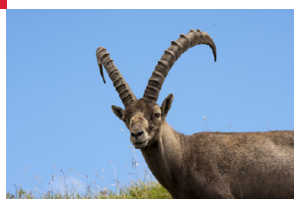

# Abstract Volume
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## 5. Geomorphology

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# 5. Geomorphology

I. Gärtner-Roer, M. Bollschweiler, R. Delaloye, C. Graf, N. Kuhn, S. Morard

*Swiss Geomorphological Society*

TALKS

5.1 Ambrosi C., Castelletti C., Soma L.: Quaternary Geologic Map of Osogna (Ticino), sheet 1293

5.2 Bennett, G.L., Molnar, P., Eisenbeiss, H., McArdell, B.W.: Probabilistic modeling and analysis of rock-slope failure in the Illgraben, Switzerland, 1963 – 2005

5.3 Caviezel C., Kuhn N.J.: Mass wasting in the Ursern valley (Switzerland): climate or land use change?

5.4 Champagnac J.-D., Molnar P., Sue C., Herman F.: Tectonics, Climate, and Mountain Topography

5.5 Meusburger K., Steel A. , Panagos P., Montanarella L., Alewell C.: Spatial and temporal variability of rainfall erosivity factor for Switzerland

5.6 Savi S., Schneuwly-Bollschweiler M., Stoffel M., and Schlunegger F.: Coupling – decoupling hillslope – channel system processes: a case study from dendrogeomorphology.

5.7 Stoffel, M., Trappmann, D., Schneuwly-Bollschweiler, M.: When science meets practice: Dendrogeomorphic documentation of rockfall trajectory frequencies, bounce heights and energies along a road in Valais

5.8 Trauerstein M., Norton K. P., Schlunegger F., Preusser F.: Climatic imprint on landscape morphology in the western escarpment of the Andes

POSTERS

P 5.1 Barboux C., Delaloye R., Strozzi T., Christophe L., Raetzo H., Collet C.: InSAR Terrasar-X visibility assessment of moving landform monitoring in alpine periglacial environment: 30 case studies in the Valais Alps (CH)

P 5.2 Bekaddour, T., Norton, K.P., Schlunegger, F.: Dip direction controls of bedrock on channel morphologies and denudation rates in the eastern Swiss Alps

P 5.3 Büchi, M., Kober, F.: Landscape Evolution of the Hörnli-region: Landforms, Processes and Rates

P 5.4 Dürst Stucki M., Schlunegger F., Christener F.: Deepening of inner gorges trough subglacial meltwater - an example from the UNESCO Entlebuch area, Switzerland

P 5.5 Juretzko G., Meusburger K., Alewell C.: Suitability of Cesium-137 and USLE for soil erosion assessment in an Alpine valley (Val Piora, Switzerland)

P 5.6 Khaksar K., Farboodi M.: Land Subsidance And Fissuring Due To Groundwater Withdrawal In The Neyshaboor Plain-Northeast Iran

P 5.7 Kuhn N.J. : Teaching with Tolkien: environmental analysis of a fantasy world

P 5.8 Moore J.R., Gischig V., Katterbach M., Loew S.: Crack air convection and resulting temperature disturbances at depth in an alpine rock slope

P 5.9 Sorg, A. , Rösch, A., Bolch, T., Shatravin, V.I., Solomina, O.N., Schneuwly-Bollschweiler, M., Stoffel, M.: Reconstruction of rock glacier activity in Northern and Inner Tien Shan based on tree rings and aerial photographs

P 5.10 Tisato N., Sauro F., Bernasconi S.M., Bruijn R., De Waele J.: Hypogenic contribution to speleogenesis in a predominant epigenic karst system: a case study from the Venetian Alps, Italy

# 5.1
# Quaternary Geologic Map of Osogna (Ticino), sheet 1293

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In January 2011 the Swiss Federal Office of Topography (swisstopo) tasked SUPSI with the creation of quaternary deposits for Osogna (1293 – Osogna sheet), part of the project "Geocover".
The study area is situated in Ticino, between Biasca on north and Bellinzona to south.

To recognize and identify the forms and deposits has been used different techniques:

- Analysis of a digital elevation model, 2 meters (DEM)
- Analysis of digital aerial photos
- Photo-interpretation

The map was made using two types of programs: ArcGIS 9.3 which had already been used successfully for the production of map of 1373 - Mendrisio, and a new program, ArcGDS.

ArcGDS is an extension of ArcGIS for viewing stereoscopic images and for capturing, editing and updating in stereoscopy (fig.1). This software allows a three-dimensional vision of the area by facilitating the recognition of the limits and forms of deposits and landslides especially in high altitude (above 2000 meters), where the DEM 2 meters is not available, thereby obtaining a detailed and comprehensive coverage of all the territory.

In the final phase of the project the verification of the results has been made directly with observations on the field.

