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Long term trend of snow depth at Sonnblick (Austrian Alps) and its relation to climate change

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Abstract:

The extensive snow measurement network of the Sonnblick region (Hohe Tauern, Austrian Alps) is used to describe temporal trends of snow-depth as well as its relation to climate change for a high-elevated site of the European Alps (2400–3100 m.a.s.l.). Spatial representativeness of single snow stakes, with readings back to 1928, is derived for maximum snow-depth in May using a spatially dense snow depth probing from glacier mass balance measurements. Long-term trends of snow depth show a significant reduction in the contribution of snow accumulation from core-winter (1 December to 1 March) compared to early and late-winter periods. Largest values of snow-depth since 1928 were measured in the 1940s and 1950s. Comparison of monthly changes in snow-depth with precipitation measurements underlines the high influence of wind drift on snow-depth during winter season from 1 October to 30 April. Whereas inter-annual variability of maximum snow-depth is better explained by low elevation precipitation measurements than by local (high elevation) precipitation measurements, the longer-term mean of local precipitation measurements, however, fits well to the snow-depth measurements, if a mean snow-density of about 400 kg m^{-3} is assumed (which matches field observations). Both maximum snow-depth and winter season precipitation show a clear decreasing trend for inter-annual variability. A statistical relationship between air temperature and fraction of solid precipitation is used for estimation of temporal trends in the fraction of solid precipitation at measurement sites. For summer a decrease of about 1% of solid precipitation per decade was found for the lowest elevated sites whereas fraction of solid precipitation in winter remains stable. Relation between snow-depth and climate is investigated by means of local climate data of Sonnblick-Observatory (SBO) and by means of the North-Atlantic Oscillation Index (NAOI). Whereas winter air-temperature is significantly correlated with the NAOI, for winter precipitation and snow depth on 1 May no correlation was found with NAOI. Copyright © 2008 John Wiley & Sons, Ltd.

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INTRODUCTION

Snow plays a crucial role in the lives of the residents of the Alps. Beside its importance for Alpine tourism and economy, snow significantly influences Alpine hydrology, ecology, geo-hazards (e.g. avalanches), permafrost as well as glacier behaviour (e.g. Haeberli and Beniston, 1998; Beniston, 2000). More than one-sixth of Earth's population relies on glaciers and seasonal snow pack for their water supply (Barnett *et al*., 2005). Thus snow has been stressed in numerous studies. The quantification of amount of snow and its change in time because of climate change is crucial for estimation of runoff. Modelled future climate warming (IPCC, 2001) would alter not only the amount of snow melt (which is of great influence on hydro-power production) but also timing of discharge and further the vegetation cycle. Therefore, various studies investigated the sensitivity of snow cover on climate change especially on air temperature (Hantel *et al*., 2000; Beniston *et al*., 2003a,b). From these references a strong height dependency of sensitivity of snow cover on air temperature can be concluded, which follows from the deviation of mean air temperature of respective altitudinal range from the melting point (0 °C).

The availability of satellite based snow records enabled scientists to investigate spatially large scale snow cover measures. In fact these series are especially useful to study temporal changes in snow cover extent. Unfortunately, the satellite snow records go back only a few decades. However, Alpine *in situ* observations of snow cover are available since the 19th century. In general snow depth was investigated for lower elevation sites (lower than 2000 m.a.s.l) of the Alps whereas information about snow cover variability and change for the period of instrumental measurements is sparse for the higher elevated sites of the Alps.

During the last few years much effort was also made to derive long term and homogeneous data sets of snow cover measures for instance the Swiss part of European Alps (Laternser and Schneebeli, 2003). On the basis of such a high quality data set Scherrer *et al*. (2004) and Scherrer and Appenzeller (2006) studied in detail the role of local- and large-scale climate variability on days with snow-cover, new snow sum and snow depth in Switzerland. Principal component analysis of new snow sum and snow depth in Switzerland yielded three major patterns which are a pattern of winter's rich or poor

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