Multifunctional monitoring in torrent catchments

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Multifunktionales Monitoring in Wildbacheinzugsgebieten

Introduction

Multifunctional monitoring in torrent catchments is generating a variety of useable synergy benefits and is also a requirement predetermined by the diversity of nature. The supplied data are used to find solutions to assignments in the field of torrent and avalanche control and to provide answers to interdisciplinary and scientific issues (Hydraulic Engineering, Geomechanics, Hydrogeology, Silviculture etc.). The measurement systems, which have been in use for many years, are also an important element of interdepartmental and transnational climate change research programs.

Reasons for installing monitoring systems in torrent catchments

For decades, the Department of Natural Hazards and Alpine Timberline of the Federal Research and Training Centre for Forests, Natural Hazards and Landscape (BFW) has been involved in the development of practice-oriented methods for the sustainable protection of human settlements and infrastructure against natural hazards in Alpine regions. In this regard, it is essential to have comprehensive knowledge about the processes taking place in nature.

In Austria, there are around 12,000 torrential watersheds. These are threatened by floods, debris flows, landslides and avalanches. But there are only a few stations to measure relevant parameters needed to explore the processes which lead to these natural disasters. For example, only a few of the pre-

Zusammenfassung

Die Beurteilung von Wildbacheinzugsgebieten im alpinen Raum wird oftmals durch das Fehlen abgesicherter Messdaten erschwert. Das Bundesforschungs- und Ausbildungszentrum für Wald, Naturgefahren und Landschaft (BFW) widmet sich dieser Aufgabe seit geraumer Zeit um ein verbessertes Prozessverständnis zu erlangen. Der vorliegende Beitrag beschreibt die Anforderungen an ein multifunktionales Monitoringsystem unter extremen Bedingungen und unterstreicht die Wichtigkeit langfristiger Studien in Wildbachgebieten. Ausgewählte Ergebnisse werden anhand eines gut beobachteten Einzugsgebiets dargestellt. Die Daten zeigen u.a. die unterschiedlichen Einflüsse der Klimaänderung, die sich besonders in den Parametern Niederschlag und Temperatur zeigen.

Schlagwörter: Wildbach, Schneewasseräquivalent, Talzuschub, Klimawandel.

Summary

The assessment of torrent catchments in the Alpine area is often hindered by a lack of confirmed data. The Federal Research and Training Centre for Forests, Natural Hazards and Landscape (BFW) has been devoted to this task for decades to close the knowledge gaps. The following paper makes an effort to show an overview of requirements on multifunctional monitoring under extreme conditions and reveal the importance of long-term studies in torrent areas. Selected results of long term monitoring in one special torrent catchment will be presented. The data show among other things the different impacts of climate change which are particularly evident in the parameters of precipitation and temperature.

Key words: Torrent, snow water equivalent, sagging of mountain slopes, climate change.

cipitation stations located at high altitudes are recording data with high temporal resolution. For this reason, the data base for the design of protective measures against natural hazards must be improved. The installation of monitoring systems in torrent catchments was and is an important contribution to the study of these processes and the generation of fundamental data.

In the past, monitoring systems were installed in torrent watersheds following disaster events (e.g. after the severe flooding of 1965/66 in Carinthia). Today, they have gained in importance in connection with the possible effects of climate change on natural hazards. Moreover, it has become evident that even state-of-the-art, computer-assisted simulation techniques need model calibration and plausibility checks which can only be implemented by using measured data and facts of nature.

Beneficiaries of monitoring data

- The operating company (for example BFW) and other national and international research institutes in the frame of research cooperation (e.g. Technical University of Vienna, Technical University Graz, University of Erlangen-Nuernberg).
- The Austrian Service for Torrent and Avalanche Control, e.g. for hazard zoning and action planning
- Other stakeholders (e.g. civil engineers and power plant operators, for project development and verification of licensing requirements).
- Policy-makers, e.g. to establish priorities for funding decisions, or ranking of hazard prevention projects.

