Observation of the Difference in Snow Cover Evolution between Open and Forested Areas

Stefan Pohl, Jakob Garvelmann, Markus Weiler

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Introduction

Forest vegetation plays a major role in the evolution of a seasonal snow cover by influencing both the accumulation as well as the ablation patterns. Snow interception and subsequent sublimation directly back to the atmosphere can reduce the amount of snow underneath the forest substantially. During the ablation the reduction of solar radiation and wind speed by the canopy decreases the melt rates of snow underneath the forest. On the other hand, the lower albedo of the trees leads to higher temperatures within the forest canopy which contributes to snowmelt energy balance through the increased flux of thermal longwave radiation.

A detailed field observation program was set up to study the relative importance of these effects in relation to vegetation and topographic characteristics as well as in relation to the meteorological conditions present at the time.

Methodology

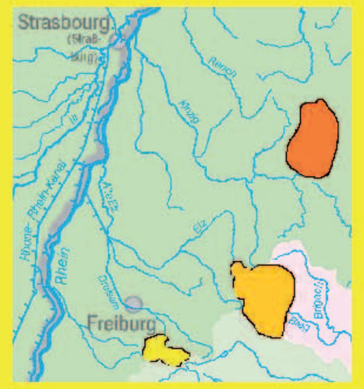
1. Snow Monitoring Stations (SnoMoS): 99 SnoMoS were deployed measuring hourly values of snow depth, air temperature, air pressure, relative humidity, incoming global radiation, wind speed, surface temperature.
2. Digital Time Lapse Cameras: 45 cameras were deployed taking hourly pictures from which information on state of precipitation, snow depth, snow albedo, and snow interception in the canopy can be derived.
3. Manual Snow Surveys: manual snow surveys measuring the small scale variability of snow depth and snow density were carried out periodically over the winter.

Measurement locations were chosen to include a wide variety of topographic and vegetational characteristics. The influence of vegetation was further investigated by setting up „paired stations" one located in an open area and one close by underneath forest vegetation.




Study Basins

Sensor networks were set up in three basins over the winter. The chosen basins differ in their sizes (40 to 158 km²) as well as their topographical and vegetational characteristics. Elevations range from 400 to 1500m.

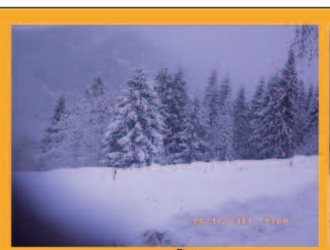
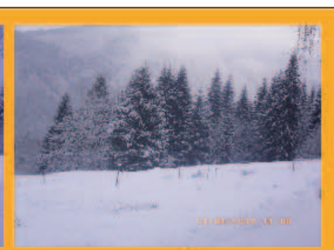
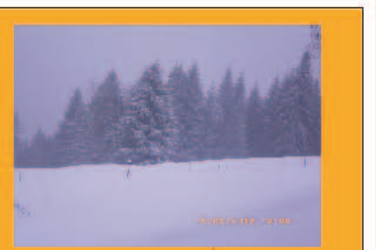
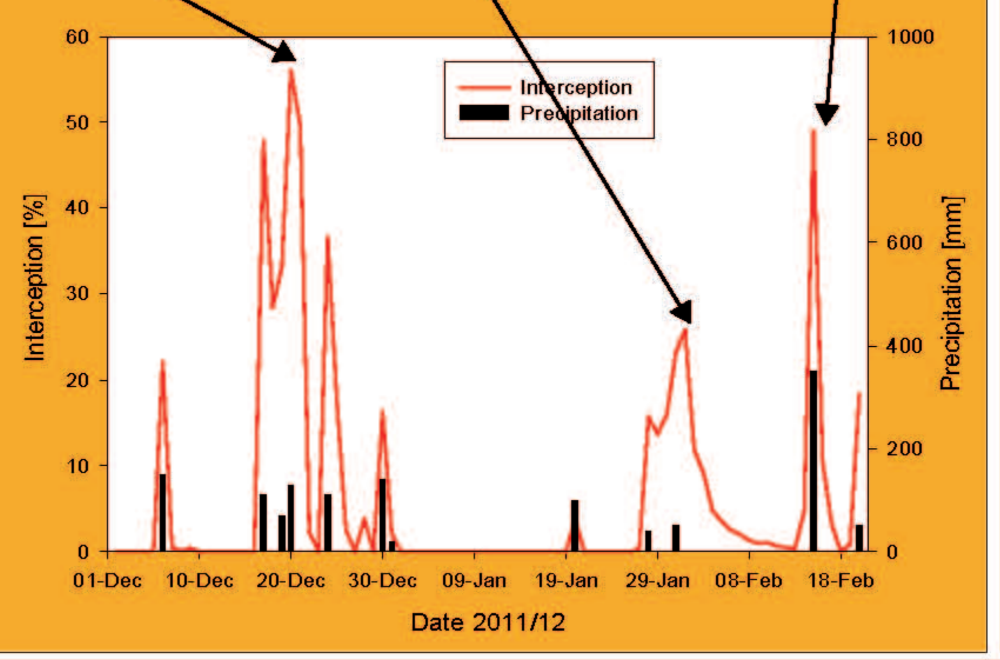


