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Climate Trends from Homogenized Snow and Precipitation Data in the Tatra Mountains

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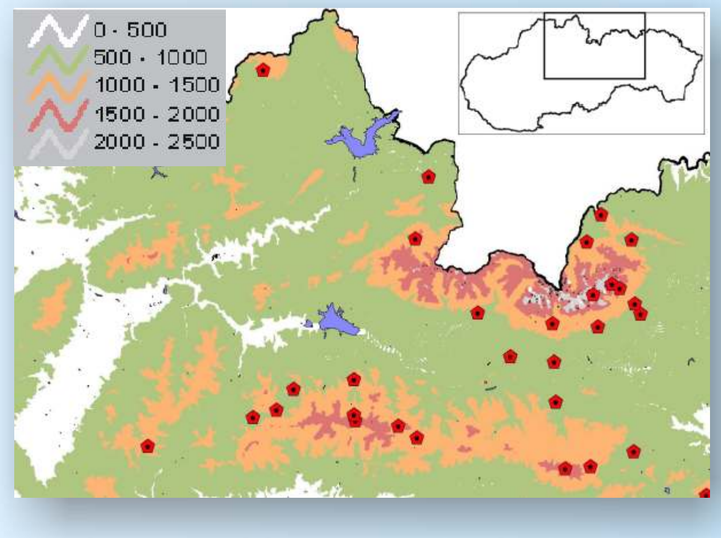
ABSTRACT

The dynamics of snow cover characteristics varies from region to region, as well as for different altitudes. Available long-term daily snow cover depths (S), precipitation types (PT) and totals (P) from selected stations (above 700 m a.s.l.) in the Tatra Mountains are used to scrutinise the mountain climate at elevations, where the station network is sparse. Prior to this inspection, an attempt to homogenize P and S time series (the longest since 1921/22 winter season) is presented. Results from several homogeneity tests (using AnClim software) are discussed and confronted with metadata. The influence of inhomogeneities, which may lead to climatological misinterpretation, is evaluated. Similar to some recent studies in the Alps, a critical altitude, where the negative trend for snow characteristics reverts to positive is analyzed and located. Generally increasing trends of both P and air temperature in analyzed area are the key factors that change the ratio of solid, mixed and liquid precipitation, changing thus the climate of snow. The negative trends of solid P become more pronounced at altitudes near the forest upper boundary (1000 - 1500 m a.s.l.), where the mixed and liquid P become prevalent. The reduction of snow in lower elevations of Slovakian mountains is slightly compensated with small increase of precipitation amounts.

Homogeneity Testing

Several homogeneity tests were performed on precipitation and snow depth time series using ***AnClim*** [5] software, focusing on Alexandersson single normal homogeneity test (***SNHT***) and Easterling & Peterson (***E-P***) test.
Absolute and relative (with reference series) homogeneity tests were first performed on raw unadjusted data. In the next step, the significant changes detected by tests were confronted with inhomogeneities documented in metadata files. The documented inhomogeneities were adjusted, and the testing repeated.



Study area with meteorological stations.

If both SNHT and E-P absolute and relative tests indicated the same year as significant, it was accepted even without any reasonable metadata. The *reference series* were created using squared correlation coefficients with surrounding stations (raw unadjusted time-series) as weights in weighted average.
Snow cover depth homogenization was based on results from precipitation testing. Relocation of a station was the most frequent reason.

SNHT and E-P test successfulness for precipitation time series. The “false” discontinuities near year 1994 are probably caused by natural climatological fluctuation. Significant years are **bold**. Adjustment factors (AF) > 1 are prevailing, what causes shifting of linear trend of time series to lower or negative values.

