



Climate change detection based on long-term historical meteorological data in the Carpathian Region

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Introduction

High quality observational time series has crucial role in climate research:

- past climate processes can be directly analysed;
- to validate climate information obtained from climate models, or other proxy data.

In the study

- we consider historical time series available in the meteorological yearbooks of the Royal Hungarian Institute of Meteorology and Geomagnetism first published in 1871.
- we compare the main statistics of the historical data sets (1871–1918) with recent data (1971–2020).

The meteorological yearbooks of the Royal Hungarian Institute of Meteorology and Geomagnetism (1871-1918)

Content

- **Preface (metadata)**
- **The list of actual stations:** name, country, county, geographical coordinates, altitude, observing hours, name and the profession of the observer
 - 47 stations in 1871
 - 204 stations in 1911 (+1222 rain gauge)
- **Notes regarding list of station**
- **Meteorological observations:**
 - **monthly and annual data:** air temperature, atmospheric pressure, water vapour pressure, relative humidity, precipitation, cloudiness, wind direction
 - **daily observations** (three times a day) from 1886 (present weather e.g. fog observations).
- **Observations of magnetism and phenology:** magnetic declination; canopy development, blooming, ripening.

III. A gyümölcsérés kezdete.
III. Beginn der Fruchtreife.

A.

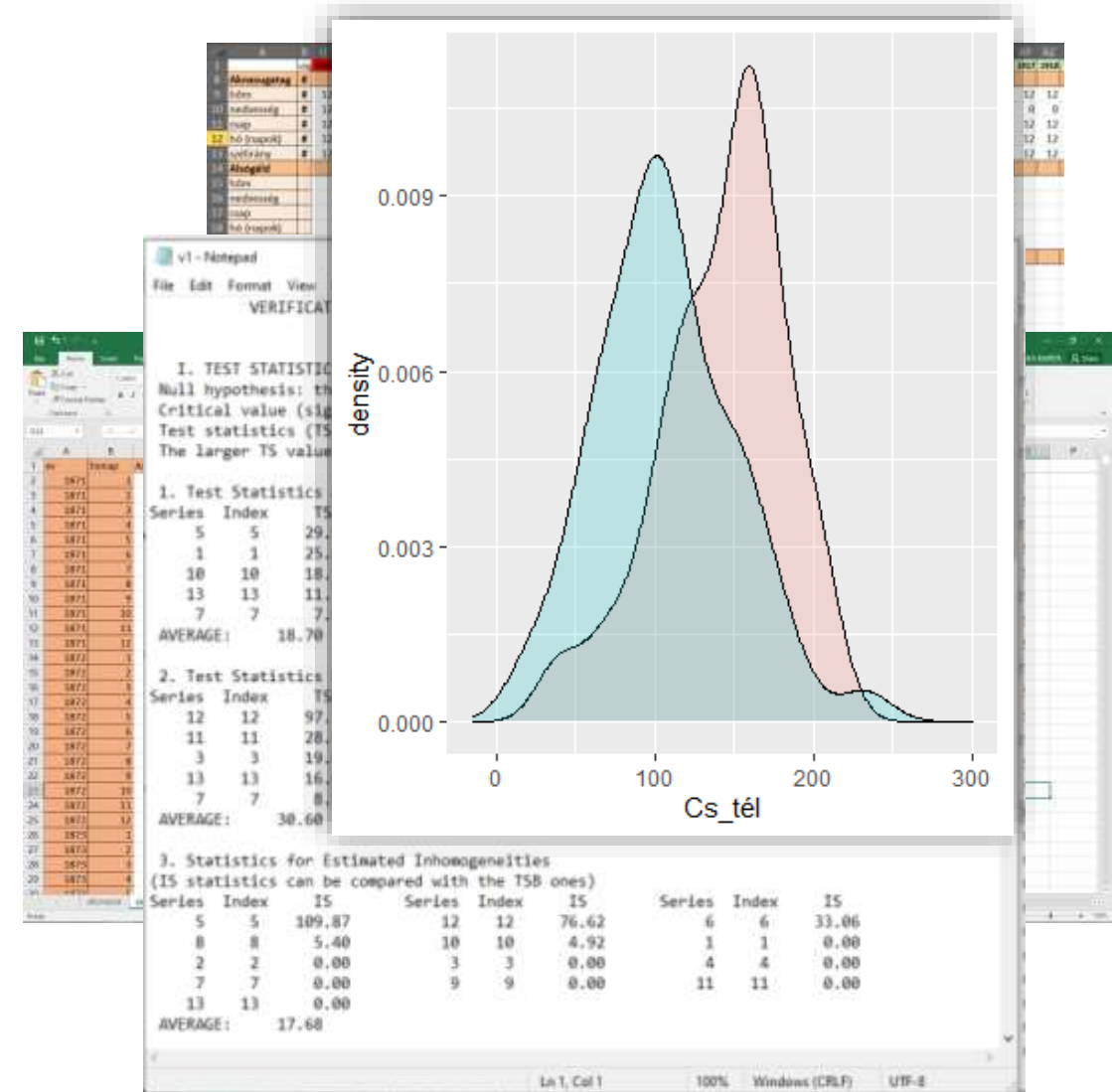
A növény neve Name der Pflanze	Középső és Mittlere Zone			Déli és -Mittlere Zone.			
	Köszeg	Környe	Bakonybél	Pécs	Miltovtza	Török-Besce	Nagy-Szeben
Ribes rubrum L. — veres ribizske, gen. Johannis-beere	—	—	6.16	5.24	5.26	6.20	6.18
Sambucus nigra L. — bodzafa, Hollunder	—	—	8.10	9.5	7.5	—	8.11
Cornus sanguinea L. — veregyűrű som, rother Hartriegel	—	—	8.28	9.30	8.1	8.10	8.23
Ligustrum vulgare L. — vesszős fagyal, Rainweide	—	—	—	—	—	—	9.10
Aesculus Hippocastanum L. — vad gesztenye, wilde, Rosskastanie	—	—	— ¹⁾	9.19	9.5	9.20	9.25
Secale cereale L. hib. — téli rozs, Winterroggen	6.30 ¹⁾	7.1 ¹⁾	7.2 ¹⁾ 7.12 ¹⁾	6.30 ¹⁾ 7.15 ¹⁾	7.5 ¹⁾	7.4 ¹⁾	7.7 ¹⁾
Hordeum vulgare L. hib. — téli árpa, Wintergerste	7.13 ¹⁾	7.1 ¹⁾	7.10 ¹⁾ 7.15 ¹⁾	6.10 ¹⁾ 6.28 ¹⁾	6.28 ¹⁾	6.20 ¹⁾	—
Triticum vulgare Vill. — búza, Weizen	6.7 ¹⁾	6.29 ¹⁾	7.18 ¹⁾ 7.20 ¹⁾	6.23 ¹⁾ 7.17 ¹⁾	7.14 ¹⁾	7.4 ¹⁾	—
Zea Mays L. — tengeri, kukorica, türksicher Mais, Kukuruta	—	—	10.1 ¹⁾	9.5	8.28 ¹⁾ 9.20 ¹⁾	9.8 ¹⁾	9.17 ¹⁾ 10.5 ¹⁾
Vitis vinifera L. — szőlő, Weinlese	10.16 ¹⁾	10.3 ¹⁾	— ¹⁾	10.10 ¹⁾	8.20 ¹⁾ 9.25 ¹⁾	9.20 ¹⁾	9.2 ¹⁾ 10.21 ¹⁾

