Long-term changes of cold indices in Hungary using homogenized and raw data series

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Introduction

The impacts of climate change are predominantly associated with hot summers, frequent heat waves, and warm temperature anomalies. However, even the cold season exhibits a warming tendency, which is discernible by monitoring alterations in the cold climatic indices, for instance frost days, ice days, cold days, sever days or cold spell duration index. The long-term evolution of these indices is significant not only from a climatological perspective but also provides useful information for several sectors, including but not limited to, healthcare, agriculture and food security, water resources and safety or reducing disaster risk. Therefore, it is essential to have representative temperature records that are both temporally and spatially reliable. To achieve this, the Unit of Climatology of the Hungarian Meteorological Service subjects temperature data sets to homogenization.

Index	Definition
Cold day	$T_{min} \leq -5$ °C
Ice day	$T_{min} \leq 0$ °C
Frost day	$T_{max} \leq 0$ °C
Sever day	$T_{min} \leq -10$ °C
CSDI (Cold-Spell-Duration-Index)	maximum length of consecutive frost days

Table 1. Examined cold indices and their definitions

Frozen in time: The cold truth about Hungarian winters

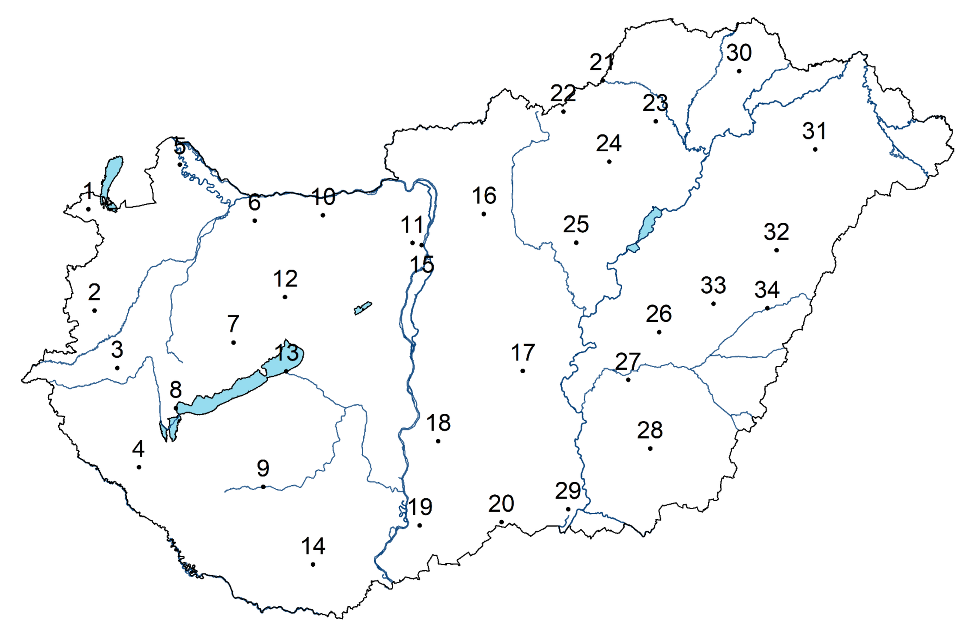

Figure 1. The stations used during homogenization

Methods

In our study we calculated the annual values of these indices (Table 1) for the whole area of Hungary from 1901 to 2022. We used raw data series to derive the cold indices and then homogenized data series created MASH method and compared the results. We applied a linear trend model to derive trends and conducted a hypothesis test for the significance of the trend using a t-test at a significance level of α=0.05, with critical values of ±1.9799. The station data series (raw and homogenized) were interpolated to a 10km resolution grid with Meteorological Interpolation based on Surface Homogenized Data Basis (MISH) (*Szentimrey* & *Bihari*) interpolation method to ensure evenly the territorial coverage (Figure 2).

