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CHANGES OF TOTAL ANNUAL RUNOFF DISTRIBUTION, HIGH AND LOW DISCHARGES IN LATVIAN RIVERS

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The paper examines climate change impacts on the hydrological regime of nineteen different river basins in Latvia. Hydrological data series for the period of 1951–2006 were analysed for river basins of four hydrological districts: Western, Central, Northern and Eastern. Climate change has influenced the temporal and spatial distribution of total annual river runoff and high and low flows in Latvia at the turn of century. The results confirm the hypothesis that the main tendency in the runoff change is a decrease in spring floods and increase in winter. Generally, statistically insignificant long-term trends were observed for summer and autumn.

Key words: *river runoff, high and low flows, trends, climate change, Latvia.*

INTRODUCTION

Climate change impacts on rivers hydrological regime have been extensively studied world-wide (Hisdal *et al.*, 2003; Pekarova *et al.*, 2006; Rödel, 2006; Rees and Collins, 2006; Dankers *et al.*, 2007; Reihan *et al.*, 2007; 2008). Kriaučiūniene *et al*. (2007) pointed out that during the 20th century the main changes in climate elements such as atmospheric circulation, air temperature, precipitation, snow and ice cover have occurred since the 1960s. These changes in weather patterns have affected the river hydrological regime and water resource availability. However, at the turn of the century, an increase of air temperature and precipitation during the cold period, decrease in days with snow cover and ice occurrence, increase in summer droughts and higher frequency of extreme air and water phenomena were observed. Hansen *et al.* (2007) have found that the six warmest years have occurred since 1998 and the 15 warmest years since 1988, with the largest air temperature changes in winter (Box, 2002). In the Baltic (Reihan *et al.*, 2007) and Nordic regions (Hisdal *et al.*, 2003) the strongest relation among temperature, precipitation and discharge, and a significant increasing trend for these indicators, occurs in the winter season. However, there is no regular pattern for other seasons, and only a significant decrease in spring floods was found in the Baltic countries.

In Latvia, there have been studies of long-term river runoff and time of ice-break for large and medium size rivers by Frisk *et al.* (2002), Kļaviņš *et al.* (2002), Kļaviņš *et al.* (2004), Klaviņš *et al.* (2006), Reihan *et al.* (2007), and river runoff prediction under different climate scenarios — by Ziverts and Apsite (2005), Rogozova (2006). These studies showed seasonal changes of long-term river runoff and ice regime. For example, Frisk *et al.* (2002) concluded that in general the discharge changes are minimal and have increased only in the main rivers in Latvia. This study considers an increase of winter runoff in relation to the total runoff. The reduction of the ice-cover period in rivers for the last thirty years is 2.8 up to 5.1 days every ten years (Klaviņš *et al.*, 2006). Briede and Lizuma (2007) and Lizuma *et al.* (2007) found that the mean annual minimal temperature increased more rapidly in winter and that the maximum diurnal sum of the monthly precipitation also increased in the cold period of the year in the period from 1950 to 2003. Therefore, these patterns in climate indicators have caused a change of total annual runoff distribution, and high and low discharges in Latvian rivers at the turn of the century.

The aim of the study was to determine the climate change impacts on the total annual river runoff distribution, and high and low discharges in Latvia, covering different river basins that vary in size and physiographical conditions in four hydrological districts.

MATERIALS AND METHODS

Data series of daily discharge (Anonymous, 2007) recorded at nineteen hydrological stations (Fig. 1) were used for the analysis of long-term trends and the distribution of total annual river runoff in percentage by month, season and three study periods.

