

# Supplementary materials

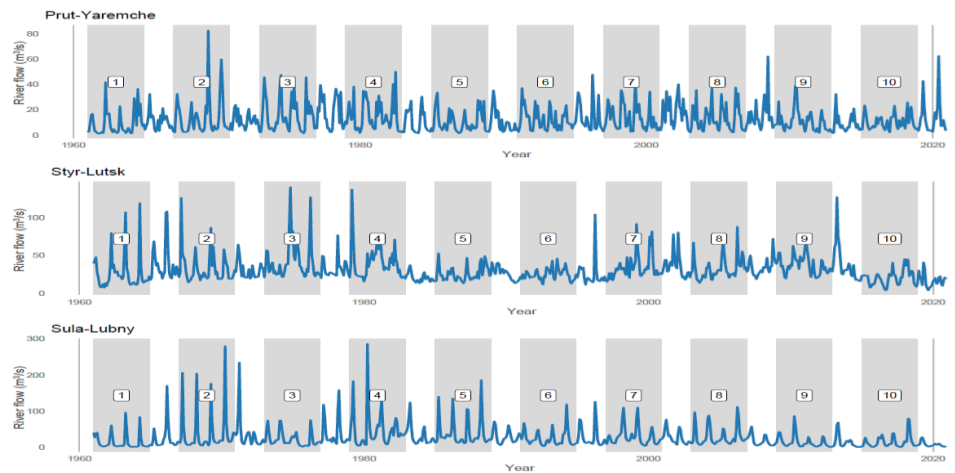
## Forecasting Monthly River Flows in Ukraine under Different Climatic Conditions

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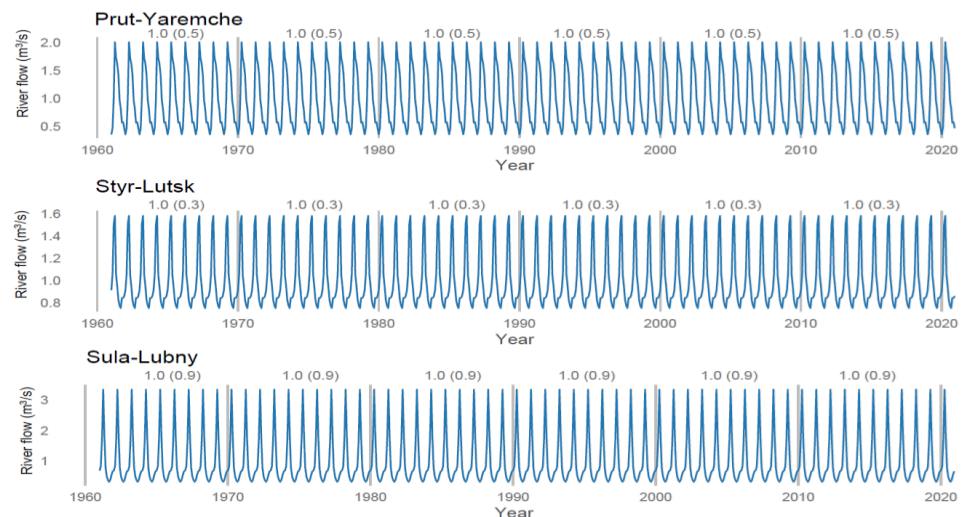
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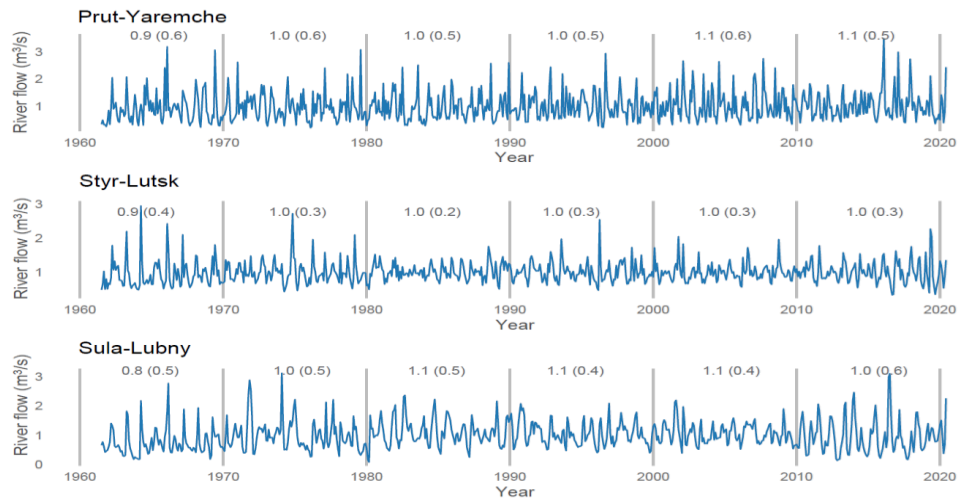
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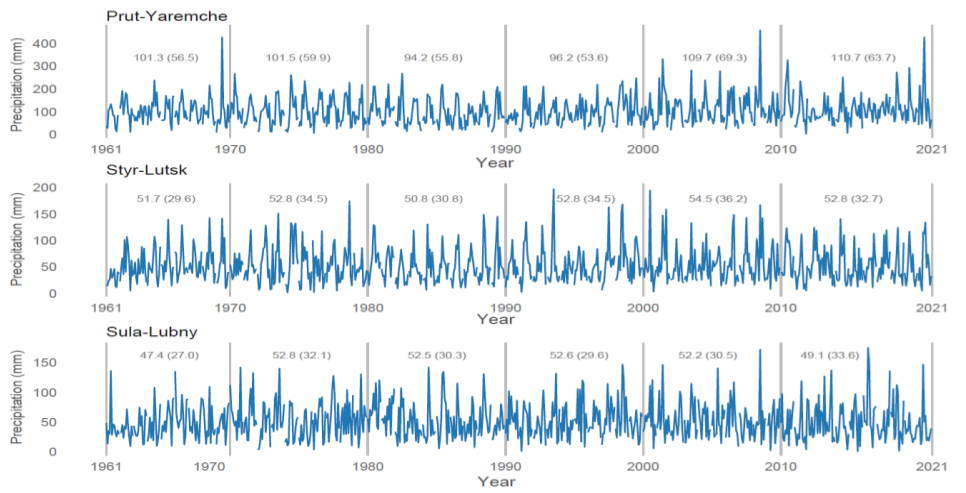
**Figure S1.** Custom validation subsets (grey areas) with skipped data (white areas) for river flow.