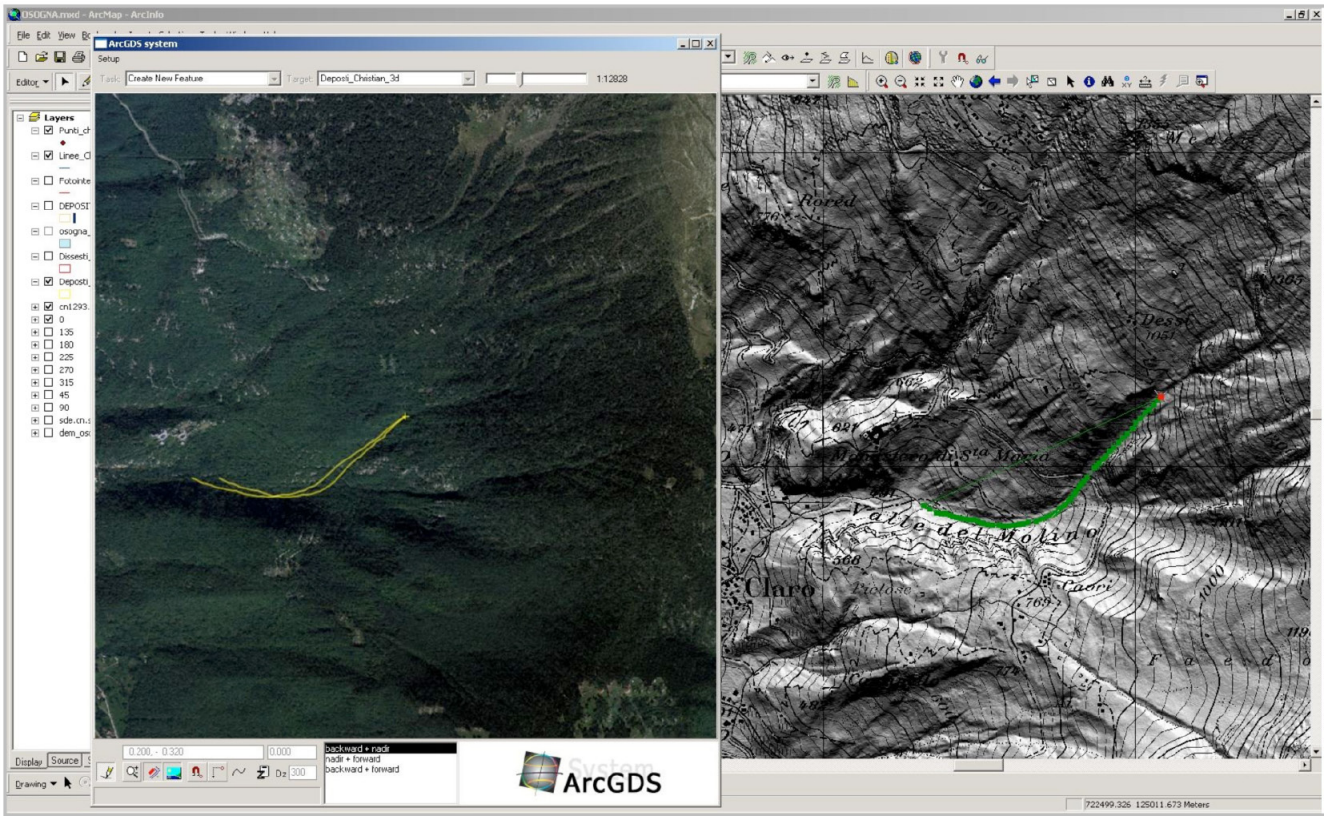


Figure 1: in the picture is visible the work page of ArcGDS (Geosoft), to the right the creation of a polygon in 3D, on the same time on the left its projection on a 2D DEM 2 meters (authorization of UMG, 08.01.08). Zone of Claro, 723770/124330

This method produces excellent and high quality results in a relatively short time, the resulting digitized maps are more homogeny and complete as the traditional. This method allows to recognize easier important structures, deposits and big landslides especially at high altitude.

## 5.2

# Probabilistic modeling and analysis of rock-slope failure in the Illgraben, Switzerland, 1963 – 2005

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Our understanding of slope failure is restricted by a lack of inventories of sufficient size and containing directly measured volumes. We used digital photogrammetry to produce a multi-temporal record of erosion of a rock-slope in the Illgraben catchment spanning 42 years. From this we extracted an inventory of ~2500 slope failures for 3 epochs of 6/7 years between 1986 and 2005 ranging over 6 orders of magnitude in volume. Through modeling the frequency-volume of these and analyzing relationships of volume-area, depth-area and depth-slope gradient we aimed to understand the characteristics of rock-slope failure at the head of this active alpine debris flow catchment.

The slope failures form a characteristic frequency-magnitude distribution with a roll-over at 50m³ and a power-law tail. We focused on modeling the exponent of this tail for the reason that it contains more than 90% of the total failure volume. We find that the accuracy of the exponent is compromised by fitting to the probability distribution and that it is advisable to estimate this using the complementary cumulative distribution function.

The low rock mass strength of the slope is indicated by the relatively small exponents in the frequency-volume and volume-area relationships as well as by the rapid rate of erosion. Our data suggest that the exceptionally rapid rate of erosion of ~350mm $yr^{-1}$ is achieved through two failure processes: (1) frequent small slumps and slides of restricted depth that occur across a range of slope gradients within the upper weathered layer of the slope; (2) rare larger and deeper fracture events that occur mainly on slopes greater than 45° along discontinuities within the slope.

Our study lends empirical support to the theoretical hypothesis that the characteristic probability distribution of landslides contains two separate processes: shallow slides in the top layer and deeper slides in the bottom layer.

## 5.3

# Mass wasting in the Ursern valley (Switzerland): climate or land use change?

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Considerable changes in land use and management practices, as well as the increased frequency of extreme weather events in mountain regions, are considered to affect landscape susceptibility for mass wasting in the Alps. Analysing alp inspection reports, written each year by farmers commissioned to supervise pasture use and condition on the communal land in the Ursern Valley, Switzerland, a non-uniform distribution of mass wasting events between 1950 and 2000 was found. To investigate variations in mass wasting frequency, controlling parameters such as climate and grazing patterns and intensity where analysed using the regional archive. The results infer that land use changes and maintenance measures modified the effects of an increasing number of high magnitude rainfall events by changing landscape susceptibility to mass wasting and land degradation since 1950.