	Size	Elevation	Sub-Basins	Forest Cover	SnoMoS	Cameras
	Km²	m		%		
Brugga	40	433-1493	6	79	38	19
Breg	158	738-1147	4	70	35	15
Kinzig	76	354-842	3	63	26	11

Interception

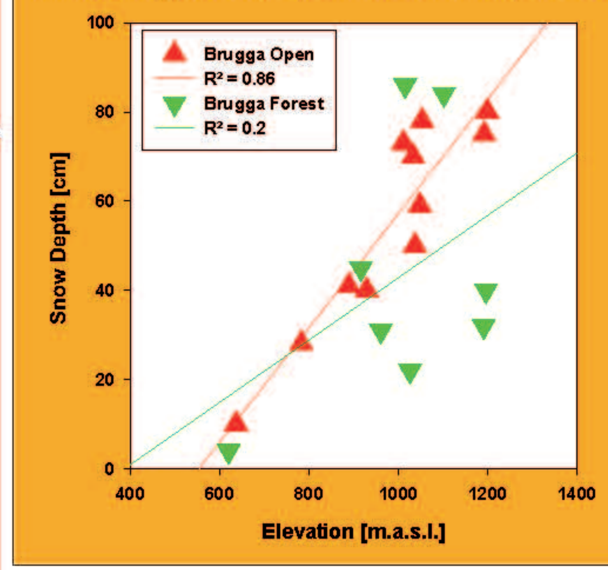
A significant amount of snowfall is initially intercepted in the forest canopy. This snow can subsequently fall to the ground as mass unload, it can melt and drip down as melt water, or it can sublimate directly back to the atmosphere.

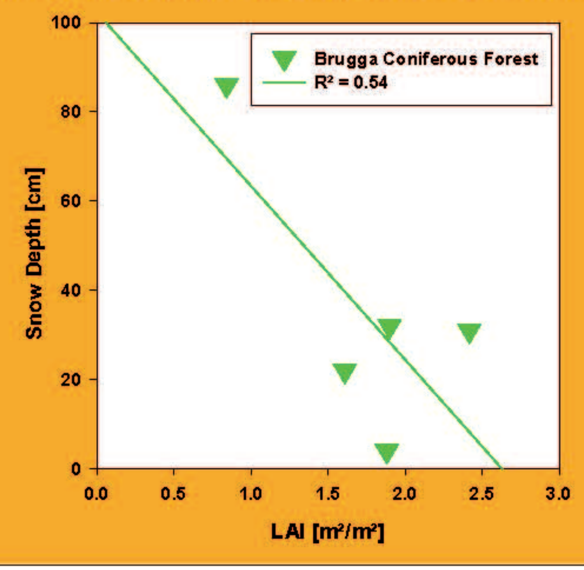
The amount of snow intercepted in the tress depend on several factors such as snowfall amounts air temperatures during the snowfall and tree species. The Figure on the right shows that more snow was intercepted in the canopy on Dec. 20, 2011 than on Feb. 15, 2012 even though more snow fell on Feb. 15. The reason is most likely the difference in air temperatures during the events which was -1.5°C in December compared to -5.5 °C in February. The warmer temperatures result in more flexible tree limbs and lead to the building of „ice bridges" between the individual needles and snowflakes. Thus more snow can accumulate in the canopy during „warmer" periods.

