Table S1. Results of the Mann–Kendall test and Sen's slope estimator for seasonal and annual air temperature time series

Station	Winter	Spring	Summer	Autumn	Annual
Aksu-Aiuly	0.29*	0.45***	0.18***	0.30***	0.29***
Atbasar	0.33**	0.39***	0.08+	0.22***	0.25***
Besoba	0.22+	0.34***	0.11**	0.24**	0.30***
Blagoveshenka	0.30*	0.36***	0.14**	0.25***	0.27***
Yrgyz	0.33**	0.40***	0.17***	0.25***	0.30***
Karabalyk	0.33*	0.40***	0.23***	0.35***	0.33***
Karaganda	0.37***	0.37***	0.04ns	0.25***	0.26***
Kushmurun	0.25+	0.33**	0.13**	0.23***	0.28***
Ruzaevka	0.32**	0.38***	0.14**	0.24**	0.29***
Taiynsha	0.44***	0.42***	0.12**	0.19**	0.29***
Vozvyshenka	0.28+	0.44***	0.14*	0.27***	0.28***
Yavlenka	0.33**	0.42***	0.11*	0.25***	0.26***
Zhana Arka	0.35**	0.37***	0.13**	0.30***	0.29***
Zhetygara	0.40***	0.44***	0.21***	0.32***	0.38***
Zhezkazgan	0.35**	0.40***	0.19***	0.29***	0.31***

Note: Values in the table correspond to Sen's slope coefficient (°C/decade); *** – $p < 0.001$; ** – $p < 0.01$; * – $p < 0.05$; + $p<0,10$; ns – statistically non-significant.

Table S2. Change points in long-term air temperature time series identified using the Pettitt test

Station	Winter	Spring	Summer	Autumn	Annual
Aksu-Aiuly	1978+	1999***	1973***	1976***	1976***
Atbasar	1980*	1999***	1980+	1976**	1987***
Bes-Oba	1978ns	1999***	1972*	1976**	1976***
Blagoveshchenka	1980*	1999**	1980**	1987**	1980***
Irgyz	1980*	1998***	1982**	1987**	1996***
Karabalyk	1980*	1999**	1980**	1987***	1987***
Karagandy	1978**	1999***	1972ns	1976***	1976***
Kushmurun	1980ns	1999**	1980*	1987**	1987***
Ruzaevka	1980*	1999**	1980*	2001*	1980***
Taiynsha	1957***	1973***	1980*	1976**	1960***
Vozvyshenka	1980ns	1999***	1980*	1987**	1987***
Yavlenka	1980**	1996***	1980*	2000**	1980***
Zhana-Arka	1978*	1999***	1973**	1977***	1976***
Zhetikara	1980***	2000***	1980***	1993***	1980***
Zhezkazgan	1978**	1999***	1982***	1976***	1978***

Note: *** – $p < 0.001$; ** – $p < 0.01$; * – $p < 0.05$; + $p<0,10$; ns – statistically non-significant.

Table S3. Results of the Mann–Kendall test and Sen's slope estimator for seasonal and annual precipitation time series

Station	Winter	Spring	Summer	Autumn	Annual
Aksu-Aiuly	5.6***	1.1ns	2.4ns	6.1***	16.0***
Atbasar	3.8***	1.1ns	1.5ns	2.0*	8.5**
Bes-Oba	-0.1ns	-3.3*	-2.2ns	-0.1ns	-7.4*
Blagoveshchenka	3.7***	1.8+	0.3ns	2.4*	8.9**
Irgyz	1.8**	0.9ns	-0.5ns	0.1ns	2.0ns
Karabalyk	4.3***	4.8**	0.2ns	0.5ns	9.9*
Karagandy	7.4***	4.7***	2.4ns	5.0***	21.1***
Kushmurun	4.2***	2.5+	2.3ns	1.9+	9.0**
Ruzaevka	6.3***	4.1**	1.5ns	3.7**	16.8***
Taiynsha	3.7***	1.6+	1.0ns	3.2***	10.9***
Vozvyshenka	0.7ns	1.9ns	1.6ns	2.5*	6.3+
Yavlenka	5.0***	4.2***	2.1ns	2.8*	14.7***
Zhana-Arka	4.4***	1.8+	1.4ns	2.6**	9.5***
Zhetikara	2.8**	4.8**	-0.4ns	2.7*	13.3**
Zhezkazgan	2.8***	2.4*	-0.2ns	1.3+	5.0*

Note: Values in the table correspond to Sen's slope coefficient (mm/decade); *** – $p < 0.001$; ** – $p < 0.01$; * – $p < 0.05$; + $p<0,10$; ns – statistically non-significant.

Table S4. Change points in seasonal and annual precipitation time series identified using the Pettitt test

Station	Winter	Spring	Summer	Autumn	Annual
Aksu-Aiuly	1970***	1965ns	2002ns	1975***	1980***
Atbasar	1970***	1978+	1986ns	1968ns	1959**
Bes-Oba	1951ns	2004*	2007ns	1994ns	2002+
Blagoveshchenka	1954***	1999*	2010ns	1962ns	1962+
Irgyz	1955**	1978ns	2004ns	1958ns	1955ns
Karabalyk	1982***	1998**	1981ns	1975ns	1984*
Karagandy	1969***	1977***	1998ns	1974***	1981***
Kushmurun	1953***	1992ns	1958ns	1976ns	1976ns
Ruzaevka	1985***	2000**	1958ns	1976**	1976***
Taiynsha	1970***	1959ns	1937ns	1962**	1957**
Vozvyshenka	1955ns	1999ns	2000ns	1976ns	2000ns
Yavlenka	1970***	1980**	1984ns	1972*	1976***
Zhana-Arka	1970***	2001ns	2000ns	1975*	1957*
Zhetikara	1993+	1992**	2007ns	1996ns	1991+
Zhezkazgan	1971***	1957*	1948ns	1958ns	1952**

Note: *** – $p < 0.001$; ** – $p < 0.01$; * – $p < 0.05$; + $p<0,10$; ns – statistically non-significant.

Table S5. Results of time-series homogeneity tests for SPI-3-month.

Meteorological station	Pettitt Test		Buishand Test		CUSUM	
	Change points	*ρ*-value	Change points	*ρ*-value	Change points	*ρ*-value
Nura–Sarysu WMB						
Aksu-Ayuly	1977***	<0.001	1977***	<0.001	1977***	<0.001
Zhana-Arka	2004*	0.013	2004***	<0.001	2004*	0.013
Bes-Oba	2002	0.052	2002**	0.004	2002*	0.045
Karagandy	1957***	<0.001	1957***	<0.001	1957***	<0.001
Korneevka	1984**	0.002	1999**	0.003	1999***	0.001
Zhezkazgan	1952**	0.006	1952**	0.001	1952***	0.001
Korgalzhyn	1986	0.451	1986	0.634	1986	0.351
Zharyk	1957***	<0.001	1957***	<0.001	1957***	<0.001
Esil WMB						
Blagoveshchenka	1962***	0.0003	1962***	0.001	1962***	<0.001
Vozvyshenka	1962**	0.008	1962*	0.012	1962*	0.010
Kishkenekol	2003	0.426	2003	0.480	2003	0.701
Akkol	1968***	<0.001	1968***	<0.001	1968***	<0.001
Ruzaevka	1976***	<0.001	1976***	<0.001	1976***	<0.001
Saumalkol	1988***	<0.001	1988***	<0.001	1988***	<0.001
Sergeevka	2000	0.057	2000	0.304	2000	0.069
Taiynsha	1950	0.091	1950**	0.002	1950	0.106
Chkalovo	1976	0.163	1976	0.103	1976	0.068
Yavlenka	1975***	<0.001	1975***	<0.001	1975***	<0.001
Arshaly	1999*	0.019	1999	0.053	1999**	0.008
Atbasar	1962***	<0.001	1968***	<0.001	1968***	<0.001
Balkashino	1977***	<0.001	1977***	<0.001	1977***	<0.001
Yegindykol	2012	0.143	2012	0.229	2012	0.055
Ereimentau	1968	0.464	1968	0.409	1968	0.205
Bulaevo	1965***	0.0002	1965***	<0.001	1965***	<0.001
Astana	1957***	<0.001	1957***	<0.001	1957***	<0.001
Shchuchinsk	2004**	0.006	2004**	0.004	2004**	0.002
Tobyl–Torgai WMB						
Dievskaya	1985	0.482	1985	0.295	1985	0.293
Amangeldy	2003**	0.005	2003***	<0.001	2003**	0.004
Arshalinsky	1984	0.413	1984	0.310	1984	0.387
Jetygara	1986*	0.010	1991*	0.022	1991**	0.004
Kostanay	1998	0.053	1998	0.118	1998*	0.035
Kushmurun	1981*	0.034	1955*	0.034	1955*	0.013
Tobol	1998	≥0.05	1998	0.958	1998	0.671
Torgai	1998**	0.007	1998***	<0.001	1998**	0.005
Irgiz	1951	0.142	1955	0.085	1955*	0.015
Karabutak	1978**	0.001	1978**	0.002	1978***	0.001
Komsomolskoye	1998	0.194	1998*	0.049	1998	0.119

$\rho \geq 0.05$, time series is homogeneous

* $\rho < 0.05$, statistically significant break

** $\rho < 0.01$, highly significant break

*** $\rho < 0.001$, very highly significant break

Table S6. Results of time-series homogeneity tests for SPEI-3-month.

Meteorological station	Pettitt Test		Buishand Test		CUSUM	
	Change points	*ρ*-value	Change points	*ρ*-value	Change points	*ρ*-value
Nura–Sarysu WMB						
Aksu-Ayuly	1975	0.112	1957	0.097	1957	0.055
Zhana-Arka	2004	0.062	2004***	<0.001	2004	0.074
Bes-Oba	1994**	0.002	1996***	0.001	1996**	0.001
Karagandy	1956***	0.003	1956**	0.001	1956***	<0.001
Korneevka	1983	0.231	1983	0.101	1983	0.172
Zhezkazgan	1952	0.053	1952**	0.001	1952*	0.013
Korgalzhyn	1996	0.264	1996	0.294	1996	0.219
Zharyk	1957***	<0.001	1957***	<0.001	1957***	<0.001
Esil WMB						
Blagoveshchenka	1957*	0.029	1962	0.091	1962*	0.024
Vozvyshenka	1962	0.204	1962	0.114	1962	0.147
Kishkenekol	1981	≥0.05	1981	0.954	1981	0.968
Akkol	1956**	0.005	1955*	0.011	1955**	0.001
Ruzaevka	1981***	0.0004	1976***	<0.001	1976***	<0.001
Saumalkol	1976***	0.0001	1976***	<0.001	1976***	<0.001
Sergeevka	1983	0.767	1983	0.792	1983	0.640
Taiynsha	1950	0.069	1950**	0.002	1950	0.095
Chkalovo	1976	≥0.05	1976	0.565	1976	0.668
Yavlenka	1975***	<0.001	1975***	<0.001	1975***	<0.001
Arshaly	2012	0.754	2012	0.576	2012	0.305
Atbasar	1957**	0.002	1957*	0.011	1957**	0.001
Balkashino	1977***	0.001	1977**	0.002	1977***	<0.001
Yegindykol	2012	0.787	2012	0.517	2012	0.419
Ereimentau	2001	0.483	2001	0.141	2001	0.508
Bulaevo	1965*	0.017	1965***	0.001	1965**	0.010
Astana	1957***	0.0002	1957***	0.001	1957***	<0.001
Shchuchinsk	2012	0.297	2012	0.449	2012	0.112
Tobyl–Torgai WMB						
Dievskaya	2002	0.420	2002	0.206	2002	0.263
Amangeldy	2004*	0.011	2004***	<0.001	2004**	0.005
Arshalinsky	2003	0.070	2003	0.139	2003	0.079
Jetygara	1962	0.566	1962	0.084	1962	0.302
Kostanay	1984	0.249	1984	0.286	1984	0.136
Kushmurun	1952	≥0.05	1952	0.509	1952	0.488
Tobol	1994	0.235	1994	0.148	1994	0.174
Torgai	1990***	<0.001	1990***	<0.001	1990***	<0.001
Irgiz	1993	0.078	1993*	0.020	1993	0.194
Karabutak	2005	0.206	2005	0.063	2005	0.181
Komsomolskoye	1971	0.685	1971	0.632	1971	0.596

$\rho \geq 0.05$, time series is homogeneous

* $\rho < 0.05$, statistically significant break

** $\rho < 0.01$, highly significant break

*** $\rho < 0.001$, very highly significant break

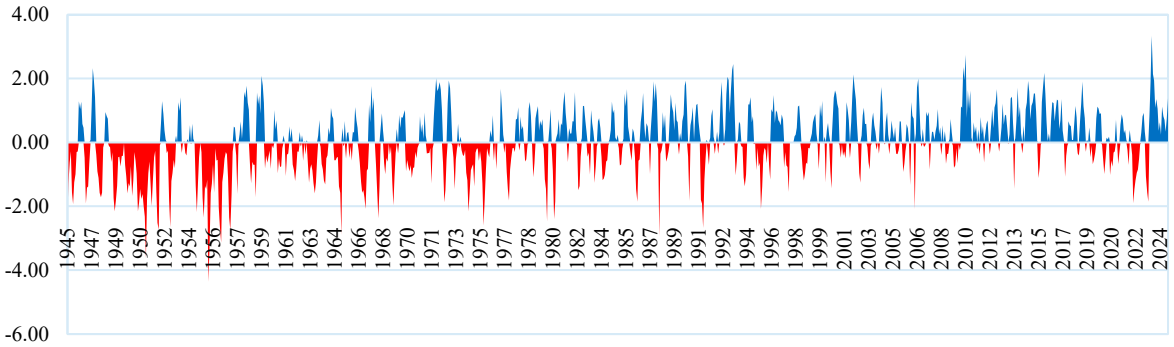
Table S7. Characteristics of Identified Structural Changes in the Hydrological Regime Based on Statistical Test Results

