on the present and past hydrogeological conditions; there are commonly some concentrations of conduits at elevations corresponding to past base-levels (palaeo-valley floors).

Consequently, the identification of inception horizons and base-levels makes it possible to predict zones of highest probability of occurrences of karst conduit. Any knowledge of the karstification history of a massif helps these predictions and may also indicate some characteristics of the anticipated karst conduits (notably, the sizes and shapes of voids, the quantities and types of sediments, the presence of water and its likely pressure and discharge, etc.).

The KarstALEA method is applied in three main stages:

1. Stage 1 “KarstALEA initial assessment” takes place at the beginning of the preliminary study or even during the initial stage of objectives definition (from SIA 197). The aim is to define if the tunnel is to be constructed within the range of its various potential alignments, and whether it presents a karst-related hazard or not. If the hazard is recognized, the KarstALEA method is applied as in stage 2.

2. 2. Stage 2 “KarstALEA investigations” starts in the preliminary study and extends all through the project study phase. This stage provides the necessary inputs for the tender documents for the project. Data required for building four 3D-models (geology, hydrogeology, speleogenesis and inception horizons; Fig.1) are acquired as part of the project study. These are iteratively improved until they reach the required level of detail. This stage is the core of the KarstALEA method.

3. Stage 3 “KarstALEA construction” continues during the construction phase of the project. The application of KarstALEA remains very similar to that in stage 2, but the nature of the data and of new problems evolves continuously as real facts on the ground conditions are revealed by the construction in progress. During this stage some previously defined construction guidelines may have to be adjusted in order to solve newly recognized problems. The KarstALEA models develop and improve throughout stages 2 and 3, and are very valuable for making decisions. The final report of this stage outlines guidelines relevant to karst hazards that may be encountered during operation of the tunnel.

A hyperlink to download the KarstALEA practical guide for the prediction of karstrelated hazards in underground works is available at www.isska.ch