# 5.4

# Tectonics, Climate, and Mountain Topography

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By regressing simple, independent variables that describe climate and tectonic processes against measures of topography and relief of 69 mountain ranges worldwide, we quantify the relative importance of these processes in shaping observed landscapes. Climate variables include latitude (as a surrogate for mean annual temperature and insolation, but most importantly for the likelihood of glaciation) and mean annual precipitation. To quantify tectonics we use shortening rates across each range. As a measure of topography, we use mean and maximum elevations and relief calculated over different length scales. We show that the combination of climate (negative correlation) and tectonics (positive correlation) explain substantial fractions (> 25%, but < 50%) of mean and maximum elevations of mountain ranges (Figure 1A and 1B), but that shortening rates account for smaller portions, <25%, of the variance in most measures of topography and relief (i.e. with low correlations and large scatter). Relief is insensitive to mean annual precipitation (Figure 1C and 1D), but does depend on latitude, especially for relief calculated over small (~1 km) length scales, which we infer to reflect the importance of glacial erosion (Figure 1C). Larger-scale (averaged over length scales of ~10 km) relief, however, correlates positively with tectonic shortening rate. Moreover, the ratio between small-scale and large-scale relief, as well as the relative relief (the relief normalized by the mean elevation of the region) varies most strongly with latitude (strong positive correlation) (Figure 1E and 1F). Therefore, the location of a mountain range on Earth and corresponding climatic conditions, not just tectonic forcing, appears to be a key factor in determining its shape and size. In any case, the combination of tectonics and climate, as quantified here, can account for approximately half of the variance in these measures of topography. The failure of present-day shortening rates to account for more than 25% of most measures of relief raises the question: Is active tectonics overrated in attempts to account for present-day relief and exhumation rates of high terrain?

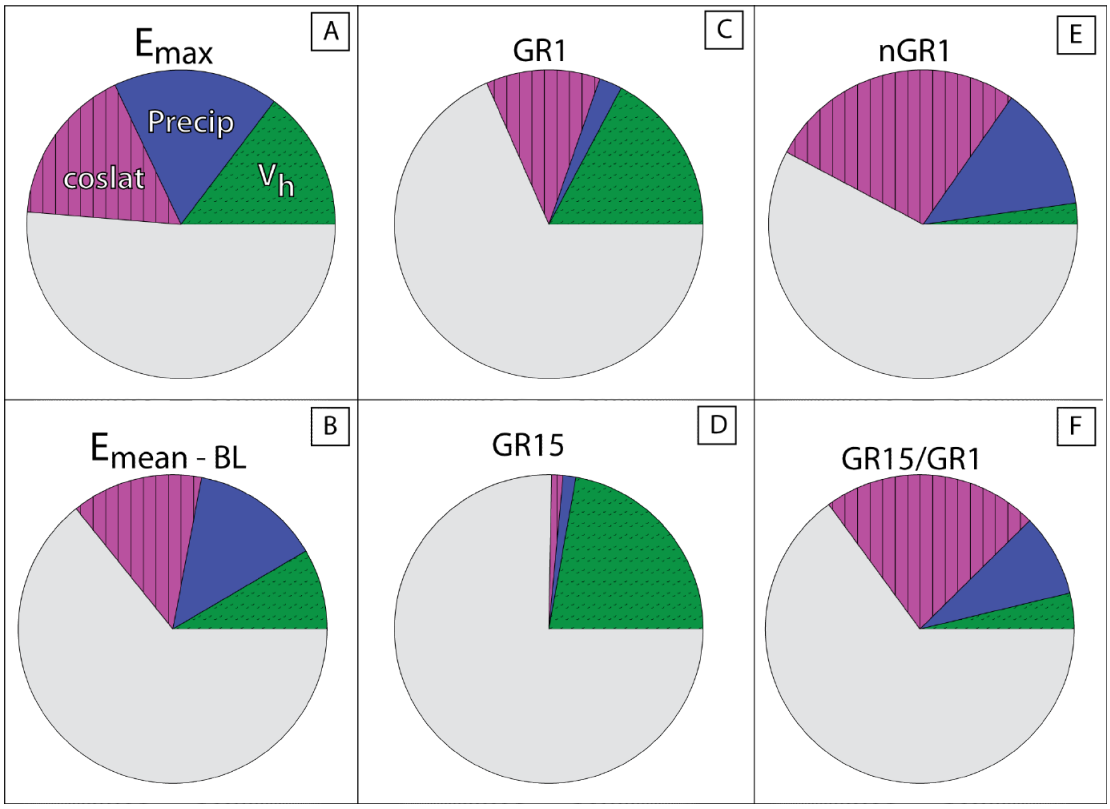


Figure 1: Pie charts of the relative contributions of each external variable – $V_h$ (tectonic shortening rate), *precip* (mean annual precipitation), and *coslat* (cosine of the latitude)– to the observed variance of the topographic variables – $E_{max}$ (maximum elevation of the topography average over a 10 km), $E_{mean}$–*BL* (mean elevation of the range above the base level *BL*), *GR1*and *GR15* (mean geophysical relief over 1 and 15km), *nGR1* (relative relief, i.e. geophysical relief normalized by the mean elevation of each range), *GR15/GR1* (Dimensionless ration between GR15 and GR1). The gray shading is the unexplained part of the variance that is due to unused variables and natural scatter.

## 5.5

# Spatial and temporal variability of rainfall erosivity factor for Switzerland

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Rainfall erosivity, considering rainfall amount and intensity, is an important parameter for soil erosion risk assessment under future land use and climate change. Despite its importance, rainfall erosivity is usually implemented in models with a low spatial and temporal resolution. The purpose of this study is to assess the temporal- and spatial distribution of rainfall erosivity (R-factor) in Switzerland. Time series of 22 years for rainfall (10min resolution) and temperature (1h resolution) data were used to calculated rainfall erosivity as defined by Renard et al. (1997) for 71 automatic gauging stations distributed throughout Switzerland. Multiple regression was used to interpolate the erosivity values of single stations and to generate a map for Switzerland. Latitude, longitude, average annual precipitation, biogeographic units (Jura, Midland, etc.), aspect and elevation were used as covariates, of which average annual precipitation, elevation and the biogeographic unit (Western Central Alps) were significant predictors. The mean value of long-term rainfall erosivity is 1323 MJ mm $ha^{-1}$ $h^{-1}$ $y^{-1}$ with a range of lowest values of 124 MJ mm $ha^{-1}$ $h^{-1}$ $y^{-1}$ at an elevated station in Grisons to highest values of 5611 MJ mm $ha^{-1}$ $h^{-1}$ $y^{-1}$ in Ticino. All stations have highest erosivity values from July to August and lowest values in the winter month. Swiss-wide the month May to October show significantly increasing trends of erosivity ($p<0.005$). Only in February a significantly decreasing trend of rainfall erosivity is found ($p< 0.01$). The increasing trends of erosivity in May, September and October when vegetation cover is susceptible are likely to enhance soil erosion risk for certain agricultural crops and alpine grasslands in Switzerland.