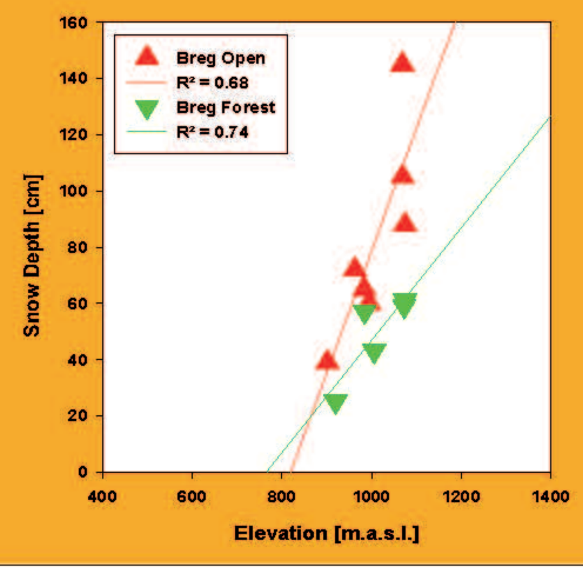





Peak Snow Depth Amounts

Peak snow amounts are often thought to be closely linked to elevation. As can be seen on the Figures, the relation between snow depth and elevation was quite strong in our study basins. However, in basins that have a lot of different types of forest cover (such as the „Brugga" basin) the relationship for forest locations becomes weak. In such basins the „Leaf Area Index" of the forest location is actually a much better predictor for peak snow cover amounts. The Figures also show that peak snow cover amounts are generally much higher for open areas compared to forest locations for comparable elevations.







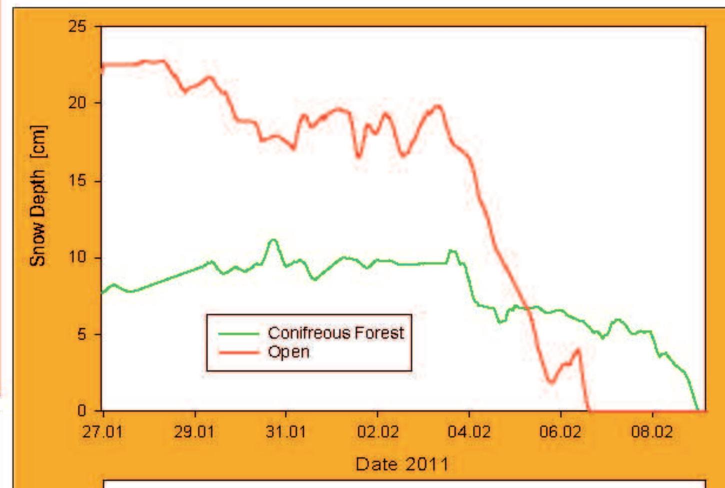
Snow Melt

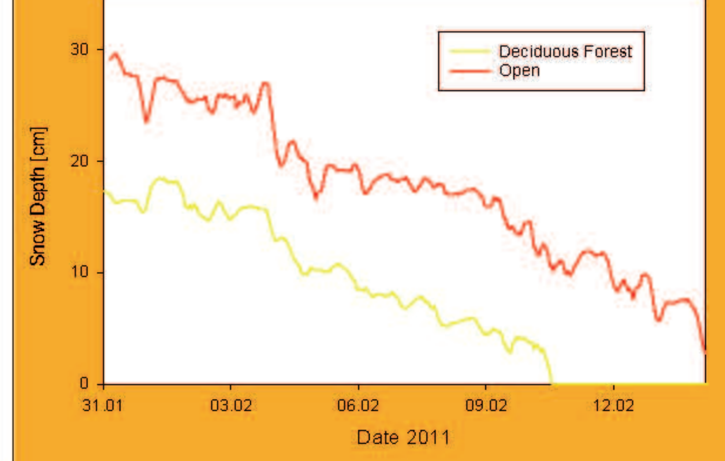
The most important terms of the snowmelt energy balance are generally net radiation and the turbulent fluxes of sensible and latent energy. The vegetation greatly influences these factors and therefore the melt of a snow cover underneath the forest vegetation in a variety of ways. Firstly, the canopy significantly reduces the amount of solar radiation reaching the snow cover. Secondly, the wind speeds underneath the forest canopy are considerably lower. This affects the turbulent exchange of sensible and latent energy. On the other hand, trees, even if they are snow covered, have a considerably lower albedo than snow covered open areas. The increased absorbed solar radiation by the canopy leads to higher canopy temperatures, which in return causes greater amounts of thermal (long wave) radiation being emitted towards the snow cover. The relative importance of these factors is dependent on several factors such as canopy density, gap size and distribution, geographical position, and meteorological conditions.

