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Climate change in alpine areas in central Austria between 1961 and 2006

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Summary

Monthly values of four different climatic elements (mean temperature, precipitation sum, sum of freshly fallen snow and maximum snow depth) from 44 meteorological stations were analysed for quantifying climatic trends over a 46 year period (1961-2006) at six high-altitude areas in the mountains of central Austria, partly located in the Hohe Tauern National Park. The trends of the four climatic elements were investigated by applying different statistical approaches. Our results indicate a significant temperature rise of mean annual temperatures of 1.3 to 1.4°C since 1961 in all six areas at the reference altitude of 2500 m a.s.l. The highest increase in temperature occurred during the summer season (JJA) with ~1.9°C. The trends of mean annual precipitation, sum of freshly fallen snow and maximum snow depth are not significant at all six sites. However, the annual precipitation sum seems to have decreased in two of the six areas (-75mm) whereas in one area it increased substantially (+160mm). The annual sum of freshly fallen snow decreased in five areas. The maximum snow depth decreased in all six areas. Our results clearly demonstrate that climatic conditions changed significantly within the last decades in central Austria.

Keywords

Temperature, Precipitation, Snow, Climatic trends, Hohe Tauern National Park.

Objectives and Study areas

The changing climate system affects high altitude regions by strong impacts on glaciers and permafrost (Haeberli & Burn 2002). Scientific research in Austria dealing with this topic is carried out in various projects and several studies have already been published (e.g. Formayer et. al. 2001). This study quantifies trends of four climatic parameters (mean temperature, precipitation sum, sum of freshly fallen snow and maximum snow depth) over a 46 year period (1961-2006) at six high-altitude areas in the mountains of central Austria (Fig. 1). These six areas (5 in the Hohe Tauern Range, 1 in the Niedere Tauern Range) are investigated by a project focussing on the effects of climate change on high mountain environments named "ALPCHANGE - Climate Change and Impacts in Southern Austrian Alpine Regions" (www.alpchange.at).

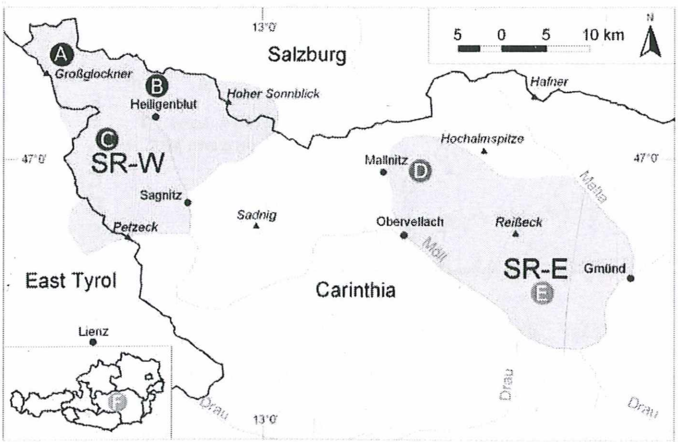

Figure 1: Location of the six selected ALPCHANGE study sites:
A=Pasterze Glacier
B=Schareck - Fallbichl
C=Central Schober Mountains
D=Dösen Valley
E=Hintereggen Valley
F=Hochreichart

Method and data base

The essential input for climate impact analysis is represented by the local data base which consisted in the framework of this study of monthly values from 44 observational meteorological stations (Table 1) nearby the six study sites depicted in Figure 1. Trends of the four climatic elements were investigated by applying different statistical approaches. Correlation analysis was used for filling data gaps, linear regression to calculate the conditions at reference altitude 2500 m a.s.l. and the overall linear trend. Mean differences of the two 23-year periods for mean temperature, precipitation sum and maximum snow depth (1961-83 vs. 1984-2006) as well as the two 18-year periods for the sum of freshly fallen snow and (1971-1988 vs. 1989-2006) were calculated. The statistical significance was tested with signal-to-noise ratios (Table 2) which are defined as the absolute trends divided by the standard deviations as well as Student´s t-tests (95% confidence limit).