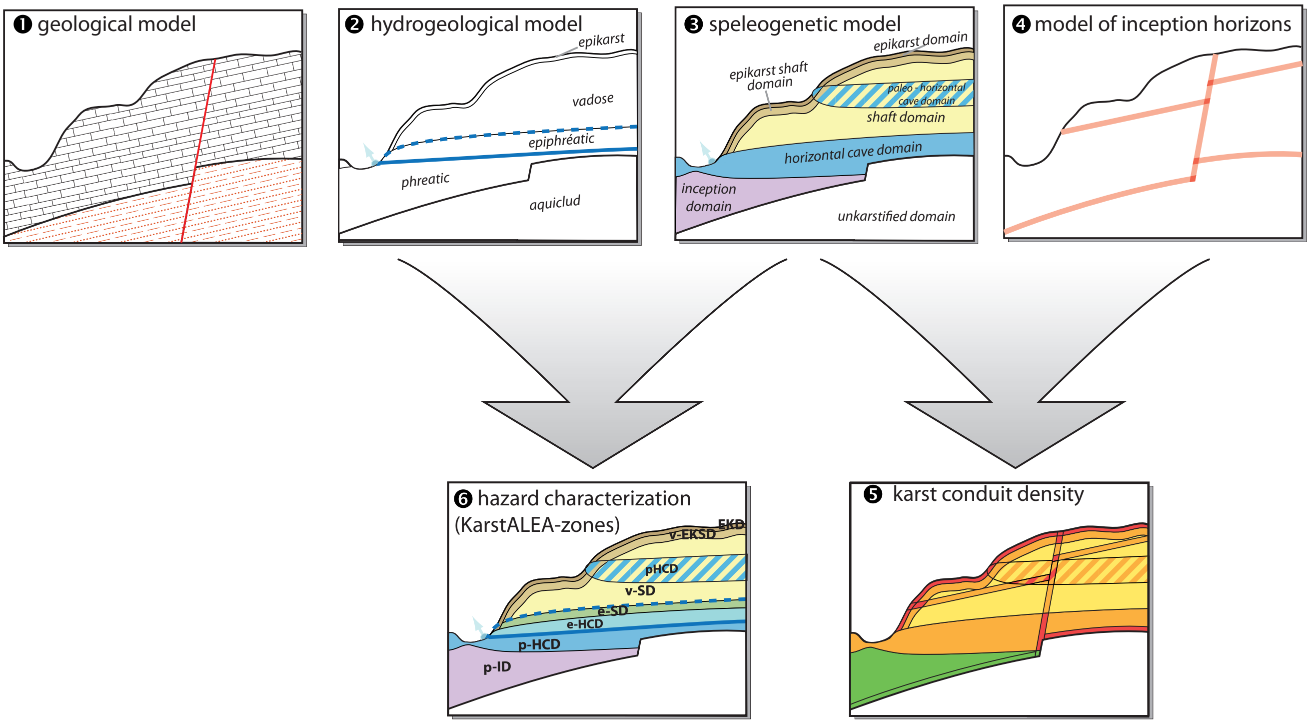

Figure 1. Principle of the KarstALEA method in 7 successive steps. Four 3D representations of the massif (models) are constructed in steps 1 to 4. In steps 5 and 6 zones with the highest expected densities of karst conduits and their characteristics are interpreted. In step 7 hazards, risks and mitigation measures are identified and discussed between the tunnel geologist and the tunnel engineer (not shown in figure). Throughout progress on the project, this cycle of 7 steps is repeated with increasing precision.

REFERENCES

Filipponi M., 2009: Spatial analysis of karst conduit networks and determination of parameters controlling the speleogenesis along preferential lithostratigraphic horizons. PhD-Thesis, Ecole Polytechnique Fédérale de Lausanne, 305 S.

Filipponi M., Jeannin P.-Y., Tacher L., 2009: Evidence of inception horizons in karst conduit networks. Geomorphology, 106, 86-99.

Filipponi, M.; Schmassmann S.; Jeannin P.-Y.; Parriaux A.; 2012. KarstALEA: Wegleitung zur Prognose von karstspezifischen Gefahren im Untertagbau. Forschungsprojekt FGU 2009/003 des Bundesamt für Strassen ASTRA, Schweizerischer Verband der Strassen- und Verkehrsfachleute VSS, Zürich

19.11
Geoscience Data Integration and Visualisation in 3D - GeoVisionary

Terrington Ricky[1], Hughes Leanne[1], Napier Bruce[1] & Ramos Luz[1]

[1] *British Geological Survey, Environmental Science Centre, Nicker Hill, Keyworth, Nottingham, UK, NG12 5GG (rte@bgs.ac.uk)*

Over the past decade, the British Geological Survey has invested significant resources into developing its 3D geoscience knowledge base. One of the ways in which this has been undertaken is by developing specialised software and modifying working practice to maximise the potential high resolution data sources.

For example field mapping was and still is an essential element to understanding geological structure and processes. In order to make best use of available data for pre-fieldwork interpretation, BGS commissioned UK Virtual Reality specialists, Virtalis Ltd., to create an immersive 3-dimensional visualisation and interpretation software environment that has revolutionised the way in which geoscientists can capture linework and descriptive information in a virtual 3D environment either on their desktop PC or in specialised 3D suites. This software, GeoVisionary, is a platform in which terabytes of the highest resolution data can be combined in one environment for seamless visualisation and analysis (Giles *et al* 2010). Some of the types of high resolution data that can be integrated include:

- Terrain models – including national scale datasets at the highest resolution, and specialist terrain data such as LiDAR
- Aerial Photography and other remote sensing data
- 3D Models – including high resolution CAD models, subsurface geological models and voxel models showing property distribution
- GIS data – e.g. geological and topographic Maps

GeoVisionary provides all of the essential tools a geoscientist would need to interrogate this plethora of data, and capture knowledge as they would in the field (Vye *et al* 2008). These include many of the standard GIS tools plus a host of others that allow the user to interrogate and immerse themselves in the data. GeoVisionary can be used not only as a reconnaissance tool but also to re-assess past observations, field maps and data.