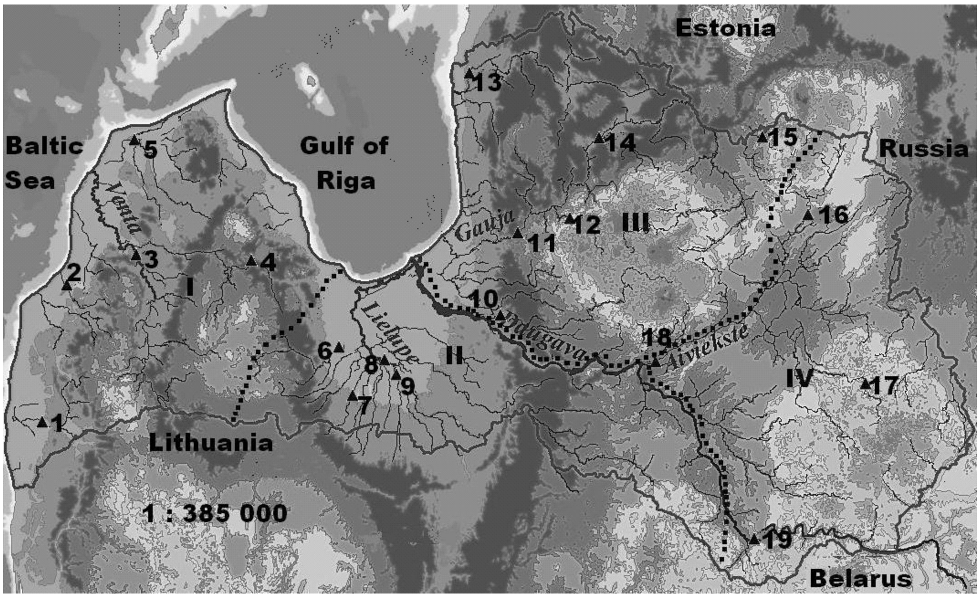

Fig. 1. Hydrological districts of Latvia: I – Western, II – Central, III – Northern and IV – Eastern (Глазачева, 1980). Hydrological stations: 1 – Bārta-Dūkupji, 2 – Rīva-Pievīķi, 3 – Venta-Kuldīga, 4 – Abava-Renda, 5 – Irbe-Vičaki, 6 – Bērze-Baloži, 7 – Svēte-Ūziņi, 8 – Lielupe-Mežotne, 9 – Mūsa-Bauska, 10 – Ogre-Lielpēči, 11 – Gauja-Sigulda, 12 – Amata-Melturi, 13 – Salaca-Lagaste, 14 – Gauja-Valmiera, 15 – Vaidava-Ape, 16 – Pededze-Lietene, 17 – Rēzekne-Griškāni, 18 – Aiviekste-Aiviekste, 19 – Daugava-Daugavpils

The study periods examined are: from 1951 to 2006 (entire study period); from 1951 to 1987 — forty years period with no substantial climate change impacts on river runoff; from 1988 to 2006 — last nineteen years period with substantial climate change impacts on river runoff. The study periods were selected for several reasons. Firstly, in the 1990s many hydrological stations were closed due to financial problems. Therefore, it was difficult to find long-term data series for the entire study period in different parts of Latvia. Finally, we selected nineteen hydrological stations for this study. Secondly, on the basis of the previous research by Kļaviņš *et al.* (2007) concerning the analysis of large-scale atmospheric circulation processes in the Baltic region, the study period from 1951 to 2006 was divided into two parts. In that study the year 1987 was identified as one of the climate turning points in a centennial perspective, associated with significant changes of climate indicators such as winter temperature, amount of precipitation, etc. By reference of Hansen *et al.* (2007) and this investigation, since 1988 in Latvia warmer winters have been occurring year by year. The increase of air temperature and precipitation has caused an increase of Latvian river runoff in winter (Fig. 2).

The low flow period was defined as the 30-day minimum discharge during the cold period (Q_{30cold}, November–February) and the warm period (Q_{30warm}, May–October). The high flow period was the maximal annual discharge (Q_{max}), which was mostly observed in the spring flood period (March–April). The ratio between annual low flow discharge, or maximal annual discharge and annual mean discharge ($Q_{30cold}/\ Q_{annual\ mean}$, $Q_{30warm}/\ Q_{annual\ mean}$ and $Q_{max}/Q_{annual\ mean}$) were calculated.

The non-parametrical Mann-Kendall test (Lisbiseller and Grimvall, 2002) was used for the trend analysis. The Mann-Kendall test was applied separately to each variable at each site, significance level of $P \leq 0.01$. The trend was considered as statistically significant at the 5% level, if the test statistic was higher than 2 or less than –2.

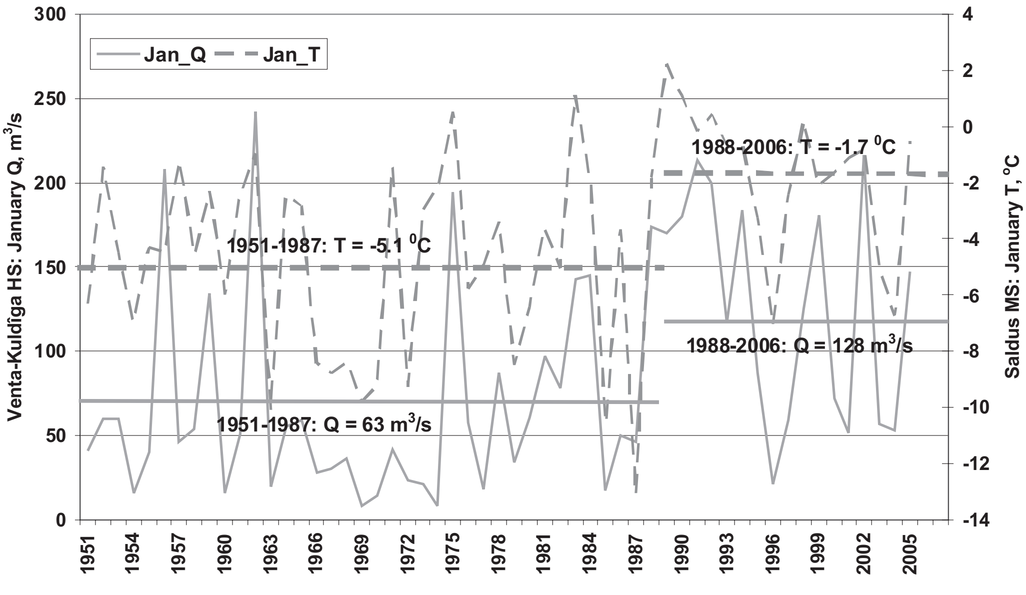

Fig. 2. Long-term average winter air temperature in Saldus meteorological station and the River Venta discharge at the Kuldīga hydrological station from 1951 to 2006.

Saldus meteorological station long-term average winter air temperature was observed: from 1951–1987 it was –5 degrees, but from 1988–2006 it was –2 (3 degrees higher).

