Historical precipitation data sets in Hungary

Olivér Szentes[1,2], Mónika Lakatos[1], Rita Pongrácz[3]

[1]Climate Department, Hungarian Meteorological Service
[2]ELTE Faculty of Science, Doctoral School of Earth Sciences
[3]ELTE Department of Meteorology

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

ORSZÁGOS METEOROLÓGIAI SZOLGÁLAT

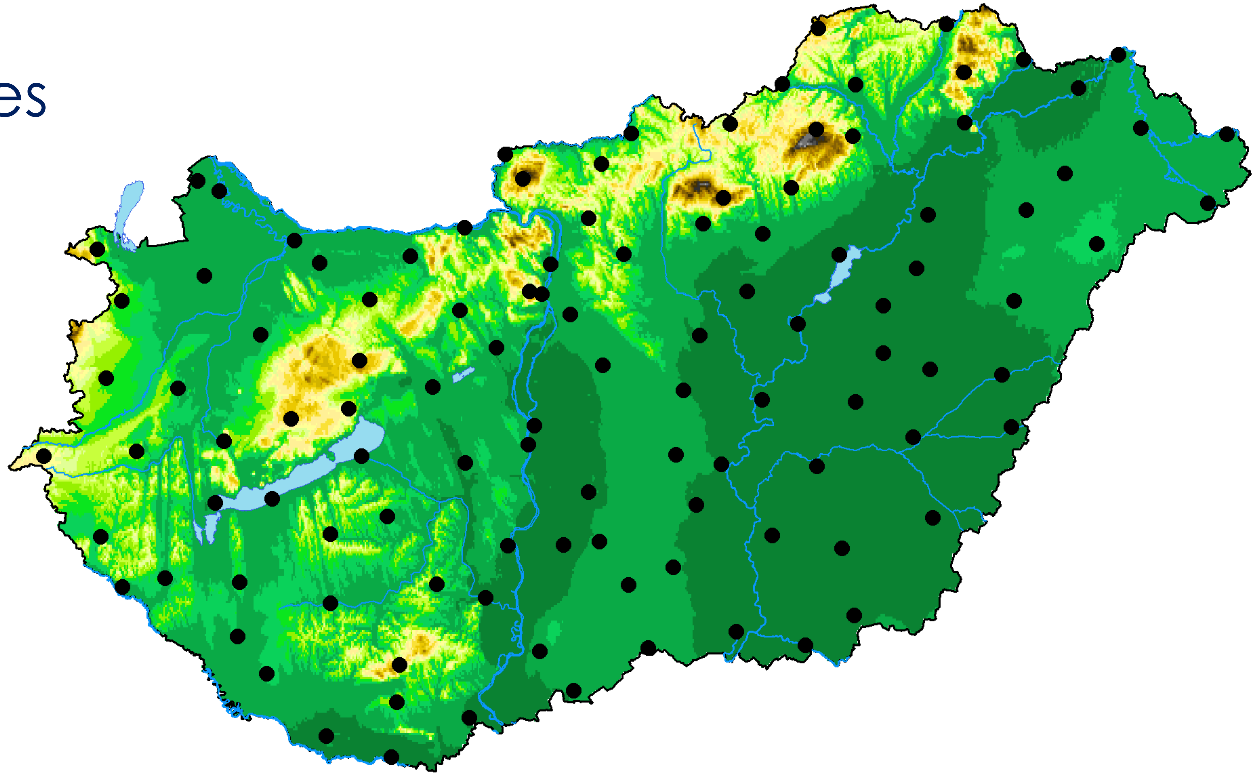
Budapest, 2023

CLIMATE CHANGE National Laboratory

What we want: a spatial and temporal representative climate database

What we have: station data series

Problems with the series:
- unequal length of data series
- inhomogeneous spatial distribution of stations
- missing data
- errors
- inhomogeneities (e.g. due to relocation, instrument or methodological changing)



Solution:
1. Homogenization, QC, missing data completion
2. After homogenization interpolation for grid

ORSZÁGOS METEOROLÓGIAI SZOLGÁLAT

The creation of representative climatological database with MASH and MISH software:

http://www.met.hu/en/omsz/rendezvenyek/homogenization_and_interpolation/software/

MASHv3.03

(Multiple Analysis of Series for Homogenization; *Szentimrey, T.*)

For temporal representativity (homogenization, quality control and missing value completion of station data series)

MISHv1.03

(Meteorological Interpolation based on Surface Homogenized Data Basis; *Szentimrey, T. and Bihari, Z.*)

For spatial representativity (interpolation of homogenized data series)

ORSZÁGOS METEOROLÓGIAI SZOLGÁLAT

References:

Szentimrey, T., Bihari, Z., 2014: Manual of interpolation software MISHv1.03, Hungarian Meteorological Service, p. 60.
Szentimrey, T. 2017: Manual of homogenization software MASHv3.03, Hungarian Meteorological Service, p.71.

HOMOGANIZATION SOFTWARE: MASH

1. **The homogenization of monthly series:**
   - relative homogeneity test procedure
   - a step-by-step iteration procedure
   - additive (e.g. temperature) or multiplicative (e.g. precipitation) model
   - quality control and missing data completion
   - homogenization of monthly, seasonal and annual series
   - metadata (probable dates of break points) can be used automatically
   - verification files generated automatically
2. **The homogenization of daily series:**
   - based on the detected monthly inhomogeneities
   - quality control and the completion of missing data in daily data

ORSZÁGOS METEOROLÓGIAI SZOLGÁLAT

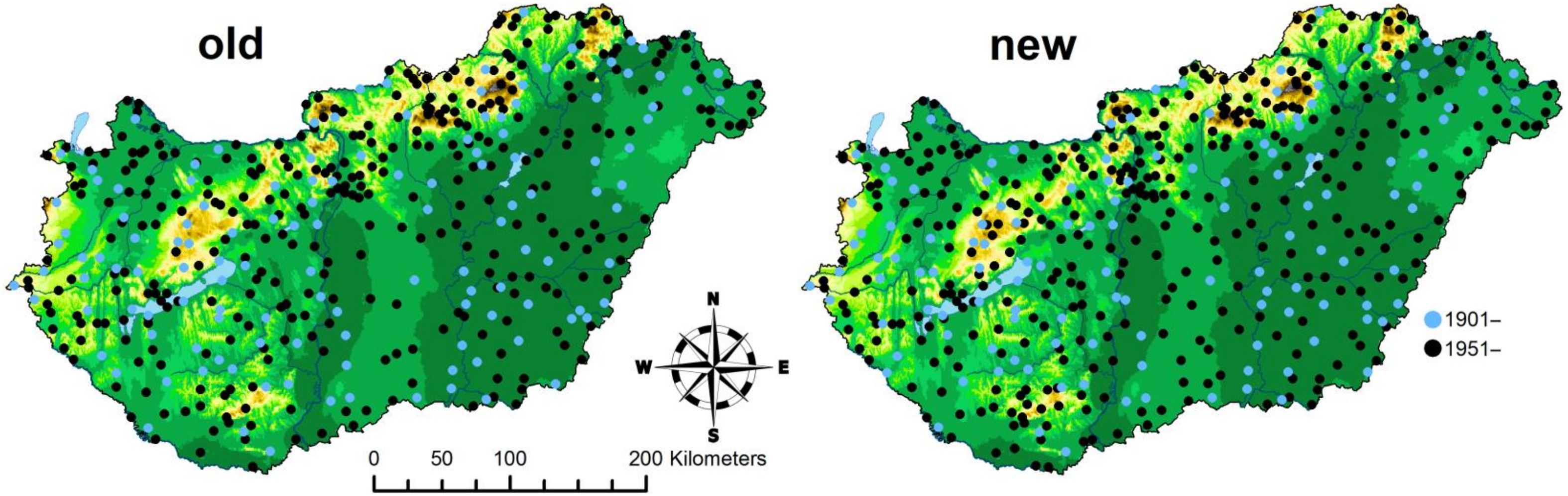
INTERPOLATION SOFTWARE: MISH

1. **The modeling subsystem for statistical (local and stochastic) climate parameters:**
   - based on long homogenized data series and supplementary deterministic model variables (height, topography, distance from the sea etc.)
   - additive (e.g. temperature) or multiplicative (e.g. precipitation) model
   - the modeling procedure must be executed only once before the interpolation applications
   - high resolution grid (e.g. 0.5'×0.5')
2. **The interpolation subsystem:**
   - using the modeled parameters at the interpolation of the meteorological elements to any point or grid
   - use of background information (e.g. satellite, radar, forecast data)
   - data series completion (missing value interpolation for daily or monthly station data)