Table 1: List of observational meteorological stations with altitude (m a.s.l.) used for the calculations of climatic elements at the six selected sites 1961-2006: A=Pasterze Glacier, B=Schareck - Fallbichl, C=Central Schober Mountains, D=Dösen Valley, E=Hintereggen Valley and F=Hochreichart.

name	altitude (m a.s.l.)	temperature	precipitation	fresh snow	snowdepth
Sonnblick	3105	A,B,C,D,E,F	A,B,C,D,E	A,B,C,D,E,F	A
TG4	3076		A,B,C		
PF3	2930				F
PF4	2893				C,D
PF2	2850				A
PF1	2800				B,D,E
Rudolfshütte	2304	A,B,C	A	A	A,B
Reisseckhütte	2256	D,E	E	D,E,F	D,E,F
Margaritze	2070	A,B,C			
Mooserboden	2036	A	A,B	A,B	A,B,F
Hochalm	2010		D		
Kölnbrein	1973	D	D		
Palik	1950		A,B,C		
Goldeck	1885	E	E	E	E
Zettersfeld	1820	C	C	C	C
Edelrautehütte	1725	F			
Gößkessel	1673		D,E		
Felbertauern	1650		A	A	A
Wastlbaueralm	1634		D		
Planneralm	1605	F		F	F
Schmelz	1560	F			F
Wöllatal	1550		D	D	D,E
Hochreichart	1500		F		
Obermillstätter Alpe	1450			E	E
Heiligenblut	1380		A,B,C	A,B	A,B
Kals	1347		C	C	C
Hohentauern	1265		F	F	F
Teuchl	1260		E	D,E	D,E
Iselsberg-Penzelsberg	1208		C	C	C
Mallnitz	1196		D	D	D
Innerfragant	1195		D	D	D
Döllach	1071		C	B,C	B
Matrei in Osttirol	1050			C	C
St.Johann am Tauern	1050		F	F	F
Oberzeiring	930		F	F	F
Wald am Schoberpass	890		F	F	F
Seckau	855		F		F
Ingering	850		F	F	F
Malta	830		E	E	F
Stall	820		D	C,D	D
St.Johann im Walde	750			C	C
Kleindorf	742			D	D
Mautern	735		F	F	F
Kraubath an der Mur	605	-	F	F	F

Table 2: Significance criteria used in this study (after Rapp & Schönwiese 1996)

significance	signal to noise ratio (SNR)	confidence limit (CL)
not significant	SNR ≤ 1.645	CL ≤ 90%
weak significant	1.645 < SNR ≤ 1.960	90% < CL ≤ 95%
significant	1.960 < SNR ≤ 2.576	95% < CL ≤ 99%
strong significant	2.576 < SNR	99% < CL