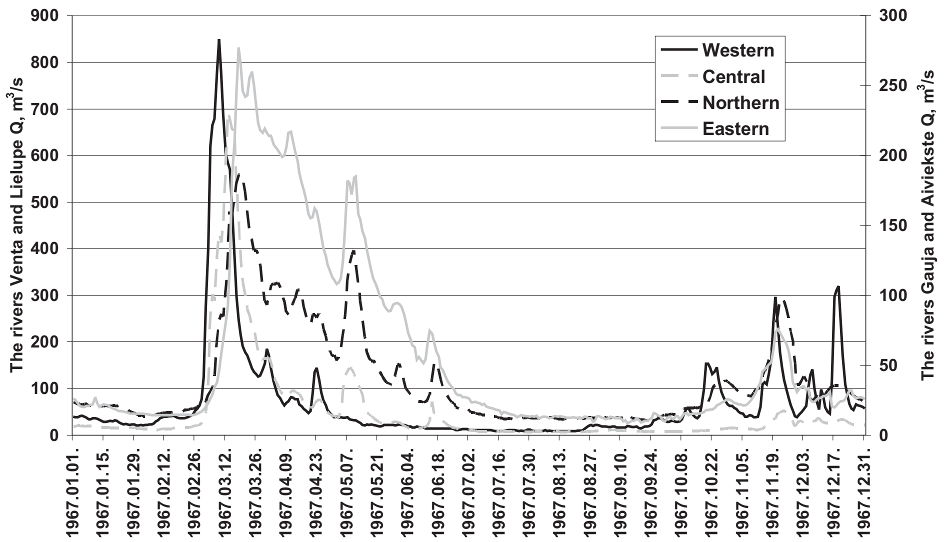

Fig. 3. Typical river hydrographs for the year 1967: the River Venta represents the Western district; River Lielupe – the Central district; River Gauja – the Northern district and the River Aivieste – Eastern district.

To interpret the obtained results we used the classification of hydrological districts by Glazacheva (Глазачева, 1980) where the territory of Latvia is divided into four districts: I – Western, II – Central, III – Northern and IV – Eastern. (Fig. 3): Western, Central, Northern and Eastern.

RESULTS

The studied period from 1951 to 1987 shows the typical distribution of total annual river runoff in Latvia when climate change did not much affect river runoff: river discharges during the winter period amount to 16–30% of the total annual river runoff compared to 38–53% in spring, 8–15% in summer and 17–24% in autumn. On average, the highest spring runoff was recorded for rivers of Central and Eastern districts (Table 1). Typically rivers of the Western district had the highest percentage in winter runoff compared to the other regions. The maximum total annual runoff was in April (19–30%) and the lowest water discharge in July and August (2–5%)

Table 1

DISTRIBUTION OF TOTAL ANNUAL RIVER RUNOFF BY MONTH AND SEASON IN LATVIA (IN PERCENTAGE)

Hydrological district	Month												Season			
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	winter	spring	summer	autumn
							1951–2006									
Western	11.5	9.8	12.9	16.5	6.0	3.0	2.5	2.8	4.0	6.7	11.6	12.5	33.8	35.5	8.3	22.4
Central	8.8	8.7	16.0	25.3	7.6	3.5	2.9	2.5	3.0	4.8	7.7	9.2	26.7	48.9	8.9	15.5
Northern	7.9	6.9	9.6	23.8	10.7	4.5	3.6	3.9	4.8	6.6	9.0	8.7	23.5	44.1	12.0	20.4
Eastern	6.2	6.1	10.2	25.9	12.9	6.3	4.8	4.1	4.3	5.3	7.0	6.9	19.2	49.0	15.2	16.6
Total in Latvia	6.2	6.1	10.2	25.9	12.9	6.3	4.8	4.1	4.3	5.3	7.0	6.9	25.8	44.4	11.1	18.7
							1951–1987									
Western	9.3	7.5	12.7	18.8	6.3	3.0	2.4	2.9	4.7	7.5	12.0	12.8	29.6	37.8	8.4	24.2
Central	6.2	6.2	16.0	29.4	8.1	3.4	2.6	2.7	3.4	5.5	7.7	8.9	21.4	53.4	8.7	16.5
Northern	6.4	4.8	7.7	26.7	11.7	4.2	3.6	4.0	5.4	7.3	9.3	8.8	20.0	46.1	11.9	22.0
Eastern	5.1	4.3	8.4	29.3	14.1	6.2	4.5	4.2	4.4	5.5	7.0	6.8	16.3	51.9	14.9	16.9
Total in Latvia	6.8	5.7	11.2	26.1	10.1	4.2	3.3	3.4	4.5	6.4	9.0	9.4	21.8	47.3	10.9	19.9
							1988–2006									
Western	14.8	13.5	13.3	12.8	5.6	3.0	2.6	2.6	2.9	5.6	11.1	12.2	40.5	31.7	8.2	19.6
Central	13.5	13.2	15.9	17.8	6.8	3.8	3.4	2.3	2.5	3.5	7.7	9.6	36.3	40.5	9.5	13.7
Northern	10.6	10.7	13.1	18.4	8.9	5.0	3.7	3.6	3.8	5.2	8.5	8.4	29.8	40.4	12.3	17.5
Eastern	8.0	9.0	13.2	20.1	10.7	6.6	5.3	4.1	4.3	4.9	6.8	7.0	24.0	44.1	15.9	16.0
Total in Latvia	11.7	11.6	13.9	17.3	8.0	4.6	3.8	3.2	3.4	4.8	8.6	9.3	32.6	39.2	11.5	16.7
							difference between 1988–2006 and 1951–1987									
Western	5.5	6.0	0.6	-6.0	-0.7	0.0	0.2	-0.4	-1.8	-1.9	-0.8	-0.6	10.9	-6.2	-0.2	-4.6
Central	7.3	6.9	-0.1	-11.5	-1.3	0.4	0.8	-0.3	-0.9	-2.0	0.1	0.6	14.9	-12.9	0.8	-2.8
Northern	4.3	5.9	5.4	-8.3	-2.8	0.7	0.1	-0.4	-1.6	-2.1	-0.8	-0.4	9.7	-5.7	0.4	-4.5
Eastern	2.9	4.7	4.8	-9.2	-3.4	0.4	0.7	-0.1	-0.1	-0.6	-0.2	0.1	7.7	-7.8	1.1	-0.9
Total in Latvia	5.0	5.9	2.7	-8.8	-2.1	0.4	0.5	-0.3	-1.1	-1.7	-0.4	-0.1	10.8	-8.1	0.5	-3.2