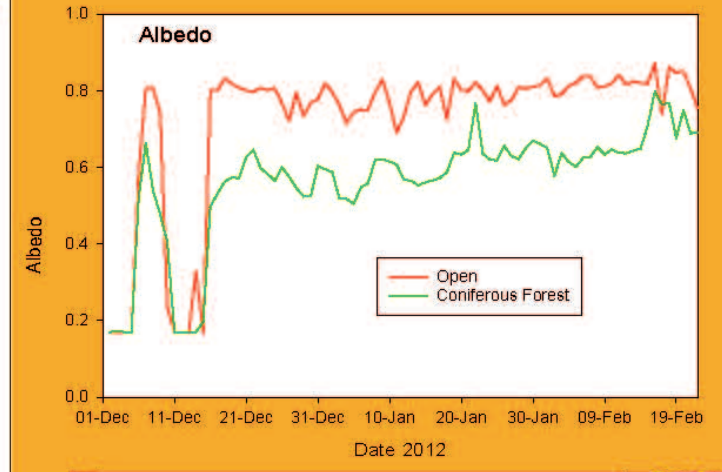
The Figures on the right show a comparison of the snow depths for the 2011 melt period for open areas versus a very dense coniferous forest and a much more open deciduous forest. The comparison shows that the dense forest vegetation results in greatly reduced melt rates while the melt rates in the deciduous forest are very similar to those observed in adjacent open areas.

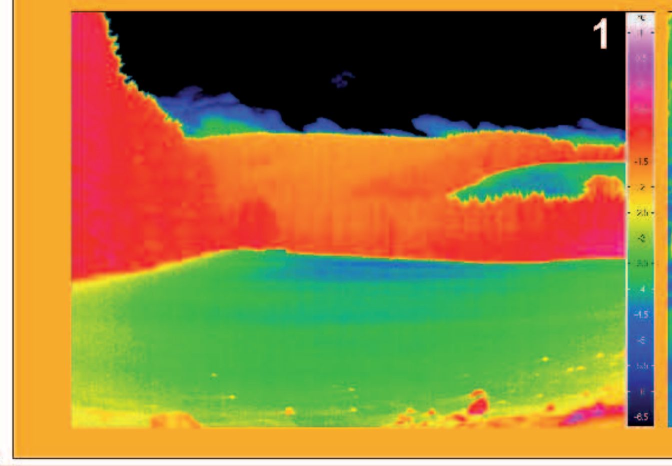
Another factor that needs to be considered is the difference of snow albedo of snow covers in open versus forested areas. The comparison shows that the albedo of snow underneath forest vegetation is almost constantly lower than in adjacent open areas mostly due to needles small branches and other debris being deposited on the forest snow cover.

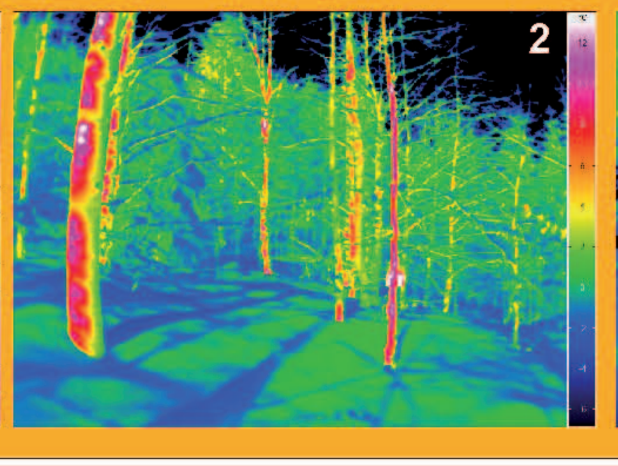
Finally, the thermal pictures below show the difference in temperatures between the forest canopy and the snow cover. Picture 1 shows the difference between the temperatures of a coniferous forest canopy versus an open snow cover for a cold overcast winter day. The second and third picture show the conditions in a deciduous and a coniferous forest for a sunny winter day. It becomes evident that the canopies and especially the stems of the trees are much warmer than the snow cover. Furthermore, the pictures show that much more solar radiation reaches the ground underneath the more open deciduous forest (Picture 2) than under a dense coniferous forest (Picture 3).