Monitoring systems of the BFW in torrential watersheds in Austria

Currently, the Department of Natural Hazards and Alpine Timberline is operating monitoring systems in the following torrential watersheds:
- Oselitzenbach/Carinthia
- Schmittenbach/Salzburg
- Gradenbach/Carinthia
- Ponholzbach/Lower Austria
- Wattener Lizum/Tyrol

The sizes of the areas range from 4 km^2 to 32 km^2.

Figure 1: Monitoring systems of the BFW in torrential watersheds
Abbildung 1: Monitoringsysteme des BFW in Wildbachgebieten

The following methods are used to collect data:

- (automated) monitoring stations to gain longterm series of measurements
- exploitation of additional information through field surveys and experiments (heavy rainfall simulation, soil and vegetation mapping, etc.)

Experimental torrent catchment of Gradenbach creek/Carinthia – an example of a multifunctional monitoring system

The catchment basin of Gradenbach creek covers an area of about 32 km². It is located south of the Alpine main ridge, near Heiligenblut in the so called "Schobergruppe", being part of the Hohe Tauern mountain range. The highest elevation is the "Petzeck" with 3283 m above sea level. The confluence to the river Möll is located at about 1045 m above sea level. The catchment is well known to experts because of the actively slumpinging mountain slope (Bercholdhang) located at the mouth of the torrent and covering an area of approximately 2 km².

Interacting with the torrent at the bottom, the slope threatens a land settlement at the mouth of the torrent and the villages downstream of the Möll Valley. During the severe flooding of 1965/66, approximately 1.3 mio. m³ of bed load – from the inner part of the gully, but especially from the gorge at the gully exit – were deposited at the alluvial fan of the Gradenbach and in the receiving river Möll. As a result the Möll has been shifted away from its river bed and flooded extensively the Möll Valley. After the disaster, the Federal Research and Training Centre for Forests, Natural Hazards and Landscape (BFW) installed a comprehensive

Figure 2: Berchtoldhang at Gradenbach
Abbildung 2: Berchtoldhang am Gradenbach

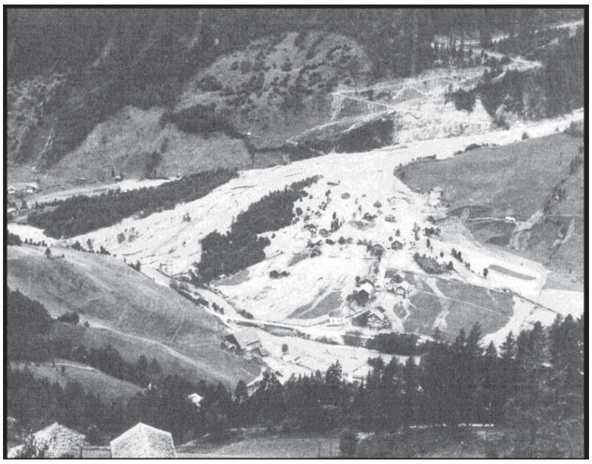

Figure 3: Debris cone of Gradenbach in the year 1966
Abbildung 3: Schwemmkegel am Gradenbach im Jahre 1966

monitoring system in the Gradenbach catchment. At the whole catchment level, meteorological and hydrological data are measured, including precipitation, snow water equivalent, runoff (at open gullies, drainage system, springs), air humidity, airflow and temperature, radiation. At several points are measured mountain water-table and temperature, natural ground water discharge and slope movement. These measurements are completed by rotational surveys and observations on-site (e.g. surveys at snow measuring courses at altitudes between 1400 m and 2100 m, at open land and at forest habitats).

Data from the experimental catchment Gradenbach are used

- To analyse extreme torrent flood events (objective: advancement of flood protection measures through availability of fundamental data)
- To investigate the water budget of the area concerned (to discuss silviculture and water management issues)
- To control the efficiency of already implemented protection measures and to allocate a basis for decision-making for future actions (slope drainage, control measures, etc.)
- To improve the understanding of cause-effect relationships and processes of large mountain slope sagging (as a basis for developing an early warning system)
- To improve existing measuring systems and develop new ones (e.g. logging of groundwater, remote sensing of slope movement)
- To discuss supra-regional key issues (e.g. climate change, regionalisation of generated knowledge)
- To increase the safety of adjacent communities/adjacent land owners through monitoring slope movement.