Table 2

RESULTS OF MANN-KENDALL TEST FOR MONTHLY DISCHARGE, ANNUAL LOW, HIGH AND MEAN DISCHARGES (1951–2006)

Hydrological station	Month												Q_{30cold}	Q_{30warm}	Q_{max}	$Q_{annual\ mean}$
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII				
Western district																
Venta–Kuldīga	**2.41**	**2.39**	1.36	**-2.62**	-0.54	**2.51**	**2.93**	0.62	0.05	0.08	0.30	0.42	**2.74**	**2.46**	**-2.40**	0.51
Abava–Renda	**2.79**	**2.67**	0.54	-0.62	0.43	**3.90**	**2.44**	1.70	0.81	0.27	0.41	0.54	**2.04**	**2.12**	-1.87	1.13
Irbe–Vičaki	1.40	1.45	1.97	-0.92	-0.99	0.99	**2.49**	0.52	-0.06	0.13	1.25	0.03	**2.42**	1.77	-1.61	1.96
Rīva–Pievīķi	**2.25**	**2.08**	0.76	-0.83	-0.52	0.86	0.58	0.31	-0.55	-0.51	-0.26	-0.02	**2.63**	-0.25	-0.11	1.91
Bārta–Dūkupji	1.87	**2.14**	1.70	-1.82	-0.75	1.16	1.74	0.45	-0.92	0.19	0.61	0.50	**2.21**	0.49	-1.47	0.78
Central district																
Lielupe–Mežotne	**3.07**	**3.00**	1.66	**-2.68**	-0.96	**2.83**	**4.21**	**2.34**	1.71	0.64	0.76	1.65	**3.34**	**3.63**	**-2.60**	0.30
Mūsa–Bauska	**2.33**	**2.57**	1.64	**-2.35**	-0.40	1.65	1.69	0.01	-0.11	0.36	0.90	1.39	**2.06**	-1.80	-1.46	0.54
Svēte–Ūziņi	**2.24**	**2.21**	0.98	**-2.71**	-1.02	1.22	1.77	-0.01	-0.23	0.21	1.78	1.46	**2.36**	0.46	**-4.00**	-1.23
Bērze–Baloži	**2.24**	**2.65**	1.34	-1.44	-0.17	1.94	1.25	-0.27	-0.46	-0.61	-0.27	0.34	**3.39**	0.74	**-3.56**	-0.39
Northern district																
Gauja–Sigulda	**2.86**	**2.91**	**3.13**	**-2.09**	-0.87	1.35	1.15	-0.56	-1.29	-1.71	0.08	0.23	**2.61**	-0.59	-1.53	0.49
Gauja–Valmiera													**3.29**	-0.74	**-2.32**	0.85
Amata–Melturi	1.79	**3.00**	**2.39**	**-2.28**	-0.59	0.38	0.00	-1.61	-2.01	-1.07	0.16	-0.16	**2.57**	**-2.74**	**-3.22**	0.13
Vaidava–Ape	**2.30**	**2.90**	**2.90**	**-2.23**	-1.12	**2.15**	1.42	-0.47	-0.60	-1.00	0.38	0.65	**2.79**	1.12	**-3.75**	1.01
Ogre–Lielpēči	**2.62**	**2.28**	**2.60**	**-2.65**	-0.85	1.58	1.31	-0.98	-1.51	-1.24	0.43	0.31	**2.57**	-0.95	**-3.19**	1.06
Salaca–Lagaste	**2.68**	**2.74**	**2.97**	-0.81	-1.02	1.22	1.48	1.08	-0.41	-0.80	0.14	0.46	**3.38**	1.69	-0.54	1.58
Eastern district																
Daugava–Daugavpils	1.56	**2.57**	**3.02**	-1.80	-1.69	-0.19	1.44	1.03	0.81	0.37	0.83	1.11	**2.54**	0.88	**-2.57**	0.98
Aiviekste–Aiviekste	**2.34**	**2.43**	**2.54**	-1.94	**-3.12**	-0.95	1.19	0.71	0.40	0.47	0.66	0.87	**2.61**	1.17	**-2.70**	0.27
Rēzekne–Griškāni	**2.26**	**2.54**	**2.60**	-1.59	1.65	**2.79**	**2.92**	1.44	1.23	0.75	0.85	0.99	**2.45**	**2.58**	**-2.19**	1.93
Pededze–Litene	**2.81**	**2.75**	**2.21**	**-2.03**	-1.46	1.56	0.69	-0.71	-0.63	-0.50	0.13	0.69	1.61	-0.06	**-2.31**	0.26

Statistically significant trend at the 5% level ($P \leq 0.01$), in bold.