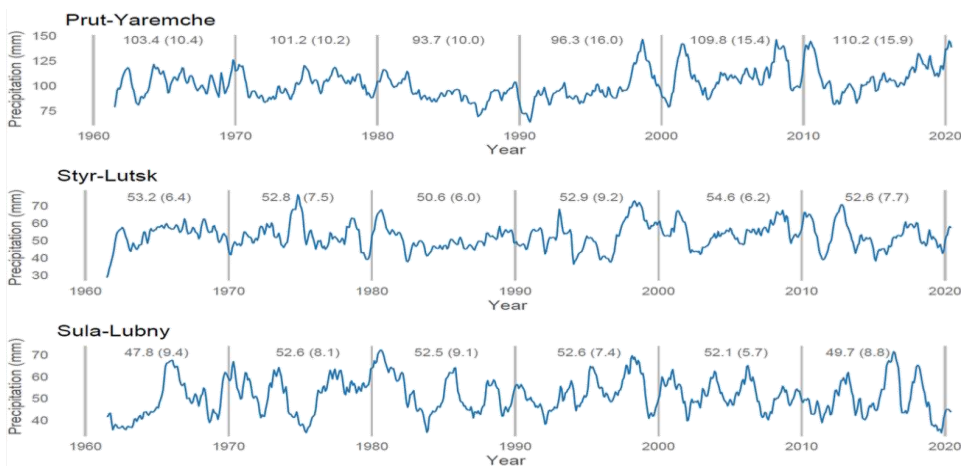
**Figure S2.** Seasonal flow values grouped by rivers (1961-2020).