ORSZÁGOS METEOROLÓGIAI SZOLGÁLAT

Precipitation database (daily)

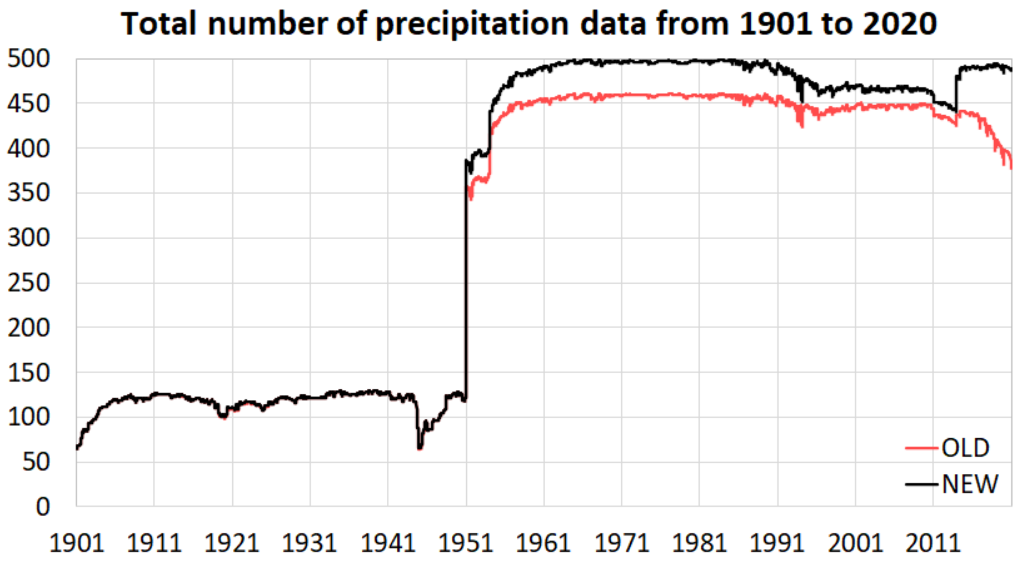
- The daily precipitation database has been renewed in the last two years.
- Previously, 131 data series from 1901 and 461 from 1951 were used.
- The 131 daily data series from 1901 remain, but from 1951 we use precipitation data from 500 stations.
- The new station system covers the country more evenly and more data series are used from mountainous areas, where there is greater spatial variability in precipitation.
- New publication in the International Journal of Climatology: http://doi.org/10.1002/joc.8097



ORSZÁGOS
METEOROLÓGIAI
SZOLGÁLAT

Precipitation data series before 1951

- The large jump in the number of data series from 1951 is explained by the fact that the majority of data series in the database were digitized from the mid-20th century.
- Recently, all the monthly precipitation data have been collected from the beginning of measurements to 1950, which have not yet been digitized. This allowed a significant expansion of the station systems used for homogenization of data from the first half of the 20th century and the second half of the 19th century.



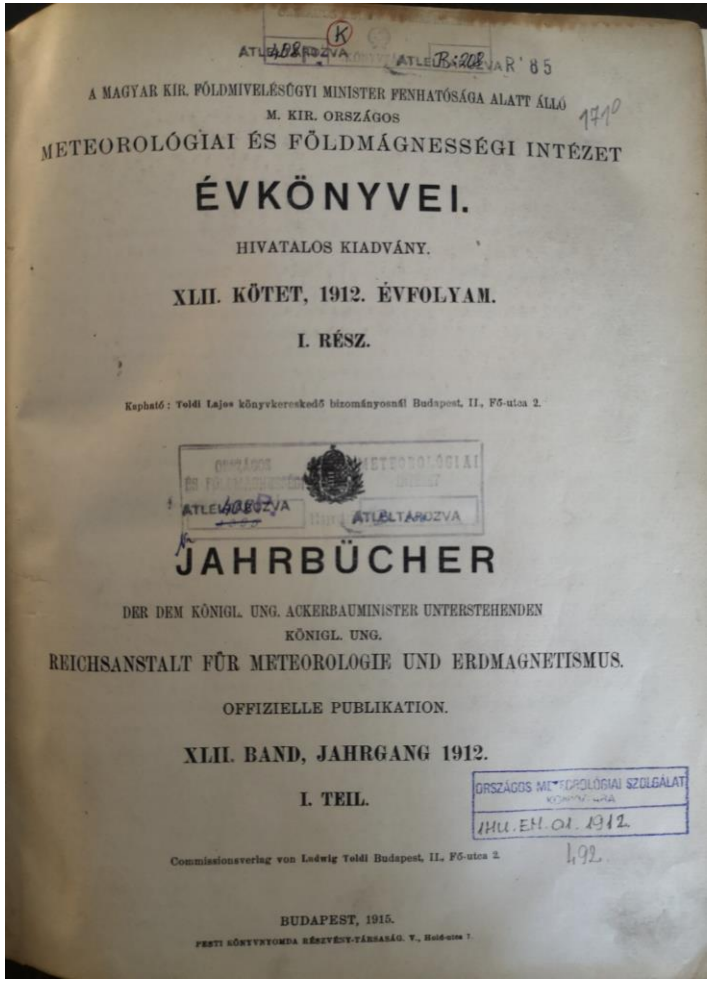
ORSZÁGOS METEOROLÓGIAI SZOLGÁLAT

Precipitation data series before 1951

- Many monthly precipitation data are available in books (e.g. yearbooks), and in an OMSZ publication/book from 1975, which contains monthly precipitation data for all stations in Hungary to 1970.

Important information:
Before 1871, precipitation was measured not in millimetres, but in Paris lines.

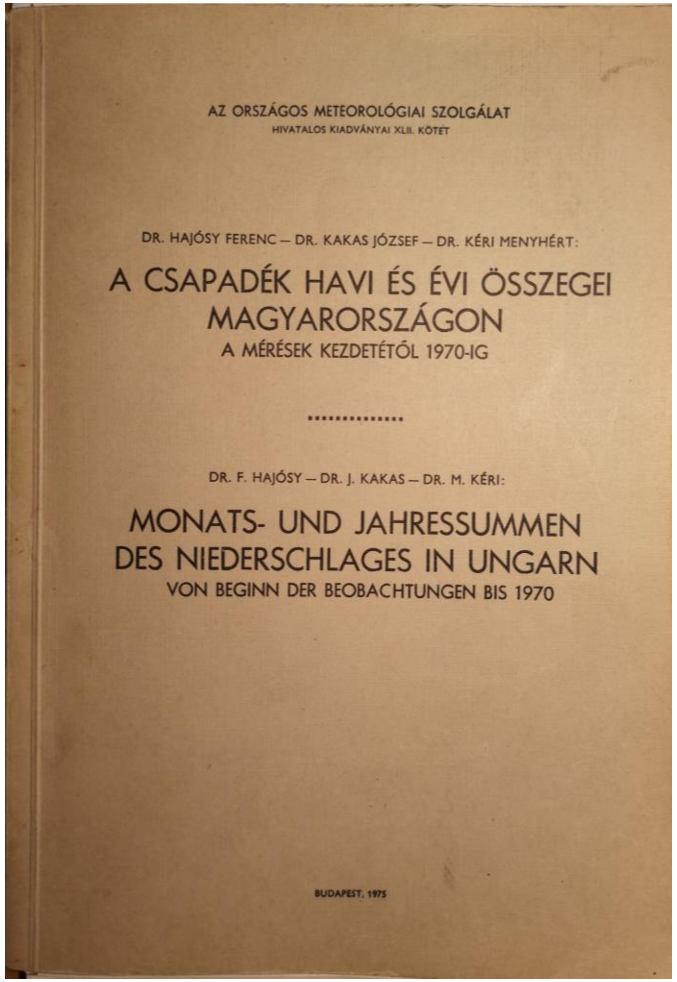
1 Paris line = 2.256 mm



A MAGYAR KIR. FÖLDMIVELÉSÜGYI MINISTER FENHATÓSÁGA ALATT ÁLLÓ
M. KIR. ORSZÁGOS
METEOROLÓGIAI ÉS FÖLDMÁGNESSÉGI INTÉZET
ÉVKÖNYVEI.
HIVATALOS KIADVÁNY.
XLII. KÖTET, 1912. ÉVFOLYAM.
I. RÉSZ.
Kapható: Toldi Lajos könyvkereskedő bizományosnál Budapest, II., Fő-utca 2.