The study period from 1988 to 2006 presents the distribution of total annual river runoff under climate change impact during the much recent nineteen years. Of the total annual river runoff, river discharges during the winter period amounted to 24–41% 32–44% in spring, 8–16% in summer and 14–20% in autumn. Higher discharge in winter was particularly evident in Central and Western districts of Latvia due to warmer winters at the turn of century (Table 1). Monthly data show (Fig. 2) that river runoff in Latvia increased in January and February (average 3–7%) and decreased in April (average 6–12%). Among the regions, the most obvious changes in river runoff occurred in the Central part, which increased by ~7% in January and February and decreased by ~12% in April.

Trends in long-term monthly river discharge for the entire study period (1951–2006) were tested using the Mann-Kendall test (Table 2). A statistically significant downward trend was obtained for April in 9 of 18 hydrological stations and particularly for the Central and Northern hydrological districts. A statistically significant upward trend was found for January, February and March in 17 of 18 hydrological stations. In Central and Western districts, river runoff increased more significantly in January and February. Moreover, in the Eastern and Northern districts, a significantly increasing river runoff trend was observed for January, February and March. Generally, statistically insignificant long-term trends were found for the summer and autumn months.

Regarding low and high flow periods from 1951 to 2006, Mann-Kendall test showed statistically significant increasing trends for 30-day minimum discharge (Q_{30cold}) of cold period in 99% of studied hydrological stations, and a decreasing trend for maximum annual discharge (Q_{max}) in 12 out of 19 hydrological stations (Table 2). Significant decreasing / increasing trends in 30-day minimum discharge (Q_{30warm}) in the warm period were found only in five hydrological stations.

Regarding the ratio between annual low flow discharge (Q_{30cold} or Q_{30warm}) and annual mean discharge ($Q_{annual\ mean}$) for the three study periods (Table 3), the ratio Q_{30cold} /$Q_{annual\ mean}$ was higher for all studied rivers in the period 1988–2006 than in the study period 1951–1987. The ratio was higher in Western and Central districts (about 0.8) and lower in the Northern and Eastern, respectively 0.73 and 0.7. The ratio Q_{30max} /$Q_{annual\ mean}$ was lower also in the period 1988–2006 for all studied rivers. The larger difference in this ratio for the study periods 1988–2006 (ratio 6.96) and 1951–1987 (ratio 11.66) was observed for rivers in the Central districts followed by rivers in Northern, Eastern and Western districts. The calculated ratio Q_{30warm} /$Q_{annual\ mean}$

Table 3

RATIO BETWEEN ANNUAL LOW OR HIGH FLOW DISCHARGE AND ANNUAL MEAN DISCHARGE

Study period	Q_{30cold}	Q_{30warm}	Q_{max}	$Q_{annual\ mean}$
		Western district		
1951–2006	0.63	0.21	6.04	1.00
1951–1987	0.53	0.22	6.30	0.98
1988–2006	0.82	0.21	5.54	1.04
		Central district		
1951–2006	0.54	0.18	10.07	1.00
1951–1987	0.40	0.18	11.66	1.00
1988–2006	0.79	0.17	6.96	1.00
		Northern district		
1951–2006	0.51	0.25	7.96	1.00
1951–1987	0.40	0.26	8.48	0.98
1988–2006	0.73	0.22	6.95	1.04
		Eastern district		
1951–2006	0.50	0.31	6.53	1.00
1951–1987	0.40	0.31	6.98	0.96
1988–2006	0.70	0.33	5.65	1.09
		Total in Latvia		
1951–2006	0.55	0.24	7.65	1.00
1951–1987	0.43	0.24	8.36	0.98
1988–2006	0.76	0.23	6.28	1.04

did not show any significant changes between studied periods of 1988–2006 and 1951–1987.

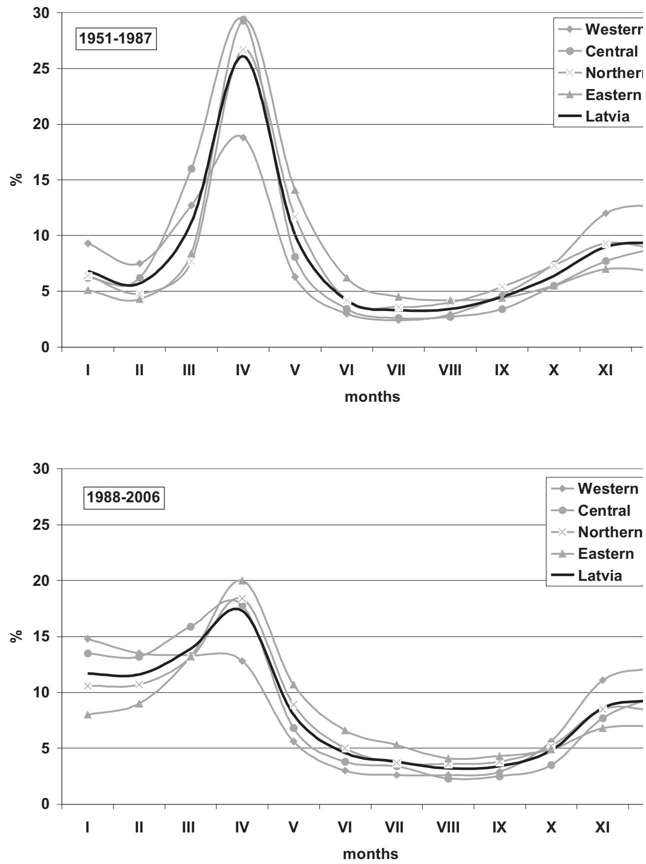

Fig. 4. Distribution of total annual river runoff in average percentage by study period and month in Latvia and hydrological districts.