Name	Inhomogeneity		AF	Absolute		Relative		Reason (from METADATA)
	Y/N	change date		SNHT	E-P	SNHT	E-P	
Lomnický štít	Yes	7.X.1959	0.766	**1961**	**1961**	**-**	**1976**	Rain gauge shifted +3 m
	Yes	II.1991	1.427	**1991**	**1991**	**1991**	**1991**	Modified evaluation method
Telgárt	No	*[1994]*	*[1.112]*	1994	1994	1997	1966;80	No
Štrbské Pleso	Yes	1.I.1961	1.058	1954	1965	**1978**	1970;78	Relocation +20 m
	Yes	2.XI.1992	1.18	1994	1982;94;65	**1993**	1992	Relocation to less wind-exposed place
Chopok	Yes	1.I.1961	0.752	**1961**	1961;82;87;94	1987	1979 **1987**	Reorganization of station network / method
Skalnaté pleso	No	*[1996]*	*[1.172]*	1996	1996; 2000	1962	-	No
Podbanské	No	-	-	**2001;**03	1996	1963	1969	No
Tatranská Lomnica	No	VII.1993	1.047	1964	1991	1980	1970;**76**;91	Relocation (down)
Oravská Lesná	No	*[1994]*	*[1.175]*	**1994**	1968;**94**	1972	1981	No
Ždiar-Javorina	No	-	-	1994	1996	1973	1973;89	No
Jasná	No	*[1990]*	*[1.127]*	**1990**	1990	1970	1990;97	changed observer
Luková p. Chopkom	No	*[1994]*	*[1.251]*	**1994**	1990;**94**	1983	-	No
Ždiar - Podspády	No	-	-	**1994**	1995	1983	-	No
Ždiar	Yes	1.IX.1987	1.169		1986		1986	Relocation (up)
	Yes	1.X.1989	1.063					Relocation (down)
	Yes	1.IX.1992	1.024	**1994**	**1996**	1996	1996	Relocation (down)
Štrba	No	-	-	2003	-	**1995**	1991	No
Zuberec-Zverovka	Yes	1.VII.2003	-	1994	1994	1982	-	Relocation

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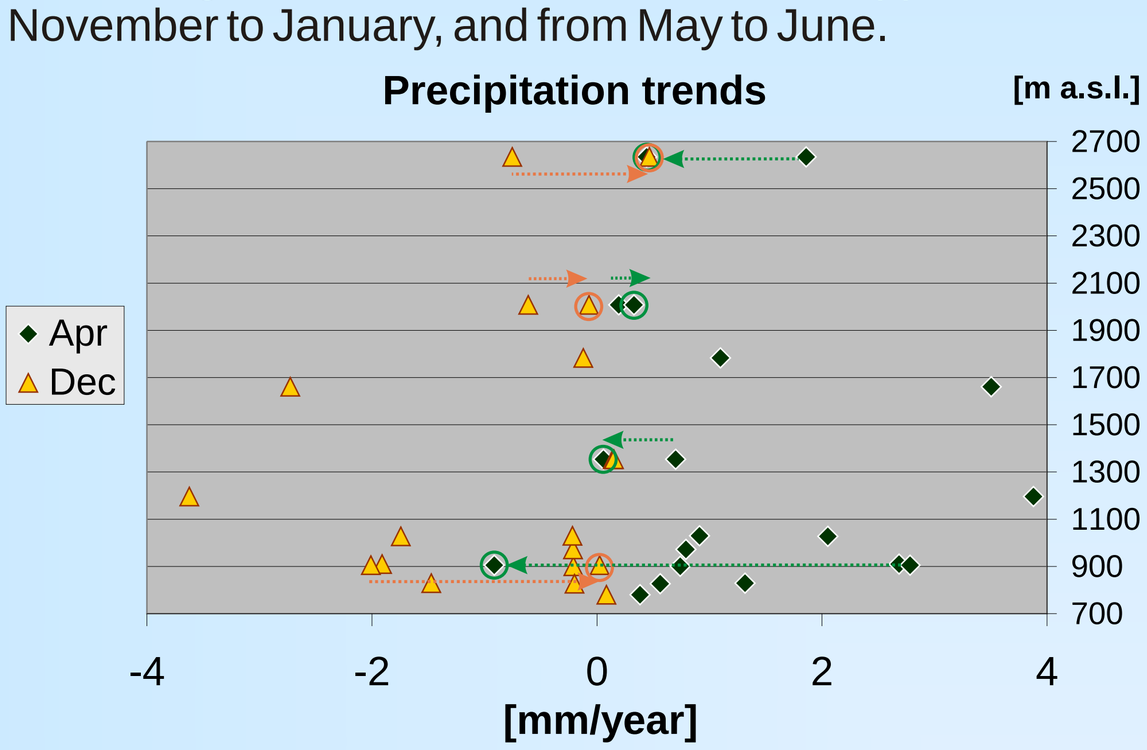
Results & Discussion

