The application of time-lapse photography for the observation of snow processes in mountainous catchments

Jakob Garvelmann, Stefan Pohl and Markus Weiler

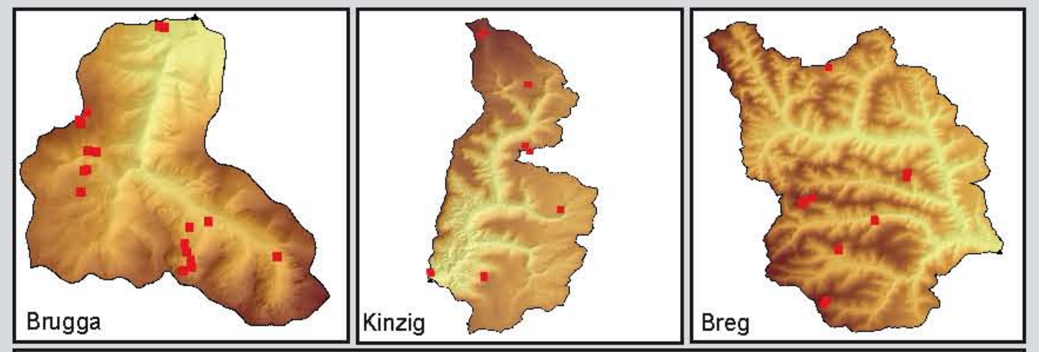
HYDROLOGY

Introduction

For the forecast of snowmelt flood events in mountainous catchments it is very important to know the spatial distribution and temporal evolution of the snowcover. Topography and vegetation have the most important influence on the spatio-temporal variability of the snowcover. Time-lapse fotography was already successful applied in snow studies (e.g. Parajka et al., 2012; Floyd and Weiler, 2008) at the small catchment scale.