JAHRBÜCHER
DER DEM KÖNIGL. UNG. ACKERBAUMINISTER UNTERSTEHENDEN
KÖNIGL. UNG.
REICHSANSTALT FÜR METEOROLOGIE UND ERDMAGNETISMUS.
OFFIZIELLE PUBLIKATION.
XLII. BAND, JAHRGANG 1912.
I. TEIL.
Commissionsverlag von Ludwig Toldi Budapest, II., Fő-utca 2.

BUDAPEST, 1915.
PESTI KÖNYVNYOMDA RÉSZVÉNY-TÁRSASÁG. V., Hold-utca 7.



AZ ORSZÁGOS METEOROLÓGIAI SZOLGÁLAT
HIVATALOS KIADVÁNYAI XLII. KÖTET

DR. HAJÓSY FERENC – DR. KAKAS JÓZSEF – DR. KÉRI MENYHÉRT:
A CSAPADÉK HAVI ÉS ÉVI ÖSSZEGEI MAGYARORSZÁGON
A MÉRÉSEK KEZDETÉTŐL 1970-IG

DR. F. HAJÓSY – DR. J. KAKAS – DR. M. KÉRI:
MONATS- UND JAHRESSUMMEN DES NIEDERSCHLAGES IN UNGARN
VON BEGINN DER BEOBACHTUNGEN BIS 1970

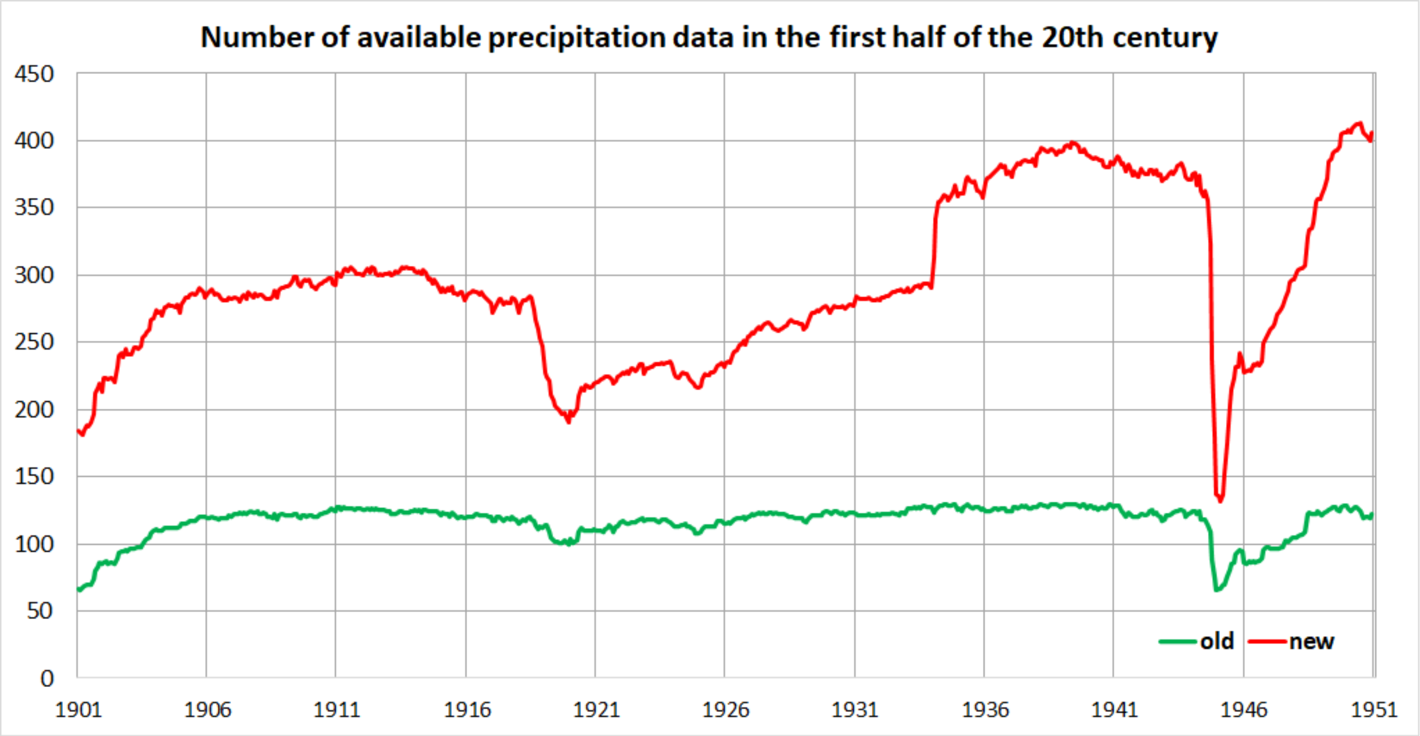
BUDAPEST, 1975

ORSZÁGOS
METEOROLÓGIAI
SZOLGÁLAT

All precipitation data (1901–1950)

- Following the collection of monthly data series, the number of data has increased significantly in the first half of the 20th century.
- Many stations were established in the early 20th century, in the 1930s and after the World War II. There was a very significant temporary decline in the precipitation measurements at the end of World War II in 1944-1945.

Previously, a MASH system was used in the first half of the 20th century. From now, we use two systems, one from 1901 and another from the 1930s, and in both systems with many more stations, compared to the previous system.

