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# River streamflow changes in the catchment of the Vilyuy reservoir, Eastern Siberia

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**Abstract.** The aim of the study is to assess river streamflow changes in the catchment area of the Vilyuy reservoir in the upstream area of the Vilyuy River, tributary of the Lena River. We analysed 2,556 time series with duration of 30, 35, 40 and 45 years sampled from the dataset of monthly discharges for eight hydrological gauges with data availability periods from 40 to 50 years. The result of a statistical trend test depends on the time series length and the coverage. The May and June river streamflow practically does not change. Most of the statistically significant positive trends were found in April, September and November. Among the eight gauges, the largest fractions of positive trends were found for the Akhtaranda River and the Vilyuy River, the northern tributaries of the Vilyuy Reservoir. Negative trends prevail on the Chona River that flows from the south and has discontinuous permafrost in the basin.

## 1. Introduction

In the Russian north, the climate changes more intensively than in the temperate zone. River runoff changes due to climate warming are still poorly understood. The annual flow of many Russian Arctic rivers increased by 4-18% in 1976-2014 in comparison with the period 1936-1975 [3]. Most of the Arctic streamflow change studies consider only outlets of large rivers, including the Lena River. Only few works present analyses of runoff changes in the medium-sized and small rivers [1, 4, 5, 6], which may show opposite tendencies in comparison with large rivers [2]. Yumina and Tereshina [6] showed that annual Vilyuy River streamflow has increased since mid-1980s but not all Vilyuy River tributaries have the same tendency.

Different methods of trend estimation are used in the analysis of hydrological changes. Although the length of the data series largely determines the test result, many studies compare the results obtained on series of different durations [4, 5, 6]. Even 1-2 years' difference in the length of the analysed series can change the result of the statistical test.

The aim of the study is to assess statistically significant trends in the monthly discharge series for samples of various durations at hydrological gauges in the Vilyuy Reservoir catchment.

## 2. Data and methods

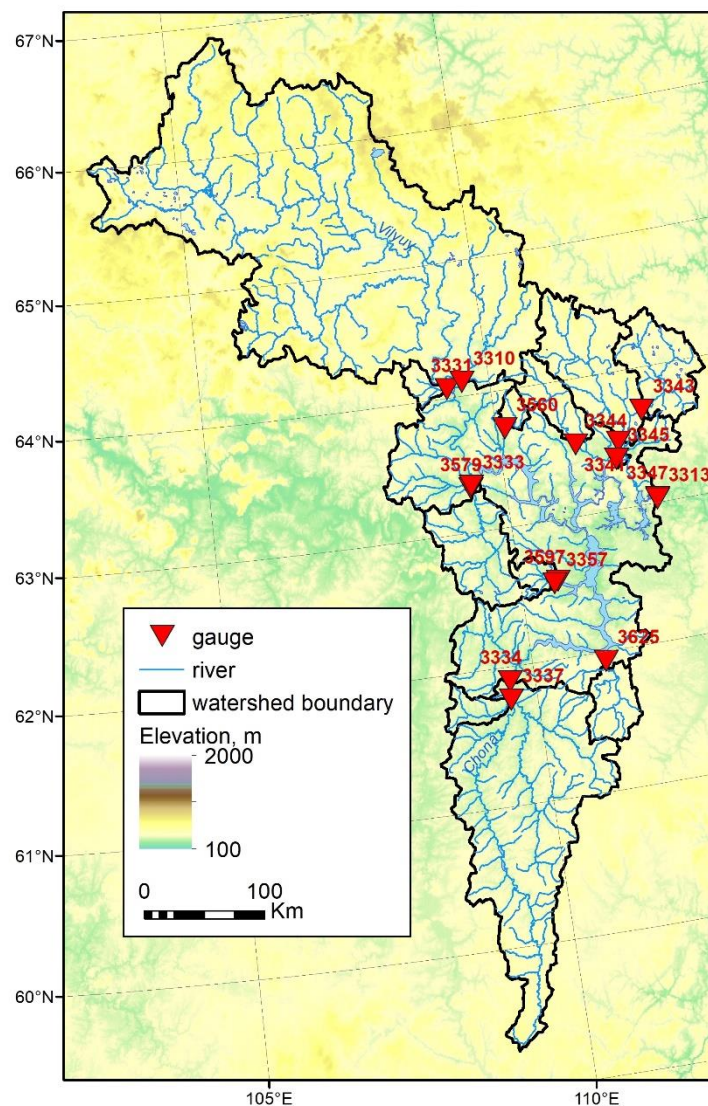
There are eight hydrological gauges on the catchment area of the Vilyuy Reservoir (141 150 sq. km) (figure 1, table 1). The catchment areas of the studied river basins range from 850 to 57300 sq. km. For each river gauge, we sampled multiple time series of monthly water discharges with duration of 30, 35, 40 and 45 years from a full available data series. Samples of a given duration start from all