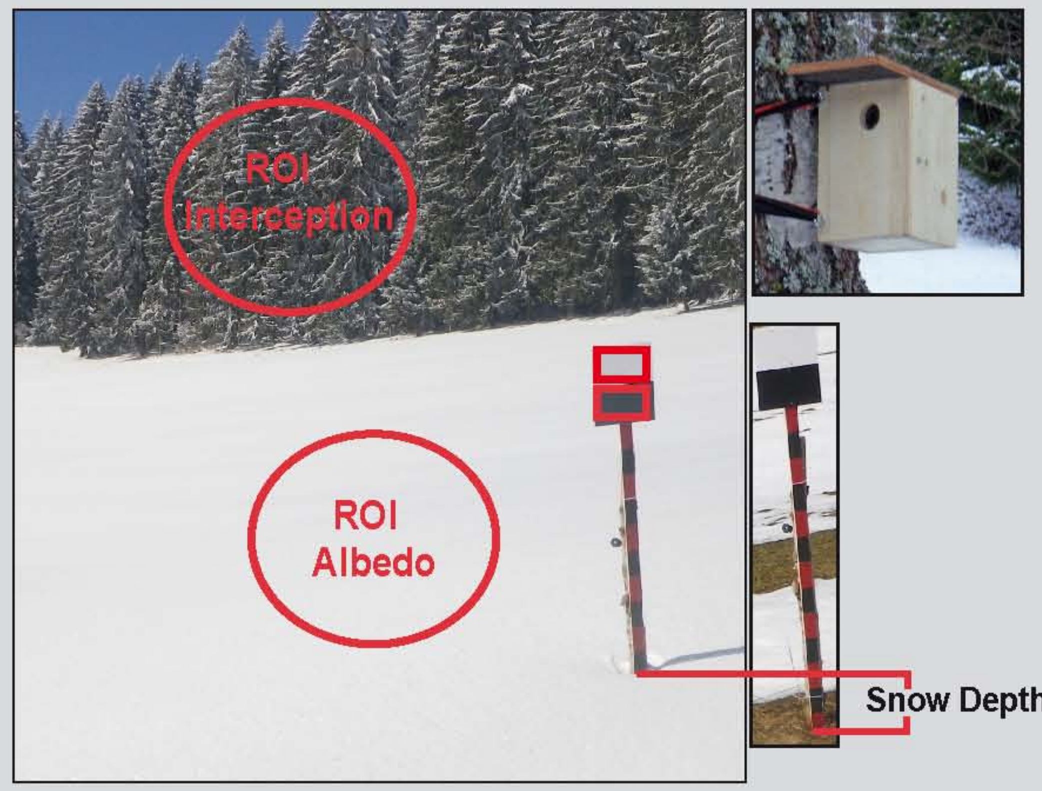
Camera Network and Methodology

In order to accomplish a continuous observation of the quantity and the status of the snowcover, a network of 45 standalone time-lapse cameras was established in three catchments in the Black Forest, a typical mid latitude medium elevation mountain range in the south-west of Germany. Within the catchments, a stratified sampling design was used to cover a wide range of altitudes and exposures. In order to investigate the influence of a vegetation cover on the snowpack beneath, cameras have been installed under the forest canopy and on adjacent open field sites, respectively.



Catchment	Size [km²]	Elevation [m.a.s.l.]	Forest [%]	Cameras
Brugga	40	433-1493	79	19
Kinzig	76	354-842	63	11
Breg	158	738-1142	70	15

We used the standard *Pentax Optio W90* digital camera equipped with an extern Lithium-Polymer battery. This allowed an interval setting of 1 hour for 41 days. Image analysis software programmed in IDL was applied to extract information about snow depth, albedo and canopy interception from the digital images. A measurement scale was installed at every camera location to allow a determination of the snow depth. Region of interests (ROIs) were defined within the images for which canopy interception and surface albedo could be calculated A black/white board was used to provide a white balance for the albedo estimation and a black/white balance for the canopy interception analysis.



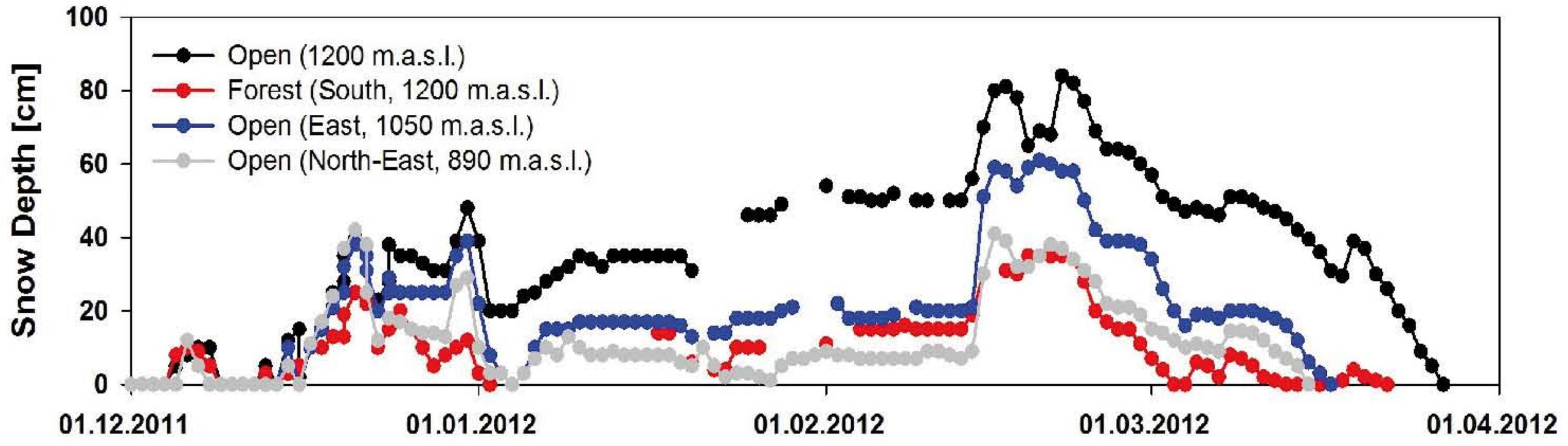
References

Parajka J., Haas P., Kirnbauer R., Jansa J. and Blöschl G. (2012): Potential of time-lapse photography of snow for hydrological purposes at the small catchment scale. Hydrological Processes.