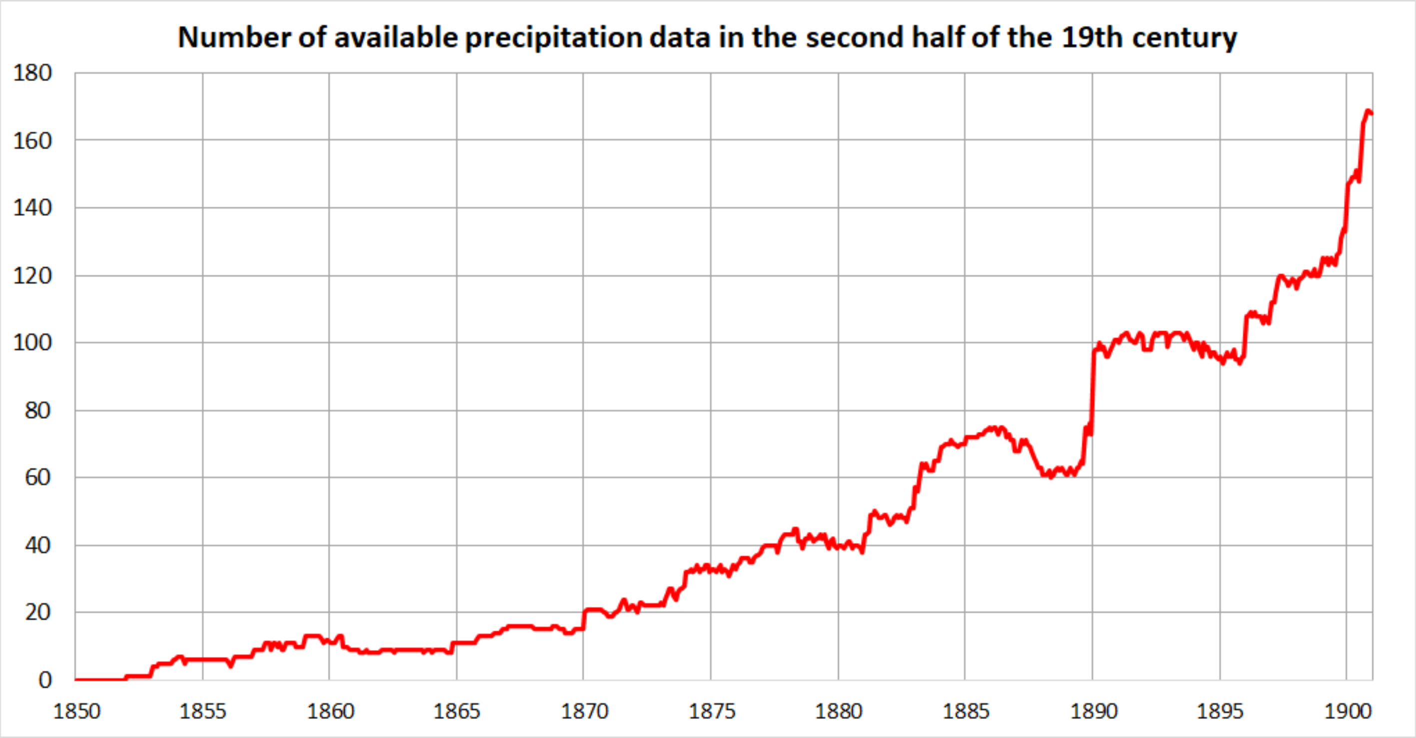


ORSZÁGOS METEOROLÓGIAI SZOLGÁLAT

All precipitation data (before 1901)

- Digitized daily data series from the 19th century are still too few, so only monthly data series are used currently and in this presentation.
- Extensive precipitation measurements in Hungary began in the 1850s (In the present territory of Hungary)
- Initially, the network of stations expanded slowly, and after the foundation of the Hungarian Meteorological Service (1870), precipitation was gradually measured in more and more places.

E.g. in the year 1870 precipitation data are available from 21 stations, while in 1890, there are already more than 100 stations recording precipitation. We use three station systems in the homogenization.



ORSZÁGOS METEOROLÓGIAI SZOLGÁLAT

HOMOGANIZATION OF PRECIPITATION

- **Six station systems with different length**
- **Multiplicative model (significance level: 0.01)**

MASH1 system:

- period: 169 years (from 1854)
- number of stations: 30

MASH2 system:

- period: 153 years (from 1870)
- number of stations: 50
- include MASH1 from 1870

MASH3 system:

- period: 142 years (from 1881)
- number of stations: 124
- include MASH1/2 from 1881

MASH4 system:

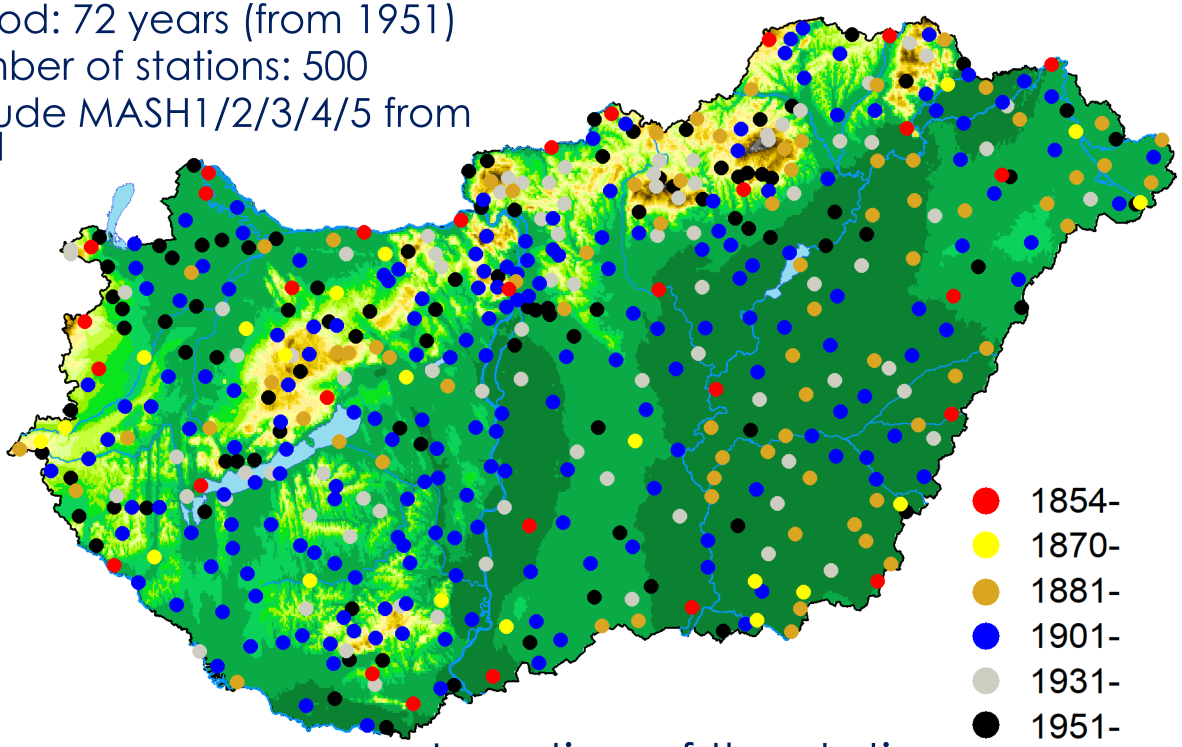
- period: 122 years (from 1901)
- number of stations: 318
- include MASH1/2/3 from 1901

MASH5 system:

- period: 92 years (from 1931)
- number of stations: 402
- include MASH1/2/3/4 from 1931

MASH6 system:

- period: 72 years (from 1951)
- number of stations: 500
- include MASH1/2/3/4/5 from 1951



Location of the stations

ORSZÁGOS METEOROLÓGIAI SZOLGÁLAT

The most important verification statistics in annual precipitation

	MASH1 (1854–2022)	MASH2 (1870–2022)	MASH3 (1881–2022)	MASH4 (1901–2022)	MASH5 (1931–2022)	MASH6 (1951–2022)
Number of series	30	50	124	318	402	500
Critical value: (significance level: 0.01)	28.00	28.00	28.00	28.00	29.00	29.00
Test Statistics Before Homogenization	87.62	87.57	122.67	73.19	53.17	46.27
Test Statistics After Homogenization	28.42	28.16	30.74	29.11	25.58	25.18
Relative Modification of Series	0.30	0.28	0.25	0.19	0.15	0.12
Representativity of station network	0.55	0.56	0.61	0.67	0.69	0.70