¹⁾ Az uralás, illet. szüret kezdete. — Beginn der Ernte, resp. Weinlese.
²⁾ Elfagyott. — Erfroren.
³⁾ Korai. — Frühzeitiger Mais.
⁴⁾ Nem fordul itt elő. — Kommt hier nicht vor.
⁵⁾ Egyes bogyók. — Einzelne Beeren.
⁶⁾ Egyes csövek. — Einzelne Kolben.

Meteor. és földmél. évkönyv. 24

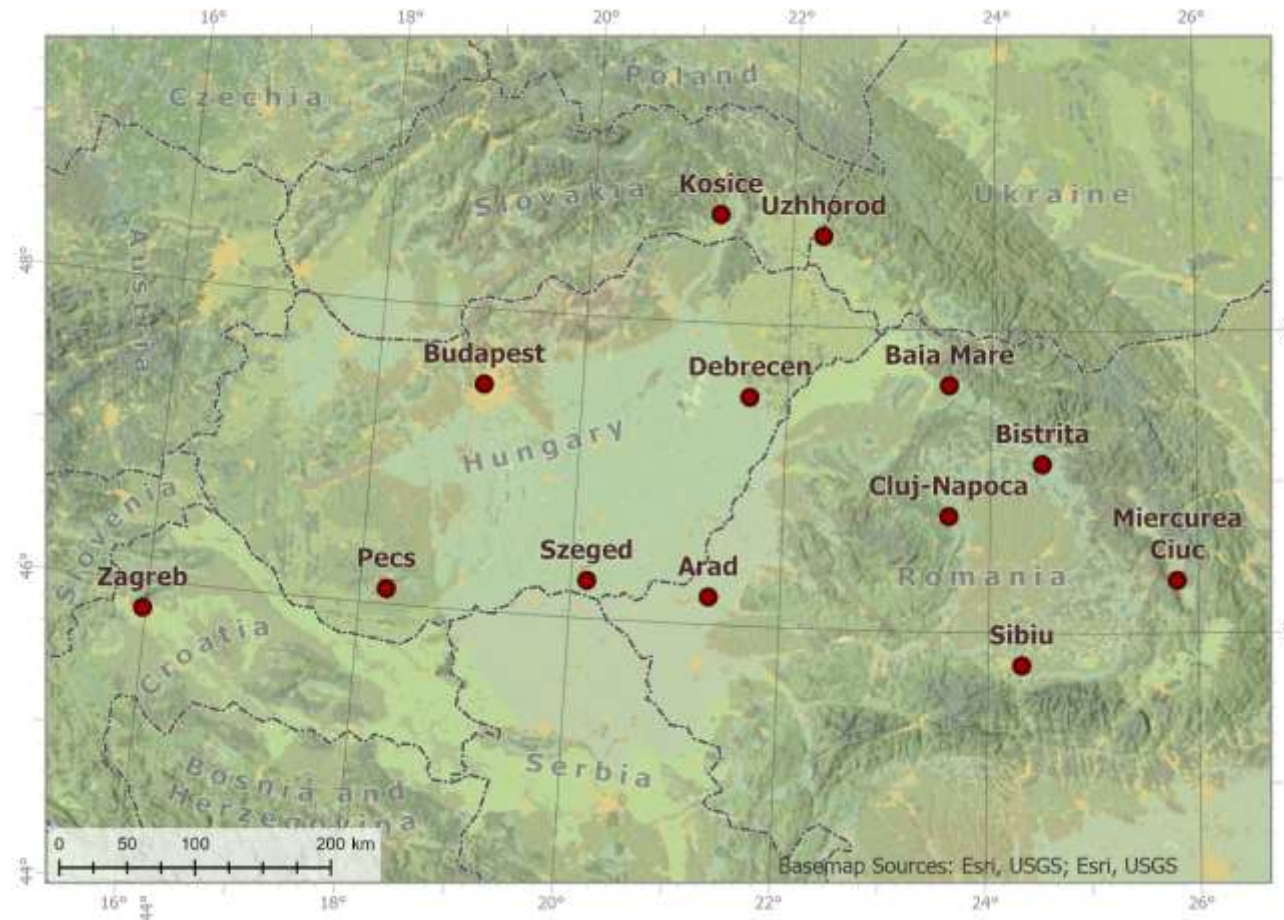
Analyzing the data of the yearbooks

1. inventory of available stations and variables
2. manual digitizing the selected datasets
3. homogenization of the datasets using MASH (Multiple Analysis of Series for Homogenization) for detecting break point, filling gaps
4. compare statistics with recent datasets 1971-2020 (National Meteorological Administration of Romania for stations in RO, and the European Climate Assessment & Dataset for other stations).



Analayzing the data of the yearbooks

- 13 stations over the Carpathian Region having complete datasets (1871-1918)
- mean temperature (estimated 24 hours), maximum temperature (lowest hourly value in the month), minimum teperature (highest hourly value in the month), precipitation amount and fog events