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## 5.6

# Coupling – decoupling hillslope – channel system processes: a case study from dendrogeomorphology.

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We quantify the frequency distribution of debris flow events in the ca. 2.5 km2-large Schimbrig catchment that is located in the central Swiss Alps. We assess this distribution using patterns of tree-ring records that register growth perturbations caused by external forcing such as landsliding and debris flows. In particular, tree-ring analyses are used for the dating and understanding the modality of sediment transfer and for the assessment of connectivity between sediment sources and sinks.

The study catchment can be divided into two distinct tributaries: the eastern area, occupied by an active earth slide (Schimbrig landslide) that underwent high slip rates several centimetres to meters per day between September 1994 and May 1995, translating a total of 350,000 $m^3$ of material; and the western segment, characterized by a deeply incised network of mixed debris flow and alluvial channels (50 m maximum incision) bordered by hillslopes that host shallow and deep-seated landslides less than 15,000 $m^2$ large. The entire catchment is mainly underlain by sandstone-mudstone alternations of the Eocene Subalpine Flysch that have been reworked by glaciers during the LGM. The unconsolidated sediments left by ice retreat are one of the main sediment sources causing instability in this region. The climate in the Schimbrig area is dominated by a very high precipitation rate.

Intense rainfall events may trigger landslides and debris flows from the steepest slopes of the channel network. Therefore we focused our study to this area of the catchment with the aim to understand the connectivity between hillslopes and channels using dendrogeomorphic techniques. We collected a total of 500 tree cores on the fan, along the main channel and in the catchment area. On the fan the analyzed trees allow the reconstruction of 16 debris-flow events occurred between AD 1857 and 2010. The most relevant event, affecting more than one-fourth of the trees on the entire fan, occurred in 1994-1995 and seems to be related to the highest activity of the Schimbrig landslide. Other important events, involving between 15 and 20% of the trees, occurred in 1997, 1967, 1964, 1957; 1951, 1881 and 1857-60. In the upper part of the catchment trees show a total of 52 events between AD 1905 and 2010 which were divided into different sectors depending on the trees' location. These events might represent several re-activation periods, as these areas are strongly affected by lateral landslides that showed different stages of movement. Particularly, periods with high activity are registered between the 1950s and 1960s, and at the end of the 1980s when growth disturbances have been registered in trees in all sectors. From the results describe above we can highlight some features of the Schimbrig catchment. The entire area is strongly affected by high instability that results in a large earth slide in the eastern tributary (Schimbrig landslide) and in a very instable channel network in the western area where several slides influence the stability of the channels' bordering slopes. The main processes affecting the upper part of the channel network seem to be related to slow slide or earth flows that continuously provide material into the channel bed so that the system might be classified as transport-limited. As the process is slow it cannot be related with single heavy rainstorm events but rather with long rainfall periods or snow melting that make infiltration and amount of soil water more important for sliding processes. From the analysis of the trees the decoupling between hillslope and channels processes becomes obvious with a mechanism of material supply from the hillslopes to the channels followed by some residence time of the sediment in the channel. Only with enough stream power (i.e. during heavy rainstorms) the river is capable to carry the material from the source areas to the depositional fan. Therefore, the timescale assed by dendrogeomorphology allow establishment of a de-coupled system between hillslopes and channel network in the Schimbrig catchment.

## 5.7

## When science meets practice: Dendrogeomorphic documentation of rockfall trajectory frequencies, bounce heights and energies along a road in Valais

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Rockfall is one of the most widespread geomorphic processes in mountainous regions, where its continuous occurrence regularly forms accumulations of rock fragments at the base of talus slopes. Sporadically, single rocks and boulders impinge on inhabited areas or transportation corridors, where they may destroy buildings or even cause fatalities. Nevertheless, data on past activity and on spatial patterns (spread and reach) of rockfalls is often sparse. The scarcity of inventory data is particularly a problem when hazards and/or risks need to be assessed or mitigation measures planned. The main road linking Stalden to Saas Fee (Valais, Swiss Alps) is particularly prone to rockfalls and cars have been affected several times in the recent past. For the purpose of rockfall net installations, their number, dimensioning (height, energy) and positioning within the slope, the Laboratory of Dendrogeomorphology was mandated by the cantonal authorities and local communities to study trajectory frequencies, bounce heights, energies and return periods of events on the slope and at the level of the main road. Work has been performed at three different segments of the road (Raaftgarte, Falllowina, Huteggen–Bodenbrücke) with roughly 500 trees to document almost 2000 rockfalls of the past few decades. Results clearly show the added value of tree-ring reconstructions for the assessment of hazards and risks, as for instance at Raaftgarte where we could document that almost one rock is passing the road per running meter and year. At Huteggen–Bodenbrücke, on the other hand, the frequency of rockfalls was smaller but the energies involved in frequent events trespassed several 1000 kJ which was much more than expected. As a consequence, we believe that these findings may help clearly authorities in prioritizing sectors and in dimensioning protective measures and lead to more realistic estimates of risks (and therefore much better cost–benefit estimates).