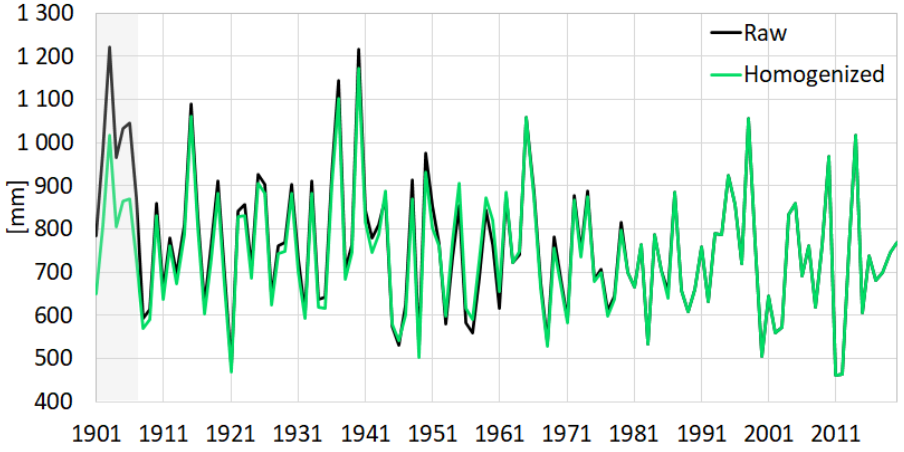
Example of inhomogeneities

Instrument replacement

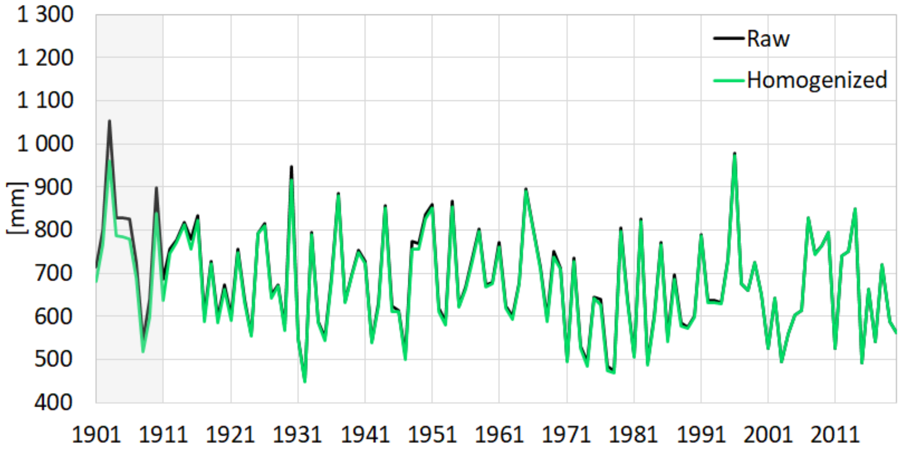
At the beginning of the 20th century, the old type rain gauge was replaced by the Hellmann-type, which is still used in the precipitation stations.

With the old rain gauges excess water could flow from the outer wall of the collecting vessel into the rain gauge, which caused false excess precipitation.

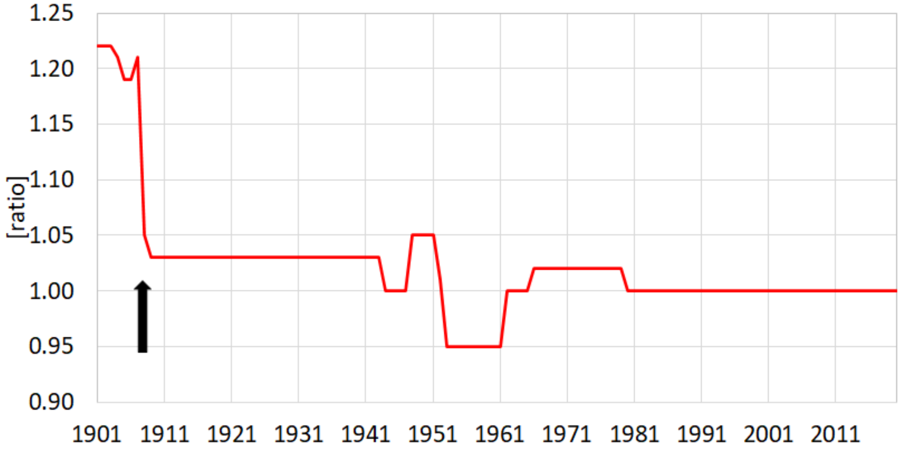
Annual precipitation at Nagykanizsa station (1901–2020)



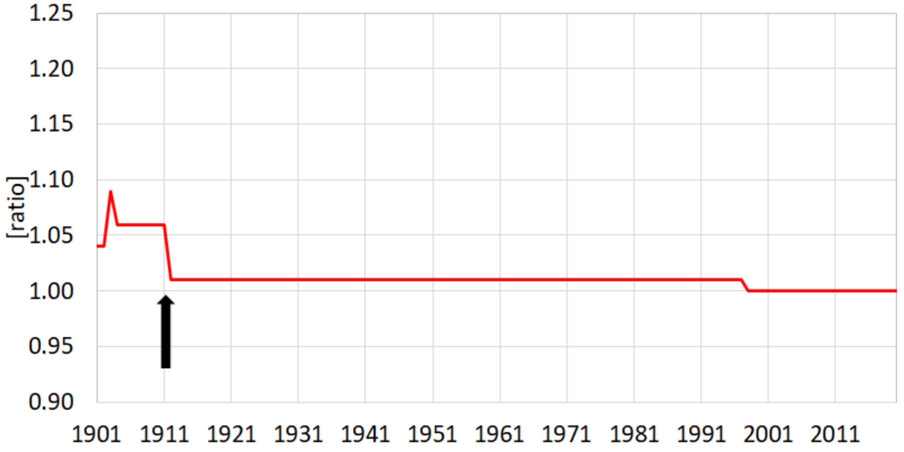
Annual precipitation at Sopron station (1901–2020)



Annual inhomogenity at Nagykanizsa station (1901–2020)



Annual inhomogenity at Sopron station (1901–2020)