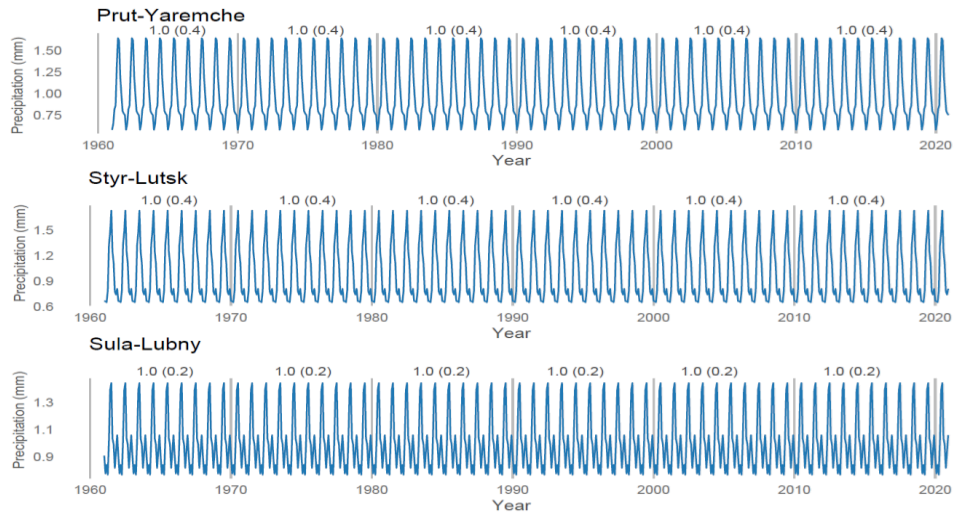
**Figure S3.** Random flow values grouped by rivers (1961-2020).



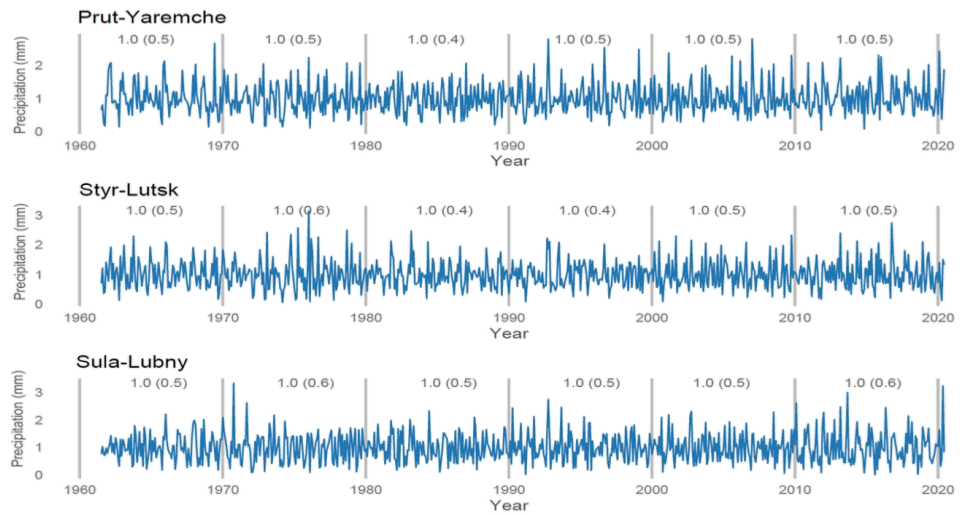
**Figure S4.** Precipitation time series distribution grouped by rivers' catchment areas (1961-2020). Note: Figure descriptions refer to non-parametric measures - mean (standard deviation).



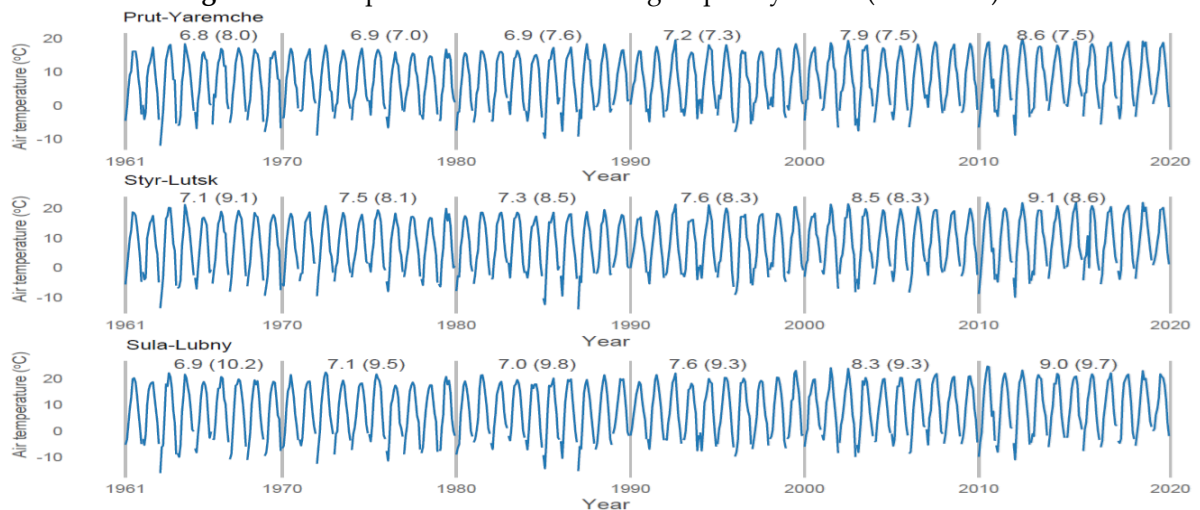
**Figure S5.** Precipitation trend values grouped by rivers (1961-2020).