Hydrological post	n	Pettitt year	Pettitt p	SNHT year	SNHT p	Buishand year	Buishand p	Consensus year	n pre	n post	Pre-break mean SDI	Post-break mean SDI	ΔSDI	Regime shift
Nura–Sarysu WMB														
Nura – Besoba	63	2012	0.189	2013	0.010	2012	0.051	2012	52	11	-0.206	0.916	1.123	Shift to wetter conditions
Nura – Sheshenkara	63	2012	0.035	2012	0.001	2012	0.007	2012	52	11	-0.257	1.124	1.381	Shift to wetter conditions
Nura – Balykty	63	2012	0.124	2012	0.005	2012	0.032	2012	52	11	-0.213	0.985	1.197	Shift to wetter conditions
Nura – Koshkarbayeva	62	1982	0.171	2014	0.032	1982	0.081	1982	21	41	-0.458	0.220	0.678	Shift to wetter conditions
Sherubainura – Karamurun	63	2012	0.290	2014	0.019	2013	0.091	2013	53	10	-0.185	0.931	1.116	Shift to wetter conditions
Sarysu – Razyezd 189	61	2013	0.086	2014	0.001	2013	0.019	2013	51	10	-0.276	1.063	1.339	Shift to wetter conditions
Zhaman-Sarysu – Atasu	63	2019	0.658	2014	0.056	2014	0.195	2014	54	9	-0.256	0.751	1.007	Shift to wetter conditions
Esil WMB														
Silety – Izobilnoye	66	1973	0.394	1964	0.406	1973	0.396	1973	16	50	0.412	-0.148	-0.560	Shift to drier conditions
Silety – Prirechnoye	62	1982	0.497	1982	0.594	1982	0.333	1982	21	41	-0.346	0.156	0.502	Shift to wetter conditions
Shagalaly – Pavlovka	84	2010	0.039	2010	0.000	2010	0.004	2010	71	13	-0.230	1.188	1.418	Shift to wetter conditions
Shagalaly – Severnoye	68	1982	0.001	2010	0.001	1982	0.001	1982	27	41	-0.585	0.369	0.955	Shift to wetter conditions
Moiyldy – Nikolayevka	50	1984	0.256	1983	0.159	1984	0.182	1984	11	39	-0.651	0.186	0.837	Shift to wetter conditions

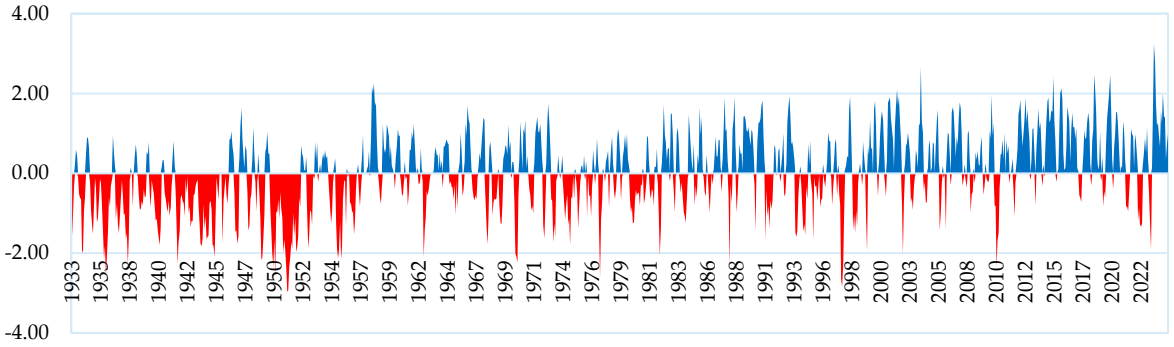
Esil – Turgen	49	2013	0.040	2013	0.016	2012	0.035	2013	39	10	-0.233	0.918	1.151	Shift to wetter conditions
Kalkutan – Kalkutan	86	1977	0.112	1977	0.115	1977	0.035	1977	40	46	-0.327	0.268	0.595	Shift to wetter conditions
Zhabay – Balkashino	63	1989	0.057	2012	0.092	1989	0.033	1989	29	34	-0.301	0.343	0.644	Shift to wetter conditions
Zhabay – Atbasar	87	1977	0.060	2013	0.003	1977	0.036	1977	41	46	-0.294	0.287	0.580	Shift to wetter conditions
Akkanburlyk – Vozvyshenka	85	1977	0.110	2013	0.024	1977	0.032	1977	39	46	-0.315	0.272	0.588	Shift to wetter conditions
Imanburlyk – Sokolovka	73	1979	0.021	1979	0.029	1979	0.008	1979	29	44	-0.465	0.295	0.760	Shift to wetter conditions
Tobyl–Torgai WMB														
Tobyl – Akkarga	58	1983	0.032	1989	0.079	1989	0.022	1989	29	29	-0.388	0.350	0.738	Shift to wetter conditions
Tobyl – Grishenka	86	1984	0.488	1940	0.215	1984	0.620	1984	47	39	-0.154	0.154	0.308	Shift to wetter conditions
Tobyl – Kostanay	92	1964	0.114	1964	0.164	1964	0.063	1964	33	59	0.335	-0.225	-0.560	Shift to drier conditions
Ayat – Varvarinka	71	1989	0.498	2014	0.213	2008	0.417	2008	56	15	0.115	-0.472	-0.586	Shift to drier conditions
Togyzak – Togyzak	87	1972	0.297	1953	0.229	1972	0.216	1972	36	51	0.247	-0.191	-0.438	Shift to drier conditions
Ubagan – Aksuat	85	1997	0.621	2021	0.703	1972	0.555	1997	59	26	-0.106	0.259	0.365	Shift to wetter conditions
Damdy – Damdy	68	2008	0.236	2008	0.111	2008	0.112	2008	53	15	0.184	-0.610	-0.794	Shift to drier conditions

Torgai – Tusum	83	1994	0.036	1994	0.155	1994	0.068	1994	54	29	0.204	-0.405	-0.610	Shift to drier conditions
Karatorgai – Urpek	82	1990	0.400	1991	0.439	1991	0.181	1991	50	32	0.220	-0.263	-0.484	Shift to drier conditions
Sarytorgai – Sarytorgai	63	1990	0.573	1968	0.772	1991	0.739	1990	30	33	0.208	-0.102	-0.310	Shift to drier conditions
Yrgyz – Shenbertal	62	2008	0.124	2018	0.031	2008	0.064	2008	47	15	0.216	-0.654	-0.870	Shift to drier conditions

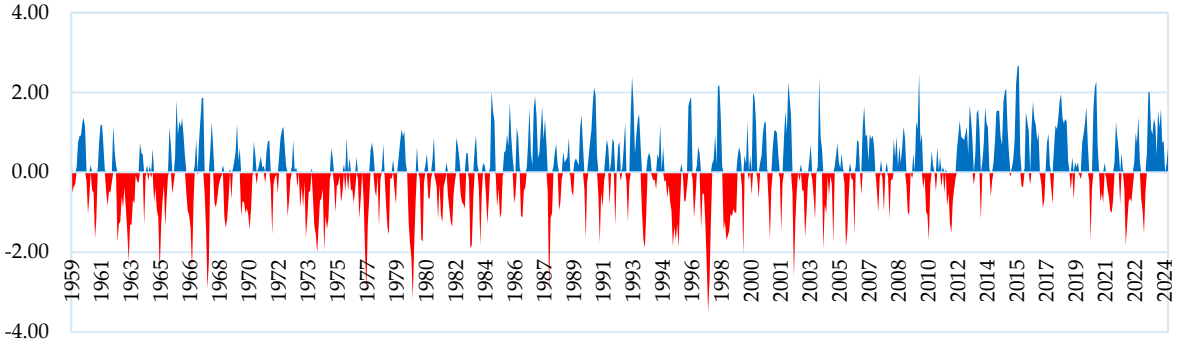
MS Aksu-Ayuly



MS Karagandy



MS Korneevka



MS Zhezkazgan

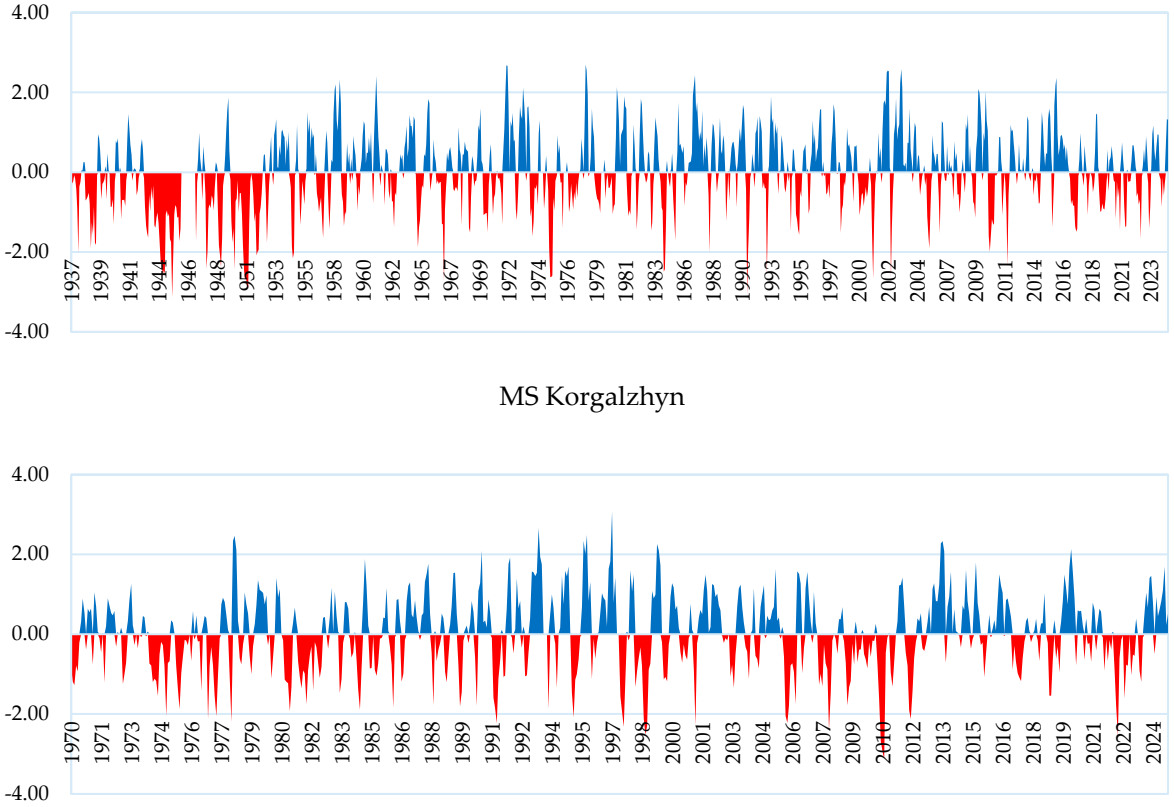
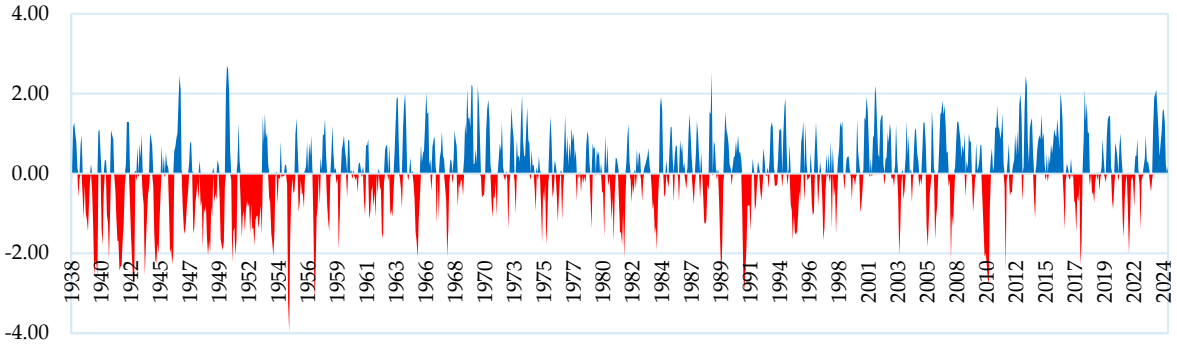
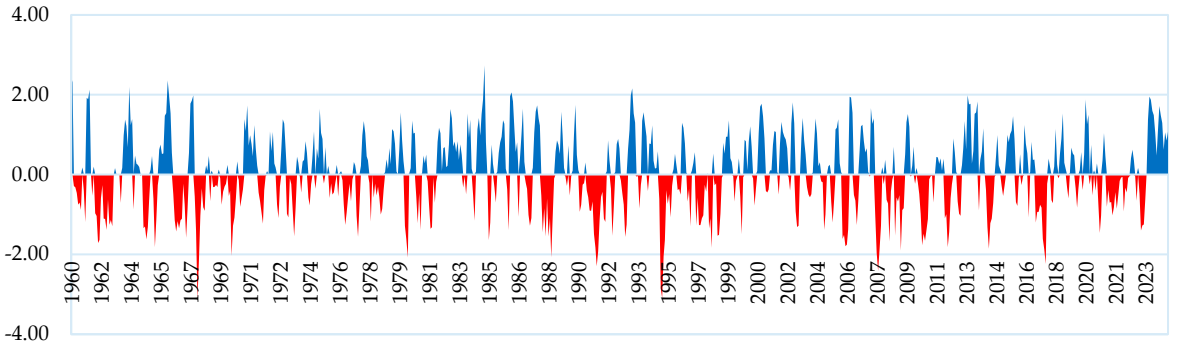


Figure S1. Long-term dynamics of the standardized precipitation index SPI-3 at the main meteorological stations of the Nura-Sarysu water management basin.