Floyd W. and Weiler M. (2008): Measuring snow accumulation and ablation dynamics during rain-on-snow events: innovative measurement techniques. Hydrological Processes 22, 4805-2097.

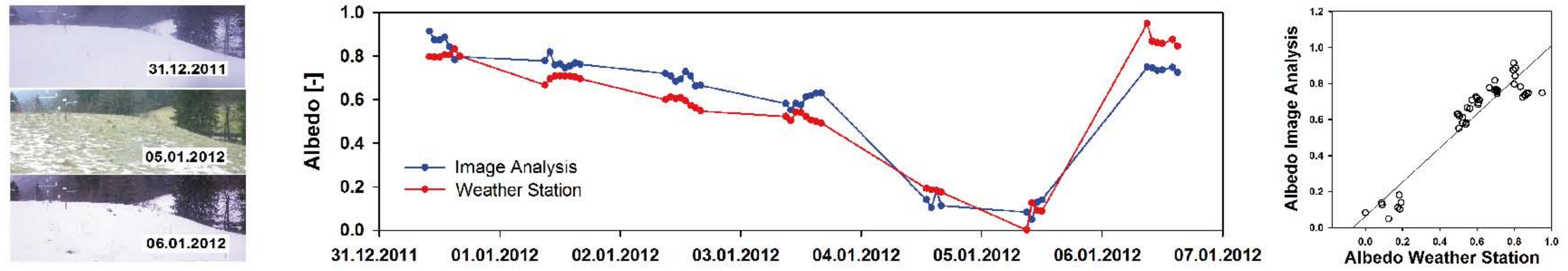
Snow Depth

The camera network allowed an continuous estimation of snow depths at different locations throughout the catchments. The figure presents the snow depths during winter 2011/2012 at different elevations in the Brugga catchment. The influence of topography can be clearly seen. The application of camera pairs (open vs. forest) allowed an estimation of the influence of a vegetation cover on the snowpack beneath. The snow depth of the forested site (LAI=1.9) at 1200 m.a.s.l. was in mean 64% below the snow depth of the adjacent open field site.