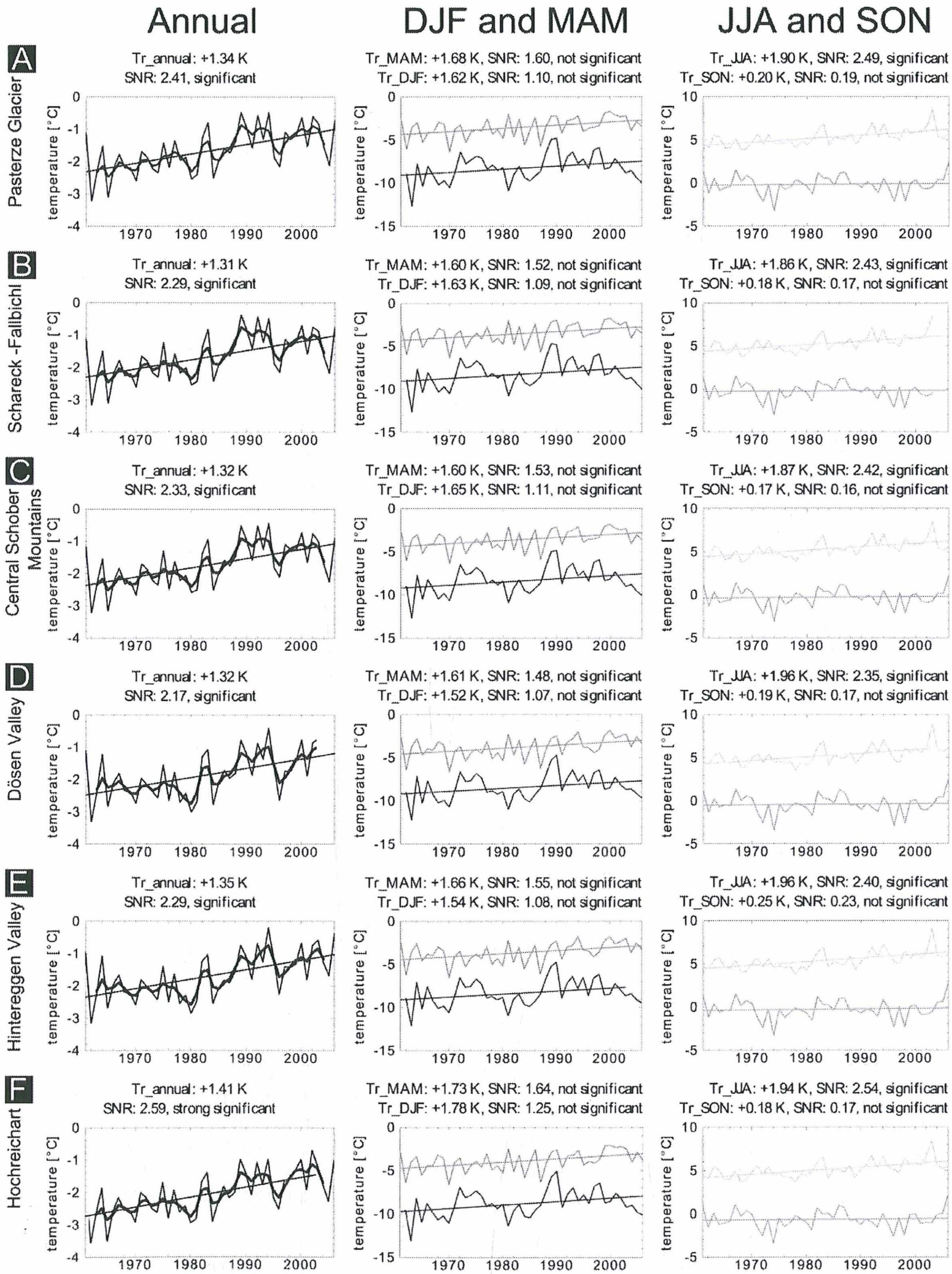

Figure 2: Mean annual (incl. moving 5-year means with gauss filter) and seasonal temperatures and absolute trends including signal-to-noise ratio (SNR) at the six selected sites in 2500 m a.s.l. 1961-2006: A=Pasterze Glacier, B=Schareck - Fallbichl, C=Central Schober Mountains, D=Dösen Valley, E=Hintereggen Valley and F=Hochreichart.

Results

Our results indicate a significant temperature rise of mean annual temperatures of 1.3 to 1.4°C since 1961 in all six areas. The highest increase in temperature occurred during the summer season (JJA) with ~1.9°C. May experienced the highest warming of all months with values of up to 2.4°C (Figs. 2. & 3).

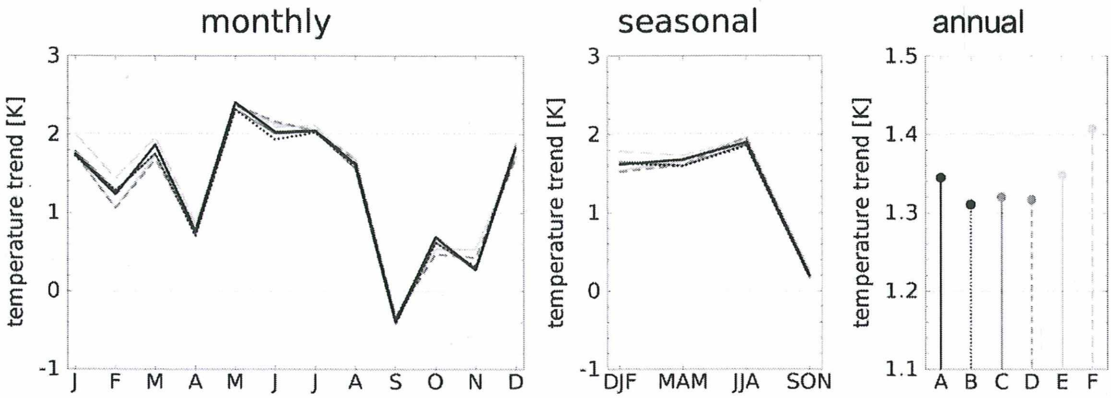

Figure 3: Monthly, seasonal and annual absolute temperature trends at the six selected sites in 2500m a.s.l. 1961-2006: A=Pasterze Glacier (black line), B=Schareck - Fallbichl (black dots), C=Central Schober Mountains (grey line), D=Dösen Valley (grey broken), E=Hintereggen Valley (light grey) and F=Hochreichart (light grey broken).