Results

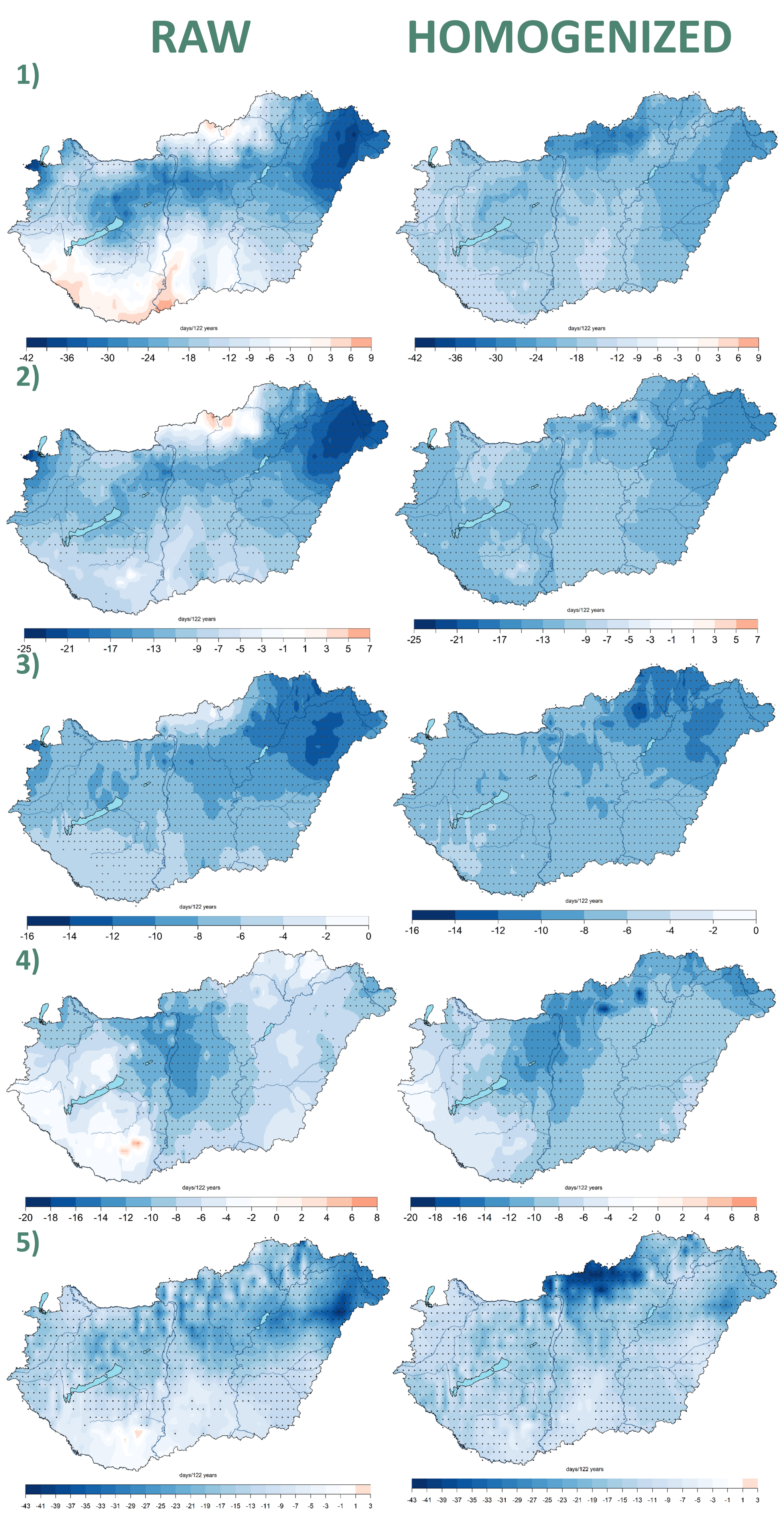

Figure 2. 122-year changes in annual amount of ice (1), cold (2) , sever (3), frost days (4) and CSDI (5) in Hungary [days/122 years] using raw and homogenized data series

Inhomogeneity degree of the daily extreme temperature station data series

Minimum temperature						Maximum temperature					
Station	TSB	TSA	Station	TSB	TSA	Station	TSB	TSA	Station	TSB	TSA
1	2004.92	23.85	18	580.03	24.45	1	168.65	22.95	18	267.23	33.09
2	566.22	17.82	19	1840.51	17.81	2	276.45	28.57	19	618.52	33.6
3	627.39	18.42	20	1832.35	32.79	3	1698.77	51.4	20	332.41	13.06
4	531.53	37.98	21	457.87	32.04	4	596.17	34.53	21	487.28	44.74
5	421.28	10.62	22	3180.07	20.09	5	377.62	14.42	22	285.04	17.99
6	581.3	40.34	23	2927.06	24.82	6	1025.71	21.83	23	511.93	33.59
7	1134.59	22.91	24	312.16	28.83	7	1917.22	17.17	24	139.6	23.64
8	707.96	17.06	25	171.8	26.41	8	220.99	14.16	25	391.22	32.25
9	146.62	28.62	26	816.67	29.87	9	421.93	21.66	26	1129.03	23.39
10	262.04	31.33	27	572.25	21.64	10	654.97	14.3	27	253.35	29.53
11	798.6	17.97	28	482.05	18.91	11	878.48	31.72	28	457.05	12.36
12	1804.12	21.67	29	836.59	12.25	12	639.38	15.89	29	673.17	27.62
13	2455.52	17.59	30	254.37	23.03	13	505.85	23.14	30	2337.8	28.05
14	579.5	14.85	31	427.93	21.99	14	1201.89	15.83	31	139.68	20.57
15	298.62	19.35	32	1057.97	19.57	15	190.9	14.95	32	327.22	18.2
16	569.28	25.15	33	281.1	24.23	16	1051.95	25.62	33	5486.64	20.82
17	181.59	18.43	34	123.93	29.00	17	184	31.04	34	508.13	29.15