By integrating all of these datasets and tools in a virtual desktop environment, it becomes particularly advantageous to study areas that are difficult to reach in reality. This opens the possibility of studying extreme environments using realistic 3D visualisations be it the remote mountainous regions of Tajikistan (Jordan *et al* 2009) or even Mars (Figure 1).

GeoVisionary has been proven to reduce resource expenditure in geological field mapping and other geoscience field studies. The 3D visualisation of both natural environmental data with human infrastructure has been an important way of communicating geosciences to stakeholders. GeoVisionary will continue to augment fieldwork, help increase our understanding of subsurface processes and deliver realistic visualisations of geosciences data.

REFERENCES
Giles, J.R.A.; Marsh, S.H.; Napier, B.. 2010 Dataset acquisition to support geoscience. Elevation models for geoscience. Geological Society of London, 135-143. (Geological Society Special Publications, 345)

Jordan, Colm; Bateson, Luke; Bow, Jennifer; Newell, Andy; Napier, Bruce; Sabine, Rosemary Johnson. 2009 GeovisionaryTM software for 3D visualisation and petroleum exploration in southern Tajikistan. In: RSPSoc 2009 : New Dimensions in Earth Observation, Leicester, UK, 8-11 Sept 2009.

Vye, Charlotte; Bateson, Luke; Marsh, Stuart. 2008 A new approach to mapping large volcanic provinces. [Speech] In: IAVCEI, Iceland, 18th-22nd August 2008. (Unpublished)

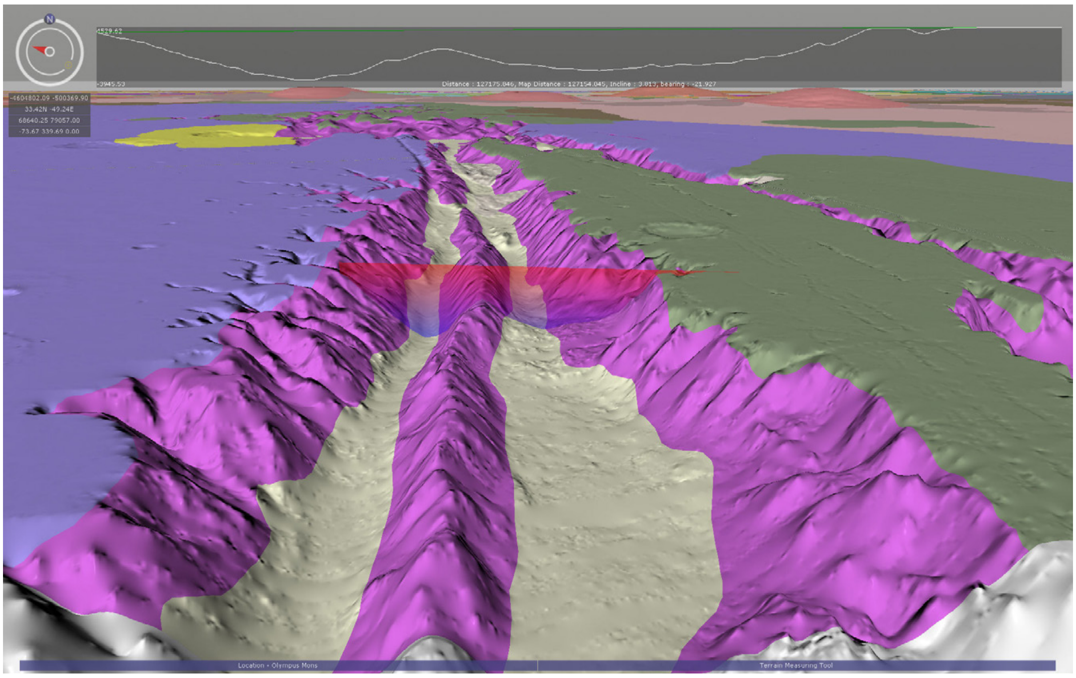

Figure 1. The Valles Marineris (Mars) with a geological map drape and terrain measurement. Geological Map: The Valles Marineris, USGS Astrogeology. Elevation Data: MOLA (Mars Orbiter Laser Altimeter), Mars Global Surveyor, NASA.