DISCUSSION

In Latvia, rivers are characterised by a typical hydrograph with two main discharge peaks: during spring snowmelt and in late autumn during intensive rainfall, and low river discharge in winter and summer (Fig. 3). However, a high discharge peak c an also be observed after intensive rainfall at any time of warm period. Rivers have mixed water feeding: rain, snowmelt water and groundwater. It is typical that the major part of the total annual river runoff generates in spring followed by winter, autumn and summer.

Latvia is a comparatively small country by territory. For example, it is 5–7 times smaller than Nordic countries (Finland, Norway and Sweden) and almost the same as Denmark, Lithuania and Estonia. However, while Latvia is a comparatively small country, climatic and hydrological conditions can still differ in different parts of the country (Fig.1). In warm winters, low river discharges are not observed in the Western district. In this district, there is a comparatively shorter ice cover period and spring floods begin earlier (Fig. 3) (Глазачева, 1980). In the West there is a greater impact on river discharge regime from meteorological processes occurring over the North Atlantic and the Baltic Sea than for other districts in Latvia, particularly when compared to the Eastern district (Kļaviņš *et al.*, 2002). Geological and climatic conditions determined the hydrological regime in the Central district: rivers receive a large part of the discharge from surface runoff, the role of groundwater is cooperatively low during the year and spring floods dominate. The rivers of the Northern district are characterised by high snow melt floods and a less pronounced runoff due to rainfall in autumn, compared to the Western district. The Eastern district is characterised by a more continental climate conditions and spring floods begin later and are longer composing more than half of the total annual river runoff.

The typical river hydrograph for Latvia was developed for the forty years study period from 1951 to 1987, when climate change did not much affect the river runoff. However, at the turn of the century the climate changed and it subsequently modified the hydrological regime of rivers (Fig. 4). The study period from 1988 to 2006 represents the distribution of total annual river runoff under climate change impact during the last nineteen years (Table 1, Fig. 5). The results show that, compared with the study period 1951–1987, river runoff considerably increased in winter (average 8–15%), decreased in spring (average 6–13%), slightly decreased in autumn (~3%) and insignificant changes occurred in summer. We can conclude that seasonal changes of total annual river runoff can be observed in all hydrological regions. This is particularly evident in the Central hydrological region, where winter runoff increased by 15%

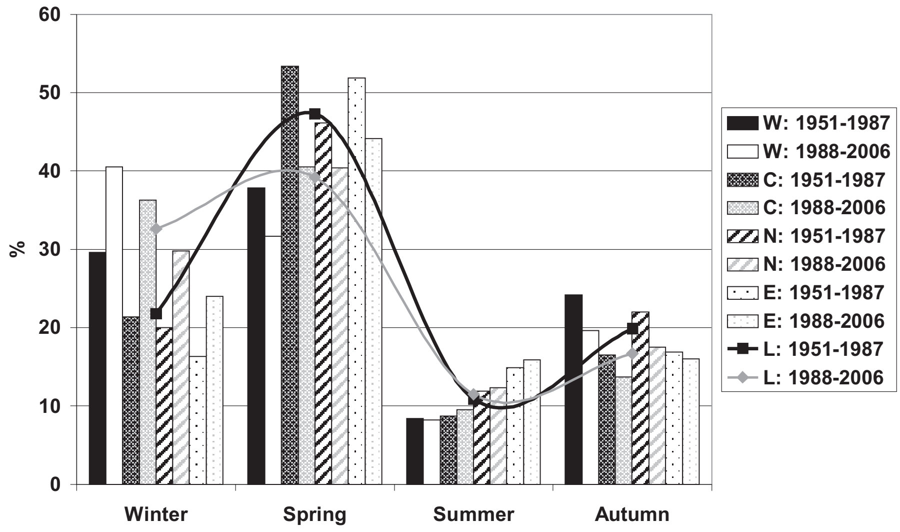

Fig. 5. Distribution of total annual river runoff. Average percentages are given by study period, season, total in Latvia (L) and hydrological districts (W – Western district; C – Central district; N – Northern district; E – Eastern district).