Mean annual precipitation trends are not significant at all six sites. However, the annual precipitation sum seem to have decreased in two of the six areas (-75mm) whereas in one area it increased substantially (+160mm). Only the autumn season (SON) reveal an increase in precipitation at all sites (Fig. 4).

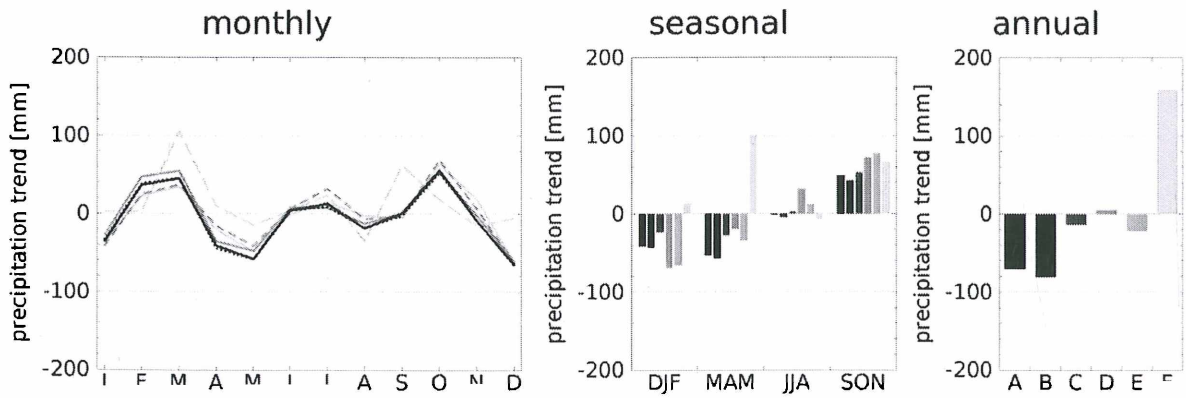

Figure 4: Monthly, seasonal and annual absolute precipitation trends at the six selected sites in 2500m a.s.l. 1961-2006: A=Pasterze Glacier (black line), B=Schareck - Fallbichl (black dots), C=Central Schober Mountains (grey line), D=Dösen Valley (grey broken), E=Hintereggen Valley (light grey) and F=Hochreichart (light grey broken). Note greyscale application for seasonal and annual values.

The trends of the annual sum of freshly fallen snow as well as the maximum snow depth reveal no statistical significance. Despite this fact the annual sum of freshly fallen snow decreased in all areas at the Hohe Tauern Range sites by 80 to 130 cm (Fig. 5). Increasing sums are revealed at the five sites located in the Hohe Tauern Range (A-E) in autumn and at the Niedere Tauern Range site (F) in winter. The annual maximum snow depth decreased in all areas by 40 to 210 cm, which is principally based on the reduction of summer values of up to 180 cm (Fig. 6).

