

KONČEK CLIMATE SHIFTS IN THE TATRA MTS. BETWEEN PERIODS 1951-1980 AND 1981-2010

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Abstract. Identification of the borders of climatic regions and analysis of their geographical shifts in time can help us understand climate evolution in any territory. Based on the Konček climatic classification, climatic regions and sub-regions in the Tatra Mts. and the surrounding area have been specified. According to this classification, certain shifts in climatic regions and sub-regions towards the higher altitudes were registered in this region between periods 1951-1980 and 1981-2010.

Introduction

Analysis based on the Konček's method is among the most frequently used climatic classifications in Slovakia (Lapin *et al.*, 2002). The boundaries between different climate types tend to shift over time. Our aim is to specify climate regions and sub-regions using the Konček climatic classification scheme and to identify the shifts in boundaries in the Tatra Mts. and the surrounding area between the periods 1951-1980 and 1981-2010. The Tatra Mts. is located in the northern part of Slovakia. It has the high-mountain relief features. A characteristic sign of the surrounding area relief are mainly the hollows and the highland and upland relief.

Data and methods

The data from the Slovak Hydrometeorological Institute in Bratislava (air temperature, precipitation totals, wind speed) for several meteorological stations from Tatra region have been analyzed.

Konček's classification is based on the Konček's moisture index values, together with some air temperature characteristics (Konček 1955, Konček 1980, Lapin *et al.* 2002). The Konček's moisture index represents a simplified water balance characteristic. Its value is given by the formula:

$$Iz = 0.5R + r - 10T - (30 + v^2),$$

where R [mm] is the precipitation total in the growing period (April-September), frequently called the warm half-year,

r [mm] is the precipitation total exceeding 105 mm in average for winter season (December-February); the negative deviations are excluded,

T [°C] is the mean air temperature in the growing period, v [m.s⁻¹] is the mean wind speed measured at 14 h of MLT in the growing period.

Based on the Iz value together with further air temperature characteristics, the climatic regions for Slovakia have been identified (Konček 1980, Lapin *et al.* 2002). Three regions were selected using this method (warm, moderately warm and cold). The warm region has 50 or more so-called summer days annually in long-term average (with daily

maximum air temperature $\geq 25^\circ\text{C}$), the moderately warm region has less than 50 summer days annually in average and the July long-term mean temperature is 16°C or more. The cold region has the July mean temperature $< 16^\circ\text{C}$. The warm region has 7 sub-regions (differences exist in the values of mean January air temperature and values of Iz). The moderately warm region has 7 sub-regions (differences are in the values of January and July mean air temperatures and values of Iz). The cold region has 3 sub-regions (all are considered as very humid, differences being only in the mean July temperature with the limits 12 and 10°C ; for further details, see Lapin *et al.*, 2002, Melo *et al.*, 2009).

For the analysis and delimitation of climatic zones according to Köppen scheme, the two thirty-year periods were selected: the standard 1951-1980 and the 1981-2010 as the latest possible period.

Results and discussion

Individual isotherms of mean annual, January and July air temperatures towards the higher altitudes were shifted in the Tatra Mts. region between the periods 1951-1980 and 1981-2010 (Table 1).

Table 1. Isotherms altitude [m a.s.l.] in the Tatra Mts. and the surrounding area in the periods 1951-1980 and 1981-2010

T [°C]	Annual		January		July	
	1951-1980	1981-2010	1951-1980	1981-2010	1951-1980	1981-2010
-11			2585			
-10			2435	2585		
-9			2270	2420		
-8			2100	2270		
-7			1950	2105		
-6			1785	1955		
-5			695	1805		
-4			505	680		
-3	2490	2570		480		
-2	2335	2420				
-1	2185	2270				
0	2030	2115				
1	1880	1975				
2	1685	1815				
3	1485	1530				
4	1190	1270			2570	
5	870	985			2430	2585
6	645	755			2285	2445
7	495	615			2145	2300
8		480			2000	2145
9					1860	2000
10					1700	1860
11					1560	1690
12					1415	1520
13					1070	1300
14					940	1000
15					795	980
16					615	770
17						620
18						495