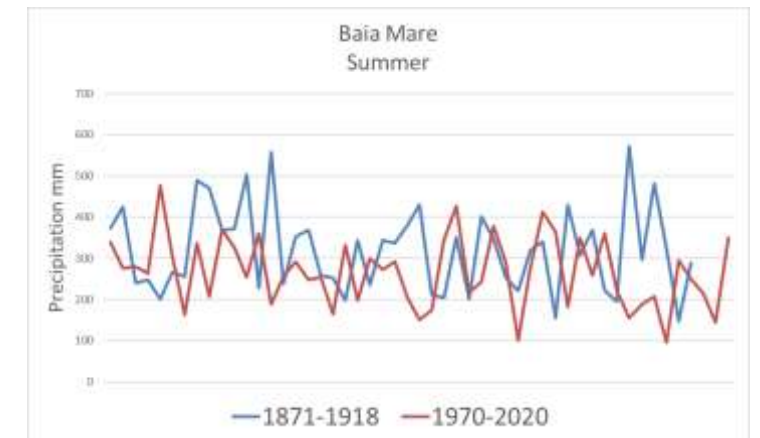
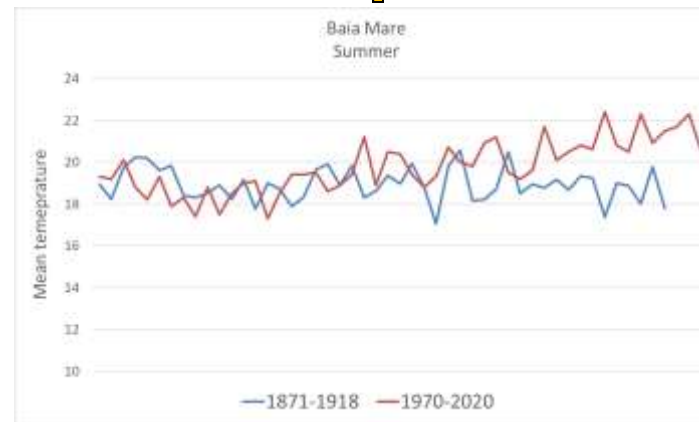
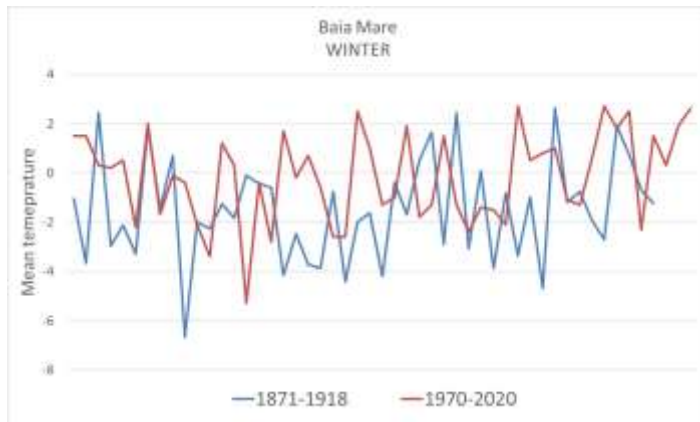


Analayzing the data of the yearbooks

Comparing the means (two-sample t-test, 95% probability)

Stations	Mean temperature				Stations	Precipitation			
	Winter	Spring	Summer	Autumn		Winter	Spring	Summer	Autumn
1 Arad					1 Arad				sig. diff.
2 Bistrița	sig. diff.	sig. diff.			2 Bistrița	sig. diff.			
3 Miercurea-Ciuc				sig. diff.	3 Miercurea-Ciuc				
4 Cluj-Napoca	sig. diff.	sig. diff.			4 Cluj-Napoca				
5 Baia Mare	sig. diff.	sig. diff.	sig. diff.	sig. diff.	5 Baia Mare		sig. diff.	sig. diff.	
6 Sibiu	sig. diff.		sig. diff.		6 Sibiu				
7 Budapest	sig. diff.	sig. diff.	sig. diff.	sig. diff.	7 Budapest		sig. diff.		sig. diff.
8 Debrecen	sig. diff.	sig. diff.	sig. diff.	sig. diff.	8 Debrecen				sig. diff.
9 Pecs	sig. diff.	sig. diff.	sig. diff.		9 Pecs		sig. diff.		sig. diff.
10 Szeged	sig. diff.	sig. diff.			10 Szeged		sig. diff.		sig. diff.
11 Ungvar		sig. diff.	sig. diff.		11 Ungvar				sig. diff.
12 Kosice	sig. diff.	sig. diff.	sig. diff.	sig. diff.	12 Kosice				sig. diff.
13 Zágráb	sig. diff.	sig. diff.	sig. diff.	sig. diff.	13 Zágráb		sig. diff.		

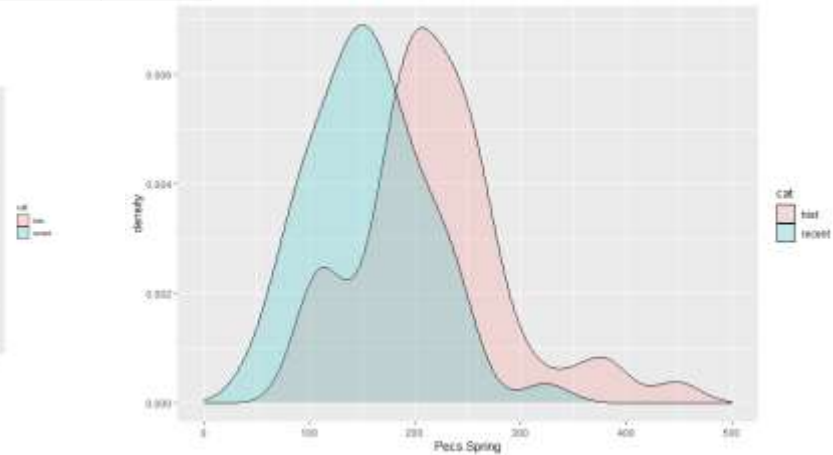
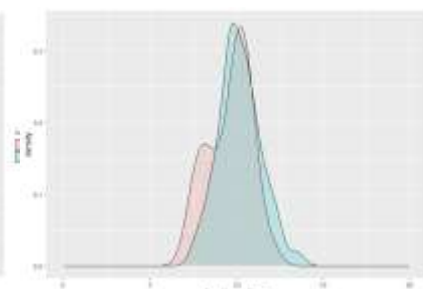
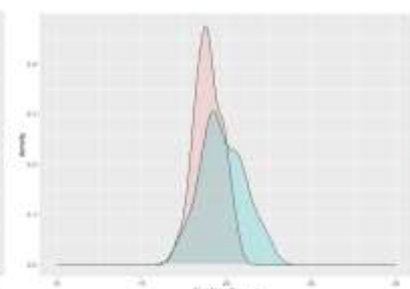
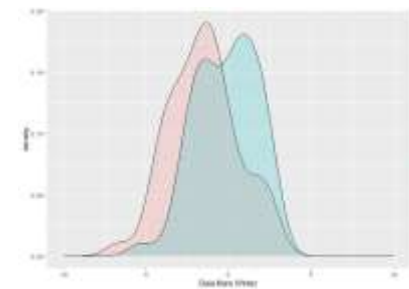
decrease
increase