**Figure S6.** Precipitation seasonal values grouped by rivers (1961-2020).



**Figure S7.** Precipitation random values grouped by rivers (1961-2020).



**Figure S8.** Air temperature time series distribution grouped by rivers' catchment areas (1961-2020). Note: Figure descriptions refer to non-parametric measures - mean (standard deviation).

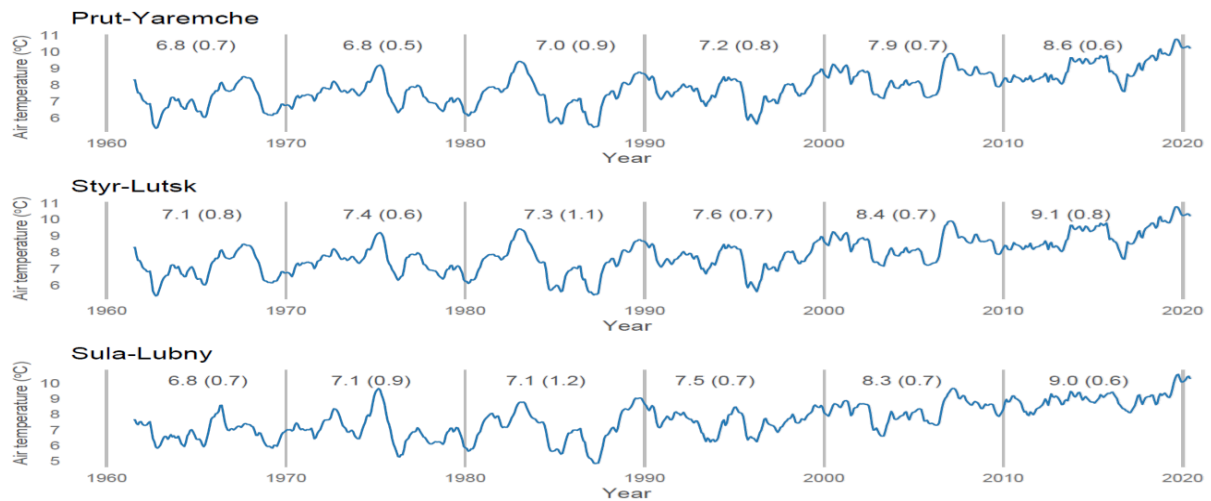


Figure S9. Air temperatur trend values grouped by rivers (1961-2020).

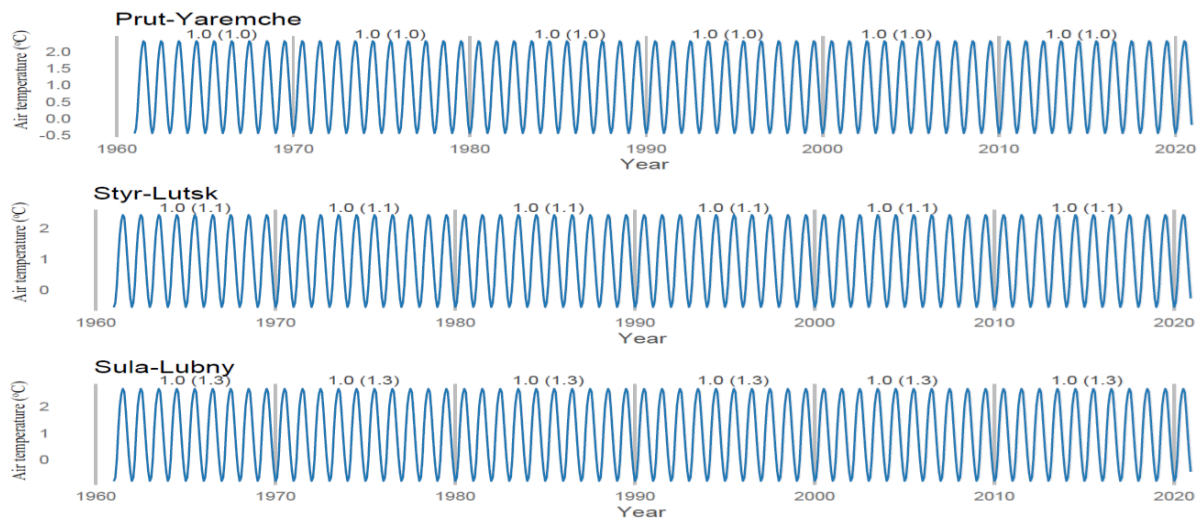


Figure S10. Air temperatur seasonal values grouped by rivers (1961-2020).