Generally, mountain climates exhibit great variation in the number of climatic sub-regions over a short distance due to

altitudinal differences and complex topography conditions. Analysis based on Konček climatic classification shows that during the 20th century and at the beginning of the 21st century certain territorial shifts in climatic sub-regions in the Tatra Mts. region have appeared. While in the period 1951-1980 three sub-regions of the moderately warm region (M2, M5, M7) and three sub-region of cold region (C1, C2, C3) occurred here (Table 2), in the periods 1981-2010 there were four sub-regions of moderately warm region (M1, M3, M5, M7) and three sub-region of cold region (C1, C2, C3). These sub-regions have following characteristics and climatic values: M1 - sub-region moderately warm, moderately humid, with mild winter, hilly land (mean January temperature above -3°C, mean July temperature $\geq 16^\circ\text{C}$, Iz = 0 to 60, up to 500 m a.s.l.), M2 - sub-region moderately warm, moderately humid, with cold winter, valley/basin (January $\leq -5^\circ\text{C}$, July $\geq 16^\circ\text{C}$, Iz = 0 to 60), M3 - sub-region moderately warm, moderately humid, hilly land or highlands (July $\geq 16^\circ\text{C}$, Iz = 0 to 60, appr. 500 m a.s.l.), M5 - sub-region moderately warm, humid, with cool to cold winter, valley/basin (January $\leq -3^\circ\text{C}$, July $\geq 16^\circ\text{C}$, Iz = 60 to 120), M7 - sub-region moderately warm, very humid, highlands (July $\geq 16^\circ\text{C}$, Iz ≥ 120 , mostly above 500 m a.s.l.), C1 - sub-region moderately cool (July $\geq 12^\circ\text{C}$ to $< 16^\circ\text{C}$), C2 - sub-region cool mountainous (July $\geq 10^\circ\text{C}$ to $< 12^\circ\text{C}$), C3 - sub-region cold mountainous (July $< 10^\circ\text{C}$). New climatic sub-regions (M1 and M3) have been classified here in 1981-2010. More shifts of climatic regions and sub-regions towards the higher altitudes were registered here during this period.

Table 2. Ratio of individual Konček climatic sub-regions [%] in the Tatra Mts. and the surrounding area in the periods 1951-1980 and 1981-2010

Sub-regions	Ratio [%] in 1951-1980	Ratio [%] in 1981-2010
M1	-	0.3
M2	5.8	-
M3	-	16.2
M5	4.0	14.0
M7	7.0	13.0
C1	76.8	52.3
C2	4.2	3.3
C3	2.2	0.9

Fig. 1 and Fig. 2 illustrate climate types changes according to Konček's classification in the southeastern part of the Tatra Mts. from the Poprad Hollow in the periods 1951-1980 and 1981-2010. While in the first period only the cold region (with 3 sub-regions: C1 – moderately cool, C2 – cool mountainous and C3 – cold mountainous) was recorded here, in 1981-2010 a new moderately warm region (sub-region M3 – moderately humid) overspread its area to this locality (to the Poprad Hollow). The boundary between the moderately warm and the cold climatic regions shifted to about 155 m higher altitude. Moderately cool sub-region (C1) shifted to about 105 m higher altitude, and cool mountainous sub-region (C2) to about 160 m higher altitude in considered periods (Figs. 1-2). Such a development was caused by the significant increase in the mean July temperature between these two periods [at Poprad (695 m a.s.l.) from 15.5°C in 1951-1980 to 16.5°C in 1981-2010, at Skalnaté Pleso (1778 m a.s.l.) from 9.5°C in 1951-1980 to 10.5°C in 1981-2010, at Lomnický štít (2635 m a.s.l.) from 3.6°C in 1951-1980 to 4.7°C in 1981-2010].

Figure 1. Climate types according to Konček's classification in the southeastern part of Tatra Mts. from the Poprad Hollow in 1951-1980

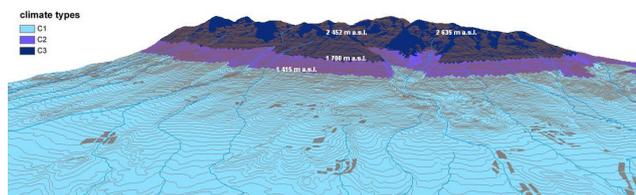
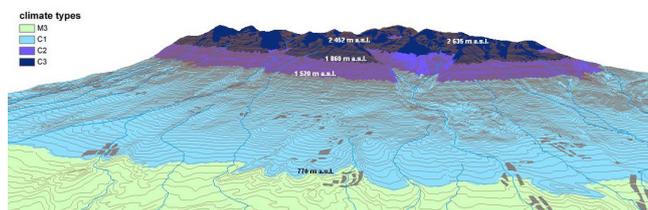


Figure 2. Climate types according to Konček's classification in the southeastern part of Tatra Mts. from the Poprad Hollow in 1981-2010



Conclusions

The climate has become warmer in the Tatra Mts. and the surrounding area during the 20th century and at the beginning of the 21st century. According to Konček classification, certain shifts in climatic regions and sub-regions towards the higher altitudes were registered in this region between the periods 1951-1980 and 1981-2010. As a result of higher temperature, we can expect similar upward shifts of vegetation zones and advances of altitudinal zones of tree lines here.

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