The station Lomnický štít (2635 m a.s.l.) is the highest meteorological station in Slovakia. Due to small area at the top of the peak and strong winds, the measurement of precipitation and snow is very problematic, and artificially increased by observer. Peak stations must be carefully used in climatological studies.

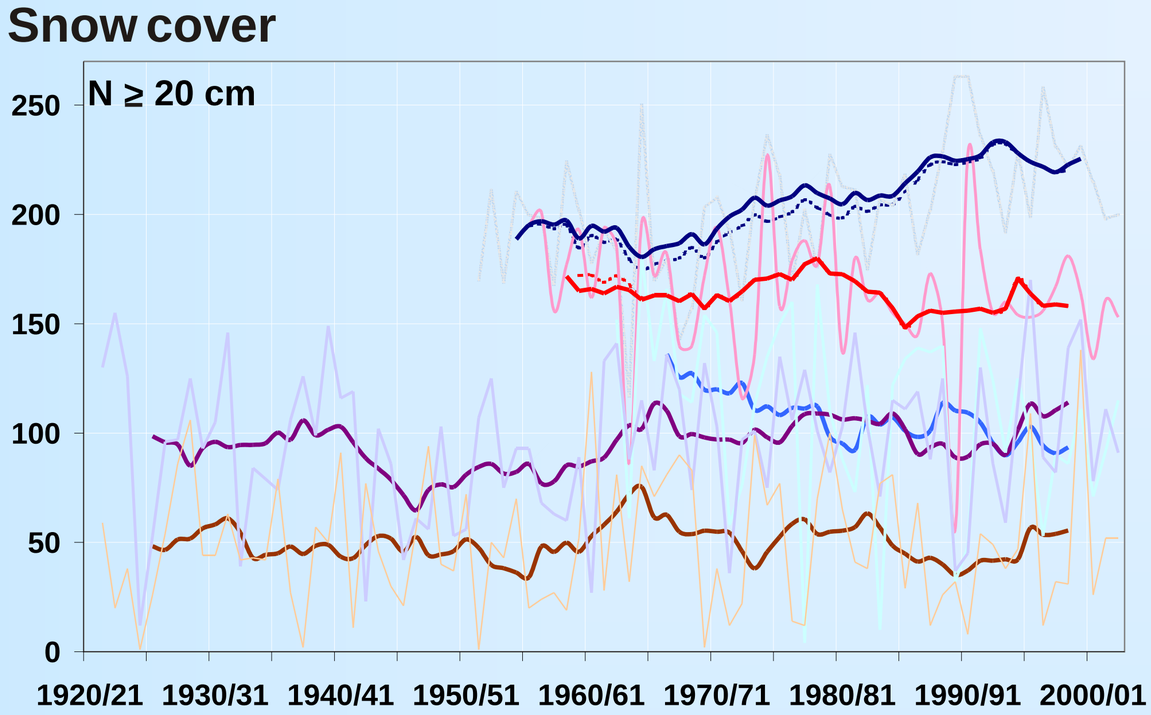
Precipitation

Unadjusted precipitation showed increase in April (significant) and July (moderate). Yearly precipitation shows slight increase. Notable decrease appears from November to January, and from May to June.