Analayzing the data of the yearbooks

Comparing the distribution (Chi-Square test of homogeneity, 95% probability)

		Mean temperature						Precipitation			
	Stations	Winter	Spring	Summer	Autumn		Stations	Winter	Spring	Summer	Autumn
1	Arad					1	Arad				
2	Bistrița		sig. diff.	sig. diff.		2	Bistrița				
3	Miercurea-Ciuc				sig. diff.	3	Miercurea-Ciuc				
4	Cluj-Napoca	sig. diff.				4	Cluj-Napoca				
5	Baia Mare	sig. diff.	sig. diff.	sig. diff.		5	Baia Mare				
6	Sibiu			sig. diff.		6	Sibiu				
7	Budapest	sig. diff.	sig. diff.	sig. diff.	sig. diff.	7	Budapest				
8	Debrecen	sig. diff.	sig. diff.	sig. diff.	sig. diff.	8	Debrecen				
9	Pecs					9	Pecs		sig. diff.		
10	Szeged					10	Szeged				
11	Ungvar			sig. diff.		11	Ungvar				
12	Kosice		sig. diff.	sig. diff.	sig. diff.	12	Kosice				
13	Zágráb	sig. diff.	sig. diff.	sig. diff.	sig. diff.	13	Zágráb				



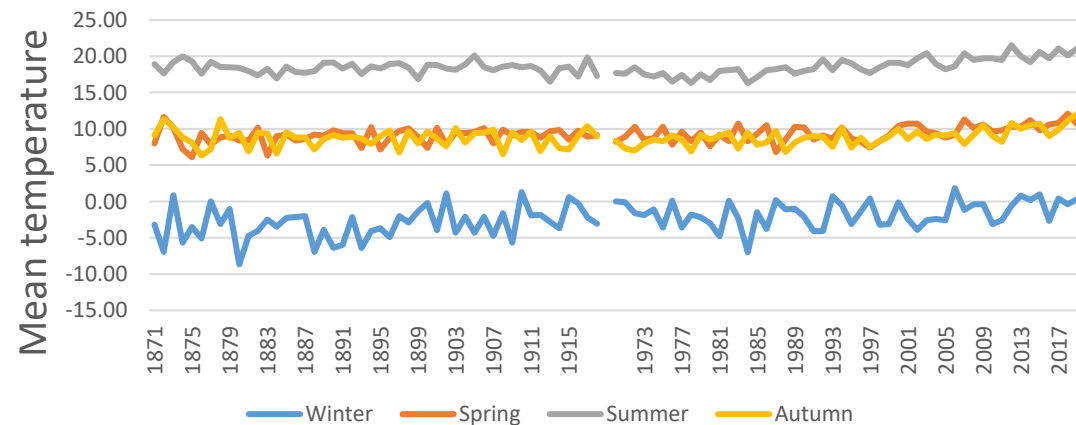
Analayzing the data of the yearbooks

Comparing the linear trends (95% probability)

	Stations	Mean temperature 1871-1918				Mean temperature 1970-2020			
		Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn
1	Arad						+	+	+
2	Bistrița					+	+	+	+
3	Miercurea-Ciuc						+	+	+
4	Cluj-Napoca	+				+	+	+	+
5	Baia Mare						+	+	+
6	Sibiu					+		+	+
7	Budapest	+					+	+	+
8	Debrecen						+	+	+
9	Pecs	+					+	+	+
10	Szeged						+	+	+
11	Ungvar							+	+
12	Kosice						+	+	+
13	Zágráb					+	+	+	+