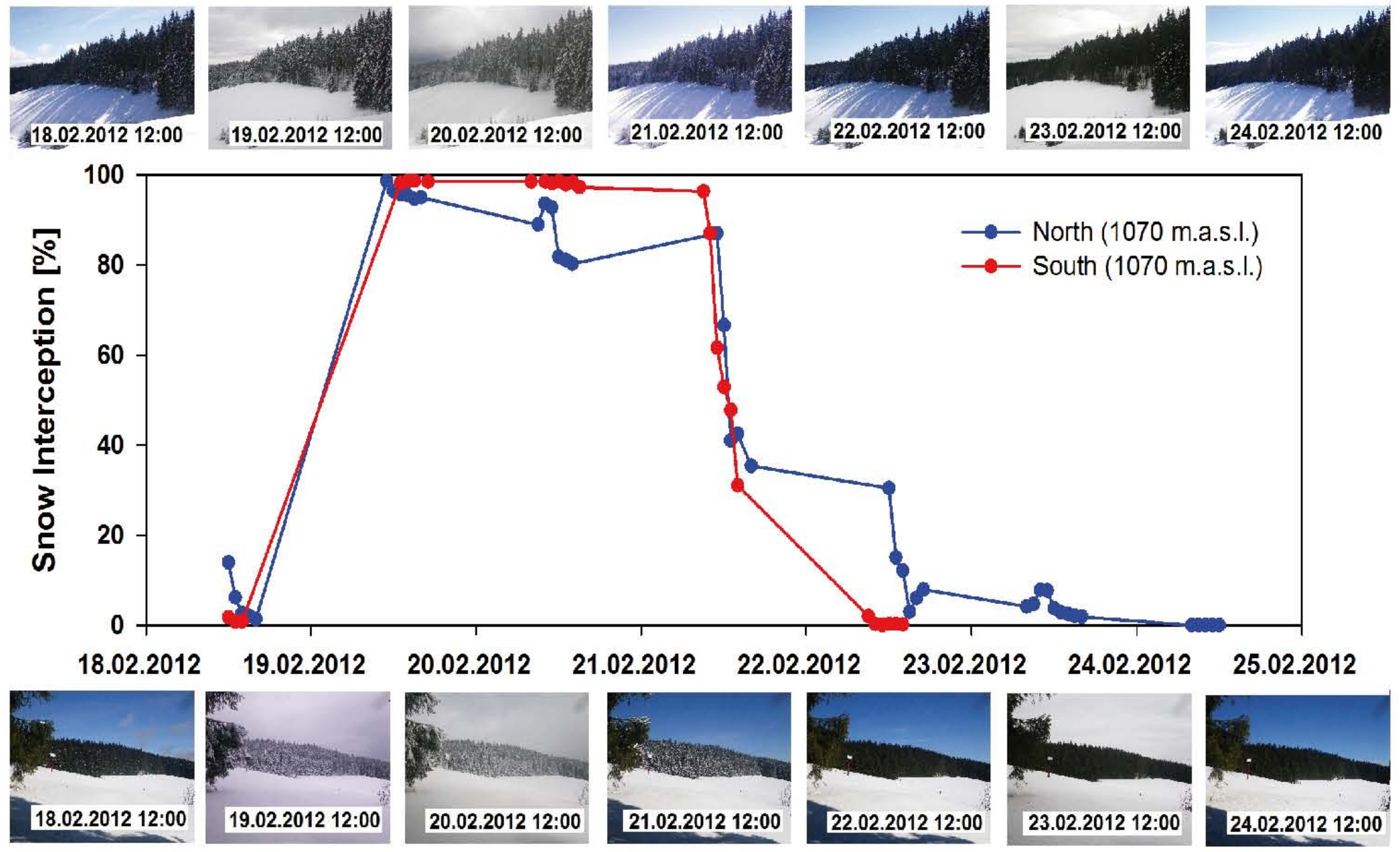
Albedo

The temporal evolution of the snow albedo during a ROS event could be calculated. The melting of the snowpack during this event and a subsequent increase of the albedo caused by new snow can be seen in the graph. The results are in good accordance with the data of a on-site weather station (R^2=0.9, RMSE=0.08, NS-Efficiency=0.93).



Snow Interception

Image analysis software was used to calculate the fraction of white pixels within a defined ROI. A continuous observation of the forest canopy allowed the estimation of interception efficiency and temporal evolution of the snow interception for different topographic situations. After a snowfall event followed by sunny days with moderate temperatures, the forest canopy at the south facing slope was 2 days earlier snow free compared to the forest canopy with a north facing exposure.