possible years in the dataset. For eight stations with periods of data availability from 40 to 50 years, 2556 samples of monthly water discharges were processed.

Mean annual air temperature (1971-2000) varies from  $-6.6^{\circ}\text{C}$  in the southern part of the Vilyuy Reservoir catchment to  $-13.1^{\circ}\text{C}$  in its northern part. Mean annual precipitation changes between 290 and 340 mm/year. Dominant landscapes are larch forests and pine-larch forests. Continuous permafrost with thickness up to 500 m covers the studied area. Discontinuous permafrost appears only in the southern part of the Chona river basin.

Time series were evaluated for stationarity in relation to the presence of monotonic trends with Mann–Kendall and Spearman rank correlation tests at the significance level of  $p < 0.05$ . If both tests suggested a trend at the significance level  $p < 0.05$ , a serial correlation coefficient was tested at unity lag  $r.1/$ . With the serial correlation coefficient  $r < 0.20$ , the trend was considered reliable. In the case of  $r > 0.20$ , to eliminate serial correlation in the input series the “trend-free pre-whitening” procedure, described by Yue et al. (2002), was carried out. “Whitened” time series were repeatedly tested with a Mann–Kendall nonparametric test at the significance level  $p < 0.05$  [4, 5].



**Figure 1.** Scheme of the Vilyuy Reservoir catchment and studied nested catchments. Gauges are numbered with the ID code from the table 1.

### 3. Results and discussions

The longer samples tend to show more positive trends than the shorter ones. 20% of the 45 year samples have statistically positive trends comparative with 10-15% of 30-, 35- and 40 year samples. Over 20% of samples finishing at 1999-2002 and 2007-2010 show positive trends. Among others fraction of positive trends is lower.

For any gauge there is no month with all samples, regardless of their duration and coverage, show a positive or negative trend. High fraction (15-25%) of January, April, July, September, November and December series have statistically significant positive trends. For 2-7 months in a year, the runoff is stable regardless of the duration and coverage of the sample. The most stable months are May and June, where no trend is found at seven and six gauges, respectively. There is a trend for at least one February sample at every gauge.

Fraction of samples with absence of any trends is higher at rivers with low mean annual flow depth. The larger river basin – the higher fraction of samples with positive trends. Among the eight studied gauges (table 1), the largest fraction of positive trends was found on the Akhtaranda River at Syuryakh-Khaya (29%) and the Vilyui River at Ust-Ambardakh (25%).

On the Akhtaranda River at Syuryakh-Khaya, positive trends prevail in December and January. Positive trends are also found in April, July, September, October and November. On the Vilyui River at Ust-Ambardakh most of the positive trends are found in January, April, September, November and December. Increasing winter discharge agree with results of other studies [1, 3, 5] and could potentially be explained by the later freezing or increasing autumn rainfall. April trends possibly relate to the earlier spring flood. July trends might be attributed to the intensifying summer rains and permafrost degradation. Additional data and methods should be used to test these hypotheses.

On the Chona River at Chona 16% of the samples show negative trends. There is no any positive trend on the Chona River. Negative trends are observed mainly in February and March, less often in January, June and December. Runoff decrease at the Chona River could relate to degradation of the discontinuous permafrost in the river basin and changing interaction between surface and ground water. All other studied river basins are covered by continuous permafrost.

On the Batyr River at Yasny positive trends are found in April in samples that finish after 2010, as well as in July and September. The runoff of the Ulakhan-Edek River at Dalny increases in July, September, October, and November in samples that begin in 1977-1980 and finish in 2007-2011. On the Churkuo River at Lavinda, the runoff mainly decreases in January and February; it increases in July. The flow of the Dyekinda River at Ular is stable and shows only rare positive and negative trends. The runoff of the Ichoda River at Mayskiy shows some tendency to increase in October, November, February, March and April mainly on short samples (30-35 years).