# 5.8

# Climatic imprint on landscape morphology in the western escarpment of the Andes

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The western continental margin of northern South America is characterized by the active subduction of the Farallón-Nazca oceanic plate beneath the South American continental plate. Collision and arc magmatism started in the Early Jurassic followed by several phases of shortening and thrusting. The last phase (10-7 Ma) resulted in the formation of a steep ramp with a distinct escarpment edge (Victor et al. 2004, Farías et al. 2005). Upstream of this ramp on the Meseta/ Altiplano (>3000 m a.s.l.), streams have remained graded to the Late Miocene base level broadly correlative with a series of Tertiary volcanic-volcaniclastic rocks that form a resistant cap rock lithology (Abbühl et al. 2011). Below the ramp, streams have incised more than 1000 m into Mesozoic plutonic and metasedimentary rocks along a series of steep, headward retreating knickzones that grade to the present-day base level defined by the Pacific Ocean (Schlunegger et al. 2006, Schildgen et al. 2007). The precipitation pattern is characterized by a strong negative north-south gradient, related to the positions of the Andean jet and the Intertropical Convergence Zone (Garreaud et al. 2003). Here, we present the results of a morphometric analysis of 36 watersheds, each separated in segments below and above the escarpment edge, in an effort to detect possible imprints of tectonics, lithology and climate on landscape metrics.

Our analysis shows no distinct relationships between rock type and landscape metrics, not only on the Meseta, but also within the incised zone. This suggests that lithology has little impact on the large-scale landscape form. Average local relief values, however, show a distinct correlation with precipitation rates, but only for the segments below the escarpment edge. Whereas previous work (e.g. from Rehak et al. 2010) found negative correlations between local relief and precipitation rates for landscapes where the drainage network is fully established, we find the opposite relationships for our study area, where the erosional response to the Late Miocene uplift pulse has not yet propagated through the entire drainage network. Additionally, the upstream distance of knickzone retreat correlates positively with the model discharge of the stream. Finally, also below the escarpment edge, we find negative relationships between the relative proportion of non-dissected palaeosurfaces and both mean annual precipitation rates and local relief, albeit with a poor correlation.

We conclude that in transient landscapes, local relief increases with increasing precipitation through a positive feedback response to fluvial incision, but that relief decays with increasing precipitation rates in landscapes where erosion has obliterated transient features related to an uplift pulse.

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# P 5.1

# InSAR Terrasar-X visibility assessment of moving landform monitoring in alpine periglacial environment: 30 case studies in the Valais Alps (CH)

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The topography of the Western Swiss Alps (Valais Alps) consists mainly of north-south oriented valleys and has proved to be an optimal situation for an application of the InSAR technique. However, inventories of active moving landforms (e.g. rock glaciers, landslides) located in mountain periglacial environment show that the objects of interest are sometimes located in areas polluted by irreversible geometric distortions in InSAR images and are moving more quickly than the maximal capabilities of InSAR technology (Delaloye et al. 2006, 2008, 2010).

The study aims to precisely determine the InSAR capability for monitoring the activity of alpine periglacial landforms based on test study sites located in Valais Alps. Geometrical distortions existing on invisible areas (shadows) and reverse imaged areas (layover) are already well explained in literature (Massonet & Feigl 1998) and the InSAR visibility is usually computed by a simple binary mask hiding them. In this study, the quality of observation of InSAR is evaluated taking into account the location and velocity of the landforms as well as the acquisition parameters of InSAR; here InSAR Terrasar-X (TSX) with high resolution X-band interferograms and 11 days time interval. Thus, under the hypothesis that the landform flow is directed toward the highest slope direction at 25m scale resolution, an index of visibility characterizing the velocity compression for each landform is computed. Then, the maximal observable deformation rate of each landform can be easily calculated. Comparisons and validations were performed by combining InSAR observations and differential GPS measurements on 30 active landforms.

According to this study, it is possible to monitor some very active rockglaciers (1-2.5m.y$^{-1}$) when geometrical distortions do not hide them with the shortest repeat pass of 11 days. Lower velocity rates could be well monitored using longer time lags. At higher rate velocities, decorrelation occurs in most of the cases and TSX appears to be unsuitable for a precise analysis of these kinds of surging landforms. Moreover, the high resolution of TSX looks suitable to monitor slope instabilities with narrow width (until 50 meters width). Thus, by combining it with field measurements needed in most of the cases to validate and confirm observations at local scale, TSX InSAR has a strong potential for moving landform survey of the alpine periglacial belt.

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# P 5.2

# Dip direction controls of bedrock on channel morphologies and denudation rates in the eastern Swiss Alps

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The bedding orientation of bedrock exerts a prime control on the nature and the rates of sediment transfer on mountainous landscapes. Here, we address one particular situation, in which the dip angle of the bedrock is subparallel to the topographic slope (termed dip-slope). Such an arrangement results in the potential for large-scale deep-seated landsliding with bedding or jointing acting as glide planes. Hillslopes with the opposite situation (non-dip slope) have no such preconditioning, and will denude through standard mechanisms. The Val Lumnezia, Eastern Swiss Alps (Graubünden) contains both dip-slope and non-dip slope valley flanks. The topographic slope of the western valley flank parallels Mesozoic metasediments (dip slope situation) whereas the Bündner schists on the opposite valley dip perpendicular to the topographic slope (non-dip slope situation). The dip slope case is transport limited, with deep-seated landslides of up to tens of km$^2$ large transferring material towards the trunk stream. The opposing, non-dip slope, valley side is dissected by <150 m deep, supply-limited, bedrock channels.

Quantifying these effects is however difficult as surface sediment transfer rates in the dip-slope case may not reflect the depth integrated sliding rate. Likewise, in non-dip slope catchments, failure events tend to be episodic. We approach this problem with multiple methods, complementing geodetic surveys with morphometric analysis and $^{10}$Be derived hillslope and channel denudation rates. In particular, we analyse the relationship between upstream size of drainage basins $A$ and channel gradients $S$. In case where channels are graded and actively shaping the landscape, then channels gradients $S$ are directly related to the size to the contributing area $A$ following Flint's (1974) law:

$$S = k_s A^{-q} \qquad (1)$$

where $k_s$ and $q$ denote the channels steepness and concavity, respectively. The type, magnitude, and relative contributions of hillslope and channel processes can result in deviations from this relationship, which are readily identified by changes in the concavity and steepness values. Accordingly, we calculated these parameters from tributary streams on dip slope and non-dip slope valley sides. Tributary channels on dip-slope valley side are characterized by low concavity values ranging from 0.1 to 0.2, and equally display low steepness indices of approximately 100 m$^{0.9}$. Streams on the non-dip slope valley side have substantially higher concavity values between 0.3 and 0.8 and higher steepness indices, reaching maximum values of ca. 200 m$^{0.9}$. Surface slip rates derived from geodetic data exceed 10 cm/yr on the dip-slope valley flank, but are below detection limits (~1 m horizontal shift) on non-dip slope hillsides (Schwab et al., 2009).