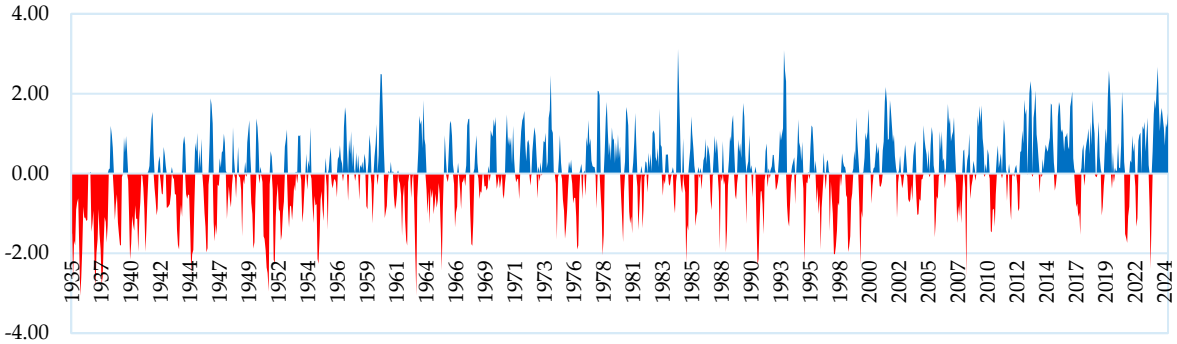
MS Blagoveshchenka



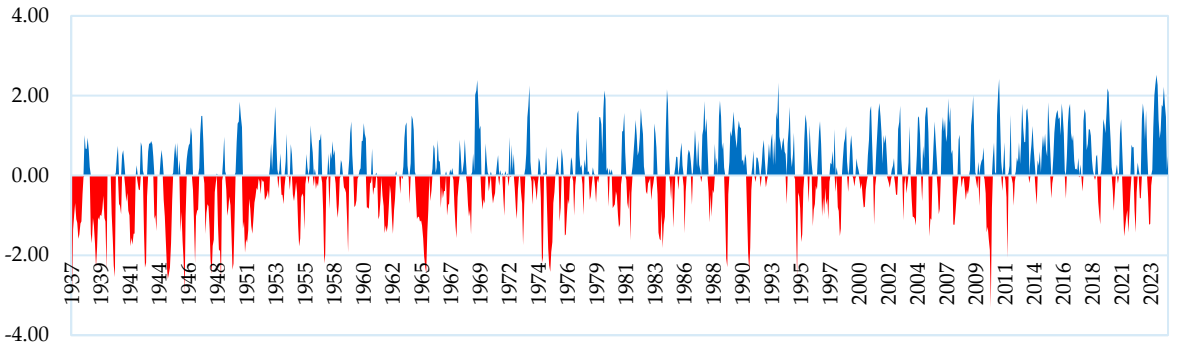
MS Kishkenekol



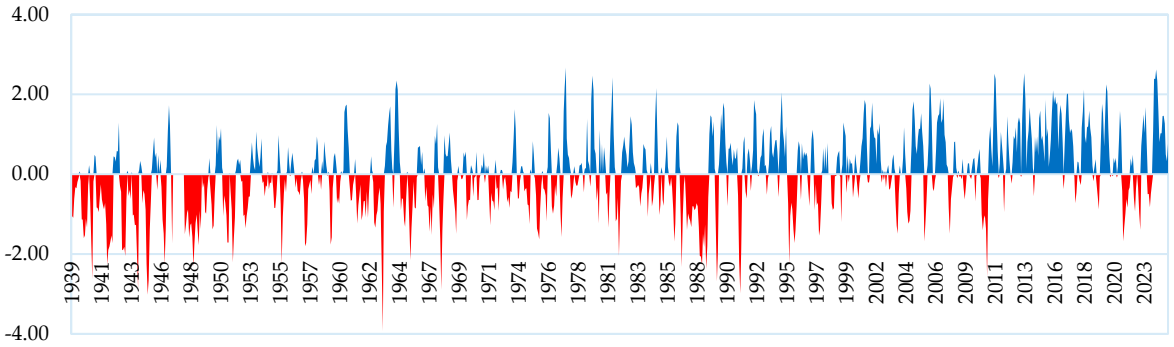
MS Akkol



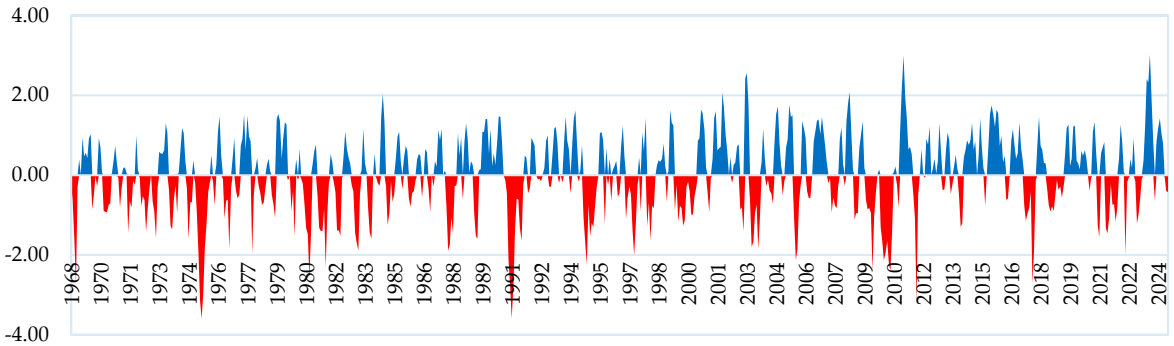
MS Ruzaevka



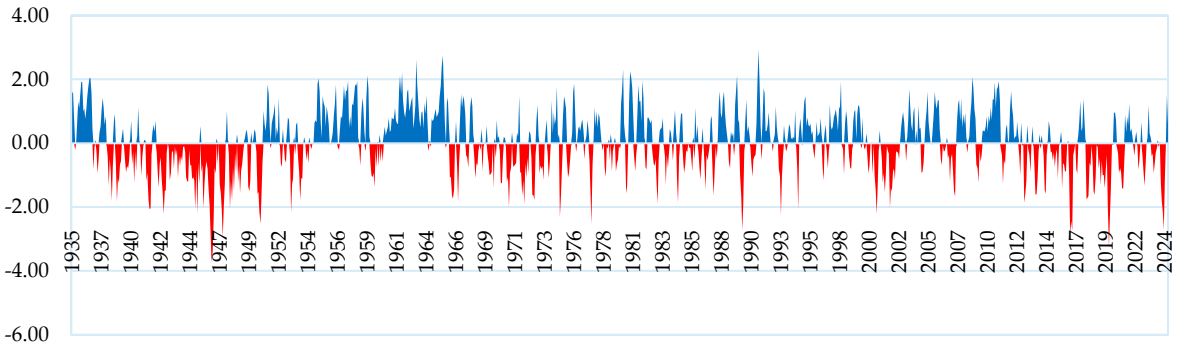
MS Saumalkol



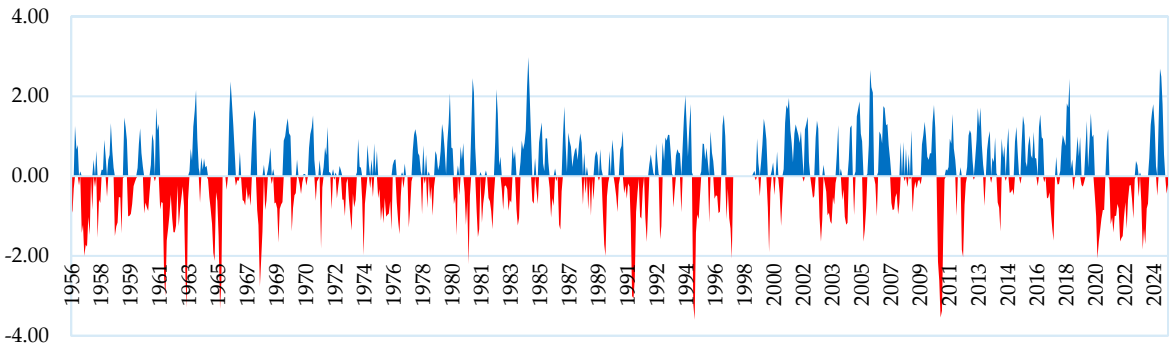
MS Sergeevka



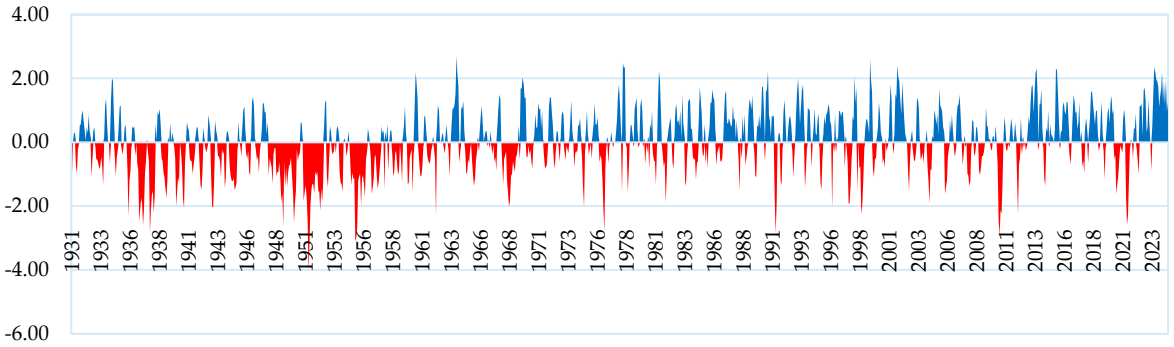
MS Taiynsha



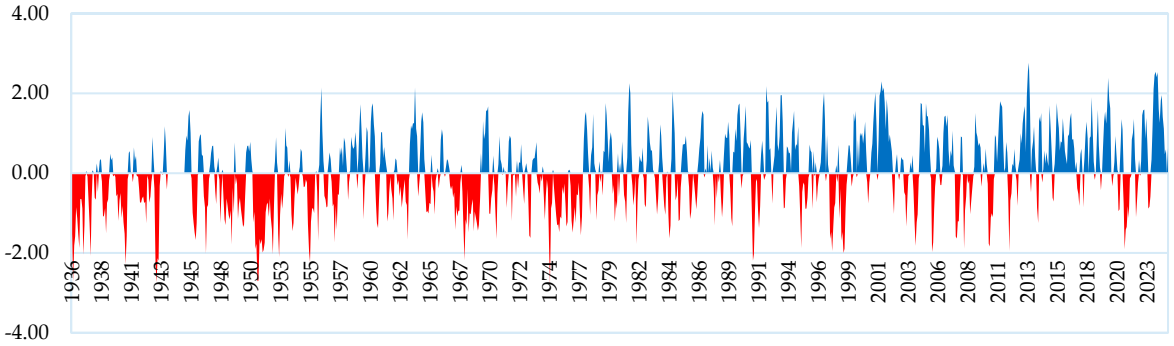
MS Chkalovo



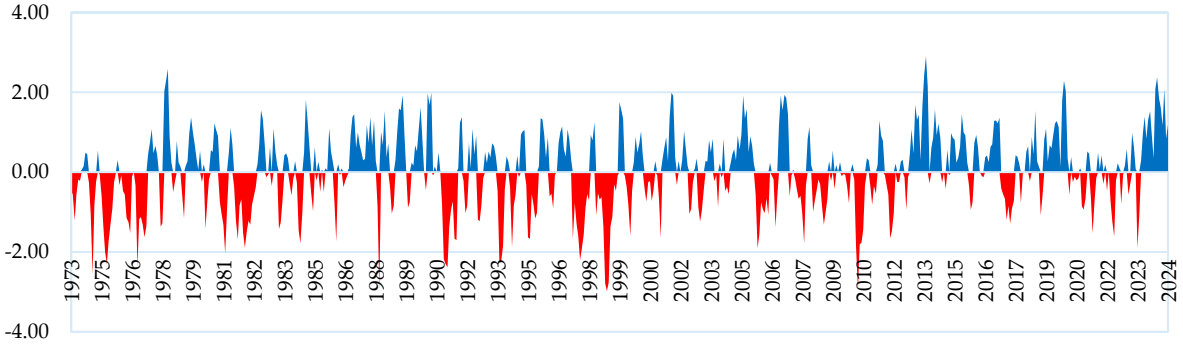
MS Atbasar



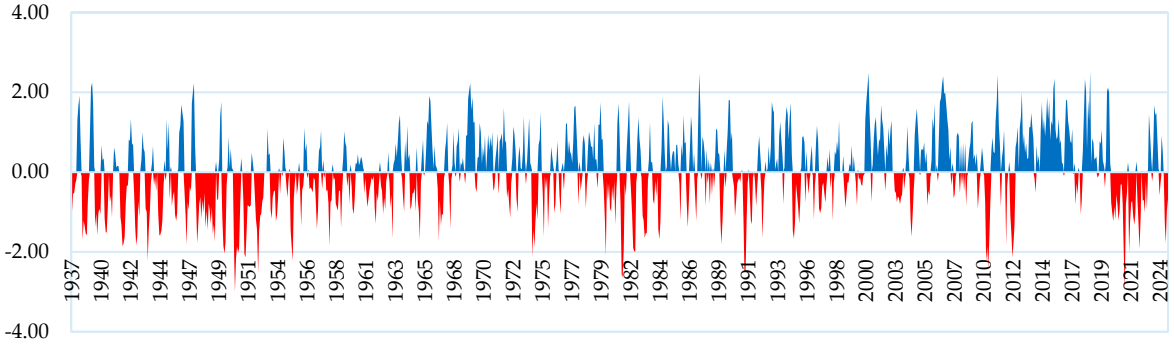
MS Balkashino



MS Yegindykol



MS Bulaevo



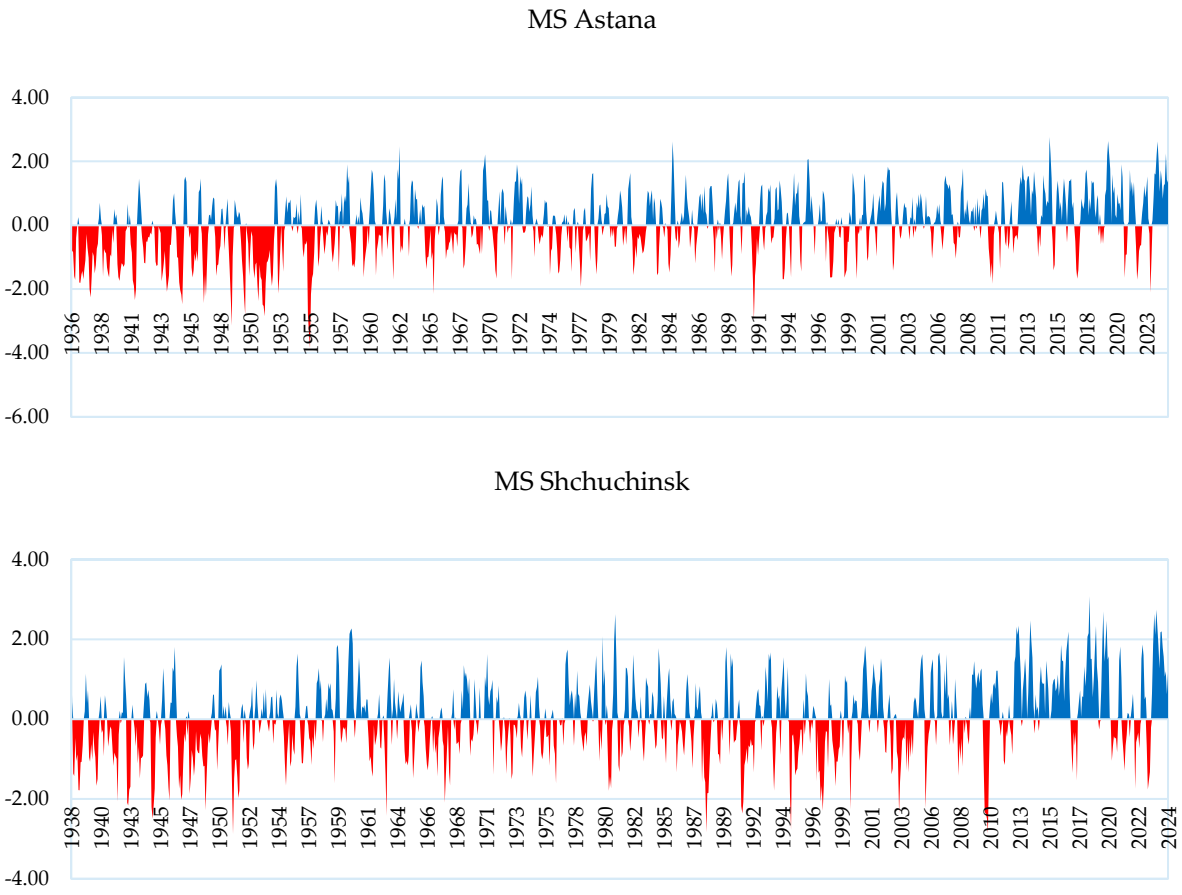