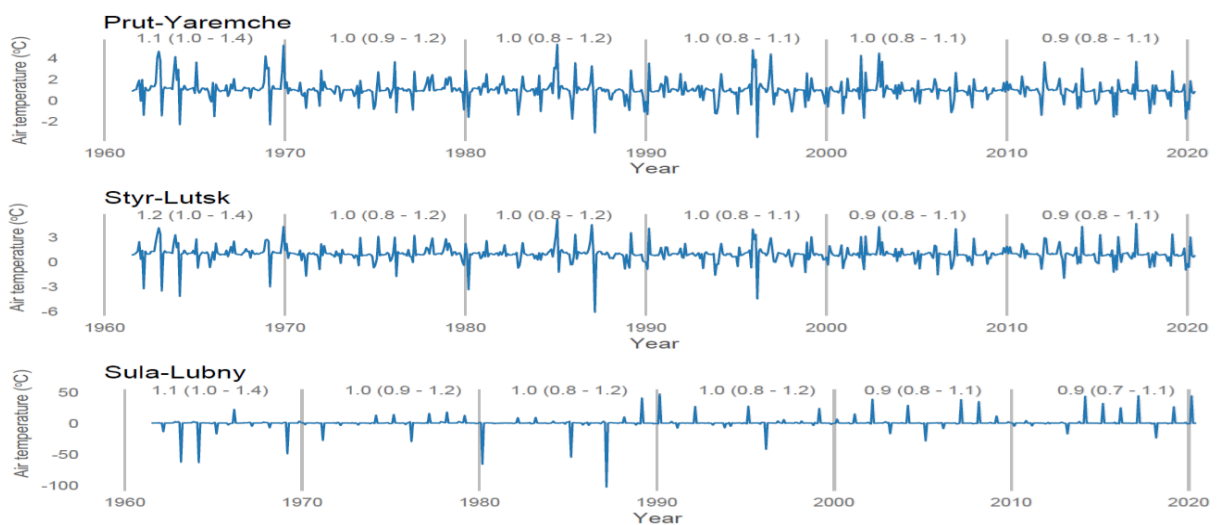
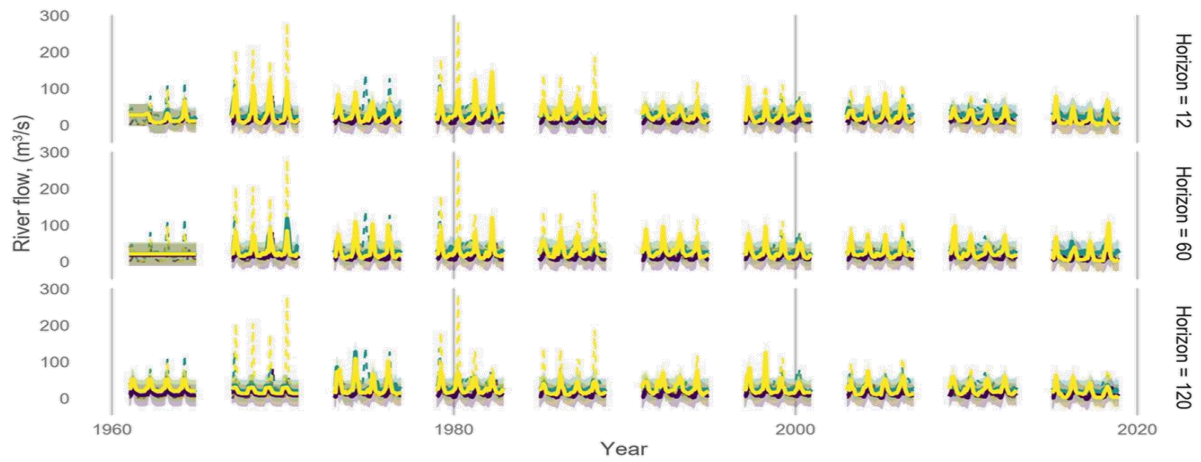
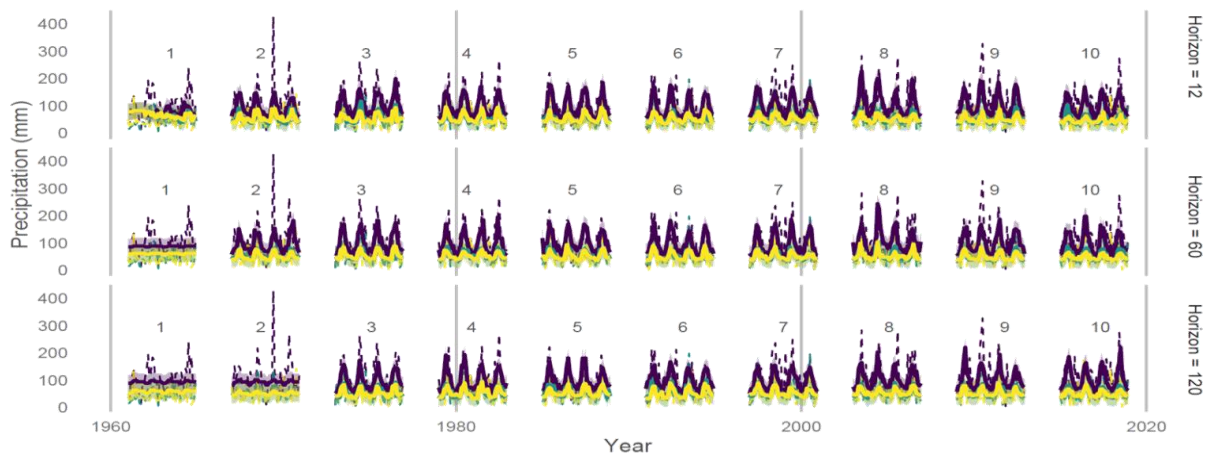