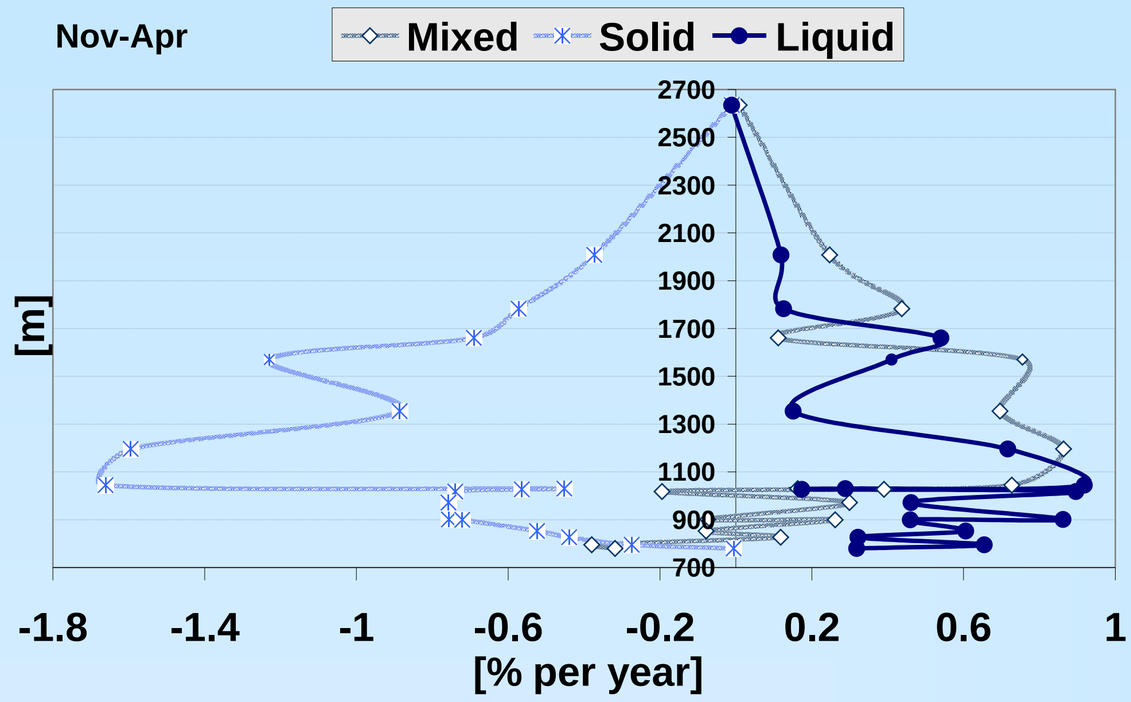
Recent monthly precipitation trends. Trends from adjusted data are circled. Arrows indicate change in trend caused by adjusting of inhomogeneity.

Snow cover



The number of days with snow cover ≥ 50 cm (and 9-year running averages) for winter seasons at selected stations (from top to low): 1 - Lomnický štít (2635 m), 2 - Chopok (2008 m), 3 - Skalnaté pleso (1783 m), 4 - Ždiar - Javorina (1030 m) and Liptovská Teplička (900 m). Note the difference between unadjusted series (dotted), and homogeneous (thick).

Precipitation types



Trends (1981/82 – 2002/03) of ratios of mixed (M), solid (S) and liquid (L) precipitation amounts to the total precipitation amount from November to April. Above upper forest boundary the decreasing trend of S and M fraction dampens. Estimated altitude, above which the snow trends become positive, lies above 2000 m.

Conclusions

Relocation of station was responsible in most cases for discontinuity in P and S time series.

Shifting of rain gauge up by only 3 meters in Lomnický štít was detected by most of tests only approximately.

The relocation of Tatranská Lomnica by few meters caused no significant change in time-series.

Absolute homogeneity tests were more successful.

Relative homogeneity tests need appropriate reference series. The best method is combination of various tests. Results for monthly time-series may be helpful when assuming abrupt change in yearly time-series.

General decrease of solid precipitation and snow cover duration was observed. There exists a critical altitude [2], where the negative trend reverts or stagnates. The trends become more pronounced at altitudes near to the forest upper boundary, where the M and L precipitation become prevalent.

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