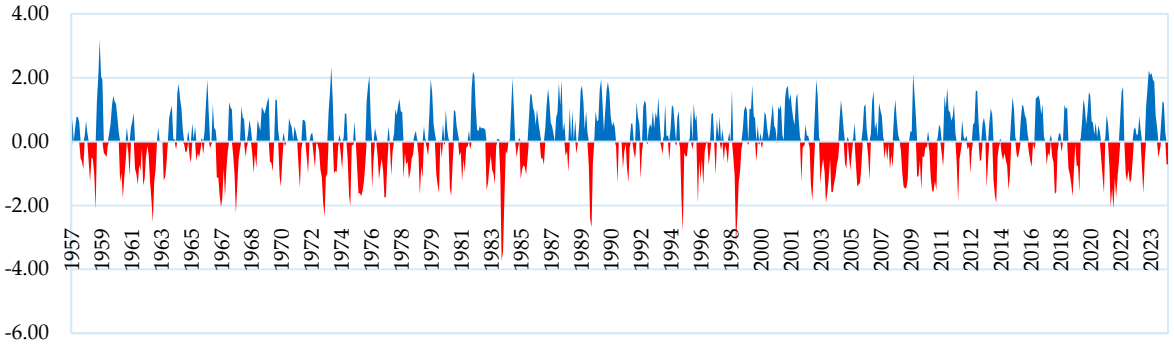
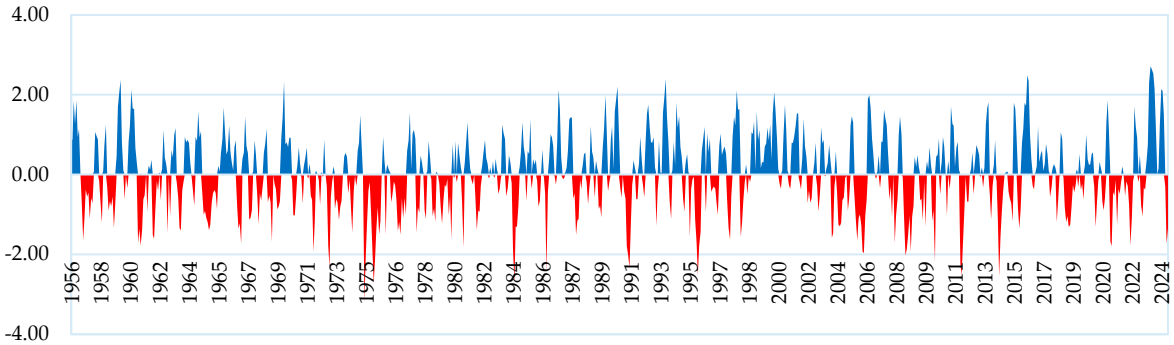


Figure S2. Long-term dynamics of the standardized precipitation index SPI-3 at the main meteorological stations of the Esil water management basin.

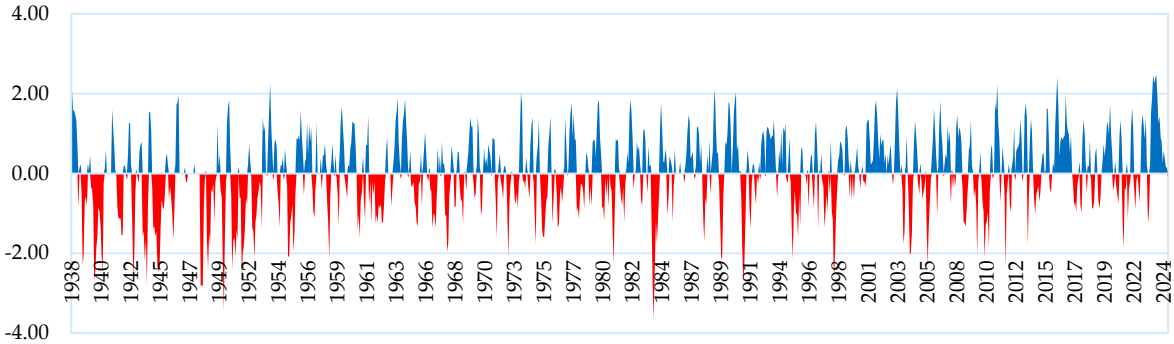
MS Dievskaya



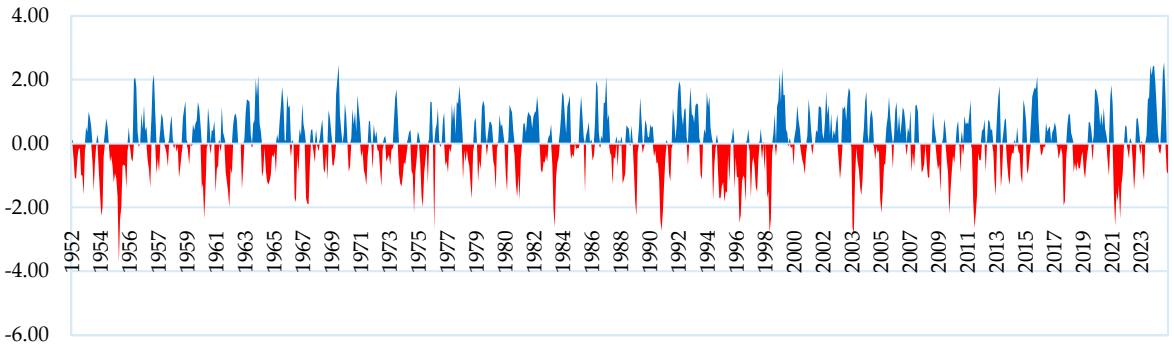
MS Arshalinsky



MS Kushmurun



MS Tobol



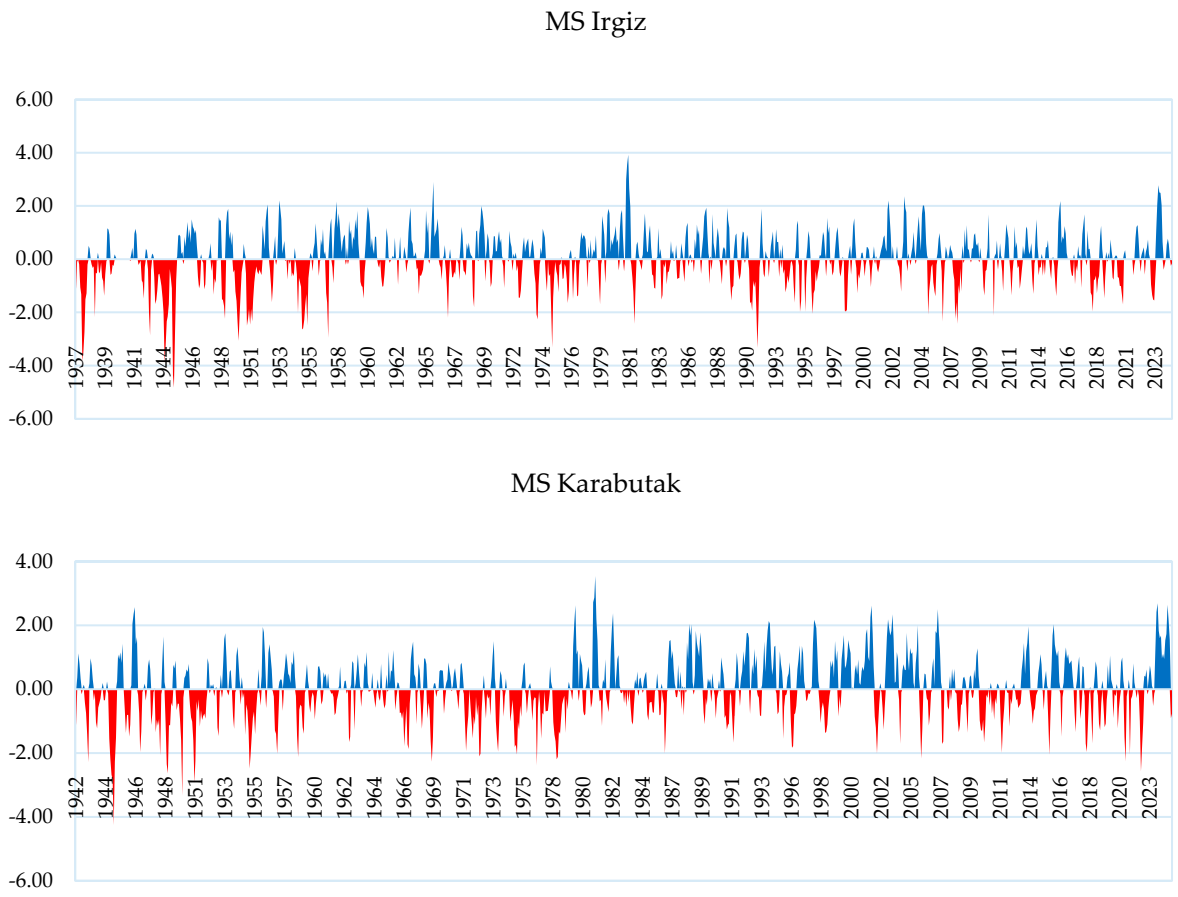
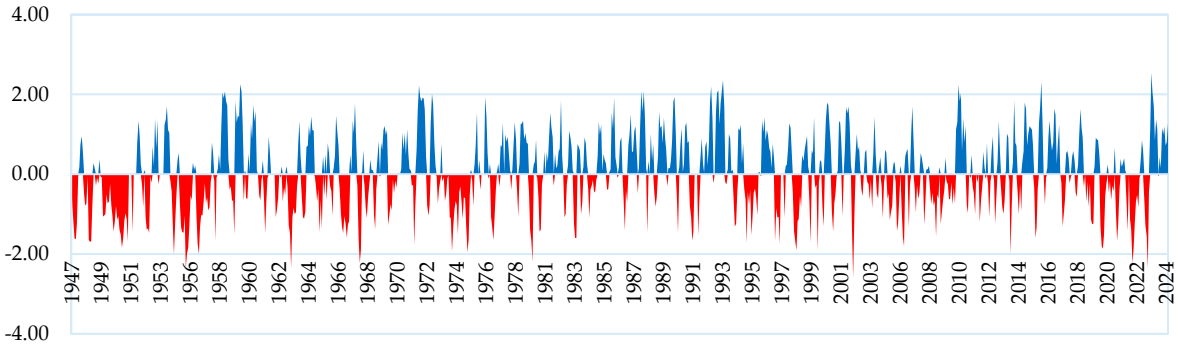
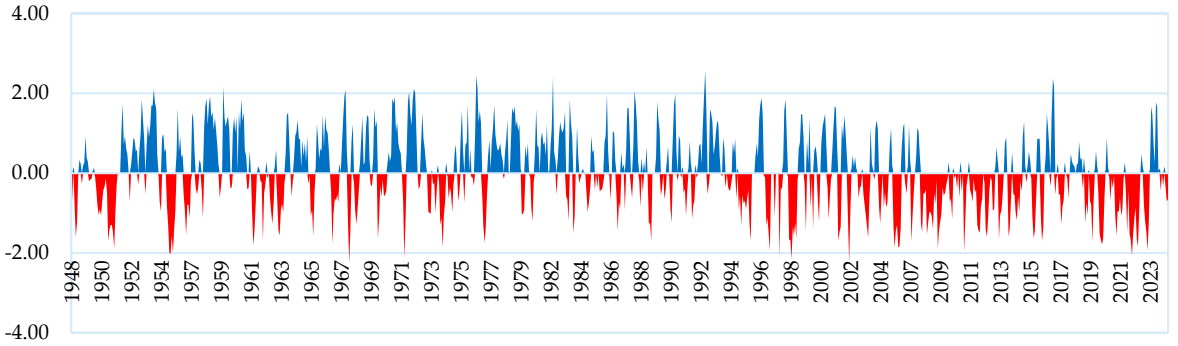


Figure S3. Long-term dynamics of the standardized precipitation index SPI-3 at the main meteorological stations of the Tobyl-Torgai water management basin.