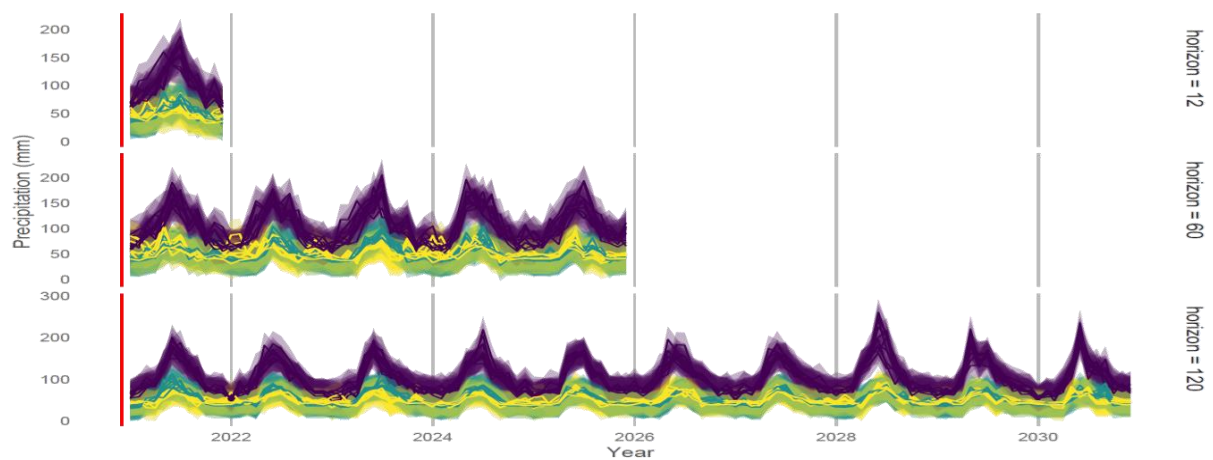
Figure S11. Air temperatur and random values grouped by rivers (1961-2020).