	Stations	Precipitation 1871-1918				Precipitation 1970-2020			
		Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn
1	Arad					+			
2	Bistrița					+			
3	Miercurea-Ciuc								
4	Cluj-Napoca					+			
5	Baia Mare								
6	Sibiu								
7	Budapest								
8	Debrecen							-	
9	Pecs								-
10	Szeged								
11	Ungvar								
12	Kosice								
13	Zágráb								

Cluj-Napoca



Analayzing the data of the yearbooks

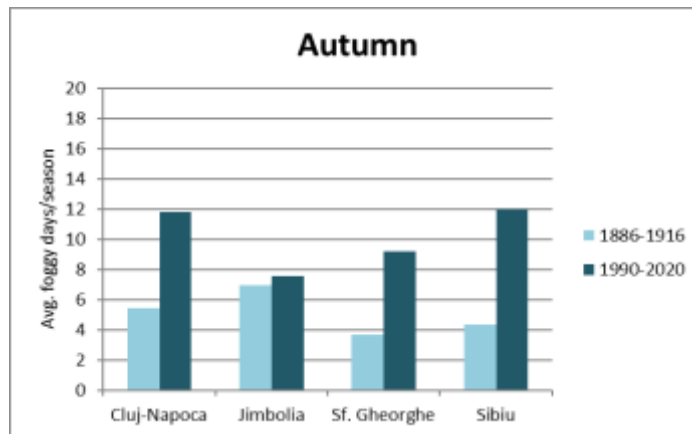
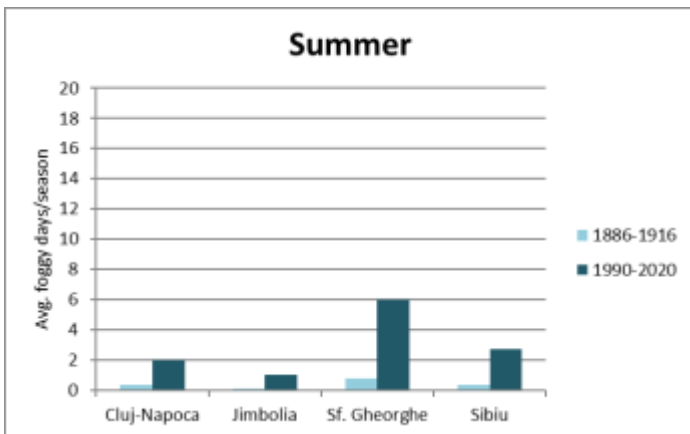
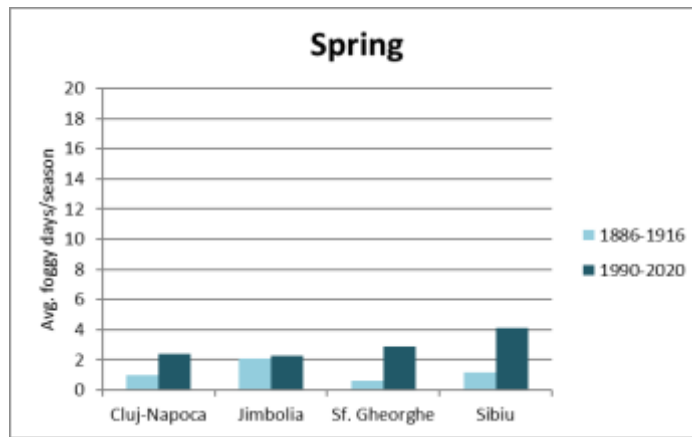
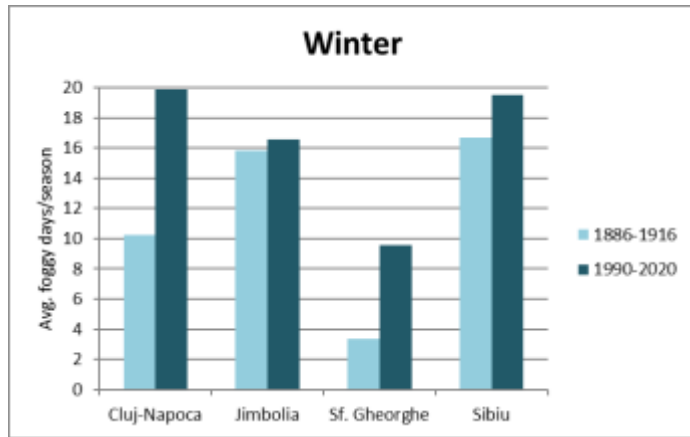
Comparing the linear trends (95% probability)