Table 2. Test statistics before (TSB) and after (TSA) homogenization homogenization of minimum and maximum temperature

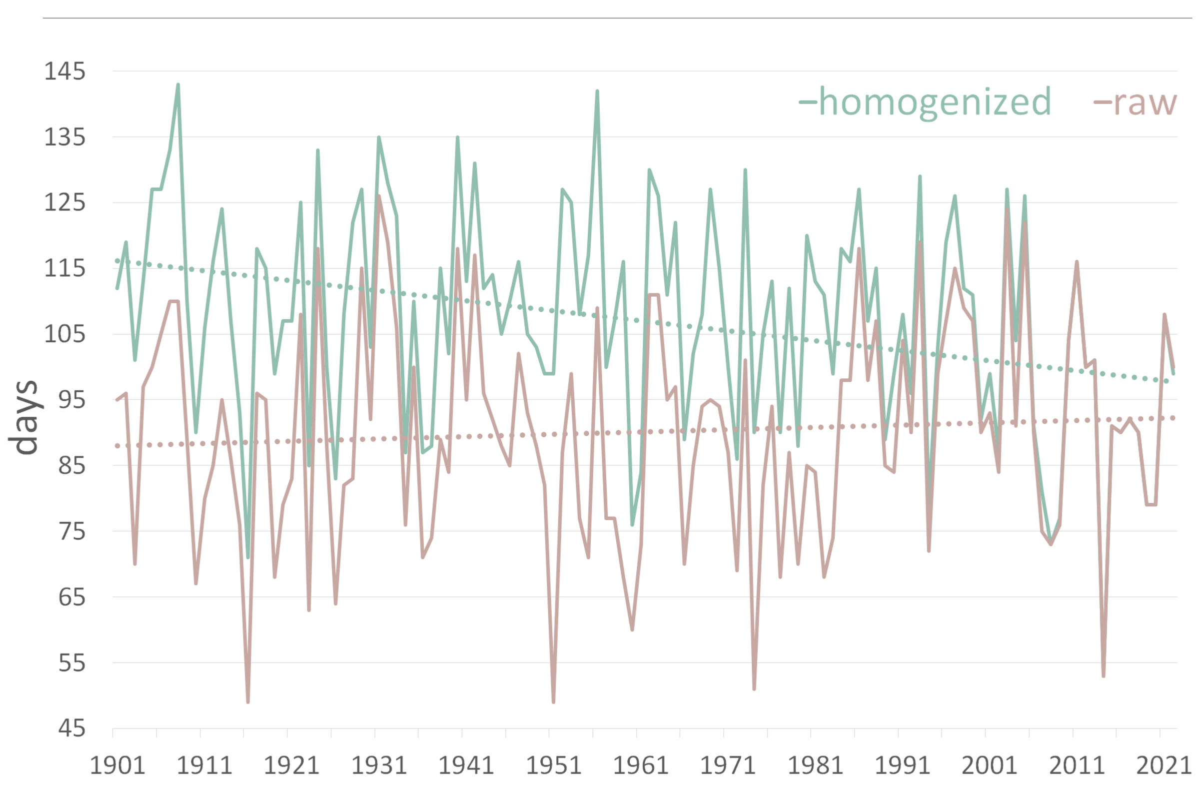

Figure 3. Annual amount of ice days between 1901 and 2022 in Baja using raw and homogenized data series

Conclusion

Differences between trend derived from raw and homogenized series

	Cold days	Sever days	Frost days	Ice days	CSDI
homogenized	-11,8	-7,8	-19,1	-8,9	-15,7
raw	-11,1	-7,7	-16,2	-7,3	-15,3
difference	0,7	0,1	2,9	1,6	0,4

Table 3. Regional averages of 122-year change in annual amount of cold indices [days/122 years] in Hungary using homogenized and raw data series

11th Seminar for Homogenization and Quality Control in Climatological Databases and 6th Interpolation Conference jointly organized with the 14th EUMETNET Data Management Workshop