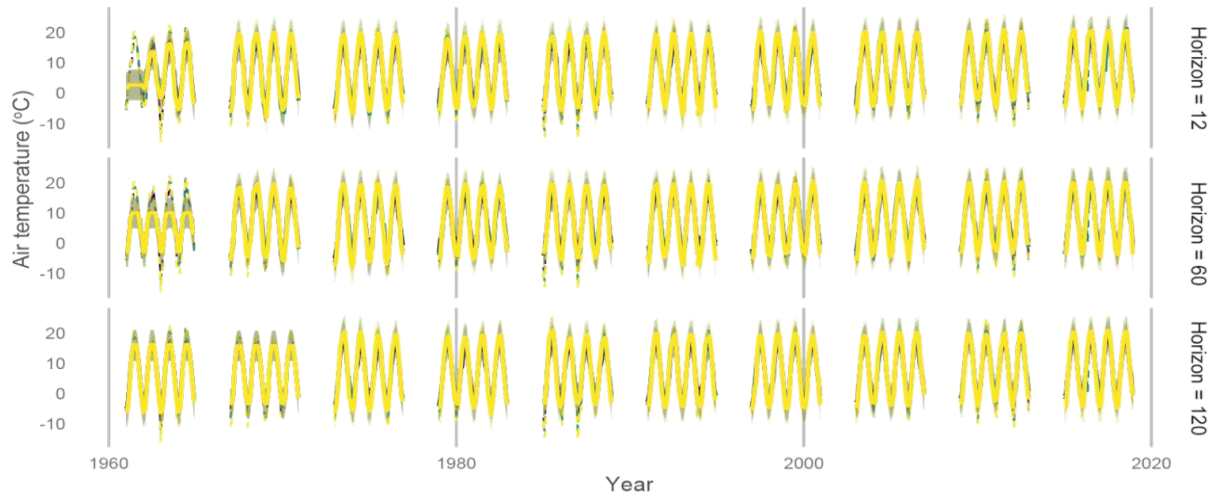
**Figure S12.** River flows predicted (solid line) vs. actual (dashed line) values grouped by horizons (purple line: the Prut River-Yaremche, turquoise line: the Styr River-Luts'k, yellow line: the Sula River-Lubny).



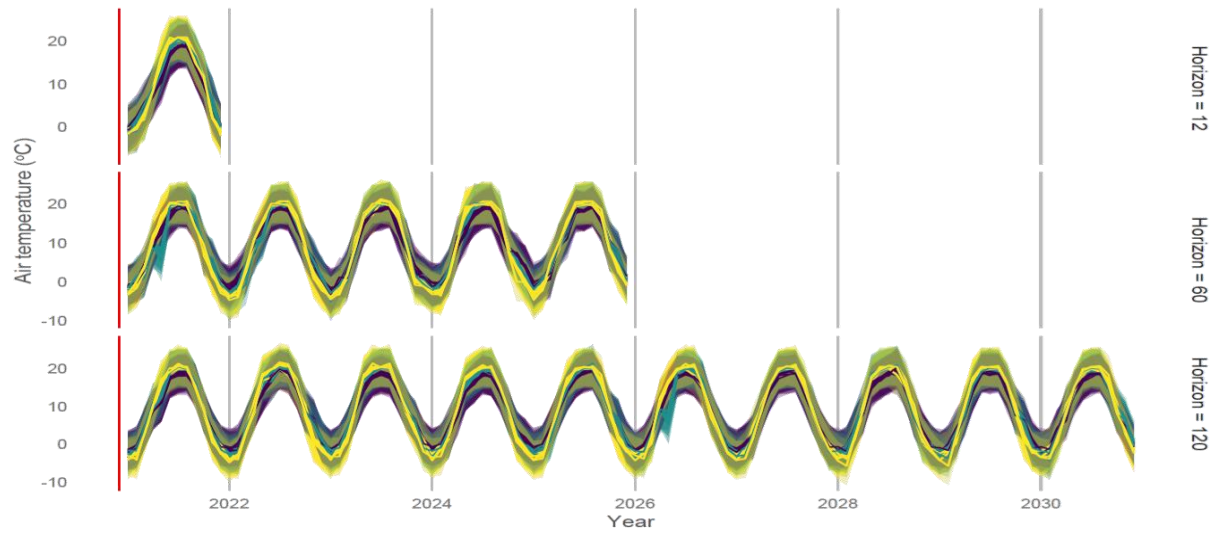
**Figure S13.** Precipitation predicted (solid) vs. actual (dashed) values grouped by horizons (purple line: Prut River catchment. turquoise line: Styr River catchment. yellow line: Sula River catchment).



**Figure S14.** 12, 60 and 120 step-ahead forecasts of precipitation (purple line: the Prut River catchment, turquoise. line: the Styr River catchment, yellow line: the Sula River catchment).



**Figure S15.** Air temperature predicted (solid) vs. actual (dashed) values grouped by horizons (purple line: PrutRiver catchment. turquoise line: Styr River catchment. yellow line: Sula River catchment).