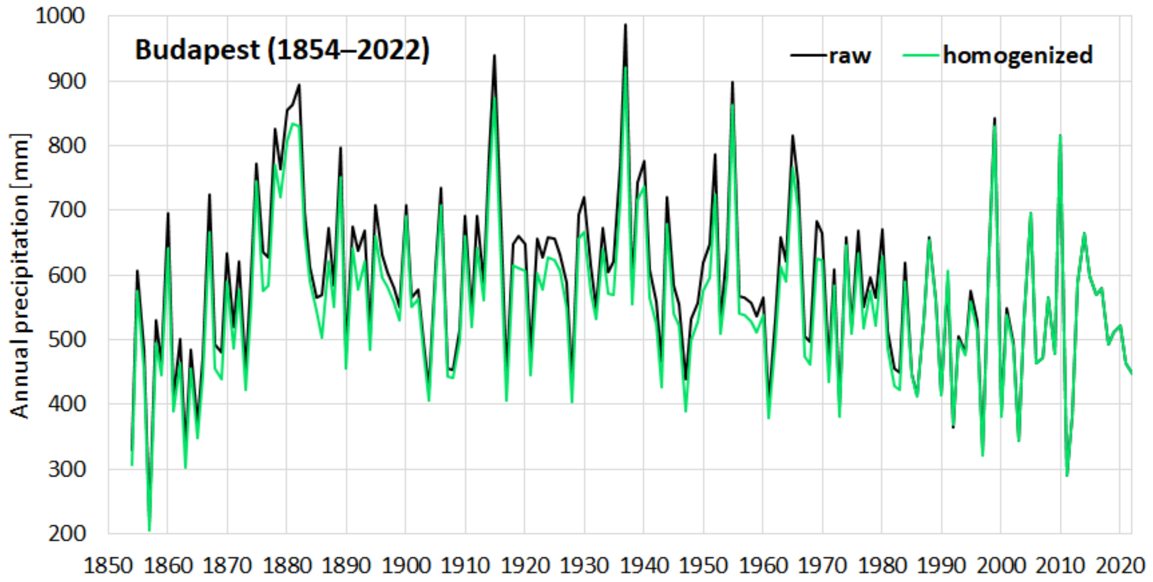


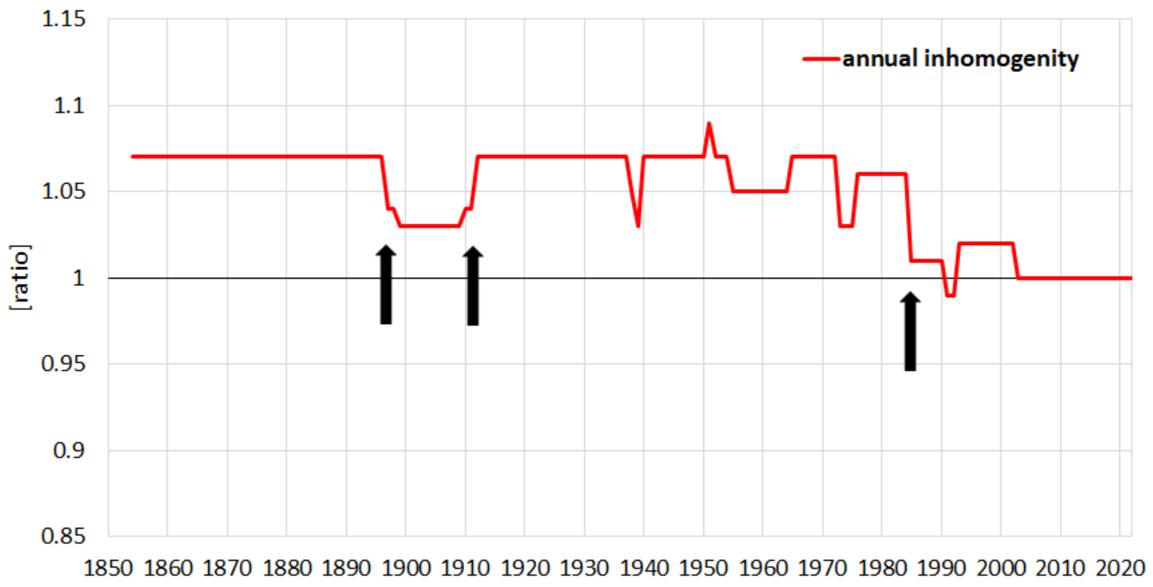
ORSZÁGOS METEOROLÓGIAI SZOLGÁLAT

Example of inhomogeneities

Station relocation

Inhomogeneity in the data series often arises when stations are relocated. Budapest belterület (innercity) station is located at the headquarters of the OMSZ. The largest breaks at this station were caused by relocations. Precipitation is currently measured on the roof of the meteorological observation tower, where the precipitation gauge was installed in 1985. Current location is much windier than before, caused a reduction of about 6% in the annual precipitation.

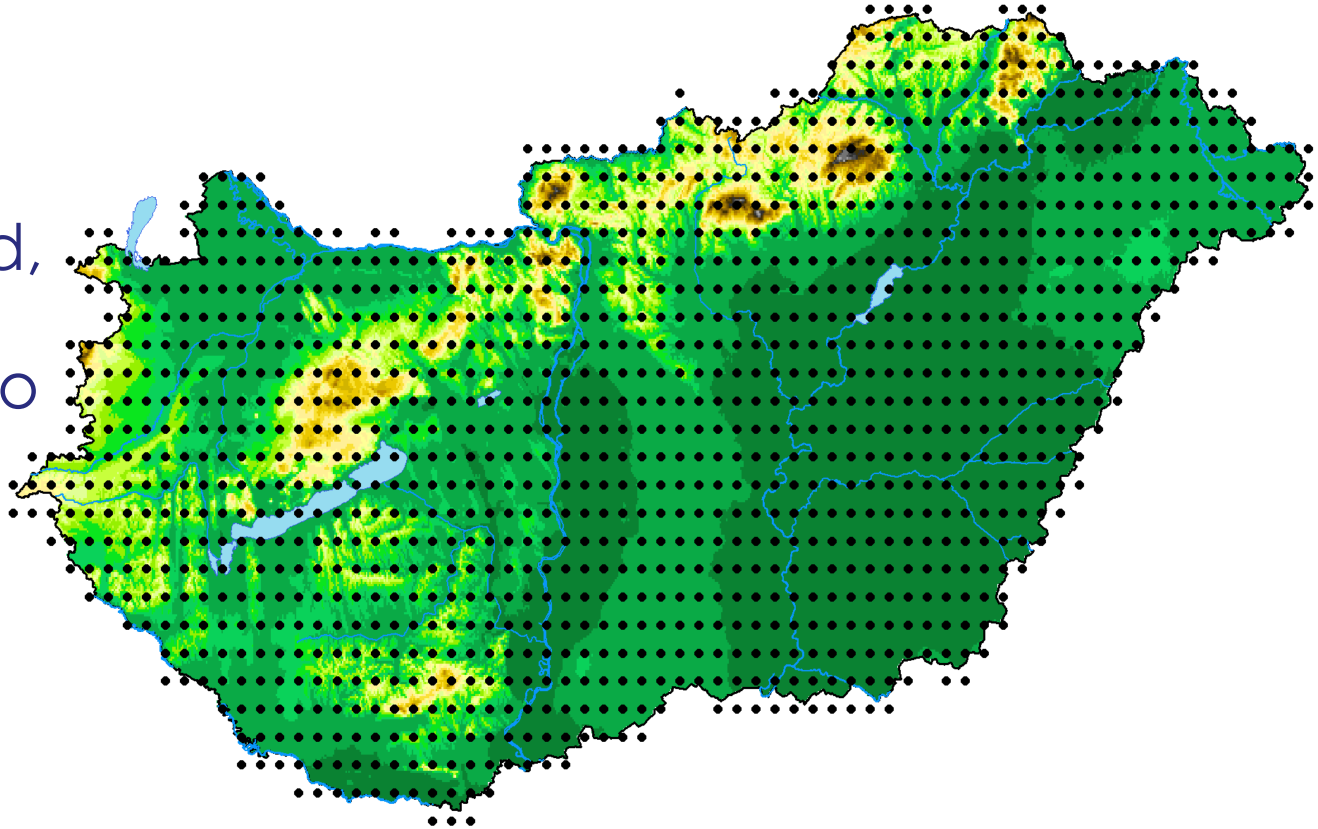




ORSZÁGOS METEOROLÓGIAI SZOLGÁLAT

Gridded datasets for Hungary

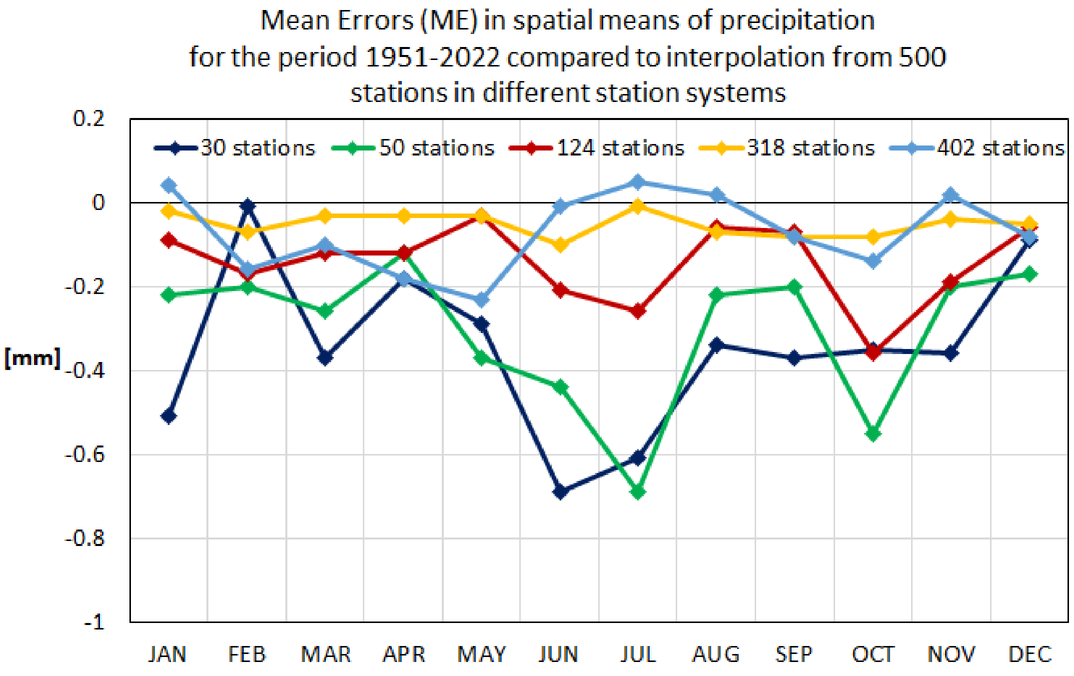
After homoganization we interpolate the homogenized, quality–controlled and completed series with MISH to a grid with the resolution of 0.1×0.1°, which means 1233 grid points in the case of Hungary.