P 19.1

The 3D-model Basel region – a planning tool

Dresmann Horst[1], Huggenberger Peter[1], Epting Jannis[1], Wiesmeier Stefan[1] & Scheidler Stefan[1]

[1] *Applied and Environmental Geology, Department of Environmental Sciences, University of Basel, Bernoullistrasse 32, CH-4056 Basel (Horst.Dresmann@unibas.ch)*

In 2008 started the EU project "GeORG" (www.geopotenziale.eu) with the idea to establish a tool for space planning of the subsurface across political boundaries along the Upper Rhine Graben. The project partners are the Applied and Environmental Geology Group of the University of Basel and the geological surveys of France (BRGM), Baden-Württemberg (RPF-LGRB) and Rheinland-Pfalz (LGB).

The aim of the project was the development of a geological 3D model between Basel and Mannheim (D), which can be used as a tool for evaluation of the possibilities and risks of the deeper underground.

The geological 3D-model of the Basel region (600 km^2) was established as the Swiss contribution to the "GeORG"-project. 12 geological horizons between the Quaternary and the crystalline basement were modelled and joint with the rest of the GeORG model.

In the Bael area additional 8 horizons were integrated to refine the shallow subsurface for a better resolution (e.g. top of Gipskeuper, base of Tuellinger Schichten, base of Elsässer Molasse) and to get a better definition of deep aquifers and aquitards (e.g. base of Anhydrit group –Muschelkalk, top of Opalinuston).

Beside the development of a static geological model, from the start it was the aim to establish a flexible tool for subsurface planning in an urban area. Ideally, the model should be easily adjustable with new data and a spatial extension, or a local refinement of the model should be possible at all time. Therefore, the designed data management concept combines database, 3d-modeling and GIS. The developed links between the different software applications allows an easy data exchange, fast integration of new data and quick insights into the model in 2D (maps or sections) and 3D (perspective view).

For each modelled horizon an own GIS-project was generated comprising all relevant basic datasets and the modelled 3D horizon geometries. Additionally, new data (e.g. boreholes) which were inserted into the database are automatically made available to the appropriate GIS-projects. There, an automated routine compares new data points with the geometry of already modelled horizons. The computed goodness of fit (differences) could be visualized and helps to assess future issues.

During the last years the administrative of the cantons Basel-Stadt and Basel-Landschaft have acknowledged the advantage of a planning tool such as the geological 3D-model of the Basel region. The possibility to generate flexible exports to be able to use the subsurface information in other software applications, as well as to combine hydro-geological information with infrastructural data for a detailed analysis gives rise to repeated requests concerning local issues. For example, the subjects are related to potential use conflicts between existing installations and planned activities in the field of use of shallow geothermal energy, groundwater protection or tunnelling.