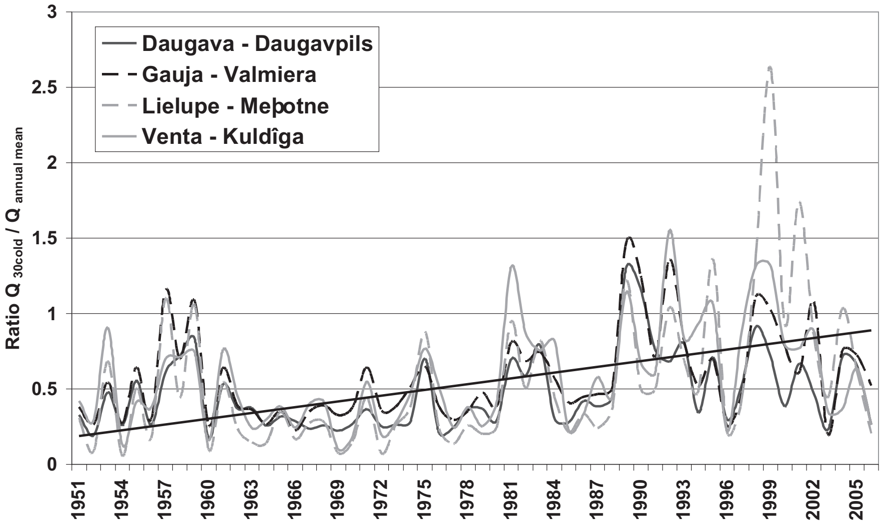

Fig. 6. Trend of river 30-day minimum discharge in the cold period of the year from 1951 to 2006.

and spring runoff decreased by 13%, which can be explained by a greater influence of climate change in winter-spring on the river runoff. During the last nineteen years, warm winters have dominated, low river discharges were not observed, spring floods began earlier in this district. Similar climatic and hydrological conditions were observed in the Western district from 1951 to 1987, when climate change did not much affect the river runoff. Also in the Northern and Eastern districts warmer winters were observed but air temperature did not increase as much. Therefore, the changes of the total river runoff distribution of the year were more gradual.

The analysis of monthly data showed that from 1988 to 2006 river runoff in Latvia increased in January, February and March by 3–6% and decreased in April by 9% (Table 1, Fig. 4). In other months the changes are less significant. Among the regions, the most significant changes in river runoff occurred in the Western and Central districts: increase in January and February (by 6–7%) and decrease in April (by 6–12%). In the Northern and Eastern districts the change in river runoff was similar to the Western and Central districts, but an increase was observed also in March and a decrease in May. The results of the Mann-Kendall test for long-term data series of monthly river discharge, low and high flow periods and the ratio of two low and one high flow periods from 1951 to 2006 allow drawing the same conclusions. The present results confirm the hypothesis that main trends in river runoff are decreased spring runoff (high flow) (Figs. 5, 7), increased winter runoff (low flow) (Figs. 5, 6) and insignificant change in summer low flow and autumn runoff. In addition, as observed previously (Kļaviņš *et al.*, 2002; Klaviņš *et al.*, 2006) in Latvia and (Reihan *et al.*, 2007) in the Baltic the beginning of the spring flood has shifted to an earlier time, contributing snowmelt to the winter season. These changes are mainly due to climate change at the turn of the century. In the Baltic Study Reihan *et al.* (2007) pointed out that the decrease in spring flood magnitude and earlier start of river flooding is evidently due to increasing air temperature in winter. The increase in air temperature causes a decrease of the water equivalent of snow and the number of days with snow as well.

In the study period, river runoff slightly decreased in autumn (~3%), which can be explained by warmer autumns, increased evapotranspiration and decreased precipitation in

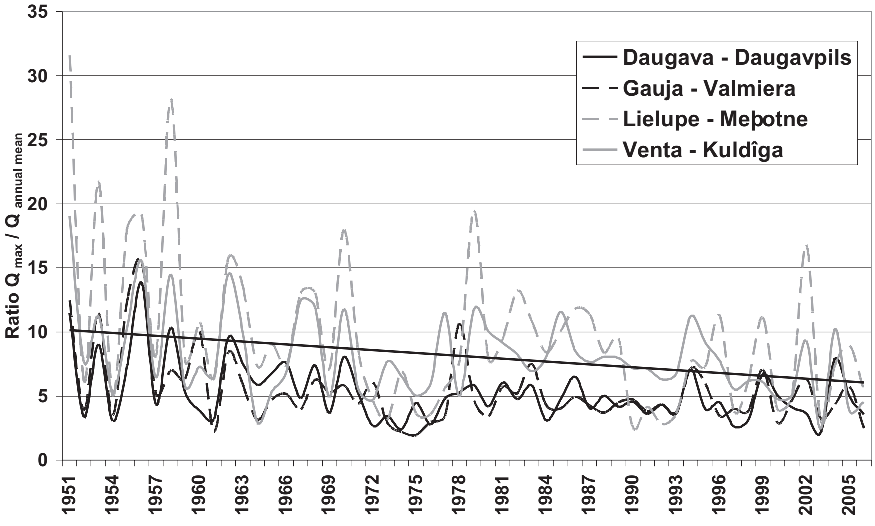

Fig. 7. Trend of the annual maximum discharge from 1951 to 2006.