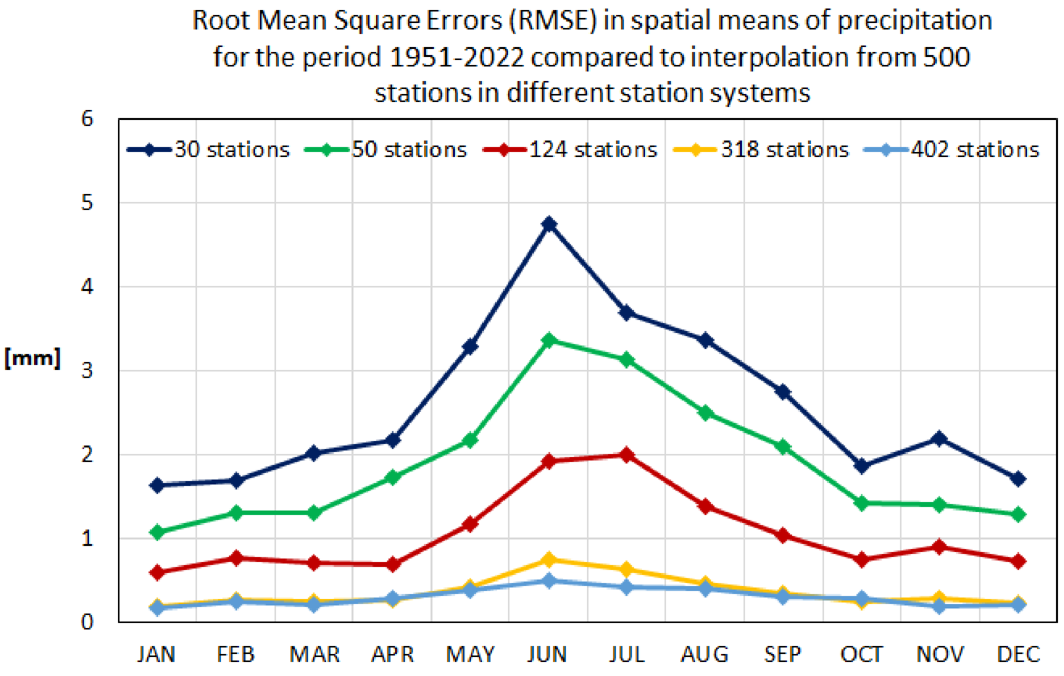


ORSZÁGOS
METEOROLÓGIAI
SZOLGÁLAT

Differences from the MASH6 system

- The mean errors are below 1 mm in each month, and the RMSE values are below 5 mm.
- In summer, much of the precipitation is convective and therefore there is much more spatial variability, which explains the slightly higher values in summer.
- These small error values are due to the very good MISH modelled climate statistical parameters.





ANOVA – Analysis of Variance

Partitioning of Total Variance (Theorem)

$$\hat{D}^2 = \frac{1}{N}\sum_{j=1}^{N}(\hat{E}(s_j) - \hat{E})^2 + \frac{1}{N}\sum_{j=1}^{N}\hat{D}^2(s_j) = \frac{1}{n}\sum_{t=1}^{n}(\hat{E}(t) - \hat{E})^2 + \frac{1}{n}\sum_{t=1}^{n}\hat{D}^2(t)$$

The analysis of these terms is recommended to characterize the spatio-temporal variability.

Spatial terms: spatial variance of temporal means $\frac{1}{N}\sum_{j=1}^{N}(\hat{E}(s_j) - \hat{E})^2$

and temporal mean of spatial variances $\frac{1}{n}\sum_{t=1}^{n}\hat{D}^2(t)$

Temporal terms: spatial mean of temporal variances $\frac{1}{N}\sum_{j=1}^{N}\hat{D}^2(s_j)$

and temporal variance of spatial means $\frac{1}{n}\sum_{t=1}^{n}(\hat{E}(t) - \hat{E})^2$

We do not show the variances but the standard deviations to make the values easier to interpret, especially in the case of precipitation.

Total standard deviation: $\hat{D} = \sqrt{\frac{1}{N\cdot n}\sum_{j=1}^{N}\sum_{t=1}^{n}(Z(s_j,t) - \hat{E})^2}$

Spatial standard deviation of temporal means: $\sqrt{\frac{1}{N}\sum_{j=1}^{N}(\hat{E}(s_j) - \hat{E})^2}$

Root spatial mean of temporal variances: $\sqrt{\frac{1}{N}\sum_{j=1}^{N}\hat{D}^2(s_j)}$

Temporal standard deviation of spatial means: $\sqrt{\frac{1}{n}\sum_{t=1}^{n}(\hat{E}(t) - \hat{E})^2}$

Root temporal mean of spatial variances: $\sqrt{\frac{1}{n}\sum_{t=1}^{n}\hat{D}^2(t)}$

ORSZÁGOS METEOROLÓGIAI SZOLGÁLAT

ANOVA for annual precipitation (1951–2022)

	30 stations	50 stations	124 stations	318 stations	402 stations	500 stations
Total mean	597.87	598.40	600.30	601.46	601.19	602.05
Total standard deviation	131.72	131.73	133.14	135.20	135.19	135.72
Spatial st. deviation of temporal means	66.54	68.17	67.95	68.69	67.96	68.38
Root spatial mean of temporal variances	113.17	112.20	113.99	115.79	116.23	116.58
Temporal st. deviation of spatial means	97.50	96.53	97.55	98.80	99.04	99.11
Root temporal mean of spatial variances	85.94	87.20	88.21	89.65	89.49	90.15

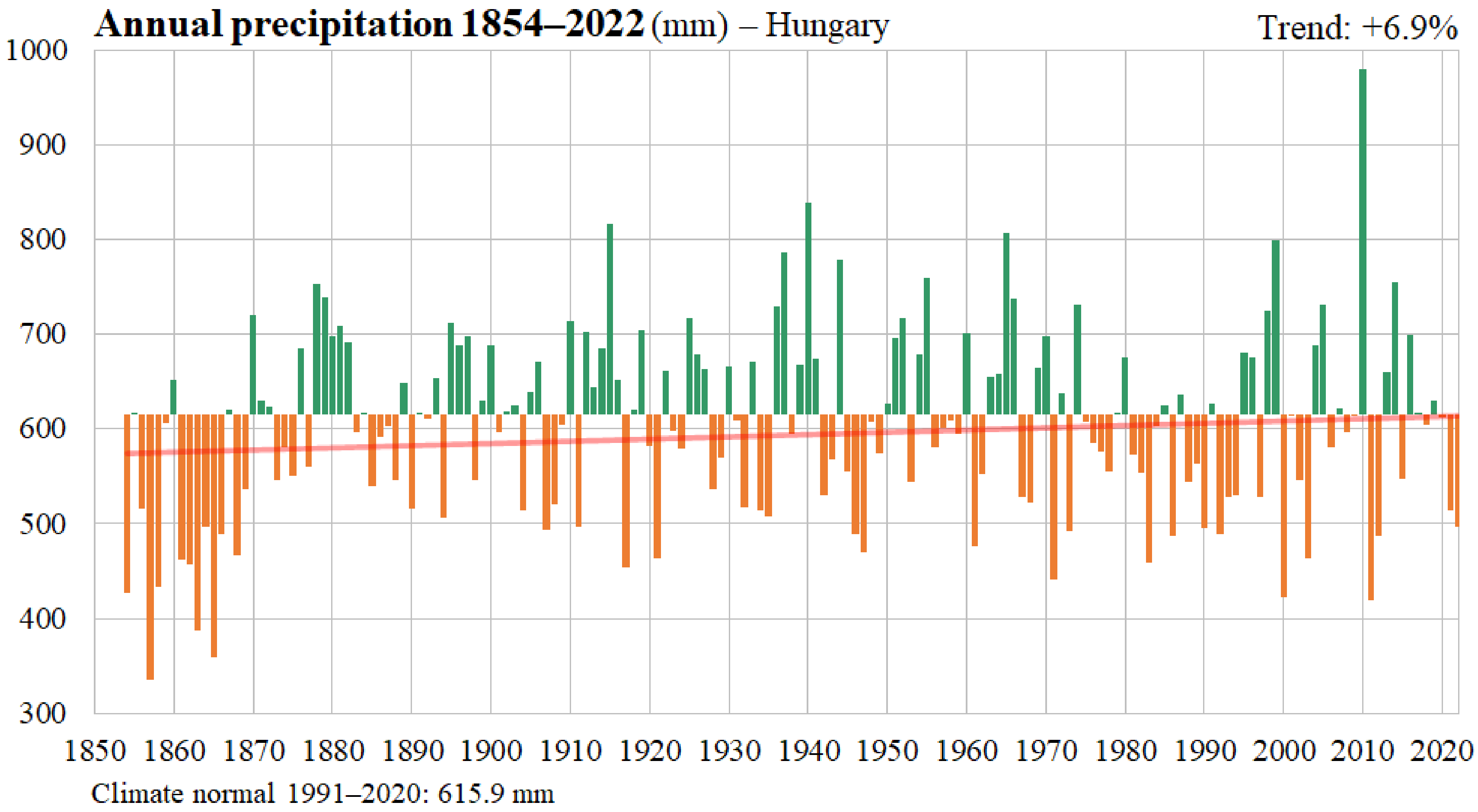
Spatial means of annual precipitation in Hungary