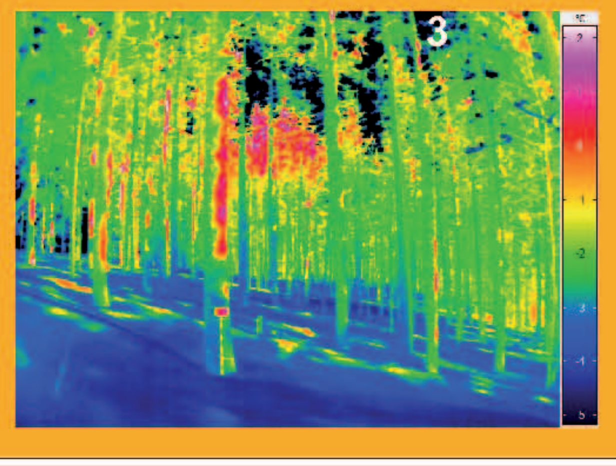




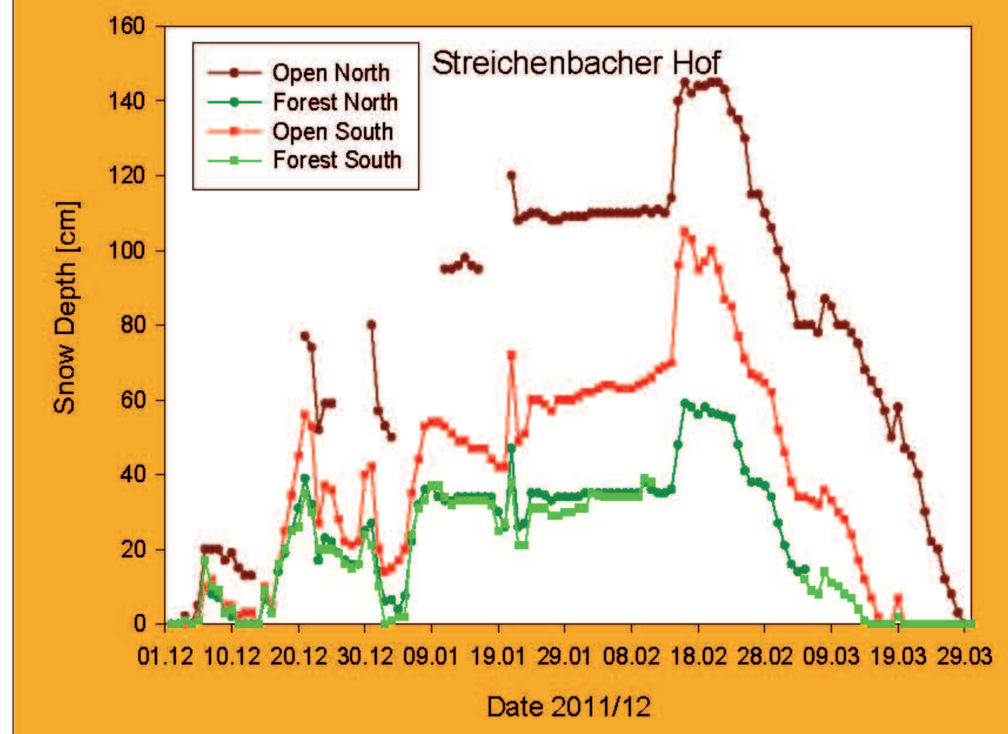








Snow Cover Evolution



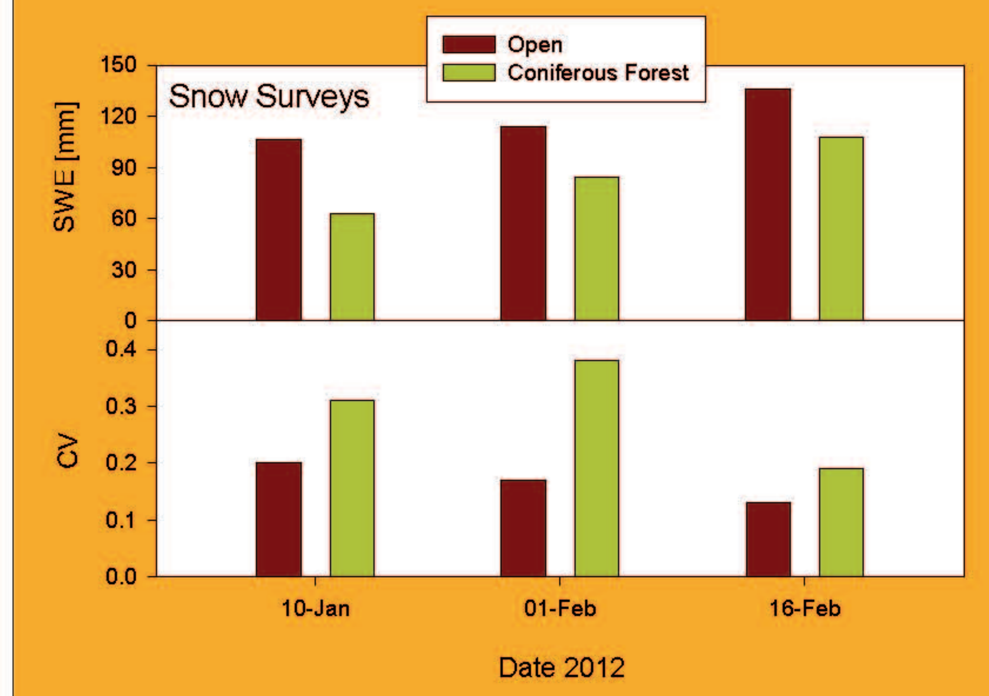
The Figure shows the comparison of 4 stations located in very close proximity two located in open areas of different exposure, two located underneath dense coniferous forests also with different exposures. The data shows that as expected, the north facing open area has the deepest snow pack. The south facing open area has considerably less snow, however, its snowpack is still much deeper than any of the forest snow covers. The two forest locations show virtually identical snow depths indicating that for forest snow covers exposure is not as important. Rather, the determining factor seems to be canopy density.

The observed overall difference in snow depth between open and forested areas clearly show how important the differences introduced by topography and vegetation are even for moderately high mountain ranges.

Numerous snowfall and snowmelt periods were analyzed for the first two winters of the project. The table shows the averages for interception losses and melt rates (compared to open areas) for coniferous and deciduous forests. The data again exhibits that the generally denser coniferous forest vegetation has a much larger impact on snow cover evolution than the less dense deciduous forests.

	Interception	Melt Rate
	%	%
Coniferous Forest	35.2 (63 Events)	66.5 (36 Events)
Deciduous Forest	9.7 (23 Events)	92.3 (20 Events)

Snow Surveys



Three detailed snow surveys were carried out over the winter to study the small scale variability present in the snow cover. The surveys included 7 locations each consisting of a survey in an open area and one in an adjacent forested area. Each survey 50 snow depth and 10 snow density measurements were conducted. The averaged results shown in the Figure beside once again show the decreased amount of snow present underneath the forest vegetation. The results also show that the small scale variability of the forest snow cover is much larger. This is the result of the more complex accumulation patterns, especially the canopy density dependent interception losses and the irregular mass unload of initially intercepted snow, but also the much more heterogeneous melt patterns with melt rates depending on things like proximity to tree stems and the very complex transmission patterns of solar radiation through the canopy.

Future Work

The continuous high spatial and temporal resolution of our observational data will allow us to analyze individual events and relate the observed snow evolution processes to the meteorological, topographical, and vegetational conditions present at the time or at the individual location. This should allow for a much better understanding of the relative importance of individual processes during specific conditions.

Furthermore, as the overall project focuses on the improved prediction of stormflow runoff during rain on snow events, the snow and meteorological data collected so far will be augmented by observations of soil moisture, ground water levels, and runoff in smaller streams to gain a better understanding of the spatially variable runoff response of basins to snowmelt and rain on snow runoff events. The obtained datasets will be used as input and validation data for several distributed hydrological models of different complexity. Models used will include complex, physically based research models and simpler process and index based models suitable for flood forecasting.

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

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