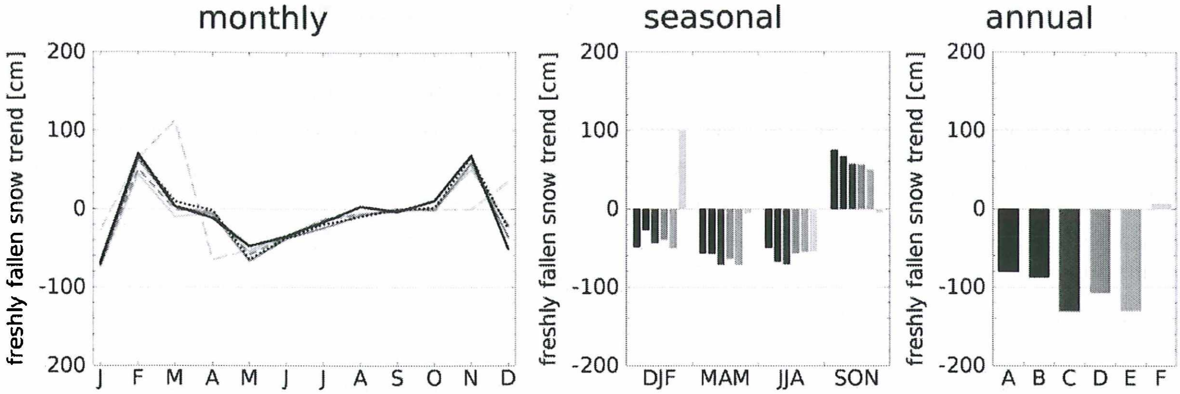

Figure 5: Monthly, seasonal and annual absolute trends in freshly fallen snow at the six selected sites in 2500m a.s.l. 1971-2006: A=Pasterze Glacier (black line), B=Schareck - Fallbichl (black dots), C=Central Schober Mountains (grey line), D=Dösen Valley (grey broken), E=Hintereggen Valley (light grey) and F=Hochreichart (light grey broken). Note greyscale application for seasonal and annual values.

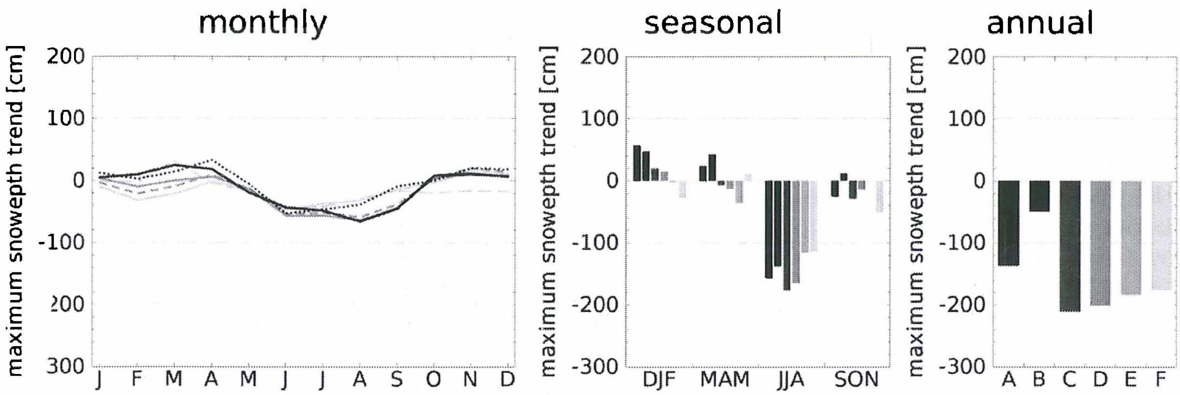

Figure 6: Monthly, seasonal and annual absolute maximum snow depth trends at the six selected sites in 2500m a.s.l. 1961-2006: A=Pasterze Glacier (black line), B=Schareck - Fallbichl (black dots), C=Central Schober Mountains (grey line), D=Dösen Valley (grey broken), E=Hintereggen Valley (light grey) and F=Hochreichart (light grey broken). Note greyscale application for seasonal and annual values.

In general, the overall linear trends for all four parameters were confirmed by the mean difference of the two 23-year (temperature, precipitation sum and maximum snow depth) and, respectively, 18-year periods (sum of freshly fallen). Furthermore, some differences of freshly fallen snow and maximum snowdepth are significant particularly in summer even though the trends are not significant.

Discussion and Conclusion

Observed atmospheric warming in the European Alps is much higher compared to the global average. Based on IPCC (2007) the global linear warming trend over the studied 46-year period is in the range of 0.46-0.74°C. Based on our study the warming in the high mountains of central Austria (reference altitude 2500 m a.s.l.) is 1.3 to 1.4°C and hence two to three times higher compared to the global average confirming previous studies (Böhm et al. 2007). Amongst other environmental effects, this significant warming caused substantial glacier retreat and perennial snow field reduction at all six sites strongly affecting their hydrological systems.

Acknowledgements

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