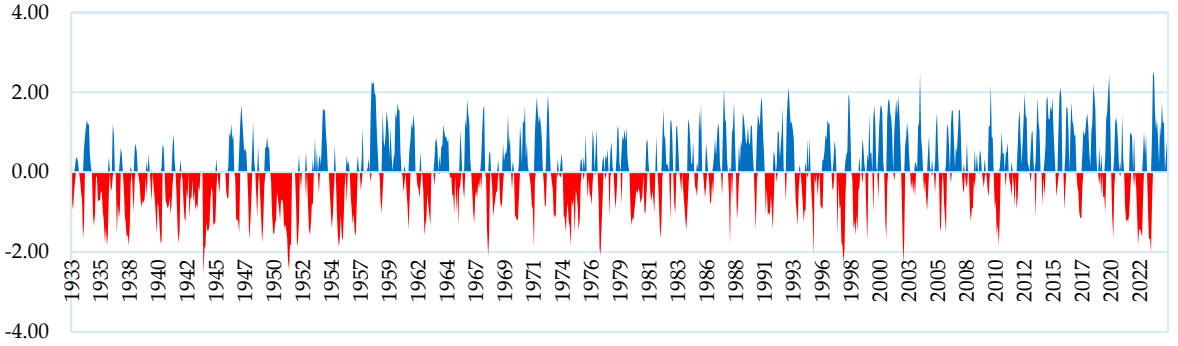
MS Aksu-Ayuly



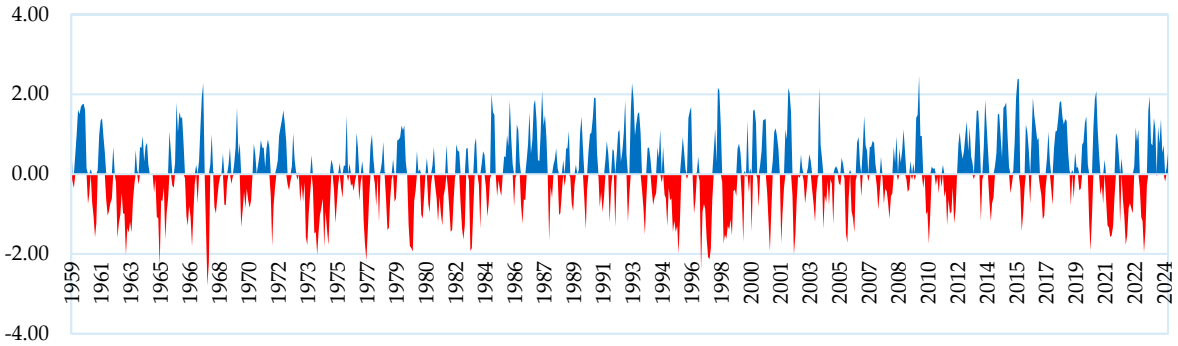
MS Bes-Oba



MS Karagandy



MS Korneevka



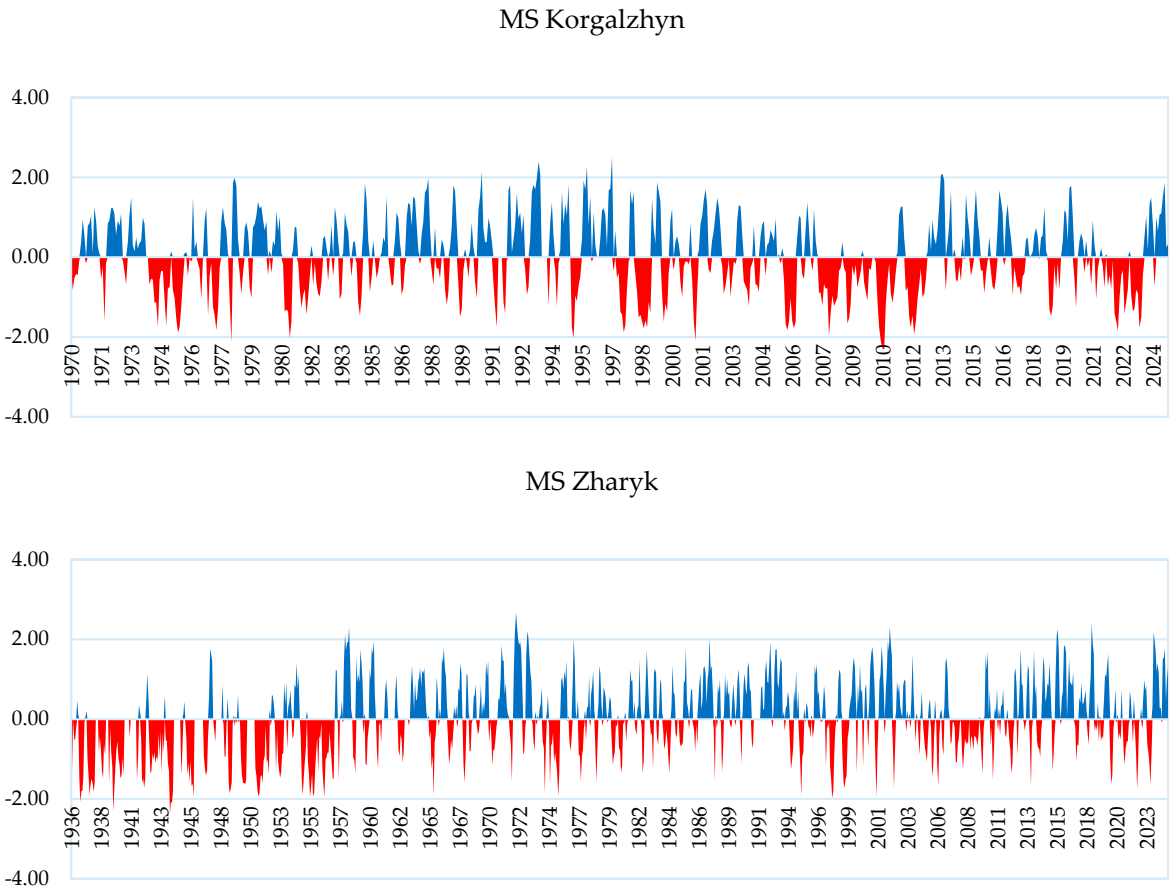
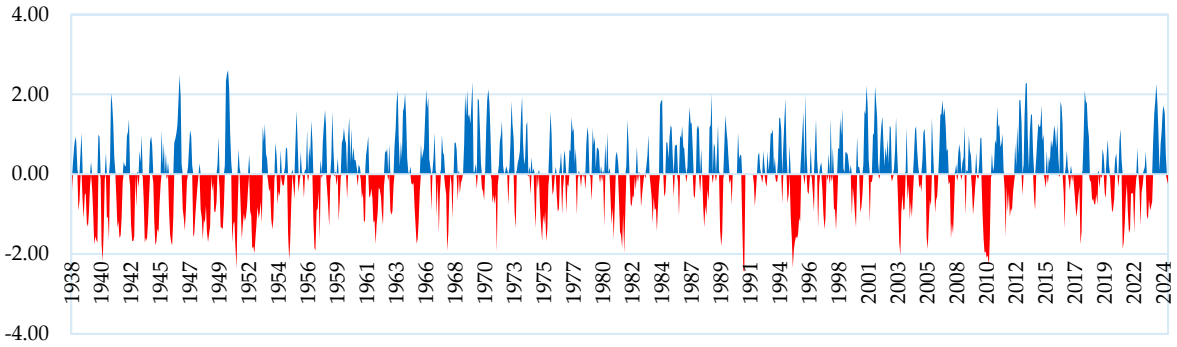
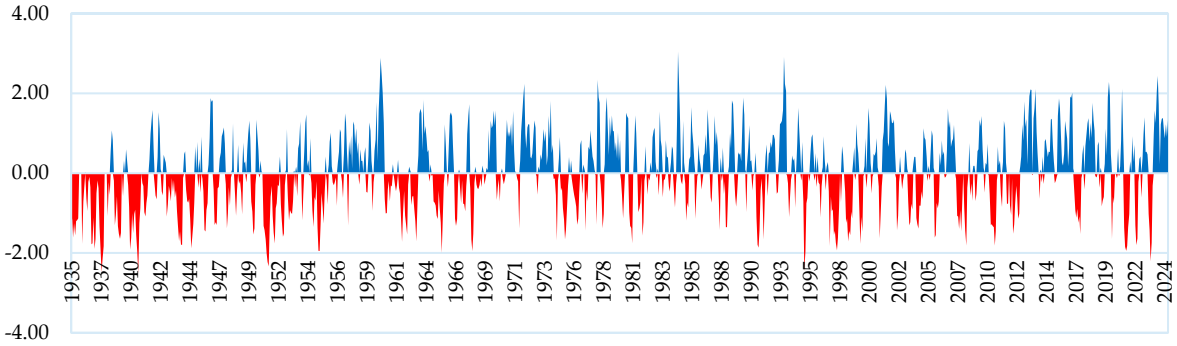


Figure S4. Long-term dynamics of the standardized precipitation evapotranspiration index SPEI-3 at the main meteorological stations of the Nura-Sarysu water management basin.