Results of long-term measurements at torrent catchment Gradenbach creek

The majority of the measurements reveals the importance of the data regarding the highly topical issue of potential climate change effects on natural hazards. Slope movement is influenced mainly by precipitation. Changes in the spread and intensity of precipitation, as well as temperature (e.g. influencing the relationship between rain and snow deposition) have a considerable impact on triggering or accelerating the mass movement. Vegetation, particularly forests, counteract slope water logging through evapotranspiration and retaining of snow in the canopy. But the growth and relative capacity of vegetation (especially forests) to mitigate these effects is also influenced by climate change. Only long-term monitoring of individual parameters, completed by field surveys can provide an insight into the complex cause-effect relationships between influential factors.

Mountain slope sagging

The long-term measurements of mass movement in the gorge area of the Gradenbach (Figure 4) demonstrated that even after indications of slope 'stabilisation' there is still a residual risk of a new disaster associated with mass movements on “Berchtoldhang”.

The annual movement at the toe of the slope reached its maximum in 2001 (Period 1979–2009: Cable 1: 55 cm; Cable 2: 62.5 cm). In 2009 large landslides were also recorded.

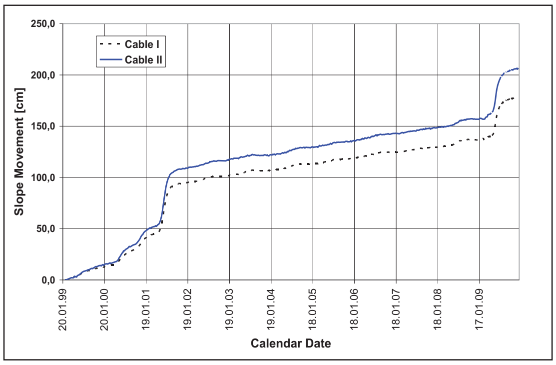

Figure 4: Slope movement in the gorge area of the Gradenbach measured by steel wire extensometer

Abbildung 4: Hangbewegungen (gemessen per Drahtextensometer) in der Schluchtstrecke des Gradenbaches

Triggering factors

Slope movement is mainly influenced by precipitation. The average annual rainfall in the period 1969–2009 was 930 mm. The maximum precipitation during the year is reached in July. Precipitation in the form of snow is measured at snow measuring lines. These lines are both in forest and open land areas to explore the effect of forests on snow interception. It has been confirmed that snow retention on the canopy is often considerably high (> 50%).

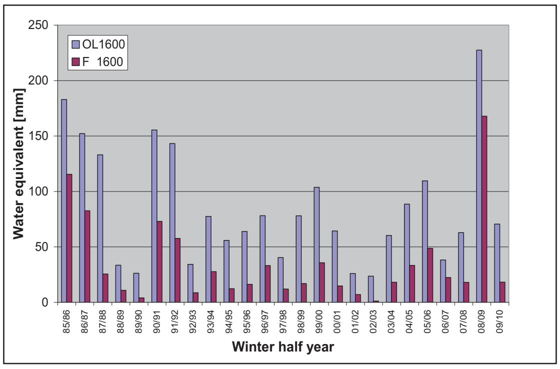

Figure 5: Water equivalent in forest (F) and open land (OL) areas (1985–2009, altitude 1600 m a.s.l.)