The high steepness and concavity values of streams on non-dip slope valley sides support the interpretation of rapid dissection of the channel network into landscape where low hillslope slip rates allow the channel network to stabilize and actively shape the landscape.

This is in contrast to the dip-slope valley side, where low steepness and concavity values suggest that the channel network is continually destabilized by rapid deep-seated landsliding. $^{10}$Be-derived denudation rates are expected to yield similar distinct relationships between landsliding, fluvial dissection and overall sediment yield.

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# P 5.3

# Landscape Evolution of the Hörnli-region: Landforms, Processes and Rates

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The Hörnli-region in NE Switzerland contrasts the surrounding lowlands by its high local relief and rugged landscape. This dichotomy can be mainly attributed to the nunatak position of the area during the Last Glacial Maximum, LGM.

30 catchments have been studied in this area combining field investigations, GIS-based landscape analysis of a high resolution DEM and catchment-wide denudation (CWD) rates based on terrestrial cosmogenic $^{10}$Be concentration in fluvial quartz sand. The investigated catchments are classified based on their morphometrics and processes as either glacially overprinted or fluvially, mass wasting dominated catchments. The former presence or absence of a glaciation in the catchments is identified to exert the principal control of the Holocene landscape evolution.

Transience is suggested for large parts of the formerly glaciated Thur river tributaries. Gorge-like incision reaches cut into the Quaternary deposits and the Tertiary bedrock and the distinct knickpoints are interpreted as the adjustment to a base level lowering of the Thur drainage system during the late-Glacial and Holocene. The landscape disequilibrium found in the Thur drainage system and the expected increased geomorphodynamics are, however, not reflected in the CWD rates with values in the order of 30 mm/ky. These values rank among the lowest rates measured in the Swiss Northern Alpine foreland. In fact, there is no significant difference in CWD rates between glacially overprinted catchments with and without incision reaches.

The Töss river drainage system was, to a large degree, not glaciated during the LGM. However, the establishment of a major glacier marginal melt water drainage channel with a strong melt water and debris discharge caused rapid bedrock incision during the late-Glacial. The base level in the melt water channel rose after its truncation from the glacier melt water supply. Today, the tributaries are partly still adjusting to the base level lowering initiated during the melt water phase. The TCN-derived CWD rates in the not formerly glaciated and fluvially, mass wasting dominated catchments are found to be in the order of 300 mm/ky. These values are in good agreement with comparable studies from the Swiss Northern Alpine foreland (e.g. Wittmann et al., 2007; Norton et al., 2008).

The comparison of catchment-wide and near-channel slope distributions was used to investigate hillslope-channel coupling. In catchments where slope distributions are mostly congruent when considering either the near-channel or the entire catchment a close hillslope-channel coupling was observed. These catchments were also found to be positively correlated with mean basin slope and drainage density. Where mixed surface processes (glacially overprinted surfaces, fluvially incised gorges) were observed the slope distributions are incongruent and indicate channels decoupled from hillslopes.

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## P 5.4

# Deepening of inner gorges trough subglacial meltwater - an example from the UNESCO Entlebuch area, Switzerland

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This paper explores the mechanisms by which inner gorges in the Alps were formed. It focuses on the ca. 1.5 km-long, 80 m-deep and a few hundreds of meters-wide *Lammschlucht* located at the northern foothills of the central Alps. We restored the glacial cover using lateral moraines and hanging talus cones that record the elevation of the ice surface at the deglaciation stage of the LGM. We use the restored ice thickness patterns to calculate the erosional potential of the subglacial meltwater. The applied model is based on the principal of energy conservation, and yields the pattern of downstream changes of the dynamic pressure, which is considered a measure for the erosional potential. The model results suggest a maximum of the dynamic pressure at the end of the inner gorge. We interpret, therefore, that the subglacial meltwater scoured the reach towards the end of the *Lammschlucht* due to the enhanced dynamic pressure, which was ultimately controlled by the ice overburden. Post glacial fluvial erosion then resulted in a readjustment through regressive shift of erosional front along the inner gorge farther upstream. The current location of this front lies almost in the middle of the *Lammschlucht* inner gorge where a step-pool channel changes into a straight plane bed channel flowing on a deeply scoured bedrock.

## P 5.5

# Suitability of Cesium-137 and USLE for soil erosion assessment in an Alpine valley (Val Piora, Switzerland)

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Soil erosion constitutes an increasing global issue. Because of its special topographic situation, the Alps are a very complex and sensitive area and can be considered an early warning system for global climate change. However, the processes and recent trends of soil erosion are not well understood yet and tools and models for erosion assessment urgently need validation.

The aim of this study was to evaluate the suitability of the Cesium-137 (Cs-137) tracer technique and the Universal Soil Loss Equation (USLE) for soil erosion quantification in the Alpine Piora Valley. The valley (22.6 $km^2$) is located in the Southern Alps and the elevation ranges from 1850 to 2773 m a.s.l.

Soil erosion rates can be determined with the Cs-137 tracer method by comparing Cs-137 inventories (kBq $m^{-2}$) of investigated sites with those of reference sites not affected by erosion or sedimentation since the initial fallout of Cs-137. Sites with lower Cs-137 inventories as the reference inventory are defined as net erosion sites, whereby those with higher Cs-137 inventories are considered as net accumulation sites. Cs-137 inventories were measured at 10 evenly distributed transect sites (n = 60). The USLE estimates are based on measured physical soil properties and a digital elevation model (25 m grid). A prerequisite for the Cs-137 method is to establish the reference inventory. Several reference sites (n = 10) showed considerable Cs-137 variability. To evaluate this heterogeneity, additional 51 in situ measurements (in a regular grid with an edge length of 10 m) were implemented on a small plot (0.4 ha). Further, it could be shown that sites located in the western part of the valley had significantly higher Cs-137 inventories, which is assigned to higher precipitation rates and thus larger deposition of Cs-137 after the Chernobyl disaster. Complex patterns in snowfall, snow coverage and snow gliding in the days after the reactor accident might also have contributed to the heterogenous deposition patterns. The USLE estimates were not related to the observed pattern of Cs-137 inventories. The potential and limitations of the two methods for Alpine areas and their relation to other soil erosion risk factors will be discussed in this contribution.