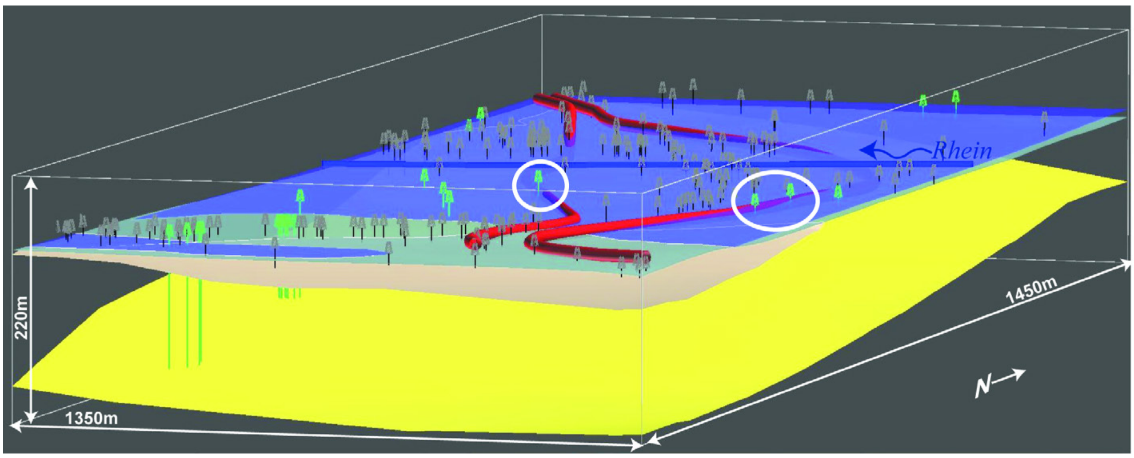

Figure 1. Planning of a tunnel project in an urban area. Example "Osttangente- Basel": Existing geothermal heat exchangers (boreholes light green) are situated next to a possible tunnel path (red). The combination of various data supports the identification of conflict situations (white circles). Legend: groundwatertable (blue transparent), base of unconsolidated rocks (green), geol. horizons (brownish and yellow)

P 9.2

The EU-project GeORG – products

GeORG-Project Team[1,2]

[1] GeORG-Project Team: E. Nitsch, G. Sokol (coordinators), B. Anders, D. Ellwanger, C. Fehn, M. Franz, R. Prestel, C. Rodat, I. Rupf, J. Schuff, U. Wielandt-Schuster, G. Wirsing, H. Zumsprekel (Baden-Württemberg Geological Survey, Germany); T. Kärcher, J. Haneke, J. Krzyzanowski, R. Storz, J. Tesch, M. Weidenfeller (Rheinland-Pfalz Geological Survey, Germany);L. Capar, L. Beccaletto, D. Cruz-Mermy, C. Dezayes, S. Urban (BRGM, France); P. Huggenberger, H. Dresmann (Basel University, Switzerland)

[2] *contact: Dresmann Horst, Applied and Environmental Geology, Department of Environmental Sciences, University of Basel, Bernoullistrasse 32, CH-4056 Basel (Horst.Dresmann@unibas.ch)*

The geological surveys of France (BRGM), Baden-Württemberg (RPF-LGRB), Rheinland-Pfalz (LGB) and the Applied and Environmental Geology Group of the University of Basel initiated in 2008 the EU project GeORG (Geopotentials of the deep Upper Rhine Graben). It is funded by the INTERREG IV A Upper Rhine programme.

GeORG aims at achieving a consistent transnational geological database of the Upper Rhine Graben between about Basel (CH) and Mannheim(D). This effort requires the collection of geological information from the German, French and Swiss regions involved and the harmonization of different standards and terminologies. In order to obtain a coherent geological model, all partners in GeORG focus on a consistent definition of stratigraphic markers, interpretation of seismic lines as well as modelling of faults and geological horizons ranging from the base of unconsolidated rocks to the top of the crystalline basement.

Following the geological modelling, a geostatistical temperature model based on well data (mainly temperature logs, BHT measurements) is generated. A conductive geothermal model is additionally calculated for a subdomain of the model (Fa. Geophysica, Aachen).

Products of the project are:

- Selected cross-sections
- Maps showing the 3D geometry of modelled horizons
- Thickness distribution maps
- Facies maps
- Temperature distribution at certain depths
- Heat in place
- Storage potential maps (CCS)

In December of 2012 the project will be finished and the products will be available to professionals and the interested public. The project homepage (www.geopotenziale.eu) contains a mapserver and download possibilities. The final report is made available in early 2013.

P 9.3

Small and Fast Motion Detection using GPS receiver Single-Frequency Carrier Phase Observations

Zhe Liu[1,2], Alain Geiger[1], Sebastien Guillaume[1], Zhenzhong Su[1], Simon Häberling[1] and Panagiotis Psimoulis[1]

[1] *Geodesy and Geodynamics Lab, ETH Zürich, Schafmattstrasse 34, CH-8093 Zürich*
[2] *Institute for Navigation, University of Stuttgart, Hummelbergstr. 18, 70195 Stuttgart Germany (zhe.liu@outlook.com)*

Movement detection technology was widely applied as an important means to monitor building deformation, research on crustal motion and so on. GPS as one of the most commonly used distance or position measurement tools, of course, can play a role in the monitoring of the movement.