Abbildung 5: Schneewasseräquivalent 1985–2009 im Wald (F) und Freiland (OL) auf 1600 m Seehöhe

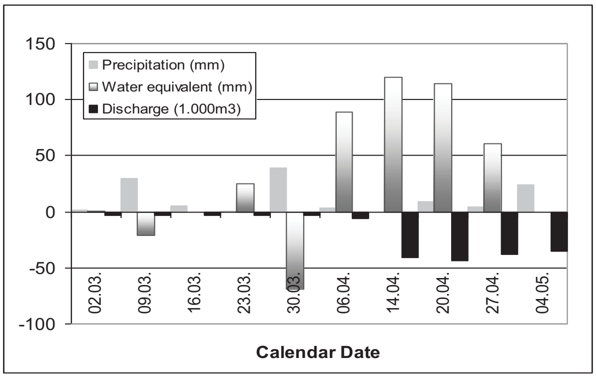

Figure 6: Precipitation, water equivalent and discharge during the snow melt of the year 2009 (open land area; altitude: 1600 m a.s.l.)

Abbildung 6: Niederschlag, Schneewasseräquivalent und Abfluss (Freiland, 1600 m Seehöhe) während der Schneeschmelze im Jahr 2009

The amount of snowmelt water varies subject to both weather conditions and snow cover, and may exceed the total amount of rainfall in the spring significantly. This means that during snowmelt, an extremely high percentage of the total water input is seeping away.

Ground water level

The amount of water which penetrates into the slope was visible in a few of the drilled holes distributed over the hillside. The results of the well logging suggest that the slope water level relevant for the velocity of the mountain slope movement is determined mainly by the quantity of melting snow. In years with strong slope movements, the hydrograph of the ground water level shows strong and rapid climbs and descents, especially at one water gauge (Figure 7, gauge 3b).

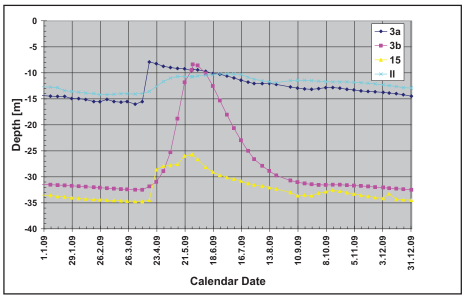

Figure 7: Ground water level at different ground water gauges (Berchtoldhang in the year 2009)

Abbildung 7: Grundwasserstand an verschiedenen Pegelmessstationen (Berchtoldhang Jahr 2009)

Climate change

Temperature

The average annual values show a clear positive trend with high statistical significance (two-tailed test; degrees of freedom: 39, level of significance: 0.1%). A comparison of the first and last (fourth) decade in the test series shows a temperature rise of +1,5 °C compared to the last one (see Figure 8). The highest seasonal change in temperature was recorded in spring (also a highly significant positive trend, Figure 9). A comparison of the averages of the first and last decade in the test series shows a temperature increase of +2.4 degrees!

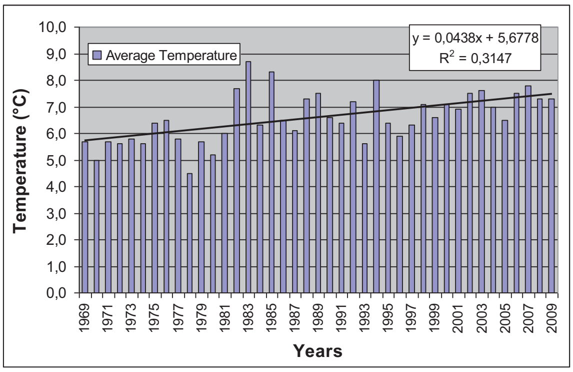

Figure 8: Average annual air temperature (1969–2009, altitude: 1210 m a.s.l.)
Abbildung 8: Mittlere jährliche Lufttemperatur 1969–2009 auf 1210 m Seehöhe