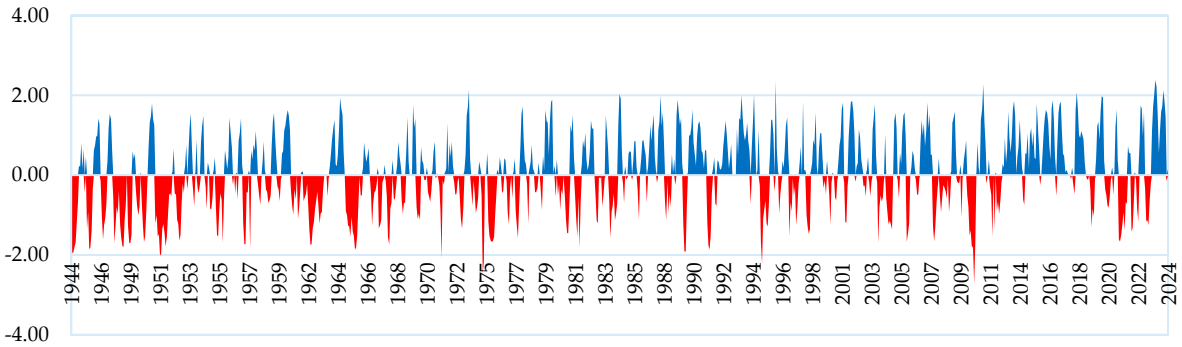
MS Blagoveshchenka



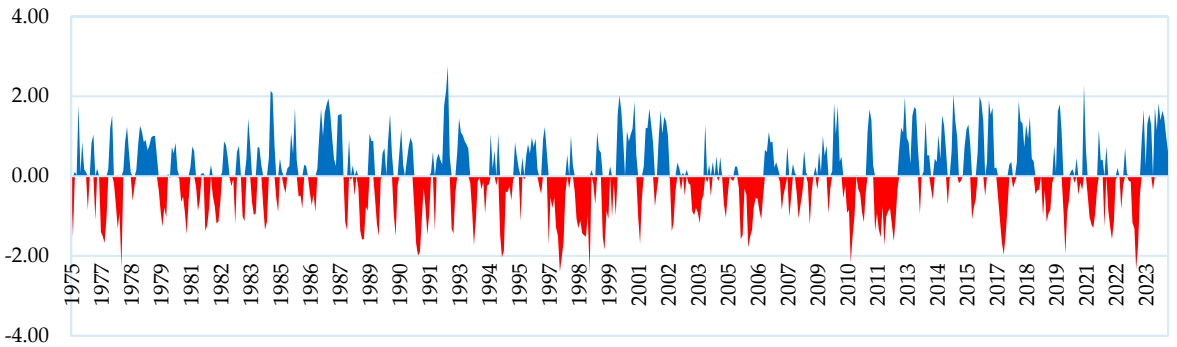
MS Akkol



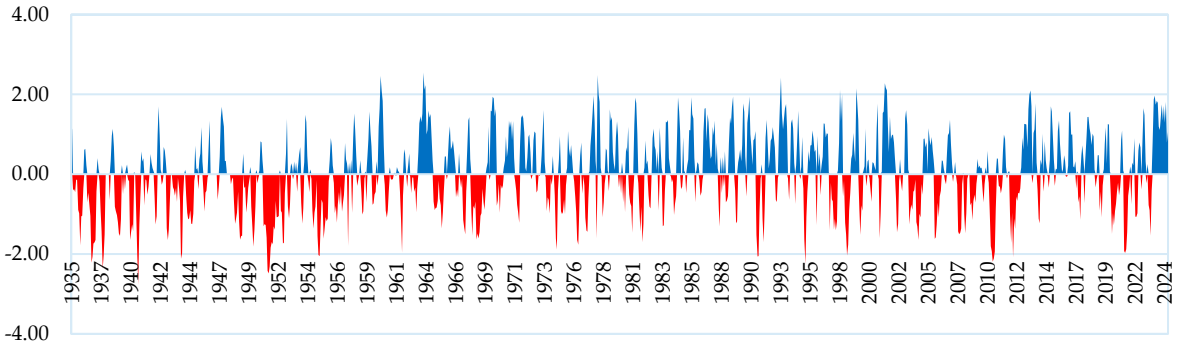
MS Ruzaevka



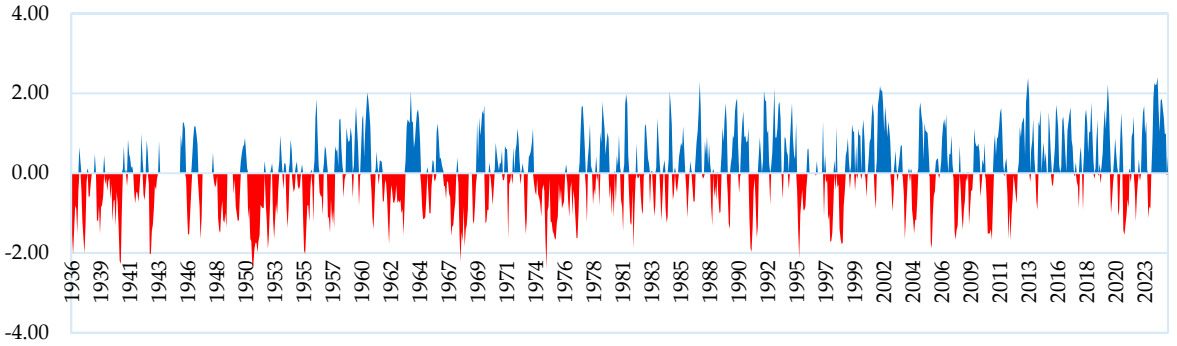
MS Arshaly



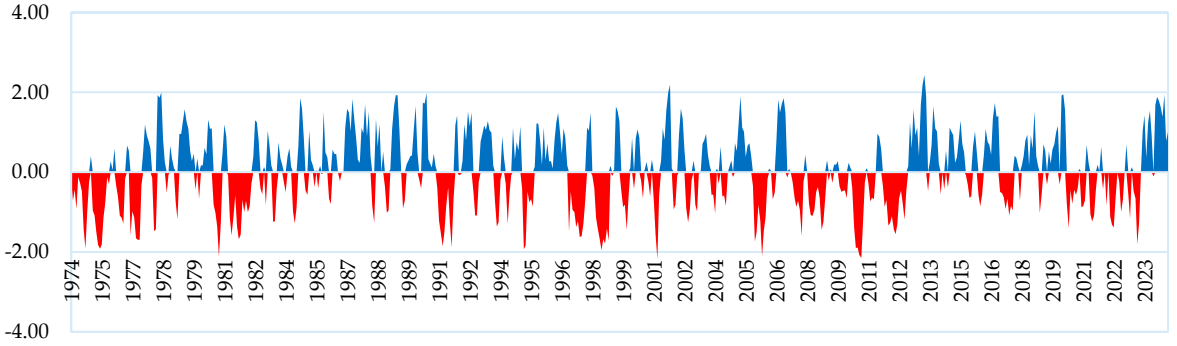
MS Atbasar



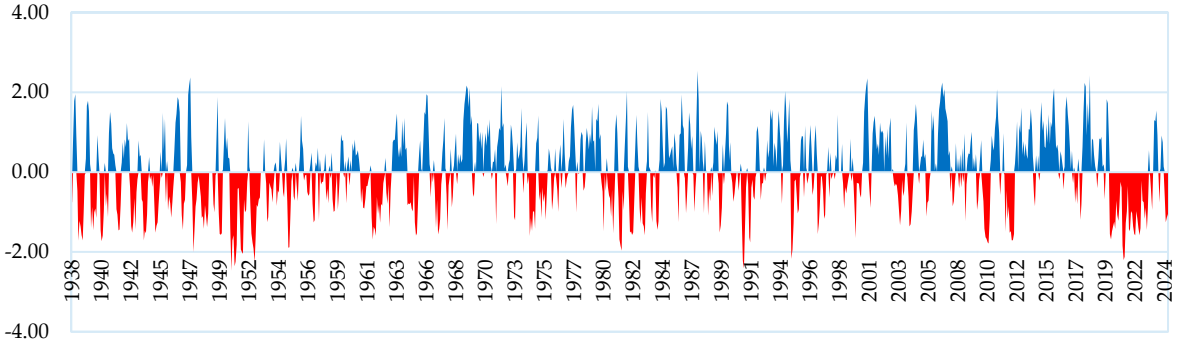
MS Balkashino



MS Yegindykol



MS Bulaevo



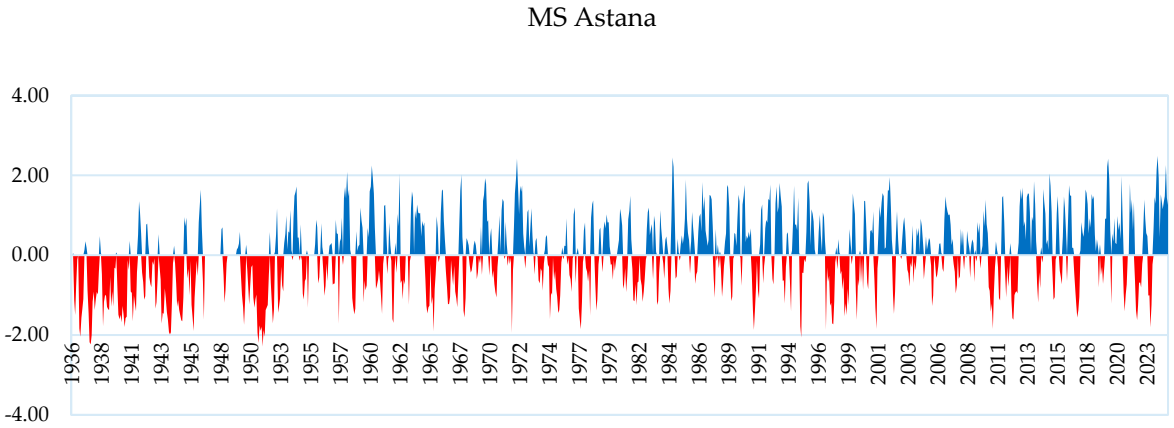
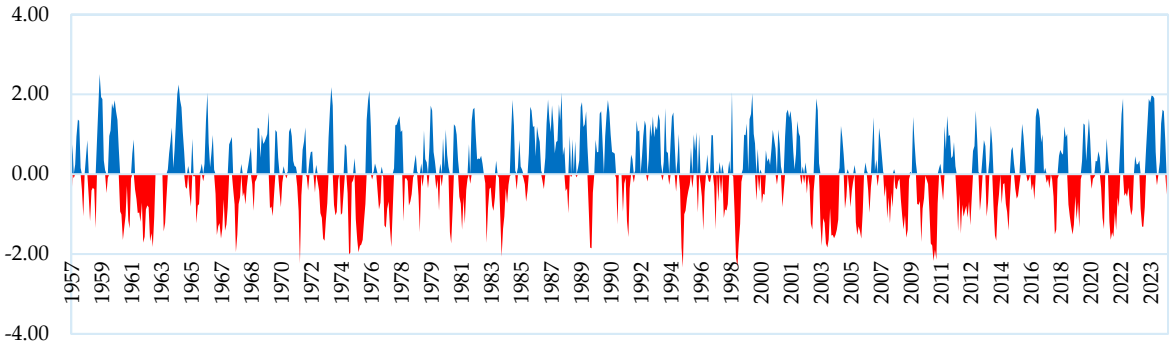
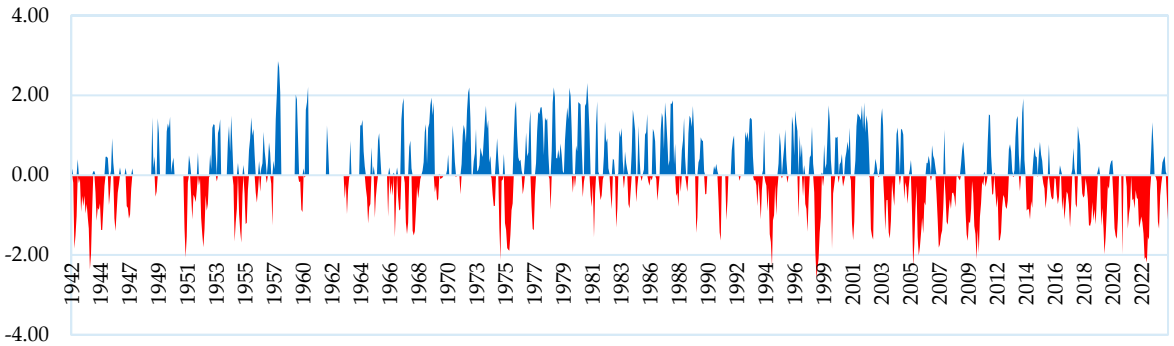


Figure S5. Long-term dynamics of the standardized precipitation evapotranspiration index SPEI-3 at the main meteorological stations of the Esil water management basin.

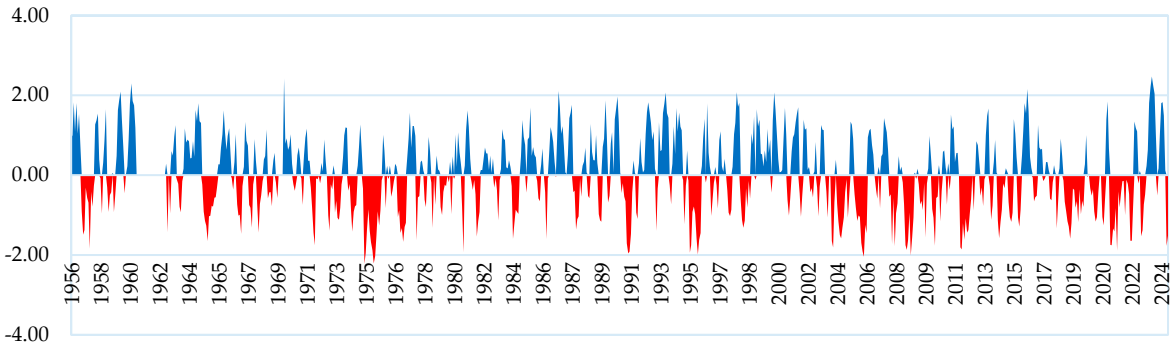
MS Dievskaya



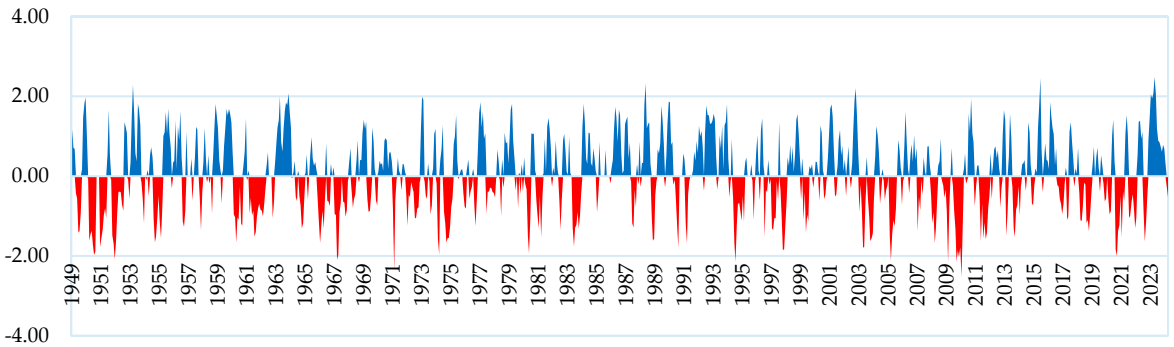
MS Amangeldy



MS Arshalinsky



MS Kushmurun



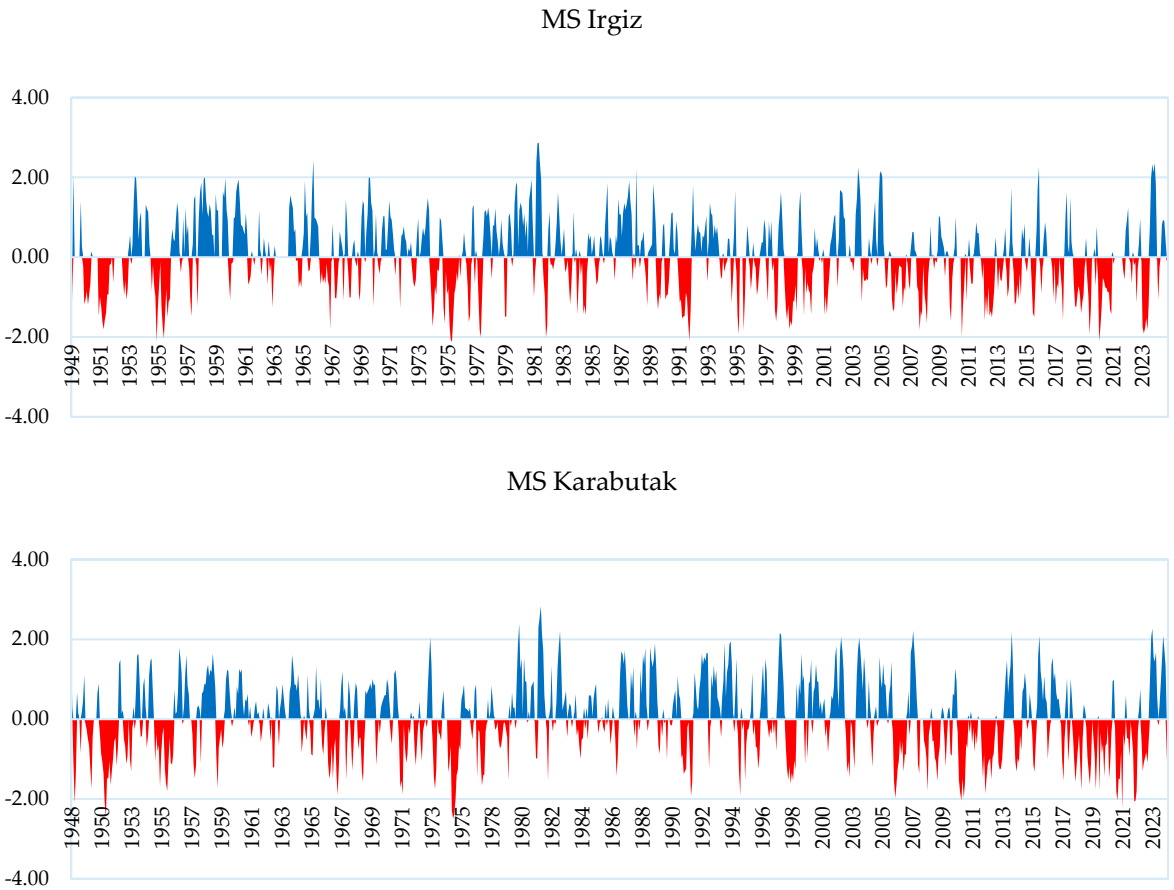
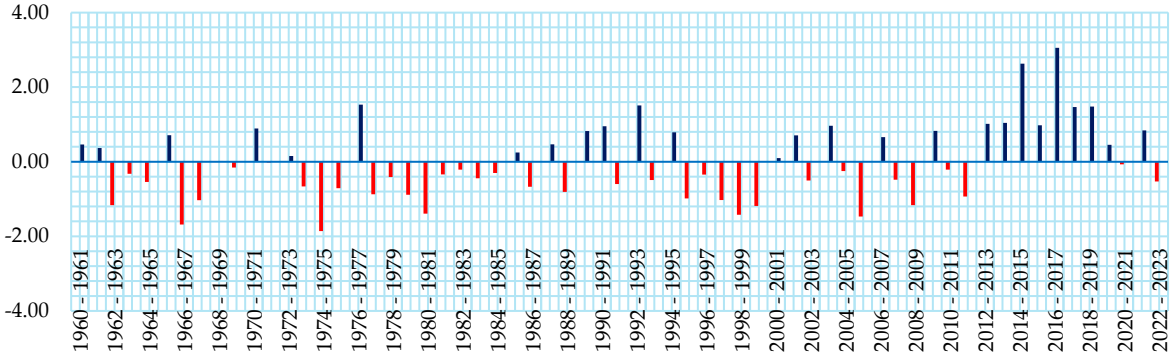
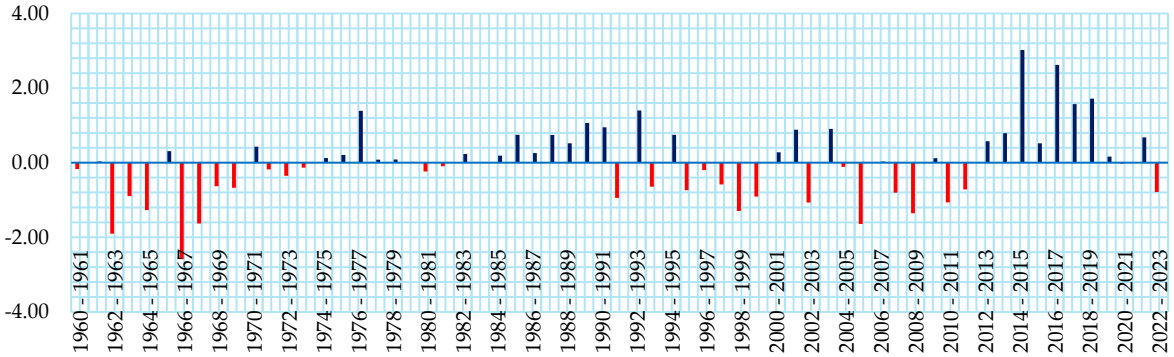


Figure S6. Long-term dynamics of the standardized precipitation evapotranspiration index SPEI-3 at the main meteorological stations of the Tobyl-Torgai water management basin.

