SNOW DEPTH AND DANGER OF AVALANCHES UNTIL NOW AND IN FUTURE

GIS-MODELLING OF CLIMATE CHANGE IMPACT ON AUSTRIAN SNOW COVER AND AVALANCHE RELEASE SUSCEPTIBILITY

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MOTIVATION

Digital maps of the snow depth are basis of the assessment of the avalanche release susceptibility and of the protection effect of forests and defence constructions. Climate scientists predict a decrease of snow accumulation and an increase of the proportion of fluid precipitation in the Austrian Alps as a response of climate change. This could lead to a change of avalanche danger. Because of their spatial resolution, presently available digital maps of recent snow depth result in insufficient avalanche susceptibility maps. These maps also may underestimate the snow depth of high altitudes as a consequence of the lack of meteorological stations in high altitudes and because of the derivation from the elevation only by linear extrapolation. There are clues to a non linear behaviour or a trend break of the gradient. Regardless of the uncertainties of predictions and modelling, avalanche risk adaptation strategies to climate change need an estimation of future average snow pack conditions and spatial avalanche susceptibility. Especially the adaptation of the protection forest and high altitude afforestation planning require maps of the terrain prone for avalanche release now and in the future.

METHODS

Snow depth data from 436 meteorological stations in Austria and a digital elevation model with a spatial resolution of 30 m had been the basic of spatial modelling of snow depth and avalanche release susceptibility for 1961-1990 and 2071-2100.
The average maximum of the full snow depth is an indicator of the frequency of large snow depth and of the average snow cover duration. Regional regressions and GIS interpolation techniques were used to compute an area-wide gridded dataset of the average maximum full snow depth of the climatic normal period 1961-1990 for Austria. The delineation of snow regions based on the regionalisation of Schöner & Mohnl (2003). This was also the basis for regional linear regressions to derivate the snow maps of the Hydrological Atlas of Austria (DIGHAÖ). Their regions were modified, because of the results of cluster analyses of snow characteristics of the climatic stations. Linear and non linear functions were used to estimate the snow depth from the altitude. Interpolation of residua was carried out with the Inverse Distance Weighting method.
From time series 1961-1990 of 86 climatic stations distributed over Austria the maximum full snow depth for different return periods was calculated by adaption of the observed distribution to the Gumbel-distribution function. Because it concerns an adaptation from average and standard deviation, the values correlate with the average of the maximum. Hence, the maximum snow depth of return periods could be calculated area-wide from the map of the average maximum snow depth.
There is a high correlation between the average snow cover duration, the average air temperature and the average maximum snow depth. Thus, an estimation of the average maximum snow depth 2071-2100 was made on basis of a map of the mean air temperature 1961-1990 and the prognosticated warming of +4° Celsius referred to results of the PRUDENCE project.
According to the GIS approach of Klebinder et al. (2009) the areas with basic susceptibility for avalanche release were calculated for snow cover conditions of 1961-1990 and 2071-2100. This

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approach supposes at least 50 cm average maximum snow depth and a slope gradient between 28 and 55 degree as limits of avalanche release susceptibility for recent climatic conditions. Because of the prediction of an increased proportion of fluid precipitation, wet snow covers could occur more frequently. For such conditions a lower limit of the slope gradient of 25 degrees was used.

RESULTS AND CONCLUSIONS

The model results are grid maps. The average maximum snow depth 1961-1990 ranges from 3 to 750 cm (Fig. 1). The mean of the maximum snow depth for a return period of 150 years is 203 cm (11-1278 cm). The non linear regression functions resulted in a higher proportion of areas with an average maximum of more than 250 cm compared with the snow model of the DIGHAÖ. The model overestimates the snow depth in some regions for altitudes over 3,000 m. Data availability is not adequate for a reliable estimation of the snow depth in the high altitudes. Linear regression models might underestimate the snow depth of the high altitudes over about 1,800 m above sea level.

An average warming of +4° Celsius may respond by a reduction of the mean duration of the snow cover of 78 % (from 6 in high to 100 % in low regions). The mean reduction of the average maximum snow depth might be 59 % (1 to 100 %). In contrast to these results up to now a decreasing trend of the maximum snow depth could be ascertained only at few Austrian snow stations. Nevertheless, the annual variability is very high in proportion the length of the time sequences. Assessments about the change of heavy snowfall are not possible up to now.

The area prone for avalanche release (without effects of forest and defence constructions) would change from 11.2 to 5.5 % of the country's territory. But the potential of the occurrence of large avalanches from high altitudes would decrease only in some regions. The today's "core areas" of the avalanche danger would be endangered furthermore. A "wet snow scenario" could activate 168.000 hectares of new potential release areas in higher altitudes. The reduction of snow accumulation and the increase of rain in winter would lead to qualitative change of snow pack. This also would entail changes of the protection effect of forests. They prevent the release of wet snow avalanches not so efficiently as those of dry ones.

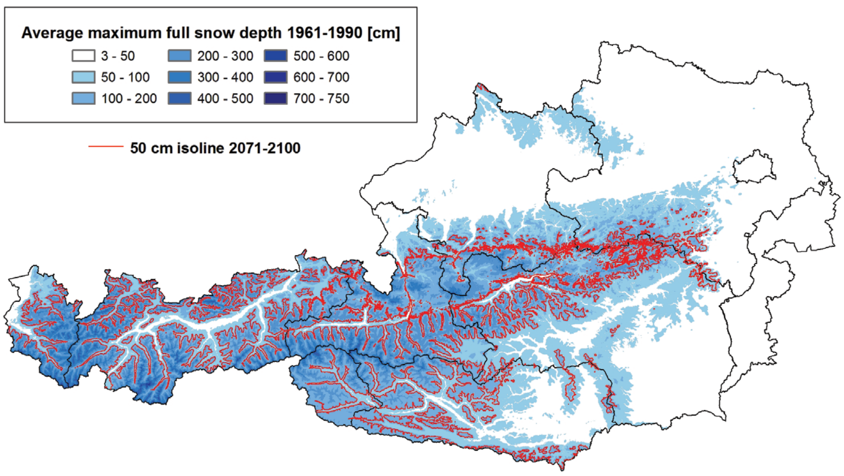

Fig. 1 Gridded dataset of the average maximum snow depth 1961-1990 and shift of the 50 cm isoline

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