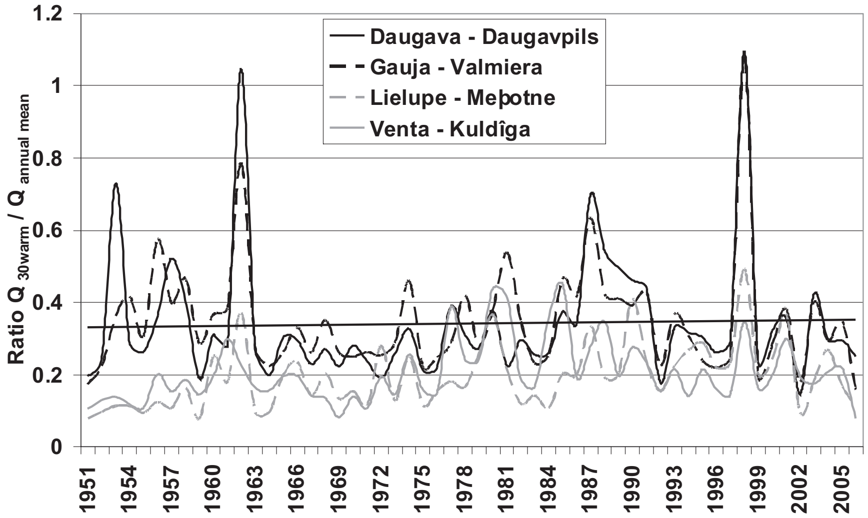

Fig. 8. The trend of river 30-day minimum discharge in the warm period of the year from 1951 to 2006.

Latvia (Briede and Lizuma, 2007). The discharge time series showed insignificant long-term changes in river runoff in summer (Fig. 8). In general, the obtained trends of the 30-day minimum discharge in the warm period were similar to the Baltic results. Reihan *et al.* (2007) concluded that differences in streamflow during summer and autumn seasons in most cases reflect tendencies observed in the precipitation and temperatures series.

The regional differences observed in total annual river runoff distribution, high and low flows by Western, Central, Northern and East hydrological districts of Latvia are mainly determined by climatic conditions. For example, in the Northern and especially Eastern district the climate is more "continental" compared to the other parts of Latvia, causing pronounced change in the river runoff during high flow in spring and low flow in winter. Generally, the climate conditions in Eastern district are similar to the Nordic countries. Korhonen (2008) studied long-term changes in discharge regime of 25 unregulated and regulated rivers in Finland. Trend analyses showed statistical significant increasing trends in winter runoff and decreasing in spring runoff in 31–42% and 50–54% of the studied sites, respectively. Similar results were obtained by Hisdal *et al.* (2003) in Nordic Studies, which indicated that in this region a longer time period is needed to identify change in river runoff in winter-spring seasons under climate change impact.

It is a generally known fact that changes in river hydrological regime are determined by climate change. In this study we did not examine meteorological parameters like air temperature and precipitation. However, the results of previous studies on long-term changes of air temperature and precipitation confirm the observed trends in rivers runoff in Latvia. For example, Lizuma *et al.* (2007) has analysed a long-term trend (1950–2003) of seasonal air temperature changes. According to the Mann-Kendall test criteria for this period, a statistically significant increase of air temperature was registered in all 22 meteorological stations. The highest increase in average air temperature was recorded in spring (March, April and May) and early winter (November and December). In the second half of winter and in summer the trend was less explicit. During autumn, air temperature in Latvia did not change. Also the mean annual maximum temperature increased more rapidly in April and May, while the minimum temperature increased more rapidly in winter.

Briede and Lizuma (2007) concluded that during 1950 to 2003, annual and seasonal precipitation showed significant variation in trends between stations. They observed an overall increasing trend (at a significance level of $P \leq 0.01$) in precipitation series for the cold period in 13 of 24 metrological stations. Statistically significance increasing trends for most stations were detected for January, March and June. A corresponding statistically significant diminishing monthly trend was observed only for September. The maximum diurnal sum of monthly precipitation also increased in the cold period of the year. They concluded that North Atlantic Oscillation seems to play an important role in the precipitation regime in Latvia, particularly, in explaining the variation in proportion of winter precipitation across the territory.

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KLIMATA MAINĪBAS IETEKME UZ LATVIJAS UPJU GADA NOTECES SADALĪJUMU, MAKSIMĀLAJIEM UN MINIMĀLAJIEM CAURPLŪDUMIEM

Pētījuma mērķis bija analizēt klimata mainības ietekmi uz Latvijas upju gada noteces sadalījumu, maksimālajiem un minimālajiem caurplūdumiem, aptverot dažādus upju baseinus četros hidroloģiskajos rajonos – Rietumu, Centrālajā, Ziemeļu un Austrumu rajonā. Pētījuma periods no 1951. līdz 2006. gadam bija sadalīts divos periodos: no 1951. līdz 1988. gadam, kad upju notecēs netika novērota būtiskas klimata mainības ietekme, un no 1989. līdz 2006. gadam, kad upju notecēs bija vērojama būtiskas klimata mainības ietekme. Salīdzinot pēdējā minētā perioda iegūtos rezultātu ar pirmo, varēja secināt, ka Latvijas upju gada noteces izmaiņas būtiski notikušas ziemas un pavasara sezonās un mēnešos. Upju notece ir pieaugusi ziemā par 11%, bet samazinājusies pavasarī par 8%. Lielākās izmaiņas upju gada noteces sadalījumā bija atrastas Centrālajā rajonā, mazākas izmaiņas – Austrumu rajonā. Neliels upju noteces samazinājums konstatēts rudenī (apmēram par 3%), bet nebūtiskas izmaiņas (pieaugums vai samazinājums) vērojamas vasarā. Līdzīgus secinājumus varēja izdarīt, analizējot mēneša vidējos, gada maksimālos, gada 30 dienu minimālos ziemas un vasaras caurplūduma datu rindas no 1951. līdz 2006. gadam.