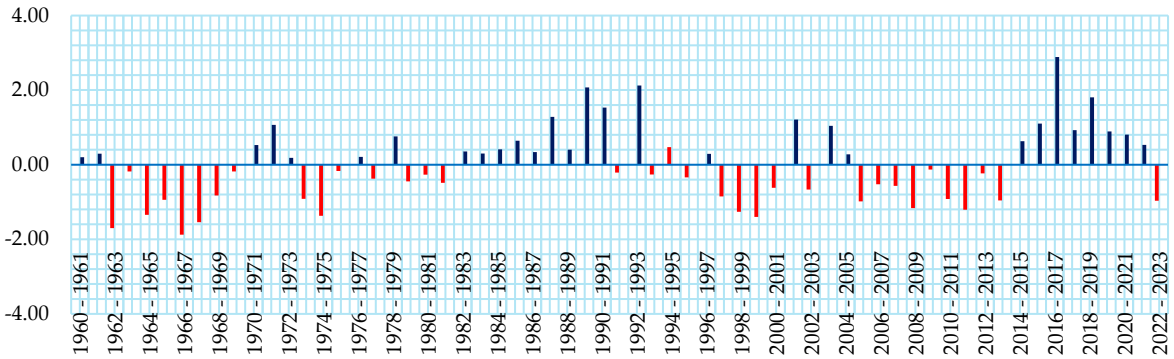
Nura – Sheshenkara



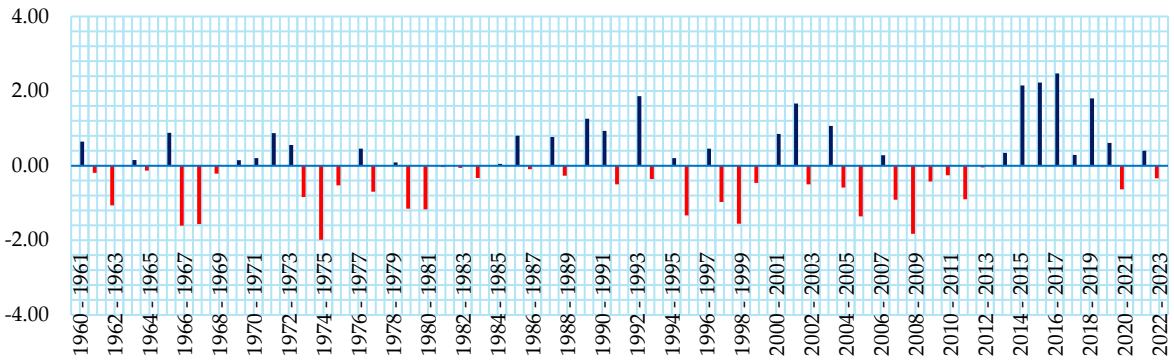
Nura-Balykty



Nura – Koshkarbayeva



Sherubainura – Karamurun



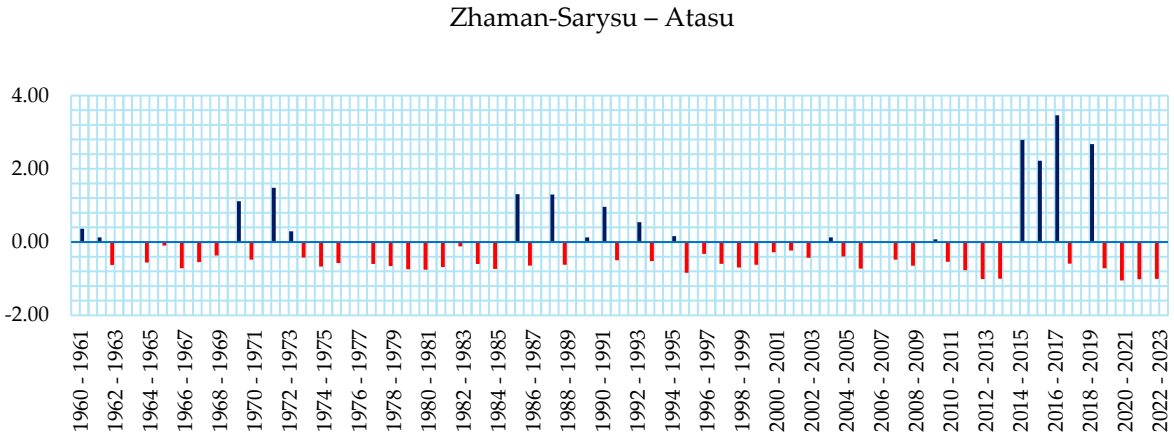
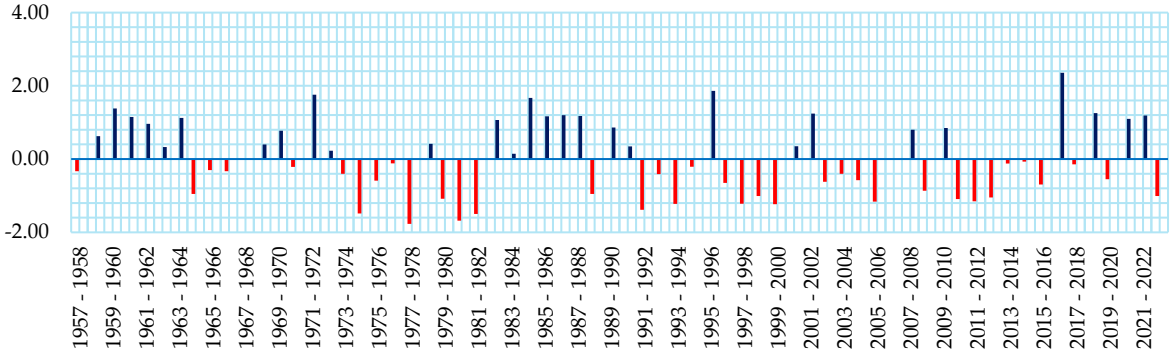
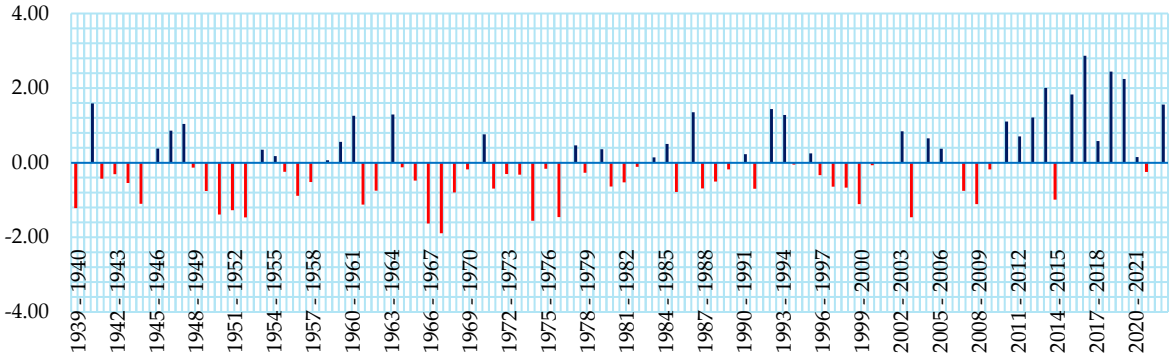


Figure S7. Long-term dynamics of the Streamflow Drought Index SDI-12 at the main hydrological posts of the Nura-Sarysu water management basin, based on a combination of observed and reconstructed data.