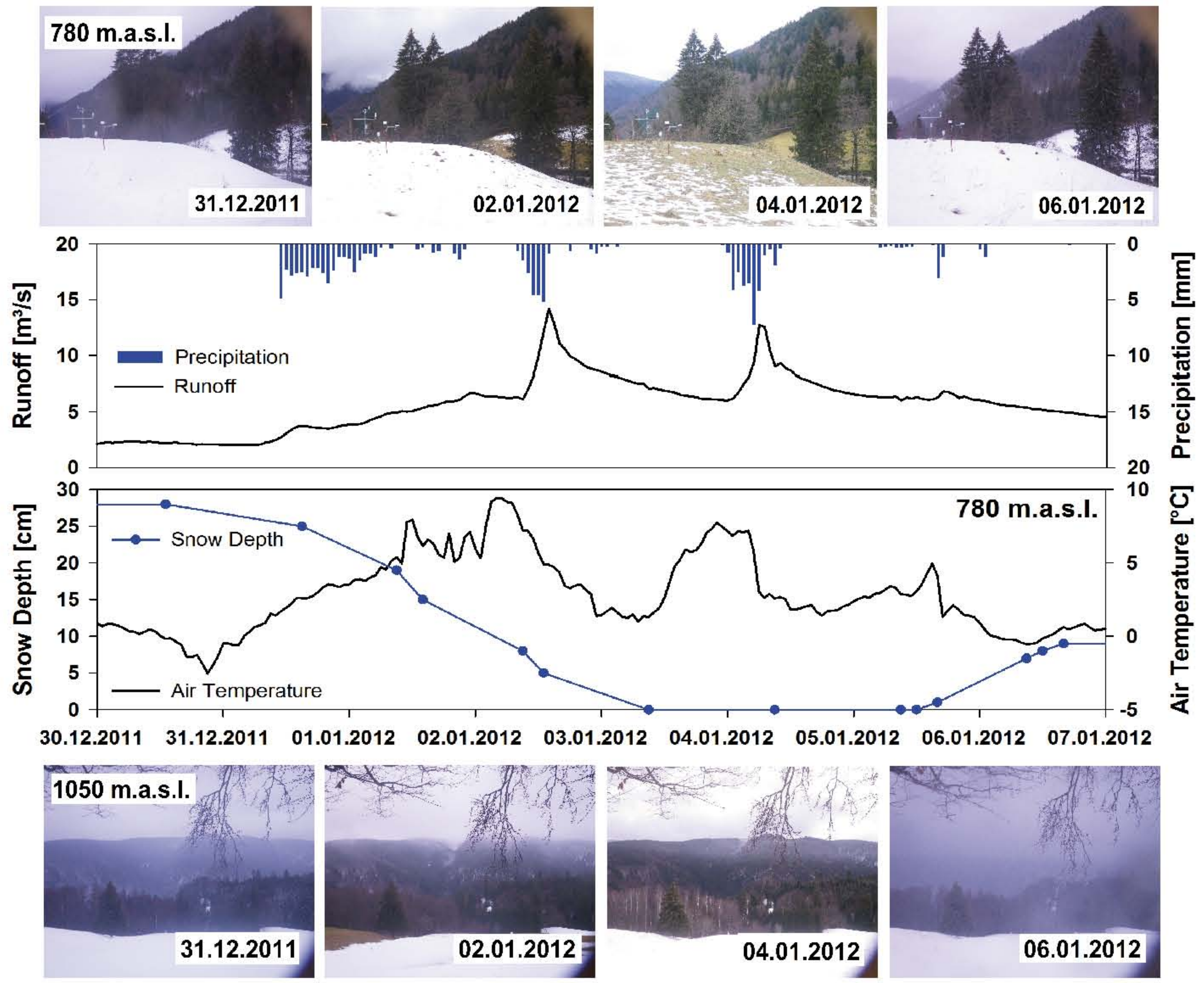


State of Precipitation

Time-lapse photography could be used to identify the state of precipitation. There is a horizontal difference of 600 m and an altitude difference of 120 m between the two camera locations presented here. It can be seen that the precipitation was rain at the lower camera location and snow at the upper, respectively. Therefore, the snow line could be identified relative exactly for this event.

Runoff Events

The hydrograph of the Brugga for a serie of three events could be interpreted with the time-lapse photographs from different locations throughout the catchment. Precipitation, air temperature and snow depth at 780 m.a.s.l. as well as images from different altitudes are presented. The first peak (02.01.2012) was a 2-year flood event generated by both liquid precipitation and snow melt water. There was a snow cover throughout the catchment prior to the event with a few cm in the lowest parts and more than 0.5 m in the highest parts of the catchment. Snow depths decreased significantly at all altitudes during this ROS event. There was another flood event 2 days later (04.12.2012). Despite a higher precipitation intensity the flood peak was slightly smaller, because there was not much snow left throughout the catchment and temperatures were again decreasing during this event. Therefore the runoff during this event was mainly rainwater. Another precipitation event (06.01.2012) caused nearly no runoff increase, because precipitation was snow in most parts of the catchment.



Conclusions

The results of the study in three mid latitude medium elevation mountain range catchments with different topographic characteristics and areal extent reveal that the application of numerous time-lapse cameras presented in this study is an appropriate technique to realize a continuous observation of the spatial distribution and temporal evolution of key aspects of a seasonal snowcover throughout a catchment. The method is easy to accomplish, competitive and provide useful data about snow depth and snow albedo as well as important snow processes as snow interception and state of precipitation. Low visibility during fog or strong snowfall as well as a snow-covered camera lense are major restrictions of the presented technique.

Institute of Hydrology, Albert-Ludwigs-University of Freiburg
jakob.garvelmann@hydrology.uni-freiburg.de www.hydro.uni-freiburg.de

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