Through continuous positioning the object to monitor the movement was the traditional GPS method, for a complete GPS receiver system, this method is convenient and intuitive, but the disadvantages of this approach are also obvious, on one hand the accuracy of the measured movement is directly affected by the impact of the positioning accuracy, on the other hand, high precision differential GPS positioning required a receiver-network, this virtually increases the cost and complexity.

In 2007, Prof. Dr. Alain Geiger and Dipl.-Ing. Sebastien Guillaume developed a new algorithm called GMoDe, with that the detection of small and fast movements using single-frequency carrier phase observations of one low-cost GPS receiver is possible. The Principle of this method is that through detection of discontinuities in phase observations, which are due to the movements of GPS receiver, to detect the movements. With observations only we can hardly locate or quantify the discontinuities. Nevertheless, if we accurately know the state of the observation model while it keeps continuous, by means of comparing the "known" state with the measured value, we can more easily determine the discontinuities.

To achieve this purpose an observation model was needed to construct first.

The quality of detection is strictly depending on the veracity and stability of the model. How we choose the type of combination of observations and its model would be described and discussed at first in this thesis. For a linear dynamic system dealing with a large number of data such as our observation model the Kalman filter is one of the most optimal and efficient method to estimate or predict the state at a particular point. These predictions would be compared with measured data, through stochastic test and transformation the significant differences would be in displacement reference system delivered, the movements are then detected and quantified. Details on Kalman filter and transformation are described; the C++ realization of this algorithm is presented in this thesis. Some improvements by detecting permanent movements or long-periodic vibration would be also introduced.

To demonstrate the validity and prove the advantages of the method and program we have also applied a simulation test, in that the GPS antenna was mounted on a shaker (Rütteltisch, this set of data was provided by Mr. Simon Häberling), which integrates with an accurate inductive displacement-measure-unit and can generate various kinds of vibrations.

The inductive observations and the output of our C++ program would be compared and analysed (see Figure 1).

REFERENCES

Guillaume S., 2007: Real-Time Small Movement Detection with a Single GPS Carrier Phase Receiver.
Hofmann-Wellenhof B., Lichtenegger H. and Collins J., 2001: GPS Theory and Practice, Fifth, revised edition, Springer.
Bauer M., 1997: Vermessung und Ortung mit Satelliten, 4. Auflage, WICHMANN.