Small scale heterogeneity has been found, which is attributed to complex erosion dynamics and processes during Cs-137 deposition. Winter processes, particularly snow gliding, may be an important factor triggering erosion (Konz et al. 2009). Lowest Cs-137 inventories were observed at sites with considerable dwarf shrub coverage. Freezing and snow gliding processes are expected to interact with the dwarf shrubs, destabilising the slopes.

Most of the other factors like slope or soil organic carbon content were not correlated with Cs-137 inventories. Those factors could have been superimposed by other ones. Fractional vegetation cover is negatively correlated with Cs-137 inventories, assumed to be an indicator for accumulation processes.
Complex processes associated with alpine environments seem to constrain the applicability of the Cs-137 tracer method and the USLE.

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## P 5.6

# LAND SUBSIDANCE AND FISSURING DUE TO GROUNDWATER WITHDRAWAL IN THE NEYSHABOOR PLAIN-NORTHEAST IRAN

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The Neyshaboor plain with 4100 km² is situated in the Khorasan province in the northeast of Iran, in the latitude 35° 40´and 39° 34 N and Longitude 58° 17and 59° 20 E situation (Fig. 1).
The topography of the study area varies from plain to mountainous and includes old to young geological formations. The exterem altitude of Neyshaboor plain is 3200 meter and the mean altitude of plain is 1900 meter.
Studied area is located in Neyshaboor plain in north of Khorasan province, Northeast of Iran. The Neyshaboor plain is one of the most important plains of Khorasan province in agricultural products and crowded population. In recent years agricultural development along with the increasing population culminate in taking the groundwater resources and a lot of pressure on these resources. The subsidence in different parts of the plain due to decrease the level of the groundwater is observed. In this plain the soil has been subsided because of the withdrawal of the groundwater level, and there are also longitudinal fissures along the altitudes, the Neyshaboor catchment restrictor, due to enhance subsidence from the sidelines to the center of the plain.
According to the information which is obtained from 100 GPS installed devices, the rate of subsidence has been reported 5-15 cm per meter of the downfall of the groundwater level. After the groundwater withdrawal, soil has been compacted, reactivated of old faults and surface fissuring and has been considerable impact on human infrastructures. So in this and hard aquifer irrevocable climate condition we discern the flood and the steep of the plain has changed.

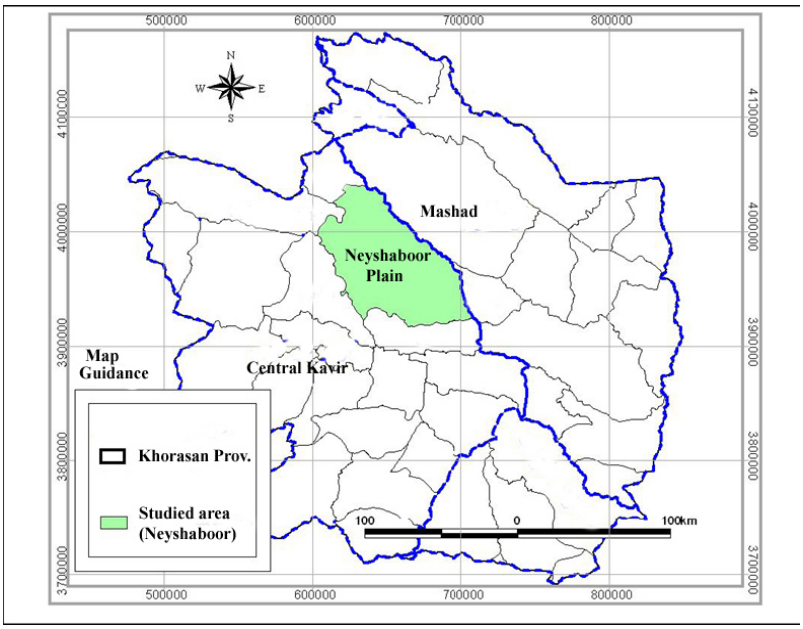


Figure. 1 Location of the study area.

Table 1. Statistics underground water resources during the year 2007 and 2010 (million cubic meters)

| Total of annual Discharge | Total number of Water Sources | Fountain | | Aqueduct | | Well | | Water resources |
|---|---|---|---|---|---|---|---|---|
| | | Discharge | number | Discharge | number | Discharge | number | Year |
| 791 | 2551 | 106/1 | 620 | 14/4 | 103 | 670/5 | 1828 | 2007 |
| 1175.4 | 4433 | 119/3 | 914 | 61/1 | 930 | 995 | 2589 | 2010 |