	Stations	Minimum temperature 1871-1918				Minimum temperature 1970-2020			
		Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn
1	Arad					NO DATA	NO DATA	NO DATA	NO DATA
2	Bistrița					NO DATA	NO DATA	NO DATA	NO DATA
3	Miercurea-Ciuc					NO DATA	NO DATA	NO DATA	NO DATA
4	Cluj-Napoca					NO DATA	NO DATA	NO DATA	NO DATA
5	Baia Mare					NO DATA	NO DATA	NO DATA	NO DATA
6	Sibiu					NO DATA	NO DATA	NO DATA	NO DATA
7	Budapest		+					+	+
8	Debrecen							+	+
9	Pecs		+						
10	Szeged			+					+
11	Ungvar					NO DATA	NO DATA	NO DATA	NO DATA
12	Kosice			+	+			+	
13	Zágráb		+						

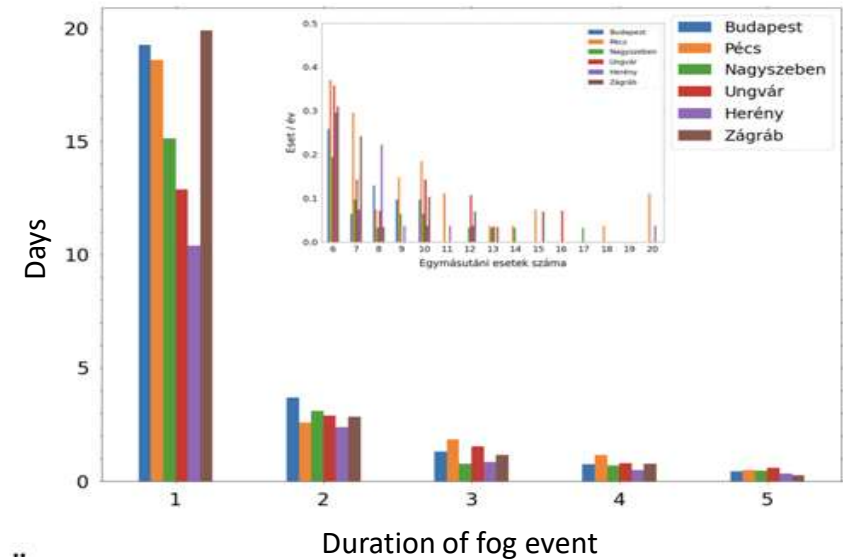
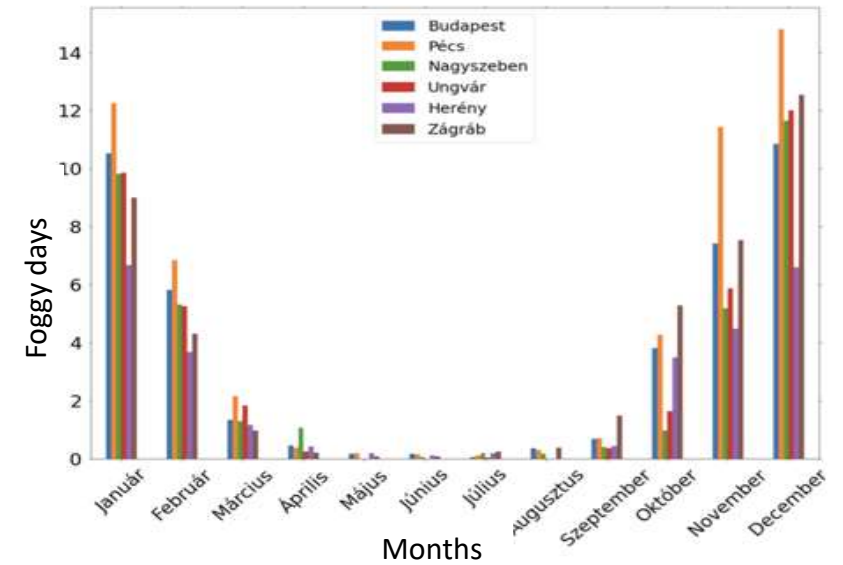
	Stations	Maximum temperature 1871-1918				Maximum temperature 1970-2020			
		Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn
1	Arad					NO DATA	NO DATA	NO DATA	NO DATA
2	Bistrița					NO DATA	NO DATA	NO DATA	NO DATA
3	Miercurea-Ciuc					NO DATA	NO DATA	NO DATA	NO DATA
4	Cluj-Napoca					NO DATA	NO DATA	NO DATA	NO DATA
5	Baia Mare					NO DATA	NO DATA	NO DATA	NO DATA
6	Sibiu					NO DATA	NO DATA	NO DATA	NO DATA
7	Budapest					+	+	+	
8	Debrecen					+	+	+	
9	Pecs					+	+	+	
10	Szeged						+	+	+
11	Ungvar					NO DATA	NO DATA	NO DATA	NO DATA
12	Kosice						+	+	+
13	Zágráb			-			+	+	+