Since 1901, 2011 was the driest year, but there was three drier years around the 1860s: 1857, 1863 and 1865.

In the 1860s, there was a long period of extreme drought. From 1861 to 1866, each year's precipitation remained below 500 mm in spatial means. For example, Lake Fertő dried up last time in the 1860s.

The wettest year was 2010 in Hungary from 1854, and the wettest period was around 1880, between 1878 and 1882.

Precipitation trend: +6,9% (not significant)

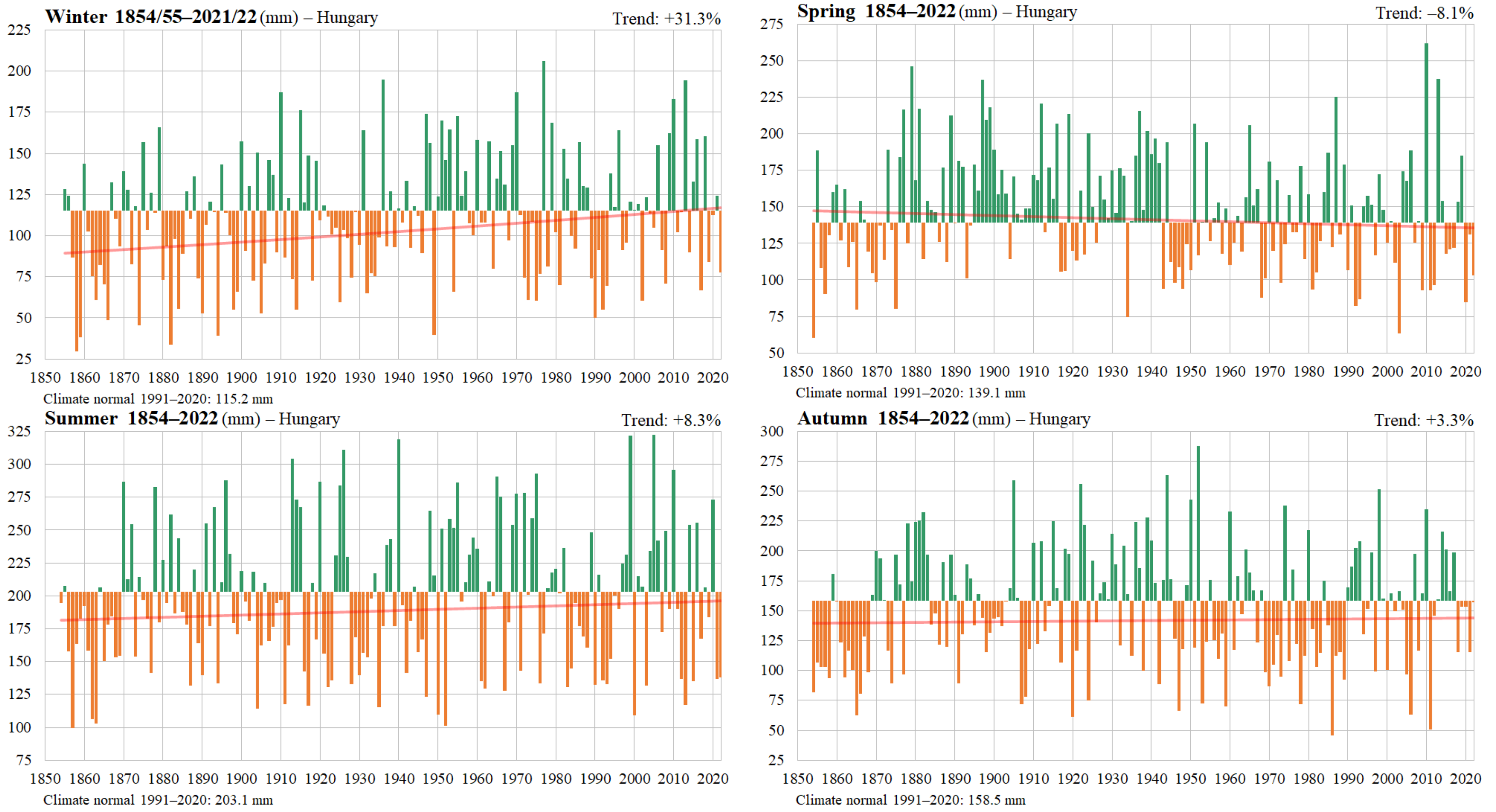


ORSZÁGOS METEOROLÓGIAI SZOLGÁLAT

Spatial means of seasonal precipitation in Hungary

In Hungary, the wettest season is in average the summer, while the driest is the winter. Over the total period, the change of the winter precipitation shows a significant increase.

There is a decrease in precipitation in spring and a slight increase in summer and autumn, but these are not significant changes.



ORSZÁGOS METEOROLÓGIAI SZOLGÁLAT

Monthly, seasonal and annual extremes in spatial means from 1854 to 2022, and the 1991–2020 climate normals

months/ seasons	DRIEST		WETTEST		1991–2020
	mm	year	mm	year	means
JAN	2.2	1964	79.6	1915	32.7
FEBR	**1.8**	**1890**	94.9	2016	36.9
MAR	2.4	2012	112.2	1937	34.3
APR	**2.4**	**1865**	**113.4**	**1879**	40.3
MAY	**16.3**	**1884**	173.8	2010	64.4
JUN	16.1	2021	144.3	1926	71.8
JUL	13.8	1952	**156.8**	**1878**	71.8
AUG	7.6	2012	160.0	2005	59.5
SEPT	**5.2**	**1865**	129.5	1996	59.0
OCT	1.8	1965	155.9	1974	50.9
NOV	0.3	2011	127.8	1965	48.6
DEC	3.4	1972	**107.8**	**1874**	45.6
WINTER	**29.7**	**1857/1858**	206.2	1976/1977	115.2
SPRING	**60.3**	**1854**	262.1	2010	139.1
SUMMER	**99.3**	**1857**	322.6	2005	203.1
AUTUMN	45.6	1986	287.6	1952	158.5
YEAR	**335.0**	**1857**	980.4	2010	615.9

ORSZÁGOS METEOROLÓGIAI SZOLGÁLAT

Summary

- We created representative climatological databases with MASH and MISH software:
  - Temporal representativity with MASH (homogenization, quality control and missing value completion)
  - Spatial representativity with MISH (interpolation, gridding)
- We use many more stations than before to create the precipitation climate database.
- The most important result is that we have first insight into the precipitation conditions in Hungary from the beginning of the precipitation measurements (from 1854) up to the present.

ORSZÁGOS
METEOROLÓGIAI
SZOLGÁLAT

Thank you for your attention!

ORSZÁGOS
METEOROLÓGIAI
SZOLGÁLAT