### 4. Conclusion

The result of a statistical trend test depends on the length and the coverage of the series. Runoff trends for May are absent at seven out of eight studied gauges in all samples, regardless of their coverage and duration. In February, trends in at least one sample are recorded at all eight gauges. Most of the statistically significant positive trends were found in April, September and November. Seasonality of the found trends could be possibly explained by earlier spring flood, later freezing, increasing summer and autumn rainfall and permafrost degradation. Among the eight studied gauges, the largest fraction of statistically significant positive trends was found on the Akhtaranda-River at Syuryakh-Khaya and the Vilyui at Ust-Ambardakh. Most of the positive trends relate to November, December, January, April and September. On the Chona River at Chona 16% of the samples show negative trends, which are found mainly in February and March. Runoff decrease at the Chona River could possibly relate to degradation of the discontinuous permafrost in the river basin while other studied river basins are covered by continuous permafrost.

**Table 1.** Characteristics of studied watersheds and fractions of samples with positive, negative trends and absence of any trends.

River - gauge	ID	Area (sq km)	Mean annual discharge (cub.ms <sup>-1</sup> )	Mean annual streamflow (mm)	Data period (year)	No of samples	Fraction of samples with positive trends (%)	Fraction of samples with negative trends (%)	Fraction of samples with no trends (%)	No data (%)
Vilyui R. at Ust-Ambardakh	3310	57300	379	208	50	504	25	0	75	0
Churkuo R. at Lavinda	3579	4130	17	133	42	252	6	7	87	0
Ulakhan-Edek R. at Dalny	3560	854	4.6	169	41	216	12	0	78	10
Chona R. at Chona	3334	21000	82	124	43	288	0	16	84	0
Ichoda River at Mayskiy Dyekinda	3625	2820	12	129	44	360	12	0	88	0
River at Ular	3597	1490	4.9	105	40	180	2	3	93	1
Akhtaranda -R. at Syuryakh-Khaya	3341	11600	50	136	42	252	29	0	71	0
Batyr R. at Yasny	3344	3380	15	137	48	504	10	0	87	3

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### References

- [1] Georgiadi A G and Kashutina Y A 2014 Mnogoletniye izmeneniya godovogo i sezonnogo stoka rek basseyna Leny [The features of long-term annual and seasonal runoff changes for lena basin rivers] *Izvestiya Rossiiskoi Akademii Nauk. Seriya Geograficheskaya* **2** pp 71–83
- [2] Rumyantseva Ye V, Shestakova Ye N, Muzhdaba O V 2017 Dinamika vodnykh resursov rek Arkticheskoy zony Zapadnoy Sibiri [Dynamics of water resources of the rivers of the Arctic zone of Western Siberia] *Nauchnyy vestnik Yamalo-Nenetskogo Avtonomnogo okruga* **3(96)** pp 53–61
- [3] Frolova N L, Magritskiy D V, Kireyeva M B, Agafonova S A and Povalishnikova Ye S 2018 Antropogennyye i klimaticheski obuslovlennyye izmeneniya stoka vody i ledovykh yavleniy rek rossiyskoy Arktiki [Runoff and ice phenomena dynamics on the rivers of Russian Arctic due to anthropogenic and climate changes] *Voprosy geografii* **145** pp 233–251
- [4] Makarieva O, Nesterova N, Post D A, Sherstyukov A and Lebedeva L 2019 Warming temperatures are impacting the hydrometeorological regime of Russian rivers in the zone of continuous permafrost *The Cryosphere* **13** pp 1635–1659
- [5] Tananaev N I, Makarieva O M and Lebedeva L S 2016 Trends in annual and extreme flows in the Lena River basin, Northern Eurasia *Geophys. Res. Lett.* **43(10)** pp 764–772
- [6] Yumina N M and Tereshina M A 2017 Mnogoletniye izmeneniya stoka rek basseyna Vilyuya [Estimating long-term changes of river runoff in the Viluy river basin] *Vestnik Moskovskogo universiteta. Seriya 5 Geografiya* **6** pp 62–70