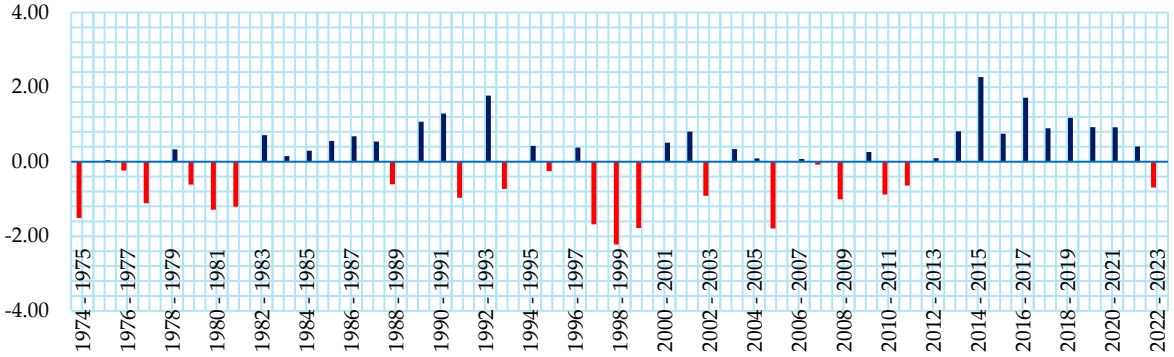
Silety – Izobilnoye



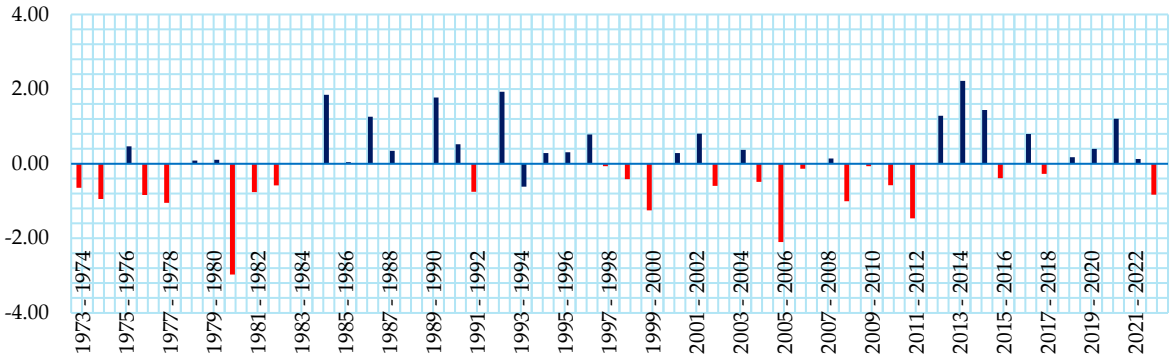
Shagalaly – Pavlovka



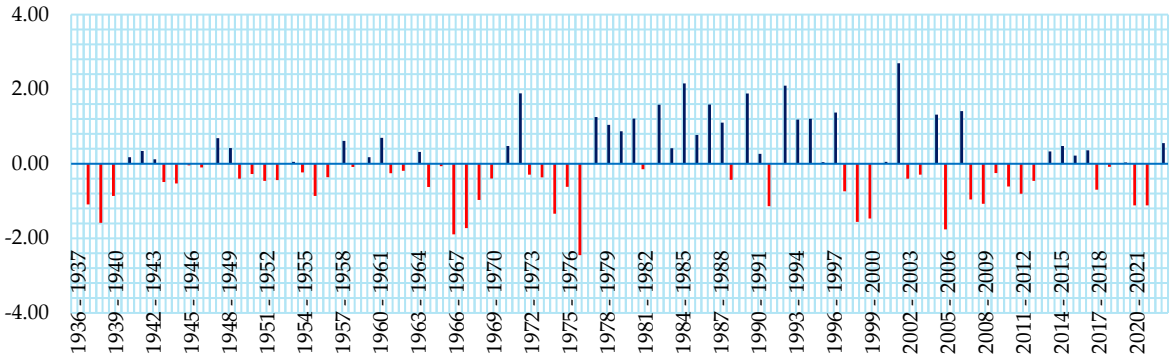
Esil – Turgen



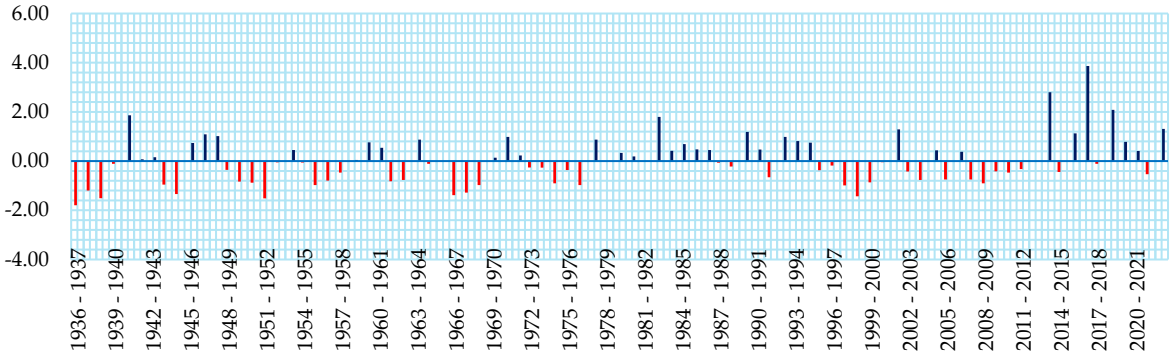
Moiyldy – Nikolayevka



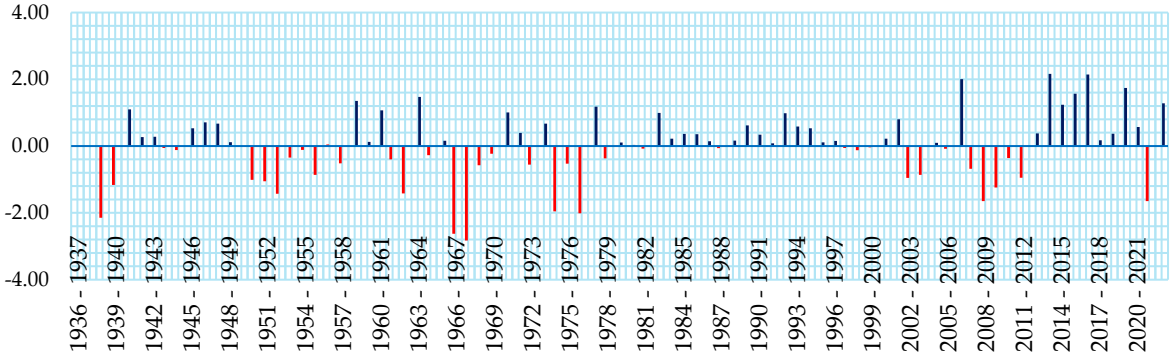
Kalkutan – Kalkutan



Zhabay – Atbasar



Akkanburlyk-Vozvyshenka



Imanburlyk – Sokolovka

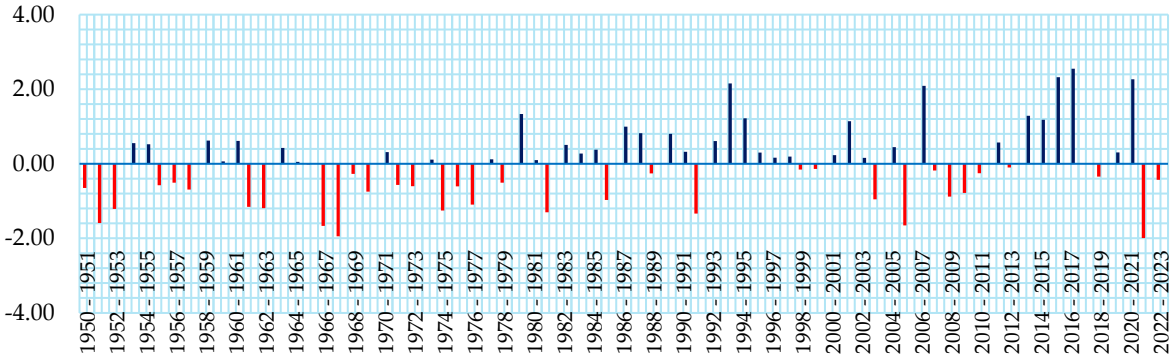
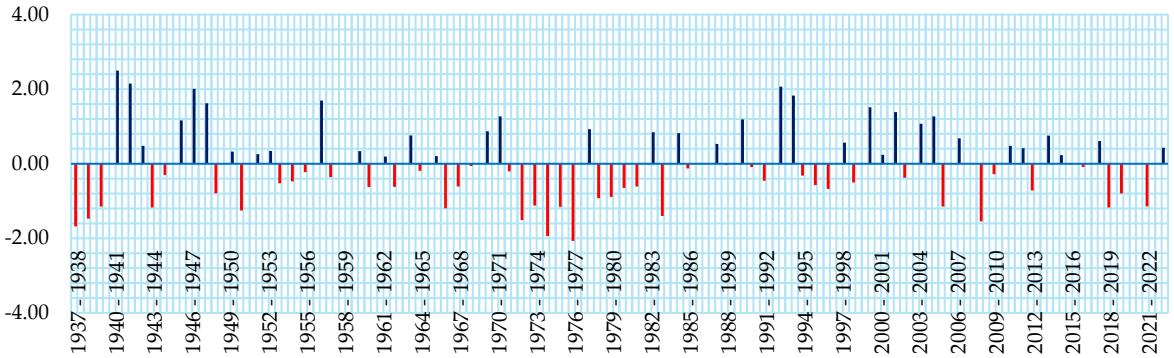
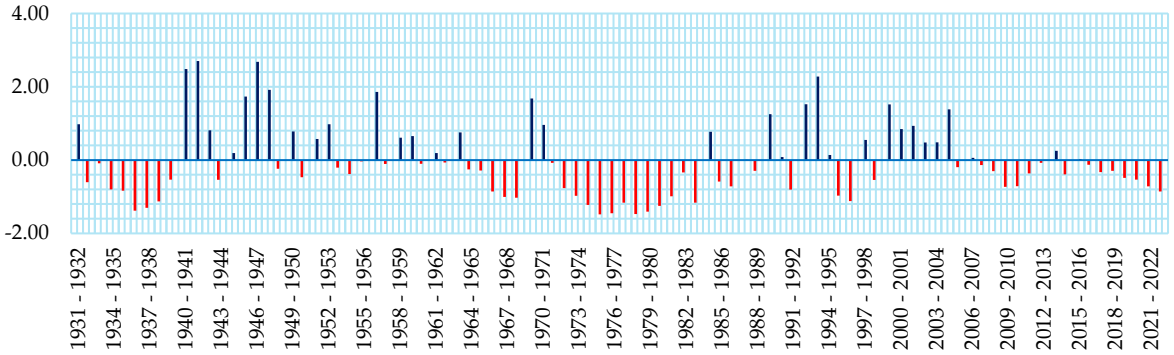


Figure S8. Long-term dynamics of the Streamflow Drought Index SDI-12 at the main hydrological posts of the Esil water management basin, based on a combination of observed and reconstructed data..

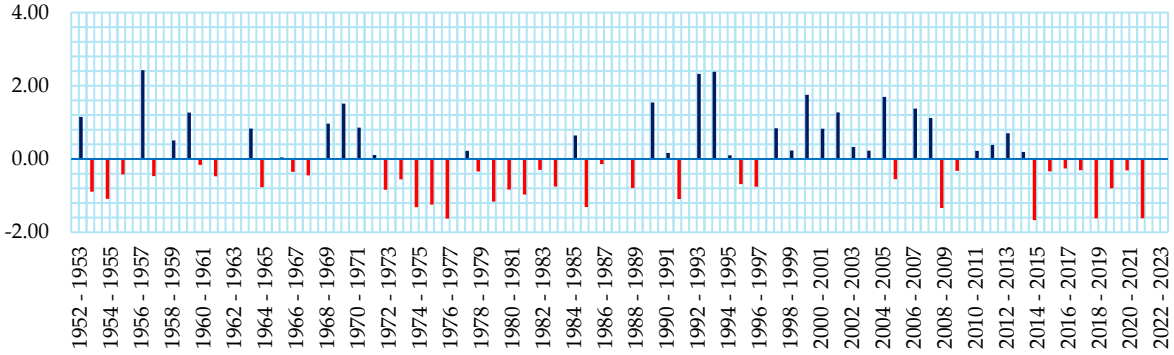
Tobyl – Grishenka



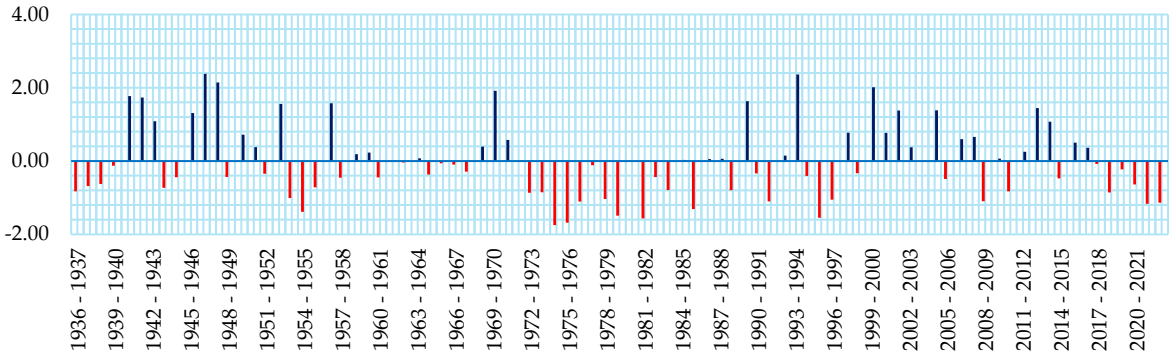
Tobyl – Kostanay



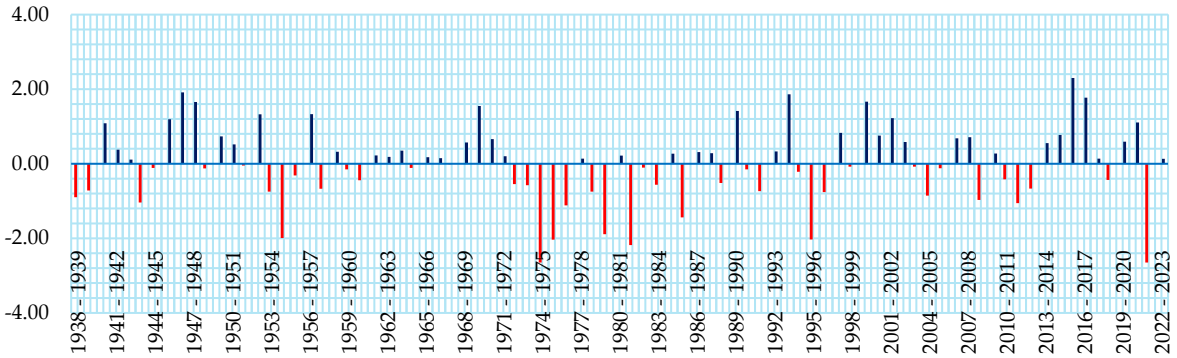
Ayat – Varvarinka



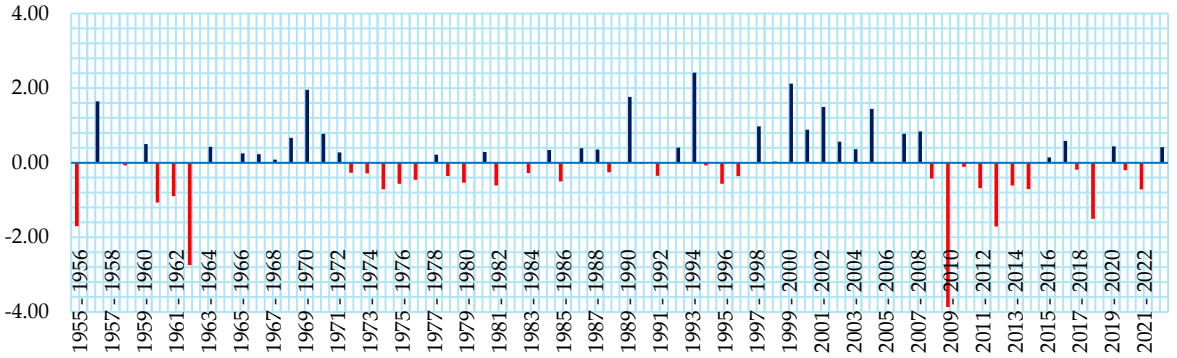
Togyzak-Togyzak



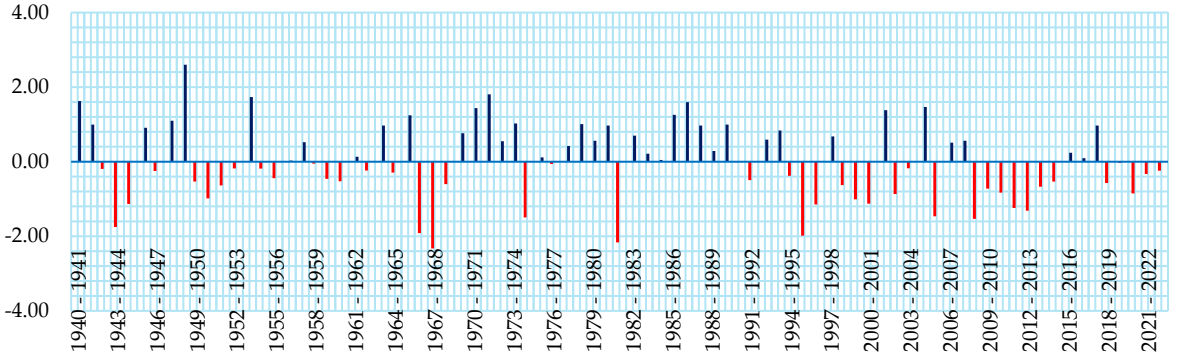
Ubagan – Aksuat



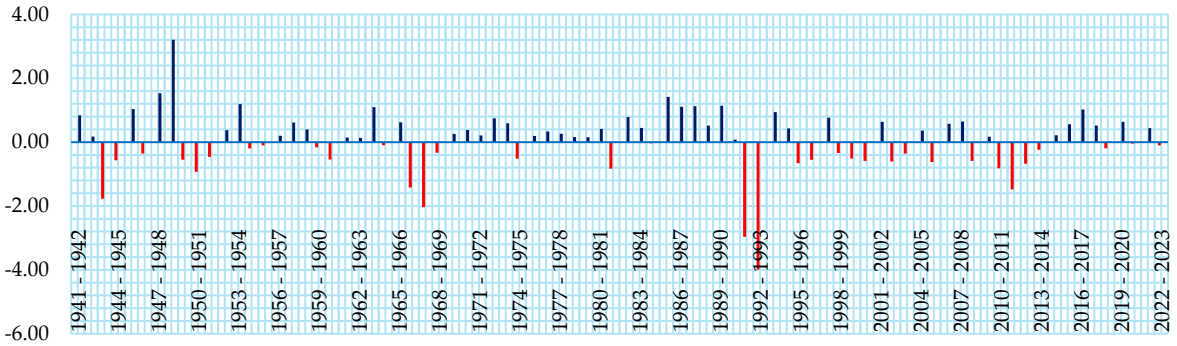
Damdy – Damdy



Torgai – Tusum



Karatorgai – Urpek



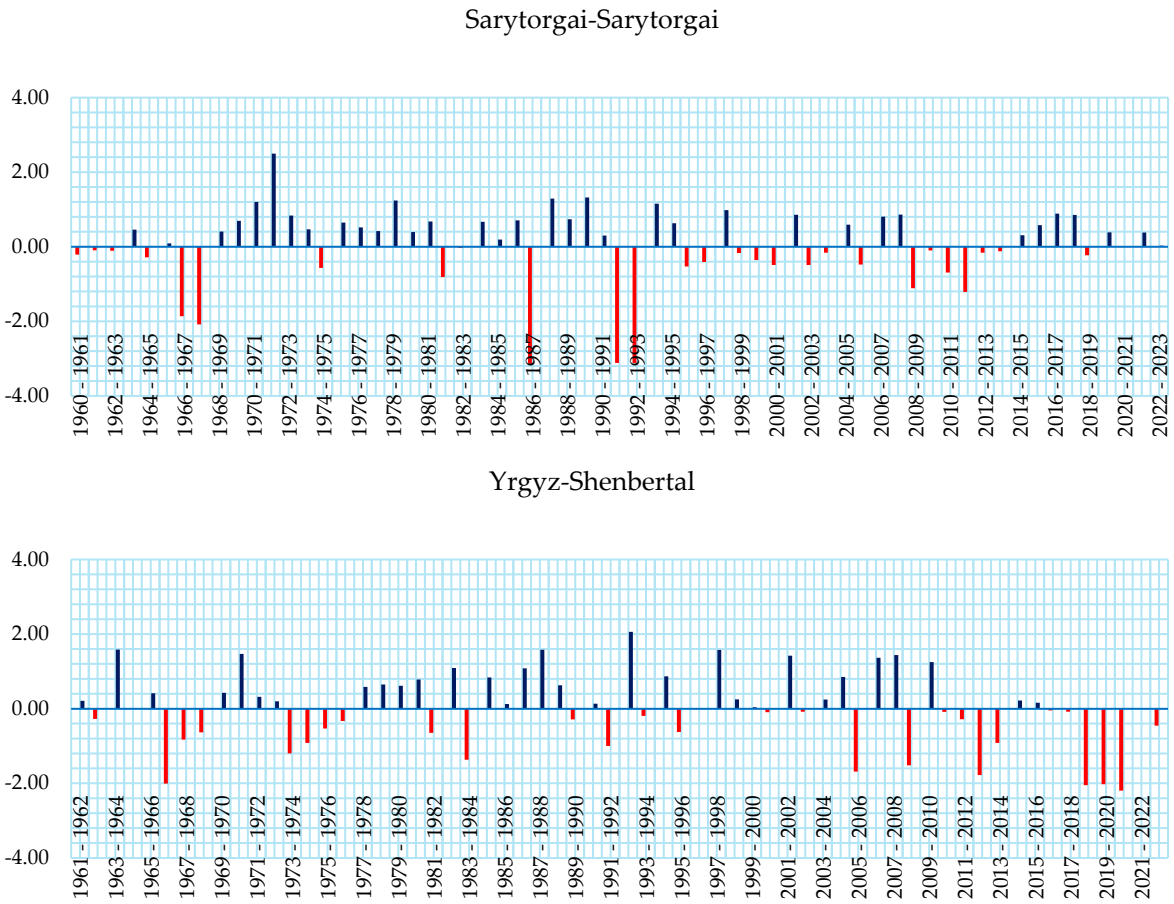


Figure S9. Long-term dynamics of the Streamflow Drought Index SDI-12 at the main hydrological posts of the Tobyl-Torgai water management basin, based on a combination of observed and reconstructed data..