**Figure S16.** 12, 60 and 120 step-ahead forecasts of air temperature (purple line: the Prut River catchment, turquoise line: the Styr River catchment, yellow line: the Sula river catchment).

**Table S1.** Forecast error by river flow forecast horizon.

Horizon (months)	River	MAE	MAPE	MDAPE	SMAPE	RMSE	NRMSE
12	Prut-Yaremche	6.48	78.09	46.99	51.23	8.42	0.80
12	Styr-Lutsk	11.23	32.35	26.23	32.59	14.47	0.81
12	Sula-Lubny	12.35	72.35	43.46	50.07	16.72	0.51
60	Prut-Yaremche	6.21	73.63	47.80	50.19	7.93	0.75
60	Styr-Lutsk	11.34	35.42	26.58	34.05	15.57	0.87
60	Sula-Lubny	15.07	84.49	46.62	55.71	21.31	0.66
120	Prut-Yaremche	6.28	76.42	47.12	52.39	8.50	0.81
120	Styr-Lutsk	11.35	33.49	26.95	32.44	15.82	0.89
120	Sula-Lubny	15.50	82.42	50.34	58.54	20.53	0.63

Explanations of the measures are provided in the Methods section.

**Table S2.** Global river flow forecast error.

River	MAE	MAPE	MDAPE	SMAPE	RMSE	NRMSE
Prut-Yaremche	6.35	75.88	47.30	51.27	8.18	0.78
Styr-Lutsk	11.30	32.87	26.45	32.82	14.57	0.82
Sula-Lubny	14.31	79.63	44.62	55.71	19.87	0.61

Explanations of the measures are provided in the Methods section.

**Table S3.** Forecast error by precipitation forecast horizon and river catchment.

Horizon (months)	River catchment	MAE	MAPE	MDAPE	SMAPE	RMSE	NRMSE
12	Prut	37.74	54.50	33.15	39.18	47.85	0.79
12	Styr	21.57	69.90	36.24	42.35	28.16	0.85
12	Sula	23.84	95.95	40.06	48.22	29.92	0.97
60	Prut	36.69	56.66	31.74	39.44	48.51	0.80
60	Styr	22.62	71.30	37.76	44.25	28.84	0.87
60	Sula	24.63	92.79	37.55	48.76	29.99	0.98
120	Prut	36.33	61.00	32.16	39.33	46.02	0.76
120	Styr	21.49	70.07	34.85	42.35	27.62	0.83
120	Sula	23.96	88.16	39.28	49.43	28.82	0.94

Explanations of the measures are provided in the Methods section.

**Table S4.** Global precipitation forecast error grouped by river catchment.

River catchment	MAE	MAPE	MDAPE	SMAPE	RMSE	NRMSE
Prut	37.01	57.00	32.16	39.33	47.55	0.79
Styr	22.07	70.14	36.24	42.92	28.36	0.86
Sula	24.15	88.16	38.48	48.48	29.45	0.96

Explanations of the measures are provided in the Methods section.

**Table S5.** Forecast error by air temperature forecast horizon and river catchment.

Horizon (months)	River catchment	MAE	MAPE	MDAPE	SMAPE	RMSE	NRMSE
12	Prut	1.64	86.96	18.80	49.43	2.14	0.28
12	Styr	1.81	60.77	16.26	47.54	2.39	0.28
12	Sula	1.87	78.85	19.06	47.51	2.45	0.29
60	Prut	1.73	94.26	19.23	50.21	2.22	0.30
60	Styr	1.86	56.90	18.64	49.44	2.36	0.28
60	Sula	2.02	84.05	17.75	43.76	2.61	0.31
120	Prut	1.70	68.20	16.28	48.27	2.18	0.29
120	Styr	1.87	57.07	17.56	46.41	2.40	0.28
120	Sula	2.07	81.56	20.08	46.07	2.61	0.31

Explanations of the measures are provided in the Methods section.

**Table S6.** Global air temperature forecast error grouped by river catchment.

<b>River catchment</b>	<b>MAE</b>	<b>MAPE</b>	<b>MDAPE</b>	<b>SMAPE</b>	<b>RMSE</b>	<b>NRMSE</b>
Prut	1.70	86.96	18.24	49.08	2.19	0.29
Styr	1.85	57.07	17.56	48.20	2.38	0.28
Sula	1.94	81.56	19.13	45.70	2.55	0.30

Explanations of the measures are provided in the Methods section.