Fog events

- daily data (1886-1916)
- fog event frequency and duration



Historical period

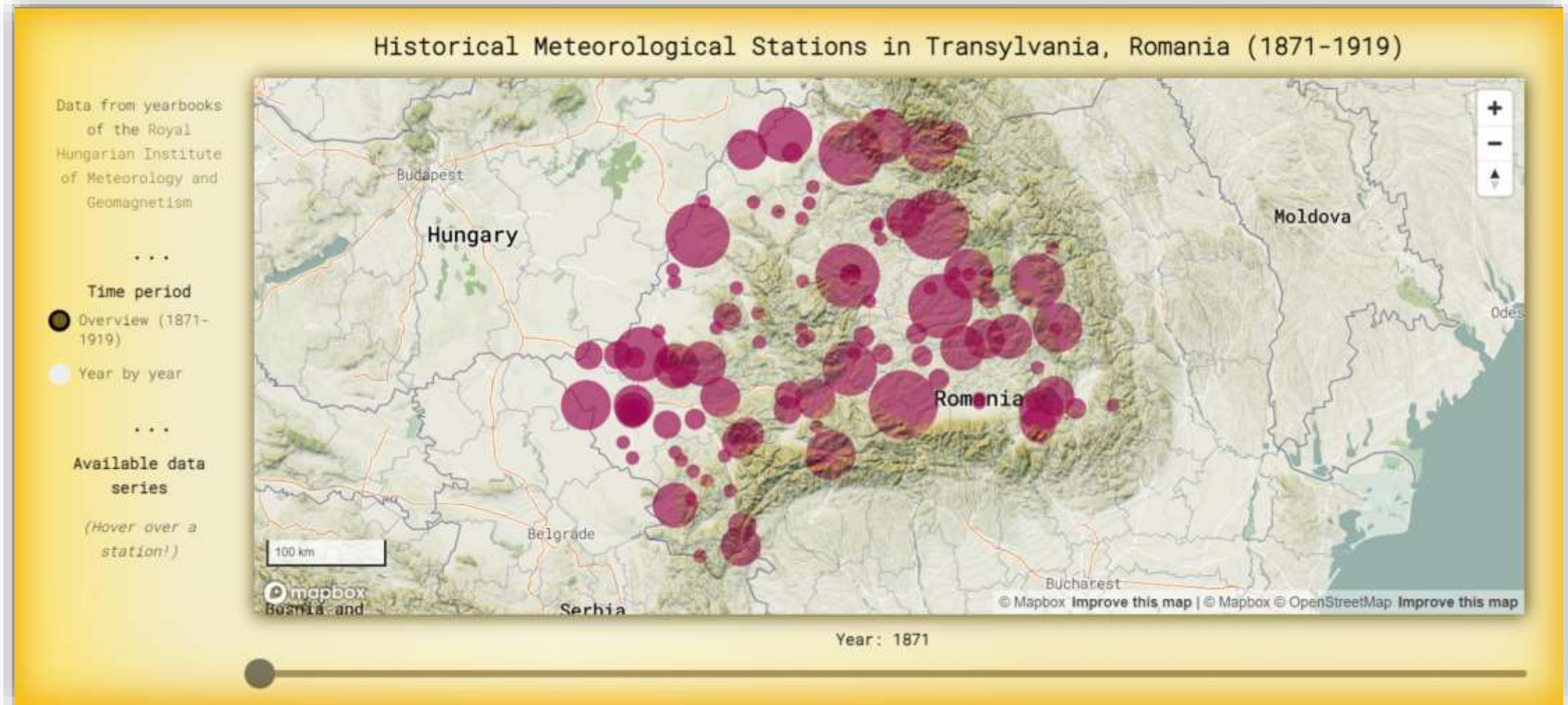


Conclusions and outlook

- comparison of the means and distributions
 - mean temperature: significant differences in all year, shifts in distributions towards high values
 - precipitation: significant differences in spring and autumn (less precipitation in the recent period), no shifts in distributions
- comparison of the trends
 - trends in winter mean temperature in some bigger cities in the historical timeserie (Cluj-Napoca, Budapest, Pecs), but positive trends during the recent period
 - no trends in precipitation
- higher frequency in fog events in the recent period
- enlarging/enhancing the dataset

Interactive map

<https://judit-gla.github.io/met4/stations.html>



Thank you for your attention!