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## P 5.7

## Teaching with Tolkien: environmental analysis of a fantasy world

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In this study, the use of a fantasy world as a tool for teaching Geosciences especially in teacher training at the University of Basel is presented. J.R.R. Tolkien's The Lord of the Rings is one of the founding texts of fantasy literature and the centrepiece of a number of writings about the geography, history and mythology of „Middleearth". The books have long become a cult phenomenon which has been transmitted to a new generation of followers by the massive success of the movie trilogy released between 2001 and 2003. The renewed interest in Tolkien's Middle-earth offers a unique opportunity to connect the Geosciences with literature studies and vice versa. Tolkien's Middle-earth is a distant and yet familiar enough world to allow for an analytical reflection of its geologic and ecologic coherence. The geographical analysis shows that the layout and description of Middle-earth roughly correlates with the paradigms of the Earth Systems Sciences. However, there are discrepancies between the spatial patterns of the various spheres which cannot be attributed just to artistic licence or ignorance, but point to significant issues connected with the moral and symbolic logic of Tolkien's work. For example, the absence of trees and woods in certain parts of "Middle-earth" where they would be expected in view of the description of climate throws into relief Tolkien's preservationist agenda. This setting, i.e. both the correlation between our world and Middle-earth, as well as the discrepancies, allow for a wide range of teaching activities. First and foremost, the geologic setting, both looking at Middle Earth as a self-contained world, but also a comparison of landmarks with their movie counterparts, offer pupils and students the opportunity to apply their knowledge of geosciences to a new world. For example, a typical question to be discussed is whether New Zealand volcanoes are of a similar type than those one would expect in Mordor. Further subjects for studies include methods, such as the reconstruction of environmental conditions from literature, but also GIS-based analysis of climate, vegetation, and land use. The lack of detailed information about the environment of Middle Earth offers students a new freedom to apply their knowledge and formulate a scientific hypothesis outside the pressure of delivering a correct answer. In our experience, this stimulates discussion and a vigorous exploration of the pupils' existing knowledge. Furthermore, a first case of breaking up the traditional barriers between humanities and natural sciences can be achieved by studying Middle-earth.

## P 5.8

# Crack air convection and resulting temperature disturbances at depth in an alpine rock slope

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In this work, we analyze a unique set of temperature measurements from an alpine rock slope at ~2400 m a.s.l. in southern Switzerland. The monitored area encompasses part of an active slope instability above the village of Randa (VS) and is traversed by a network of open cracks, some which have been traced to >80 m depth. We first describe distributed temperature measurements and borehole profiles, highlighting deep steady temperatures and different transient effects. In a second step, we analyze the impact of air and water circulation in deep open fractures on the subsurface thermal field. On multiple visits to the study site in winter, we consistently noted the presence of warm air vents in the snowpack following the trace of deep tension cracks. Measurements showed that venting air changed temperature gradually from ~3 to 2 °C between December and May, which is similar to the rock temperature at around 50 m depth. Comparison with ambient air temperature suggests that winter conditions favor buoyancy-driven convective air flow in these fractures, which acts to cool the deep subsurface as rock gives up heat to incoming air. The impact of this process on the local thermal field is revealed by a disturbed temperature profile in one borehole and transient signals at depths well below the thermally active layer. Seasonal water infiltration during snowmelt appears to have little impact on the local temperature field.

## P 5.9

# Reconstruction of rock glacier activity in Northern and Inner Tien Shan based on tree rings and aerial photographs

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Rock glaciers are a widespread geomorphic landform in continental Northern and Inner Tien Shan, where they expand from continuous permafrost regions above 3500 masl down to forested areas at 2700 masl. Rock glaciers generally respond to climate change with a larger time-lag than glaciers, which stresses their importance as fresh water resources in the future (e.g. for large cities like Almaty and Bishkek). Possibly a consequence of rising temperatures, Northern Tien Shan rock glaciers were found to have extraordinarily high downslope movements of >10 m $yr^{-1}$ (in the case of the Burkutty rock glacier). However, velocity rates vary strongly among the rock glaciers in this region and their complex behavior has not yet been fully understood. As long-term data from direct measurements is sparse, we analyzed tree rings and aerial photographs to reconstruct distinct periods of advance and to assess velocity rates for three rock glaciers in Northern and Inner Tien Shan. All juniper (*Juniperus sp.)* and Tien Shan spruce (*Picea shrenkiana)* trees growing in the immediate proximity to or even on the investigated rock glaciers were sampled. Responses such as the formation of reaction wood will be used as an indicator for periods of pronounced rock glacier advance. The results will then be complemented by velocity rates assessed from photogrammetric analysis of aerial photographs taken in the 1950s, 1960s, and 1980s as well as projected photographs taken in the early 2000s and 2011. The results will be checked for synchronous trends among the investigated rock glaciers and put into relation with historical climate data.

# 5.10

# Hypogenic contribution to speleogenesis in a predominant epigenic karst system: a case study from the Venetian Alps, Italy

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Buso della Rana and Buso della Pisatela are two karstic caves located in the Venetian forealps (north-east Italy). They are part of the same karst system and are developed in the Castelgomberto calcarenitic marine sediment, which was deposited in a shallow Caribbean-type sea during the Eocene (Munier-Chalmas and De Lapparent, 1893). The Buso della Rana-Pisatela system developed mostly at the contact between the Castelgomberto calcarenite and underlying volcanic rocks. The system of caves is ~37 km long and has only three entrances, two of which are semi-artificial. The overlying karst plateau is not directly connected to the Buso della Rana-Pisatela system and, with the exception of one deep abyss, shows a rather scarcely developed karst. This is unexpected considering the presence of such a large and long cave at depth.

The genesis of the Buso della Rana-Pisatela system is considered to be epigenic (Allegranzi et al., 1960; Gleria and Zampieri, 1978). However, we present evidence that demonstrates how the genesis of this karstic system is strongly related to hypogenic mechanisms.

Gypsum ($CaSO_4 \bullet 2H_2O$) has locally been observed on the walls of the Buso della Pisatela cave. Energy dispersive X-ray spectroscopy (EDS), performed with a scanning electron microscope (SEM), reveals the presence of sulfur-bearing minerals within the host rock. Gypsum was formed by oxidation of these minerals as indicated by negative $\delta^{34}S$ values and Raman spectroscopy analyses. The oxidation of sulfide minerals forms a sulfuric-acid solution that dissolves the Castelgomberto calcarenite and, once it is oversaturated in calcium, precipitates as gypsum.

The lack of well-developed karst on top of the plateau and the analyses suggest that the formation mechanisms for the Buso della Rana-Pisatela system differ from classical epigenic speleogenesis. The “pyrite-effect” recognized in other caves is an example of hypo-speleogenetic process responsible for the dissolution of large portions of buried rocks in karst plateaus (e.g. Furman, 1993; Bottrell et al., 2001).

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