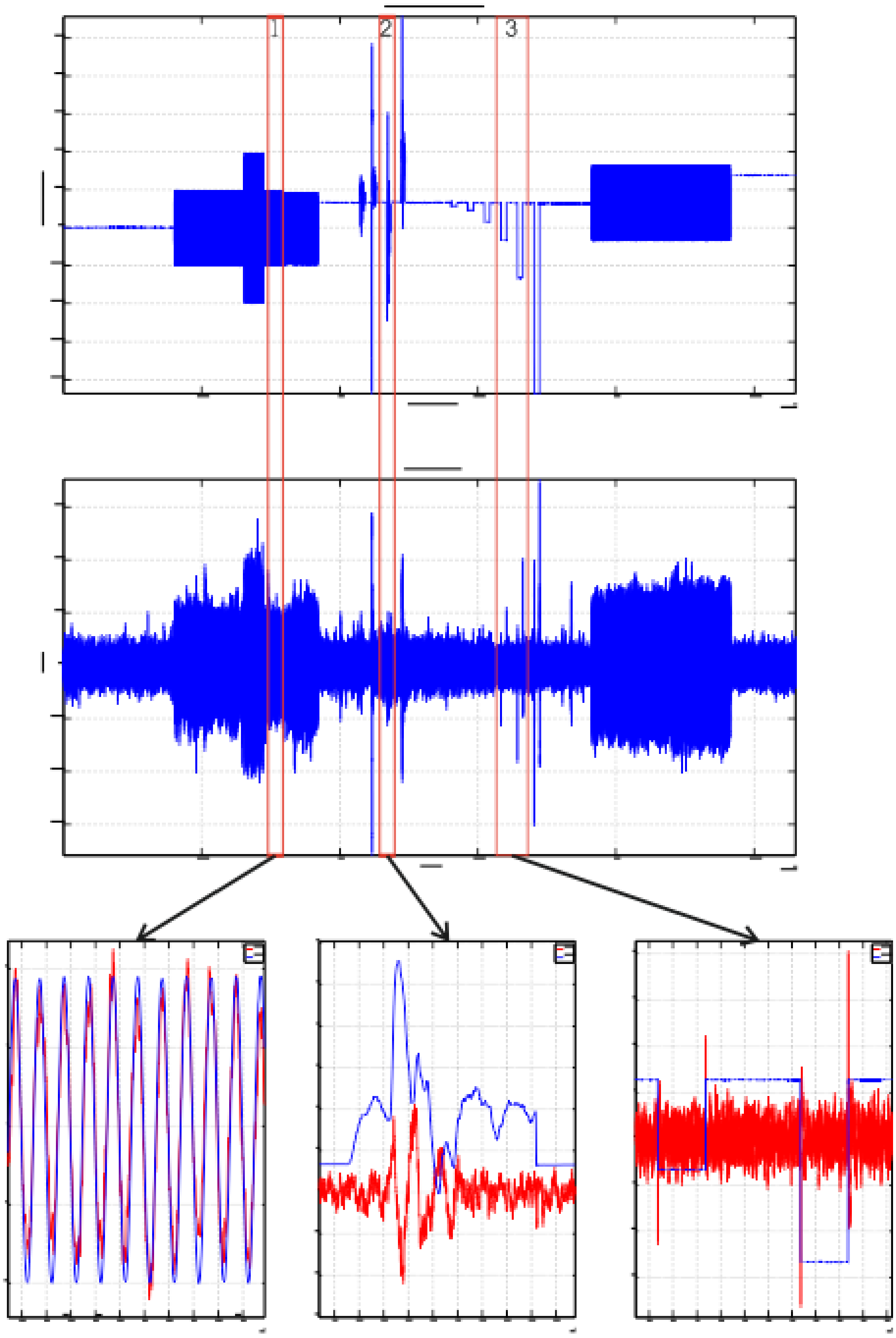

Figure 1 Inductive sensor measurements (Up); GMoDe Results (GPS RINEX File as Input) (Middle); detailed comparison between true value (blue) and result (red)(Down)..

P 19.4

Visualizing vector data: Clustering noisy displacement fields

Neyer Fabian

Institute of Geodesy and Photogrammetry, ETH Zürich, Schafmattstrasse 34, CH-8093 Zürich (fabian.neyer@geod.baug.ethz.ch)

The growing number of areal measurement devices and surface displacement studies increase the amount of available vector data in terms of density, coverage, and accuracy. It is known that there is no possibility to obtain noise-free measurements, hence every dataset is contaminated by the measurement uncertainty. Analysing noise contaminated vector field data is a challenging task and often involves assumptions about the signal itself. This limitation can be reduced if the vector field is grouped into domains with common statistical characteristics.

The goal of the present work is to demonstrate a robust vector clustering method. Resulting vector clusters can be used either for direct interpretation of the dataset or for further data processing. For example, when dealing with displacement maps derived from remote sensing devices (f.e. InSAR, optical flow, ect.), data clustering results in discrete boundaries of different types of motions. If the displacement measurements are further processed, noise filtering and other domain specific applications can easily be applied to the individual motion areas.

The proposed clustering algorithm is based on robust statistical and topological analyses and features a variety of optimization routines. One of the main differences to common clustering algorithms, like k-means, is the treatememt of input coordinates and vector components as separate clustering criterias. Using the principle of Lloyd's algorithm, clustering is carried out iteratively whereas the statistical properties, i.e. the individual cluster proxys, are continuously recomputed to ensure fast convergence.

REFERENCES

Lloyed, S. 1982: Least square quantization in PCM, IEEE Trans. Inform. Theory 28, 129-137.
Steiner, D.C., Alliez, P., Desbrun, M.: Variational Shape Approximation, ACM Trans. on Graph. 23, 3 (2004), 905–914.