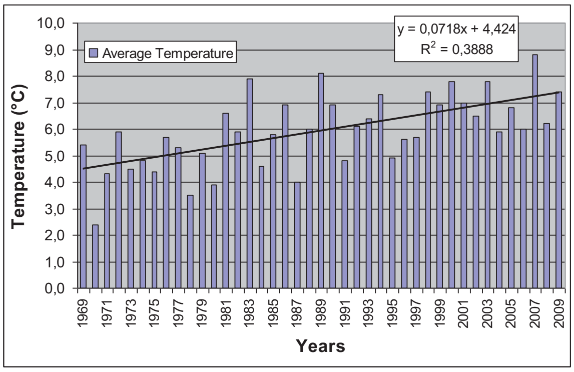

Figure 9: Average air temperature in spring (1969–2009, altitude: 1210 m a.s.l.)
Abbildung 9: Mittlere Lufttemperatur im Frühjahr (1969–2009 auf 1210 m Seehöhe)

Precipitation

The figures of the annual totals of about 40 years show a very slight trend towards smaller or increasing precipitation. However, this picture changes in the seasonal analysis of the measurements. While rainfall in spring and winter has a tendency to decrease, precipitation increases clearly in summer and autumn. In relative terms, the largest increase between first and last (fourth) decade was in autumn (+38.6%).

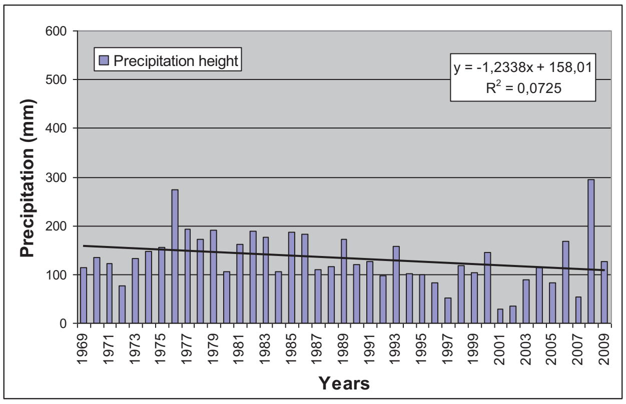

Figure 10: Winter precipitation (1969–2009, altitude: 1210 m a.s.l.)
Abbildung 10: Winter-Niederschlag (1969–2009 auf 1210 m Seehöhe)

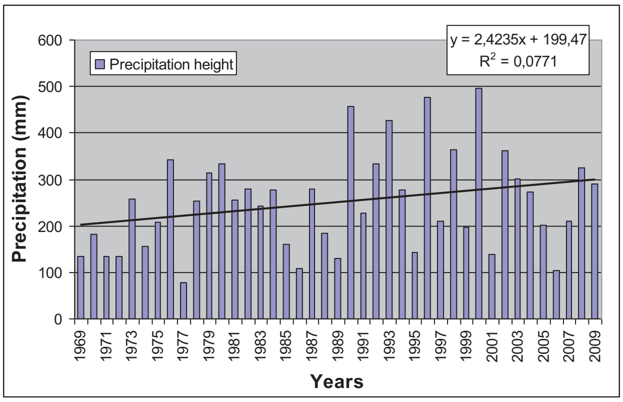

Figure 11: Autumn precipitation (1969–2009, altitude: 1210 m a.s.l.)
Abbildung 11: Niederschlag im Herbst (1969–2009, 1210 m Seehöhe)

Different trend curves were checked. None of them showed sufficient significance. Despite these strong alterations we can assume that only the future will reveal whether these are signs of a lasting climate change.

Conclusions

Monitoring systems in torrent catchments are installed for several purposes. In order to fulfil these multiple tasks, expensive and time-consuming preparations are necessary.

The often extreme exposure in the field and the harsh climate in Alpine regions require robust, precision measuring equipment. Despite the sophisticated measuring technique, it is evident that the complex monitoring systems can only be operated reasonably by a sufficient number of well trained staff. Experience shows that measuring systems only supply representative data when trained staff are able to recognize and eliminate immediately any sources of error. Disturbances such as sedimentation at runoff gauging stations or changes affecting precipitation measuring points etc. can be recognized and removed in time, which facilitates checking the plausibility of doubtful data.

The costs associated with the installation and long-term operation of monitoring systems should not be underestimated. However the environmental and experimental benefits of such systems are worth the expense, especially with regard to climate change scenarios.

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